Potential Impacts of Climate Change on Regional Air Quality

New England Climate Change Forum – June 19, 2008

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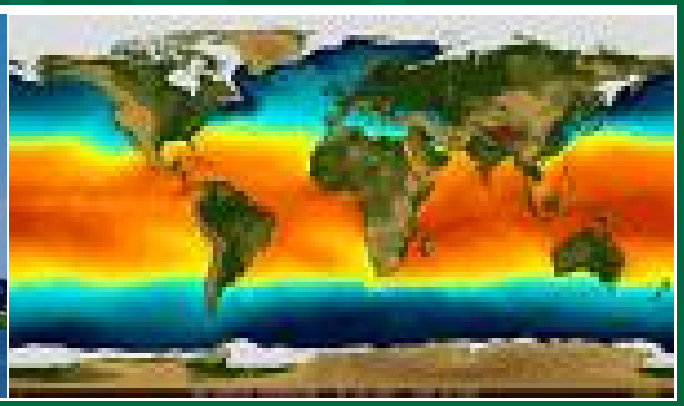
US EPA ORD National Center for Environmental Assessment



The views expressed are the author's own and do not represent official EPA views or policy

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Outline

- Background and key questions
- Design of GCRP climate/air quality project
- Initial results:
  - Climate change impacts on U.S. ozone concentrations
  - Key modeling uncertainties
  - Implications for future clean air
- Moving forward to the next phase of the assessment

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Background – What is the issue?

- 1989 EPA Effects Report
  - An increase of 5° C might cause a 20% increase in ozone (direct effects on chemical reaction rates in an urban area)
- 1991 NRC Report: *Rethinking the Ozone Problem*
  - Progress toward reducing ozone concentrations in the United States has been severely hampered by the lack of a coordinated national research program directed at elucidating the chemical, physical, and meteorological processes that control ozone formation and concentrations over North America.
  - In particular, the program should elucidate the response of ambient ozone concentrations to possible regulatory actions or to natural changes in atmospheric composition or climate.
- 2001 NRC Report: *Global Air Quality: An Imperative for Long-Term Observational Strategies*
  - Key Question: How can global air quality change affect, and in turn be affected by, global climate change?

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Background – What is the issue?

- 2007 IPCC Fourth Assessment Report
  - Climate change would modify a number of chemical and physical processes that control air quality and the net effects are *likely* to vary from one region to another.
  - Climate change can affect air quality by modifying the rates at which pollutants are dispersed, the rate at which aerosols and soluble species are removed from the atmosphere, the general chemical environment for pollutant generation and the strength of emissions from the biosphere, fires and dust.
  - Overall, the net effect of climate change on air quality is highly uncertain.

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Background – Why is this important?

- 2004 NRC Report: *Air Quality Management in the US*
  - Identified *"adapting the air quality management system to a changing (and most likely warmer) climate"* as key challenge in coming decade
- Climate change expected to impact air pollution in ways that have not been explicitly considered in AQ program planning
  - *Chemical reaction rates and atmospheric transport processes*
  - *Biogenic (and anthropogenic) emissions rates*
- Potential to affect attainment of clean air objectives?
- Critical assessment of emerging science needed to assist in making significant, long-term decisions

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Goal

- Enhance the ability of air quality managers to consider global change in their decisions through improved characterization of the potential impacts on air quality
  - Developing research tools and a knowledge base to answer science questions about the impacts of global change on regional U.S. air quality
  - Providing an answer to the basic question, “is global change something we will have to account for when moving forward with U.S. air quality policy?”
  - Delivering to the air quality policy and management community an improved understanding of the behavior and complexities of the global change-air quality system and an appreciation for the strengths and limitations of the available scientific tools and methods
  - Setting the stage for applying these scientific insights and tools to help answer specific policy and management questions.

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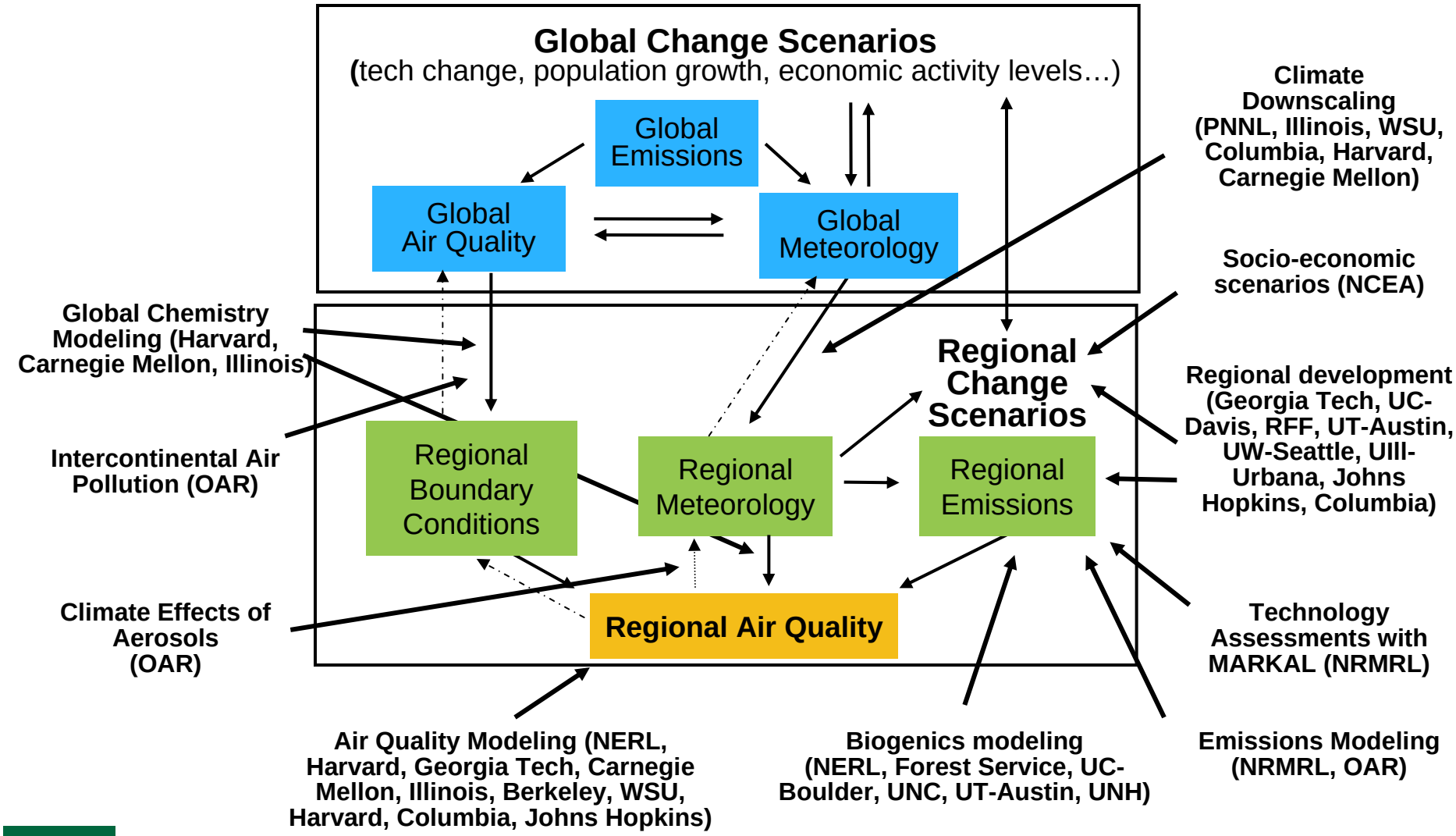
Collaborative Effort

- Across EPA labs, academic community, and, critically, OAR
- NERL: AQ modeling and emissions inventories expertise: regional-scale simulations under present and future climate conditions
- NRMRL: Expertise in developing future emissions scenarios: energy demand and technology penetration
- NCER: Enables strong collaboration with extramural research: nearly 40 STAR grants ($30 million) to support assessment
- NCEA: organization, infrastructure support, synthesis reports
- OAQPS: Close, two-way partnership with ORD to understand relevance and implications of the science

