For the two counties in question, the trends in 8-hour ozone (e.g., number of days above standard and design value) indicate a decrease from the late 1980s through the early 1990's, but little change since then.

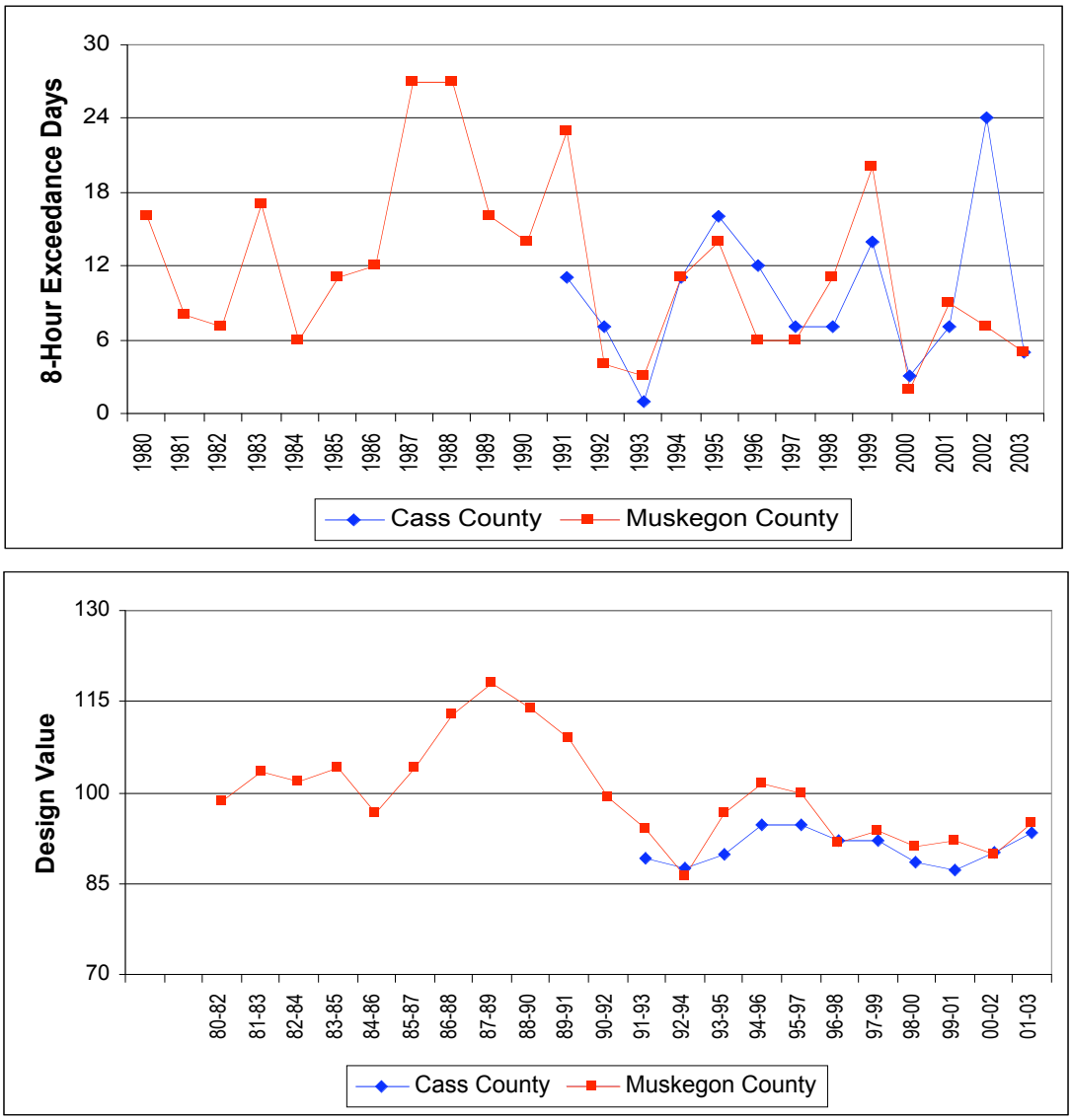


Figure 3. Trends in 8–Hour Ozone in Two Counties

Given the effect of meteorology on ozone, it is necessary to adjust the ozone trends for meteorological influences. A simple metric was considered here (i.e., number of exceedance days divided by the number of hot days). The plot of this metric below shows that the 8-hour trends are relatively flat over the past decade.

