Evaluation of 2005 Multi-Pollutant Platform: Ozone, Particulate Matter, Deposition & Air Toxics

US EPA's Office of Air Quality Planning and Standards

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HARMO13 Conference – Paris, France
June 3, 2010

What is a “Modeling Platform”?

- Structured system of connected modeling-related tools and data that provide a consistent and transparent basis for assessing the air quality response to changes in emissions and/or meteorology

- Ultimate goal is a single, “harmonized” platform for modeling criteria pollutants (e.g., ozone and PM) and hazardous air pollutants (HAPs) as well as deposition and visibility

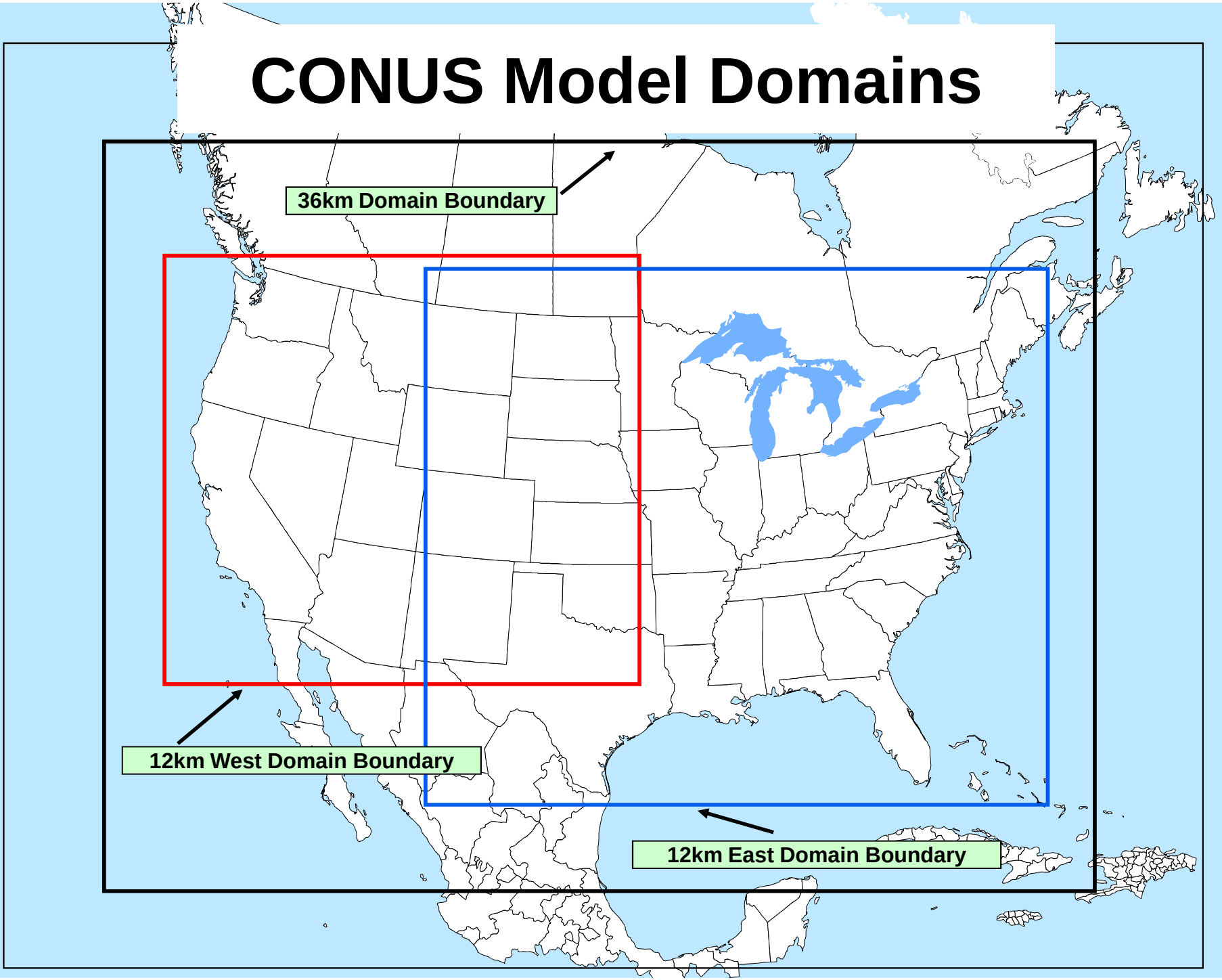
Components of 2005 MP Modeling Platform

- 2005 National Emissions Inventory (NEI) v4
  - Criteria (CAPs) and HAPs
- 2005 Meteorological Data
  - MM-5 v3.7.4 and MCIP v3.4
  - 36km US, 12 km EUS, 12km WUS
- Emissions Models, Tools and Ancillary Data
  - Emissions Modeling Framework (EMF)
  - Emissions processing: SMOKE version 2.3.2
  - Biogenics: BEIS 3.14
  - Onroad/nonroad emissions: NMIM (w/ draft MOVES & NONROAD2005)
  - Ancillary data: speciation, temporal, spatial allocation
- Boundary Condition Concentrations
  - 2005 simulations of GEOS-Chem: 2° x 2° grids & 30 layers up to stratosphere
  - 36-km US domain for CAPS, mercury, and some HAPS (e.g. formaldehyde)
  - For toxics not simulated by GEOS-Chem we used concs based on remote measurements and literature values (joint effort b/n AQAG & ORD)
- Air Quality Model
  - CMAQ v4.7 multi-pollutant version - (http://www.cmascenter.org)
  - CB-05 chemical mechanism with mercury and chlorine chemistry
  - Ozone, PM, S & N deposition, and additional 38 HAPs

Why a Modeling Platform?

- Promotes multi-pollutant assessments
  - Integrated inventory (criteria and air toxics)
- Provides consistency, transparency, and efficient development of modeling baselines for:
  - EPA regulatory assessments (e.g., Renewable Fuel Std Rule)
    - http://www.epa.gov/ttn/scram/reportsindex.htm
  - CMAQ evaluations & research efforts by ORD
  - Accountability efforts across EPA
  - Public health & exposure assessments
- Provides data and examples for Regional, State, local agencies and public
  - For example, emissions inventory data: http://www.epa.gov/ttn/chief/emch/index.html#2005

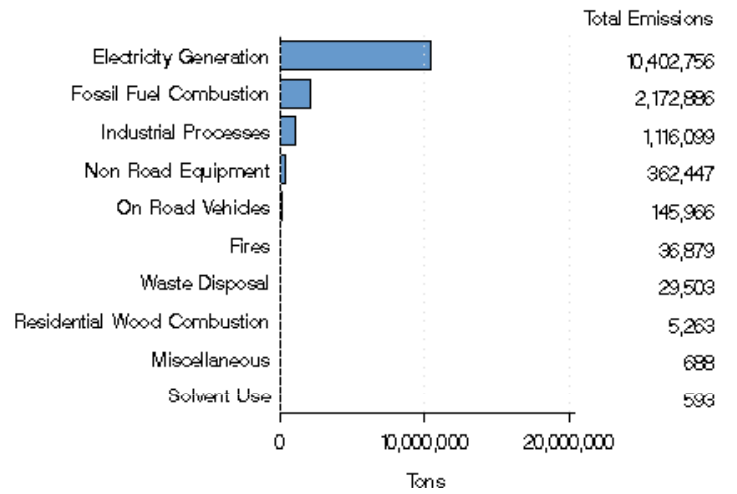
CONUS Model Domains



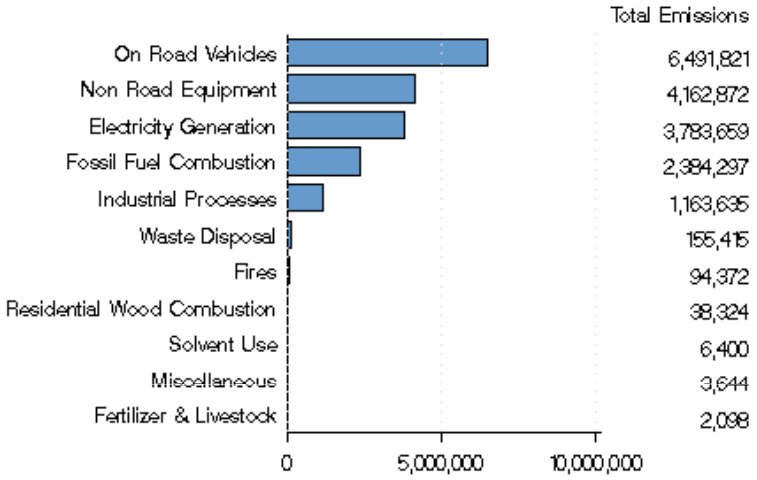
2005 US Emissions Summary:

Selected Criteria Pollutants

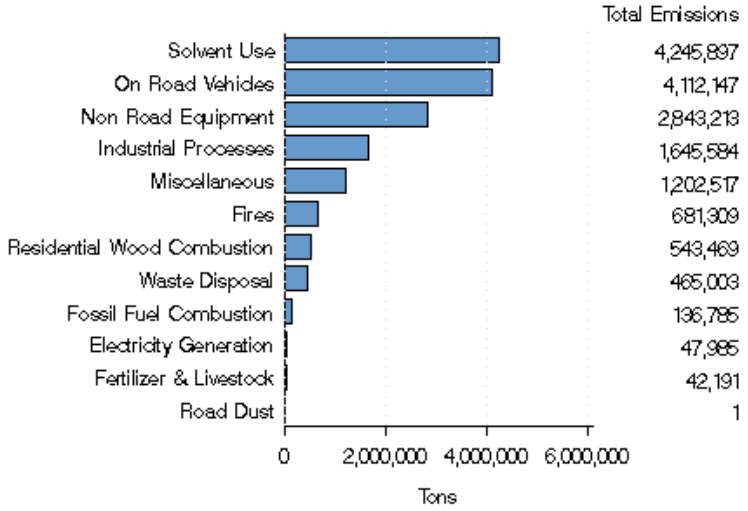
National Sulfur Dioxide Emissions by Source Sector
in 2005



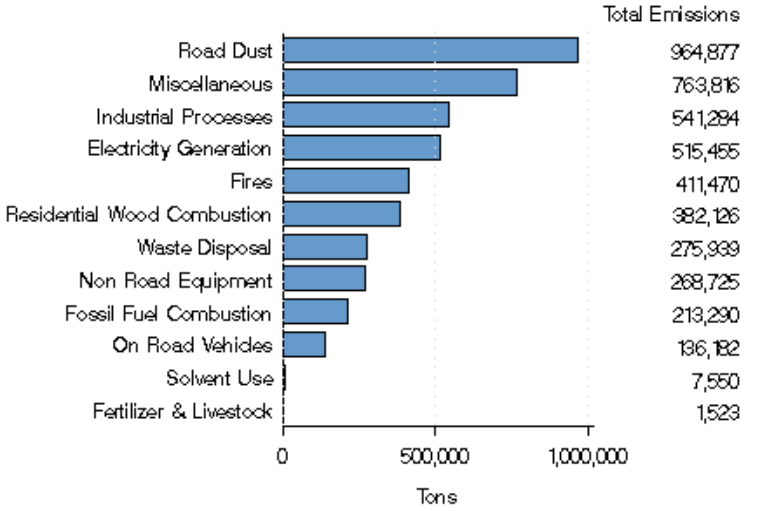
National Nitrogen Oxides Emissions by Source Sector
in 2005



