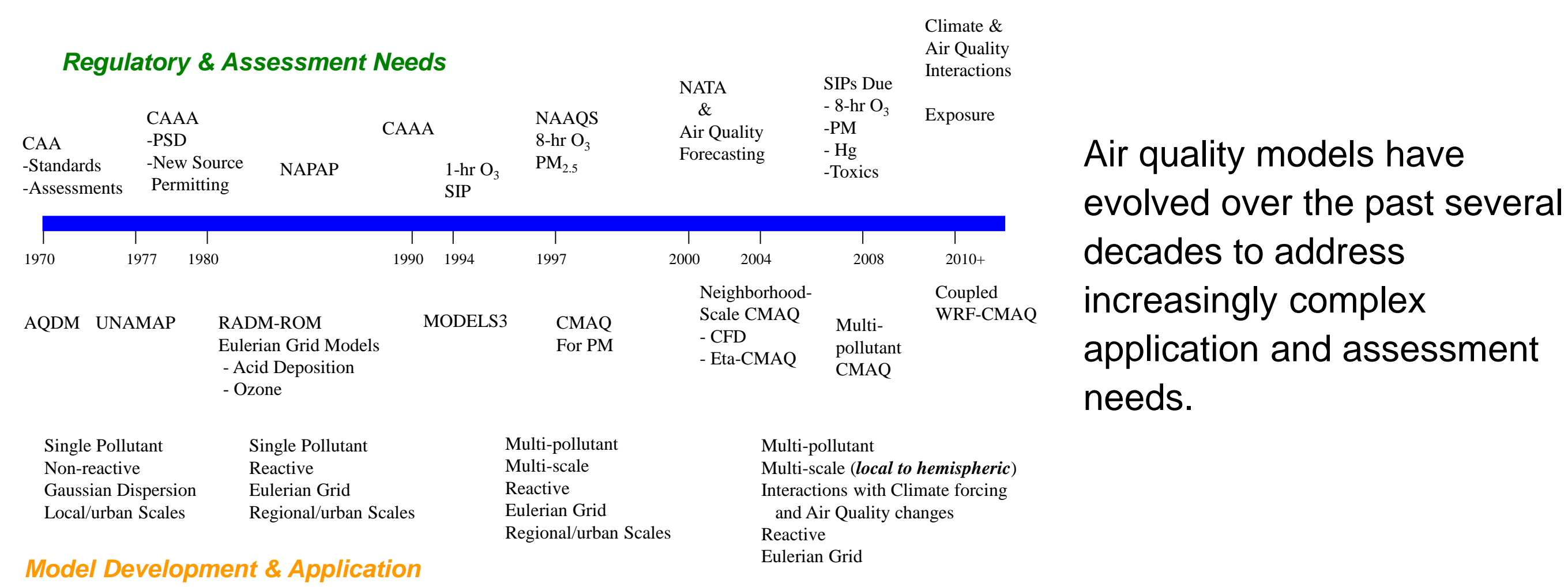


Background

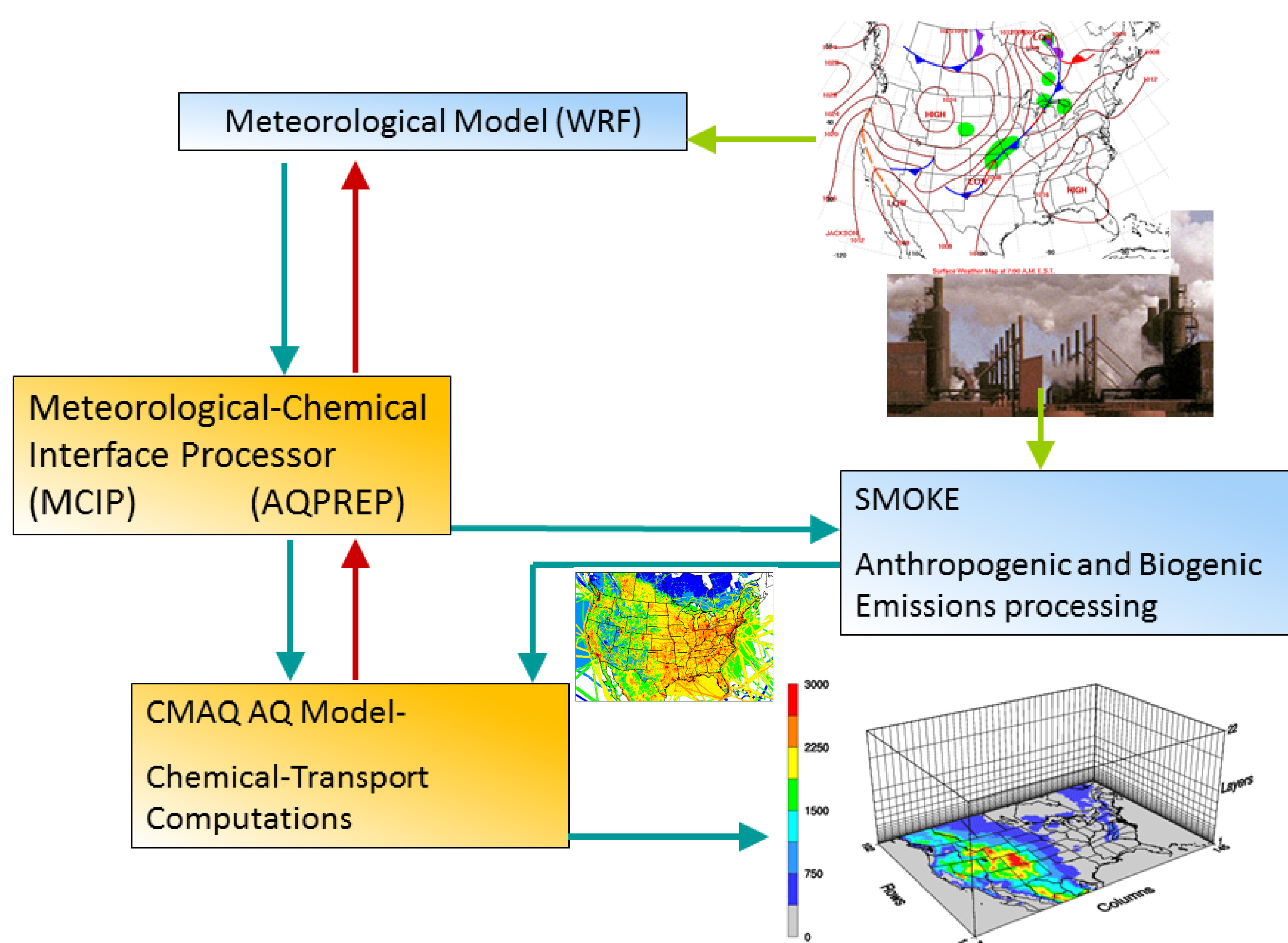
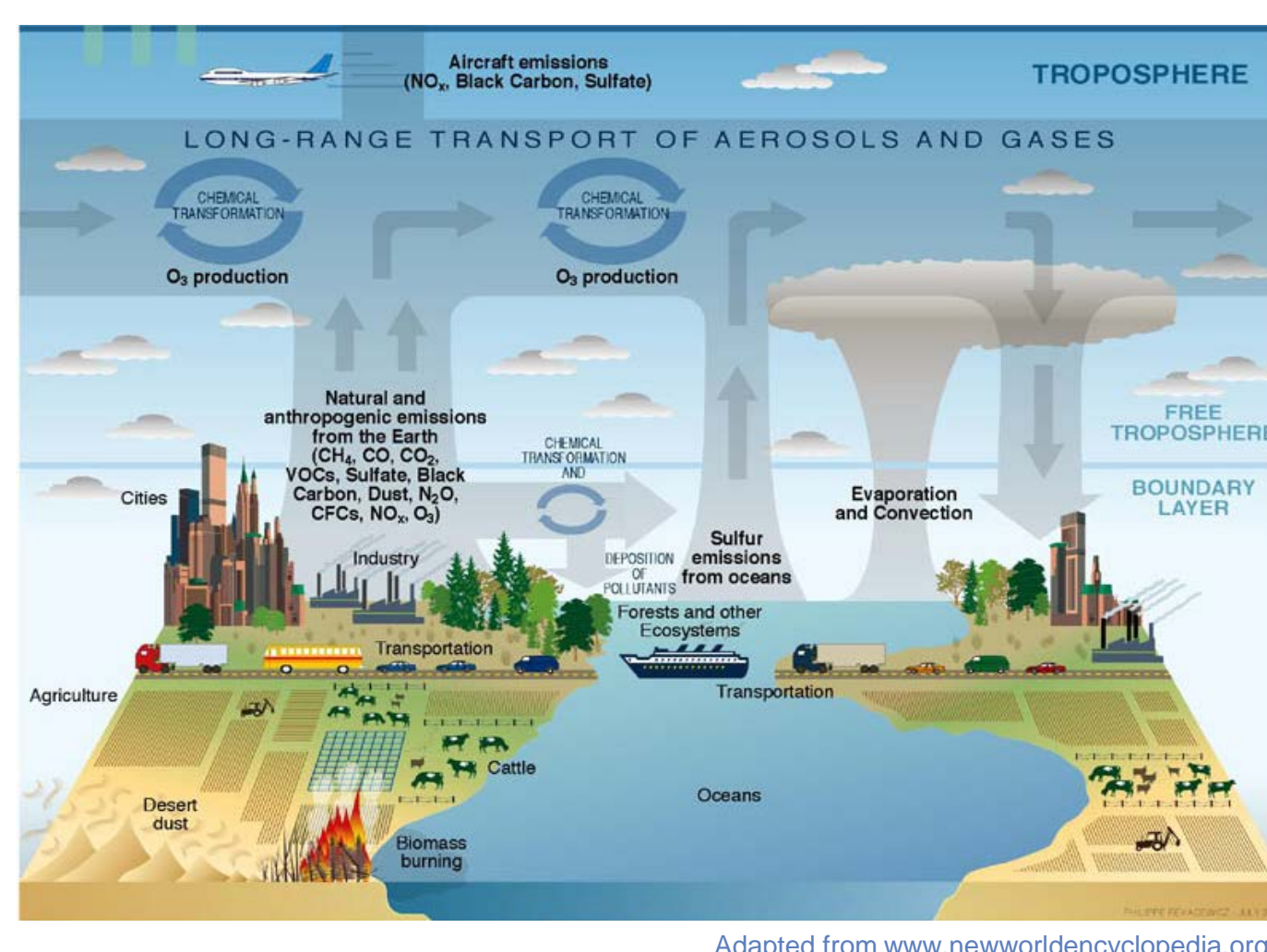
Drivers for Air Quality Models



Air quality models have evolved over the past several decades to address increasingly complex application and assessment needs.

The CMAQ Modeling System: A "Numerical Laboratory"

CMAQ is a comprehensive *state-of-the-science* atmospheric modeling system that integrates and synthesizes our evolving knowledge of the various atmospheric processes regulating the fate of atmospheric pollutants.



- Eulerian grid-based **Multi-pollutant** model:
- Gas-phase chemistry (e.g., O₃ and precursors); aerosols (PM_{2.5} and PM₁₀); air toxics (e.g., Hg)
- Multi-scale**: simulates processes from urban (few km) to regional (hundreds of km) to inter-continental (thousands of km) scales of transport
- Community** model:
 - First version publicly released in ~2000
 - CMAQv5.1 to be released in October 2015

