# Overview of Air Quality Modeling for SIPs

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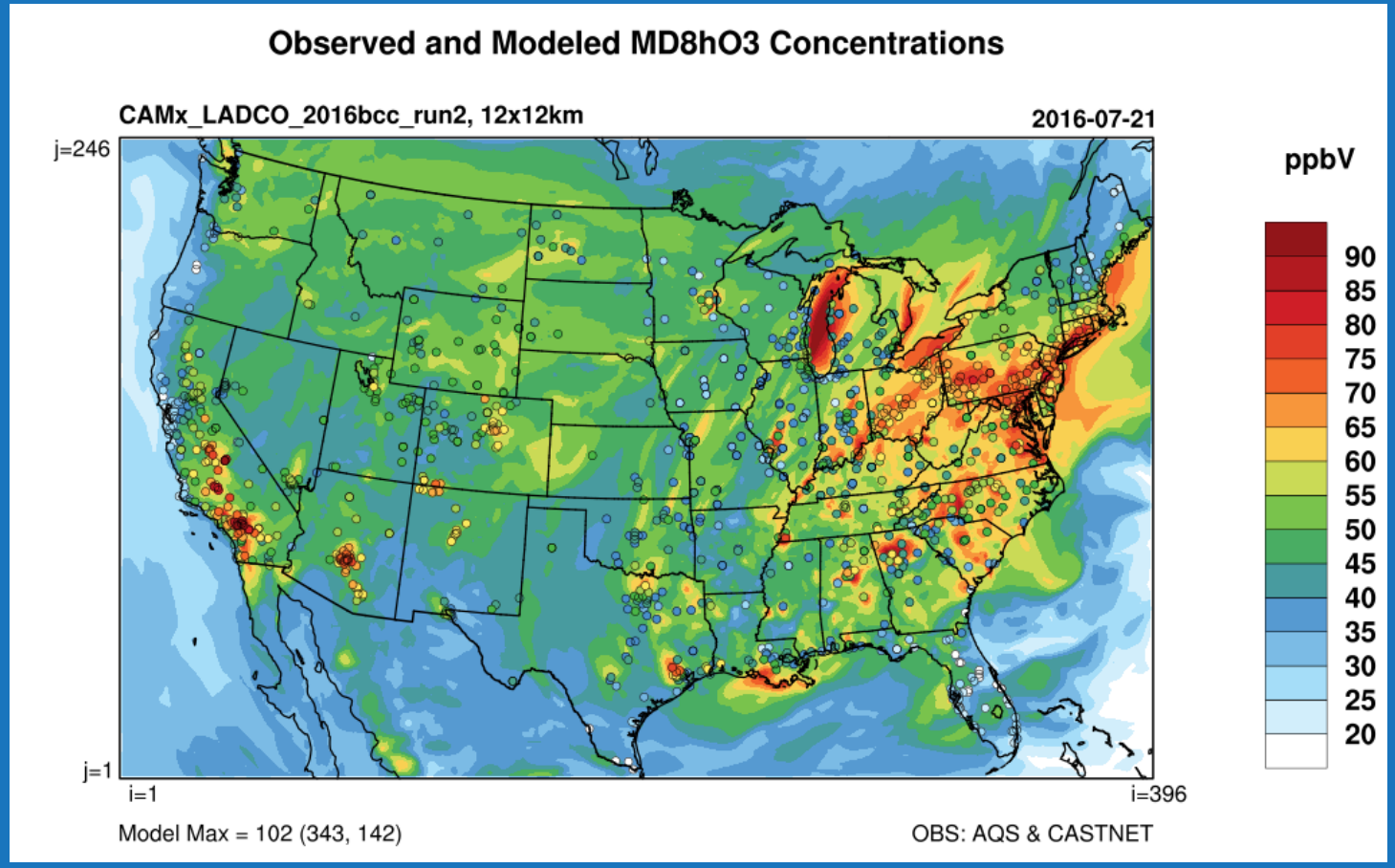


# How is Modeling Used in Air Quality Planning?

- Estimate the air quality impacts of emissions from a source
- Predict future pollution concentrations
- Screen emissions control strategies for meeting NAAQS attainment
- Estimate visibility conditions relative to regional haze glidepaths
- Nonattainment area designations
- Redesignation plans
- Good Neighbor/transport assessments
- Exceptional event demonstrations
- Technical support for 126 petitions

# Air Quality Modeling in SIPs

- CAA Section 172(c) requires states with a nonattainment area (NAA) to submit an attainment demonstration
  - Emissions inventory (base and future years)
  - Adopted control measures
- For $PM_{2.5}$, all States (with NAA's) must submit an attainment demonstration which includes modeling (§51.1007)
  - Photochemical grid modeling and/or local dispersion modeling
- For ozone, moderate and above NAA's are required to submit an attainment demonstration with modeling (§51.908)
  - Photochemical grid modeling

Nonattainment Area SIP Revisions

# Air Quality Modeling in SIPs

- CAA Section 110(a)(2)(D) requires states to address the interstate transport of pollution that affects downwind states' ability to meet or attain the NAAQS
  - Good Neighbor SIP revisions are submitted as part of the Infrastructure SIPs that are due 3 years after promulgation of a new NAAQS
- CAA Section 169A(a)(1) sets the goal of natural visibility conditions at Class I areas
  - The Regional Haze Rule of 1999 requires that modeling be used to assess future visibility conditions and support long term strategies towards remedying manmade impairment at Class I areas

Good Neighbor SIP Revisions

Regional Haze SIP Revisions

# Air Quality Modeling 101

What are the different types of models?

What are the components of an air quality model?

