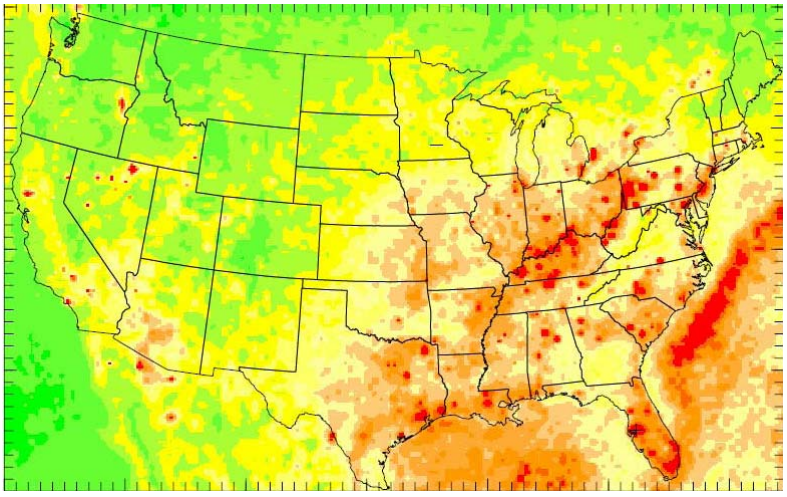
# Model-Based Analysis And Tracking Of Airborne Mercury Emissions To Assist in Watershed Planning



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# Model-Based Analysis And Tracking Of Airborne Mercury Emissions To Assist in Watershed Planning

August 2008

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# List of Acronyms

ARL = Air Resources Laboratory
CAIR = Clean Air Interstate Rule
CAMR = Clean Air Mercury Rule
CART = Classification and Regression Tree
CB-V = Carbon-Bond chemical mechanism, Version 5
CMAQ = Community Multiscale Air Quality
CTM = Chemical Transport Model
EPA = Environmental Protection Agency
EPS2.5 = Emissions Preprocessing System, version 2.5

GEOS = Goddard Earth Observing System
GIS = Geographical Information Systems
GRAHM = Global/Regional Atmospheric Heavy Metals
IPM = Integrated Planning Model
MACT = Maximum Available Control Technology
MDN = Mercury Deposition Network
NADP= National Acid Deposition Program
NAMMIS = North American Mercury Model Inter-comparison Study
NEI = National Emissions Inventory

NOAA = National Oceanographic and Air Administration
NWS = National Weather Service (NWS)
PPTM = Particle and Precursor Tagging Methodology
PSU/NCAR MM5 = Pennsylvania State University/National Center for Atmospheric Research Fifth Generation Mesoscale Model
RADM = Regional Acid Deposition Model
REMSAD = REgional Modeling System for Aerosols and Deposition
RUC = Rapid Update Cycle
SCC = Source Category Code
TMDL = Total Maximum Daily Loads
USGS = U.S. Geological Survey

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# Executive Summary

## Purpose

This study was undertaken in partnership with state and EPA Regional Air and Water Offices in order to assist developing and implementing strategies to achieve state water quality standards for mercury. This report summarizes the application of several air quality modeling systems and data analysis tools to support an assessment of the sources of airborne mercury and their contribution to water quality impairment and fish contamination throughout the continental U.S.

The objective of this study was to use atmospheric deposition modeling to quantify contributions of specific sources and source categories to mercury deposition within each of the lower 48 states. It is expected that the results of this study will provide state and local air and water quality agencies with 1) an improved understanding of the sources and mechanisms contributing to mercury deposition; 2) supporting information for future development of Total Maximum Daily Loads (TMDLs); and 3) assistance in developing implementation plans for TMDLs and related activities designed to help achieve water quality standards.

## Modeling Protocols for TMDL Applications

The modeling protocols followed in this nationwide study were based upon a pilot project conducted focusing on Wisconsin (Myers et al., 2006). The Devil's Lake TMDL Pilot Project was conducted by EPA's Offices of Water, Air and Radiation, and Region 5 together with personnel from the Wisconsin Department of Natural Resources. The use of mercury deposition modeling to estimate mercury deposition in a TMDL context was examined. The conclusions and recommendations of an external peer review of the pilot study, including emissions, meteorological inputs, grid resolution, and source attribution (tagging) were incorporated into the nationwide study discussed in this report.
These same basic modeling protocols, including application of the tagging feature in the primary model used in this study, were also followed by others (e.g., Myers and Wei, 2004) in developing publicly reviewed TMDLs – most recently the Northeastern States Mercury TMDL approved by EPA in December 2007. (http://www.nescaum.org/focus-areas/science-and-technology/regional-air-quality-modeling-program).

## Overview of the Deposition Modeling Tools

The primary modeling system used for this study is the REgional Modeling System for Aerosols and Deposition (REMSAD). REMSAD is a three-dimensional grid model designed to calculate the concentrations of both inert and chemically reactive pollutants by simulating the physical and chemical processes in the atmosphere that affect pollutant concentrations. REMSAD is designed to support a better understanding of the distributions, sources, and removal processes relevant to fine particles and other airborne pollutants, including soluble acidic components and several toxic species (mercury, cadmium, dioxin, polycyclic organic matter (POM), atrazine, and lead).
Mercury may be present in the atmosphere both in the gas and particulate phases. The mercury species included in REMSAD are HG0 (elemental mercury vapor), HG2 (divalent mercury compounds in gas phase), and HGP (divalent mercury compounds in particulate phase). These species represent the oxidation state of mercury, and the gas and particulate phases. The reactions in REMSAD, which are based on Lin and Pehkonen (1999) and other recently published studies, simulate the transfer of mercury mass from one of these states to another. REMSAD simulates both wet and dry deposition of mercury. Wet deposition occurs as a result of precipitation scavenging. Dry deposition is calculated for each species based on land-use characteristics and meteorological parameters. REMSAD also includes algorithms for the re-

emission of previously deposited mercury (originating from anthropogenic and natural sources) into the atmosphere from land and water surfaces.

The mercury treatment in REMSAD can be expanded to include additional, tagged mercury species. The Particle and Precursor Tagging Methodology (PPTM) feature allows the user to tag or track emissions from selected sources or groups of sources, and quantify their contribution to mercury deposition throughout the modeling domain and simulation period.

Results from the Community Multiscale Air Quality (CMAQ) modeling system were used to enhance the analysis of the effects of global background on mercury deposition. The CMAQ model is a state-of-the-science, regional air quality modeling system that supports the detailed simulation of the emission, chemical transformation, transport, and wet and dry deposition of elemental, divalent, and particulate forms of mercury. For this study, CMAQ was also applied with PPTM to provide a basis for assessing the uncertainty of the REMSAD PPTM results.

The outputs from three global models were used to specify the boundary conditions for both REMSAD and CMAQ and thus represent a plausible range of global background contributions based on current scientific understanding. The results from these models were made available as part of the North American Mercury Model Inter-comparison Study (NAMMIS) (Bullock et al., 2008).

## Particle and Precursor Tagging Methodology

The Particle and Precursor Tagging Methodology (PPTM) was used in this study to track emissions from selected sources and source categories and to quantify their contribution to simulated annual mercury deposition totals for each of the 48 states that comprise the coterminous U.S.

PPTM for mercury tracks emitted mass from its source through the modeling system processes. Mercury species in the emissions and initial and boundary condition files are tagged and tracked throughout the REMSAD simulation. Tags can be applied to emissions from selected source regions, source categories, and individual sources, both separately and in combination. PPTM quantifies the contribution of the tagged emissions sources (and/or initial/boundary conditions) to the simulated species concentrations and deposition, for each mercury species considered by the model. The emissions from each selected source, source category, or grouping are tagged in the simulation and each grouping is referred to as a “tag.”

Within the model, tagging (PPTM) is accomplished by the addition of duplicate model variables for each species and tag. The tagged species have the same properties and are subjected to the same processes (e.g., advection, chemical transformation, deposition) as the actual (or base) species. PPTM was developed to utilize model algorithms as much as possible to track simulated tag species concentrations. At each time step in the simulation, the effects of linear processes, such as advection and dry deposition, are calculated directly for all tagged species. Potentially non-linear processes, such as gas-phase chemistry, aqueous chemistry, and particle dynamics are calculated for the overall (or base) species and apportioned to the tagged species.

Some example uses of the mercury PPTM methodology include 1) quantifying the contribution of mercury emissions from various source sectors to mercury deposition at selected locations throughout the modeling domain, 2) quantifying the contribution from boundary conditions to mercury deposition throughout the modeling domain, 3) examining the range of influence of emissions from selected facilities, and 4) tracking the fate of mercury emissions from a specific source category to estimate the contribution to deposition to water bodies throughout the modeling domain.

# REMSAD/PPTM Application Procedures

The REMSAD modeling domain for this study encompasses the continental U.S. and portions of Canada and Mexico, with 12-km horizontal grid resolution over the entire U.S. portion of the domain. The annual simulation period is 2001. The baseline emissions data and the meteorological databases used for the modeling were provided by EPA.

The modeling analysis included a detailed review and revision of the mercury emissions for each state in order to better represent the 2001 time period. This review was conducted by ICF, EPA, and state agencies; revisions were incorporated based on information provided by the states. Model-ready emission inventories were prepared using the revised emissions.

A total of 18 REMSAD simulations were conducted. The first simulation utilized the full Carbon Bond Version V (CB-V) chemical mechanism to simulate ozone, particulate matter (PM), and related species. The simulated concentrations of ozone, OH radicals, and other species that react with mercury in the atmosphere were stored and used as input to the remaining 17 mercury tagging (REMSAD/PPTM) simulations.

Each of the remaining 17 annual REMSAD/PPTM simulations included approximately 15 to 20 tags (for a total of approximately 300 tagged sources). The tags were defined on a state-by-state basis, based on the emissions sources within each state. The general procedure was to assign the first three tags for each state to the top three emitters of divalent gaseous mercury. Then the top total mercury emitter not already tagged was assigned the fourth tag. Additional tags were assigned to the remaining larger sources and source categories, in order to capture the high emitters as well as the range of source types in each state and potentially important contributors to local and regional mercury deposition in areas with known or suspected mercury water quality problems. State agencies and EPA regional offices were involved in selecting the sources for application of PPTM.

PPTM was also used to estimate the contribution from global background to mercury deposition. Three alternate specifications of the boundary conditions based on global model simulations were used in the REMSAD simulations. Each of the three global models, the Chemical Transport Model (CTM) (developed and applied by AER), the Global/Regional Atmospheric Heavy Metals model (GRAHM) (developed and applied by Environment Canada), and the GEOS-Chem model (developed and applied by researchers at Harvard University), utilized the same year 2000 emissions inventory.

# Overview of Model Performance

A variety of graphical analyses and statistical measures were used to evaluate REMSAD model performance. This evaluation focused on concentrations for ozone, sulfur dioxide ($SO_2$) and fine particulate matter ($PM_{2.5}$) and deposition for selected PM species and mercury on a monthly and/or annual basis, depending on the pollutant. The goal was to examine the ability of the REMSAD modeling system to replicate the observed concentration and deposition characteristics of the 2001 annual simulation period.

For mercury, the simulated spatial distribution of mercury deposition were found to be consistent with the emissions and annual transport and rainfall patterns. Wet deposition accounts for much of the deposition that occurs throughout the domain and this emphasizes the importance of rainfall in determining mercury deposition patterns.

The REMSAD wet deposition values were compared to data from the Mercury Deposition Network (MDN), as available from the National Acid Deposition Program (NADP). There are a total of 98 MDN monitors in the modeling domain, although annual total deposition was available for only 53 of those monitors for 2001. Model performance for mercury was evaluated for each set of boundary conditions. These results are summarized in Table ES-1.

**Table ES-1. REMSAD Model Performance Statistics for Mercury Wet Deposition (g km$^{-2}$) for the 12-km Resolution Grid at MDN Sites: 2001 Annual Simulation Period.**

| Boundary Conditions | Mean Observed (g km$^{-2}$) | Mean Simulated (g km$^{-2}$) | Normalized bias (%) | Normalized gross error (%) | Correlation ($R^2$) |
|---|---|---|---|---|---|
| CTM | 9.26 | 14.21 | 59.7 | 65.8 | 0.74 |
| GRAHM | 9.26 | 12.91 | 45.7 | 55.3 | 0.73 |
| GEOS-CHEM | 9.26 | 15.58 | 73.8 | 78.7 | 0.75 |

The statistical measures of model performance indicate that the REMSAD simulation results tend to overestimate wet deposition of mercury, as compared to the MDN monitoring data, using each of the three sets of boundary conditions. The simulated values derived using the GRAHM boundary conditions are consistently better matched with the observed values. It should be noted that emerging research suggests that the MDN wet deposition data may underestimate wet deposition of mercury by approximately 16 percent (Miller et al., 2005). It was not possible to evaluate the simulated dry deposition results because an adequate network of dry deposition monitoring data does not exist.

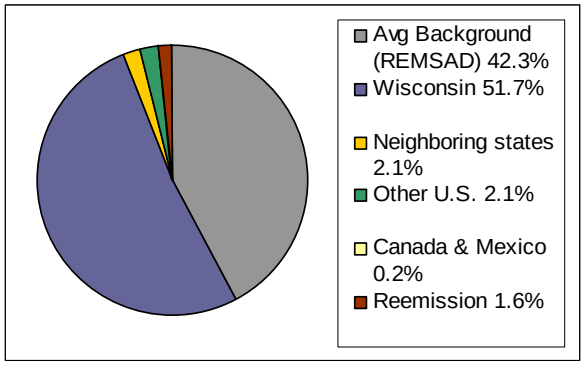
# PPTM Results

For each state, the contributions to mercury deposition were examined for the location of greatest deposition from sources located within that same state. Displays summarizing 1) the contributions from U.S., Canadian, and Mexican emissions as well as re-emissions (collectively referred to as "emissions" in the figures in this report) versus background (for all three sets of boundary conditions calculated using both REMSAD and CMAQ), 2) wet versus dry deposition of emissions as simulated in REMSAD and wet versus dry deposition of average background deposition simulated by both REMSAD and CMAQ, 3) contributions from global background, various source regions and natural re-emissions, 4) primary source contributions from in-state sources. Example displays of the contribution by category and region for Wisconsin, New York, Virginia, and Texas are given in Figure ES-1 and illustrate some of the variations in percent contributions from the selected categories that are found in the full set of modeling results. Note again that these figures summarize deposition at a particular grid cell where the sources within the given state contribute the most to deposition in that state. These are not, therefore, statewide summaries. The pie charts display the percent contributions to total deposition from 1) global background (average of the three sets of boundary conditions), 2) emissions from sources within the state, 3) emissions from sources in neighboring states, 4) emissions from all other U.S. states, 4) emissions from Canada and Mexico, and 5) re-emission processes.

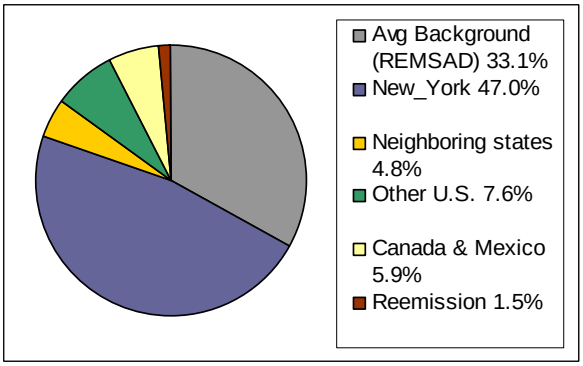
**Figure ES-1. Summary of Mercury Tagging Results for 2001 for Wisconsin, New York, Virginia, and Texas (with Average Background) at the Location of the Maximum Simulated Annual Mercury Deposition from Sources within the State.**

- *(Note that these summaries apply to the single grid cell in each state where source in that state contributed the most to deposition and should not be assumed to apply statewide.)*

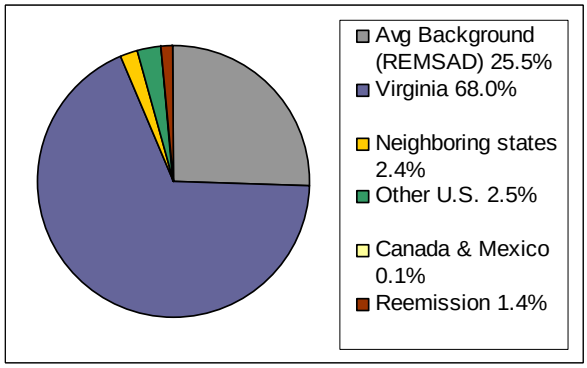
**(a) Wisconsin**



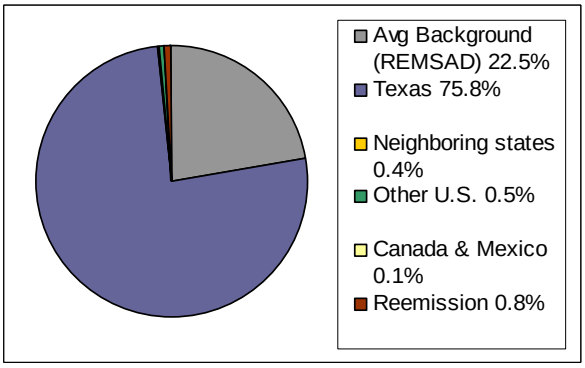

***(b) New York***




**(c) Virginia**




***(d) Texas***




The REMSAD-derived simulated contributions at the location of maximum deposition for many of the states are dominated by one local source. For other states, several sources or statewide emissions from one or more categories are major contributors. Three diverse examples of the source-specific contributions from in-state sources are given in Figure ES-2. The examples are for Arkansas (one dominant source), Michigan (multiple contributing sources), and Vermont (collective statewide source categories). Note that, in each case, the in-state contributions comprise a different percentage of the total contribution.

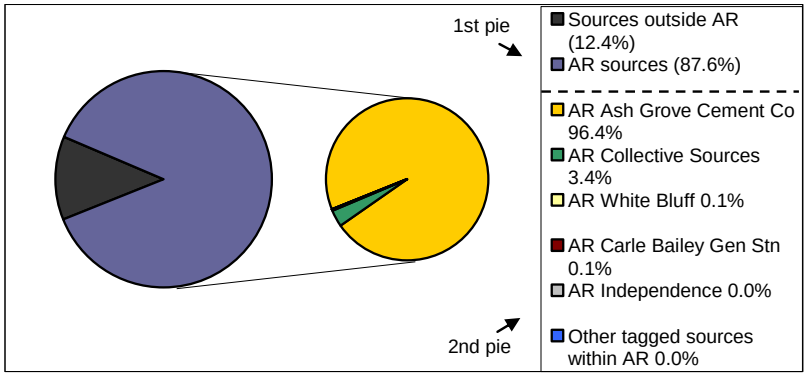
The pie-in-pie charts in Figure ES-2 highlight the percent contributions from the in-state sources to the grid cell with maximum impact from in-state sources. The larger pie gives the proportion of the overall contribution from emissions sources that are located both outside of and in the state, and the smaller pie details the contributions from the in-state sources (specifically, the largest in-state contributors as well as all other in-state sources). If there are five or fewer tags for a given state, all of the tagged source contributions are displayed. The names of the sources are given in the legend. The “Collective Sources” tag for each state includes all point and area sources in the state that are not tagged individually, as part of a source category, or part of a region. The legend also includes the percentages represented by the various segments of the

pie charts. Note that the percentages for the cut-out pie chart segments are calculated based on the total represented only in the smaller, cut-out pie chart. “Other sources within“ a state refers to sources that were tagged, but for the particular location displayed contributed only a small amount to deposition. They were therefore aggregated in order to simplify the chart.

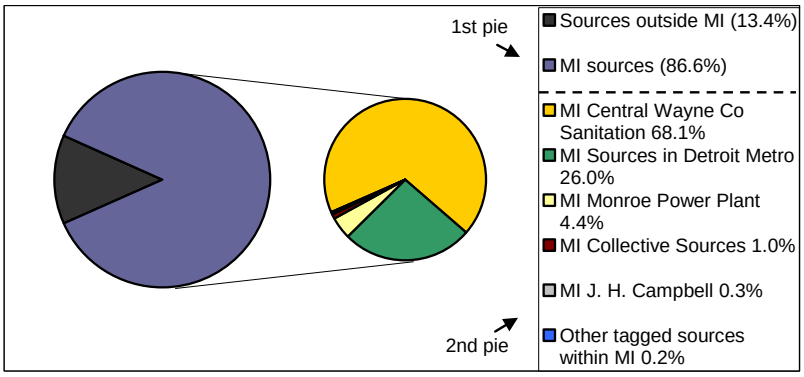
**Figure ES-2. Summary of Source-Specific Mercury Tagging Results for 2001 for Arkansas, Michigan, and Vermont at the Location of the Maximum Simulated Annual Mercury Deposition from Sources within the State.**

- *(Note that these summaries apply to the single grid cell in each state where sources in that state contributed the most to deposition and should not be assumed to apply statewide.)*

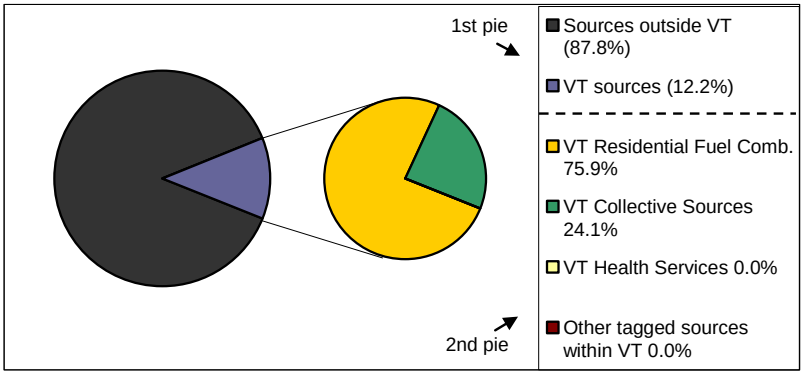
**(a) Arkansas**




**(b) Michigan**



**(c) Vermont**




The modeling results contain much more information than is presented in this report. To facilitate future analysis, the tagging results have also been incorporated into a database tool (an enhanced version of ARC-Hydro, developed by ESRI under a separate effort) that allows users to calculate the simulated contribution from each tagged source or source category to any area of interest, such as a body of water, watershed, or county.

## Comparison of REMSAD PPTM, CMAQ PPTM, and Other Source Attribution Techniques

Source apportionment studies founded on observed data are limited in number, but the REMSAD PPTM results were compared to a study by Keeler et al. (2006). The Keeler study used air monitoring and wet deposition data along with statistical receptor modeling to estimate contributors to wet deposition of mercury at their Steubenville, Ohio site. Keeler's study estimated that about 70 percent of the mercury wet deposition at the Steubenville site came from coal combustion. Analyzing the REMSAD PPTM results for the same location indicate that 55 percent or more of the wet deposition at this site comes from coal-fired utilities. Given that the present methodology did not tag all coal combustion sources, the REMSAD PPTM results are quite consistent with the conclusions of the Keeler study.

To compare PPTM results for the REMSAD and CMAQ models, CMAQ was applied for a 12-km domain around Illinois and a summer 2001 simulation period. Seven tags were included in a simulation representing a mix of individual sources, groups of sources, and source regions (including global background). The relative contributions from the tagged sources as derived from the REMSAD and CMAQ simulations were compared for several locations within Illinois and were found to be consistent, for the area and time period considered.

# Summary of Key Findings

This study has provided an improved understanding of the sources and mechanisms contributing to mercury deposition throughout the U.S. Key sources and source categories contributing to mercury deposition within each state were identified and their contribution to total mercury deposition quantified for an annual 2001 simulation period. It is expected that the modeling results will provide supporting information for the future assessment of control measures and development and implementation of Total Maximum Daily Loads (TMDLs).
Based on available data for the 2001 simulation period, REMSAD is able to reasonably replicate the observed concentration patterns for ozone and $PM_{2.5}$, and the observed deposition patterns for $PM_{2.5}$ and mercury wet deposition.
PPTM gives expected results and the simulated contributions are consistent with the emissions data (including magnitude and speciation characteristics), source locations, source types, and current knowledge/theories regarding the contribution from global background. The REMSAD PPTM results are consistent with those obtained using the CMAQ model and are also consistent with results from a recent receptor modeling study for a specific location in Ohio.
The relative proportion of global, regional, and local (general and source-specific) contributions varies widely among the states at the location of maximum deposition by sources within the same state. The REMSAD results for these higher deposition areas indicate that the source contributions are frequently dominated by

- One or more nearby sources (this finding may be linked to horizontal grid resolution and, in this case, the use of relatively high-resolution (12-km) grids), or
- “Collective” sources within the state (defined in this study as all point and area sources in the state that are not tagged individually, as part of a source category, or as part of a region).

Overall the results are characterized by contributions from a greater number of diverse sources when large sources are not present in the state.

# 1. Introduction

This report summarizes the application of several air quality modeling systems and data analysis tools to support an assessment of the sources of airborne mercury and their contribution to water quality impairment and fish contamination throughout the continental U.S. The primary modeling system used for this study is the REgional Modeling System for Aerosols and Deposition (REMSAD). The REMSAD Particle and Precursor Tagging Methodology (PPTM), sometimes referred to as simply "tagging," was used to track emissions from selected sources and source categories and to quantify their contribution to simulated annual mercury deposition totals for each of the 48 states that comprise the coterminous U.S. Results from the Community Multiscale Air Quality (CMAQ) modeling system were used to enhance the analysis of the effects of global background on mercury deposition, and CMAQ was applied with PPTM to provide a basis for assessing the uncertainty of the REMSAD PPTM results. The outputs from three global models were used to specify the boundary conditions for both REMSAD and CMAQ and thus represent a plausible range of global background.
The REMSAD modeling results were also used to estimate the variability in wet and dry deposition for several locations throughout the U.S. Classification and Regression Tree (CART) analysis was used to link the modeled results to observed data and to estimate mercury deposition for the selected locations for a ten-year period.

## 1.1. Background and Objectives

The primary route of human exposure to mercury is through the consumption of contaminated fish. Due to high levels of mercury in fish, all 50 states, 1 territory, and 2 tribes in the U.S. have, in recent years, issued fish consumption advisories. These advisories may suggest limits on the consumption of certain types of fish, including limits on consumption by certain groups (e.g., prospective and new mothers), or not eating fish from certain bodies of water because of unsafe levels of mercury contamination. In addition, under the Clean Water Act, states must identify waters not meeting state water quality standards, or impaired waters. States have identified more than 8,800 individual bodies of water as mercury-impaired.

Once a body of water is listed as impaired by a state, the Clean Water Act calls for the calculation of a Total Maximum Daily Load (TMDL). TMDLs identify the pollutant reductions or limits that are needed in order to achieve water quality standards. TMDLs also allocate the reductions to the different sources of pollution, including air sources. In many parts of the U.S., atmospheric deposition of mercury is the primary source of mercury contamination in surface waters.

In developing TMDLs, states are not required to allocate reductions to individual non-point sources, including air sources. However, to determine which sources may need to reduce emissions in order to achieve water quality standards, states may wish to identify the specific categories of mercury sources within their state contributing to deposition and quantify the contributions. From this information, the EPA and states can determine whether to assign additional pollution limits or allocate further reductions to certain sources or categories of sources and, ultimately, to develop appropriate management strategies for meeting water quality criteria and protecting human health. Examples of mercury air sources include combustion sources, medical waste incinerators, and municipal waste incinerators.

Atmospheric modeling provides an analytic method for quantifying the contributions from sources of airborne mercury to mercury deposition. In particular, the Particle and Precursor Tagging Methodology (PPTM), or "tagging," which is available in both the REMSAD and CMAQ

models) allows one to track or tag mercury emissions from selected sources, and quantify their contribution to mercury deposition throughout the modeling domain and simulation period.

For REMSAD modeling studies, this approach has been used to estimate the relative contribution of mercury deposition from various sources and geographic areas (e.g., surrounding states) to Devil's Lake in the Wisconsin TMDL Pilot. The REMSAD model was peer reviewed in 1999 (Seigneur et al., 1999), and the modeling in the TMDL Pilot (including the tagging application) was subjected to an external peer review resulting in an updated modeling report in March 2006 (Myers et al., 2006). In addition to the Wisconsin pilot study, REMSAD PPTM was used to provide total mercury deposition estimates for each of the lower 48 U.S. states, and to provide, for each state, an estimate of the mercury contribution from in-state versus out-of-state sources.

The REMSAD PPTM has been used in a TMDL context by EPA Region 6 (Myers and Wei, 2004) and by EPA Region 3 (Myers et al., 2004). In addition, the Northeast States for Coordinated Air Use Management (NESCAUM) utilized REMSAD in source attribution studies in support of the Northeastern States Mercury TMDL, approved by EPA in December 2007. (http://www.nescaum.org/focus-areas/science-and-technology/regional-air-quality-modeling-program).

CMAQ was used to support the development of the Clean Air Mercury Rule (EPA, 2005). CMAQ with PPTM is currently being used to estimate the regional, national, and global contributions to airborne mercury deposition for the Commonwealth of Virginia and to examine the effects of expected future-year emissions changes on the modeled deposition amounts (Douglas et al., 2007, 2008).

Both CMAQ and REMSAD were included in the North American Mercury Model Intercomparison Study (NAMMIS) for mercury (Bullock et al., 2008) and the performance and response of both models was found to be reasonable and substantially similar.

The primary objective of this study was to use the REMSAD PPTM method and other air quality modeling tools (such as CMAQ PPTM and several global models) to quantify contributions of specific sources of mercury to mercury deposition within each of the lower 48 states. The PPTM feature was used to identify the major categories of air sources of mercury loadings, and to conduct an in-depth analysis of the specific sources of mercury that may be contributing to water quality impairment.

This study also examined the impacts of year-to-year variability in meteorological inputs on mercury deposition modeling results. This was accomplished by using Classification and Regression Tree (CART) analysis to link the REMSAD results to observed meteorological data in order to estimate the amount and variability of wet and dry mercury deposition for selected locations for a ten-year period.

## 1.2. Overview of the Air Deposition Modeling Tools

REMSAD is the primary modeling system used for this study. REMSAD was developed and is maintained by ICF International (ICF, 2005). Major portions of its development were funded by the U.S. Environmental Protection Agency (EPA). REMSAD was originally intended as a screening tool—a model that could be run (quickly) for a continental-scale modeling domain (specifically the continental U.S.) and for a full-year simulation period—to provide information on the distribution and composition of particulate matter, the deposition of pollutant (including toxic) species onto the

surfaces of inland and coastal bodies of water, and the expected change in air quality and deposition that results from changes in emissions. All of these parameters were intended to be primarily represented in terms of seasonal or annual averages or deposition totals. What began as a simple screening tool has evolved into a more complex one-atmosphere modeling system that simulates the chemistry, transport, and deposition of airborne pollutants (with emphasis on particulate matter (PM), ozone, and mercury) using algorithms that reflect the state-of-the science and current knowledge of the important physical and chemical processes.

For this study, the representation of mercury chemistry and wet and dry deposition processes are of primary importance. The chemical transformations of mercury included in REMSAD are based on the review of current status of atmospheric chemistry of mercury presented by Lin and Pehkonen (1999), with modifications and revisions based on more recent literature. Species representing the oxidation state of mercury and the phase (gas or particulate) are tracked. These include HG0 (elemental mercury vapor), HG2 (divalent mercury compounds in gas phase), and HGP (divalent mercury compounds in particulate phase). REMSAD simulates both wet and dry deposition of gaseous and particulate species. Wet deposition occurs as a result of precipitation scavenging. Dry deposition is calculated for each species based on land-use characteristics and meteorological parameters. The mercury modeling capabilities of REMSAD, as well as the algorithms pertaining to the other pollutants, have undergone external peer review (Seigneur et al., 1999) independently of and prior to initiation of the EPA-sponsored Mercury Total Maximum Daily Load (TMDL) Pilot Project for Devil's Lake, Wisconsin (Myers et al., 2006). In the Devil's Lake Pilot, EPA Air and Water Offices and EPA Region 5 worked with personnel from Wisconsin DNR in part to test REMSAD for potential application in TMDL development. Specifically, the model was run with tagging of individual sources in Wisconsin with the same type of meteorological data and at the same scale as described in this report. The findings of the Devil's Lake Pilot underwent external peer review. Recommendations from the peer review have been incorporated into this nationwide application, most notably a suggestion that meteorological and emissions inputs target the same year to the extent possible.

The REMSAD Particle and Precursor Tagging Methodology (PPTM) was used to track emissions from selected sources and source categories and to quantify their contribution to mercury deposition. With PPTM, mercury species in the emissions and initial and boundary condition files are tagged and tracked throughout the REMSAD simulation. Tags can be applied to emissions from selected source regions, source categories, and individual sources, both separately and in combination. PPTM quantifies the contribution of the tagged emissions sources (and/or initial/boundary conditions) to the simulated species concentrations and deposition, for each mercury species considered by the model.

CMAQ was used in this study primarily to enhance and provide perspective to the REMSAD simulation results. The CMAQ model is a state-of-the-science, regional air quality modeling system that is designed to simulate the physical and chemical processes that govern the formation, transport, and deposition of gaseous and particulate species in the atmosphere (Byun and Ching, 1999). The CMAQ model was designed as a "one-atmosphere" model and can be used to simulate ozone, particulate matter, and mercury. Mercury simulation capabilities were first incorporated into the CMAQ model by adding gaseous and aqueous chemical reactions involving mercury to the CMAQ chemical mechanism (Bullock and Brehme, 2002). CMAQ supports the detailed simulation of the emission, chemical transformation, transport, and wet and dry deposition of elemental, divalent, and particulate forms of mercury (HG0, HG2 and HGP) (Bullock et al., 2008). CMAQ also includes PPTM for mercury (Douglas et al., 2006) which provides detailed,

quantitative information about the contribution of selected sources, source categories, and/or source regions to simulated mercury concentrations and (wet and dry) deposition.

Finally, the outputs from three global models were used to specify the boundary conditions for both REMSAD and CMAQ and thus represent global background. These include the Chemical Transport Model (CTM) (Shia et al., 1999; Seigneur et al., 2001), the Global/Regional Atmospheric Heavy Metals model (GRAHM) (Dastoor and Larocque, 2004; Ariya et al., 2004), and the GEOS-Chem model (Selin et al., 2007). Estimates of boundary concentrations of elemental mercury, divalent gas mercury, and particulate mercury prepared using each of these models and intended for use in continental scale modeling were made available as part of the North American Mercury Model Inter-comparison Study (NAMMIS) (Bullock et al., 2008). All three global models are included in this study in part because the NAMMIS evaluation concluded that they were each based upon sound science, and, absent a much more widespread mercury monitoring network including dry deposition, it is not now possible to determine which best replicates actual global contributions.

## 1.3. Overview of the Modeling Approach

For this study, 18 REMSAD simulations were conducted. The first simulation utilized the full chemical mechanism to simulate ozone, PM, and related species. The simulated concentrations of ozone, OH radicals, and other species that react with mercury in the atmosphere were stored and used as input to an additional 16 mercury tagging simulations. A meteorological sensitivity simulation was also made with REMSAD.

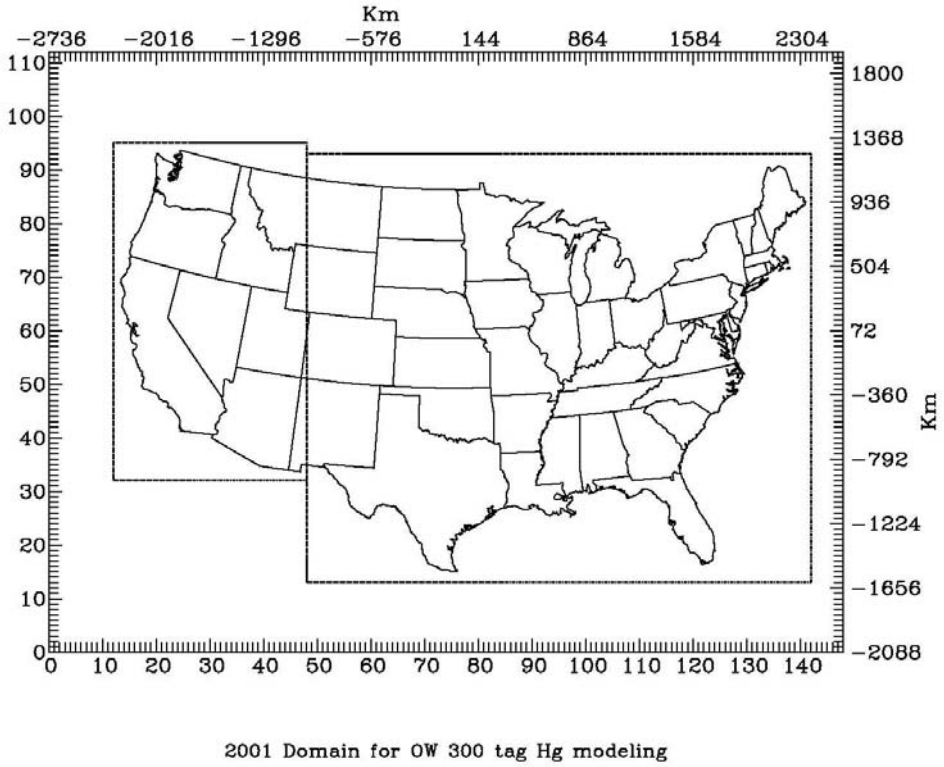
A CMAQ simulation was made using the tagging feature implemented by ICF for a sub-domain surrounding Illinois. The results of this simulation are contrasted with the REMSAD results for the same area.

Additional CMAQ simulation results for the continental US were provided by EPA. These results were for simulations using each of the three available global model based boundary conditions. Again, these results are compared and contrasted with the REMSAD results.

The emissions data and the meteorological databases used for the modeling were provided by EPA. The REMSAD modeling domain encompasses the continental U.S. and portions of Canada and Mexico, with a 36-km resolution outer grid; in addition two 12-km resolution nested grids are located approximately over the eastern three quarters and western quarter of the U.S., respectively. The entire U.S. is encompassed by the 12-km grids. The modeling domain is depicted in Figure 1-1. The annual simulation period is 2001.

**Figure 1-1. REMSAD Modeling Domain for the Mercury PPTM Simulations.**

- *Horizontal Resolution is 36 km for the Outer Grid and 12 km for the Two Inner Grids.*




The modeling analysis included a detailed review and revision of the mercury emissions for each state. This review was conducted by ICF, EPA, and state agencies and revisions were incorporated based on information provided by the states. Model-ready emission inventories were prepared using the revised emissions.

The modeling analysis also included a review of the meteorological inputs and a sensitivity simulation in order to examine the effects of elevated precipitation inputs on the REMSAD results. This simulation focused on a high simulated precipitation area over northern Utah.

In the mercury tagging simulations, the initial conditions, boundary conditions, and approximately 300 emissions sources were tagged using PPTM. The tags represent various source categories and sources within each of the lower 48 states, with emphasis on the largest sources of mercury emissions for each state. In addition, tags were allocated to emissions from Canada and Mexico. Post-processing software was used to combine information from the tagging simulations. Since use of the tagging technique does not affect the simulation results, the results from the separate simulations can be combined and compared.

The REMSAD mercury tagging results are summarized in this report and were also processed for incorporation into an interactive Geographical Information Systems (GIS) database tool (an enhanced version of ARC-Hydro, developed by ESRI under a separate effort). This tool allows users to extract the modeling results for any grid cell or combination of grid cells and calculate the simulated contribution from each tagged source or source category to any area of interest in the modeling domain, e.g., a reservoir, watershed, or tribal area.

A CMAQ simulation was also conducted as part of this study, in order to compare the PPTM results for REMSAD with those for CMAQ. CMAQ was applied for a three-month subset of the annual simulation period (summer 2001) using PPTM for seven tags. The CMAQ modeling

domain includes an outer grid with 36-km horizontal resolution (the same as used for REMSAD) and a one-way nested (inner) grid with 12-km resolution, covering Illinois and portions of several surrounding states. The emissions and meteorological inputs for the two models are the same, accounting for grid resolution.
The remaining model outputs from CMAQ and the global models were obtained from EPA and the application procedures used to generate these results are described by Bullock et al. (2008).

## 1.4. Report Contents

This report summarizes the methods and results of the mercury deposition modeling analysis conducted to quantify the potential loadings of airborne mercury emissions on bodies of water in the lower 48 states. The modeling tools are described in Section 2. The meteorological and geographical inputs are summarized in Section 3, and the emissions inputs are summarized in Section 4. The base case simulations for mercury are evaluated and discussed in Section 5. The mercury PPTM results are presented in Section 6. Finally, a summary of key findings is provided in Section 7.
The report also includes several appendixes. Appendix A presents additional information related to model performance for non-mercury species. Appendix B compares the CMAQ and REMSAD PPTM results. Appendix C gives a detailed summary of the revisions made to the national-scale emission inventory as part of this study. Appendix D presents the results of the meteorological sensitivity simulation. Appendix E presents the CART-based assessment of mercury deposition variability.

# 2. Description of the Deposition Modeling Tools

Several air quality models were used to support this assessment of mercury deposition. These tools are described in this section of the report. Most of the modeling was conducted using REMSAD. Therefore, most of this section contains a detailed technical description of the REMSAD model, including the Particle and Precursor Tagging Methodology (PPTM) for mercury. CMAQ and several global models were also used in this assessment. These are more briefly described at the end of this section; references are provided for a more detailed discussion of each model.

## 2.1. REMSAD Modeling System

Version 8 of the Regional Modeling System for Aerosols and Deposition (REMSAD) was used for this modeling analysis. REMSAD is a three-dimensional grid model designed to calculate the concentrations of both inert and chemically reactive pollutants by simulating the physical and chemical processes in the atmosphere that affect pollutant concentrations. REMSAD is designed to support a better understanding of the distributions, sources, and removal processes relevant to fine particles and other airborne pollutants, including soluble acidic components and several toxic species (mercury, cadmium, dioxin, polycyclic organic matter (POM), atrazine, and lead). REMSAD provides estimates of the concentrations and deposition of the simulated pollutants at each grid location in the modeling domain. Both wet and dry deposition processes are simulated. Post-processing can provide concentration averages and deposition totals for any subset of the time span of the simulation for any location within the domain.
REMSAD was designed to account for the many factors that affect the concentration and distribution of aerosols and mercury, including:

- Spatial and temporal distribution of toxic and particulate emissions (both anthropogenic and non-anthropogenic),
- Composition of the emitted particulate and mercury species,
- Spatial and temporal variations in the wind fields,
- Dynamics of the boundary layer, including stability and the level of mixing,
- Chemical reactions involving $SO_2$, $NO_x$, mercury and other important precursor species,
- Diurnal variations of solar insulation and temperature,
- Loss of primary and secondary aerosols and toxics by dry and wet deposition, and
- Ambient air quality immediately upwind and above the region of study.

The basis for the REMSAD model is the atmospheric diffusion or species continuity equation. This equation represents a mass balance in which all of the relevant emissions, transport, diffusion, chemical reactions, and removal processes are expressed in mathematical terms. The REMSAD system consists of a series of preprocessor programs, the core model, and several post-processing programs.

The REMSAD model is capable of “nesting” one or more finer-scale subgrids within a coarser overall grid. The fully interactive two-way nesting capability permits high resolution over selected source and/or receptor regions of interest. The modeling system may be applied at scales ranging from a single metropolitan area to a continent containing multiple urban areas.

This version of REMSAD (Version 8) utilizes version V (five) of the carbon-bond chemical mechanism (CB-V) to simulate gas-phase photochemical processes in the atmosphere and also includes a chemical mechanism to calculate the transformations of mercury.

The particulate matter species modeled by REMSAD include a primary coarse fraction (corresponding to particulates in the 2.5 to 10 micron size range), a primary fine fraction (corresponding to particulates less than 2.5 microns in diameter), and several secondary particulates (e.g., sulfates, nitrates, and organics). The sum of the primary fine fraction and all of the secondary species is assumed to be representative of $PM_{2.5}$. This is calculated as part of a post-processing step.

For the simulation of mercury, REMSAD carries the species HG0 (representing elemental mercury), HG2 (representing divalent gas mercury), and HGP (representing divalent particulate mercury). Mercury simulations can be run separately from the full PM simulations, provided that the full PM simulation has been run and the outputs have been saved for use in the mercury only simulations. This substantially reduces the computer requirements for REMSAD.

Of particular importance to the current work is that the mercury treatment in REMSAD can be expanded to include additional, tagged mercury species. The PPTM feature allows the user to tag or track emissions from selected sources, and quantify their contribution to mercury deposition throughout the modeling domain and simulation period.

### 2.1.1. Input File Requirement

There are seventeen input files for REMSAD. These fall into the general categories of emissions, initial and boundary conditions, meteorological fields, surface characteristics, chemical parameters, and simulation control parameters. The files are listed and briefly described in Table 2-1.

**Table 2-1. REMSAD Input Files.**

| File Type/Name | Description | Source of Data/Information for REMSAD PPTM Application |
|---|---|---|
| *Emissions* | | |
| EMISSIONS | Low-level (surface-layer) emissions for area, mobile, low-level point, non-road, and biogenic sources | EPA OAQPS |
| PTSOURCE | Elevated (upper-layer) point-source emissions | EPA OAQPS |
| *Initial and Boundary Conditions* | | |
| AIRQUALITY | Initial species concentrations for each grid cell within the modeling domain | Derived from global model simulations of mercury, or estimated from the literature |
| BOUNDARY | Species concentrations along the lateral boundaries of the modeling domain | Derived from global model simulations of mercury, or estimated from the literature |
| CHLORINE | Surface chlorine concentrations | Estimated from the literature |
| *Meteorological Fields* | | |
| WIND | u- and v- wind components | MM5 files from EPA OAQPS |
| TEMPERATURE | Temperature | MM5 files from EPA OAQPS |
| PSURF | Surface pressure | MM5 files from EPA OAQPS |
| H2O | Water vapor concentration | MM5 files from EPA OAQPS |
| VDIFFUSION | Vertical diffusivities or exchange coefficients | MM5 files from EPA OAQPS |
| CLW | Cloud-water mixing ratio | MM5 files from EPA OAQPS |
| RLW | Rain-water mixing ratio | MM5 files from EPA OAQPS |
| RAIN | Rainfall rate | MM5 files from EPA OAQPS |

| File Type/Name | Description | Source of Data/Information for REMSAD PPTM Application |
|---|---|---|
| *Surface Characteristics* | | |
| SURFACE | Land-use characteristics | USGS LULC data |
| TERRAIN | Terrain heights | MM5 files from EPA OAQPS |
| *Chemistry Parameters* | | |
| CHEMPARAM | Chemical reaction rates and other CB-V parameters | Standard REMSAD file |
| RATES | Photolysis rates | Standard REMSAD file |
| *Simulation Control* | | |
| SIMCONTROL | Simulation control parameters and option specifications | User specified |

## 2.1.2. Carbon-Bond V Chemical Mechanism

The carbon-bond V (five) photochemical mechanism (CB-V) is an updated version of CB-IV (Gery et al., 1989) as enhanced to include radical-radical termination reactions. The CB-V mechanism is derived from the mechanism implemented in UAM-V (SAI, 1999) with some specific adaptations for REMSAD.

Secondary organic aerosols (SOA) are known to result from the reactions of hydrocarbons in the atmosphere, and version 8 of REMSAD includes a calculation of the yield of SOA from both anthropogenic and biogenic hydrocarbon species. The REMSAD mechanism accounts for the anthropogenic contribution of toluene (TOL) and xylene (XYL) reactions to SOA formation. In addition, the mechanism includes reactions with biogenic monoterpenes (TERP), which are the principal biogenic precursors of SOA.

Table 2-2 lists the CB-V gas-phase reactions. Of these, only the reaction of $SO_2$ with the OH radical to form sulfate directly affects particulate concentrations. However, a number of the gas-phase species affect the production of particulates in aqueous phase. Peroxide, which is a product of the gas-phase chemistry, is important in the aqueous production of sulfate. To a lesser degree, ozone also affects the production of sulfate in aqueous phase. Nitric acid produced in gas phase can later be converted to particulate via reaction with ammonia. Radical species such as OH and $HO_2$ can affect the evolution of toxics such as POM and mercury. The gas-phase products (ozone, peroxide, nitric acid, and radicals) are the result of a complex interaction of many reactions in the mechanism. SOA is also a known product of gas-phase interactions, and the gas-phase production of SOA is included in the mechanism.

**Table 2-2. CB-V Reaction Set.**

| | REACTION | RATE CONSTANT* ($ppm^{-1}$-$min^{-1}$) |
|---|---|---|
| 1 | NO2 = NO + O – NOXY | 4.926E-01 |
| 2 | O = O3 | 4.641E+06 |
| 3 | O3 + NO = NO2 + NOXY | 2.808E+01 |
| 4 | O3 + NO2 = NO3 | 4.726E-02 |
| 5 | O3 + OH = HO2 | 1.149E+02 |
| 6 | O3 + HO2 = OH | 2.957E+00 |
| 7 | O3 + NO3 = NO2 | 1.499E-02 |
| 8 | O3 = O | 2.611E-02 |
| 9 | O3 = O1D | 1.681E-03 |
| 10 | NO + NO = 2.0000 NO2 + 2.0000 NOXY | 1.499E-04 |
| 11 | NO + NO2 + H2O = 2.0000 HNO2 – NOXY | 2.997E-08 |

| | REACTION | RATE CONSTANT* ($ppm^{-1}$-$min^{-1}$) |
|---|---|---|
| 12 | NO + O = NO2 + NOXY | 2.458E+03 |
| 13 | NO + OH = HNO2 | 1.104E+04 |
| 14 | NO + HO2 = NO2 + OH + NOXY | 1.196E+04 |
| 15 | NO + XO2 = NO2 + NOXY | 1.139E+04 |
| 16 | NO + XO2N = NTR | 1.139E+04 |
| 17 | NO + NO3 = 2.0000 NO2 + NOXY | 3.840E+04 |
| 18 | NO2 + O = NO – NOXY | 1.433E+04 |
| 19 | NO2 + O = NO3 | 2.325E+03 |
| 20 | NO2 + OH = HNO3 – NOXY | 1.346E+04 |
| 21 | NO2 + HO2 = PNA – NOXY | 2.053E+03 |
| 22 | NO2 + NO3 = NO2 + NO – NOXY | 9.691E-01 |
| 23 | NO2 + NO3 = N2O5 | 1.741E+03 |
| 24 | HNO2 + HNO2 = NO2 + NO + NOXY | 1.499E-05 |
| 25 | HNO2 + OH = NO2 + NOXY | 6.644E+03 |
| 26 | HNO2 = NO + OH | 9.729E-02 |
| 27 | HNO3 + OH = NO3 + NOXY | 2.191E+02 |
| 28 | PNA + OH = NO2 + NOXY | 6.793E+03 |
| 29 | PNA = NO2 + HO2 + NOXY | 5.173E+00 |
| 30 | PNA = 0.6100 NO2 + 0.6100 HO2 + 0.3900 OH + 0.3900 NO3 + NOXY | 2.775E-04 |
| 31 | N2O5 + H2O = 2.0000 HNO3 -2.0000 NOXY | 2.997E-06 |
| 32 | N2O5 = NO2 + NO3 | 2.262E+00 |
| 33 | H2O2 + OH = HO2 | 2.511E+03 |
| 34 | H2O2 = 2.0000 OH | 4.020E-04 |
| 35 | O1D = O | 4.362E+10 |
| 36 | O1D + H2O = 2.0000 OH | 3.247E+05 |
| 37 | CO + OH = HO2 | 3.544E+02 |
| 38 | H2 + OH = HO2 + H2O | 9.891E+00 |
| 39 | HO2 + OH = | 1.625E+05 |
| 40 | HO2 + HO2 = H2O2 | 5.259E+03 |
| 41 | HO2 + HO2 + H2O = H2O2 | 3.662E+03 |
| 42 | HO2 + XO2 = | 1.199E+04 |
| 43 | HO2 + XO2N = | 1.199E+04 |
| 44 | XO2 + XO2 = | 1.998E+02 |
| 45 | XO2 + XO2N = | 3.996E+02 |
| 46 | XO2N + XO2N = | 1.998E+02 |
| 47 | NO3 + OH = NO2 + HO2 | 3.247E+04 |
| 48 | NO3 + HO2 = HNO3 – NOXY | 5.195E+03 |
| 49 | NO3 + NO3 = 2.0000 NO2 | 3.397E-01 |
| 50 | NO3 = 0.8900 NO2 + 0.8900 O + 0.1100 NO -0.1000 NOXY | 1.670E+01 |
| 51 | FORM + O = OH + HO2 + CO | 2.358E+02 |
| 52 | FORM + OH = HO2 + CO | 1.477E+04 |
| 53 | FORM + NO3 = HNO3 + HO2 + CO – NOXY | 8.592E-01 |
| 54 | FORM = 2.0000 HO2 + CO | 1.652E-03 |
| 55 | FORM = CO | 2.297E-03 |
| 56 | ACET + O = C2O3 + OH | 6.644E+02 |
| 57 | ACET + OH = C2O3 | 2.068E+04 |
| 58 | ACET + NO3 = C2O3 + HNO3 – NOXY | 3.497E+00 |
| 59 | ACET = FORM + 2.0000 HO2 + CO + XO2 | 2.855E-04 |

| | REACTION | RATE CONSTANT* ($ppm^{-1}$-$min^{-1}$) |
|---|---|---|
| 60 | ALDX + O = CXO3 + OH – PAR | 1.010E+03 |
| 61 | ALDX + OH = CXO3 – PAR | 2.957E+04 |
| 62 | ALDX + NO3 = CXO3 + HNO3 - PAR – NOXY | 8.393E+00 |
| 63 | ALDX = ACET + 2.0000 HO2 + CO + XO2 – PAR | 1.006E-03 |
| 64 | C2O3 + NO = NO2 + FORM + HO2 + XO2 + NOXY | 2.658E+04 |
| 65 | C2O3 + NO2= PAN – NOXY | 1.283E+04 |
| 66 | C2O3 + HO2 = 0.2600 O3 | 2.008E+04 |
| 67 | C2O3 + C2O3 = 2.0000 FORM + 2.0000 XO2 + 2.0000 HO2 | 2.215E+04 |
| 68 | CXO3 + NO = NO2 + ACET + HO2 + XO2 + NOXY | 2.957E+04 |
| 69 | CXO3 + NO2 = PANX – NOXY | 1.369E+04 |
| 70 | CXO3 + HO2 = 0.3300 O3 | 2.088E+04 |
| 71 | CXO3 + C2O3 = ACET + FORM + 2.0000 XO2 + 2.0000 HO2 | 2.448E+04 |
| 72 | PAN = NO2 + C2O3 + NOXY | 2.289E-02 |
| 73 | PANX = NO2 + CXO3 + NOXY | 2.443E-02 |
| 74 | PANX + OH = NO2 + ACET + NOXY | 1.699E+03 |
| 75 | CH4 + OH = FORM + XO2 + HO2 | 1.689E+01 |
| 76 | PAR + OH = 0.8700 XO2 + 0.1300 XO2N + 0.1100 HO2 -0.1100 PAR + 0.0600 ACET + 0.7600 ROR + 0.0500 ALDX | 1.196E+03 |
| 77 | ROR = 0.9600 XO2 + 0.6000 ACET + 0.9400 HO2 -2.1000 PAR + 0.0400 XO2N + 0.0200 ROR + 0.5000 ALDX | 1.318E+05 |
| 78 | ROR = HO2 | 9.592E+04 |
| 79 | ROR + NO2 = NTR – NOXY | 2.215E+04 |
| 80 | ETH + O = 0.9500 FORM + 1.5500 HO2 + 0.9500 CO + 0.6000 XO2 + 0.3500 OH | 1.077E+03 |
| 81 | ETH + OH = XO2 + 1.5600 FORM + 0.2200 ALDX + HO2 | 1.249E+04 |
| 82 | ETH + O3 = 1.0200 FORM + 0.3300 CO + 0.0800 HO2 + 0.0200 H2O2 | 2.398E-03 |
| 83 | OLE + O = 0.1900 ACET + 0.2900 HO2 + 0.1900 XO2 + 0.2000 CO + 0.2000 FORM + 0.0070 XO2N + 0.6100 PAR + 0.3000 ALDX + 0.1000 OH | 5.907E+03 |
| 84 | OLE + OH = 0.7100 FORM + 0.3600 ACET + 0.5900 ALDX -0.7100 PAR + 0.7100 XO2 + 0.9500 HO2 | 3.948E+04 |
| 85 | OLE + O3 = 0.2000 ACET + 0.8600 FORM + 0.4500 XO2 - PAR + 0.3100 OH + 0.4000 CO + 0.4200 HO2 + 0.3200 ALDX + 0.0800 H2O2 | 1.499E-02 |
| 86 | OLE + NO3 = 0.9100 XO2 + FORM + 0.0900 XO2N - PAR + 0.3500 ACET + 0.5600 ALDX + NO2 | 1.409E+01 |
| 87 | IOLE + O = 1.1400 ACET + 0.7600 ALDX + 0.1000 HO2 + 0.1000 XO2 + 0.1000 CO + 0.1000 PAR | 3.397E+04 |
| 88 | IOLE + OH = 1.2000 ACET + 0.8000 ALDX + HO2 + XO2 | 9.422E+04 |
| 89 | IOLE + O3 = 0.6000 ACET + 0.4000 ALDX + 0.2500 FORM + 0.2500 CO + 0.5000 O + 0.5000 OH + 0.5000 HO2 | 3.097E-01 |
| 90 | IOLE + NO3 = 1.0900 ACET + 0.7300 ALDX + HO2 + NO2 | 5.725E+02 |
| 91 | TOL + OH = 0.4400 HO2 + 0.0800 XO2 + 0.3600 CRES + 0.5600 TO2 + $a_{11}$ SV1 + $a_{12}$ SV2 | 8.752E+03 |
| 92 | TO2 + NO = 0.9000 NO2 + 0.9000 HO2 + 0.9000 OPEN + 0.1000 NTR + 0.9000 NOXY | 1.199E+04 |
| 93 | TO2 = CRES + HO2 | 2.518E+02 |
| 94 | CRES + OH = 0.4000 CRO + 0.6000 XO2 + 0.6000 HO2 + 0.3000 OPEN | 6.055E+04 |
| 95 | CRES + NO3 = CRO + HNO3 – NOXY | 3.247E+04 |
| 96 | CRO + NO2 = NTR – NOXY | 1.998E+04 |
| 97 | CRO + HO2 = CRES | 8.093E+03 |
| 98 | OPEN + OH = XO2 + 2.0000 CO + 2.0000 HO2 + C2O3 + FORM | 4.426E+04 |
| 99 | OPEN + O3 = 0.0300 ALDX + 0.6200 C2O3 + 0.7000 FORM + 0.0300 XO2 + 0.6900 CO + 0.0800 OH + 0.7600 HO2 + 0.2000 MGLY | 1.499E-02 |

| | REACTION | RATE CONSTANT* ($ppm^{-1}$-$min^{-1}$) |
|---|---|---|
| 100 | OPEN = C2O3 + HO2 + CO | 1.493E-02 |
| 101 | XYL + OH = 0.7000 HO2 + 0.5000 XO2 + 0.2000 CRES + 0.8000 MGLY + 1.1000 PAR + 0.3000 TO2 + $a_{21}$ SV1 + $a_{22}$ SV2 | 3.697E+04 |
| 102 | MGLY + OH = XO2 + C2O3 | 2.508E+04 |
| 103 | MGLY = C2O3 + HO2 + CO | 1.084E-02 |
| 104 | ISOP + O = 0.2500 HO2 + 0.2500 XO2 + 0.7500 ISPD + 0.2500 CXO3 + 0.2500 PAR + 0.5000 FORM | 5.315E+04 |
| 105 | ISOP + OH = 0.9100 ISPD + 0.9900 XO2 + 0.9100 HO2 + 0.6290 FORM + 0.0880 XO2N | 1.469E+05 |
| 106 | ISOP + O3 = 0.6000 FORM + 0.6500 ISPD + 0.1500 ALDX + 0.2000 CXO3 + 0.3500 PAR + 0.2700 OH + 0.2000 XO2 + 0.0700 HO2 + 0.0700 CO | 1.898E-02 |
| 107 | ISOP + NO3 = 0.2000 ISPD + XO2 + 0.8000 HO2 + 0.2000 NO2 + 0.8000 ALDX + 2.4000 PAR + 0.8000 NTR -0.8000 NOXY | 9.951E+02 |
| 108 | ISOP + NO2 = 0.2000 ISPD + XO2 + 0.8000 HO2 + 0.2000 NO + 0.8000 ALDX + 2.4000 PAR + 0.8000 NTR – NOXY | 2.198E-04 |
| 109 | ISPD + OH = 0.3300 CO + 0.2500 ACET + 0.1700 FORM + 1.5650 PAR + 0.1680 MGLY + 0.5000 HO2 + 0.7130 XO2 + 0.2100 C2O3 + 0.2900 CXO3 | 4.962E+04 |
| 110 | ISPD + O3 = 0.0200 ACET + 0.1500 FORM + 0.2300 CO + 0.8500 MGLY + 0.3600 PAR + 0.1100 C2O3 + 0.0640 XO2 + 0.2700 OH + 0.1500 HO2 | 1.049E-02 |
| 111 | ISPD + NO3 = 0.6400 CO + 0.2800 FORM + 0.3600 ALDX + 1.2820 PAR + 0.9250 HO2 + 0.0800 CXO3 + 0.0750 XO2 + 0.8500 NTR + 0.1500 HNO3 – NOXY | 1.477E+00 |
| 112 | ISPD = 0.3300 CO + 0.0700 ACET + 0.9000 FORM + 0.8320 PAR + 1.0330 HO2 + 0.7000 XO2 + 0.2670 C2O3 + 0.7000 CXO3 | 9.195E-05 |
| 113 | TERP + O = 0.1500 ALDX + 0.5100 PAR + 993.0000 SV3 + 994.0000 SV4 | 5.263E+04 |
| 114 | TERP + OH = 0.7500 HO2 + 1.2500 XO2 + 0.2500 XO2N + 0.2800 FORM + 0.4700 ALDX + 995.0000 SV3 + 996.0000 SV4 | 9.915E+04 |
| 115 | TERP + O3 = 0.5700 OH + 0.0700 HO2 + 0.7600 XO2 + 0.1800 XO2N + 0.2400 FORM + 0.0010 CO + 7.0000 PAR + 0.2100 ALDX + 0.3900 CXO3 + 997.0000 SV3 + 998.0000 SV4 | 1.099E-01 |
| 116 | TERP + NO3 = 0.4700 NO2 + 0.2800 HO2 + 1.0300 XO2 + 0.2500 XO2N + 0.4700 ALDX + 0.5300 NTR -0.5300 NOXY + 999.0000 SV3 + 990.0000 SV4 | 9.811E+03 |
| 117 | SO2 + OH = SULF + HO2 | 1.321E+03 |
| 118 | ETOH + OH = 0.9500 ACET + 0.1000 XO2 + HO2 + 0.1000 FORM | 4.726E+03 |

- ** For single reactant processes, rate is in $min^{-1}$. Reaction rates are for noon (zenith angle 17 degrees) at approximately 100W longitude, 40N latitude, 298 K, 1 atm.*

As an option, REMSAD also includes a reduced-form version of the CB_V , termed “micro-CB” (μCB). This form of the mechanism was used in REMSAD prior to version 8. The mechanism is based on a drastic reduction in the speciation of the organic compounds; the inorganic and radical parts of the mechanism are identical to CB-V. Further details on micro-CB can be found in the REMSAD user’s manual (ICF, 2005).

REMSAD requires information on solar radiation in order to calculate photolysis rates for the photochemical reactions that drive the formation of OH radical and the steady-state concentrations of NO, $NO_2$, and ozone.

Photolysis rates are calculated as a preprocessing step using a parameterized light model developed by Schippnick and Green (1982). Lookup tables for photolysis rates for $NO_2$ and ozone for various zenith angles and altitudes are generated and used by the model (through linear interpolation) to assign a photolysis rate to each grid cell and time step.

The ratios of ozone, formaldehyde, and acetaldehyde to $NO_2$ photolysis rate have been defined for two altitudes (1380 m and 10000 m) that approximately represent the average altitude of the boundary layer and the upper troposphere. These ratios, and ozone photolysis rates, were used to generate OH lookup tables for the lower and upper atmospheres. Photolysis rates for several other photochemical reactions are derived from these values using scaling factors (see Gery et al., 1989).

Cloud cover is not treated by the photolysis rate preprocessor, but at the end of each time step all photolysis rates are corrected for cloud cover using the algorithm developed by Chang (1987) for the Regional Acid Deposition Model (RADM). The cloud cover scaling factors applied to the photolysis rates vary from 1 for clear skies to 0.01 for completely overcast conditions (under some cloud vertical distribution this scaling factor can be higher than 1). This procedure assumes that the cloud cover effects for all photolysis rates are the same as for $NO_2$.

### 2.1.3. Mercury Chemistry

Mercury (Hg) is volatile in elemental form but involatile in many oxidized inorganic forms and therefore may be present both in the gas and particulate phases. Gaseous mercury species other than elemental Hg may be present in the atmosphere (e.g., organo-mercury compounds). Estimates of mercury emissions include a significant fraction of gaseous, oxidized mercury (EPA, 1997).

The chemical transformations of mercury included in REMSAD are based on the review of current status of atmospheric chemistry of mercury presented by Lin and Pehkonen (1999) with a number of updates based on more recent literature. The mercury species included in REMSAD are HG0 (elemental mercury vapor), HG2 (divalent mercury compounds in gas phase), and HGP (divalent mercury compounds in particulate phase). These species represent the oxidation state of mercury, and the gas and particulate phases. The reactions in REMSAD cause transfer of mercury mass from one of these states to another.

In cloud water, HGP is assumed to dissolve with the solubility of HgO (mercury (II) oxide). Some HG2 is assumed to be adsorbed to soot particles (e.g., see Seigneur et al., 1998). In REMSAD, the treatment is parameterized using a simple formula. The species PEC (primary elemental carbon) is used as an indicator of the amount of soot present. Fifty-five percent (based on the upper limit suggested by Seigneur et al., 1998) of the dissolved divalent mercury ($Hg^{2+}$) in aqueous phase is assumed to be adsorbed to soot particles when PEC is 55 μg/(mole of air) or greater. When PEC is zero, no adsorption takes place. Between these two extremes, the fraction of adsorbed $Hg^{2+}$ is linearly interpolated. This parameterization is based in part on results of comparing the REMSAD aqueous mercury chemistry with published information on the aqueous mercury chemistry in other models such as CMAQ (Myers, 2004; Ryaboshapko, 2002).

REMSAD does not have an internal estimate of chlorine concentrations, which is important in many of the aqueous phase reactions. Therefore, an input file is required to specify chlorine. The chlorine pathway is considered to be active only at night and chlorine at upper levels is typically set to zero. Chlorine concentrations are supplied for the surface level with differing values over the ocean and over land. A typical value used for chlorine over the ocean is 125 ppt (Tokos et al., 1998). Chlorine over land areas is much lower. A value of 5 ppt over land was chosen. Chlorine concentrations are reduced linearly from the surface to zero at a height of 2000 m over the ocean or at a height of 1000 m over land. The ocean value for chlorine was used approximately 18 km inland in addition to over the ocean.
In order to treat reduction of HG2 by sulfur compounds, the average amount of dissolved $SO_2$ is estimated during the calculation of the aqueous formation of sulfate (via reaction of $SO_2$ with $H_2O_2$, $O_3$, and $O_2$). Equilibrium concentrations of $HgSO_3$ and $Hg(SO_3)_2^{2-}$ are calculated and then

the production rate of HG0 from $HgSO_3$ is calculated. The pH of cloud water is needed in order to calculate the Henry's law coefficients of some species. In these cases, pH is assumed to be 4.5.

Some of the individual species-specific reactions such as photoreduction (for halo-compounds of divalent Hg) and reactions of dimethylmercury by O3, OH, and other radicals have been neglected, since their effects are expected to be small.

The routine that calculates chemical transformations of mercury is provided with total concentrations of HG0, HG2, and HGP. The routine calculates the fraction in gas and aqueous phases of each of these categories. Gas and aqueous chemical transformations are calculated independently. The routine then recombines the gas and aqueous fractions to return the new total concentrations of HG0, HG2, and HGP.

Table 2-3 lists the reactions that are included in the REMSAD mechanism for mercury.

**Table 2-3. Mercury Chemical Mechanism in REMSAD, Version 8.**

| Reaction | Rate (unit) |
|---|---|
| **For HG0** | |
| *Gas phase* | |
| HG0 + $O_3$ → ½ HGP + ½ HG2 | 3.0e-20 ($cm^3 molecule^{-1} s^{-1}$) |
| HG0 + $H_2O_2$ → HG2 | 8.5e-19 ($cm^3 molecule^{-1} s^{-1}$) |
| HG0 + OH → ½ HGP + ½ HG2 | 7.7e-14 ($cm^3 molecule^{-1} s^{-1}$) (lower bound of range in Pal & Ariya, 2004; also within range in Sommar et al., 2001) |
| *Aqueous phase* | |
| HG0 + $O_3$ → HG2 | 4.7e+7 ($M^{-1} s^{-1}$) |
| HG0 + OH → HG2 | 2.0e+9 ($M^{-1} s^{-1}$) |
| HG0 + $Cl_{aq}$ → HG2 | (See eq. 8 in Lin and Pehkonen, 1999) |
| HgSO3 → HG0 | T $e^{(31.971\,T - 12595)/T}$ $s^{-1}$ (Van Loon et al., 2000) |
| **For HG2** | |
| *Aqueous phase* | |
| HG2 + $HO_2$ → HG0 | 1.7e+4 ($M^{-1} s^{-1}$) |
| HG2 + $SO_3^{2-}$ ↔ $HgSO_3$ | 5.e+12 ($M^{-1}$) |
| $HgSO_3$ + $SO_3^{2-}$ ↔ $Hg(SO_3)_2^{2-}$ | 2.5e+11 ($M^{-1}$) |
| Hg2 + $OH^-$ ↔ $Hg(OH)^+$ | 4.27e+10 ($M^{-1}$) |
| Hg2 + 2 $OH^-$ ↔ $Hg(OH)_2$ | 1.74e+22 ($M^{-1}$) |
| Hg2 + $OH^-$ + $Cl^-$ ↔ HgOHCl | 1.78e+18 ($M^{-2}$) |
| Hg2 + $Cl^-$ ↔ $HgCl^+$ | 2.0e+7 ($M^{-1}$) |
| Hg2 + 2 $Cl^-$ ↔ $HgCl_2$ | 1.e+14 ($M^{-2}$) |
| Hg2 + 3 $Cl^-$ ↔ $HgCl_3^-$ | 1.e+15 ($M^{-3}$) |
| Hg2 + 4 $Cl^-$ ↔ $HgCl_4^{2-}$ | 3.98e+15 ($M^{-4}$) |

- *Source: Lin and Pehkonen, 1999, except as noted.*

## 2.1.4. Mercury Re-Emission Treatment

Re-emission of mercury from land or water surface is believed to occur but has not been accurately quantified. Sofiev and Galperin (2000) note that mercury can be reduced (or methilated) and re-emitted back into the air after oxidation and deposition. Syrakov (1998) finds

that airborne mercury (both anthropogenic and natural) deposited on land and water surfaces is re-emitted back to the atmosphere through natural processes, such as microbial activity. He also reports that natural emissions and the re-emission of mercury are mainly in the form of Hg0. Very small amounts are in the form of organic mercury compounds, since these are very quickly reduced to metal vapor in the atmosphere. Other modelers (Shia, et al., 1999) note that the emissions from land and ocean surfaces consist of 1) cycling of mercury with its natural budget estimated to be 2000 Mg $yr^{-1}$ and 2) recycling of previously deposited mercury of anthropogenic origin which is estimated to also be on the order of 2000 Mg $yr^{-1}$. All of their natural and re-emitted mercury emissions are in the form of Hg0.

Syrakov describes a methodology for incorporating re-emission into a transport model, and this methodology is used in REMSAD. This method estimates the rate at which mercury becomes fixed (and therefore unavailable for re-emission) and the rate at which mercury is re-emitted. A re-emission mass, which is a measure of the amount of mercury that could be re-emitted, is tracked. Syrakov suggests the following parameterization and constants:

$$dQ_{av}/dt = D + W - a_{reemis}Q_{av} - a_{fix}Q_{av},$$

$$dQ_{fix}/dt = a_{fix}Q_{av},$$

$$RE = a_{reemis}Q_{av}$$

Here D is the dry deposition flux, W is the wet deposition flux, $Q_{av}$ is the re-emission mass, $Q_{fix}$ is the fixed (unavailable) mass, RE is the re-emission flux, and $a_{fix}$ and $a_{reemis}$ are fixation and re-emission coefficients (see Table 2-4).

**Table 2-4. Mercury Re-Emission Coefficients.**

| Coefficient | $a_{reemis}$ | $a_{fix}$ |
|---|---|---|
| Sea | 0.005 | 0.000002 |
| Land | 0.0002T | 0.000002T |

- *($a_{reemis}$ and $a_{fix}$ in $hr^{-1}$. T is temperature in C. $a_{reemis}$ and $a_{fix}$ over land are zero when T < 0.)*

It is clear from the magnitude of these coefficients that the rate of re-emission of newly deposited material will be much faster than its rate of fixation. (The time to fix half of deposited mercury mass is on the order of years while the time to re-emit half of the deposited mercury is on the order of weeks.) Therefore, although conceptually attractive, initializing the $Q_{av}$ mass with the deposition results of an existing simulation would result in an apparent over estimation of $Q_{av}$. (Simulation results show annual deposition of between 10 and 100 g/$km^2$ while Syrakov estimates $Q_{av}$ at only 0.2 g/$km^2$ over water and between 1.7 and 3.9 g/$km^2$ over land.) It was decided therefore to initialize $Q_{av}$ to 0.2 g/$km^2$ over water and 2.0 g/$km^2$ over land. Syarkov's treatment is followed, except that $Q_{fix}$ is not tracked since it does not affect the evolution of $Q_{av}$.

Because of the uncertainties inherent in virtually all of the parameters required to implement this treatment, the base calculation was not made dependent on the re-emission calculation. However, because of the availability of the mercury tagging species, the re-emitted mercury can be tracked as a separate species. Calculation of $Q_{av}$ is dependent on deposition of all emissions

and boundary concentrations. Re-emission takes place into one specific tag as elemental mercury.

## 2.1.5. Wet Deposition

Wet deposition is the scavenging of gasses and particulates from the atmosphere by precipitation, and their subsequent deposition (via rainwater) to the surface. Wet deposition is one of the mechanisms for the removal of pollutants from the atmosphere that is represented in REMSAD. Separate treatments are used for gasses and particulates.

### Gaseous Wet Deposition

The gaseous wet scavenging algorithm in REMSAD is based on Henry's law and specifically Hales and Sutter (1973). According to Henry's Law, the dissolved concentration of a gas in water is proportional to the partial pressure of the gas over the water. Mathematically, this can be expressed as $[A(aq)] = H_A P_A$, where $[A(aq)]$ is the aqueous concentration of the gas in mole/liter, $H_A$ is the Henry's Law constant for the gas, and $P_A$ is the partial pressure of the gas in atmospheres. Some gases, such as $SO_2$, react with the hydrogen ions present in water and are effectively more soluble than predicted by the above law. The increased solubility is accounted for by using the effective Henry's law coefficient, which is dependent on the hydrogen ion concentration. Expressions for the effective Henry's law coefficients are included in REMSAD for the standard simulated species. The approach developed by Hales and Sutter involves calculating the amount of gas dissolved in water and the rate at which the liquid water rains out of the system. It originally focused on sulfur dioxide. As used in REMSAD, it has been generalized for any gaseous species (assuming low concentration).

The REMSAD wet deposition algorithm considers six gaseous (NO, $NO_2$, $SO_2$, $NH_3$, VOC, $HNO_3$) plus seven toxic species. Temperature dependencies for Henry's Law constants are incorporated for all species. Solubility ($K_H$), ionization ($K_{1D}$, $K_{2D}$), and vapor pressure constants for the toxic species were obtained from recent literature.

The following scavenging rate was derived by Hales and Sutter (for derivation, see below).

$$RWET = RANM / H(LWC + SOL),$$

where SOL is solubility, LWC is liquid water content, H is the layer depth, and RANM is rainfall in m/hr. This scavenging rate is used to adjust (reduce) the species concentration in each model layer. Scavenging is applied successively to each layer and the total flux (wet deposition to the surface) is the sum of the mass removed from all layers that extend from near cloud top to the ground.

According to Hales and Sutter, the ratio of the gaseous concentration of a given species to the liquid-phase concentration ($C_g / C_l$) in the atmosphere can be expressed as:

$$SOL = C_g / C_\ell = 1/\left(K_H + \frac{K_{1D} K_H}{[H^+]} + \frac{K_{2D} K_{1D} K_H}{[H^+]^2}\right)$$

Where

| | | |
|---|---|---|
| $C_l$ | = | liquid-phase concentration (mol/l water) |
| $C_g$ | = | gaseous-phase concentration (atm) |
| $[H^+]$ | = | concentration of hydrogen ions (mol/l water) |
| $K_H$ | = | species-dependent Henry's Law equilibrium constant (mol/l-atm) |

and $K_{1D}$ and $K_{2D}$ are species-dependent first and second ionization constants. For the purpose of estimating the hydrogen ion concentration, REMSAD assumes a cloud water pH of 4.5. For the purpose of the current modeling, the species of interest are elemental mercury and divalent gas mercury. The Henry's law coefficients (at 298 K) used for these species in REMSAD are shown in Table 2-5.

**Table 2-5. Henry's Law Coefficients Used in REMSAD (at 298 K).**

| Species | $K_H$ (mol/l-atm) |
|---|---|
| HG0 | 0.112 |
| HG2 | 1.4 X $10^6$ |

Conservation of mass requires the following relationship between gas-phase concentration, liquid-phase concentration, and total (liquid and gas) concentration ($C_o$):

$$C_g + (C_l \times \mathrm{LWC}) = C_o$$

where *LWC* is the liquid water content (of the atmosphere). Substituting from above and rearranging terms the liquid-phase concentration is expressed as:

$$C_l = C_o/(\mathrm{LWC} + \mathrm{SOL})$$

where *LWC* is taken from the rain liquid water input data file. The scavenging of pollutant mass by precipitation can be generally expressed by the equation:

$$W_i = \rho_w \bullet \mathrm{RANM} \bullet \chi_i/H$$

Where

$W_i$ = mass of species *i* material scavenged per unit volume of air per unit time
$_w$ = the water density
$_i$ = mass of species i scavenged per unit mass of water
$H$ = the layer depth.

The scavenging rate for gaseous removal, RWET, can be expressed by dividing the above equation for $W_i$ by the species concentration, $C_o$:

$$RWET = W_i / C_o = \left(\rho_w \bullet RANM \bullet \chi_i\right) / HC_o$$

By substituting into the above expression and using the alternative definition for $C_l = \rho_w \cdot {}_i$.

$$RWET = RANM / H(LWC + SOL)$$

## Particulate Wet Deposition

Wet deposition of aerosols in REMSAD utilizes many of the relationships established by Scott (1978), which relate rainfall rate and cloud type to fraction of ambient sulfate within rainwater reaching the ground. The equations have been expanded from sulfate only to treat any aerosol species. Non-sulfate aerosols are assumed to scavenge at a constant fraction of the sulfate rate. This fraction can be specified by the user in the CHEMPARAM file and is dependent upon each species' hygroscopic nature and its affinity to exist with other hygroscopic species. Settings for this fraction in current CHEMPARAM files are given in Table 2-6.

**Table 2-6. Estimated Fractions of Sulfate Wet Scavenging Rate, by Species, as Used in REMSAD.**

| | |
|---|---|
| PNO3 | 1.0 |
| GSO4 | 1.0 |
| ASO4 | 1.0 |
| NH4N | 1.0 |
| NH4S | 1.0 |
| SOA | 0.5 |
| POA | 0.2 |
| PEC | 0.2 |
| PMFINE | 0.2 |
| PMCOARS | 0.2 |

For aerosols smaller than 1μm in diameter, it is assumed that the capture of aerosols by phoretic attachment or Brownian motion is negligible and that the principal scavenging mechanism is the nucleation of cloud droplets around aerosols followed by particle growth through coalescence and accretion of cloud droplets to sizes large enough to fall through the cloud as precipitation. Aerosols larger than 1μm are removed strictly by impaction with falling raindrops.

For the portion of clouds in which Bergeron (mixed cloud of ice crystals and liquid water) processes for rain initiation occurs, it is expected that aerosols do not participate in the nucleation of cloud ice crystals, and therefore are not present in ice crystals as they coalesce into larger precipitating crystals. In warm clouds, including both stratiform and convective clouds, nucleation and coalescence are assumed to be the dominant process for cloud droplet growth with aerosols acting as nuclei. However, the cloud layer depth over which these processes occur is treated separately for stratiform and convective clouds.

Relationships between rainfall rate, median drop size and fallspeed, and precipitable water content have been developed by Scott (1978) and Kessler (1969) as:

$$V = 130D^{0.5}$$
$$D = 8.95 \times 10^{-4} R^{0.21}$$
$$M = 0.071R^{0.88}$$

where $V$ is fallspeed or velocity (m $s^{-1}$), $D$ is median drop diameter (m), $M$ is precipitable water content (g $m^{-3}$), and $R$ is the rainfall rate converted to mm $h^{-1}$.

These relationships are used in REMSAD to determine the precipitable water content, drop diameter, and velocity of the hydrometeor at cloud base and at top of the riming zone. The depth over which active hydrometeor growth is occurring is estimated based on the particular layer structure of the cloud and rainfall rate within the cell. A typical residence time $t$ in the riming zone of 384 s for stratiform clouds and 769 s for convective clouds has been used to initially estimate the depth of the riming zone. Final residence time is determined once the top of the riming zone has been determined. The residence time is then used to calculate the vertically averaged cloudwater mass, $\overline{m}$ whose relationship is expressed as:

$$\overline{m} = (1/C_1 t)(3.12 + 0.88 \ln R)$$

where $C_1 = 5.2 \times 10^{-3}\ m^3\ g^{-1} s^{-1}$ (for raindrops) and t is time. The washout rate $w_{rat}$ for the layer just above the riming zone is given by:

$$w_{rat} = M_o / \overline{m} - t$$

where $-t = 435R^{-0.71} + 1200$ based on continental warm phase-clouds and

$$M_o = 3.15 \times 10^{-3}\ g\ m^{-3}.$$

If the cloud type is stratiform and the layer just above the riming zone is freezing, then the washout rate is considered negligible and the contribution from this layer is ignored.
To determine the washout rate for each cloud layer within the riming zone, the precipitable water content $M_k$ is determined for each layer from the expression:

$$M_{k+1} = M_k / \exp(-C_1 \overline{m}\, t_k)$$

where

$M_{k+1}$ = precipitable water within layer $k + 1$,
$M_k$ = precipitable water within layer $k$,
$t_k$ = time hydrometeor is within layer $k$.

The $w_{rat}$ for each layer $k$ is calculated in an analogous manner to the top layer,

$$w_{rat} = M_k / \overline{m}\, t_k$$

For the layer just below the cloud base down to layer one the $w_{rat}$ removes particles strictly through impaction with falling raindrops. The expression for their removal is given by:

$$w_{rat} = 2.14 \quad 10^{-2} C_1 R^{0.88}$$

with an assumed inertial impaction efficiency of 0.3.

The effective washout rate fraction for each species is then adjusted logarithmically for the hygroscopic affinity (fc) and aerosol size distribution of each species and the aerosol available for incorporation into the cloud water. This washout or scavenging rate is used to adjust (reduce) the aerosol concentration in each model layer. Washout is applied successively to each layer and the total flux (wet deposition to the surface) is the sum of the mass removed from all layers that extend from near cloud top to the ground.

### 2.1.6. Dry Deposition

The dry deposition algorithm in REMSAD is based on the scheme in the Regional Acid Deposition Model (RADM) as described by Wesely (1989). A more complete description of this algorithm is provided by Scire (1991). In this methodology, the flux of pollutant material to the surface (the lower boundary of the modeling domain), $F_0$, is expressed as a product of the concentration in the lowest model layer ($C_i$) and the deposition velocity ($V_d$):

$$F_0 = -C_i\ V_d$$

Thus dry deposition of a given species is directly proportional to the concentration of that species within the lowest model layer.

The deposition velocity is estimated as an inverse sum of a series of resistances (such that the greater the resistance, the lower the deposition velocity). For gaseous species this is expressed as follows:

$$V_d = \frac{1}{R_a + R_b + R_s}$$

where $R_a$ is aerodynamic resistance, $R_b$ is boundary-layer resistance, and $R_s$ is surface resistance. These represent the effects of turbulent diffusion (within the lowest layer), molecular diffusion (that occurs very near the surface), and finally uptake at the surface (once the surface is reached). The aerodynamic resistance ($R_a$) is dependent on the surface characteristics and atmospheric stability conditions. It is calculated from two surface-layer similarity parameters: the friction velocity and the Monin-Obukhov length (see Gray et al., 1991).

The boundary or quasi-laminar layer resistance ($R_b$) represents the process of molecular diffusion of the transport of pollutants through the laminar layer around solid objects and is highly dependent on the Schmidt number (the ratio of air kinematic viscosity to the molecular diffusivity of the pollutant in air; see Gray et al., 1991). Note that molecular diffusion is inversely proportional to the molecular weight.

The surface resistance ($R_s$) is actually a set of parallel resistances associated with (1) leaf stomata, (2) leaf cuticles, (3) lower canopy resistances (e.g., bark, stems, etc.), and (4) surface soil, litter, and water (see Wesely, 1989). Surface resistance (resistance to uptake) is both species and surface dependent.

The deposition velocity of particulate species also depends on particle size distribution and density. Particles have a sedimentation velocity ($V_{sed}$) or fall-out rate that can be a significant component of the deposition velocity for large particles. Very small particles have a negligible sedimentation velocity and behave in a manner similar to gases. In REMSAD particle deposition velocity is calculated as:

$$V_d = V_{sed} + \frac{1}{R_a + R_b + R_a R_b V_{sed}}$$

where $V_{sed}$ (m/s) is given by the equation

$$V_{sed} = g\, d_p^{\,2}\, (\rho - \rho_{air})\, C/18\mu,$$

where $\rho$ is the particle density ($gm^{-3}$), $\rho_{air}$ is the air density, $g$ is the acceleration due to gravity (9.8 $ms^{-2}$), $dp$ is particle diameter (m), and $\mu$ is the viscosity of air. $C$ is the slip correction factor given by

$$C = 1 + 2(l/d_p)[A_1 + A_2 exp(-A_3 d_p/l)],$$

where $l$ is the mean free path, and $A_1$, $A_2$, and $A_3$ are 1.257, 0.4, and 0.55 (Friedlander, 1977).

## Calculation of Micrometeorological Parameters

Two meteorological scaling parameters (with a basis in similarity theory) are needed for the calculation of the aerodynamic resistance term used in the dry deposition algorithm. These are the friction velocity and the Monin-Obukhov length and are calculated within REMSAD from the gridded wind, temperature, and pressure input fields. These scaling parameters for velocity and length are essentially invariant with the atmospheric surface layer and enable the calculation of various turbulence-related effects. The approach to calculation of these parameters is based on similarity theory. Temperature and pressure for the surface and the lowest model layer are used to calculate

a potential temperature gradient, which is then combined with wind speed for the lowest model layer to determine stability within the layer. Friction velocity and Monin-Obukov length are then calculated following the formulation of Louis (1979) for each land-use category. These parameters vary according to land-use category due to differences in roughness length, which is also considered in the calculation. Wind speed at a height of 10 m above ground level (agl) is also estimated. Recognizing that the roughness of a water surface depends on surface stress (i.e., wind speed), water roughness length is specifically calculated from friction velocity and subsequently used in the calculation of the resistance terms for grid cells containing water surfaces.

## Calculation of Resistance Terms

The surface (10 m) wind speed, friction velocity, and Monin-Obukhov length for each land-use category within a grid cell are used to calculate aerodynamic and boundary resistances for each land-use type in that cell. The resistances are combined with the land-use-dependent surface resistance to obtain a land-use-dependent deposition velocity. The velocities are then weighted by fractional area covered by each land-use type within the grid cell to obtain a single deposition velocity for each grid cell for each species. Other key effects that are incorporated into the calculation of the resistance terms include moisture stress, differences due to water surfaces, and surface moisture.

### Effects of Moisture Stress on Stomatal Resistance

Stomatal resistance, which controls daytime gaseous dry deposition to vegetated surfaces via the surface resistance term, increases markedly during periods of moisture stress (Scire, 1991). The deposition algorithm in REMSAD identifies three vegetation states for each grid cell: active unirrigated vegetation in unstressed conditions or irrigated vegetation (State A), active unirrigated vegetation in stressed conditions (State B); and inactive vegetation (State C). Of these states, however, State A is used almost exclusively since data indicating one of the other two states are usually not available. The resistance is approximated for each state as follows:

- For State A, stomatal resistance is parameterized in terms of a reference resistance (which is season and land-use dependent), solar radiation, and surface air temperature. Solar flux is calculated as a function of solar zenith angle, and adjusted directly by the percentage of cloud cover for each cell. A surface air temperature correction factor to stomatal resistance is also included. Default values for minimum, maximum, and optimum temperatures for stomatal closing of 0, 40, and 20°C, respectively, are used.
- For State B, which by definition corresponds to minimum stomatal opening, stomatal resistance is arbitrarily set to a multiple of the resistance for State A. The multiplication factor is equal to 10.
- For State C, stomatal resistance is set to a large value ($1.0 \times 10^5$) that effectively prevents deposition.

For applications in which a lack of data does not allow either accurate determination of moisture stress conditions or the breakdown of irrigated versus unirrigated vegetation (most cases), only state A is considered.

### DEPOSITION TO WATER SURFACES

To accommodate that the deposition to water surfaces can be rapid for many soluble gases a formulation for surface resistance over water based on the work of Slinn et al. (1978) is used by REMSAD. In liquid-phase, resistance is given by

$$R_s = \frac{H}{\alpha_* \; k_l} \quad (1)$$

where $H$ is the Henry's law coefficient, $\alpha_*$ is an effective enhancement of solubility of each gas in water, and $k_l$ is the liquid-phase transfer velocity, which includes the effects of surface stress. Slinn et al. (1978) expressed $k_l$ in terms of surface friction velocity $u_*$ over water as:

$$k_l = 4.8 \times 10^{-4} \; u_*$$

### EFFECTS OF SURFACE MOISTURE

The REMSAD dry deposition algorithm includes modifications to the surface resistances for dew- and rain-wetted surfaces per Wesely (1989). The extent of dew is estimated internally by the REMSAD based on relative humidity and wind speed. As suggested by Scire (1991), a formula given by Wesley and Lesht (1988) is used to determine that dew is present when the quantity: (100 – RH) (u + 0.6) is less than 19, where RH is the relative humidity (%) and u is the wind speed (m/s). As recommended by Wesley, dew wetted surfaces have enhanced deposition for SO2 and other soluble species but increased resistance for ozone. For rain wetted surfaces, resistance to uptake is increased for all species.

## 2.1.7. Particle and Precursor Tagging Methodology (PPTM) for Mercury

Using the PPTM approach, mercury species in the emissions and initial and boundary condition files are tagged and tracked throughout the REMSAD simulation. Tags can be applied to emissions from selected source regions, source categories, and individual sources, both separately and in combination. PPTM quantifies the contribution of the tagged emissions sources (and/or initial/boundary conditions) to the simulated species concentrations and deposition, for each mercury species considered by the model.

PPTM for mercury tracks emitted mass from its source through the modeling system processes. Within the model, tagging (PPTM) is accomplished by the addition of duplicate model variables for each species and tag. The tagged species have the same properties and are subjected to the same processes (e.g., advection, chemical transformation, deposition) as the actual (or base) species. Typically, each tag includes all of the species necessary to keep track of the mercury emissions from a particular source or source grouping, but, the different species that comprise mercury emissions (e.g., elemental, divalent, and particulate) can also be tagged separately. Because the tagged species are separate from the base species, PPTM does not alter or affect the base simulation results.

The emissions from each selected source, source category, or grouping are tagged in the simulation and each grouping is referred to as a “tag.” The tagged species are differentiated from the regular species used in the REMSAD model by a suffix added to the species name. Each individual species from a given source or source grouping is tagged and the combination of all of the individual species represents the tag. As an example, in order to track the mercury emissions from incinerators, the species HG0_t1, HG2_t1, and HGP_t1, referring to elemental (HG), divalent (HG2), and particulate (HGP) emissions from incinerators, will be created. The “t” refers to tagging and the number one is the tag number. Collectively, these species (are referred to as the incinerator tag.

PPTM was developed to utilize model algorithms as much as possible to track simulated tag species concentrations. At each time step in the simulation, the effects of linear processes, such as advection and dry deposition, are calculated directly for all tagged species. Potentially non-linear processes, such as gas-phase chemistry, aqueous chemistry, and particle dynamics are calculated for the overall (or base) species and apportioned to the tagged species. The results for the tagged species are not normalized to ensure that the sum of the tagged species equals the total. Thus, the difference between the sum of all tags and the overall concentration gives an estimate of the numerical uncertainty in the calculated contribution.

Some example uses of the mercury PPTM methodology include 1) quantifying the contribution of mercury emissions from various source sectors to mercury deposition at selected locations throughout the modeling domain, 2) quantifying the contribution from boundary conditions to mercury deposition throughout the modeling domain, 3) examining the range of influence of emissions from selected facilities, and 4) tracking the fate of mercury emissions from a particular source category estimate the contribution to deposition to water bodies throughout the modeling domain.

### 2.1.8. Summary of Outputs and Information Provided by REMSAD

Key REMSAD output files contain information on the simulated concentrations and deposition totals. Specifically, the average file contains time-averaged (typically hourly averaged) concentrations for each species for each grid cell for the entire modeling region. The deposition file contains wet and dry deposition (g/km2) for a selected output interval for each species in each grid cell for the entire modeling domain.

The simulation results are typically displayed using spatial distribution plots and a variety of other graphical analysis products. The base case simulation results are compared with observed data using scatter plots and a variety of statistical measures.

The tagged species are included as additional species in the model output files and the results can be post-processed and displayed in the same way as the standard species. Spatial plots of the tagged species can be used to show the extent and magnitude of the contributions from the tagged sources within the modeling domain. The contribution from each tag at individual locations throughout the domain can also be extracted from the gridded model output. Finally, the tags can be summed and compared with the base simulation results to quantify the numerical accuracy of the results.

### 2.1.9. REMSAD/PPTM Application Procedures

Application of REMSAD with PPTM for a single base year includes the following steps:

#### REMSAD Application Procedures

- Select a modeling domain (considering extent and horizontal and vertical grid resolution)
- Select a simulation period (typically an annual period, and preferably with typical (not extreme) meteorological conditions)
- Prepare emissions inventory, meteorological, and initial and boundary condition, and geographical input files for the selected domain and simulation period
- Apply REMSAD for criteria pollutants (ozone, PM, etc.) and evaluate model performance
- Apply REMSAD for mercury and evaluate model performance.

### PPTM Application Procedures

- Identify sources for tagging, conceptually and within the emissions inventory
- Prepare the tagged emissions inventory and initial/boundary condition files.
- Apply REMSAD for mercury only with PPTM for up to approximately 20 tags (repeat, as needed, to accommodate all identified tags)
- Post-process and analyze the PPTM contributions.

Other applications of REMSAD may include future-year emissions projections and model runs. Tagging can be applied for the future-year scenarios as well.

## 2.2. CMAQ Modeling System

The CMAQ model is a state-of-the-science, regional air quality modeling system that is designed to simulate the physical and chemical processes that govern the formation, transport, and deposition of gaseous and particulate species in the atmosphere (Byun and Ching, 1999). The CMAQ model was designed as a "one-atmosphere" model and can be used to simulate ozone, particulate matter, and mercury. For mercury, CMAQ supports the detailed simulation of the emission, chemical transformation, transport, and wet and dry deposition of elemental, divalent, and particulate forms of mercury. Version 4.6 of CMAQ was used for this study.

According to Bullock et al. (2008), the CMAQ model reflects the current state-of-the-science in simulating the atmospheric processes that influence the dispersion, advection, chemical transformation, and deposition of mercury. The CMAQ model includes three mercury (Hg) species; elemental mercury ($Hg^0$ or HG in CMAQ), reactive gaseous mercury (RGM or HGIIGAS in CMAQ), and particulate-bound mercury (PHg or APHGJ and APHGI in CMAQ). Reactive gaseous mercury is known to be comprised almost entirely of divalent mercury ($Hg^{2+}$), since Hg compounds at other valence states tend to be chemically unstable in the atmosphere. Particulate-bound mercury is also primarily comprised of divalent mercury, but may also include elemental mercury.

Mercury simulation capabilities were first incorporated into the CMAQ model by adding gaseous and aqueous chemical reactions involving mercury to the CMAQ chemical mechanism (Bullock and Brehme, 2002). Since that time, the chemical mechanism has been further updated to include additional reactions and updated information on reaction rates. The most recent changes to CMAQ for mercury include an updated dry deposition algorithm and the incorporation of natural mercury emissions. The CMAQ modeling system, including the mercury modeling component, has been peer reviewed (e.g., Amar et al., 2005).

In addition to the state-of-the science chemical mechanism for mercury, other key features of the CMAQ model in simulating mercury deposition include state-of-the-science advection, dispersion and deposition algorithms, the latest version of the Carbon Bond chemical mechanism (CB05), and the CMAQ Particle and Precursor Tagging Methodology (PPTM).

PPTM for mercury (Douglas et al., 2006) provides detailed, quantitative information about the contribution of selected sources, source categories, and/or source regions to simulated mercury concentrations and (wet and dry) deposition. Mercury emissions from selected sources, source categories, or source regions are (numerically) tagged and then tracked throughout a simulation, and the contribution from each tag to the resulting simulated concentration or deposition for any given location can be quantified. By tracking the emissions from selected sources or source locations, the methodology also provides information on the fate of the emissions from these sources.

The CMAQ model has been used by EPA to support the development of the Clean Air Mercury Rule (CAMR) (EPA, 2005a). This study included the evaluation of global modeling results to prescribe boundary conditions for CMAQ, evaluation of simulated mercury deposition vs. MDN data, and assessment of the contribution of mercury emissions from coal-fired power plants on mercury deposition in the U.S.

CMAQ was also included in the North American Mercury Model Intercomparison Study (NAMMIS) for mercury (Bullock et al., 2008) and the performance and response of CMAQ was found to be reasonable and also consistent with that for REMSAD).

Additional information on the CMAQ modeling system can be found in Byun and Ching (1999).

## 2.3. CTM, GRAHM and GEOS-Chem Models

Three global simulation models provided boundary conditions for the continental scale modeling. The results from these models were made available as part of the North American Mercury Model Inter-comparison Study (NAMMIS) (Bullock et al., 2008). The three models include the Chemical Transport Model (CTM), the Global/Regional Atmospheric Heavy Metals model (GRAHM), and the GEOS-Chem model. Results from these three global modeling tools were used to prepare three estimates of boundary concentrations of elemental mercury, divalent gas mercury, and particulate mercury for the REMSAD and CMAQ simulations conducted for this study and also for the CMAQ simulations conducted by EPA and used to support this study. According to Bullock et al. 2008), all three of the global models are based on reasonable scientific definitions and assumptions.

The CTM model (Shia et al., 1999; Seigneur et al., 2001) simulates the emission and transport of mercury, mercury transformation processes, and wet and dry deposition, particularly of HG2 and HGP. To generate initial and boundary conditions for regional-scale modeling, the CTM is run for several years using the same set of annual meteorological conditions until a steady state is achieved. As used in this study, CTM was applied with a horizontal resolution of 8 degrees latitude by 10 degrees longitude, and nine vertical layers extending to the stratosphere. For this study, monthly average CTM concentrations were calculated and used in preparing the initial and boundary conditions for the REMSAD (and CMAQ) model simulations.

The GEOS-Chem model (Selin et al., 2007) also simulates the emission and atmospheric transport of mercury on the global scale. It includes HG0, HG2, and primary HGP. The chemistry includes HG0 oxidation to HG2 by OH and ozone as well as aqueous-phase photochemical reduction of HG2 to HG0 (Bullock et al, 2008). Wet and dry deposition are also simulated. GEOS-Chem version 7.01 (http://www-as.harvard.edu/chemistry/trop/geos/) was used for this study with a horizontal resolution of 2 degrees latitude by 2.5 degrees longitude. For this study, 3-hour outputs from GEOS-Chem were used to calculate monthly average concentrations and prepare the initial and boundary conditions for the REMSAD (and CMAQ) model simulations.

The Global/Regional Atmospheric Heavy Metals (GRAHM) model (Dastoor and Larocque, 2004; Ariya et al., 2004) is an extended version of the Canadian operational weather forecasting model, the Global Environmental Multiscale (GEM) model. The GRAHM model simulates HG0, HG2, and HGP. The model simulates the oxidation of HG0 by ozone to HG2 and HGP, several aqueous-phase chemical transformations, and wet and dry deposition, primarily of HG2 and HGP. As used in this study, GRAHM was applied with a horizontal resolution of 5 degrees latitude by 5 degrees longitude, and 28 vertical layers. For this study, 6-hourly outputs from

GEOS-Chem were used to calculate monthly average concentrations and thus prepare the initial and boundary conditions for the REMSAD (and CMAQ) model simulations.

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# 3. Meteorological and Geographical Inputs

In this section, the meteorological inputs and the data and methods used to prepare the geographical input files for the application of REMSAD are discussed. Similar datasets and methods were used to prepare the meteorological and geographical inputs for the supporting application of CMAQ.

## 3.1. Meteorological Inputs

For this application of REMSAD, the existing meteorological inputs used are those that were developed by EPA for use in their evaluation of emissions rules. The meteorological data files were prepared by EPA using the outputs from the Fifth Generation Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesocale Model (MM5). The gridded meteorological fields provided by EPA cover the full REMSAD modeling domain with approximately 36-km horizontal resolution. The simulation period includes the calendar year 2001 (plus the last several days of December 2000, as a model "spin-up" period). These 2001 meteorological input fields were used in the EPA's evaluation of the Clean Air Interstate Rule (CAIR) and the Clean Air Mercury Rule (CAMR) (EPA, 2005a and b). The MM5-derived meteorological fields were mapped directly to the REMSAD grids shown in Figure 1-1, such that the 36-km MM5 results were interpolated to the 12-km REMSAD grids and used directly to specify the meteorological inputs throughout the remainder of the modeling domain.
Since these input fields were evaluated by EPA and utilized in prior applications, the files were not subjected to extensive evaluation or quality assurance. However, some comparisons with observed data and with a set of alternative meteorological input fields derived from Rapid Update Cycle (RUC) model output for 2001 were made as part of the meteorological dataset selection process (Douglas et al., 2005). This evaluation showed that the relative performance of the two models varies by month, by geographic region, and among the key meteorological parameters. For consistency with other EPA studies (including the CAMR modeling) and to possibly take advantage of higher-resolution MM5-based meteorological fields for future applications, the MM5-derived fields were selected for use in this study.

### *3.1.1. Description of the Meteorological Inputs*

Simulated MM5-derived surface pressure patterns for the 15$^{th}$ day of each month were visually compared with the surface weather analyses prepared by the National Weather Service (NWS). Of interest are the locations of high and low-pressure systems, the simulated and observed surface pressure values near the locations of the primary highs and lows, and the overall patterns across the continental U.S.
The MM5-derived surface pressure fields represent the overall pressure patterns and the general distribution of high and low pressure centers. The MM5 results show good agreement with the observed patterns and pressures for the middle days of January through April and December, and less skill during the summer and autumn months. Overall, the MM5-derived fields show less spatial variability in surface pressure than is suggested by the data (i.e., the observed range in pressure is not captured).
The MM5-derived heights corresponding to constant pressure surfaces for 850 and 700 mb were compared with analyses from the National Oceanographic and Air Administration (NOAA) Air Resources Laboratory (ARL). A comparison time of 0700 EST was used, since the upper-air data are available at that time. The analyses were derived using upper-air radiosonde observations. The high and lows in the height fields reflect high and low pressure systems aloft. MM5 depicts the range of patterns (including the distinctive ridge/trough and zonal patterns) that characterize the middle days of each month. The high-pressure ridge over the central U.S. in mid-July and mid-September is depicted by MM5.

Observed and MM5-derived annual rainfall totals are presented and compared in Figure 3-1. The observed precipitation plot was obtained from the National Atmospheric Deposition Program (NADP) web site (http://nadp.sws.uius.edu) (NADP, 2005).The annual rainfall patterns from the MM5 model show the highest precipitation areas over British Columbia, Canada and over the Atlantic Ocean (off the coast of Florida and northward). The MM5 results show a significant amount of precipitation over the southern Appalachian Mountains, along the eastern seaboard, and in southern Arizona. Compared to observation-derived precipitation amounts, the model appears to overestimate total precipitation over the interior western states (the amounts are better in line with the observations for the coastal western states). MM5 produces far too much precipitation in southern Arizona but gives reasonable annual precipitation totals for the central states and throughout the Northeast. MM5 underestimates the area of highest observed annual precipitation over Louisiana, Mississippi, southern Arkansas, southwestern Tennessee, and eastern Texas, and significantly overestimates precipitation over Alabama, Georgia, the Carolinas, and portions of peninsular Florida.

**Figure 3-1a. Observed Annual Rainfall Totals (cm) for 2001.**

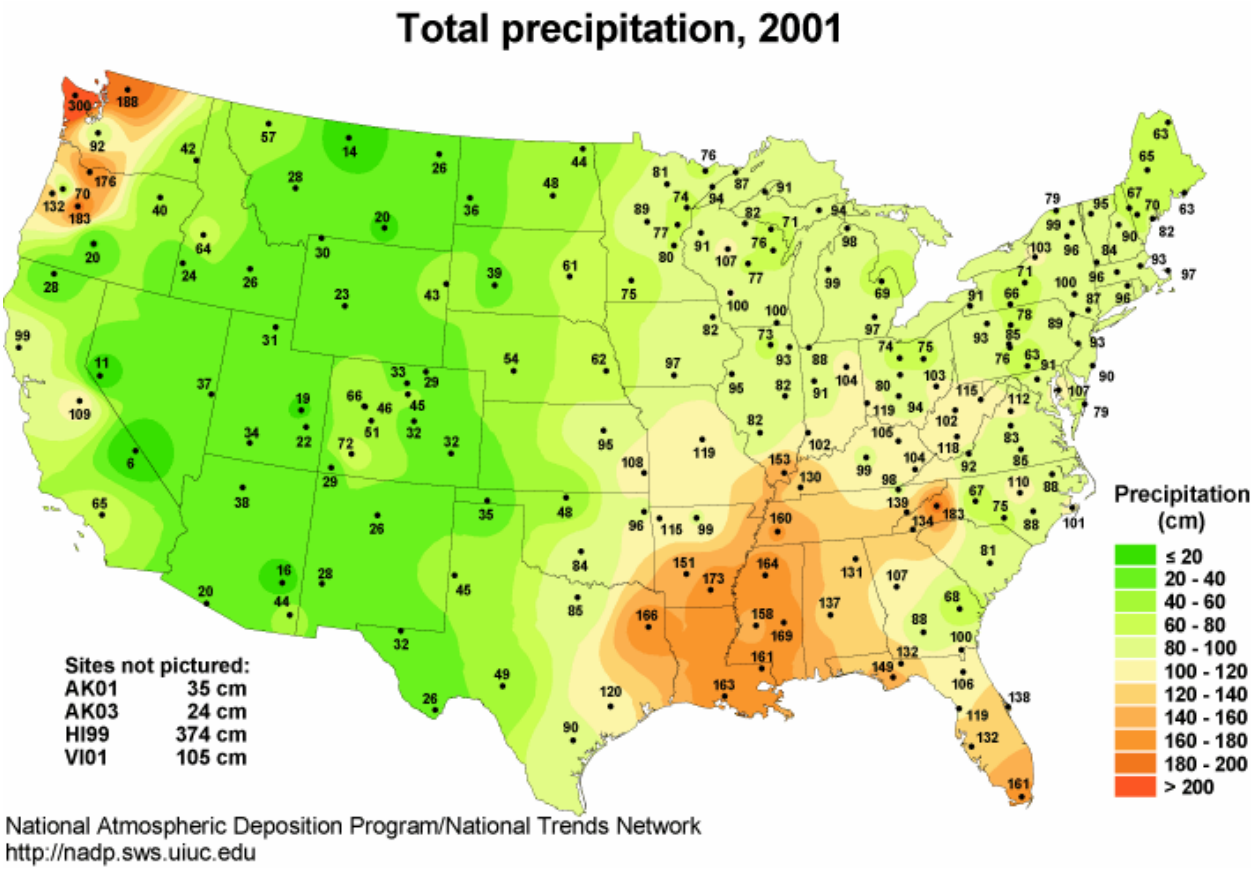


**Figure 3-1b. MM5-derived Annual Rainfall Totals (cm) for 2001.**

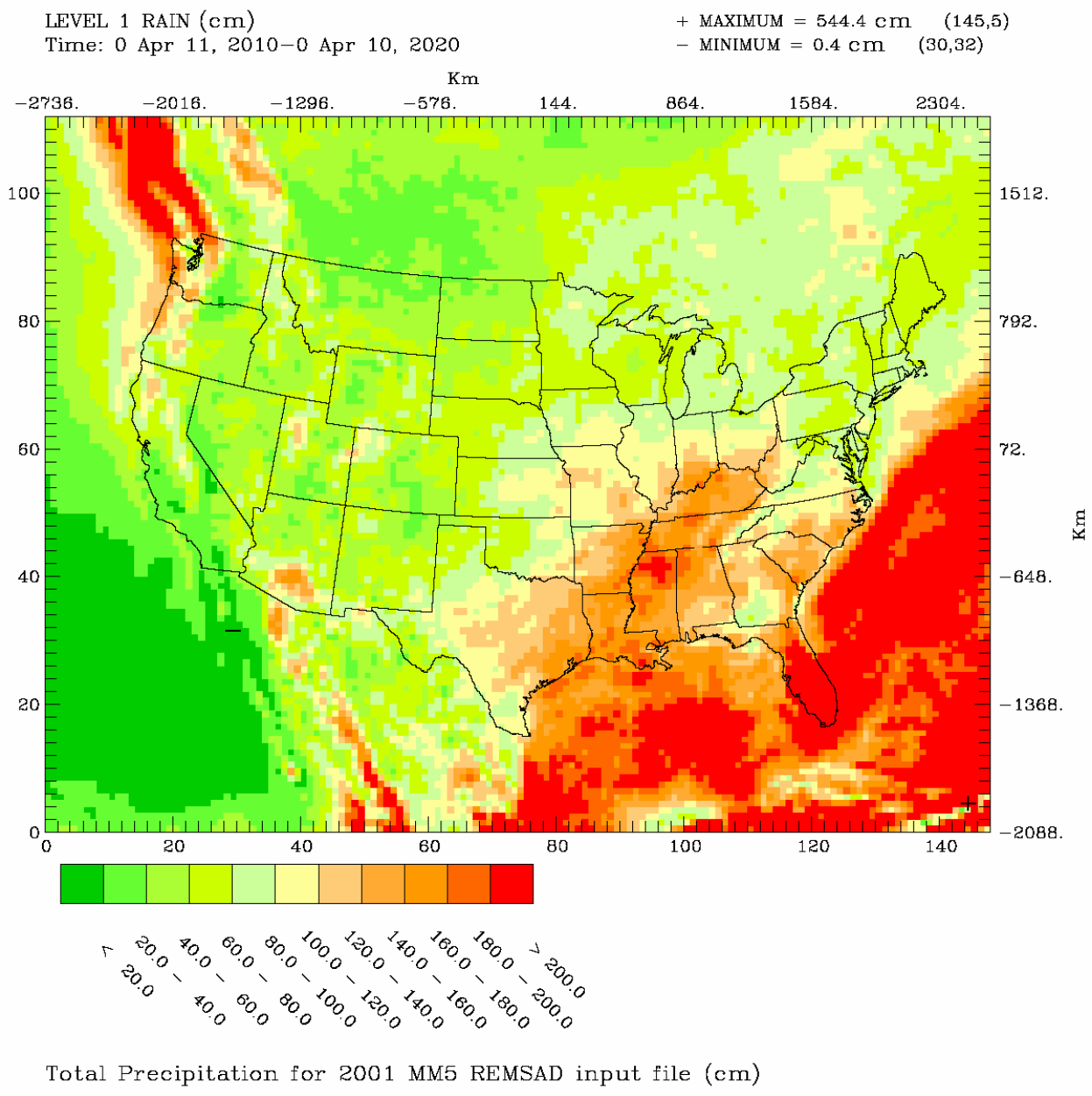
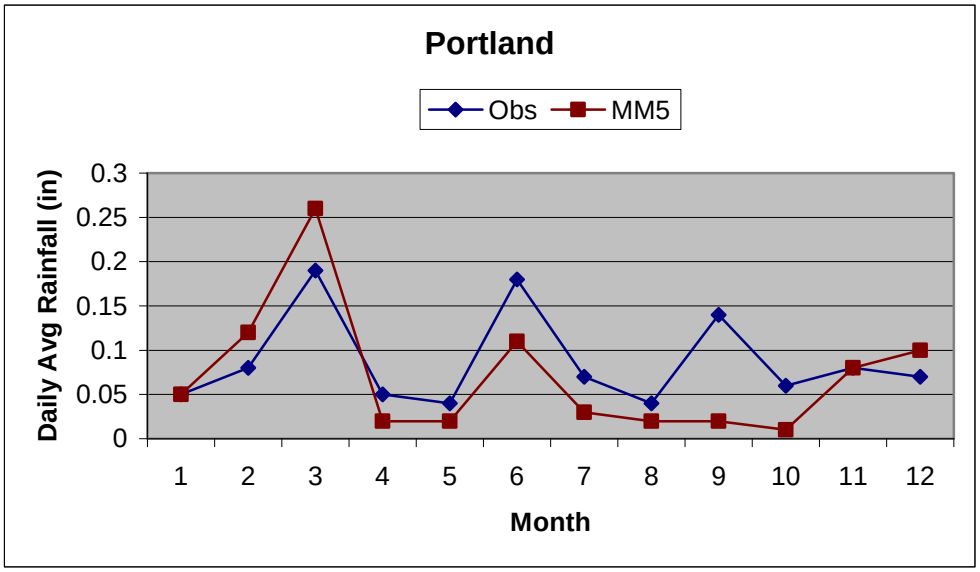


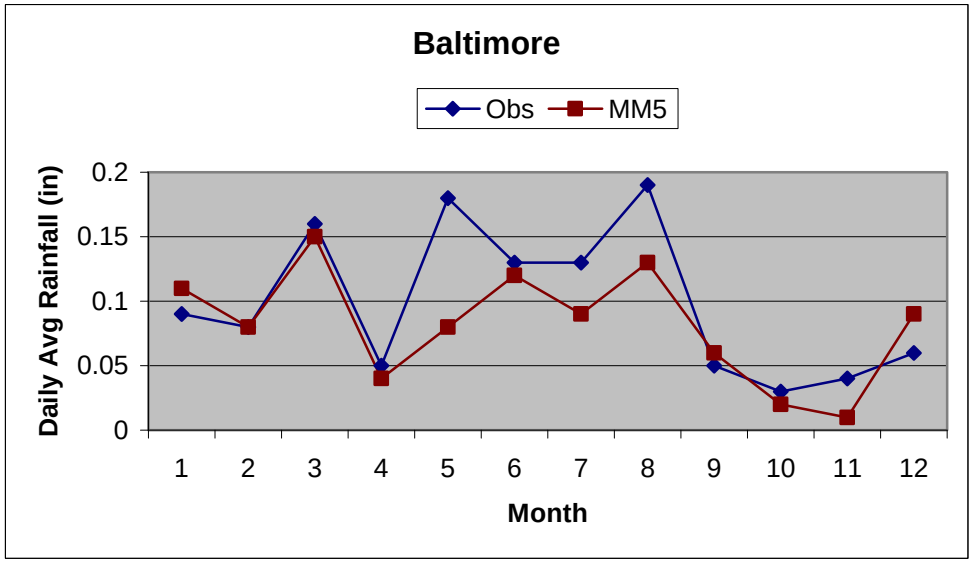
Figure 3-2 shows the variation in monthly mean rainfall amounts, observed and simulated by MM5 for five geographically diverse areas (Portland, ME; Baltimore, MD/Washington, D.C.; Baton Rouge/Slidell, LA; Madison/Green Bay, WI; and Oakland, CA). The month-to-month variations and rainfall amounts are generally well represented.

**Figure 3-2. Monthly Average Rainfall amount (in)**
**Based on Observed and Simulated Daily Precipitation Values.**

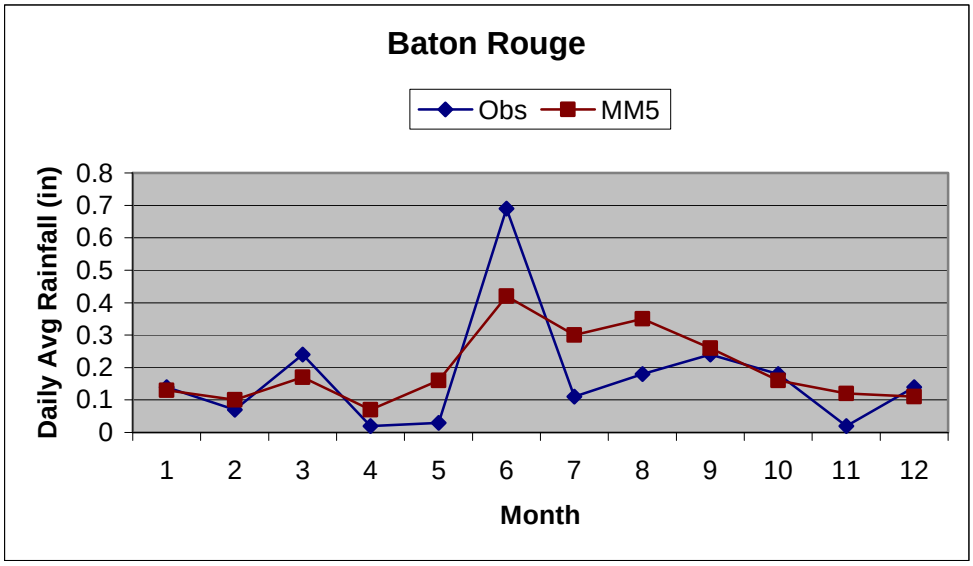
**(a) Portland**



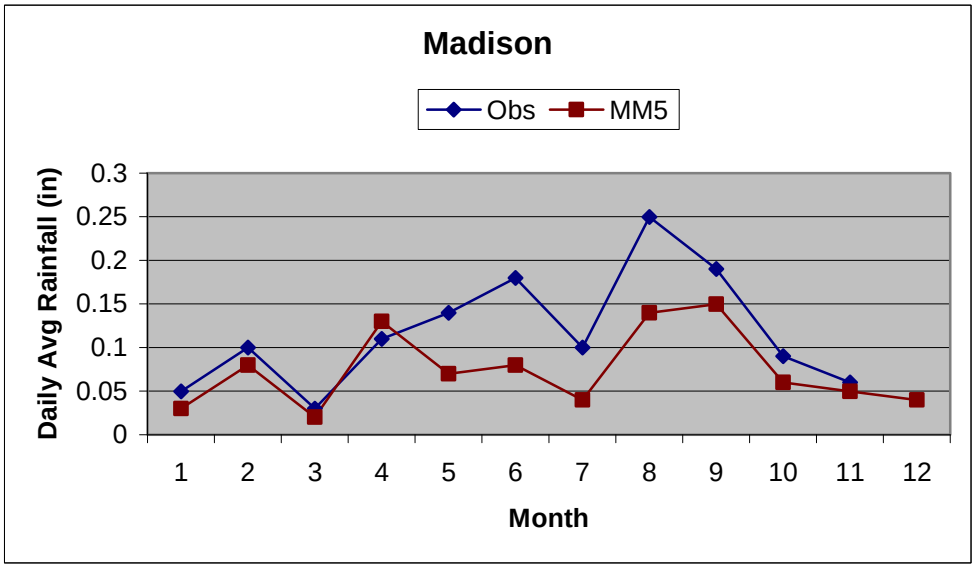

**(b) Baltimore**



**(c) Baton Rouge**




**(d) Madison**



**(e) Oakland**

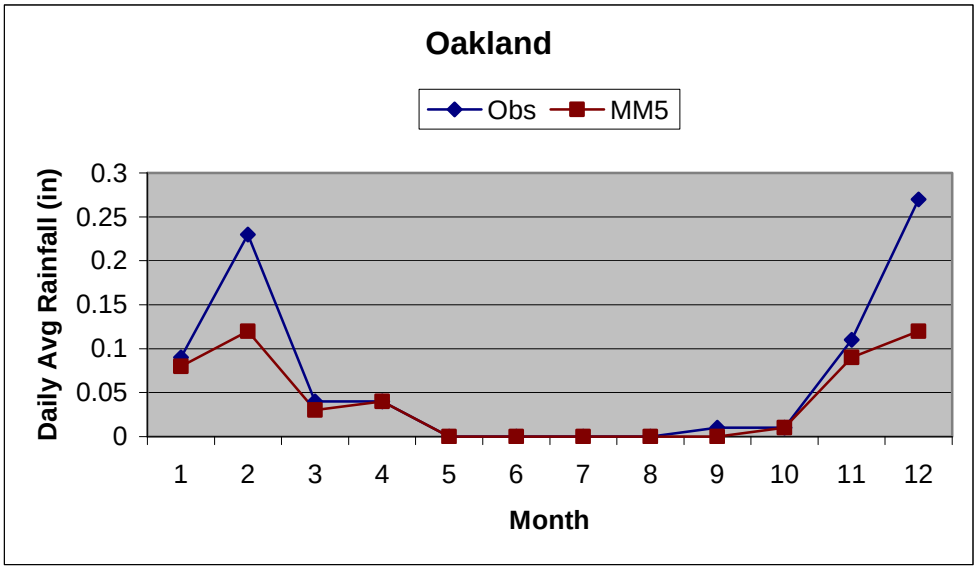
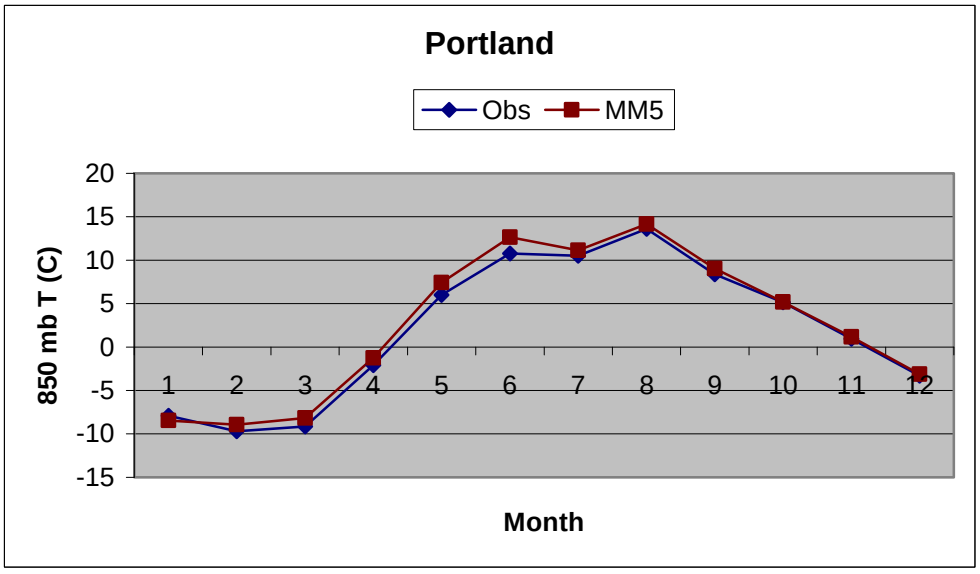


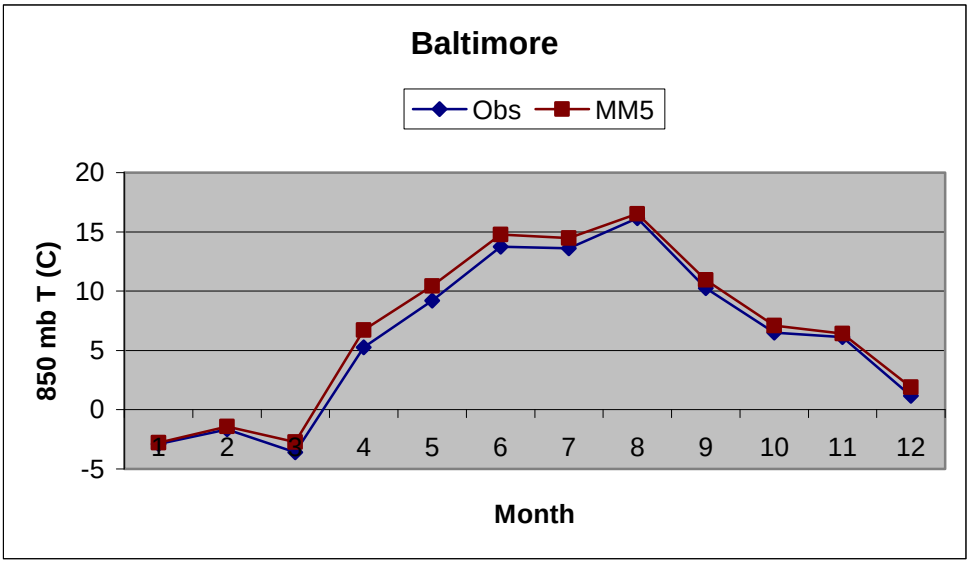

Figure 3-3 provides mean observed and simulated 850 mb upper-air temperatures for the time of the morning observation for these same sites. For all five sites, the input fields agree very well with the observed upper-air temperature data for the 850 mb level. The MM5-based temperatures tend to be slightly higher than observed.

**Figure 3-3. Monthly Average Observed and Simulated 850 mb Temperature (°C) for the Time of the Morning Sounding.**

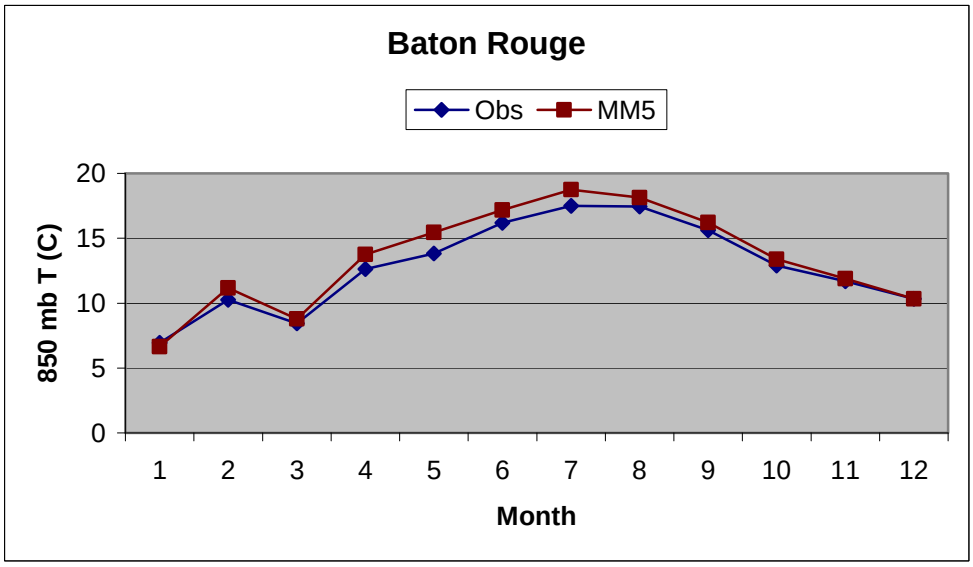
**(a) Portland**



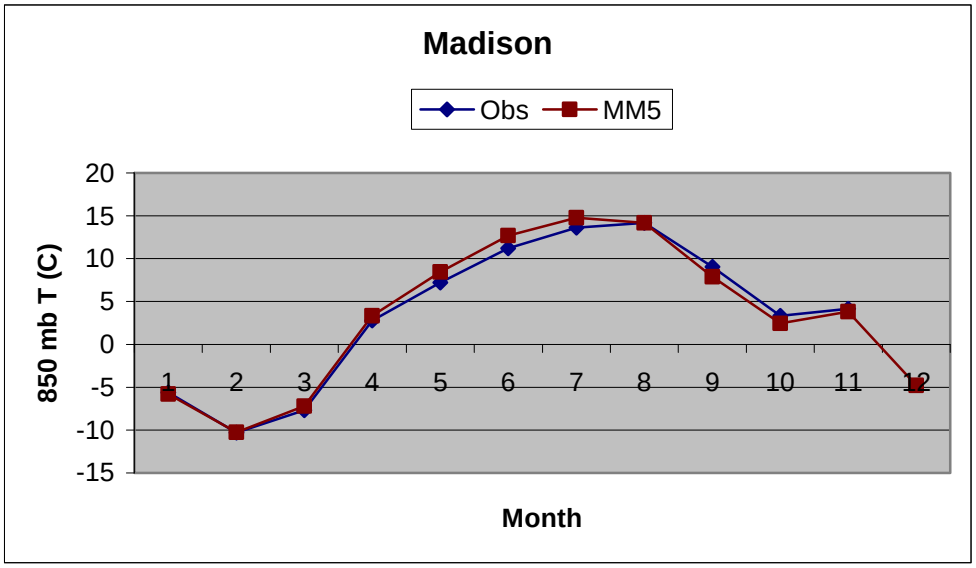
**(b) Baltimore**




**(c) Baton Rouge**



**(d) Madison**




**(e) Oakland**

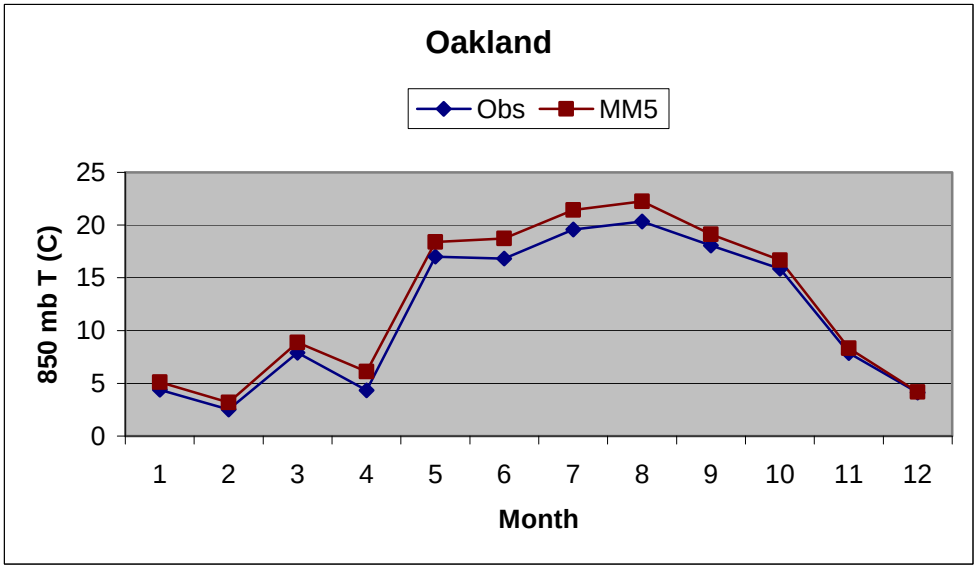
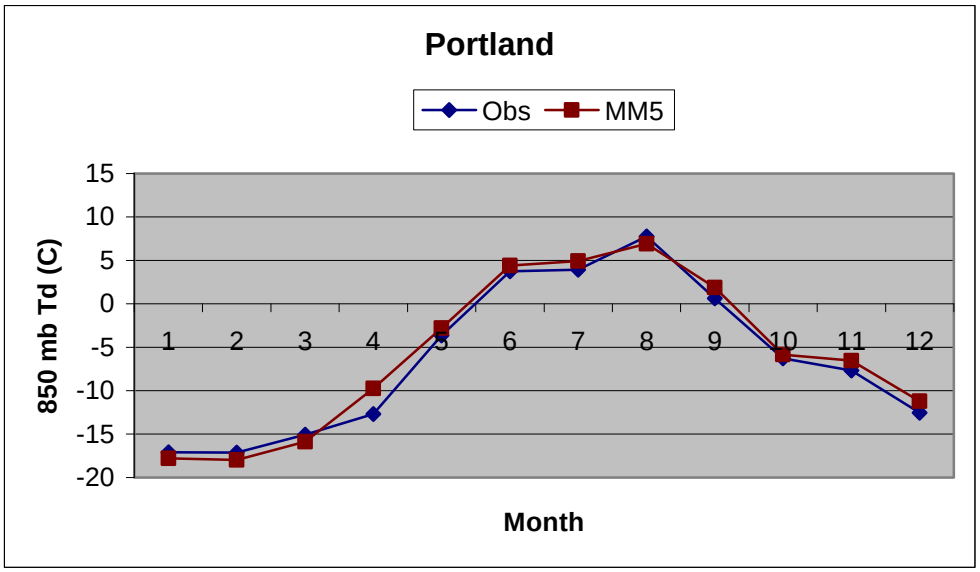


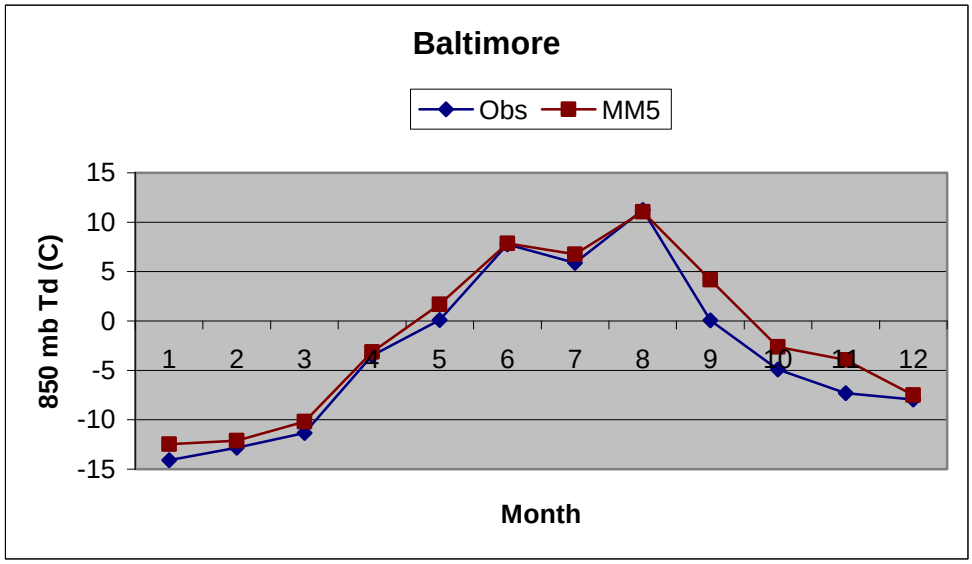
Figure 3-4 displays the mean observed and simulated 850 mb upper-air dew-point temperatures, also for the morning observation time. For four of the five example sites (Portland, Baltimore/Washington, Baton Rouge/Slidell, and Madison/Green Bay), the input fields agree well with the observed upper-air dew-point temperature data for the 850 mb level. For Oakland, MM5 does not capture the lower dew-point temperatures and thus the drier air over this part of the country during the summer months.