CMAQ Formulation

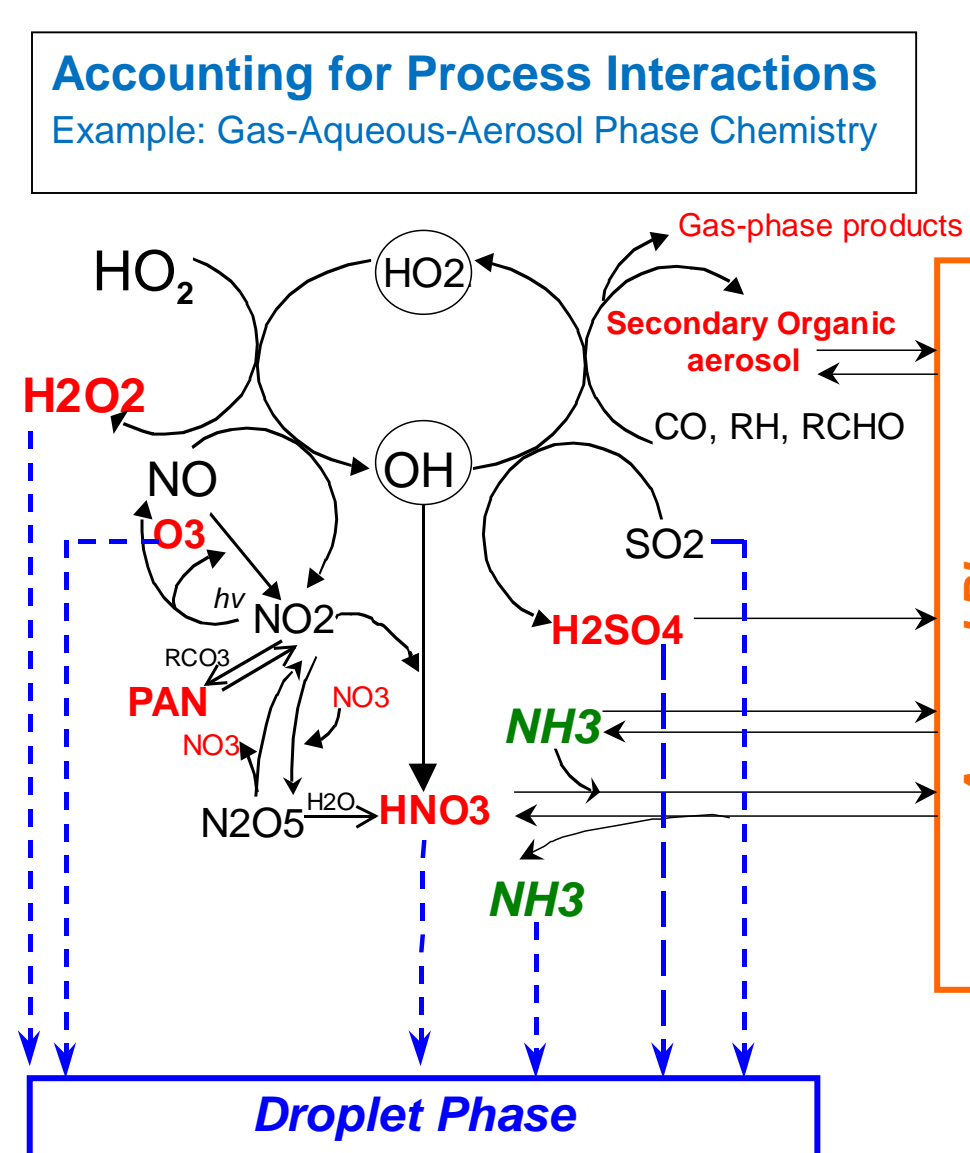
The theoretical basis for model formulation is the **conservation of mass** for atmospheric trace species transport, chemistry, and deposition:

$$\frac{\partial \phi_i}{\partial t} + \nabla_{\phi} \cdot [\phi_i \vec{V}_{\phi}] + \frac{\partial (\phi_i \vec{v}_{\phi}^3)}{\partial x^3} + \nabla_{\phi} \cdot [\rho \sqrt{\bar{v}} \vec{E}_{\phi}] + \frac{\partial (\rho \sqrt{\bar{v}} \vec{E}_{\phi}^3)}{\partial x^3}$$

horizontal advection vertical advection horizontal diffusion vertical diffusion

$$= \sqrt{\bar{v}} R_{\phi} (\bar{\phi}_1, \dots, \bar{\phi}_N) + \sqrt{\bar{v}} S_{\phi} + \frac{\partial (\phi_i)}{\partial t}_{\text{cloud}} + \frac{\partial (\phi_i)}{\partial t}_{\text{aero}}$$