Air Quality Assessment – Collaborations



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Two Phase Assessment Effort:

Phase I

- Develop capabilities of climate and atmospheric chemistry models to investigate current and future meteorological effects on regional AQ
- Explore range of scenarios and alternative model specifications to begin defining uncertainty space of climate change/AQ simulations
- Investigate potential impacts of climate change alone on regional U.S. AQ (initial focus on O_3)

Phase II

- Extend capabilities of modeling systems from Phase I (new pollutants, improved processes, ensembles of more simulations)
- Develop tools to project land use, technology, and demographic changes to construct plausible scenarios of U.S. pollutant emissions 50 years from now
- Investigate combined impact of changing climate and changing anthropogenic emissions on AQ

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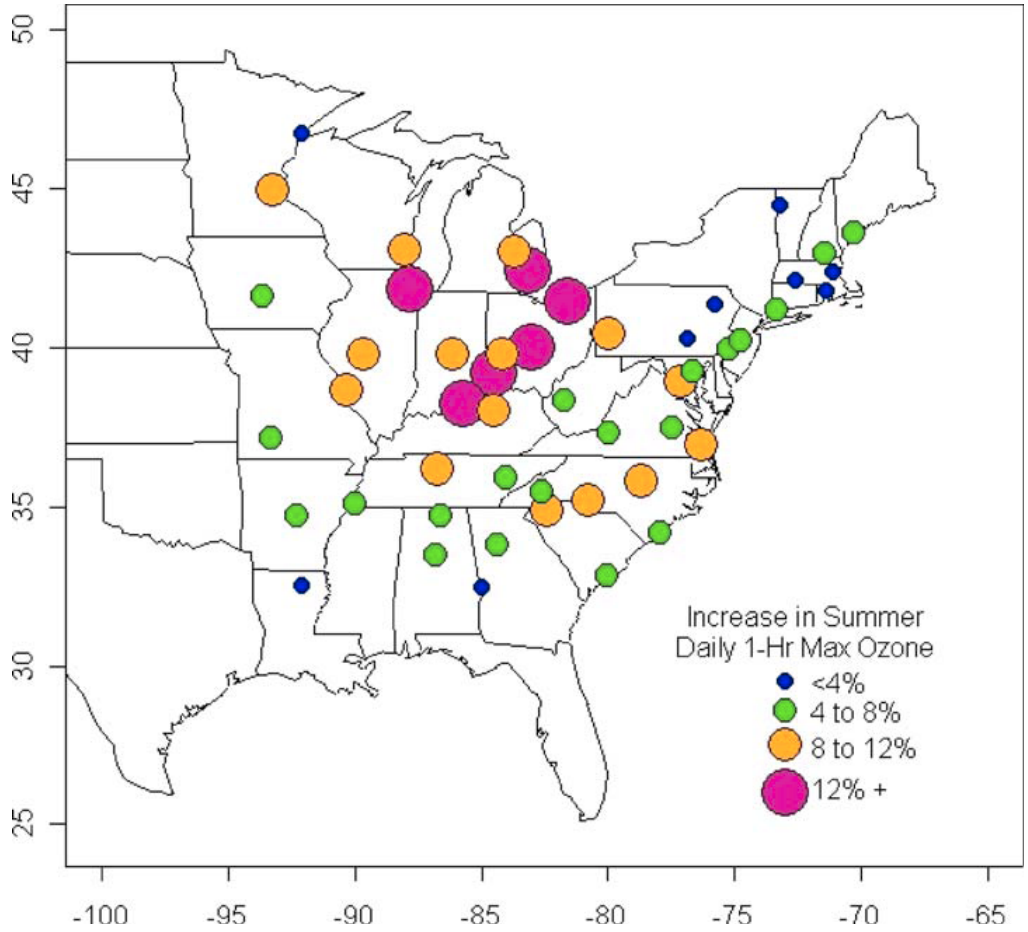
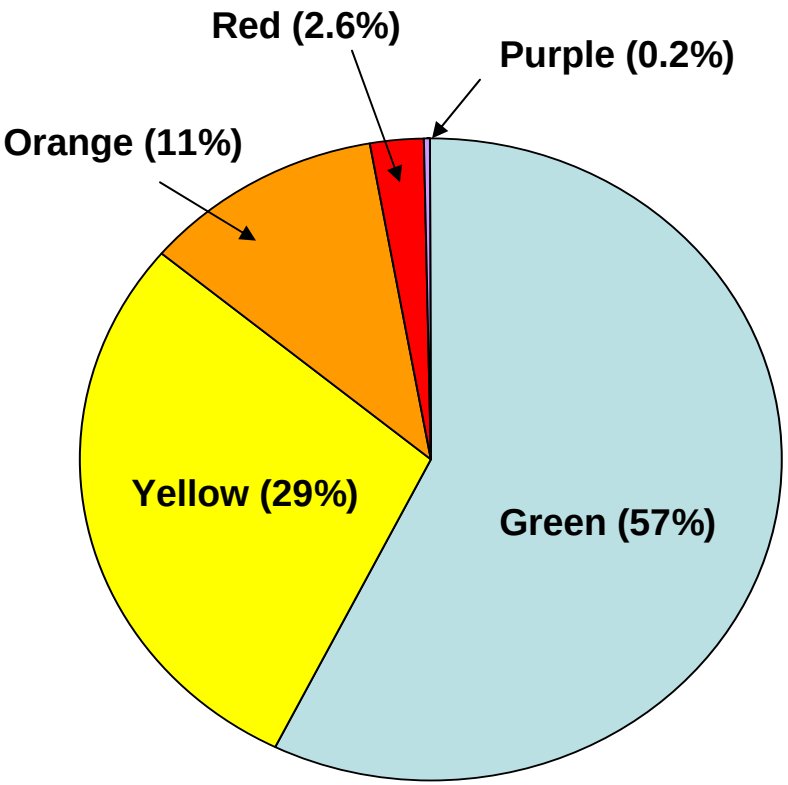
- Can only give a few results here
- Many more results can be viewed at the NCER web-site: http://es.epa.gov/ncer/science/globalclimate/02_22_07_event.html
- Additional information on intramural modeling can be found at the NERL Web-site: http://www.epa.gov/asmdnerl/Climate/index.html
- Information on energy and emissions modeling can be found on the NRMRL web-site: http://www.epa.gov/appcdwww/apb/globalchange/quality.html

