TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

TCEQ

Final Cross-State Air Pollution Rule (formerly Transport Rule) Modeling

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Presented to Southeast Texas Photochemical Modeling
Technical Committee
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CSAPR Modeling

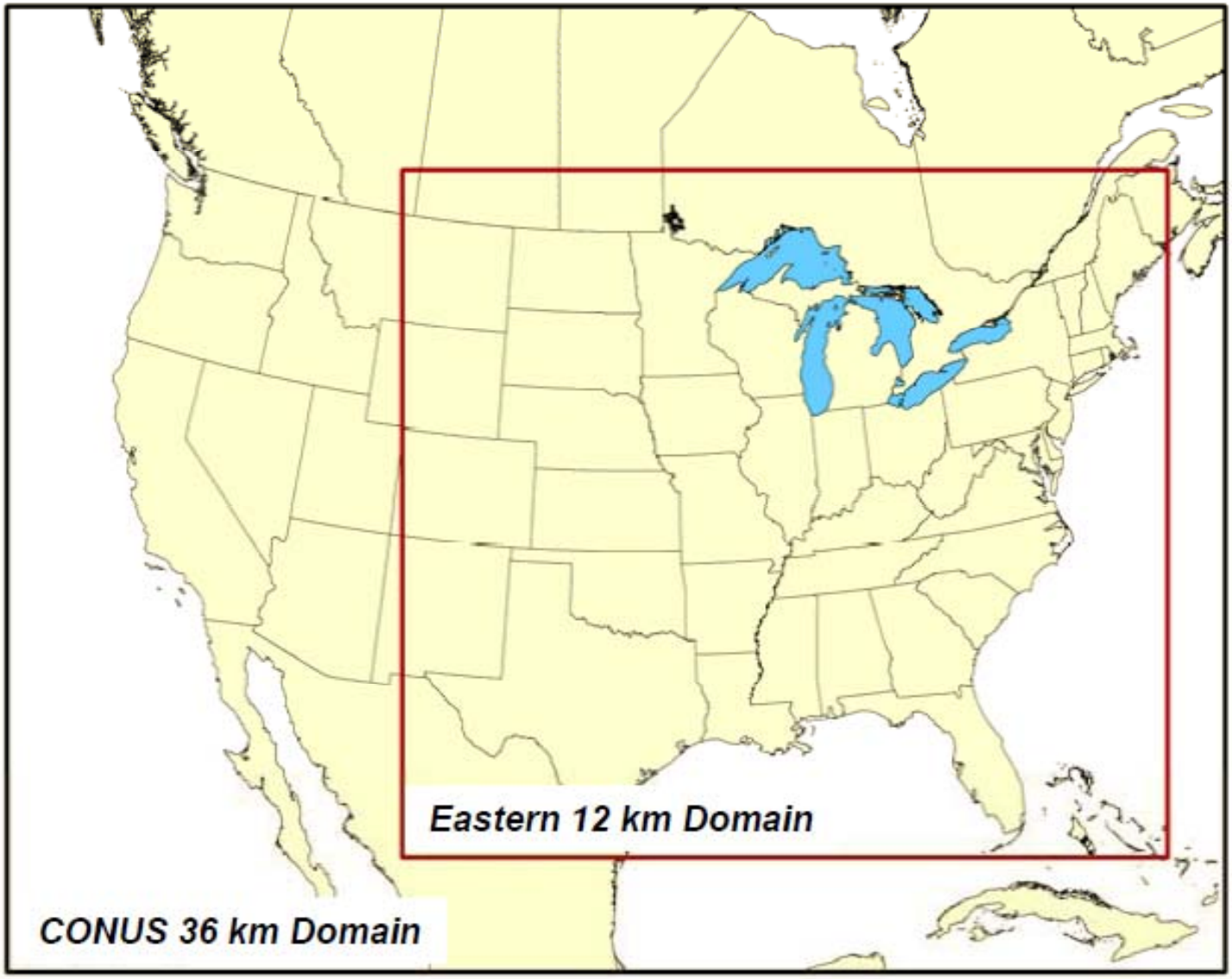
- The EPA conducted the Cross-State Air Pollution Rule (CSAPR) modeling using CAMx, since the EPA CMAQ model lacks the source apportionment capabilities of CAMx.
  - Anthropogenic Precursor Culpability Assessment (APCA)
  - Particulate Source Apportionment Technique (PSAT)

- Modeled entire years
  - 2005 baseline
  - 2012 and 2014 future years
  - 2014 “remedy” (control case)

CSAPR Modeling

- Continental U.S. (CONUS) domain modeled at 36 Km, with 12 Km Eastern U.S. subgrid.
- MM5 meteorology using same grid resolution as CAMx
  - 34 vertical layers, aggregated into 12 layers for CAMx
- GEOS-Chem boundary and initial conditions

CSAPR Modeling Domains



Baseline Modeling Inventory

Platform Sector	2005 NEI Sector	Description and resolution of the data input to SMOKE
IPM sector: *ptipm*	Point	2005v2 NEI point source EGUs mapped to the Integrated Planning Model (IPM) model using the National Electric Energy Database System (NEEDS, 2006 version 3.02) database. Hourly files for continuous emission monitoring (CEM) sources are included only for the 2005 evaluation case. Day-specific emissions for non-CEM sources created for input into SMOKE.
Non-IPM sector: *ptnonipm*	Point	All 2005v2 NEI point source records not matched to the ptipm sector, annual resolution. Includes all aircraft emissions.
Average-fire sector: *avefire*	N/A	Average-year wildfire and prescribed fire emissions derived from the 2002 Platform avefire sector, county and annual resolution. Used for the 2005 base year and the future base model runs, but not for the model evaluation case.
Agricultural sector: *ag*	Nonpoint	NH3 emissions from NEI nonpoint livestock and fertilizer application, county and annual resolution.
Area fugitive dust sector: *afdust*	Nonpoint	PM10 and PM2.5 from fugitive dust sources from the NEI nonpoint inventory (e.g., building construction, road construction, paved roads, unpaved roads, agricultural dust), county/annual resolution.
Remaining nonpoint sector: *nonpt*	Nonpoint	Primarily 2002 NEI nonpoint sources not otherwise included in other SMOKE sectors, county and annual resolution. Also includes updated Residential Wood Combustion emissions and year 2005 non-California Western Regional Air Partnership (WRAP) oil and gas "Phase II" inventory.
Nonroad sector: *nonroad*	Mobile: Nonroad	Monthly nonroad emissions from the National Mobile Inventory Model (NMIM) using NONROAD2005 version nr05c-BondBase for all states except California. Monthly emissions for California created from annual emissions submitted by the California Air Resources Board (CARB) for the 2005v2 NEI.

Baseline Modeling Inventory

Platform Sector	2005 NEI Sector	Description and resolution of the data input to SMOKE
locomotive, and non-C3 commercial marine: *alm_no_c3*	Mobile: Nonroad	Year 2002 non-rail maintenance locomotives, and category 1 and category 2 commercial marine vessel (CMV) emissions sources, county and annual resolution. Unlike prior platforms, aircraft emissions are now included in the ptnonipm sector and category 3 CMV emissions are now contained in the seca_c3 sector
C3 commercial marine: *seca_c3*	Mobile : Nonroad	Annual point source formatted year 2005 category 3 (C3) CMV emissions, developed for the EPA rule called "Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder", usually described as the Emissions Control Area (ECA) study, originally called SO2 ("S") ECA.
Onroad California, NMIM-based, and MOVES sources not subject to temperature adjustments: *on_noadj*	Mobile: onroad	Three, monthly, county-level components: 1) Onroad emissions from NMIM using MOBILE6.2, other than for California. 2) California onroad, created using annual emissions submitted by CARB for the 2005v2 NEI. Onroad gasoline non-motorcycle vehicle emissions from draft MOVES not subject to temperature adjustments: exhaust CO, NOX, VOC, some VOC HAPs, and evaporative VOC and some VOC Hazardous Air Pollutants (HAPs).
Onroad cold-start gasoline exhaust mode vehicle from MOVES subject to temperature adjustments: *on_moves_startpm*	Mobile: onroad	Monthly, county-level draft MOVES-based onroad non-motorcycle gasoline emissions subject to temperature adjustments. Limited to exhaust mode only for PM species and Naphthalene. California emissions not included. This sector is limited to cold start mode emissions that contain different temperature adjustment curves from running exhaust (see on_moves_runpm sector).

Baseline Modeling Inventory

Platform Sector	2005 NEI Sector	Description and resolution of the data input to SMOKE
Onroad running gasoline exhaust mode vehicle from MOVES subject to temperature adjustments: *on_moves_runpm*	Mobile: onroad	Monthly, county-level draft MOVES-based onroad non-motorcycle gasoline emissions subject to temperature adjustments. Limited to exhaust mode only for PM species and Naphthalene. California emissions not included. This sector is limited to running mode emissions that contain different temperature adjustment curves from cold start exhaust (see on_moves startpm sector).
Biogenic: *biog*	N/A	Hour-specific, grid cell-specific emissions generated from the BEIS3.14 model -includes emissions in Canada and Mexico.
Other point sources not from the NEI: *othpt*	N/A	Point sources from Canada's 2006 inventory and Mexico's Phase III 1999 inventory, annual resolution. Also includes annual U.S. offshore oil 2005v2 NEI point source emissions.
Other point sources not from the NEI, Hg only: *othpt_hg*	N/A	Annual year 2000 Canada speciated mercury point source emissions.
Other nonpoint and nonroad not from the NEI: *othar*	N/A	Annual year 2006 Canada (province resolution) and year 1999 Mexico Phase III (municipio resolution) nonpoint and nonroad mobile inventories, annual resolution.
Other nonpoint sources not from the NEI, Hg only: *othar_hg*	N/A	Annual year 2000 Canada speciated mercury from nonpoint sources.
Other onroad sources not from the NEI: *othon*	N/A	Year 2006 Canada (province resolution) and year 1999 Mexico Phase III (municipio resolution) onroad mobile inventories, annual resolution.

2012, 2014 Modeling Inventories

Platform Sector	Projection Methods Used
IPM sector (*ptipm*)	Unit-specific estimates from IPM, version 4.10.
Non-IPM sector (*ptnonipm*)	Projection factors and percent reductions reflect Transport Rule comments and emission reductions due to control programs, plant closures, consent decrees and settlements, and 1997 and 2001 ozone State Implementation Plans in NY, CT, and VA. We also used projection approaches for point-source livestock, and aircraft and gasoline stage II emissions that are consistent with projections used for the sectors that contain the bulk of these emissions. Terminal area forecast (TAF) data aggregated to the national level were used for aircraft to account for projected changes in landing/takeoff activity. Year-specific speciation was applied to some portions of this sector and is discussed in Section 4.2.8.
Average-fire Sector (*avefire*)	No growth or control.
Agricultural Sector (*ag*)	Projection factors for livestock estimates based on expected changes in animal population from 2005 Department of Agriculture data; no growth or control for NH3 emissions from fertilizer application.
Area fugitive dust Sector (*afdust*)	Projection factors for dust categories related to livestock estimates based on expected changes in animal population; no growth or control for other categories in this sector.
Remaining nonpoint sector (*nonpt*)	Projection factors that implement Transport Rule Proposal comments and reflect emission reductions due to control programs. Residential wood combustion projections based on growth in lower-emitting stoves and a reduction in higher emitting stoves. PFC projection factors reflecting impact of the final Mobile Source Air Toxics (MSAT2) rule. Gasoline stage II projection factors based on National Mobile Inventory Model (NMIM)-estimated VOC refueling estimates for future years. Oil and gas projection estimates are provided for the non-California WRAP states as well as Oklahoma and Texas. Year-specific speciation was applied to some portions of this sector and is discussed in Section 4.2.8.