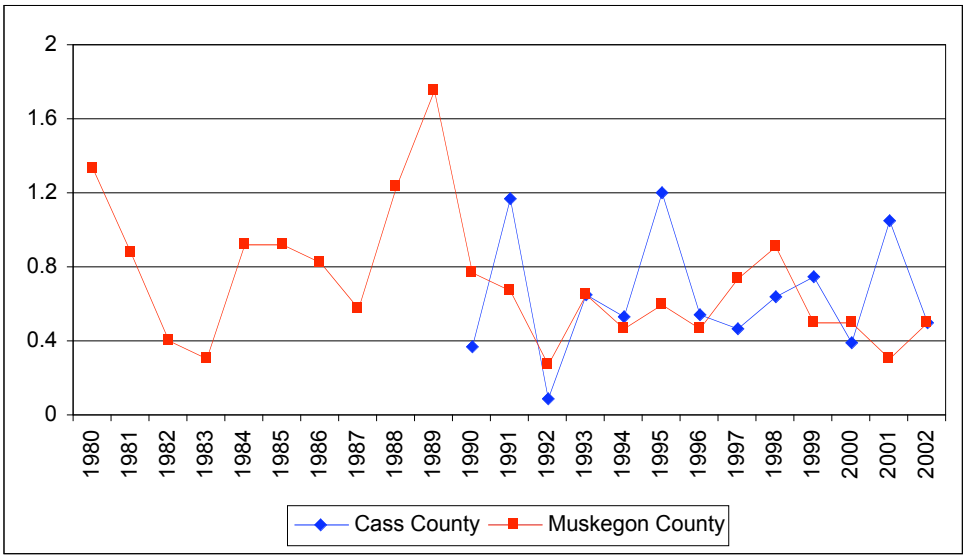


Figure 4. Trends in Weather-Adjusted Ozone Metric (No. Exc. Days/No. Hot Days) in Two Counties

More rigorous (statistical) adjustments were used to support ozone trends analyses for sites in the Lake Michigan region (see "Mid-Course Review for 1-Hour Ozone in the Lake Michigan Region", May 10, 2004). The analyses show a slight downward trend in 8-hour ozone levels over the past 10 years for Muskegon, although the trend is not statistically significant. These results suggest that additional emission reductions (i.e., regional NOx emissions) are needed to improve ozone air quality in the region. The effect of these emission reductions is discussed in the following section.

Modeling Results I

A preliminary 8-hour assessment was conducted by LADCO using regional modeling data and the USEPA's recommended 8-hour attainment test (see "8-Hour Ozone Assessment", May 2, 2001).[1] The modeled future year design values for 2007 are shown in the table below.

Site	County	Observed Design Value	Future Year Design Value (2007) CAA Controls	Regional Strategy[2]
Cassopolis	Cass	93	88	81
Muskegon	Muskegon	97	92	86

[1] This modeling was performed to support the 1-hour attainment demonstration for the Lake Michigan area and, as such, there are limitations with using it to assess 8-hour ozone. For example, the episodes and modeling domain were selected for the Lake Michigan area and may not accurately represent other cities in the modeling domain, such as St. Louis and Detroit, and the modeling reflects a 2007 future year scenario (note: the actual 8-hour attainment date is expected to be about 2012). On the other hand, it should be noted that three of the four modeled episodes are representative periods for high 8-hour ozone in the Lake Michigan area and basecase model performance for 8-hour ozone was found to be as good as (or better than) that for 1-hour ozone.

[2] The 1-hour regional control strategy includes CAA controls, Tier II/low S, NOx SIP call, and WI's NOx rule.

The modeling results indicate that the (1-hour) regional control strategy will reduce 8-hour ozone levels but may not be enough to provide for attainment of the 8-hour standard at all locations. It should be noted, however, that the observed design values are based on the average of the design values of the three 3-year periods which include 1996 (i.e., the base inventory year used in the modeling). The three 3-year design values for each site are as follows:

Site	1994-1996	1995-1997	1996-1998	Average
Cassopolis	94	94	92	93
Muskegon	101	99	91	97

The USEPA's draft modeling guidance ("Draft Guidance on the Use of Models and Other Analyses in Attainment Demonstrations for the 8-Hour Ozone NAAQS," May 1999, EPA-454/R-99-004) recommends using the higher of the 3-year period "straddling" the inventory year (i.e., 1995-1997 for a 1996 inventory) and the 3-year period used to designate the area nonattainment. The design values associated with this approach, compared to the alternative approach above generally shows similar results.

