Final Report

Emissions and Air Quality Modeling for SEMAP

Contract # S-2010-04-01

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October 15, 2014

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List of Acronyms

AIRS	Atmospheric Infrared Sounder
AMET	Atmospheric Model Evaluation Tool
AOD	Aerosol Optical Depth
AQM	Air Quality Model
BC	Boundary Conditions
BEIS3	Biogenic Emission Inventory System, version 3
CAMx	Comprehensive Air quality Model with extension
CB05	Carbon Bond—Version 2005
CEM	Continuous Emissions Monitor
CEMPD	Center for Environmental Modeling for Policy Development
CENRAP	Central Regional Air Planning (association)
CIRA	Cooperative Institute for Research in the Atmosphere
CMAS	Community Modeling and Analysis System
CMAQ	Community Multiscale Air Quality
CTM	Chemistry-Transport Model
DDM	Decoupled Direct Method
DVC	Current Year Design Value
DVF	Future Year Design Value
EC	Elemental Carbon
EGU	Electrical Generating Unit
EMP	Emissions Modeling Platform
FAQS	Fall-line Air Quality Study
FB	Fractional Bias
FE	Fractional Error
GIS	Geographic Information System
GIT	Georgia Institute of Technology
HAP	Hazardous Air Pollutant
IC	Initial Conditions
IDT	Interactive Database Tool
I/O API	Input/Output Applications Programming Interface
IMPROVE	Interagency Monitoring of Protected Visibility Environments
JFSP	Joint Fire Science Program
MAQSIP	Multiscale Air Quality Simulation Platform
MAT	Modeled Attainment Test
MCIP	Meteorology-Chemistry Interface Processor
MEGAN	Model of Emissions and Gases from Nature
MSA	Metropolitan Statistical Area
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NATA	National-scale Air Toxics Assessment
NCDAQ	North Carolina Division of Air Quality
NEI	National Emissions Inventory

netCDF	network Common Data Form
NIF	National Inventory Format
NMIM	National Mobile Inventory Model
NMOC	Non-Methane Organic Compounds
OAQPS	Office of Air Quality Planning and Standards
OC	Organic Carbon
ORD	Office of Research and Development
ORL	One-Record-per-Line
OSAT	Ozone Source Apportionment Technology
OTAQ	Office of Transportation and Air Quality
PAMS	Photochemical Assessment Monitoring Stations
PAVE	Package for Analysis and Visualization of Environmental Data
PM	Particulate Matter
PPTM	Particle and Precursor Tagging Methodology
PSAT	PM Source Apportionment Technology
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RDBMS	Relational Database Management System
RFP	Request for Proposal
ROSES	Research Opportunities in Space and Earth Sciences
RPO	Regional Planning Organization
RRF	Relative Reduction Factor
SAMI	Southern Appalachian Mountains Initiative
SANDWICH	Sulfates, Adjusted Nitrates, Derived Water, Inferred Carbonaceous Mass and estimated aerosol acidity (H+)
SDBMS	Spatial Database Management System
SEARCH	Southeastern Aerosol Research and Characterization Study
SEMAP	Southeastern Modeling Analysis and Planning
SERDP	Strategic Environmental Research and Development Program
SLAMS	State and Local Air Monitoring Stations
STN	Speciated Trends Network
TAWG	Technical Analysis Work Group
UNC	University of North Carolina
VIEWS	Visibility Information Exchange Web System
WRAP	Western Regional Air Partnership

Document Change Record

Revision	Date	Remarks
0.1	October 15, 2010	Draft version for SESARM review
0.2		Revised version after SESARM review
1.0		Final version

Chapter 1: Project Overview

1.1 Introduction

In 2009, SESARM initiated a new Southeastern Modeling, Analysis and Planning (SEMAP) project to produce technical analyses to aid member states, in the development of SIPs for O_3 and $PM_{2.5,}$ and in the demonstration of reasonable progress for the regional haze rule, required under the Clean Air Act Amendments. Specifically, since the precursor emissions and some of the atmospheric chemical processes are interlinked in the way one can control the chemical formation for fine particles, ozone and regional haze, an integrated assessment using a one-atmosphere modeling approach is needed to address the air pollution problems in the SESARM states. It is anticipated that this analysis will help the SESARM state agencies to protect human health as well as the environment from the impacts of air pollutants.

To address the air quality and emissions modeling needs of the SEMAP project, Georgia Institute of Technology Environmental Engineering Department (Georgia Tech), the University of North Carolina Institute for the Environment (UNC) and the Colorado State University Cooperative Institute for Research in the Atmosphere (CSU) formed a team. The work was performed under a contract (Contract # S-2010-04-01 executed on April 13, 2010 and its 9 amendments) between SESARM and Georgia Tech, the lead organization, and Georgia Tech subcontracts to UNC and CSU. Dr. Talat Odman from Georgia Tech acted as the project principal investigator. Mr. Zac Adelman from UNC and Mr. Shawn McClure from CSU were the co-investigators. They were joined by a large number of investigators and staff from all three institutions to perform the tasks of this project.

This document presents the final report for the project. Its intent is to describe the methods and approaches that were used in the project and to present the results. After a brief introduction of the key personnel in leading roles, the tasks performed will be summarized in this first chapter. The task descriptions contain a list of related deliverables and information on how to reach them. Chapter 2 is a complete documentation of the emissions modeling performed in this project. The emissions that were prepared for subsequent air quality modeling are documented in detail. Three chapters are devoted to the air quality modeling pieces. The performance of the air quality model is evaluated in Chapter 3. The air quality simulation of the year 2018 is documented and projected ozone, $PM_{2.5}$ and haze levels are presented in Chapter 4. Finally, the sensitivity of ozone to NO_x and VOC emissions is addressed in Chapter 5.

1.2 Key Personnel and Roles

1.2.1 Georgia Institute of Technology (Georgia Tech)

Dr. Talat Odman, Principal Research Engineer in the School of Civil and Environmental Engineering at Georgia Institute of Technology, was the Project Manager and Principal Investigator.

Dr. Yongtao Hu, Senior Research Scientist in the School of Civil and Environmental Engineering was the Air Quality Model and Data Manager.

1.2.2 University of North Carolina (UNC)

Mr. Zachariah Adelman, Research Associate at the UNC Institute for the Environment, was the UNC Project Manager and Co-Principal Investigator in charge of Emissions Data Management.

Dr. Saravanan Arunachalam, Research Associate Professor at the UNC Institute for the Environment, was the Air Quality Data Manager.

Dr. Adel Hanna, Research Professor and the Director of the Center for Environmental Modeling for Policy Development (CEMPD) of the Institute for the Environment at UNC, was the Quality Assurance Manager.

Ms. Uma Shankar, Research Associate at the UNC Institute for the Environment**,** was the Observavational Data Manager.

Dr. Aijun Xiu, Research Associate at the UNC Institute for the Environment, was the Meteorology Data Manager. .

Ms. Jeanne Eichinger, Senior Technical Editor for the UNC Institute for the Environment, was the Documentation and Deliverables Manager.

1.2.3 Colorado State University (CSU)

Mr. Shawn McClure, Software Engineer for the Cooperative Institute for Research in the Atmosphere (CIRA), was the CSU Project Manager and Co-Principal Investigator in charge of Interactive Database Tool and Technical Website development.

1.3 Tasks Performed

This section presents an overview of the work performed. The project was broken into 16 tasks. The overview of each task starts with the name of the task leader who was responsible for the technical oversight as well as managing the performance and deliverables for the task. A brief statement of the objectives of the task is followed be a summary of the technical approach used to accomplish those objectives. Finally, the list of deliverables under each task is presented along with information on where to find them.

1.3.1 Task 1: Project Management

Our team used a matrix of project managers, task technical leaders, data managers, and technical staff to satisfy the planning, documentation, and technical requirements of this contract. Dr. Talat Odman from Georgia Tech served as the principal technical leader and overall project manager. Mr. Zac Adelman from UNC served as the project co-investigator managing the modeling, development, and evaluation work at UNC. Ms. Jeanne Eichinger of UNC served as the documentation coordinator for the entire project. Senior members of the project team served as data managers for each of the key data components collected and generated during the SEMAP project. As curators of the project data, the data managers were responsible for the acquisition and initial screening of model input data and observational data, confirming that they are the correct data for the SEMAP project modeling grids and time periods. They also supervised the quality control (QC) of the data generated during the project, ensuring the generation and utilization of quality assurance (QA) products. Finally the data managers were responsible for the archival, transfer, and documentation of their data.

Communication with the Project Coordinator, SEMAP Technical Analysis Work Group (TAWG) and other SESARM contractors was accomplished through conference calls. Other project management activities included responding to questions raised by the SEMAP Project Coordinator or other project participants; coordination of all members of the project team to assure the timely flow of data and delivery of products, tracking and reporting progress and making sure that the SEMAP project schedule is followed; reporting problems and concerns, along with options for solutions, to the SEMAP Project Coordinator; identifying resources for revisions and additional work.

1.3.1.1 Final Project Work Plan

The objective of the project work plan was to ensure that the SEMAP project objectives are understood completely and accurately, and that measures aligned to EPA guidance are taken to achieve those

objectives on time and within budget. A draft work plan was developed describing the methods and approaches to be used in the project, including information about the products and software tools that will be employed for evaluation as well as the emissions and air quality modeling website that will be developed. Team leaders, deliverables and schedule were specified for each task. The projected levels of effort and associated costs were also included. The work plan was finalized by incorporating the direction received from SESARM. The final version is available at: http://www.ie.unc.edu/cempd/projects/SEMAP/secure/documents/PWP_SEMAP_DRAFT_4-27-10_UNC_CIRA_Gatech.pdf.

1.3.1.2 Quality Assurance Project Work Plan

The overall objective of the Quality Assurance Project Plan (QAPP) is to ensure that deliverables are of sufficient quality to support their intended use by SESARM and participating agencies. The deliverables can include, but are not limited to datasets (including modeling inputs/outputs), software documentation, presentations, technology transfer efforts, and all forms of communication. We prepared a draft plan and revised it twice: once after SEMAP internal review and a second time after US EPA review. The EPA approved quality assurance project plan is available at:

http://www.ie.unc.edu/cempd/projects/SEMAP/secure/documents/QAPP_SEMAP_DRAFT_5-10-10.pdf.

1.3.2 Task 2: Modeling Protocol

The objective of this task was to establish a living document that describes the data, methodologies, and techniques used to conduct, complete, and document all modeling and evaluation tasks in the SEMAP modeling project. We prepared an initial version of the emissions and air quality modeling protocol. The protocol described all aspects of the data collection, modeling, evaluation, and archival that will be conducted during the SEMAP project, including:

- The technical modeling approach
- Evaluation of methods and techniques for thoroughly and efficiently analyzing large amounts of data
- Recommended model configurations
- Emissions processing methods and data sources
- Ancillary emissions data configuration, (e.g. sources and evaluation of temporal, chemical speciation, and spatial surrogate data)
- Vegetation and land use data
- Development of initial and boundary conditions
- Chemistry parameters/chemical mechanism configurations
- Vertical diffusivity parameters
- Computer resources
- Project schedule
- Quality assurance procedures for each task, including procedures for identifying and correcting errors
- Observational data sets to be used for model performance evaluations and additional analyses

The protocol was revised during the course of the project based upon feedback from SESARM, and based upon other developments during the modeling. For instance, the results from one diagnostic sensitivity

simulation provided the motivation for performing another sensitivity that was not originally planned. To address the needs of a 'living' document as discussed above, we posted the modeling protocol on a Wiki, which facilitates collaborative modification as well as being able to track the changes over time. The Wiki can be reached at:

http://www.airqualitymodeling.org/semapwiki/index.php?title=Main_Page

We implemented the methods and techniques described in the modeling protocol to guide the data handling, modeling, and evaluation of all work conducted on the SEMAP project.

1.3.3 Task 3: Data Acquisition/Dataset Preparation for Modeling and Evaluation

This task was divided into subtasks for each of the different classes of data used in the SEMAP project. The subsections below describe the detailed approaches used to acquire and prepare each dataset for modeling and evaluation.

1.3.3.1 Emissions

We developed a collection of emissions modeling platforms (EMPs) for the SEMAP modeling project. An EMP is a collection of data and modeling tools needed to simulate emissions in support of air quality modeling studies. In addition to being useful for organizing emissions modeling tasks, EMPs provide a clean method for packaging and distributing all of the data and scripts needed to reproduce an emissions simulation. We acquired the appropriate emissions inventory data to run and evaluate the air quality modeling, including:

- 2007 emissions data for the SEMAP states
- Future year emissions data for the SEMAP states
- 2007 emissions data for the non-SEMAP states
- Future year emissions data for the non-SEMAP states
- 2007 emissions data for Canada and Mexico
- The gridded land use and emission factor data

From these inventories we prepared the following EMP's to support the air quality modeling:

- Actual 2007
- Typical 2007
- 2018 Baseline

A detailed description of the emissions inventory data used and the EMPs developed in this project can be found in Chapter 2.

1.3.3.2 Meteorology

We acquired the Weather Research and Forecasting (WRF) model output data from SESARM and processed them with the Meteorology-Chemistry Interface Processor (MCIP) for input to the emissions and quality modeling.

1.3.3.3 Initial and Boundary Conditions

GEOS-Chem based initial and boundary conditions were acquired from the SEMAP project coordinator, quality assured and prepared for CMAQ simulations.

1.3.3.4 Ambient Air Quality Data

The ambient air quality data that was used for evaluating model performance are summarized in Table 1-1. The networks providing these data are described below.

Table 1-1. Ambient air quality data available for model performance evaluation and input to receptor models for the Southeast.

Variable	Averaging time	Networks
PM_{10}	daily, hourly	AIRS, IMPROVE, SEARCH
$PM_{2.5}$	daily, hourly	AIRS, IMPROVE, SEARCH
Sulfate	daily, hourly, weekly	AIRS, IMPROVE, SEARCH, CASTNet
Nitrate	daily, hourly	AIRS, IMPROVE, SEARCH
Ammonium	daily, hourly, weekly	AIRS, SEARCH, CASTNet [(a)]
EC (BC)	daily, hourly	AIRS, IMPROVE, SEARCH
OC	daily, hourly	AIRS, IMPROVE, SEARCH
Trace Metals in $PM_{2.5}$	daily	AIRS, IMPROVE, SEARCH
NO, NO_2 and NO_y	hourly	AIRS, SEARCH
SO_2	hourly, daily, weekly	AIRS, CASTNet, IMPROVE, SEARCH
VOCs, HAPs	hourly	AIRS, SEARCH [(b)]
Total Nitrate [I]	daily, weekly	CASTNet, SEARCH

(a) Ammonium data from IMPROVE are estimated from sulfate and nitrate based on complete neutralization of those ions. Independent measurements from CASTNet are more appropriate for model evaluation purposes

(b) ARIES program measures HAPs and other VOCs at the SEARCH sites in Atlanta, GA area.

(c) CASTNet weekly measurements of PM nitrate and HNO_3 will be evaluated as total nitrate due to issues relating to filter-based methods to collect volatile nitrate species.

AIRS: AIRS compiles and provides access to datasets from multiple national observational networks/programs including STN, SLAMS and PAMS. The STN network provides 24-hr measurements of $PM_{2.5}$ and its composition. The SLAMS network provides hourly measurements of criteria air pollutants including $PM_{2.5}$, PM_{10}, O_3, SO_2, NO_2, CO etc. The PAMS network measures photochemical smog related species such as O_3, NO, NO_2, NO_y, NMOC, and VOC compounds in non-attainment areas.

IMPROVE: IMRPOVE includes measurements of chemical constituents of $PM_{2.5}$ as well as related gaseous species at Class I areas.

CASTNet: CASTNet provides dry and wet acid deposition at rural sites as well as ozone and chemical constituents of $PM_{2.5}$.

SEARCH: SEARCH provides continuous and speciated PM data in one urban and one rural location in Alabama, Georgia, Florida and Mississippi. In addition to 24-hr PM mass (fine and coarse) and composition (EC, OC, sulfate, nitrate, ammonium and metals) SEARCH provides hourly PM mass and ion components (BC, OC, sulfate, nitrate, ammonium) and a wide range of complementary gaseous species (O_3, NO, NO_2, NO_y, HNO_3, SO_2, CO, CO_2).

1.3.4 Task 4: Conceptual Description

The objective of this task was to develop a qualitative characterization of the nature of the ozone, $PM_{2.5}$, and regional haze problem in the SEMAP region. We gathered all readily available information from the SEMAP states and other sources. This included design values for monitors in the Southeast, speciated PM data, best/worst visibility day information, emissions information, and answers to questions in Chapter 11 of EPA's *Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze (April 2007)*. Results from previous modeling studies in the region included daily air quality forecasts since 2006 [*Odman et al.*, 2007b], the emission sensitivity modeling for VISTAS and analyses of the sources of O_3, PM, and haze problems in the region [*Odman et al.*, 2007a]; [*Odman et al.*, 2009]. We reviewed these results to better understandthe nonattainment problem in terms of urban versus rural areas and coastal, inland and mountain areas in the SEMAP region. We prepared a draft interim conceptual description report according to EPA Guidance and finalized it after SEMAP TAWG review. This report can be found at:

http://semap.ce.gatech.edu/sites/default/files/files/final_conceptual_description_v1.1.pdf

1.3.5 Task 5: 36 km/12 km Emissions/AQ Annual Actual Base Year Simulations

The objective of this task was to develop a final annual "actual" 2007 base year air quality model simulation on 36-km and 12-km resolution modeling grids (Figure 1-1). This was accomplished by performing and evaluating the following two annual simulations:

- 2007 Actual – Initial SMOKE & Initial CMAQ (to be performed before Task 6)
- 2007 Actual – Final SMOKE & Final CMAQ (to be performed after Task 6)

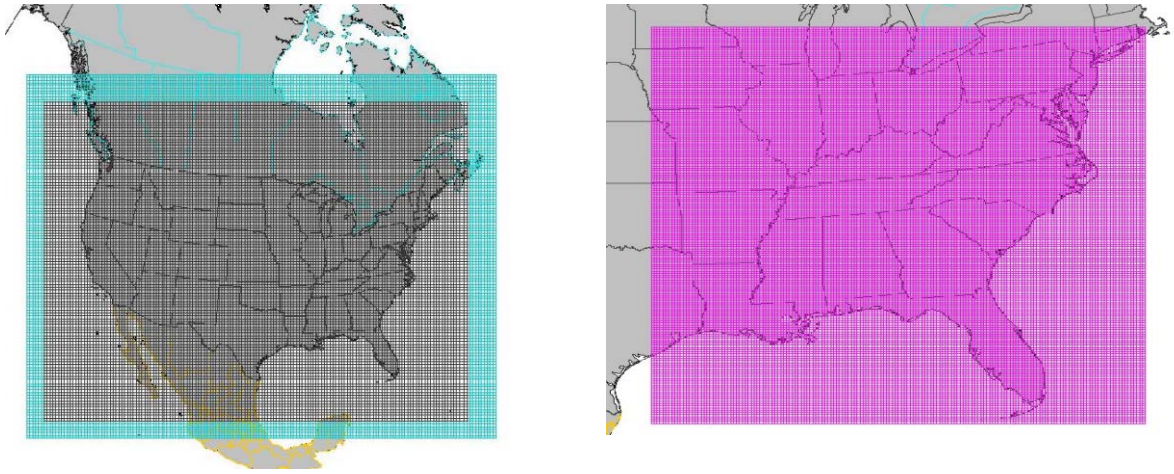


Figure 1-1. 36-km (left) and 12-km (right) SEMAP air quality modeling grids

We used the "Actual 2007" emissions modeling platform (EMP) developed in Task 3 with SMOKE version 2.6 and version 3.0 to prepare emissions inputs for CMAQ. The initial "Actual 2007" simulation was performed using CMAQ version 5.0.1 with the configuration shown in Table 1-2 and the following runtime options:

1) Windblown dust: NO

2) Lightning NO_x: Inline informed by lightning detection network data. [1]
3) In-line deposition velocities: YES
4) Ammonia bi-directional flux: NO[2]
5) Surface HONO interaction: YES[3]
6) BEIS or MEGAN for biogenic emissions: BEIS
7) In-line biogenic emissions: NO
8) In-line plume rise: YES

The CMAQ model configuration was modified after the diagnostic sensitivity tests in Task 6 below for the final "Actual 2007" simulation.

Table 1-2. CMAQ configuration options

Model Parameter	**CMAQ_v5.0**
Horizontal Advection	Yamartino (hyamo)
Vertical Advection	WRF (vwrf[4])
Horizontal Diffusion	Multiscale
Vertical Diffusion	Advanced Convective Method (ACM2)
Gas Chemistry Mechanism	CB05 with Chlorine (cb05tucl_ae6_aq[5])
Gas Chemistry Solver	Euler Backward Iterative (ebi_cb05tucl)
Aerosol Mechanism	CMAQ 6th Generation (aero6[6])
Clouds/Aqueous Chemistry	ACM clouds with aero6 (cloud_acm_ae6)
Plume in Grid	none

Quality of emissions inputs to CMAQ was assured through a systematic process. In addition to generating quality assurance reports that summarize annual and typical ozone season day emissions by county, pollutant, and SCC for all states and countries in the SEMAP modeling domain, we produced time series, spatial plots, and vertical profiles of the emissions results to aid in the QA/QC and evaluation of the SMOKE output. Figure 1-2 shows an example of 3 types of plots that are automatically generated using the emissions QA/QC tool used in the SEMAP project. Quality of the air quality simulations was assured through visualization of the modeling results and the model performance evaluation under Task 10.

[1] We used the monthly flash count frequency (flash / m^2) file that EPA prepared for the CONUS 12-km grid.
[2] Investigating the difference in NH_3 emissions this option would create over those already in use is a research project that may not fit well into the modeling schedule.
[3] HONO is produced via heterogeneous reaction on ground surfaces. This used to affect NO_2 deposition in prior versions but not anymore.
[4] First the change in column mass is computed and then the vertical velocity is computed layer-by-layer using the horizontal mass divergence.
[5] Updated toluene chemistry and reactions of toluene and xylene with chlorine
[6] PM-other speciation includes non-carbon organic matter and metals. Primary organic carbon is aged. ISORROPIA v1.7 is replaced with ISORROPIA v.2.1 which treats the thermodynamics of crustal material.

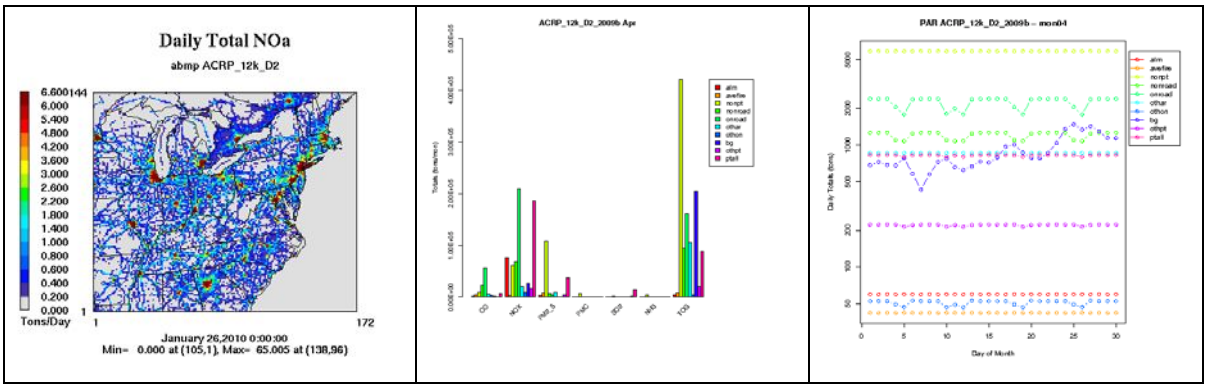


Figure 1-2. Example SMOKE emissions analysis products: (Left) daily tile plot; (Center) pollutant bar chart; (Right) monthly inventory sector time series

Two drives were prepared all the inputs and outputs of the "Actual 2007" SMOKE and CMAQ simulations. A detailed discussion of the "Actual 2007" emissions can be found in Chapter 2. The results of the "Actual 2007" simulations are summarized in Chapter 3.

1.3.6 Task 6: Model Configuration Diagnostic Sensitivity Modeling

Diagnostic sensitivity modeling was performed to determine the final model configuration that will be used in 2007 typical and future year simulations as well as emissions sensitivity modeling. These diagnostic tests and the final model configuration are described in Chapter 3.

1.3.7 Task 7: Emissions and Air Quality Benchmark Simulations

We created a custom data transfer and benchmarking protocol for the SEMAP project, where we incorporated the following steps:

a) Verify the computing architecture (OS, processors), compiler versions available

b) Install netCDF, I/O API

c) Install and run SMOKE for a 5-day period

d) Install and run CMAQ for a 5-day period

e) Install and run CAMx for a 5-day period

f) Compare outputs from above with the outputs created by the SEMAP project modeling team as part of Task 5, and generate paired statistics.

In this protocol, we included detailed step-by-step instructions for each of the above and discussed steps to ensure that the model outputs (from the Georgia Tech/UNC runs) are reproducible within reasonable bounds. Further, we provided explicit instructions to ensure that the model versions, associated libraries, and compilers used for the Georgia Tech/UNC modeling are documented. Along with this protocol, we provided an archive (Linux tar file) that includes all of the code and scripts that the Georgia Tech/UNC modelers used for the SEMAP simulations. We included a README file along with this archive to distinguish between the various scripts and possible iterations that the team went through during the course of the project. The SMOKE and CMAQ archives and their README files can be downloaded from the SEMAP ftp site at CSU.

- SMOKE software tar file and the README file:
  - ftp://viking.cira.colostate.edu/SEMAP/Benchmark/SMOKE/SEMAP_SMOKE_Benchmarking_README_v09-14.pdf
  - ftp://viking.cira.colostate.edu/SEMAP/Benchmark/SMOKE/SEMAP_SMOKE_Benchmark_Software_v0914.tar.gz
- CMAQ script/code archive and Benchmark and the README file:
  - ftp://viking.cira.colostate.edu/SEMAP/Benchmark/CMAQ/SEMAP_CMAQv5.0.1_Benchmark_Software_v0914.tar.gz
  - ftp://viking.cira.colostate.edu/SEMAP/Benchmark/CMAQ/SEMAP_CMAQ_Benchmarking_README_v09-14.pdf

1.3.8 Task 8: 36 km/12 km Annual Typical/Future Year Emissions AQ Modeling

The emissions modeling platforms (EMPs) for the typical and future year emissions data prepared by UNC under Task 3 were combined with the actual 2007 meteorology and BCs used in Task 5 to simulate typical and future year air quality with CMAQ. The same SMOKE configuration, including the use of representative days to optimize the emissions processing tasks, was applied to the typical and future year simulations. We used the final CMAQ model configuration from Task 5 to perform the annual simulations for this task on both SEMAP modeling grids..

Various analysis products were produced for the typical and future year simulations conducted here and posted to the project web site. Some of them can also be found in Chapter 3 (typical 2007) and Chapter 4 (2018 future year). In addition to the plots and statistics of the typical and future year simulations, we also produced analysis products comparing the future year results to the typical year simulation results.

1.3.9 Task 9: Emission Sensitivity Modeling

This task, which was planned to include source apportionment simulations and sensitivity simulations both with the Direct Decoupled Method (DDM) and the "Brute Force" method, was cancelled. Later, under Task 15, we performed 28 emission reduction simulations with CMAQ using the 12-km SEMAP grid during the 5-month O_3 season. We analyzed the responses of 8-hour maximum O_3 to 30% reductions of NO_x and VOC emissions from the SESARM states and the neighboring RPOs.

1.3.10 Task 10: Model Performance Evaluation

The objective of this task was to evaluate the performance of the CMAQ model for O_3, $PM_{2.5}$ and regional haze in the 2007air quality simulations over the 12-km SEMAP domain, using a suite of comparisons of model outputs against ground-based observations. We calculated various model performance metrics and generated several types of graphics depicting model performance using the procedures identified in the Quality Assurance Project Plan (Task 1) and the Modeling Protocol (Task 2). We performed model performance evaluations for all 2007 simulations, including "Typical 2007". We provided all of the analyses described in Attachment A of the contract. Version 2.0 of the Atmospheric Model Evaluation Tool (AMET) was used to produce the analyses in the form of tables and graphic displays needed for this task. AMET offers the high degree of automation required to handle the large number of analyses listed in Attachment A.

All model performance metrics and graphics employed in this project are illustrated in Chapter 3 and the full set of performance evaluation products can be found on the project technical website.

1.3.11 Task 11: Future Year Model Projections

The objective of this task was to demonstrate progress towards regulatory goals for O_3, $PM_{2.5}$ and regional haze. The U.S. EPA guidance (U.S. EPA, 2007) for demonstrating modeled attainment of air quality goals for O_3, $PM_{2.5}$ and regional haze prescribes an approach to use model outputs in a relative sense. In

this guidance, the attainment test methodology uses model outputs and ambient data to estimate future year concentrations. Specifically,

1. Relative Reduction Factor (RRF) = Model predicted change (in %) from base year to future year
2. Future Year Design Value (DVF) = Base Year Design Value (DVC) X RRF

This procedure is fairly straightforward for O_3, since there is only one component, and no speciation is involved. However, for $PM_{2.5}$ and the regional haze reasonable progress, the attainment test needs to use all the $PM_{2.5}$ species, where the RRFs need to be calculated for each individual $PM_{2.5}$ speciated component, and total $PM_{2.5}$ is reconstructed from the sum of all $PM_{2.5}$ components. This procedure called the Speciated Modeled Attainment Test (SMAT) can be directly applied where speciated $PM_{2.5}$ information is available. Since FRM monitors are the only ones that can be used to demonstrate attainment, the SMAT process can be applied relatively easily if the FRM monitors have collocated STN monitors. However, speciated information is not available at most FRM locations. Further, the measurements collected at the STN and IMPROVE monitors are not directly comparable to FRM measurements. To give a rough idea of this discrepancy, there are ~1200 FRM monitors in the country, but only ~250 STN and ~165 IMPROVE monitors, and over 75% of the FRM monitors do not have a collocated STN monitor. Figure 1-3 shows a map of the U.S. with the locations of the various monitors.

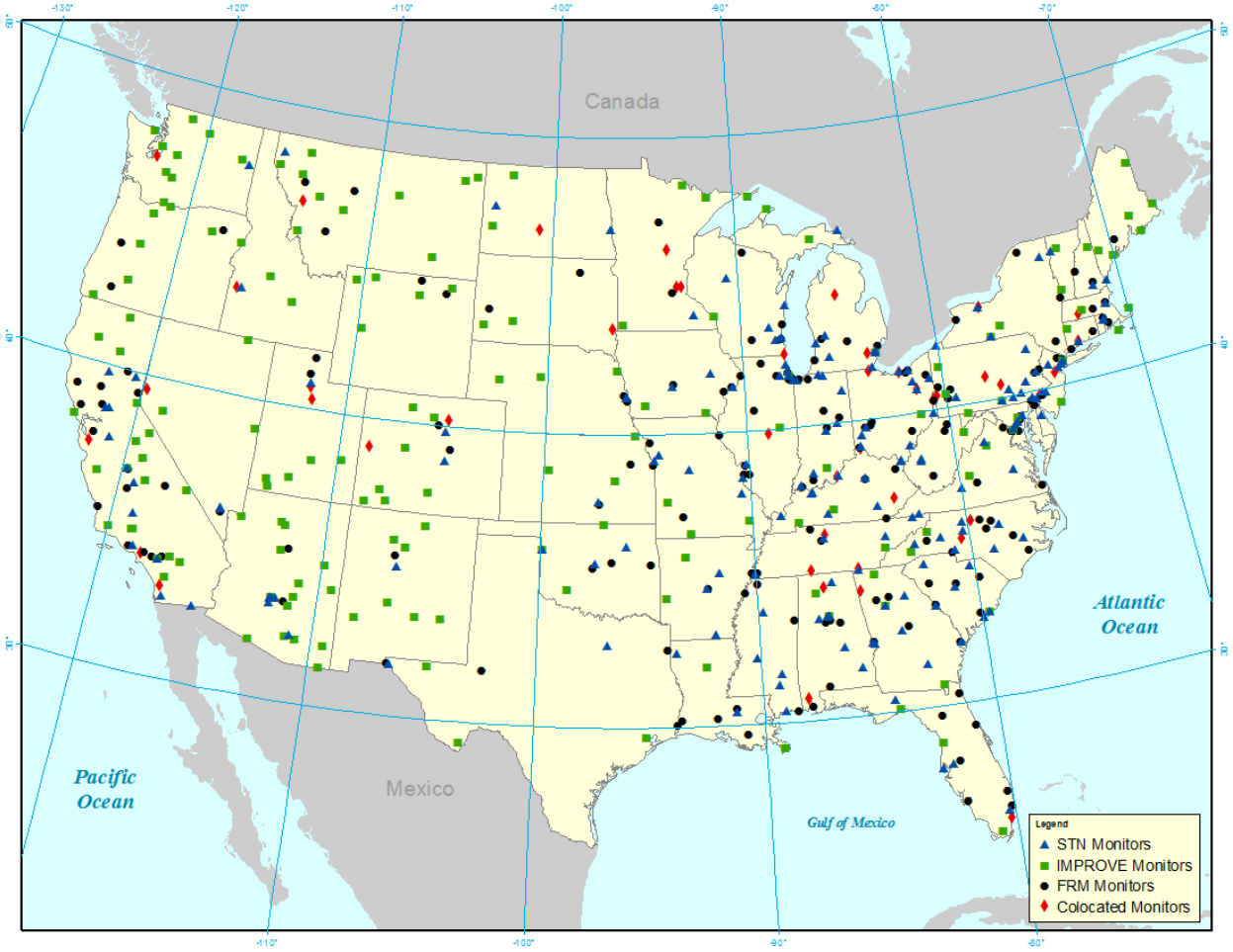


Figure 1-3. Location of various $PM_{2.5}$ monitors in the U.S. for SMAT

We applied the Modeled Attainment Test Software (MATS) [*Abt Associates*, 2009] to the 2018 future year in comparison to the 2007 typical base year, and computed RRFs and DVFs for O_3, $PM_{2.5}$ and for regional haze rate of progress. We computed DVFs at all monitoring locations, and also used the gradient adjusted interpolation option within MATS to perform this analysis at the unmonitored locations within the modeling domain.

We developed visual outputs of the DVFs for O_3, $PM_{2.5}$ and posted them to the project's technical website at Georgia Tech (http://semap.ce.gatech.edu/node/1851). Some of these products can also be found in Chapter 4. Regional haze projections were used by SEMAP in the glide slopes for evaluating the rate of progress towards regional haze goals on the best 20% and worst 20% visibility days. MATS inputs and outputs can be found at http://semap.ce.gatech.edu/node/1852 as well as on the SEMAP-CMAQ drive.

1.3.12 Task 12: Interactive Database Tool

An interactive database tool was developed to allow the SEMAP states to easily review, compare, and make assessments of the emissions and air quality modeling results. The development was largely leveraged by the database and website infrastructure of the VIEWS/TSS system, which were tailored to the needs of the SEMAP end users.

1.3.12.1 Raw Data and Metadata Analysis

As a first step toward importing and managing the SEMAP data to be accessed and served by the Interactive Database Tool (IDT), we identified the specific datasets and output products to be managed by the IDT and determined the best mechanisms for both initially acquiring these products as well as making updates to them over time if any revisions and/or corrections are made to the underlying data. Then we identifies the relevant subsets of both data and metadata to extract from the raw datasets for inclusion in the relational database management system (RDBMS).

Next, we acquired representative samples of each type of dataset to be managed and subsequently analyzed the internal schema of each dataset to identify and understand key aspects of both the data and metadata, such as column names, primary and candidate key fields, field lengths, value domains and ranges, data types, temporal frequencies, spatial granularity and distribution, etc. The external schema of the datasets were also studied in order to understand important characteristics such as file types (netCDF, HDF, etc), naming conventions, temporal and spatial partitioning, and expected volume. These respective schemas were then compared to the existing schema of the VIEWS/TSS integrated database in order to determine the nature and extent of any modifications and/or extensions that were necessary to accommodate the SEMAP data. The entire process of understanding the schema of the SEMAP data and making any necessary extensions to the VIEWS database had to be handled as a cyclic process consisting of several iterations, depending upon the timing with which various datasets become available as modeling proceeded.

1.3.12.2 Database Design and Enhancement

When this inventory of target SEMAP data has been completed, we extended the schema of its relational and geospatial databases to accommodate the management of the data. To make these extensions, 1) database tables were defined and/or extended with the appropriate fields, data types, default values, and other specifications as necessary, 2) primary and candidate keys were determined for each modified table, 3) appropriate relationships and cardinality were defined between entities, and 4) the resulting entities and fields were normalized into at least 3rd Normal Form. The existing set of database codes, conventions, and lookup tables used in the database swere extended as necessary to serve the SEMAP data. In addition, the operational and administrative infrastructure of the VIEWS database were enhanced to accommodate the increased density and volume of the SEMAP data. We 1) built appropriate table indexes, 2) developed inserted, updated, and deleted logic as needed, 3) implemented triggers and user-defined functions as

indicated, 4) and created data definition language (DDL) scripts for managing and maintaining the database schema over time.

In preparation for actual data import, we developed the SQL stored procedures, scripts, and any associated program code for importing the data from its native format and transforming it into the integrated database schema. These operations included 1) the bulk import of data into as-is tables, 2) removal of any unnecessary native fields, 3) renaming and/or reorganizing of the source data columns, and 4) "pivoting" of source fields into the normalized schema. We also developed procedures and policies for verifying basic data integrity and completeness, such as SQL scripts to tally and compare checksums of the raw versus imported data to identify and correct any discrepancies.

1.3.12.3 Development of Interactive Database Tool

After the database has been appropriately enhanced, existing tools were extended in order to facilitate the creation of an IDT capable of providing online exploration, visualization, and analysis, of the SEMAP project data. Existing tools were examined to determine the optimal way to extend and possibly consolidate their user interface (UI) with the textual cues, selection items, and HTML controls that are relevant. These enhancements were implemented in a manner commensurate with current web UI design guidelines, and the IDT was developed as necessary to provide integrated, seamless access to the SEMAP data. The IDT was designed to interact directly with the database and generate a variety of dynamic graphs, charts, plots, and maps. In particular, the VIEWS Query Wizard, Trends and Composition tools, Dataset Index, Site Browser, Image Browser, File System Browser, and Data Statistics tool were enhanced to provide seamless access to the SEMAP data and generate the appropriate output products. This enabled SEMAP IDT users to visualize and compare existing ground-based measurements, modeled data, and emissions inventories by using an integrated suite of tools that have already been tested and proven useful by a large community of users with similar goals and needs.

1.3.13 Task 13: Receptor Modeling

This task was cancelled.

1.3.14 Task 14: Development of Technical Web Site

1.3.14.1 Web/FTP Site Development

The purpose of the technical web site is to serve as the primary means for distributing emissions and air quality modeling results, data, and documentation to the SEMAP TAWG and SESARM states. Team member CSU created a website that is easy to understand, navigate, and interact with (http://views.cira.colostate.edu/SEMAP/).

1.3.14.1.1 Development of the Technical Website

The relevant tools previously developed for the VIEWS website have been modified to SEMAP project specifications and existing technologies and software infrastructure were leveraged to create a separate and distinct website with a SEMAP-specific logo, theme, and style. The lessons learned from the development of the VIEWS/TSS websites were applied to improve the features and operation of the SEMAP website.

The website is hosting the tools for serving the specific needs of the SEMAP end users. The technical web site is designed to serve as the primary means for 1) distributing and evaluating the emissions and air quality modeling results and summaries and 2) communicating the corresponding documentation to the SEMAP TAWG. The web site was organized so that SEMAP states can easily navigate through large amounts of data to quickly find information relevant to their specific areas of interest. In addition, the IDT and other website tools were designed to enable SEMAP users to easily locate and download arbitrary

subsets of the data and relevant products to their local hard drives. To facilitate this, appropriate records were added to the VIEWS "meta-base" to ensure that the user would be able to easily identify the individual SEMAP datasets that are available through both the website and the FTP site. In addition, the various HTML selection controls used on the website pages were checked to make sure that the new metadata records are presented intuitively. Names and codes for the datasets were refined until collaborators agreed that it is straightforward for the end user to browse and select the data from the website tools.

The web site incorporates a logical set of menus, dropdown lists, selection boxes, and forms that allow interactive access to any of the graphical and statistical analyses generated throughout this project. CSU-CIRA is committed to work with end users to evolve and refine the tools as necessary to provide seamless access to the SEMAP data in a manner commensurate with desired thematic guidelines and data flow practices.

1.3.14.1.2 Delivery and Transfer of the IDT and Website

The website, database, IDT, and any supporting source code or software resources are designed in such a way that the system as a whole can be transferred to the Metro 4/SESARM or any other designated server, and can subsequently be configured to be fully functional in its new environment.

1.3.14.2 Data Transfer and Archival

All essential modeling data used and produced in the above tasks has been archived using a combination of electronic transfer protocols (HTTP and FTP) and physical storage media based on the size of the data being transferred. In general, model scripts, emissions input data, observational data, and analysis products can be transferred electronically from Web/FTP sites through an intuitive interface for accessing and downloading these data. Larger datasets, including model-ready meteorology (MCIP output), SMOKE output data, and air quality modeling results (CMAQ output) were loaded onto two external USB drives and made available to the SEMAP members by mail.

Additional archives of the SEMAP project data, including the sensitivity modeling data described under Task 15 below, are available at Georgia Tech and UNC back-up systems. These data will be maintained for up to three years following the completion of the SEMAP contract. If requested, we can provide all SEMAP modeling data to the SEMAP Project Coordinator on USB drives purchased for this project.

1.3.15 Task 15: Other Tasks as Assigned

This task was originally reserved for any other work that may be added to the project after project start. It was used primarily for a redefinition of the emission sensitivity modeling under Task 9. We performed five-month ozone season simulations with the CMAQ model on the 12-km SEMAP grid for 28 different emission reduction scenarios to quantify the sensitivities of ozone to NO_x and VOC emissions. 2018 future year emissions were reduced by 30% for either anthropogenic NO_x or anthropogenic VOCs, in each of the ten SESARM states, each of the three RPO portions in the 12-km SEMAP domain, and the State of Maryland. We prepared stacked bar charts of the ozone sensitivities and posed them to the project website at http://semap.ce.gatech.edu/node/1861. A detailed discussion of this sensitivity analysis can be found in Chapter 5.

1.3.16 Task 16: Reporting

We prepared monthly reports to track the progress by project tasks. These reports were submitted to the SEMAP Project Coordinator each month. Interim technical reports were prepared at the completion of some tasks as required by the contract. We documented the data sources, methods, results, and lessons learned at the completion of each task milestone. We collated these documents into a final project report at the completion of the project.

1.4 References

Abt Associates, Inc. (2009) Modeled Attainment Test Software (MATS) User's Guide prepared for the U.S. EPA Office of Air Quality Planning and Standards, Bethesda, MD, March 2009.

Arunachalam, S., R. Mathur, Z. Adelman, D. Olerud, Jr., and A. Holland, (2001). A Comparison of Models-3/CMAQ and the MAQSIP modeling systems for Ozone Modeling in North Carolina, In Proceedings of the 94th Annual Meeting of the A&WMA, Orlando, FL, June 2001.

Baek, J., 2009: Improving aerosol simulations: Assessing and improving emissions and secondary organic aerosol formation in air quality modeling, School of Civil and Environmental Engineering, Georgia Institute of Technology, 140 pp.

Bhave, P., A. M. Carlton, S. Napelenok, T. Kleindienst, J. Offenberg, M. Lewandowski, and M. Jaoui, 2009: Evaluation of CMAQ for the Precursor-Specific Contributions to SOA in the Southeastern U.S. 8th Annual Community Modeling & Analysis System (CMAS) Conference.

Boylan and Russell, PM model performance metrics, goals, and criteria for 3-D AQMs, Atmos. Environ., 40 (26): 4946-4959, 2006.

Byun, D.W., and K.L. Schere, Review of the Governing Equations, Computational Algorithms, and Other Components of the Models-3 Community Multiscale Air Quality (CMAQ) Modeling System, J. Applied Mechanics Reviews, 59 (51), 2006.

Eberly, S. 2005. EPA PMF 1.1 User's Manual. RTP, NC: US Environmental Protection Agency.

Eder, B., D. Kang, R. Mathur, S. Yu, and K. Schere, 2006: An operational evaluation of the Eta-CMAQ air quality forecast model. Atmospheric Environment, 40, 4894-4905.

Foley, K.M., et al., Incremental testing of the community multiscale air quality (CMAQ) modeling system version 4.7, Geosci. Model. Dev. Discuss., 2, 1245-1297, 2009.

Fehsenfeld, F., et al., Emissions of volatile organic compounds from vegetation and the implications for atmospheric chemistry, Global Biogeo. Cycles, 6, 389-430, 1992.

Hand, J. L. and W. C. Malm, 2005: Review of the IMPROVE equation for estimating ambient light extinction coefficients.

Henze, D. K., and J. H. Seinfeld, Global secondary organic aerosol from isoprene oxidation, Geophys. Res. Lett., 33, L09812, doi:10.1029/2006GL025976, 2006.

Hao, W. M., D. E. Ward, R. A. Babbitt, R. E. Susott, S. P. Baker, R. Ottmar, R. E. Vihnanek, and D. Wade, 2002: Emissions of trace gases and aerosol particles from biomass fires in the southeastern and central United States. USDA Forest Service.

Hogrefe, C., S. T. Rao, P. Kasibhtla, W. Hao, G. Sistla, R. Mathur, and J. McHenry, 2001a: Evaluating the performance of regional-scale photochemical modeling system: Part II - ozone predictions. Atmospheric Environment, 35.

Hogrefe, C., S. T. Rao, P. Kasibhtla, G. Kallos, C. J. Tremback, W. Hao, D. Olerud, A. Xiu, J. McHenry, and K. Alapaty, 2001b: Evaluating the performance of regional-scale photochemical modeling system: Part I - meteorological predictions. Atmospheric Environment, 35.

Hu, Y., M. T. Odman, M. E. Chang, and A. G. Russell, 2009a: Comprehensive evaluation on air quality forecasting ability of Hi-Res in southeastern United States. 8th Annual Community Modeling & Analysis System (CMAS) Conference, 19-21 October, 2009, Chapel Hill, NC.

Jimenez, J. L., M. R. Canagaratna, N. M. Donahue, A. S. H. Prevot, Q. Zhang, J. H. Kroll, P. F. DeCarlo, J. D. Allan, H. Coe, N. L. Ng, A. C. Aiken, K. S. Docherty, I. M. Ulbrich, A. P. Grieshop, A. L. Robinson, J. Duplissy, J. D. Smith, K. R. Wilson, V. A. Lanz, C. Hueglin, Y. L. Sun, J. Tian, A. Laaksonen, T. Raatikainen, J. Rautiainen, P. Vaattovaara, M. Ehn, M. Kulmala, J. M. Tomlinson, D. R. Collins, M. J. Cubison, E. J. Dunlea, J. A. Huffman, T. B. Onasch, M. R. Alfarra, P. I. Williams, K. Bower, Y. Kondo, J. Schneider, F. Drewnick, S. Borrmann, S. Weimer, K. Demerjian, D. Salcedo, L. Cottrell, R. Griffin, A. Takami, T. Miyoshi, S. Hatakeyama, A. Shimono, J. Y. Sun, Y. M. Zhang, K. Dzepina, J. R. Kimmel, D. Sueper, J. T. Jayne, S. C. Herndon, A. M. Trimborn, R. Williams, E. C. Wood, A. M. Middlebrook, C. E. Kolb, U. Baltensperger, and D. R. Worsnop, 2009: Evolution of Organic Aerosols in the Atmosphere. Science, 326, 1525, doi:10.1126/science.1180353.

Lee, D., S. Balachandran, J. Pachon, R. Shankaran, S. Lee, J. A. Mulholland & A. G. Russell (2009) Ensemble-Trained PM2.5 Source Apportionment Approach for Health Studies. Environmental Science & Technology, 43, 7023-7031.

Napelenok, S. L., A. G. Carlton, P. V. Bhave, G. Sarwar, G. Pouliot, R. W. Pinder, E. Edney, and M. Houyoux, 2008: Updates to the Treatment of Secondary Organic Aerosol in CMAQv4.7 7th Annual Community Modeling & Analysis System (CMAS) Conference, 6-8 October, 2008, Chapel Hill, NC.

Odman, M. T., Y. Hu, A. G. Russell, A. Hanedar, J. W. Boylan, and P. F. Brewer, 2009: Quantifying the sources of ozone, fine particulate matter, and regional haze in the Southeastern United States. Journal of Environmental Management 3155-3168, doi:10.1016/j.jenvman.2009.05.028.

Odman, M. T., Y. Hu, A. Unal, A. G. Russell, and J. W. Boylan, 2007a: Determining the sources of regional haze in the Southeastern U.S. using the CMAQ model. Journal of Applied Meteorology and Climatology, 46, 1731-1743,

Odman, M. T., Y. Hu, M. E. Chang, and A. G. Russell, 2007b: Forecasting ozone and PM2.5 in southeastern U.S. Developments in Environmental Science, Volume 6, C. Borrego and E. Renner, Eds., Elsevier Ltd., 219-288.

Pinder, R.W., Dennis, R.L., and Bhave, P.V., 2007. Observable indicators of the sensitivity of PM2.5 nitrate to emission reductions - Part I: Derivation of the adjusted gas ratio and applicability to regulatory-relevant time scales. *Atmospheric Environment*, 42 (6): 1275-1286.

Russell, A. and R. Dennis, 2000: NARSTO critical review of photochemical models and modeling. Atmospheric Environment, 34, 2283-2324.

Sakulyanontvittaya, T., A. Guenther, D. Helmig, J. Milford, and C. Wiedinmyer, 2008a: Secondary Organic Aerosol from Sesquiterpene and Monoterpene Emissions in the United States. Environ. Sci. Technol., 42, 8784-8790, doi:10.1021/es800817r.

Sakulyanontvittaya, T., T. Duhl, C. Wiedinmyer, D. Helmig, S. Matsunaga, M. Potosnak, J. Milford, and A. Guenther, 2008b: Monoterpene and Sesquiterpene Emisison Estimates for the United States. Environ. Sci. Technol., 42, 1623-1629, doi:10.1021/es702274e.

Stavrakou, T., Müller, J.-F., De Smedt, I., Van Roozendael, M., van der Werf, G. R., Giglio, L., and Guenther, A., Evaluating the performance of pyrogenic and biogenic emission inventories against one decade of space-based formaldehyde columns, Atmos. Chem. Phys., 9, 1037-1060, 2009.

Tesche, T. W., R. Morris, G. Tonnesen, D. McNally, J. Boylan, and P. Brewer, 2006: CMAQ/CMAx annual 2002 performance evaluation over the eastern US. Atmospheric Environment, 40, 4906-4919.

U.S. Environmental Protection Agency (2007), Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze, EPA-454/B-07-002, Office of Air Quality Planning and Standards, RTP, NC, April 2007.

US EPA. 2004. CMB 8.2 User's Manual. RTP, NC: US Environmental Protection Agency.

Watson, J. G., J. A. Cooper & J. J. Huntzicker (1984) The Effective Variance Weighting for Least-Squares Calculations Applied to the Mass Balance Receptor Model. Atmospheric Environment, 18, 1347-1355.

Wilczak, J. M., I. Djalalova, S. McKeen, L. Bianco, J.-W. Bao, G. Grell, S. Peckham, R. Mathur, J. McQueen, and P. Lee, Analysis of regional meteorology and surface ozone during the TexAQS II field program and an evaluation of the NMM-CMAQ and WRF-Chem air quality models, J. Geophys. Res., 114, D00F14, doi:10.1029/2008JD011675, 2009.

Chapter 2: Emissions Modeling

2.1 Emissions Data, Modeling and Results

This section details the air pollution emissions data and processing approaches used to prepare emissions inputs for the SEMAP air quality model simulations. The process for creating model-ready emissions inputs includes defining the scope of the modeling study, collecting the most relevant data for the study, preparing the data for input to air quality modeling software, and performing quality assurance on both the data and preparation procedures. This process uwas led by the University of North Carolina Institute for the Environment (UNC) and began for the SEMAP project in early Summer 2010 with the initial scoping and data collection for year-2007 base case simulations. The project scope included gathering the best available year-2007 criteria pollutant inventory and ancillary emissions data for North America and preparing these for input to CMAQ. Following the 2007 base year emissions processing, UNC developed typical year, 2007-based emissions using averaged and smoothed fire inventories for the SESARM states. The emissions processing phase of the project concluded with the development of 2018 future year emissions estimates for North America. Data sources for the emissions estimates included SESARM, other Regional Planning Organizations, and the U.S. EPA. Once gathered, these data needed to be formatted for input to the Sparse Matrix Operator Kernel Emissions (SMOKE) system, concatenated into emissions processing sectors, and verified for completeness before being input to CMAQ.
SMOKE (www.smoke-model.org) is an open-source, Linux software suite for processing emissions inventory data into the formats required by gridded air quality models. The primary functions of SMOKE include:

- Inventory import – read in point source or county inventories of air pollutants and verify that all of the fields that are necessary to properly characterize emissions are present
- Gridding – allocate county or point emission inventories to model grid cells
- Speciation – convert inventory pollutants to the chemical species required by air quality models
- Temporal allocation – calculate hourly emissions from annual or daily inventory data
- Merging – combine all of the emissions for multiple inventory sectors into a single file per day in the data format required by a particular air quality model
- Reporting/Quality assurance – create tabulated summaries of the emissions that include different types of information (i.e. gridding, speciation, temporal) to use in verifying the emissions data and processing

UNC used a combination of SMOKE version 2.6 and version 3.0 for processing the emissions for the SEMAP project. SMOKE version 2.6, which was the current version of SMOKE at the start of the SEMAP modeling, was used for most of the inventory sectors other than on-road mobile. UNC used SMOKE version 3.0 to process the Motor Vehicle Emissions Simulator (MOVES) data for the base and future years. UNC developed or applied other specialized software for processing different inventory sectors, such as Continuous Emission Monitor (CEM) point sources and landing/takeoff (LTO) aircraft point sources.
UNC organized the emissions input and output datasets for the SEMAP project using Emissions Modeling Platforms (EMPs). An EMP consists of the software, scripts, and data used to develop emissions inputs for an air quality modeling simulation. For this project UNC developed the EMPs to prepare inputs to the Community Multiscale Air Quality (CMAQ) model version 5.0. EMPs are a useful construct, particularly for the distribution of emissions datasets because they organize all of the components of a simulation into a single platform. UNC developed three EMPs for the SEMAP project:

- SEMAP Base 2007 (Described in Section 2.1.2)

- SEMAP Typical 2007 (Described in Section 2.1.3)
- SEMAP Future 2018 (Described in Section 2.1.4)

Following a brief introduction to emissions data and processing, UNC will describe the details of each of these EMPs in Sections 2.1.2 through 2.1.4. Section 2.2 describes known issues or corrections made to the final SEMAP emissions results. Section 2.3 includes annual state total summaries for all of the SEMAP inventory sectors. Section 2.4 shows plots of the state total pollutant comparisons between the SEMAP 2007 and 2018 emissions results.

2.1.1 SEMAP Emissions data collection and preparation

Emissions data come in many forms and are generally based on the attributes required for characterizing particular aspects of emissions sources. Inventory data include spatio-temporal totals or averages of emissions fluxes for explicit pollution sources. In general, the SEMAP nonpoint inventories are annual county totals by source, with unique sources identified by state-county Federal Information Processing Standard (FIPS) codes and source classification codes (SCCs). The SEMAP point inventories are by stack, identified by a unique combination of FIPS code, SCC, facility code, stack code, and latitude-longitude coordinate. Additional attributes of the point inventories include stack height, exit gas temperature, and exit gas velocity. The SEMAP fire inventories are a type of point inventory and include daily acres burned and fuel loading estimates to be used for calculating buoyancy of individual fire plumes. The SEMAP project used the Motor Vehicle Emissions Simulator (MOVES) to estimate on-road mobile emissions. SESARM contractors ran MOVES (http://www.epa.gov/otaq/models/moves/) in emission-factor mode for the SEMAP project. The SMOKE-ready on-road mobile inventory data are a combination of county inventories and emissions factor look-up tables output from MOVES. The on-road mobile inventories include county total vehicle miles traveled (VMT), county-averaged speeds, and county total vehicle population (VPOP) by vehicle type and road class. The look-up tables, which are output from MOVES, contain county-level emissions factors as a function of temperature and relative humidity. Land cover data and biogenic emissions factors by land cover type were used to estimate biogenic emissions fluxes. UNC used non-inventory, or ancillary emissions data, to convert the inventories into the format required by CMAQ.

Ancillary emissions data refer to the non-inventory data used to prepare emissions for input to an air quality model, including:

- ***Spatial data.*** All anthropogenic non-point inventory data, including on-road and non-road mobile sources, are estimated at the county level. Data files called spatial surrogates are used to map the county-level emission inventories to the model grid cells. Spatial surrogates are generated from Geographic Information System (GIS) Shapefiles using software that calculates the fractions of county-level different geospatial attributes in a model grid cell. For example, a Shapefile of the housing distribution in Los Angeles County is combined with a description of a modeling grid to calculate the percentage of L.A. County housing assigned to each grid cell. This information is then used to allocate county-level emission inventory sources that are associated with housing (e.g. residential wood combustion) to the modeling grids.

- ***Temporal data.*** Air quality modeling systems, such as CMAQ and CAMx, require hourly emissions input data. With the exception of a few source types (e.g. Continuous Emissions Monitoring data, biogenic emissions and some fire inventories), most inventory data include annual or daily emission estimates. Temporal profiles are used to compute hourly emissions from the annual or daily inventory estimates. The SMOKE model uses three types of temporal profiles:

    1. Monthly profiles: Convert annual inventory to monthly emissions accounting for seasonal and other effects.

    2. Daily profiles: Convert monthly emissions to daily emissions accounting for day-of-week and other effects.

    3. Hourly profiles: Convert daily emissions to hourly emissions accounting for the diurnal variation in emissions (e.g., work schedules and commute times).

- ***Chemical speciation data.*** Emissions inventories have limited chemical composition information. The emissions inventories for SEMAP include 6 criteria pollutants: carbon monoxide (CO), nitrogen oxides (NO_X), volatile organic compounds (VOC), ammonia (NH_3), sulfur dioxide (SO_2), particulate matter with a mean diameter < 10 $\mu g/m^3$ (PM_{10}), and particulate matter with a mean diameter < 2.5 $\mu g/m^3$ ($PM_{2.5}$). Chemical speciation profiles are used to describe the chemical compositions of the effluent from particular emissions sources. The exact specification of the source-specific emissions species is determined by the chemistry mechanism selected for the AQM simulation. Speciation profiles convert the inventory pollutants to more detailed source-specific species in terms required by the AQM chemistry mechanism. For example, there is a speciation profile that converts the inventory pollutant NO_X to the AQM input species NO, NO_2, and HONO. Speciation profiles are required to convert inventory NO_X, VOC, SO_2, and $PM_{2.5}$ into AQM species. For the SEMAP emissions modeling UNC used the CB05 chemical mechanism and speciated the VOC emissions using source specific speciation profiles developed using the SPECIATE 4.3 database[7].

    Spatial surrogates, temporal profiles, and chemical speciation profiles are all assigned to inventory sources using cross-referencing data that match the profiles and inventory sources using country/state/county (FIPS) and SCCs.

2.1.1.1 2007 emissions data

The year 2007 emissions data for the SEMAP project came from several different sources. Inventory contractors on the SEMAP project produced the anthropogenic and fire inventories for the SESARM states. UNC converted the SEMAP point and non-point NIF-formatted inventories to ORL format for input to SMOKE using SQL queries built into the Access databases delivered by the SEMAP inventory contractors. The anthropogenic inventories for the non-SESARM states, Canada, and Mexico came from either Regional Planning Organizations (RPOs) or EPA in SMOKE-ready format. Figure 2-1 is a map of the RPO regions corresponding to the inventory collection efforts for the SEMAP project. In general, UNC gathered inventory data by RPO region, with a preference for data distributed by the RPOs, to build a national 2007 EMP. UNC either collected the ancillary data from EPA or developed it specifically for

[7] http://www.epa.gov/ttnchie1/software/speciate/

the SEMAP project. UNC collected biogenic emissions inputs from EPA and the National Center for Atmospheric Research.

Figure 2-1. Regional Planning Organization Map. Inventory data were collected for each RPO region to build the SEMAP EMP.

Part of the preparation process of the inventory data included splitting the data into smaller subsectors. UNC split-up many of the SEMAP inventories to support the application of source-specific parameterizations of temporal and spatial patterns, to facilitate source-based emissions sensitivities, and to support targeted quality assurance of important inventory sectors. Although anthropogenic inventories can be generally classified as point, non-point, or mobile, UNC ended up with over 30 individual anthropogenic inventory sectors in the final SEMAP EMPs. Table 2-1 is a listing of the inventory processing sectors used for the SEMAP project. The table lists the inventory processing sectors, sector abbreviation, and code identifying the sector as either area (A), mobile (M), or point (P), the temporal resolution of the inventory, and any notes about how the data were prepared for the SEMAP modeling.

Table 2-1. SEMAP emission inventory processing sectors

Inventory Sector	AMP	Temporal Resolution	Notes
Nonpoint (**nonpt**)	A	Annual	Does not contain rwc, fdust, ft, or lv sources (see below)
Residential Wood Combustion (**rwc**)	A	Annual	Meteorology-based temporal allocation
Fugitive dust (**fdust**)	A	Annual	Does not include dust transport factors
MARAMA fugitive dust (**mv_fdust**)	A	Annual	Includes dust transport factors
Fertilizer (**ft**)	A	Annual	
Livestock (**lv**)	A	Annual	Meteorology-based temporal allocation

Mexico & Canada Nonpoint (**nusar**)	A	Annual	Includes off-road mobile
Off-road mobile (**nonroad**)	A	Monthly	Does not include locomotives, airports, or commercial marine
Locomotive & Marine (**alm**)	A	Annual	
On-road mobile (**usmb**)	M	Monthly	Does not include SESARM or MANE-VU; generated from runs inventory-mode MOVES
On-road mobile running PM (**runpm**)	M	Monthly	Does not include SESARM or MANE-VU states
On-road mobile start PM (**startpm**)	M	Monthly	Does not include SESARM or MANE-VU states
SESARM MOVES rate-per-distance (**sesarm_rpd**)	M	Annual and monthly	Does not include VA; monthly MOVES emission rate look-up tables
SESARM MOVES rate-per-profile (**sesarm_rpp**)	M	Annual and monthly	Does not include VA; monthly MOVES emission rate look-up tables
SESARM MOVES rate-per-vehicle (**sesarm_rpv**)	M	Annual and monthly	Does not include VA; monthly MOVES emission rate look-up tables
Virginia MOVES rate-per-distance (**va_rpd**)	M	Annual and monthly	VA-only from SESARM MOVES runs; monthly MOVES emission rate look-up tables
Virginia MOVES rate-per-profile (**sesarm_rpp**)	M	Annual and monthly	VA-only from SESARM MOVES runs; monthly MOVES emission rate look-up tables
Virginia MOVES rate-per-vehicle (**va_rpv**)	M	Annual and monthly	VA-only from SESARM MOVES runs; monthly MOVES emission rate look-up tables
MANE-VU MOVES rate-per-distance (**manevu_rpd**)	M	Annual and monthly	Does not include VA; gridded 12-km hourly SMOKE output
MANE-VU MOVES rate-per-profile (**manevu_rpp**)	M	Annual and monthly	Does not include VA; gridded 12-km hourly SMOKE output
MANE-VU MOVES rate-per-vehicle (**manevu_rpv**)	M	Annual and monthly	Does not include VA; gridded 12-km hourly SMOKE output
Mexico & Canada on-road mobile (**nusmb**)	A	Annual	
Airport points (**airpt**)	P	Annual	Modified by UNC to include stack-heights for landing-takeoff sources
SESARM point fires (**sesarm_ptf**)	P	Daily	All SESARM states except MS; acres burned and fuel loadings used to calculate heat flux for plume rise
Point fires (**ptfire**)	P	Daily	MS + all non-SESARM states
Offshore commercial marine (**ptseca**)	P	Annual	
SESARM EGU CEM point (**sesarm_ptcem_EGU**)	P	Hourly	Hourly CEM data for electricity generating units (EGUs)
SESARM non-EGU CEM point (**sesarm_ptcem_nEGU**)	P	Hourly	Hourly CEM data for non-EGUs

SESARM EGU non-CEM point (**sesarm_ptncem_EGU**)	P	Annual	
SESARM non-EGU non-CEM point (**sesarm_ptncem_nEGU**)	P	Annual	
MANE-VU CEM point (**mv_ptcem**)	P	Hourly	Hourly CEM data
MANE-VU non-CEM point (**mv_ptncem**)	P	Annual	
US point sources (**uspt**)	P	Annual	
Mexico & Canada point (**nuspt**)	P	Annual	

2.1.1.2 2018 emissions data

Collection and preparation of the SEMAP 2018 inventories followed a similar pattern to the 2007 inventories. Inventory contractors on the SEMAP project produced the anthropogenic and typical year fire inventories for the SESARM states. UNC converted the SEMAP point and non-point NIF-formatted inventories to ORL format for input to SMOKE. UNC worked with SESARM to develop an approach to project the 2007 gridded on-road emissions data to 2018 using 2018/2007 ratios provided by each of the SESARM states. The anthropogenic inventories for the non-SESARM states, Canada, and Mexico came from either Regional Planning Organizations (RPOs) or EPA in SMOKE-ready format.

The inventory sector abbreviations in Table 2-1 will be referred to in subsequent sections. Descriptions of the sources of the inventories used in the different SEMAP EMPs and details on any special processing of these sectors are included below.

2.1.2 SEMAP 2007 Emissions Modeling Platform

The SEMAP Base 2007 EMP presents that best emissions data to estimate year 2007 emissions available during the SEMAP project. The inventory data for the SESARM states were developed specifically for this project and include improvements over the National Emission Inventory (NEI) data for this time period. UNC used local or regional inventories to estimate emissions for the regions outside of the SESARM states and defaulted to the NEI when other data were not available. The ancillary data used for the 2007 EMP came mostly from the EPA NEI 2008 version 2, with some improvements based on local sources of information.

This section presents the details of the data that UNC collected and processed for the SEMAP 2007 EMP. Section 2.1.2.1 first presents the overall results of the 2007 EMP in terms of the annual total emissions for each of the 10 SESARM states. The subsequent sections begin with a table describing the sources, versions, and notes on the inventory data for each of the RPO regions. These sections are organized by inventory processing sector and include details on the sector and any special processing used to prepare these data for input the CMAQ model.

2.1.2.1 SESARM state 2007 emissions summary

The plots in this section illustrate the contribution of the different inventory processing sectors to the annual total 2007 criteria pollutant emissions in the SESARM states. The stacked bar plots show the total emissions for each pollutant by state with each segment in the stack representing a different emissions processing sector. An important detail to keep in mind when reviewing all of the annual emissions summary plots in this report is that some of the emissions sectors have strong seasonal temporal patterns that are not reflected in the annual totals. Biogenic emissions, for example, are much higher in the warmer months than the cold months. For most of the continental U.S., biogenic sources contribute a much larger fraction of the total VOC emissions during the summer than the winter. This seasonality is

somewhat lost in the annual total summary plots. Details of the processing and emissions totals for each sector are provided in the subsequent sections of this report.

Carbon Monoxide (CO)

In the 2007 SEMAP modeling, onroad mobile is the largest source of CO emissions in all of the SESARM states except Mississippi. Secondary important regional CO sources include nonroad mobile, fires, and biogenic sources. Overall Florida, Georgia, and North Carolina are the largest regional sources of CO. Virginia is the smallest regional source of CO. The onroad mobile CO emissions in each of these three states are higher than the sum of all sources of CO in the other SESARM states.

Nitrogen Oxides (NOx)

Onroad mobile and CEM point are the largest sources of NOx in all of the SESARM states. Other large sources of NOx include nonroad mobile, non-CEM point, and aircraft/locomotive/marine sources. Florida and Georgia are the largest regional of source of NOx. Virginia is the smallest regional source of NOx. The onroad NOx emissions in Florida are higher than the sum of all NOx sources in the other SESARM states, with the exception of Georgia.

Volatile Organic Compounds (VOCs)

Biogenic sources are the dominant VOC source in all of the SESARM states. Significant anthropogenic sources of VOC include onroad mobile, nonpoint, nonroad mobile. Florida and Georgia are the largest sources of VOC in the region. West Virginia is the smallest regional source of VOC.

Ammonia (NH3)

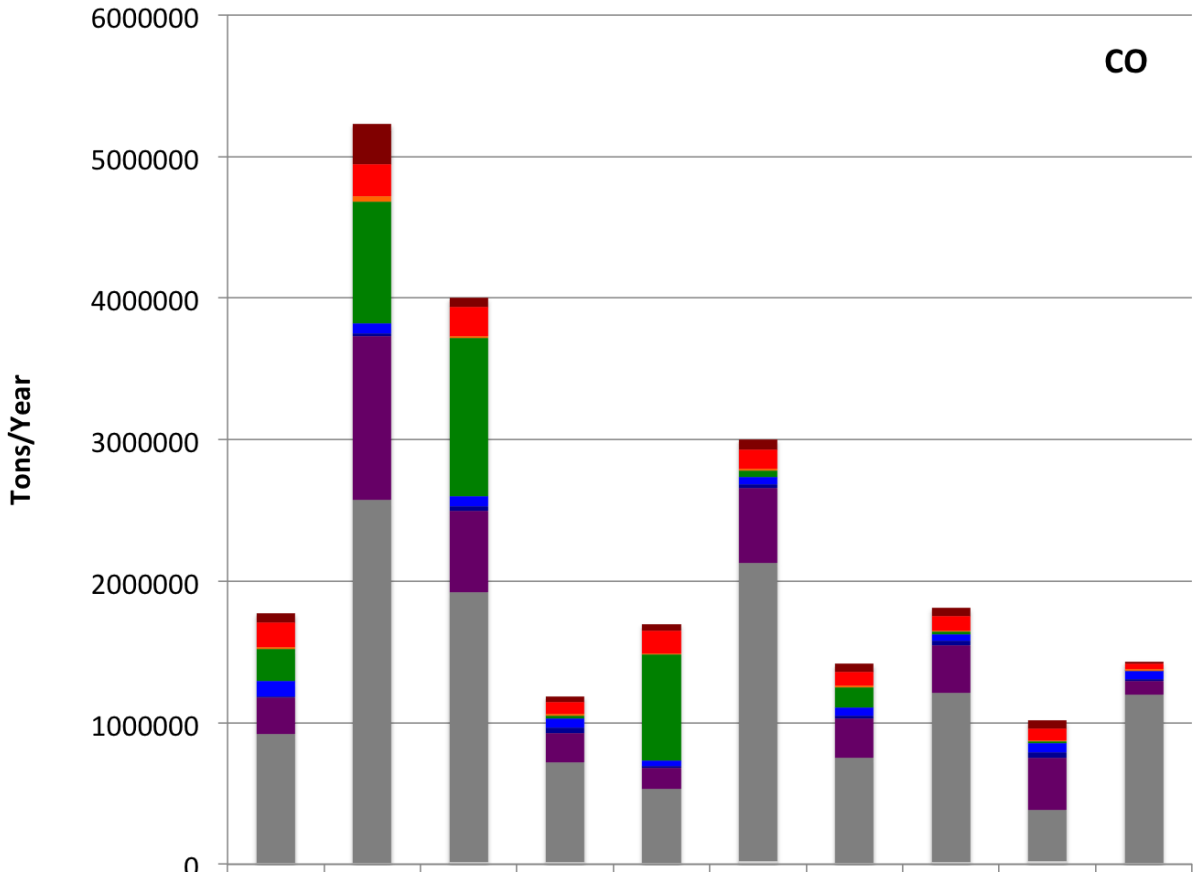
Livestock is the dominant source of NH3 in all of the SESARM states. Other significant sources of NH3 include fires, fertilizer, and onroad mobile sources. North Carolina and Georgia are the largest regional sources of NH3. West Virginia is the smallest regional source of NH3. The livestock NH3 emissions in North Carolina are much higher than the sum of all sources of NH3 in the other SESARM states.

Sulfur Dioxide (SO2)

SO2 emissions are dominated by CEM point sources in all of the SESARM states. Secondary sources of SO2 include non-CEM point and nonpoint sources. Georgia and Alabama are the largest regional sources of SO2. Mississippi is the smallest regional source.

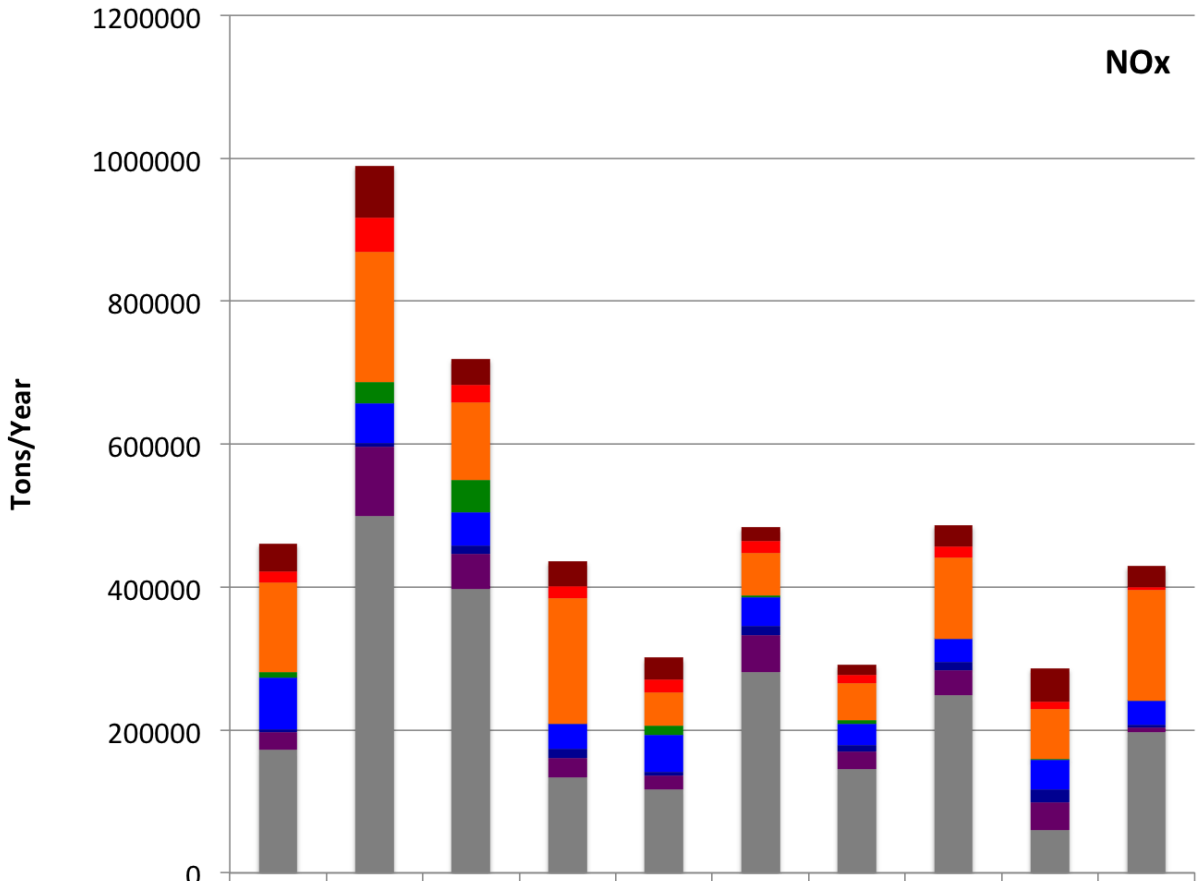
Particulate Matter < 2.5 µm (PM2.5)

Unlike the other pollutants, no single inventory sector is the dominant PM2.5 source throughout the region. Fires are the largest source of PM2.5 in many of the states. Fugitive dust is also a large source of PM2.5 in many states. Other significant sources of PM2.5 include non-CEM point, CEM point, nonpoint, and onroad mobile. Georgia and Florida are the largest regional sources of PM2.5, primarily because of an active fire year in 2007. West Virginia is the smallest regional source of PM2.5.



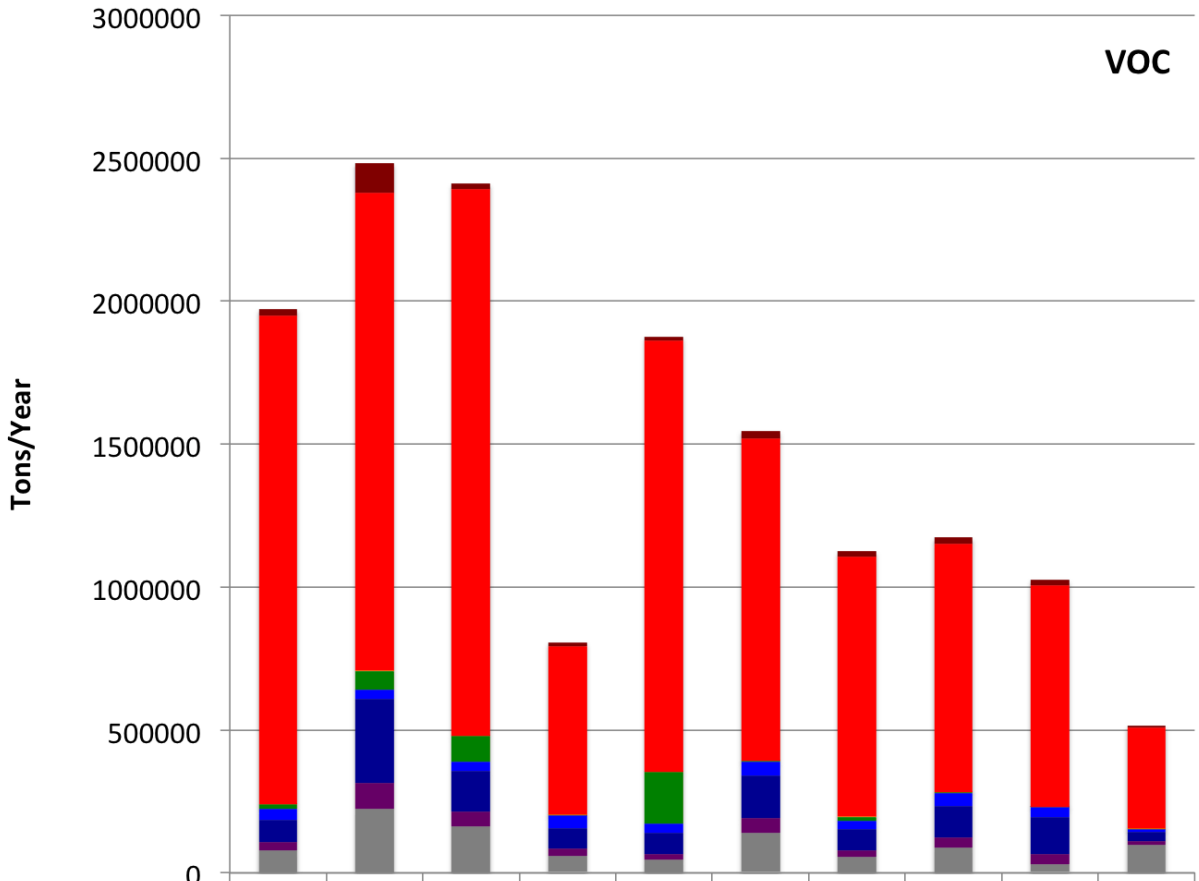
	AL	FL	GA	KY	MS	NC	SC	TN	VA	WV
ALM	62407	285996	62667	40352	44018	72900	55949	57694	52220	14719
Biogenic	177338	229020	205821	80573	162064	133292	98976	98607	86868	40390
CEM Point	12733	39384	12410	15076	6832	17067	7951	8762	8863	10352
Dust	0	0	0	0	0	0	0	0	0	0
Fertilizer	0	0	0	0	0	0	0	0	0	0
Fires	226950	857630	1121800	16091	753720	43910	147030	23097	10329	1516
Livestock	0	0	0	0	0	0	0	0	0	0
non-CEM Point	106611	71896	70137	67478	33463	49744	52424	42423	63167	54878
Nonpoint	5817	19134	32720	37204	16444	27646	25183	31560	40395	14760
Nonroad	259995	1153970	571979	205407	147902	526733	274140	335680	370899	96726
Onroad	909848	2565466	1909807	704306	525670	2111242	745572	1198308	357736	1188925
RWC	9335	9414	12517	18245	5933	19733	7025	13111	23442	8729

Figure 2-2. SESARM 2007 state total CO emissions by inventory sector



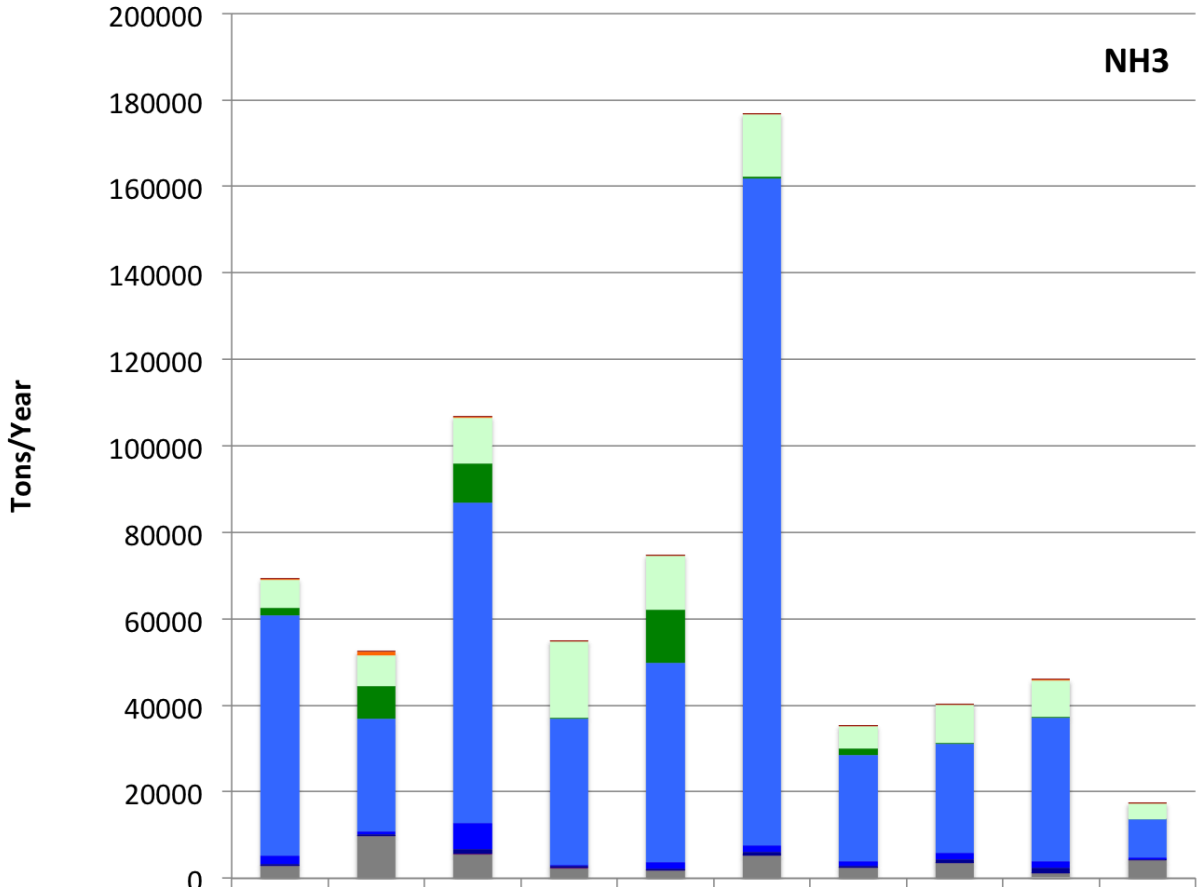
	AL	FL	GA	KY	MS	NC	SC	TN	VA	WV
ALM	39210	72520	37084	34278	29905	19405	13129	29565	46664	29428
Biogenic	15052	47773	24779	17652	18848	16055	11864	16030	10070	3608
CEM Point	125598	182390	107400	175007	46841	60281	51514	113331	70790	155290
Dust	0	0	0	0	0	0	0	0	0	0
Fertilizer	0	0	0	0	0	0	0	0	0	0
Fires	7944	30157	45254	657	12454	1864	6171	792	362	62
Livestock	0	0	0	0	0	0	0	0	0	0
non-CEM Point	72367	55083	46638	35208	51342	40098	29707	31431	42147	33339
Nonpoint	3789	5823	12143	12400	5995	12394	9239	12211	17356	3434
Nonroad	23938	96595	49087	26919	18198	52163	24526	34216	38550	7026
Onroad	172674	498934	396844	133430	117231	280672	144481	248811	60062	196779
RWC	151	160	207	293	95	321	114	211	384	140

Figure 2-3. SESARM 2007 state total NOx emissions by inventory sector



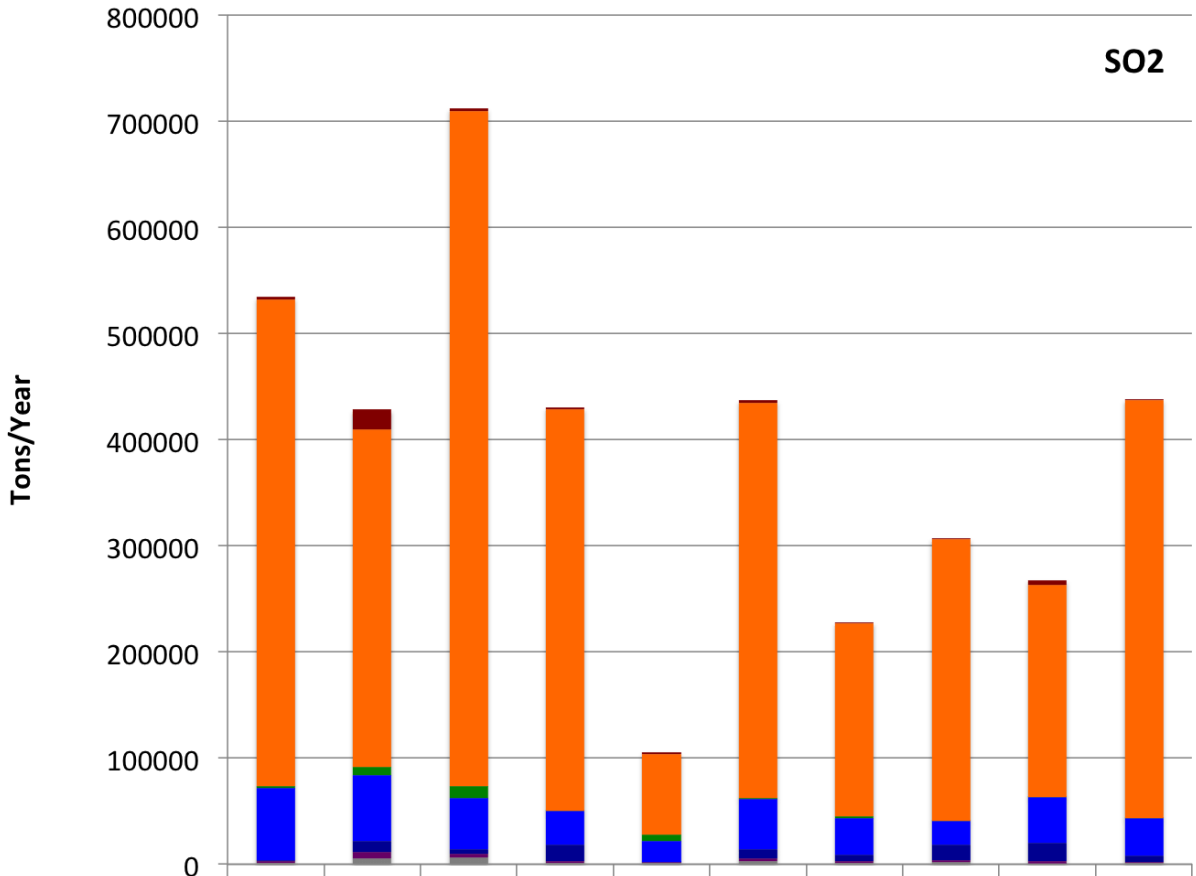
	AL	FL	GA	KY	MS	NC	SC	TN	VA	WV
ALM	22240	104423	20985	13609	15119	27238	19205	20778	20886	4366
Biogenic	1710315	1670058	1909704	588613	1508176	1126955	908485	868972	773553	354681
CEM Point	1059	2531	1576	1417	640	1006	625	961	734	1216
Dust	0	0	0	0	0	0	0	0	0	0
Fertilizer	0	0	0	0	0	0	0	0	0	0
Fires	15861	64526	88902	1272	178430	3541	12789	1576	722	119
Livestock	0	0	0	0	0	0	0	0	0	0
non-CEM Point	37818	31152	35142	46262	33946	47343	28655	47141	34884	11286
Nonpoint	77313	293960	141190	71730	73663	149180	75542	108690	129620	30475
Nonroad	29099	91403	50488	24259	19531	50060	23676	35159	35982	13986
Onroad	77122	222898	160962	55923	45136	137084	54030	86874	25237	96303
RWC	1717	1671	2280	3371	1092	3648	1297	2437	4316	1615

Figure 2-4. SESARM 2007 state total VOC emissions by inventory sector



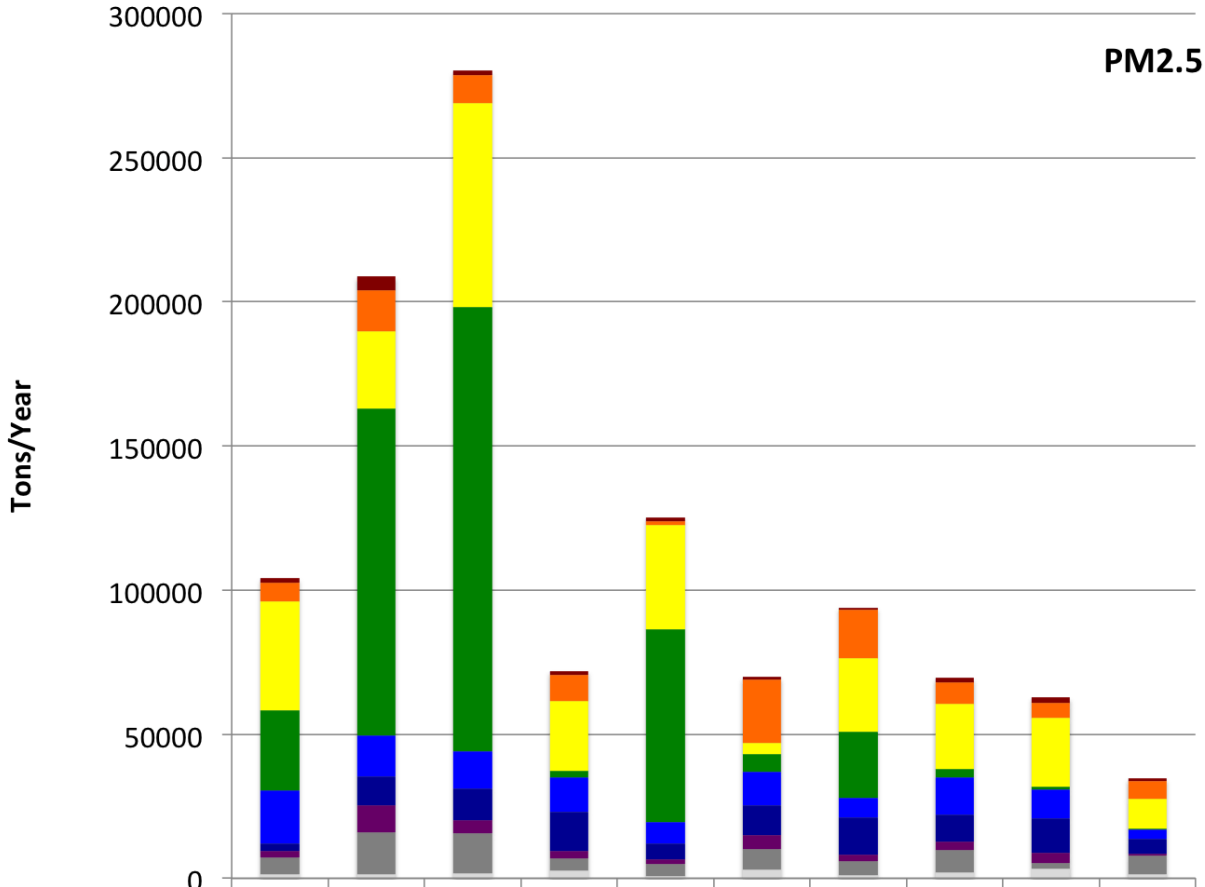
	AL	FL	GA	KY	MS	NC	SC	TN	VA	WV
ALM	22	61	21	22	18	14	10	18	25	14
Biogenic	0	0	0	0	0	0	0	0	0	0
CEM Point	163	1016	96	1	137	61	3	57	216	42
Dust	0	0	0	0	0	0	0	0	0	0
Fertilizer	6517	7157	10569	17645	12377	14341	5181	8830	8414	3631
Fires	1687	7400	9113	139	12413	391	1486	167	77	13
Livestock	55443	26179	74088	34003	46080	154190	24622	25381	33179	8795
non-CEM Point	2028	646	5950	112	1503	1646	1122	1372	1614	323
Nonpoint	387	246	1202	531	267	744	385	960	1247	359
Nonroad	24	106	51	24	17	51	24	32	39	8
Onroad	2823	9676	5416	2172	1809	5053	2303	3322	875	4041
RWC	79	84	108	152	50	166	59	108	197	73

Figure 2-5. SESARM 2007 state total NH3 emissions by inventory sector



	AL	FL	GA	KY	MS	NC	SC	TN	VA	WV
ALM	2026	18747	2384	1247	1977	2081	1462	1184	4620	1256
Biogenic	0	0	0	0	0	0	0	0	0	0
CEM Point	458368	317460	635610	378521	75547	372630	181227	265355	199401	393617
Dust	0	0	0	0	0	0	0	0	0	0
Fertilizer	0	0	0	0	0	0	0	0	0	0
Fires	2137	7923	11619	180	6328	511	1616	217	99	17
Livestock	0	0	0	0	0	0	0	0	0	0
non-CEM Point	68248	62134	47752	31897	19431	47804	34900	22313	43645	34731
Nonpoint	411	10313	4831	15549	331	8322	6033	14386	16970	6484
Nonroad	1392	6287	2991	1571	1085	3005	1449	1798	2246	392
Onroad	1509	5151	6407	1022	920	2534	1313	1857	488	1429
RWC	20	21	27	42	13	43	15	29	53	20

Figure 2-6. SESARM 2007 state total SO2 emissions by inventory sector



	AL	FL	GA	KY	MS	NC	SC	TN	VA	WV
ALM	1576	4653	1508	1272	1187	971	684	1363	1915	1013
Biogenic	0	0	0	0	0	0	0	0	0	0
CEM Point	6388	14331	9578	9140	1289	21828	16802	7472	4970	5885
Dust	37867	26815	70809	24109	36421	3722	25657	22827	23839	10556
Fertilizer	0	0	0	0	0	0	0	0	0	0
Fires	27666	113420	154220	2235	66621	6345	22984	2753	1272	208
Livestock	0	0	0	0	0	0	0	0	0	0
non-CEM Point	18541	14087	12718	11971	7442	11616	6692	12931	9905	3288
Nonpoint	2363	10026	10948	13592	5476	10239	12860	9230	11782	5043
Nonroad	2339	9443	4754	2544	1802	4769	2247	3164	3621	846
Onroad	5888	14481	13682	4365	4062	7382	4995	7784	1928	6513
RWC	1357	1397	1837	2641	861	2867	1020	1895	3413	1264

Figure 2-7. SESARM 2007 state total PM2.5 emissions by inventory sector

2.1.2.2 U.S. Nonpoint (nonpt)

Region	Data Source	Final Version	Notes
SESARM	TranSystems	March 2012	NIF to ORL conversion by UNC
MANE-VU	MARAMA	Version 3.3	Downloaded from ftp.marama.org in ORL format; VA removed by UNC
MWRPO	LADCO	BaseCv7	NIF to ORL conversion by UNC
CENRAP	US EPA	NEI2008v2	Downloaded from ftp://ftp.epa.gov/EmisInventory/2008dev/ in ORL format
WRAP	US EPA	NEI2008v2	

The **Nonpoint (or area)** data category contains emission estimates for sources which individually are too small in magnitude or too numerous to inventory as individual point sources, and which can often be estimated more accurately as a single aggregate source for a county or tribal area. Nonpoint emissions sources are summed over a geographic region, rather than specifically located. Examples of these sources include small industrial, residential, consumer product, and agricultural emissions. Explicit nonpoint inventory sources are defined by state and county (or tribal) identifiers and source classification codes (SCCs).

TranSystems Corporation (2012) developed the 2007 SESARM state nonpoint inventory for the SEMAP project. UNC obtained inventories for the northeast states from MARAMA and for the Great Lakes region from LADCO. UNC used the NEI2008v2 for the rest of the states in the U.S.

The nonpoint source category includes several sub-categories that merit special attention: residential wood combustion (RWC), fugitive dust, agricultural ammonia, and nonroad mobile. UNC extracted these nonpoint source sub-categories from the regional nonpoint inventories and processed them as separate emissions categories. Details on these sub-categories are provided in the following sections.

The remaining sources in the nonpoint processing sector following extraction of the sub-categories are listed in

Table 2-2, organized by SCC Tier 2 identification codes. Table 2-18 includes the 2007 state total annual nonpoint source emissions used for the SEMAP modeling. *Note that all of the results presented in this section include only the sources listed in* Table 2-18 *and do not include RWC, fugitive dust, agricultural ammonia, or offroad mobile source emissions.*

Figure 2-8 displays the 2007 annual state total nonpoint emissions for the 10 SESARM states. Virginia is the largest emitter of nonpoint CO in the region, contributing 16.1% of the SESARM region total, followed by Kentucky (14.8%), Georgia (13%), and Tennessee (12.6%). Virginia is the largest emitter of nonpoint NOx (18.3%) in the region, followed by North Carolina (13.1%), Kentucky (13.1%), and Tennessee (12.9%). Virginia is the largest emitter of nonpoint NH3 (19.7%) in the region followed by Georgia (19%), Tennessee (15.2%), and North Carolina (11.8%). Virginia is also the largest emitter of nonpoint SO2 (20.3%) in the region, followed by Kentucky (18.6%), Tennessee (17.2%), and Florida (12.3%). Florida is the largest emitter of nonpoint VOC (25.5%) in the region, followed by North Carolina (13%), Georgia (12.3%), and Virginia (11.3%). Tennessee is the largest emitter of PM10 (16.7%) in the region, followed by Kentucky (15.5%), Florida (13%), and South Carolina (13%). Kentucky is the largest emitter of PM2.5 (14.8%) in the region, followed by South Carolina (14%), Virginia (12.9%), and Georgia (12%).

Table 2-2. Tier 2 descriptions of sources in the SEMAP nonpoint processing sector

Industrial Processes;Chemical Manufacturing: SIC 28
Industrial Processes;Fabricated Metals: SIC 34
Industrial Processes;Food and Kindred Products: SIC 20
Industrial Processes;Industrial Processes: NEC
Industrial Processes;Industrial Refrigeration
Industrial Processes;Mineral Processes: SIC 32
Industrial Processes;Mining and Quarrying: SIC 14
Industrial Processes;Oil and Gas Exploration and Production
Industrial Processes;Oil and Gas Production: SIC 13
Industrial Processes;Petroleum Refining: SIC 29
Industrial Processes;Rubber/Plastics: SIC 30
Industrial Processes;Secondary Metal Production: SIC 33
Industrial Processes;Wood Products: SIC 24
Miscellaneous Area Sources;Agriculture Production - Crops
Miscellaneous Area Sources;Catastrophic/Accidental Releases
Miscellaneous Area Sources;Domestic Activity
Miscellaneous Area Sources;Domestic Animals Waste Emissions
Miscellaneous Area Sources;Health Services
Miscellaneous Area Sources;Humans
Miscellaneous Area Sources;Miscellaneous Repair Shops
Miscellaneous Area Sources;Other Combustion
Miscellaneous Area Sources;Wild Animals Waste Emissions
Mobile Sources;Aircraft
Solvent Utilization;Degreasing
Solvent Utilization;Dry Cleaning
Solvent Utilization;Graphic Arts
Solvent Utilization;Miscellaneous Industrial
Solvent Utilization;Miscellaneous Non-industrial: Commercial
Solvent Utilization;Miscellaneous Non-industrial: Consumer
Solvent Utilization;Miscellaneous Non-industrial: Consumer and Commercial
Solvent Utilization;Rubber/Plastics
Solvent Utilization;Surface Coating
Stationary Source Fuel Combustion;Commercial/Institutional
Stationary Source Fuel Combustion;Electric Utility
Stationary Source Fuel Combustion;Industrial
Stationary Source Fuel Combustion;Residential
Storage and Transport;Bulk Materials Storage
Storage and Transport;Organic Chemical Storage
Storage and Transport;Organic Chemical Transport
Storage and Transport;Petroleum and Petroleum Product Storage
Storage and Transport;Petroleum and Petroleum Product Transport
Waste Disposal, Treatment, and Recovery;Composting
Waste Disposal, Treatment, and Recovery;Landfills
Waste Disposal, Treatment, and Recovery;Leaking Underground Storage Tanks
Waste Disposal, Treatment, and Recovery;On-site Incineration
Waste Disposal, Treatment, and Recovery;Open Burning
Waste Disposal, Treatment, and Recovery;TSDFs
Waste Disposal, Treatment, and Recovery;Wastewater Treatment

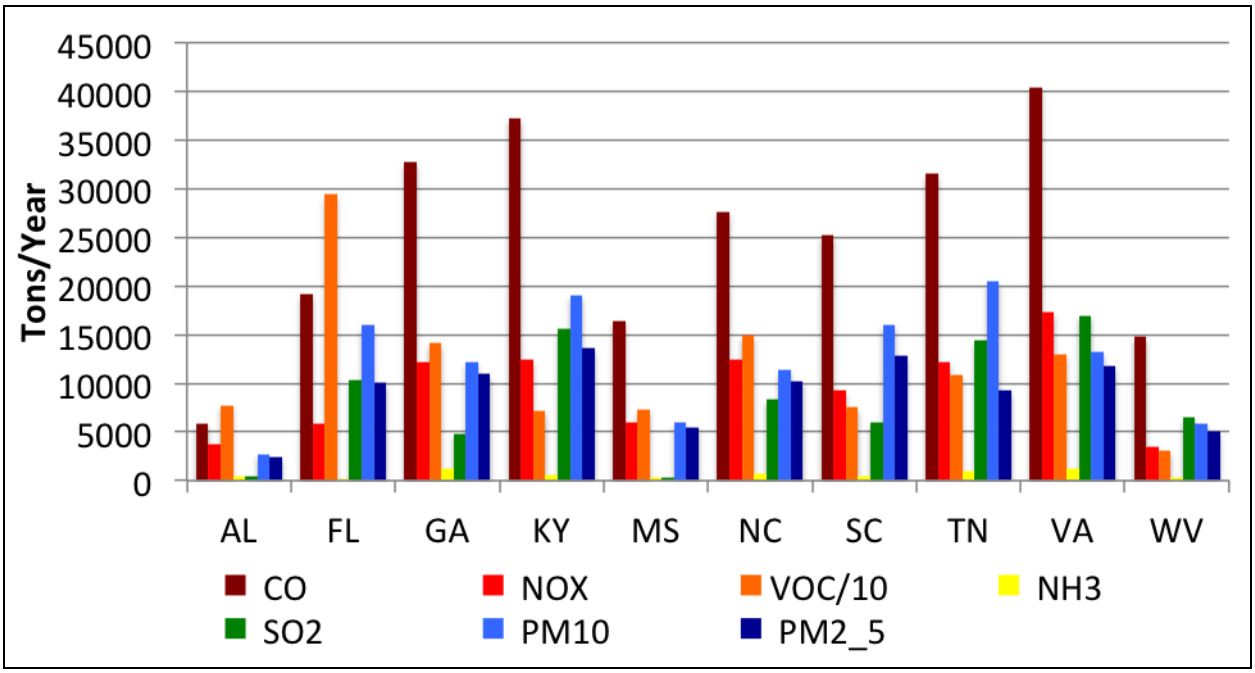


Figure 2-8. SESARM state annual total 2007 nonpoint source emissions; note that the VOC emissions are divided by 10 to normalize their magnitude

2.1.2.3 Residential wood combustion (RWC)

Region	Data Source	Final Version	Notes
SESARM	TranSystems	March 2012	NIF to ORL conversion by UNC
MANE-VU	MARAMA	Version 3.3	Downloaded from ftp.marama.org in ORL format; VA removed by UNC
MWRPO	LADCO	BaseCv7	NIF to ORL conversion by UNC
CENRAP	US EPA	NEI2008v2	Downloaded from ftp://ftp.epa.gov/EmisInventory/2008dev/ in ORL format
WRAP	US EPA	NEI2008v2	

The **Residential wood combustion (RWC)** data category is a subsector of the nonpoint sector and contains emission estimates for residential heating and cooking devices that use wood or wood derivatives as their primary fuel. The RWC sector includes wood stoves, fireplaces, and wood furnaces.

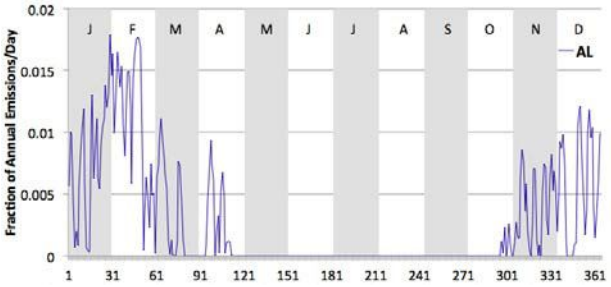
TranSystems Corporation (2012) developed the 2007 SESARM state RWC inventory for the SEMAP project. UNC obtained inventories for the northeast states from MARAMA and for the Great Lakes region from LADCO. UNC used the NEI2008v2 for the rest of the states in the U.S.
UNC defined RWC sources for the SEMAP project according to Tier 3 source classification codes (SCC). UNC extracted all nonpoint sources with Tier 3 codes 2104008 (Stationary Source Fuel Combustion;Residential;Wood) and 2014009 (Stationary Source Fuel Combustion;Residential;Firelog) into the RWC processing sector and eliminated these records from the nonpoint processing sector. The 11 SCCs that make up the SEMAP RWC sector are listed in Table 2-3, including the Tier 3-4 descriptions of these sources.

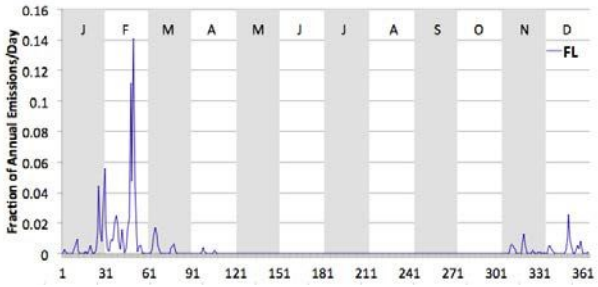
Table 2-3. SEMAP RWC processing sector SCCs and Tier 3-4 descriptions

2104008100 - Fireplace: general
2104008210 - Woodstove: fireplace inserts; non-EPA certified
2104008220 - Woodstove: fireplace inserts; EPA certified; non-catalytic
2104008230 - Woodstove: fireplace inserts; EPA certified; catalytic
2104008300 - Woodstove: freestanding, general
2104008310 - Woodstove: freestanding, non-EPA certified
2104008320 - Woodstove: freestanding, EPA certified, non-catalytic
2104008330 - Woodstove: freestanding, EPA certified, catalytic
2104008400 - Woodstove: pellet-fired, general (freestanding or FP insert)
2104008510 - Wood;Furnace: Indoor, cordwood-fired, non-EPA certified
2104009000 - Firelog;Total: All Combustor Types

UNC simulated RWC as an explicit processing sector in SMOKE to take advantage of the temporal profile generation tool Gentpro. Gentpro uses a regression model to estimate the daily temporal variability of RWC sources as a function of daily minimum temperatures. UNC developed this approach in cooperation with U.S. EPA as an improvement over the static RWC temporal profiles, which do not reflect variations in regional or annual climate. Gentpro creates county-specific temporal profiles for converting annual RWC emissions to daily emissions (Figure 2-9). Gentpro uses a threshold of 50°F to activate RWC emissions. A day will only factor into the annual distribution of RWC emissions if the county average daily minimum temperature is at or below 50°F. The algorithm allocates more emissions to colder days. A static diurnal profile (Figure 2-10) is then applied to convert the daily emissions to hourly for input to the air quality model. Adelman et al (2010) describe the development and testing of the Gentpro RWC temporal profile model.

The program Gentpro creates a unique temporal profile for each county and SMOKE applies the county-specific profiles to the RWC inventory sources. Figure 2-9 shows the state average RWC temporal profiles for each of the ten SESARM states. Each point plotted in the time series is an average of the daily fractions for all of the counties in the state. Note that the plot for Florida has a dependent axis scale that is 8x the scale of the rest of the states. This higher scale means that for most of the counties in Florida in 2007 the 50°F threshold was reached on relatively few days and the emissions are concentrated on those days. In the other SESARM states, where the threshold is reached more regularly, the RWC emissions are spread over a larger number of days.





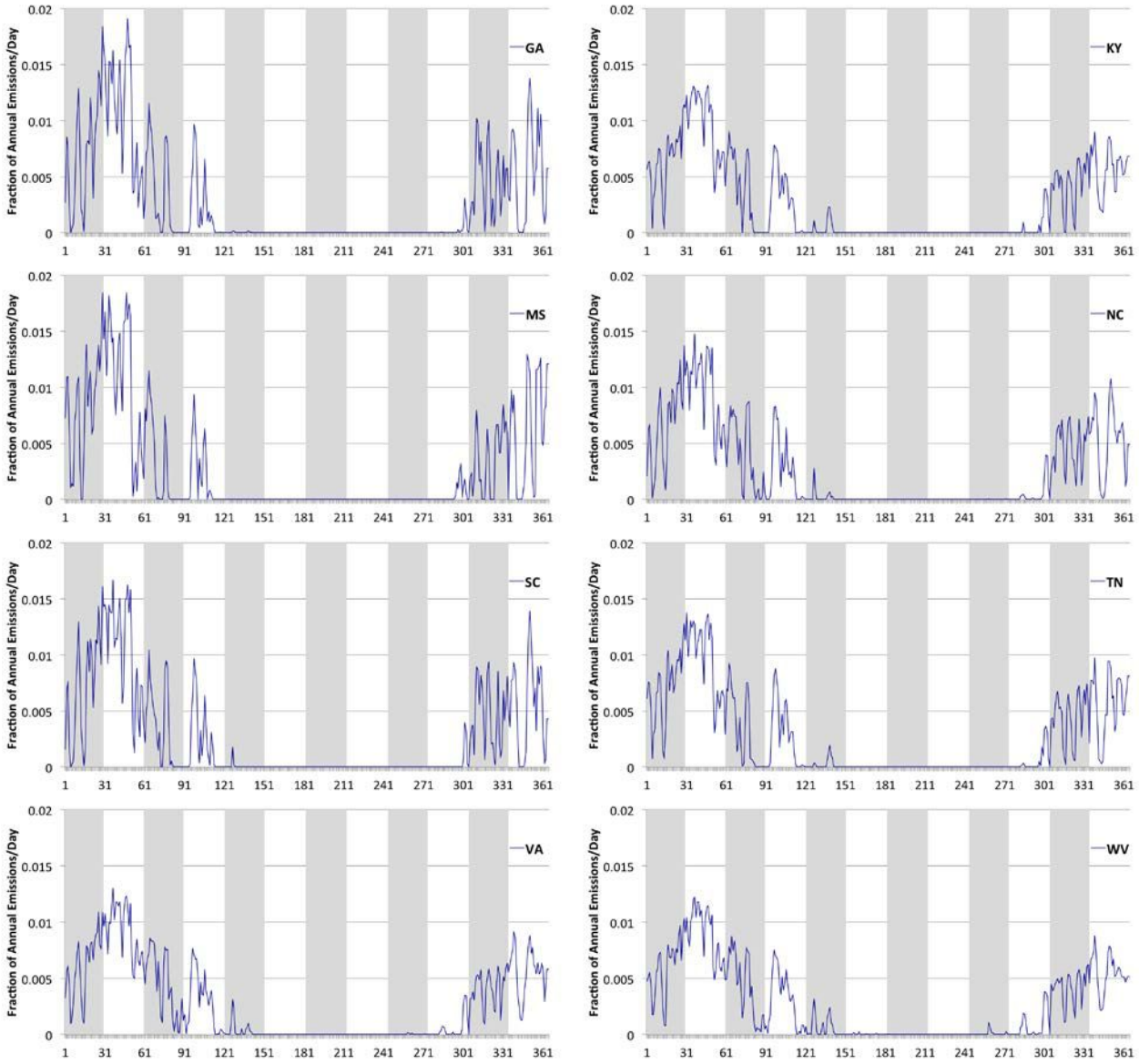


Figure 2-9. SESARM state average residential wood combustion temporal profiles

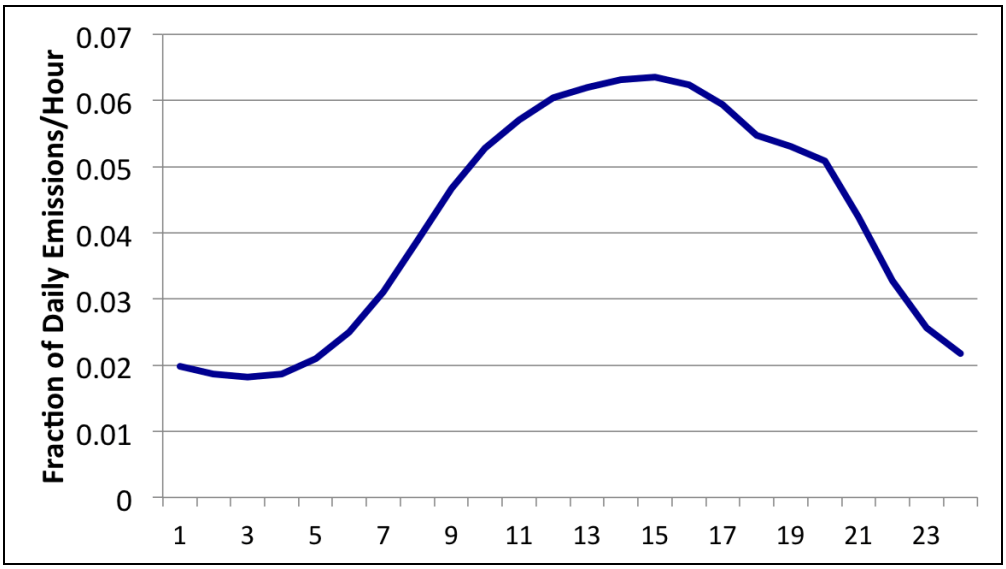


Figure 2-10. RWC source diurnal temporal profile

Table 2-19 includes the 2007 state total annual RWC source emissions used for the SEMAP modeling. Figure 2-11 displays the 2007 state total RWC emissions for the 10 SESARM states. The distribution of RWC emissions is consistent across pollutants with Virginia contributing the highest emissions in the region with 18.5% of the 10-state total for all pollutants. Virginia is followed by North Carolina (15.5%), Kentucky (14.3%), and Tennessee (10.3%) as the next largest sources of regional total RWC emissions for all pollutants.

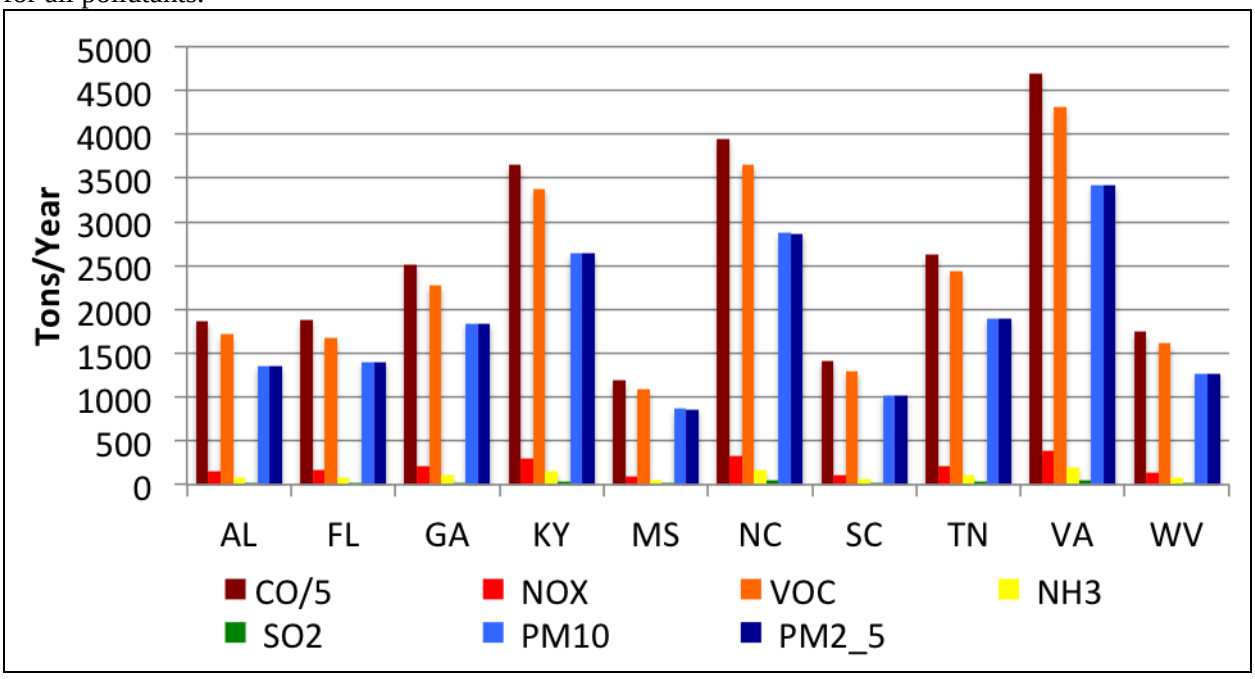


Figure 2-11. SESARM state annual total 2007 RWC source emissions; note that the CO emissions are divided by 5 to normalize their magnitude

2.1.2.4 Road and fugitive dust (fdust and mv_fdust)

Region	Data Source	Final Version	Notes
SESARM	TranSystems	March 2012	NIF to ORL conversion by UNC
MANE-VU	MARAMA	Version 3.3	Downloaded from ftp.marama.org in ORL format; VA removed by UNC
MWRPO	LADCO	BaseCv7	NIF to ORL conversion by UNC
CENRAP	US EPA	NEI2008v2	Downloaded from ftp://ftp.epa.gov/EmisInventory/2008dev/ in ORL format
WRAP	US EPA	NEI2008v2	

EPA defines fugitive dust as "small particles of geological origin that are suspended into the atmosphere from non-ducted emitters (Watson et al., 2000)." This general definition includes particle emissions from wind erosion, roads, parking lots, construction sites, open pits and mines, agricultural fields, and material transfer operations. As an emissions inventory component, dust emission sources are typically accounted for as non-point sources, meaning that they are estimated as annual, state or county total emissions by source. For SEMAP, UNC defined three principal categories of dust emissions: (1) windblown dust; (2) paved and unpaved road dust; and (3) all other dust sources resulting from the mechanical disturbance of soils. The SEMAP **Fugitive Dust (fdust)** processing sector refers to the second and third categories of dust sources. Road dust sources represent particle emissions resulting from vehicles traveling on roadways or across parking lots. The road dust inventory is split between paved and unpaved roads. The third dust category above includes dust from agricultural, mining, and construction activities. Both of these categories are subsectors of the nonpoint inventory. Windblown dust was estimated for the SEMAP modeling using the CMAQ in-line dust model. Additional sources of dust-like particles, such as brake wear, tire wear and industrial sources, such as gypsum and cement plants, are included in the on-road mobile and point source inventory sectors.

TranSystems Corporation (2012) developed the 2007 SESARM state fugitive dust inventory for the SEMAP project. UNC obtained inventories for the northeast states from MARAMA and for the Great Lakes region from LADCO. UNC used the NEI2008v2 for the rest of the states in the U.S.

UNC split the dust processing into two sectors: (1) **fdust** includes all states other than the MANE-VU states and (2) **fdust_mv** includes only the MANE-VU states. It was necessary to split the dust inventories into these two processing sectors because the MANE-VU inventories include vegetative scavenging factors while the rest of the states do not. As described below, UNC applied adjustments to the dust emissions as a post process, outside of SMOKE. UNC needed to isolate the MANE-VU emissions to avoid double counting the vegetative scavenging adjustments.

Table 2-4 lists the inventory source classification codes (SCCs) included in the SEMAP road dust and fugitive dust inventories. These nonpoint sources of dust are quantified as annual, county total emissions. UNC extracted all of the SCCs in Table 2-4 from the nonpoint inventory into the fdust processing sector and eliminated these records from the nonpoint processing sector.

Table 2-4. SEMAP road and fugitive dust sector SCCs

2275085000 - Mobile Sources;Aircraft;Unpaved Airstrips;Total
2294000000 - Mobile Sources;Paved Roads;All Paved Roads;Total: Fugitives
2296000000 - Mobile Sources;Unpaved Roads;All Unpaved Roads;Total: Fugitives
2311000000 - Industrial Processes;Construction: SIC 15 - 17;All Processes;Total
2311010000 - Industrial Processes;Construction: SIC 15 - 17;Residential;Total
2311020000 - Industrial Processes;Construction: SIC 15 - 17;Industrial/Commercial/Institutional;Total
2311030000 - Industrial Processes;Construction: SIC 15 - 17;Road Construction;Total
2325000000 - Industrial Processes;Mining and Quarrying: SIC 14;All Processes;Total

2601010000 - Waste Disposal, Treatment, and Recovery;On-site Incineration;Industrial;Total
2801000000 - Miscellaneous Area Sources;Agriculture Production - Crops;Agriculture - Crops;Total
2801000002 - Miscellaneous Area Sources;Agriculture Production - Crops;Agriculture - Crops;Planting
2801000003 - Miscellaneous Area Sources;Agriculture Production - Crops;Agriculture - Crops;Tilling
2801000005 - Miscellaneous Area Sources;Agriculture Production - Crops;Agriculture - Crops; Harvesting
2801000008 - Miscellaneous Area Sources;Agriculture Production - Crops;Agriculture - Crops;Transport
2805001000 - Miscellaneous Area Sources;Agriculture Production - Livestock;Beef cattle - finishing operations on feedlots (drylots);Dust Kicked-up by Hooves
2805001300 - Miscellaneous Area Sources;Agriculture Production - Livestock;Beef cattle - finishing operations on feedlots (drylots);Land application of manure
2805002000 - Miscellaneous Area Sources;Agriculture Production - Livestock;Beef cattle production composite;Not Elsewhere Classified
2805010000 - Miscellaneous Area Sources;Agriculture Production - Livestock;Dairy Operations;Total
2805018000 - Miscellaneous Area Sources;Agriculture Production - Livestock;Dairy cattle composite; Not Elsewhere Classified
2805020000 - Miscellaneous Area Sources;Agriculture Production - Livestock;Cattle and Calves Waste Emissions;Total

UNC extracted road and fugitive dust sources from the nonpoint inventory to a separate processing sectors to allow for the application of post-hoc adjustments to the dust emissions that account for two important dust emissions mitigation processes. The emissions factors for fugitive dust sources consider the parameters and conditions that produce dust emissions for different processes, such as the mechanisms of soil disturbance and the moisture and silt content of the disturbed surface. Although some fugitive dust emissions are based off of wind speeds and surface roughness, they do not explicitly include the direct effects of vegetative cover on dust scavenging and recent precipitation on dust emissions. Pace (2005) originally suggested the concept of a transportable fraction as the amount of dust that is not captured by near source removal. Pouliout et al. (2010) suggested a methodology for adjusting dust emissions following rain and snow events.

For the SEMAP modeling, UNC implemented fugitive dust reductions for both vegetative scavenging and precipitation impacts. Following the approach of Pouliot et al. (2010) UNC adjusted the fugitive and road dust emissions as a post-processing step after the emissions data were output from SMOKE. UNC used transport factors by BELD3 (Vukovich and Pierce, 2002) land cover category gridded to each of the SEMAP modeling domains to reduce the dust emissions. Vegetative scavenging factors were only applied to the **fdust** sector and not to the **fdust_mv** sector. The BELD3 dust transport factors are available in Pouliot et al. (2010). Figure 2-12 is a plot of the fugitive dust transport multipliers on the 36-km SEMAP modeling grid. UNC multiplied the fugitive dust emissions output from SMOKE by these factors to apply the vegetative scavenging reductions. The lower numbers in Figure 2-12 indicate larger reductions in the dust emissions.

UNC applied precipitation adjustments to the dust emissions to account for recent rain or snow events that would mitigate dust emissions. The precipitation adjustments were applied to both the **fdust** and **fdust_mv** sectors. Figure 2-13 illustrates an example of applying the precipitation adjustment to the dust emissions. The figure shows February 2007 total fugitive and road dust PM2.5 with and without the precipitation adjustment. The rightmost image in Figure 2-13 is a ratio of the PM2.5 emissions with and without the precipitation adjustment. The lower ratios in Figure 2-13 indicate larger reductions in the dust emissions. UNC applied the vegetative scavenging and precipitation adjustments to the dust emissions in series.

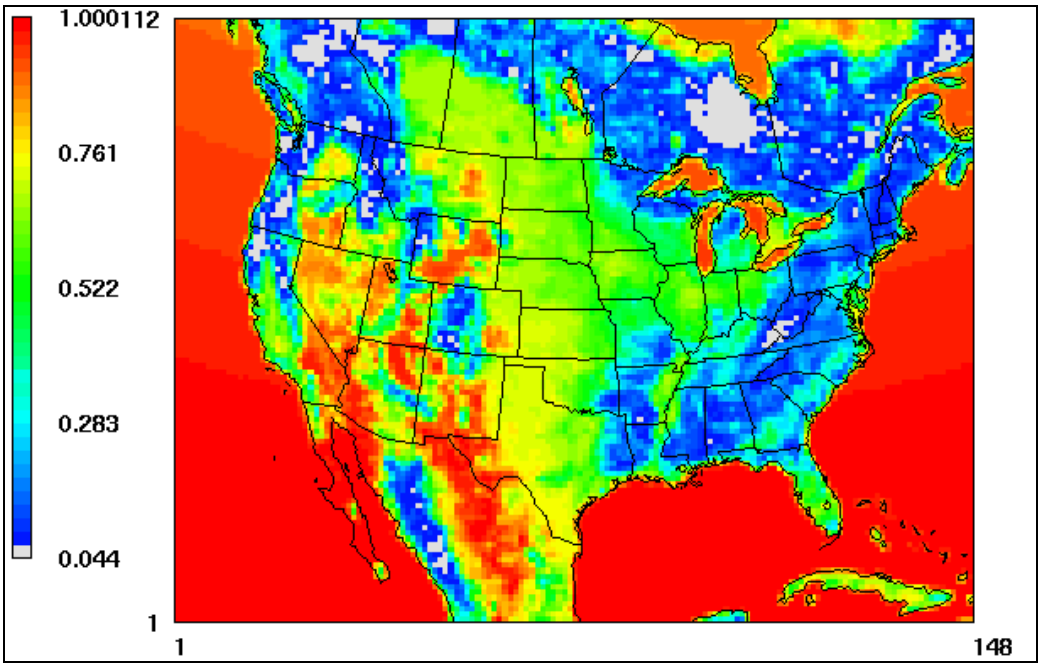


Figure 2-12. Road and fugitive dust vegetative scavenging multipliers on the SEMAP 36km modeling domain

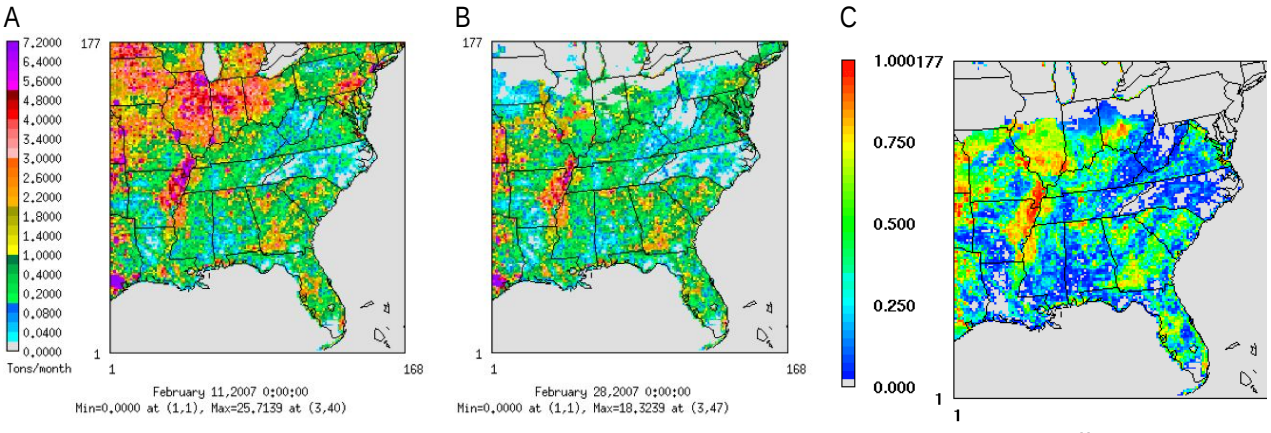


Figure 2-13. February 2007 total fugitive and road dust PM2.5; (A) is without meteorology adjustment, (B) includes meteorology adjustment, (C) is ratio of (B)/(A)

Table 2-20 includes the 2007 state total annual road and fugitive dust source emissions used for the SEMAP modeling. **Note that only the MANE-VU state inventory includes vegetative scavenging factors; the rest of the state totals in**

Table 2-20 *do not include any adjustments to the dust emissions. With the exception of the MANE-VU emissions, all dust emission adjustments were applied as a post-processing step to the SMOKE output files.* Figure 2-14 displays the 2007 state total emissions for the 10 SESARM states. Georgia is the largest emitter of road and fugitive dust PM10 in the region, contributing 24.7% of the SESARM region total, followed by Alabama (13.7%), Mississippi (12.6%), and Florida (12%).

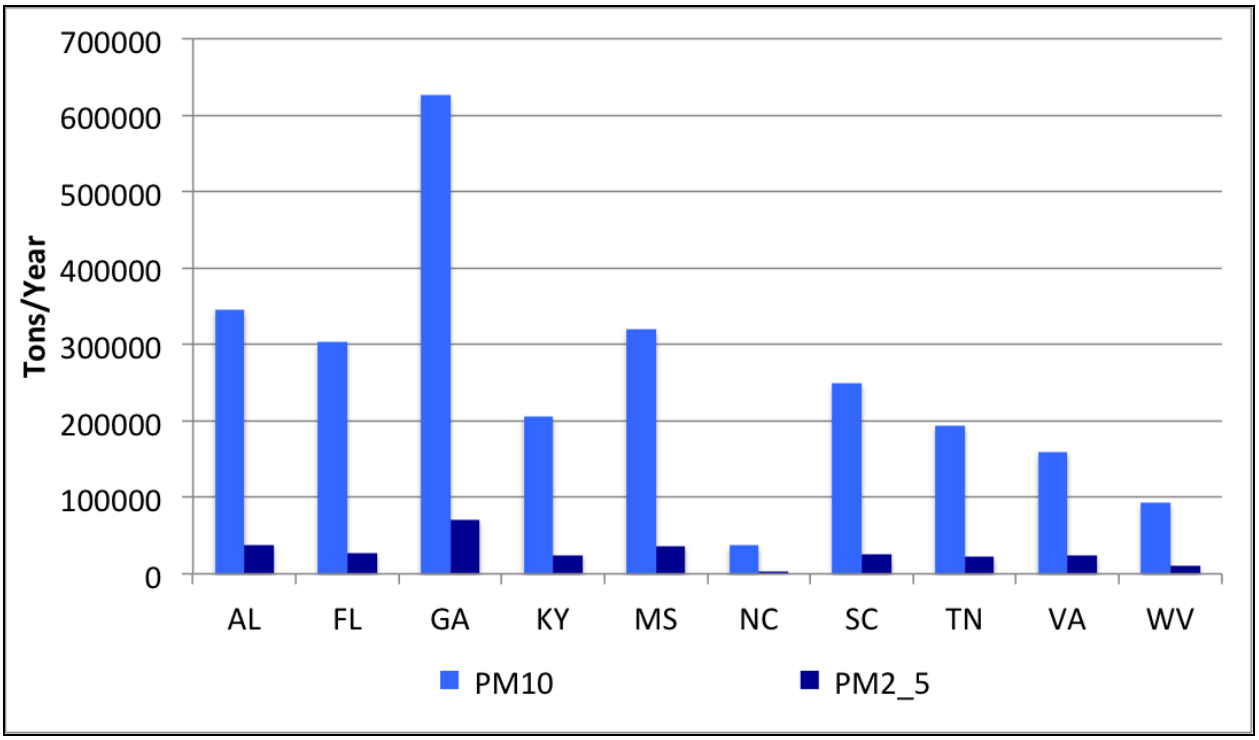


Figure 2-14. SESARM state annual total 2007 road and fugitive dust source emissions; note that these values do not reflect the application of any adjustment factors

Table 2-5 lists the surrogate assignments that were used to map road dust and fugitive dust emissions to the SEMAP modeling grids.

Table 2-5. Spatial surrogates used for modeling the SEMAP road and fugitive dust sources

Inventory Sectors	Surrogate	Surrogate Description	Surrogate Source
Paved Roads	240	Total Road Miles	US Census – TIGER (2010)
Unpaved Roads	130	Rural Population	US Census (2010)
Construction	140	Housing Change + Population	US Census (2010)
Mining and Quarrying	330	Strip Mines/Quarries	NLCD (1992)
Livestock	310	Total Agriculture	NLCD (1992)
Crop Production	310	Total Agriculture	NLCD (1992)

2.1.2.5 Agricultural ammonia (lv and ft)

Region	Data Source	Final Version	Notes
SESARM	TranSystems	March 2012	NIF to ORL conversion by UNC
MANE-VU	MARAMA	Version 3.3	Downloaded from ftp.marama.org in ORL format; VA removed by UNC
MWRPO	LADCO	BaseCv7	NIF to ORL conversion by UNC
CENRAP	US EPA	NEI2008v2	Downloaded from ftp://ftp.epa.gov/EmisInventory/2008dev/ in
WRAP	US EPA	NEI2008v2	

			ORL format

A broad category of many different types of emission sources, the nonpoint sector contains two agricultural sources that are significant emitters of NH_3. **Livestock** and **fertilizer** sources are included in the nonpoint inventory and represent the majority of anthropogenic NH_3 emissions. As with most nonpoint sources, emissions in the agricultural NH_3 inventory is calculated as

$$E_{i,s} = A_{i,s} * F_s$$

Where $E_{i,s}$ = Emissions in county *i* for source *s*

$A_{i,s}$ = Activity in county *i* for source s

F_s = Emission factor for source *s*

For livestock sources, the activity (A) is the population of a particular animal per county and the emission factor (F) is the emitted mass (kg) of NH_3 per animal per month. For fertilizer sources, A is the mass (kg) of fertilizer consumed per county and F is the % of N in the fertilizer volatilized as NH_3. Livestock refers to domesticated animals intentionally reared for the production of food, fiber, or other goods or for the use of their labor. The definition of livestock in this category includes beef cattle, dairy cattle, ducks, geese, goats, horses, poultry, sheep, and swine. Fertilizer in this category refers to any nitrogen-based compound, or mixture containing such a compound, that is applied to land to improve plant fitness.

TranSystems Corporation (2012) developed the 2007 SESARM state agricultural ammonia inventory for the SEMAP project. UNC obtained inventories for the northeast states from MARAMA and for the Great Lakes region from LADCO. UNC used the NEI2008v2 for the rest of the states in the U.S.
Table 2-6 lists the inventory SCC Tier 2 and 3 descriptions of the sources included in the SEMAP livestock and fertilizer inventories. These nonpoint sources of ammonia are quantified as annual, county total emissions. UNC extracted ammonia for all of the SCCs in Table 2-6 from the nonpoint inventory into the **lv** and **ft** processing sectors and eliminated these records from the nonpoint processing sector. If these SCCs included other pollutants, such as PM or VOC, they were left in the nonpoint processing sector.

Table 2-6. SEMAP livestock and fertilizer Tier 2-3 SCC descriptions

Agriculture Production - Crops;Fertilizer Application
Agriculture Production - Livestock;Beef cattle - finishing operations on feedlots (drylots)
Agriculture Production - Livestock;Beef cattle - finishing operations on pasture/range
Agriculture Production - Livestock;Beef cattle production composite
Agriculture Production - Livestock;Cattle and Calves Waste Emissions
Agriculture Production - Livestock;Dairy cattle composite
Agriculture Production - Livestock;Dairy cattle - deep pit dairy
Agriculture Production - Livestock;Dairy cattle - drylot/pasture dairy
Agriculture Production - Livestock;Dairy cattle - flush dairy
Agriculture Production - Livestock;Dairy cattle - scrape dairy
Agriculture Production - Livestock;Dairy Operations
Agriculture Production - Livestock;Goats Waste Emissions
Agriculture Production - Livestock;Hog Operations
Agriculture Production - Livestock;Horses and Ponies Waste Emissions
Agriculture Production - Livestock;Poultry Operations
Agriculture Production - Livestock;Poultry production - broilers

Agriculture Production - Livestock;Poultry production - layers with dry manure management systems
Agriculture Production - Livestock;Poultry production - layers with wet manure management systems
Agriculture Production - Livestock;Poultry production - turkeys
Agriculture Production - Livestock;Poultry Waste Emissions
Agriculture Production - Livestock;Sheep and Lambs Waste Emissions
Agriculture Production - Livestock;Swine production composite
Agriculture Production - Livestock;Swine production - deep-pit house operations (unspecified animal age)
Agriculture Production - Livestock;Swine production - operations with lagoons (unspecified animal age)
Agriculture Production - Livestock;Swine production - outdoor operations (unspecified animal age)

UNC extracted livestock and fertilizer sources from the nonpoint inventory to separate processing sectors for the purposes of explicitly tracking agricultural NH3 sources and to take advantage of the Gentpro algorithm for estimating meteorology-based hourly temporal profiles for livestock emissions. Adelman et al (2010) describe the implementation of an algorithm in Gentpro that uses county-averaged hourly temperatures and wind speeds to convert monthly livestock emissions to hourly estimates. For the SEMAP modeling UNC used state-specific temporal profiles distributed as part of the U.S EPA 2005 EMP to convert the annual inventory to monthly emission estimates. UNC then used the hourly 36 and 12-km SEMAP meteorology data to estimate county-level monthly-to-hourly temporal profiles with Gentpro. The meteorology-based temporal profile approach is only applicable to livestock sources. UNC used static, state-specific temporal profiles from the U.S. EPA 2005 EMP to convert the annual fertilizer inventory to hourly estimates.

Table 2-21 includes the 2007 state total annual fertilizer and livestock NH3 source emissions used for the SEMAP modeling. Figure 2-15 displays the 2007 state total emissions for the 10 SESARM states. North Carolina is the largest emitter of livestock NH3 in the region, contributing 32% of the SESARM region total, followed by Georgia (15.4%), Alabama (11.5%), and Mississippi (9.6%). Kentucky is the largest emitter of fertilizer NH3 in the region, contributing 18.6% of the SESARM region total, followed by North Carolina (15.1%), Mississippi (13.1%), and Georgia (11.2%).

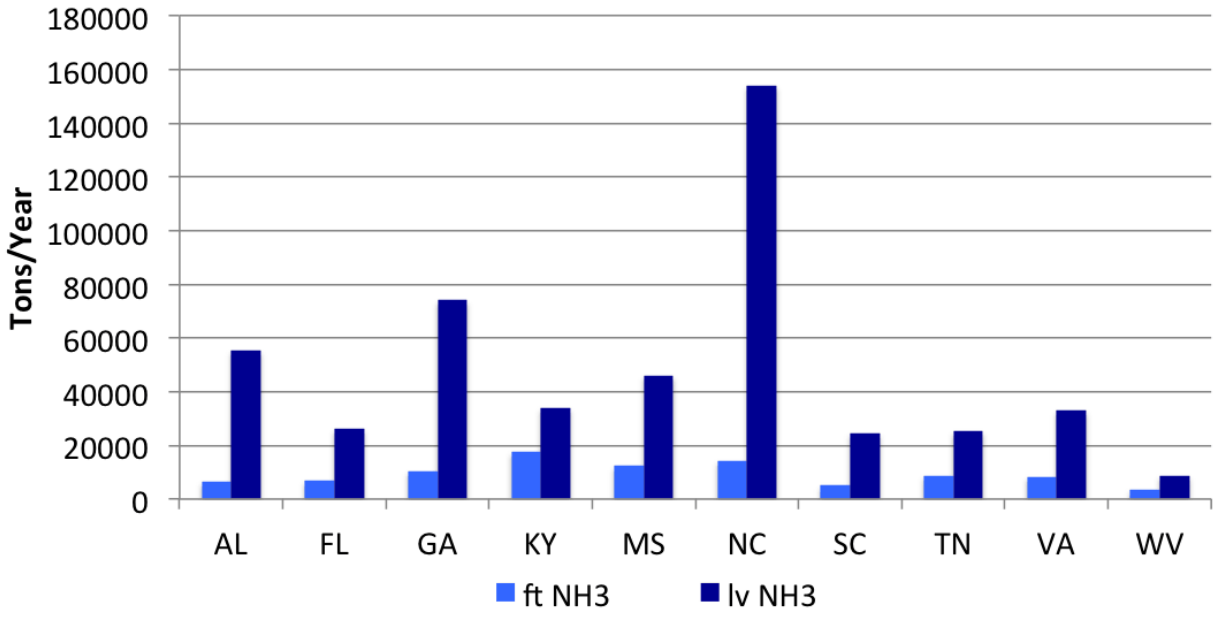


Figure 2-15. SESARM state annual total 2007 fertilizer and livestock source emissions

2.1.2.6 Offroad mobile (nonroad)

Region	Data Source	Final Version	Notes
SESARM	TranSystems	March 2012	Monthly ORL-formatted files provided by TranSystems
MANE-VU	MARAMA	Version 3.3	Downloaded from ftp.marama.org in ORL format; VA removed by UNC
MWRPO	LADCO	BaseCv7	NIF to ORL conversion by UNC
CENRAP	US EPA	NEI2008v2	Downloaded from ftp://ftp.epa.gov/EmisInventory/2008dev/ in ORL format
WRAP	US EPA	NEI2008v2	

Offroad mobile (nonroad) source emissions result from the use of fuel in a diverse collection of vehicles and equipment that usually do not travel along paved or un-paved roadways, including vehicles and equipment in the following categories:

- Recreational vehicles, such as all-terrain vehicles, off-road motorcycles and snow mobiles;
- Logging equipment, such as chain saws;
- Agricultural equipment, such as tractors;
- Construction equipment, such as graders and back hoes;

- Industrial equipment, such as fork lifts, sweepers and cranes; and
- Residential and commercial lawn and garden equipment, such as lawn mowers and leaf and snow blowers

The NONROAD emissions model predicts emissions for almost all non-road equipment including the categories listed above. The model includes more than 80 basic and 260 specific types of non-road equipment, and further stratifies equipment types by horsepower rating. Fuel types include gasoline, diesel, compressed natural gas (CNG), and liquefied petroleum gas (LPG). NONROAD does not provide emission estimates for the airplane, locomotive and commercial marine non-road mobile source categories.

The NONROAD model estimates emissions for each specific type of non-road equipment by multiplying the following input data estimates:

- Equipment population for base year (or base year population grown to a future year), distributed by age, power, fuel type, and application;
- Average load factor expressed as average fraction of available power;
- Available power in horsepower;
- Activity in hours of use per year; and
- Emission factor with deterioration and/or new standards.

TranSystems Corporation (2012) developed the 2007 SESARM state nonroad mobile inventory for the SEMAP project. UNC obtained inventories for the northeast states from MARAMA and for the Great Lakes region from LADCO. UNC used the NEI2008v2 for the rest of the states in the U.S.

The SEMAP nonroad mobile processing sector includes only sectors from the NONROAD model. Table 2-7 shows the Tier 3 SCC's included in the nonroad processing sector. UNC split the aircraft, locomotive, commercial marine, pleasure craft, and airport point sources to separate processing categories. UNC combined monthly nonroad inventories for the ten SESARM states with monthly inventories for the other RPOs to create national nonroad emissions estimates for the SEMAP project. UNC developed a special nonroad temporal profile cross-reference dataset that assigns flat monthly profiles to all of the nonroad SCCs to avoid double temporalization of the emissions.

Table 2-7. SEMAP nonroad mobile processing sector Tier 3 SCC descriptions

22650020: Construction and Mining Equipment
22600030: Industrial Equipment
22600040: Lawn and Garden Equipment
22600050: Agricultural Equipment
22600060: Commercial Equipment
22600070: Logging Equipment
22650010: Recreational Equipment
22700090: Underground Mining Equipment

Table 2-22 includes the 2007 state total annual nonroad source emissions used for the SEMAP modeling. Figure 2-16 displays the 2007 state total emissions for the 10 SESARM states. Florida is the largest emitter of nonroad emissions in the region, contributing about 27% of the SESARM region total nonroad emissions for all pollutants, followed by Georgia and North Carolina (13.5%), Virginia (10.0%), and Tennessee (9.0%). Figure 2-17 and Figure 2-18 show the contribution of the different Tier 3 SCCs to the annual state total NOx and VOC emissions for each SESARM state. Construction and mining equipment is the largest NOx emitter in this sector for all SESARM states. Different sources then contribute to the total in different proportions for each state. For most SESARM states lawn and garden equipment is the largest VOC emitter in this sector. Other large sources of nonroad VOC include recreational equipment and commercial equipment.

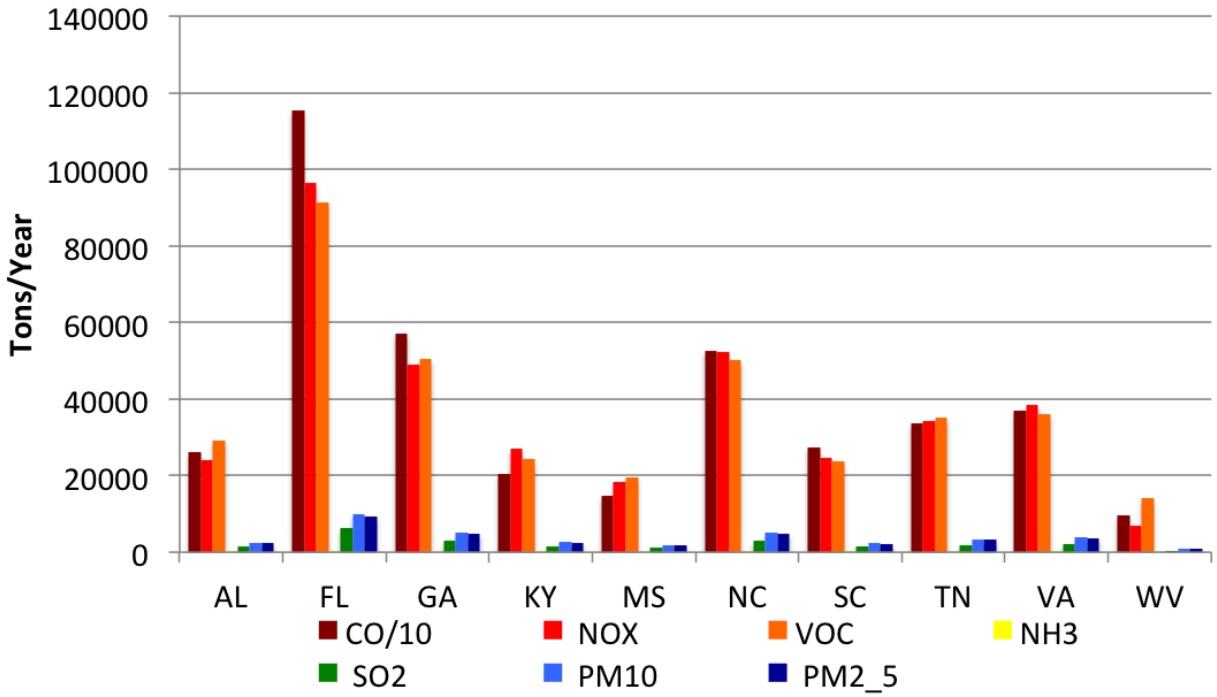


Figure 2-16. SESARM state annual total 2007 nonroad mobile source emissions; note that the CO emissions are divided by 10 to normalize their magnitude

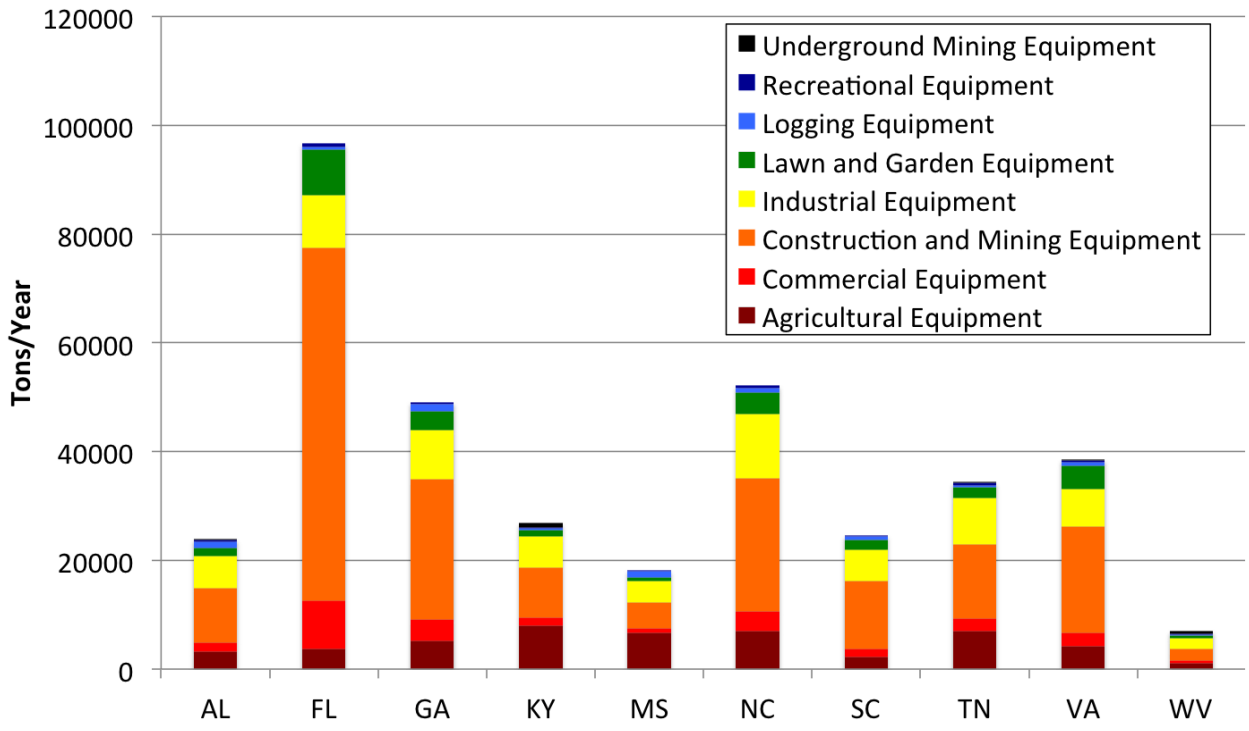


Figure 2-17. SESARM state annual total nonroad mobile NOx emissions by SCC Tier 3

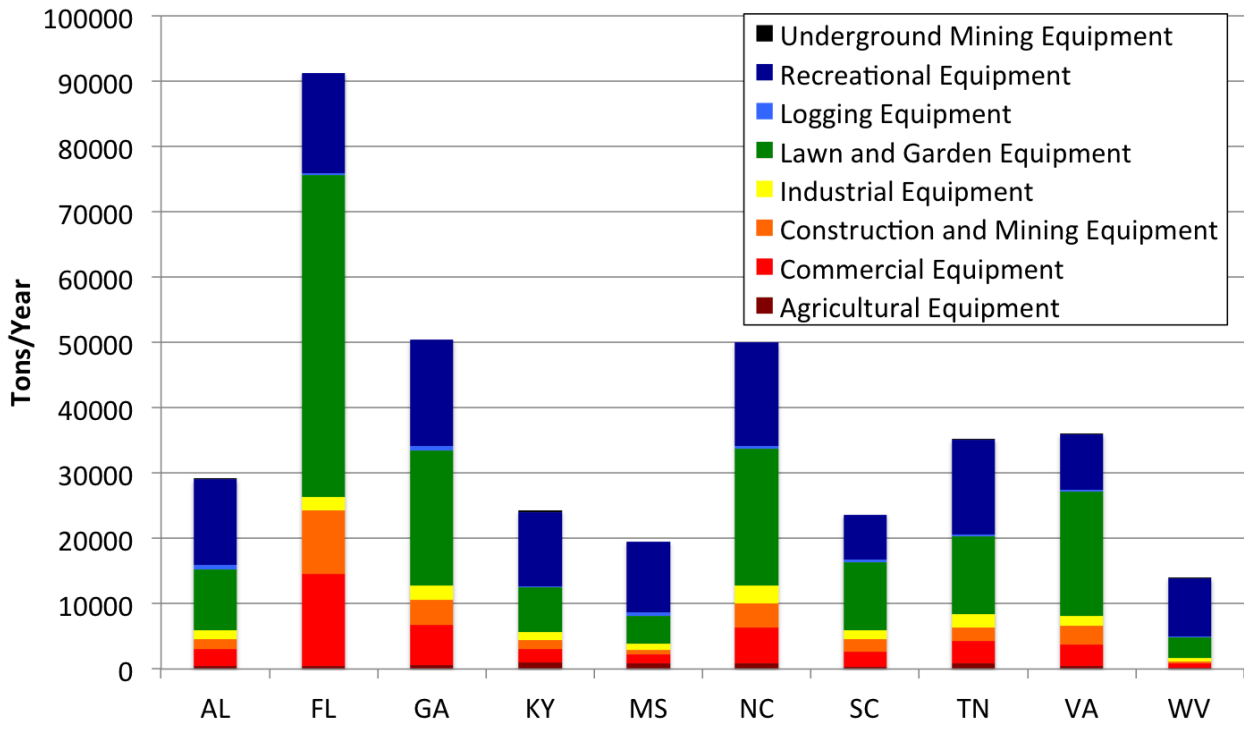


Figure 2-18. SESARM state annual total nonroad mobile VOC emissions by SCC Tier 3

2.1.2.7 Aircraft locomotive marine (ALM)

Region	Data Source	Final Version	Notes
SESARM	TranSystems	March 2012	NIF to ORL conversion by UNC
MANE-VU	MARAMA	Version 3.3	Downloaded from ftp.marama.org in ORL format; VA removed by UNC
MWRPO	LADCO	BaseCv7	NIF to ORL conversion by UNC
CENRAP	US EPA	NEI2008v2	Downloaded from ftp://ftp.epa.gov/EmisInventory/2008dev/ in ORL format
WRAP	US EPA	NEI2008v2	

The Aircraft, locomotive, marine (ALM) source emissions are a combination of on-rail locomotive, pleasure craft, and commercial marine equipment that are taken from a combination of the nonroad mobile and nonpoint (area) inventories. The aircraft emissions, including airport support equipment, have been moved out of the ALM processing category to a subsector of the point inventory called airport point sources (**airpt**).

TranSystems Corporation (2012) developed the 2007 SESARM state ALM and airpt inventories for the SEMAP project. UNC obtained inventories for the northeast states from MARAMA and for the Great Lakes region from LADCO. UNC used the NEI2008v2 for the rest of the states in the U.S.

Table 2-8 lists all of the SCCs and descriptions in the SEMAP project ALM processing sector.

Table 2-8. SEMAP ALM processing sector SCC descriptions

2280000000	Mobile Sources;Marine Vessels, Commercial;All Fuels;Total, All Vessel Types
2280002100	Mobile Sources;Marine Vessels, Commercial;Diesel;Port emissions
2280002200	Mobile Sources;Marine Vessels, Commercial;Diesel;Underway emissions
2282005010	Mobile Sources;Pleasure Craft;Gasoline 2-Stroke;Outboard
2282005015	Mobile Sources;Pleasure Craft;Gasoline 2-Stroke;Personal Water Craft
2282010005	Mobile Sources;Pleasure Craft;Gasoline 4-Stroke;Inboard/Sterndrive
2282020005	Mobile Sources;Pleasure Craft;Diesel;Inboard/Sterndrive
2282020010	Mobile Sources;Pleasure Craft;Diesel;Outboard
2285000000	Mobile Sources;Railroad Equipment;All Fuels;Total
2285002006	Mobile Sources;Railroad Equipment;Diesel;Line Haul Locomotives: Class I Operations
2285002007	Mobile Sources;Railroad Equipment;Diesel;Line Haul Locomotives: Class II / III
2285002008	Mobile Sources;Railroad Equipment;Diesel;Line Haul Locomotives: Passenger Trains
2285002010	Mobile Sources;Railroad Equipment;Diesel;Yard Locomotives
2285002015	Mobile Sources;Railroad Equipment;Diesel;Railway Maintenance
2285004015	Mobile Sources;Railroad Equipment;Gasoline, 4-Stroke;Railway Maintenance
2285006015	Mobile Sources;Railroad Equipment;LPG;Railway Maintenance

Table 2-26 includes the 2007 state total annual ALM source emissions used for the SEMAP modeling. Figure 2-19 displays the 2007 state total ALM emissions for the 10 SESARM states. Florida is the largest emitter of ALM emissions in the region, contributing about 21% of the NOx and 40% of the VOC emissions for the SESARM region ALM sources. Other large regional sources of ALM NOx include Virginia (13.3%), Alabama (11.2%), and Georgia (10.6%). The other large regional sources of ALM VOC include North Carolina (10.1%) and Alabama (8.3%). Figure 2-20 and Figure 2-21 show the contribution of the different ALM Tier 2 SCCs to the annual state total NOx and VOC emissions for each SESARM state. Commercial marine vessels are the largest NOx emitter in this sector for all SESARM states. For all states other than Florida, railroad equipment is the next largest source of ALM NOx.

Pleasure craft is by far the dominant source of ALM VOC emissions, with Florida contributing 40% to the regional total pleasure craft VOC emissions.