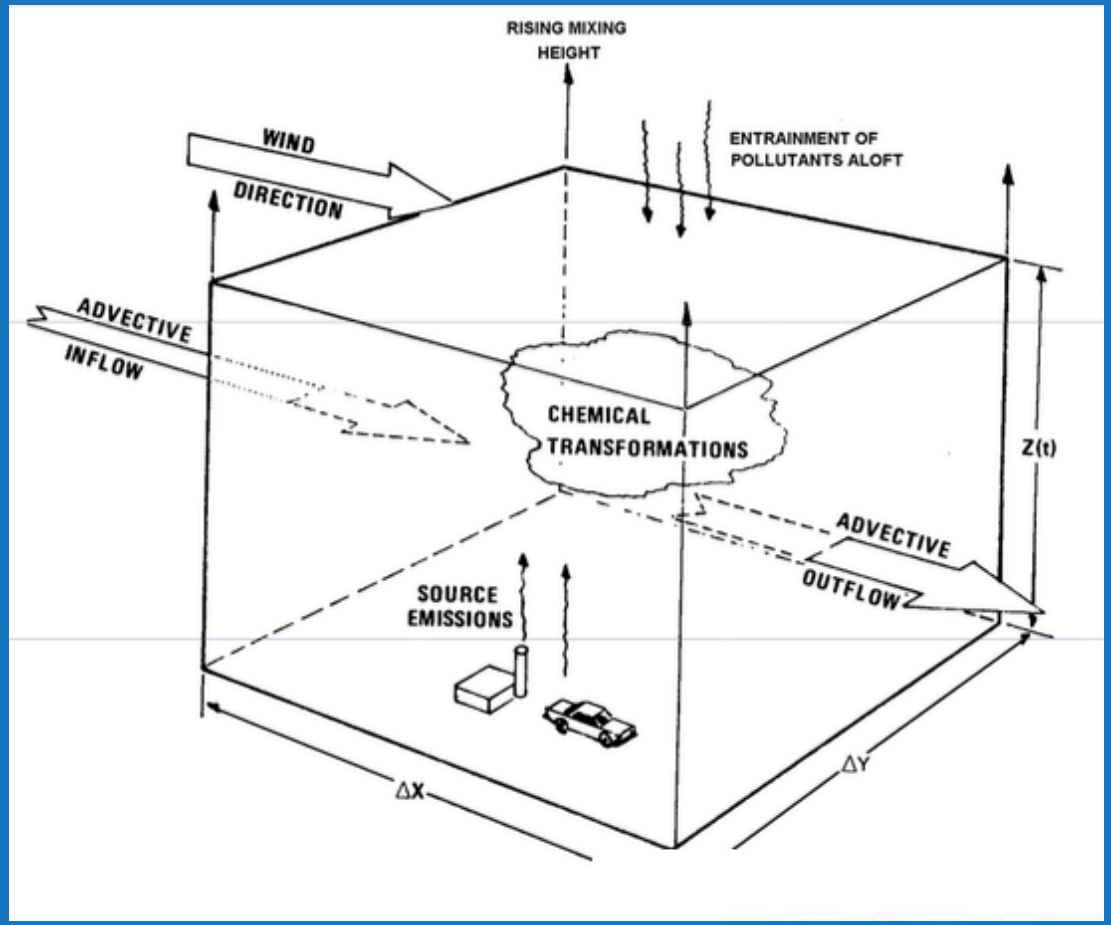
# Air Quality Modeling 101

**Photochemical models**

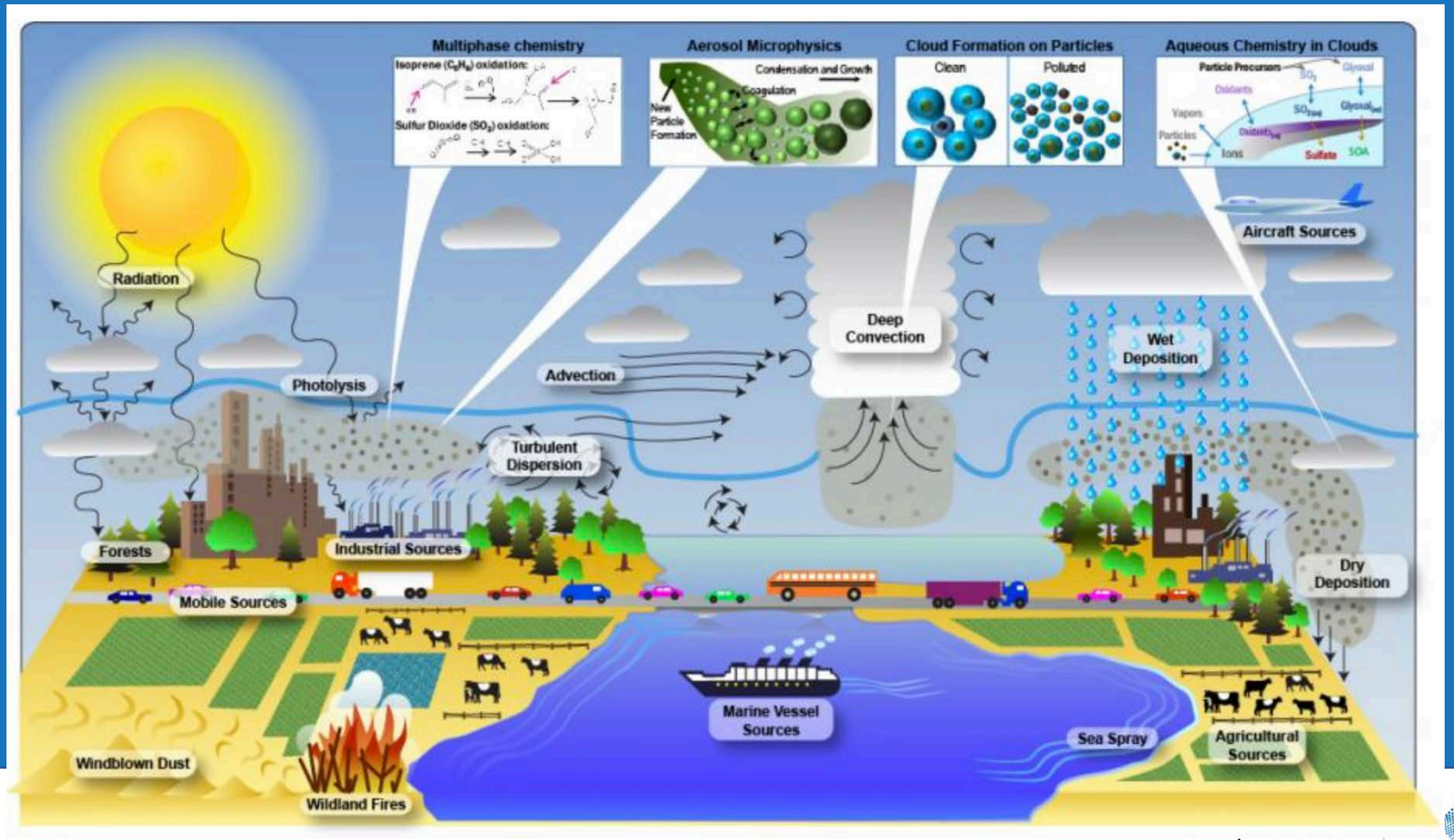
Large-scale air quality models that account for chemical and physical atmospheric processes in predicting pollutant concentrations.

Also known as: gridded models, chemistry-transport models, regional air quality model

Model names: CMAQ, CAMx, WRF-Chem



# Photochemical Model Processes




Source: www.epa.gov/cmaq

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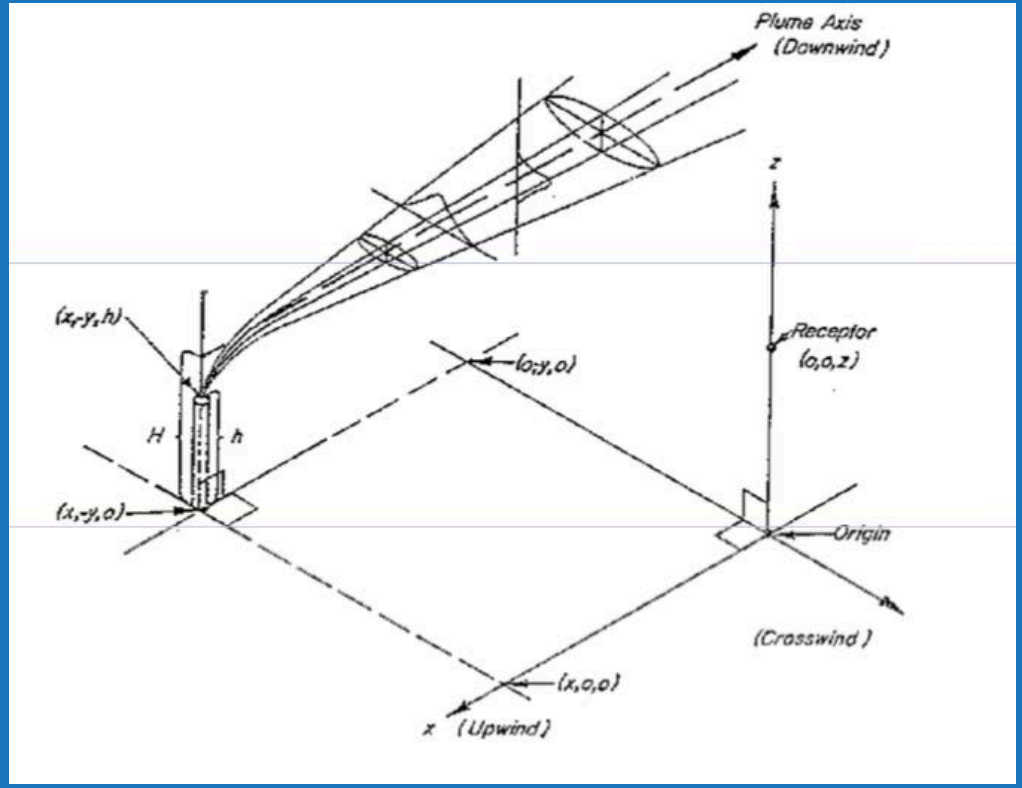
# Air Quality Modeling 101

## Dispersion models

Source-oriented models that characterize atmospheric processes by dispersing a directly emitted pollutant to predict concentrations at selected downwind receptor locations.