	Higher of….		Average of Three
Site	**1995-1997**	**2001-2003**	**3-year Periods**
Cassopolis	**94**	93	**93**
Muskegon	**99**	95	**97**

Modeling Results II

Additional 8-hour ozone results are available from recent modeling conducted by LADCO to assess the impact of the USEPA's proposed Clean Air Interstate Rule (CAIR) - e.g., "Interstate Air Quality Rule: Modeling Assessment," March 26, 2004.

The resulting modeled design values are shown in the table below.

Site	County	Observed Design Value	2010 base[3]	2010 IAQR[4]
Cassopolis	Cass	90	80.5 (79.6)	79.8 (79.1)
Muskegon	Muskegon	89	81.0 (79.6)	80.1 (79.0)

* = result based on IPM source-specific data

[3] The 2010 base inventory for all sectors, except EGUs, was developed using economic and population growth projections, along with emission reductions from current regulations, including the NOx SIP Call; Tier II vehicle standards; heavy duty diesel vehicle standards; non-road diesel proposed standards; NOx and VOC reductions from recreational vehicle/large spark ignition engine rules; SO2 and PM2.5 reductions from the industrial boiler MACT; mostly VOC reductions from a large number of earlier MACTs; PM, SO2, and NOx reductions from a small set of MACTs; and VOC reductions from national rules for Marine Vessel Loading of Petrol Liquids, TSDFs, and Landfills. It does not include reductions from two other recent MACTs (Gas Turbines and Reciprocating Internal Combustion Engines), but these are relatively small reductions.

[4] The 2010 CAIR strategy includes the 2010 base, plus the SOx and NOx reductions from the proposed Interstate Air Quality Rule.

These results, which are consistent with the USEPA's modeling for the proposed rule (see "Technical Support Document for the CAIR, Air Quality Modeling Analyses" January 2004), show that the two counties in question are expected to be in compliance with the 8-hour ozone standard by 2010.

The relevance of this modeling for 2007 needs to consider the difference in emissions (especially, NOx emissions) between 2007 and 2010. An approximation of this difference can be made comparing the 2007 inventory developed by the USEPA for its heavy-duty diesel (HDD) rulemaking and the 2010 (base) inventory developed by the USEPA for the proposed CAIR. (Note, the derivation of the 2010 CAIR inventory relied on the 2007 HDD inventory[5], as well as the 2010 inventory developed by the USEPA for its proposed land-based nonroad diesel engine (LNDE) rulemaking[6].) A simple comparison of the 2007 HDD (with an adjustment for nonroad emissions) and the 2010 CAIR inventories shows about a nine percent difference in NOx emissions. (Note, the VOC emissions for these two inventory years are within a few percent of each other). Furthermore discussion of the difference in NOx emissions is provided below by source sector.

> Point Sources: NOx emissions from EGUs are about eight percent less in the 2010 CAIR (base) inventory compared to the 2007 HDD inventory. The major control program affecting EGUs is the NOx SIP call. The NOx SIP Call requires 22 States and the District of Columbia to submit State Implementation Plans that address the regional transport of ground-level ozone through reductions in NOx emissions. The rule affects EGUs, as well as large non-utility point sources (i.e., large industrial boilers and turbines, large internal combustion engines, and cement manufacturing). The compliance date for the NOx emission budgets is May 2004.
>
> On-Road Highway Vehicles: NOx emissions from on-road sources are about 17 percent less in the 2010 CAIR (base) inventory compared to the 2007 HDD inventory. The major control programs affecting on-road sources are Tier 2/low sulfur gasoline and the HDD rule (2007 Heavy-Duty Highway Rule). The Tier 2/low sulfur gasoline program establishes new tailpipe standards for all classes of passenger vehicles, light-duty trucks, and SUVs that will be phased-in between 2004 and 2007, and requires that the level of sulfur in gasoline be reduced by up to 90 percent in phases between 2004 and 2007. The HDD rule establishes new emission standards for heavy-duty highway engines and vehicles that will be phased-in between 2007 and 2010, and requires that the level of sulfur in highway diesel fuel be reduced by 97 percent by mid-2006.