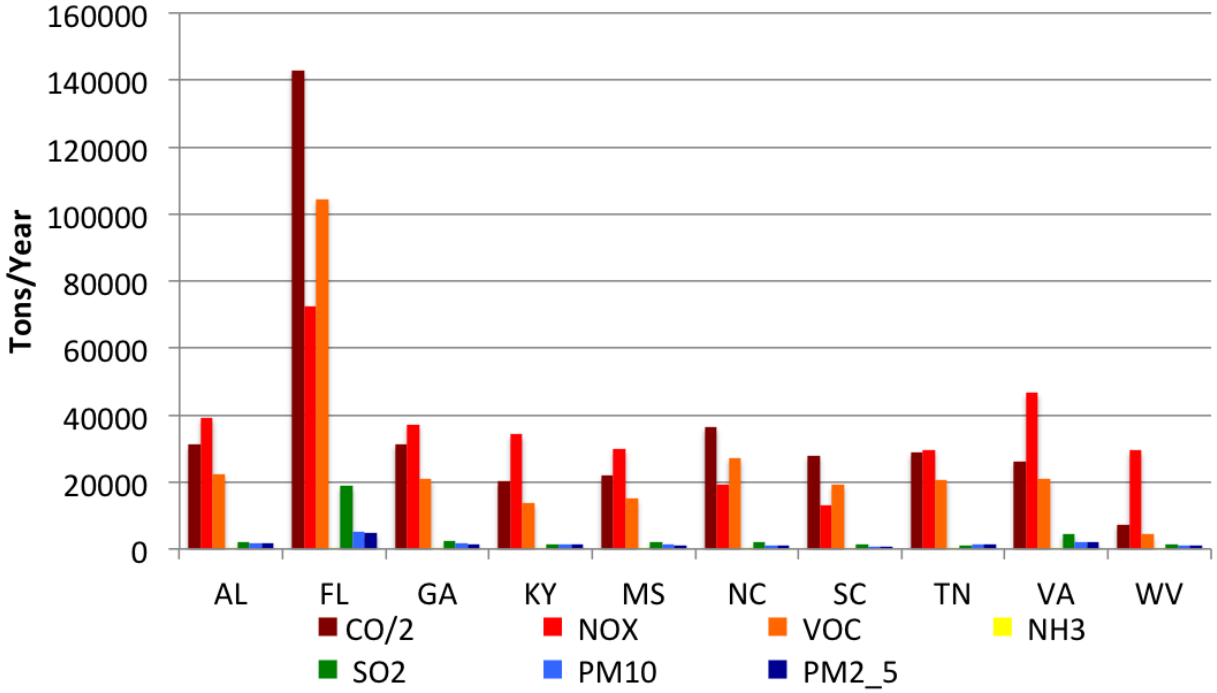


Figure 2-19. SESARM state annual total 2007 ALM source emissions; note that the CO emissions are divided by 2 to normalize their magnitude

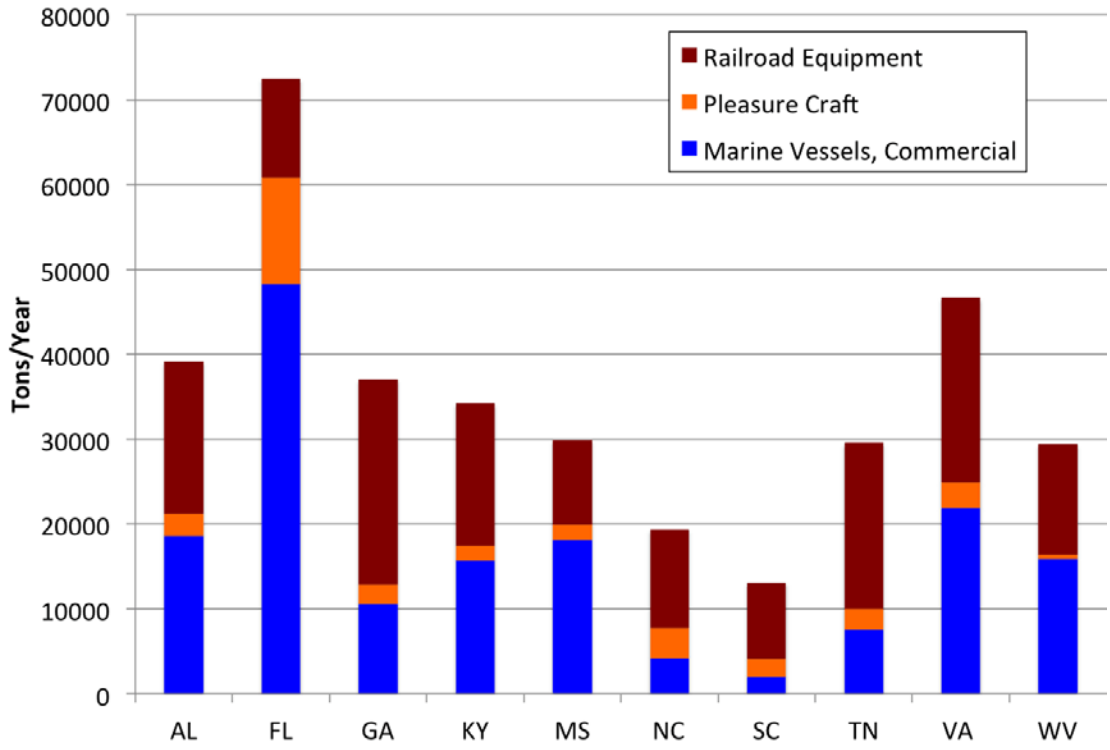


Figure 2-20. SESARM state annual total ALM NOx emissions by SCC Tier 2

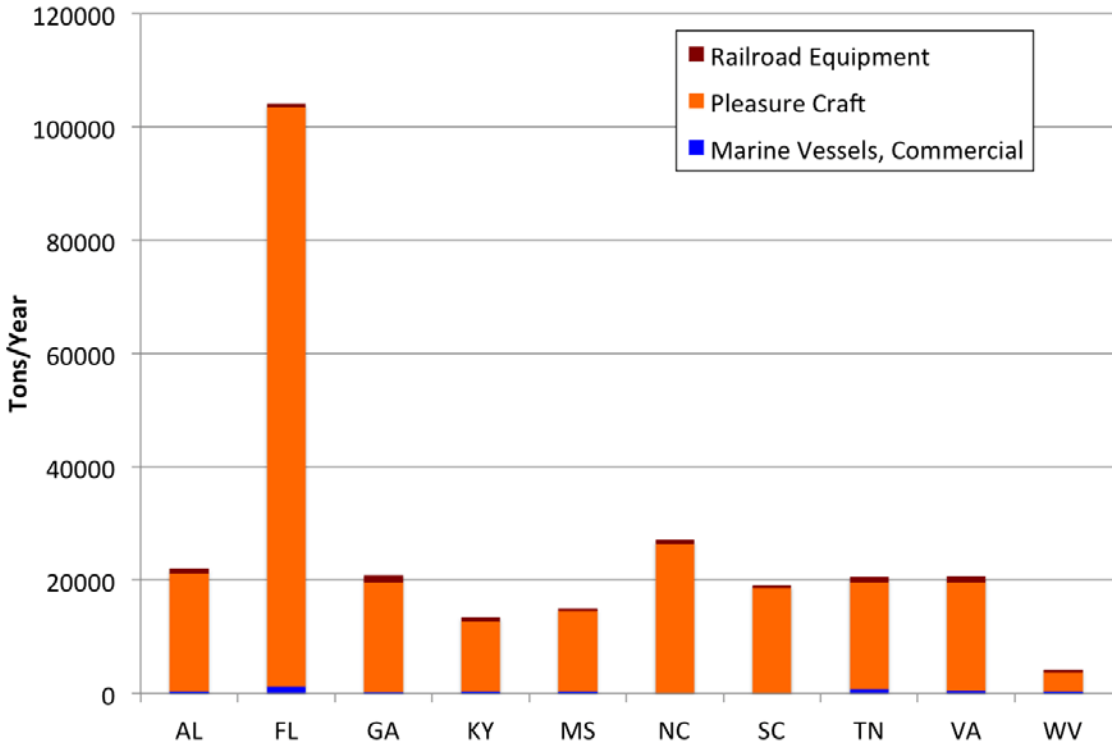


Figure 2-21. SESARM state annual total ALM VOC emissions by SCC Tier 2

2.1.2.8 Onroad mobile

Region	Data Source	Final Version	Notes
SESARM (without VA)	AMEC/Alpine Geophysics	September 11, 2011	MOVES 2010a run in emissions factor mode
VA	AMEC/Alpine Geophysics/VA DEQ	February 7, 2012 EI and September 11, 2011 MOVES	MOVES 2010a run in emissions factor mode with VMT and VPOP updates provided by VA DEQ
MANE-VU (without VA)	MARAMA		Gridded to the OTC 36 and 12-km modeling grids
MWRPO	US EPA	NEI2005v4	MOVES2010a run in emissions inventory mode, monthly inventories with adjustments for running and start PM emissions; downloaded from ftp://ftp.epa.gov/EmisInventory/2005v4/2005emis/
CENRAP	US EPA	NEI2005v4	
WRAP	US EPA	NEI2005v4	

The **Onroad Mobile (or onroad)** data category describes a wide variety of vehicles, engines, and equipment that under their own power can move from one location to another on paved and un-paved roads. There is a distinction between on-road sources and those sources that are non-road. On-road sources include vehicles used for the transportation of passengers or freight. Non-road sources distinguish between commercial-military marine vessels/railroad (on-rail)/aircraft and all other non-road categories (e.g., construction equipment, recreational equipment, agricultural equipment, etc.).
On-road mobile sources include light-duty vehicles, light-duty trucks, heavy-duty vehicles, buses and motorcycles used for transportation of goods and passengers on established roadways. On-road vehicles may be fueled with gasoline, diesel fuel, or alternative fuels such as alcohol or natural gas.
The Motor Vehicle Emissions Simulator (MOVES[8]) is EPA's current tool to construct on-road mobile source emissions estimates for national, state, and county level inventories of criteria air pollutants, greenhouse gas emissions, and some mobile source air toxics from highway vehicles (EPA, 2012a). In addition, MOVES can make projections for energy consumption (total, petroleum-based, and fossil-based). EPA requires that all new regulatory modeling use the MOVES model for mobile source emissions (EPA, 2012c).
The SEMAP on-road mobile source emission modeling was conducted using MOVES2010a. In April 2012 EPA released MOVES2010b after SESARM contractors completed their MOVES simulations. According to EPA's documentation, the primary difference between MOVES2010b and MOVES2010a is related to performance issues (e.g., computing run time) and the emission estimates produced by the two versions of MOVES are nearly identical[9]. EPA's technical guidance for State Implementation Plans (SIPs) and transportation conformity notes that studies that started with MOVES2010a do not have to switch to the new MOVES2010b (EPA, 2012b[10]).
MOVES2010a can be configured to estimates emissions directly (i.e., emissions inventory mode) or estimates emissions factors (i.e., emissions factor mode). There are two main approaches for using MOVES to generate hourly gridded speciated emission inputs needed for photochemical grid models:

- Emissions Inventory Mode (EIM): Run MOVES in emissions inventory mode using county-specific representative hourly temperature, vehicle miles traveled (VMT) and other inputs (e.g.,

[8] http://www.epa.gov/otaq/models/moves/index.htm
[9] http://www.epa.gov/otaq/models/moves/documents/420f12014.pdf
[10] http://www.epa.gov/otaq/models/moves/documents/420b12028.pdf

fleet mix and fuel type) to generate hourly, daily, monthly, or annual county-level on-road mobile source emissions. The Sparse Matrix Operator Kernel Emissions (SMOKE) emissions modeling system is then used to grid, temporalize, and speciate the county-level MOVES inventories.

- Emissions Factor Mode (EFM): Use the SMOKE-MOVES tool that accesses a MOVES emission factor lookup table using gridded hourly meteorological data and representative VMT, vehicle population (VPOP), fleet mix, fuel type, etc. for the grid cell to generate gridded hourly on-road emission estimates that are then speciated into the appropriate chemical species. The MOVES lookup table is generated by running MOVES multiple times in emissions factor mode for different temperatures, fuel types, etc.

UNC used a combination of MOVES2010a EFM and EIM simulations to estimate the 2007 base year onroad emissions for the SEMAP project. UNC used 2007 MOVES EIM results from the US EPA NEI2005v4 modeling platform for the LADCO, CENRAP, and WRAP states. These data included monthly, county-level criteria pollutant inventories and Python scripts for adjusting the start and running PM emissions based on simulated temperatures. MANE-VU provided hourly, gridded SMOKE-output emissions on the CONUS 36-km domain and the MANE-VU 12-km domain produced from an annual 2007 MOVES EFM simulation. These results did not include emissions for VA. UNC had to re-grid the 12-km MAVE-VU MOVES results to the SESARM 12-km domain. Alpine Geophysics provided annual MOVES EFM inventories, look-up tables, and MOVES meteorology inputs for all SESARM states, including VA. UNC ran these data through the SMOKE-MOVES processor to generate hourly emissions estimates for three MOVES operating modes: rate-per-distance (RPD), rate-per-vehicle (RPV), and rate-per-profile (RPP). Details of this processing are included below.

SESARM SMOKE-MOVES Processing

UNC received year 2007 onroad mobile inventories for the 10 SESARM states that included annual, county-level total vehicle miles traveled (VMT), total vehicle population (VPOP), and average speeds. Table 2-9 lists the versions of the onroad mobile inventory files used for the SEMAP final base 2007 emissions estimates. Table 2-10 describes and lists the versions and origins of the other SMOKE-MOVES input files. Alpine Geophysics provided MOVES emissions factor lookup tables, a reference county cross-reference file (MCREF), and fuel months for each SESARM state. UNC developed the MOVES emissions process (MEPROC) file for each of the MOVES operating modes (Table 2-11). The SESARM states commented on and/or provided updates to the MOVES county speed cross-reference (SPDREF) and profile (SPDPRO) files:

- AL – MOVES default county average speeds from March 2011
- FL – EPA OTAQ county speed profiles
- GA – State updates to the OTAQ county speed profiles
- KY – EPA OTAQ county speed profiles
- MS – MOVES default county average speeds from March 2011
- NC – State updates to the OTAQ county speed profiles
- SC – EPA OTAQ county speed profiles
- TN (Shelby County) – State updates to the county average speed inventory
- TN (Rest of state) – State updates to the OTAQ county speed profiles
- VA – State updates to the county average speed inventory
- WV – EPA OTAQ county speed profiles

Table 2-9. SEMAP state onroad mobile 2007 inventory versions

State	VPOP	VMT	SPEED
AL	v1 (18Aug2011)	v1 (18Aug2011)	v1 (18Aug2011)

FL	v2 (11Sep2011)	v1 (18Aug2011)	v1 (18Aug2011)
GA	v1 (18Aug2011)	v1 (18Aug2011)	v1 (18Aug2011)
KY	v1 (18Aug2011)	v1 (18Aug2011)	v1 (18Aug2011)
MS	v1 (18Aug2011)	v2 (11Sep2011)	v2 (11Sep2011)
NC	v1 (18Aug2011)	v1 (18Aug2011)	v1 (18Aug2011)
SC	v1 (18Aug2011)	v1 (18Aug2011)	v1 (18Aug2011)
TN	v1 (18Aug2011)	v1 (18Aug2011)	v2 (11Sep2011)
VA	v3 (07Feb2012)	v3 (07Feb2012)	v3 (07Feb2012)
WV	v1 (18Aug2011)	v2 (11Sep2011)	v2 (11Sep2011)

Table 2-10. SEMAP SMOKE-MOVES input files

File	Data Source	Final Version	Notes
EFTable	Alpine Geophysics	31Aug2012	MOVES2010a emissions factor tables for representative counties
MCREF	Alpine Geophysics	31Aug2012	Representative county emissions factor cross-reference file
MEPROC	UNC	05Sep2011	MOVES emissions process table, defines the pollutant emissions generated from the MOVES processes
Fuel month	Alpine Geophysics	31Aug2012	Representative county fuel month cross-reference file
SPDREF	EPA/SESARM	09Dec2011	County/SCC speed profile assignments
SPDPRO	EPA/SESARM	09Dec2011	Diurnal speed profile look up table

Table 2-11. SEMAP SMOKE-MOVES modeled emissions processes

MOVES Process	Mode	Pollutants
RPD	Exhaust (EXH)	CO, NO, NO2, HONO, SO2, NH3, TOG, VOC_INV, POC, PEC, PSO4, PNO3, PMFINE, NH4, PMC
	Evaporative (EVP)	CO, NO, NO2, HONO, SO2, NH3, TOG, VOC_INV
	Brake wear (BRK)	PM25BRAKE, PMC
	Tire wear (TIR)	PM25TIRE, PMC
RPP	EVP	TOG, VOC_INV, BENZENE
RPV	EXH	CO, NO, NO2, HONO, SO2, NH3, TOG, VOC_INV, BENZENE, POC, PEC, PSO4, PNO3, PMFINE, NH4, PMC
	EVP	CO, NO, NO2, HONO, SO2, NH3, TOG, VOC_INV, BENZENE

Table 2-24 includes the 2007 state total annual onroad mobile source emissions used for the SEMAP modeling. Note that for all of the states outside of the SESARM region the totals in Table 2-24 are

derived from the gridded SMOKE output files using a GIS. UNC needed to use a post-processing GIS program to estimate the state totals for the MARAMA states because UNC didn't process these emissions through SMOKE-MOVES and received only gridded SMOKE output data from MANE-VU. UNC needed to use this GIS approach for the MWRPO, CENRAP, and WRAP states because these emissions were processed using a post-processing (post-SMOKE) program to apply temperature adjustments to the emissions. The implication of using a GIS to estimate the state totals is that there will be errors of about 1-3% in the annual state totals due to misalignments between the GIS state boundary layer and the modeling grid.

Figure 2-22 displays the 2007 state total onroad mobile emissions for the 10 SESARM states. Florida is the largest emitter of onroad mobile emissions in the region, contributing about 22% of the NOx and 23% of the VOC emissions for the SESARM region onroad sources. Other large regional sources of onroad mobile NOx include Georgia (17.6%), North Carolina (12.5%), and Tennessee (11.1%). The other large regional sources of onroad mobile VOC include Georgia (16.7%), North Carolina (14.3%), and West Virginia (10%).

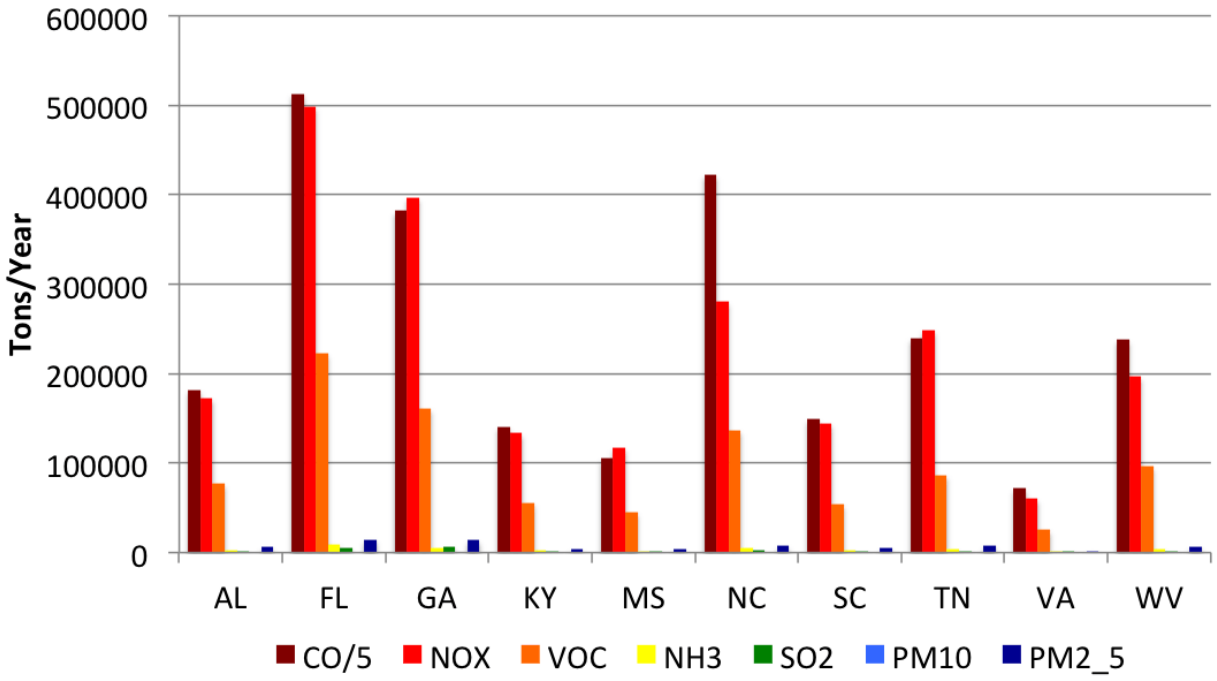


Figure 2-22. SESARM state annual total 2007 onroad mobile source emissions; note that the CO emissions are divided by 5 to normalize their magnitude

2.1.2.9 EGU and Non-EGU point

Region	Data Source	Final Version	Notes
SESARM	AMEC	2007v1.10a	NIF to ORL conversion by UNC
MANE-VU	MARAMA	Version 3.3	Downloaded from ftp.marama.org in ORL format; VA removed by UNC
MWRPO	US EPA	NEI2008v2	Downloaded from ftp://ftp.epa.gov/EmisInventory/2008dev/ in ORL format
CENRAP			
WRAP			

The **Point** data category contains emission estimates for sources that are inventoried at specific geographic locations using latitude and longitude coordinates. While point emissions data are typically inventories of sources that emit from a stack, other discrete emissions sources, such as airports and landfills, can also be characterized as point sources. In general, point sources can be characterized as **elevated** or **low-level** sources. Elevated point sources produce emissions at elevations above the surface and are typically emitted from a smoke stack. Elevated point source inventories include stack parameters for each source (stack height, stack diameter, exit gas velocity, exit gas temperature) that are used to calculate an hourly vertical plume distribution (i.e., plume rise) for the emissions from the source. Examples of elevated point sources include power plants, smelters, and cement kilns. Low-level point sources produce emissions at the surface and as such low level point inventories include stack parameters that do not result in significant plume rise for the emissions from these sources, such as stack heights of 0. Examples of low-level point sources include wastewater treatment facilities, quarries, and landfills. For emissions modeling purposes, point sources are defined by an administrative unit (state and county (or tribal) codes), release point (plant, stack, and unit identifier), release location (latitude and longitude coordinate), SCC codes and SIC codes.

Other ways to separate the point source inventory include by electric generating unit (EGU) versus non-EGU sources and Continuous Emission Monitoring (CEM) vs. non-CEM sources. For the SEMAP modeling UNC used these distinctions to define the point source processing sectors based on whether the sources have records in the EPA Clean Air Markets Division (CAMD) CEM database and if they're EGU or non-EGU sources. The SESARM and MANE-VU states further defined their CEM point inventories based on whether they reported emissions to CAMD on annual or ozone-season cycles.

AMEC (2013) developed the 2007 SESARM state point inventory for the SEMAP project. UNC obtained the 2007 point inventory for the northeast states from MARAMA. UNC used the NEI2008v2 for the rest of the states in the U.S.

To accommodate the different data requirements of the point source inventories used for the SEMAP project, UNC defined the following emissions processing categories:

- SESARM EGU CEM point (**sesarm_ptcem_EGU)**
    - Criteria air pollutants for EGU sources that reported to CAMD for all SESARM states, including VA
    - Includes CEM data with anomalies removed and for partial reporting units (see next section)
    - Hourly CEM and annual point inventories normalized based on state guidance
- SESARM non-EGU CEM point (**sesarm_ptcem_nEGU)**
    - Criteria air pollutants for non-EGU sources that reported to CAMD for all SESARM states, including VA
    - Includes CEM data with anomalies removed and for partial reporting units (see next section)
    - Hourly CEM and annual point inventories normalized based on state guidance
- SESARM EGU non-CEM point (**sesarm_ptncem_EGU)**
    - Criteria air pollutants for EGU sources that did not report to CAMD for all SESARM states, including VA
- SESARM non-EGU non-CEM point (**sesarm_ptncem_nEGU)**
    - Criteria air pollutants for non-EGU sources that did not report to CAMD for all SESARM states, including VA

- MANE-VU CEM point (**mv_ptcem**)
    - Criteria air pollutants for all MANE-VU states except VA
    - Includes CEM units that report to CAMD for 12-months of the year, 5-month (ozone season only) reporting CEM units, and 6-month reporting CEM units for sources in MD
    - Includes 2007 hourly CEM inventories from MARAMA
- MANE-VU non-CEM point (**mv_ptncem**)
    - Criteria air pollutants for all MANE-VU states except VA
    - Seven month non-ozone season emissions for CEM units that only report to CAMD during the ozone season
    - Includes a corresponding set of temporal profiles for these sources
- US point sources (**uspt**)
    - Criteria air pollutants from the NEI08v2 for the MWRPO, CENRAP, and WRAP states, tribes, and Gulf of Mexico offshore drilling platforms
    - Includes MANE-VU (MARAMAv3.3) sources without CEM data
    - Includes 2007 hourly CEM inventories from CAMD
    - Does not include airports (see Section 2.1.2.10 on Airport points)

Other emissions source categories that are inventoried as point sources include airports, fires, and commercial shipping. These categories are described in subsequent sections of this report.

UNC worked with Georgia Environmental Protection Division (GA EPD) to generate annual CEM inventories for sources in the SESARM states that operate annually but only report emissions to CAMD for the ozone season. UNC also developed an approach to identify and remove anomalous data points in the CAMD CEM inventories. Details of CEM data and how these data are prepared for emissions modeling are included in the next sections.

2.1.2.9.1 CEM anomaly corrections and gapfilling

UNC developed a methodology for blending hourly CEM data with annual inventories to ensure both internal consistency in the inventory data and accuracy in representing the temporal emissions patterns of large point sources. These methods were developed through discussions between the UNC-IE, SESARM, and the SEMAP EGU working group. All of the methods described here were applied to the final version of the SESARM "actual" 2007 point source inventory developed for the SEMAP project.
Under Part 75 of Volume 40 in the Code of Federal Regulations, CEM and reporting is required for large EGUs and industrial facilities. The U.S. EPA Clean Air Markets Division (CAMD) collects and distributes hourly CEM data for NOx and SO2 emissions (lbs/hr), heat input (mmBTU), gross load (MW), and steam load (1000 lbs/hr) for thousands of U.S. sources from the year 1995 to the present. Some units are required to report hourly emissions year-round (annual reporters), while other units are only required to report hourly emissions for part of the year (partial year reporters). To satisfy the Part 75 requirement that CEM data are reported for every operating hour that is required to report emissions, a complex process for reporting and filling in missing data has been defined. Many times, missing emissions are substituted with values that are much larger than the actual emissions that were emitted. In order to properly address the issues described above, four steps must be followed to correctly simulate the emissions from these sources.

1. Anomalous data points in the CEM database that resulted from the Part 75 substitution methodology must be identified and corrected.

2. Differences between the reported CEM emissions and annual emissions estimates reported by the states for the CEM units must be reconciled and simulated accordingly
3. Hourly emissions for the non-reporting periods need to be generated.
4. Annual NOx and SO2 inventories for CEM point sources should be reconciled with the annual total of the corrected CEM hourly data.

In some cases the Part 75 substitution methodology results in hourly emission spikes in the NOx and/or SO2 CEM data that are clearly anomalous relative to the surrounding hourly data. Figure 2-23 shows an example of anomalous SO2 emissions in the actual 2007 CEM database. UNC developed a method to identify and replace anomalous data points in SMOKE-formatted CEM files. These corrections must be made before reconciling the CEM data with the annual emissions estimates.

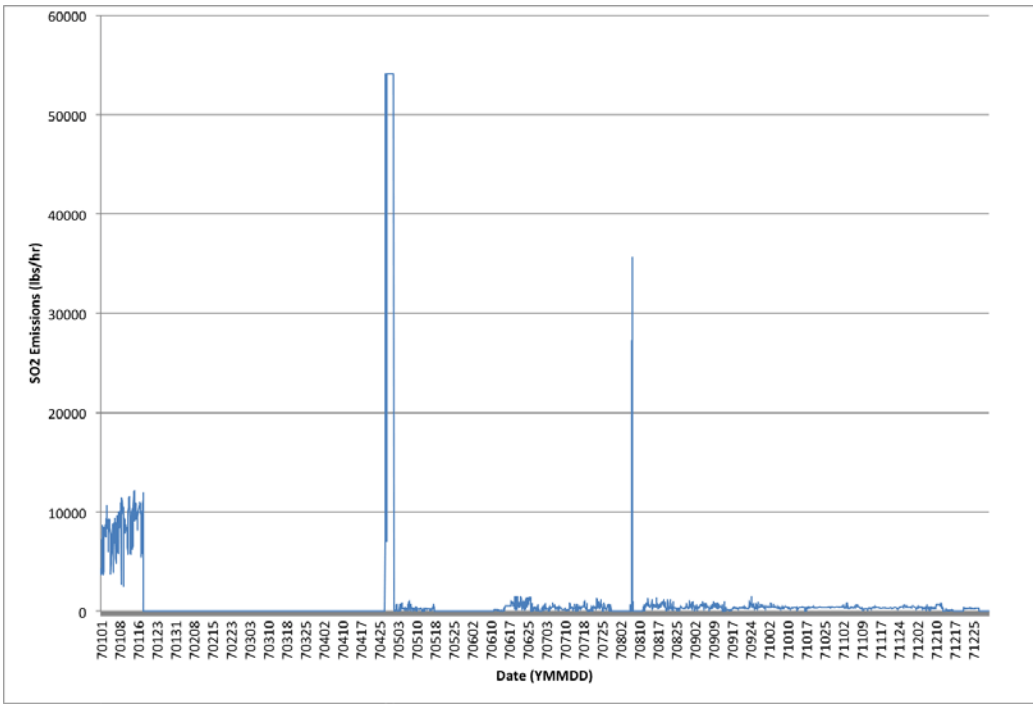


Figure 2-23. Example of anomalous SO_2 emissions in the CEM data

UNC developed an approach to correct anomalous data points in the CEM data resulting from Part 75 substitutions. The approach was developed for SESARM and has been reviewed by EPA OAQPS and CAMD[11] and presented at technical conferences (Adelman et al., 2012).

Figure 2-24 and Figure 2-25 illustrate the CEM emissions for two sources that were impacted by the anomaly correction procedure. Two CEM datasets are plotted in these figures. The black line shows the original CEM data and the red line shows the corrected data after removal of the anomalous emissions. Figure 2-24 is a time series plot of the hourly CEM NO_X emissions for Dominion-Hopewell Power #2 in Virginia. The black lines seen early April in this plot are substituted data that are present in the original CEM data from CAMD. The red lines during the same period in early April are the corrected data.

11 http://www.ie.unc.edu/cempd/projects/SEMAP/secure/documents/SEMAP_EGU_Modeling_Approach_11_17_2011.pdf

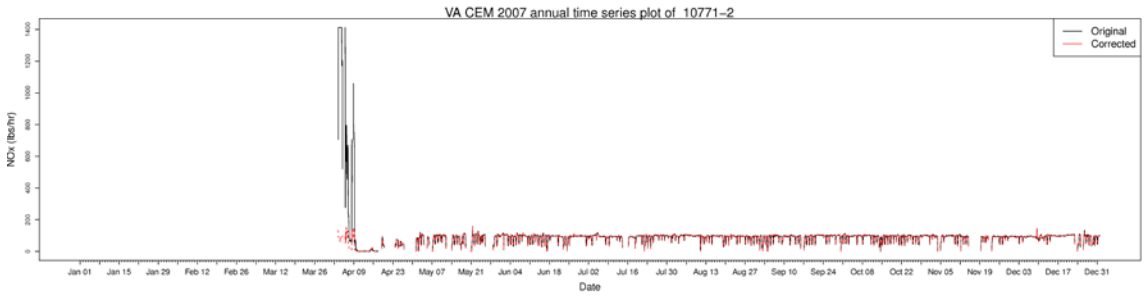


Figure 2-24. Virginia Dominion-Hopewell #2 2007 CEM NO_X emissions; illustration of anomalous data correction approach

Figure 2-25 is a time series plot of the hourly CEM SO_2 emissions for Mountaineer #1 in West Virginia. This plot shows a similar trend with the correction of anomalous emissions data in mid-February. These plots illustrate that the corrected data used to replace the anomalous emissions records for these two units is consistent with the overall magnitude of the CEM emissions during the rest of the year.

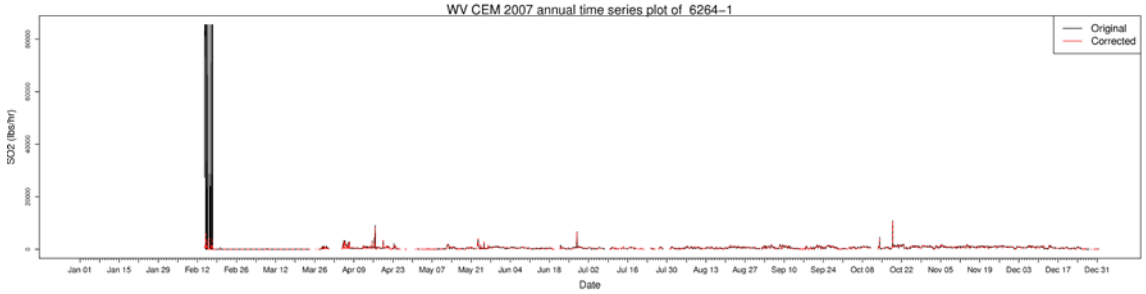


Figure 2-25. West Virginia Mountaineer #1 2007 CEM SO_2 emissions; illustration of anomalous data correction approach

UNC used the approach described above to identify and correct anomalies in the 2007 CAMD CEM database for the SESARM states.

Table 2-12 shows for each SESARM state the total amount of anomalous NOx and SO2 emissions (tons) and heat input (HI, mmBTU) identified and removed from the 2007 CEM data. The values in parentheses in

Table 2-12 are the total number of hours across the year that UNC scrubbed from the CEM data for each variable. Sources in Florida accounted for the most NOx anomalies in the SESARM region (1,777 tons and 2,291 hours), with three facilities (TAMPA ELECTIC COMPANY, FLORIDA POWER CORPDBAPROGRESS ENERGY FLA, and FLORIDA POWER & LIGHT (PSN)) contributing over 90% of these anomalies. Sources in West Virginia accounted for the most SO_2 anomalies in the SESARM region (2,288 tons and 453 hours), with two facilities (OHIO POWER – MITCHELL PLANT and APPALACHIAN POWER – MOUNTAINEER PLANT) contributing over 90% of these anomalies. Sources in North Carolina accounted for the most HI anomalies in the SESARM region (1,331 mmBTU and 420 hours), with two facilities (DUKE ENERGY CAROLINAS, LLC – MARSHALL ST. and PLANT ROWAN COUNTY) contributing over 90% of these anomalies.

Table 2-12. SESARM state 2007 CEM anomaly correction summary

State	Tons NOx Anomaly (Hours)	Tons SO_2 Anomaly (Hours)	mmBTU HI Anomaly (Hours)
AL	187.5 (1351)	31.1 (14)	32.6 (69)
FL	1777.0 (2291)	124.3 (233)	279.0 (72)
GA	77.3 (519)	2.4 (11)	3.2 (4)
KY	132.6 (399)	1376.4 (271)	10.8 (15)
MS	76.3 (326)	284.6 (390)	48.9 (106)
NC	713.1 (1977)	895.3 (305)	1331.4 (420)
SC	14.3 (174)	3.3 (17)	14.1 (38)
TN	97.6 (728)	16.4 (3)	0.7 (3)
VA	144.7 (507)	167.8 (416)	99.2 (141)
WV	765.9 (323)	2287.9 (453)	0.0 (0)

2.1.2.9.2 CEM partial year reporters

CEM sources can be classified as either full or partial reporters. In general, CEM data for full reporters contain nearly continuous hourly emissions throughout their operating year. Full reporters don't always operate for the entire calendar year, but they do report emissions continuously for the period that they operated. In general, the development of the annual point (PTINV) NO_x and SO_2 inventories for CEM units is accomplished by summing the hourly CEM data to annual values. The CEM units are classified as partial reporters when both of the following criteria are met:

- The sum of the hourly CEM emissions is less than the annual value in the PTINV inventory
- CEM data are missing for at least one full month, including when a full month of reported CEM data have zero or null (-9) values

Identifying whether a source is a full or partial year reporter requires a comparison of the annual PTINV and CEM inventories for sources in the CEM database. Unique CEM sources are identified through a combination of the ORIS and boiler ID inventory fields. Once the CEM sources are matched with records in the PTINV file, UNC can classify the CEM sources as full or partial reporters.

After the partial reporters in the CEM database are identified, UNC used the following approach to estimate emissions for the reporting and non-reporting periods. The reporting period is defined as the period(s) for which the partial CEM reporters provide data; the non-reporting period is defined as the period(s) for which the partial CEM reporters do not provide data. Conceptually this approach will use full reporting sources to simulate the temporal patterns during the non-reporting period for the partial reporters. The details of this approach include estimating the total non-reporting period emissions for each partial reporter, identifying sources most similar to each partial reporter from the database of full reporters, estimating typical hourly emissions from these similar sources, and then using these typical hourly emissions to simulate the temporal patterns during the non-reporting period(s) for the partial reporting CEM unit.

The first step in simulating the emissions from a particular unit for a partial reporter is to calculate the emissions for the reporting (E_{on}) and non-reporting (E_{off}) periods. Emissions for E_{on} are calculated by summing the hourly CEM values for the unit across the entire reporting period (Equation 1).

(Equation 1) $E_{on} = \Sigma CEM_{hr}$

Emissions for E_{off} are calculated by subtracting E_{on} from the annual inventory value for a particular emissions unit (Equation 2).

(Equation 2) $E_{off} = E_{ann} - E_{on}$

where if $E_{off} < 0$, then $E_{off} = 0.0$

E_{off} emissions will only be simulated under the following conditions:

- The source is partial reporter
- $R > 5$, where $R = ABS(100 - 100*E_{on}/E_{ann})$, and
- $E_{off} > 10$ ton/yr

Since CEM data are available only for NOx and SO_2, the CEM heat input (HI) field is used to calculate the temporal variability for the other inventory pollutants (i.e. $PM_{2.5}$, NH_3, CO, etc). The heat input values for the reporting (HI_{on}) and non-reporting (HI_{off}) are calculated with Equations 3 and 4, respectively.

(Equation 3) $HI_{on} = \Sigma CEM_{hr,HI}$

(Equation 4) $HI_{off} = HI_{on} * \Sigma HI_{off,MS} / \Sigma HI_{on,MS}$

The terms $HI_{on,MS}$ and $HI_{off,MS}$ in Equation 4 are summed total heat inputvalues for the reporting and non-reporting periods, respectively, calculated from matching sources (MS) in the same state that have similar source classification codes (SCCs). Section 6 below provides details on how similar sources are identified.

After calculating E_{on} and E_{off} for NO_x and SO_2, UNC can then use the CEM data to estimate the hourly temporal variability in the emissions. Because the partial reporters do not have CEM data for the non-reporting period, we've developed an approach for matching the partial reporters to similar full reporting CEM sources. The hourly temporal variability for these representative sources will be used to estimate the temporal profiles for the partial reporters during the non-reporting period.

UNC use a state and SCC-based matching system to identify the full reporting sources in the CEM database to use for calculating representative hourly emissions for the non-reporting periods. The code structure for an 8-digit point source SCC is:

(SCC Code Structure) A BB CCC DD

where, A = Tier 1, Process Type (e.g., External Combustion Boiler or Industrial Process)
B = Tier 2, Application (e.g., Electricity Generation or Industrial)
C = Tier 3, Fuel (e.g., Anthracite Coal or Gasoline)
D = Tier 4, Technology Type (e.g., Turbine or Stoker)

After identifying the partial reporters, the ORIS and Boiler ID fields are cross-referenced to the annual PTINV inventory file to find the SCCs associated with each CEM unit. In some cases there may be multiple SCCs associated with a single ORIS and Boiler ID combination. UNC assign the SCC to the unit that has the largest amount of emissions in the annual PTINV file. After assigning an SCC to each partial reporter in the CEM database UNC identify representative sources in the list of full reporters using the following hierarchy.

(1) Match by State ID and Tier-4 SCC

(2) If no match in (1), then match by State ID and Tier-3 SCC

(3) If no match in (2), then match by State ID and Tier-2 SCC

(4) If no match in (3), then match by State ID and Tier-1 SCC

If multiple representative sources are identified for a single partial reporting unit, the CEM data will be averaged across all of the sources for each month of the non-reporting period.

For each partial reporter in the CEM database, hourly heat input (HI) data from the group of representative sources are used to estimate the CEM emissions during the non-reporting periods. UNC

calculate hourly average HI for all representative sources for the entire non-reporting period to create a single average representative source. Only valid HI fields (skip "-9") are used to in the calculation of the representative hourly HI values. Hourly emissions of NO_x and SO_2 for the non-reporting period ($CEM_{off,hr}$) are calculated using Equation 5. Equation 5 uses hourly HI from representative sources to estimate emissions on each hour of the non-reporting period. The term $\Sigma HI_{hr,off,MS}$ in Equation 5 is the sum of the HI values from matching sources (MS) with similar SCCs for each hour of the non-reporting period; the term $\Sigma HI_{off,MS}$ is the sum of the HI values for matching sources with similar SCCs for the entire non-reporting period. The ratio of these two HI terms is an estimate of the fractional emissions for each hour of the non-reporting period for matching sources in the CEM database. The product of the total non-reporting period emissions (E_{off}) and these hourly fractions produces an estimate of the hourly emissions for the non-reporting period ($CEM_{off,hr}$).

(Equation 5) $$CEM_{off,hr,} = E_{off} * (\Sigma HI_{hr,off,MS}/\Sigma HI_{off,MS})$$

Equation 6 shows that substituting the non-reporting period emissions term in Equation 5 (E_{off}) with total non-reporting period HI (from Equation 4) estimates non-reporting period hourly HI values to use for calculating hourly emissions for the pollutants other than NO_x and SO_2. Null hourly CEM records (-9) are excluded from Equations 5 and 6.

(Equation 6) $$CEM_{off,hr} = HI_{off} * (\Sigma HI_{hr,off,,MS}/\Sigma HI_{off,MS})$$

The result of this step will be a SMOKE-formatted CEM file that contains hourly SO_2, NO_x, and HI fields for the non-reporting periods for each partial reporter in the CEM database. These data will be combined with the CEM data for the reporting period to create a full set of annual CEM data for each partial reporter.

Figure 2-26 illustrates CEM emissions for a source in which hourly non-reporting period emissions were calculated using the approach described above. This plot shows two sets of data. The black line shows the CEM data after any anomalous data points were removed. The red line shows the full year CEM data that includes the hourly non-reporting period emissions. Figure 2-26 is a time series plot of CEM NOx emissions at a unit in Virginia. This unit reported an annual total of 711.10 tons of NOx and hourly CEM data for 5 months that sum to 276.87 tons. The non-reporting period emissions, calculated as the difference between the annual total and the sum of the CEM data, of 434.2 tons were distributed to the non-reporting months using hourly heat input profiles from similar sources. The red dashed line in Figure 2-26 shows the hourly emissions in the non-reporting period relative to the reporting period emissions (shows as the overlaid black and red lines). Table 2-13 shows the monthly total CEM NOx emissions before and after the distribution of the non-reporting period emissions. One feature to note in this table is that the emissions in the reporting months (May-September) are not changed by the distribution of the non-reporting period emissions. All of the non-reporting period emissions were allocated to January-April and October-December, based on the heat input profiles from similar CEM sources.

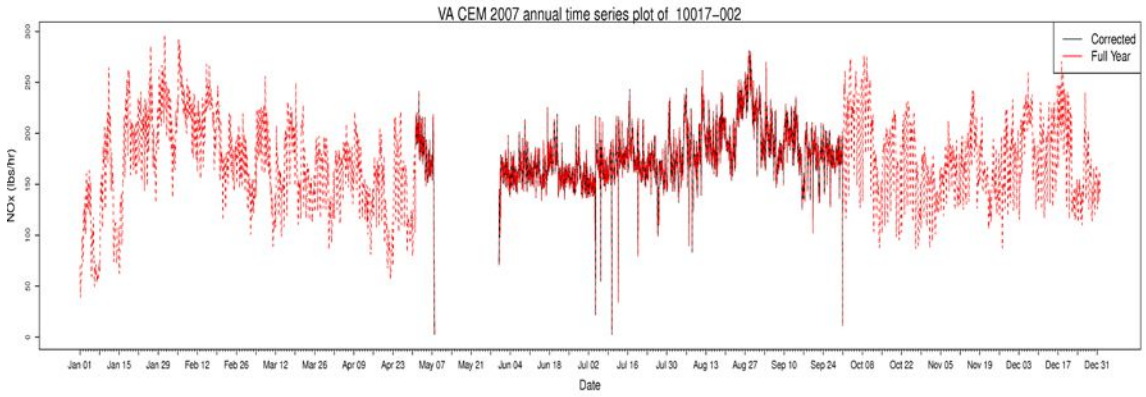


Figure 2-26. Virginia Stone Container Enterprises #2 2007 CEM NOx emissions; illustration of distribution of non-reporting period data

Table 2-13. Stone Container Enterprises #2 2007 CEM NOx emissions before and after distribution of non-reporting period data

Month	CEM NOx before distribution (tons/month)	CEM NOx after distribution (tons/month)
1	0.00	61.40
2	0.00	68.45
3	0.00	60.93
4	0.00	52.48
5	16.56	16.56
6	58.86	58.86
7	62.04	62.04
8	73.25	73.25
9	66.17	66.17
10	0.00	67.16
11	0.00	57.99
12	0.00	65.82
Total	276.87	711.10

For both full and partial reporters, the hourly CEM data are used to directly simulate NO_x and SO_2 emissions and the HI is used to estimate temporal profiles to convert the annual inventory for the other inventory pollutants to hourly emissions. Equations 7 and 8 show how the hourly CEM NO_x and SO_2 emissions are modeled with SMOKE.

(Equation 7) If $CEM_{NOx,hr} \leq 0.0$ then $E_{hr} = 0.0$ for all pollutants

If $CEM_{NOx,hr} > 0.0$ then

$$\mathbf{E_{NOx,hr} = (E_{NOx,SCC}/\Sigma E_{NOx,SCC}) * CEM_{NOx,hr} * lb2ton}$$

Else $E_{NOx,hr} = 0.0$

(Equation 8) If $CEM_{SO2,hr} > 0.0$ then

$$\mathbf{E_{SO2,hr} = (E_{SO2,SCC}/\Sigma E_{SO2,SCC}) * CEM_{SO2,hr} * lb2ton}$$

Else $E_{SO2,hr} = 0.0$

where, $CEM_{NOx,hr}$ = hourly CEM NO_x emissions at hour *hr*
$CEM_{SO2,hr}$ = hourly CEM SO_2 emissions at hour *hr*
$E_{NOx,SCC}$ = Annual NO_x emissions for a particular SCC at the CEM unit from the annual inventory file (PTINV)

$E_{SO2,SCC}$ = Annual SO_2 emissions for a particular SCC at the CEM unit from the annual inventory file (PTINV)
lb2ton = 0.0005 short tons/lb

For the other inventory pollutants (i.e., VOC, NH_3, $PM_{2.5}$, PM_{10}, CO) at units with CEM data, the hourly emissions fraction derived from the CEM heat input data will be used to allocate the annual emissions to the hourly estimates required for air quality modeling. Equation 9 shows how the hourly emissions will be calculated for the other inventory pollutants.

(Equation 9) $E_{hr} = F_{hr} * E_{ann}$

If $HI_{hr} > 0.0$, then $F_{hr} = HI_{hr}/\Sigma HI_{hr}$

If $HI_{hr} = 0.0$, then $E_{hr} = 0.0$ for all pollutants

where, HI_{hr} = hourly heat input value from CEM
F_{hr} = fraction of emissions at hour *hr*
E_{hr} = Emissions at hour *hr*.

After calculating $CEM_{off,hr}$ for the partial reporters, loop over all the sources and scale the CEM emissions so that the annual total CEM emissions are equal to the annual PTINV values for each unique CEM source (Equation 10). This scaling only applies to NO_x and SO_2. If the annual CEM value equals the annual PTINV value, the scaling factor will be 1.0.

(Equation 10) $S\_CEM_{hr} = CEM_{hr} * (E_{ann}/\Sigma CEM_{hr})$

where, S_CEM = scaled hourly NO_x and SO_2 CEM data

2.1.2.9.3 Point source emissions results

Table 2-25 includes the 2007 state total annual point source emissions used for the SEMAP modeling. These totals are the sum of the CEM and non-CEM point inventories and represent the total stationary point source emissions used for the SEMAP 2007 modeling.

Figure 2-27 and Figure 2-28 display the 2007 state total non-CEM and CEM point source emissions for the 10 SESARM states. Alabama is the largest source of non-CEM point NOx emissions in the region, contributing about 17.4% of the NOx emissions for the SESARM region non-CEM point sources. Other large regional sources of non-CEM point source NOx include Florida (12.6%), Mississippi (11.7%), and Georgia (10.7%). Alabama is also the largest source of non-CEM point SO_2 (16.5%), followed by Florida (15%), Georgia (11.6%), and North Carolina (11.6%). North Carolina is the largest source of non-CEM point VOC (13.4%), followed by Tennessee (13.3%), Kentucky (13.1%), and Alabama (10.7%).

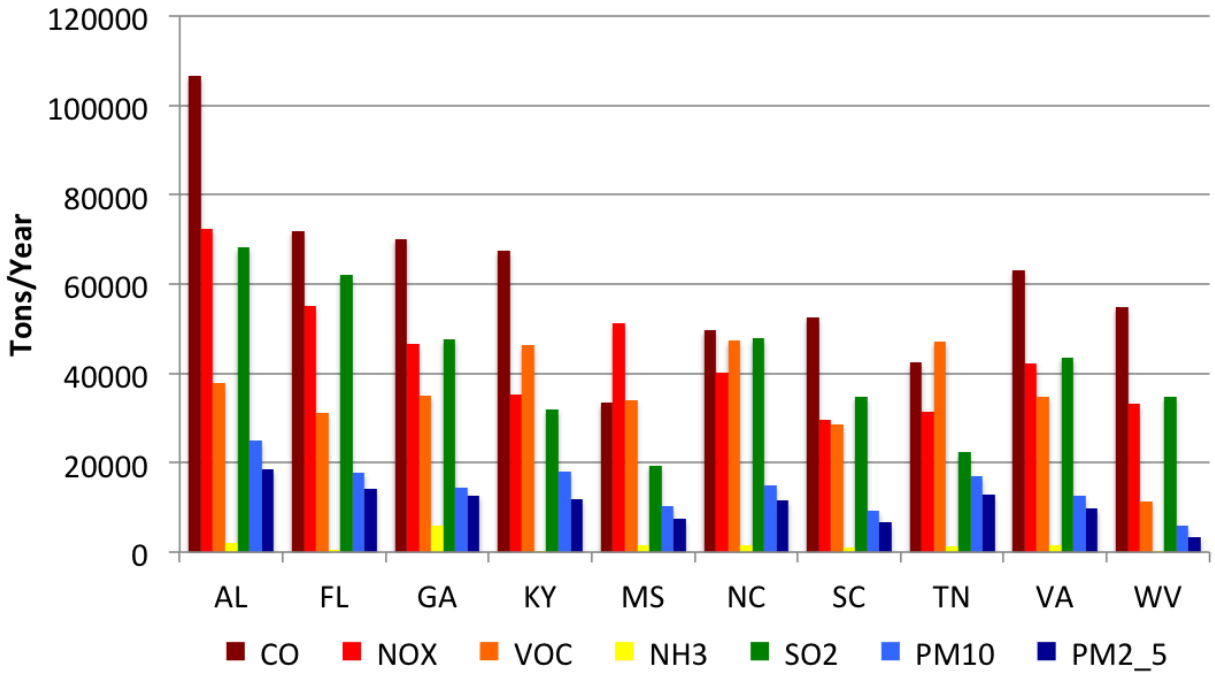


Figure 2-27. SESARM state annual total 2007 non-CEM point source emissions

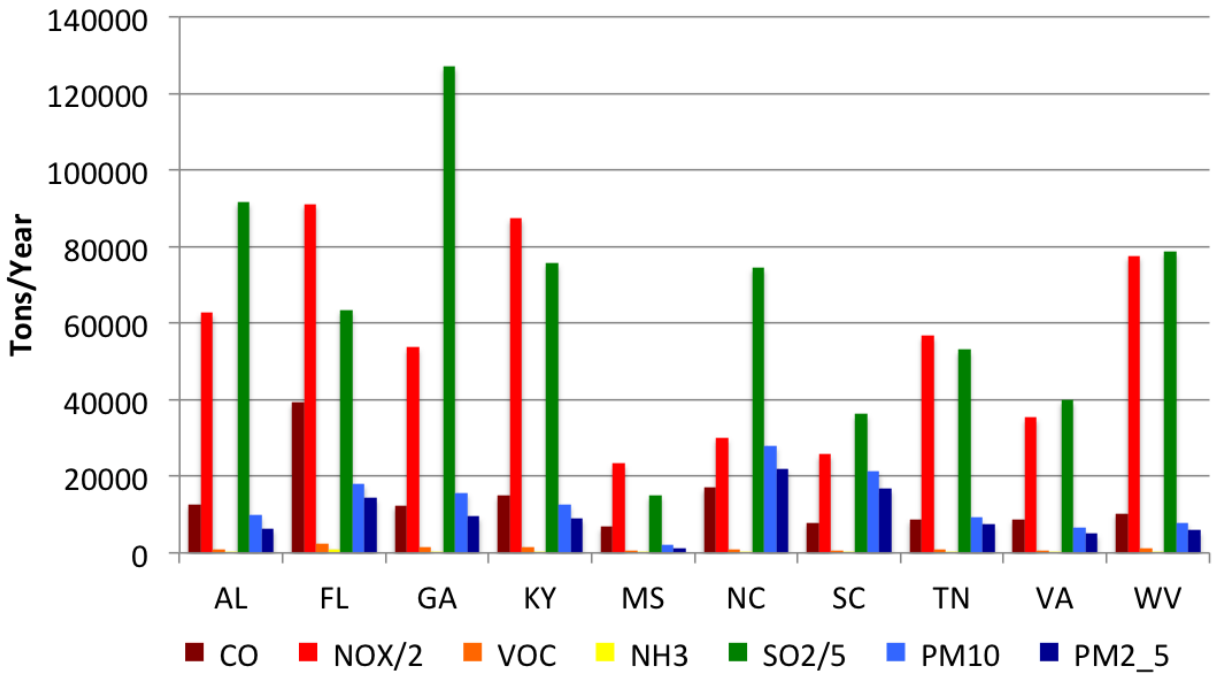


Figure 2-28. SESARM state annual total 2007 CEM point source emissions; note that the NOx emissions are divided by 2 and the SO2 emissions are divided by 5 to normalize their magnitudes.

2.1.2.10 Airport points (airpt)

Region	Data Source	Final Version	Notes
SESARM	TranSystems	March 2012	NIF to ORL conversion by UNC; stack parameters for aircraft based on FAA EDMS airport data
MANE-VU	N/A	N/A	The MANE-VU airport inventory is part of the non-point ALM sector
MWRPO	US EPA	NEI2008v2	Downloaded from ftp://ftp.epa.gov/EmisInventory/2008dev/ in ORL format
CENRAP			
WRAP			

The airport point processing sector (**airpt**) is a subset of the ALM sector. It includes airport ground support equipment and aircraft in their landing/takeoff (LTO) cycles, up to 3,000 feet. The inventory for the airpt sources used for the SEMAP project is a point inventory, with latitude-longitude coordinates used to locate these sources on the modeling grid. Only the MANE-VU states are missing from this processing sector; the airport sources for MANE-VU are nonpoint sources and are contained in the ALM processing sector. UNC separated the SEMAP airpt sources from both the ALM and other point sectors to distinguish it as a point source nonroad mobile sector and to apply vertical profiles to the airports in the SESARM states.

TranSystems Corporation (2012) developed the 2007 SESARM state airport point inventory for the SEMAP project. MARAMA included the airport sources, including LTO aircraft, in their nonpoint ALM inventory. UNC used the NEI2008v2 for the rest of the states in the U.S.

The airport point inventory was developed as a two-dimensional dataset with latitude-longitude coordinates and no stack information to support allocation of the emissions to the vertical layers. To properly model the aircraft component of the airport inventories, which represent emissions from the ground up to 3,000 feet, it was necessary to add vertical profiles to the inventory data before processing them using SMOKE. UNC developed an approach to add a vertical distribution to the aircraft SCCs in the airpt sector by adding stack heights for these sources. For the ground support equipment UNC imposed stack heights of 2.0 meters, effectively putting these emissions in the surface layer. For the aircraft SCCs, UNC used airport profile data associated with the Federal Aviation Administration (FAA) Emissions and Dispersion Modeling System (EDMS)[12] to distribute the emissions to different heights. UNC developed pollutant-specific vertical profiles for the 100 airports in the EDMS database. As the EDMS database only contains data for the 100 largest airports in the U.S., UNC had to create a generic "small airport" vertical profile to apply to the airports in the SEMAP inventory that didn't have matches in the database. UNC created this small airport profile as an average of the vertical profiles for all airports in the 4th quartile of column total CO emissions in the EDMS database. UNC then used the vertical profiles for the airports that had exact matches between the EDMS database and SEMAP inventory to create stack parameters for the airports in the SESARM states. UNC used the average small airport vertical profile to create stack parameters for the airports in the SEMAP inventory that didn't have exact matches in the EDMS database. UNC only added vertical distributions to the airports in the SESARM states; the airport inventory for the rest of the country was simulated as low-level (surface) point sources.

Figure 2-29 illustrates two example airport vertical profiles used for the SEMAP airpt inventory. The figure on the left shows the pollutant-specific vertical profile for the Atlanta Jackson-Hartsfield airport and the figure on the right shows the profile for the generic small airport. Both plots show that the majority of the LTO aircraft CO, VOC, and SO2 emissions occur below 40 feet. The NOx and PM2.5 emissions also peak below 40 feet, they are also significant sources aloft.

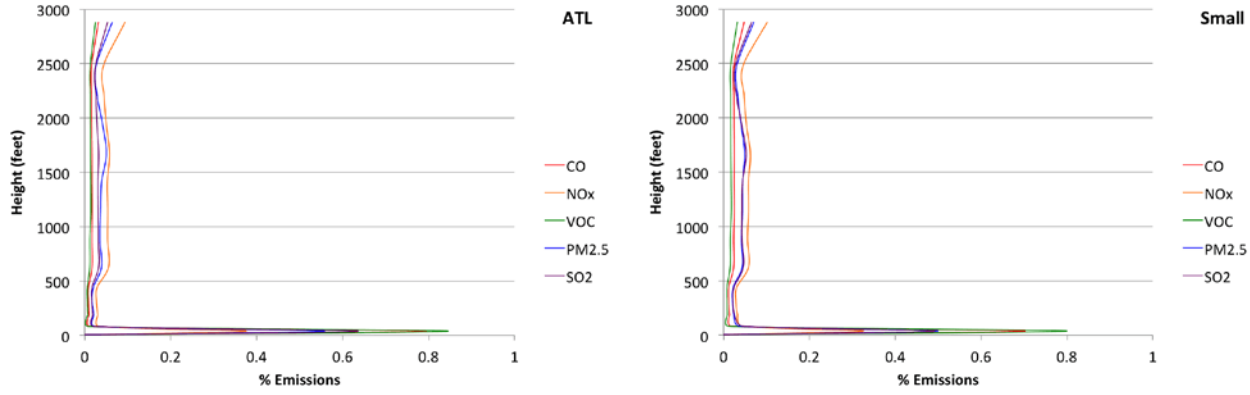


Figure 2-29. Atlanta Jackson-Hartsfield (L) and average small airport (R) pollutant-specific vertical emissions profiles

Table 2-26 includes the 2007 state total annual airport point source emissions used for the SEMAP modeling. This table does not include the airport emissions in the MANE-VU states because these are contained in the nonpoint ALM sector.

Figure 2-30 displays the 2007 state total airport point source emissions for the 10 SESARM states. Florida is the largest source of airport emissions in the region, contributing about 37% of the airport NOx emissions and 27% of the airport VOC emissions for the SESARM region. Virginia, Georgia, and North Carolina are also significant regional sources of airport emissions.

[12] http://www.faa.gov/about/office_org/headquarters_offices/apl/research/models/edms_model/

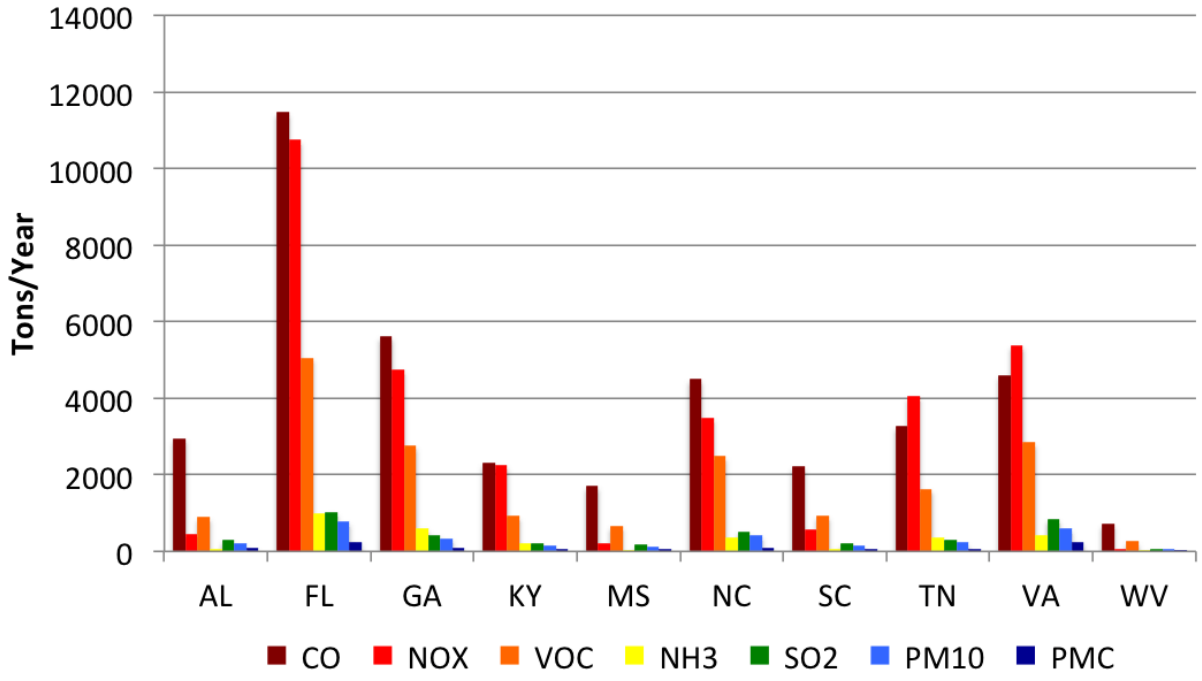


Figure 2-30. SESARM state annual total 2007 airport point source emissions

2.1.2.11 Fires (sesarm_ptf and ptfire)

Region	Data Source	Final Version	Notes
SESARM (except MS)	AMEC	July 2011	NIF to ORL-fire conversion by UNC; daily inventories do not include MS
MS	US EPA	2007aq_07c	SMARTFIREv1 downloaded from ftp.epa.gov in ORL-fire format
MANE-VU			
MWRPO			
CENRAP			
WRAP			

Fires are significant local and regional sources of ozone precursor and PM emissions. The plumes from large fires can rise several kilometers high and travel hundreds of kilometers down wind. Inventories with high spatial and temporal resolution are required to capture the spatial heterogeneity and episodic nature of fire emissions. Contemporary fire inventory methods track these data as point sources, typically with either daily or hourly temporal resolution. SESARM provided daily point source fire inventories for all SESARM states other than Mississippi. UNC converted the NIF-formatted fire data to ORL-fire format for input to the SMOKE processor.

The **sesarm_ptf** processing sector includes all of the 2007 prescribed and wildfires for nine of the SESARM states. AMEC developed the 2007 SESARM state (excluding Mississippi) fire inventory for the SEMAP project. UNC used the SMARTFIREv1 (SF1) 2007 inventory available from the EPA to represent fires in Mississippi and the rest of the U.S. outside of the SESARM region. The **ptfire** processing sector includes the SF1 inventories outside of the SESARM states. All of the fire inventories

used for the SEMAP project include daily fire emissions. The SESARM inventories also include daily fuel loads and acres burned for each fire event while the SF1 inventories include daily heat flux and acres burned for each fire. The fuel loads, acres burned, and heat flux information is used by SMOKE to estimate plume rise for the fires and to distribute these emissions to the vertical model layers. To convert the daily fire emissions to hourly estimates, UNC applied the generic diurnal profile shown in Figure 2-31 to all fire emissions in the SEMAP project.

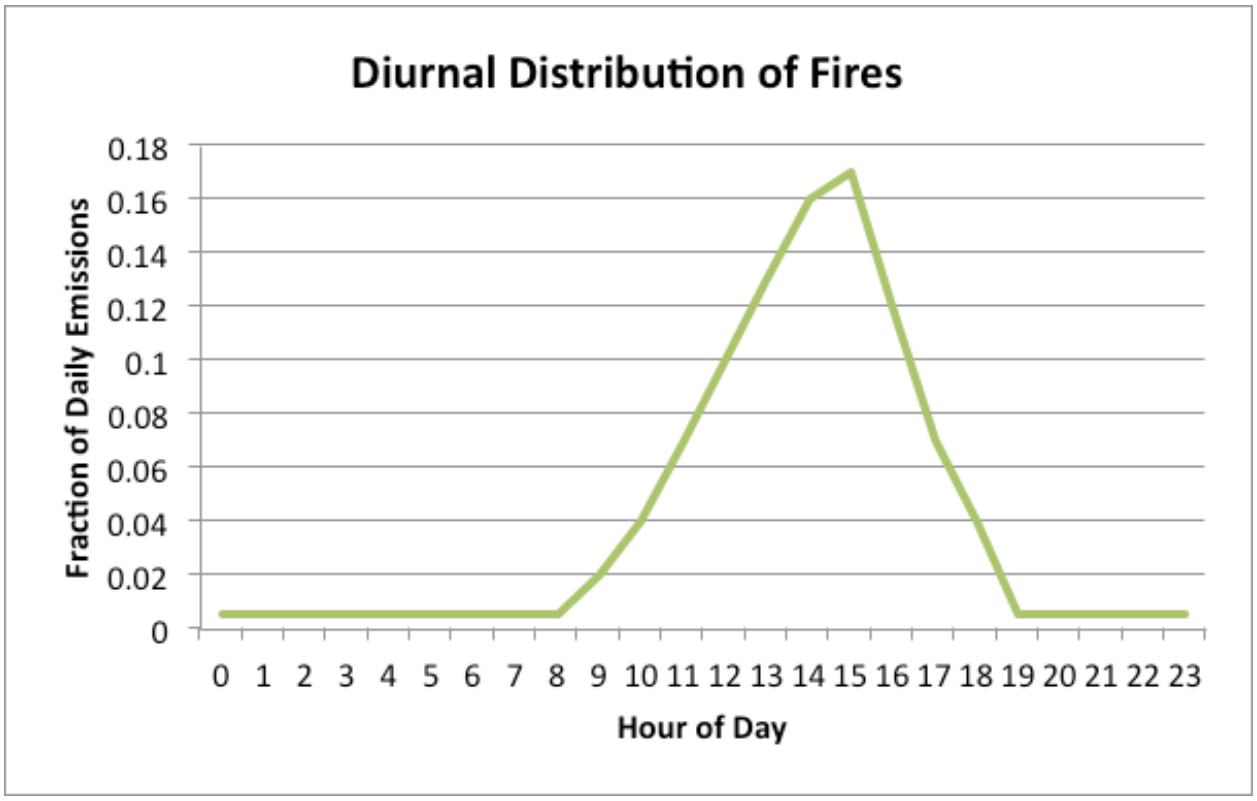


Figure 2-31. Diurnal distribution of the fire emissions used for the SEMAP modeling

Table 2-27 includes the 2007 state total annual fire source emissions used for the SEMAP modeling. This table includes the annual emissions for both the SEMAP and SF1 inventories used for this project. Figure 2-32 displays the 2007 state total fire source emissions for the 10 SESARM states. In 2007, Georgia was the largest source of fire emissions in the region, contributing about 43% of the fire NOx emissions and 40% of the fire PM10 emissions for the SESARM region. Florida was the next largest source of fire emissions in the region in 2007 followed by Mississippi. Although Mississippi was the third highest source of fire CO, NOx, and PM emissions, it was the largest source of VOC emissions (48.5%) in the region. This disconnect in the VOC emissions for Mississippi relative to the rest of the SESARM states is likely due to the differences in inventory methodology between the SESARM and SF1 inventories.

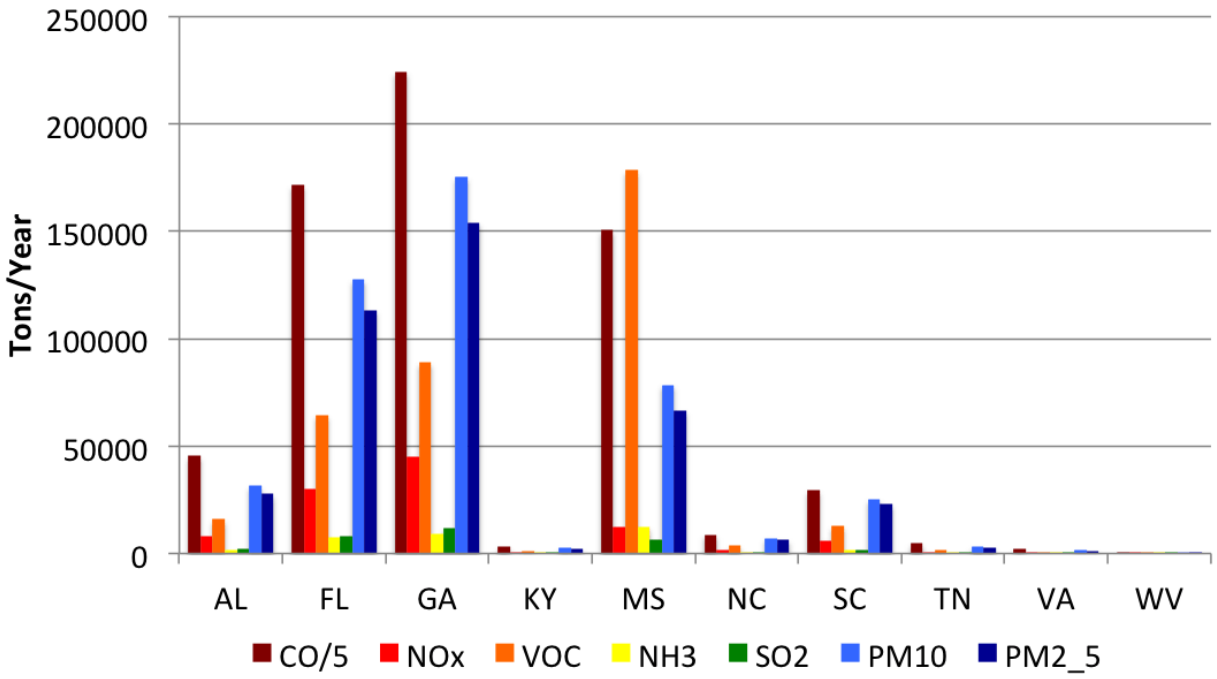


Figure 2-32. SESARM state annual total 2007 fire emissions; note that the CO emissions are divided by 5 to normalize their magnitude

2.1.2.12 C2/C3 Commerical Marine (ptseca)

Region	Data Source	Final Version	Notes
US and offshore	US EPA	NEI2005v4.1	In-port, near and offshore elevated sources

Large ships, such as container ships, tankers, bulk carriers and cruise ships, are significant contributors to air pollution in many of our nation's cities and ports. There are two types of diesel engines used on large ships: main propulsion and auxiliary engines. The main propulsion engines on most large ships are "Category 3" marine diesel engines, which can stand over three stories tall and run the length of two school buses. Auxiliary engines on large ships typically range in size from small portable generators to locomotive-size engines.

To account for these emissions, a separate set of SMOKE input files was developed for the 2005 NEIv4.1. Based on earlier 1996 and 2002 inventories, the current 2005 inventory was developed by ICF International[13] combining updated port and maneuvering estimation methods. These estimates are combined with detailed spatial information regarding port locations and shipping lanes. The sulfur emission control area point source (**ptseca**) emissions processing category includes shipping sources in-port, near shore, and in commercial shipping lanes. These emissions are developed and carried as point sources, rather than the area-level files generally used for off-road mobiles sources, including marine emissions sources. Using the point source format allows for: (1) detailed location information for the emissions, rather than use of generalized spatial allocation profiles; and (2) processing of the emissions as

[13] ftp://ftp.epa.gov/EmisInventory/2005_nei/mobile/commercial_marine_vessels_2002_and_2005.pdf

elevated sources, rather than distributing all of Class 2/3 marine emissions into the lowest level of the model.

Details on the Off-Shore Shipping emissions are provided in a report "Documentation for the Commercial Marine Vessel Component of the National Emissions Inventory – Methodology" prepared by Eastern Research Group[14] dated March 30, 2010. It should be noted that the Off Shore Shipping emissions category discussed here only includes the Class 2 and 3 Commercial Marine source. Smaller vessels (Class 1) are included with the nonroad source processing sector.

The C2/C3 emissions estimates for the SESARM states are included in the ALM processing sector described in Section 2.1.2.7. The ptseca processing sector described here includes only emissions for in-port sources outside of the SESARM region and for near and off-shore sources around the continental U.S. and Canada.

Table 2-28 shows the annual total near and offshore emissions for the commercial shipping sector. The state total emissions represent the in-port emissions, the near shore emissions are between 0-0.5 km from port, and the SECA emissions are the offshore sources in commercial shipping lanes.

2.1.2.13 Biogenic

Data	Data Source	Final Version	Notes
Landcover	US EPA	BELD3	BELD3 tiles gridded to the SEMAP modeling domains
Emission Factors	US EPA	Version 3.14 (14May2008)	

Emissions from vegetation, mostly from the leaves of plants, are the largest source of volatile organic compounds (VOC) in the global atmosphere, although VOC emissions from cars, factories and fires dominate in urban and industrial areas. In the atmosphere, the oxidation of VOC can influence aerosol particles, precipitation acidity, and regional ozone distributions. Accurate predictions of biogenic VOC emissions are important for developing regulatory ozone and aerosol control strategies for at least some rural and urban areas. One of the great challenges associated with characterizing biogenic VOC (BVOC) is the large variety of compounds involved. Isoprene is the single most important BVOC with an emission that is about half of the global BVOC emission and is highly reactive so can be an important component of ozone formation. Many monoterpenes have been observed in the atmosphere but only a few, such as α-pinene, make a significant contribution to the global total emissions. The dominant sesquiterpenes, such as β-caryophyllene, have lifetimes of only minutes in the atmosphere and so are present at very low levels, but their reaction products may be an important source of secondary organic aerosol (SOA). Oxygenated BVOC include a wide range of alcohols, aldehydes, ketones, acids, ethers, and esters but are dominated by relatively low molecular weight compounds such as methanol, acetaldehyde and acetone. Other BVOC include alkanes (e.g., heptane), alkenes (e.g., ethene), aromatic hydrocarbons (e.g., toluene), sulfur compounds (e.g., dimethyl sulfide), and nitrogen compounds (e.g., hydrogen cyanide). Observations of land–atmosphere interactions must include not only primary emissions but also the larger number of reaction products that impact atmospheric oxidants and particle formation and growth. Soil emissions of nitric oxide (NO) are also treated by biogenic emissions models. Investigations of NO emission from soils began in the 1960s with agronomists that were interested in the fate of fertilizer applied to soil, but the amount lost to the atmosphere was a relatively small part (a few percent) of the total fertilizer applied. NO emissions were later observed from unfertilized landscapes and it was recognized that this could be an important source of atmospheric NO in some regions. Early studies of the microbial and ecological processes and environmental controls over NO emissions led to what has been

[14] http://www.epa.gov/ttn/chief/net/nei08_alm_popup.html

called the "hole-in-the-pipe" model, which conceptualizes NO emission regulation at two levels: (1) the rate of nitrogen cycling (the amount of nitrogen flowing through the pipe); and (2) factors influencing the ability of NO to escape from the soil into the atmosphere (the hole in the pipe). The nitrogen cycling includes two components: (1) nitrification (converting NH4 to NO3; and (2) denitrification (converting NO3 to N2). Nitrification is considered the main source of NO emission. Fertilizer, atmospheric nitrogen deposition, leaf litter, soil temperature and perhaps other factors can influence the rate of nitrogen cycling in the soil while soil properties and water content and perhaps other factors influence the amount that can leak into the atmosphere. Although NO emissions have been observed from a wide range of landscapes under various conditions, the implementation in regional to global models has been relatively simple due to the lack of suitable databases for scaling observations to regional scales.

For the SEMAP project, UNC tested both the Model of Emissions of Gases and Aerosols from Nature version 2.04 (MEGAN) and the Biogenic Emission Inventory System version 3 (BEIS3) to estimate emissions for the SESARM states. Based on the work of Hogrefe et al (2011) SESARM instructed UNC that the BEIS3 model was more appropriate for the southeast U.S. UNC regridded the BELD3 land use database to the SEMAP modeling grids using the Spatial Allocator and used version 3.14 of BEIS emission factors to estimate biogenic emissions for the SEMAP modeling.

Table 2-29 includes the 2007 state total annual biogenic source emissions used for the SEMAP modeling. This table includes annual emissions for all states in the CONUS 36-km modeling domain. Figure 2-33 displays the 2007 state total biogenic source emissions for the 10 SESARM states. In 2007, Georgia was the largest source of biogenic VOCs in the region (16.7%), followed by Alabama (15%), Florida (14.6%), and Mississippi (13.2%). Florida was the largest regional source of biogenic NO (26.3%), followed by Georgia (13.6%), Mississippi (10.4%), and Kentucky (9.7%). Florida is also the largest regional source of biogenic CO (17.4%), followed by Georgia (15.7%), Alabama (13.5%), and Mississippi (12.3%).

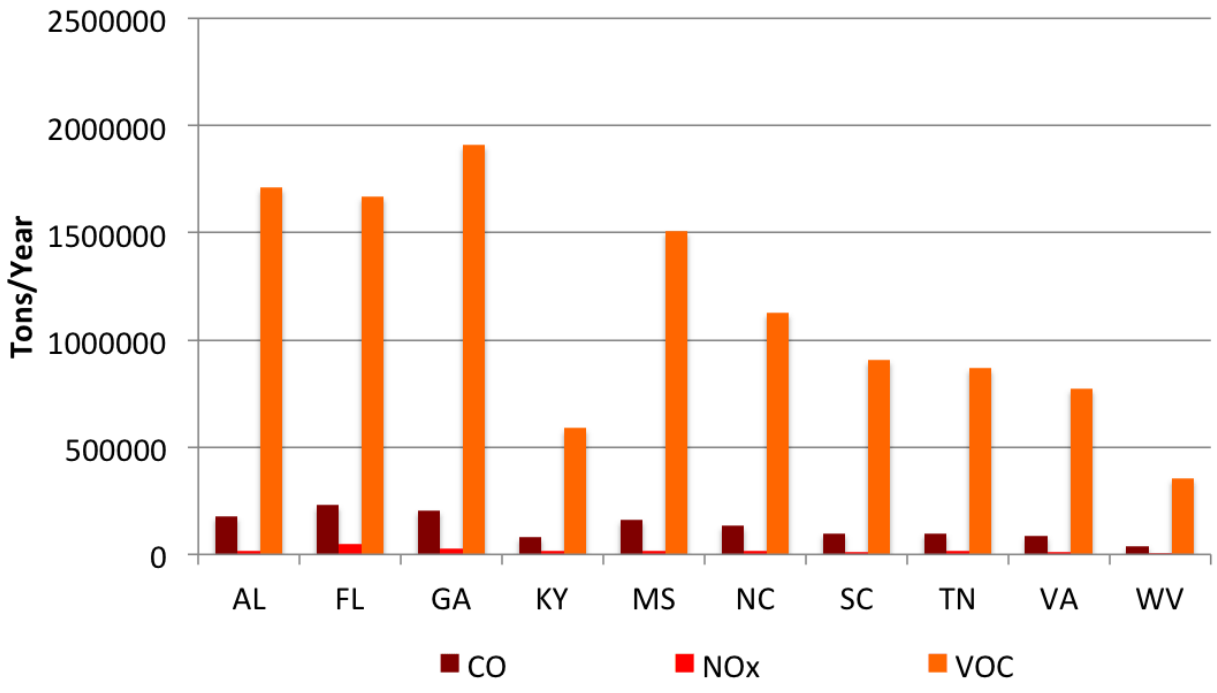


Figure 2-33. SESARM state annual total 2007 biogenic emissions

2.1.2.14 Canada and Mexico

Region	Data Source	Final Version	Notes
Canada	Environment Canada	2006	
Mexico	INE and ERG, Inc.	2008	Mexico National Emission Inventory projected from 1999 to 2008

The SEMAP 2007 base case emissions for Canada are based on a 2006 emissions inventory from Environment Canada (EC). This national inventory contains provincial-level emissions for all source categories. The EC 2006 inventory is based on Canada's National Pollutant Release Inventory (NPRI[15]) for 2006. The database files are in SMOKE-ready ORL format. The database provides annual emissions of seven criteria air pollutants (CAPs): VOC, CO, NO_x, PM_{10}, $PM_{2.5}$, SO_2, and NH_3 for all of Canada. The EC 2006 CAP stationary point source inventory includes a separate file for speciated VOC emissions (Carbon Bond CB05 chemical species). The EC inventory also includes stationary area, mobile and upstream oil and gas point source emissions data. Although emissions reported to NPRI could overestimate typical emissions, as they include upset and accidental releases, the EC inventory is considered the most updated Canadian national inventory. EC applied a fugitive dust transport factor (FDTF) to account for fugitive dust emissions that are deposited locally and so are not transported downwind. More specifically, particulate matter (PM) dust emissions for road dust, construction and agriculture were reduced by 75% in the EC 2006 emissions inventory (i.e., a 0.25 FDTF).

The EC 2006 inventory is based on the NPRI inventory so the documentation is on the NPRI website[1] which also has summary emissions for all of Canada[16]. The EC 2006 emissions inventory was processed by the SMOKE emissions model in three batches: (1) elevated point source; (2) on-road mobile sources; and (3) area sources, which also included non-road mobile sources. Temporal allocation of the annual EC inventory to month, day-of-week and hour-of-day used U.S. EPA profiles and assignments by inventory Source Classification Codes (SCC). Spatial aggregation of the Provincial area and mobile sources to the 36/12 km modeling domains was also based on SCCs using spatial surrogate distributions from the EC. Chemical speciation for the area and mobile sources was also based on SCCs. However, as noted above, the Canadian point sources in the EC 2006 emissions database were already speciated into the CB05 chemical species used by the photochemical grid models (PGMs).

Many of the Canadian point sources were classified using the same miscellaneous SCC code in order to keep the confidentiality of the process of the point source. This makes it difficult to isolate specific types of point sources (e.g., coal-fired power plants) and results in the application of flat temporal allocation profiles (i.e. the emissions don't change from month-to-month, day-to-day, or hour-to-hour).

[15] http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=4A577BB9-1
[16] http://www.ec.gc.ca/pdb/websol/emissions/2006/2006_canada_e.cfm

Table 2-14 shows the annual pollutant totals in the 36-km CONUS modeling domain for the Canadian inventory sectors.

Table 2-14. SEMAP 2007 Canada emissions in the 36-km CONUS domain (TPY)

Sector	CO	NOx	VOC	NH3	SO2	PM10	PM2_5
Area	1270565	857750	447490	21170	1664035	117165	68620
Mobile	4403725	524870	270830	21170	5475	14600	10220
Point	3794540	733285	1282245	546040	94900	1665130	432160
Total	9468830	2115905	2000565	588380	1764410	1796895	511000

For Mexico, the SEMAP 2007 modeling used year 2008 projections off of the 1999 Mexican National Emission Inventory (MNEI) to represent anthropogenic emissions sources for Mexico. The 1999 MNEI was finalized in the year 2006 and represented a joint effort between U.S. and Mexican government agencies.[17] The MNEI includes annual estimates of NO_X, SO_X, VOC, PM_{10}, $PM_{2.5}$, and NH_3 emissions for the entire country of Mexico at the municipality level from point, non-point/area, on-road mobile, off-road mobile and natural sources. As the first national-scale inventory for Mexico, the 1999 MNEI was designed to meet the following objectives:

- Comply with the Mexican Federal Environmental Law mandate to integrate and update a National Emissions Inventory for Mexico;
- Promote Mexican institutional capacity-building to compile, maintain, and update emissions inventories;
- Provide a technical basis for improved air quality and health impact analyses in Mexico and the U.S.;
- Assist with regional haze requirements in the U.S.; and
- Support the development of a tri-national emissions inventory of criteria pollutants for Mexico, the U.S. and Canada.

The year 1999 was selected as the inventory year because of data accessibility within Mexican government agencies and to correspond with the U.S. EPA triennial national emissions inventory (NEI) cycle. While the 1999 MNEI represented a significant improvement over previous emissions estimates for Mexico, there were several opportunities to improve the quality of the data and to increase the quantity of data used to estimate the emissions.

In the year 2009, the Western Governors' Association sponsored Eastern Research Group, Inc. (ERG) to project the 1999 MNEI to 2008, 2012, and 2030.[18] This work was used to support research at the National Institute of Ecology in Mexico and the National Renewable Energy Laboratory in the U.S. Continuing with the same spatial coverage (national, municipality-level) and pollutants in the 1999 MNEI, ERG derived growth and control factors from various sources of historical economic indicators and emissions trends and from forecasts of energy use, technology changes, and economic changes.

In the summary of the projections trends for the 1999 MNEI, ERG states the following:

"In general, the emissions from point sources, area sources, and non-road mobile sources are projected to increase in future years relative to the 1999 base year. The projection factors for these source types are

[17] http://www.epa.gov/ttn/chief/net/mexico/1999_mexico_nei_final_report.pdf

[18] http://www.wrapair.org/forums/ef/inventories/MNEI/2018_Mexico/2009-01_Mexico_Projections_2008-2012-2030_Final_Report_01-09.pdf

primarily driven by population growth, growth in gross domestic product (GDP), and fuel growth. There are also a few source categories with decreasing emissions (i.e., area source SO_2, PM_{10}, and $PM_{2.5}$); these are due to projected decreases in certain fuel types and uses (e.g., commercial combustion of residual fuel oil and residential wood combustion). On-road motor vehicle NO_X, SO_2, VOC, and CO emissions are projected to decrease in future years relative to the 1999 base year, while PM_{10}, $PM_{2.5}$, and NH_3 emissions increase. Although the demand for motor vehicle fuel will increase in the future, the decreases in NO_X, SO_2, VOC, and CO emissions are due to effects of new control technologies that are gradually incorporated into the overall vehicle fleet due to turnover, as well as low sulfur fuels. Because new motor vehicle standards are not being implemented for PM_{10}, $PM_{2.5}$, and NH_3, emissions are projected to increase in the future for these pollutants."

The 2008 MNEI was prepared for air quality modeling with the SMOKE emissions processor for area/non-point and off-road mobile sources, stationary point sources, and on-road mobile sources. Emissions from the active volcanoes in Mexico were not included in the SEMAP inventory because year 2008 data were not readily available for these sources. Temporal allocation of the MNEI annual inventories to month, day-of-week and hour-of-day used U.S. EPA profiles and assignments based on inventory Source Classification Codes (SCC). Spatial distribution of the municipality non-point and mobile sources to the 36/12 km modeling domains was also based on SCCs using spatial surrogate distributions provided by the Mexican National Institute of Ecology. Chemical speciation for the MNEI was also based on speciation profiles and SCC assignments from the U.S. EPA.

Table 2-15 shows the annual pollutant totals in the 36-km CONUS modeling domain for the Mexican inventory sectors.

Table 2-15. SEMAP 2007 Mexico emissions in the 36-km CONUS domain (TPY)

Sector	CO	NOx	VOC	NH3	SO2	PM10	PM2_5
Area	127020	375950	150015	0	968345	154395	107310
Mobile	907025	125560	129575	4015	8395	10585	9855
Point	881475	292730	746425	285795	66430	168265	109865
Total	1915520	794240	1026015	289810	1043170	333245	227030

2.1.2.15 Ancillary data

Most of the ancillary data used to simulation emissions for the SEMAP project came from the EPA. The EPA's 2008 National Emissions Inventory version 2 (NEI08v2) EMP[19] was the primary source of the spatial, temporal and speciation data used for the SEMAP project. Source-specific improvements were made to these data; particularly the temporal profiles for the livestock and residential wood combustion sectors. UNC used the SMOKE program GenTPRO to estimate meteorology-dependent temporal variability for livestock and residential wood combustion sources for all of the SEMAP EMPs.

For air quality modeling studies prior to 2012, EPA used geospatial data primarily from the year 2000 and earlier for estimating the spatial surrogates that characterize the spatial distribution of non-point anthropogenic emissions sources. In November 2011 UNC initiated updates to the spatial surrogate and Shapefile database used by the EPA Office of Air Quality Planning and Standards for emissions modeling. By July 2012 many of the original surrogates were updated with weight Shapefiles that reflected North American geospatial data collected since the year 2006. UNC used these updated surrogates for the SEMAP project. Table 2-16 shows the vintage of the surrogate classes used for the SEMAP modeling (shown as the Current Year).

[19] http://www.epa.gov/ttn/chief/emch/index.html - 2008

Table 2-16. SEMAP spatial surrogate data

Shapefile	Surrogates	Current Year	Previous Year
Population and Housing	100-140	2010	2000
Home Heating	150-165	2005-2010	2000
Road and Rail	200-280	2010	2000
Land-use/Land Cover	300-350	2006	1992
Building Square Footage	500-595	2000-2006	1990
Gas Stations and oil & gas	600-699	2008-2011	2000
Shipping	800-820	2010	1999-2003
Other industrial and commercial	850-890	2010	2000

2.1.3 SEMAP Typical 2007 Modeling Platform

The SEMAP Typical 2007 EMP differs from the Base 2007 EMP only in the fire inventories. The rest of the anthropogenic and natural emissions data for the SEMAP Typical 2007 simulation are exactly the same as in the Base 2007 simulation. The purpose of the Typical emissions estimates is to construct a baseline against which future year emissions can be compared. Typical year fire inventories smooth the episodic nature of fire emissions by averaging the emissions across multiple years.

This section present the details of how UNC developed the SEMAP typical year fire emissions, including the testing and analysis of different fire inventories.

2.1.3.1 Fires (sesarm_ptf and ptfire)

Region	Data Source	Final Version	Notes
SESARM (except MS)	AMEC	July 2011	NIF to ORL-fire conversion by UNC; daily inventories do not include MS
MS	US EPA	02Jan2013	SMARTFIREv2 downloaded from ftp.epa.gov in ORL-fire format and scaled by GA EPD
MANE-VU			
MWRPO			
CENRAP			
WRAP			

The initial plan for creating typical year fires for the SEMAP project included combining the SESARM typical year fire inventory developed for this project by AMEC with 3-year averaged SMARTFIRE-based emissions estimates from the EPA Fire Averaging Tool (FAT). Analysis of the CMAQ results using the FAT emissions showed large positive biases for $PM_{2.5}$ species outside of the SESARM states, particularly in Southern Louisiana. UNC attributed these biases to a combination of the SMARTFIRE1 (SF1) inventories and FAT outputs, which result in the fire emissions all being allocated to the surface layer as area sources. Figure 2-34 shows year 2007 fire $PM_{2.5}$ estimates from the SF1, SF2, and SEMAP fire inventories for the SESARM and bordering states. For all SESARM states other than Georgia and Florida, the SF1 inventory is high relative to the SEMAP base 2007 fire inventory. The SF1 inventory is particularly high in Louisiana relative to the surrounding states. In consultation with GA DNR, UNC reasoned that given the efforts to improve the SESARM fire inventories for this project, the SEMAP base 2007 fire inventory is a better estimate of fire emissions than SF1. With SF1 biased high relative to the SEMAP inventory, UNC suspected that it was high in the surrounding states as well. Using the FAT software to average 2006-2008 SF1 inventories to create typical fire estimates for the non-SESARM states made this high bias worse. Figure 2-35 shows monthly distributions of Louisiana fire $PM_{2.5}$

emissions from the SF1 2007 inventory and the FAT average of SF1 2006-2008 inventories. For most months, the FAT inventory was higher than SF1 2007 in both the extremes and averages of the data.

These analyses confirmed our suspicion of the quality of the FAT and SF1 inventories for the non-SESARM states. UNC then sought to improve the typical year fire estimates outside of the SESARM region through using other sources of fire inventory data. GA DNR proposed a solution for the non-SESARM typical fire inventories that used SMARTFIRE2 (SF2) year 2007 inventories with caps on the emissions magnitudes based on the typical year SEMAP fire inventory. GA DNR calculated the monthly maximum fire emissions in the SEMAP typical year inventory for each inventory pollutant across all of the SESARM states. The SF2 inventories outside of the SESARM states, including Mississippi, were then scaled back if the magnitude of the monthly emissions in a state was larger then the maximum emissions in any of the SESARM states. UNC combined the scaled SF2 inventories with the base 2007 SF2 heat flux and acres burned parameters to calculate new typical year fires for the non-SESARM states and Mississippi.

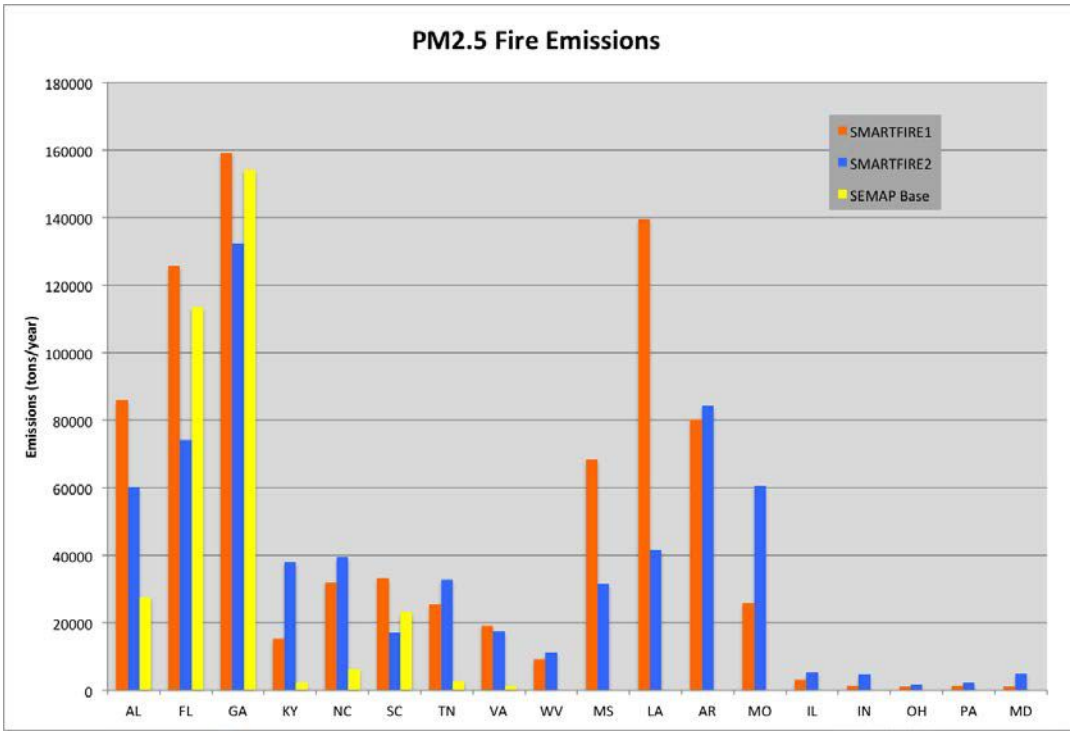


Figure 2-34.Comparison of 2007 fire PM2.5 inventories for the SESARM and bordering states

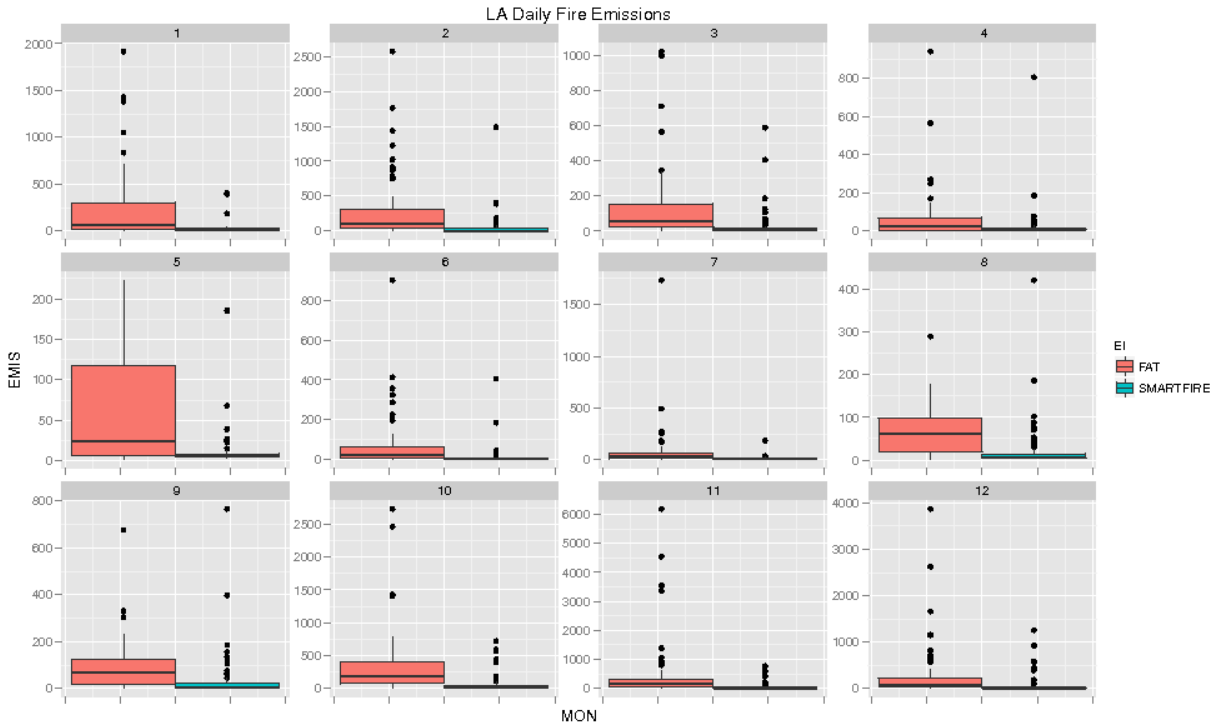


Figure 2-35. Box plots of Louisiana year fire emissions from SMARTFIRE1 and FAT

Table 2-30 shows the state total annual typical year fire source emissions used for the SEMAP modeling. Figure 2-36 displays the typical year state total fire source emissions for the 10 SESARM states. Unlike in the 2007 base year, Georgia was not the largest source of fire emissions in the region in the typical year inventory. Florida surpasses Georgia as the largest source of typical fire emissions in the region. Figure 2-37 compares the base 2007 and typical year fires emissions for NOx, VOC, and PM2.5 for the SESARM states. This plot illustrates that for all pollutants and all states, the typical year fire inventory has a lower magnitude of emissions than the base year inventory.

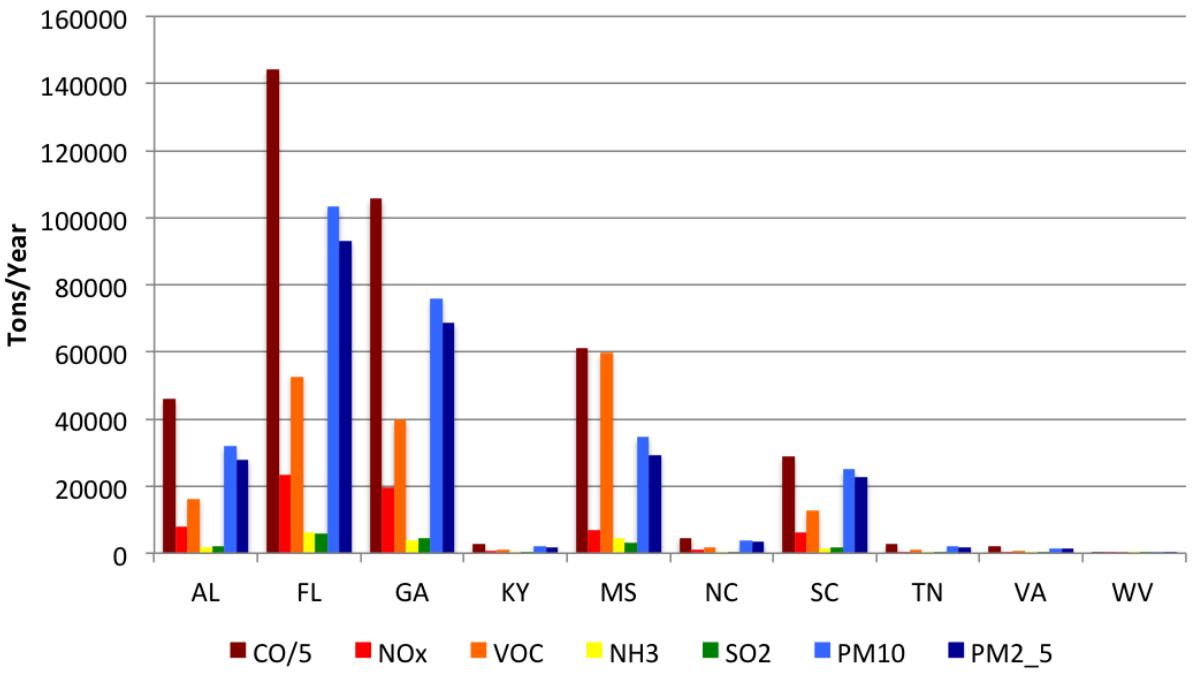


Figure 2-36. SESARM state annual total typical year fire emissions; note that the CO emissions are divided by 5 to normalize their magnitude

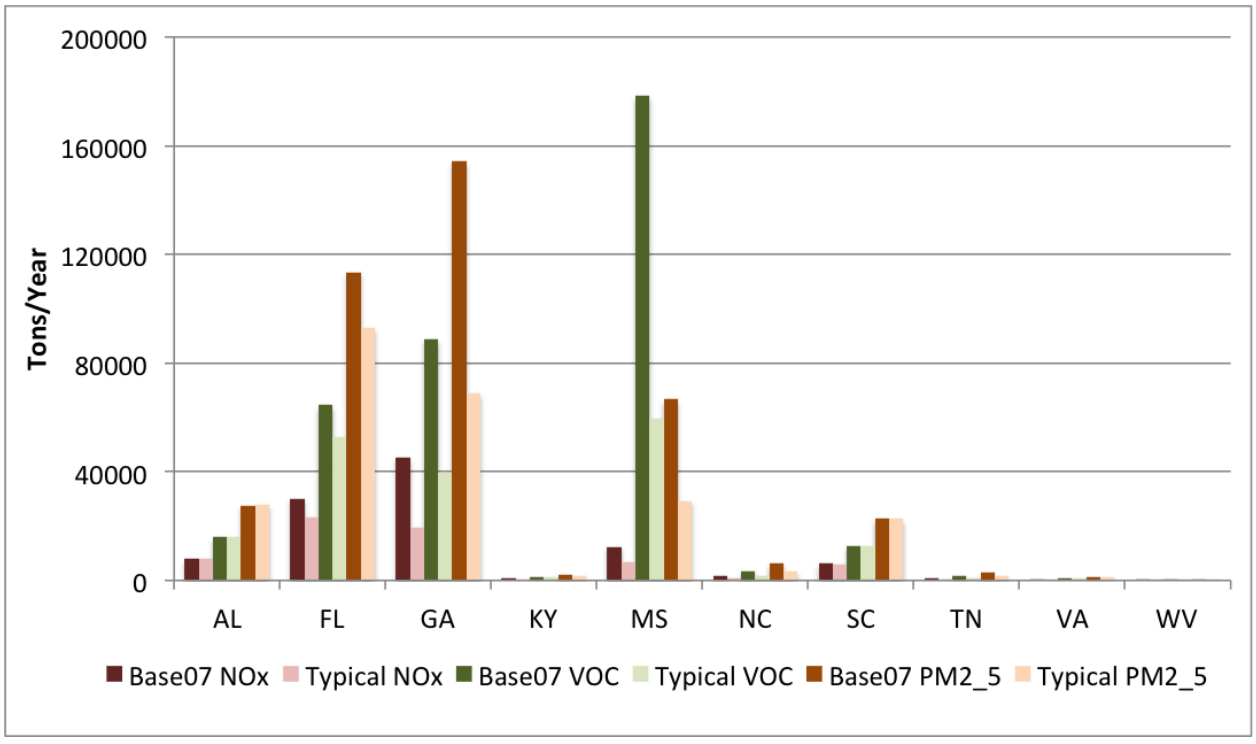


Figure 2-37. SESARM base 2007 and typical annual total fire emissions of NOx, VOC, and PM2.5

2.1.4 SEMAP Base 2018 Modeling Platform

UNC developed the SEMAP Base 2018 EMP to estimate future year air quality in the SESARM region. The 2018 inventory data for the SESARM states were developed specifically for the SEMAP project and used the best available information on emissions growth projections and the impacts of emissions control strategies to estimate county level emissions for the year 2018. UNC used local or regional inventories to estimate emissions for the regions outside of SESARM states and defaulted to the NEI when other data were not available. UNC used the same biogenic emissions and ancillary data for the 2018 EMP as were used for the SEMAP 2007 base and typical EMPs.

This section presents the details of the data that UNC collected for the SEMAP 2018 EMP, including details of the processing with SMOKE and results for each inventory processing sector. Section 2.1.4.1 first presents the overall results of the 2018 EMP in terms of the annual total emissions for each of the 10 SESARM states. The subsequent sections begin with a table describing the sources, versions, and notes on the inventory data for each of the RPO regions. These sections are organized by inventory processing sector and include details on the sector and any special processing used to prepare these data for input the CMAQ model.

2.1.4.1 SESARM state 2018 emissions summary

The plots in this section illustrate the contribution of the different inventory processing sectors to the total annual 2018 criteria pollutant emissions. The stack bar plots show the total emissions for each pollutant by state with each segment in the stack representing a different emissions processing sector. Details of the processing and emissions totals for each sector are provided in the subsequent sections of this report.

Carbon Monoxide (CO)

In the 2018 SEMAP modeling, onroad mobile is projected to be the largest source of CO emissions in all of the SESARM states except Mississippi. Secondary important regional CO sources include nonroad mobile, fires, and biogenic sources. Overall Florida, Georgia, and North Carolina are projected to be the largest regional sources of CO. West Virginia is projected to be the smallest regional source of CO.

Nitrogen Oxides (NOx)

Unlike in the base year, the 2018 NOx emissions are not dominated by any major sector. Onroad mobile and CEM point are projected to still be significant sources of NOx, other sectors have relatively large contributions as well. Other large contributors to NOx are projected to include nonroad mobile, non-CEM point, biogenic, and aircraft/locomotive/marine sources. Florida and Georgia are projected to be the largest regional of source of NOx. West Virginia is projected to be the smallest regional source of NOx.

Volatile Organic Compounds (VOCs)

Biogenic sources are projected to still be the dominant VOC source in all of the SESARM states. Significant anthropogenic sources of VOC include onroad mobile and nonpoint. Florida and Georgia are projected to be the largest sources of VOC in the region. West Virginia is projected to be the smallest regional source of VOC.

Ammonia (NH3)

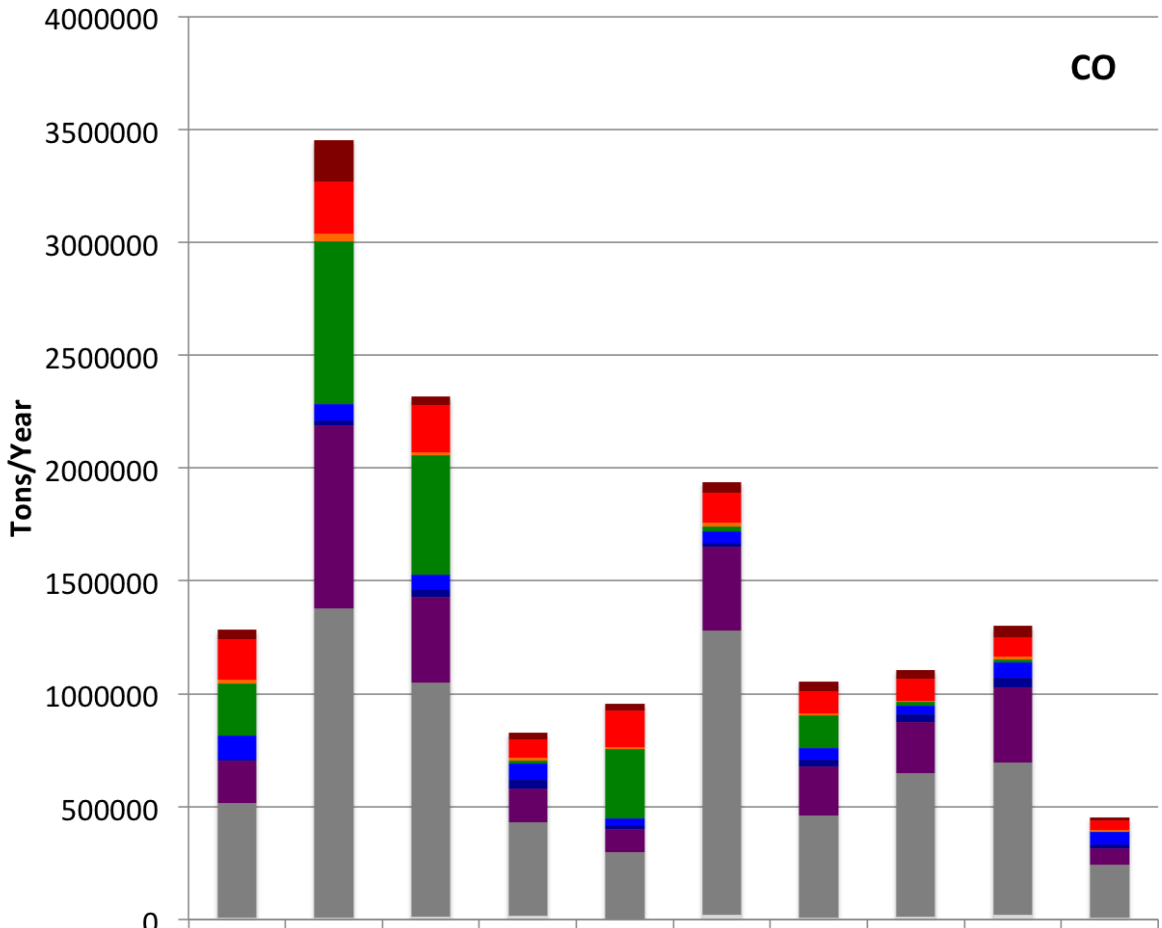
Livestock is still projected to be the dominant source of NH3 in all of the SESARM states. Other significant sources of NH3 include fires, fertilizer, and onroad mobile sources. North Carolina and Georgia are projected to be the largest regional sources of NH3. West Virginia is projected to be the smallest regional source of NH3. The livestock NH3 emissions in North Carolina are still projected to be much higher than the sum of all sources of NH3 in the other SESARM states.

Sulfur Dioxide (SO2)

While SO2 emissions are still projected to be dominated by CEM point sources in all of the SESARM states, the relative contribution of this sector to the total will decline. The non-CEM point sector is projected to become a larger relative contributor to SO2 emissions. Florida and Tennessee are projected to be the largest regional contributors to SO2. Georgia is projected to be the smallest regional source.

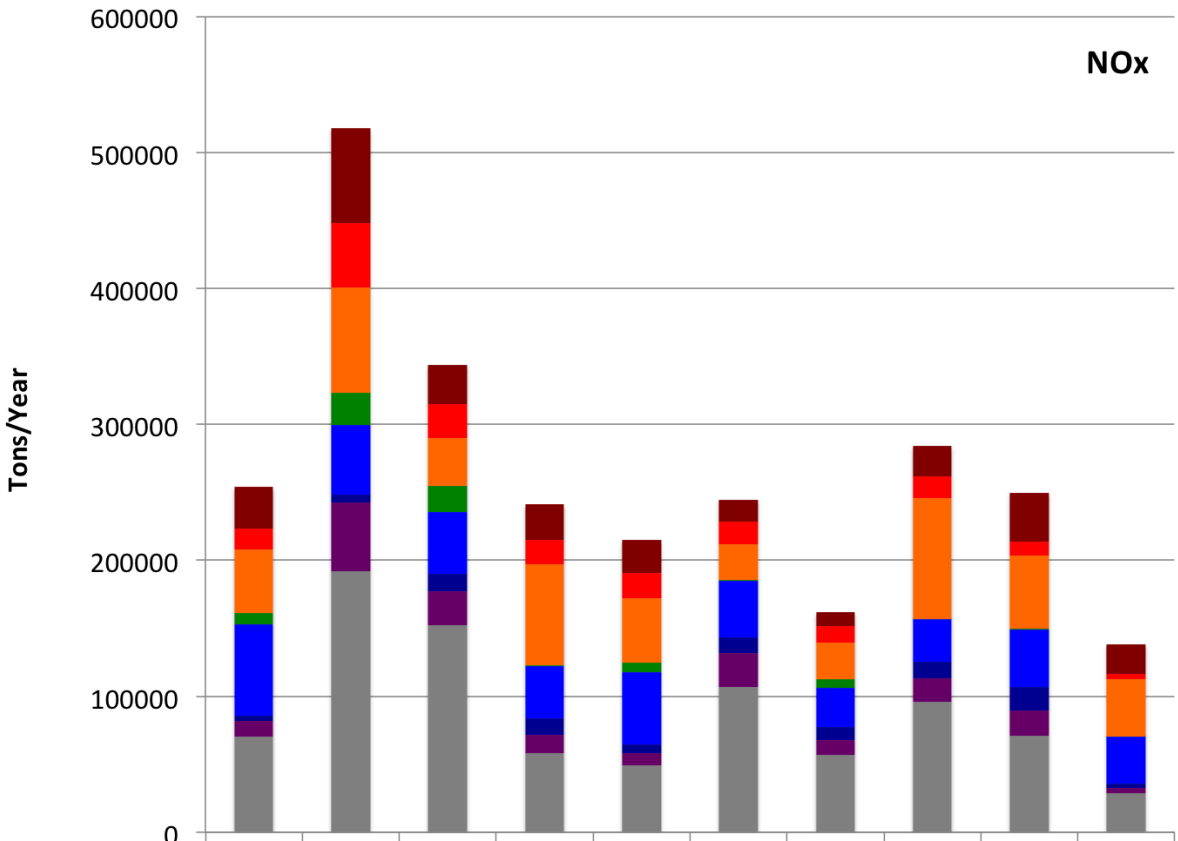
Particulate Matter < 2.5 µm (PM2.5)

Fires and dust are projected to be the largest source of PM2.5 in many of the states. Other significant sources of PM2.5 include non-CEM point, CEM point, and nonpoint. Georgia and Florida are projected to be the largest regional sources of PM2.5, primarily because of large contributions from fires. West Virginia is the smallest regional source of PM2.5.



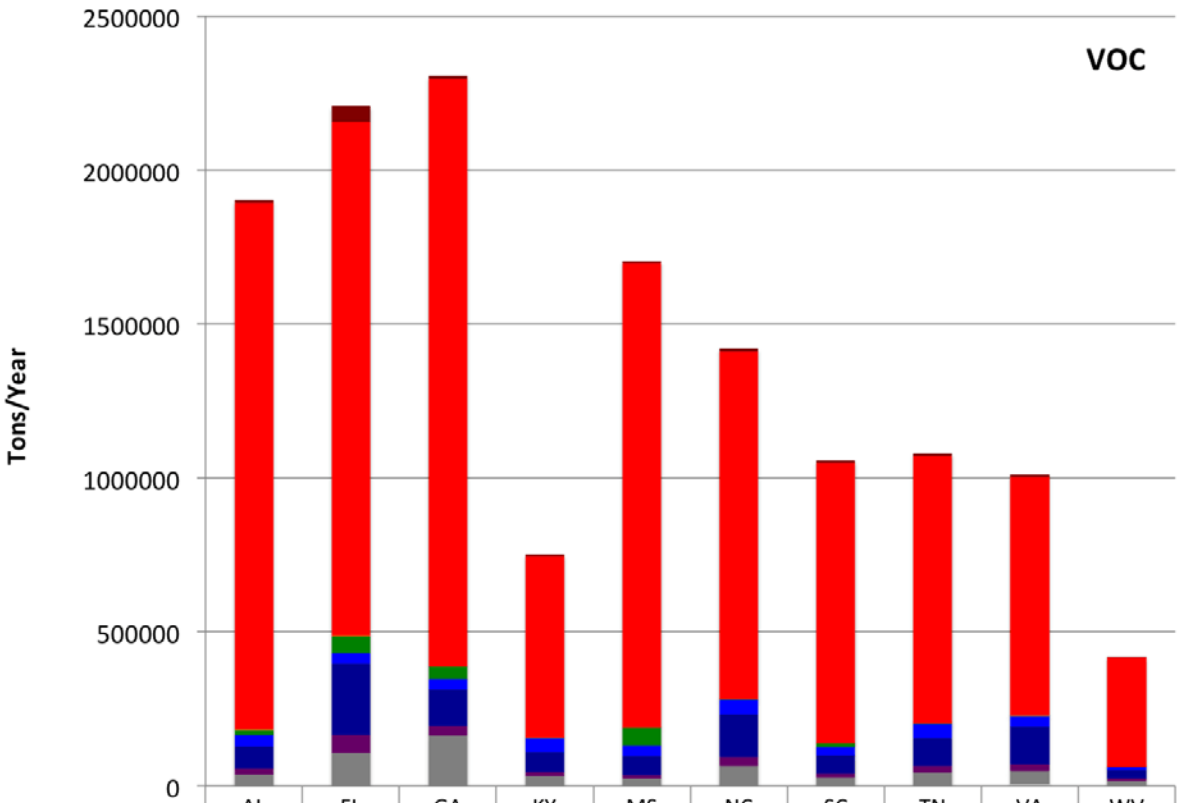
	AL	FL	GA	KY	MS	NC	SC	TN	VA	WV
ALM	43177	186861	40209	28097	29945	49554	43578	38769	49661	11262
Biogenic	177338	229020	205821	80573	162064	133292	98976	98607	86868	40390
CEM Point	18839	32327	13600	11683	9923	15498	6617	7111	13146	9453
Dust	0	0	0	0	0	0	0	0	0	0
Fertilizer	0	0	0	0	0	0	0	0	0	0
Fires	230240	721450	528320	13247	305180	23144	144800	14238	9862	577
Livestock	0	0	0	0	0	0	0	0	0	0
non-CEM Point	106095	75961	66627	74644	31922	48369	53960	40656	67829	57681
Nonpoint	6135	20872	35126	38616	17092	19369	27027	33117	42820	15173
Nonroad	184263	809861	378180	147336	103692	371460	221277	228021	333903	72202
Onroad	508548	136849	103713	414019	290728	125922	451974	633649	673648	234835
RWC	8820	9171	12007	17093	5603	18703	6662	12351	22268	8245

Figure 2-38. SESARM 2018 state total CO emissions by inventory sector



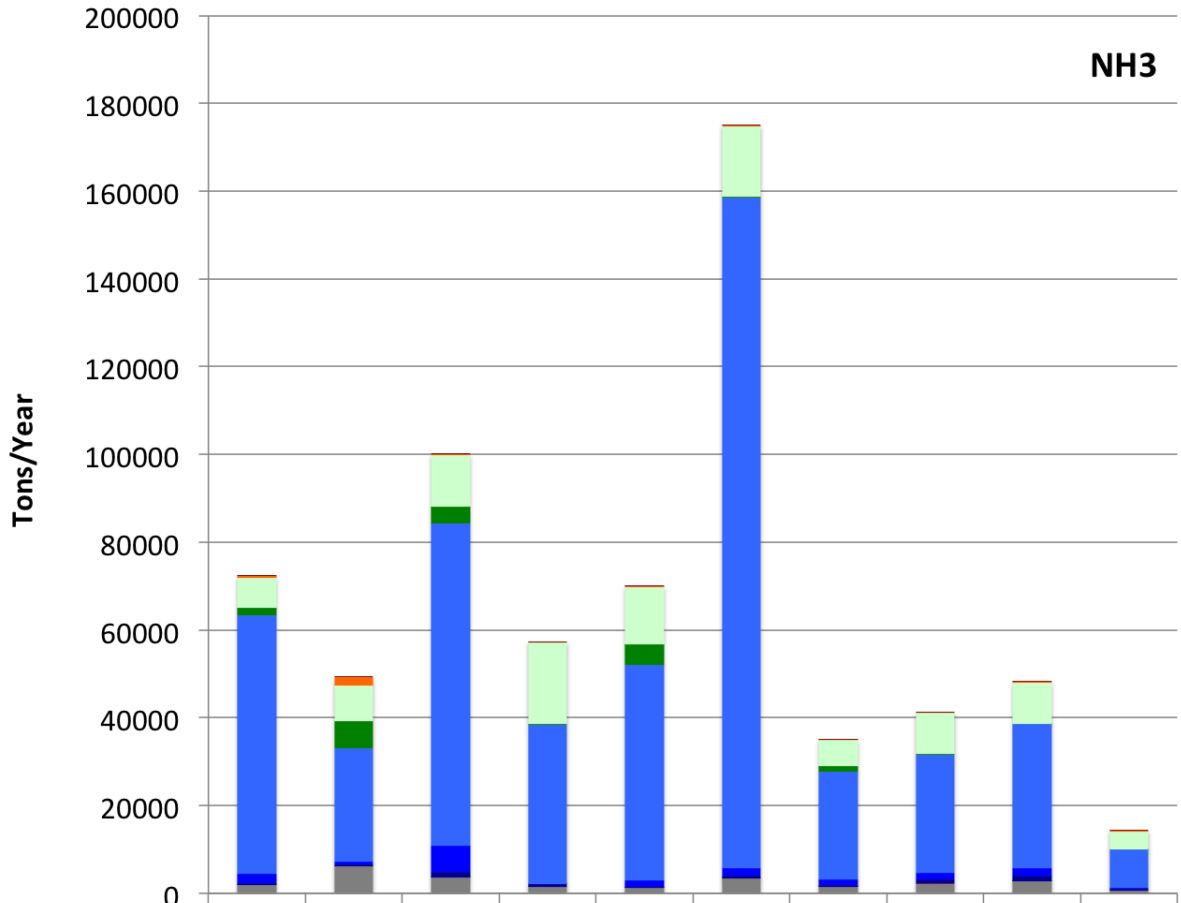
	AL	FL	GA	KY	MS	NC	SC	TN	VA	WV
ALM	30914	69490	29146	26170	24093	16169	10264	22573	36122	22029
Biogenic	15052	47773	24779	17652	18848	16055	11864	16030	10070	3608
CEM Point	46916	77446	35093	74581	47170	26408	27224	88667	53791	42081
Dust	0	0	0	0	0	0	0	0	0	0
Fertilizer	0	0	0	0	0	0	0	0	0	0
Fires	8019	23429	19424	552	6821	977	6072	479	379	22
Livestock	0	0	0	0	0	0	0	0	0	0
non-CEM Point	67637	51184	45535	38191	53600	41095	28703	31192	42587	34543
Nonpoint	3689	6052	12669	12235	6081	11749	9456	12252	17121	3329
Nonroad	11544	50336	24737	13771	9085	25339	11367	16840	18719	3743
Onroad	70068	191926	152195	57657	49097	106182	56589	95973	70499	28648
RWC	146	161	206	280	92	315	112	203	378	137

Figure 2-39. SESARM 2018 state total NOx emissions by inventory sector



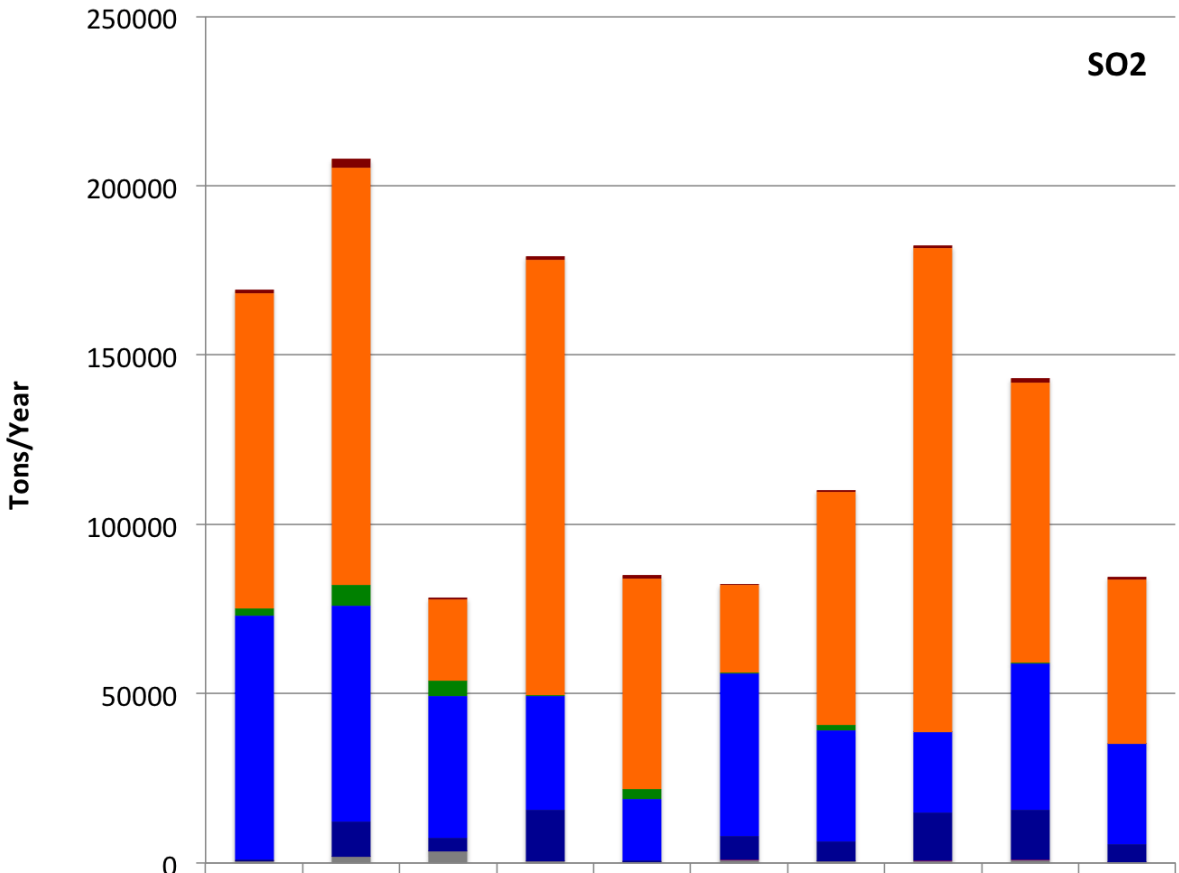
	AL	FL	GA	KY	MS	NC	SC	TN	VA	WV
ALM	10197	50631	9714	5899	7009	11316	8197	9403	8785	2054
Biogenic	1710315	1670058	1909704	588613	1508176	1126955	908485	868972	773553	354681
CEM Point	1464	2628	1563	1132	832	939	446	754	1094	838
Dust	0	0	0	0	0	0	0	0	0	0
Fertilizer	0	0	0	0	0	0	0	0	0	0
Fires	16011	52696	39877	1064	59615	1861	12642	956	743	44
Livestock	0	0	0	0	0	0	0	0	0	0
non-CEM Point	37379	33123	33886	45887	34609	47021	27006	47091	35881	11560
Nonpoint	71654	233020	117550	63531	59674	140740	58713	89190	121170	25427
Nonroad	18238	58411	30964	14645	12300	29696	14742	21417	23519	9066
Onroad	36082	105343	160914	27271	21502	59021	24622	40676	42414	13263
RWC	1537	1553	2084	2994	977	3291	1170	2175	3902	1450

Figure 2-40. SESARM 2018 state total VOC emissions by inventory sector



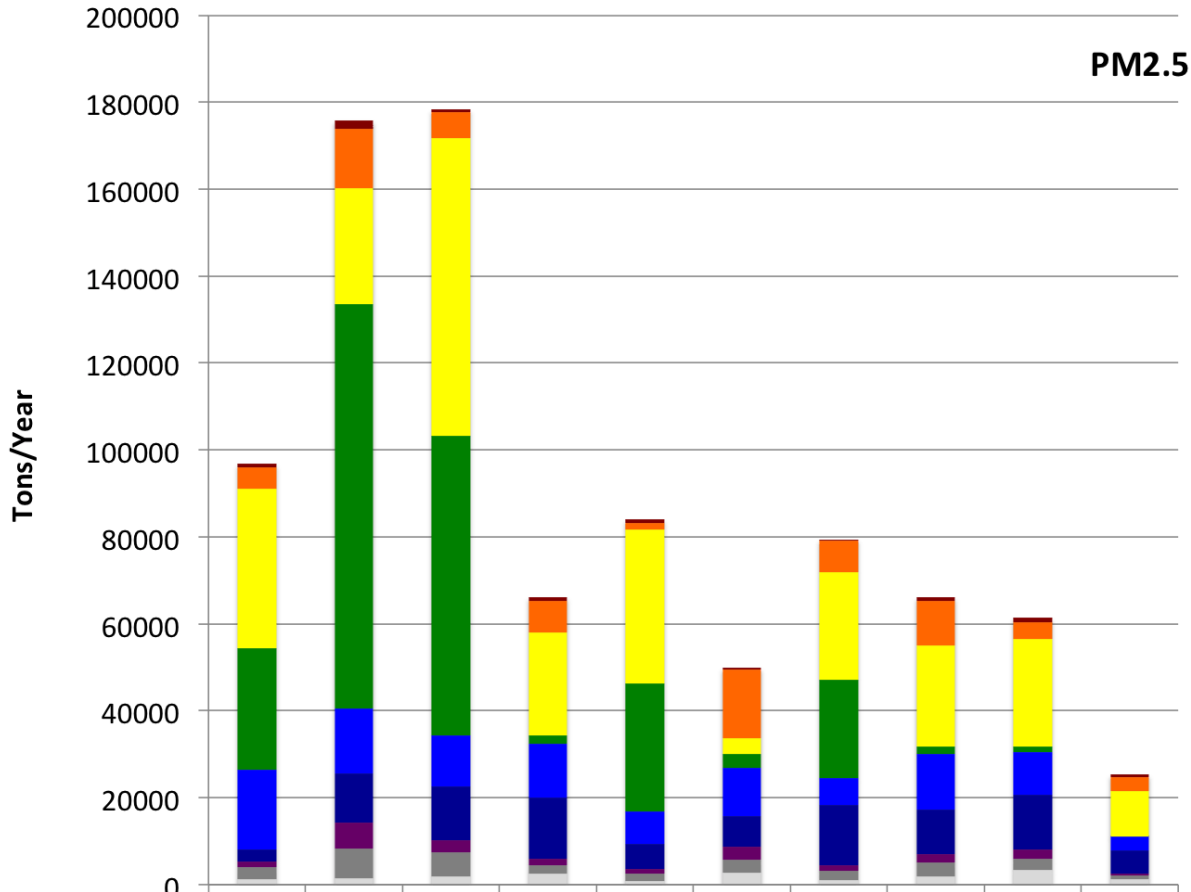
	AL	FL	GA	KY	MS	NC	SC	TN	VA	WV
ALM	22	69	21	21	18	15	10	17	26	14
Biogenic	0	0	0	0	0	0	0	0	0	0
CEM Point	236	2002	70	2	215	37	3	44	246	32
Dust	0	0	0	0	0	0	0	0	0	0
Fertilizer	6918	8009	11828	18730	13138	16050	5798	9373	9417	4063
Fires	1701	6156	3709	116	4596	205	1473	101	80	5
Livestock	58994	25939	73407	36181	49031	152770	24396	27006	32874	8715
non-CEM Point	2103	698	6122	119	1591	1680	1274	1457	1541	325
Nonpoint	379	253	1272	524	264	769	402	945	1267	375
Nonroad	30	132	63	30	21	62	30	40	48	10
Onroad	1772	6022	3392	1373	1102	3132	1456	2088	2575	567
RWC	77	83	105	146	49	160	57	105	191	70

Figure 2-41. SESARM 2007 state total NH3 emissions by inventory sector



	AL	FL	GA	KY	MS	NC	SC	TN	VA	WV
ALM	1145	2625	675	991	1101	305	585	759	1289	993
Biogenic	0	0	0	0	0	0	0	0	0	0
CEM Point	93079	123220	23930	128694	61985	25827	68767	142866	82890	48406
Dust	0	0	0	0	0	0	0	0	0	0
Fertilizer	0	0	0	0	0	0	0	0	0	0
Fires	2157	6006	4491	151	3035	268	1586	131	103	6
Livestock	0	0	0	0	0	0	0	0	0	0
non-CEM Point	72050	63932	41897	33730	18189	47935	32760	23763	43340	29546
Nonpoint	338	10273	3935	15228	324	7024	6002	14116	14714	5435
Nonroad	31	119	62	30	21	66	31	43	47	10
Onroad	533	1729	3439	375	323	849	430	582	793	158
RWC	20	21	27	41	13	43	15	28	52	20

Figure 2-42. SESARM 2018 state total SO2 emissions by inventory sector



	AL	FL	GA	KY	MS	NC	SC	TN	VA	WV
ALM	887	1842	751	749	708	420	283	763	979	645
Biogenic	0	0	0	0	0	0	0	0	0	0
CEM Point	4908	13639	5788	7414	1689	15835	7225	10340	3877	3129
Dust	36565	26751	68672	23643	35320	3428	24749	23277	24787	10395
Fertilizer	0	0	0	0	0	0	0	0	0	0
Fires	27951	93131	68750	1873	29353	3304	22732	1672	1309	76
Livestock	0	0	0	0	0	0	0	0	0	0
non-CEM Point	18317	14852	11932	12330	7581	11143	6179	12797	9632	3202
Nonpoint	2785	11423	12183	14223	5856	7063	13764	10284	12636	5213
Nonroad	1411	5950	2921	1413	987	2891	1371	1859	2296	518
Onroad	2663	6832	5601	1965	1680	2988	2160	3251	2547	889
RWC	1298	1382	1790	2504	824	2760	983	1807	3293	1212

Figure 2-43. SESARM 2018 state total PM2.5 emissions by inventory sector

2.1.4.2 U.S. Nonpoint (nonpt)

Region	Data Source	Final Version	Notes
SESARM	TranSystems	January 22, 2013	NIF to ORL conversion by UNC
MANE-VU	MARAMA	2017v3.3, existing controls	Downloaded from ftp.marama.org in ORL format; VA removed by UNC
MWRPO	LADCO	BaseCv7	NIF to ORL conversion by UNC
CENRAP	US EPA	NEI2008v2	Downloaded from ftp://ftp.epa.gov/EmisInventory/2008dev/ in ORL format
WRAP	US EPA	NEI2008v2	

The SEMAP 2018 nonpoint sector includes the same sources as the 2007 processing sector described in Section 2.1.2.2. UNC used future year (2018) nonpoint inventories for only the SESARM and MANE-VU states in the SEMAP 2018 modeling; UNC held the nonpoint emissions for the other RPOs constant at 2007 levels. UNC kept the emissions for these other RPOs constant because SESARM was not comfortable with the magnitudes of the differences between the base and future years. UNC and SESARM reviewed plots of the national 2018 emissions and noted steep spatial gradients between the RPOs. Figure 2-44 illustrates the nonpoint sector NOx emissions spatial gradients in the final and preliminary SEMAP 2018 modeling. The preliminary annual total nonpoint sector NOx plot on the top left of this figure shows a noticeable increase in emissions outside of the SESARM and MANE-VU states. The plot on the bottom pane of this figure, which shows January monthly total nonpoint sector NOx differences for the preliminary 2018 SEMAP emissions simulation, emphasizes these increases outside of the SESARM and MANE-VU states. The top right plot in the figure shows the final SEMAP 2018 annual total nonpoint NOx emissions, which include 2007 inventories for the regions outside of the SESARM and MANE-VU states. With the other inventory pollutants showing similar patterns, UNC consulted with SESARM and ultimately decided to hold the 2018 nonpoint emissions constant at 2007 levels for the states outside of the SESARM and MANE-VU regions.

TranSystems Corporation (2012b) developed the 2018 nonpoint inventory for the SEMAP project. UNC obtained inventories for the northeast states from MARAMA and for the Great Lakes region from LADCO. UNC used the NEI2008v2 for the rest of the states in the U.S.

Table 2-31 shows the annual 2018 state total nonpoint source emissions used for the SEMAP modeling. Figure 2-45 displays the 2018 annual state total nonpoint emissions for the 10 SESARM states. Virginia is projected to be the largest emitter of nonpoint CO in the region, contributing 16.8% of the SESARM region total, followed by Kentucky (15.1%), Georgia (13.8%), and Tennessee (13.0%). Virginia is projected to be the largest emitter of nonpoint NOx (18.1%) in the region, followed by Georgia (13.4%), Kentucky (12.9%), and Tennessee (12.9%). Georgia is projected to be the largest emitter of nonpoint NH_3 (19.7%) in the region followed by Virginia (19.6%), Tennessee (14.7%), and North Carolina (11.9%). Kentucky is projected to be the largest emitter of nonpoint SO2 (19.7%) in the region, followed by Virginia (19.0%), Tennessee (18.2%), and Florida (13.3%). Florida is projected to be the largest emitter of nonpoint VOC (23.8%) in the region, followed by North Carolina (14.4%), Virginia (12.4%), and Georgia (12.0%). Tennessee is projected to be the largest emitter of PM10 (16.9%) in the region, followed by Kentucky (15.5%), Florida (13.7%), and South Carolina (13.4%). Kentucky is projected to be the largest emitter of PM2.5 (14.9%) in the region, followed by South Carolina (14.4%), Virginia (13.2%), and Georgia (12.8%).

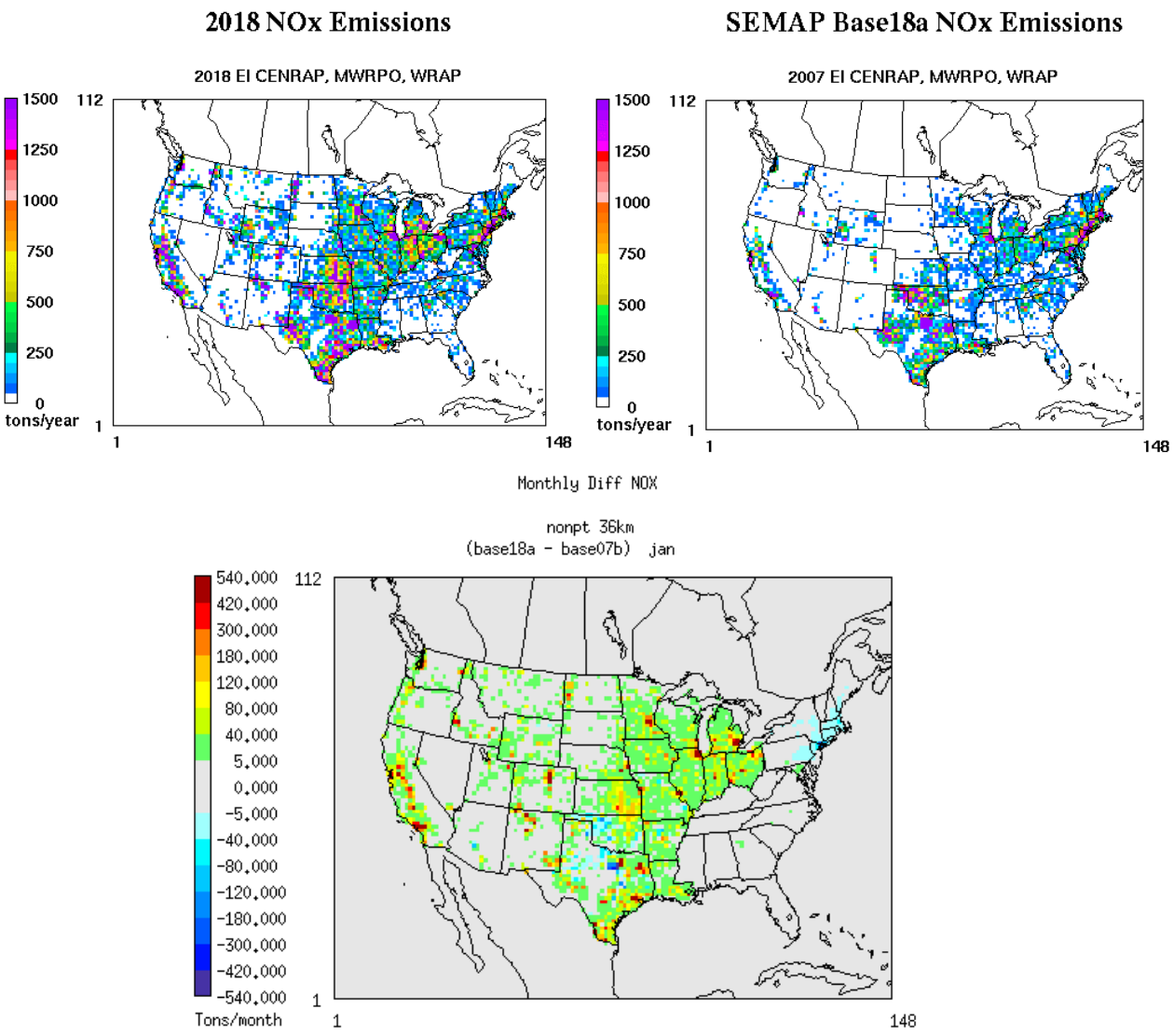


Figure 2-44. SEMAP 2018 modeling emissions with 2007 data for the MWRPO, CENRAP and WRAP states (left); 2018 emissions for the entire country (right); difference in January monthly total preliminary 2018 NOx (bottom)

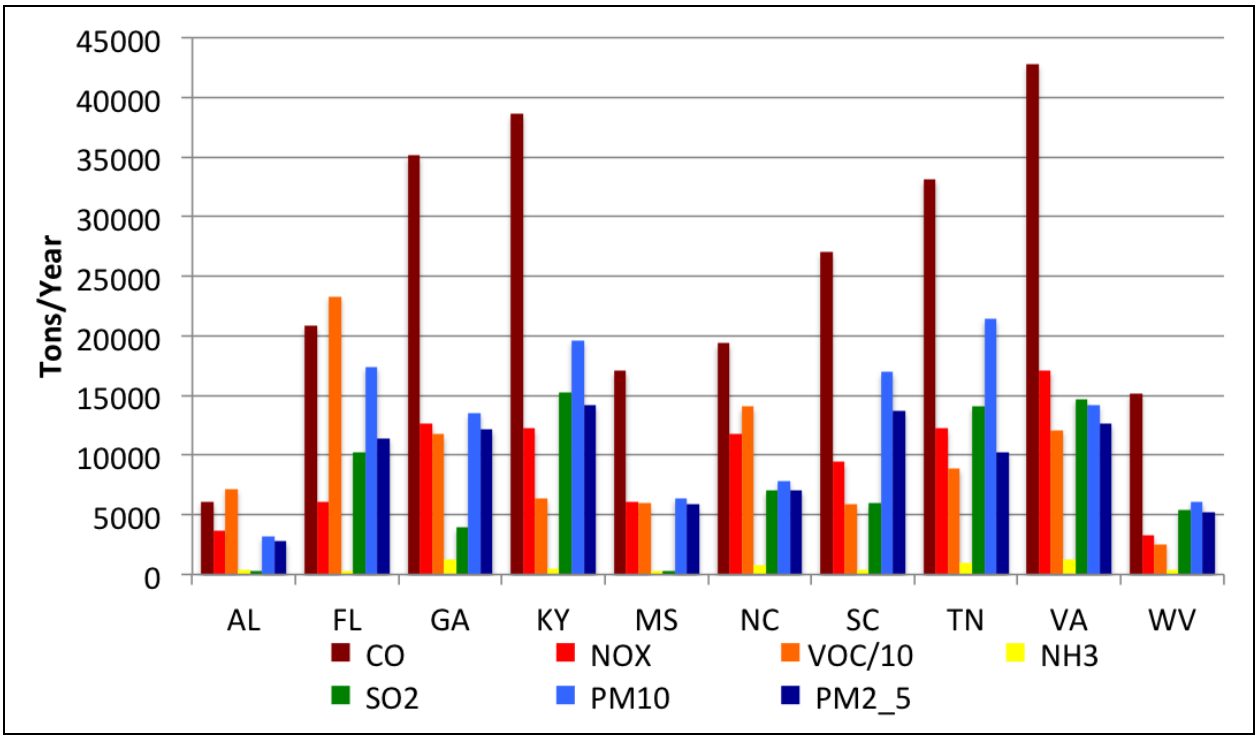


Figure 2-45. SESARM state annual total 2018 nonpoint source emissions; note that the VOC emissions are divided by 10 to normalize their magnitude

2.1.4.3 Residential wood combustion (RWC)

Region	Data Source	Final Version	Notes
SESARM	TranSystems	January 22, 2013	NIF to ORL conversion by UNC
MANE-VU	MARAMA	2017v3.3, existing controls	Downloaded from ftp.marama.org in ORL format; VA removed by UNC
MWRPO	LADCO	BaseCv7	NIF to ORL conversion by UNC
CENRAP	US EPA	NEI2008v2	Downloaded from ftp://ftp.epa.gov/EmisInventory/2008dev/ in ORL format
WRAP	US EPA	NEI2008v2	

The SEMAP 2018 RWC sector includes the same sources as the 2007 processing sector described in Section 2.1.2.3. As a subsector of the nonpoint inventory, UNC used future year (2018) inventories for only the SESARM and MANE-VU states in the SEMAP 2018 modeling; UNC held the RWC emissions for the other RPOs constant at 2007 levels.

TranSystems Corporation (2012b) developed the 2018 RWC inventory for the SEMAP project. UNC obtained inventories for the northeast states from MARAMA and for the Great Lakes region from LADCO. UNC used the NEI2008v2 for the rest of the states in the U.S.

Table 2-32 shows the annual 2018 state total RWC source emissions used for the SEMAP modeling. Figure 2-46 displays the 2018 state total RWC emissions for the 10 SESARM states. The distribution of RWC emissions is consistent across pollutants with Virginia projected to contribute the highest emissions

in the region with 18.5% of the 10-state total for all pollutants. Virginia is followed by North Carolina (15.5%), Kentucky (14.3%), and Tennessee (10.3%) as the next largest sources of regional total RWC emissions for all pollutants.

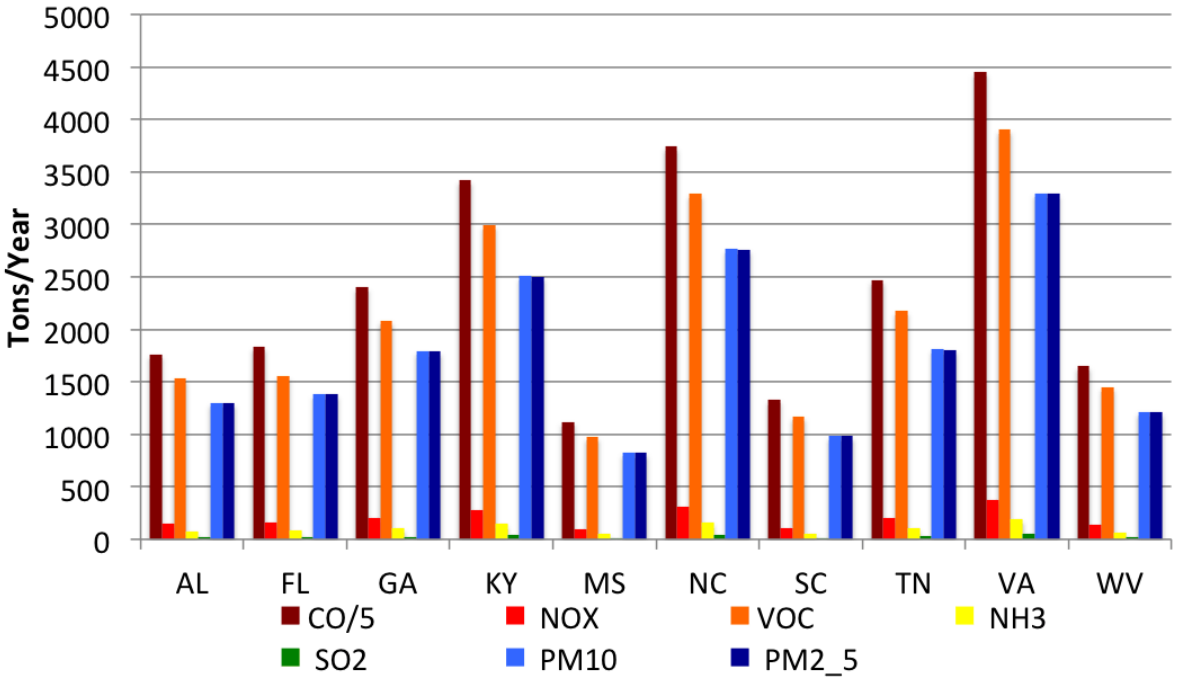


Figure 2-46. SESARM state annual total 2018 RWC source emissions; note that the CO emissions are divided by 5 to normalize their magnitude

2.1.4.4 Road and fugitive dust (fdust and mv_fdust)

Region	Data Source	Final Version	Notes
SESARM	TranSystems	January 22, 2013	NIF to ORL conversion by UNC
MANE-VU	MARAMA	2017v3.3, existing controls	Downloaded from ftp.marama.org in ORL format; VA removed by UNC
MWRPO	LADCO	BaseCv7	NIF to ORL conversion by UNC
CENRAP	US EPA	NEI2008v2	Downloaded from ftp://ftp.epa.gov/EmisInventory/2008dev/ in ORL format
WRAP	US EPA	NEI2008v2	

The SEMAP 2018 dust sectors include the same sources as the 2007 processing sector described in Section 2.1.2.4. As a subsector of the nonpoint inventory, UNC used future year (2018) inventories for only the SESARM and MANE-VU states in the SEMAP 2018 modeling; UNC held the dust emissions for the other RPOs constant at 2007 levels.

TranSystems Corporation (2012b) developed the 2018 fugitive and road dust inventory for the SEMAP project. UNC obtained inventories for the northeast states from MARAMA and for the Great Lakes region from LADCO. UNC used the NEI2008v2 for the rest of the states in the U.S.

Table 2-33 shows the annual 2018 state total dust source emissions used for the SEMAP modeling. Figure 2-47 displays the 2007 state total dust emissions for the 10 SESARM states. Georgia is the largest emitter of road and fugitive dust PM10 in the region, contributing 24.5% of the SESARM region total, followed by Alabama (13.4%), Florida (12.6%), and Mississippi (12.4%).

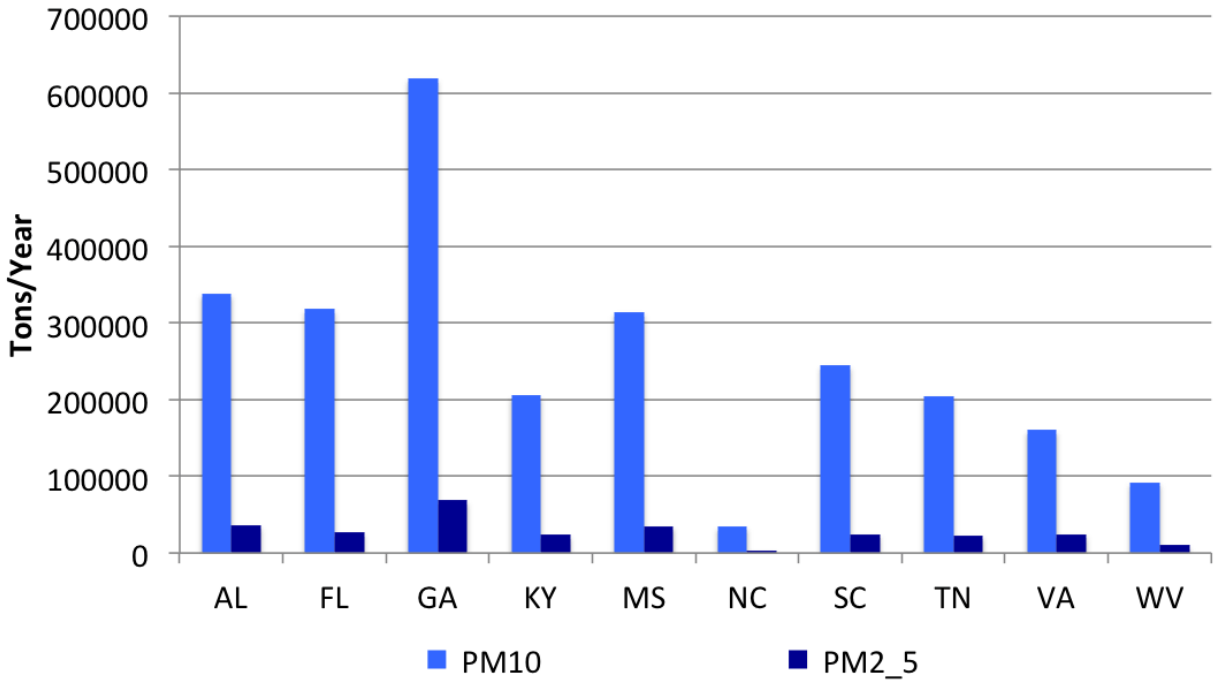


Figure 2-47. SESARM state annual total 2018 road and fugitive dust source emissions; note that these values do not reflect the application of any adjustment factors

2.1.4.5 Agricultural ammonia (lv and ft)

Region	Data Source	Final Version	Notes
SESARM	TranSystems	January 22, 2013	NIF to ORL conversion by UNC
MANE-VU	MARAMA	2017v3.3, existing controls	Downloaded from ftp.marama.org in ORL format; VA removed by UNC
MWRPO	LADCO	BaseCv7	NIF to ORL conversion by UNC
CENRAP	US EPA	NEI2008v2	Downloaded from ftp://ftp.epa.gov/EmisInventory/2008dev/ in ORL format
WRAP	US EPA	NEI2008v2	

The SEMAP 2018 agricultural ammonia sector includes the same sources as the 2007 processing sector described in Section 2.1.2.5. As a subsector of the nonpoint inventory, UNC used future year (2018) inventories for only the SESARM and MANE-VU states in the SEMAP 2018 modeling; UNC held the agricultural ammonia emissions for the other RPOs constant at 2007 levels.

TranSystems Corporation (2012b) developed the 2018 agricultural ammonia inventory for the SEMAP project. UNC obtained inventories for the northeast states from MARAMA and for the Great Lakes region from LADCO. UNC used the NEI2008v2 for the rest of the states in the U.S.

Table 2-34 shows the annual 2018 state total agricultural ammonia emissions used for the SEMAP modeling. Figure 2-48 displays the 2018 state total agricultural ammonia emissions for the 10 SESARM states. North Carolina is projected to be the largest emitter of livestock NH_3 in the region, contributing 31.2% of the SESARM region total, followed by Georgia (15%), Alabama (12.1%), and Mississippi (10.0%). Kentucky is projected to be the largest emitter of fertilizer NH_3 in the region, contributing 18.1% of the SESARM region total, followed by North Carolina (15.5%), Mississippi (12.7%), and Georgia (11.4%).

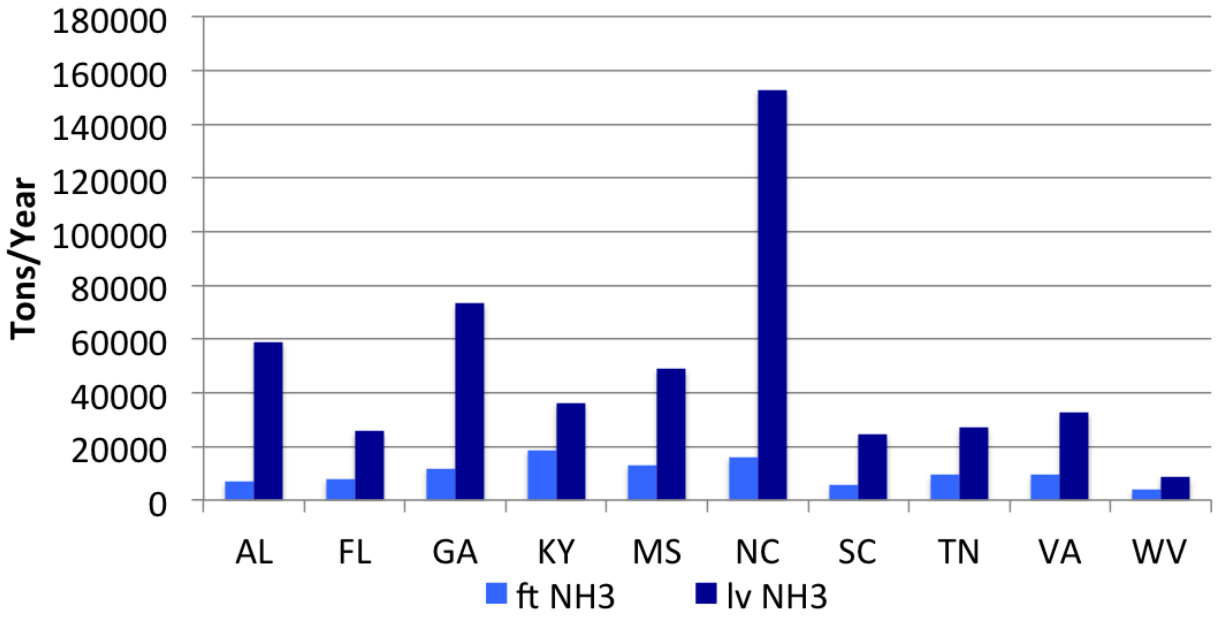


Figure 2-48. SESARM state annual total 2018 fertilizer and livestock source emissions

2.1.4.6 Offroad mobile (nonroad)

Region	Data Source	Final Version	Notes
SESARM	TranSystems	October 2012	Monthly ORL-formatted files provided by TranSystems
MANE-VU	MARAMA	2017v3.3, existing controls	Downloaded from ftp.marama.org in ORL format; VA removed by UNC
MWRPO	US EPA	NEI2005v4.3 2017ct_ref_05b	Downloaded from ftp://ftp.epa.gov/EmisInventory/2005v4_3/mats/2017emis/ in ORL format
CENRAP	US EPA	NEI2005v4.3 2017ct_ref_05b	
WRAP	US EPA	NEI2005v4.3 2017ct_ref_05b	

The SEMAP 2018 offroad mobile (nonroad) sector includes the same sources as the 2007-processing sector described in Section 2.1.2.6. UNC used future year nonroad inventories for all areas of the U.S. TranSystems (2012b) provided 2018 monthly nonroad inventories in ORL, SMOKE-ready format. MARAMA provided 2017 monthly nonroad projection inventories for the MANE-VU states. UNC used the NEI2005v4.3 modeling platform for 2017 projected monthly nonroad inventories for the rest of the

country. UNC moved all aircraft, locomotive, and marine sources, including pleasure craft, from the nonroad to the ALM sector before processing these data with SMOKE.
Table 2-35 shows the annual 2018 state total nonroad mobile emissions used for the SEMAP modeling. Figure 2-49 displays the 2018 state total nonroad emissions for the 10 SESARM states. Florida is projected to be the largest emitter of nonroad emissions in the region, contributing about 27% of the SESARM region total nonroad emissions for all pollutants, followed by Georgia and North Carolina (13.5%), Virginia (10.5%), and Tennessee (9.0%).