Also known as: single-source models, Gaussian models

Model names: AERMOD

# Photochemical Grid Modeling

- Capabilities
  - Simulate the multiple and complex chemical and physical processes that produce air pollution
  - Integrate multiple emissions source categories and emissions control strategies in a single simulation
- Goals
  - Predict the effects of emissions control strategies on future concentrations
    - Controls necessary for SIP attainment demonstrations (states)
    - Air quality impacts of national rules (EPA)
  - Quantify source-receptor relationships

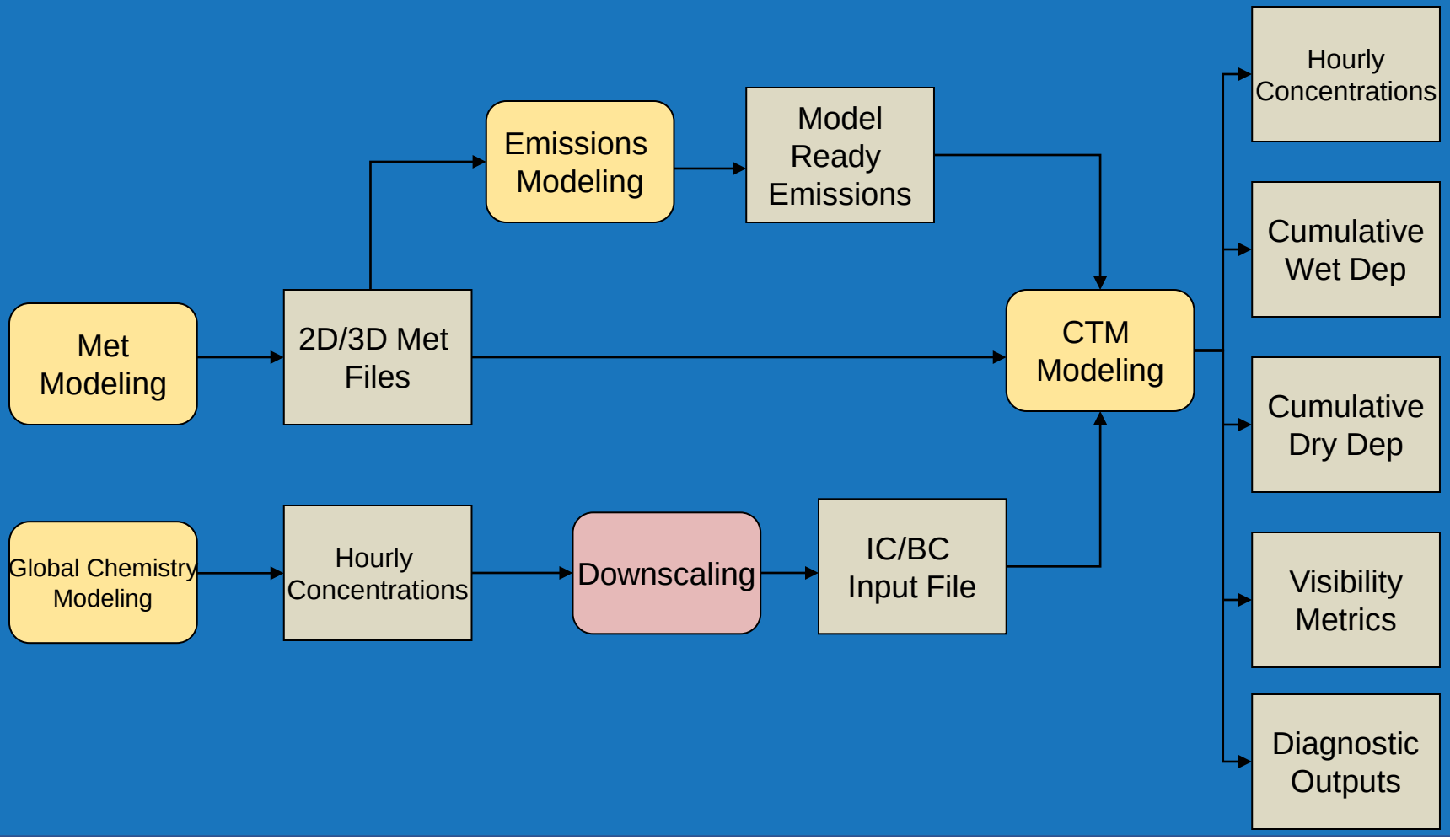
# Modeling the Future

- Impossible to verify the accuracy of future year predictions
- Simulate historical periods to validate model performance
  - If the model can replicate what happened in the past, it then can be used to predict future changes in pollutant concentrations
- Modeled Future year air quality = Projected emissions, all other inputs are the same

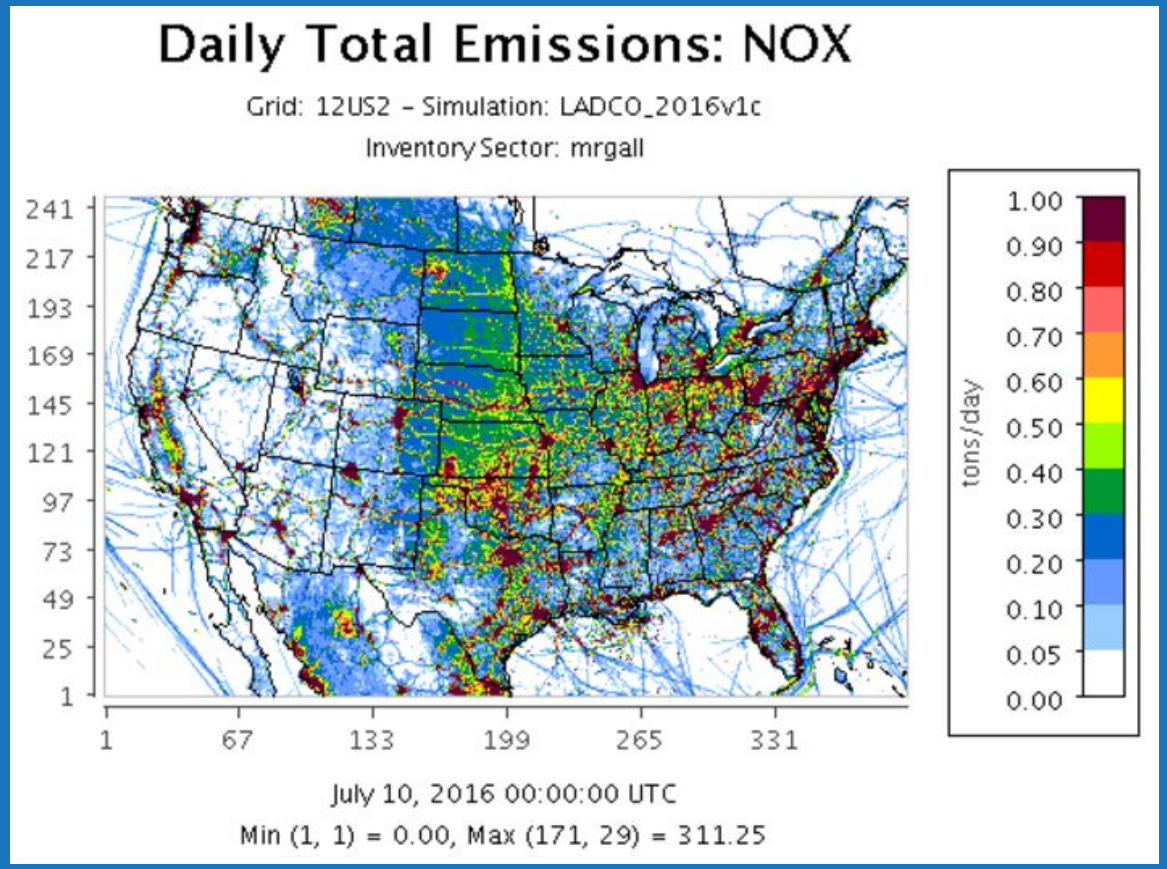
**Policy applications use models in a relative sense to predict the future**