National Volatile Organic Compounds Emissions by Source Sector
in 2005

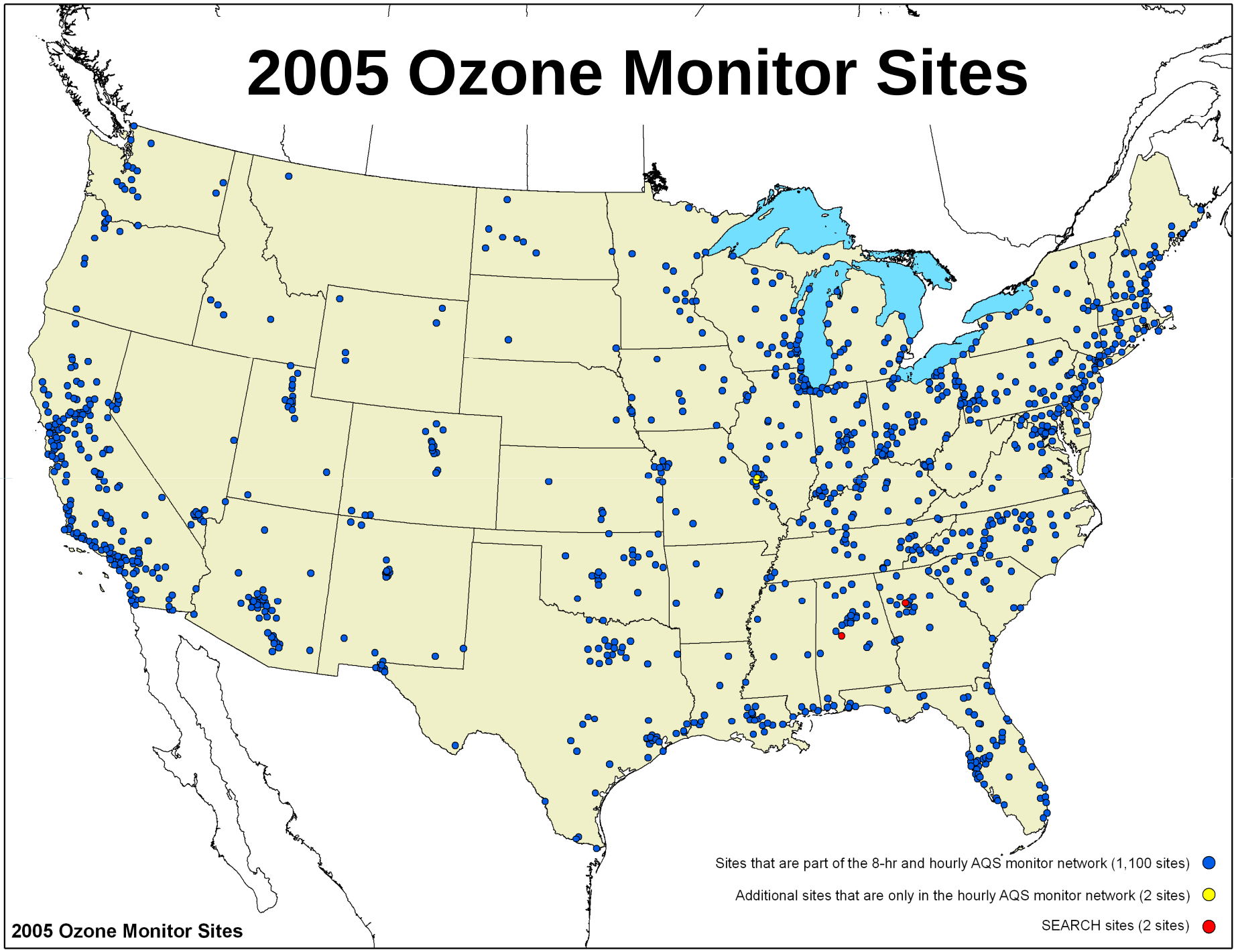


National PM2.5 Emissions by Source Sector
in 2005

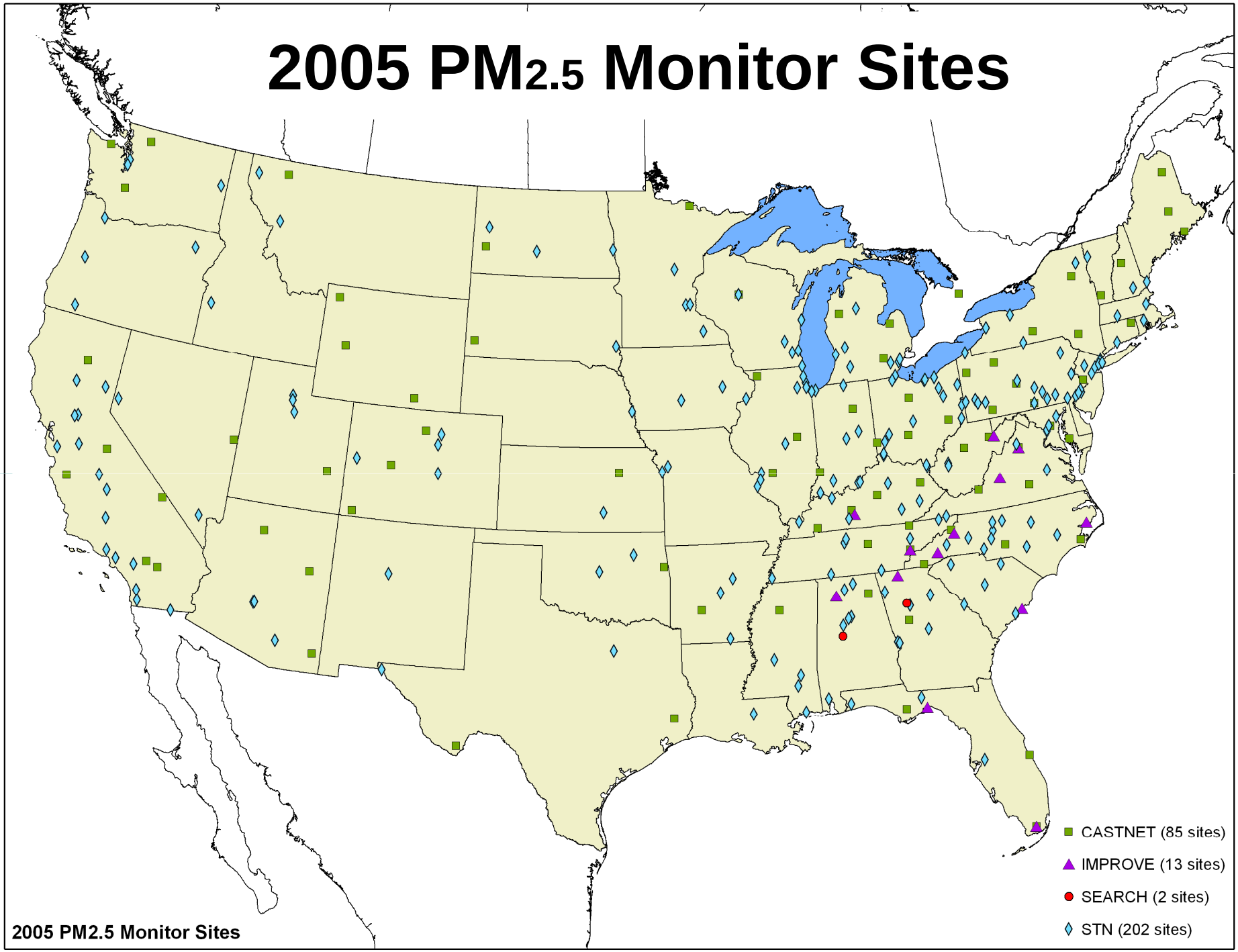


US Ambient Monitoring Networks

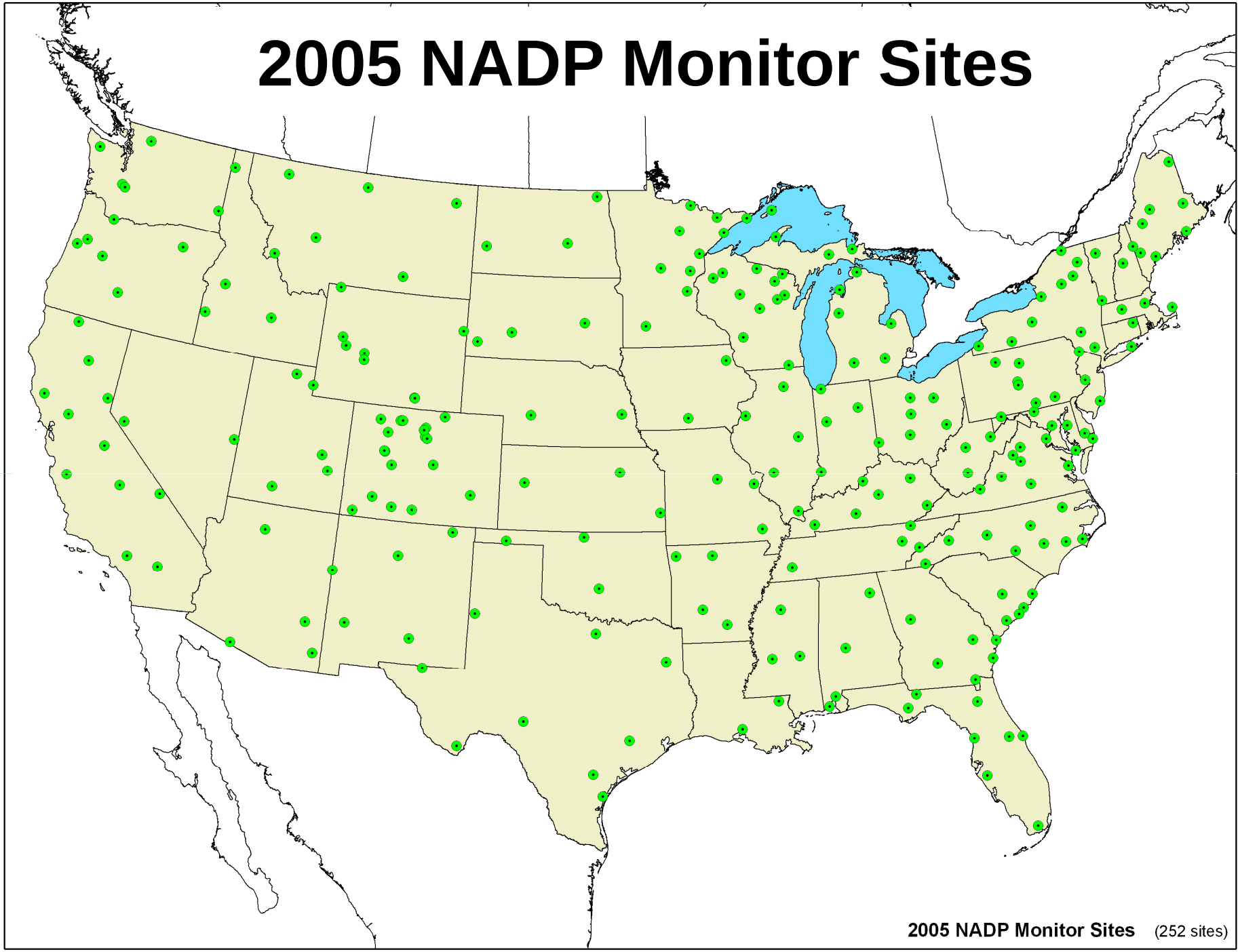
- **A**ir **Q**uality **S**ystem (AQS); http://www.epa.gov/ttn/airs/airsaqs/index.htm
- **C**lean **A**ir **S**tatus and **T**rends **Net**work (CASTNet); http://www.epa.gov/castnet/
- **S**peciation **T**rend **N**etwork (STN); **C**hemical **S**peciation **N**etwork; http://www.epa.gov/aqspubl1/select.html
- **I**nteragency **M**onitoring of **PRO**tected **V**isual **E**nvironments (IMPROVE); http://vista.cira.colostate.edu/improve/
- **S**outh **E**astern **A**erosol **R**esearch and **Ch**aracterization (SEARCH); http://www.atmospheric-research.com/studies/SEARCH/index.html
- **N**ational **A**cid **D**eposition **P**rogram (NADP); http://nadp.sws.uiuc.edu/
- **M**ercury **D**eposition **N**etwork (MDN); http://nadp.sws.uiuc.edu/mdn/
- **N**ational **A**ir **T**oxics **T**rends **S**tations (NATTS); http://www.epa.gov/ttnamti1/airtox.html