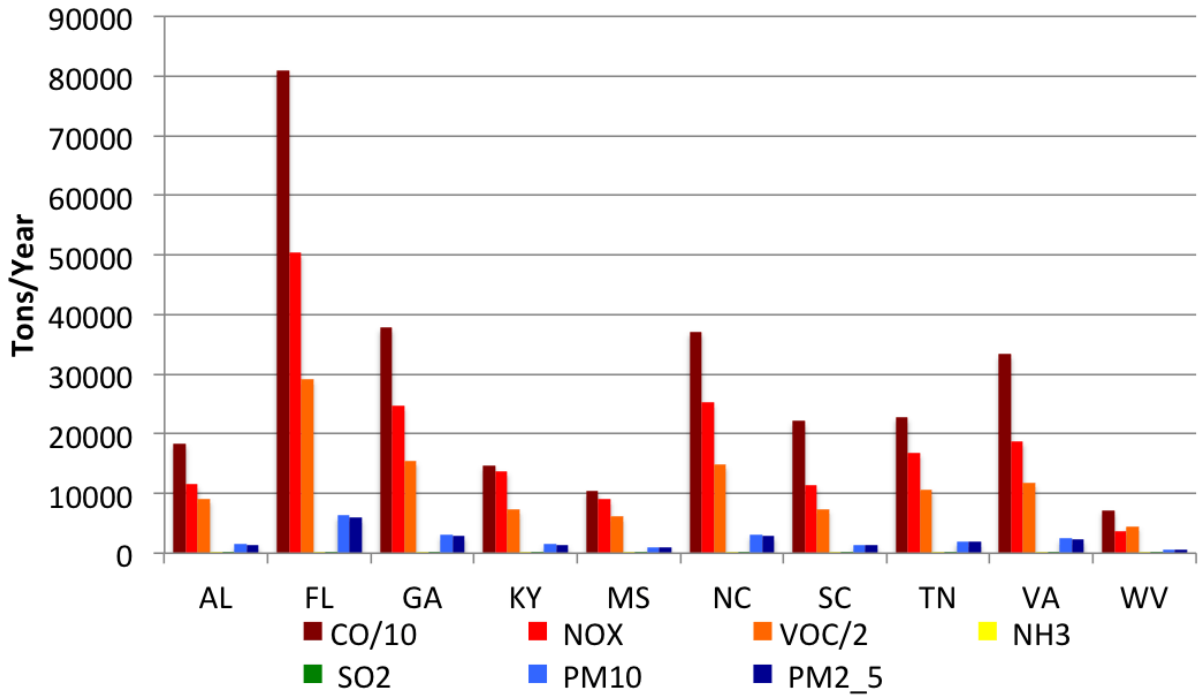


Figure 2-49. SESARM state annual total 2018 nonroad mobile source emissions; note that the CO emissions are divided by 10 to normalize their magnitude

2.1.4.7 Aircraft locomotive marine (ALM)

Region	Data Source	Final Version	Notes
SESARM	TranSystems	October 2012	NIF to ORL conversion by UNC
MANE-VU	MARAMA	2017v3.3, existing controls	Downloaded from ftp.marama.org in ORL format; VA removed by UNC
MWRPO	US EPA	NEI2005v4.3 2017ct_ref_05b	Downloaded from ftp://ftp.epa.gov/EmisInventory/2005v4_3/mats/2017emis/ in ORL format
CENRAP	US EPA	NEI2005v4.3 2017ct_ref_05b	
WRAP	US EPA	NEI2005v4.3 2017ct_ref_05b	

The SEMAP 2018 Aircraft, Locomotive, Marine (ALM) sector includes the same sources as the 2007-processing sector described in Section 2.1.2.7. UNC obtained the 2018 ALM inventories from the same sources as the 2018 nonpoint inventories.

Table 2-36 shows the annual 2018 state total ALM emissions used for the SEMAP modeling. Figure 2-50 displays the 2018 state total ALM emissions for the 10 SESARM states. Florida is the projected to be largest emitter of ALM emissions in the region, contributing about 24% of the NOx and 36% of the VOC emissions for the SESARM region ALM sources. Other large regional sources of ALM NOx are projected to include Virginia (12.6%), Alabama (10.8%), and Georgia (10.2%). The other large regional sources of ALM VOC are projected to include North Carolina (9.2%) and Alabama (8.3%).

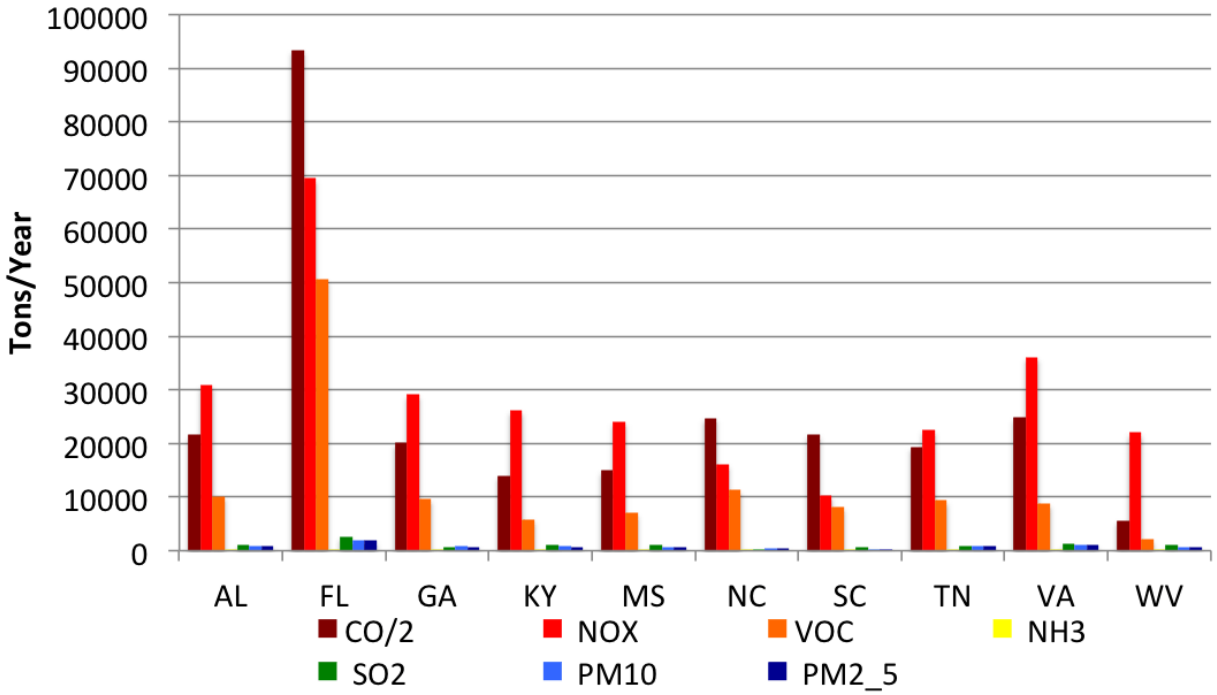


Figure 2-50. SESARM state annual total 2018 ALM source emissions; note that the CO emissions are divided by 2 to normalize their magnitude

2.1.4.8 Onroad mobile

Region	Data Source	Final Version	Notes
SESARM (without VA)	AMEC/Alpine Geophysics	September 11, 2011	MOVES 2010a run in emissions factor mode
VA	AMEC/Alpine Geophysics/VA DEQ	February 7, 2012 EI and September 11, 2011 MOVES	MOVES 2010a run in emissions factor mode with VMT and VPOP updates provided by VA DEQ
MANE-VU (without VA)	MARAMA	2007→2018 Projection factors received July 19, 2013 from UMD	Document titled "Creating Tier 3 2017 Mobile Emissions" used as guidance.
MWRPO	US EPA	NEI2005v4.3 2017ct_ref_05b	MOVES2010a run in emissions inventory mode, monthly inventories with adjustments for running and start PM emissions; downloaded from ftp://ftp.epa.gov/EmisInventory/2005v4_3/mats/2017emis/
CENRAP	US EPA	NEI2005v4.3 2017ct_ref_05b	
WRAP	US EPA	NEI2005v4.3 2017ct_ref_05b	

2.1.4.9 MOVES Projections

UNC used information provided by each of the SESARM states to project the MOVES onroad mobile emissions from the base year 2007 to the future year 2018. With guidance and scripts from GA DNR, each of the SESARM states ran MOVES in emission inventory mode for 2007 and 2018. They then provided UNC with either ratios of 2018/2007 emissions or their 2007 and 2018 MOVES inventories to use in calculating ratios. UNC used these ratios to develop a SMOKE onroad mobile emissions control factor input file (CFPRO). UNC then used SMOKE to apply the factors in the CFPRO file to generate 2018 onroad mobile emissions estimates for the SESARM states from the 2007 MOVES emissions factor mode tables. Using these projection ratios avoided the resource-intensive processes of running MOVES and SMOKE-MOVES in emission factor mode.

The SESARM states sent data to UNC in a few different forms, which UNC then had to process to get them in the CFPRO format for SMOKE. Each of the 10 SESARM states provided the following information for estimating future year 2018 onroad mobile emissions:

- Alabama – annual, state-wide ratios for all criteria pollutants (CO, NO, NO2, NOx, VOC, SO2, NH3, PM10 exhaust, PM10 brakewear, PM10 tirewear, PM2.5 exhaust, PM2.5 brakewear, PM.5 tirewear) with no-SCC level assignments. UNC applied a single annual ratio for each pollutant to all counties, all SCCs, for all days of the year to estimate future year onroad emissions for AL.
- Florida - annual, state-wide ratios for all criteria pollutants with no SCC-level assignments. UNC applied a single annual ratio for each pollutant to all counties, all SCCs, for all days of the year to estimate future year onroad emissions for FL.
- Georgia – annual 2007 and 2018 inventories for 20 Atlanta counties and 2 counties to be used for the rest of the counties in the state. The inventories included all of the criteria pollutants with no SCC-level assignments. UNC used the inventories to develop annual 2018/2007 ratios, which UNC then applied for each pollutant and representative county to all counties, all SCCs, for all days of the year to estimate future year onroad emissions for GA.
- Kentucky – monthly 2007 and 2018 inventories for 5 representative counties for all criteria pollutants with SCC-level assignments. UNC used the inventories to develop monthly 2018/2007 ratios, which UNC then applied for each pollutant, representative county, and SCC to all counties, all SCCs, for all days in each month to estimate future year onroad emissions for KY.
- Mississippi – state-wide annual inventories and ratios for all criteria pollutants with SCC-level assignments. UNC used the inventories to develop annual 2018/2007 ratios, which UNC then applied for each pollutant and SCC to all counties, all SCCs, for all days of the year to estimate future year onroad emissions for MS.
- North Carolina – annual, state-wide ratios for all criteria pollutants with no-SCC level assignments. UNC applied a single annual ratio for each pollutant to all counties, all SCCs, for all days of the year to estimate future year onroad emissions for NC.
- South Carolina – annual, state-wide ratios for all criteria pollutants with no-SCC level assignments. UNC applied a single annual ratio for each pollutant to all counties, all SCCs, for all days of the year to estimate future year onroad emissions for SC.
- Tennessee – monthly, county-level ratios for all criteria pollutants with no-SCC level assignments. UNC applied monthly ratios for each pollutant and county to all counties, all SCCs, for all days in each month to estimate future year onroad emissions for TN.
- Virginia – monthly 2007 and 2018 inventories for 4 representative counties for all criteria pollutants with SCC-level assignments. UNC used the inventories to develop monthly 2018/2007

ratios, which UNC then applied for each pollutant, representative county, and SCC to all counties, all SCCs, for all days in each month to estimate future year onroad emissions for VA.

- West Virginia – monthly 2007 and 2018 inventories for 1 representative county for all criteria pollutants with SCC-level assignments. UNC used the inventories to develop monthly 2018/2007 ratios, which UNC then applied for each pollutant and SCC to all counties, all SCCs, for all days in each month to estimate future year onroad emissions for WV.

UNC created a series of analysis products to help the states verify the projected emissions using the state-provided ratios. UNC developed an interactive spreadsheet that allowed the states to display annual county-total 2007 emissions, 2018 emissions, and ratios by pollutant. Figure 2-51 and Figure 2-52 are example scatter and bar plots for Georgia NO emissions extracted from the spreadsheet. The final version of the spreadsheet (ftp://ftp.unc.edu/pub/empd/SEMAP/MOVES/SEMAP_MOVES_Projections.Counties.Aug.vMay2013.xlsx) is provided as an electronic docket to this report. UNC also generated thematic maps of the emissions and ratios. Figure 2-53 includes county maps of the annual total 2007 and 2018 emission and the 2018/2007 county emissions ratios that UNC developed from the data provided by the SESARM states.

UNC used a combination of MOVES projection factors and MOVES future year emissions factors to estimate onroad mobile emission outside of the SESARM states. For the MANE-VU states, excluding Virginia, UNC developed projection factors by pollutant from a guidance document provided by the University of Maryland[20]. UNC applied these projection factors to the 2007 base-year, gridded MOVES outputs from MARAMA to create 2018 onroad emissions. For the MWRPO, CENRAP, and WRAP states, UNC used the year 2017 SMOKE-MOVES projections from the NEI 2005v4.3 modeling platform. UNC ran SMOKE-MOVES in emissions factor mode to estimate gridded onroad mobile emissions in these states.

[20] Creating Tier 3 2017 Mobile Emissions

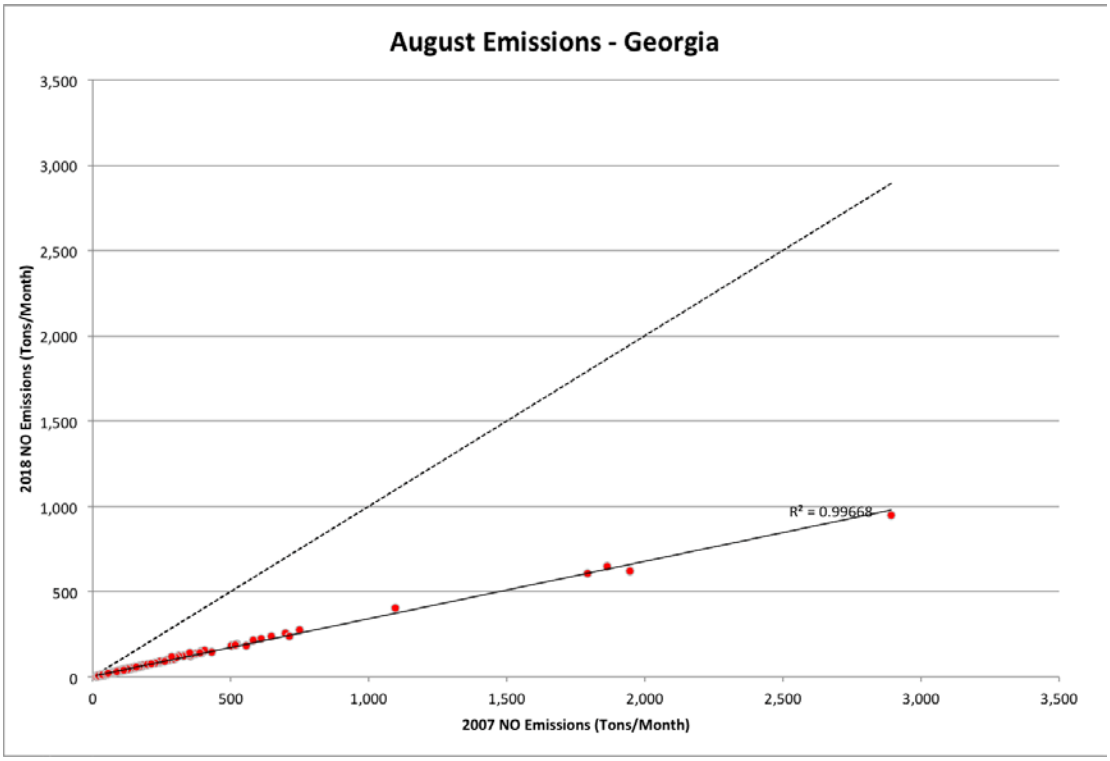


Figure 2-51. Scatter plot of 2018 vs 2007 onroad mobile NO emissions; each point represents a different county

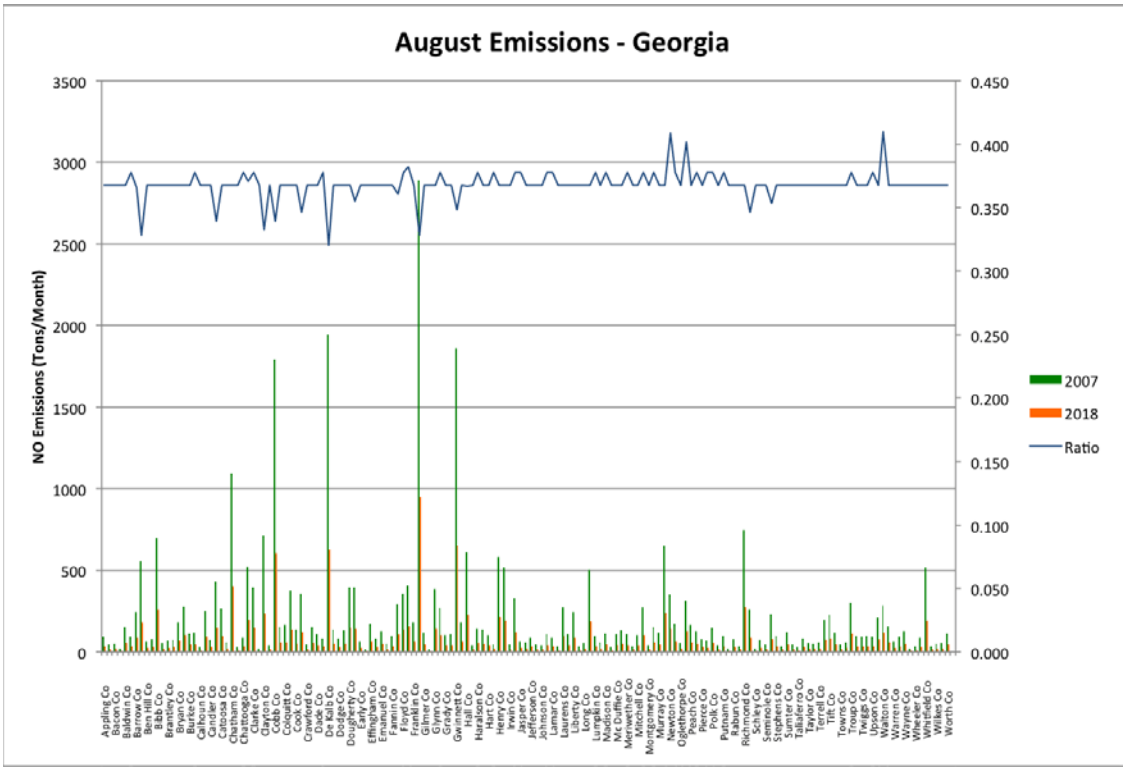
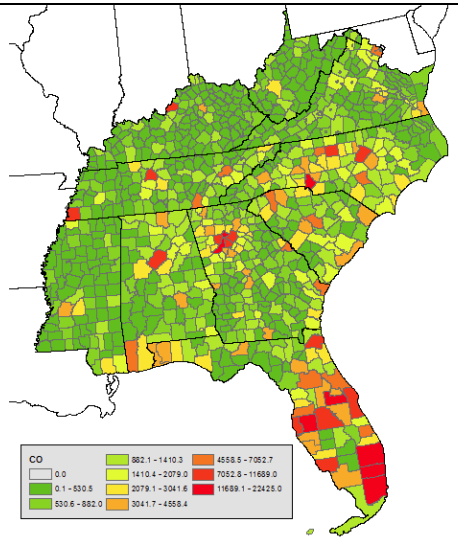
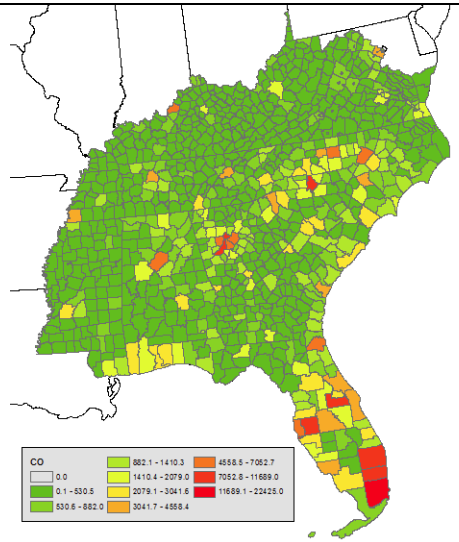
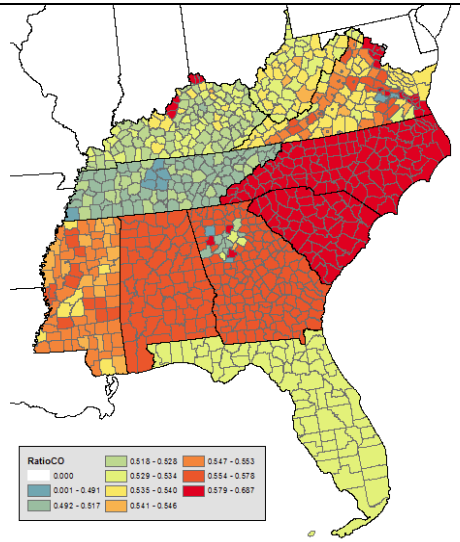
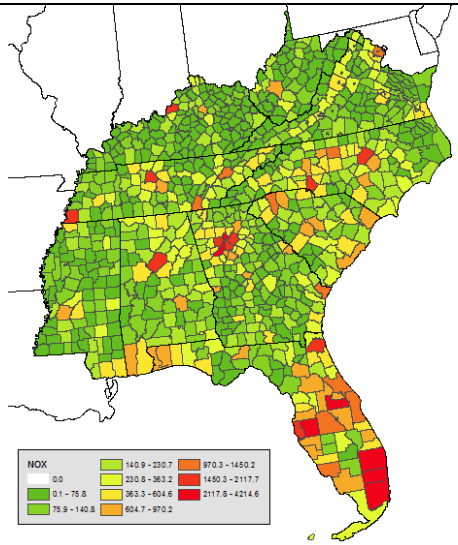
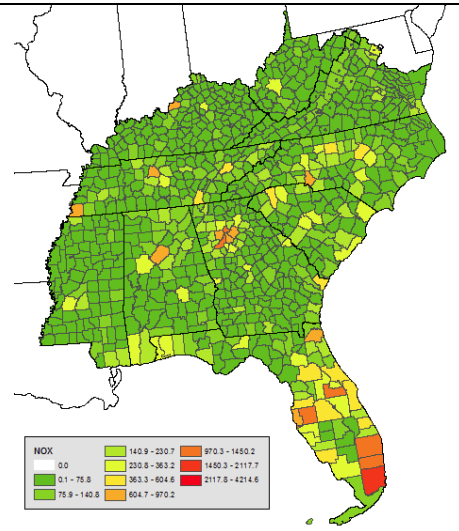
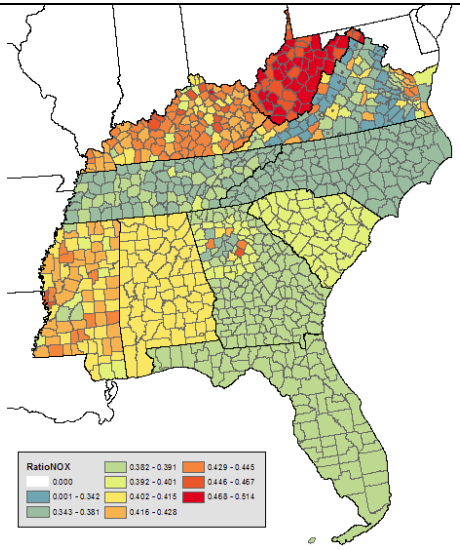
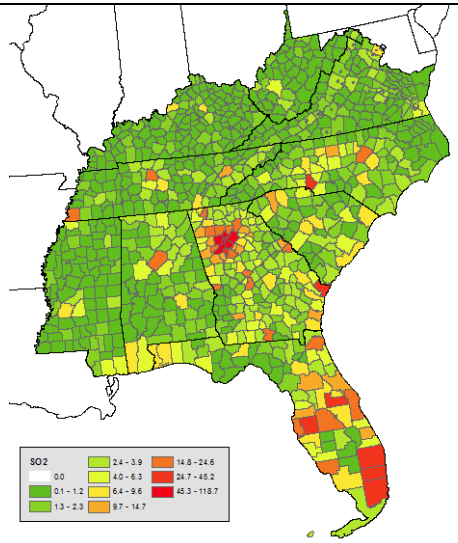
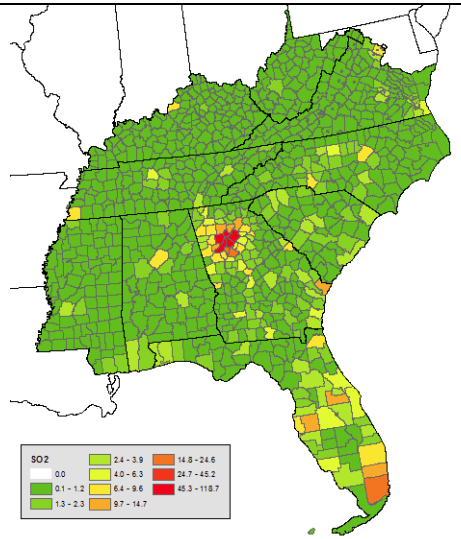
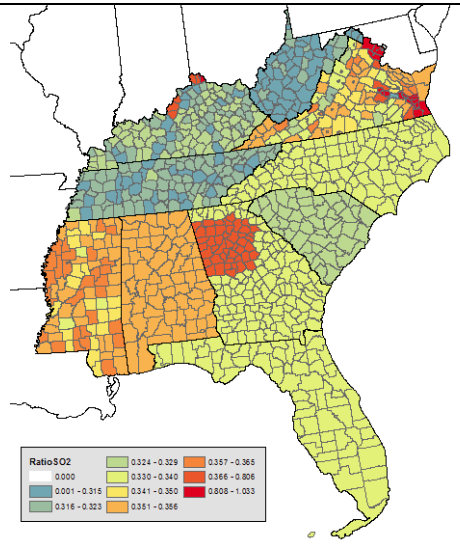
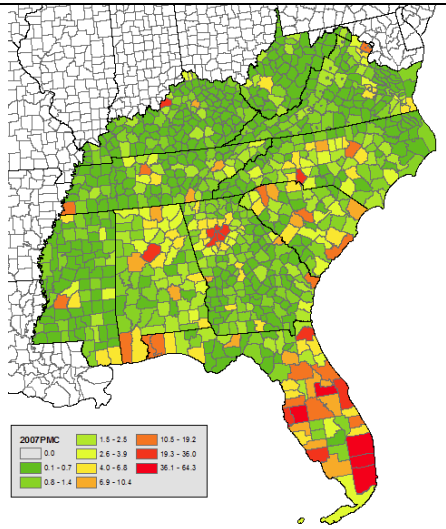
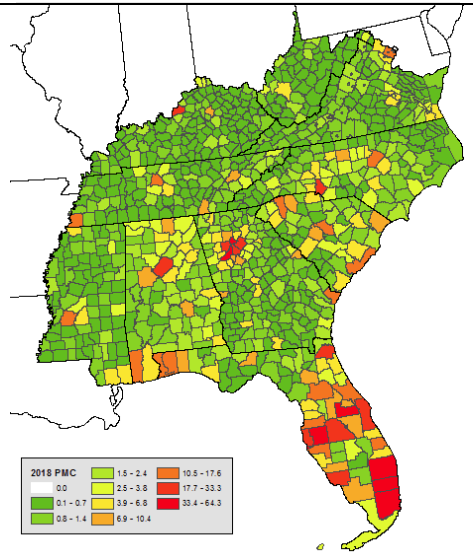
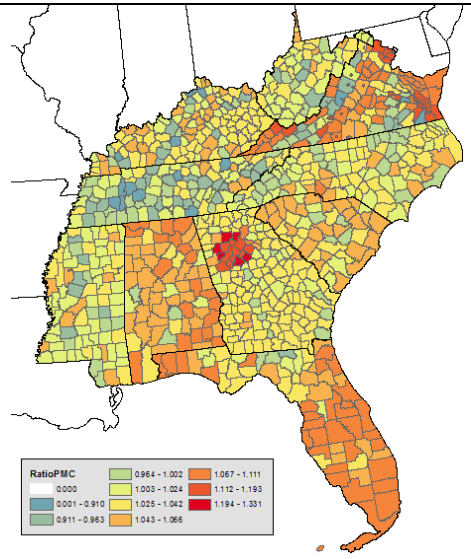
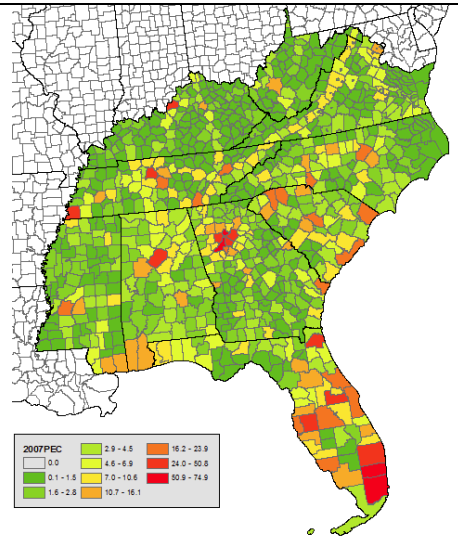
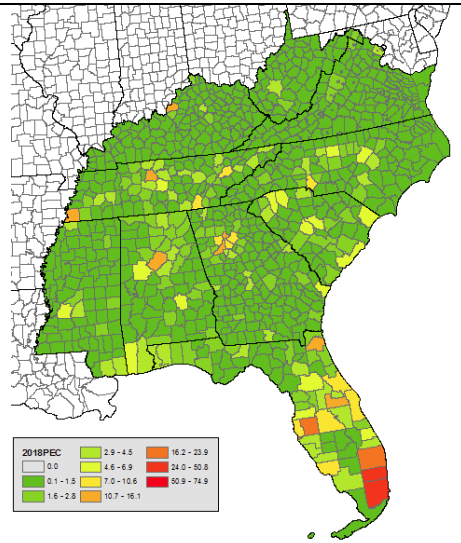
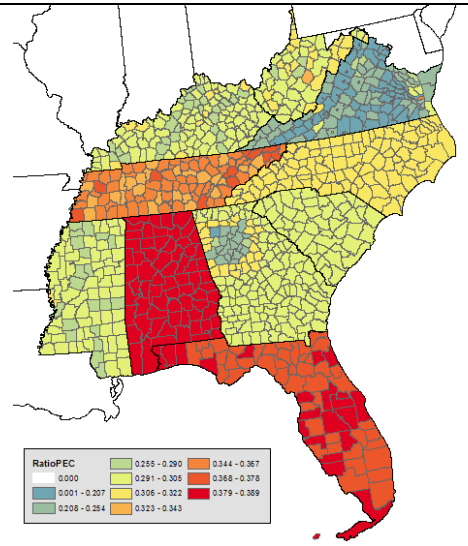
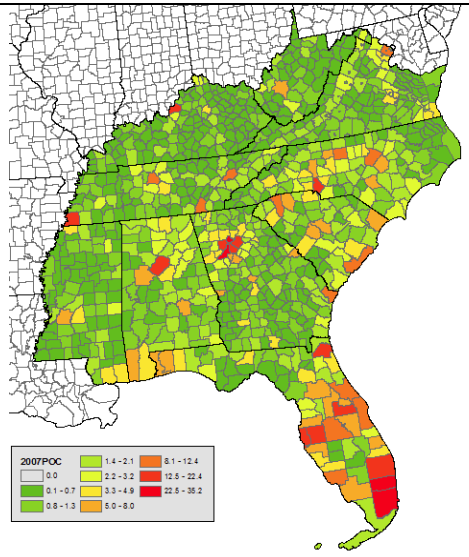
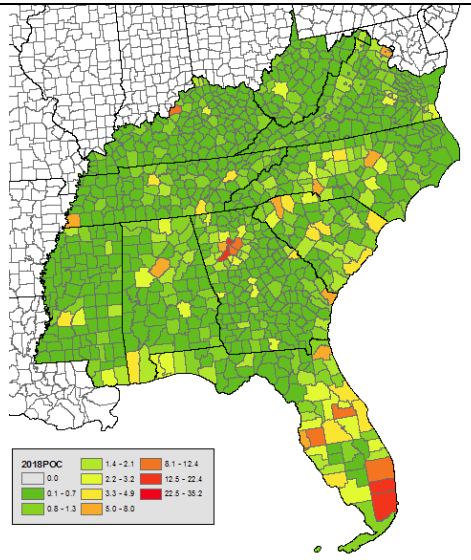
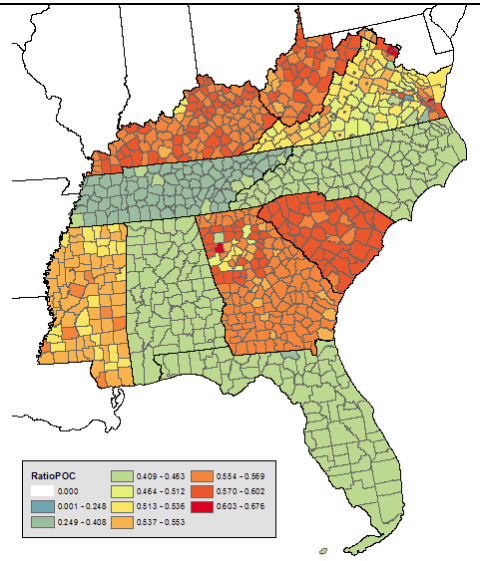
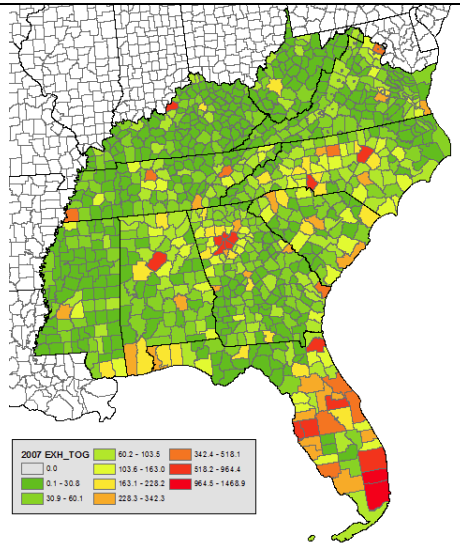
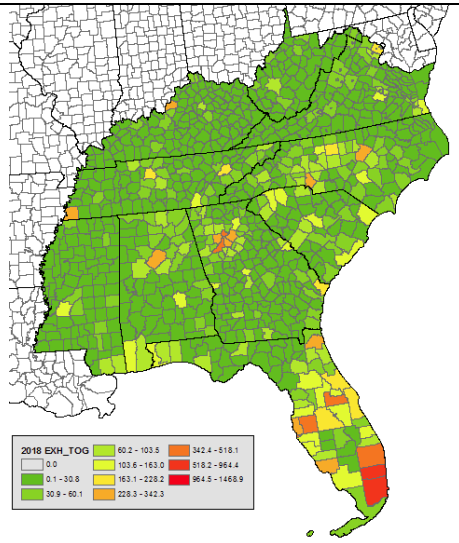
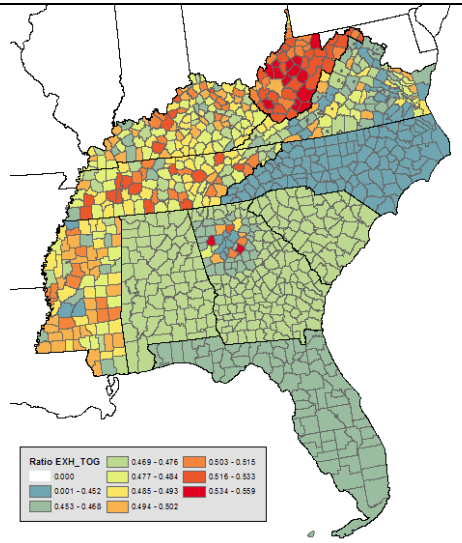
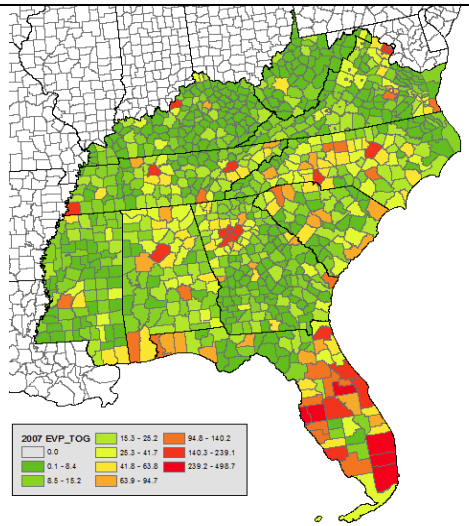
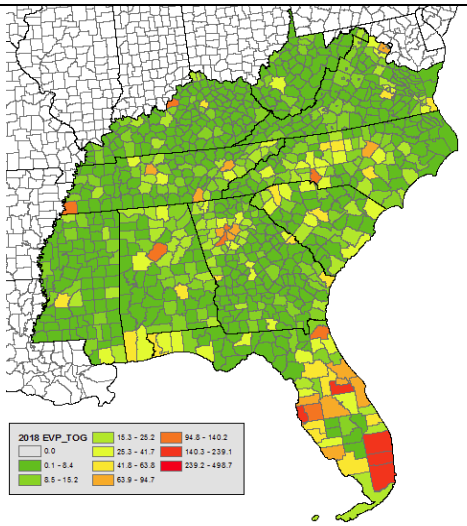
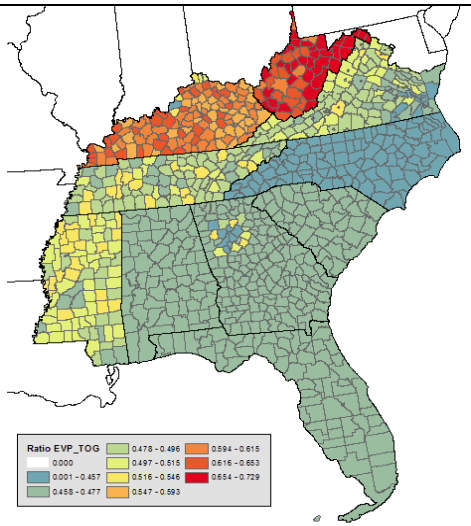


Figure 2-52. Bar plot showing the 2007, 2018 and 2018/2007 ratios for onroad mobile NO emissions for each county in Georgia

	2007	2018	2018/2007
CO			
NOx			

	2007	2018	2018/2007
SO2			
PMC			

	2007	2018	2018/2007
PEC			
POC			

	2007	2018	2018/2007
EXH TOG			
EVP TOG			

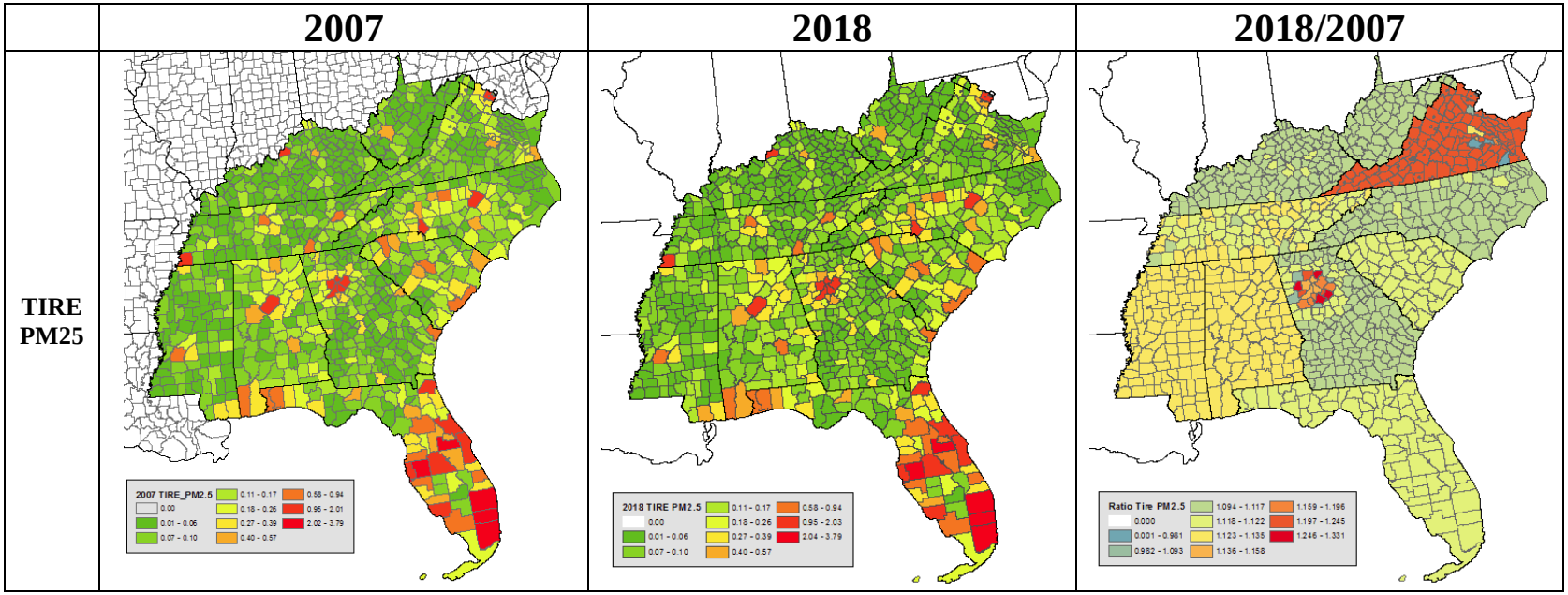


Figure 2-53. County maps of SEMAP 2007, 2018, and 2018/2007 ratios of MOVES emissions

Table 2-37 shows the annual 2018 state total onroad mobile emissions used in the SEMAP modeling. Figure 2-54 displays the 2018 state total onroad mobile emissions for the 10 SESARM states. Florida is projected to be the largest emitter of onroad mobile CO and NOx emissions in the region, contributing about 20% of the CO and 22% of the NOx emissions for the SESARM region onroad sources. Georgia is projected to be the largest emitter of onroad mobile VOC (30%) Other large regional sources of onroad mobile NOx include Georgia (17%), North Carolina (12%), and Tennessee (11%). The other large regional sources of onroad mobile VOC include Florida (20%) and North Carolina (11%).

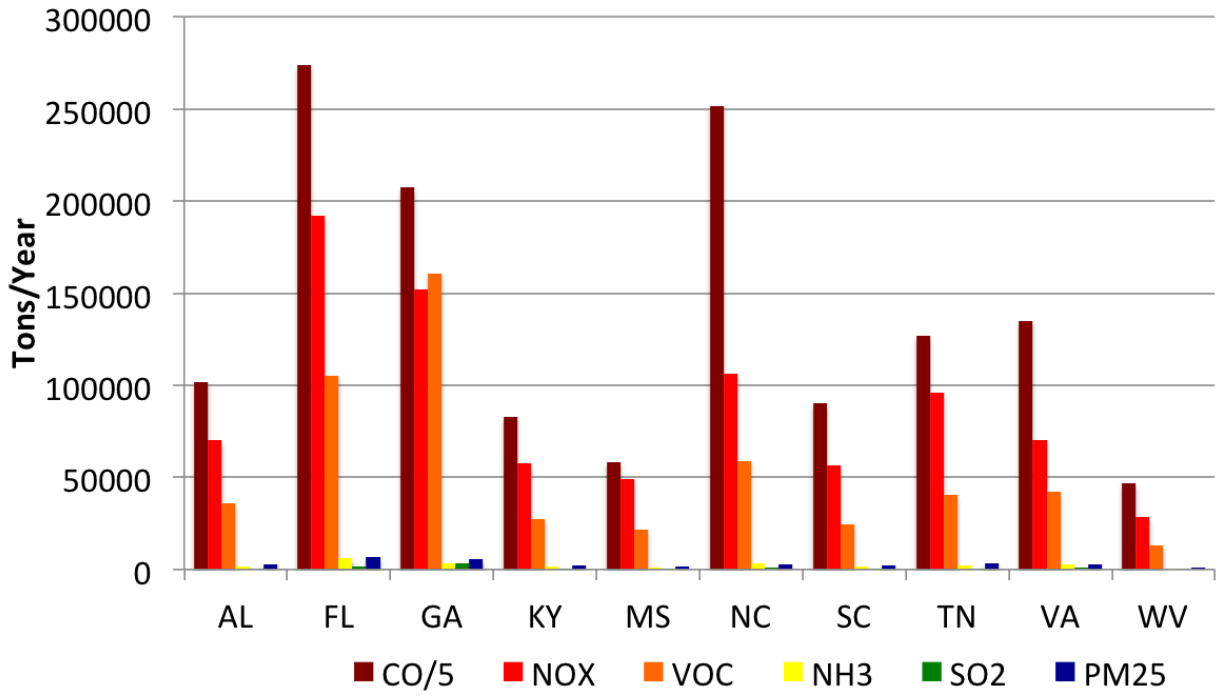


Figure 2-54. SESARM state annual total 2018 onroad mobile source emissions; note that the CO emissions are divided by 5 to normalize their magnitude

2.1.4.10 EGU and Non-EGU point

Region	Data Source	Final Version	Notes
SESARM	AMEC	2018 v1c (19Oct2013)	NIF to ORL conversion by UNC; 2007 hourly CEM scaled to 2018 using annual inventory ratios
MANE-VU	MARAMA	2020 hourly CEM and 2017v3.3 existing controls	Downloaded from ftp.marama.org in ORL format and hourly EMS-95 format; VA removed by UNC
MWRPO	US EPA	NEI2005v4.3 2017ct_ref_05b	Downloaded from ftp://ftp.epa.gov/EmisInventory/2005v4_3/mats/2017emis/ in ORL format
CENRAP			
WRAP			

UNC received the 2018 point inventory from SESARM (AMEC, 2014) as an Access database and converted the data to ORL format for SMOKE. As described in Section 2.1.2.9, UNC split the point inventories into CEM/non-CEM and EGU/non-EGU processing sectors. For the CEM sources, UNC created annual totals for each ORIS+Boiler ID combination in the 2018 and 2007 SESARM inventories and computed 2018/2007 ratios for each unique combination. UNC used these ratios to scale the 2007 hourly CEM data to 2018.

UNC gave special consideration to SESARM-state CEM sources that are projected to experience operational changes to the emissions control device from the base to future year. Table 2-17 lists the sources that transitioned from seasonal to annual controls between the base and future modeling years. UNC only applied the 2007→2018 projection ratios for these sources to the period(s) when the control device was not operating in the base year. The rationale for this approach is that the reductions reflected in the projection ratios are due to the additional operating time of the control device in the future year. UNC did not want to further reduce the future emissions during the period when the control device was already in operation during the base year.

Figure 2-55 illustrates how UNC only applied the projection ratios to the uncontrolled periods of the base year CEM inventory. In this figure the black line shows the hourly 2007 NOx emissions and the green line shows the hourly 2018 NOx emissions. The 2007 and 2018 emissions are the same during the ozone season; the reductions from 2007 to 2018 are realized outside of the ozone season, as shown by the differences in the black and green lines.

Table 2-17. SESARM CEM sources with seasonal controls in 2007 and annual controls in 2018

ORIS ID	Unit ID	State	Facility Name
703	1BLR	GA	Bowen
703	2BLR	GA	Bowen
703	3BLR	GA	Bowen
703	4BLR	GA	Bowen
708	4	GA	Hammond
3935	1	WV	John Amos
3935	2	WV	John Amos
3935	3	WV	John Amos
3944	1	WV	Harrison Power Station
3944	2	WV	Harrison Power Station
3944	3	WV	Harrison Power Station
3948	1	WV	Mitchell (WV)
3948	2	WV	Mitchell (WV)
6004	1	WV	Pleasants Power Station
6004	2	WV	Pleasants Power Station
6052	1	GA	Wansley (6052)
6052	2	GA	Wansley (6052)
6264	1	WV	Mountaineer (1301)
1356	1	KY	KY Utilities Co - Ghent Station
1356	3	KY	KY Utilities Co - Ghent Station
1356	4	KY	KY Utilities Co - Ghent Station
1364	3	KY	LOU GAS & ELEC, MILL CREEK
1364	4	KY	LOU GAS & ELEC, MILL CREEK
1374	1	KY	Owensboro Municipal Utilities - Elmer Smith Station
1374	2	KY	Owensboro Municipal Utilities - Elmer Smith Station
1378	1	KY	Tennessee Valley Authority - Paradise Fossil Plant
1378	2	KY	Tennessee Valley Authority - Paradise Fossil Plant
1378	3	KY	Tennessee Valley Authority - Paradise Fossil Plant
1382	H1	KY	Western KY Energy Corp - Reid HMP&L Station 2

1382	H2	KY	Western KY Energy Corp - Reid HMP&L Station 2
47	5	AL	TVA
50	7	AL	TVA
50	8	AL	TVA
6002	1	AL	ALABAMA POWER COMPANY (MILLER POWER PLANT)
6002	2	AL	ALABAMA POWER COMPANY (MILLER POWER PLANT)
6002	3	AL	ALABAMA POWER COMPANY (MILLER POWER PLANT)
6002	4	AL	ALABAMA POWER COMPANY (MILLER POWER PLANT)
6018	2	KY	Duke Energy KY East Bend
6041	1	KY	East KY Power Coop - Spurlock Station
6041	2	KY	East KY Power Coop - Spurlock Station
6071	1	KY	Louisville Gas & Electric Co - Trimble Co Generating Station
6823	W1	KY	Western KY Energy Corp - Wilson Station
3803	4	VA	VIRGINIA POWER CHESAPEAKE
3944	2	WV	MONONGAHELA POWER CO-HARRISON
3944	3	WV	MONONGAHELA POWER CO-HARRISON
3954	1	WV	MOUNT STORM POWER PLANT
3954	2	WV	MOUNT STORM POWER PLANT
3954	3	WV	MOUNT STORM POWER PLANT

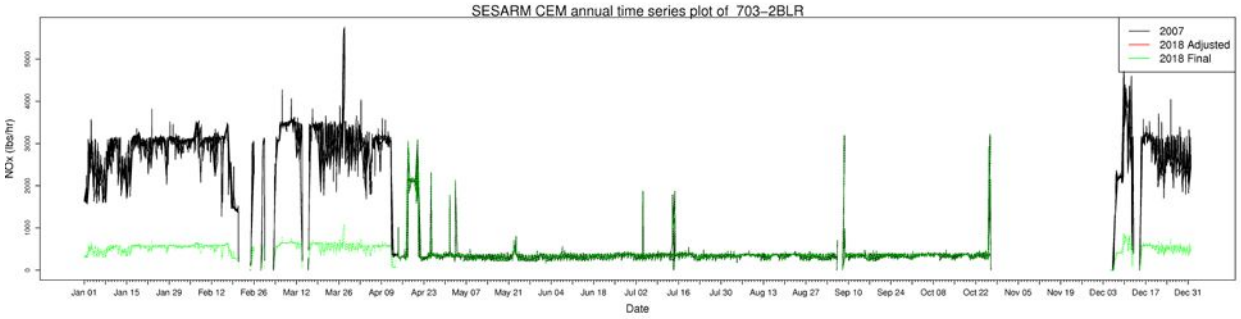


Figure 2-55. Timeseries of 2007 and 2018 hourly CEM NOx at Bowen Power Plant in Georgia

UNC collected future year point inventories for sources outside of the SESARM region from MARAMA and EPA. MARAMA provided both annual and hourly 2020 point source inventories in formats similar to their base-year inventories. For the MWRPO, CENRAP, and WRAP states UNC used the EPA 2005v4.3 modeling platform projections to 2017.

Table 2-38 shows the annual 2018 state total point source emissions used for the SEMAP modeling. These totals are the sum of the CEM and non-CEM point inventories and represent the total stationary point source emissions used for the SEMAP 2018 modeling. Figure 2-56 and Figure 2-57 display the 2018 state total non-CEM and CEM point source emissions for the 10 SESARM states. Alabama is projected to be the largest source of non-CEM point NOx emissions in the region, contributing about 15.6% of the NOx emissions for the SESARM region. Other large regional sources of non-CEM point NOx are projected to include Florida (11.8%), Mississippi (12.3%), and Georgia (10.5%). Alabama is also projected to be the largest source of non-CEM point SO_2 (17.7%), followed by Florida (15.7%), Georgia (10.3%), and North Carolina (11.8%). Tennessee is projected to be the largest source of non-

CEM point VOC (13.3%), followed by North Carolina (13.3%), Kentucky (13.0%), and Alabama (10.6%).

Tennessee is projected to be the largest regional emitter of CEM point NOx (17.1%) and SO2 (17.9%). Other large regional CEM point sources are projected to include Florida for CO (23.4%), NOx (14.9%), VOC (22.5%), and NH3 (69.3%); and North Carolina for PM10 (21.3%) and PM2.5 (21.4%).

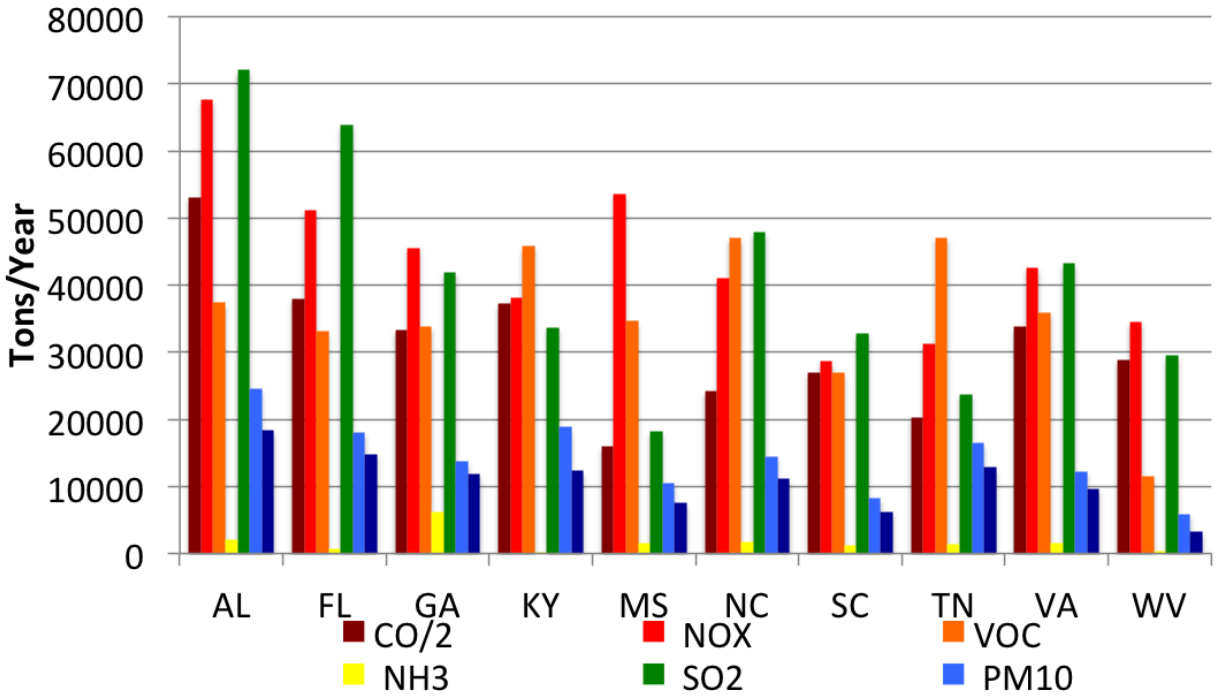


Figure 2-56. SESARM state annual total 2018 non-CEM point source emissions; note that the CO emissions are divided by 2 to normalize their magnitude.

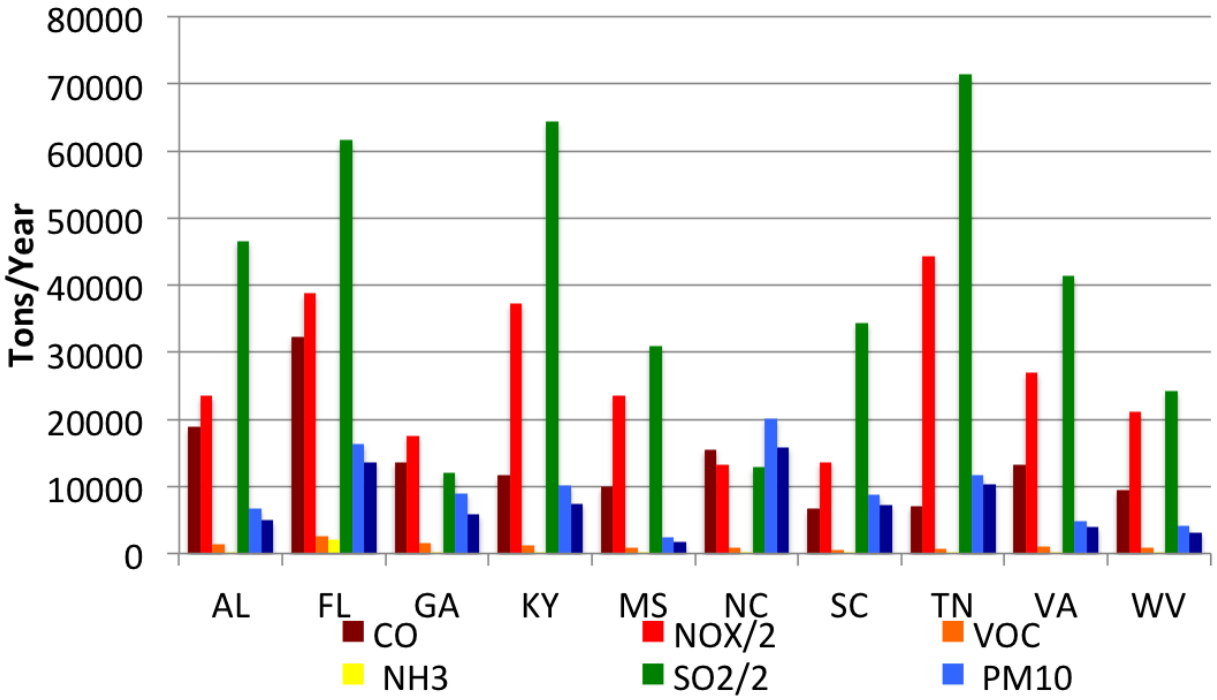


Figure 2-57. SESARM state annual 2018 CEM point source emissions; note that the NOx and SO2 emissions are divided by 2 to normalize their magnitudes.

2.1.4.11 Airport points (airpt)

Region	Data Source	Final Version	Notes
SESARM	TranSystems	22 January 2013	NIF to ORL conversion by UNC; stack parameters for aircraft based on FAA EDMS airport data
MANE-VU	N/A	N/A	The MANE-VU airport inventory is part of the non-point ALM sector
MWRPO	US EPA	NEI2005v4.3 2017ct_ref_05b	Downloaded from ftp://ftp.epa.gov/EmisInventory/2005v4_3/mats/2017emis/ in ORL format
CENRAP			
WRAP			

The SEMAP 2018 airport point sector includes the same sources as the 2007 processing sector described in Section 2.1.2.10. Like in the base year inventory, UNC converted the 2-d LTO sources in the SESARM states to 3-d sources using vertical profiles derived from the FAA EDMS model. There are not sources in the MANE-VU region under the airpt sector; these sources are included in the MANE-VU nonpoint inventory.

Table 2-39 shows the 2018 state total annual airport point source emissions used for the SEMAP modeling. This table does not include the airport emissions in the MANE-VU states because these are contained in the nonpoint ALM sector. Figure 2-58 displays the 2018 state total airport point source emissions for the 10 SESARM states. Florida is the largest source of airport emissions in the region, contributing about 35% of the airport NOx emissions and 27% of the airport VOC emissions for the

SESARM region. Virginia, Georgia, and North Carolina are also significant regional sources of airport emissions.

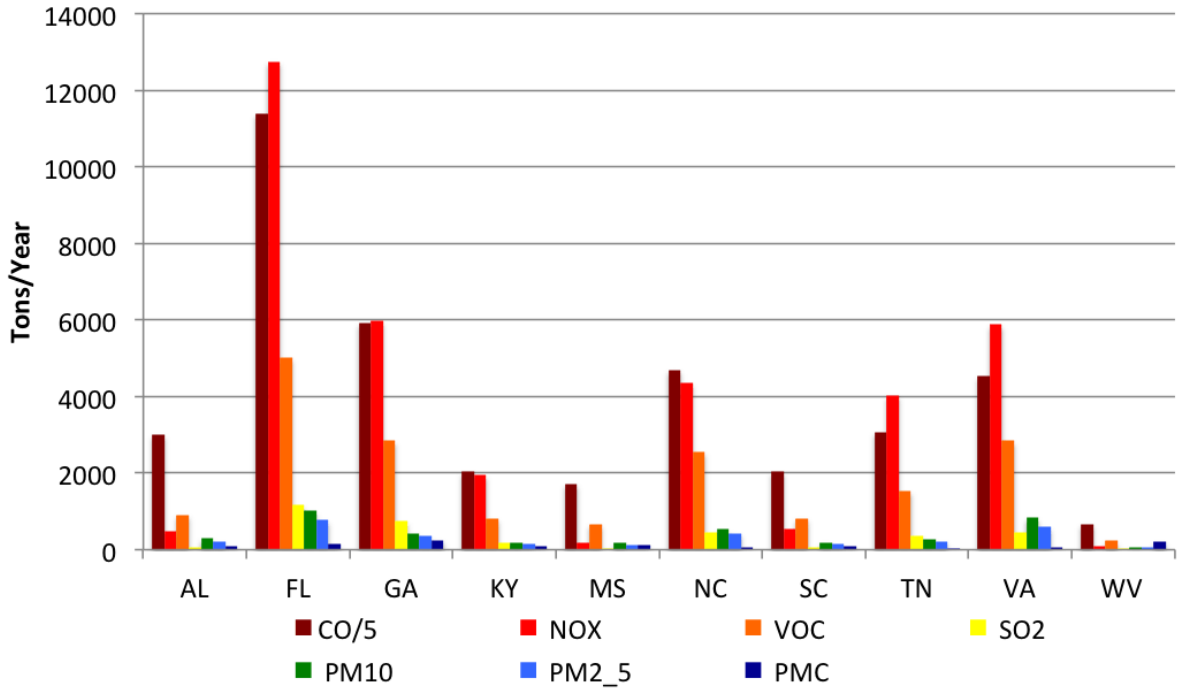


Figure 2-58. SESARM state annual total 2018 airport point source emissions

2.1.4.12 C2/C3 Commerical Marine (ptseca)

Region	Data Source	Final Version	Notes
US and offshore	US EPA	NEI2005v4.3 2017ct_ref_05b	In-port, near, and offshore elevated sources

EPA projected the near-shore/offshore C1/C2 commercial marine inventories to 2017 in the NEI2005v4.3 modeling platform. UNC gridded these point source inventories directly to the SEMAP 36 and 12km modeling grids.

Table 2-40 shows the annual total near and offshore emissions for the commercial shipping sector. The state total emissions represent the in-port emissions, the near shore emissions are between 0-0.5 km from port, and the SECA emissions are the offshore sources in commercial shipping lanes. UNC used the point SECA emissions from the EPA for all in-port, near-short, and commercial shipping sources, including the in-port emissions for the SESARM states, in the 2018 SEMAP modeling.

2.1.4.13 Canada and Mexico

Region	Data Source	Final Version	Notes
Canada	Environment Canada	2006	

Mexico	INE and ERG, Inc.	2008	Mexico National Emission Inventory projected from 1999 to 2008

The SEMAP future year simulation used the same inventories for Canada and Mexico as the base year simulation. Future year projections for these inventories were not available during the SEMAP project period.

2.2 Errata

Emission inventories are best-guess approximations of the actual pollution fluxes from air pollution sources. Most of the inventories used for the SEMAP project were developed from the "bottom-up", meaning that they were derived from the product of an average emissions factor and an estimate of the activity of an emissions sources in a county. Uncertainty arises from both parameters in the inventory equation. The practice of developing inventories, compiling ancillary emissions data, and preparing the emissions for input to air quality models is enormously complex. There are many places in this process where uncertainty and errors may be introduced. It is the job of the modelers using these data to employ as many QA steps as practically possible to reveal multiple facets of the data. By seeing the data from many different angles (temporal, spatial, chemical), the hope is that one may be able to identify and correct major uncertainties and/or errors. Despite the best efforts of emissions modelers, errors persist in the data and modeling. This section describes known omissions or discrepancies in the SEMAP emissions data and/or modeling.

- US EPA C2/C3 in-port commercial marine inventories were used for the SESARM states in the 2018 simulation. While SESARM provided in-port C2/C3 inventories for both the base and future years, UNC used the SESARM inventories in only the base year simulation. There is no double counting or omission of these sources in the future year simulation.
- UNC corrected an error in the MANE-VU future year on-road MOVES emissions in which the future year projection factors were double counted. UNC received from the OTC both projected gridded MOVES emissions files and state projection factors. When UNC were instructed by SESARM to apply the projection factors to the base year gridded MOVES data, UNC mistakenly applied them to the future year gridded MOVES data, effectively double counting the projection. UNC corrected this error in version B of the SEMAP 2018 emissions simulation.

2.3 State Emissions Summaries

2.3.1 2007 Base

Table 2-18. SEMAP 2007 nonpoint source emissions state totals (TPY)

	CO	NOX	VOC	NH3	SO2	PM10	PM2_5
AL	5817	3789	77313	387	411	2713	2363
AZ	36371	15594	91491	8884	3393	14752	12832
AR	92376	12901	77452	330	1157	13930	12348
CA	161900	68074	281610	62981	6088	58210	44615
CO	5602	6469	46543	1222	125	1623	1611
CT	6298	11828	50642	1647	15991	2237	2102
DE	3555	2157	8608	508	1131	2175	910
DC	999	1477	4740	145	1232	208	196
FL	19134	5823	293960	246	10313	15933	10026
GA	32720	12143	141190	1202	4831	12172	10948
ID	85226	11343	90460	2222	8865	6317	5468
IL	46416	44581	193300	5112	4481	10825	10410
IN	19458	21068	140870	1043	15859	7413	6791
IA	27483	5255	64911	695	2143	5394	5076
KS	65497	19025	71627	4961	7440	16039	9191
KY	37204	12400	71730	531	15549	18989	13592
LA	126120	30012	136600	27343	2540	17365	16123
ME	21137	6212	26735	747	9710	3013	2869
MD	37561	9765	57803	956	5861	6376	5085
MA	30146	19424	76978	9998	19721	6565	5822
MI	19463	31311	147330	3611	12227	0	0
MN	80915	17952	98514	1777	8114	15506	13403
MS	16444	5995	73663	267	331	5991	5476
MO	67561	18157	113580	1348	44313	11036	10338
MT	11443	1897	14970	218	321	1842	1620
NE	12603	2682	38591	372	200	2733	2641
NV	5341	4077	36104	250	4459	2983	1900
NH	20525	4445	19015	190	5210	2704	2175
NJ	37343	23537	90305	12080	8711	10455	7255
NM	18296	2710	32217	323	53	3021	2583
NY	89565	70698	186020	4913	69814	22978	18991
NC	27646	12394	149180	744	8322	11339	10239
ND	19865	1734	20319	119	658	2402	2344
OH	71706	35234	152460	3063	12152	13481	12580

OK	104080	84275	246080	781	4514	13355	9867
OR	25565	3201	45126	444	691	4449	3897
PA	116330	45937	157340	930	66311	27831	21306
RI	4098	3276	22077	274	3866	1011	862
SC	25183	9239	75542	385	6033	15986	12860
SD	6719	1733	25561	137	299	1478	1363
TN	31560	12211	108690	960	14386	20461	9230
TX	215430	322650	1713600	2093	1452	27780	22179
UT	33138	8411	70332	5531	1243	6612	4810
VT	16057	3522	8615	156	3571	3335	2869
VA	40395	17356	129620	1247	16970	13269	11782
WA	48360	6134	80418	807	1223	7863	6866
WV	14760	3434	30475	359	6484	5915	5043
WI	58760	24954	106210	1787	5484	10918	10365
WY	13102	17156	113670	125	1675	792	690

Table 2-19. SEMAP 2007 RWC source emissions state totals (TPY)

	CO	**NOX**	**VOC**	**NH3**	**SO2**	**PM10**	**PM2_5**
AL	9335	151	1717	79	20	1359	1357
AZ	18127	310	3244	154	48	2642	2638
AR	9904	162	1823	84	22	1432	1430
CA	274630	3528	17968	2044	530	39296	37829
CO	91792	1414	16522	744	224	13146	13137
CT	35199	594	6611	281	92	4983	4979
DE	4711	79	874	38	13	669	668
DC	4489	70	828	38	10	650	649
FL	9414	160	1671	84	21	1400	1397
GA	12517	207	2280	108	27	1840	1837
ID	15629	264	3131	119	40	2252	2250
IL	45995	654	8425	393	100	6531	6531
IN	31764	444	5950	263	68	4472	4472
IA	24230	384	4438	197	67	3456	3452
KS	16441	265	3012	134	44	2355	2352
KY	18245	293	3371	152	42	2644	2641
LA	16563	234	5504	59	30	2313	2311
ME	29359	444	5231	243	102	4201	4197
MD	36626	547	6627	304	98	5257	5251
MA	49080	828	8892	405	139	7049	7042
MI	55839	797	10347	500	120	7967	7967
MN	81970	1199	14458	667	248	11941	11940
MS	5933	95	1092	50	13	863	861

MO	37831	606	6898	311	103	5425	5419
MT	9516	161	1699	80	27	1377	1375
NE	13160	211	2413	107	36	1879	1877
NV	12029	232	3309	93	317	1700	1697
NH	19152	293	3328	160	73	2745	2747
NJ	40344	638	7816	318	100	5683	5678
NM	14256	243	2561	120	39	2062	2060
NY	115490	1355	9957	827	230	12817	12817
NC	19733	321	3648	166	43	2872	2867
ND	4957	80	910	40	14	708	707
OH	64992	903	12271	532	138	9123	9123
OK	9370	151	1723	80	21	1356	1355
OR	86810	1544	15091	724	243	12917	12906
PA	100750	1608	19438	811	274	14183	14195
RI	11321	193	2137	89	31	1592	1591
SC	7025	114	1297	59	15	1022	1020
SD	5632	91	1034	46	15	804	804
TN	13111	211	2437	108	29	1901	1895
TX	46739	790	8237	419	105	6939	6928
UT	14603	270	2495	128	46	2149	2146
VT	35052	474	5494	289	180	5032	5030
VA	23442	384	4316	197	53	3419	3413
WA	102740	1590	18437	822	239	14564	14564
WV	8729	140	1615	73	20	1266	1264
WI	64571	901	12262	513	141	9178	9178
WY	5327	90	952	45	15	771	770

Table 2-20. SEMAP 2007 road and fugitive dust source emissions state totals (TPY); note that only the MANE-VU states include vegetative adjustment factors

	PM10	**PM2_5**
AL	345910	37867
AZ	257610	36317
AR	369000	54140
CA	695090	84793
CO	285880	45894
CT	8371	1315
DE	4365	829
DC	1587	275
FL	303450	26815
GA	626540	70809
ID	383230	61947

IL	715050	114840
IN	493800	67155
IA	513550	87591
KS	770150	117710
KY	205200	24109
LA	190760	22034
ME	13013	1679
MD	26888	4373
MA	44766	5758
MI	345010	49828
MN	647080	95043
MS	319500	36421
MO	781810	101580
MT	330020	45470
NE	488000	74247
NV	221530	24527
NH	5201	910
NJ	8663	2010
NM	799970	84087
NY	104970	15215
NC	37467	3722
ND	407480	71066
OH	434810	56711
OK	711740	90618
OR	209430	26379
PA	96556	15354
RI	2949	504
SC	249740	25657
SD	248400	43419
TN	193320	22827
TX	2300200	289610
UT	210350	25839
VT	10730	1536
VA	159580	23839
WA	194560	25946
WV	93249	10556
WI	237410	40031
WY	476820	52628

Table 2-21. SEMAP 2007 livestock and fertilizer source emissions state totals (TPY)

	ft NH3	lv NH3
AL	6517	55443
AZ	6356	22327
AR	42570	77632
CA	65914	192380
CO	14537	53940
CT	429	2063
DE		11232
FL	7157	26179
GA	10569	74088
ID	25721	76041
IL	69613	46914
IN	42503	59125
IA	89461	206090
KS	59036	92101
KY	17645	34003
LA	18925	18048
ME	1708	3038
MD	4823	19923
MA	731	1426
MI	24271	36522
MN	72561	111050
MS	12377	46080
MO	44848	79482
MT	33715	21230
NE	64673	111500
NV	786	4585
NH	113	1037
NJ	1365	1973
NM	13996	31895
NY	4231	35722
NC	14341	154190
ND	63948	14742
OH	31318	52213
OK	25037	72133
OR	24687	17952
PA	9565	61263
RI	93	170
SC	5181	24622
SD	84902	46529

TN	8830	25381
TX	86218	202030
UT	1702	34105
VT	758	6810
VA	8414	33179
WA	17920	24800
WV	3631	8795
WI	32876	82453
WY	6877	12382

Table 2-22. SEMAP 2007 nonroad source emissions state totals (TPY)

	CO	NOX	VOC	NH3	SO2	PM10	PM2_5
AL	259995	23938	29099	24	1392	2454	2339
AZ	338650	32347	32160	37	656	3304	3154
AR	170842	23422	22356	22	447	2412	2308
CA	1859978	155642	161279	175	169	15116	14398
CO	282835	30691	30216	34	602	3143	3002
CT	167319	13895	14190	14	634	1140	1087
DE	41976	4030	3524	4	216	363	343
DC	13788	2639	1113	3	166	215	208
FL	1153970	96595	91403	106	6287	9872	9443
GA	571979	49087	50488	51	2991	4977	4754
ID	100231	13376	17445	15	268	1538	1468
IL	650896	95003	65671	87	5726	8714	8369
IN	343662	52527	36331	46	3057	4620	4435
IA	181834	53171	24240	46	1031	4996	4819
KS	169036	41912	15979	36	810	3866	3732
KY	205407	26919	24259	24	1571	2655	2544
LA	216450	22029	26070	24	431	2272	2168
ME	110013	5939	22953	11	358	972	918
MD	260942	22039	23112	25	1221	2172	2063
MA	300362	23162	25325	25	1098	1931	1841
MI	634763	58714	104763	68	3353	6385	6060
MN	321232	56143	59951	57	1062	5841	5592
MS	147902	18198	19531	17	1085	1884	1802
MO	308848	44583	32181	42	847	4291	4117
MT	69625	16526	10448	15	331	1710	1646
NE	104913	35443	12168	30	694	3317	3204
NV	149855	16476	15027	19	316	1717	1640
NH	78087	6043	13036	8	307	693	655
NJ	415529	31876	34180	35	1520	2743	2613

NM	82749	8071	8742	9	161	821	784
NY	828687	62147	84204	72	3187	5851	5594
NC	526733	52163	50060	51	3005	4988	4769
ND	63854	34302	10064	28	682	3280	3173
OH	687488	72633	65166	70	4135	6540	6254
OK	202772	25987	19364	25	499	2517	2415
OR	206533	21777	23440	23	414	2227	2124
PA	664375	49345	65070	54	2518	4728	4505
RI	44100	3411	3231	4	167	279	267
SC	274140	24526	23676	24	1449	2350	2247
SD	56098	24391	8727	20	482	2346	2267
TN	335680	34216	35159	32	1798	3310	3164
TX	1134327	126351	98320	130	2474	11841	11347
UT	129435	12471	19179	14	243	1399	1331
VT	46076	3196	8304	4	188	429	408
VA	370899	38550	35982	39	2246	3791	3621
WA	333154	35098	34783	38	672	3499	3342
WV	96726	7026	13986	8	392	893	846
WI	383012	43118	65850	46	2482	4544	4327
WY	39648	4540	7598	5	91	544	517

Table 2-23. SEMAP 2007 alm source emissions state totals (TPY)

	CO	**NOX**	**VOC**	**NH3**	**SO2**	**PM10**	**PM2_5**
AL	62407	39210	22240	22	2026	1675	1576
AZ	30742	25062	11370	14	260	954	879
AR	36093	25301	11276	15	588	981	916
CA	164885	97866	59483	51	3300	3952	3728
CO	14356	15763	4819	8	163	579	533
CT	19056	10455	6669	6	1612	537	493
DE	14915	7021	4229	2	2154	422	386
DC	441	591	160	0	42	16	15
FL	285996	72520	104423	61	18747	4998	4653
GA	62667	37084	20985	21	2384	1615	1508
ID	14818	9275	4889	5	95	366	337
IL	63635	70499	20972	40	2641	2402	2215
IN	45977	30393	14460	18	883	1116	1031
IA	53513	30395	14432	19	396	1127	1041
KS	15359	36530	5347	17	382	1255	1151
KY	40352	34278	13609	22	1247	1348	1272
LA	102139	153103	30525	73	8337	5712	5503
ME	53218	4067	6784	2	325	615	551

MD	47448	25078	12791	11	2547	1078	952
MA	39730	14793	11218	5	1098	950	818
MI	162899	29583	40322	24	4816	1450	1338
MN	75445	39971	27558	23	1207	1663	1561
MS	44018	29905	15119	18	1977	1256	1187
MO	64107	50424	21319	28	1203	1962	1832
MT	10328	24210	3139	12	250	827	762
NE	18352	72343	6554	34	752	2480	2283
NV	11701	7643	4149	4	75	297	274
NH	13397	3444	3796	2	639	160	144
NJ	50417	25034	15091	15	7413	1174	1073
NM	11335	25313	3880	12	263	878	808
NY	99228	62986	32276	13	11029	2980	2772
NC	72900	19405	27238	14	2081	1046	971
ND	7098	15874	2562	8	162	540	498
OH	74110	47373	22723	28	1719	1823	1685
OK	35634	21520	12536	12	248	847	781
OR	32118	21185	10648	11	625	822	775
PA	77555	38668	22839	27	3850	1963	1742
RI	11541	3949	3427	2	693	193	180
SC	55949	13129	19205	10	1462	745	684
SD	6062	4583	2289	2	44	167	154
TN	57694	29565	20778	18	1184	1480	1363
TX	137508	110413	46606	45	7482	4330	4119
UT	16813	9952	5368	7	709	386	350
VT	7769	1081	1926	1	25	94	78
VA	52220	46664	20886	25	4620	2035	1915
WA	60284	46537	18889	25	1820	1824	1729
WV	14719	29428	4366	14	1256	1069	1013
WI	99705	21229	37060	18	1212	1207	1114
WY	9961	37003	3298	17	387	1280	1178

Table 2-24. SEMAP 2007 onroad mobile source emissions state totals (TPY)

	CO	NOX	VOC	NH3	SO2	PM2_5
AL	909848	172674	77122	2823	1509	5888
AZ	705781	197933	74094	2973	1201	6258
AR	461467	96388	41768	1537	779	2952
CA	2339866	577924	255866	34289	3386	20521
CO	604386	128832	59801	2241	1184	4320
CT	383443	54821	34949	1360	415	2067
DE	94312	17153	8037	295	145	550

DC	17151	3070	1557	77	26	112
FL	2565466	498934	222898	9676	5151	14481
GA	1909807	396844	160962	5416	6407	13682
ID	208516	42254	19036	650	406	1461
IL	1556441	323575	157678	5181	2679	11422
IN	949063	208151	93414	3274	1693	6470
IA	492064	94726	47431	1530	825	3190
KS	383243	84487	36913	1397	778	2563
KY	704306	133430	55923	2172	1022	4365
LA	541618	124974	53436	2119	1065	3776
ME	224820	37704	15953	661	381	1467
MD	639880	119948	58926	2468	965	4137
MA	569774	72885	48529	2084	734	2801
MI	1509734	292799	143454	4597	2996	10564
MN	828165	155580	79078	2553	1164	5665
MS	525670	117231	45136	1809	920	4062
MO	879899	187661	84722	2978	1719	5928
MT	160938	37191	14159	513	312	1230
NE	238299	61038	24330	835	473	2089
NV	205385	41799	22287	932	289	1073
NH	204365	33469	14860	570	288	1370
NJ	820749	149986	79052	3429	1035	5519
NM	352296	94933	35178	1345	734	2926
NY	1930531	291087	155595	6699	2105	13160
NC	2111242	280672	137084	5053	2534	7382
ND	106359	22527	10177	324	172	755
OH	1546417	297954	137326	5072	2848	9762
OK	621094	129700	57927	2228	1175	4017
OR	445332	87721	40252	1496	669	2590
PA	1911032	348665	159478	5265	2479	12378
RI	126441	16485	9226	423	145	638
SC	745572	144481	54030	2303	1313	4995
SD	116213	28063	11693	403	217	903
TN	1198308	248811	86874	3322	1857	7784
TX	2525929	690334	267639	10847	5286	23642
UT	375141	70635	34346	1268	751	2345
VT	109376	16898	8985	335	162	678
VA	357736	60062	25237	875	488	1928
WA	1161832	194724	93056	3881	1423	6443
WV	831852	167358	72384	2684	1291	6026
WI	1188925	196779	96303	4041	1429	6513

WY	124339	31643	11510	421	256	1033

Table 2-25. SEMAP 2007 total point source emissions state totals (TPY)

	CO	NOX	VOC	NH3	SO2	PM10	PM2_5
AL	119344	197965	38877	2191	526616	34777	24929
AZ	16928	56475	2614	973	78272	11317	5975
AR	37897	74686	27738	1189	87262	10924	7647
CA	72401	78943	39442	11593	25914	38543	23187
CO	37770	109930	71428	469	64717	20478	8961
CT	4541	11125	1550	0	10090	1513	1395
DE	8408	18034	3279	105	45264	3927	3569
DC	384	911	64	0	613	66	59
FL	111280	237473	33682	1661	379594	35795	28418
GA	82547	154038	36718	6046	683362	30226	22296
ID	21142	12379	1028	1100	7462	3000	2350
IL	75920	198670	50091	1486	376550	28795	19123
IN	345190	262840	39116	1188	672340	74108	58005
IA	53220	89420	22304	3419	160880	17017	11422
KS	28046	105540	18521	1935	103180	8110	5356
KY	82554	210215	47679	113	410418	30678	21111
LA	129540	188390	68272	7710	226190	58667	49959
ME	14446	17684	4710	664	17174	4868	3828
MD	62669	75544	4132	55	324520	19278	15859
MA	10167	24054	4560	665	63663	5716	4930
MI	77885	180990	28299	920	389290	25132	15601
MN	27215	116740	22566	2056	99013	28730	16304
MS	40295	98183	34586	1640	94978	12368	8731
MO	92463	131830	17537	1656	367380	18551	11417
MT	27608	42328	4542	55	26659	5788	2202
NE	10995	56644	4061	1212	78223	5416	3932
NV	4638	26566	2429	302	10991	5605	3357
NH	3158	7409	913	128	45210	1922	1661
NJ	9472	29528	10284	684	40728	7426	6635
NM	32878	56904	8953	274	22810	2874	1734
NY	66894	93180	11688	2602	180990	9656	6061
NC	66811	100379	48349	1706	420434	42995	33444
ND	15347	78599	3790	6372	142080	4423	2574
OH	248770	301970	31785	3077	858750	73688	64874
OK	47178	142500	25551	3059	137050	14399	8951
OR	29273	22327	8245	255	15811	11414	9040
PA	102188	262346	27926	2388	1038778	50176	32821

RI	1653	1444	824	74	1516	189	140
SC	60375	81221	29281	1125	216127	30605	23493
SD	572	13851	126	34	13537	242	229
TN	51185	144762	48103	1429	287668	26134	20403
TX	395800	371810	113790	6646	601750	58169	41417
UT	16769	84673	6942	568	28185	9250	4005
VT	2146	811	395	0	322	146	114
VA	72029	112938	35618	1830	243046	19202	14875
WA	54479	35632	12033	442	15500	5025	4329
WV	65230	188629	12502	366	428348	13736	9173
WI	43521	88123	27598	923	193140	12376	3420
WY	45007	114610	18227	722	106960	44501	24200

Table 2-26. SEMAP 2007 total airport point source emissions state totals (TPY)

	CO	**NOX**	**VOC**	**NH3**	**SO2**	**PM10**	**PM2_5**
AL	14778	440	891	51	294	205	14778
AZ	18174	3532	876	346	378	119	18174
AR	6445	358	226	46	135	24	6445
CA	52260	15405	2863	1404	1057	479	52260
CO	13229	3303	764	322	226	88	13229
FL	57330	10746	5060	992	1028	772	57330
GA	28081	4759	2772	608	433	346	28081
ID	4357	302	161	38	94	17	4357
IL	19004	7118	1171	684	333	166	19004
IN	7188	1392	423	132	144	44	7188
IA	3051	315	133	40	62	15	3051
KS	4540	224	190	30	94	17	4540
KY	11555	2257	918	219	204	154	11555
LA	7319	886	318	99	163	37	7319
MI	12743	2830	788	299	255	97	12743
MN	9228	2408	518	239	177	66	9228
MS	8519	219	665	26	168	117	8519
MO	7491	1984	508	217	134	61	7491
MT	3055	252	149	33	68	15	3055
NE	2849	394	156	45	56	17	2849
NV	7789	3338	523	305	145	77	7789
NM	4062	557	188	58	80	20	4062
NC	22481	3499	2487	370	521	423	22481
ND	2141	143	87	20	53	10	2141
OH	14477	2327	748	256	310	88	14477
OK	7068	574	270	67	142	29	7068

OR	7109	1176	309	120	136	37	7109
SC	11116	586	930	68	210	149	11116
SD	2285	165	98	21	50	10	2285
TN	16318	4055	1623	354	292	227	16318
TX	87665	21870	9192	2272	1795	1360	87665
UT	5112	1300	276	134	91	38	5112
VA	23031	5385	2842	410	844	594	23031
WA	14018	2901	674	273	281	81	14018
WV	3607	59	257	7	72	50	3607
WI	32060	1310	3869	181	301	215	32060
WY	1413	99	79	12	28	6	1413

Table 2-27. SEMAP 2007 total fire emissions state totals (TPY)

	CO	**NOX**	**VOC**	**NH3**	**SO2**	**PM10**	**PM2_5**
AL	226950	7944	15861	1687	2137	31473	27666
AZ	166730	3091	39565	2752	1502	17690	14992
AR	927270	11989	218590	15206	6766	93738	79439
CA	2503400	31127	589770	41028	17886	251960	213520
CO	42683	761	10120	704	376	4502	3815
CT	299	5	71	5	3	32	27
DE	1157	21	274	19	10	122	104
FL	857630	30157	64526	7400	7923	127610	113420
GA	1121800	45254	88902	9113	11619	175460	154220
ID	9474700	90718	2224600	154760	59411	929410	787640
IL	32847	524	7771	541	270	3409	2889
IN	14486	282	3441	239	135	1549	1313
IA	7840	148	1861	129	71	834	707
KS	107130	2356	25526	1776	1079	11697	9913
KY	16091	657	1272	139	180	2573	2235
LA	1645100	13215	385550	26821	9540	159110	134840
ME	3219	53	762	53	27	336	284
MD	11890	221	2822	196	107	1262	1069
MA	1309	25	311	22	12	139	118
MI	225230	2208	52899	3680	1428	22140	18763
MN	609730	6622	143380	9974	4063	60511	51281
MS	753720	12454	178430	12413	6328	78612	66621
MO	285840	4951	67731	4712	2470	30017	25438
MT	4969200	54558	1168700	81301	33293	493690	418380
NE	33852	300	7942	552	205	3299	2796
NV	130910	3320	31314	2178	1453	14686	12446
NH	1691	27	400	28	14	176	149

NJ	56198	536	13194	918	352	5511	4670
NM	147990	2187	34963	2432	1163	15205	12885
NY	11181	214	2655	185	103	1192	1010
NC	43910	1864	3541	391	511	7234	6345
ND	34796	276	8154	567	201	3362	2850
OH	11252	186	2664	185	94	1173	994
OK	346600	5815	82076	5710	2937	36229	30702
OR	2669800	25910	626940	43613	16847	262200	222200
PA	15128	245	3580	249	126	1574	1334
RI	93	2	22	2	1	10	8
SC	147030	6171	12789	1486	1616	25334	22984
SD	171300	1114	40074	2788	913	16334	13842
TN	23097	792	1576	167	217	3195	2753
TX	614250	9577	145250	10105	4982	63555	53860
UT	292460	4534	69152	4811	2364	30236	25624
VT	1105	20	262	18	10	117	99
VA	10329	362	722	77	99	1462	1272
WA	956530	8524	224410	15611	5804	93264	79037
WV	1516	62	119	13	17	241	208
WI	45056	745	10666	742	378	4699	3983
WY	834290	7356	195710	13615	5038	81275	68877

Table 2-28. SEMAP 2007 near and offshore shipping totals (TPY)

	CO	**NOX**	**VOC**	**NH3**	**SO2**	**PM10**	**PM2_5**
CA	1235	11208	339	7118	794	729	1235
IL	8	102	3	64	8	8	8
IN	4	45	2	31	4	4	4
LA	1686	17774	613	11762	1538	1412	1686
MI	861	10822	366	6396	862	793	861
MN	25	306	10	196	26	24	25
OH	200	2499	85	1499	201	185	200
OR	218	2175	114	1248	198	182	218
TX	1040	9057	346	9516	1246	1143	1040
WA	1604	18713	747	11280	1643	1490	1604
WI	61	772	26	465	62	57	61
Near-shore	50171	618630	21320	376180	50385	46307	50171
SECA	147220	1816500	62564	1094800	147310	135730	147220
Canada	13792	169824	5858	102543	13827	12671	13792

Table 2-29. SEMAP 2007 total biogenic source emissions state totals (TPY)

	CO	NOX	VOC
AL	177338	15052	1710315
AZ	372403	28838	1745470
AR	148167	25780	1196200
CA	443660	58754	2878423
CO	156469	38653	813819
CT	7164	608	45825
DE	3690	980	29447
DC	134	18	1354
FL	229020	47773	1670058
GA	205821	24779	1909704
ID	191117	18659	933657
IL	91914	40988	498253
IN	59237	23002	328383
IA	77835	39867	342040
KS	138739	78281	493332
KY	80573	17652	588613
LA	145624	23350	1188400
ME	59315	2405	269255
MD	18248	3462	146514
MA	10925	1235	71506
MI	92045	18684	557100
MN	121644	35016	799671
MS	162064	18848	1508176
MO	134674	35781	1134279
MT	258440	66233	1184863
NE	114114	63262	449645
NV	218927	15583	935198
NH	14625	630	80710
NJ	13006	1921	115180
NM	253239	43743	1089017
NY	64785	9139	310364
NC	133292	16055	1126955
ND	79601	48209	272168
OH	63858	20274	331671
OK	138875	58222	846239
OR	234223	17465	1139088
PA	64135	9831	425753
RI	1533	167	11371
SC	98976	11864	908485

SD	111279	55723	468773
TN	98607	16030	868972
TX	719359	276603	3154149
UT	162402	13618	743872
VT	14172	1123	63772
VA	86868	10070	773553
WA	157221	18411	613604
WV	40390	3608	354681
WI	78821	24639	501936
WY	142027	17806	705019

2.3.2 2007 Typical

Table 2-30. SEMAP typical year total fire emissions state totals (TPY)

	CO	NOX	VOC	NH3	SO2	PM10	PM2_5
AL	230240	8019	16011	1701	2157	31785	27951
AZ	86791	1581	13223	1140	744	10185	8705
AR	579680	10760	86705	7777	5087	67884	58252
CA	396260	8861	60373	5177	3672	47877	40844
CO	49551	813	8081	690	408	5550	4737
CT	780	16	140	11	8	95	80
DE	1212	24	247	18	11	130	111
FL	721450	23429	52696	6156	6006	103410	93131
GA	528320	19424	39877	3709	4491	76011	68750
ID	626470	16922	64132	6389	6256	87609	75130
IL	56406	945	10787	864	478	6098	5181
IN	24038	388	4118	344	199	2645	2252
IA	35017	694	7605	558	328	3789	3211
KS	335130	8743	70399	5256	3723	38519	32702
KY	13247	552	1064	116	151	2154	1873
LA	382040	6373	68325	5540	3264	42648	36350
ME	2999	33	512	43	20	300	254
MD	15366	282	2786	222	135	1736	1483
MA	2092	43	394	32	20	238	204
MI	26654	541	3775	330	240	3294	2814
MN	246580	4174	33178	2997	2046	29811	25449
MS	305180	6821	59615	4596	3035	34533	29353
MO	521970	7750	79943	7344	4122	58541	50082
MT	405540	10298	45808	4353	3948	55956	47928
NE	60945	1265	12369	941	584	6751	5734
NV	21650	706	2594	234	232	2976	2541

NH	1612	25	334	25	13	167	141
NJ	32042	588	4231	394	260	3861	3295
NM	47560	972	7821	639	434	5613	4777
NY	11368	207	1632	141	103	1376	1177
NC	23144	977	1861	205	268	3792	3304
ND	111940	2244	22196	1705	1052	12480	10604
OH	17273	335	3114	250	162	1982	1687
OK	429020	9199	77469	6222	4146	49386	42139
OR	484980	7211	66566	6084	3786	57016	48789
PA	21679	364	4078	323	186	2393	2033
RI	185	4	44	3	2	20	17
SC	144800	6072	12642	1473	1586	25012	22732
SD	84244	1260	14662	1192	656	9270	7903
TN	14238	479	956	101	131	1941	1672
TX	383400	8731	77498	5828	3912	43925	37363
UT	47199	1238	6466	567	463	6225	5326
VT	956	16	168	14	8	108	92
VA	9862	379	743	80	103	1504	1309
WA	184760	3177	27336	2380	1528	21856	18682
WV	577	22	44	5	6	88	76
WI	41341	656	8221	623	337	4449	3780
WY	106580	2067	15454	1370	918	12934	11052

2.3.3 2018 Base

Table 2-31. SEMAP 2018 nonpoint source emissions state totals (TPY)

	CO	NOX	VOC	NH3	SO2	PM10	PM2_5
AL	6135	3689	71654	379	338	3182	2785
AZ	36371	15594	91491	8884	3393	14752	12832
AR	92376	12901	77452	330	1157	13930	12348
CA	161900	68074	281610	62981	6088	58210	44615
CO	5602	6469	46543	1222	125	1623	1611
CT	6111	10516	40639	1584	12856	2080	1963
DE	3594	2131	7873	519	934	2173	910
DC	998	1491	4579	151	986	215	204
FL	20872	6052	233020	253	10273	17408	11423
GA	35126	12669	117550	1272	3935	13536	12183
ID	85226	11343	90460	2222	8865	6317	5468
IL	46416	44581	193300	5112	4481	10825	10410
IN	19458	21068	140870	1043	15859	7413	6791
IA	27483	5255	64911	695	2143	5394	5076

KS	65497	19025	71627	4961	7440	16039	9191
KY	38616	12235	63531	524	15228	19636	14223
LA	126120	30012	136600	27343	2540	17365	16123
ME	21222	5541	21609	711	7781	2835	2708
MD	38793	10420	51191	1050	1582	6898	5534
MA	30245	18163	58390	10075	15865	6448	5719
MI	19463	31311	147330	3611	12227	0	0
MN	80915	17952	98514	1777	8114	15506	13403
MS	17092	6081	59674	264	324	6404	5856
MO	67561	18157	113580	1348	44313	11036	10338
MT	11443	1897	14970	218	321	1842	1620
NE	12603	2682	38591	372	200	2733	2641
NV	5341	4077	36104	250	4459	2983	1900
NH	20276	3890	17917	191	4111	2671	2147
NJ	37427	22718	83268	12667	613	10685	7336
NM	18296	2710	32217	323	53	3021	2583
NY	88488	62174	172970	4755	11389	22012	18393
NC	19369	11749	140740	769	7024	7854	7063
ND	19865	1734	20319	119	658	2402	2344
OH	71706	35234	152460	3063	12152	13481	12580
OK	104080	84275	246080	781	4514	13355	9867
OR	25565	3201	45126	444	691	4449	3897
PA	114430	44390	148310	975	55630	26661	20596
RI	4126	3112	18461	276	3193	998	853
SC	27027	9456	58713	402	6002	16964	13764
SD	6719	1733	25561	137	299	1478	1363
TN	33117	12252	89190	945	14116	21447	10284
TX	215430	322650	1713600	2093	1452	27780	22179
UT	33138	8411	70332	5531	1243	6612	4810
VT	16473	3210	7681	150	3007	3435	2964
VA	42820	17121	121170	1267	14714	14180	12636
WA	48360	6134	80418	807	1223	7863	6866
WV	15173	3329	25427	375	5435	6109	5213
WI	58760	24954	106210	1787	5484	10918	10365
WY	13102	17156	113670	125	1675	792	690

Table 2-32. SEMAP 2018 RWC source emissions state totals (TPY)

	CO	**NOX**	**VOC**	**NH3**	**SO2**	**PM10**	**PM2_5**
AL	8820	146	1537	77	20	1300	1298
AZ	18127	310	3244	154	48	2641	2638
AR	9904	162	1823	84	22	1432	1430

CA	274629	3528	17968	2044	530	39296	37829
CO	91792	1414	16522	744	224	13146	13137
CT	32049	585	5725	260	87	4602	4598
DE	4287	78	758	35	12	617	617
DC	4249	69	745	37	10	625	624
FL	9171	161	1553	83	21	1385	1382
GA	12007	206	2084	105	27	1793	1790
ID	15629	264	3131	119	40	2252	2250
IL	45995	654	8425	393	100	6531	6531
IN	31764	444	5950	263	68	4472	4472
IA	24230	384	4438	197	67	3456	3452
KS	16441	265	3012	134	44	2355	2352
KY	17093	280	2994	146	41	2508	2504
LA	16563	234	5504	59	30	2313	2311
ME	26045	420	4505	218	90	3775	3770
MD	33838	528	5853	285	91	4924	4918
MA	45237	821	7821	379	130	6592	6584
MI	55839	797	10347	500	120	7967	7967
MN	81970	1199	14458	667	248	11941	11940
MS	5603	92	977	49	13	825	824
MO	37831	606	6898	311	103	5425	5419
MT	9516	161	1699	80	27	1377	1375
NE	13160	211	2413	107	36	1879	1877
NV	12029	232	3309	93	317	1700	1697
NH	17129	262	2977	143	65	2455	2457
NJ	36135	613	6704	288	93	5162	5157
NM	14256	243	2561	120	39	2062	2060
NY	129885	1537	11298	930	262	14567	14567
NC	18703	315	3291	160	43	2765	2760
ND	4957	80	910	40	14	708	707
OH	64992	903	12271	532	138	9122	9122
OK	9370	151	1723	80	21	1356	1355
OR	86810	1544	15091	724	243	12917	12906
PA	89064	1535	16555	728	248	12706	12719
RI	10182	190	1830	81	29	1452	1450
SC	6662	112	1170	57	15	984	983
SD	5632	91	1034	46	15	804	804
TN	12351	203	2175	105	28	1813	1807
TX	46739	790	8237	419	105	6939	6927
UT	14603	270	2495	128	46	2149	2146
VT	30078	432	4630	247	152	4360	4358

VA	22268	378	3902	191	52	3299	3293
WA	102740	1590	18437	822	239	14564	14564
WV	8245	137	1450	70	20	1214	1212
WI	64571	901	12262	513	141	9178	9178
WY	5327	90	952	45	15	771	770

Table 2-33. SEMAP 2018 road and fugitive dust source emissions state totals (TPY); note that only the MANE-VU states include vegetative adjustment factors

	PM10	**PM2_5**
AL	338680	36565
AZ	257610	36317
AR	369000	54140
CA	695090	84793
CO	285880	45894
CT	8698	1379
DE	4777	915
DC	1675	289
FL	318490	26751
GA	619270	68672
ID	383230	61947
IL	715050	114840
IN	493800	67155
IA	513550	87591
KS	770150	117710
KY	205290	23643
LA	190760	22034
ME	13212	1717
MD	29338	4790
MA	44939	5800
MI	345010	49828
MN	647080	95043
MS	314100	35320
MO	781810	101580
MT	330020	45470
NE	488000	74247
NV	221530	24527
NH	5532	976
NJ	9631	2252
NM	799970	84087
NY	113210	16742
NC	34534	3428

ND	407480	71066
OH	434810	56711
OK	711740	90618
OR	209430	26379
PA	100300	16030
RI	3300	573
SC	244890	24749
SD	248400	43419
TN	204900	23277
TX	2300200	289610
UT	210350	25839
VT	10500	1492
VA	160240	24787
WA	194560	25946
WV	92394	10395
WI	237410	40031
WY	476820	52628

Table 2-34. SEMAP 2018 livestock and fertilizer source emissions state totals (TPY)

	ft NH3	lv NH3
AL	6918	58994
AZ	6356	22327
AR	42570	77632
CA	65914	192380
CO	14537	53940
CT	405	2203
DE	429	14250
FL	8009	25939
GA	11828	73407
ID	25721	76041
IL	69613	46914
IN	42503	59125
IA	89461	206090
KS	59036	92101
KY	18730	36181
LA	18925	18048
ME	1986	3288
MD	4823	19923
MA	731	2727
MI	24271	36522
MN	72561	111050

MS	13138	49031
MO	44848	79482
MT	33715	21230
NE	64673	111500
NV	786	4585
NH	116	1078
NJ	1403	2017
NM	13996	31895
NY	4131	36404
NC	16050	152770
ND	63948	14742
OH	31318	52213
OK	25037	72133
OR	24687	17952
PA	9695	65985
RI	92	180
SC	5798	24396
SD	84902	46529
TN	9373	27006
TX	86218	202030
UT	1702	34105
VT	758	6858
VA	9417	32874
WA	17920	24800
WV	4063	8715
WI	32876	82453
WY	6877	12382

Table 2-35. SEMAP 2018 nonroad source emissions state totals (TPY)

	CO	NOX	VOC	NH3	SO2	PM10	PM2_5
AL	184263	11544	18238	30	31	1493	1411
AZ	256634	18253	22015	44	45	2305	2184
AR	121022	13692	15170	26	28	1473	1403
CA	1470933	87045	107290	208	185	11120	10513
CO	226991	18096	21351	40	42	2149	2039
CT	131700	6689	8914	17	25	826	785
DE	30924	2108	2162	5	5	246	232
DC	9845	1396	633	3	3	121	117
FL	809861	50336	58411	132	119	6283	5950
GA	378180	24737	30964	63	62	3087	2921
ID	76403	8359	12342	17	18	987	936

IL	481546	53296	42443	111	116	5164	4926
IN	250091	28070	23309	58	65	2708	2583
IA	144220	32892	16576	54	50	2881	2770
KS	125075	25921	10579	42	40	2230	2146
KY	147336	13771	14645	30	30	1485	1413
LA	165404	12514	17709	28	31	1463	1387
ME	77890	3658	16207	13	13	736	685
MD	220181	11847	15373	31	30	1564	1482
MA	222308	11575	15789	30	34	1387	1314
MI	441431	32052	70784	85	100	4218	3972
MN	253585	32811	43721	63	64	3588	3416
MS	103692	9085	12300	21	21	1040	987
MO	241333	26302	21914	50	53	2689	2566
MT	49010	10810	7098	18	16	987	947
NE	84604	22227	8205	35	31	1875	1806
NV	118964	9422	10383	22	21	1182	1121
NH	63125	3142	9070	10	11	510	481
NJ	337307	16403	21630	43	46	2017	1903
NM	64889	4716	6030	11	11	550	522
NY	650282	33951	54035	87	93	3993	3780
NC	371460	25339	29696	62	66	3051	2891
ND	49938	22322	6764	33	27	1801	1739
OH	472792	33867	39206	78	90	3870	3666
OK	150304	15532	13157	30	31	1591	1517
OR	160476	12338	16231	28	31	1496	1418
PA	494127	25534	42147	66	75	3265	3090
RI	31868	1640	1897	4	5	196	187
SC	221277	11367	14742	30	31	1448	1371
SD	44560	15708	5978	24	20	1306	1259
TN	228021	16840	21417	40	43	1961	1859
TX	835847	72140	64597	154	164	7760	7388
UT	95630	7279	13239	17	19	940	889
VT	31653	1859	5759	5	6	305	284
VA	333903	18719	23519	48	47	2428	2296
WA	252505	20131	24040	45	49	2357	2236
WV	72202	3743	9066	10	10	551	518
WI	251943	22321	40007	53	59	2678	2532
WY	30712	2902	5406	6	7	352	333

Table 2-36. SEMAP 2018 alm source emissions state totals (TPY)

	CO	**NOX**	**VOC**	**NH3**	**SO2**	**PM10**	**PM2_5**

AL	43177	30914	10197	22	1145	934	887
AZ	22467	18688	6133	19	14	495	489
AR	25725	25881	6245	27	94	682	638
CA	139834	112436	32235	226	2619	4393	4178
CO	10810	12258	2457	7	8	315	311
CT	15973	7427	3040	6	245	265	240
DE	10894	5083	2304	2	281	152	138
DC	340	438	84	0	1	9	9
FL	186861	69490	50631	69	2625	1955	1842
GA	40209	29146	9714	21	675	799	751
ID	10422	5362	2249	6	5	249	249
IL	56682	77825	10868	66	176	2039	1957
IN	38180	37823	7633	31	84	965	907
IA	46089	23790	4558	17	36	574	578
KS	13182	27892	2985	15	18	719	726
KY	28097	26170	5899	21	991	787	749
LA	83540	128129	15694	57	825	3407	3449
ME	46151	3634	3030	2	36	291	254
MD	37882	17911	6508	12	478	530	454
MA	32928	11442	5502	6	297	615	517
MI	99677	19938	19288	19	72	610	594
MN	63244	38644	13060	24	147	1063	1062
MS	29945	24093	7009	18	1101	743	708
MO	50355	51762	11302	30	138	1379	1387
MT	7454	14518	1568	9	9	382	385
NE	16135	44713	3486	25	27	1148	1160
NV	8909	7129	2142	5	6	198	198
NH	10831	3310	1780	2	86	105	92
NJ	46220	23278	7948	17	946	607	550
NM	10521	24054	2384	13	14	620	627
NY	83668	46497	14834	13	1654	1473	1385
NC	49554	16169	11316	15	305	449	420
ND	7115	14834	1498	9	9	383	387
OH	62792	64869	11033	48	218	1677	1605
OK	26214	19042	6762	12	17	513	513
OR	25313	28248	5454	14	99	705	684
PA	62865	28428	10923	27	808	1075	928
RI	6140	2705	1011	2	97	109	98
SC	43578	10264	8197	10	585	309	283
SD	4895	2934	1113	2	3	80	80
TN	38769	22573	9403	17	759	824	763

TX	104207	140653	27368	82	502	4617	4294
UT	12242	9498	2711	9	7	80	74
VT	5590	1136	923	1	14	66	53
VA	49661	36122	8785	26	1289	1031	979
WA	43035	35964	9142	30	187	813	789
WV	11262	22029	2054	14	993	675	645
WI	70174	22256	17498	24	42	668	618
WY	7576	19941	1587	11	12	512	517

Table 2-37. SEMAP 2018 onroad mobile source emissions state totals (TPY)

	CO	NOX	VOC	NH3	SO2	PM2_5
AL	508548	70068	36082	1772	533	2663
AZ	573197	106555	32603	3225	941	5549
AR	201059	35718	15002	907	339	1390
CA	2362995	478752	116181	16794	3206	29876
CO	365686	60028	26317	1528	568	2616
CT	268239	26665	18669	1180	359	1353
DE	65875	8337	4269	256	126	360
DC	7218	1055	524	39	17	55
FL	1368494	191926	105343	6022	1729	6832
GA	1037134	152195	160914	3392	3439	5601
ID	126124	19433	7628	518	186	798
IL	748596	123224	51458	3179	1193	5360
IN	541534	85018	36302	2145	795	3572
IA	247280	37395	16392	957	333	1536
KS	206834	33666	14435	839	316	1387
KY	414019	57657	27271	1373	375	1965
LA	269089	47959	20452	1249	473	1833
ME	148121	17635	7924	514	317	940
MD	405901	54527	28818	1950	787	2545
MA	398893	35478	25890	1810	637	1835
MI	857335	134988	48801	4051	1286	5482
MN	497136	70576	28586	1856	655	3174
MS	290728	49097	21502	1102	323	1680
MO	446790	75618	31031	1927	725	3134
MT	193186	24876	5292	581	219	789
NE	139497	21405	9461	538	200	921
NV	118991	22184	10170	555	208	908
NH	141642	16167	7774	487	247	892
NJ	572884	72840	42050	2967	896	3605
NM	213616	39777	13637	1116	340	2023

NY	1314465	138809	80369	5505	1770	8546
NC	1259227	106182	59021	3132	849	2988
ND	131901	16352	3566	363	140	553
OH	8872	2066	552	3066	1135	51
OK	341361	56121	24454	1424	538	2221
OR	225977	40450	15805	998	369	1694
PA	1308558	166488	82958	4484	2103	7901
RI	88431	8016	4920	366	126	417
SC	451974	56589	24622	1456	430	2160
SD	64337	9639	4358	239	89	434
TN	633649	95973	40676	2088	582	3251
TX	2940409	549293	105546	18693	4408	37236
UT	187841	31475	13592	802	284	1277
VT	75154	8114	4672	282	139	441
VA	673648	70499	42414	2575	793	2547
WA	785801	117871	29180	3443	1069	3908
WV	234835	28648	13263	567	158	889
WI	472457	74339	32408	1826	686	3440
WY	63919	9614	4348	244	91	419

Table 2-38. SEMAP 2018 total point source emissions state totals (TPY)

	CO	**NOX**	**VOC**	**NH3**	**SO2**	**PM10**	**PM2_5**
AL	124934	114553	38842	2339	165129	31344	23225
AZ	35054	48414	5893	1303	60983	11426	7536
AR	71938	68360	32257	2608	104942	18073	13331
CA	162908	100084	48114	14320	25998	36765	20900
CO	28144	68197	15515	520	75463	18398	10729
CT	5007	12407	1779	0	10140	1462	1347
DE	8656	16239	2704	101	43599	3703	3361
DC	411	957	66	0	522	49	45
FL	108288	128630	35751	2700	187152	34439	28491
GA	80227	80628	35448	6192	65827	22663	17720
ID	27604	10199	1603	1287	17296	3197	2089
IL	122028	119213	51422	2660	199244	32999	21731
IN	376597	169724	52173	2321	274837	58602	35863
IA	29664	73532	30112	1506	108021	19993	11268
KS	36056	87346	23068	61478	56019	16279	10078
KY	86327	112772	47019	120	162424	28986	19744
LA	161886	179469	67951	6909	272110	43132	33892
ME	21401	21094	4920	645	14355	4623	3783
MD	72529	76951	5348	137	324007	19462	15809

MA	11530	25370	4265	645	62636	5590	4840
MI	105657	143915	35267	1957	211648	28965	19602
MN	37347	99196	24507	28402	76922	23009	12450
MS	41845	100770	35441	1806	80174	12796	9271
MO	91381	94567	21500	2084	211664	20641	13278
MT	28900	26052	6966	411	31212	12112	6411
NE	14642	41748	10156	1820	77770	9499	5168
NV	31193	29013	3158	1314	16088	9745	6426
NH	5883	7396	929	134	45174	2042	1771
NJ	9539	27562	9888	475	39871	7704	6818
NM	35151	105434	11029	598	17984	5669	4556
NY	69231	85444	12293	2463	179722	9639	6089
NC	63867	67503	47960	1717	73762	34520	26978
ND	13106	61581	2773	536	115246	8070	6655
OH	257951	154745	34615	7067	274393	42811	31137
OK	71631	115119	43444	4256	169258	13676	9162
OR	55321	32785	16150	1154	22926	12795	9182
PA	103390	251484	29515	2429	1030499	48368	31900
RI	1471	1348	994	71	1431	191	140
SC	60577	55927	27452	1277	101527	17123	13404
SD	9073	20014	4558	276	31358	4890	3124
TN	47766	119858	47846	1501	166629	28121	23137
TX	305007	383970	134805	8937	378740	74290	55757
UT	52495	84689	5897	716	41423	13606	7994
VT	2686	1161	338	0	253	128	98
VA	80975	96378	36976	1787	126230	17125	13510
WA	59886	34503	12536	1159	25198	7536	5741
WV	67134	76624	12398	357	77952	9918	6331
WI	71718	74120	30749	1106	111793	18651	13105
WY	26929	99785	13490	950	68686	20878	15881

Table 2-39. SEMAP 2018 total airport point source emissions state totals (TPY)

	CO	NOX	VOC	SO2	PM10	PM2_5
AL	15032	474	915	55	299	209
AZ	5223	2008	412	205	179	162
AR	984	183	79	21	39	34
CA	6821	4222	631	394	283	267
CO	3536	2208	337	207	161	153
FL	56979	12755	5019	1165	1009	770
GA	29653	5972	2849	750	426	349
ID	427	169	25	19	24	23

IL	8047	10183	1354	658	339	327
IN	1316	614	170	63	66	61
IA	478	186	61	21	31	29
KS	625	77	43	9	20	17
KY	10228	1963	820	191	181	136
LA	1765	657	163	69	73	66
MI	4005	1999	662	219	197	188
MN	2592	2008	396	200	17	15
MS	8631	190	671	23	171	119
MO	3120	2298	546	233	172	166
MT	537	155	81	18	24	22
NE	612	216	72	25	26	24
NV	2856	1899	259	184	116	111
NM	1401	371	102	40	45	39
NC	23500	4356	2567	455	527	433
ND	279	76	43	9	11	10
OH	2792	1290	443	137	144	136
OK	2553	395	166	45	77	63
OR	1348	761	116	75	71	68
SC	10235	554	825	64	194	138
SD	243	60	32	7	12	11
TN	15390	4036	1542	349	276	215
TX	13008	6521	1360	671	615	568
UT	1455	945	129	88	63	59
VA	22735	5883	2843	455	832	589
WA	2614	1587	269	151	129	123
WV	3381	77	237	9	67	46
WI	1325	542	216	63	75	71
WY	174	27	16	3	7	6

Table 2-40. SEMAP 2018 in-port, near and offshore shipping totals (TPY)

	CO	**NOX**	**VOC**	**SO2**	**PM10**	**PM2_5**
AL	459	917	42	29	14	13
CA	2225	15667	613	506	200	182
CO	175	1648	72	51	24	22
DE	272	2288	114	474	35	32
DC	0	2	0	0	0	0
FL	2694	25412	1057	921	421	385
GA	246	2170	109	83	33	30
IL	10	108	4	3	1	1
IN	5	48	2	1	1	1

LA	2377	19138	863	593	297	270
ME	136	1262	54	43	19	18
MD	578	5384	243	163	82	75
MA	448	4154	184	162	64	59
MI	1054	11460	447	277	140	127
MN	30	324	13	8	4	4
MS	127	1173	51	38	18	17
NJ	905	7801	387	457	125	114
NY	607	5659	268	152	79	72
NC	184	1685	76	94	25	23
OH	244	2646	104	65	33	30
OR	393	3040	206	89	50	45
PA	382	3718	151	154	54	49
RI	27	247	11	26	4	3
SC	414	3648	176	218	57	52
TX	1466	9752	487	480	240	219
VA	371	3453	157	126	52	47
WA	2368	21630	1102	645	334	302
WV	3	33	1	1	0	0
WI	75	818	32	20	10	9
Near-shore	80379	785660	34170	108590	21484	19696
SECA	243840	2622600	103500	1812700	243970	225280
Canada	22194	211165	9427	6045	3036	2763

2.4 2018 vs 2007 State Total Comparisons

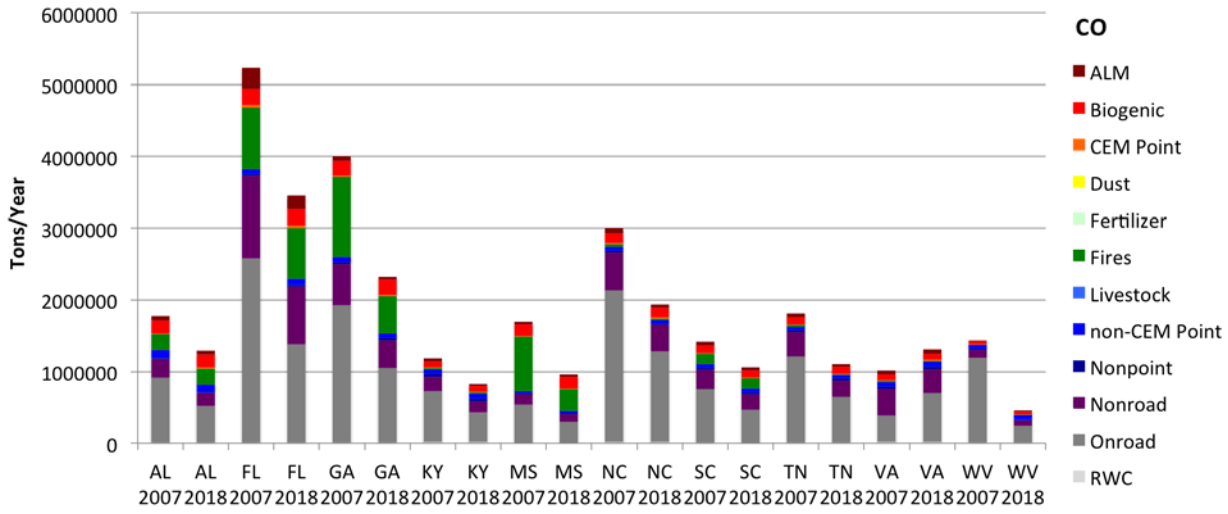


Figure 2-59. 2007 and 2018 annual total CO emissions by SESARM state

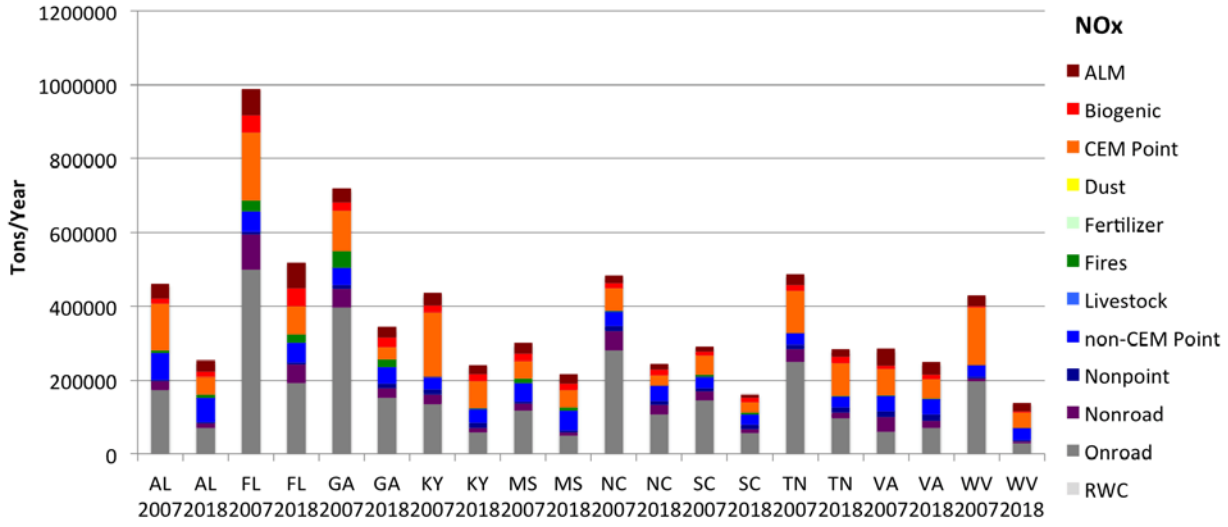


Figure 2-60. 2007 and 2018 annual total NOx emissions by SESARM state

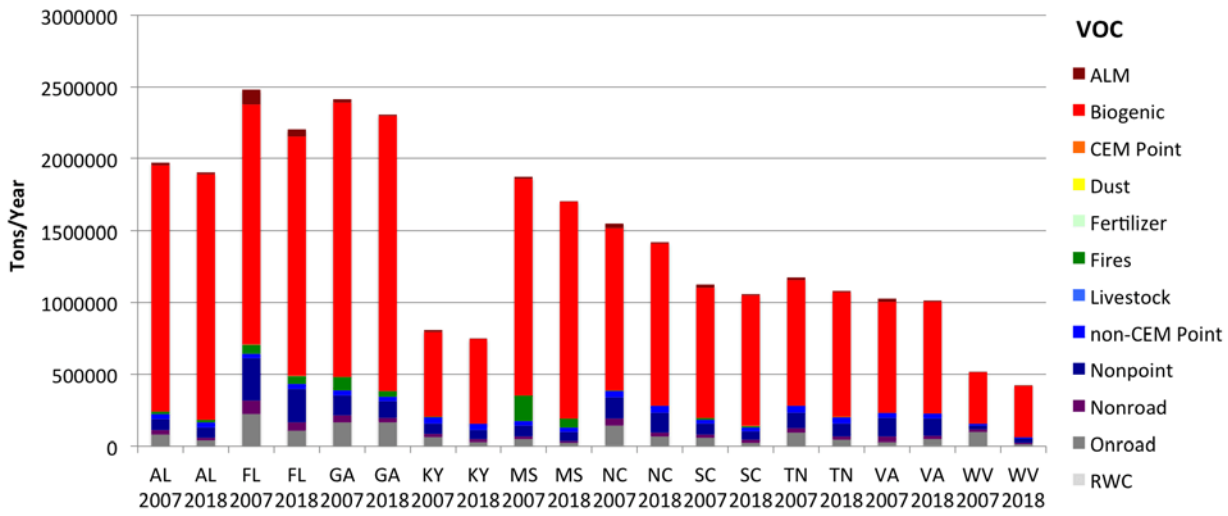


Figure 2-61. 2007 and 2018 annual total VOC emissions by SESARM state

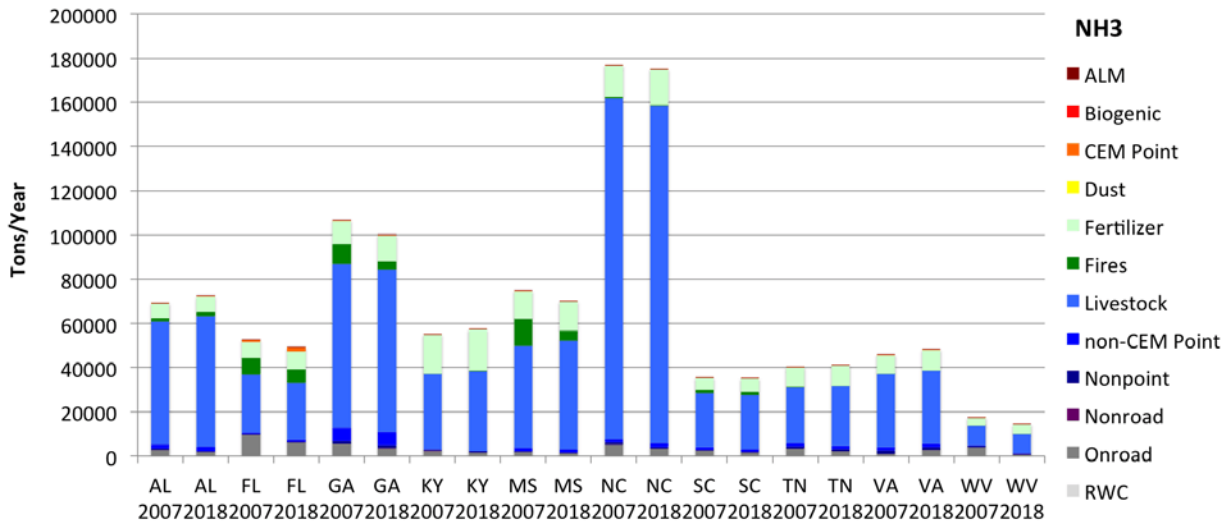


Figure 2-62. 2007 and 2018 annual total NH3 emissions by SESARM state

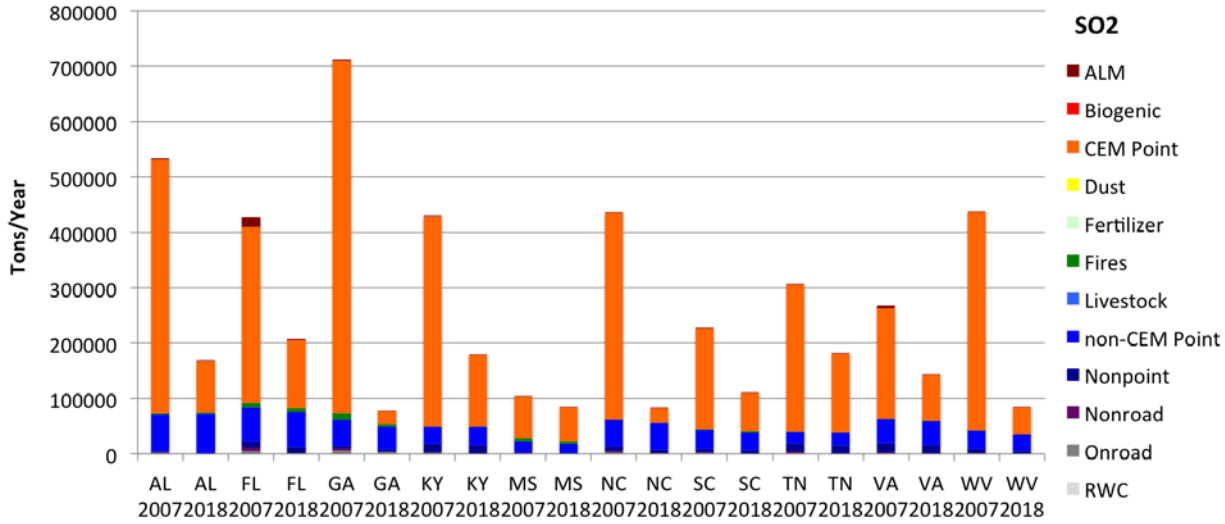


Figure 2-63. 2007 and 2018 annual total CO emissions by SESARM state

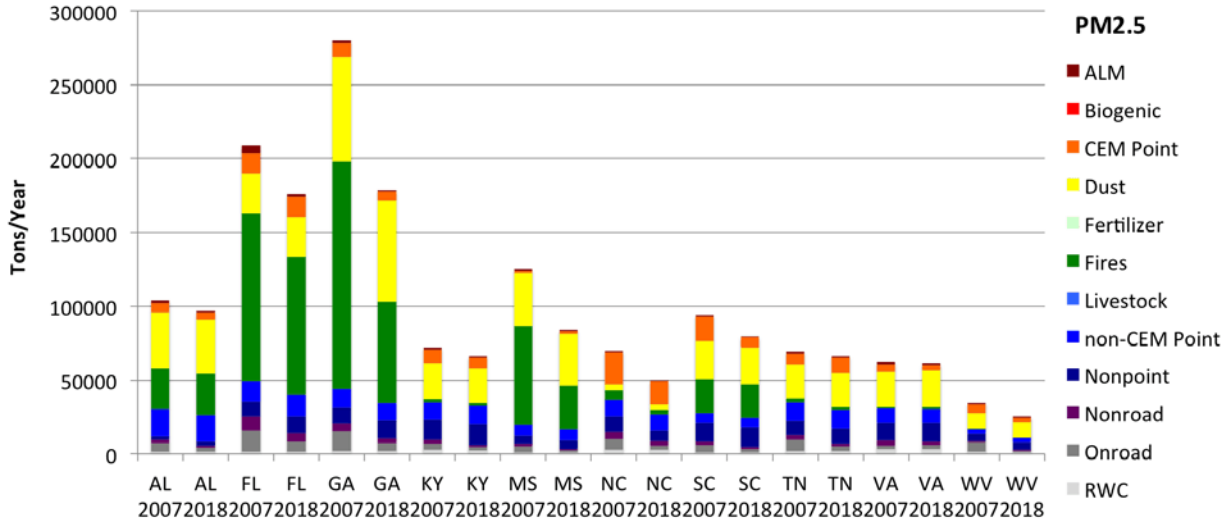


Figure 2-64. 2007 and 2018 annual total PM2.5 emissions by SESARM state

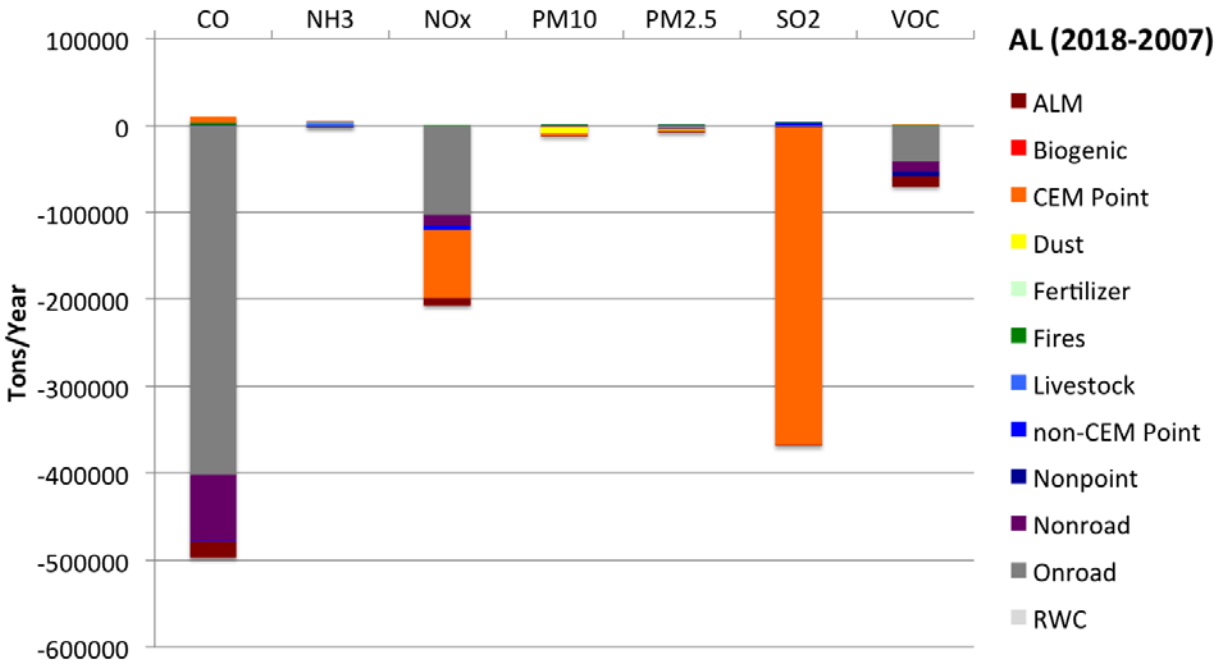


Figure 2-65. Alabama annual emissions differences (2018-2007) by pollutant

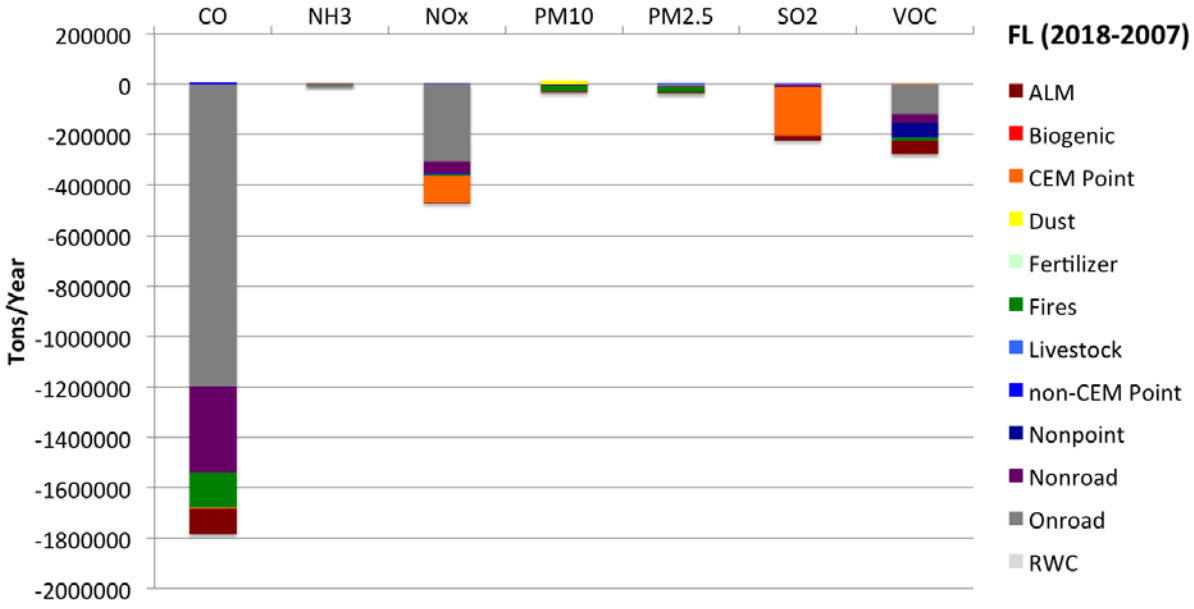


Figure 2-66. Florida annual emissions differences (2018-2007) by pollutant

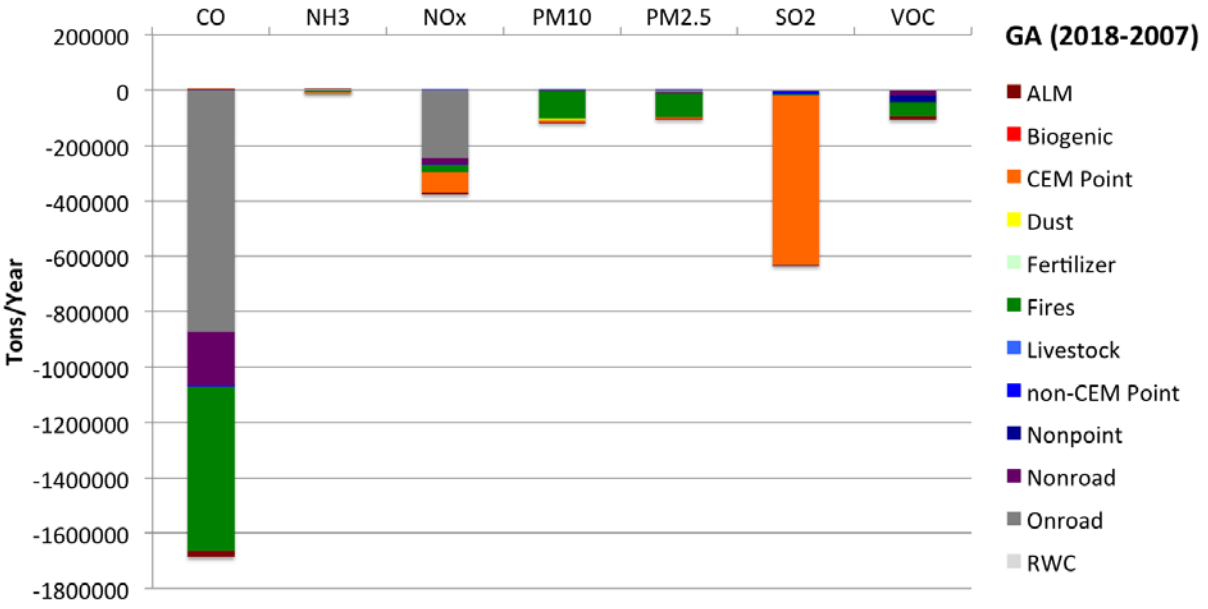


Figure 2-67. Georgia annual emissions differences (2018-2007) by pollutant

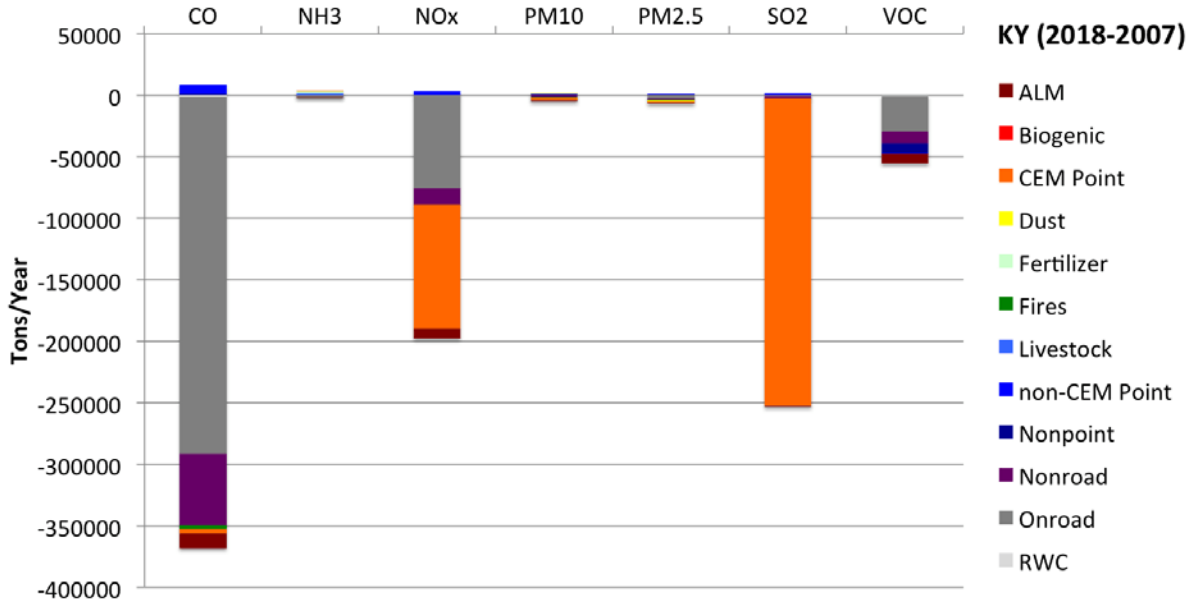


Figure 2-68. Kentucky annual emissions differences (2018-2007) by pollutant

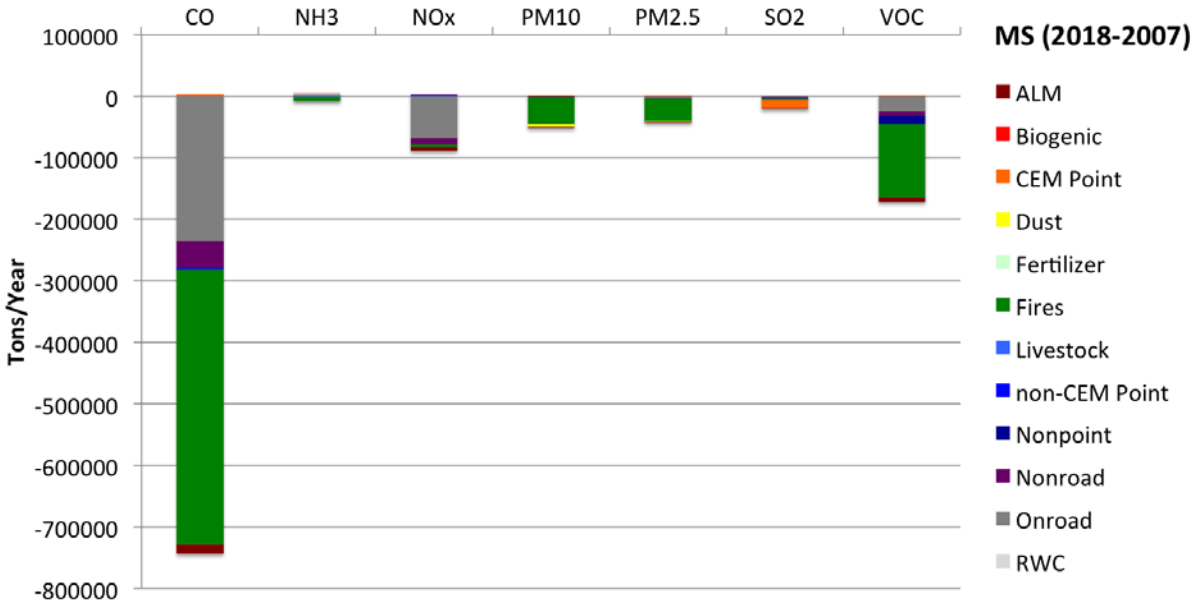


Figure 2-69. Mississippi annual emissions differences (2018-2007) by pollutant

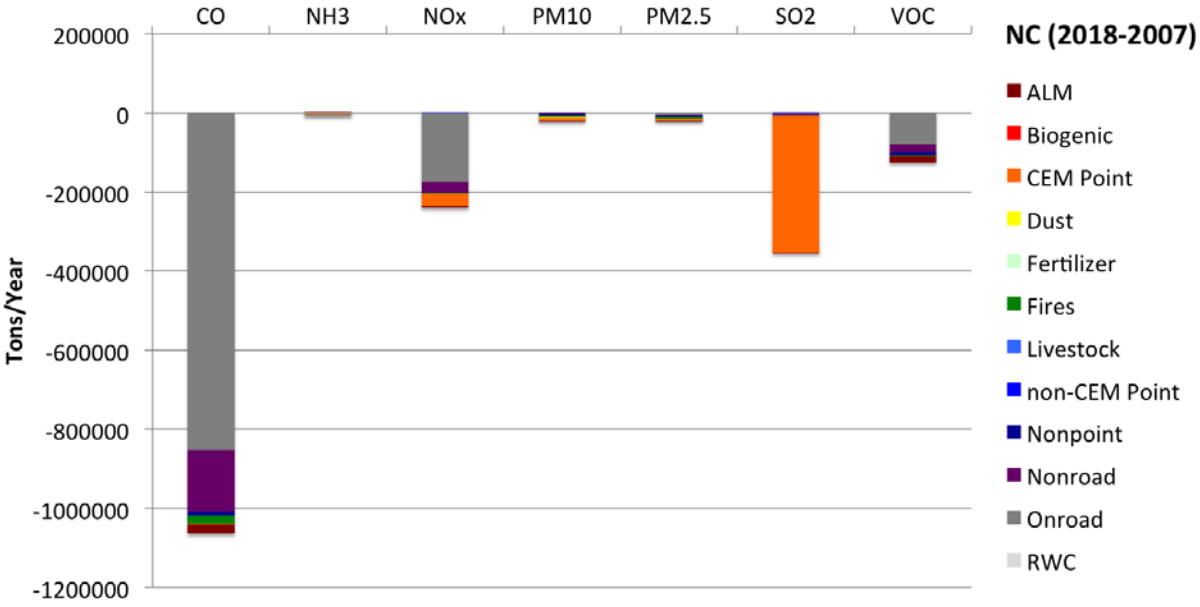


Figure 2-70. North Carolina annual emissions differences (2018-2007) by pollutant

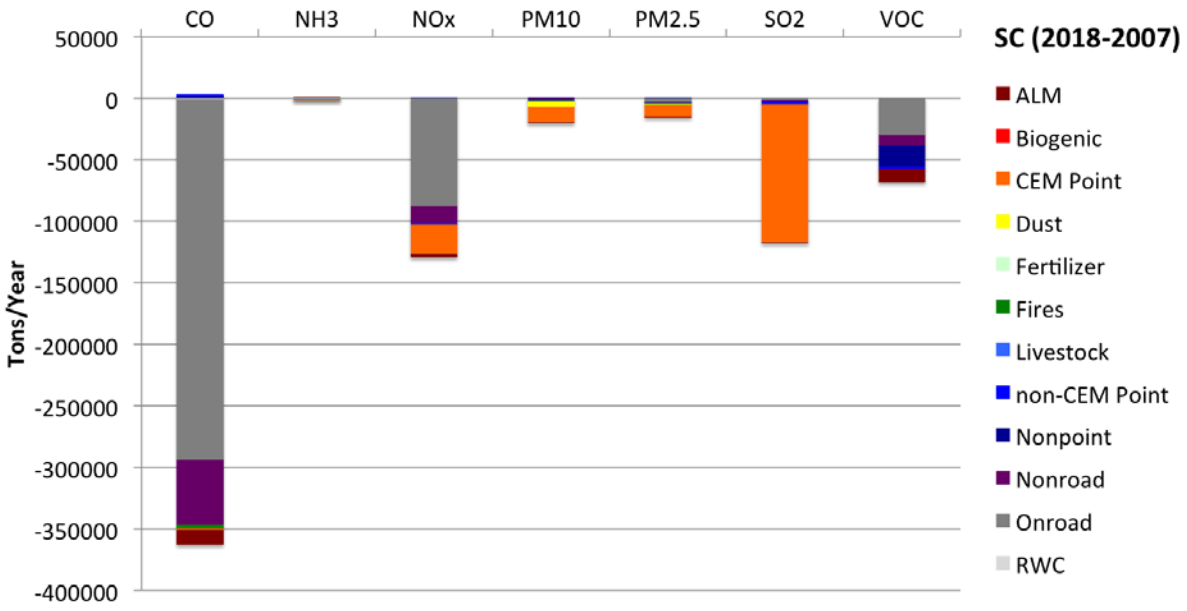


Figure 2-71. South Carolina annual emissions differences (2018-2007) by pollutant

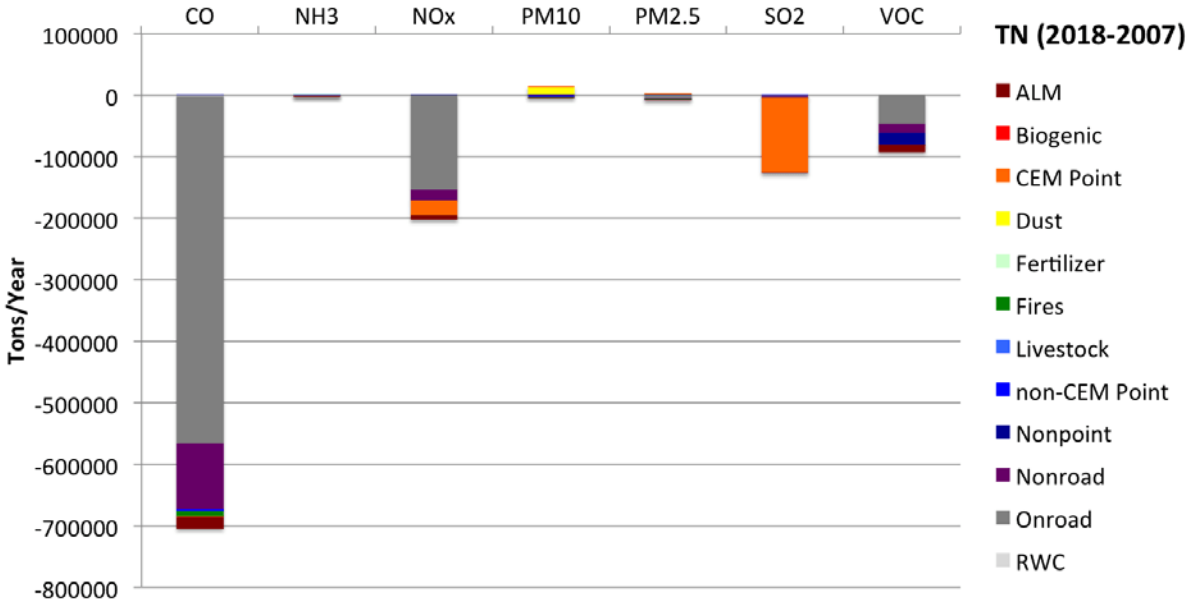


Figure 2-72. Tennessee annual emissions differences (2018-2007) by pollutant

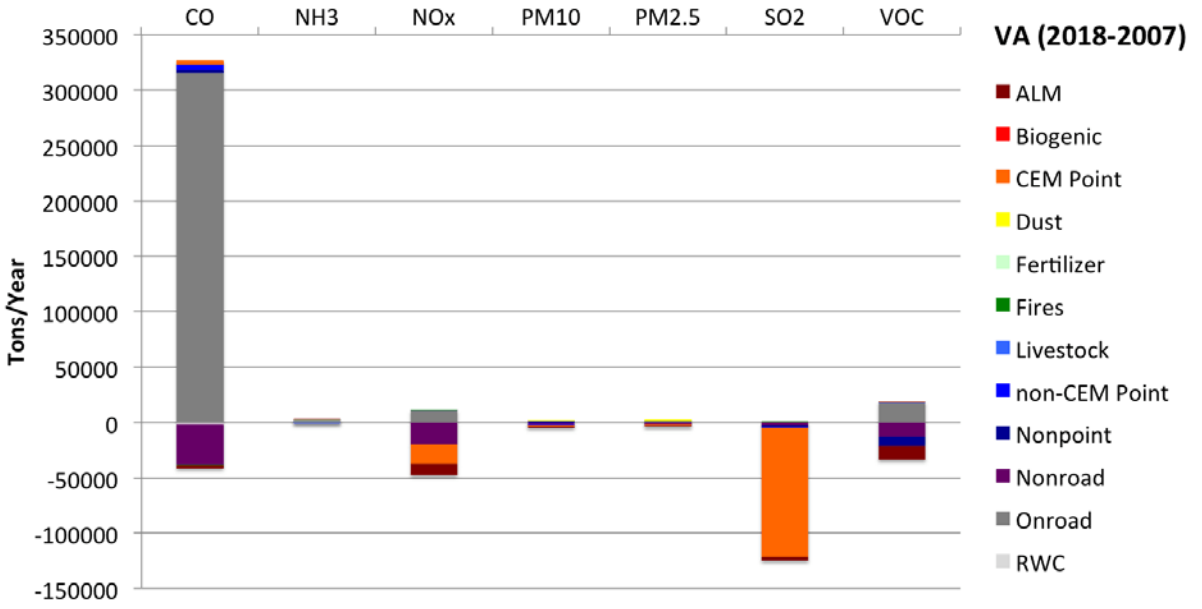


Figure 2-73. Virgina annual emissions differences (2018-2007) by pollutant

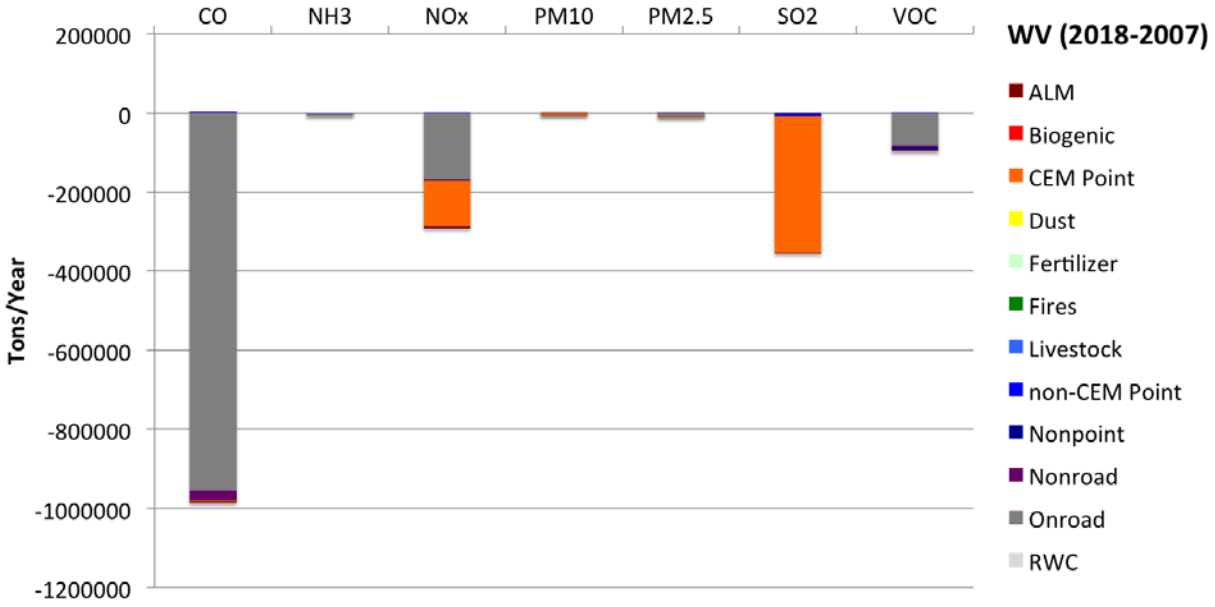


Figure 2-74. West Virginia annual emissions differences (2018-2007) by pollutant

2.5 References

Adelman et al., (2011) A Detailed Approach for Improving Continuous Emissions Monitoring Data for Regulatory Air Quality Modeling, presented at the 2011 Community Modeling and Analysis System Conference, Chapel Hill, NC.

Adelman et al., (2012) A Detailed Approach for Improving Continuous Emissions Monitoring Data for Regulatory Air Quality Modeling, presented at the 20th Annual International Emission Inventory Conference, Tampa, FL.

Adelman et al., (2010) Preliminary Results for a Model of Temporal Variability in Residential Wood Combustion Emissions, presented at the 19th Annual International Emission Inventory Conference, San Antonio, TX. http://www.epa.gov/ttn/chief/conference/ei19/session9/adelman.pdf

AMEC (2013) Development of the Point Source Emission Inventory for 2007 in the SESARM Region – version 1.10b, prepared for SESARM by AMEC Environment & Infrastructure, Inc. Newberry, FL.

AMEC (2014) Development of the 2018 Projection Point Source Emission Inventory in the SESARM Region – version 1.0, prepared for SESARM by AMEC Environment & Infrastructure, Inc. Newberry, FL.

EPA. (2012a) Motor Vehicle Emissions Simulator (MOVES) – User Guide for MOVES2010b. U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Assessment and Standards Division. EPA 420-B-12-001b. June. (http://www.epa.gov/otaq/models/moves/documents/420b12001b.pdf).

EPA. (2012b) Using MOVES to Prepare Emissions Inventories in State Implementation Plans and Transportation Conformity. Technical Guidance for MOVRS2010, 2010a and 2010b. U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Assessment and Standards Division. EPA 420-B-12-028. April. (http://www.epa.gov/otaq/models/moves/documents/420b12028.pdf).

EPA. (2012c) Policy Guidance on the Use of MOVES2010 and Subsequent Minor Revisions for State Implementation Plan Development, Transportation Conformity and Other Purposes. U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Transportation and Climate Division. EPA 420-B-12-010. April. (http://www.epa.gov/otaq/models/moves/documents/420b12010.pdf).

Hogrefe, C., S.S. Isukapalli, X. Tang, P.G. Georgopoulos, S. He, E.E. Zalewsky,W. Hao, J.-Y. Ku, T. Key, and G.Sistla, Impact of Biogenic Emission Uncertainties on the Simulated Response of O3 and PM2.5 to Anthropogenic Emission Reductions,J. Air Waste Manag. Assoc., 61, 92-108.

Pace, T.G. (2005) Methodology to Estimate the Transportable Fraction (TF) of Fugitive Dust Emissions for Regional and Urban Scale Air Quality Analyses, U.S. EPA, Research Triangle Park NC. http://www.epa.gov/ttnchie1/emch/dustfractions/transportable_fraction_080305_rev.pdf

Pouliot, G. et al. (2010) Assessing the Anthropogenic Fugitive Dust Emission Inventory and Temporal Allocation Using an Updated Speciation of Particulate Matter, presented at the 19th International Inventory Conference, San Antonio, TX. http://www.epa.gov/ttn/chief/conference/ei19/session9/pouliot.pdf

TranSystems Corporation (2012) Area and Nonroad 2007 Base Year Inventories – Revised Final Report. Prepared for SESARM by TranSystems Corporation, March 2012.

TranSystems Corporation (2012b) Area and Nonroad Projection Year Inventories – Final Report. Prepared for SESARM by TranSystems Corporation, October 2012.

Watson, J.G., J.C. Chow, T.G. Pace (2000) Fugitive Dust Emissions. *Air Poll. Eng. Man.*

Vukovich, J. and T. Pierce (2002) The Implementation of BEIS3 within the SMOKE Modeling Framework, presented at the 11th International Emissions Inventory Conference, Atlanta, Georgia. http://www.epa.gov/ttn/chief/conference/ei11/modeling/vukovich.pdf

Chapter 3: Air Quality Model Performance Evaluation

3.1 Introduction

This chapter is devoted to the performance evaluation of the CMAQ model as applied to the SEMAP project. First the evaluation methodology is described. This is followed by a definition of the performance metrics and performance goals. Then, the observational data used in model evaluations are described. A comprehensive list of the performance evaluation products follows the data description. The discussion of the performance starts with the initial "Actual 2007" simulation. Ozone, $PM_{2.5}$ and wet deposition performances are evaluates. This is followed by the diagnostic tests performed to improve the initial model performance and the model configuration recommended for use. Then the model performance discussion continues with the final "Actual 2007" simulation and end with the "Typical 2007" simulation. In the conclusion section the findings of the comprehensive performance evaluation are summarized.

3.2 Evaluation Methodology

EPA's integrated ozone, $PM_{2.5}$ and regional haze modeling guidance calls for a comprehensive, multi-layered approach to model performance testing, consisting of the four major components: operational, diagnostic, mechanistic (or scientific) and probabilistic (EPA, 2007a). The CMAQ model performance evaluation effort for $PM_{2.5}$ and ozone discussed in this Chapter focused on the first two components of the EPA's recommended evaluation approach, namely:

3.2.1 Statistical Evaluation

Statistical evaluation tests the ability of the model to estimate ozone and $PM_{2.5}$ mass concentrations and the components of $PM_{2.5}$ that is sulfate, nitrate, ammonium, organic carbon matter, elemental carbon, and other inorganic $PM_{2.5}$. This evaluation examines whether the measurements are properly represented by the model predictions but does not necessarily ensure that the model is getting "the right answer for the right reason"; and

3.2.2 Diagnostic Evaluation

Diagnostic evaluation tests the ability of the model to predict visibility and extinction, PM chemical composition including PM and ozone precursors (e.g., SOx, NOx, VOC, and NH_3) and associated oxidants (e.g., nitric acid); PM size distribution; temporal variation; spatial variation; mass fluxes; and components of light extinction (i.e., scattering and absorption).

The diagnostic evaluation also includes the performance of diagnostic tests to better understand model performance and identify potential flaws in the modeling system that can be corrected. In this final model performance evaluation, the statistical evaluation has been given the greatest attention since this is the primary thrust of EPA's modeling guidance. However, we have also examined certain diagnostic features dealing with the model's ability to simulate sub-regional and monthly/diurnal gas phase and aerosol concentration distributions. In the course of the SEMAP studies numerous diagnostic sensitivity tests were performed to investigate and improve model performance and test the model assumptions that are available on the SEMAP modeling website:

3.3 Performance Metrics and Goals

To quantify model performance, several statistical measures were calculated and evaluated for all the IMPROVE, STN, CASTNet, SEARCH, FRM, NADP and AQS monitors within the SEMAP region,

individually for each monitoring network and individually for each SEMAP state. The statistical measures selected were based on the recommendations outlined in section 18.4 of the USEPA's Guidance On The Use Of Models And Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze (EPA, 2007a).

Although numerous model performance statistics measures are routinely calculated, SEMAP have found that the fractional bias and fractional gross error provide the best descriptive power over a wide range of concentrations. The fractional bias and error are expressed as a percentage and are normalized by the average of the predicted and gross observed values. Consequently, they are bounded statistics, with the fractional bias bounded by -200% to +200% and the fractional gross error bounded by 0 to 200%. Table 3-2 summarized the formulas for the fractional bias and gross error statistics. The SEMAP model performance goals and criteria are given in **Error! Reference source not found.**. Note that for ozone model performance the traditional (EPA, 1991) ≤ ±15% and ≤ 35% performance goals for mean normalized bias (MNB) and mean normalized gross error (MNGE) using hourly predicted and observed ozone pairs with the observed ozone value greater than 60 ppb are used. The MNB and MNGE statistics are similar to the fractional statistics given in Table 3-1, only the normalized statistics are divided by just the observed value rather than the average of the predicted and observed values.

Table 3-1 Definitions of the fractional bias and fractional error statistical model performance metrics

Statistical Measure	Shorthand Notation	Mathematical Expression	Notes
Mean Fractional Gross Error (Fractional Error)	MFE	$\frac{2}{N}\sum_{i=1}^{N}\left\|\frac{P_i - O_i}{P_i + O_i}\right\|$	Reported as %
Mean Fractionalized Bias (Fractional Bias)	MFB	$\frac{2}{N}\sum_{i=1}^{N}\left(\frac{P_i - O_i}{P_i + O_i}\right)$	Reported as %

Table 3-2 SEMAP model performance goals and criteria for components of fine particle mass

Fractional Bias	Fractional Error	Comment
≤±15%	≤35%	Goal for PM model performance based on ozone model performance, considered excellent performance
≤±30%	≤50%	Goal for PM model performance, considered good performance
≤±60%	≤75%	Criteria for PM model performance, considered average performance. Exceeding this level of performance indicates fundamental concerns with the modeling system.

3.4 Observational Networks

We collected the available surface air quality measurement data, measured atmospheric deposition data, and satellite data for the 2007 SEMAP modeling periods and domains. Particularly, we collected surface measurement data of air quality from the following sources: EPA database AIRS (including STN, PAMS, SLAMS and Air Toxics networks) and networks CASTNet, IMPROVE and SEARCH, and atmospheric deposition data from the network NADP and NASA's satellite air quality data from OMI and MODIS. The following sections describe the data that we use for this project.