2012, 2014 Modeling Inventories

Platform Sector	Projection Methods Used
Nonroad mobile sector (nonroad)	Other than for California, this sector uses data from a run of NMIM that utilized the NR05d-Bond-final version of NONROAD (which is equivalent to NONROAD2008a), using future-year equipment population estimates and control programs to the years 2012 and 2015 and using national level inputs. Year 2014 emissions were created by interpolating 2012 and 2015 emissions. Final controls from the final locomotive-marine and small spark ignition OTAQ rules are included. California-specific data provided by the state of California, except NH3 used 2012 and 2014 (interpolated) NMIM. Year-specific speciation was applied to some portions of this sector and is discussed in Section 4.3.5.
Locomotive, and non-Class 3 commercial marine sector (alm_no_c3)	Projection factors for Class 1 and Class 2 commercial marine and locomotives which reflect Transport Rule comments and activity growth and final locomotive-marine controls.
Class 3 commercial marine vessel sector (seca_c3)	Base-year 2005 emissions grown and controlled to 2012 and 2014, incorporating Transport Rule comments and controls based on Emissions Control Area (ECA) and International Marine Organization (IMO) global NOX and SO2 controls.
Onroad mobile sector with no adjustment for daily temperature (on_noadj)	MOVES2010 run (state-month) for 2012 and 2014 with results disaggregated to the county level in proportion to NMIM 2012 and NMIM 2015 emissions estimates. Temperature impacts at the monthly average resolution. California-specific data provided by the state of California, except NH3 which was obtained from MOVES2010. VOC speciation uses different future-year values to take into account both the increase in ethanol use, and the existence of Tier 2 vehicles that use a different speciation profile. Other than California, this sector includes all non-refueling onroad mobile emissions (exhaust, evaporative, brake wear and tire wear modes) except exhaust mode gasoline PM and naphthalene emissions that are provided in the on_moves_startpm and on_moves_runpm sectors.

2012, 2014 Modeling Inventories

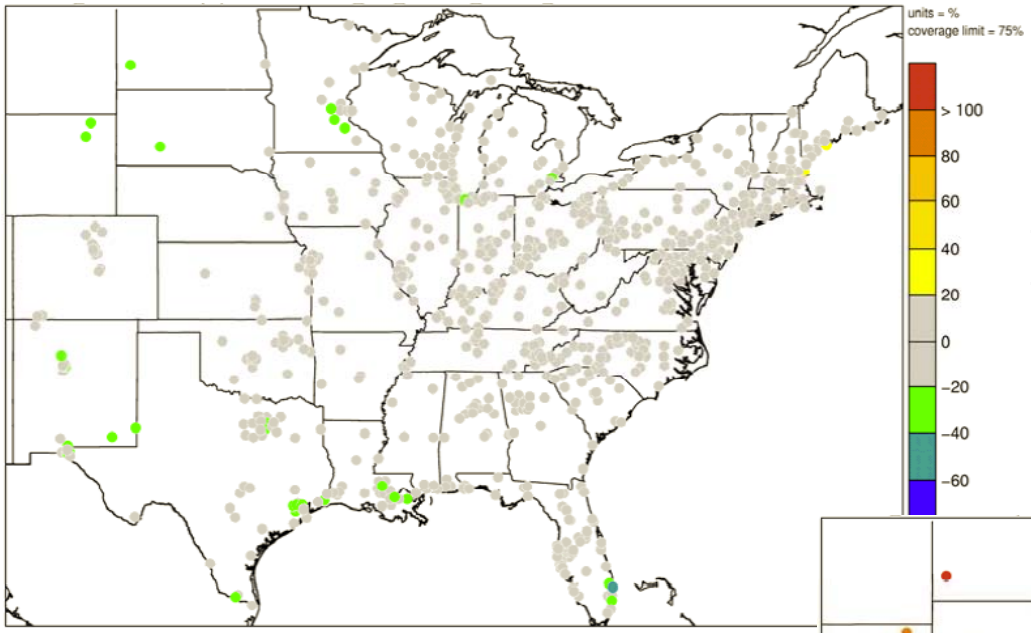
Platform Sector	Projection Methods Used
Onroad PM gasoline running mode sector (on_moves_startpm)	Running mode MOVES2010 year 2012 and 2014 future-year state-month estimates for PM and naphthalene, apportioned to the county level using NMIM 2012 and NMIM 2015 state-county ratios matched to vehicle and road types. Use future-year temperature adjustment file for adjusting the 72°F emissions to ambient temperatures (for elemental and organic carbon) based on grid cell hourly temperature (note that lower temperatures result in increased emissions).
Onroad PM gasoline start mode sector (on_moves_startpm)	Cold start MOVES2010 future-year 2012 and 2014 state-month estimates for PM and naphthalene, apportioned to the county level using NMIM 2012 and NMIM 2015 state-county ratios of local urban and rural roads by vehicle type. Use future-year temperature adjustment file for adjusting the 72°F emissions (for elemental and organic carbon) to ambient temperatures based on grid cell hourly temperatures (lower temperatures result in increased emissions).
Other nonpoint and nonroad not from the NEI (*othar)*	No growth or control.
Other onroad sector (othon)	No growth or control.
Other nonroad / nonpoint (othar):	No growth or control.
Other point (othpt)	No growth or control.
Biogenic	2005 emissions used for all future-year scenarios.

Note: Projections did <u>not</u> include any reductions implemented under the Clean Air Interstate Rule (CAIR).

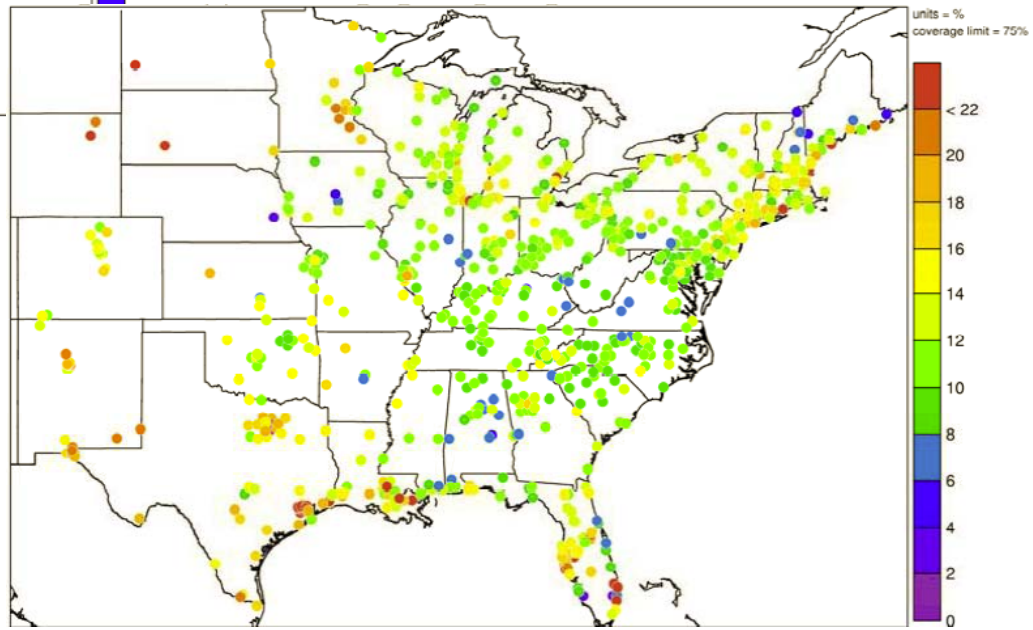
Model Performance Evaluation

- Summary model performance statistics were calculated across four subregions defined by regional planning organizations (RPOs)
  - Central: AR, IA, KS, LA, MN, MO, NE, OK, and TX
  - Midwest: IL, IN, MI, OH, and WI
  - Southeast: AL, FL, GA, KY, MS, NC, SC, TN, VA, and WV
  - Northeast: CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, and VT
- Also evaluated performance at monitors predicted to exceed ozone, annual $PM_{2.5}$ or 24-hour $PM_{2.5}$ NAAQS in 2012. Of particular relevance to Texas are:
  - 260050003 – Allegan County, Mi – Ozone;
  - 220330003 – East Baton Rouge, La – Ozone; and
  - 171192009 – Madison County, Ill – Annual and 24-Hour $PM_{2.5}$

Model Performance Evaluation: Ozone

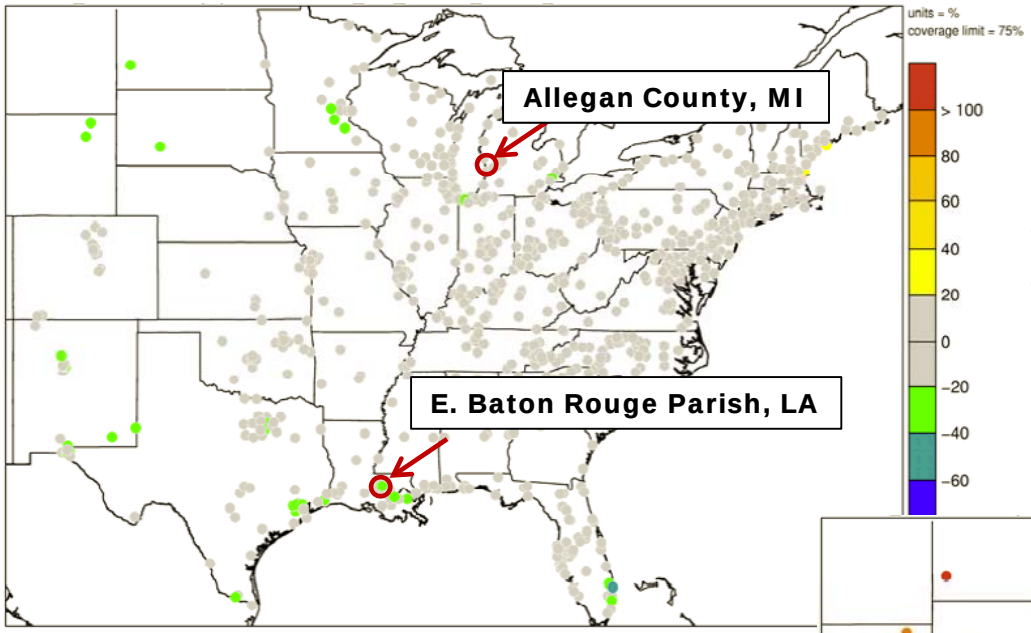


Normalized Mean Bias (%) of 8 hour daily maximum ozone greater than 60 ppb over the period May through September 2005 at monitoring sites in Eastern modeling domain