Relative Response Factor (RRF) = [future year model]/[base year model]
Future year concentration = [base year observed] * RRF

# Air Quality Model Schematic

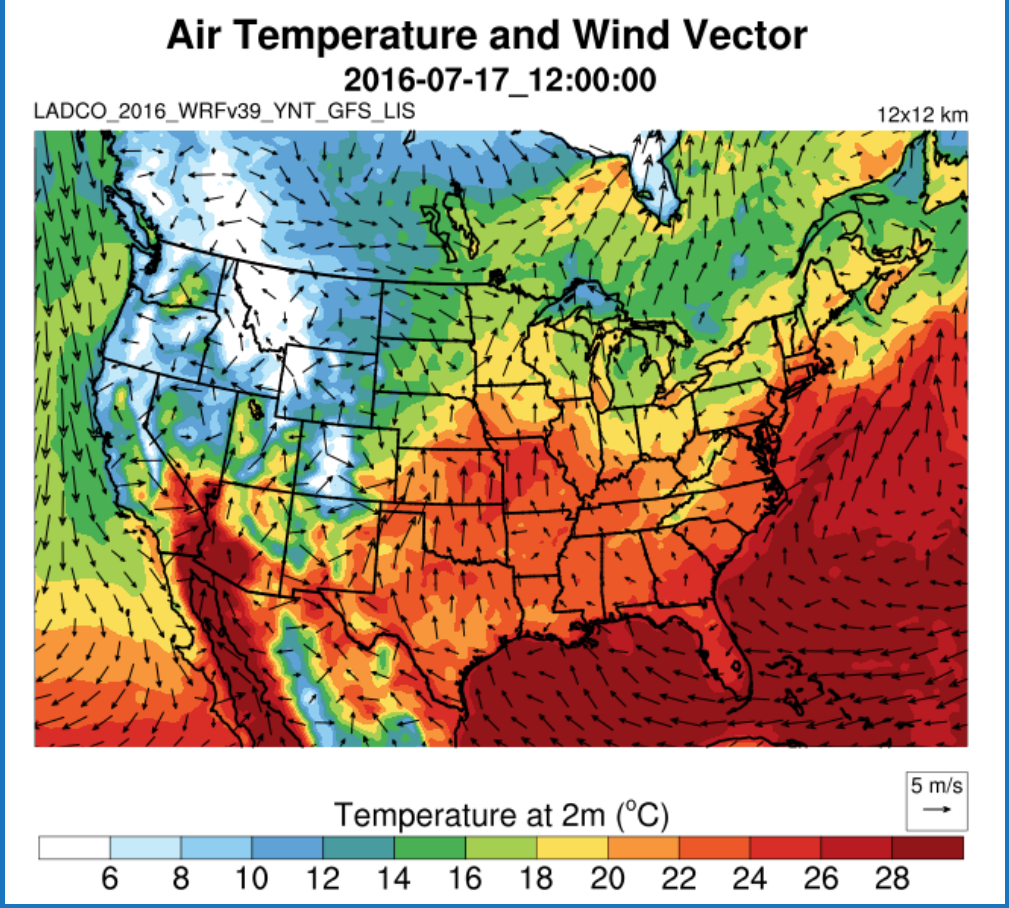


# Model Inputs: Emissions




- Hourly, gridded, and speciated to air quality model terms
- NEI → SMOKE → Model-ready
- Emissions sectors
  - Nonpoint and offroad mobile: industrial equipment, recreational marine, gasoline vapors from refilling, lawn mowers, surface coatings, rail, etc.
  - Mobile: on-road and parked cars, trucks, buses, etc.
  - Point: utilities, refineries, etc.
  - Biogenic: certain tree and plant species emit ozone and PM precursors

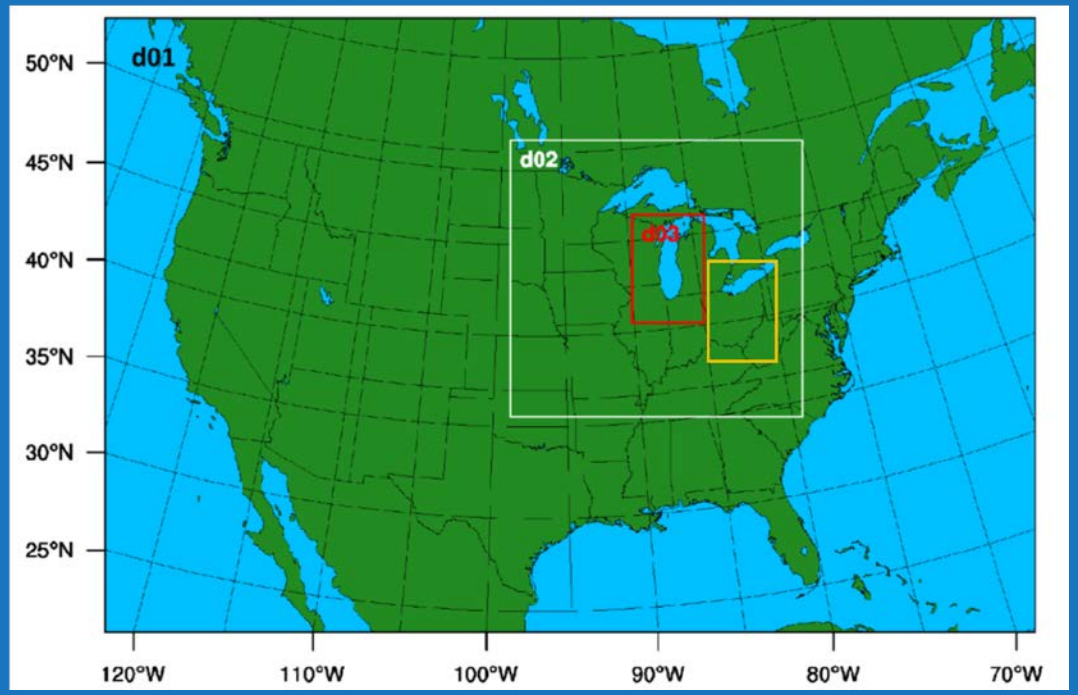
# Model Inputs: Meteorology




- Models need many meteorological variables (gridded, hourly) as input to simulate transport, deposition, and chemistry
  - Winds
  - Temperature
  - Moisture
  - Planetary Boundary Layer (PBL) height
  - Clouds and solar radiation
- Air quality models use gridded data from a meteorological model such as WRF

