Overview of Emissions Inventories

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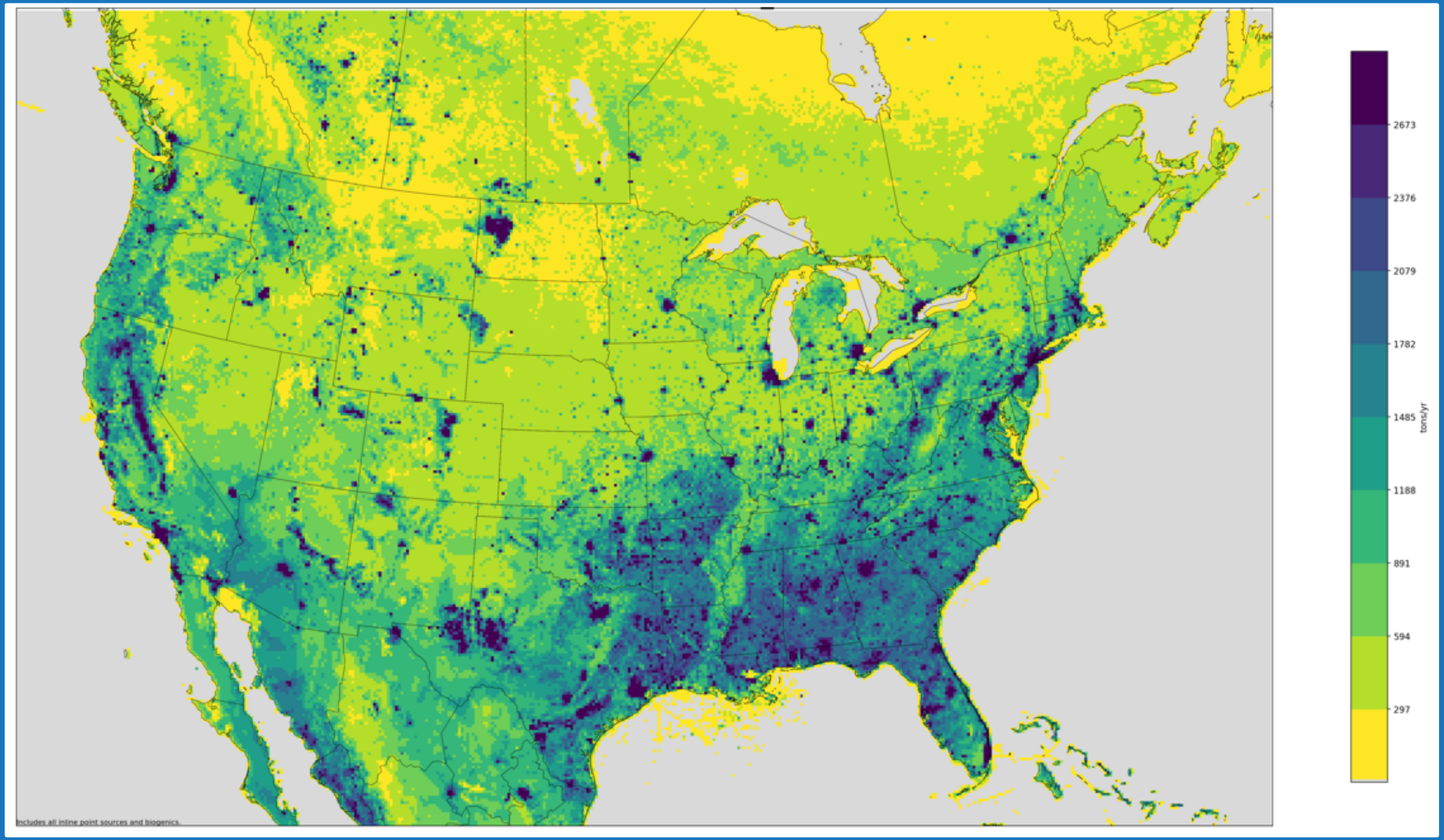

2016 Annual Total VOC Emissions

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What is an Emissions Inventory?

- Comprehensive listing by sources of air pollutant emissions in a geographical area during a specific time-period
- Uses: air program reporting, trends analysis, air quality modeling, regulatory impact assessments, and human exposure modeling
- Pollutants:
  - Criteria Air Pollutants & precursors (CO, NOx, SO_2, NH_3, VOC, $PM_{2.5}$ and PM_{10})
  - Hazardous Air Pollutants (e.g., Benzene, Acetaldehyde)
  - Greenhouse Gases (e.g. CO_2, CH_4, N_2O)

Statutory and Regulatory Requirements for Emissions Inventories

- Section 110(a)(2)(F) of CAA: Requiring SIPs to provide for the reporting of criteria air pollutants
- Section 172(c)(3): Discretionary authority to require other emissions data
- Section 169(a): Authority for emission inventories to be required in SIPs developed to protect visibility in Federal Class I areas

Types of Air Pollution Emissions Inventories

- National Emissions Inventory (NEI)
- SIP Planning Inventory
  - Periodic NAA inventory
  - ROP/RFP NAA inventory
  - Maintenance NAA inventory
- SIP Modeling Inventory
  - Modeled attainment demonstrations
  - EPA rule making
- Projection/Future Year Inventory

National Emissions Inventory (NEI)

- Complete estimates of Criteria Air Pollutant (CAP) and Hazardous Air Pollutant (HAP) emissions prepared by S/L/T agencies and the U.S. EPA
- Sources of the data
  - Submissions from S/L/T agencies
  - Industry reporting
  - Gapfilling by U.S. EPA
- Created for EPA, federal, and state decision makers to support the NAAQS
  - CAA requires states to submit emissions to EPA as part of their SIPs that describe how they will attain the NAAQS

What is in the NEI?

- Geographic Coverage
  - Entire U.S.
  - Individual process level inventory for point sources
  - County level inventory for non-point and mobile sources
- Pollutants coverage:
  - Criteria Air Pollutants (CAPs)
    - CO, VOC, NOx, NH_3, SO_2, PM_{10}, $PM_{2.5}$, Pb,
  - Hazardous Air Pollutants (HAPs)
    - 188 air toxics