Normalized Mean Error (%) of 8 hour daily maximum ozone greater than 60 ppb over the period May through September 2005 at monitoring sites in Eastern modeling domain

Model Performance Evaluation: Ozone



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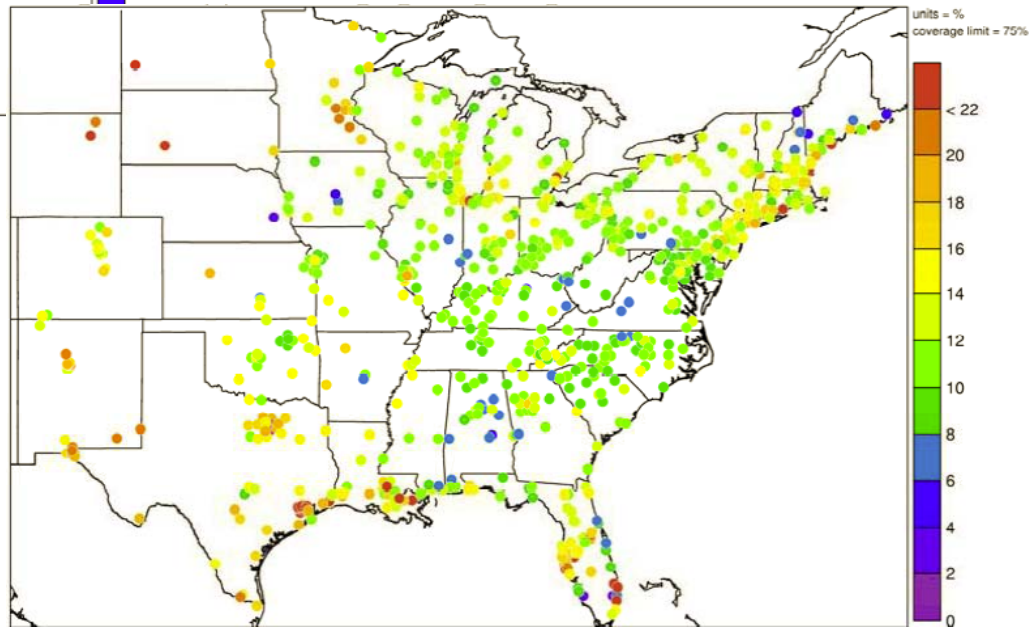
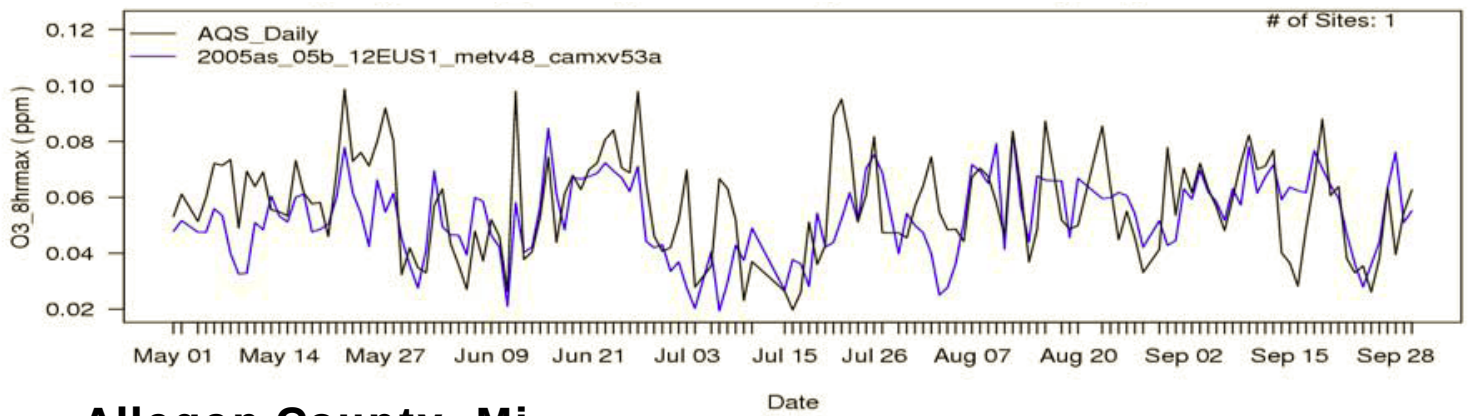


Normalized Mean Error (%) of 8 hour daily maximum ozone greater than 60 ppb over the period May through September 2005 at monitoring sites in Eastern modeling domain

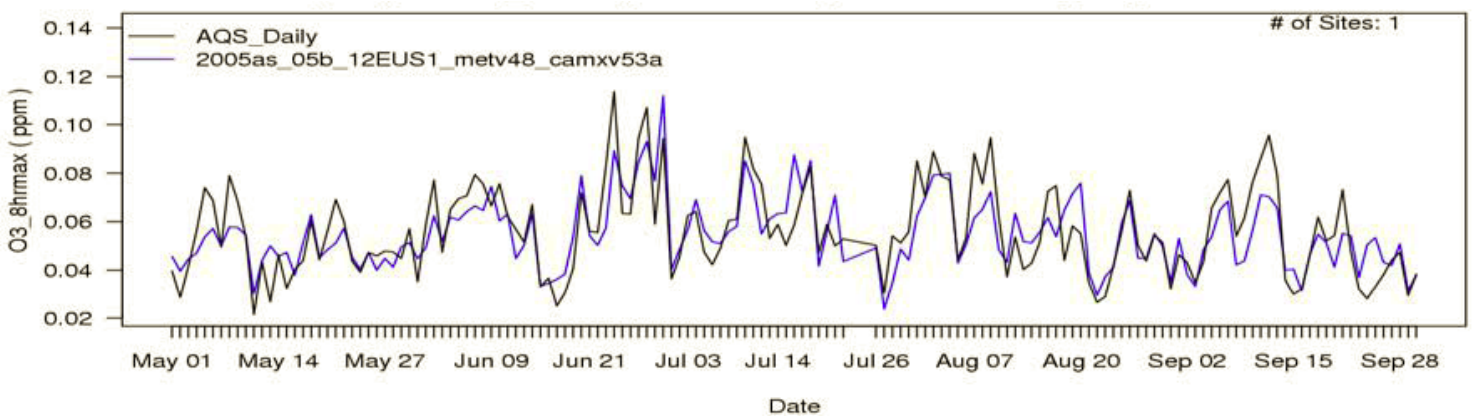
Model Performance Evaluation: Ozone

Time series of observed (black) and predicted (blue) 8-hour daily maximum ozone for the period May through September 2005:

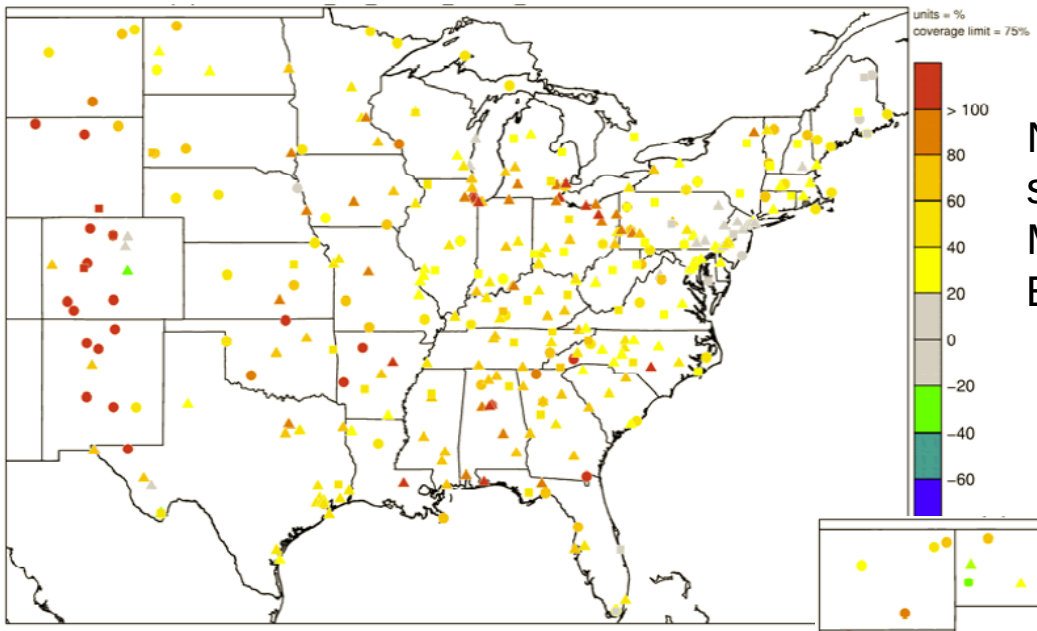
East Baton Rouge, La



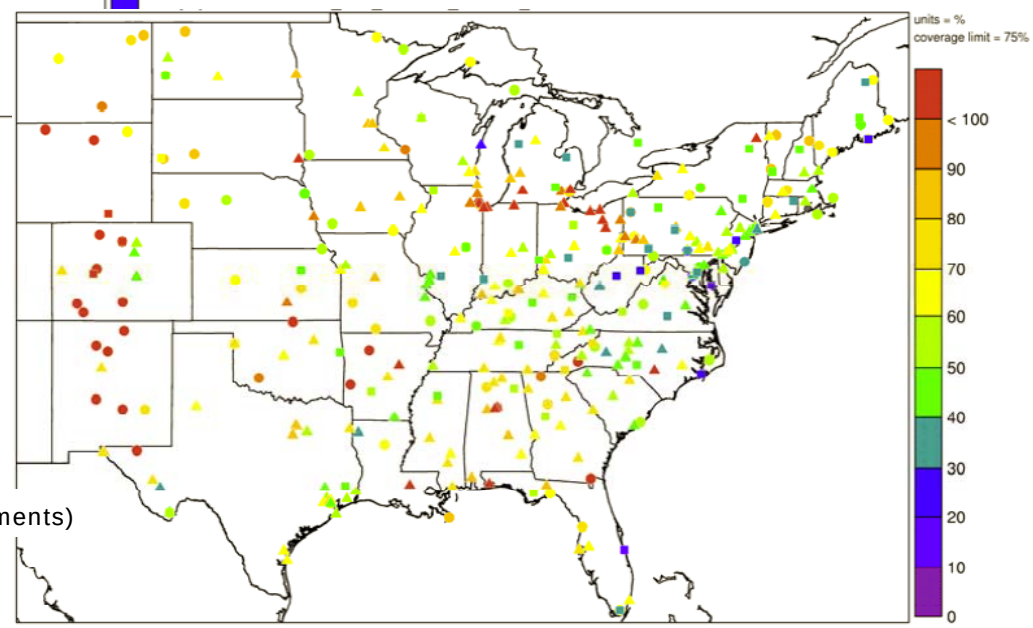
Allegan County, Mi



Model Performance Evaluation – $PM_{2.5}$: Sulfate, Jan-Mar



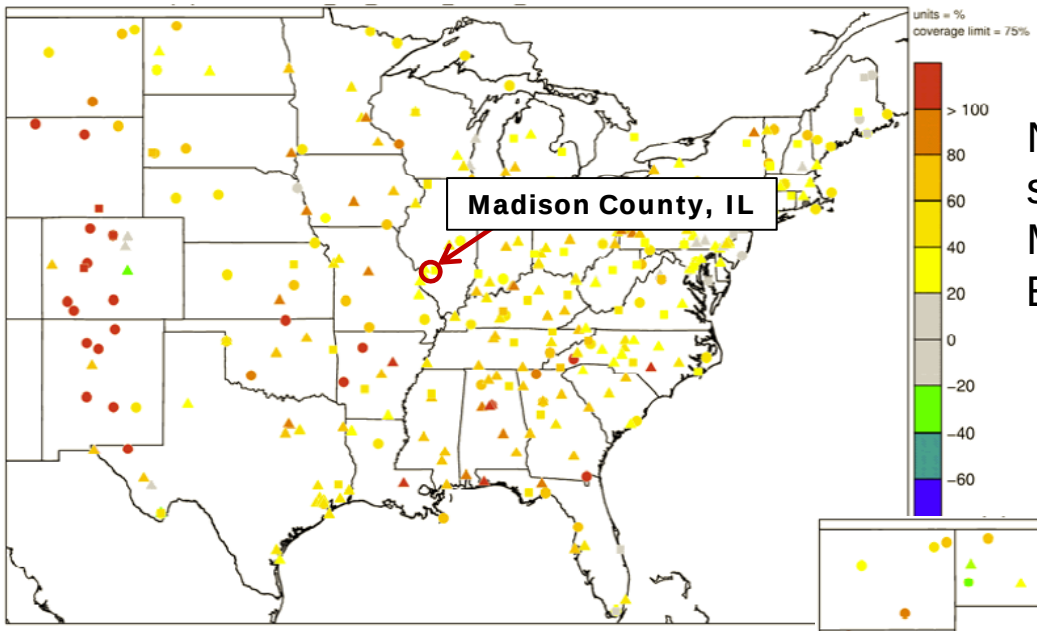
Normalized Mean Bias (%) of sulfate during January through March 2005 at monitoring sites in Eastern modeling domain



Normalized Mean Error (%) of sulfate during January through March 2005 at monitoring sites in Eastern modeling domain

- IMPROVE (Interagency Monitoring of PROtected Visual Environments)
- CSN (Chemical Speciation Network)
- CASTNet (Clean Air Status and Trends Network)

Model Performance Evaluation – $PM_{2.5}$: Sulfate, Jan-Mar



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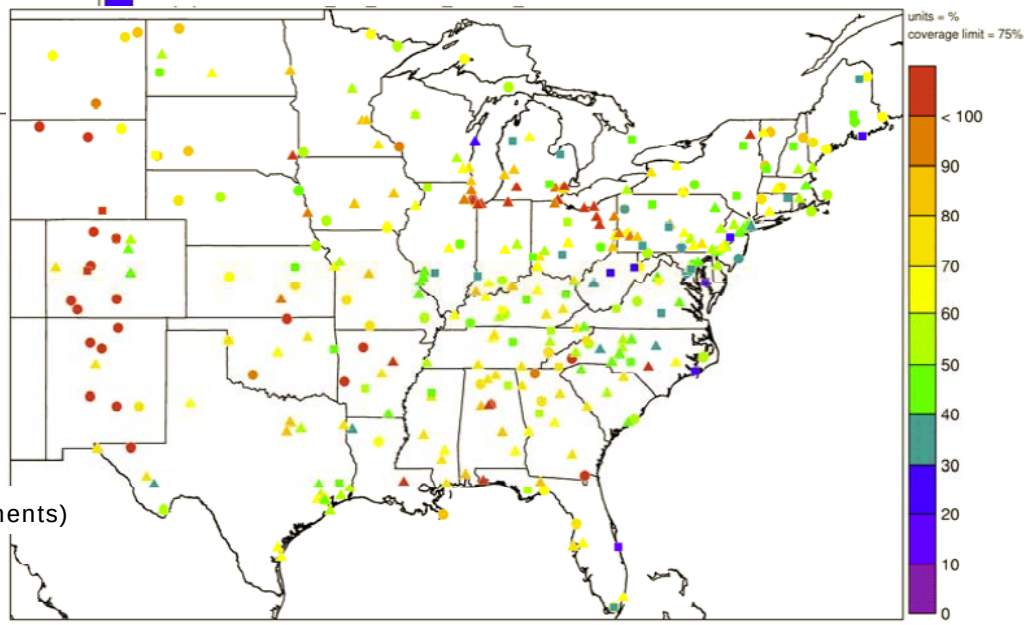

Normalized Mean Error (%) of sulfate during January through March 2005 at monitoring sites in Eastern modeling domain

- IMPROVE (Interagency Monitoring of PROtected Visual Environments)
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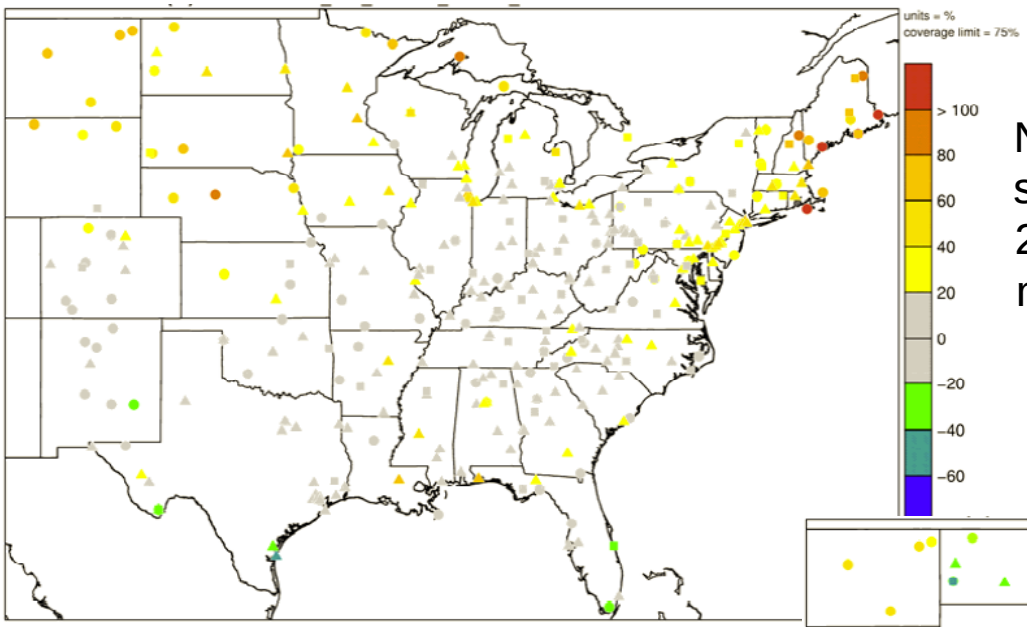
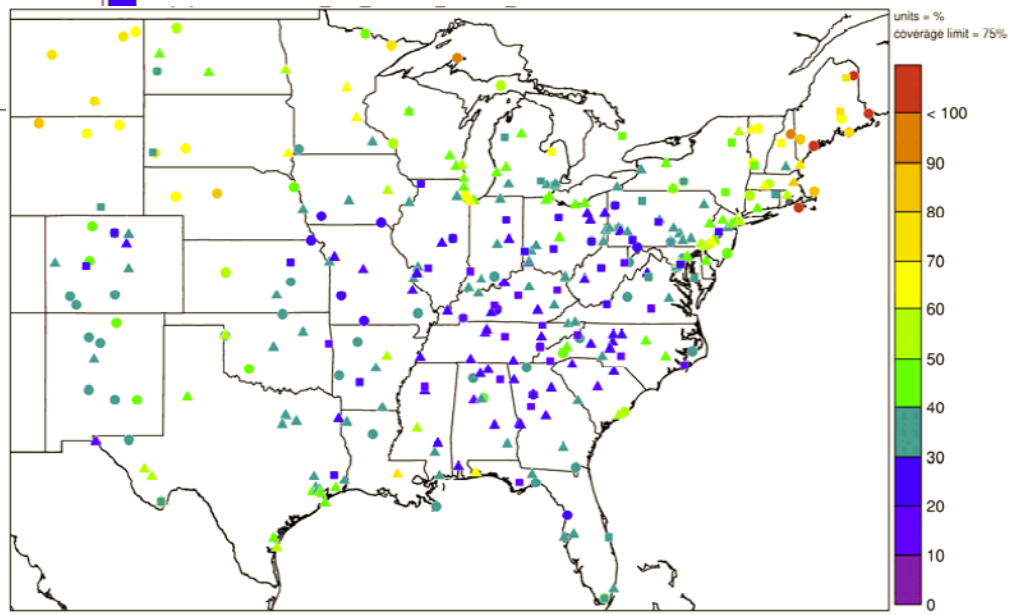
Model Performance Evaluation – $PM_{2.5}$: Sulfate, Apr-Jun



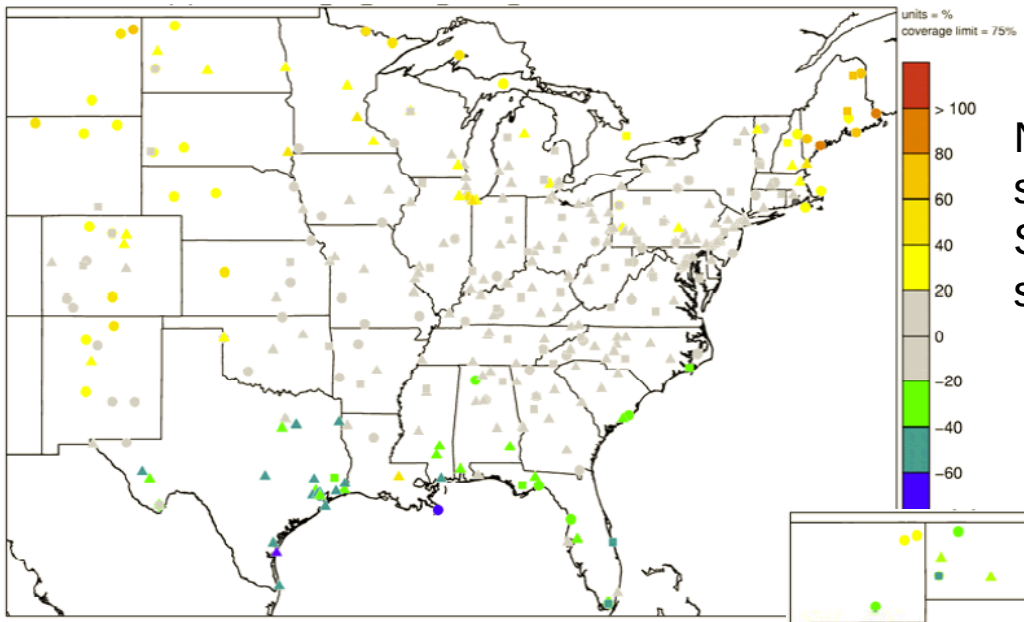
Normalized Mean Bias (%) of sulfate during April through June 2005 at monitoring sites in Eastern modeling domain