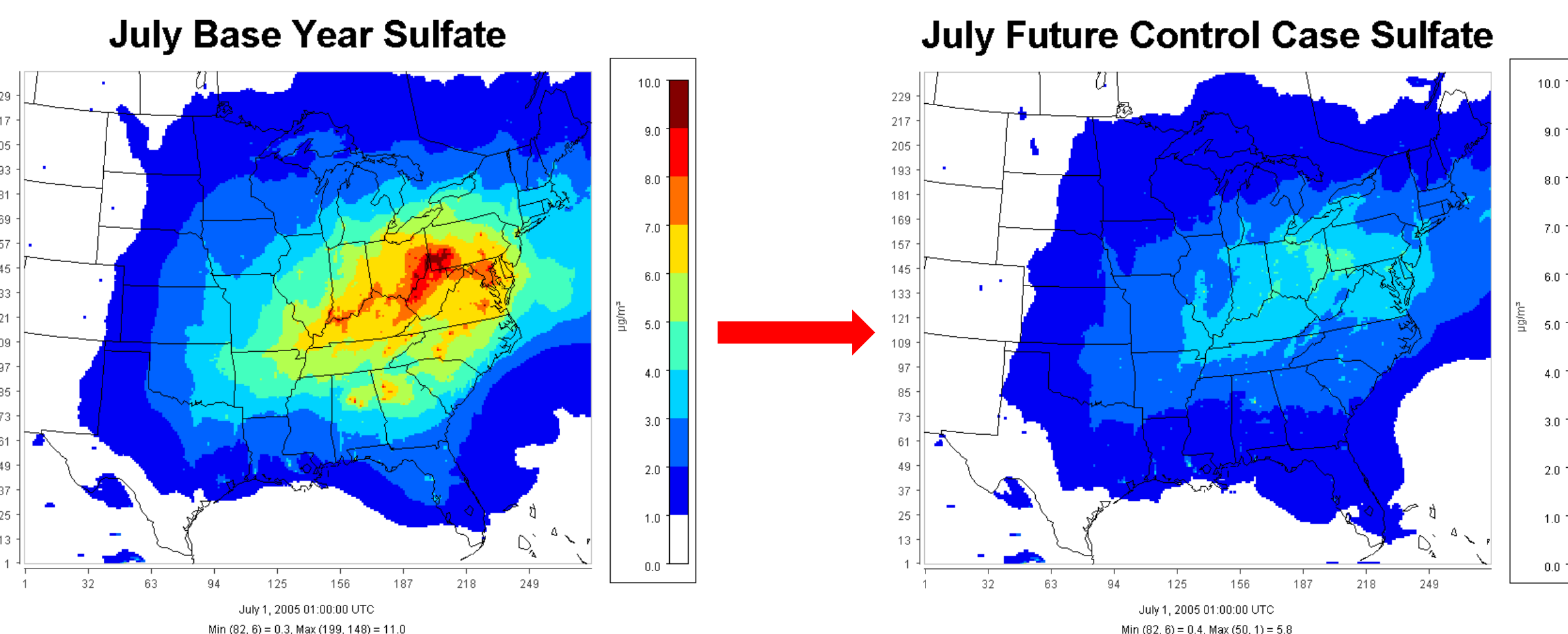
chemistry emissions clouds aerosols



CMAQ Applications

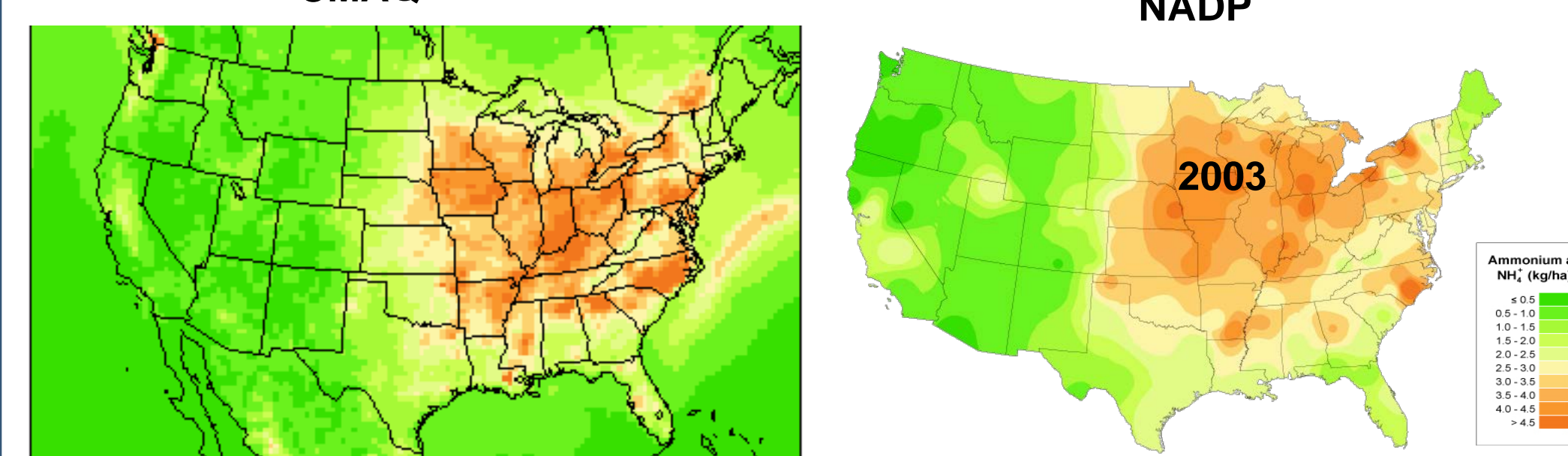
Policy Analysis

Assessing effectiveness of emission control strategies for National Rules, State Implementation Plans