---

[5] See "Procedures for Developing Base Year and Future Year Mass and Modeling Inventories for the Heavy-Duty Engine and Vehicle Standards and the Highway Diesel Fuel (HDD) Rulemaking" (EPA/420-R-00-020, October 2000) and "Data Summaries of Base Year and Future Year Mass and Modeling Inventories for the Heavy-Duty Engine and Vehicle Standards and the Highway Diesel Fuel (HDD) Rulemaking – Detailed Report" (EPA/420-R-00-019, October 2000).

[6] See USEPA's "Regulatory Impact Analysis" EPA420-R-04-007, May 2004

Nonroad Sources: NOx emissions from nonroad sources are about six percent less in the 2010 CAIR (base) inventory compared to the 2007 HDD inventory. The major control program affecting nonroad sources is the USEPA's May 2004 Clean Air Nonroad Diesel Rule. This rule requires pollution controls on diesel engines used in industries such as construction, agriculture and mining, and it will reduce sulfur content of diesel fuel. Standards for new engines will be phased-in starting with the smallest engines in 2008, until all but the very largest diesel engines meet both NOx and PM standards in 2014. Some of the largest engines, 750+ horsepower, will have one additional year to meet the emissions standards. Diesel fuel currently contains about 3,000 parts per million (ppm) sulfur. The new rule will cut that to 500 ppm in 2007 and 15 ppm by 2010.

This information suggests that a significant difference in NOx emissions is expected between 2007 and 2010. As such, it may be worthwhile to conduct a 2007 sensitivity analysis by adjusting (increasing) the NOx emissions as follows: EGUs (increase by ten percent); On-Road (increase by fifteen percent); and Non-Road (increase by five percent).

ADDITIONAL PHOTOCHEMICAL MODELING

Photochemical Model Selection

Several one-atmosphere photochemical models treat the physical processes and chemistry that form ozone. These models include the Community Multiscale Air Quality modeling system (CMAQ) and the Comprehensive Air Quality Model with Extensions (CAMx4) by ENVIRON. Fast simulation times and full science make the CAMx4 model the ideal choice for modeling grid simulations over regional domains and multiple month episodes. The summers (i.e., June through August) of 2001 and 2002 were used for this analysis to capture the variety of high ozone episodes that occurred across the Upper Midwest.

ENVIRON developed an ozone source attribution approach that has become known as the "Ozone Source Apportionment Technology," or OSAT (Yarwood et al., 1996). This method was originally implemented in the urban airshed model and was then built into CAMx. The OSAT provides a method for estimating the contributions of multiple source areas, categories, and pollutant types to ozone formation in a single model run. The OSAT also includes a methodology for diagnosing the temporal relationships between ozone and emissions from groups of sources.

The OSAT allows CAMx to track source region and/or source emissions category contributions to predicted grid cell ozone concentration; thus, for any selected receptor point and time, the model gives a clear picture of the likely distribution of ozone and ozone precursors by source emissions category and/or source region, as well as an indication as to whether the ozone at the selected time and location would more likely respond to upwind NOx or VOC controls.

The CAMx (version 4.03), with the OSAT technology, was used in this analysis to determine the geographic source (i.e., Chicago) contribution of ozone precursors and source emissions type (i.e., on-road mobile) contribution at specific locations such as the Cassopolis and Muskegon monitors.

CAMx OSAT Results for Cassopolis Monitor (Cass County)
To provide high credibility the OSAT results, only modeled results from days where the CAMx predicted concentrations within 20 percent of actual *and* the Cassopolis monitor recorded an actual concentration of 85 ppb or greater were used. This screening criteria yielded 18 modeled days for analysis during the simulated summers of 2001 and 2002. Results from these 18 days were weighted by actual ozone concentration to give greater value to the higher ozone days.

Geographic regions were broken down by states surrounding Michigan and by counties within Michigan. Emission types were broken down by: biogenics, on-road mobile, non-road mobile, low level point sources, elevated point sources, and area sources. Results of local contribution compared to transport concentrations from surrounding areas are as follows:

Contribution Percentage to Cassopolis Monitor by Geographic Area and by Emissions Type

	Biogenics	On-Road	Non-Road	Low Point	Elevated Point	Area	**TOTAL**
Local Contribution							
Cass & St. Joseph Counties	0.05%	0.27%	0.15%	0.02%	0.02%	0.07%	**0.58%**
Out-of-State Transport							
Chicago Area	0.05%	3.06%	2.22%	0.50%	2.51%	1.32%	**9.66%**
Illinois (excluding Chicago)	0.51%	2.01%	1.75%	0.39%	3.42%	0.55%	**8.63%**
Indiana	0.80%	8.65%	5.52%	0.41%	6.52%	2.83%	**24.73%**
Ohio	0.03%	0.59%	0.42%	0.01%	0.52%	0.29%	**1.86%**
Wisconsin	0.11%	0.88%	0.57%	0.02%	0.43%	0.01%	**0.38%**

Leftover contributions are from the following areas; 4.04 percent from remaining Michigan counties; 17.86 percent from other non-listed states; and 32.26 percent from background.