**Figure 3-4. Monthly Average Observed and Simulated 850 mb Dew-Point Temperature (°C) for the Time of the Morning Sounding.**

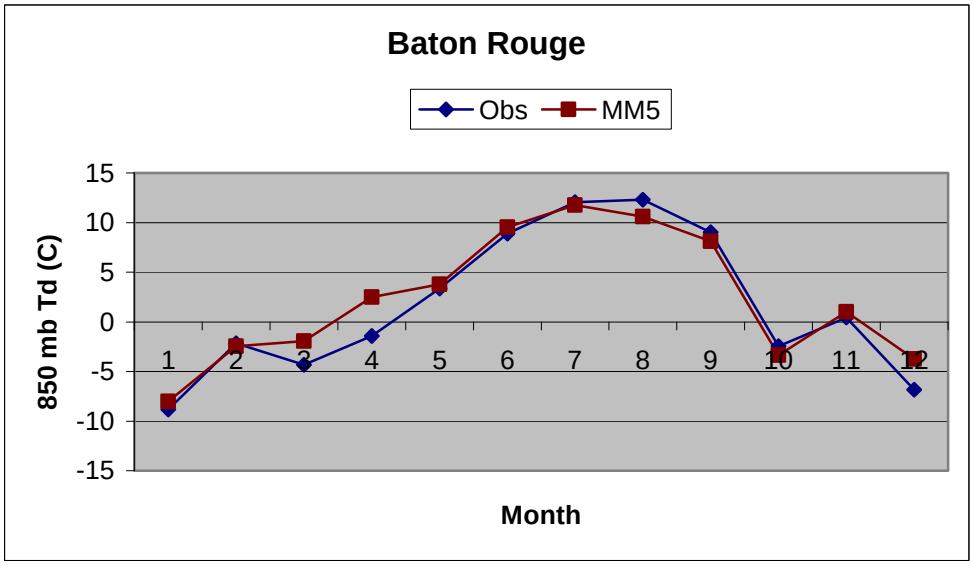
**(a) Portland**



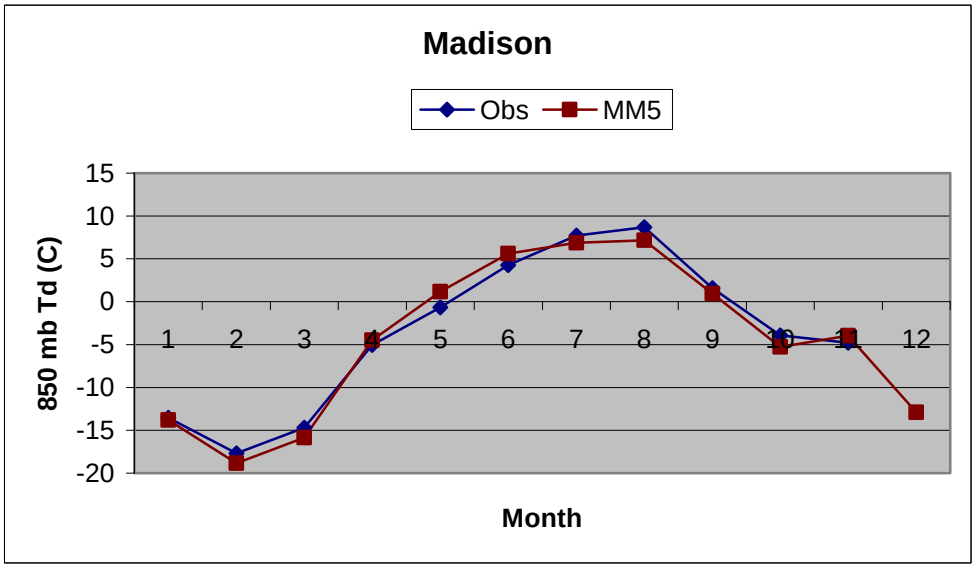

**(b) Baltimore**



**(c) Baton Rouge**




**(d) Madison**



**(e) Oakland**

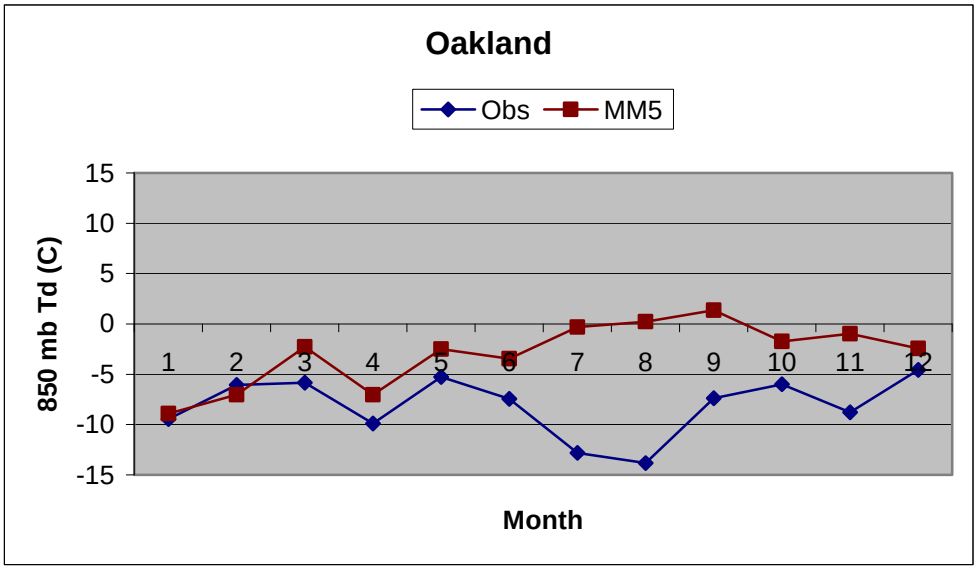
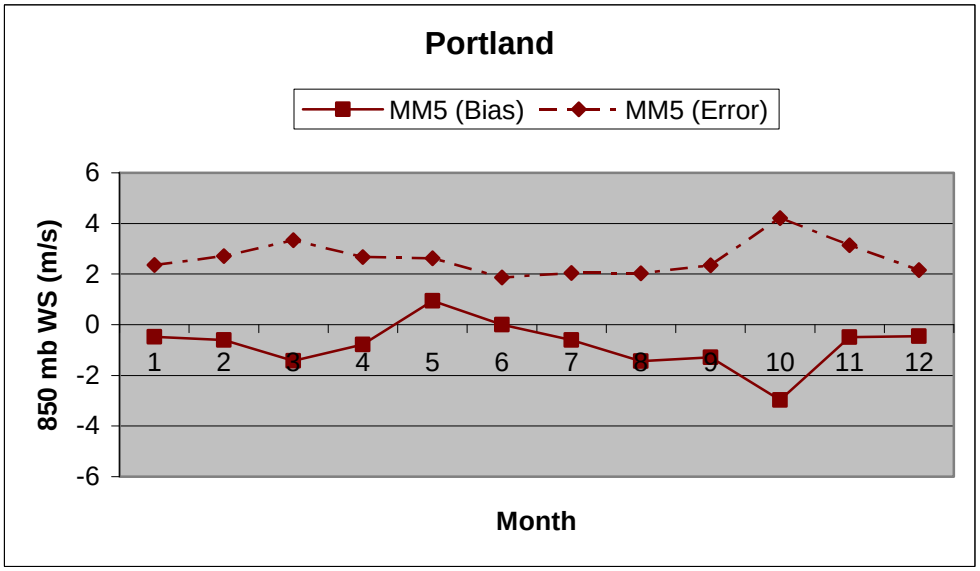


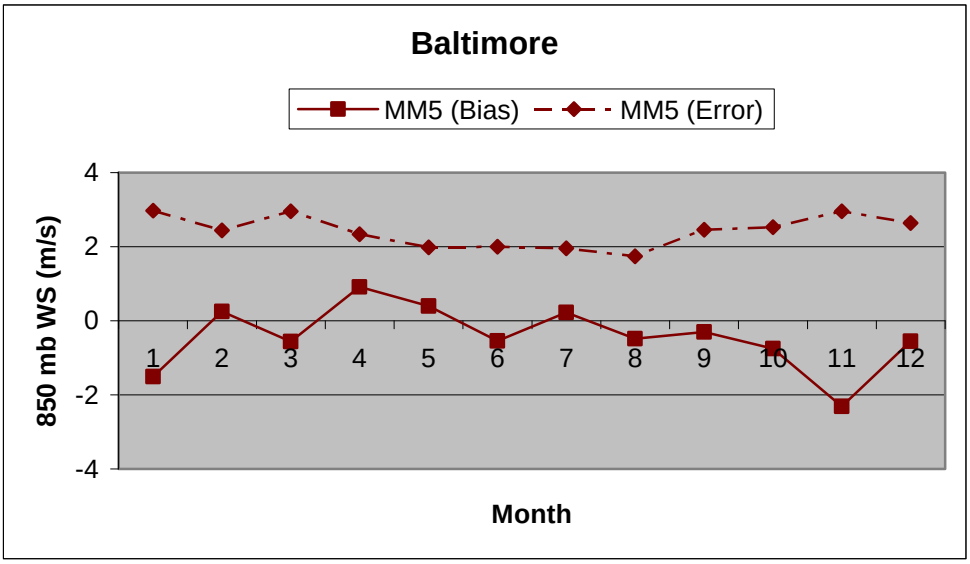

Figure 3-5 compares the bias and error values for 850 mb wind speed for the time of the morning sounding. The MM5-derived wind speeds tend to be higher than observed, with a bias on the order of 2 to 4 $ms^{-1}$.

**Figure 3-5. Monthly Average Bias and Error Statistics for 850 mb Wind Speed ($ms^{-1}$) for the Time of the Morning Sounding.**

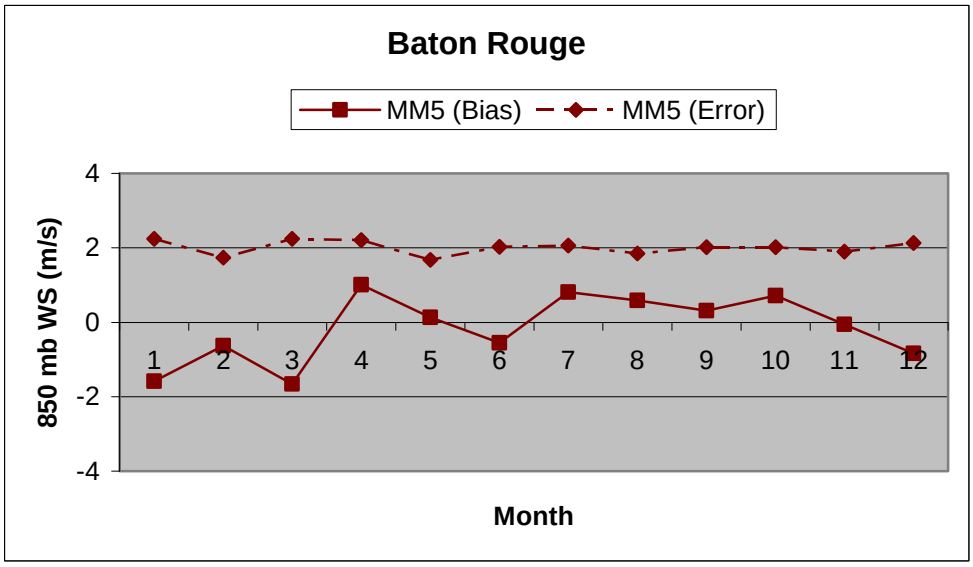
**(a) Portland**



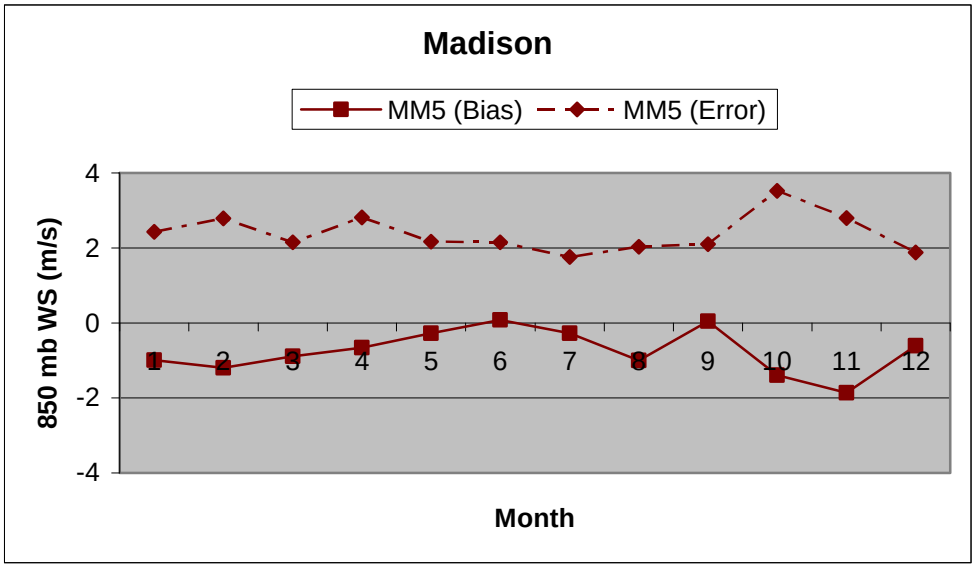
**(b) Baltimore**




**(c) Baton Rouge**



**(d) Madison**




**(e) Oakland**

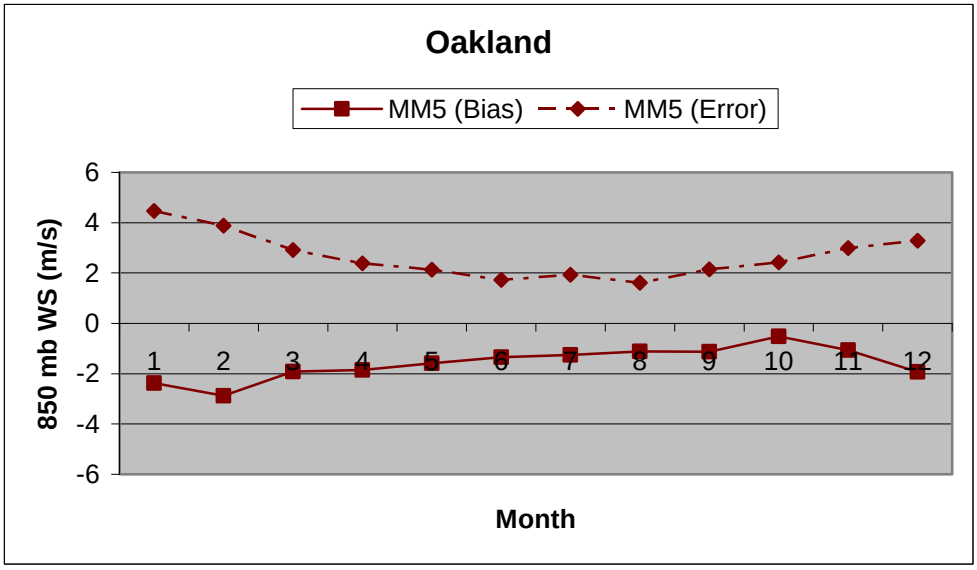
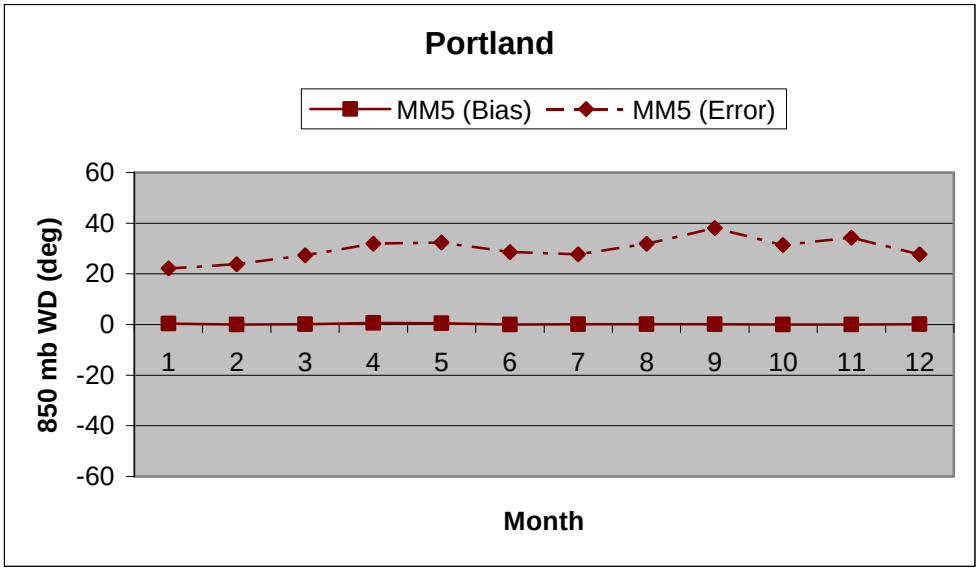


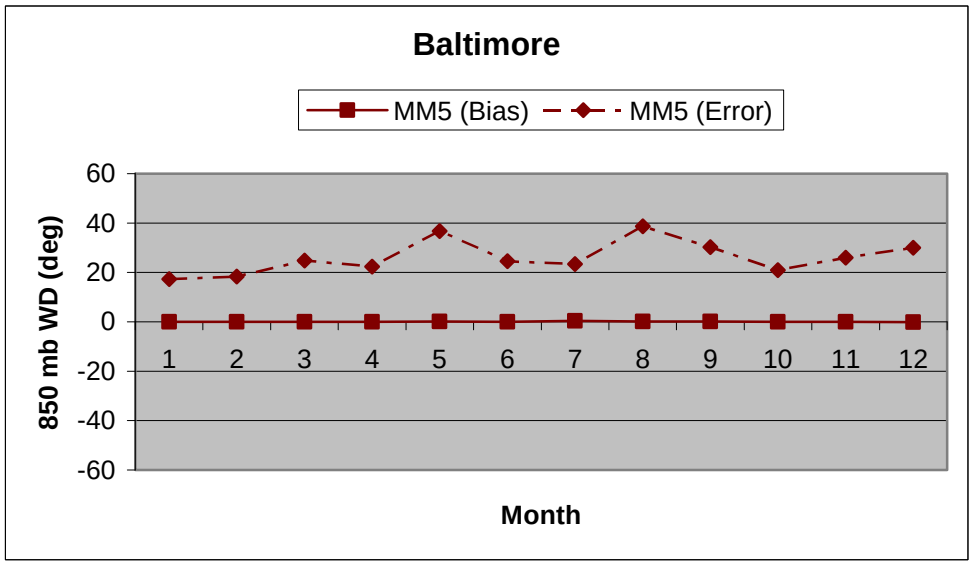
Figure 3-6 compares the bias and error values for 850 mb wind direction, again for the time of the morning sounding. A bias on the order of 20 to 40 degrees appears to be present in the MM5 fields, although this varies by site and by month.

**Figure 3-6. Monthly Average Bias and Error Statistics for 850 mb Wind Direction (degrees) for the Time of the Morning Sounding.**

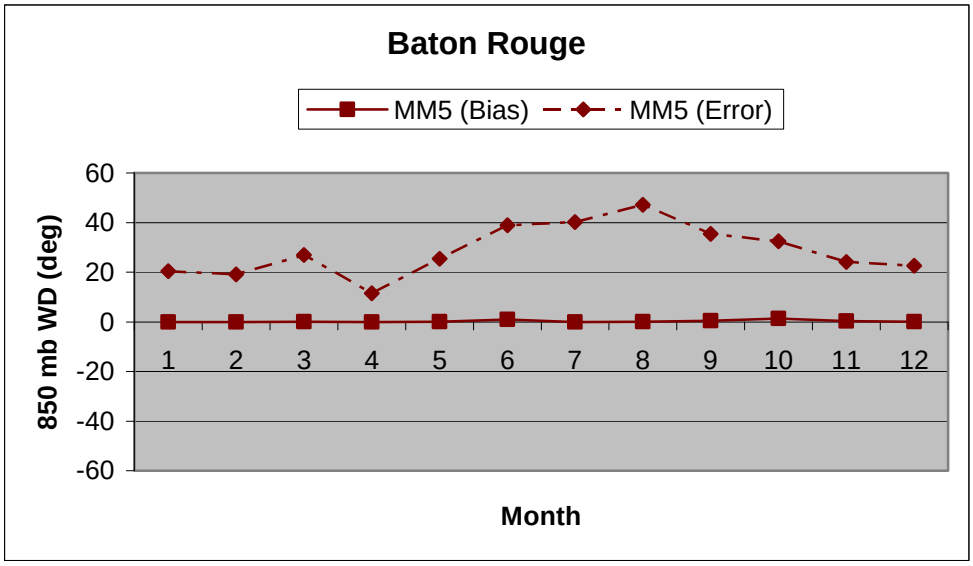
**(a) Portland**



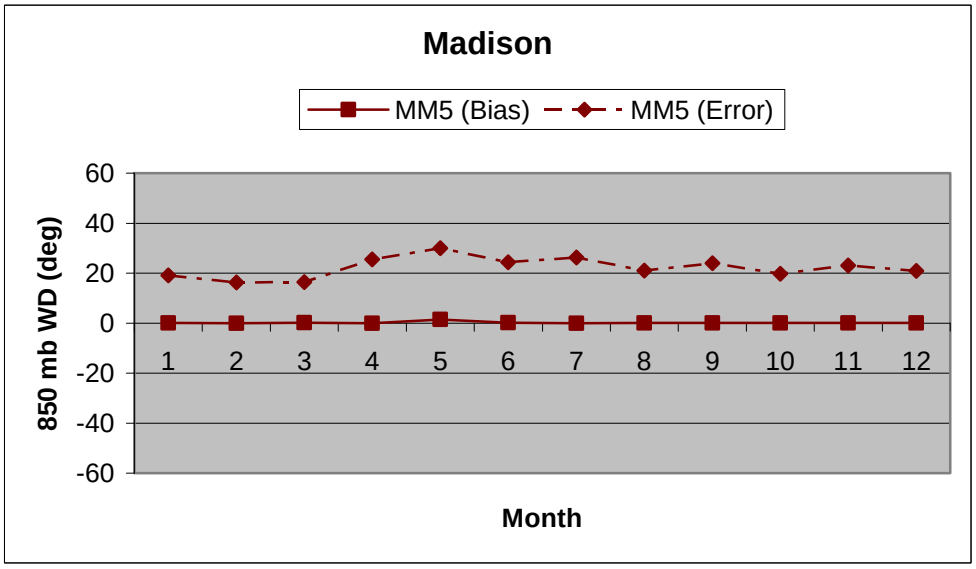

**(b) Baltimore**



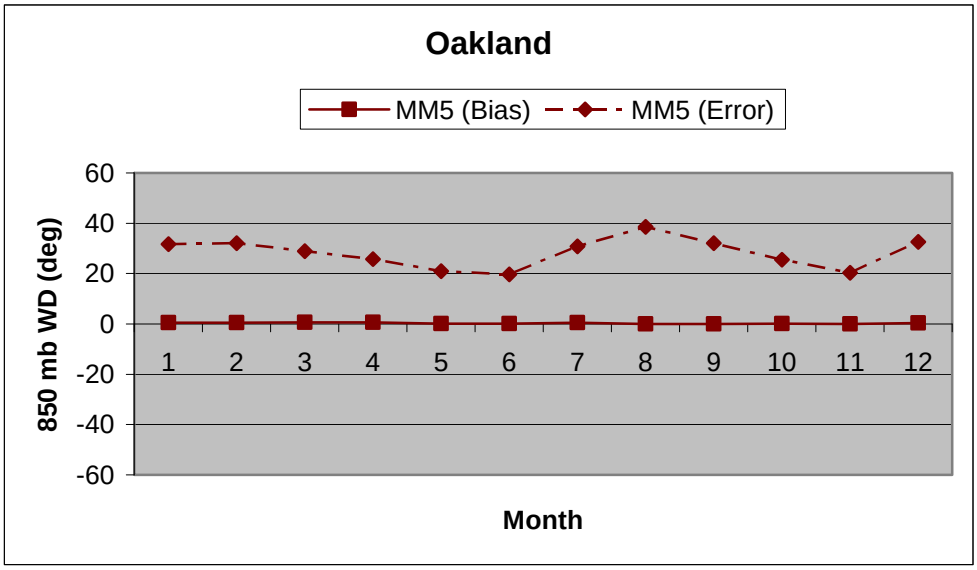
**(c) Baton Rouge**




**(d) Madison**



**(e) Oakland**




## 3.2. Preparation of Geographical Inputs

Geographic input fields used by the REMSAD model are terrain height and land-use category. The terrain heights were derived from terrain data provided by EPA (along with the MM5-derived meteorological files). Land-use information, which defines the fractional coverage of several different land-cover types for each grid cell, was derived from USGS Land Use and Land Cover (LULC) data. The land use data used for this project are available at approximately 200 m horizontal resolution. A description of the data is available at http://edcwww.cr.usgs.gov/products/landcover/lulc.html. Land-use inputs were prepared for the REMSAD 36- and 12-km grids. The 200 m data were averaged over the area of each 36-km or 12-km grid cell in order to derive the land use fractions within each grid cell.

The land use categories used by REMSAD and the associated surface roughness lengths for each category are presented in Table 3-1.

**Table 3-1. Land-Use Categories Recognized by REMSAD.**

| Category Number | Land-Use Category | Surface Roughness (meters) |
|---|---|---|
| 1 | Urban | 3.00 |
| 2 | Agricultural | 0.25 |
| 3 | Range | 0.05 |
| 4 | Deciduous forest | 1.00 |
| 5 | Coniferous forest including wetland | 1.00 |
| 6 | Mixed forest | 1.00 |
| 7 | Water | 0.0001 |
| 8 | Barren land | 0.002 |
| 9 | Nonforest wetlands | 0.15 |
| 10 | Mixed agricultural and range | 0.10 |
| 11 | Rocky (low shrubs) | 0.10 |

# 4. Emissions Inputs

In this section, the preparation of the REMSAD-ready emission inventories are summarized for both the criteria pollutants and mercury. Similar datasets and methods were used to prepare the emissions inputs for the application of CMAQ (as applied for this study). The detailed corrections to the emission inventories were specific to this study and were not included in CMAQ simulations conducted by EPA.

## 4.1. Emission Inventory Preparation for Non-mercury Particulate and Gaseous Species

The REMSAD base emissions inventory for the criteria pollutants includes anthropogenic and biogenic emissions for the species listed in Table 4-1.

**Table 4-1. REMSAD Emissions Species for the Criteria Pollutant Emissions Inventory.**

| REMSAD (Version 6) Emissions Species | Species ID |
|---|---|
| Nitrogen oxide | NO |
| Nitrogen dioxide | NO2 |
| Primary organic aerosols | POA |
| Primary elemental carbon | PEC |
| Gaseous sulfate | GSO4 |
| Particulate nitrate | PNO3 |
| Volatile organic carbon | VOC |
| Sulfur dioxide | SO2 |
| Particulate matter with a diameter less than 2.5 microns | PMFINE |
| Particulate matter with a diameter greater than 2.5 but less than 10 microns | PMCOARS |
| Ammonia | NH3 |
| Carbon monoxide | CO |
| Carbonyl | CARB |
| Monoterpenes | TERP |
| Isoprene | ISOP |

### *4.1.1. Emissions Data*

The REMSAD base emissions inventory for the criteria pollutants was prepared using the EPA 2001 CAIR database including the emissions data and associated PM speciation profile and cross reference files (except the splits for VOC and CARB), temporal profile and cross-reference files, and surrogate data and cross-reference files. The various CAIR emissions inventory files were converted to the formats required for processing with EPS2.5. A brief description of each emission component is provided below.

## U.S.

### AREA SOURCE DATA

- 2001 area source data includes the following sectors: fugitive dust, agricultural (NH3 emissions from livestock and fertilizer application), fires (2001-specific wildfires, prescribed burning, agricultural burning, and open burning), and other area (airport and onroad mobile refueling emissions, and other area source emissions).
- County-specific transportable fraction adjustments were applied to the emissions included in the fugitive dust sector.

### NONROAD MOBILE SOURCE DATA

- 2001 nonroad mobile source data includes monthly emissions calculated by the National Mobile Inventory Model (NMIM), and 2001 annual emissions for airports, railroads, commercial marine vessels (ARM).

### ONROAD MOBILE SOURCE DATA

- 2001 onroad mobile source data includes monthly emissions calculated by the National Mobile Inventory Model (NMIM) for all states except for State of California; and annual mobile source emissions data for State of California.
- California-specific temporal profiles were applied to the annual emissions to obtain the monthly emissions.

### POINT SOURCE DATA

- 2001 point source data includes point source and fugitive dust sectors.
- County-specific transportable fraction adjustments were applied to the emissions included in the fugitive dust sector.

## Canada

- Area, nonroad, and mobile source data are for 1995.
- Point source data are for 1995 and only available for Eastern Canada.

## Mexico

- Area, nonroad, onroad mobile, and point source data were as used in the CAIR modeling studies (see EPA. 2004. CAIR Emissions Inventory Overview).

## Offshore

- Offshore emissions data for a small portion of the Gulf of Mexico provided by the Texas Commission on Environmental Quality (TCEQ). (Emissions for the bulk of sources in the Gulf are not included.)
- Offshore point source emissions were prepared for each season.

## *4.1.2. Emissions Processing*

The emissions were processed using version 2.5 of the Emissions Preprocessing System (EPS2.5). EPS2.5 consists of series of computer modules that incorporate spatial, temporal,

and chemical resolution into an emission inventory used for modeling. Anthropogenic point-, area-, and mobile-source emissions data are processed separately through the EPS2.5 system. The key processing steps include:

- **Chemical speciation**—Point, area, and mobile source emissions are chemically speciated from VOC into the CB-V species.
- **Temporal allocation**—Emissions are temporally allocated based on temporal profiles. These include monthly, weekly, and/or diurnal profiles for on-road motor-vehicle emissions, and in some cases, operating schedule (months/year, days/week, hours/day, and start hour) information for point sources.
- **Spatial allocation**—Point-source emissions are directly assigned to grid cells based on the source location coordinates included in the input emissions data for each source. Area- and mobile-source emissions are allocated to grid cells using gridded spatial allocation surrogates.

For this study, area source emissions were prepared for each month and spatially allocated in the modeling domain using the EPA provided surrogates. The nonroad mobile source emissions were prepared for each month except for the ARM data (which were prepared for each season) and spatially allocated in the modeling domain using the EPA provided surrogates. The onroad mobile source emissions were prepared for each month and spatially allocated in the modeling domain using the EPA provided surrogates. Point source and offshore emissions were prepared for each season.

Following processing of each inventory component, the area-, mobile-, and low-level point source emissions were merged with the biogenic emissions to form the low-level emissions input file for REMSAD. Emissions associated with elevated points sources were incorporated into the separate point-source emissions file. In this file, each stack or facility is treated as a separate emissions source.

### *4.1.3. Summary of the Criteria Pollutant Emissions*

The 2001 base-year criteria pollutant emissions for the U.S. portion of the modeling domain are presented by major source category and by season in Table 4-2. This table highlights the key source categories for each component and the variations in the emissions throughout the year.

**Table 4-2. Average Seasonal Daily Emissions (tpd) for the U.S. Portion of the REMSAD Modeling Domain: 2001 Base Case.**

| Species | Point | Area | Mobile | Biogenic | Total |
|---|---|---|---|---|---|
| **Winter** | | | | | |
| **NOx** | 21,304 | 5,508 | 32,224 | 2,626 | 61,662 |
| **VOC** | 4,448 | 23,984 | 19,465 | 28,280 | 76,178 |
| **SO2** | 38,157 | 4,451 | 1,699 | | 44,308 |
| **PM2.5** | 3,606 | 9,453 | 996 | | 14,055 |
| **PMC** | 978 | 22,807 | 169 | | 23,955 |
| **NH3** | 249 | 5,333 | 707 | | 6,289 |
| **CO** | 12,135 | 34,061 | 242,859 | 6,842 | 295,897 |
| **Spring** | | | | | |
| **NOx** | 21,398 | 4,453 | 33,121 | 6,643 | 65,615 |
| **VOC** | 4,466 | 21,257 | 19,418 | 120,914 | 166,054 |
| **SO2** | 37,647 | 3,466 | 1,897 | | 43,011 |

| Species | Point | Area | Mobile | Biogenic | Total |
|---|---|---|---|---|---|
| **PM2.5** | 3,519 | 9,053 | 1,235 | | 13,808 |
| **PMC** | 986 | 23,101 | 185 | | 24,272 |
| **NH3** | 246 | 11,212 | 756 | | 12,214 |
| **CO** | 12,028 | 34,638 | 225,649 | 20,066 | 292,381 |
| | | | **Summer** | | |
| **NOx** | 22,254 | 3,618 | 34,800 | 9,070 | 69,742 |
| **VOC** | 4,481 | 19,161 | 24,160 | 325,886 | 373,688 |
| **SO2** | 38,722 | 2,817 | 2,221 | | 43,760 |
| **PM2.5** | 3,588 | 8,642 | 1,677 | | 13,907 |
| **PMC** | 1,020 | 23,529 | 217 | | 24,766 |
| **NH3** | 248 | 11,031 | 832 | | 12,111 |
| **CO** | 12,111 | 34,703 | 233,602 | 46,824 | 327,240 |
| | | | **Fall** | | |
| **NOx** | 21,462 | 4,123 | 32,764 | 5,551 | 63,900 |
| **VOC** | 4,514 | 20,516 | 19,054 | 117,805 | 161,890 |
| **SO2** | 37,452 | 3,398 | 1,909 | | 42,758 |
| **PM2.5** | 3,575 | 8,106 | 1,233 | | 12,914 |
| **PMC** | 999 | 22,983 | 185 | | 24,167 |
| **NH3** | 250 | 8,720 | 767 | | 9,737 |
| **CO** | 12,210 | 25,248 | 218,147 | 23,244 | 278,848 |

The spatial distribution of emissions throughout the domain is illustrated in Figures 4-1 and 4-2. These examples focus on $NO_x$ and $SO_2$ emissions for a typical summer weekday, but the spatial distributions are characteristic of most anthropogenic species. Figures 4-1a and b show the distribution of low-level sources of $NO_x$ and $SO_2$, respectively. Figures 4-2a and b illustrate the spatial distribution of $NO_x$ and $SO_2$ emissions from elevated (point) sources. In the plots, the different colors designate different ranges of total daily emissions. Note that the $NO_x$ and $SO_2$ plots use different intervals for the color representation of the emissions. Figures 4-1 and 4-2 display the emissions for the 36-km (coarse) grid. Emissions files were also produced for the 12-km resolution nested grids (not shown).

**Figure 4-1a. Low-level $NO_x$ Emissions (tons) for the 36-km Grid for a Summer Weekday.**

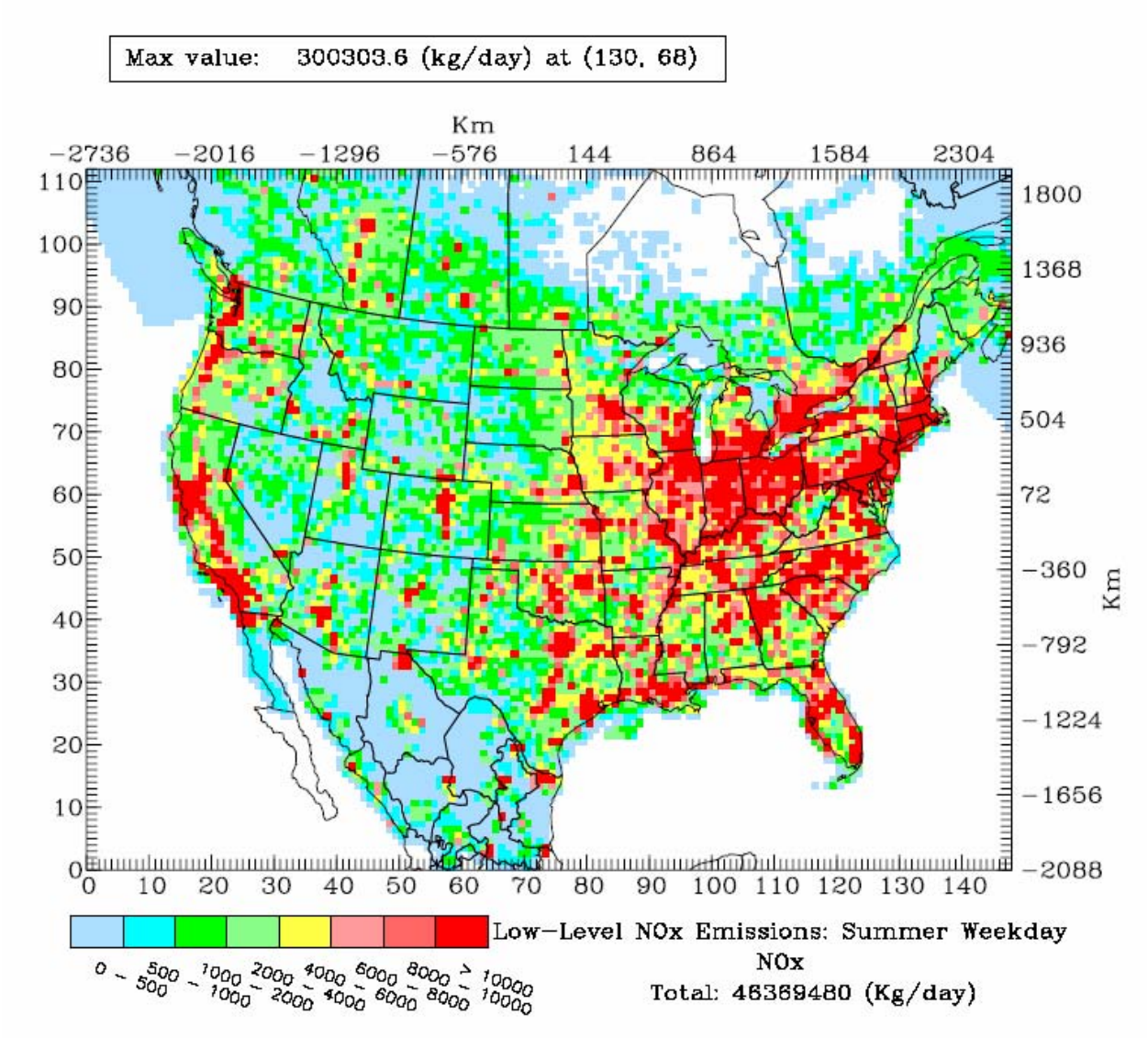


**Figure 4-1b. Low-level $SO_2$ Emissions (tons) for the 36-km Grid for a Summer Weekday.**

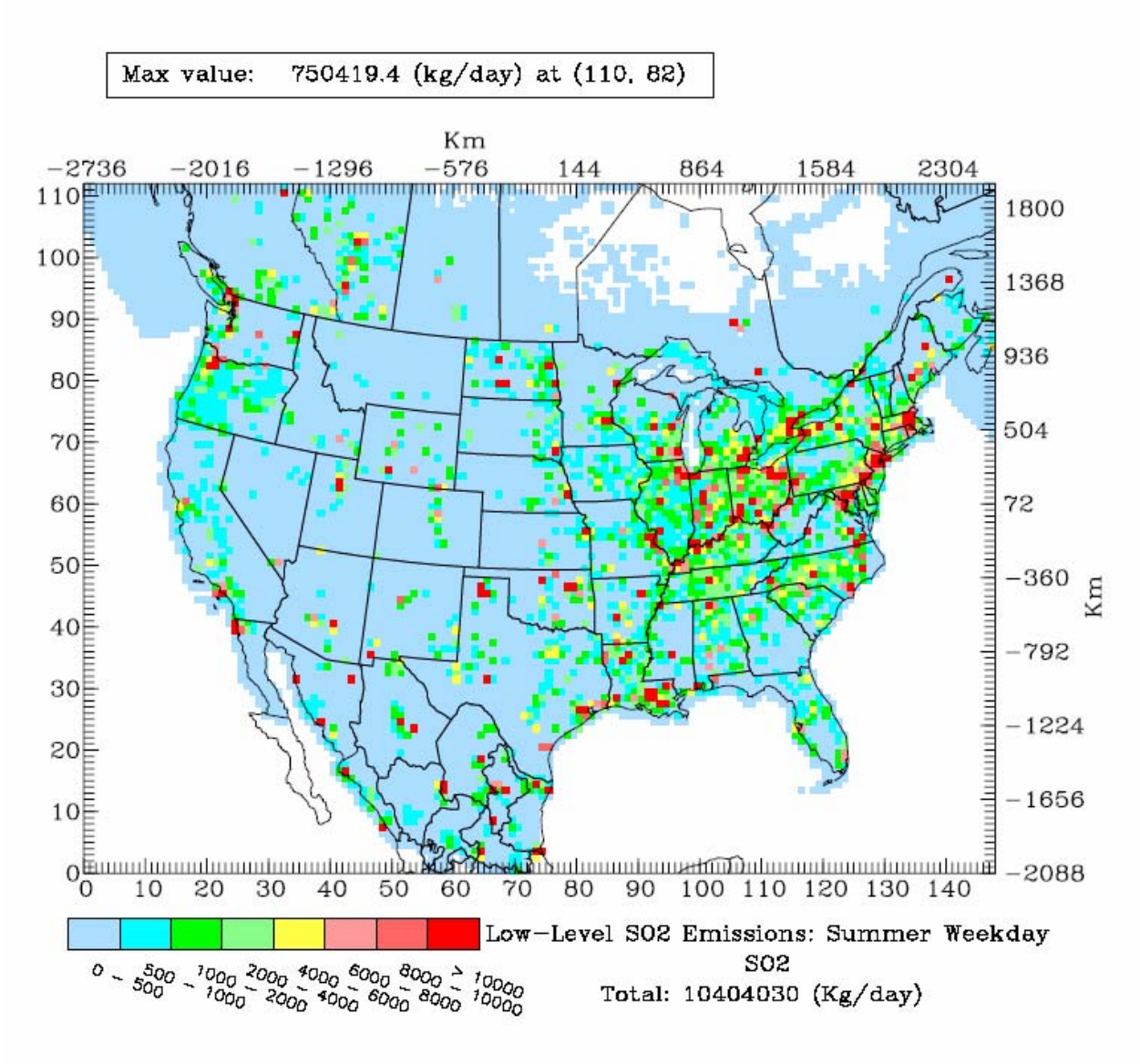


**Figure 4-2a. Elevated Point-source $NO_x$ Emissions (tons) for the 36-km Grid for a Summer Weekday.**

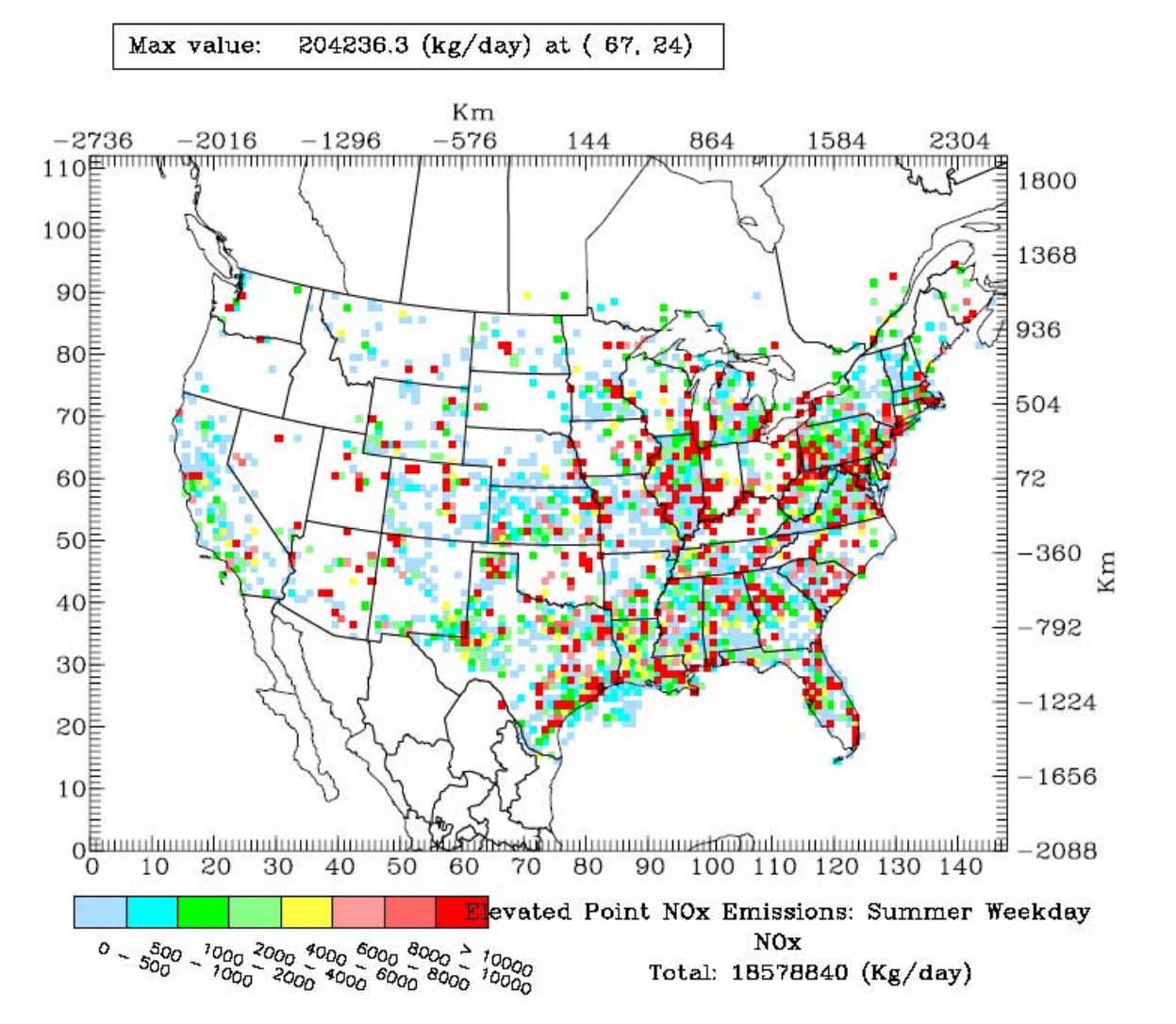
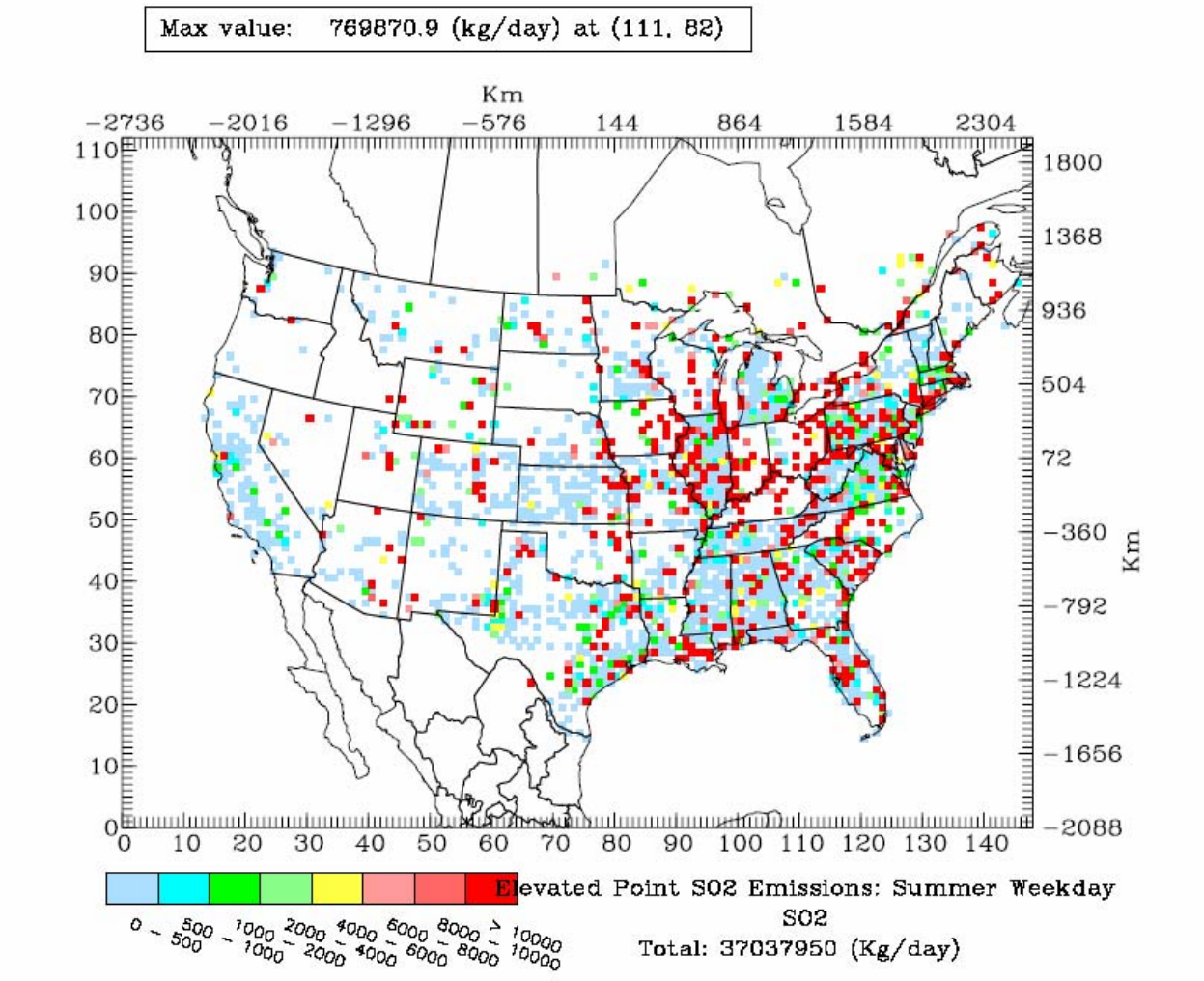


**Figure 4-2b. Elevated Point-Source $SO_2$ Emissions (tons) for the 36-km Grid for a Summer Weekday.**




## 4.2. Emission Inventory Preparation for Mercury

In this study, emphasis was placed on the preparation and quality assurance of the mercury emissions inventory. The starting point for the mercury inventory preparation was the 2001 emissions data utilized by EPA in the Clean Air Mercury Rule (CAMR) modeling. Further information on these emissions can be found in “Emissions Inventory and Emissions Processing for the Clean Air Mercury Rule (CAMR)” (EPA, 2005c).

Briefly, the 2001 CAMR contains point- and area-source mercury emissions for the U.S. and Canada, reported as elemental, divalent gas, and divalent particulate species. The point source emissions are divided into two categories, primarily for the purposes of future projections. These include 1) utility and other combustion-related point sources for which emissions are projected using the Integrated Planning Model (IPM) (EPA, 2004) and 2) all other point sources. In keeping with the CAMR nomenclature, these are referred to as IPM and non-IPM sources throughout the remainder of this section.
The peer review of the REMSAD mercury deposition modeling conducted during the Devil's Lake TMDL Pilot Project (mentioned in the introduction) recommended that the meteorological

and mercury emissions data should target the same year to the extent possible. This recommendation was made in order to facilitate model validation by comparisons to measured data. The meteorological data used in this project was the same as that used by EPA as part of the Clean Air Mercury Rule (CAMR) modeling and represented the year 2001. However, with the exception of medical waste incinerator emissions, other mercury emissions from the CAMR were from the year 1999; medical waste incinerator emissions in CAMR were from 2002. Therefore, summaries of the mercury emissions from the CAMR inventory were prepared for each state and asked the EPA Regional offices to lead a review of those data, with participation from their member states where necessary, and determine the representativeness of the emissions for the year 2001. The following discussion details the changes, additions, and deletions made to the CAMR inventory as a result of this effort to produce a more accurate picture of 2001 emissions. A summary of state specific, speciated mercury emissions is presented in Section 7.

### 4.2.1. Review and Revision of the CAMR Mercury Emissions Inventory

Detailed summaries of the top emitters in the CAMR mercury inventory were prepared for each state, and this information was provided to the appropriate EPA regional offices and state agencies for review. In some cases, the state agencies asked to be allowed to conduct a more detailed review of emissions beyond the list of top emitters. In these cases, the states were provided the complete inventory for the state, and changes to the inventory were incorporated as directed by the state. For cases where these changes were extensive, detailed lists of the changes are included in Appendix C. The revisions to the mercury emissions are summarized in the remainder of this section, by EPA region and by state. For those regions/states not listed here, there were no revisions.

## EPA Region 1

#### STATE OF CONNECTICUT

Revisions were made to the top five emitters of divalent gaseous mercury and the top five emitters of total mercury in the state based on the Connecticut Department of Environmental Protection (CTDEP) 2001 mercury emission estimates. The revised emissions were provided by NESCAUM (2006a) and CTDEP (2006).

In addition, per the request of CTDEP, the speciation profile used for Naugatuck Treatment Co. and Mattabassett Regional Sewage Authority was changed from the default (50 percent elemental, 30 percent gaseous divalent, and 20 percent particulate mercury) to that for sewage sludge incineration (22 percent elemental, 58 percent gaseous divalent, and 20 percent particulate mercury). In the CAMR database, the MACT code assigned to the facilities is 00000, and the SCC code is for miscellaneous industrial process.

The revisions resulted in total mercury emission increases of 0.04 tons/year for non-IPM point sources, compared to the CAMR base emissions for Connecticut.

#### STATE OF MAINE

The emissions for Holtra Chemical Manufacturing Co. were removed from the inventory (total mercury emissions in the CAMR database for the facility is 0.065 tons/year). The chlor-alkali plant closed prior to 2001 (NESCAUM, 2006a).

#### STATE OF NEW HAMPSHIRE

Revisions were made to the top five emitters of divalent gaseous mercury and the top five total mercury emitters in the state, based on the New Hampshire Department of Environmental Conservation (NHDEC) 2001 mercury emission estimates (NESCAUM, 2006b). The mercury

speciation profile was also revised for coal-fired units for two point sources (Merrimack and Schiller) using NHDEC's stack test data.

The revisions resulted in 0.04 tons/year total mercury emissions increases for IPM sources, and 0.06 tons/year total mercury emissions decreases for non-IPM sources.

The location for Design Contempo Inc provided in the CAMR database puts the facility outside the state. The coordinates were changed to the centroid of Lisbon, NH where the facility is located.

### STATE OF VERMONT

The Vermont Air Pollution Control Division (VT APCD) provided 2001 mercury emissions estimates for the top ten fuel-combustion facilities and the top five process/manufacturing facilities in the state with total mercury emissions of about 7 lbs per year (NESCAUM, 2006c). Four of the 15 facilities from the VT APCD list could be matched to sources in the CAMR database, and the emissions were revised (total emissions from the four facilities are 1.7 lbs/year). The emissions for remainder of the sources were not added to the 2001 inventory, since the emissions may already be included in the CAMR database as non-point sources.

## EPA Region 2

### STATE OF NEW JERSEY

The revisions were made to the point- and area-source emissions based on the New Jersey Department of Environmental Protection (NJDEP) 2001 mercury emission estimates (NJDEP, 2006a). Revisions are summarized below. For additional detail, see Appendix C.
The revisions for the point sources included the following:

- Total mercury emissions were revised for several facilities. The revisions resulted in a net increase total mercury emissions of 0.03 tons/year (resulting from an increase of 0.14 tons/year for IPM sources and a decrease of 0.11 tons/year for non-IPM point sources).
- In the CAMR database, the MACT code assigned to U. S. Pipe & Foundry Co. and CO Steel Raritan is 0107 for Industrial/Commercial/Institutional Boilers & Process Heaters. Thus the mercury emissions of the facilities were speciated as 50, 30, and 20 percent elemental, gaseous divalent, and particulate mercury, respectively. The speciation for CO Steel Raritan was changed to the profile for iron and steel foundries, which is 80, 10, and 10 percent for elemental, divalent gaseous, and particulate mercury, respectively. In addition, the speciation for U. S. Pipe & Foundry Co. was changed based on stack test data for the facility (to 62.3 percent elemental, 37.5 percent divalent gaseous, and 0.2 percent particulate mercury).
- An iron manufacturing plant, Griffin Pipe Products, is not included in the CAMR database. The facility was added to the inventory based on the information provided by NJDEP (NJDEP, 2006b and c) including stack parameters and total mercury emissions of 0.025 tons/year. The emissions were speciated using the iron foundries profile.
- The locations for Stepan Chemical Company, Geon Company, and Owens Corning provided in the CAMR database put the facilities outside the state. The locations for the facilities were changed using the coordinates provided in the EPA 2001 criteria pollutant inventory.

The revisions for the non-point (area) sources included the following:

- In the CAMR database, the emissions totals for human and animal cremation for the state are identical. The emissions for animal cremation (0.052 tons/year) were removed from the inventory.

- Additional elemental mercury emissions for fluorescent lamp breakage (200 lbs/year) and miscellaneous volatilization (300 lbs/year) were included in the inventory. The additional emissions were distributed among the counties based on the original distribution of fluorescent lamp breakage emissions.

## EPA Region 3

### STATE OF VIRGINIA

For Virginia, a steel mill with one fairly large electric arc furnace plus mill equipment (Chaparral) in the state is not represented in the CAMR database. The facility was added to the inventory based on emissions and stack parameter information provided by the Virginia Department of Environmental Quality (VA DEQ). The 2001 mercury emissions for this facility are 0.14 tons/year (VA DEQ, 2006). The emissions were speciated using the steel manufacturing speciation profile.

Also, Cogentrix of Richmond is assigned the FIPS code for Mecklenburg County, North Carolina in the CAMR database. After double checking with the EPA Region 3, it was confirmed that the facility is located at Richmond, VA, and the FIPS code was changed accordingly. The emissions from the source (0.003 tons/year) were moved from the State of North Carolina to the State of Virginia. This is an IPM point source.

### STATE OF WEST VIRGINIA

The locations for CNG-Yellow Creeks and Weirton Steel Corporation provided in the CAMR database put the facilities outside the state. The locations for the facilities were changed using the coordinates provided in the EPA 2001 criteria pollutant inventory.

## EPA Region 4

### STATE OF GEORGIA

The emissions for a hazardous waste incineration facility in the state (Searle) were reduced from 0.202 tons/year (CAMR database) to 0.002 tons/year, based on 2004 stack test results (EPA Region 4, 2006). According to specialists at EPA Region 4, the 0.002 tons/year is a better estimate of the 2001 emissions from the incinerator than the 0.202 tons/year, because the facility burns a consistent waste stream generated on-site that has not changed significantly since before 2001. Also, no process changes or physical changes were made to the incinerator from 2000-2004 when the stack test was done.

### STATE OF NORTH CAROLINA

The IPM source (Cogentrix of Richmond), incorrectly placed in Mecklenburg County, North Carolina in the CAMR database, and was relocated to Virginia. After double checking with the EPA Region 3, it was confirmed that the facility is located at Richmond, VA, and FIPS code was changed accordingly. The emissions from the source (0.003 tons/year) were reassigned from North Carolina to Virginia.

# EPA Region 5

## STATE OF ILLINOIS

Revisions were made to the IPM and non-IPM point-source emissions based on the Illinois EPA 2001 mercury emission estimates (IL EPA, 2006a, b and c; EPA OW, 2006). Details of the revisions are included in Appendix C. A summary of the point-source revisions follows:

- Emissions for all coal-fired utilities in the state were adjusted to represent 2001 operating conditions. This accounted for a switch from bituminous to sub-bituminous coal during the period 1999-2001 for some of the larger mercury sources, as well as an overall increase in amount of coal combusted at many Illinois utilities. The switch to western coal plus the increase in coal combustion resulted in increased mercury emissions and a change in the speciation profiles for some of the plants.
- Emissions for the top six mercury emitters in the cement and lime manufacturing category in the state were revised, based on the state's 2002 NEI inventory submittal. The 2002 data are the closest data to 2001 and indicate significantly lower emissions than the CAMR database.
- The revisions resulted in a net decrease in total mercury emissions of 1.24 tons/year (from an increase in mercury emissions of 0.17 tons/year for IPM sources, and a decrease of 1.41 tons/year for non-IPM sources).
- Due to changes in coal type (bituminous vs. sub-bituminous) usage, speciation profiles were changed for the Baldwin, Hennepin and Wood River plants.
- The locations for Baxter Healthcare Corp and Radco Industries provided in the CAMR database put the facilities outside the state. The locations for the facilities were changed using the coordinates provided in the EPA 2001 criteria pollutant inventory.

## STATE OF INDIANA

Revisions were made to the point-source emissions based on the Indiana Department of Environmental Management (IDEM) 2001 mercury emission estimates (IDEM, 2006a). Details of the emissions changes are included in Appendix C. Changes are summarized below.

The revisions for the point sources included the following:

- Revised emissions and stack parameters for the top 20 mercury emitters in the state. The revisions resulted in 0.16 tons/year total mercury emissions deceases for IPM sources, and 0.19 tons/year total mercury emissions increases for non-IPM sources.
- Added the emissions (0.077 tons/year) for Indiana Harbor Coke Company, which is not included in the CAMR database.
- Removed two waste incinerators (Ball Memorial and Clarian Health Partners) with total mercury emissions of 0.66 tons/year from the inventory. According to IDEM, these facilities ceased operations and reported no emissions in 2001 (IDEM, 2006b).

## STATE OF MICHIGAN

A Portland cement manufacturing plant (LaFarge Midwest Inc.) that operates five dry process cement kilns in the state is not included in the CAMR database. The facility was added to the inventory based on emissions and stack parameter information provided by the Michigan Department of Environmental Quality (MDEQ). The mercury emissions for 2001 for this plant

total 0.29 tons/year (MDEQ, 2006). The emissions were speciated using the cement manufacturing (dry process) speciation profile.

### STATE OF MINNESOTA

Revisions were made to the point-source emissions based on the Minnesota Pollution Control Agency (MPCA) 2001 mercury emission estimates (EPA OW, 2006b; MPCA, 2006a).

The revisions for the point sources included the following:

#### Revised Speciation for Coal-fired Power Plants

*Sherburn County Generating Plant*

- Revised speciation based on the test data from the plant (Mostardi Platt, 2000).
- Units 1 and 2: 90.7 percent elemental, 7.1 percent divalent gaseous, 2.0 percent particulate mercury.
- Unit 3: 96.3 percent elemental, 2.0 percent divalent gaseous, 21.7 percent particulate mercury.

*Clay Boswell*

- Test data available for Units 3 and 4 (Roy F. Weston, 2000).
- Unit 3: 98.98 percent elemental, 1.0 percent divalent gaseous, 0.02 percent particulate mercury.
- Unit 4: 91.5 percent elemental, 5.9 percent divalent gaseous, 2.6 percent particulate mercury.

*Allen S. King Generating Plant*

- Revised speciation based on the test data from the plant (MPCA, 2006c).
- 93.9 percent elemental, 6.1 percent divalent gaseous, 0 percent particulate.

#### Revised Emissions and Speciation for Sludge Incinerator

- The emissions for the sludge incinerator (MCES Metropolitan WWTP – St. Paul) were revised using the MPCA 2001 emissions estimates. Based on the documented decline in the mercury concentration in the incinerated sludge, the emissions were reduced from 350 lb/year to 102 lb/year.
- The speciation profile for the incinerator was also revised in consideration of wet scrubbers in operation during the 2001 time period. Based on the Method 29 stack testing data from the facility, the speciation was changed from the EPA profile for sewage sludge incineration (22 percent elemental, 58 percent divalent gaseous, and 20 percent particulate) to 95.3 percent elemental, 3.5 percent divalent gaseous, and 1.2 percent particulate mercury.

#### Revised Emissions and Speciation for Municipal Waste Combustors

- The emissions for the municipal waste combustors were revised using the MPCA 2001 emissions estimates. The emissions for the combustors were reduced from 555 lb/year to 95 lb/year based on compliance stack tests, and emissions for the Perham Renewable RF facility were omitted due to closure.
- The EPA profile for municipal waste combustors (22 percent elemental, 58 percent divalent gaseous, and 20 percent particulate mercury) was replaced with facility-specific speciation

profiles for Polk Co. Solid Waste Resource Recovery (0.6 percent elemental, 97.2 percent divalent gaseous, and 2.2 percent particulate mercury) and Olmstead WTE Facility (16.9 percent elemental, 81.2 percent divalent gaseous, and 2.0 percent particular mercury). MPCA provided speciation test data based upon Method 29 testing for the two facilities.

#### Revised Emissions and Speciation Profiles for Taconite Plants

- Emissions for the taconite plants were revised using the MPCA 2001 emissions estimates. The emissions for the taconite plants were reduced from 792 lb/year to 480 lb/year based on a mass balance study conducted for the MPCA and accounting for one closed facility: LTV Steel Pellet Co.
- Speciation for the taconite plants was revised based on test data (using the Ontario Hydro method) provided by MPCA (MPCA, 2006b) as follows:
  - Hibbing Taconite Company: 93.31 percent elemental, 6.6 percent divalent gaseous, and 0.09 percent particulate mercury (based on test data for the company's Line 2, a straight grate furnace fired with natural gas, tested from 9/29/98 to 10/2/98)
  - United Taconite: 98.71 percent elemental, 1.08 percent divalent gaseous, and 0.21 percent particulate mercury (based on test data for the company's Line 1, a grate-kiln furnace fired with natural gas, tested on 5/4/2005).
  - National Steel: 50 percent elemental, 30 percent divalent gaseous, and 20 percent particulate mercury. This is the only taconite facility that did not have a wet scrubber, hence the default profile was kept (MPCA, 2006a).
  - Other taconite plants: average of Hibbing Taconite Company's and United Taconite's profile (96.01 percent elemental, 3.84 percent divalent gaseous, and 0.15 percent particulate mercury).

### STATE OF WISCONSIN

During the review of emissions for a previous mercury modeling analysis for Wisconsin (Myers et al., 2006), the Wisconsin Department of Natural Resources (WDNR) recommended that the emissions from the Superior Special Services site remediation be reduced from 940 lb/year to 33 lb/yr (WDNR, 2005). That recommendation is followed in this study.

## EPA Region 7

### STATE OF IOWA

Revisions were made to the IPM and non-IPM point sources and Medical Waste Incinerators (MWI) based on the Iowa Department of Natural Resources 2001 mercury emission estimates (Iowa DNR, 2006 and Iowa DNR, 2007). Details of the emissions changes are included in Appendix C. Changes are summarized below.

In the CAMR database, one set of stack parameters is used for all stacks/units for a given source. Iowa DNR provided more detailed information for stack parameters for the IPM sources, i.e., different sets of stack parameters for the stacks/units in a facility. Iowa DNR also provided revised emissions for the state's top 40 divalent gaseous emitters. All of the state provided information was incorporated in the point source revisions.

The revisions resulted in total mercury emissions increases of 0.01 tons/year for IPM sources and 0.02 tons/year for non-IPM and MWI sources.

### STATE OF KANSAS

Revisions were made to the IPM and non-IPM point sources based on the Kansas Department of Heath and Environment (KDHE) data (KDHE, 2006). The revisions were for the stack locations and parameters for the top five divalent gaseous emitters in the state. No changes were made to the emissions totals.

### STATE OF NEBRASKA

Revisions were made to the point-source emissions based on the information provided by EPA Region 7 and the Lincoln/Lancaster County Health Department (LLCHD, 2006; EPA Region 7, 2006a and b).
The revisions made to the point source emissions files include the following:

- Emissions for the Sheldon facility were changed from 0.034 tons/year to 0.0445 tons/year
- Emissions for Goodyear Tire & Rubber Co. (0.058 tons/year in the CAMR database) were omitted because there are no mercury emissions for 2001, nor are there any mercury emissions in any of the subsequent years from the facility.
- Deeter Foundry Inc. was added to the inventory with mercury emissions of 0.002 tons/year, the EPA speciation profile for iron foundries was applied for this facility.

### STATE OF MISSOURI

Revisions were made to the point-source emissions based on the information provided by EPA Region 7 and the Missouri Department of Natural Resources (MO DNR).

#### Revisions to the State Top Mercury Emitters

- Emissions and stack parameters for the top five divalent gaseous and top five total mercury emitters in the state were revised (MO DNR, 2006a; EPA Region 7, 2006c). The revisions resulted in total mercury emissions increases of 0.06 tons/year for IPM sources and a very small amount ($9.0 \times 10^{-5}$ tons/year) for non-IPM sources

#### Revisions to the Lead Smelters

- Considerable efforts were made to estimate the emissions from the lead smelters operated by the Doe Run Company. EPA Region 7 and MO DNR (MO DNR, 2006b; EPA Region 7, 2006d and e) estimated that total 2001 mercury emissions from three sites of the Doe Run Company (Glover, Herculaneum, and Buick) are 0.32 tons/year, while the EPA CAMR database only provides emissions for one site with 0.00026 tons/year.
- For Glover and Herculaneum sites, the stack parameters were provided by EPA Region 7, and for Buick site, the stack parameters were obtained from the EPA criteria pollutant inventory.
- Assuming the same mercury control efficiency and speciation as the Minnesota taconite facilities that have been tested, the average profile for the Minnesota taconite facilities (96.01 percent elemental, 3.84 percent divalent gaseous, and 0.15 percent particulate) were used for the speciation of the primary smelters at Glover and Herculaneum sites.
- The EPA profile for secondary lead smelting used for Doe Run Company in the CAMR database (80 percent elemental, 10 percent divalent gaseous, and 10 percent particulate) was used for the secondary smelter at the Buick site.

## EPA Region 8

### STATE OF COLORADO

The emissions for a steel mill in the state (CF&I Steel L P DBA Rocky Mountain Steel Mills) were increased from 0.0436 tons/year (CAMR database) to 0.2825 tons/year, based on the information provided by EPA Region 8 (EPA Region 8, 2007).

### STATE OF UTAH

Revisions were made to the point sources based on the Utah Department of Environment Quality 2005 mercury emission estimates (Utah DEQ, 2007b). Changes are summarized below. Further detail on these changes is included in Appendix C.

- The emissions for the IPM, non-IPM and Medical Waste Incinerators included in the CAMR database were updated to 2005 levels along with the revisions to stack parameters which provided by Utah DEQ
- There were point sources in the CAMR database that were not included in the Utah DEQ 2005 inventory. Of the sources in the CAMR inventory but not in the Utah DEQ inventory, special attention was focused on the top 10 emitters (i.e., those emitting 3 lb/year or more). The total emissions of these top 10 emitters are about 98% of all emissions in CAMR but not in the Utah DEQ inventory. After careful examination of other databases (i.e., TRI) and Utah DEQ's confirmation, 6 of these top 10 emitters were dropped from the inventory because independent verification could not be found that the sources exist or emitted mercury. Details regarding the sources that were excluded are shown in Appendix C.
- The mercury speciation for the coal fired boilers in Kenecott Utah Copper Corporation (50 percent elemental, 30 percent divalent gaseous, and 20 percent particulate mercury) was revised based on the information provided by Utah DEQ (Utah DEQ, 2007a). The information included the coal type, boiler type, and controls for each of the 4 boilers at the facility. Based on data used in the CAMR rule making for similar facilities, a speciation profile of 37.26 percent elemental, 57.84 percent divalent gaseous, and 4.9 percent particulate mercury was used for the Kenecott boiler.

The revisions resulted in total mercury emissions increases of 0.31 tons/year for IPM sources and decreases of 0.45 tons/year for non-IPM and MWI sources.

## EPA Region 9

### STATE OF ARIZONA

Four copper mine facilities of Phelps Dodge are not represented in the CAMR database. Following the EPA Region 9's direction (EPA Reg. 9, 2006d), mercury emissions of 0.12 tons/year for the facilities were added to the inventory based on the 2001 TRI database. The emissions were speciated using the EPA speciation profile for metal mining (80 percent elemental, 10 percent divalent gaseous, and 10 percent particulate). The stack parameters for one of the copper mine facilities (Phelps Dodge Morenci Inc.) are available in the EPA 2001 criteria pollutant inventory, and the average stack parameters for this facility were used for other three facilities.

### STATE OF CALIFORNIA

Revisions were made to the non-IPM point and non-point source emissions following direction provided by EPA Region 9 (EPA Reg. 9, 2006e). Based on information received from Barrick,

Inc, the Homestake goldmine in California has been closed since 2002. At EPA's direction, it was removed from the inventory (EPA, 2007).

### Cement Plants

- Mercury emissions are available for ten cement plants in California in the 2001 TRI database, and these emissions were incorporated into the inventory. The revisions resulted in an increase in mercury emissions of 1.37 tons/year.
- The emissions were speciated using the EPA speciation profile for Portland cement manufacturing (75 percent elemental, 13 percent divalent gaseous, and 12 percent particulate mercury).
- The stack parameters for Calaveras Cement Company and California Portland Cement Co. are missing in the CAMR database. The missing stack parameters for both facilities were replaced using the available information for Calaveras Cement Company provided in the EPA 2001 criteria pollutant inventory.
- The stack parameters for Long Beach City-SERRF Project are missing in the CAMR database. The missing stack parameters were replaced with those for similarly named Long Beach (SERRF) that is listed in the database, after EPA Region 9 (EPA Reg. 9, 2006f) confirmed that they are the same facility.

### Gold Mining

- The mercury speciation for Home Stake Mining Company (99.86 percent elemental, 0.09 percent divalent gaseous, and 0.06 percent particulate mercury) were revised using the speciation profile (78 percent elemental, 19.3 percent divalent gaseous, and 2.7 percent particulate mercury) for Cortez Gold Mines #2 (aka Pipeline Mill) in Nevada. This information was provided by the EPA Region 9 (EPA Reg. 9, 2006f).
- The Homestake Gold Mine was removed from the inventory because the facility was closed in 2002 (Barrick, 2007; EPA, 2007).

### Residential Home Construction

- In the CAMR database, the mercury emissions from residential home construction in State of California are about 1.3 tons/year. However, there is no mercury emissions from the source category included in the 2002 NEI (EPA, 2007). The emissions were removed from the inventory.

## STATE OF NEVADA

Revisions were made to the IPM and non-IPM point source emissions following direction provided by EPA Region 9, as summarized below and detailed in Appendix C.

### Gold Mines

*Emissions and Speciation Revisions*

- The mercury emissions and associated speciation data for all gold mines in the State of Nevada were revised based on information from several data sources. The final information used was tabulated by EPA Region 9 (EPA Region 9, 2007). Further references are given in Appendix C.

*Stack Parameters Revisions*

- Location and stack parameters for all gold mines were revised based on the information provided in the MACT questionnaire (NDEP, 2006).

### Cement Plant

- Emissions for Nevada Cement Company were added from the TRI 2001 database.
- The emissions were speciated using EPA speciation profile for Portland cement manufacturing.
- Stack parameters for this plant were unavailable in the EPA inventories, so the average stack parameters for California cement plants were used.

### IPM

- The mercury emissions, associated speciation and stack parameters for a coal fired utility (Mohave) were revised based on the information provided by EPA Region 9 (NDEP. 2007).

The revisions to gold mines resulted in a decrease in total mercury emissions of 8.42 tons/year. Adding the cement plant emissions increased total mercury emissions by 0.0095 tons/year. The revisions to the IPM source resulted in a decrease in total mercury emissions of 0.074 tons/year.

## EPA Region 10

### STATE OF OREGON

The revisions were made to the non-IPM point source emissions based on information provided by the Oregon Department of Environmental Quality (OR DEQ).

### Cement Plant

- The emissions, speciation, and stack parameters were revised for Ash Grove Cement Company based results of Ontario hydro testing supplied by OR DEQ (OR DEQ, 2007a, b, and c). The revisions resulted in mercury emissions increases of 1.14 tons/year, from 0.1154 tons/year in CAMR to 1.255 tons/year. Speciation was revised from 75/13/12 to 29/63/8 (%HG0/%HG2/%HGP).

### Steel Mill

- Emissions for Oregon Steel Mills, Inc and Cascade Steel Rolling Mills, Inc were revised based on information from OR DEQ (2007a). The revisions resulted in mercury emissions decreases of 1.71 tons/year.
- The mercury speciation for Cascade Steel Rolling Mills, Inc (50 percent elemental, 30 percent divalent gaseous, and 20 percent particulate mercury) was revised using the EPA

speciation profile for iron and steel foundries (80 percent elemental, 10 percent divalent gaseous, and 10 percent particulate).

### Municipal Waste Incinerator

- The emissions for Covanta Marion, Inc. were decreased by 0.09 tons/year (OR DEQ, 2006c).

The locations for Alsea Veneer Inc and Pacific Softwood Co. provided in the CAMR database put the facilities outside the state. The locations for the facilities were changed using the coordinates provided in the EPA Facility Registry System web site.

### State of Washington

Revisions were made to the non-IPM point source emissions based on information provided by the Northwest Clean Air Agency and Puget Sound Clean Air Agency.

### Refineries

- Emissions for Tesoro (formerly Shell Oil Co.) were changed from 43 lb/year to 9 lb/year.
- Emissions for the Puget Sound facility (Equilon Enterprises) were changed from 9.2 lb/year to zero.

### Cement Plant

- Two cement plants located in King County, WA are not included in the CAMR database. Mercury emissions of 44 lb/year and 68 lb/year were added to the inventory for Ash Grove Cement Company and Lafarge Corporation, respectively. The emissions were speciated using the EPA speciation profile for Portland cement manufacturing (75 percent elemental, 13 percent divalent gaseous, and 12 percent particulate). The stack parameters for the facilities from the EPA 2001 criteria pollutant inventory were used.

### Georgia Pacific West Inc

- Emissions were lowered by 83 percent for this facility, because the facility only operated in February and March of 2001 (WA DE 2006).

### Tacoma

- Emissions were lowered by 83 percent for this facility, because the facility only operated two months in 2001 (WA DE 2007).

## Canada

One location correction was made to the Canadian point sources. The coordinates provided for Ontario Hydro - Lambton TGS (with total mercury emissions of 0.19 tons/year) in the CAMR database put the facility outside the province and modeling domain. Based on the information provided in Canadian web sites, the facility is located on the St. Clair River, approximately 21 kilometers south of Sarnia, Ontario. The correct coordinates for the facility were obtained and incorporated into the inventory.

One incinerator (Burnaby Refuse Incinerator) was added to the Canadian point source emissions based on the information provided by Environment Canada (Canada, 2007a) and

Metro Vancouver (Canada 2007b). The revisions resulted in mercury emissions increases of 0.06 tons/year.

### Mexico

The Mexico point source emissions, which are not available in the CAMR database, were added to the 2001 inventory used for REMSAD modeling. The point source emissions data were provided by Commission for Environmental Cooperation (CEC, 2001). These data include speciated mercury emissions for 268 point sources in Mexico along with source locations and stack height. Default stack diameter, exit velocity and temperature information was added to the data for processing the emissions for Mexico.

Total mercury emissions from the point source data for Mexico are 29.42 tons/year with 20.89 tons/year of elemental, 5.76 tons/year of divalent gaseous, and 2.77 tons/year of particulate mercury. About 69 percent of these emissions are from point sources located within the modeling domain (13.07 tons/year of elemental, 4.68 tons/year of divalent gaseous and 2.43 tons/year of particulate mercury).

## *4.2.2. Mercury Emissions Processing for REMSAD*

For this application, the mercury emissions data were processed using the Emissions Preprocessing System (EPS2.5).

The revised 2001 CAMR mercury emissions data for area and point sources were speciated into particulate, divalent, and elemental emissions. For sources with speciated emissions data, the speciation was retained. For sources reporting total mercury emissions (unspeciated), speciation was accomplished using the speciation profiles and cross-reference file provided by EPA. The emissions for each of the three species were gridded and temporally allocated by month, day, and hour using the EPS2.5 algorithms. The emissions were prepared for weekday, Saturday, and Sunday for each season. For the low-level (area) sources, separate emissions files were prepared for the 36-km grid and for each of the 12-km grids.

## *4.2.3. Quality Assurance of the Mercury Emission Inventory*

The goal of the quality assurance procedures was to ensure that the emission estimates from the EPA CAMR inventory and all additions and corrections provided by the states and EPA regional offices are properly represented in the REMSAD input files. As noted above, the modified CAMR emissions inventory is referred to as the updated emission inventory.
The QA procedures included:

- Cross checks of emissions totals in the updated inventory files compared to the REMSAD input files.
  - These types of checks were used to ensure that the processing did not result in emissions being left out of the inventory and that there were no errors in converting the units of emissions.
- Displays of emissions density of area sources
  - These displays were used to check for inconsistencies in the emissions among the states.
- Plots of point source emissions by emissions category or by individual state
  - These displays were used to confirm that the elevated point sources of mercury were located within the correct state.

– For the tagged emissions, these same plots were used to verify that the emissions tagged for a particular state were properly located in the domain.

Some additional checks were made in order to identify possible unrealistic values or parameters in the updated emissions inventory files.

The 2001 base-year criteria pollutant emissions for the U.S. portion of the modeling domain are presented by major source category and by season in Table 4-2. This table highlights the key source categories for each component and the variations in the emissions throughout the year.

### 4.2.4. Summary of the Mercury Emissions

The mercury emissions are briefly summarized in this section of the report. Table 4-3 lists annual mercury emissions for each state, the 48 U.S. states, Canada, and Mexico. The emissions totals are provided for each species and for the sum of the three mercury species.

**Table 4-3. Summary of Mercury Emissions Totals by Species for Each U.S. State and for the 48 U.S. States, Canada, and Mexico.**

| State | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|
| Alabama | 2.146 | 1.351 | 0.228 | 3.726 |
| Arizona | 0.887 | 0.106 | 0.049 | 1.043 |
| Arkansas | 0.805 | 0.350 | 0.164 | 1.320 |
| California | 3.815 | 1.329 | 0.951 | 6.095 |
| Colorado | 0.564 | 0.155 | 0.057 | 0.776 |
| Connecticut | 0.200 | 0.202 | 0.084 | 0.485 |
| Delaware | 0.593 | 0.108 | 0.015 | 0.716 |
| District of Columbia | 0.004 | 0.001 | 0.001 | 0.006 |
| Florida | 1.510 | 1.242 | 0.462 | 3.214 |
| Georgia | 1.466 | 0.969 | 0.137 | 2.572 |
| Idaho | 0.562 | 0.155 | 0.118 | 0.835 |
| Illinois | 3.336 | 1.462 | 0.318 | 5.116 |
| Indiana | 1.895 | 1.511 | 0.343 | 3.749 |
| Iowa | 0.806 | 0.313 | 0.032 | 1.150 |
| Kansas | 0.963 | 0.178 | 0.081 | 1.222 |
| Kentucky | 1.818 | 1.299 | 0.446 | 3.564 |
| Louisiana | 1.910 | 0.335 | 0.115 | 2.359 |
| Maine | 0.247 | 0.105 | 0.038 | 0.389 |
| Maryland | 0.753 | 0.931 | 0.236 | 1.920 |
| Massachusetts | 0.320 | 0.454 | 0.152 | 0.926 |
| Michigan | 1.484 | 1.124 | 0.261 | 2.869 |
| Minnesota | 1.139 | 0.286 | 0.104 | 1.530 |
| Mississippi | 0.518 | 0.326 | 0.122 | 0.966 |
| Missouri | 1.519 | 0.594 | 0.118 | 2.230 |
| Montana | 0.475 | 0.070 | 0.022 | 0.567 |
| Nebraska | 0.362 | 0.095 | 0.005 | 0.462 |
| Nevada | 1.765 | 1.243 | 0.075 | 3.082 |
| New Hampshire | 0.075 | 0.124 | 0.033 | 0.232 |
| New Jersey | 1.043 | 0.408 | 0.192 | 1.643 |

| State | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|
| New Mexico | 1.083 | 0.056 | 0.019 | 1.157 |
| New York | 1.252 | 0.919 | 0.361 | 2.532 |
| North Carolina | 1.019 | 1.273 | 0.239 | 2.531 |
| North Dakota | 0.930 | 0.159 | 0.032 | 1.122 |
| Ohio | 2.901 | 2.066 | 0.313 | 5.280 |
| Oklahoma | 0.875 | 0.298 | 0.064 | 1.237 |
| Oregon | 0.734 | 0.870 | 0.208 | 1.812 |
| Pennsylvania | 3.003 | 3.766 | 0.773 | 7.541 |
| Rhode Island | 0.085 | 0.062 | 0.035 | 0.182 |
| South Carolina | 0.709 | 0.658 | 0.246 | 1.613 |
| South Dakota | 0.050 | 0.021 | 0.002 | 0.074 |
| Tennessee | 1.251 | 0.882 | 0.148 | 2.281 |
| Texas | 5.610 | 2.115 | 0.596 | 8.321 |
| Utah | 0.488 | 0.219 | 0.065 | 0.772 |
| Vermont | 0.017 | 0.007 | 0.004 | 0.028 |
| Virginia | 0.722 | 0.790 | 0.209 | 1.721 |
| Washington | 0.408 | 0.149 | 0.042 | 0.599 |
| West Virginia | 1.458 | 1.564 | 0.155 | 3.177 |
| Wisconsin | 1.579 | 0.520 | 0.094 | 2.193 |
| Wyoming | 0.923 | 0.096 | 0.024 | 1.043 |
| U. S. Total | 58.074 | 33.319 | 8.588 | 99.981 |
| **Canada** | 4.540 | 2.909 | 0.869 | 8.318 |
| **Mexico** | 13.07 | 4.676 | 2.430 | 20.17 |
| **Grand Total** | **75.679** | **40.903** | **11.886** | **128.469** |

The spatial distribution of mercury emissions throughout the domain is illustrated in Figures 4-3 and 4-4. Figure 4-3 illustrates the distribution of low-level mercury emissions corresponding to the 2001 REMSAD emissions inventory for each of the three species and for all three species combined. Figure 4-4 similarly displays the elevated point source emissions. Note that, although these displays present the emissions at 36 km resolution, the emissions were processed for each sub-domain to 12-km resolution.

**Figure 4-3a. Spatial Distribution of Low-Level Mercury Emissions (tons) for the 2001 REMSAD Emissions Inventory for the 36-km Grid for a Summer Weekday: Elemental Mercury.**

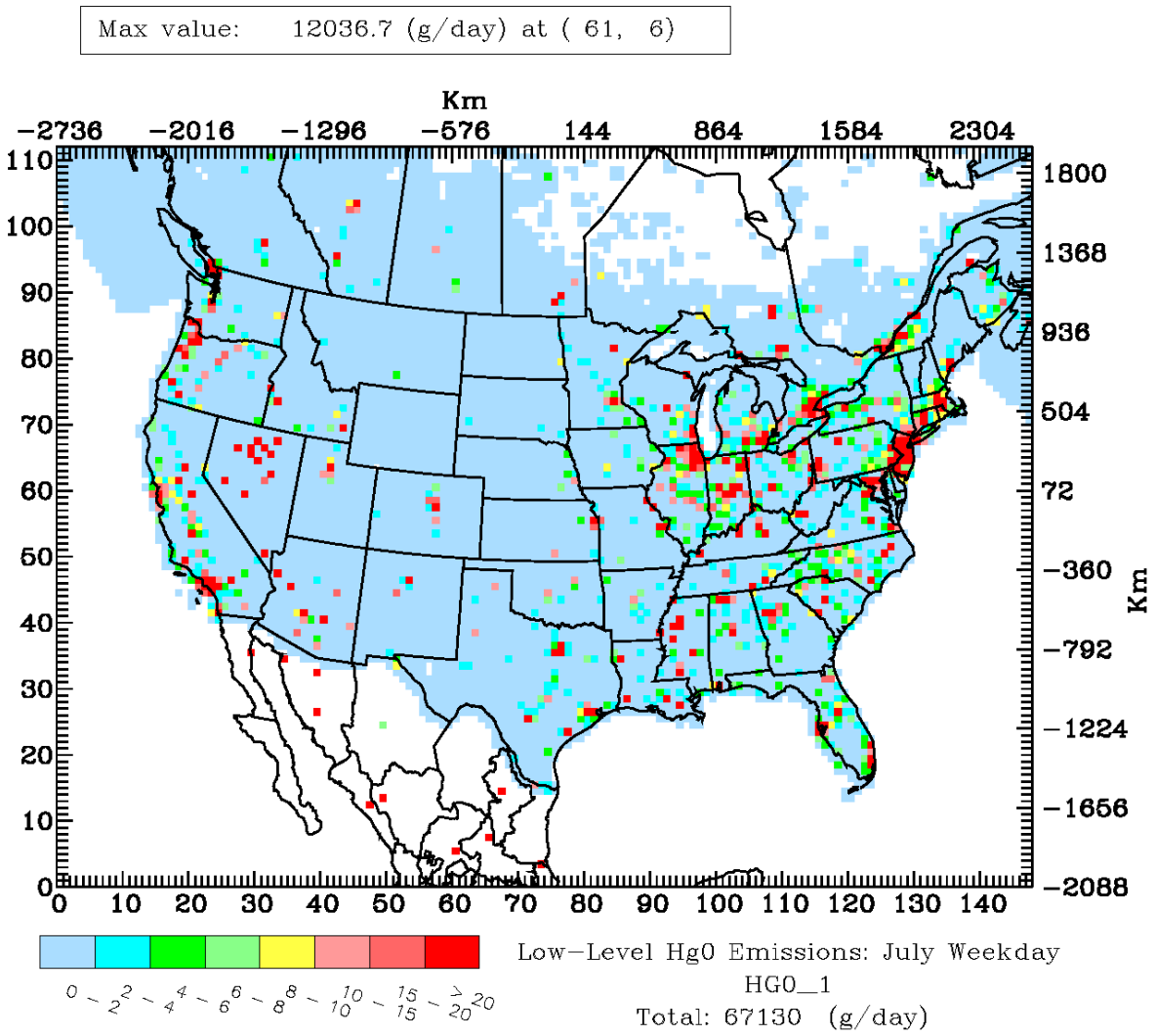


**Figure 4-3b. Spatial Distribution of Low-Level Mercury Emissions (tons) for the 2001 REMSAD Emissions Inventory for the 36-km Grid for a Summer Weekday: Divalent Gaseous Mercury.**

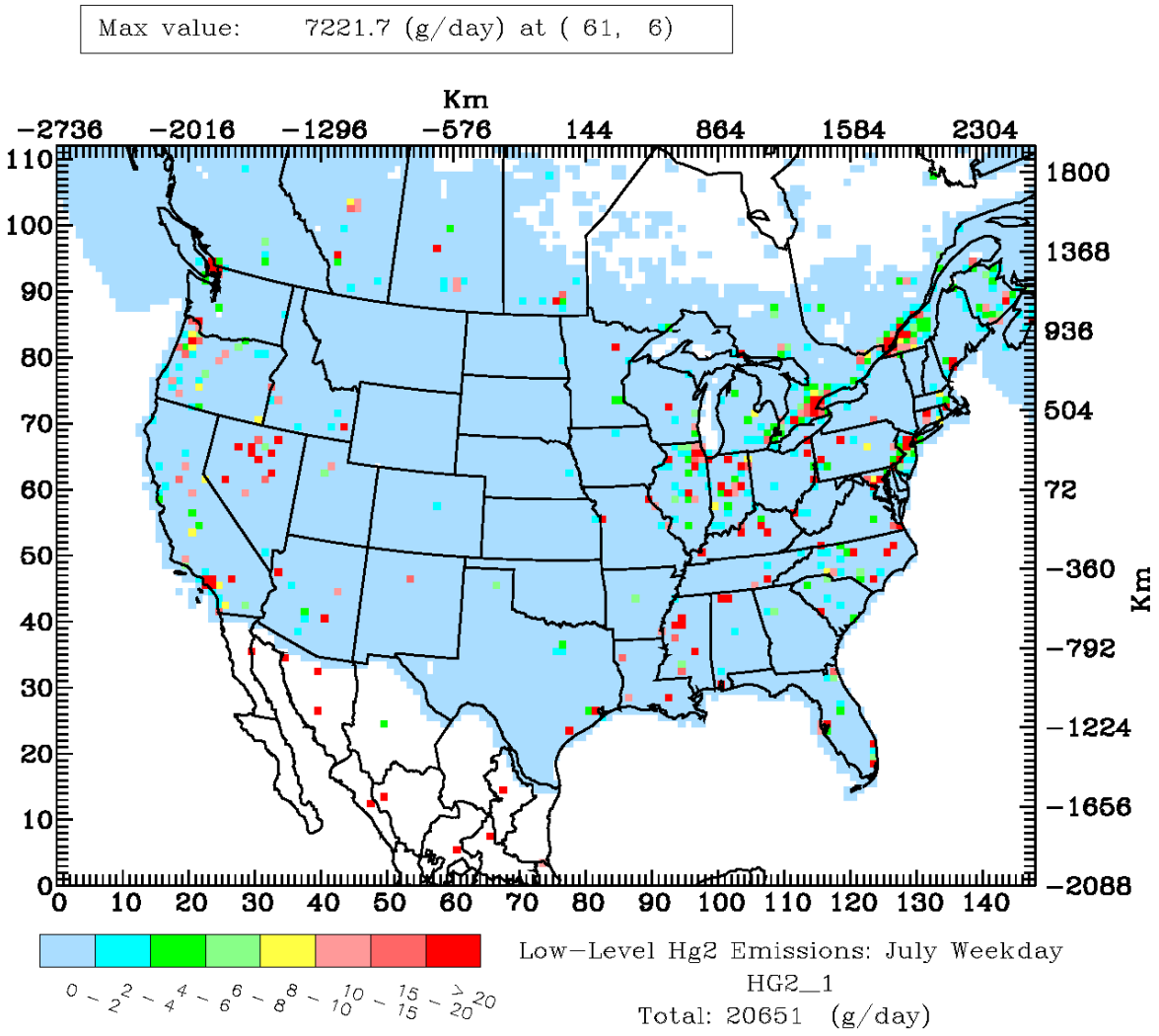


**Figure 4-3c. Spatial Distribution of Low-Level Mercury Emissions (tons) for the 2001 REMSAD Emissions Inventory for the 36-km Grid for a Summer Weekday: Particulate Mercury.**

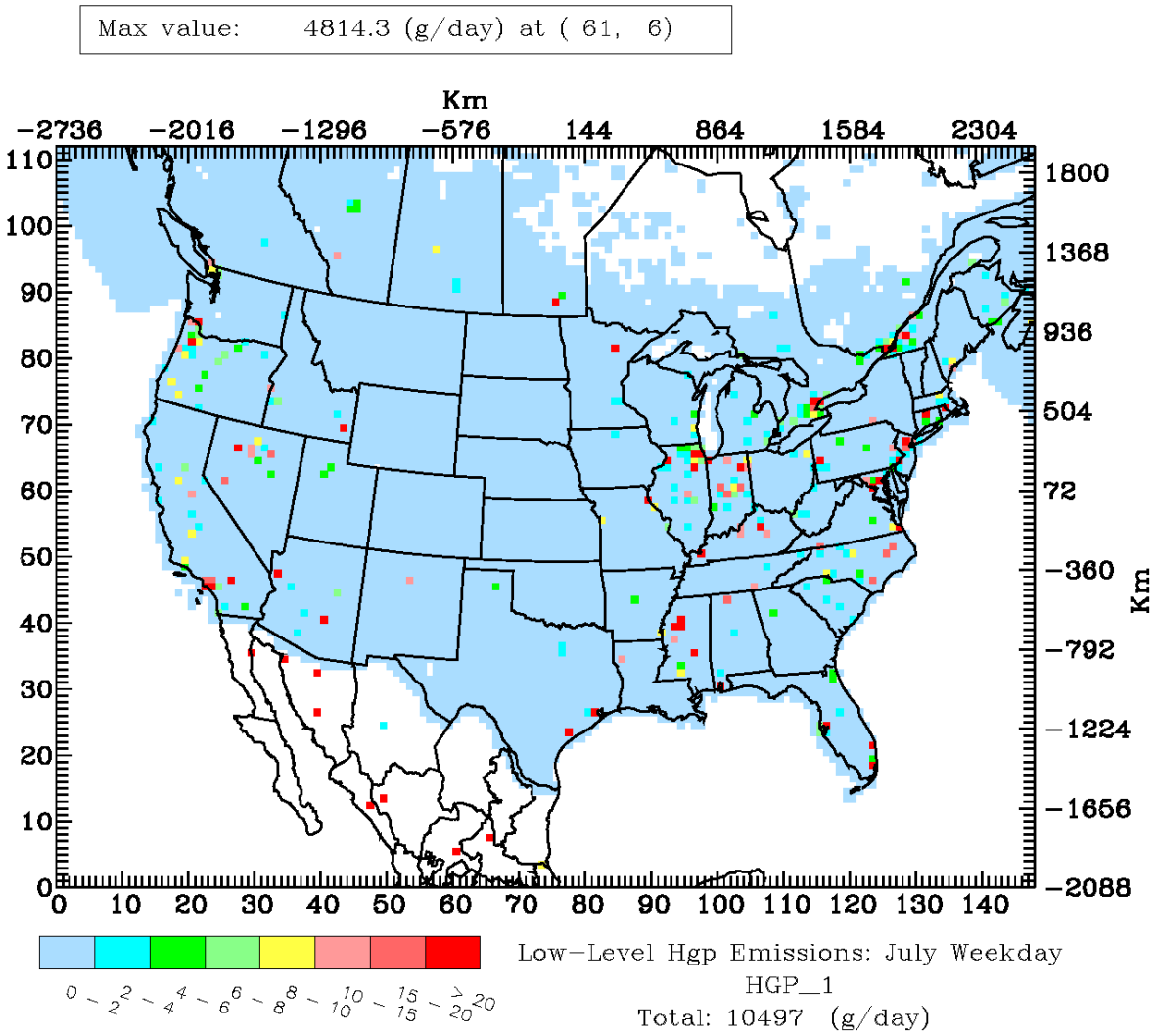


**Figure 4-3d. Spatial Distribution of Low-Level Mercury Emissions (tons) for the 2001 REMSAD Emissions Inventory for the 36-km Grid for a Summer Weekday: All Species.**

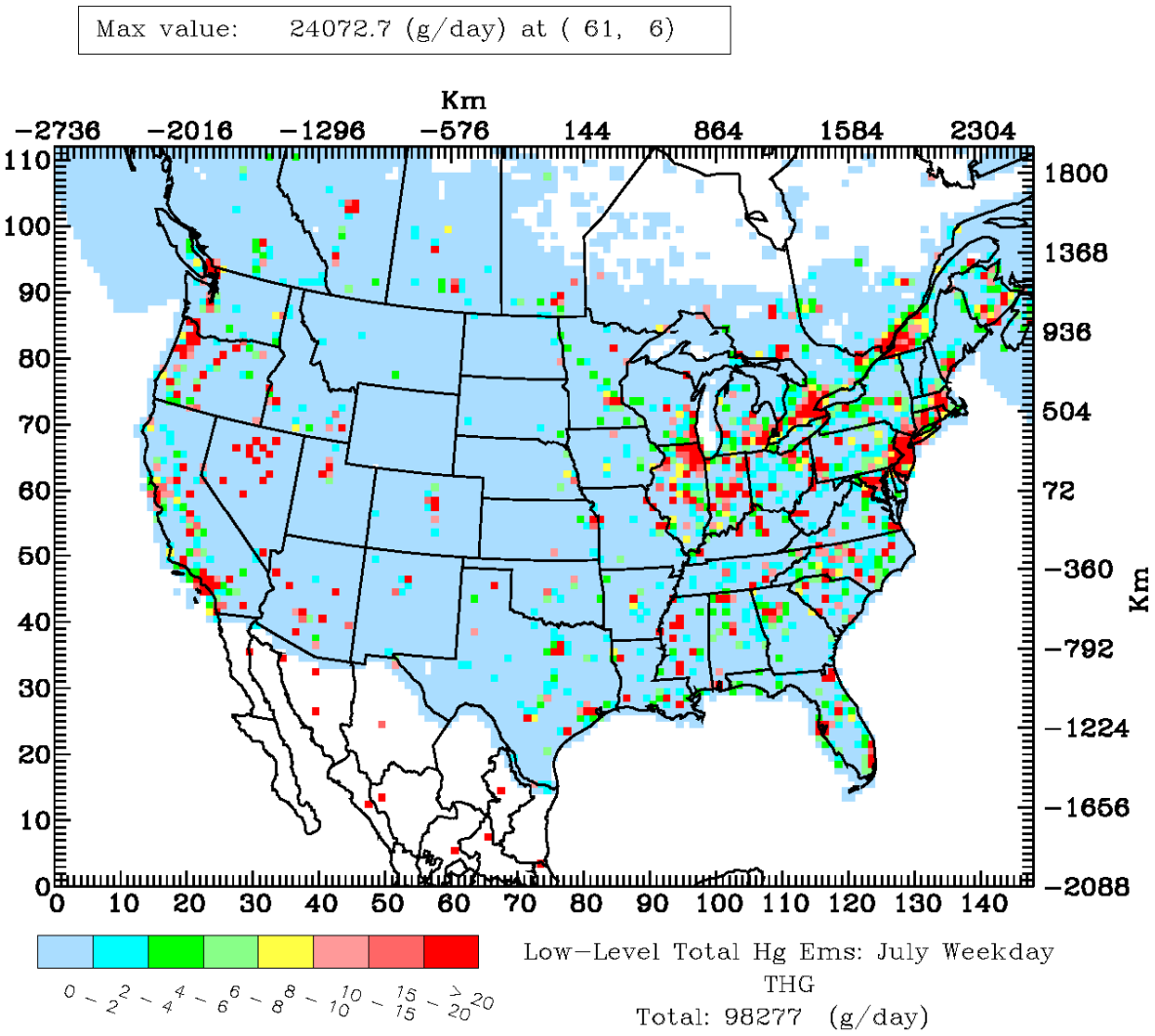


**Figure 4-4a. Spatial Distribution of Elevated Point-Source Mercury Emissions (tons) for the 2001 REMSAD Emissions Inventory for the 36-km Grid for a Summer Weekday: Elemental Mercury.**

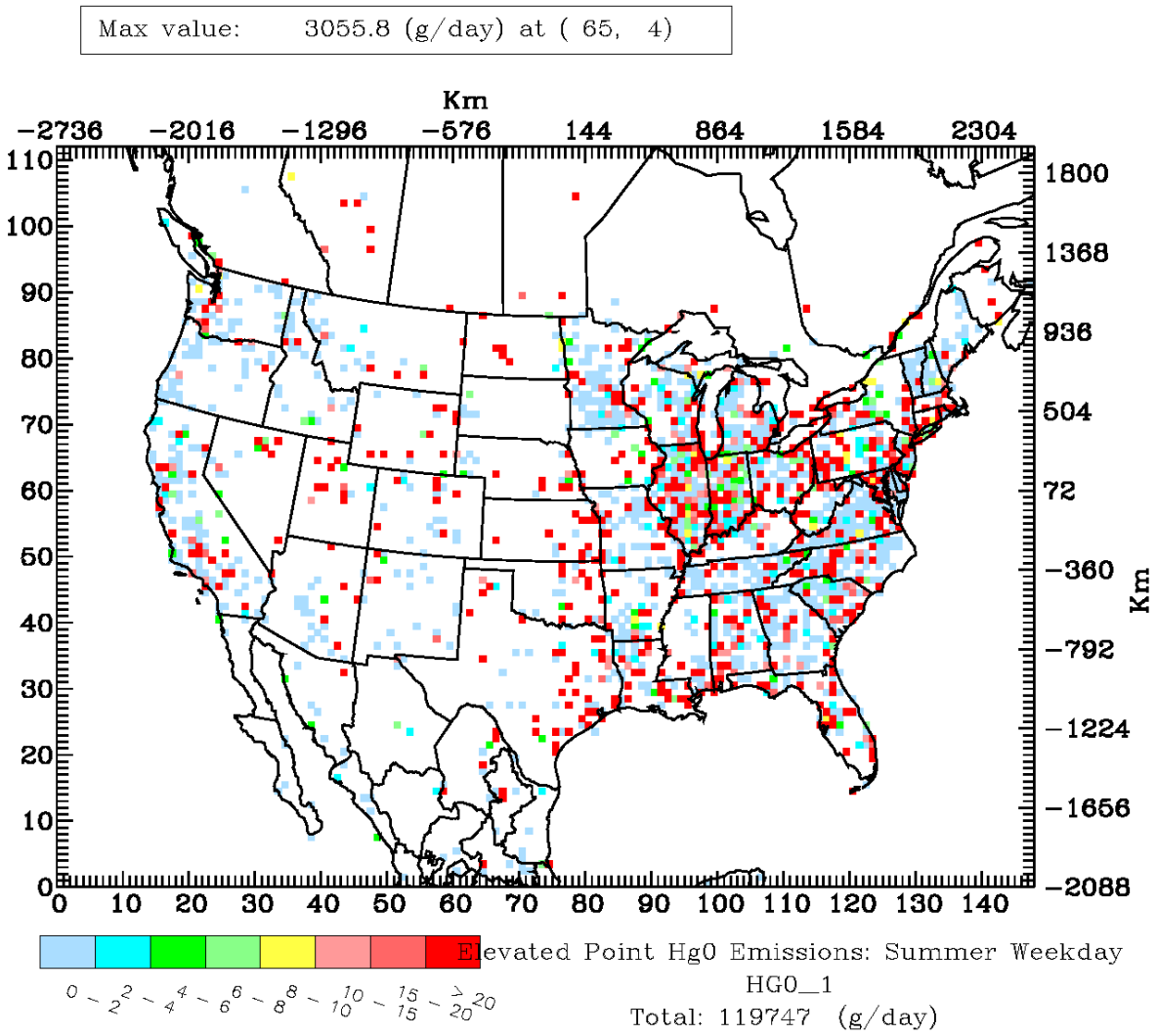


**Figure 4-4b. Spatial Distribution of Elevated Point-Source Mercury Emissions (tons) for the 2001 REMSAD Emissions Inventory for the 36-km Grid for a Summer Weekday: Divalent Gaseous Mercury.**

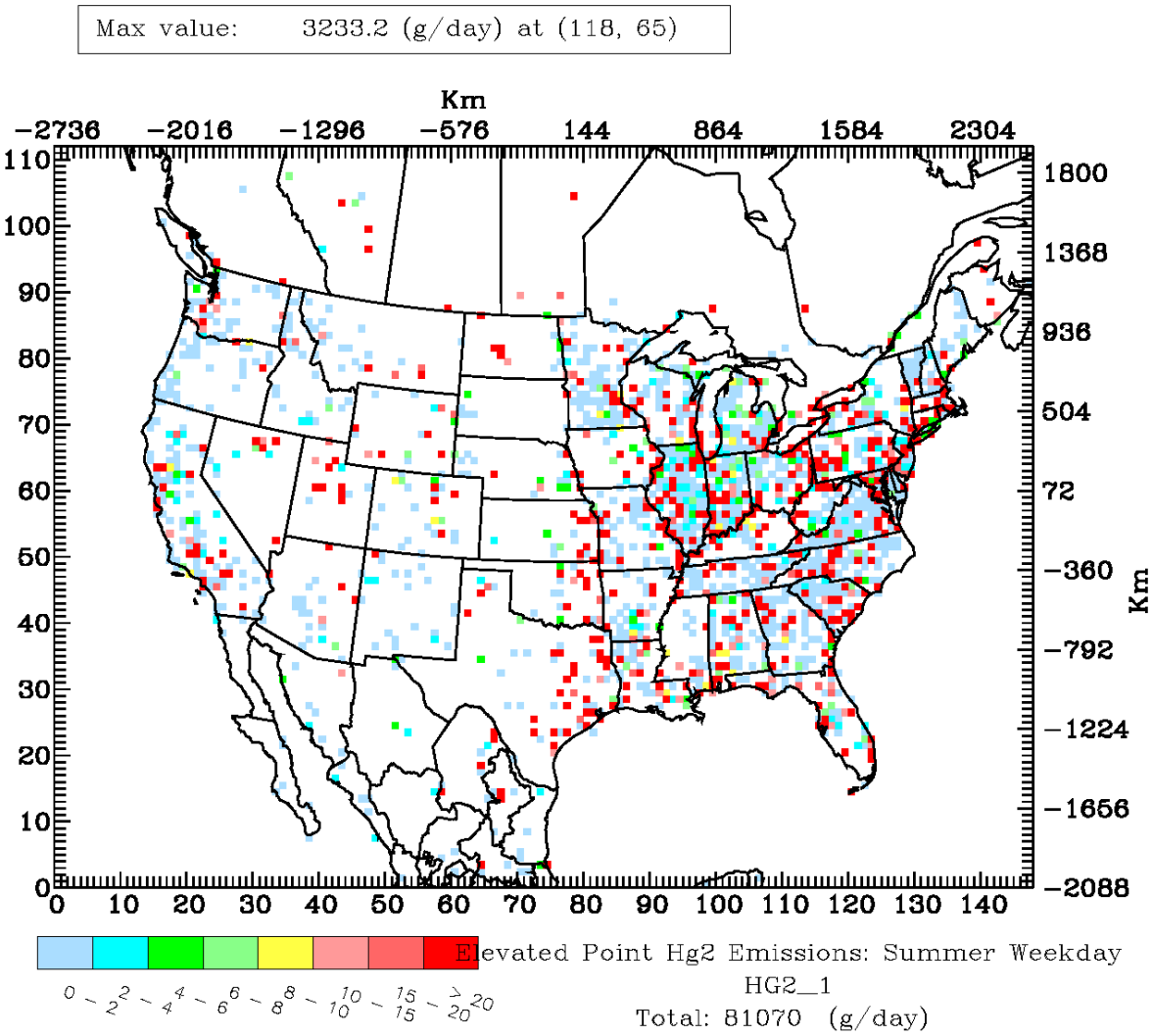


**Figure 4-4c. Spatial Distribution of Elevated Point-Source Mercury Emissions (tons) for the 2001 REMSAD Emissions Inventory for the 36-km Grid for a Summer Weekday: Particulate Mercury.**

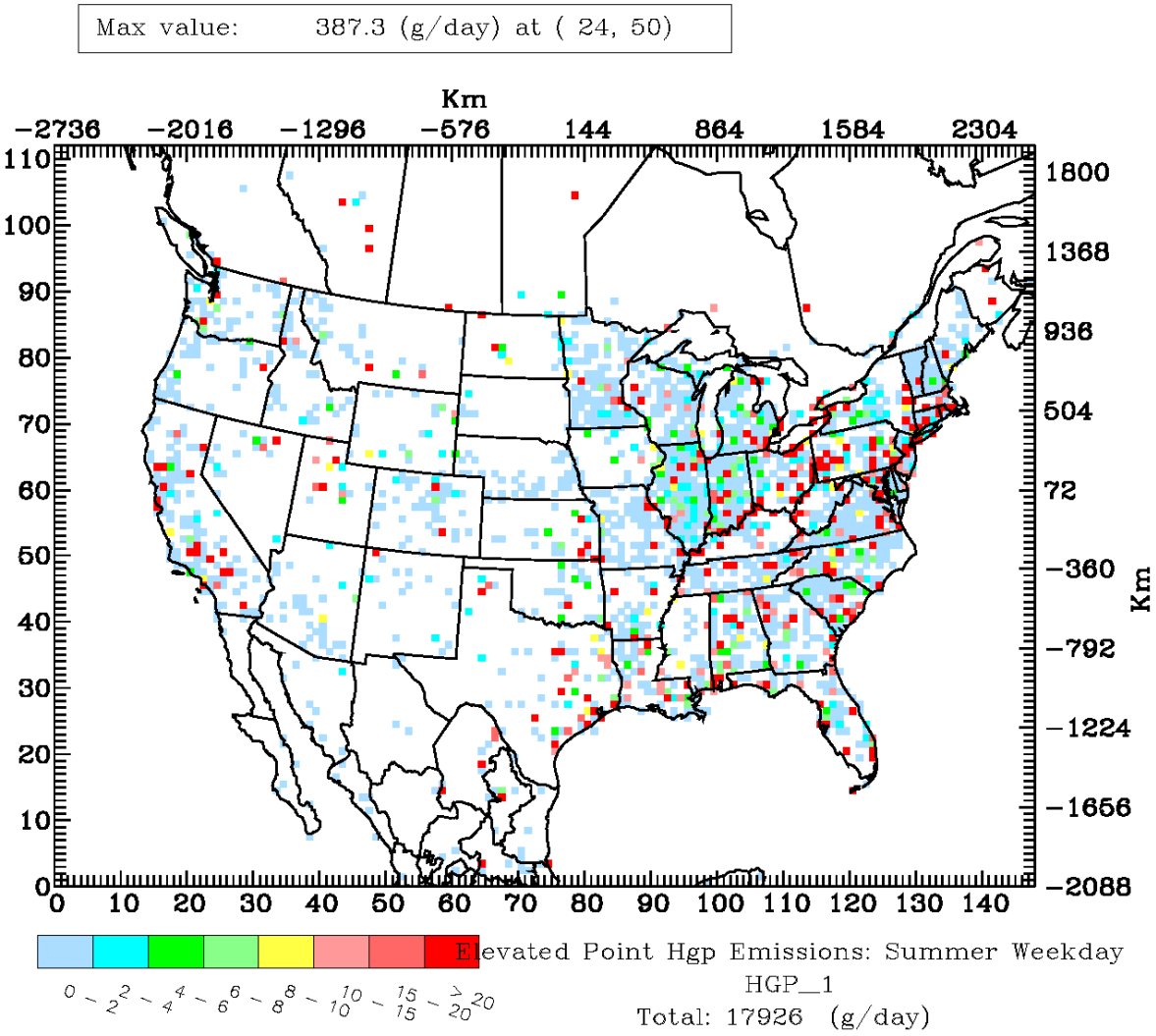
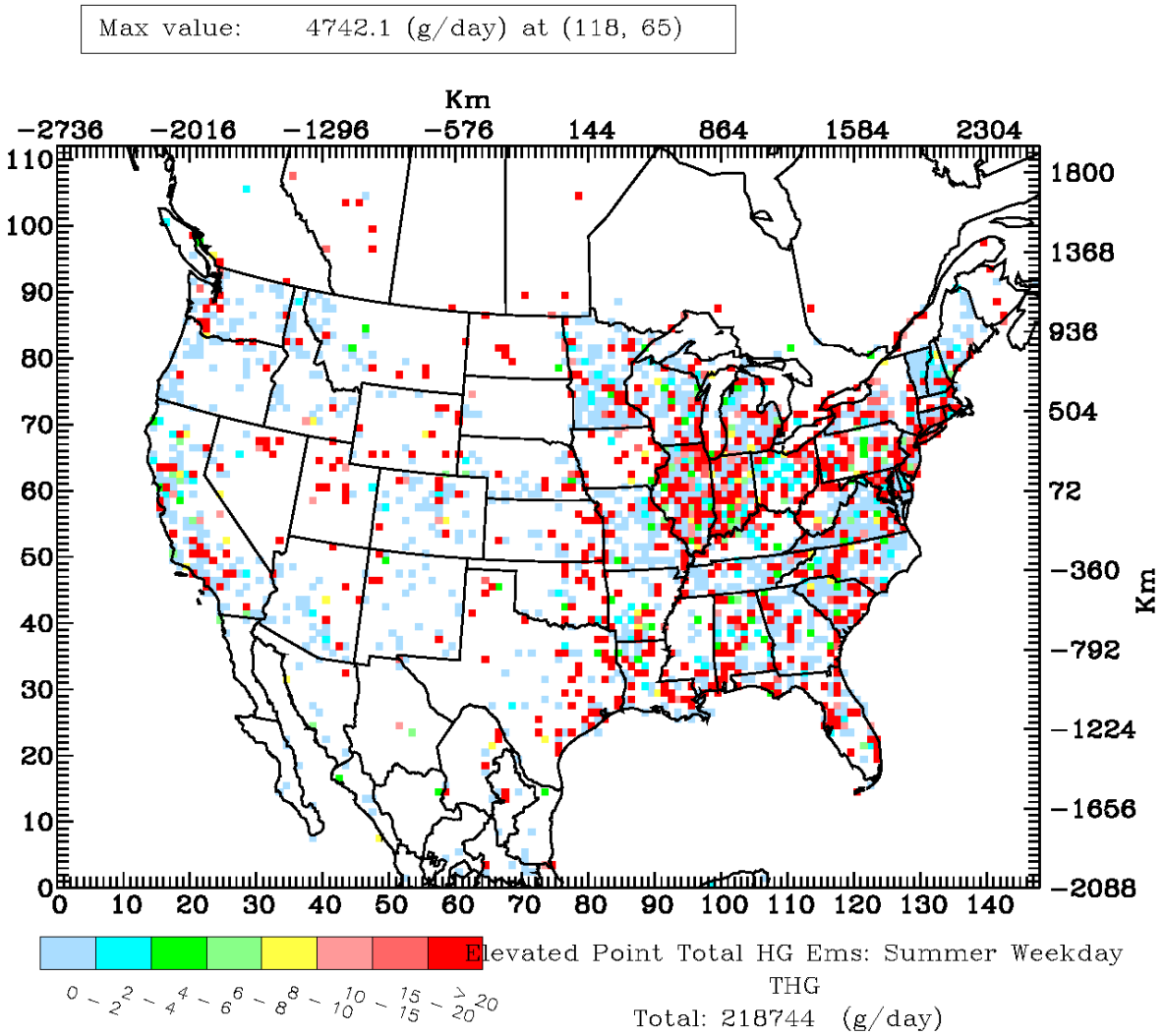


**Figure 4-4d. Spatial Distribution of Elevated Point-Source Mercury Emissions (tons) for the 2001 REMSAD Emissions Inventory for the 36-km Grid for a Summer Weekday: All Species.**



# 5. Initial and Boundary Condition Inputs

In this section, the preparation of the initial and boundary condition input files for the application of REMSAD is discussed. The same datasets and similar methods were used to prepare the initial and boundary conditions inputs for the CMAQ simulations conducted by EPA (that are referenced later in this report).
The initial conditions assign the species concentrations for each grid cell the initial simulation time. The boundary conditions define the concentrations along the lateral boundaries of the modeling domain for each hour of the simulation period. A default value of $1 \times 10^{-20}$ ppm is assigned to concentrations of all species at the top of the modeling domain.

## 5.1. Specification of Initial and Boundary Conditions for the PM Simulation

The initial and boundary conditions for the criteria pollutant simulation were based on those used by EPA for the CAIR modeling (EPA, 2005a). The initial and boundary conditions fields are derived from global modeling using the GEOS-CHEM model (Yantosca, 2004). The boundary concentration files vary in both space and time.

## 5.2. Specification of Initial and Boundary Conditions for the Mercury Simulations

It is expected that global background concentrations of mercury are high enough to influence the magnitude of mercury deposition within the U.S. The magnitude of global background concentrations is not, however, well known. In particular, the concentrations of the oxidized forms of mercury are very uncertain. Background concentrations of about 1.6 nanograms per cubic meter (ng $m^{-3}$) of elemental mercury have been used in past modeling exercises (Pai et al., 1999; Myers et al., 2003). These exercises have indicated that background mercury may make up more than 50 percent of the total airborne mercury in some areas, and support for this estimate can be found in experimental studies (e.g., Blanchard et al., 2002). Estimates of the fraction of oxidized mercury in total gaseous mercury range from a small fraction of a percent to as much as five percent. Given the potentially large influence of background mercury and the meager set of observations, other methods for setting boundary and initial concentrations have been sought.

During the North American Mercury Model Inter-comparison Study (NAMMIS) (Bullock et al., 2008), the results of several global simulation models were made available for the purpose of preparing boundary conditions for continental scale modeling. The results from three models, the Chemical Transport Model (CTM) (developed and applied by AER), the Global/Regional Atmospheric Heavy Metals model (GRAHM) (developed and applied by Environment Canada), and the GEOS-Chem model (developed and applied by researchers at Harvard University), were used to prepare three estimates of boundary concentrations of elemental mercury, divalent gas mercury, and particulate mercury. All three global models utilized a year 2000 global emissions inventory. Resolution varied among the global models: 2 by 2.5 degrees for GEOS-CHEM, 5 by 5 degrees for GRAHM, and 8 by 10 degrees for CTM. Formulations of the models differ in the specific chemical reactions included for mercury species and in other details, as reported by Bullock et al. (2008). Further discussion of the global model estimates of boundary concentrations is included in Section 6.

For the current modeling, three baseline simulations were prepared, one using each of the global model derived boundary concentrations. The files were prepared as monthly average

files and the simulated horizontal and vertical variation in the concentrations was retained in the files. Each of the three versions of boundary concentrations was simulated as a separate tag to allow analysis of differences in results due to variations in the boundary concentrations. This will be discussed further in the section on the results of the tagging simulations.

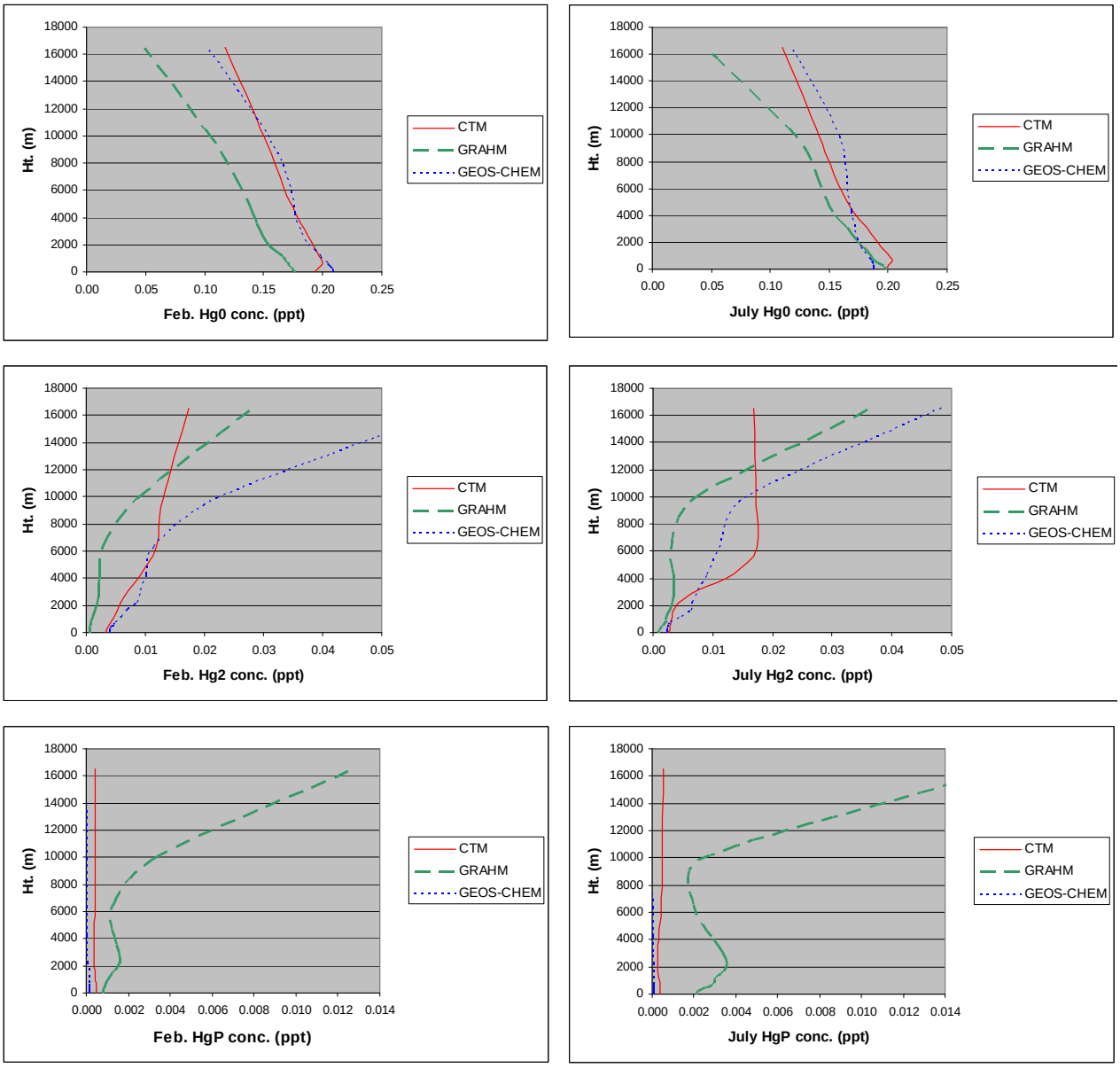
Three sets of initial concentrations were also prepared (one for each global model) based on an average of the simulated boundary concentrations for January. The initial conditions do not vary horizontally, but the vertical variation from the boundary files was retained. Since the simulation is initialized ten days prior to the beginning of the analysis period (January 1, 2001), the initial concentrations are not expected to have a large influence on the results.

A summary and comparison of the boundary concentrations derived from the three global models is presented in Figure 5-1. The concentrations depicted in the plots represent the average around the perimeter of the outermost REMSAD domain (see Figure 1-1), for the species HG0 (elemental mercury), HG2 (divalent gas mercury), and HGP (particulate mercury). The boundary conditions are compared for February and July in order to examine the temporal variation of concentrations. The units are parts per trillion (ppt). At standard temperature and pressure conditions (STP), 0.2 ppt is approximately 1.8 ng $m^{-3}$ of mercury.

Although these charts do not show all of the variation present in the boundary concentrations (e.g., the horizontal variation is not depicted), the variation with height and differences among the models are apparent. The order of magnitude is similar among the global models for HG0 and HG2, although the GRAHM model has lower concentrations of these species than the other two models. HGP concentrations are low for the CTM and GEOS-CHEM models, but the GRAHM model has a considerable amount of divalent mercury as particulate. The vertical profiles of concentrations are rather different among the models for HG2 and HGP.

The differences in boundary concentrations derived from the three models can lead to some differences in the simulation results for mercury, as will be discussed later in the section on tagging results.

**Figure 5-1. Comparison of CTM, GRAHM, and GEOS-CHEM Derived Boundary Concentrations (ppt) for the REMSAD Modeling Domain for HGO, HG2, and HGP: February and July 2001.**



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# 6. REMSAD Base Simulation Results

In this section, the ability of the REMSAD modeling system to replicate the observed deposition characteristics of mercury is examined, on a seasonal and annual basis. Model performance for ozone, sulfur dioxide ($SO_2$) and fine particulate matter ($PM_{2.5}$) is presented in Appendix A.

Model performance for mercury is evaluated for total wet deposition of mercury against the monitors in the Mercury Deposition Network (MDN) available from the National Acid Deposition Program (NADP). There are a total of 98 MDN monitors in the modeling domain. It should be noted that some emerging research suggests that the MDN measurement techniques may underestimate wet deposition by about 16 percent (Miller et al., 2005). Nevertheless, the evaluations below use the MDN observations without any adjustment.

Simulated values in this comparison include the contribution from re-emitted mercury, using the method discussed in Section 2 of this report. Three alternate sets of boundary conditions were used, CTM, GRAHM, and GEOS-CHEM, as discussed in Section 5. Model performance for mercury is evaluated for each set of boundary conditions.

The following metrics and statistical measures were used to quantify model performance:

Mean observed deposition = $1/N \sum O_I$
Mean simulated deposition = $1/N \sum S_I$
Mean residual = $1/N \sum (S_I - O_I)$
Normalized bias (expressed as percent) = $100 \cdot 1/N \sum (S_I - O_I)/ O_I$
Normalized gross error (expressed as percent) = $100 \cdot 1/N \sum |S_I - O_I|/ O_I$

Where S is the simulated concentration, O is the observed concentration, and N is the number simulation-observation pairs used in the calculation.

In preparing the statistics and scatter plots, simulated and observed wet deposition were compared for 1) each site and 2) the average over all sites. All results are for 12-km resolution.

Table 6-1 summarizes seasonal and annual model performance, considering all MDN sites within the modeling domain. Here, winter is defined as January, February and December, spring is March, April, and May, and so forth. Results for the three sets of boundary conditions are presented separately.

**Table 6-1a. REMSAD Model Performance Statistics for Mercury Wet Deposition (g km$^{-2}$) for the 12-km Resolution Grid at MDN Sites: CTM Boundary Conditions.**

| Period | Mean Observed (g km$^{-2}$) | Mean Simulated (g km$^{-2}$) | Mean residual (g km$^{-2}$) | Normalized bias (%) | Normalized gross error (%) |
|---|---|---|---|---|---|
| Winter | 1.30 | 1.65 | 0.35 | 29.6 | 74.6 |
| Spring | 2.31 | 3.52 | 1.21 | 70.3 | 92.8 |
| Summer | 3.66 | 6.32 | 2.66 | 91.2 | 96.7 |
| Autumn | 1.89 | 3.37 | 1.48 | 121.9 | 129.2 |
| Annual | 9.26 | 14.84 | 5.58 | 59.7 | 65.8 |

**Table 6-1b. REMSAD Model Performance Statistics for Mercury Wet Deposition (g km$^{-2}$) for the 12-km Resolution Grid at MDN Sites: GRAHM Boundary Conditions.**

| Period | Mean Observed (g km$^{-2}$) | Mean Simulated (g km$^{-2}$) | Mean residual (g km-2) | Normalized bias (%) | Normalized gross error (%) |
|---|---|---|---|---|---|
| Winter | 1.30 | 1.55 | 0.25 | 25.0 | 69.8 |
| Spring | 2.31 | 3.05 | 0.74 | 46.3 | 78.5 |
| Summer | 3.66 | 5.74 | 2.08 | 72.7 | 81.1 |
| Autumn | 1.89 | 3.25 | 1.35 | 115.6 | 123.6 |
| Annual | 9.26 | 13.55 | 4.29 | 45.7 | 55.3 |

**Table 6-1c. REMSAD Model Performance Statistics for Mercury Wet Deposition (g km$^{-2}$) for the 12-km Resolution Grid at MDN Sites: GEOS-CHEM Boundary Conditions.**

| Period | Mean Observed (g km$^{-2}$) | Mean Simulated (g km$^{-2}$) | Mean residual (g km$^{-2}$) | Normalized bias (%) | Normalized gross error (%) |
|---|---|---|---|---|---|
| Winter | 1.30 | 2.01 | 0.72 | 58.7 | 94.7 |
| Spring | 2.31 | 4.09 | 1.79 | 97.4 | 116.7 |
| Summer | 3.66 | 6.51 | 2.85 | 98.2 | 103.3 |
| Autumn | 1.89 | 3.60 | 1.70 | 139.6 | 145.8 |
| Annual | 9.26 | 16.20 | 6.94 | 73.8 | 78.7 |

The statistical measures of model performance indicate that the REMSAD simulations tend to overestimate the observed mercury deposition values using each of the three sets of boundary conditions, on an annual and seasonal basis. Performance tends to degrade throughout the year, perhaps due to a build up of excess mercury over time. The simulated values derived using the GRAHM boundary conditions are consistently better matched with the observed values. In interpreting the evaluations against the MDN monitoring data, it should be kept in mind that some emerging research suggests that the MDN measurement techniques may underestimate wet deposition by about 16 percent (Miller et al., 2005).

Scatter plots showing the REMSAD simulated total annual wet deposition of mercury versus the observed values at the MDN sites are presented in Figure 6-1. For all three sets of boundary conditions, there is some positive bias in the simulation results, and there is some scatter about the 1:1 line, primarily for the lower range of values. The $R^2$ correlation values are similar and on the order of 0.75 for all three sets of boundary conditions. As indicated by the plots and the statistics, the GEOS-CHEM boundary conditions result in the greatest amount of overestimation of mercury deposition. The GRAHM boundary conditions give the best overall model performance.

**Figure 6-1a. Annual Simulated versus Observed Mercury Wet Deposition (g km$^{-2}$) for the REMSAD 12-km Grid at MDN Sites: CTM Boundary Conditions.**

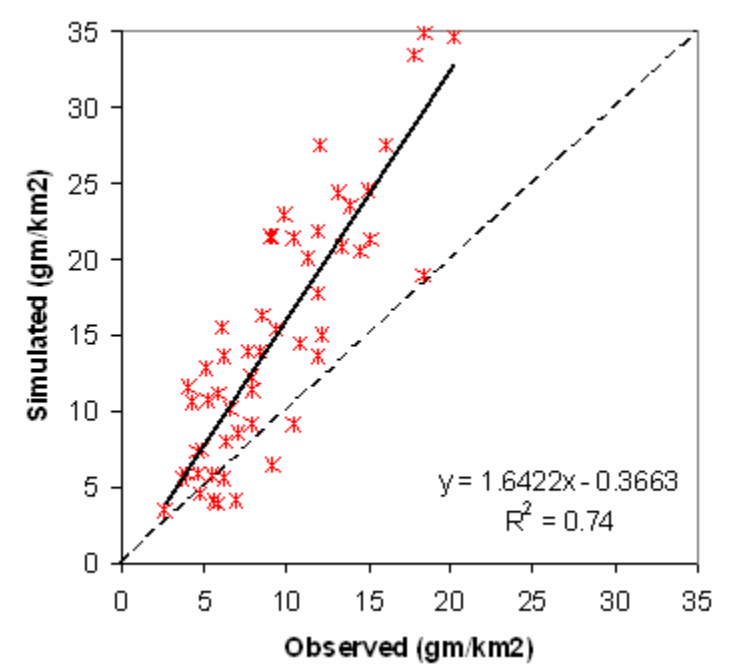



**Figure 6-1b. Annual Simulated versus Observed Mercury Wet Deposition (g km$^{-2}$) for the REMSAD 12-km Grid at MDN Sites: GRAHM Boundary Conditions.**

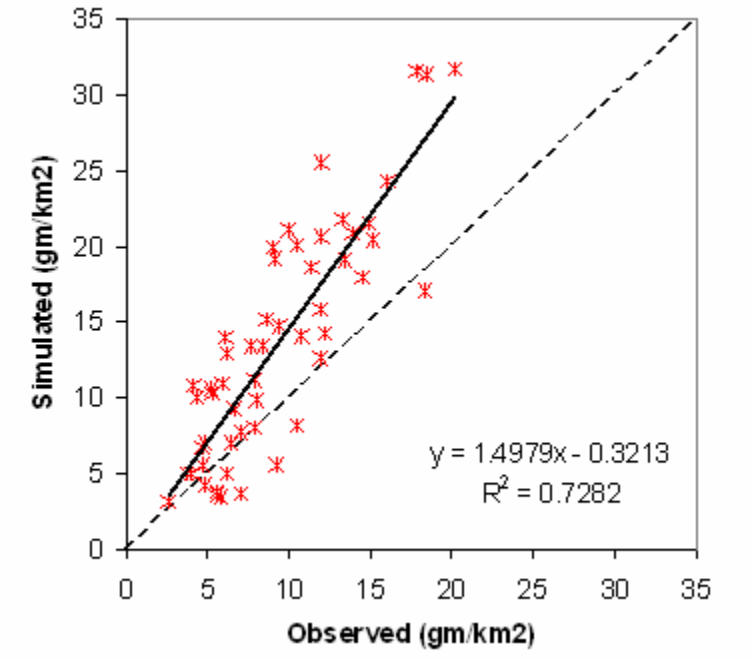
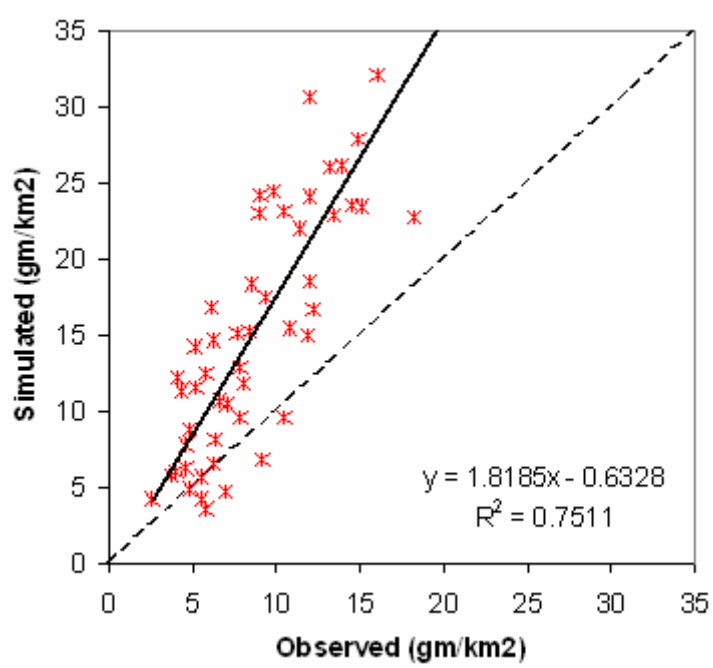


**Figure 6-1c. Annual Simulated versus Observed Mercury Wet Deposition (g $km^{-2}$) for the REMSAD 12-km Grid at MDN Sites: GEOS-CHEM Boundary Conditions.**




Spatial distribution plots of the REMSAD simulated mercury concentrations are provided for the annual simulation period and for the region covered by the 12-km grids in Figure 6-2. The patterns are similar for all three sets of boundary conditions and the plot gives the results with the average of the three sets of boundary conditions. The plots show annual average concentrations for elemental, divalent, and particulate mercury, respectively. Divalent mercury concentrations are the highest of the three species, especially over portions of the mid-Atlantic states and California. This spatial distribution is consistent with the emissions and annual transport patterns.