Increase in Summertime Ozone: 1990s to 2050s

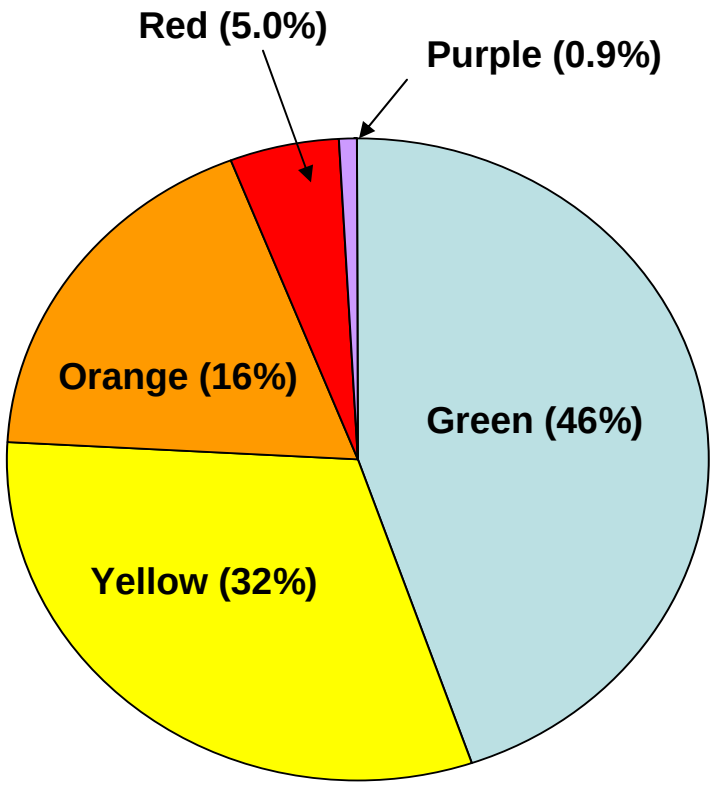


Bell et al, 2006

Percent of Summer Days in Each Ozone Action Category



Current Climate



Future Climate

Bell et al, 2006

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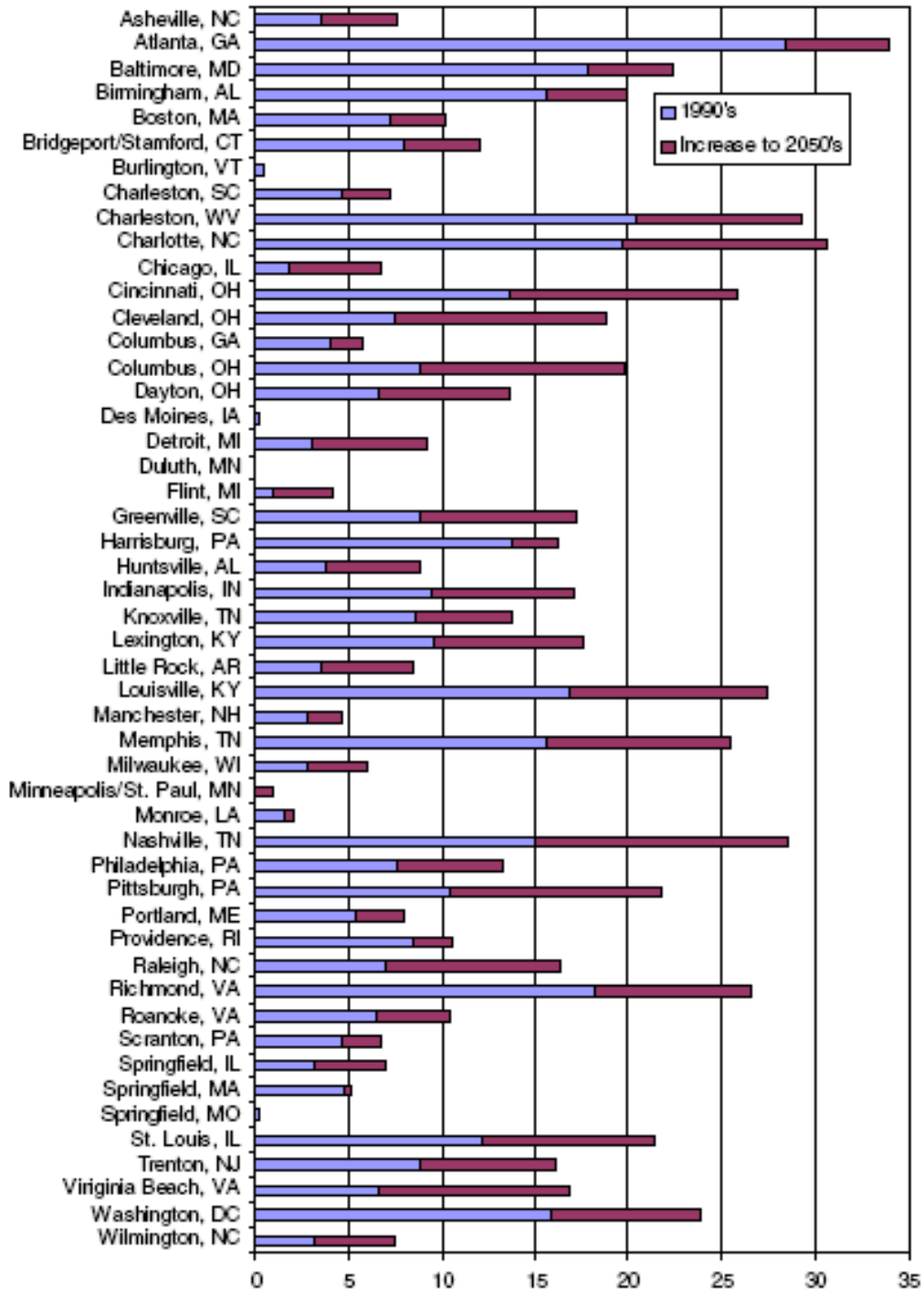
IPCC A2 Scenario:

Average number of 8-hr O_3 NAAQS exceedences (days/summer).

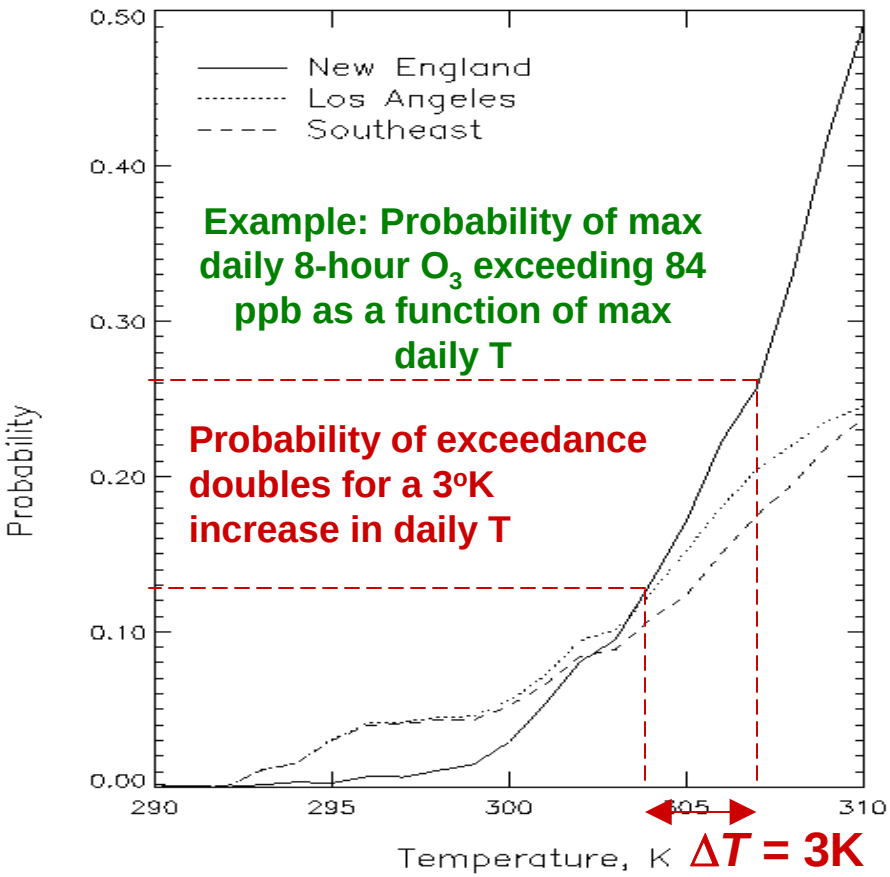


Bell and Hogrefe in *Climatic Change* (2007)

Impacts of Climate Change on Ozone

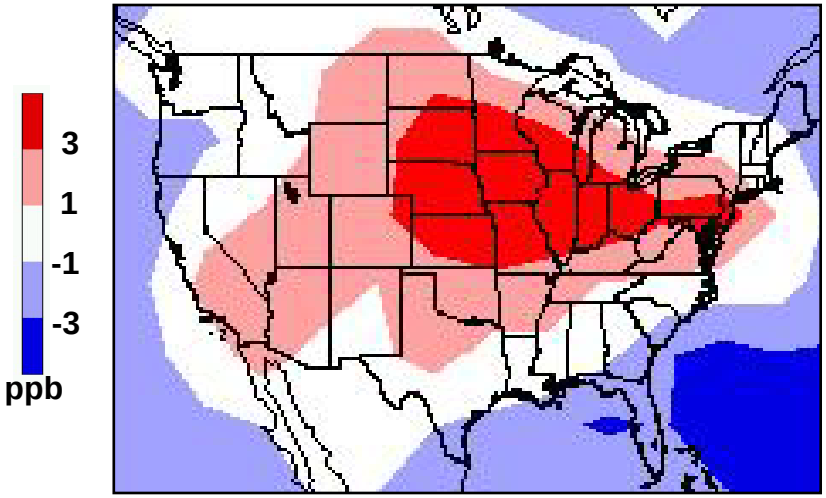
- O_3 episodes (mostly summer) are generally what we care about
- Not a simple relationship
- Right combination of meteorological conditions – e.g., high temperature, clear skies, stagnant air – with the right blend of precursor pollutants, e.g., NO_x, VOCs
- Likely to see different degrees of change in different regions