2005 Ozone Monitor Sites
Sites that are part of the 8-hr and hourly AQS monitor network (1,100 sites)
Additional sites that are only in the hourly AQS monitor network (2 sites)
SEARCH sites (2 sites)
2005 Ozone Monitor Sites

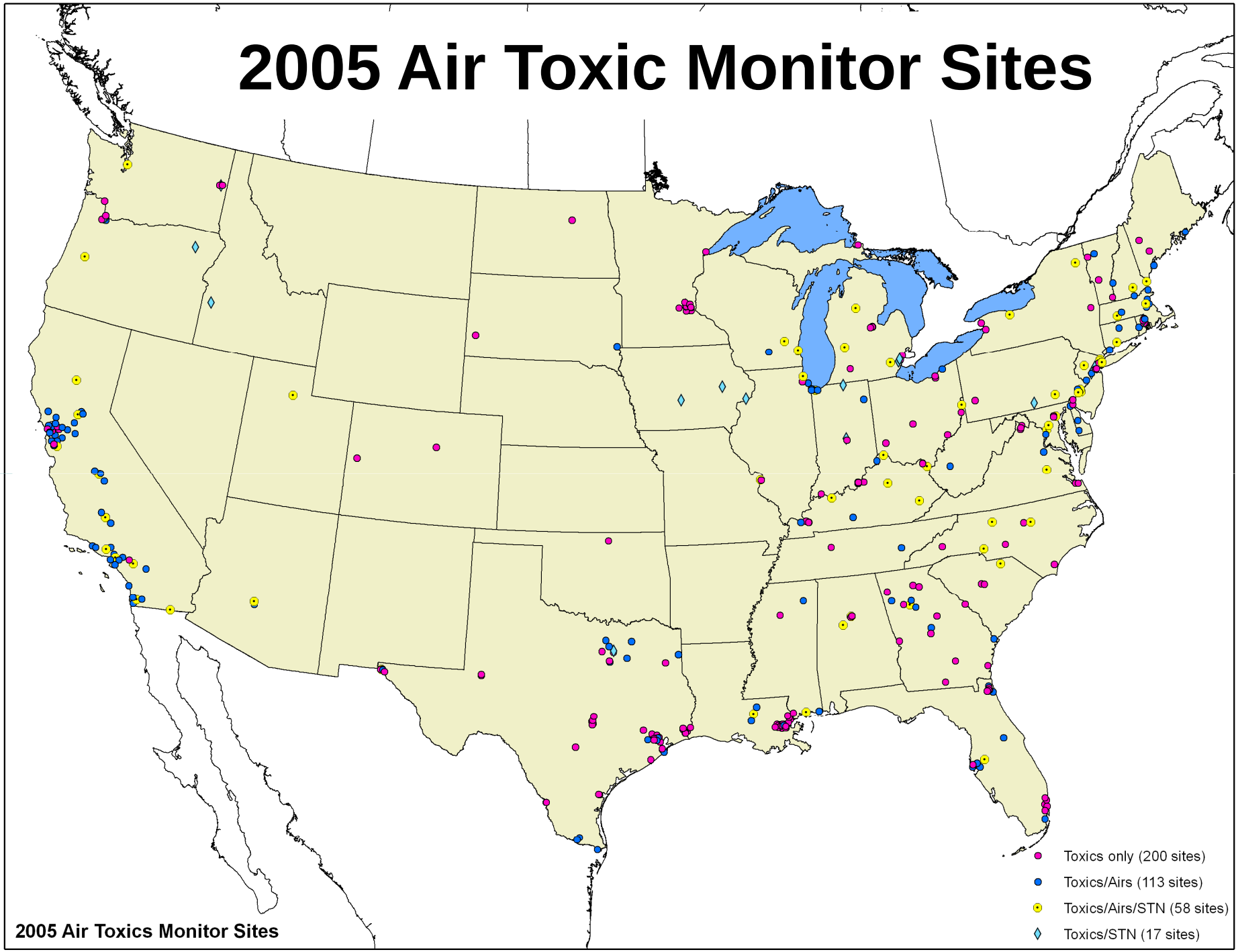
2005 $PM_{2.5}$ Monitor Sites



2005 NADP Monitor Sites



2005 Air Toxic Monitor Sites



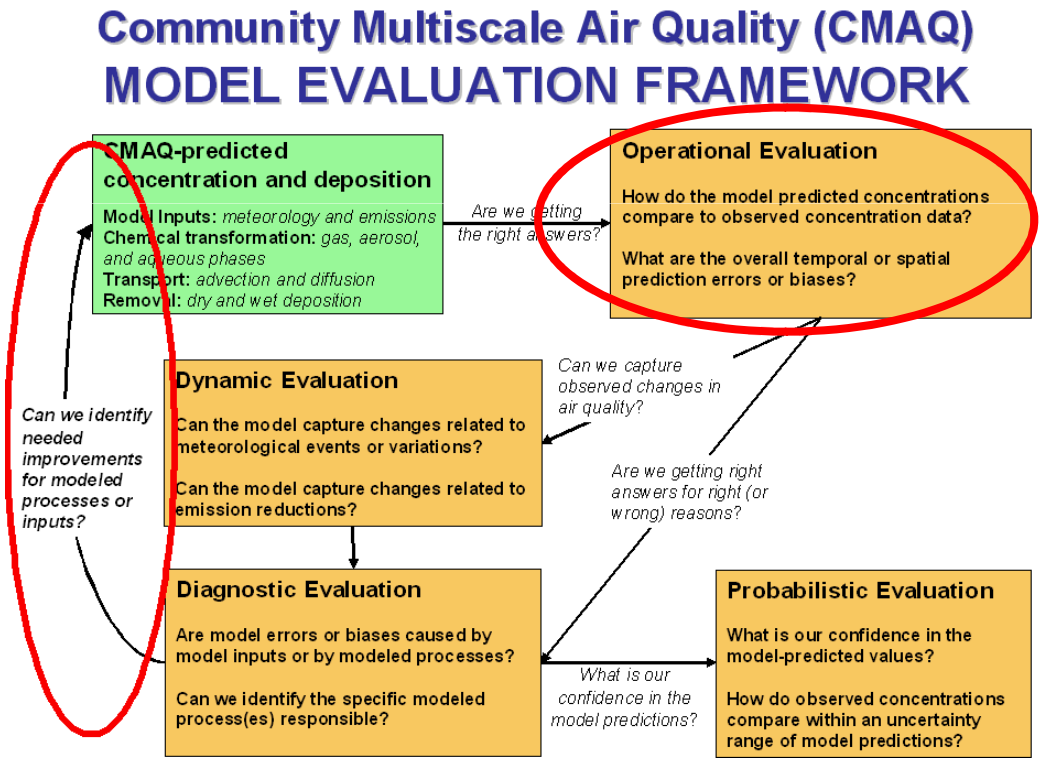
Model Performance Analysis

- Ozone: 1 hr-max & 8 hr-max
  - AQS, SEARCH
- $PM_{2.5}$ Species: SO_4, NO_3, TNO_3, OC, EC, SO_2
  - STN, CASTNet, IMPROVE, NADP
- HAPs: Formaldehyde, Acetaldehyde, Benzene, etc., + metals
  - MDN, NATTS, STN, IMPROVE

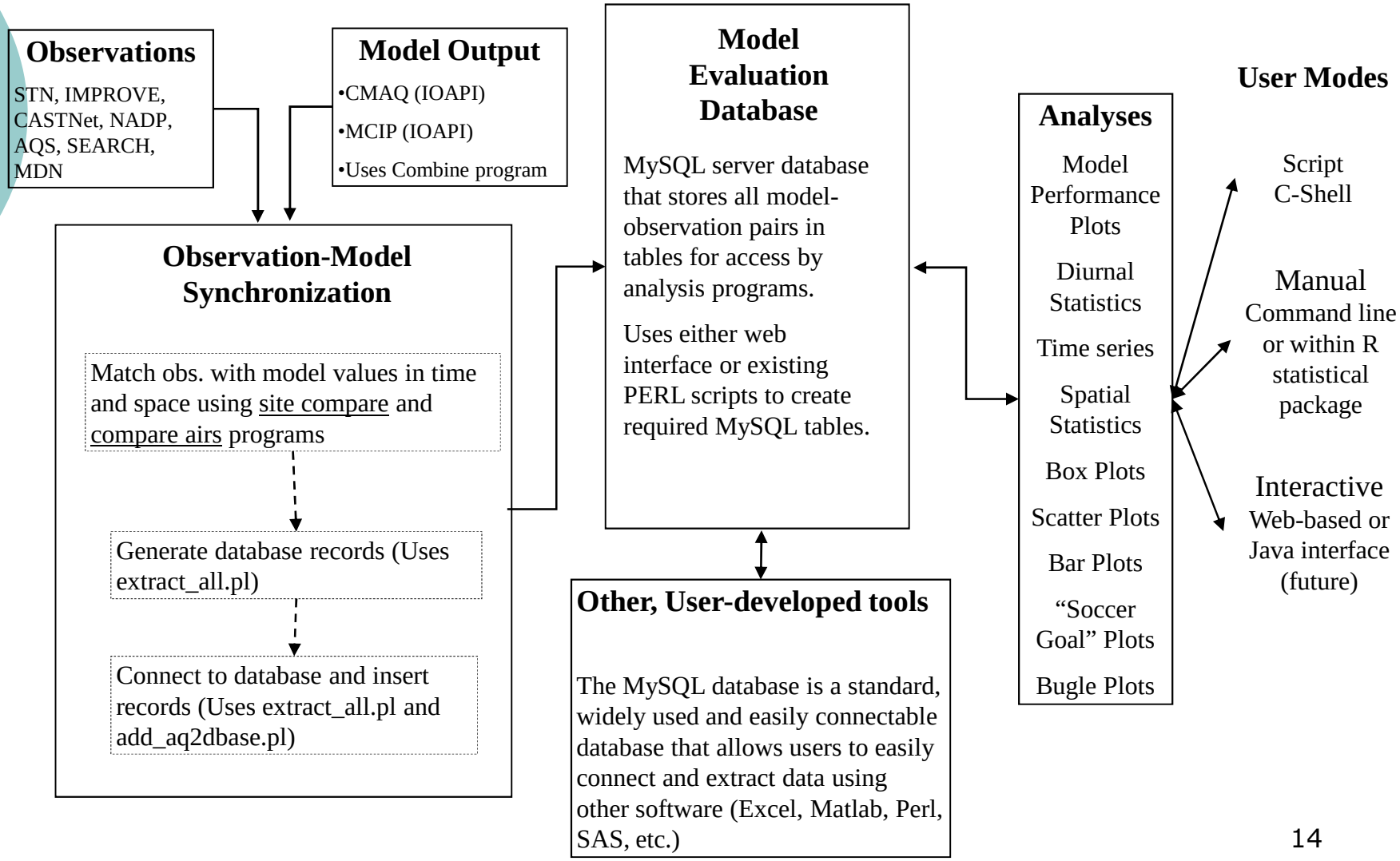
- Atmospheric Model Evaluation Tool (AMET)
  - Hourly, daily, monthly, seasonal & annual comparisons
  - Spatial tile maps comparing observed and predicted species concentrations/deposition
  - Scatter plots of observations vs predictions
  - Time-series plots of observations vs predictions
  - Statistics:
    - Normalized Mean Bias (NMB) / Fractional Bias (FB)
    - Normalized Mean Error (NME) / Fractional Error (FE)
    - Root Mean Square Error (RMSE)

What is AMET?