Nutrient Loading to Sensitive Ecosystems

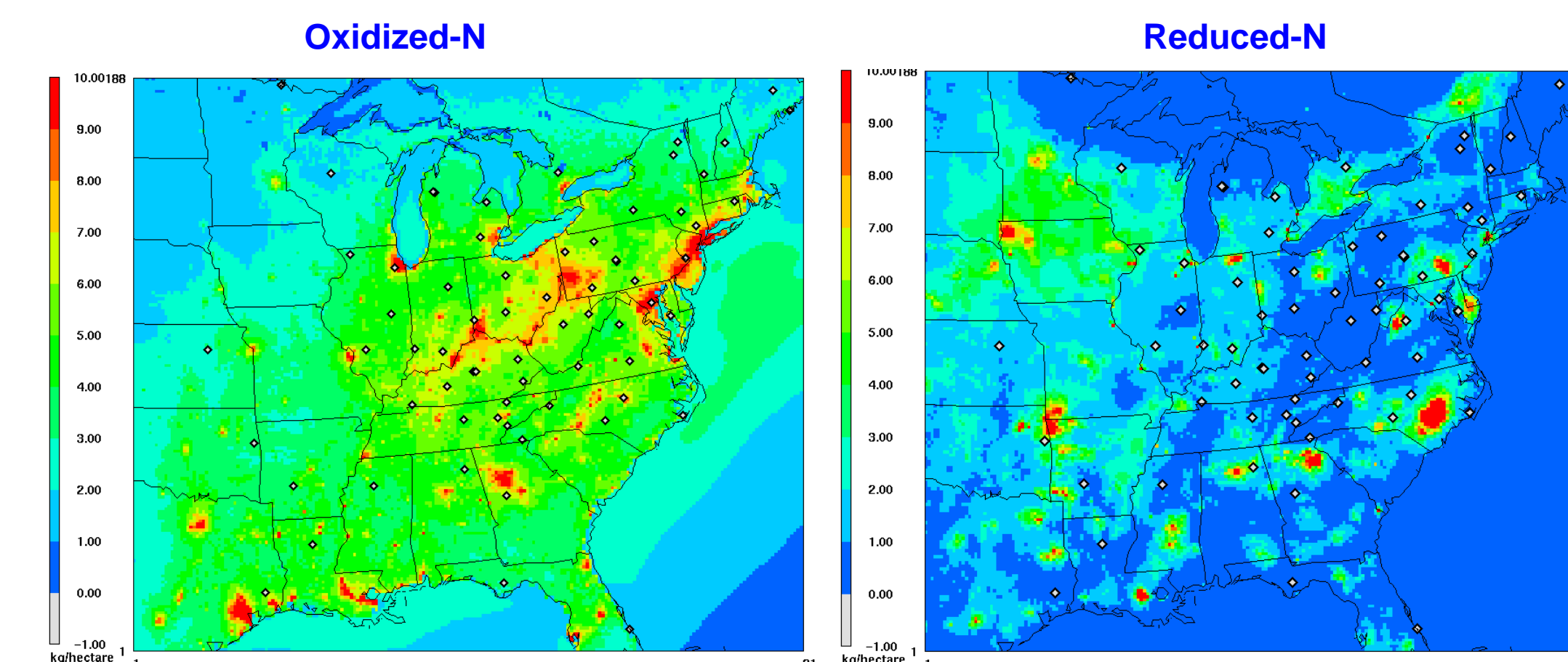
Ammonium Ion Wet Deposition



Wet and dry deposition are key removal processes for airborne pollutants, but also the pathway for atmospheric input to terrestrial and aquatic ecosystems

Help Design Monitoring Network

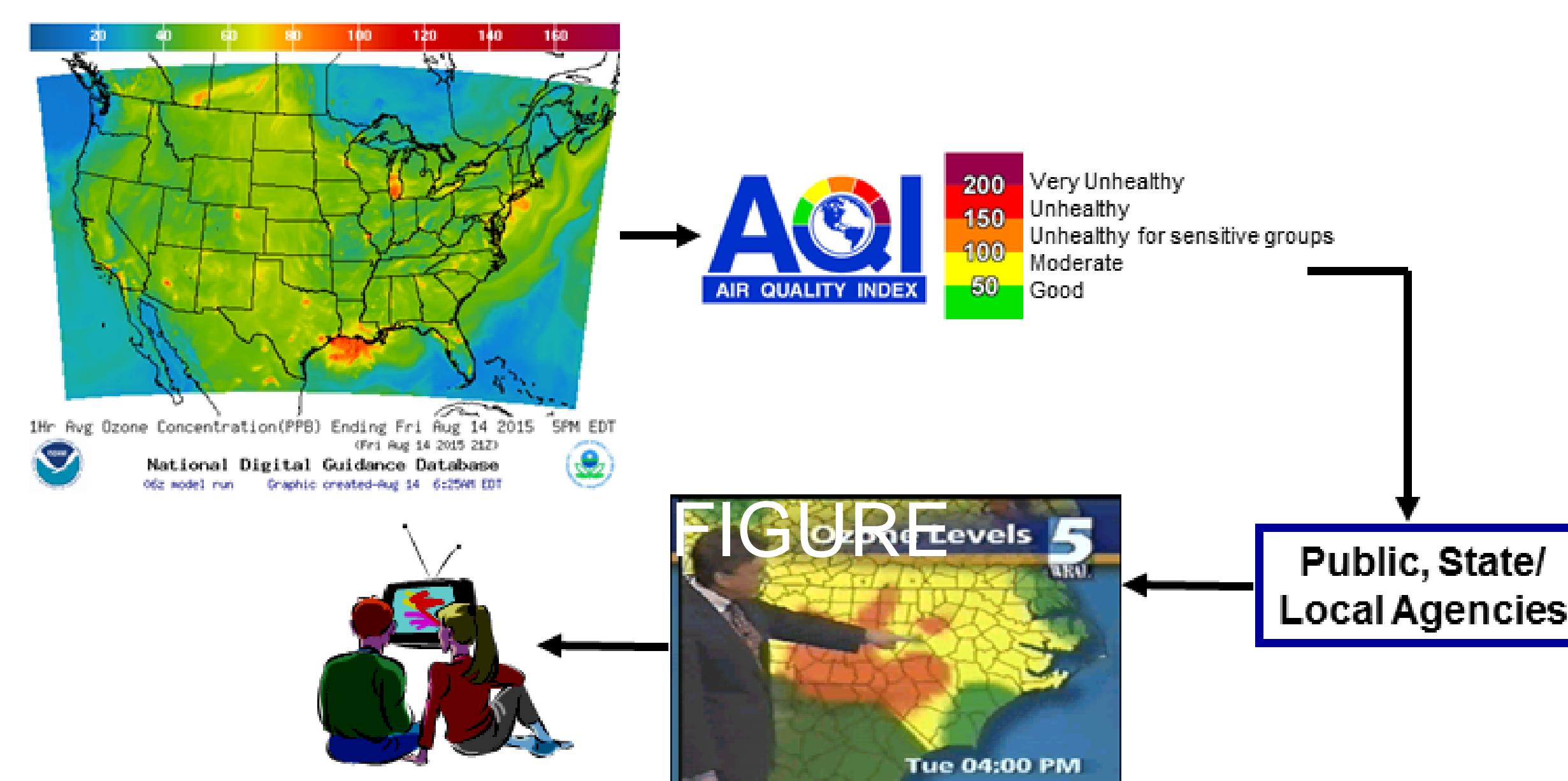
Modeled spatial trends vs. CASTNET locations



Current coverage of sites may not be sufficient to capture hot-spots. Thus budgets based solely on observations will be misleading