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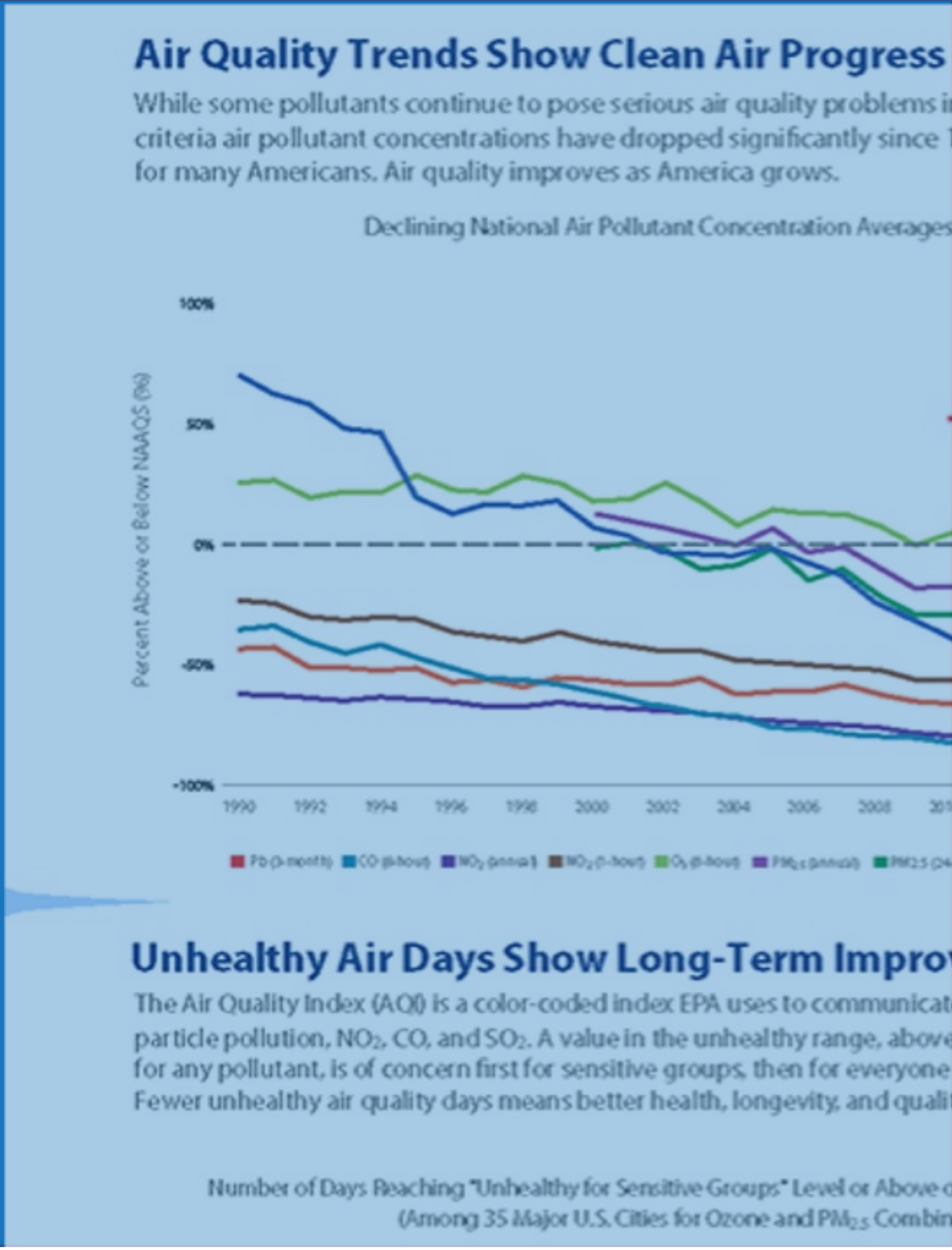
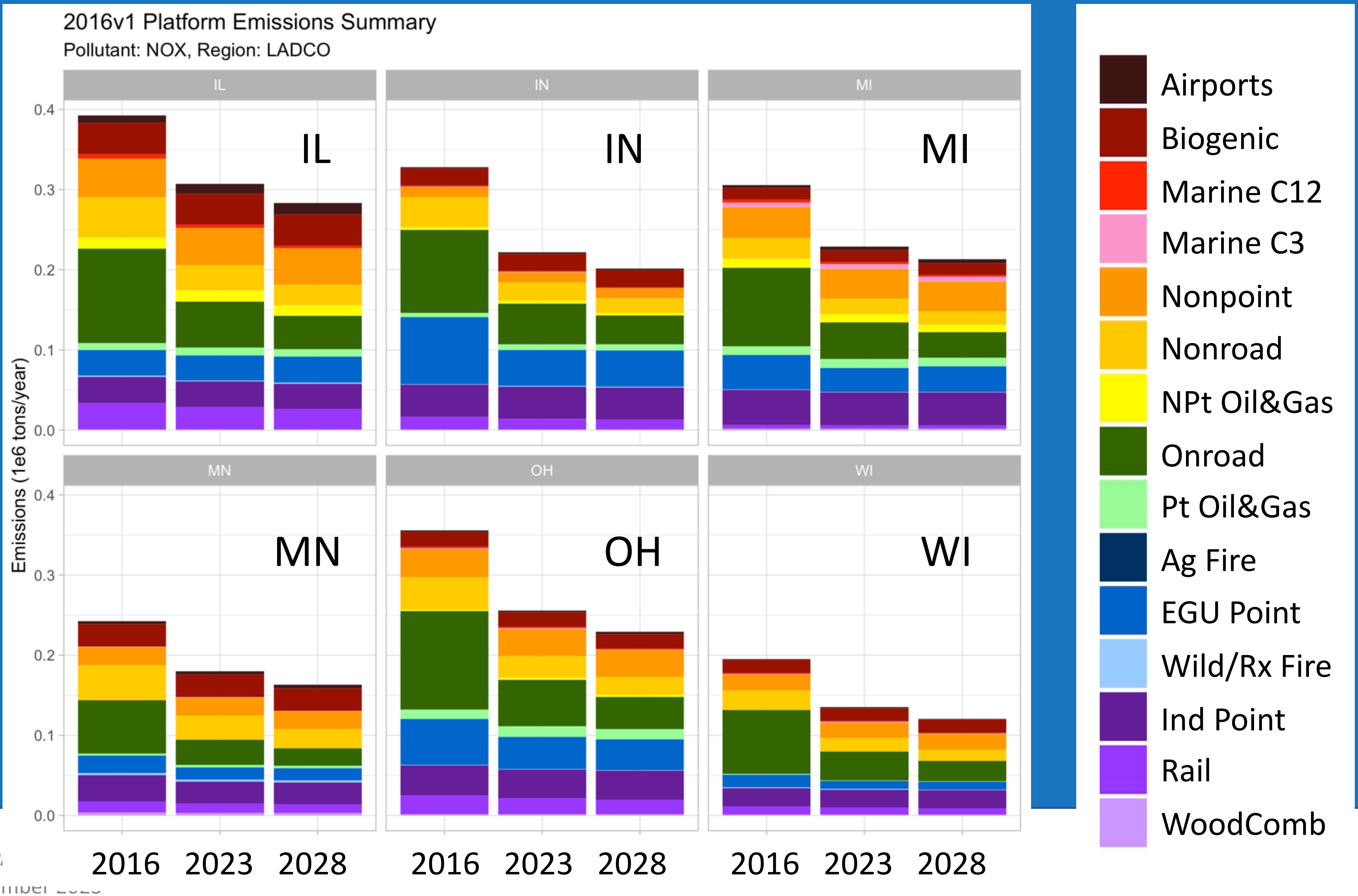
Uses of the NEI

- Regional- and local-scale air quality & human exposure modeling
- Control strategy analysis
- Regulatory impact analysis
- Risk assessment studies
- Emission trends and program accountability
- Public reporting
- International reporting



National NOx Emissions by Sector



The National Emissions Inventory (NEI) is organized by types of sources (sectors)

Sectors group sources with similar characteristics and data processing requirements

Periodic Inventory

- Complete and comprehensive estimates of CAP and precursor emissions submitted by S/L/Ts to EPA
- Meets requirements of the Air Emissions Reporting Rule (AERR)
- Purpose: national trends, analyze control strategies, modeling
- Annual emissions, all states
- 3-year submission cycle

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Non-Attainment SIP Inventory

- Required by CAA sections 172(c)(3) and 182(a)(1)
- Used by States and MJOs for Rate of Progress/Reasonable Further Progress
- Assessment of adequacy of Maintenance Plans over their 10-year life cycle
- Purpose: Pollution control strategies
- Base and future year emissions
- Pollutants: CAPs and precursors

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Attainment Demonstration Inventories

- Purpose: Modeling, regional control strategy planning
  - Primarily for PM and Ozone NAAQS control strategy modeling
  - Also used for the Regional Haze Program to demonstrate progress
- Inter-regional cooperation and data sharing among states and EPA
- Base and future year emissions

EPA Rulemaking Inventory

- Emissions Modeling Platforms (EMPs)
  - EPA OAQPS, MJOs, and some states develop EMPs with the best available inventories to support rulemaking
  - Combination of all available inventories
- Purpose: Support Federal NAAQS revisions, SIP calls, and rulemakings
- Base and future year emissions
- Includes ancillary emissions data, modeling tools, and technical support documentation

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Emission Inventory Development

- Bottom-up inventories are based on a basic parameterization of emissions fluxes
  - EF relates the quantity of a pollutant released into the atmosphere with the activity that releases it
- Equation becomes more complex when A and EF vary under different conditions (space, time, technology differences, control programs…)
- Both A and EF can be parameterized as "process-based" models

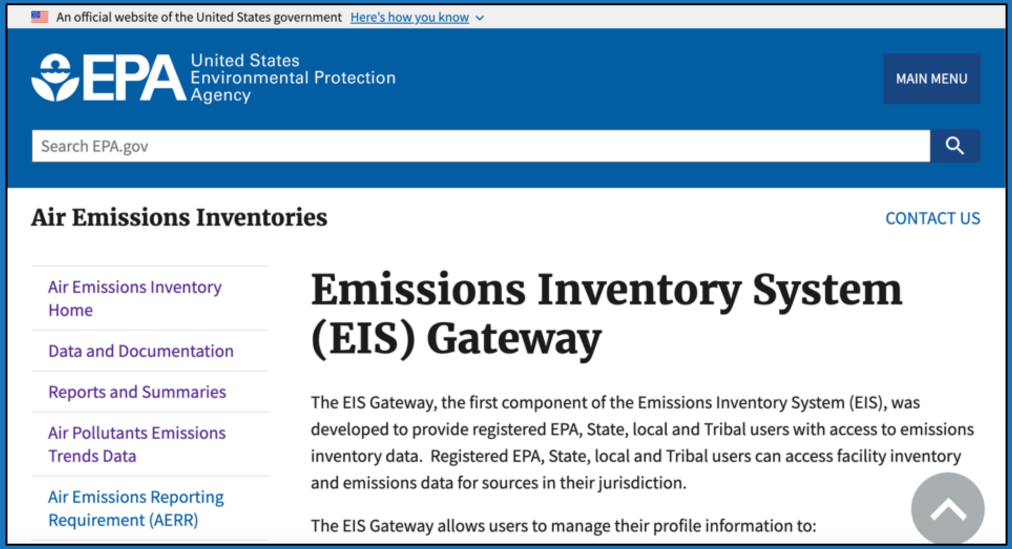
$$E = A \times EF$$

E = Emissions (e.g. tons/year)
A = Activity (e.g. # emitting process/year)
EF = Emissions Factor (e.g. tons/emitting process)

Emissions Equation

Emissions Inventory System (EIS)

- Process for submitting, developing, quality assuring, storing and distributing emissions inventory data.
- Conforms to the EPA's strategic plans for air quality and information management
- EIS includes a database and web portal (EIS Gateway) for S/L/Ts to submit and obtain periodic emissions inventories



The EIS Gateway is where many states go to submit inventory data for the NEI

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S/L/T Roles in the NEI Process

- **Document and plan** the inventory development process
- **Gather information** on S/L/T activities and emissions factors for the inventory year
  - Engage with stakeholders and researchers in the state/region to collect the best-available data
  - Develop a state inventory database and reporting tool
- Inventory active mandatory and voluntary **control** programs
- **Collate** all, best-available inventory data into the NEI format
- **Submit** data to the EIS
- **QA/QC** data

Emissions Modeling Platform

- The NEI is the building blocks for all types of inventories (SIP, modeling, tracking, etc.)
- Emissions modeling is the process of converting the NEI to inputs for air quality modeling
- An emissions modeling platform contains inventories, ancillary emissions data, software/tools, and scripts for emissions modeling
  - Including future year projections