**Figure 6-2a. Annual Average Simulated Mercury Concentration (ng $m^{-3}$) for the REMSAD 12-km Modeling Domain (with Average Boundary Conditions): Elemental Mercury (HG0).**

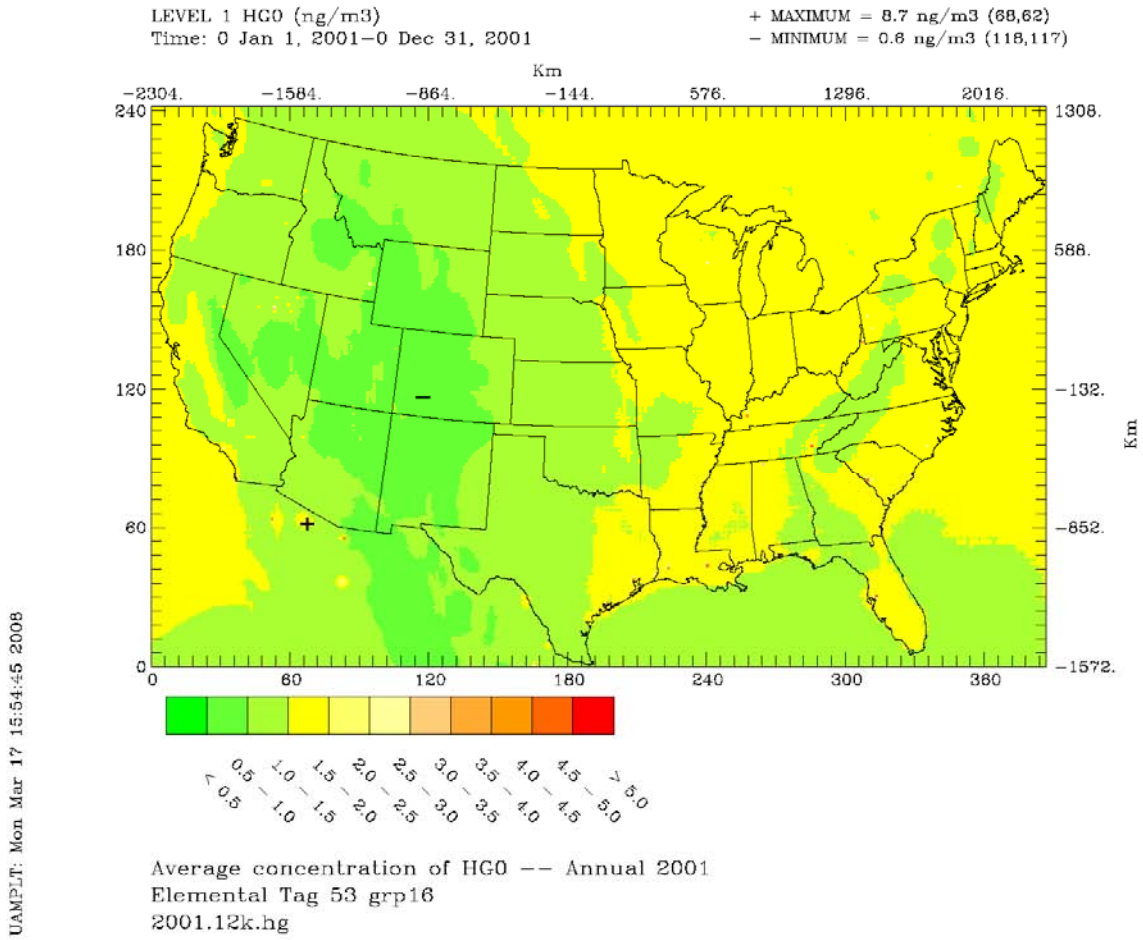


**Figure 6-2b. Annual Average Simulated Mercury Concentration (ng $m^{-3}$) for the REMSAD 12-km Modeling Domain (with Average Boundary Conditions): Divalent Mercury (HG2).**

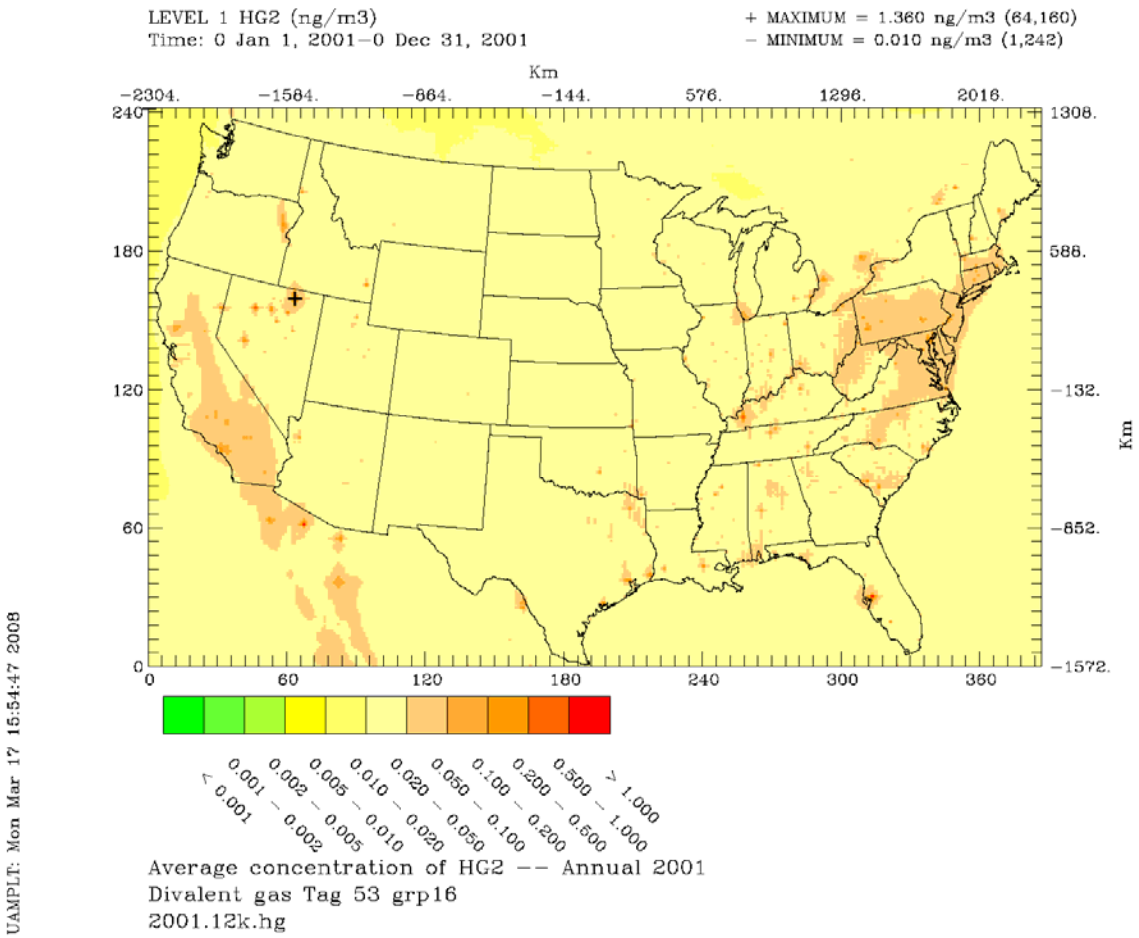
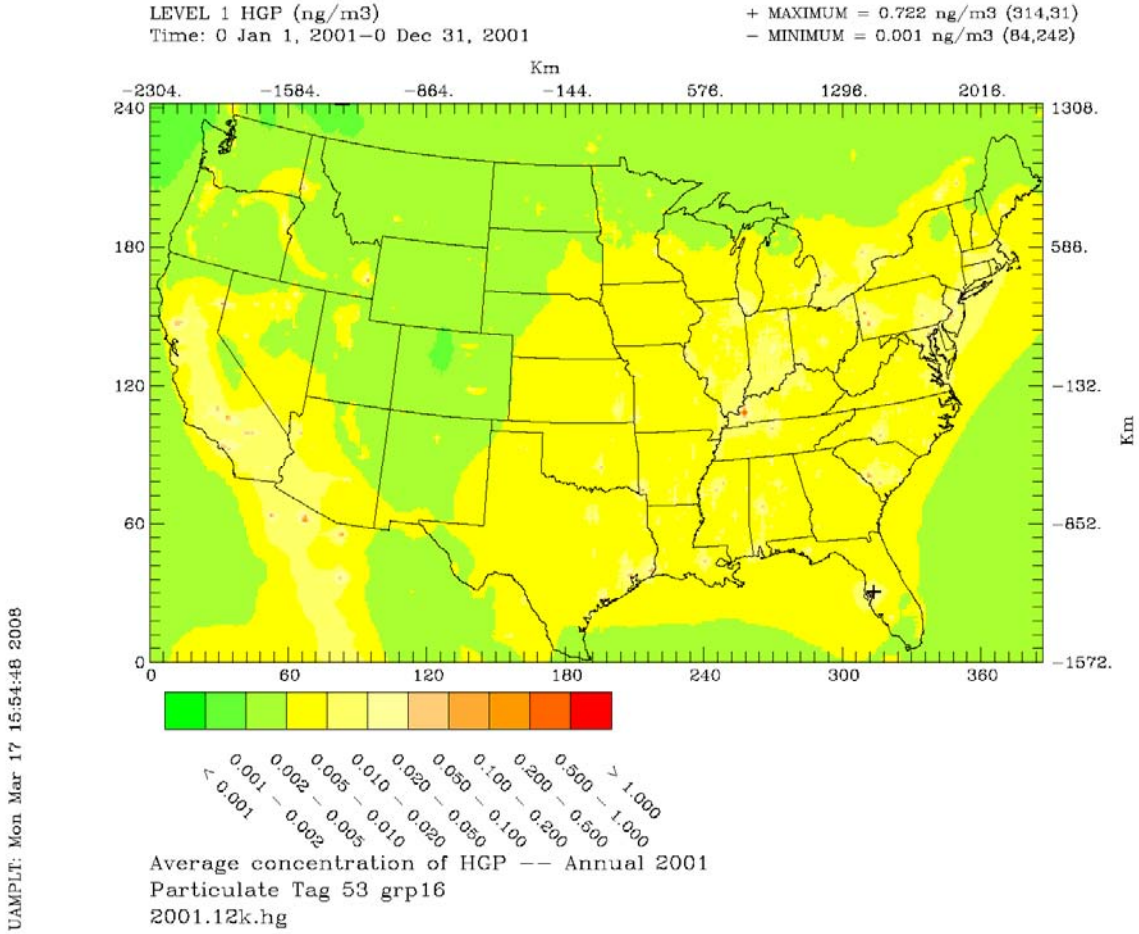


**Figure 6-2c. Annual Average Simulated Mercury Concentration (ng $m^{-3}$) for the REMSAD 12-km Modeling Domain (with Average Boundary Conditions): Particulate Mercury (HGP).**




Spatial distribution plots of the REMSAD simulated total mercury deposition are provided for the annual simulation period and for the region covered by the 12-km grids in Figure 6-3. Again, the display incorporates the average boundary conditions. The plots show annual average concentrations for dry, wet, and total deposition, respectively. Clearly wet deposition accounts for much of the deposition that occurs throughout the domain. This spatial distribution is consistent with the emissions and annual transport and rainfall patterns. These displays emphasize the importance of rainfall in determining mercury deposition patterns.

**Figure 6-3a. Simulated Annual Mercury Deposition (g km$^{-2}$) for the REMSAD 12-km Modeling Domain (with Average Boundary Conditions): Dry Deposition.**

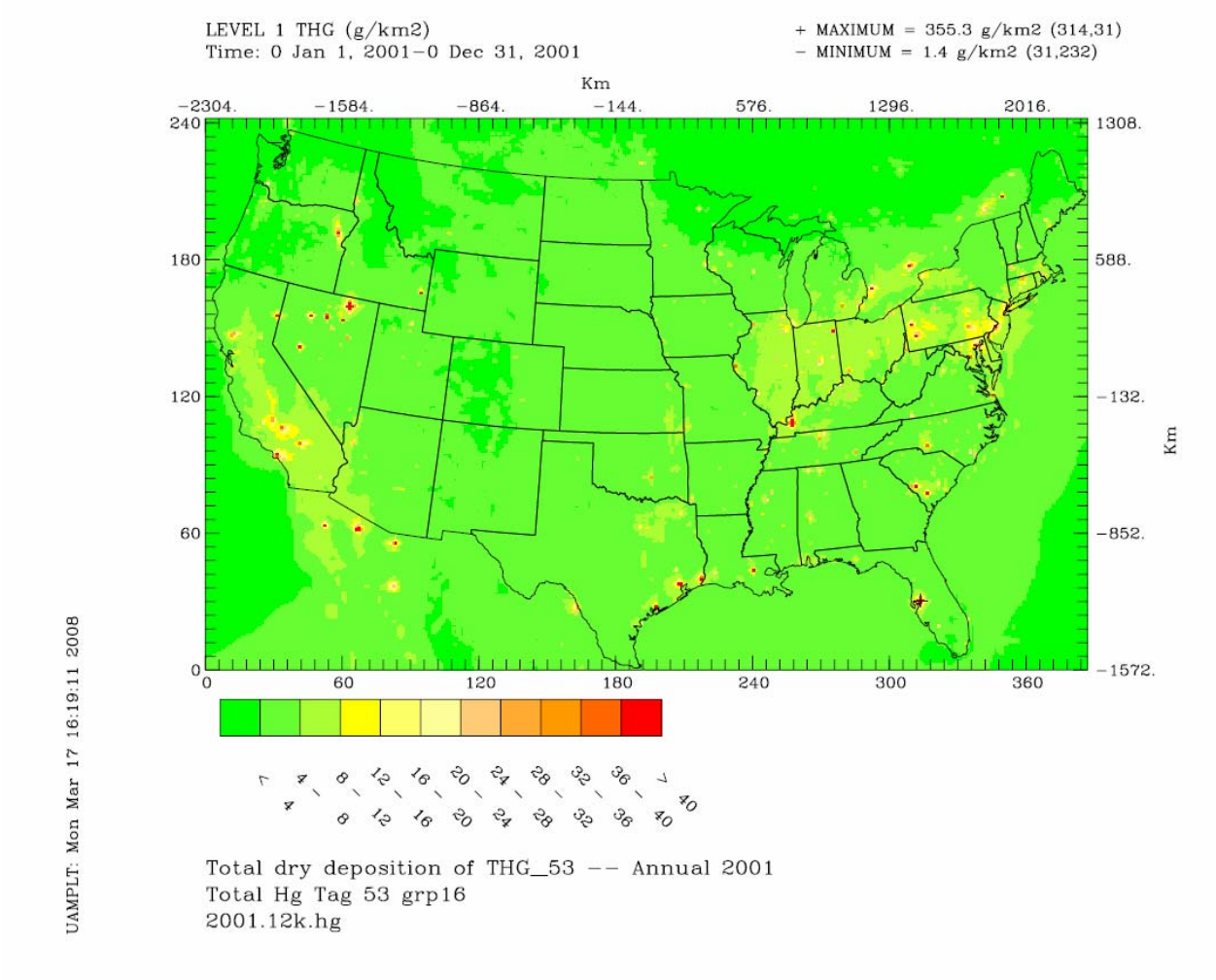


**Figure 6-3b. Simulated Annual Mercury Deposition (g km$^{-2}$) for the REMSAD 12-km Modeling Domain (with Average Boundary Conditions): Wet Deposition.**

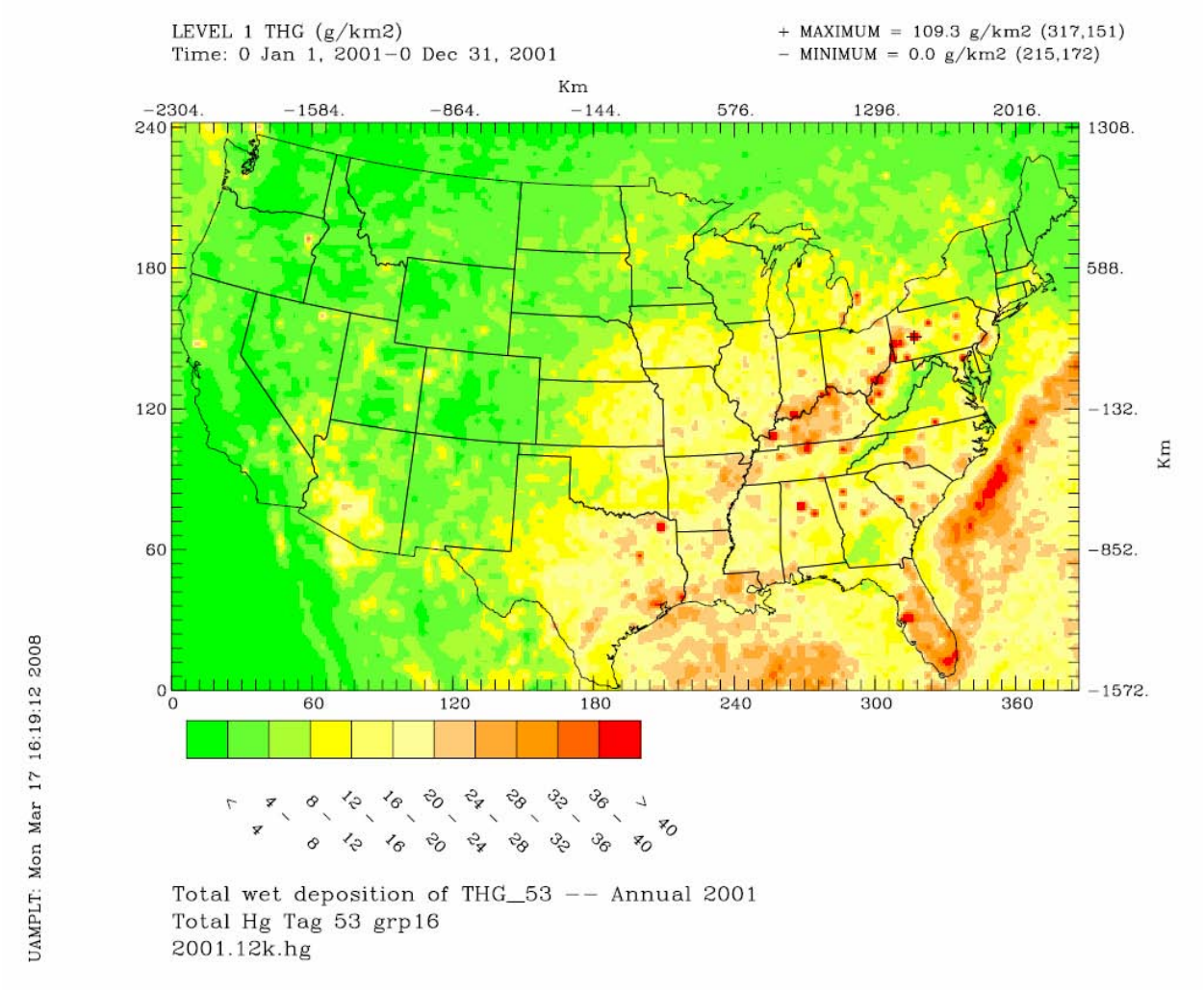
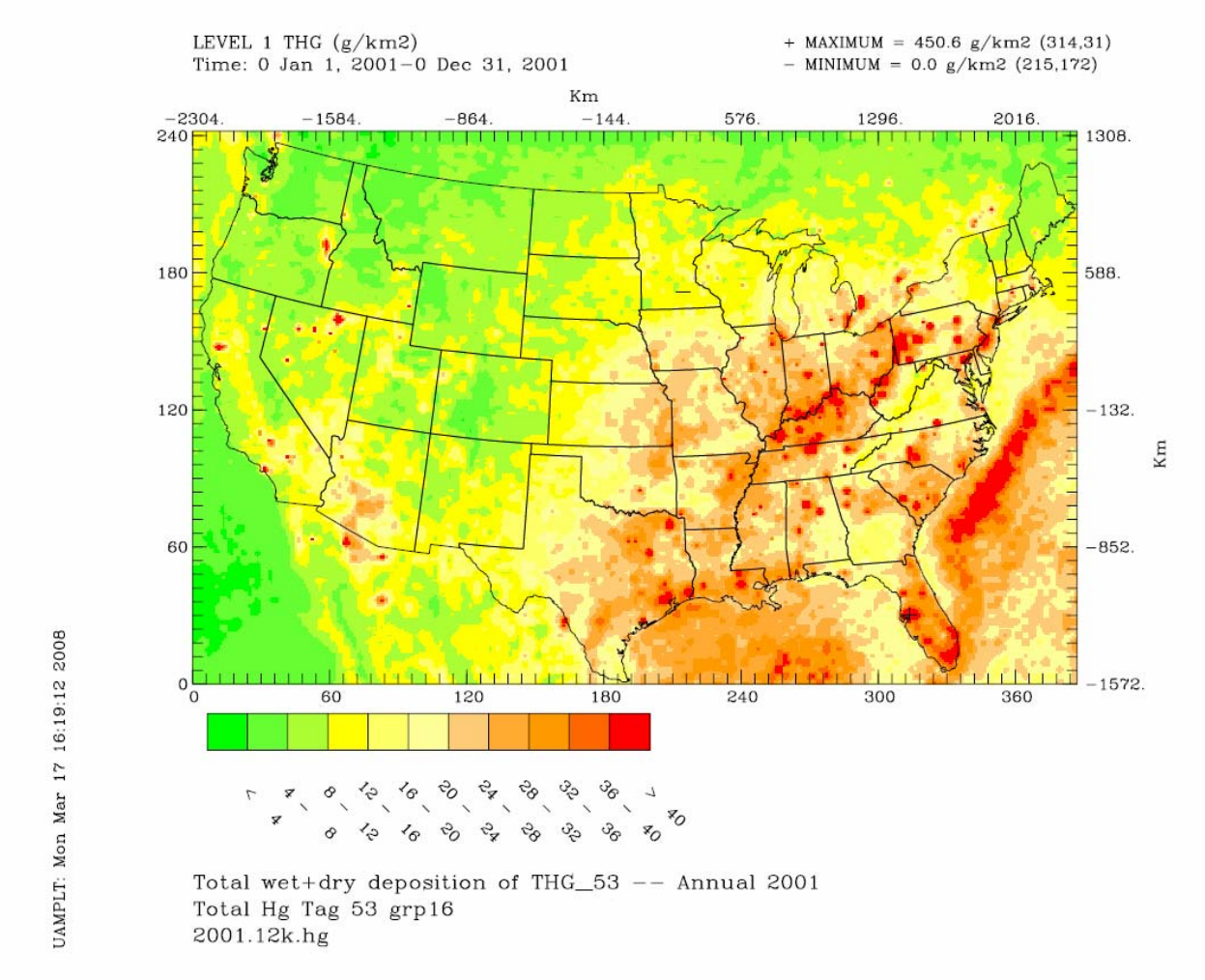


**Figure 6-3c. Simulated Annual Mercury Deposition (g km$^{-2}$) for the REMSAD 12-km Modeling Domain (with Average Boundary Conditions): Total (Dry + Wet) Deposition.**




CMAQ model performance for wet mercury deposition for this same simulation period was assessed by Bullock et al. (2008) as part of the NAMMIS study. Overall, Bullock found CMAQ performance to be comparable to that for REMSAD, with some statistical measures better for CMAQ, when both models were applied with 36-km horizontal resolution. A key finding of the NAMMIS study related to model performance is that performance for both the CMAQ and REMSAD models is influenced by the specification of boundary conditions, but the differences in model performance among the three sets of boundary conditions is different for the two models. CMAQ shows better agreement with observed wet deposition data with the CTM-derived boundary conditions and REMSAD performance is better with the GRAHM-derived boundary conditions. Another key finding of the NAMMIS study is that model performance is limited by the ability of the meteorological inputs to accurately represent the location and amount of precipitation.

Researchers involved in the NAMMIS study also concluded that each global model was based upon sound science, and, absent a much more extensive monitoring network that includes dry deposition measurements, it is not now possible to conclude which global model performs the best. It is for these reason that it was chosen to present results from all three global models, driving both REMSAD and CMAQ (see Section 7), so that the reader can more thoroughly understand the likely range of background contributions.

# 7. REMSAD PPTM Results: Mercury Deposition Contribution Analysis

The results of the REMSAD mercury tagging simulations are presented in this section, beginning with an overview of the application procedures. The tagging results are then summarized for selected locations, and examine the contributions in relation to a source receptor study.

For ease of reading, all figures follow the text of this section.

## 7.1. PPTM Application Procedures

The entire modeling analysis included 18 annual REMSAD simulations, and each simulation included approximately 15 to 20 tags (for a total of approximately 300 tagged sources). The tags were defined on a state by state basis. As noted in Section 4, summaries of the mercury emissions inventory for each state were provided to the EPA regional offices and to each state to facilitate their review of emissions. These same summaries were used to identify candidate sources for mercury tagging. The summaries listed and ranked the top five divalent gas mercury emitters and the top five total mercury emitters (excluding those already in the divalent gas ranking). The rankings were made on a facility basis, not on an individual stack basis, to avoid using multiple tags for a single facility.

Nominally, five tags were to be defined for each state. Four of these tags were to be assigned to individual sources or source categories, and the fifth tag was reserved to collectively tag all remaining sources. Since approximately 300 tags were to be simulated, this would leave about 50 additional tags that could be used for a more detailed breakdown of the source contributions for selected states and/or source categories. These 50 tags were assigned based on recommendations from EPA Regional and state personnel.

The general procedure was to assign the first three tags to the top three emitters of divalent gaseous mercury. Then the top total mercury emitter not already tagged was assigned the fourth tag. On occasion, there was deviation from this approach due to wide disparities in magnitude of emissions or other extraordinary circumstances. In a few cases, states with very low mercury emissions were assigned fewer than five tags. States with multiple large sources and thus a greater need for detail in the emissions breakdown were assigned more than five tags. Because of the magnitude of the emissions and in order to allow an analysis of the importance of speciation, three tags were assigned to individual species emitted from a goldmine in Nevada.

The states and EPA regional offices were informed of this general procedure when asked for their input. Some states and regional offices made specific requests for tags and recommendations for changes in the assignment. Where possible, these requests were accommodated.

The tags used for the application of PPTM are listed and summarized in Table 7-1.

## Table 7-1. Tags used for the REMSAD PPTM Application for Mercury for the Annual 2001 Simulation Period.

- *Tags are Ordered by Region Number, State, and Emissions Totals for Elemental (HG0), Divalent Gaseous (HG2), and Particulate (HGP) Mercury Emissions.*

| | | | Mercury Emissions (tpy) | | |
|---|---|---|---|---|---|
| **Region/State** | **Source Name/ Description** | **Source Type** | **HGO** | **HG2** | **HGP** |
| *Region 1* | | | | | |
| Connecticut | Bridgeport RES CO | Incineration | 0.018 | 0.049 | 0.017 |
| | Mattabassett Reg. Sewage | Incineration | 0.008 | 0.021 | 0.007 |
| | Mid-CT Project (CRRA) | Incineration | 0.010 | 0.027 | 0.009 |
| | Naugatuck Treatment Co. | Incineration | 0.006 | 0.017 | 0.006 |
| | Southeastern CTt RRF | Incineration | 0.010 | 0.027 | 0.009 |
| | Collective Sources (remaining sources in state) | | 0.146 | 0.061 | 0.035 |
| Maine | Dragon Products Co. | Miscellaneous industrial processes | 0.013 | 0.002 | 0.002 |
| | Greater Portland Region RRF | Incineration | 0.003 | 0.008 | 0.003 |
| | Mid Maine Waste Action Corp. | Incineration | 0.015 | 0.039 | 0.013 |
| | Penobscot Energy Recovery | Incineration | 0.001 | 0.002 | 0.001 |
| | Collective Sources (remaining sources in state) | | 0.215 | 0.053 | 0.019 |
| Massachusetts | Brayton Point | Coal fired utility | 0.031 | 0.083 | 0.007 |
| | Pittsfield RRF | Incineration | 0.045 | 0.119 | 0.041 |
| | SE Mass RRF | Incineration | 0.021 | 0.056 | 0.019 |
| | Springfield RRF | Incineration | 0.027 | 0.070 | 0.024 |
| | Collective Sources (remaining sources in state) | | 0.196 | 0.126 | 0.060 |
| Rhode Island | Narragansett Bay Comm. | Incineration | 0.005 | 0.012 | 0.004 |
| | Rhode Island Hospital | Incineration | 0.020 | 0.012 | 0.008 |
| | Woonsocket WWTF/NET Co | Incineration | 0.013 | 0.008 | 0.005 |
| | Zambarano Memorial Hospital | Incineration | 0.019 | 0.011 | 0.007 |
| | Collective Sources (remaining sources in state) | | 0.029 | 0.019 | 0.010 |
| Vermont | Health Services | Health Services | 0.004 | 0.0 | 0.0 |
| | Residential Fuel Comb. | Residential Fuel Comb. | 0.009 | 0.005 | 0.004 |
| | Collective Sources (remaining sources in state) | | 0.004 | 0.001 | 0.001 |
| New Hampshire | Merrimack | Coal fired utility | 0.003 | 0.052 | 2.0E-04 |
| | Schiller | Coal fired utility | 0.001 | 0.003 | 2.7E-04 |
| | SES Claremont RRF | Incineration | 0.015 | 0.039 | 0.013 |
| | Wheelabrator Concord | Incineration | 0.002 | 0.005 | 0.002 |
| | Collective Sources (remaining sources in state) | | 0.054 | 0.026 | 0.017 |
| *Region 2* | | | | | |
| New Jersey | Camden RRF | Incineration | 0.011 | 0.029 | 0.010 |
| | Co Steel Sayreville | Miscellaneous industrial processes | 0.179 | 0.022 | 0.022 |
| | Essex Co. RRF | Incineration | 0.047 | 0.123 | 0.042 |
| | Hudson | Coal fired utility | 0.011 | 0.028 | 0.002 |
| | NY/NJ Harbor Counties | | 0.334 | 0.077 | 0.048 |
| | Collective Sources (remaining sources in state) | | 0.462 | 0.129 | 0.067 |
| New York | American Ref-Fuel Co Niagara | Utility - Other fuel | 0.130 | 0.078 | 0.052 |
| | Niagara Falls | Incineration | 0.035 | 0.093 | 0.032 |
| | Niagara Mohawk Pwr Corp | Miscellaneous industrial processes | 0.137 | 0.082 | 0.055 |
| | Wheelabrator Westchester | Incineration | 0.024 | 0.064 | 0.022 |
| | Counties along Lake Ontario | | 0.144 | 0.077 | 0.031 |
| | Counties along NY/NJ Harbor | | 0.242 | 0.060 | 0.039 |
| | Collective Sources (remaining sources in state) | | 0.540 | 0.464 | 0.130 |

| | | | Mercury Emissions (tpy) | | |
|---|---|---|---|---|---|
| **Region/State** | **Source Name/ Description** | **Source Type** | **HGO** | **HG2** | **HGP** |
| *Region 3* | | | | | |
| Delaware | Edge Moor | Coal fired utility | 0.011 | 0.023 | 0.003 |
| | Indian River | Coal fired utility | 0.019 | 0.049 | 0.005 |
| | Motiva Enterprises | Petroleum refineries & related industries | 0.041 | 0.006 | 0.005 |
| | Occidental Chemical Corp. | Inorganic chem processes (chlor-alkali) | 0.510 | 0.027 | 0.0 |
| | Collective Sources (remaining sources in state) | | 0.013 | 0.003 | 0.002 |
| District of Columbia | Benning | Oil fired utility | 0.001 | 3.3E-04 | 2.2E-04 |
| | Collective Sources (remaining sources in District) | | 0.003 | 0.001 | 0.001 |
| Maryland | Baltimore Res Co | Incineration | 0.027 | 0.071 | 0.024 |
| | Brandon Shores | Coal fired utility | 0.100 | 0.154 | 0.013 |
| | Chalk Point | Coal fired utility | 0.055 | 0.137 | 0.014 |
| | Lehigh Portland Cement | Miscellaneous industrial processes | 0.030 | 0.005 | 0.005 |
| | Morgantown | Coal fired utility | 0.050 | 0.132 | 0.012 |
| | Phoenix Services_Inc. | Incineration | 0.003 | 0.047 | 0.012 |
| | Collective utilities | | 0.108 | 0.136 | 0.013 |
| | Collective Sources (remaining sources in state) | | 0.381 | 0.250 | 0.143 |
| Pennsylvania | Bruce Mansfield | Coal fired utility | 0.315 | 0.173 | 0.016 |
| | General Electric Co. | Mineral Products | 0.210 | 0.126 | 0.084 |
| | Harrisburg WTE | Incineration | 0.070 | 0.185 | 0.064 |
| | Homer City | Coal fired utility | 0.238 | 0.631 | 0.057 |
| | Keystone | Coal fired utility | 0.238 | 0.631 | 0.057 |
| | Montour | Coal fired utility | 0.157 | 0.415 | 0.037 |
| | Shawville | Coal fired utility | 0.119 | 0.316 | 0.028 |
| | Collective utilities | | 0.719 | 0.834 | 0.128 |
| | Collective Sources (remaining sources in state) | | 0.936 | 0.456 | 0.302 |
| Virginia | Chesapeake Energy Center | Coal fired utility | 0.023 | 0.062 | 0.006 |
| | Chesterfield Power Station | Coal fired utility | 0.047 | 0.125 | 0.011 |
| | Jewel Coke Company LLP | Ferrous Metals Processing | 0.135 | 0.017 | 0.017 |
| | NASA Refuse-fired Steam Gen. | Incineration | 0.025 | 0.066 | 0.023 |
| | Norfolk Navy Yard | Incineration | 0.021 | 0.056 | 0.019 |
| | Collective Sources (remaining sources in state) | | 0.470 | 0.464 | 0.133 |
| West Virginia | Fort Martin | Coal fired utility | 0.058 | 0.153 | 0.014 |
| | John E Amos | Coal fired utility | 0.124 | 0.329 | 0.029 |
| | Mitchell (WV) | Coal fired utility | 0.058 | 0.153 | 0.014 |
| | Mt. Storm Power Station | Coal fired utility | 0.168 | 0.294 | 0.026 |
| | Philip Sporn | Coal fired utility | 0.071 | 0.188 | 0.017 |
| | PPG Industries, Inc | Inorganic chem processes (chlor-alkali) | 0.537 | 0.028 | 0.000 |
| | Collective utilities | | 0.352 | 0.384 | 0.033 |
| | Collective Sources (remaining sources in state) | | 0.090 | 0.035 | 0.022 |
| *Region 4* | | | | | |
| Alabama | Gaston | Coal fired utility | 0.164 | 0.254 | 0.022 |
| | Gorgas | Coal fired utility | 0.136 | 0.291 | 0.026 |
| | Miller | Coal fired utility | 0.604 | 0.189 | 0.002 |
| | Occidental Chem Muscle Shoal | Inorganic chem processes (chlor-alkali) | 0.380 | 0.020 | 0.000 |
| | Mobile Bay area | | 0.287 | 0.211 | 0.048 |
| | Collective Sources (remaining sources in state) | | 0.574 | 0.386 | 0.131 |
| Florida | Crist | Coal fired utility | 0.028 | 0.075 | 0.007 |
| | Crystal River | Coal fired utility | 0.071 | 0.188 | 0.017 |
| | F. J. Gannon | Coal fired utility | 0.054 | 0.089 | 0.007 |
| | St. Josephs Hospital | Incineration | 0.492 | 0.296 | 0.197 |
| | Pensacola Bay area | | 0.019 | 0.014 | 0.007 |
| | South-FL urban area | | 0.141 | 0.130 | 0.056 |

| | | | Mercury Emissions (tpy) | | |
|---|---|---|---|---|---|
| **Region/State** | **Source Name/ Description** | **Source Type** | **HGO** | **HG2** | **HGP** |
| | Collective Sources (remaining sources in state) | | 0.705 | 0.451 | 0.170 |
| Georgia | Bowen | Coal fired utility | 0.088 | 0.233 | 0.021 |
| | Olin Corp | Miscellaneous industrial processes | 0.587 | 0.031 | 0.000 |
| | Scherer | Coal fired utility | 0.375 | 0.219 | 0.007 |
| | Wansley | Coal fired utility | 0.045 | 0.120 | 0.011 |
| | Collective Sources (remaining sources in state) | | 0.370 | 0.366 | 0.098 |
| Kentucky | Big Sandy | Coal fired utility | 0.072 | 0.190 | 0.017 |
| | Ghent | Coal fired utility | 0.104 | 0.121 | 0.010 |
| | H. L. Spurlock | Coal fired utility | 0.062 | 0.096 | 0.008 |
| | Paradise Fossil Plant | Coal fired utility | 0.125 | 0.149 | 0.013 |
| | Collective Sources (remaining sources in state) | | 1.456 | 0.743 | 0.398 |
| Mississippi | Chambers of MS Inc-Clearview | Landfills | 0.071 | 0.009 | 0.009 |
| | Jack Watson | Coal fired utility | 0.047 | 0.084 | 0.007 |
| | Pascagoula ERF | Incineration | 0.019 | 0.050 | 0.017 |
| | Victor J. Daniel | Coal fired utility | 0.062 | 0.037 | 0.002 |
| | Collective Sources (remaining sources in state) | | 0.319 | 0.146 | 0.087 |
| North Carolina | Belews Creek | Coal fired utility | 0.067 | 0.177 | 0.016 |
| | BMW NC | Incineration | 0.107 | 0.064 | 0.043 |
| | Marshall | Coal fired utility | 0.058 | 0.155 | 0.014 |
| | Roxboro | Coal fired utility | 0.116 | 0.259 | 0.023 |
| | Waccama Lake area | | 0.223 | 0.124 | 0.030 |
| | Collective Sources (remaining sources in state) | | 0.448 | 0.494 | 0.114 |
| South Carolina | Foster Wheeler Charleston RRF | Incineration | 0.021 | 0.055 | 0.019 |
| | Safety Disposal Systems | Incineration | 0.008 | 0.124 | 0.033 |
| | Wateree | Coal fired utility | 0.032 | 0.083 | 0.008 |
| | Winyah Generating Station | Coal fired utility | 0.049 | 0.037 | 0.003 |
| | Collective Sources (remaining sources in state) | | 0.599 | 0.358 | 0.183 |
| Tennessee | Gallatin Fossil Plant | Coal fired utility | 0.048 | 0.128 | 0.011 |
| | Johnsonville Fossil Plant | Coal fired utility | 0.056 | 0.148 | 0.013 |
| | Kingston Fossil Plant | Coal fired utility | 0.069 | 0.182 | 0.016 |
| | Olin Corp. | Miscellaneous industrial processes | 0.615 | 0.032 | 0.000 |
| | Collective Sources (remaining sources in state) | | 0.463 | 0.392 | 0.107 |
| *Region 5* | | | | | |
| Illinois | Joliet 29 | Coal fired utility | 0.222 | 0.099 | 5.0E-04 |
| | Joppa Steam | Coal fired utility | 0.210 | 0.094 | 4.7E-04 |
| | Powerton | Coal fired utility | 0.440 | 0.197 | 0.001 |
| | Waukegan | Coal fired utility | 0.310 | 0.090 | 4.6E-04 |
| | Util in Chicago | | 0.359 | 0.149 | 0.001 |
| | Util outside Chicago | | 0.530 | 0.417 | 0.022 |
| | Non-util in Chicago | | 0.621 | 0.178 | 0.132 |
| | Collective Sources (remaining sources in state) | | 0.644 | 0.239 | 0.161 |
| Indiana | Clifty Creek | Coal fired utility | 0.120 | 0.113 | 0.007 |
| | Gibson Generating Station | Coal fired utility | 0.108 | 0.162 | 0.014 |
| | Lehigh Portland Cement Kilns | Cement kilns | 0.059 | 0.010 | 0.009 |
| | Rockport | Coal fired utility | 0.121 | 0.321 | 0.029 |
| | Tanners Creek | Coal fired utility | 0.031 | 0.082 | 0.007 |
| | Utilities in Gary, IN | | 0.105 | 0.049 | 0.001 |
| | Utilities outside Gary, IN | | 0.522 | 0.469 | 0.039 |
| | Collective sources in Gary, IN | | 0.089 | 0.029 | 0.030 |
| | Collective Sources (remaining sources in state) | | 0.740 | 0.276 | 0.208 |
| Michigan | Central Wayne Co Sanitation | Incineration | 0.037 | 0.097 | 0.034 |
| | J. H. Campbell | Coal fired utility | 0.095 | 0.149 | 0.012 |
| | Monroe Power Plant | Coal fired utility | 0.159 | 0.229 | 0.017 |
| | St Clair Power Plant | Coal fired utility | 0.070 | 0.050 | 0.002 |
| | Sources in Detroit Metro | | 0.440 | 0.279 | 0.058 |
| | Lafarge Midwest Inc | Mineral Products | 0.218 | 0.038 | 0.035 |

| | | | Mercury Emissions (tpy) | | |
|---|---|---|---|---|---|
| **Region/State** | **Source Name/ Description** | **Source Type** | **HGO** | **HG2** | **HGP** |
| | Collective Sources (remaining sources in state) | | 0.465 | 0.282 | 0.104 |
| Minnesota | Clay Boswell | Coal fired utility | 0.154 | 0.012 | 0.003 |
| | Olmstead WTE Facility | Solid waste incineration | 0.004 | 0.020 | 0.000 |
| | Pope-Douglas Waste | Solid waste incineration | 0.009 | 0.024 | 0.008 |
| | Sherburne Co. Generating Plant | Coal fired utility | 0.269 | 0.016 | 0.006 |
| | Taconite Facilities | Taconite | 0.226 | 0.024 | 0.010 |
| | Collective "wetland" sources near Lake Superior | | 0.028 | 0.016 | 0.007 |
| | Collective Minn./St. Paul area | | 0.333 | 0.080 | 0.035 |
| | Collective Sources (remaining sources in state) | | 0.117 | 0.096 | 0.036 |
| Ohio | ASHTA Chemicals Inc. | Miscellaneous industrial processes | 0.786 | 0.041 | 0.000 |
| | Cardinal | Coal fired utility | 0.096 | 0.201 | 0.018 |
| | Conesville | Coal fired utility | 0.175 | 0.253 | 0.022 |
| | Eastlake | Coal fired utility | 0.076 | 0.197 | 0.018 |
| | Kyger Creek | Coal fired utility | 0.066 | 0.175 | 0.016 |
| | W. H. Sammis | Coal fired utility | 0.073 | 0.187 | 0.016 |
| | Collective utilities | | 1.103 | 0.798 | 0.068 |
| | Collective Sources (remaining sources in state) | | 0.526 | 0.214 | 0.155 |
| Wisconsin | Columbia | Coal fired utility | 0.125 | 0.036 | 1.8E-04 |
| | Pleasant Prairie | Coal fired utility | 0.282 | 0.126 | 0.001 |
| | South Oak Creek | Coal fired utility | 0.077 | 0.056 | 0.002 |
| | Vulcan Materials Chem Div | Inorganic chem processes (chlor-alkali) | 0.514 | 0.027 | 0.0 |
| | Collective Sources (remaining sources in state) | | 0.580 | 0.275 | 0.091 |
| | | | | | |
| *Region 6* | | | | | |
| Arkansas | Ash Grove Cement Co | Incineration | 0.145 | 0.050 | 0.055 |
| | Carle Bailey Gen Stn | Miscellaneous industrial processes | 0.100 | 0.060 | 0.040 |
| | Independence | Coal fired utility | 0.129 | 0.058 | 2.9E-04 |
| | White Bluff | Coal fired utility | 0.172 | 0.077 | 0.001 |
| | Collective Sources (remaining sources in state) | | 0.259 | 0.106 | 0.068 |
| Louisiana | Big Cajun 2 | Coal fired utility | 0.187 | 0.084 | 0.001 |
| | Pioneer Americas Inc. | Miscellaneous industrial processes | 0.572 | 0.030 | 0.0 |
| | PPG Industries-Inc. | Inorganic chem processes (chlor-alkali) | 0.580 | 0.031 | 0.001 |
| | R. S. Nelson | Coal fired utility | 0.073 | 0.033 | 1.7E-04 |
| | Collective Sources (remaining sources in state) | | 0.499 | 0.157 | 0.113 |
| New Mexico | Escalante | Coal fired utility | 0.042 | 0.001 | 1.9E-04 |
| | Four Corners | Coal fired utility | 0.502 | 0.019 | 0.004 |
| | Los Alamos Natl Lab | Miscellaneous industrial processes | 0.012 | 0.007 | 0.005 |
| | San Juan | Coal fired utility | 0.491 | 0.023 | 0.006 |
| | Collective Sources (remaining sources in state) | | 0.035 | 0.005 | 0.004 |
| Oklahoma | AES Shady Point-Inc. | Coal fired utility | 0.198 | 0.007 | 0.001 |
| | Holnam-Inc. | Mineral products | 0.110 | 0.053 | 0.037 |
| | Muskogee | Coal fired utility | 0.138 | 0.061 | 3.1E-04 |
| | Sooner | Coal fired utility | 0.099 | 0.044 | 2.2E-04 |
| | Collective Sources (remaining sources in state) | | 0.330 | 0.132 | 0.027 |
| Texas | ALCOA Al & Chem | Non-ferrous metals processing | 0.558 | 0.077 | 0.074 |
| | Big Brown | Coal fired utility | 0.153 | 0.280 | 0.001 |
| | Chemical Waste Mgmt | Incineration | 0.340 | 0.117 | 0.129 |
| | Monticello | Coal fired utility | 0.511 | 0.533 | 0.003 |
| | Collective Sources (remaining sources in state) | | 4.047 | 1.108 | 0.389 |

| | | | Mercury Emissions (tpy) | | |
|---|---|---|---|---|---|
| **Region/State** | **Source Name/ Description** | **Source Type** | **HGO** | **HG2** | **HGP** |
| *Region 7* | | | | | |
| Iowa | Council Bluffs | Coal fired utility | 0.114 | 0.045 | 2.9E-04 |
| | Dubuque | Coal fired utility | 0.002 | 0.005 | 4.8E-04 |
| | George Neal North | Coal fired utility | 0.137 | 0.052 | 0.001 |
| | George Neal South | Coal fired utility | 0.097 | 0.043 | 2.4E-04 |
| | Collective utilities | | 0.362 | 0.122 | 0.002 |
| | Collective Sources (remaining sources in state) | | 0.094 | 0.045 | 0.028 |
| Kansas | Ash Grove Cement Co. | Incineration | 0.085 | 0.029 | 0.032 |
| | Jeffrey Energy Center (Westar) | Coal fired utility | 0.411 | 0.013 | 0.002 |
| | La Cygne (KCP&L) | Coal fired utility | 0.163 | 0.043 | 0.003 |
| | Lawrence (Westar) | Coal fired utility | 0.063 | 0.009 | 0.001 |
| | Collective Sources (remaining sources in state) | | 0.241 | 0.085 | 0.043 |
| Missouri | Doe Run Buick | Lead Smelter | 0.134 | 0.017 | 0.017 |
| | Iatan | Coal fired utility | 0.066 | 0.029 | 1.5E-04 |
| | Labadie | Coal fired utility | 0.252 | 0.112 | 0.001 |
| | Rush Island | Coal fired utility | 0.120 | 0.054 | 2.7E-04 |
| | Sioux | Coal fired utility | 0.076 | 0.072 | 0.004 |
| | Thomas Hill | Coal fired utility | 0.123 | 0.055 | 2.8E-04 |
| | Counties around Kansas City | | 0.062 | 0.029 | 0.004 |
| | Collective Sources (remaining sources in state) | | 0.686 | 0.225 | 0.092 |
| Nebraska | Gerald Gentlemen Station | Coal fired utility | 0.134 | 0.019 | 9.6E-05 |
| | Nebraska City | Coal fired utility | 0.073 | 0.032 | 1.8E-04 |
| | North Omaha | Coal fired utility | 0.062 | 0.028 | 1.4E-04 |
| | Sheldon | Coal fired utility | 0.040 | 0.004 | 4.0E-04 |
| | Collective Sources (remaining sources in state) | | 0.054 | 0.012 | 0.004 |
| *Region 8* | | | | | |
| Colorado | CEMEX-Inc.-Lyons Cement | Mineral products | 0.117 | 0.020 | 0.019 |
| | Comanche | Coal fired utility | 0.007 | 0.035 | 0.001 |
| | Craig | Coal fired utility | 0.075 | 0.004 | 0.001 |
| | Pawnee | Coal fired utility | 0.008 | 0.040 | 0.001 |
| | CF & I Steel L P DBA Rocky Mtn Steel Mills | Ferrous Metals Processing | 0.226 | 0.028 | 0.028 |
| | Collective Sources (remaining sources in state) | | 0.166 | 0.032 | 0.012 |
| Montana | Colstrip | Coal fired utility | 0.407 | 0.022 | 0.006 |
| | Colstrip Energy | Coal fired utility | 0.003 | 0.008 | 4.5E-05 |
| | Livingston/Park County MWC | Incineration | 0.009 | 0.024 | 0.008 |
| | Stone Container Corp. | Wood, Pulp& Paper, Publishing Prod. | 0.008 | 0.005 | 0.003 |
| | Collective Sources (remaining sources in state) | | 0.049 | 0.011 | 0.005 |
| North Dakota | Antelope Valley Station | Coal fired utility | 0.163 | 0.024 | 0.001 |
| | Coal Creek | Coal fired utility | 0.219 | 0.034 | 0.002 |
| | Coyote | Coal fired utility | 0.095 | 0.022 | 0.013 |
| | Milton R. Young | Coal fired utility | 0.189 | 0.034 | 0.001 |
| | Collective Sources (remaining sources in state) | | 0.264 | 0.045 | 0.015 |
| South Dakota | Big Stone | Coal fired utility | 0.037 | 0.018 | 2.4E-04 |
| | Health Services | Health services | 0.006 | 0.0 | 0.0 |
| | Collective Sources (remaining sources in state) | | 0.007 | 0.003 | 0.002 |
| Utah | Hunter | Coal fired utility | 0.172 | 0.017 | 0.002 |
| | Intermountain Power | Coal fired utility | 0.069 | 0.037 | 0.007 |
| | Ash Grove | Mineral Products | 0.044 | 0.015 | 0.017 |
| | Clean Harbors (formerly Aptus) | Incineration | 0.016 | 0.005 | 0.006 |
| | Davis/Wasatch | Incineration | 0.008 | 0.021 | 0.007 |
| | Huntington | Coal fired utility | 0.050 | 0.065 | 0.006 |
| | Nucor Steel | Internal Combustion: Other fuel | 0.059 | 0.007 | 0.007 |
| | Collective Sources (remaining sources in state) | | 0.070 | 0.051 | 0.013 |
| Wyoming | Dave Johnston | Coal fired utility | 0.123 | 0.030 | 0.001 |
| | Jim Bridger | Coal fired utility | 0.297 | 0.009 | 0.001 |
| | Laramie River Station | Coal fired utility | 0.239 | 0.008 | 0.001 |

| | | | Mercury Emissions (tpy) | | |
|---|---|---|---|---|---|
| **Region/State** | **Source Name/ Description** | **Source Type** | **HGO** | **HG2** | **HGP** |
| | Naughton | Coal fired utility | 0.071 | 0.018 | 2.3E-04 |
| | Collective Sources (remaining sources in state) | | 0.194 | 0.031 | 0.020 |
| *Region 9* | | | | | |
| Arizona | Apache Station | Coal fired utility | 0.057 | 0.003 | 0.001 |
| | Cholla | Coal fired utility | 0.118 | 0.009 | 0.001 |
| | copper mines | Copper Mines | 0.098 | 0.012 | 0.012 |
| | Coronado | Coal fired utility | 0.118 | 0.006 | 0.002 |
| | Navajo | Coal fired utility | 0.119 | 0.031 | 0.001 |
| | Northstar Steel Arizona | Ferrous Metals Processing | 0.150 | 0.019 | 0.019 |
| | Springerville | Coal fired utility | 0.152 | 0.007 | 0.002 |
| | Collective Sources (remaining sources in state) | | 0.075 | 0.019 | 0.012 |
| California | Calaveras Cement Co | Mineral Products | 0.956 | 0.166 | 0.153 |
| | Hanson Permanente Cement | Mineral Products | 0.187 | 0.032 | 0.030 |
| | Long Beach SERRF | Utility - Other fuel & Incineration | 0.211 | 0.206 | 0.104 |
| | PG&E-Geysers Units 13&16 | Internal Combustion | 0.398 | 0.239 | 0.159 |
| | Riverside Cement Co. | Mineral Products | 0.256 | 0.044 | 0.041 |
| | RMC Pacific Materials | Mineral Products | 0.123 | 0.021 | 0.020 |
| | Sierra Army Depot | Incineration | 0.304 | 0.105 | 0.115 |
| | Collective cement plants | Mineral Products | 0.224 | 0.039 | 0.036 |
| | Collective Sources (remaining sources in state) | | 1.156 | 0.477 | 0.292 |
| Nevada | Newmont Lone Tree | Gold mining | 0.269 | 0.038 | 0.005 |
| | Newmont Mining Corporation - Gold Quarry Operations | Gold mining | 0.106 | 0.045 | 0.008 |
| | Newmont Mining Corporation - Twin Creeks Mine | Gold mining | 0.194 | 0.018 | 0.006 |
| | Barrick Goldstrike Mines, Inc | Gold mining | 0.282 | 0.023 | 0.007 |
| | Florida Canyon | Gold mining | 0.078 | 0.135 | 0.008 |
| | Glammis Marigold | Gold mining | 0.397 | 0.054 | 0.005 |
| | Queenstake Resources USA Inc - Jerritt Canyon Mine | Gold mining | 0.121 | 0.720 | 0.018 |
| | Cortez Gold Mines Mill #2 | Gold mining | 0.056 | 0.026 | 0.002 |
| | Bald Mountain Mine | Gold mining | 0.066 | 0.034 | 0.002 |
| | Denton Rawhide | Gold mining | 0.062 | 0.107 | 0.007 |
| | Other NV Gold Mines Collective Emissions | Gold mining | 0.037 | 0.021 | 0.001 |
| | Mohave | Coal fired utility | 0.032 | 0.008 | 0.000 |
| | Collective Sources (remaining sources in state) | | 0.064 | 0.015 | 0.005 |
| *Region 10* | | | | | |
| Idaho | Amalgamated Sugar | Industrial Boilers - Coal | 2.9E-04 | 1.7E-04 | 1.1E-04 |
| | INEEL INTEC | Miscellaneous Industrial Processes | 0.004 | 0.002 | 0.002 |
| | P4 Production LLC | Inorganic Chemical Mfg | 0.367 | 0.046 | 0.046 |
| | Potlatch Pulp and Paperboard | Wood, Pulp & Paper, & Publishing Products | 0.125 | 0.075 | 0.050 |
| | Potlatch Wood Products Div. | Industrial Boilers - Other Fuel | 0.010 | 0.006 | 0.004 |
| | Collective Sources (remaining sources in state) | | 0.056 | 0.025 | 0.017 |
| Oregon | Ash Grove Cement Co. | Mineral Products | 0.358 | 0.792 | 0.106 |
| | Cascade Steel | Ferrous Metals Processing | 0.043 | 0.005 | 0.005 |
| | Portland General Electric Co. | Utility: Internal Combustion | 0.030 | 0.018 | 0.012 |
| | Oregon Steel Mills-Inc. | Ferrous Metals Processing | 0.012 | 0.001 | 0.001 |
| | Weyerhaeuser Company | Industrial Boilers - Internal Combustion | 2.5E-04 | 1.5E-04 | 1.0E-04 |
| | Boardman | Coal fired utility | 0.055 | 0.028 | 0.001 |
| | Collective Sources (remaining sources in state) | | 0.235 | 0.025 | 0.083 |
| Washington | Ash Grove and Lafarge | Mineral Products | 0.042 | 0.007 | 0.007 |
| | Centralia | Coal fired utility | 0.183 | 0.082 | 0.000 |
| | Georgia Pacific West Inc | Inorganic Chemical Mfg | 0.047 | 0.006 | 0.003 |
| | Long View Fibre Co. | Wood, Pulp & Paper, & Publishing Products | 0.022 | 0.013 | 0.009 |

| | | | Mercury Emissions (tpy) | | |
|---|---|---|---|---|---|
| **Region/State** | **Source Name/ Description** | **Source Type** | **HGO** | **HG2** | **HGP** |
| | Spokane Reg. Disposal | Incinerator | 0.003 | 0.007 | 0.002 |
| | Tacoma | Incinerator | 0.001 | 0.002 | 0.001 |
| | Collective pulp and paper | Wood, Pulp & Paper, & Publishing Products | 0.032 | 0.019 | 0.013 |
| | Collective Whatcom County | | 0.007 | 0.002 | 0.001 |
| | Collective Sources (remaining sources in state) | | 0.072 | 0.011 | 0.006 |
| *Other Region* | | | | | |
| Ontario, Canada | Collective Sources | | 1.191 | 1.021 | 0.314 |
| Canada | Burnaby Refuse Incinerator | | 0.012 | 0.036 | 0.012 |
| All Other Canada | Collective Sources | | 3.337 | 1.852 | 0.543 |
| Mexico | Collective Sources | | 13.065 | 4.676 | 2.430 |
| *Initial & Boundary Condition Tags* | | | | | |
| CTM | Global model providing boundary conditions | | – | – | – |
| GEOS-CHEM | Global model providing boundary conditions | | – | – | – |
| GRAHM | Global model providing boundary conditions | | – | – | – |
| GRAHM (HG0) | Global model providing boundary condition contribution from HG0 | | – | – | – |
| GRAHM (HG2) | Global model providing boundary condition contribution from HG2 | | – | – | – |
| GRAHM (HGP) | Global model providing boundary condition contribution from HGP | | – | – | – |

## 7.2. Mercury PPTM Results

In this section, the REMSAD mercury tagging results are examined for selected locations throughout the modeling domain. This section also examines, in some detail, the simulated contributions in relation to a source receptor study in Ohio.

The modeling results contain much more information than is presented here. To facilitate future analysis, the tagging results have been incorporated into a GIS database tool (an enhanced version of ARC-Hydro, developed by ESRI under a separate effort) that allows users to extract the results for any grid cell or combination of grid cells and calculate the simulated contribution from each tagged source or source category to any area of interest in the modeling domain, such as a county, watershed, or body of water.

### *7.2.1. Contributions to Statewide Maximum Deposition*

For each state, the contributions to mercury deposition were examined for the location of greatest deposition from sources located within that same state. This is not necessarily the location of overall maximum deposition for the state, but this approach allows us to focus on the intra-state contributions. **Note that contributions are summarized only for a single location in each state. The summaries should not be taken as necessarily representative of contributions on a statewide basis.**

Figures 7-1 through 7-49 summarize, for each of the 48 states included in the modeling domain and the District of Columbia, the simulated contributions at the location of maximum deposition from in-state sources. The plots are ordered by EPA region and then alphabetically by state for each region, as follows:

- Figures 7-1 through 7-6 are for Region 1 (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont).

- Figures 7-7 and 7-8 are for Region 2 (New Jersey and New York).
- Figures 7-9 through 7-14 are for Region 3 (Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, and West Virginia).
- Figures 7-15 through 7-22 are for Region 4 (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee).
- Figures 7-23 through 7-28 are for Region 5 (Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin).
- Figures 7-29 through 7-33 are for Region 6 (Arkansas, Louisiana, New Mexico, Oklahoma, and Texas).
- Figures 7-34 through 7-37 are for Region 7 (Iowa, Kansas, Missouri, and Nebraska).
- Figures 7-38 through 7-43 are for Region 8 (Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming).
- Figures 7-44 through 7-46 are for Region 9 (Arizona, California, and Nevada).
- Figures 7-47 through 7-49 are for Region 10 (Idaho, Oregon, and Washington).

Part (a) of each figure is a map that shows the annual total mercury deposition for the state in question. The location of the maximum simulated contribution from in-state sources is indicated by the blue triangle on this plot.
Part (b) gives the modeling results for the grid cell location of the triangle in Part (a). The annual total mercury deposition as simulated by REMSAD for this grid cell is given in the caption for Part (b). The information in Part (b) includes the REMSAD modeling results as well as CMAQ-derived information for global background contributions. Note the contributions to mercury deposition are displayed only for this one grid cell location within the state. Since the REMSAD modeling domain is defined by 12-km horizontal resolution, each grid cell covers a 12 by 12 km area. Results should not be extrapolated to indicate source contributions on a statewide basis.
Part (b) of each figure consists of four plots, as follows:

1. The bar chart in the upper left-hand corner of the display compares the contribution to total deposition from emissions versus background conditions. The first bar represents the contribution to total deposition from all emissions sources, i.e., sources in the U.S., Canada, Mexico, and re-emissions. The next four bars display the contribution of global background concentrations to total deposition as estimated using REMSAD and the three sets of initial/boundary conditions (CTM, GRAHM and GEOS-CHEM (G-C)), which are referred to here as background. The average of the three initial/boundary contributions for REMSAD is also presented. The next four bars display the contribution of global background concentrations to total deposition as estimated using CMAQ and the three sets of initial/boundary conditions (CTM, GRAHM, and G-C). The average of the three initial/boundary contributions for CMAQ is also presented. The average values are used in the remaining summary charts.
2. The bar chart in the upper right-hand corner of the display illustrates and compares wet and dry deposition amounts comprising 1) total deposition from emissions sources, 2) average background deposition from the REMSAD simulation, 3) average background deposition for the corresponding CMAQ simulations, and 4) total overall deposition from REMSAD.
3. The pie chart in the lower left-hand corner of the display illustrates the percent contributions to total deposition at the selected grid cell from 1) the initial and boundary conditions or

background (average of the three sets of conditions for REMSAD), 2) emissions from sources within the state, 3) emissions from sources in neighboring states, 4) emissions from all other U.S. states, 4) emissions from Canada and Mexico, and 5) re-emission processes. Re-emissions on the plots refers to mass that has been re-emitted and subsequently redeposited, as described in Section 2.1.4.

4. The double (or pie-in-pie) pie chart in the lower right hand corner of the display summarizes the contributions from emissions sources only, without including the background. This plot highlights the percent contributions from the in-state sources. The larger pie gives the proportion of the overall contribution from emissions sources that are located outside of vs. inside of the state, and the smaller pie details the contributions from the in-state sources (specifically, the five largest in-state contributors as well as all other in-state sources). If there are five or fewer tags for a given state, all of the tagged source contributions are displayed.

   The names of the sources are given in the legend. The “Collective Sources” tag for each state includes all point and area sources in the state that are not tagged individually, as part of a source category, or as part of a region. When a chart refers to “Other tagged sources within” a state, it refers to sources that were tagged but contributed only a small amount to deposition at the location chosen. These sources were therefore aggregated for the purposes of the chart. The legend also includes the percentages represented by the various segments of the pie charts. Note that the percentages for the cut-out pie chart segments are calculated based on the total represented only in the smaller, cut-out pie chart. Note also that very small contributions sometimes appear as zero percent.

In interpreting the results presented for the tagging simulations, the reader is reminded that all model simulation results include some uncertainty, and that uncertainty is often difficult to quantify. Therefore, although contribution values may be repored to tenths of a percent, this is done to differentiate values that range widely in magnitude, not because of actual precision to that level. The contribution results should be viewed in a relative sense more than an absolute sense.

### 7.2.2. Example Analysis Using the Contribution Charts

To aid the use and interpretation of the contribution charts, the following discussion of the results is provided for Connecticut (Figures 7-1a and b).

The map in Figure 7-1a shows the location of maximum simulated mercury deposition within Connecticut from sources located within Connecticut. The location, in the northern part of the state, is marked with the blue triangle. All of the charts in Figure 7-1b summarize deposition amounts at this location and are not meant to represent an analysis for the entire state. Note that this is not the location of maximum deposition within the illustrated area. That maximum, indicated by a small “+” sign, is located in the southeastern part of the domain, in the NY/NJ harbor area.

In Figure 7-1b, mercury deposition at the marked location is broken down in various ways. The total deposition is 46.9 g $km^{-2}$, consisting of (from the upper left chart) 32.9 g $km^{-2}$ from emissions (from the U.S., Canada, Mexico, and re-emission) and 14.0 g $km^{-2}$ from the average background from REMSAD. For comparison purposes, the average background as simulated by CMAQ is 18.3 g $km^{-2}$.

The chart in the upper right-hand corner of the display indicates that the contribution to total deposition from dry deposition is approximately double (31.3 g $km^{-2}$) that from wet deposition (15.6 g $km^{-2}$) at the selected location. The relative amount of wet versus dry deposition is

different for the emissions versus the background. The emissions contribution is characterized by a much higher dry deposition amount (6.0 versus 26.9 g $km^{-2}$ for wet and dry deposition, respectively). The REMSAD average background contribution is characterized by higher wet deposition (9.6 versus 4.4 g $km^{-2}$ for wet and dry deposition, respectively). The CMAQ-derived average background estimates indicate more similar amounts of wet and dry deposition (8.4 versus 9.9 g $km^{-2}$, respectively).

In the pie charts, the contributions from emissions sources are broken out in detail.

The chart in the lower left-hand corner indicates that 55.8 percent of the total mercury deposition is from sources that are located in Connecticut. Average background (boundary conditions) contributes 29.8 percent. The remaining deposition is broken down as follows: 7.6 percent from emissions sources in neighboring states (states that share a state boundary with Connecticut), 5.2 percent from emissions sources in other U.S. states, 0.3 percent from emissions sources in Canada and Mexico, and 1.4 percent from re-emission processes. The lower right pie-in-pie chart displays percent contribution to the emissions-only portion of the total contribution, i.e. not including background, from emissions sources outside Connecticut and sources located within the state. The first pie chart indicates that 20.5 percent of the emissions-only contribution to mercury deposition at the selected location is from outside sources and 79.5 percent is from in-state sources. The second pie chart indicates that, of the contributions from in-state sources, 92.5 percent is from the Mid-CT Project (CRRA). From this it can be computed that emissions from the Mid-Ct Project (CRRA) account for 73.5 percent (92.5 percent of the 79.5 percent contribution from Connecticut sources) of the deposition from emissions sources and 51.6 percent (92.5 percent of the 55.8 percent contribution from CT sources) of the overall deposition. “CT Collective Sources” (those sources in Connecticut that were not tagged as individual sources, as part of a category of sources, or as part of a region) contribute the next largest amount at 4.6 percent of the in-state emissions contribution, which is 3.7 percent (4.6 percent of 79.5 percent) of the total emissions contribution and 2.6 percent (4.6 percent of 55.8 percent) of the overall deposition. “Other tagged sources within CT” contribute 0.3 percent of the in-state emissions contribution, or less than 0.2 percent (0.3 percent of 55.8 percent) of the overall deposition. Note that this terminology “Other sources within CT” refers to sources that were tagged individually or as part of a source category but that contributed only a small amount of the deposition at this location, and so they are aggregated for the purposes of this chart.

An appropriate summary for this location would be that about half the deposition is from the Mid-CT Project (CRRA), about one-third from background and re-emissions, with the remainder from other sources located in Connecticut, neighboring states, other states, Canada, and Mexico.

### *7.2.3. Comparison with a Source Apportionment Study for Ohio*

It is of great interest to evaluate the contribution analysis against studies of apportionment based on observed data, but such studies are very limited in number. A study by Keeler et al. (2006) used receptor modeling to estimate contributions to wet deposition of mercury at Steubenville, Ohio. Although the study was for the years 2003 and 2004 (while this modeling is for 2001), it is still interesting to compare the conclusions of that study with the results of the contribution analysis derived from this modeling.

The Keeler study used air monitoring and wet deposition data along with statistical receptor modeling to estimate contributors to wet deposition of mercury at their Steubenville, Ohio site. In order to compare to the results of the Keeler study, simulation results were extracted from the

REMSAD 2001 tagging simulations at the location of the Steubenville site (40.379 N, 80.620 W). The simulation results are summarized in Figure 7-50a in the same format as has been presented for the state-by-state results. Since Keeler's study dealt only with wet deposition, simulation results are presented in Figure 7-50b for wet deposition only. The wet deposition charts include details of the contributions from sources within Ohio (lower left chart) and sources within neighboring states (lower right). The location of the site is shown on the spatial map in Figure 7-51.

Keeler's study estimated that about 70 percent of the mercury wet deposition at the Steubenville site came from coal combustion. Another 6 percent came from iron/steel production. Since the Keeler study used the presence of trace elements as indicators of the originating processes, these estimates would apply to all coal combustion and all iron and steel production, not to specific sources. Although the methodology did not tag all coal combustion sources, estimates can be developed from the REMSAD simulation results for the purpose of comparison with the Keeler study.

Utilizing the average background contributions, the REMSAD PPTM results indicate that 49.8 percent of the wet deposition is from Ohio sources at Steubenville. Of that portion, at least 97.6 percent is from coal fired utilities. Another 13.6 percent of the overall deposition comes from neighboring states, and, of this portion, at least 66.6 percent is from coal fired utilities. This gives an estimate that 57.7 percent or more of the wet deposition at this site comes from coal-fired utilities. Since all coal-fired utilities in the states neighboring Ohio or in the rest of the U.S. were not tagged, it is likely that there is some additional contribution to deposition from coal combustion. Iron and steel production in this area also were not tagged, so a comparison for this source category cannot be made.

Although the Keeler study did not apportion dry deposition among industrial sectors, it was found from the REMSAD PPTM analysis that the total wet and dry deposition contribution from utility sources is on the order of at least 50 to 60 percent.

The REMSAD-based estimates are consistent with the results from the Steubenville study. Additional tags are needed in order to account for a greater fraction of the coal combustion and to ascertain whether a comparable estimate to Keeler's could be made for the contribution from iron and steel production.

**Figure 7-1. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^2$) for Connecticut.**

a.

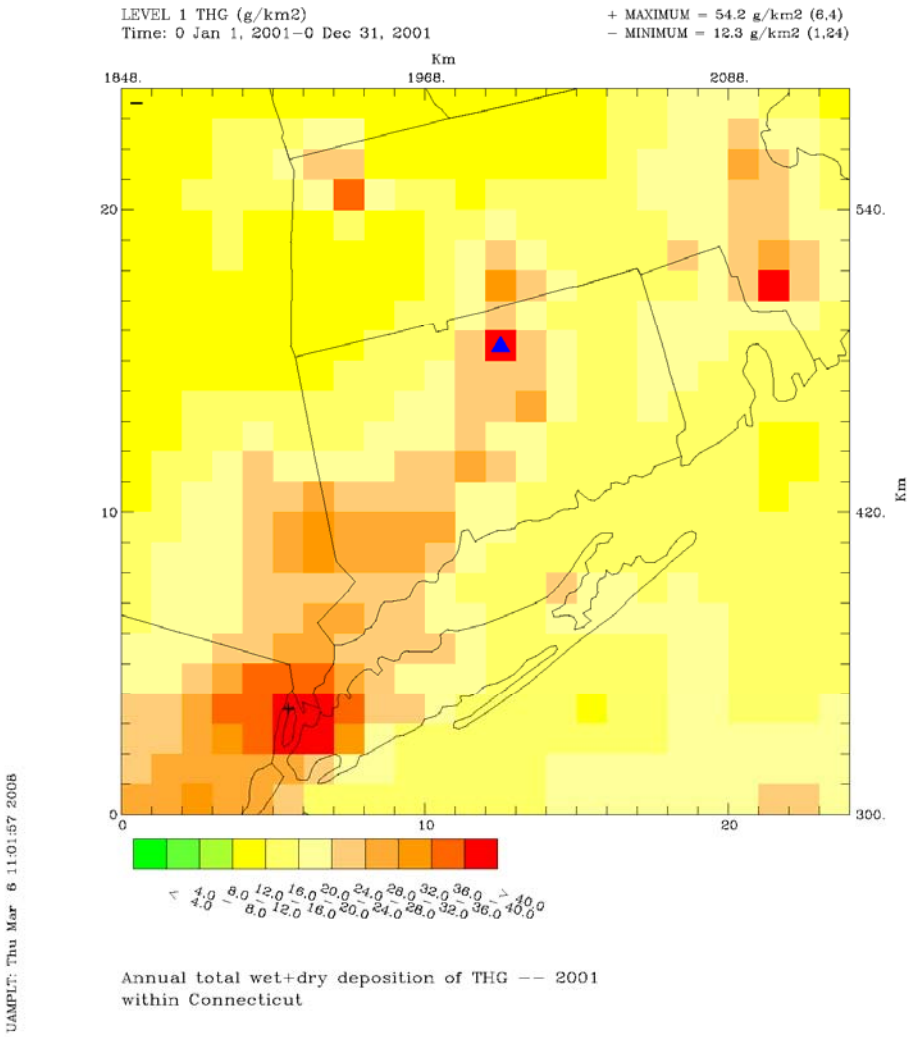
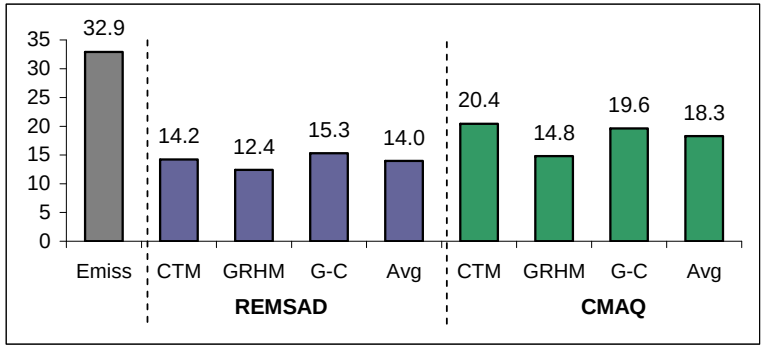


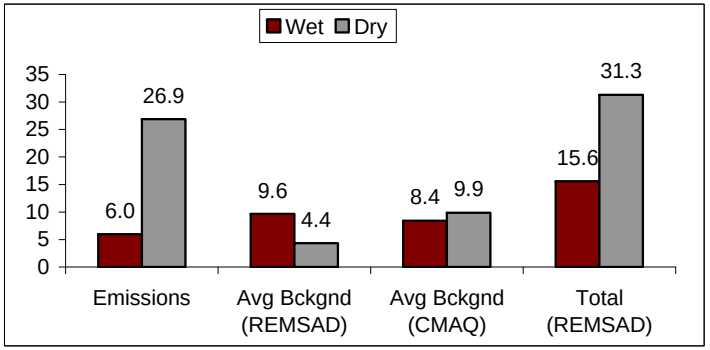
Figure 7-1b. Connecticut. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (46.9 g/km2).

**Connecticut**

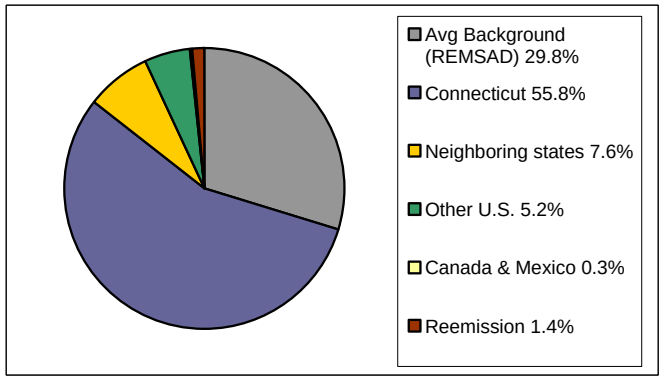
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



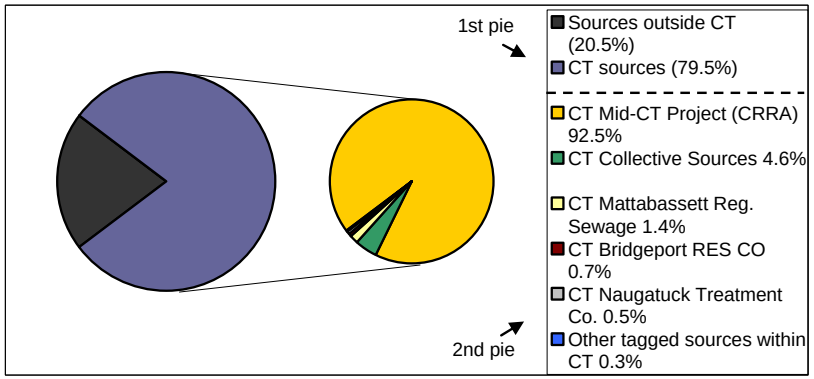

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Connecticut Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-2. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Maine.**

a.

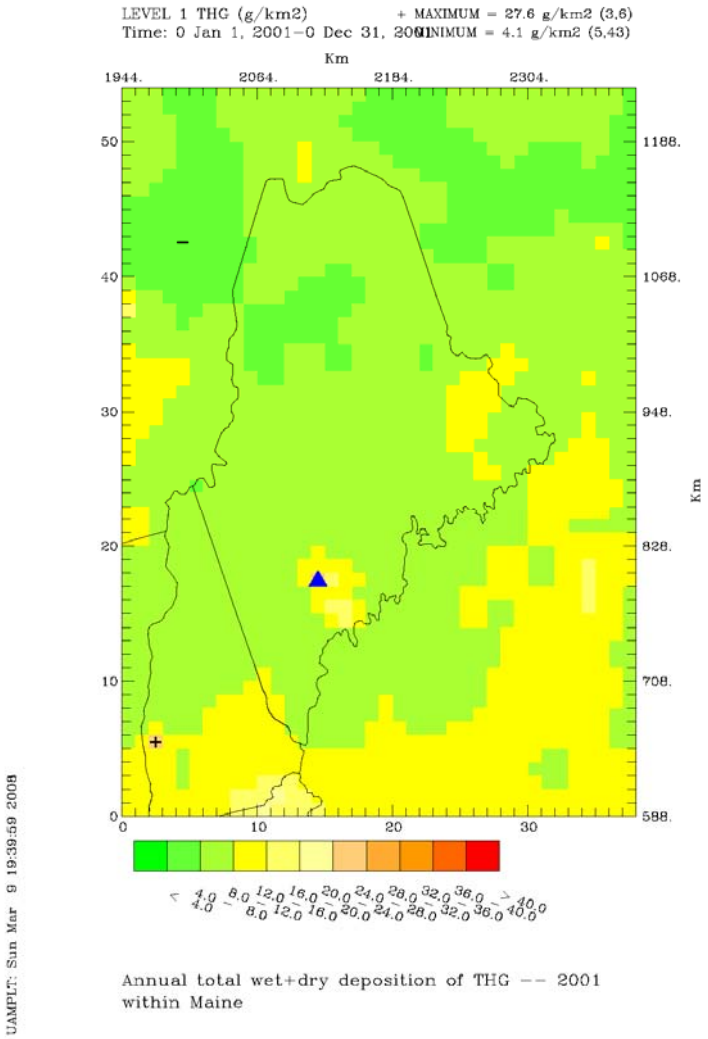
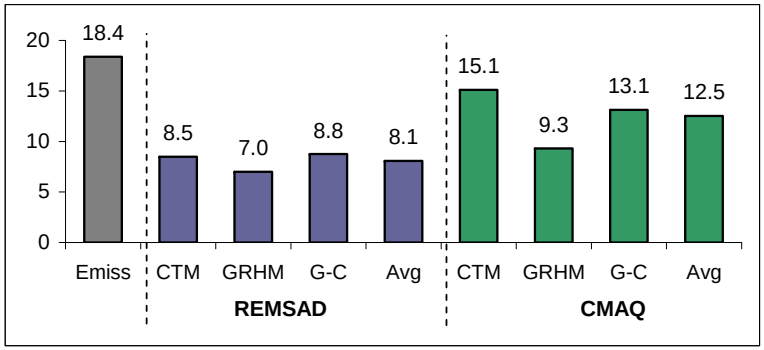


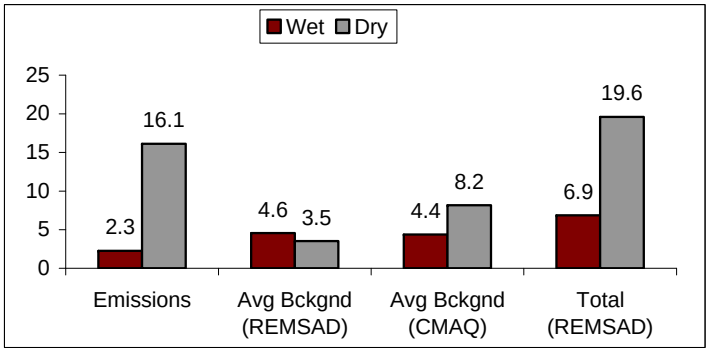
Figure 7-2b. Maine. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (26.5 g/km2).

**Maine**

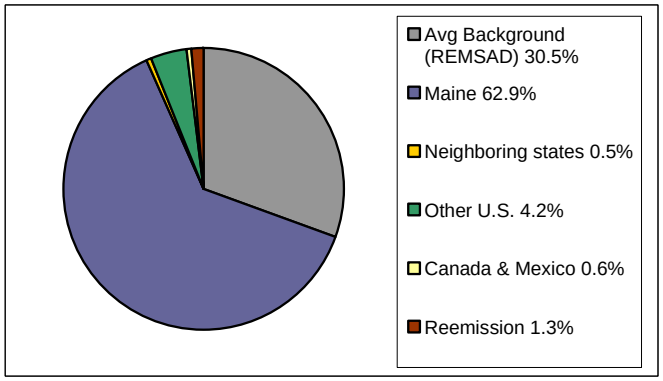
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



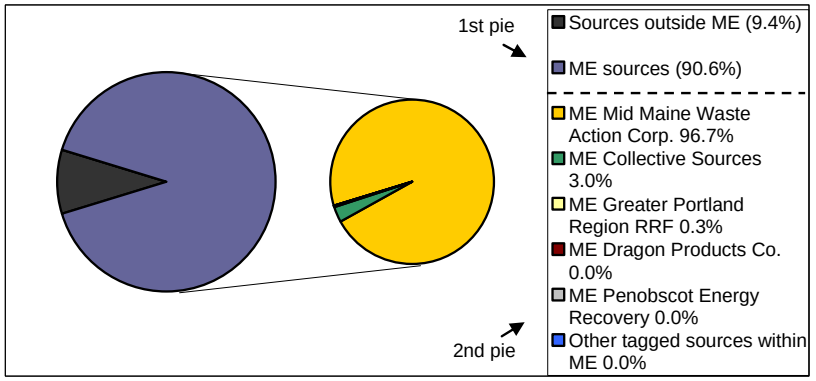

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Maine Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-3. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Massachusetts.**

a.

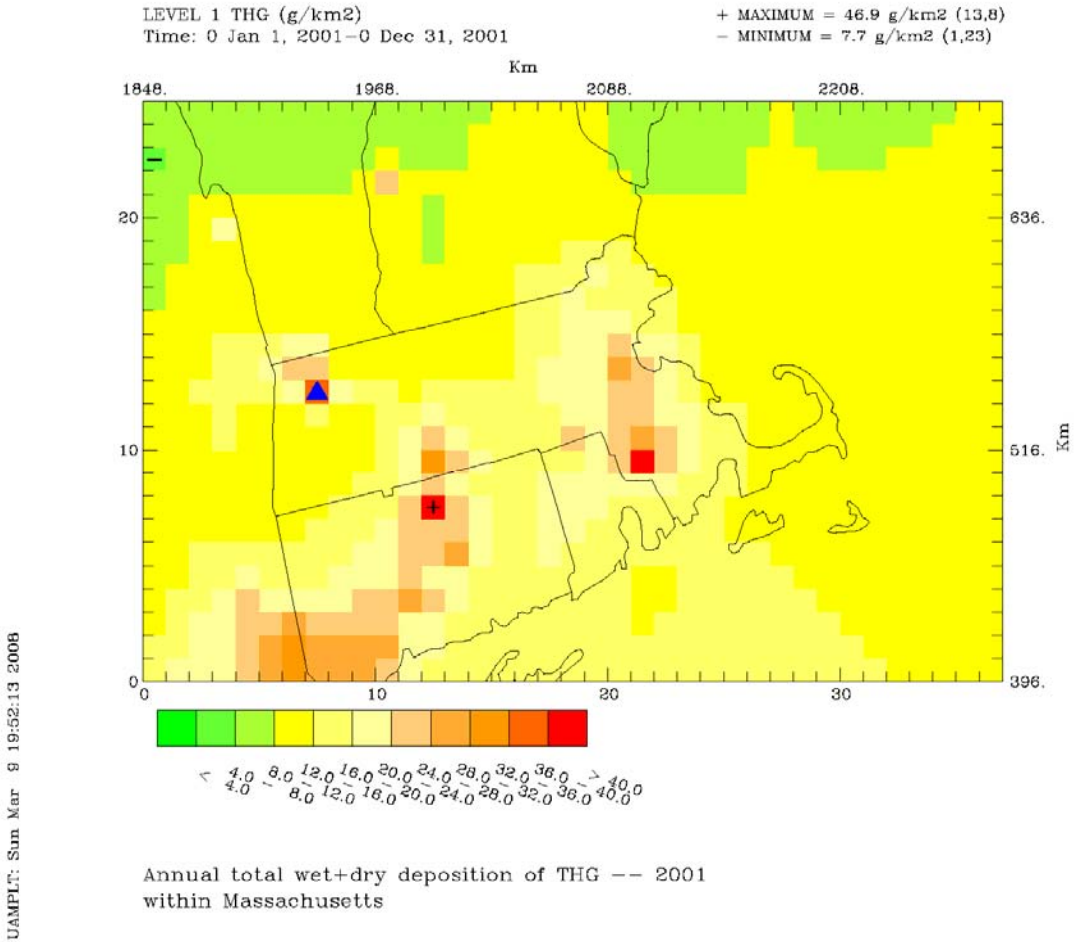
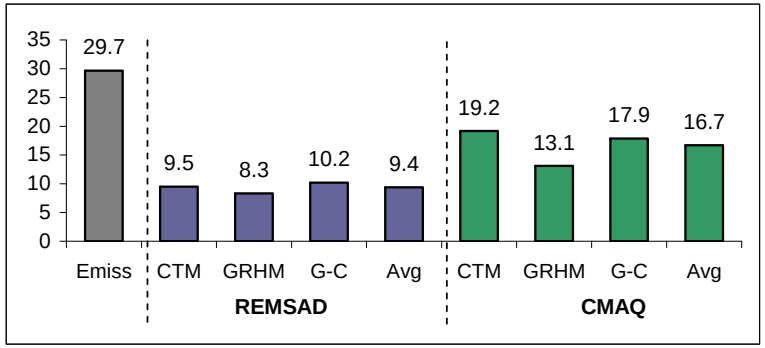


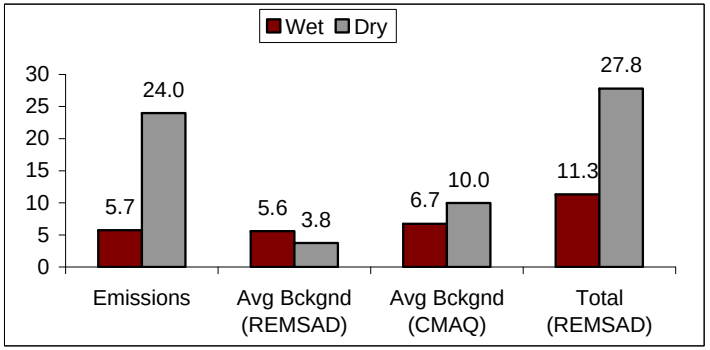
Figure 7-3b. Massachusetts. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (39.1 g/km2).

**Massachusetts**

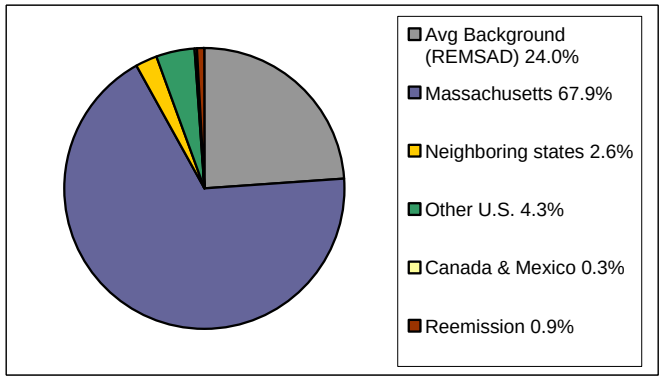
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



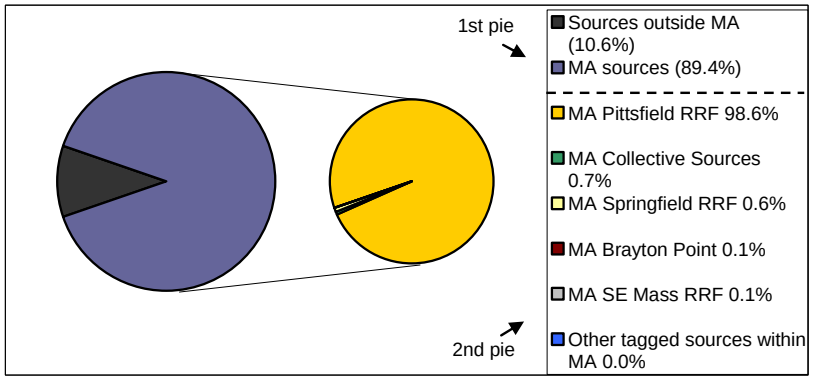

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Massachusetts Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-4. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for New Hampshire.**

a.

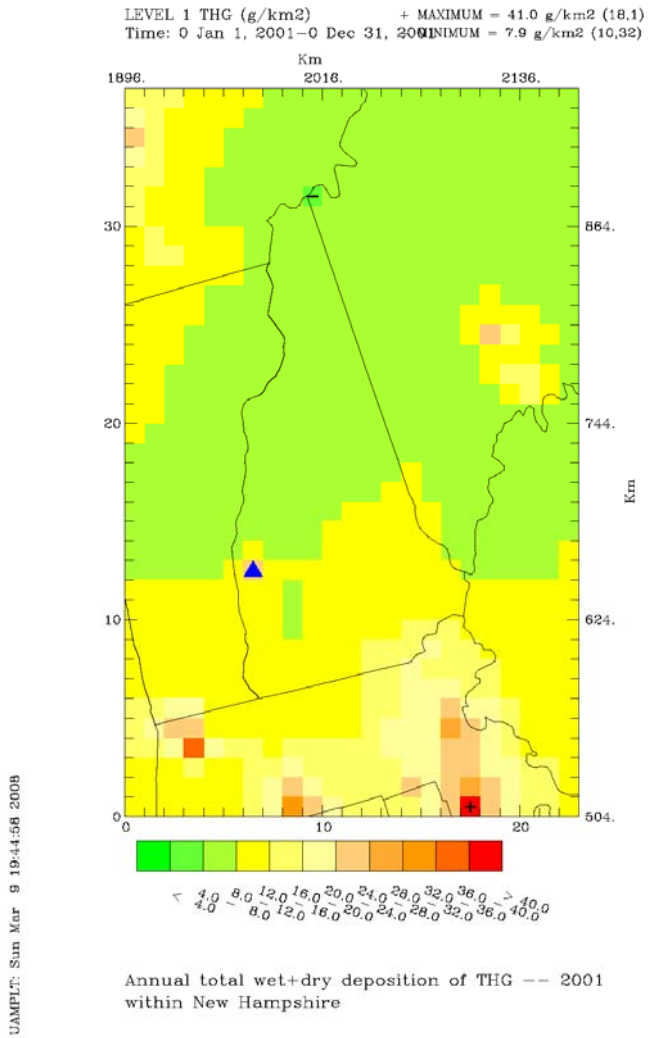
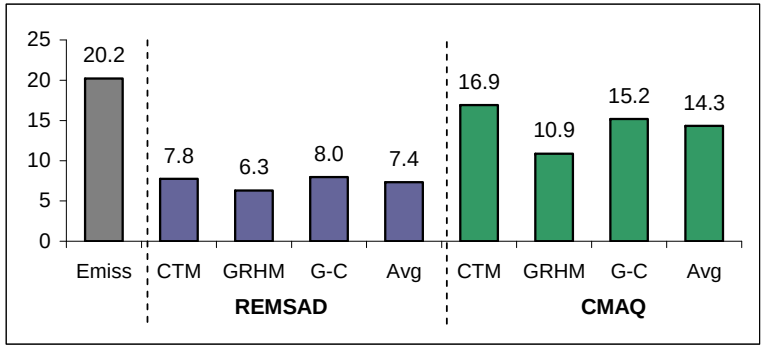


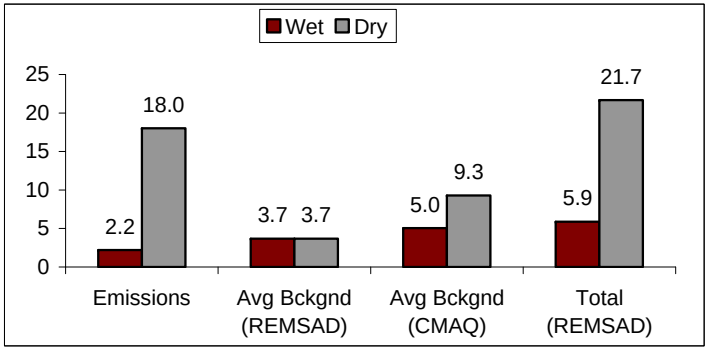
Figure 7-4b. New_Hampshire. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (27.6 g/km2).

**New_Hampshire**

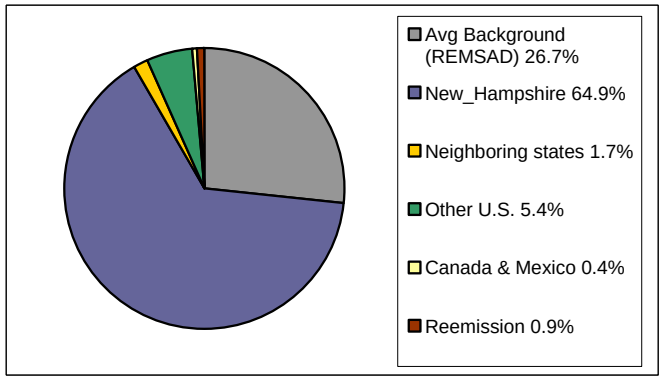
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



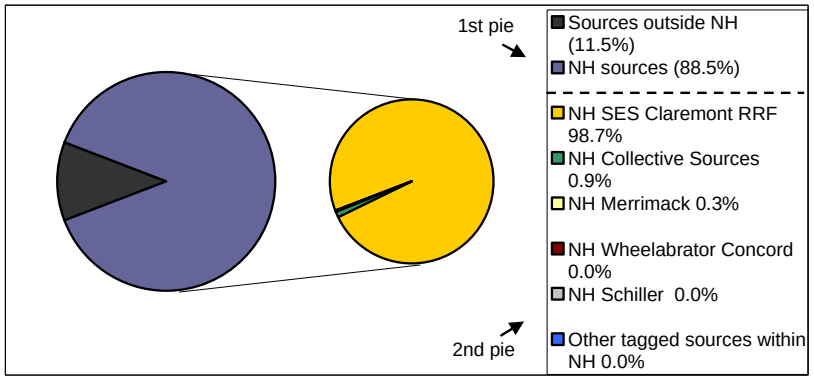

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from New_Hampshire Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-5. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Rhode Island .**

a.

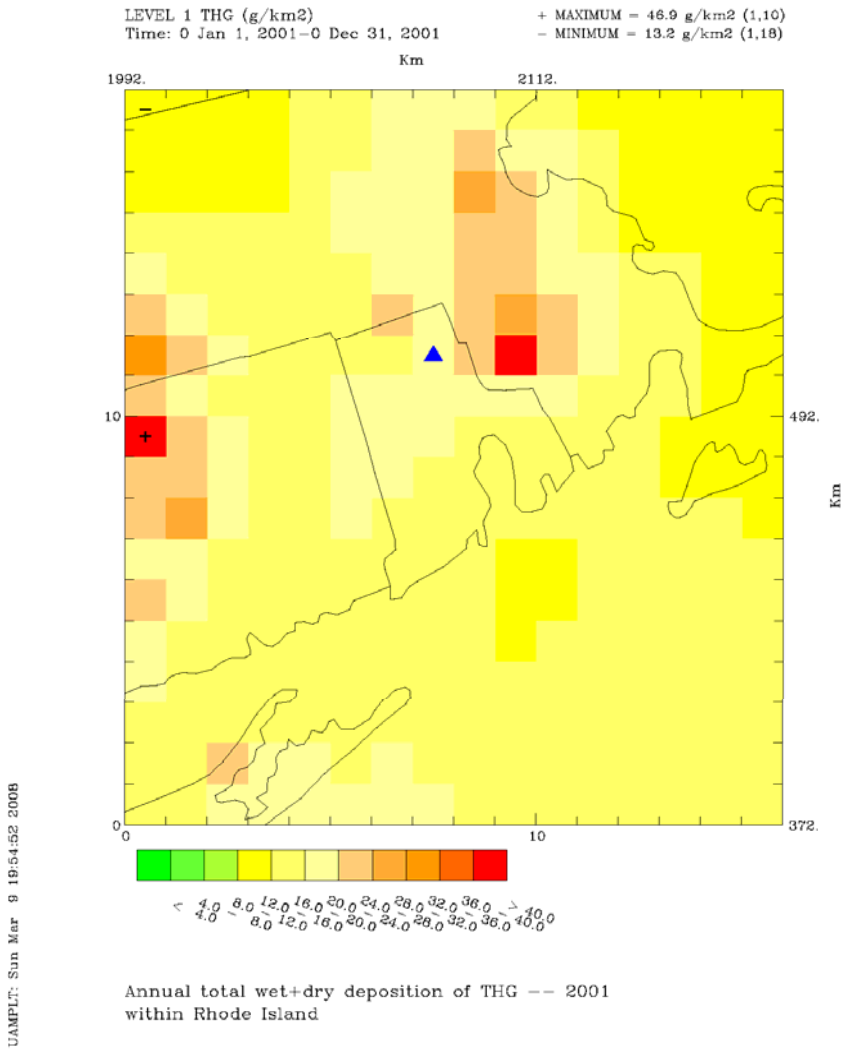
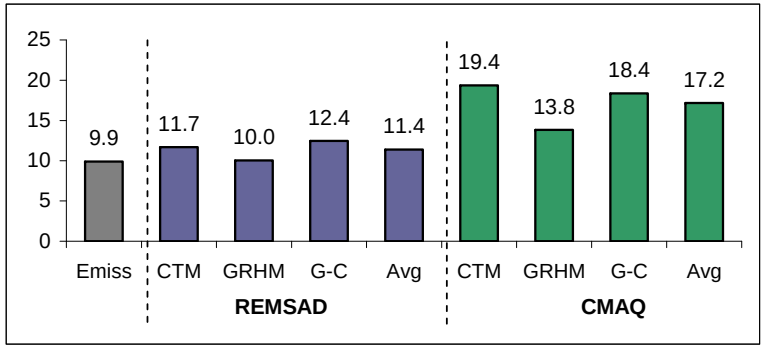


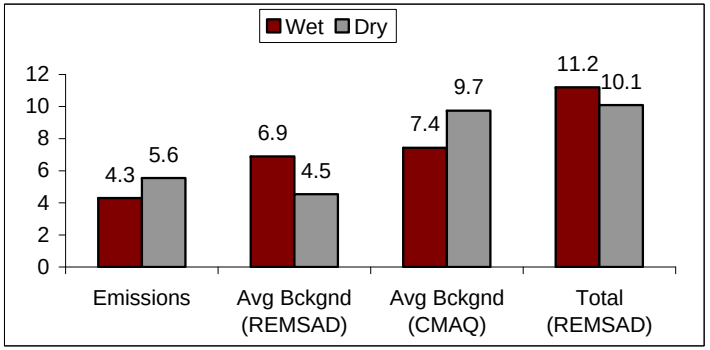
Figure 7-5b. Rhode_Island. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (21.3 g/km2).

**Rhode_Island**

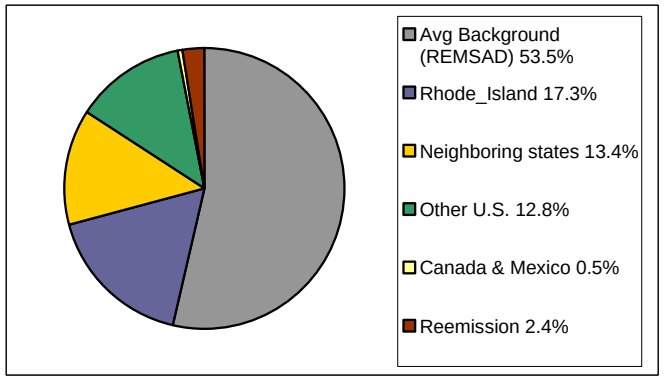
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



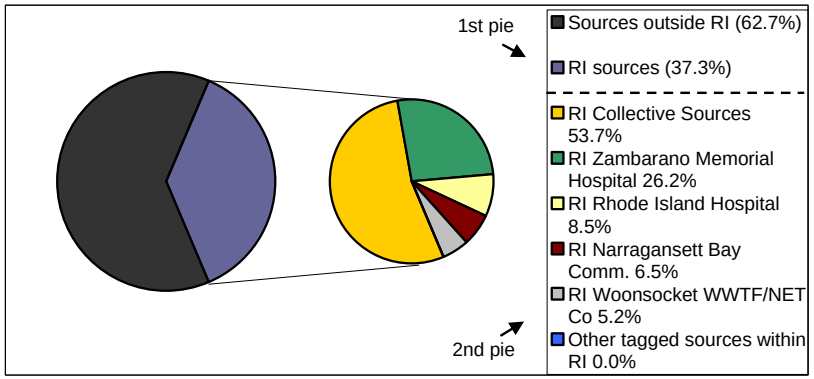

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Rhode_Island Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-6. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Vermont.**

a.

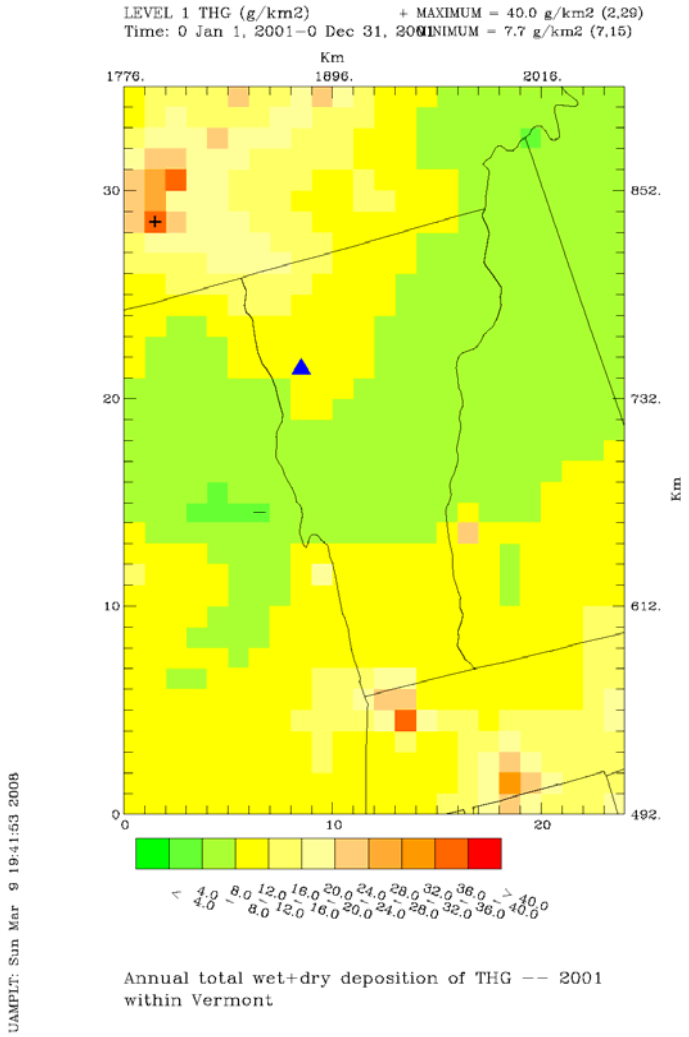
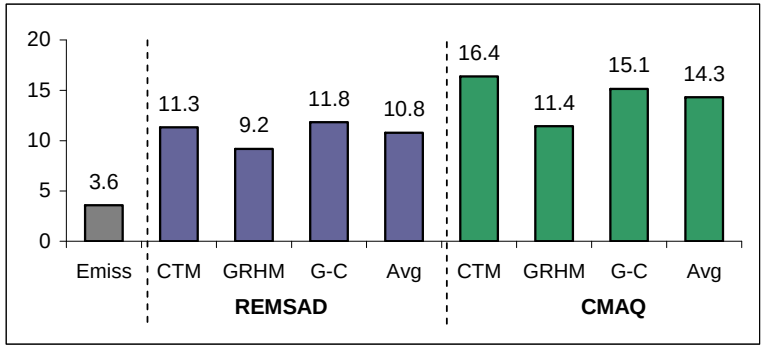


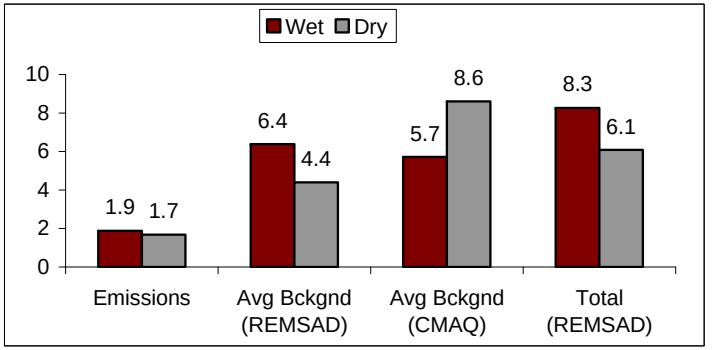
Figure 7-6b. Vermont. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (14.4 g/km2).

**Vermont**

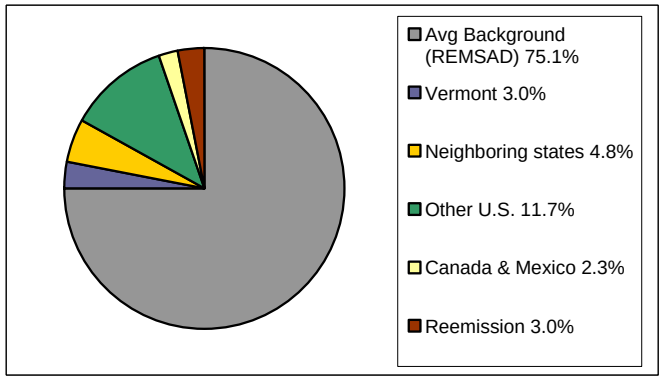
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



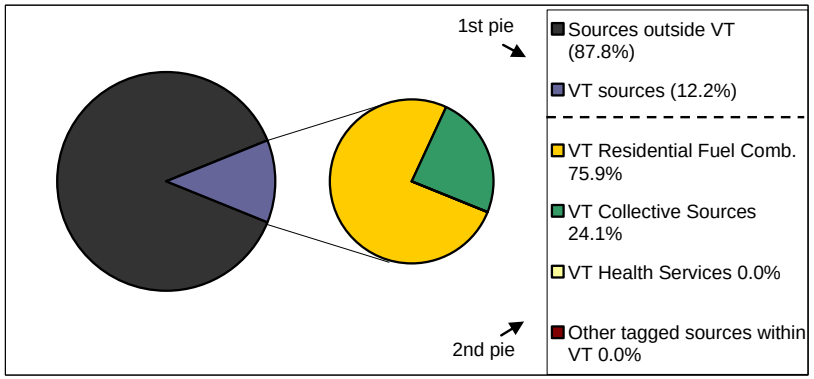

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Vermont Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-7. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for New Jersey.**

a.

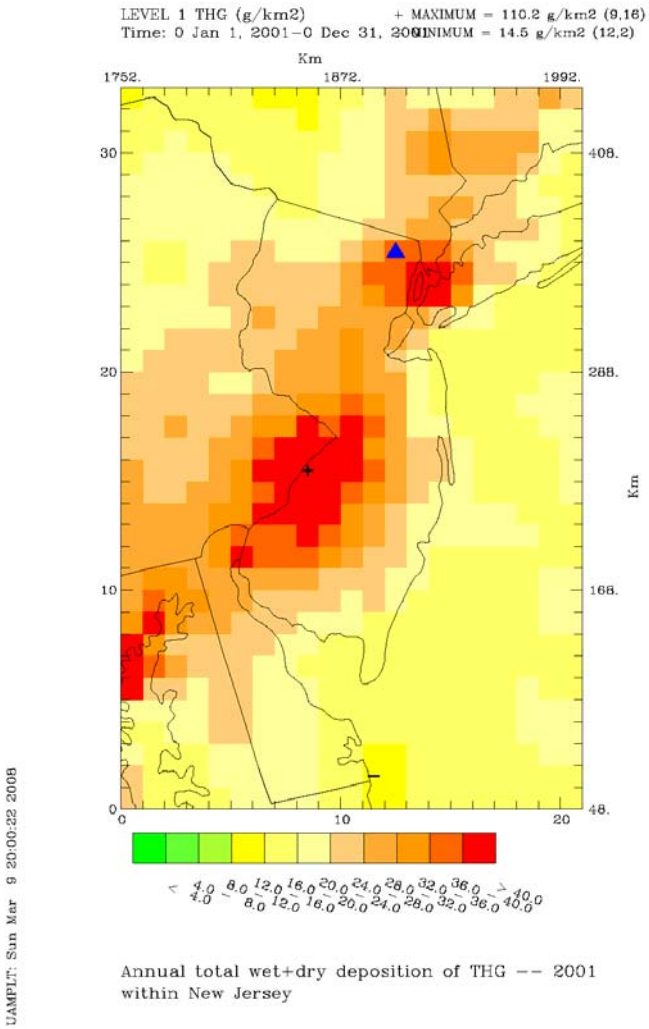
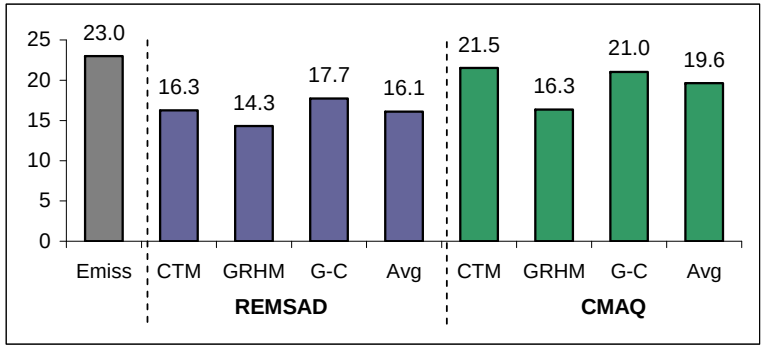


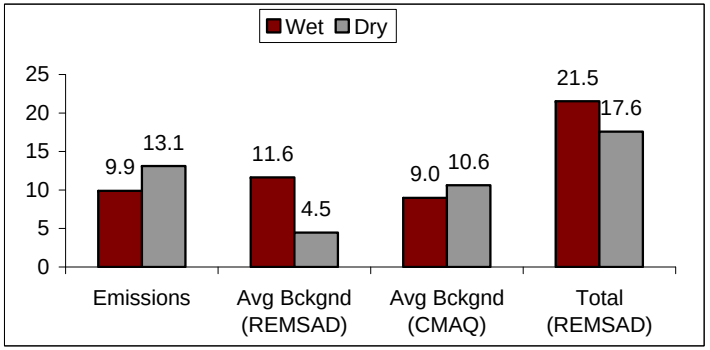
Figure 7-7b. New_Jersey. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (39.1 g/km2).

**New_Jersey**

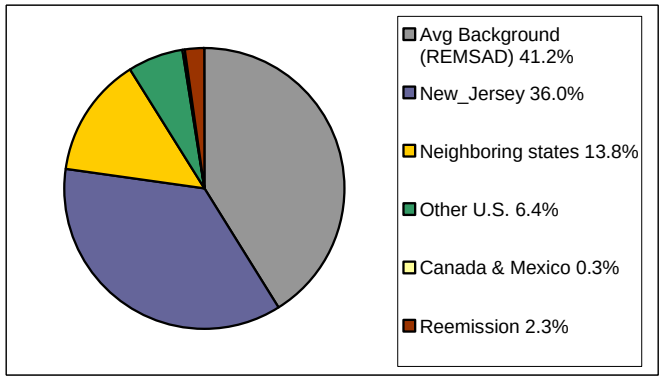
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



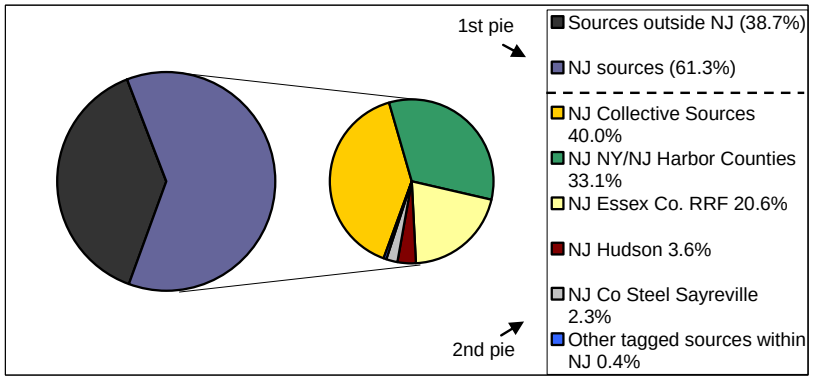

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from New_Jersey Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-8. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for New York.**

a.

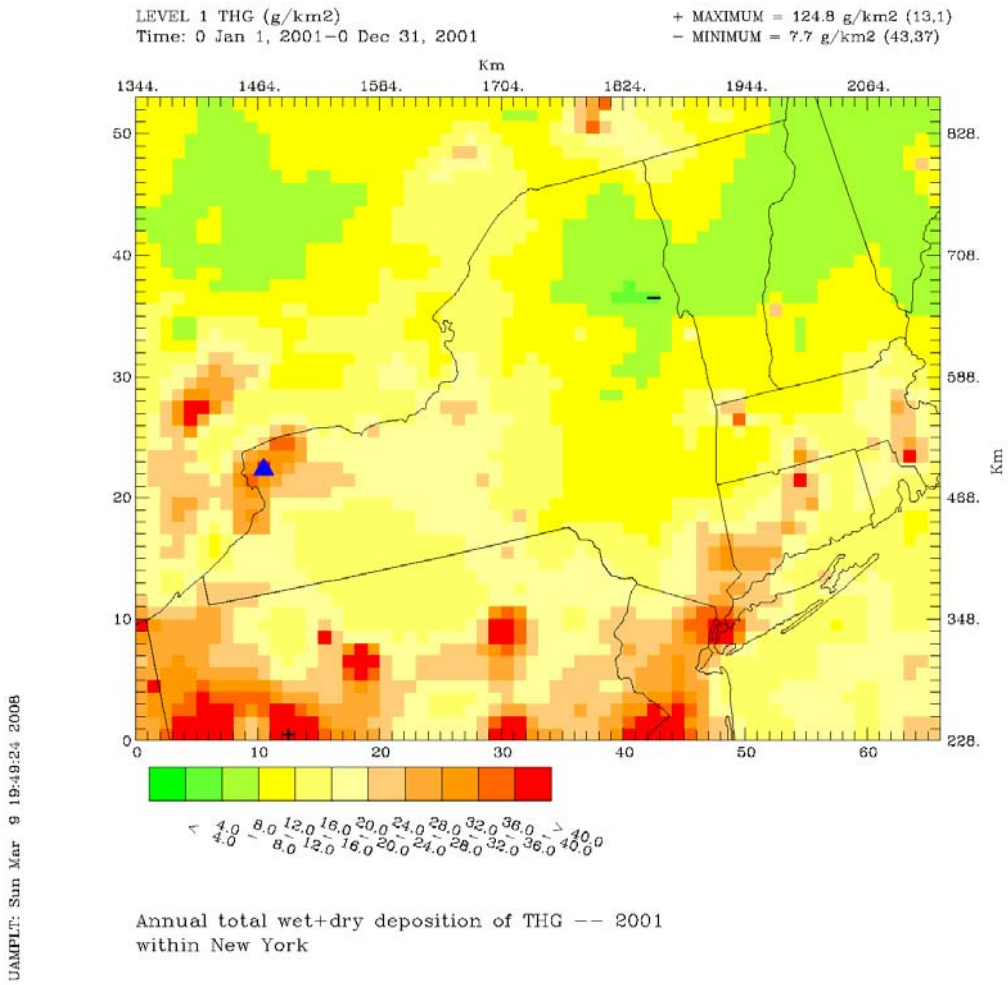
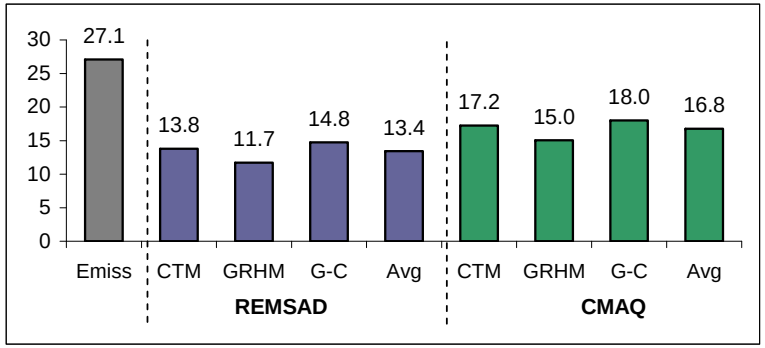


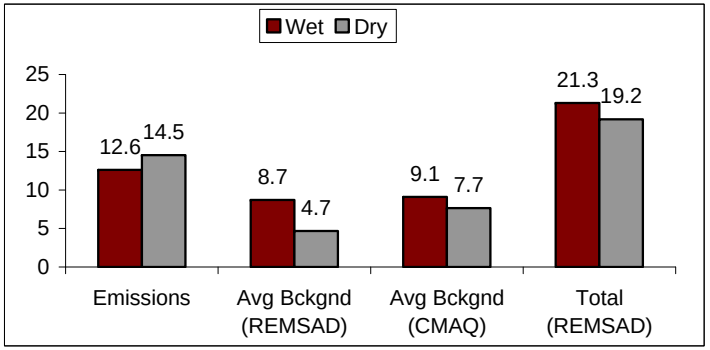
Figure 7-8b. New_York. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (40.5 g/km2).

**New_York**

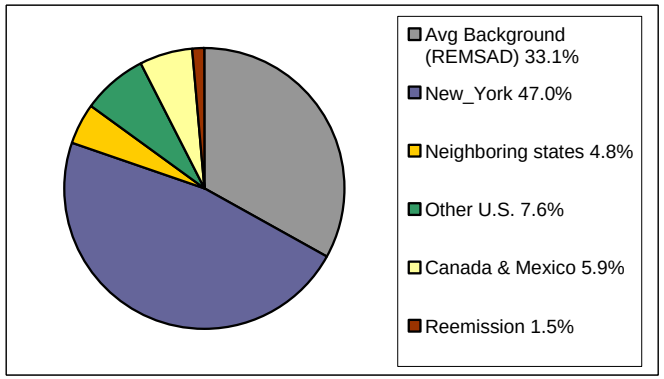
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



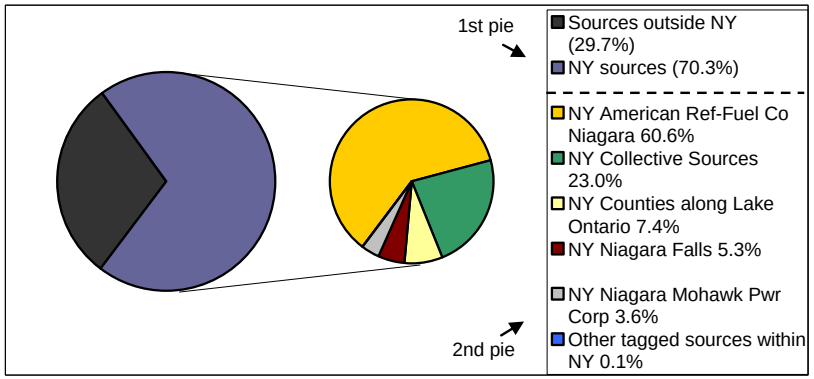

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from New_York Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-9. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Delaware.**

a.

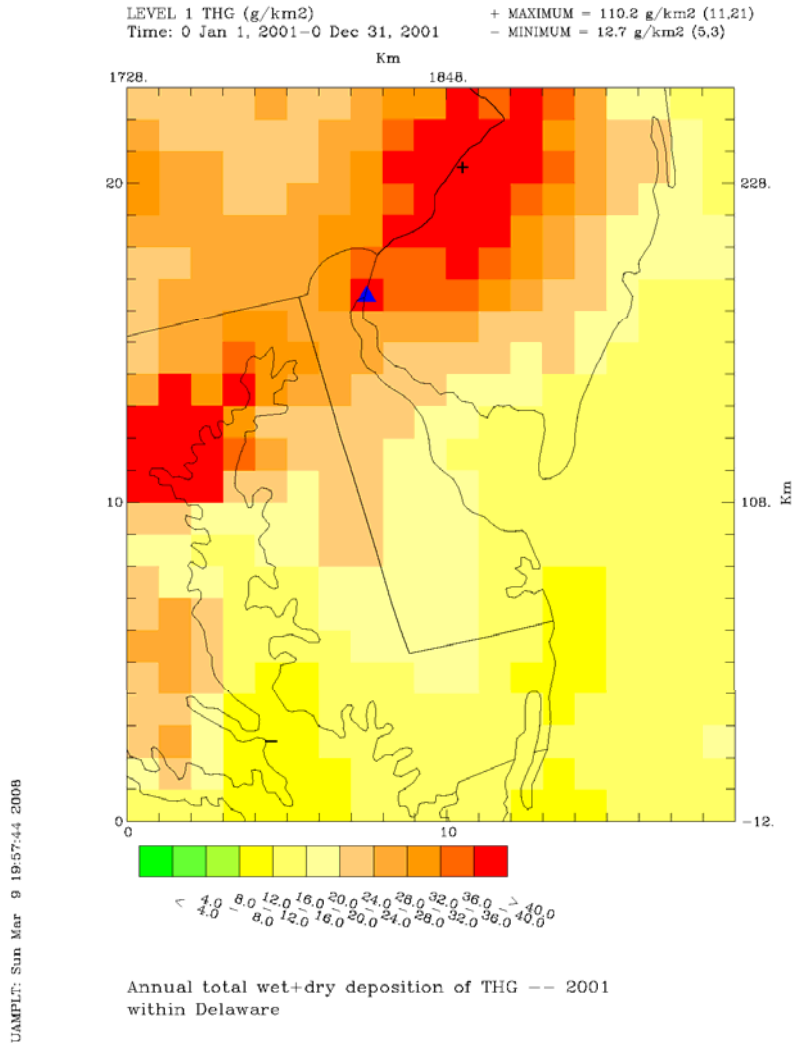
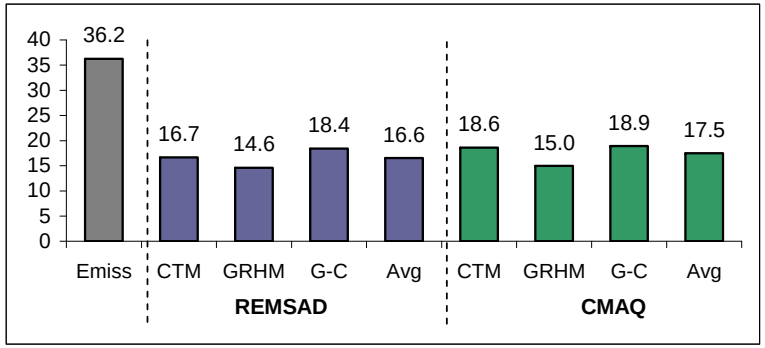


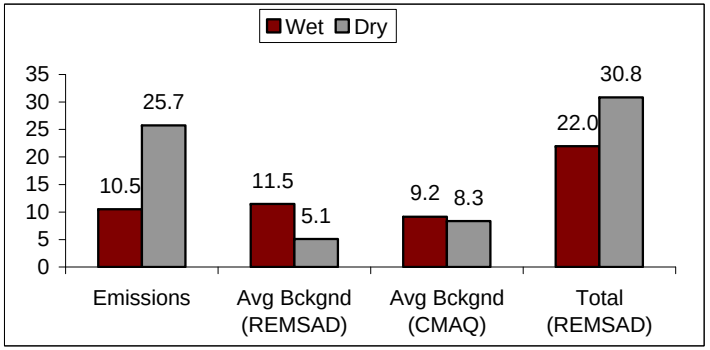
Figure 7-9b. Delaware. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (52.8 g/km2).

**Delaware**

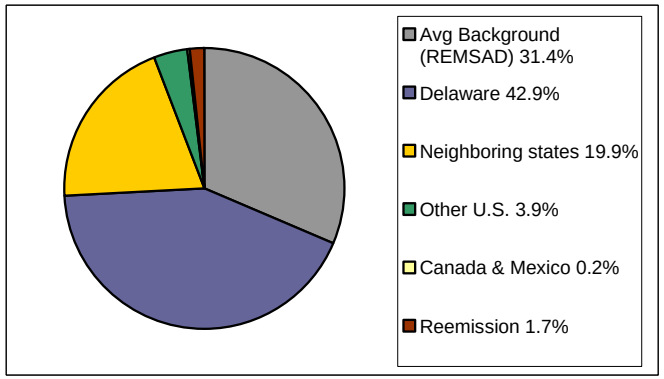
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



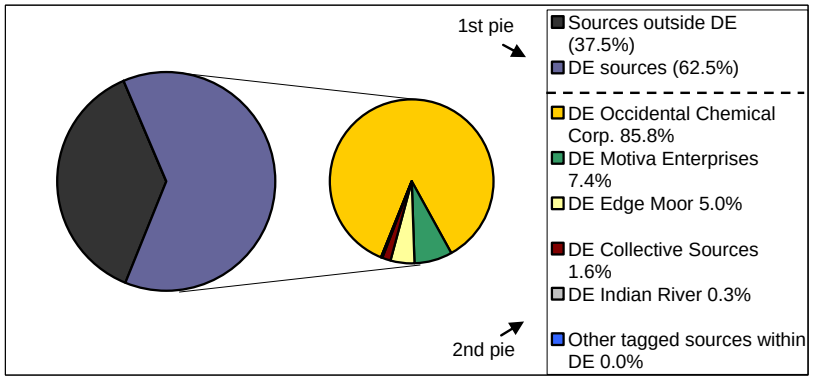

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Delaware Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-10. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Washington, D.C.**

a.

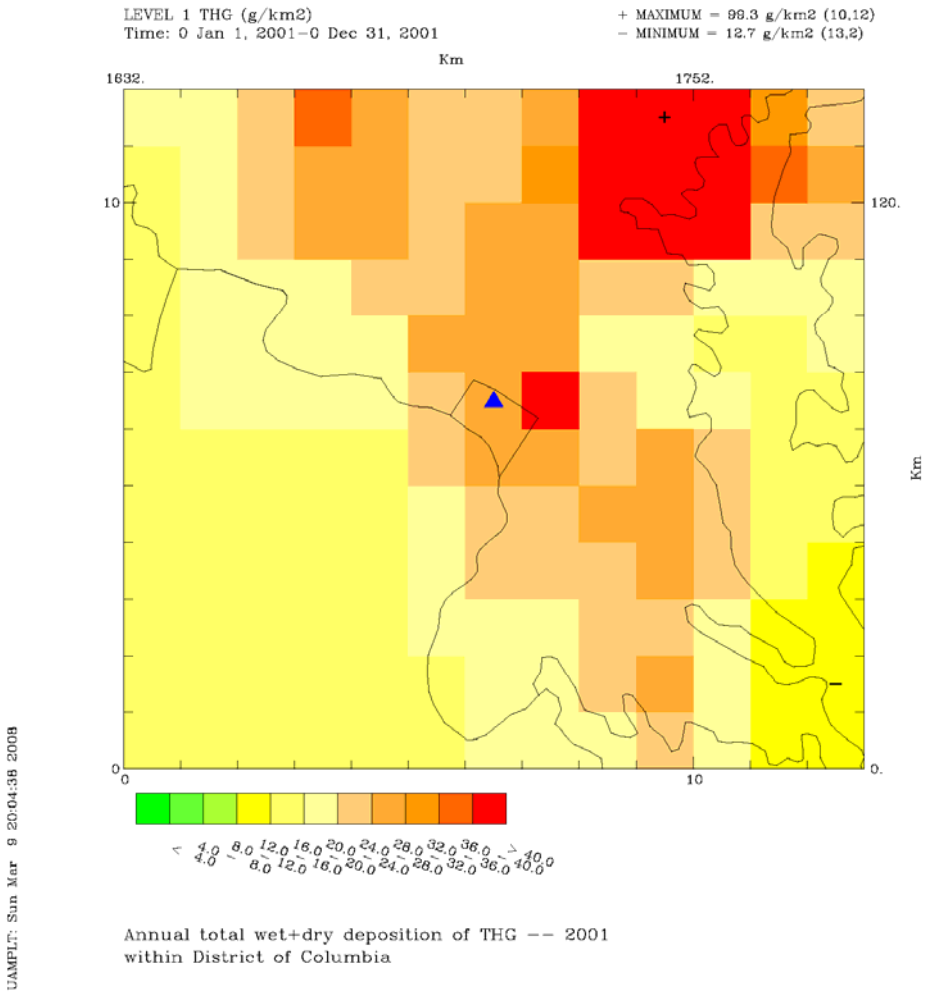
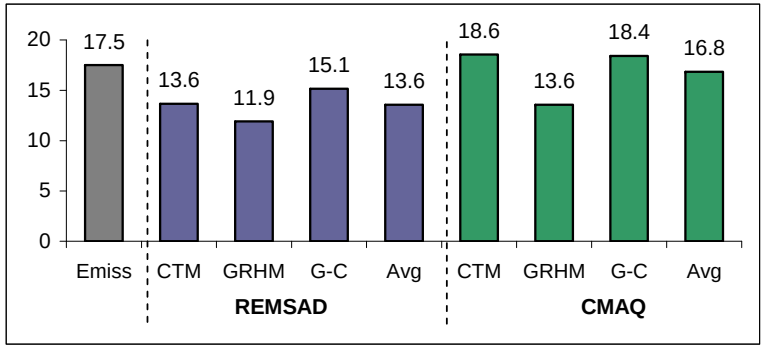


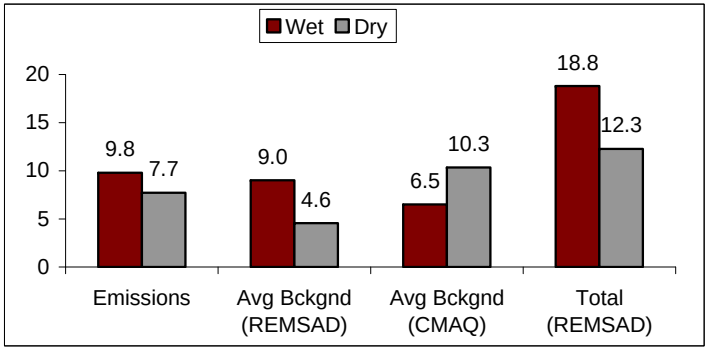
Figure 7-10b. Washington DC. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (31.1 g/km2).

**Washington DC**

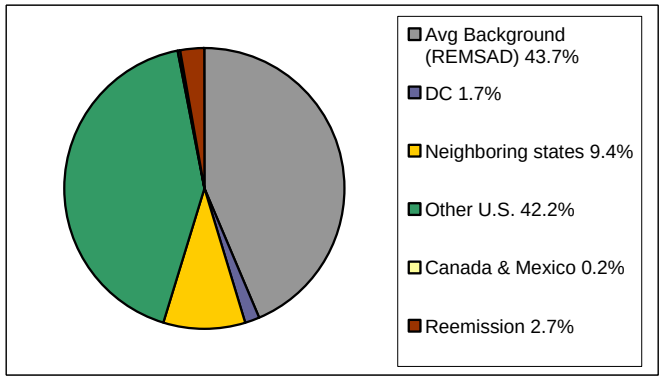
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



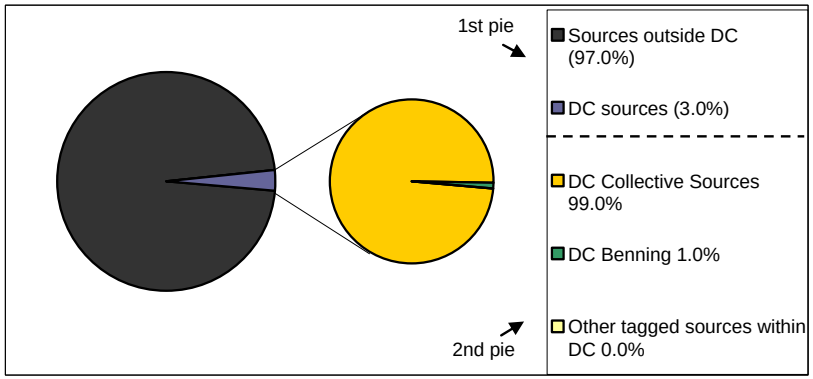

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from DC Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-11. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Maryland.**

a.