- **A**tmospheric **M**odel **E**valuation **T**ool v1.1 (www.cmascenter.org)
- Two modules
  - Meteorology
  - Air Quality
- AMET-AQ specifically designed to compare observations with CMAQ model predictions



AMET-AQ Flow Chart

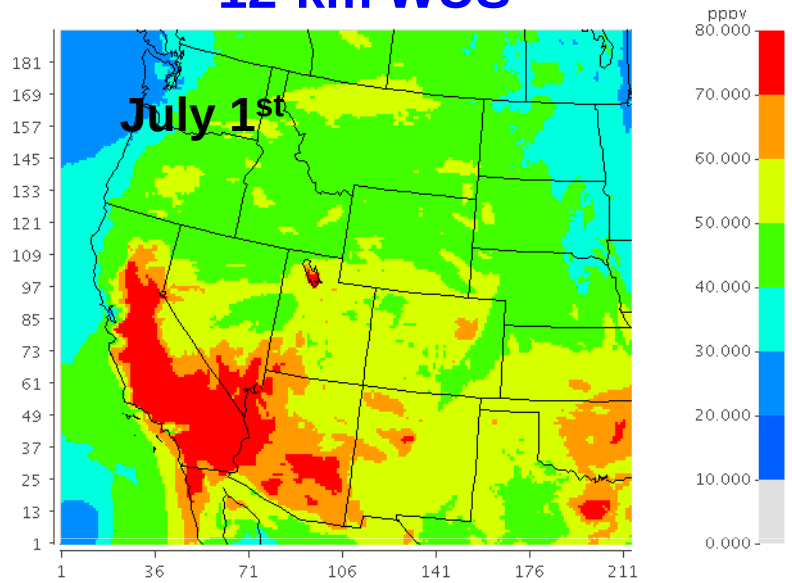


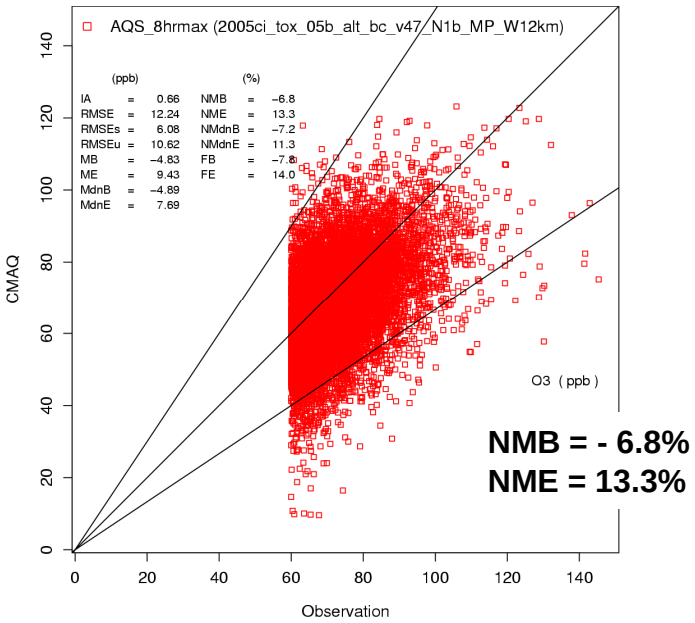
Highlights of 2005 Model Evaluation for Criteria Air Pollutants

- Ozone
  - Under predicted (~ 5 to 10%) for 1-hr & 8-hr daily max. for O_3 > 60 ppb
- Sulfate PM
  - Under predicted (~ up to 30%) during all seasons in the EUS & WUS
- Sulfur Dioxide
  - Over predicted (~ 5 to 75%) in all seasons in the EUS & WUS
- Nitrate PM
  - In the Winter, under predicted (~ 5 to 40%) at urban sites in the EUS & WUS as well as rural sites in the WUS; over predicted (~ 2 to 45%) at rural sites in the EUS
  - Overall, nitrate PM and total nitrate is over-predicted in EUS and under-predicted in the WUS
- Organic PM
  - Moderately under-predicted at urban and rural sites in the EUS & WUS
  - Largest under-predictions occur during the summer season
- Elemental Carbon
  - In general, over-predicted at urban sites and under-predicted at rural sites in the EUS and WUS

2005 8-hr max. Ozone (May-September)

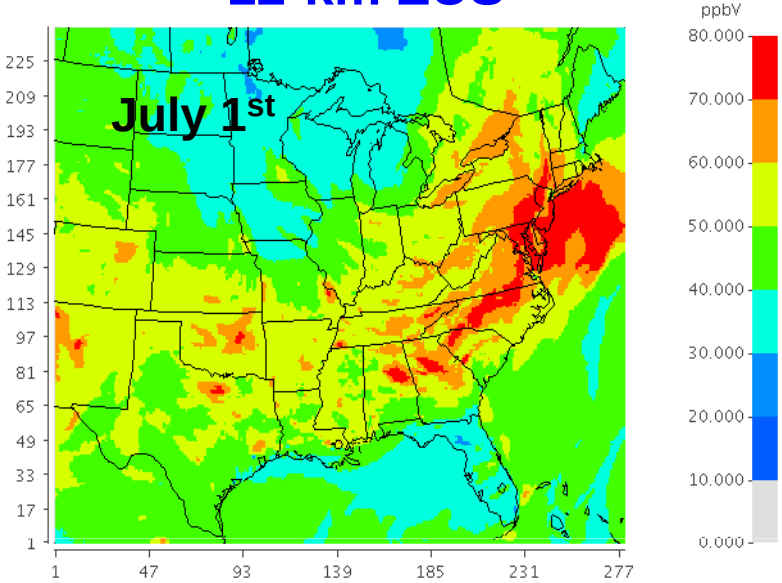
12-km WUS

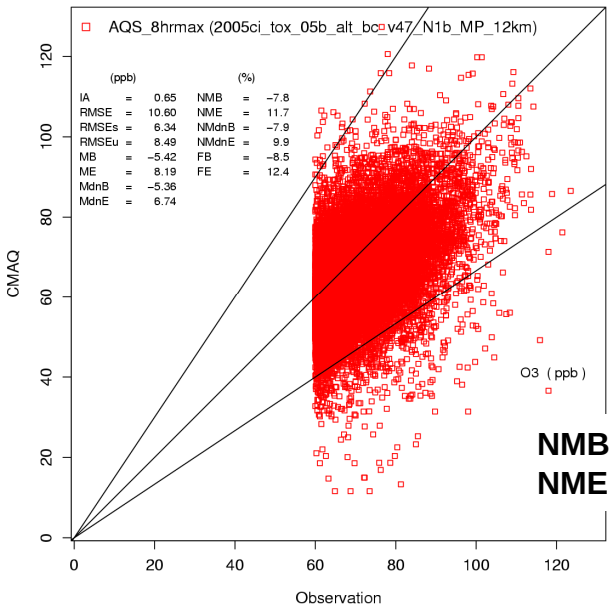




NMB = - 6.8%
NME = 13.3%

12-km EUS

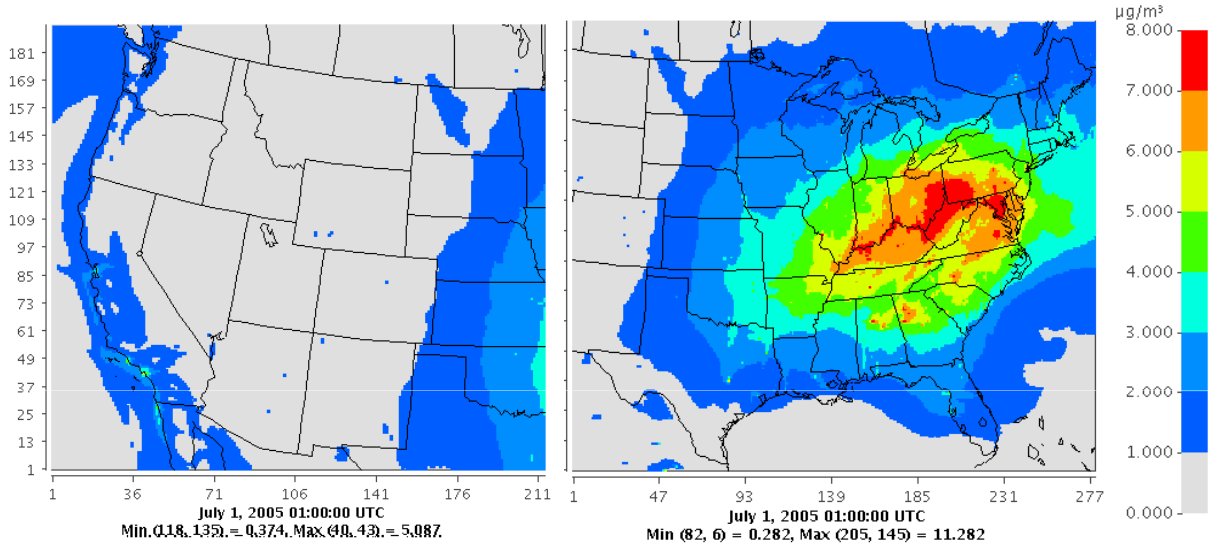




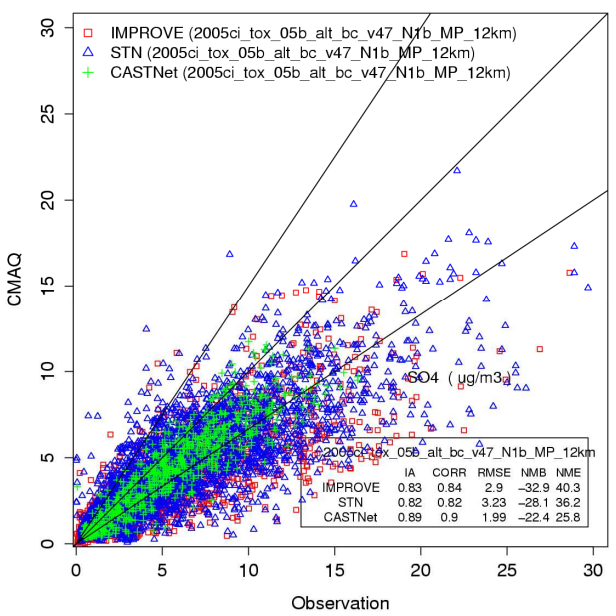
NMB = -7.8%
NME = 11.7%

Applying a threshold of 60ppb

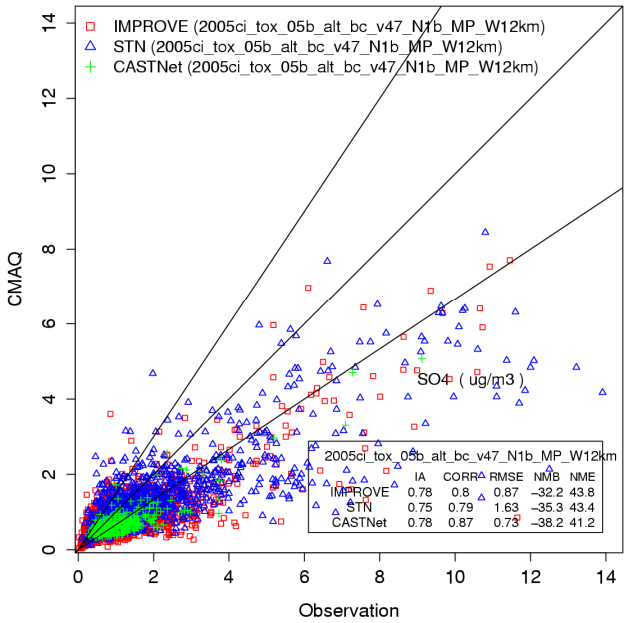
2005 Summer Sulfate PM (June-July-August)