The NEI: New Challenges

- Better characterization of smaller source categories
- New program requirements will require better resolution: spatially and temporally
  - Sector approach
  - Voluntary/innovative programs
- More transparency and stakeholder engagement
- Faster, more agile development cycle

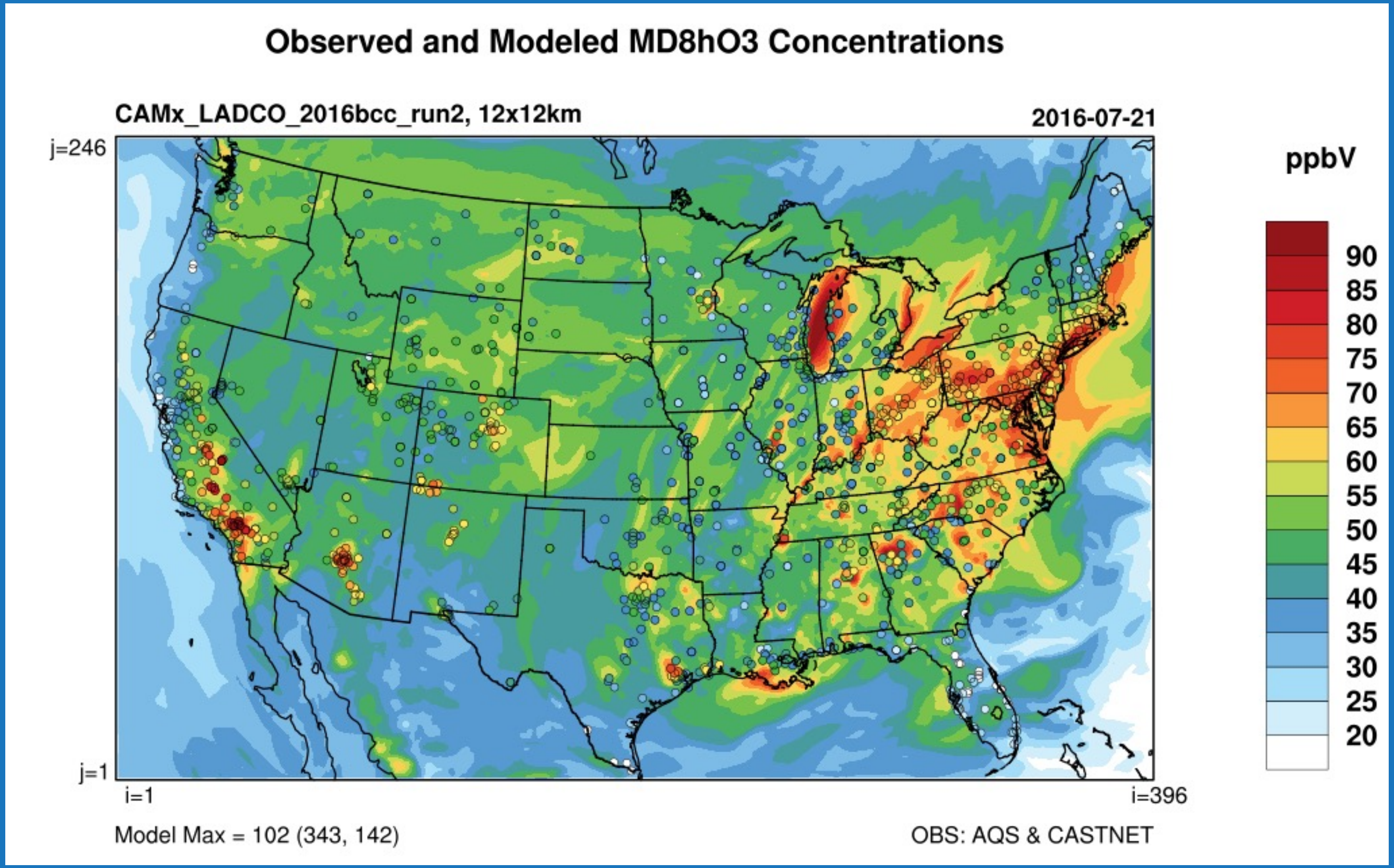
Step	S/L/T	US EPA
Planning	X	
Information gathering	X	
Emissions estimation	X	
Database compilation	X	X
QA/QC	X	X
Data augmentation		X
Documentation		X
Allow public access		X

Inventory Development Steps

Emissions Inventories
Resources

- Clearinghouse for Inventories & Emissions Factors (CHIEF)
  - https://www.epa.gov/chief
- National Emissions Inventory (NEI) and Emissions Factors
  - www.epa.gov/air-emissions-inventories
- Emissions Inventory System (EIS)
  - https://www.epa.gov/air-emissions-inventories/emissions-inventory-system-eis-gateway
- Electric Generating Unit (EGU) Continuous Emissions Monitoring Systems (CEMS)
  - https://campd.epa.gov/
- Emissions Inventory Guidance
  - https://www.epa.gov/air-emissions-inventories/air-emissions-inventory-guidance-documents
- Motor Vehicle Emissions Simulator (MOVES)
  - https://www.epa.gov/moves

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

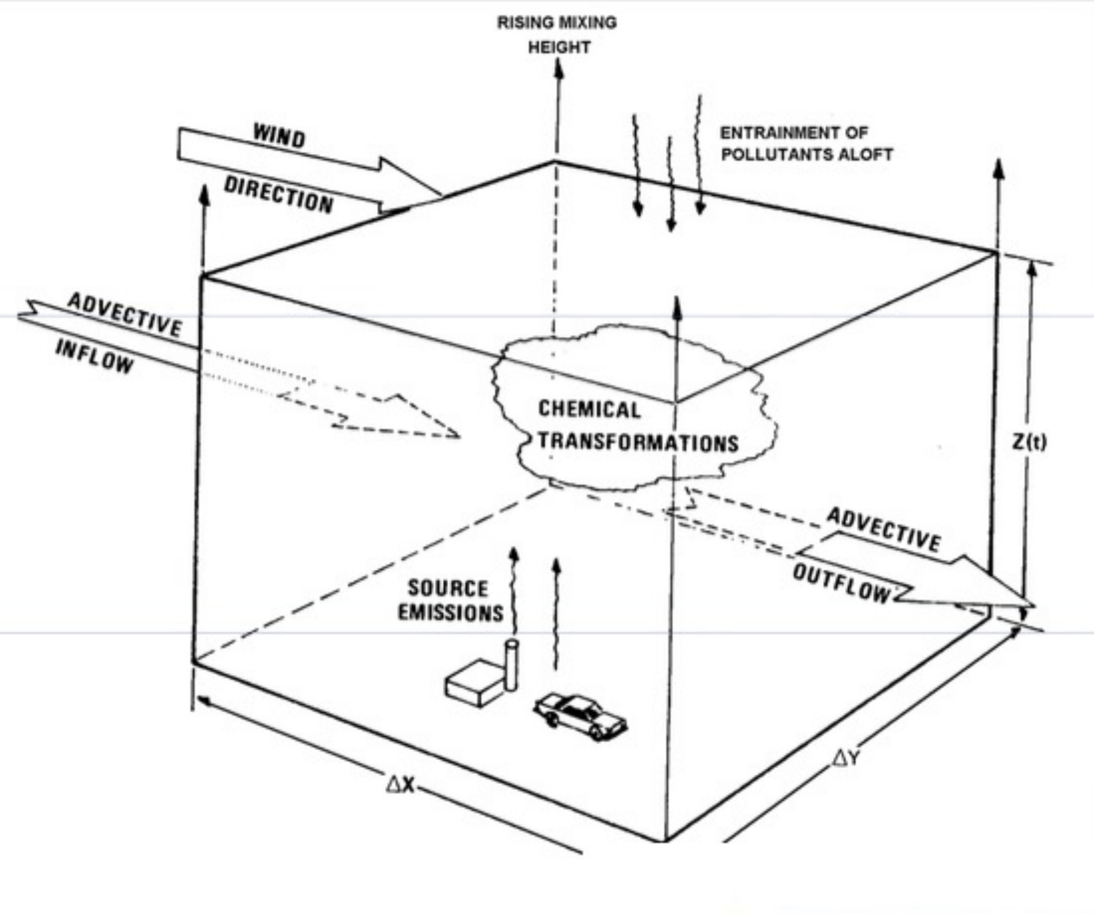
What are the different types of models?

What are the components of an air quality model?