3.4.1 AIRS

AIRS compiles and provides access to datasets from multiple national observational networks/programs including STN, PAMS, SLAMS and Air Toxics. The STN network provides 24-hr (midnight to midnight) measurements of $PM_{2.5}$ and its composition including trace metals at every 3rd day or every 6th day. The SLAMS network provides hourly measurements of criteria air pollutants including $PM_{2.5}$, PM_{10}, O_3, SO_2, NO_2, CO etc. The PAMS network measures photochemical smog related species such as O_3, NO, NO_2, NO_y, Total NMOC, and 60 PAMS target VOC compounds in non-attainment areas. The AIRS datasets are spatially dense in populated areas with intensive sampling frequency in the SEMAP states and is the backbone for model performance evaluation and receptor modeling. In addition the monitoring data from the Air Toxics program provides a critically important role by characterizing HAPs concentrations to support exposure assessments, and can be a supplement for air quality model evaluation and input for receptor modeling. The AMET evaluation tool developed at UNC can take all AIRS datasets in their original AQS engineering format directly.

In addition, AIRS includes meteorological data at STN and PAMS sites that can be used for quality assurance of the MCIP files and as an independent evaluation of WRF performance, especially if the meteorological modeling contractor is not using this dataset.

3.4.2 IMPROVE

The IMPROVE network was developed to monitor visibility degradation at wildness and remote areas in the nation. IMRPOVE includes measurements of chemical constituents including trace metals of $PM_{2.5}$ as well as related gaseous species at each site. From these measurements, light extinction values are also calculated and provided. Note that different carbonaceous analysis methods have been used among the major national networks with IMPROVE using TOR and STN using TOT in measuring EC/OC.

3.4.3 CASTNet

CASTNet was developed to monitor dry and wet acid deposition. Monitoring site locations are predominantly rural by design to assess the relationship between regional pollution and changes in regional patterns in deposition. CASTNet also includes measurements of rural ozone and the chemical constituents of $PM_{2.5}$.

3.4.4 NADP

NADP provides atmospheric deposition data. The weekly cumulative deposition data was extracted from CMAQ/CAMx outputs between the hours of data collection and assigned to the measured species.

3.4.5 SEARCH

SEARCH provides continuous and speciated PM data in one urban and one rural location in each one of the following four SEMAP states: Alabama, Georgia, Florida and Mississippi. In addition to 24-hr particulate matter mass (fine and coarse) and composition (EC, OC, sulfate, nitrate, ammonium and metals) SEARCH also measures hourly PM mass and ion components (BC, OC, sulfate, nitrate, ammonium) and a wide range of complementary gaseous species (O_3, NO, NO_2, NO_y, HNO_3, SO_2, CO, CO_2). This dataset is extremely useful to evaluate how well the models reproduce the diurnal variability (which is not possible with the daily averaged data),

spatial variability (urban versus rural), and if the secondary PM formation processes were simulated correctly. Speciated the SEARCH OC data (and OC data from ASACA sites which are operated by Georgia Tech) into individual compounds for use as molecular markers for periods of the February 2007 prescribed burning event and the May-June 2007 Florida-Georgia wildfire episodes ((Yan, Zheng et al. 2008)). These additional datasets are very useful for evaluating the model performance in capturing the important Southeastern fire events during 2007. In addition, the HAP and other VOC data collected at the SEARCH sites in the Atlanta, GA metropolitan area are valuable for both model performance evaluation and receptor modeling.

3.4.6 Satellite Data

Air quality data collected by satellites provide a powerful supplement to ground-based air quality observations. Where ground-based observations are finite spatial measurements at the earth's surface, satellite data provide atmospheric measurements on spatial grids that are commensurate with regional air quality modeling grids. Further, satellite data observe three-dimensional columns of pollutants. Satellite air quality data can be processed to match the spatial and vertical resolution of air quality model predictions, providing an observational dataset that is more spatially commensurate than ground-based measurements.

We use satellite observations of gases and particulate matter to provide supplemental evaluation data for diagnosing CMAQ and CAMx model performance. While these data are not used to replace the ground-based monitoring networks, they provide an additional dimension of atmospheric measurements to use in the model evaluations as they observe the entire tropospheric column of pollution. In particular satellite data is useful in the SEMAP project to diagnose the ability of CMAQ and CAMx to simulate the impacts of the southern Georgia wildfire events in May-July 2007, the impacts of dust transport into the region, and other important episodic pollution events. These data are not intended for use in the SIP process, they are only going to used to lend insight into the skill of the air quality models to simulate air quality in the Southeast.

We acquire ambient air quality data, including satellite data from the OMI instrument on tropospheric NO2 and formaldehyde (HCHO), and aerosol optical depth (AOD) data from the OMI and MODIS instruments. Advanced post-processing tools developed by UNC are available to process the satellite data products, the Level 2 swath, or gridded data (Level 2 and Level 3), from their native lat-long grid to the Lambert conformal conic grid used by CAMx and CMAQ, for a user-specified domain and grid resolution. The UNC satellite data toolkit also consists of an advanced version of AMET that allows statistical comparisons of satellite data against CMAQ for selected sub-domains of the data. CMAQ output is not directly comparable with column-integrated trace-gas concentrations, e.g., tropospheric column measurements of NO_2, and HCHO.

We downloaded the satellite data from the data warehouses (GIOVANNI or VIEWS as appropriate) for the base year 2007, re-grid them to the model grid, and post-process CMAQ and CAMx output for comparison with these data for the specified sub-yearly periods.

For detailed information, the surface ambient air quality measurement data that will be used for evaluating model performance and input to receptor models are summarized in

Table 3-3.

Table 3-3 SEMAP model performance goals and criteria for components of fine particle mass

Variable	Averaging time	Database/Networks
PM_{10}	daily, hourly	AIRS, IMPROVE, SEARCH
$PM_{2.5}$	daily, hourly	AIRS, IMPROVE, SEARCH
Sulfate	daily, hourly, weekly	AIRS, IMPROVE, SEARCH, CASTNet
Nitrate	daily, hourly	AIRS, IMPROVE, SEARCH
Ammonium	daily, hourly, weekly	AIRS, SEARCH, CASTNet [(a)]
EC (BC)	daily, hourly	AIRS, IMPROVE, SEARCH
OC	daily, hourly	AIRS, IMPROVE, SEARCH
Trace Metals in $PM_{2.5}$	daily	AIRS, IMPROVE, SEARCH
NO, NO_2 and NO_y	hourly	AIRS, SEARCH
SO_2	hourly, daily, weekly	AIRS, CASTNet, IMPROVE, SEARCH
VOCs, HAPs	hourly	AIRS, SEARCH [(b)]
Total Nitrate [(c)]	daily, weekly	CASTNet, SEARCH

(a) Ammonium data from IMPROVE are estimated from sulfate and nitrate based on complete neutralization of those ions. Independent measurements from CASTNet are more appropriate for model evaluation purposes

(b) ARIES program measures HAPs and other VOCs at the SEARCH sites in Atlanta, GA area.

(c) CASTNet weekly measurements of PM nitrate and HNO_3 will be evaluated as total nitrate due to issues relating to filter-based methods to collect volatile nitrate species.

As existing data, surface measurements from the above specific networks or from EPA AIRS database are already quality-checked and well documented. Use of these existing data is fully documented with data's original documentation archived. In addition we use the provided measuring uncertainty information to further screen the datasets and to decide excluding particular data points. Spatial plots and time series plots are made for visual check of outliers that seems less reasonable. Also, descriptive statistics (mean, standard deviation, frequency distributions, etc.) are calculated and used for data presentation and cross comparison and to facilitate peer review. Cross-checking among the networks are made too if applicable for further assurance of the data reliability.

Special cautions are used to double-check the quality of the acquired satellite data from OMI and MODIS instruments. The cloud cover information is used in combination of other information to decide uncertainty for each individual data point. This uncertainty information is used for screening the final data to be used and be used to weight the reliability of each data point. Descriptive statistics (mean, standard deviation, frequency distributions, etc.) of the data are also calculated and compared to the surface measurement, which is considered more reliable. Spatial plots are made for satellite data and further compared with surface measurements for data screening purpose. All of the above procedures are documented for quality assurance.

3.5 Evaluation Products

A variety of evaluation products are available for download at http://semap.ce.gatech.edu/node/1835. Tables 4-11 contain a summary of the available products on the website. See Appendix B for examples.

Table 3-4 Bugle Plots (PM2.5)

Spatial / **Temporal**	Network-wide	By region	By state	By site

Annual				
Ozone season				
By month		(& multi-network)	(& multi-network)	
By Day				

Table 3-5 Quantile-Quantile Plots

Spatial **Temporal**	Network-wide	By region	By state	By site
Annual				Other networks
Ozone season				Ozone networks
By month				
By Day				

Table 3-6 Scatter Plots

Spatial **Temporal**	Network-wide	By region	By state	By site
Annual				
Ozone season				
By month				
By Day				

Table 3-7 Soccer Plots (PM2.5)

Spatial **Temporal**	Network-wide	By region	By state	By site
Annual				
Ozone season				
By month		(& multi-network)	(& multi-network)	
By Day				

Table 3-8 Stacked Bar Charts

Spatial **Temporal**	Network-wide	By region	By state	By site
Annual				
Ozone season				
By month				CSN & IMPROVE
By Day				

Table 3-9 Tables of Statistics

Spatial **Temporal**	Network-wide	By region	By state	By site
Annual				
Ozone season				

By month				
By Day				

Table 3-10 Tile Plots

Spatial **Temporal**	Network-wide	By region	By state	By site
Annual				
Ozone season				
By month	8-hr max O_3, $PM_{2.5}$			
By Day	8-hr max O_3, $PM_{2.5}$			

Table 3-11 Time Series Plots

Spatial **Temporal**	Network-wide	By region	By state	By site
Annual				Other networks
Ozone season				
By month				Ozone networks
By Day				

3.6 Initial Model Performance

3.6.1 AQS Ozone

Network-wide, MB for annual ozone with no cut-off is +3.1 ppb (out of 31 ppb, for a NMB of +10%) and ME is 13 ppb (NME = 40%). Using a cut-off of 60 ppb, the network-wide, MB is -1.9 ppb (out of 69 ppb) and ME is 12 ppb. MFB is -5.8% and MFE is 19%. Bias and error are smallest for coastal SEMAP states (MFB = -2.0%; MFE= 18%) and larger for interior SEMAP (KY, TN and WV; MFB = -9.3% and MFE = 20%) or neighboring states. In some SEMAP states the bias is positive, most notably in GA (MB +3.6 ppb; MFB +2.2%).

The network-wide 8-hr ozone MB with no cut-off is +7.1 ppb (out of 47 ppb). MFB is +12%. ME is 11 ppb and MFE is 23%. Annual, network-wide MB with a 60 ppb cut-off is +1.8 ppb (out of 69 ppb). MFB is +1.4%. ME is 9.3 ppb and MFE is 13%. The bias and error are smallest for the interior SEMAP states and larger for coastal SEMAP and neighboring states. In WW, TN, KY, MBs are -1.3 to +1.0ppb and MEs are 7.5 to 9.1 ppb (MFEs are 11% to 13%). In VA and GA bias and error are the largest. MBs are +5.6 and +6.9 ppb (MFBs are +6.6 and +8.0%) and MEs are 10 and 11 ppb (MFEs are 14 and 15%). In Georgia, August monthly MB is +18 ppb (out of 73 ppb; MFB is +21%) and ME is 19 ppb (MFE is 23%). Site 130590002 in Georgia has observations on 14 days in August. At this site, MB is +25 ppb (out of 70 ppb; MFB = +30%) and ME is 25 ppb (MFE = 30%).

3.6.2 $PM_{2.5}$

The AQS 24-hr network-wide $PM_{2.5}$ annual MB is +1.5 ug/m3 (out of 13 ug/m3; MFB is 8%) and ME is 5.5 ug/m3 (MFE = 38%). For the CSN network, annual MB is +0.41 ug/m3 (out of 15 ug/m3 NMB is 2.7%) and ME is 6.0 ug/m3 (NME = 40%). MB is negative (about 3 mg/m3; MFB is about -20%) for SEMAP states and positive for neighboring states (MB is +2.2 mg/m3 out of 15 ug/m3). Annual bias is largest in West Virginia (MB = -5.8 ug/m3; MFB = -37%). In Georgia, annual MB is -2.9 ug/m3 (out of 17 ug/m3; MFB is -16%) and ME is 5.5 ug/m3 (MFE = 34%). The largest monthly MBs are in May

(recall that FL-GA fires were in May) and in Alabama (-14 ug/m3 out of 27 ug/m3), Florida (-14 ug/m3 out of 23 ug/m3) and Georgia (-13 ug/m3 out of 24 ug/m3). Bias is high in NC in August (

Table 3-12). MB is -11 ug/m3 (out of 26 ug/m3; MFB is -54%).

A bugle plot of domain-wide annual PM2.5 and its major components shows the performance of individual species of PM2.5 during the entire year Figure 3-1. All species of PM2.5 show good performance, within the goal fractional bias, except organic matter (OM). However, OM is within the criteria fractional bias.

Table 3-12 *Statistical evaluation metrics of $PM_{2.5}$ for stites in North Carolina during the August 2007*

Site	Model mean	CSN mean	# of Pairs	cor	ME	MB	NME	NMB	MNE	MNB	MFB	MFE	RMSE
370210034	9.75	25	5	0.67	15.25	-15.25	61.01	-61.01	58.63	-58.63	-84.12	84.12	16.44
370350004	14.34	26.22	5	0.79	11.88	-11.88	45.31	-45.31	43.72	-43.72	-56.6	56.6	12.97
370570002	14.84	27.22	5	0.81	12.38	-12.38	45.47	-45.47	44	-44	-57.3	57.3	13.55
370670022	16.02	27.92	5	0.62	11.9	-11.9	42.63	-42.63	39.65	-39.65	-51.19	51.19	14.38
371070004	9.02	21.12	5	0.6	12.1	-12.1	57.28	-57.28	55.61	-55.61	-78.87	78.87	13.22
371190041	19.06	27.25	10	0.71	8.19	-8.19	30.07	-30.07	29.41	-29.41	-35.76	35.76	9.15
371590021	14.66	28.2	5	0.88	13.54	-13.54	48.01	-48.01	44.99	-44.99	-59.24	59.24	15.37
371830014	16.59	24.74	9	0.56	8.15	-8.15	32.95	-32.95	32.53	-32.53	-40.65	40.65	9.18

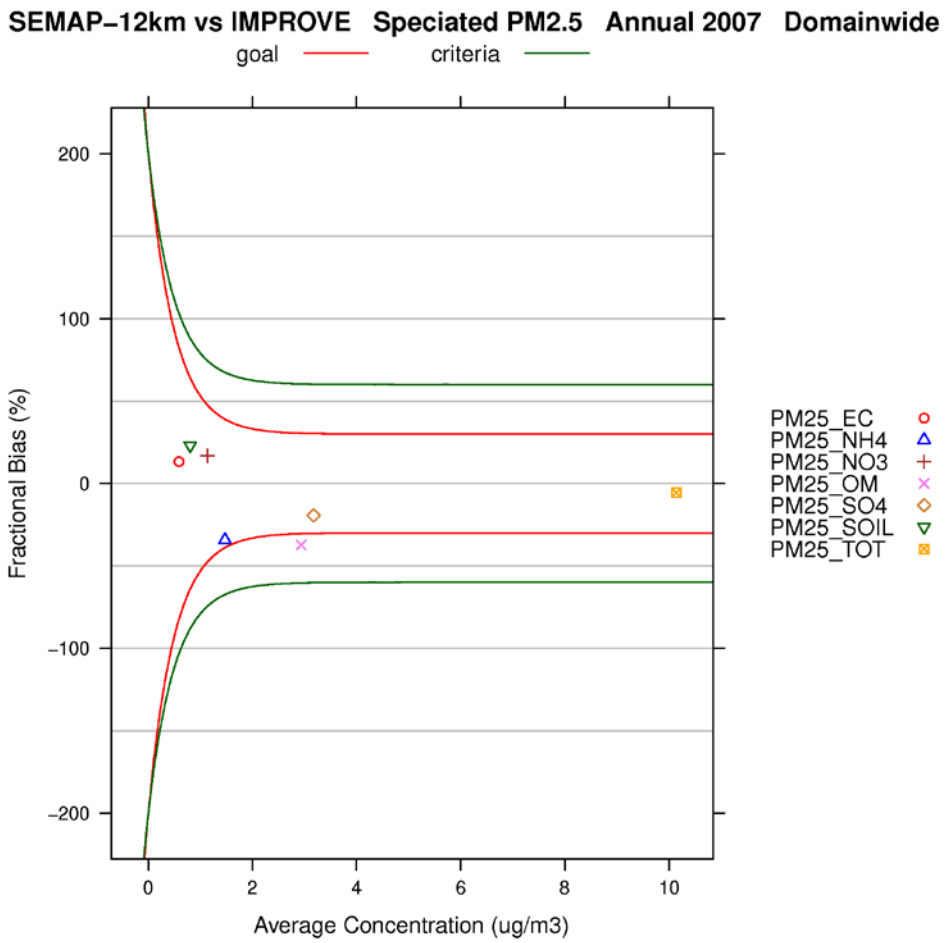


Figure 3-1 Bugle plot of total annual PM2.5 and its major components for the year 2007 base scenario from IMPROVE sites in the entire domain

3.6.3 NADP

Network-wide, annual precipitation MB is -0.37 mm (NMB = -2%) and ME is 12.4 mm (NME=63%). Sulfate deposition performed well with MB of -0.06 kg/ha (NMB = -18%) and ME is 0.2 kg/ha (NME=60%). Nitrate deposition MB is +0.34 kg/ha (NMB = -150%) and ME is 0.4 kg/ha (NME=170%) while ammonium deposition MB is -0.02 kg/ha (NMB = -30%) and ME is 0.05 kg/ha (NME=64%).

Precipitation MB ranges from -3.5 mm in Mississippi (NMB=-17%) to +5.0 mm in West Virginia (NMB=+22%). Sulfate deposition MB ranges from -0.09 kg/ha in Virginia (MFB=-29%) to 0.05 kg/ha in West Virginia (MFB=+4.8%). Nitrate deposition MB tends to be biased high with ranges from +0.18kg/ha in Virginia (NMB=+82%) to 0.63 kg/ha in Florida (NMB=+350%). On the other hand, ammonium deposition is biased low with MB ranges from -0.02kg/ha in Kentucky (MFB=-16%) to 0.00 kg/ha in West Virginia (MFB=-10%). In Florida, Nitrate Deposition MFB is over +115% in June-and 135% in July and August when precipitation MFB is +55% to +65%. Nitrate Deposition MFB is +175% at FL14 where Precipitation MFB is +115% at FL14

3.7 Diagnostics

The initial simulation of the air quality in the year 2007 did not meet all of the model performance goals. In particular, normalized mean error in modeled ozone exceeded the monthly average target of 30-35% (Tesche, 1990) at several monitors. In general, ozone was overestimated at monitors of the Southeast during the summer months, especially in August and in Florida and Georgia. Modeled NO_x concentrations were also very high compared to the observations. To improve model performance the following configurations were tested:

1) Increasing the minimum PBL height and mixing coefficient,
2) Changing the PBL heights along the land-water interface,
3) Reducing the boundary conditions,
4) Removing lightning NO_x emissions,
5) Reducing ground-level NO_x emissions.

3.7.1 Sensitivity to PBL height and Mixing Coefficients

A comparison of the modeled PBL heights to PBL heights inferred from soundings at 15 stations throughout the Southeast revealed that the model may be underestimating the early morning PBL heights. The minimum PBL height in CMAQ 5.0 is set to 20 m. In this sensitivity test minimum PBL heights were changed to typical observed values according to land type (Table 3-13). The minimum values for mixing coefficient K_{zz} were also changed to the values used in version 4.7.1 of CMAQ (Table 3-14).

Table 3-13. Minimum PBL heights used in the sensitivity run

Land type	Minimum PBL height (m)
Coastal rural	60
Coastal urban	100
Inland rural	200
Inland urban	300

Table 3-14. Minimum K_{zz} values used in CMAQ 5.0 and in the sensitivity run (also in CMAQ 4.7.1)

Land type	Minimum K_{zz} (m^2/s)	
	CMAQ 5.0	CMAQ 4.7.1
Rural	0.01	0.5
Urban	1.0	2.0

These changes decreased the early morning NO_x concentrations (Figure 3-2). Because of the decreases in nighttime NO_x, which titrates ozone, nighttime ozone concentrations went up by about 40 ppb over the Southeast (Figure 3-3). This results in a degradation of nighttime ozone performance.

Afternoon NO_x concentrations also decreased in this sensitivity run (Figure 3-4). The largest decreases are observed at coastal areas where the PBL heights are relatively low, and are probably due to the increase in minimum K_{zz} values. There were both increases and decreases in afternoon ozone (Figure 3-5). Note that decreases in NO_x are not always accompanied by decreases in ozone. In fact, at a number of places such as New Orleans, Tampa and Savannah, ozone increased. Ozone may be NO_x inhibited at these locations. These changes in afternoon ozone concentrations have little impact on the 8-hr ozone performance.

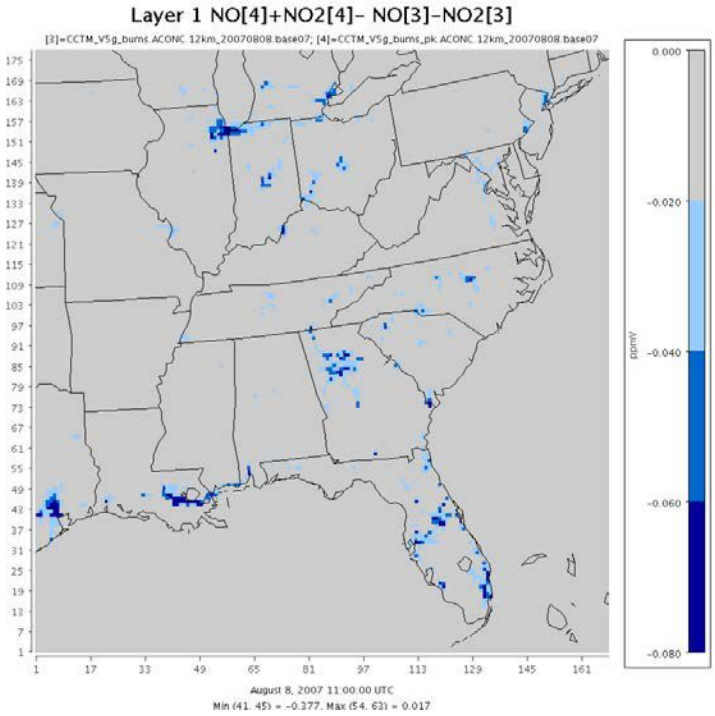


Figure 3-2. Changes in early morning NOx concentrations after the minimum PBL height and minimum Kzz modifications: 11 UTC August 8, 2007

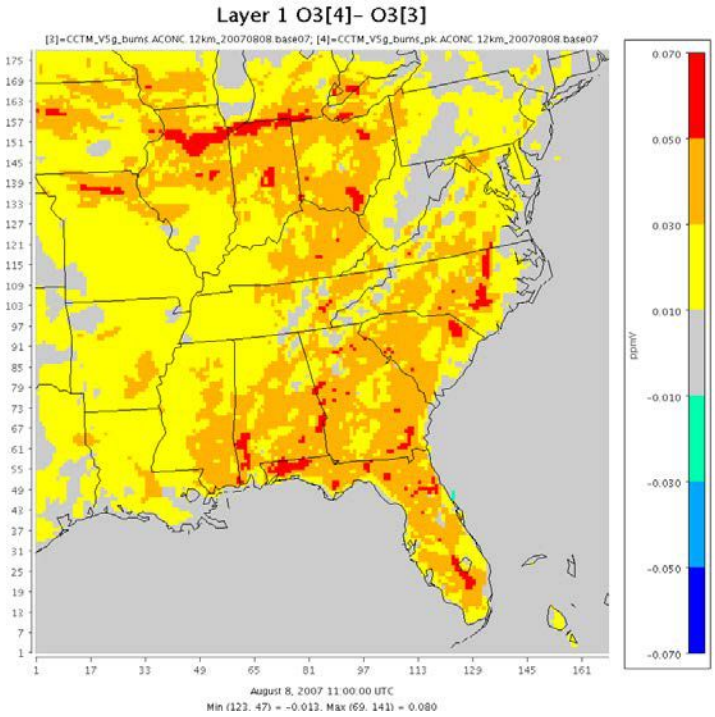


Figure 3-3. Changes in nighttime/early morning ozone after the minimum PBL height and minimum K_{zz} modifications: 11 UTC August 8, 2007

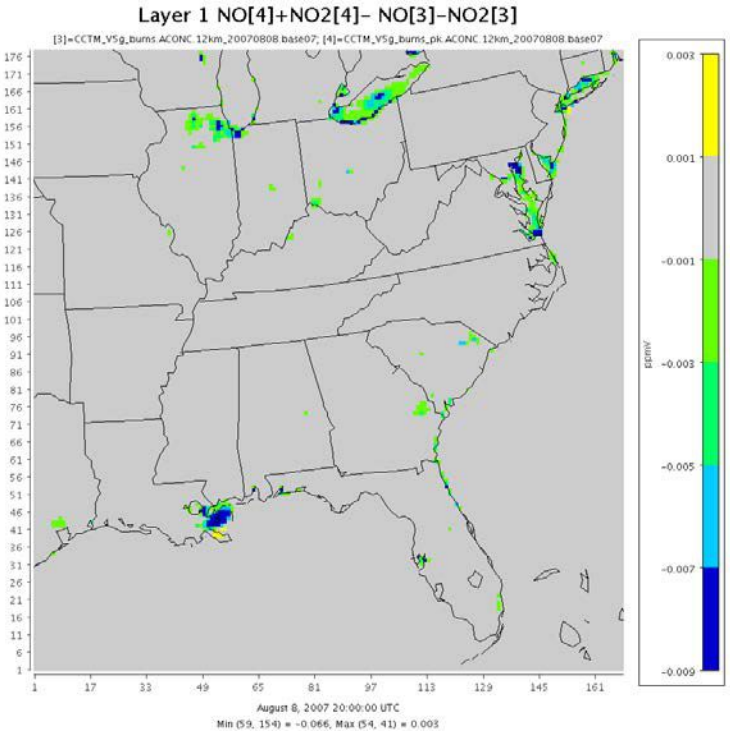


Figure 3-4. Changes in afternoon NO_x concentrations after the minimum PBL height and minimum K_{zz} modifications: 20 UTC August 8, 2007

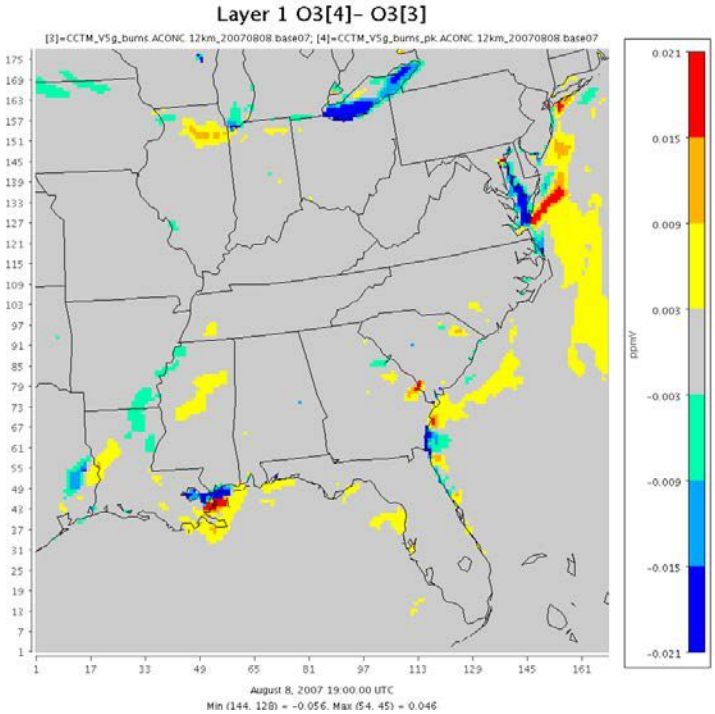


Figure 3-5. Changes in afternoon ozone after the minimum PBL height and minimum K_{zz} modifications: 19 UTC August 8, 2007

3.7.2 Sensitivity to Land-Water Interface

Model performance was compared to performance reported by US EPA for their simulations of the same year. This comparison focused on two coastal sites: one in Delaware and one in Long Island, NY. It was concluded that the differences in ozone between SEMAP and EPA simulations were due to the differences in daytime PBL heights. EPA's WRF runs used a more accurate database to identify the land-water interface. These sites were being assigned land PBL heights in EPA's simulation while they were being assigned, incorrectly, water PBL heights in SEMAP runs; consequently, ozone was being over-predicted at these sites.

In this sensitivity run, the land-water interface was modified by changing the PBL heights along the coast (Figure 3-6). In particular, the PBL heights of blue cells in Figure 3-6 were changed from their original "over-the-water" values to PBL heights of nearby land cells. The minimum PBL height was kept at its original CMAQ 5.0 value of 20 m. However, minimum K_{zz} values were changed to 2.0 and 0.5 m^2/s for urban and rural areas, respectively. In CMAQ 5.0 these values are 1.0 and 0.01 m^2/s, respectively (Table 3-14).

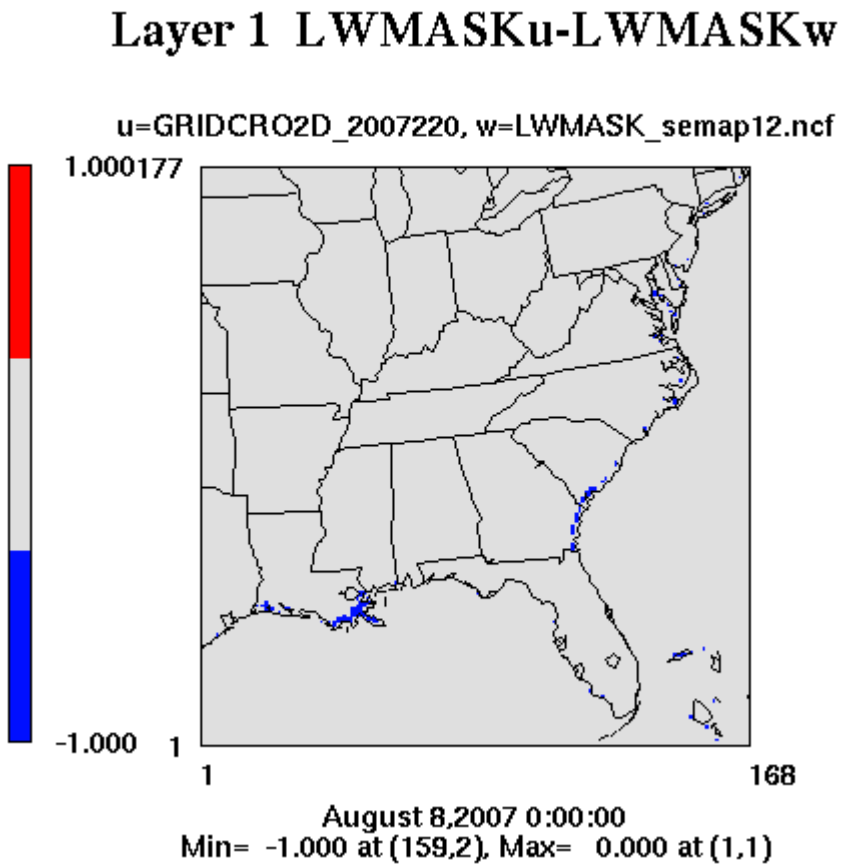


Figure 3-6. Changes made to the land-water interface: land to water (red), no change (gray), and water to land (blue)

Because of the differences in minimum K_{zz} values between this sensitivity run and the initial CMAQ 5.0 run, the results will be compared to the sensitivity run in Section 1.1 (with modified minimum PBL height and minimum K_{zz} values). However, although both sensitivity runs used the same minimum K_{zz} values, the minimum PBL values were different; therefore, the differences between this sensitivity run and the one in Section 1.1 are not solely due to the difference in land-water interface shown in Figure 3-6.

The difference in early morning NO_x between this sensitivity run and the sensitivity run in Section 3.7.1 is shown in Figure 3-7. This difference proves that most of the NO_x decreases shown in Figure 3-2 were due to changing the minimum K_{zz} values. NO_x concentrations increased relative to the previous sensitivity run (by a fraction of the NO_x decreases caused by increasing the K_{zz} values) because of the decrease in minimum PBL heights from 200-300 m inland to 20 m in this sensitivity run. The decrease in NO_x at New Orleans source region is most likely due to switching from water to land PBL heights.

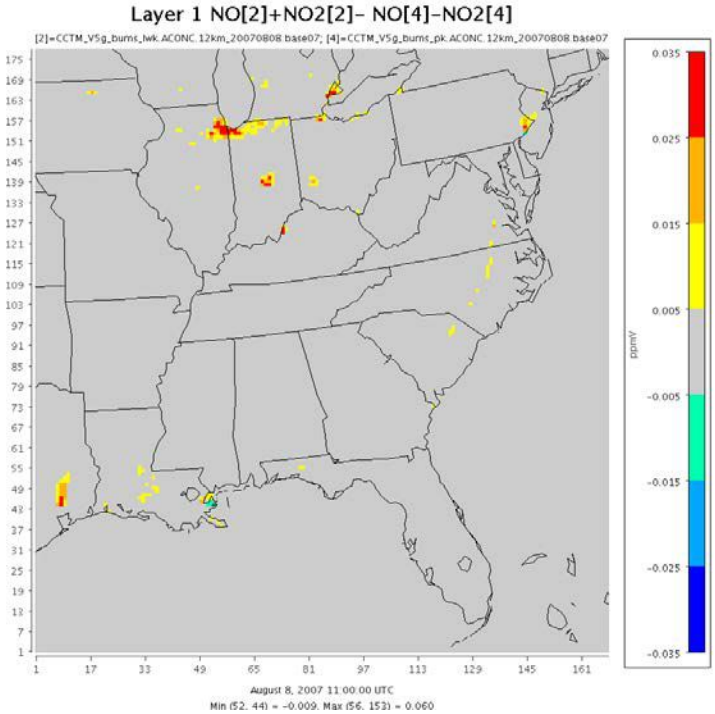


Figure 3-7. Difference in early morning NO_x concentrations between this sensitivity run and the sensitivity run with minimum PBL height and minimum K_{zz} modifications: 11 UTC August 8, 2007

The difference in early morning ozone between this sensitivity run and the sensitivity run in Section 3.7.1 is shown in Figure 3-8. This difference proves that most of the ozone increases in Figure 3-2 were due to changing the minimum K_{zz} values. The inland differences between the two sensitivity runs are manifested mostly as a decrease in ozone in this sensitivity run due to the slight increase in NO_x, which was due to the decrease in minimum PBL height from 200-300 m to 20 m. The increases in ozone at New Orleans and other places may be due to decreases in NO_x or decreases in PBL heights.

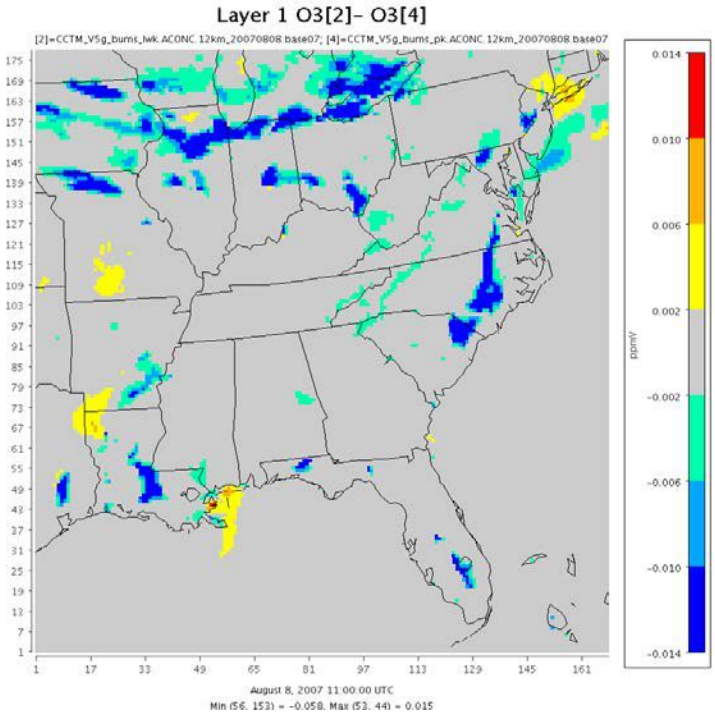


Figure 3-8. Difference in nighttime/early morning ozone concentrations between this sensitivity run and the sensitivity run with minimum PBL height and minimum K_{zz} modifications: 11 UTC August 8, 2007

The difference in afternoon NO_x between the two sensitivity runs is shown in Figure 3-9. The decrease in NO_x at New Orleans is most likely due to switching from water to land PBL heights, which would be higher in the afternoon.

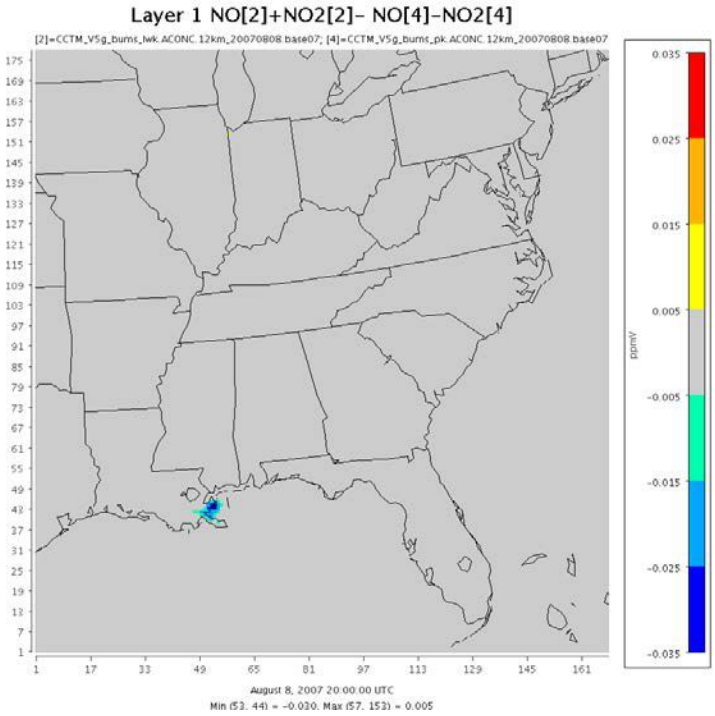


Figure 3-9. Difference in afternoon NO_x concentrations between this sensitivity run and the sensitivity run with minimum PBL height and minimum K_{zz} modifications: 20 UTC August 8, 2007

The difference in afternoon ozone between the two sensitivity runs is illustrated in Figure 3-10. The differences inland and over the Great Lakes are due to the difference in the minimum PBL height. Ozone can increase due to the decrease in minimum PBL height from 200-300 m to 20 m but it can also decrease in places where NO_x emissions are trapped in a shallower PBL and this NO_x abundance is inhibiting ozone, or in places where NO_x emissions from elevated point sources are detached from the PBL. On the other hand, the differences along the coastline, especially in the Gulf of Mexico and South- and Mid-Atlantic, are more likely the effect of switching from water to land PBL heights rather than decreasing the minimum PBL height from 60-100 m to 20 m although the two effects cannot be completely discerned. Regardless of the reason, these differences may slightly improve the afternoon ozone performance at some coastal sites.

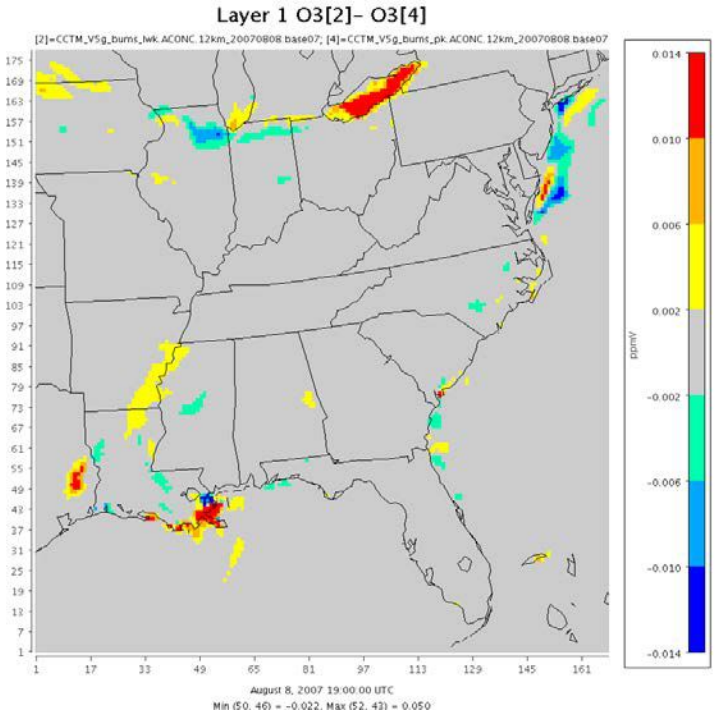


Figure 3-10. Difference in afternoon ozone concentrations between this sensitivity run and the sensitivity run with minimum PBL height and minimum K_{zz} modifications: 19 UTC August 8, 2007

3.7.3 Sensitivity to Boundary Conditions

Modeled ozone was also compared to upper air data. For example, comparison to aircraft data collected during a flight between Maryland and Charlotte, NC in August 2007 showed that ozone aloft is over-predicted just like the surface ozone. Comparison with ozonesonde data from Huntsville, AL and Wallops Island, VA supported this conclusion. It was hypothesized that the over-prediction aloft, as well as at the ground level, may be due to high ozone boundary conditions. The flow patterns were analyzed and it was seen that due to the high pressure system over the Southeast, the conditions along the southeastern boundary of the 36-km domain may affect the ozone concentrations over Florida and along the coast of Gulf of Mexico, in early August 2007. Those boundary conditions were obtained from the GEOS-Chem model.

A sensitivity run was conducted by reducing the levels of all species by 50% along the boundaries of the 36-km domain. The results of this simulation were then applied as boundary conditions to the 12-km SEMAP domain.

The decreases in afternoon ozone levels due to 50% reduction of boundary conditions are shown in Figure 3-11 and Figure 3-12. On August 8, 2007, a poor ozone performance day, the decreases in afternoon ozone would be less than 6 ppb over large portions of the Southeast. However, on August 15, a good ozone performance day, the decreases would be larger, as much as 10 ppb, over most of the Southeast. This may degrade ozone performance on August 15 by more than the improvement that can be achieved on August 8.

In this sensitivity run, the reductions in ozone concentrations led to increases in early morning NO_x, which was already overestimated throughout the region.

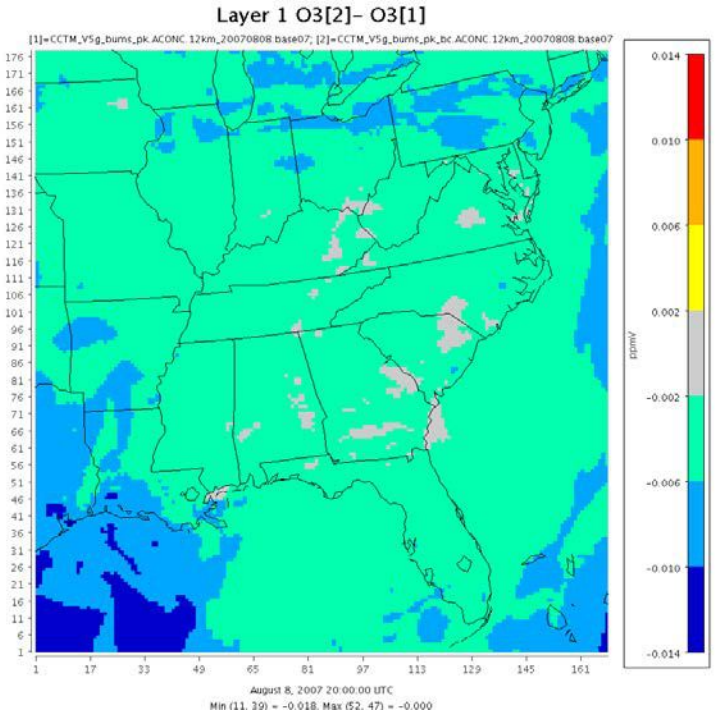


Figure 3-11. Changes in afternoon ozone due to 50% reduction of boundary conditions: 20 UTC August 8, 2007

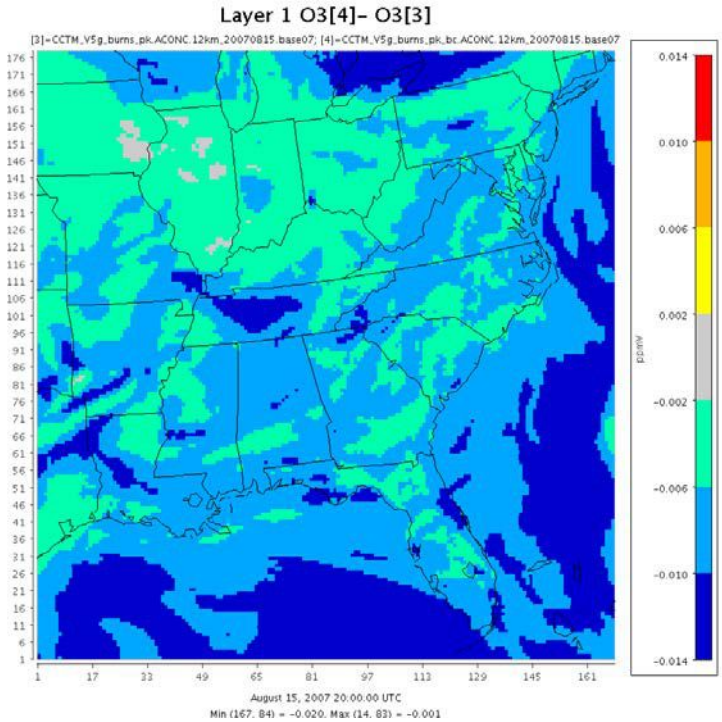


Figure 3-12. Changes in afternoon ozone due to 50% reduction of boundary conditions: 20 UTC August 15, 2007

3.7.4 Sensitivity to Lightning NO_x Emissions

In the initial simulation, CMAQ 5.0 was configures to calculate lightning NO_x emissions inline. One option for inline lightning NO_x emission calculation in CMAQ 5.0 is to use the modeled lightning strikes but due to the large uncertainty in modeled lightning this option is not recommended. Alternatively, modeled lightning can be adjusted using data from lightning detection networks. We chose this option and employed the monthly flash count frequency (flash/m^2) file prepared by US EPA for the CONUS 12-km grid. This method is relatively new and may be subject to uncertainties. As a diagnostic sensitivity, the lightning NO_x emissions were turned off and the differences in NO_x and ozone concentrations were observed.

On August 8, 2007, turning off lightning NO_x emissions decreased afternoon ozone by 5 to 20 ppb (Figure 3-13). Since afternoon ozone was over-predicted on that day, turning off lightning NO_x emissions would certainly improve ozone performance.

On August 15, 2007, turning off lightning NO_x emissions did not have any effect over the inland portion of the SEMAP domain (Figure 3-14). It only decreased ozone along the coast and also in Florida. Since afternoon ozone performance was good on that day except in Florida, turning off lightning NO_x emissions would not degrade ozone performance. In fact, it would improve it in Florida where ozone was over-predicted.

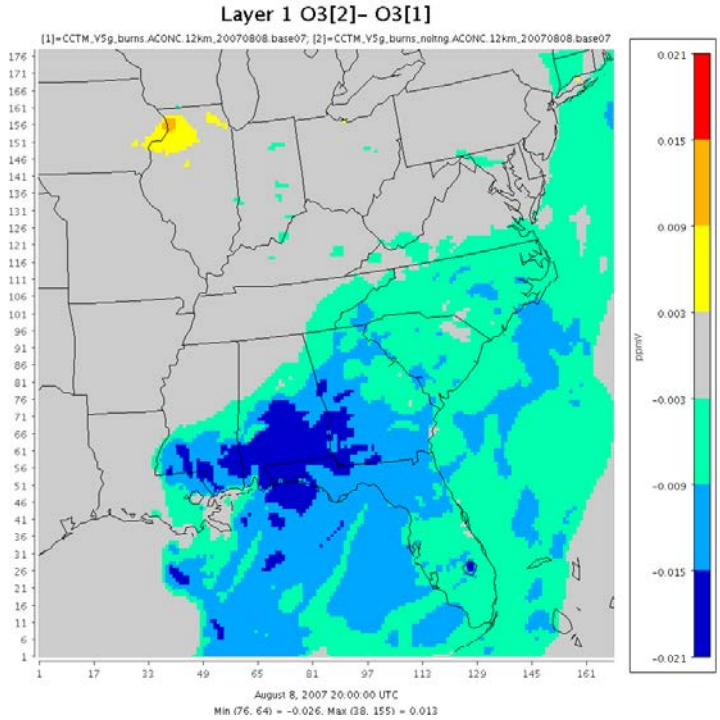


Figure 3-13. Changes in afternoon ozone after turning off lightning NO_x emissions: 20 UTC August 8, 2007

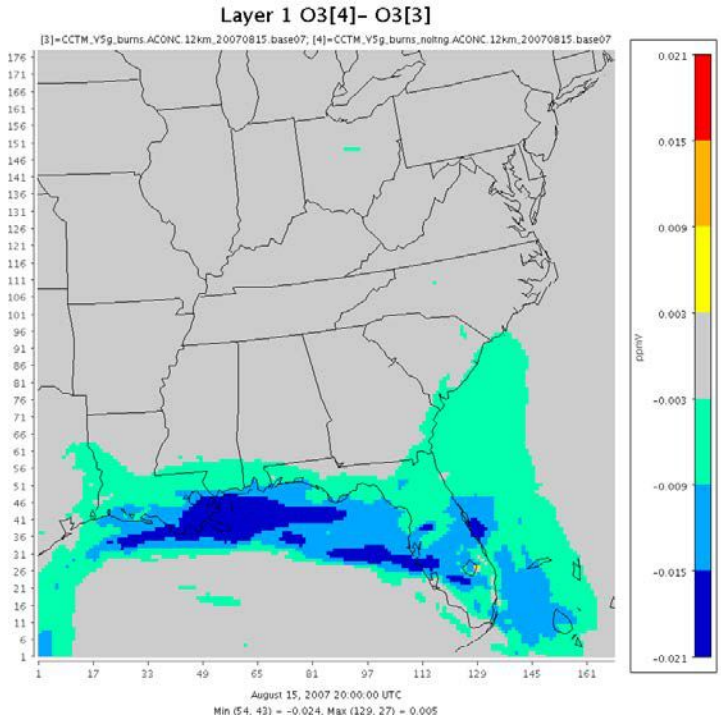


Figure 3-14. Changes in afternoon ozone after turning off lightning NO_x emissions: 20 UTC August 15, 2007

3.7.5 Sensitivity to Ground-level NO_x Emissions

Excessive lightning NO_x emissions may explain part of the ozone over-prediction at the ground-level and aloft. But there must be other factors leading to the ozone over-prediction. Also, since lightning NO_x emissions have little effect on the ground-level NO_x concentrations, the over-prediction of ground-level NO_x must be due to other factors.

At part of the investigation, model performance in initial simulation was compared to the model performance in Georgia Tech's past air quality forecasts for the year 2007. Ozone performance during the month of August was acceptable in those forecasts. What could be the reason(s) for this difference in ozone performance?

One interesting discovery made during the investigation was that the ground-level NO_x emissions in the SEMAP inventory were approximately 30% larger than those used in Georgia Tech's forecasts. The emissions used in the forecasts were grown from the VISTAS typical 2002 inventory.

A sensitivity run was conducted by reducing ground-level NO_x emissions by 30%. The differences in afternoon ozone between this sensitivity run and the initial simulation are shown in Figure 3-15 and Figure 3-16. On August 8, at 20 UTC, the decrease in ozone is 5-10 ppb over most of the Southeast. This would potentially improve ozone performance. Meanwhile, ozone increased at a number of urban areas including Houston, New Orleans, Tampa, Miami, Norfolk and Baltimore. This may degrade ozone performance at those locations. Also, on August 15, the decrease in ozone may degrade performance.

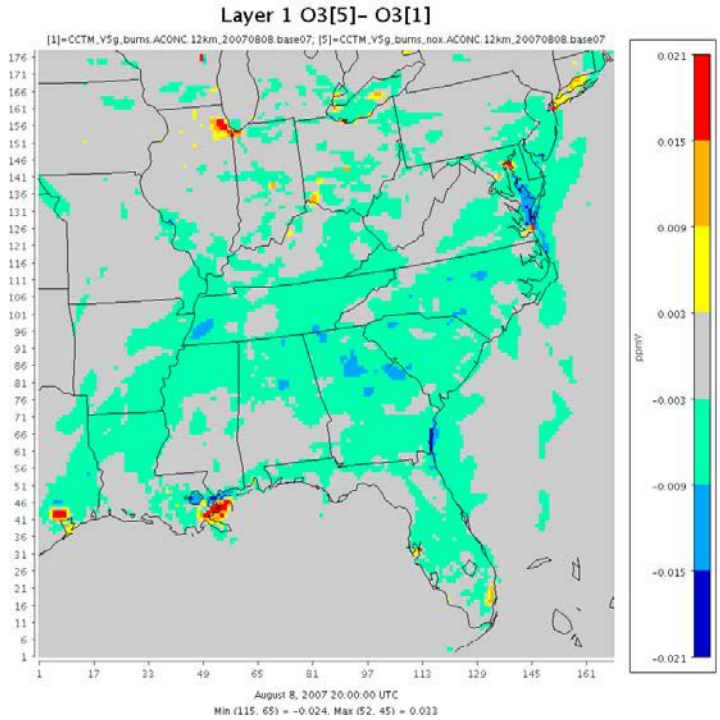


Figure 3-15. Changes in afternoon ozone after 30% reduction of ground-level NO_x emissions: 20 UTC August 8, 2007

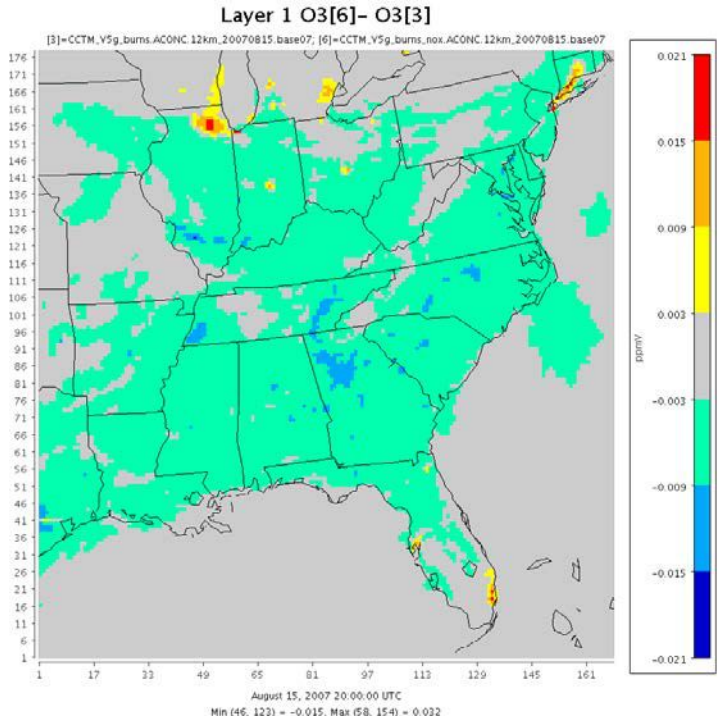


Figure 3-16. Changes in afternoon ozone after 30% reduction of ground-level NO_x emissions: 20 UTC August 15, 2007

3.7.6 Uncertainties in Meteorological Inputs

Comparisons of clouds and rain in SEMAP modeling to satellite and radar observations showed that the ozone performance issues may be related, in part, to the performance of the meteorological model. For example, at 21 UTC on August 8, 2007 the observed clouds and rain were more scattered while the modeled clouds and rain appeared to be clustered (Figure 3-17). Both of these fields were more scattered in the Georgia Tech forecasts. Clouds and rain may have direct effects on ozone performance.

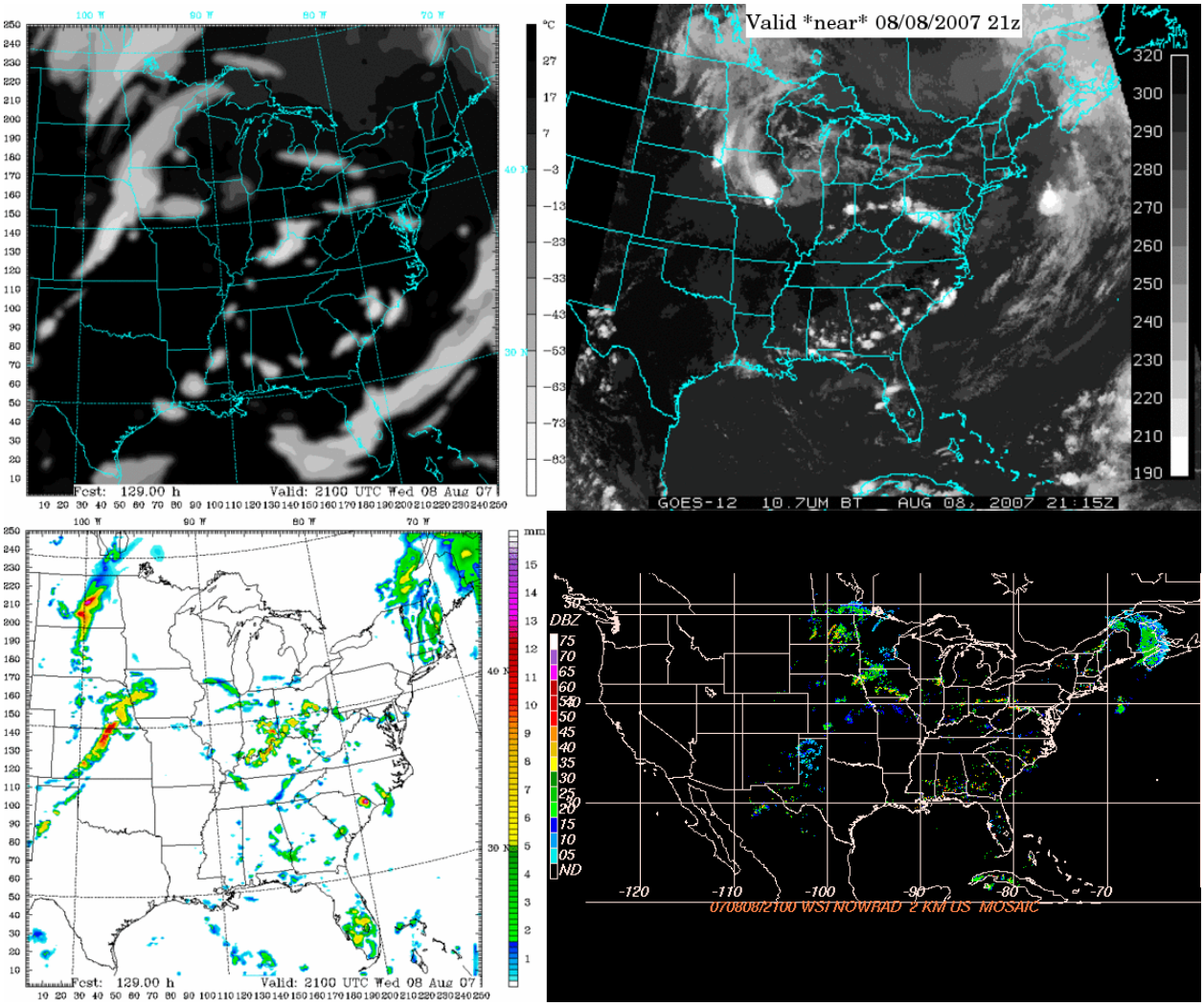


Figure 3-17. Modeled (left) and observed (right) clouds (top) and rain (bottom): 21 UTC August 8, 2007 (provided by Mr. Nick Witcraft of North Carolina DENR, Division of Air Quality)

Another factor that may affect ozone performance is wind speed. The wind speeds in SEMAP's WRF simulation were underestimated (Figure 3-18). Typically, low wind speeds lead to high ozone concentrations; therefore, the wind speed under-prediction may be one of the reasons for ozone over-prediction. The wind speeds were higher in the Georgia Tech forecasts.

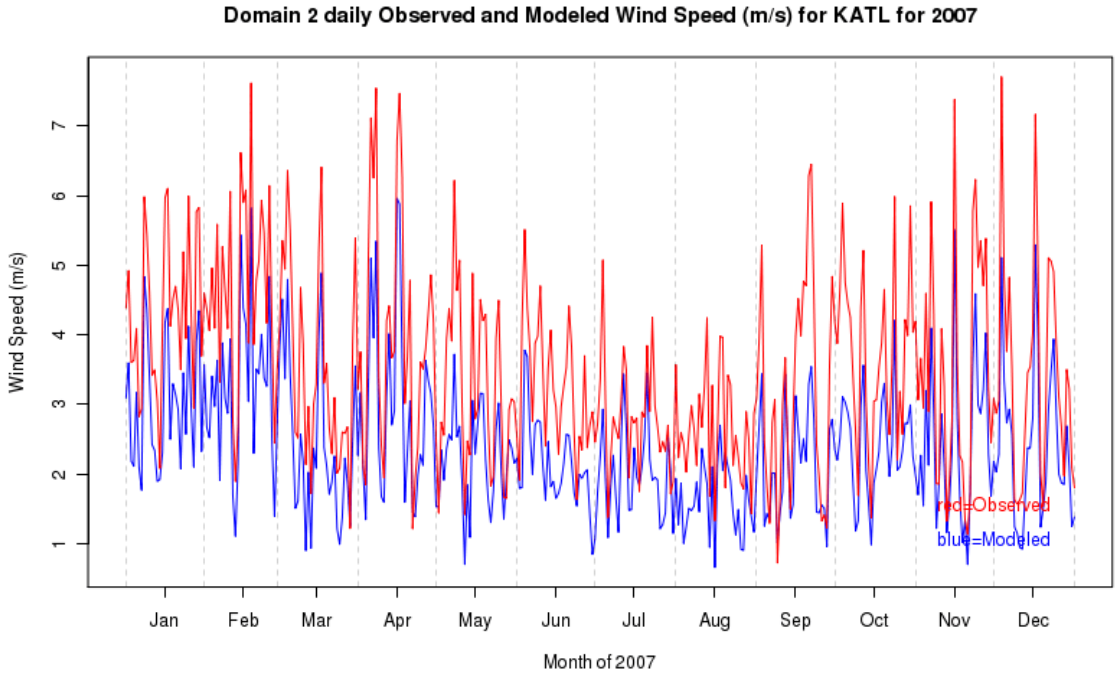


Figure 3-18. Comparison of observed (red) and modeled (blue) wind speeds in Atlanta (from page 61 of AER's WRF Performance Evaluation Report-Part 1)

3.7.7 Recommendations for Final Model Configuration

Based on the results of the diagnostic sensitivity analysis, here are our recommendations for the final modeling configuration.

1) Some of the meteorological fields such as clouds, rain and winds could be improved and those improvements might improve ozone modeling performance. Any changes to the meteorological fields should be done through WRF runs to preserve the consistency among the fields. Rerunning the meteorology of the entire year using a different version or configuration of WRF would be costly and time consuming. Therefore, it is not recommended at this point.
2) The NO_x emissions have been reviewed by UNC and no anomalies were found. Since the 2007 SEMAP inventory is one of the best estimates available, any arbitrary changes to the inventory such as 30% reduction of ground-level NO_x emissions or emissions from a certain sector such as on-road mobile emissions cannot be justified.
3) Similarly, there is little evidence to justify the reduction of boundary conditions that were derived from GEOS-Chem, one of the state-of-the-art global chemistry models commonly used for providing boundary conditions to regional-scale models.
4) On the other hand, the reduction of lightning NO_x emissions can be justified. No study to date indicated as large an impact on surface ozone as the lightning NO_x emissions in the initial simulation has produced. The method used for adjusting the flash counts is relatively new and may be enhancing the impact. Therefore, we recommend turning off the lightning NO_x emissions in the final modeling.
5) Also, we recommend reverting back to the minimum K_{zz} values used in CMAQ 4.7.1. This did not have a significant impact on ozone performance but it did improve NO_x performance. Also, it improved the overall elemental carbon performance.

6) We recommend changing the PBL heights along the coast from "over-the-water" values to nearby land cell values if the cells are more than 50% land according to the more accurate coastal information. In our sensitivity tests, this change improved ozone performance at coastal monitors.
7) We do not recommend changing the minimum PBL height. It did not have a significant impact on ozone performance inland. Along the coast, changing the minimum PBL height may interfere with the switch from water to land PBL heights recommended above.

3.8 Final Model Performance

3.8.1 AQS Ozone

Annual network-wide O_3 MB without using a cut-off is +5.2 ppb (out of 31 ppb, for a NMB of +17%) and ME is 12 ppb (NME = 37%). With a 60 ppb cut-off, the network-wide annual O_3 MB is -5.4 ppb (out of 69 ppb, for a NMB of -8%) and ME is 11 ppb. MFB is -10% and MFE is 17%. Bias and error are smallest for coastal SEMAP states (MFB = -8% and MFE = 15%) and larger for interior SEMAP (KY, TN and WV; MFB = -13% and MFE = 17%) or neighboring states. The network-wide 8-hr max ozone with no cut-off MB is +3 ppb (out of 47 ppb). MFB is +6%. ME is 8 ppb. MFE is 19%. With a cut-off of 60 ppb the MB is -3 ppb (out of 69 ppb). MFB is -5%. ME is 8 ppb. MFE is 12%. The bias and error are smallest for the coastal SEMAP states and larger for the interior SEMAP and neighboring states. In WV, TN and KY MBs are -4 to -6 ppb and MEs are 8 ppb (MFEs are 12%). In VA ans GA biases are positive and small but the errors are large. MBs are 0.09 and 0.63 ppb (MFBs are -0.74 and -0.25%) and MEs are 8.1 and 8.2 ppb (MFEs are both 11.8%).

3.8.2 $PM_{2.5}$

The AQS 24-hr network-wide, MB for $PM_{2.5}$ is -0.53 ug/m3 (out of 13 ug/m3; MFB is -5.2%) and ME is 5 ug/m3 (MFE is 38%). For total $PM_{2.5}$ at CSN sites, the network-wide MB is -1.4 ug/m3 (out of 15 ug/m3; MFB is -11%) and ME is 5.5 ug/m3 (MFE is 37%). MB is negative (about 5ug/m3; MFB is about -33%) for SEMAP states and positive for neighboring states (MB is 0.4 ug/m3 out of 15 ug/m3). Annual bias is largest in Louisiana and WV (MB = 10.5 and -6.1 ug/m3; MFB = 41% and -42%). In GA MB is -5.3 ug/m3 (out of 17 ug/m3; MFB = -33%) and ME is 6.3 ug/m3 (MFE = 42%). The largest monthly biases are in May for coastal SEMAP states (recall that FL-GA fires were in May) and in May and August for all interior SEMAP states. In Alabama MB is -15.5 ug/m3 out of 26.6 ug/m3. In Florida MB is -15 ug/m3 out of 23 ug/m3 and in Georgia MB is -14.6 ug/m3 out of 24 ug/m3. Bias is high in NC in August. MB is -12.6 ug/m3 (out of 25.6 ug/m3; MFB is -66%) (

Table 3-15).

A bugle plot of domain-wide annual PM2.5 and its major components shows the performance of individual species of PM2.5 during the entire year Figure 3-1. All species of PM2.5 show similar good performance, within the goal fractional bias, except organic matter (OM). In the final scenario, OM is still within the criteria fractional bias.

Table 3-15 Statistical evaluation metrics of PM2.5 for stites in North Carolina during the August 2007

Site	Month	Model Mean	CSN mean	# pairs	cor	ME	MB	NME	NMB	MNE	MNB	MFB	MFE	RMSE
370210034	2007-08	10.7	25.0	5	0.84	14.32	-14.32	57.28	-57.28	54.60	-54.60	-76.28	76.28	15.48
370350004	2007-08	12.2	26.2	5	0.80	13.98	-13.98	53.31	-53.31	52.42	-52.42	-71.51	71.51	14.90
370570002	2007-08	12.4	27.2	5	0.74	14.85	-14.85	54.56	-54.56	53.48	-53.48	-74.03	74.03	16.03
370670022	2007-08	13.4	27.9	5	0.72	14.54	-14.54	52.07	-52.07	49.95	-49.95	-67.69	67.69	16.46
371070004	2007-08	7.7	21.1	5	0.62	13.43	-13.43	63.60	-63.60	62.82	-62.82	-93.15	93.15	14.42
371190041	2007-08	16.5	27.3	10	0.78	10.79	-10.79	39.61	-39.61	39.67	-39.67	-50.52	50.52	11.38
371590021	2007-08	11.0	23.9	4	0.80	12.88	-12.88	53.88	-53.88	52.83	-52.83	-72.26	72.26	13.50
371830014	2007-08	14.9	24.7	9	0.67	9.85	-9.85	39.80	-39.80	39.77	-39.77	-50.98	50.98	10.50

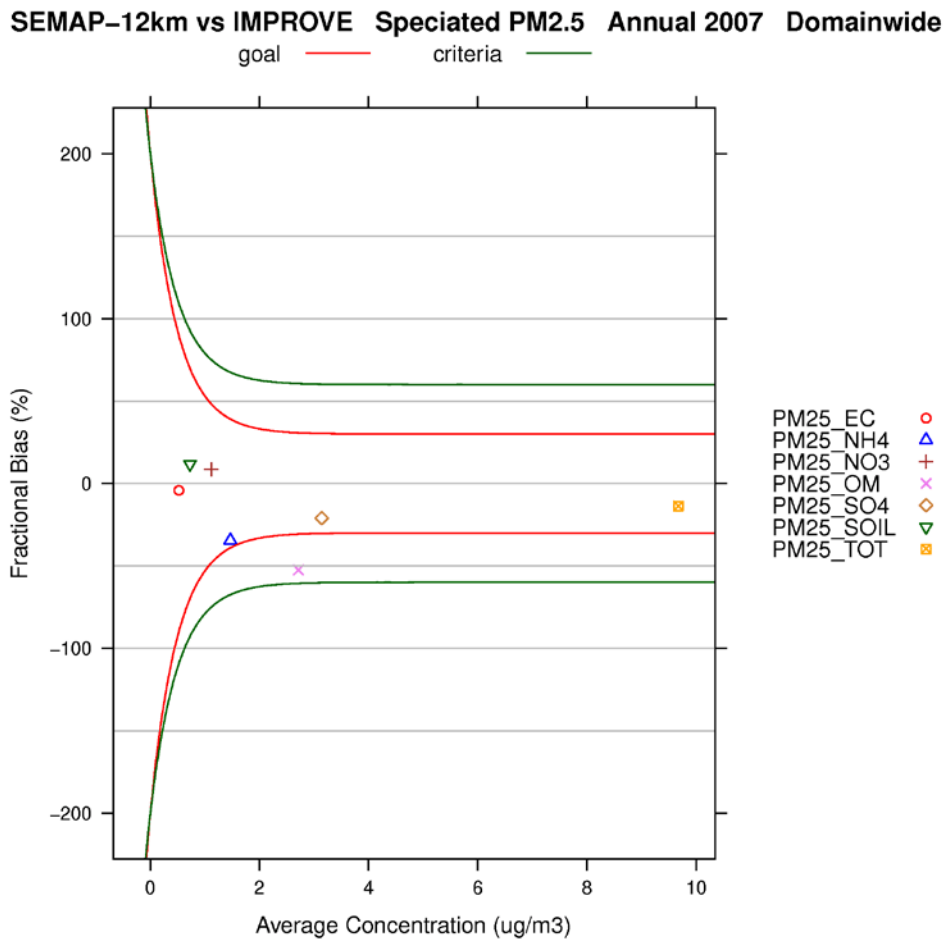


Figure 3-19 Bugle plot of total annual PM2.5 and its major components for the year 2007 final scenario from IMPROVE sites in the entire domain

3.8.3 NADP

Network-wide, annual precipitation MB is -0.4 mm (NMB = -2%) and ME is 12.5 mm (NME = 62%). Sulfate deposition performed well with MB of -0.06 kg/ha (NMB = -19%) and ME is 0.2 kg/ha (NME = 60%). Nitrate deposition performed better than the initial runs, with MB of -0.03 kg/ha (NMB = -13%) and ME is 0.13 kg/ha (NME = 58%) while ammonium deposition MB is -0.02 kg/ha (NMB = -26%) and ME is 0.05 kg/ha (NME = 65%).

Precipitation MB ranges from -3.5 mm in Mississippi (NMB = -17%) to +5.0 mm in West Virginia (NMB = +22%). Sulfate deposition MB ranges from -0.2 kg/ha in Delaware (NMB = -48%) to 0.07 kg/ha in West Virginia (NMB = 17%). The Nitrate deposition high bias is fixed in this run, with bias ranges from -0.15 kg/ha in Kansas (NMB = -48%) to 0.05 kg/ha in West Virginia (NMB = 20.7%). Also, ammonium deposition low bias in the initial runs are higher, with MB ranges from -0.09 kg/ha in Iowa (NMB = -58%) to 0.0 kg/ha in West Virginia (NMB = 6.4%).

3.9 Typical vs. Actual Year Performance

3.9.1 Capping of fire emissions

In addition to using typical fire emissions in the SESARM states, another difference of the 2007 typical case from the 2007 actual case has been the capping of fire emissions in the non-SESARM states. During the comparisons of typical emissions to actual emissions it was noticed that the fire emissions from the non-SESARM states are probably too high. Especially in Mississippi and Louisiana some fire emissions estimated by SMARTFIRE-V2 appeared to be unreasonably high. The maximum of the Alabama and Tennessee fire emissions from the 2007 SEMAP inventory was used to cap the fire emissions in non-SESARM states.

The actual 2007 simulation was not repeated with these capped non-SESARM state fire emissions since the effects were found to be limited to a handful of monitors close to the boundaries with non-SESARM states. The typical 2007 performance may be a more accurate representation of model performance at those monitors.

3.9.2 AQS Ozone

Overall, the typical year simulation performed similarly to the actual year simulation. Annual network-wide O_3 MB without using a cut-off is +5.1 ppb (out of 31 ppb, for a NMB of +16%) and ME is 12 ppb (NME = 37%). With a 60 ppb cut-off, the network-wide annual O_3 MB is -5.7 ppb (out of 69 ppb, for a NMB of -8%) and ME is 11 ppb. MFB is -10% and MFE is 17%. MFB is -10% and MFE is 17%. As for the actual year simulations, typical year bias and error are smallest for coastal SEMAP states (MFB = -8% and MFE = 15%) and larger for interior SEMAP (KY, TN and WV; MFB = -13% and MFE = 17%) or neighboring states. The network-wide 8-hr max ozone with no cut-off MB is +3 ppb (out of 47 ppb). MFB is +6%. ME is 8 ppb. MFE is 19%. Using a cut-off of 60 ppb, the actual and typical year simulations performed almost identically, with the MB is -3 ppb (out of 69 ppb). MFB is -5%. ME is 8 ppb. MFE is 12%. The bias and error are smallest for the coastal SEMAP states and larger for the interior SEMAP and neighboring states. In WV, TN and KY MBs are -4 to -6 ppb and MEs are 8 ppb (MFEs are 12%). In Georgia the bias are positive and small but the errors are large. MB is 0.4 ppb (MFB is -0.54 %) and MEs are 8.3ppb (MFE is 11.9%).

3.9.3 $PM_{2.5}$

The PM2.5 performance for the actual and typical year simulations are also similar. The AQS 24-hr network-wide, MB for $PM_{2.5}$ is MB is -0.77 ug/m3 (out of 13 ug/m3; MFB is -6.4%) and ME is 5 ug/m3 (MFE is 38%). For total $PM_{2.5}$ at CSN sites, the network-wide MB is --1.6 ug/m3 (out of 15 ug/m3; MFB is -12%) and ME is 5.5 ug/m3 (MFE is 38%). MB is negative (about 5ug/m3; MFB is about -34%) for SEMAP states and positive for neighboring states (MB is 0.2 ug/m3 out of 15 ug/m3). For the typical year simulation, annual bias is largest in Alabama, as opposed to Louisiana, and WV (MB = -6.1 and -6.2 ug/m3; MFB = -35% and -44%). In GA MB is -5.4 ug/m3 (out of 17 ug/m3; MFB = -34%) and ME is 6.5 ug/m3 (MFE = 43%). Again, the largest monthly biases are in May for coastal SEMAP states and in May and August for all interior SEMAP states. In Alabama MB is -16.4 ug/m3 out of 26.6 ug/m3. In Florida MB is -16.1 ug/m3 out of 23 ug/m3 and in Georgia MB is -15.4 ug/m3 out of 24 ug/m3. Similar to the typical year simulation, bias is high in NC in August. MB is -13 ug/m3 (out of 25.6 ug/m3; MFB is -70%) (

Table 3-16).

A bugle plot of domain-wide annual PM2.5 and its major components shows the performance of individual species of PM2.5 during the entire year Figure 3-1. All species of PM2.5 show similar good performance to the final, within the goal fractional bias, except organic matter (OM). In the final scenario, OM is still within the criteria fractional bias. Ammonia aerosol is also just reaching the goal performance.

Table 3-16 Statistical evaluation metrics of PM2.5 for stites in North Carolina during the August 2007

Site	Month	Model Mean	CSN mean	# pairs	cor	ME	MB	NME	NMB	MNE	MNB	MFB	MFE	RMSE
370210034	2007-08	10.1	25.0	5	0.96	14.95	-14.95	59.79	-59.79	57.46	-57.46	-81.53	81.53	16.02
370350004	2007-08	11.6	26.2	5	0.73	14.58	-14.58	55.62	-55.62	54.77	-54.77	-75.99	75.99	15.55
370570002	2007-08	11.9	27.2	5	0.78	15.31	-15.31	56.24	-56.24	55.35	-55.35	-77.36	77.36	16.40
370670022	2007-08	12.9	27.9	5	0.75	15.06	-15.06	53.95	-53.95	52.00	-52.00	-71.28	71.28	16.89
371070004	2007-08	7.4	21.1	5	0.59	13.69	-13.69	64.83	-64.83	63.77	-63.77	-95.14	95.14	14.71
371190041	2007-08	16.2	27.3	10	0.80	11.06	-11.06	40.59	-40.59	40.65	-40.65	-51.91	51.91	11.60
371590021	2007-08	10.7	23.9	4	0.88	13.21	-13.21	55.25	-55.25	54.37	-54.37	-74.99	74.99	13.77
371830014	2007-08	14.0	24.7	9	0.67	10.72	-10.72	43.34	-43.34	43.11	-43.11	-56.03	56.03	11.30

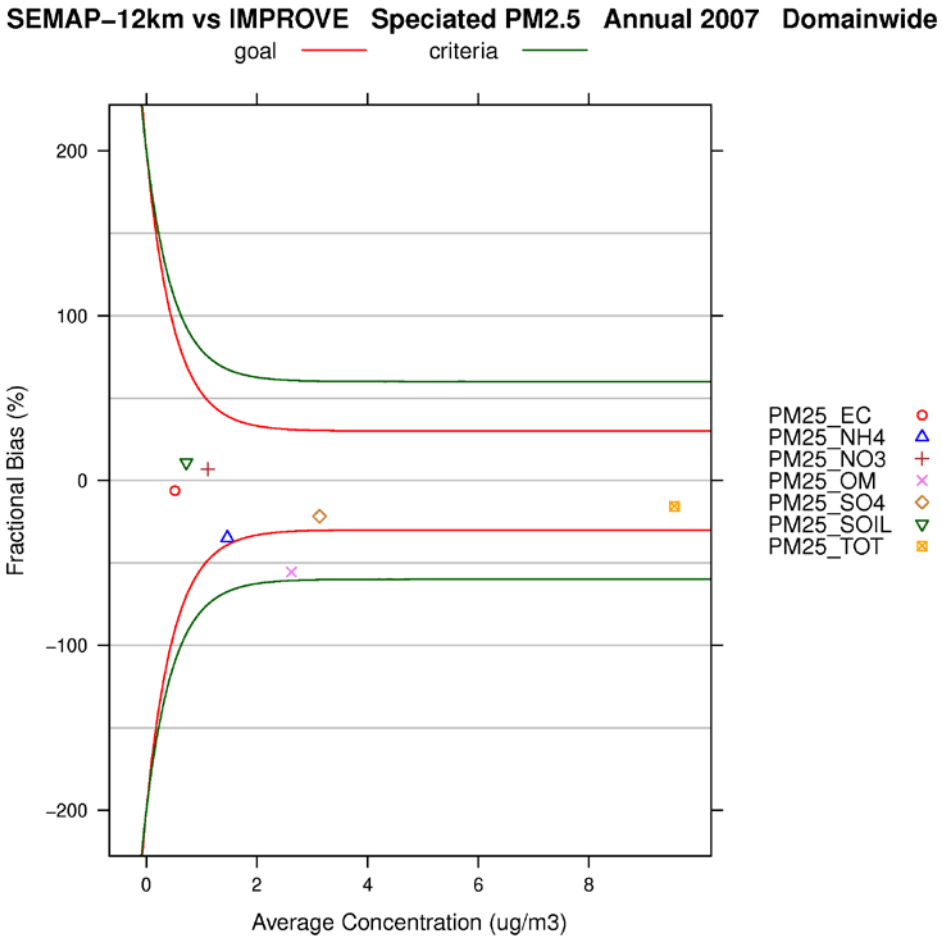


Figure 3-20 Bugle plot of total annual PM2.5 and its major components for the year 2007 final typical emissions scenario from IMPROVE sites in the entire domain

3.9.4 NADP

The actual and typical year simulations also performed similarly for deposition. Network-wide, annual precipitation MB is -0.4 mm (NMB = -2%) and ME is 12.5 mm (NME = 62%). Sulfate deposition performed well with MB of -0.07 kg/ha (NMB = -19%) and ME is 0.2 kg/ha (NME = 60%). Nitrate deposition performed better than the initial runs, with MB of -0.03 kg/ha (NMB = -13%) and ME is 0.13 kg/ha (NME = 58%) while ammonium deposition MB is -0.02 kg/ha (NMB = -26%) and ME is 0.05 kg/ha (NME = 65%).

State-by-state, actual and typical year simulations performed almost identically for deposition. Precipitation MB ranges from -3.5 mm in Mississippi (NMB = -17%) to +5.0 mm in West Virginia (NMB = +22%). Sulfate deposition MB ranges from -0.2 kg/ha in Delaware (NMB = -48%) to 0.07 kg/ha in West Virginia (NMB = 17%). The Nitrate deposition high bias is fixed in this run, with bias ranges from -0.15 kg/ha in Kansas (NMB = -48%) to 0.05 kg/ha in West Virginia (NMB = 20.7%). Also, ammonium deposition low bias in the initial runs are higher, with MB ranges from -0.09 kg/ha in Iowa (NMB = -58%) to 0.0 kg/ha in West Virginia (NMB = 6.4%).

3.10 Conclusions

3.10.1 Ozone and precursors

Monthly mean normalized biases (MNB) in 8-hr maximum O_3 at the AQS sites of the SEMAP 12-km domain generally remained between -15% and +15% in April, May, and October 2007 with a few exceptions (Figure 3-21 through Figure 3-27). In June most Florida sites were biased more than +15%. The high bias spread to some Alabama and Georgia sites in July and persisted through September. On the other hand, monthly mean normalized errors (MNE) in 8-hr maximum O_3 remained less than 35%, except at a very few AQS sites (Figure 3-28 through Figure 3-34). Note that MNB and MNE used in this section were calculated only for values of 8-hr maximum O_3 larger than 60 ppb. In general, it was not possible to find precursor data and perform diagnostic evaluation at the sites that did not meet the ozone performance goals.

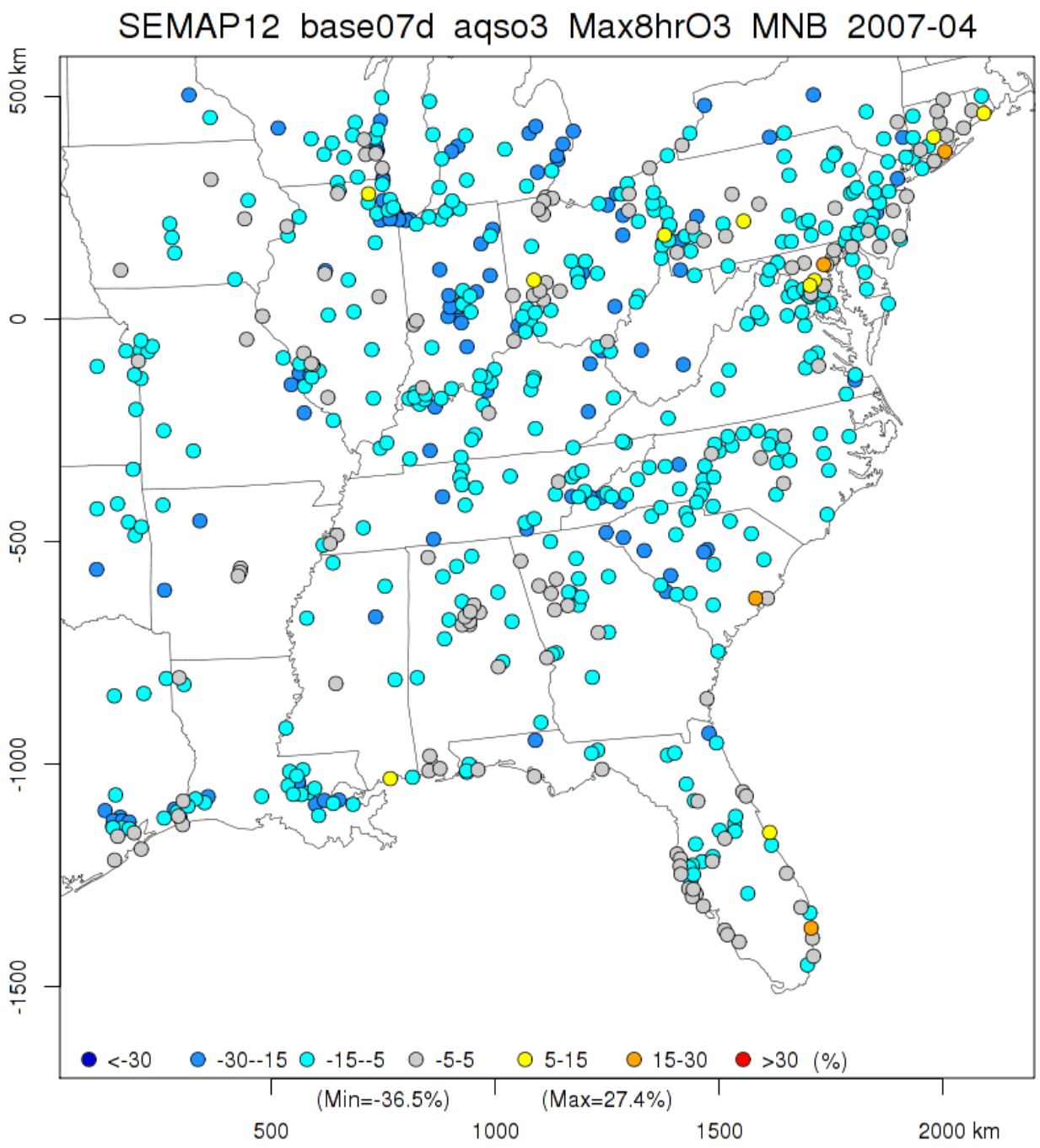


Figure 3-21 April 2007 mean normalized biases (MNB) in 8-hr maximum O_3 at AQS sites.

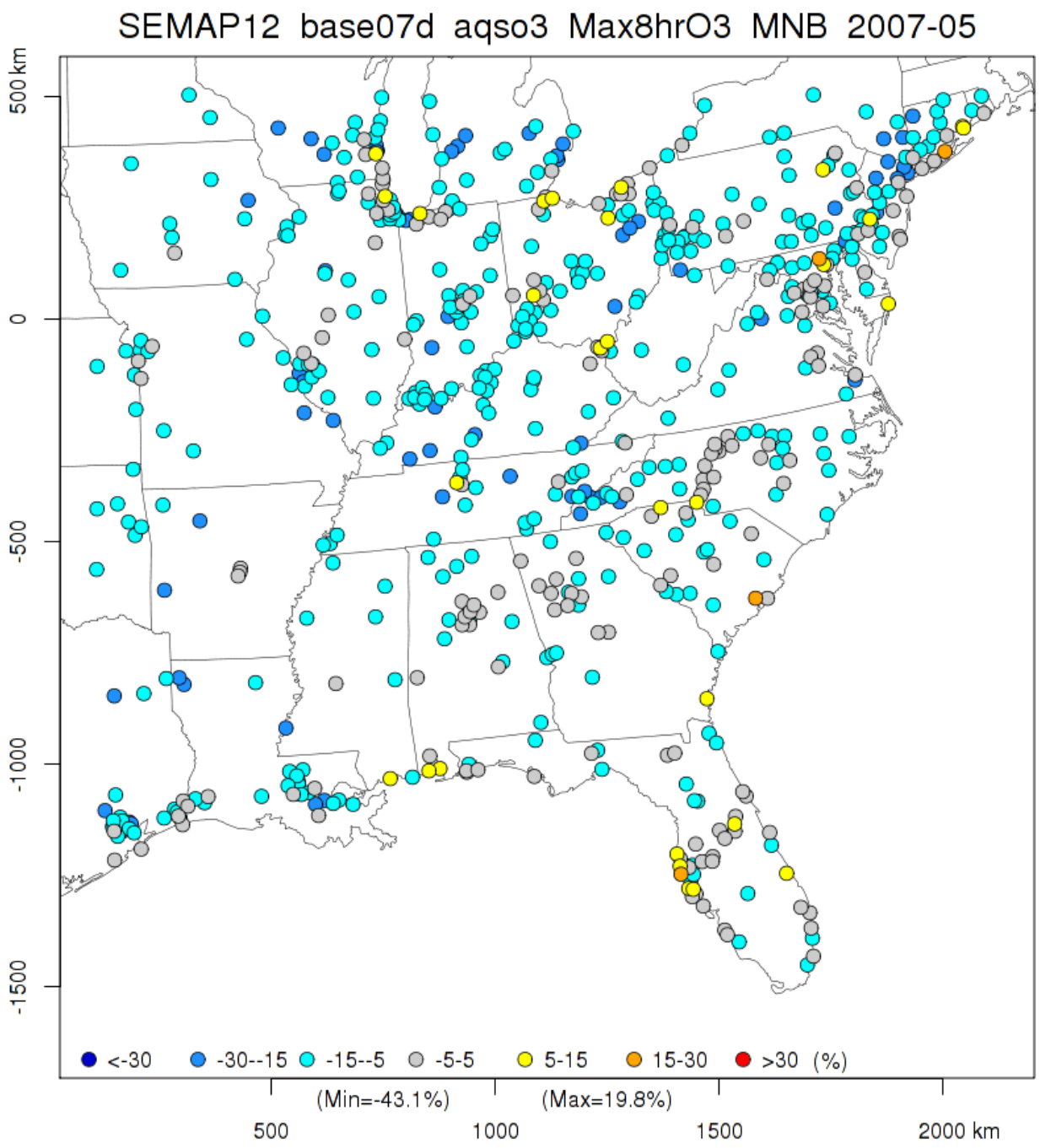


Figure 3-22 May 2007 mean normalized biases (MNB) in 8-hr maximum O_3 at AQS sites.

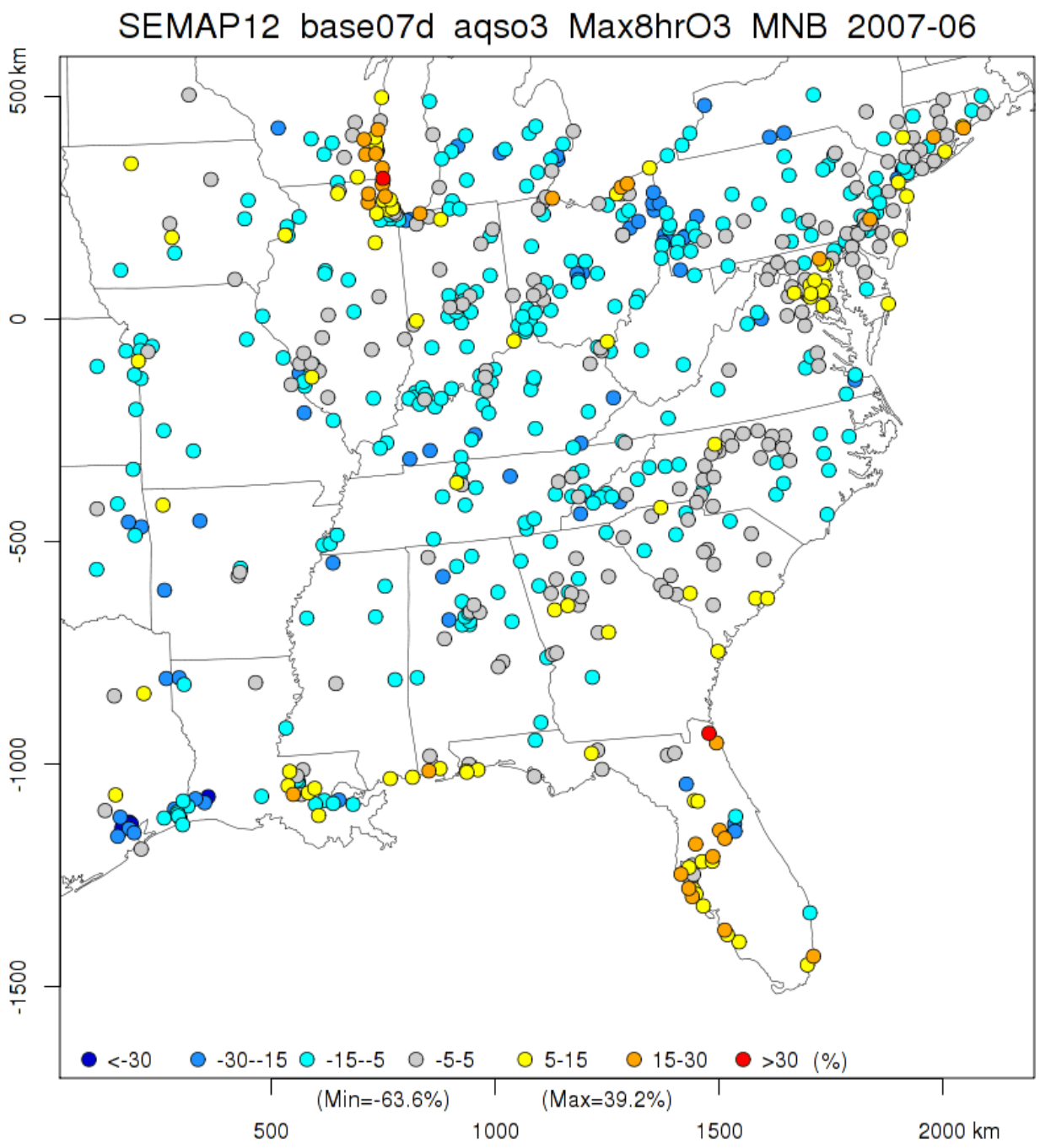


Figure 3-23 June 2007 mean normalized biases (MNB) in 8-hr maximum O_3 at AQS sites.

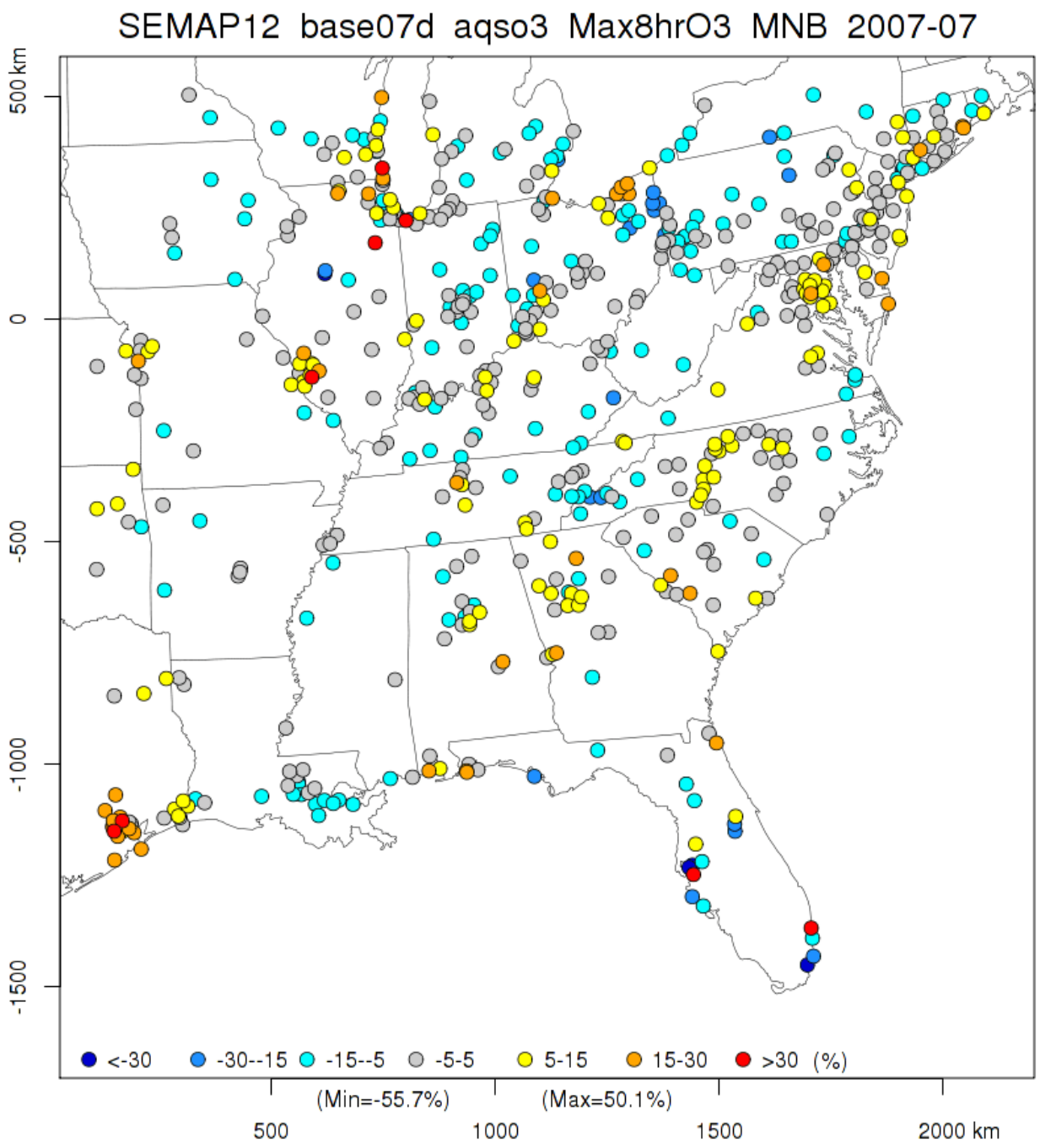


Figure 3-24 July 2007 mean normalized biases (MNB) in 8-hr maximum O_3 at AQS sites.

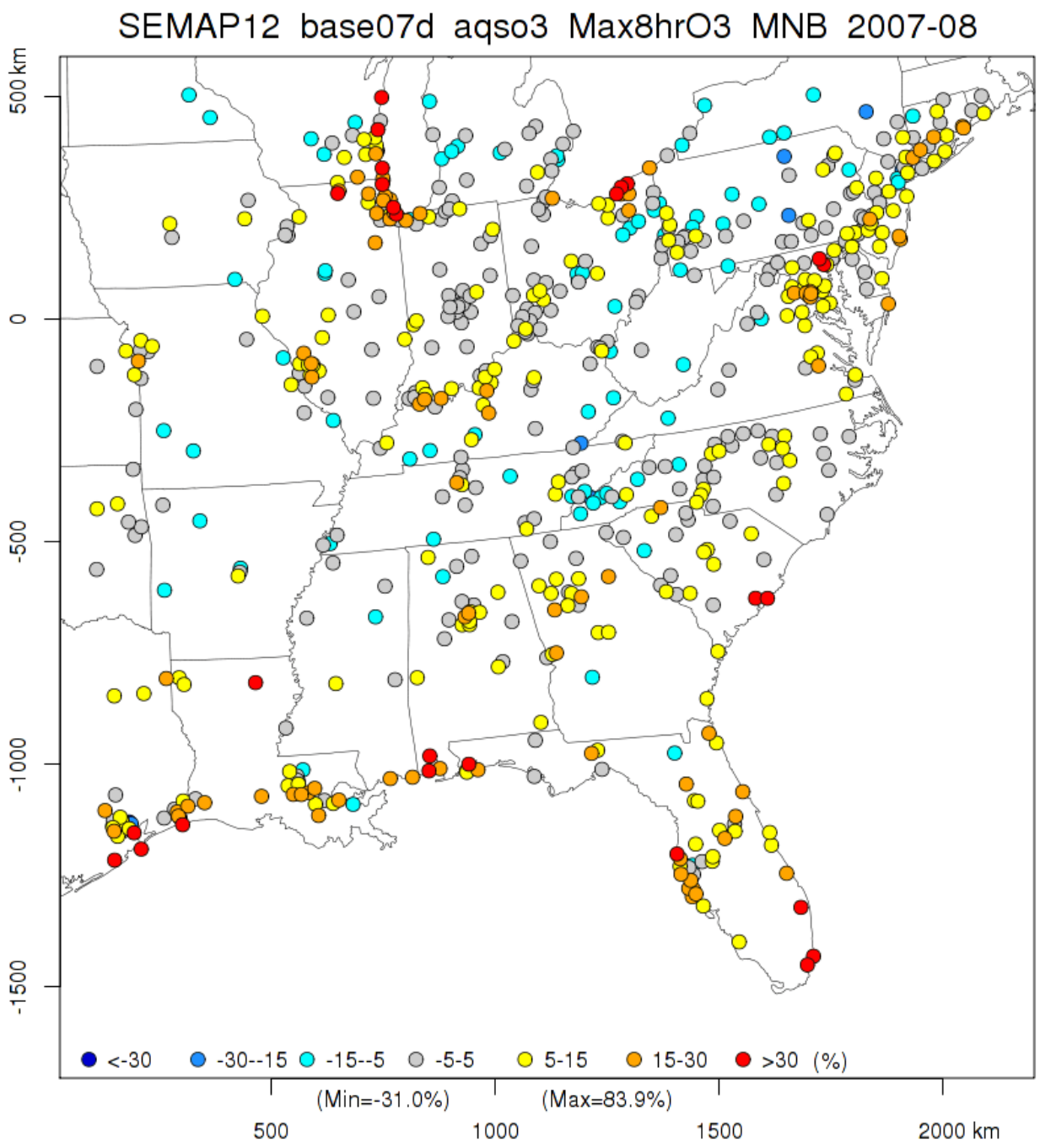


Figure 3-25 August 2007 mean normalized biases (MNB) in 8-hr maximum O_3 at AQS sites.

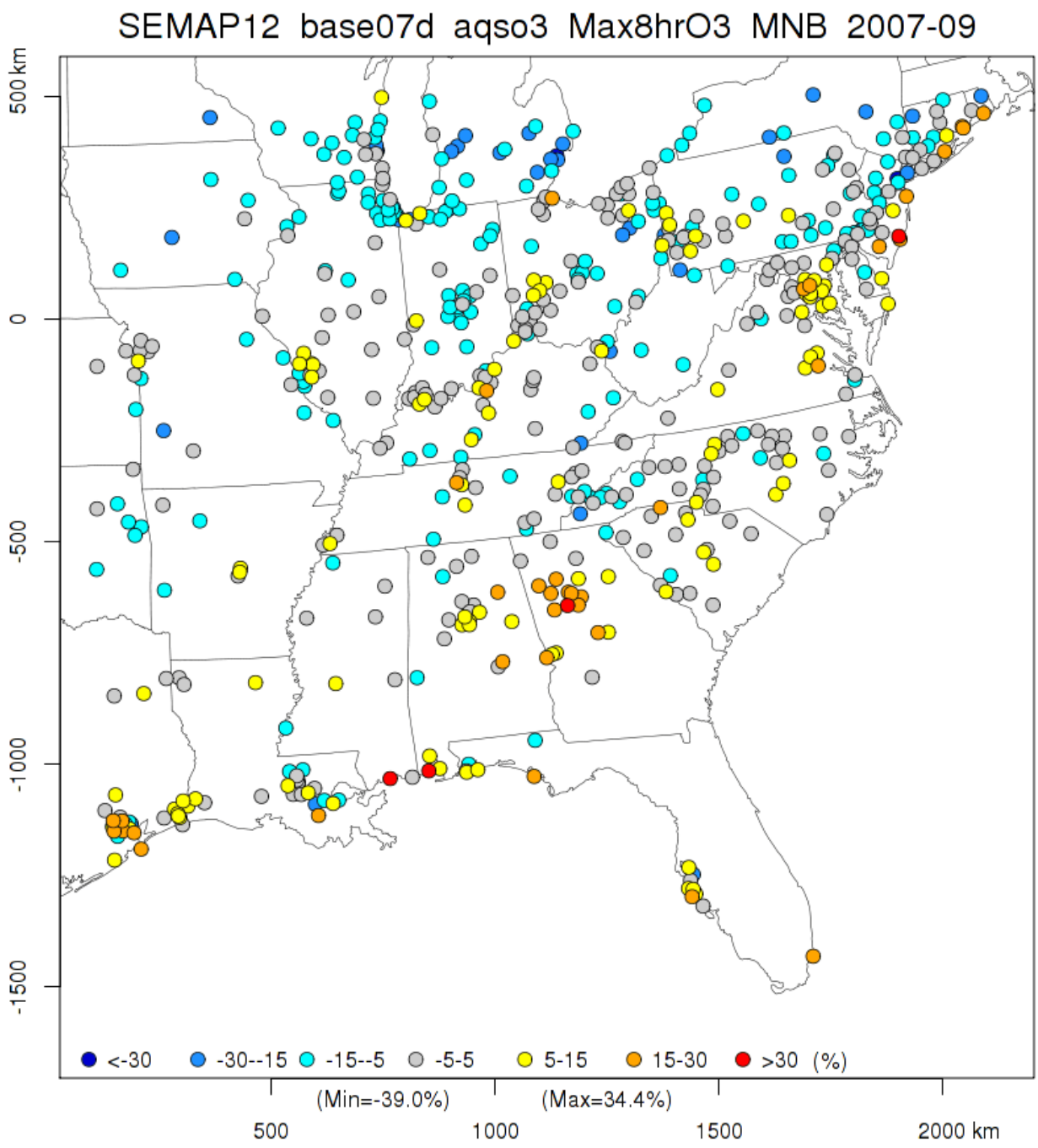


Figure 3-26 September 2007 mean normalized biases (MNB) in 8-hr maximum O_3 at AQS sites.

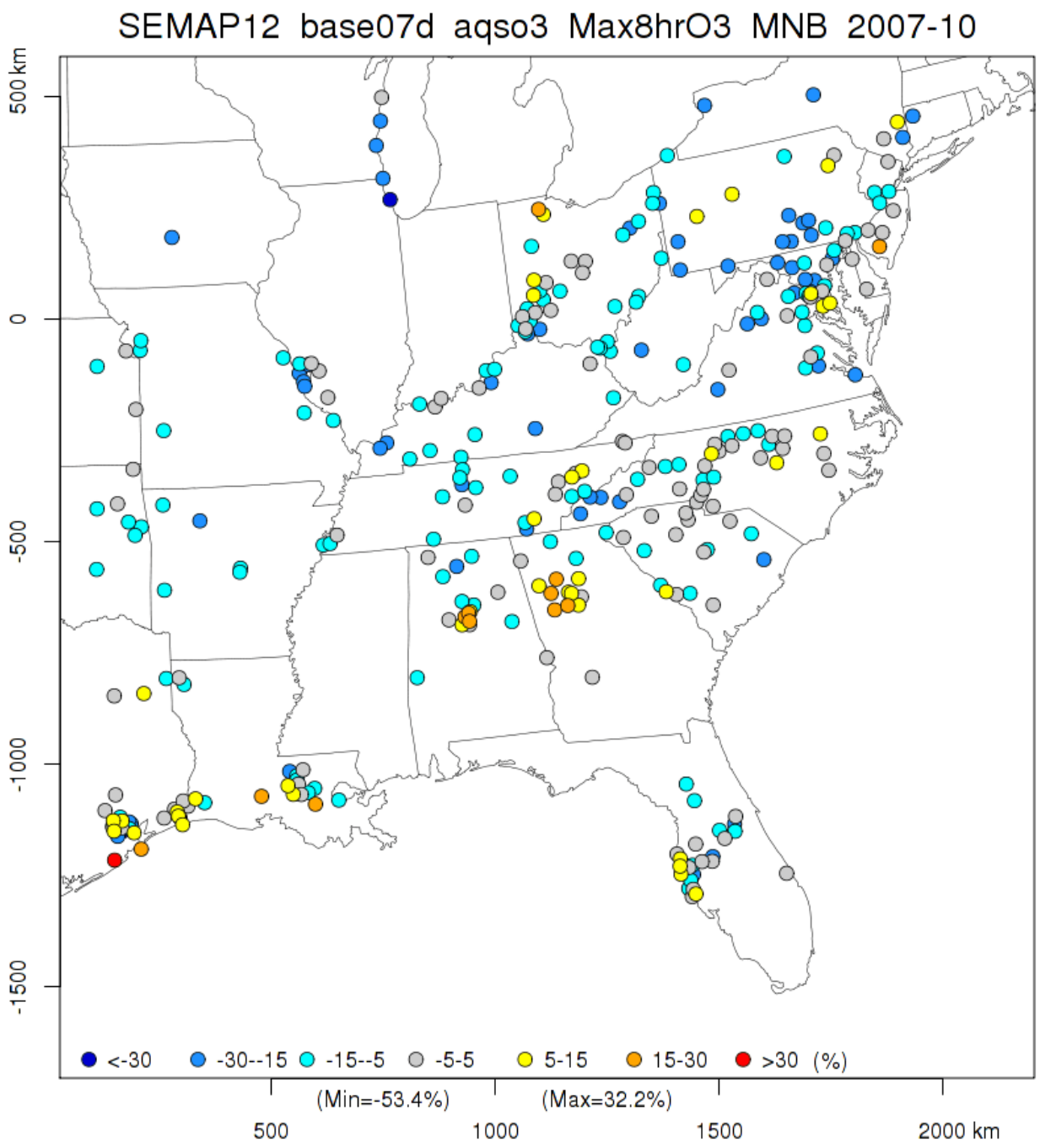


Figure 3-27 October 2007 mean normalized biases (MNB) in 8-hr maximum O_3 at AQS sites.

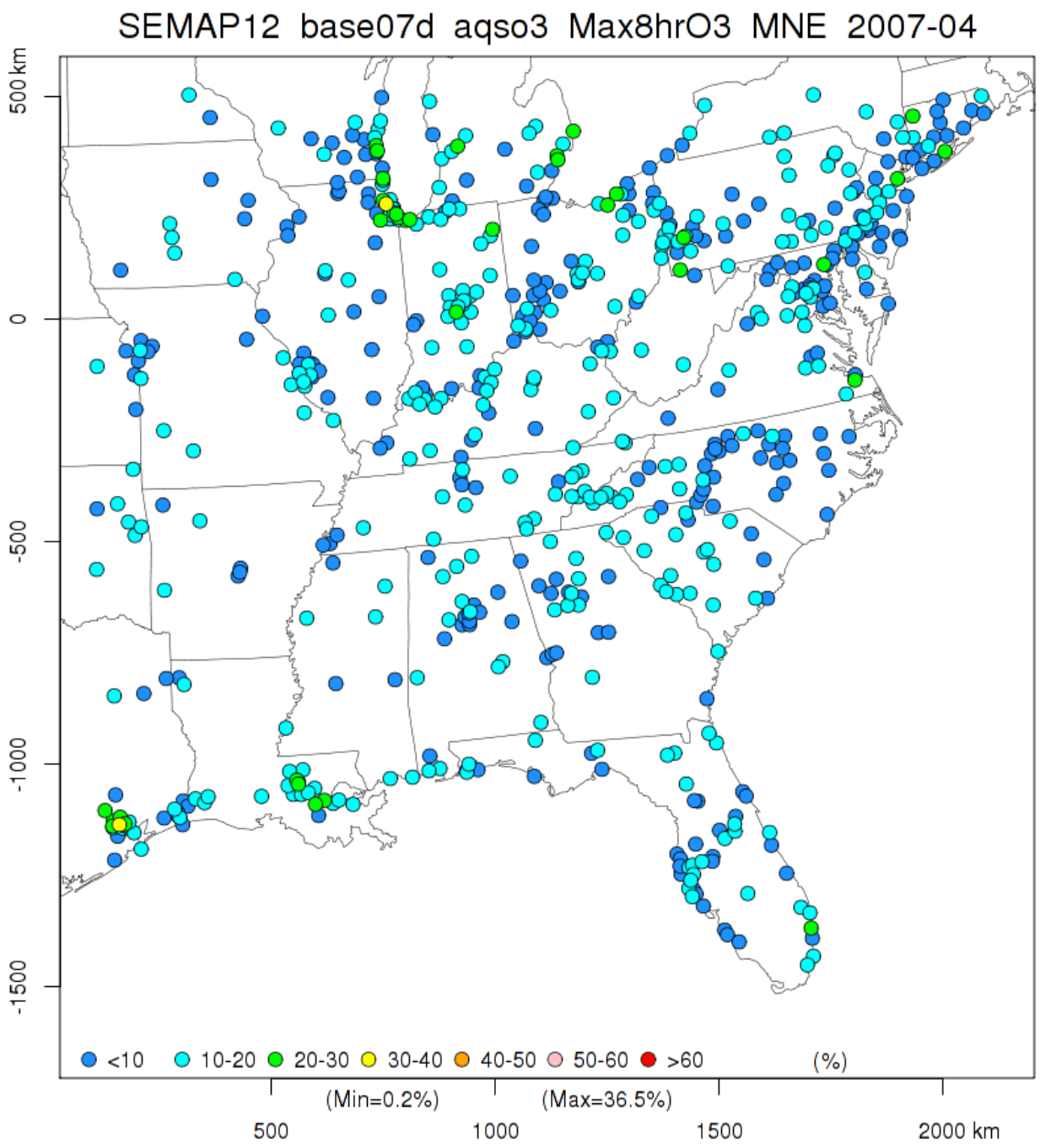


Figure 3-28 April 2007 mean normalized errors (MNE) in 8-hr maximum O_3 at AQS sites.

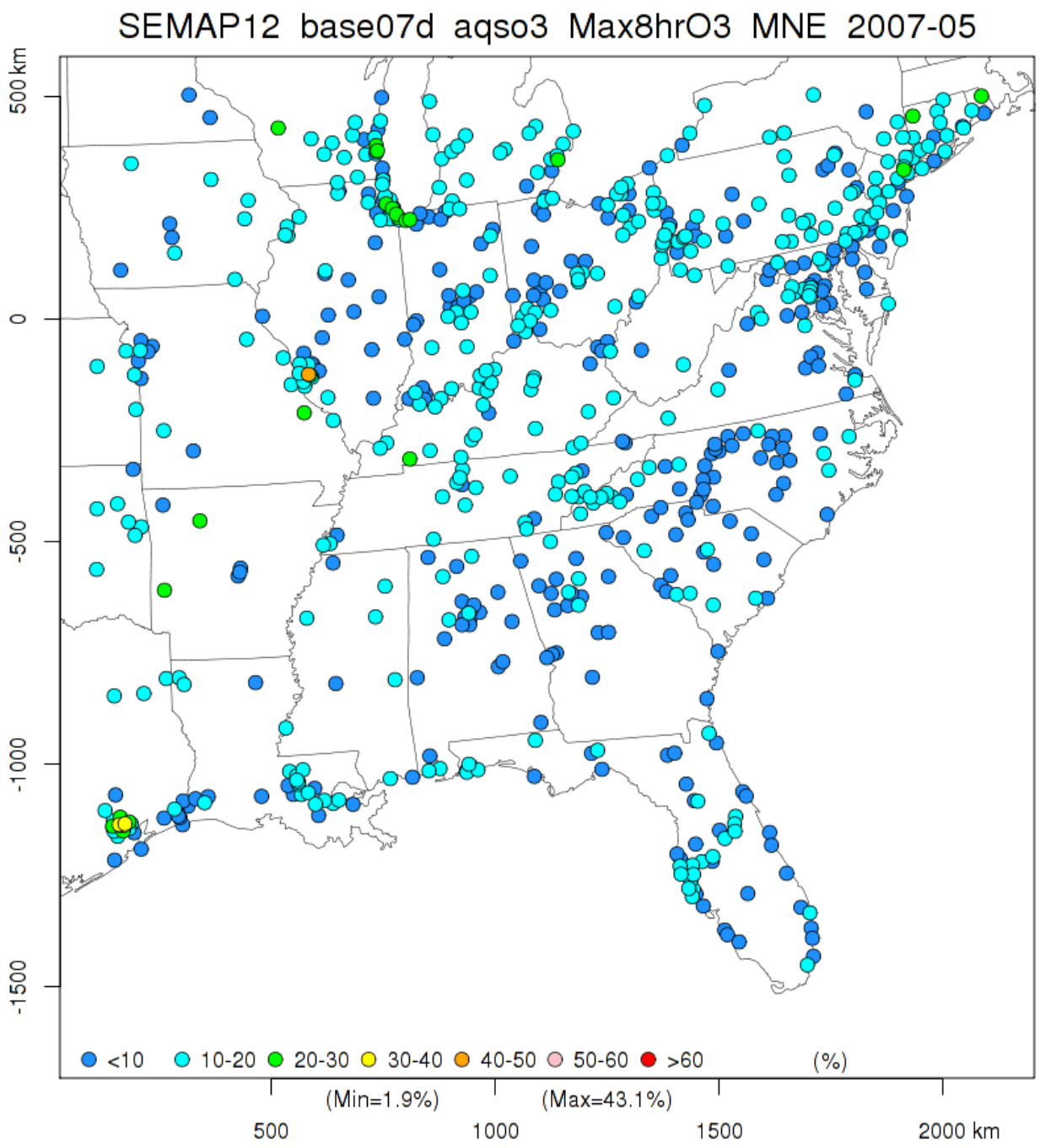


Figure 3-29 May 2007 mean normalized errors (MNE) in 8-hr maximum O_3 at AQS sites.

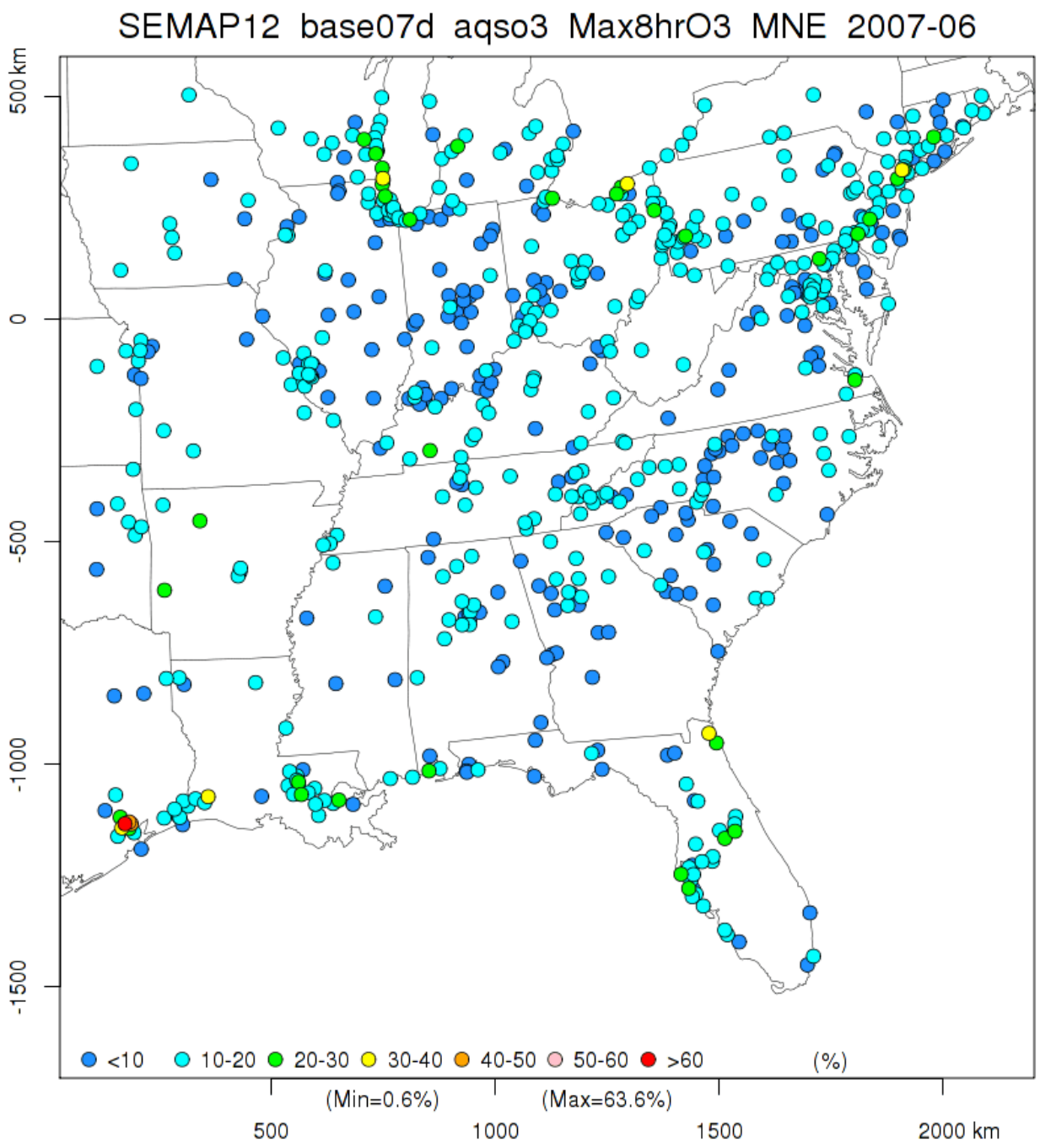


Figure 3-30 June 2007 mean normalized errors (MNE) in 8-hr maximum O_3 at AQS sites.

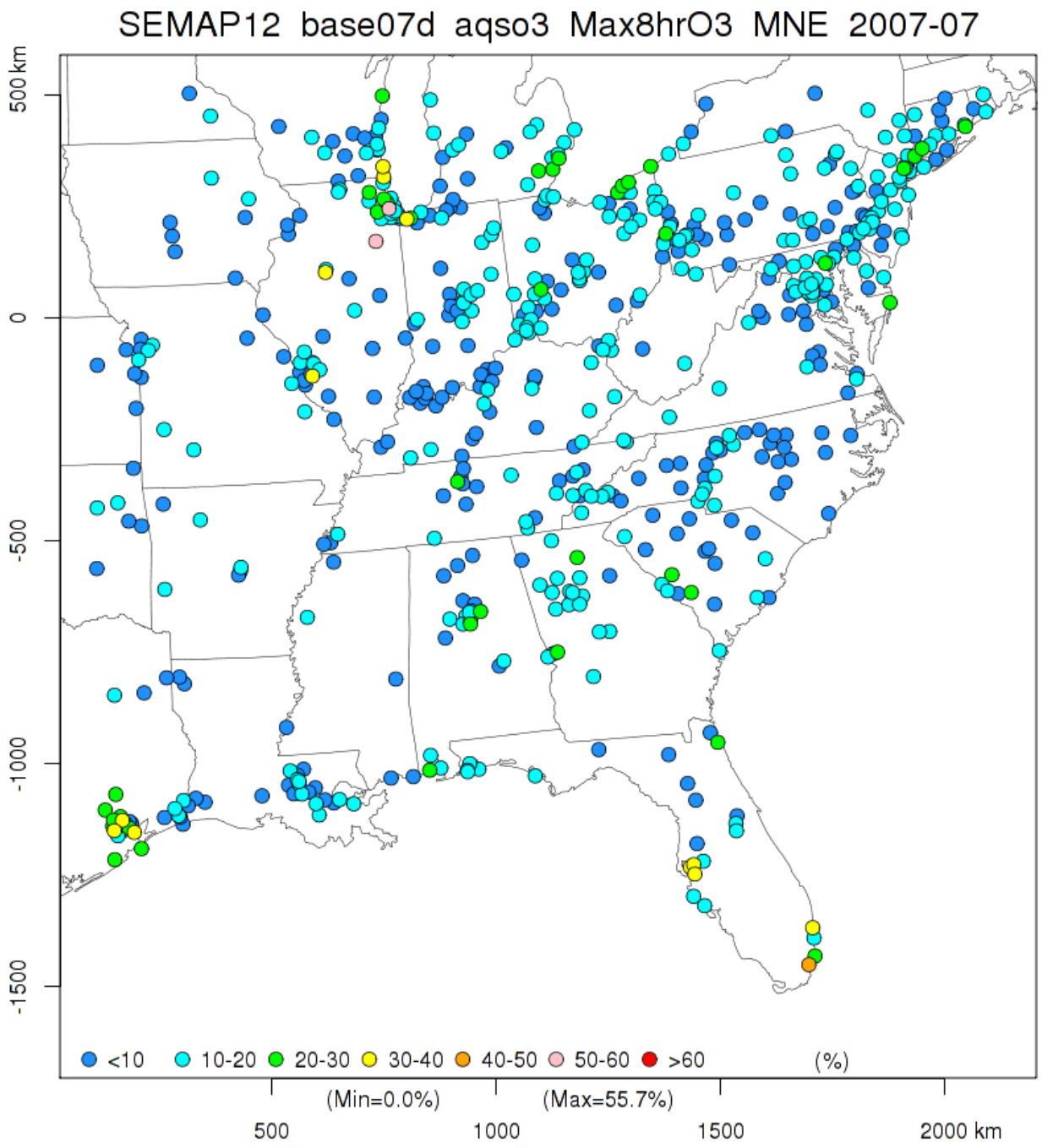


Figure 3-31 July 2007 mean normalized errors (MNE) in 8-hr maximum O_3 at AQS sites.

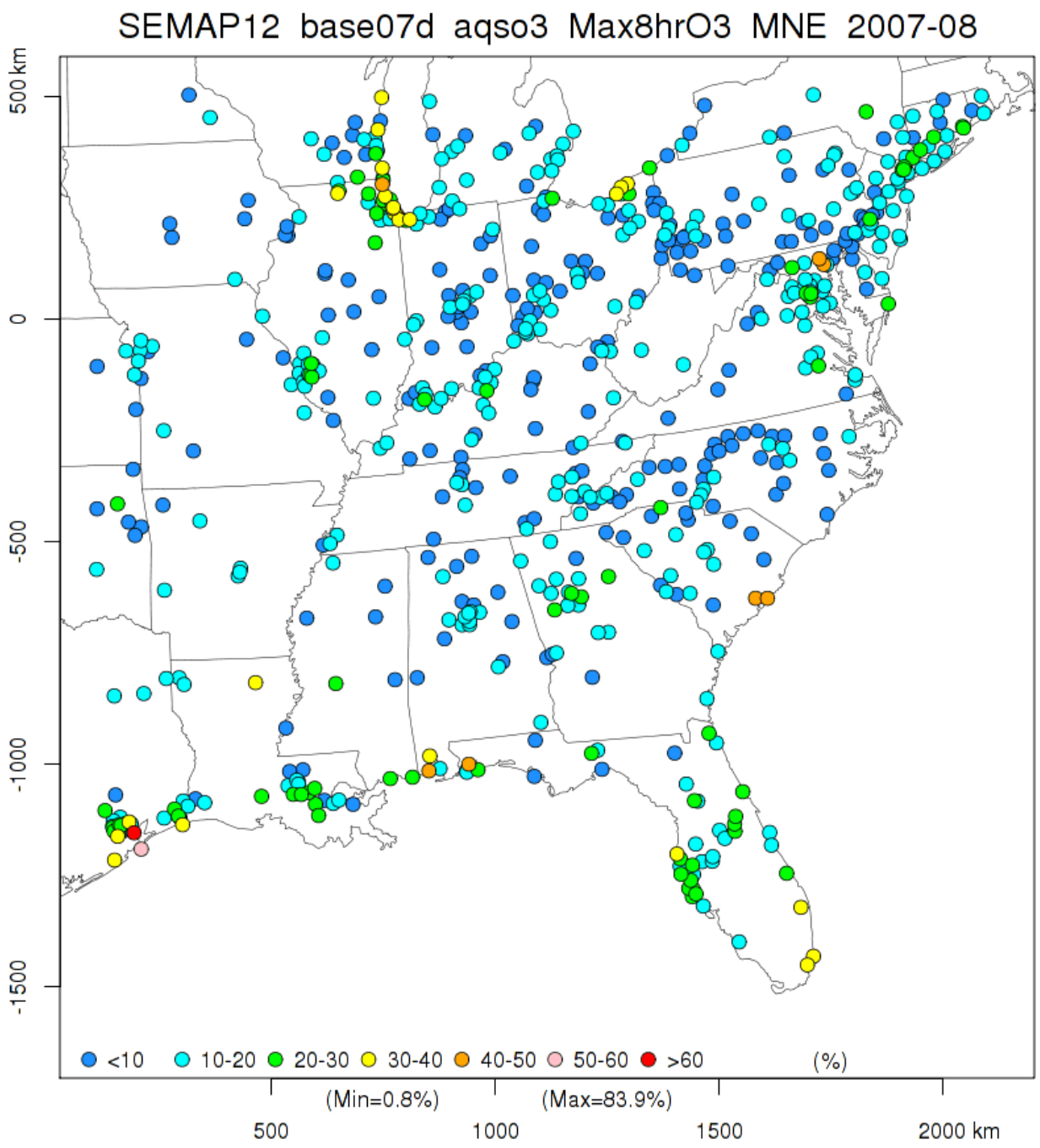


Figure 3-32 August 2007 mean normalized errors (MNE) in 8-hr maximum O_3 at AQS sites.

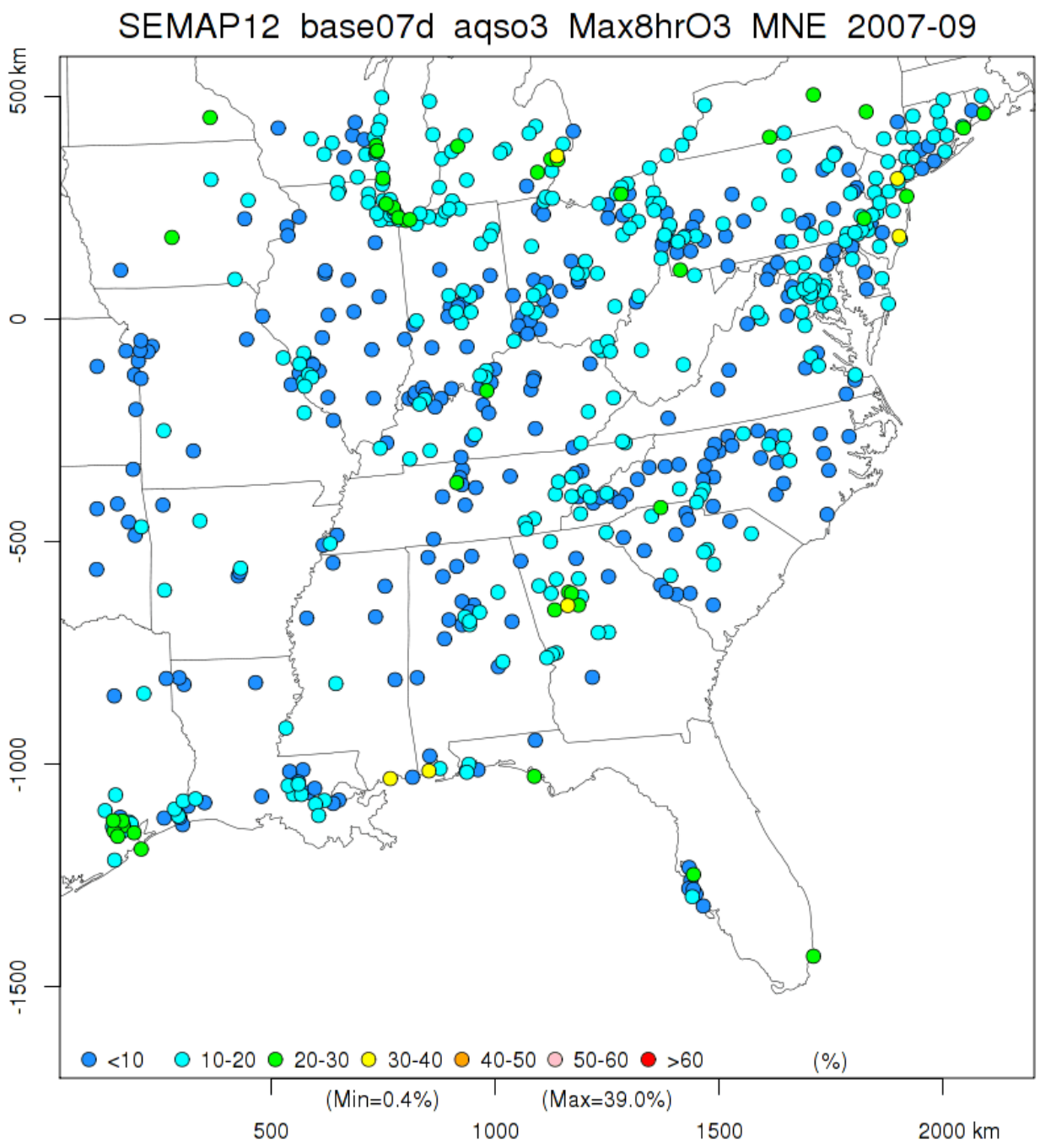


Figure 3-33 September 2007 mean normalized errors (MNE) in 8-hr maximum O_3 at AQS sites.

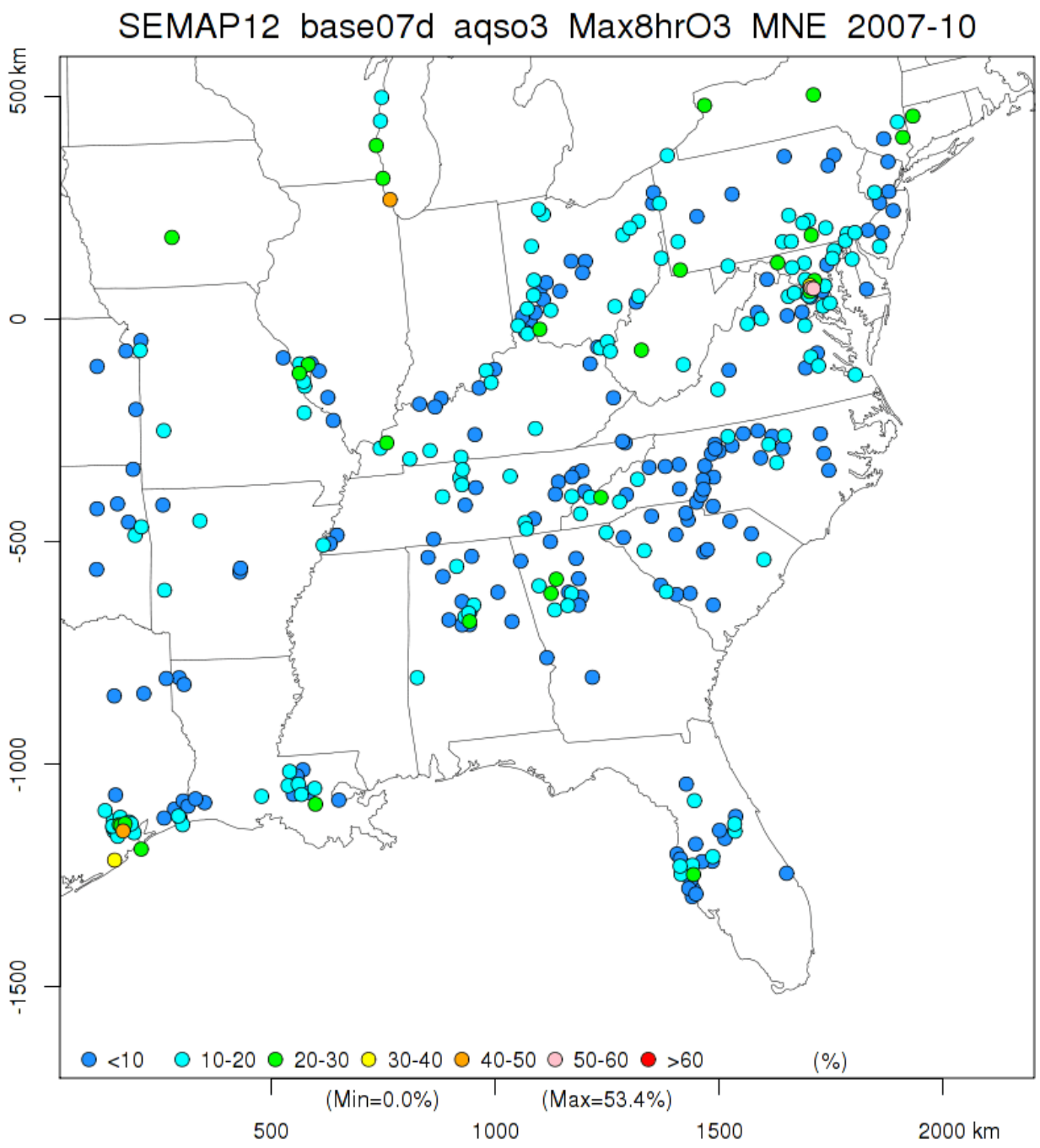


Figure 3-34 October 2007 mean normalized errors (MNE) in 8-hr maximum O_3 at AQS sites.

3.10.2 $PM_{2.5}$

Monthly mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ at the AQS sites of the SEMAP 12-km domain generally remained between -30% and +30% in spring and fall with some exceptions in each state (Figure 3-35 through Figure 3-46). Winter overestimations and summer underestimations were outside the limits of the $PM_{2.5}$ goal at several sites. Summertime underestimations did not meet the PM2.5 criteria of greater than -60% at several sites in the SEMAP states. Monthly mean fractional errors (MFE) in 24-hr average $PM_{2.5}$ remained less than 50% January through April and September through December, except at a few AQS sites (Figure 3-47 through Figure 3-58). However, from May through August MFE exceeded 75% at several sites.

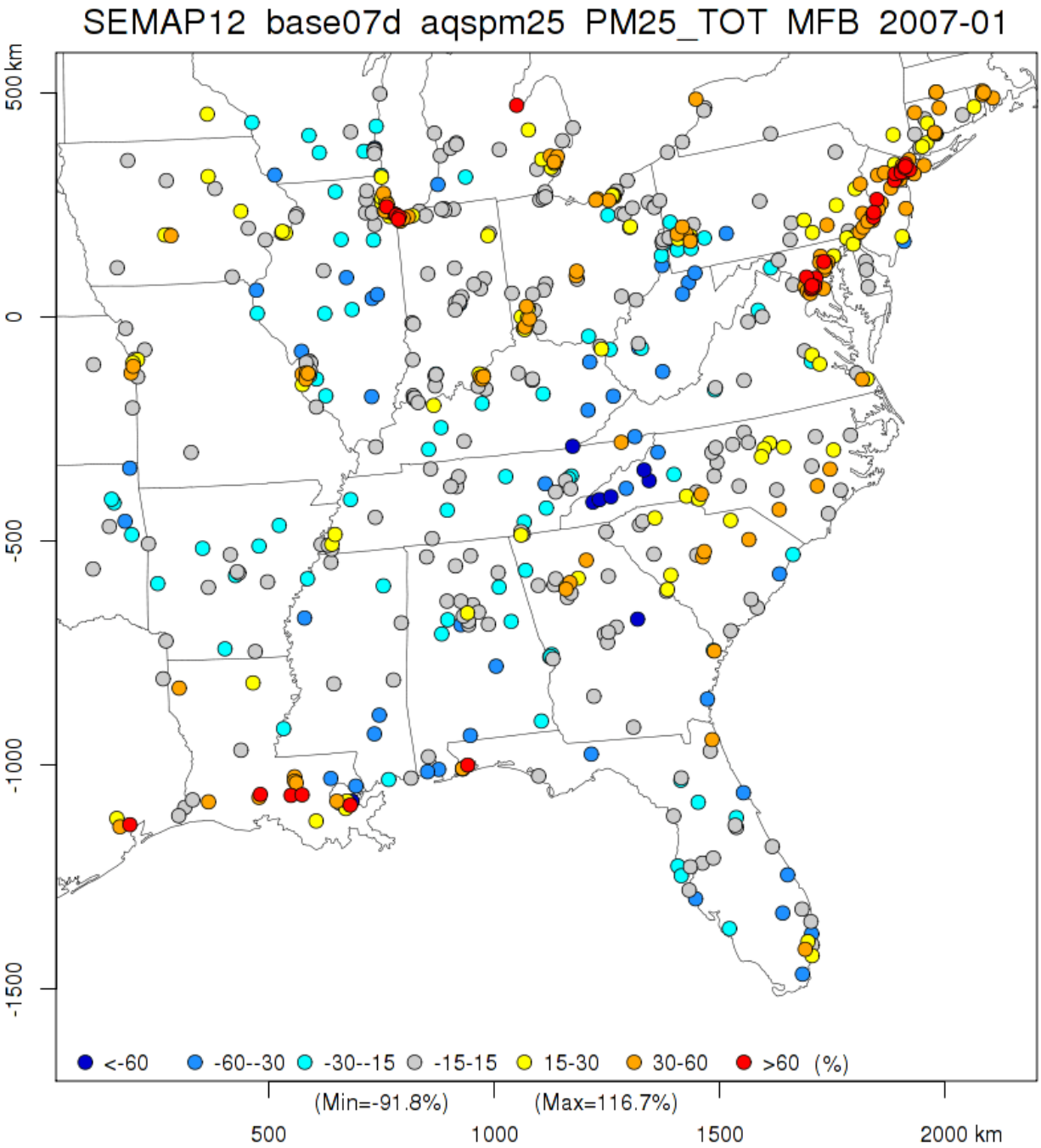


Figure 3-35 January 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ at AQS sites.

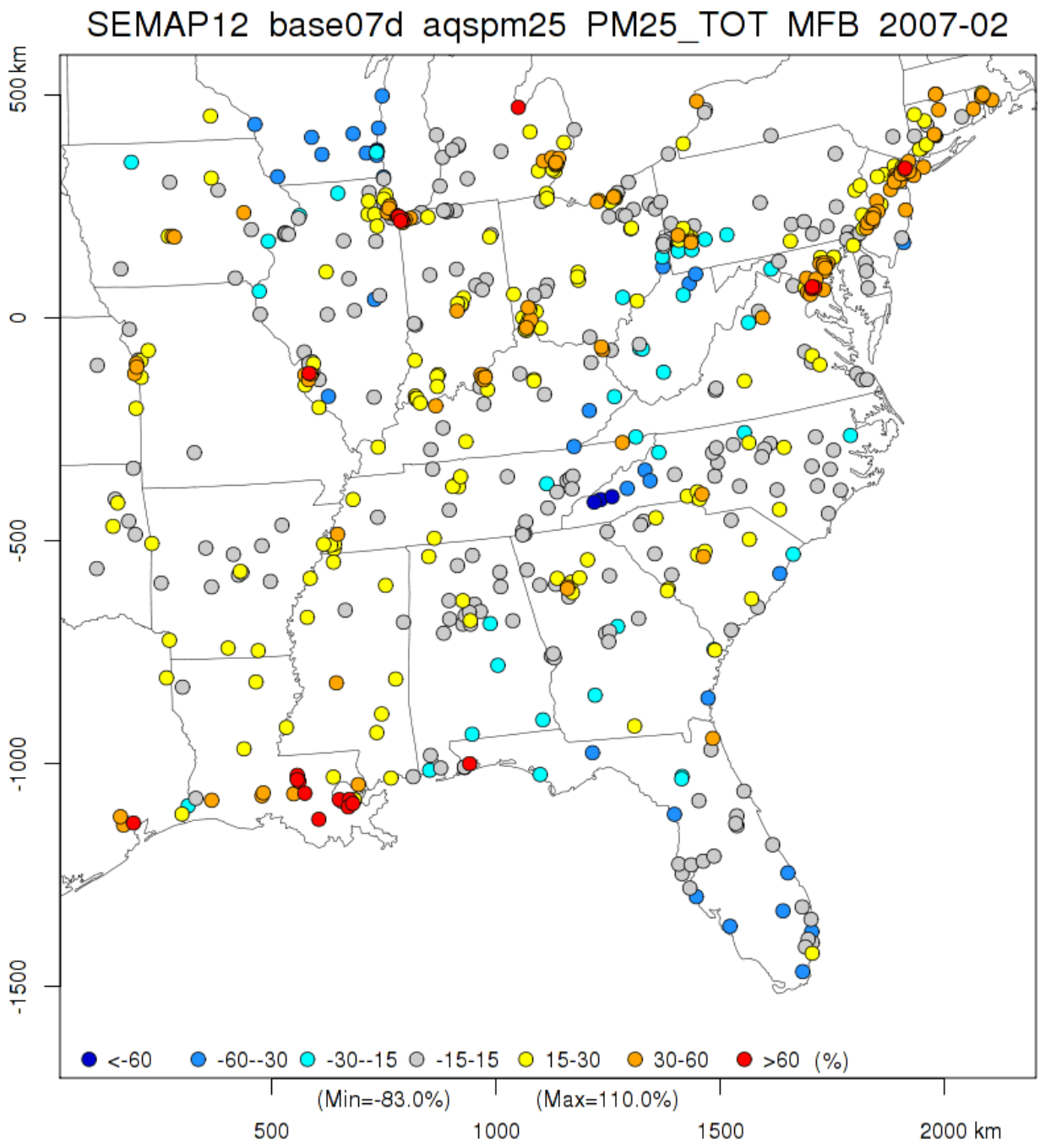


Figure 3-36 February 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ at AQS sites.

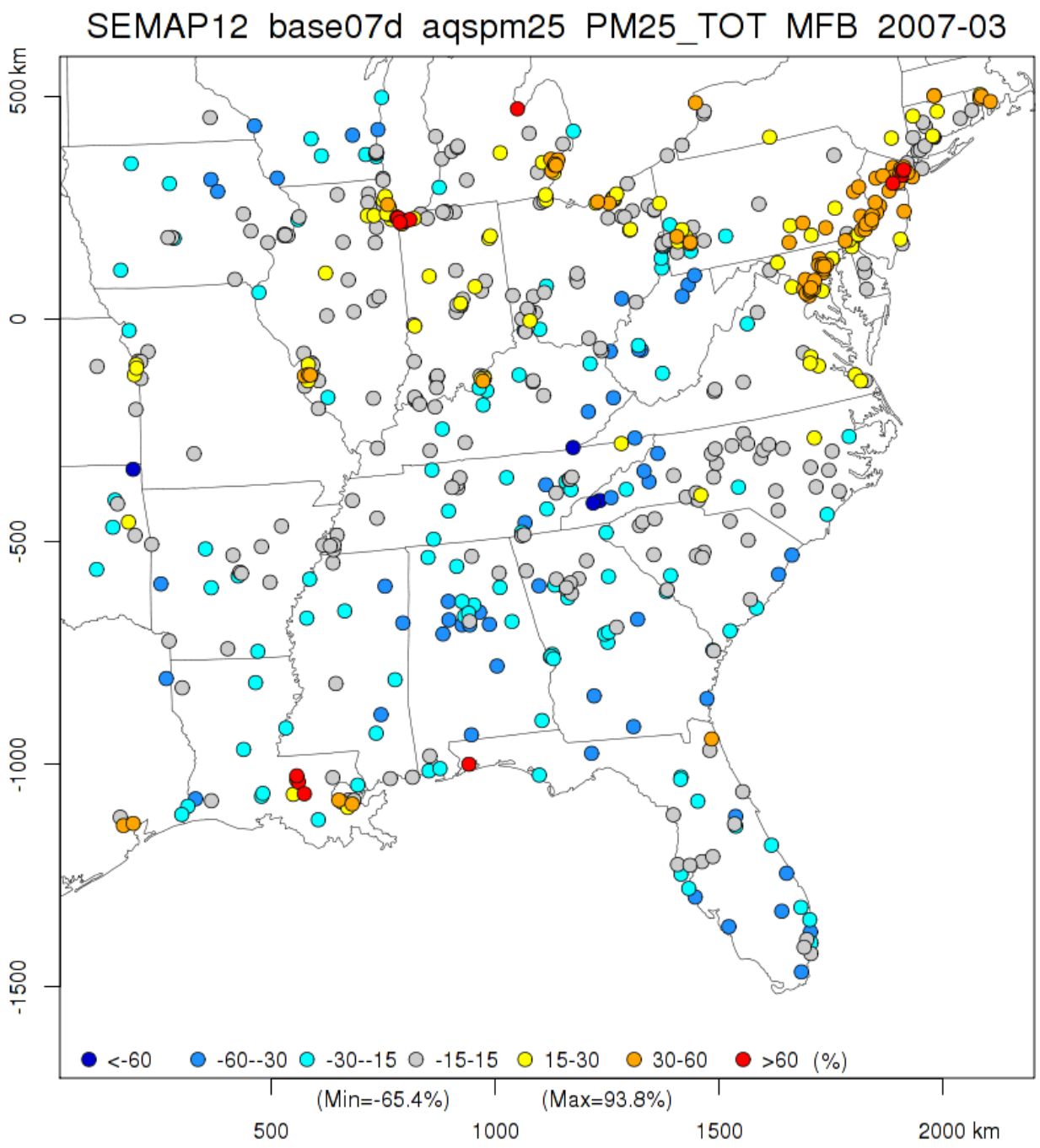


Figure 3-37 March 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ at AQS sites.

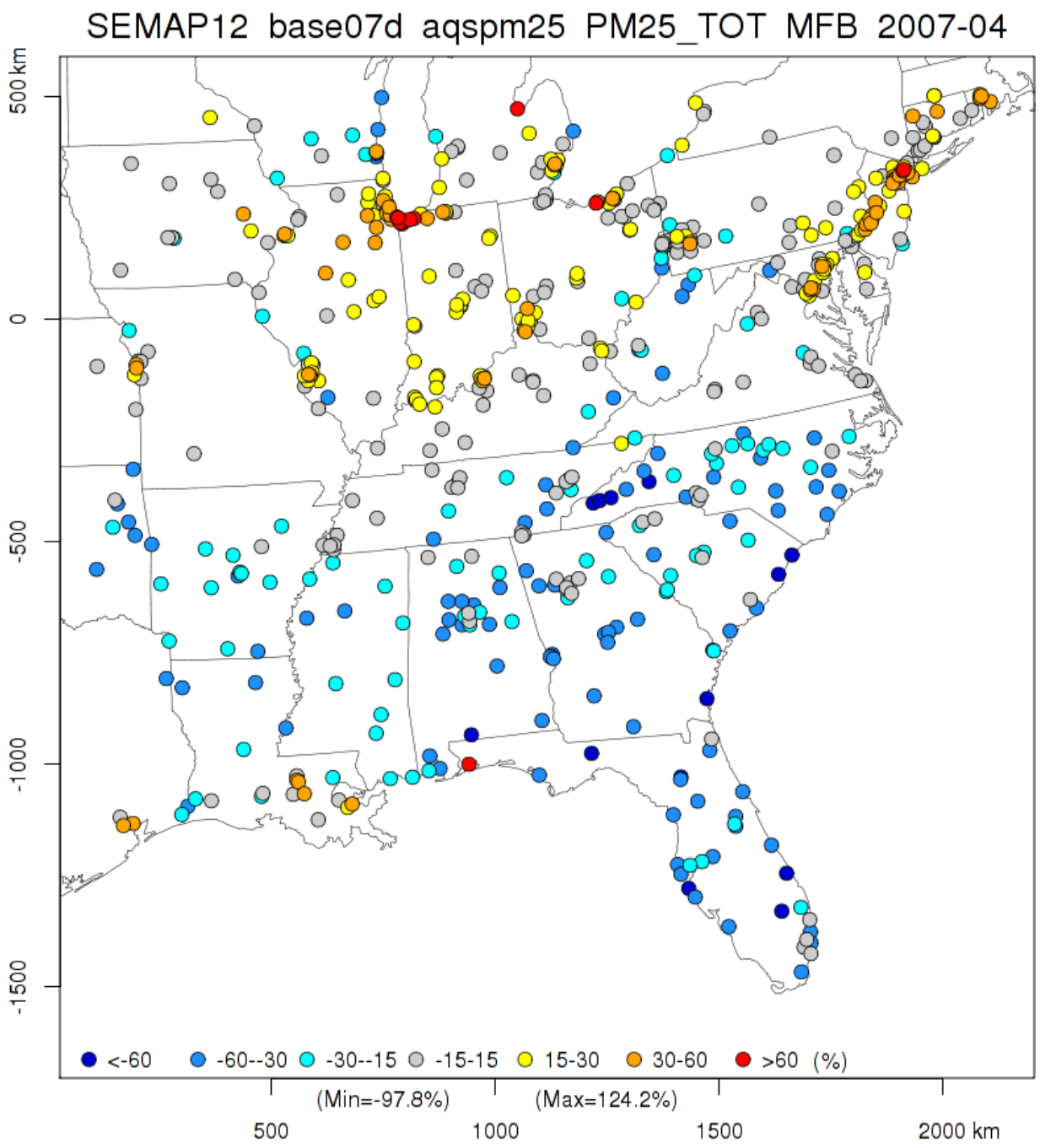


Figure 3-38 April 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ at AQS sites.

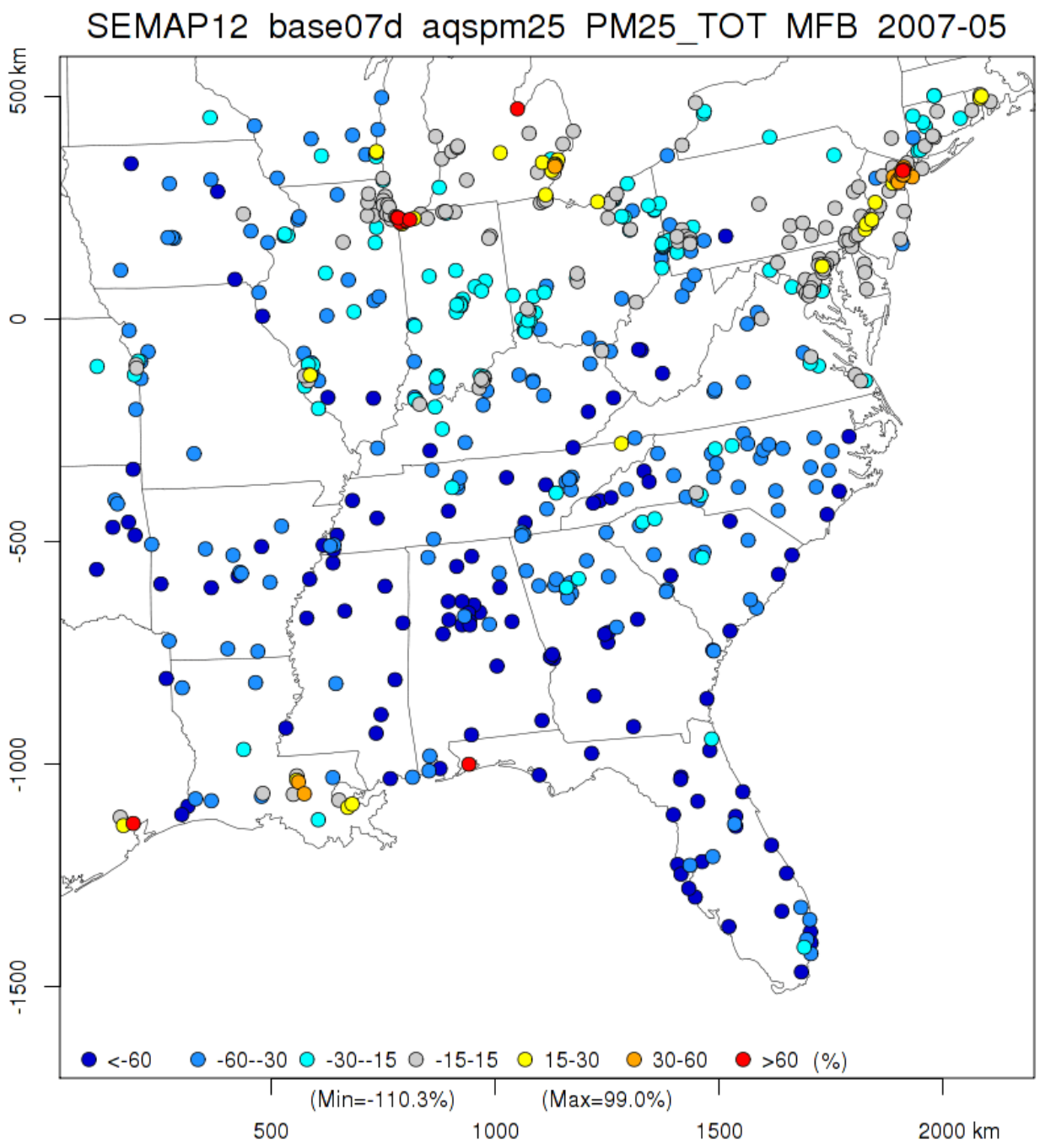


Figure 3-39 May 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ at AQS sites.

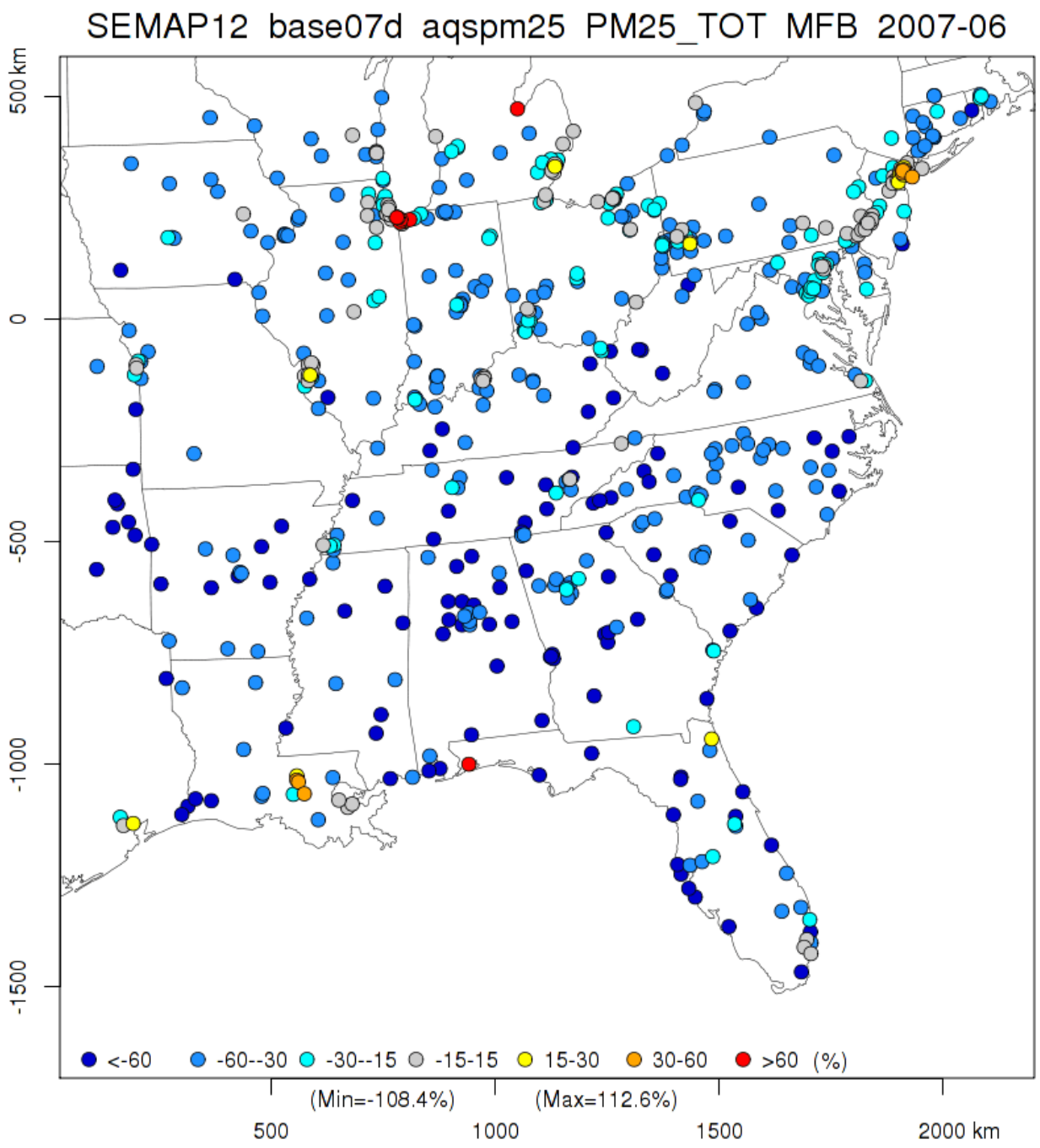


Figure 3-40 June 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ at AQS sites.