12-km EUS

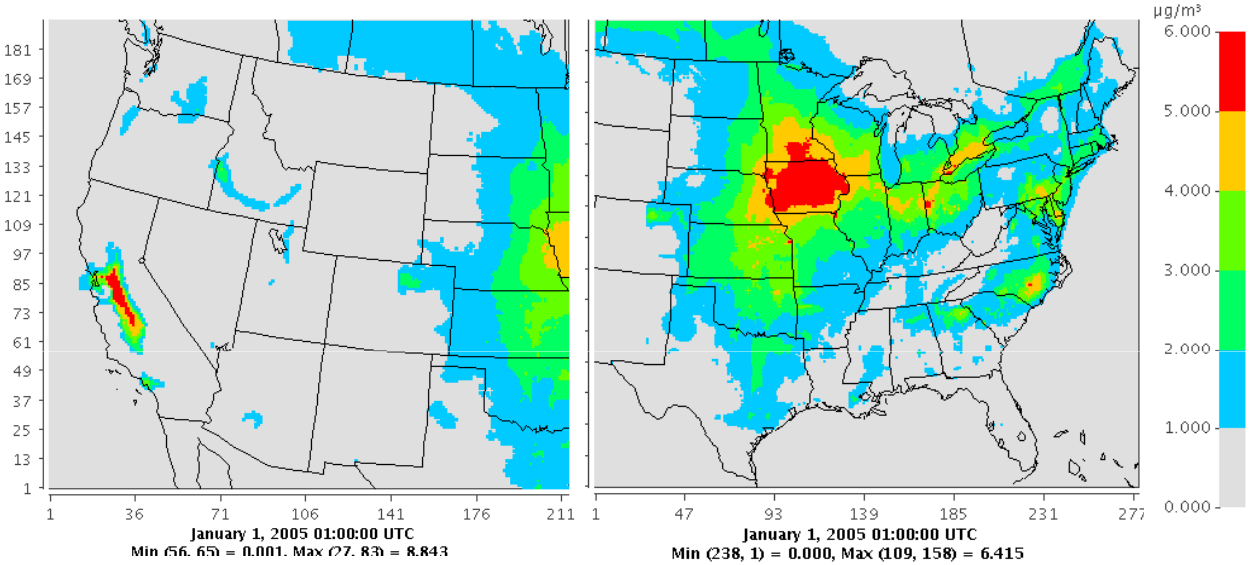


12-km WUS

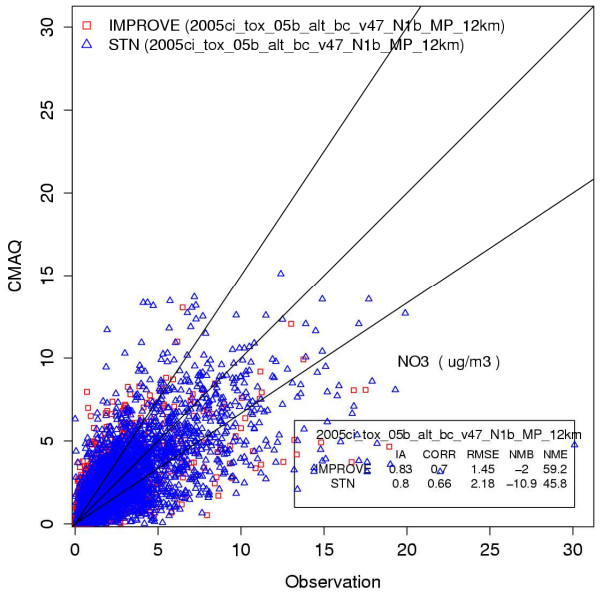


	12-km EUS		12-km WUS	
	NMB (%)	NME (%)	NMB (%)	NME (%)
IMPROVE	-32.9	40.3	-32.2	43.8
STN	-28.1	36.2	-35.3	43.4
CASTNet	-22.4	25.8	-38.2	41.2

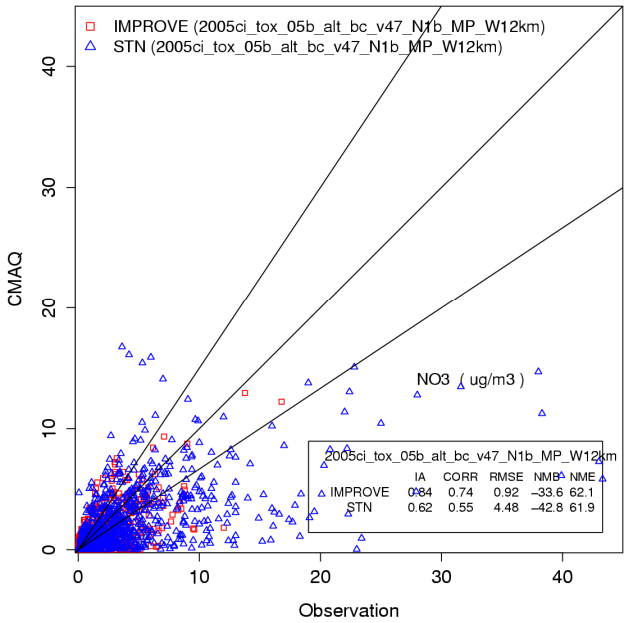
2005 Winter Nitrate PM (January-February-March)



12-km EUS

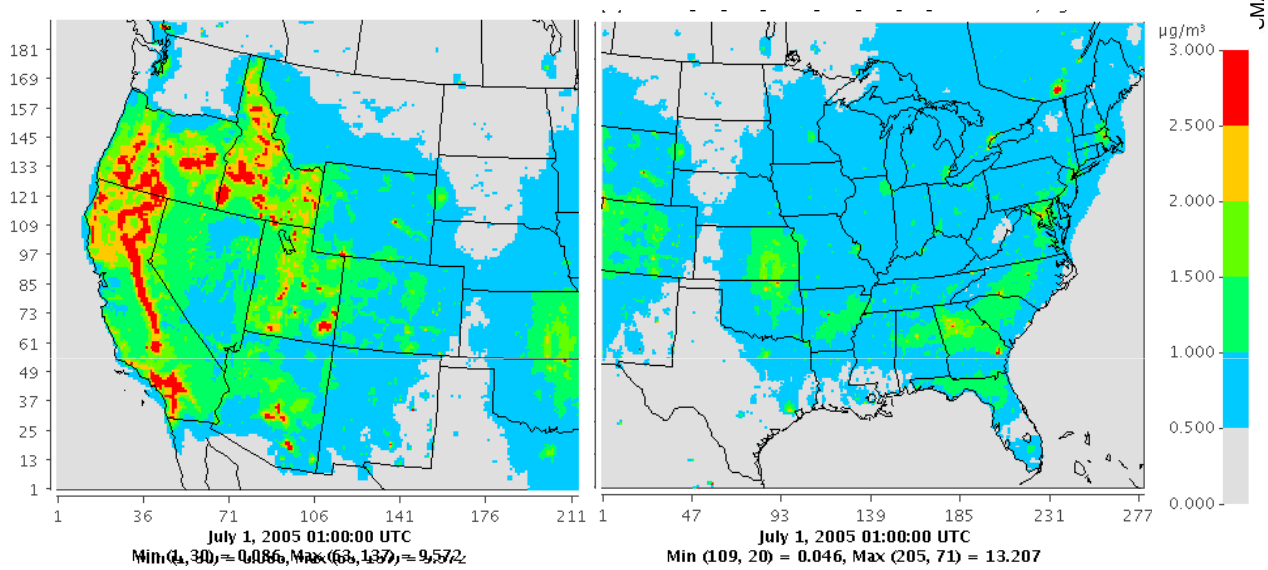


12-km WUS

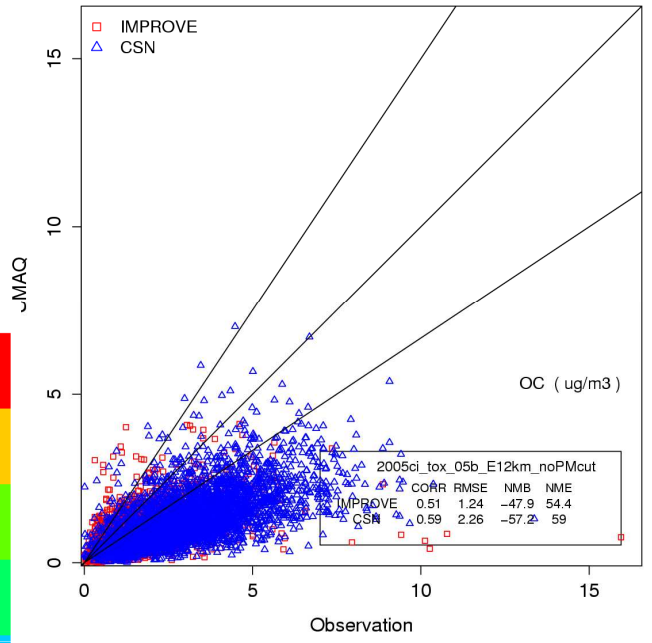


	12-km EUS		12-km WUS	
	NMB (%)	NME (%)	NMB (%)	NME (%)
IMPROVE	-2.0	59.2	-33.6	62.1
STN	-10.9	45.8	-42.6	61.9
CASTNet (TNO_3)	10.5	27.9	13.2	40.4

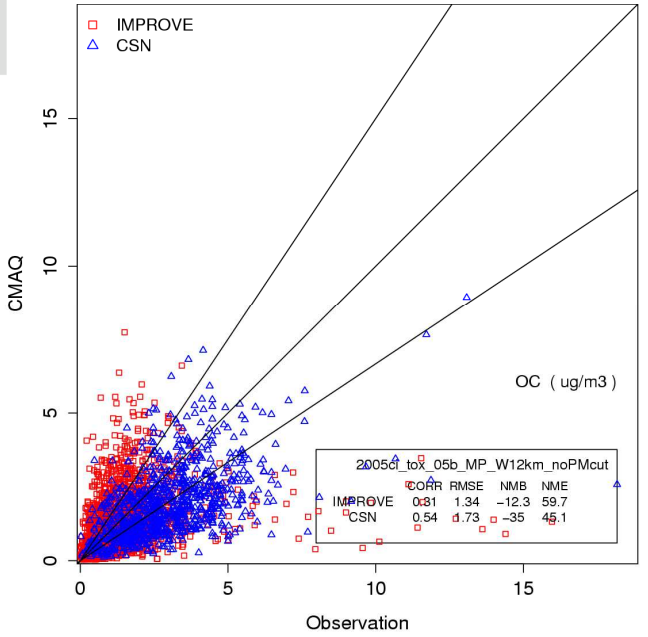
2005 Summer Organic Carbon (June-July-August)