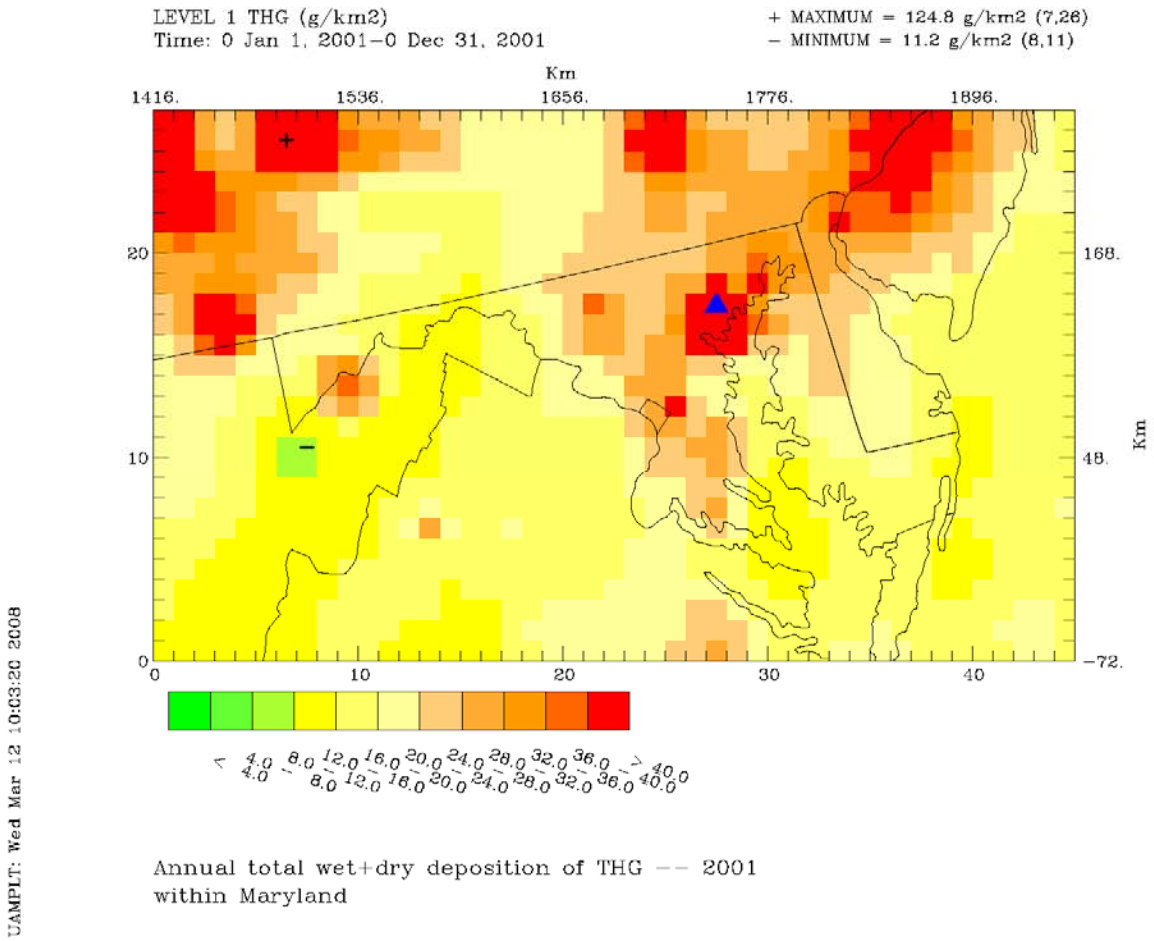
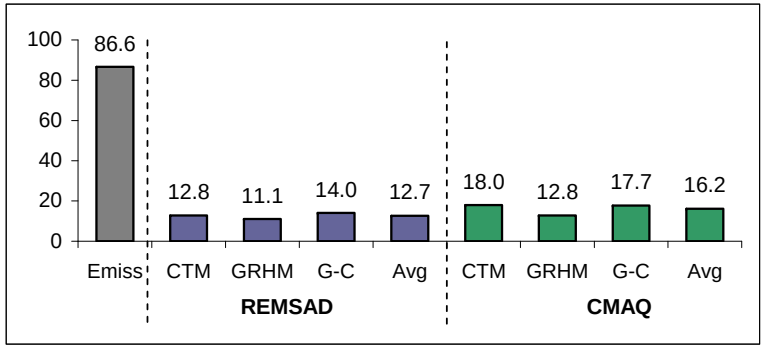


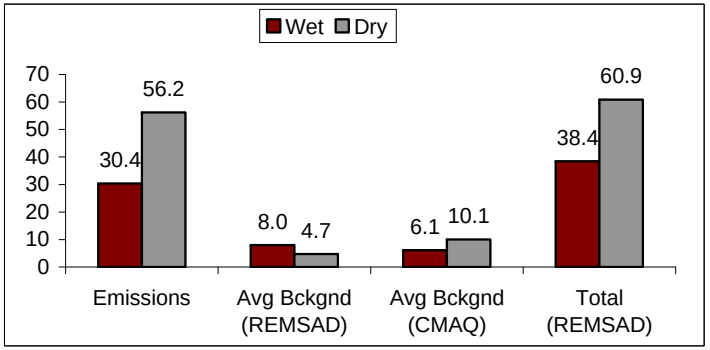
Figure 7-11b. Maryland. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (99.3 g/km2).

**Maryland**

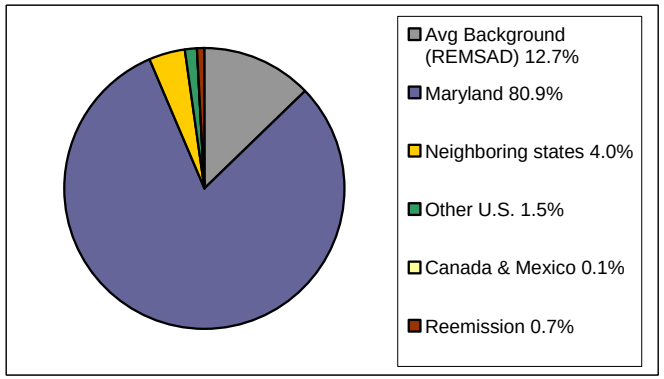
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



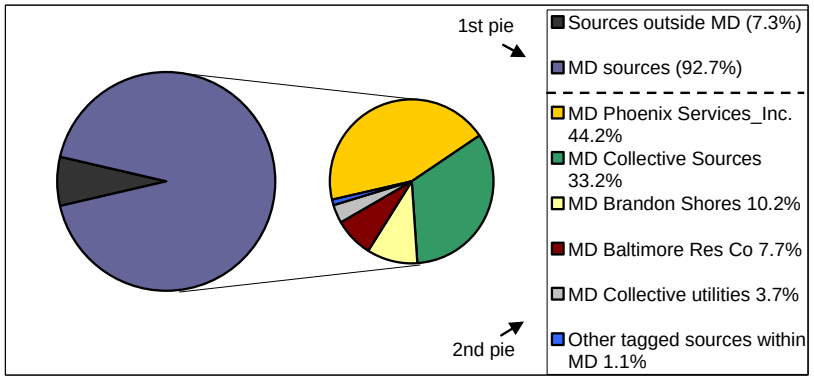

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Maryland Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-12. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Pennsylvania.**

a.

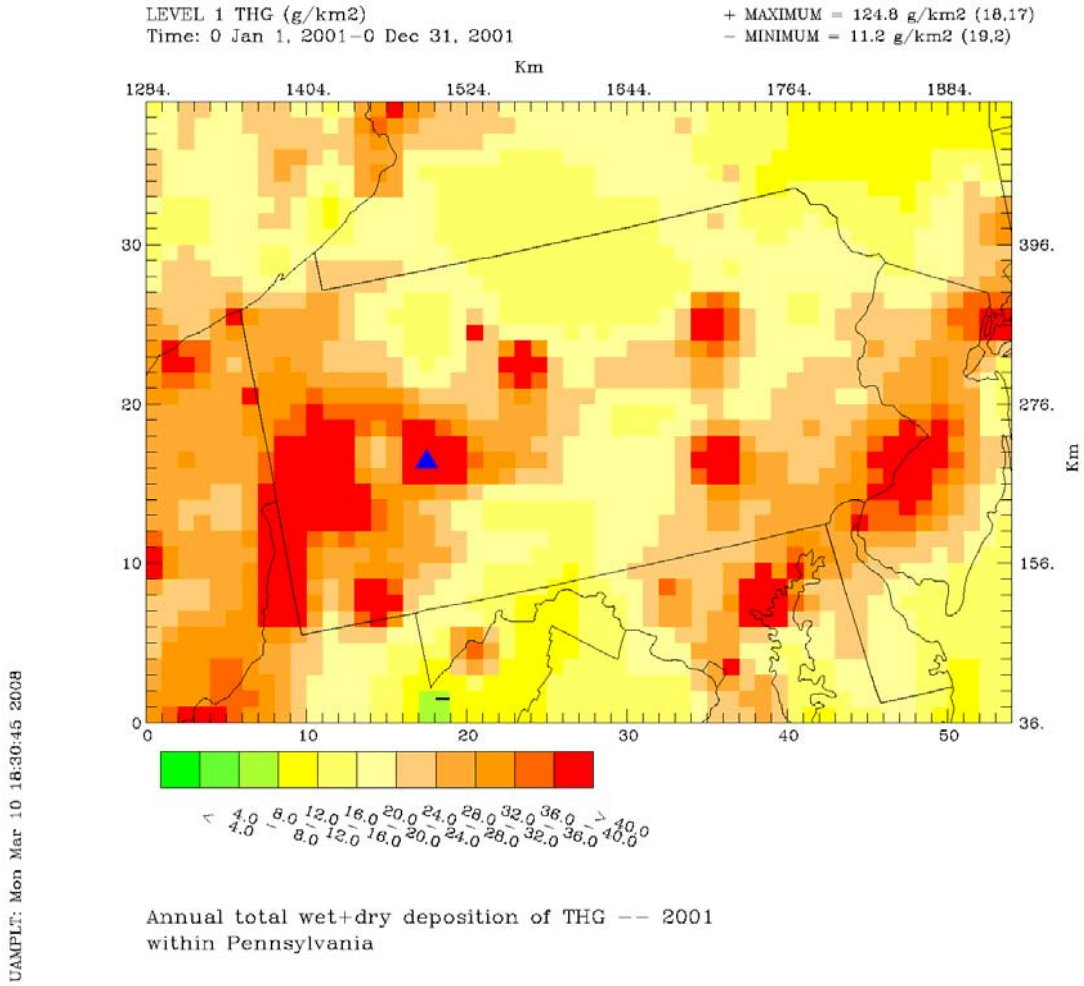
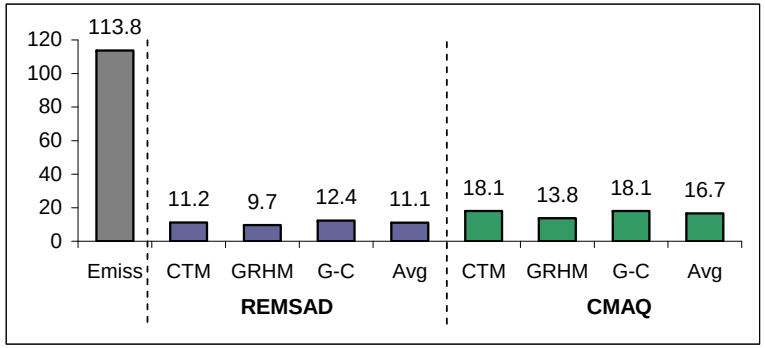


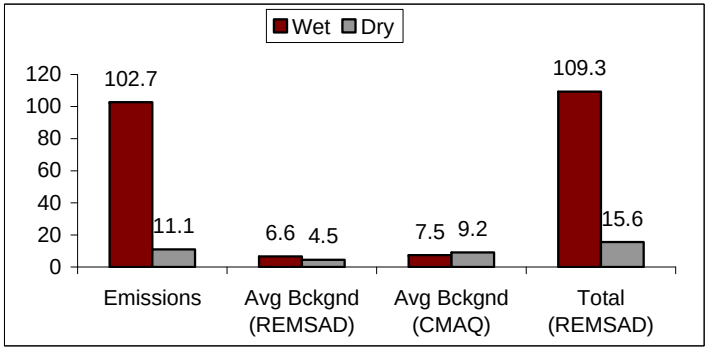
Figure 7-12b. Pennsylvania. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (124.9 g/km2).

**Pennsylvania**

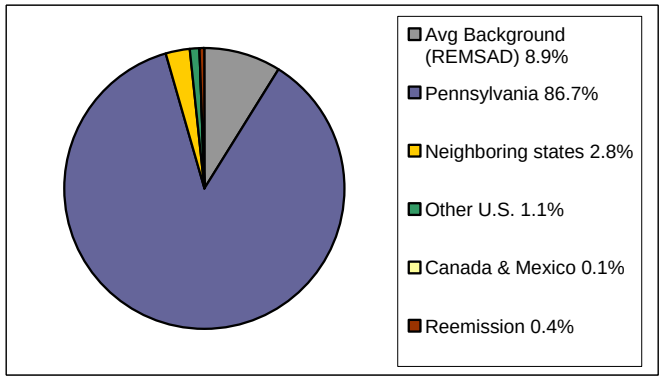
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



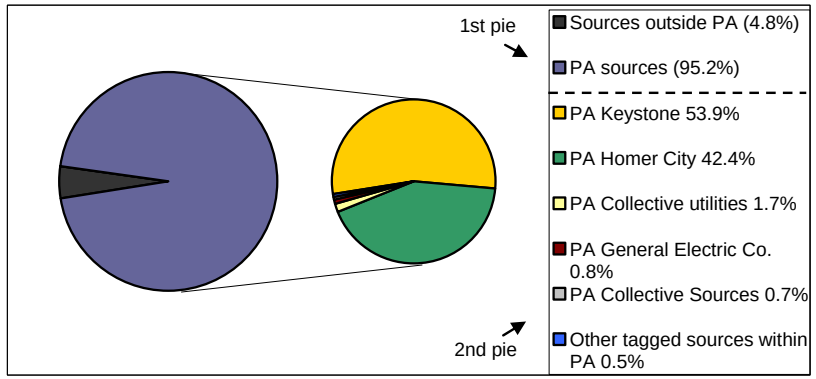

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Pennsylvania Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-13. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Virginia.**

a.

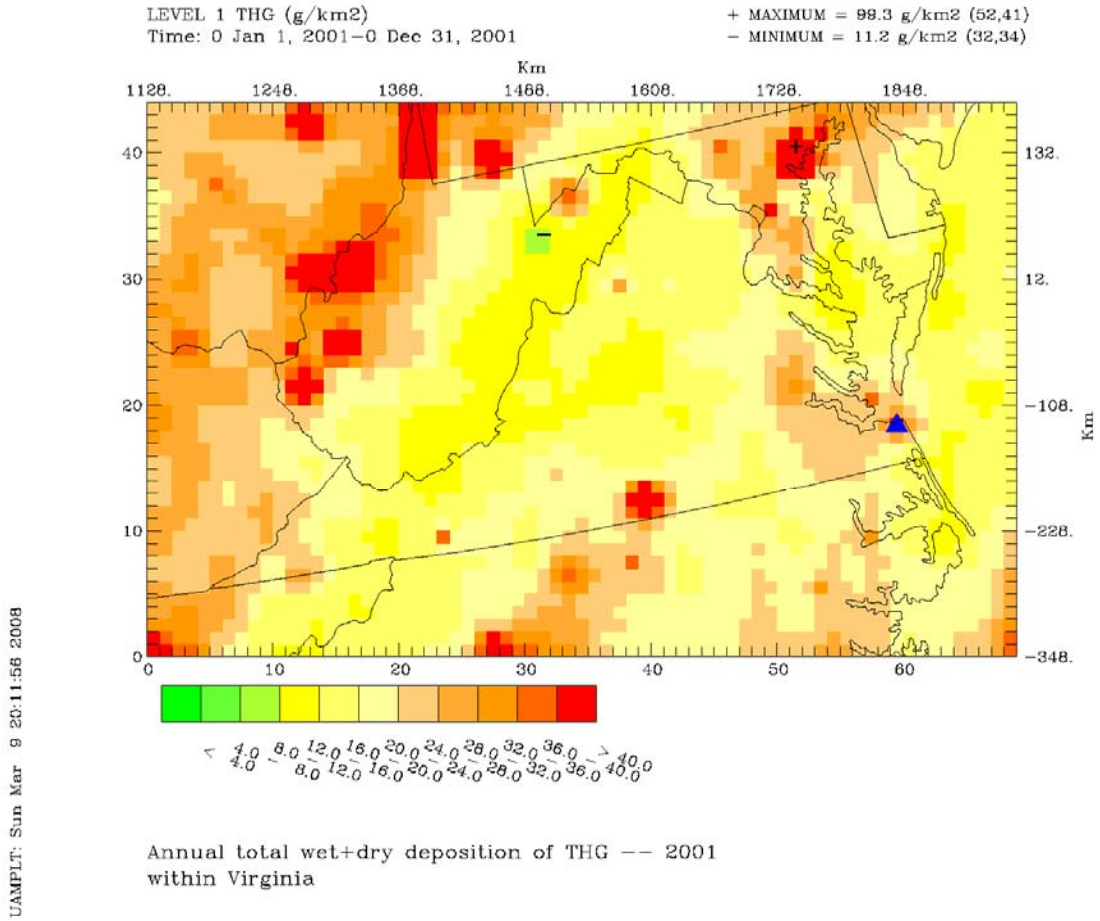
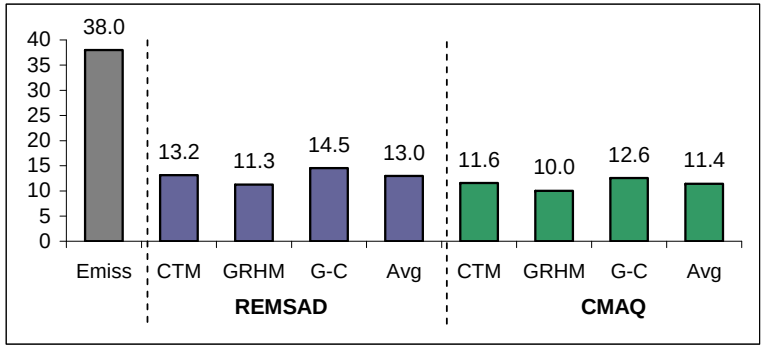


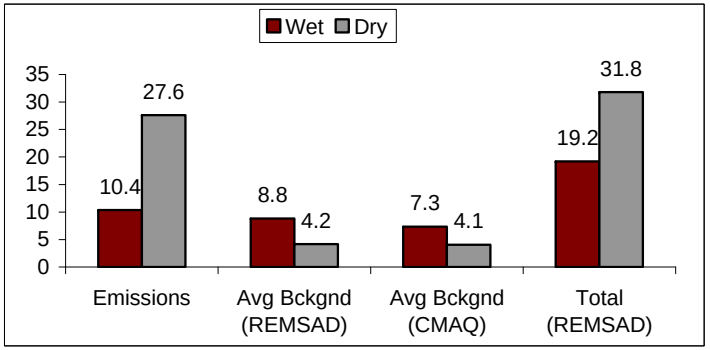
Figure 7-13b. Virginia. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (51.0 g/km2).

**Virginia**

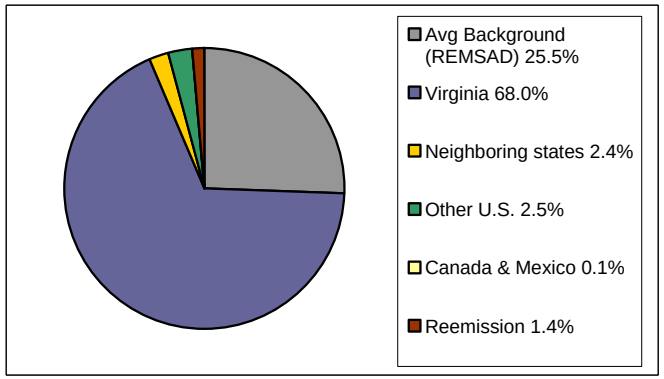
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



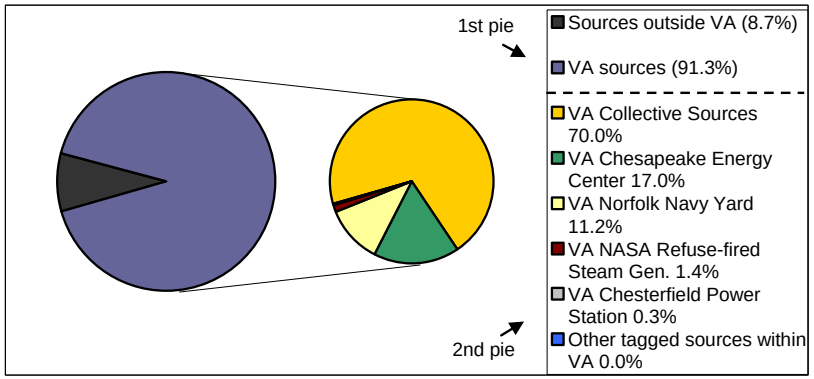

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Virginia Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-14. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for West Virginia.**

a.

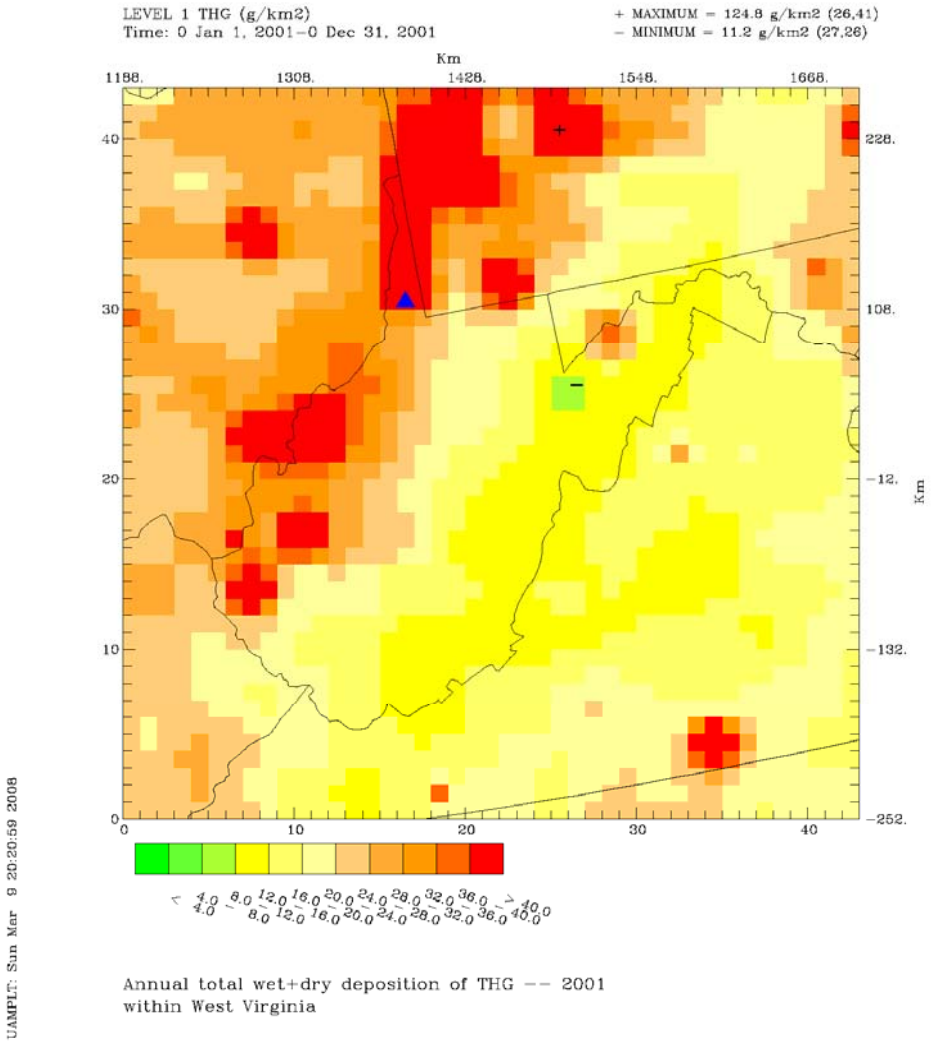
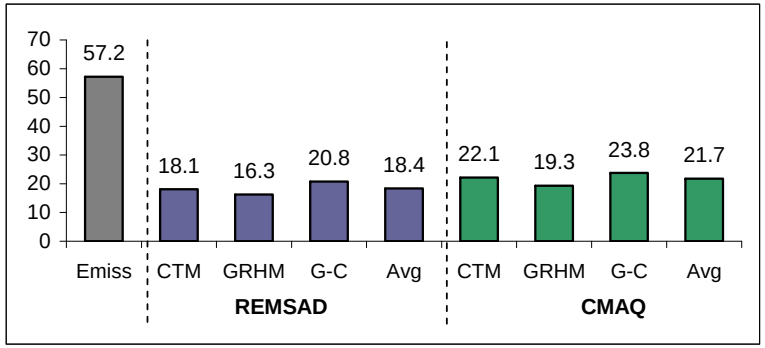


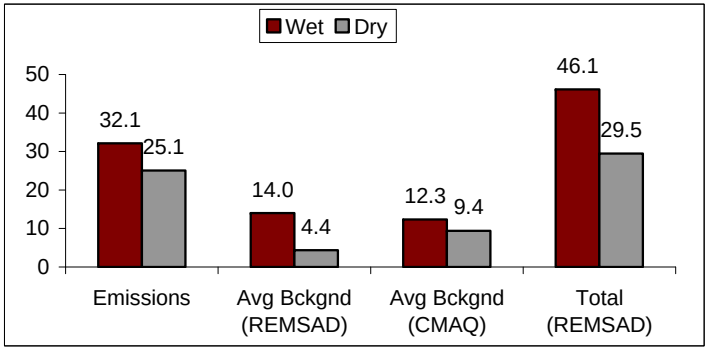
Figure 7-14b. West_Virginia. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (75.6 g/km2).

**West_Virginia**

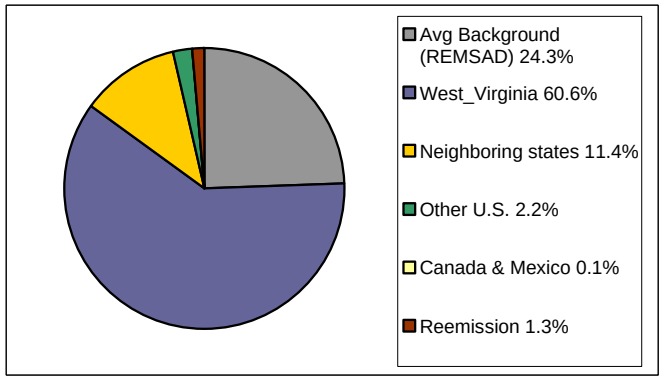
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



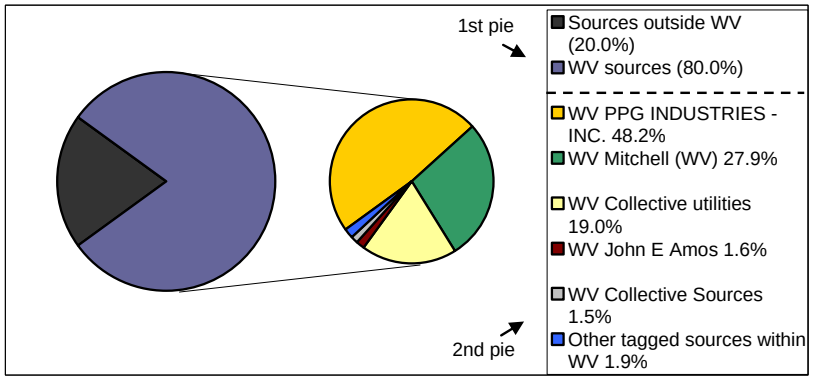

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from West_Virginia Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-15. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Alabama.**

a.

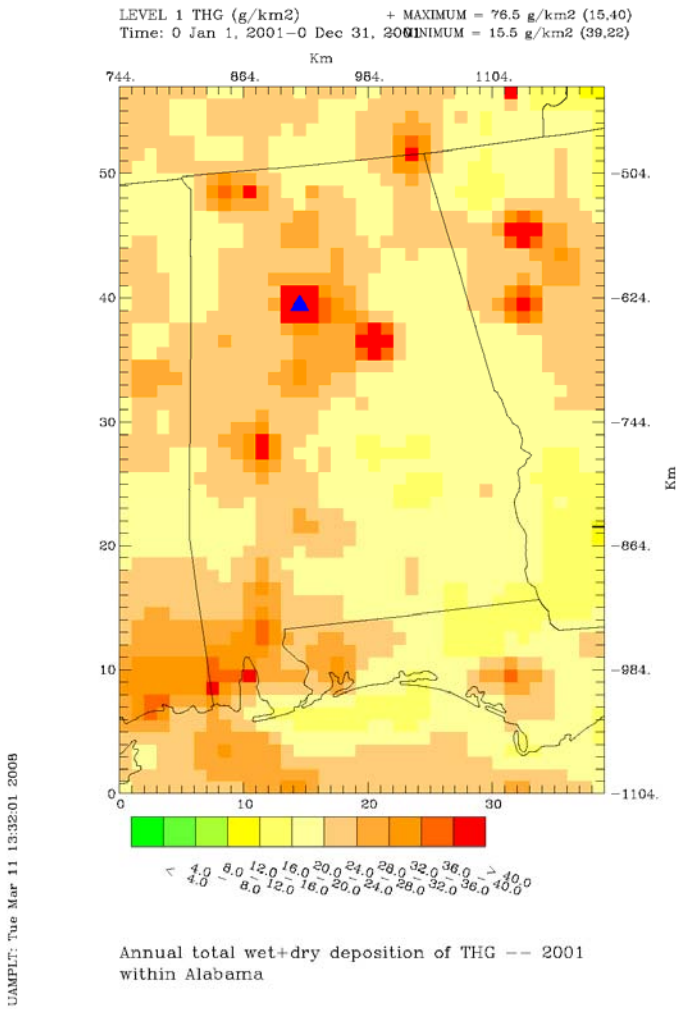
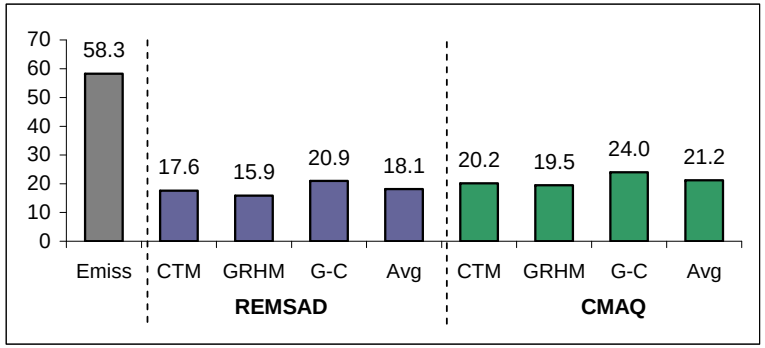


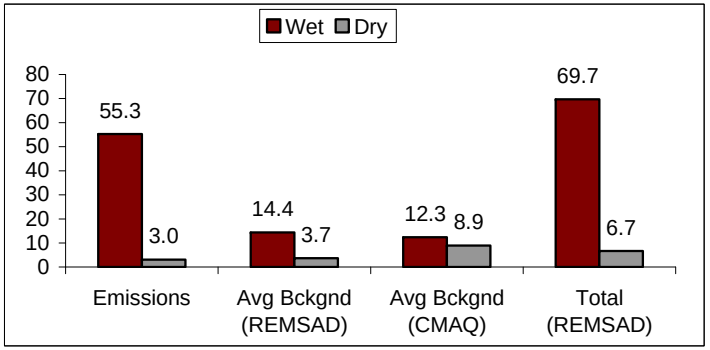
Figure 7-15b. Alabama. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (76.4 g/km2).

**Alabama**

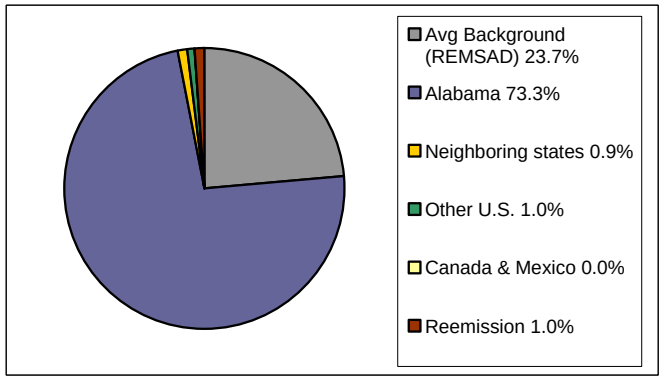
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



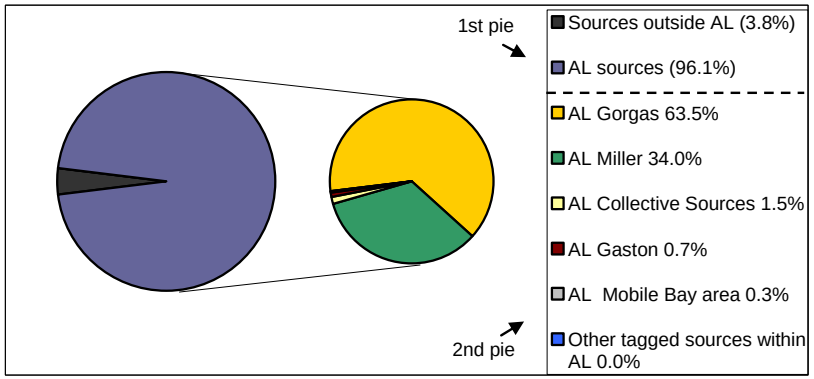

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Alabama Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-16. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Florida.**

a.

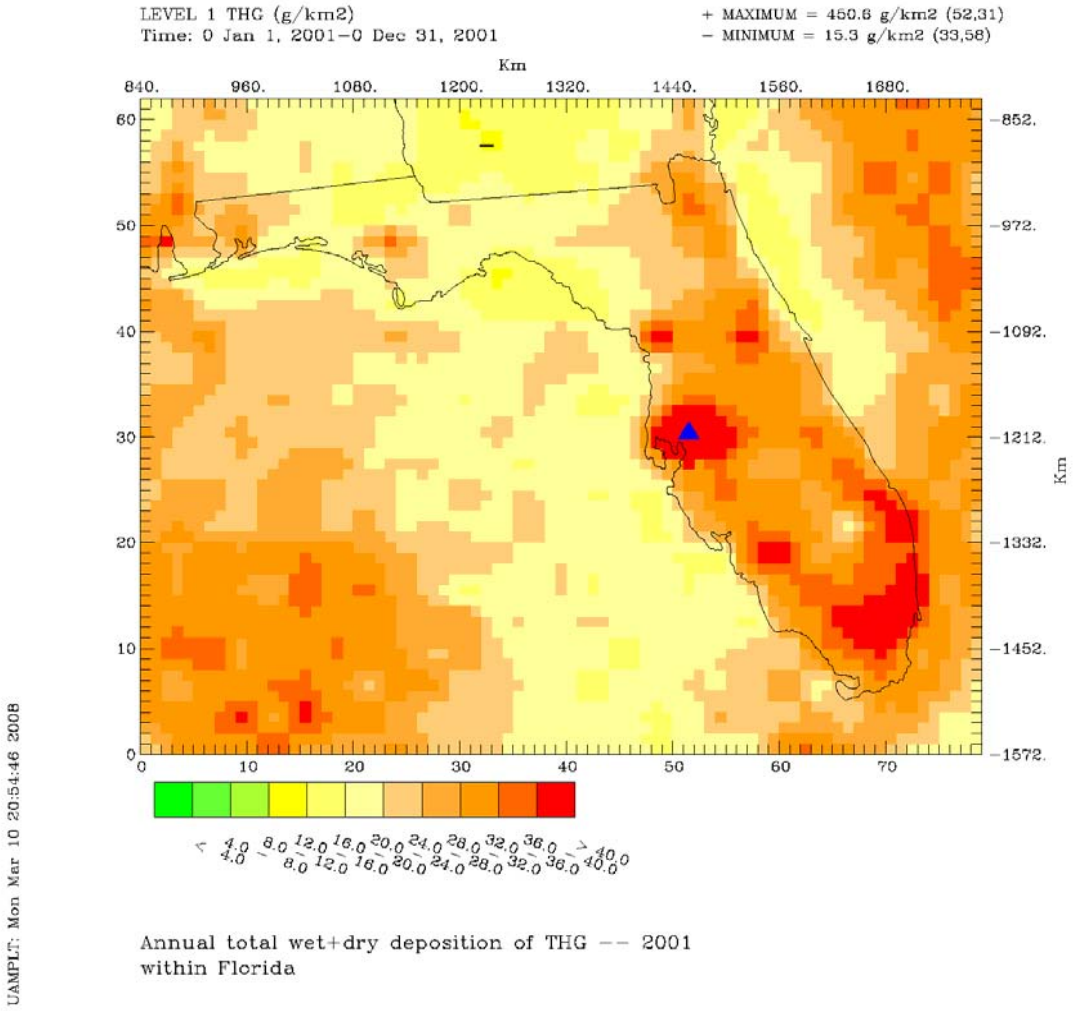
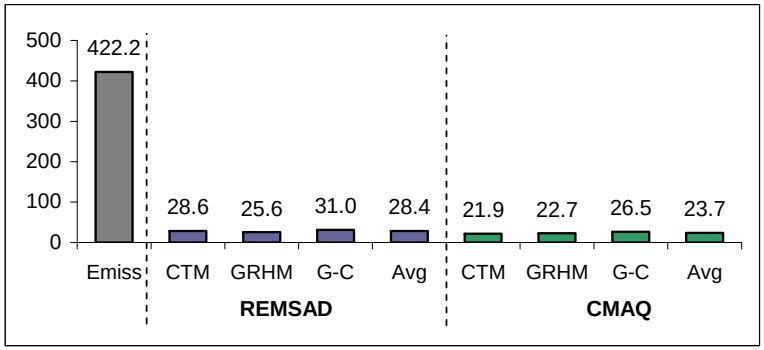


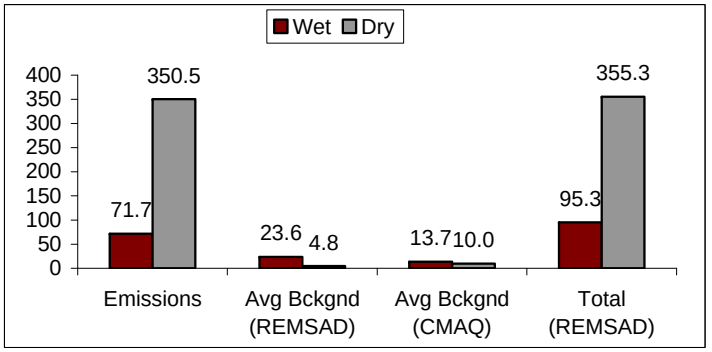
Figure 7-16b. Florida. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (450.6 g/km2).

**Florida**

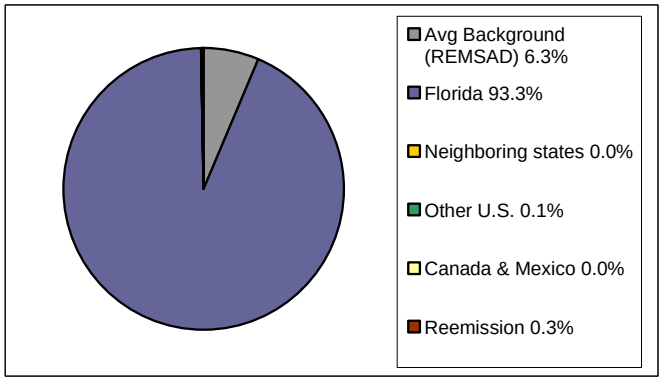
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



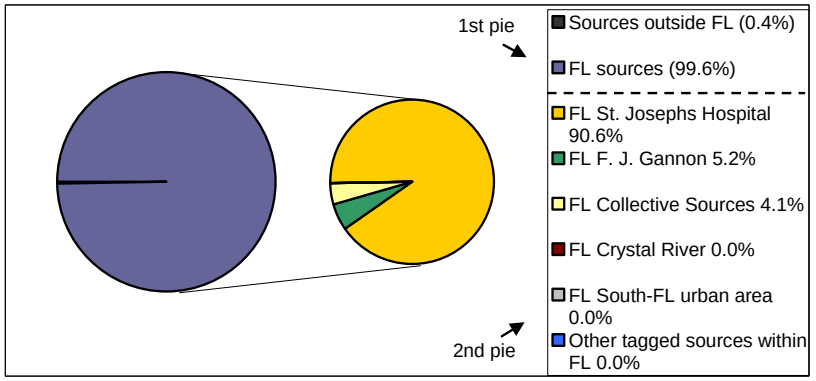

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Florida Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-17. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Georgia.**

a.

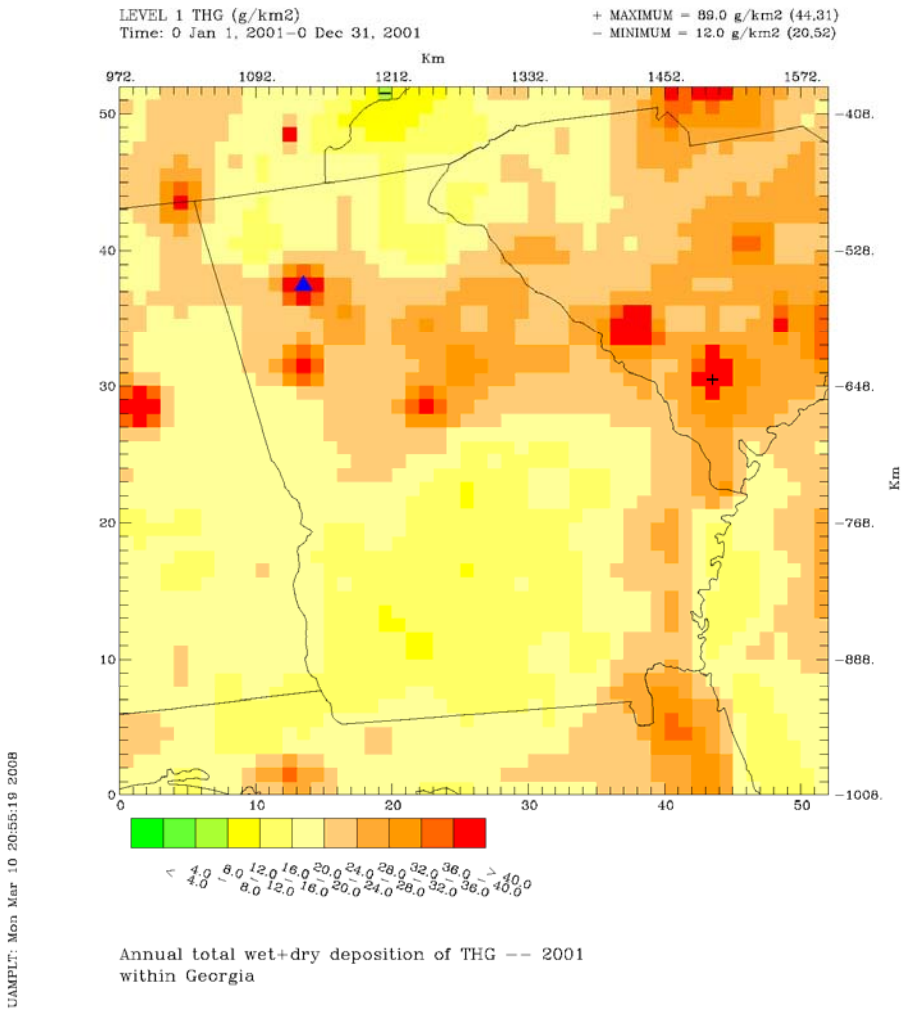
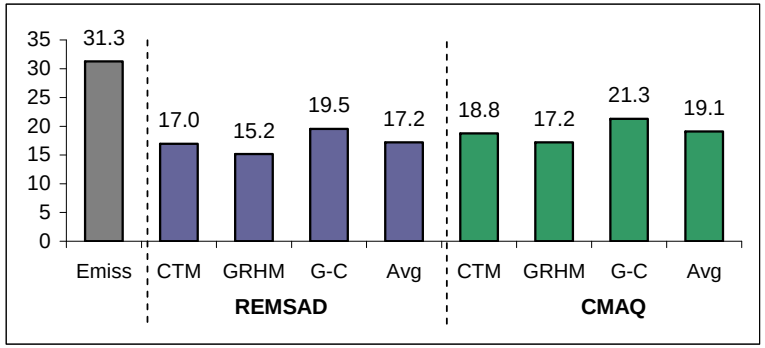


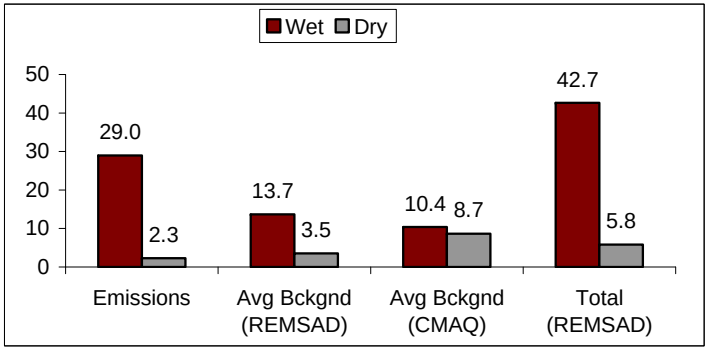
Figure 7-17b. Georgia. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (48.5 g/km2).

**Georgia**

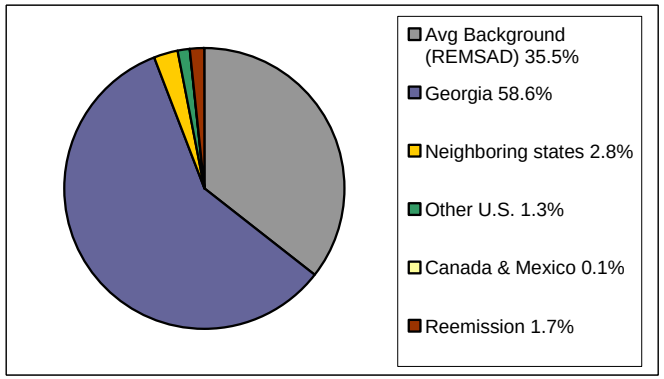
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



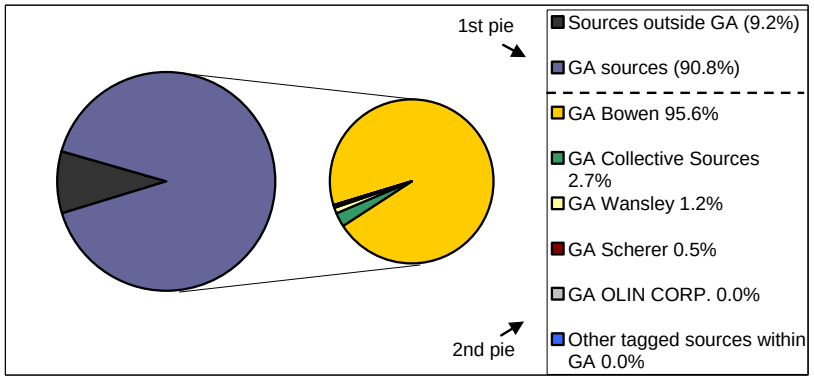

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Georgia Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-18. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Kentucky.**

a.

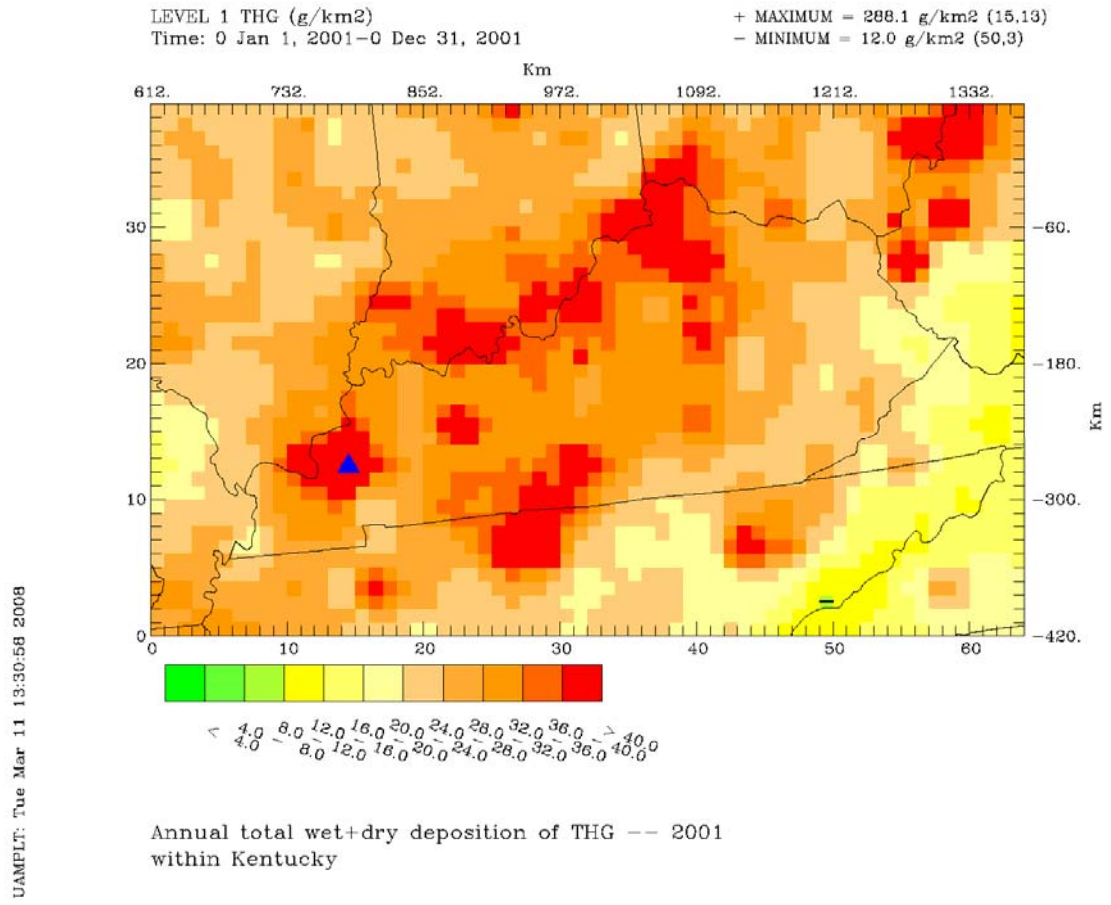
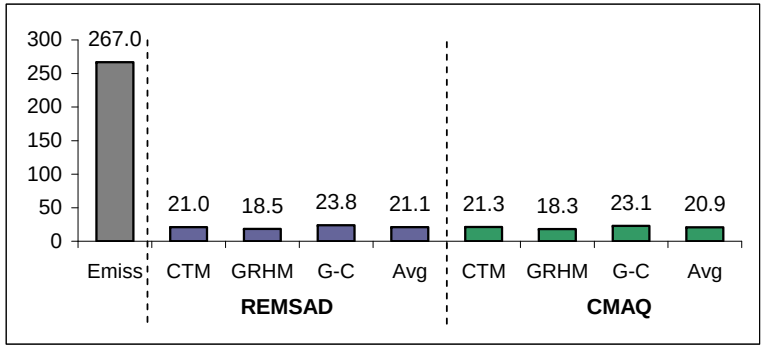


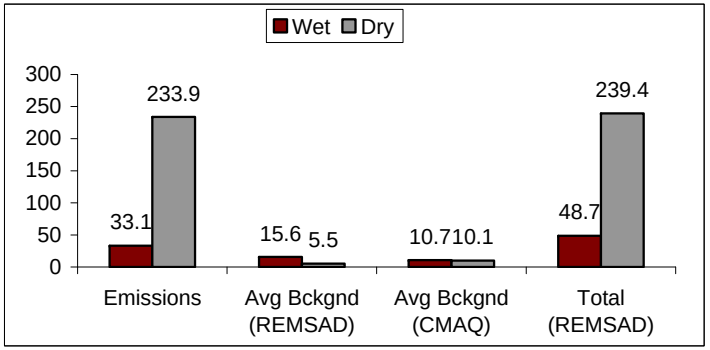
Figure 7-18b. Kentucky. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (288.1 g/km2).

**Kentucky**

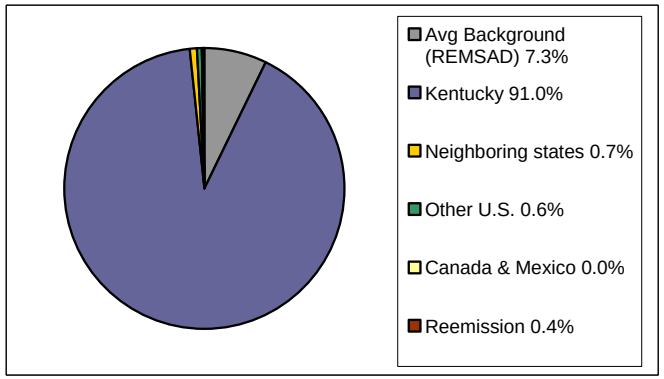
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



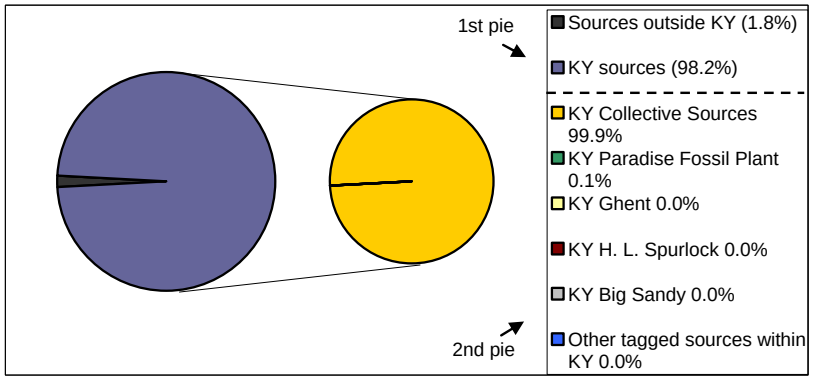

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Kentucky Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-19. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Mississippi.**

a.

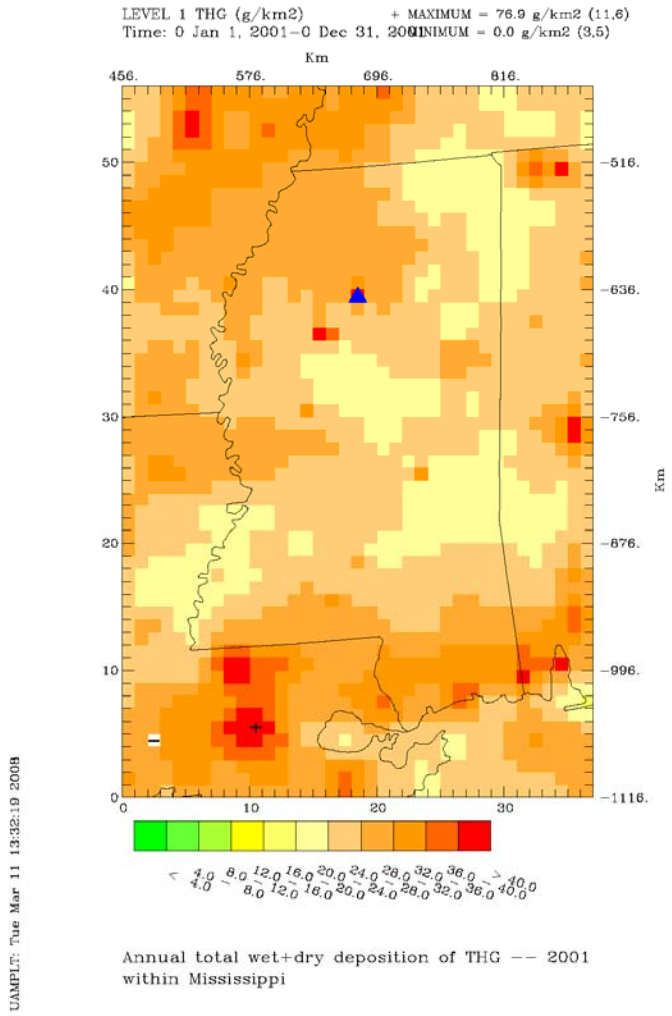
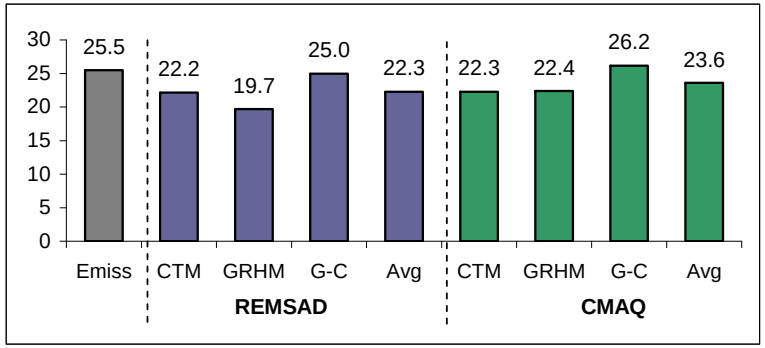


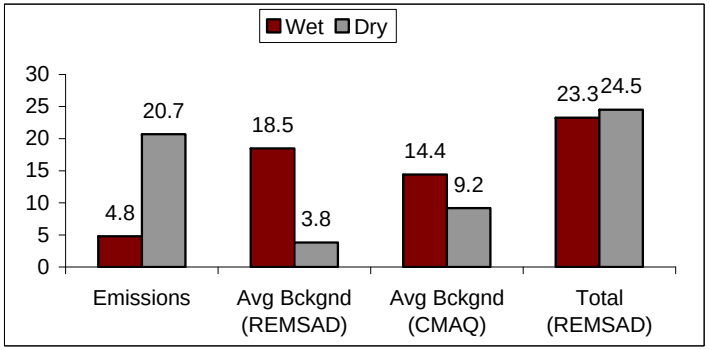
Figure 7-19b. Mississippi. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (47.8 g/km2).

**Mississippi**

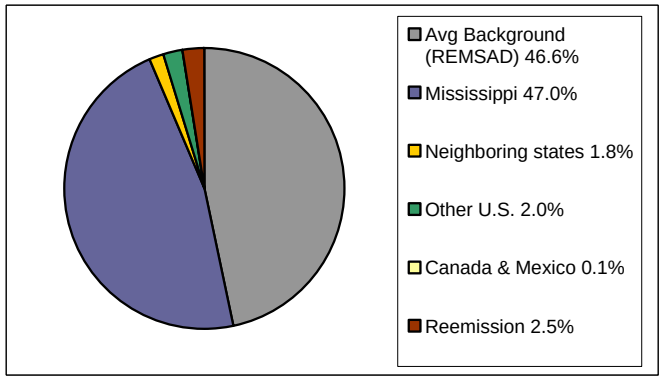
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



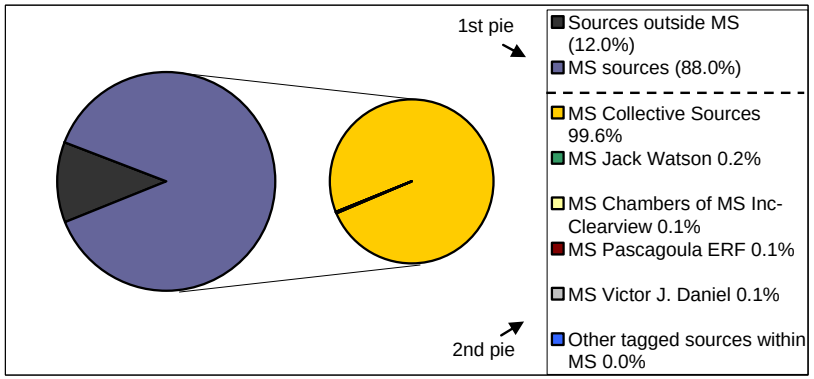

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Mississippi Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-20. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for North Carolina.**

a.

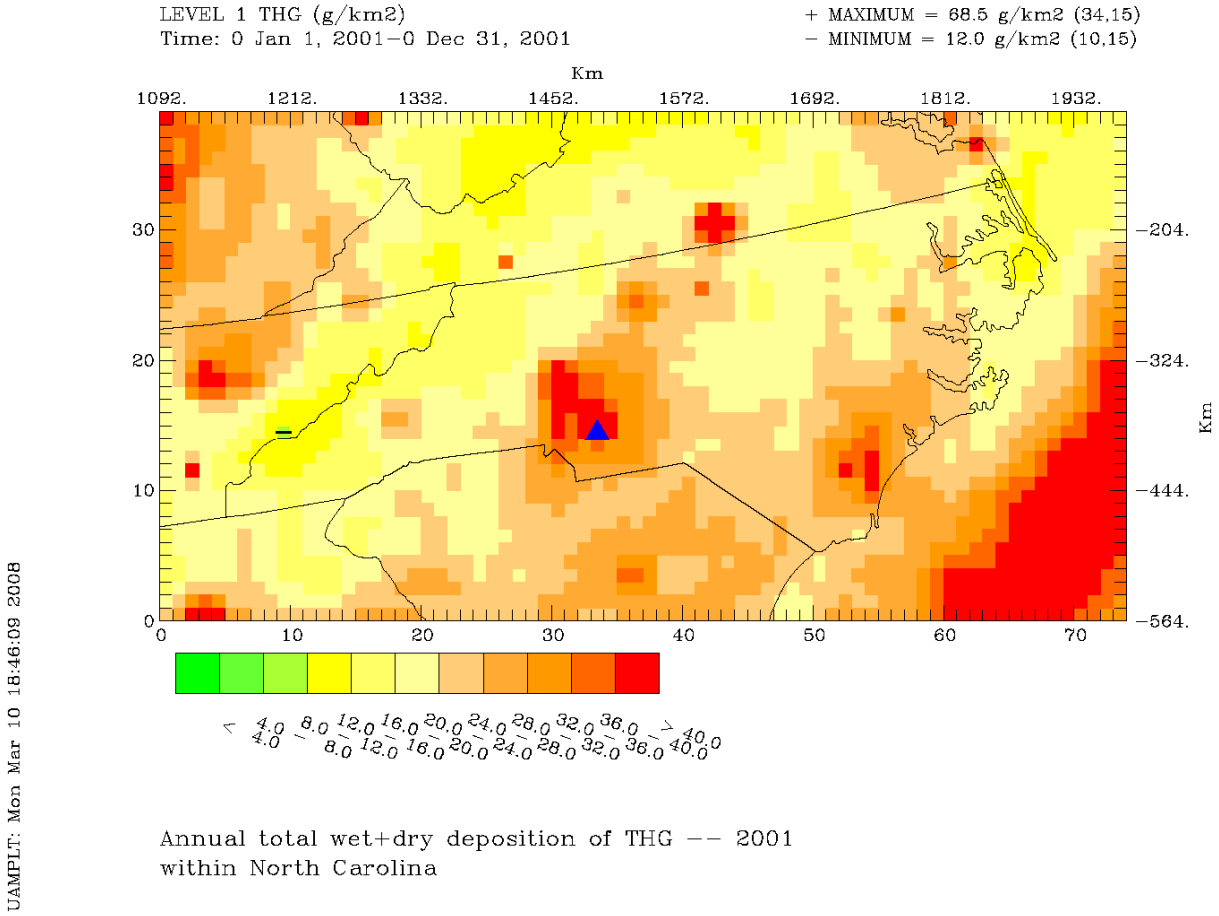
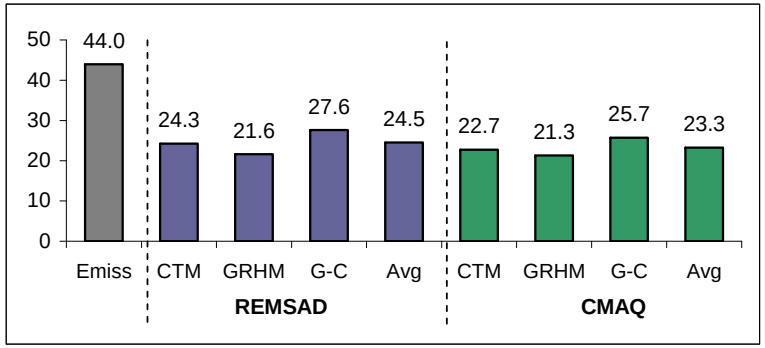


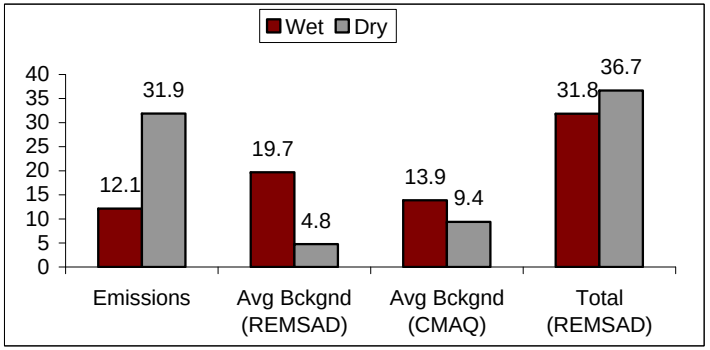
Figure 7-20b. North_Carolina. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (68.5 g/km2).

**North_Carolina**

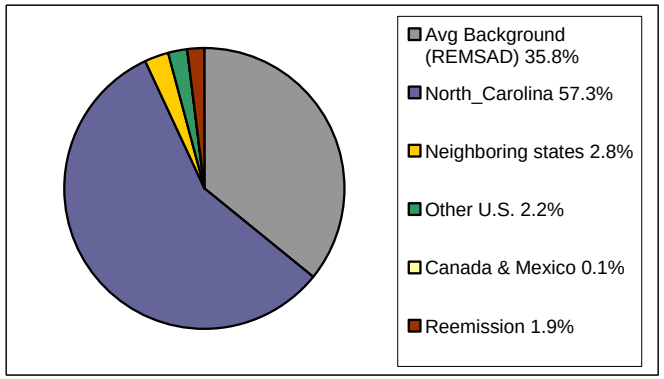
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



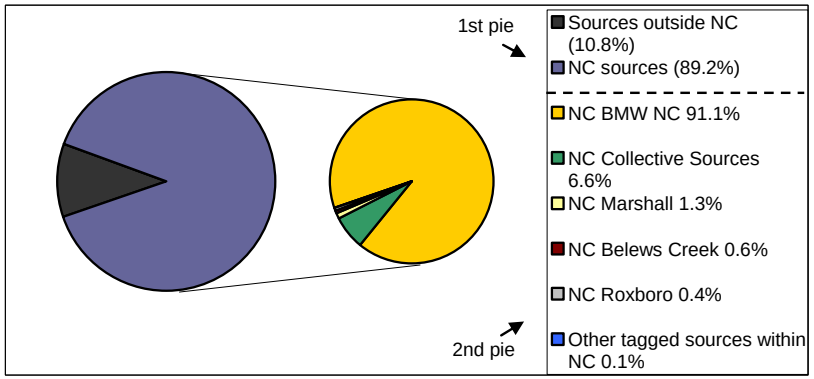

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from North_Carolina Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-21. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for South Carolina.**

a.

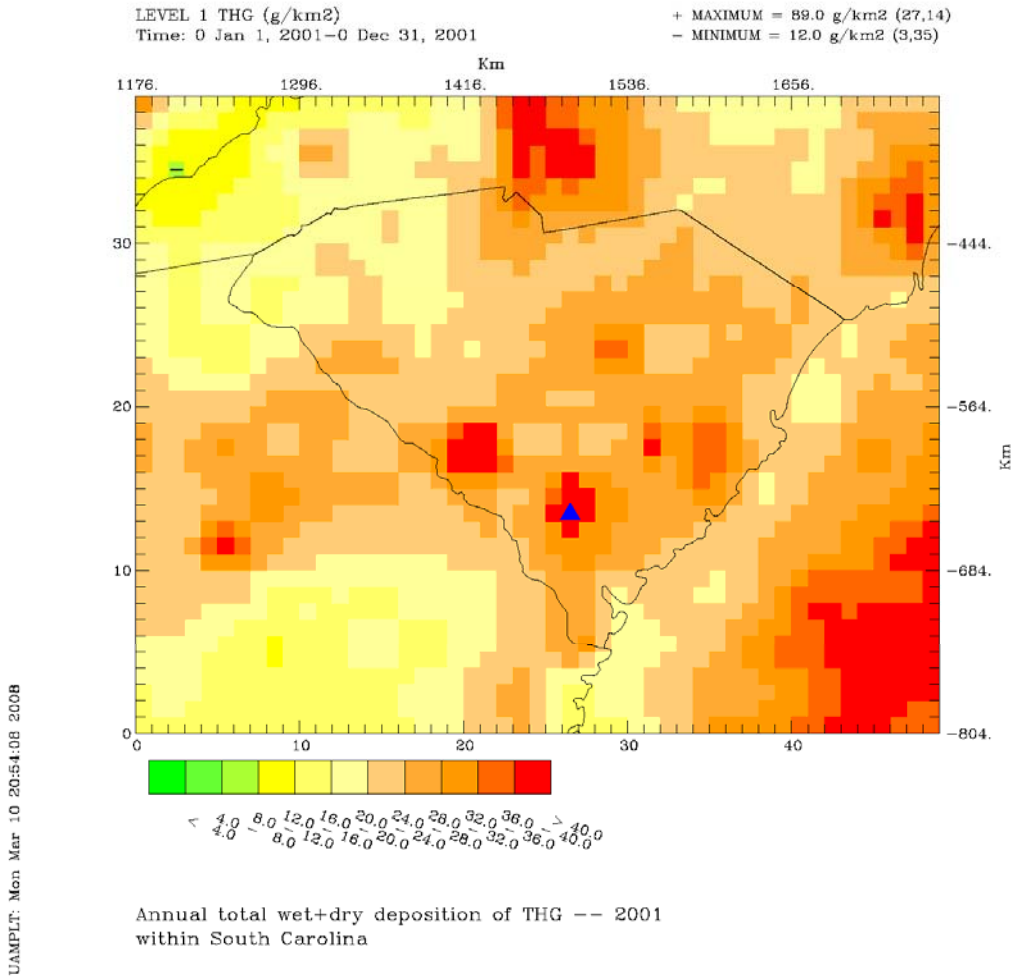
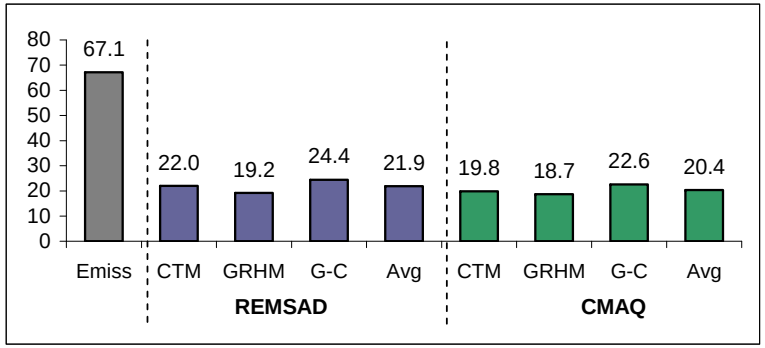


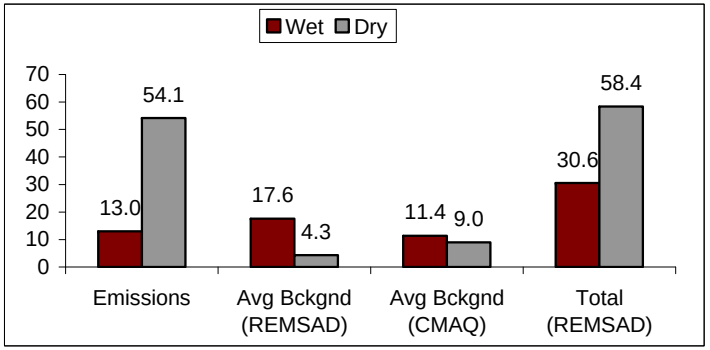
Figure 7-21b. South_Carolina. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (89.0 g/km2).

**South_Carolina**

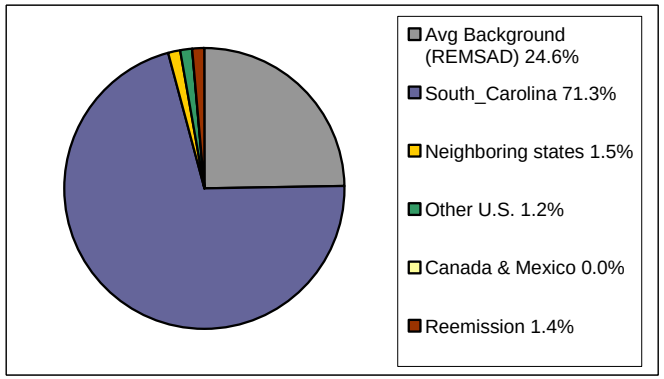
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



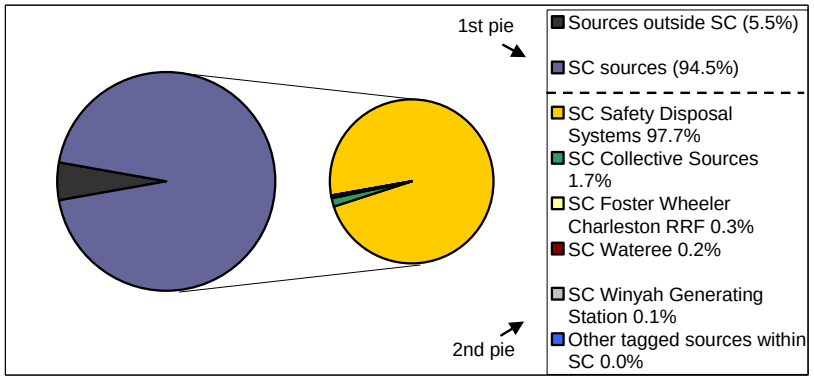

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from South_Carolina Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-22. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Tennessee.**

a.

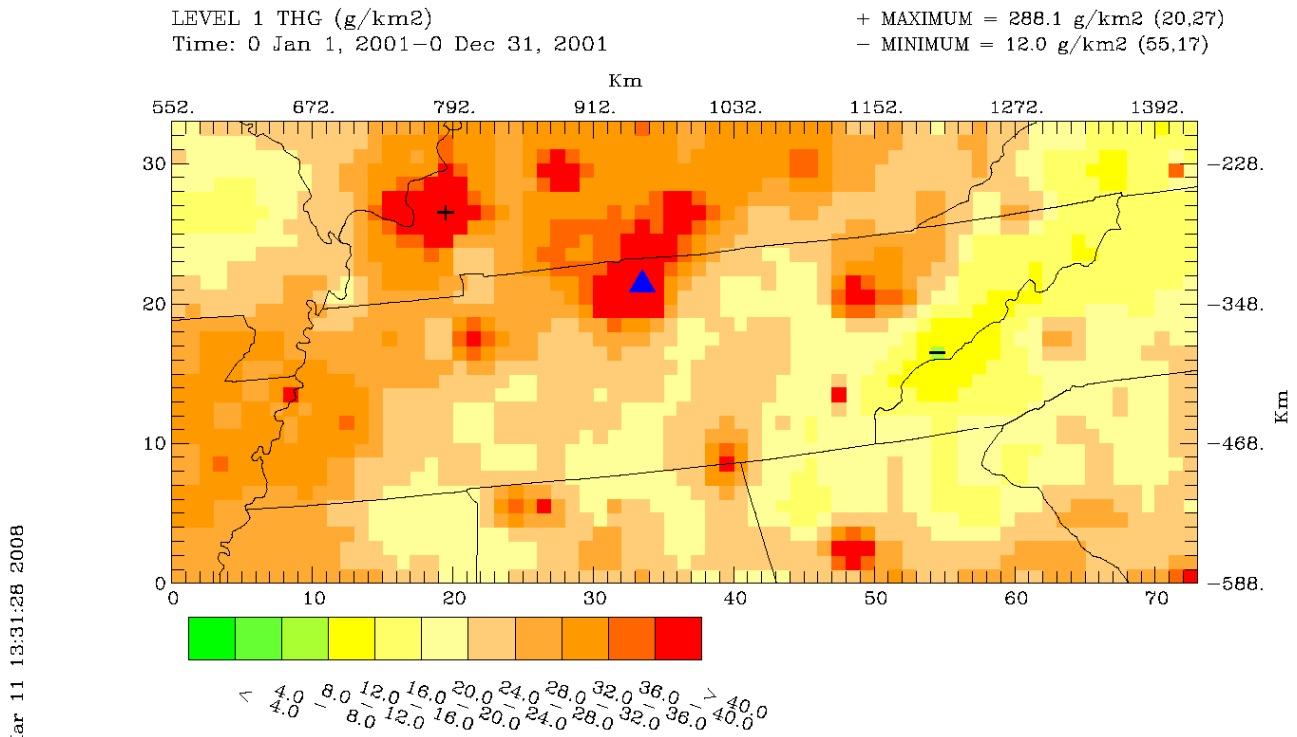
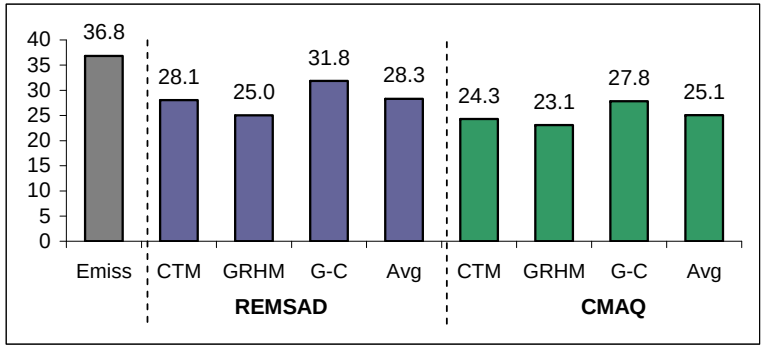


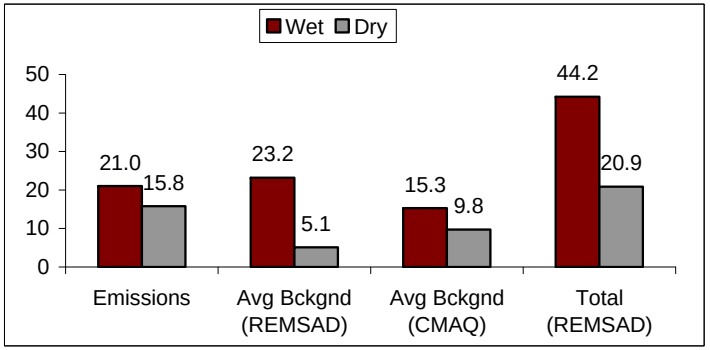
Figure 7-22b. Tennessee. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (65.1 g/km2).

**Tennessee**

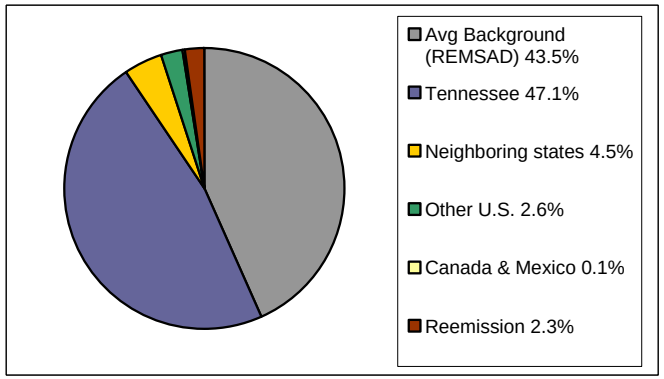
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



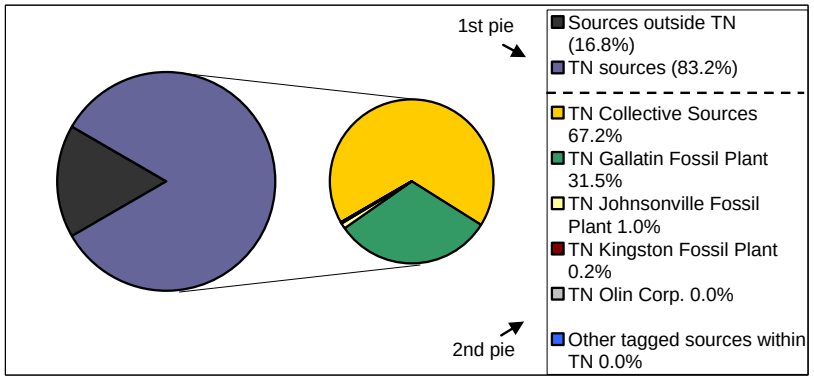

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Tennessee Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-23. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Illinois.**

a.

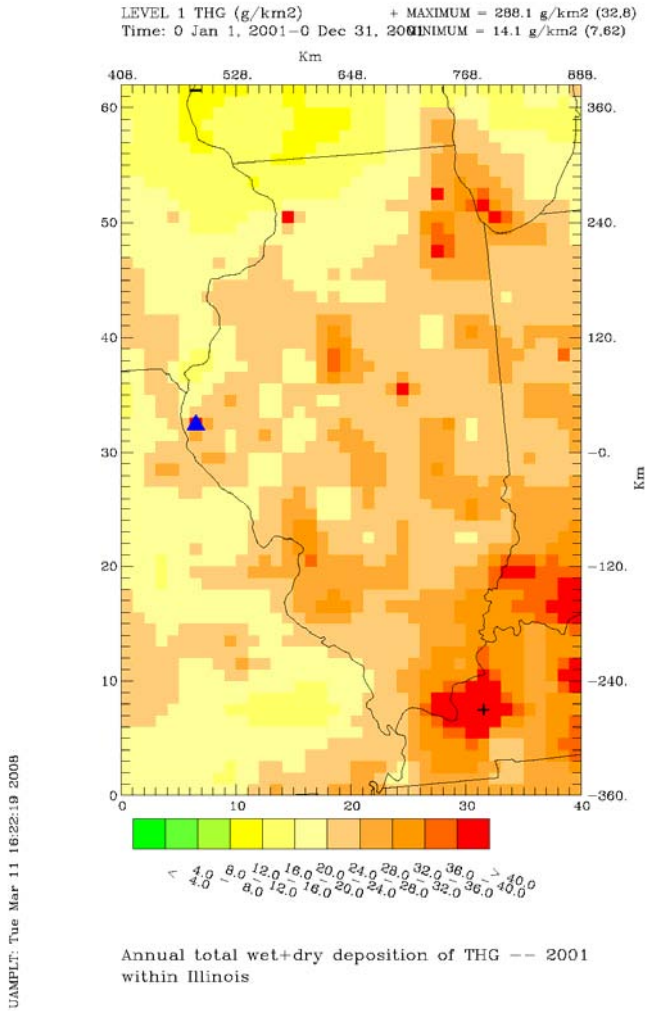
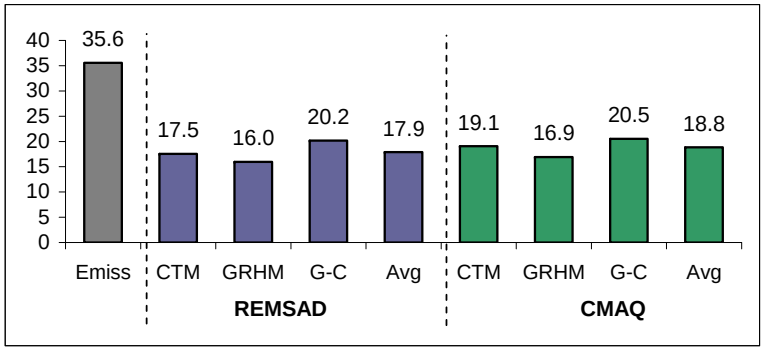


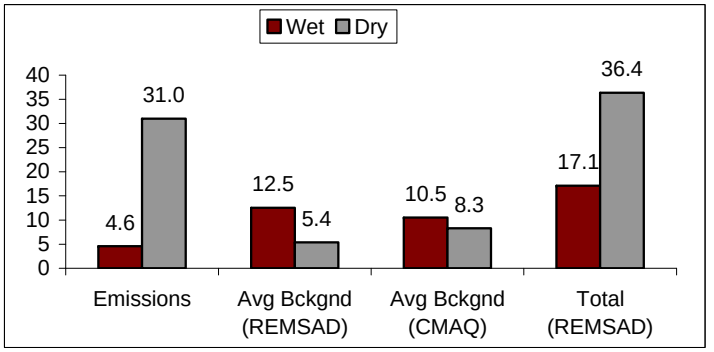
Figure 7-23b. Illinois. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (53.5 g/km2).

**Illinois**

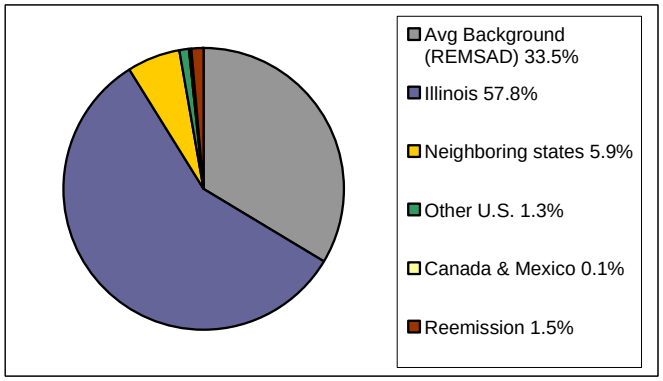
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



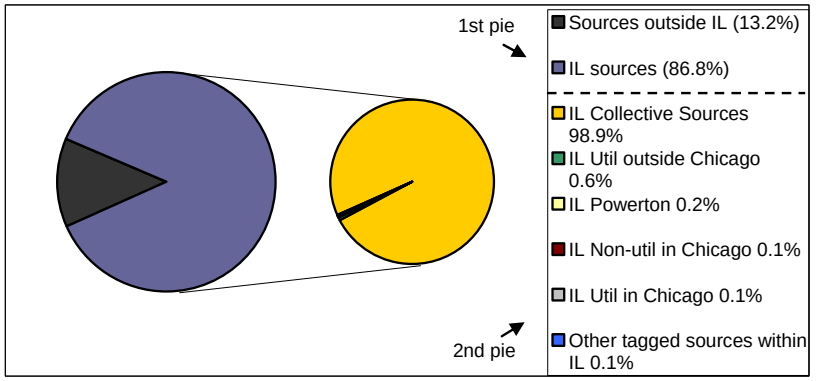

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Illinois Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-24. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Indiana.**

a.

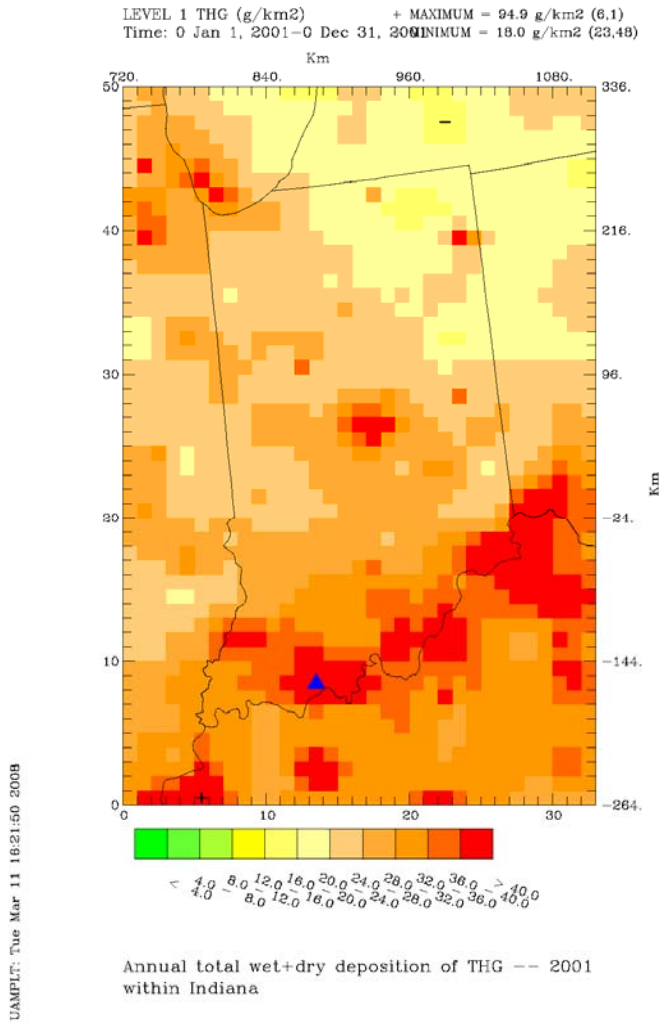
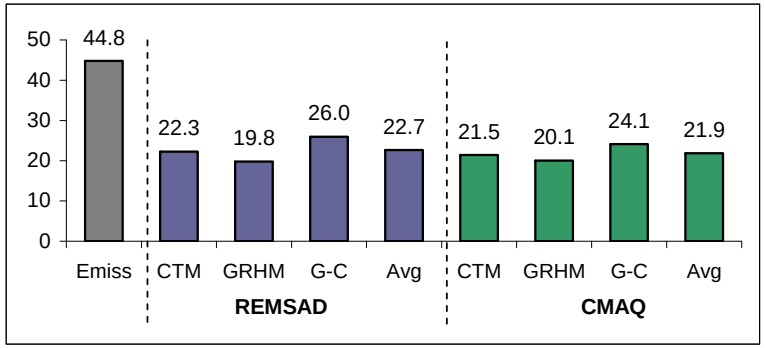


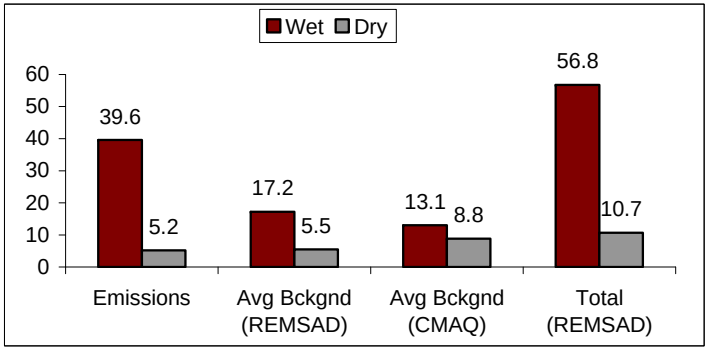
Figure 7-24b. Indiana. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (67.5 g/km2).

**Indiana**

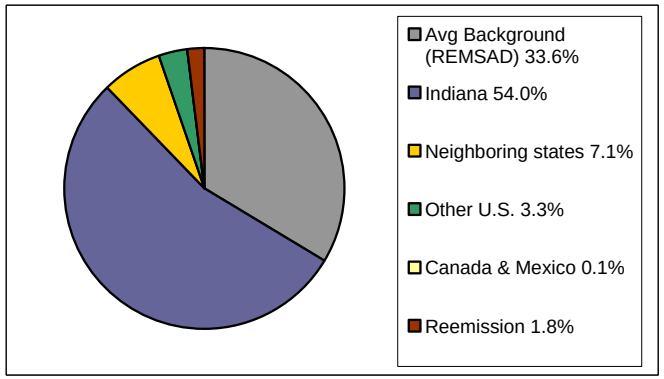
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



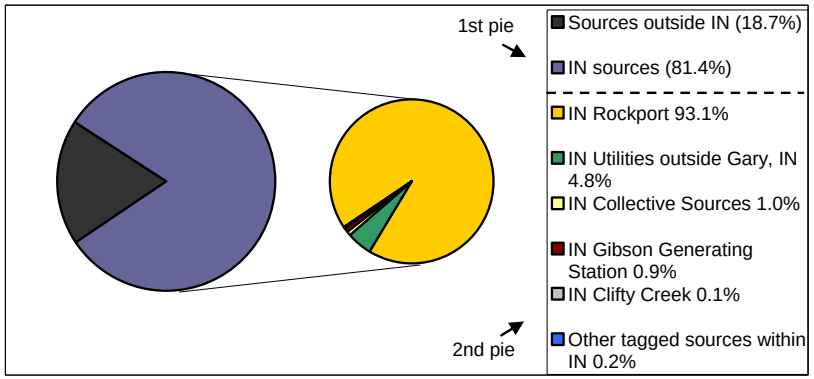

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Indiana Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-25. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Michigan.**

a.

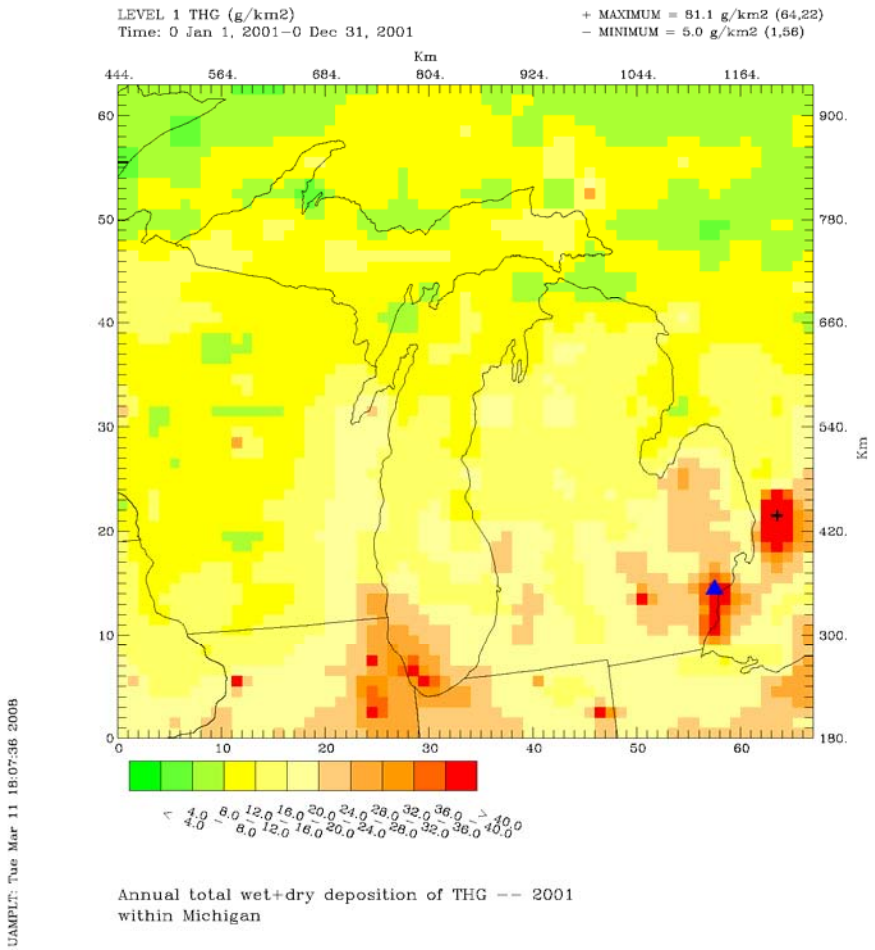
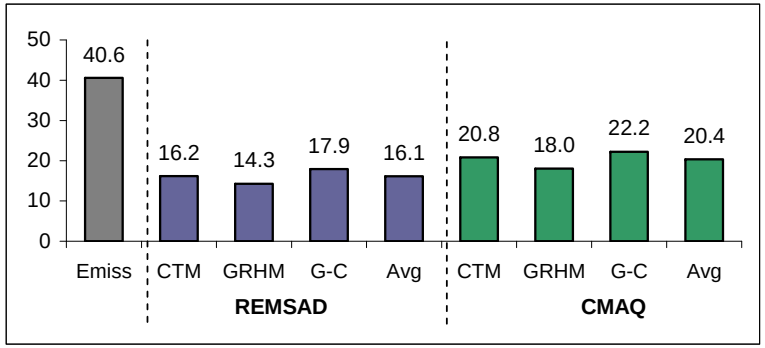


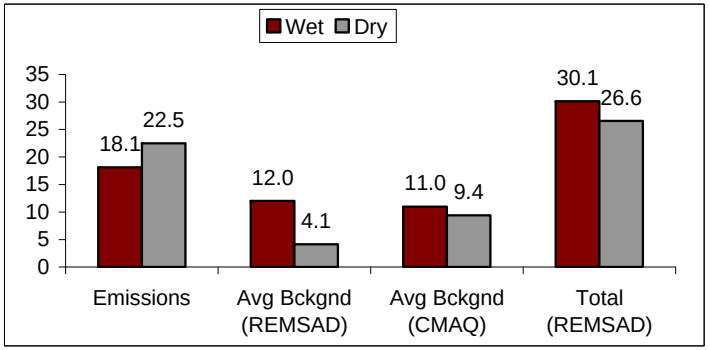
Figure 7-25b. Michigan. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (56.7 g/km2).

**Michigan**

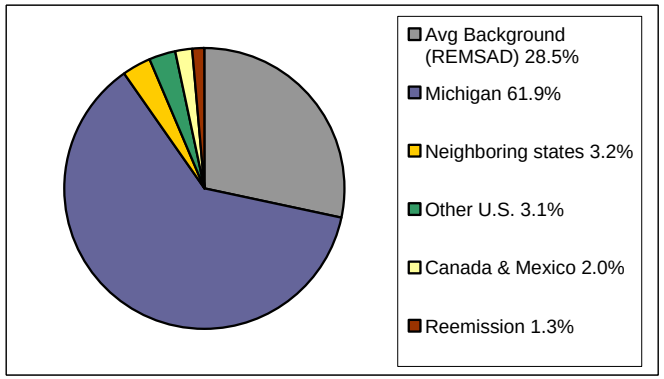
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



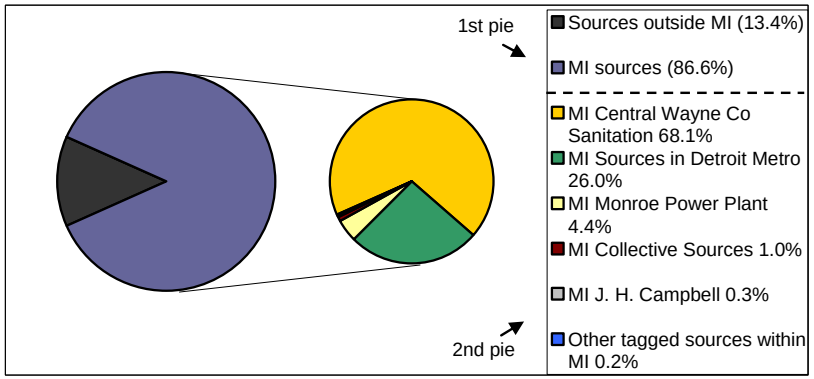

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Michigan Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-26. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Minnesota.**

a.

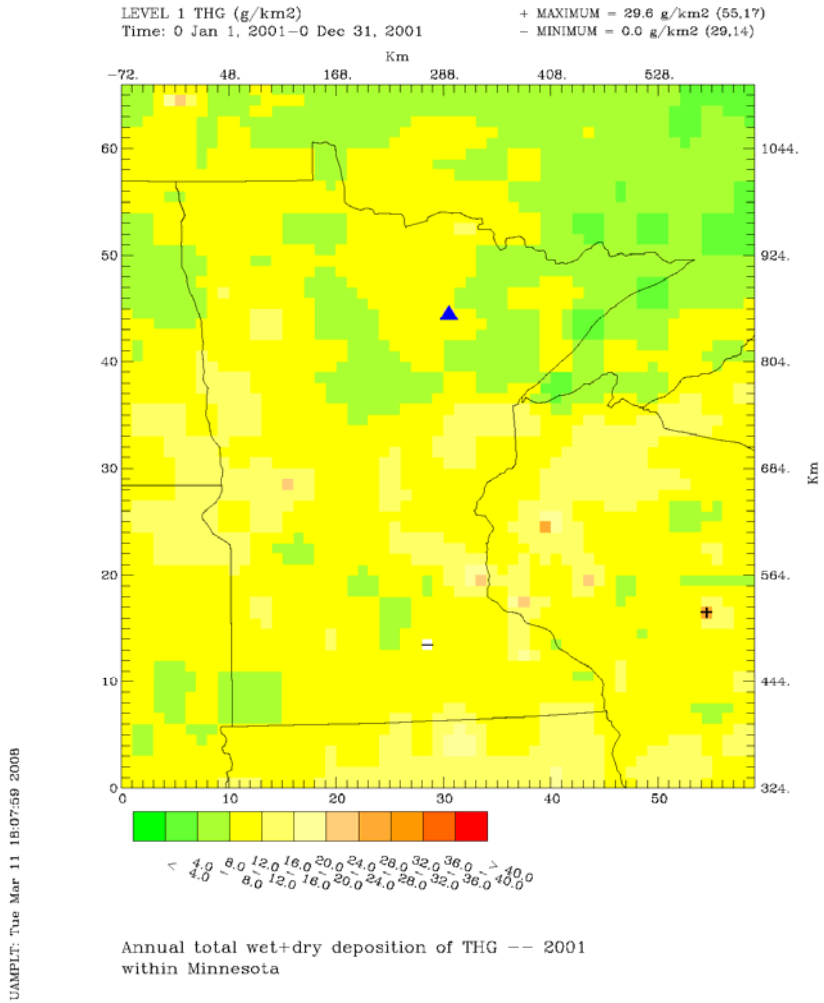
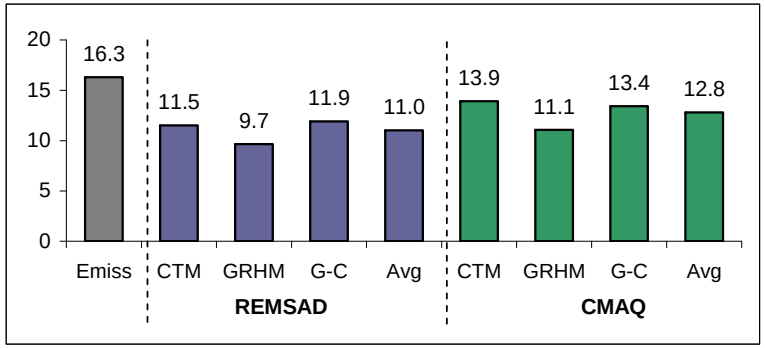


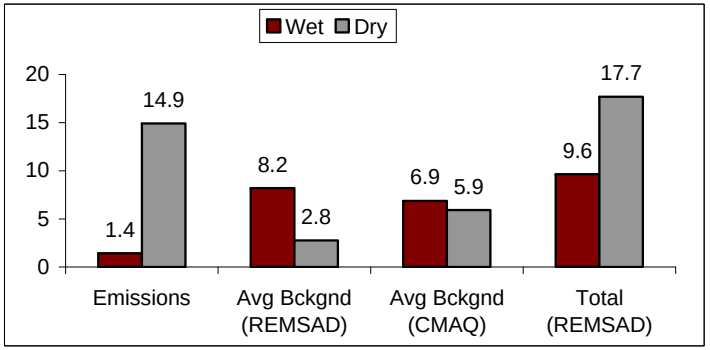
Figure 7-26b. Minnesota. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (27.3 g/km2).

**Minnesota**

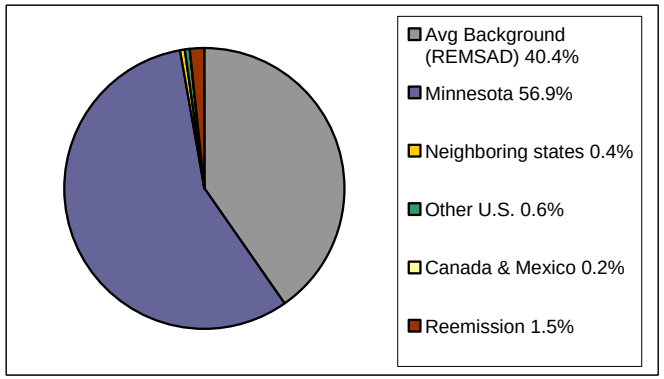
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



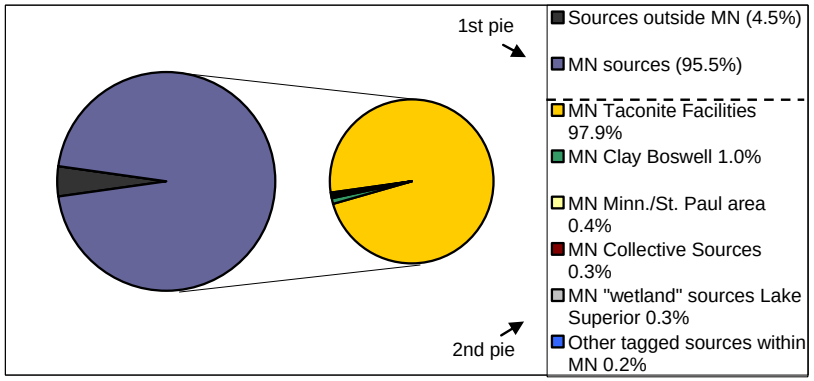

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Minnesota Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-27. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Ohio.**

a.

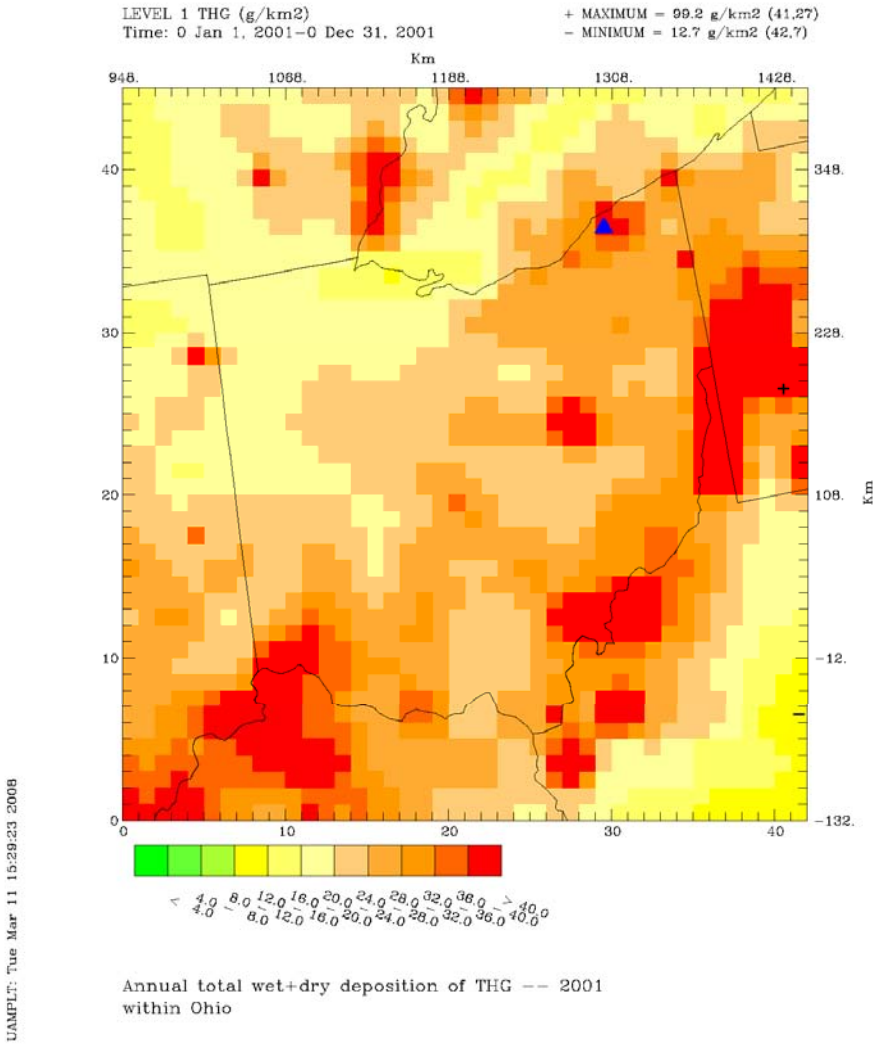
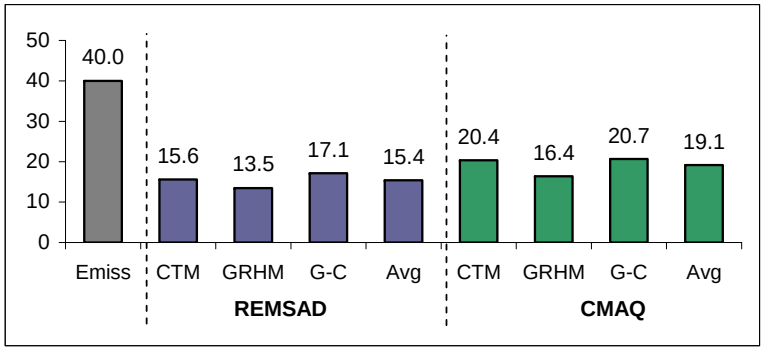


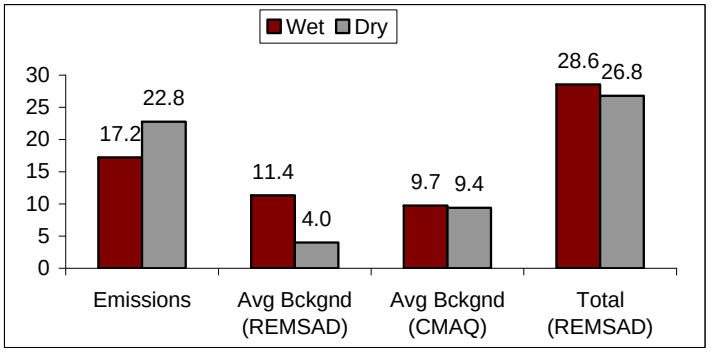
Figure 7-27b. Ohio. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (55.4 g/km2).

**Ohio**

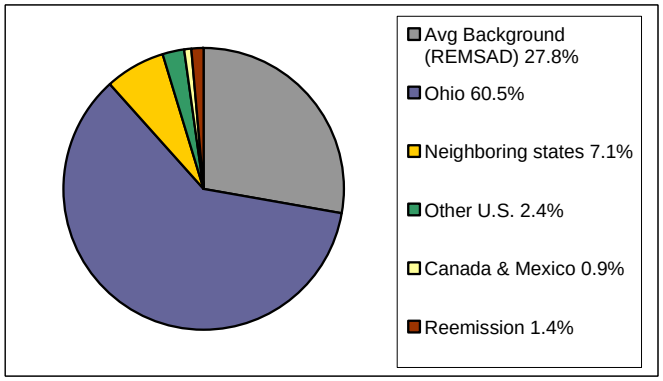
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



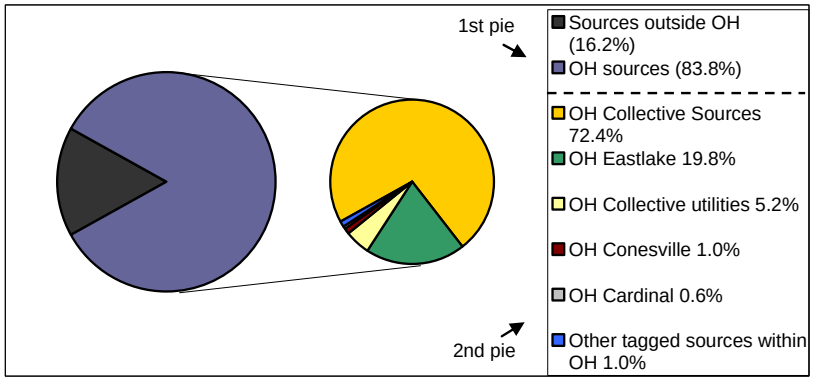

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Ohio Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-28. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Wisconsin.**

a.

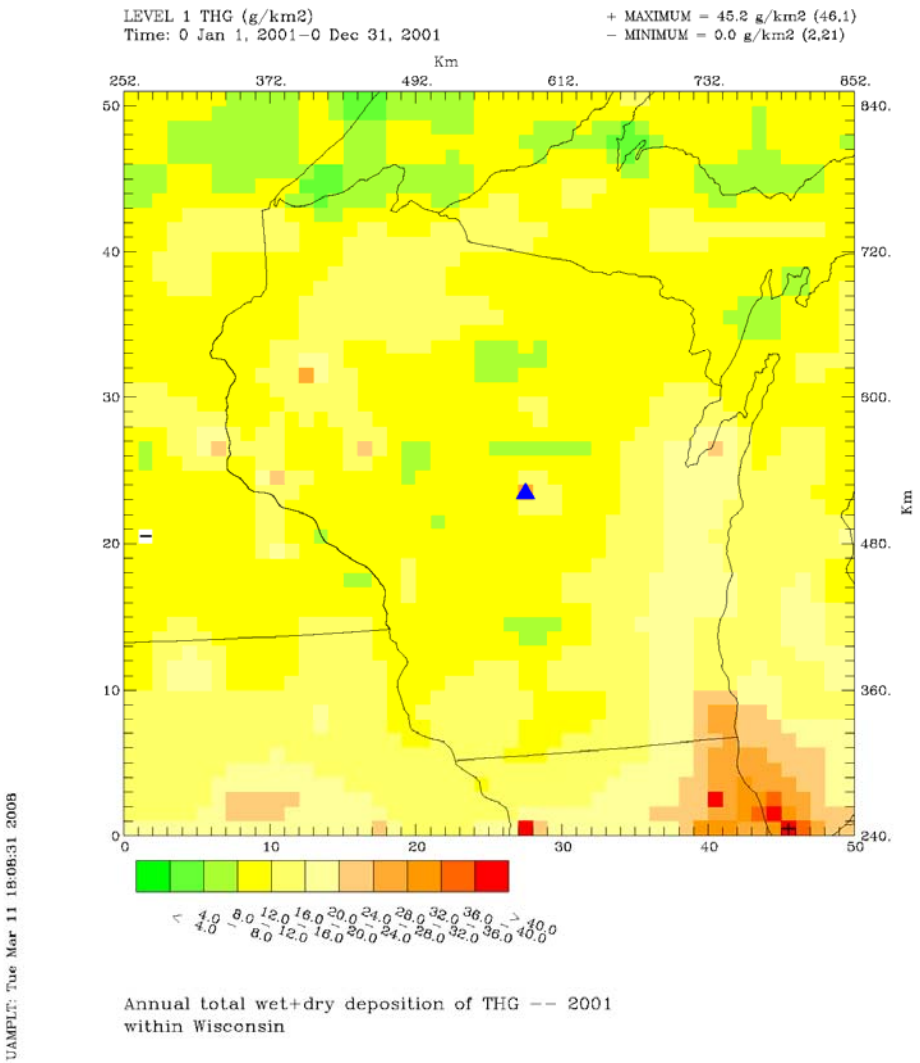
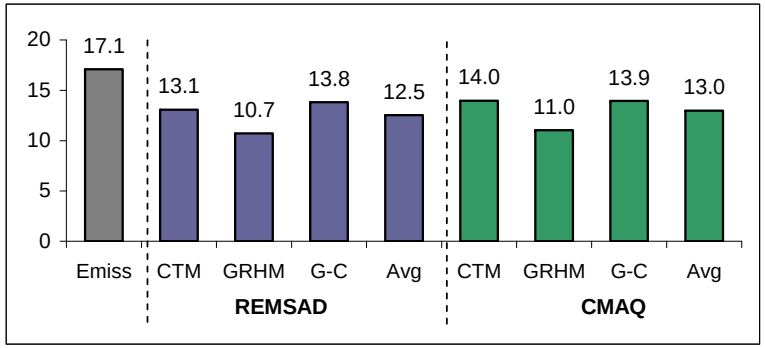


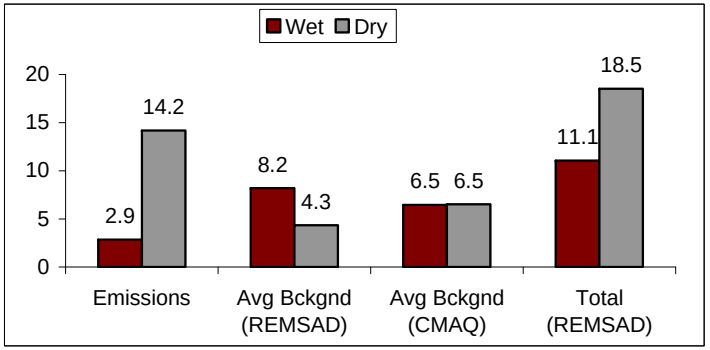
Figure 7-28b. Wisconsin. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (29.6 g/km2).

**Wisconsin**

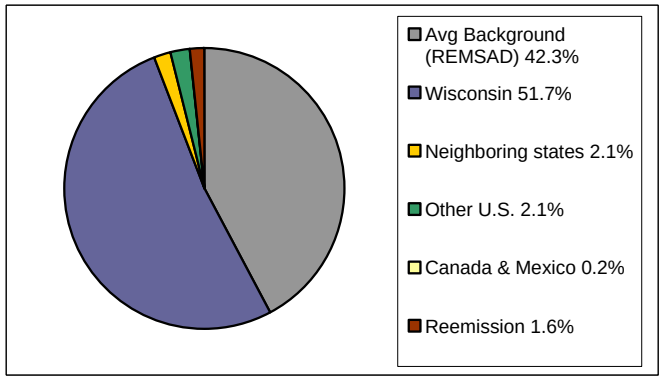
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



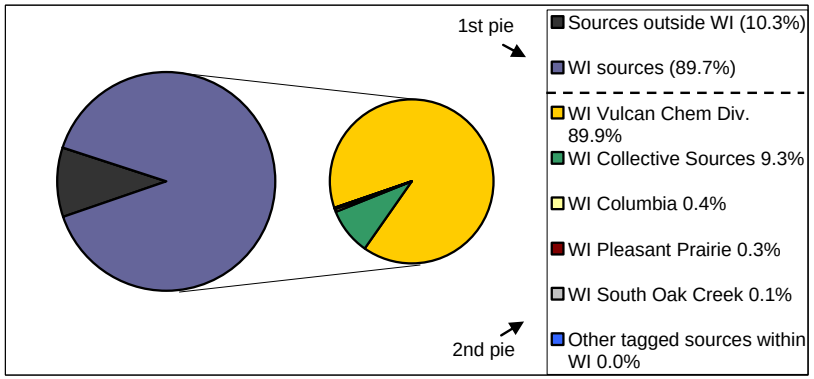

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Wisconsin Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-29. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Arkansas.**

a.

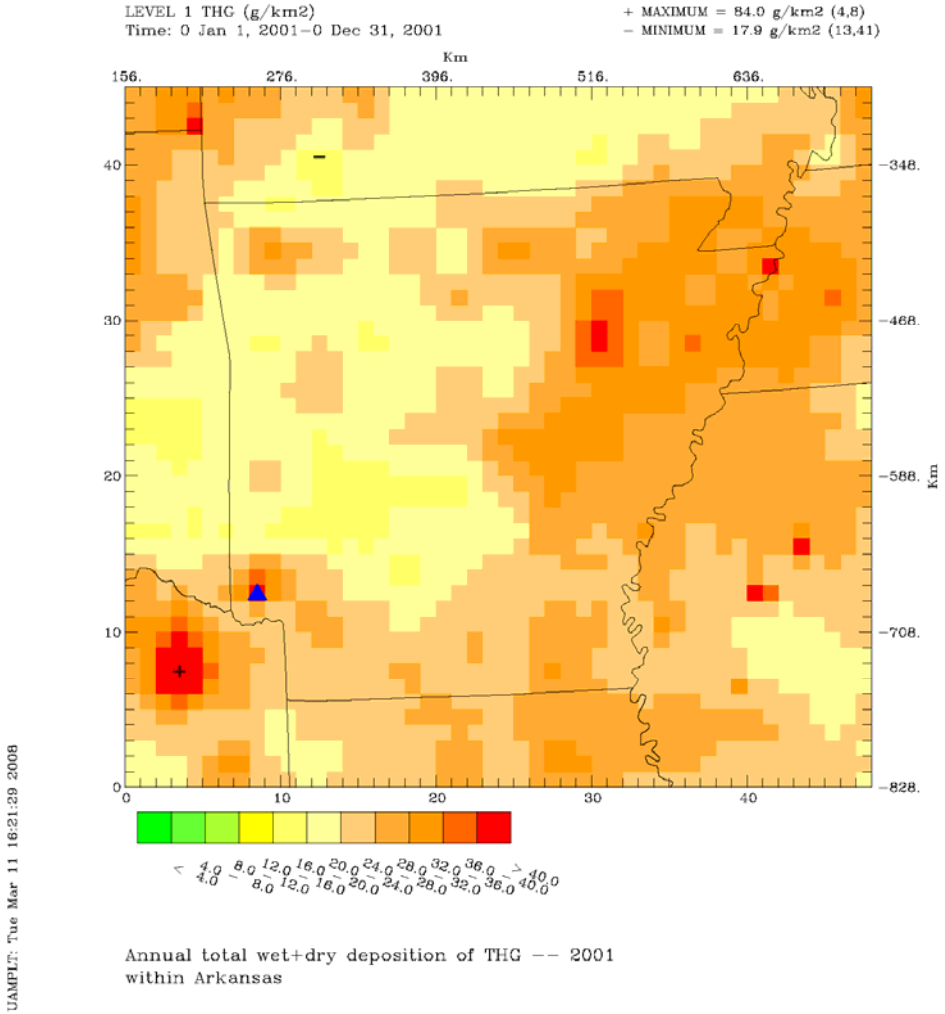
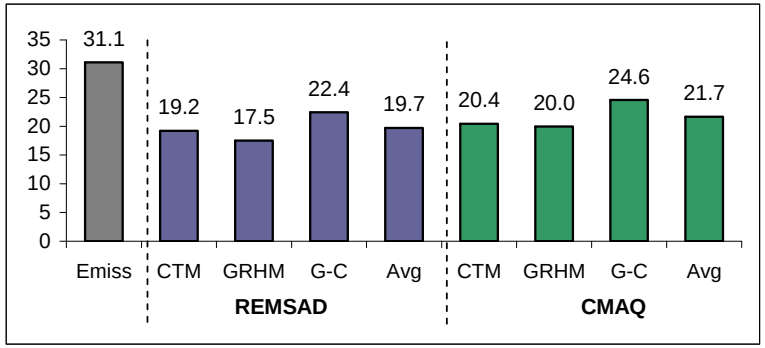


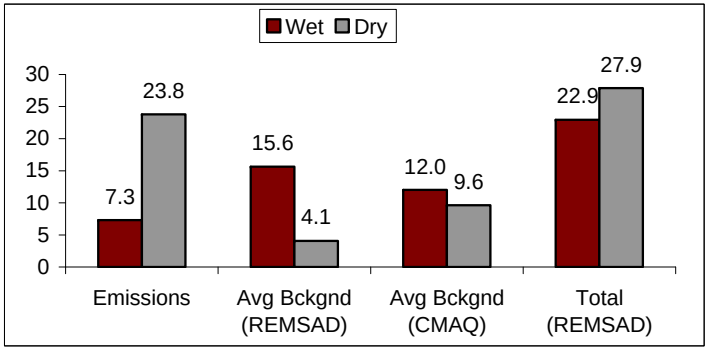
Figure 7-29b. Arkansas. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (50.8 g/km2).

**Arkansas**

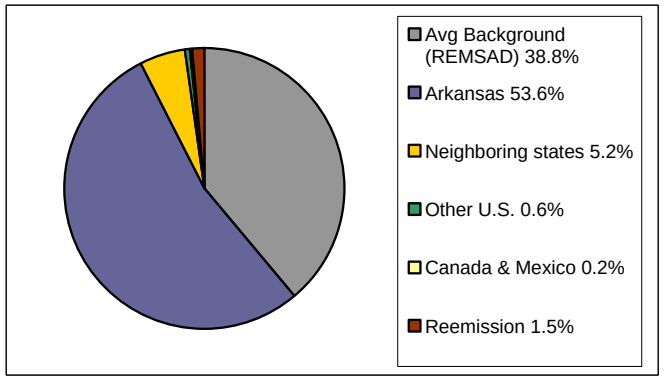
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



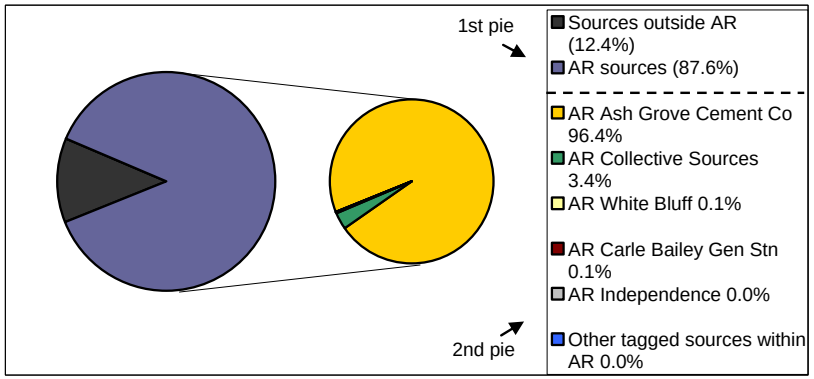

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Arkansas Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-30. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g $km^{-2}$) for Louisiana.**

a.

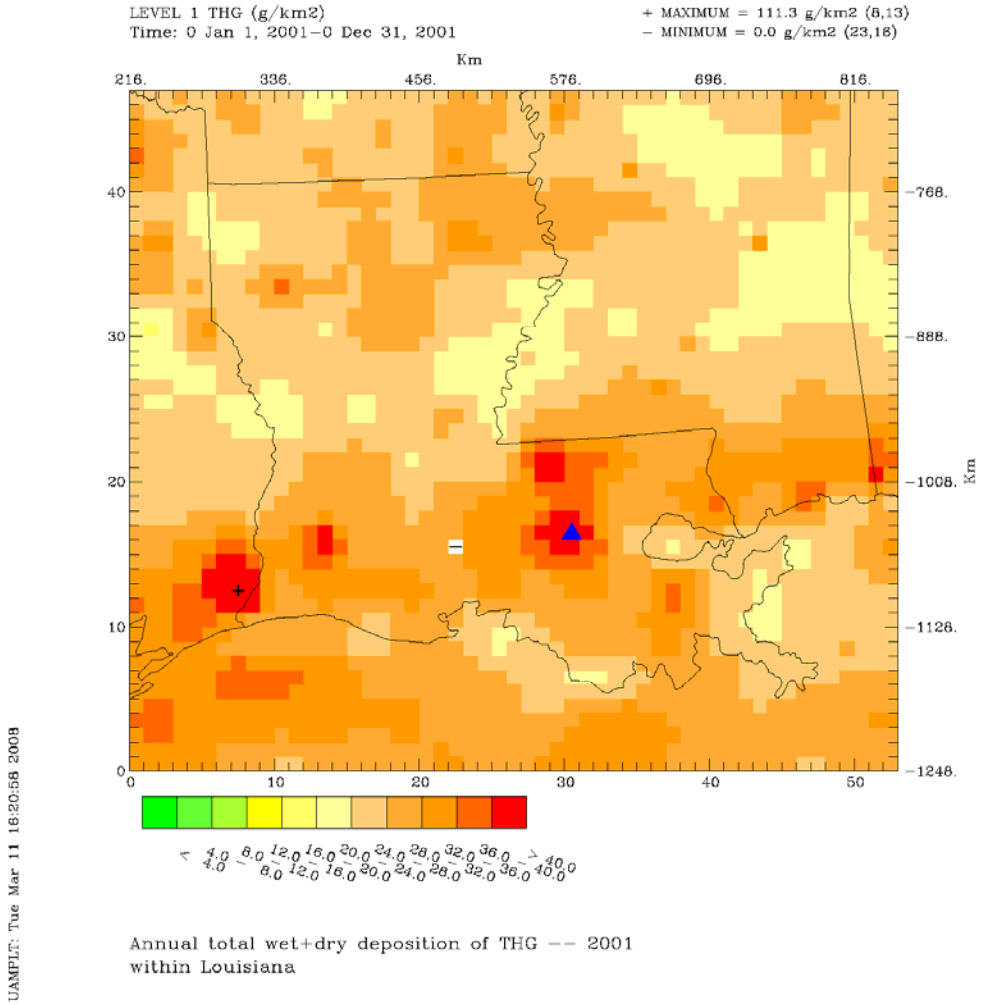
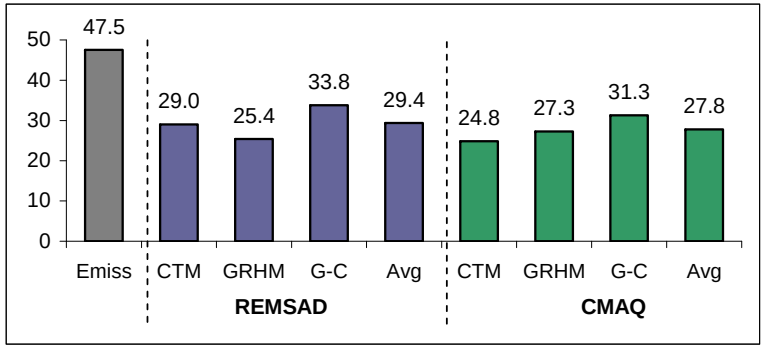


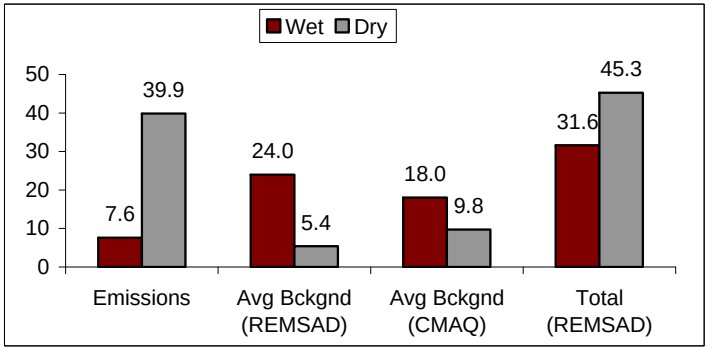
Figure 7-30b. Louisiana. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (76.9 g/km2).

**Louisiana**

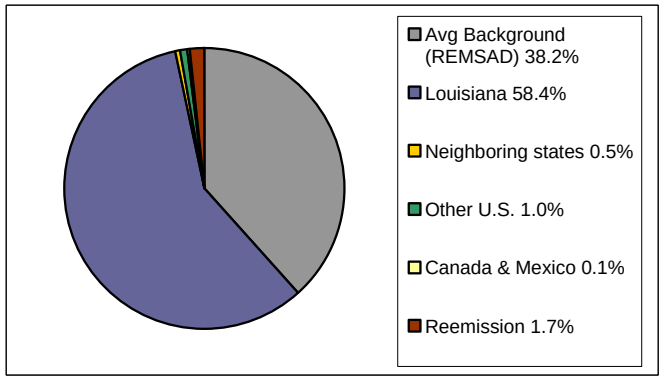
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



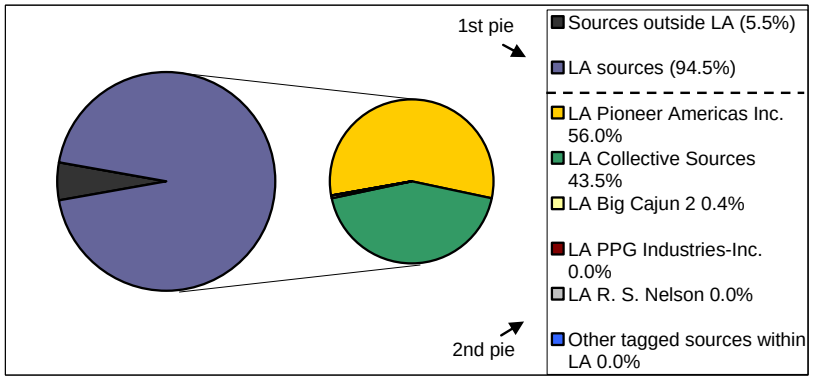

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Louisiana Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-31. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for New Mexico.**

a.

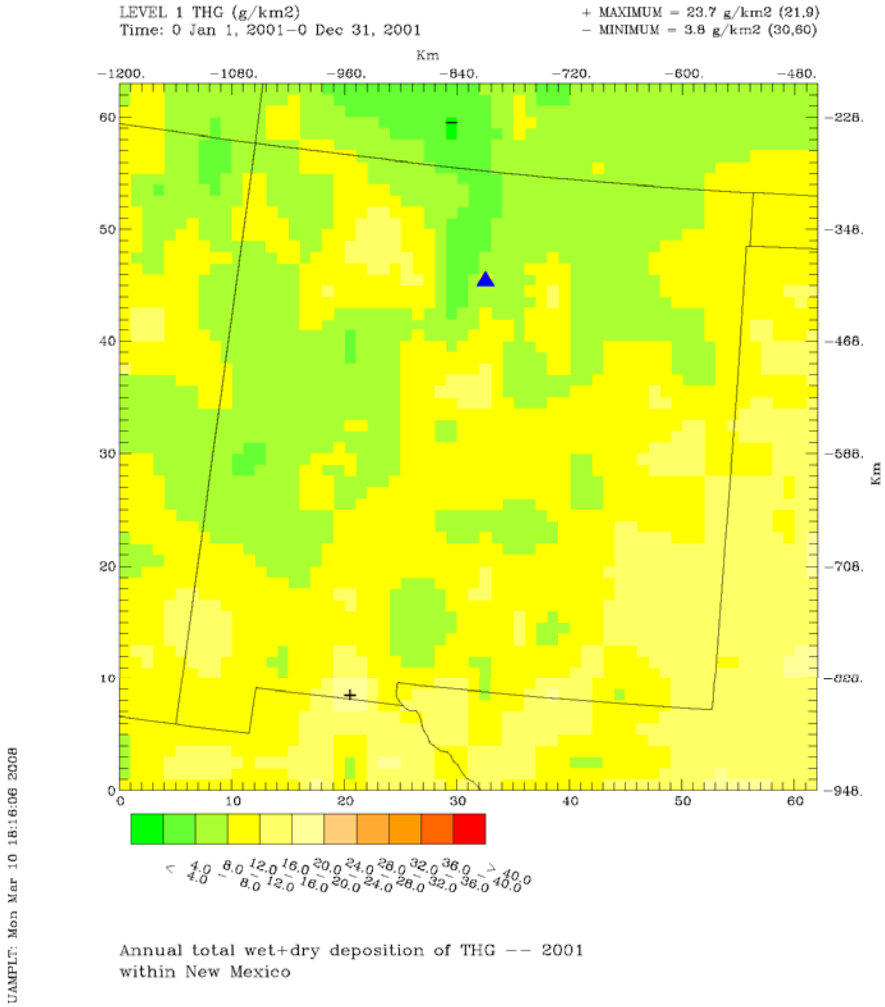
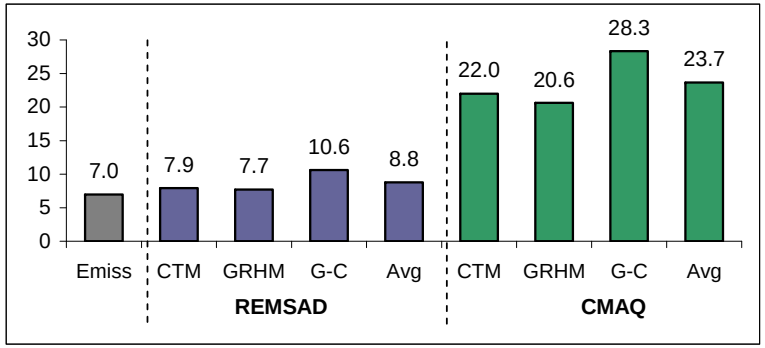


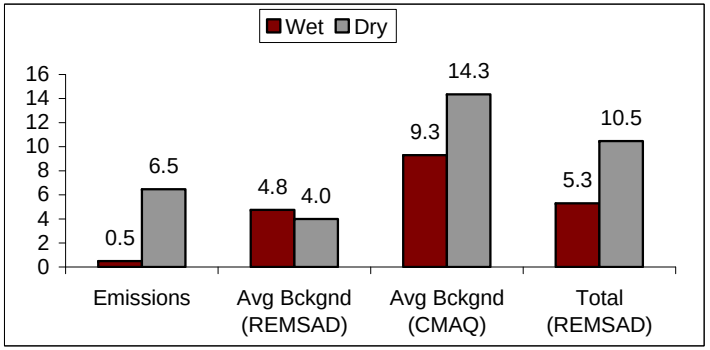
Figure 7-31b. New_Mexico. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (15.8 g/km2).