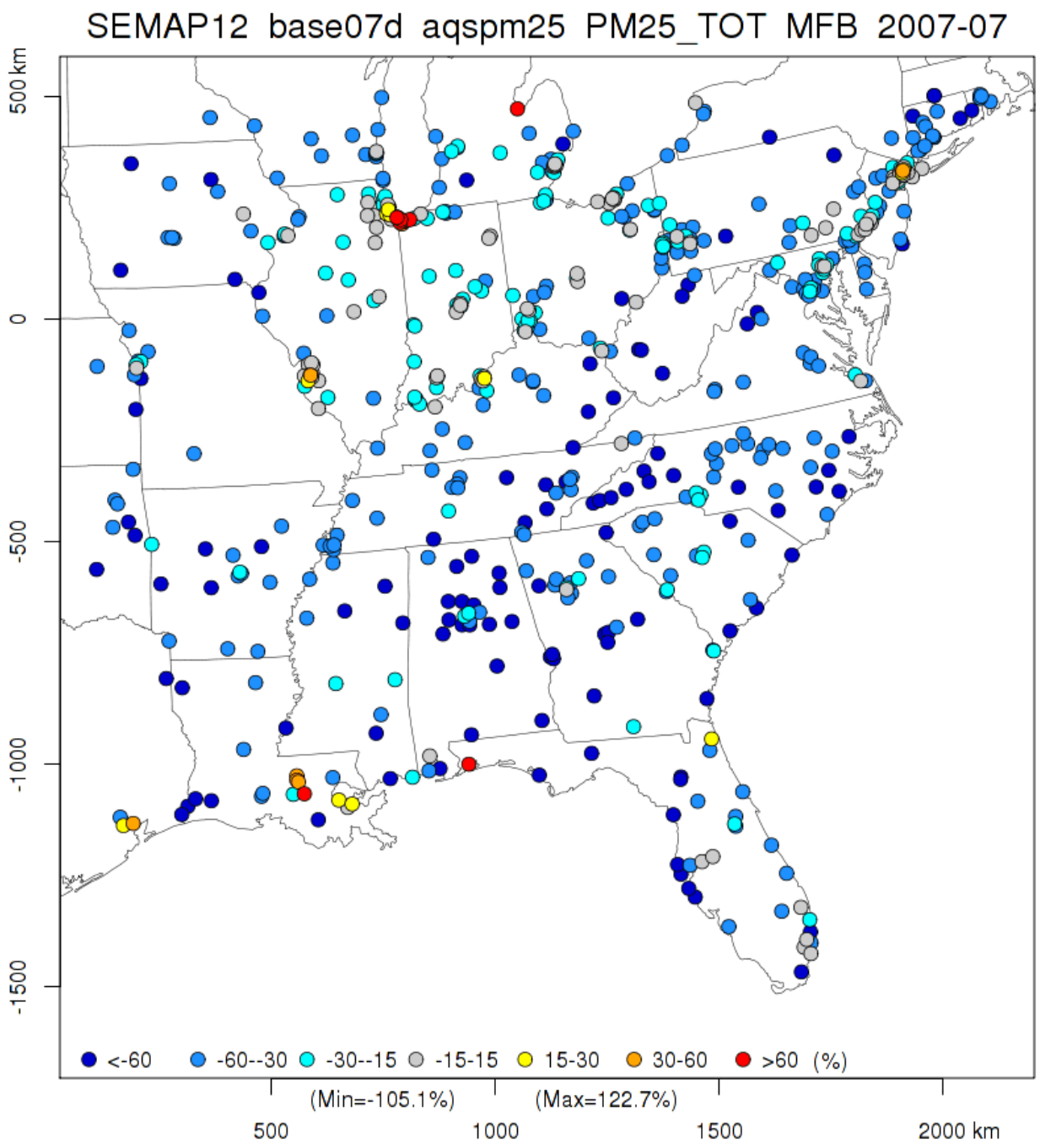


Figure 3-41 July 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ at AQS sites.

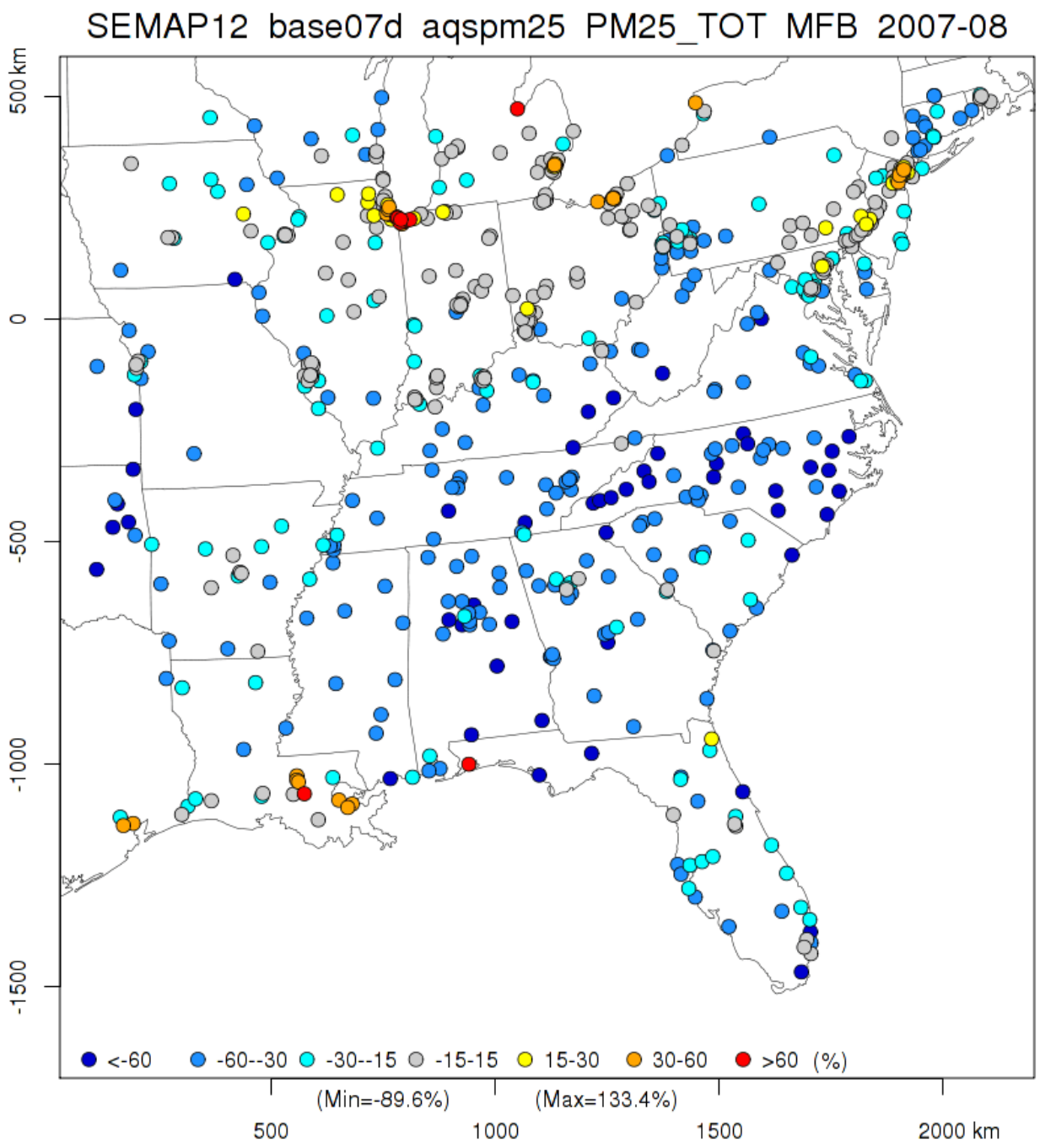


Figure 3-42 August 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ at AQS sites.

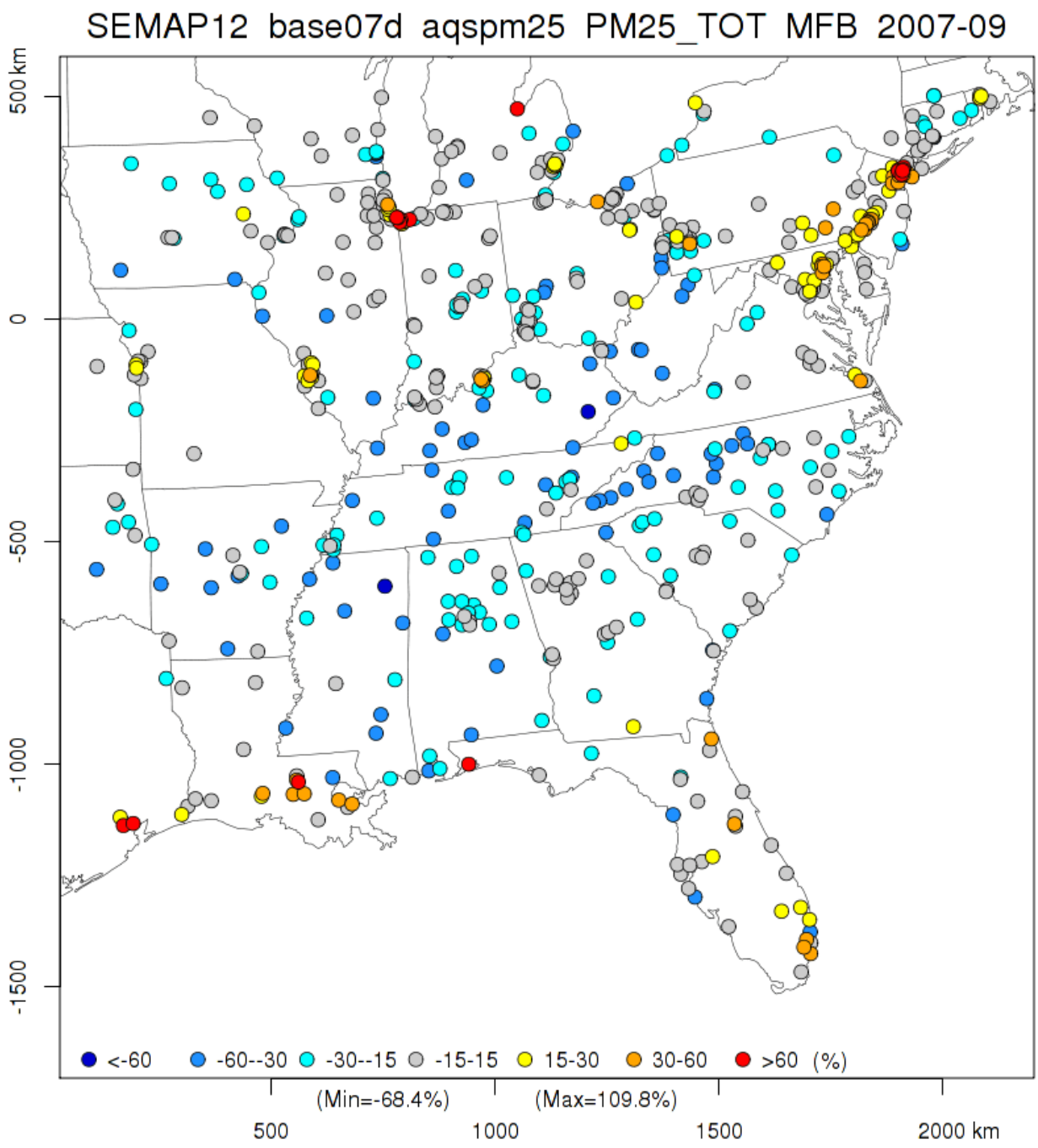


Figure 3-43 September 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ at AQS sites.

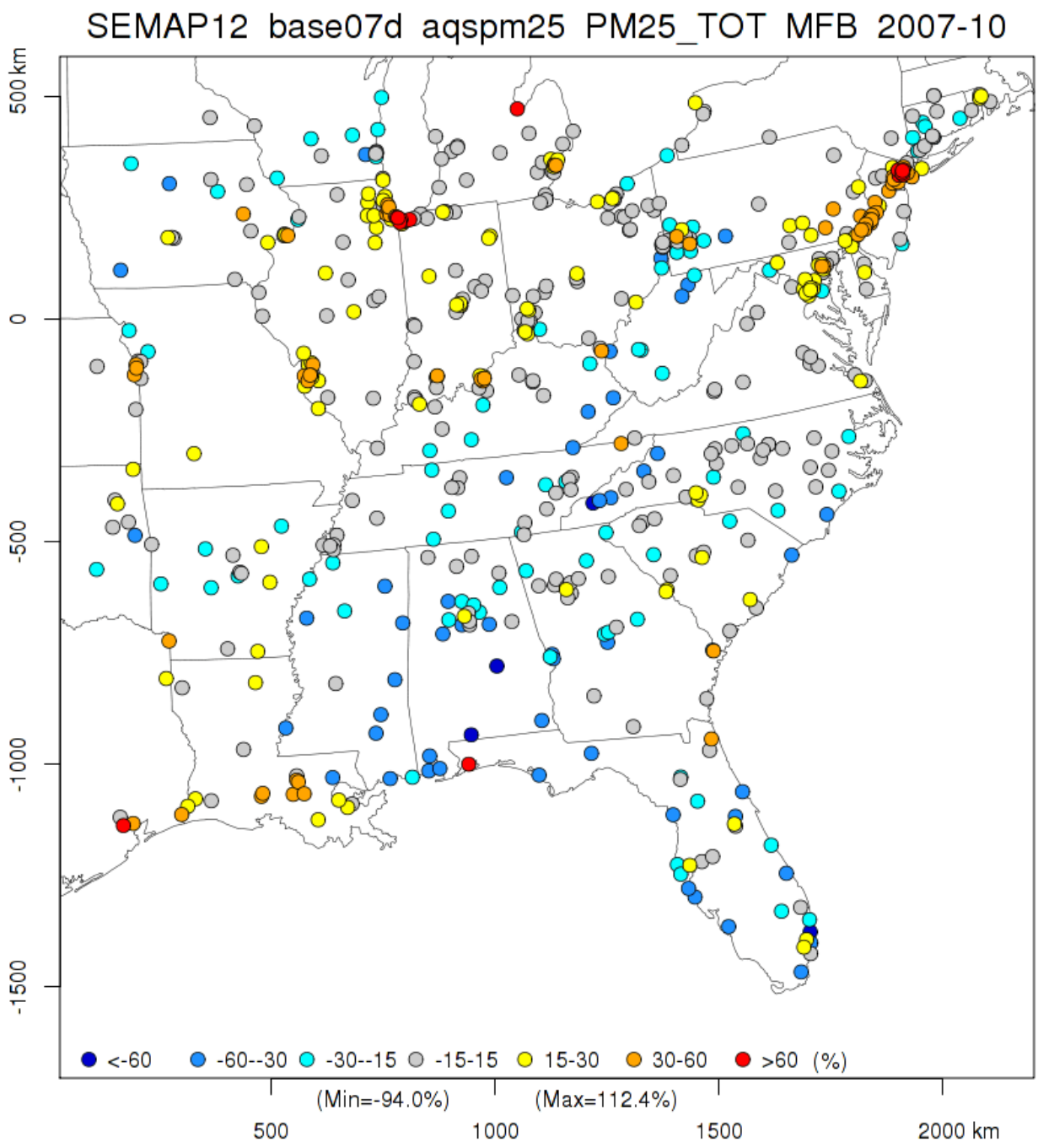


Figure 3-44 October 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ at AQS sites.

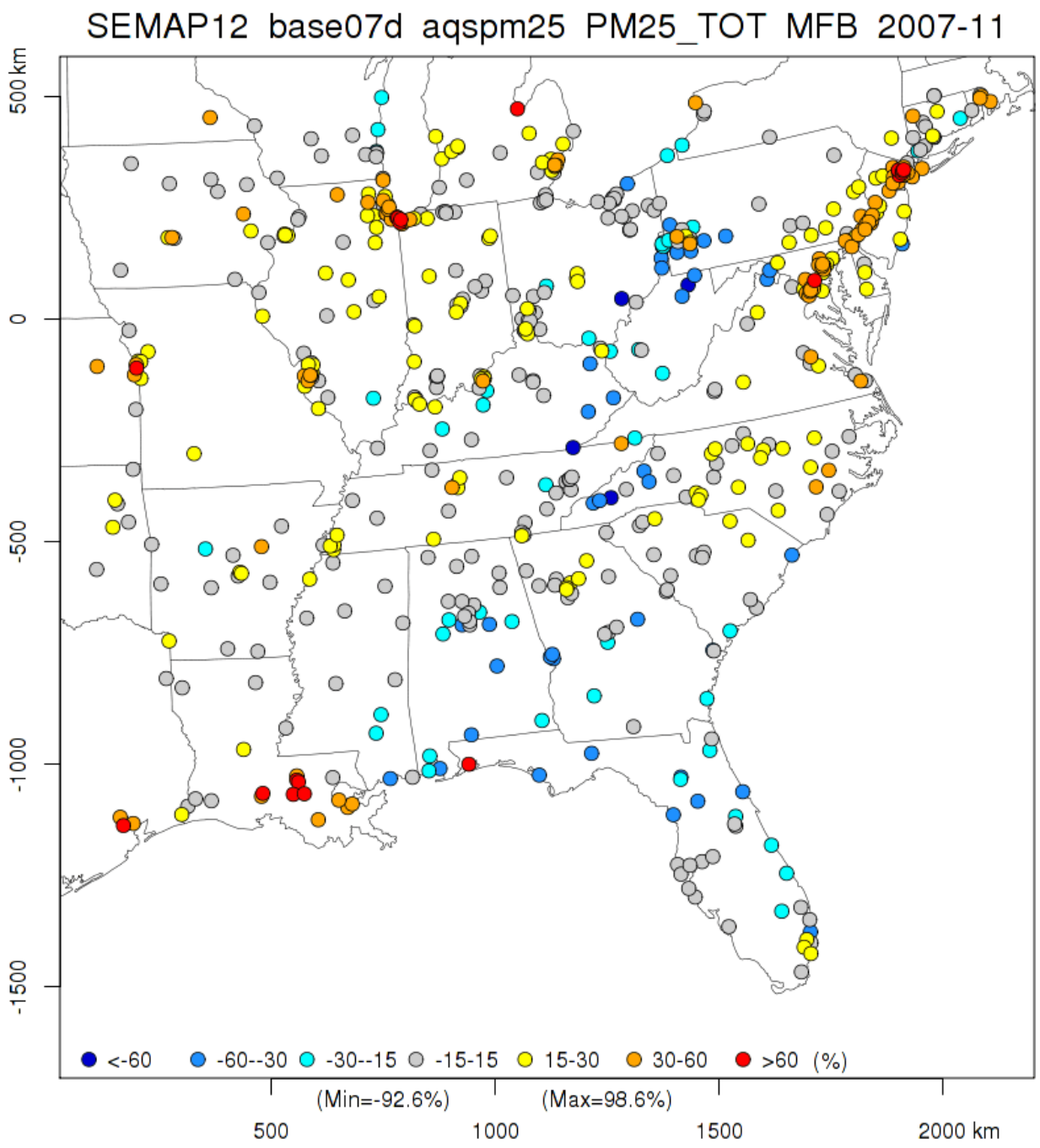


Figure 3-45 November 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ at AQS sites.

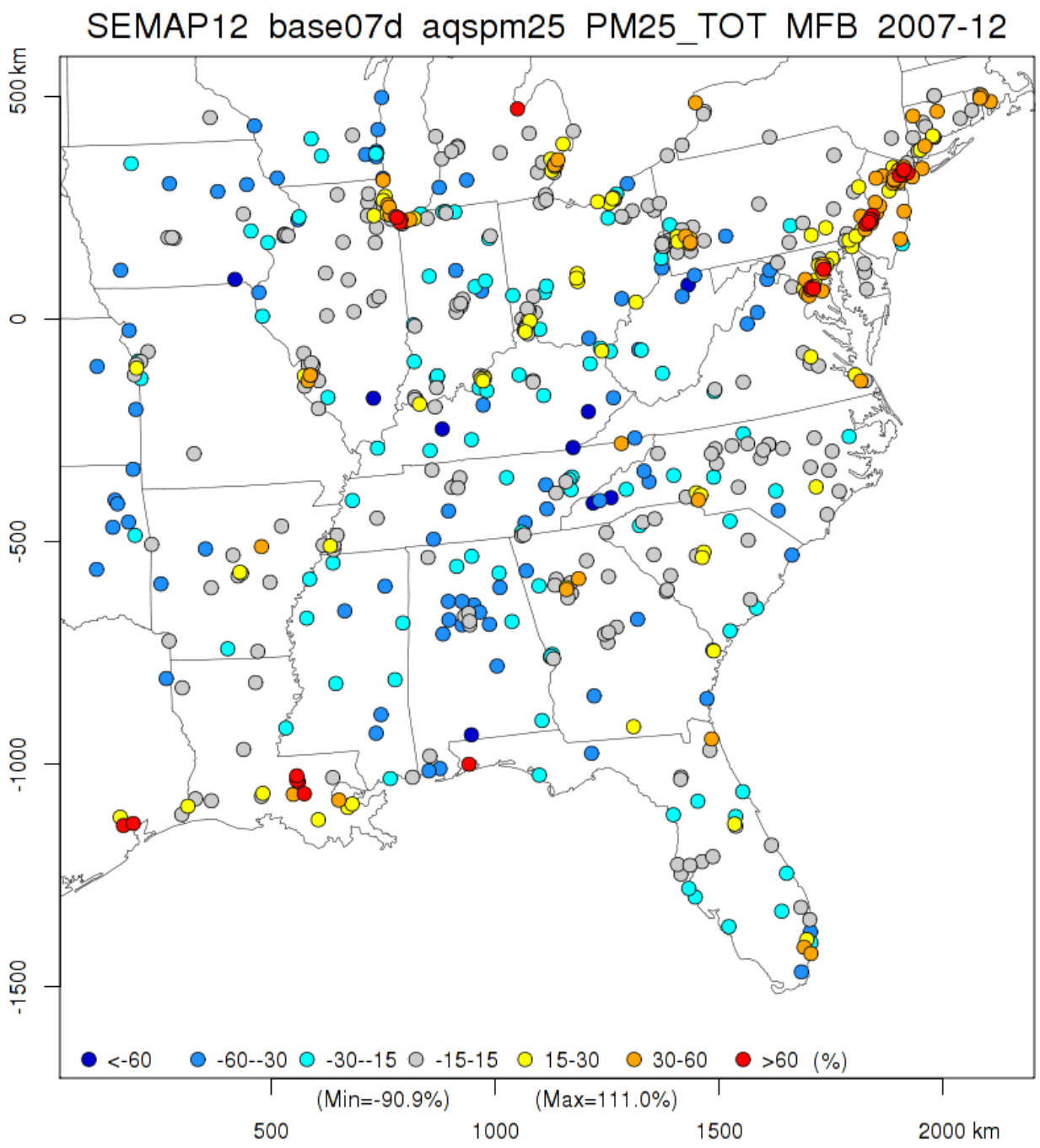


Figure 3-46 December 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ at AQS sites.

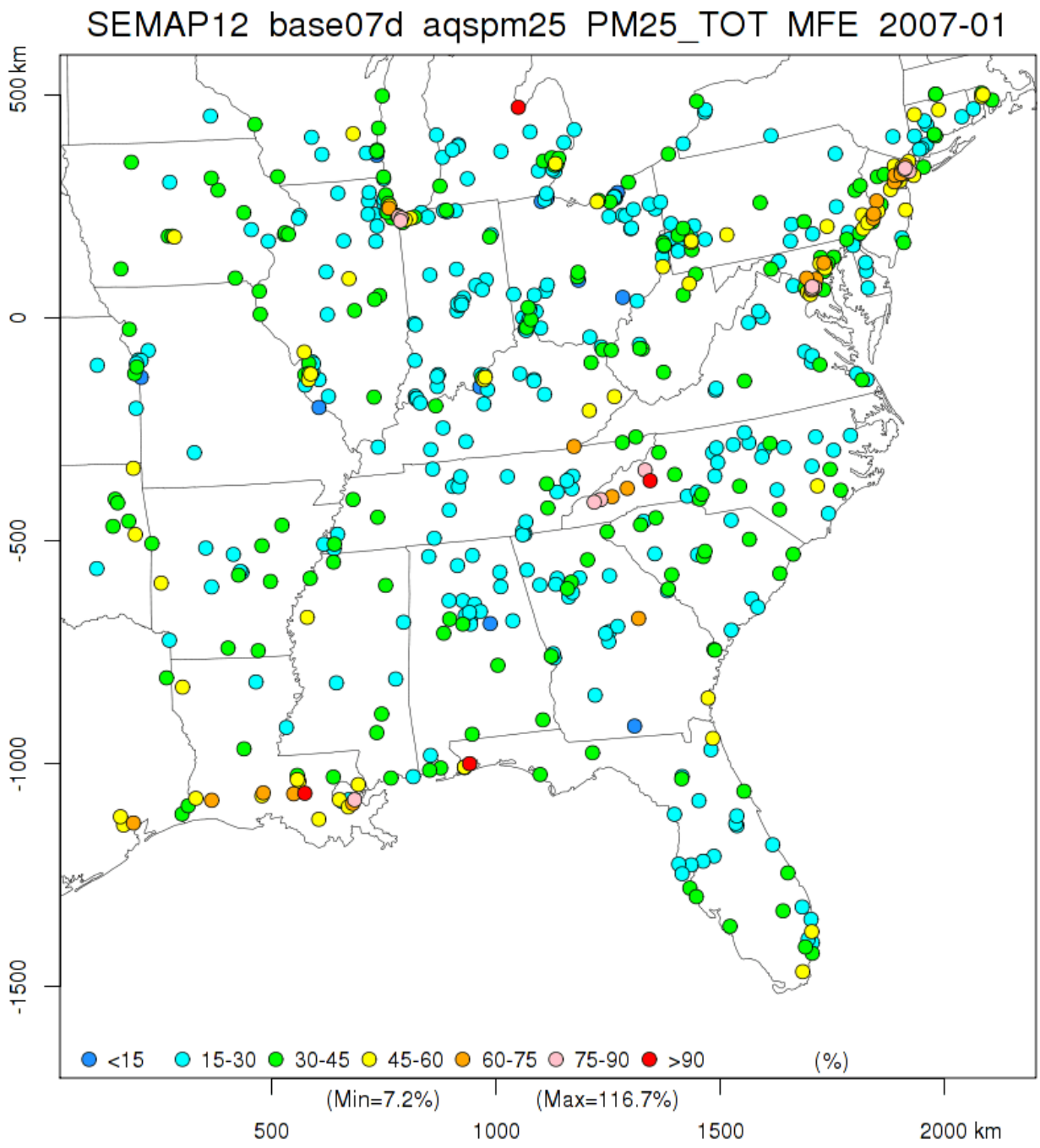


Figure 3-47 January 2007 mean fractional errors (MFE) in 24-hr average $PM_{2.5}$ at AQS sites.

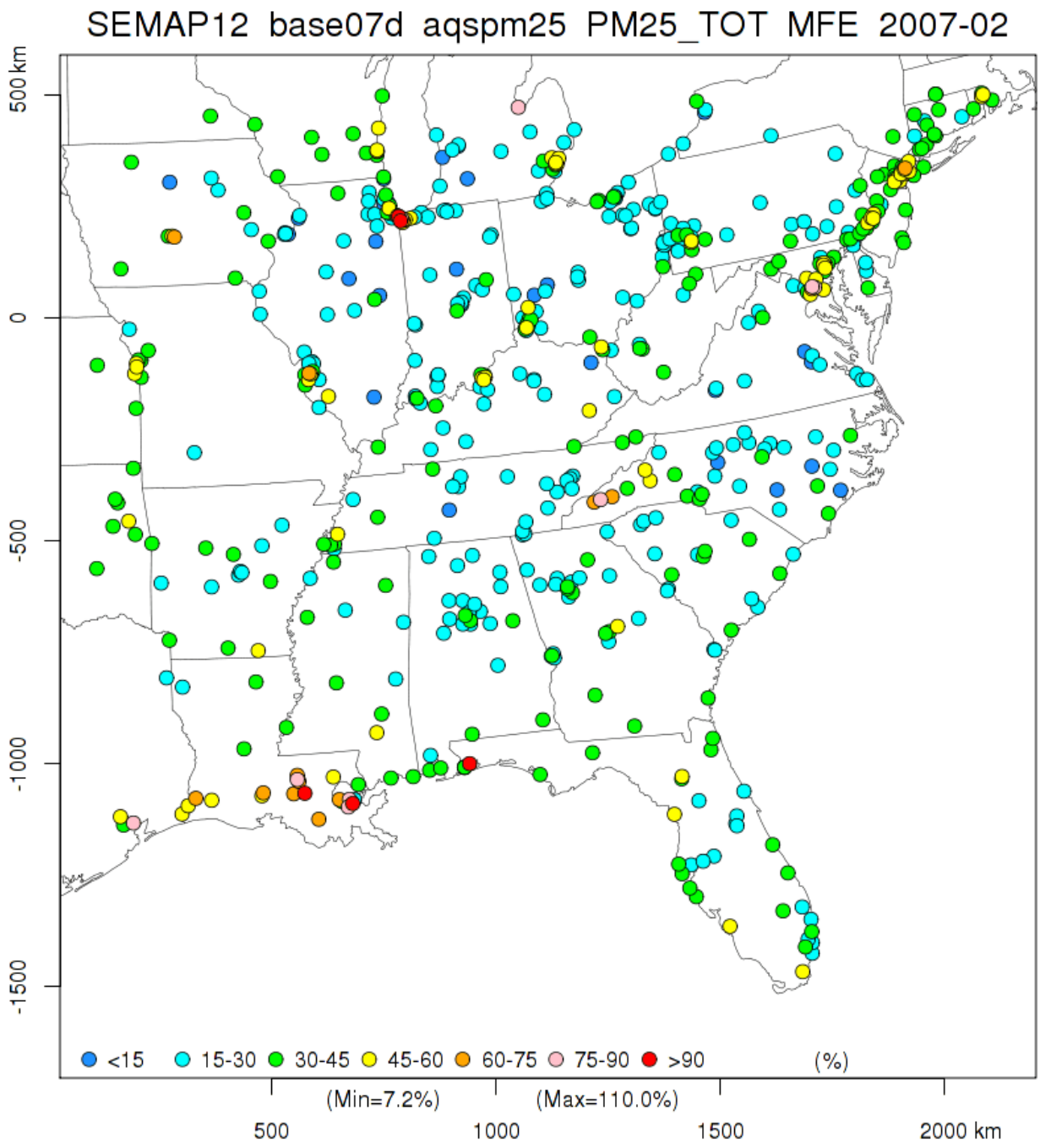


Figure 3-48 February 2007 mean fractional errors (MFE) in 24-hr average $PM_{2.5}$ at AQS sites.

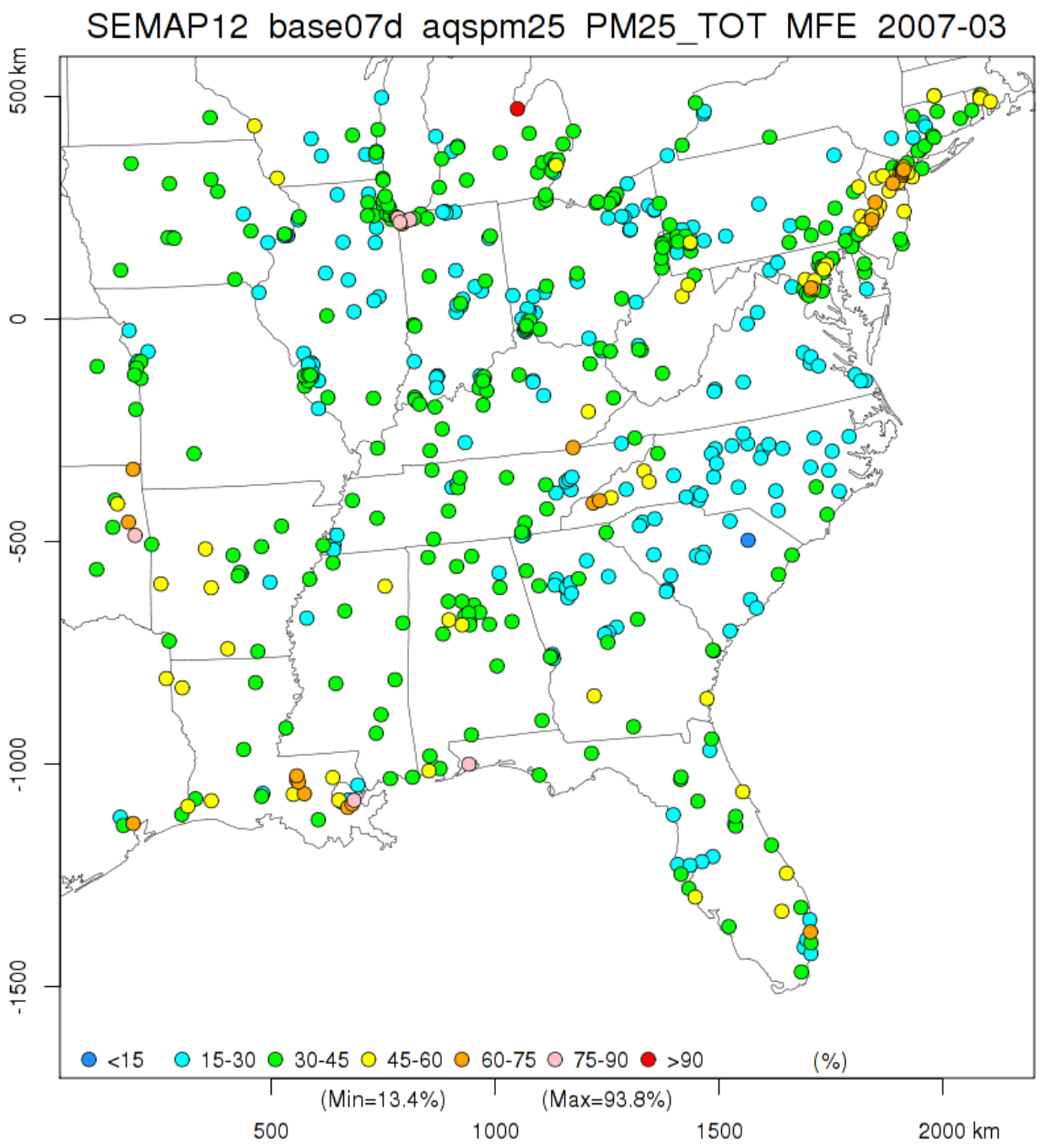


Figure 3-49 March 2007 mean fractional errors (MFE) in 24-hr average $PM_{2.5}$ at AQS sites.

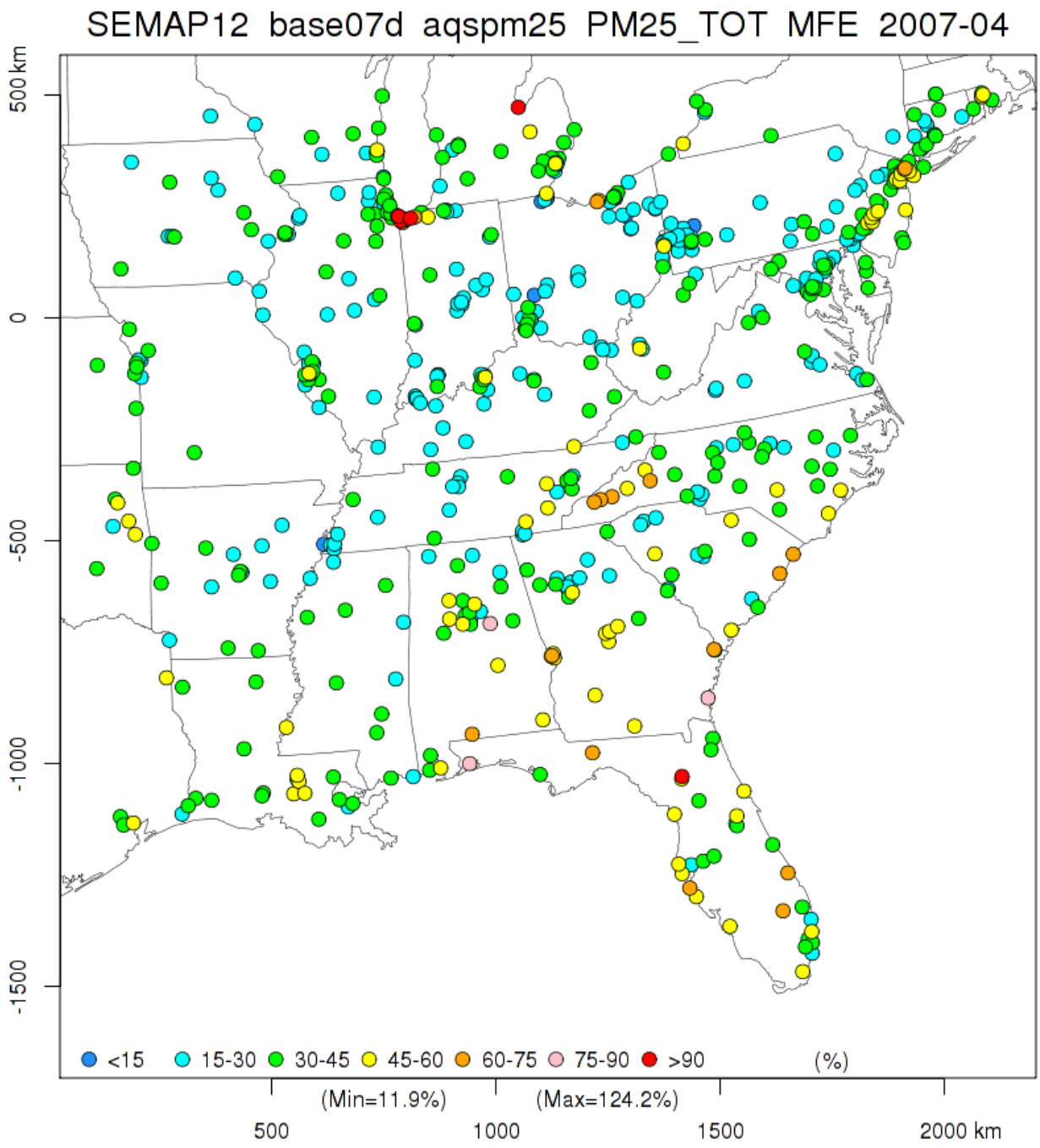


Figure 3-50 April 2007 mean fractional errors (MFE) in 24-hr average $PM_{2.5}$ at AQS sites.

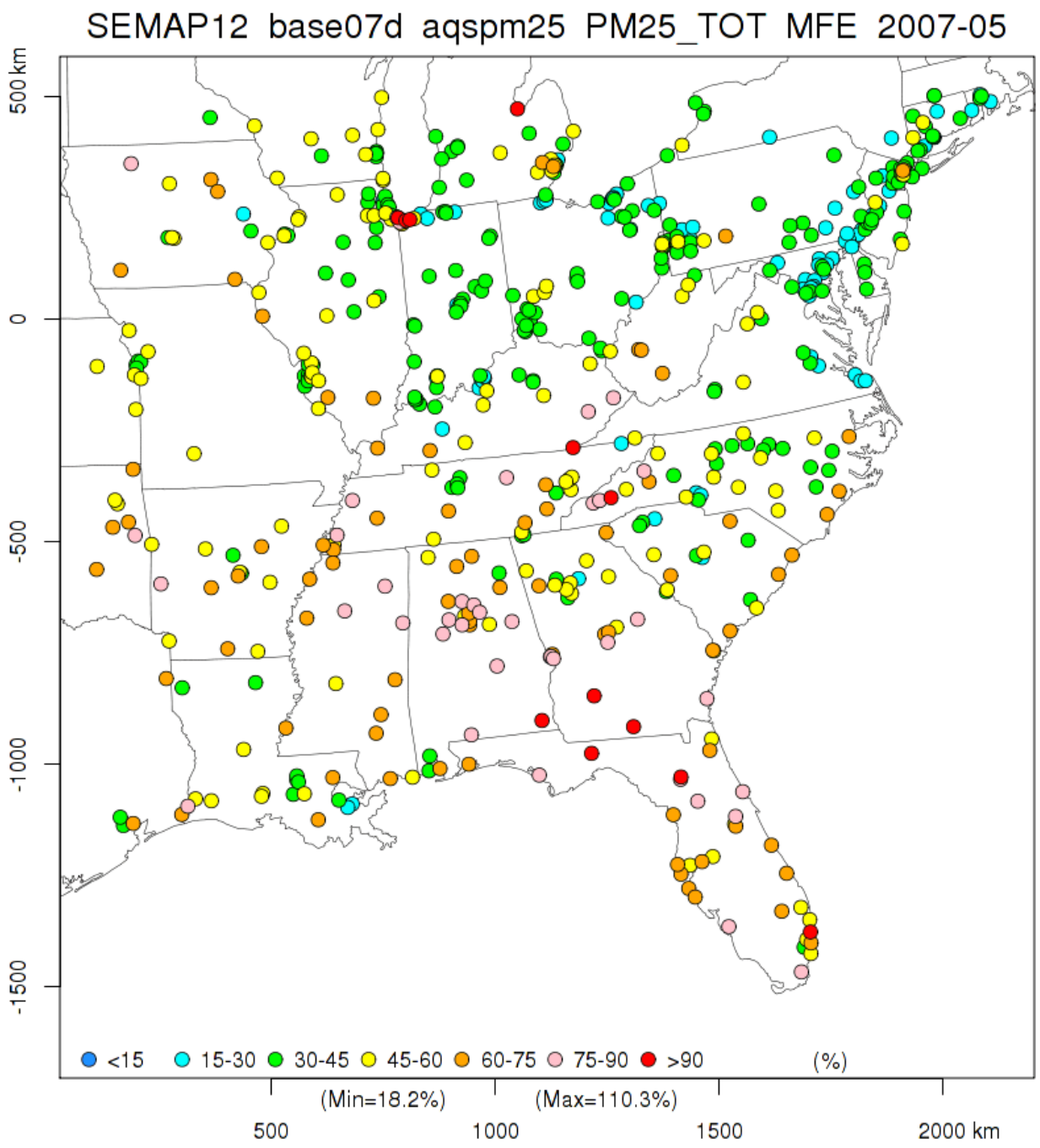


Figure 3-51 May 2007 mean fractional errors (MFE) in 24-hr average $PM_{2.5}$ at AQS sites.

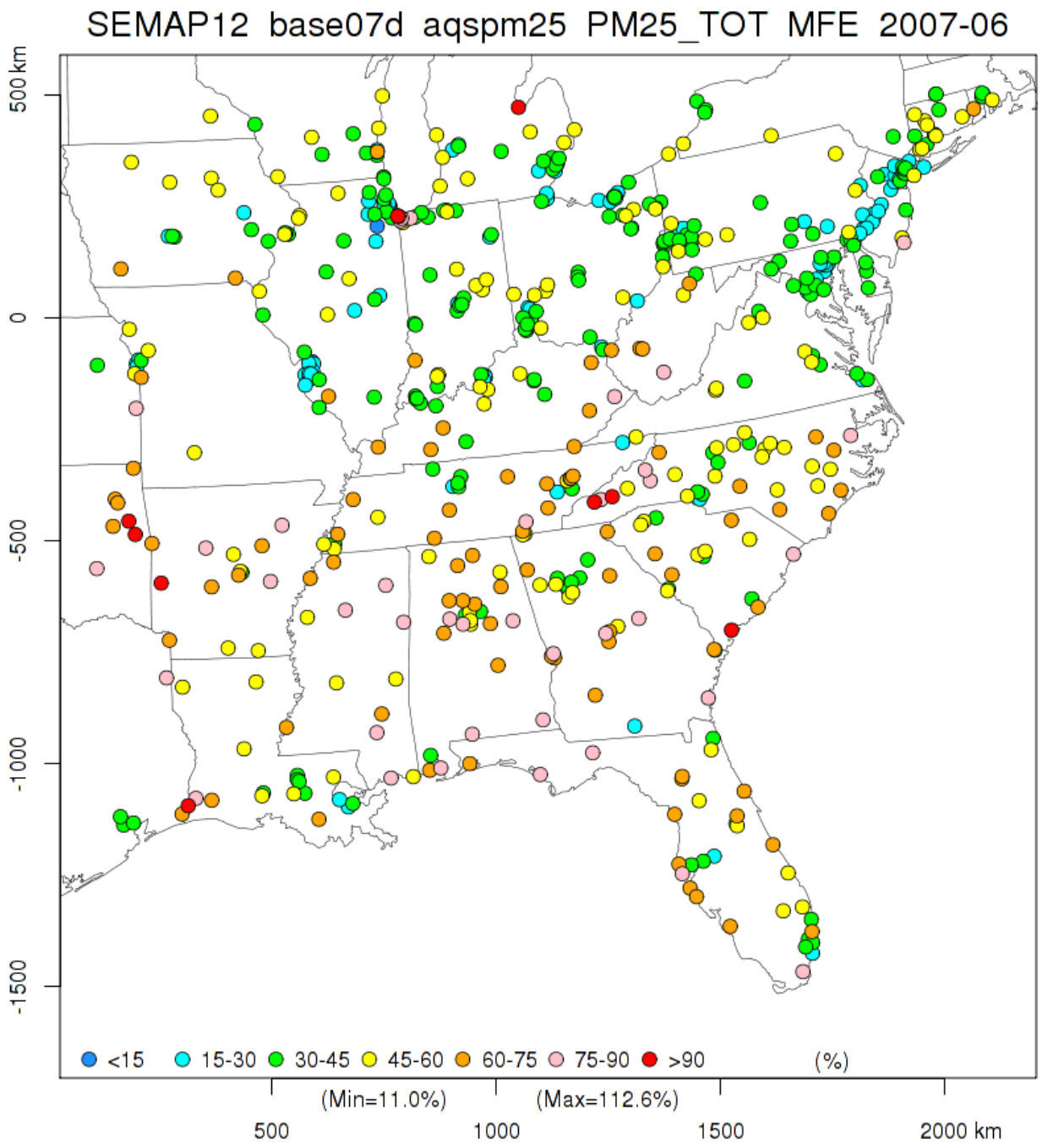


Figure 3-52 June 2007 mean fractional errors (MFE) in 24-hr average $PM_{2.5}$ at AQS sites.

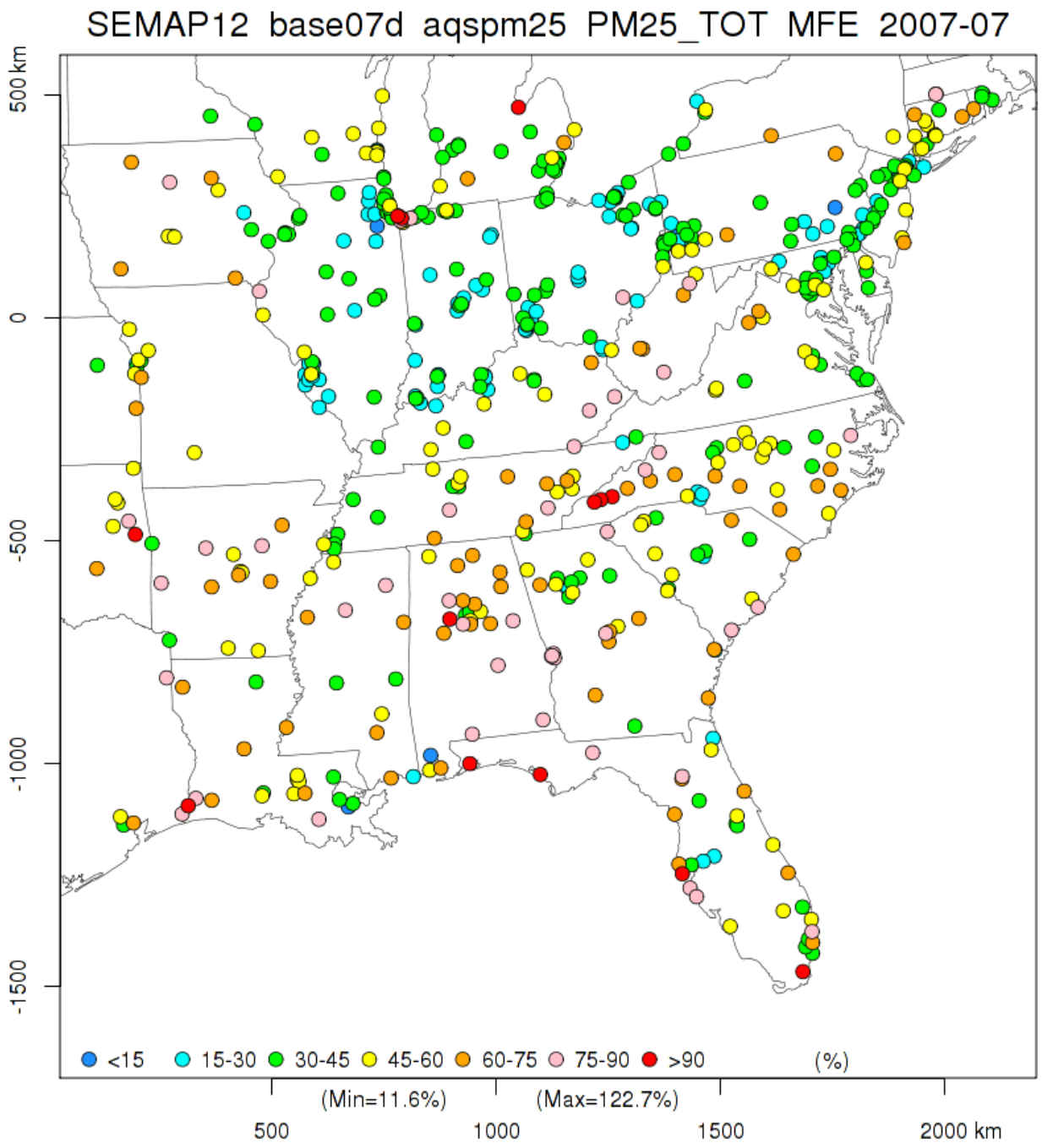


Figure 3-53 July 2007 mean fractional errors (MFE) in 24-hr average $PM_{2.5}$ at AQS sites.

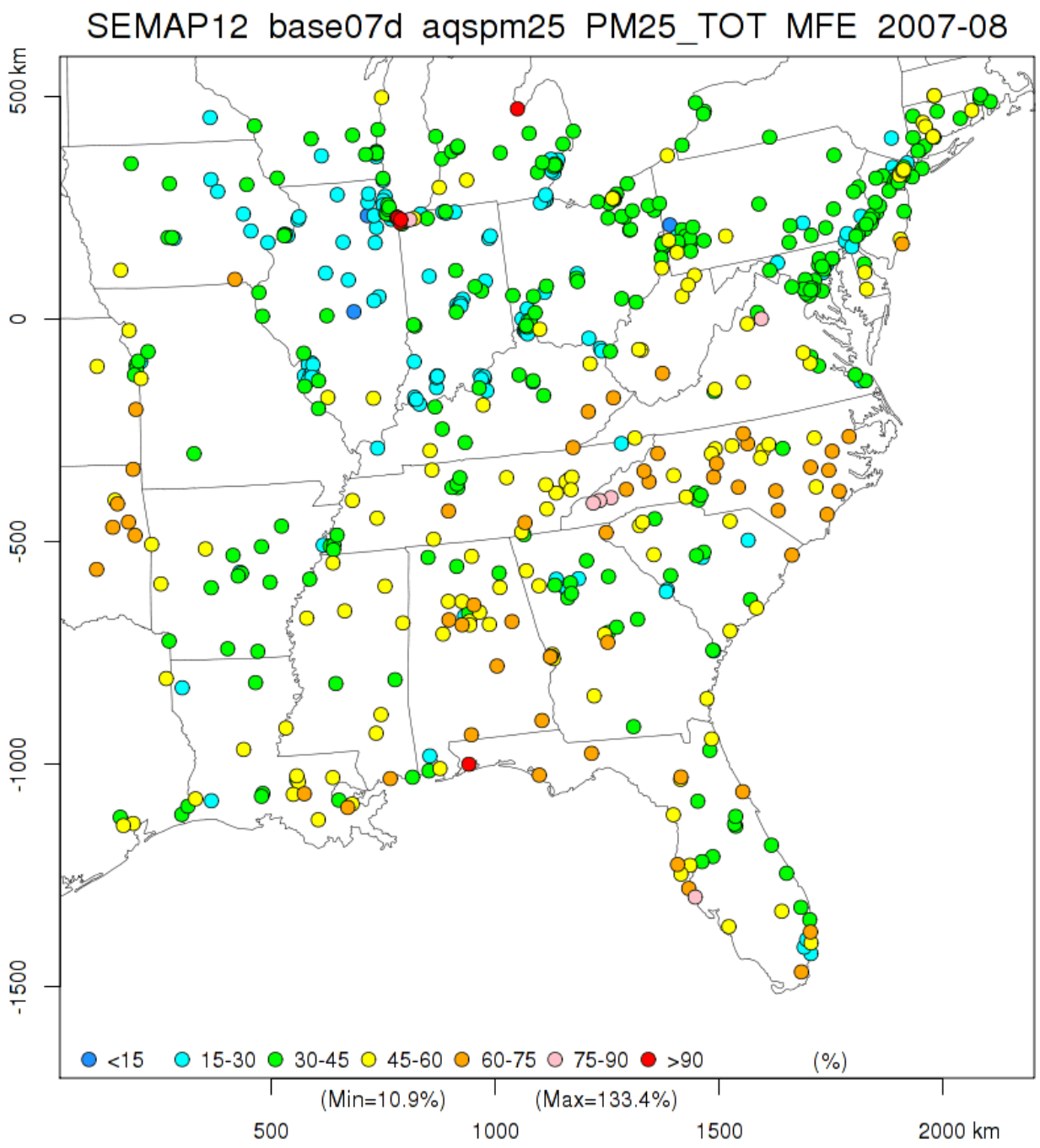


Figure 3-54 August 2007 mean fractional errors (MFE) in 24-hr average $PM_{2.5}$ at AQS sites.

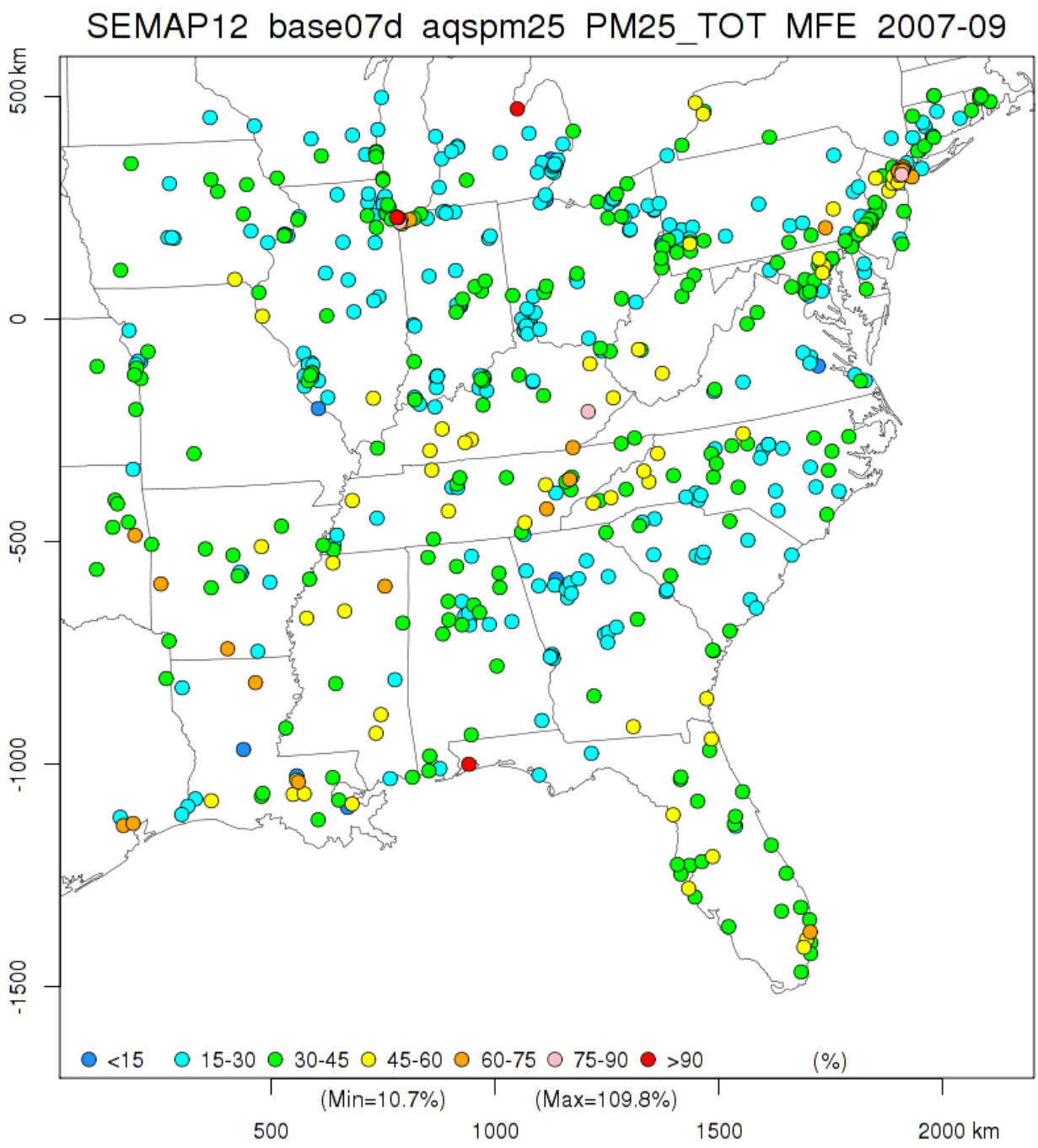


Figure 3-55 September 2007 mean fractional errors (MFE) in 24-hr average $PM_{2.5}$ at AQS sites.

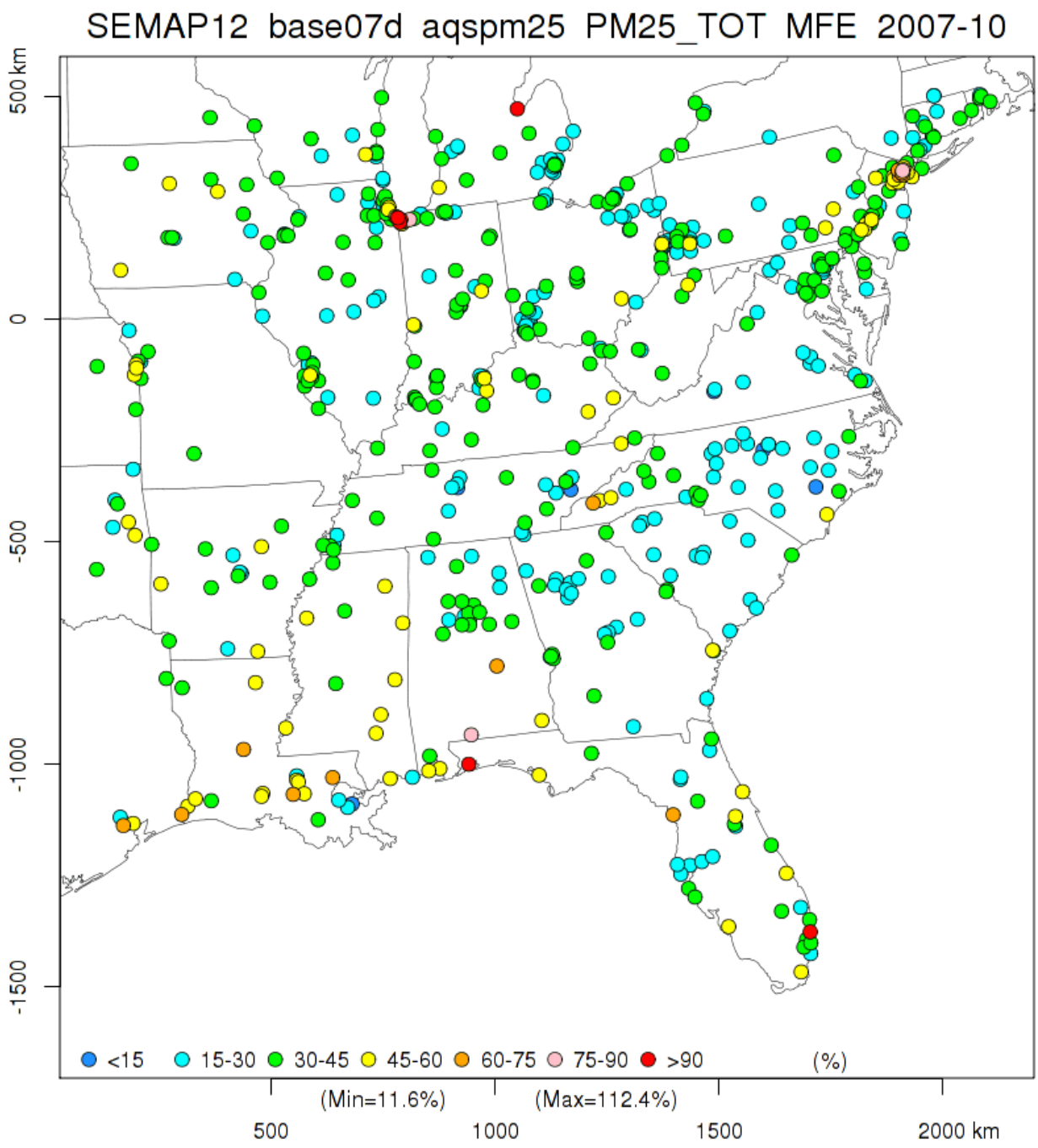


Figure 3-56 October 2007 mean fractional errors (MFE) in 24-hr average $PM_{2.5}$ at AQS sites.

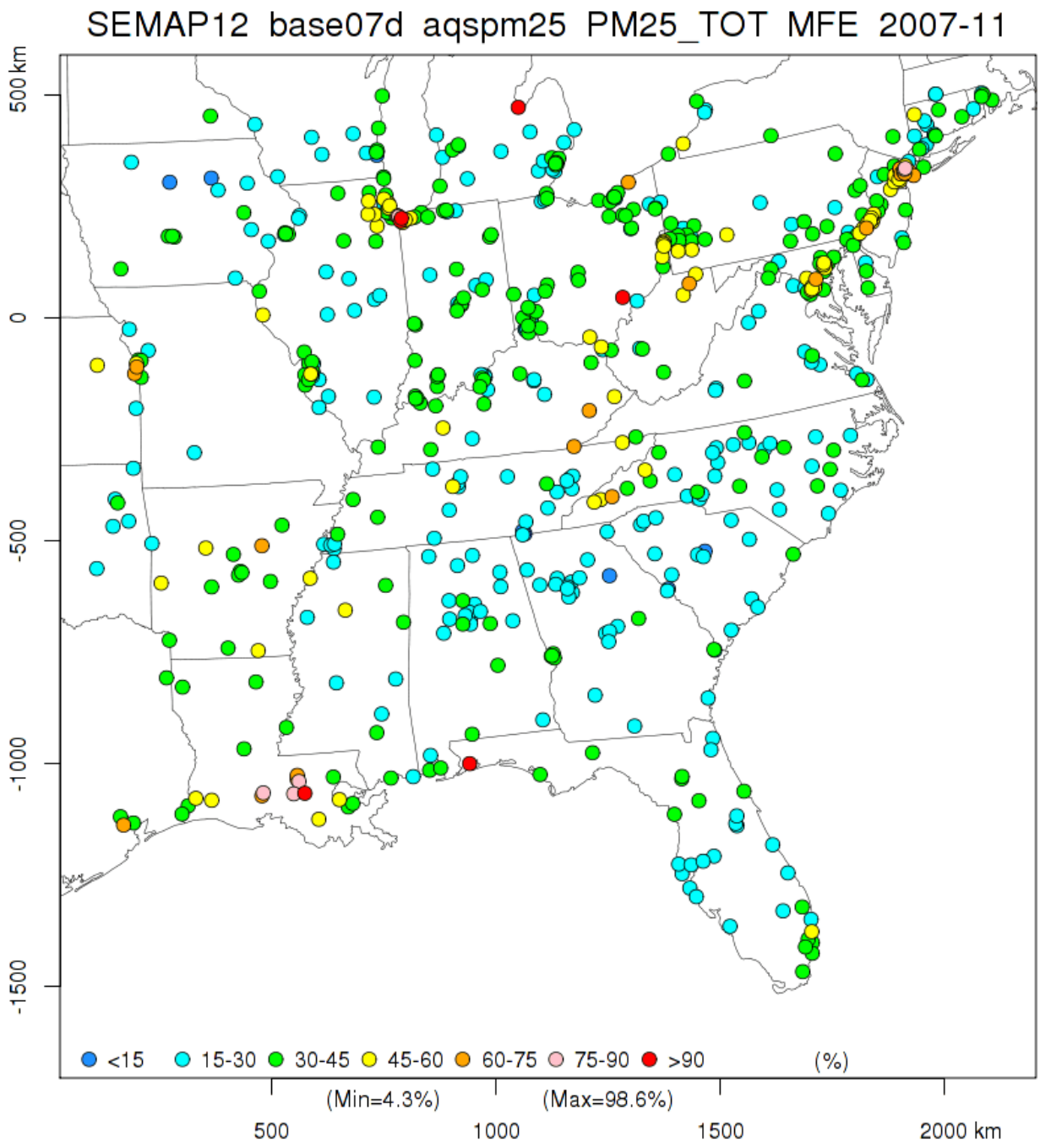


Figure 3-57 November 2007 mean fractional errors (MFE) in 24-hr average $PM_{2.5}$ at AQS sites.

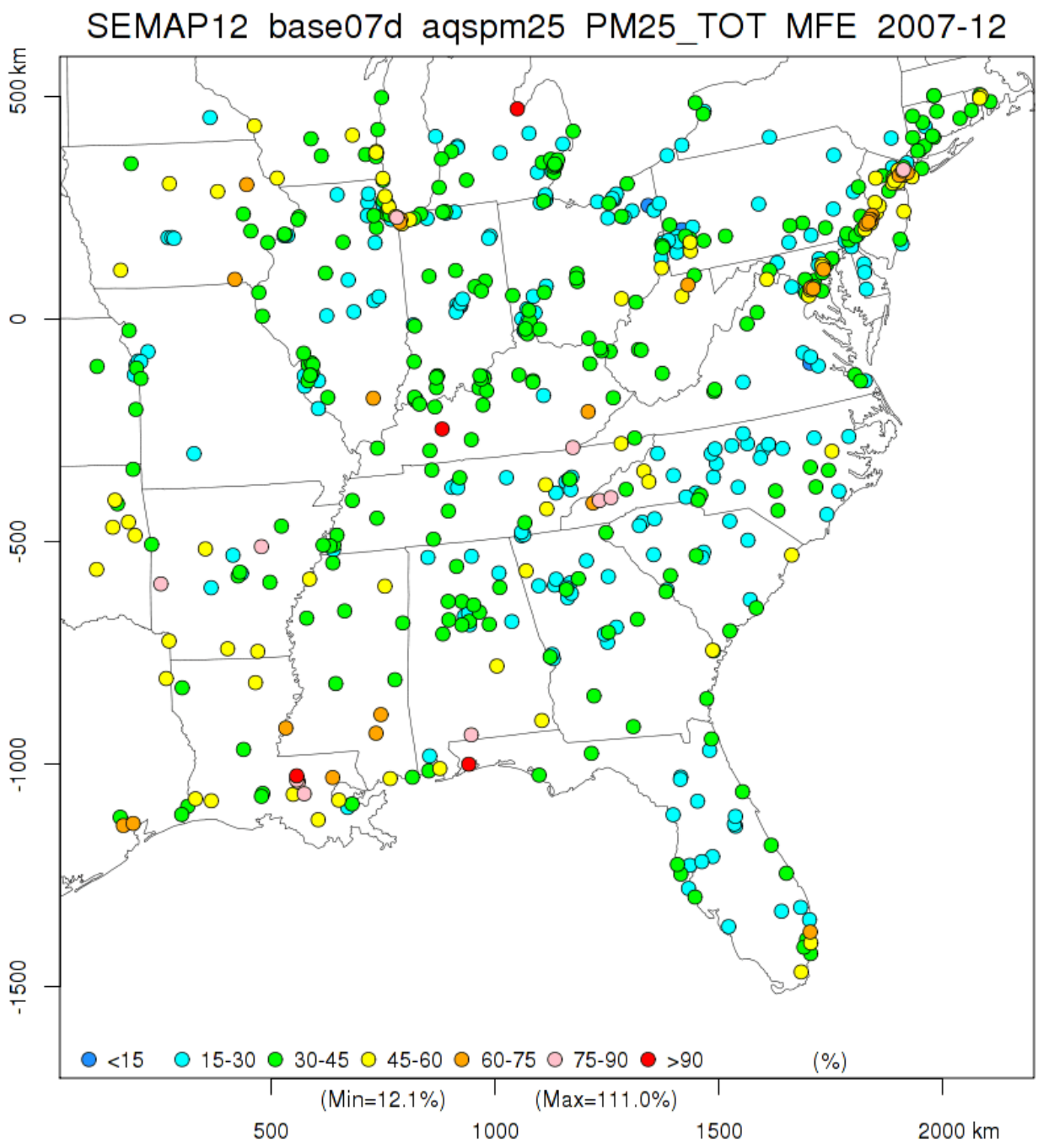


Figure 3-58 December 2007 mean fractional errors (MFE) in 24-hr average $PM_{2.5}$ at AQS sites.

3.10.3 $PM_{2.5}$ Components

At the CSN sites of the SEMAP 12-km domain, sulfate was predicted accurately in spring and fall but underestimated both in winter and in summer months (Figure 3-59 through Figure 3-70), nitrate was overestimated in winter and fall months but underestimated in spring and summer months (Figure 3-71 through Figure 3-82), ammonium was underestimated similarly to sulfate in summer and overestimated similarly to nitrate in winter months (Figure 3-83 through Figure 3-94), elemental carbon was overestimated in winter and summer months but underestimated in spring and fall months (Figure 3-95 through Figure 3-106), and organic carbon was underestimated throughout the year.

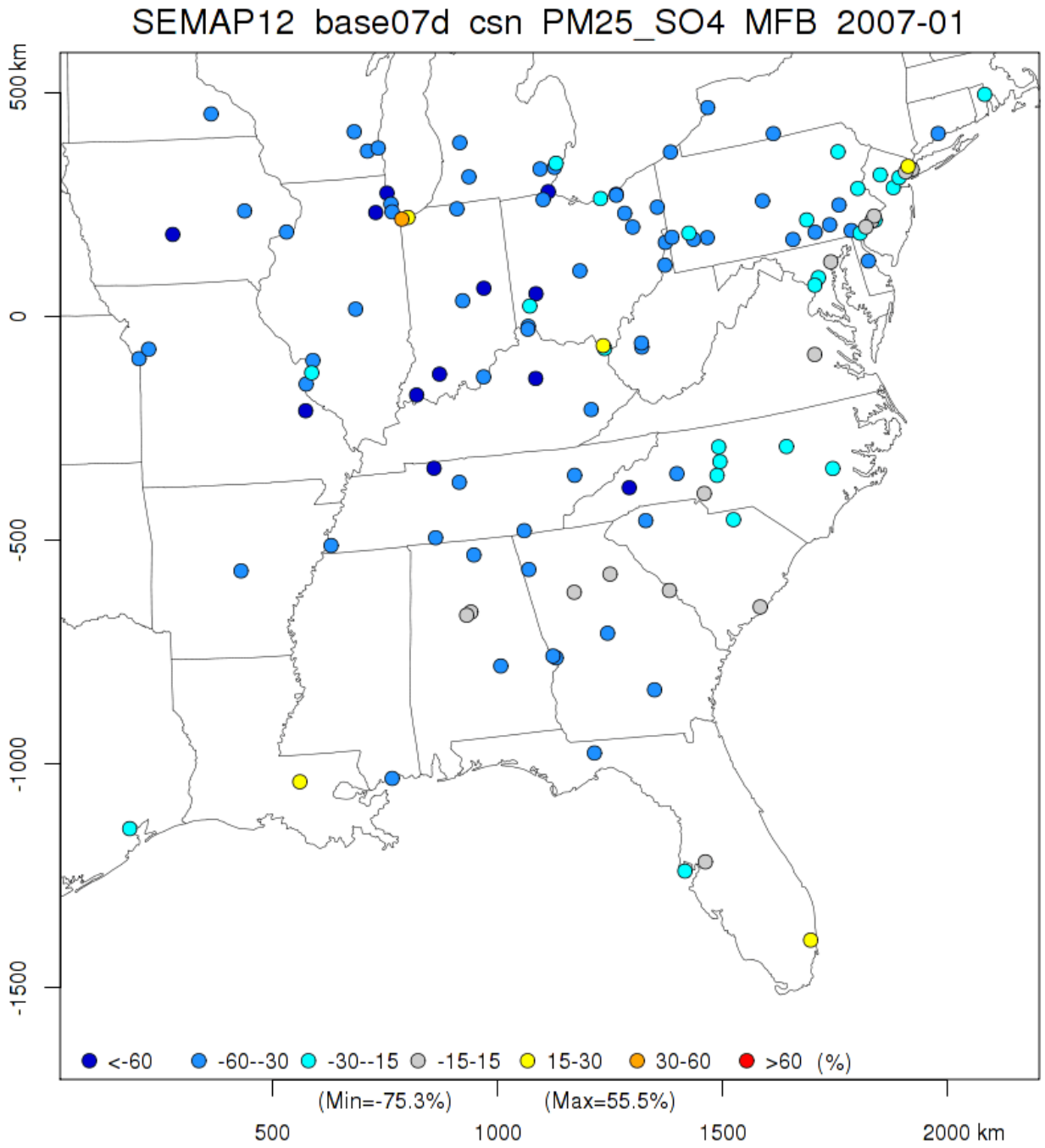


Figure 3-59 January 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ sulfate at CSN sites.

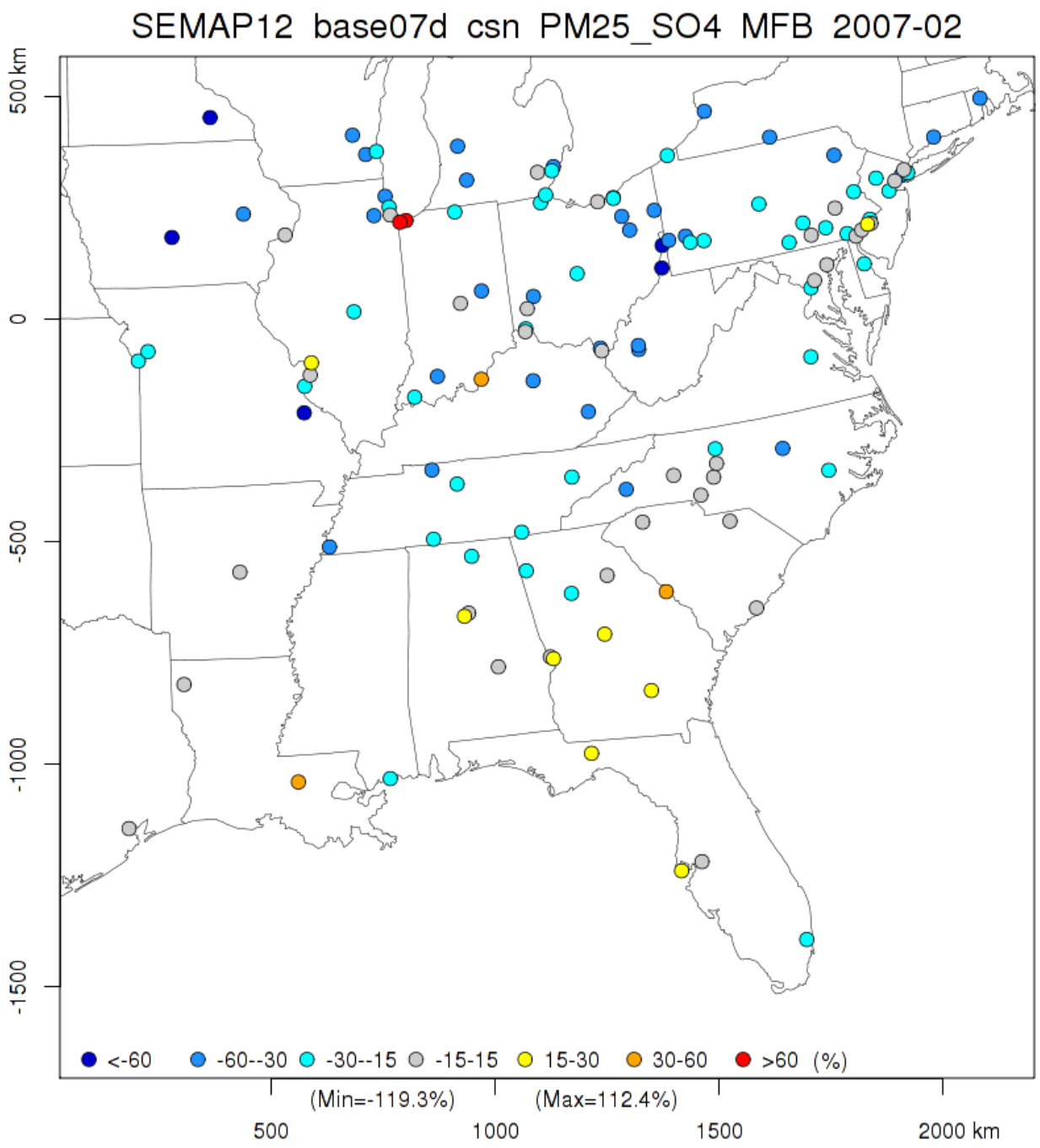


Figure 3-60 February 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ sulfate at CSN sites.

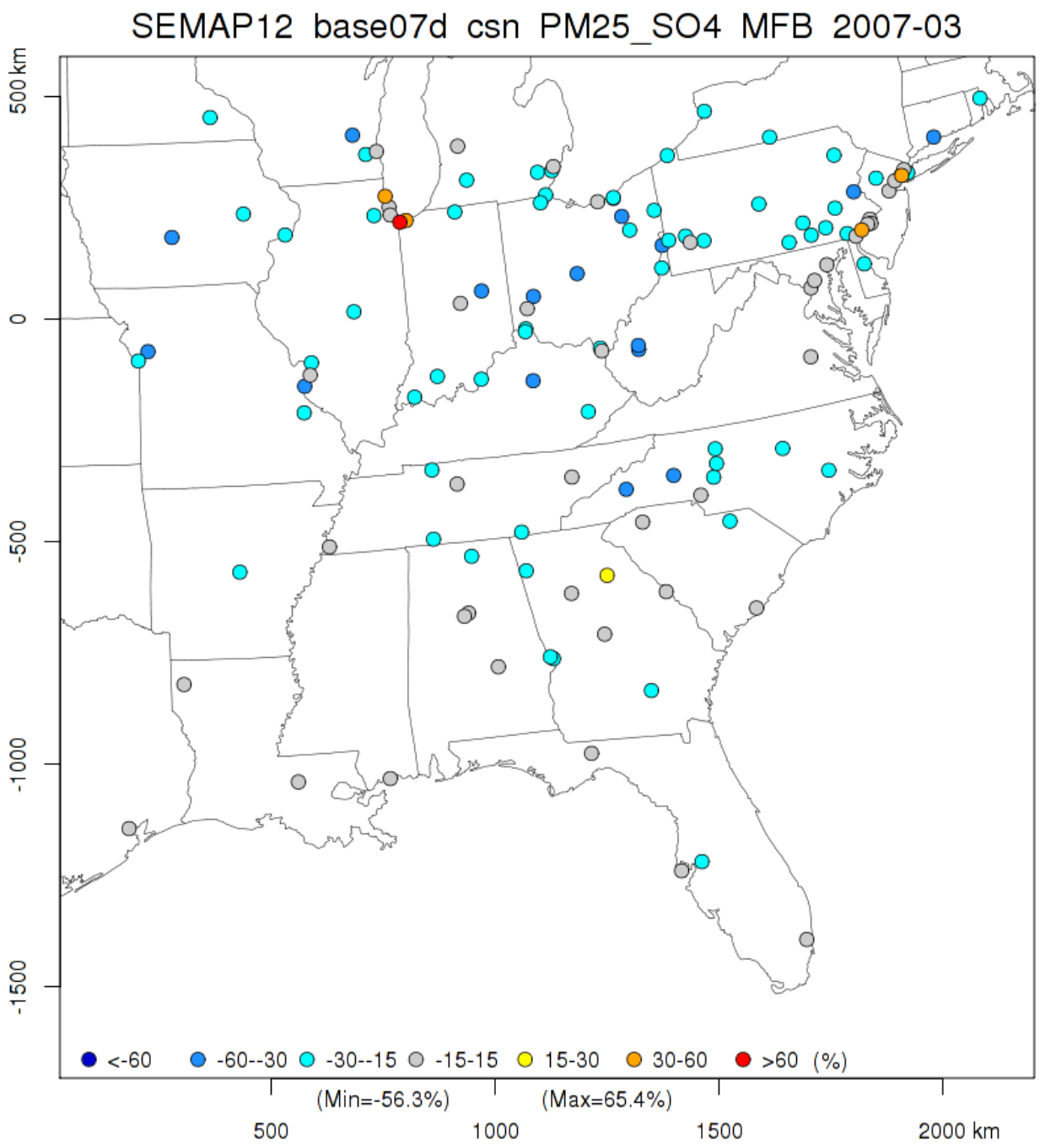


Figure 3-61 March 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ sulfate at CSN sites.

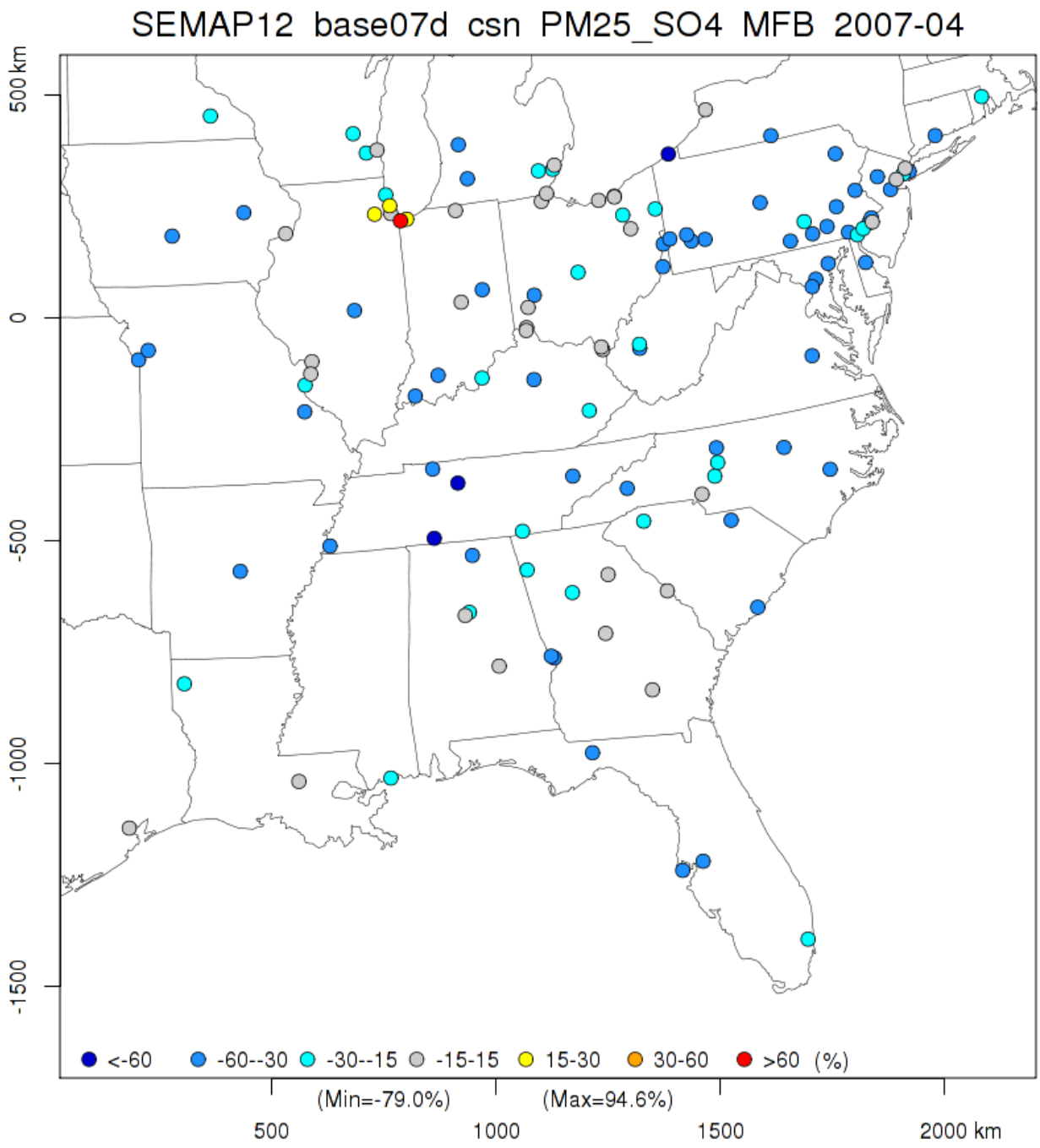


Figure 3-62 April 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ sulfate at CSN sites.

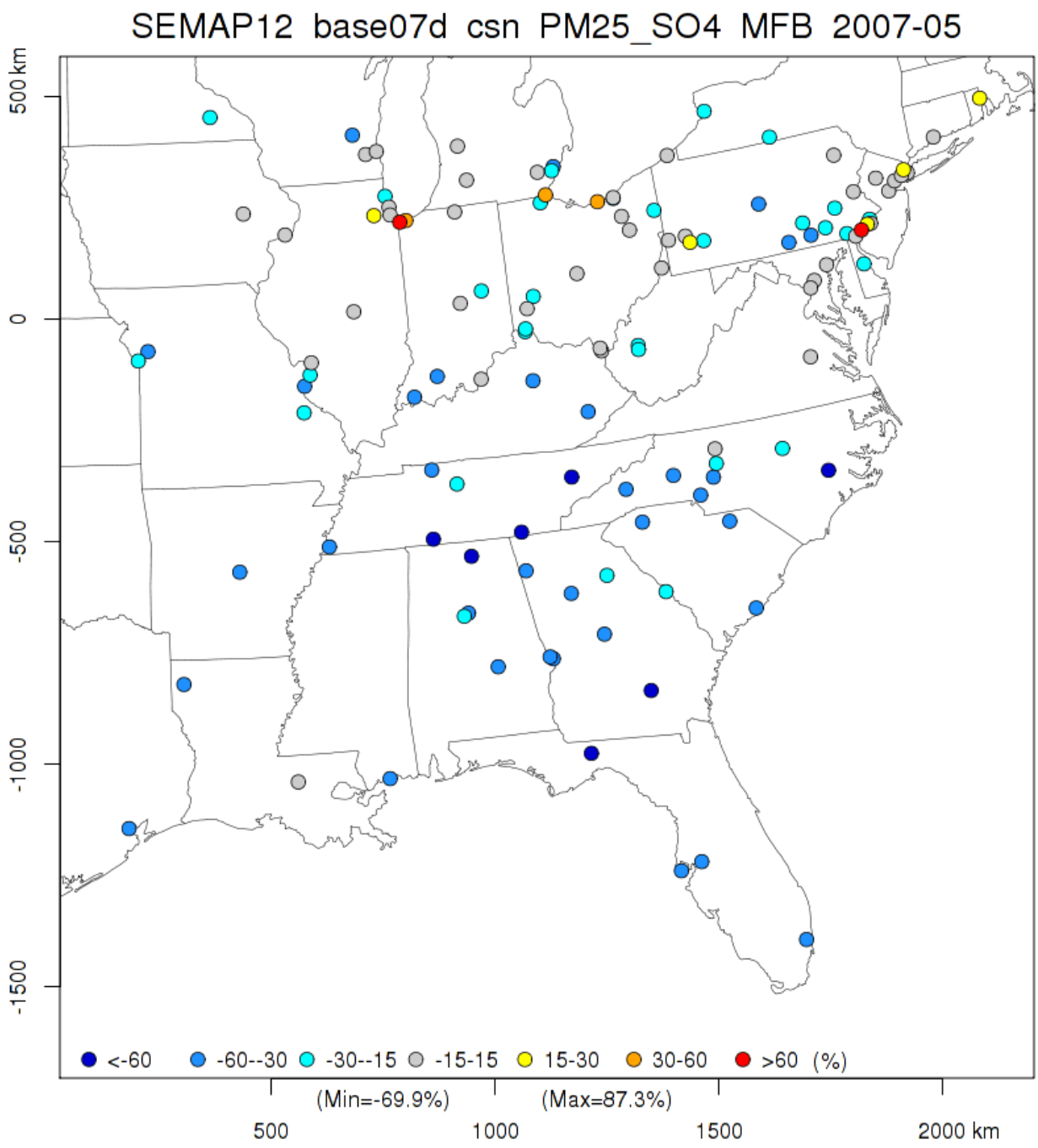


Figure 3-63 May 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ sulfate at CSN sites.

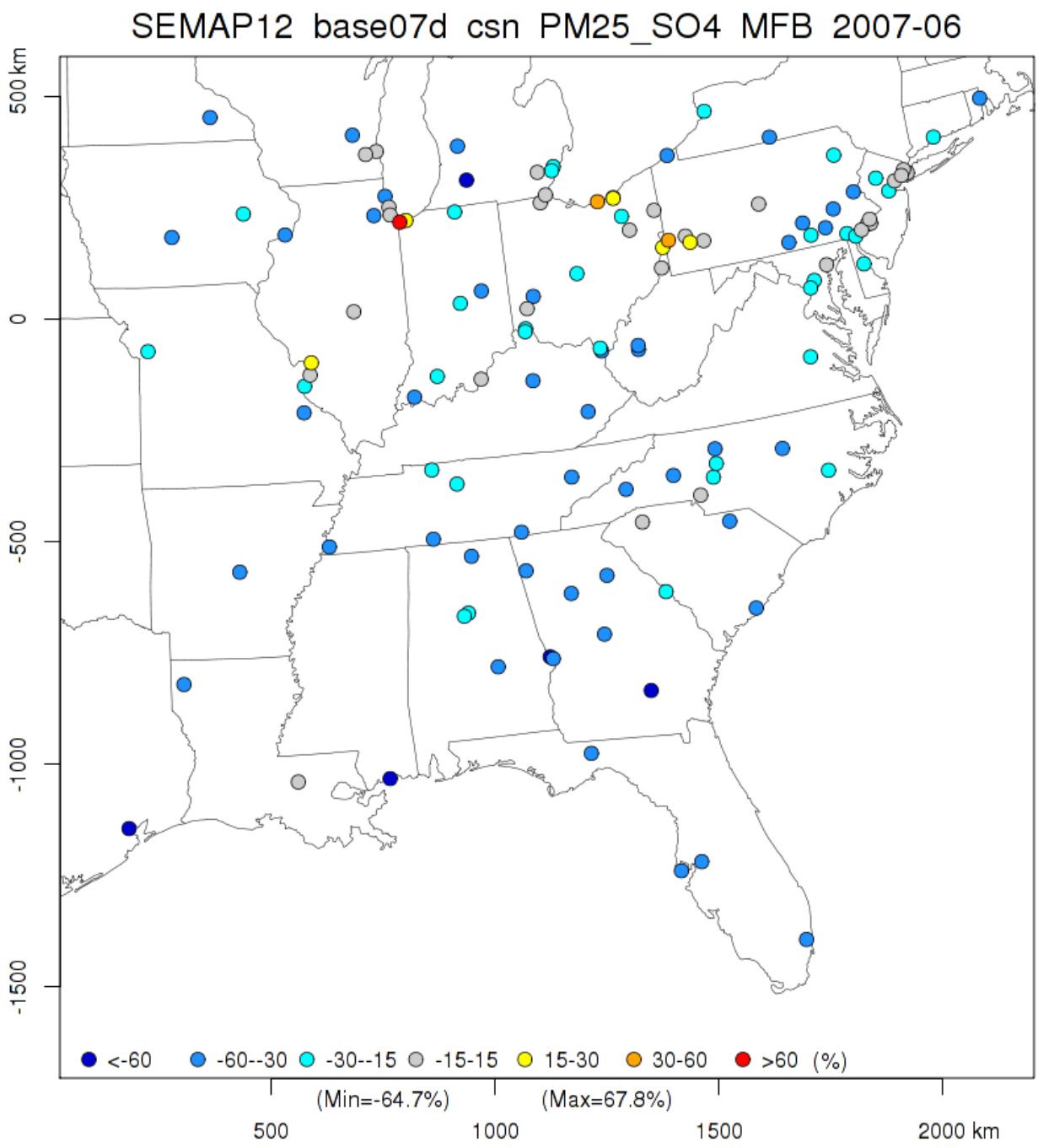


Figure 3-64 June 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ sulfate at CSN sites.

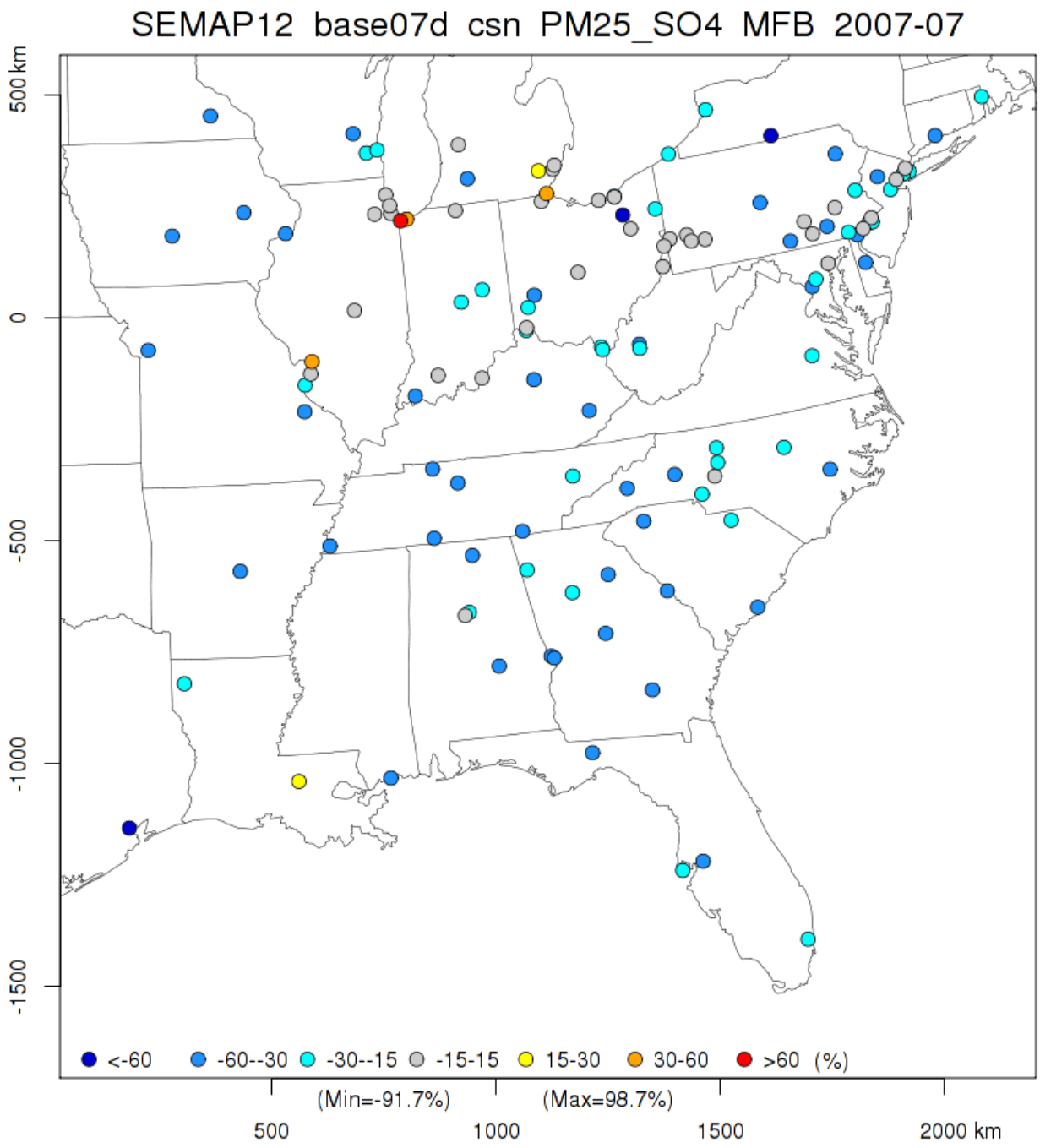


Figure 3-65 July 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ sulfate at CSN sites.

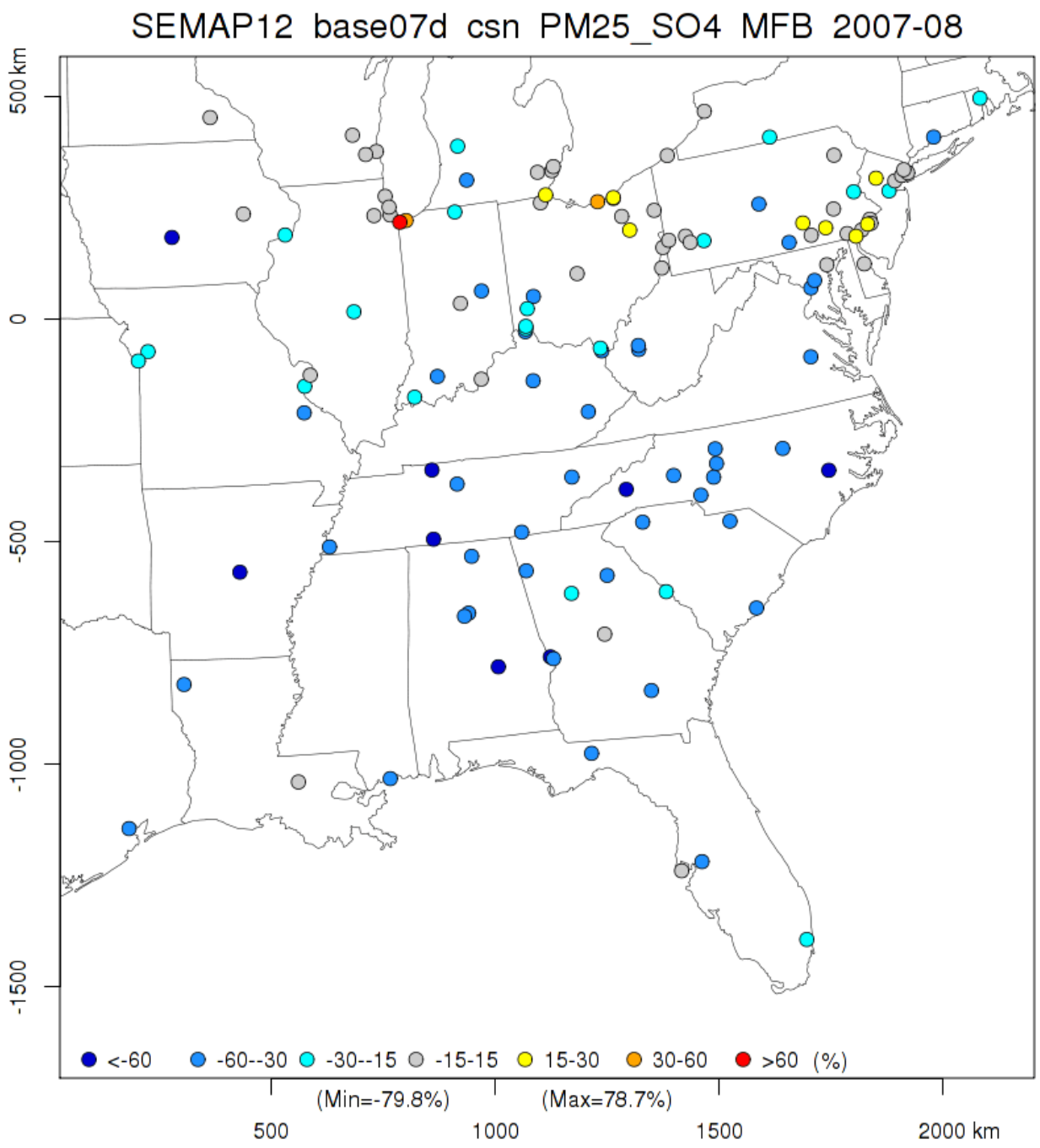


Figure 3-66 August 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ sulfate at CSN sites.

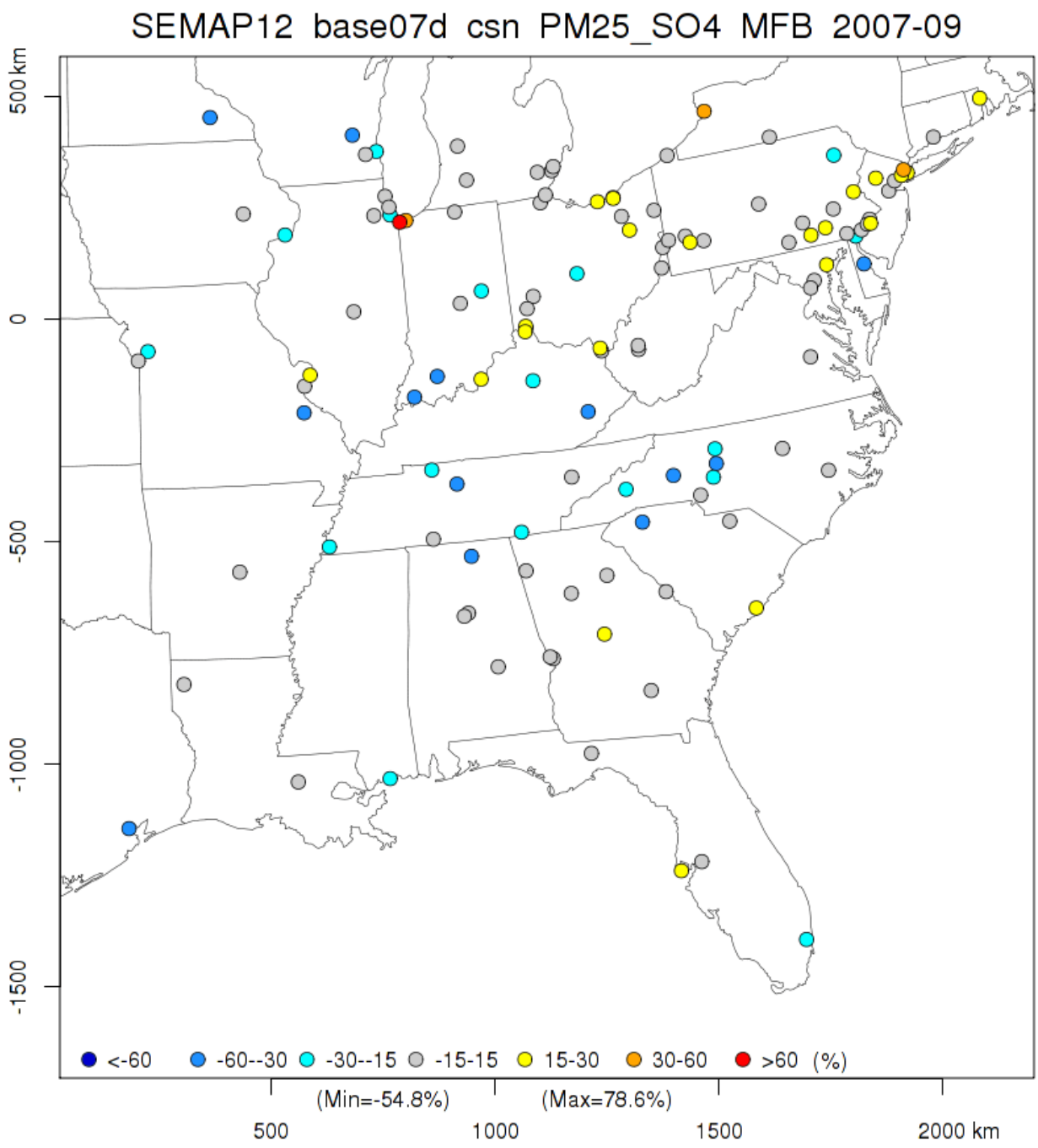


Figure 3-67 September 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ sulfate at CSN sites.

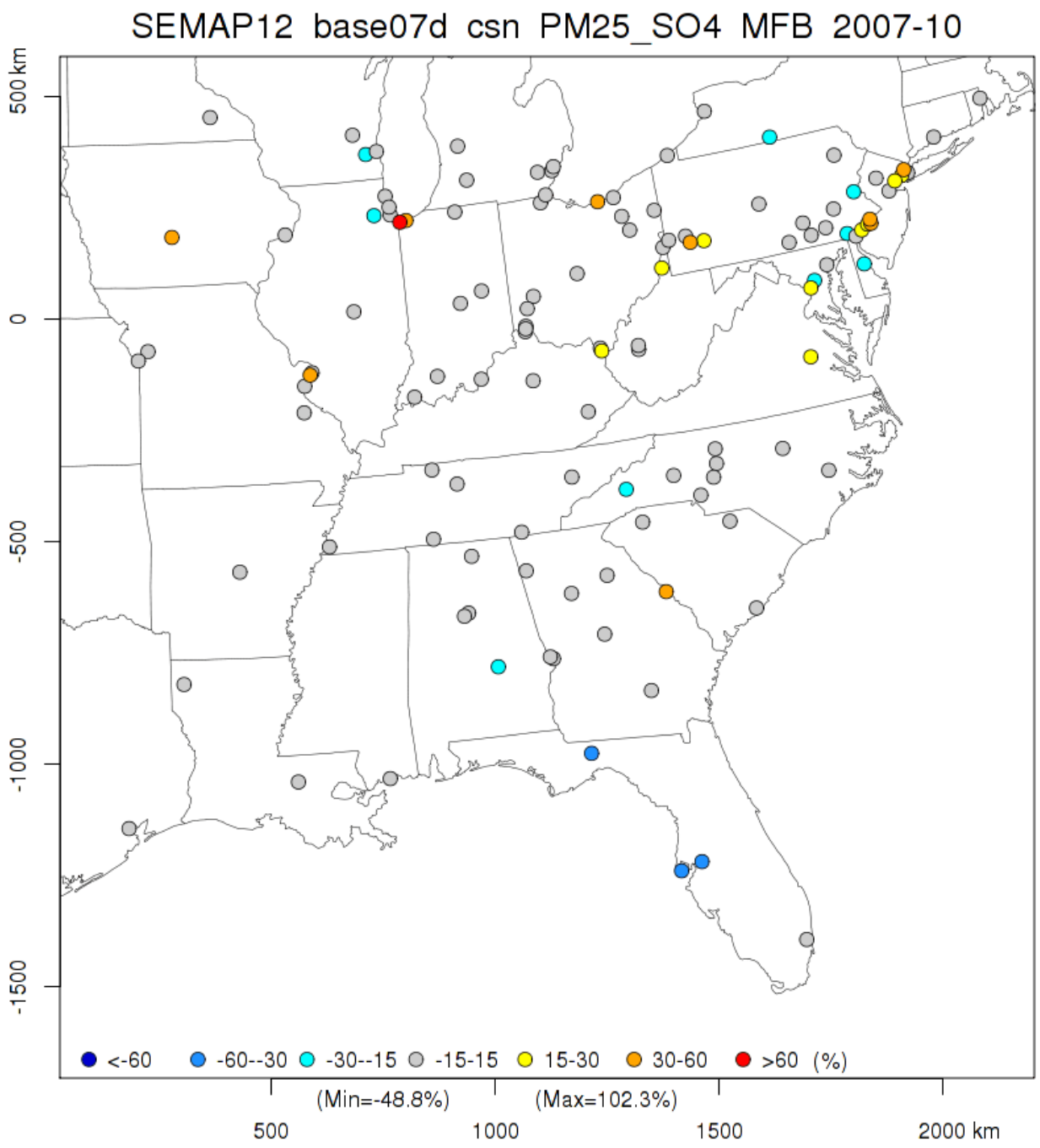


Figure 3-68 October 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ sulfate at CSN sites.

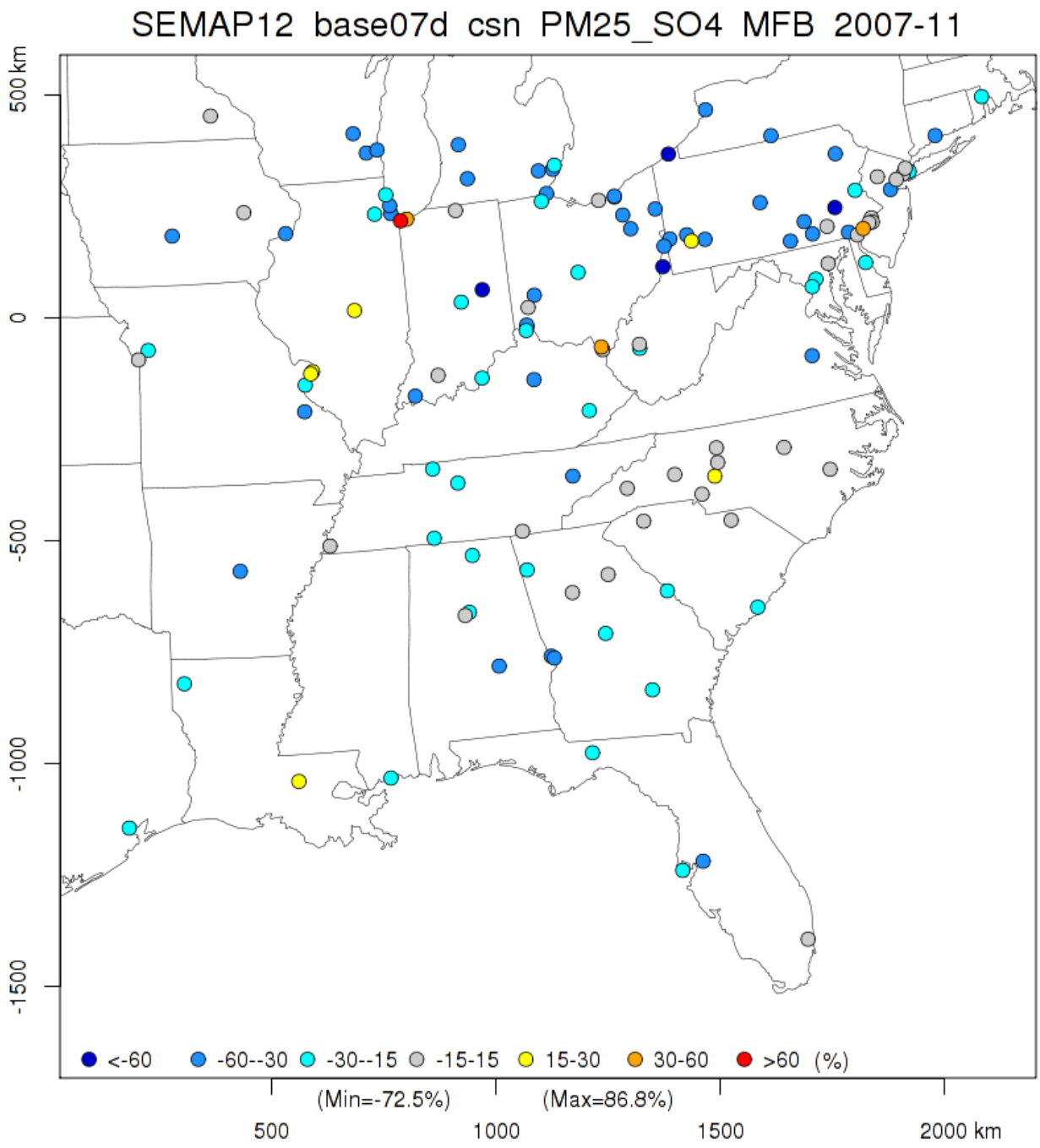


Figure 3-69 November 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ sulfate at CSN sites.

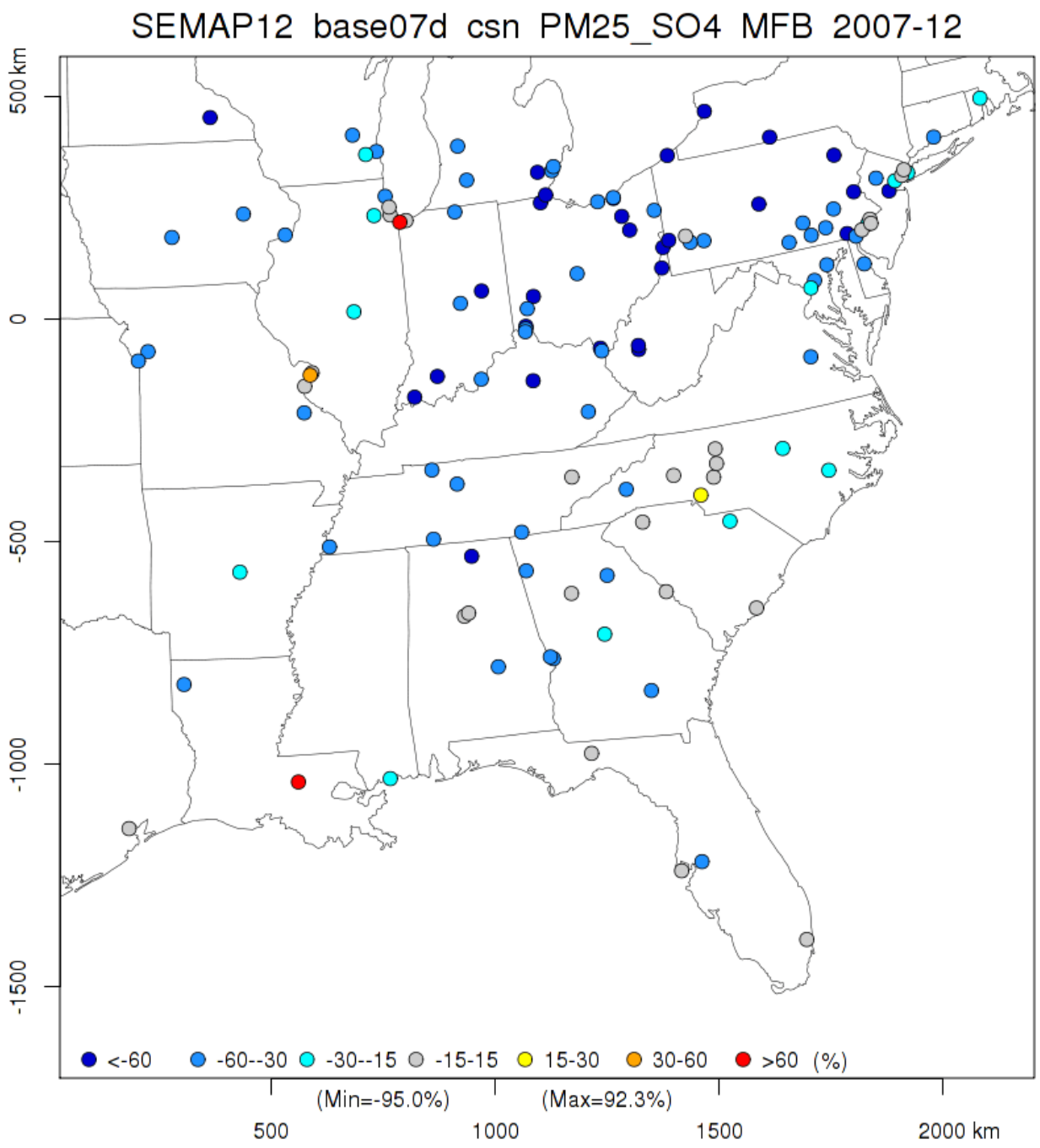


Figure 3-70 December 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ sulfate at CSN sites.

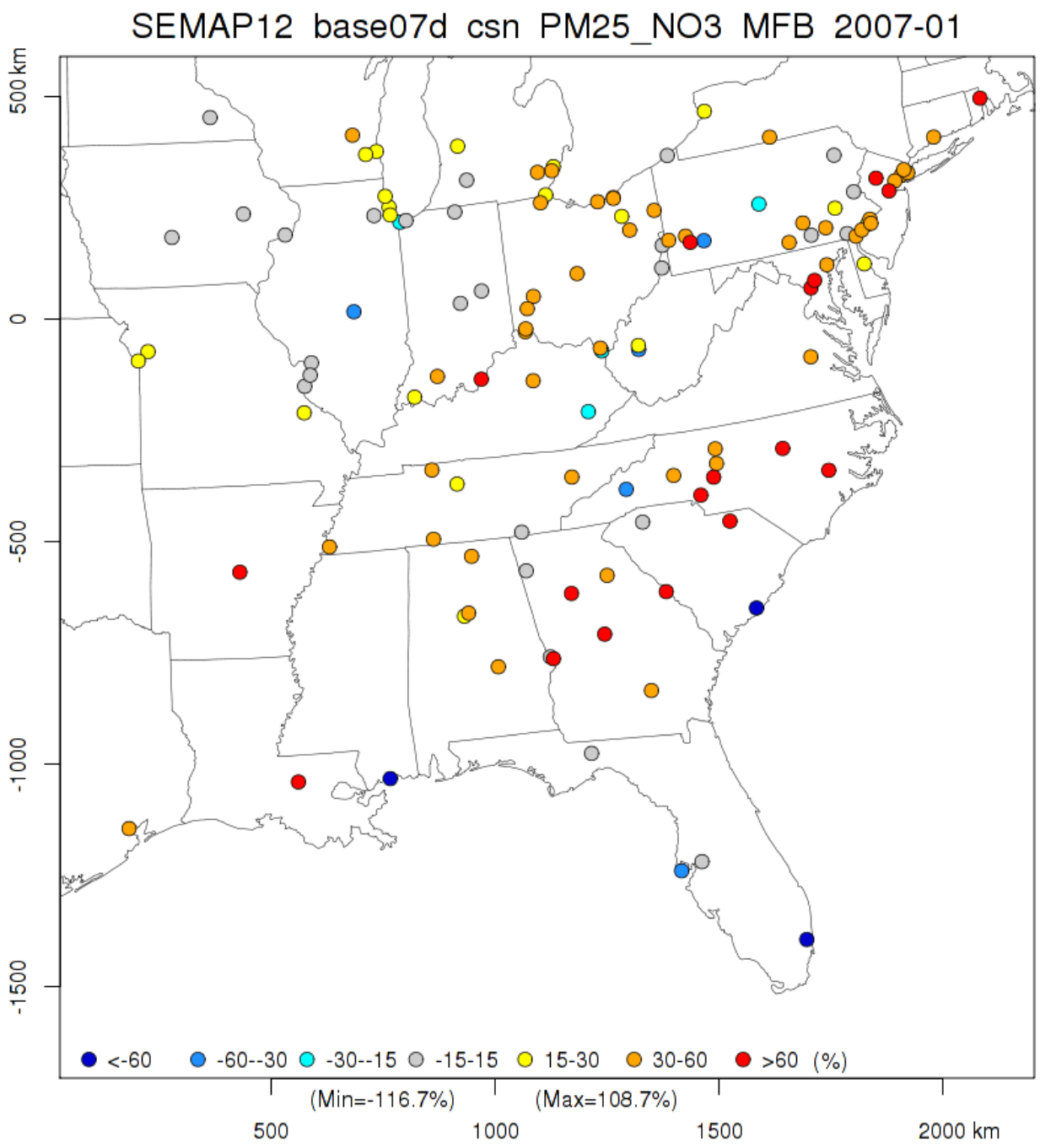


Figure 3-71 January 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ nitrate at CSN sites.

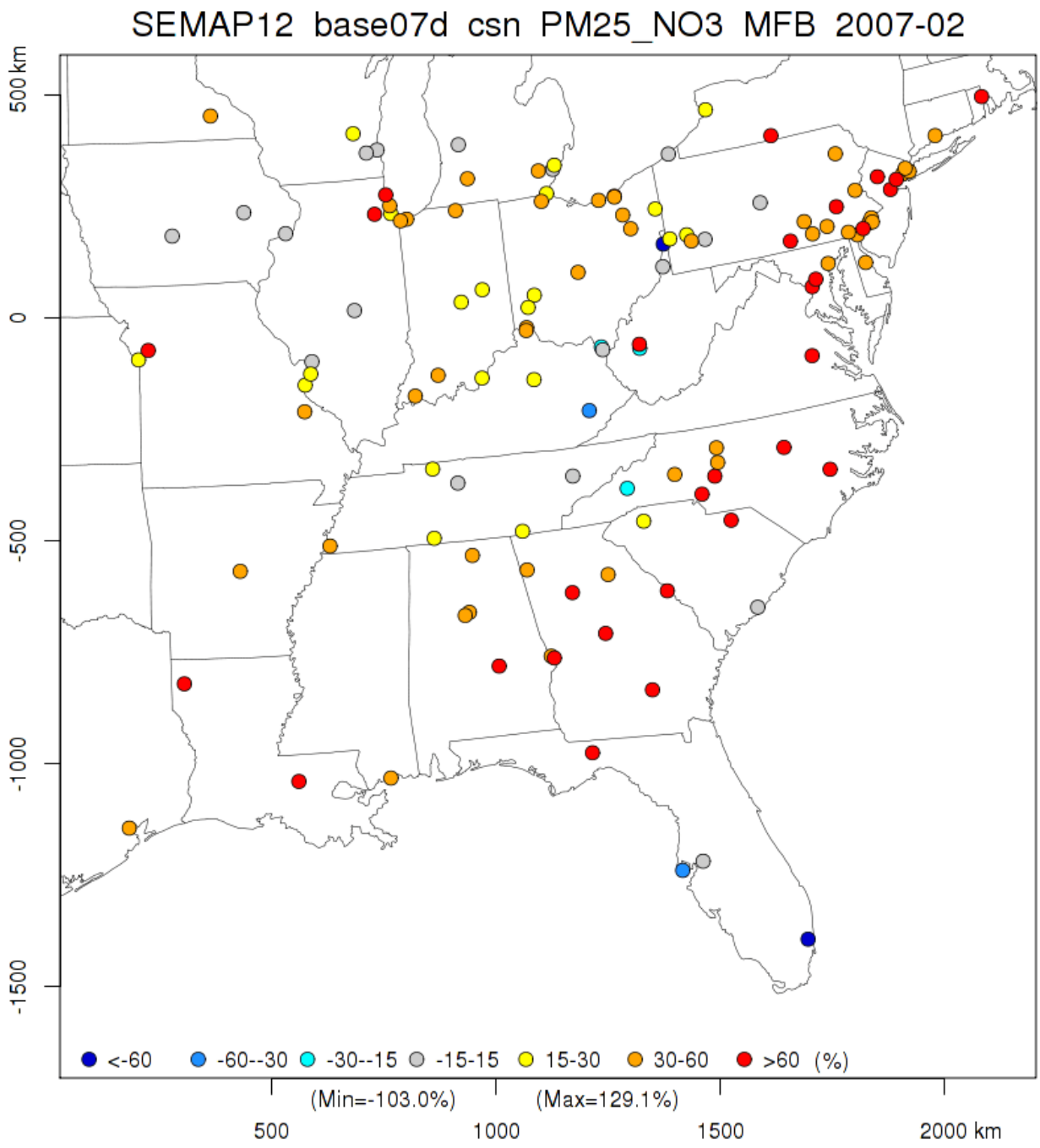


Figure 3-72 February 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ nitrate at CSN sites.

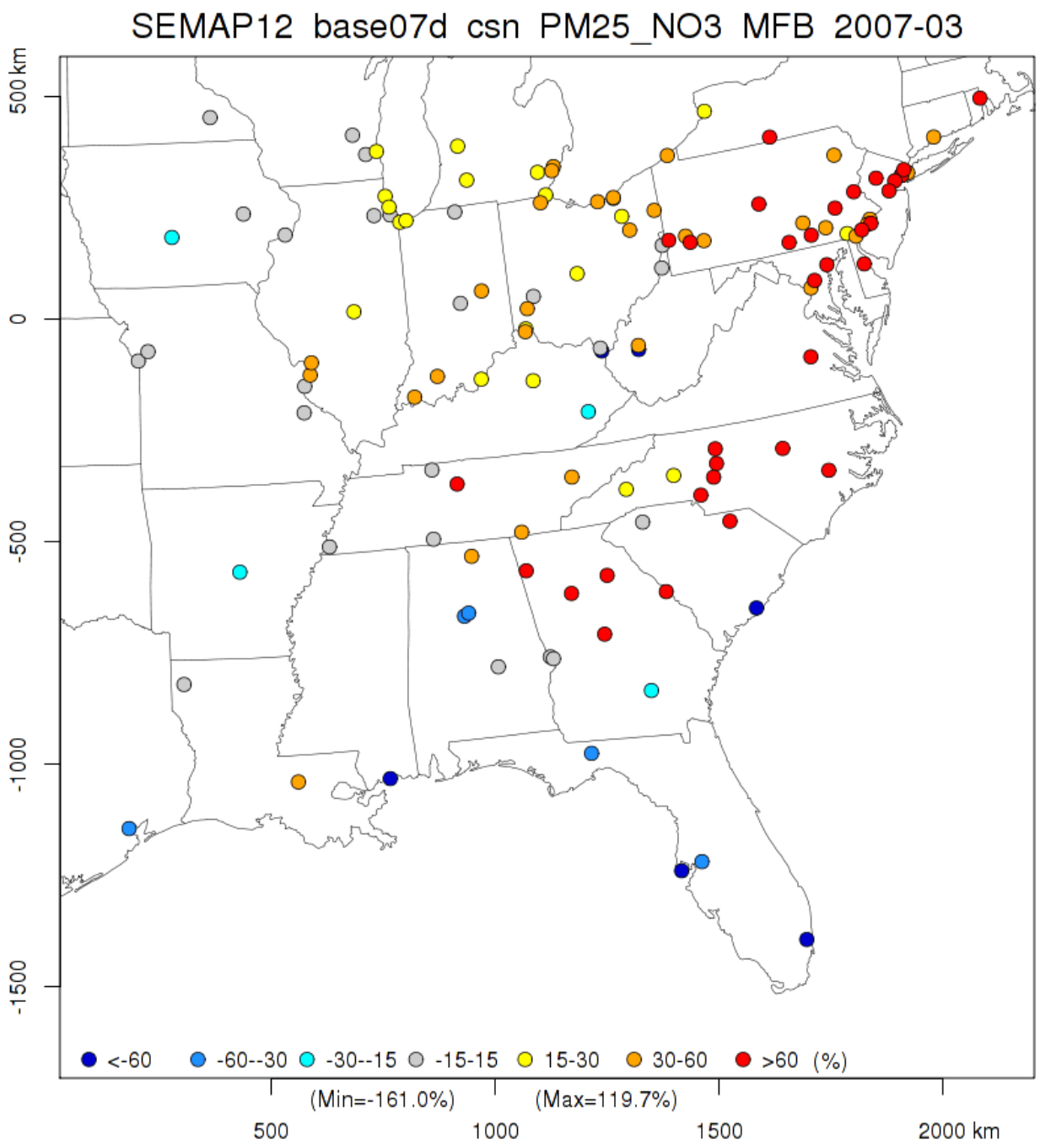


Figure 3-73 March 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ nitrate at CSN sites.

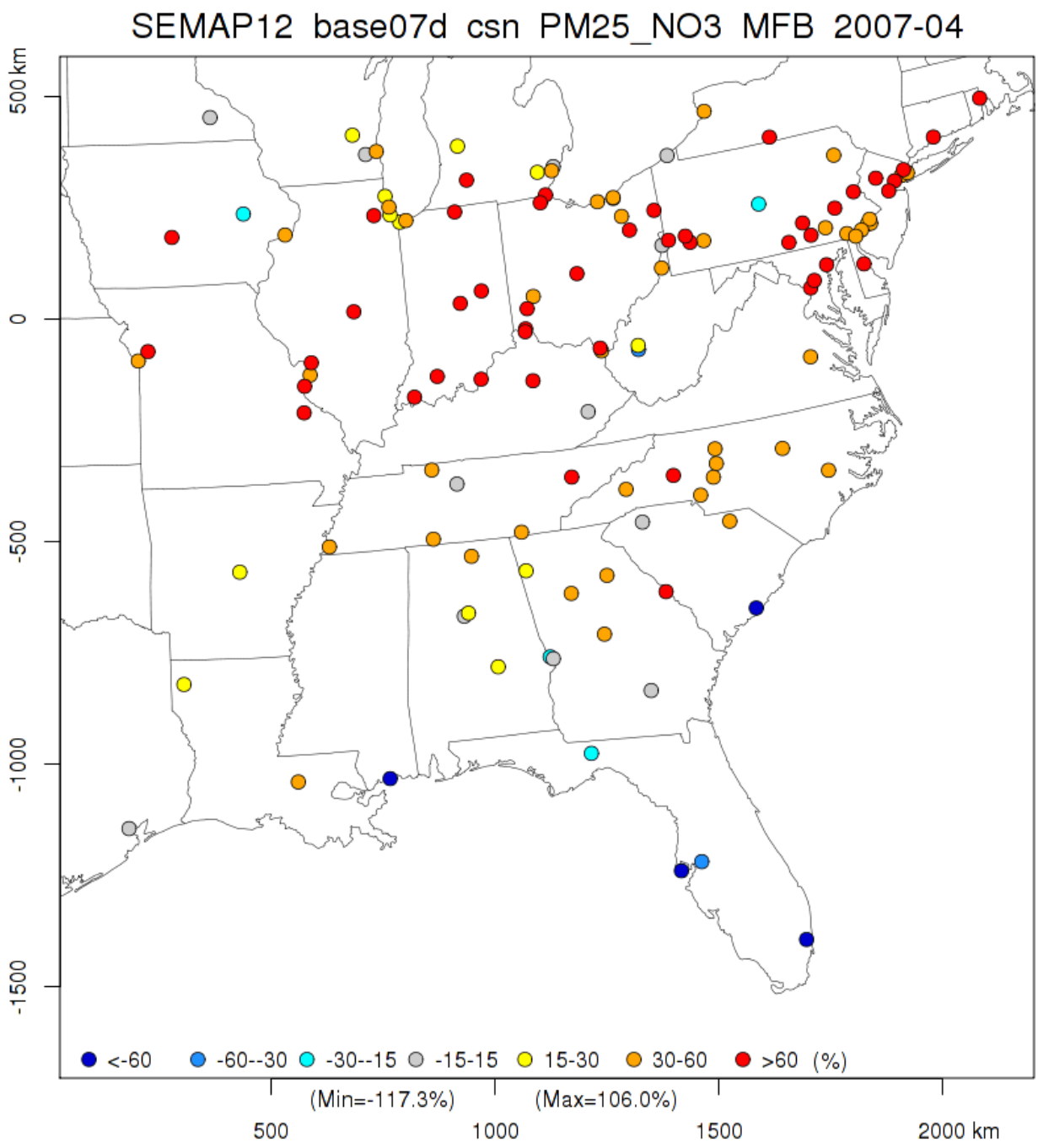


Figure 3-74 April 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ nitrate at CSN sites.

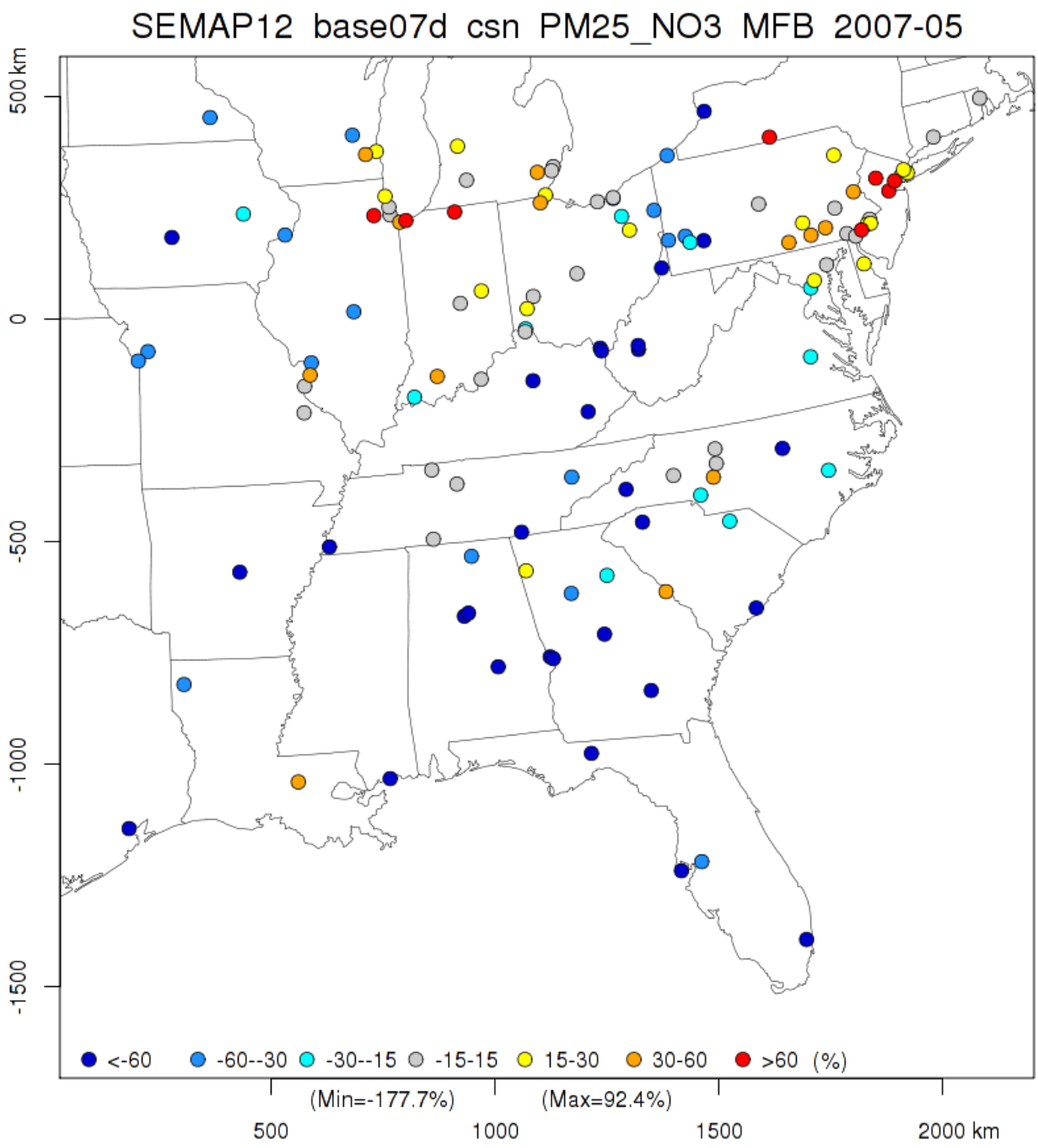


Figure 3-75 May 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ nitrate at CSN sites.

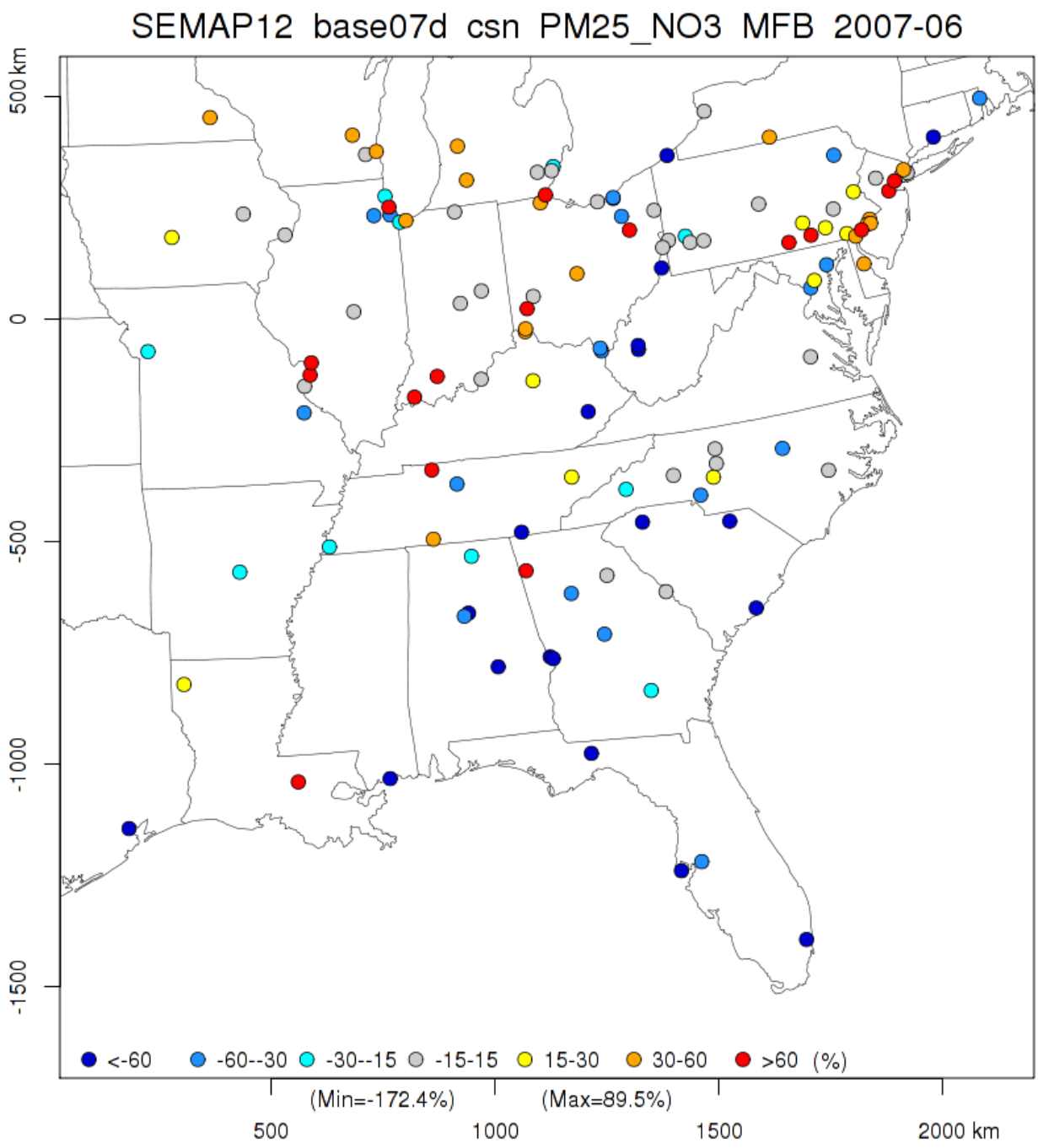


Figure 3-76 June 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ nitrate at CSN sites.

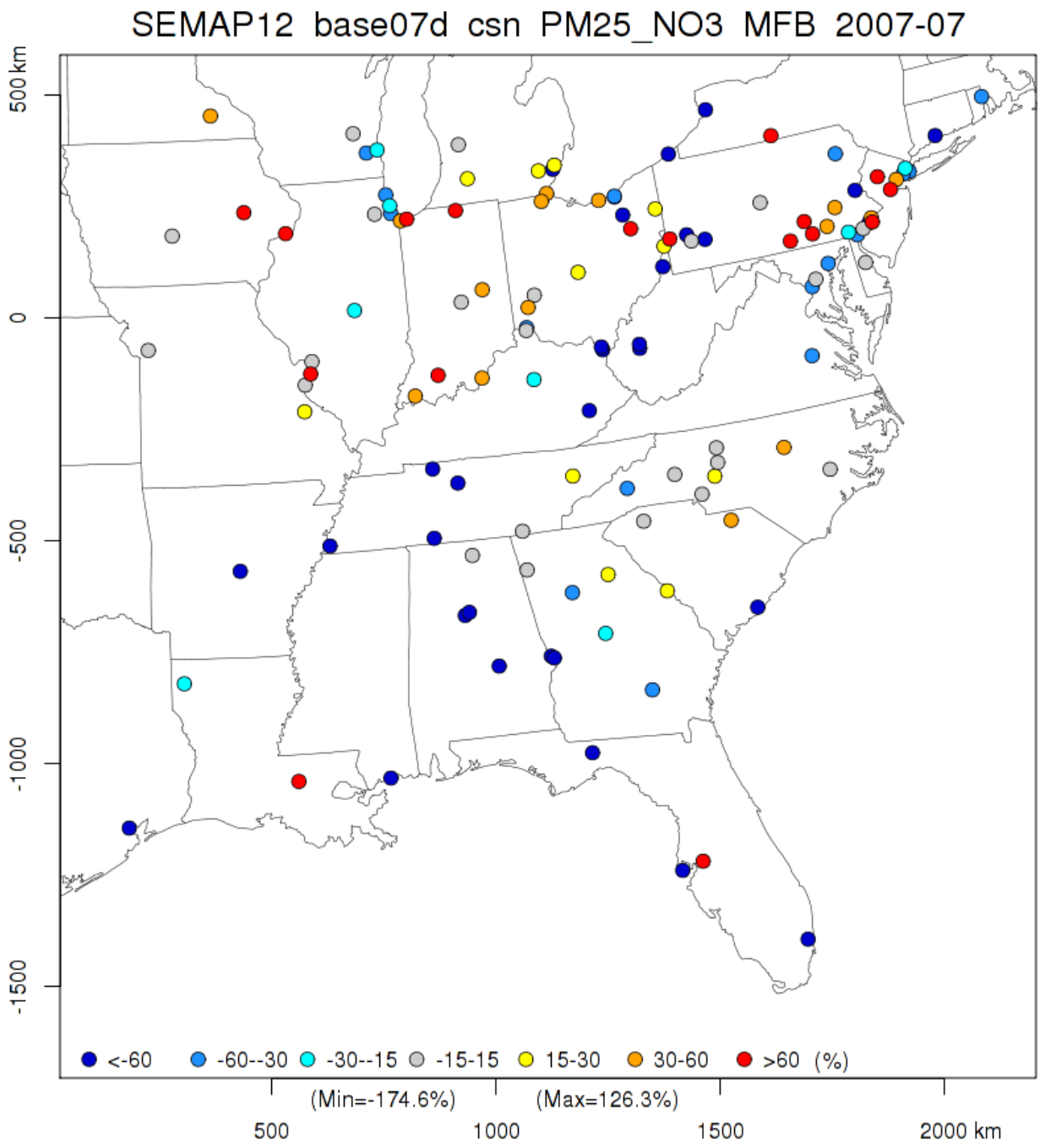


Figure 3-77 July 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ nitrate at CSN sites.

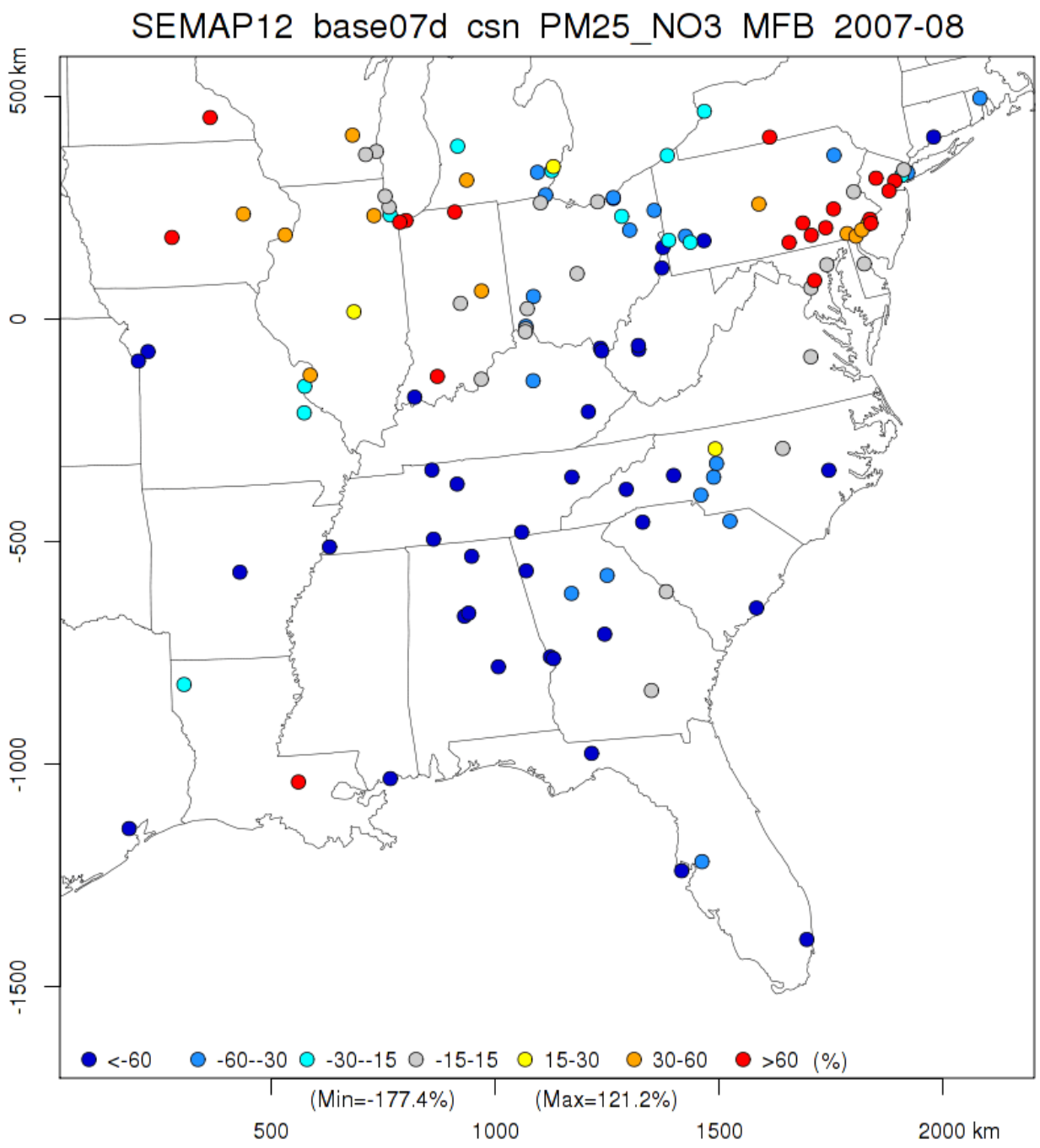


Figure 3-78 August 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ nitrate at CSN sites.

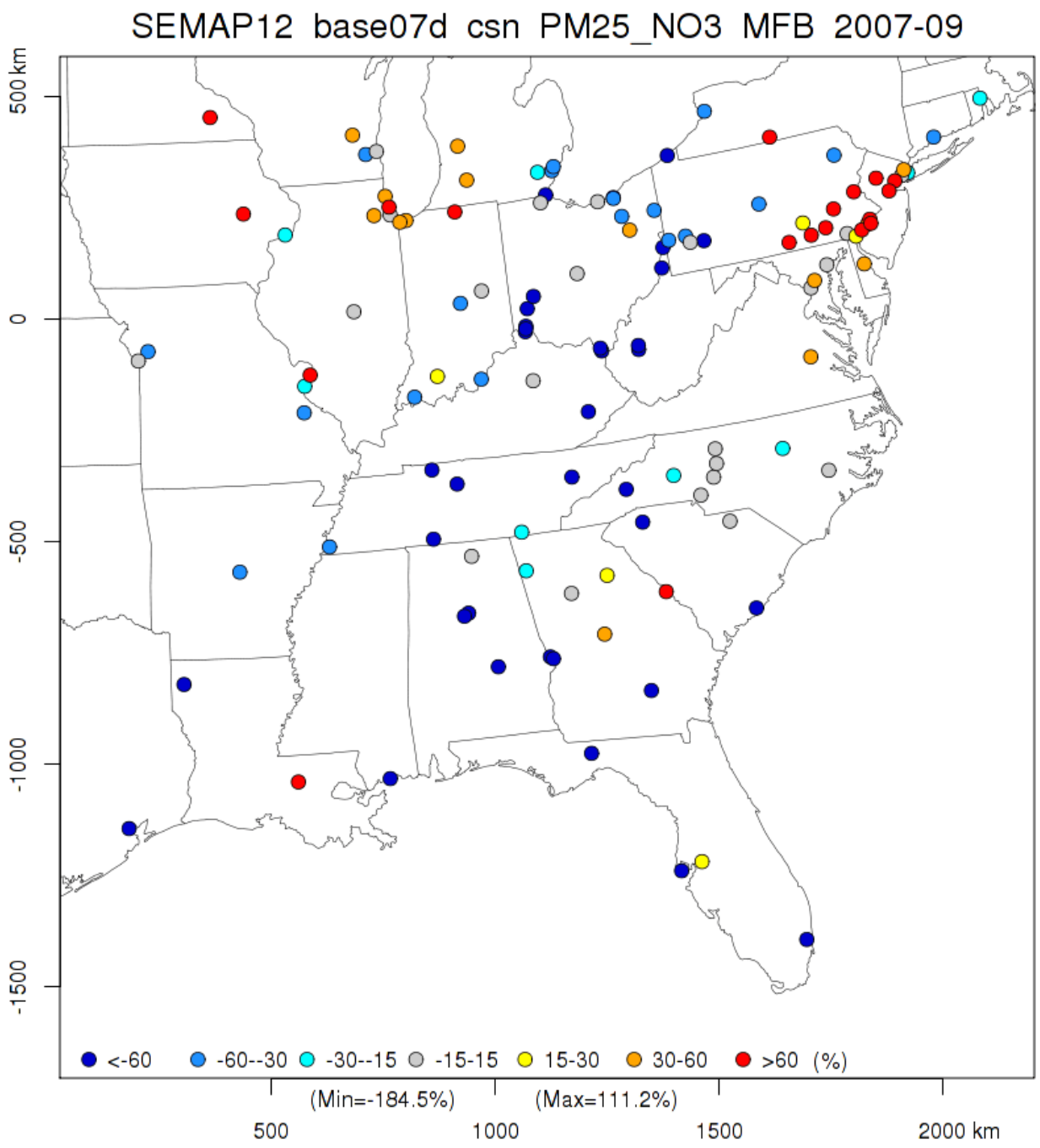


Figure 3-79September 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ nitrate at CSN sites.

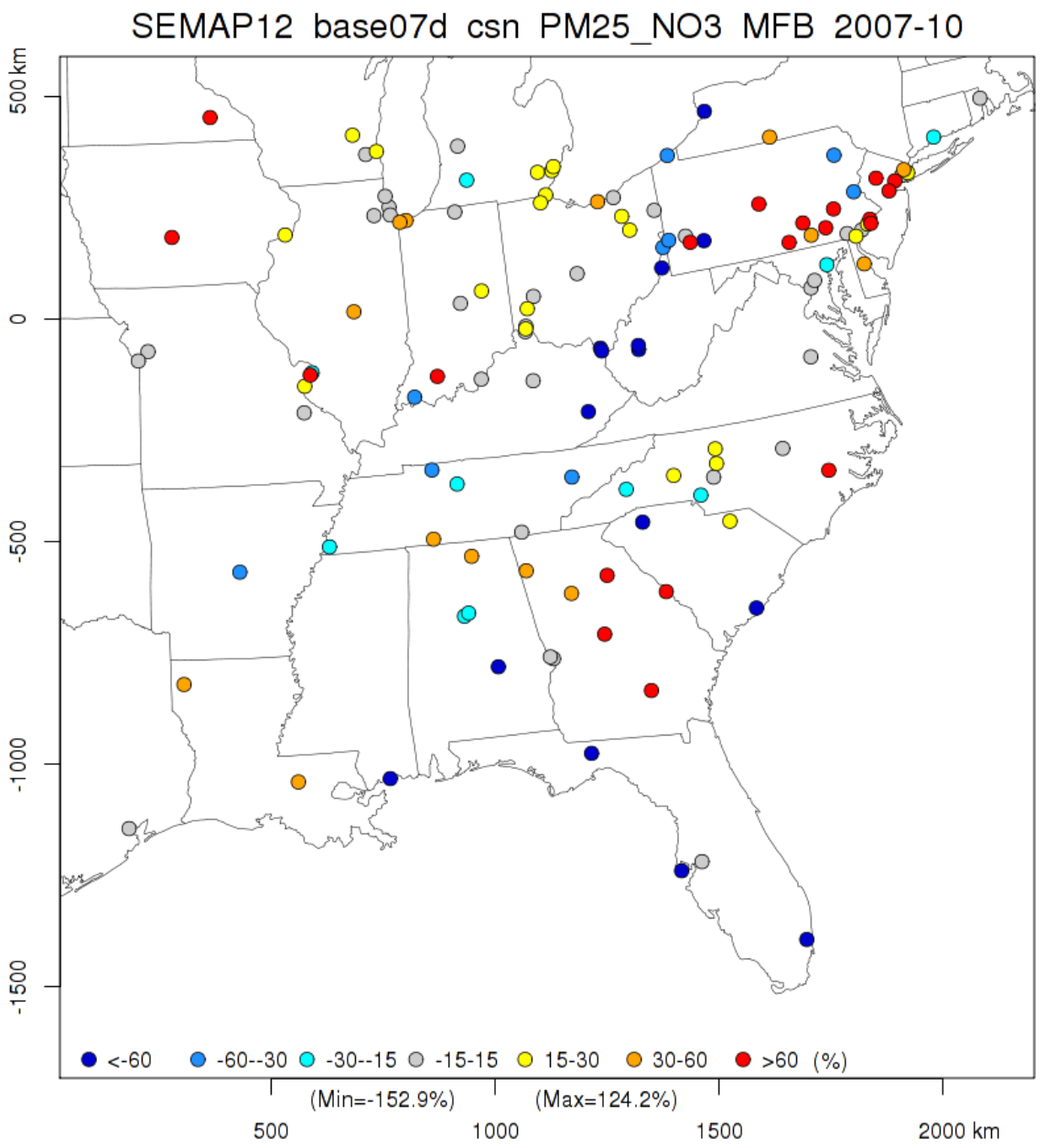


Figure 3-80 October 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ nitrate at CSN sites.

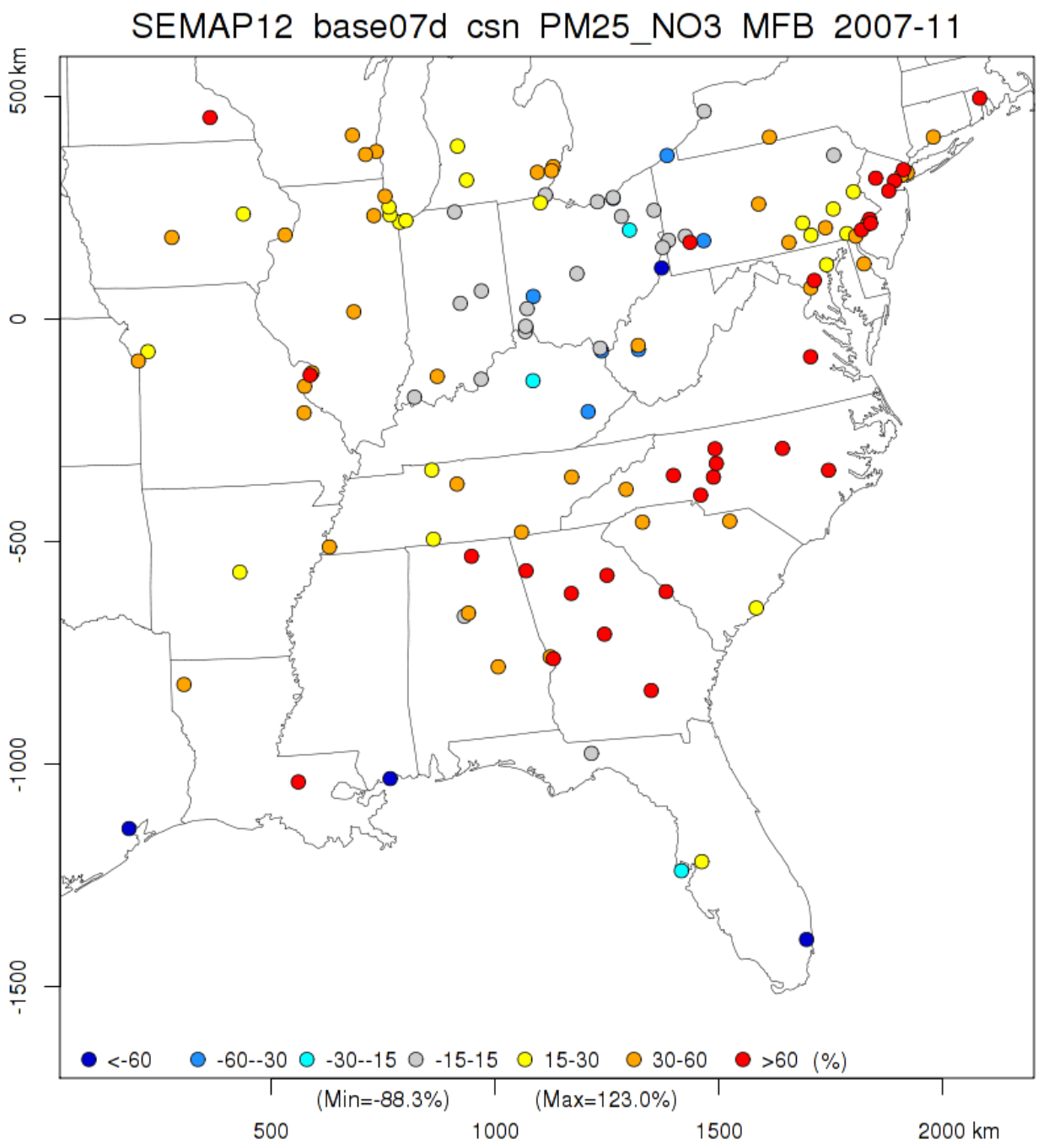


Figure 3-81 November 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ nitrate at CSN sites.