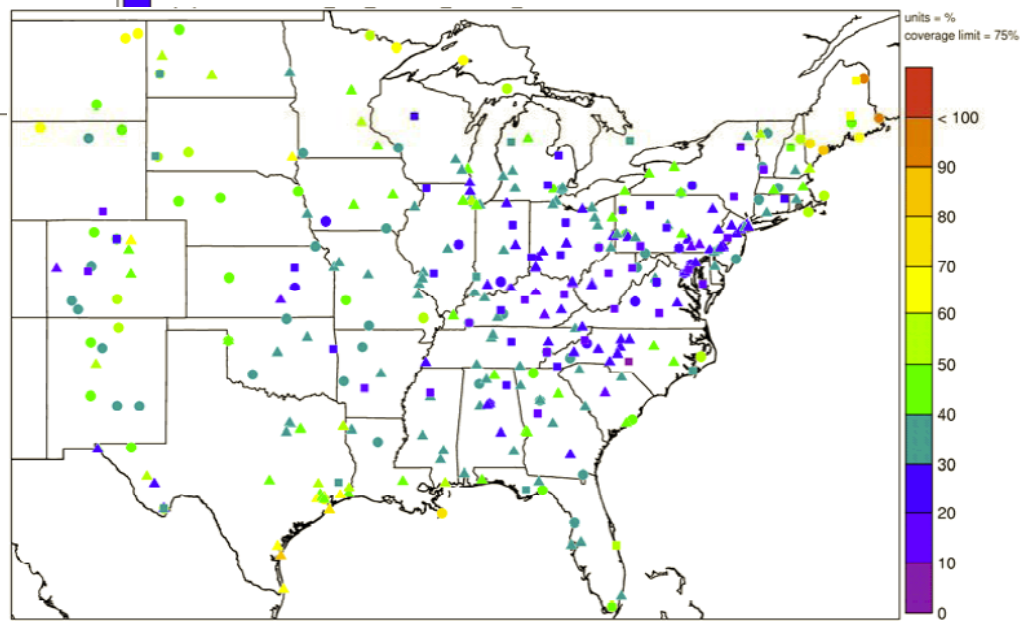
Normalized Mean Error (%) of sulfate during April through June 2005 at monitoring sites in Eastern modeling domain

- IMPROVE
- CSN
- CASTNet

Model Performance Evaluation – $PM_{2.5}$: Sulfate, Jul-Sep



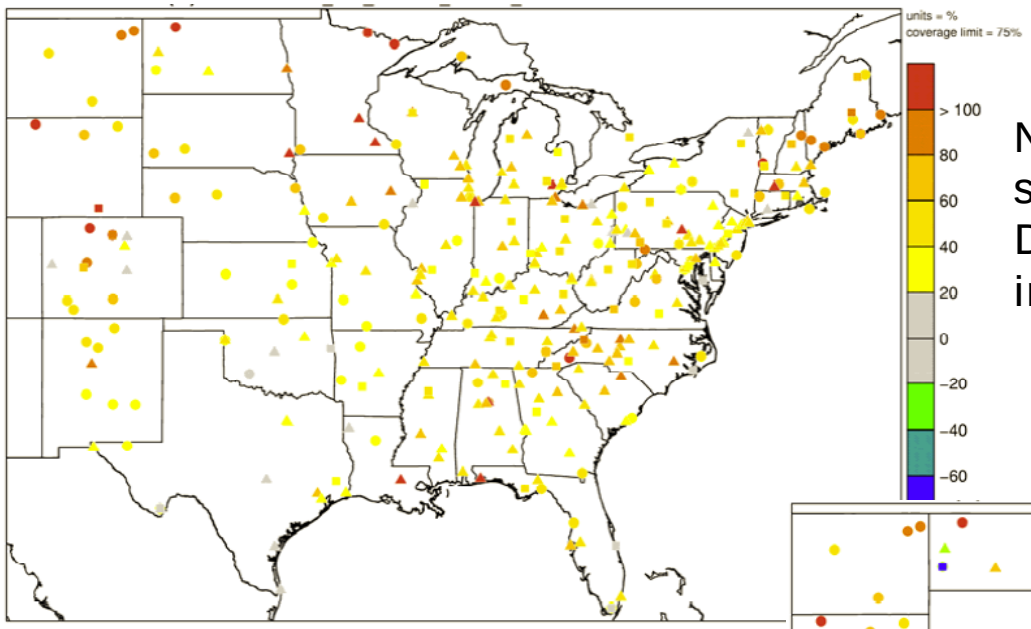
Normalized Mean Bias (%) of sulfate during July through September 2005 at monitoring sites in Eastern modeling domain



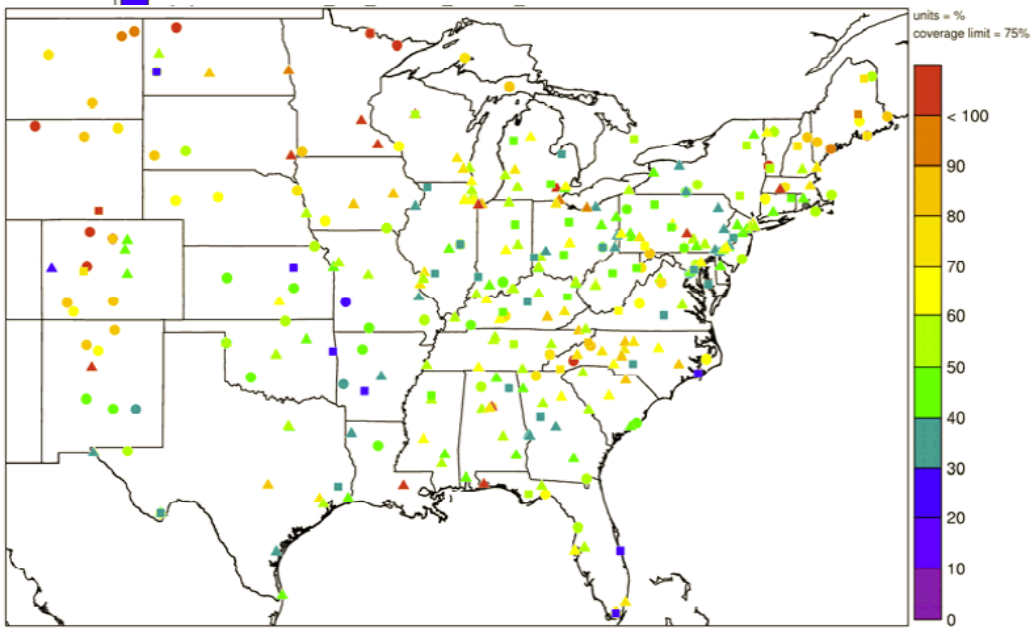
Normalized Mean Error (%) of sulfate during July through September 2005 at monitoring sites in Eastern modeling domain

- IMPROVE
- CSN
- CASTNet

Model Performance Evaluation – $PM_{2.5}$: Sulfate, Oct-Dec



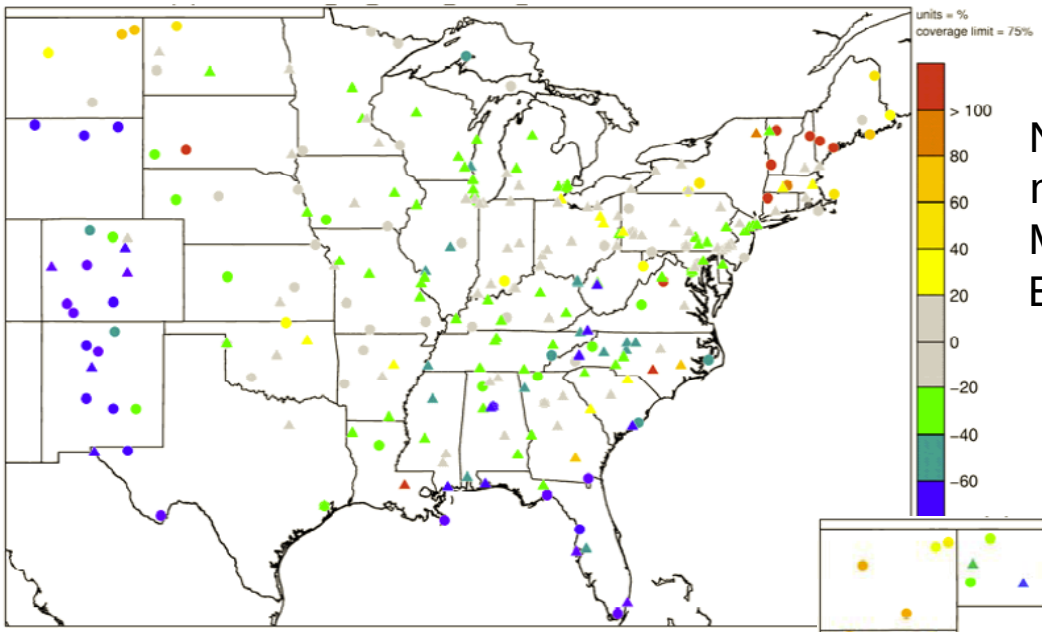
Normalized Mean Bias (%) of sulfate during October through December 2005 at monitoring sites in Eastern modeling domain



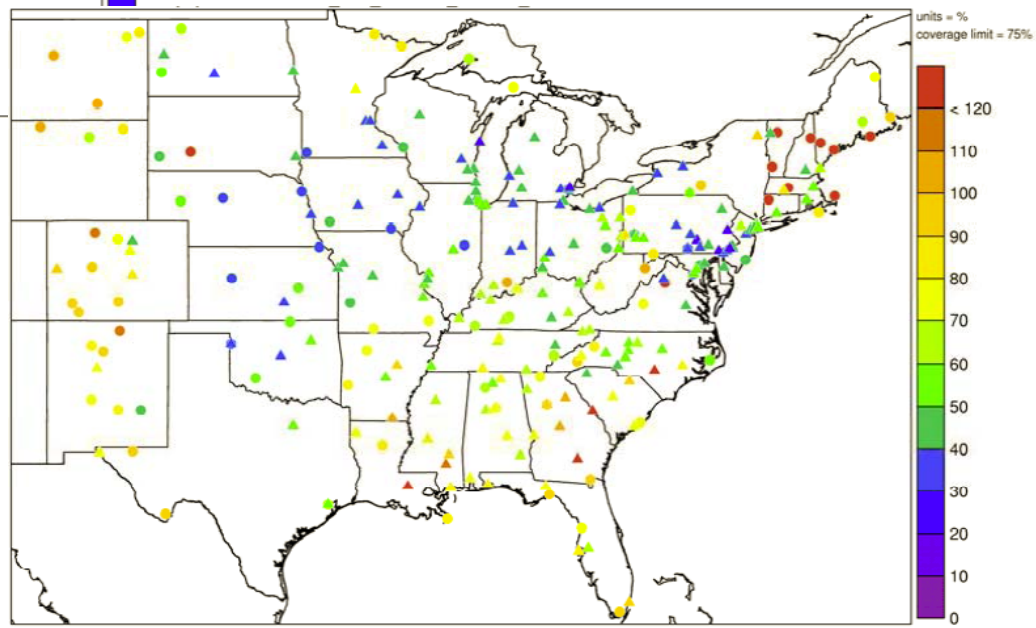
Normalized Mean Error (%) of sulfate during October through December 2005 at monitoring sites in Eastern modeling domain