Air Quality Modeling 101

Photochemical models

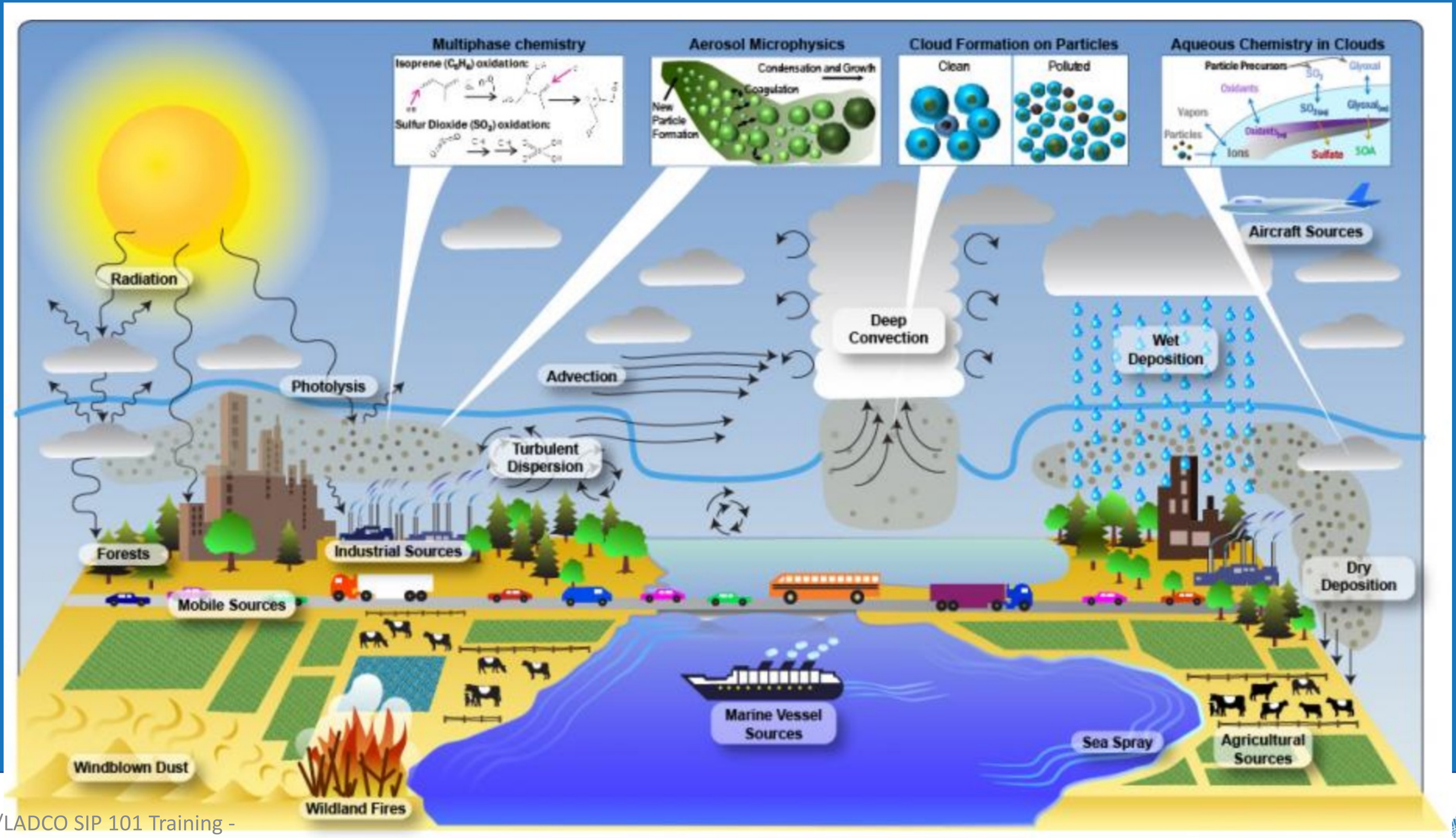
Large-scale air quality models that account for chemical and physical atmospheric processes in predicting pollutant concentrations.



<u>Also known as</u>: gridded models, chemistry-transport models, regional air quality model

<u>Model names</u>: CMAQ, CAMx, WRF-Chem

Photochemical Model Processes

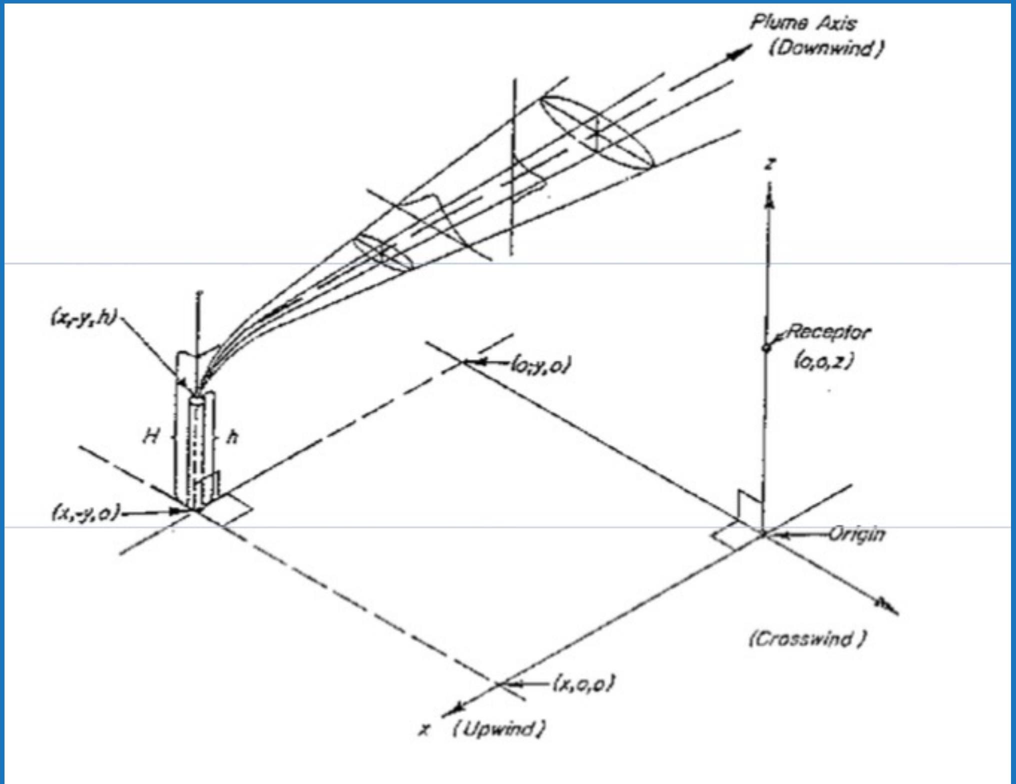


Source: www.epa.gov/cmaq

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

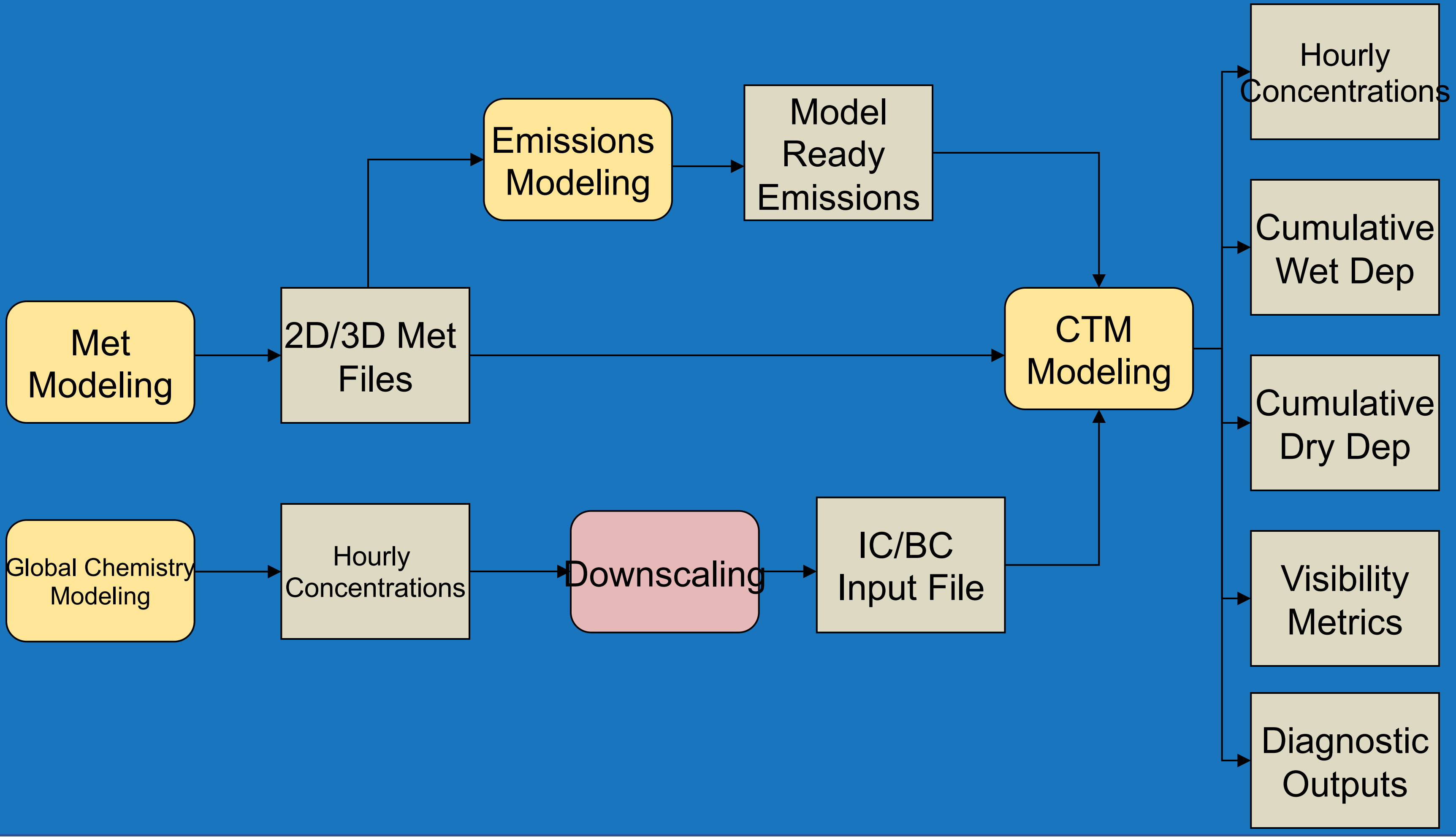
- Impossible to verify the accuracy of future year predictions
- Simulate historical periods to validate model performance
  - If the model can replicate what happened in the past, it then can be used to predict future changes in pollutant concentrations
- Modeled Future year air quality = Projected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