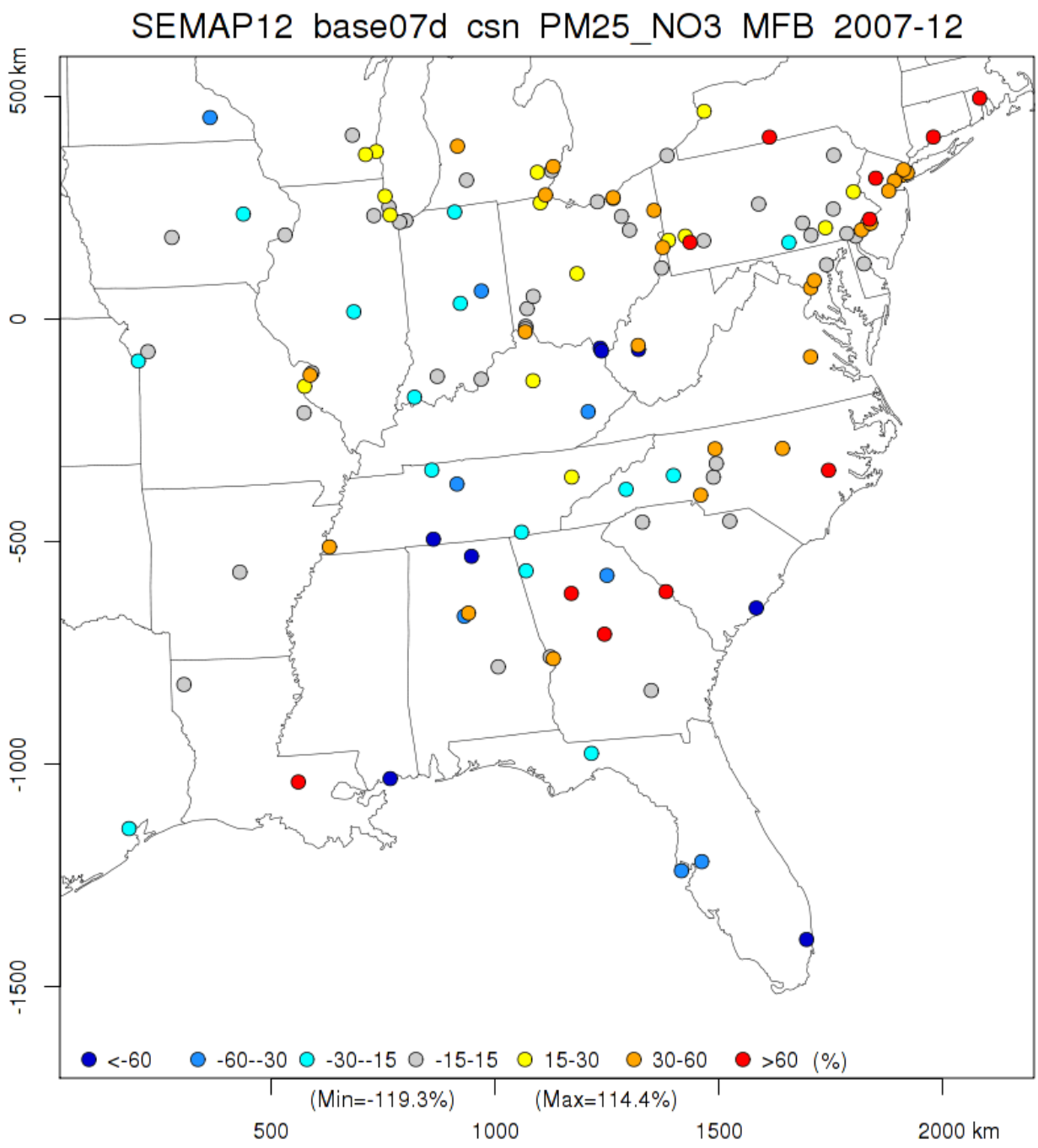


Figure 3-82 December 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ nitrate at CSN sites.

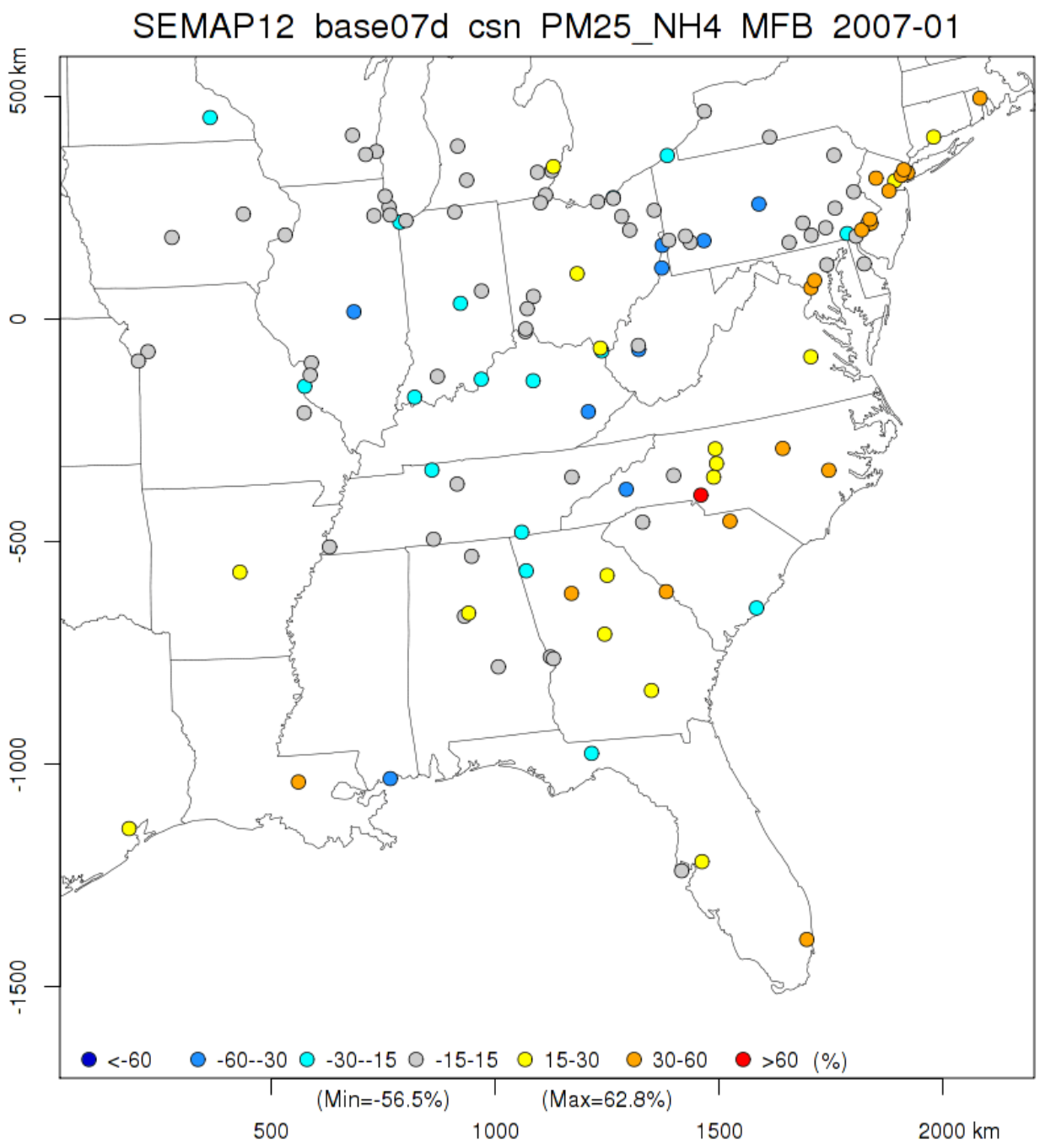


Figure 3-83 January 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ ammonium at CSN sites.

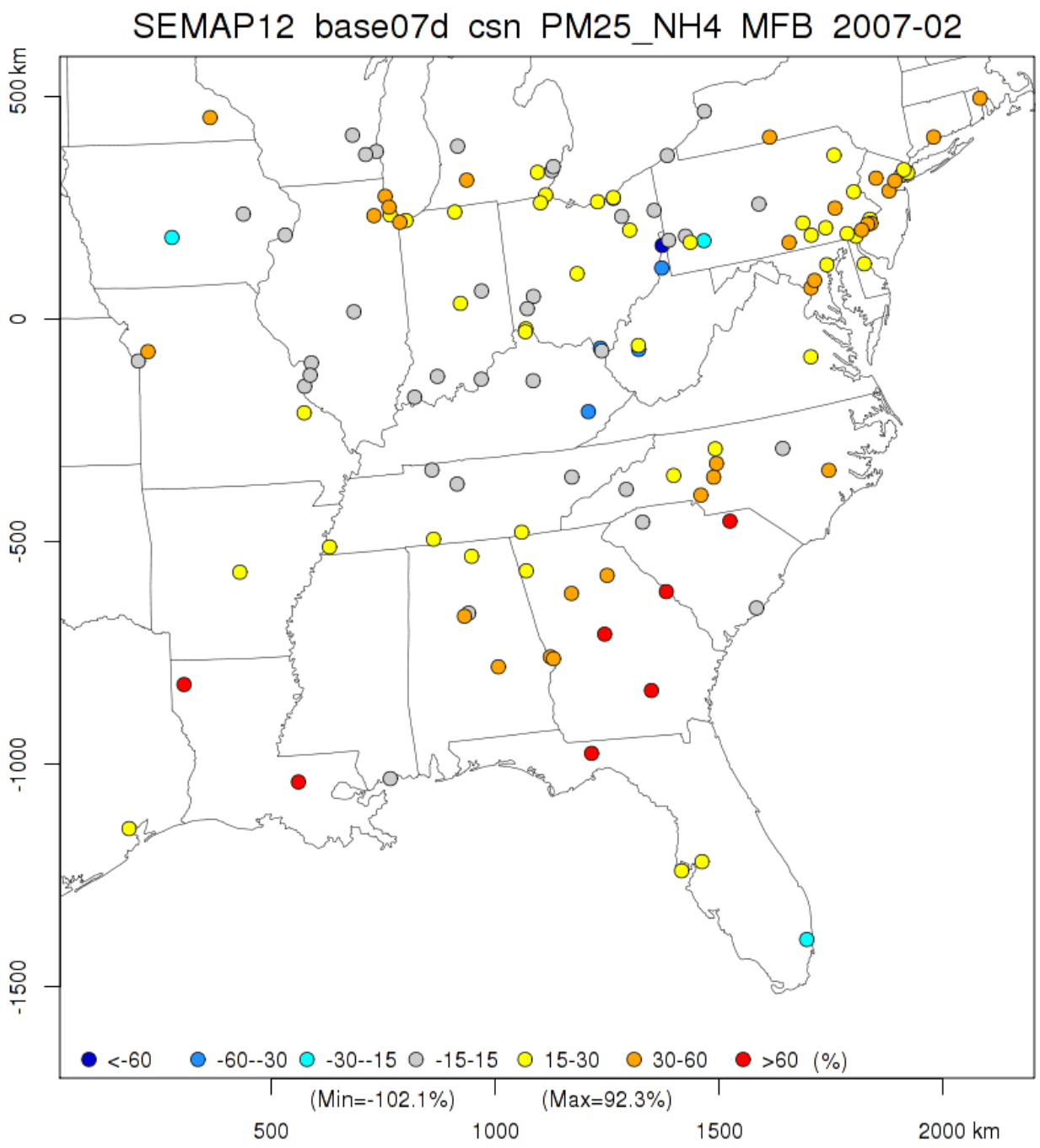


Figure 3-84 February 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ ammonium at CSN sites.

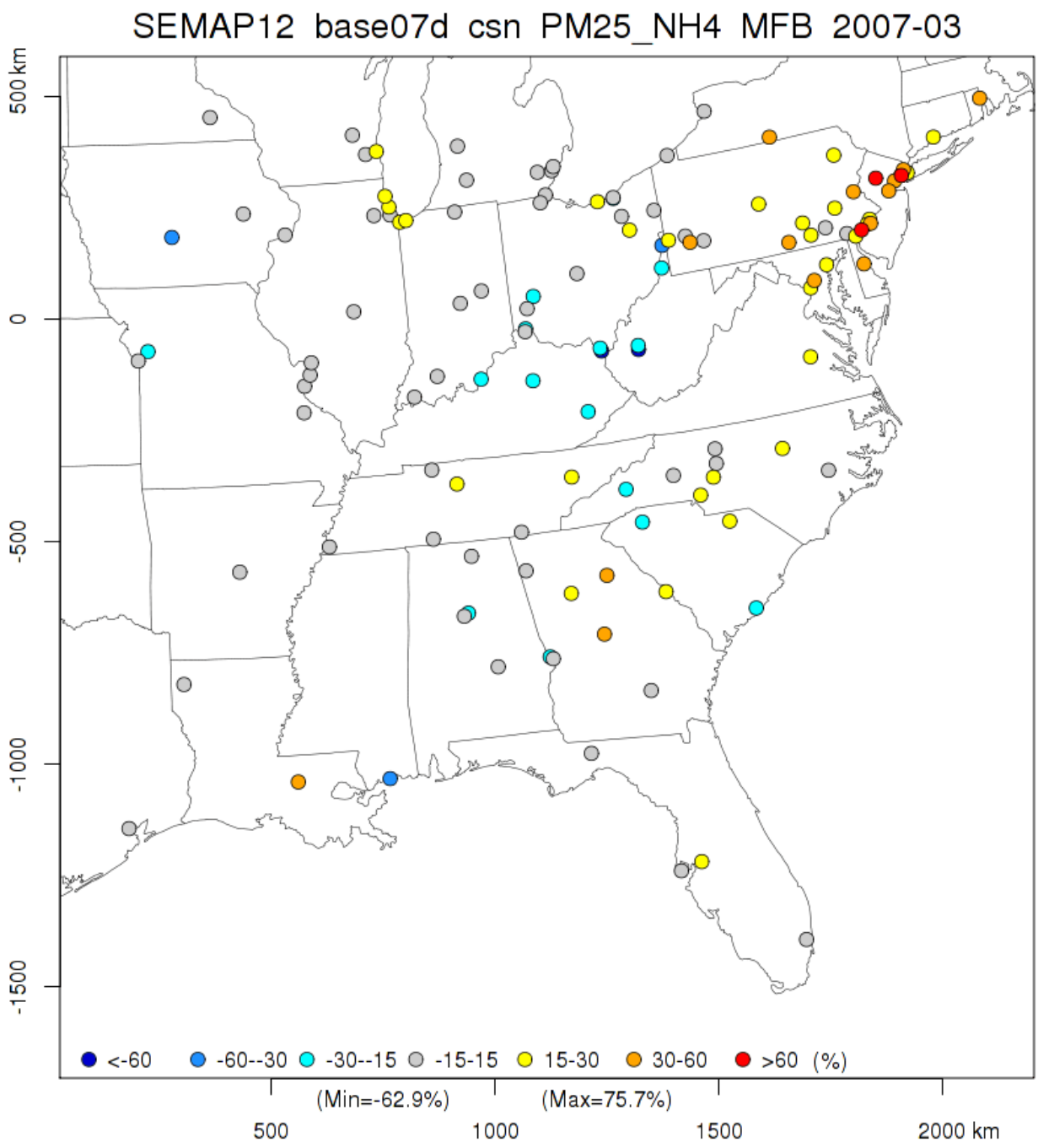


Figure 3-85 March 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ ammonium at CSN sites.

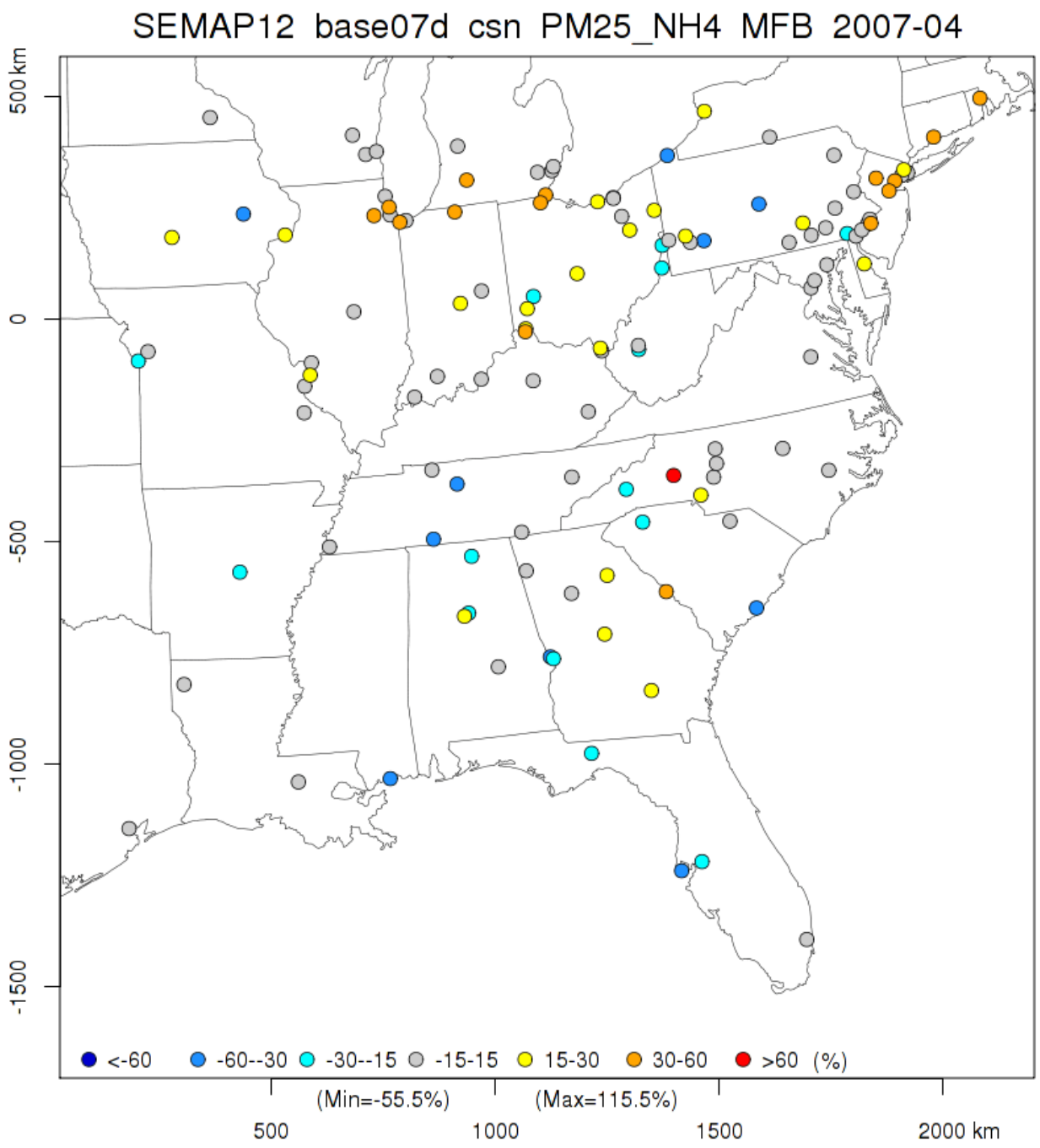


Figure 3-86 April 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ ammonium at CSN sites.

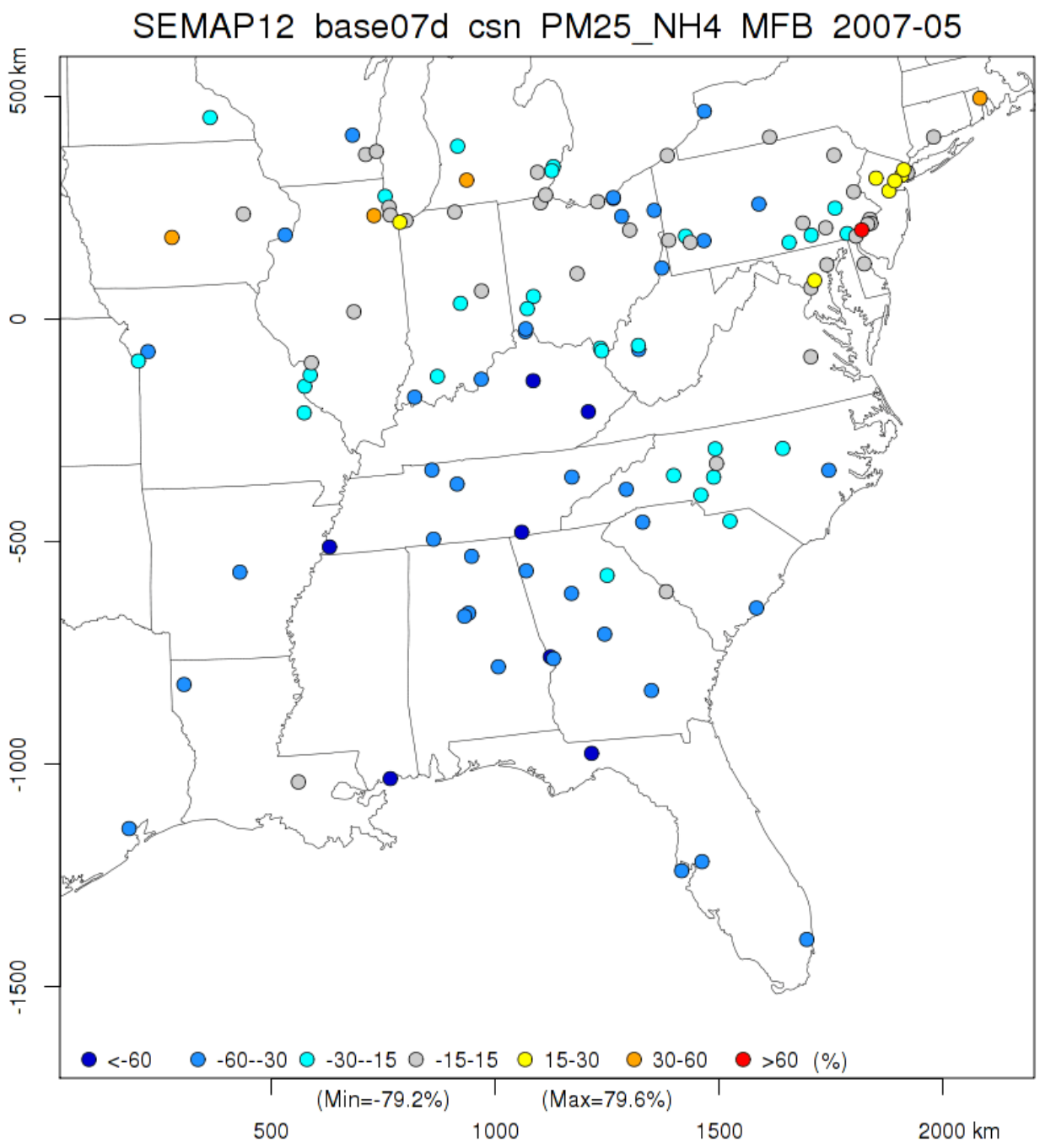


Figure 3-87 May 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ ammonium at CSN sites.

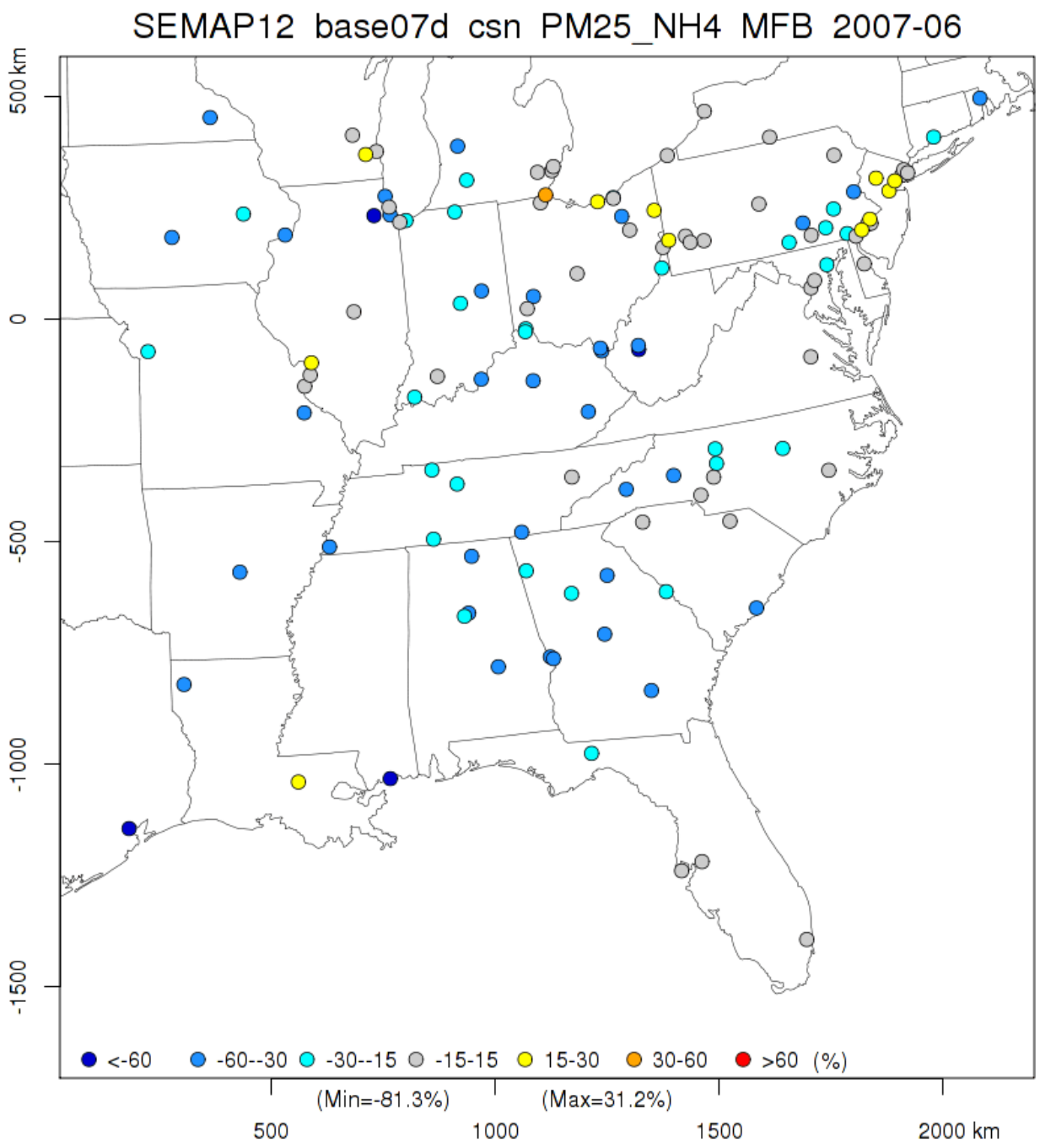


Figure 3-88 June 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ ammonium at CSN sites.

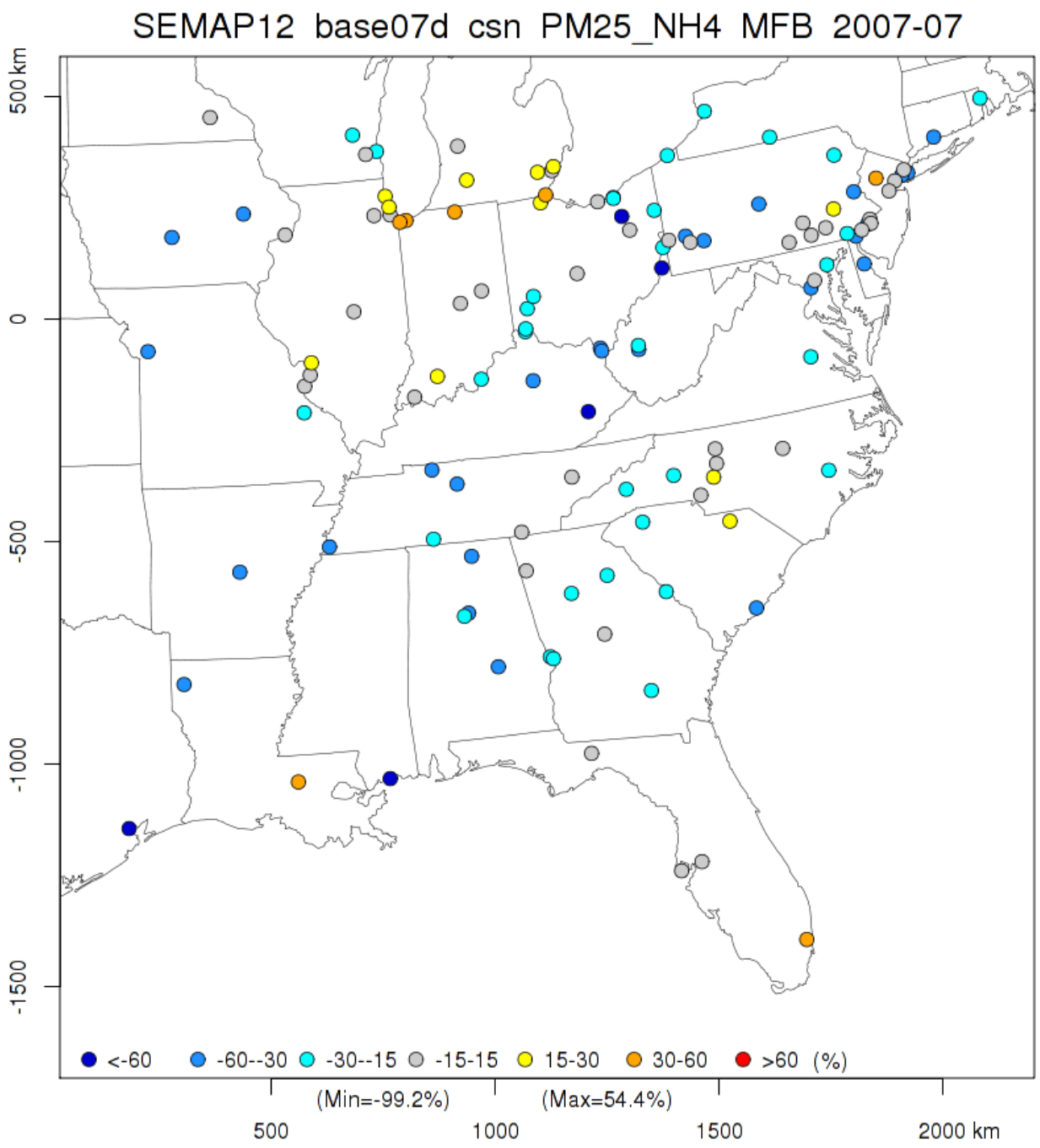


Figure 3-89 July 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ ammonium at CSN sites.

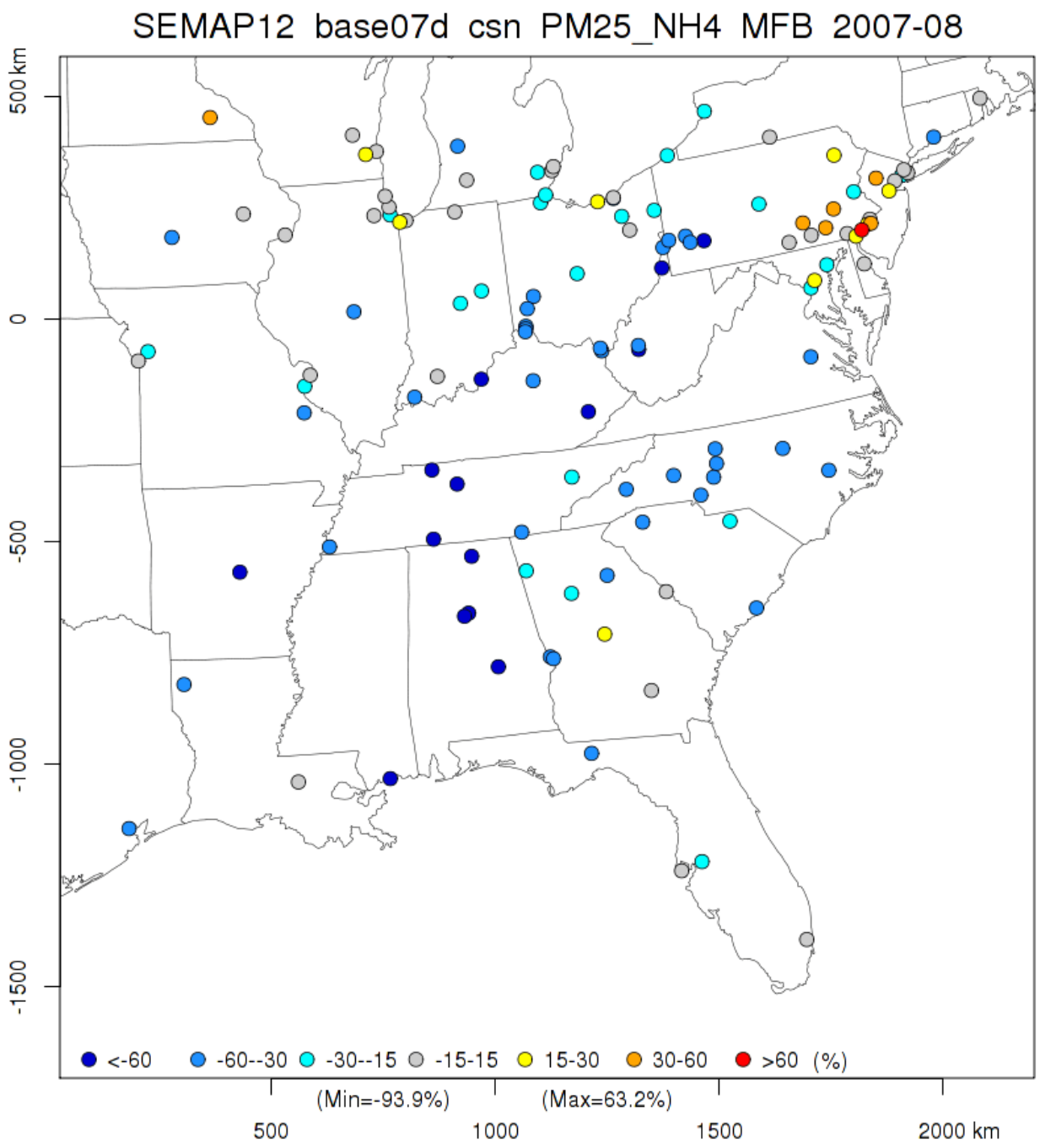


Figure 3-90 August 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ ammonium at CSN sites.

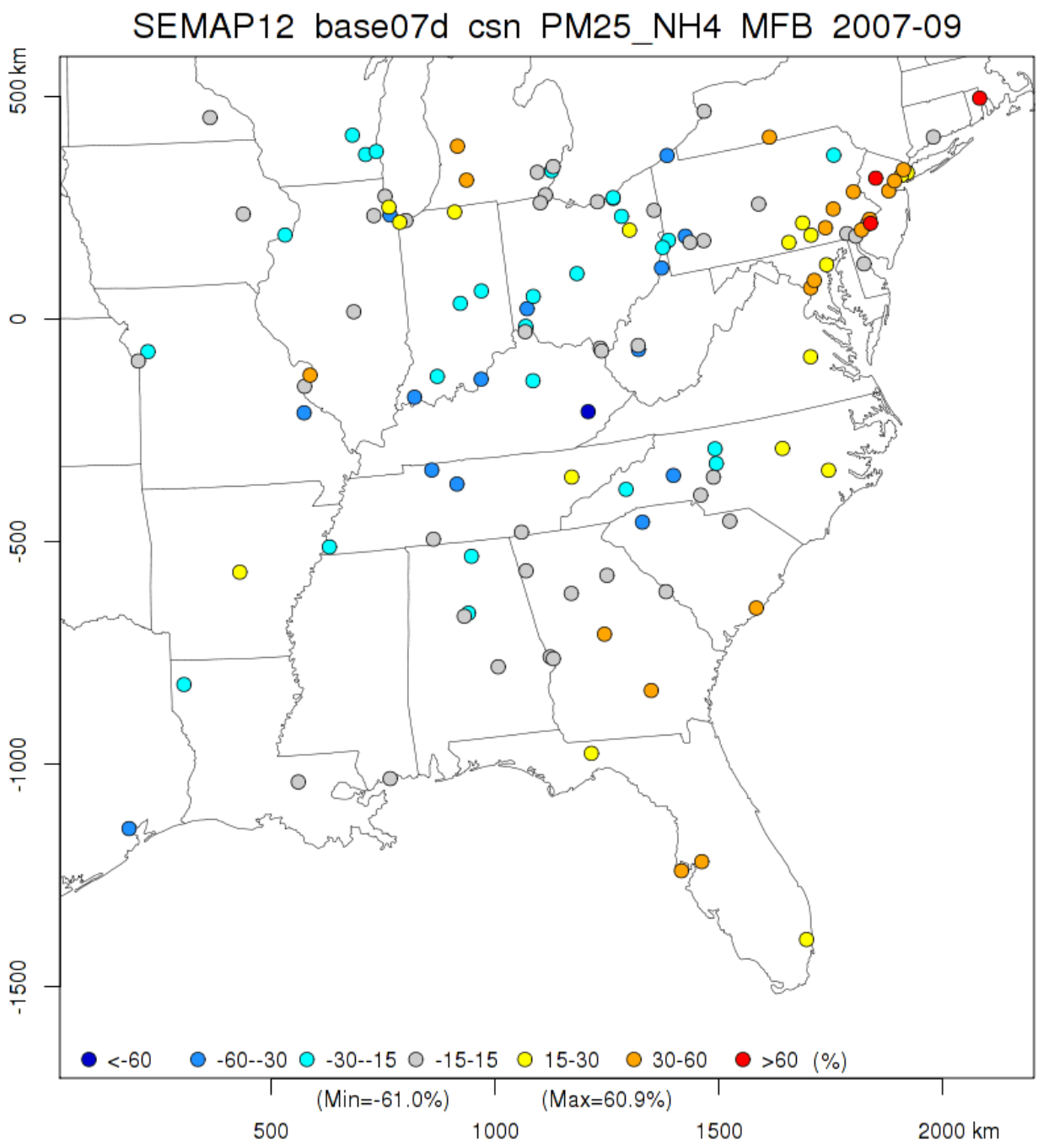


Figure 3-91 September 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ ammonium at CSN sites.

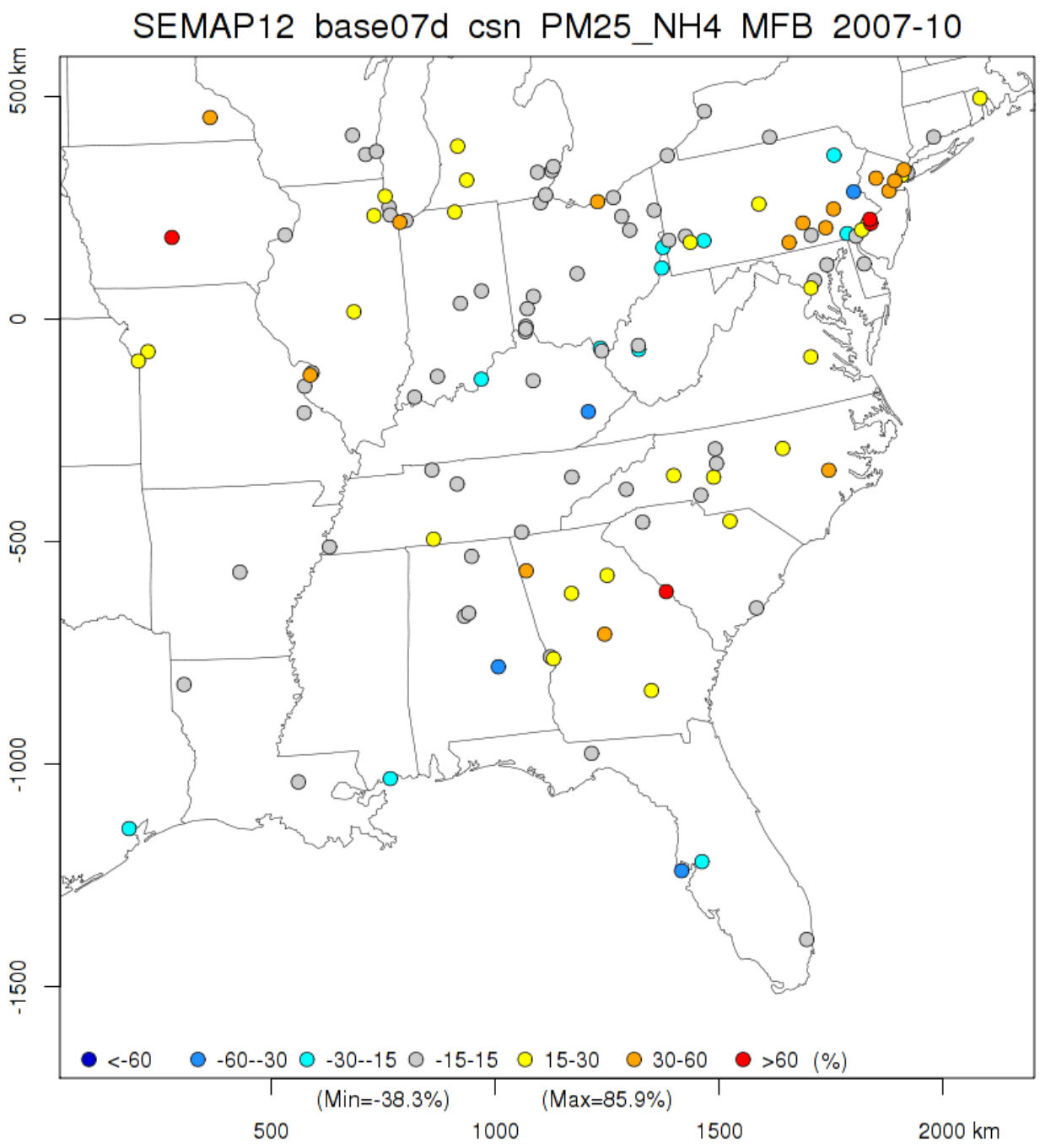


Figure 3-92 October 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ ammonium at CSN sites.

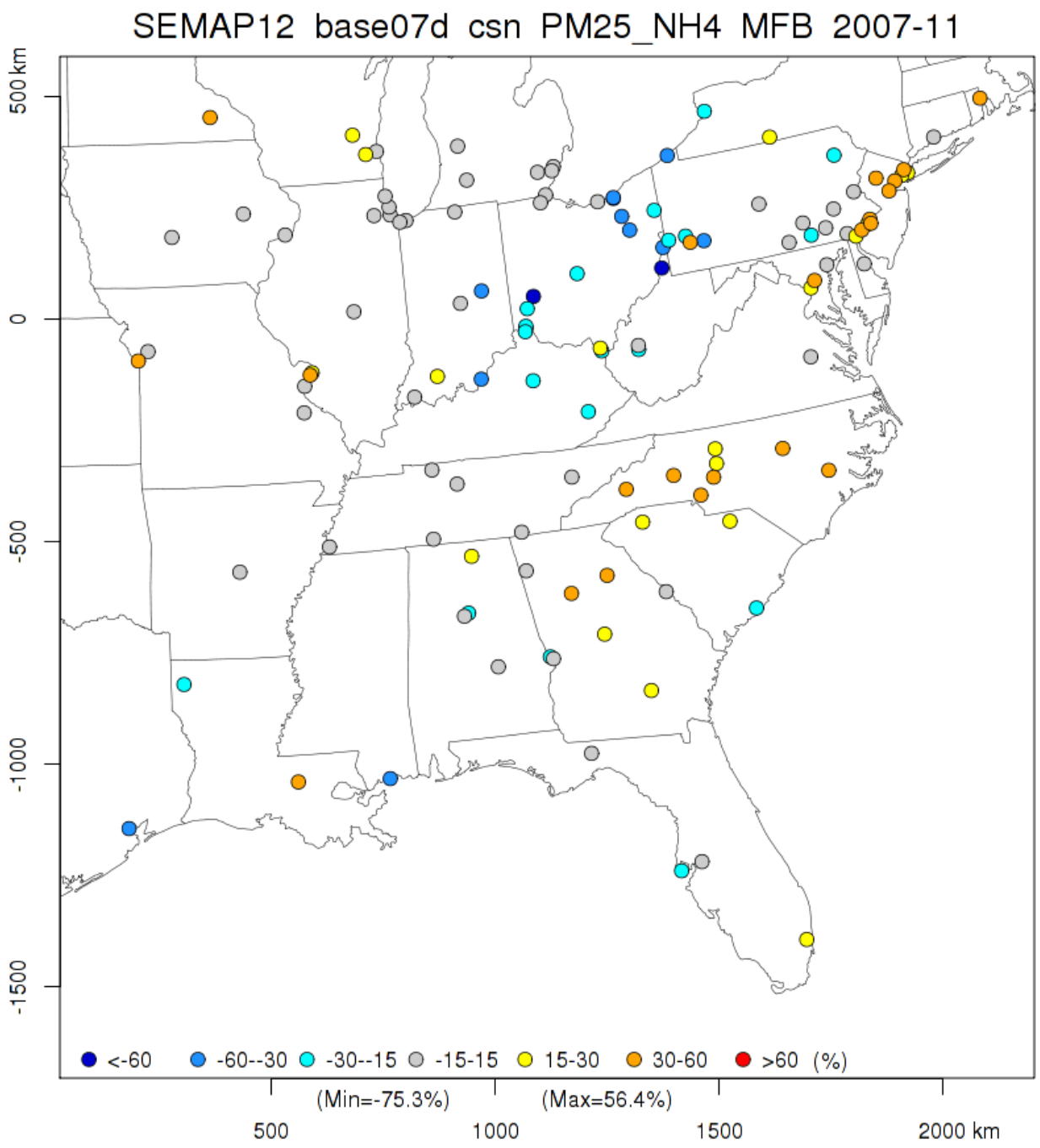


Figure 3-93 November 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ ammonium at CSN sites.

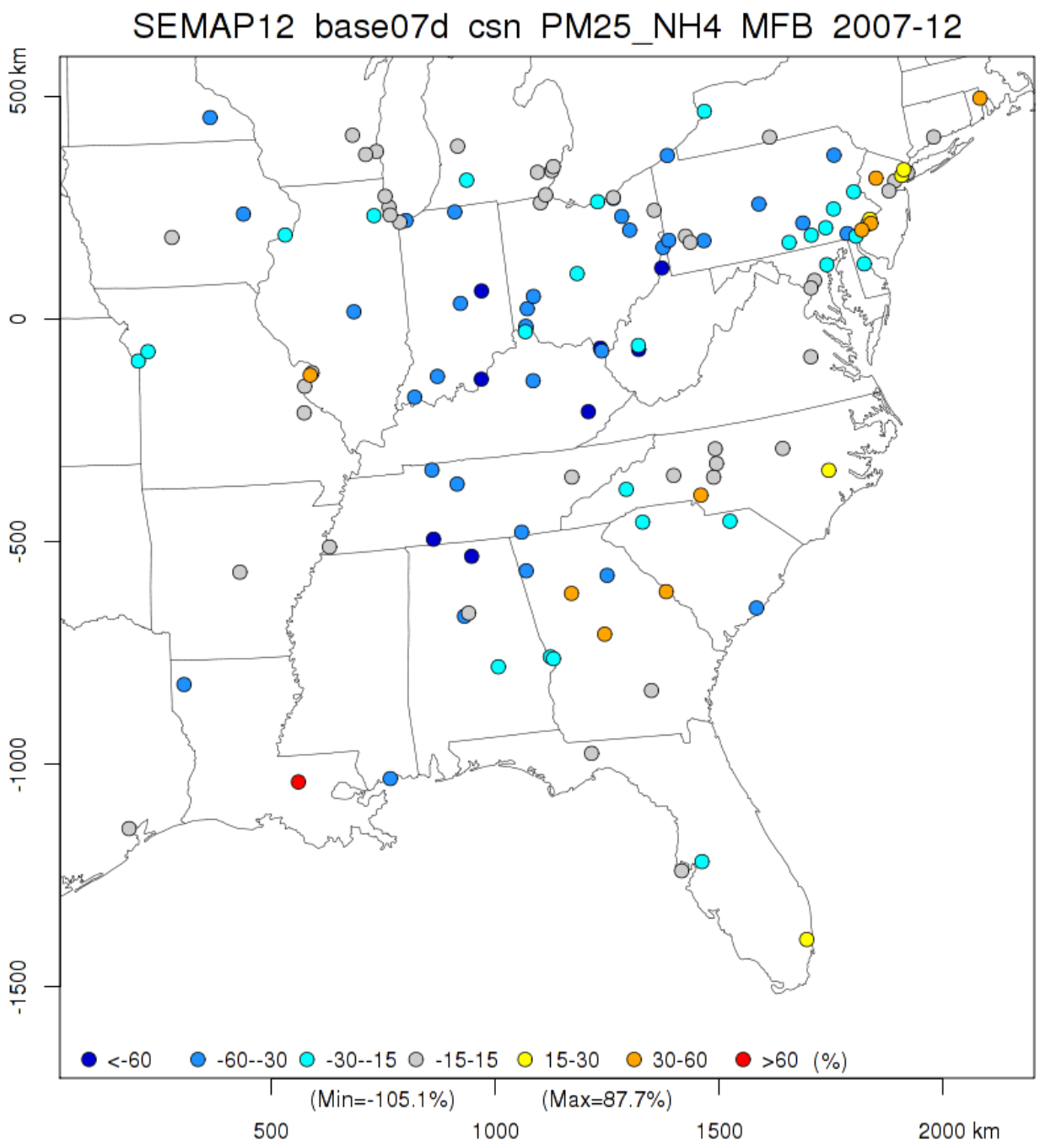


Figure 3-94 December 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ ammonium at CSN sites.

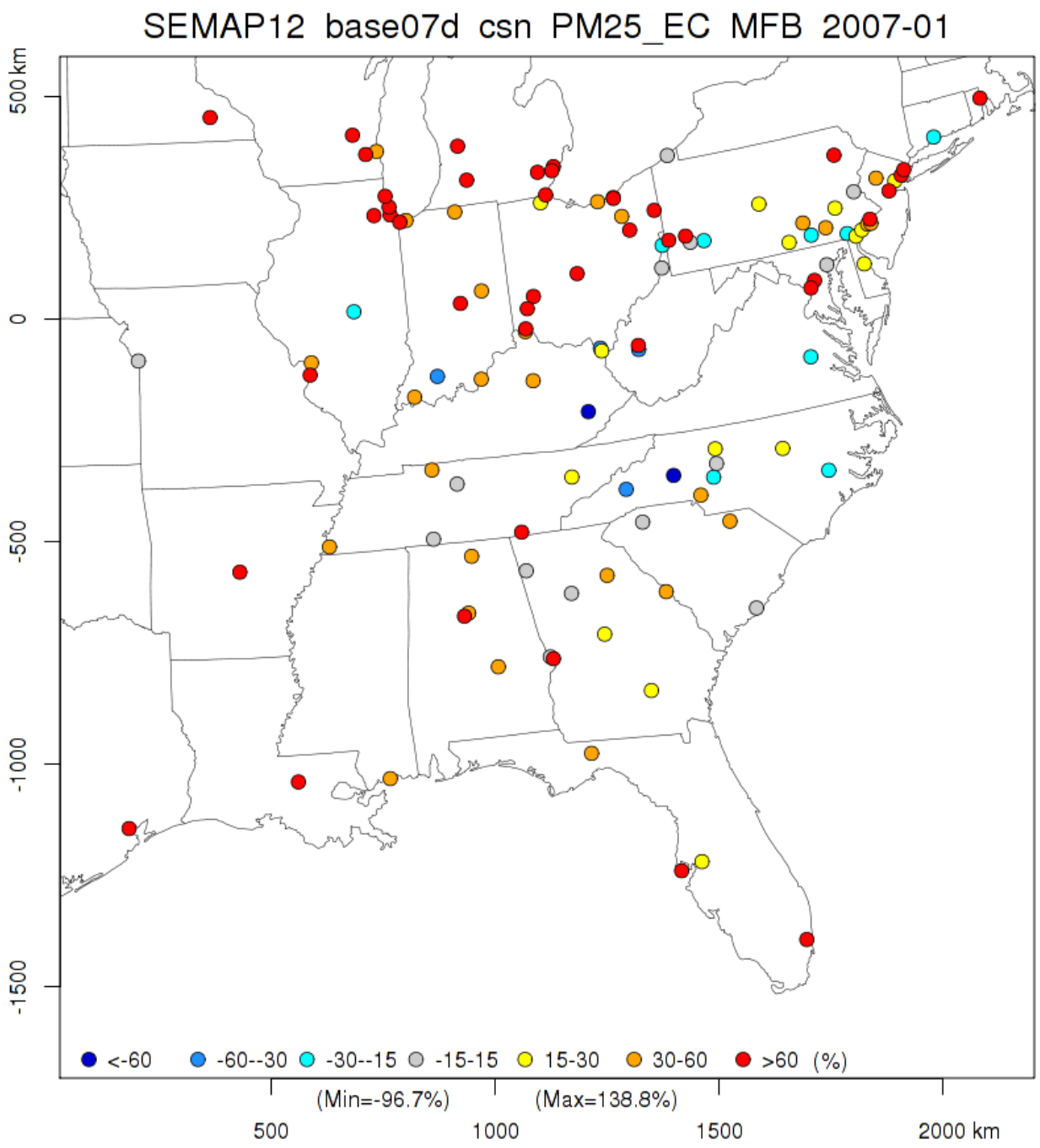


Figure 3-95 January 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ elemental carbon at CSN sites.

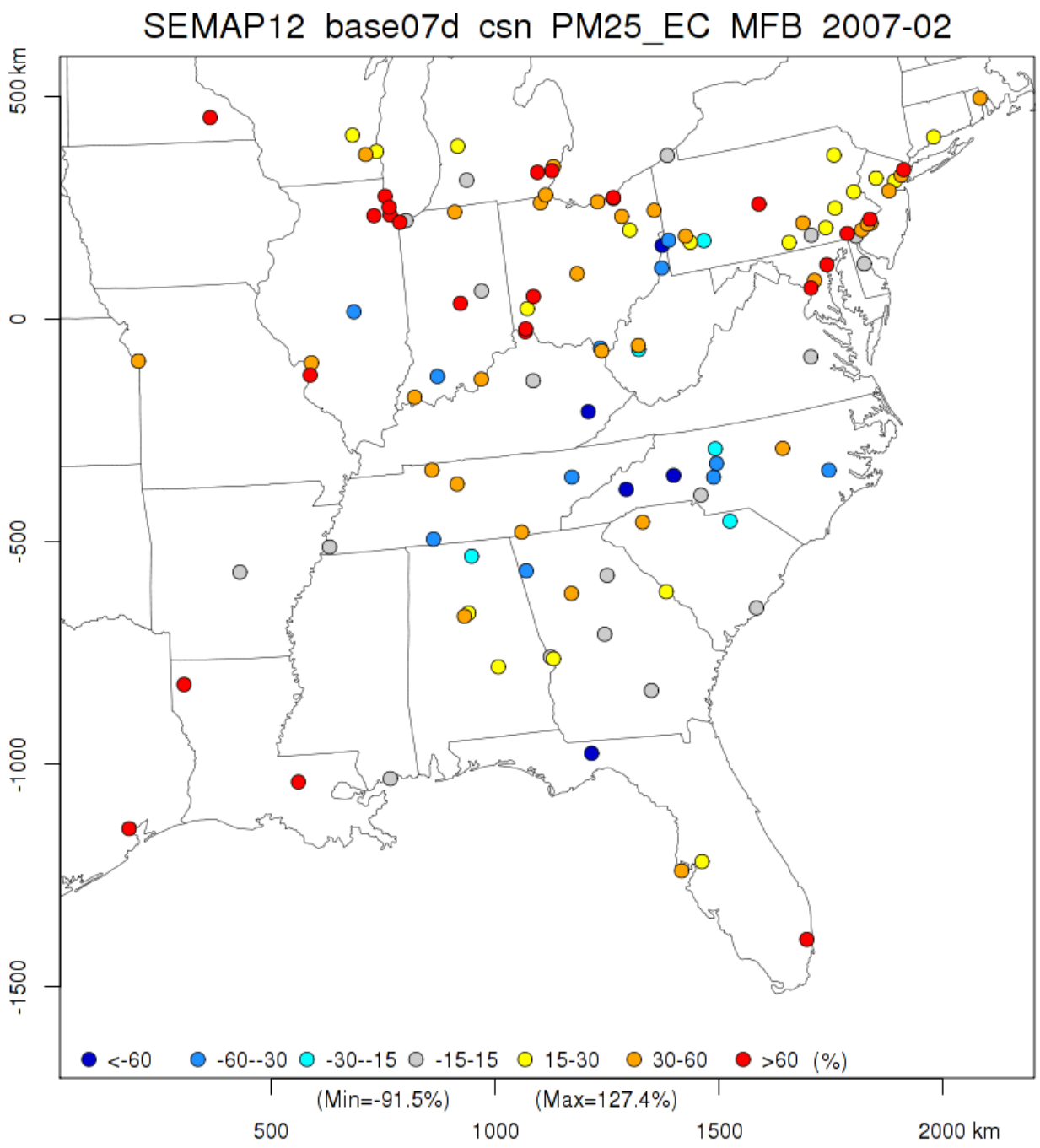


Figure 3-96 February 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ elemental carbon at CSN sites.

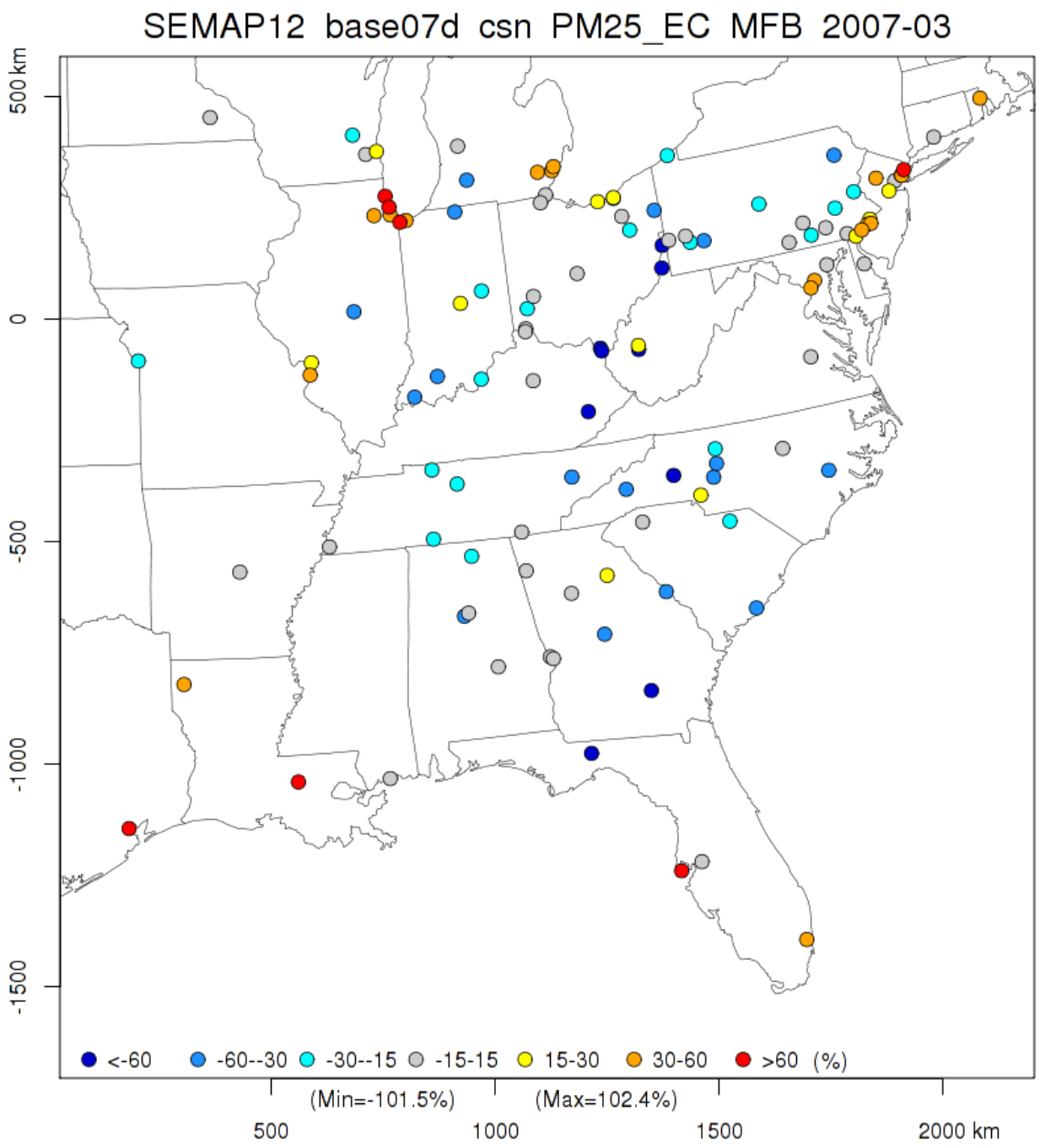


Figure 3-97 March 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ elemental carbon at CSN sites.

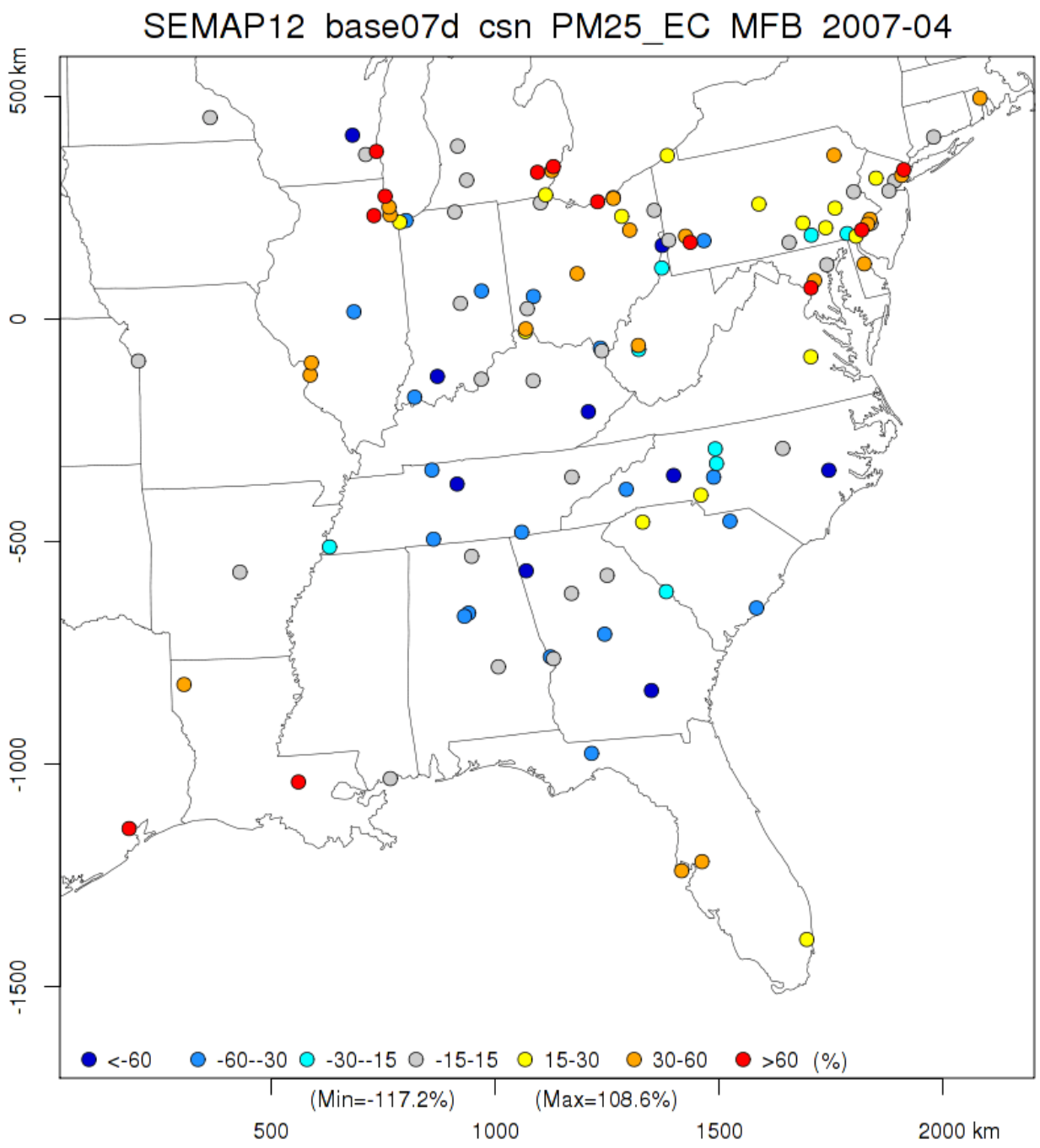


Figure 3-98 April 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ elemental carbon at CSN sites.

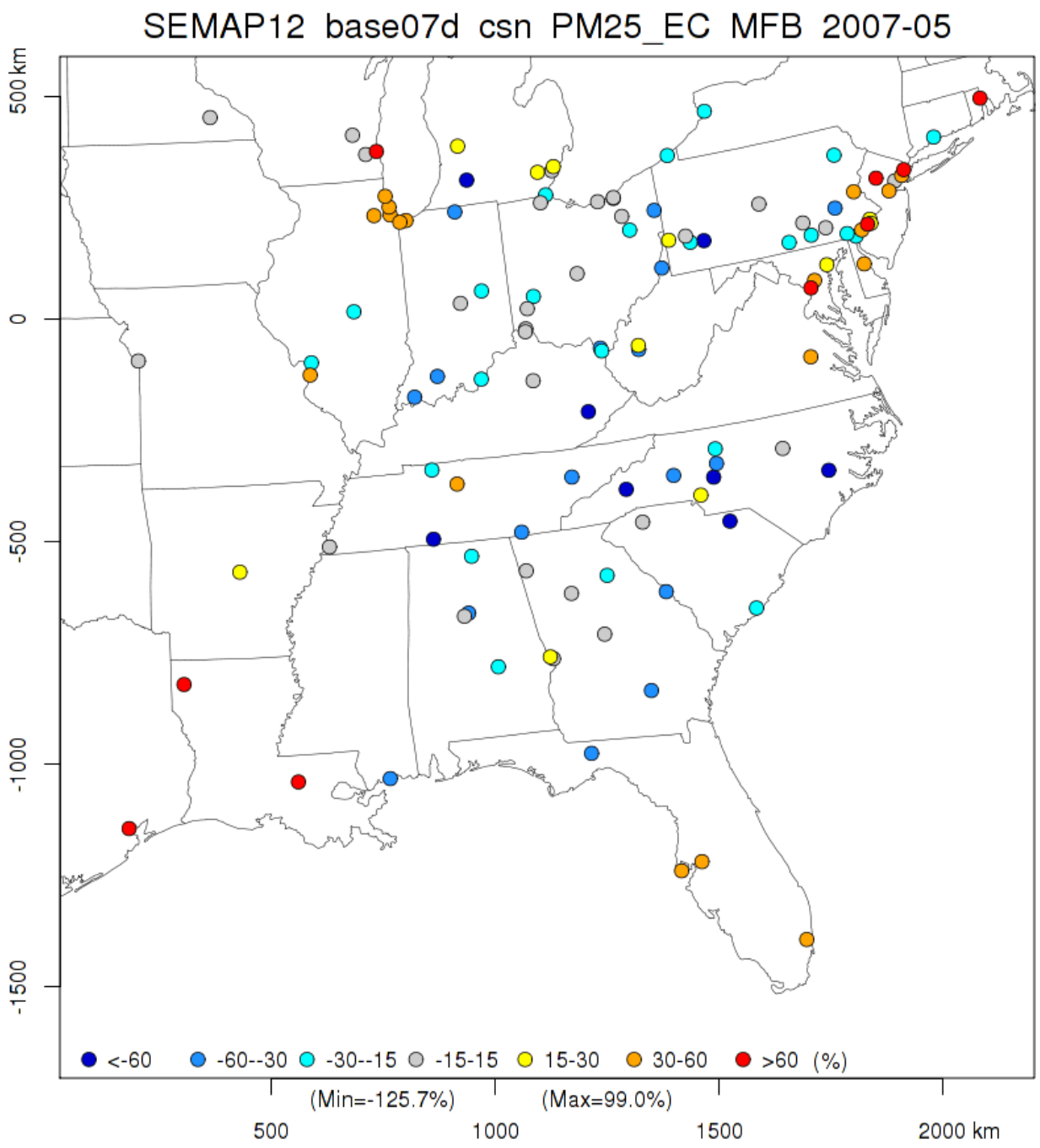


Figure 3-99 May 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ elemental carbon at CSN sites.

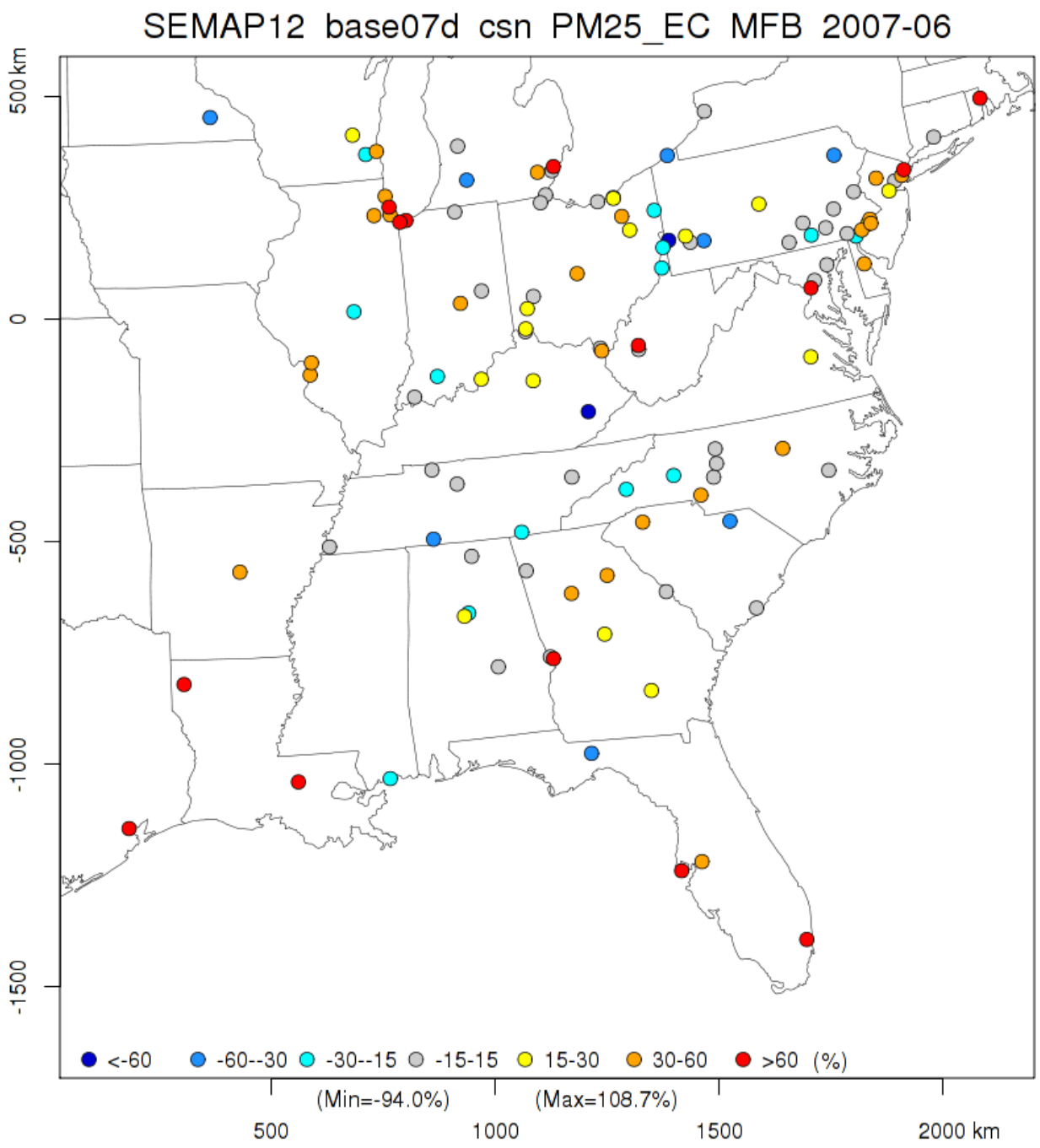


Figure 3-100 June 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ elemental carbon at CSN sites.

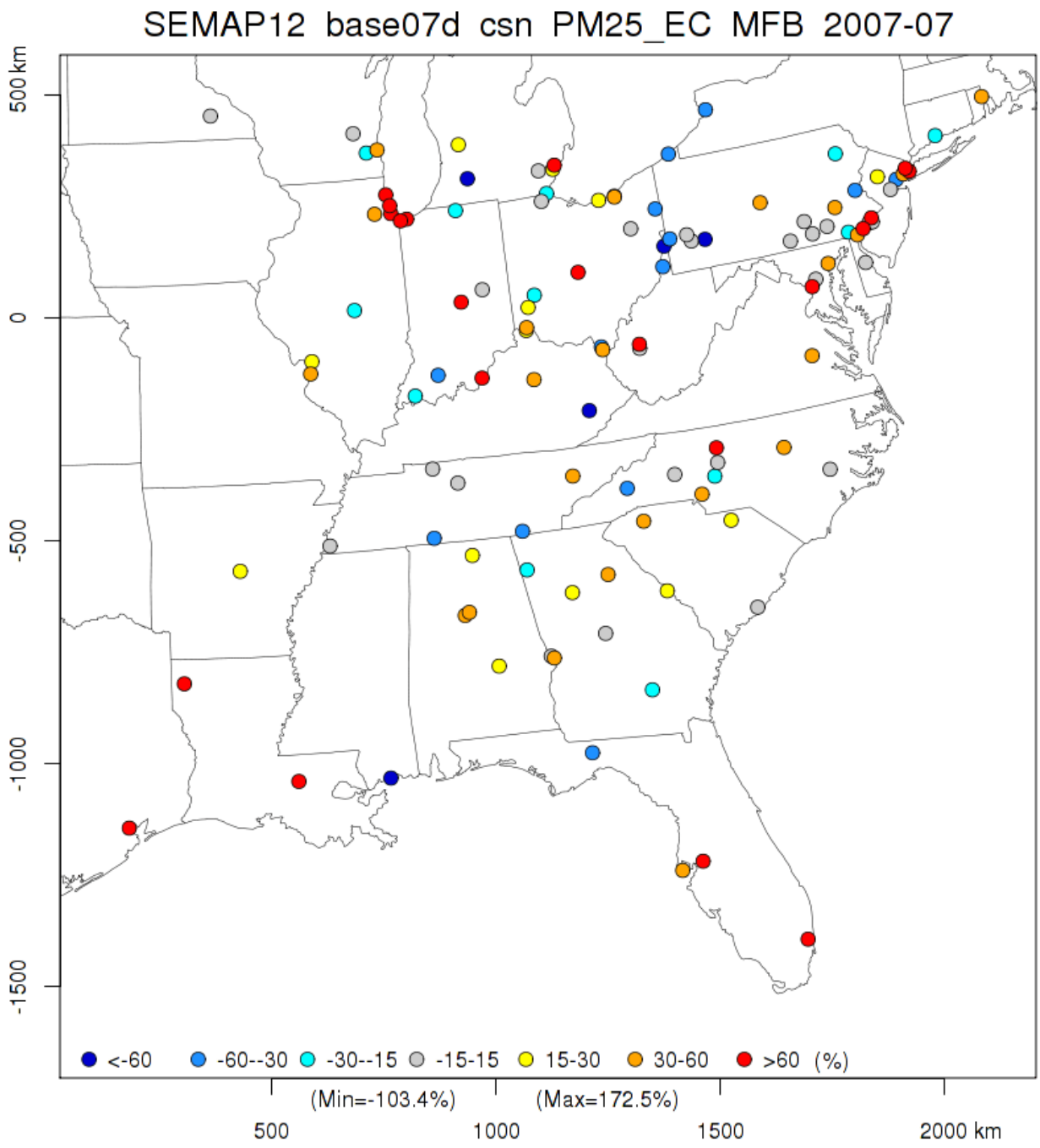


Figure 3-101 July 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ elemental carbon at CSN sites.

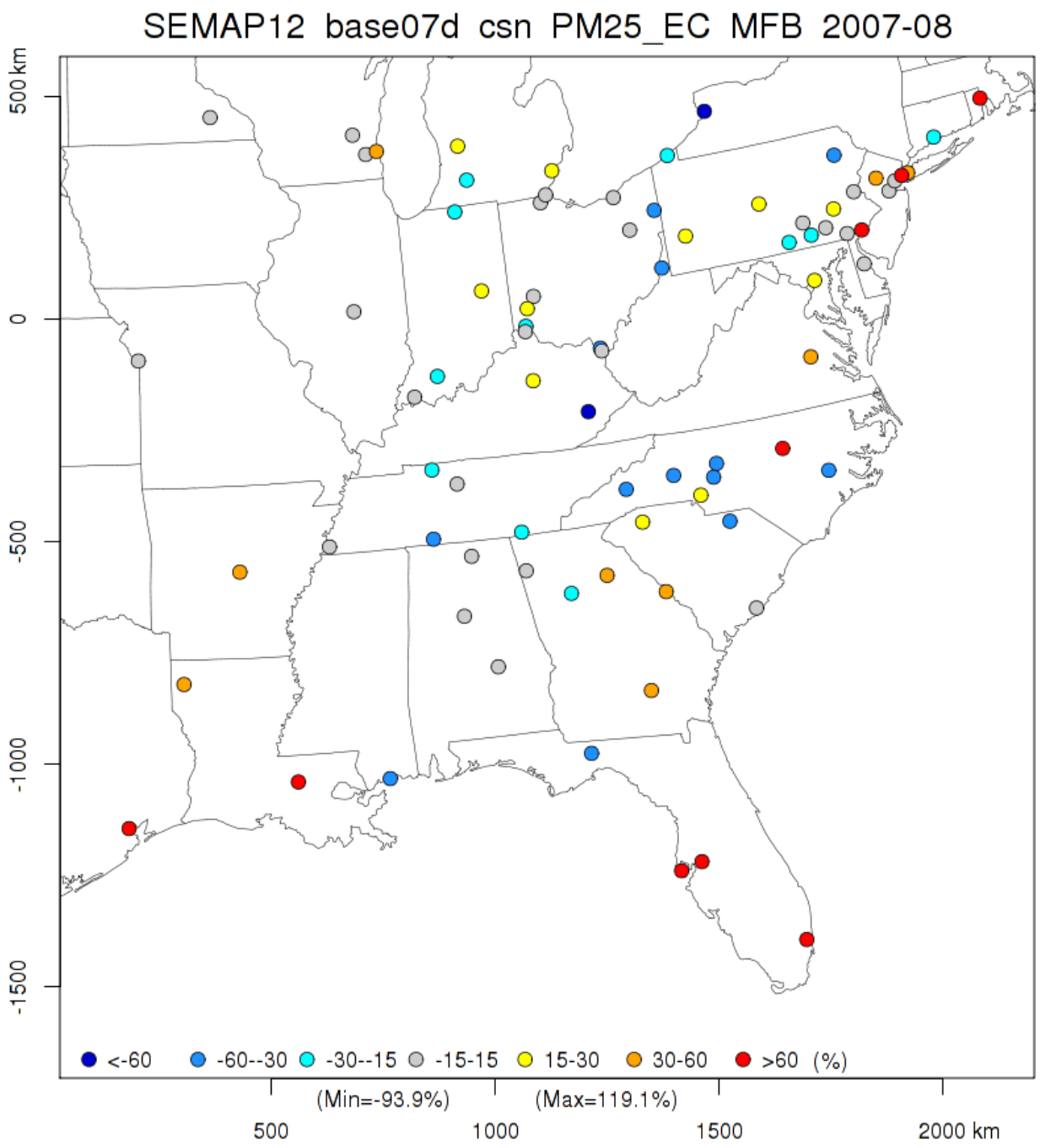


Figure 3-102 August 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ elemental carbon at CSN sites.

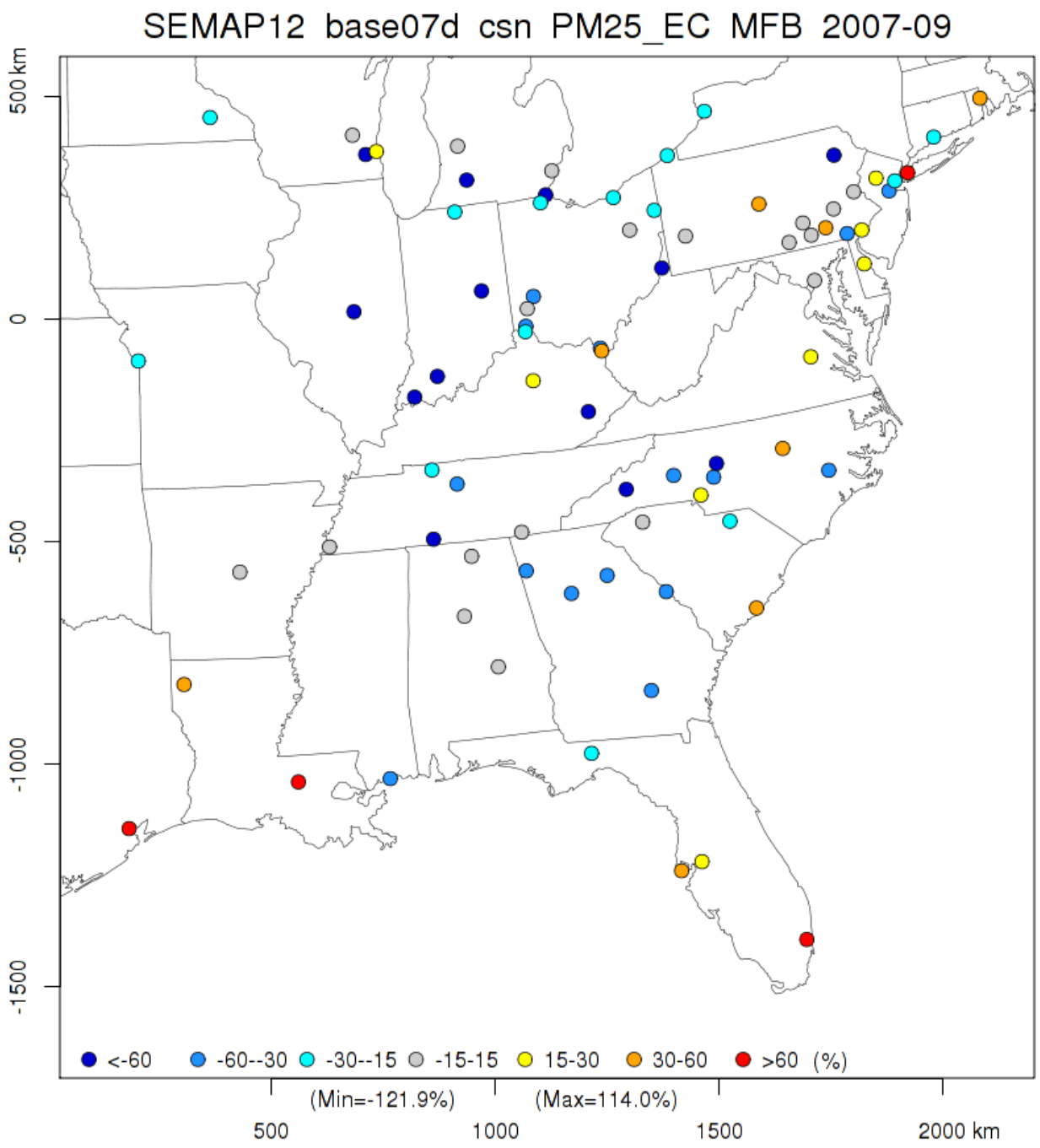


Figure 3-103 September 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ elemental carbon at CSN sites.

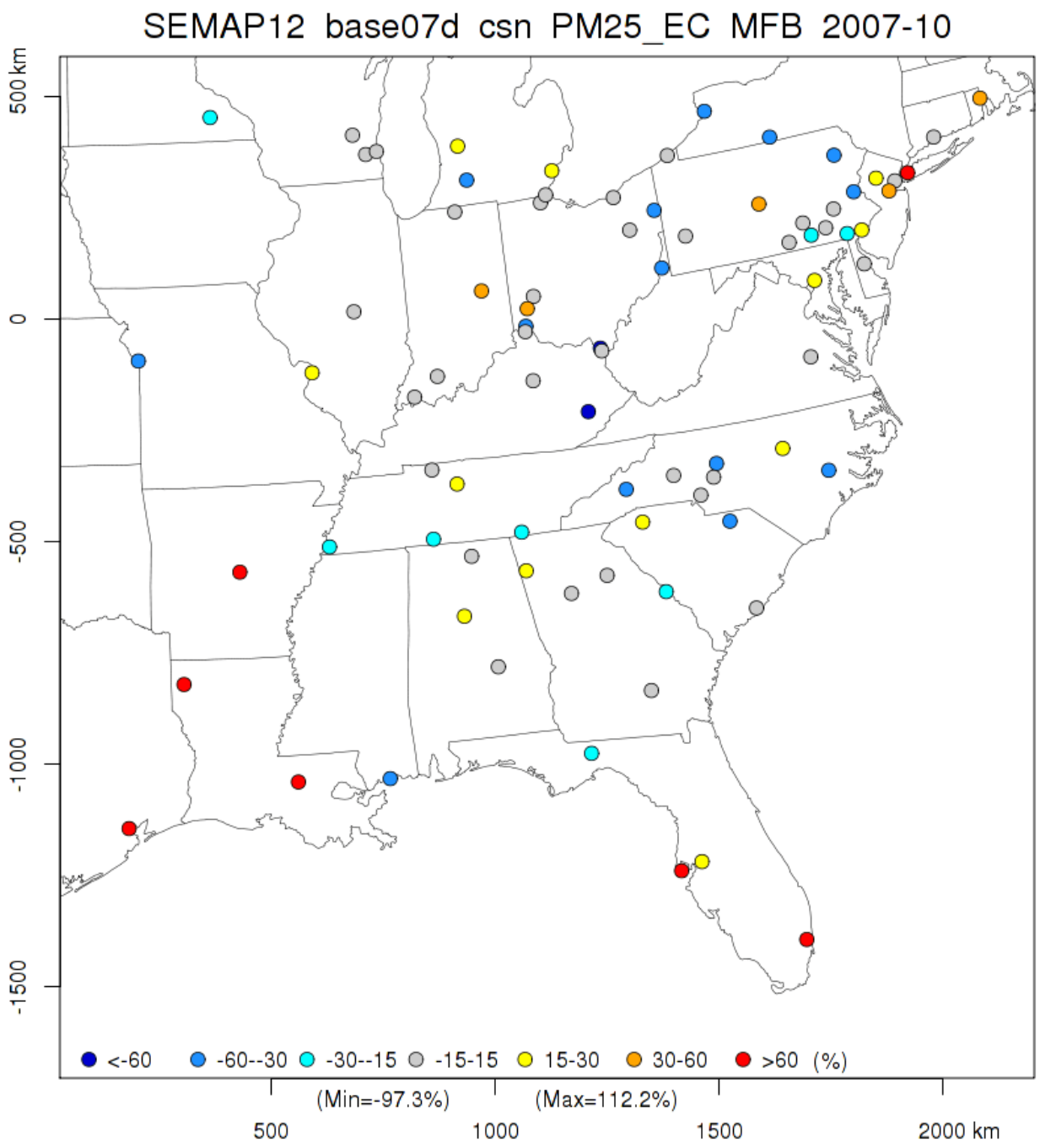


Figure 3-104 October 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ elemental carbon at CSN sites.

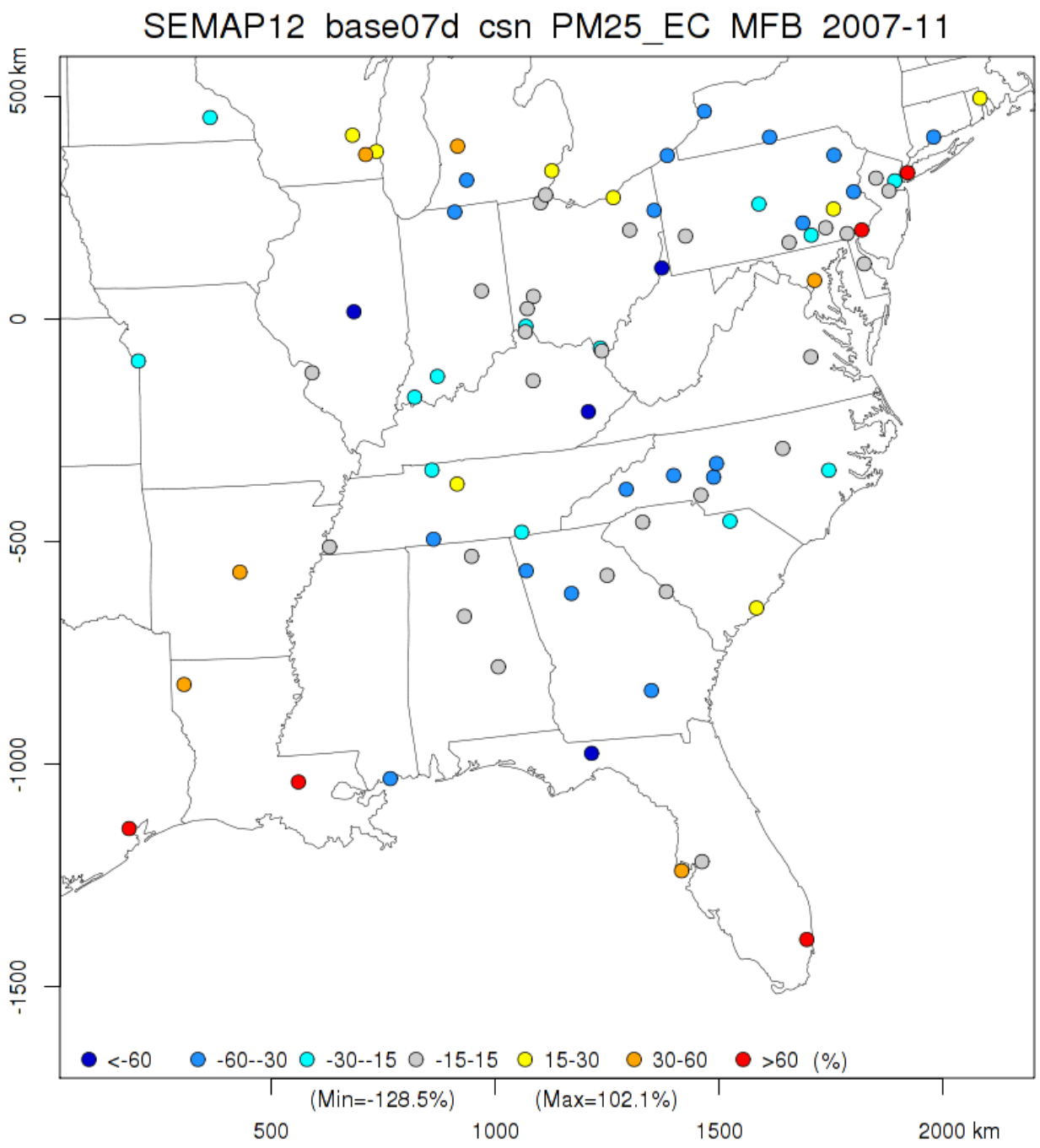


Figure 3-105 November 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ elemental carbon at CSN sites.

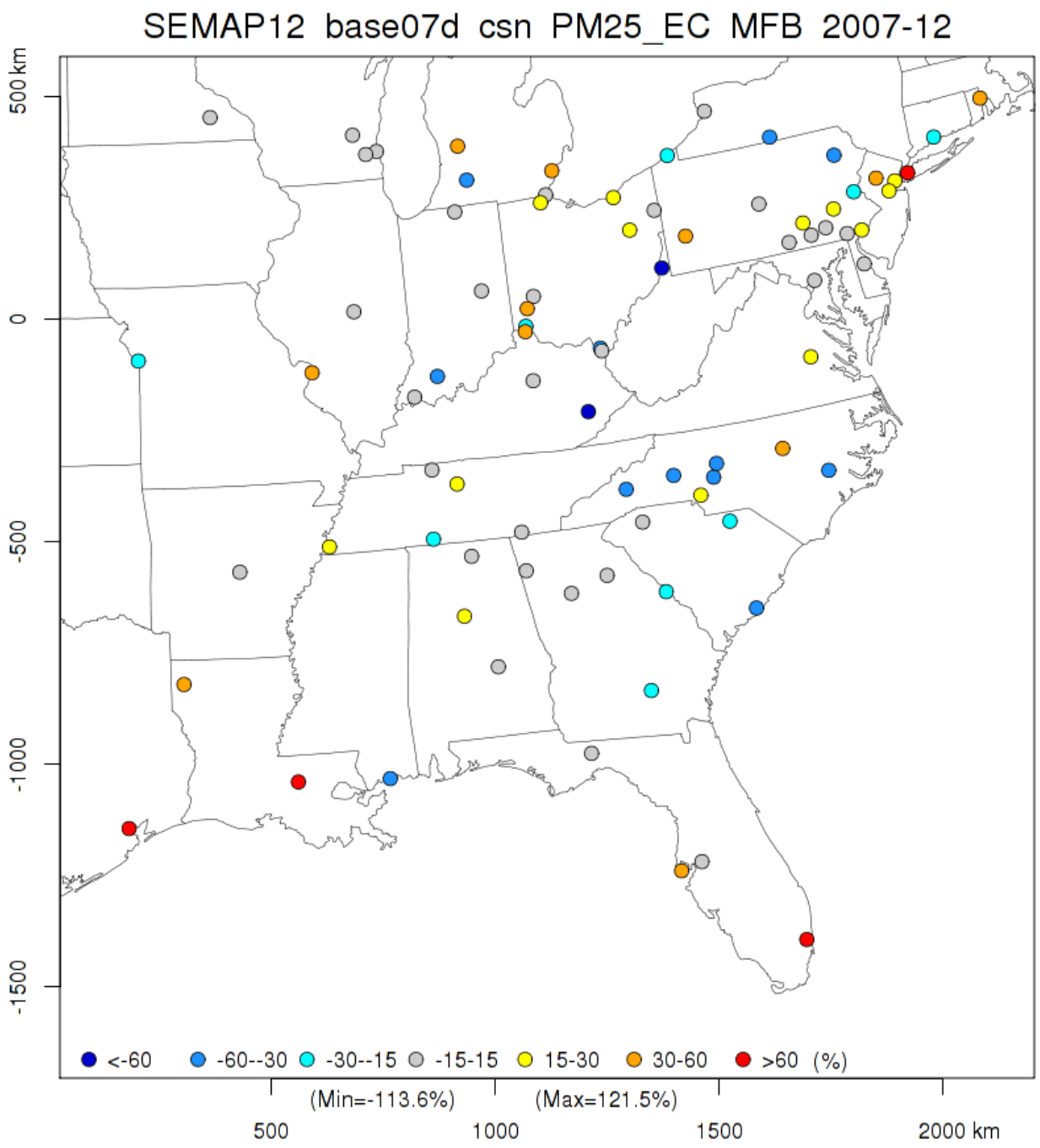


Figure 3-106 December 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ elemental carbon at CSN sites.

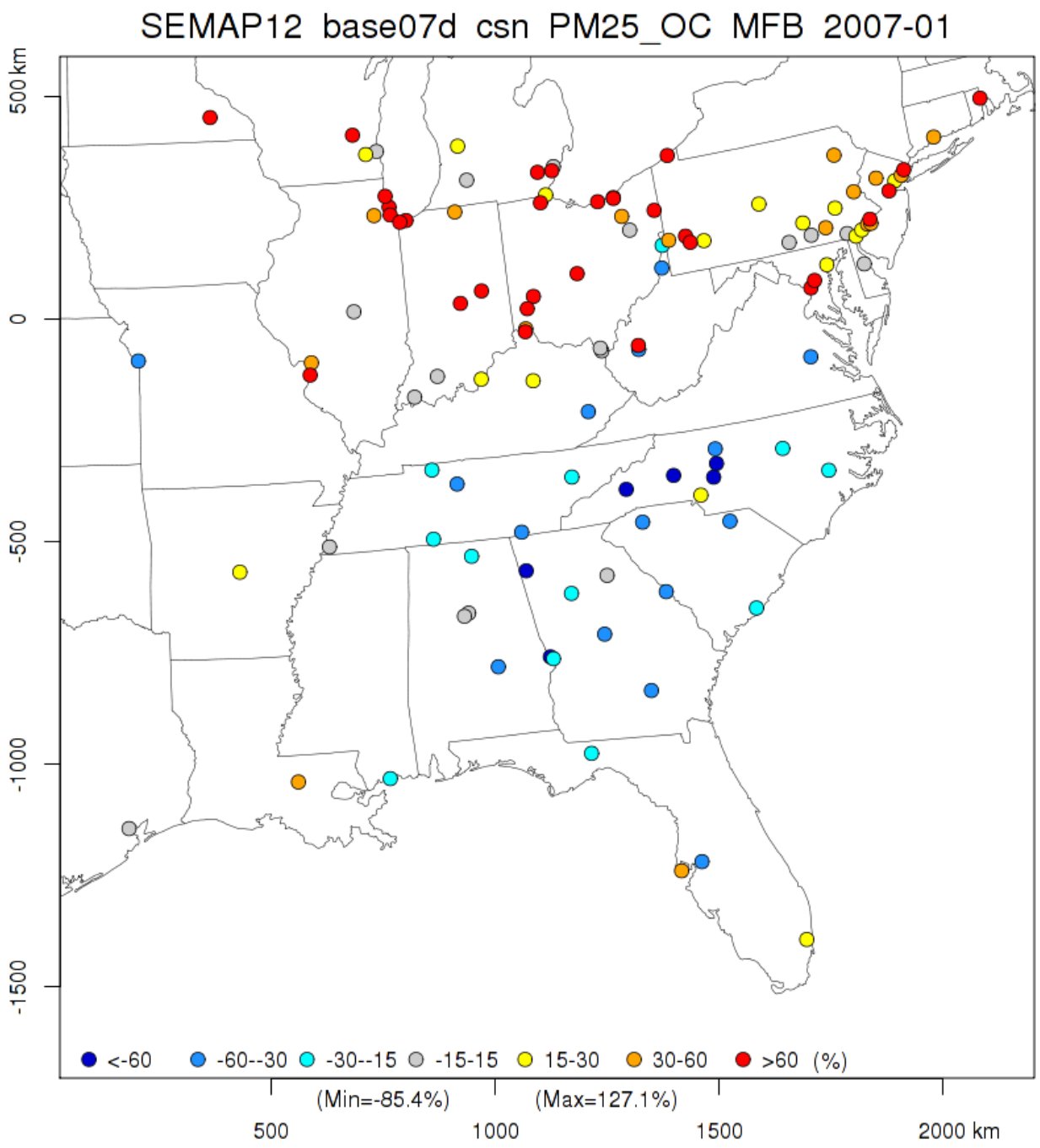


Figure 3-107 January 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ organic carbon at CSN sites.

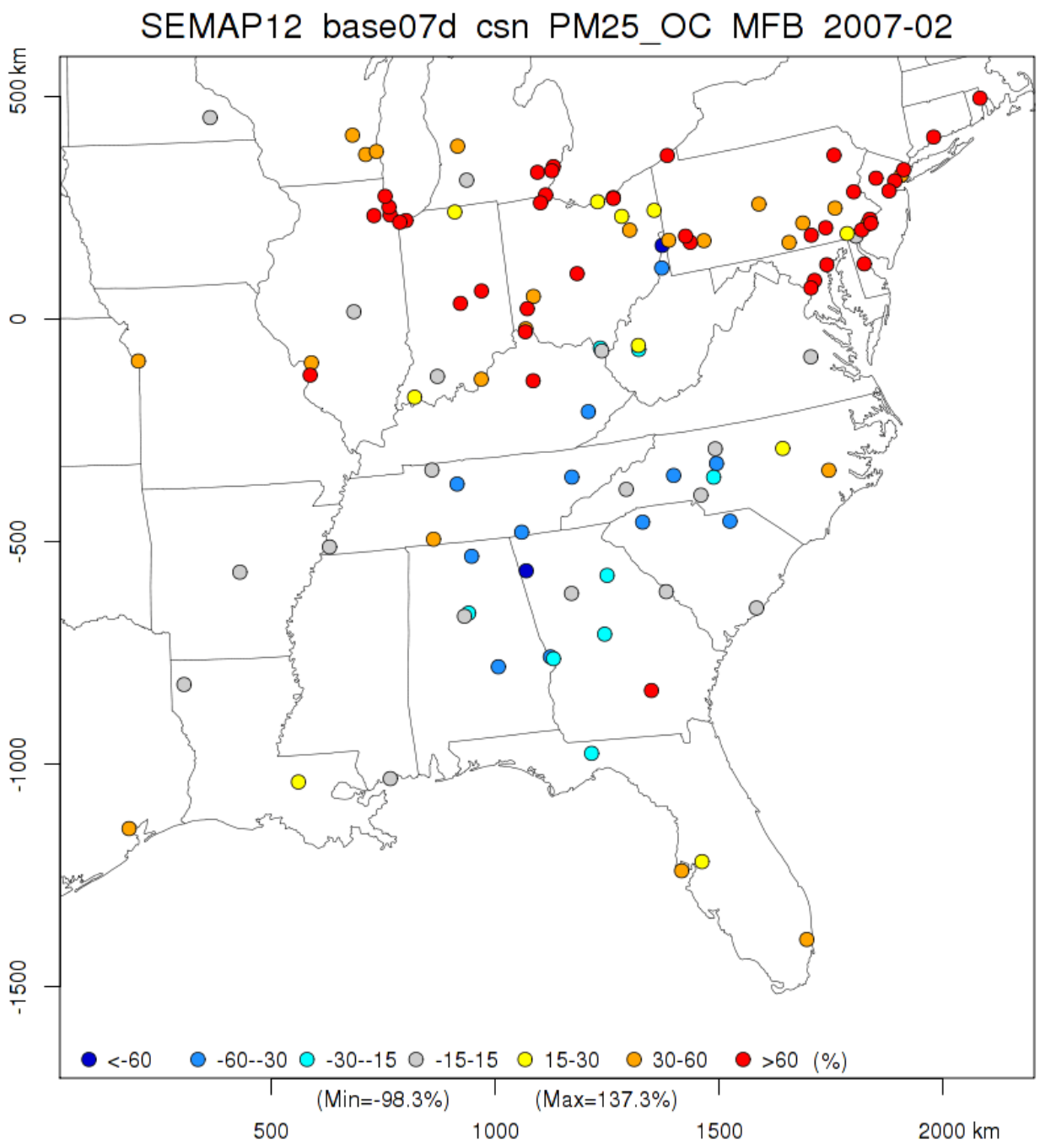


Figure 3-108 February 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ organic carbon at CSN sites.

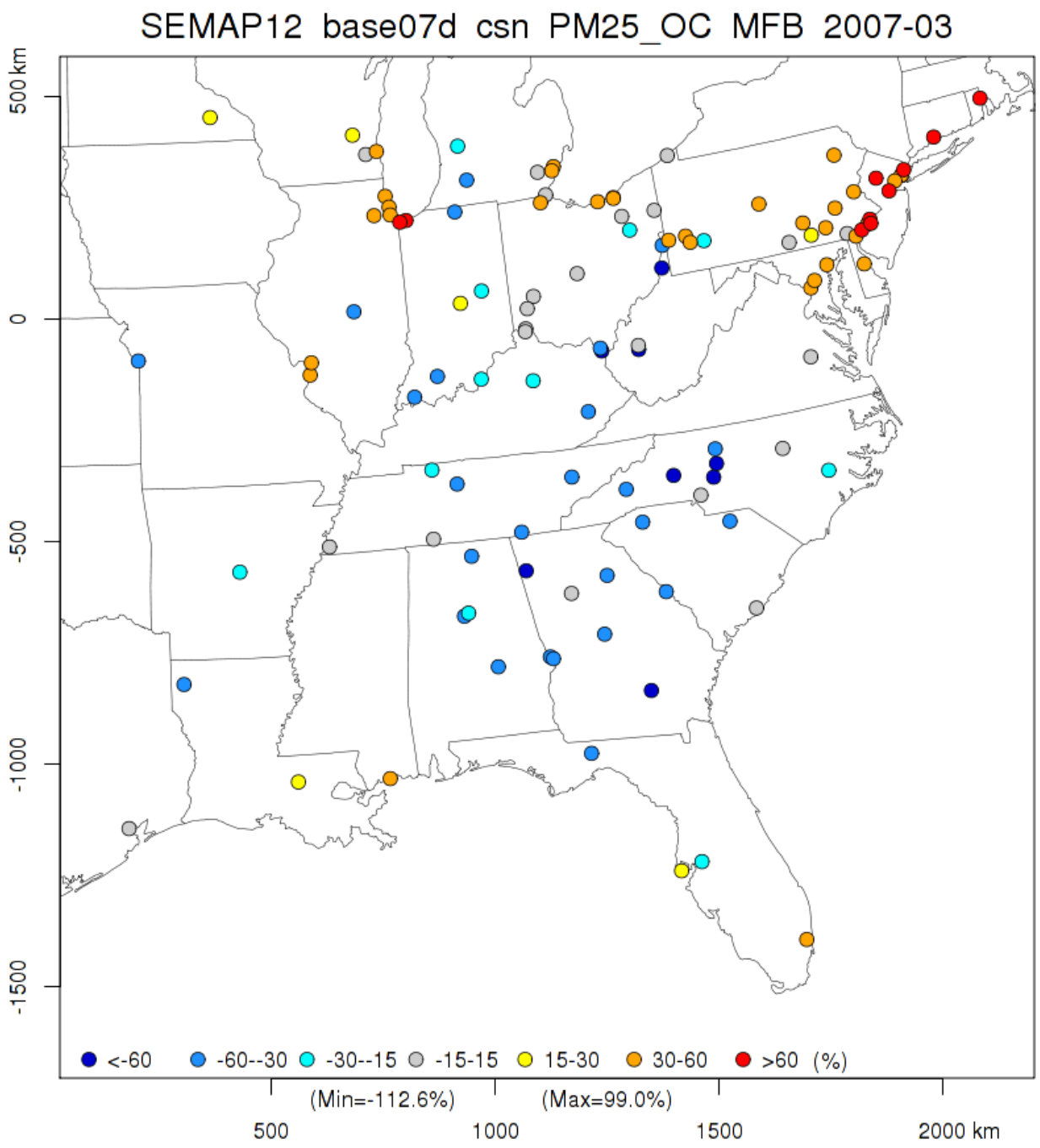


Figure 3-109 March 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ organic carbon at CSN sites.

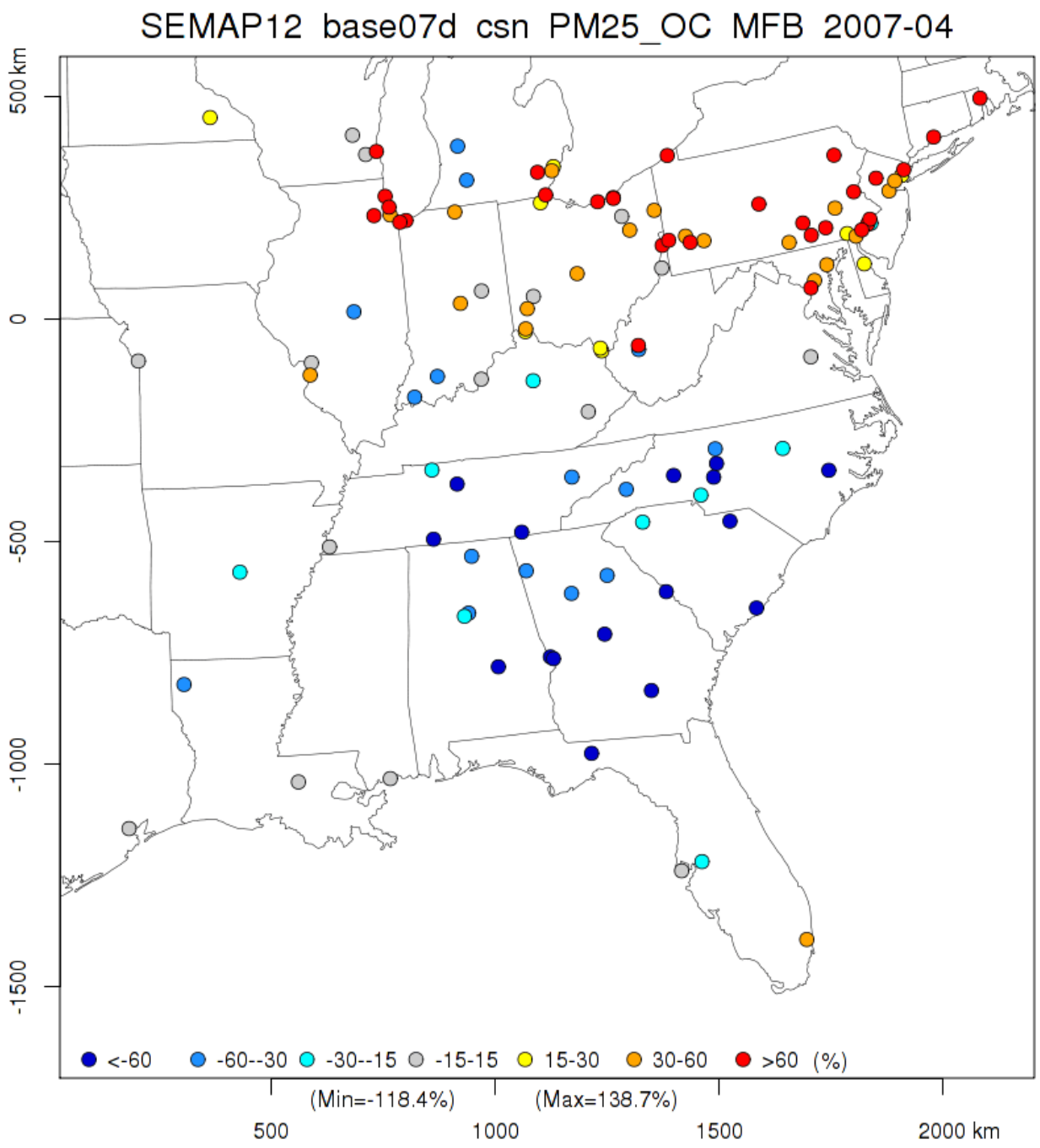


Figure 3-110 April 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ organic carbon at CSN sites.

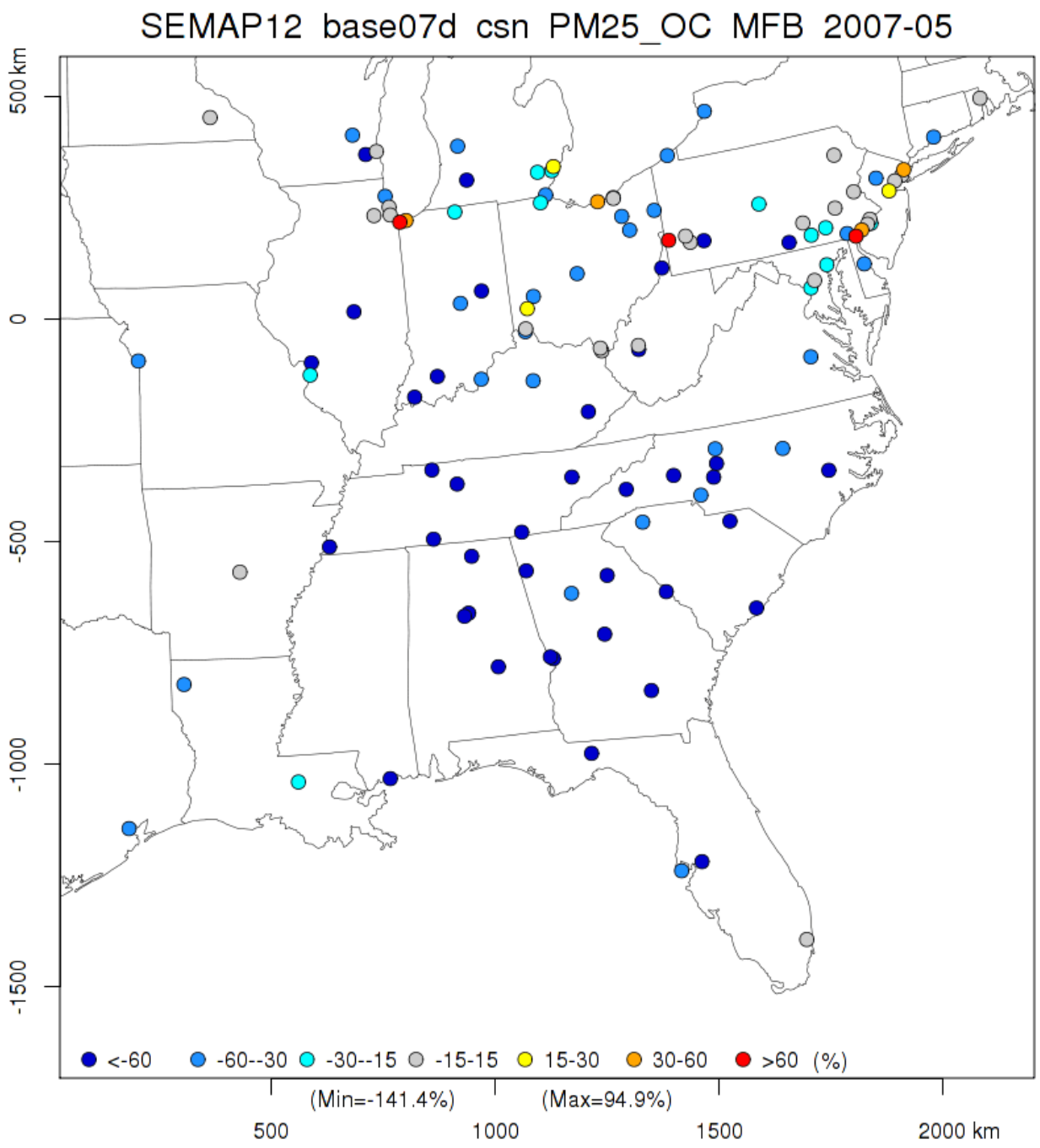


Figure 3-111 May 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ organic carbon at CSN sites.

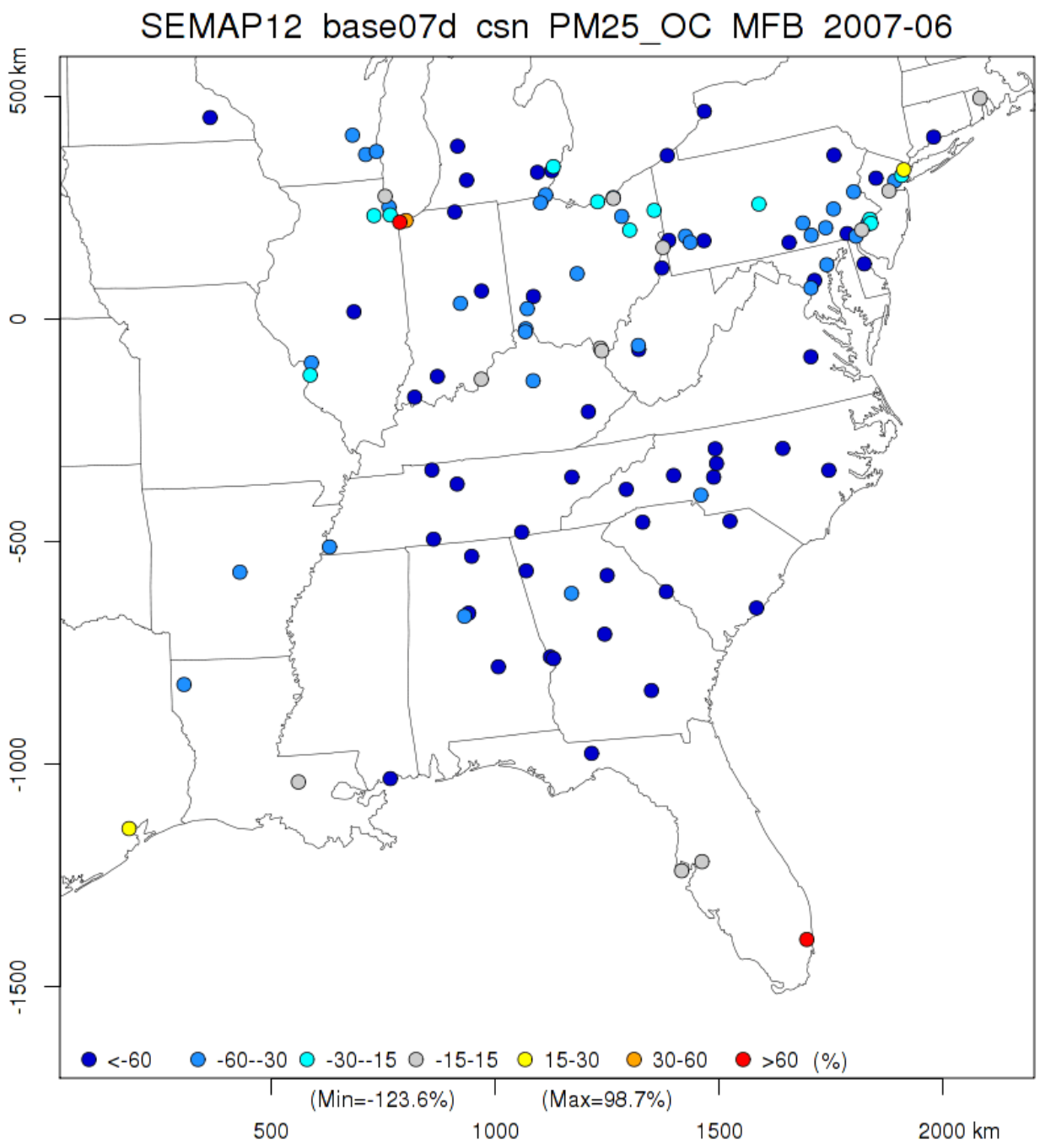


Figure 3-112 June 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ organic carbon at CSN sites.

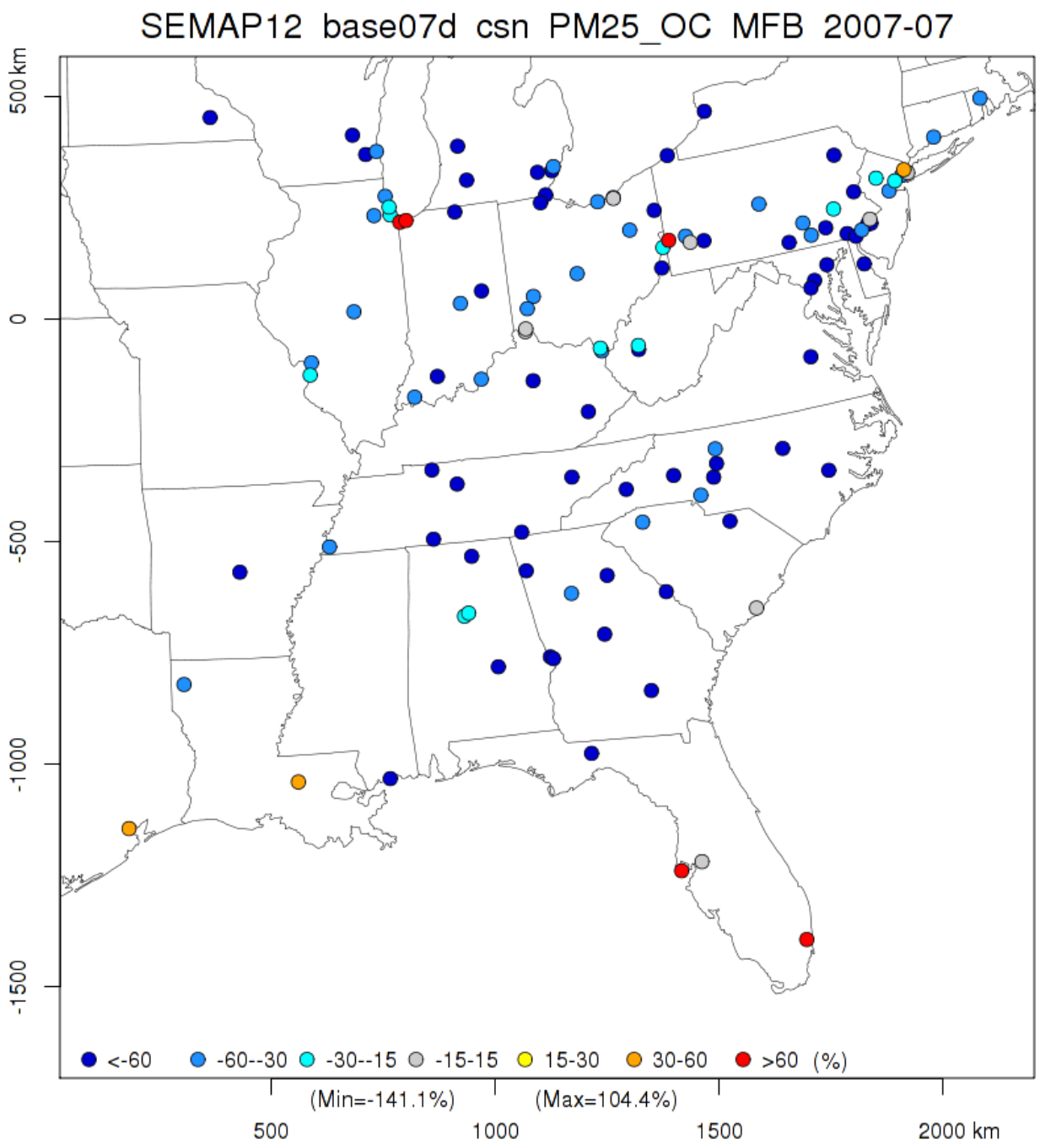


Figure 3-113 July 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ organic carbon at CSN sites.

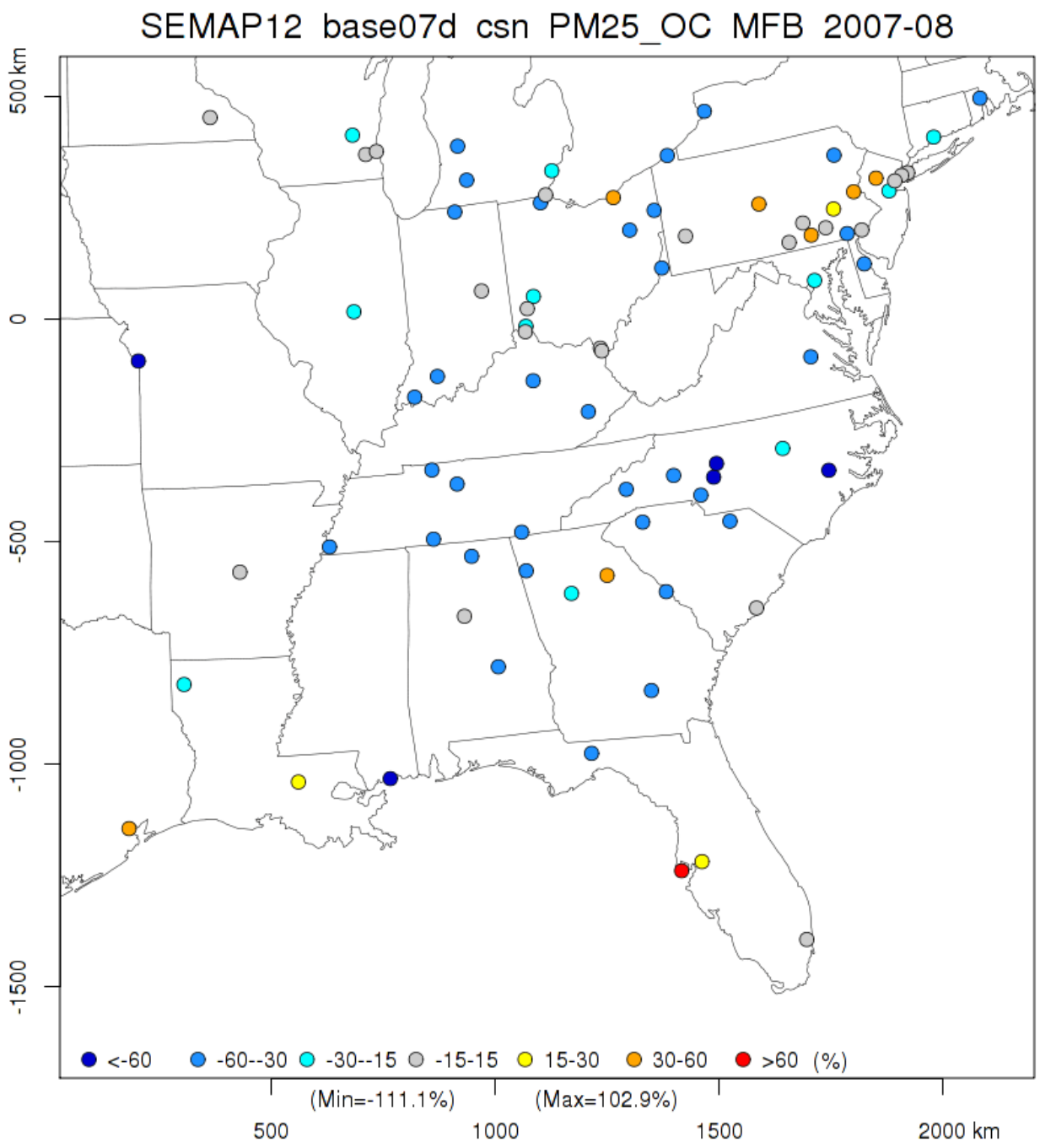


Figure 3-114 August 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ organic carbon at CSN sites.

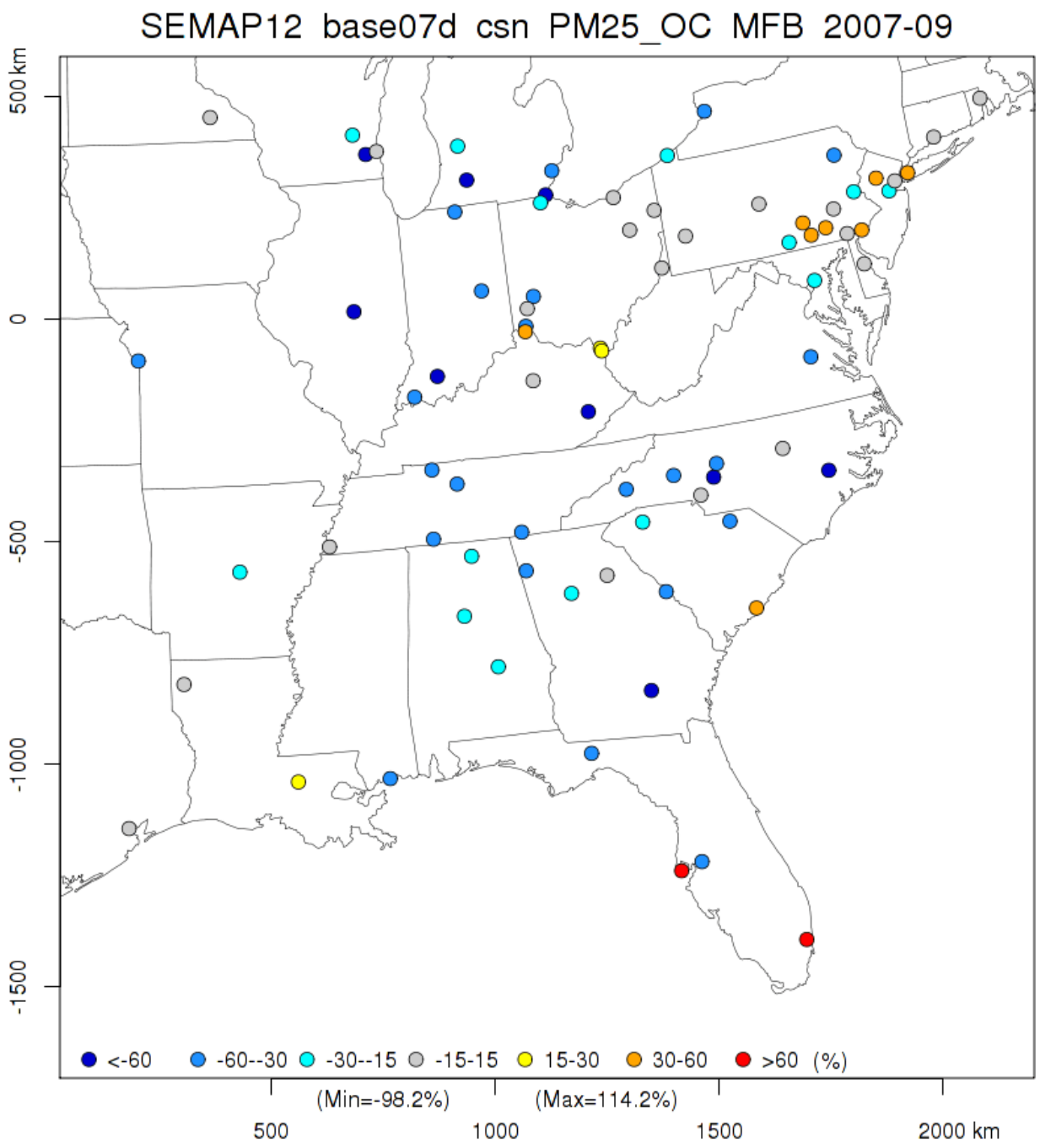


Figure 3-115 September 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ organic carbon at CSN sites.

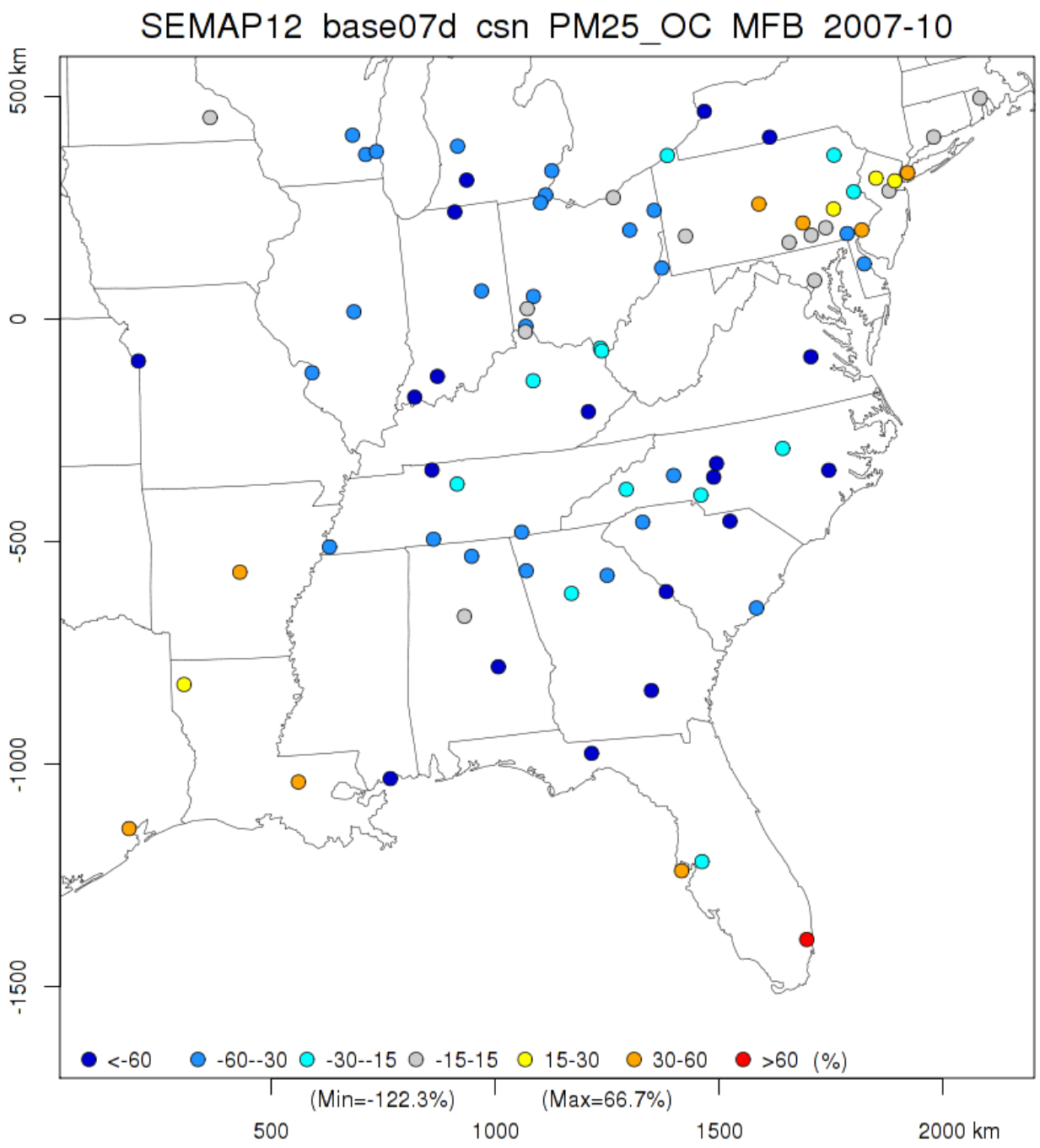


Figure 3-116October 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ organic carbon at CSN sites.

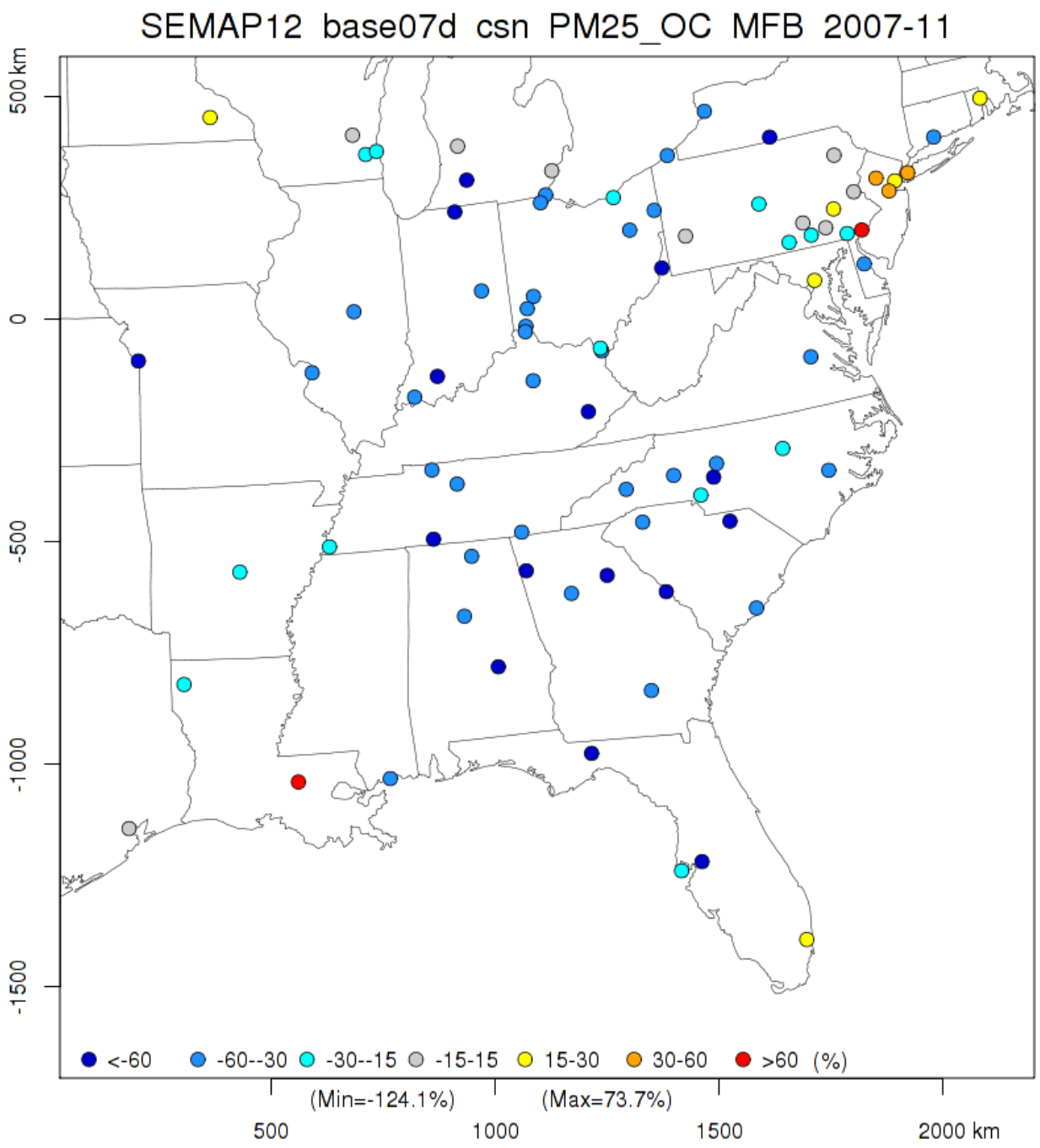


Figure 3-117 November 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ organic carbon at CSN sites.

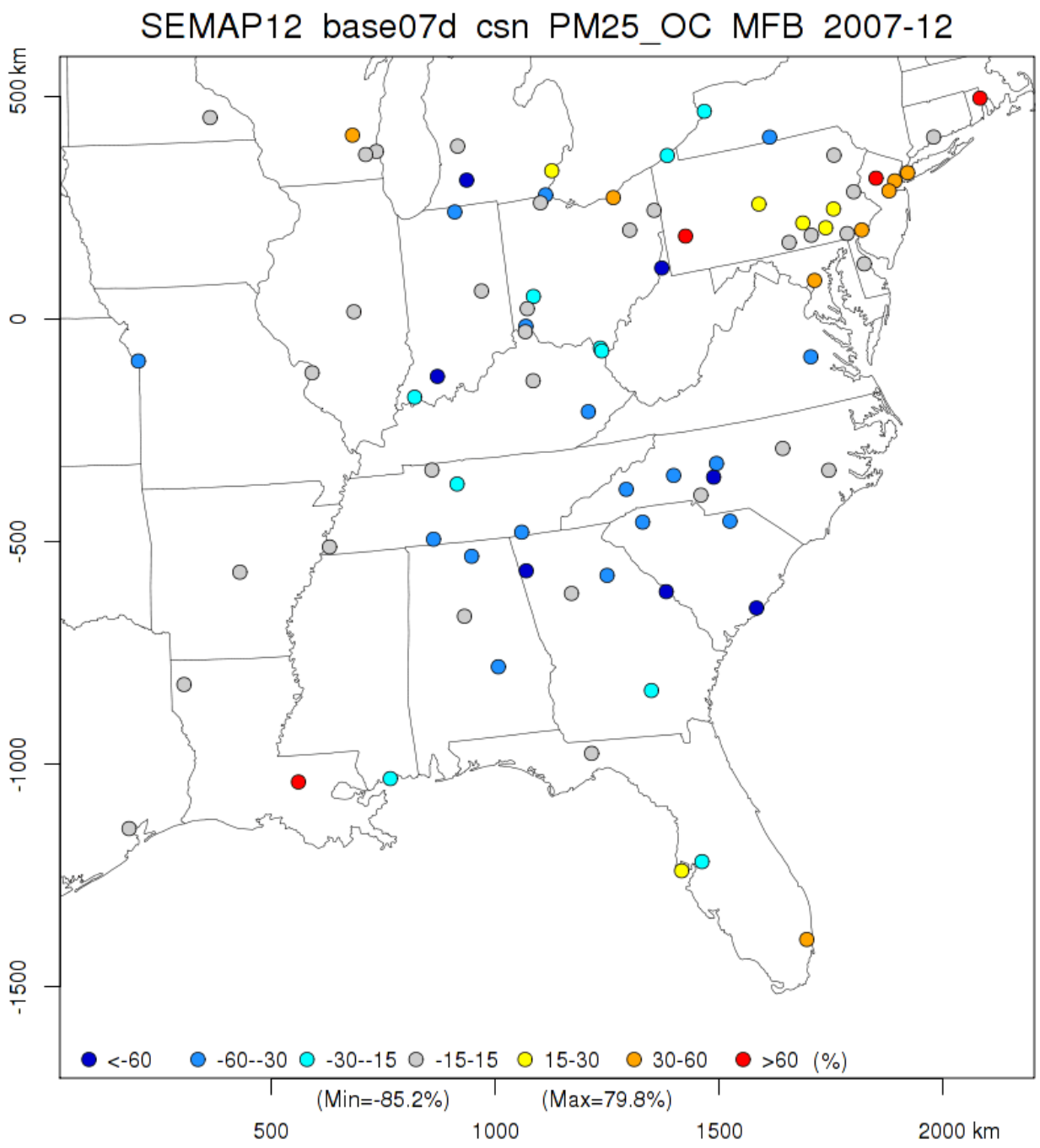


Figure 3-118 December 2007 mean fractional biases (MFB) in 24-hr average $PM_{2.5}$ organic carbon at CSN sites.

Chapter 4: Future Year (2018) Simulation

4.1 Introduction

The year 2018 was simulated with the CMAQ model using the emission projections of Chapter 2. The results were used in conjunction with the results of the 2007 typical simulation of Chapter 3 to calculate relative response factors. Air quality data for the 2005-2009 period were used to calculate future year design values for ozone, annual and daily $PM_{2.5}$, and visibility in the year 2018.
In this chapter, first the methodology used for projecting the current design values to 2018 will be described. Then the results of the 2018 ozone, $PM_{2.5}$ and visibility projections will be presented. The compositions of $PM_{2.5}$ and the contributions of $PM_{2.5}$ constituents to light extinction for the years 2007 and 2018 will be compared. Finally conclusions will be drawn.

4.2 Methodology

The 2007 SEMAP meteorology and 2018 SEMAP emissions were used in the 2018 annual simulation of air quality, first over the 36-km then the 12-km-grid SEMAP domains. The boundary conditions for the 12-km domain were derived from the simulation over the 36-km domain. The model used is CMAQv5.01 with the SEMAP modifications described in Chapter 3. Recall that the performance of this model version was evaluated for the final 2007 actual simulation and the same version was used for the 2007 typical simulation in Chapter 3. As in the 2007 simulations, the year was split into four quarters and each quarter was run separately using a 15-day spin-up period in the beginning, for which the results were discarded. The model results were post-processed to obtain daily maximum 8-hr ozone concentrations, and daily 24-hr average $PM_{2.5}$ concentrations. Movies showing the evolution of ozone and $PM_{2.5}$ concentrations and their differences from the 2007 typical simulation can be found at http://semap.ce.gatech.edu/node/1848. EPA's Modeled Attainment Test Software (MATS)[21] was used to calculate the relative response factors (RRFs) and future design values (DVFs). The calculations performed by MATS for ozone, $PM_{2.5}$ and visibility will be summarized next. The parameters used to run MATS will also be listed.

4.2.1 Calculation of Ozone DVFs

Two sets of modeled concentrations are input to MATS: a "baseline" and a "forecast". Here, the results of the 2007 typical simulation are the "baseline" and the results of the 2018 base case simulation are the "forecast". The RRF calculated by MATS is their ratio:

$$RRF = O_3\,(2018_{base}) / O_3\,(2007_{typ})$$

where O_3 denotes the daily maximum 8-hr ozone with the simulation year and case in parenthesis. MATS calculated the ozone DVF as:

$$DVF = DVC \times RRF$$

where DVC is the current design value.
Four different DVFs were calculated using two different sets of DVCs and two different sets of RRFs. The DVCs are:

- 2007 design value, which uses ozone measurements from three years (2005-2007)
- 5-year (2005-2009) weighted average design value, which is the average of 2007, 2008 and 2009 design values

The two different RRFs are:

- Monitor (1×1) cell RRF
- 3x3 cell block's maximum RRF

[21] http://www.epa.gov/ttn/scram/guidance/guide/MATS-2-5-1_manual.pdf

Note that the 3x3 cell block'smaximum RRF may produce non-intuitive results. The 3x3 cell block'smaximum may be in one cell for the 2007 typical ozone and in another cell for the 2018 base case ozone as illustrated in Figure 4-1. This may result in an RRF that is not specific to any cell in the 3x3 matrix.

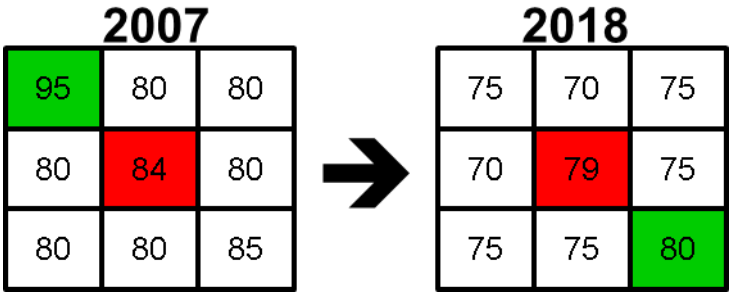


Figure 4-1 Illustration of how the design value can shift into a different cell in a 3×3 block of cells around the monitor.

The RRFs were produced using the following thresholds in MATS based on the modeled 2007 typical daily 8-hr maximum ozone concentrations:

- Initial threshold value = 75 ppb
- Minimum number of days in baseline at or above threshold = 10
- Minimum allowable threshold value = 65 ppb
- Minimum number of days at or above minimum allowable threshold = 5

4.2.2 Calculation of $PM_{2.5}$ DVFs

Once again, the results of the 2007 typical simulation are input to MATS as the "baseline" and the results of the 2018 base case simulation are input as the "forecast". However, different from the ozone RRF calculations, MATS calculates different RRFs for each of the four quarters and for each of the $PM_{2.5}$ species as:

$$RRF_{Q,S} = PM_{2.5}(2018_{base})_{Q,S} / PM_{2.5}(2007_{typ})_{Q,S}$$

Here $PM_{2.5}$ denotes the daily 24-hr average $PM_{2.5}$ with the simulation year and case in parenthesis, and Q and S are the quarter and species indices, respectively.

The future design values for each quarter and each $PM_{2.5}$ species are obtained from $RRF_{Q,S}$ using the current design values $DVC_{Q,S}$, also calculated for each quarter and $PM_{2.5}$ species, as follows:

$$DVF_{Q,S} = DVC_{Q,S} \times RRF_{Q,S}$$

Then, for each $PM_{2.5}$ species, $DVF_{Q,S}$ are averaged across the four quarters:

$$DVF_S = \frac{1}{4}\sum_{Q=1}^{4} DVF_{Q,S}$$

Finally, DVF_S are summed for all species to yield the DVF for total $PM_{2.5}$

$$DVF = \sum_S DVF_s$$

Similar to ozone DVFs, $PM_{2.5}$ DVFs were also calculated in four different ways using two different sets of DVCs and two different sets of RRFs. The DVCs are:

- 2007 design value, which uses $PM_{2.5}$ values from three years (2005-2007)
- 5-year (2005-2009) weighted average design value

The two different sets of RRFs are:
- Monitor (1×1) cell RRF
- 3x3 cell block average RRF

Note that while the 3x3 cell block's maximum RRF was used for ozone, 3x3 cell block's average RRF is used for $PM_{2.5}$.

4.2.3 Calculation of 2018 Visibility

We ran MATS with the 2007 typical simulation results as the "baseline" and 2018 base-case simulation results as "forecast" to get the RRFs for each $PM_{2.5}$ species, *S*, as:

$$RRF_S = PM_{2.5}(2018_{base})_S / PM_{2.5}(2007_{typ})_S$$

Then, using these RRF_S, the future light extinction for each species was calculated from that species' current light extinction as follows:

$$\text{Future } Bext_S = \text{Base } Bext_S \times RRF_S$$

Both Base $Bext_S$ and RRF_S were calculated for each species on the 20% worst and 20% best visibility days. Future $Bext_S$, which are the contributions of $PM_{2.5}$ species to light extinction, were summed for all species to give the future light extinction:

$$Future\ Bext = \sum_S Future\ Bext_s$$

Finally, the Haze Index (in deciViews) is the base 10 logarithm of the total light extinction:

$$\text{Haze Index (dV)} = 10 \ln (B_{ext}/10)$$

Two different sets of future light extinctions were calculated, both using the 5-year (2005-2009) straight average Base *Bex*t but two different sets of RRFs. The RRFs are:
- Monitor (1×1) cell RRF
- 3x3 cell block's average RRF

4.3 Future Design Values

Projected 2018 future design values for ozone as well as annual and daily $PM_{2.5}$ are presented in this section.

4.3.1 Future Ozone Design Values

Before presenting the 2018 future ozone design values, let's first take a look at the current ozone design values. In 2007, in every SESARM state there were multiple non-attainment sites where the ozone design value exceeded 75 ppb (Figure 4-2).
Ozone design values were projected to 2018 in four different ways as described in Section Calculation of Ozone DVFsabove. "Bubble" plots were prepared with color-coded circles denoting the level of ozone

over each monitor of the 12-km SEMAP modeling domain. The resulting 2018 future design values are shown in Figure 4-3 through Figure 4-6 for the four different ways of calculation. Figure 4-7 shows that using the 2007 design values as DVCs results in higher DVFs than using the 5-year (2005-2009) weighted average design values. This is due to the decreasing trend of ozone from 2007 to 2009 throughout the domain. On the other hand, the DVFs are higher at some sites when the 3×3 cell block's maximum RRF is used while the monitor (1×1 cell) RRF leads to higher DVFs at other sites (Figure 4-8). The 2007 DVC and 3×3 cell block's maximum RRF lead to the most extensive violations of the ozone standard in the SESARM states, with several monitors above 75 ppb and one monitor in Atlanta, GA over 80 ppb (Figure 4-3).

Table 4-1 lists the sites projected to be in non-attainment in 2018 based on the five-year (2005-2009) weighted average DVC both for the 3×3 cell maximum and monitor (1×1) cell RRFs. Non-attainment here is defined as the 2018 ozone DFV exceeding 75 ppb. For the 3×3 cell block's maximum RRF there are four nonattainment sites in Georgia and only one of them is in non-attainment if the monitor (1×1) cell RRF is used.