Key Point: Effect could be quite large

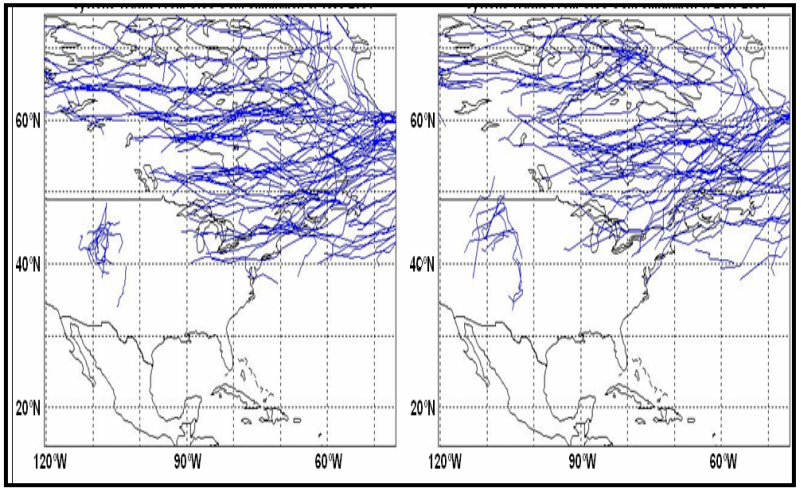


Lin et al. [2001]

Harvard Simulation Results:
Present-day to 2050s change in summertime average Maximum Daily 8-Hour (MDA8) O_3 and Storm Tracks



MDA8 O_3 change by 2050s



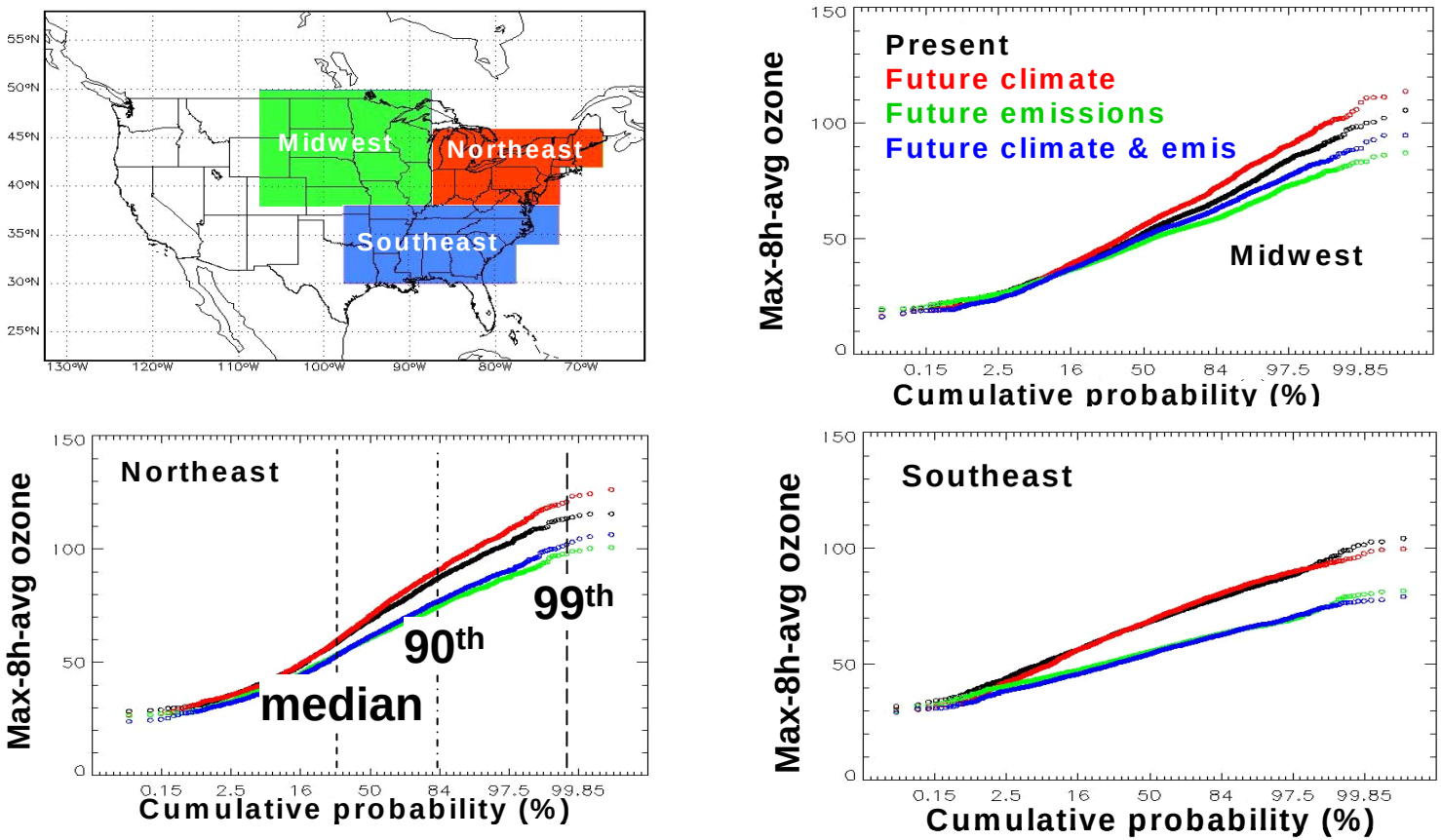
Mid-latitude Storm Tracks: Present day and 2050s climate

- **Main Points:**
- Climate change effect only (no emissions changes)
- Impact is few ppb, but with strong regional variability
- Cold fronts associated with mid-latitude cyclones tracking across Canada are the principal process ventilating Midwest and Northeast. Summertime cyclone frequency decreases by 17% in 2050 climate

For additional results, see www.as.harvard.edu:16080/chemistry/trop/gcap/

SENSITIVITY OF POLLUTION EPISODES TO GLOBAL CHANGE

Summer probability distribution of daily 8-h max ozone



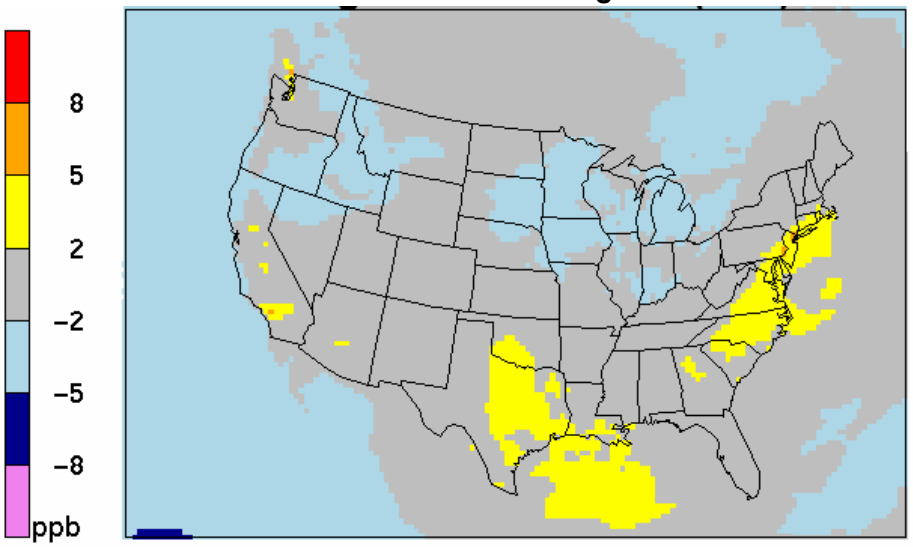
- In northeast and midwest, climate change effect reaches 10 ppbv for high-O_3 events; near-zero effect in southeast