12-km EUS

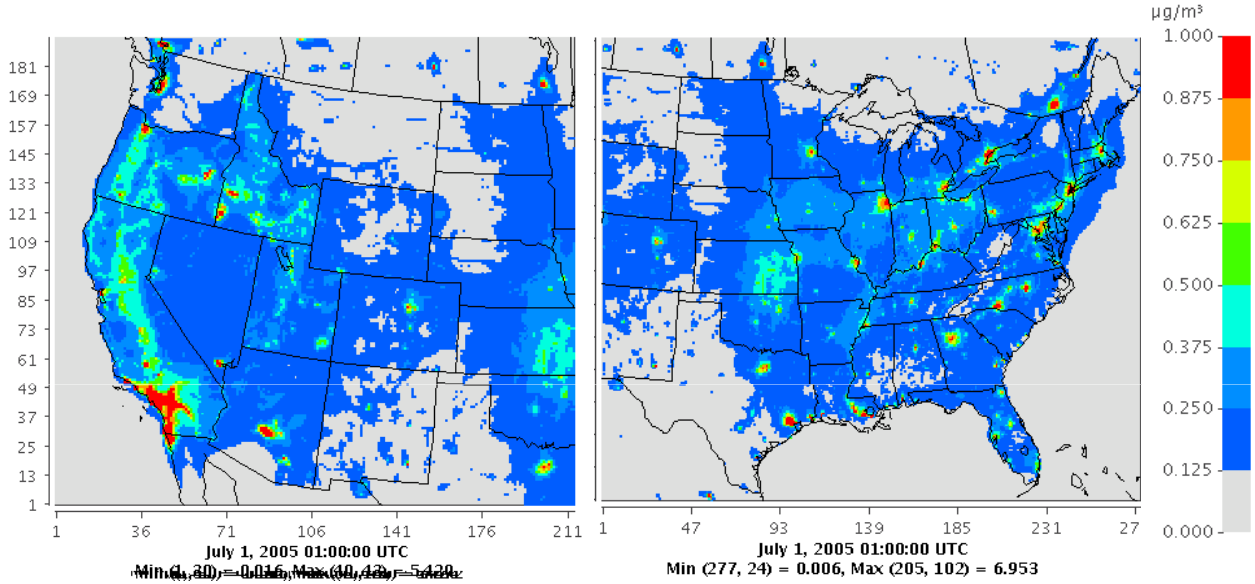


12-km WUS

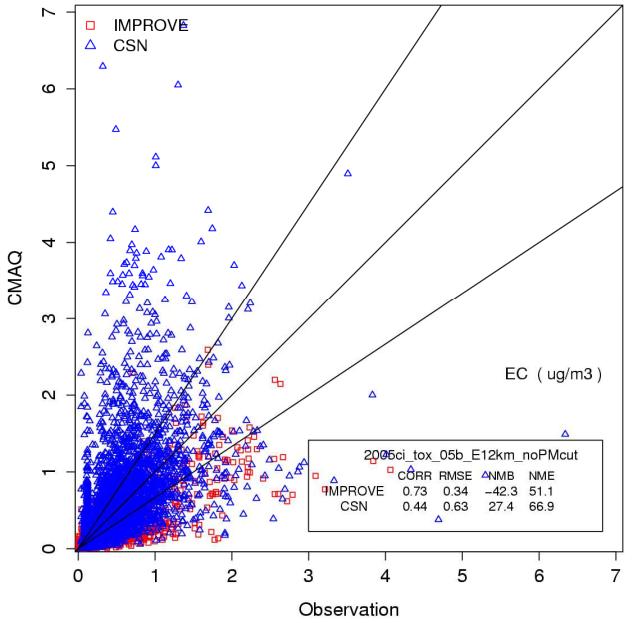


	12-km EUS		12-km WUS	
	NMB (%)	NME (%)	NMB (%)	NME (%)
IMPROVE	-47.9	54.4	-12.3	59.7
STN	-57.2	59.0	-35.0	45.1

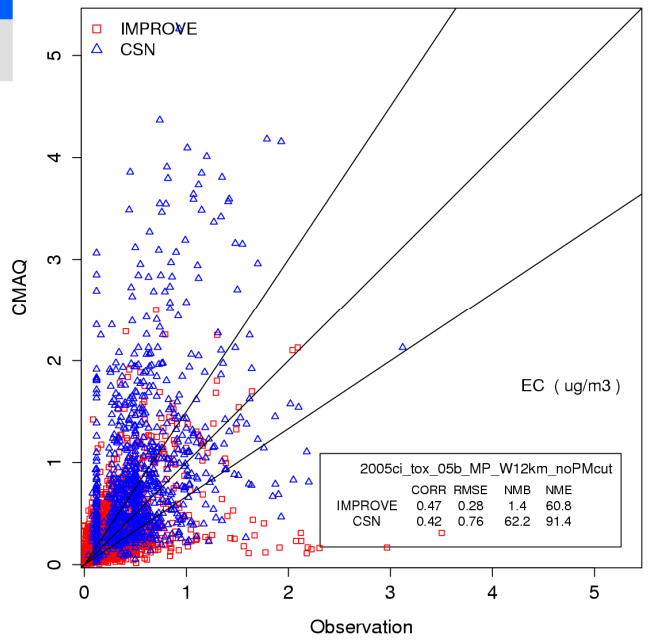
2005 Summer Elemental Carbon (June-July-August)



12-km EUS



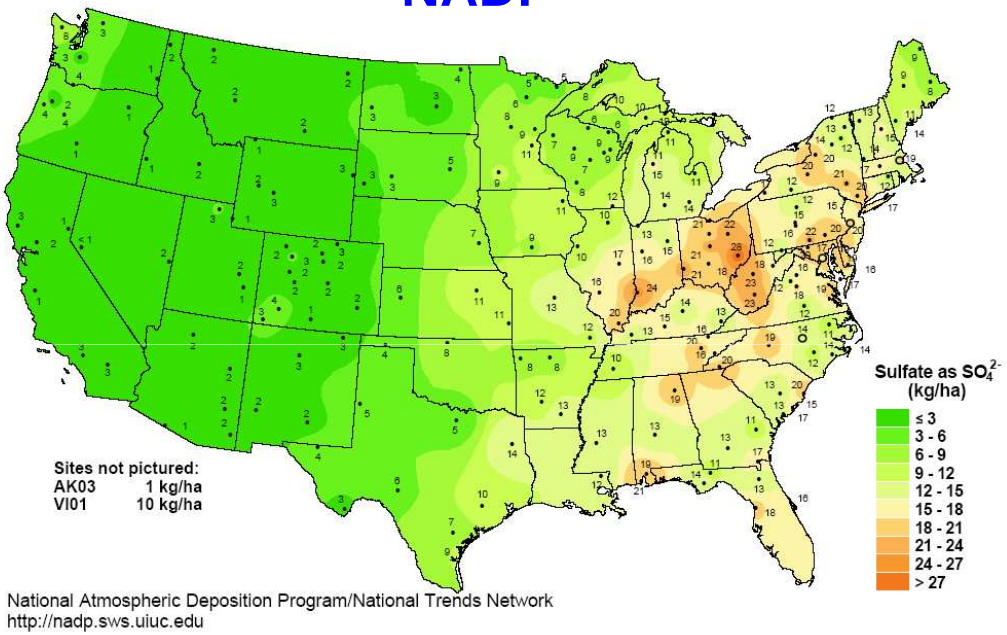
12-km WUS



	12-km EUS		12-km WUS	
	NMB (%)	NME (%)	NMB (%)	NME (%)
IMPROVE	-42.3	51.1	1.4	60.8
STN	27.4	66.9	62.2	91.4

SO_4 Wet Deposition
2005 Total

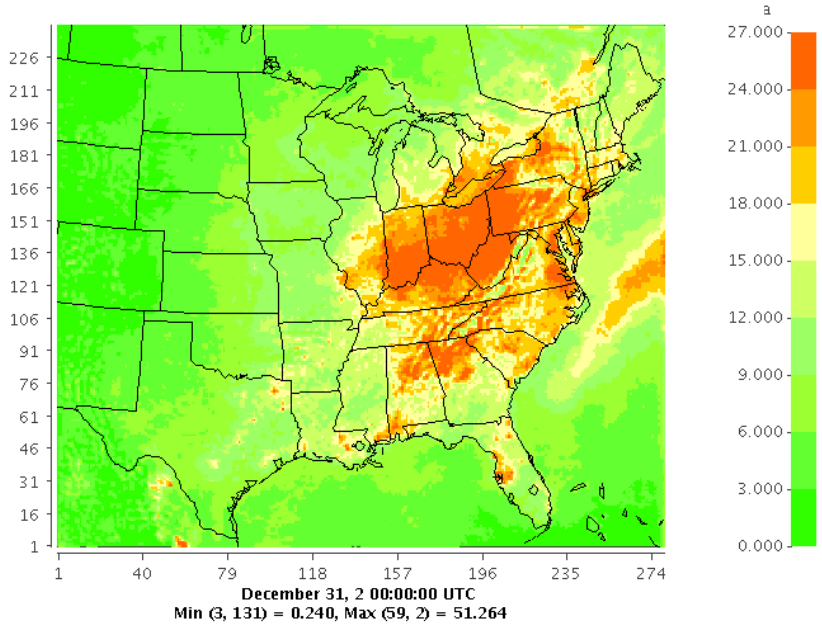
NADP



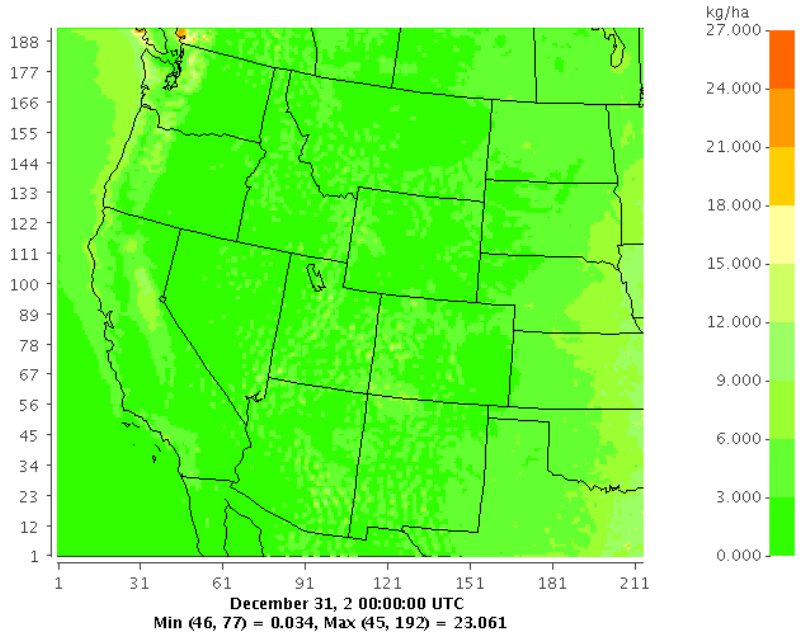
National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu

Summer Mean		
	NMB (%)	NME (%)
EUS	2.3	73.4
WUS	-5.5	73.9

12-km EUS

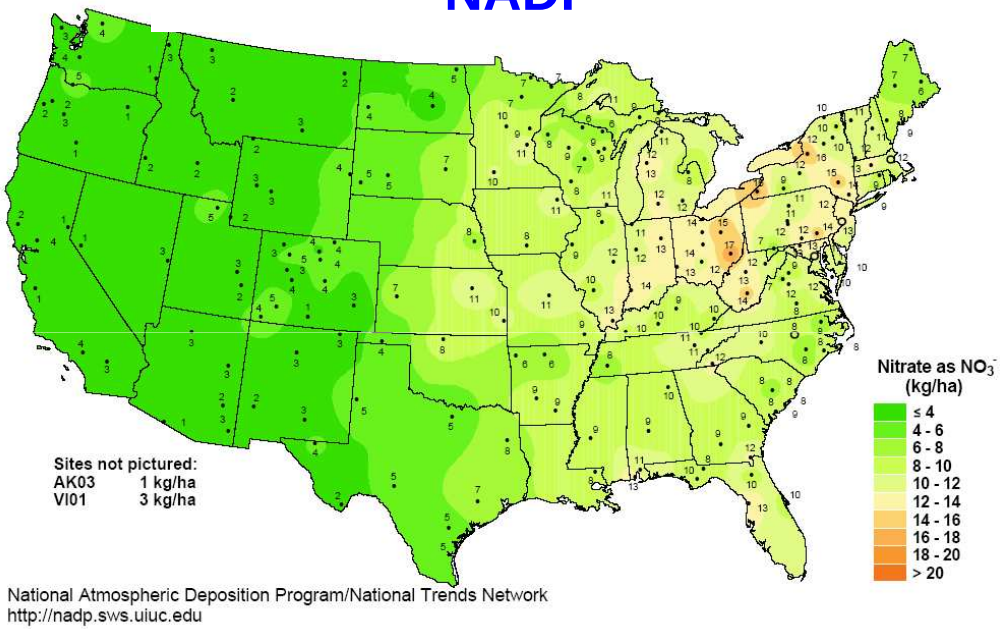


12-km WUS



NO_3 Wet Deposition
2005 Total

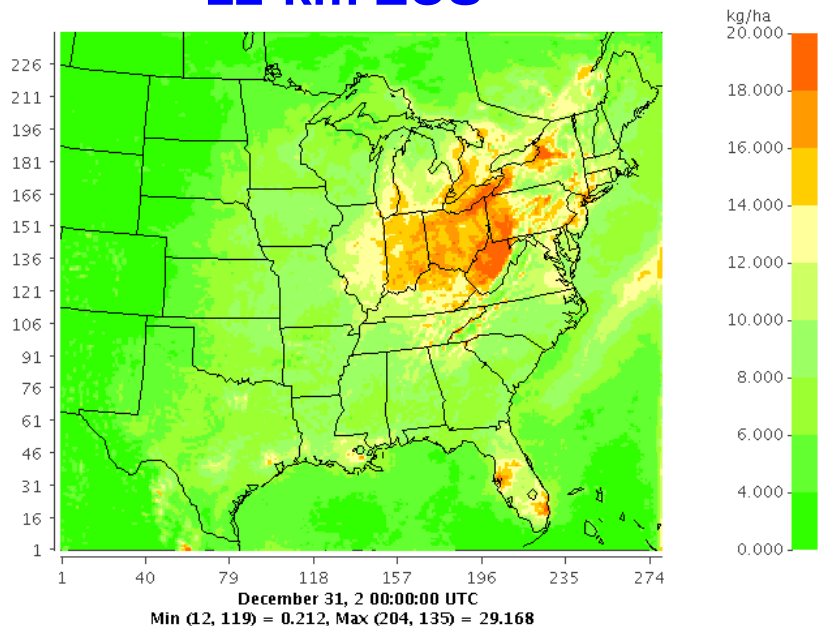
NADP



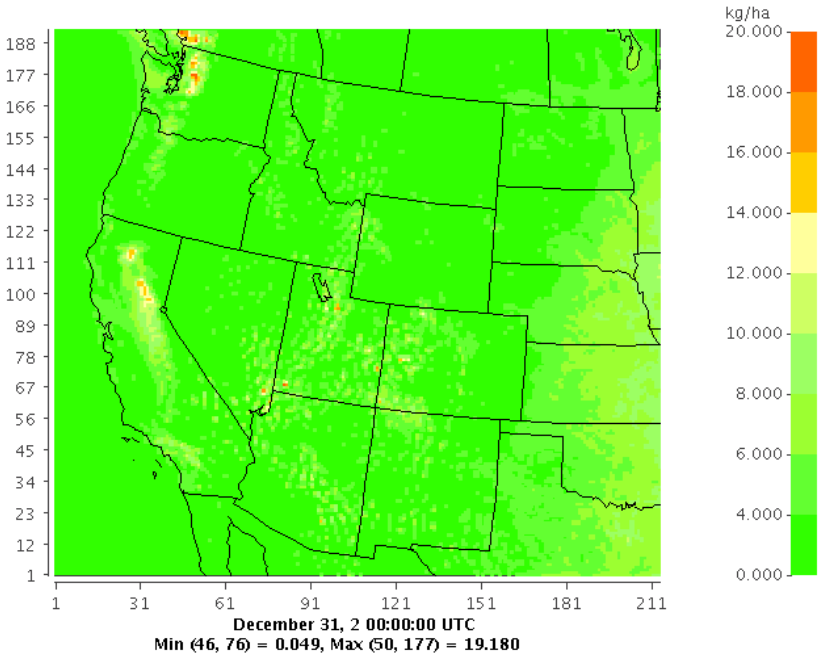
National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu

Winter Mean		
	NMB (%)	NME (%)
EUS	23.5	70.1
WUS	-0.9	79.3

12-km EUS



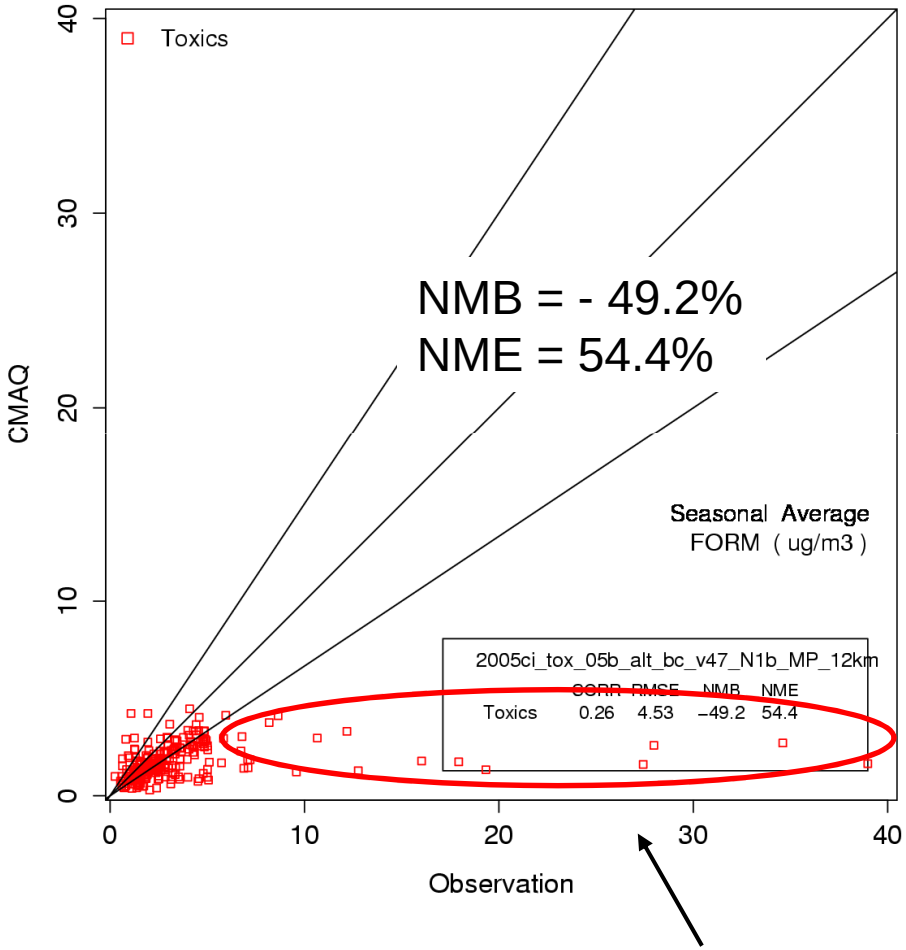
12-km WUS



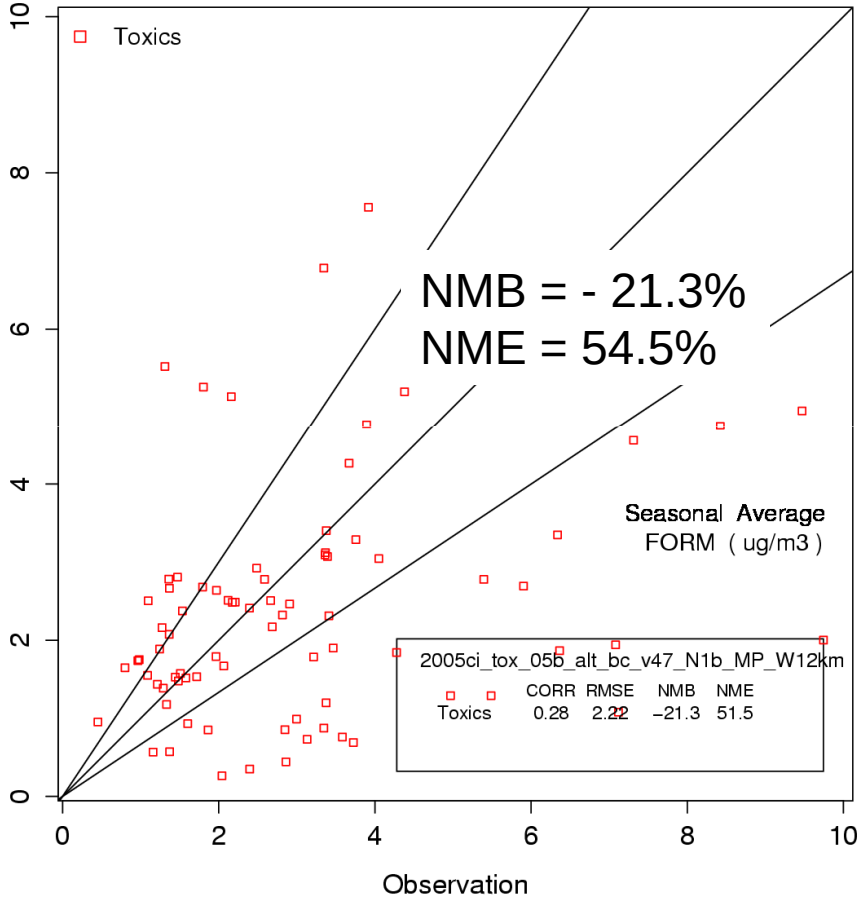
2005 Formaldehyde

Seasonal Means

12-km EUS



12-km WUS

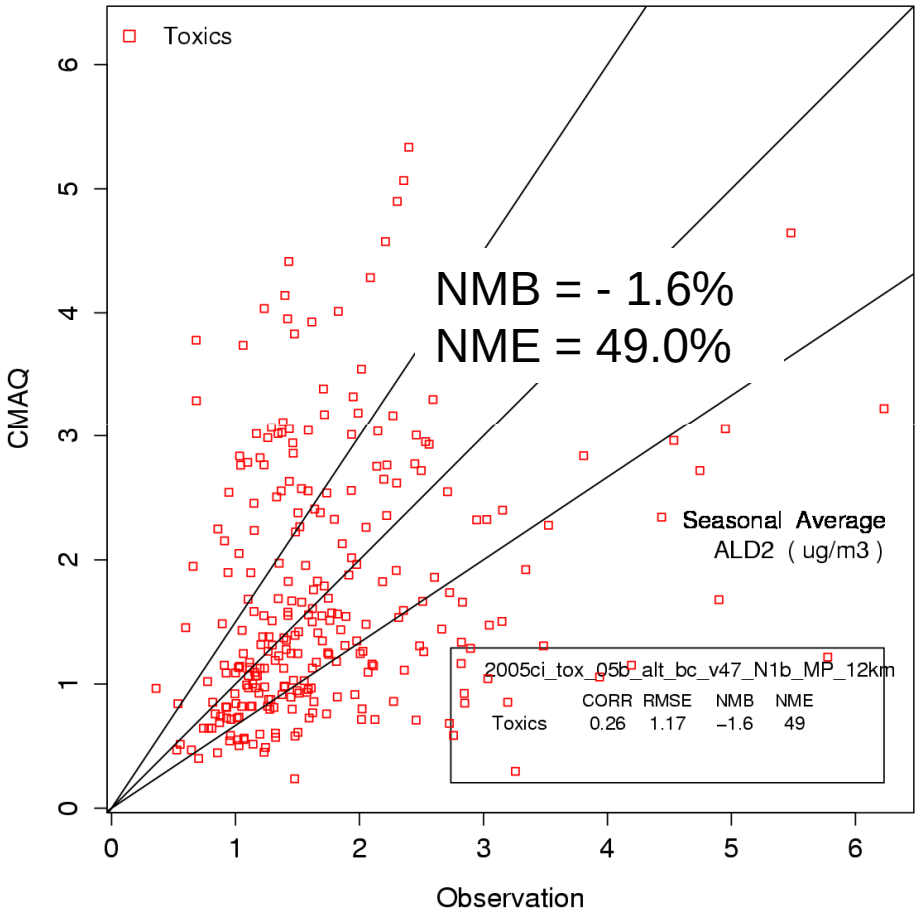


High observations – possibly due to short-term releases, near-source monitors, or instrument issues