Table 4-2 lists the "maintenance" sites for which the DVFs based on the five-year (2005-2009) weighted average DVC are less than 75 ppb but the DVFs based on the 2007 DVC exceed 75 ppb. If the 3×3 cell block's maximum RRF is used there is one maintenance site in Alabama, one in Georgia, two in Virginia and one in West Virginia. If the monitor (1×1) cell RRF is used then there are three maintenance sites in Alabama and one in Virginia. 4.2.1

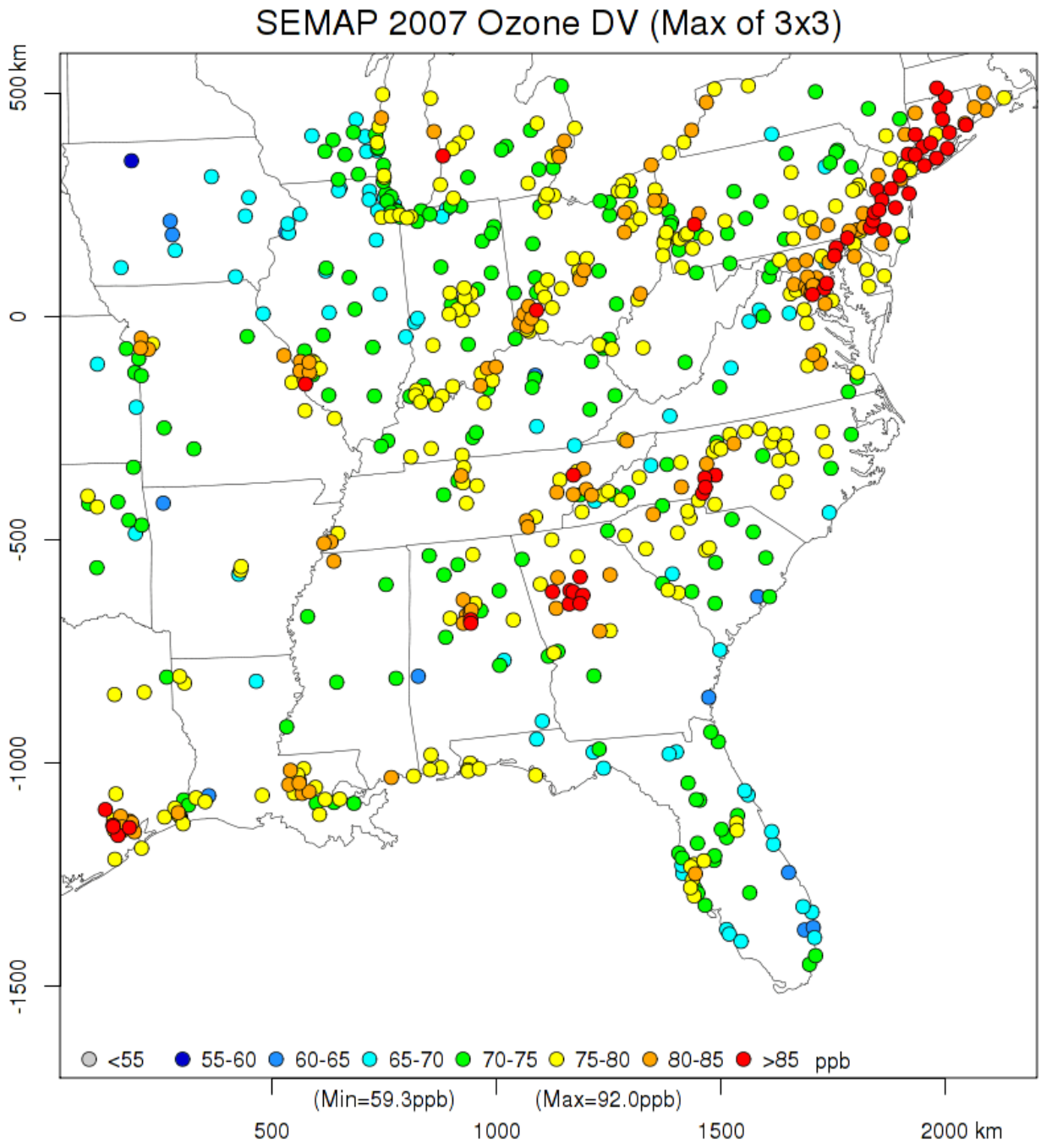


Figure 4-2 Five year (2005-2009) weighted average O_3 DVCs

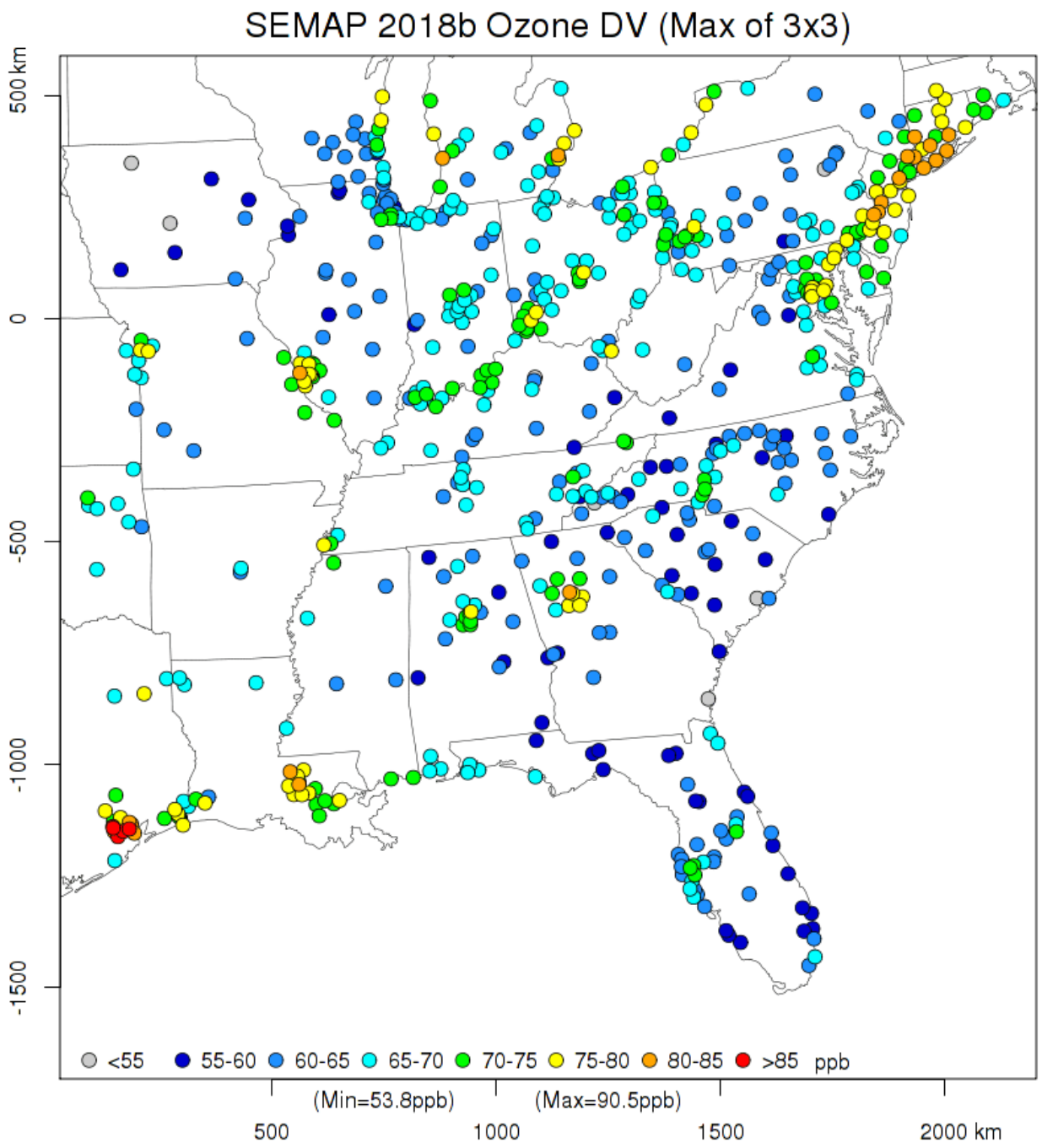


Figure 4-3 2018 O_3 DVFs: 3×3 RRF & 2007 DVC

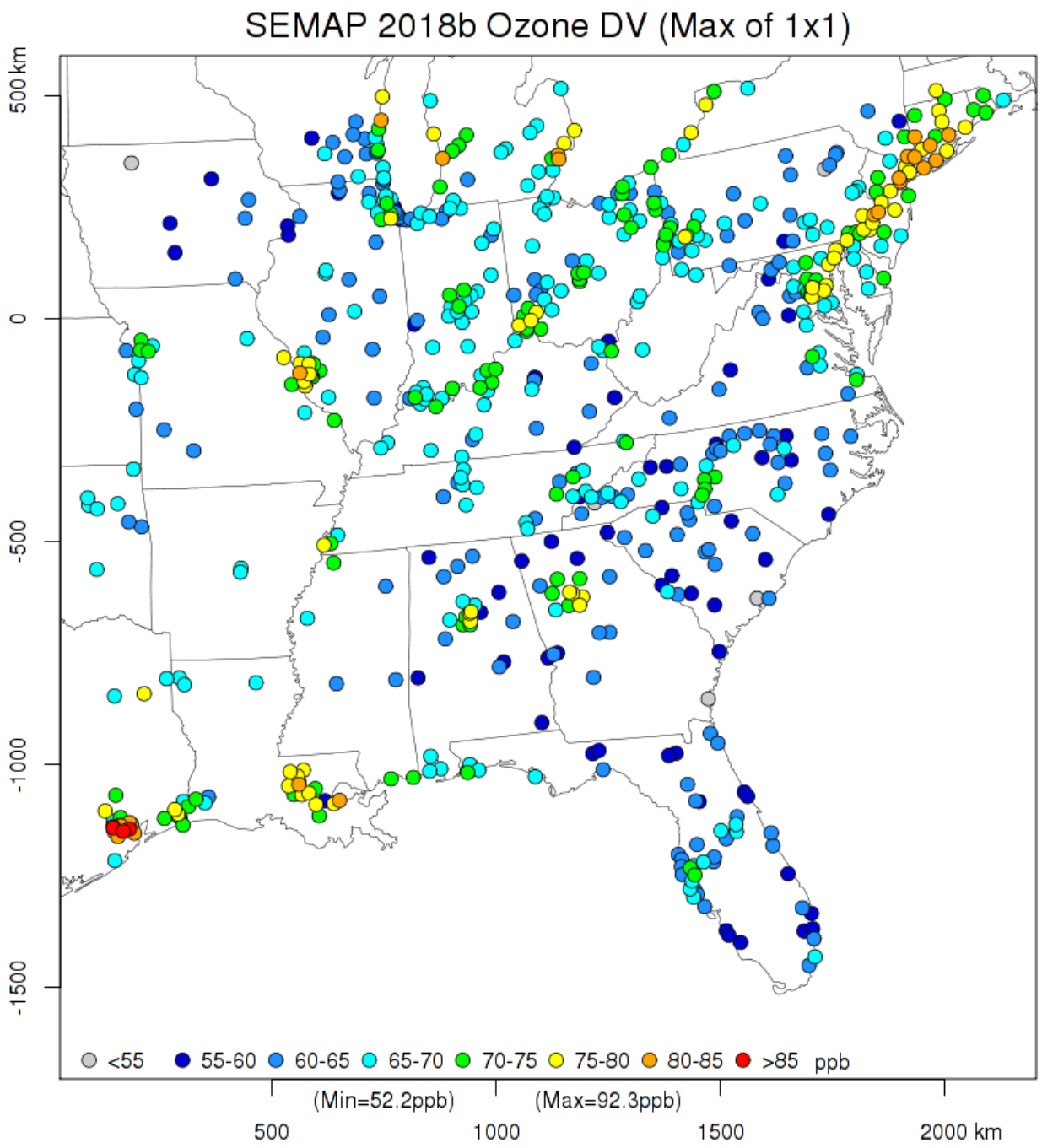


Figure 4-4 2018 O_3 DVFs: 1x1 RRF & 2007 DVC

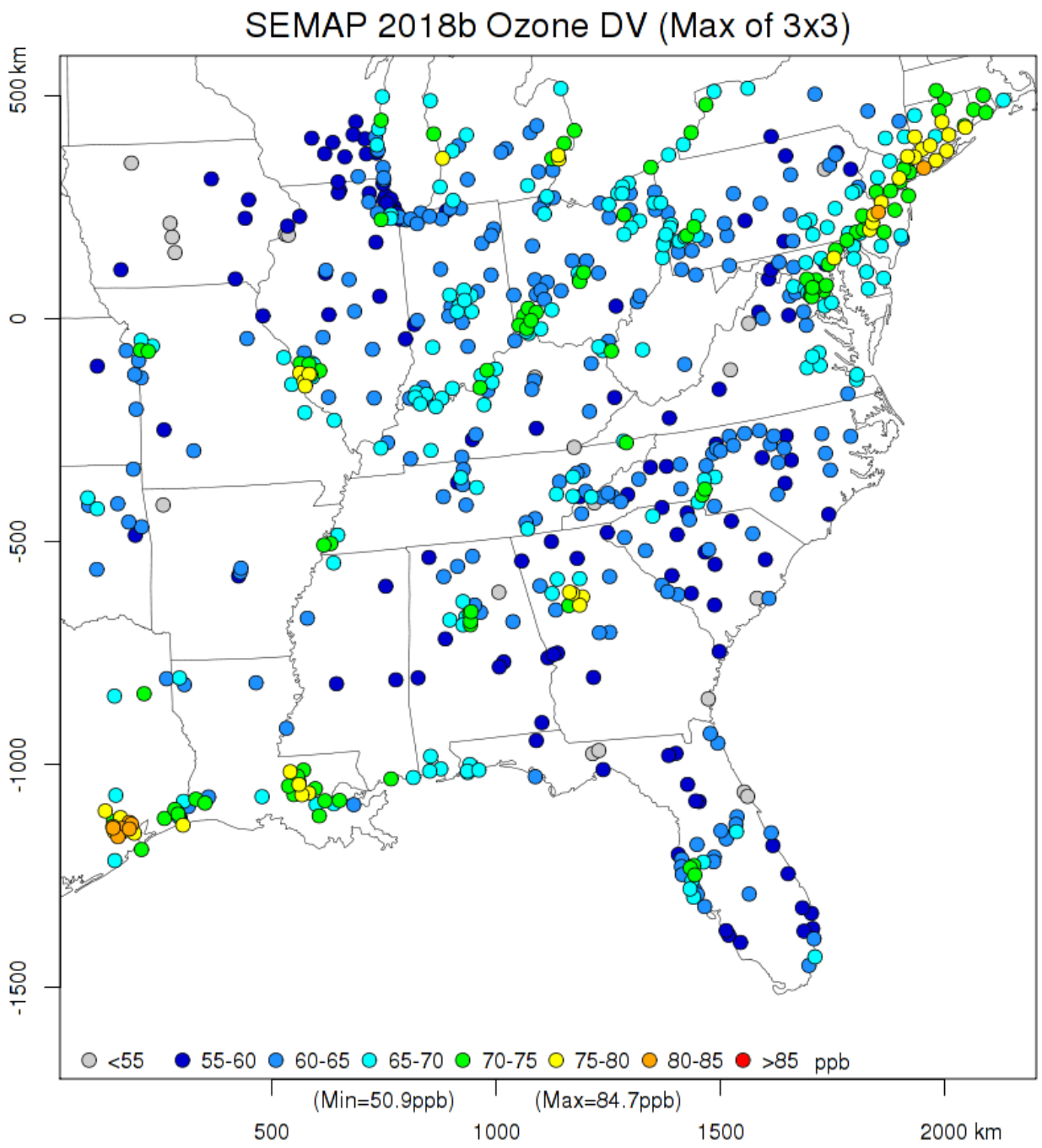


Figure 4-5 2018 O_3 DVFs: 3×3 RRF & 2005-2009 DVC

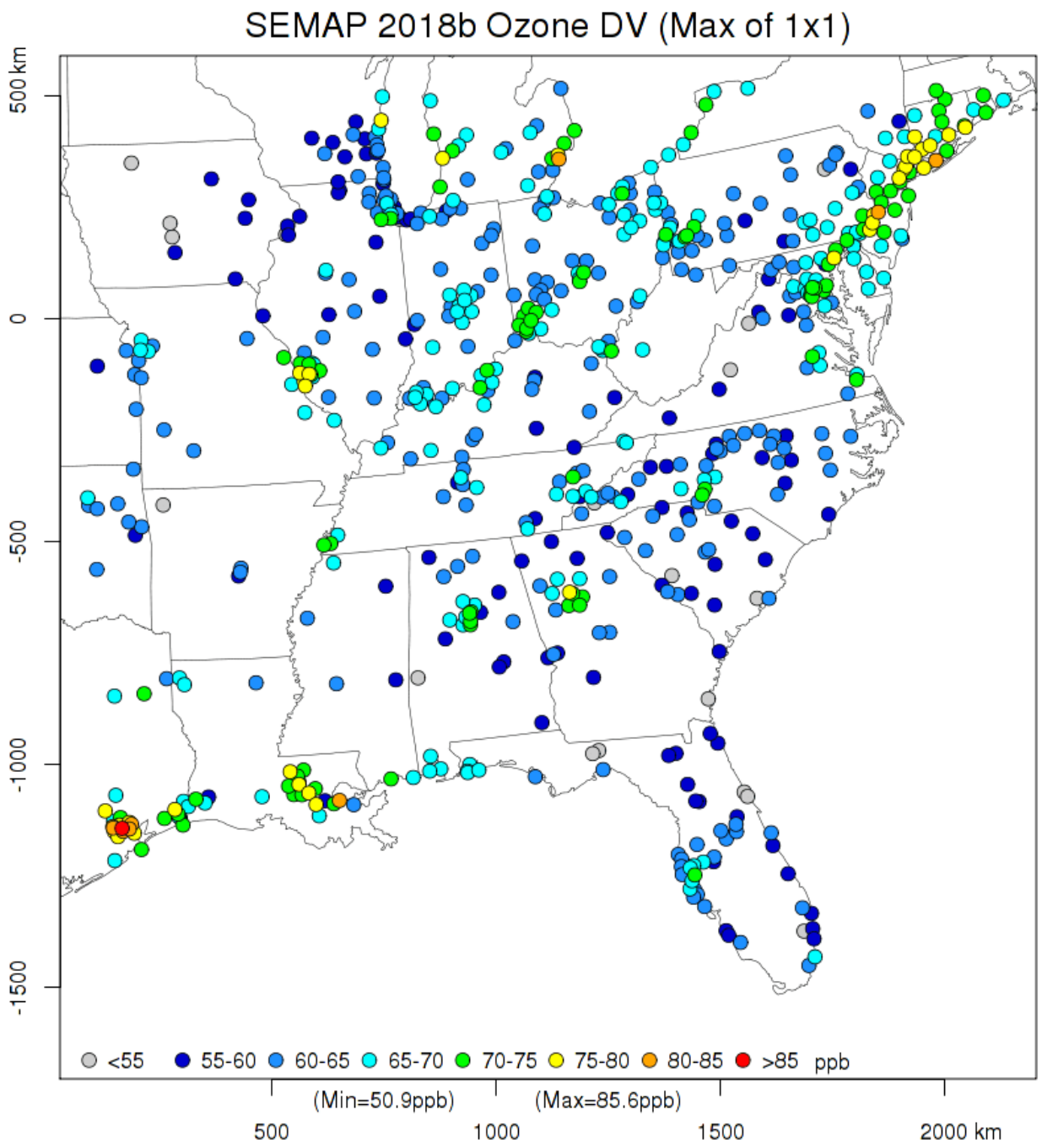


Figure 4-6 2018 O_3 DVFs: 1×1 RRF & 2005-2009 DVC

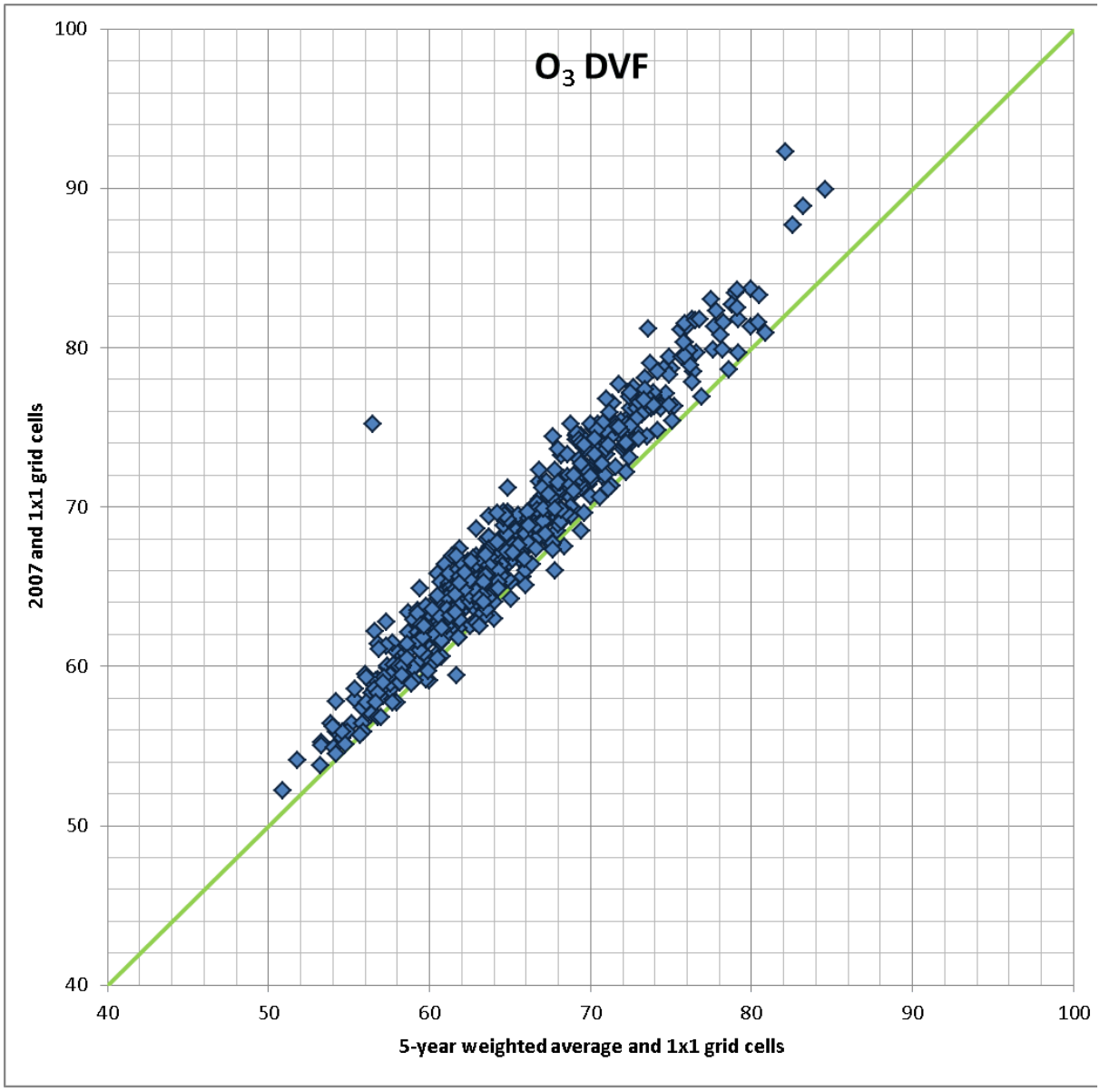


Figure 4-7 2018 O_3 DVFs calculated using 2007 DVCs vs. 5-year weighted DVCs

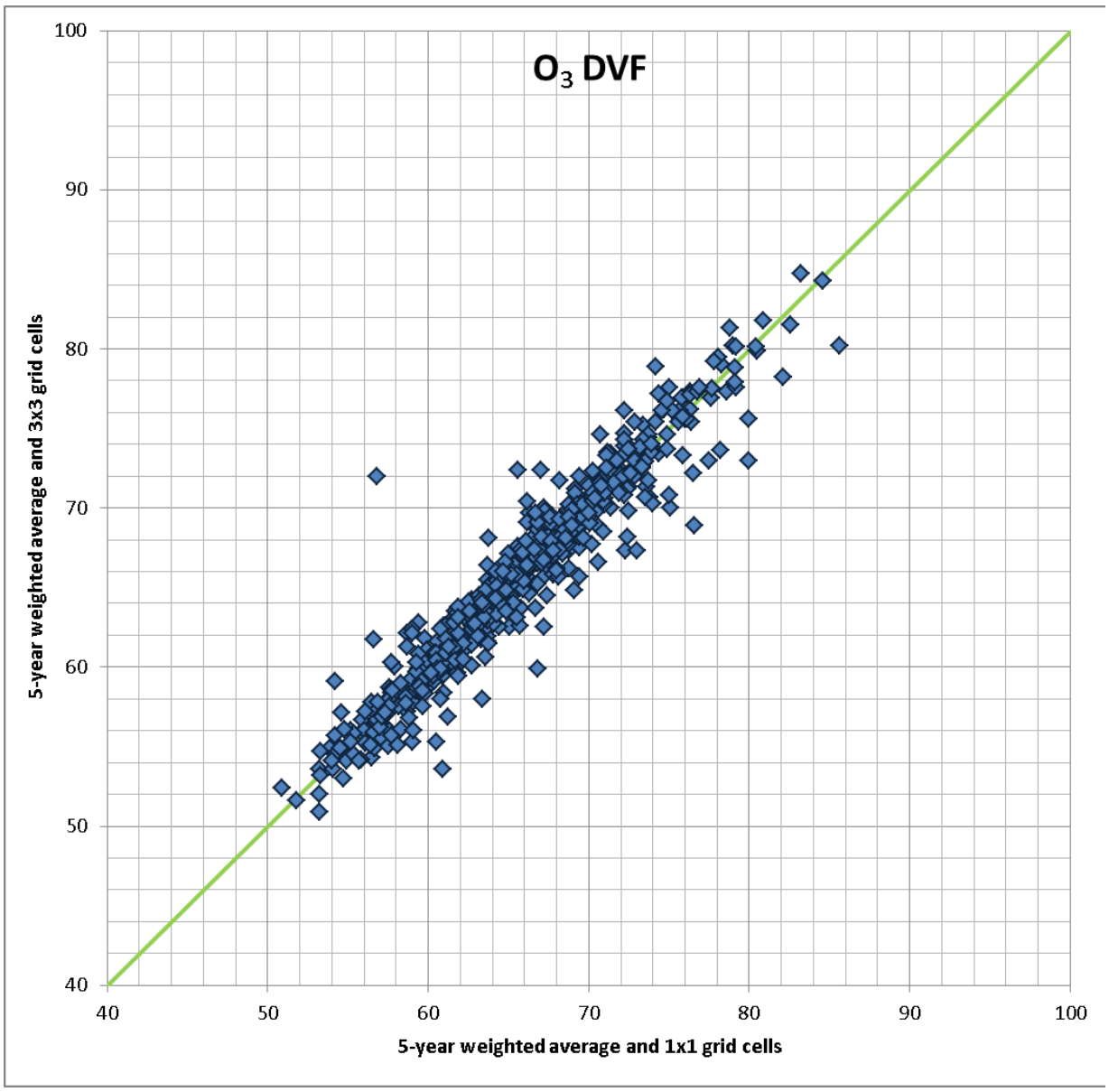


Figure 4-8 2018 O_3 DVFs calculated using 3×3 Max vs. 1×1 Cell RRFs

Table 4-1 2018 Ozone "Nonattainment" (DVF ≥ 75 ppb based on 2005-2009 DVC)

STATE	AIRS ID	DVC	3x3 MAX	1x1 CELL
CT	90010017	86.3	78.8	79.1
CT	90011123	88.7	76.9	75.8
CT	90013007	87	77.9	79.1
CT	90019003	85.3	77.1	76.3
CT	90070007	87	75.4	74.2
CT	90093002	87.3	77.3	76.8
CT	90110008	88	77.6	76.9
GA	130890002	90.7	77.2	74.4
GA	131210055	90.3	77.3	76.3
GA	131510002	92	76.2	74.7
GA	132470001	91.7	75.2	73.4
LA	220050004	81.7	75.4	76.4
LA	220330003	83	76.2	76.3
LA	220470012	81.3	75.4	72.9
LA	220511001	79.3	73	80
LA	220770001	82	77.6	75
LA	220930002	74	68.9	76.6
MD	240251001	90.7	77.1	76.2
MI	260050003	86.7	75.4	75.6
MI	260991003	81.3	76.9	75.9
MI	261630019	81.7	75.6	80
MO	290990012	86	77.3	78.6
MO	291890004	82	76.1	75.7
MO	291890014	82.3	75.6	76
MO	295100086	83.5	76.9	77.6

Table 4-1 (Continued) 2018 Ozone "Nonattainment" (DVF ≥ 75 ppb based on 2005-2009 DVC)

STATE	AIRS ID	DVC	3x3 MAX	1x1 CELL
NJ	340070003	87.5	77.6	79.2
NJ	340150002	85.7	76.1	75.2
NJ	340170006	85	77.5	77.7
NJ	340210005	86.3	76.1	74.6
NY	360050133	74.7	70	75.1
NY	360610135	76	70.8	75
NY	361030002	85.3	80.2	79
NY	361030004	86	76.7	74.9
NY	361030009	88	79.9	80.5
NY	361192004	86.3	79	78.3
PA	420170012	90.7	80.1	80.4
PA	421010024	88	79.5	78.1
TX	480391004	86.7	81.3	78.8
TX	482010024	83.3	78.9	74.2
TX	482010026	80.3	80.1	79.2
TX	482010029	86.7	75.6	76.1
TX	482010051	81	75.7	75.9
TX	482010055	90.3	84.3	84.6
TX	482010062	81	78.2	82.1
TX	482010066	86.7	81.5	82.6
TX	482010070	75.7	73	77.5
TX	482010075	76.3	73.6	78.2
TX	482010416	83.5	80.2	85.6
TX	482011015	82	81.8	80.9
TX	482011034	78	75.1	
TX	482011039	87	84.7	83.2
TX	482011050	81.3	79.2	77.8
TX	482450009	78.3	73.3	75.9
TX	482450101	79	76.1	72.2
WI	551170006	83.3	72.2	76.5

Table 4-2 2018 Ozone "Maintenance" (DVF < 75 ppb based on 2005-2009 DVC but DVF ≥ 75 ppb based on 2007 DVC)

STATE	AIRS ID	DVC	3x3 MAX	1x1 CELL
AL	10730023	86	72.9	76.2
AL	10732006	89	74.4	75.7
AL	10736002	89	75.8	76.2
AR	50350005	89	76.7	76.8
CT	90031003	90	75.9	76.7
DC	110010043	87	75.4	76.4
GA	131130001	89	75.9	71.9
IL	170310001	82	73.3	75.2
LA	220190002	81	76.4	69.3
LA	220330013	81	75.5	75.4
LA	220331001	84	78.6	77.5
LA	220470007	86	79.7	79
LA	220470009	81	75	74.4
LA	220890003	77	70.1	75.2
LA	221210001	83	76.7	77.1
MD	240030014	90	75.8	75.2
MD	240053001	87	75.7	76.5
MD	240150003	93	77.9	77
MD	240259001	91	76.8	77
MD	240338003	91	76.5	75.2
MA	250130008	92	76.8	77.2
MI	260990009	86	77.1	76.6
MI	261210039	88	75.6	75
MI	261470005	85	75	76.5

Table 4-2 (Continued) 2018 Ozone "Maintenance" (DVF < 75 ppb based on 2005-2009 DVC but DVF ≥ 75 ppb based on 2007 DVC)

STATE	AIRS ID	DVC	3x3 MAX	1x1 CELL
MO	290470005	87	76.5	74.6
MO	290470006	87	75.2	74.2
MO	291130003	87	74.6	75.2
MO	291831002	89	79	79.4
MO	291831004	89	78.8	77.7
MO	295100085	84	77.4	78.1
NJ	340071001	89	76.6	74.5
NJ	340190001	89	75	73.6
NJ	340230011	91	78.3	77.4
NJ	340250005	88	77.3	74.7
NJ	340290006	92	78.3	75.9
NY	360130006	86	76.5	75.8
NY	360290002	86	75.6	76.9
NY	360810124	79	72.4	76.3
NY	360850067	89	78.6	81.2
OH	390071001	90	76.9	71.2
OH	390490029	87	76	74.9
OH	390610006	86	75.2	76.4
OH	390610010	84	74.9	75
OH	391650007	88	75.6	75.5
PA	420030010	83	74.3	77.2
PA	420031005	87	76.1	73.9
PA	420450002	85	74.6	76.7
PA	420910013	86	76.4	75.1
TX	481830001	84	76.4	75.3
TX	482011035	79	76.1	
TX	482450018	83	76.4	76.4
VA	510130020	87	75.4	73.9
VA	510590018	89	76.2	75
WV	540110006	84	75.1	74.8
WI	550710007	86	75.8	75.2

4.3.2 Future Annual $PM_{2.5}$ Design Values

The current annual $PM_{2.5}$ design values are shown in Figure 4-9 (2007 DVC) and Figure 4-10 (5-year weighted average DVC). In 2007 wide-spread exceedance of the annual $PM_{2.5}$ standard, which is currently at 12 μg m^{-3}, is observed across the SESARM states as well as the neighboring RPOs. The coastal sites appear to be the only compliant SESARM sites according to the 2007 DVC and some mountain sites along the Southern Appalachians are added to the non-exceedance list according to the five-year (2005-2009) weighted average DVC.

Annual $PM_{2.5}$ design values were projected to 2018 in four different ways as described in Section Calculation of Ozone DVFsabove. The resulting 2018 future design values are shown in Figure 4-11 through Figure 4-14. The 2007 DVCs lead to higher DVFs than the 5-year (2005-2009) weighted average

DVCs (Figure 4-15). This is due to the decreasing trend of $PM_{2.5}$ from 2007 to 2009 throughout the domain. On the other hand, while the 3×3 cell average RRFs lead to higher DVFs at some sites the monitor (1×1) cell RRFs lead to higher DVFs at other sites (Figure 4-16). The 2007 DVC and monitor (1×1) cell RRF show more exceedances of the $PM_{2.5}$ standard than the other DVC–RRF combinations. The DVFs exceed 12 μg m^{-3} at Macon, GA, Knoxville, TN and at two sites around Birmingham, AL they are larger than 13 μg m^{-3} (Figure 4-12).

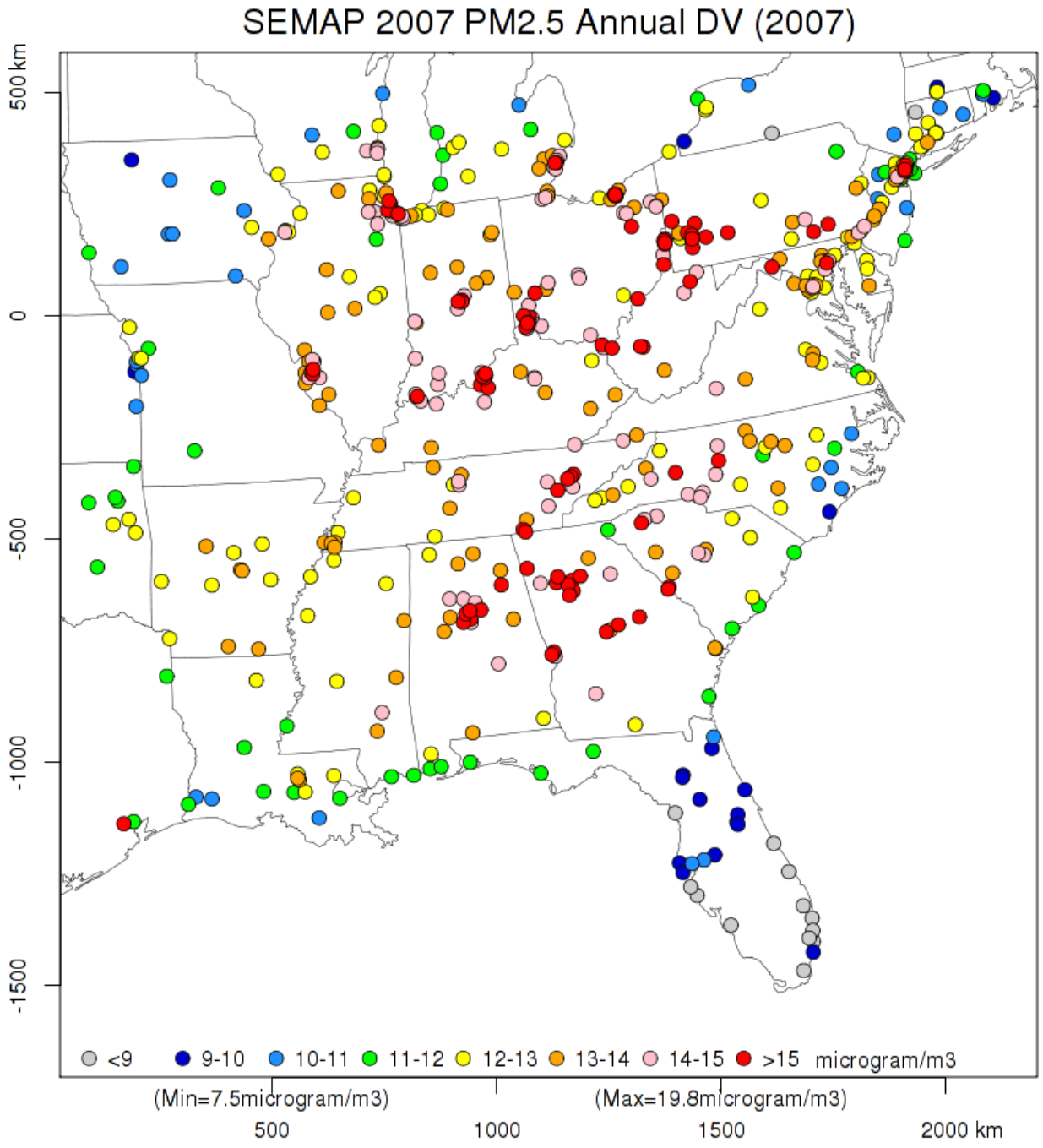


Figure 4-9 2007 Annual $PM_{2.5}$ DVC

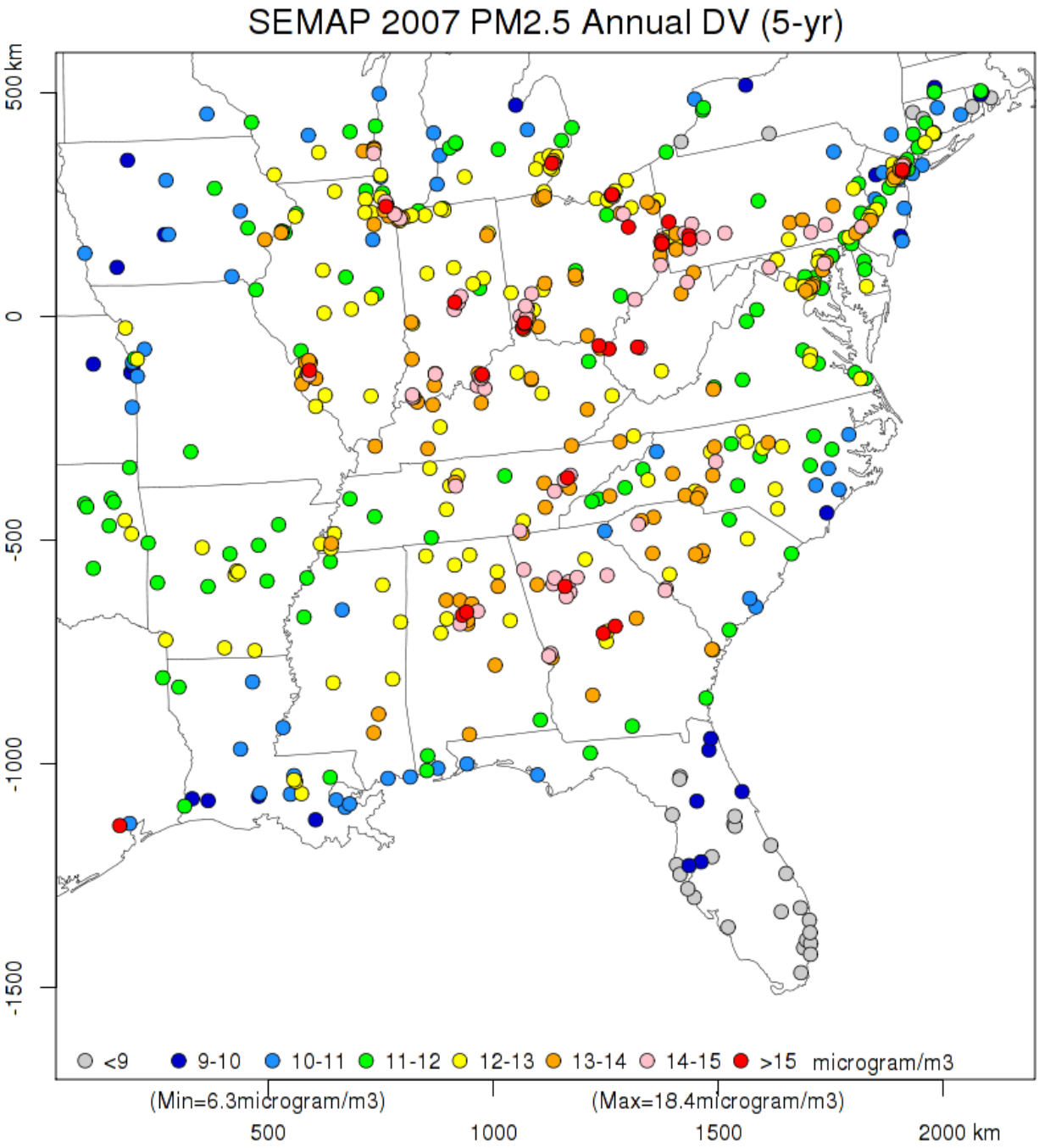


Figure 4-10 5-Year (2005-09) Annual $PM_{2.5}$ DVC

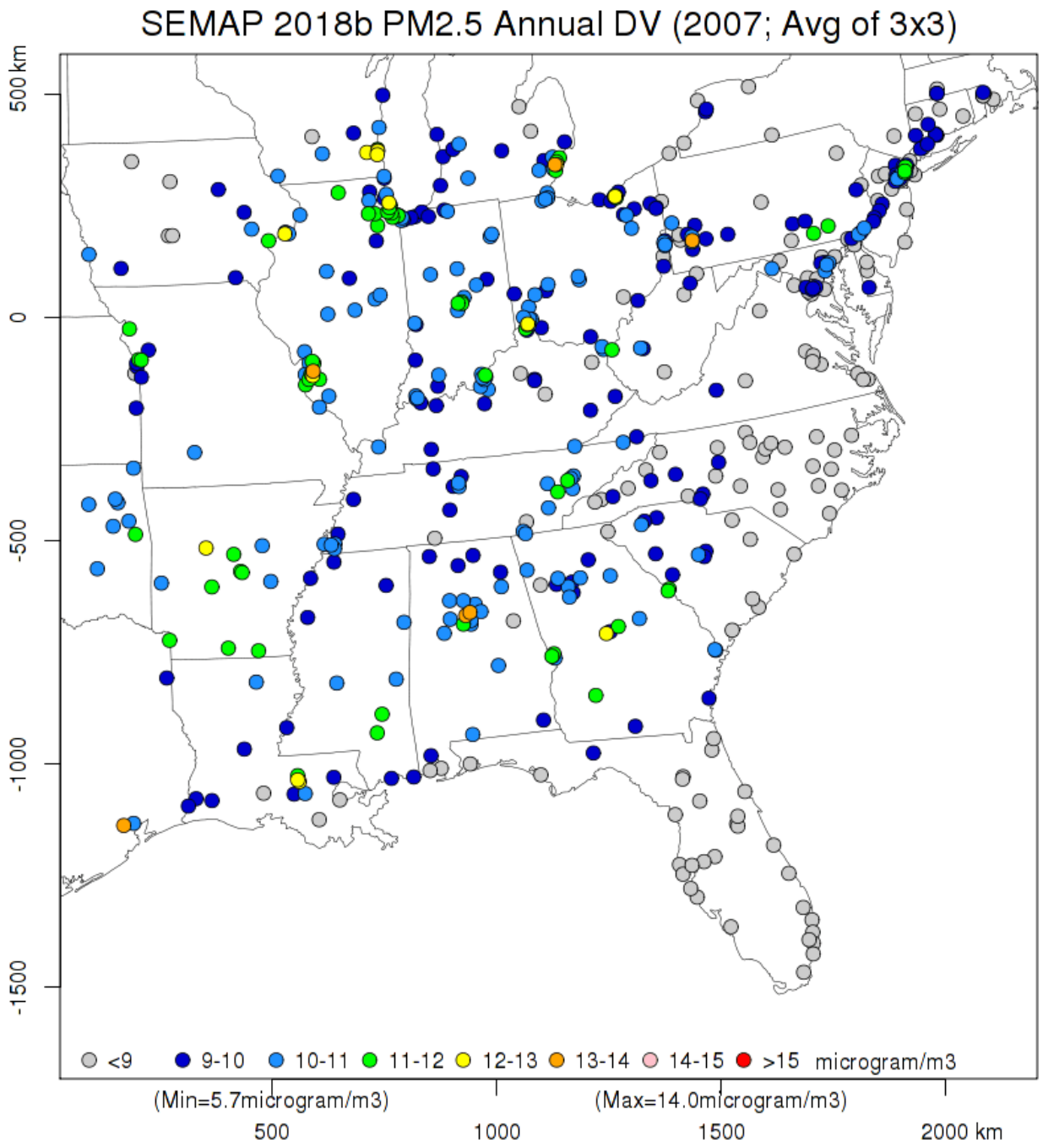


Figure 4-11 2018 Annual $PM_{2.5}$ DVFs: 3×3 RRF & 2007 DVC

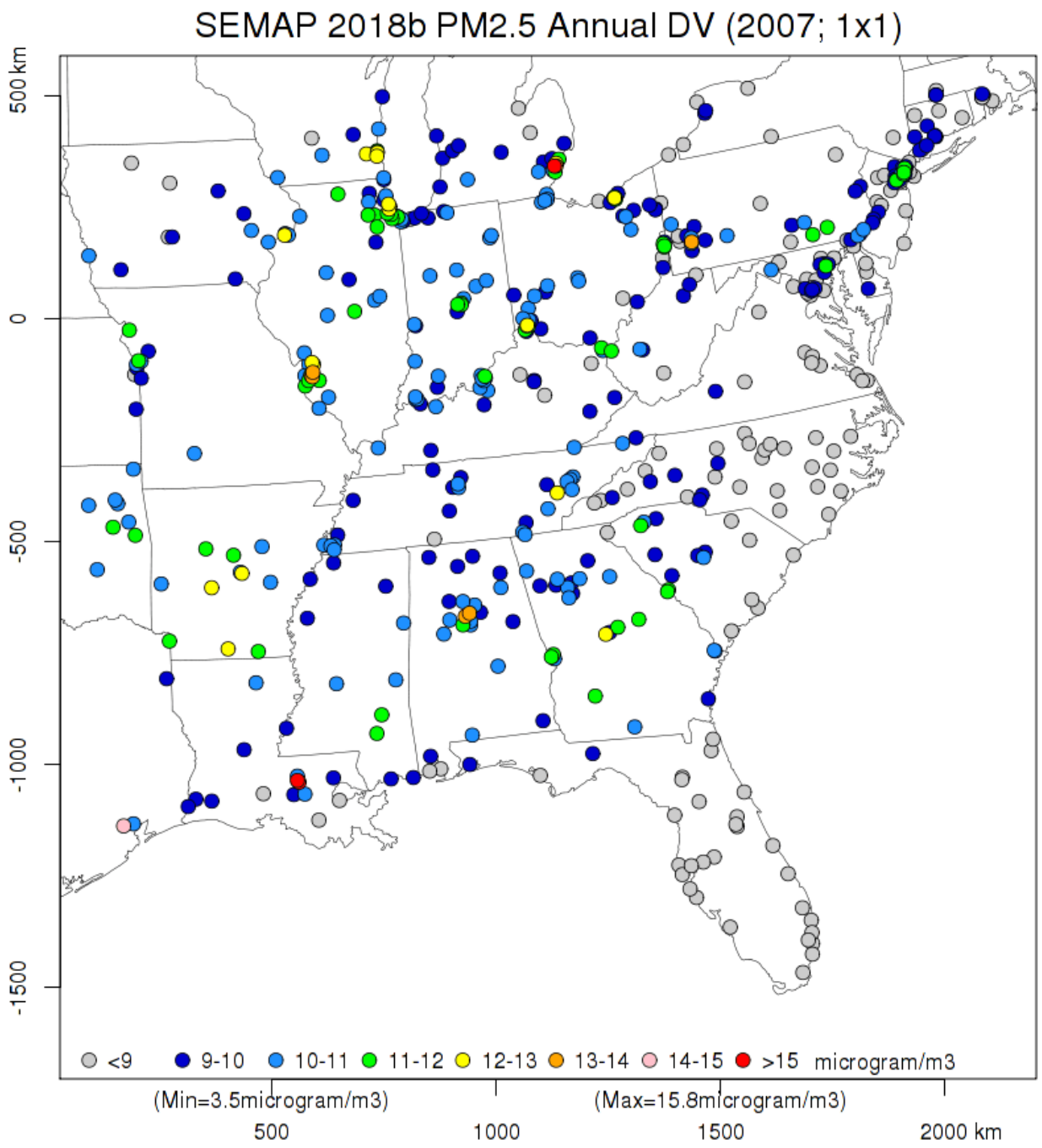


Figure 4-12 2018 Annual $PM_{2.5}$ DVFs: 1x1 RRF & 2007 DVC

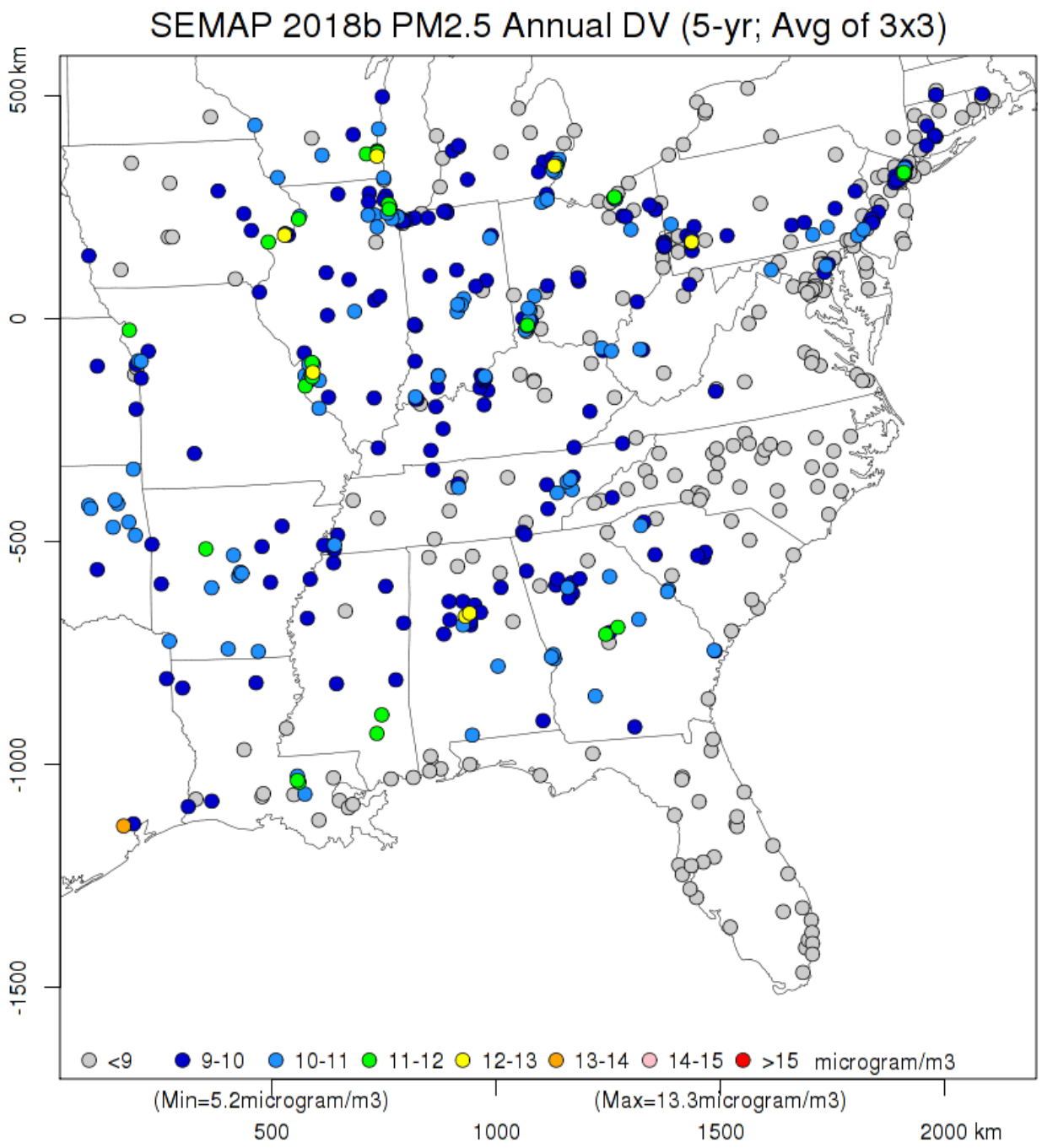


Figure 4-13 2018 Annual $PM_{2.5}$ DVFs: 3×3 RRF & 2005-2009 DVC

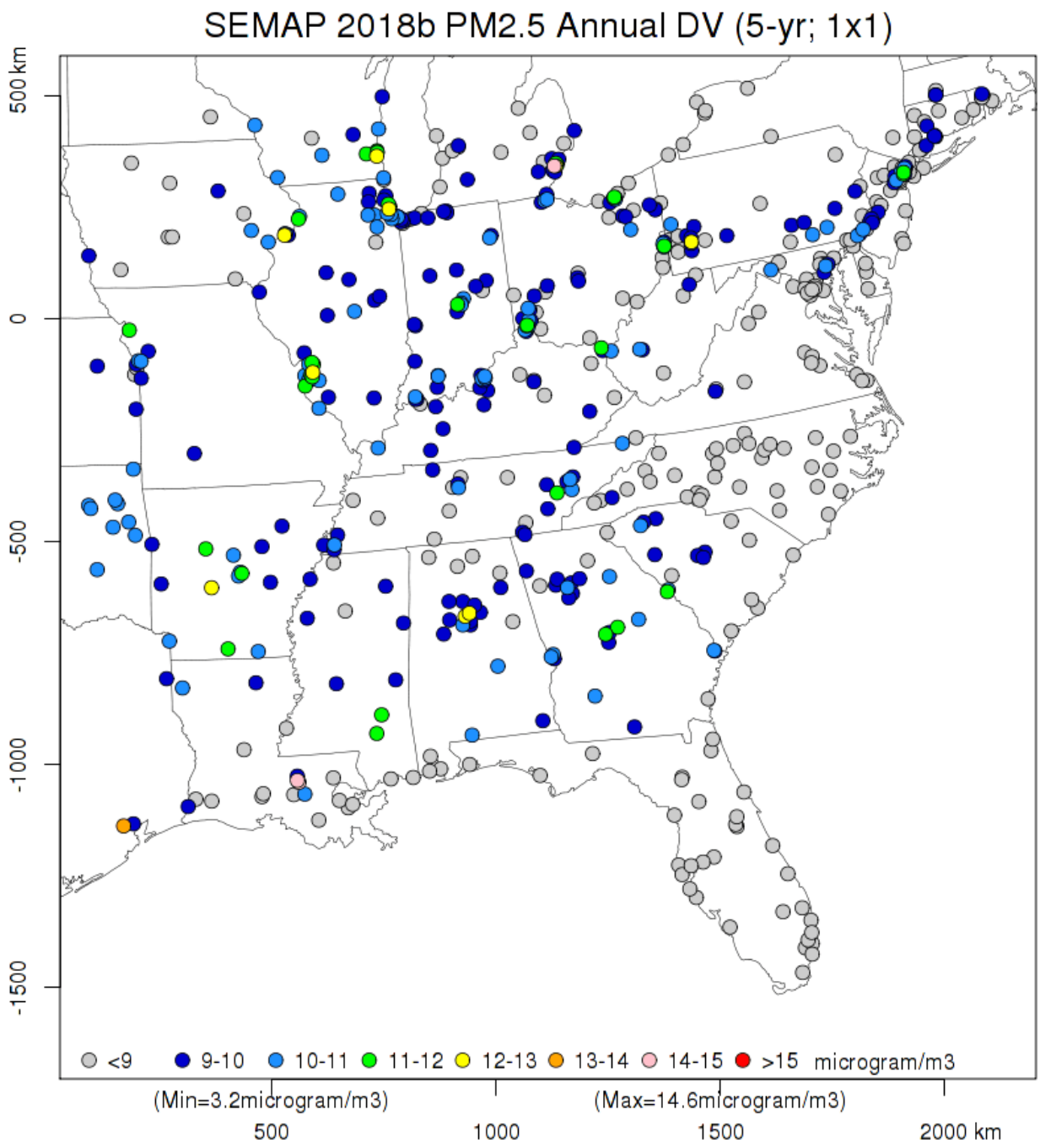


Figure 4-14 2018 Annual $PM_{2.5}$ DVFs: 1×1 RRF & 2005-2009 DVC

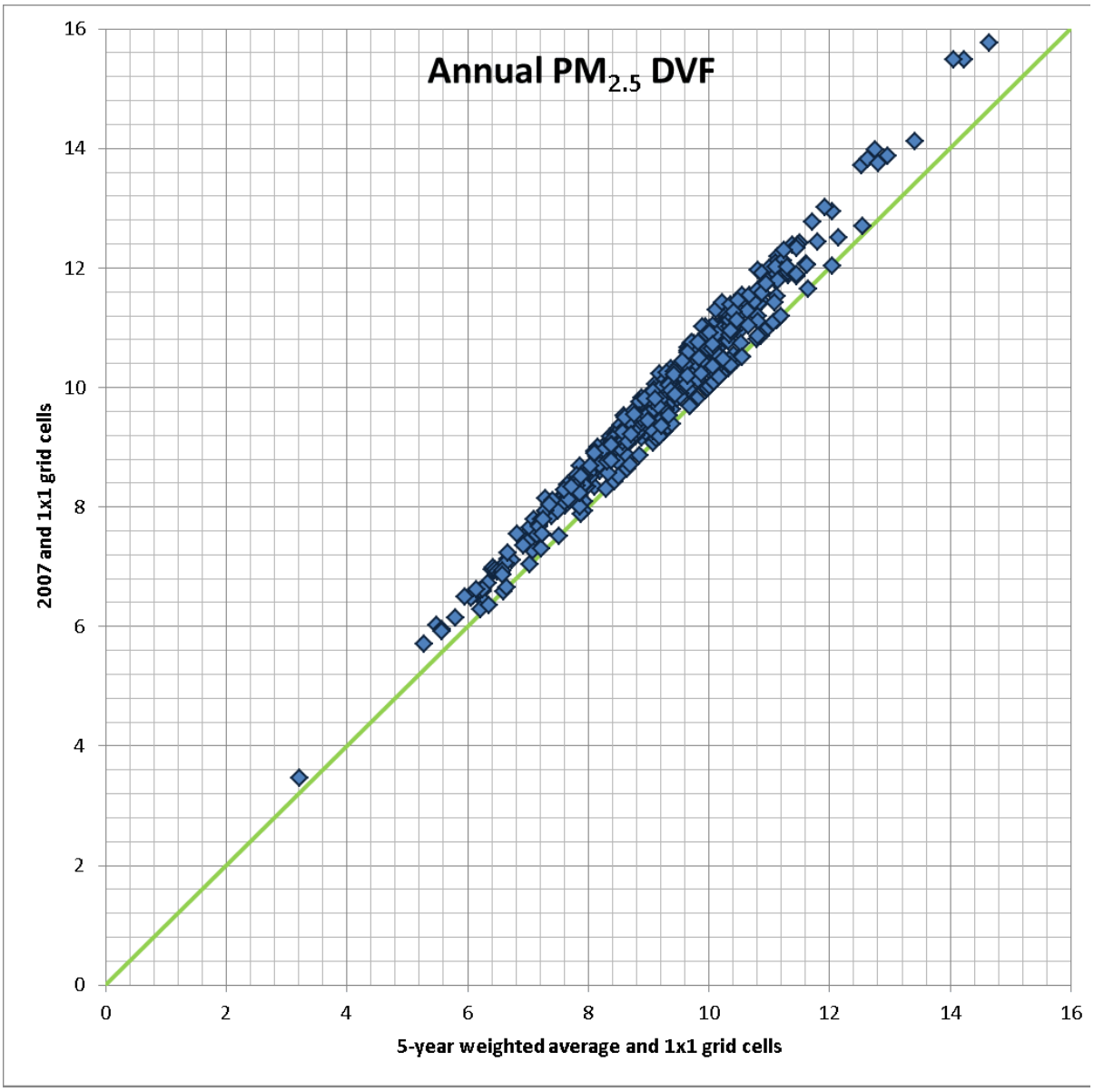


Figure 4-15 Annual $PM_{2.5}$ DVFs calculated using 2007 DVCs vs. 5-year weighted DVCs

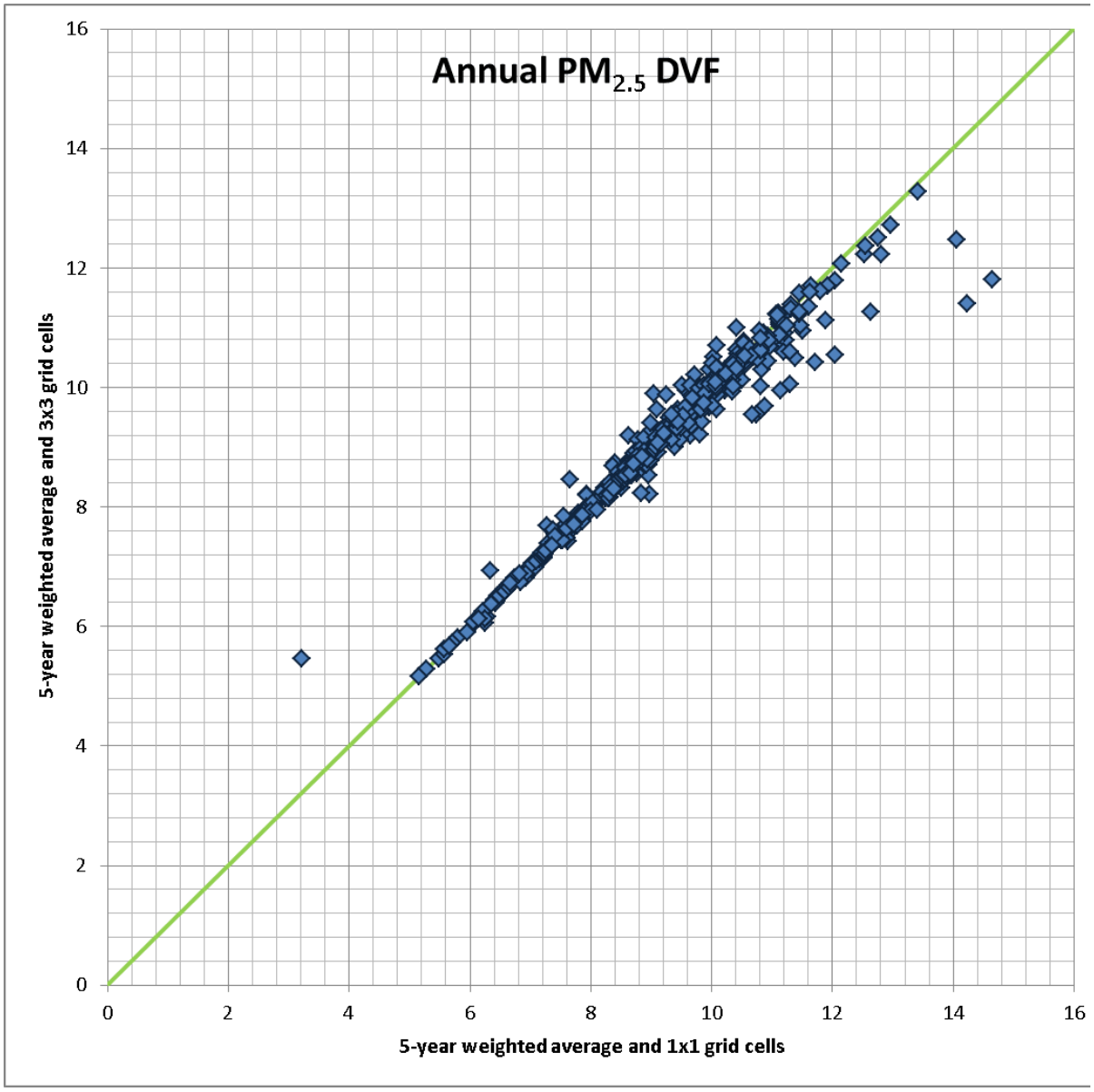


Figure 4-16 Annual $PM_{2.5}$ DVFs calculated using 3×3 Cell Average vs. 1×1 Cell RRFs

4.3.3 Future Daily $PM_{2.5}$ Design Values

The current daily $PM_{2.5}$ design values are shown in Figure 4-17Figure 4-9 (2007 DVC) and Figure 4-18 (5-year weighted average DVC). In 2007 only a few exceedances of the daily $PM_{2.5}$ standard, which is currently at 35 μg m^{-3} in the US (30 μg m^{-3} in Canada) were observed in the SESARM states, primarily in Alabama, Tennessee, Kentucky, and West Virginia. However, if the standard were changed to 30 μg m^{-3} there would be wide-spread exceedances in the SESARM states with the exception of the coastal sites. Also, there are more exceedances according to the 2007 DVC compared to the 5-year weighted average DVC.

Daily $PM_{2.5}$ design values were projected to 2018 in four different ways as described in Section Calculation of Ozone DVFsabove. The resulting 2018 future design values are shown in Figure 4-19 through Figure 4-22Figure 4-14. The 2007 DVCs lead to higher DVFs than the 5-year (2005-2009)

weighted average DVCs (Figure 4-23). This is due to the decreasing trend of $PM_{2.5}$ from 2007 to 2009 throughout the domain. On the other hand, while the 3×3 cell average RRFs lead to higher DVFs at some sites, the monitor (1×1) cell RRFs lead to higher DVFs at other sites (Figure 4-24). The 2007 DVC and monitor cell RRF lead to higher daily $PM_{2.5}$ DVFs than the other DVC–RRF combinations but no exceedances of the $PM_{2.5}$ standard are projected. In the SESARM states, only in Birmingham, AL the DVF is expected to exceed 30 μg m^{-3} (Figure 4-20).

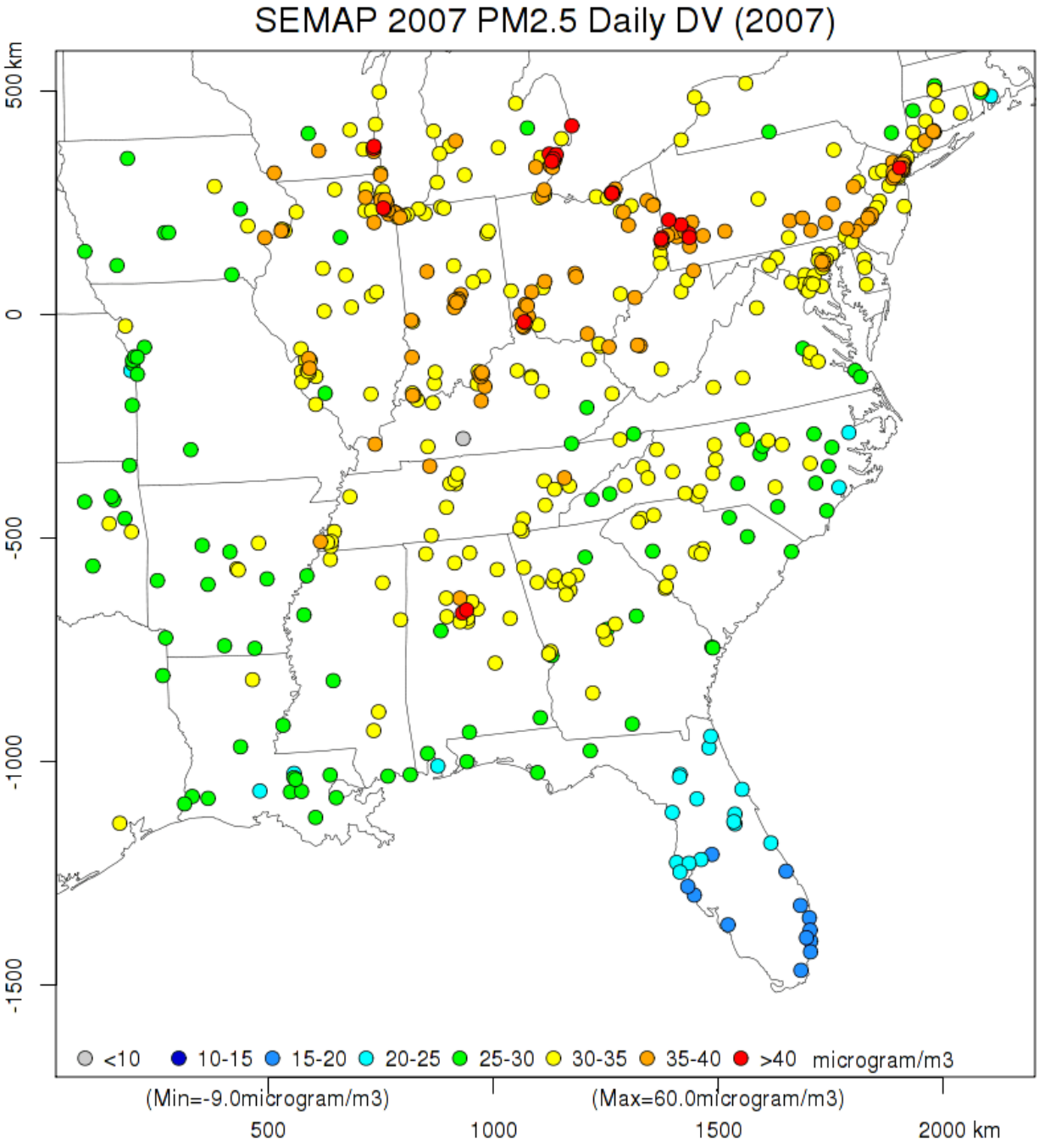


Figure 4-17 2007 Daily $PM_{2.5}$ DVC

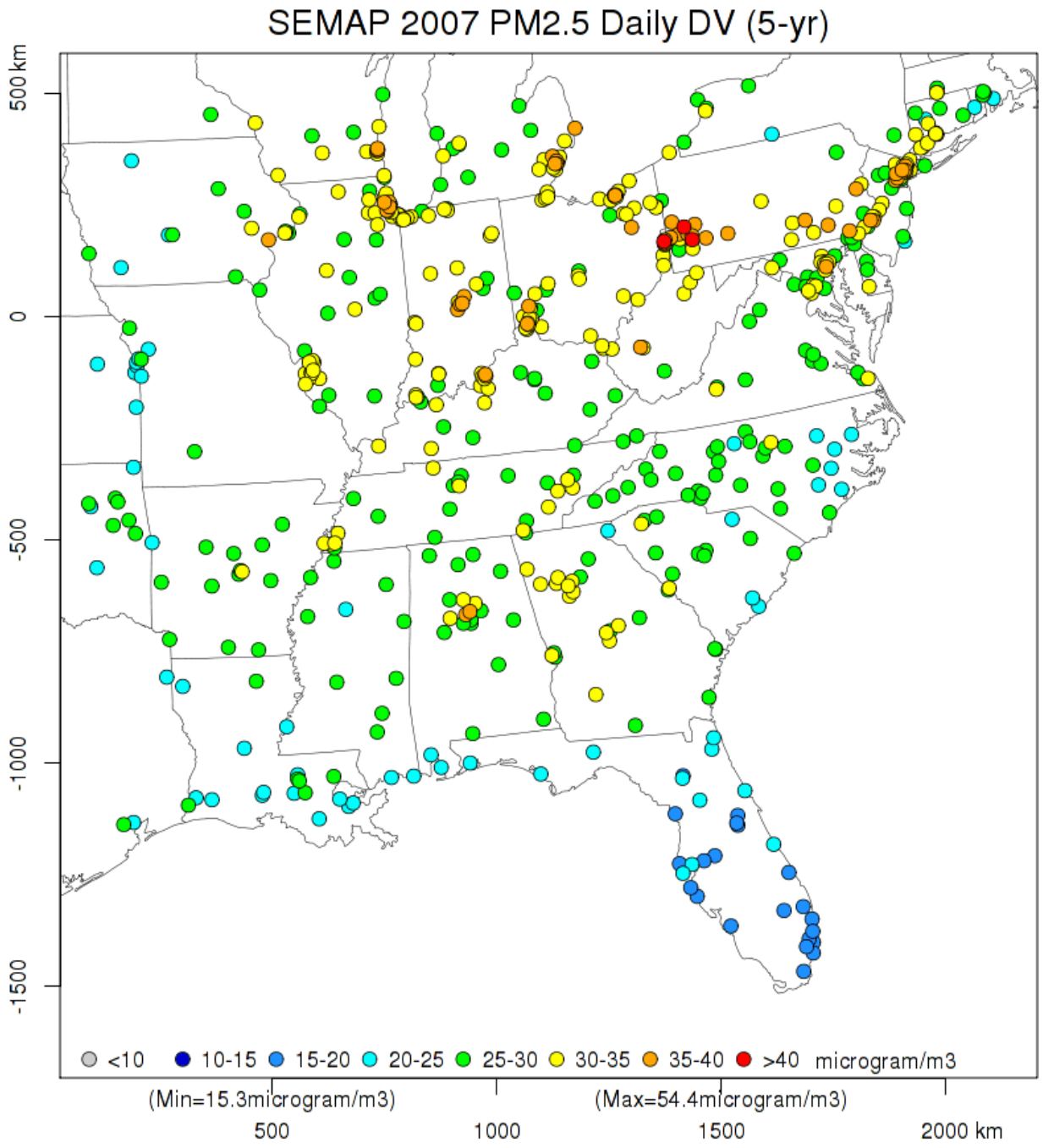


Figure 4-18 5-Year (2005-09) Daily $PM_{2.5}$ DVC

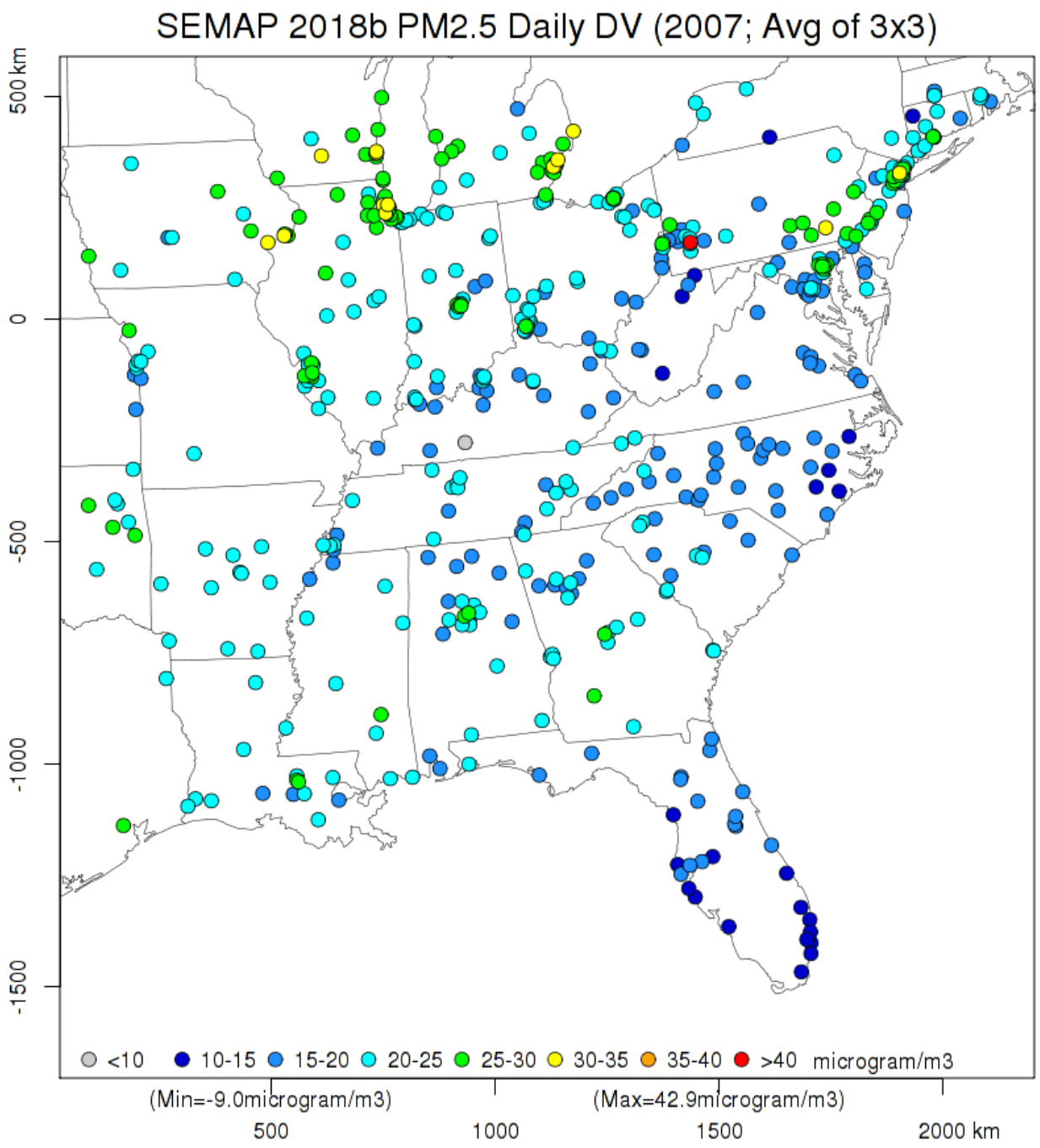


Figure 4-19 2018 Daily $PM_{2.5}$ DVFs: 3×3 RRF & 2007 DVC

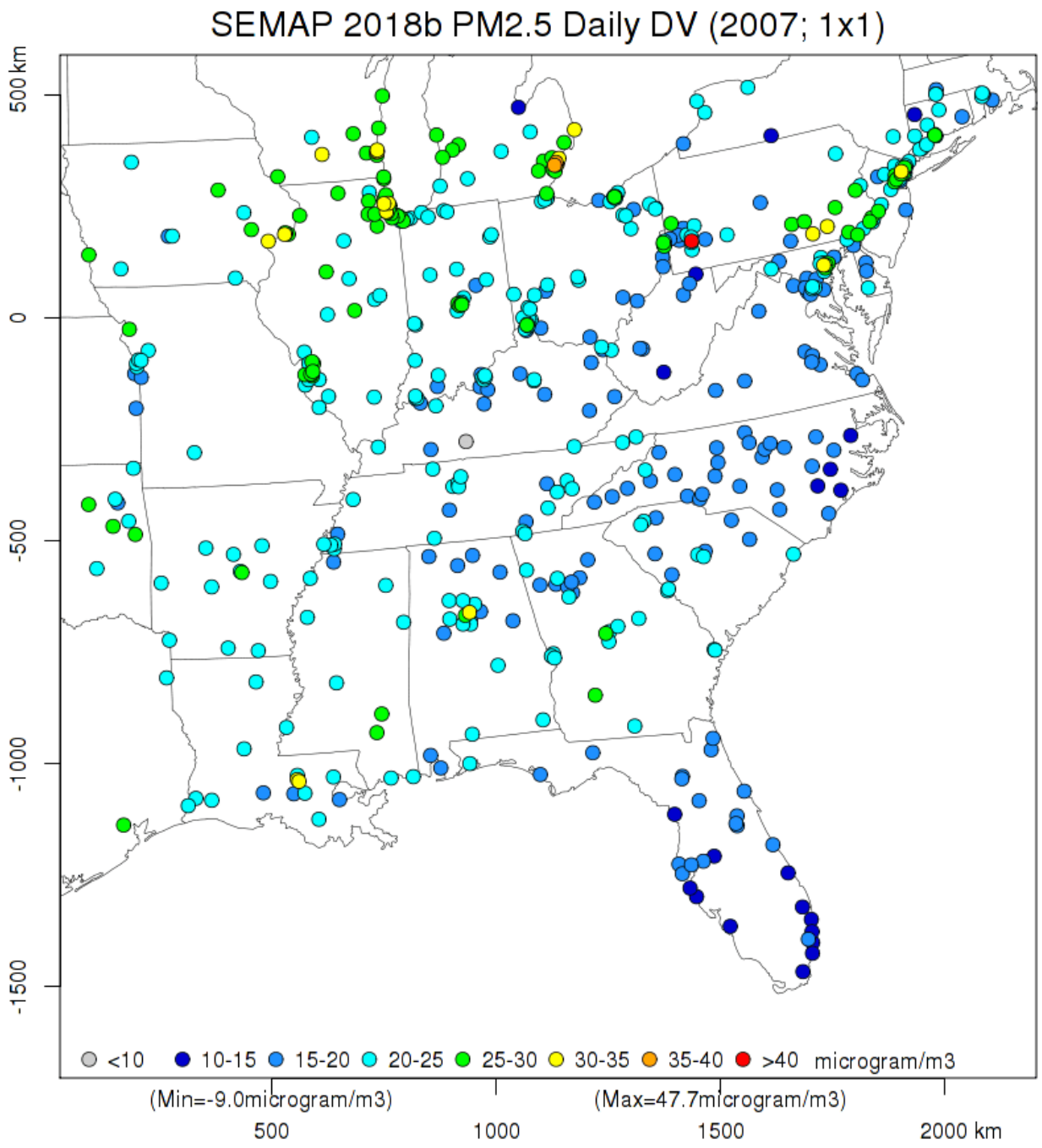


Figure 4-20 2018 Daily $PM_{2.5}$ DVFs: 1x1 RRF & 2007 DVC

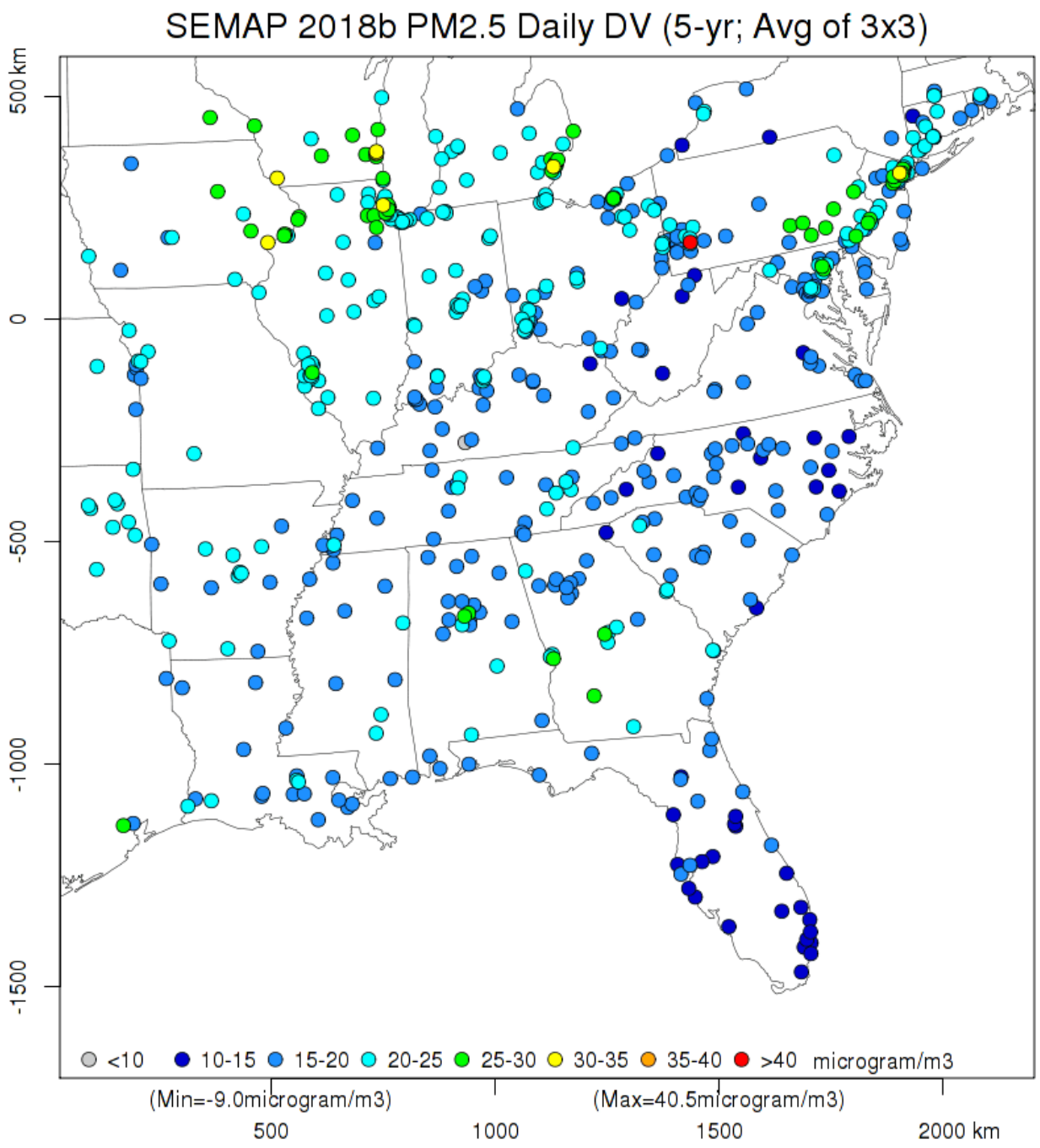


Figure 4-21 2018 Daily $PM_{2.5}$ DVFs: 3×3 RRF & 2005-2009 DVC

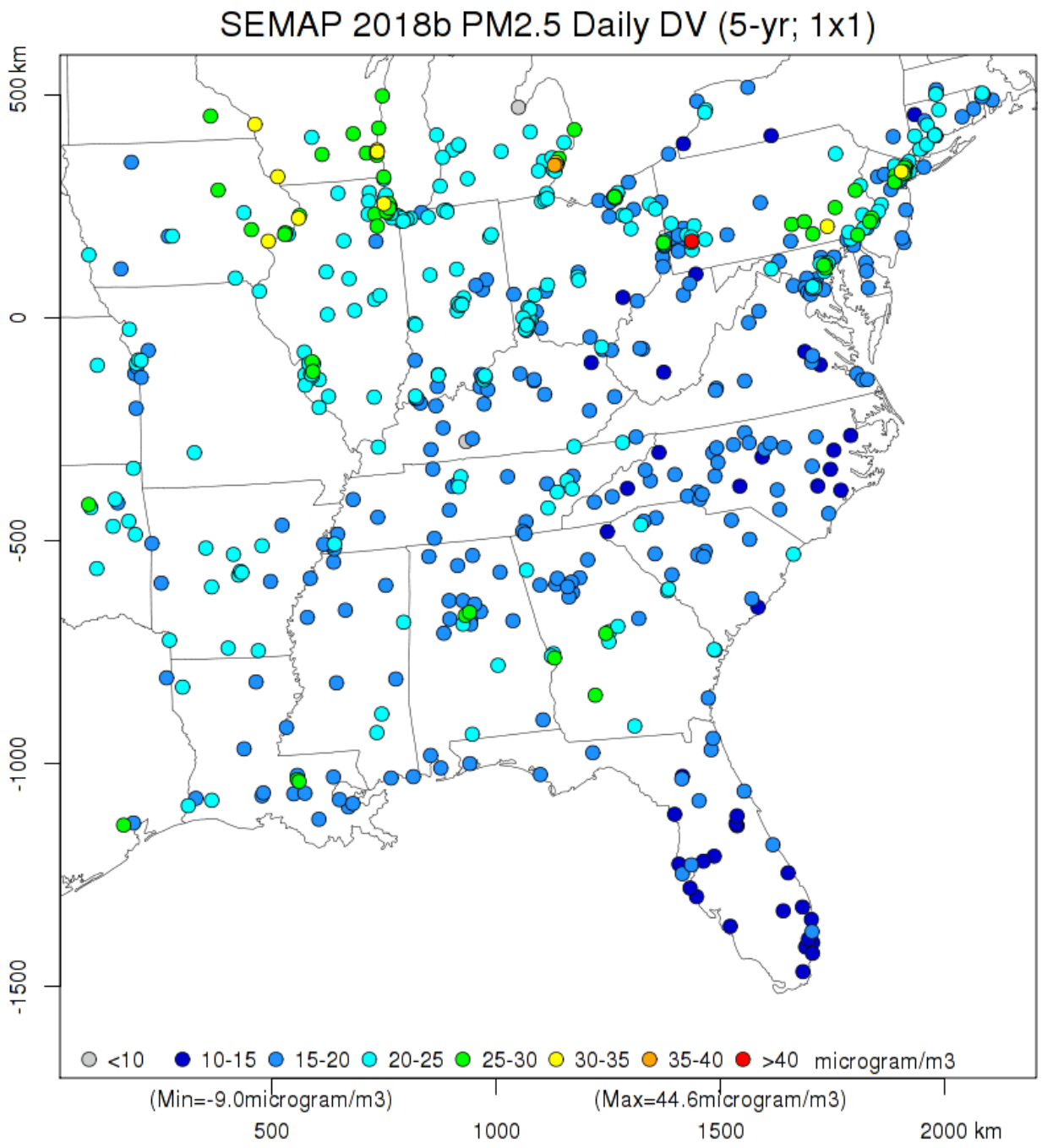


Figure 4-22 2018 Daily $PM_{2.5}$ DVFs: 1×1 RRF & 2005-2009 DVC

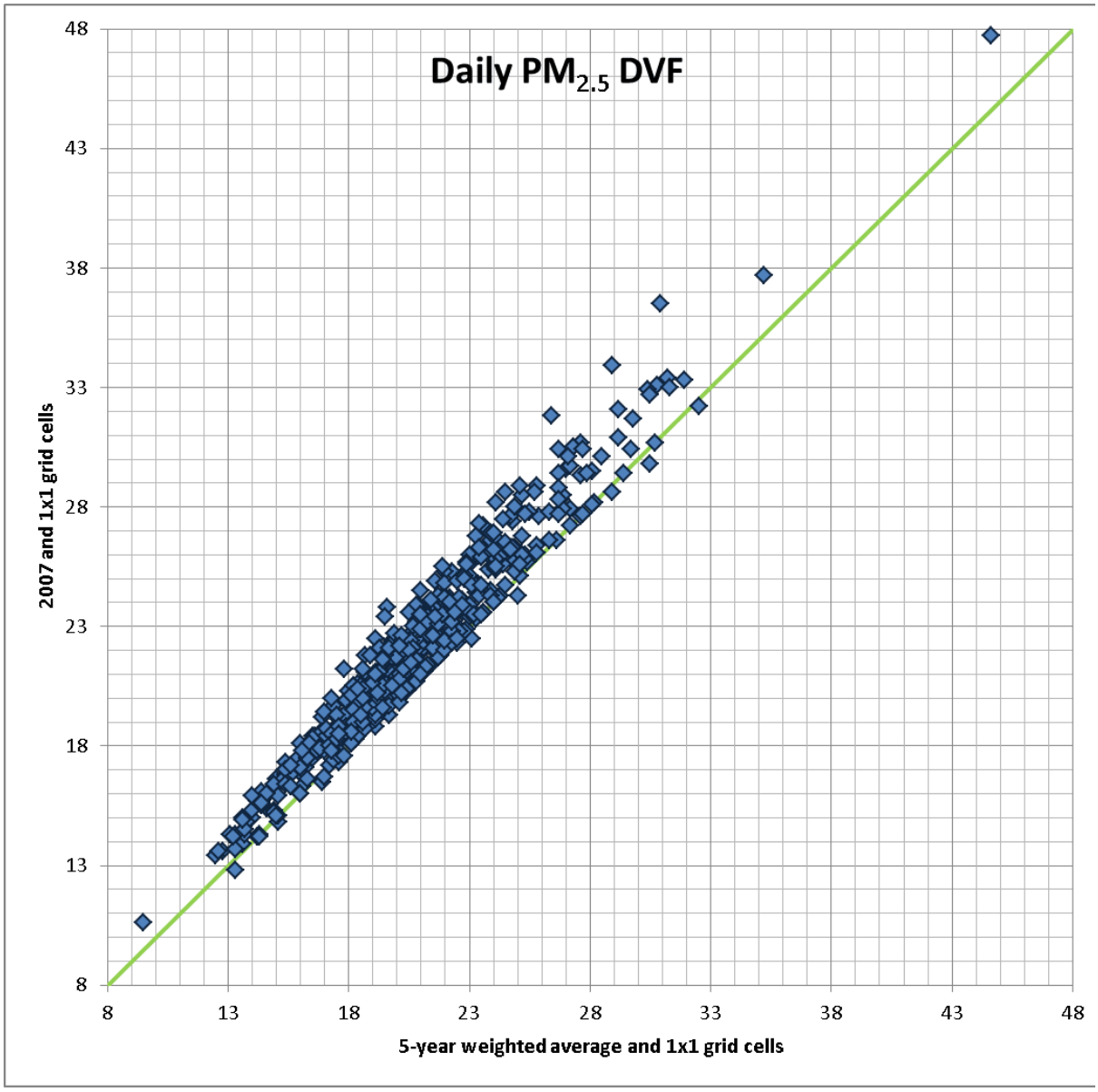


Figure 4-23 2018 Daily $PM_{2.5}$ DVFs calculated using 2007 DVCs vs. 5-year weighted DVCs

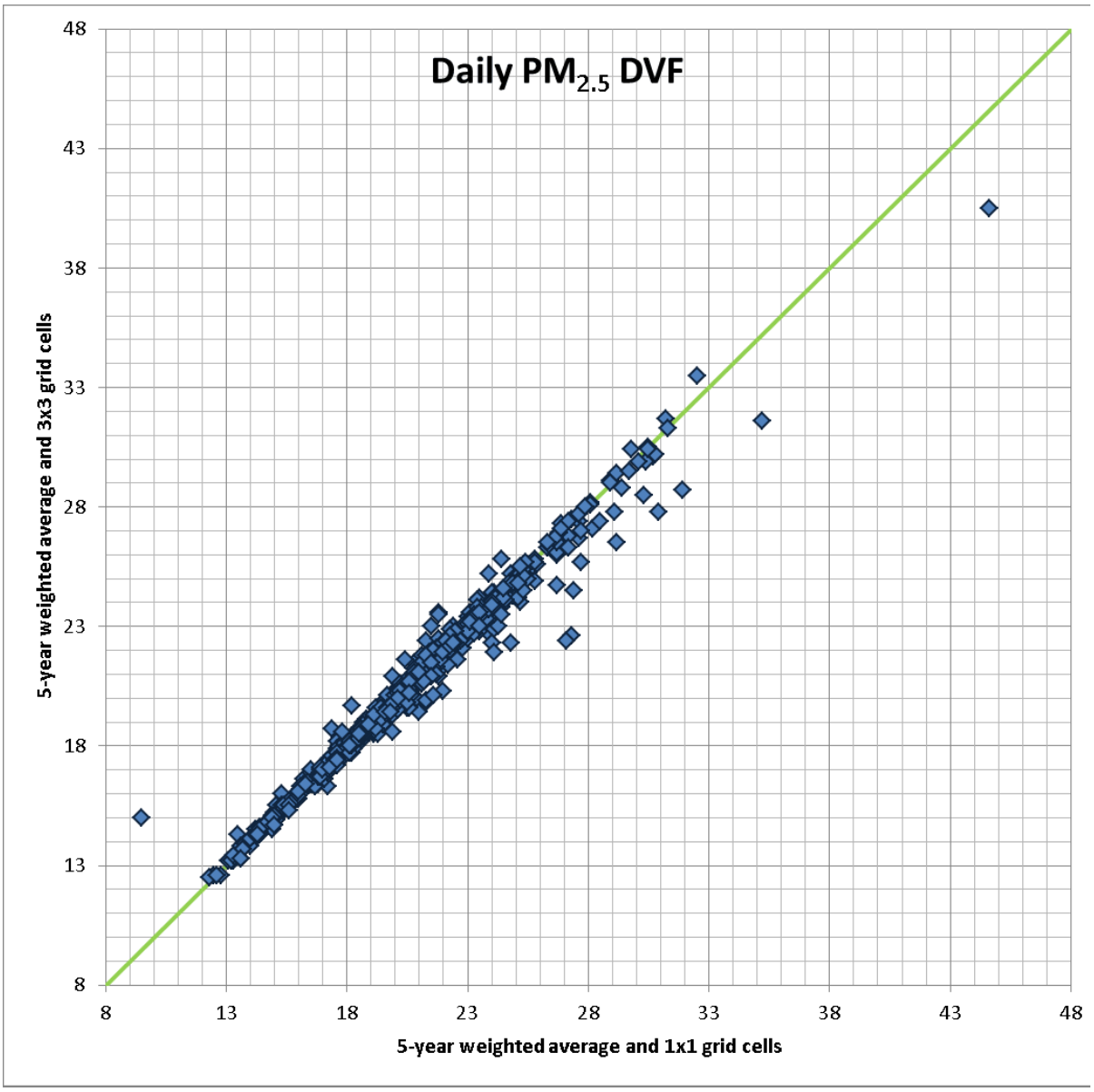


Figure 4-24 2018 Daily $PM_{2.5}$ DVFs calculated using 3×3 cell average vs. 1×1 cell RRFs

4.4 Projected changes in $PM_{2.5}$ composition

Comparisons were made between the 2007 and 2018 compositions of $PM_{2.5}$ at each site of the 31 states in the 12-km SEMAP domain. Figure 4-25 through Figure 4-34 show the comparisons for annual and daily $PM_{2.5}$ components for the 10 SESARM states. In general, the sulfate component of $PM_{2.5}$ is expected to decrease considerably in 2018 relative to 2007. As a result of the sulfate decrease the particle bound water will also decrease. The nitrate component is expected to increase significantly at a number of sites while the other components will generally stay the same.

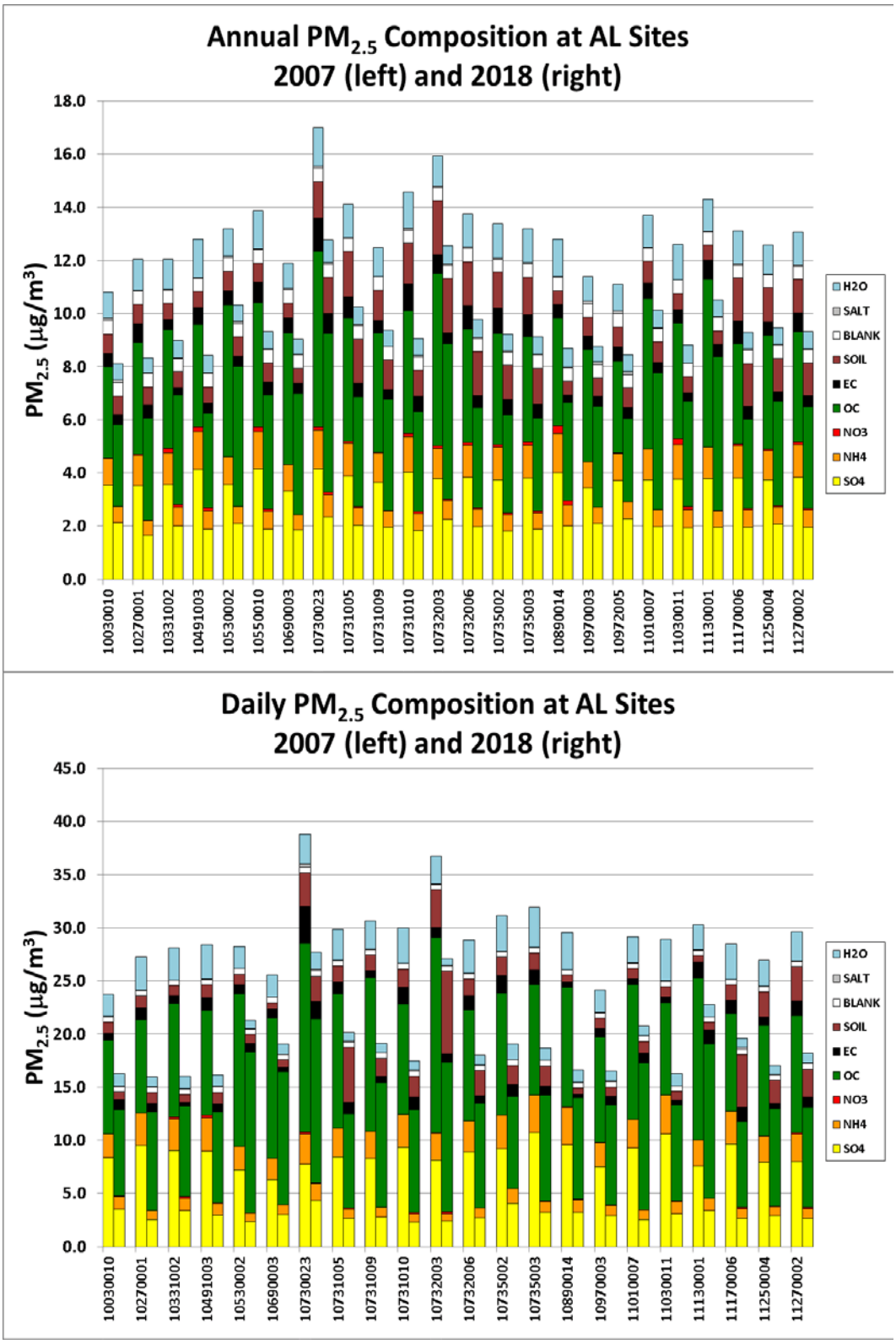


Figure 4-25 2007 and 2018 $PM_{2.5}$ compositions at Alabama sites for annual (top) and daily (bottom) $PM_{2.5}$design values

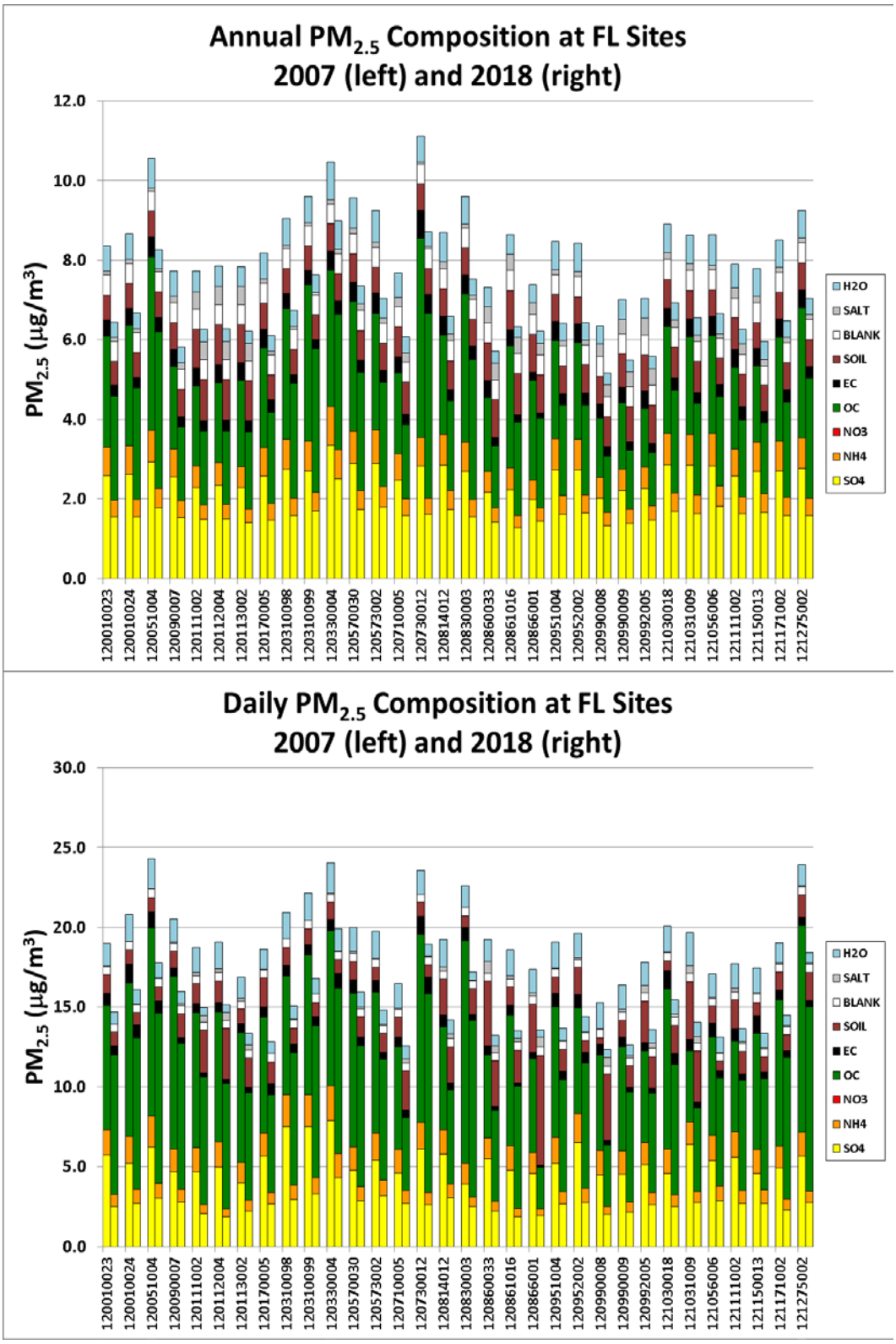


Figure 4-26 2007 and 2018 $PM_{2.5}$ compositions at Florida sites for annual (top) and daily (bottom) $PM_{2.5}$design values

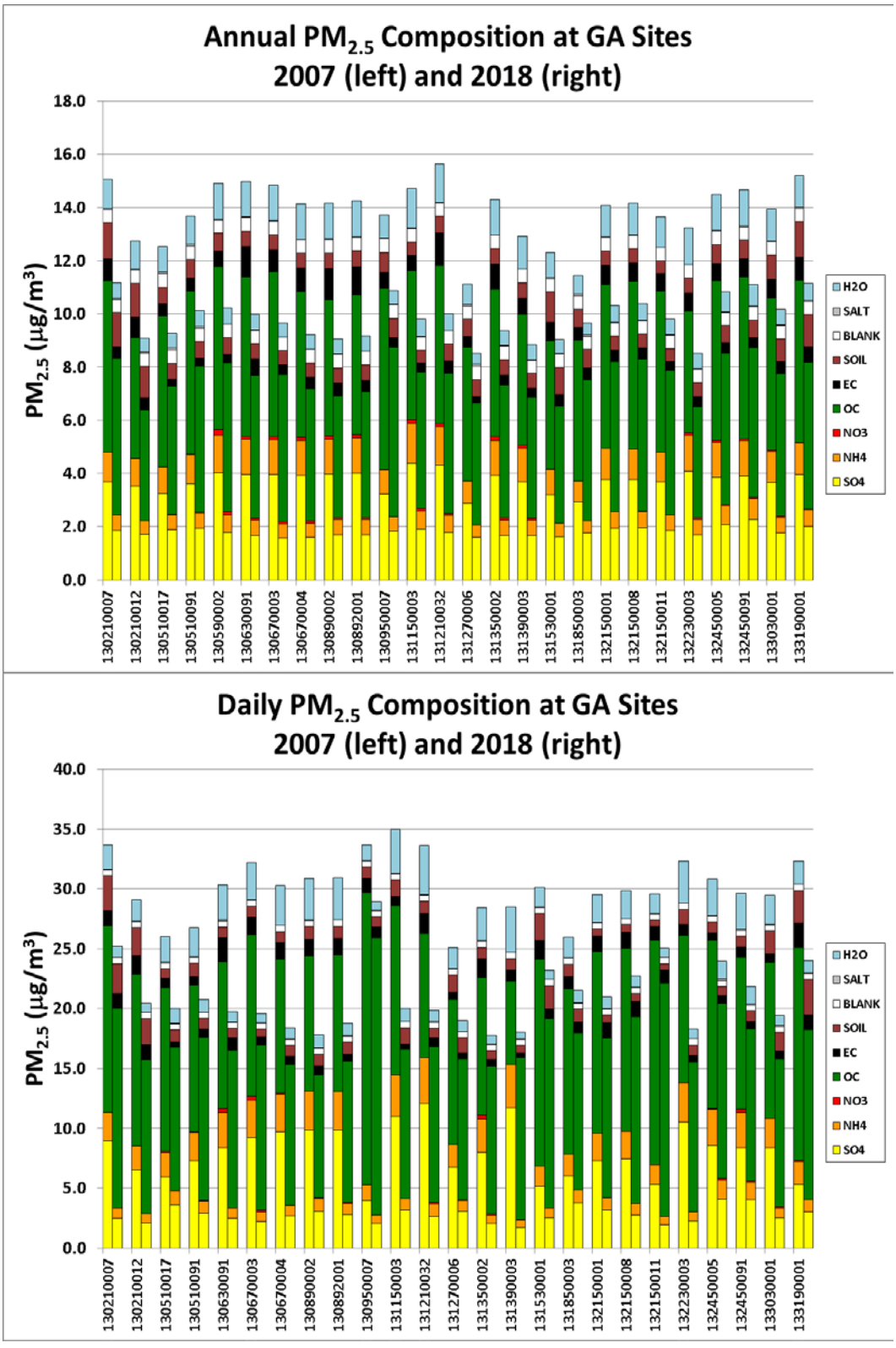


Figure 4-27 2007 and 2018 $PM_{2.5}$ compositions at Georgia sites for annual (top) and daily (bottom) $PM_{2.5}$design values

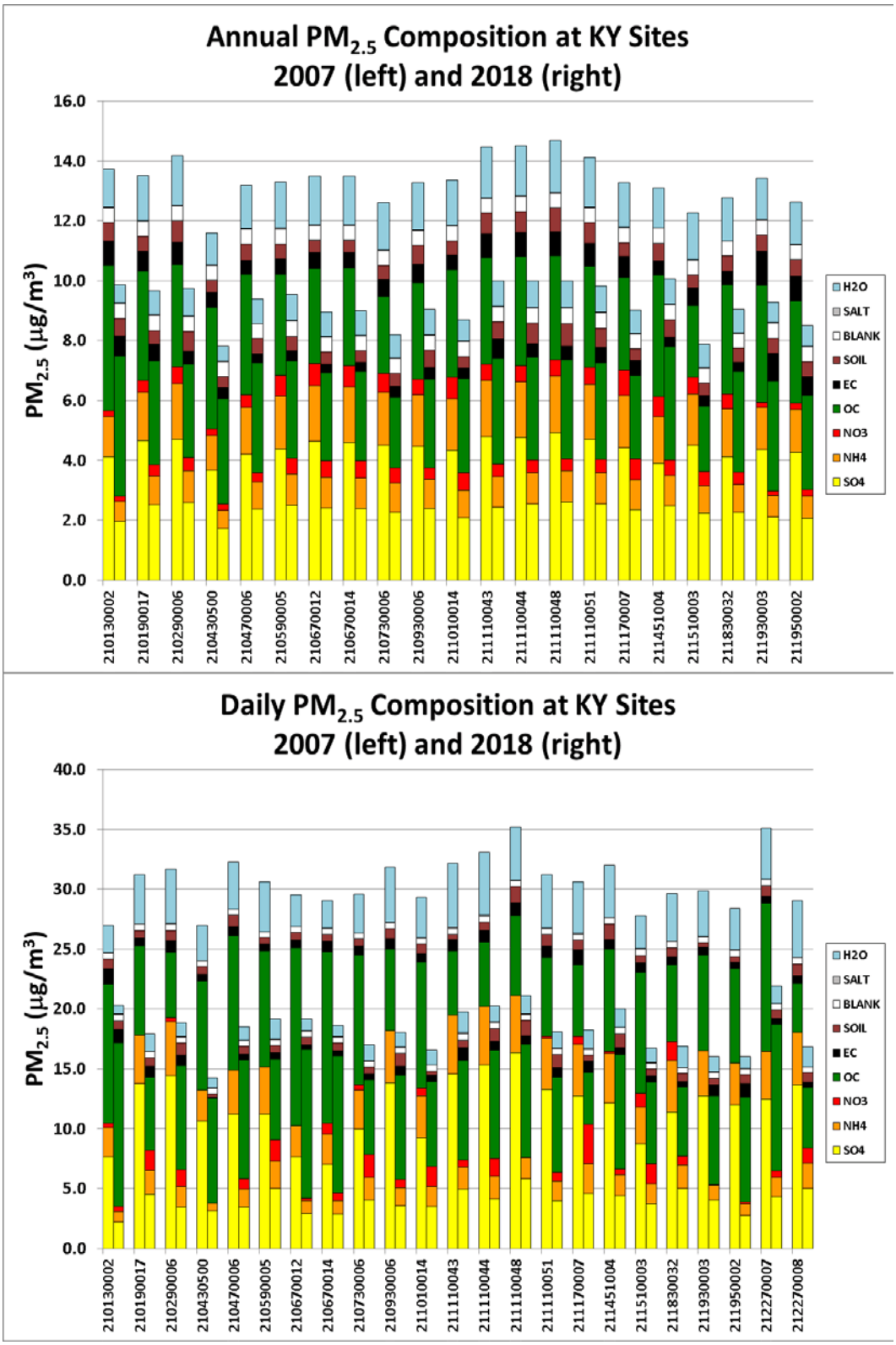


Figure 4-28 2007 and 2018 $PM_{2.5}$ compositions at Kentucky sites for annual (top) and daily (bottom) $PM_{2.5}$design values

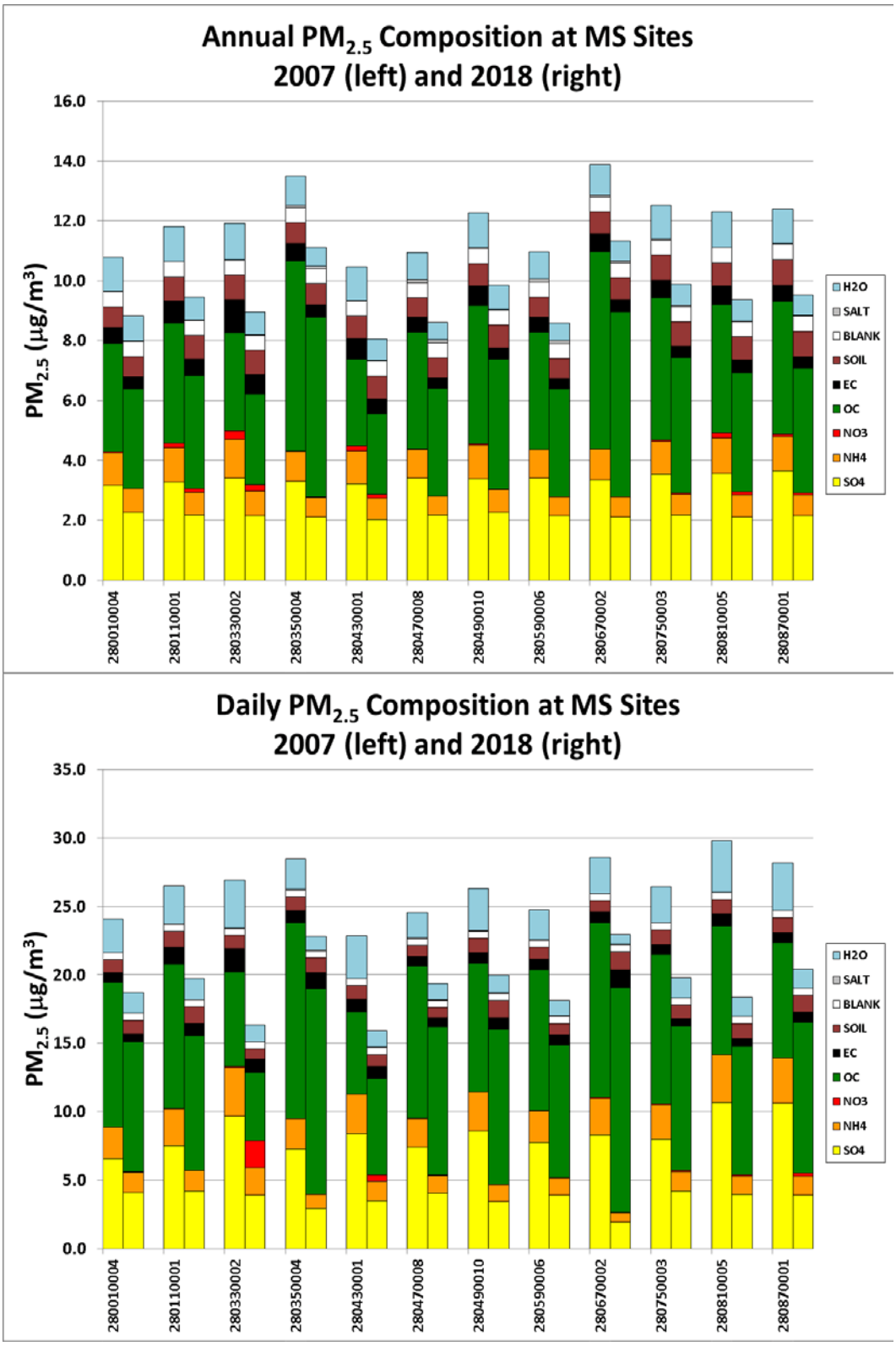


Figure 4-29 2007 and 2018 $PM_{2.5}$ compositions at Mississippi sites for annual (top) and daily (bottom) $PM_{2.5}$design values

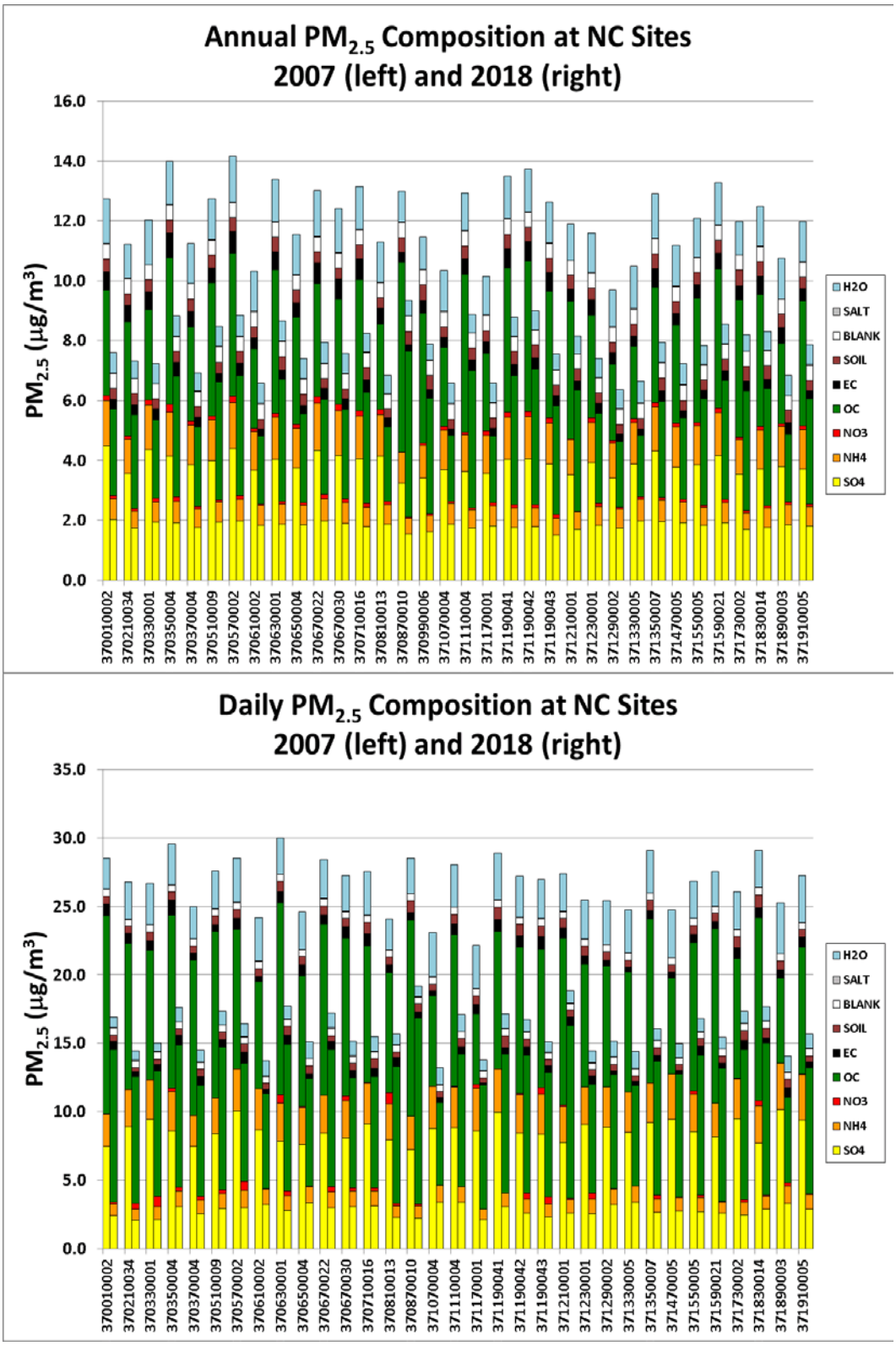


Figure 4-30 2007 and 2018 $PM_{2.5}$ compositions at North Carolina sites for annual (top) and daily (bottom) $PM_{2.5}$design values

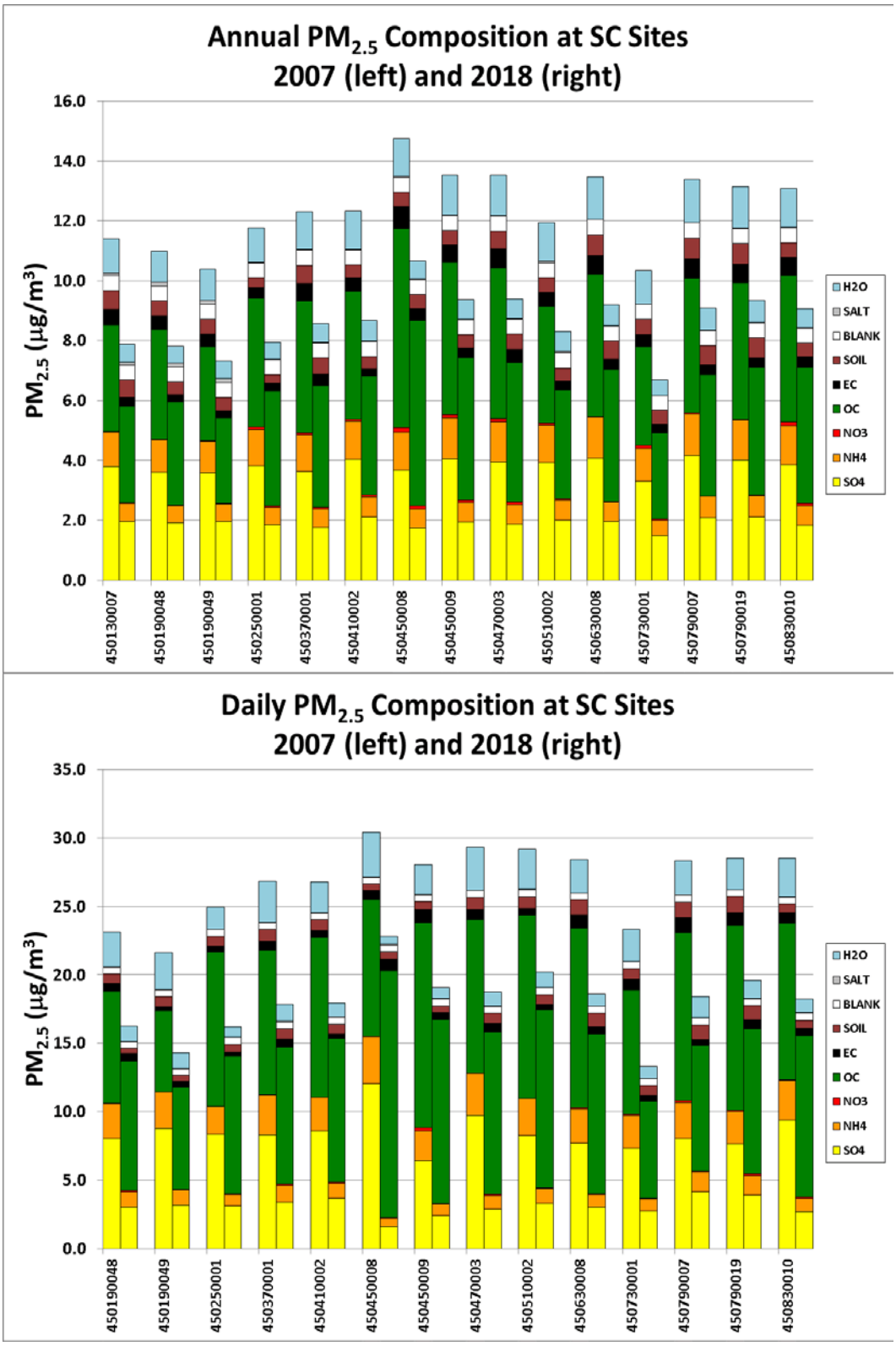


Figure 4-31 2007 and 2018 $PM_{2.5}$ compositions at South Carolina sites for annual (top) and daily (bottom) $PM_{2.5}$design values

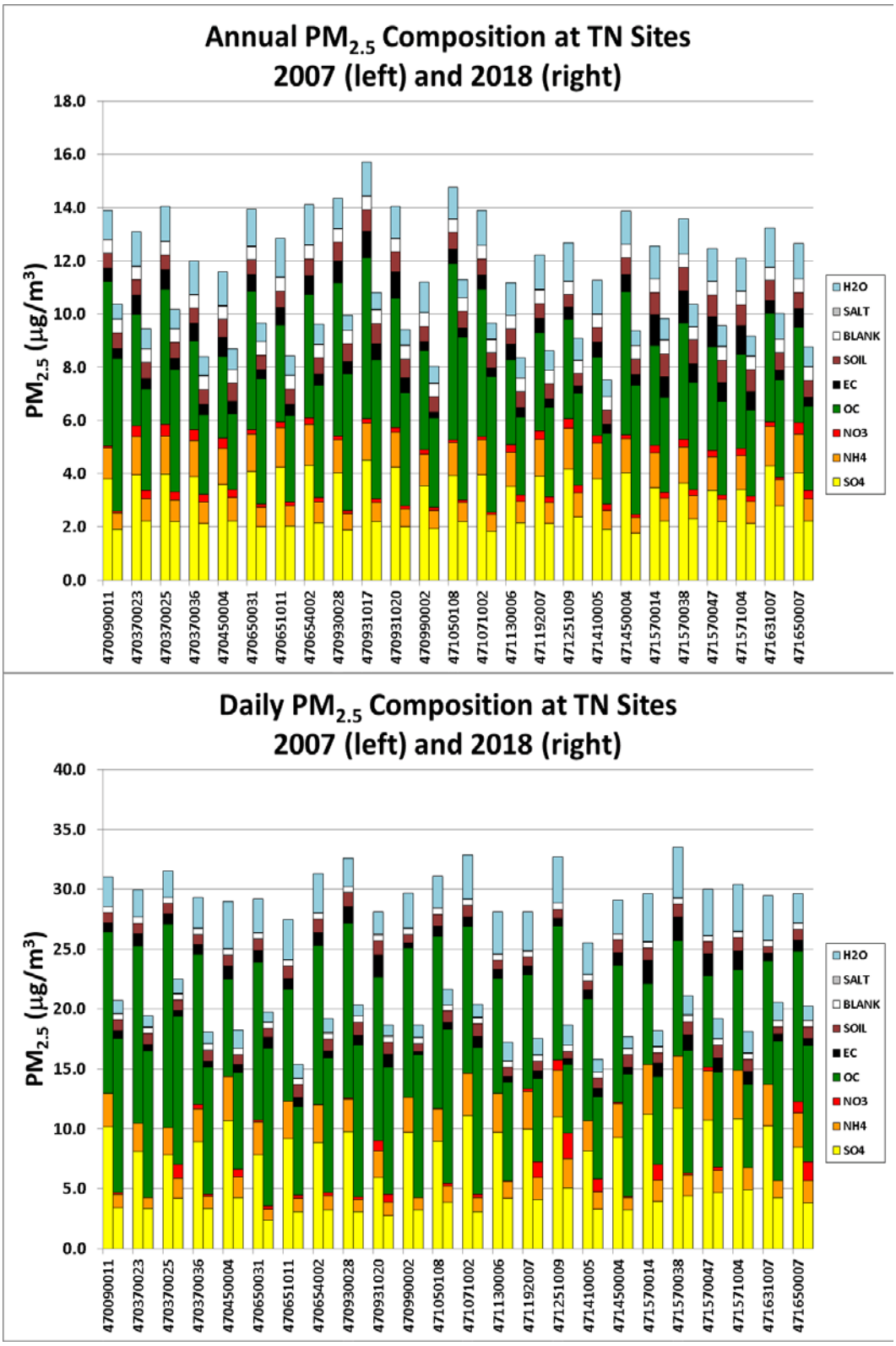


Figure 4-32 2007 and 2018 $PM_{2.5}$ compositions at Tennessee sites for annual (top) and daily (bottom) $PM_{2.5}$design values

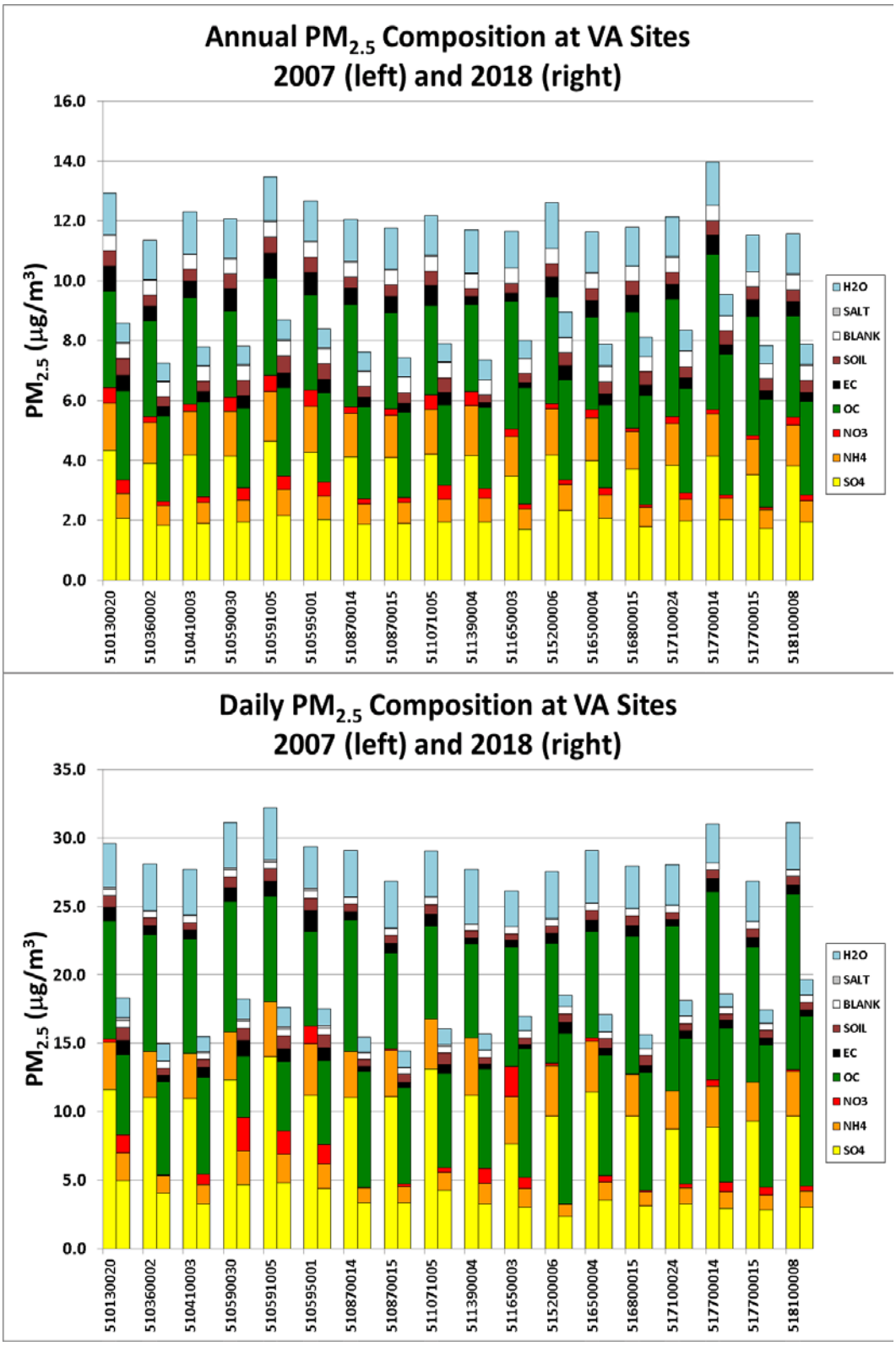


Figure 4-33 2007 and 2018 $PM_{2.5}$ compositions at Virginia sites for annual (top) and daily (bottom) $PM_{2.5}$design values

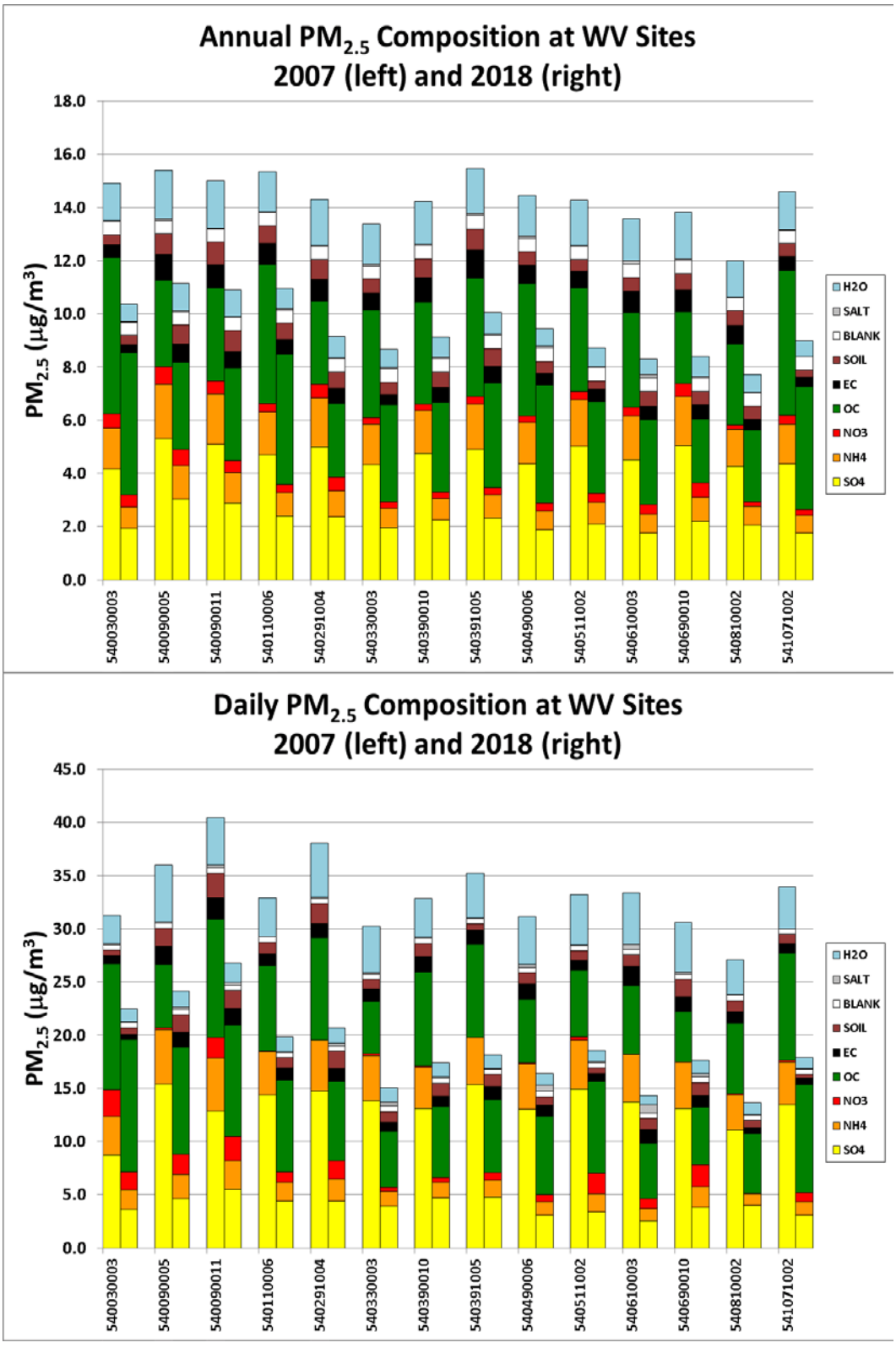


Figure 4-34 2007 and 2018 $PM_{2.5}$ compositions at West Virginia sites for annual (top) and daily (bottom) $PM_{2.5}$design values

4.5 Future Visibility Projections

The light extinctions obtained from the 3×3 cell average and monitor (1×1) cell RRF were compared on the best 20% and worst 20% visibility days. On the best 20% visibility days the 3×3 cell average RRF leads to lower light extinction hence better visibility (Figure 4-35). On the worst 20% visibility days the 3×3 cell average RRF leads to higher light extinction hence worst visibility (Figure 4-36).
In Table 4-3 the 2007 and 2018 haze indices (dV) obtained from 5-year (2005-2009) average DVCs and 3x3 cell average RRFs are compared for best and worst 20% visibility days. The haze indices decrease in 2018 both for best and worst visibility.

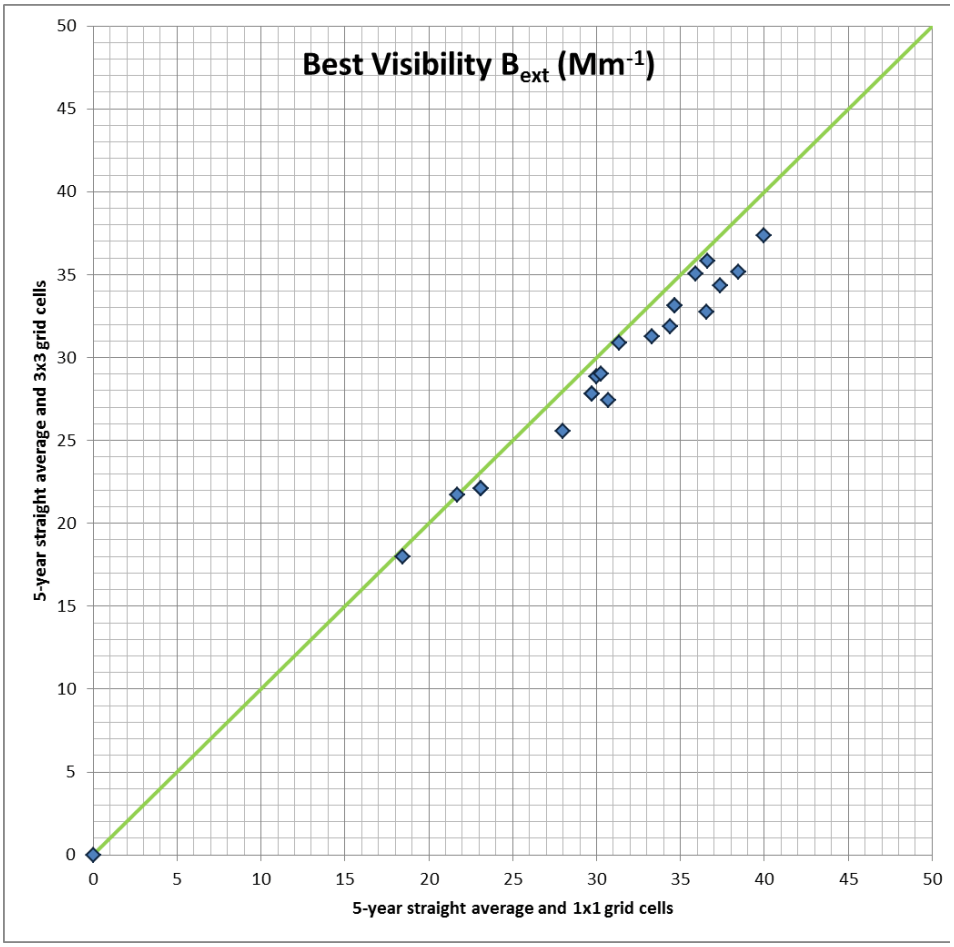


Figure 4-35 Best Visibility DVF: 3×3 vs. 1×1

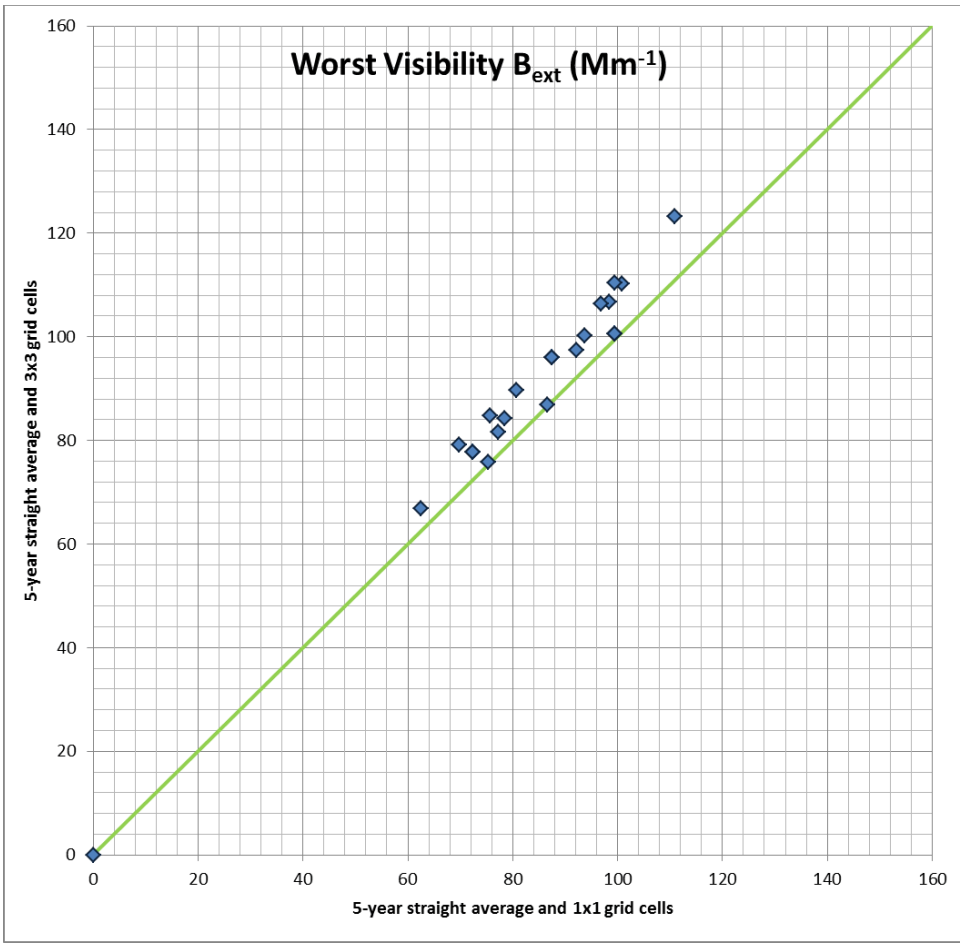


Figure 4-36 Worst Visibility DVF: 3×3 vs. 1×1

Table 4-3. 5-year average (2005-2009) current visibility design values and future visibility projections (in deciViews) using 3x3 cell average RRFs.

IMPROVE	Best Visibility		Worst Visibility	
Site	2007	2018	2007	2018
BRIG	13.87	11.65	27.32	22.04
CHAS	15.43	12.63	23.68	19.53
COHU	12.5	9.77	28.01	20.26
DOSO	10.21	7.64	27.55	18.75
EVER	11.92	10.59	20.41	18.29
GRSM	12.38	9.92	28.5	21.11
HEGL	12.52	11.17	26.05	22.71
JARI	13.61	10.92	27.29	19.9
JOYC	12.38	9.92	28.5	21.11
LIGO	11.29	9.14	27.39	19.74
MACA	15.76	12.89	30.68	23.65
MING	13.9	12.06	27.08	23

OKEF	14.46	11.9	26	21.47
OTCR	10.21	7.64	27.55	18.75
ROMA	14.97	12.47	26.45	20.44
SAMA	14.77	12.43	25.58	21.77
SHEN	9.72	7.39	27.26	19.03
SHRO	7.3	5.68	26.6	19.45
SIPS	14.06	11.54	28.32	22.04
SWAN	13.04	10.57	24.56	18.18
UPBU	11.73	10.35	25.86	22.79
WOLF	14.46	11.9	26	21.47

4.6 Contributions to Light Extinctions

Comparisons were made between the 2007 and 2018 contributions of $PM_{2.5}$ components to light extinction at each of the 22 IMPROVE sites in the 12-km SEMAP domain. Figure 4-37shows the comparison on the best 20% visibility days. The light extinctions are expected to decrease due to the large decreases in the contributions of ammonium sulfate. Ammonium nitrate contributions are also expected to decrease. The contributions of other $PM_{2.5}$ components are expected to remain the same. Figure 4-38 shows the comparison of the contributions of $PM_{2.5}$ components to light extinction on the worst 20% visibility days. The light extinctions are expected to decrease due to the large decreases in the contributions of ammonium sulfate. Ammonium nitrate contributions are also expected to decrease at several sites. The contributions of other $PM_{2.5}$ components are expected to remain the same.

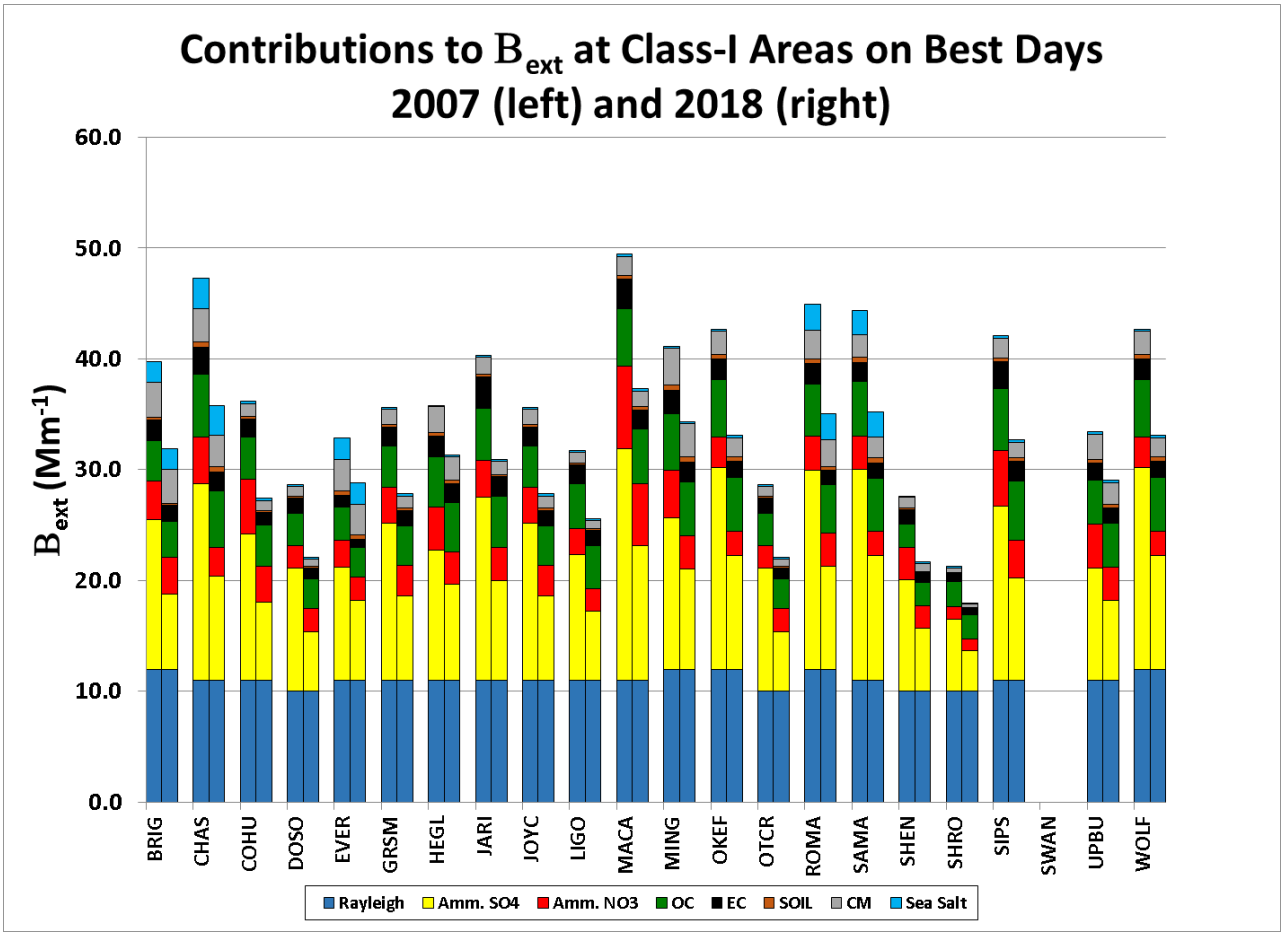


Figure 4-37 Comparison of contributions of $PM_{2.5}$ components to light extinction on best 20% visibility days in 2007 and 2018

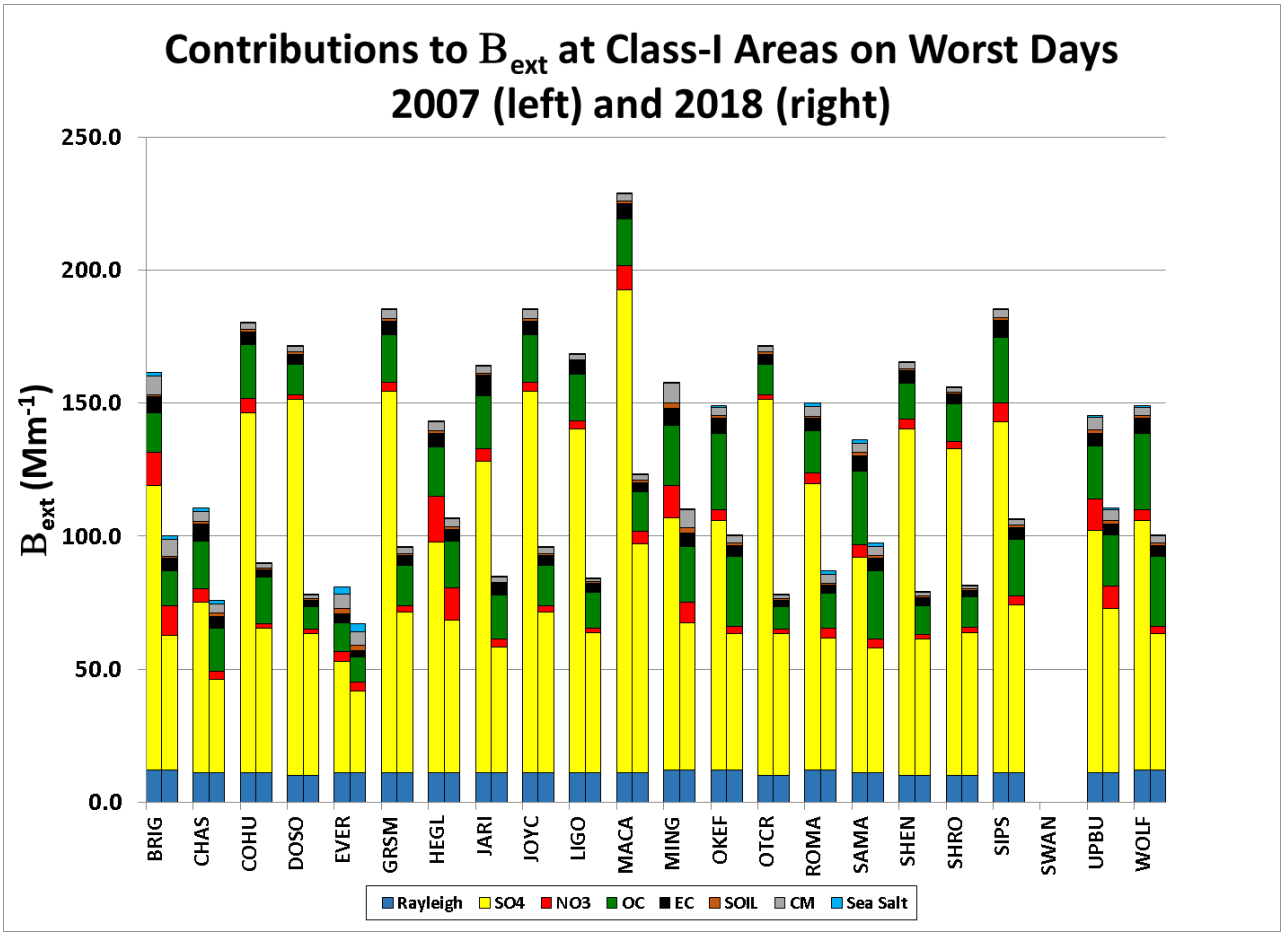


Figure 4-38 Comparison of contributions of $PM_{2.5}$ components to light extinction on worst 20% visibility days in 2007 and 2018

4.7 Conclusions

In 2018, future ozone design values (DVFs) will remain below the current 75 ppb standard in the SESARM states, except at a handful of sites around Atlanta, GA. However, DVFs are expected to exceed 70 ppb at several sites in almost every SESARM state. The use of 2007 DVCs and 3×3 cell block's maximum RRFs generally led to higher ozone DVFs.

Both for annual and daily $PM_{2.5}$, the use of 2007 DVCs and monitor (1×1) cell RRFs generally led to higher DVFs. In 2018, annual $PM_{2.5}$ DVFs are not expected to exceed the current 12 μg m^{-3} standard in the SESARM states, except at a few sites. Birmingham, AL is expected to be the most problematic area. In 2018, daily $PM_{2.5}$ DVFs are not expected to exceed the current 35 μg m^{-3} anywhere in the SESARM states. However, they are expected to be higher than 30 μg m^{-3}around Birmingham, AL.

The expected decreases in $PM_{2.5}$ from 2007 to 2018 will be primarily due to the large decreases of sulfate and associated ammonium in the SESARM states. Ammonium nitrate is expected to increase at a number of sites. No significant changes are expected for other components of $PM_{2.5}$.

Visibility will improve in Class I areas of the SEMAP region, primarily due to the decrease in ammonium sulfate. Based on the 2007/2018 SEMAP modeling, the 2018 visibility is projected to have less

impairment on the 20% worst days compared to the previous 2002/2018 VISTAS modeling (Odman et al., 2007)[22].

[22] Odman, M. T., Y. Hu, A. Unal, A. G. Russell and J. W. Boylan (2007). "Determining the sources of regional haze in the southeastern United States using the CMAQ model." Journal of Applied Meteorology and Climatology **46**(11): 1731-1743.

Chapter 5: Sensitivity of Ozone to NO_x and VOC Emissions

5.1 Introduction

A sensitivity analysis was conducted to study how ozone responds to NO_x and VOC emission reductions. The objective was to determine the direction of the response (i.e., increase or decrease) and quantify its magnitude. Simulations of various 2018 scenarios were conducted reducing NO_x and VOC emissions individually from different states and Regional Planning Organizations (RPOs) in the SEMAP domain. The amount of reductions used in this analysis is 30%. Since ozone response is nonlinear the results are most accurate for the amount of reduction used here, i.e., 30% of either NO_x or VOC emissions. Caution should be exercised if the results are used for other purposes, for example in attempts to calculate the responses to other levels of emission reductions, especially those larger than 30%, or responses to combined NO_x and VOC reductions. An extreme attempt might be to extrapolate the results to 100% and calculate interstate contributions. The nonlinear nature of the relation between ozone and NO_x or VOC emissions should be kept in mind in such interpretations of the results. Any such attempt can only be a first estimate and should be followed by simulations of the actual emission reduction case.

In this chapter, first the methodology used in the sensitivity analysis will be described. Then, the results of the simulations will be presented as absolute sensitivities or responses of ozone to emission reductions. This will be followed by relative sensitivities calculated from the relative response factors and future ozone design values. The relative sensitivities will be normalized by the amount of emissions reduced and presented as responses per ton of NO_x and VOC emission reductions. Finally conclusions will be drawn.

5.2 Methodology

The sensitivity analysis method used here is known as the "Brute Force" method. Air quality simulations are conducted for the base case and reduced emission scenarios. The difference in ozone between the reduced emission case and the base case yields the response of ozone to emission reductions. The base case is the simulation with the 2018 baseline emission projections. Recall that the annual 2018 simulation in Chapter 4 was completed in four quarterly runs, each with a 15-day period in the beginning for model spin-up. June 1, the first day of the third quarter, was Day 16 of the third quarter run in that annual simulation. The 15-day spin-up period is generally long enough for the effects of initial conditions to damp out and the differences from a continuous run are small. However, since we are going to look at the differences from the reduced emission scenarios, which are also relatively small, it is desirable to get rid of any other source of difference. Therefore the 2018 ozone season (May 1 through September 30) was (re-) simulated with a continuous model run over the 12-km grid, using boundary conditions derived from the annual simulation over the 36-km grid. All of the emission reduction scenarios were also simulated for the ozone season over the 12-km grid using the same boundary conditions. Hence the only source of difference between the base case and the reduced emissions cases are the emissions.

In each emission reduction scenario anthropogenic emissions, either NO_x or VOC, from a geographic region were reduced by 30%. The geographic region where the emissions were reduced was either one of the ten SESARM states (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Virginia and West Virginia), the state of Maryland, or one of the three portions of RPOs in the 12-km grid domain (CENRAP or Central, LADCO or Midwest, and MANE-VU or Northeast RPOs). When NO_x emissions were reduced VOC emissions were held constant and vice versa. A total of 28 (2 precursors x 14 regions) emission reduction scenarios were simulated.

The CMAQ code was modified to apply the desired amount of reduction in a specified geographic region during the simulation (i.e., inline). This approach was preferred over inputting reduced emissions because of the ease in processing and time savings. The off-line process of preparing reduced emissions inputs is not only tedious but also prone to human errors. The modified CMAQ code on the other hand, once

verified leaves little room for error. The user has to input only a few parameters such as the amount of reduction, the type of emissions to be reduced (NO_x or VOC) and a description of the region where the reduction is to be applied. Since CMAQ was configured to process point-source emissions (i.e., calculate the plume rise and distribute the emissions to the model's vertical layers) inline, the point-source emissions inputs are already in a form that can be tracked by their stationary source IDs (SSIDs). These IDs contain the Federal Information Processing Standards (FIPS) numeric codes for states. Hence the point sources belonging to the state or states forming the geographic region where emission reductions are to be applied is easily identifiable. The area source on the other had are already gridded (i.e. blended into the 12km×12km grid cells) therefore they cannot be split back to the states they belong. The modified CMAQ code expects a description of the boundary of the geographic region. Gridded emissions are distributed according to the fractional area of the grid cell that lies inside this boundary. If the entire cell lies in the geographic region, all the emissions of the specified type in that grid cell are reduced by the specified amount. If only a certain fraction of the grid cell lays in the geographic domain only that fraction of the grid cell emissions of the specified type are reduced by the specified amount.
Only anthropogenic emissions were reduced including point, area, residential wood combustion, mobile, nonroad, airport, aircraft/locomotive/marine emissions. The individual source categories of emissions that were reduced are listed in Table 5-1. Biogenic, livestock, fertilizer, fugitive dust, and fire emissions as well as non-US anthropogenic and off-shore shipping emissions were not reduced (Table 5-2).

Table 5-1 Emission sectors that were reduced

	Source Sector
Area	2. Nonpoint (**nonpt**) – area sources with ammonia, residential wood combustion, and dust sources removed 5. Aircraft/locomotive/marine (**alm**) 6. Residential wood combustion (**rwc**) 9. Nonroad mobile (**nonroad**) 10. U.S. onroad (**usmb**) – WRAP, CENRAP, and LADCO using monthly EPA MOVES proxy 2007 inventories 11. U.S. running PM (**runpm**) – WRAP, CENRAP, and LADCO using monthly EPA MOVES proxy 2007 inventories 12. U.S. start PM (**startpm**) – WRAP, CENRAP, and LADCO using monthly EPA MOVES proxy 2007 inventories 25. SESARM MOVES rate-per-profile (**sesarm_rpp**) 26. SESARM MOVES rate-per-vehicle (**sesarm_rpv**) 27. SESARM MOVES rate-per-distance (**sesarm_rpd**) 28. MARAMA rate-per-profile (**manevu_rpp)** 29. MARAMA rate-per-vehicle (**manevu-rpv**) 30. MARAMA rate-per-distance (**manevu-rpd**) 31. VA MOVES rate-per-profile (**va_rpp**) 32. VA MOVES rate-per-vehicle (**va_rpv**) 33. VA MOVES rate-per-distance (**va_rpd**)
Point	13. Airport point (**airpt**) – SESARM only 20a. SESARM non-CEM point EGU (**sesarm_ptncem_EGU)** 20b. SESARM non-CEM point non-EGU (**sesarm_ptncem_nonEGU)** 21a. SESARM CEM point EGU (**sesarm_ptcem_EGU**) 21b. SESARM CEM point non-EGU (**sesarm_ptcem-nonEGU**) 22. MARAMA non-CEM point (**mv_ptncem**) 23. MARAMA CEM point (**mv_ptcem**) 24. U.S point sources (**uspt**) – LADCO, CENRAP, and WRAP point sources from the NEI08v2

Table 5-2 Emission sectors that remained unchanged

	Source Sector
Area	1. MEGAN biogenic (**bg**) 3. Livestock ammonia (**lv**) 4. Fertilizer ammonia (**ft**) 7. Fugitive dust (**fdust**) – WRAP, CENRAP, and LADCO using NEI2008 and SESARM using SEMAP 2007 inventory 8. MARAMA fugitive dust (**mv_fdust**) – MARAMA 2007v3.3 inventory with transport factors applied at the county level 16. Non-US nonpoint (**nusar**) – Canada and Mexico non-point and nonroad mobile 17. Non-US onroad (**nusmb**) – Canada and Mexico onroad mobile
Point	14. Point fires (**ptfire**)_- WRAP, CENRAP, LADCO, MARAMA, and MS 2007 Smartfire inventories 15. SESARM point fires (**sesarm_ptf**) – SESARM 2007 fire inventories (no MS) 18. Non-US point (**nuspt**) – Canada and Mexico point 19. Offshore shipping (**ptseca**) - > 0.5km offshore

The differences between this study and a prior sensitivity analysis conducted for the same region (Odman et al., 2009)[23] are summarized in Table 5-3. In the previous study, VISTAS 2009 "on-the-way" emission projections were used as the base case to simulate one summer month. NO_x emission reductions were applied only in the non-attainment areas of the Southeast while VOC reductions were applied simultaneously in all SESARM states. Here the modern version of the CMAQ model (CMAQv5.01) is used to simulate the entire ozone season. Mobile emissions are modeled using the MOVES model. There are also differences in the ways the sensitivities are calculated.

[23] Odman, M. T., Y. T. Hu, A. G. Russell, A. Hanedar, J. W. Boylan and P. F. Brewer (2009). "Quantifying the sources of ozone, fine particulate matter, and regional haze in the Southeastern United States." Journal of Environmental Management **90**(10): 3155-3168.

Table 5-3 Updates to the previous sensitivity analysis

Previous Sensitivity Modeling (Odman et al., 2009)	**New Sensitivity Modeling**
CMAQv4.4	CMAQv5.01
1-Month summer episode	5-Month ozone season
VISTAS 2009 OTW BaseD	SEMAP 2018
SEMAP-wide VOC reductions	State-wide VOC reductions
County/state NO_x reductions	State-wide NO_x reductions
MOBILE6	MOVES
Absolute difference	Absolute difference and RRF approach (MATS)
>70 ppb cutoff (based on modeled base year values)	>70 ppb cutoff (based on modeled future year values)

5.2.1 Calculation of Absolute Sensitivities

Absolute sensitivities, or ΔO_3, are calculated by taking the difference of daily maximum 8-hr ozone between the 2018 emission reduction or sensitivity case and the 2018 base case.

$$\Delta O_3 = O_3\,(2018_{sens}) - O_3\,(2018_{base})$$

A negative value of ΔO_3 indicates a decrease in ozone in response to the emission reduction while a positive value indicated an increase. A decrease should be viewed as a benefit and an increase as a disbenefit.

After ΔO_3 were calculated for all days of the ozone season they were averaged in three different ways:

1. Over all days
2. Over days with 2007_{typ} daily maximum 8-hr O_3 above 75 ppb
3. Over days with 2018_{base} daily maximum 8-hr O_3 above 70 ppb

The first average gives an overall picture of the sensitivities during the simulated ozone season. The second one focuses on days when simulated 2007 typical ozone exceeds the current national standard. The third one can be viewed as the projected 2018 sensitivity on potential exceedance days with the assumption that the national ozone standard, currently at 75 ppb, may be lowered to 70 ppb.

5.2.2 Calculation of Relative Sensitivities

Relative sensitivities, or DDVF, can be obtained from the relative response factors (RRFs), which are the ratios of projected 2018 ozone to simulated typical 2007 ozone, and the current design values (DVCs). DVCs are derived from measured ozone concentrations; therefore, relative sensitivities are probably more realistic than absolute sensitivities, which use the simulated ozone concentrations as the only basis. Here, simulated ozone concentrations are used in a relative sense by taking the ratio of one modeled case to another. The method used here to calculate DDVFs is slightly different than taking the difference of two future design values as will be described below but the essence is the same in that there is a reality basis. EPA's Modeled Attainment Test Software (MATS)[24] was used to calculate the RRFs. MATS expects two sets of modeled concentrations as inputs: a "baseline" and a "forecast". Here, the 2018 base case was provided as the "baseline" and the sensitivity or reduced emission case was provided as the "forecast". Hence the RRF that MATS calculates is:

$$RRF = O_3\,(2018_{sens}) / O_3\,(2018_{base})$$

MATS was executed for each of the 28 sensitivity cases to calculate 28 different sets of RRFs, one for each emission reduction scenario. An RRF was produced by MATS for all sites with at least one day in 2018 with ozone projection above 70 ppb. This was assured by using the following thresholds in MATS based on the 2018 baseline daily 8-hr maximum ozone concentrations:

- Initial threshold value = 75 ppb
- Minimum number of days in baseline at or above threshold = 10
- Minimum allowable threshold value = 70 ppb
- Minimum number of days at or above minimum allowable threshold = 1

Finally, DDVF was calculated from the RRF and the DVF as follows:

$$DDVF = (DVF \times RRF) - DVF = DVF \times (RRF - 1)$$

Recall that future design values (DVFs) were already calculated in Chapter 4. Out of the four different sets of DVFs calculated, the DVFs obtained from the 5-year (2005-2009) weighted average DVCs and the monitor cell RRF (i.e., 1 × 1 cell maximum) were employed here.

5.2.3 Normalized Sensitivities

Normalized sensitivities are calculated by dividing the relative sensitivities by the amount of emissions reduced. Here normalized sensitivities were calculated only for the ten SESARM states. They were not calculated for the RPO portions in the domain since the emissions in those RPOs vary too much from one state to another; therefore, an average sensitivity divided by the total emission reduction from all states in the RPO portion would not yield a very reliable normalized sensitivity. The annual average emissions were used for normalization. A more accurate calculation would require the averaging of emissions during the ozone season since emissions vary from day to day and month to month. The reductions are 30% of either NO_x or VOC emissions statewide. The amounts of daily emission reductions, in tons per day (TPD) for each state are listed in

[24] http://www.epa.gov/ttn/scram/guidance/guide/MATS-2-5-1_manual.pdf

Table 5-4.

Table 5-4 Emission Reductions (30% of annual average emissions)

State	NOx (TPD)	VOC (TPD)
Alabama	190	146
Florida	378	403
Georgia	251	223
Kentucky	185	133
Mississippi	156	113
North Carolina	190	242
South Carolina	119	112
Tennessee	223	174
Virginia	201	197
West Virginia	111	53

The normalized sensitivities that will be reported below are equal to the relative NO_x or VOC sensitivity for the home state, calculated using MATS as described in the previous section, divided by the NO_x or VOC emission reduction amount for that state. Unit conversion to parts per trillion (ppt) per TPD, or ppt/TPD, was performed as follows:

$(DDVF_{NOx} \times 1000)/TPD_{NOx}$

and

$(DDVF_{VOC} \times 1000)/TPD_{VOC}$

5.3 Absolute Sensitivities

Absolute sensitivities were calculated for each of the 674 ozone monitoring sites in the SEMAP 12-km modeling domain. They are available in day-by-day form for each site and also in averaged forms for all the sites in each of the 31 states in the domain.

5.3.1 Site-by-Site Absolute Sensitivities

Absolute sensitivities were calculated for each day at each site as described in Section Calculation of Absolute Sensitivitiesabove. The responses to NO_x or VOC reductions from each state and RPO are shown as stacked bars so that they can be compared to each other for any given day (e.g., Figure 5-1). The left axis is for ΔO_3 while the right axis is for O_3 and the x-axis labels the date for the day the stacked bar represents. There are charts that show all the days, days above 75 ppb in 2007 (used for 2007 to 2018

projections) and days above 70 ppb in 2018 (used for 2018 sensitivities). Hence there are 6 charts for each site (2 precursors × 3 groups of days) showing absolute sensitivities to emission reductions.

The set of 6 charts are illustrated here for Atlanta, GA (Figure 5-1 through Figure 5-6) and Baltimore, MD (Figure 5-7 through Figure 5-12). On the days when ozone in 2018 is above 70 ppb (Figure 5-3) the greatest sensitivity of Atlanta's ozone is to Georgia's NO_x emissions. On August 15 the response to 30% Georgia NO_x emissions is almost 9 ppb for a predicted 8-hour maximum ozone in 2018 of 95 ppb. Depending on wind direction the second largest sensitivity can be to NO_x emissions from Alabama, Tennessee, Florida, North Carolina, South Carolina or even Kentucky but those sensitivities are generally smaller than 2 ppb. The largest sensitivity of Atlanta's ozone to 30% VOC reductions is less than 2.5 ppb on August 3 (Figure 5-6). VOC reductions from states other than Georgia have no significant impact on Atlanta's ozone.

30% of NO_x emissions from SESARM states have a combined impact less than 3 ppb on Baltimore's ozone on days above 70 ppb in 2018 (Figure 5-9). The largest impacts are from Virginia followed by West Virginia. The largest impact of 30% VOC emissions from Virginia is less than 0.2 ppb on any day above 70 ppb in 2018 (Figure 5-12).

The absolute sensitivity charts for other sites can be found at http://semap.ce.gatech.edu/node/1861.