As shown, less than one percent of the ozone recorded at the Cassopolis monitor can be attributed to local (i.e., Cass Co. plus St. Joseph Co.) emissions. With a design value of 93 ppb, ALL Michigan emissions contributions to the Cassopolis monitor (e.g., 4.62 percent of total) could be eliminated and the monitor would still be in violation of the 8-hour standard. The modeling evidence, in conjunction with common sense analysis, demonstrates overwhelming out-of-state transport.

CAMx OSAT Results for Muskegon Monitor (Muskegon County)
Similar to the previous analysis, only modeled results from days where the CAMx predicted concentrations within 20 percent of actual *and* the Muskegon monitor recorded an actual concentration of 85 ppb or greater were used. This screening

criteria yielded 12 modeled days for analysis during the simulated summers of 2001 and 2002. Results from these 12 days were weighted by actual ozone concentration to give greater value to the higher ozone days.

Geographic regions were broken down by states surrounding Michigan and by counties within Michigan. Emission types were broken down by: biogenics, on-road mobile, non-road mobile, low level point sources, elevated point sources, and area sources. Results of local contribution compared to transport concentrations from surrounding areas are as follows:

Contribution Percentage to Muskegon Monitor by Geographic Area and by Emissions Type

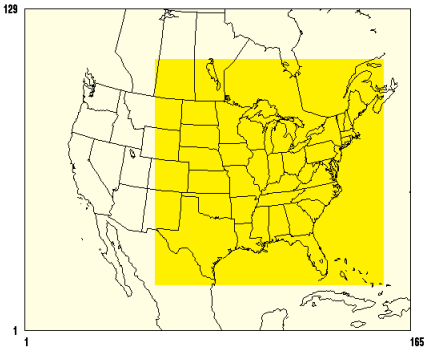
	Biogenics	On-Road	Non-Road	Low Point	Elevated Point	Area	**TOTAL**
Local Contribution							
Muskegon County	0.01%	0.30%	0.10%	0.01%	0.17%	0.06%	**0.65%**
Out-of-State Transport							
Chicago Area	0.05%	5.40%	4.32%	0.82%	3.16%	2.73%	**16.48%**
Illinois (excluding Chicago)	0.25%	1.80%	1.52%	0.33%	2.65%	0.58%	**7.13%**
Indiana	0.13%	3.84%	2.67%	0.19%	4.23%	1.78%	**12.84%**
Ohio	0.01%	0.89%	0.64%	0.02%	0.77%	0.46%	**2.79%**
Wisconsin	0.05%	1.18%	0.69%	0.02%	0.57%	0.60%	**3.11%**

Leftover contributions are from the following areas; 11.07 percent from remaining Michigan counties; 18.11 percent from non-listed states; and 27.82 percent from background.

As shown, less than one percent of the ozone recorded at the Muskegon monitor can be attributed to local (i.e., Muskegon Co.) emissions. With a design value of 95 ppb, ALL Michigan emissions contributions to the Muskegon monitor (e.g., 11.72 percent of total) could be eliminated and the monitor would still have a design value of 84 ppb, barely below non-attainment threshold. The modeling evidence, in conjunction with common sense analysis, demonstrates overwhelming out-of-state transport.

Grid Projection and Domains

The CAMx model was applied with a Lambert projection centered at (-97, 40) and true latitudes at 33 and 45. The photochemical modeling domain consists of 97 cells in the X direction and 90 cells in the Y direction covering the Central and Eastern United States with 36 km grid cells. This is shown in the figure to the right as the dark yellow box. The lighter yellow box shows the MM5 modeling domain. The emissions modeling domain is similar to the MM5 domain, but with 9 fewer cells in each direction.



CAMx4 is applied with the vertical atmosphere resolved with 16 layers up to approximately 15 kilometers above ground level.