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

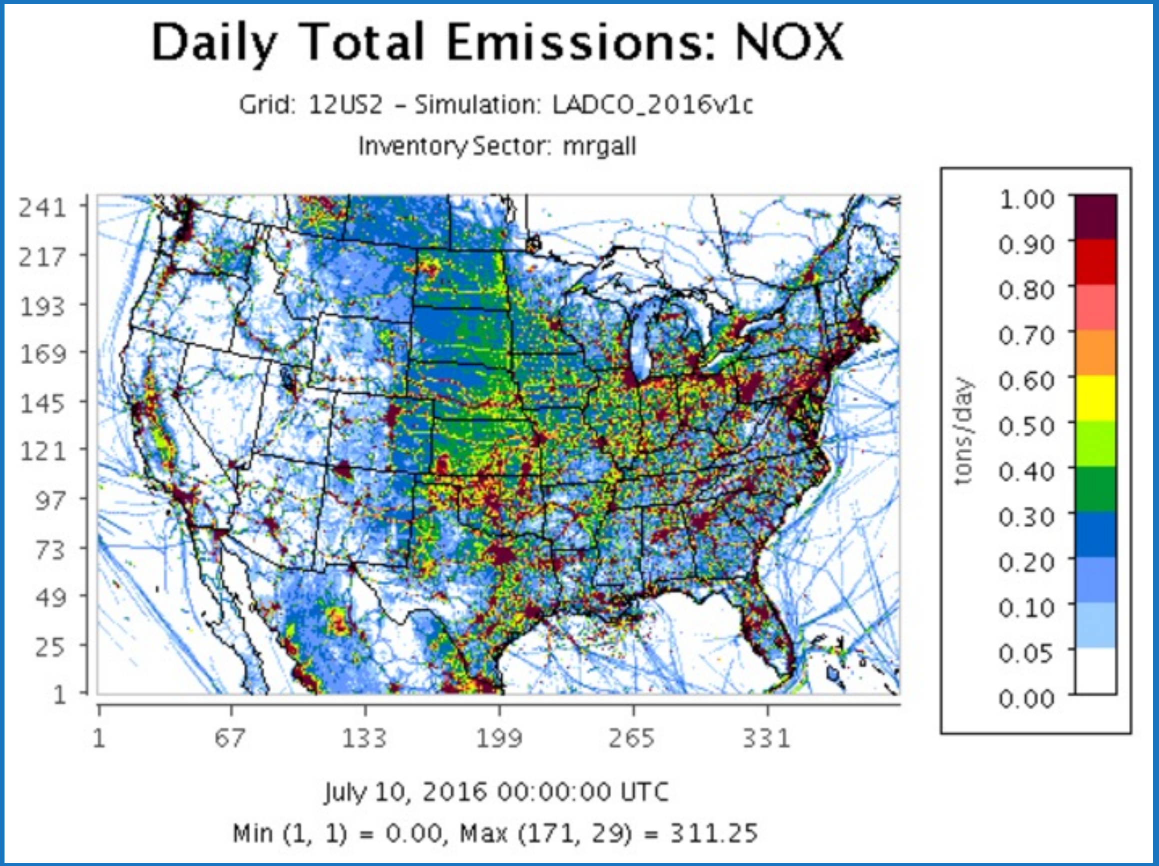
Relative Response Factor (RRF) = [future year model]/[base year model]