Wu et al. [2007]

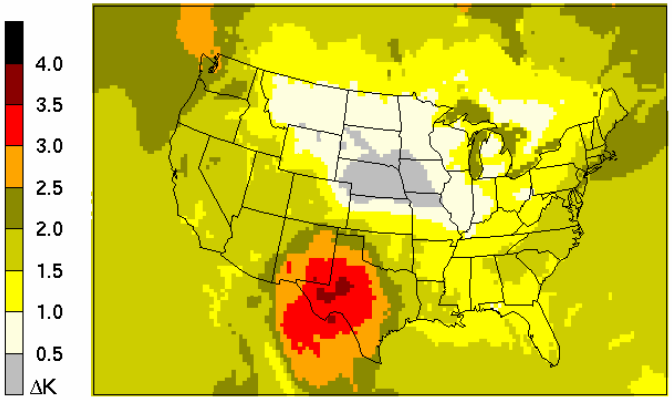
EPA NERL Simulation Results:

Present-day to 2050s change in summertime average Maximum Daily 8-Hour (MDA8) O_3, temperature, and surface solar radiation

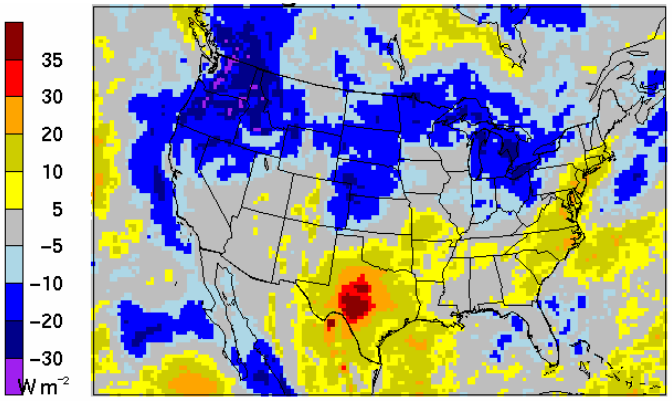
MDA8 O_3



Temperature



Surface Solar



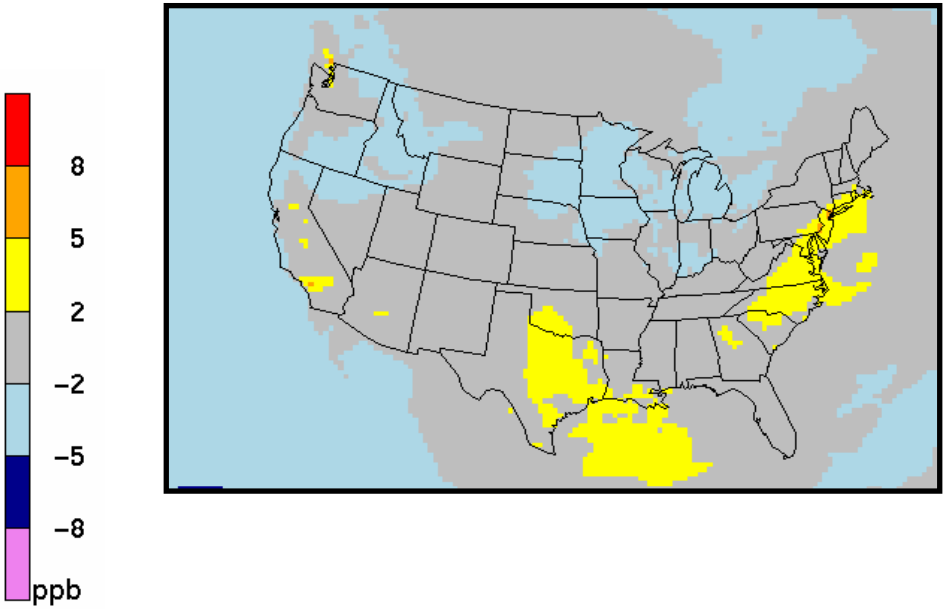
Main Points:

- Climate change effect only (no emissions changes)
- Impact is few ppb, but with strong regional variability
- T and sunlight (cloud cover) are key drivers, along with biogenic emissions in some regions

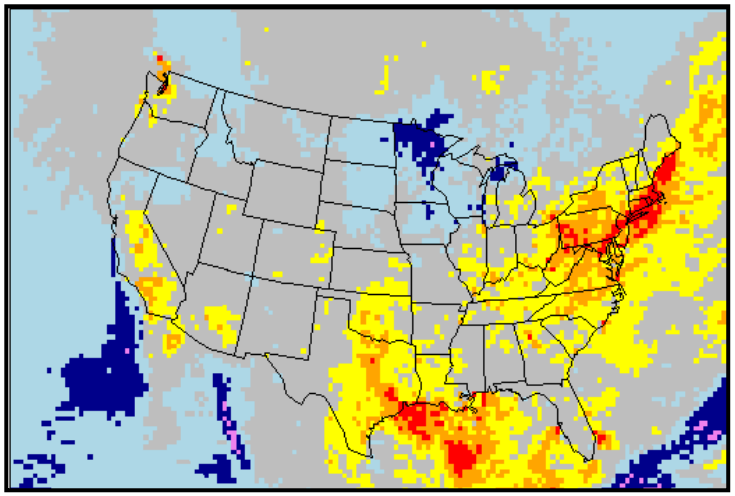
Nolte et al. in press

Disproportionately large climate-induced changes for high-O_3 extremes …

Mean MDA8 O_3



95th Percentile MDA8 O_3



For additional details, see www.epa.gov/AMD/Climate/index.html

Nolte et al. in press

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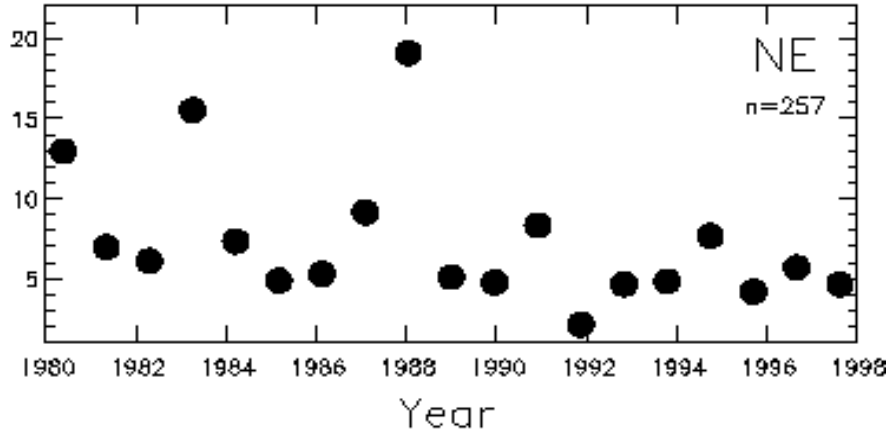
Implications

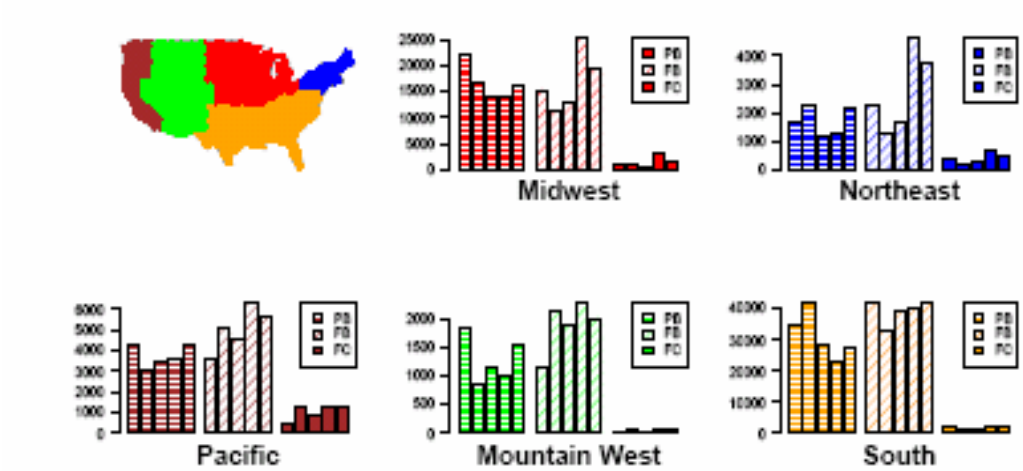
- All else being equal, what kind of additional pressure might climate change put on our existing concerns and strategies? Is this something we need to begin folding into our planning?