Grid	Cell Size	X, Y Origin (km)	X, Y Offset (from MM5 grid)	NX, NY
Meteorological	36 km	(-2952., -2304.)	N/A	165, 129
Emissions	36 km	(-2628.,-1980.)	9, 9	147, 111
Photochemical	36 km	(-900.,-1620.)	57, 19	97, 90

Meteorological Inputs

Meteorological input data for the CAMx photochemical modeling runs were processed using the NCAR's 5th generation Mesoscale Model (MM5) version 3.5 (Dudhia, 1993). Key model parameters and options used in MM5 are shown in the table below. A more detailed discussion of MM5 applications to support photochemical modeling may be found in the MM5 Modeling Protocol at www.ladco.org (Baker, 2004). The parameterizations and modules selected were determined to be an optimal model configuration for the Upper Midwest based on extensive sensitivity simulations (Johnson, 2003).

Configuration	36km and 12km Domains
Explicit Moisture	Simple ice
Cumulus	Kain-Fritsch
PBL	Pleim-Chang (ACM)
Radiation	RRTM
Multi-Layer Soil Model	Pleim-Xu
Shallow convection	No
4-D Data Assimilation	Analysis nudging on above PBL
Moist Physics Table	No

The meteorological fields output by MM5 are prepared for use by the photochemical model with processing utilities. These programs translate certain meteorological parameters from the MM5 grid to the photochemical grid. Additionally, these processors must estimate parameters that are not explicitly output by MM5. Since the meteorological processing programs for each model not only translate data, but also diagnose certain key parameters, this step must be scrutinized to achieve optimal model results.

Emissions Inputs

Emissions data was processed using EMS-2003. The EMS-2003 model is selected for its ability to efficiently process the large requirements of regional and daily emissions processing. In addition to extensive quality assurance and control capabilities, EMS-2003 also performs basic emissions processes such as chemical speciation, spatial allocation, temporal allocation, and control of area, point, and motor vehicle emissions (Janssen, 1998). Outputs from EMS-2003 include a coordinate-based elevated point source file and gridded emissions estimates for low-point, area, mobile, and biogenics sources. Anthropogenic emission estimates are made for a weekday, Saturday, and Sunday for each month. The biogenic emissions are day-specific. Volatile organic compounds are speciated to the CB4 chemical speciation profile.

The point source inventory is based on the 1999 National Emission Inventory version 2.0. Temporal profiles were applied to all CEM units located in the Upper Midwest (IL, IN, WI, MI, OH, MN, IA, MO, KY, TN, WV, PA) by hour of the day, day of the week, and month of the year. The 1995 Canadian point sources are included in the elevated point source inventory. No Mexican point source emissions are included.

Area sources include all categories that are not included in the point, on-road, off-road, biogenic, or ammonia inventory. Categories such as solvent utilization and non-point fuel combustion are included in the area inventory. The area source inventory is based on the 1999 National Emission Inventory. A 90 percent reduction factor to all dust categories was applied to the inventory to remove the non-transportable fraction of these emissions. This area inventory also includes all non-point emissions from the Canadian inventory, which includes non-road, on-road, and ammonia estimates.

On-road emissions are estimated with the MOBILE6 using MM5 output surface temperature and 15 m relative humidity. The default temporal tables were modified to represent a more complex distribution of vehicle miles traveled for weekend. Off-road emissions are estimated with the latest release of USEPA's NONROAD 2002 model.

The biogenic emissions were estimated with EMS-2003 using BIOME3/BEIS3 and the BELD3 land use dataset. Other inputs to the biogenic emissions model include hourly satellite photosynthetically activated radiation (PAR) and 15 m temperature data output from MM5. The 15 m temperature data was selected for its spatial representation of the tree canopy layer.

SPECIE	DESCRIPTION
ALD2	Aldehydes
ETH	Ethylene
FORM	Formaldehyde
ISOP	Isoprene
OLE	Olefins - Anthropogenic
OLE2	Olefins - Biogenic (OVOC)
PAR	Paraffins
TOL	Toluene
XYL	Xylene
NH3	Ammonia
CO	Carbon monoxide
NO2	Nitrogen dioxide
NO	Nitrogen oxide
SULF	Sulfur
SO2	Sulfur dioxide
PEC	Primary PM-fine elemental carbon
PNO3	Primary PM-fine nitrate
POA	Primary PM-fine organic aerosol
PSO4	Primary PM-fine sulfate
CCRS	Primary PM-coarse crustal
FCRS	Primary PM-fine crustal
CPRM	Primary PM-coarse "other"
FPRM	Primary PM-fine "other"