Future year concentration = [base year observed] * RRF

Air Quality Model Schematic

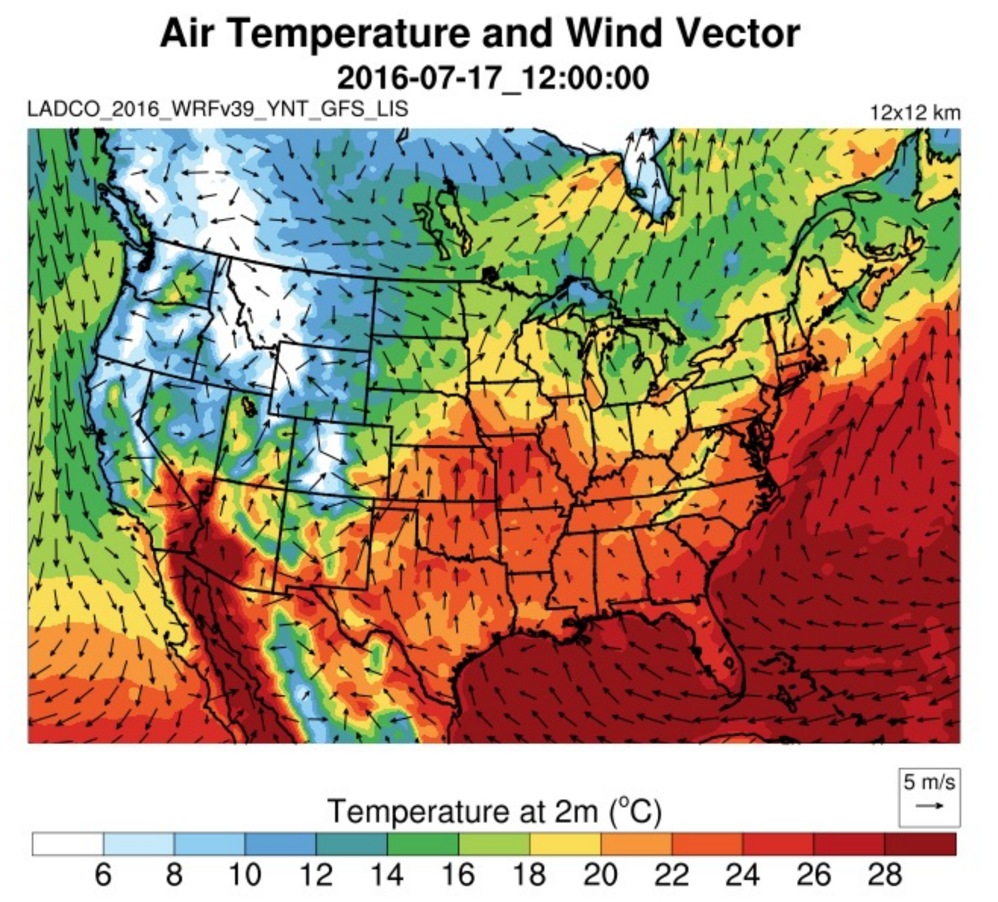


Model Inputs: Emissions



- 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

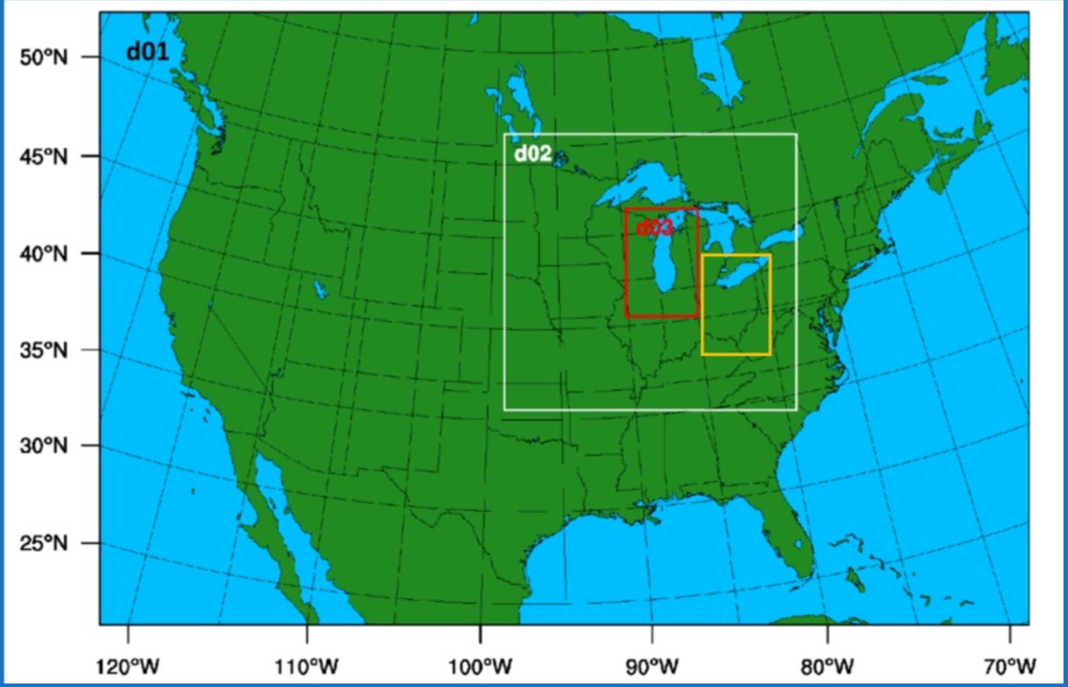
Model Inputs: Meteorology



- 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



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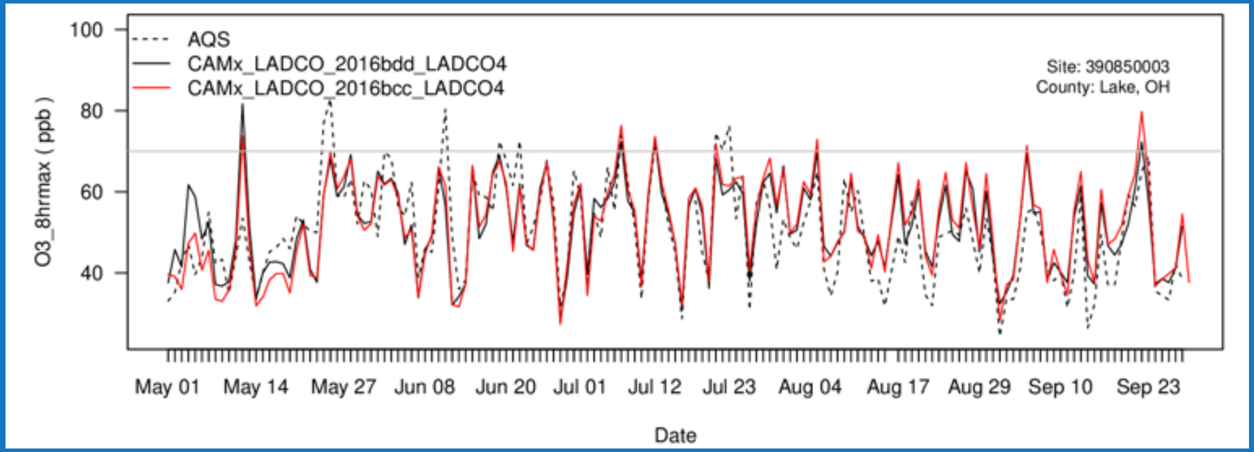
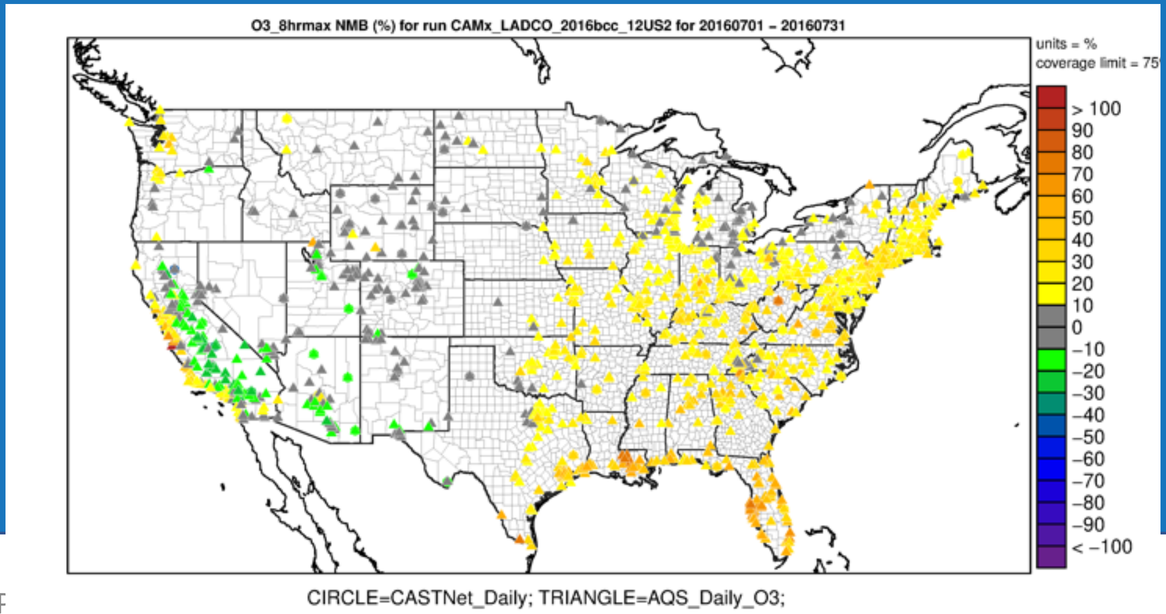
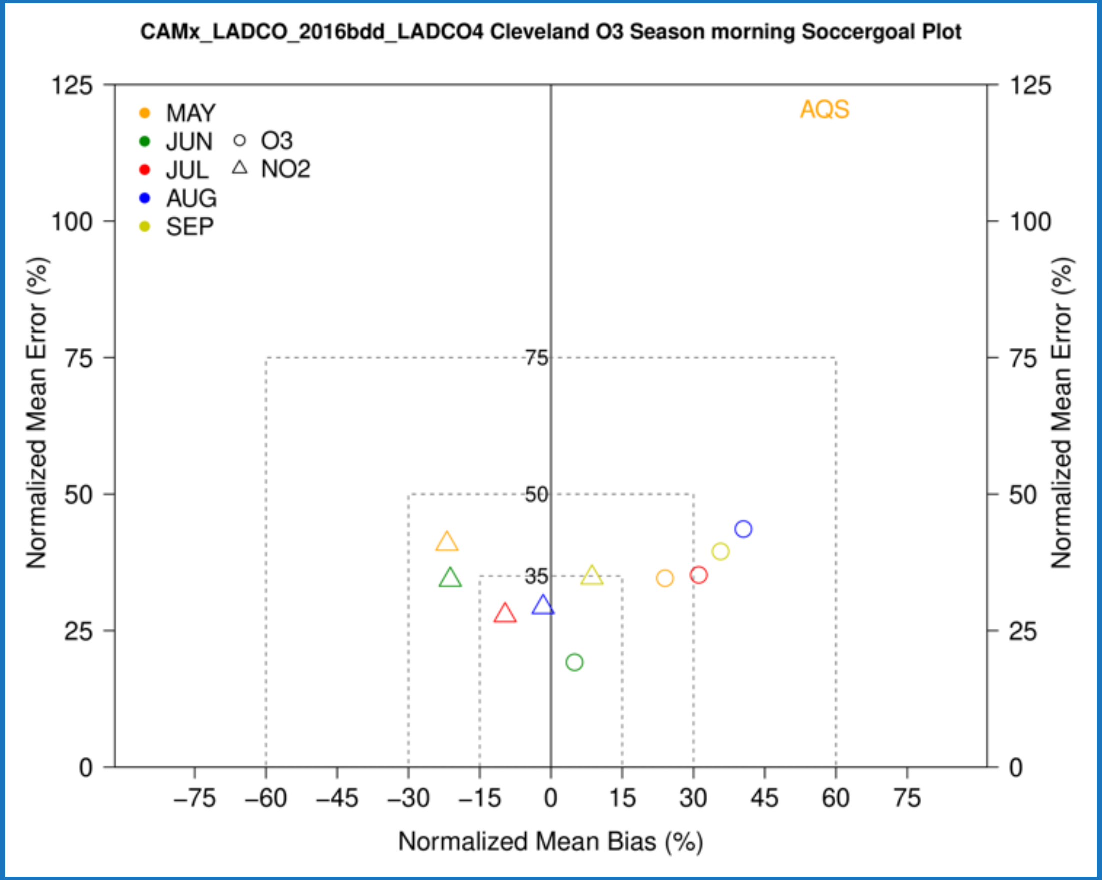
Model Performance Evaluation