# Model Inputs: Boundary Conditions

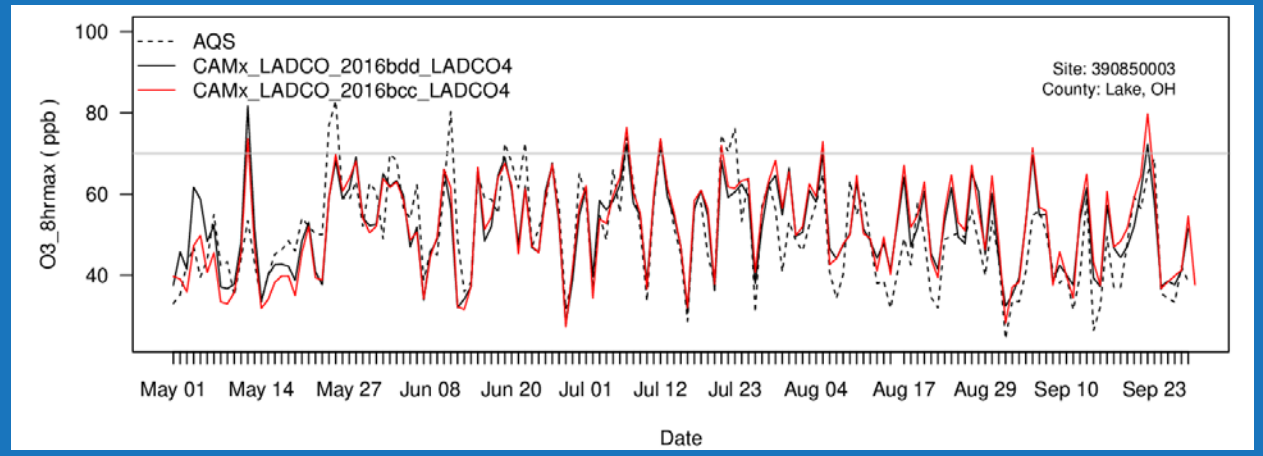
- Boundary conditions are the flux of pollution across the borders into the modeling domain
  - Proxy to the global background
- Global or hemispheric scale photochemical grid models are ”downscaled” to regional model inputs
- Inner, nested modeling domain derive boundary conditions from outer, parent domains

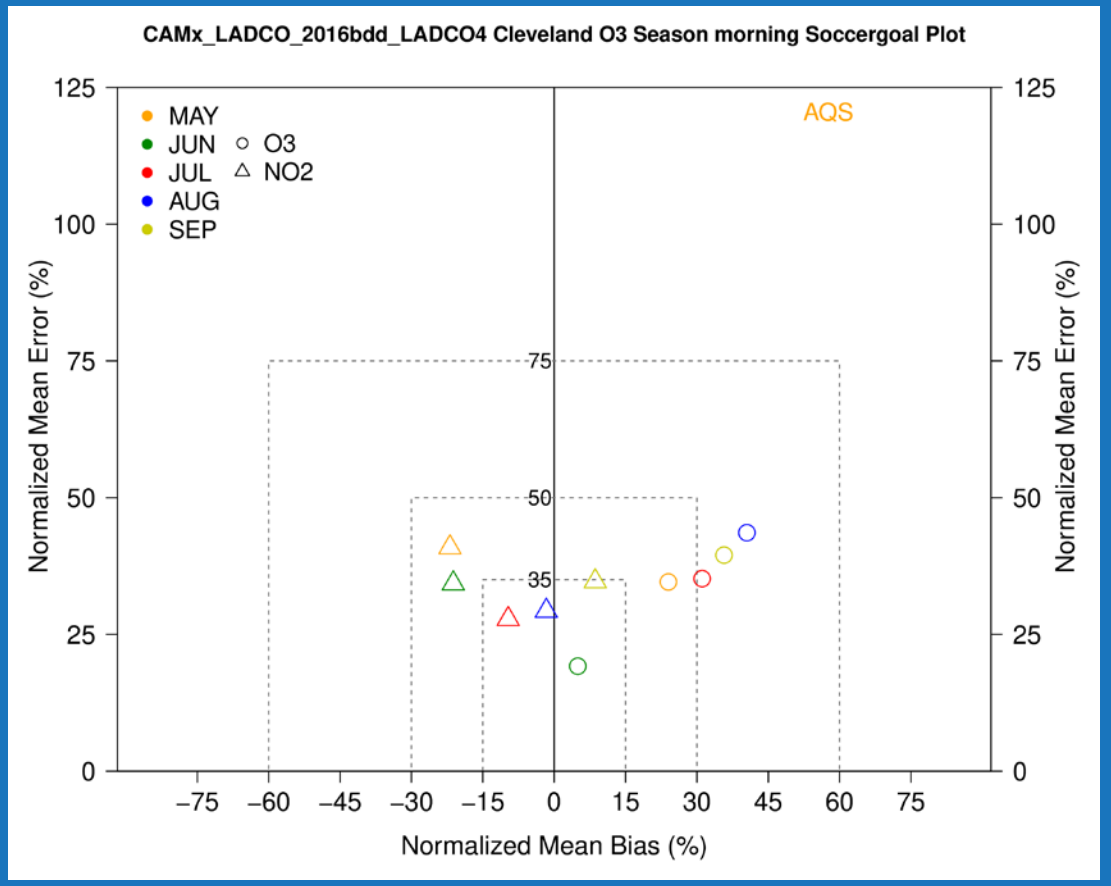


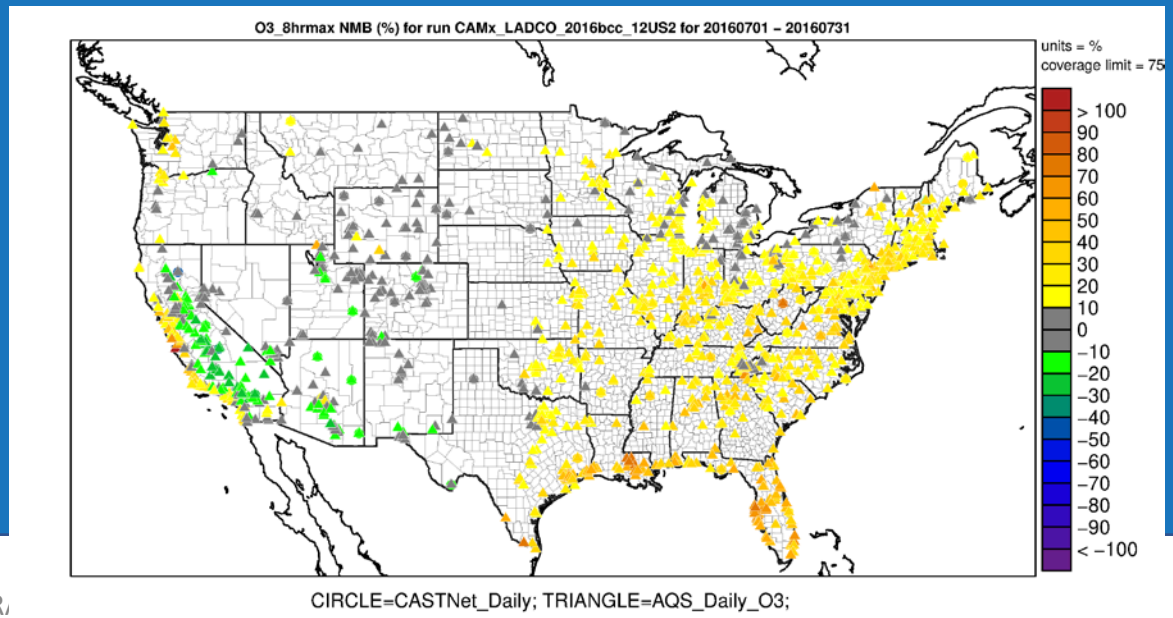
# Model Performance Evaluation

- Operational Evaluation: compare predicted concentrations to observed concentrations
  - Statistics (bias, error, etc.)
  - Scatterplots
  - Time series plots
- If model performance is “acceptable” then the modeling system can be used to predict air quality in the future.