Improving Public Health: Air Quality Forecast Guidance

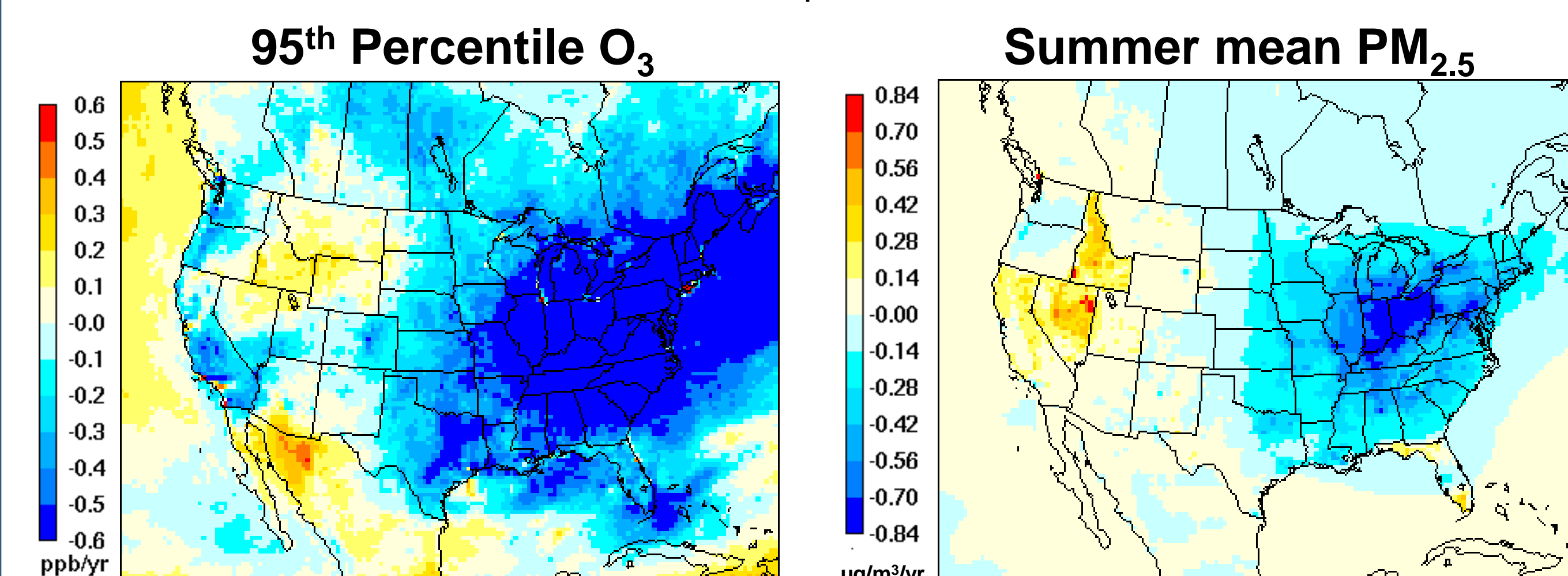
CMAQ deployed at NOAA-NWS to develop next day air quality forecast



Developing accurate short-term air quality forecasts enables state and local agencies to alert the public of the onset, severity and duration of unhealthy air, and to encourage public and industry to reduce emission producing activities.

Characterizing Long-term Trends in Air Pollution Exposure

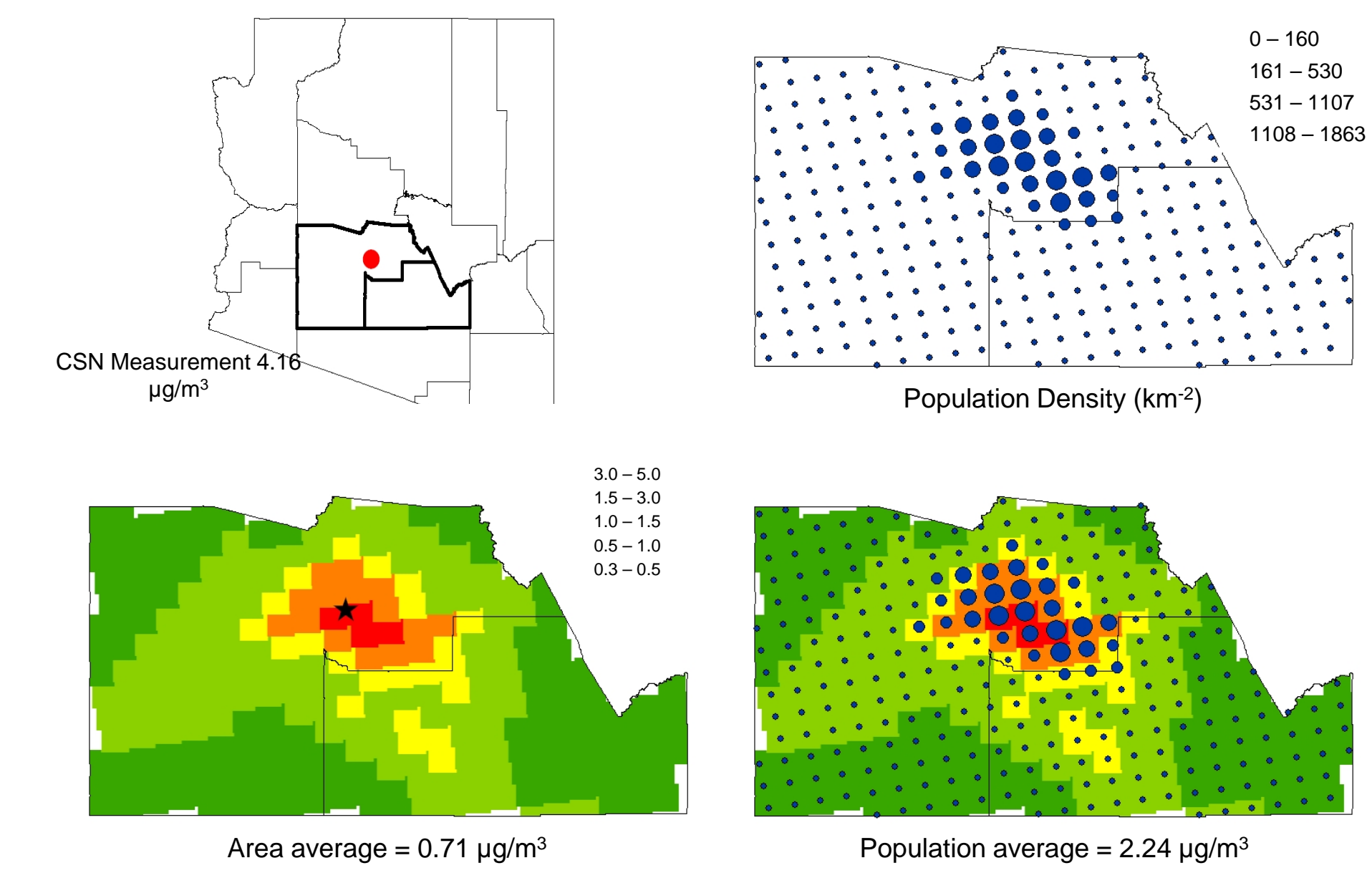
1990-2010 Trends; Impact of the Clean Air Act



Regulatory actions over the past two decades have resulted in substantial reductions in levels of criteria pollutants across the Nation and in reducing the exposure of sensitive populations to harmful levels of air pollution.