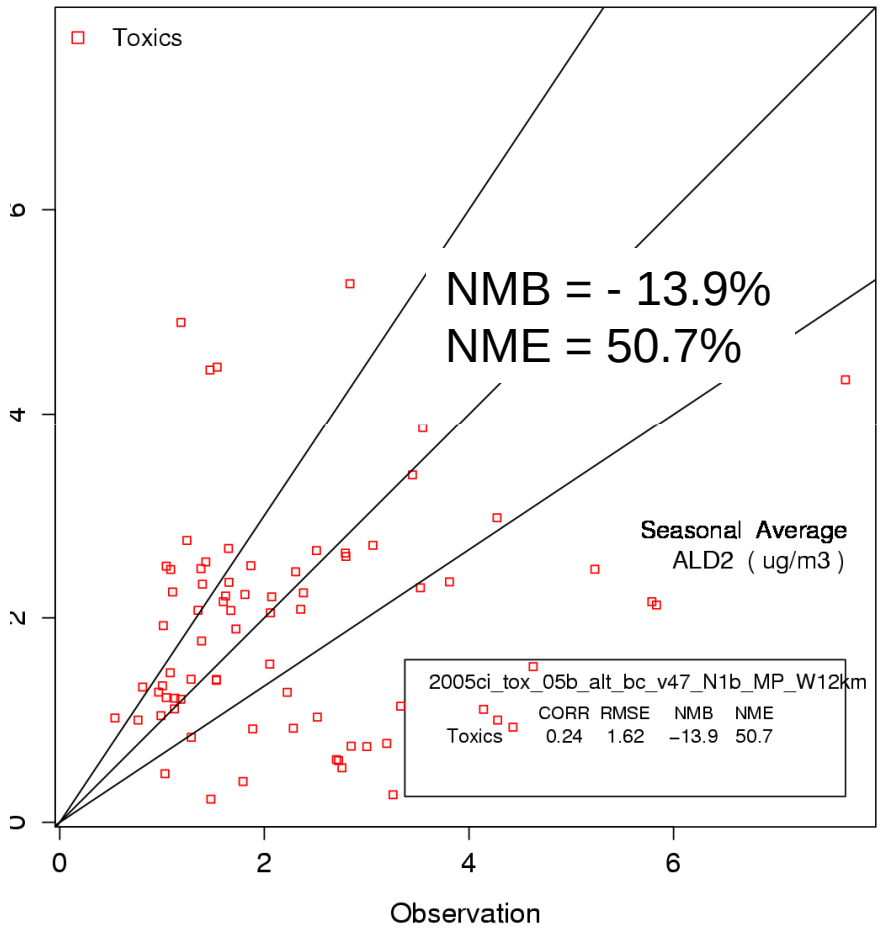
2005 Acetaldehyde

Seasonal Means

12-km EUS



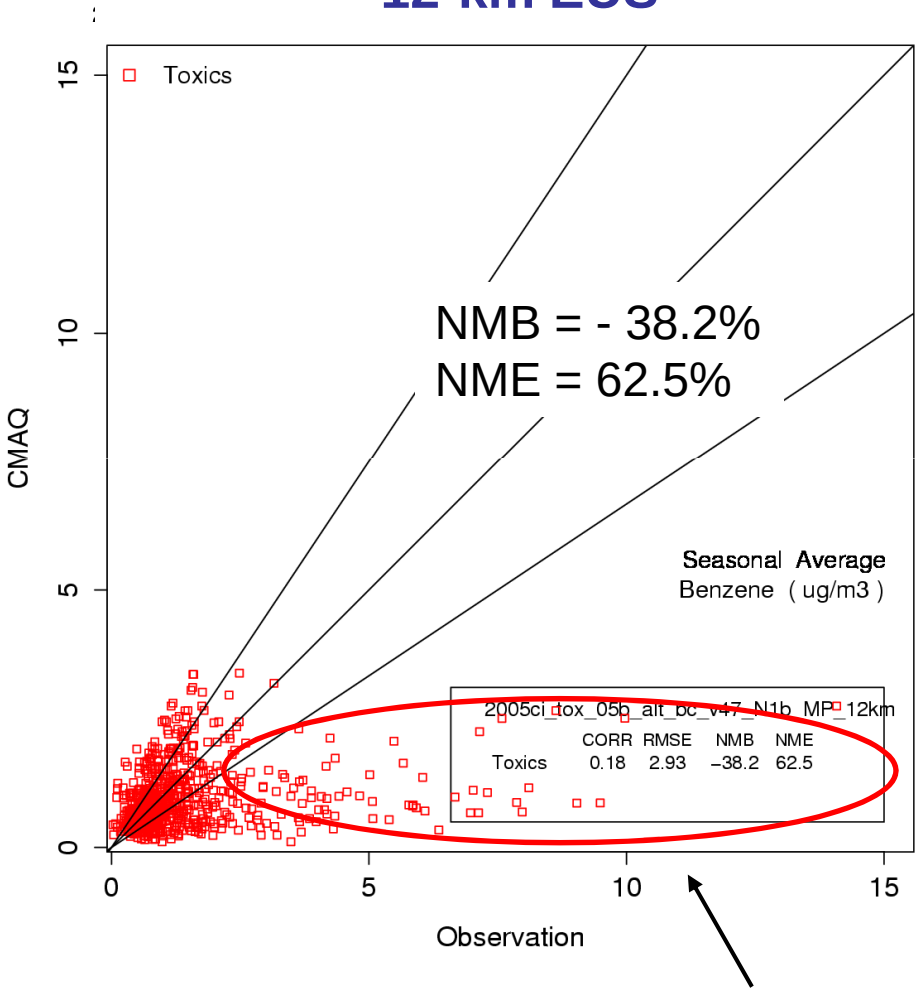
12-km WUS



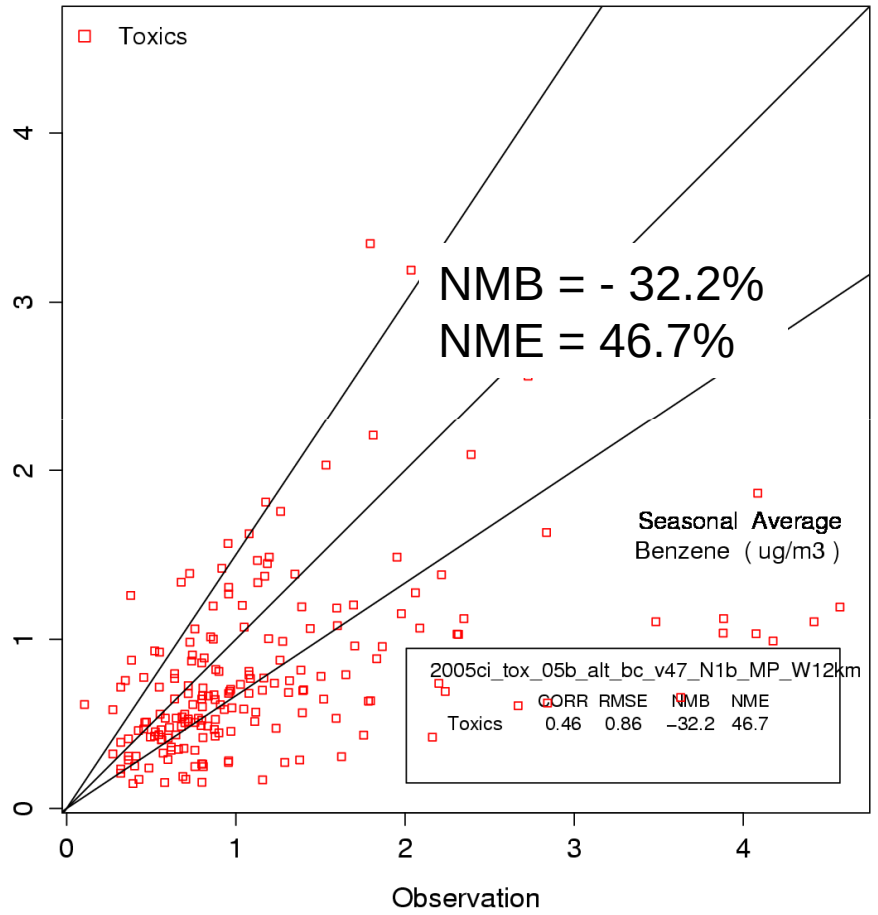
2005 Benzene

Seasonal Means

12-km EUS



12-km WUS



Higher benzene concentrations at monitors near sources such as roadways so commensurability issue with coarse model gridcells

Summary

- Model performance for some non-ubiquitous HAPs is not as "good" as that for ozone & $PM_{2.5}$
  - Uncertainties in monitoring methods for air toxics
  - Limited measurements in time/space to characterize ambient concentrations
    - Given local nature of most toxics, requires fine scale modeling at 4 or 1 km
  - Commensurability issues between measurements (point in space) and model predictions (grid cell averages)
  - Emissions and science uncertainty issues also affects model performance
  - Limited data for estimating intercontinental transport (i.e., boundary conditions)
    - Boundary estimates for some species are much higher than predicted values inside the domain

Summary (continued)

- Emissions-related issues for air toxics
  - No available HAP inventories for Canada (except Hg) & Mexico
  - Inconsistencies between emissions factors for CAPs and HAPs
  - Criteria/HAP emissions are not easily integrated
    - Inconsistencies in CAP/HAP emissions reported by States
    - Inconsistencies between VOC speciation and HAP inventories – need for coordinated research effort
  - Periodic nature of some toxic releases that are not well characterized in our inventories
- Uncertainties in science (e.g., although not shown here, mercury chemistry and re-emissions) and evolving science for various components of the modeling system

Future Efforts

- Continue model evaluation efforts and investigate performance issues in conjunction with EPA/ORD
  - EPA/OAR Reports at: http://www.epa.gov/ttn/scram/reportsindex.htm
- Multi-year model evaluations for EPA collaboration with Centers for Disease Control (CDC): 2001-2010
  - Environmental Public Health Tracking Network: http://ephtracking.cdc.gov/showAirLanding.action
- 2008 modeling platform and evaluation with EPA/ORD during 2011