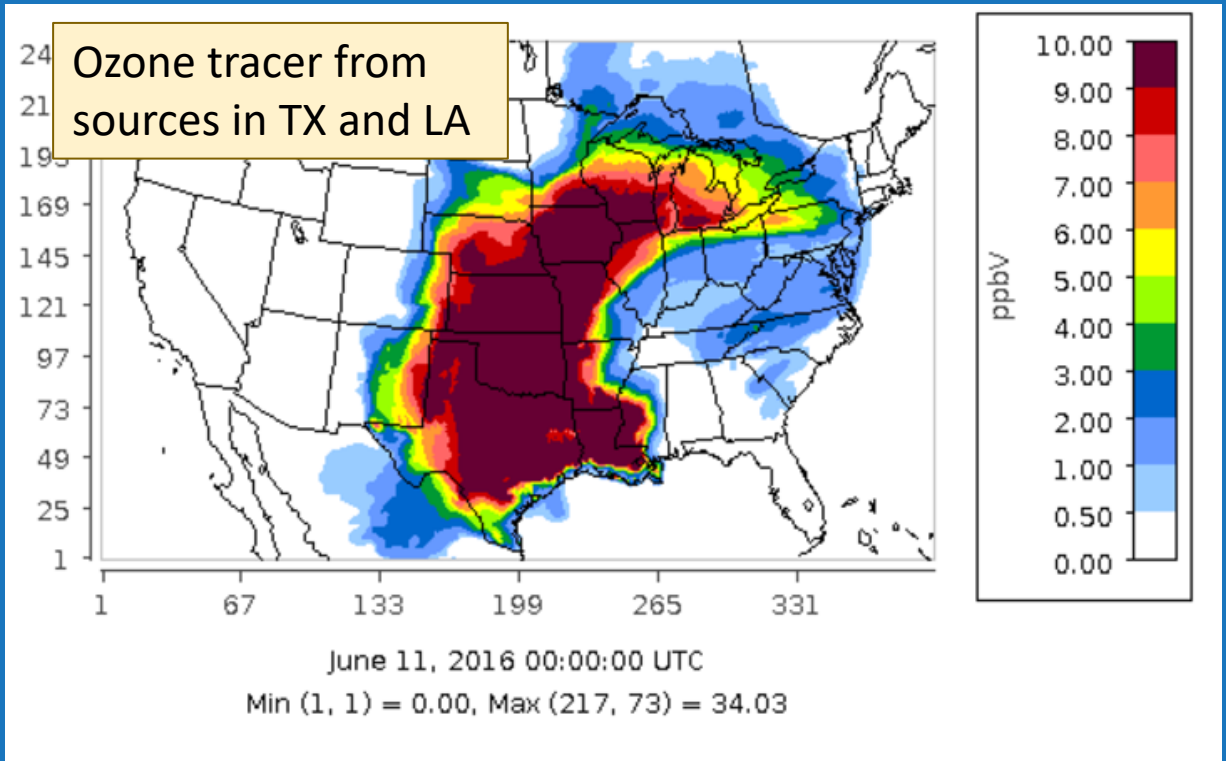
# Example Model Performance Evaluation



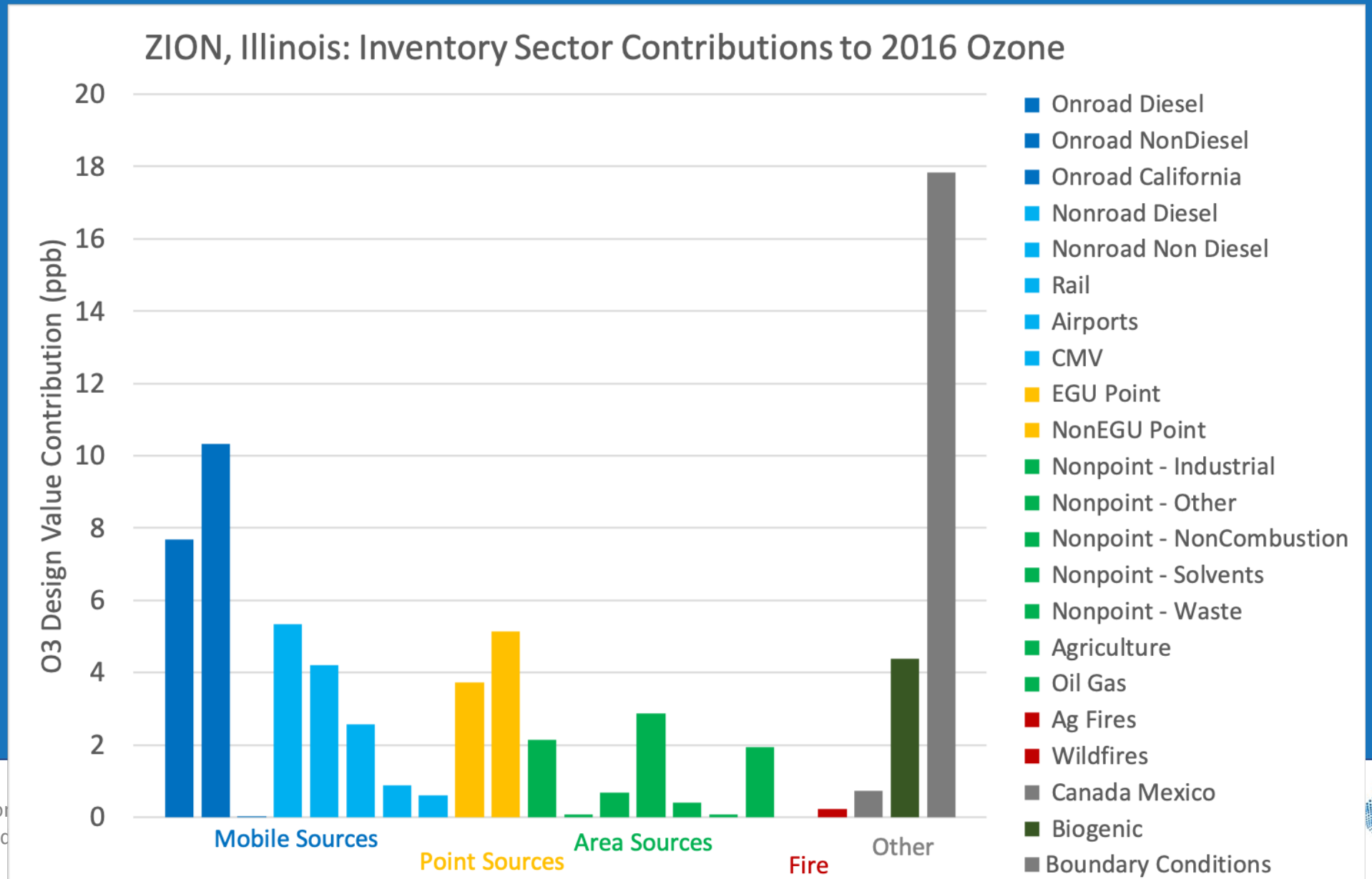



# Source Apportionment




- Model configuration for tracking $O_3$ and PM pollution precursor impacts on receptors
  - Distinct from observation-based receptor modeling
- Emissions are tagged as tracers
  - Tracers are tracked through the model chemistry
- Result: hourly concentrations of tracers in each model grid cell