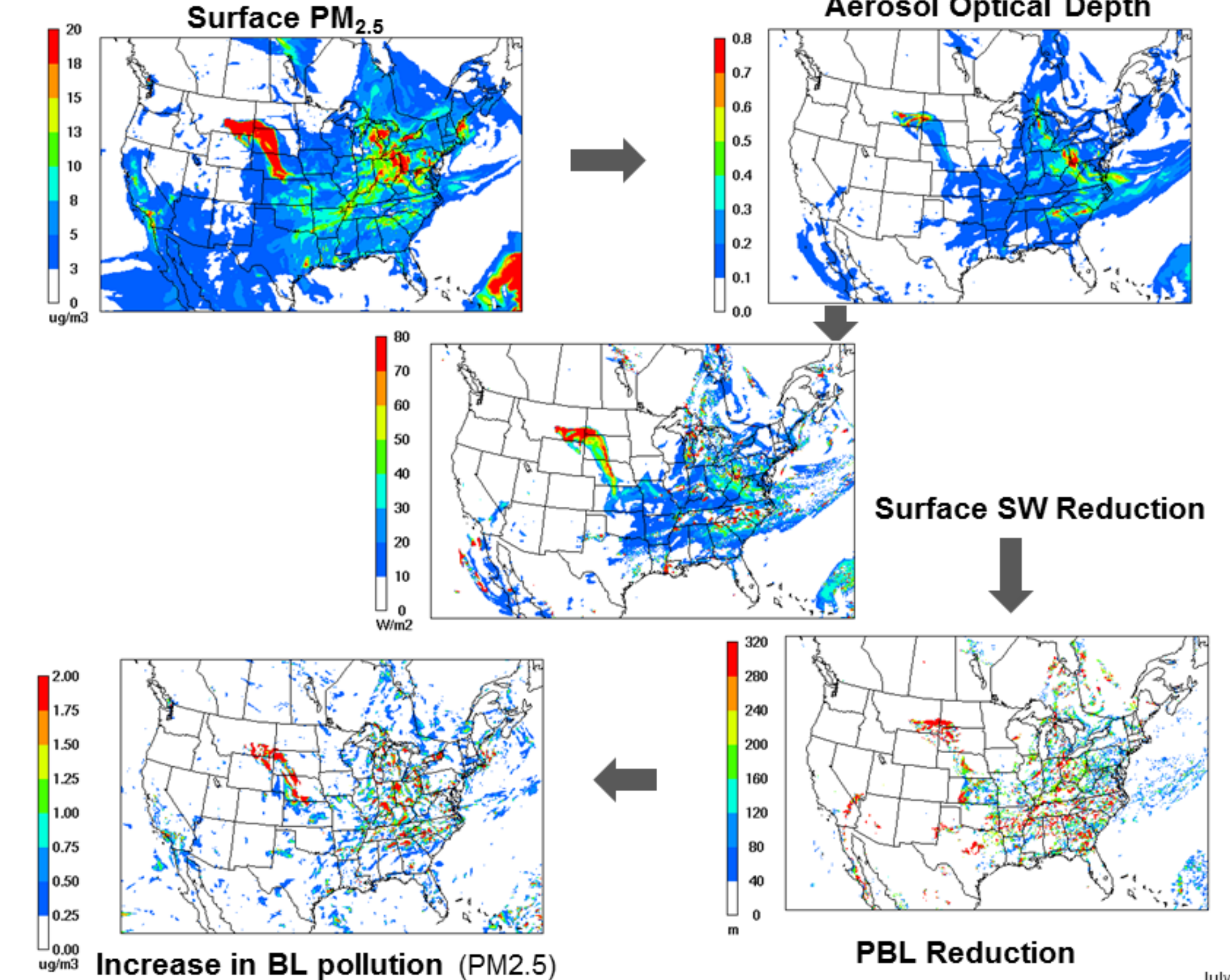
Emerging Application Needs

Informing Human Exposure & Health Studies



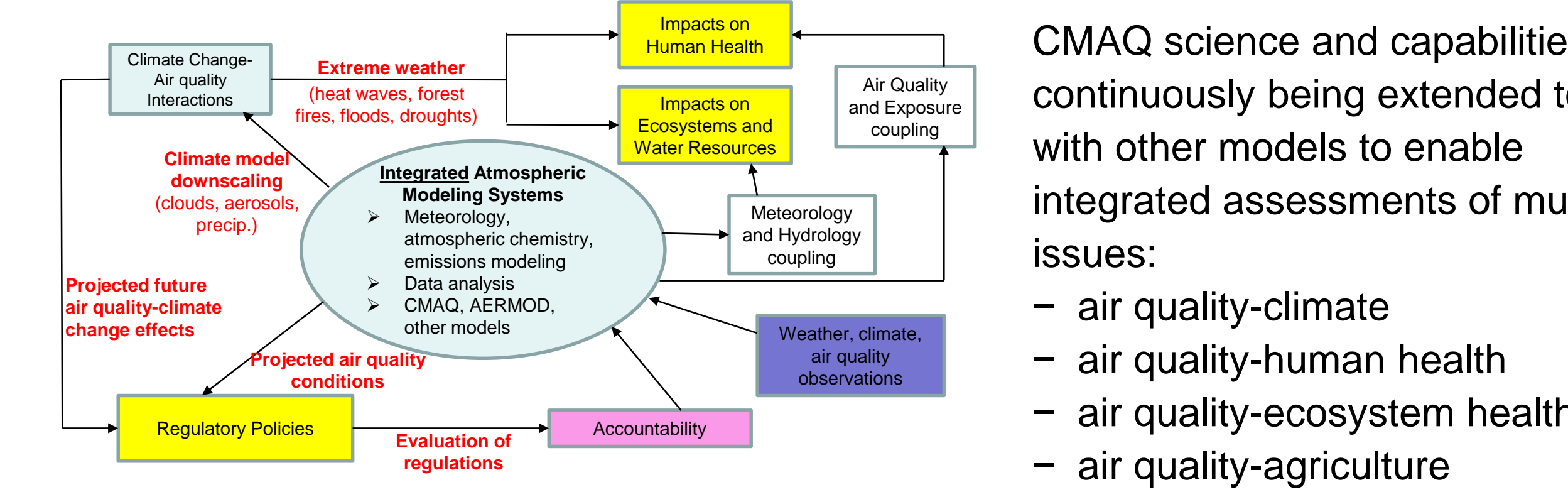
Accounting for spatial variation in air concentrations & population density, enables a more accurate estimate of the average exposure across metropolitan areas

Air Pollution-Meteorology-Climate Interactions



Many air pollutants (PM_{2.5}, O₃) are radiatively active and are also short-lived climate forcers. In regions of high PM_{2.5}, feedback effects on atmospheric dynamics can be significant and can impact air pollutant levels. The consideration of such interactions could be important for examining air quality-climate co-benefits of various policy options.

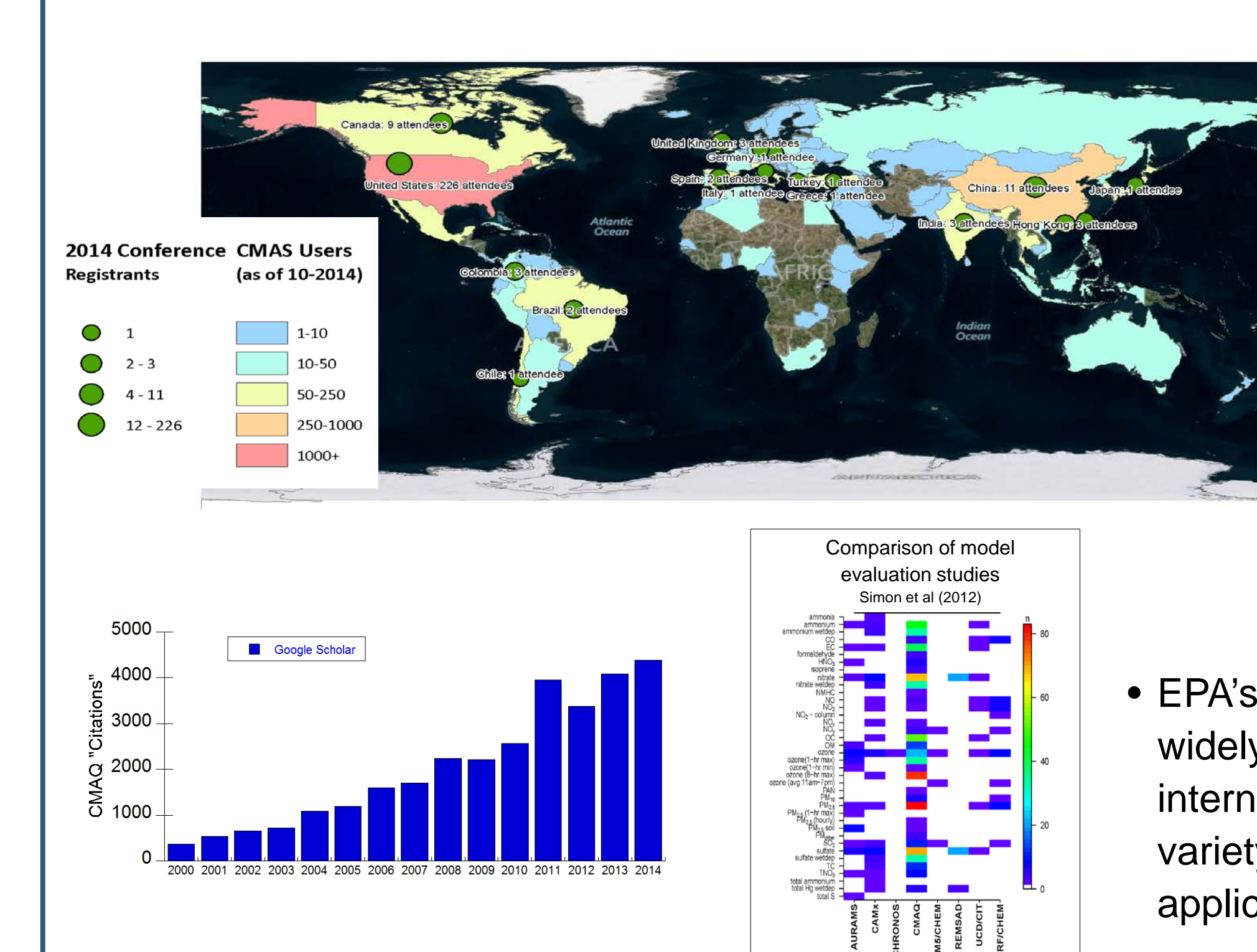
Integrated Approaches to Address Multiple Problems



CMAQ science and capabilities are continuously being extended to link with other models to enable integrated assessments of multiple issues:

- air quality-climate
- air quality-human health
- air quality-ecosystem health
- air quality-agriculture

Dissemination and User Community



CMAQ is publicly available through the Community Modeling & Analysis (CMAS) center.

- Periodic scientific updates to CMAQ have led to creation of a dynamic and diverse user community
- Annual Conference and training

EPA's CMAQ modeling system is widely used by a growing international community for a variety of research and regulatory applications

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