- 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







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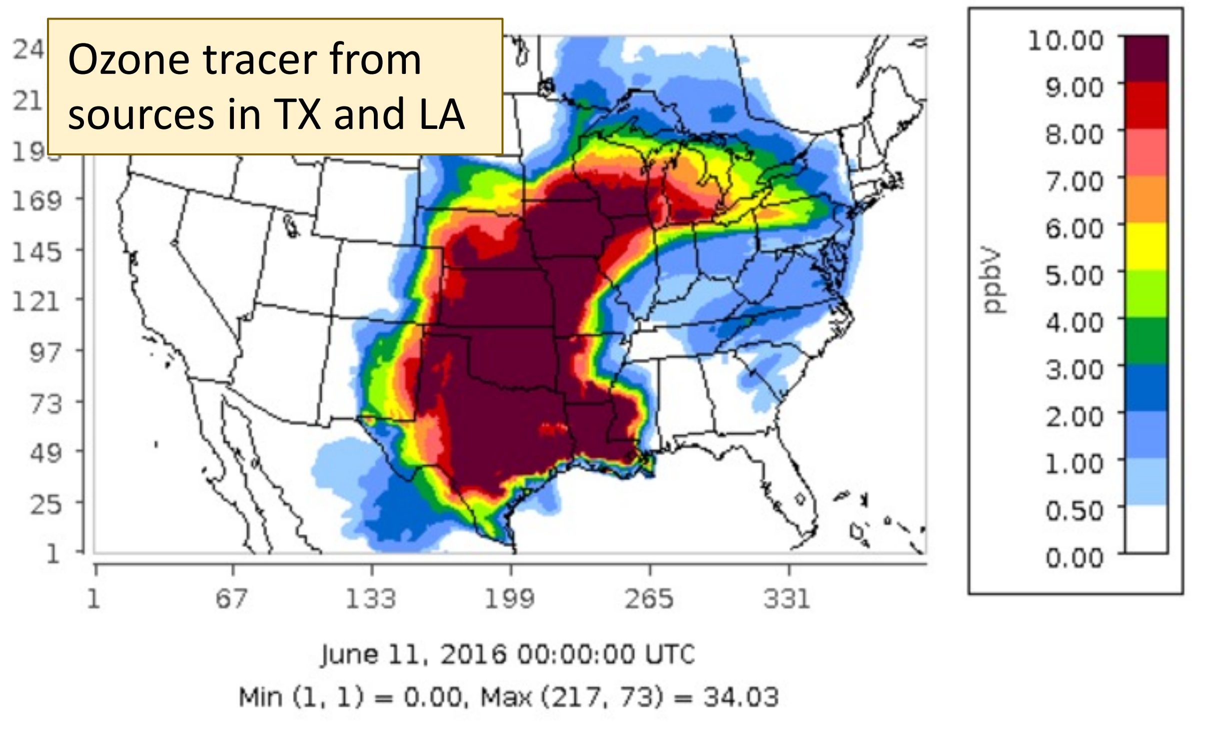
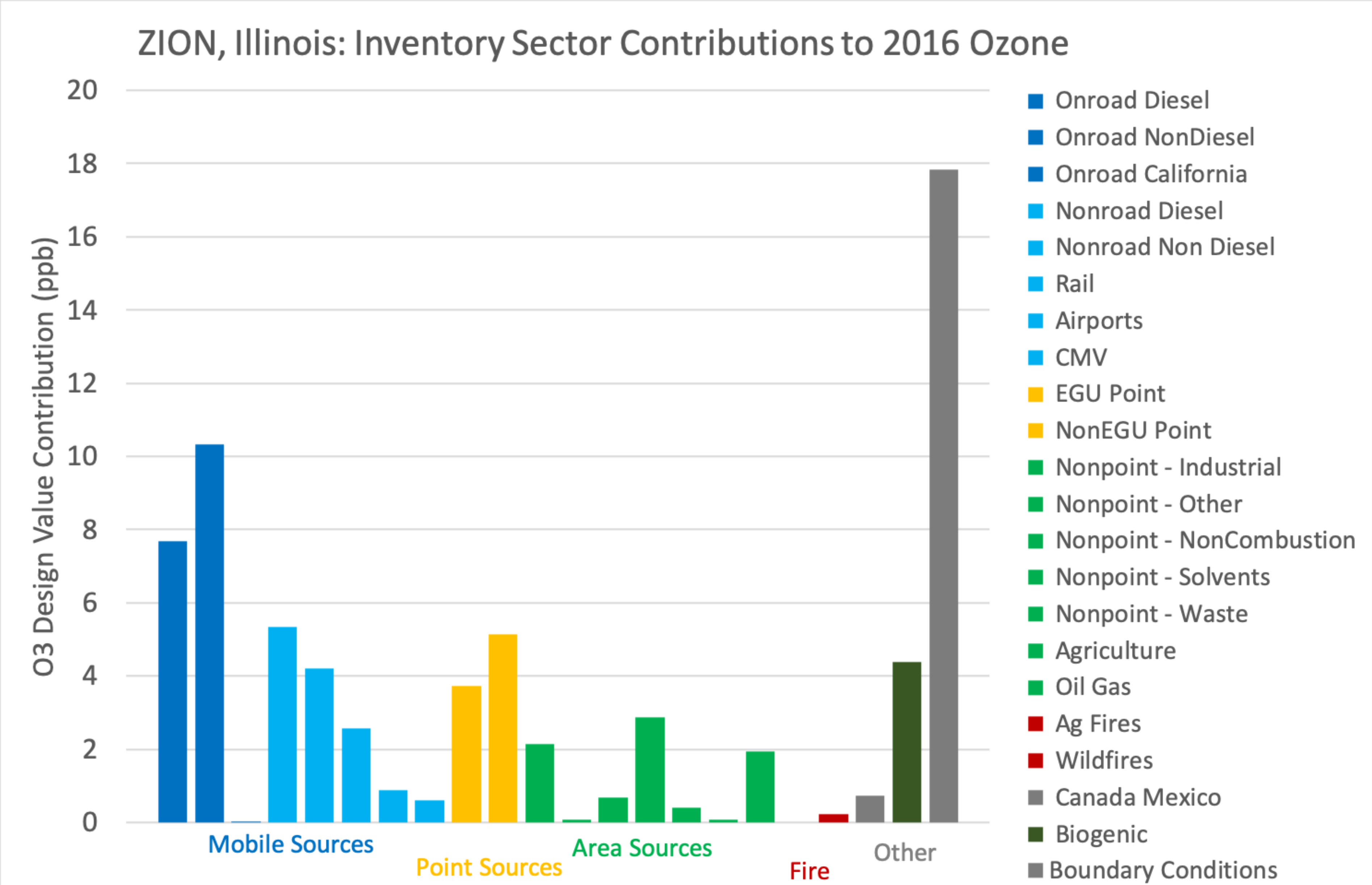
Source Apportionment



- 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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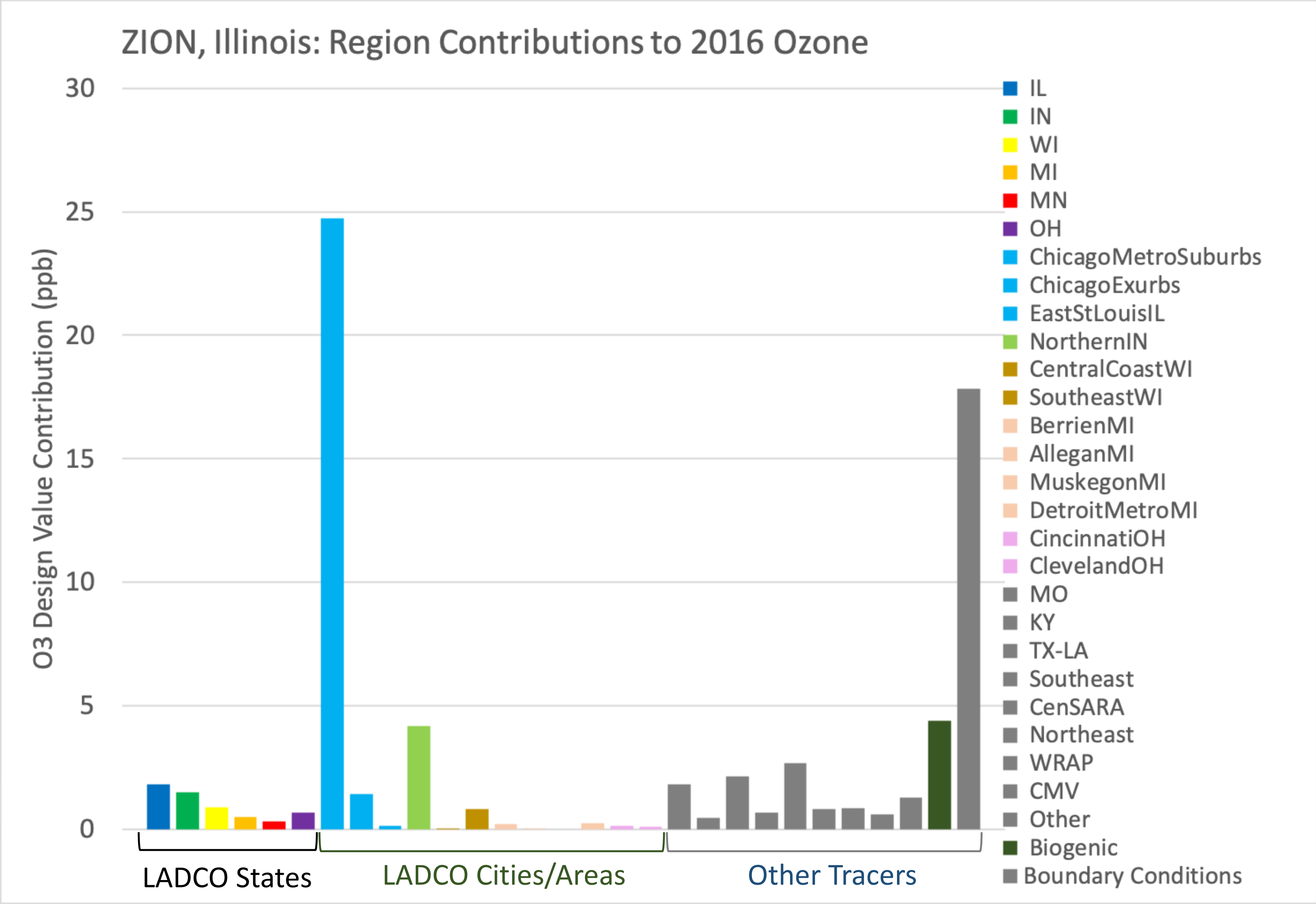
Ozone Source Apportionment Modeling: Regions