# Ozone Source Apportionment Modeling: Sectors



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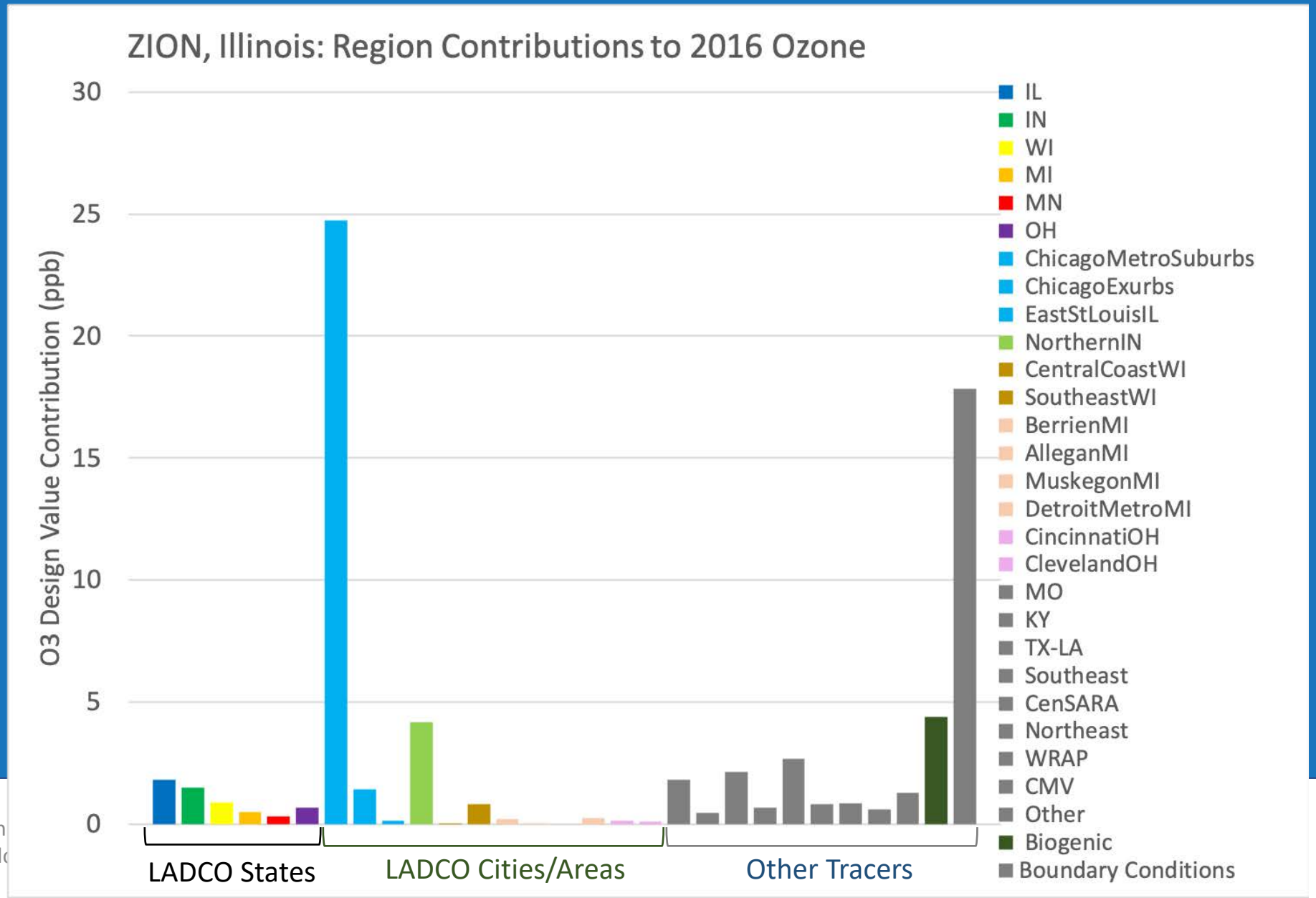
# Ozone Source Apportionment Modeling: Regions



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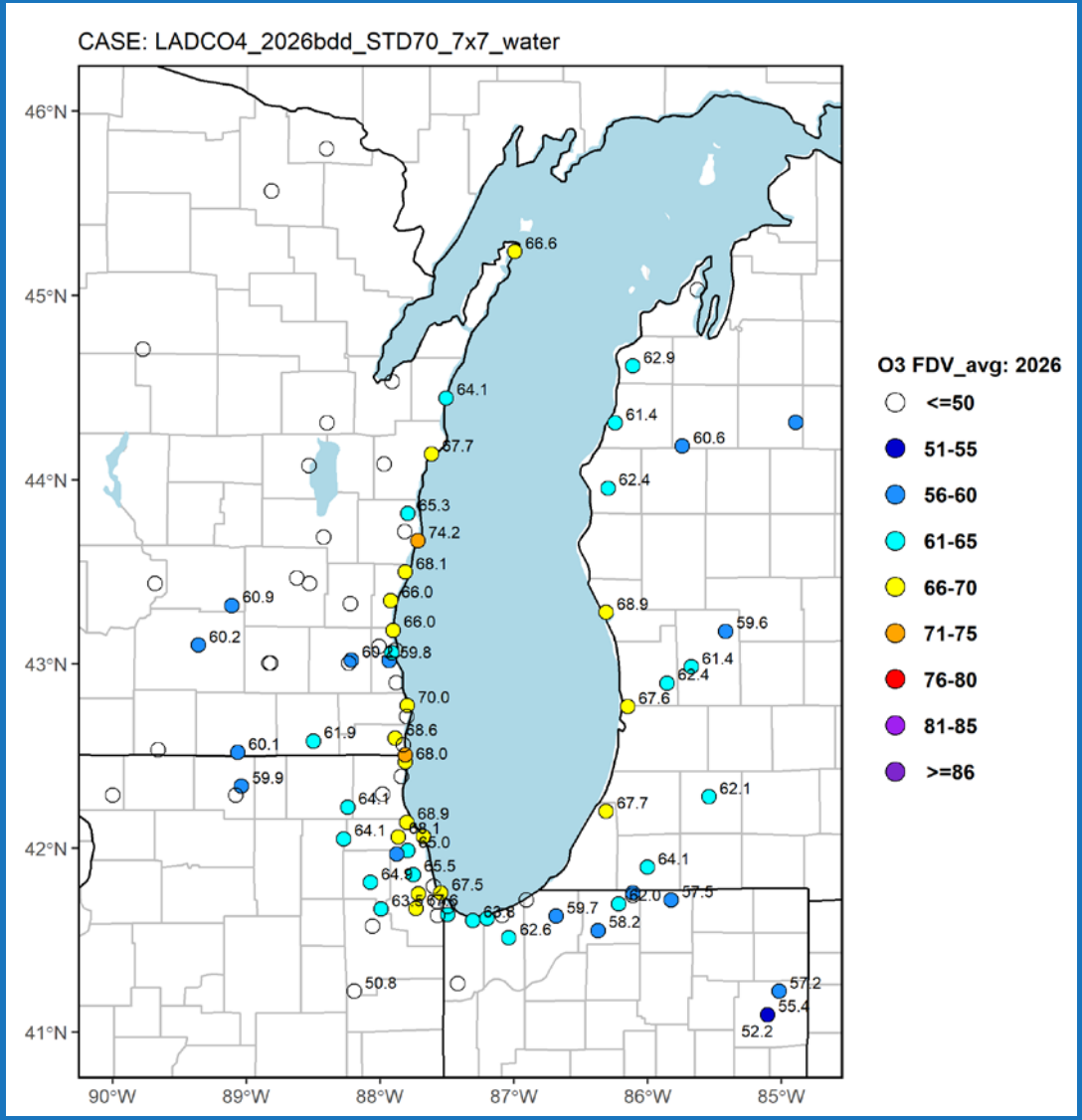
# Model Applications in SIPs

How are models used in SIPs?