**New_Mexico**

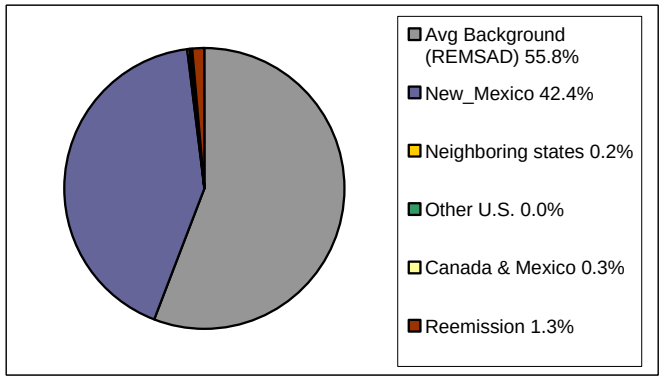
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



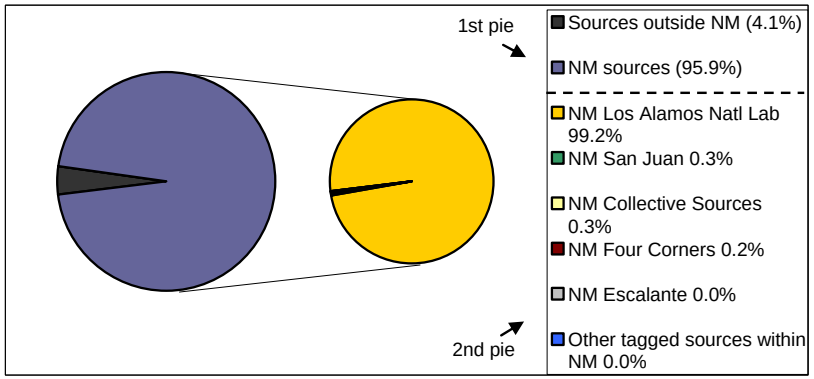

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from New_Mexico Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-32. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Oklahoma.**

a.

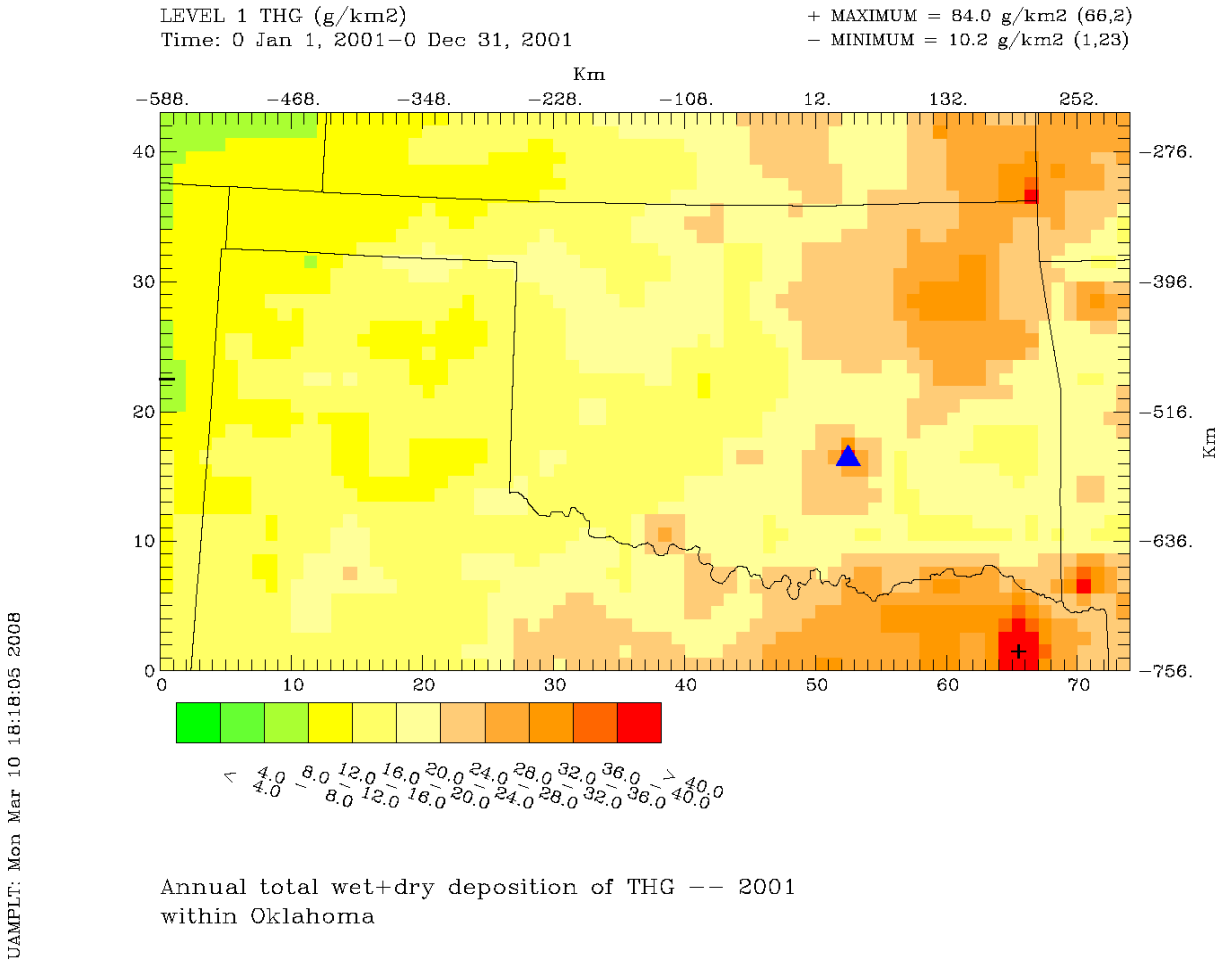
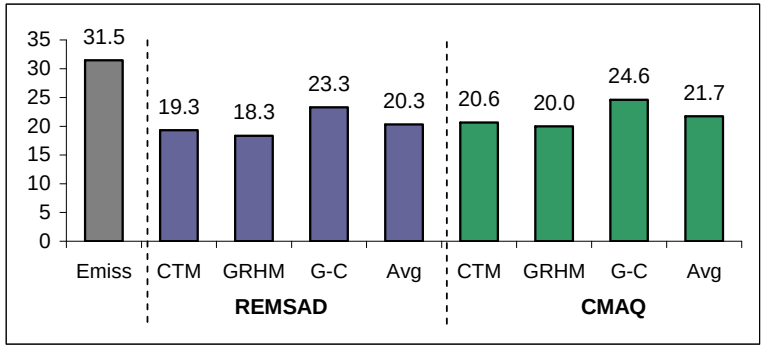


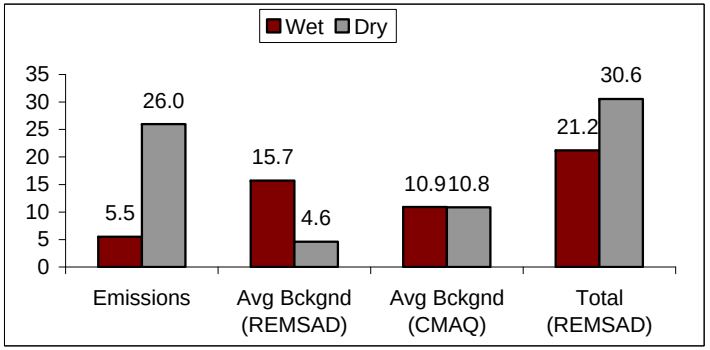
Figure 7-32b. Oklahoma. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (51.8 g/km2).

**Oklahoma**

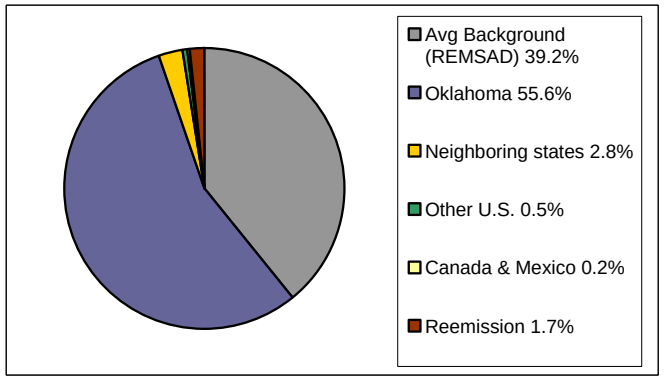
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



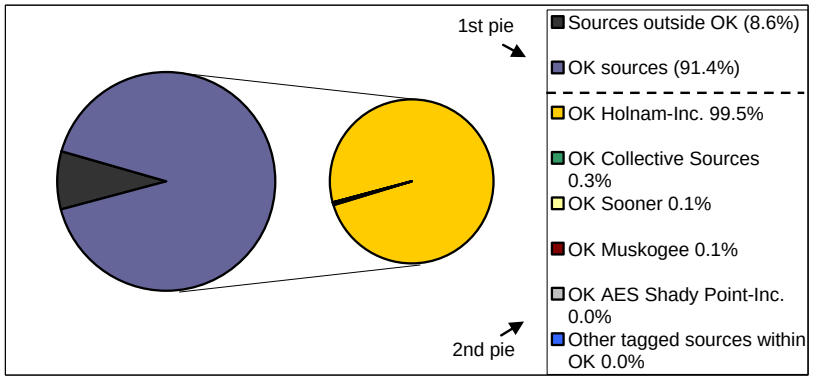

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Oklahoma Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-33. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Texas.**

a.

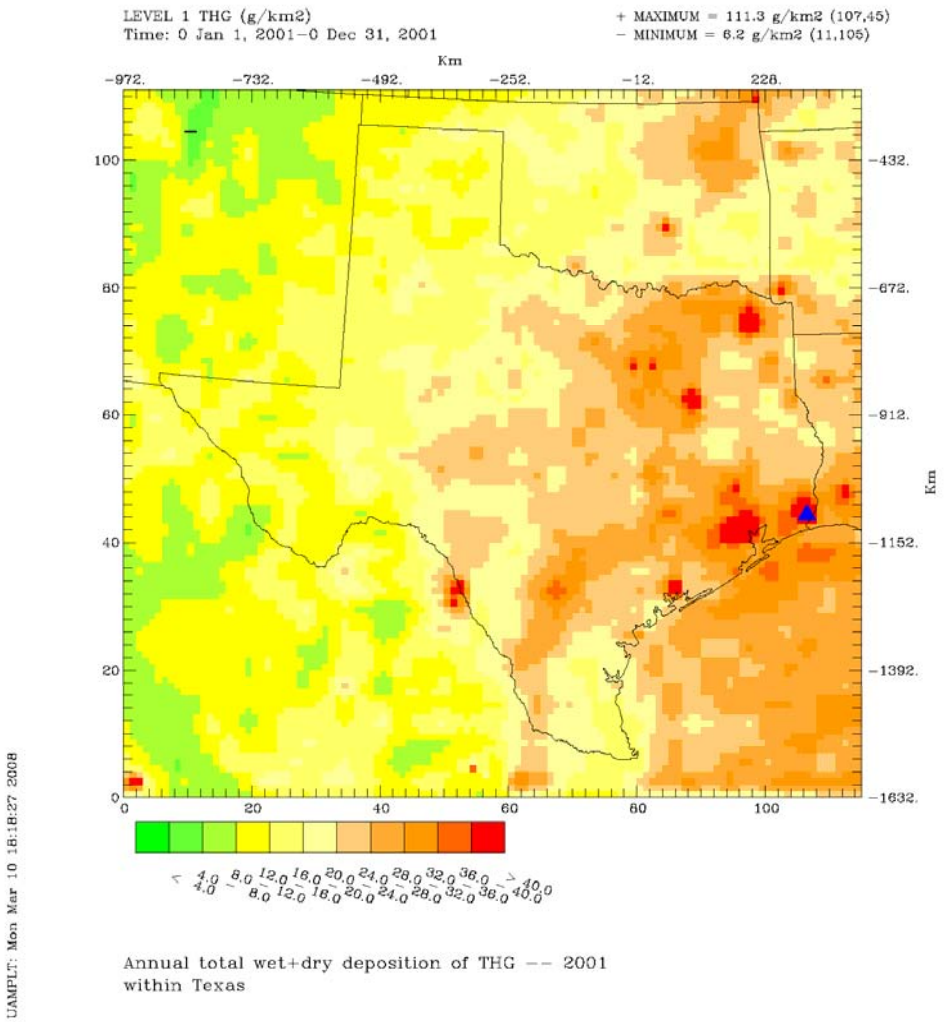
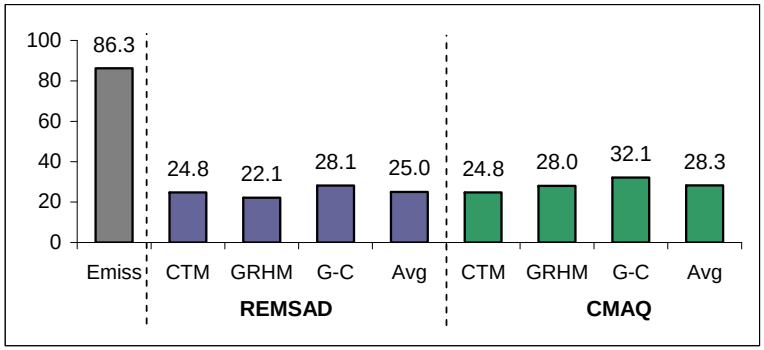


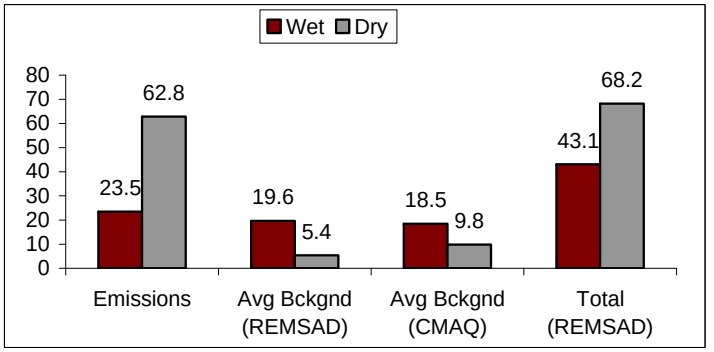
Figure 7-33b. Texas. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (111.3 g/km2).

**Texas**

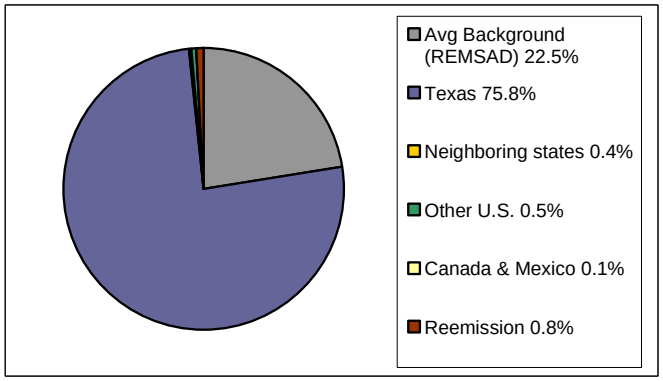
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



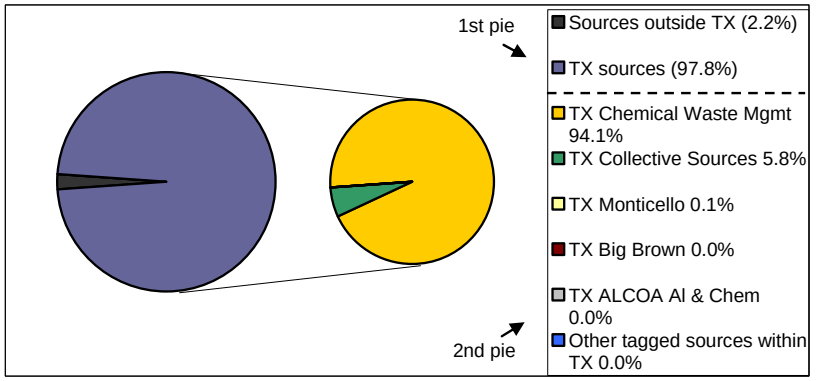

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Texas Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-34. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Iowa.**

a.

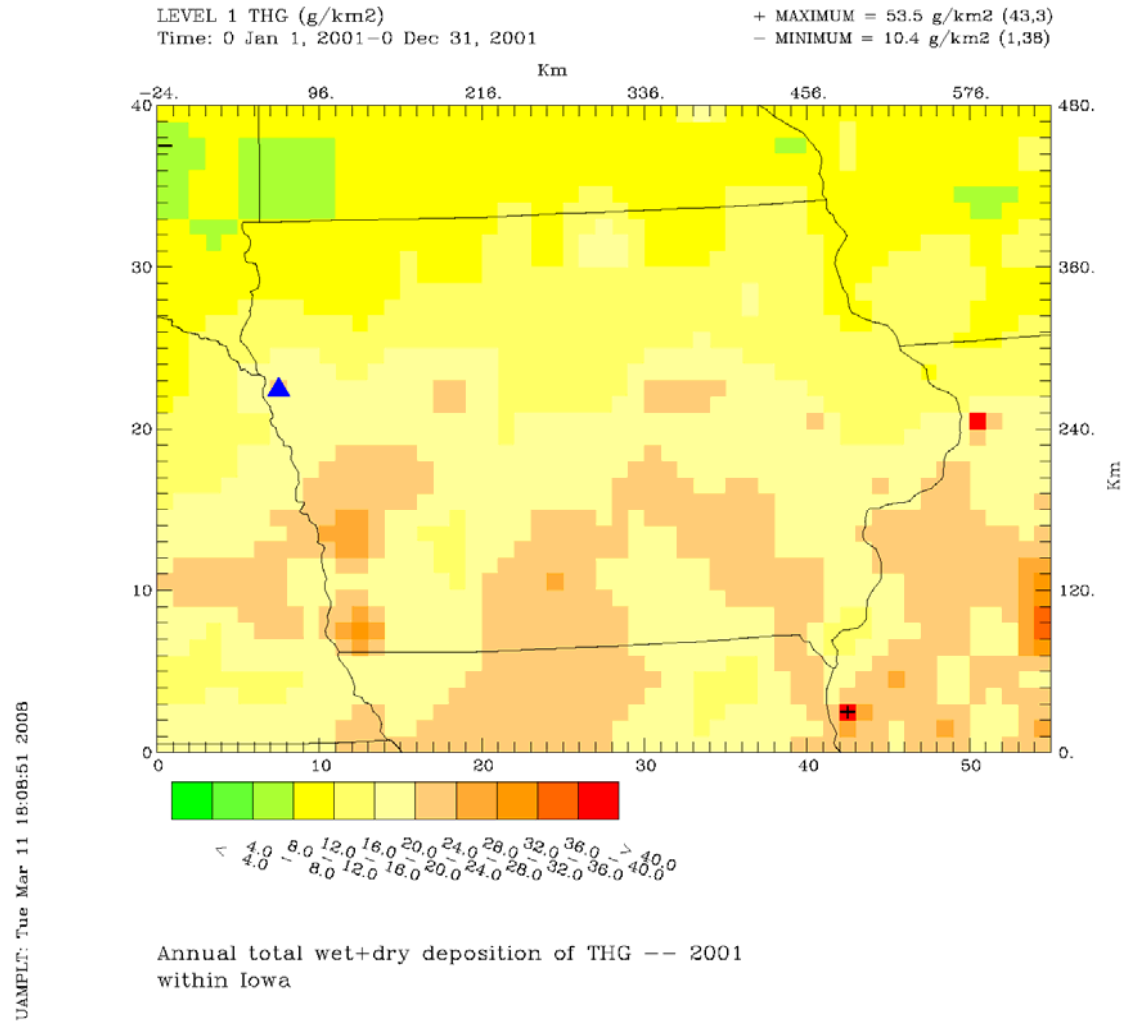
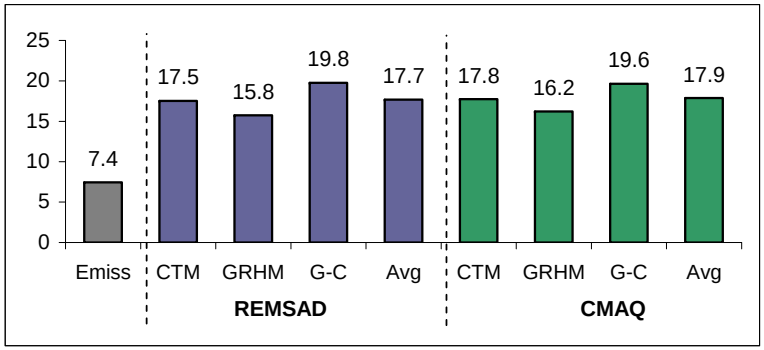


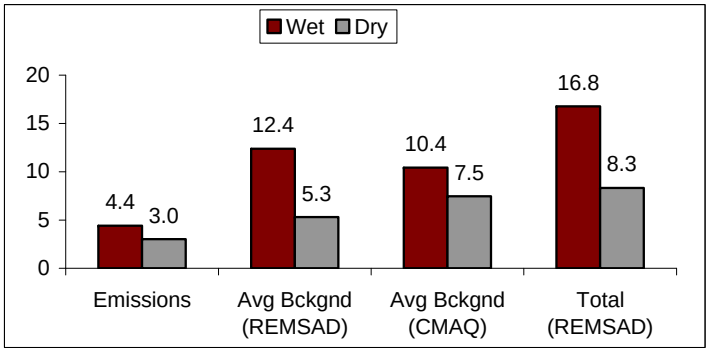
Figure 7-34b. Iowa. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (25.1 g/km2).

**Iowa**

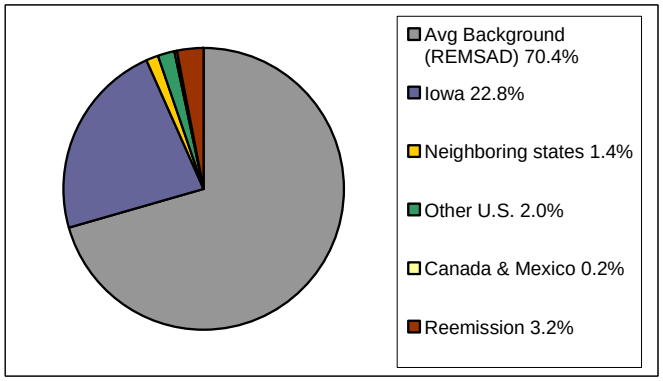
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



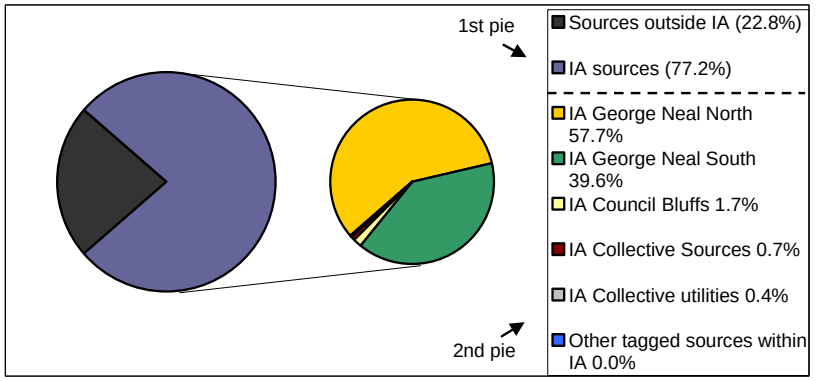

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Iowa Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-35. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Kansas.**

a.

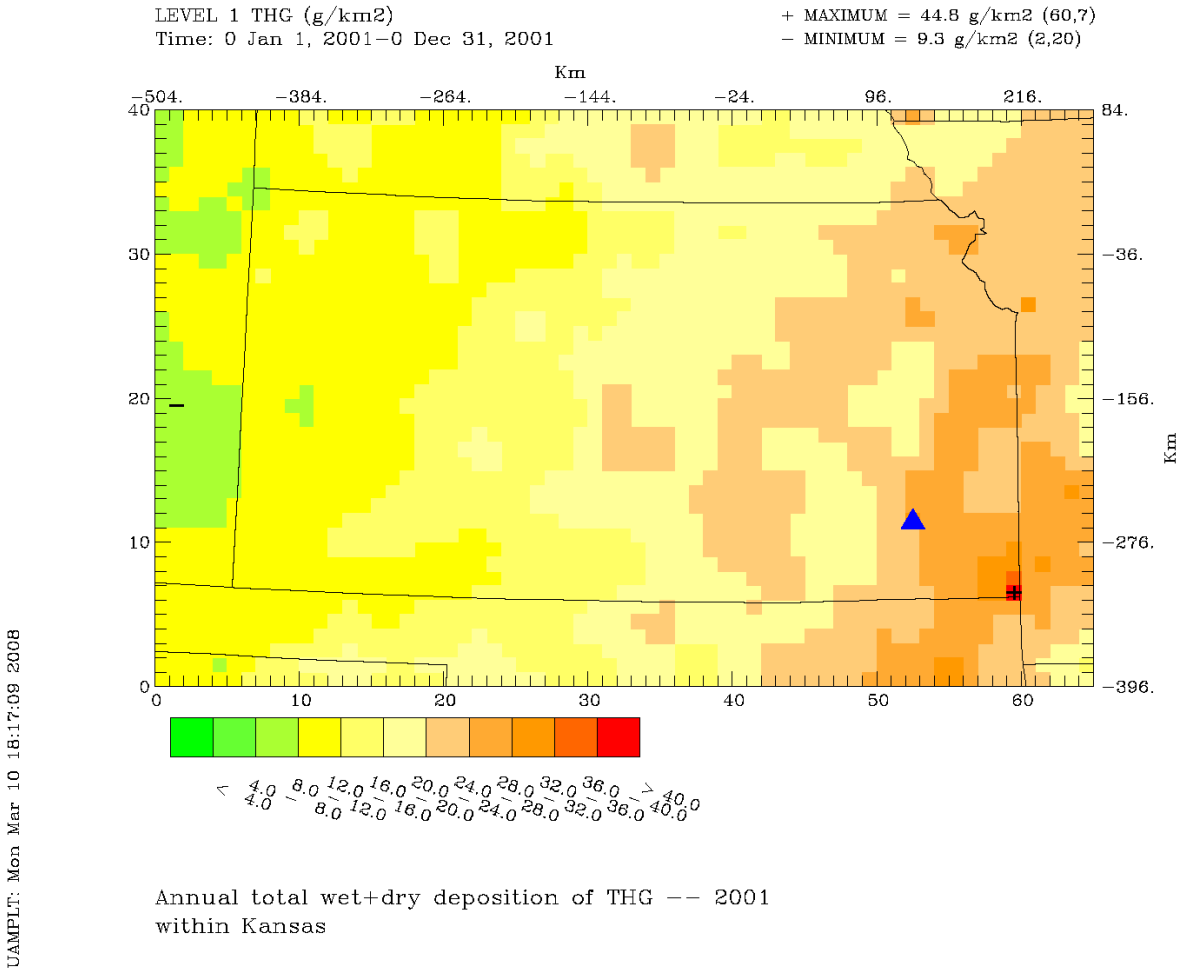
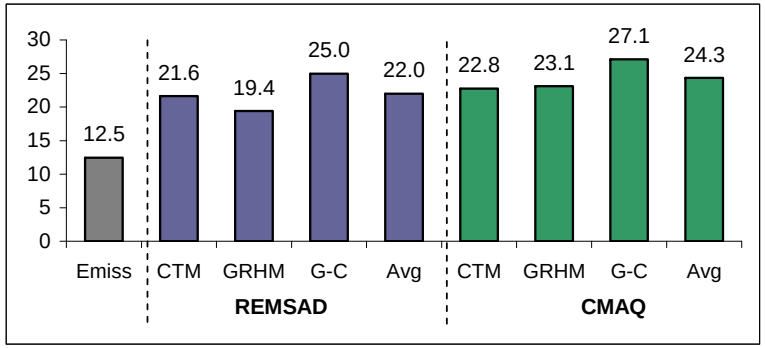


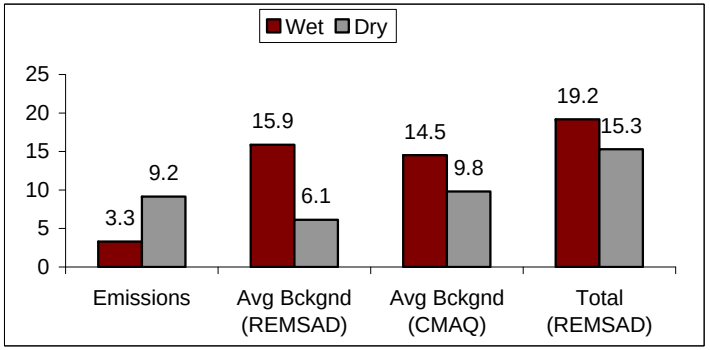
Figure 7-35b. Kansas. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (34.5 g/km2).

**Kansas**

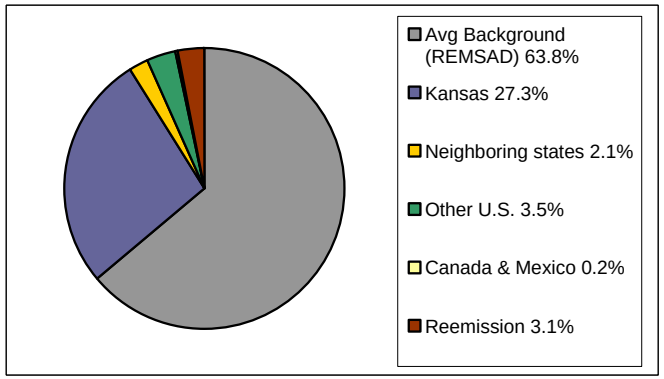
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



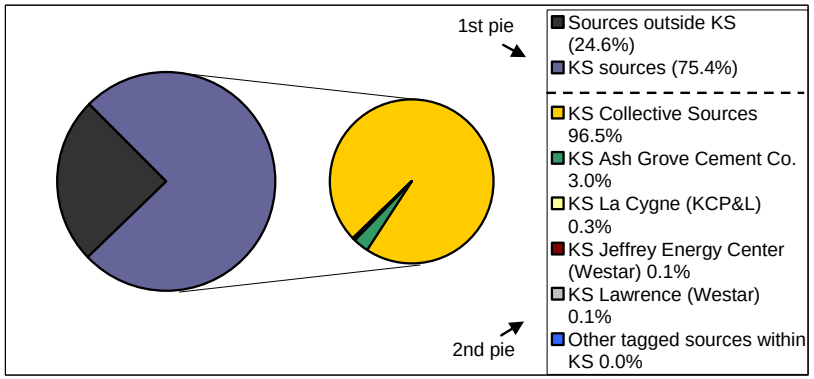

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Kansas Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-36. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Missouri.**

a.

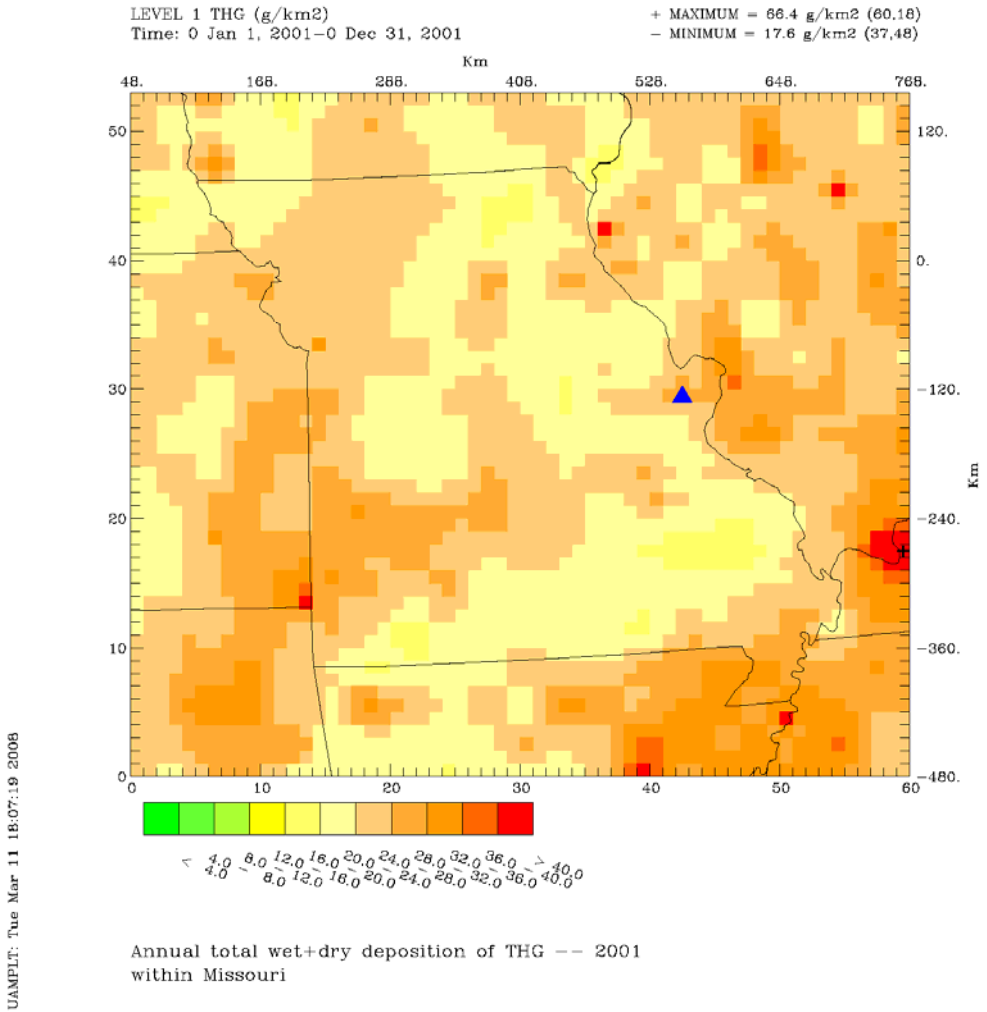
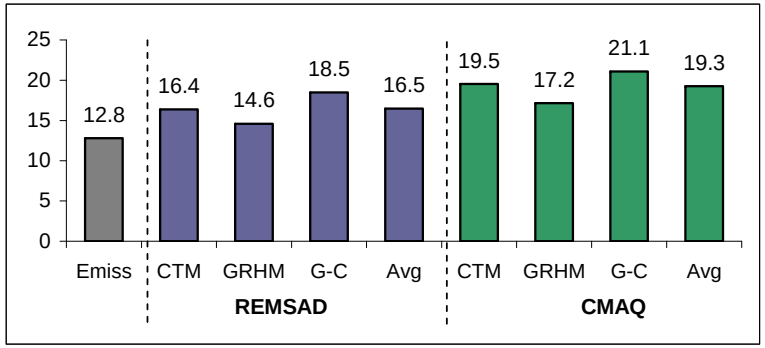


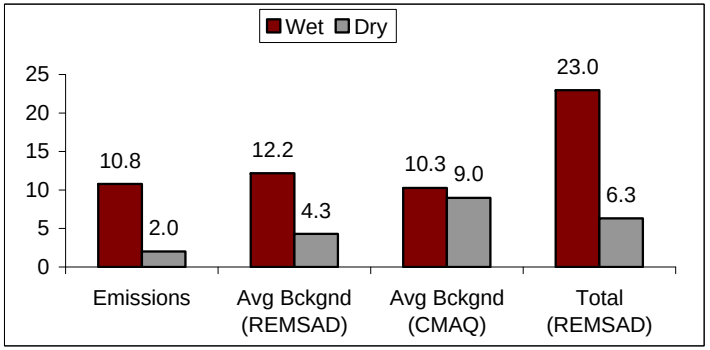
Figure 7-36b. Missouri. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (29.3 g/km2).

**Missouri**

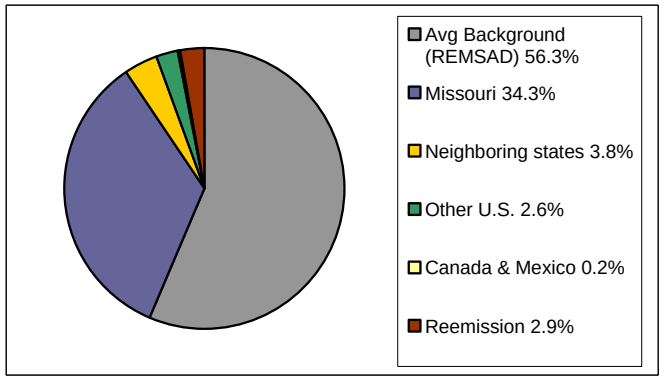
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



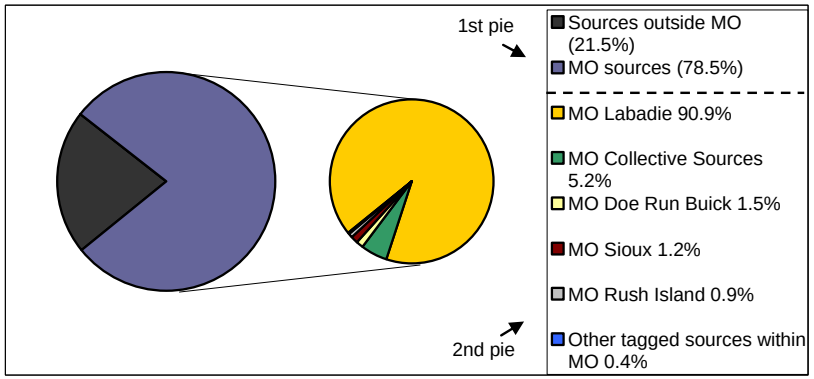

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Missouri Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-37. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Nebraska.**

a.

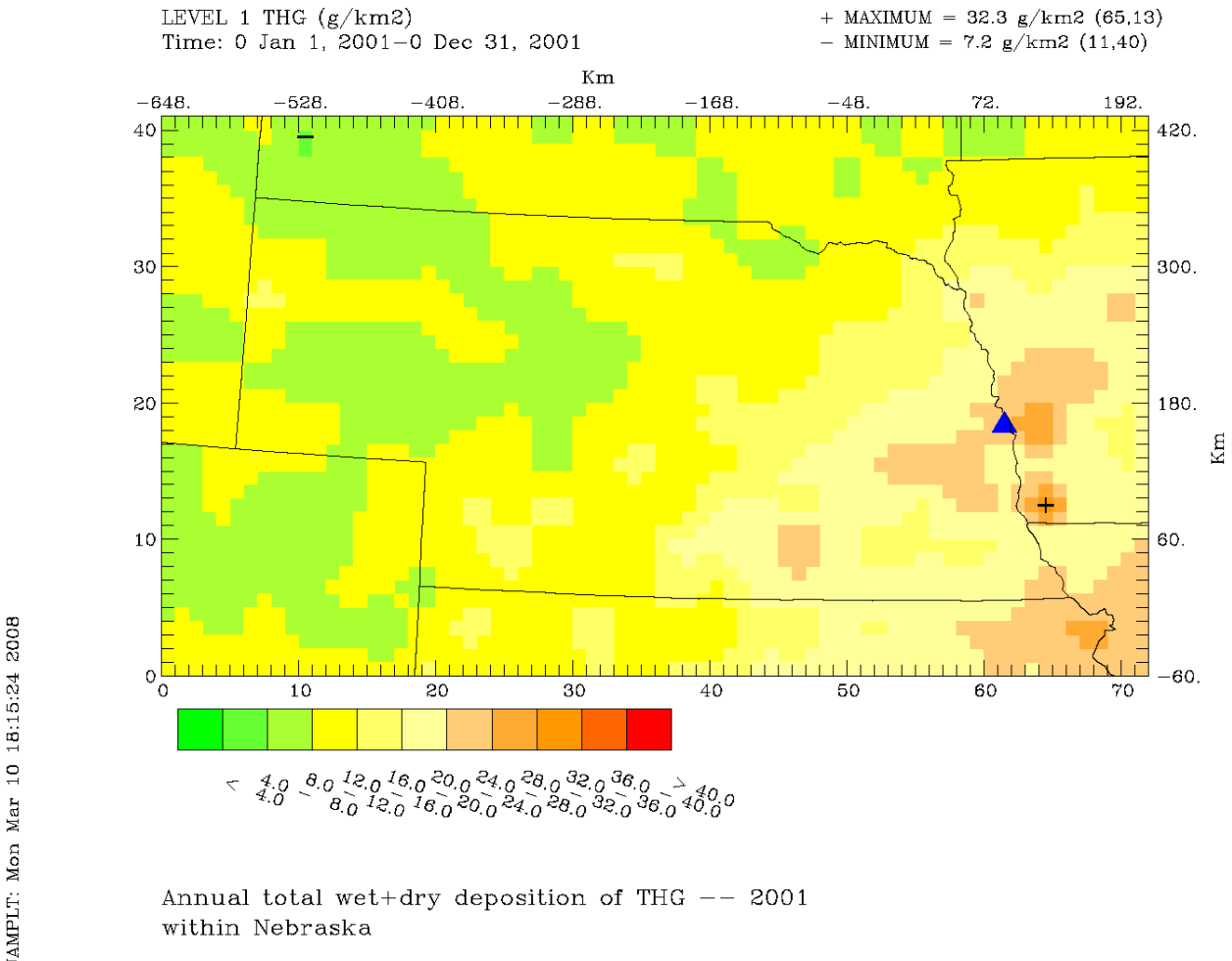
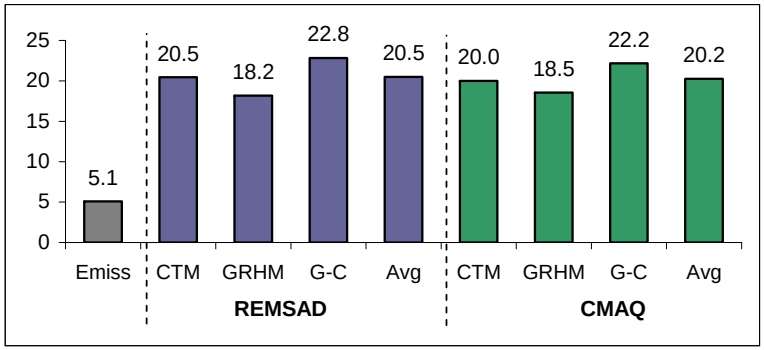


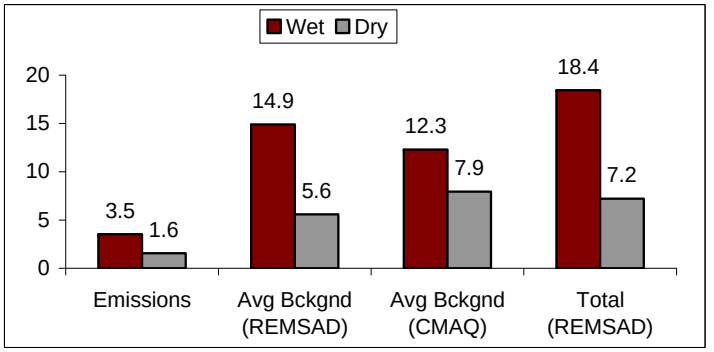
Figure 7-37b. Nebraska. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (25.6 g/km2).

**Nebraska**

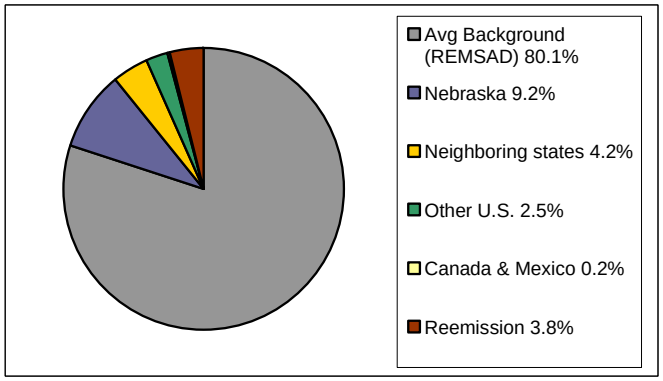
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



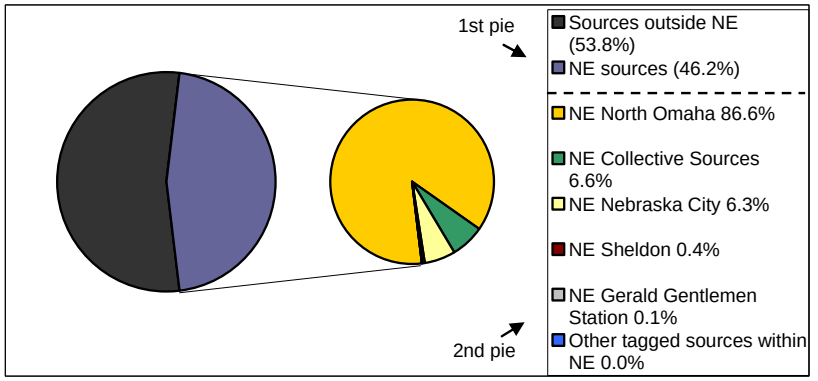

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Nebraska Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-38. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Colorado.**

a.

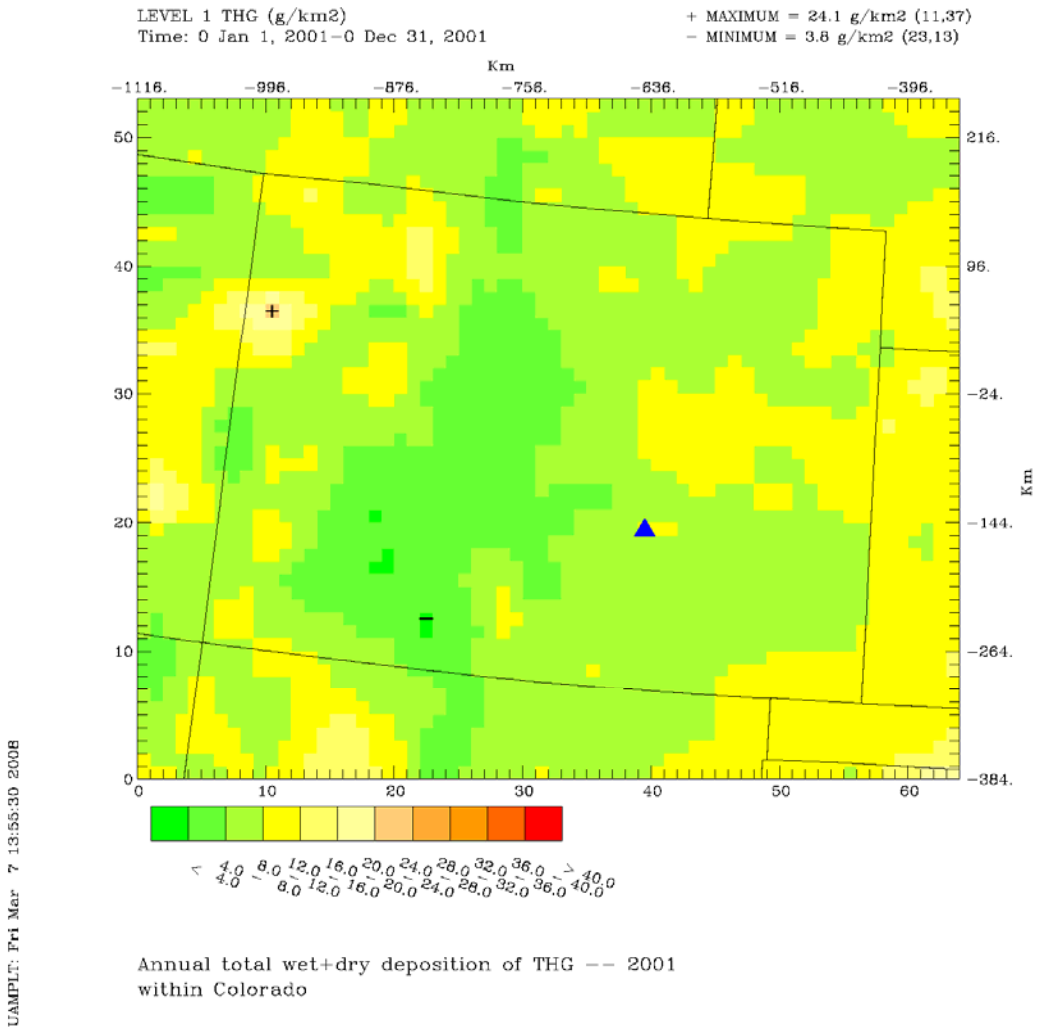
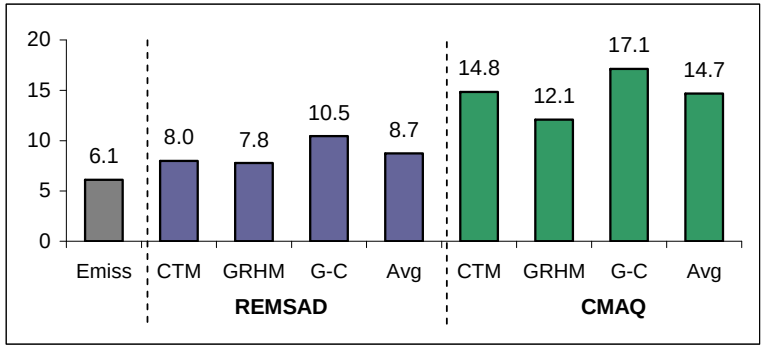


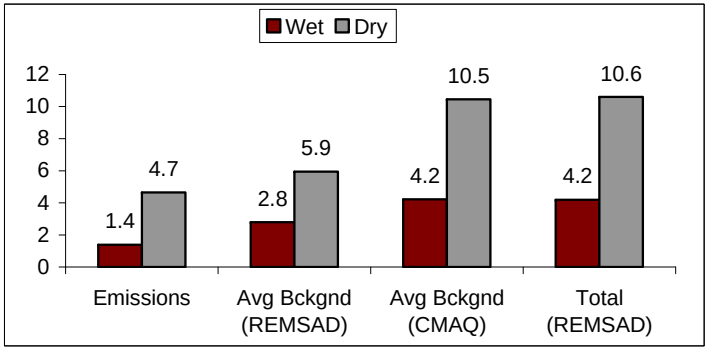
Figure 7-38b. Colorado. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (14.8 g/km2).

**Colorado**

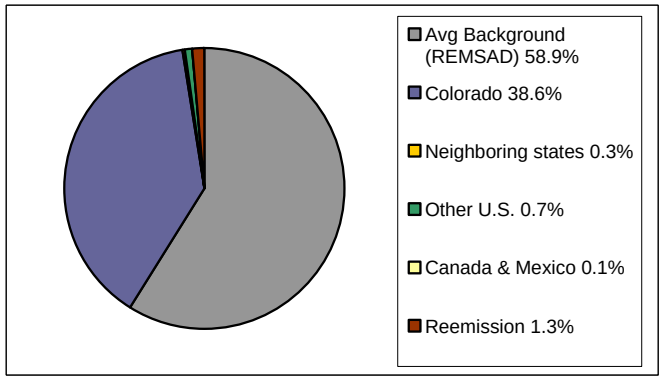
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



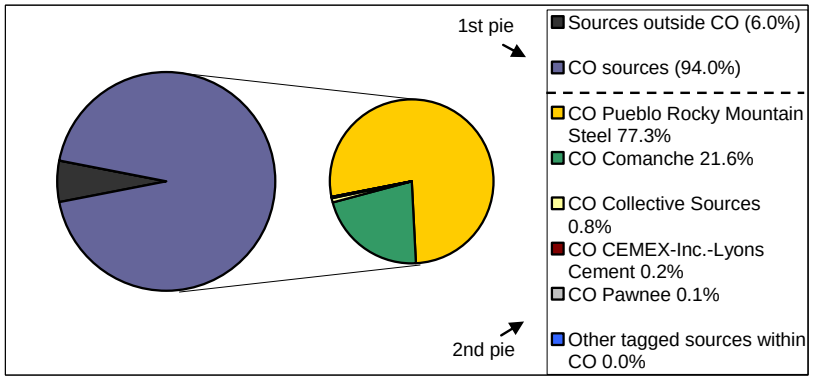

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Colorado Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-39. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Montana.**

a.

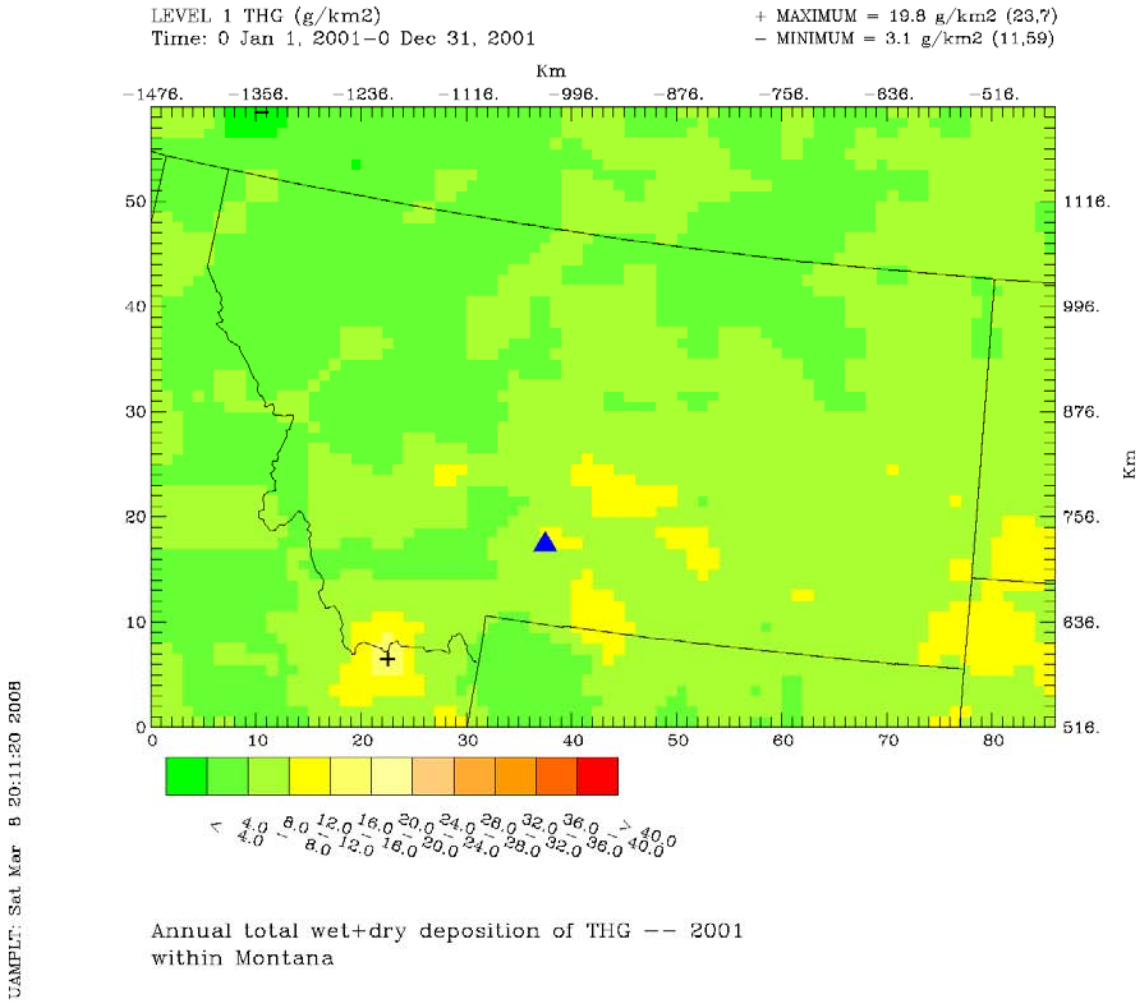
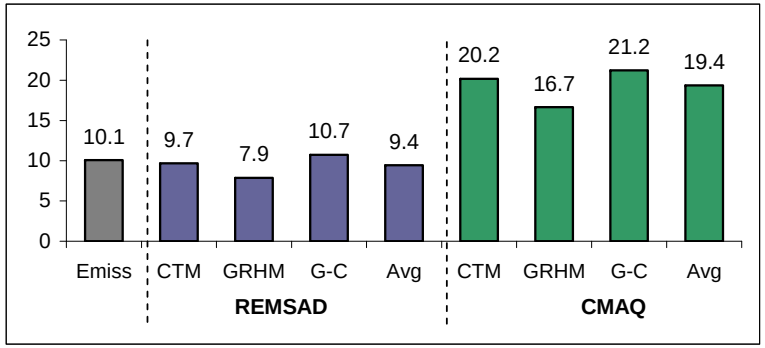


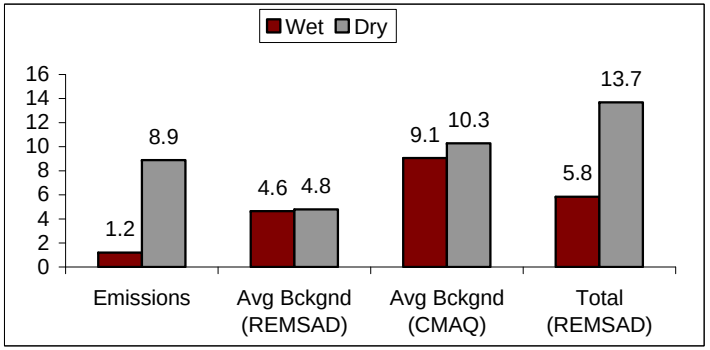
Figure 7-39b. Montana. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (19.5 g/km2).

**Montana**

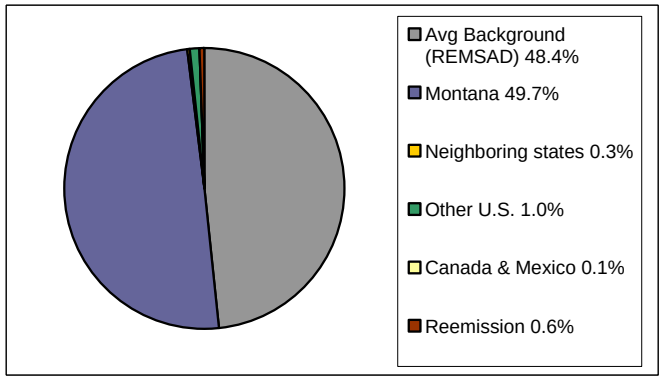
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



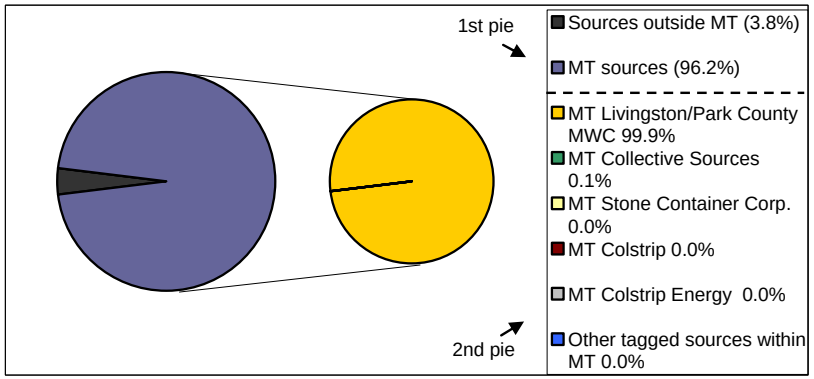

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Montana Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-40. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for North Dakota.**

a.

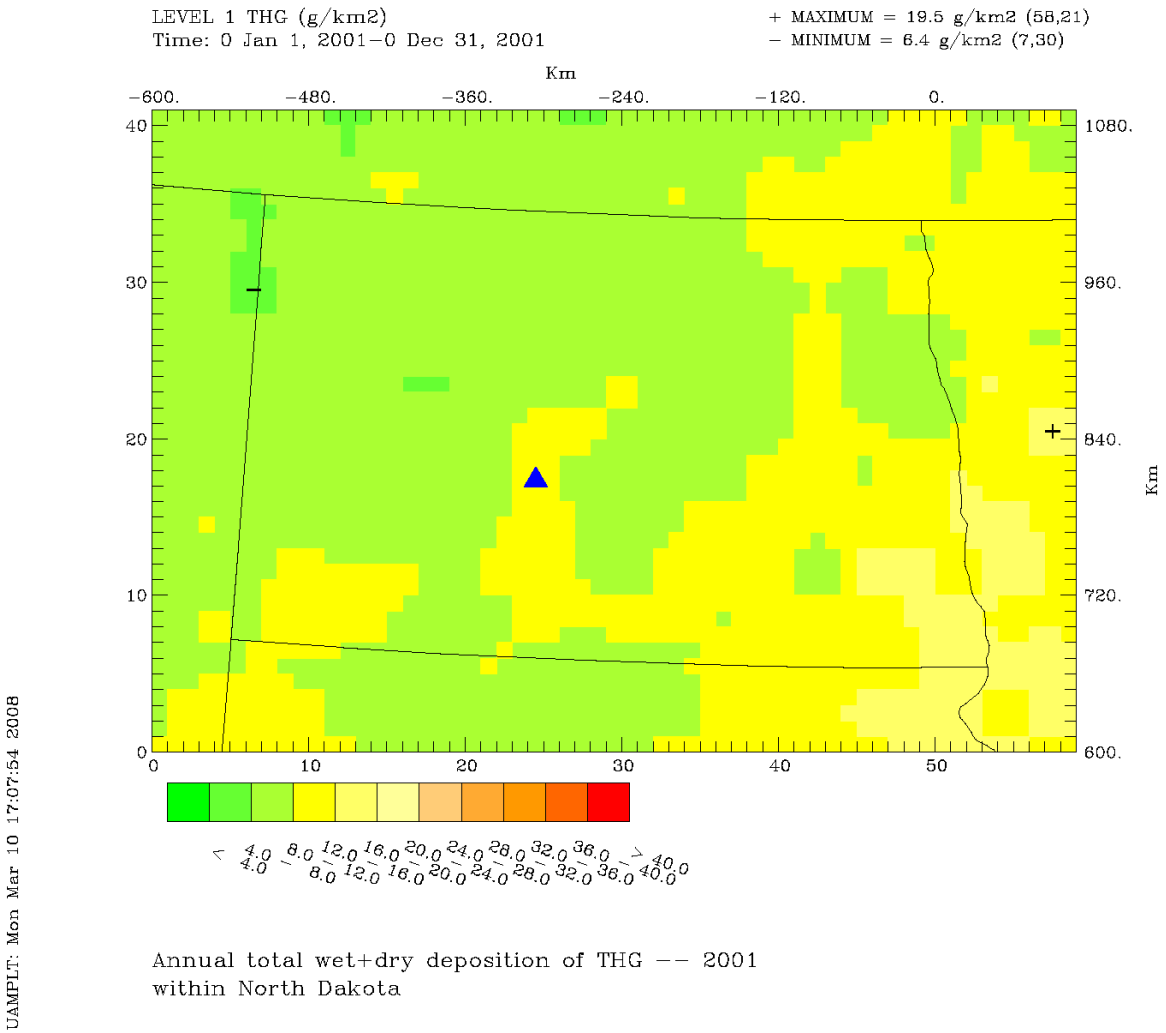
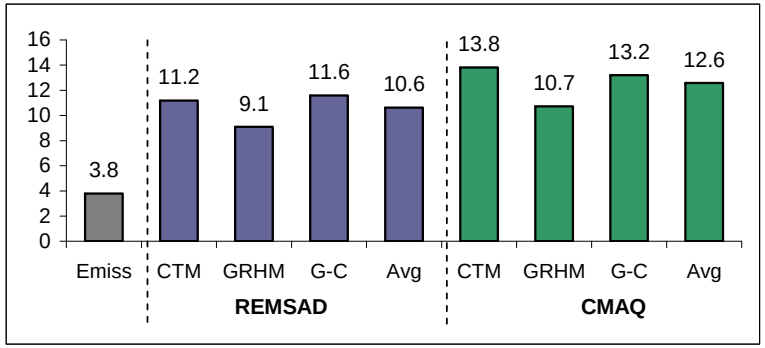


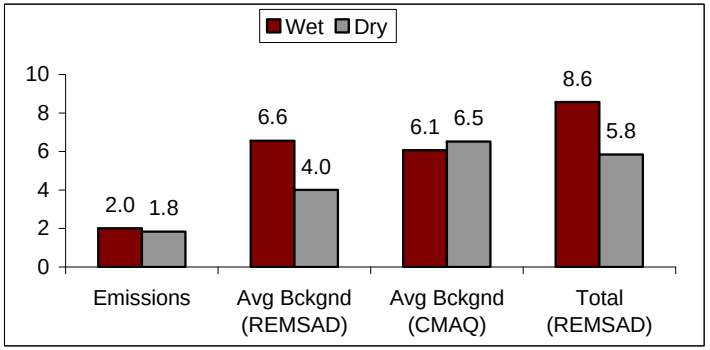
Figure 7-40b. North_Dakota. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (14.4 g/km2).

**North_Dakota**

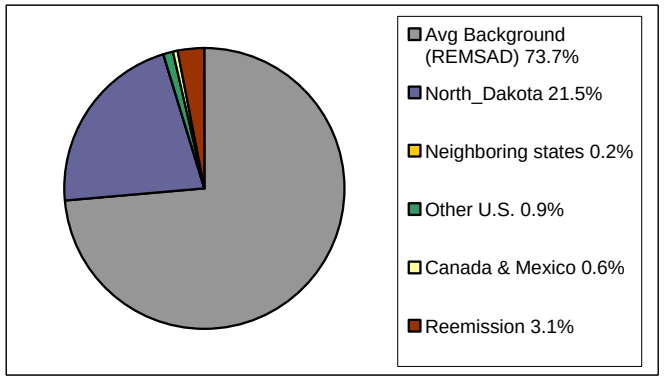
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



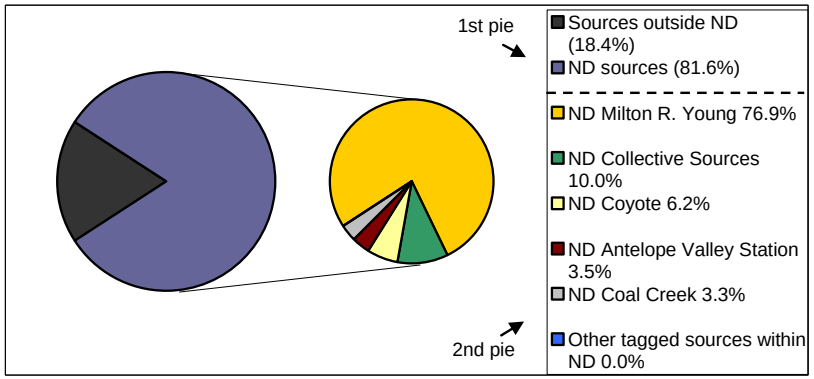

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from North_Dakota Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-41. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for South Dakota.**

a.

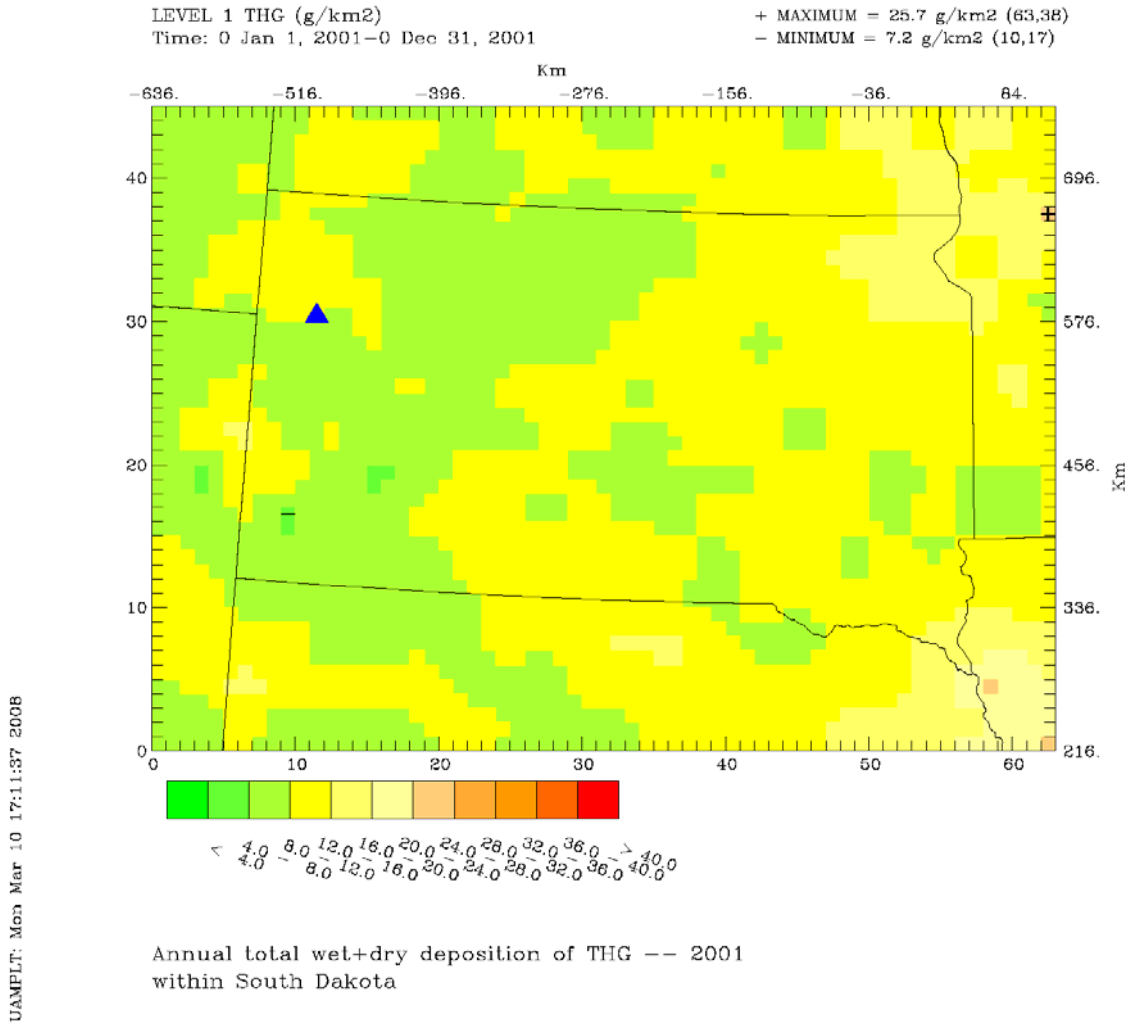
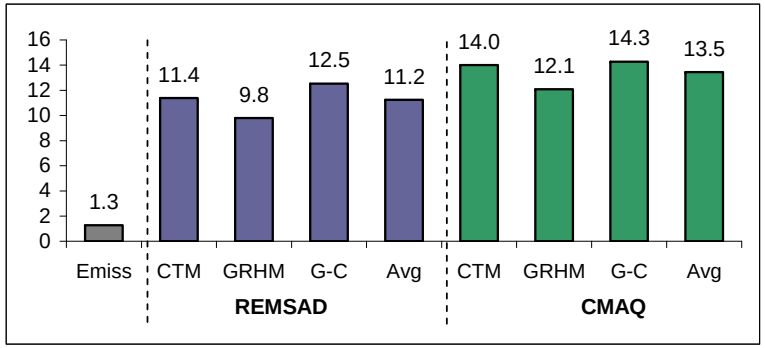


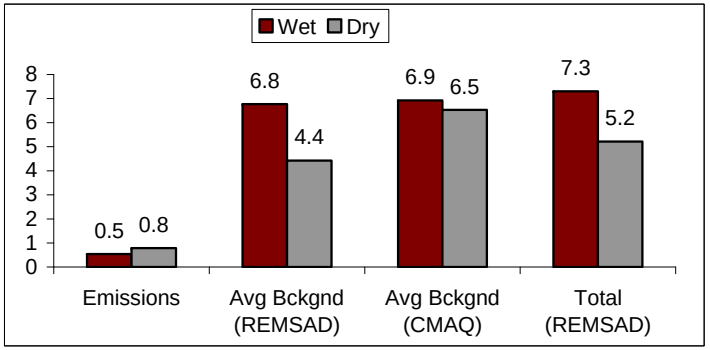
Figure 7-41b. South_Dakota. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (12.5 g/km2).

**South_Dakota**

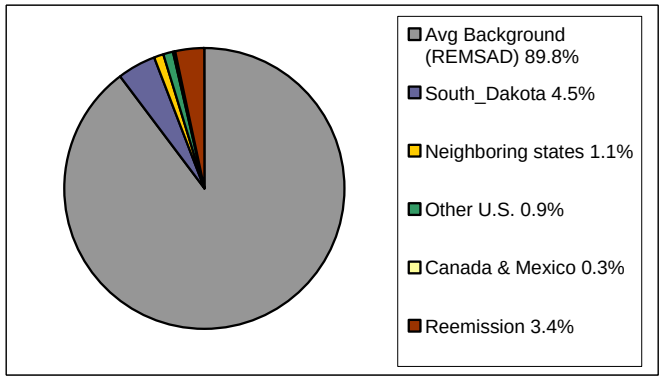
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



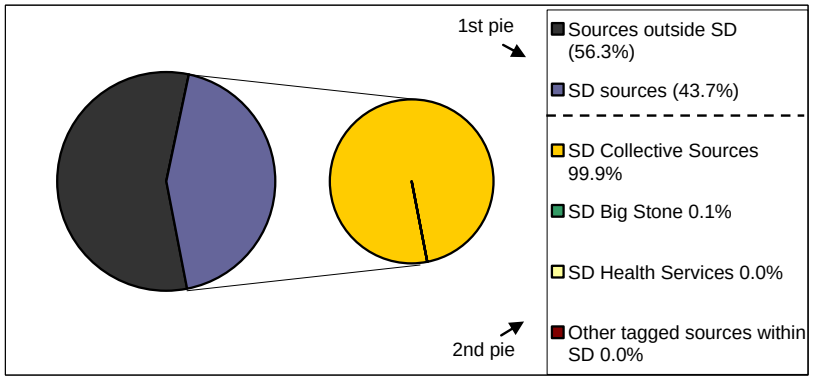

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from South_Dakota Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-42. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Utah.**

a.

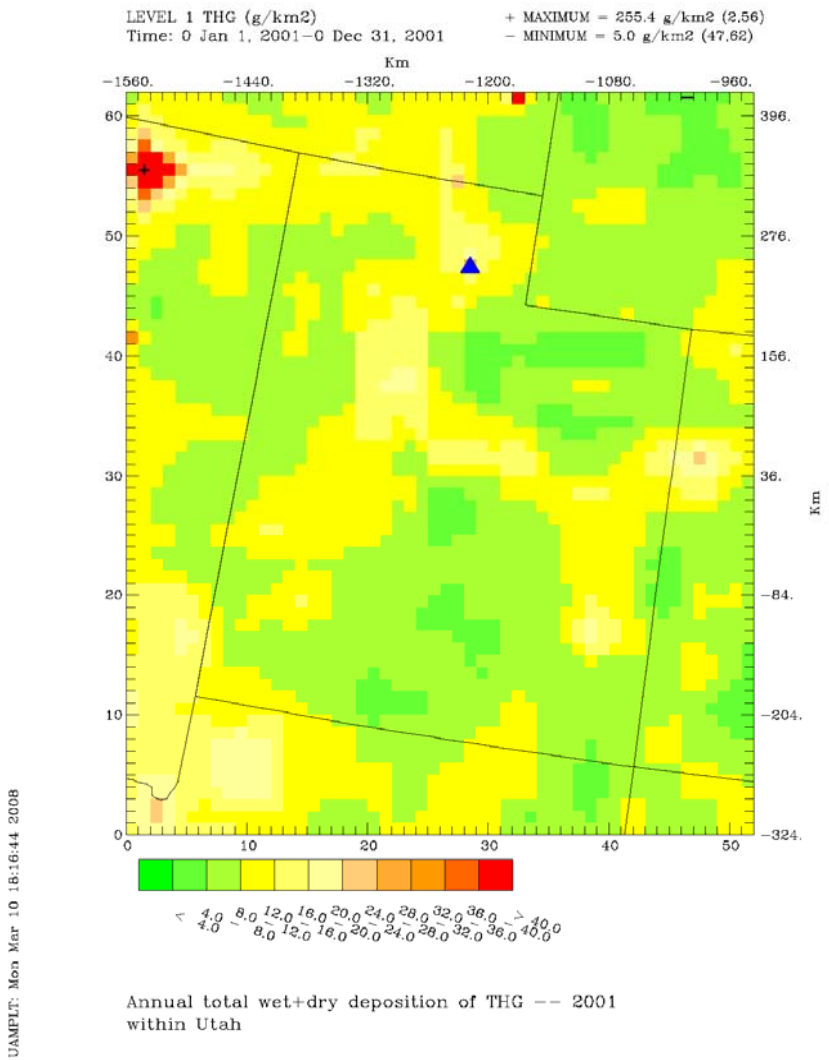
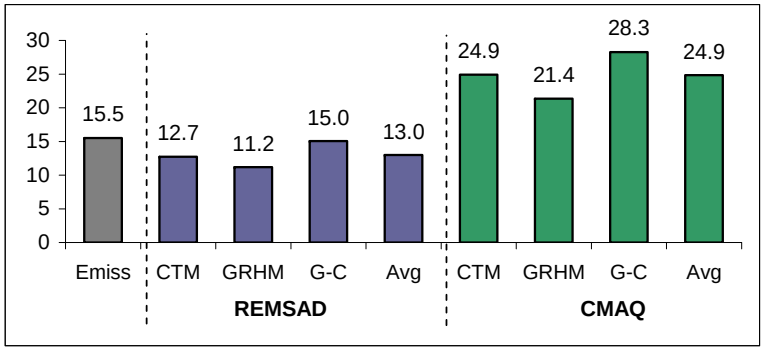


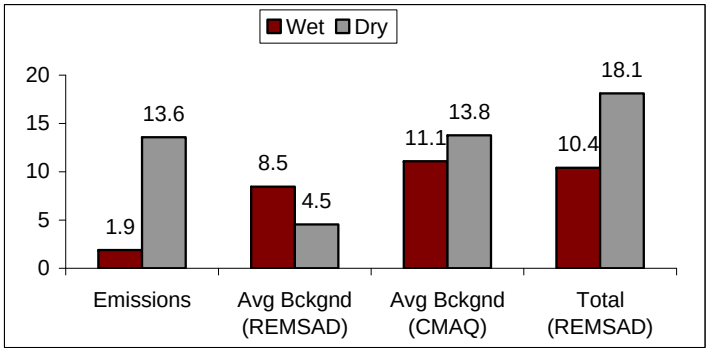
Figure 7-42b. Utah. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (28.5 g/km2).

**Utah**

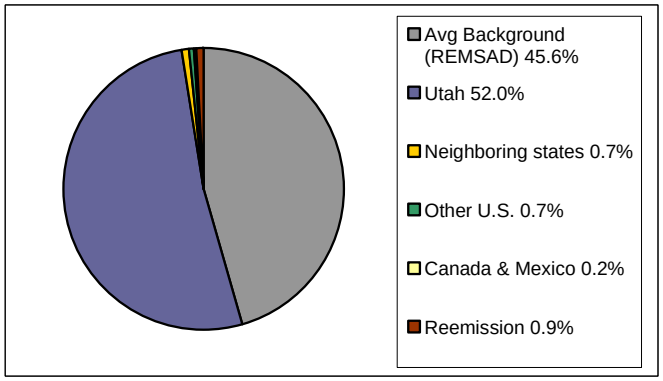
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



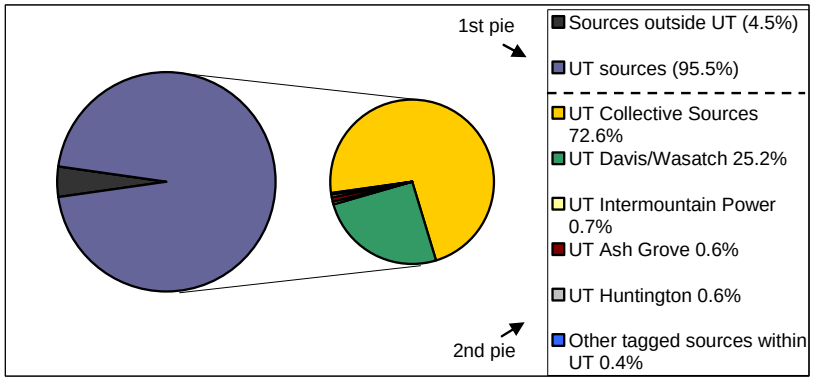

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Utah Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-43. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Wyoming.**

a.

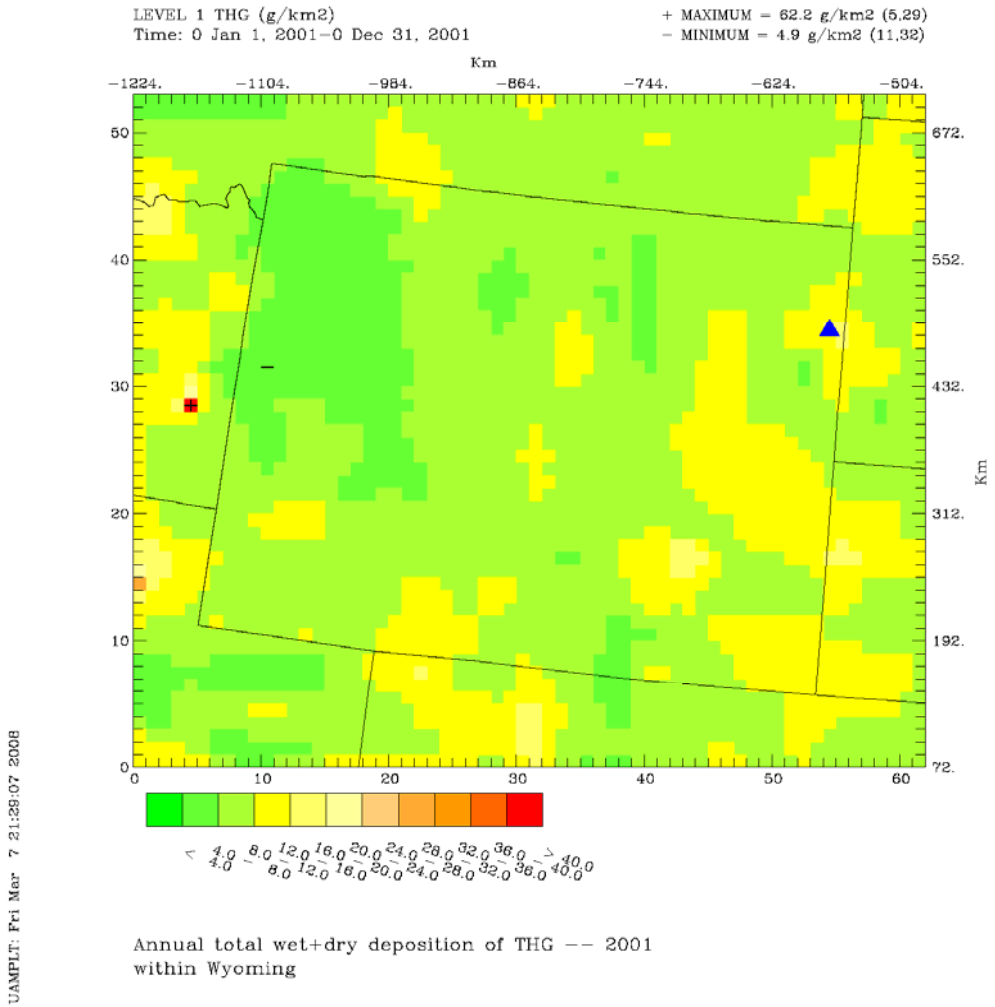
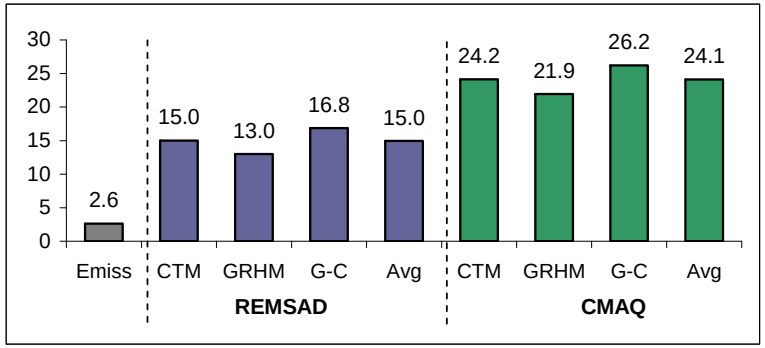


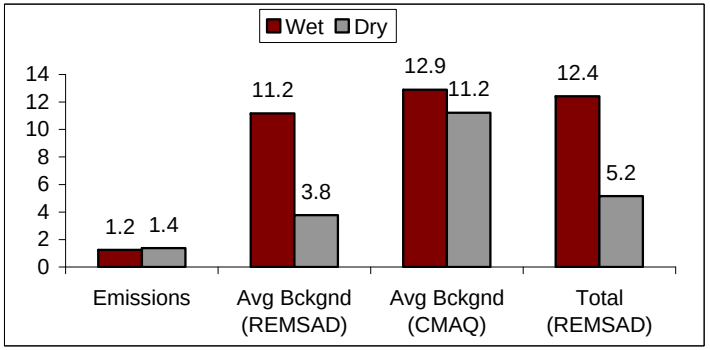
Figure 7-43b. Wyoming. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (17.6 g/km2).

**Wyoming**

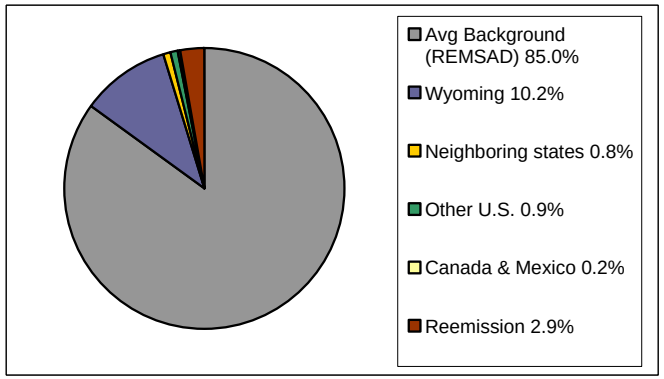
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



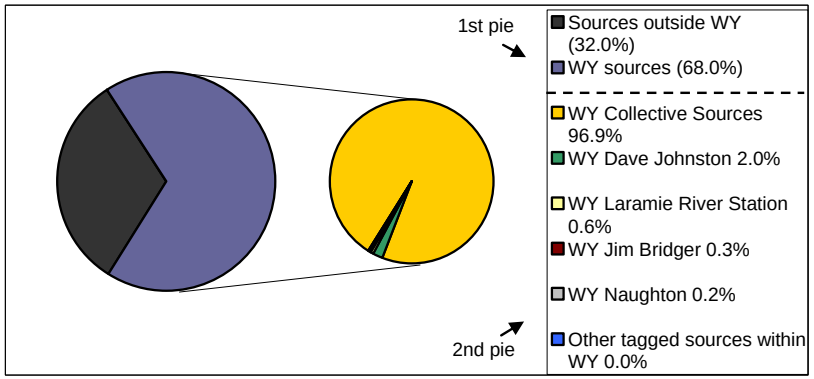

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Wyoming Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-44. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Arizona.**

a.

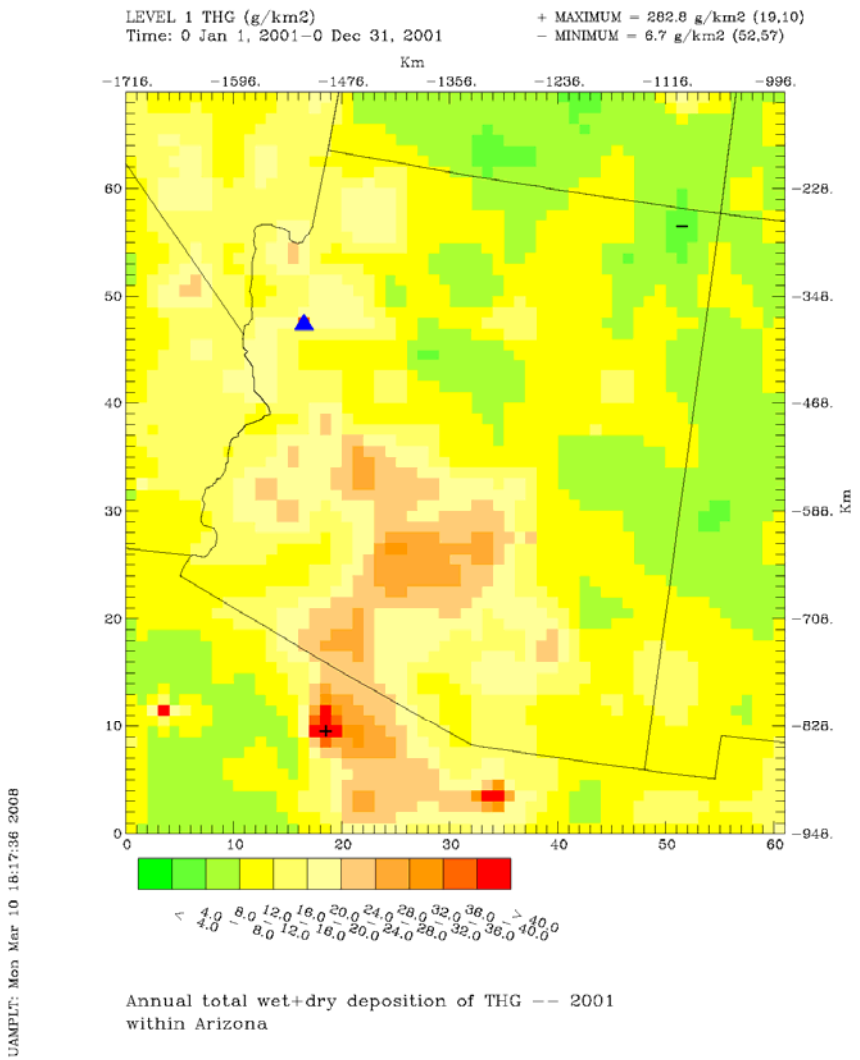
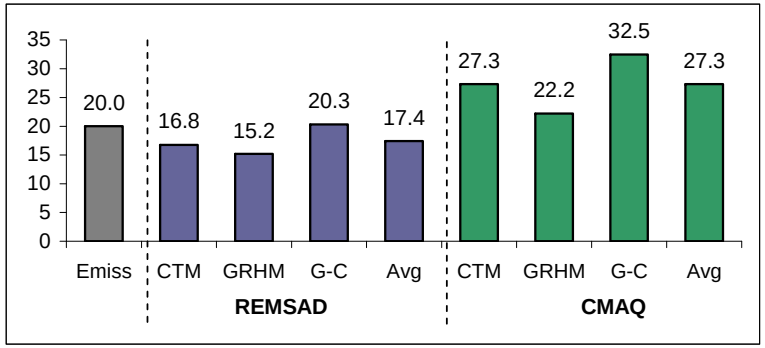


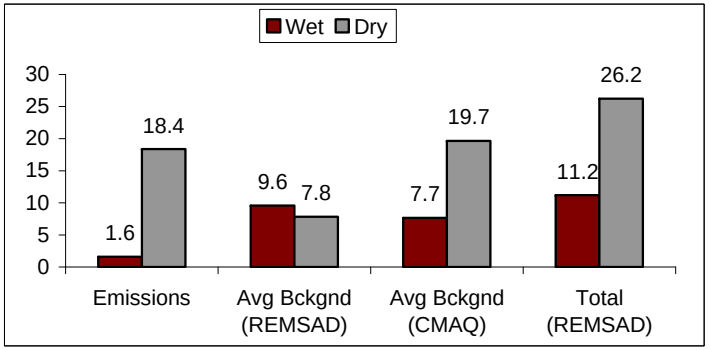
Figure 7-44b. Arizona. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (37.4 g/km2).

**Arizona**

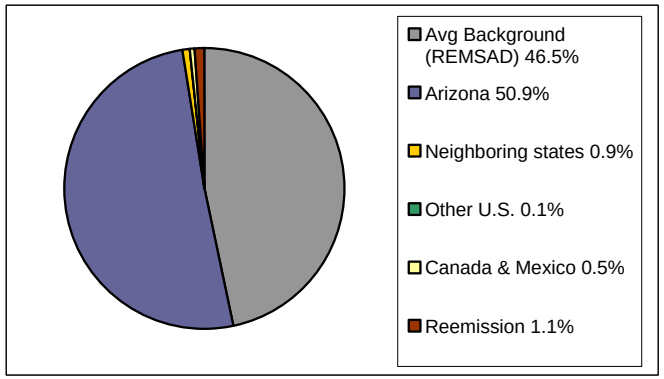
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



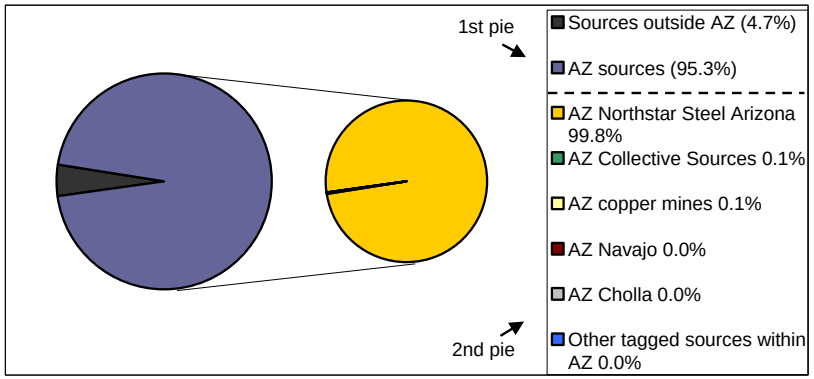

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Arizona Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-45. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for California.**

a.

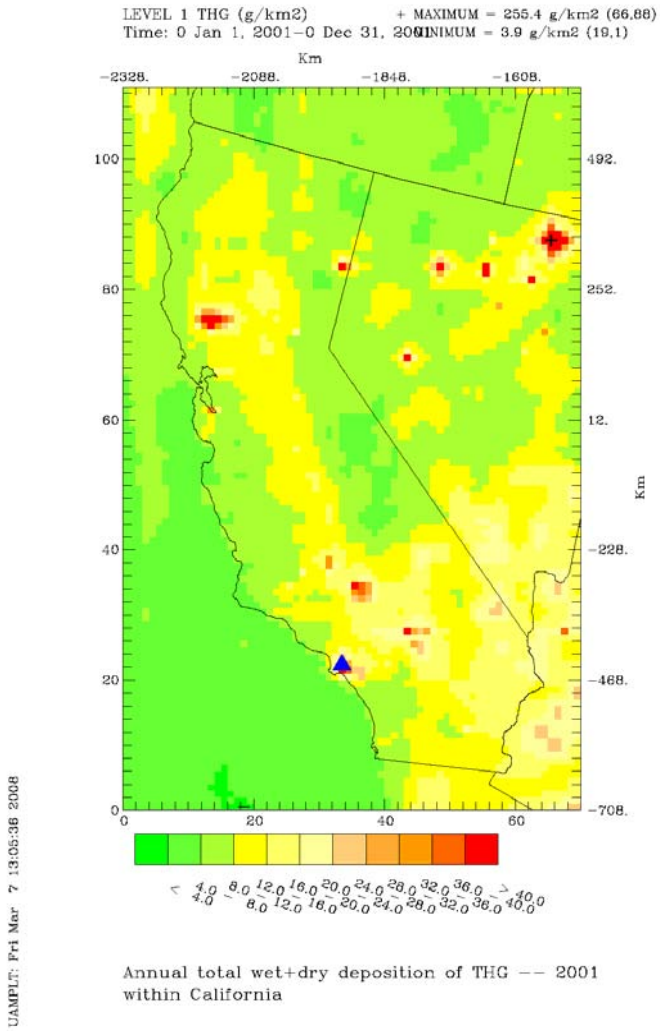
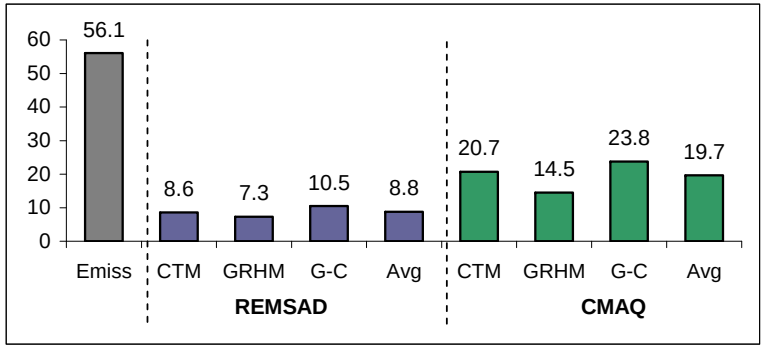


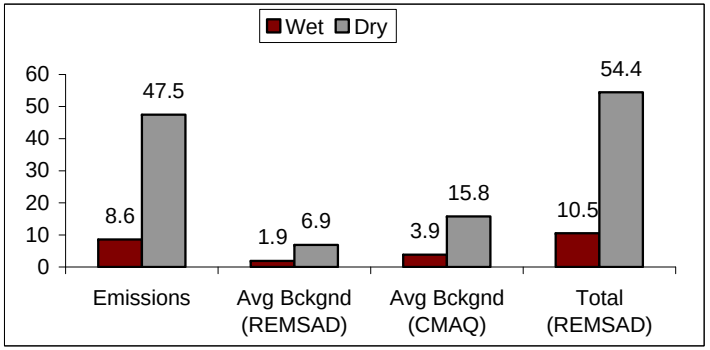
Figure 7-45b. California. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (64.9 g/km2).

**California**

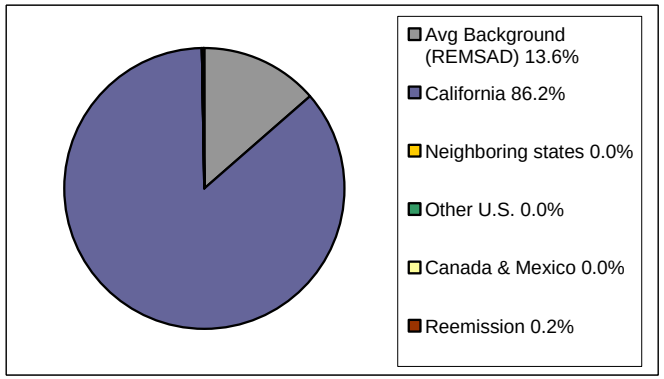
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



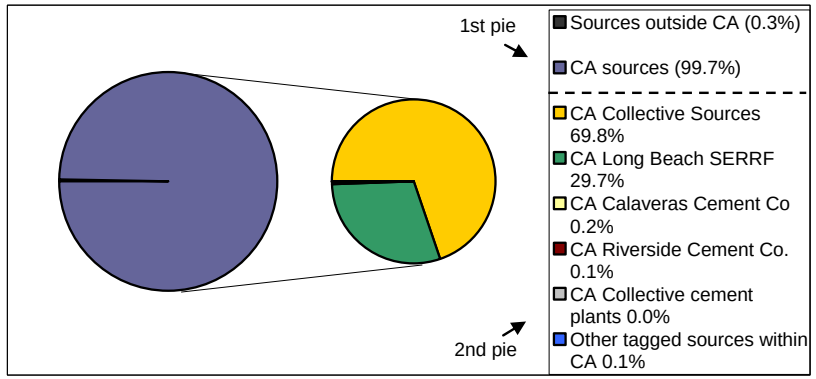

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from California Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-46. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Nevada.**

a.

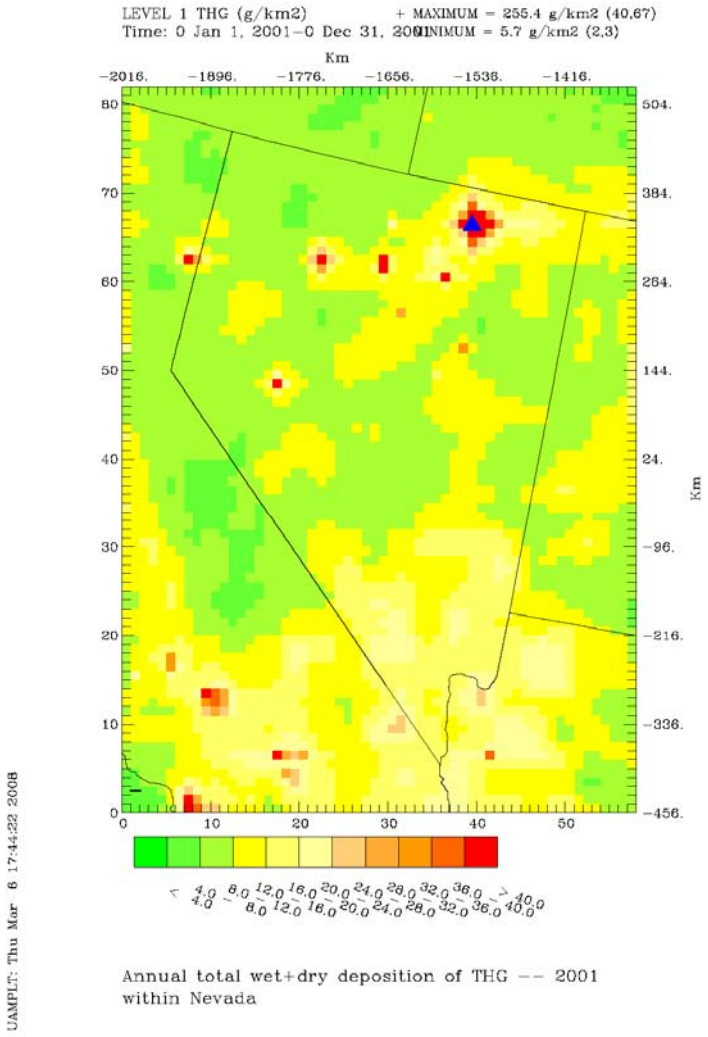
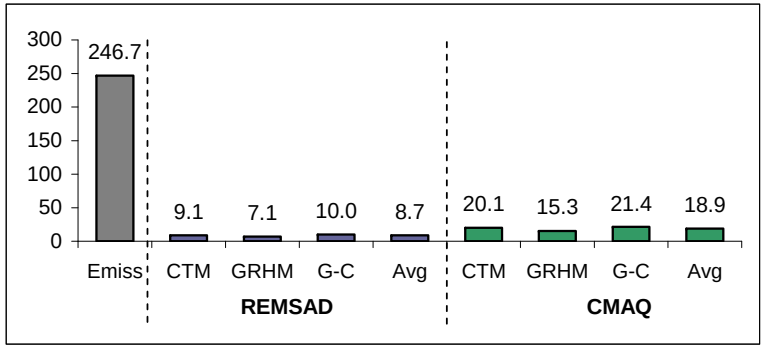


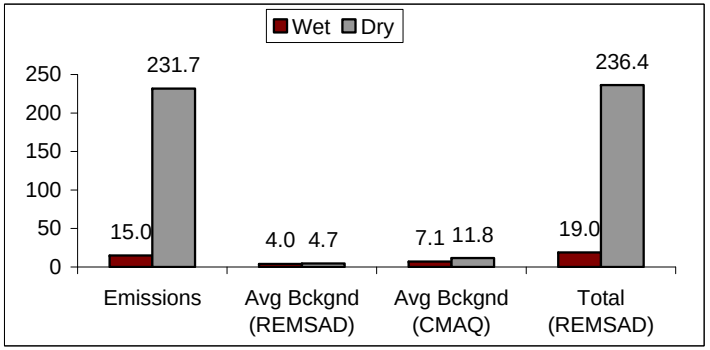
Figure 7-46b. Nevada. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (255.4 g/km2).

**Nevada**

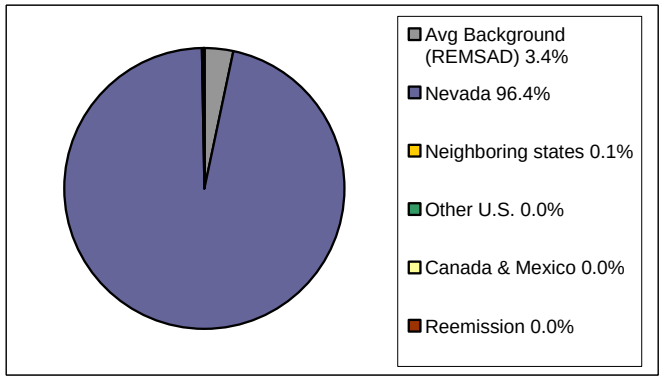
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



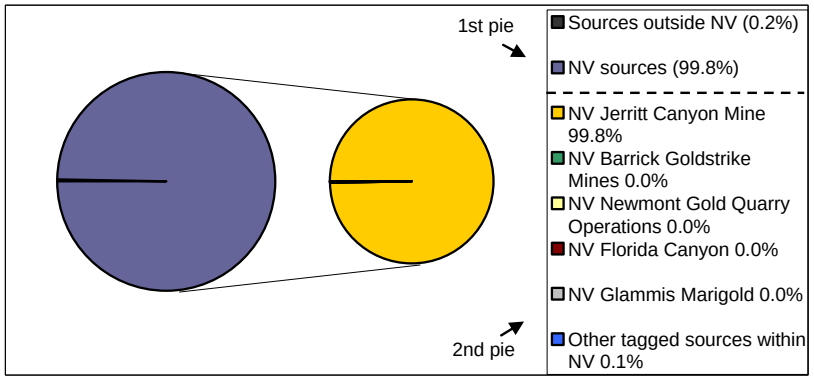

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Nevada Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-47. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Idaho.**

a.

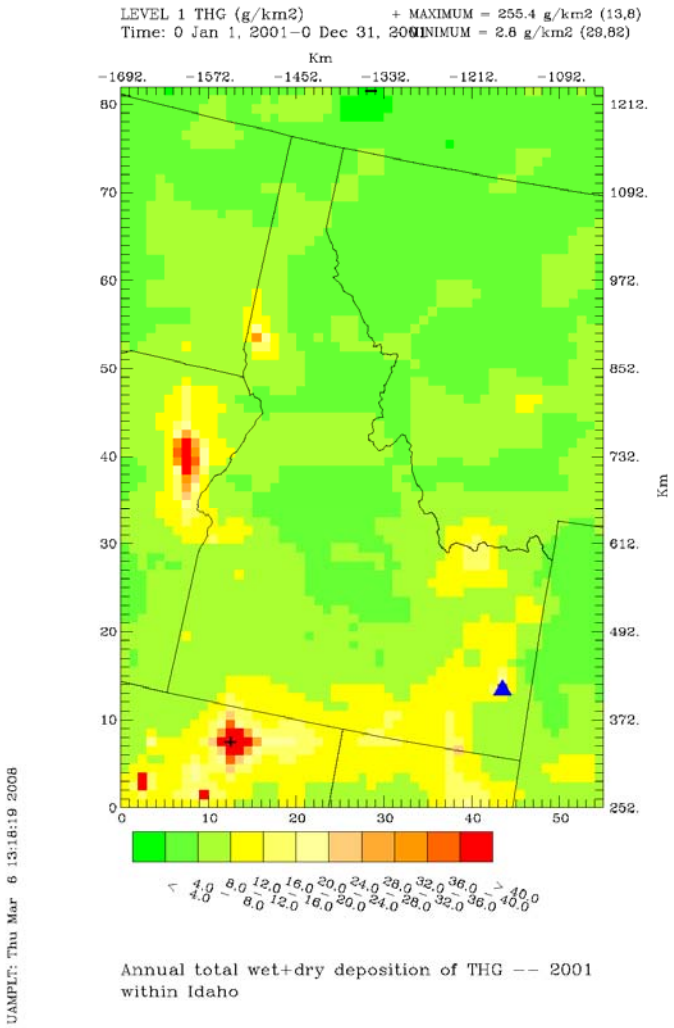
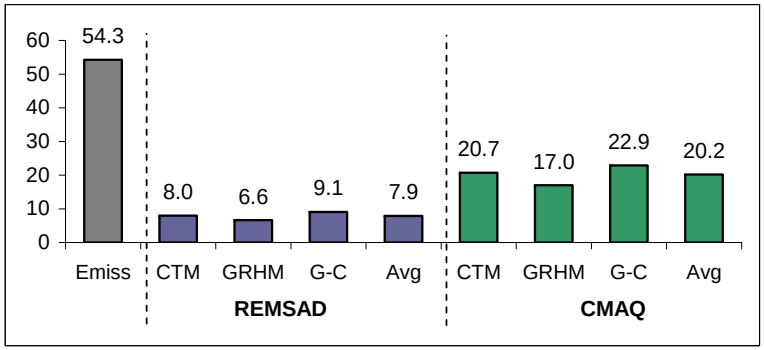


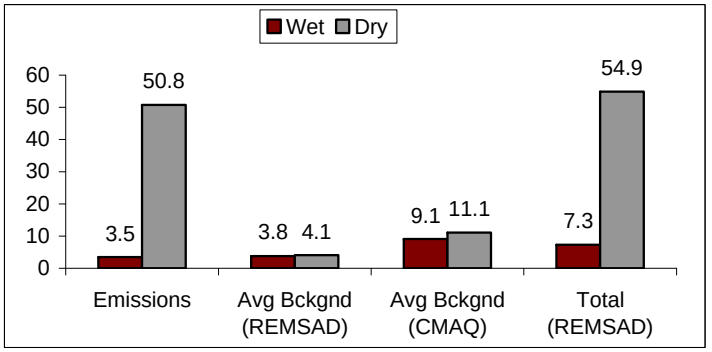
Figure 7-47b. Idaho. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (62.2 g/km2).

**Idaho**

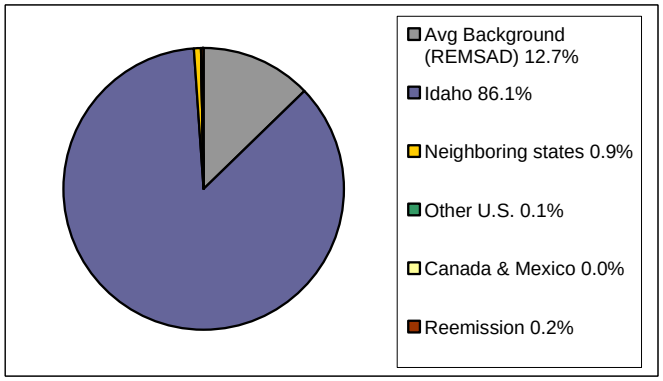
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



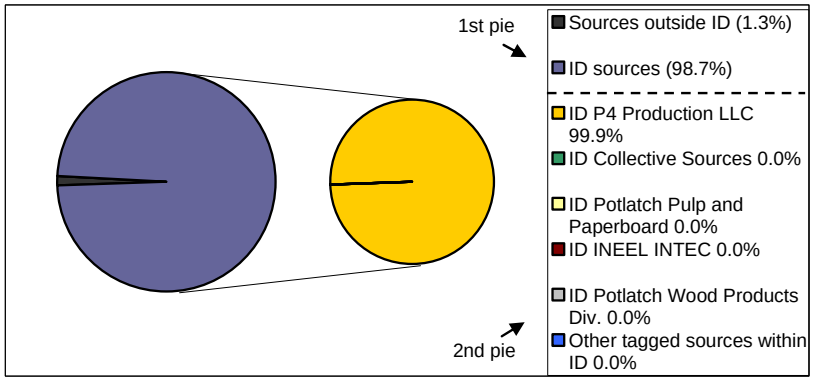

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Idaho Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-48. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Oregon.**

a.

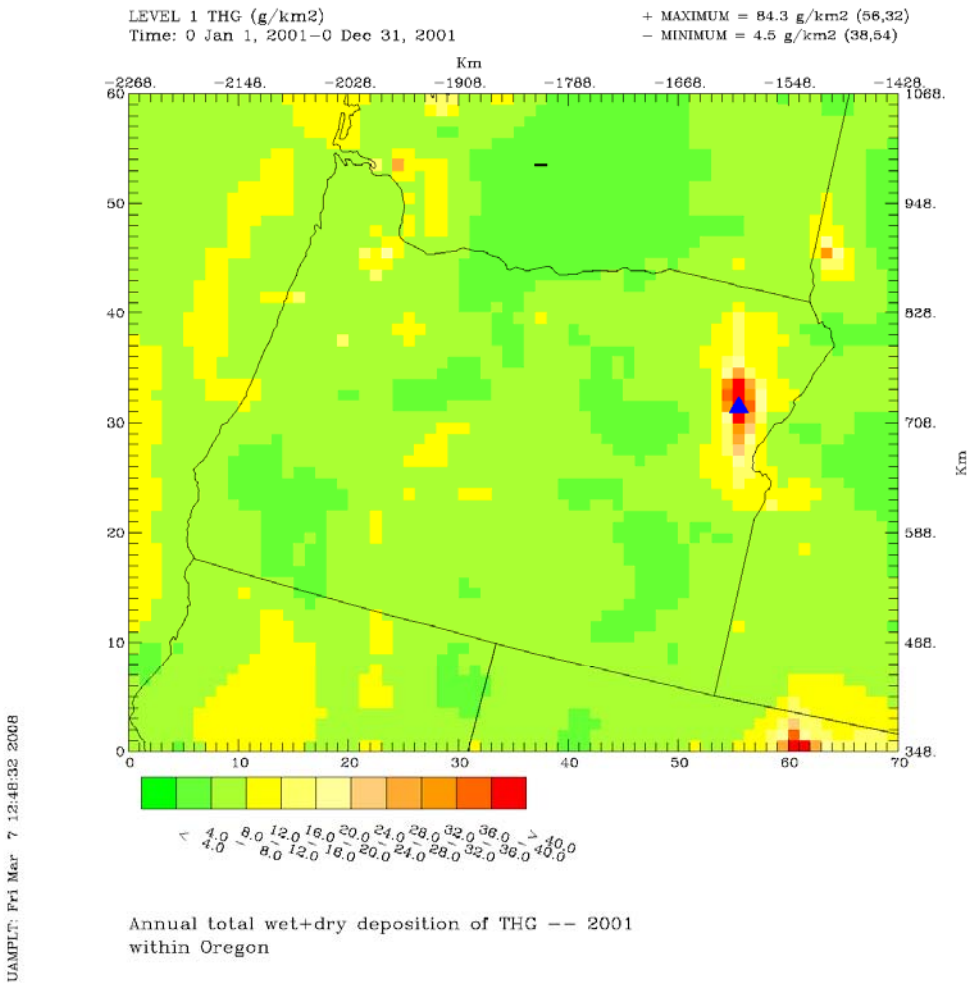
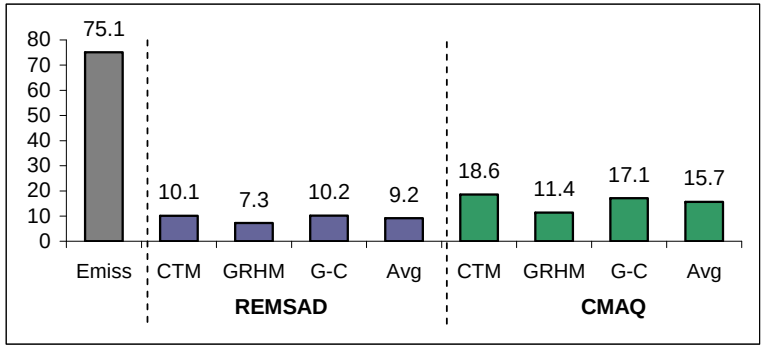


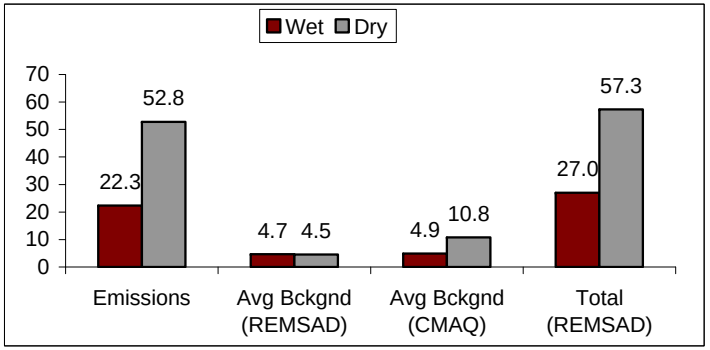
Figure 7-48b. Oregon. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (84.3 g/km2).

**Oregon**

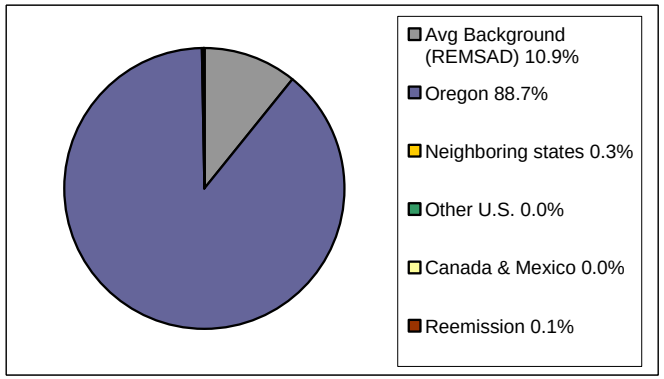
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



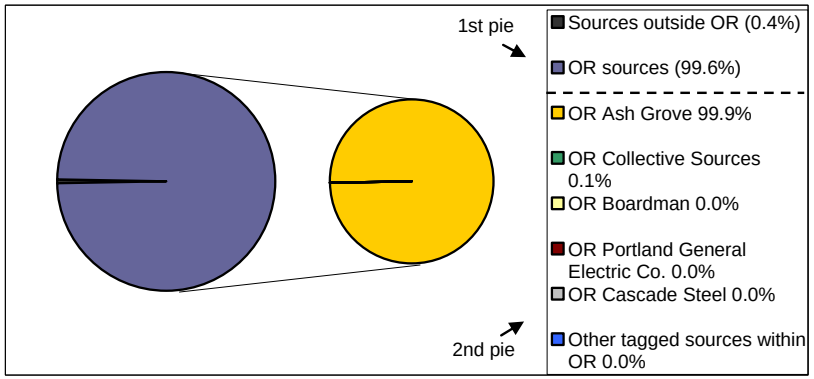

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Oregon Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-49. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Washington.**

a.

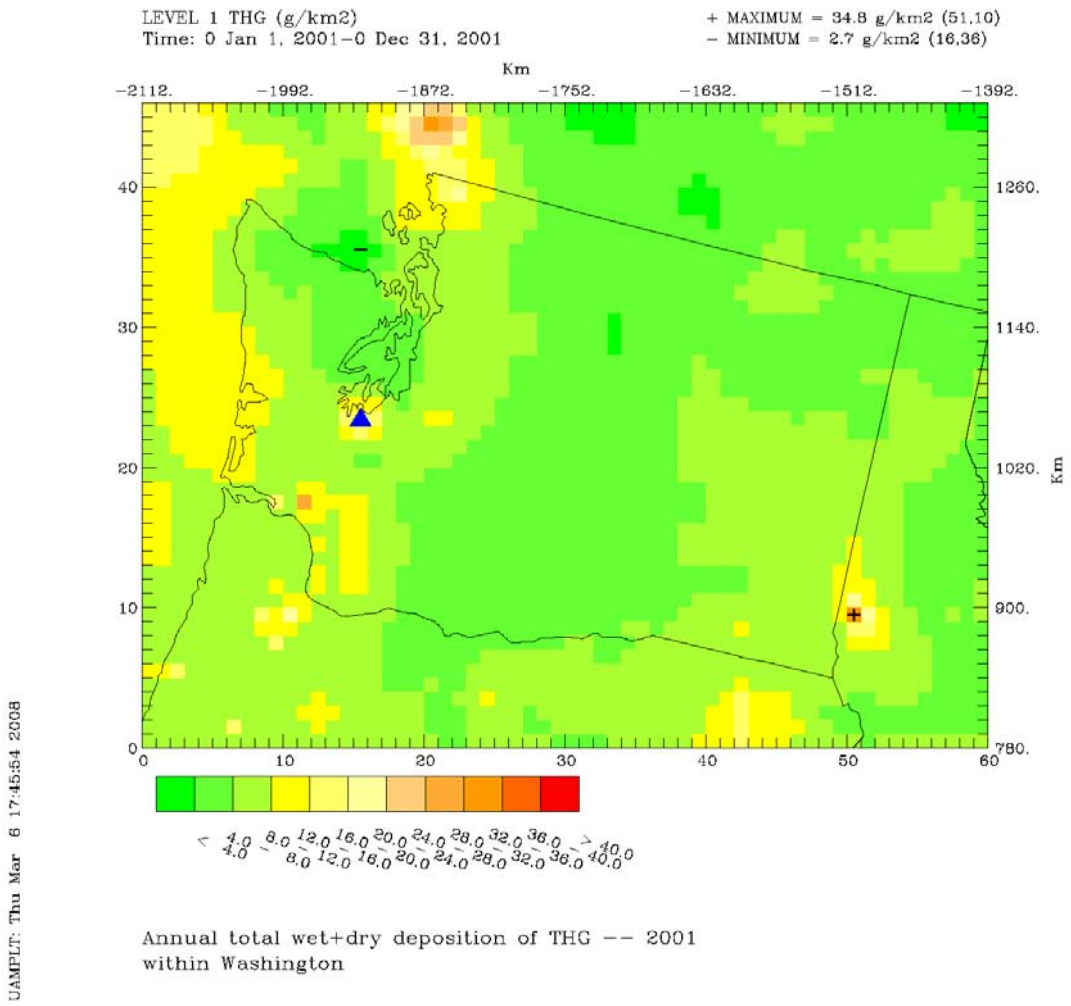
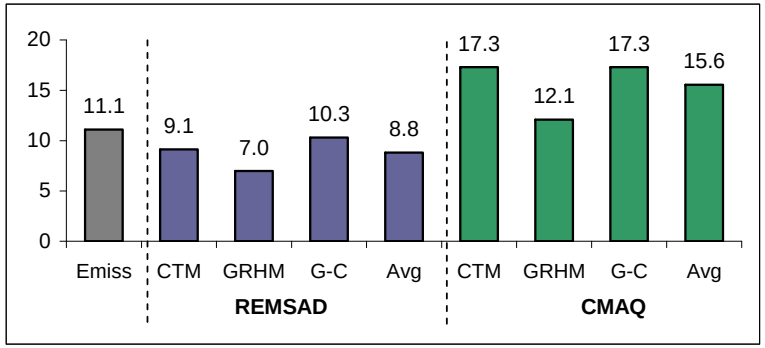


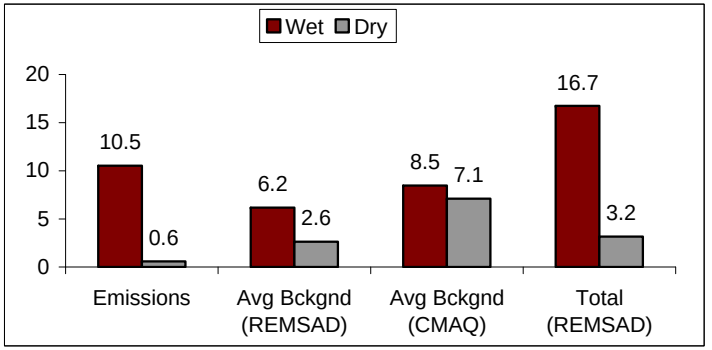
Figure 7-49b. Washington. Deposition Analysis for the Single Grid Cell (the Blue Triangle in the Accompanying Spatial Plot) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (19.9 g/km2).

**Washington**

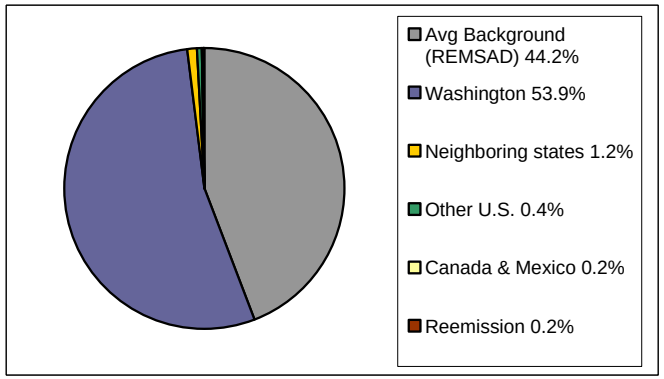
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



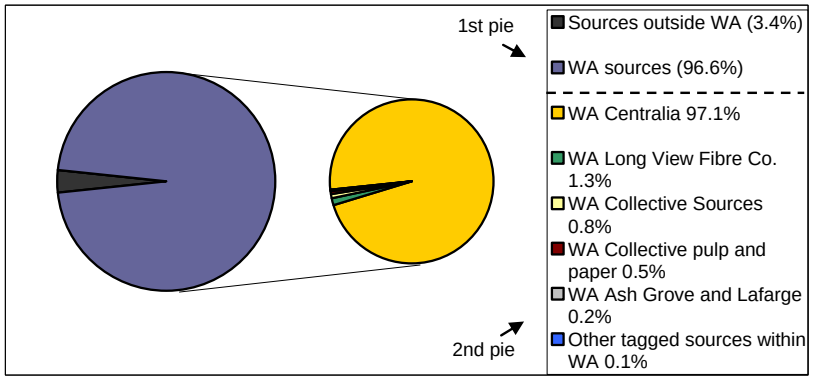

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Washington Sources without Background (5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

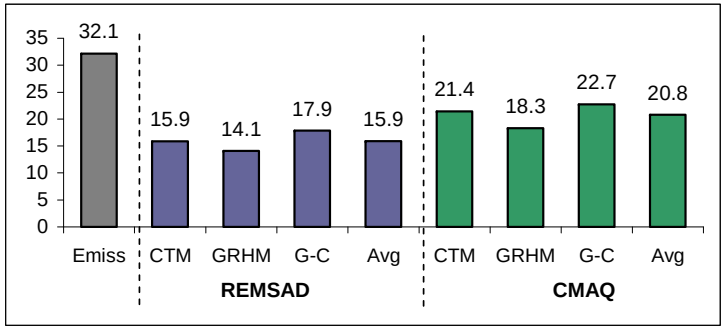
*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

## Figure 7-50. REMSAD PPTM Results for Steubenville, Ohio for Annual Total (Wet and Dry) Mercury Deposition (a) and Annual Wet Mercury Deposition (b).

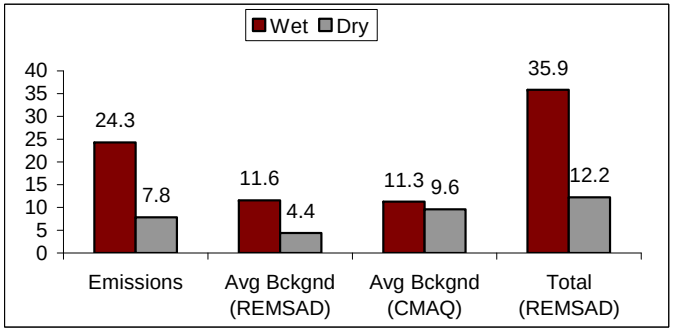
Figure 7-50a. Deposition Analysis for the Single Grid Cell Including Steubenville, Ohio.
Simulated Annual Total Mercury Deposition for 2001 (48.1 g/km2).

**Ohio**

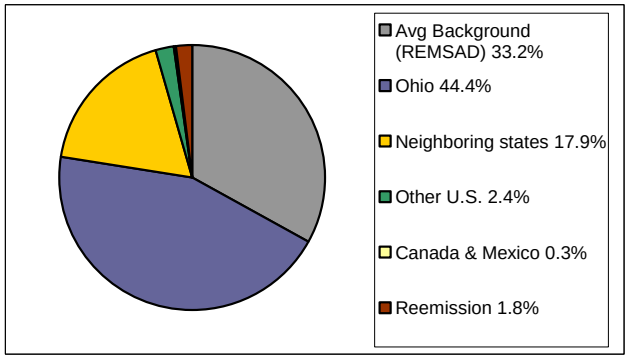
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



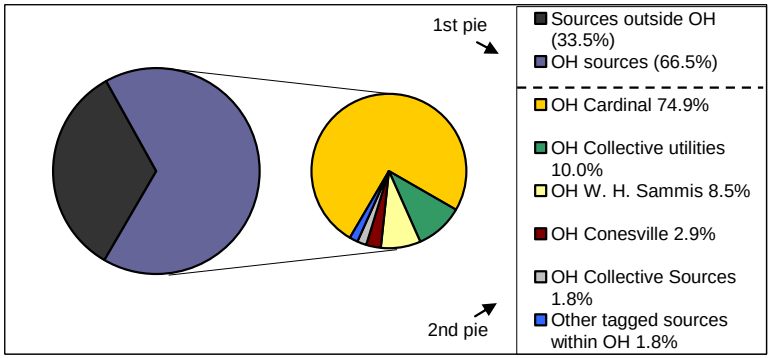

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2,4)




Contributions from Ohio Sources without Background (5,6)



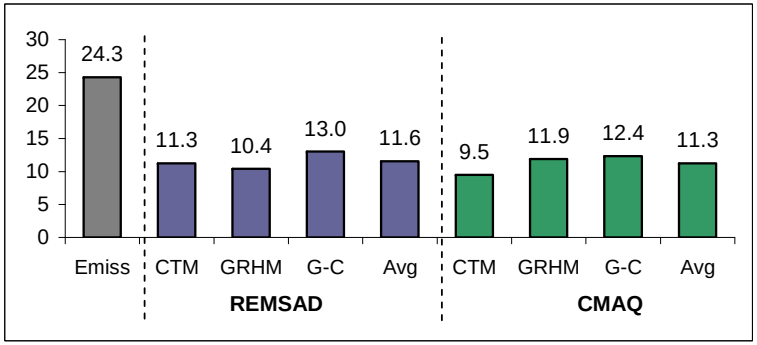

Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the cell containing the location used in a specific monitoring study. Results should not be extrapolated to indicate source contributions on a statewide basis.*

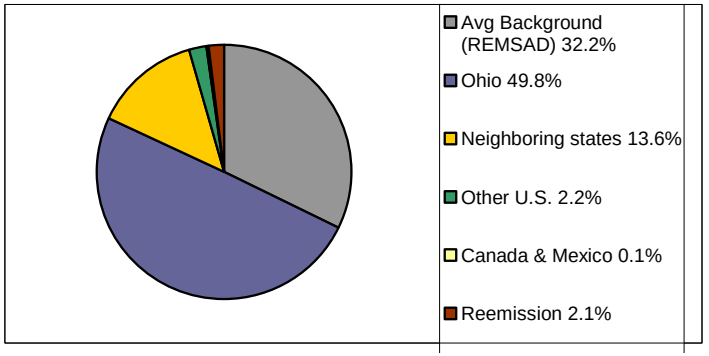
Figure 7-50b. Wet Deposition Analysis for the Single Grid Cell Including Steubenville, Ohio.
Simulated Annual Wet Mercury Deposition for 2001 (35.9 g/km2).

**Ohio**

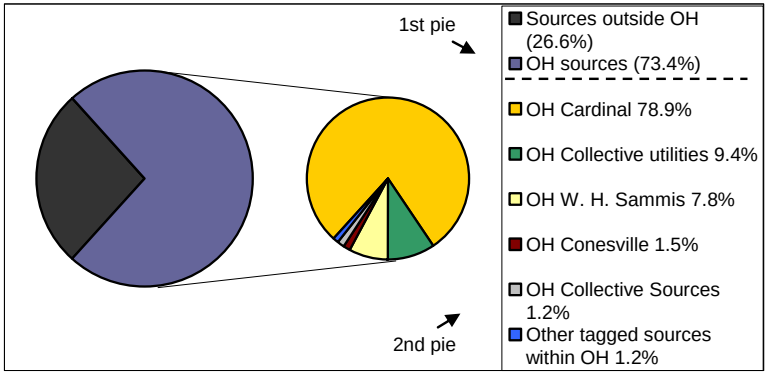
Emissions vs. Background Contributions (g/km2) (1,2,3,4)



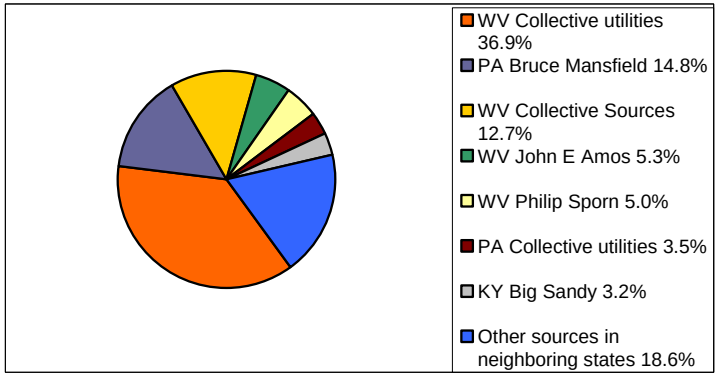

Contributions to Wet Deposition (2,4)




Contributions from Ohio Sources without Background (5,6)



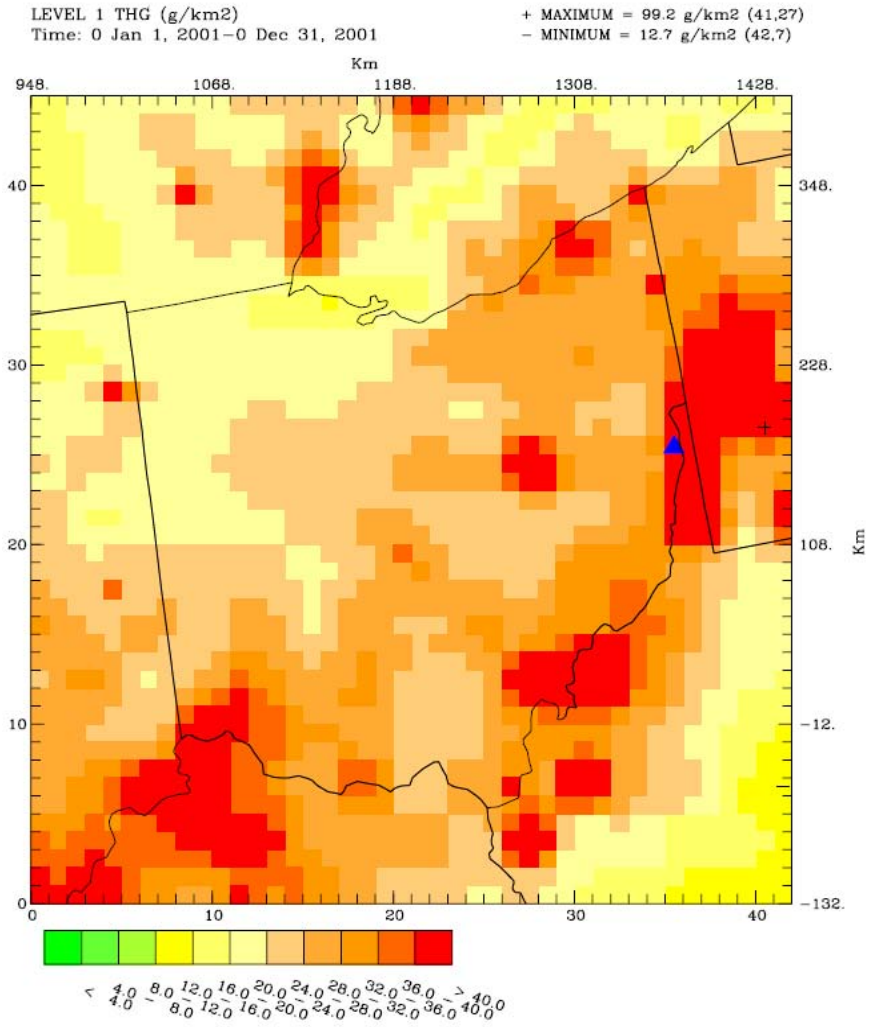

Breakdown of contributions from sources in neighboring states(5,6)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) "Avg" uses the average of REMSAD or CMAQ simulation results for the three global model background estimates.
5) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
6) "Collective Sources" tag for each state includes all point and area sources in the state that are not individually tagged.

*Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the cell containing the location used in a specific monitoring study. Results should not be extrapolated to indicate source contributions on a statewide basis.*

**Figure 7-51.Location of the Steubenville, Ohio study site (indicated by the blue triangle).**



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# 8. Summary of Key Findings and Recommendations for Future Study

This study has provided an improved understanding of the sources and mechanisms contributing to mercury deposition throughout the U.S. Key sources and source categories contributing to mercury deposition within each state have been identified, and their contribution to total mercury deposition for an annual 2001 simulation period quantified. It is expected that the modeling results will provide supporting information for the future assessment of control measures and calculation of Total Maximum Daily Loads (TMDLs).

## 8.1. Summary of Findings

- Based on available data for the 2001 simulation period, REMSAD is able to reasonably replicate the observed concentration patterns for ozone and $PM_{2.5}$, and the observed deposition patterns for $PM_{2.5}$ and mercury (wet deposition only). Wet deposition of mercury is typically overestimated by 30 percent or more, on both an annual and seasonal basis, when compared to MDN monitoring data. Some emerging research suggests, however, that the MDN measurement techniques may underestimate wet deposition by about 16 percent (Miller et al., 2005).
- Wet deposition accounts for much of the deposition that occurs throughout the domain. The simulated spatial distribution of mercury deposition is consistent with the emissions and annual transport and rainfall patterns.
- Since only wet deposition monitoring data are available, the evaluation of model performance for mercury is driven by the reliability of the meteorological input fields, and in particular precipitation. The ability to evaluate model performance for air concentrations and dry deposition of mercury and, thus, the overall emissions influence on mercury deposition is limited by a lack of data.
- PPTM gives expected results and the simulated contributions are consistent with the emissions data (including magnitude and speciation characteristics), source locations, source types, and current knowledge/theories regarding the contribution from global background. The REMSAD PPTM results are consistent with those obtained using the CMAQ model and are also consistent with results from a recent receptor modeling study for a specific location in Ohio.
- The mercury emission inventory used as the starting point for this study was that used in the CAMR modeling and, for the most part, represented emissions levels up to several years prior to 2001. In order to more accurately represent 2001, EPA Regions and states recommended a number of adjustments to the emissions inventory affecting the magnitude, stack parameters, and speciation of emissions for many sources.
- Boundary conditions are an important consideration in national- and regional-scale mercury deposition modeling. In order to address the inherent uncertainty in global contributions (i.e., boundary concentrations), results from three global models (CTM, GRAHM, and GEOS-CHEM) were used to establish boundary conditions for the REMSAD simulations. At locations where estimated deposition was dominated by local sources, contributions from boundary conditions were relatively consistent regardless of the global model used.
- CMAQ estimates of dry deposition attributable to the boundary conditions are consistently greater than REMSAD estimates of dry deposition attributable to the boundary conditions. For several Rocky Mountain and Southwest states, CMAQ estimates of deposition attributable to the boundary conditions are considerably higher for both wet and dry deposition than the REMSAD estimates. Since observed dry deposition data are not available, it is not possible to determine which estimates better represent actual conditions.

- Re-emission of mercury is a small but consistent contributor to mercury deposition.
- Simulated wet deposition of mercury is sensitive to rainfall amount, and overestimation of rainfall in certain areas can lead to overestimation of mercury deposition.
- National-scale, annual mercury deposition and source attribution modeling at 12-km resolution is practicable, especially if, like REMSAD, the model can be applied once for non-mercury species and then as needed for mercury.
- Based on the analysis of available meteorological and wet mercury deposition data for a ten-year period, the 2001 annual simulation period is an average year for mercury deposition.
- For the 2001 simulation period, the relative amount of wet and dry mercury deposition varies by state, with generally a higher wet-to-dry deposition ratio for the eastern U.S. where precipitation is greater and is distributed more evenly throughout the year.
- The relative contribution of global background generally decreases from west to east. However, in the vicinity of large emitters, particularly of divalent mercury, local sources can dominate deposition, regardless of geographic region.
- Deposition at the location of maximum deposition by sources within the same state is frequently dominated by one or more nearby sources. This finding may be linked to horizontal grid resolution and, in this case, the use of relatively high-resolution (12-km) grids.
- There are numerous instances where deposition at the location of maximum deposition by sources within the same state is dominated by “collective” sources within the state (defined here as all point and area sources in the state that are not tagged individually, as part of a source category, or as part of a region). This finding suggests that quality assurance of emissions information for the smaller sources, as well as the larger sources, is important, especially where multiple small sources are concentrated in a limited area.

## 8.2. Recommendations for Future Study

- This study has generated a large amount of information and additional analysis (and mining) of the results is needed in order to fully utilize the results in addressing state- and water-body specific mercury deposition issues.
- Additional analysis of the results for impaired water bodies is an important next step.
- Extraction, synthesis, and application of the results to support specific TMDL calculations or the identification of effective mercury deposition issues are other important areas of analysis.
- Continued improvement of the mercury emissions inventory with emphasis on speciation, motor-vehicle emissions, and emissions and stack parameter information for smaller sources will benefit future modeling efforts.
- Future modeling efforts for this simulation period should consider the use of improved or alternative meteorological inputs, with particular emphasis on improved simulated rainfall amounts for the western U.S.
- Similar modeling for additional base years (for example, 2002 and 2005) with different meteorological conditions and emissions would allow the assessment of year-to-year variations in overall deposition and the contributions to deposition and would also provide a check on the 2001 results.

- Application of both REMSAD and CMAQ with PPTM for additional tags, including source categories and multi-state source regions, to obtain a more complete and more detailed understanding of the source contributions to mercury deposition, is also recommended.

- The databases and tools used for this are also well suited for the analysis of the effects of future changes in mercury emissions on mercury deposition.

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# References


Ariya, P., A. Dastoor, M. Amyot, W. Schroeder, L. Barrie, K. Anlauf, F. Raofie, A. Ryzhkov, D. Davignon, J. Lalonde, and A. Steffen. 2004. Arctic: A sink for mercury. *Tellus*, 56B: 397-403.

Barrick, Inc. 2007. Letter from M. Barbanell to EPA Region 9. Re: Comments on ICF Report: Mercury-Based Analysis and Tracking of Airborne Mercury Emissions to Assist in Watershed Planning. 6 July 2007.

Blanchard, P., F.A. Froude, J.B. Martin, H. Dryfhout-Clark, J.T. Woods. 2002. Four years of continuous total gaseous mercury (TGM) measurements at sites in Ontario, Canada. *Atmos. Environ.,* 36: 3735–3743.

Bullock, O.R., Brehme, K.A. 2002. Atmospheric mercury simulation using the CMAQ model: formulation description and analysis of wet deposition results. *Atmos. Environ.,* 36: 2135–2146.

Bullock, O. R., D. Atkinson, T. Braverman, K. Civerolo, A. Dastoor, D. Davignon, J. Ku. K. Lohman, T. Myers, R. Park, C. Seigneur, N. Selin, G. Sistla, and K. Vijayaraghavan. 2008. The North American mercury model intercomparison study (NAMMIS). (*Parts 1 and 2 submitted to the J. Geophys. Res.*).

Byun, D. W., and J. K. S. Ching. 1999. "Science Algorithms of the EPA Models-3 Community Multiscale Air Quality (CMAQ) Modeling System." U.S. EPA Office of Research and Development, Washington, D.C. (EPA/600/R-99/030).

Canada. 2007a. E-mail correspondence from Environment Canada D. Davignon dated September 18 and 19, 2007.

Canada. 2007b. E-mail correspondence from Metro Vancouver C. Allan dated September 27, 2007.

CEC. 2001. *Preliminary Atmospheric Emissions Inventory of Mercury in Mexico, Report No. 3.2.1.04*, Commission for Environmental Cooperation.

CT DEP. 2006. E-mail correspondence from E. Pierce dated April 18, 2006.

Dastoor, A., and Y. Larocque. 2002. Global circulation of atmospheric mercury: A modeling study, *Atmos. Environ.*, 38: 147-161.

Douglas, S., B. Hudischewskyj, S. Beckmann, and T. Myers. 2005. "Comparison of MM5- and RUC-Based Meteorological Input Fields for REMSAD Mercury Modeling (Revised)," memorandum dated 14 December, ICF International, San Rafael, California.

Douglas, S., T. Myers, and Y. Wei. 2006. "Implementation of Sulfur and Nitrogen Tagging in the Community Multi-scale Air Quality Model." Prepared for the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. ICF International, San Rafael, California (06-076).

EPA. 1997. "Mercury Study Report to Congress; Volume III: Fate and Transport of Mercury in the Environment." EPA OAQPS/ORD, EPA-452/R-97-005, (http://www.epa.gov/ttn/atw/112nmerc/volume3.pdf).

EPA. 2001. EPA Toxics Release Inventory for 2001 available at: http://www.epa.gov/tri/tridata/tri01/data/index.htm.

EPA, 2004. Information and documentation on the IPM model available at www.epa.gov/airmarkets/epa-ipm.

EPA. 2005a. "Technical Support Document for the Final Clean Air Interstate Rule: Air Quality Modeling," EPA OAQPS (http://www.epa.gov/cair/pdfs/finaltech02.pdf).

EPA. 2005b. "Technical Support Document for the Final Clean Air Mercury Rule: Air Quality Modeling," EPA OAQPS (http://www.epa.gov/ttn/atw/utility/aqm_oar-2002-0056-6130.pdf).

EPA. 2005c. "Emissions Inventory and Emissions Processing for the Clean Air Mercury Rule (CAMR)," EPA OAQPS.

EPA. 2006. "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze," Draft 3.2. EPA Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina (September 2006).

EPA. 2007. E-mail correspondence from A. Pope dated August 22, 2007.

EPA OW. 2006a. E-mail correspondence from D. Atkinson email dated April 12, 2006.

EPA OW. 2006b. "Summary of 2001 Hg Emissions Inventory Modifications for Minnesota" memorandum prepared by R. Dwight Atkinson dated April 8, 2005.

EPA OW. 2006c. Personal communication by phone from D. Atkinson on September 19, 2006.

EPA Region 4. 2006. E-mail correspondence from R. Gillam dated March 10, 2006.

EPA Region 7. 2006a. E-mail correspondence from M. S Jay dated March 28, 2006.

EPA Region 7. 2006b. E-mail correspondence from M. S Jay dated March 29, 2006.

EPA Region 7. 2006c. E-mail correspondence from M. S. Jay with attachment "Mercury Comparison.xls" dated March 29, 2006.

EPA Region 7. 2006d. E-mail correspondence from M. S. Jay dated May 19, 2006.

EPA Region 7. 2006e. E-mail correspondence from M. S. Jay dated June 5, 2006.

EPA Region 8. 2007. E-mail correspondence from M. Langenfeld dated August 7, 2007.

EPA Region 9. 2006a. E-mail correspondence from S. Frey with attachment "DOC.PDF" dated August 15, 2006.

EPA Region 9. 2006b. E-mail correspondence from S. Frey dated September 11, 2006.

EPA Region 9. 2006c. Ontario Hydro test results provided by e-mail by S. Frey on August 25, 2006.

EPA Region 9. 2006d. Phelps Dodge in AZ air dep inventory provided by e-mail by P. Tsai on August 7, 2006.

EPA Region 9. 2006e. NEI/TRI data for R9 for OW mercury modeling study, e-mail by L. McClain-Vanderpool on May 4, 2006.

EPA Region 9. 2006f. Hg Inventory latest: discussion of Long Beach SERRF and CA gold mine, e-mail by S. Frey on August 21, 2006.

EPA Region 9. 2007. E-mail correspondence from S. Chilingaryan with attachment "speciationformodelingoct31.xls" dated October 31, 2007.

Friedlander, S. K. 1977. *Smoke, Dust, and Haze: Fundamentals of Aerosol Behavior.* John Wiley & Sons, New York.

Gery, M. W., G. Z. Whitten, J. P Killus, and M. C. Dodge. 1989. A Photochemical kinetics mechanism for urban and regional computer modeling. *J. Geophys. Res*., 94:12,925-12,956.

Gray, H. A., M. P. Ligocki, G. E. Moore, C. A. Emery, R. C. Kessler, J. P. Cohen, C. C. Chang, S. I. Balestrini, S. G. Douglas, R. R. Schulhof, J. P. Killus, and C. S. Burton. 1991. "Deterministic Modeling in the Navajo Generating Station Visibility Study." Systems Applications International, San Rafael, California (SYSAPP-91/045).

Hales, J. M., and S. L. Sutter. 1973. Solubility of sulfur dioxide in water at low concentrations. *Atmos. Environ.*, 7: 997-1001.

ICF. 2005. "User's Guide to the Regional Modeling System for Aerosols and Deposition (REMSAD), Version 7." ICF International, San Rafael, CALIFORNIA. (Available at www.remsad.com).

IDEM. 2006. E-mail correspondence from K. Watson with attachment "EPACopy of 2001 Hg top 20_w_stks_2_22_06.xls" dated February 24, 2006.

IDEM. 2006b. E-mail correspondence from J. Bates dated March 8, 2006.

IL EPA. 2006a. E-mail correspondence from A. Russo with attachment "REMSAD_review2.xls" dated April 11, 2006.

IL EPA. 2006b. E-mail correspondence from A. Russo with attachment "REMSAD_review2.xls" April 13, 2006.

IL EPA. 2006c. E-mail correspondence from R. Kaleel dated April 4, 2006.

Iowa DNR. 2006. E-mail correspondence from M. Stein with attachment2001_IA_top_40_hg2_emitters.xls" dated April 18, 2006.

Iowa DNR. 2007. E-mail correspondence from M. Johnson dated July 10, 2007.

KDHE. 2006. E-mail correspondence from L. Deahl with attachment "pic23754.jpg" dated February 22, 2006.

Kessler, E. 1969. "On the Distribution and Continuity of Water Substance in Atmospheric Circulation." *Meteor. Monographs*, No. 32, 84 pp.

Lin, C. A., and S.O. Pehkonen. 1999. The chemistry of atmospheric mercury: A review, *Atmos. Environ*, 33: 2067-2079.

LLCHD. 2006. E-mail correspondence from G. R. Bergstrom dated March 22, 2006.

Louis, J. F. 1979. Parametric model of vertical eddy fluxes in the atmosphere. *Boundary Layer Meteor.*, 17:187-202.

Miller, E., A. VanArsdale, G. Keeler, A. Chalmers, L. Poissant, N. Kamman, and R. Brulotte. 2005. Estimation and mapping of wet and dry mercury deposition across northeastern North America. *Ecotoxicology*, 14:53–70.

Mostardi Platt. 2000. "Speciated Mercury Testing Performed for Northern States Power Company at the Sherburne County Generating Plant Unit 3." http://www.epa.gov//ttn/atw/combust/utiltox/mercury/sherburnr.pdf

MDEQ. 2006. E-mail correspondence from J. Taylor-Morgan dated March 14, 2006.

MO DNR. 2006a. E-mail correspondence from J. Wade dated March 21, 2006.

MO DNR. 2006b. E-mail correspondence from M. Freebairn dated March 30, 2006.

MPCA. 2006a. Comments from E. Swain on e-mail correspondence from D. Atkinson titled "Suggested MN sources to tag" dated January 13, 2005.

MPCA . 2006b. E-mail correspondence from H. Jiang dated April 17, 2006.

MPCA. 2006c. E-mail correspondence from E. Swain to D. Atkinson titled "Speciation profiles for Riverside, High Bridge, or King" dated April 13, 2005.

Myers, T. C., Y. H. Wei, G. Glass, J. Mangahas, and B. Hudischewskyj. 2002. "Application of the REMSAD Modeling System to Estimate the Deposition of Nitrogen and Mercury." ICF International, San Rafael, California (02-101).

Myers, T., Y. Wei, B. Hudischewskyj, and S. Douglas. 2003. "Application of the REMSAD Modeling System to Estimate the Deposition of Mercury in Support of the Wisconsin TMDL Pilot." ICF International, San Rafael, California (03-050).

Myers, T. 2004. "Recent revisions to REMSAD mercury chemistry routine." Memorandum to Dwight Atkinson dated 20 January 2004.

Myers, T. and Y. Wei. 2004. "REMSAD Air Deposition Modeling in Support of TMDL Development for Southern Louisiana." ICF International, San Rafael, California (04-038).

Myers, T., Y. Wei, B. Hudischewskyj, and S. Douglas. 2004. "Mercury Air Deposition TMDL Development for Maryland." ICF International, San Rafael, California (04-068).

Myers, T., Y. Wei, B. Hudischewskyj, and S. Douglas. 2006. "Application of the REMSAD Modeling System to Estimate the Deposition of Mercury in Support of the Wisconsin TMDL Pilot (Revised)." Systems Applications International/ICF International, San Rafael, California (06-017)].

Myers, T. and S. Douglas. 2006. "Comparison of REMSAD Model Performance for Non-Mercury Species for 12- and 36-km Grid Resolution." Memorandum dated 13 November, ICF International, San Rafael, California.

National Atmospheric Deposition Program (NRSP-3). 2005. NADP Program Office, Illinois State Water Survey, 2204 Griffith Dr., Champaign, Illinois.

NDEP. 2006. "Precious Metal Mining - Mercury Air Emissions Questionnaire," Nevada Division of Environmental Protection. March 2006.

NDEP. 2007. E-mail correspondence from F. Forsgren with attachment "NV Hg Sources.xls" dated July 18, 2007.

NESCAUM. 2006a. E-mail correspondence from J. Graham with attachment "CT 2001 Hg Inv Update.xls" dated April 11, 2006.

NESCAUM. 2006b. E-mail correspondence from J. Graham with attachment "2001 NH Emissions Revision.xls" dated March 27, 2006.

NESCAUM. 2006c. E-mail corresponded from J. Graham with attachment "Copy of VT HG emiss – JRM.ICF.xls" dated April 14, 2006.

NJDEP. 2006a. E-mail correspondence from M. Aucott with attachment "DEP_revised_2001_NJ_Hg_sources.xls" dated March 21, 2006.

NJDEP. 2006b. E-mail correspondence from S. Agrawal dated March 22, 2006.

NJDEP. 2006c. E-mail correspondence from S. Agrawal dated April 6, 2006.

OR DEQ. 2006a. E-mail correspondence from G. Ebersole dated August 8, 2006.

OR DEQ. 2006b. E-mail correspondence from G. Ebersole dated August 9, 2006.

OR DEQ. 2006c. E-mail correspondence from G. Ebersole dated August 1, 2006.

OR DEQ. 2007a. E-mail correspondence from G. Ebersole dated April 5, 2007.

OR DEQ. 2007b. E-mail correspondence from M. Bailey dated August 28, 2007.

OR DEQ. 2007c. Personal communication by phone between EPA OW D. Atkinson and OR DEQ M. Bailey on June 4, 2007.

Pai, P., P. Karamchandani, and C. Seigneur. 1999. Sensitivity of simulated atmospheric mercury concentrations and deposition to model input parameters." *J. Geophys. Res.*, 104:13,855 - 13,868.

Roy F. Weston. 2000. *Emissions Test Report.* Minnesota Power Company. Boswell Energy Center. http://www.epa.gov//ttn/atw/combust/utiltox/mercury/clayboswellr.pdf.

Ryaboshapko, A., R. Bullock, R. Ebinghaus, I. Ilyin, K. Lohman, J. Munthe, G. Petersen, C. Seigneur, and I. Wangberg. 2002. Comparison of mercury chemistry models, *Atmos. Env.*, 36:3881-3898.

SAI. 1999. "User's Guide to the Variable-Grid Urban Airshed Model (UAM-V)." Systems Applications International, San Rafael, California.

Scire, J. S. 1991. "A Review of the UAM-V Dry Deposition Algorithm and Recommendations for Dry Deposition Modeling in the LMOS Study Region." Sigma Research Corporation, Westford, Massachusetts (Document A195-100).

Scott, B. C. 1978. Parameterization of sulfate removal by precipitation. *J. Appl. Meteor*., 17: 1375-1389.

Seigneur, C., H. Abeck, G. Chia, M. Reinhard, N. Bloom, E. Prestbo, and P. Saxena. 1998. Mercury adsorption to elemental carbon (soot) particles and atmospheric particulate matter. *Atmos. Env.*, 32: 2649-2657.

Seigneur, C., G. Hidy, I. Tombach, J. Vimont, and P. Amar. 1999. "Scientific Peer-Review of the Regulatory Modeling System for Aerosols and Deposition (REMSAD)." The KEVRIC Company, Inc. Durham, North Carolina.

Seigneur, C., P. Karamchandani, K. Lohman, K. Vijayaraghavan, and R. Shia. 2001. Multiscale modeling of the atmospheric fate and transport of mercury. *J. Geophys. Res.*, 106: 27,795 - 27,809.

Selin, N., D. Jacob, R. Park, R. Yantosca, S. Strode, L. Jaegle, and D. Jaffe. 2002. Chemical cycling and deposition of atmospheric mercury: Global constraints from observations. *J. Geophys. Res.*, 112.

Shia, R., C. Seigneur, P. Pai, M. Ko, and N. D. Sze. 1999. Global simulation of atmospheric mercury concentrations and deposition fluxes. *J. Geophys. Res.,* 99 :23,747 – 23,760.

Slinn, W.G.N., L. Hasse, B. B. Hicks, A. W. Hogan, D. Lal, P. S. Liss, K. O. Munnich, G. A. Sehmel, and O. Vittori. 1978. Some aspects of the transfer of atmospheric trace constituents past the air-sea interface. *Atmos. Environ.,* 14:1013-1016.

Sofiev, M., and M. Galperin. 2000. "Long-Range Transport Modeling of the Particle-Carried and Persistent Toxic Pollutants." *Proceedings of the Millennium NATO/CCMS ITM*, May 15-19, 2000, Boulder, CO, AMS, pp. 148-155.

Syrakov, D. 1998. "Long-Term Calculation of Bulgarian Impact in Mercury Pollution over SE Europe." Bulgarian contribution to *1998 Annual Report* for 1998, NIMH, EMEP/MSC-E, Sofia-Moscow.

Tokos, J. J. S., B. Hall, J. A. Calhoun, and E. M. Prestbo. 1998. Homogeneous gas-phase reaction of Hg0 with H2O2, O3, CH3I, and (CH3)2S: Implications for atmospheric Hg cycling. Atmos. Environ., 32:823-827.

Utah DEQ. 2007a. E-mail correspondence from B. LeBaron with attachment "Brock Kennecott2.xls" dated July 27, 2007.

Utah DEQ. 2007b. E-mail correspondence from D. McMurtrie with attachment "Mercury Inventory revised for EPA modeling083107.xls" dated August 31, 2007.

VA DEQ. 2006. E-mail correspondence from J. Schneider with attachment "51264 2000 thru 2005 Hg.pdf" dated May 31, 2006.

Van Loon, L. L., E. A. Mader, and S. L. Scott. 2001. Sulfite stabilization and reduction of the aqueous mercuric ion: Kinetic determination of sequential formation constants." *J. Phys. Chem. A,* 105:3190-3195.

WA. DE. 2006. E-mail correspondence from E. Guilfoil, Subj: cement plants, dated August 8, 2006.

WA. DE. 2007. E-mail correspondence from E. Guilfoil, Subj: changes to WA area Hg emissions, dated September 6, 2007.

WDNR. 2006. E-mail correspondence from O. Cabrera-Rivera (forwarded by D. Atkinson) dated February 2, 2005.

Wesley, M. L., and B. M. Lesht. 1988. *Comparison of the RADM Dry Deposition Module with Site-Specific Routines for Inferring Dry Deposition.* U.S. EPA, Research Triangle Park, North Carolina (EPA/600/54-88/027).

Yantosca, B. 2004. "GEOS-CHEMv7-01-02 User's Guide," Atmospheric Chemistry Modeling Group, Harvard University.

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# Appendix A: Model Performance Evaluation for Non-Mercury Species

In this section, the ability of the REMSAD modeling system to replicate the observed concentration and deposition characteristics of the simulation period is examined. The assessment of model performance considers concentrations for ozone, sulfur dioxide ($SO_2$) and fine particulate matter ($PM_{2.5}$), and deposition for selected PM species on a monthly and/or annual basis, depending on the pollutant.

## Methodology

A variety of statistical measures were used to quantify model performance for ozone, $SO_2$ and $PM_{2.5}$, as follows:

Normalized bias (expressed as percent) = $100 \cdot 1/N \sum (S_I - O_I)/ O_I$

Normalized gross error (expressed as percent) = $100 \cdot 1/N \sum |S_I - O_I|/ O_I$

Fractional bias (expressed as percent) = $200 \cdot 1/N \sum (S_I - O_I)/ (S_I + O_I)$

Fractional error (expressed as percent) = $200 \cdot 1/N \sum |S_I - O_I|/ (S_I + O_I)$

Mean residual = $1/N \sum (S_I - O_I)$

Mean unsigned error = $1/N \sum |S_I - O_I|$

Coefficient of determination ($R^2$) =

$$(\sum S_I O_I - \sum S_I \sum O_I/\mathrm{N})^2 / [ (\sum O_I^2 - (\sum O_I)^2/\mathrm{N}) \cdot (\sum S_I^2 - (\sum S_I)^2/\mathrm{N}) ]$$

Where S is the simulated concentration, O is the observed concentration, and N is the number simulation-observation pairs used in the calculation.

Model performance for ozone was evaluated against observations available from the EPA Air Quality System (AQS) network. The number of sites ranges from 500 to 1100, depending on the time of year. The sites are primarily located in urban areas. The daily maximum simulated ozone concentration for each monitor for each day was compared to the corresponding maximum observed concentration. Monthly values for each measure were calculated using the daily comparisons.

Model performance for $SO_2$ was evaluated against observations available from the AQS network, which includes more than 4,000 sites (primarily located in urban areas). The monthly average values were compared.

Simulated concentrations of $PM_{2.5}$ were compared with observed values from the Speciated Trends Network (AQS-STN), which includes more than 200 sites, and from Interagency Monitoring of Protected Visual Environments (IMPROVE) network sites, which sample approximately100 Class I national parks and wilderness areas throughout the U.S. Simulated concentrations of sulfate and nitrate were evaluated against observations from the IMPROVE and Clean Air Status and Trends Network (CASTNet) monitoring sites. CASTNet includes more than 70 sites that are a mix of mostly rural and suburban sites. Simulated concentrations of ammonium were evaluated against observations from the CASTNet sites. Monthly and annual average simulated concentrations for each monitor were compared to the corresponding observed concentrations.

Simulated wet deposition amounts of sulfate, nitrate, and ammonia were compared with observed values from the National Acid Deposition Program (NADP), which includes more than 200, typically rural, sites. Monthly and annual deposition totals for each monitor were compared to the corresponding observed totals.

Model performance measures for the REMSAD 12-km modeling domain are presented in the tables below. The 12-km results were used for all subsequent analyses. A comparison of the 12- and 36-km results is provided by Myers and Douglas (2006). This comparison provides some insight into the benefits of using the 12 –km grid.

## Summary of Monthly Model Performance for Gaseous and Particulate Species Concentrations

Statistical measures of model performance for ozone are presented for each month in Table A-1.

**Table A-1. Month-by-Month REMSAD Model Performance Statistics for the 12-km Resolution Grids: Daily Maximum Ozone Concentration ($\mu gm^{-3}$) at AQS Sites.**

| Month | Normalized bias (%) | Normalized gross error (%) | Fractional bias (%) | Fractional error (%) | Mean residual ($\mu gm^{-3}$) | Mean unsigned error ($\mu gm^{-3}$) | Coefficient of Determination, $R^2$ |
|---|---|---|---|---|---|---|---|
| Jan | 25.2 | 45.2 | 6.1 | 29.9 | 3.96 | 18.87 | 0.130 |
| Feb | 19.1 | 35.4 | 7.2 | 26.3 | 4.88 | 18.67 | 0.135 |
| Mar | 9.5 | 27.2 | 1.5 | 22.1 | 0.99 | 19.26 | 0.169 |
| Apr | 11.1 | 21.6 | 6.8 | 18.7 | 6.95 | 19.48 | 0.185 |
| May | 7.1 | 21.3 | 3.1 | 19.3 | 2.51 | 22.01 | 0.316 |
| Jun | 13.0 | 27.5 | 6.9 | 23.7 | 5.76 | 26.82 | 0.377 |
| Jul | 14.4 | 30.3 | 6.9 | 25.6 | 8.13 | 30.11 | 0.259 |
| Aug | 16.9 | 31.7 | 9.0 | 26.5 | 10.13 | 31.74 | 0.266 |
| Sep | 13.0 | 28.3 | 6.2 | 24.0 | 4.93 | 23.92 | 0.307 |
| Oct | 2.2 | 20.9 | -2.3 | 19.2 | -3.53 | 19.98 | 0.248 |
| Nov | 21.4 | 37.3 | 7.9 | 26.6 | 5.51 | 19.92 | 0.247 |
| Dec | 25.2 | 42.7 | 9.1 | 29.7 | 5.89 | 18.73 | 0.106 |

The normalized bias ranges from 2 to 25 percent. The bias is positive for each month, indicating some overestimation of ozone throughout the domain. The values of bias are lowest for the transitional months (in terms of meteorology) of March through May and October and highest for the winter months, when ozone concentrations are typically low. The values for the typical ozone season for most areas (April through October) range from 2 to 17 percent, which indicates reasonable model performance for ozone (EPA, 2006). Similarly the normalized gross error is largest during the winter months, and indicative of reasonable model performance for the ozone season. The fractional bias and error values confirm that the higher normalized bias and error values during the winter months are driven, in part, by low concentrations. The mean residual values tend to be largest during the summer months, when ozone concentrations are highest. The correlation statistics indicate that the simulation-observation pairs are generally not well correlated, but the greatest correlations occur during the ozone season months.

Statistical measures of model performance for $SO_2$ are presented for each month in Table A-2.

**Table A-2. Month-by-Month REMSAD Model Performance Statistics for the 12-km Resolution Grids: Monthly Average $SO_2$ Concentration ($\mu gm^{-3}$) at AQS-STN Sites.**

| Month | Normalized bias (%) | Normalized gross error (%) | Fractional bias (%) | Fractional error (%) | Mean residual ($\mu gm^{-3}$) | Mean unsigned error ($\mu gm^{-3}$) | Coefficient of Determination, $R^2$ |
|---|---|---|---|---|---|---|---|
| Jan | -12.5 | 46.9 | -31.7 | 54.9 | -3.47 | 8.77 | 0.323 |
| Feb | -3.6 | 48.4 | -23.4 | 52.9 | -1.56 | 7.29 | 0.171 |
| Mar | -0.3 | 50.2 | -20.9 | 54.0 | -0.99 | 6.52 | 0.142 |
| Apr | -6.6 | 51.3 | -28.5 | 58.1 | -1.82 | 6.55 | 0.199 |
| May | 7.0 | 59.6 | -19.2 | 60.1 | -0.51 | 6.49 | 0.171 |
| Jun | 22.0 | 66.9 | -8.3 | 59.4 | 1.00 | 6.65 | 0.176 |
| Jul | 28.4 | 69.2 | -3.1 | 58.6 | 1.28 | 6.88 | 0.128 |
| Aug | 31.7 | 69.6 | 0.8 | 58.1 | 2.04 | 7.27 | 0.133 |
| Sep | 38.6 | 73.8 | 4.9 | 58.7 | 2.38 | 6.75 | 0.141 |
| Oct | 22.6 | 63.5 | -3.8 | 57.8 | 0.86 | 7.15 | 0.173 |
| Nov | 20.7 | 58.2 | -3.3 | 51.7 | 0.85 | 7.04 | 0.268 |
| Dec | 13.9 | 57.5 | -10.6 | 54.5 | 0.69 | 6.83 | 0.268 |

The normalized bias ranges from -12 to nearly 40 percent. The bias is negative for January through April, and positive for each month thereafter. The normalized gross error ranges from approximately 45 to 75 percent. Both measures indicate that the $SO_2$ concentrations, which are often urban-scale in nature, are not well represented by the model. Differences between the normalized and fractional bias values indicate that the normalized values are influenced by overestimation of (very) low concentrations. The fractional bias is more frequently negative. The correlation statistics indicate that the simulation-observation pairs are generally not well correlated, but the greatest correlations occur during the winter months.

Statistical measures of model performance for total $PM_{2.5}$ concentration for the AQS-STN sites are presented for each month in Table A-3.

**Table A-3. Month-by-Month REMSAD Model Performance Statistics for the 12-km Resolution Grids: Monthly Average $PM_{2.5}$ Concentration ($\mu gm^{-3}$) at AQS-STN Sites.**

| Month | Normalized bias (%) | Normalized gross error (%) | Fractional bias (%) | Fractional error (%) | Mean residual ($\mu gm^{-3}$) | Mean unsigned error ($\mu gm^{-3}$) | Coefficient of Determination, $R^2$ |
|---|---|---|---|---|---|---|---|
| Jan | 5.7 | 37.0 | -7.1 | 36.7 | -0.16 | 5.76 | 0.130 |
| Feb | 6.4 | 36.5 | -5.3 | 36.2 | 0.48 | 4.54 | 0.119 |
| Mar | 15.0 | 35.4 | 5.3 | 32.1 | 1.51 | 3.89 | 0.319 |
| Apr | 4.0 | 35.8 | -6.0 | 35.3 | 0.41 | 3.94 | 0.259 |
| May | -11.5 | 30.7 | -19.6 | 34.6 | -1.24 | 3.49 | 0.417 |
| Jun | -17.6 | 31.0 | -26.2 | 37 | -2.20 | 3.85 | 0.598 |
| Jul | -13.7 | 33.6 | -22.9 | 38.0 | -2.06 | 4.25 | 0.394 |
| Aug | -6.6 | 33.2 | -16.0 | 34.2 | -1.46 | 4.53 | 0.402 |
| Sep | 12.5 | 33.6 | 3.6 | 29.7 | 0.98 | 3.35 | 0.261 |
| Oct | 14.0 | 36.8 | 4.7 | 34.1 | 1.39 | 3.88 | 0.320 |
| Nov | 12.0 | 41.5 | -0.5 | 40.8 | 1.09 | 5.61 | 0.123 |
| Dec | 36.1 | 60.1 | 15.3 | 50.4 | 3.11 | 6.33 | 0.070 |

The normalized bias ranges from 4 to approximately 18 percent for most months, but is higher for December (36 percent). The bias is negative for the summer months (May through August), and positive for the remaining months, indicating some underestimate of the typically higher summertime PM concentrations. The normalized gross error ranges from approximately 30 to 40 percent, except again for December. The correlation statistics indicate that the simulation-observation pairs are fairly well correlated, and the correlation values are highest for the summer months.

Statistical measures of model performance for total $PM_{2.5}$ concentration for the IMPROVE sites are presented for each month in Table A-4.

**Table A-4. Month-by-Month REMSAD Model Performance Statistics for the 12-km Resolution Grids: Monthly Average $PM_{2.5}$ Concentration ($\mu gm^{-3}$) at IMPROVE Sites.**

| Month | Normalized bias (%) | Normalized gross error (%) | Fractional bias (%) | Fractional error (%) | Mean residual ($\mu gm^{-3}$) | Mean unsigned error ($\mu gm^{-3}$) | Coefficient of Determination, $R^2$ |
|---|---|---|---|---|---|---|---|
| Jan | 46.6 | 56.7 | 24.9 | 36.5 | 1.51 | 1.97 | 0.669 |
| Feb | 10.5 | 39.3 | 0.9 | 36.5 | 0.31 | 1.59 | 0.642 |
| Mar | 8.6 | 32.9 | 0.6 | 31.6 | 0.57 | 1.81 | 0.719 |
| Apr | -23.0 | 42.8 | -37.7 | 52.9 | -1.36 | 2.61 | 0.429 |
| May | -37.0 | 42.2 | -54.0 | 58.5 | -2.34 | 2.88 | 0.588 |
| Jun | -36.3 | 43.7 | -54.1 | 60.0 | -2.75 | 3.07 | 0.671 |
| Jul | -26.5 | 38.7 | -39.8 | 49.5 | -2.39 | 3.09 | 0.508 |
| Aug | -3.6 | 42.2 | -19.8 | 38.3 | -0.80 | 2.96 | 0.411 |
| Sep | -10.2 | 34.7 | -20.5 | 39.9 | -0.66 | 2.16 | 0.430 |
| Oct | -4.7 | 31.6 | -12.4 | 33.3 | -0.04 | 2.01 | 0.570 |
| Nov | 3.1 | 43.1 | -9.7 | 43.9 | 0.51 | 2.39 | 0.635 |
| Dec | 56.1 | 75.5 | 26.4 | 51.1 | 1.82 | 2.48 | 0.629 |

The normalized bias ranges from -40 to approximately 10 percent for most months, but is higher for January (47 percent) and December (56 percent). A lower fractional bias for these months suggests that the high values are driven by overestimation of low concentrations. The normalized bias is negative for the warmer months (April through October), and positive for the remaining months, and the values indicate some underestimate of the typically higher summertime PM concentrations. The normalized gross error ranges from approximately 30 to 40 percent, except again for January and December. The correlation statistics indicate that the simulation-observation pairs are fairly well correlated, and this does not vary much by month.
Statistical measures of model performance for sulfate concentration for the CASTNet sites are presented for each month in Table A-5.

**Table A-5. Month-by-Month REMSAD Model Performance Statistics for the 12-km Resolution Grids: Monthly Average Sulfate Concentration ($\mu gm^{-3}$) at CASTNet Sites.**

| Month | Normalized bias (%) | Normalized gross error (%) | Fractional bias (%) | Fractional error (%) | Mean residual ($\mu gm^{-3}$) | Mean unsigned error ($\mu gm^{-3}$) | Coefficient of Determination, $R^2$ |
|---|---|---|---|---|---|---|---|
| Jan | -32.4 | 36.2 | -42.0 | 45.4 | -0.89 | 0.92 | 0.880 |
| Feb | -28.9 | 33.8 | -37.8 | 42.1 | -0.79 | 0.82 | 0.792 |
| Mar | -22.4 | 24.7 | -28.3 | 30.4 | -0.56 | 0.58 | 0.850 |
| Apr | -26.0 | 29.1 | -34.5 | 37.3 | -0.90 | 0.95 | 0.498 |
| May | -26.7 | 33.6 | -36.1 | 42.0 | -0.84 | 0.99 | 0.824 |
| Jun | -41.1 | 42.5 | -56.2 | 57.3 | -2.00 | 2.00 | 0.661 |
| Jul | -47.9 | 49.3 | -67.9 | 69.1 | -2.42 | 2.44 | 0.783 |
| Aug | -40.6 | 41.5 | -55.3 | 56.1 | -1.96 | 1.97 | 0.824 |
| Sep | -30.6 | 31.3 | -41.1 | 41.8 | -0.82 | 0.84 | 0.880 |
| Oct | -13.2 | 22.2 | -19.8 | 28.1 | -0.19 | 0.38 | 0.642 |
| Nov | -18.3 | 25.2 | -23.6 | 29.1 | -0.46 | 0.50 | 0.880 |
| Dec | 17.6 | 32.5 | 9.8 | 28.5 | 0.13 | 0.35 | 0.819 |

The normalized bias ranges from approximately -50 to 20 percent. The largest (negative) bias values are associated with the summer months, when sulfate concentrations tend to be highest. This indicates that regional-scale sulfate concentrations are underestimated during these months. The normalized gross error also ranges from approximately 20 to 50 percent; consistency with the absolute value of the bias indicates that the concentrations are generally over- or underestimated and not mixed. Despite the differences between the simulated and observed values, the values are well correlated.

Statistical measures of model performance for sulfate concentration for the IMPROVE sites are presented for each month in Table A-6.

**Table A-6. Month-by-Month REMSAD Model Performance Statistics for the 12-km Resolution Grids: Monthly Average Sulfate Concentration ($\mu gm^{-3}$) at IMPROVE Sites.**

| Month | Normalized bias (%) | Normalized gross error (%) | Fractional bias (%) | Fractional error (%) | Mean residual ($\mu gm^{-3}$) | Mean unsigned error ($\mu gm^{-3}$) | Coefficient of Determination, $R^2$ |
|---|---|---|---|---|---|---|---|
| Jan | -27.8 | 32.0 | -35.6 | 39.3 | -0.31 | 0.35 | 0.845 |
| Feb | -23.0 | 25.9 | -29.0 | 31.7 | -0.34 | 0.36 | 0.778 |
| Mar | -18.7 | 24.8 | -25.0 | 30.1 | -0.32 | 0.37 | 0.859 |
| Apr | -17.7 | 32.7 | -25.4 | 38.2 | -0.31 | 0.52 | 0.719 |
| May | -33.4 | 39.7 | -46.0 | 51.4 | -0.61 | 0.71 | 0.767 |
| Jun | -38.8 | 49.5 | -59.2 | 67.0 | -0.90 | 0.99 | 0.848 |
| Jul | -45.7 | 48.4 | -66.9 | 69.3 | -1.18 | 1.23 | 0.736 |
| Aug | -39.3 | 44.2 | -55.6 | 59.7 | -1.01 | 1.07 | 0.837 |
| Sep | -28.9 | 43.3 | -44.9 | 54.9 | -0.46 | 0.65 | 0.689 |
| Oct | -25.2 | 34.8 | -35.8 | 44.0 | -0.29 | 0.46 | 0.797 |
| Nov | -23.7 | 31.5 | -32.3 | 39.0 | -0.29 | 0.39 | 0.841 |
| Dec | 44.3 | 58.8 | 20.0 | 38.0 | 0.06 | 0.22 | 0.861 |

The normalized bias ranges from approximately -45 to 45 percent. The bias values are all negative, except for December, indicating that the sulfate concentrations at the more remote approximately 30 to 45 percent, but is higher for December. Differences between the normalized IMPROVE sites are generally underestimated. The normalized gross error ranges from gross

error and the absolute value of the bias indicate a mix of over- and underestimation. Despite the differences between the simulated and observed values, the values are well correlated.

Statistical measures of model performance for particulate nitrate concentration for the CASTNet sites are presented for each month in Table A-7.

**Table A-7. Month-by-Month REMSAD Model Performance Statistics for the 12-km Resolution Grids: Monthly Average Nitrate Concentration ($\mu gm^{-3}$) at CASTNet Sites.**

| Month | Normalized bias (%) | Normalized gross error (%) | Fractional bias (%) | Fractional error (%) | Mean residual ($\mu gm^{-3}$) | Mean unsigned error ($\mu gm^{-3}$) | Coefficient of Determination, $R^2$ |
|---|---|---|---|---|---|---|---|
| Jan | 75.1 | 98.7 | 28.2 | 59.1 | 0.34 | 1.00 | 0.648 |
| Feb | 64.1 | 96.1 | 14.2 | 62.4 | 0.21 | 0.72 | 0.585 |
| Mar | 114.3 | 146.2 | 27.7 | 77.2 | 0.58 | 1.02 | 0.584 |
| Apr | 49.6 | 95.6 | 1.4 | 73.5 | 0.40 | 0.87 | 0.214 |
| May | -10.9 | 70.9 | -51.8 | 86.4 | -0.15 | 0.39 | 0.343 |
| Jun | 158.1 | 219.2 | 6.2 | 117.8 | 0.27 | 0.56 | 0.055 |
| Jul | 42.7 | 124.0 | -36.9 | 111.8 | -0.02 | 0.35 | 0.001 |
| Aug | 87.9 | 163.4 | -22.5 | 117.6 | 0.04 | 0.41 | 0.000 |
| Sep | 99.8 | 169.8 | -13.6 | 114.5 | 0.17 | 0.52 | 0.027 |
| Oct | 93.6 | 140.3 | 14.6 | 96.9 | 0.58 | 0.86 | 0.333 |
| Nov | 125.3 | 149.0 | 39.9 | 77.6 | 1.00 | 1.20 | 0.630 |
| Dec | 107.7 | 128.5 | 39.3 | 73.1 | 0.79 | 0.94 | 0.671 |

Since the values of nitrate can be very low for many sites (especially in the eastern U.S.) the calculation of the relative measures of model performance (which use the observed value in the denominator) is not very meaningful. This is manifested in Table A-7 as very large normalized bias and error statistics. The fractional bias and error are likely more meaningful metrics for this pollutant. The fractional bias indicates underestimate of nitrate from April through September and overestimation of nitrate during the colder months. The fractional errors are smaller than when normalized directly by the observations, but are still quite large (on the order of 60 to 120 percent). The simulated and observed values are reasonably well correlated during the winter months, when nitrate concentrations tend to be highest, and less well to poorly correlated during the summer months, when nitrate concentrations tend to be low.

Statistical measures of model performance for particulate nitrate concentration for the IMPROVE sites are presented for each month in Table A-8.

**Table A-8. Month-by-Month REMSAD Model Performance Statistics for the 12-km Resolution Grids: Monthly Average Nitrate Concentration ($\mu gm^{-3}$) at IMPROVE Sites.**

| Month | Normalized bias (%) | Normalized gross error (%) | Fractional bias (%) | Fractional error (%) | Mean residual ($\mu gm^{-3}$) | Mean unsigned error ($\mu gm^{-3}$) | Coefficient of Determination, $R^2$ |
|---|---|---|---|---|---|---|---|
| Jan | 5.7 | 52.7 | -14 | 52.5 | -0.02 | 0.50 | 0.669 |
| Feb | 0.3 | 53.7 | -20.8 | 58.3 | 0.01 | 0.44 | 0.434 |
| Mar | 34.5 | 68.1 | 6.9 | 52.7 | 0.33 | 0.56 | 0.734 |
| Apr | 27.9 | 70.3 | -4.8 | 60 | 0.19 | 0.34 | 0.848 |
| May | -60.0 | 70.3 | -110.5 | 118.2 | -0.16 | 0.25 | 0.717 |
| Jun | -35.7 | 86.0 | -96.9 | 123.2 | -0.06 | 0.29 | 0.332 |
| Jul | -58.8 | 87.8 | -126.9 | 141.4 | -0.15 | 0.25 | 0.350 |
| Aug | -56.5 | 85.7 | -123.4 | 136 | -0.08 | 0.25 | 0.213 |
| Sep | -24.7 | 93.2 | -87.8 | 122.6 | 0.00 | 0.30 | 0.326 |
| Oct | 59.7 | 116.0 | -4.7 | 86.2 | 0.38 | 0.57 | 0.429 |
| Nov | 81.4 | 114.7 | 24 | 71.2 | 0.62 | 0.82 | 0.420 |
| Dec | 101.5 | 140.1 | 22.5 | 80.1 | 0.50 | 0.79 | 0.490 |

The large bias and error values reflect the low nitrate concentrations for many sites (especially in the eastern U.S.) and are likely not very meaningful. The simulated and observed values are reasonably well correlated during the winter months, when nitrate concentrations tend to be highest, and less well to poorly correlated during the summer months, when nitrate concentrations tend to be low. Statistical measures of model performance for particulate ammonium concentration for the CASTNet sites are presented for each month in Table A-9.

**Table A-9. Month-by-Month REMSAD Model Performance Statistics for the 12-km Resolution Grids: Monthly Average Ammonium Concentration ($\mu gm^{-3}$) at CASTNet Sites.**

| Month | Normalized bias (%) | Normalized gross error (%) | Fractional bias (%) | Fractional error (%) | Mean residual ($\mu gm^{-3}$) | Mean unsigned error ($\mu gm^{-3}$) | Coefficient of Determination, $R^2$ |
|---|---|---|---|---|---|---|---|
| Jan | 4.8 | 28.3 | -0.9 | 26.7 | -0.06 | 0.30 | 0.819 |
| Feb | 7.0 | 32.2 | -1.2 | 29.4 | -0.04 | 0.25 | 0.781 |
| Mar | 18.5 | 33.8 | 10.3 | 29.9 | 0.14 | 0.28 | 0.821 |
| Apr | 22.8 | 38.6 | 12 | 33.2 | 0.19 | 0.41 | 0.352 |
| May | -13.1 | 29.0 | -20.6 | 33.2 | -0.15 | 0.28 | 0.781 |
| Jun | -27.6 | 30.7 | -37.4 | 40.2 | -0.38 | 0.42 | 0.629 |
| Jul | -37.1 | 40.6 | -50.5 | 53.5 | -0.49 | 0.53 | 0.760 |
| Aug | -33.1 | 34.7 | -44.7 | 46.2 | -0.44 | 0.45 | 0.834 |
| Sep | -14.3 | 29.0 | -22.8 | 35.9 | -0.06 | 0.23 | 0.826 |
| Oct | 39.7 | 61.3 | 22.4 | 50.5 | 0.36 | 0.47 | 0.638 |
| Nov | 31.8 | 44.8 | 19.9 | 35.5 | 0.34 | 0.40 | 0.882 |
| Dec | 69.0 | 75.4 | 39.9 | 48 | 0.38 | 0.41 | 0.830 |

The normalized bias ranges from approximately -40 to 40 percent, with the exception of December for which the value is nearly 70 percent. The values are negative for the warmer months May through September and positive for the remaining (cooler) months. Differences in the bias and error values indicate a mix of over- and underestimation for most months. Despite the differences between the simulated and observed values, the values are well correlated.

## Summary of Monthly Model Performance for Deposition

As noted earlier in this section, there are fewer measurements for the assessment of model performance for deposition, compared to air concentration.

Statistical measures of model performance for sulfate deposition at NADP sites are presented for each month in Table A-10.

**Table A-10. Month-by-Month REMSAD Model Performance Statistics for the 12-km Resolution Grids: Monthly Sulfate Deposition (kg ha$^{-1}$) at NADP Sites.**

| Month | Grid Resolution (km) | Normalized bias (%) | Normalized gross error (%) | Fractional bias (%) | Fractional error (%) | Mean residual ($\mu gm^{-3}$) | Mean unsigned error ($\mu gm^{-3}$) | Coefficient of Determination, $R^2$ |
|---|---|---|---|---|---|---|---|---|
| Jan | 12 | -51.6 | 60.4 | -82.9 | 94.4 | -0.25 | 0.25 | 0.709 |
| Feb | 12 | -51.0 | 59.3 | -81.7 | 89.9 | -0.40 | 0.40 | 0.676 |
| Mar | 12 | -59.0 | 68.3 | -100.3 | 105.5 | -0.55 | 0.56 | 0.561 |
| Apr | 12 | -35.2 | 60.7 | -66.4 | 81 | -0.40 | 0.46 | 0.454 |
| May | 12 | -26.5 | 51.3 | -49.1 | 66.4 | -0.34 | 0.44 | 0.569 |
| Jun | 12 | -47.0 | 53.2 | -74.2 | 79 | -0.69 | 0.72 | 0.526 |
| Jul | 12 | -18.0 | 67.6 | -54.4 | 74.7 | -0.47 | 0.61 | 0.444 |
| Aug | 12 | -32.6 | 62.0 | -63.6 | 79.8 | -0.60 | 0.70 | 0.490 |
| Sep | 12 | -49.3 | 67.7 | -89.5 | 96.5 | -0.60 | 0.63 | 0.429 |
| Oct | 12 | -38.4 | 63.7 | -70.5 | 91.7 | -0.32 | 0.36 | 0.558 |
| Nov | 12 | -37.0 | 60.4 | -67.7 | 86.7 | -0.20 | 0.25 | 0.307 |
| Dec | 12 | -52.4 | 65.0 | -86.9 | 101.8 | -0.43 | 0.43 | 0.542 |

The normalized bias ranges from approximately -60 to -20 percent. The bias is negative for each month, indicating the overall underestimation of sulfate deposition by the model. There is no clear tendency in the bias with respect to time of year. The normalized gross error ranges from approximately 50 to 70 percent, and differences between the bias and error values indicate a mix of over- and underestimation. The fractional bias and error measures have similar tendencies but indicate somewhat larger errors. Despite the large relative errors, the mean residual and unsigned error values are small, and the correlation statistics indicate that the simulation-observation pairs are moderately correlated.

Statistical measures of model performance for nitrate deposition at NADP sites are presented for each month in Table A-11.

**Table A-11. Month-by-Month REMSAD Model Performance Statistics for the 12-km Resolution Grids: Monthly Nitrate Deposition (kg ha$^{-1}$) at NADP Sites.**

| Month | Grid Resolution (km) | Normalized bias (%) | Normalized gross error (%) | Fractional bias (%) | Fractional error (%) | Mean residual ($\mu gm^{-3}$) | Mean unsigned error ($\mu gm^{-3}$) | Coefficient of Determination, $R^2$ |
|---|---|---|---|---|---|---|---|---|
| Jan | 12 | -7.4 | 73.7 | -48.2 | 89.1 | -0.04 | 0.29 | 0.262 |
| Feb | 12 | 4.6 | 85.6 | -48.4 | 90.5 | -0.11 | 0.41 | 0.153 |
| Mar | 12 | -24.8 | 61.0 | -59 | 79.3 | -0.29 | 0.43 | 0.274 |
| Apr | 12 | 41.8 | 90.6 | -6.9 | 67.7 | 0.03 | 0.40 | 0.317 |
| May | 12 | 37.4 | 72.6 | 3.3 | 52.8 | 0.11 | 0.45 | 0.465 |
| Jun | 12 | 11.7 | 56.7 | -11.5 | 50.8 | -0.07 | 0.52 | 0.333 |
| Jul | 12 | 47.5 | 92.3 | -6.2 | 58.6 | 0.00 | 0.53 | 0.298 |
| Aug | 12 | 30.3 | 76.1 | -5.9 | 60.4 | 0.08 | 0.55 | 0.391 |
| Sep | 12 | 9.3 | 75.6 | -31.6 | 65.7 | -0.12 | 0.39 | 0.301 |
| Oct | 12 | 76.0 | 121.2 | 1 | 70.3 | 0.07 | 0.29 | 0.533 |
| Nov | 12 | 108.7 | 155.2 | 7.4 | 81.3 | 0.22 | 0.38 | 0.257 |
| Dec | 12 | -2.0 | 68.6 | -40.4 | 78.7 | -0.04 | 0.33 | 0.461 |

The normalized bias ranges from -25 to 108 percent. The bias is negative for January, March, and December, and positive for the remaining months. The normalized gross error ranges from

approximately 55 to 155 percent. The large range for the relative metrics may be driven by some low observed deposition values. Differences between the bias and error values indicate a mix of over- and underestimation. The fractional bias reveals a greater tendency for underestimation and suggests that much of the overestimation indicated by the normalized bias is for sites with low nitrate deposition. The mean residual and unsigned error values are small, and the correlation statistics indicate that the simulation-observation pairs are moderately correlated.

Statistical measures of model performance for sulfate deposition at NADP sites are presented for each month in Table A-12.

**Table A-12. Month-by-Month REMSAD Model Performance Statistics for the 12-km Resolution Grids: Monthly Ammonia Deposition (kg ha$^{-1}$) at NADP Sites.**

| Month | Normalized bias (%) | Normalized gross error (%) | Fractional bias (%) | Fractional error (%) | Mean residual ($\mu gm^{-3}$) | Mean unsigned error ($\mu gm^{-3}$) | Coefficient of Determination, $R^2$ |
|---|---|---|---|---|---|---|---|
| Jan | -13.6 | 56.1 | -28.5 | 79.3 | -0.03 | 0.04 | 0.318 |
| Feb | -21.9 | 55.2 | -43.5 | 73.5 | -0.05 | 0.06 | 0.391 |
| Mar | -27.8 | 63.2 | -63.1 | 81.2 | -0.08 | 0.10 | 0.205 |
| Apr | -4.2 | 65.4 | -31.8 | 71.7 | -0.08 | 0.12 | 0.482 |
| May | -16.5 | 53.8 | -38 | 66.1 | -0.09 | 0.13 | 0.437 |
| Jun | -26.0 | 50.5 | -46.9 | 70.7 | -0.11 | 0.15 | 0.241 |
| Jul | -12.9 | 65.1 | -42.1 | 78.6 | -0.09 | 0.15 | 0.141 |
| Aug | -11.1 | 68.7 | -46.6 | 77 | -0.09 | 0.14 | 0.176 |
| Sep | -29.9 | 64.8 | -64 | 85.6 | -0.09 | 0.11 | 0.289 |
| Oct | -1.1 | 67.0 | -27.5 | 79.4 | -0.03 | 0.06 | 0.593 |
| Nov | -7.4 | 67.5 | -40.2 | 76.4 | -0.03 | 0.06 | 0.388 |
| Dec | -30.6 | 51.0 | -48.7 | 78.6 | -0.04 | 0.06 | 0.271 |

The normalized bias ranges from approximately -30 to -1 percent. The bias is negative for each month, indicating an overall underestimation of ammonia deposition by the model. The normalized gross error ranges from approximately 50 to 70 percent, and differences between the bias and error values indicate a mix of over- and underestimation. The mean residual and unsigned error values are small, and the correlation statistics indicate that the simulation-observation pairs are moderately correlated.

## Summary of Annual Model Performance for Particulate Species Concentration and Deposition

Statistical measures of model performance for $PM_{2.5}$ and several component species are presented for each month in Table A-13.

**Table A-13. Annual REMSAD Model Performance Statistics for the 12-km Resolution Grids for the Various Observational Networks.**

Units for Annual Average PM2.5 and Species Concentrations are μgm-3.
Units for Annual Deposition Totals are kg ha-1.

| Network/ Species | No. of Sites | Normalized bias (%) | Normalized gross error (%) | Fractional bias (%) | Fractional error (%) | Mean residual ($\mu gm^{-3}$) | Mean unsigned error ($\mu gm^{-3}$) | Coefficient of Determination, $R^2$ |
|---|---|---|---|---|---|---|---|---|
| AQS-STN | | | | | | | | |
| PM2.5 | | -0.6 | 28.4 | -7.9 | 29.6 | 0.2 | 3.54 | 0.407 |
| IMPROVE | | | | | | | | |
| PM2.5 | | -3.4 | 38.9 | -18.8 | 36.1 | -0.38 | 1.82 | 0.676 |
| CASTNet | | | | | | | | |
| Sulfate | | -32.6 | 33.5 | -41.5 | 42.3 | -0.97 | 0.98 | 0.918 |
| IMPROVE | | | | | | | | |
| Sulfate | | -26 | 40.9 | -41 | 46.6 | -0.51 | 0.55 | 0.869 |
| CASTNet | | | | | | | | |
| Nitrate | | 49.5 | 86.2 | 9.1 | 66.9 | 0.33 | 0.60 | 0.561 |
| IMPROVE | | | | | | | | |
| Nitrate | | 14.4 | 68 | -15.2 | 63.3 | 0.19 | 0.41 | 0.623 |
| CASTNet | | | | | | | | |
| Ammonium | | -5.8 | 20.0 | -9.8 | 22.3 | -0.02 | 0.16 | 0.914 |
| NADP | | | | | | | | |
| Sulfate deposition | | -52.2 | 52.4 | -75.8 | 75.9 | -5.63 | 5.63 | 0.738 |
| NADP | | | | | | | | |
| Nitrate deposition | | -3.5 | 35.3 | -14.4 | 39.7 | 0.1 | 3.28 | 0.523 |
| NADP | | | | | | | | |
| Ammonia deposition | | -31.3 | 38 | -46.6 | 52.3 | -0.74 | 0.86 | 0.497 |

On an annual basis, $PM_{2.5}$ is very well represented, but this may be a result of underestimation of sulfate and overestimation of nitrate and other species. Deposition is underestimated, especially for sulfate and ammonia. Overall, the annual errors tend to be smaller than the monthly values due to a mix of over and underestimation of the various species. The results are fairly consistent across the monitoring networks.

For $PM_{2.5}$, the errors are larger for the IMPROVE sites, compared to the AQS-STN sites, but the correlations favor the IMPROVE sites—possibly due to the lower concentrations at the Class I area sites.

For sulfate, the metrics are similar for the CASTNet and IMPROVE sites. For nitrate, there is a greater tendency for overestimation at the CASTNet sites, compared to the IMPROVE sites.

# Appendix B: Preliminary Comparison of CMAQ and REMSAD Tagging Simulations

Due to reliable performance in past TMDL modeling studies (e.g., Myers and Wei, 2004), computational efficiency, and the availability of the Particle and Precursor Tagging Methodology (PPTM) at the initiation of this project, REMSAD was used for the tagging simulations reported in the main document. Since that time, ICF has implemented PPTM for mercury in the CMAQ model (Douglas et al., 2006). To compare the results for the two models with PPTM, CMAQ was applied for a three-month subset of the annual simulation period (summer 2001) using PPTM for seven tags. This appendix compares the CMAQ and REMSAD results for this summer simulation period. The REMSAD results were extracted from the simulation that is discussed in the main report.

## Model Setup

The CMAQ modeling domain includes an outer grid with 36-km horizontal resolution and a one-way nested (inner) grid with 12-km resolution. The nested grid covers Illinois and portions of several surrounding states. The outer 36-km domain for CMAQ matches the 36-km domain used for the REMSAD simulations. The 2001 meteorological input files for the 36-km domain are those used in the CAIR and CAMR modeling and were derived from the same MM5 simulation as the inputs for the REMSAD simulation. For the 12-km domain, 2001 high resolution meteorological input files were acquired from the EPA OAQPS. The 12-km meteorological fields were derived from a recent MM5 simulation that covered approximately the eastern two-thirds of the U.S. A subset of these 12-km input fields was extracted for the nested grid simulation. The 12-km grid is depicted in the deposition plots that follow.
Emissions for CMAQ were prepared using the SMOKE processing system using the updated 2001 inventory that is discussed in detail in the main report. The emissions inputs for the two models are therefore the same.

Seven PPTM tags were applied in the CMAQ simulation, as follows:

- Powerton
- Joliet 29
- Joppa Steam
- Other IL utilities
- Remaining IL sources
- All other emissions including those from other states, Canada, and Mexico, as well as from natural and re-emission processes
- Initial and boundary conditions (IC/BC).

Note that the first three tags are individual utility sources in Illinois. This set of tags overlaps the tags prepared for REMSAD modeling and, with appropriate aggregation of some REMSAD tags, allows a direct comparison of the simulated source contributions for the two modeling platforms.

As described in the main report (Section 5), REMSAD simulations were conducted using boundary concentrations based on each of three different global model simulations. For the 36-km CMAQ simulation, the boundary concentrations used were based on the GRAHM global

model simulation. Therefore, the CMAQ simulation results are compared to the REMSAD simulation that also used the GRAHM-based boundary concentrations.

The CMAQ simulation was set up to be as similar as possible to the REMSAD simulation, while utilizing the best available data. Differences in model formulation may result in somewhat different deposition estimates from the two models (e.g., Bullock et al., 2006), but the focus here is on comparing the estimates of relative contributions from different sources made by the two models. In interpreting the differences in the simulation results, keep in mind that in addition to differences in model formulation the following differences, and possibly others, are present between the two applications:

- The REMSAD simulation used 12-km resolution over the entire U.S. The CMAQ simulation used a 12-km domain only around Illinois and parts of the surrounding states.
- Because the 12-km MM5 files were not available at the initiation of this project, 12-km meteorological fields for REMSAD were interpolated from files based on 36-km MM5 results. The 12-km resolution meteorological fields used for CMAQ were derived from a 12-km resolution MM5 simulation that were recently acquired from EPA OAQPS. Thus, the meteorological fields are expected to have some differences. In particular, the REMSAD 12-km fields may not embody some of the features contained in the CMAQ 12-km meteorological files. These differences have not been investigated here.
- The REMSAD results presented here are for the summer season (defined as June, July, and August) of a full annual simulation of 2001. The CMAQ results are for a simulation covering the summer season with a ten-day spin-up period prior to June 1, 2001.
- REMSAD calculates re-emission of mercury dynamically (during the course of the simulation). The CMAQ simulation includes re-emission estimates directly in the emissions input files (as direct emissions).
- The REMSAD emissions files do not include natural emissions of mercury (e.g., volcanic emissions) within the modeling domain (roughly North America). Natural emissions are included in the inventories used for the global simulations that provide boundary concentrations for both the REMSAD and CMAQ simulations. The CMAQ input emissions files do include natural emissions of mercury within the CMAQ modeling domain.

## Simulation Results

The simulation results for the two models are compared in this section for the 12-km grid, as utilized in the CMAQ simulation and for the three-month (summer 2001) simulation period. Figure B-1 presents and compares: (a) simulated wet and dry deposition of total mercury for the CMAQ run, and (b) simulated wet and dry deposition of total mercury for the REMSAD run. Overall, the two distributions are similar although, in some areas, one or the other model may produce higher deposition estimates.

The estimates of the contributions from the tagged sources are quite similar. This is examined in further detail for the locations of the greatest impact from each of the three individually tagged sources and for the location at which the REMSAD simulation predicts the greatest impact from Illinois sources (the blue triangle in the REMSAD deposition plot).

Figure B-2 compares the simulated contributions to wet and dry deposition from both models at the location of the greatest impact from the Powerton facility tag. For both models, about 50

percent of the deposition is attributed to background (IC/BC) and the largest source contribution is from the Powerton plant, followed by a contribution from other Illinois utilities.
The contributions at the location of maximum contribution from Joliet 29 (Figure B-3) and at the location of maximum contribution from Joppa Steam (Figure B-4) follow a similar pattern. The background contribution is well over half at both the Joliet 29 and the Joppa Steam location. In each case, though, the individual source contributes more than 10 percent of the deposition. The two models are consistent on the ranking of contributions from the tags.

Contributions at the location of the greatest impact of Illinois sources (Figure B-5) show the largest contribution from remaining Illinois sources (that is, sources in Illinois that were not individually tagged). The relative contributions estimated by the two models are virtually identical. About half of the deposition is from Illinois sources with an additional contribution from emissions from outside the state and the remainder from background.

## Summary

A comparison of CMAQ and REMSAD modeling results for a 12-km domain around Illinois and a summer 2001 simulation period shows that the simulated spatial patterns of mercury deposition are similar between the two models.

PPTM was used to tag seven different emissions sources (a mix of individual sources, groups of sources, and source regions (including global background)). The estimates of source contributions to mercury deposition are very similar between the two models.

Thus, despite some differences in the base simulation results, the relative contributions from the tagged sources are consistent between the CMAQ and REMSAD PPTM results, for the area and time period considered. The two models are also quite consistent on the ranking of contributions from the tagged sources/categories. The length of the simulation period may contribute to the similarities. Despite potential day-to-day differences in the meteorological input files, the seasonal average conditions are likely represented in both sets of meteorological inputs. The contribution results suggest that given the same emissions and boundary condition inputs, PPTM is able to resolve the relative contributions from the tagged emission sources and IC/BCs within the context of each model and that the results are effectively the same.

**Figure B-1. Summer Total Wet and Dry Deposition of Mercury Simulated by (a) CMAQ and (b) REMSAD.**

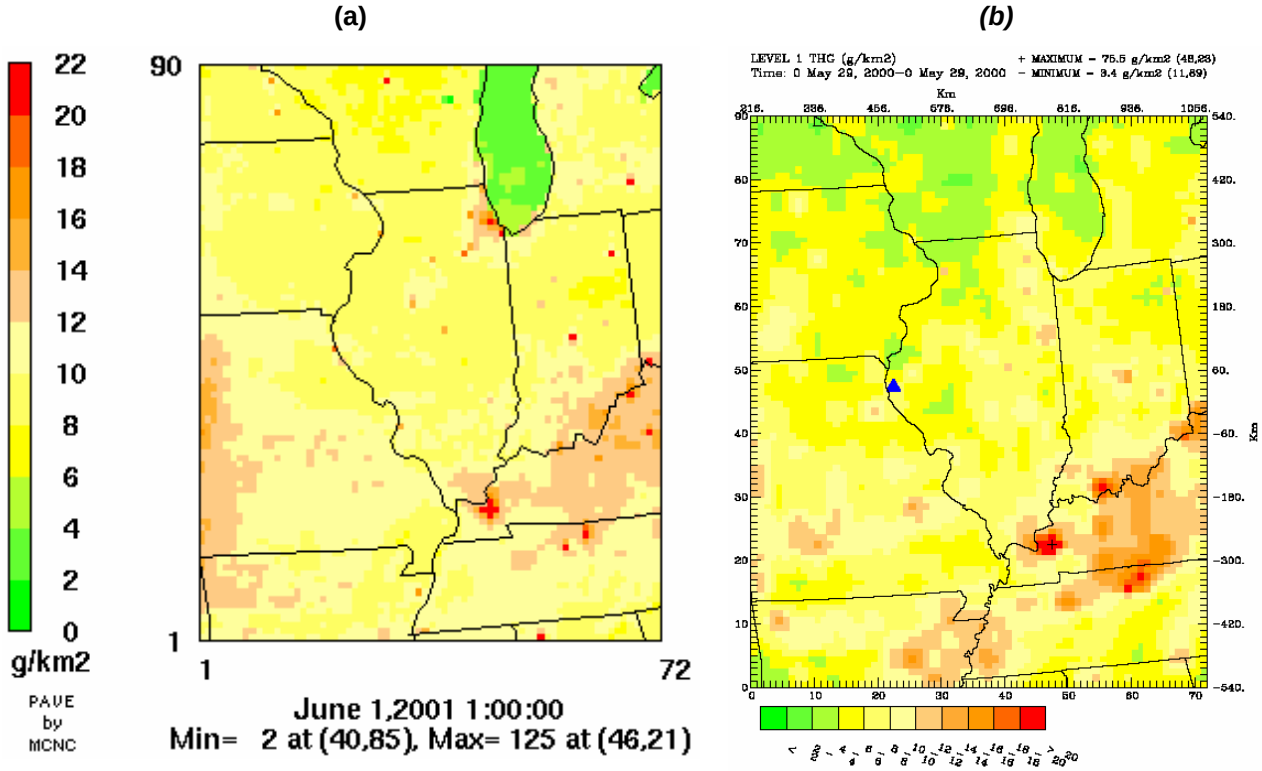
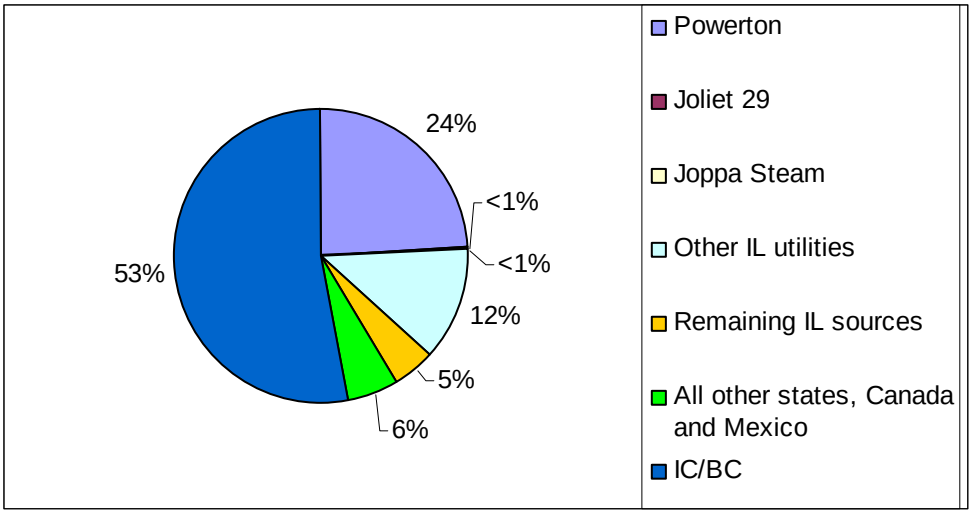


**Figure B-2. Estimates of Contributions to Total of Wet and Dry Deposition at the Location of Greatest Impact from Powerton Based on PPTM Simulations by CMAQ and REMSAD.**

**CMAQ**




**REMSAD**

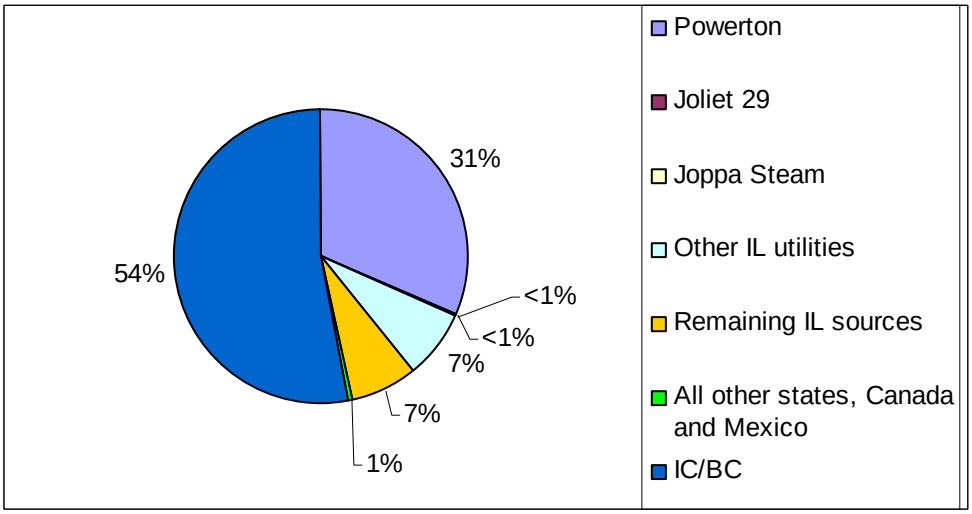
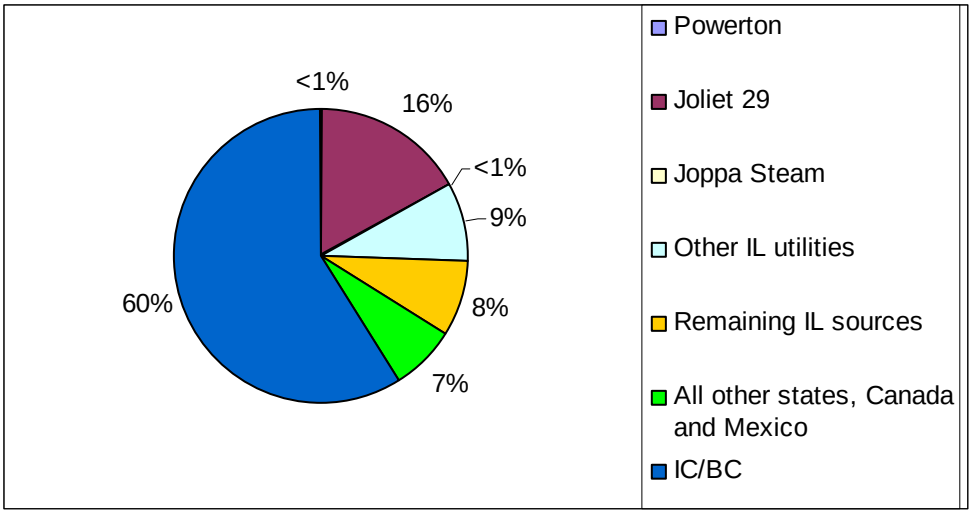


**Figure B-3. Estimates of Contributions to Total of Wet and Dry Deposition at the Location of Greatest Impact from Joliet 29 Based on PPTM Simulations by CMAQ and REMSAD.**

**CMAQ**




**REMSAD**

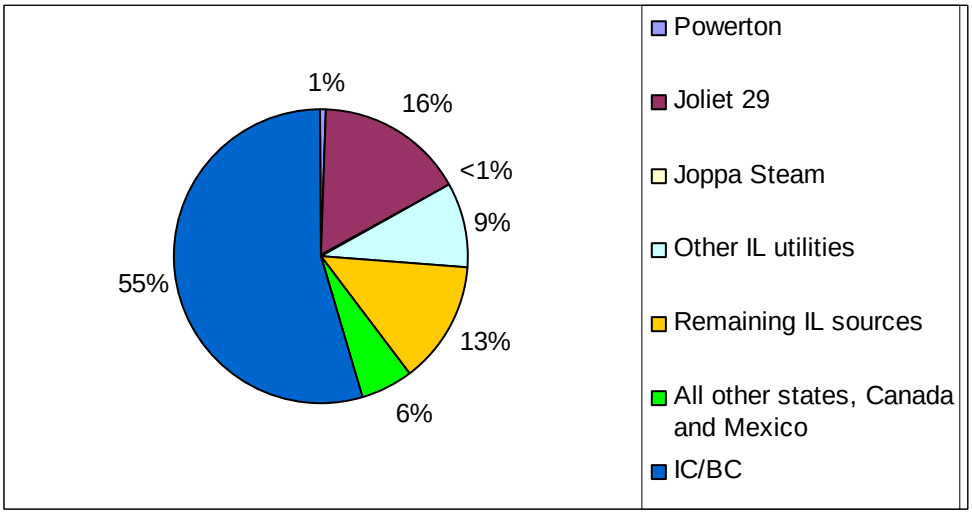
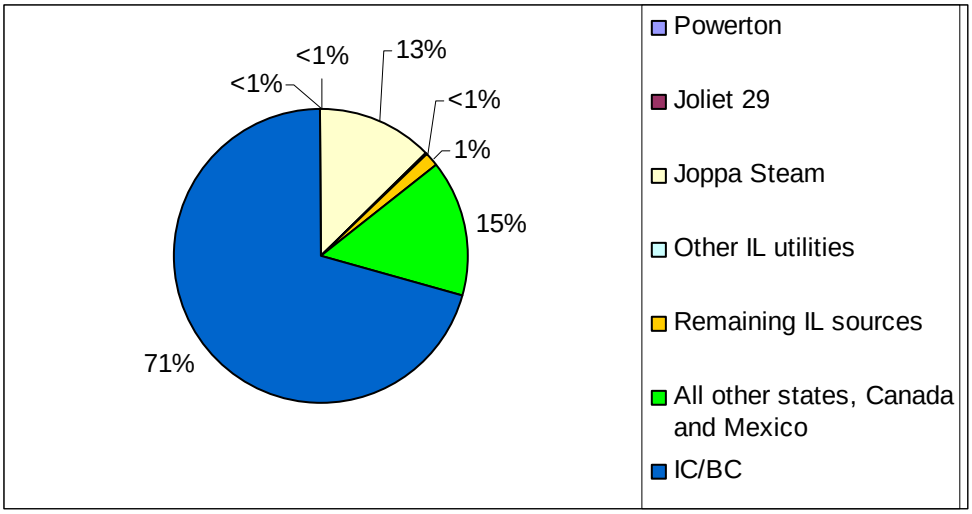


**Figure B-4. Estimates of Contributions to Total of Wet and Dry Deposition at the Location of Greatest Impact from Joppa Steam Based on PPTM Simulations by CMAQ and REMSAD.**

**CMAQ**




**REMSAD**

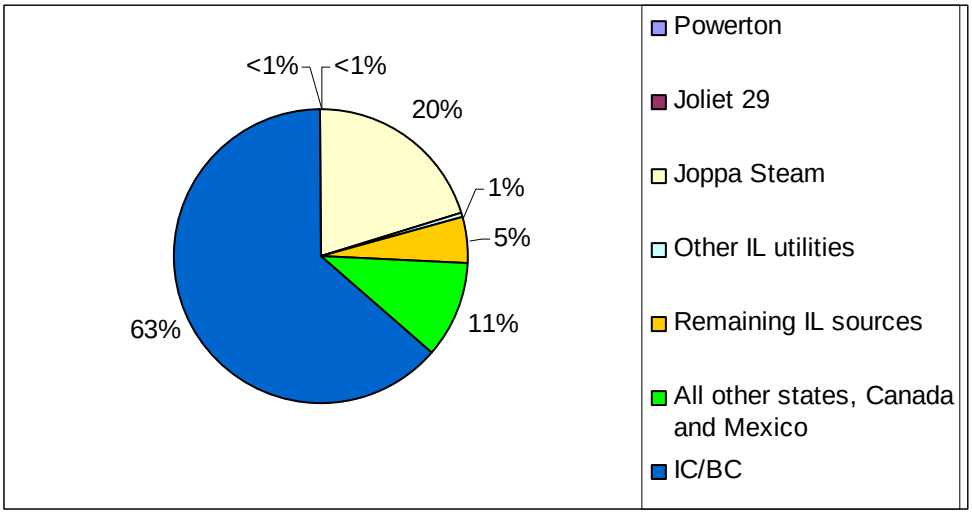
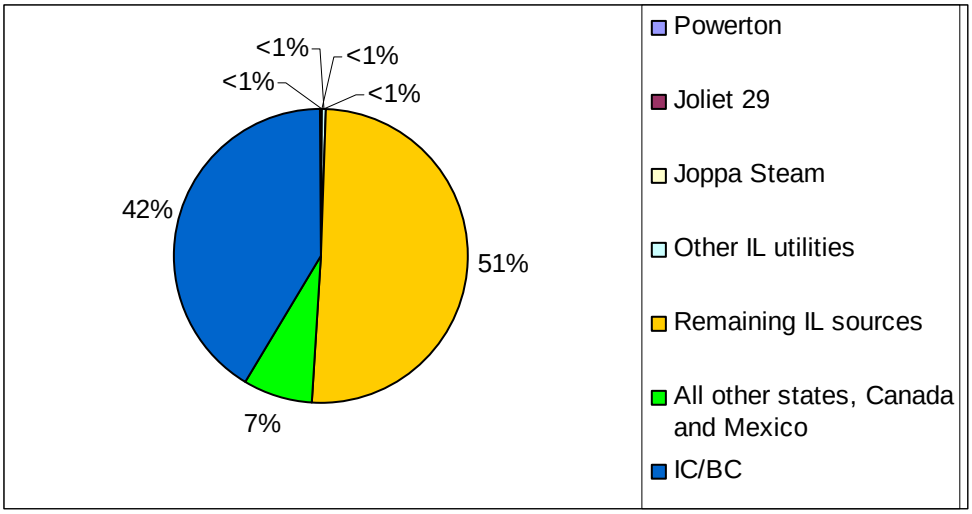
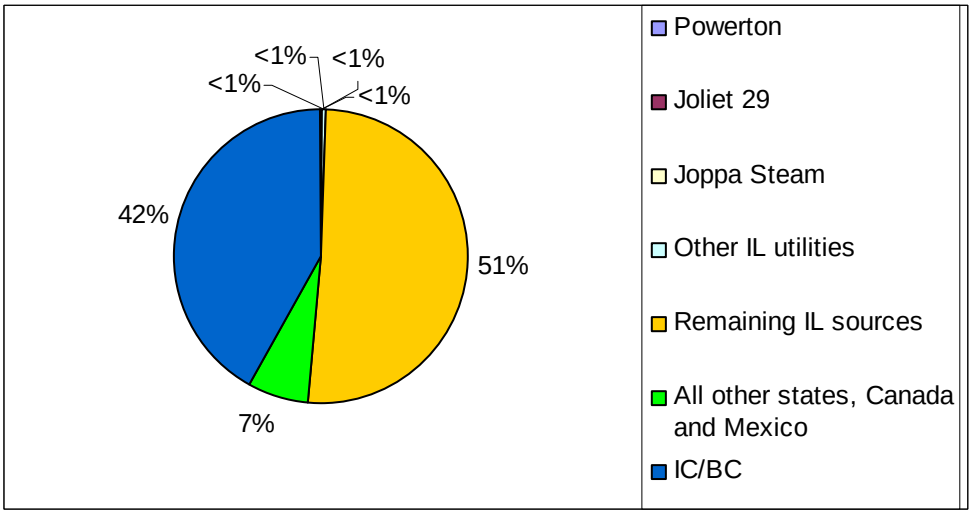


**Figure B-5. Estimates of Contributions to Total of Wet and Dry Deposition at the Location of Greatest Impact from Illinois Sources Based on PPTM Simulations by CMAQ and REMSAD.**

**CMAQ**




**REMSAD**



## References

Bullock, O. R., K. Lohman, C. Seigneur, K. Vijayaraghavan, A. Dastoor, D. Davignon, N. Selin, D. Jacob, T. Myers, K. Civerolo, C. Hogrefe, J. Ku, G. Sistla, D. Atkinson, and T. Braverman. 2006. "Results from the North American Mercury Model Inter-comparison Study (NAMMIS)." Poster session at the Eighth International Conference on Mercury as a Global Pollutant, Aug. 6-11, 2006, Madison, Wisconsin.

Douglas, S., T. Myers, and Y. Wei. 2006. "Implementation of Mercury Tagging in the Community Multi-scale Air Quality Model." (Draft) Prepared for the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. ICF International, San Rafael, California (06-051).

Myers, T. and Y. Wei. 2004. *REMSAD Air Deposition Modeling in Support of TMDL Development for Southern Louisiana.* ICF Consulting (04-038).

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# Appendix C: Details of Emissions Revisions for Selected States

This appendix includes details of emissions revisions made for certain states that provided extensive information on mercury emissions within the states. For a discussion of the revisions, see Section 4 of the main report.

Also included in this section is a tabulation of sources that were included in the "Collective Sources" tag for each state in which the in-state maximum was due to "Collective Sources."

## Illinois

**Table C-1. Summary of Emissions Revisions Made to IPM Sources in State of Illinois**

| Facility Name | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|
| **Coal Fired Utilities located Inside Chicago, IL MSA** | | | | |
| *Original Emissions* | | | | |
| Crawford | 0.076 | 0.034 | 1.7E-04 | 0.110 |
| Fisk | 0.057 | 0.025 | 1.3E-04 | 0.082 |
| Waukegan | 0.235 | 0.069 | 3.5E-04 | 0.304 |
| Joliet 29 | 0.298 | 0.133 | 6.7E-04 | 0.432 |
| Joliet 9 | 0.097 | 0.043 | 2.2E-04 | 0.140 |
| Will County | 0.168 | 0.061 | 3.1E-04 | 0.229 |
| Total | 0.931 | 0.365 | 0.002 | 1.298 |
| *Revised Emissions* | | | | |
| Crawford | 0.104 | 0.047 | 2.3E-04 | 0.151 |
| Fisk | 0.059 | 0.027 | 1.3E-04 | 0.086 |
| Waukegan | 0.310 | 0.091 | 4.6E-04 | 0.401 |
| Joliet 29 | 0.222 | 0.099 | 5.0E-04 | 0.322 |
| Joliet 9 | 0.057 | 0.026 | 1.3E-04 | 0.083 |
| Will County | 0.139 | 0.050 | 2.5E-04 | 0.189 |
| Total | 0.892 | 0.339 | 0.002 | 1.232 |
| **Coal Fired Utilities located Outside Chicago, IL MSA** | | | | |
| *Original Emissions* | | | | |
| Kincaid Generation L.L.C. | 0.103 | 0.063 | 0.002 | 0.167 |
| Hutsonville | 0.003 | 0.008 | 0.001 | 0.012 |
| Duck Creek | 0.016 | 0.001 | 0.000 | 0.017 |
| Newton | 0.087 | 0.043 | 0.001 | 0.131 |
| Wood River | 0.009 | 0.024 | 0.002 | 0.035 |
| Havana | 0.008 | 0.020 | 0.002 | 0.030 |
| Joppa Steam | 0.205 | 0.091 | 0.000 | 0.297 |
| Coffeen | 0.018 | 0.045 | 0.004 | 0.066 |
| Meredosia | 0.007 | 0.018 | 0.002 | 0.026 |
| E. D. Edwards | 0.019 | 0.051 | 0.005 | 0.075 |
| Hennepin | 0.012 | 0.015 | 0.001 | 0.028 |
| Baldwin | 0.040 | 0.107 | 0.010 | 0.156 |
| Dallman | 0.012 | 0.015 | 0.001 | 0.028 |
| Lakeside | 0.001 | 0.003 | 0.000 | 0.004 |
| Powerton | 0.389 | 0.174 | 0.001 | 0.564 |

| Facility Name | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|
| Vermilion | 0.003 | 0.008 | 0.001 | 0.012 |
| Southern Illinois Power Cooperative | 0.022 | 0.010 | 0.001 | 0.033 |
| Total | 0.954 | 0.695 | 0.032 | 1.681 |
| *Revised Emissions* | | | | |
| Kincaid Generation L.L.C. | 0.129 | 0.079 | 0.003 | 0.210 |
| Hutsonville | 0.006 | 0.015 | 0.001 | 0.021 |
| DuckCreek | 0.013 | 0.001 | 0.000 | 0.014 |
| Newton | 0.092 | 0.045 | 0.001 | 0.138 |
| Wood River | 0.024 | 0.014 | 0.000 | 0.039 |
| Havana | 0.005 | 0.013 | 0.001 | 0.019 |
| Joppa Steam | 0.210 | 0.094 | 0.000 | 0.305 |
| Coffeen | 0.022 | 0.055 | 0.005 | 0.082 |
| Meredosia | 0.008 | 0.022 | 0.002 | 0.033 |
| E. D. Edwards | 0.020 | 0.054 | 0.005 | 0.079 |
| Hennepin | 0.026 | 0.012 | 0.000 | 0.038 |
| Baldwin | 0.138 | 0.062 | 0.000 | 0.200 |
| Dallman | 0.014 | 0.017 | 0.001 | 0.032 |
| Lakeside | 0.003 | 0.007 | 0.001 | 0.010 |
| Powerton | 0.440 | 0.197 | 0.001 | 0.638 |
| Vermilion | 0.004 | 0.009 | 0.001 | 0.014 |
| Southern Illinois Power Cooperative | 0.028 | 0.012 | 0.001 | 0.041 |
| Total | 1.181 | 0.708 | 0.023 | 1.913 |
| *Total Emissions Changes for IPM* | | | | |
| Emissions Changes | 0.188 | -0.014 | -0.009 | 0.165 |

## Table C-2. Summary of Emissions Revisions Made to Non-IPM Sources in State of Illinois

| Facility Name | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|
| **Coal Fired Utilities located Inside Chicago, IL MSA** | | | | |
| *Original Emissions* | | | | |
| Marblehead Lime Co. | 0.435 | 0.054 | 0.054 | 0.544 |
| Marblehead Lime Co. - South Chicago Plt. | 0.193 | 0.024 | 0.024 | 0.242 |
| Lone Star Industries Inc - Oglesby Plant | 0.170 | 0.030 | 0.027 | 0.227 |
| Dixon - Marquette Cement Inc. | 0.148 | 0.026 | 0.024 | 0.198 |
| Vulcan Materials - McCook Lime Plt. | 0.150 | 0.019 | 0.019 | 0.187 |
| Illinois Cement Co. | 0.135 | 0.023 | 0.022 | 0.180 |
| Lafarge Corporation | 0.000 | 0.000 | 0.000 | 0.000 |
| Total | 1.232 | 0.176 | 0.170 | 1.578 |
| *Revised Emissions* | | | | |
| Marblehead Lime Co. | 0.020 | 0.003 | 0.003 | 0.025 |
| Marblehead Lime Co. - South Chicago Plt. | 0.009 | 0.001 | 0.001 | 0.011 |
| Lone Star Industries Inc - Oglesby Plant | 0.075 | 0.013 | 0.012 | 0.100 |
| Dixon - Marquette Cement Inc. | 0.001 | 0.000 | 0.000 | 0.002 |
| Vulcan Materials - McCook Lime Plt. | 0.015 | 0.002 | 0.002 | 0.019 |
| Illinois Cement Co. | 0.004 | 0.001 | 0.001 | 0.006 |
| Lafarge Corporation | 0.004 | 0.001 | 0.001 | 0.006 |
| Total | 0.129 | 0.020 | 0.019 | 0.168 |
| *Total Emissions Changes for Non-IPM* | | | | |
| Emissions Changes | -1.104 | -0.156 | -0.151 | -1.410 |

## Indiana

**Table C-3. Summary of Emissions Revisions Made to IPM Sources in State of Indiana**

| Facility Name | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|
| *Original Emissions* | | | | |
| Tanners Creek | 0.038 | 0.101 | 0.009 | 0.148 |
| R. Gallagher Station | 0.031 | 0.082 | 0.007 | 0.121 |
| Gibson Generating Station | 0.114 | 0.170 | 0.015 | 0.298 |
| R. M. Schahfer | 0.145 | 0.061 | 0.001 | 0.207 |
| Clifty Creek | 0.132 | 0.125 | 0.007 | 0.264 |
| State Line | 0.039 | 0.026 | 0.000 | 0.065 |
| E. W. Stout | 0.020 | 0.053 | 0.005 | 0.078 |
| Petersburg | 0.104 | 0.009 | 0.000 | 0.113 |
| Rockport | 0.131 | 0.348 | 0.031 | 0.510 |
| Merom | 0.054 | 0.005 | 0.000 | 0.059 |
| Cayuga (IN) | 0.027 | 0.072 | 0.006 | 0.106 |
| Wabash River Generating Station | 0.041 | 0.054 | 0.005 | 0.100 |
| Warrick Power Plant | 0.022 | 0.057 | 0.005 | 0.084 |
| Total | 0.897 | 1.163 | 0.092 | 2.152 |
| *Revised Emissions* | | | | |
| Tanners Creek | 0.031 | 0.082 | 0.007 | 0.121 |
| R. Gallagher Station | 0.031 | 0.081 | 0.007 | 0.119 |
| Gibson Generating Station | 0.108 | 0.162 | 0.014 | 0.284 |
| R. M. Schahfer | 0.122 | 0.051 | 0.001 | 0.173 |
| Clifty Creek | 0.120 | 0.113 | 0.007 | 0.240 |
| State Line | 0.040 | 0.028 | 0.000 | 0.068 |
| E. W. Stout | 0.019 | 0.051 | 0.005 | 0.074 |
| Petersburg | 0.104 | 0.009 | 0.000 | 0.114 |
| Rockport | 0.121 | 0.321 | 0.029 | 0.471 |
| Merom | 0.052 | 0.004 | 0.000 | 0.057 |
| Cayuga (IN) | 0.026 | 0.068 | 0.006 | 0.100 |
| Wabash River Generating Station | 0.042 | 0.056 | 0.005 | 0.102 |
| Warrick Power Plant | 0.019 | 0.049 | 0.004 | 0.072 |
| Total | 0.834 | 1.075 | 0.086 | 1.995 |
| *Total Emissions Changes for IPM* | | | | |
| Emissions Changes | -0.063 | -0.088 | -0.007 | -0.157 |

## Table C-4. Summary of Emissions Revisions Made to Non-IPM Sources in State of Indiana

| Facility Name | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|
| *Original Emissions* | | | | |
| Parkview Memorial Hospital-Inc | 0.0803 | 0.0482 | 0.0321 | 0.1605 |
| Lone Star Industries - Inc. | 0.0539 | 0.0186 | 0.0205 | 0.0930 |
| Lehigh Portland Cement Company | 0.0577 | 0.0100 | 0.0092 | 0.0769 |
| Essroc Cement-Speed Plant | 0.0540 | 0.0094 | 0.0086 | 0.0720 |
| Amoco Oil Co. | 0.0161 | 0.0055 | 0.0061 | 0.0277 |
| Waupaca Foundry-Inc. Plant 5 | 0.0192 | 0.0024 | 0.0024 | 0.0240 |
| Wishard Memorial Hospital | 1.5E-05 | 9.0E-06 | 6.0E-06 | 3.0E-05 |
| Total | 2.8E-01 | 9.4E-02 | 7.9E-02 | 4.5E-01 |
| *Revised Emissions* | | | | |
| Facility Name | | | | |
| Parkview Memorial Hospital-Inc | 0.054 | 0.032 | 0.021 | 0.107 |
| Lone Star Industries - Inc. | 0.070 | 0.024 | 0.026 | 0.120 |
| Lehigh Portland Cement Company | 0.059 | 0.010 | 0.009 | 0.079 |
| Essroc Cement-Speed Plant | 0.059 | 0.010 | 0.009 | 0.079 |
| Amoco Oil Co. | 0.069 | 0.024 | 0.026 | 0.118 |
| Waupaca Foundry-Inc. Plant 5 | 0.057 | 0.007 | 0.007 | 0.071 |
| Wishard Memorial Hospital | 0.037 | 0.022 | 0.015 | 0.073 |
| Total | 0.404 | 0.129 | 0.115 | 0.648 |
| *Total Emissions Changes for Non-IPM* | | | | |
| Emissions Changes | 0.123 | 0.035 | 0.036 | 0.194 |

# Iowa

## Table C-5. Summary of Emissions Revisions made to IPM Sources in State of Iowa

| FIPS | Facility Name | Plant ID | Stk ID | Unit ID | StkHt (m) | Diam (m) | Temp (Deg K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Original Emissions* | | | | | | | | | | | | |
| 19193 | George Neal North | 13452 | | | 121.9 | 6.10 | 436 | 30.0 | 0.146 | 0.055 | 0.001 | 0.202 |
| 19193 | George Neal South | 13453 | | | 143.0 | 7.86 | 387 | 19.2 | 0.100 | 0.045 | 2.5E-04 | 0.145 |
| 19155 | Council Bluffs | 13713 | | | 167.6 | 7.62 | 408 | 23.2 | 0.108 | 0.043 | 2.7E-04 | 0.151 |
| 19005 | Lansing | 13530 | | | 152.1 | 4.69 | 403 | 24.7 | 0.042 | 0.021 | 3.9E-04 | 0.064 |
| 19179 | Ottumwa | 13581 | | | 182.9 | 7.62 | 408 | 27.7 | 0.040 | 0.018 | 1.2E-04 | 0.058 |
| 19115 | Louisa | 13535 | | | 185.9 | 9.14 | 422 | 22.3 | 0.123 | 0.018 | 8.9E-05 | 0.140 |
| 19045 | Milton L. Kapp | 13206 | | | 74.7 | 3.96 | 416 | 24.1 | 0.013 | 0.013 | 0.001 | 0.027 |
| 19057 | Burlington | 13689 | | | 93.3 | 3.57 | 400 | 29.9 | 0.018 | 0.008 | 4.9E-05 | 0.026 |
| 19061 | Dubuque | 13730 | | | 155.4 | 4.45 | 381 | 18.9 | 0.003 | 0.007 | 0.001 | 0.010 |
| 19127 | Sutherland | 13340 | | | 75.6 | 2.90 | 441 | 19.5 | 0.010 | 0.007 | 1.1E-04 | 0.017 |
| 19139 | Muscatine | 13564 | | | 67.1 | 2.59 | 436 | 19.8 | 0.064 | 0.006 | 2.6E-04 | 0.071 |
| 19163 | Riverside | 13294 | | | 105.5 | 4.08 | 420 | 23.8 | 0.011 | 0.005 | 2.9E-05 | 0.017 |
| 19113 | Prairie Creek | 13593 | | | 61.0 | 3.96 | 413 | 17.1 | 0.026 | 0.004 | 2.3E-05 | 0.030 |
| Total | | | | | | | | | 0.705 | 0.250 | 0.004 | 0.958 |
| *Revised Emissions* | | | | | | | | | | | | |
| 19193 | George Neal North | 13452 | 1 | 001 | 68.6 | 2.87 | 433 | 39.7 | 0.014 | 0.005 | 5.5E-05 | 0.020 |
| | | | 2 | 002 | 91.4 | 4.65 | 416 | 25.1 | 0.036 | 0.014 | 1.4E-04 | 0.050 |
| | | | 3 | 003 | 121.9 | 6.10 | 450 | 33.2 | 0.087 | 0.033 | 3.3E-04 | 0.120 |
| 19193 | George Neal South | 13453 | 1 | 001 | 143.0 | 7.62 | 422 | 20.7 | 0.097 | 0.043 | 2.4E-04 | 0.140 |
| 19155 | Council Bluffs | 13713 | 1 | 001 | 76.2 | 3.66 | 433 | 8.5 | 0.007 | 0.003 | 1.8E-05 | 0.010 |
| | | | 2 | 002 | 76.2 | 3.66 | 416 | 14.0 | 0.007 | 0.003 | 1.8E-05 | 0.010 |
| | | | 3 | 003 | 167.6 | 7.62 | 411 | 21.6 | 0.100 | 0.040 | 2.5E-04 | 0.140 |
| 19005 | Lansing | 13530 | 1 | 001 | 93.3 | 3.58 | 478 | 10.8 | 0.026 | 0.013 | 2.5E-04 | 0.040 |
| 19179 | Ottumwa | 13581 | 1 | 001 | 182.9 | 7.62 | 478 | 33.2 | 0.083 | 0.037 | 2.4E-04 | 0.120 |
| 19115 | Louisa | 13535 | 1 | 001 | 185.9 | 9.14 | 422 | 22.3 | 0.114 | 0.016 | 8.3E-05 | 0.130 |
| 19045 | Milton L. Kapp | 13206 | 1 | 001 | 74.7 | 3.96 | 450 | 35.1 | 0.015 | 0.014 | 0.001 | 0.030 |
| 19057 | Burlington | 13689 | 1 | 001 | 93.3 | 3.58 | 478 | 43.3 | 0.021 | 0.009 | 5.7E-05 | 0.030 |
| 19061 | Dubuque | 13730 | 1 | 001 | 48.2 | 2.74 | 450 | 15.1 | 0.002 | 0.005 | 4.8E-04 | 0.008 |
| 19127 | Sutherland | 13340 | 1 | 001 | 75.9 | 2.90 | 450 | 13.4 | 0.006 | 0.004 | 6.5E-05 | 0.010 |
| | | | 2 | 002 | 75.9 | 2.90 | 450 | 13.4 | 0.006 | 0.004 | 6.5E-05 | 0.010 |
| | | | 3 | 003 | 75.9 | 3.05 | 436 | 23.2 | 0.006 | 0.004 | 6.5E-05 | 0.010 |
| 19139 | Muscatine | 13564 | 1 | 001 | 68.6 | 2.60 | 450 | 20.0 | 0.009 | 0.001 | 3.7E-05 | 0.010 |
| | | | 2 | 002 | 91.4 | 3.20 | 355 | 22.8 | 0.027 | 0.003 | 1.1E-04 | 0.030 |
| 19163 | Riverside | 13294 | 1 | 001 | 105.5 | 4.08 | 420 | 23.8 | 0.014 | 0.006 | 3.5E-05 | 0.020 |
| 19113 | Prairie Creek | 13593 | 1 | 001 | 61.0 | 3.96 | 438 | 22.1 | 0.017 | 0.003 | 1.6E-05 | 0.020 |
| | | | 2 | 002 | 26.4 | 3.79 | 445 | 9.1 | 0.009 | 0.001 | 7.8E-06 | 0.010 |
| Total | | | | | | | | | 0.732 | 0.338 | 0.010 | 1.080 |
| *Total Emissions Changes* | | | | | | | | | | | | |
| | Emissions Changes | | | | | | | | -0.002 | 0.012 | -1.3E-04 | 0.010 |

## Table C-6. Summary of Emissions Revisions made to non-IPM and MWI Sources in State of Iowa

| FIPS | Facility Name | Plant ID | Stk ID | Unit ID | StkHt (m) | Diam (m) | Temp (Deg K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

| FIPS | Facility Name | Plant ID | Stk ID | Unit ID | StkHt (m) | Diam (m) | Temp (Deg K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Original Emissions* | | | | | | | | | | | | |
| 19113 | City Of Cedar Rapids WPCF | 12181 | | | 17.3 | 0.73 | 433 | 10.1 | 0.013 | 0.008 | 0.005 | 0.026 |
| 19045 | Adm Corn Processing - Clinton | 15091 | | | 43.1 | 2.01 | 461 | 10.3 | 0.003 | 0.002 | 0.001 | 0.005 |
| 19169 | Iowa State University | B25 | | | 26.9 | 1.16 | 457 | 9.3 | 2.3E-04 | 8.0E-05 | 8.8E-05 | 4.0E-04 |
| 19041 | Spencer Hospital | M104 | | | 2.6 | 0.14 | 855 | 1.8 | 9.8E-07 | 1.5E-05 | 3.9E-06 | 2.0E-05 |
| Total | | | | | | | | | 0.016 | 0.009 | 0.006 | 0.031 |
| *Revised Emissions* | | | | | | | | | | | | |
| 19113 | City Of Cedar Rapids WPCF | 12181 | 1 | 001 | 16.0 | 1.59 | 323 | 14.7 | 0.013 | 0.008 | 0.005 | 0.026 |
| 19045 | Adm Corn Processing - Clinton | 15091 | 1 | 001 | 91.4 | 3.96 | 453 | 19.3 | 0.005 | 0.003 | 0.002 | 0.010 |
| 19169 | Iowa State University | B25 | 1 | 001 | 26.9 | 1.16 | 457 | 9.3 | 0.006 | 0.002 | 0.002 | 0.010 |
| 19041 | Spencer Hospital | M104 | 1 | 001 | 2.4 | 0.46 | 1255 | 14.8 | 0.000 | 0.007 | 0.002 | 0.010 |
| Total | | | | | | | | | 0.024 | 0.020 | 0.011 | 0.056 |
| *Total Emissions Changes* | | | | | | | | | | | | |
| | Emissions Changes | | | | | | | | 0.008 | 0.011 | 0.005 | 0.024 |

## New Jersey

**Table C-7. Summary of Emissions Revisions made to IPM Sources in State of New Jersey**

| Facility Name | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|
| *Original Emissions* | | | | |
| B L England | 0.026 | 0.004 | 0.001 | 0.032 |
| Hudson | 0.014 | 0.037 | 0.003 | 0.054 |
| Mercer | 0.004 | 0.002 | 0.002 | 0.008 |
| Deepwater | 0.001 | 0.001 | 0.000 | 0.002 |
| Logan Generating Company - L.P. | 0.001 | 0.001 | 0.001 | 0.003 |
| Chambers Cogeneration - L.P. | 0.001 | 0.001 | 0.000 | 0.002 |
| Total | 0.047 | 0.046 | 0.007 | 0.100 |
| *Revised Emissions* | | | | |
| B L England | 0.094 | 0.016 | 0.004 | 0.114 |
| Hudson | 0.011 | 0.028 | 0.003 | 0.041 |
| Mercer | 0.030 | 0.015 | 0.011 | 0.057 |
| Deepwater | 0.002 | 0.004 | 0.000 | 0.006 |
| Logan Generating Company - L.P. | 0.001 | 0.000 | 0.000 | 0.002 |
| Chambers Cogeneration - L.P. | 0.010 | 0.006 | 0.004 | 0.021 |
| Total | 0.147 | 0.070 | 0.023 | 0.240 |
| *Total Emissions Changes for IPM* | | | | |
| Emissions Changes | 0.100 | 0.024 | 0.016 | 0.139 |

## Table C-8. Summary of Emissions Revisions made to Non-IPM Sources in State of New Jersey

| Facility Name | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|
| *Original Emissions* | | | | |
| Co Steel Raritan | 0.049 | 0.030 | 0.020 | 0.099 |
| Atlantics Tates Cast Iron Pipe | 0.039 | 0.005 | 0.005 | 0.049 |
| U.S. Pipe & Fndy. Co. | 0.053 | 0.032 | 0.021 | 0.107 |
| Co Steel Sayreville | 0.164 | 0.020 | 0.020 | 0.205 |
| Essex Co. RRF | 0.034 | 0.090 | 0.031 | 0.156 |
| Camden RRF | 0.021 | 0.054 | 0.019 | 0.093 |
| Union Co. RRF | 0.003 | 0.007 | 0.002 | 0.012 |
| Gloucester County | 0.002 | 0.005 | 0.002 | 0.008 |
| Warren Energy RF | 0.001 | 0.001 | 0.000 | 0.002 |
| Howarddown | 0.001 | 0.000 | 0.000 | 0.002 |
| Hoeganese | 0.005 | 0.003 | 0.002 | 0.011 |
| Camden Co. Muassi | 0.026 | 0.016 | 0.011 | 0.053 |
| Stonybrook Regional Sewerage Authority | 0.023 | 0.014 | 0.009 | 0.045 |
| Bayshore Regional Sewerage Authority | 0.008 | 0.005 | 0.003 | 0.015 |
| Somerset Raritanvalley Sewerage Authority | 0.007 | 0.004 | 0.003 | 0.015 |
| Northwest Bergen County Utilities Authority | 0.006 | 0.004 | 0.002 | 0.012 |
| Parsippany - Troyhills Township WWTP | 0.004 | 0.003 | 0.002 | 0.008 |
| Atlantic County Utilities Authority | 0.003 | 0.002 | 0.001 | 0.005 |
| Gloucester County Utilities Authority | 0.002 | 0.001 | 0.001 | 0.004 |
| Total | 0.449 | 0.295 | 0.155 | 0.899 |
| *Revised Emissions* | | | | |
| Co Steel Raritan | 0.090 | 0.011 | 0.011 | 0.112 |
| Atlantics Tates Cast Iron Pipe | 0.033 | 0.004 | 0.004 | 0.041 |
| U.S. Pipe & Fndy. Co. | 0.019 | 0.011 | 0.000 | 0.030 |
| Co Steel Sayreville | 0.178 | 0.022 | 0.022 | 0.223 |
| Essex Co. RRF | 0.047 | 0.123 | 0.042 | 0.212 |
| Camden RRF | 0.011 | 0.029 | 0.010 | 0.050 |
| Union Co. RRF | 0.003 | 0.008 | 0.003 | 0.014 |
| Gloucester County | 0.002 | 0.005 | 0.002 | 0.009 |
| Warren Energy RF | 0.001 | 0.001 | 0.001 | 0.003 |
| Howarddown | 0.002 | 0.001 | 0.001 | 0.003 |
| Hoeganese | 0.005 | 0.003 | 0.002 | 0.011 |
| Camden Co. Muassi | 0.005 | 0.003 | 0.002 | 0.010 |
| Stonybrook Regional Sewerage Authority | 0.011 | 0.007 | 0.005 | 0.023 |
| Bayshore Regional Sewerage Authority | 0.004 | 0.002 | 0.002 | 0.008 |
| Somerset Raritanvalley Sewerage Authority | 0.007 | 0.004 | 0.003 | 0.014 |
| Northwest Bergen County Utilities Authority | 0.005 | 0.003 | 0.002 | 0.010 |
| Parsippany - Troyhills Township WWTP | 0.004 | 0.003 | 0.002 | 0.009 |
| Atlantic County Utilities Authority | 0.003 | 0.002 | 0.001 | 0.005 |
| Gloucester County Utilities Authority | 0.001 | 0.001 | 0.000 | 0.002 |
| Total | 0.429 | 0.243 | 0.114 | 0.786 |
| *Total Emissions Changes for Non-IPM* | | | | |
| Emissions Changes | -0.020 | -0.052 | -0.041 | -0.113 |

# Nevada

## Table C-9. Summary of Emissions Revisions Made to Non-IPM Sources in State of Nevada

| Facility Name | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|
| **Gold Mines** | | | | |
| *Original Emissions* | | | | |
| Jerritt Canyon (Main) | 6.780 | 0.000 | 0.000 | 6.780 |
| Pipeline Mining Operation | 2.284 | 0.000 | 0.000 | 2.284 |
| Twin Creeks/Newmont Mining Corp. | 1.370 | 0.000 | 0.000 | 1.370 |
| Barrick Gold Strike Mine | 0.706 | 0.000 | 0.000 | 0.706 |
| Goldstrike Mine | 0.042 | 0.000 | 0.000 | 0.042 |
| Newmont Mining Corporation - Carlin South Area | 0.090 | 0.054 | 0.036 | 0.180 |
| Getchell Gold Corp. | 0.002 | 0.001 | 0.001 | 0.004 |
| Newmont Gold Co. - Lone Tree Mine | 0.001 | 4.5E-04 | 3.0E-04 | 0.002 |
| Coeur Rochester Inc. | 0.002 | 0.001 | 0.001 | 0.004 |
| Total | 11.277 | 0.057 | 0.038 | 11.371 |
| *Revised Emissions* | | | | |
| Queenstake Resources USA Inc - Jerritt Canyon Mine | 0.121 | 0.719 | 0.018 | 0.858 |
| Cortez Gold Mines Mill #2 (aka Pipeline Mill) | 0.056 | 0.026 | 0.002 | 0.083 |
| Newmont Mining Corporation - Twin Creeks Mine | 0.194 | 0.018 | 0.006 | 0.218 |
| Barrick Goldstrike Mines, Inc | 0.282 | 0.023 | 0.007 | 0.312 |
| Newmont Mining Corporation - Lone Tree Mine | 0.269 | 0.038 | 0.005 | 0.312 |
| Newmont Mining Corporation - Gold Quarry Operations | 0.106 | 0.045 | 0.008 | 0.159 |
| Newmont Midas Operations | 0.003 | 0.005 | 3.1E-04 | 0.009 |
| Coeur Rochester, Inc | 0.001 | 0.001 | 5.5E-05 | 0.001 |
| Florida Canyon Mine | 0.078 | 0.134 | 8.4E-03 | 0.220 |
| Glamis Marigold Mine | 0.397 | 0.054 | 0.005 | 0.455 |
| Round Mountain Gold Corporation - Smokey Valley Common Operation | 0.023 | 0.005 | 3.5E-04 | 0.029 |
| Homestake Mining Corporation - Ruby Hill Mine | 7.5E-03 | 0.006 | 4.0E-04 | 0.014 |
| Bald Mountain Mine (including Mooney Basin Operation) | 0.066 | 0.034 | 0.002 | 0.102 |
| Denton - Rawhide Mine | 0.062 | 0.107 | 0.007 | 0.176 |
| Placer Turquoise Ridge, Inc | 0.002 | 0.003 | 2.0E-04 | 0.005 |
| Battle Mountain Gold Company | 0.001 | 1.3E-04 | 8.6E-06 | 0.001 |
| Total | 1.667 | 1.218 | 0.070 | 2.955 |
| **Cement Plant** | | | | |
| *Revised Emissions* | | | | |
| Nevada Cement Co. | 0.007 | 0.001 | 0.001 | 0.010 |
| **Total Emissions Changes for Non-IPM** | | | | |
| **Emissions Changes** | **1.674** | **1.220** | **0.071** | **2.965** |

## Table C-10. Summary of Origin of Data for Mercury Emissions and Speciation for Nevada Gold Mines

| Facility Name | Process | Speciation | | | | |
|---|---|---|---|---|---|---|
| | | Total Emissions of Hg (tpy) | HG0 | HG2 | HGP | Notes |
| Newmont Lone Tree Mine | Laboratory Drying Oven | 0.001 | 35.0% | 61.2% | 3.8% | 1 |
| | Laboratory Fire Assay Furnace | 4.0E-06 | 35.0% | 61.2% | 3.8% | 4 |
| | Laboratory LECO Furnace | 1.5E-06 | 35.0% | 61.2% | 3.8% | 4 |
| | Phase I Lime Slaker | 5.0E-04 | 0.0% | 0.0% | 100.0% | 4 |
| | Autoclave | 0.018 | 78.10% | 8.30% | 13.60% | 1 |
| | Carbon Kiln | 0.286 | 88.2% | 11.0% | 0.7% | 1 |
| | Electrowinning Cells | 0.006 | 35.0% | 61.2% | 3.8% | 1 |
| | Pregnant and Barren Solution Tanks | 0.001 | 35.0% | 61.2% | 3.8% | 1 |
| Newmont Gold Quarry Operations | ROTP Dry Grinding Static Separator | 3.0E-04 | 0.0% | 0.0% | 100.0% | 1 |
| | ROTP Ore Preheaters | 2.6E-02 | 99.5% | 0.3% | 0.2% | 1,2 |
| | ROTP Ore Roasters | 1.7E-03 | 57.2% | 38.7% | 4.0% | 1,2 |
| | ROTP Calcine Quench (N & S) | 7.0E-02 | 28.0% | 61.0% | 11.0% | 1 |
| | AARL Carbon Kiln | 3.6E-02 | 99.0% | 0.9% | 0.1% | 1,2 |
| | AARL Carbon Kiln combustion | 6.6E-04 | 99.0% | 0.9% | 0.1% | 1,2 |
| | Zadra Carbon Kiln | 8.6E-03 | 99.0% | 0.9% | 0.1% | 1,2 |
| | Zadra Carbon Kiln combustion | 1.6E-04 | 98.4% | 0.0% | 1.6% | 1,2 |
| | AARL Carbon Stripping Tanks(solution tank 1) | 3.5E-03 | 95.7% | 1.9% | 2.4% | 2 |
| | AARL Carbon Stripping Tanks(solution tank 2 and 3) | 1.6E-03 | 85.7% | 13.4% | 0.8% | 2 |
| | Refinery Retorts | 4.6E-03 | 98.2% | 1.6% | 0.3% | 1,2 |
| | Refinery Induction & Four Furnaces | 3.1E-03 | 97.2% | 2.5% | 0.3% | 1,2 |
| | Refinery Barren Tank & Electrowinning (EW) Cells | 2.7E-03 | 97.7% | 2.1% | 0.3% | 1 |
| | Integrated Lab Furnaces (Lines 1 & 2) | 5.0E-05 | 97.7% | 2.1% | 0.3% | 1 |
| | Manual Lab Furnaces | 6.5E-05 | 97.7% | 2.1% | 0.3% | 1 |
| | Integrated Lab Grieve Drying Ovens | 5.0E-05 | 35.0% | 61.2% | 3.8% | 1 |
| Newmont Twin Creeks Mine | Aotoclave Phase 1 | 0.077 | 97.9% | 1.6% | 0.5% | 1 |
| | Aotoclave Phase 2 | 0.032 | 97.9% | 1.6% | 0.5% | 1 |
| | Juniper Carbon Kiln | 0.012 | 13.3% | 57.6% | 29.1% | 1 |
| | Electrowinning Cells Exhaust | 0.021 | 99.1% | 0.8% | 0.0% | 1 |
| | Juniper Hg Retort A | 0.000 | 99.1% | 0.8% | 0.0% | 1 |

| Facility Name | Process | Speciation | | | | |
|---|---|---|---|---|---|---|
| | | Total Emissions of Hg (tpy) | HG0 | HG2 | HGP | Notes |
| | **Juniper Hg Retort B** | **0.000** | **99.1%** | **0.8%** | **0.0%** | **1** |
| | **Juniper Hg Retort C** | **0.000** | **99.1%** | **0.8%** | **0.0%** | **1** |
| | **Juniper Hg Retort D** | **0.000** | **99.1%** | **0.8%** | **0.0%** | **1** |
| | **Juniper Induction Furnaces** | **0.000** | **99.1%** | **0.8%** | **0.0%** | **1** |
| | **Pregnant/Barren solution tanks** | **0.073** | **88.0%** | **11.0%** | **1.0%** | **1** |
| | **Lab Sample Drying Ovens (2)** | **0.002** | **35%** | **61.20%** | **3.80%** | **1** |
| | **Lab Assay Furnaces (5)** | **5.0E-04** | **35%** | **61.20%** | **3.80%** | **4** |
| | **Phase 1 Lime Verti-mill** | **5.0E-04** | **0.0%** | **0.0%** | **100.0%** | **4** |
| | **Phase 2 Lime Verti-mill** | **5.0E-04** | **0.0%** | **0.0%** | **100.0%** | **4** |
| Newmont Midas Operations | **Retort 1** | **4.7E-05** | **99.1%** | **0.8%** | **0.0%** | **1** |
| | **Retort 2** | **3.1E-04** | **99.1%** | **0.8%** | **0.0%** | **1** |
| | **Smelting Furnace** | **8.2E-03** | **35%** | **61.20%** | **3.80%** | **1** |
| Barrick Goldstrike Mines, Inc | **Autoclave/Refinery** | **0.005** | **78.0%** | **8.3%** | **13.8%** | **1,2** |
| | | **0.014** | **78.0%** | **8.3%** | **13.8%** | **1,2** |
| | | **0.007** | **78.0%** | **8.3%** | **13.8%** | **1,2** |
| | | **0.015** | **78.0%** | **8.3%** | **13.8%** | **1,2** |
| | **Roaster** | **0.117** | **90.1%** | **9.5%** | **0.4%** | **1,2** |
| | **Carbon Regeneration Kiln** | **0.124** | **98.3%** | **1.6%** | **0.2%** | **1,2** |
| | **Retort 1-3** | **0.002** | **98.8%** | **0.2%** | **1.0%** | **1,2** |
| | **West Smelting Furnace, East Smelting Furnace, Electrowinning** | **0.015** | **99.1%** | **0.8%** | **0.0%** | **1,2** |
| | **Retort Room** | **0.0036792** | **53.6%** | **31.0%** | **15.5%** | **2** |
| | **Assay & Met Laboratory** | **0.008** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **AA Machine** | **0.000** | **35.0%** | **61.2%** | **3.8%** | **1** |
| Coeur Rochester, Inc | **Smelting Furnace** | **0.001** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Assay Lab** | **4.0E-06** | **35.0%** | **61.2%** | **3.8%** | **1** |
| Florida Canyon Mine | **Retort** | **0.001** | **99.1%** | **0.8%** | **0.0%** | **1** |
| | **Smelting Furnace** | **0.025** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Assay Lab** | **4.3E-06** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Electrowinning** | **0.013** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Carbon Kiln** | **0.181** | **35.0%** | **61.2%** | **3.8%** | **1** |
| Glamis Marigold Mine | **Electrowinning** | **0.004** | **35.0%** | **61.2%** | **3.8%** | **1** |

| Facility Name | Process | Speciation | | | | |
|---|---|---|---|---|---|---|
| | | Total Emissions of Hg (tpy) | HG0 | HG2 | HGP | Notes |
| | **Retort** | **3.8E-04** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Carbon Regeneration Kiln** | **0.447** | **88.2%** | **11.0%** | **1.0%** | **1** |
| | **Electro-Winning Circuit (3 Cells)** | **0.0000011** | **97.7%** | **2.1%** | **0.3%** | |
| | **Smelting Furnace** | **0.001** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Pregnant Tank** | **0.001** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Barren Tank** | **0.001** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Assay Lab (2 Drying Ovens)** | **1.1E-06** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Assay Lab (Atomic Adsorption Analytical Instrument)** | **2.5E-07** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Assay Lab (2 Assay Furnaces)** | **7.5E-07** | **35.0%** | **61.2%** | **3.8%** | **1** |
| **Total Annual ems (calculated)** | | | | | | |
| **Total Annual ems (documented)** | | | | | | |
| Queenstake Resources USA Inc.— Jerritt Canyon Mine (QRJC) | **West Roaster** | **6.2E-01** | **16.8%** | **78.9%** | **2.5%** | |
| | **East Roaster** | **2.3E-01** | **1.8%** | **95.7%** | **0.9%** | |
| | **Carbon Regeneration Kiln** | **0.001** | **37.3%** | **62.5%** | **0.2%** | **1,3** |
| | **Ore Dryer** | **0.007** | **99.5%** | **0.3%** | **0.2%** | **1** |
| | **Refining Process** | **0.001** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Large Ore Drying Ovens (5 units)** | **0.016** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Laboratory Small Ore Dryer** | **3.4E-04** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Laboratory Hot Plates (2 units)** | **1.4E-06** | **35.0%** | **61.2%** | **3.8%** | **1** |
| Round Mountain Gold Corporation | **Carbon Regeneration Kiln** | **0.016** | **98.3%** | **1.5%** | **0.2%** | **1** |
| | **Electric Induction Furnace** | **0.005** | **88.0%** | **11.0%** | **1.0%** | **1** |
| | **Other Thermal Processes** | **8.5E-06** | **35.0%** | **61.2%** | **3.8%** | **4** |
| | **Refinery Electrowining Vent** | **0.007** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Assay Lab** | **7.0E-06** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **High Grade Area** | **1.7E-06** | **35.0%** | **61.2%** | **3.8%** | **1** |
| Cortez Gold Mines Mill #2 (aka Pipeline Mill) | **Carbon Regeneration Kiln (2)** | **0.046** | **88.2%** | **11.0%** | **0.7%** | **1,2** |
| | **Smelting Furnaces (2)** | **0.028** | **35.0%** | **61.2%** | **3.8%** | **1,2** |
| | **EW System #1** | **0.003** | **98.2%** | **0.5%** | **1.3%** | **1,2** |
| | **EW System #2** | **0.001** | **92.9%** | **1.9%** | **5.2%** | **1,2** |
| | **Assay Laboratory Furnace Baghouse** | **0.002** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Gold Sluge Drying Oven** | **0.002** | **35.0%** | **61.2%** | **3.8%** | **1** |

| Facility Name | Process | Speciation | | | | |
|---|---|---|---|---|---|---|
| | | Total Emissions of Hg (tpy) | HG0 | HG2 | HGP | Notes |
| | **Assay Laboratory, Atomic Absorption Spectrometers** | **6.5E-07** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Assay Laboratory, Drying Ovens** | **0.002** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Assay Laboratory, Furnaces** | **6.5E-06** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Assay Laboratory, Hotplates** | **8.0E-07** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Strip Circuit Area, AA Machine** | **5.0E-08** | **35.0%** | **61.2%** | **3.8%** | **1** |
| Homestake Mining Corporation—Ruby Hill Mine | **Smelting Furnace** | **0.000** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Electric Carbon Kiln** | **0.005** | **88.20%** | **11%** | **0.70%** | **1** |
| | **Electric Mercury Retort** | **0.00000025** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Electrowinning Cells** | **0.010** | **35.0%** | **61.2%** | **3.8%** | **1** |
| Bald Mountain Mine (including Mooney Basin Operation) | **Carbon Regeneration Kiln** | **0.048** | **98.3%** | **1.5%** | **0.2%** | **1** |
| | **Retort** | **1.4E-04** | **99.1%** | **0.8%** | **0.0%** | **1** |
| | **Smelting Furnace** | **0.054** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Fire Assay Lab** | **9.3E-06** | **35.0%** | **61.2%** | **3.8%** | **1** |
| **Total Annual ems (calculated)** | | **0.102** | | | | |
| **Total Annual ems (documented)** | | | | | | |
| Denton - Rawhide Mine | **Retort** | **0.001** | **99.1%** | **0.8%** | **0.0%** | **1** |
| | **Electrowinning Circuit** | **0.048** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Refinery Furnace Baghouse** | **0.127** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Fire Assay Lab Furnace Baghouse** | **2.5E-07** | **35.0%** | **61.2%** | **3.8%** | **1** |
| Placer Turquoise Ridge, Inc. | **Lab Fire Assay/Furnaces** | **1.8E-04** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Drying Room** | **0.004** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Drying Ovens** | **0.001** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Annealing Furnaces** | **4.5E-07** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Hotplates** | **4.7E-06** | **35.0%** | **61.2%** | **3.8%** | **1** |
| Battle Mountain Gold Company—Reona and Phoenix Projects | **Electric Carbon Kiln** | **0.001** | **88.20%** | **11%** | **0.70%** | **1** |
| | **Electrowining Cells** | **1.5E-05** | **35.0%** | **61.2%** | **3.8%** | **1** |
| | **Pregnant & Barren Solution Vent** | **8.5E-07** | **35.0%** | **61.2%** | **3.8%** | **1** |

Notes:

(1) Emissions from "2006 Cumulative Mercury Emissions Data Submittal Public.xls", supplied by NDEP (NDEP, 2007), which represents calendar year 2006 emissions. Only some of the emissions in this document were based on stack testing. The rest are engineering estimates. The Nevada Control Program required all sources to do emissions testing in 2007.
(2) Speciation from NDEP 2006 Tier-1 Test Data in document "VMRP testing Overview6.pdf" supplied by NDEP (NDEP, 2007)
(3) Speciation from Ontario Hydro test results as reported in Western Environmental Services and Testing, Inc. 2006.
(4) Emissions from NDEP. 2006. Precious Metal Mining - Mercury Air Emissions Questionnaire, Nevada Division of Environmental Protection. March 2006

### Table C-11. Summary of Emissions Revisions Made to IPM Sources in State of Nevada

| Facility Name | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|
| *Original Emissions* | | | | |
| Mohave | 0.029 | 0.078 | 0.007 | 0.115 |
| *Revised Emissions* | | | | |
| Mohave | 0.032 | 0.008 | 0.000 | 0.041 |
| **Total Emissions Changes for IPM** | | | | |
| **Emissions Changes** | **0.003** | **-0.070** | **-0.007** | **-0.074** |

## Utah

### Table C-12. Summary of Emissions Revisions Made to Non-IPM Sources in State of Utah

| Facility Name | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|
| *Original Emissions* | | | | |
| Nucor Steel | 1.25E-06 | 7.5E-07 | 5E-07 | 2.5E-06 |
| Wasatch Energy Systems | 0.022 | 0.058 | 0.020 | 0.100 |
| Holcim (US) Inc. | 0.005 | 0.003 | 0.002 | 0.009 |
| Tesoro West Coast | 0.003 | 0.001 | 0.000 | 0.004 |
| Kennecott Utah Copper Corporation - Smelter, refinery | 0.004 | 0.001 | 0.001 | 0.005 |
| Kennecott Utah Copper Corporation | 0.028 | 0.005 | 0.005 | 0.038 |
| Staker & Parson Companies | 8.0E-08 | 5.0E-08 | 3.0E-08 | 1.6E-07 |
| Utelite Corporation | 2.1E-07 | 1.3E-07 | 8.0E-08 | 4.2E-07 |
| Clean Harbors Aragonite LLC | 0.272 | 0.094 | 0.103 | 0.469 |
| Laidlaw Environmental Services - Inc. | 0.048 | 0.016 | 0.018 | 0.082 |
| Us Gypsum Sigurd Plant | 0.002 | 0.001 | 0.001 | 0.005 |
| Pacif Corp Gadsby | 0.004 | 0.003 | 0.002 | 0.009 |
| Alliant Tech Systems Inc. Bacchus Works | 0.001 | 0.001 | 4.5E-04 | 0.002 |
| Alliant Tech Systems Plant 2 | 0.001 | 0.001 | 3.5E-04 | 0.002 |
| Hill Air Force Main Base | 0.003 | 0.002 | 0.001 | 0.006 |
| Total | 0.394 | 0.184 | 0.153 | 0.731 |
| *Revised Emissions* | | | | |
| Nucor Steel | 0.059 | 0.007 | 0.007 | 0.074 |
| Wasatch Energy Systems | 0.008 | 0.021 | 0.007 | 0.037 |
| Ash Grove Cement Company | 0.044 | 0.015 | 0.017 | 0.076 |
| Graymont Western US Incorporated | 0.004 | 0.001 | 0.001 | 0.005 |
| Holcim (US) Inc. | 0.005 | 0.002 | 0.002 | 0.009 |
| Tesoro West Coast | 0.007 | 0.001 | 0.001 | 0.008 |
| Kennecott Utah Copper Corporation - Smelter, refinery | 0.004 | 4.7E-04 | 4.7E-04 | 0.005 |
| Kennecott Utah Copper Corporation | 0.010 | 0.016 | 0.001 | 0.027 |
| Staker & Parson Companies | 0.001 | 9.1E-05 | 9.1E-05 | 0.001 |
| Utelite Corporation | 0.002 | 0.001 | 0.001 | 0.005 |
| Clean Harbors Aragonite LLC | 0.016 | 0.005 | 0.006 | 0.027 |
| Deseret Chemical Depot | 0.004 | 0.003 | 0.002 | 0.008 |
| Laidlaw Environmental Services - Inc. | 0 | 0 | 0 | 0 |
| Us Gypsum Sigurd Plant | 0 | 0 | 0 | 0 |

| Facility Name | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|
| Pacif Corp Gadsby | 0 | 0 | 0 | 0 |
| Alliant Tech Systems Inc. Bacchus Works | 0 | 0 | 0 | 0 |
| Alliant Tech Systems Plant 2 | 0 | 0 | 0 | 0 |
| Hill Air Force Main Base | 0 | 0 | 0 | 0 |
| Total | 0.165 | 0.073 | 0.045 | 0.283 |
| **Total Emissions Changes for Non-IPM** | | | | |
| **Emissions Changes** | -0.229 | -0.112 | -0.108 | -0.448 |

## Table C-13. Summary of Emissions Revisions Made to IPM Sources in State of Utah

| Facility Name | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|
| *Original Emissions* | | | | |
| Pacificorp - Carbon Power Plant | 0.005 | 0.014 | 0.001 | 0.020 |
| Sunnyside Cogeneration Associates | 0.000 | 0.000 | 0.000 | 0.000 |
| Pacificorp - Hunter Power Plant | 0.037 | 0.004 | 0.000 | 0.041 |
| Pacificorp - Huntington Power Plant | 0.031 | 0.040 | 0.003 | 0.074 |
| Intermountain Power Services Corp | 0.003 | 0.001 | 0.000 | 0.005 |
| Total | 0.076 | 0.059 | 0.005 | 0.140 |
| *Revised Emissions* | | | | |
| Pacificorp - Carbon Power Plant | 0.007 | 0.019 | 0.002 | 0.028 |
| Sunnyside Cogeneration Associates | 0.000 | 0.000 | 0.000 | 0.001 |
| Pacificorp - Hunter Power Plant | 0.172 | 0.017 | 0.002 | 0.191 |
| Pacificorp - Huntington Power Plant | 0.050 | 0.065 | 0.006 | 0.121 |
| Intermountain Power Services Corp | 0.069 | 0.037 | 0.007 | 0.113 |
| Total | 0.298 | 0.139 | 0.016 | 0.453 |
| **Total Emissions Changes for IPM** | | | | |
| **Emissions Changes** | 0.222 | 0.080 | 0.011 | 0.313 |

## Table C-14. Summary of Emissions Revisions Made to MWI Sources in State of Utah

| Facility Name | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total (tpy) |
|---|---|---|---|---|
| *Original Emissions* | | | | |
| Stericycle Incorporated | 3.1E-04 | 0.005 | 1.2E-03 | 0.006 |
| *Revised Emissions* | | | | |
| Stericycle Incorporated | 3.4E-04 | 0.005 | 1.4E-03 | 0.007 |
| **Total Emissions Changes for MWI** | | | | |
| **Emissions Changes** | 3.4E-05 | 0.001 | 1.4E-04 | 0.001 |

## Breakdown of Collective Sources

In the following tables, collective sources are broken down for those states where the maximum in-state contribution was due to collective sources. In each case, only those point sources that were within a two grid cell range of the location of the maximum impact shown in Section 7 are included. Area sources included in the collective sources tag are presented in a separate table for counties in the immediate vicinity of the maximum impact. States are presented in alphabetical order.
For California, which included more than 600 smaller point sources in the collective sources category in the vicinity of the maximum, the top 34 point sources are tabulated. These 34 sources account for more than 90% of the collective source emissions in the vicinity of the maximum.