- Examples:
  - Interannual variability
  - Extension of O_3 “season” into spring and fall
  - “Climate Penalty” on control strategies: additional emissions reductions required in the future?

Interannual Variability …

Observed average number of summer days in the Northeast U.S. with 8-hour O_3 > 84 ppb



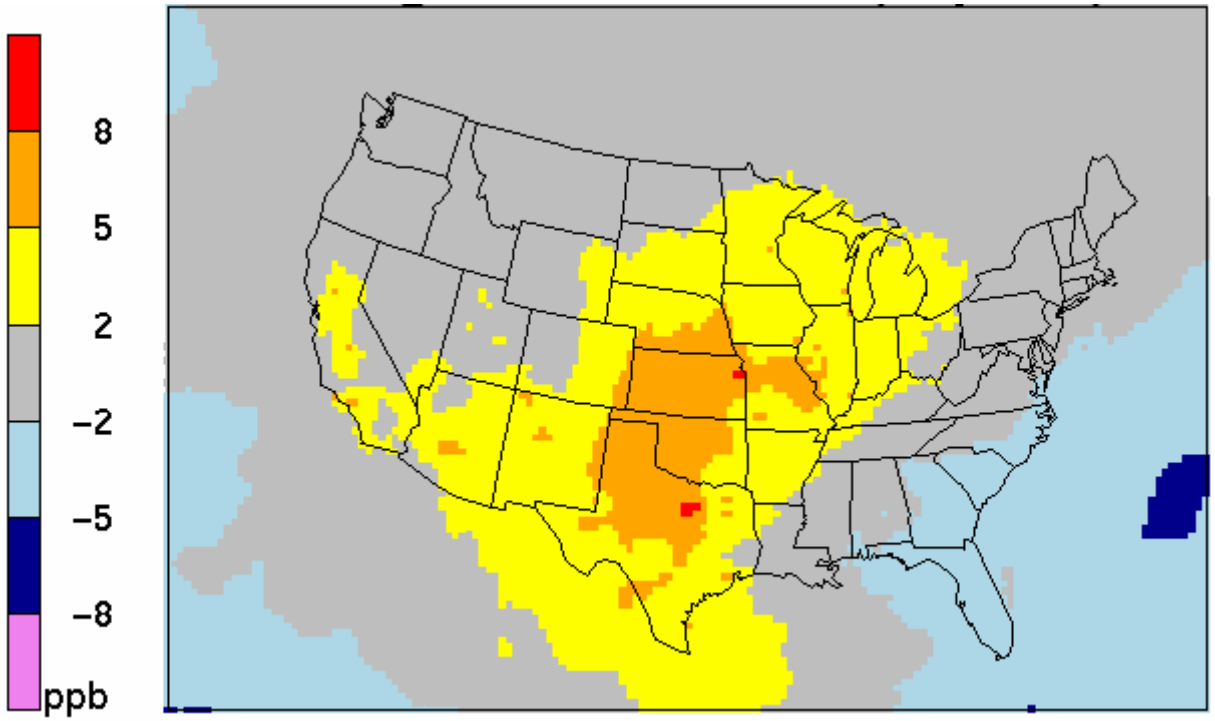


From EPA NERL study, simulated increases in O_3 in 2050 are of same order as present-day year-to-year variability in some regions.

Nolte et al. [2007]

Extension of O_3 Season?

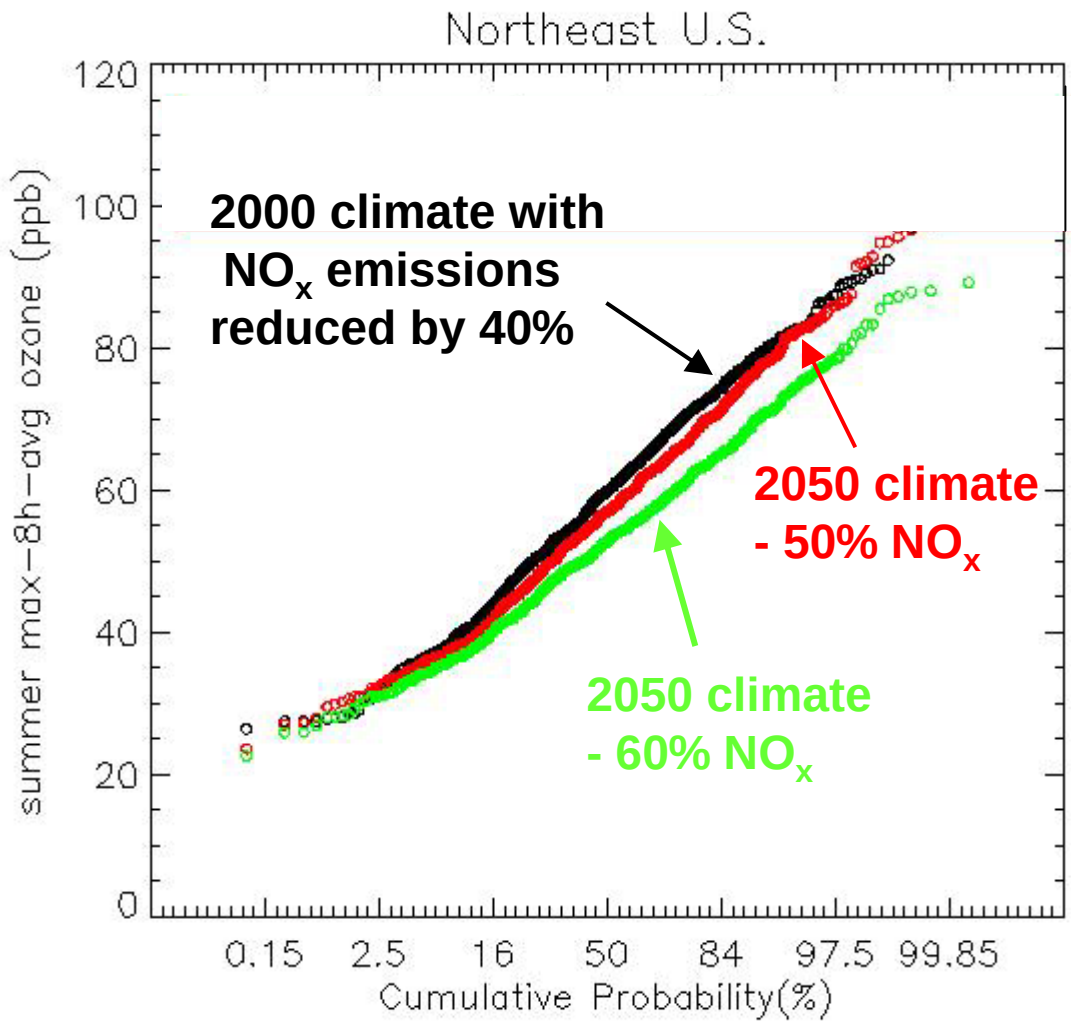
EPA NERL Simulation Results: Change in MDA8 O_3 from present to 2050s for September-October



Nolte et al. [2007]

"Climate Change Penalty"

One Harvard study suggests that climate change in the Northeast U.S. would necessitate a 50% NO_x reduction to achieve the same O_3 goals as a 40% reduction today



Wu et al. [2007]

Many Sources of Uncertainty

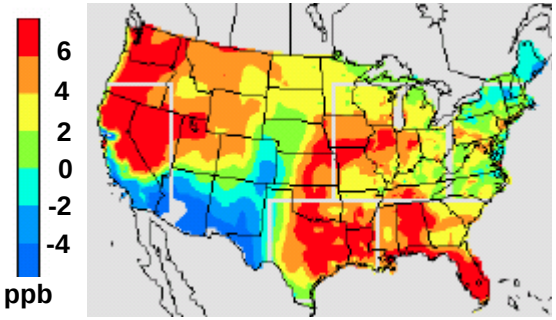
In some simulations, certain regions experience some of the largest climate-induced O_3 increases, while in other simulations these same regions experience little change, or even O_3 decreases

Why?