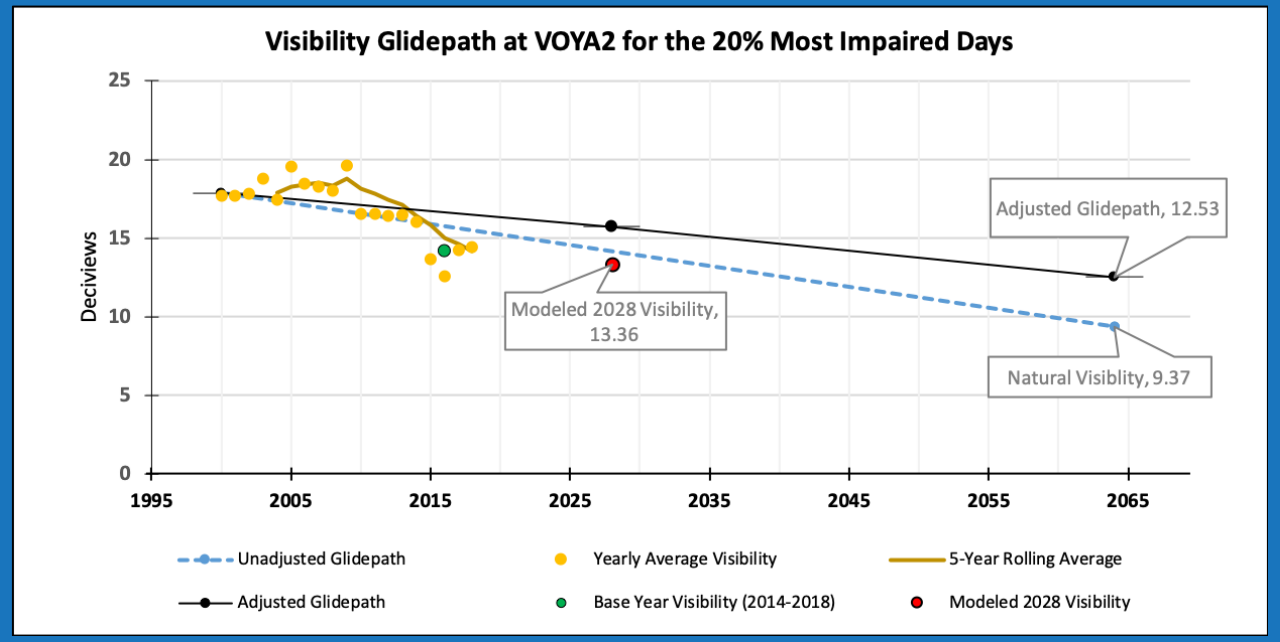
# Attainment Testing

- Model is run with emissions projected to a future year (all other inputs are the same)
- SMAT-CE – Speciated Model Attainment Test – Community Edition
  - Calculates **RRF** and future year design values (DVFs)
- **DVF** is the metric for identifying future year attainment or maintenance areas



# Regional Haze Glide Paths

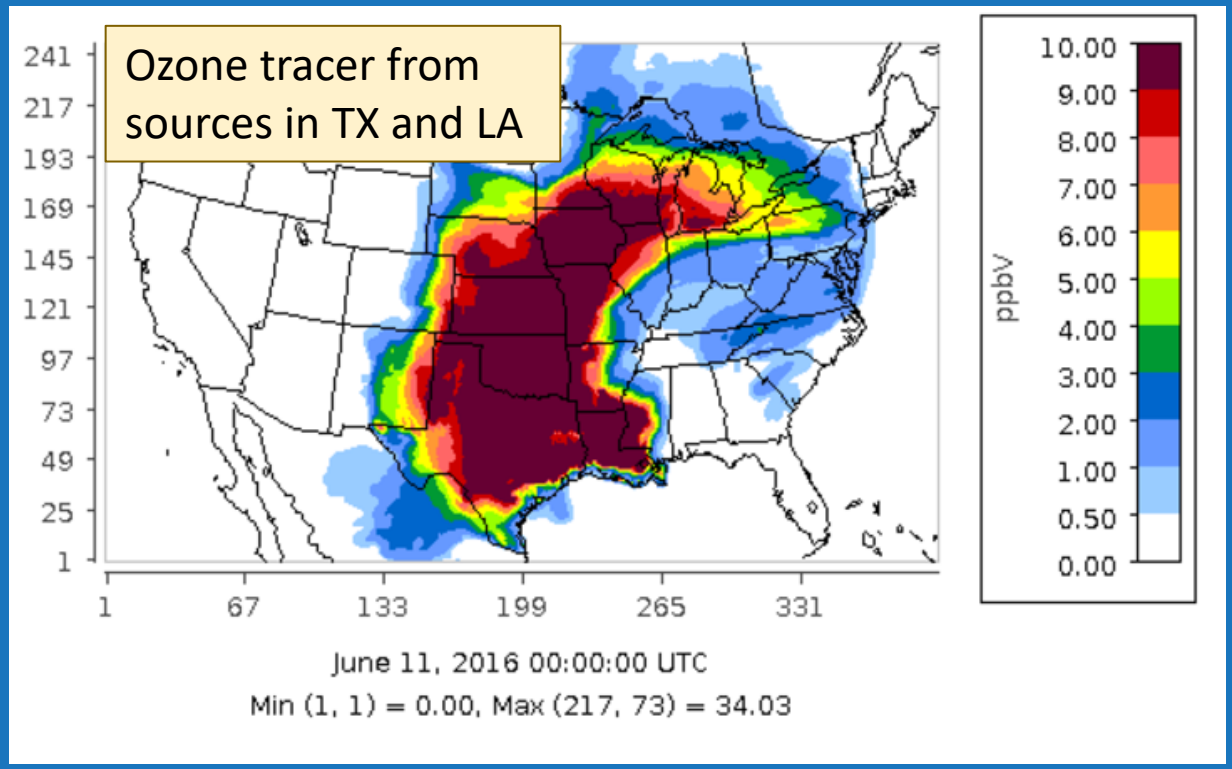
- Models are used to predict future year PM concentrations at Class I areas
- SMAT-CE
  - Calculates future year haze conditions using a visibility equation




- Modeled future year visibility is compared to the pathway to natural visibility conditions in 2065

# Transport “Good Neighbor” Contributions

- Tracers in the models are used to track emissions from source regions (states) to receptors
- Relative Contribution Factor (RCF)
  - RCF = [State A O3]/[Total O3]
  - State A Contribution = DVF * RCF
- Compare the contribution from each state to a prescribed threshold; e.g., 0.7 ppb for ozone



# Ozone, PM2.5, & Regional Haze SIP Modeling Guidance

- "Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze"
- Prescribes how to use models for SIPs, including validation and documentation
- Does not cover NSR or PSD permit modeling
  - Guideline on Air Quality Models "**Appendix W**" addresses requirements for permit modeling

# Weight of Evidence

- All attainment demonstrations should include “supplemental” analyses to corroborate the modeling results
  - Three main categories of supplemental analyses
    - Additional modeling and analysis
    - Emissions and air quality trends analysis
    - Additional emissions controls (e.g., voluntary measures or those difficult to quantify)
- Weight of evidence (WOE) must be more rigorous when future design values are “close to” NAAQS (either above or below)

# Discussion Questions

- What level of understanding of modeling is needed by a SIP writer?
- How should uncertainty in modeling be addressed in the air quality management process?
- In what ways should modelers and SIP writers coordinate to meet the goals of an air program?