## Table C-15a. Point Sources Included in the Collective Sources Tag for California.

Only the top 34 point sources in the vicinity of the maximum in-state contribution to mercury deposition are included. These sources account for more than 90% of the collective sources point source emissions in the vicinity of the maximum.

| FIPS | County | Facility Name | Plant ID | Point ID | Stack ID | Latitude | Longitude | StkHt (m) | Diam (m) | Temp (K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 06037 | Los Angeles | OLDQUAKERPAINTCOMPANY | 19102621976 | 1 | 3560 | 33.8358 | -118.2630 | 3.0 | 0.00 | 295 | 0.0 | 5.67E-02 | 7.09E-03 | 7.09E-03 | 7.09E-02 |
| 06059 | Orange | COSMOTRONICCOCORP | 30102612583 | 70102 | 4577 | 33.6936 | -117.8307 | 3.0 | 0.00 | 295 | 0.0 | 1.80E-02 | 1.08E-02 | 7.19E-03 | 3.60E-02 |
| 06037 | Los Angeles | QUEMETCOINC | 1910268547 | 70001 | 3722 | 34.0199 | -117.9855 | 3.0 | 0.00 | 295 | 0.0 | 1.80E-02 | 2.25E-03 | 2.25E-03 | 2.25E-02 |
| 06037 | Los Angeles | SHELLOILCO(EISUSEONLY) | 191026800116 | 70120 | 3639 | 33.8092 | -118.2423 | 3.0 | 0.00 | 295 | 0.0 | 8.66E-03 | 5.20E-03 | 3.46E-03 | 1.73E-02 |
| 06037 | Los Angeles | SHELLOILCO(EISUSEONLY) | 191026800116 | 70122 | 3640 | 33.8092 | -118.2423 | 3.0 | 0.00 | 295 | 0.0 | 8.57E-03 | 5.14E-03 | 3.43E-03 | 1.71E-02 |
| 06037 | Los Angeles | DAICOINDINC | 19102644023 | 70002 | 3583 | 33.8535 | -118.2322 | 3.0 | 0.00 | 295 | 0.0 | 0.00E+00 | 1.68E-02 | 0.00E+00 | 1.68E-02 |
| 06037 | Los Angeles | CommerceRefuse-to-EnergyFac. | LMWC-2 | LMWC-1 | 4253 | 33.9966 | -118.1509 | 34.7 | 1.98 | 422 | 12.3 | 3.52E-03 | 9.28E-03 | 3.20E-03 | 1.60E-02 |
| 06037 | Los Angeles | UltramarDiamondShamrock | ESD032 | CCU_1 | 3918 | 33.7836 | -118.2315 | 42.3 | 2.16 | 505 | 16.2 | 8.40E-03 | 1.05E-03 | 1.05E-03 | 1.05E-02 |
| 06037 | Los Angeles | QUEMETCOINC | 1910268547 | 70001 | 3723 | 34.0199 | -117.9855 | 3.0 | 0.00 | 295 | 0.0 | 7.60E-03 | 9.50E-04 | 9.50E-04 | 9.50E-03 |
| 06037 | Los Angeles | CHAPELOFTHEPINES | 19102621472 | 70001 | 3559 | 34.0440 | -118.2999 | 3.0 | 0.00 | 295 | 0.0 | 3.73E-04 | 5.59E-03 | 1.49E-03 | 7.45E-03 |
| 06037 | Los Angeles | SULLYMILLERCONTRACTINGCO | 19102634055 | 70001 | 3577 | 34.0999 | -117.9322 | 3.0 | 0.00 | 295 | 0.0 | 4.37E-03 | 5.46E-04 | 5.46E-04 | 5.46E-03 |
| 06037 | Los Angeles | LIFEPAINTCO | 19102618990 | 70001 | 3555 | 33.9209 | -118.0601 | 3.0 | 0.00 | 295 | 0.0 | 4.28E-03 | 5.36E-04 | 5.36E-04 | 5.36E-03 |
| 06037 | Los Angeles | CONSOLIDATEDDRUMRECONDITIONI | 19102615490 | 70001 | 3547 | 33.9799 | -118.1258 | 3.0 | 0.00 | 295 | 0.0 | 2.37E-03 | 1.42E-03 | 9.46E-04 | 4.73E-03 |
| 06059 | Orange | BORALRESOURCESINC-IRVINEPL | 30102650079 | 70001 | 4613 | 33.6936 | -117.8307 | 3.0 | 0.00 | 295 | 0.0 | 3.60E-03 | 4.50E-04 | 4.50E-04 | 4.50E-03 |
| 06059 | Orange | LOMAVISTAMEMPARK | 3010266999 | 1 | 4616 | 33.8985 | -117.9300 | 3.0 | 0.00 | 295 | 0.0 | 1.91E-03 | 1.15E-03 | 7.65E-04 | 3.82E-03 |
| 06037 | Los Angeles | EVERGREENMEMORIALCAREINC-EV | 191026100800 | 1 | 3537 | 34.0411 | -118.2009 | 3.0 | 0.00 | 295 | 0.0 | 1.81E-03 | 1.09E-03 | 7.26E-04 | 3.63E-03 |
| 06059 | Orange | UNIONOILCO-SCIENCE&TECHD | 30102613979 | 70018 | 4585 | 33.9090 | -117.8544 | 3.0 | 0.00 | 295 | 0.0 | 1.75E-03 | 1.05E-03 | 7.00E-04 | 3.50E-03 |
| 06059 | Orange | SENTINELCREMATIONSOCIETIESI | 30102610472 | 70001 | 4574 | 33.7924 | -117.8965 | 3.0 | 0.00 | 295 | 0.0 | 1.74E-04 | 2.61E-03 | 6.95E-04 | 3.47E-03 |
| 06059 | Orange | SENTINELCREMATIONSOCIETIESI | 30102610472 | 70003 | 4575 | 33.7924 | -117.8965 | 3.0 | 0.00 | 295 | 0.0 | 1.74E-04 | 2.61E-03 | 6.95E-04 | 3.47E-03 |
| 06037 | Los Angeles | BLUEDIAMONDMATERIALS-SUNVA | 19102619390 | 70002 | 3557 | 34.0999 | -117.9322 | 3.0 | 0.00 | 295 | 0.0 | 2.35E-03 | 2.94E-04 | 2.94E-04 | 2.94E-03 |
| 06037 | Los Angeles | Equilon(formerlyTexacoRefining&Marketing | ESD019 | CCU_1 | 3814 | 33.7948 | -118.2291 | 42.3 | 2.16 | 505 | 16.2 | 1.95E-03 | 2.43E-04 | 2.43E-04 | 2.43E-03 |
| 06037 | Los Angeles | INDUSTRIALASPHALT | 19102621395 | 70002 | 3558 | 34.1303 | -117.9326 | 3.0 | 0.00 | 295 | 0.0 | 1.60E-03 | 2.00E-04 | 2.00E-04 | 2.00E-03 |
| 06037 | Los Angeles | BP(formerlyAtlanticRichfieldCo.(ARCO)) | ESD014 | CCU_1 | 3737 | 33.8163 | -118.2449 | 42.3 | 2.16 | 505 | 16.2 | 1.39E-03 | 1.74E-04 | 1.74E-04 | 1.74E-03 |
| 06037 | Los Angeles | AshlandChemicalCompany | 704 | 1 | 3732 | 33.9875 | -118.1389 | 26.9 | 1.16 | 457 | 9.3 | 9.30E-04 | 3.21E-04 | 3.53E-04 | 1.60E-03 |
| 06059 | Orange | UNIONOILCO-SCIENCE&TECHD | 30102613979 | 70019 | 4586 | 33.9090 | -117.8544 | 3.0 | 0.00 | 295 | 0.0 | 7.50E-04 | 4.50E-04 | 3.00E-04 | 1.50E-03 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 06037 | Los Angeles | BLUEDIAMONDMATERIALS-GARDEN | 1910266578 | 70001 | 3621 | 34.0999 | -117.9322 | 3.0 | 0.00 | 295 | 0.0 | 1.20E-03 | 1.50E-04 | 1.50E-04 | 1.50E-03 |
| 06037 | Los Angeles | BLUEDIAMONDMATERIALS-SUNVA | 19102619390 | 70001 | 3556 | 34.0999 | -117.9322 | 3.0 | 0.00 | 295 | 0.0 | 1.17E-03 | 1.47E-04 | 1.47E-04 | 1.47E-03 |
| 06037 | Los Angeles | L.A.COUNTYDEPT.OFPUBLICWO | 060370354 | A185 | 3523 | 34.0851 | -118.1510 | 12.3 | 1.04 | 595 | 25.6 | 6.70E-04 | 4.02E-04 | 2.68E-04 | 1.34E-03 |
| 06037 | Los Angeles | ARCOCQCKILN | 19102647232 | 70001 | 3595 | 33.7699 | -118.2202 | 3.0 | 0.00 | 295 | 0.0 | 9.60E-04 | 1.20E-04 | 1.20E-04 | 1.20E-03 |
| 06037 | Los Angeles | LACODEPTHEALTHSRV-UCLAHAR | 191026457 | 70010 | 3594 | 33.8312 | -118.2967 | 3.0 | 0.00 | 295 | 0.0 | 0.00E+00 | 1.11E-03 | 0.00E+00 | 1.11E-03 |
| 06037 | Los Angeles | LIVEOAKMEMORIALPARK | 19102622839 | 70001 | 3566 | 34.1316 | -117.9976 | 3.0 | 0.00 | 295 | 0.0 | 4.25E-05 | 6.38E-04 | 1.70E-04 | 8.50E-04 |
| 06037 | Los Angeles | LIVEOAKMEMORIALPARK | 19102622839 | 70002 | 3567 | 34.1316 | -117.9976 | 3.0 | 0.00 | 295 | 0.0 | 4.25E-05 | 6.38E-04 | 1.70E-04 | 8.50E-04 |
| 06037 | Los Angeles | LIVEOAKMEMORIALPARK | 19102622839 | 70003 | 3568 | 34.1316 | -117.9976 | 3.0 | 0.00 | 295 | 0.0 | 4.25E-05 | 6.38E-04 | 1.70E-04 | 8.50E-04 |
| 06037 | Los Angeles | UNIVERSITYSOCALIFORNIA-HEALT | 19102656 | 72011 | 3611 | 34.0599 | -118.2027 | 3.0 | 0.00 | 295 | 0.0 | 3.46E-04 | 2.08E-04 | 1.39E-04 | 6.93E-04 |

## Table C-15b. Non-point Sources Included in the Collective Sources Tag for California.

Counties in the vicinity of the maximum in-state contribution to mercury deposition with significant non-point emissions are included.

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 06037 | LOS ANGELES | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 3.25E-02 | 0.00E+00 | 0.00E+00 | 3.25E-02 |
| 06037 | LOS ANGELES | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Dental Alloy (Mercury Amalgams) Production | 1.54E-02 | 0.00E+00 | 0.00E+00 | 1.54E-02 |
| 06059 | ORANGE | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Dental Alloy (Mercury Amalgams) Production | 1.40E-02 | 0.00E+00 | 0.00E+00 | 1.40E-02 |
| 06059 | ORANGE | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 9.62E-03 | 0.00E+00 | 0.00E+00 | 9.62E-03 |
| 06037 | LOS ANGELES | Miscellaneous Area Sources, Other Combustion, Cremation | 1.28E-03 | 3.38E-03 | 1.17E-03 | 5.83E-03 |
| 06037 | LOS ANGELES | External Combustion Boilers, Industrial, Liquid Waste | 2.09E-03 | 1.25E-03 | 8.35E-04 | 4.17E-03 |
| 06059 | ORANGE | Miscellaneous Area Sources, Other Combustion, Cremation | 3.80E-04 | 1.00E-03 | 3.45E-04 | 1.73E-03 |
| 06059 | ORANGE | External Combustion Boilers, Industrial, Liquid Waste | 7.40E-04 | 4.44E-04 | 2.96E-04 | 1.48E-03 |
| 06037 | LOS ANGELES | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 6.10E-04 | 3.66E-04 | 2.44E-04 | 1.22E-03 |
| 06059 | ORANGE | Stationary Source Fuel Combustion, Industrial, Residual Oil | 5.41E-04 | 3.24E-04 | 2.16E-04 | 1.08E-03 |
| 06059 | ORANGE | External Combustion Boilers, Industrial, Distillate Oil | 3.52E-04 | 2.11E-04 | 1.41E-04 | 7.04E-04 |
| 06059 | ORANGE | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 2.12E-04 | 1.27E-04 | 8.49E-05 | 4.24E-04 |
| 06037 | LOS ANGELES | Miscellaneous Area Sources, Other Combustion, Motor Vehicle Fires | 9.07E-05 | 2.39E-04 | 8.24E-05 | 4.12E-04 |
| 06059 | ORANGE | Miscellaneous Area Sources, Other Combustion, Motor Vehicle Fires | 1.85E-05 | 4.87E-05 | 1.68E-05 | 8.40E-05 |
| 06037 | LOS ANGELES | Industrial Processes, Chemical Manufacturing, Other Not Classified | 1.84E-05 | 2.30E-06 | 2.30E-06 | 2.30E-05 |
| 06059 | ORANGE | Industrial Processes, Chemical Manufacturing, Other Not Classified | 4.18E-06 | 5.20E-07 | 5.20E-07 | 5.22E-06 |
| 06037 | LOS ANGELES | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 3.08E-06 | 0.00E+00 | 0.00E+00 | 3.08E-06 |
| 06059 | ORANGE | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 9.10E-07 | 0.00E+00 | 0.00E+00 | 9.10E-07 |

## Table C-16a. Point Sources Included in the Collective Sources Tag for District of Columbia.

Only sources in the vicinity of the maximum in-state contribution to mercury deposition are included.

| FIPS | County | Facility Name | Plant ID | Point ID | Stack ID | Latitude | Longitude | StkHt (m) | Diam (m) | Temp (K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11001 | Dist. Columbia | PWCWashington | 11001F001 | A812 | 9339 | 38.8834 | -77.0147 | 8.7 | 0.46 | 493 | 19.2 | 5.70E-06 | 3.42E-06 | 2.28E-06 | 1.14E-05 |
| 11001 | Dist. Columbia | BollingAFB | 11001F002 | A809 | 9340 | 38.8834 | -77.0147 | 12.3 | 1.04 | 595 | 25.6 | 1.73E-05 | 1.04E-05 | 6.93E-06 | 3.46E-05 |
| 11001 | Dist. Columbia | WALTERREEDARMYMEDICALCENTER | 11001F003 | A813 | 9341 | 38.8834 | -77.0147 | 13.0 | 0.82 | 404 | 8.8 | 1.11E-05 | 6.64E-06 | 4.43E-06 | 2.21E-05 |
| 11001 | Dist. Columbia | FORTLESLEYJ.MCNAIR | 11001F004 | A810 | 9342 | 38.8834 | -77.0147 | 13.0 | 0.82 | 404 | 8.8 | 3.44E-06 | 2.06E-06 | 1.38E-06 | 6.88E-06 |
| 11001 | Dist. Columbia | NavalResearchLaboratory | 110010033 | A811 | 9338 | 38.8194 | -77.0214 | 8.7 | 0.46 | 493 | 19.2 | 2.74E-05 | 1.64E-05 | 1.10E-05 | 5.48E-05 |

## Table C-16b. Non-point Sources Included in the Collective Sources Tag for District of Columbia.

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 11001 | DIST. COLUMBIA | Stationary Source Fuel Combustion, Residential, Distillate Oil | 9.17E-04 | 5.50E-04 | 3.67E-04 | 1.83E-03 |
| 11001 | DIST. COLUMBIA | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 1.71E-03 | 0.00E+00 | 0.00E+00 | 1.71E-03 |
| 11001 | DIST. COLUMBIA | Miscellaneous Area Sources, Other Combustion, Cremation | 4.79E-05 | 1.26E-04 | 4.36E-05 | 2.18E-04 |
| 11001 | DIST. COLUMBIA | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Dental Alloy (Mercury Amalgams) Production | 2.05E-04 | 0.00E+00 | 0.00E+00 | 2.05E-04 |
| 11001 | DIST. COLUMBIA | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 6.32E-05 | 3.79E-05 | 2.53E-05 | 1.26E-04 |
| 11001 | DIST. COLUMBIA | External Combustion Boilers, Industrial, Liquid Waste | 5.33E-05 | 3.20E-05 | 2.13E-05 | 1.07E-04 |
| 11001 | DIST. COLUMBIA | Stationary Source Fuel Combustion, Industrial, Residual Oil | 3.90E-05 | 2.34E-05 | 1.56E-05 | 7.79E-05 |
| 11001 | DIST. COLUMBIA | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 3.89E-05 | 2.33E-05 | 1.56E-05 | 7.77E-05 |
| 11001 | DIST. COLUMBIA | External Combustion Boilers, Industrial, Distillate Oil | 2.54E-05 | 1.52E-05 | 1.01E-05 | 5.07E-05 |
| 11001 | DIST. COLUMBIA | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 8.85E-06 | 5.31E-06 | 3.54E-06 | 1.77E-05 |
| 11001 | DIST. COLUMBIA | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 1.70E-07 | 0.00E+00 | 0.00E+00 | 1.70E-07 |
| 11001 | DIST. COLUMBIA | Industrial Processes, Chemical Manufacturing, Other Not Classified | 2.00E-08 | 0.00E+00 | 0.00E+00 | 2.00E-08 |

## Table C-17a. Point Sources Included in the Collective Sources Tag for Illinois.

Only sources in the vicinity of the maximum in-state contribution to mercury deposition are included.

| FIPS | County | Facility Name | Plant ID | Point ID | Stack ID | Latitude | Longitude | StkHt (m) | Diam (m) | Temp (K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17001 | Adams | Blessing Hospital | 001065ADQ | 0001 | 10671 | 39.9492 | -91.4071 | 9.1 | 1.22 | 308 | 0.5 | 0.0481 | 0.0289 | 0.0192 | 0.0962 |
| 17001 | Adams | Diamond Construction Co. | 001820AAB | 0001 | 10713 | 39.9583 | -91.3747 | 9.8 | 0.10 | 294 | 0.1 | 0.0022 | 0.0003 | 0.0003 | 0.0027 |
| 17001 | Adams | Quincy soy bean co. | 15169 | 60541 | 10715 | 39.9056 | -91.4100 | 43.1 | 2.01 | 461 | 10.3 | 0.0003 | 0.0002 | 0.0001 | 0.0005 |
| 17001 | Adams | Quincy soy bean co. | 15169 | 60542 | 10716 | 39.9056 | -91.4100 | 43.1 | 2.01 | 461 | 10.3 | 0.0003 | 0.0002 | 0.0001 | 0.0005 |
| 17169 | Schuyler | Freesen incorporated | 169802AAA | 0001 | 17522 | 40.2251 | -90.8605 | 9.1 | 3.05 | 339 | 2.1 | 0.0005 | 0.0001 | 0.0001 | 0.0006 |
| 17001 | Adams | Blessing hospital | 001065AAJ | 0004 | 10668 | 39.9364 | -91.3990 | 9.1 | 0.40 | 432 | 10.3 | 0.0001 | 0.0001 | 0.0001 | 0.0003 |
| 17001 | Adams | Quincy humane society | 001815ABK | 0001 | 10712 | 39.8903 | -91.3964 | 10.1 | 0.10 | 294 | 0.1 | 6.01E-05 | 3.61E-05 | 2.41E-05 | 1.20E-04 |
| 17001 | Adams | Titan wheel international Inc. | 001806AAB | 0010 | 10679 | 39.9492 | -91.3692 | 63.1 | 1.22 | 585 | 8.1 | 4.52E-05 | 2.71E-05 | 1.81E-05 | 9.04E-05 |
| 17001 | Adams | Quincy Wilbert vault company | 001806AAR | 0001 | 10693 | 39.9564 | -91.3491 | 6.1 | 0.52 | 866 | 5.7 | 1.91E-05 | 1.15E-05 | 7.63E-06 | 3.82E-05 |
| 17001 | Adams | ADM quincy | 001815AAF | 0045 | 10699 | 39.9056 | -91.4100 | 12.2 | 1.52 | 561 | 2.4 | 1.75E-05 | 1.05E-05 | 6.99E-06 | 3.50E-05 |
| 17001 | Adams | Blessinghospital | 001065AAJ | 0003 | 10667 | 39.9364 | -91.3990 | 10.7 | 0.10 | 294 | 0.1 | 1.23E-05 | 7.38E-06 | 4.92E-06 | 2.46E-05 |
| 17001 | Adams | Blessing hospital | 001065ADQ | 0002 | 10673 | 39.9492 | -91.4071 | 33.5 | 2.29 | 366 | 1.1 | 1.23E-05 | 7.38E-06 | 4.92E-06 | 2.46E-05 |
| 17001 | Adams | Adm quincy | 001815AAF | 0046 | 10700 | 39.9056 | -91.4100 | 12.2 | 1.52 | 561 | 2.4 | 1.12E-05 | 6.75E-06 | 4.50E-06 | 2.25E-05 |
| 17001 | Adams | Trinity industries Inc. | 001815AAD | 0005 | 10695 | 39.9019 | -91.4089 | 6.1 | 0.10 | 294 | 0.1 | 8.96E-06 | 5.38E-06 | 3.58E-06 | 1.79E-05 |
| 17001 | Adams | Blessing hospital | 001065AAJ | 0003 | 10666 | 39.9364 | -91.3990 | 10.7 | 0.10 | 294 | 0.1 | 8.35E-06 | 5.01E-06 | 3.34E-06 | 1.67E-05 |
| 17001 | Adams | Blessing hospital | 001065ADQ | 0002 | 10672 | 39.9492 | -91.4071 | 33.5 | 2.29 | 366 | 1.1 | 8.35E-06 | 5.01E-06 | 3.34E-06 | 1.67E-05 |
| 17001 | Adams | Titan wheel international Inc. | 001806AAB | 0013 | 10680 | 39.9492 | -91.3692 | 63.1 | 1.22 | 585 | 8.1 | 8.12E-06 | 4.87E-06 | 3.25E-06 | 1.62E-05 |
| 17001 | Adams | Prairie farms dairy-Quincy milk div. | 001065ACS | 0002 | 10670 | 39.9358 | -91.3869 | 9.4 | 0.10 | 294 | 0.1 | 8.11E-06 | 4.86E-06 | 3.24E-06 | 1.62E-05 |
| 17001 | Adams | J.M.Huber corporation | 001815AAS | 0103 | 10707 | 39.8939 | -91.4103 | 10.1 | 0.10 | 294 | 0.1 | 7.41E-06 | 4.45E-06 | 2.96E-06 | 1.48E-05 |
| 17067 | Hancock | Memorial hospital | 067025AAL | 0001 | 14787 | 40.4078 | -91.1306 | 7.0 | 0.24 | 700 | 9.3 | 7.01E-06 | 4.21E-06 | 2.81E-06 | 1.40E-05 |
| 17001 | Adams | J.M.Huber corporation | 001815AAS | 0116 | 10708 | 39.8939 | -91.4103 | 10.1 | 0.10 | 294 | 0.1 | 6.53E-06 | 3.92E-06 | 2.61E-06 | 1.31E-05 |
| 17001 | Adams | Adm quincy | 001815AAF | 0061 | 10702 | 39.9056 | -91.4100 | 10.1 | 0.10 | 294 | 0.1 | 6.27E-06 | 3.76E-06 | 2.51E-06 | 1.25E-05 |
| 17001 | Adams | Klingele veterinary clinic | 001065AGA | 0001 | 10677 | 39.9352 | -91.3415 | 5.5 | 0.10 | 294 | 0.1 | 5.70E-07 | 8.59E-06 | 2.29E-06 | 1.15E-05 |
| 17001 | Adams | J.M.Huber corporation | 001815AAS | 0091 | 10706 | 39.8939 | -91.4103 | 10.1 | 0.10 | 294 | 0.1 | 5.39E-06 | 3.24E-06 | 2.16E-06 | 1.08E-05 |
| 17001 | Adams | Titan wheel international Inc. | 001806AAB | 0013 | 10681 | 39.9492 | -91.3692 | 63.1 | 1.22 | 585 | 8.1 | 4.91E-06 | 2.95E-06 | 1.97E-06 | 9.83E-06 |
| 17001 | Adams | Adm quincy | 001815AAF | 0063 | 10701 | 39.9056 | -91.4100 | 17.1 | 0.10 | 294 | 0.1 | 4.26E-06 | 2.56E-06 | 1.70E-06 | 8.52E-06 |
| 17001 | Adams | Adm quincy | 001815AAF | 0044 | 10697 | 39.9056 | -91.4100 | 12.2 | 1.46 | 411 | 9.8 | 3.32E-06 | 1.99E-06 | 1.33E-06 | 6.64E-06 |
| 17001 | Adams | Archer daniels midland company | 001806AAM | 0001 | 10692 | 39.9917 | -91.2335 | 10.1 | 0.10 | 294 | 0.1 | 8.02E-06 | 1.00E-06 | 1.00E-06 | 1.00E-05 |
| 17001 | Adams | Adm quincy | 001815AAF | 0044 | 10698 | 39.9056 | -91.4100 | 12.2 | 1.46 | 411 | 9.8 | 2.14E-06 | 1.28E-06 | 8.60E-07 | 4.28E-06 |
| 17001 | Adams | J.M.Huber corporation | 001815AAS | 0106 | 10705 | 39.8939 | -91.4103 | 16.8 | 0.91 | 294 | 8.6 | 1.87E-06 | 1.12E-06 | 7.50E-07 | 3.74E-06 |
| 17067 | Hancock | Memorial hospital | 067025AAL | 0002 | 14788 | 40.4078 | -91.1306 | 9.1 | 0.76 | 433 | 4.1 | 1.79E-06 | 1.07E-06 | 7.20E-07 | 3.58E-06 |
| 17001 | Adams | Quincy municipal #4 Landfill | LF10363 | A302 | 10717 | 39.9786 | -91.2111 | 3.0 | 0.00 | 295 | 0.0 | 4.58E-06 | 5.70E-07 | 5.70E -07 | 5.72E-06 |

| FIPS | County | Facility Name | Plant ID | Point ID | Stack ID | Latitude | Longitude | StkHt (m) | Diam (m) | Temp (K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17001 | Adams | Titan wheel international Inc. | 001806AAB | 0026 | 10682 | 39.9492 | -91.3692 | 13.7 | 0.67 | 383 | 10.1 | 1.12E-06 | 6.70E-07 | 4.50E-07 | 2.24E-06 |
| 17001 | Adams | Gemcity concrete Llc. | 001065AEK | 0003 | 10674 | 39.9364 | -91.4150 | 6.1 | 0.40 | 422 | 11.5 | 9.10E-07 | 5.50E-07 | 3.70E-07 | 1.83E-06 |
| 17001 | Adams | Prairie farms dairy-Quincy milk div. | 001065ACS | 0001 | 10669 | 39.9358 | -91.3869 | 15.8 | 0.10 | 294 | 0.1 | 8.80E-07 | 5.30E-07 | 3.50E-07 | 1.76E-06 |
| 17001 | Adams | Foam productscorp | 001815ABG | 0005 | 10711 | 39.8784 | -91.3983 | 10.1 | 0.10 | 294 | 0.1 | 8.70E-07 | 5.20E-07 | 3.50E-07 | 1.74E-06 |
| 17001 | Adams | Gemcity concrete Llc | 001806AAC | 0004 | 10685 | 39.9572 | -91.3653 | 6.1 | 0.40 | 366 | 3.8 | 7.50E-07 | 4.50E-07 | 3.00E-07 | 1.50E-06 |
| 17001 | Adams | Trinity industries-Inc. | 001815AAD | 0009 | 10696 | 39.9019 | -91.4089 | 7.6 | 0.46 | 478 | 2.9 | 5.90E-07 | 3.50E-07 | 2.40E-07 | 1.18E-06 |
| 17001 | Adams | Amerencips | 001815ABD | 0001 | 10709 | 39.9459 | -91.2913 | 1.5 | 0.10 | 294 | 0.1 | 6.10E-07 | 3.70E-07 | 2.40E-07 | 1.22E-06 |
| 17001 | Adams | Prairie farms dairy inc.-Durst div. | 001065AEN | 0001 | 10675 | 39.9358 | -91.3777 | 3.4 | 0.40 | 475 | 28.7 | 4.60E-07 | 2.80E-07 | 1.90E-07 | 9.30E-07 |
| 17001 | Adams | Gardner Denver machinery Inc. | 001815AAK | 0018 | 10703 | 39.9083 | -91.4111 | 10.1 | 0.10 | 294 | 0.1 | 4.00E-07 | 2.40E-07 | 1.60E-07 | 8.00E-07 |
| 17001 | Adams | Titan wheel international Inc. | 001806AAB | 0027 | 10683 | 39.9492 | -91.3692 | 13.7 | 0.67 | 383 | 10.1 | 3.20E-07 | 1.90E-07 | 1.30E-07 | 6.40E-07 |
| 17001 | Adams | Gardner Denver machinery Inc. | 001815AAK | 0019 | 10704 | 39.9083 | -91.4111 | 10.1 | 0.10 | 294 | 0.1 | 3.30E-07 | 2.00E-07 | 1.30E-07 | 6.60E-07 |
| 17001 | Adams | Huckstore fixture inc. | 001065AFU | 0008 | 10676 | 39.9439 | -91.3703 | 15.1 | 0.82 | 445 | 7.9 | 2.80E-07 | 1.70E-07 | 1.10E-07 | 5.60E-07 |
| 17001 | Adams | Chesterbross construction co. | 001811AAA | 0001 | 10694 | 40.0000 | -91.0000 | 10.1 | 0.10 | 294 | 0.1 | 7.10E-07 | 9.00E-08 | 9.00E-08 | 8.90E-07 |
| 17001 | Adams | Amerencips | 001815ABD | 0002 | 10710 | 39.9459 | -91.2913 | 1.5 | 0.10 | 294 | 0.1 | 1.20E-07 | 7.00E-08 | 5.00E-08 | 2.40E-07 |
| 17001 | Adams | Midwest patterns Inc. | 001820AAG | 0004 | 10714 | 39.9919 | -91.3961 | 2.1 | 0.30 | 811 | 1.2 | 7.00E-08 | 4.00E-08 | 3.00E-08 | 1.40E-07 |
| 17067 | Hancock | Wlmiller company | 067040AAB | 0001 | 14791 | 40.3842 | -91.3575 | 8.8 | 0.85 | 450 | 44.5 | 2.60E-07 | 3.00E-08 | 3.00E-08 | 3.20E-07 |
| 17001 | Adams | Archer daniels midland company | 001806AAF | 0015 | 10689 | 39.9447 | -91.3669 | 15.1 | 0.82 | 445 | 7.9 | 5.00E-08 | 3.00E-08 | 2.00E-08 | 1.00E-07 |
| 17001 | Adams | Archer daniels midland company | 001806AAF | 0019 | 10691 | 39.9447 | -91.3669 | 18.3 | 0.10 | 294 | 0.1 | 1.28E-09 | 7.68E-10 | 5.12E-10 | 2.56E-09 |
| 17001 | Adams | Kuester tool and die inc. | 001065AGH | 0001 | 10678 | 39.9597 | -91.3774 | 6.7 | 0.30 | 978 | 3.7 | 1.17E-09 | 7.02E-10 | 4.68E-10 | 2.34E-09 |
| 17001 | Adams | Archer daniels midland company | 001806AAF | 0014 | 10688 | 39.9447 | -91.3669 | 16.2 | 0.70 | 561 | 91.7 | 3.90E-10 | 2.34E-10 | 1.56E-10 | 7.80E-10 |
| 17001 | Adams | Archer daniels midland company | 001806AAF | 0001 | 10687 | 39.9447 | -91.3669 | 10.4 | 0.76 | 561 | 77.6 | 3.77E-10 | 2.26E-10 | 1.51E-10 | 7.55E-10 |
| 17001 | Adams | Archer daniels midland company | 001806AAF | 0001 | 10686 | 39.9447 | -91.3669 | 10.4 | 0.76 | 561 | 77.6 | 3.25E-10 | 1.95E-10 | 1.30E-10 | 6.50E-10 |
| 17001 | Adams | Titan wheel international Inc. | 001806AAB | 0028 | 10684 | 39.9492 | -91.3692 | 13.7 | 0.67 | 383 | 10.1 | 1.95E-11 | 1.17E-11 | 7.80E-12 | 3.90E-11 |
| 17001 | Adams | Archer daniels midland company | 001806AAF | 0016 | 10690 | 39.9447 | -91.3669 | 15.1 | 0.82 | 445 | 7.9 | 9.75E-12 | 5.85E-12 | 3.90E-12 | 1.95E-11 |

## Table C-17b. Non-point Sources Included in the Collective Sources Tag for Illinois.

The county in the vicinity of the maximum in-state contribution to mercury deposition with significant non-point emissions is included.

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 17001 | ADAMS | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 2.33E-04 | 0.00E+00 | 0.00E+00 | 2.33E-04 |
| 17001 | ADAMS | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 2.21E-04 | 0.00E+00 | 0.00E+00 | 2.21E-04 |
| 17001 | ADAMS | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Dental Alloy (Mercury Amalgams) Production | 2.05E-04 | 0.00E+00 | 0.00E+00 | 2.05E-04 |
| 17001 | ADAMS | External Combustion Boilers, Industrial, Liquid Waste | 1.90E-05 | 1.14E-05 | 7.62E-06 | 3.81E-05 |
| 17001 | ADAMS | Stationary Source Fuel Combustion, Industrial, Residual Oil | 1.39E-05 | 8.35E-06 | 5.57E-06 | 2.78E-05 |
| 17001 | ADAMS | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 1.33E-05 | 7.96E-06 | 5.31E-06 | 2.66E-05 |
| 17001 | ADAMS | Miscellaneous Area Sources, Other Combustion, Cremation | 5.06E-06 | 1.33E-05 | 4.60E-06 | 2.30E-05 |
| 17001 | ADAMS | Stationary Source Fuel Combustion, Residential, Distillate Oil | 9.41E-06 | 5.65E-06 | 3.76E-06 | 1.88E-05 |
| 17001 | ADAMS | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 4.61E-06 | 2.77E-06 | 1.84E-06 | 9.22E-06 |
| 17001 | ADAMS | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 1.86E-06 | 1.12E-06 | 7.40E-07 | 3.72E-06 |
| 17001 | ADAMS | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 1.04E-06 | 6.20E-07 | 4.20E-07 | 2.08E-06 |
| 17001 | ADAMS | Industrial Processes, Chemical Manufacturing, Other Not Classified | 2.00E-08 | 0.00E+00 | 0.00E+00 | 2.00E-08 |
| 17001 | ADAMS | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 2.00E-08 | 0.00E+00 | 0.00E+00 | 2.00E-08 |

## Table C-18a. Point Sources Included in the Collective Sources Tag for Kansas.

Only sources in the vicinity of the maximum in-state contribution to mercury deposition are included.

| FIPS | County | Facility Name | Plant ID | Point ID | Stack ID | Latitude | Longitude | StkHt (m) | Diam (m) | Temp (K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20205 | WILSON | Lafarge | 323 | 1 | 20091 | 37.5094 | -95.8217 | 26.9 | 1.16 | 457 | 9.3 | 3.25E-02 | 1.12E-02 | 1.23E-02 | 5.61E-02 |
| 20205 | WILSON | Lafarge | 322 | 1 | 20090 | 37.5094 | -95.8217 | 26.9 | 1.16 | 457 | 9.3 | 1.06E-02 | 3.65E-03 | 4.01E-03 | 1.82E-02 |
| 20001 | ALLEN | MONARCHCEMENTCOMPANY(THE) | 00009 | 000006 | 19903 | 37.7983 | -95.4244 | 42.7 | 3.35 | 372 | 19.8 | 2.65E-03 | 4.59E-04 | 4.24E-04 | 3.53E-03 |
| 20001 | ALLEN | MONARCHCEMENTCOMPANY(THE) | 00009 | 000007 | 19904 | 37.7983 | -95.4244 | 42.7 | 3.35 | 372 | 19.8 | 2.50E-03 | 4.33E-04 | 4.00E-04 | 3.33E-03 |
| 20001 | ALLEN | MONARCHCEMENTCOMPANY(THE) | 00009 | 000005 | 19902 | 37.7983 | -95.4244 | 43.1 | 2.68 | 434 | 15.7 | 1.00E-03 | 1.74E-04 | 1.60E-04 | 1.34E-03 |
| 20001 | ALLEN | AllenCountyLandfill | LF10150 | A36 | 19908 | 37.9155 | -95.2979 | 3.0 | 0.00 | 295 | 0.0 | 9.51E-06 | 1.19E-06 | 1.19E-06 | 1.19E-05 |
| 20133 | NEOSHO | CityofChanuteLandfill | LF4022 | A874 | 20050 | 37.6677 | -95.4413 | 3.0 | 0.00 | 295 | 0.0 | 1.21E-06 | 1.50E-07 | 1.50E-07 | 1.51E-06 |
| 20205 | WILSON | WilsonCountyLandfill | LF254 | A1510 | 20092 | 37.5592 | -95.7436 | 3.0 | 0.00 | 295 | 0.0 | 9.30E-07 | 1.20E-07 | 1.20E-07 | 1.17E-06 |
| 20133 | NEOSHO | NeoshoCountyLandfill | LF4021 | A2652 | 20049 | 37.5588 | -95.3066 | 3.0 | 0.00 | 295 | 0.0 | 4.90E-07 | 6.00E-08 | 6.00E-08 | 6.10E-07 |
| 20207 | WOODSON | WoodsonCountyTransferStation | LF204 | A1106 | 20093 | 37.8865 | -95.7401 | 3.0 | 0.00 | 295 | 0.0 | 4.20E-07 | 5.00E-08 | 5.00E-08 | 5.20E-07 |
| 20205 | WILSON | ARCHERDANIELSMIDLANDCO. | 202050007 | A1224 | 20089 | 37.5356 | -95.7603 | 8.7 | 0.46 | 493 | 19.2 | 1.70E-07 | 1.00E-07 | 7.00E-08 | 3.40E-07 |
| 20133 | NEOSHO | CITYOFCHANUTEELEC.DEPT.-S.SANTAFE | 201330002 | A1213 | 20046 | 37.6883 | -95.4006 | 12.3 | 1.04 | 595 | 25.6 | 1.00E-08 | 1.00E-08 | 1.00E-08 | 3.00E-08 |

## Table C-18b. Non-point Sources Included in the Collective Sources Tag for Kansas.

Counties in the vicinity of the maximum in-state contribution to mercury deposition with significant non-point emissions are included.

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Hg total |
|---|---|---|---|---|---|---|
| 20133 | NEOSHO | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 5.80E-05 | 0.00E+00 | 0.00E+00 | 5.80E-05 |
| 20133 | NEOSHO | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 5.49E-05 | 0.00E+00 | 0.00E+00 | 5.49E-05 |
| 20001 | ALLEN | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 5.03E-05 | 0.00E+00 | 0.00E+00 | 5.03E-05 |
| 20001 | ALLEN | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 4.76E-05 | 0.00E+00 | 0.00E+00 | 4.76E-05 |
| 20205 | WILSON | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 3.60E-05 | 0.00E+00 | 0.00E+00 | 3.60E-05 |
| 20205 | WILSON | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 3.41E-05 | 0.00E+00 | 0.00E+00 | 3.41E-05 |
| 20133 | NEOSHO | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 1.53E-05 | 9.19E-06 | 6.13E-06 | 3.07E-05 |
| 20001 | ALLEN | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 1.10E-05 | 6.57E-06 | 4.38E-06 | 2.19E-05 |
| 20133 | NEOSHO | External Combustion Boilers, Industrial, Liquid Waste | 6.76E-06 | 4.06E-06 | 2.70E-06 | 1.35E-05 |
| 20001 | ALLEN | External Combustion Boilers, Industrial, Liquid Waste | 6.25E-06 | 3.75E-06 | 2.50E-06 | 1.25E-05 |
| 20205 | WILSON | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 5.20E-06 | 3.12E-06 | 2.08E-06 | 1.04E-05 |
| 20133 | NEOSHO | Stationary Source Fuel Combustion, Industrial, Residual Oil | 4.94E-06 | 2.96E-06 | 1.98E-06 | 9.88E-06 |
| 20001 | ALLEN | Stationary Source Fuel Combustion, Industrial, Residual Oil | 4.57E-06 | 2.74E-06 | 1.83E-06 | 9.14E-06 |
| 20205 | WILSON | External Combustion Boilers, Industrial, Liquid Waste | 4.12E-06 | 2.47E-06 | 1.65E-06 | 8.24E-06 |
| 20133 | NEOSHO | External Combustion Boilers, Industrial, Distillate Oil | 3.22E-06 | 1.93E-06 | 1.29E-06 | 6.44E-06 |
| 20205 | WILSON | Stationary Source Fuel Combustion, Industrial, Residual Oil | 3.01E-06 | 1.81E-06 | 1.20E-06 | 6.02E-06 |
| 20001 | ALLEN | External Combustion Boilers, Industrial, Distillate Oil | 2.97E-06 | 1.78E-06 | 1.19E-06 | 5.94E-06 |
| 20133 | NEOSHO | Miscellaneous Area Sources, Other Combustion, Cremation | 1.18E-06 | 3.12E-06 | 1.08E-06 | 5.38E-06 |
| 20001 | ALLEN | Miscellaneous Area Sources, Other Combustion, Cremation | 1.03E-06 | 2.71E-06 | 9.30E-07 | 4.67E-06 |
| 20205 | WILSON | External Combustion Boilers, Industrial, Distillate Oil | 1.96E-06 | 1.18E-06 | 7.80E-07 | 3.92E-06 |
| 20205 | WILSON | Miscellaneous Area Sources, Other Combustion, Cremation | 7.40E-07 | 1.94E-06 | 6.70E-07 | 3.35E-06 |
| 20133 | NEOSHO | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 1.14E-06 | 6.80E-07 | 4.50E-07 | 2.27E-06 |
| 20133 | NEOSHO | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 8.70E-07 | 5.20E-07 | 3.50E-07 | 1.74E-06 |
| 20001 | ALLEN | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 6.20E-07 | 3.80E-07 | 2.50E-07 | 1.25E-06 |
| 20205 | WILSON | Stationary Source Fuel Combustion, Residential, Distillate Oil | 4.00E-07 | 2.40E-07 | 1.60E-07 | 8.00E-07 |
| 20133 | NEOSHO | Stationary Source Fuel Combustion, Residential, Distillate Oil | 3.40E-07 | 2.00E-07 | 1.30E-07 | 6.70E-07 |
| 20205 | WILSON | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 3.00E-07 | 1.80E-07 | 1.20E-07 | 6.00E-07 |
| 20133 | NEOSHO | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 2.20E-07 | 1.30E-07 | 9.00E-08 | 4.40E-07 |
| 20001 | ALLEN | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 1.50E-07 | 9.00E-08 | 6.00E-08 | 3.00E-07 |
| 20001 | ALLEN | Stationary Source Fuel Combustion, Residential, Distillate Oil | 1.00E-07 | 6.00E-08 | 4.00E-08 | 2.00E-07 |
| 20205 | WILSON | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 8.00E-08 | 5.00E-08 | 3.00E-08 | 1.60E-07 |
| 20205 | WILSON | Industrial Processes, Chemical Manufacturing, Other Not Classified | 7.00E-08 | 1.00E-08 | 1.00E-08 | 9.00E-08 |

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Hg total |
|---|---|---|---|---|---|---|
| 20133 | NEOSHO | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 3.00E-08 | 2.00E-08 | 1.00E-08 | 6.00E-08 |
| 20001 | ALLEN | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 2.00E-08 | 1.00E-08 | 1.00E-08 | 4.00E-08 |
| 20205 | WILSON | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 1.00E-08 | 1.00E-08 | 0.00E+00 | 2.00E-08 |
| 20133 | NEOSHO | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 1.00E-08 | 0.00E+00 | 0.00E+00 | 1.00E-08 |

## Table C-19a. Point Sources Included in the Collective Sources Tag for Kentucky.

Only sources in the vicinity of the maximum in-state contribution to mercury deposition are included.

| FIPS | County | Facility Name | Plant ID | Point ID | Stack ID | Latitude | Longitude | StkHt (m) | Diam (m) | Temp (K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21157 | Marshall | LWD-Inc. | 210 | 1 | 20248 | 37.0475 | -88.3386 | 26.9 | 1.16 | 457 | 9.3 | 3.39E-01 | 1.17E-01 | 1.29E-01 | 5.84E-01 |
| 21157 | Marshall | WESTLAKECA&OCORP. | T$5563 | 1 | 20253 | 37.0553 | -88.3308 | 17.3 | 0.76 | 359 | 7.1 | 2.75E-01 | 1.65E-01 | 1.10E-01 | 5.50E-01 |
| 21157 | Marshall | LWD-Inc. | 211 | 1 | 20249 | 37.0475 | -88.3386 | 26.9 | 1.16 | 457 | 9.3 | 1.37E-01 | 4.71E-02 | 5.18E-02 | 2.35E-01 |
| 21157 | Marshall | WESTLAKEMONOMERS-INC | 15267 | 59625 | 20247 | 37.0481 | -88.3569 | 68.6 | 0.18 | 293 | 0.7 | 6.85E-04 | 4.11E-04 | 2.74E-04 | 1.37E-03 |
| 21157 | Marshall | AIRPRODUCTS&CHEMICALS | 15113 | 60360 | 20245 | 37.0464 | -88.3503 | 43.1 | 2.01 | 461 | 10.3 | 6.85E-04 | 4.11E-04 | 2.74E-04 | 1.37E-03 |
| 21157 | Marshall | AIRPRODUCTS&CHEMICALS | 15113 | 60371 | 20246 | 37.0464 | -88.3503 | 43.1 | 2.01 | 461 | 10.3 | 6.85E-04 | 4.11E-04 | 2.74E-04 | 1.37E-03 |
| 21157 | Marshall | BFGOODRICHCO | 14082 | 58274 | 20244 | 37.0517 | -88.3322 | 43.1 | 2.01 | 461 | 10.3 | 6.85E-04 | 4.11E-04 | 2.74E-04 | 1.37E-03 |
| 21157 | Marshall | ElfAtochemNorthAmerica-Inc. | A27 | 1 | 20251 | 37.0542 | -88.3650 | 26.9 | 1.16 | 457 | 9.3 | 2.48E-04 | 8.54E-05 | 9.40E-05 | 4.27E-04 |
| 21157 | Marshall | LWD-Inc. | 212 | 1 | 20250 | 37.0475 | -88.3386 | 26.9 | 1.16 | 457 | 9.3 | 2.12E-04 | 7.30E-05 | 8.03E-05 | 3.65E-04 |
| 21157 | Marshall | BFGOODRICHCO | 14082 | 58264 | 20243 | 37.0517 | -88.3322 | 43.1 | 2.01 | 461 | 10.3 | 1.19E-04 | 7.13E-05 | 4.75E-05 | 2.38E-04 |
| 21033 | Caldwell | Crider&RogersLandfill | LF9348 | A2028 | 20148 | 37.1191 | -87.8752 | 3.0 | 0.00 | 295 | 0.0 | 1.55E-06 | 1.90E-07 | 1.90E-07 | 1.93E-06 |

## Table C-19b. Non-point Sources Included in the Collective Sources Tag for Kentucky.

The county in the vicinity of the maximum in-state contribution to mercury deposition with significant non-point emissions is included.

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 21157 | MARSHALL | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 1.05E-04 | 0.00E+00 | 0.00E+00 | 1.05E-04 |
| 21157 | MARSHALL | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 9.98E-05 | 0.00E+00 | 0.00E+00 | 9.98E-05 |
| 21157 | MARSHALL | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 1.10E-05 | 6.60E-06 | 4.40E-06 | 2.20E-05 |
| 21157 | MARSHALL | External Combustion Boilers, Industrial, Liquid Waste | 9.99E-06 | 5.99E-06 | 4.00E-06 | 2.00E-05 |
| 21157 | MARSHALL | Stationary Source Fuel Combustion, Residential, Distillate Oil | 8.68E-06 | 5.21E-06 | 3.47E-06 | 1.74E-05 |
| 21157 | MARSHALL | Miscellaneous Area Sources, Other Combustion, Cremation | 8.70E-07 | 2.29E-06 | 7.90E-07 | 3.95E-06 |
| 21157 | MARSHALL | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 1.54E-06 | 9.20E-07 | 6.20E-07 | 3.08E-06 |
| 21157 | MARSHALL | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 1.02E-06 | 6.10E-07 | 4.10E-07 | 2.04E-06 |
| 21157 | MARSHALL | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 7.10E-07 | 4.30E-07 | 2.90E-07 | 1.43E-06 |
| 21157 | MARSHALL | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 1.00E-08 | 0.00E+00 | 0.00E+00 | 1.00E-08 |

## Table C-20a. Point Sources Included in the Collective Sources Tag for Mississippi.

Only sources in the vicinity of the maximum in-state contribution to mercury deposition are included.

| FIPS | County | Facility Name | Plant ID | Point ID | Stack ID | Latitude | Longitude | StkHt (m) | Diam (m) | Temp (K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 28043 | Grenada | NEWSPRINTSOUTH | 2804300015 | 011 | 26623 | 33.8345 | -89.8169 | 3.0 | 0.00 | 295 | 0.0 | 3.72E-02 | 2.23E-02 | 1.49E-02 | 7.45E-02 |
| 28013 | Calhoun | MEMPHISHARDWOOD | 14606 | 59254 | 26602 | 33.9419 | -89.3236 | 23.8 | 1.01 | 476 | 10.5 | 1.13E-04 | 6.75E-05 | 4.50E-05 | 2.25E-04 |
| 28013 | Calhoun | MEMPHISHARDWOOD | 14606 | 59255 | 26601 | 33.9419 | -89.3236 | 23.8 | 1.01 | 476 | 10.5 | 1.13E-04 | 6.75E-05 | 4.50E-05 | 2.25E-04 |
| 28013 | Calhoun | WEYERHAEUSERCO | 15804 | 60734 | 26603 | 33.9419 | -89.3236 | 23.8 | 1.01 | 476 | 10.5 | 1.13E-04 | 6.75E-05 | 4.50E-05 | 2.25E-04 |
| 28013 | Calhoun | WEYERHAEUSERCO | 15804 | 60735 | 26604 | 33.9419 | -89.3236 | 23.8 | 1.01 | 476 | 10.5 | 1.13E-04 | 6.75E-05 | 4.50E-05 | 2.25E-04 |
| 28013 | Calhoun | WEYERHAEUSERCO | 15804 | 60736 | 26605 | 33.9419 | -89.3236 | 23.8 | 1.01 | 476 | 10.5 | 1.13E-04 | 6.75E-05 | 4.50E-05 | 2.25E-04 |
| 28013 | Calhoun | WEYERHAEUSERCO | 280130032 | 001 | 26606 | 33.9419 | -89.3236 | 23.8 | 1.01 | 476 | 10.5 | 8.54E-05 | 5.12E-05 | 3.42E-05 | 1.71E-04 |
| 28013 | Calhoun | WEYERHAEUSERCO | 280130032 | 002 | 26607 | 33.9419 | -89.3236 | 23.8 | 1.01 | 476 | 10.5 | 8.54E-05 | 5.12E-05 | 3.42E-05 | 1.71E-04 |
| 28013 | Calhoun | WEYERHAEUSERCO | 280130032 | 003 | 26608 | 33.9419 | -89.3236 | 23.8 | 1.01 | 476 | 10.5 | 8.54E-05 | 5.12E-05 | 3.42E-05 | 1.71E-04 |
| 28043 | Grenada | KOPPERSINDUSTRIESINC | 2804300012 | 001 | 26622 | 33.7300 | -89.7814 | 24.4 | 0.00 | 295 | 0.0 | 5.00E-05 | 3.00E-05 | 2.00E-05 | 1.00E-04 |
| 28161 | Yalobusha | WaterValleySanitaryLandfill | LF107 | A367 | 26828 | 34.0295 | -89.7194 | 3.0 | 0.00 | 295 | 0.0 | 3.30E-07 | 4.00E-08 | 4.00E-08 | 4.10E-07 |

## Table C-20b. Non-point Sources Included in the Collective Sources Tag for Mississippi.

Counties in the vicinity of the maximum in-state contribution to mercury deposition with significant non-point emissions are included.

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 28043 | GRENADA | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 7.41E-05 | 0.00E+00 | 0.00E+00 | 7.41E-05 |
| 28013 | CALHOUN | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 4.92E-05 | 0.00E+00 | 0.00E+00 | 4.92E-05 |
| 28043 | GRENADA | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 2.23E-05 | 1.34E-05 | 8.93E-06 | 4.46E-05 |
| 28043 | GRENADA | External Combustion Boilers, Industrial, Liquid Waste | 1.30E-05 | 7.80E-06 | 5.20E-06 | 2.60E-05 |
| 28043 | GRENADA | Stationary Source Fuel Combustion, Industrial, Residual Oil | 9.50E-06 | 5.70E-06 | 3.80E-06 | 1.90E-05 |
| 28013 | CALHOUN | External Combustion Boilers, Industrial, Liquid Waste | 6.82E-06 | 4.09E-06 | 2.73E-06 | 1.36E-05 |
| 28043 | GRENADA | External Combustion Boilers, Industrial, Distillate Oil | 6.19E-06 | 3.71E-06 | 2.47E-06 | 1.24E-05 |
| 28013 | CALHOUN | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 5.20E-06 | 3.12E-06 | 2.08E-06 | 1.04E-05 |
| 28013 | CALHOUN | Stationary Source Fuel Combustion, Industrial, Residual Oil | 4.99E-06 | 2.99E-06 | 1.99E-06 | 9.97E-06 |
| 28013 | CALHOUN | External Combustion Boilers, Industrial, Distillate Oil | 3.25E-06 | 1.95E-06 | 1.30E-06 | 6.50E-06 |
| 28043 | GRENADA | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 1.27E-06 | 7.60E-07 | 5.10E-07 | 2.54E-06 |
| 28043 | GRENADA | Miscellaneous Area Sources, Other Combustion, Cremation | 5.30E-07 | 1.41E-06 | 4.90E-07 | 2.43E-06 |
| 28013 | CALHOUN | Miscellaneous Area Sources, Other Combustion, Cremation | 3.50E-07 | 9.30E-07 | 3.20E-07 | 1.60E-06 |
| 28013 | CALHOUN | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 3.00E-07 | 1.80E-07 | 1.20E-07 | 6.00E-07 |
| 28013 | CALHOUN | Stationary Source Fuel Combustion, Residential, Distillate Oil | 9.00E-08 | 5.00E-08 | 3.00E-08 | 1.70E-07 |
| 28043 | GRENADA | Stationary Source Fuel Combustion, Residential, Distillate Oil | 8.00E-08 | 5.00E-08 | 3.00E-08 | 1.60E-07 |
| 28043 | GRENADA | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 1.00E-08 | 0.00E+00 | 0.00E+00 | 1.00E-08 |

## Table C-21. Non-point Sources Included in the Collective Sources Tag for New Jersey.

The county in the vicinity of the maximum in-state contribution to mercury deposition with significant non-point emissions is included.
*(Note: this is an area source. No point sources in the collective source tag were located near the simulated peak.)*

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 34031 | PASSAIC | Stationary Source Fuel Combustion, Industrial, Residual Oil | 9.94E-05 | 5.97E-05 | 3.98E-05 | 1.99E-04 |

## Table C-22a. Point Sources Included in the Collective Sources Tag for Ohio.

Only sources in the vicinity of the maximum in-state contribution to mercury deposition are included.

| FIPS | County | Facility Name | Plant ID | Point ID | Stack ID | Latitude | Longitude | StkHt (m) | Diam (m) | Temp (K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39085 | Lake | LubrizolCorp. | B30 | 1 | 30477 | 41.6111 | -81.4794 | 26.9 | 1.16 | 457 | 9.3 | 1.17E-01 | 4.05E-02 | 4.45E-02 | 2.02E-01 |
| 39035 | Cuyahoga | NEORSDEASTERLYWASTEWATERTREATMENTPLA | 12213 | 53881 | 30304 | 41.5694 | -81.5850 | 17.3 | 0.73 | 433 | 10.1 | 2.82E-04 | 1.69E-04 | 1.13E-04 | 5.64E-04 |
| 39085 | Lake | EAGLEPICHERIND.-MATSDIV. | 13778 | 57654 | 30472 | 41.6444 | -81.4156 | 43.1 | 2.01 | 461 | 10.3 | 1.37E-04 | 8.25E-05 | 5.50E-05 | 2.75E-04 |
| 39085 | Lake | LubrizolCorporation | A36 | 1 | 30476 | 41.7203 | -81.2736 | 26.9 | 1.16 | 457 | 9.3 | 3.18E-05 | 1.10E-05 | 1.21E-05 | 5.48E-05 |
| 39085 | Lake | LakeCountyRecycling&DisposalLF | LF5858 | A1289 | 30478 | 41.6323 | -81.4095 | 3.0 | 0.00 | 295 | 0.0 | 3.16E-05 | 3.95E-06 | 3.95E-06 | 3.95E-05 |
| 39085 | Lake | LINCOLNELECTRIC | 13897 | 57958 | 30473 | 41.6911 | -81.3097 | 35.1 | 1.62 | 464 | 8.4 | 1.95E-05 | 1.17E-05 | 7.79E-06 | 3.89E-05 |
| 39007 | Ashtabula | WMI-GenevaLandfill | LF10003 | A3 | 30255 | 41.7940 | -80.9054 | 3.0 | 0.00 | 295 | 0.0 | 3.04E-05 | 3.80E-06 | 3.80E-06 | 3.80E-05 |
| 39085 | Lake | LakeCountySolidWasteLandfill | LF5859 | A1290 | 30479 | 41.7550 | -81.2047 | 3.0 | 0.00 | 295 | 0.0 | 1.62E-05 | 2.03E-06 | 2.03E-06 | 2.03E-05 |
| 39085 | Lake | CityofWilloughbyLandfill | LF5860 | A1291 | 30480 | 41.6456 | -81.3963 | 3.0 | 0.00 | 295 | 0.0 | 1.67E-06 | 2.10E-07 | 2.10E-07 | 2.09E-06 |

## Table C-22b. Non-point Sources Included in the Collective Sources Tag for Ohio.

Counties in the vicinity of the maximum in-state contribution to mercury deposition with significant non-point emissions are included.

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 39035 | CUYAHOGA | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 4.78E-03 | 0.00E+00 | 0.00E+00 | 4.78E-03 |
| 39035 | CUYAHOGA | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Dental Alloy (Mercury Amalgams) Production | 4.68E-03 | 0.00E+00 | 0.00E+00 | 4.68E-03 |
| 39035 | CUYAHOGA | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 4.53E-03 | 0.00E+00 | 0.00E+00 | 4.53E-03 |
| 39035 | CUYAHOGA | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 2.23E-03 | 1.34E-03 | 8.91E-04 | 4.46E-03 |
| 39035 | CUYAHOGA | External Combustion Boilers, Industrial, Liquid Waste | 5.11E-04 | 3.07E-04 | 2.04E-04 | 1.02E-03 |
| 39085 | LAKE | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 7.91E-04 | 0.00E+00 | 0.00E+00 | 7.91E-04 |
| 39085 | LAKE | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 7.50E-04 | 0.00E+00 | 0.00E+00 | 7.50E-04 |
| 39035 | CUYAHOGA | Stationary Source Fuel Combustion, Industrial, Residual Oil | 3.73E-04 | 2.24E-04 | 1.49E-04 | 7.47E-04 |
| 39007 | ASHTABULA | Stationary Source Fuel Combustion, Residential, Distillate Oil | 2.54E-04 | 1.53E-04 | 1.02E-04 | 5.09E-04 |
| 39085 | LAKE | Stationary Source Fuel Combustion, Residential, Distillate Oil | 2.44E-04 | 1.46E-04 | 9.75E-05 | 4.88E-04 |
| 39035 | CUYAHOGA | External Combustion Boilers, Industrial, Distillate Oil | 2.43E-04 | 1.46E-04 | 9.72E-05 | 4.86E-04 |
| 39035 | CUYAHOGA | Miscellaneous Area Sources, Other Combustion, Cremation | 1.07E-04 | 2.82E-04 | 9.72E-05 | 4.86E-04 |
| 39085 | LAKE | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 2.36E-04 | 1.42E-04 | 9.44E-05 | 4.72E-04 |
| 39035 | CUYAHOGA | Stationary Source Fuel Combustion, Residential, Distillate Oil | 1.91E-04 | 1.14E-04 | 7.63E-05 | 3.82E-04 |
| 39007 | ASHTABULA | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 3.60E-04 | 0.00E+00 | 0.00E+00 | 3.60E-04 |
| 39007 | ASHTABULA | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 3.41E-04 | 0.00E+00 | 0.00E+00 | 3.41E-04 |
| 39035 | CUYAHOGA | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 1.27E-04 | 7.60E-05 | 5.07E-05 | 2.53E-04 |
| 39035 | CUYAHOGA | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 1.22E-04 | 7.33E-05 | 4.89E-05 | 2.44E-04 |
| 39085 | LAKE | External Combustion Boilers, Industrial, Liquid Waste | 9.59E-05 | 5.75E-05 | 3.84E-05 | 1.92E-04 |
| 39085 | LAKE | Stationary Source Fuel Combustion, Industrial, Residual Oil | 7.01E-05 | 4.20E-05 | 2.80E-05 | 1.40E-04 |
| 39007 | ASHTABULA | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 6.74E-05 | 4.04E-05 | 2.69E-05 | 1.35E-04 |
| 39085 | LAKE | External Combustion Boilers, Industrial, Distillate Oil | 4.56E-05 | 2.74E-05 | 1.82E-05 | 9.12E-05 |
| 39085 | LAKE | Miscellaneous Area Sources, Other Combustion, Cremation | 1.77E-05 | 4.67E-05 | 1.61E-05 | 8.05E-05 |
| 39085 | LAKE | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Dental Alloy (Mercury Amalgams) Production | 7.56E-05 | 0.00E+00 | 0.00E+00 | 7.56E-05 |
| 39007 | ASHTABULA | External Combustion Boilers, Industrial, Liquid Waste | 3.16E-05 | 1.90E-05 | 1.26E-05 | 6.32E-05 |
| 39007 | ASHTABULA | Stationary Source Fuel Combustion, Industrial, Residual Oil | 2.31E-05 | 1.38E-05 | 9.23E-06 | 4.61E-05 |
| 39007 | ASHTABULA | Miscellaneous Area Sources, Other Combustion, Cremation | 8.05E-06 | 2.12E-05 | 7.32E-06 | 3.66E-05 |
| 39035 | CUYAHOGA | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 1.71E-05 | 1.03E-05 | 6.84E-06 | 3.42E-05 |
| 39007 | ASHTABULA | External Combustion Boilers, Industrial, Distillate Oil | 1.50E-05 | 9.01E-06 | 6.01E-06 | 3.00E-05 |
| 39085 | LAKE | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 1.34E-05 | 8.05E-06 | 5.37E-06 | 2.68E-05 |
| 39085 | LAKE | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 1.30E-05 | 7.79E-06 | 5.19E-06 | 2.60E-05 |

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 39007 | ASHTABULA | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 1.14E-05 | 6.83E-06 | 4.56E-06 | 2.28E-05 |
| 39035 | CUYAHOGA | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 5.51E-06 | 3.31E-06 | 2.21E-06 | 1.10E-05 |
| 39085 | LAKE | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 4.98E-06 | 2.99E-06 | 1.99E-06 | 9.96E-06 |
| 39035 | CUYAHOGA | Industrial Processes, Chemical Manufacturing, Other Not Classified | 7.22E-06 | 9.00E-07 | 9.00E-07 | 9.02E-06 |
| 39007 | ASHTABULA | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 3.83E-06 | 2.30E-06 | 1.53E-06 | 7.66E-06 |
| 39007 | ASHTABULA | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 3.78E-06 | 2.26E-06 | 1.51E-06 | 7.55E-06 |
| 39085 | LAKE | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 1.82E-06 | 1.09E-06 | 7.30E-07 | 3.64E-06 |
| 39085 | LAKE | Industrial Processes, Chemical Manufacturing, Other Not Classified | 1.76E-06 | 2.20E-07 | 2.20E-07 | 2.20E-06 |
| 39007 | ASHTABULA | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 5.30E-07 | 3.20E-07 | 2.10E-07 | 1.06E-06 |
| 39007 | ASHTABULA | Stationary Source Fuel Combustion, Residential, Anthracite Coal | 3.00E-07 | 1.80E-07 | 1.20E-07 | 6.00E-07 |
| 39035 | CUYAHOGA | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 4.50E-07 | 0.00E+00 | 0.00E+00 | 4.50E-07 |
| 39035 | CUYAHOGA | Stationary Source Fuel Combustion, Residential, Anthracite Coal | 1.50E-07 | 9.00E-08 | 6.00E-08 | 3.00E-07 |
| 39007 | ASHTABULA | Industrial Processes, Chemical Manufacturing, Other Not Classified | 2.10E-07 | 3.00E-08 | 3.00E-08 | 2.70E-07 |
| 39085 | LAKE | Stationary Source Fuel Combustion, Residential, Anthracite Coal | 1.30E-07 | 8.00E-08 | 5.00E-08 | 2.60E-07 |
| 39085 | LAKE | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 7.00E-08 | 0.00E+00 | 0.00E+00 | 7.00E-08 |
| 39007 | ASHTABULA | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 3.00E-08 | 0.00E+00 | 0.00E+00 | 3.00E-08 |

## Table C-23a. Point Sources Included in the Collective Sources Tag for Rhode Island.

Only sources in the vicinity of the maximum in-state contribution to mercury deposition are included.

| FIPS | County | Facility Name | Plant ID | Point ID | Stack ID | Latitude | Longitude | StkHt (m) | Diam (m) | Temp (K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 44007 | Providence | ALGONQUINGASTRANSMISSIONCO.(B) | 00500 | 003 | 32028 | 41.9875 | -71.7597 | 16.6 | 0.76 | 605 | 23.8 | 2.00E-03 | 1.20E-03 | 8.00E-04 | 4.00E-03 |
| 44007 | Providence | BROWNUNIVERSITY | 00033 | 002 | 32018 | 41.8271 | -71.3991 | 3.0 | 0.00 | 295 | 0.0 | 5.00E-04 | 3.00E-04 | 2.00E-04 | 1.00E-03 |
| 44007 | Providence | BROWNUNIVERSITY | 00033 | 001 | 32016 | 41.8271 | -71.3992 | 18.3 | 1.16 | 454 | 7.6 | 4.75E-05 | 2.85E-05 | 1.90E-05 | 9.50E-05 |
| 44007 | Providence | SEVILLEDYEINGCO.-INC. | 00013 | 001 | 32011 | 42.0029 | -71.5267 | 15.2 | 0.61 | 464 | 8.2 | 3.25E-05 | 1.95E-05 | 1.30E-05 | 6.50E-05 |
| 44007 | Providence | DORADOPROCESSINGCO.-INC. | 00034 | 001 | 32020 | 42.0053 | -71.5242 | 10.7 | 0.61 | 456 | 8.2 | 2.83E-05 | 1.70E-05 | 1.13E-05 | 5.65E-05 |
| 44007 | Providence | SLATERDYEWORKS&SLATERSCREENPRINT | 00030 | 001 | 32015 | 41.8587 | -71.3742 | 32.0 | 3.05 | 468 | 9.4 | 2.25E-05 | 1.35E-05 | 9.00E-06 | 4.50E-05 |
| 44007 | Providence | TEKNORAPEXCO.(CENTRALAVENUE) | 00029 | 001 | 32013 | 41.8856 | -71.3630 | 24.4 | 0.61 | 466 | 8.2 | 1.25E-05 | 7.50E-06 | 5.00E-06 | 2.50E-05 |
| 44007 | Providence | CCLCUSTOMMFG. | 00453 | 001 | 32026 | 41.9276 | -71.4272 | 9.4 | 0.61 | 468 | 9.4 | 1.00E-05 | 6.00E-06 | 4.00E-06 | 2.00E-05 |
| 44007 | Providence | OSRAMSYLVANIAPRODUCTSINC. | 00003 | 001 | 32010 | 41.8962 | -71.3887 | 24.4 | 1.52 | 439 | 9.4 | 1.00E-05 | 6.00E-06 | 4.00E-06 | 2.00E-05 |
| 44007 | Providence | BROWNUNIVERSITY | 00033 | 001 | 32017 | 41.8271 | -71.3992 | 18.3 | 1.16 | 454 | 7.6 | 8.75E-06 | 5.25E-06 | 3.50E-06 | 1.75E-05 |
| 44007 | Providence | PROVIDENCEMETALLIZINGCO.-INC. | 06011 | 001 | 32032 | 41.8736 | -71.4101 | 17.7 | 0.76 | 589 | 9.1 | 7.50E-06 | 4.50E-06 | 3.00E-06 | 1.50E-05 |
| 44007 | Providence | ELIZABETHWEBBINGMILLSCO.-INC. | 09008 | 001 | 32033 | 41.8860 | -71.3821 | 24.4 | 0.30 | 451 | 8.8 | 7.50E-06 | 4.50E-06 | 3.00E-06 | 1.50E-05 |
| 44007 | Providence | AMERICANINSULATEDWIRECORP.PAWTUCKET | 80000 | 001 | 32040 | 41.8856 | -71.3668 | 53.3 | 3.05 | 468 | 9.4 | 7.50E-06 | 4.50E-06 | 3.00E-06 | 1.50E-05 |
| 44007 | Providence | SEVILLEDYEINGCO.-INC. | 00013 | 001 | 32012 | 42.0029 | -71.5267 | 15.2 | 0.61 | 464 | 8.2 | 7.45E-06 | 4.47E-06 | 2.98E-06 | 1.49E-05 |
| 44007 | Providence | ELIZABETHWEBBINGMILLSCO.-INC. | 09008 | 001 | 32034 | 41.8860 | -71.3821 | 24.4 | 0.30 | 451 | 8.8 | 6.00E-06 | 3.60E-06 | 2.40E-06 | 1.20E-05 |
| 44007 | Providence | BICCGENERAL | 09046 | 001 | 32038 | 41.9231 | -71.4807 | 10.7 | 1.22 | 468 | 9.4 | 5.50E-06 | 3.30E-06 | 2.20E-06 | 1.10E-05 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 44007 | Providence | DORADOPROCESSINGCO.-INC. | 00034 | 001 | 32019 | 42.0053 | -71.5242 | 10.7 | 0.61 | 456 | 8.2 | 5.00E-06 | 3.00E-06 | 2.00E-06 | 1.00E-05 |
| 44007 | Providence | OCEANSTATEPOWER | 00545 | 001 | 32029 | 41.9918 | -71.6829 | 45.7 | 4.80 | 370 | 18.7 | 3.50E-06 | 2.10E-06 | 1.40E-06 | 7.00E-06 |
| 44007 | Providence | SLATERDYEWORKSCUMBERLAND | 00706 | 001 | 32030 | 41.9531 | -71.4018 | 5.5 | 0.91 | 468 | 9.4 | 1.75E-06 | 1.05E-06 | 7.00E-07 | 3.50E-06 |
| 44007 | Providence | FOAMTECHNOLOGY | 00716 | 001 | 32031 | 41.8812 | -71.4050 | 18.3 | 0.61 | 451 | 8.8 | 1.25E-06 | 7.50E-07 | 5.00E-07 | 2.50E-06 |
| 44007 | Providence | TEKNORAPEXCO.(CENTRALAVENUE) | 00029 | 001 | 32014 | 41.8856 | -71.3630 | 24.4 | 0.61 | 466 | 8.2 | 1.25E-06 | 7.50E-07 | 5.00E-07 | 2.50E-06 |
| 44007 | Providence | NorthProvidenceSanitaryLandfill | LF2954 | A1795 | 32043 | 41.8716 | -71.5590 | 3.0 | 0.00 | 295 | 0.0 | 1.53E-06 | 1.90E-07 | 1.90E-07 | 1.91E-06 |
| 44007 | Providence | ALGONQUINGASTRANSMISSIONCO.(B) | 00500 | 001 | 32027 | 41.9875 | -71.7597 | 3.0 | 0.00 | 295 | 0.0 | 5.00E-07 | 3.00E-07 | 2.00E-07 | 1.00E-06 |
| 44007 | Providence | BICCGENERAL | 09046 | 002 | 32039 | 41.9231 | -71.4807 | 3.0 | 0.00 | 295 | 0.0 | 4.00E-07 | 2.40E-07 | 1.60E-07 | 8.00E-07 |
| 44007 | Providence | BurrillvilleSanitaryLandfill | LF2956 | A1796 | 32044 | 41.8716 | -71.5590 | 3.0 | 0.00 | 295 | 0.0 | 2.20E-07 | 3.00E-08 | 3.00E-08 | 2.80E-07 |
| 44007 | Providence | PAWTUCKETPOWERASSOCIATED | 90069 | 002 | 32042 | 41.8601 | -71.4083 | 54.1 | 3.58 | 389 | 21.9 | 3.00E-08 | 2.00E-08 | 1.00E-08 | 6.00E-08 |

## Table C-23b. Non-point Sources Included in the Collective Sources Tag for Rhode Island.

The county in the vicinity of the maximum in-state contribution to mercury deposition with significant non-point emissions is included.

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 44007 | PROVIDENCE | Stationary Source Fuel Combustion, Residential, Distillate Oil | 7.62E-03 | 4.57E-03 | 3.05E-03 | 1.52E-02 |
| 44007 | PROVIDENCE | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 2.00E-03 | 0.00E+00 | 0.00E+00 | 2.00E-03 |
| 44007 | PROVIDENCE | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 1.89E-03 | 0.00E+00 | 0.00E+00 | 1.89E-03 |
| 44007 | PROVIDENCE | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 7.44E-04 | 4.47E-04 | 2.98E-04 | 1.49E-03 |
| 44007 | PROVIDENCE | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Dental Alloy (Mercury Amalgams) Production | 8.10E-04 | 0.00E+00 | 0.00E+00 | 8.10E-04 |
| 44007 | PROVIDENCE | External Combustion Boilers, Industrial, Liquid Waste | 1.96E-04 | 1.17E-04 | 7.82E-05 | 3.91E-04 |
| 44007 | PROVIDENCE | Miscellaneous Area Sources, Other Combustion, Cremation | 8.34E-05 | 2.20E-04 | 7.59E-05 | 3.79E-04 |
| 44007 | PROVIDENCE | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 7.44E-05 | 4.46E-05 | 2.97E-05 | 1.49E-04 |
| 44007 | PROVIDENCE | Stationary Source Fuel Combustion, Residential, Anthracite Coal | 1.25E-05 | 7.52E-06 | 5.01E-06 | 2.51E-05 |
| 44007 | PROVIDENCE | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 1.04E-05 | 6.25E-06 | 4.16E-06 | 2.08E-05 |
| 44007 | PROVIDENCE | Industrial Processes, Chemical Manufacturing, Other Not Classified | 1.24E-06 | 1.50E-07 | 1.50E-07 | 1.54E-06 |
| 44007 | PROVIDENCE | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 1.90E-07 | 0.00E+00 | 0.00E+00 | 1.90E-07 |

## Table C-24a. Point Sources Included in the Collective Sources Tag for South Dakota.

Only sources in the vicinity of the maximum in-state contribution to mercury deposition are included.

| FIPS | County | Facility Name | Plant ID | Point ID | Stack ID | Latitude | Longitude | StkHt (m) | Diam (m) | Temp (K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46019 | Butte | AMERICANCOLLOIDCO | 13876 | 57859 | 32793 | 44.8927 | -103.5066 | 40.1 | 1.92 | 459 | 7.5 | 2.78E-03 | 1.67E-03 | 1.11E-03 | 5.56E-03 |

## Table C-24b. Non-point Sources Included in the Collective Sources Tag for South Dakota.

The county in the vicinity of the maximum in-state contribution to mercury deposition with significant non-point emissions is included.

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 46019 | BUTTE | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 3.05E-05 | 0.00E+00 | 0.00E+00 | 3.05E-05 |
| 46019 | BUTTE | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 2.89E-05 | 0.00E+00 | 0.00E+00 | 2.89E-05 |
| 46019 | BUTTE | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 5.52E-06 | 3.31E-06 | 2.21E-06 | 1.10E-05 |
| 46019 | BUTTE | Stationary Source Fuel Combustion, Residential, Distillate Oil | 5.11E-06 | 3.07E-06 | 2.04E-06 | 1.02E-05 |
| 46019 | BUTTE | Miscellaneous Area Sources, Other Combustion, Cremation | 4.70E-07 | 1.24E-06 | 4.30E-07 | 2.14E-06 |
| 46019 | BUTTE | External Combustion Boilers, Industrial, Liquid Waste | 6.10E-07 | 3.70E-07 | 2.50E-07 | 1.23E-06 |
| 46019 | BUTTE | Stationary Source Fuel Combustion, Industrial, Residual Oil | 4.50E-07 | 2.70E-07 | 1.80E-07 | 9.00E-07 |
| 46019 | BUTTE | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 3.80E-07 | 2.30E-07 | 1.50E-07 | 7.60E-07 |
| 46019 | BUTTE | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 3.30E-07 | 2.00E-07 | 1.30E-07 | 6.60E-07 |
| 46019 | BUTTE | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 3.10E-07 | 1.90E-07 | 1.30E-07 | 6.30E-07 |
| 46019 | BUTTE | External Combustion Boilers, Industrial, Distillate Oil | 3.00E-07 | 1.80E-07 | 1.20E-07 | 6.00E-07 |
| 46019 | BUTTE | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 6.00E-08 | 3.00E-08 | 2.00E-08 | 1.10E-07 |

## Table C-25a. Point Sources Included in the Collective Sources Tag for Tennessee.

Only sources in the vicinity of the maximum in-state contribution to mercury deposition are included.

| FIPS | County | Facility Name | Plant ID | Point ID | Stack ID | Latitude | Longitude | StkHt (m) | Diam (m) | Temp (K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 47165 | Sumner | ResourceAuthorityinSumnerCo. | SMWC-29 | SMWC-1 | 33263 | 36.3832 | -86.4548 | 31.1 | 1.89 | 505 | 13.3 | 1.25E-02 | 3.30E-02 | 1.14E-02 | 5.69E-02 |
| 47165 | Sumner | ResourceAuthorityinSumnerCo. | SMWC-29 | SMWC-2 | 33264 | 36.3832 | -86.4548 | 31.1 | 1.89 | 505 | 13.3 | 1.25E-02 | 3.30E-02 | 1.14E-02 | 5.69E-02 |
| 47165 | Sumner | CRESENTMANUFACTURINGCOMPANY | 15352 | 60975 | 33259 | 36.3832 | -86.4548 | 25.5 | 1.25 | 452 | 10.5 | 2.51E-05 | 1.51E-05 | 1.00E-05 | 5.02E-05 |
| 47165 | Sumner | GALLATINBLOCKCOMPANY | 14981 | 60054 | 33256 | 36.3832 | -86.4548 | 45.6 | 2.07 | 482 | 9.7 | 1.02E-05 | 6.10E-06 | 4.07E-06 | 2.03E-05 |
| 47165 | Sumner | CRESENTMANUFACTURINGCOMPANY | 15352 | 60973 | 33257 | 36.3832 | -86.4548 | 25.5 | 1.25 | 452 | 10.5 | 8.95E-06 | 5.37E-06 | 3.58E-06 | 1.79E-05 |
| 47111 | Macon | LAFAYETTEMANUFACTURINGCOMPANY | 14549 | 59152 | 33045 | 36.5404 | -86.0122 | 4.7 | 0.65 | 295 | 9.0 | 6.98E-06 | 4.19E-06 | 2.79E-06 | 1.40E-05 |
| 47189 | Wilson | WilsonCountyLandfill | LF252 | A501 | 33306 | 36.2626 | -86.2944 | 3.0 | 0.00 | 295 | 0.0 | 8.15E-06 | 1.02E-06 | 1.02E-06 | 1.02E-05 |
| 47165 | Sumner | CRESENTMANUFACTURINGCOMPANY | 15352 | 60974 | 33258 | 36.3832 | -86.4548 | 25.5 | 1.25 | 452 | 10.5 | 4.47E-06 | 2.68E-06 | 1.79E-06 | 8.94E-06 |
| 47111 | Macon | LAFAYETTEMANUFACTURINGCOMPANY | 14549 | 59149 | 33042 | 36.5404 | -86.0122 | 31.6 | 1.40 | 430 | 11.5 | 4.13E-06 | 2.48E-06 | 1.65E-06 | 8.26E-06 |
| 47111 | Macon | LafayetteManufacturingCompany | 470560002 | 001 | 33046 | 36.5388 | -86.0119 | 31.6 | 1.40 | 430 | 11.5 | 3.13E-06 | 1.88E-06 | 1.25E-06 | 6.26E-06 |
| 47111 | Macon | LAFAYETTEMANUFACTURINGCOMPANY | 14549 | 59150 | 33043 | 36.5404 | -86.0122 | 4.7 | 0.65 | 295 | 9.0 | 3.60E-07 | 2.20E-07 | 1.40E-07 | 7.20E-07 |
| 47111 | Macon | LAFAYETTEMANUFACTURINGCOMPANY | 14549 | 59151 | 33044 | 36.5404 | -86.0122 | 4.7 | 0.65 | 295 | 9.0 | 3.60E-07 | 2.20E-07 | 1.40E-07 | 7.20E-07 |
| 47165 | Sumner | HendersonvilleLandfill | LF1181 | A457 | 33262 | 36.4487 | -86.4799 | 3.0 | 0.00 | 295 | 0.0 | 3.90E-07 | 5.00E-08 | 5.00E-08 | 4.90E-07 |
| 47165 | Sumner | SumnerCountyLandfill | LF1180 | A456 | 33261 | 36.4487 | -86.4799 | 3.0 | 0.00 | 295 | 0.0 | 3.40E-07 | 4.00E-08 | 4.00E-08 | 4.20E-07 |
| 47169 | Trousdale | Hartsville/TrousdaleLandfill | LF984 | A7275 | 33265 | 36.3926 | -86.1311 | 3.0 | 0.00 | 295 | 0.0 | 3.30E-07 | 4.00E-08 | 4.00E-08 | 4.10E-07 |
| 47111 | Macon | LafayetteCityLandfil | LF5073 | A3510 | 33047 | 36.5260 | -86.0088 | 3.0 | 0.00 | 295 | 0.0 | 3.30E-07 | 4.00E-08 | 4.00E-08 | 4.10E-07 |
| 47165 | Sumner | GallatinCityLandfill | LF1179 | A454 | 33260 | 36.4487 | -86.4799 | 3.0 | 0.00 | 295 | 0.0 | 2.60E-07 | 3.00E-08 | 3.00E-08 | 3.20E-07 |

## Table C-25b. Non-point Sources Included in the Collective Sources Tag for Tennessee.

Counties in the vicinity of the maximum in-state contribution to mercury deposition with significant non-point emissions are included.

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 47165 | SUMNER | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 4.39E-04 | 0.00E+00 | 0.00E+00 | 4.39E-04 |
| 47165 | SUMNER | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 4.16E-04 | 0.00E+00 | 0.00E+00 | 4.16E-04 |
| 47189 | WILSON | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 3.01E-04 | 0.00E+00 | 0.00E+00 | 3.01E-04 |
| 47189 | WILSON | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 2.85E-04 | 0.00E+00 | 0.00E+00 | 2.85E-04 |
| 47165 | SUMNER | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Dental Alloy (Mercury Amalgams) Production | 2.05E-04 | 0.00E+00 | 0.00E+00 | 2.05E-04 |
| 47189 | WILSON | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Dental Alloy (Mercury Amalgams) Production | 2.05E-04 | 0.00E+00 | 0.00E+00 | 2.05E-04 |
| 47165 | SUMNER | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 7.57E-05 | 4.54E-05 | 3.03E-05 | 1.51E-04 |
| 47189 | WILSON | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 6.25E-05 | 3.75E-05 | 2.50E-05 | 1.25E-04 |
| 47165 | SUMNER | External Combustion Boilers, Industrial, Liquid Waste | 3.84E-05 | 2.30E-05 | 1.54E-05 | 7.68E-05 |
| 47111 | MACON | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 6.46E-05 | 0.00E+00 | 0.00E+00 | 6.46E-05 |
| 47111 | MACON | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 6.12E-05 | 0.00E+00 | 0.00E+00 | 6.12E-05 |
| 47165 | SUMNER | Stationary Source Fuel Combustion, Industrial, Residual Oil | 2.81E-05 | 1.68E-05 | 1.12E-05 | 5.61E-05 |
| 47165 | SUMNER | External Combustion Boilers, Industrial, Distillate Oil | 1.83E-05 | 1.10E-05 | 7.30E-06 | 3.65E-05 |
| 47189 | WILSON | External Combustion Boilers, Industrial, Liquid Waste | 1.79E-05 | 1.07E-05 | 7.15E-06 | 3.57E-05 |
| 47189 | WILSON | Stationary Source Fuel Combustion, Industrial, Residual Oil | 1.31E-05 | 7.83E-06 | 5.22E-06 | 2.61E-05 |
| 47165 | SUMNER | Stationary Source Fuel Combustion, Residential, Distillate Oil | 1.16E-05 | 6.95E-06 | 4.64E-06 | 2.32E-05 |
| 47165 | SUMNER | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 1.12E-05 | 6.70E-06 | 4.46E-06 | 2.23E-05 |
| 47189 | WILSON | External Combustion Boilers, Industrial, Distillate Oil | 8.49E-06 | 5.10E-06 | 3.40E-06 | 1.70E-05 |
| 47189 | WILSON | Stationary Source Fuel Combustion, Residential, Distillate Oil | 8.14E-06 | 4.88E-06 | 3.26E-06 | 1.63E-05 |
| 47165 | SUMNER | Miscellaneous Area Sources, Other Combustion, Cremation | 3.45E-06 | 9.08E-06 | 3.13E-06 | 1.57E-05 |
| 47111 | MACON | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 7.36E-06 | 4.42E-06 | 2.95E-06 | 1.47E-05 |
| 47189 | WILSON | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 7.36E-06 | 4.42E-06 | 2.94E-06 | 1.47E-05 |
| 47111 | MACON | External Combustion Boilers, Industrial, Liquid Waste | 5.46E-06 | 3.28E-06 | 2.19E-06 | 1.09E-05 |
| 47189 | WILSON | Miscellaneous Area Sources, Other Combustion, Cremation | 2.37E-06 | 6.24E-06 | 2.15E-06 | 1.08E-05 |
| 47165 | SUMNER | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 4.30E-06 | 2.58E-06 | 1.72E-06 | 8.60E-06 |
| 47111 | MACON | Stationary Source Fuel Combustion, Industrial, Residual Oil | 3.99E-06 | 2.39E-06 | 1.60E-06 | 7.98E-06 |
| 47189 | WILSON | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 3.55E-06 | 2.13E-06 | 1.42E-06 | 7.10E-06 |
| 47111 | MACON | Stationary Source Fuel Combustion, Residential, Distillate Oil | 3.27E-06 | 1.96E-06 | 1.31E-06 | 6.54E-06 |
| 47111 | MACON | External Combustion Boilers, Industrial, Distillate Oil | 2.60E-06 | 1.56E-06 | 1.04E-06 | 5.20E-06 |
| 47165 | SUMNER | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 2.40E-06 | 1.44E-06 | 9.60E-07 | 4.80E-06 |
| 47165 | SUMNER | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 1.57E-06 | 9.40E-07 | 6.30E-07 | 3.14E-06 |
| 47189 | WILSON | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 1.31E-06 | 7.90E-07 | 5.20E-07 | 2.62E-06 |
| 47111 | MACON | Miscellaneous Area Sources, Other Combustion, Cremation | 5.10E-07 | 1.33E-06 | 4.60E-07 | 2.30E-06 |
| 47189 | WILSON | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 1.03E-06 | 6.20E-07 | 4.10E-07 | 2.06E-06 |
| 47111 | MACON | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 8.30E-07 | 5.00E-07 | 3.30E-07 | 1.66E-06 |
| 47111 | MACON | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 4.20E-07 | 2.50E-07 | 1.70E-07 | 8.40E-07 |
| 47111 | MACON | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 1.10E-07 | 7.00E-08 | 5.00E-08 | 2.30E-07 |

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 47165 | SUMNER | Industrial Processes, Chemical Manufacturing, Other Not Classified | 5.00E-08 | 1.00E-08 | 1.00E-08 | 7.00E-08 |
| 47189 | WILSON | Industrial Processes, Chemical Manufacturing, Other Not Classified | 5.00E-08 | 1.00E-08 | 1.00E-08 | 7.00E-08 |
| 47165 | SUMNER | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 4.00E-08 | 0.00E+00 | 0.00E+00 | 4.00E-08 |
| 47189 | WILSON | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 3.00E-08 | 0.00E+00 | 0.00E+00 | 3.00E-08 |
| 47111 | MACON | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 1.00E-08 | 0.00E+00 | 0.00E+00 | 1.00E-08 |

## Table C-26a. Point Sources Included in the Collective Sources Tag for Utah.

Only sources in the vicinity of the maximum in-state contribution to mercury deposition are included.

| FIPS | County | Facility Name | Plant ID | Point ID | Stack ID | Latitude | Longitude | StkHt (m) | Diam (m) | Temp (K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 49029 | MORGAN | Holcim (US) Inc. | N/A | N/A | N/A | 41.0614 | -111.5296 | 89.0 | 3.43 | 533 | 8.4 | 5.42E-03 | 1.87E-03 | 2.06E-03 | 9.35E-03 |

## Table C-26b. Non-point Sources Included in the Collective Sources Tag for Utah.

The county in the vicinity of the maximum in-state contribution to mercury deposition with significant non-point emissions is included.

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 49029 | MORGAN | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 2.38E-05 | 0.00E+00 | 0.00E+00 | 2.38E-05 |
| 49029 | MORGAN | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 3.25E-06 | 1.95E-06 | 1.30E-06 | 6.50E-06 |
| 49029 | MORGAN | External Combustion Boilers, Industrial, Liquid Waste | 1.02E-06 | 6.10E-07 | 4.10E-07 | 2.04E-06 |
| 49029 | MORGAN | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 8.20E-07 | 4.90E-07 | 3.30E-07 | 1.64E-06 |
| 49029 | MORGAN | Stationary Source Fuel Combustion, Industrial, Residual Oil | 7.50E-07 | 4.50E-07 | 3.00E-07 | 1.50E-06 |
| 49029 | MORGAN | Miscellaneous Area Sources, Other Combustion, Cremation | 3.10E-07 | 8.30E-07 | 2.90E-07 | 1.43E-06 |
| 49029 | MORGAN | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 5.50E-07 | 3.30E-07 | 2.20E-07 | 1.10E-06 |
| 49029 | MORGAN | External Combustion Boilers, Industrial, Distillate Oil | 4.80E-07 | 2.90E-07 | 1.90E-07 | 9.60E-07 |
| 49029 | MORGAN | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 1.90E-07 | 1.10E-07 | 7.00E-08 | 3.70E-07 |
| 49029 | MORGAN | Stationary Source Fuel Combustion, Residential, Distillate Oil | 1.10E-07 | 7.00E-08 | 4.00E-08 | 2.20E-07 |

## Table C-27a. Point Sources Included in the Collective Sources Tag for Virginia.

Only sources in the vicinity of the maximum in-state contribution to mercury deposition are included.

| FIPS | County | Facility Name | Plant ID | Point ID | Stack ID | Latitude | Longitude | StkHt (m) | Diam (m) | Temp (K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 51710 | Norfolk | STERICYCLE_INC.(FORMERLYAMERICANWASTEIND | MWI-39 | 39—1 | 89 | 36.8345 | -76.2727 | 4.6 | 0.29 | 512 | 3.2 | 1.45E-03 | 2.18E-02 | 5.81E-03 | 2.91E-02 |
| 51710 | Norfolk | STERICYCLE_INC.(FORMERLYAMERICANWASTEIND | MWI-39 | 39—2 | 90 | 36.8345 | -76.2727 | 4.6 | 0.29 | 512 | 3.2 | 1.45E-03 | 2.18E-02 | 5.81E-03 | 2.91E-02 |
| 51740 | Portsmouth | SPSAWastetoEnergySteam&PowerPlant | LMWC-64 | LMWC-3 | 35413 | 36.8676 | -76.3770 | 3.0 | 0.30 | 295 | 4.6 | 7.11E-04 | 1.87E-03 | 6.46E-04 | 3.23E-03 |
| 51740 | Portsmouth | SPSAWastetoEnergySteam&PowerPlant | LMWC-64 | LMWC-1 | 35411 | 36.8676 | -76.3770 | 3.0 | 0.30 | 295 | 4.6 | 3.81E-04 | 1.00E-03 | 3.46E-04 | 1.73E-03 |
| 51740 | Portsmouth | SPSAWastetoEnergySteam&PowerPlant | LMWC-64 | LMWC-4 | 35414 | 36.8676 | -76.3770 | 3.0 | 0.30 | 295 | 4.6 | 3.23E-04 | 8.53E-04 | 2.94E-04 | 1.47E-03 |
| 51740 | Portsmouth | SPSAWastetoEnergySteam&PowerPlant | LMWC-64 | LMWC-2 | 35412 | 36.8676 | -76.3770 | 3.0 | 0.30 | 295 | 4.6 | 2.60E-04 | 6.84E-04 | 2.36E-04 | 1.18E-03 |
| 51550 | Chesapeake | CARGILLINC | 15334 | 59766 | 35357 | 36.8039 | -76.2856 | 43.1 | 2.01 | 461 | 10.3 | 7.67E-05 | 4.60E-05 | 3.07E-05 | 1.53E-04 |
| 51810 | Virginia Beach | HamptonRoadsSanitationDist.-AtlanticPlan | 51810M001 | A3326 | 35454 | 36.8369 | -76.0256 | 12.3 | 1.04 | 595 | 25.6 | 3.93E-05 | 2.36E-05 | 1.57E-05 | 7.87E-05 |
| 51710 | Norfolk | ThrasherDebrisLandfill | LF3912 | A848 | 35402 | 36.7379 | -76.1955 | 3.0 | 0.00 | 295 | 0.0 | 2.40E-05 | 3.01E-06 | 3.01E-06 | 3.01E-05 |
| 51650 | Hampton | HamptonCityLF | LF7087 | A1564 | 35371 | 37.0411 | -76.3623 | 3.0 | 0.00 | 295 | 0.0 | 1.47E-05 | 1.84E-06 | 1.84E-06 | 1.84E-05 |
| 51710 | Norfolk | HamptonRoadsSanitationDist.-VIP | 517100197 | A3300 | 35397 | 36.8819 | -76.3172 | 8.7 | 0.46 | 493 | 19.2 | 9.05E-06 | 5.43E-06 | 3.62E-06 | 1.81E-05 |
| 51650 | Hampton | WilliamsPavingCo-bigBethel | LF7088 | A1565 | 35372 | 37.0764 | -76.3833 | 3.0 | 0.00 | 295 | 0.0 | 1.40E-05 | 1.75E-06 | 1.75E-06 | 1.75E-05 |
| 51810 | Virginia Beach | VirginiaBeachLandfillWasteManagement | LF642 | A1447 | 35457 | 36.7891 | -76.2020 | 3.0 | 0.00 | 295 | 0.0 | 1.25E-05 | 1.56E-06 | 1.56E-06 | 1.56E-05 |
| 51810 | Virginia Beach | CHRISTIANBROADCASTINGNETWORK | 518100030 | A3323 | 35450 | 36.8031 | -76.1936 | 12.3 | 1.04 | 595 | 25.6 | 6.98E-06 | 4.19E-06 | 2.79E-06 | 1.40E-05 |
| 51710 | Norfolk | NavalBaseNorfolk | 51710F002 | A3301 | 35400 | 36.8950 | -76.2590 | 12.3 | 1.04 | 595 | 25.6 | 6.91E-06 | 4.15E-06 | 2.76E-06 | 1.38E-05 |
| 51650 | Hampton | BethelLandfill | LF7089 | A1566 | 35373 | 37.0411 | -76.3623 | 3.0 | 0.00 | 295 | 0.0 | 6.66E-06 | 8.30E-07 | 8.30E-07 | 8.32E-06 |
| 51550 | Chesapeake | ChesapeakeCity/CivicCtrLF | LF9070 | A6685 | 35364 | 36.7650 | -76.2860 | 3.0 | 0.00 | 295 | 0.0 | 5.79E-06 | 7.20E-07 | 7.20E-07 | 7.23E-06 |
| 51740 | Portsmouth | NavalMedicalCenterPortsmouth(PWCN.) | 517400007 | A3306 | 35408 | 36.8442 | -76.3064 | 8.7 | 0.46 | 493 | 19.2 | 3.58E-06 | 2.15E-06 | 1.43E-06 | 7.16E-06 |
| 51740 | Portsmouth | NORFOLKVENEERMILLS | 14647 | 59329 | 35406 | 36.8083 | -76.2956 | 20.7 | 0.98 | 476 | 10.4 | 3.27E-06 | 1.96E-06 | 1.31E-06 | 6.54E-06 |
| 51650 | Hampton | LangleyAFB | 516500007 | A3290 | 35367 | 37.0706 | -76.3608 | 12.3 | 1.04 | 595 | 25.6 | 2.86E-06 | 1.72E-06 | 1.15E-06 | 5.73E-06 |
| 51810 | Virginia Beach | LittleCreekNavalAmphibiousBase | 518100013 | A3328 | 35449 | 36.9089 | -76.1753 | 12.3 | 1.04 | 595 | 25.6 | 1.89E-06 | 1.13E-06 | 7.60E-07 | 3.78E-06 |
| 51810 | Virginia Beach | FCTCLANTDAMNECK | 518100006 | A3324 | 35447 | 36.7717 | -75.9644 | 12.3 | 1.04 | 595 | 25.6 | 1.37E-06 | 8.20E-07 | 5.50E-07 | 2.74E-06 |
| 51650 | Hampton | BigBethelRdLandfill/WilliamsPavingCo | LF7085 | A1562 | 35369 | 37.0764 | -76.3833 | 3.0 | 0.00 | 295 | 0.0 | 2.00E-06 | 2.50E-07 | 2.50E-07 | 2.50E-06 |
| 51810 | Virginia Beach | OceanaNavalAirStation | 518100004 | A3330 | 35445 | 36.8092 | -76.0381 | 12.3 | 1.04 | 595 | 25.6 | 1.09E-06 | 6.50E-07 | 4.40E-07 | 2.18E-06 |
| 51710 | Norfolk | NCTAMSLANTNorfolk | 51710F001 | A3304 | 35399 | 36.8950 | -76.2590 | 8.7 | 0.46 | 493 | 19.2 | 1.01E-06 | 6.10E-07 | 4.00E-07 | 2.02E-06 |

| FIPS | County | Facility Name | Plant ID | Point ID | Stack ID | Latitude | Longitude | StkHt (m) | Diam (m) | Temp (K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 51810 | Virginia Beach | FewIncDebrisLandfill | LF640 | A1435 | 35455 | 36.8857 | -76.1836 | 3.0 | 0.00 | 295 | 0.0 | 1.30E-06 | 1.60E-07 | 1.60E-07 | 1.62E-06 |
| 51710 | Norfolk | FISCNorfolk | 517100204 | A3298 | 35398 | 36.9406 | -76.3258 | 8.7 | 0.46 | 493 | 19.2 | 7.30E-07 | 4.40E-07 | 2.90E-07 | 1.46E-06 |
| 51810 | Virginia Beach | LakesideConstruction | LF641 | A4529 | 35456 | 36.7411 | -76.0480 | 3.0 | 0.00 | 295 | 0.0 | 1.16E-06 | 1.50E-07 | 1.50E-07 | 1.46E-06 |
| 51810 | Virginia Beach | CentervilleTpk/MtTrashmoreli | LF643 | A4541 | 35458 | 36.7411 | -76.0480 | 3.0 | 0.00 | 295 | 0.0 | 1.08E-06 | 1.40E-07 | 1.40E-07 | 1.36E-06 |
| 51810 | Virginia Beach | FORTSTORY | 518100005 | A3325 | 35446 | 36.9244 | -76.0081 | 12.3 | 1.04 | 595 | 25.6 | 6.30E-07 | 3.80E-07 | 2.50E-07 | 1.26E-06 |
| 51740 | Portsmouth | NorfolkNavalShipyard(PWCNorfolk) | 517400006 | A3307 | 35407 | 36.8156 | -76.3006 | 12.3 | 1.04 | 595 | 25.6 | 5.20E-07 | 3.10E-07 | 2.10E-07 | 1.04E-06 |
| 51650 | Hampton | FORTMONROE | 516500052 | A3289 | 35368 | 37.0050 | -76.3036 | 12.3 | 1.04 | 595 | 25.6 | 4.60E-07 | 2.80E-07 | 1.80E-07 | 9.20E-07 |
| 51810 | Virginia Beach | NSGANorthwest | 51810F001 | A3329 | 35453 | 36.7411 | -76.0480 | 3.0 | 0.30 | 295 | 4.6 | 4.10E-07 | 2.50E-07 | 1.70E-07 | 8.30E-07 |
| 51550 | Chesapeake | CHESAPEAKEGENERALHOSPITAL | 515500051 | A3283 | 35358 | 36.7506 | -76.2411 | 12.3 | 1.04 | 595 | 25.6 | 3.30E-07 | 2.00E-07 | 1.30E-07 | 6.60E-07 |
| 51810 | Virginia Beach | VABEACHGENHOSPITAL | 518100008 | A3331 | 35448 | 36.8650 | -76.0264 | 12.3 | 1.04 | 595 | 25.6 | 3.30E-07 | 2.00E-07 | 1.30E-07 | 6.60E-07 |
| 51740 | Portsmouth | MARYVIEWHOSPITAL | 517400012 | A3305 | 35409 | 36.8364 | -76.3492 | 12.3 | 1.04 | 595 | 25.6 | 3.20E-07 | 1.90E-07 | 1.30E-07 | 6.40E-07 |
| 51710 | Norfolk | NAVYPUBLICWKSCTR | 517100010 | A3303 | 35395 | 36.9469 | -76.3194 | 12.3 | 1.04 | 595 | 25.6 | 2.30E-07 | 1.40E-07 | 9.00E-08 | 4.60E-07 |
| 51800 | Suffolk | HollandLandfill/Suffolk | LF1254 | A156 | 35441 | 36.8253 | -76.3196 | 3.0 | 0.00 | 295 | 0.0 | 3.20E-07 | 4.00E-08 | 4.00E-08 | 4.00E-07 |
| 51650 | Hampton | WilliamsBigBethelRdLF | LF7086 | A1563 | 35370 | 37.0764 | -76.3833 | 3.0 | 0.00 | 295 | 0.0 | 3.10E-07 | 4.00E-08 | 4.00E-08 | 3.90E-07 |
| 51550 | Chesapeake | SOUTHEASTERNVATRAININGCENTER | 515500086 | A3287 | 35359 | 36.7933 | -76.2247 | 8.7 | 0.46 | 493 | 19.2 | 1.90E-07 | 1.20E-07 | 8.00E-08 | 3.90E-07 |
| 51810 | Virginia Beach | WESTMINSTER-CANTERBURY | 518100042 | A3332 | 35452 | 36.9094 | -76.0800 | 12.3 | 1.04 | 595 | 25.6 | 1.80E-07 | 1.10E-07 | 7.00E-08 | 3.60E-07 |
| 51700 | Newport News | HamptonRoadsSanitationDist.-BoatHarbor | 517000068 | A3296 | 35388 | 36.9885 | -76.4212 | 8.7 | 0.46 | 493 | 19.2 | 1.40E-07 | 8.00E-08 | 6.00E-08 | 2.80E-07 |
| 51710 | Norfolk | HamptonRoadsSanitationDist.-ArmyBase | 517100196 | A3299 | 35396 | 36.9214 | -76.3258 | 8.7 | 0.46 | 493 | 19.2 | 1.40E-07 | 8.00E-08 | 6.00E-08 | 2.80E-07 |
| 51550 | Chesapeake | MORSONINC | 14633 | 59303 | 35356 | 36.7622 | -76.2281 | 19.9 | 0.98 | 418 | 10.1 | 1.40E-07 | 8.00E-08 | 6.00E-08 | 2.80E-07 |
| 51810 | Virginia Beach | HamptonRoadsSanitationDist.-Chesapeake-E | 518100034 | A3327 | 35451 | 36.9067 | -76.1664 | 8.7 | 0.46 | 493 | 19.2 | 1.40E-07 | 8.00E-08 | 6.00E-08 | 2.80E-07 |
| 51740 | Portsmouth | St.Julien'sCreekAnnex(PWCNorfolk) | 51740F001 | A3308 | 35410 | 36.8676 | -76.3770 | 12.3 | 1.04 | 595 | 25.6 | 1.30E-07 | 8.00E-08 | 5.00E-08 | 2.60E-07 |

## Table C-27b. Non-point Sources Included in the Collective Sources Tag for Virginia.

Counties in the vicinity of the maximum in-state contribution to mercury deposition with significant non-point emissions are included.

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 51810 | VIRGINIA BEACH | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 1.51E-03 | 0.00E+00 | 0.00E+00 | 1.51E-03 |
| 51810 | VIRGINIA BEACH | Stationary Source Fuel Combustion, Residential, Distillate Oil | 7.55E-04 | 4.53E-04 | 3.02E-04 | 1.51E-03 |
| 51810 | VIRGINIA BEACH | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 1.43E-03 | 0.00E+00 | 0.00E+00 | 1.43E-03 |
| 51710 | NORFOLK | Stationary Source Fuel Combustion, Residential, Distillate Oil | 6.71E-04 | 4.02E-04 | 2.68E-04 | 1.34E-03 |
| 51710 | NORFOLK | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Dental Alloy (Mercury Amalgams) Production | 1.17E-03 | 0.00E+00 | 0.00E+00 | 1.17E-03 |
| 51700 | NEWPORT NEWS | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Dental Alloy (Mercury Amalgams) Production | 1.07E-03 | 0.00E+00 | 0.00E+00 | 1.07E-03 |
| 51810 | VIRGINIA BEACH | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 4.47E-04 | 2.68E-04 | 1.79E-04 | 8.93E-04 |
| 51550 | CHESAPEAKE | Stationary Source Fuel Combustion, Residential, Distillate Oil | 4.17E-04 | 2.50E-04 | 1.67E-04 | 8.33E-04 |
| 51710 | NORFOLK | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 7.87E-04 | 0.00E+00 | 0.00E+00 | 7.87E-04 |
| 51700 | NEWPORT NEWS | Stationary Source Fuel Combustion, Residential, Distillate Oil | 3.81E-04 | 2.29E-04 | 1.52E-04 | 7.62E-04 |
| 51710 | NORFOLK | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 7.45E-04 | 0.00E+00 | 0.00E+00 | 7.45E-04 |
| 51550 | CHESAPEAKE | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 7.06E-04 | 0.00E+00 | 0.00E+00 | 7.06E-04 |
| 51550 | CHESAPEAKE | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 6.69E-04 | 0.00E+00 | 0.00E+00 | 6.69E-04 |
| 51700 | NEWPORT NEWS | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 6.24E-04 | 0.00E+00 | 0.00E+00 | 6.24E-04 |
| 51700 | NEWPORT NEWS | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 5.91E-04 | 0.00E+00 | 0.00E+00 | 5.91E-04 |
| 51810 | VIRGINIA BEACH | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Dental Alloy (Mercury Amalgams) Production | 4.86E-04 | 0.00E+00 | 0.00E+00 | 4.86E-04 |
| 51650 | HAMPTON | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 4.78E-04 | 0.00E+00 | 0.00E+00 | 4.78E-04 |
| 51650 | HAMPTON | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 4.53E-04 | 0.00E+00 | 0.00E+00 | 4.53E-04 |
| 51650 | HAMPTON | Stationary Source Fuel Combustion, Residential, Distillate Oil | 2.13E-04 | 1.28E-04 | 8.50E-05 | 4.25E-04 |
| 51700 | NEWPORT NEWS | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 2.05E-04 | 1.23E-04 | 8.21E-05 | 4.11E-04 |
| 51550 | CHESAPEAKE | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 2.00E-04 | 1.20E-04 | 8.01E-05 | 4.01E-04 |
| 51550 | CHESAPEAKE | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Dental Alloy (Mercury Amalgams) Production | 3.89E-04 | 0.00E+00 | 0.00E+00 | 3.89E-04 |
| 51740 | PORTSMOUTH | Stationary Source Fuel Combustion, Residential, Distillate Oil | 1.67E-04 | 1.00E-04 | 6.68E-05 | 3.34E-04 |
| 51740 | PORTSMOUTH | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 3.24E-04 | 0.00E+00 | 0.00E+00 | 3.24E-04 |

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 51650 | HAMPTON | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Dental Alloy (Mercury Amalgams) Production | 2.05E-04 | 0.00E+00 | 0.00E+00 | 2.05E-04 |
| 51740 | PORTSMOUTH | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Dental Alloy (Mercury Amalgams) Production | 2.05E-04 | 0.00E+00 | 0.00E+00 | 2.05E-04 |
| 51740 | PORTSMOUTH | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 8.16E-05 | 4.90E-05 | 3.27E-05 | 1.63E-04 |
| 51700 | NEWPORT NEWS | External Combustion Boilers, Industrial, Liquid Waste | 7.55E-05 | 4.53E-05 | 3.02E-05 | 1.51E-04 |
| 51810 | VIRGINIA BEACH | Miscellaneous Area Sources, Other Combustion, Cremation | 2.70E-05 | 7.13E-05 | 2.46E-05 | 1.23E-04 |
| 51710 | NORFOLK | External Combustion Boilers, Industrial, Liquid Waste | 4.26E-05 | 2.56E-05 | 1.71E-05 | 8.52E-05 |
| 51700 | NEWPORT NEWS | External Combustion Boilers, Industrial, Distillate Oil | 3.59E-05 | 2.15E-05 | 1.44E-05 | 7.18E-05 |
| 51710 | NORFOLK | Miscellaneous Area Sources, Other Combustion, Cremation | 1.41E-05 | 3.71E-05 | 1.28E-05 | 6.40E-05 |
| 51550 | CHESAPEAKE | Miscellaneous Area Sources, Other Combustion, Cremation | 1.26E-05 | 3.33E-05 | 1.15E-05 | 5.75E-05 |
| 51810 | VIRGINIA BEACH | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 2.54E-05 | 1.52E-05 | 1.02E-05 | 5.08E-05 |
| 51700 | NEWPORT NEWS | Miscellaneous Area Sources, Other Combustion, Cremation | 1.12E-05 | 2.94E-05 | 1.02E-05 | 5.08E-05 |
| 51810 | VIRGINIA BEACH | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 2.25E-05 | 1.35E-05 | 9.01E-06 | 4.51E-05 |
| 51710 | NORFOLK | External Combustion Boilers, Industrial, Distillate Oil | 2.03E-05 | 1.22E-05 | 8.11E-06 | 4.05E-05 |
| 51710 | NORFOLK | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 1.99E-05 | 1.20E-05 | 7.97E-06 | 3.99E-05 |
| 51650 | HAMPTON | Miscellaneous Area Sources, Other Combustion, Cremation | 8.55E-06 | 2.26E-05 | 7.78E-06 | 3.89E-05 |
| 51810 | VIRGINIA BEACH | External Combustion Boilers, Industrial, Liquid Waste | 1.91E-05 | 1.15E-05 | 7.64E-06 | 3.82E-05 |
| 51710 | NORFOLK | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 1.78E-05 | 1.07E-05 | 7.12E-06 | 3.56E-05 |
| 51550 | CHESAPEAKE | External Combustion Boilers, Industrial, Liquid Waste | 1.59E-05 | 9.51E-06 | 6.34E-06 | 3.17E-05 |
| 51810 | VIRGINIA BEACH | Stationary Source Fuel Combustion, Industrial, Residual Oil | 1.40E-05 | 8.37E-06 | 5.58E-06 | 2.79E-05 |
| 51740 | PORTSMOUTH | Miscellaneous Area Sources, Other Combustion, Cremation | 6.13E-06 | 1.62E-05 | 5.57E-06 | 2.79E-05 |
| 51650 | HAMPTON | External Combustion Boilers, Industrial, Liquid Waste | 1.23E-05 | 7.36E-06 | 4.91E-06 | 2.45E-05 |
| 51700 | NEWPORT NEWS | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 1.17E-05 | 7.01E-06 | 4.67E-06 | 2.34E-05 |
| 51550 | CHESAPEAKE | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 1.14E-05 | 6.83E-06 | 4.56E-06 | 2.28E-05 |
| 51700 | NEWPORT NEWS | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 9.79E-06 | 5.88E-06 | 3.92E-06 | 1.96E-05 |
| 51550 | CHESAPEAKE | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 9.42E-06 | 5.65E-06 | 3.77E-06 | 1.88E-05 |
| 51810 | VIRGINIA BEACH | External Combustion Boilers, Industrial, Distillate Oil | 9.07E-06 | 5.45E-06 | 3.63E-06 | 1.82E-05 |
| 51650 | HAMPTON | Stationary Source Fuel Combustion, Industrial, Residual Oil | 8.97E-06 | 5.38E-06 | 3.59E-06 | 1.79E-05 |
| 51650 | HAMPTON | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 8.96E-06 | 5.38E-06 | 3.58E-06 | 1.79E-05 |

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 51650 | HAMPTON | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 7.80E-06 | 4.68E-06 | 3.12E-06 | 1.56E-05 |
| 51550 | CHESAPEAKE | External Combustion Boilers, Industrial, Distillate Oil | 7.53E-06 | 4.52E-06 | 3.01E-06 | 1.51E-05 |
| 51740 | PORTSMOUTH | External Combustion Boilers, Industrial, Liquid Waste | 6.72E-06 | 4.04E-06 | 2.69E-06 | 1.35E-05 |
| 51740 | PORTSMOUTH | Stationary Source Fuel Combustion, Industrial, Residual Oil | 4.91E-06 | 2.95E-06 | 1.97E-06 | 9.83E-06 |
| 51740 | PORTSMOUTH | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 4.64E-06 | 2.79E-06 | 1.86E-06 | 9.29E-06 |
| 51710 | NORFOLK | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 4.33E-06 | 2.60E-06 | 1.73E-06 | 8.66E-06 |
| 51740 | PORTSMOUTH | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 4.24E-06 | 2.54E-06 | 1.70E-06 | 8.48E-06 |
| 51740 | PORTSMOUTH | External Combustion Boilers, Industrial, Distillate Oil | 3.20E-06 | 1.92E-06 | 1.28E-06 | 6.40E-06 |
| 51810 | VIRGINIA BEACH | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 3.16E-06 | 1.89E-06 | 1.26E-06 | 6.31E-06 |
| 51710 | NORFOLK | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 2.49E-06 | 1.49E-06 | 1.00E-06 | 4.98E-06 |
| 51700 | NEWPORT NEWS | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 1.37E-06 | 8.20E-07 | 5.50E-07 | 2.74E-06 |
| 51550 | CHESAPEAKE | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 1.32E-06 | 7.90E-07 | 5.30E-07 | 2.64E-06 |
| 51700 | NEWPORT NEWS | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 1.28E-06 | 7.60E-07 | 5.10E-07 | 2.55E-06 |
| 51650 | HAMPTON | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 1.09E-06 | 6.50E-07 | 4.40E-07 | 2.18E-06 |
| 51810 | VIRGINIA BEACH | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 7.80E-07 | 4.70E-07 | 3.10E-07 | 1.56E-06 |
| 51740 | PORTSMOUTH | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 6.00E-07 | 3.60E-07 | 2.40E-07 | 1.20E-06 |
| 51550 | CHESAPEAKE | Industrial Processes, Chemical Manufacturing, Other Not Classified | 8.40E-07 | 1.00E-07 | 1.00E-07 | 1.04E-06 |
| 51550 | CHESAPEAKE | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 4.50E-07 | 2.70E-07 | 1.80E-07 | 9.00E-07 |
| 51650 | HAMPTON | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 3.70E-07 | 2.20E-07 | 1.50E-07 | 7.40E-07 |
| 51740 | PORTSMOUTH | Industrial Processes, Chemical Manufacturing, Other Not Classified | 2.10E-07 | 3.00E-08 | 3.00E-08 | 2.70E-07 |
| 51710 | NORFOLK | Stationary Source Fuel Combustion, Residential, Anthracite Coal | 1.00E-07 | 6.00E-08 | 4.00E-08 | 2.00E-07 |
| 51810 | VIRGINIA BEACH | Industrial Processes, Chemical Manufacturing, Other Not Classified | 1.40E-07 | 2.00E-08 | 2.00E-08 | 1.80E-07 |
| 51810 | VIRGINIA BEACH | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 1.40E-07 | 0.00E+00 | 0.00E+00 | 1.40E-07 |
| 51550 | CHESAPEAKE | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 7.00E-08 | 0.00E+00 | 0.00E+00 | 7.00E-08 |
| 51710 | NORFOLK | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 7.00E-08 | 0.00E+00 | 0.00E+00 | 7.00E-08 |
| 51700 | NEWPORT NEWS | Stationary Source Fuel Combustion, Residential, Anthracite Coal | 3.00E-08 | 2.00E-08 | 1.00E-08 | 6.00E-08 |

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 51700 | NEWPORT NEWS | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 6.00E-08 | 0.00E+00 | 0.00E+00 | 6.00E-08 |
| 51650 | HAMPTON | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 5.00E-08 | 0.00E+00 | 0.00E+00 | 5.00E-08 |
| 51810 | VIRGINIA BEACH | Stationary Source Fuel Combustion, Residential, Anthracite Coal | 2.00E-08 | 1.00E-08 | 1.00E-08 | 4.00E-08 |
| 51710 | NORFOLK | Industrial Processes, Chemical Manufacturing, Other Not Classified | 3.00E-08 | 0.00E+00 | 0.00E+00 | 3.00E-08 |
| 51740 | PORTSMOUTH | Industrial Processes, Electrical Equipment, Fluorescent Lamp Recycling | 3.00E-08 | 0.00E+00 | 0.00E+00 | 3.00E-08 |
| 51550 | CHESAPEAKE | Stationary Source Fuel Combustion, Residential, Anthracite Coal | 1.00E-08 | 1.00E-08 | 0.00E+00 | 2.00E-08 |
| 51650 | HAMPTON | Stationary Source Fuel Combustion, Residential, Anthracite Coal | 1.00E-08 | 1.00E-08 | 0.00E+00 | 2.00E-08 |
| 51650 | HAMPTON | Industrial Processes, Chemical Manufacturing, Other Not Classified | 2.00E-08 | 0.00E+00 | 0.00E+00 | 2.00E-08 |
| 51700 | NEWPORT NEWS | Industrial Processes, Chemical Manufacturing, Other Not Classified | 1.00E-08 | 0.00E+00 | 0.00E+00 | 1.00E-08 |

### Table C-28a. Point Sources Included in the Collective Sources Tag for Wyoming.

Only sources in the vicinity of the maximum in-state contribution to mercury deposition are included.

| FIPS | County | Facility Name | Plant ID | Point ID | Stack ID | Latitude | Longitude | StkHt (m) | Diam (m) | Temp (K) | Vel (m/s) | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 56045 | Weston | BLACKHILLSOSAGE | 58182 | 135277 | 4568 | 43.9600 | -104.4000 | 38.1 | 2.96 | 446 | 27.1 | 1.24E-02 | 7.43E-03 | 4.95E-03 | 2.48E-02 |

## Table C-28b. Non-point Sources Included in the Collective Sources Tag for Wyoming.

The county in the vicinity of the maximum in-state contribution to mercury deposition with significant non-point emissions is included.

| FIPS | County | Source Description | HG0 (tpy) | HG2 (tpy) | HGP (tpy) | Total Hg (tpy) |
|---|---|---|---|---|---|---|
| 56045 | WESTON | Stationary Source Fuel Combustion, Residential, Bituminous/Subbituminous Coal | 1.59E-05 | 9.52E-06 | 6.35E-06 | 3.17E-05 |
| 56045 | WESTON | Miscellaneous Area Sources, Fluorescent Lamp Breakage, Total | 2.23E-05 | 0.00E+00 | 0.00E+00 | 2.23E-05 |
| 56045 | WESTON | Industrial Processes, Photo Equip/Health Care/Labs/Air Condit/SwimPools, Laboratories | 2.11E-05 | 0.00E+00 | 0.00E+00 | 2.11E-05 |
| 56045 | WESTON | Stationary Source Fuel Combustion, Residential, Distillate Oil | 5.35E-06 | 3.21E-06 | 2.14E-06 | 1.07E-05 |
| 56045 | WESTON | Stationary Source Fuel Combustion, Commercial/Institutional, Distillate Oil | 3.82E-06 | 2.29E-06 | 1.53E-06 | 7.64E-06 |
| 56045 | WESTON | Miscellaneous Area Sources, Other Combustion, Cremation | 6.00E-07 | 1.59E-06 | 5.50E-07 | 2.74E-06 |
| 56045 | WESTON | External Combustion Boilers, Industrial, Liquid Waste | 8.20E-07 | 4.90E-07 | 3.30E-07 | 1.64E-06 |
| 56045 | WESTON | Stationary Source Fuel Combustion, Industrial, Residual Oil | 6.00E-07 | 3.60E-07 | 2.40E-07 | 1.20E-06 |
| 56045 | WESTON | External Combustion Boilers, Industrial, Distillate Oil | 3.90E-07 | 2.30E-07 | 1.60E-07 | 7.80E-07 |
| 56045 | WESTON | Stationary Source Fuel Combustion, Commercial/Institutional, Residual Oil | 2.20E-07 | 1.30E-07 | 9.00E-08 | 4.40E-07 |
| 56045 | WESTON | Stationary Source Fuel Combustion, Commercial/Institutional, Bituminous/Subbituminous Coal | 1.80E-07 | 1.10E-07 | 7.00E-08 | 3.60E-07 |
| 56045 | WESTON | Stationary Source Fuel Combustion, Commercial/Institutional, Anthracite Coal | 3.00E-08 | 1.00E-08 | 1.00E-08 | 5.00E-08 |

## References

EPA Region 9. 2007. E-mail correspondence from S. Chilingaryan with attachment "speciationformodelingoct31.xls" dated October 31, 2007.

NDEP. 2007. E-mail correspondence from F. Forsgren with attachments '2006 Cumulative

Mercury Emissions Data Submittal Public.xls' and 'VMRP testing Overview6.pdf' dated July 18, 2007

Western Environmental Services and Testing, Inc. 2006. "Mercury Emissions Test: Ontario Hydro Method." (http://ndep.nv.gov/bapc/mercury/2006_Queenstake_OHM.pdf.

# Appendix D: Sensitivity of REMSAD Results for Northern Utah to Precipitation Amount

## Introduction

This sensitivity analysis examines and quantifies the effects of rainfall amount on the REMSAD simulation results. High amounts of rainfall over northern Utah, southwestern Wyoming, and northwestern Colorado in the MM5-based files used as input to the REMSAD simulation result in high mercury wet deposition in this area. The MM5-derived precipitation input files were reviewed and it was found the simulated rainfall amounts to be higher than observed in the area of the country referenced above. To examine the effect of this overestimation of precipitation, a sensitivity simulation was conducted in which the rainfall amounts were reduced. Specifically, the rainfall amount was reduced based on the monthly ratio of observed to simulated rainfall at six meteorological monitoring sites. Adjustments were made to all grid cells within a rectangular area including the area of interest. For consistency, rain liquid water content was also adjusted. (Rain liquid water content is the amount of precipitable moisture in the air expressed as a mixing ratio.) The sensitivity simulation was run for a three-month period that includes June, July, and August of 2001. The effects of reducing the rainfall and other moisture-related parameters were quantified by comparing the simulated mercury deposition amounts to the original REMSAD simulation results.

The methods and results of the sensitivity analysis are presented in this appendix.

## Evaluation of the MM5-Based Meteorological Input Fields for Utah

The first step in this analysis was to examine how well the MM5-derived meteorological fields for 2001 represent the observed rainfall and other key meteorological parameters in northwestern Utah and the surrounding areas. The MM5 inputs were used in the recent REMSAD-based mercury deposition modeling analysis discussed in the main report. The evaluation methodology for the meteorological inputs was based on that used for the entire U.S., as discussed by Douglas et al. (2005).

Surface and upper-air meteorological monitoring sites were identified in the area of interest (which includes Salt Lake City and the surrounding areas) and compared the simulated and observed monthly average values of temperature, dew-point temperature, wind speed, wind direction, rainfall amount, and several other derived parameters.

Statistical measures (bias, unsigned error, and RMS error) were also used to compare the daily values of these parameters with observed data. These include:

Bias = $1/N \sum (S_l - O_l)$

Unsigned Error = $1/N \sum |S_l - O_l|$

RMS Error = $\sqrt{\left(\frac{1}{N}\right)\sum_{l=1}^{N}(S_l - O_l)^2}$

The surface and upper-air meteorological monitoring sites are listed in Table D-1.

**Table D-1. Locations and Identifiers of Surface and Upper-Air Monitoring Sites Used for the Statistical Evaluation of MM5 for Utah.**

| Site Name (ID) | Latitude | Longitude |
|---|---|---|
| | **Surface Sites** | |
| Salt Lake City, UT (24127) | 40°47'N | 111° 58'W |
| Logan, UT (94128) | 41°47'N | 111° 51'W |
| Ogden, UT (24126) | 41°12'N | 112° 01'W |
| Vernal, UT (94030) | 40°26'N | 109° 33'W |
| Evanston, WY (04111) | 41°16'N | 111° 02'W |
| Rock Springs, WY (24027) | 41°36'N | 109° 04'W |
| | **Upper-Air Sites** | |
| Salt Lake City, UT (24127) | 40°47'N | 111° 58'W |
| Riverton, WY (24127) | 43°04'N | 108° 28'W |

Note that for Rock Springs, data are available for May through December only.
A focal point of this comparison is rainfall amount, since this parameter is important in the simulation of mercury wet deposition. A visual comparison of plots of measured annual rainfall amount (Figure D-1a) and MM5 derived precipitation fields (Figure D-1b) shows relatively high amounts of precipitation estimated by MM5 over northwestern Utah and along the Utah/Colorado boundary. Similar high values of precipitation are not indicated by the observations (Figure D-1a). The observed precipitation plot was obtained from the National Atmospheric Deposition Program (NADP) web site (http://nadp.sws.uius.edu) (NADP 2005).

**Figure D-1a. Observed Annual Rainfall Totals (cm) for 2001.**

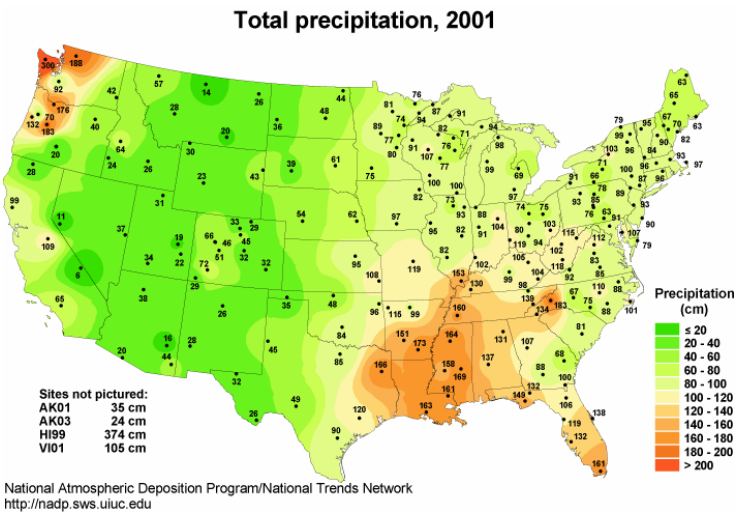
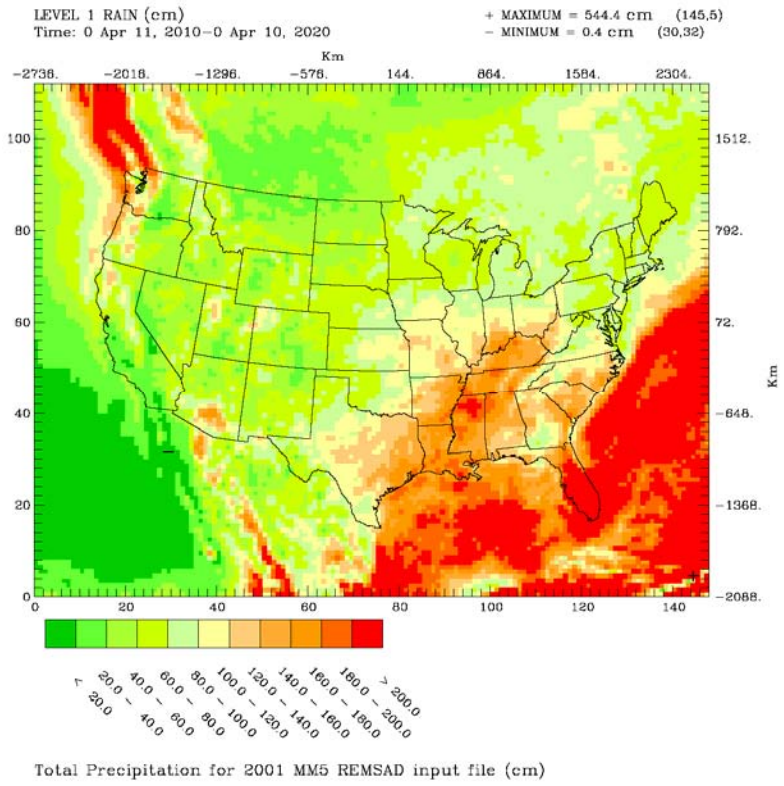


**Figure D-1b. MM5-Derived Annual Rainfall Totals (cm) for 2001.**




For each of the meteorological monitoring sites listed in Table D-1, MM5-derived monthly and annual mean values of a variety of surface and upper-air meteorological parameters were calculated and compared with the observed mean values. Monthly and annual values of the bias, unsigned error, and RMS error were also calculated. Table D-2 summarizes selected annual metrics and statistical measures for each surface monitoring site.

**Table D-2a. Summary of Annual Average Metrics and Statistical Measures for MM5 for the 2001 Annual Simulation Period: Salt Lake City, UT (Surface).**

| Parameter | Mean Observed | Mean Simulated | Bias | Unsigned Error |
|---|---|---|---|---|
| Maximum Temperature (°C) | 17.78 | 11.91 | -5.87 | 6.08 |
| Minimum Temperature (°C) | 6.89 | 2.34 | -4.56 | 4.70 |
| Dew Point Temperature (°C) | 0.73 | -2.49 | -3.21 | 3.73 |
| Surface Wind Speed ($ms^{-1}$) | 0.78 | 2.02 | 0.9 | 1.52 |
| Surface Wind Direction (degrees) | 166.81 | 149.39 | 2.65 | 59.58 |
| Total Daily Rainfall (in) | 0.04 | 0.07 | 0.03 | 0.06 |

**Table D-2b. Summary of Annual Average Metrics and Statistical Measures for MM5 for the 2001 Annual Simulation Period: Logan, UT (Surface).**

| Parameter | Mean Observed | Mean Simulated | Bias | Unsigned Error |
|---|---|---|---|---|
| Maximum Temperature (°C) | 15.47 | 11.08 | -4.39 | 5.44 |
| Minimum Temperature (°C) | 0.04 | 0.92 | 0.88 | 3.32 |
| Dew Point Temperature (°C) | -0.67 | -2.94 | -2.27 | 3.35 |
| Surface Wind Speed ($ms^{-1}$) | 0.27 | 1.21 | 1.83 | 1.90 |
| Surface Wind Direction (degrees) | 257.08 | 166.8 | 1.51 | 80.26 |
| Total Daily Rainfall (in) | 0.04 | 0.06 | 0.02 | 0.05 |

**Table D-2c. Summary of Annual Average Metrics and Statistical Measures for MM5 for the 2001 Annual Simulation Period: Ogden, UT (Surface).**

| Parameter | Mean Observed | Mean Simulated | Bias | Unsigned Error |
|---|---|---|---|---|
| Maximum Temperature (°C) | 16.85 | 11.99 | -4.86 | 5.02 |
| Minimum Temperature (°C) | 6.03 | 2.06 | -3.97 | 4.04 |
| Dew Point Temperature (°C) | -0.39 | -2.19 | -1.8 | 2.80 |
| Surface Wind Speed ($ms^{-1}$) | 1.31 | 1.48 | 0.65 | 1.23 |
| Surface Wind Direction (degrees) | 185.92 | 149.26 | 0.08 | 50.98 |
| Total Daily Rainfall (in) | 0.04 | 0.08 | 0.04 | 0.06 |

**Table D-2d. Summary of Annual Average Metrics and Statistical Measures for MM5 for the 2001 Annual Simulation Period: Vernal, UT (Surface).**

| Parameter | Mean Observed | Mean Simulated | Bias | Unsigned Error |
|---|---|---|---|---|
| Maximum Temperature (°C) | 16.23 | 10.92 | -5.32 | 5.55 |
| Minimum Temperature (°C) | 1.79 | 1.14 | -0.65 | 2.72 |
| Dew Point Temperature (°C) | -1.1 | -3.9 | -2.8 | 3.32 |
| Surface Wind Speed ($ms^{-1}$) | 0.82 | 1.92 | 1.87 | 1.95 |
| Surface Wind Direction (degrees) | 273.04 | 294.81 | 0.91 | 50.66 |
| Total Daily Rainfall (in) | 0.03 | 0.05 | 0.02 | 0.05 |

**Table D-2e. Summary of Annual Average Metrics and Statistical Measures for MM5 for the 2001 Annual Simulation Period: Evanston, WY (Surface).**

| Parameter | Mean Observed | Mean Simulated | Bias | Unsigned Error |
|---|---|---|---|---|
| Maximum Temperature (°C) | 11.87 | 11.43 | -0.44 | 1.74 |
| Minimum Temperature (°C) | 0.73 | 1.01 | 0.28 | 1.66 |
| Dew Point Temperature (°C) | -4.03 | -3.55 | 0.48 | 2.21 |
| Surface Wind Speed ($ms^{-1}$) | 2.22 | 2.43 | 0.4 | 0.89 |
| Surface Wind Direction (degrees) | 233.81 | 235.7 | 0.32 | 33.04 |
| Total Daily Rainfall (in) | 0.03 | 0.05 | 0.02 | 0.05 |

**Table D-2f. Summary of Annual Average Metrics and Statistical Measures for MM5 for the 2001 Annual Simulation Period: Rock Springs, WY (Surface).**

| Parameter | Mean Observed | Mean Simulated | Bias | Unsigned Error |
|---|---|---|---|---|
| Maximum Temperature (°C) | 18 | 16.15 | -1.86 | 2.43 |
| Minimum Temperature (°C) | 4.3 | 3.82 | -0.48 | 2.11 |
| Dew Point Temperature (°C) | -3.3 | -1.62 | 1.68 | 2.96 |
| Surface Wind Speed ($ms^{-1}$) | 2.85 | 2.71 | 0.06 | 1.33 |
| Surface Wind Direction (degrees) | 243.62 | 252.15 | 0.12 | 29.91 |
| Total Daily Rainfall (in) | 0.02 | 0.06 | 0.04 | 0.05 |

On an annual basis, the comparison of the simulated and observed values show that MM5 tends to underestimate surface temperature and dew point temperature and overestimate rainfall amounts. Surface wind speeds are also overestimated. Surface wind direction errors are on the order of 30 to 80 degrees considering all sites.

Table D-3 summarizes the annual metrics and statistical measures for the two upper-air monitoring sites for both sets of meteorological fields. For this analysis, the 700 mb level which is approximately 3000 meters above sea level was examined. This level was chosen to account for the high elevations in the area of interest.