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Model Applications in SIPs

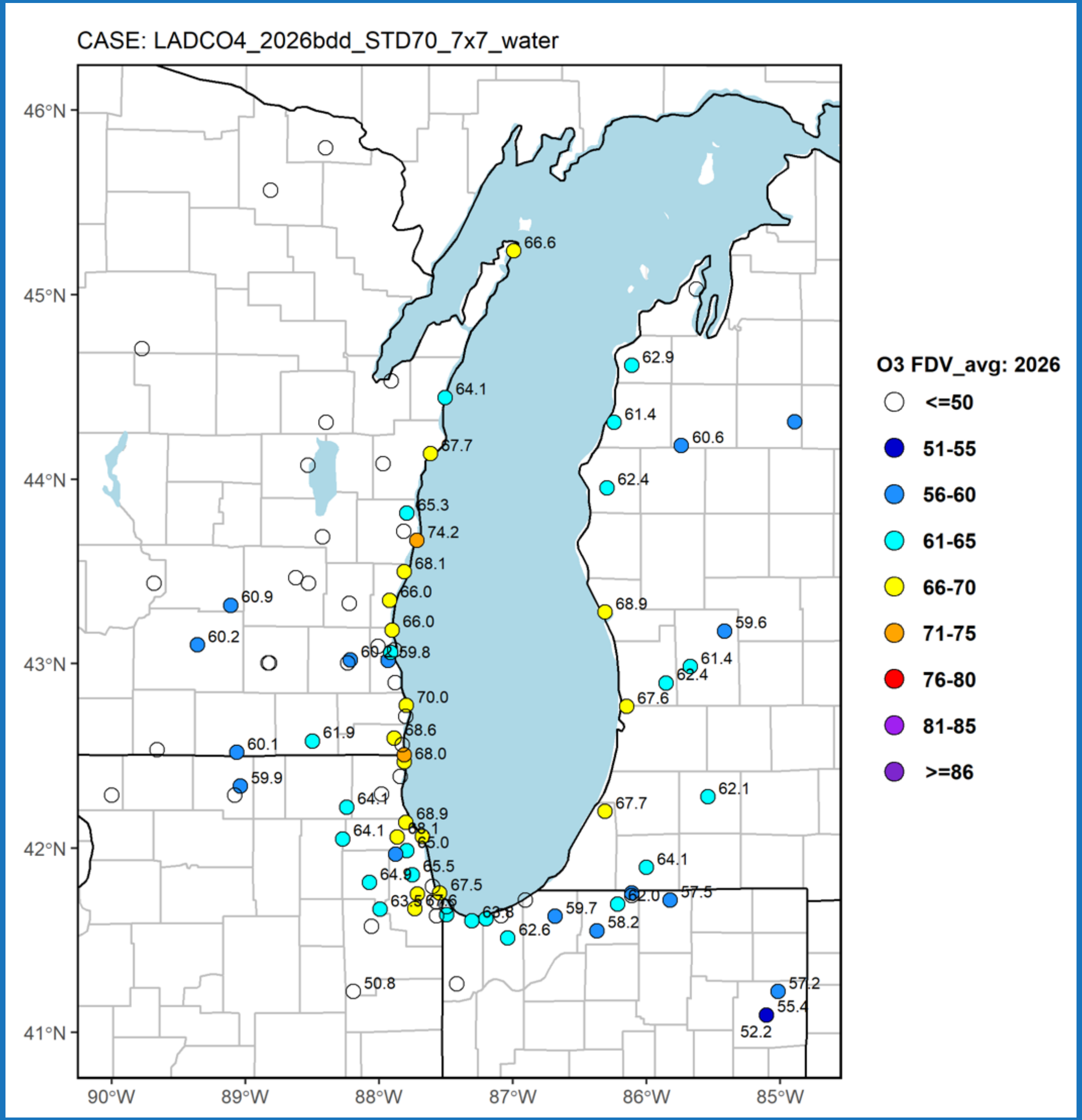
How are models used in SIPs?

SIP Modeling Guidance
Modeled Attainment Tests

- All O_3/$PM_{2.5}$/Regional Haze modeled attainment tests use model estimates in a "relative" sense
  - Premise: models are better at predicting relative changes in concentrations than absolute concentrations
- Relative Response Factors (RRF) are calculated by taking the ratio of the model's future to current predictions of PM2.5 or ozone
  - RRF = Future predicted concentration/Current Measured Concentration

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



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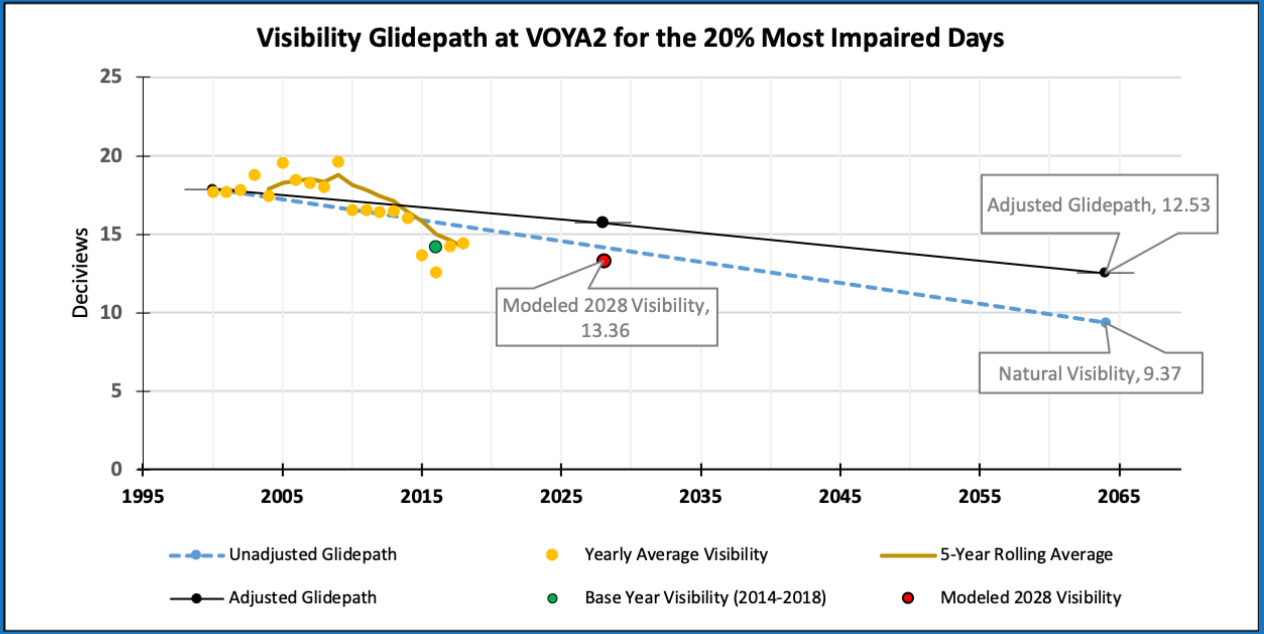
Regional Haze Glide Paths

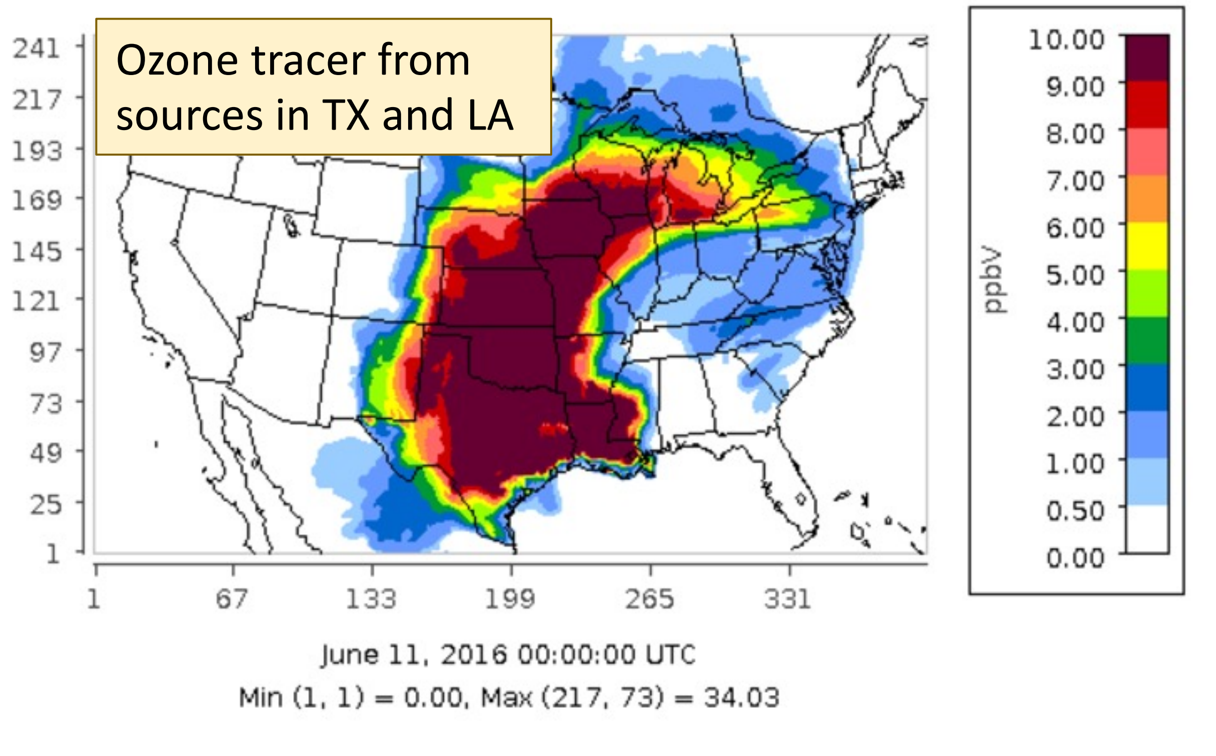
- Models are used to predict future year PM concentrations at Class I areas
- SMAT-CE
  - Calculates future year haze conditions using a visibility equation



- 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



Weight of Evidence

- All SIPs that use modeling 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)

Region 5 State Modeling Partners

- LADCO
  - Meteorology, emissions, and air quality modeling
  - Technical support documents
  - Data science and visualization
  - Technical support
- US EPA Region 5
  - Modeling protocol and SIP reviews
  - Feedback on policy applications of models
- US EPA OAQPS
  - Modeling tools and data
  - Application guidance
  - Modeling guidance and policy interpretation

Modeling Resources

- Examples of modeling in action
  - 2015 Ozone NAAQS Moderate Area attainment demonstrations
  - 2nd Regional Haze Implementation Period SIPs

- EPA Tools and Resources
  - Support Center for Regulatory Atmospheric Modeling (https://www.epa.gov/scram)
  - Modeling Guidance for Demonstrating Air Quality Goals … (Link)