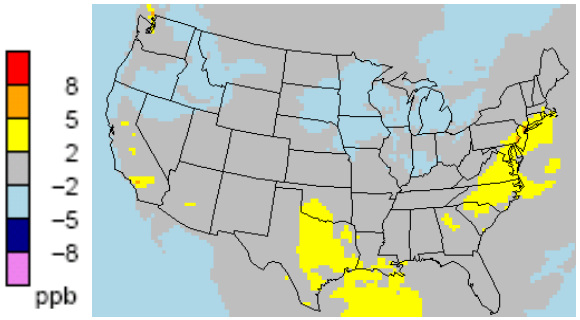
- Differences in greenhouse gas emission scenarios and global circulation models and simulations
- Differences in simulating the details of how important regional weather patterns, like temperature, clouds, precipitatation or mid-latitude storm tracks will change as a function of global climate change
- Differences in simulating the biogenic emissions and details of the chemical lifecycle of certain biogenic VOC emissions

Present-Day to 2050s Change in Summertime Average MDA8 O_3 from 6 Sets of Simulations

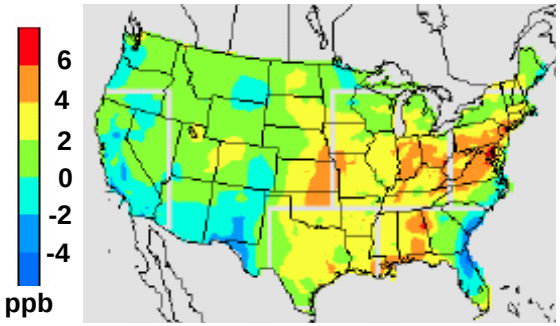
Univ. Illinois 1



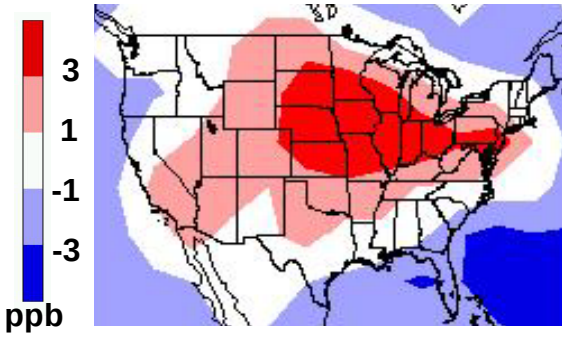
EPA NERL



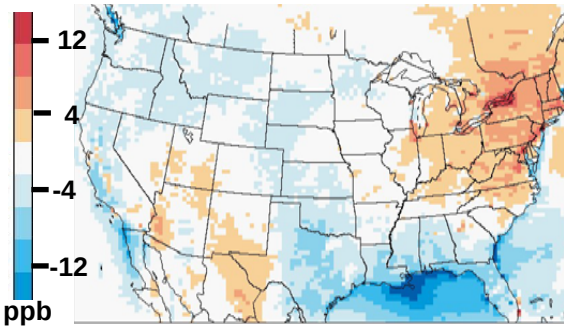
Univ. Illinois 2



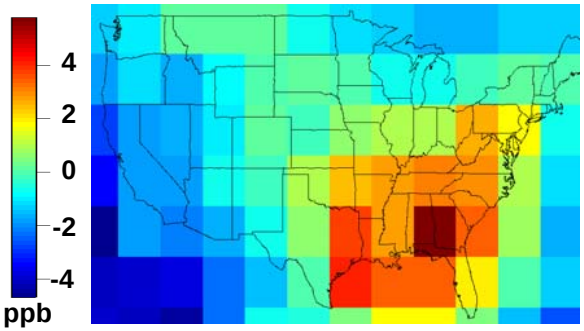
Harvard



Washington State



Carnegie Mellon



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Key Question: How can this information be used to help inform air quality management decisions?

- Answer depends critically on the decision context
- Need to engage with air quality managers to scope out how improved system understanding can be incorporated into decision making

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Workshop: December 2007

- Integrating Climate Change Adaptation into Air Quality Decision Making
  - Four breakout groups
    - Multi-pollutant control strategies and co-benefits
    - Un-regulated sources
    - Translation of global issues to local scales
    - Planning now for future climate
  - Addressing planning needs
    - Scientific or technical support
    - Guidance
    - Coordination

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Moving Ahead to Phase II: Ongoing/Upcoming Work:

Extending the Modeling Systems

- Explore modeling uncertainty space with ensemble approach
- Improve process representations of biogenic VOC emissions
- Expand on O_3 findings
- Two-way feedbacks between climate and chemistry
- Additional pollutants – PM
- Additional pollutants – Hg

Projecting Future Emissions

- Population growth, migration and land use
- Energy use projections
- Economic growth and technology choices
- Transportation patterns
- Changes in biogenic emissions due to land use
- Changing patterns and amounts of wildfire emissions
- Reconcile global and regional emissions assumptions

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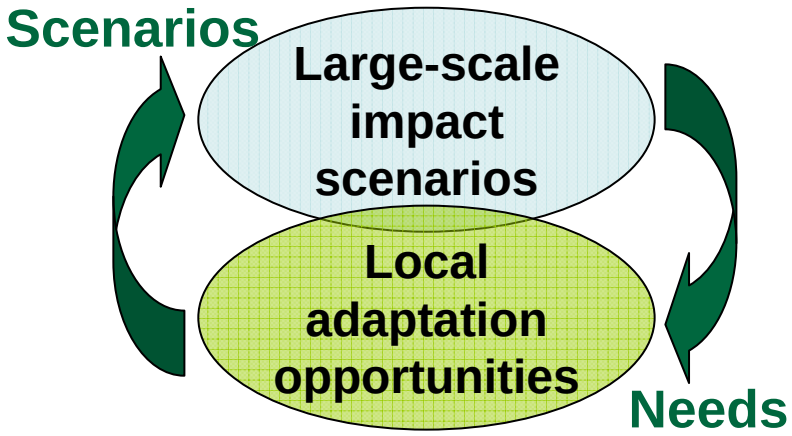
Integrated climate and land use change scenarios

Goals:

- Create seamless land use scenarios for conterminous US consistent with IPCC storylines
- Provide consistent benchmarks for local and regional land use studies
- Identify geographic areas where climate-land use interactions may exacerbate impacts or create adaptation opportunities