- IMPROVE
- CSN
- CASTNet

Model Performance Evaluation – $PM_{2.5}$: Nitrate, Jan-Mar



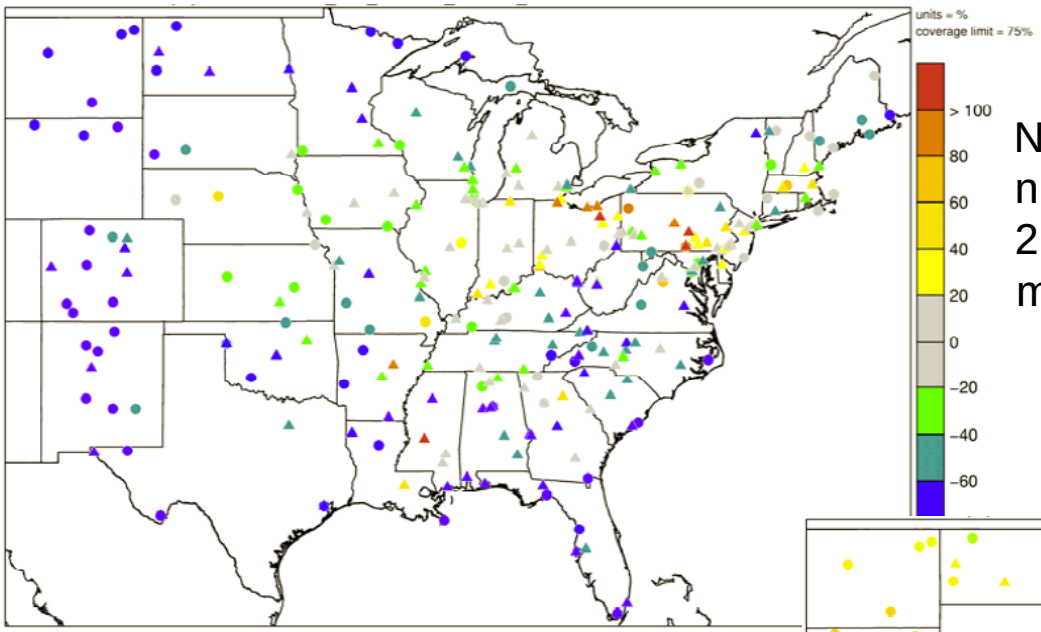
Normalized Mean Bias (%) of nitrate during January through March 2005 at monitoring sites in Eastern modeling domain



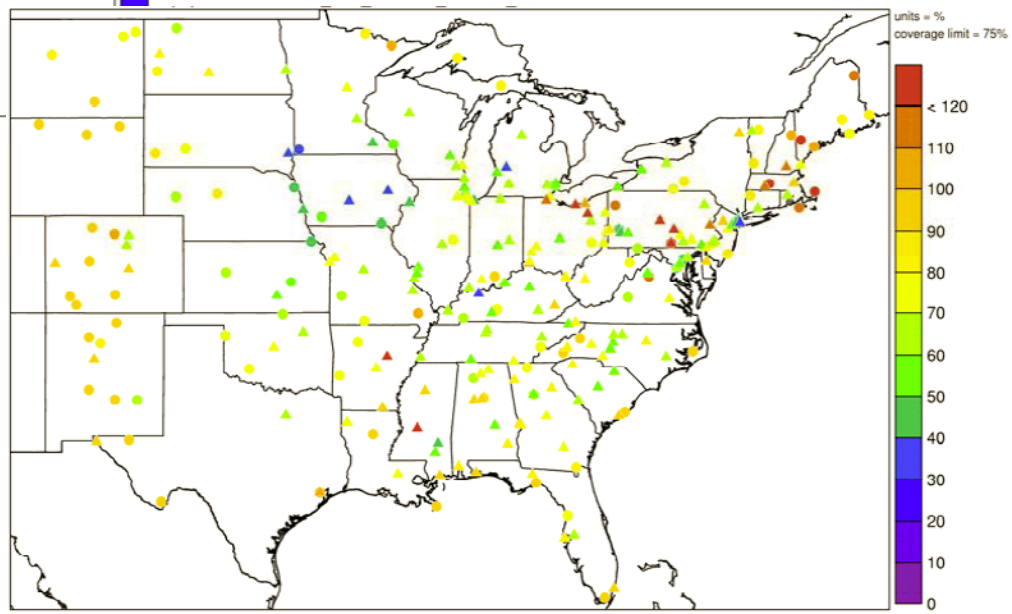
Normalized Mean Error (%) of nitrate during January through March 2005 at monitoring sites in Eastern modeling domain

- IMPROVE
- CSN
- CASTNet

Model Performance Evaluation – $PM_{2.5}$: Nitrate, Apr-Jun



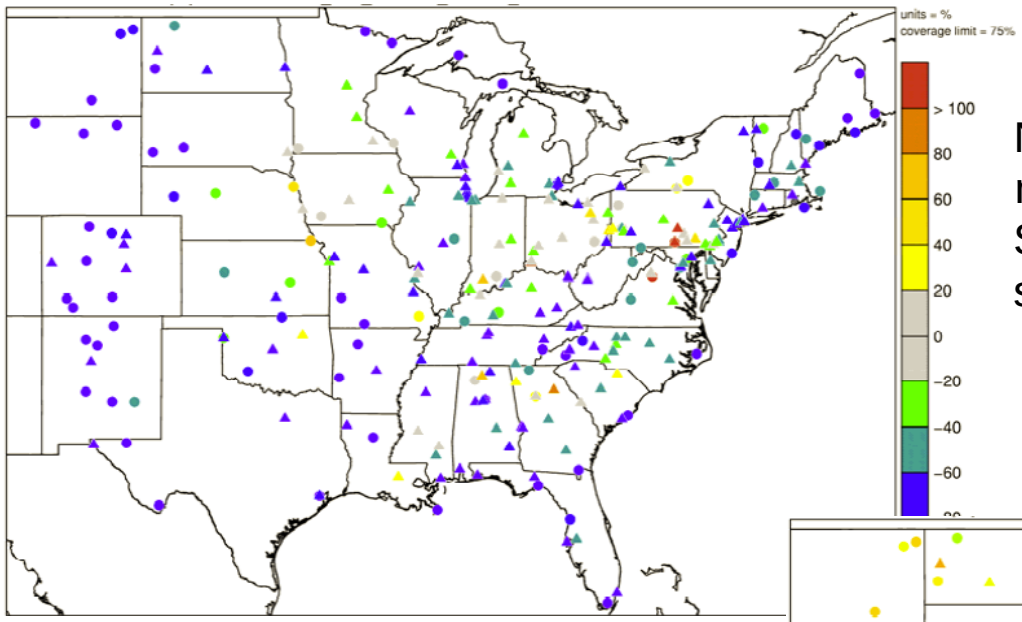
Normalized Mean Bias (%) of nitrate during April through June 2005 at monitoring sites in Eastern modeling domain



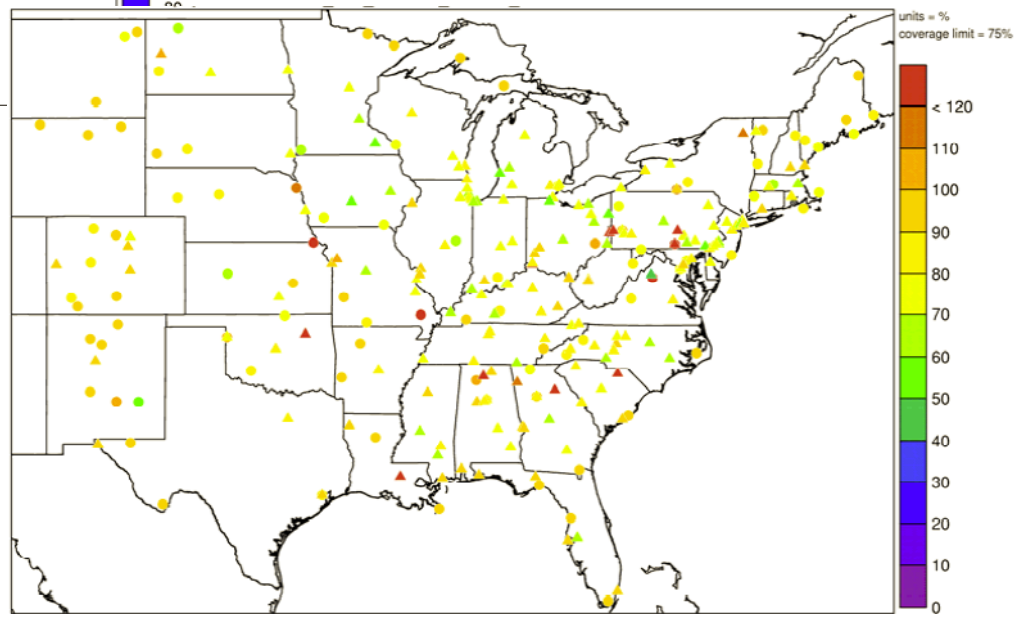
Normalized Mean Error (%) of nitrate during April through June 2005 at monitoring sites in Eastern modeling domain

- IMPROVE
- CSN
- CASTNet

Model Performance Evaluation – $PM_{2.5}$: Nitrate, Jul-Sep



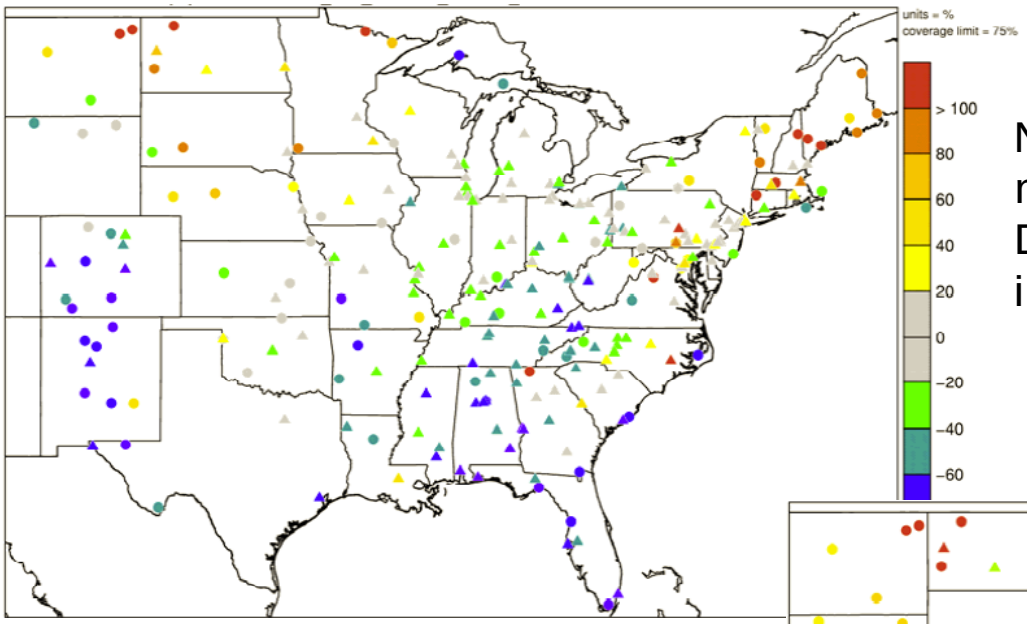
Normalized Mean Bias (%) of nitrate during July through September 2005 at monitoring sites in Eastern modeling domain