**Table D-3a. Summary of Annual Metrics and Statistical Measures for MM5 for the 2001 Annual Simulation Period: Salt Lake City, UT (Upper-Air).**

| Parameter | Mean Observed | Mean Simulated | Bias | Unsigned Error |
|---|---|---|---|---|
| 700 mb Temperature (am) (°C) | 1.62 | 2.33 | 0.79 | 1.30 |
| 700 mb Temperature (pm) (°C) | 2.16 | 2.37 | 0.27 | 1.03 |
| 700 mb Dew Point Temperature (am) (°C) | -9.7 | -8.68 | 1.16 | 3.25 |
| 700 mb Dew Point Temperature (pm) (°C) | -10.19 | -7.51 | 2.7 | 4.13 |
| 700 mb Wind Speed (am) ($ms^{-1}$) | 4.87 | 3.79 | -0.73 | 2.50 |
| 700 mb Wind Speed (pm) (degrees) | 4.62 | 4.01 | -1.18 | 2.48 |
| 700 mb Wind Direction (am) ($ms^{-1}$) | 260.85 | 252.12 | 0.18 | 28.63 |
| 700 mb Wind Direction (pm) (degrees) | 245.84 | 241.74 | 0.67 | 24.27 |

**Table D-3b. Summary of Annual Metrics and Statistical Measures for MM5 for the 2001 Annual Simulation Period: Riverton, WY (Upper-Air).**

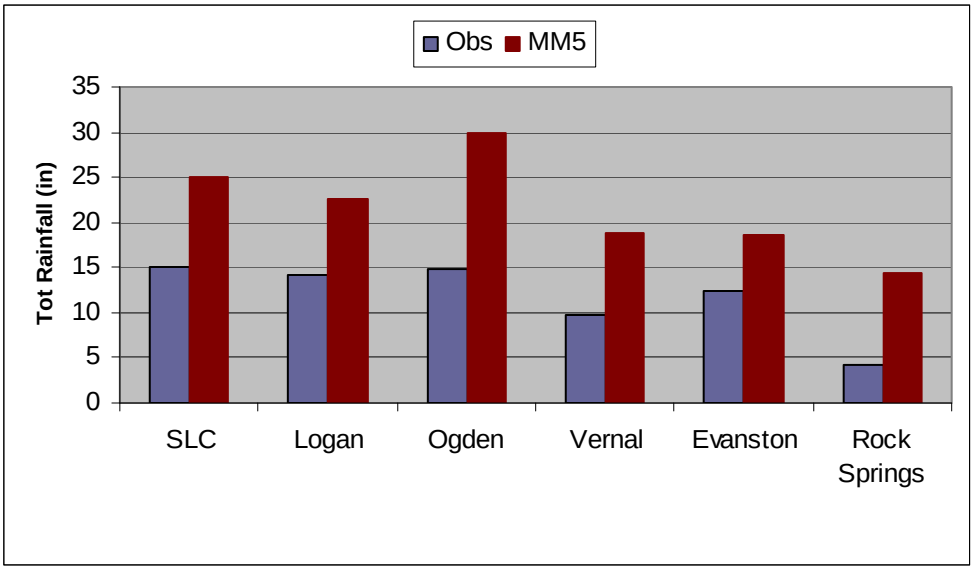
| Parameter | Mean Observed | Mean Simulated | Bias | Unsigned Error |
|---|---|---|---|---|
| 700 mb Temperature (am) (°C) | 0.92 | 1.34 | 0.44 | 1.44 |
| 700 mb Temperature (pm) (°C) | 2.49 | 1.95 | -0.51 | 1.50 |
| 700 mb Dew Point Temperature (am) (°C) | -10.97 | -9.65 | 1.31 | 3.47 |
| 700 mb Dew Point Temperature (pm) (°C) | -11.14 | -9.78 | 1.35 | 3.14 |
| 700 mb Wind Speed (am) ($ms^{-1}$) | 5.33 | 4.65 | -0.39 | 2.72 |
| 700 mb Wind Speed (pm) (degrees) | 4.98 | 4.27 | -1.06 | 2.60 |
| 700 mb Wind Direction (am) ($ms^{-1}$) | 276.74 | 288.36 | 0.15 | 32.10 |
| 700 mb Wind Direction (pm) (degrees) | 269.68 | 281.74 | 0.2 | 33.19 |

At the 700 mb level, temperatures and dew point temperatures are well represented and slightly overestimated for both sites in the MM5 estimates. Wind speed errors are on the order of 2 to 3 $ms^{-1}$ and wind speeds tend to be underestimated by MM5. Wind directions aloft are well represented, with errors on the order of 25 to 35 degrees.

Thus, on an annual average basis, and for the sites considered here, MM5 has difficulty representing the surface conditions and overestimates precipitation. The model appears to do a good job representing upper-air temperature, moisture, and wind conditions.

Focusing in on rainfall, Figure D-2 compares observed and simulated annual rainfall totals for the six surface sites considered in this analysis.

**Figure D-2. Comparison of Observed and Simulated Annual Rainfall Amount (in).**




This plot illustrates the overestimation of annual rainfall by MM5 in northern Utah and the surrounding area.
Figure D-3 shows the variation in monthly mean rainfall amounts, observed and simulated by MM5.

**Figure D-3a. Daily Average Rainfall Amount (in)**
**Based on Observed and Simulated Daily Precipitation Values: Salt Lake City, UT.**

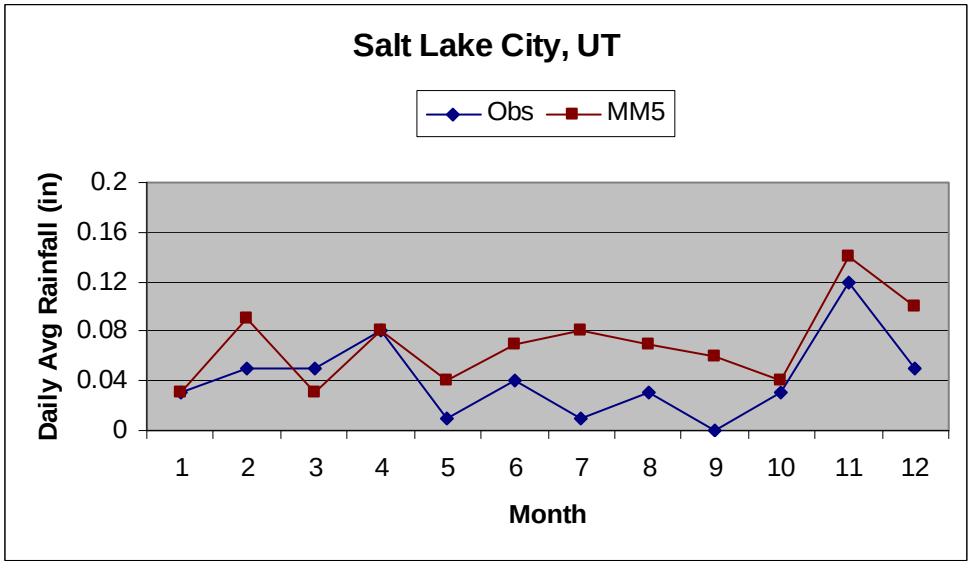


**Figure D-3b. Daily Average Rainfall Amount (in)
Based on Observed and Simulated Daily Precipitation Values: Logan, UT.**

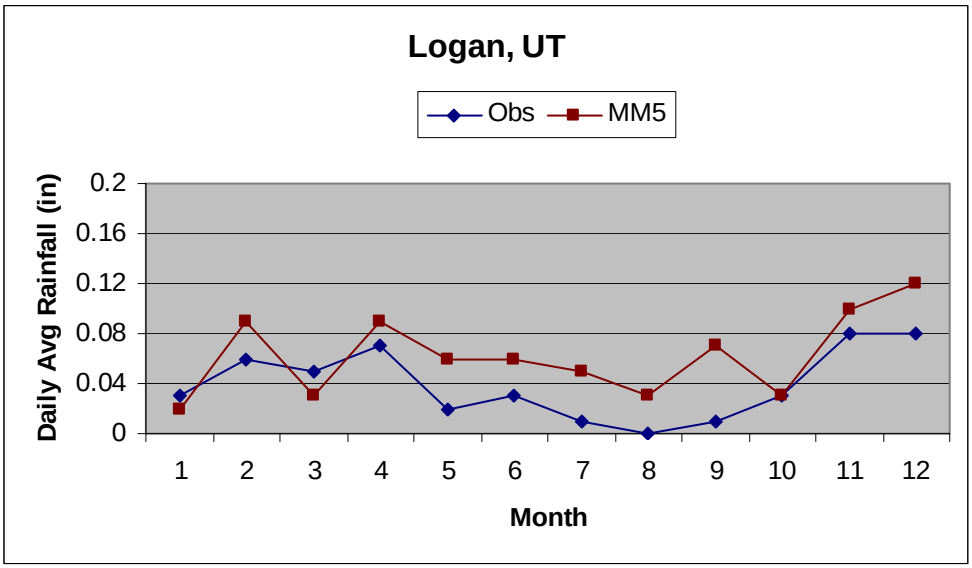



**Figure D-3c. Daily Average Rainfall Amount (in)
Based on Observed and Simulated Daily Precipitation Values: Ogden, UT.**

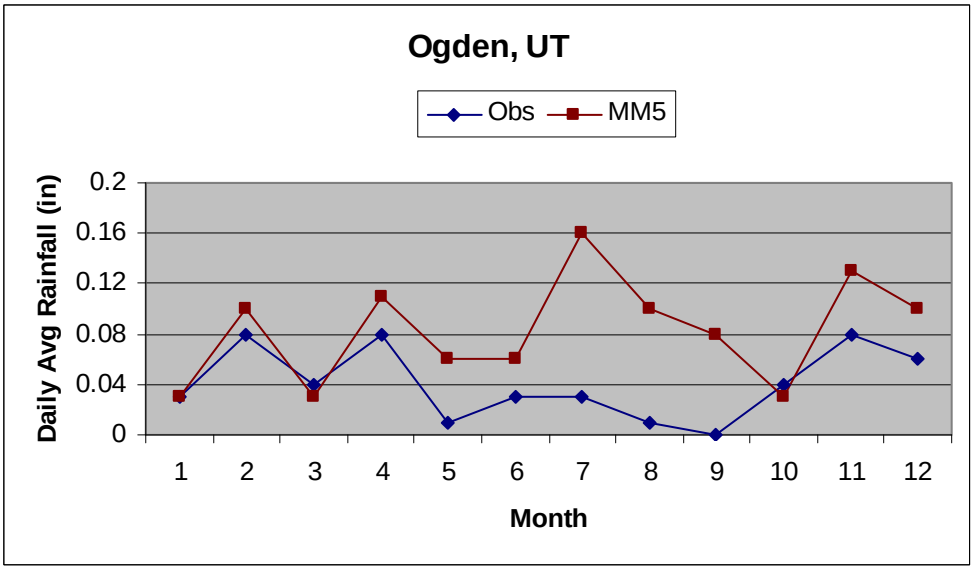


**Figure D-3d. Daily Average Rainfall Amount (in)
Based on Observed and Simulated Daily Precipitation Values: Vernal, UT.**

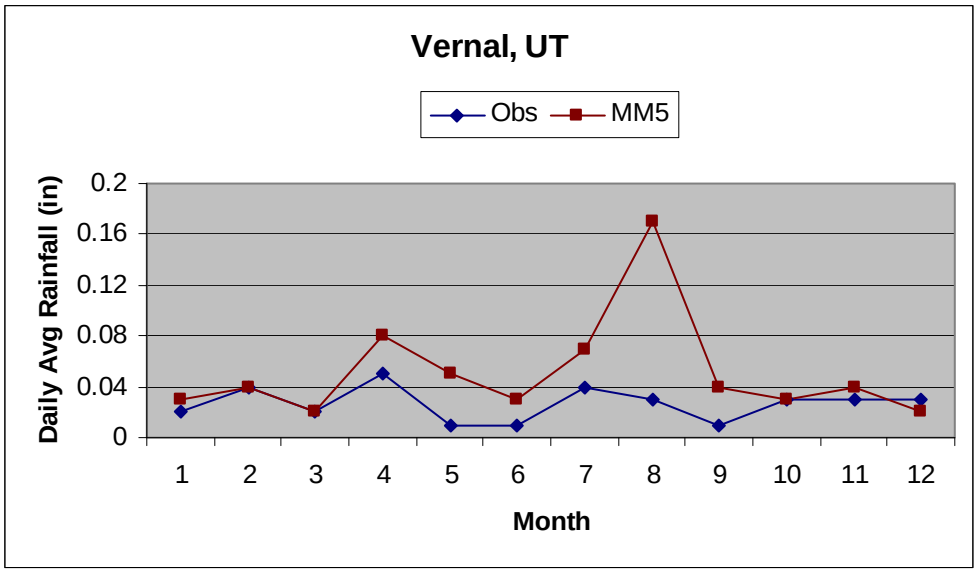



**Figure D-3e. Daily Average Rainfall Amount (in)
Based on Observed and Simulated Daily Precipitation Values: Evanston, WY.**

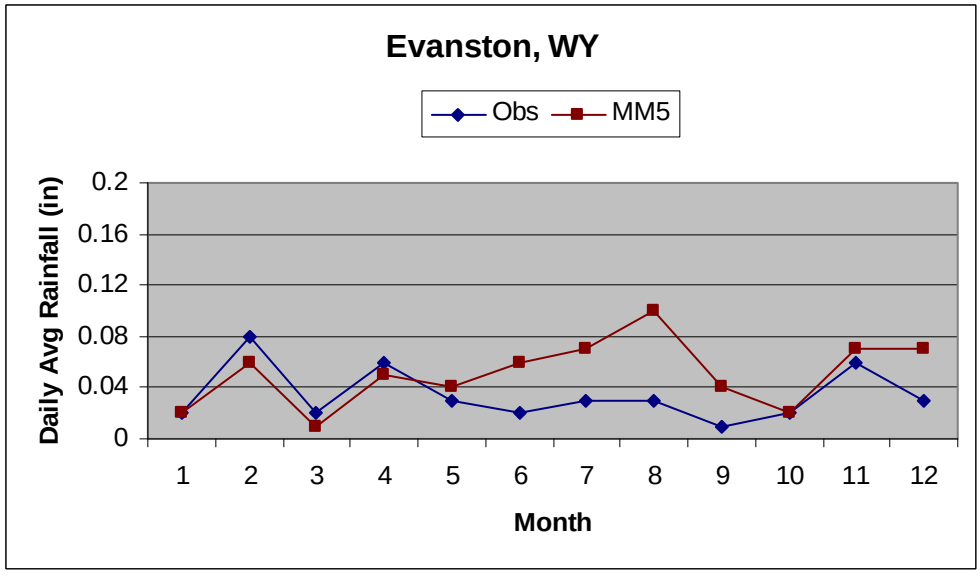


**Figure D-3f. Daily Average Rainfall Amount (in)
Based on Observed and Simulated Daily Precipitation Values: Rock Springs, WY.**

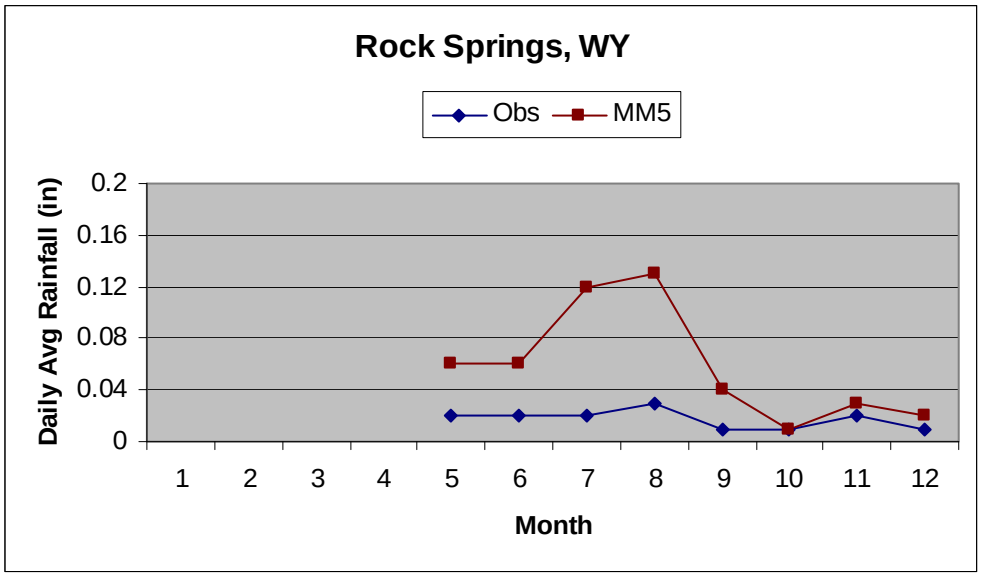


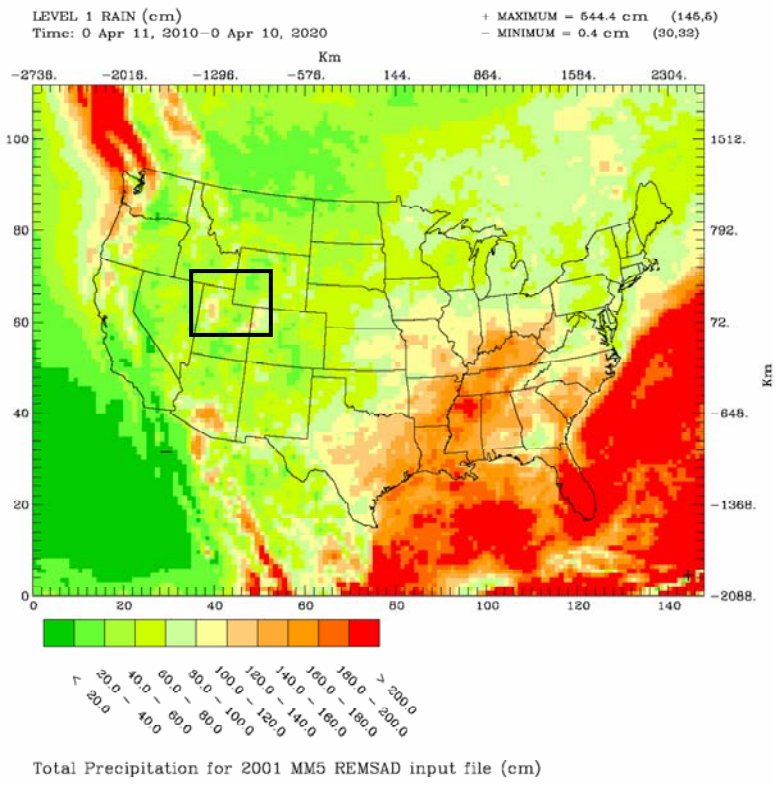

Figure D-3 illustrates that most of the overestimation of rainfall occurs during the summer months, but that there is also some higher than observed rainfall during the spring and fall transition periods. MM5 most severely overestimates precipitation for Ogden, Vernal, and Rock Springs.

## Adjustment Methodology

Based on these findings, a sensitivity simulation was conducted to examine and quantify the effects of the overabundant rainfall on the REMSAD simulation results. Specifically, the precipitation amounts were reduced over northern Utah, southwestern Wyoming, and northwestern Colorado. The amount of reduction was based on the monthly ratio of observed to simulated rainfall at the sites considered in this analysis. The rain liquid water content was also reduced by a percentage amount equal to that used for the precipitation.

The area over which the moisture parameters were adjusted is shown in Figure D-4.

**Figure D-4. REMSAD Grid Cells Corresponding to Northern Utah, Southwestern Wyoming, and Northwestern Colorado.**




Adjustment factors, calculated as the ratio of the average observed to average MM5 rainfall for all sites, are shown below. The factors were applied by month for June, July, and August to precipitation and rain liquid water mixing ratio uniformly in all grid cells in this area in order to compensate for overestimation by MM5.

| | | SLC | Logan | Ogden | Vernal | Evanston | Rock Springs | Avg. | Adj. Factor |
|---|---|---|---|---|---|---|---|---|---|
| **June** | Obs. | 0.04 | 0.03 | 0.03 | 0.01 | 0.02 | 0.02 | 0.03 | 0.44 |
| | MM5 | 0.07 | 0.06 | 0.06 | 0.03 | 0.06 | 0.06 | 0.06 | |
| **July** | Obs. | 0.01 | 0.01 | 0.03 | 0.04 | 0.03 | 0.02 | 0.02 | 0.25 |
| | MM5 | 0.08 | 0.05 | 0.16 | 0.07 | 0.07 | 0.12 | 0.09 | |
| **August** | Obs. | 0.03 | 0.00 | 0.01 | 0.03 | 0.03 | 0.03 | 0.02 | 0.22 |
| | MM5 | 0.07 | 0.03 | 0.10 | 0.17 | 0.10 | 0.13 | 0.10 | |

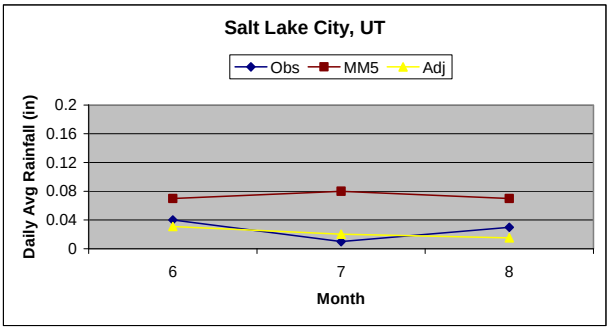
After applying the factors, minimum values were assigned as follows:

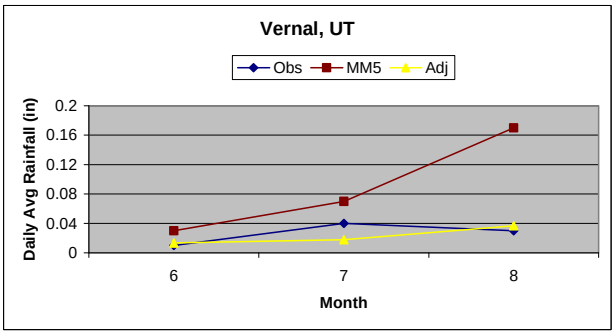
Water vapor (mixing ratio): 0.0001 kg/kg

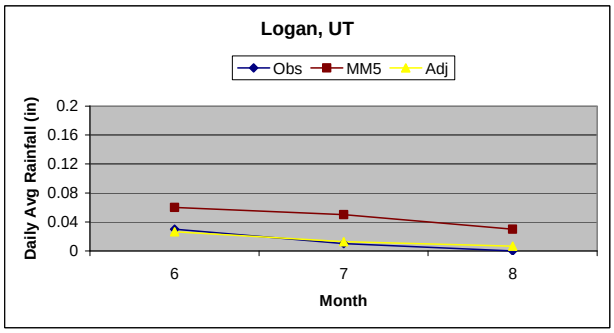
Rain liquid water mixing ratio: 0.0001 kg/kg

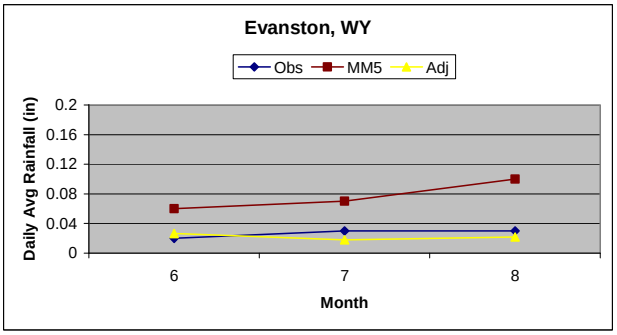
Figure D-5 illustrates the results of applying the reduction factors.

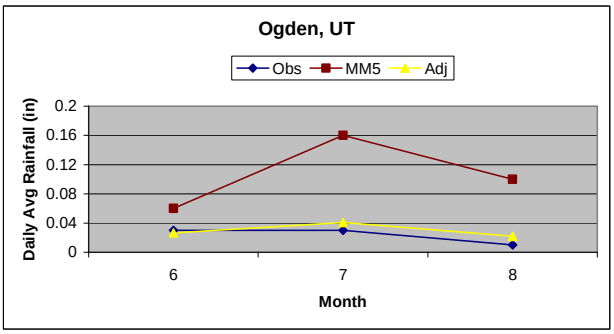
**Figure D-5. Daily Average Rainfall Amount (in): Observed, Simulated (MM5), and Adjusted (Adj).**

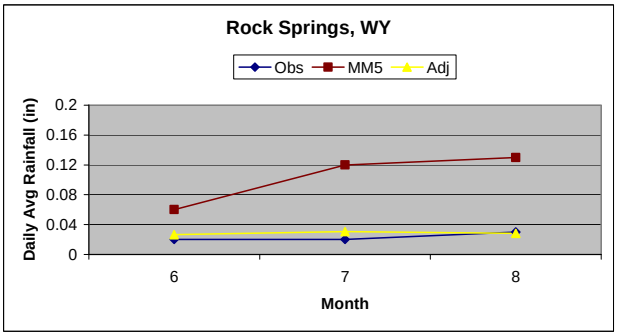


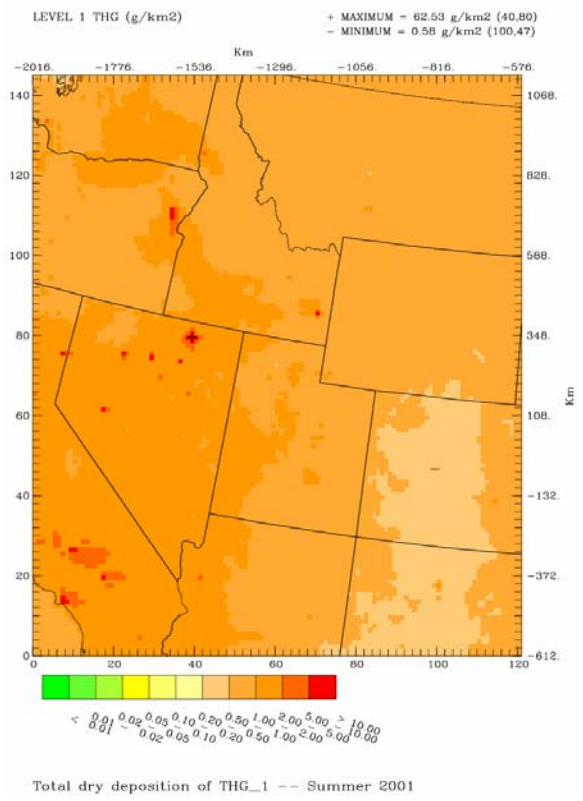

## REMSAD Simulation Results

The summer season consisting of the months June, July, and August 2001 was simulated with REMSAD using the adjusted meteorological fields and the base emissions files. A limited number of tags were simulated including the CTM background tag, re-emissions, and four Utah tags: Intermountain Power, Ash Grove, Hunter, Nucor Steel, and UT Collective Sources. Dry, wet, and total mercury deposition for the summer period for both the base simulation using unadjusted meteorology and the sensitivity simulation using adjusted meteorology are presented in Figures D-6 through D-8. For the sensitivity case, the area over which rainfall was adjusted in outlined in blue. Small differences are present in the dry deposition distributions, presumably due to the changes in overall air concentration resulting from the reduced wet deposition. The largest changes in wet deposition are several g/km$^2$, and these changes carry over into the change in total deposition. The change in wet deposition can be more clearly seen in the plot in Figure D-9, which shows the calculated difference of the summer deposition from

the sensitivity simulation minus the summer deposition in the base simulation. (The adjusted area is again outlined in blue.) The largest reduction in wet deposition occurs in eastern Nevada near the location of goldmine operations in that state. Reductions of 1 or 2 g/km2 are present throughout most of the area of Utah in which the rainfall was adjusted. Interestingly, there is an increase in wet deposition just east of the area in which the rainfall was adjusted, implying that reduced removal of mercury in the target area might lead to more mercury in the atmosphere immediately downwind of the target area compared to the baseline and hence higher deposition in that downwind area.

**Figure D-6. Summer Dry Deposition of Mercury: (a) Base Simulation; (b) Sensitivity Simulation with Reduced Rainfall.**

**(a)**




**(b)**

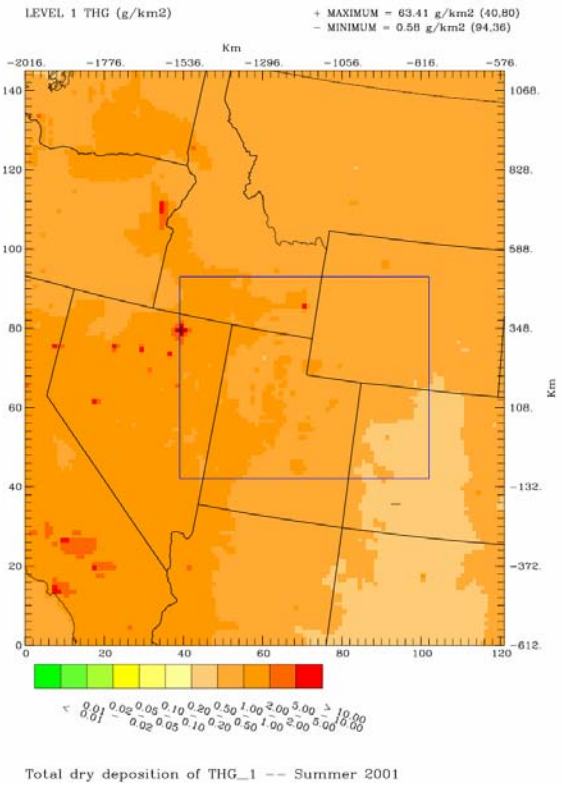
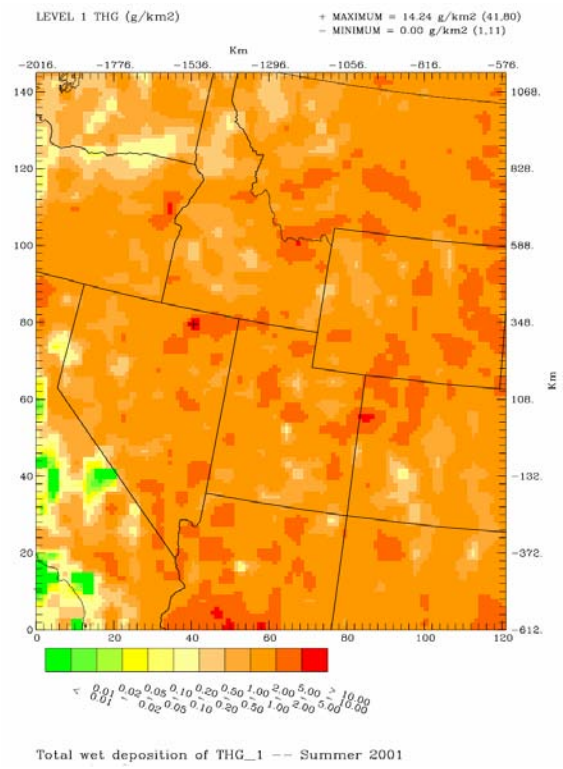


**Figure D-7. Summer Wet Deposition of Mercury: (a) Base Simulation; (b) Sensitivity Simulation with Reduced Rainfall.**

**(a)**




**(b)**

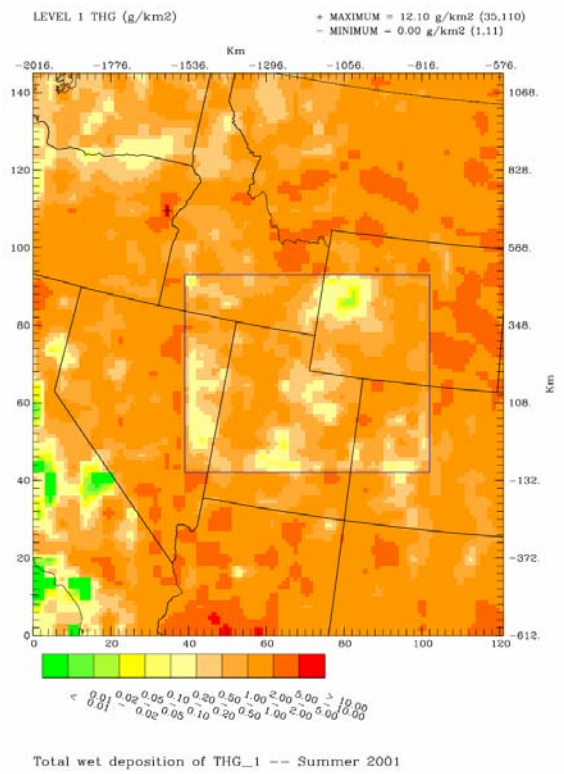
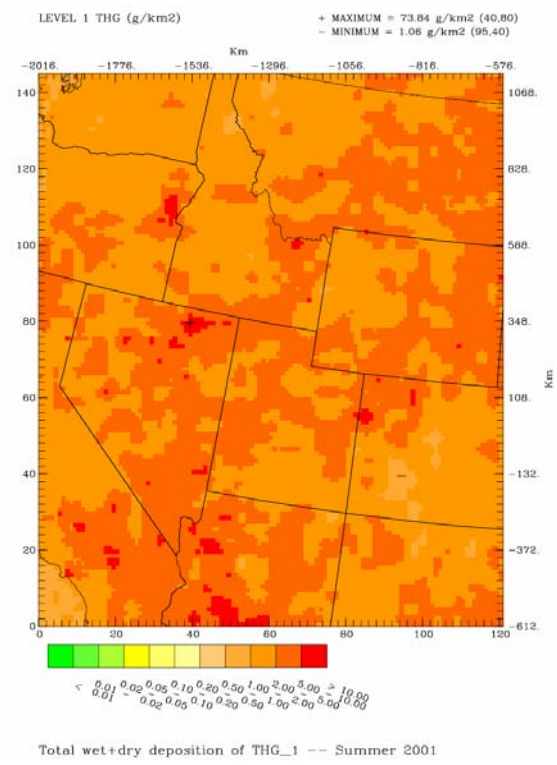


**Figure D-8. Summer Total Deposition of Mercury: (a) Base Simulation; (b) Sensitivity Simulation with Reduced Rainfall.**

**(a)**




**(b)**

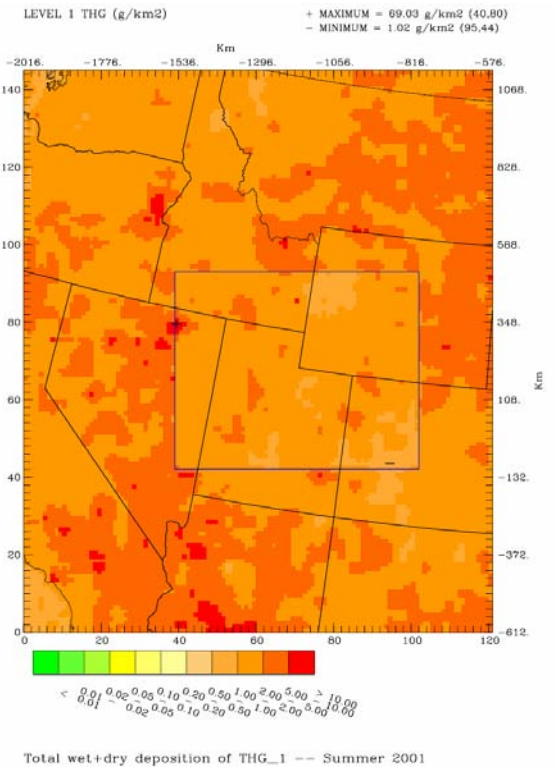
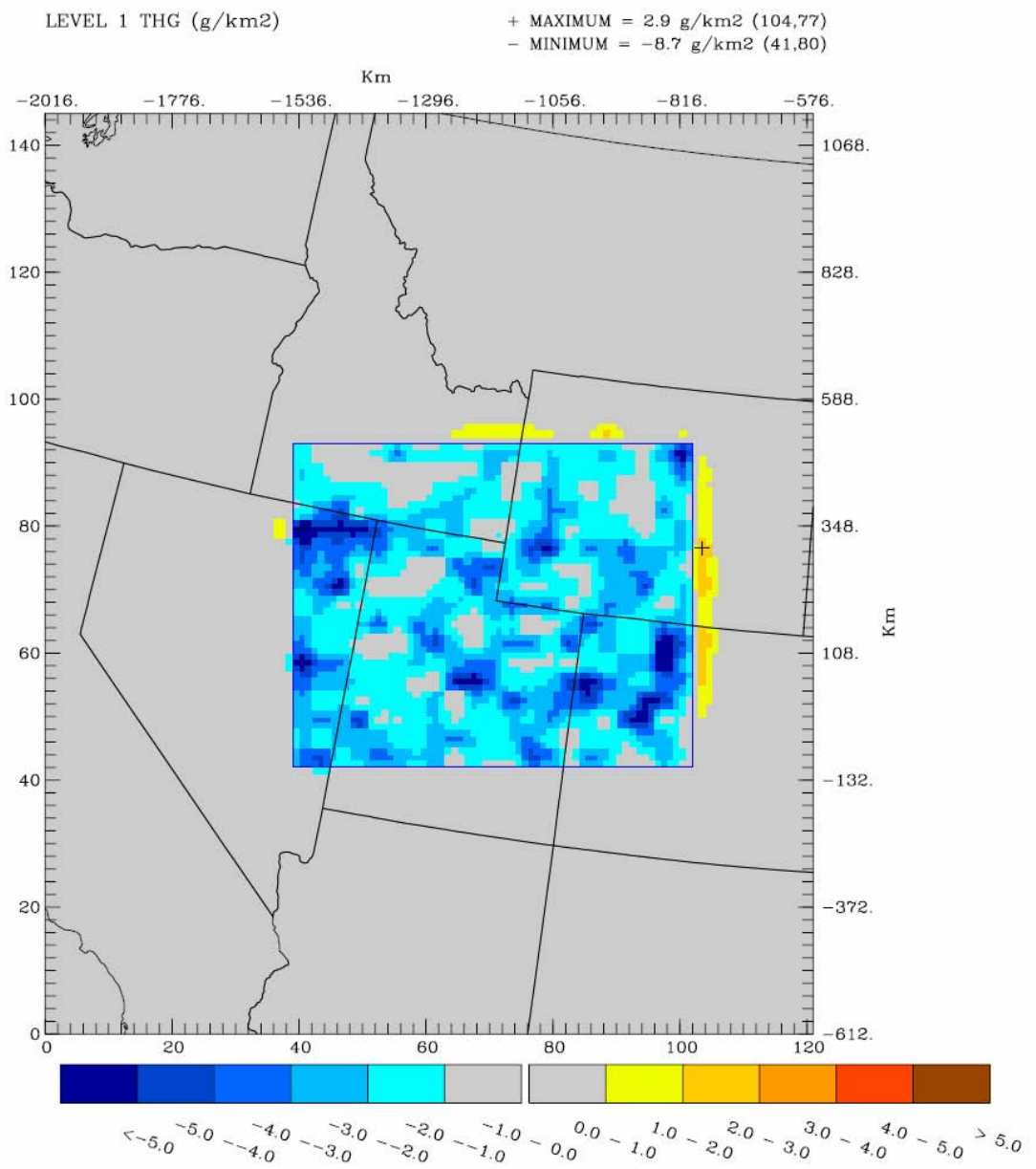


**Figure D-9. Difference in Summer Wet Deposition of Mercury: Sensitivity Simulation minus Base Simulation.**

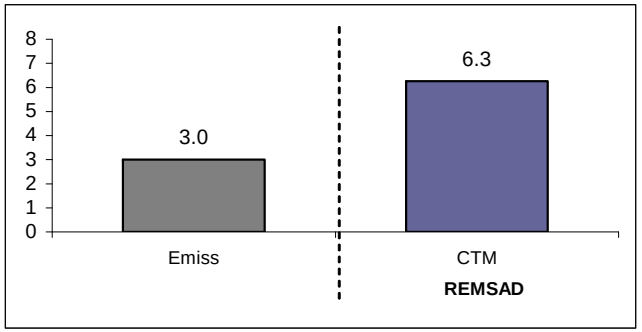



The above displays show that reduced rainfall, as expected, reduces wet deposition. It is also of interest to know whether the contributors to deposition also change due to alterations in the wet deposition patterns. Figure D-10a and D-10b present a summary of contributions to mercury deposition for summer 2001 in the base run and in the sensitivity simulation. These summaries are for the same grid cell, the location of the maximum in-state contribution to mercury deposition for Utah that was presented in the main report (see Figures 7-42a and 7-42b; Figure 7-42a is repeated here as Figure D-10c).

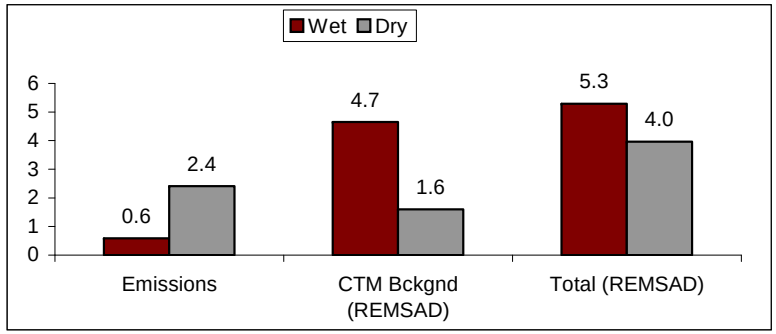
Figure D-10a. Utah. Analysis of Summer Deposition with Base Rainfall for the Single Grid Cell (the Blue Triangle in the Figure 7-42a) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (Summer deposition: 9.3 g/km2).

**Utah**

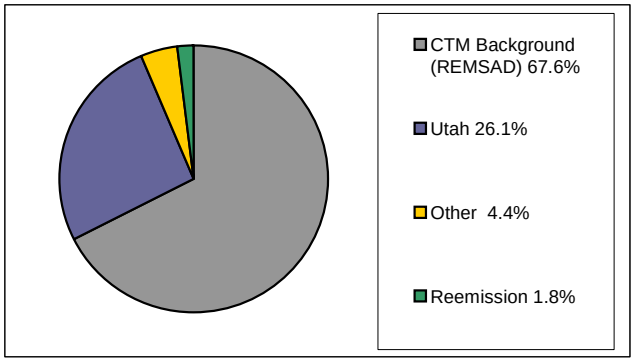
Emissions vs. Background Contributions (g/km2) (1,2,3)



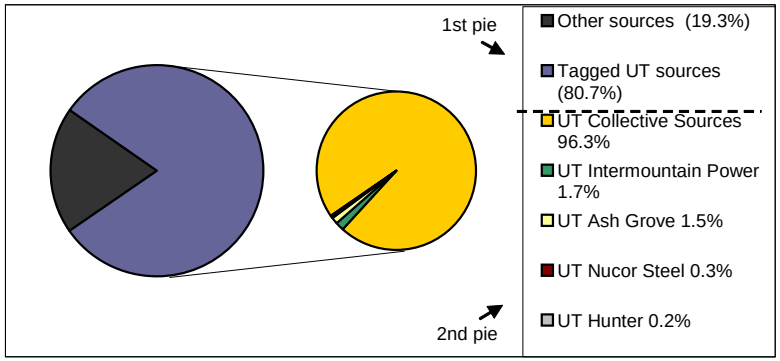

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2)




Contributions from Utah Sources without Background (4,5)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
5) This sensitivity simulation used a limited number of Utah tags. Sources such as Davis/Wasatch are included in "Other sources".

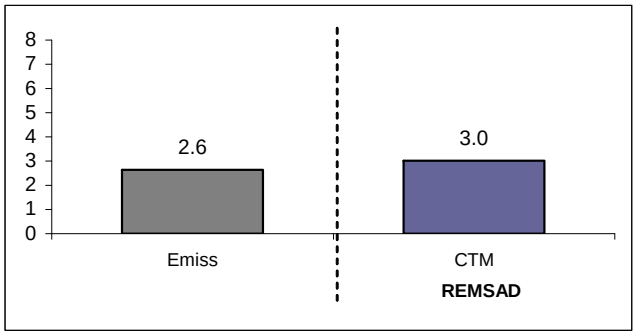
- *Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within*

*that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

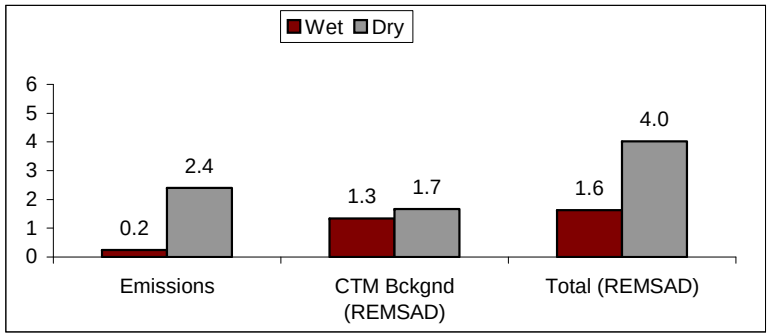
Figure D-10b. Utah. Analysis of Summer Deposition with Reduced Rainfall for the Single Grid Cell (the Blue Triangle in the Figure 7-42a) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (Summer deposition: 5.7 g/km2).

**Utah**

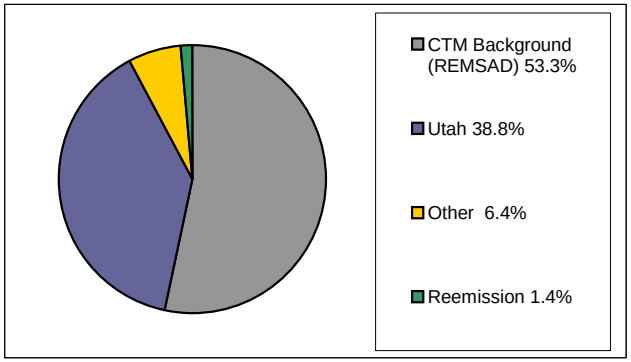
Emissions vs. Background Contributions (g/km2) (1,2,3)



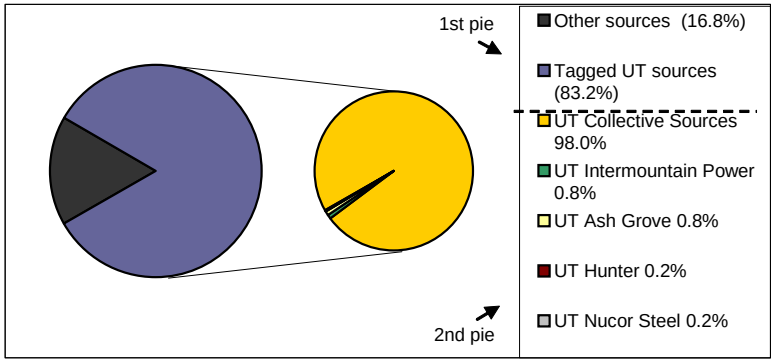

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2)



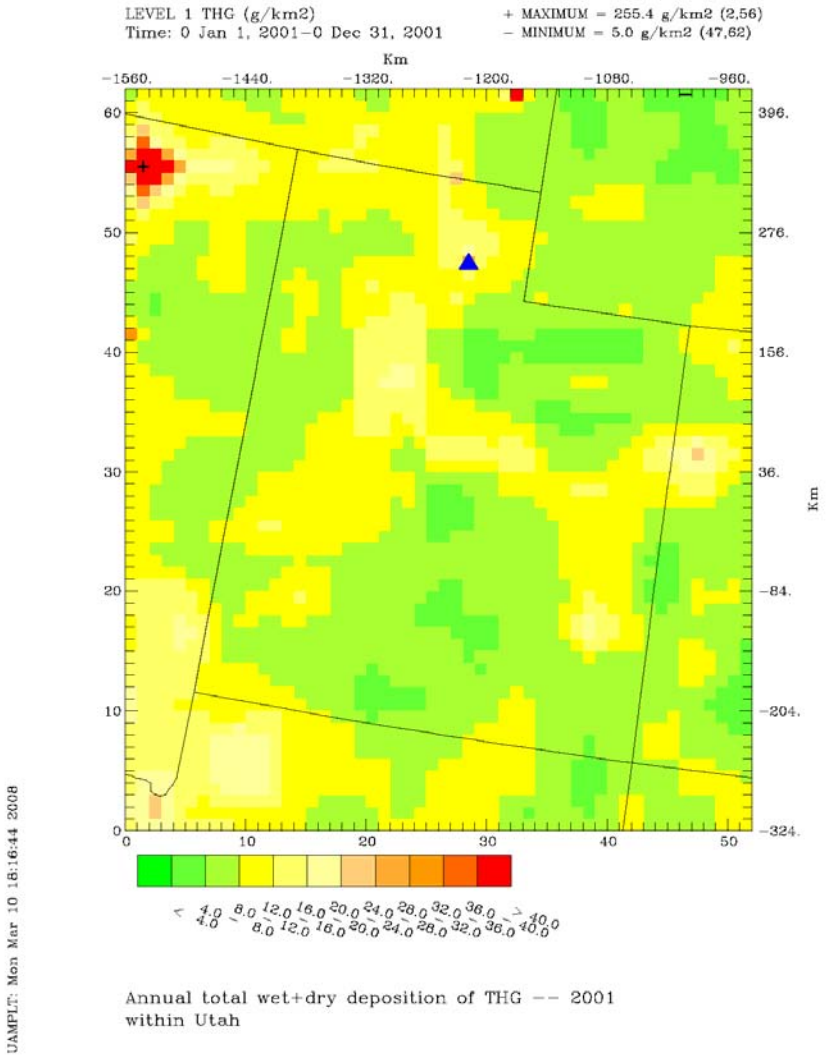

Contributions from Utah Sources without Background (4,5)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
5) This sensitivity simulation used a limited number of Utah tags. Sources such as Davis/Wasatch are included in "Other sources".

- *Contributions to mercury deposition are displayed only for one grid cell within the state, i.e., the grid cell of greatest deposition from sources located within that same state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

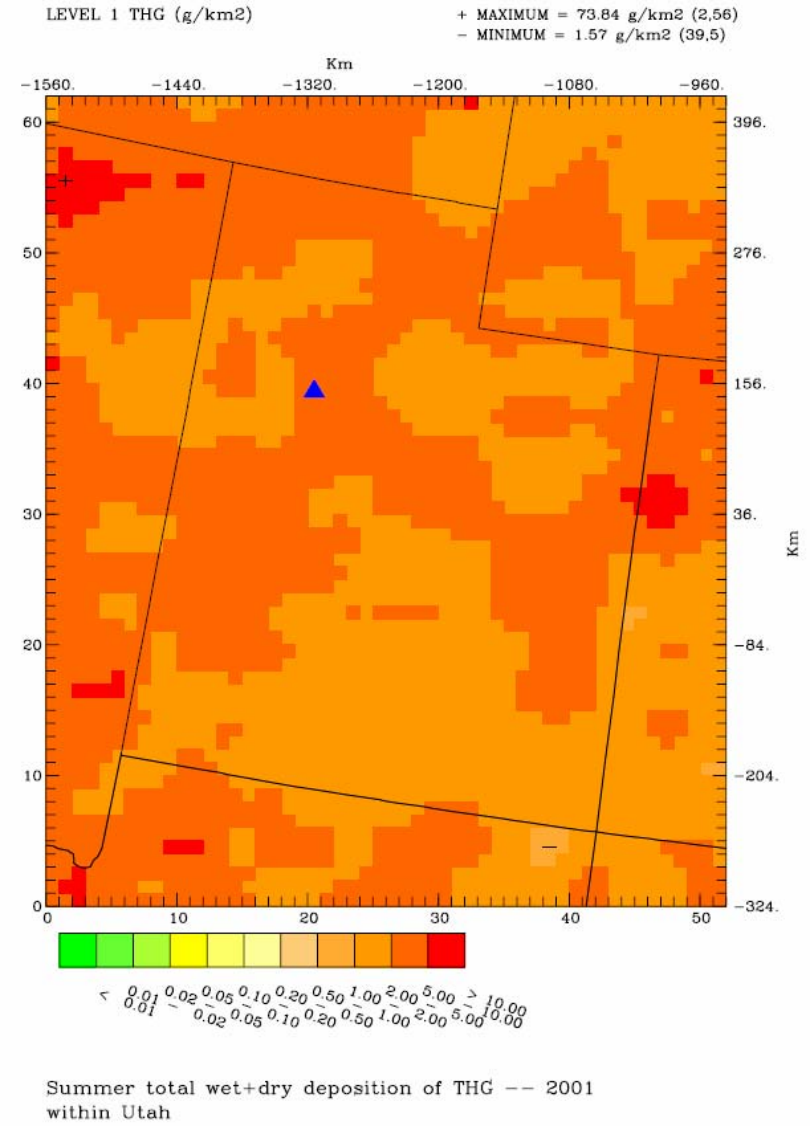
**Figure D-10c. REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km$^{-2}$) for Utah.**




Differences are clearly visible between the two sets of charts. The change in the contribution from background concentrations is greater than change in the contribution from emissions sources. Consequently, the relative proportions of background and emissions contributions are different between the base and sensitivity simulations. The most important emissions contributor (UT collective sources) is the same in both cases.

The particular grid cell examined in Figure D-10 includes a large contribution from emissions sources. In order to see how contributions are affected in an area not so strongly affected by emissions, another grid cell located to the southwest of the peak was also examined. The location of this grid cell is denoted by the blue triangle in Figure D-11.

**Figure D-11. Alternate Location for Analysis of Deposition Contributions.**

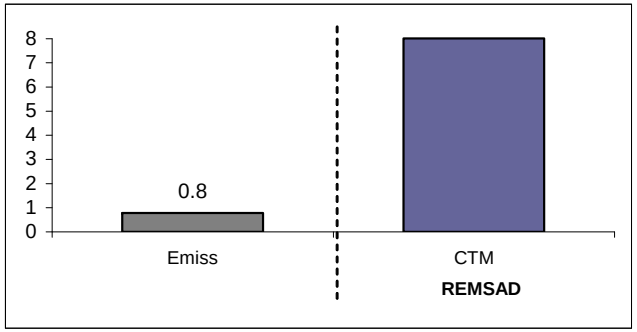



Contributions (summarized in Figure D-12a for the base meteorology and Figure D-12b for the sensitivity simulation) are more dominated by background for this grid cell, compared to the grid cell shown in Figure D-10. Because of the dominance of background, the relative contribution from background versus emissions sources is less affected by the change in rainfall than at the other location. However, overall deposition still changes considerably. The relative amounts contributed by various Utah sources do not change a great deal between the base and sensitivity runs.

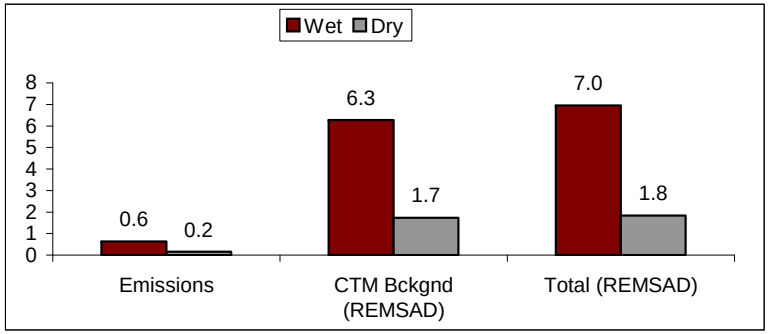
Figure D-12a. Utah. Analysis of Summer Deposition with Base Rainfall for the Single Grid Cell (the Blue Triangle in the Figure 7-42a) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (Summer deposition: 8.8 g/km2).

**Utah**

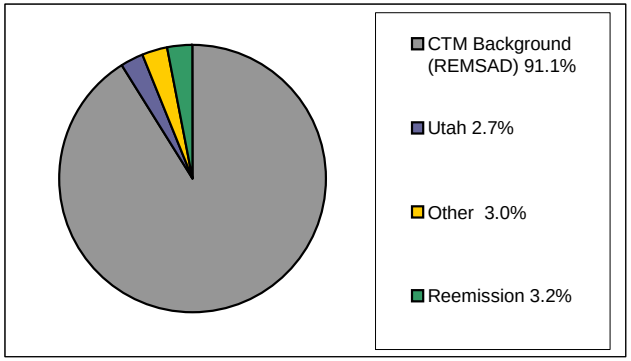
Emissions vs. Background Contributions (g/km2) (1,2,3)



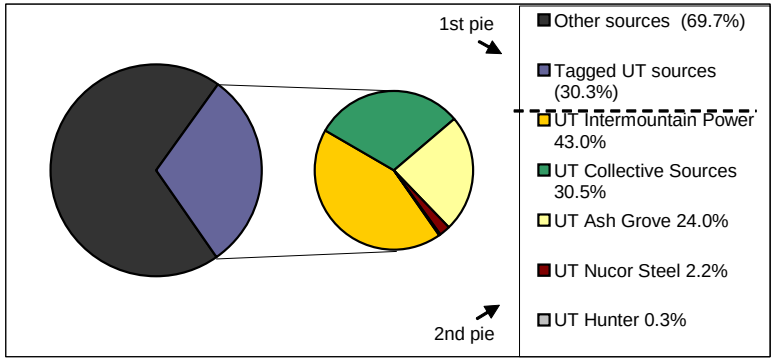

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2)




Contributions from Utah Sources without Background (4,5)



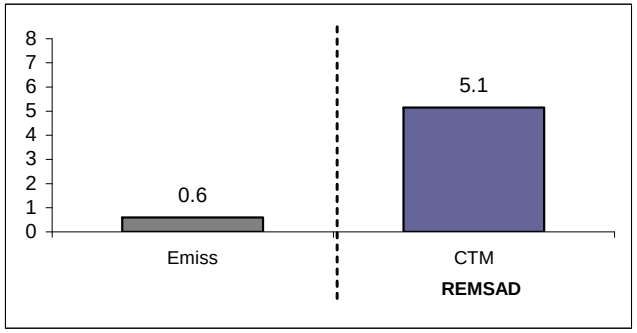

Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
5) This sensitivity simulation used a limited number of Utah tags. Sources such as Davis/Wasatch are included in "Other sources".

*Contributions to mercury deposition are displayed only for a single, arbitrarily chosen grid cell within the state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

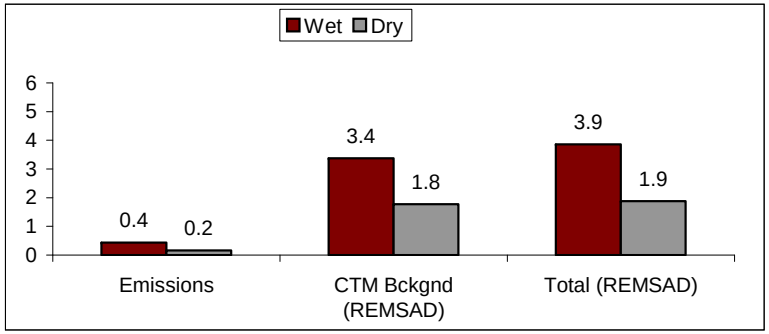
Figure D-12b. Utah. Analysis of Summer Deposition with Reduced Rainfall for the Single Grid Cell (the Blue Triangle in the Figure 7-42a) Where In-State Sources Contributed the Most to Simulated Annual Total Mercury Deposition for 2001 (Summer deposition: 5.7 g/km2).

**Utah**

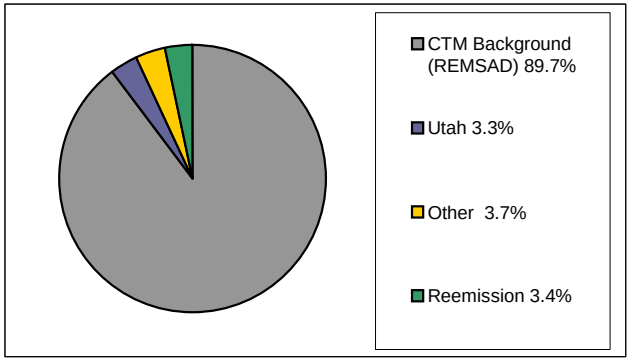
Emissions vs. Background Contributions (g/km2) (1,2,3)



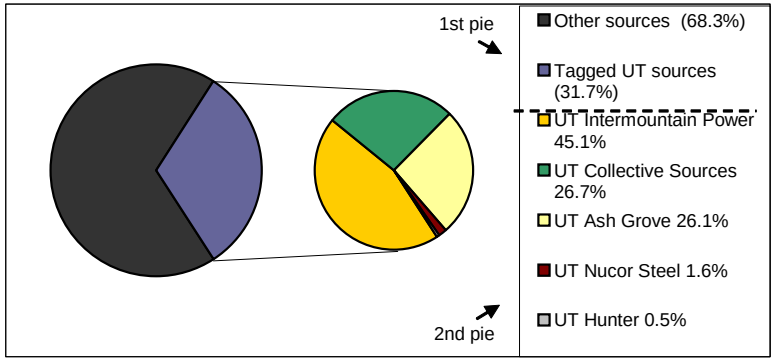

Wet vs. Dry Contributions (g/km2) (1,2)




Contributions to Total Deposition (2)




Contributions from Utah Sources without Background (4,5)




Notes: 1) "Emissions" refers to emissions contributions from the U.S., Canada, and Mexico as simulated by REMSAD.
2) "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions.
3) The CTM, GRAHM (GRHM), and GEOS-Chem (G-C) global models provided boundary conditions for REMSAD and CMAQ, as discussed in Section 5.2.
4) Percentages of cut-out pie segments are calculated based on total represented in only the cut-out pie.
5) This sensitivity simulation used a limited number of Utah tags. Sources such as Davis/Wasatch are included in "Other sources".

*Contributions to mercury deposition are displayed only for a single, arbitrarily chosen grid cell within the state. Results should not be extrapolated to indicate source contributions on a statewide basis.*

The modeling results suggest that, even for national-scale applications, accurate representation of regional meteorological conditions, especially the timing and amount of rainfall, is key to reliable mercury deposition modeling.

Future modeling efforts for this simulation period, should consider the use of improved or alternative meteorological inputs. A diagnostic evaluation of MM5 for the western U.S. should be performed and the MM5 options pertaining to grid resolution, cloud parameterizations, and moist physics, radiation, and soil temperature schemes should be examined. It is possible that the options selected for the full (continental-scale) application of MM5 could be refined for the west and specifically for the Utah/Colorado/Wyoming area. Alternatively, the inputs could be prepared using other meteorological modeling tools such as WRF or RUC.

## References

Douglas, S., B. Hudischewskyj, S. Beckmann, and T. Myers. 2005. “Comparison of MM5- and RUC-Based Meteorological Input Fields for REMSAD Mercury Modeling (Revised)”, Memorandum to Ruth Chemerys and Dwight Atkinson, EPA Office of Water. Prepared by ICF International, San Rafael, California.

National Atmospheric Deposition Program (NRSP-3). 2005. NADP Program Office, Illinois State Water Survey, 2204 Griffith Dr., Champaign, Illinois, 61820.

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# Appendix E: Use of Classification and Regression Tree (CART) Analysis to Examine the Impact of Year-to-Year Meteorological Variability on Mercury Deposition for Several Locations throughout the U.S.

## Introduction

The REMSAD simulations reported in the main body of this report are limited to a single year (2001), largely due to the level of effort involved in preparing the necessary inputs and conducting regional-scale mercury deposition modeling. It is of interest, however, to have some estimate of how much the simulation results might vary due to differing meteorological conditions that are present in other years. In this companion study, statistical analysis is used to estimate the potential year-to-year variability in the simulation results due to variations in meteorology.

The technique examines the annual variability in wet and dry mercury (Hg) deposition for several locations throughout the U.S., based on the integrated analysis of observed meteorological data and mercury deposition modeling results. The objective of this study was to use the meteorological and deposition information available from the mercury deposition modeling study described in the main body of this report to estimate the variability in deposition for a ten-year period for selected locations of interest. Since mercury wet deposition data are typically not available for a full ten-year period for most locations, it was of interest to use the available simulation results and a longer period of record of meteorological data to estimate variability in wet deposition. Dry deposition measurements are also typically not available, except during short-term special monitoring programs, so this technique also provides a means to estimate the amount and variability of dry deposition over a multi-year period.

The modeling results used for this analysis are from the national-scale application of the Regional Modeling System for Aerosols and Deposition (REMSAD) discussed in the main body of this report. The modeling was conducted for the EPA Office of Water (OW). REMSAD was applied to the study of mercury transport and deposition and to quantify the contributions of specific sources and source categories to mercury deposition within the contiguous 48 states. REMSAD simulates wet and dry mercury deposition. Wet deposition occurs as a result of precipitation scavenging. Dry deposition is calculated for each species based on land-use characteristics and meteorological parameters. REMSAD also includes algorithms for the re-emission of mercury into the atmosphere from land and water surfaces, due to naturally occurring (e.g., microbial) processes. REMSAD provides estimates of the concentrations and deposition of mercury and all other simulated pollutants at each grid location in the modeling domain. For the OW study, the REMSAD modeling domain encompasses the contiguous 48 states with a horizontal grid spacing of approximately 12 km. REMSAD was applied for the annual simulation period 2001.

The modeling results were used in conjunction with observed data and the Classification and Regression Tree (CART) analysis technique to estimate wet and dry mercury deposition for fifteen selected locations for each year of the ten-year period 1997-2006. CART was used in combination with the REMSAD meteorological input fields and simulated deposition values to match the deposition values to specific meteorological parameters. The CART results were used to identify

the meteorological conditions associated with certain ranges of deposition. Each day for the one-year simulation period was placed into a classification bin based on the values of the meteorological input parameters and the simulated deposition. The resulting bins contained days with similar deposition values and meteorological characteristics.

The CART results then provided the framework for estimating the deposition characteristics for all days within the ten-year period of record. Actual meteorological data were obtained for each day and based on these data the days were placed in the CART bins (as derived using the REMSAD inputs and outputs as described above). Each day for the ten-year period was then assigned a deposition value, which was equal to the calculated average for the similar (REMSAD-simulated) days. In this manner, estimated daily totals of Hg deposition for each day of the ten-year periods were obtained. These were summed to provide annual totals, from which the variance could be calculated.

The deposition analysis was conducted for 15 locations throughout the continental U.S, representing different climate zones and different areas within the climate zone. For each location, the analysis was conducted separately for wet and dry Hg deposition.

The results are intended to provide perspective to the analysis and use of the REMSAD simulation results for the 2001 annual simulation period and for use in water quality modeling. When examining the results, the reader should keep in mind that the purpose of this analysis was only to investigate the impact on deposition of year-to-year variability due to meteorological influences. Other important factors that would affect changes in deposition from one year to another were beyond the scope of this analysis. Most notably, the year-to-year changes in emissions from U.S. and other global sources were not accounted for and were beyond the scope. Instead, the analysis includes the implicit assumption that all emissions are constant throughout the 10-year CART study period.

The methods and results of the CART-based mercury deposition analysis are presented in the remainder of this appendix. The following three sections address site selection, CART analysis methods and results, and use of the CART results to estimate mercury deposition. A summary and some conclusions are presented in the final section.

The CART analysis method used here was first tested in the context of mercury deposition variability due to meteorological parameters as part of the Devil's Lake TMDL Pilot (Myers et al., 2003). Application of CART in this report is consistent with that earlier peer reviewed methodology.

## Site Selection

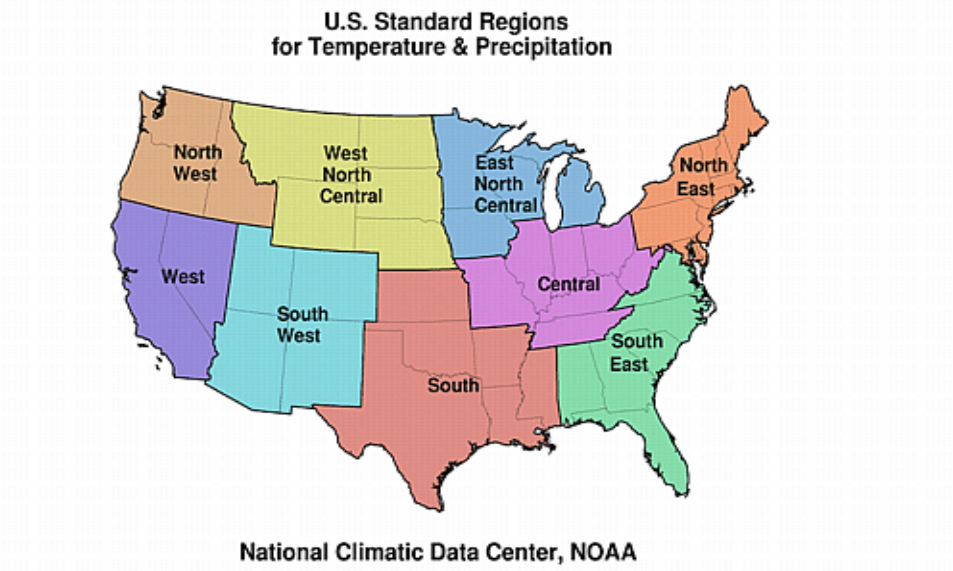
The mercury deposition analysis was conducted for 15 sites, located throughout the continental U.S, representing different climate zones and different regions within each climate zone. The site selection procedures and the selected locations are summarized in this section.

### Site Selection Procedures

The National Climatic Data Center (NCDC) divides the contiguous U.S. into nine regions in order to summarize climate data and information and to analyze climate anomalies in the context of an historical perspective. These regions have been identified through climate analysis as climatically consistent, especially with respect to temperature and precipitation (NCDC, 2007; Karl and Koss,

1984). The regions include Northwest, West, Southwest, West North Central, East North Central, Central, South, Southeast, and Northeast and are shown in Figure E-1.

**Figure E-1. U.S. Climate Regions for Temperature and Precipitation (Source: NCDC, 2008).**




The normal temperature and precipitation amounts for these regions (based on thirty years of observed data for 1961-1990) are listed in Table E-1, along with the national average values.

**Table E-1. Normal Precipitation and Temperature for the Nine NCDC Climate Regions and the Contiguous U.S., Based on Observed Data for 1961-1990.**

| Zone/Region | Normal Precipitation (in) | Normal Temperature (°F) |
|---|---|---|
| **Northwest** | **27.5** | **46.7** |
| **West** | **16.5** | **55.0** |
| **Southwest** | **13.6** | **51.8** |
| **West North Central** | **16.9** | **43.3** |
| **East North Central** | **30.5** | **43.5** |
| **Central** | **43.1** | **53.2** |
| **South** | **35.7** | **62.0** |
| **Southeast** | **51.0** | **62.4** |
| **Northeast** | **41.6** | **46.1** |
| National | 29.5 | 52.4 |

For the mercury deposition study, the goal was to identify one or more locations within each of the climate zones for further analysis, while keeping the total number of locations to within 15. In order to have some mercury deposition data to verify the reasonableness of the results, the focus was on the locations of Mercury Deposition Network (MDN) sites and identified several MDN sites to represent each climate zone. To refine this list, the following were also considered:

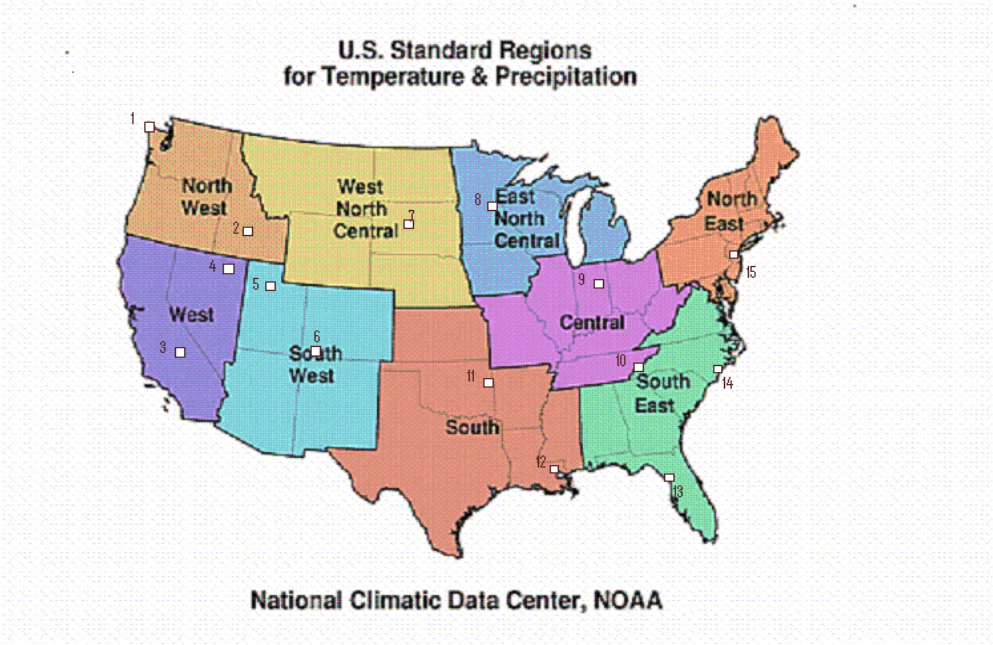
- Variability in geography within each climate zone,
- Observed and/or simulated (REMSAD) mercury deposition (specifically, locations with high deposition), and
- Data availability for each MDN site.

Data availability during the analysis period was considered so that there would be some observed data to compare with the results. This was done to ensure that the estimated values were within a reasonable range, compared to the observed data. The selected sites/locations are listed in Table E-2 and plotted in Figure E-2.

**Table E-2. Mercury Deposition Analysis Locations, by Climate Region.**

| Site # | MDN Site ID | Site Name | Start Date | Status | Elev (m) | Lat (deg) | Lon (deg) |
|---|---|---|---|---|---|---|---|
| | | | Region: Northwest | | | | |
| 1 | WA03 | Makah National Fish Hatchery | 3/2/2007 | Active | 6 | 48.2892 | -124.6519 |
| 2 | ID03 | Craters of the Moon National Monument | 10/20/2006 | Active | 1807 | 43.4605 | -113.5551 |
| | | | Region: West | | | | |
| 3 | CA75 | Sequoia National Park-Giant Forest | 7/22/2003 | Active | 1902 | 36.5661 | -118.7776 |
| 4 | NV99 | Gibb's Ranch | 2/13/2003 | Active | 1805 | 41.5516 | -115.2132 |
| | | | Region: Southwest | | | | |
| 5 | UT97 | Salt Lake City | 5/16/2007 | Active | 1297 | 40.7118 | 111.9609 |
| 6 | CO99 | Mesa Verde National Park-Chapin Mesa | 12/26/2001 | Active | 2172 | 37.1981 | -108.4903 |
| | | | Region: West North Central | | | | |
| 7 | SD18 | Eagle Butte | 3/21/2007 | Active | 742 | 44.9931 | -101.2403 |
| | | | Region: East North Central | | | | |
| 8 | MN23 | Camp Ripley | 7/2/1996 | Active | 410 | 46.2494 | -94.4972 |
| | | | Region: Central | | | | |
| 9 | IN20 | Roush Lake | 10/26/2000 | Active | 244 | 40.8400 | -85.4639 |
| 10 | TN11 | Great Smoky Mountains National Park-Elkmont | 1/30/2002 | Active | 640 | 35.6645 | -83.5903 |
| | | | Region: South | | | | |
| 11 | OK99 | Stilwell | 4/29/2003 | Active | 304 | 35.7514 | -94.6717 |
| 12 | LA28 | Hammond | 10/7/1998 | Active | 9 | 30.5031 | -90.3769 |
| | | | Region: Southeast | | | | |
| 13 | FL05 | Chassahowitzka National Wildlife Refuge | 7/1/1997 | Active | 3 | 28.7486 | -82.5551 |
| 14 | NC08 | Waccamaw State Park | 2/27/1996 | Active | 10 | 34.2592 | -78.4777 |
| | | | Region: Northeast | | | | |
| 15 | NJ30 | New Brunswick | 1/17/2006 | Active | 21 | 40.4728 | -74.4226 |

**Figure E-2. Mercury Deposition Analysis Locations, by Climate Region.**




## DEPOSITION SITES, CHARACTERISTICS AND METEOROLOGICAL SITE PAIRS

Two sites represent the Northwest climate zone. The Makah National Fish Hatchery site (WA03) became operational in March 2007. This site represents the coastal portion of the Northwest climate zone. The Craters of the Moon National Monument site (ID03) became operational in October 2006. This site represents the interior portion of the Northwest climate zone.

Two sites represent the West climate zone. The Sequoia National Park site (CA75) became active in July 2003 and the Gibb's Ranch site (NV99) was established in February 2003. Both sites are high elevation sites. NV99 is near several potential sources of mercury (mines) and also near an area of high simulated mercury deposition in the REMSAD modeling.

Two sites represent the Southwest climate zone. The Salt Lake City site (UT97) is a new site and was established in July 2007. This site is of interest because it is near several potential sources of mercury (mines) and also near an area of high simulated mercury deposition in the REMSAD modeling. The Mesa Verde National Park site (CO99) has a longer period of record with data going back to December 2001. It is a high elevation site and is centrally located within the Southwest climate zone.

The Eagle Butte site (SD18) is nearly centrally located in the West North Central climate zone. It is a new site (March 2007) and one of only a few sites in this region.

The Camp Ripley (MN23) site represents the East North Central climate zone. It was established in July 1996 and thus the data for this site fully overlap with the analysis period. This site is located within a region characterized by mercury-sensitive water bodies (especially in Minnesota and Wisconsin).

Two sites represent the Central climate zone. The Roush Lake site (IN20) was established in October 2000. Further south within this climate zone and at a higher elevation is the Great Smoky Mountains National Park site (TN11). This site was established in January 2002.
Two sites represent the South climate zone. The Stilwell site (OK99) became operational in April 2003. This site represents the interior (plains) portion of the South climate zone. The Hammond site (LA28), established in October 1998, represents the coastal Gulf of Mexico region (a mercury sensitive area).

Two sites represent the Southeast climate zone. The Chassahowitzka site (FL05) is also along the Gulf of Mexico (to the east of the Gulf) and represents Florida, another mercury sensitive area. Further north in the Southeast climate zone is Waccamaw State Park (NC08) which is located along the Atlantic coast. Both sites have long periods of record that nearly fully overlap the analysis period.

Finally, the New Brunswick site (NJ30) is located in the Northeast climate zone. It was established in January 2006. As the representative site for the northeastern U.S, it is expected to represent sites that are potentially influenced by local and regional sources of mercury as well as long-range transport.

For the purposes of conducting the CART analysis, each site was paired with one surface and one or more upper-air meteorological monitoring sites. The meteorological data for these sites were used to match each day for the period 1997-2006 to the CART classification bins (one wet deposition and one dry deposition bin) to obtain estimates of mercury deposition for that day. The meteorological site pairs are listed in Table E-3, and for each site the elevation and distance from the MDN site are given. It is assumed that upper-air data within approximately 300 km of a site can be used to represent wind, temperature, and moisture conditions aloft. This assumption is consistent with the spacing of the National Weather Service (NWS) upper-air sites.

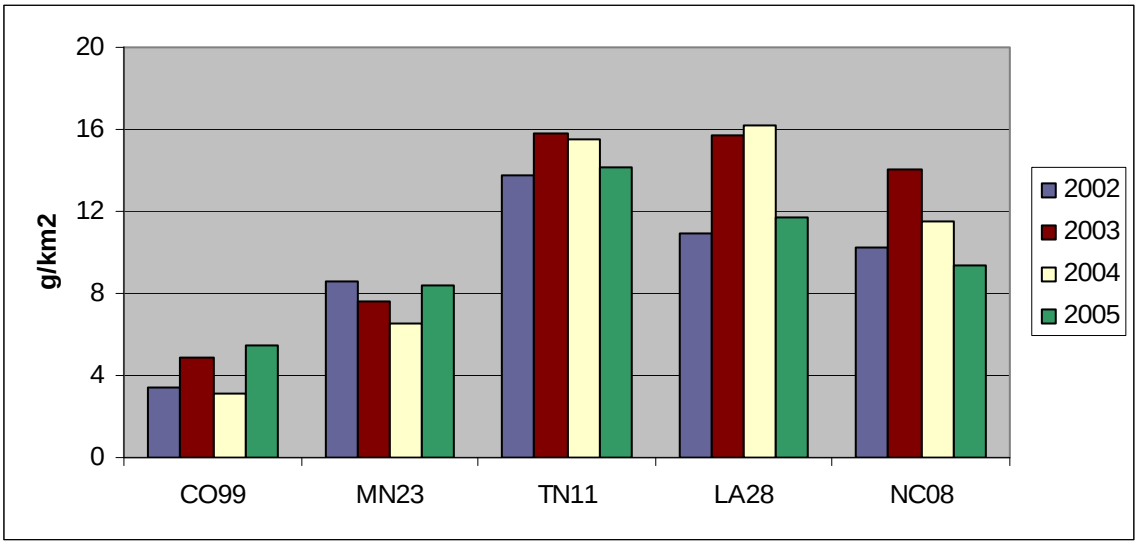
**Table E-3. MDN and Meteorological Site Pairings for Use in Estimating Mercury Deposition Based on Meteorological Parameters.**

| Site # | MDN Site ID | Surface Meteorological Site WBAN No. | Elev (m) | Distance (km) | Upper-Air Meteorological Site Name (WBAN No.) | Distance (km) |
|---|---|---|---|---|---|---|
| | | | Region: Northwest | | | |
| **1** | **WA03** | **94240** | **59** | **38.5** | **Quillayute, WA (94240)** | **38.5** |
| **2** | **ID03** | **24156** | **1353** | **100.7** | **Boise, ID (24131)** | **215.2** |
| | | | Region: West | | | |
| **3** | **CA75** | **23157** | **1264** | **94.7** | **Oakland, CA (23230)** | **330.4** |
| **4** | **NV99** | **4114** | **1650** | **83.1** | **Elko, NV (4105)** | **87.4** |
| | | | Region: Southwest | | | |
| **5** | **UT97** | **24127** | **1287** | **7.9** | **Salt Lake City, UT (24127)** | **6.5** |
| **6** | **CO99** | **93069** | **1803** | **17.0** | **Grand Junction, CO (23066)** | **213.9** |
| | | | Region: West North Central | | | |
| **7** | **SD18** | **94056** | **787** | **61.3** | **Rapid City, SD (94043)** | **188.1** |
| | | | Region: East North Central | | | |
| **8** | **MN23** | **94938** | **374** | **32.6** | **Minneapolis, MN (94983)** | **174.8** |
| | | | Region: Central | | | |
| **9** | **IN20** | **14827** | **241** | **28.4** | **Wilmington, OH (13841)** | **212.0** |
| **10** | **TN11** | **13891** | **293** | **39.3** | **Atlanta, GA (53819)** | **272.9** |
| | | | | | **Nashville, TN (13897)** | **275.3** |
| | | | | | **Greensboro, NC (13723)** | **330.7** |
| | | | Region: South | | | |
| **11** | **OK99** | **93993** | **381** | **53.2** | **Springfield, MO (13995)** | **199.5** |
| | | | | | **Little Rock, AR (3952)** | **242.2** |
| | | | | | **Norman, OK (3948)** | **260.9** |
| **12** | **LA28** | **12916** | **1** | **57.3** | **Slidell, LA (53813)** | **56.9** |
| | | | Region: Southeast | | | |
| **13** | **FL05** | **12818** | **23** | **33.0** | **Tampa Bay, FL (12842)** | **117.7** |
| **14** | **NC08** | **13748** | **14** | **48.7** | **Moorehead City, NC (93768)** | **161.2** |
| | | | Region: Northeast | | | |
| **15** | **NJ30** | **14734** | **2** | **33.2** | **Brookhaven, NY (94703)** | **137.9** |

Note that for all sites, the MDN data consist of wet deposition measurements only. The available data indicate that there is considerable year-to-year variability in wet mercury deposition. For example, annual wet deposition for five of the selected MDN sites is plotted in Figure E-3, for the

period 2002-2005. For these five sites, the quarterly standard deviation from the mean represents from 7 to 26 percent of the mean for each site, which indicates significant variability. Note that this variability in the observed data is attributable to a combination of meteorological and emissions factors. In this study, only the meteorological variability is addressed, and the goal was to extend the analysis of variability to cover the ten-year period and both wet and dry mercury deposition for all of the selected locations. When the data collection periods overlap with the analysis period, the wet deposition measurements are used as a basis for assessing the reasonableness of the CART-based deposition estimates (both in terms of the overall magnitude of wet deposition and that portion of the year-to-year variability of the deposition estimates attributable to meteorological influences).

**Figure E-3. Annual Mercury Wet Deposition (g km$^{-2}$) for 2002-2005 for the Mesa Verde (CO99), Camp Ripley (MN23), Great Smoky Mountains (TN11), Hammond (LA28) and Waccamaw State Park (NC08) MDN Monitoring Sites.**




## CART Application

The CART analysis software is a statistical analysis tool developed by Breiman, et al. (1984) and enhanced by Steinberg, et al. (1997) and Salford Systems (2007). For air quality and deposition analysis purposes, the CART technique provides a method for segregating days into categories that are representative of certain observed meteorological, air quality and deposition conditions. In this study CART analysis is used to obtain information on the relationships between meteorology and mercury deposition.

Application of the CART analysis technique requires several data elements to be used as input to the classification scheme. Of these, one is identified as the “classification” parameter. Days are segregated according to the value of the classification parameter and each resulting classification bin corresponds to a specified range of values for this parameter. For this study, the classification parameter for the CART application was specified to be the REMSAD-simulated daily mercury deposition. The range for each classification category was determined based on the distribution of

the simulated deposition values for each analysis site; thus, the range in deposition associated with each classification category is different for each analysis site. The remaining input data for application of CART are selected to enable the segregation of days with respect to the classification parameter and are referred to as the "independent" parameters. For this study, these comprise various meteorological parameters, which were obtained from the MM5 meteorological files used as inputs for the REMSAD simulations described in this report.

The result of a CART application is typically referred to as a "tree," and the branches lead to the classification bins. The splits that define the branches are based on the values of certain of the independent parameters and are chosen (by CART) to provide the best segregation of the data. CART allows for the possibility that various combinations of meteorological parameters may lead to similar values of the classification parameter. That is, multiple branches may each lead to classification bins that represent the same category and, consequently, each category may have multiple bins associated with it. This feature of CART is especially important for this analysis, because it accommodates more combinations of meteorological parameters and deposition amounts, and thus a more detailed reconstruction of the annual deposition.

CART provides information on the independent parameters and the values of these parameters that are used to assign the days to the classification bins (i.e., branches). The resulting population of each classification group (or CART classification bin) also provides information on the frequency of occurrence of the meteorological conditions associated with each classification bin.

For this study, the average deposition for each bin is calculated (based on the REMSAD-simulated deposition for all days in the bin) and this value was subsequently assigned to other similarly classified days (from the 10 year analysis period).

The remainder of this section summarizes the application procedures and results for the mercury deposition CART analysis.

## CART Application Procedures

The dependent parameters used for this study for the application of CART were derived from the REMSAD-simulated total daily wet and dry mercury deposition at each site. For each day, the classification variable was assigned a value of 1 to 5 (for wet) or 1 to 4 (for dry), such that each value corresponded to a different range in daily total mercury deposition. The ranges, which vary from site to site and for wet deposition vs. dry deposition, were determined based on the distribution of the data at each site. The ranges represent (approximately) the 70, 90 and 97 percentile values of simulated dry deposition and non-zero wet deposition. For wet deposition, the additional category is for days with zero wet deposition. These category definitions are typical for CART applications and emphasize good classification of important high deposition days. These ranges are presented in Table E-4. The deposition amounts used to define the classification ranges were extracted from the REMSAD grid cell corresponding to each site/location.

**Table E-4a. Range in Daily Mercury Wet Deposition (g km$^{-2}$) for Each CART Wet Deposition Classification Category.**

| Site # | MDN Site ID | Site Name | CART Classification Category Range (g km$^{-2}$) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 |
| 1 | WA03 | Makah National Fish Hatchery | 0 | 0 < Hg < 0.076 | 0.076 ≤ Hg < 0.184 | 0.184 ≤ Hg < 0.282 | ≥ 0.282 |
| 2 | ID03 | Craters of the Moon National Monument | 0 | 0 < Hg < 0.027 | 0.027 ≤ Hg < 0.138 | 0.138 ≤ Hg < 0.243 | ≥ 0.243 |
| 3 | CA75 | Sequoia National Park-Giant Forest | 0 | 0 < Hg < 0.026 | 0.026 ≤ Hg < 0.081 | 0.081 ≤ Hg < 0.204 | ≥ 0.204 |
| 4 | NV99 | Gibb's Ranch | 0 | 0 < Hg < 0.075 | 0.075 ≤ Hg < 0.250 | 0.250 ≤ Hg < 0.419 | ≥ 0.419 |
| 5 | UT97 | Salt Lake City | 0 | 0 < Hg < 0.090 | 0.090 ≤ Hg < 0.212 | 0.212 ≤ Hg < 0.434 | ≥ 0.434 |
| 6 | CO99 | Mesa Verde National Park-Chapin Mesa | 0 | 0 < Hg < 0.065 | 0.065 ≤ Hg < 0.149 | 0.149 ≤ Hg < 0.337 | ≥ 0.337 |
| 7 | SD18 | Eagle Butte | 0 | 0 < Hg < 0.072 | 0.072 ≤ Hg < 0.140 | 0.140 ≤ Hg < 0.223 | ≥ 0.223 |
| 8 | MN23 | Camp Ripley | 0 | 0 < Hg < 0.082 | 0.082 ≤ Hg < 0.236 | 0.236 ≤ Hg < 0.419 | ≥ 0.419 |
| 9 | IN20 | Roush Lake | 0 | 0 < Hg < 0.160 | 0.160 ≤ Hg < 0.293 | 0.293 ≤ Hg < 0.425 | ≥ 0.425 |
| 10 | TN11 | Great Smoky Mountains National Park | 0 | 0 < Hg < 0.070 | 0.070 ≤ Hg < 0.170 | 0.170 ≤ Hg < 0.235 | ≥ 0.235 |
| 11 | OK99 | Stilwell | 0 | 0 < Hg < 0.201 | 0.201 ≤ Hg < 0.550 | 0.550 ≤ Hg < 0.869 | ≥ 0.869 |
| 12 | LA28 | Hammond | 0 | 0 < Hg < 0.188 | 0.188 ≤ Hg < 0.240 | 0.240 ≤ Hg < 0.444 | ≥ 0.444 |
| 13 | FL05 | Chassahowitzka NWR | 0 | 0 < Hg < 0.160 | 0.160 ≤ Hg < 0.291 | 0.291 ≤ Hg < 0.404 | ≥ 0.404 |
| 14 | NC08 | Waccamaw State Park | 0 | 0 < Hg < 0.153 | 0.153 ≤ Hg < 0.420 | 0.420 ≤ Hg < 0.650 | ≥ 0.650 |
| 15 | NJ30 | New Brunswick | 0 | 0 < Hg < 0.155 | 0.155 ≤ Hg < 0.320 | 0.320 ≤ Hg < 0.516 | ≥ 0.516 |

**Table E-4b. Range in Daily Mercury Dry Deposition (g km$^{-2}$) for Each CART Dry Deposition Classification Category.**

| Site # | MDN Site ID | Site Name | CART Classification Category Range (g km$^{-2}$) | | | |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 |
| 1 | WA03 | Makah National Fish Hatchery | 0 ≤ Hg < 0.007 | 0.007 ≤ Hg < 0.012 | 0.012 ≤ Hg < 0.018 | ≥ 0.018 |
| 2 | ID03 | Craters of the Moon National Monument | 0 ≤ Hg < 0.018 | 0.014 ≤ Hg < 0.032 | 0.032 ≤ Hg < 0.040 | ≥ 0.040 |
| 3 | CA75 | Sequoia National Park-Giant Forest | 0 ≤ Hg < 0.028 | 0.028 ≤ Hg < 0.041 | 0.041 ≤ Hg < 0.048 | ≥ 0.048 |
| 4 | NV99 | Gibb's Ranch | 0 ≤ Hg < 0.031 | 0.031 ≤ Hg < 0.051 | 0.051 ≤ Hg < 0.071 | ≥ 0.071 |
| 5 | UT97 | Salt Lake City | 0 ≤ Hg < 0.017 | 0.017 ≤ Hg < 0.032 | 0.032 ≤ Hg < 0.039 | ≥ 0.039 |
| 6 | CO99 | Mesa Verde National Park-Chapin Mesa | 0 ≤ Hg < 0.014 | 0.014 ≤ Hg < 0.023 | 0.023 ≤ Hg < 0.032 | ≥ 0.032 |
| 7 | SD18 | Eagle Butte | 0 ≤ Hg < 0.016 | 0.016 ≤ Hg < 0.026 | 0.026 ≤ Hg < 0.036 | ≥ 0.036 |
| 8 | MN23 | Camp Ripley | 0 ≤ Hg < 0.018 | 0.018 ≤ Hg < 0.028 | 0.028 ≤ Hg < 0.038 | ≥ 0.038 |
| 9 | IN20 | Roush Lake | 0 ≤ Hg < 0.031 | 0.031 ≤ Hg < 0.044 | 0.044 ≤ Hg < 0.057 | ≥ 0.057 |
| 10 | TN11 | Great Smoky Mountains National Park | 0 ≤ Hg < 0.016 | 0.016 ≤ Hg < 0.024 | 0.024 ≤ Hg < 0.030 | ≥ 0.030 |
| 11 | OK99 | Stilwell | 0 ≤ Hg < 0.017 | 0.017 ≤ Hg < 0.027 | 0.027 ≤ Hg < 0.037 | ≥ 0.037 |
| 12 | LA28 | Hammond | 0 ≤ Hg < 0.020 | 0.020 ≤ Hg < 0.029 | 0.029 ≤ Hg < 0.037 | ≥ 0.037 |
| 13 | FL05 | Chassahowitzka NWR | 0 ≤ Hg < 0.023 | 0.023 ≤ Hg < 0.032 | 0.032 ≤ Hg < 0.040 | ≥ 0.040 |
| 14 | NC08 | Waccamaw State Park | 0 ≤ Hg < 0.019 | 0.019 ≤ Hg < 0.030 | 0.030 ≤ Hg < 0.037 | ≥ 0.037 |
| 15 | NJ30 | New Brunswick | 0 ≤ Hg < 0.044 | 0.044 ≤ Hg < 0.058 | 0.058 ≤ Hg < 0.068 | ≥ 0.068 |

Tables E-5 and E-6 define the surface and upper-air meteorological parameters used in the CART analysis, respectively. These parameters were extracted from the meteorological files used as input to REMSAD. The meteorological parameters for each site were extracted for the grid cell in which the actual meteorological monitoring sites (as paired with the MDN site) are located – in order to accommodate the use of actual meteorological data in estimating deposition for additional years.

For the surface parameters, the hourly meteorological values from the REMSAD input were averaged to provide daily (24-hour average) values. For the upper-air parameters, the input values for the two times at which sounding data are available (1200 GMT for morning and 0000 GMT afternoon/evening) were used. Note that the upper-air parameters are for two levels 850 and 700 mb (which correspond to approximately 1500 and 3000 m above ground level (agl), respectively). For some high-elevation sites, only the 700 mb parameters were available. Temperature and moisture parameters for the lower of these two levels were used, as available. In addition, the DT90AM (difference between the temperature at 900mb and the surface temperature) parameter requires temperature at an even lower level (900 mb) and this parameter was not available for several high elevation sites. Temperature at the lowest level available (850 or 700 mb) was used as a surrogate for this parameter.

**Table E-5. Surface Meteorological Parameters used in the Mercury Deposition CART Analysis.**

| Parameter Name | Description |
|---|---|
| **TMAX** | **Maximum surface temperature (°C)** |
| **TMIN** | **Minimum surface temperature (°C)** |
| **Q12** | **Specific humidity at the surface at 1200 LST (g kg$^{-1}$)** |
| **AVGWS** | **24-hour average surface wind speed (m s$^{-1}$)** |
| **AVGWBIN** | **24-hour average surface wind direction bin (1=N, 2=E, 3=S, 4=W, 5=Calm)** |
| **P12** | **Surface pressure at 1200 LST (mb)** |
| **TOT_RAIN** | **Total daily rainfall (in)** |

**Table E-6. Upper-Air Meteorological Parameters used in the Mercury Deposition CART Analysis.**

| Parameter Name | Description |
|---|---|
| **T*plevel*[1]AVG** | **Average temperature aloft based on the average of the morning (1200 GMT) and afternoon/evening sounding (0000 GMT) for either 700 or 850 mb on the current day (°C)** |
| **Q*plevel*AVG** | **Average specific humidity aloft a based on the average of the morning (1200 GMT) and afternoon/evening sounding (0000 GMT) for either 700 or 850 mb on the current day (g kg$^{-1}$)** |
| **WS*plevel*AM** | **Wind speed aloft at the time of the morning (1200 GMT) sounding for either 700 or 850 mb on the current day (m s$^{-1}$)** |
| **WS*plevel*PM** | **Wind speed aloft at the time of the afternoon/evening (0000 GMT) sounding for either 700 or 850 mb on the current day (m s$^{-1}$)** |
| **YWS*plevel*PM** | **Wind speed aloft at the time of the afternoon/evening (0000 GMT) sounding for either 700 or 850 mb on the prior day (m s$^{-1}$)** |
| **WB*plevel*AM** | **Wind direction bin value of 1 through 5, indicating the wind direction [1=N, 2=E, 3=S, 4=W, 5=Calm] at either 700 or 850 mb and the time of the afternoon/evening sounding (1200 GMT) on the current day.** |
| **Wb*plevel*PM** | **Wind direction bin value of 1 through 5, indicating the wind direction [at either 700 or 850 mb and the time of the afternoon/evening sounding (0000 GMT) on the current day.** |
| **YWB*plevel*PM** | **Wind direction bin value of 1 through 5, indicating the wind direction at either 700 or 850 mb and the time of the afternoon sounding on the prior day (0000 GMT).** |

[1] *plevel* = 85 or 70, indicating either 850 or 700 mb

## CART Analysis Results

As discussed in the previous section, CART analysis was used to classify or group all days from the 2001 REMSAD simulation period into bins that were characterized by specified ranges in daily deposition amount. CART was applied separately for each site/location and for wet and dry mercury deposition. Given the specified ranges and input variables, CART develops the tree/bin structure that provides the best segregation and grouping of the data relative to the REMSAD-simulated deposition amounts. However, some misclassification of days into bins with ranges that do not correspond to the simulated deposition amounts is expected. For this analysis, the misclassification is attributable to the inability of the selected meteorological variables to fully describe the detailed physical and chemical processes that are simulated by REMSAD and result in the deposition amounts. Nevertheless, classification accuracy is very good and ranges from about 80 to more than 90 percent, for both wet and dry deposition. This indicates that the meteorological conditions can be used to describe to a large extent the deposition characteristics of the simulation. The number of bins and classification accuracy for each CART analysis is provided in Table E-7.

**Table E-7a. Number of CART Classification Bins and Classification Accuracy for Mercury Wet Deposition, Using Meteorological Inputs and Simulated Deposition Values from the REMSAD Base-Case simulation for 2001.**

| Site # | MDN Site ID | Site Name | Number of CART Classification Bins: Wet Deposition | Percent (%) of Days Correctly Classified by CART: Wet Deposition |
|---|---|---|---|---|
| 1 | WA03 | Makah National Fish Hatchery | 31 | 93 |
| 2 | ID03 | Craters of the Moon National Monument | 26 | 91 |
| 3 | CA75 | Sequoia National Park-Giant Forest | 24 | 89 |
| 4 | NV99 | Gibb's Ranch | 35 | 89 |
| 5 | UT97 | Salt Lake City | 24 | 90 |
| 6 | CO99 | Mesa Verde National Park-Chapin Mesa | 28 | 92 |
| 7 | SD18 | Eagle Butte | 30 | 90 |
| 8 | MN23 | Camp Ripley | 27 | 92 |
| 9 | IN20 | Roush Lake | 24 | 90 |
| 10 | TN11 | Great Smoky Mountains National Park | 28 | 91 |
| 11 | OK99 | Stilwell | 34 | 90 |
| 12 | LA28 | Hammond | 30 | 84 |
| 13 | FL05 | Chassahowitzka NWR | 32 | 89 |
| 14 | NC08 | Waccamaw State Park | 27 | 85 |
| 15 | NJ30 | New Brunswick | 30 | 91 |

**Table E-7b. Number of CART Classification Bins and Classification Accuracy for Mercury Dry Deposition, Using Meteorological Inputs and Simulated Deposition Values from the REMSAD Base-Case Simulation for 2001.**

| Site # | MDN Site ID | Site Name | Number of CART Classification Bins: Dry Deposition | Percent (%) of Days Correctly Classified by CART: Dry Deposition |
|---|---|---|---|---|
| 1 | WA03 | Makah National Fish Hatchery | 27 | 85 |
| 2 | ID03 | Craters of the Moon National Monument | 33 | 88 |
| 3 | CA75 | Sequoia National Park-Giant Forest | 30 | 90 |
| 4 | NV99 | Gibb's Ranch | 29 | 84 |
| 5 | UT97 | Salt Lake City | 27 | 88 |
| 6 | CO99 | Mesa Verde National Park-Chapin Mesa | 30 | 90 |
| 7 | SD18 | Eagle Butte | 28 | 88 |
| 8 | MN23 | Camp Ripley | 27 | 86 |
| 9 | IN20 | Roush Lake | 35 | 88 |
| 10 | TN11 | Great Smoky Mountains National Park | 35 | 90 |
| 11 | OK99 | Stilwell | 25 | 89 |
| 12 | LA28 | Hammond | 33 | 87 |
| 13 | FL05 | Chassahowitzka NWR | 32 | 81 |
| 14 | NC08 | Waccamaw State Park | 34 | 84 |
| 15 | NJ30 | New Brunswick | 33 | 84 |

The key classification parameters vary among the areas and for the two different forms of deposition. For wet deposition, key classification parameters include total daily rainfall, specific humidity near the surface and aloft, and temperature near the surface and aloft. Wind speed aloft is also used frequently in the CART trees.

For dry deposition, the key classification parameters include temperature, moisture and wind speed, both near the surface and aloft. Temperature may be important because it is an indicator of time of year and consequently of vegetation characteristics which are important in dry deposition. Wind directions are not used frequently enough in the CART trees to be considered key parameters to the overall classification, but they are often used near the end of the CART pathways to distinguish different levels of mercury deposition.

To summarize parameter importance, the individual parameters are grouped into the following categories: surface temperature (ST), surface moisture (SQ), surface wind speed (SWS), surface wind direction (SWD), sea level pressure (SLP), total rainfall (RAIN), upper-air temperature (UAT), upper-air moisture (UAQ), upper-air wind speed (UAWS), and upper-air wind direction (UAWD). The average importance (averaged over all sites) for each category (on a scale of 0 to 100) is shown in Figure E-4. Figure E-4a summarizes relative importance for the wet deposition analyses. Figure E-4b summarizes relative importance for the dry deposition analyses.

**Figure E-4a. Relative Importance of the Independent Parameter Categories for the CART Wet Deposition Analyses.**

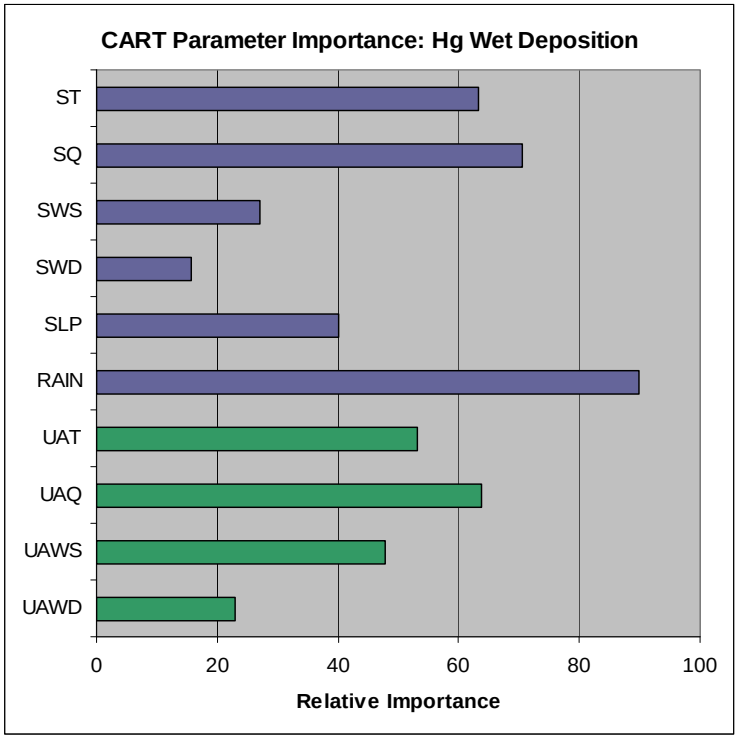
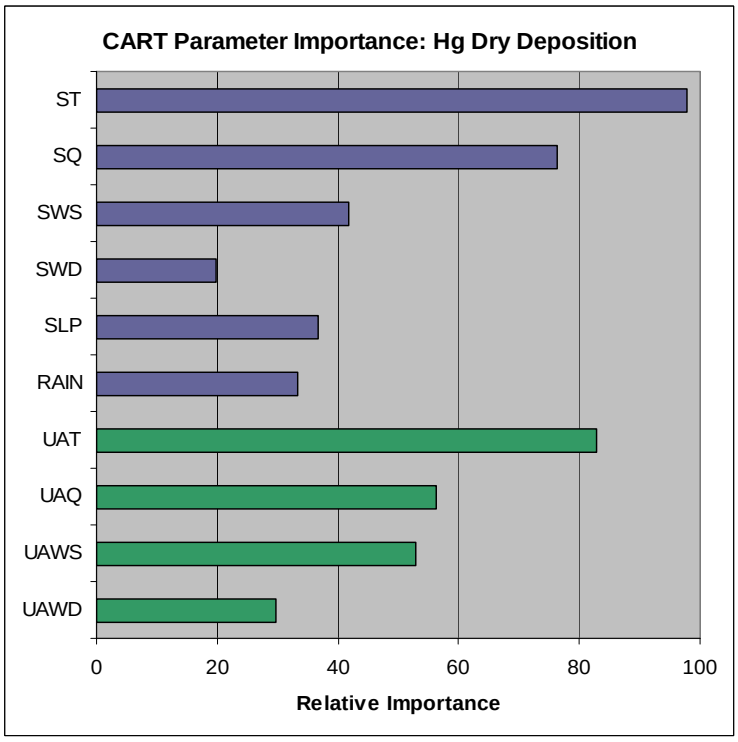



**Figure E-4b. Relative Importance of the Independent Parameter Categories for the CART Dry Deposition Analyses.**



The CART classification trees for each area provided the framework for estimating wet and dry mercury deposition for days within the ten-year period. This is described in the following section.

## Estimation of Mercury Deposition

The methods and results for estimating mercury deposition are discussed in this section.

### USE OF THE CART RESULTS TO ESTIMATE MERCURY DEPOSITION

Daily meteorological data for a ten-year period of record extending from 1997 through 2006 were assembled for each surface and upper-air meteorological monitoring site listed in Table E-3. These data were processed to represent the CART meteorological input parameters presented in Tables E-5 and E-6 and discussed earlier in this report.

For each separate CART classification tree (corresponding to a particular site/location and either wet or dry deposition), the observed meteorological data were used to classify each day for the ten-year period using the classification parameters provided by CART. In this manner, for each CART tree, each day was assigned to (or placed in) one of the CART classification bins. The day was then assigned a deposition value equal to the average of all days within the bin (from the REMSAD simulation period). The result of this step was that each day for the ten-year period was assigned a wet and dry deposition amount for each site/location of interest.

In the next step, these values were summed and annual deposition amounts were calculated for each site (for both wet and dry deposition).

For wet deposition, the tendency for REMSAD to overestimate wet deposition amounts (as presented in Section 6 of the main report) was also taken into account. It is noted numerous times in the main report that MDN observed data may be biased low due to missed periods of precipitation, especially toward the beginning of precipitation events. However, the overestimation by REMSAD is often greater than what is expected based on the potential underestimation in the observed wet deposition. Prior to calculating estimated wet deposition, the REMSAD-derived wet deposition was adjusted by region and by season in accordance with model performance. Since the REMSAD values provide the basis for estimating deposition for all years, any overestimate of wet deposition by REMSAD would result in high values for all years.

Specifically, the REMSAD-derived wet deposition estimates were adjusted by the ratio of the mean observed to mean simulated wet deposition. These ratios were calculated for each season and for the western, southeastern, and northeastern states. The western region encompasses the Northwest, West, Southwest, and West North Central climate zones (refer to Figure E-1). The northeast region encompasses the East North Central, Central, and Northeast climate zones. The southeast region includes the South and Southeast climate zones. The calculated ratios are as follows:

West: Winter = 1.09, Spring = 0.84, Summer = 0.49, Autumn = 0.54
Northeast: Winter = 0.81, Spring = 0.84, Summer = 0.55, Autumn = 0.61
Southeast: Winter = 0.71, Spring = 0.49, Summer = 0.0.61, Autumn = 0.53

Estimated wet deposition was recalculated using the adjusted REMSAD wet deposition values. Both sets of wet deposition estimates are presented in the following sections, and are intended to bound the uncertainty in the calculations due to model performance.

## MERCURY DEPOSITION RESULTS

The CART-based estimates for wet, dry, and total mercury deposition for the selected locations are presented in Table E-8. The calculated annual mercury wet deposition estimates are presented in Table E-8a, dry deposition is presented in Table E-8b, and total deposition is given in Table E-8c. For wet and total deposition, both the adjusted and unadjusted values are presented and represent lower and upper bounds of the estimate. Due to a lack of meteorological data, values could not be estimated for NV99, UT97, and SD18 for 1997 and for NV99 for 1998.

When examining the results, the reader should keep in mind that the purpose of this analysis was to investigate the impact on deposition of year-to-year variability due to meteorological influences. Other important factors, such as year-to-year changes in U.S. and other global emissions that would affect changes in deposition from one year to another were beyond the scope of this analysis.

**Table E-8a. Estimated Annual Mercury Wet Deposition (g km$^{-2}$) for 1997-2006 for Selected MDN Sites.**

| Site ID | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|
| WA03 (Adjusted) | 11.6 | 10.3 | 11.3 | 10.7 | 10.6 | 9.4 | 10.7 | 10.5 | 9.3 | 12.4 |
| (Unadjusted) | 15.2 | 12.8 | 13.6 | 12.8 | 13.5 | 11.6 | 13.6 | 13.9 | 12.2 | 14.8 |
| ID03 (Adjusted) | 2.0 | 1.7 | 1.4 | 1.3 | 1.4 | 1.4 | 1.7 | 1.5 | 1.4 | 1.3 |
| (Unadjusted) | 3.5 | 3.0 | 2.5 | 2.3 | 2.6 | 2.4 | 3.1 | 2.6 | 2.6 | 2.3 |
| CA75 (Adjusted) | 4.2 | 4.7 | 4.6 | 4.1 | 4.4 | 3.5 | 3.9 | 4.1 | 3.7 | 4.5 |
| (Unadjusted) | 5.5 | 5.6 | 6.1 | 5.3 | 5.6 | 4.4 | 5.0 | 5.2 | 4.6 | 5.7 |
| NV99 (Adjusted) | NA | NA | 4.0 | 3.9 | 4.1 | 4.3 | 5.2 | 4.2 | 4.7 | 5.2 |
| (Unadjusted) | NA | NA | 8.0 | 7.6 | 8.1 | 8.6 | 10.2 | 8.2 | 9.4 | 10.3 |
| UT97 (Adjusted) | NA | 6.2 | 4.5 | 6.0 | 5.6 | 5.1 | 6.3 | 6.0 | 7.5 | 5.5 |
| (Unadjusted) | NA | 10.4 | 7.5 | 10.0 | 9.6 | 8.4 | 10.5 | 9.6 | 12.2 | 9.0 |
| CO99 (Adjusted) | 1.1 | 1.2 | 1.9 | 2.5 | 2.0 | 1.3 | 1.9 | 1.9 | 1.7 | 2.2 |
| (Unadjusted) | 2.0 | 2.2 | 3.5 | 4.5 | 3.5 | 2.3 | 3.5 | 3.4 | 3.0 | 3.9 |
| SD18 (Adjusted) | NA | 2.5 | 3.6 | 2.9 | 3.1 | 3.0 | 2.6 | 3.1 | 3.3 | 1.9 |
| (Unadjusted) | NA | 4.0 | 5.7 | 4.5 | 5.1 | 4.9 | 4.0 | 5.0 | 5.3 | 3.0 |
| MN23 (Adjusted) | 4.7 | 4.6 | 5.2 | 4.9 | 3.9 | 5.0 | 3.4 | 5.4 | 4.3 | 4.7 |
| (Unadjusted) | 7.6 | 7.7 | 8.4 | 8.3 | 6.5 | 8.4 | 5.7 | 9.0 | 7.2 | 7.9 |
| IN20 (Adjusted) | 11.1 | 10.9 | 11.9 | 12.2 | 12.8 | 11.6 | 11.5 | 12.5 | 12.6 | 11.1 |
| (Unadjusted) | 15.8 | 16.3 | 17.2 | 17.3 | 18.3 | 17.1 | 16.8 | 17.9 | 18.2 | 16.1 |
| TN11 (Adjusted) | 8.7 | 10.1 | 7.2 | 8.6 | 8.0 | 9.3 | 10.3 | 8.9 | 8.8 | 7.1 |
| (Unadjusted) | 12.2 | 14.9 | 10.7 | 12.4 | 11.6 | 13.5 | 15.3 | 13.1 | 12.8 | 10.1 |
| OK99 (Adjusted) | 14.7 | 14.3 | 11.0 | 13.7 | 14.0 | 13.4 | 15.6 | 13.9 | 13.2 | 11.1 |
| (Unadjusted) | 25.3 | 24.5 | 19.0 | 23.6 | 24.2 | 23.3 | 27.2 | 24.3 | 22.7 | 19.2 |
| LA28 (Adjusted) | 20.4 | 23.6 | 18.6 | 19.7 | 17.2 | 18.8 | 18.5 | 18.8 | 23.8 | 18.4 |
| (Unadjusted) | 34.4 | 39.3 | 31.0 | 32.8 | 29.2 | 31.7 | 31.3 | 31.9 | 39.9 | 30.8 |
| FL05 (Adjusted) | 13.7 | 15.8 | 12.8 | 11.1 | 11.4 | 13.0 | 12.7 | 12.1 | 13.3 | 12.2 |
| (Unadjusted) | 23.0 | 26.6 | 21.7 | 18.9 | 19.4 | 22.1 | 21.5 | 20.5 | 22.5 | 20.6 |
| NC08 (Adjusted) | 11.3 | 12.1 | 10.8 | 10.7 | 10.4 | 11.5 | 13.7 | 12.3 | 17.8 | 14.6 |
| (Unadjusted) | 19.3 | 20.7 | 18.5 | 18.2 | 17.8 | 19.7 | 23.4 | 20.8 | 29.8 | 24.9 |
| NJ30 (Adjusted) | 9.6 | 9.9 | 10.2 | 11.0 | 10.1 | 10.0 | 11.8 | 12.3 | 9.7 | 10.5 |
| (Unadjusted) | 14.1 | 15.0 | 14.7 | 16.9 | 15.2 | 14.3 | 17.5 | 18.8 | 14.0 | 15.7 |

**Table E-8b. Estimated Annual Mercury Dry Deposition (g km$^{-2}$) for 1997-2006 for Selected MDN Sites.**

| Site ID | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|
| WA03 | 1.9 | 1.7 | 1.7 | 1.7 | 1.6 | 1.9 | 1.8 | 1.7 | 2.0 | 2.0 |
| ID03 | 5.7 | 5.6 | 6.2 | 5.8 | 6.2 | 6.2 | 5.9 | 5.7 | 5.7 | 5.7 |
| CA75 | 9.6 | 8.7 | 10.1 | 9.6 | 10.1 | 9.3 | 9.6 | 10.0 | 9.6 | 9.7 |
| NV99 | NA | NA | 12.1 | 12.4 | 12.2 | 11.1 | 11.9 | 11.4 | 11.5 | 11.1 |
| UT97 | NA | 4.7 | 5.9 | 5.5 | 6.1 | 5.8 | 6.4 | 6.2 | 5.9 | 6.0 |
| CO99 | 4.6 | 5.0 | 5.3 | 5.1 | 5.1 | 5.5 | 5.1 | 5.3 | 5.2 | 4.9 |
| SD18 | NA | 5.1 | 4.6 | 5.1 | 5.1 | 5.2 | 5.1 | 5.1 | 5.1 | 5.6 |
| MN23 | 5.2 | 5.5 | 5.4 | 5.5 | 5.3 | 5.5 | 5.6 | 5.6 | 5.7 | 5.6 |
| IN20 | 8.2 | 8.6 | 8.7 | 8.5 | 8.2 | 8.6 | 8.8 | 8.7 | 8.9 | 8.3 |
| TN11 | 4.2 | 4.1 | 4.3 | 4.4 | 4.3 | 3.9 | 3.9 | 4.1 | 4.3 | 4.3 |
| OK99 | 5.5 | 5.8 | 6.1 | 5.7 | 5.9 | 5.8 | 6.0 | 6.0 | 6.1 | 5.8 |
| LA28 | 5.7 | 6.0 | 6.3 | 6.7 | 6.3 | 5.8 | 6.0 | 5.8 | 6.2 | 6.3 |
| FL05 | 7.5 | 7.2 | 7.3 | 7.5 | 7.0 | 6.9 | 7.6 | 7.2 | 7.0 | 7.1 |
| NC08 | 6.4 | 5.9 | 6.1 | 5.9 | 6.1 | 5.8 | 5.8 | 6.0 | 6.0 | 6.1 |
| NJ30 | 14.2 | 14.4 | 14.5 | 14.0 | 13.9 | 14.0 | 14.0 | 13.6 | 14.5 | 13.8 |

**Table E-8c. Estimated Annual Total Mercury Deposition (g km$^{-2}$) for 1997-2006 for Selected MDN Sites.**

| Site ID | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|
| WA03 (Adjusted) | 13.5 | 12.0 | 13.0 | 12.3 | 12.2 | 11.3 | 12.5 | 12.2 | 11.3 | 14.4 |
| (Unadjusted) | 17.1 | 14.5 | 15.3 | 14.5 | 15.1 | 13.5 | 15.4 | 15.6 | 14.1 | 16.8 |
| ID03 (Adjusted) | 7.6 | 7.4 | 7.6 | 7.1 | 7.6 | 7.6 | 7.6 | 7.2 | 7.1 | 7.0 |
| (Unadjusted) | 9.2 | 8.7 | 8.7 | 8.1 | 8.9 | 8.7 | 9.0 | 8.3 | 8.3 | 8.0 |
| CA75 (Adjusted) | 13.8 | 13.4 | 14.7 | 13.7 | 14.5 | 12.7 | 13.5 | 14.0 | 13.3 | 14.2 |
| (Unadjusted) | 15.0 | 14.3 | 16.1 | 14.9 | 15.6 | 13.7 | 14.6 | 15.2 | 14.2 | 15.4 |
| NV99 (Adjusted) | NA | NA | 16.1 | 16.3 | 16.3 | 15.4 | 17.0 | 15.5 | 16.3 | 16.3 |
| (Unadjusted) | NA | NA | 20.1 | 20.0 | 20.3 | 19.7 | 22.1 | 19.5 | 20.9 | 21.4 |
| UT97 (Adjusted) | NA | 10.9 | 10.4 | 11.5 | 11.7 | 11.0 | 12.7 | 12.2 | 13.4 | 11.5 |
| (Unadjusted) | NA | 15.1 | 13.4 | 15.6 | 15.7 | 14.2 | 16.9 | 15.8 | 18.1 | 15.0 |
| CO99 (Adjusted) | 5.7 | 6.2 | 7.2 | 7.6 | 7.1 | 6.8 | 7.0 | 7.2 | 6.8 | 7.1 |
| (Unadjusted) | 6.6 | 7.1 | 8.7 | 9.6 | 8.6 | 7.8 | 8.6 | 8.7 | 8.1 | 8.9 |
| SD18 (Adjusted) | NA | 7.6 | 8.2 | 8.0 | 8.2 | 8.2 | 7.7 | 8.3 | 8.4 | 7.5 |
| (Unadjusted) | NA | 9.1 | 10.4 | 9.6 | 10.2 | 10.1 | 9.1 | 10.1 | 10.4 | 8.5 |
| MN23 (Adjusted) | 9.9 | 10.1 | 10.7 | 10.4 | 9.3 | 10.5 | 9.0 | 11.0 | 10.0 | 10.3 |
| (Unadjusted) | 12.8 | 13.2 | 13.8 | 13.8 | 11.9 | 13.8 | 11.3 | 14.6 | 12.9 | 13.5 |
| IN20 (Adjusted) | 19.3 | 19.5 | 20.6 | 20.7 | 21.0 | 20.2 | 20.3 | 21.2 | 21.5 | 19.4 |
| (Unadjusted) | 24.0 | 24.9 | 25.9 | 25.8 | 26.5 | 25.8 | 25.6 | 26.6 | 27.1 | 24.4 |
| TN11 (Adjusted) | 13.0 | 14.2 | 11.5 | 12.9 | 12.3 | 13.2 | 14.2 | 13.0 | 13.1 | 11.4 |
| (Unadjusted) | 16.4 | 19.0 | 15.0 | 16.7 | 15.9 | 17.4 | 19.2 | 17.2 | 17.1 | 14.4 |
| OK99 (Adjusted) | 20.2 | 20.1 | 17.1 | 19.4 | 19.9 | 19.2 | 21.6 | 19.9 | 19.2 | 16.9 |
| (Unadjusted) | 30.9 | 30.3 | 25.1 | 29.2 | 30.1 | 29.1 | 33.2 | 30.3 | 28.7 | 25.1 |
| LA28 (Adjusted) | 26.1 | 29.6 | 24.9 | 26.4 | 23.5 | 24.6 | 24.5 | 24.5 | 30.0 | 24.7 |
| (Unadjusted) | 40.1 | 45.3 | 37.3 | 39.5 | 35.5 | 37.5 | 37.2 | 37.7 | 46.1 | 37.1 |
| FL05 (Adjusted) | 21.1 | 22.9 | 20.2 | 18.6 | 18.4 | 20.0 | 20.3 | 19.3 | 20.3 | 19.3 |

| Site ID | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|
| **(Unadjusted)** | **30.5** | **33.8** | **29.0** | **26.4** | **26.4** | **29.0** | **29.1** | **27.7** | **29.5** | **27.7** |
| **NC08 (Adjusted)** | **17.8** | **18.1** | **17.0** | **16.6** | **16.5** | **17.3** | **19.6** | **18.3** | **23.8** | **20.7** |
| **(Unadjusted)** | **25.7** | **26.6** | **24.7** | **24.1** | **23.9** | **25.5** | **29.2** | **26.8** | **35.8** | **31.0** |
| **NJ30 (Adjusted)** | **23.9** | **24.3** | **24.7** | **25.0** | **24.0** | **24.0** | **25.8** | **25.9** | **24.2** | **24.3** |
| **(Unadjusted)** | **28.3** | **29.4** | **29.2** | **30.9** | **29.1** | **28.3** | **31.5** | **32.4** | **28.4** | **29.6** |

It is informative to summarize these results in terms of the average value and the standard deviation over the ten-year period. This information is provided in Table E-9.

**Table E-9. Ten-Year Average Estimated Annual Mercury Deposition (g km$^{-2}$) for 1997-2006 for Selected MDN Sites: Wet, Dry, and Total.**

| Site ID | Wet Deposition | | Dry Deposition | | Total Deposition | |
|---|---|---|---|---|---|---|
| | 10-Year Average (g km$^{-2}$) | Standard Deviation (g km$^{-2}$) | 10-Year Average (g km$^{-2}$) | Standard Deviation (g km$^{-2}$) | 10-Year Average (g km$^{-2}$) | Standard Deviation (g km$^{-2}$) |
| **WA03 (Adjusted)** | **10.7** | **0.95** | **1.8** | **0.15** | **12.5** | **0.97** |
| **(Unadjusted)** | **13.4** | **1.10** | **1.8** | **0.15** | **15.2** | **1.12** |
| **ID03 (Adjusted)** | **1.5** | **0.22** | **5.9** | **0.24** | **7.4** | **0.26** |
| **(Unadjusted)** | **2.7** | **0.39** | **5.9** | **0.24** | **8.6** | **0.38** |
| **CA75 (Adjusted)** | **4.2** | **0.41** | **9.6** | **0.40** | **13.8** | **0.58** |
| **(Unadjusted)** | **5.3** | **0.51** | **9.6** | **0.40** | **14.9** | **0.73** |
| **NV99 (Adjusted)** | **4.5** | **0.49** | **11.7** | **0.51** | **16.2** | **0.51** |
| **(Unadjusted)** | **8.8** | **1.03** | **11.7** | **0.51** | **20.5** | **0.90** |
| **UT97 (Adjusted)** | **5.9** | **0.83** | **5.9** | **0.51** | **11.7** | **0.94** |
| **(Unadjusted)** | **9.7** | **1.36** | **5.9** | **0.51** | **15.5** | **1.40** |
| **CO99 (Adjusted)** | **1.8** | **0.46** | **5.1** | **0.25** | **6.9** | **0.56** |
| **(Unadjusted)** | **3.2** | **0.81** | **5.1** | **0.25** | **8.3** | **0.89** |
| **SD18 (Adjusted)** | **2.9** | **0.50** | **5.1** | **0.24** | **8.0** | **0.33** |
| **(Unadjusted)** | **4.6** | **0.85** | **5.1** | **0.24** | **9.7** | **0.67** |
| **MN23 (Adjusted)** | **4.6** | **0.60** | **5.5** | **0.15** | **10.1** | **0.59** |
| **(Unadjusted)** | **7.7** | **0.98** | **5.5** | **0.15** | **13.2** | **0.98** |
| **IN20 (Adjusted)** | **11.8** | **0.70** | **8.5** | **0.24** | **20.4** | **0.77** |
| **(Unadjusted)** | **17.1** | **0.88** | **8.5** | **0.24** | **25.7** | **0.98** |
| **TN11 (Adjusted)** | **8.7** | **1.06** | **4.2** | **0.16** | **12.9** | **0.94** |
| **(Unadjusted)** | **12.7** | **1.66** | **4.2** | **0.16** | **16.8** | **1.53** |
| **OK99 (Adjusted)** | **13.5** | **1.46** | **5.9** | **0.18** | **19.4** | **1.42** |
| **(Unadjusted)** | **23.3** | **2.56** | **5.9** | **0.18** | **29.2** | **2.51** |
| **LA28 (Adjusted)** | **19.8** | **2.23** | **6.1** | **0.31** | **25.9** | **2.23** |
| **(Unadjusted)** | **33.2** | **3.62** | **6.1** | **0.31** | **39.3** | **3.60** |
| **FL05 (Adjusted)** | **12.8** | **1.31** | **7.2** | **0.24** | **20.0** | **1.31** |
| **(Unadjusted)** | **21.7** | **2.16** | **7.2** | **0.24** | **28.9** | **2.15** |
| **NC08 (Adjusted)** | **12.5** | **2.29** | **6.0** | **0.18** | **18.6** | **2.27** |
| **(Unadjusted)** | **21.3** | **3.74** | **6.0** | **0.18** | **27.3** | **3.72** |
| **NJ30 (Adjusted)** | **10.5** | **0.91** | **14.1** | **0.29** | **24.6** | **0.75** |
| **(Unadjusted)** | **15.6** | **1.62** | **14.1** | **0.29** | **29.7** | **1.43** |

Overall, year-to-year variability is less for dry deposition than for wet deposition, presumably due to variations in precipitation that influence wet deposition. There is also considerably less year-to-year variability in wet deposition (and total deposition) for sites located in the western states (consistent with less frequent and less variable rainfall).

The CART-based values for 2001 indicate that, based on meteorological variability, this was an average year for mercury deposition at most sites, with slightly higher than average estimated deposition for CA75 and OK99, and slightly lower than average deposition for CO99, MN23, TN11, LA28 FL05, and NC08.

The adjusted values are consistently lower than the unadjusted values for wet (and total) deposition. By accounting for the tendency for REMSAD to overestimate wet deposition these values represent a lower bound for the estimated mercury deposition.

### COMPARISON WITH OBSERVED MERCURY WET DEPOSITION DATA

One of the key motivations for this analysis was the lack of a long-term record of both wet and dry deposition data for mercury. As indicated, however, in Table E-2, wet deposition data are available for ten sites for some portion of the analysis period (the number of years with complete data availability within the 10-year analysis period ranges 0 to 10). For sites with five or more complete years of data during the analysis period, these data are used as a check on the reasonableness of the results. The mean values of estimated and observed wet deposition are compared to determine whether the estimated values are within a reasonable range, compared to the observed data. The estimated standard deviation in annual mercury wet deposition is also compared with that based on the observed data. This provides a check of the reasonableness of the meteorological variability of the CART-based estimates with the overall (meteorological and emissions based) variability revealed by the observed data (it is expected that the variability present in the estimated values should be lower than that for the observed data, especially if emissions changes or fluctuations occurred during the years for which data are available). As discussed later, this comparison can also be used to infer the role of meteorology versus emissions in producing the variations in the observed data.

This information is summarized in Table E-10. The adjusted estimates in Table E-10a are followed by the unadjusted estimates in Table E-10b.

**Table E-10a. Summary of Observed and Estimated (Based on Adjusted REMSAD Results) Variability in Annual Wet Deposition (g km$^{-2}$ ) for MDN Monitoring Sites with Five or More Years of Data During the Analysis Period.**

| Site ID | Observed or Estimated | Number of Analysis Years with Complete Data | Minimum Annual Value (g km$^{-2}$) | Maximum Annual Value (g km$^{-2}$) | Average Annual Deposition (g km$^{-2}$) | Standard Deviation (g km$^{-2}$) |
|---|---|---|---|---|---|---|
| **CO99** | **Observed** | **5** | **3.3** | **6.0** | **4.7** | **1.2** |
| | **Estimated** | | **1.1** | **2.5** | **1.8** | **0.5** |
| **MN23** | **Observed** | **10** | **6.7** | **12.4** | **8.8** | **2.0** |
| | **Estimated** | | **3.4** | **5.4** | **4.6** | **0.6** |
| **IN20** | **Observed** | **6** | **8.0** | **13.2** | **10.7** | **1.9** |
| | **Estimated** | | **10.9** | **12.8** | **11.8** | **0.7** |
| **LA28** | **Observed** | **8** | **11.0** | **21.3** | **15.2** | **3.4** |
| | **Estimated** | | **17.2** | **23.8** | **19.8** | **2.2** |
| **FL05** | **Observed** | **9** | **13.1** | **21.5** | **16.0** | **2.9** |
| | **Estimated** | | **11.1** | **15.8** | **12.8** | **1.3** |
| **NC08** | **Observed** | **10** | **9.3** | **18.1** | **12.8** | **3.0** |
| | **Estimated** | | **10.4** | **17.8** | **12.5** | **2.3** |

**Table E-10b. Summary of Observed and Estimated (Based on Unadjusted REMSAD Results) Variability in Annual Wet Deposition (g km$^{-2}$ ) for MDN Monitoring Sites with Five or More Years of Data During the Analysis Period.**

| Site ID | Observed or Estimated | Number of Analysis Years with Complete Data | Minimum Annual Value (g km$^{-2}$) | Maximum Annual Value (g km$^{-2}$) | Average Annual Deposition (g km$^{-2}$) | Standard Deviation (g km$^{-2}$) |
|---|---|---|---|---|---|---|
| **CO99** | **Observed** | **5** | **3.3** | **6.0** | **4.7** | **1.2** |
| | **Estimated** | | **2.0** | **4.5** | **3.2** | **0.8** |
| **MN23** | **Observed** | **10** | **6.7** | **12.4** | **8.8** | **2.0** |
| | **Estimated** | | **5.7** | **9.0** | **7.7** | **1.0** |
| **IN20** | **Observed** | **6** | **8.0** | **13.2** | **10.7** | **1.9** |
| | **Estimated** | | **15.8** | **18.3** | **17.1** | **0.9** |
| **LA28** | **Observed** | **8** | **11.0** | **21.3** | **15.2** | **3.4** |
| | **Estimated** | | **29.2** | **39.9** | **33.2** | **3.6** |
| **FL05** | **Observed** | **9** | **13.1** | **21.5** | **16.0** | **2.9** |
| | **Estimated** | | **18.9** | **26.6** | **21.7** | **2.2** |
| **NC08** | **Observed** | **10** | **9.3** | **18.1** | **12.8** | **3.0** |
| | **Estimated** | | **17.8** | **29.8** | **21.3** | **3.7** |

Focusing first on the minimum, maximum, and mean values, the results indicate that the CART-based estimates are reasonably consistent in both magnitude and range with the observed values. For IN20, LA28, FL05, and NC08, the results derived using the adjusted REMSAD values are more consistent with the observed ranges and averages. The mean estimated wet deposition amounts for these sites are considerably higher than the mean observed values. This indicates that REMSAD overestimates wet deposition on types of days that occur with some frequency during the

analysis period. For CO99 and MN23, the results derived using the unadjusted REMSAD values are more consistent with the observed ranges and averages.

When compared with the observation-based values, the standard deviation (used here to characterize year-to-year variability) is less for all sites for the results derived using the adjusted REMSAD values, but greater for some sites for the results derived using the unadjusted values. The greater variability with the unadjusted values is consistent with the overall higher deposition amounts. Since it is expected that the variability present in these results should be lower than that for the observed data, the estimates based on the adjusted REMSAD values are expected to be more reliable.

Based on the results derived using the adjusted REMSAD values, it is estimated that meteorological variability accounts for between 30% and 75% of the year-to-year variability in mercury wet deposition for these six locations for the period 1997-2006.

## Summary and Conclusions

In this exercise, a combination of mercury deposition modeling results, observed meteorological data, and statistical analysis were used to estimate annual wet and dry mercury deposition for a ten-year period for 15 locations throughout the U.S., and specifically the potential year-to-year variability in mercury deposition simulation results due to variations in meteorology. This methodology appears to provide reasonable estimates of annual mercury deposition that account for year-to-year variability in the meteorological conditions that influence mercury deposition. The estimated deposition amounts show agreement with annual observed deposition amounts, especially when the tendency for the REMSAD simulation results for the 2001 simulation period to overestimate wet deposition is taken into account. Key finding from this analysis include:

- Classification and Regression Tree (CART) analysis is able to correctly classify 80 to 90 percent of days that comprise the 2001 REMSAD simulation period into bins defined by mercury deposition amount, based on input meteorological parameters.
- Key classification parameters for wet deposition include total daily rainfall, specific humidity near the surface and aloft, and temperature near the surface and aloft.
- Key classification parameters for dry deposition include temperature, moisture and wind speed, both near the surface and aloft.
- Overall, estimated year-to-year variability is less for dry deposition than for wet deposition and less for sites located in the western states.
- The CART-based values indicate that, based on meteorological variability, 2001 was an average year for mercury deposition at most of the selected sites.
- The CART-based estimates of mercury deposition are reasonably consistent in both magnitude and range with available data.
- When adjusted to account for REMSAD model performance, the estimated values are consistently lower than the unadjusted values for wet (and total) deposition. The adjusted estimates show better agreement with observed annual wet deposition data, but less year-to-year variability.
- Meteorology contributes to observed variability in annual mercury deposition and differences in meteorological conditions are expected to contribute to year-to-year differences in any

corresponding simulation results. Based on the results derived using the adjusted REMSAD values for selected sites, it is estimated that meteorological variability accounts for between 30% and 75% of the year-to-year variability in mercury wet deposition for the period 1997-2006.

## References

Breiman, Leo, Jerome Friedman, Richard Olshen, and Charles Stone. Classification and Regression Trees. Pacific Grove: Wadsworth, 1984.

NCDC, 2007. National Climatic Data Center web site: www.ncdc.noaa.gov/oa/climate/research/.

Karl, T. R., and W. J. Koss. 1984. "Regional and National Monthly, Seasonal, and Annual Temperature Weighted by Area, 1895-1983." Historical Climatology Series 4-3, National Climatic Data Center, Asheville, NC, 38 pp.

Myers, T., Y. Wei, B. Hudischewskyj, and S. Douglas. 2003. “Application of the REMSAD Modeling System to Estimate the Deposition of Mercury in Support of the Wisconsin TMDL Pilot.” ICF International, San Rafael, California (03-050).

Salford Systems. 2007. CART user’s guide online at: http://www.salford-systems.com/doc/CARTtrifold.ddf

Steinberg, Dan, and Phillip Colla. CART—Classification and /regression Trees. San Diego, CA: Salford Systems, 1997.

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