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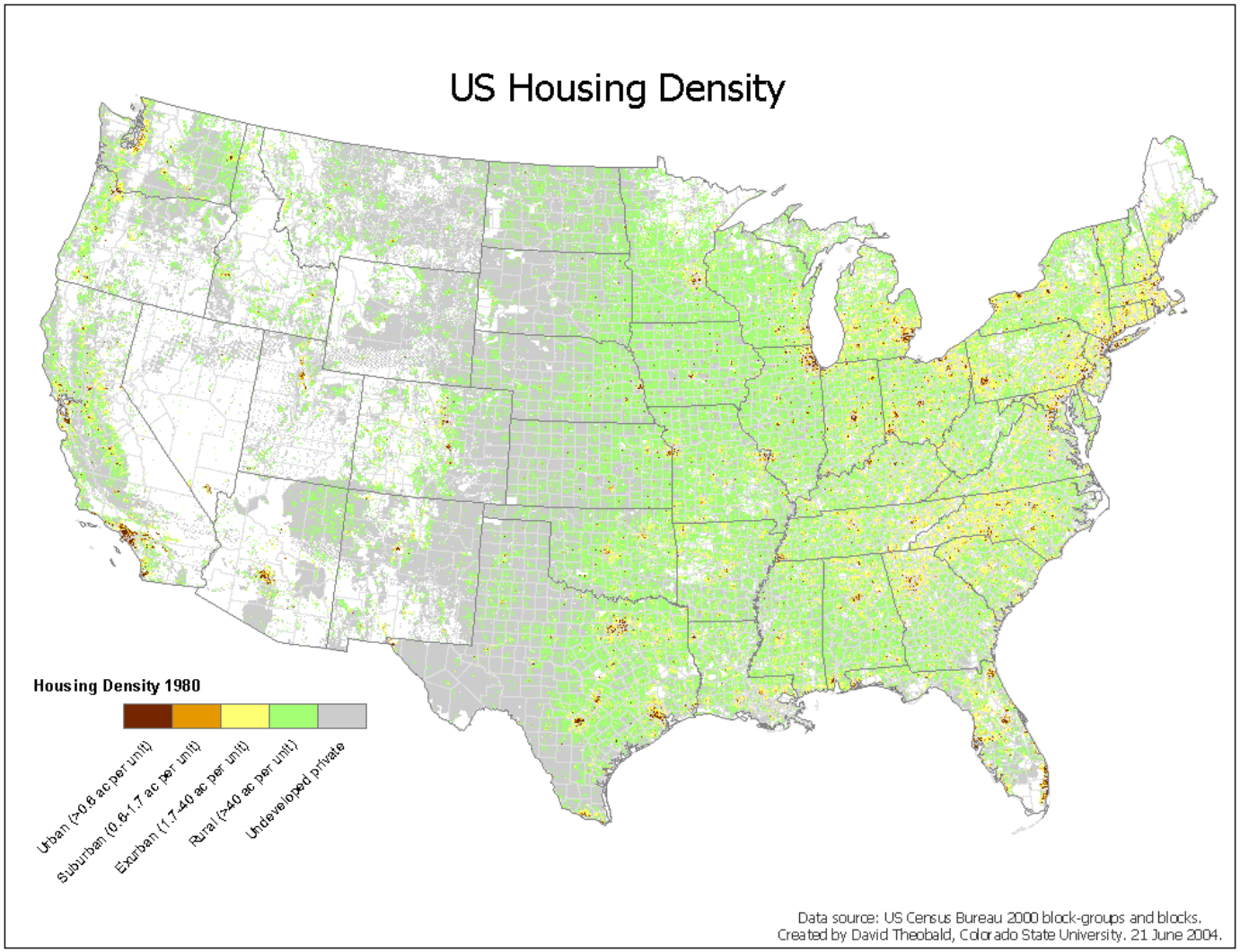
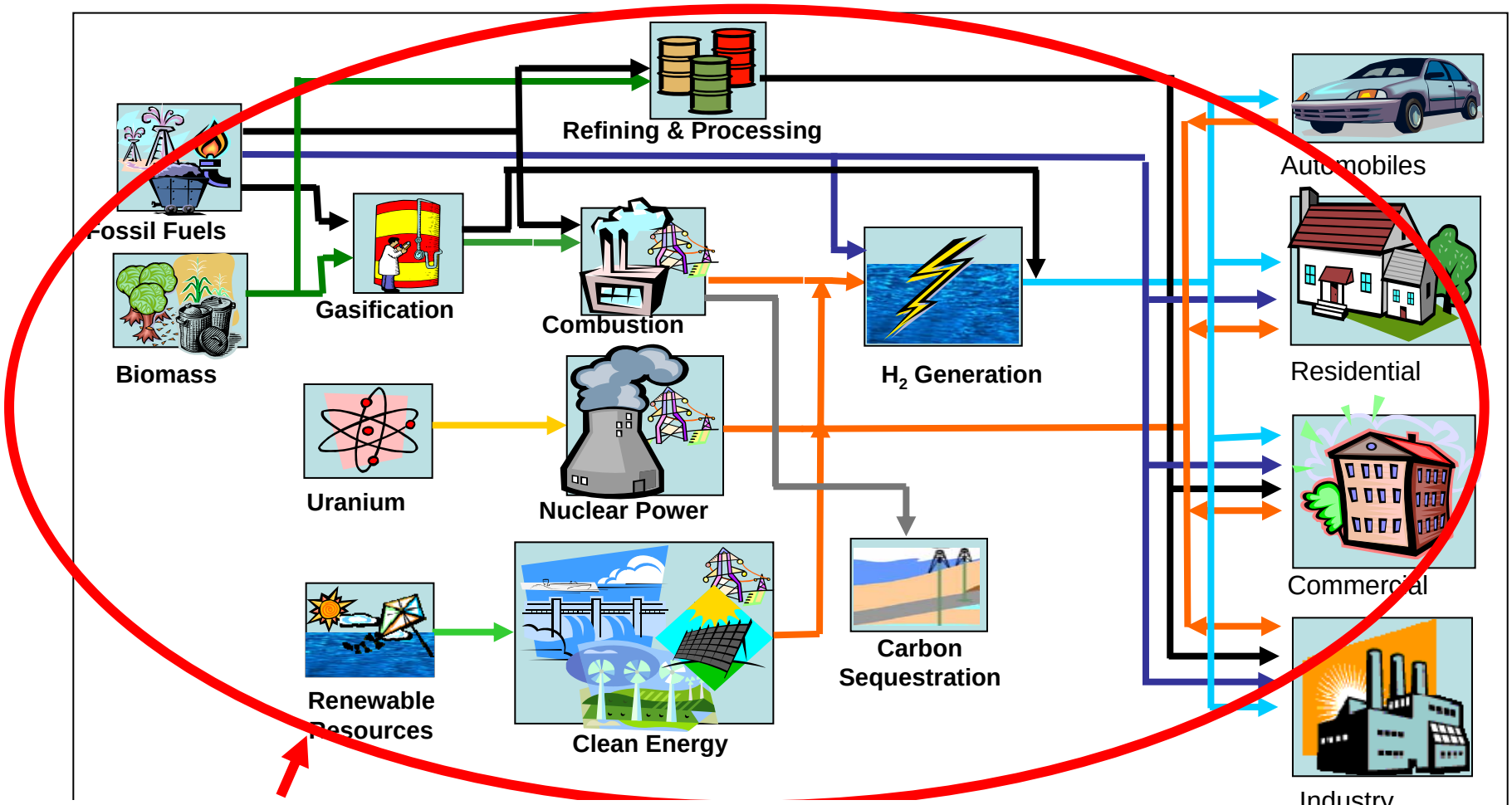


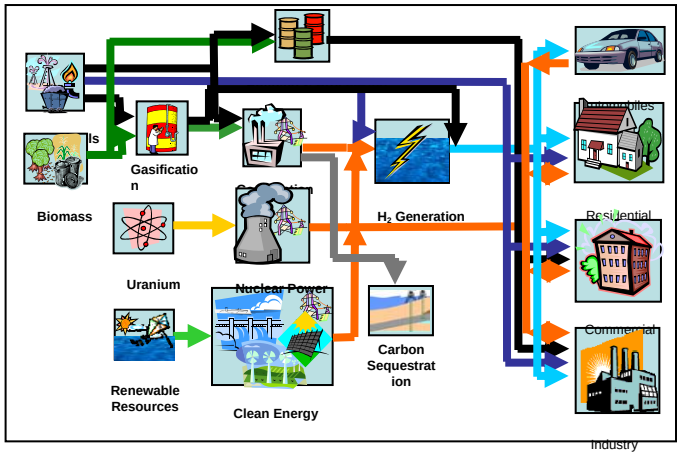
Potential Role of Energy System Technologies



How the energy system evolves can have a great impact on air quality…

For additional details, see www.epa.gov/appcdwww/apb/globalchange/

Technology Change Modeling: MARKAL



MARKAL inputs:

Future-year energy service demands, current and future technology characteristics, and emissions regulations are modeled

MARKAL outputs:

- **Technology penetrations** for meeting electricity generation, industrial, residential, commercial, and transportation demands
- **Fuel use** by type and region

Post-processing generates:

- **Emissions growth factors** at the aggregated SCC level

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Thank you!

Questions?