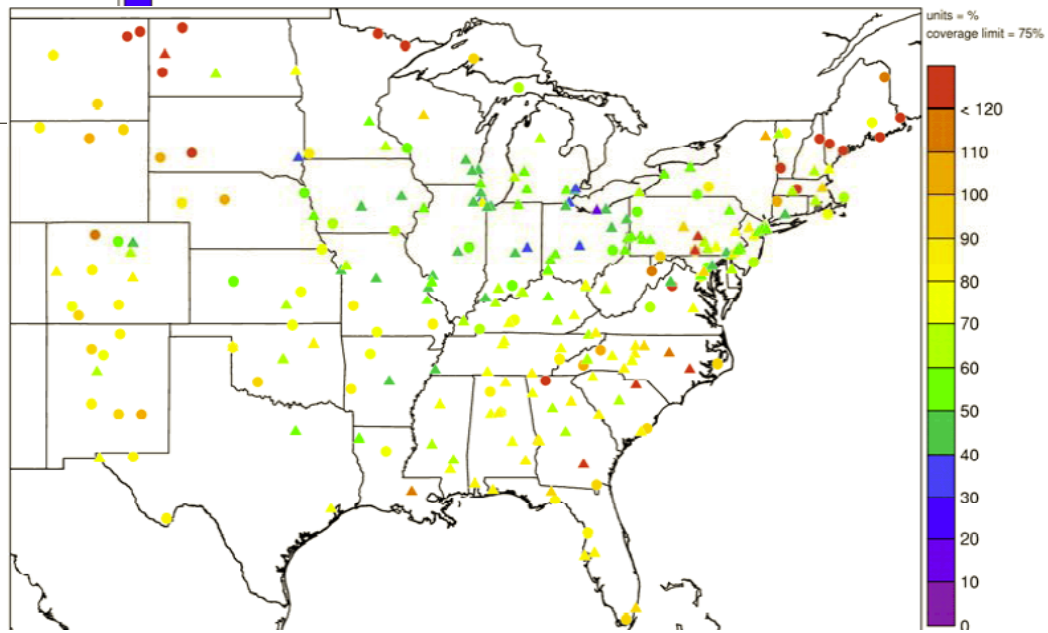
Normalized Mean Error (%) of nitrate during July through September 2005 at monitoring sites in Eastern modeling domain

- IMPROVE
- CSN
- CASTNet

Model Performance Evaluation – $PM_{2.5}$: Nitrate, Oct-Dec



Normalized Mean Bias (%) of nitrate during October through December 2005 at monitoring sites in Eastern modeling domain



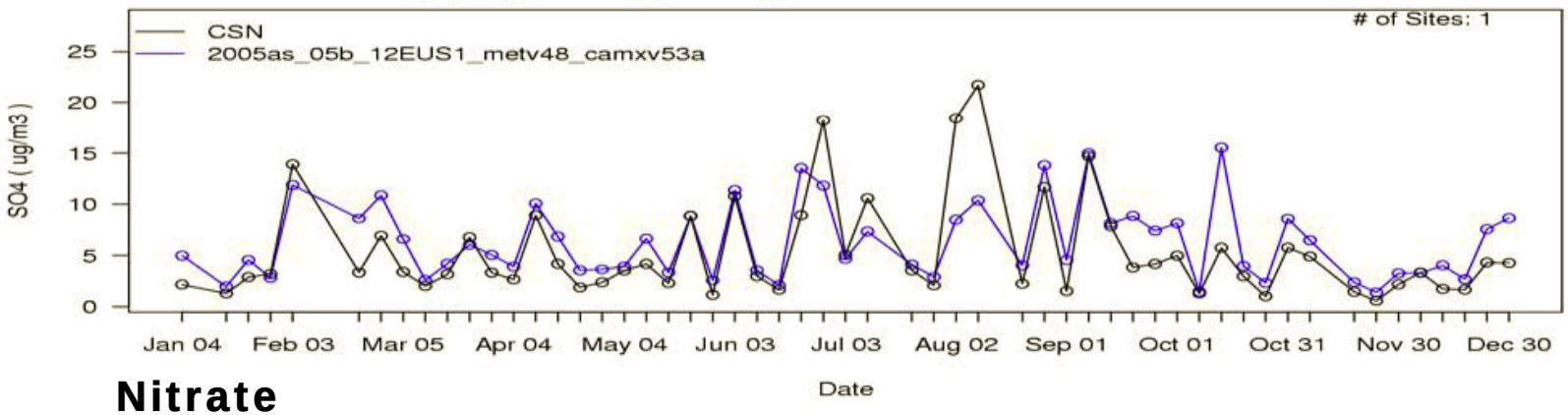
Normalized Mean Error (%) of nitrate during October through December 2005 at monitoring sites in Eastern modeling domain

- IMPROVE
- CSN
- CASTNet

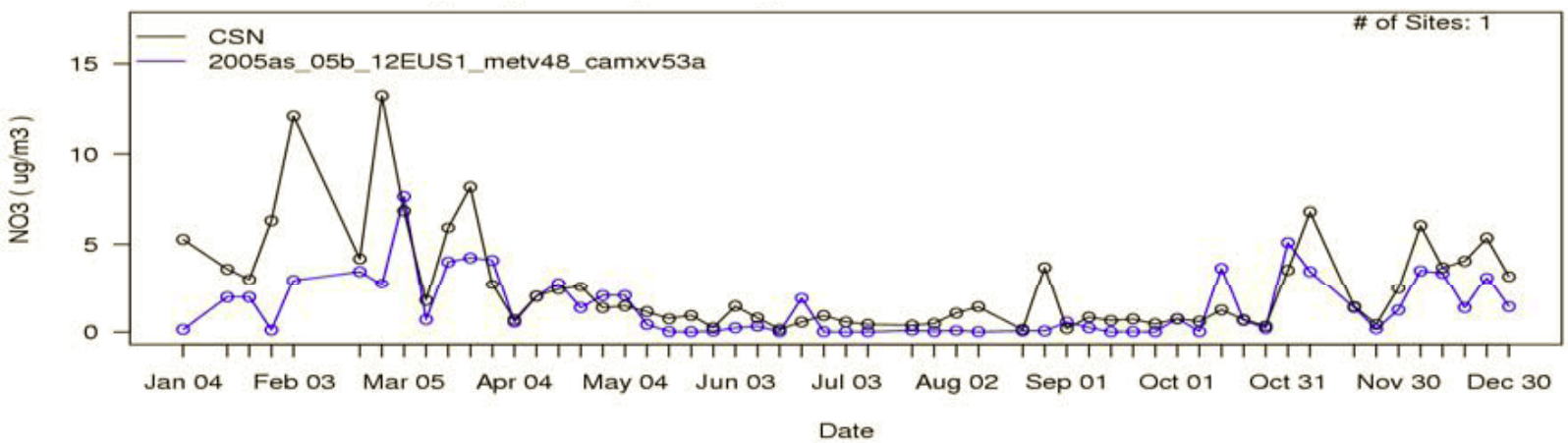
Model Performance Evaluation – Sulfate and Nitrate, Madison County, Il

Time series of observed (black) and predicted (blue) 24-hour average sulfate and nitrate at site 1711192009 in Madison County, Il:

Sulfate



Nitrate



Model Performance Evaluation

- The EPA concluded that model performance for both ozone and $PM_{2.5}$ was acceptable.
- The performance evaluation focused only on static evaluation of the model vs. base-case measurements.
- No consideration was apparently given to evaluating model *response* to emission changes as described in Section 18.5 of the guidance. These types of analyses are especially relevant when the model is used in a relative sense as in CSAPR

Projecting Nonattainment/ Maintenance Areas

- As per the EPA's guidance, design values at monitoring sites are projected using relative response factors:

$$\text{RRF} = \frac{\text{Avg. future modeled conc. near monitor}}{\text{Avg. baseline modeled conc. near monitor}}$$

- Projected design values are based on a three-year average of design values which include the base year (2005):

$$\text{Baseline DV} = (DV_{2005} + DV_{2006} + DV_{2007}) / 3$$

where DV_{2005} = Avg. 4th highest conc. from 2003, 2004, **2005**

DV_{2006} = Avg. 4th highest conc. from 2004, **2005**, 2006

DV_{2007} = Avg. 4th highest conc. from **2005**, 2006, 2007

Projecting Nonattainment/ Maintenance Areas

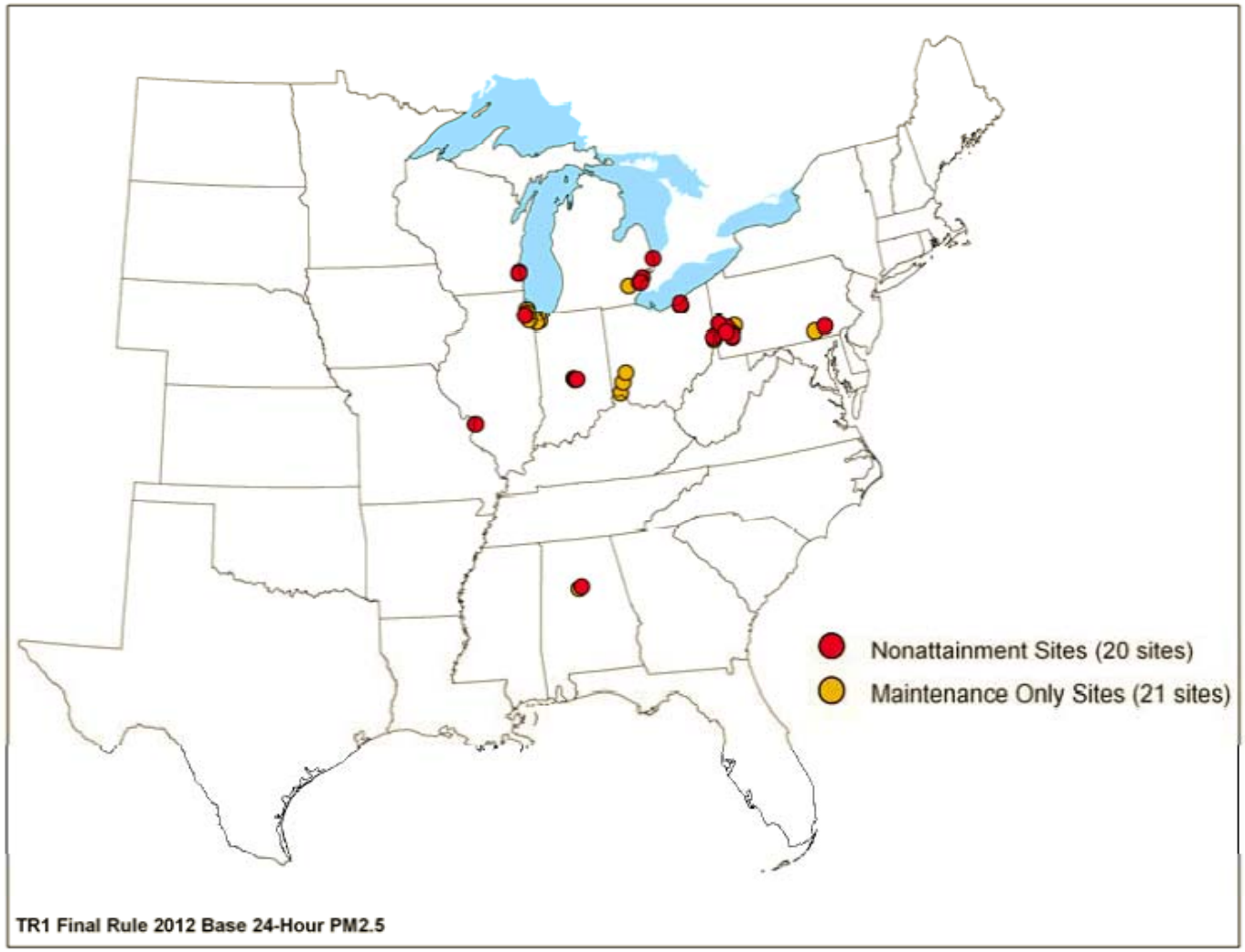
- Future (2012) design value is calculated as:

  Future DV = Baseline DV x RRF

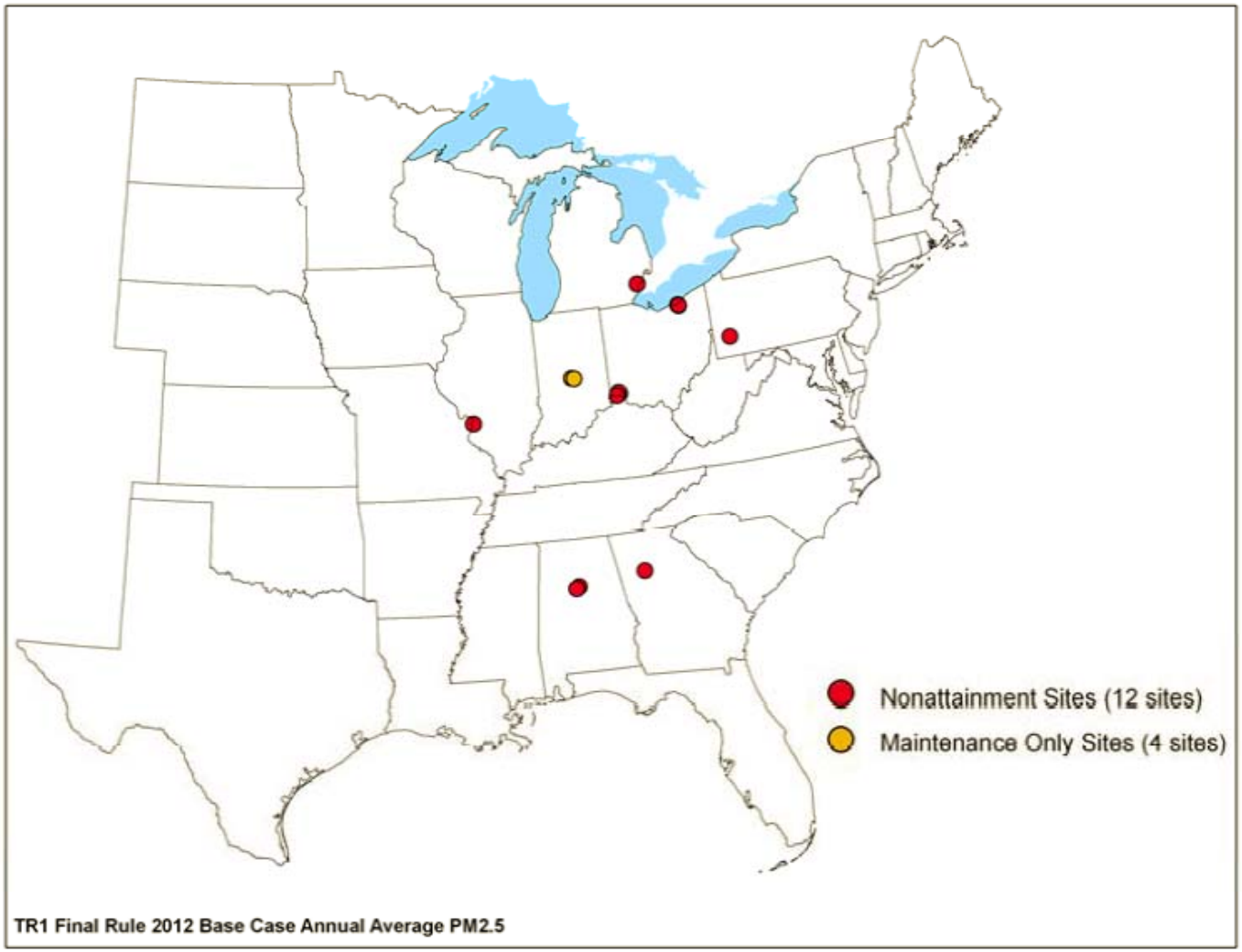
  This value is used to identify projected Nonattainment monitors.

- To identify projected Maintenance areas, the EPA repeated this calculation using the <u>average</u> of three design values, EPA used the <u>maximum</u> of the three.

Projected 2012 Annual $PM_{2.5}$ Nonattainment Areas



Projected 2012 24-Hour $PM_{2.5}$ Nonattainment Areas



Projected 2012 8-Hour Ozone Nonattainment Areas

Evaluation of Interstate Contributions

- The EPA established threshold concentrations of 1 percent of each of the three NAAQS as shown:

Pollutant	Level of the NAAQS	One-Percent Threshold
8-Hour Ozone	0.08 ppm	0.0008 ppm (0.8 ppb)
Annual $PM_{2.5}$	15.0 $\mu g/m^3$	0.15 $\mu g/m^3$
24-Hour $PM_{2.5}$	35.0 $\mu g/m^3$	0.35 $\mu g/m^3$

  - For each monitor labeled "nonattainment" or "maintenance," the 2012 contribution from each state is calculated by APCA or PSAT, then compared to the appropriate threshold.
  - If a state's contribution exceeds the threshold, that state is "linked" to the site.

Evaluation of Interstate Contributions - Texas

- Texas' predicted contribution to every nonattainment/maintenance monitor was below the threshold concentration, except:

Monitor	Pollutant	2012 Base Case Avg. Value*	2012 Base Case Max. Value	Actual 2010 Design Value	Projected 2010 Texas Contri-bution	Threshold Value
260050003 Allegan County Mi	8-Hour Ozone	82.4 ppb	85.1 ppb	74 ppb	1.9 ppb	0.8 ppb
220330003 East Baton Rouge Parish La	8-Hour Ozone	85.6 ppb	89.3 ppb	78 ppb	3.9 ppb	0.8 ppb
171191007 Madison County Il	Annual $PM_{2.5}$	15.46 $\mu g/m^3$	15.73 $\mu g/m^3$	13.8 $\mu g/m^3$	0.18 $\mu g/m^3$	0.15 $\mu g/m^3$
	24-Hour $PM_{2.5}$	36.5 $\mu g/m^3$	36.8 $\mu g/m^3$	29 $\mu g/m^3$	0.37 $\mu g/m^3$	0.35 $\mu g/m^3$

*More familiarly the Future Design Value or DV_F

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Should Texas Be Included in CSAPR for Ozone?

- Both sites "linked" to Texas for ozone show 2010 design values well below the 1997 8-hour ozone NAAQS of 85 ppb:
  - 2010 DV for Allegan County Mi is 11 ppb below the 1997 NAAQS[1].
  - 2010 DV for East Baton Rouge Parish is 7 ppb below the 1997 NAAQS[2].
  - Had the EPA used measured design values in its assignment of monitors to "nonattainment" and "maintenance," Texas would not be linked with them.

[1] In September, 2010, the EPA approved Michigan's request to redesignate Allegan County to Attainment for the 1997 8-hour ozone NAAQS.
[2] In June 2010, the EPA proposed redesignation of the Baton Rouge area to Attainment status for this NAAQS.

Should Texas Be Included in CSAPR for Ozone?

- Without inclusion of CAIR Phase I reductions, the model might be expected to over-predict the 2012 concentrations, but could the differences of 7 and 11 ppb be attributed to CAIR alone?
  - The EPA has not presented results of modeling including CAIR reductions, so the predicted effects of CAIR Phase I are unknown.
  - The under-prediction of the highest 8-hour ozone peaks at these two sites may dampen the model's response to the 2005-to-2012 emission reductions, but since the EPA did not evaluate model response, the answer is also unknown.

Should Texas Be Included in CSAPR for $PM_{2.5}$?

- The Madison County Il monitor shows 2010 design values below both the annual and 24-hour NAAQS.
- This monitor was sited to assess air quality near a large steel mill in Granite City, Il.
- Source culpability analysis by the Illinois EPA predicts that nearly 4 $\mu g/m^3$ of the 2012 design value is locally-generated primary particulates, which are not proposed for regulation by the CSAPR.

Should Texas Be Included in CSAPR for $PM_{2.5}$?

Should Texas Be Included in CSAPR for $PM_{2.5}$?

- Should a monitored sited for a specific source be used to “link” another state?
- Can 12 Km CAMx modeling account for the effect of local sources on the monitor?
  - When emissions from the local sources are dumped into a large grid cell, the emissions from the local source will be greatly diluted and the source-receptor relationship will be obscured.
  - Relative response at the monitor will be correspondingly damped.
  - Local source-receptor relationships are typically modeled with a dispersion model like AERMOD.

Conclusions

- The CSAPR modeling links Texas to two monitors for ozone, one in Michigan and one in Louisiana, and to one site in Illinois for both annual and 24-hour $PM_{2.5}$.

- All three monitors have 2010 design values below their relevant NAAQS, but the EPA's modeling predicts nonattainment or maintenance issues in 2012. Texas would not be linked to these monitors if monitored design values were used.

Conclusions

- It is not possible to determine whether the apparent over-prediction is due to not including CAIR reductions, but the magnitude of the over-prediction suggests that other factors may be in play.

- The EPA did not assess the performance of the model response to emission reductions, but the base case under-prediction of ozone peaks at two sites suggests that the model response could be damped.

Conclusions

- The monitor in Madison County (Granite City) IL was placed near a large local source. The large grid size of the model would not allow the model to correctly estimate the response to these controls.

- Finally, using a monitor sited for local sources to assess contributions from another state is questionable. The EPA did not consider a monitor in Allegheny County, Pa for exactly this reason.

References

- US Environmental Protection Agency; Air Quality Modeling Final Rule TSD, http://www.epa.gov/airtransport/pdfs/AQModeling.pdf

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- Sonoma Technology, Inc.; Assessment of Local-Scale Emissions Inventory Development by State and Local Agencies http://www.epa.gov/ttn/chief/local_scale/sti_epa_local_scale_ei_final_report.pdf