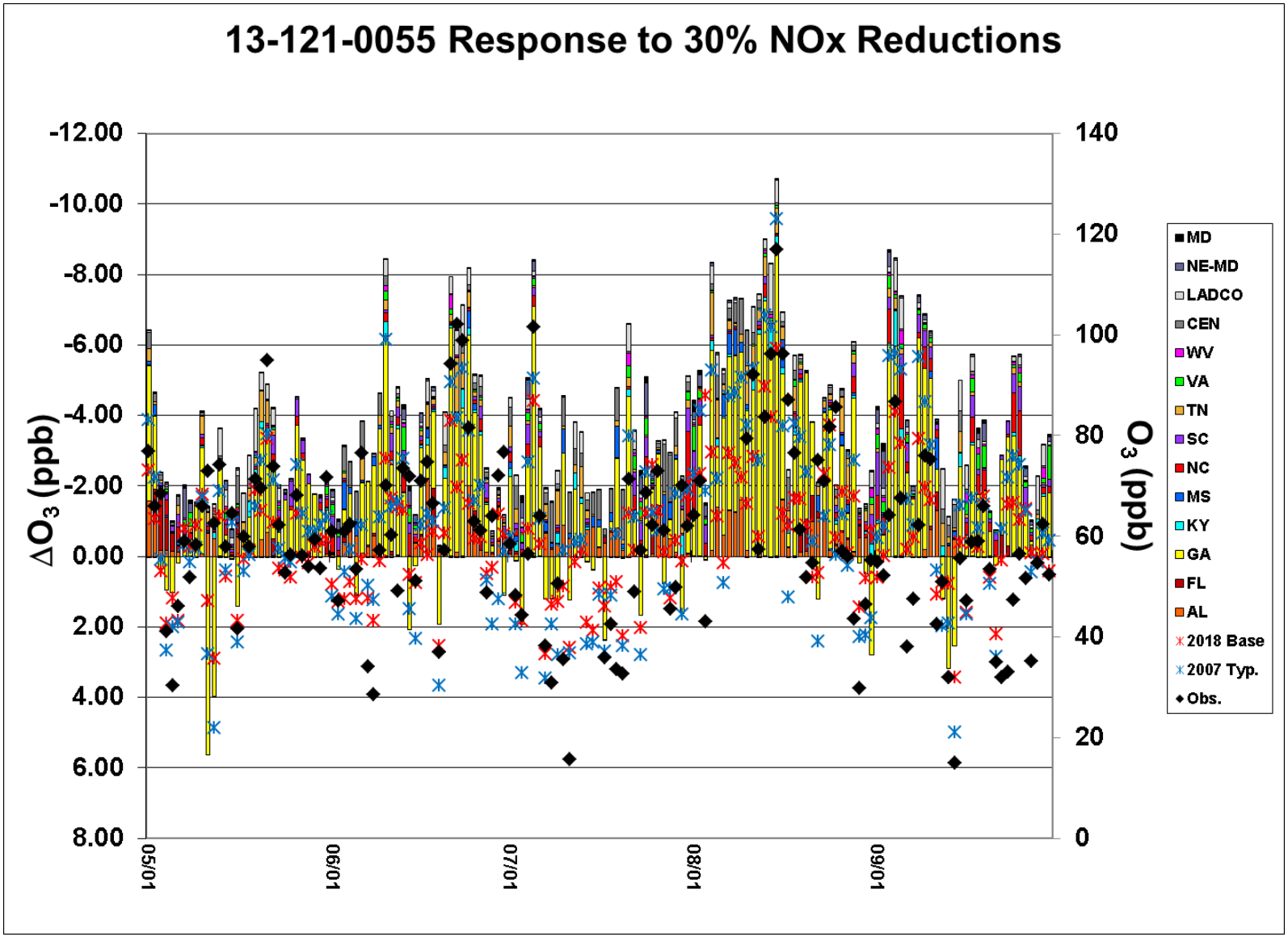


Figure 5-1 Absolute NO_x sensitivities at Atlanta, GA (all days)

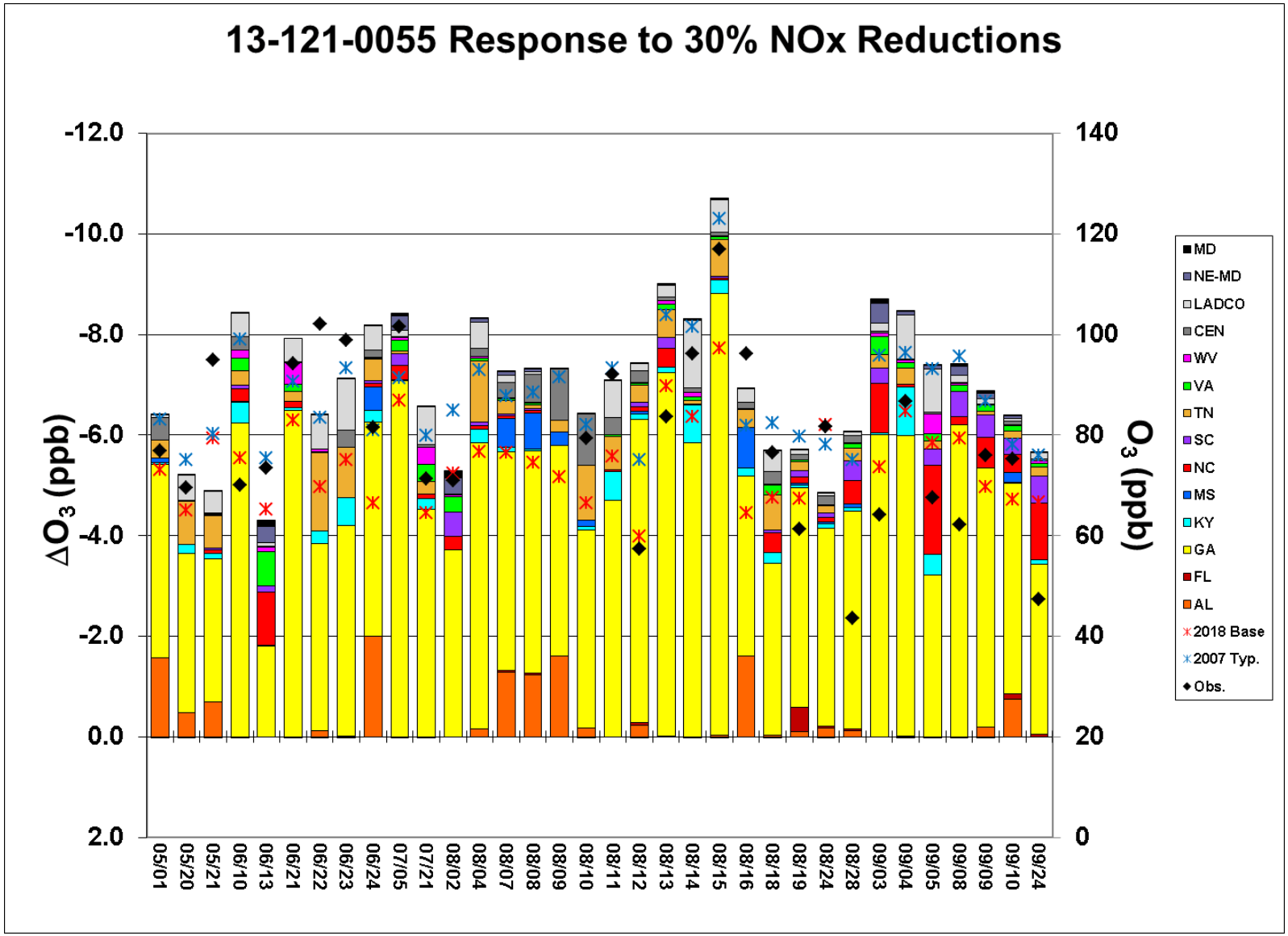


Figure 5-2 Absolute NO_x sensitivities at Atlanta, GA (days with $O_3 \geq 75$ ppb in 2007)

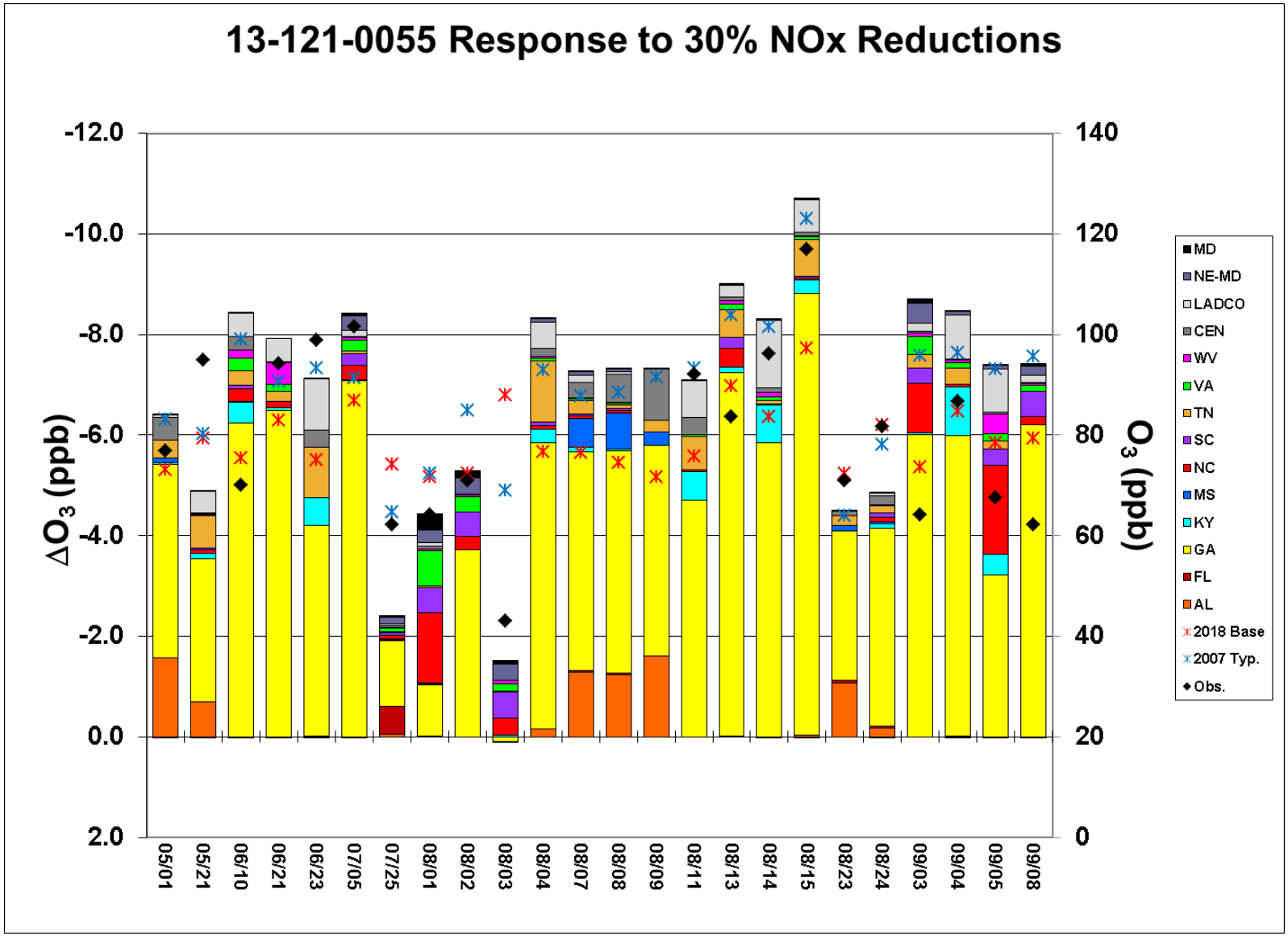


Figure 5-3 Absolute NO_x sensitivities at Atlanta, GA (days with $O_3 \geq 70$ ppb in 2018)

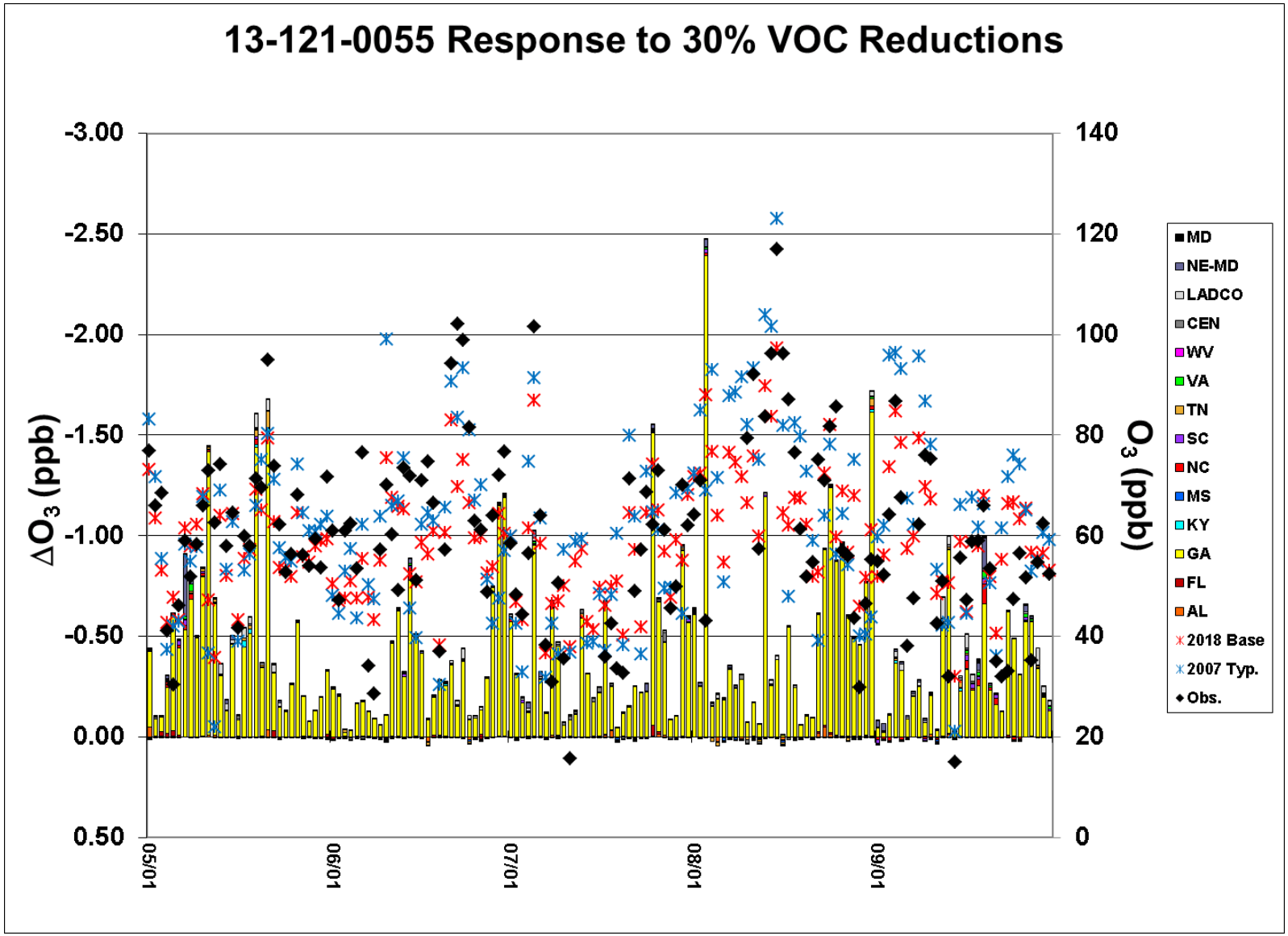


Figure 5-4 Absolute VOC sensitivities at Atlanta, GA (all days)

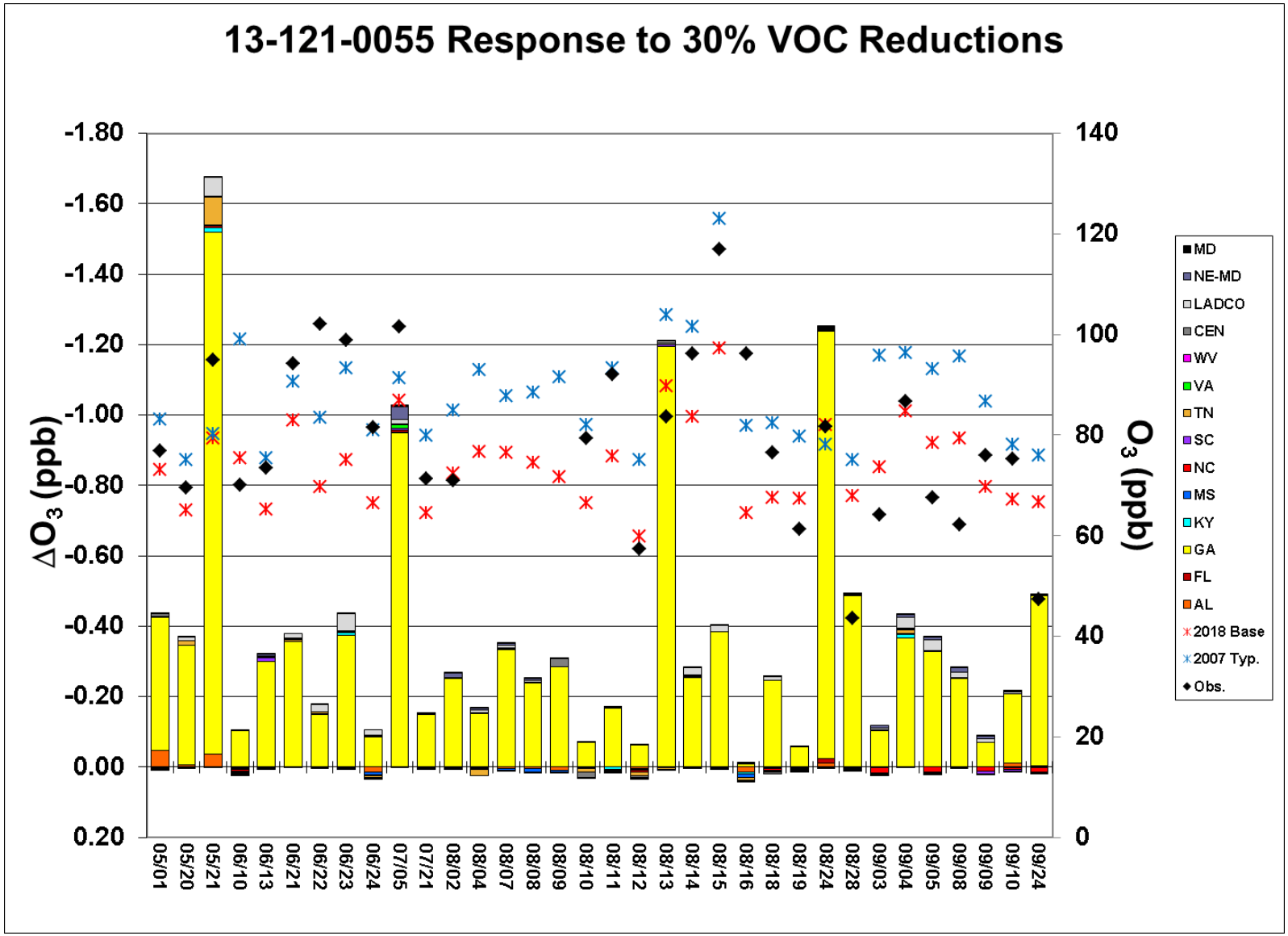


Figure 5-5 Absolute VOC sensitivities at Atlanta, GA (days with $O_3 \geq 75$ ppb in 2007)

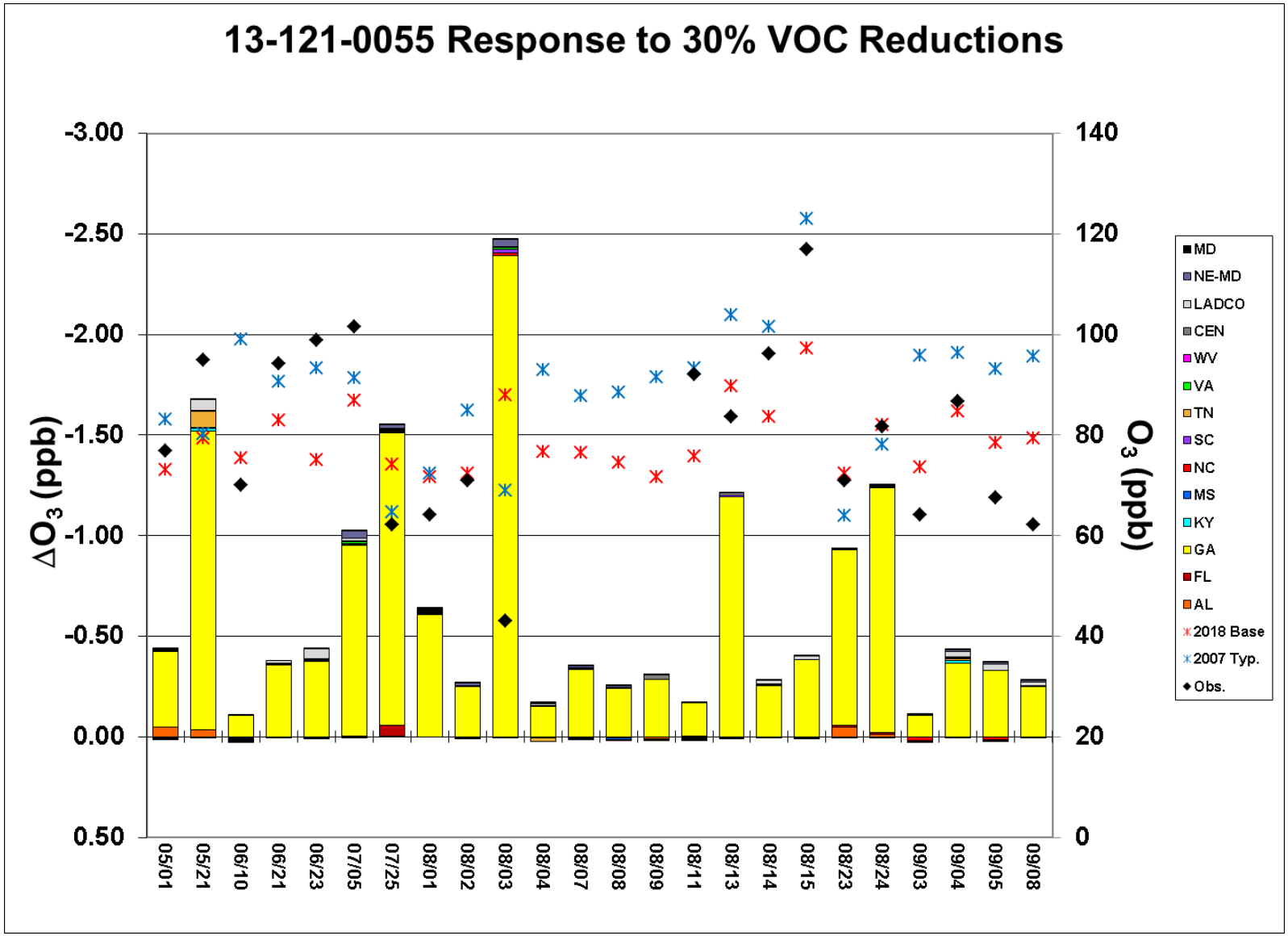


Figure 5-6 Absolute VOC sensitivities at Atlanta, GA (days with $O_3 \geq 70$ ppb in 2018)

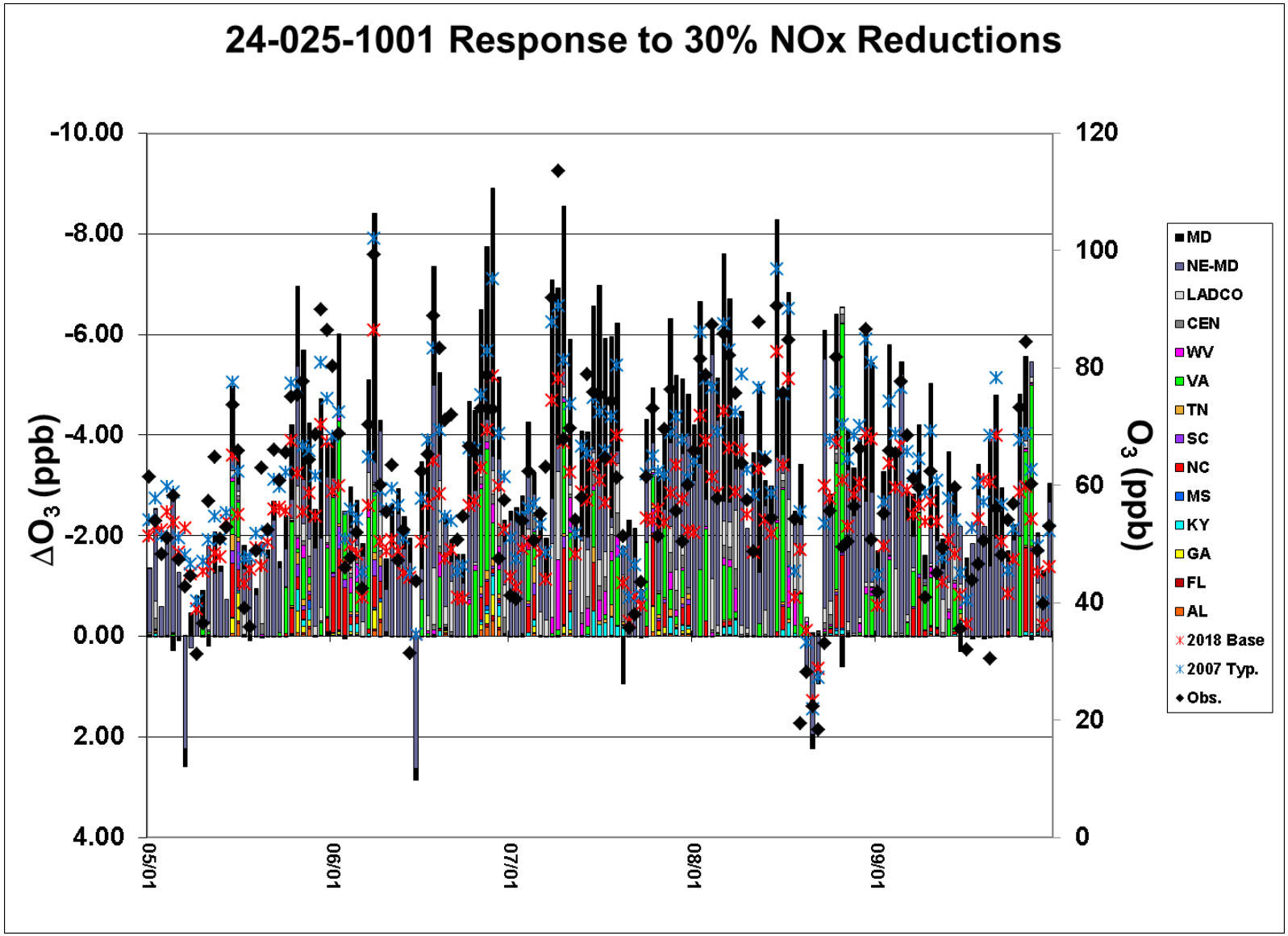


Figure 5-7 Absolute NO_x sensitivities at Baltimore, MD (all days)

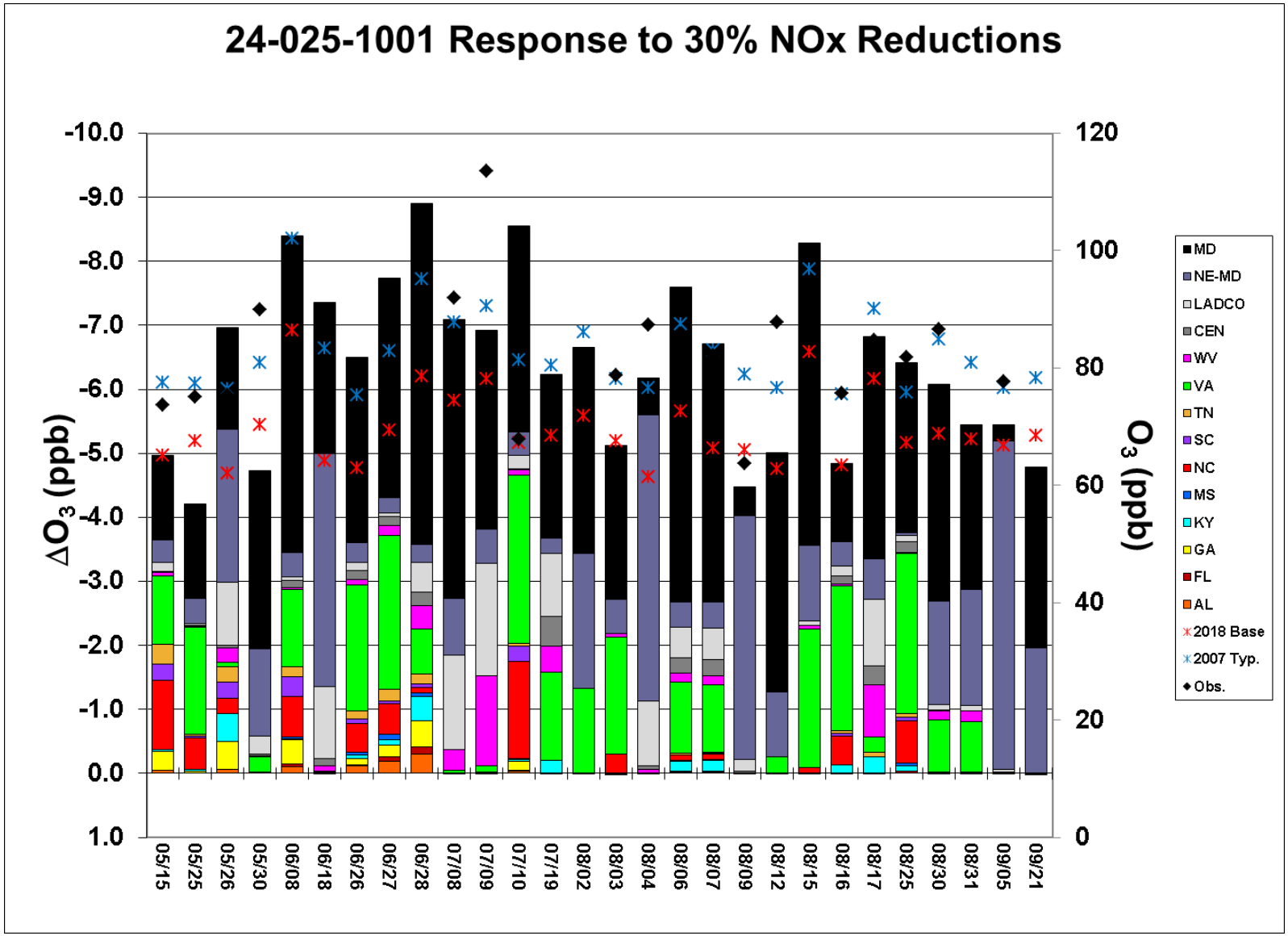


Figure 5-8 Absolute NO_x sensitivities at Baltimore, MD (days with $O_3 \geq 75$ ppb in 2007)

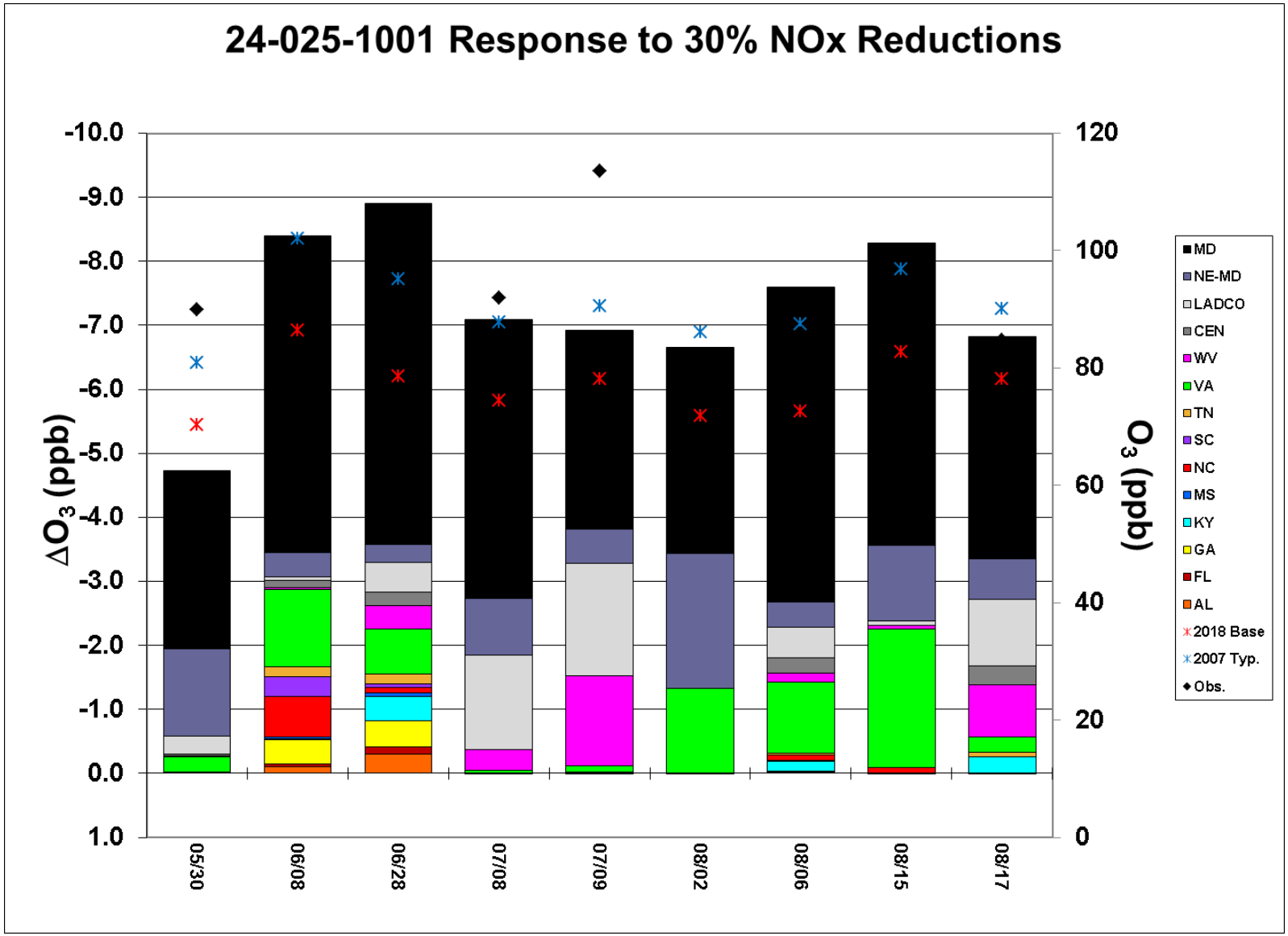


Figure 5-9 Absolute NO_x sensitivities at Baltimore, MD (days with $O_3 \geq 70$ ppb in 2018)

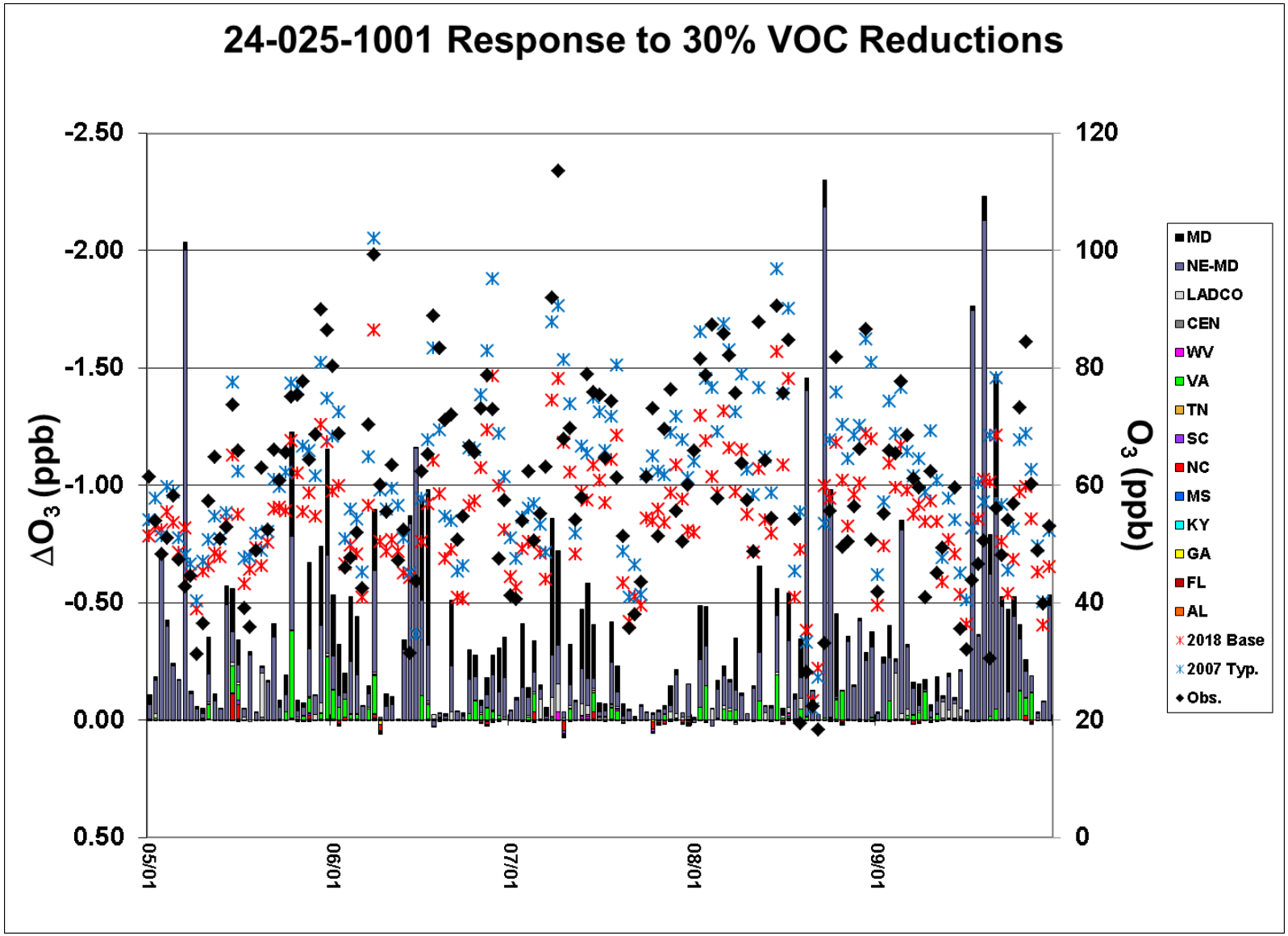


Figure 5-10 Absolute VOC sensitivities at Baltimore, MD (all days)

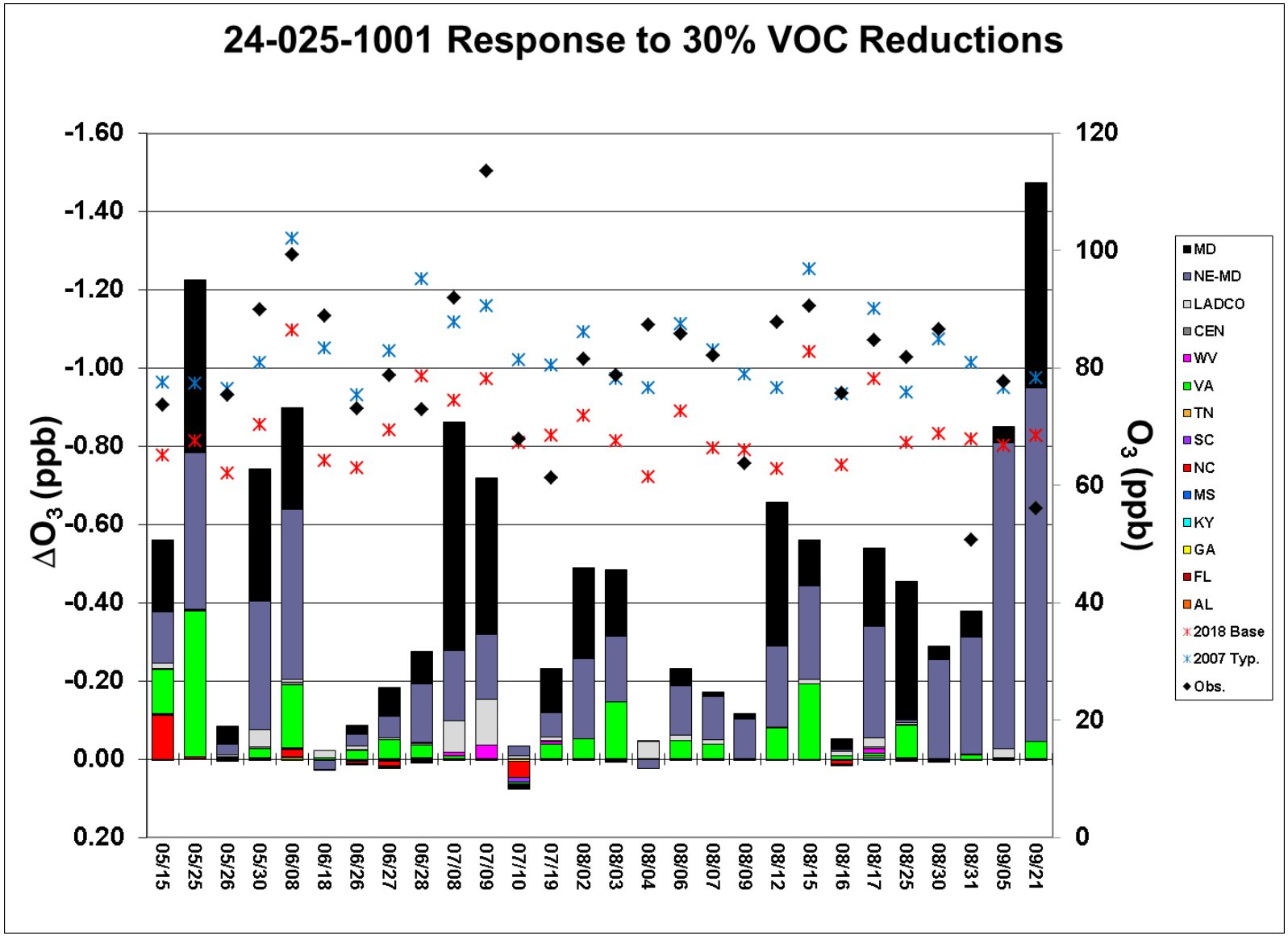


Figure 5-11 Absolute VOC sensitivities at Baltimore, MD (days with $O_3 \geq 75$ ppb in 2007)

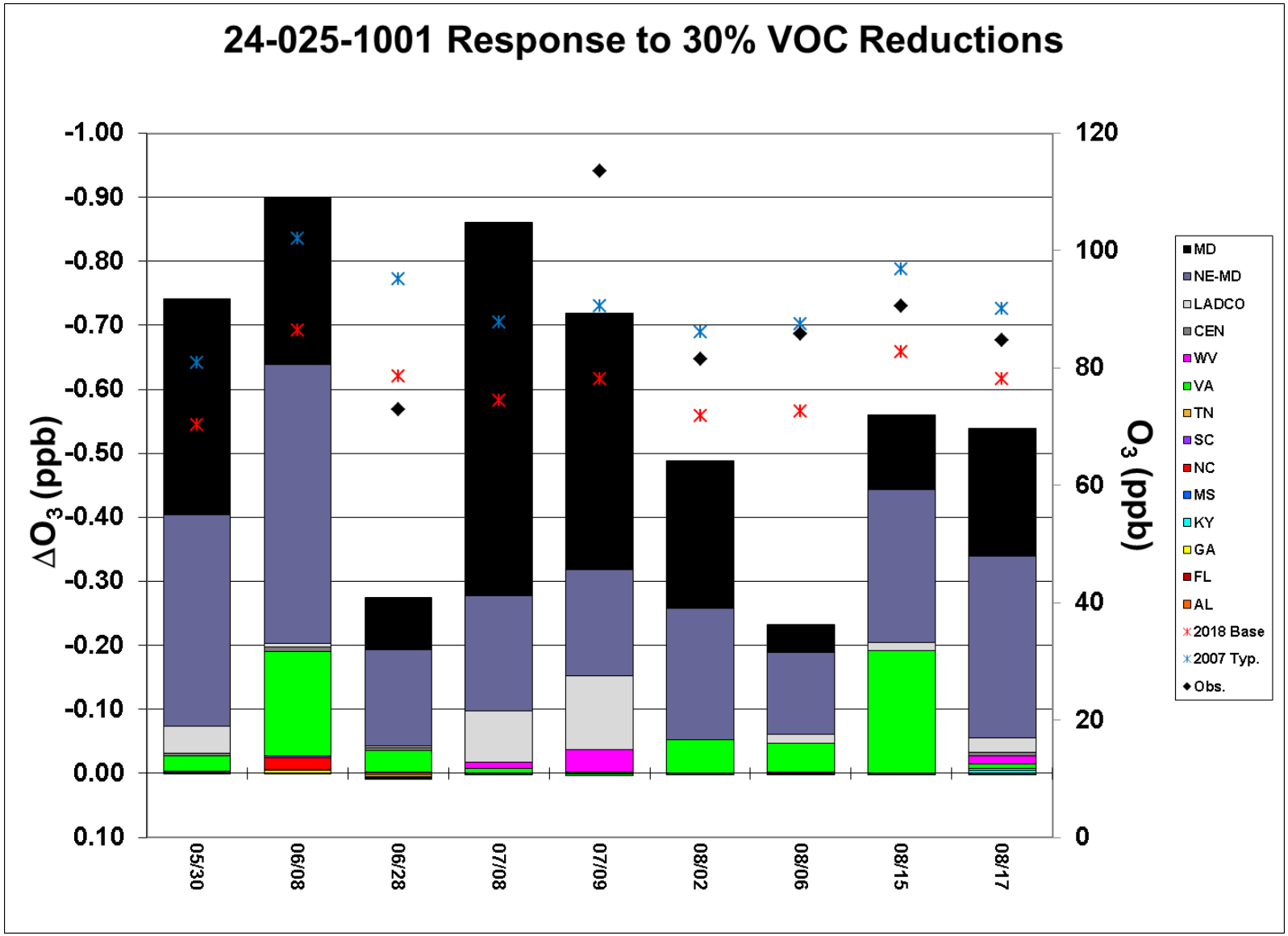


Figure 5-12 Absolute VOC sensitivities at Baltimore, MD (days with $O_3 \geq 70$ ppb in 2018)

5.3.2 State Summaries

The absolute sensitivities were averaged on days when modeled 8-hr maximum ozone in 2018 was above 70 ppb and the results for each state's sites were summarized on a single chart. These state summaries were created for 31 states in the SEMAP 12-km modeling domain. Figure 5-13 through Figure 5-23 show the absolute NO_x sensitivity state summaries for the 10 SESARM states (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Virginia and West Virginia) and Maryland. Figure 5-24 through Figure 5-34 show the absolute VOC sensitivity state summaries for the 10 SESARM states and Maryland. The summary charts for the other 20 states in the SEMAP domain can be found at http://semap.ce.gatech.edu/node/1861.

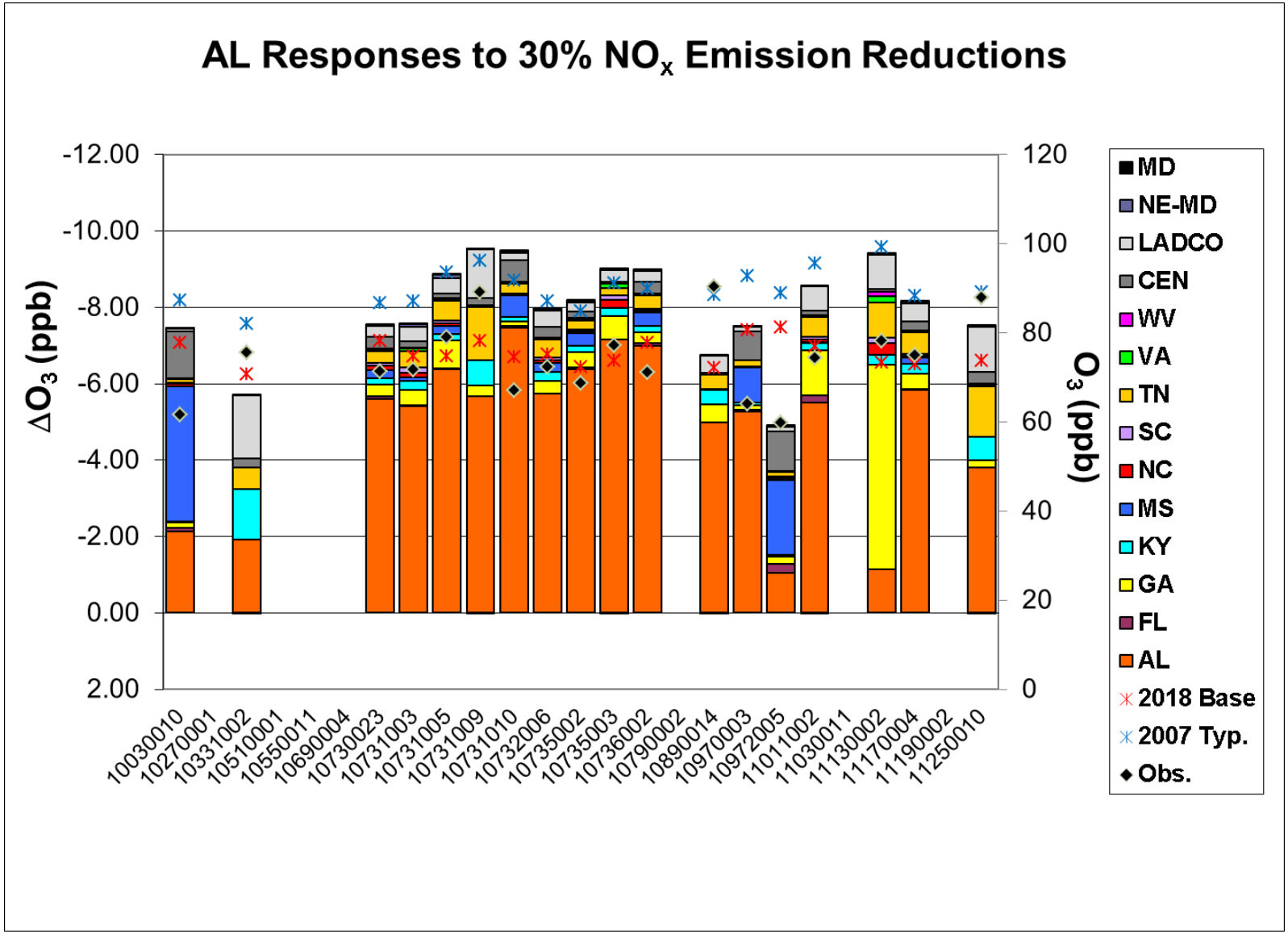


Figure 5-13 Absolute NO_x sensitivities at Alabama sites (days with $O_3 \geq 70$ ppb in 2018)

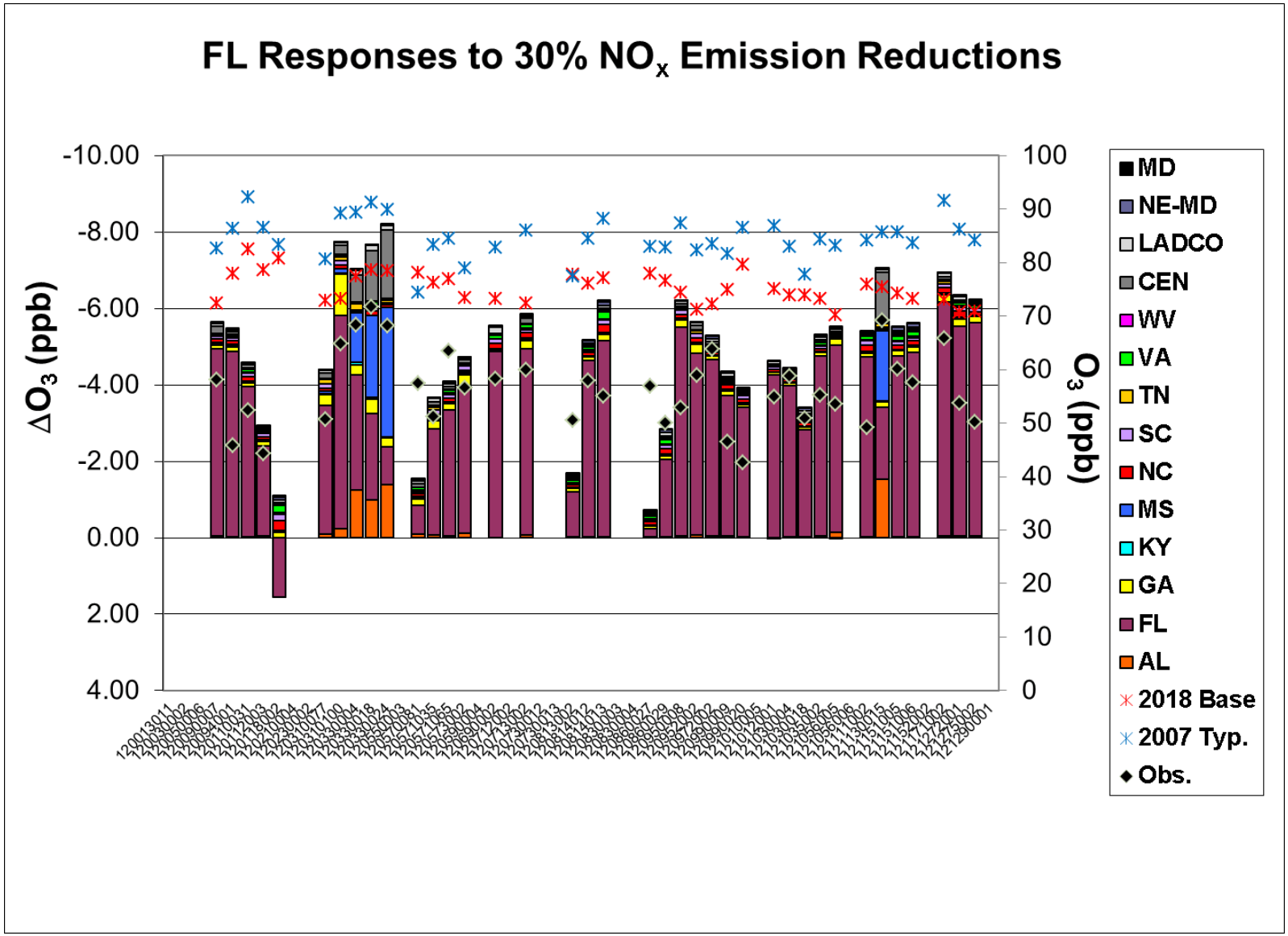


Figure 5-14 Absolute NO_x sensitivities at Florida sites (days with $O_3 \geq 70$ ppb in 2018)

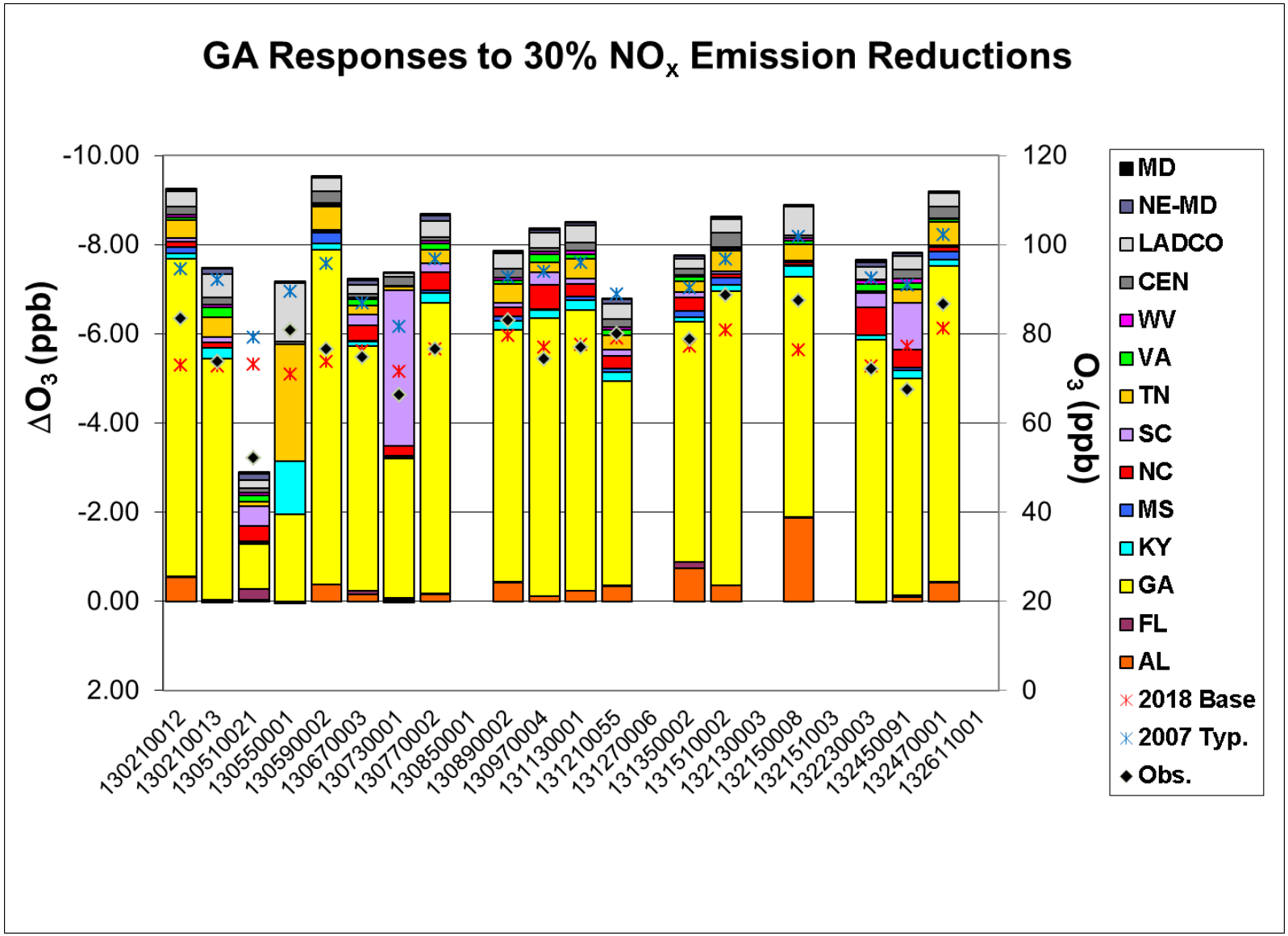


Figure 5-15 Absolute NO_x sensitivities at Georgia sites (days with $O_3 \geq 70$ ppb in 2018)

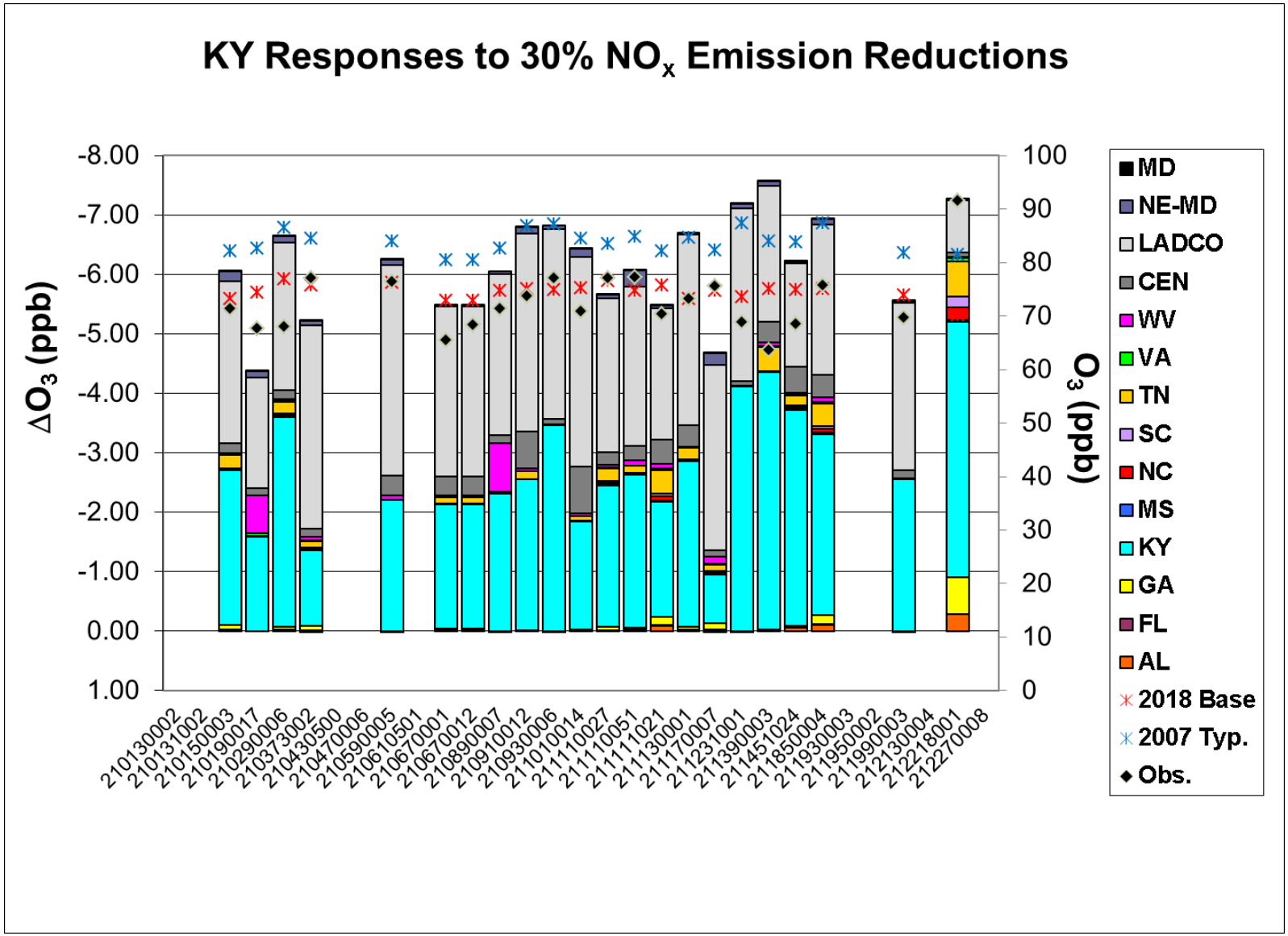


Figure 5-16 Absolute NO_x sensitivities at Kentucky sites (days with $O_3 \geq 70$ ppb in 2018)

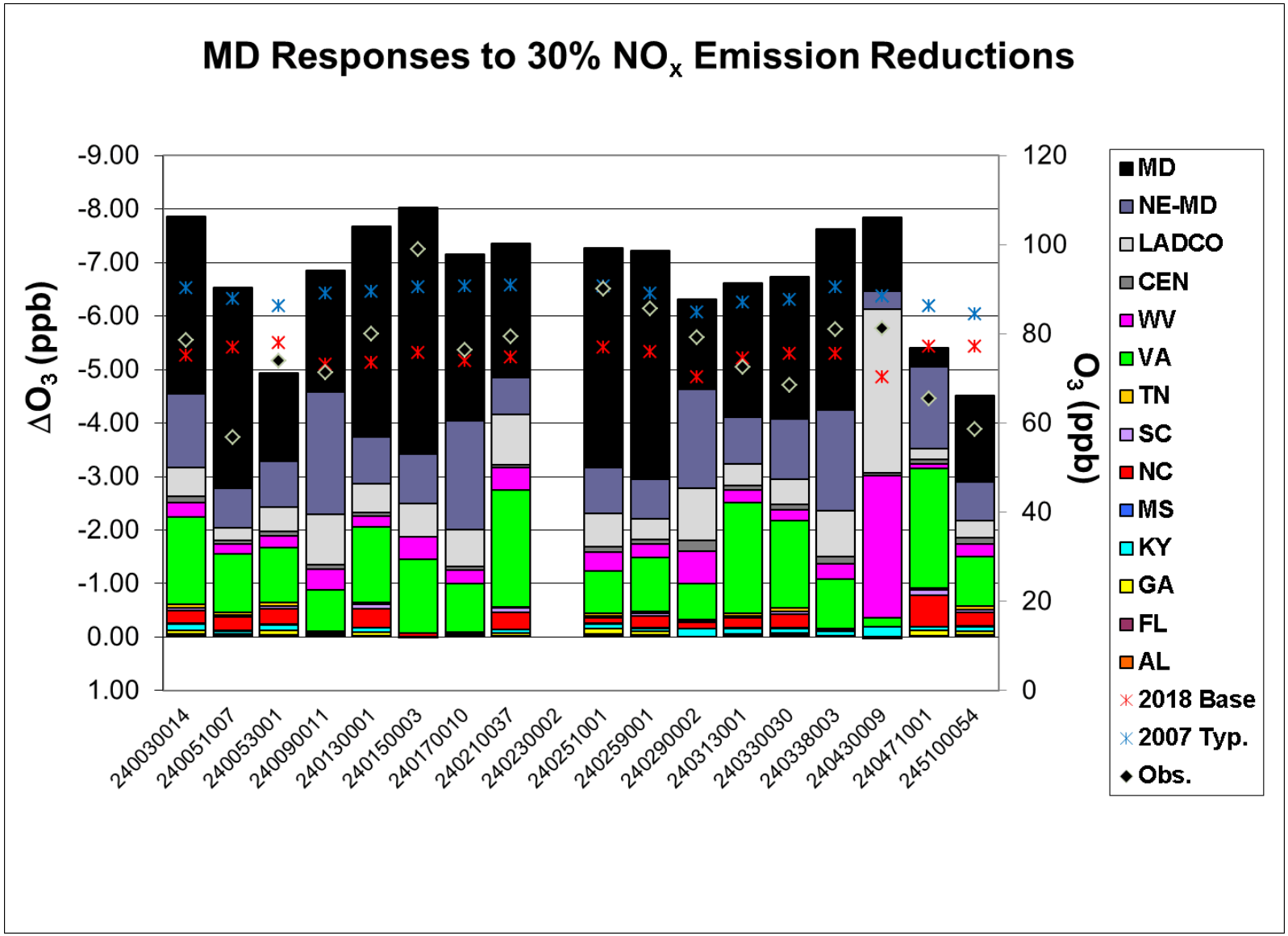


Figure 5-17 Absolute NO_x sensitivities at Maryland sites (days with $O_3 \geq 70$ ppb in 2018)

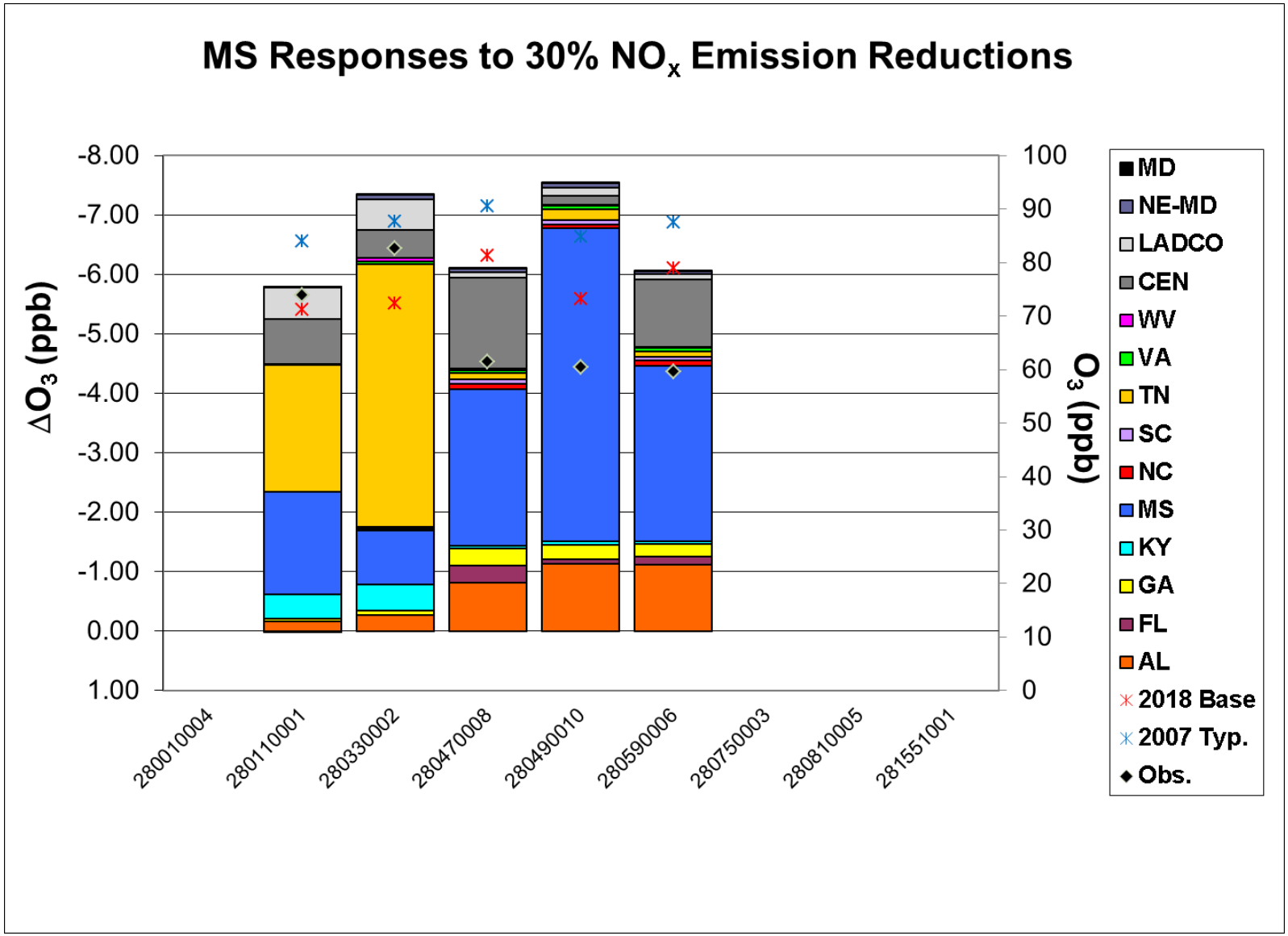


Figure 5-18 Absolute NO_x sensitivities at Mississippi sites (days with $O_3 \geq 70$ ppb in 2018)

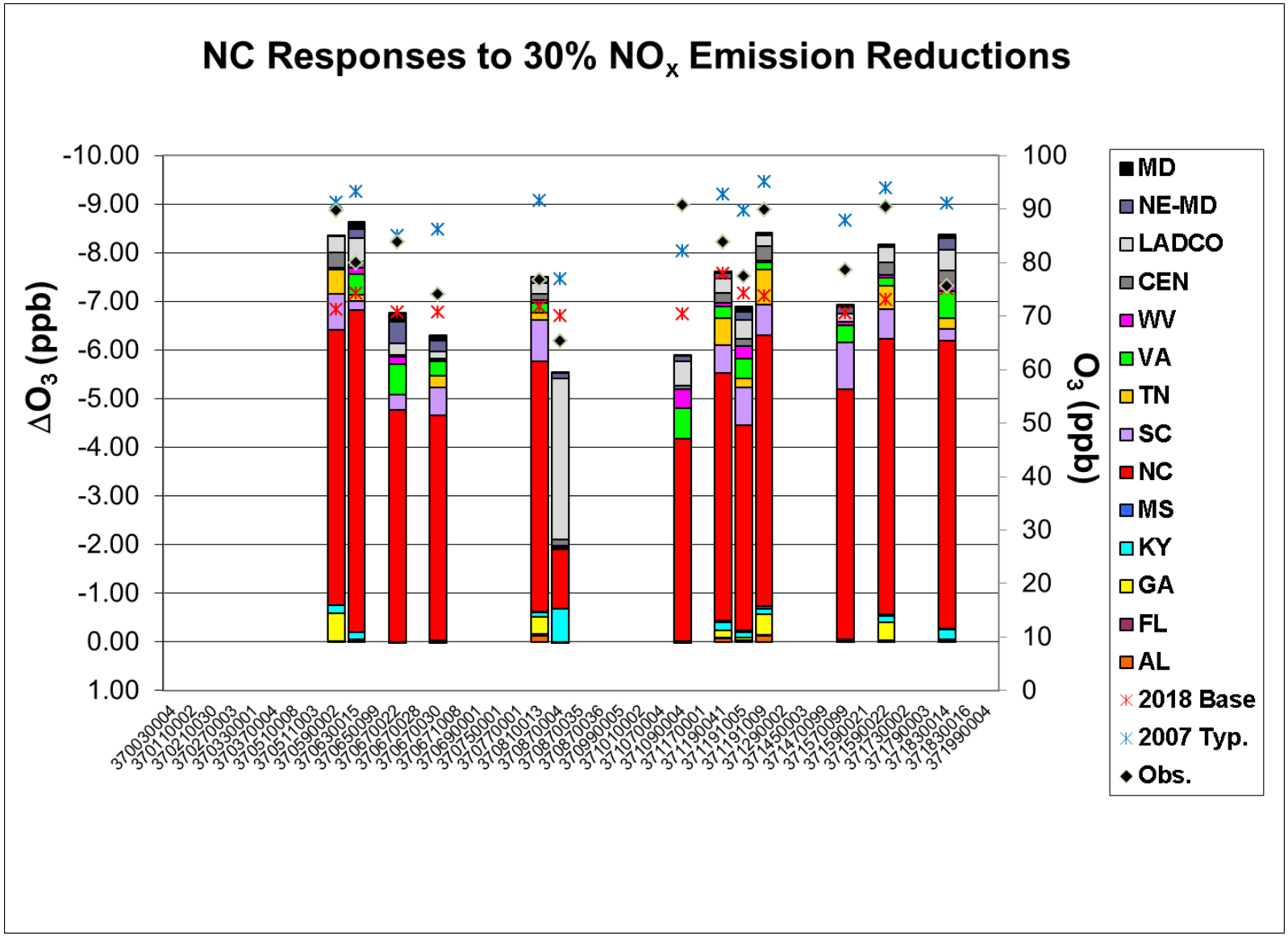


Figure 5-19 Absolute NO_x sensitivities at North Carolina sites (days with $O_3 \geq 70$ ppb in 2018)

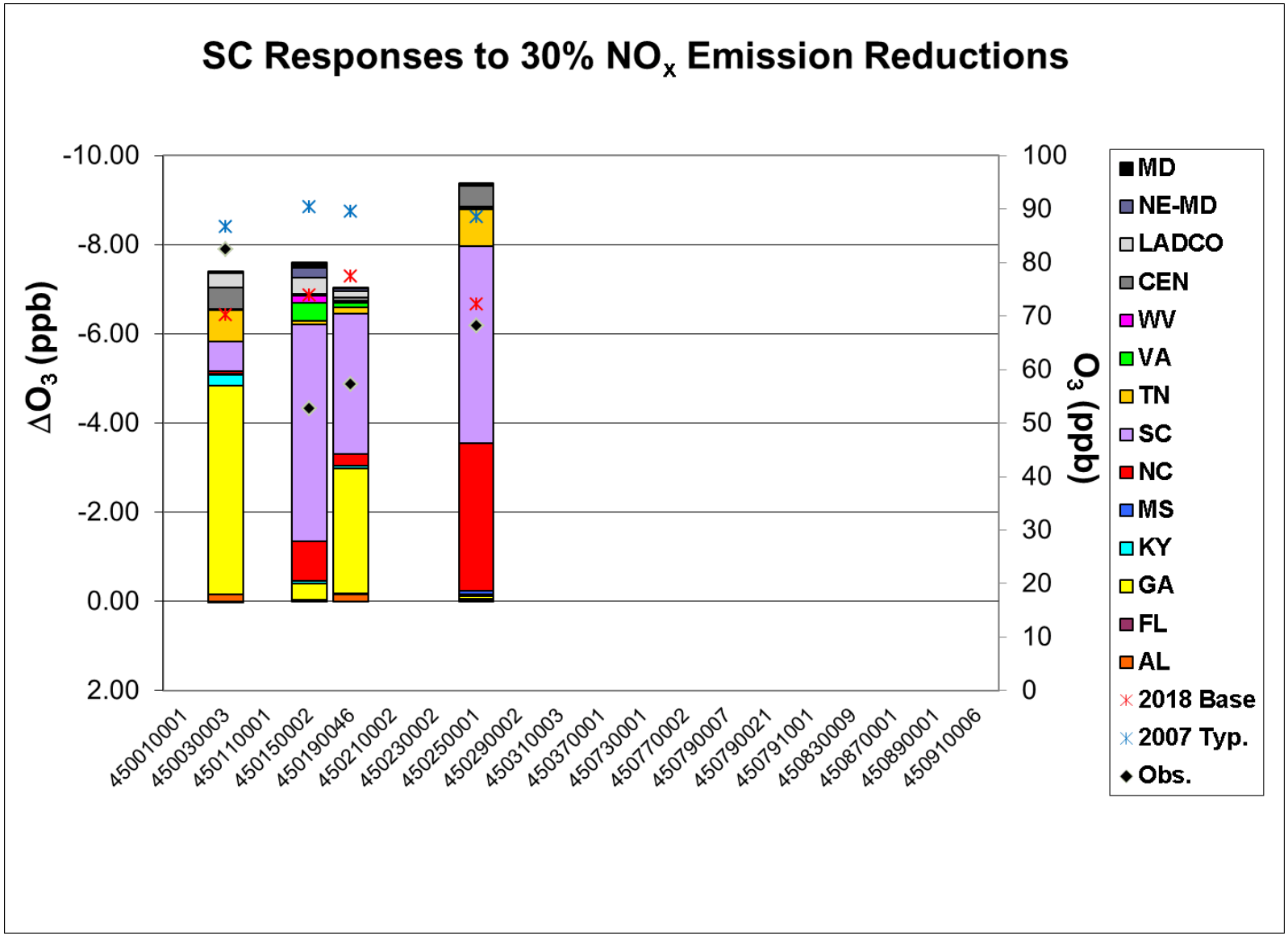


Figure 5-20 Absolute NO_x sensitivities at South Carolina sites (days with $O_3 \geq 70$ ppb in 2018)

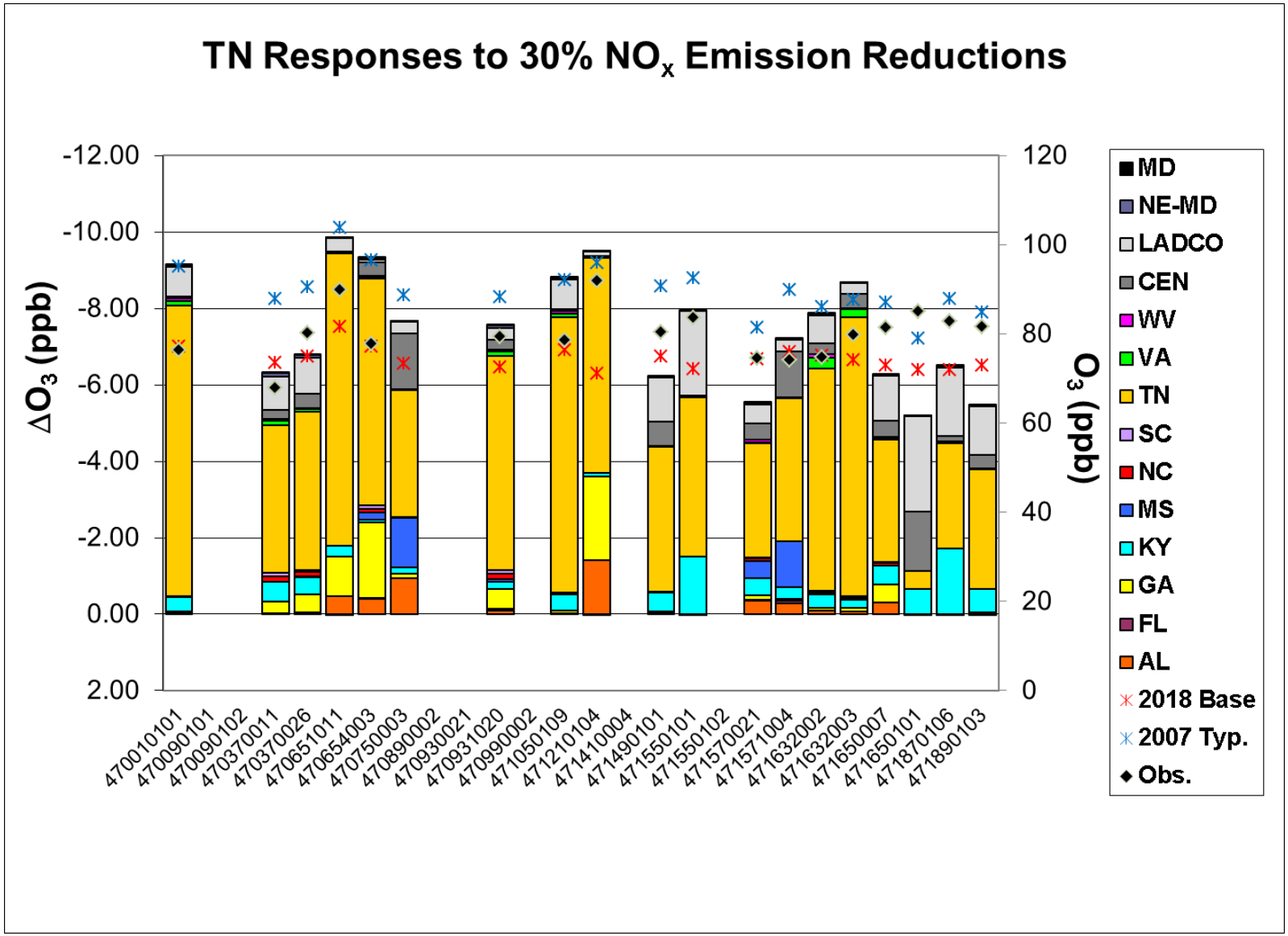


Figure 5-21 Absolute NO_x sensitivities at Tennessee sites (days with $O_3 \geq 70$ ppb in 2018)

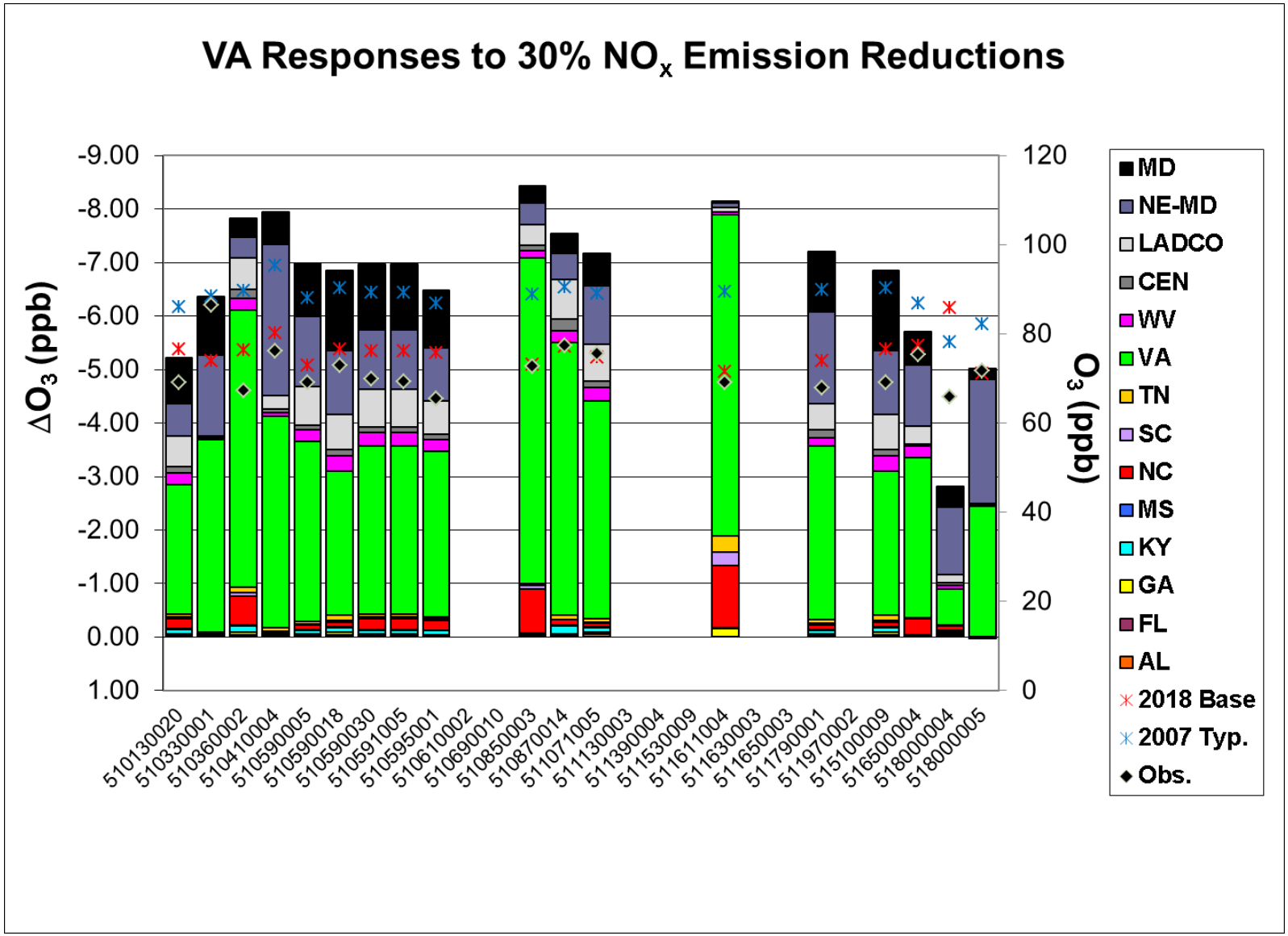


Figure 5-22 Absolute NO_x sensitivities at Virginia sites (days with $O_3 \geq 70$ ppb in 2018)

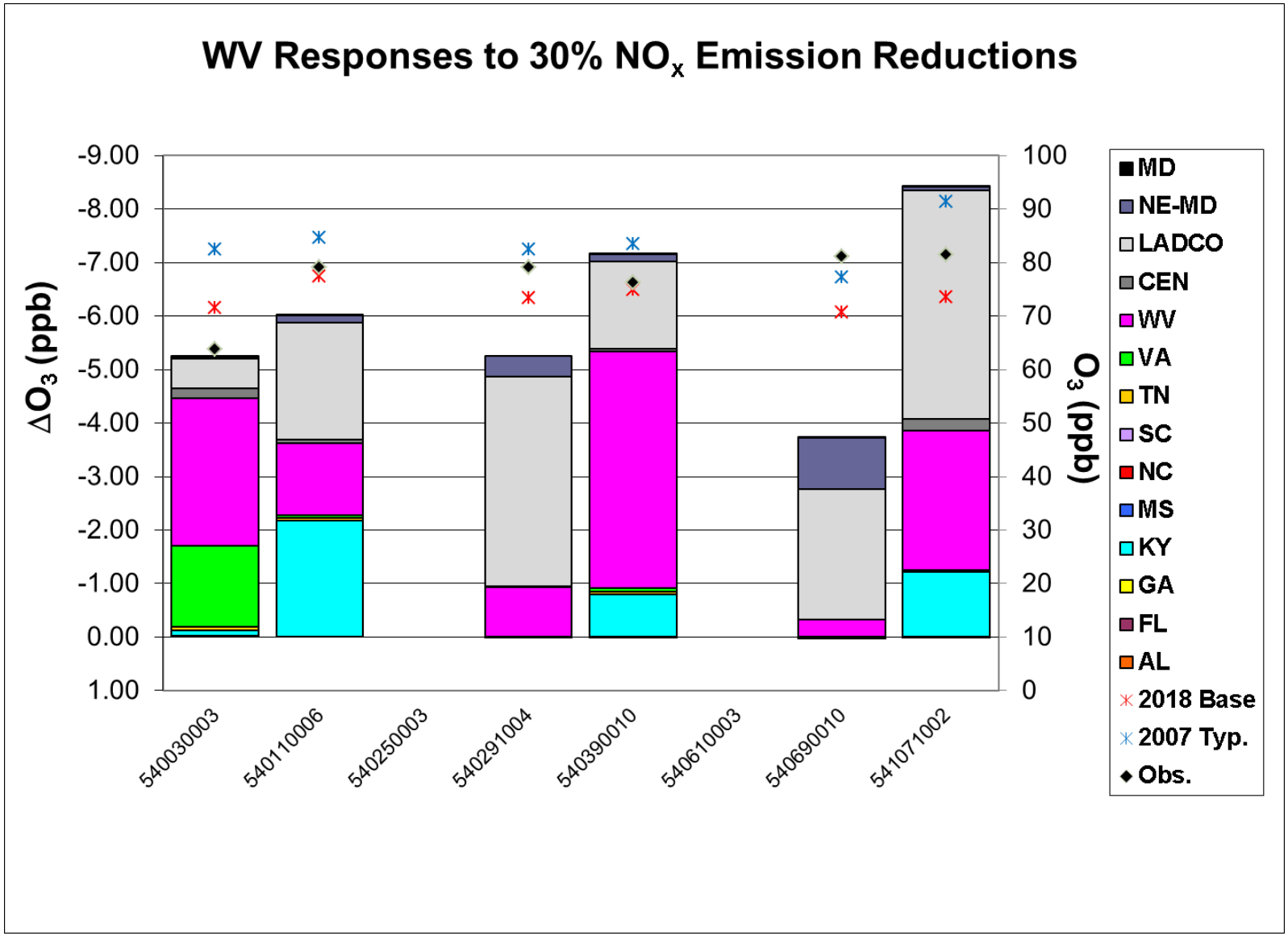


Figure 5-23 Absolute NO_x sensitivities at West Virginia sites (days with $O_3 \geq 70$ ppb in 2018)

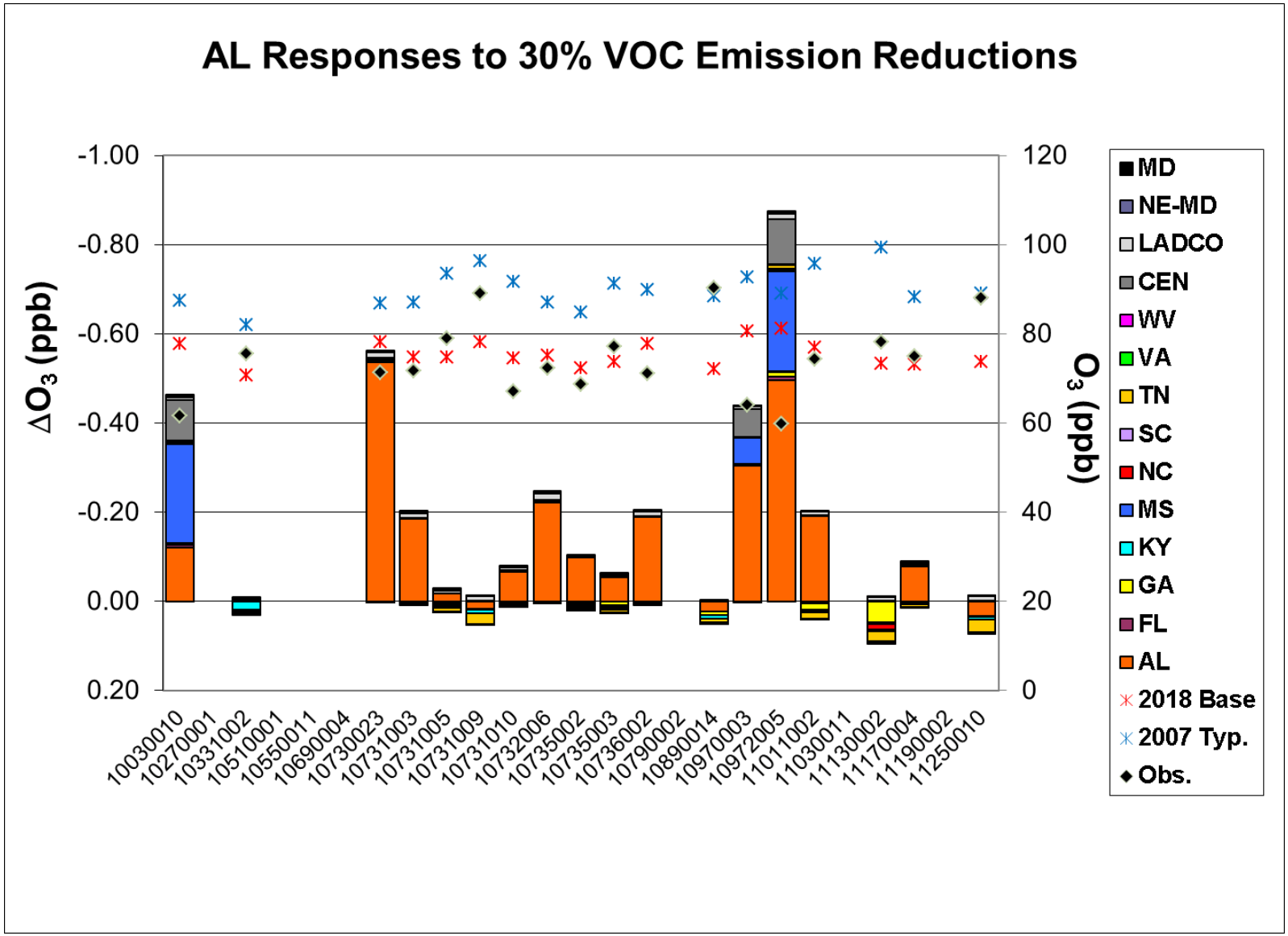


Figure 5-24 Absolute VOC sensitivities at Alabama sites (days with $O_3 \geq 70$ ppb in 2018)

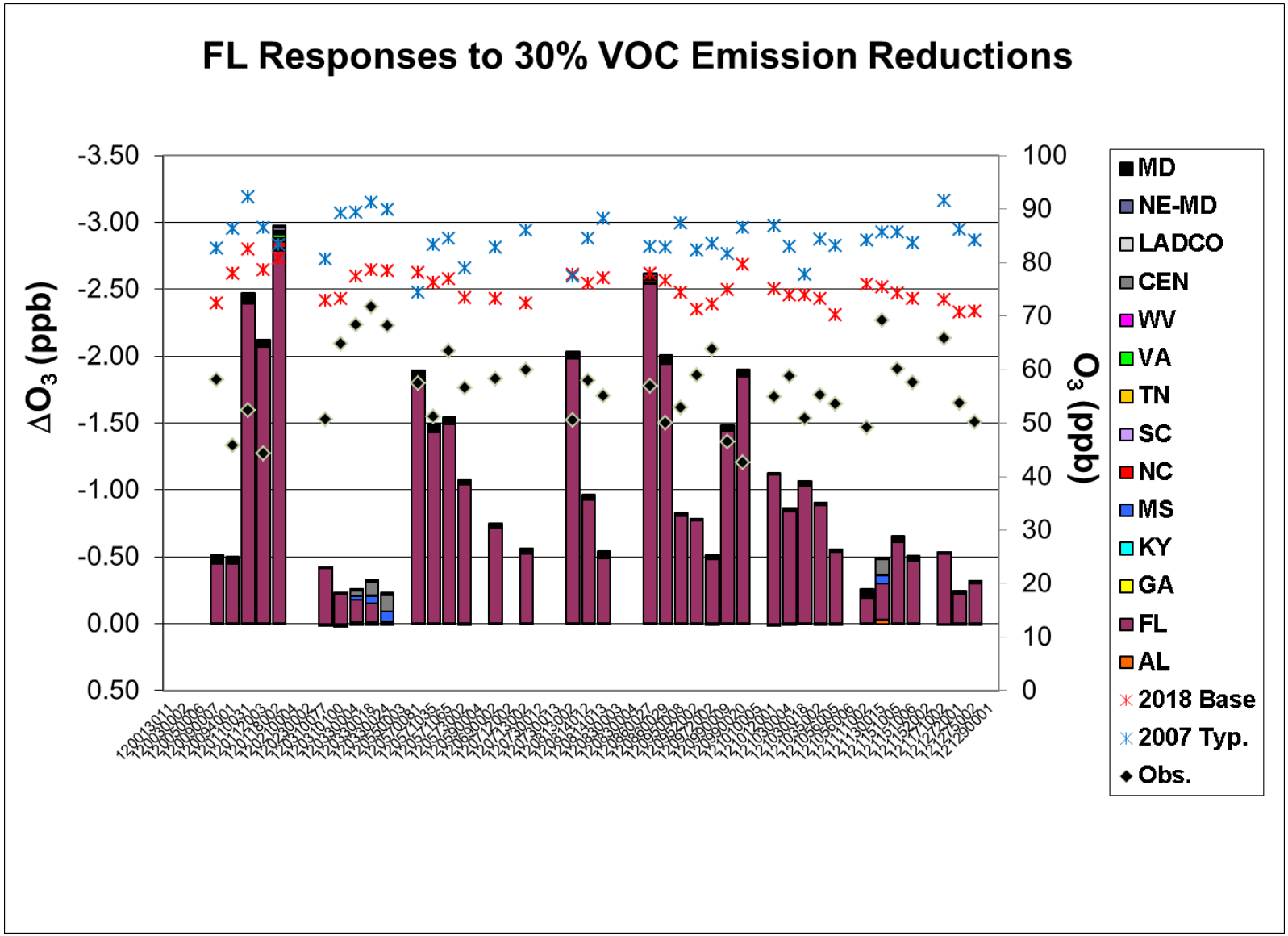


Figure 5-25 Absolute VOC sensitivities at Florida sites (days with $O_3 \geq 70$ ppb in 2018)

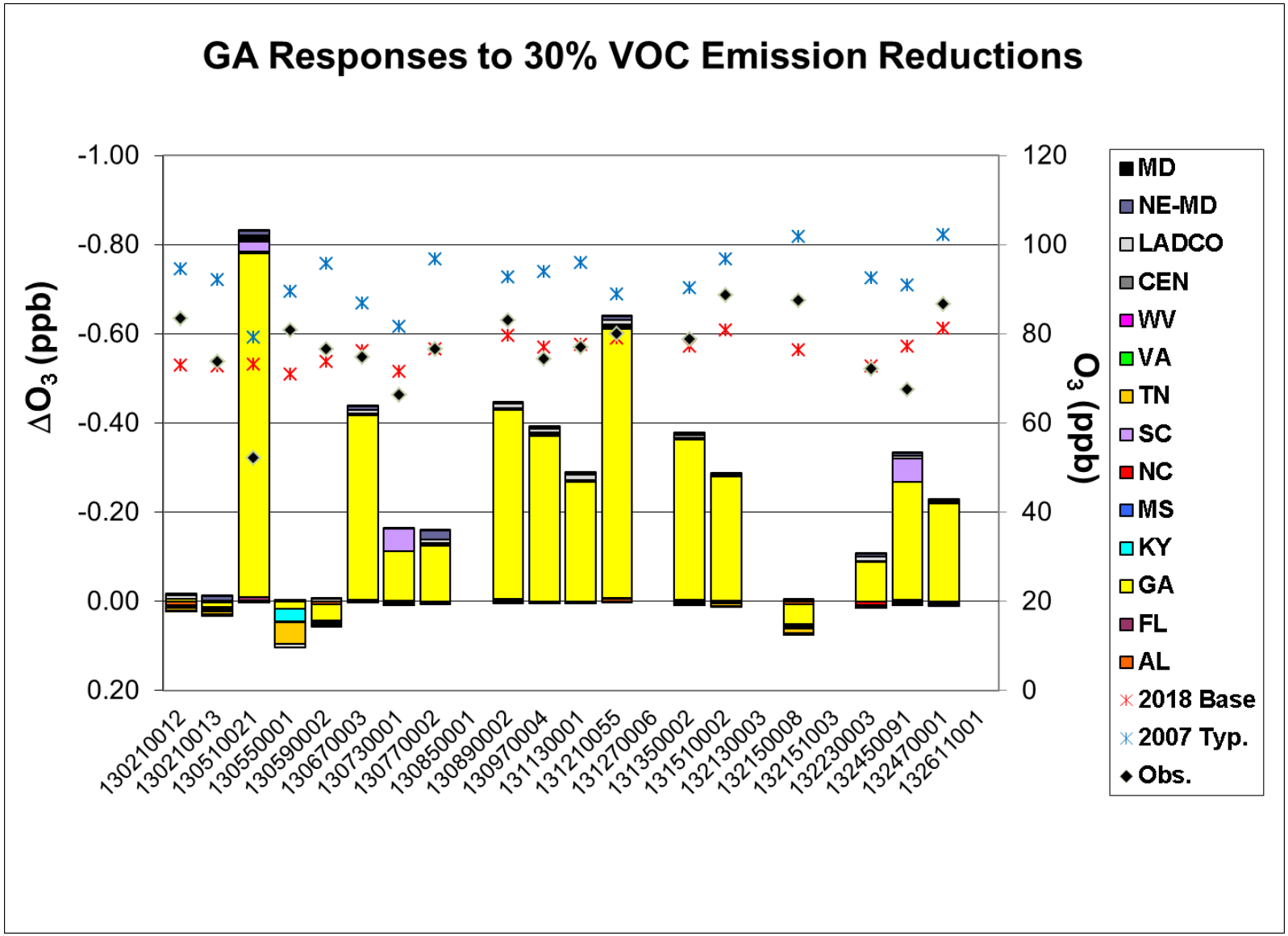


Figure 5-26 Absolute VOC sensitivities at Georgia sites (days with $O_3 \geq 70$ ppb in 2018)

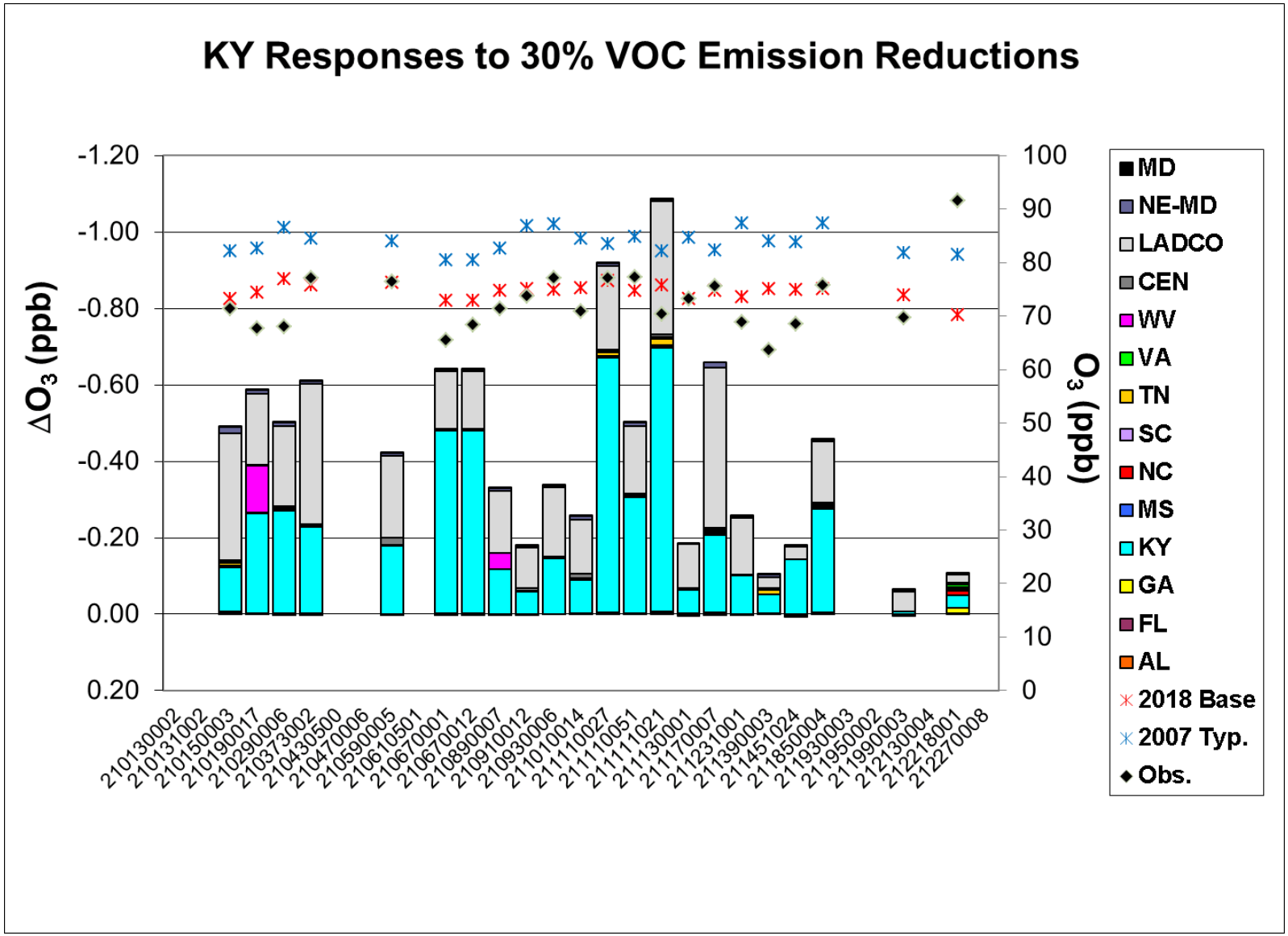


Figure 5-27 Absolute VOC sensitivities at Kentucky sites (days with $O_3 \geq 70$ ppb in 2018)

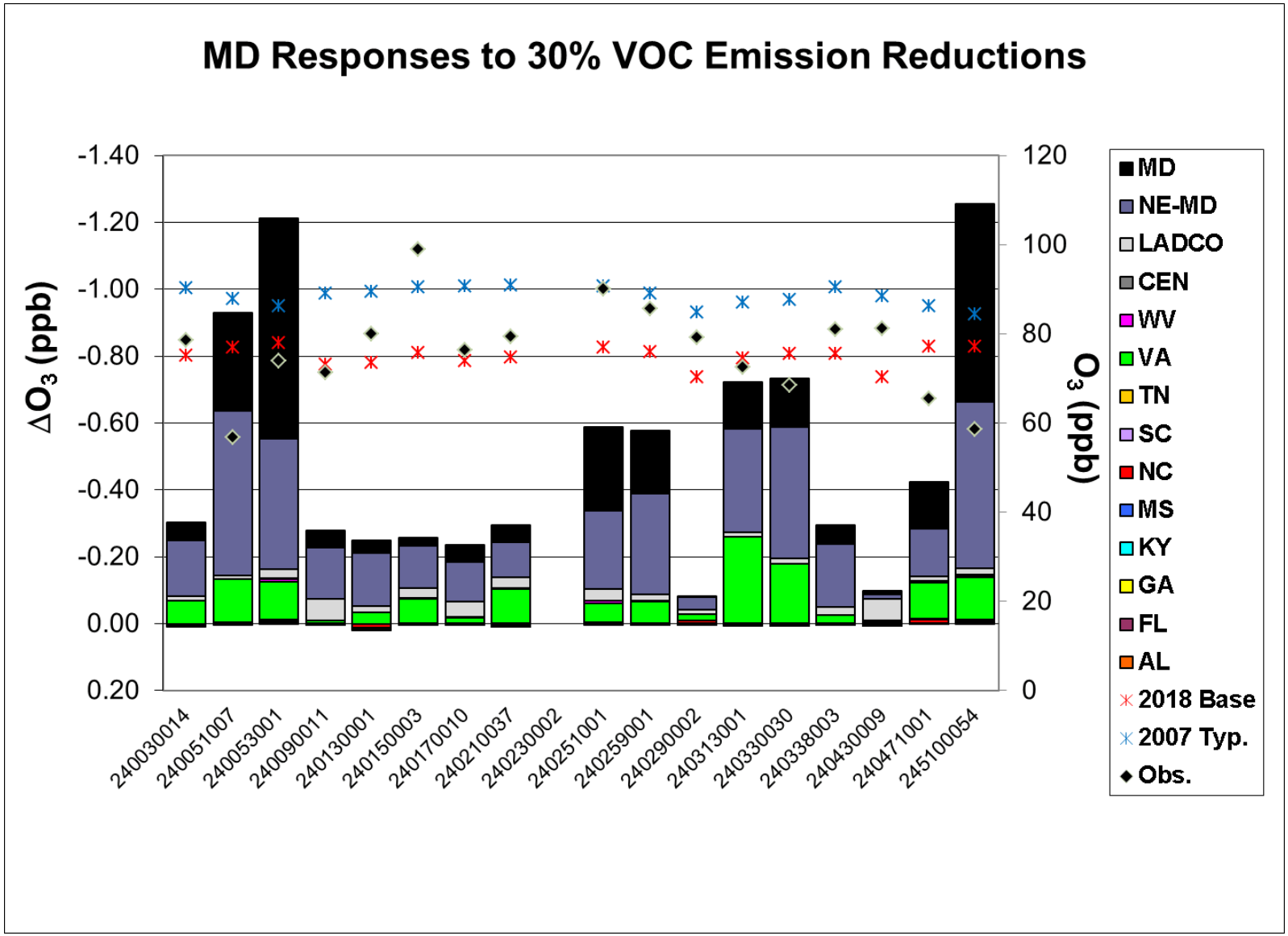


Figure 5-28 Absolute VOC sensitivities at Maryland sites (days with $O_3 \geq 70$ ppb in 2018)

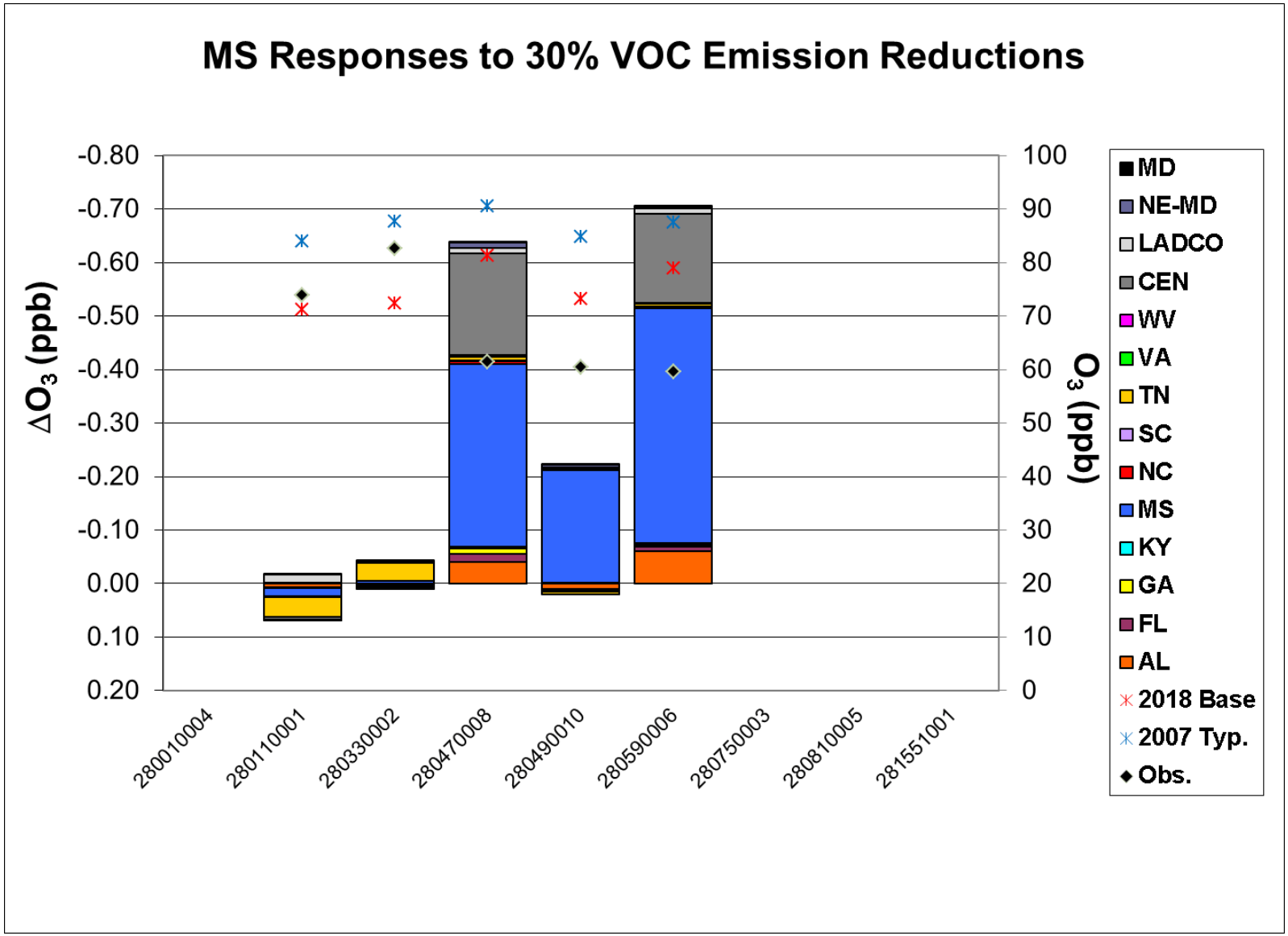


Figure 5-29 Absolute VOC sensitivities at Mississippi sites (days with $O_3 \geq 70$ ppb in 2018)

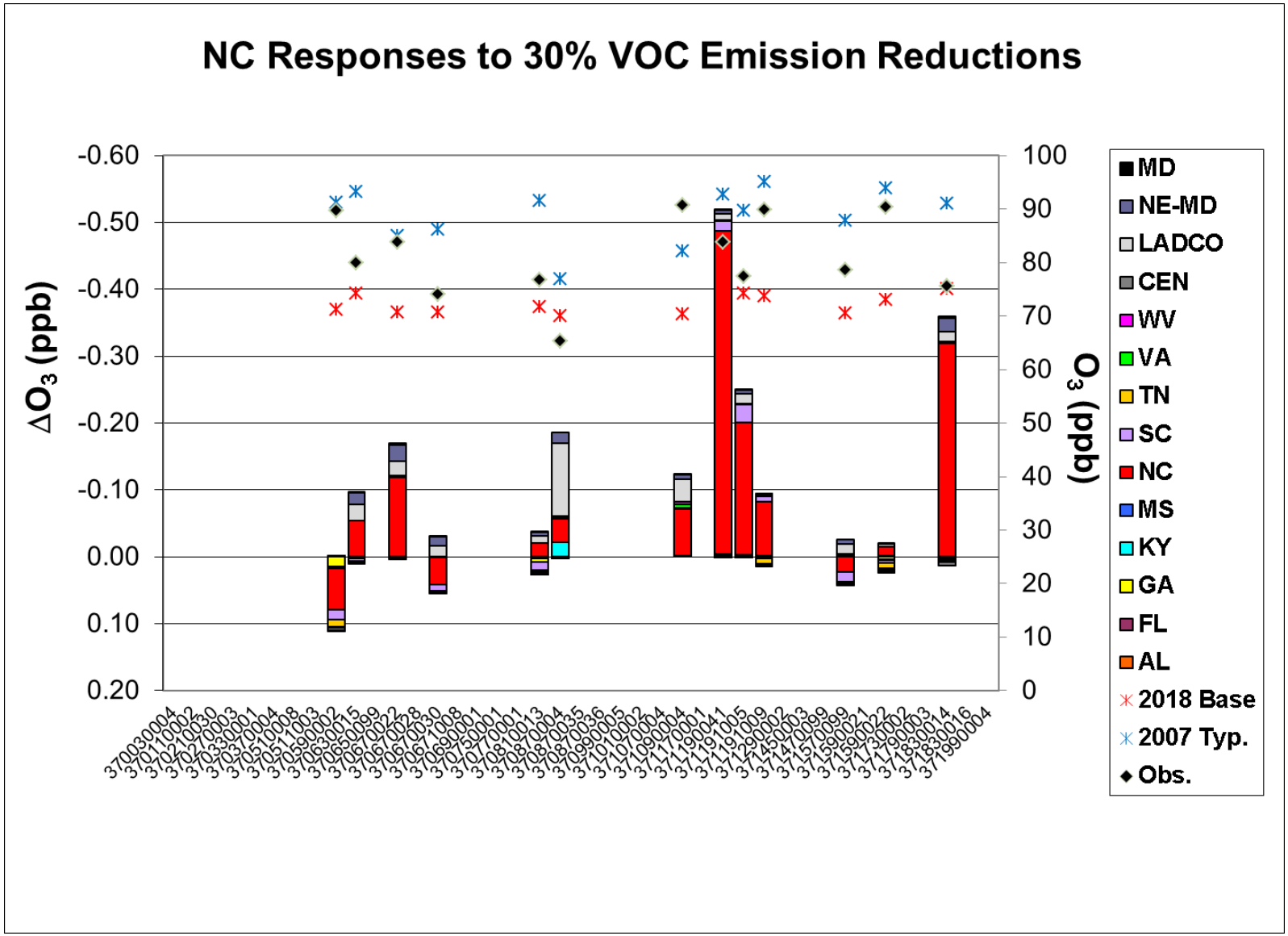


Figure 5-30 Absolute VOC sensitivities at North Carolina sites (days with $O_3 \geq 70$ ppb in 2018)

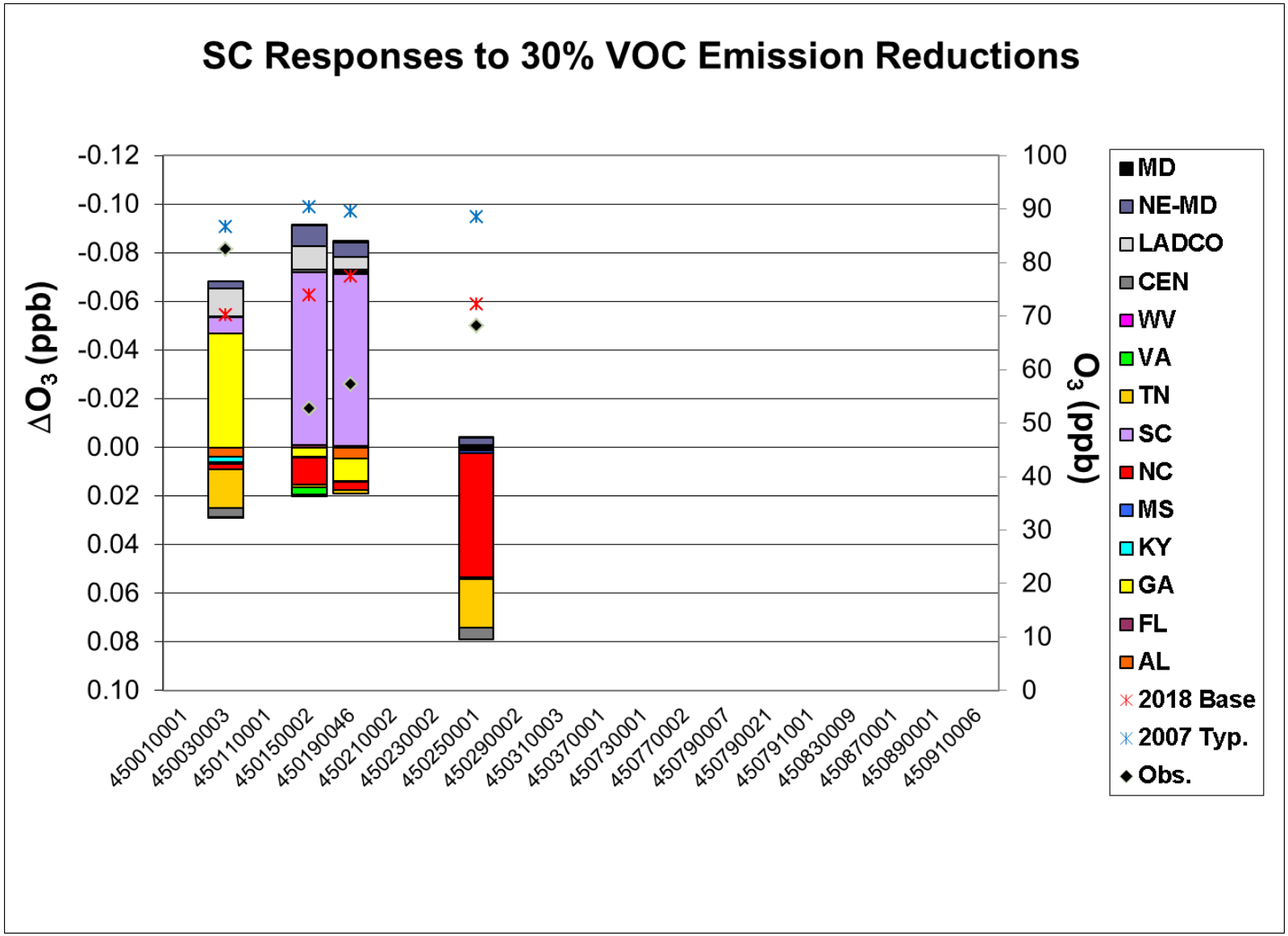


Figure 5-31 Absolute VOC sensitivities at South Carolina sites (days with $O_3 \geq 70$ ppb in 2018)

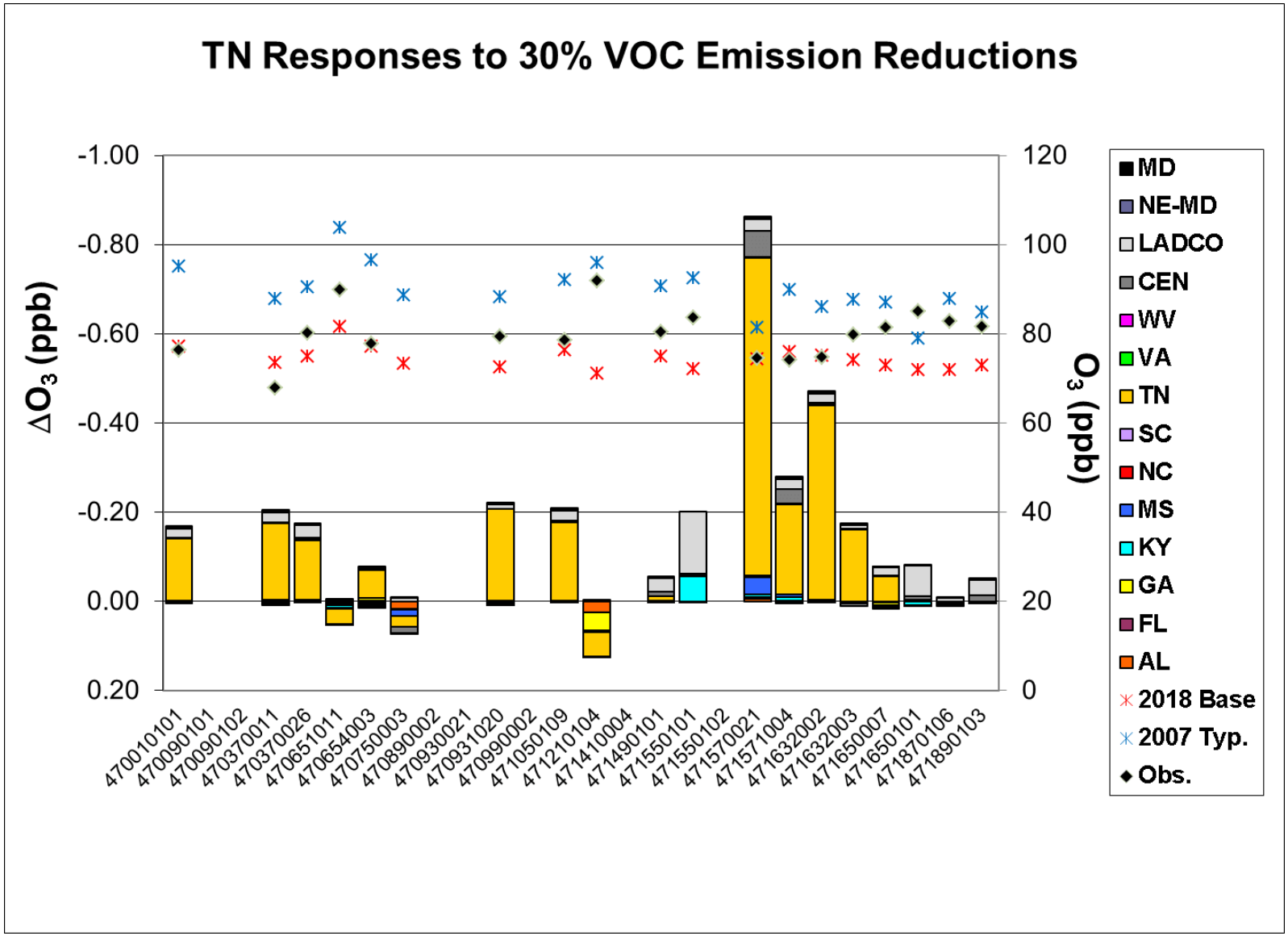


Figure 5-32 Absolute VOC sensitivities at Tennessee sites (days with $O_3 \geq 70$ ppb in 2018)

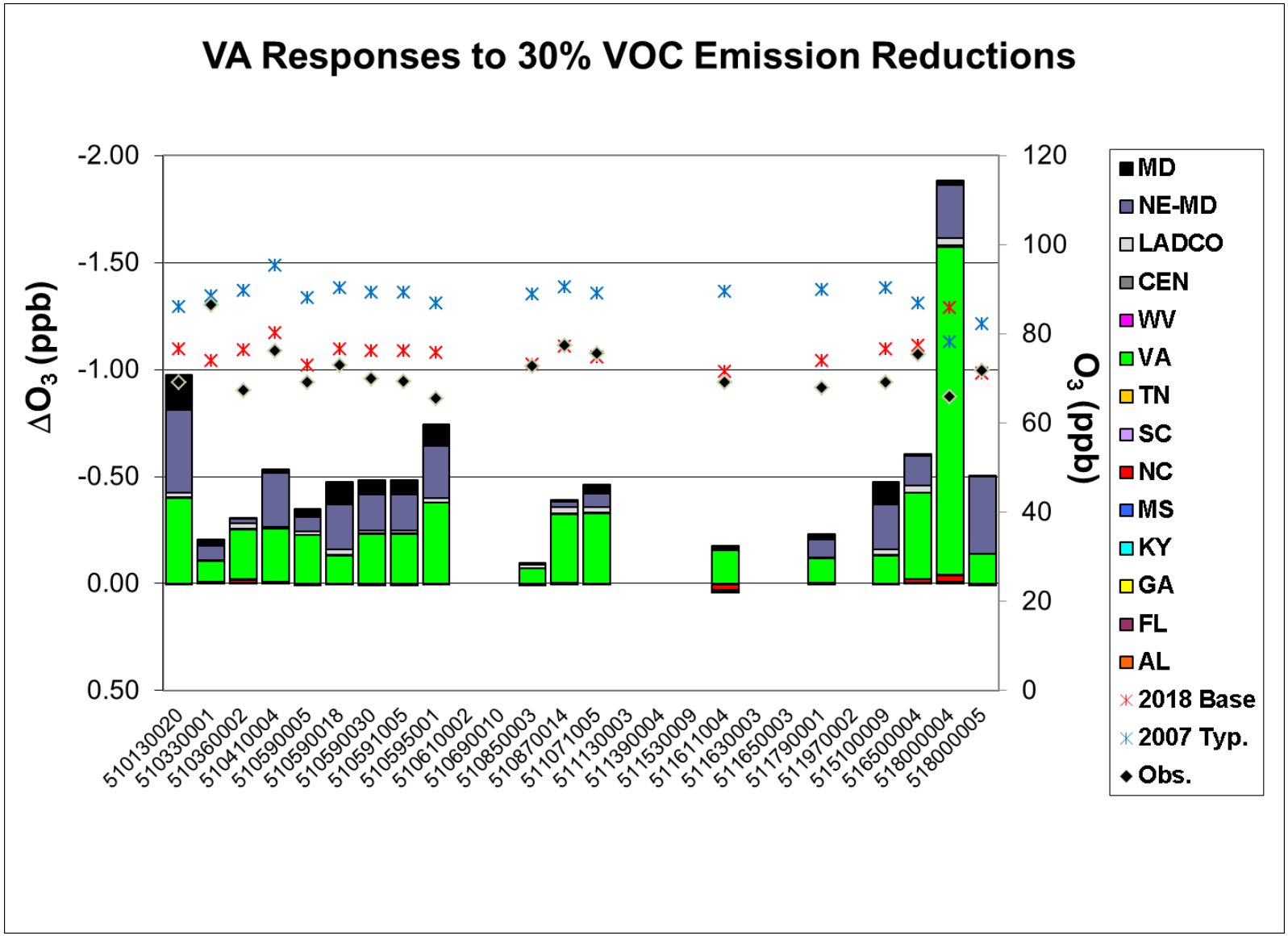


Figure 5-33 Absolute VOC sensitivities at Virginia sites (days with $O_3 \geq 70$ ppb in 2018)

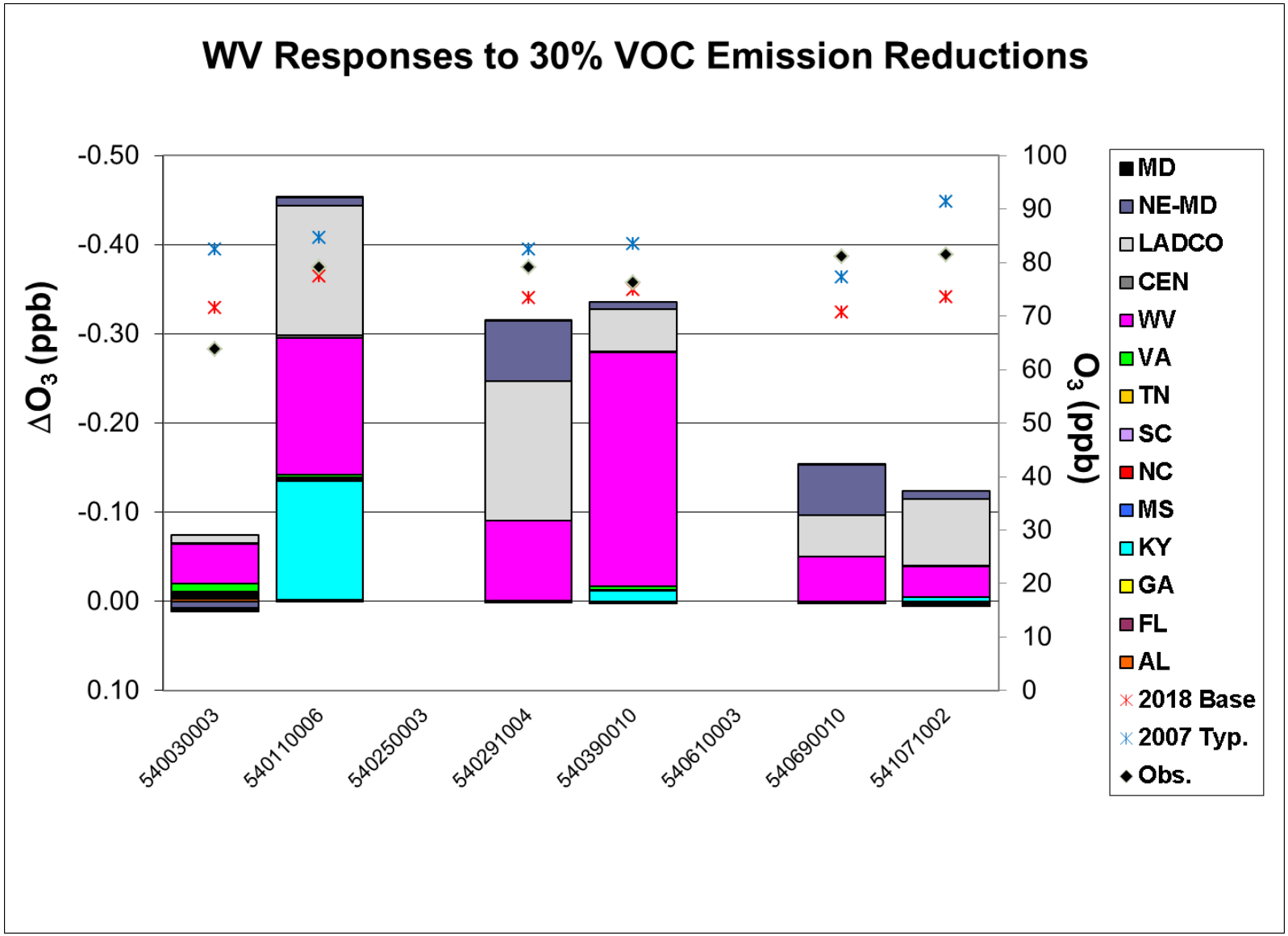


Figure 5-34 Absolute VOC sensitivities at West Virginia sites (days with $O_3 \geq 70$ ppb in 2018)

5.4 Relative Sensitivities

Relative sensitivities were calculated using RRFs derived from MATS and 2018 DVFs of Chapter 4, as described in Section Calculation of Relative Sensitivitiesfor sites that have at least one day in 2018 with predicted 8-hr maximum ozone concentration above 70 ppb. Charts were prepared showing the relative sensitivities as stacked bars for every monitor of each state in the domain.

5.4.1 Relative Sensitivities to NO_x emissions

Figure 5-35 through Figure 5-45 show the relative NO_x sensitivities for the 10 SESARM states (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia) and Maryland. The charts for the other 20 states in the 12-km SEMAP modeling domain can be found at http://semap.ce.gatech.edu/node/1861.

5.4.2 Relative Sensitivities to VOC emissions

Figure 5-46 through Figure 5-56 show the relative VOC sensitivities for the 10 SESARM states (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia) and Maryland. The charts for the other 20 states in the 12-km SEMAP modeling domain can be found at http://semap.ce.gatech.edu/node/1861.

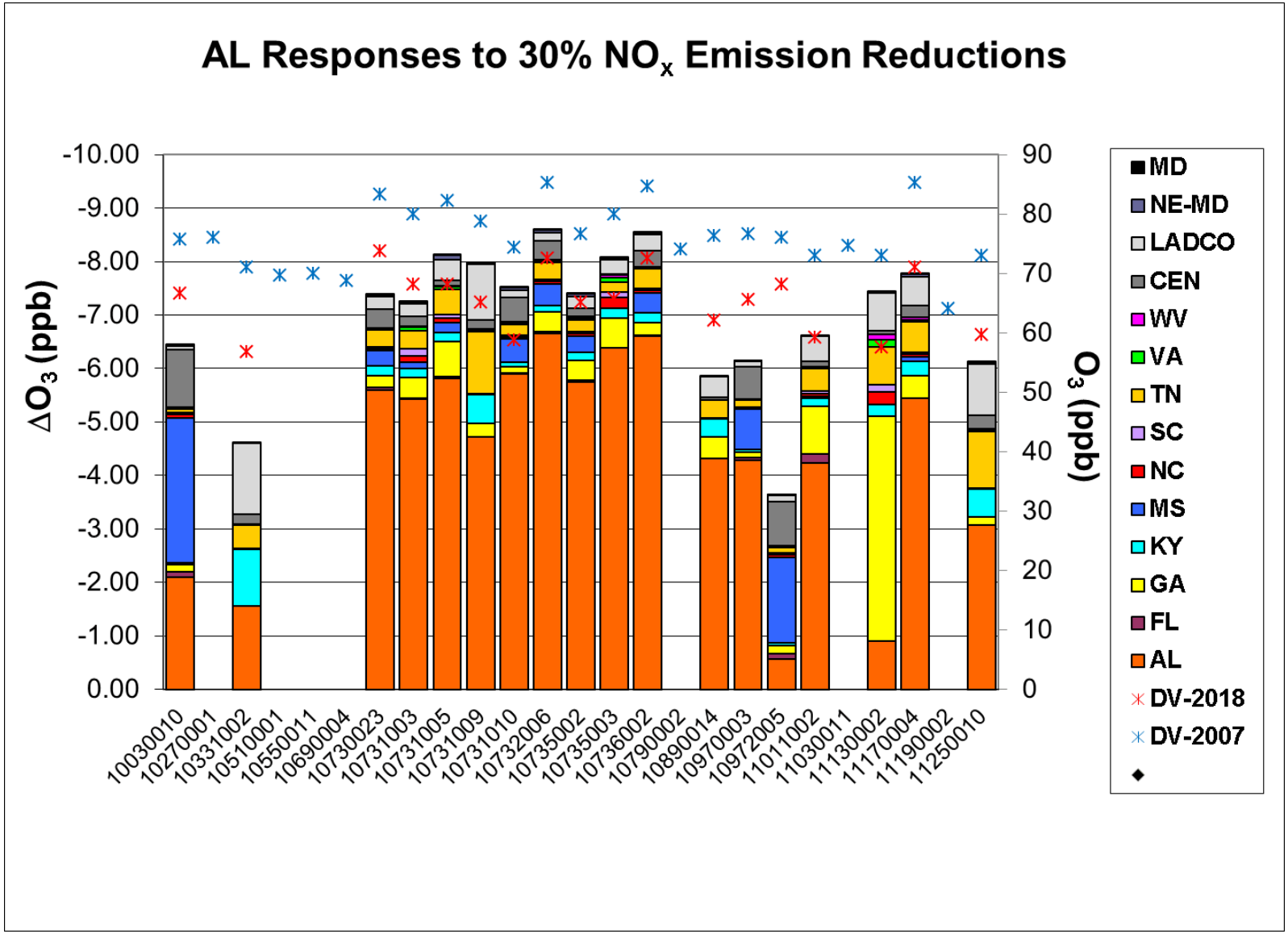


Figure 5-35 Relative NO_x sensitivities at Alabama sites

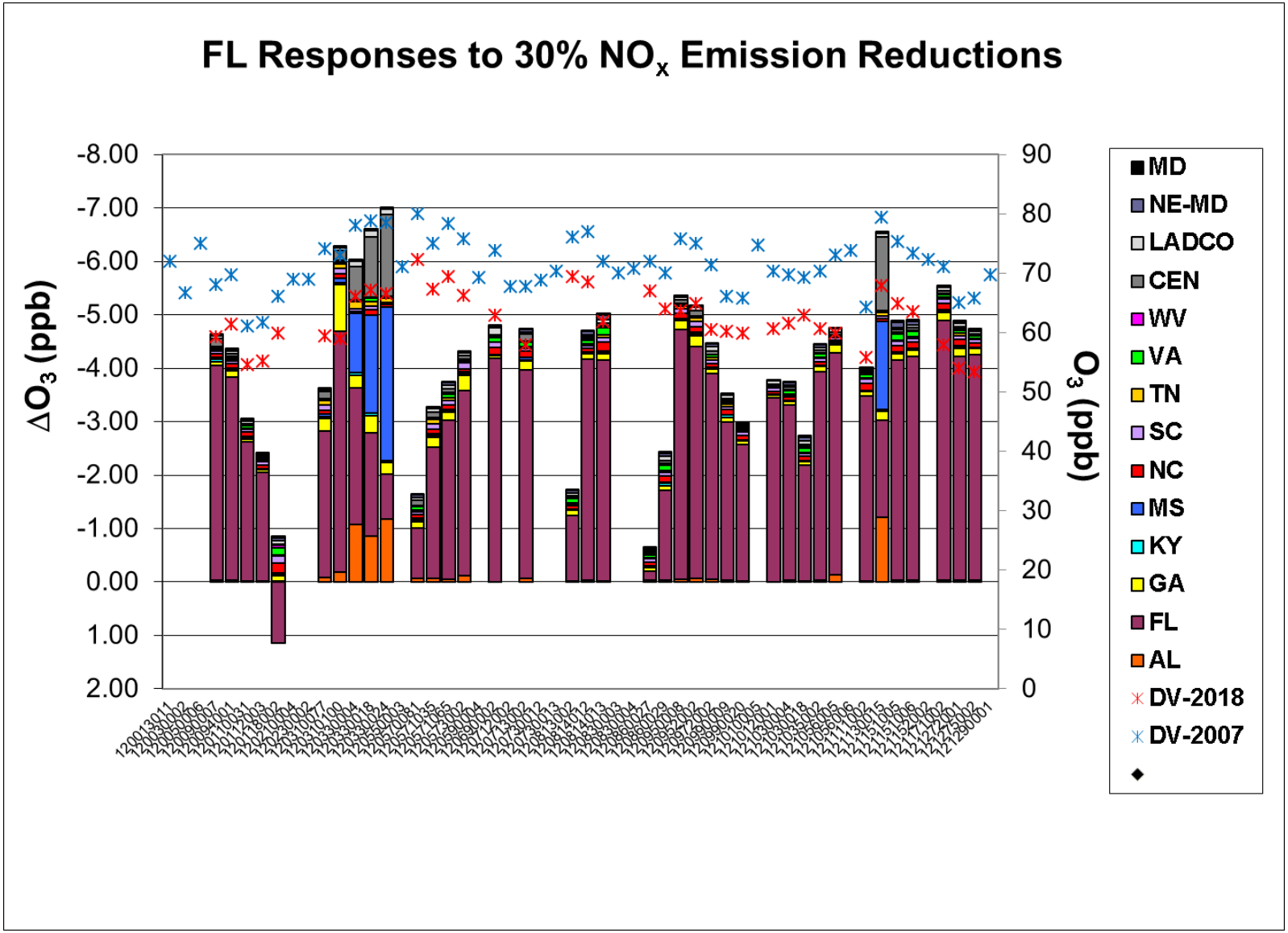


Figure 5-36 Relative NO_x sensitivities at Florida sites

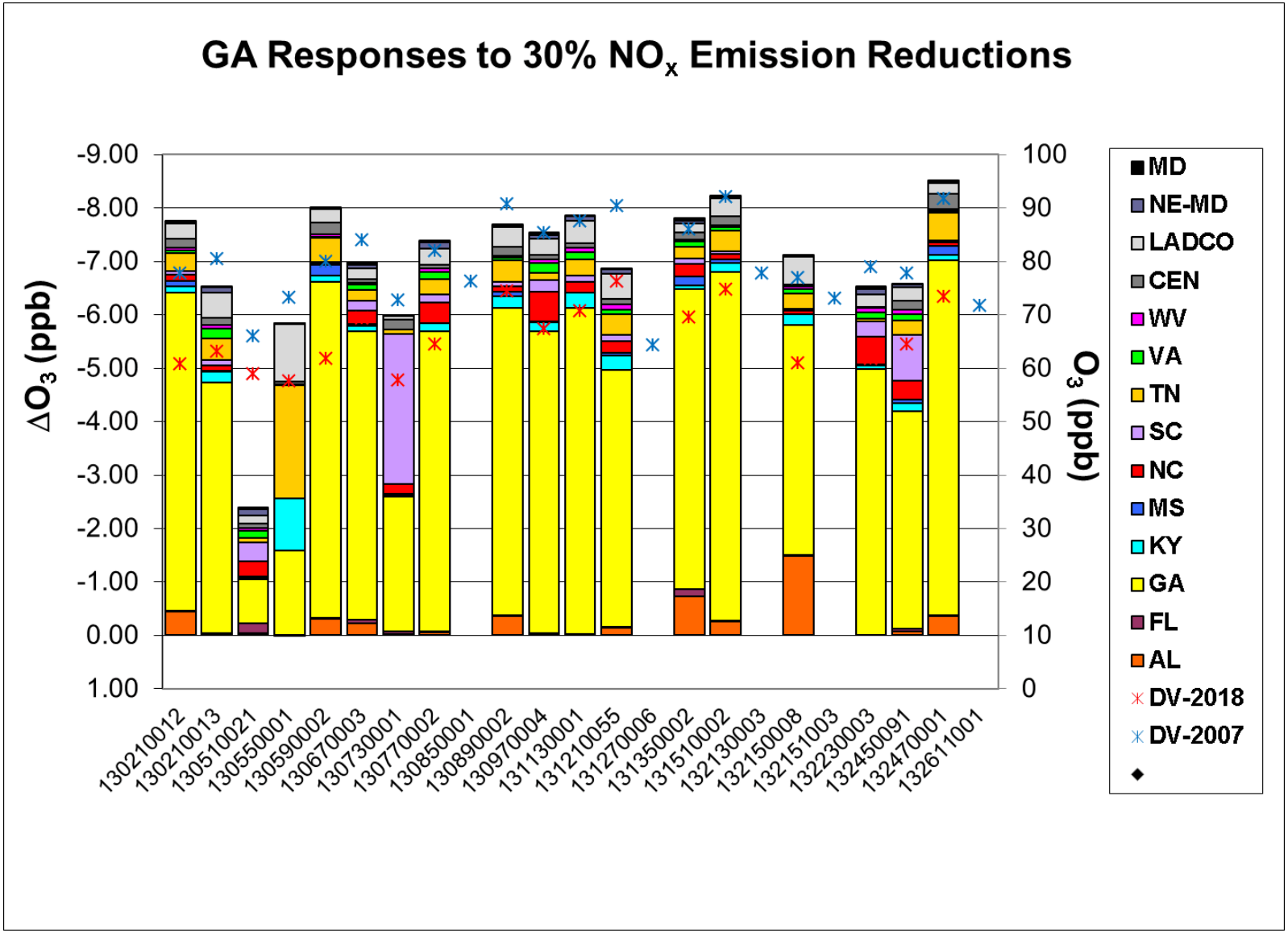


Figure 5-37 Relative NO_x sensitivities at Georgia sites

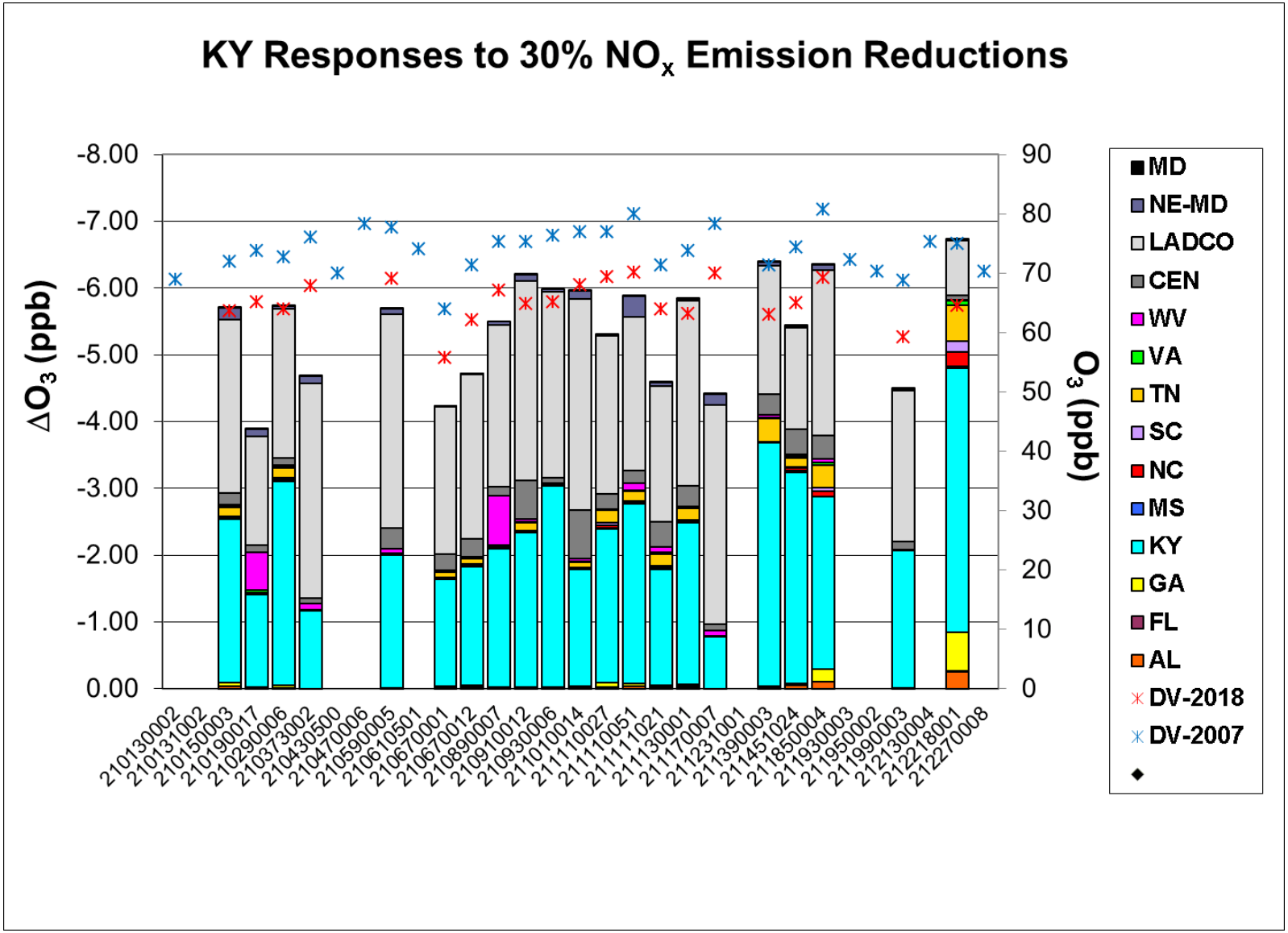


Figure 5-38 Relative NO_x sensitivities at Kentucky sites

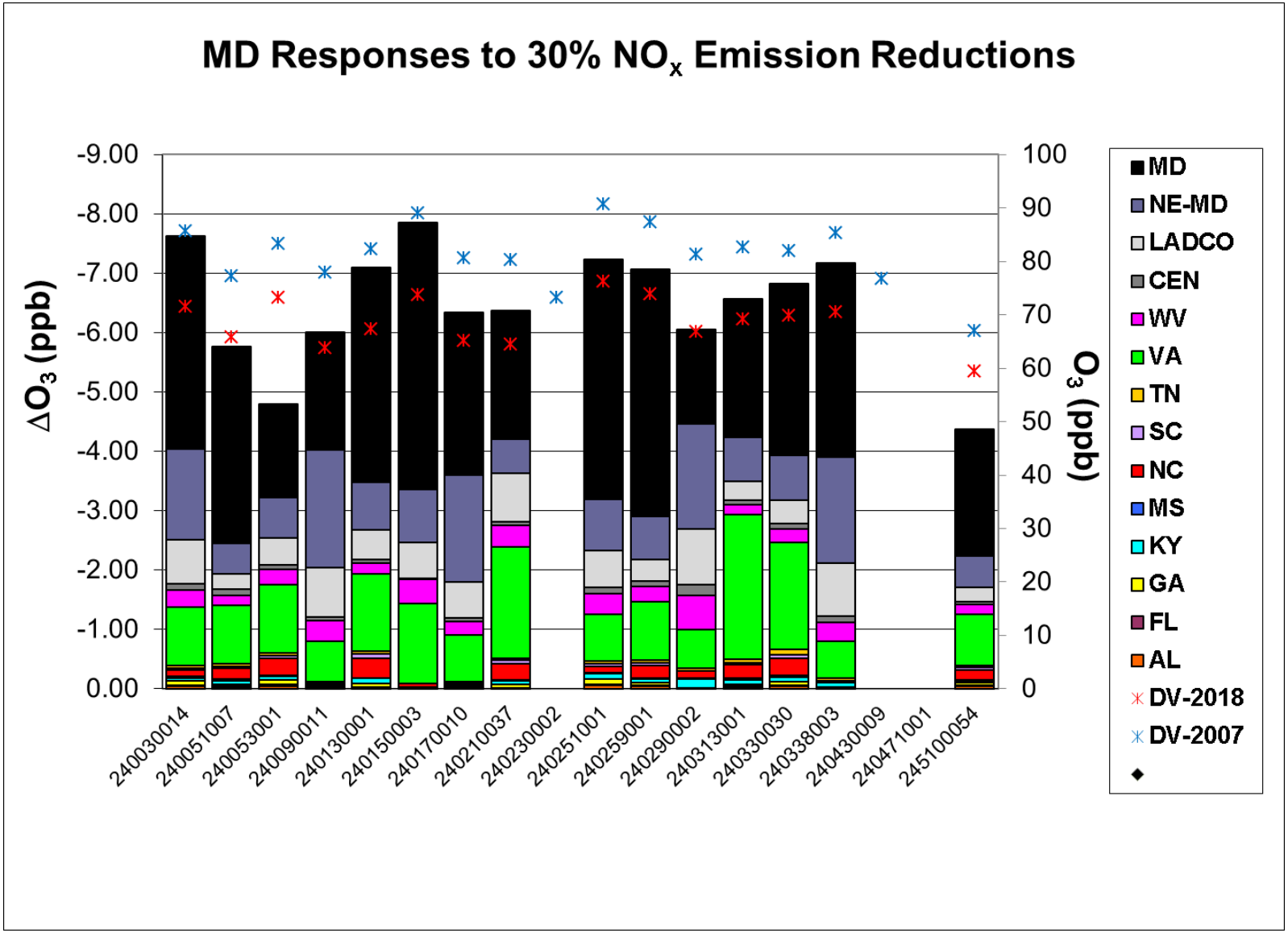


Figure 5-39 Relative NO_x sensitivities at Maryland sites

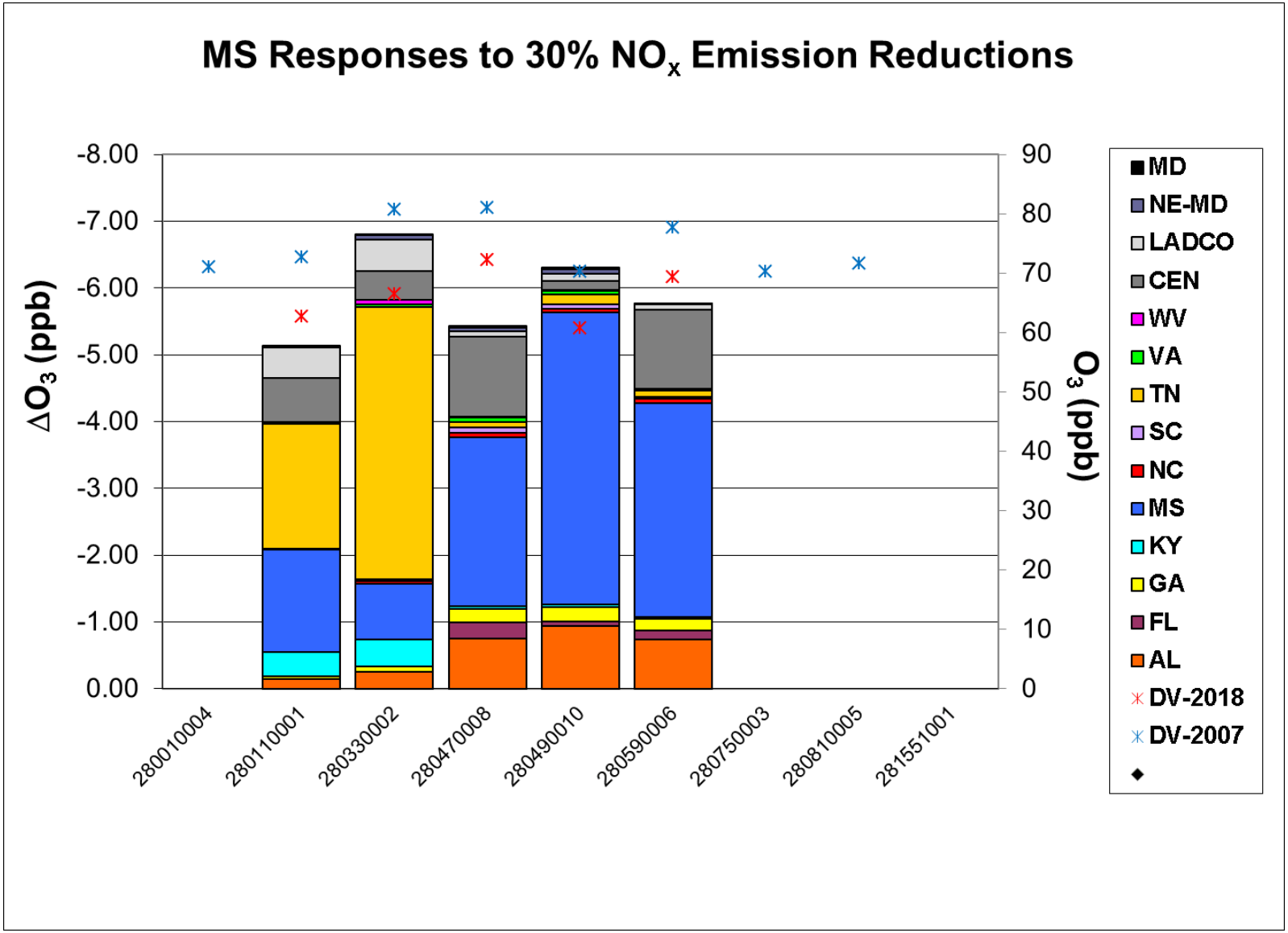


Figure 5-40 Relative NO_x sensitivities at Mississippi sites

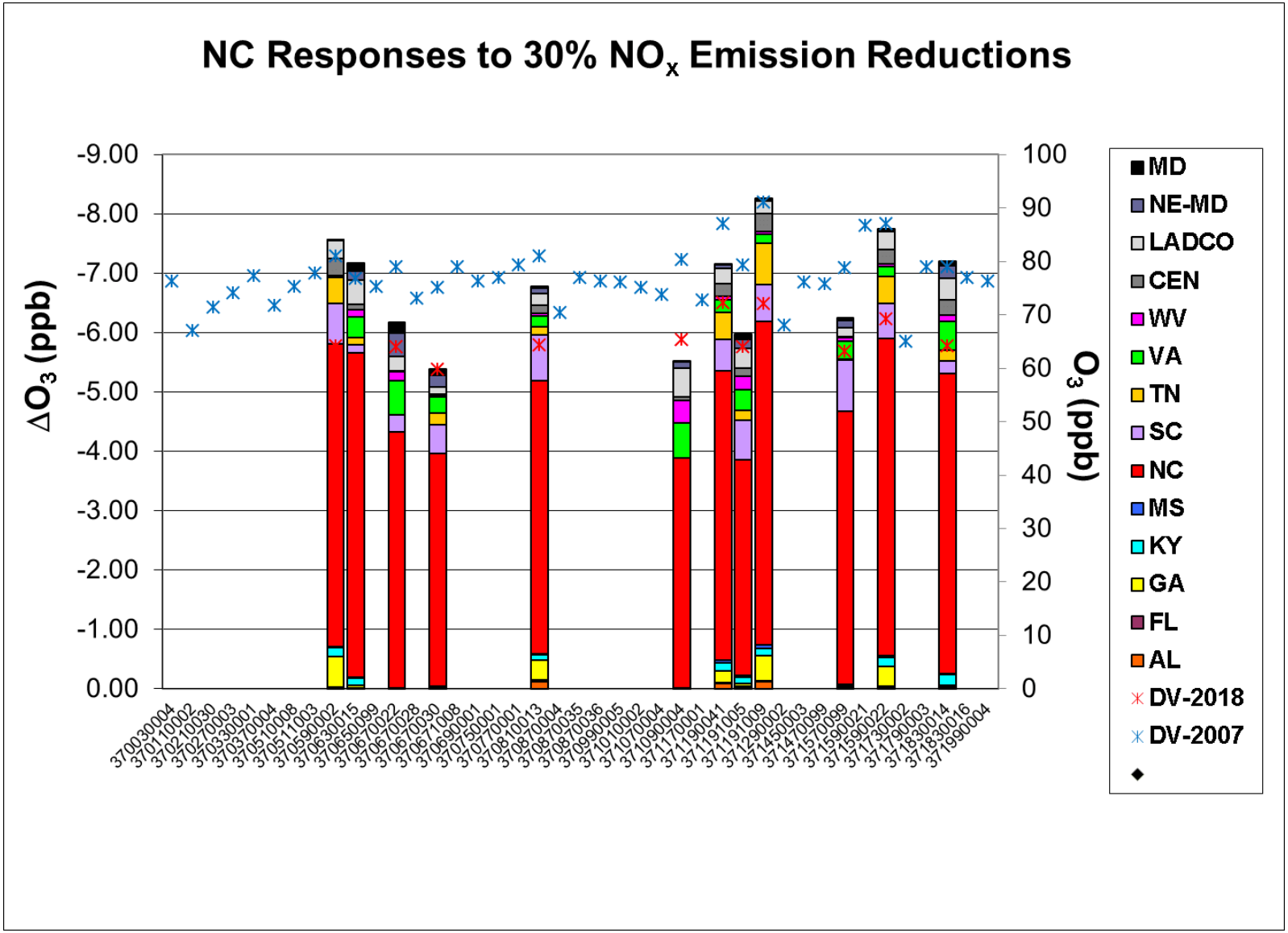


Figure 5-41 Relative NO_x sensitivities at North Carolina sites

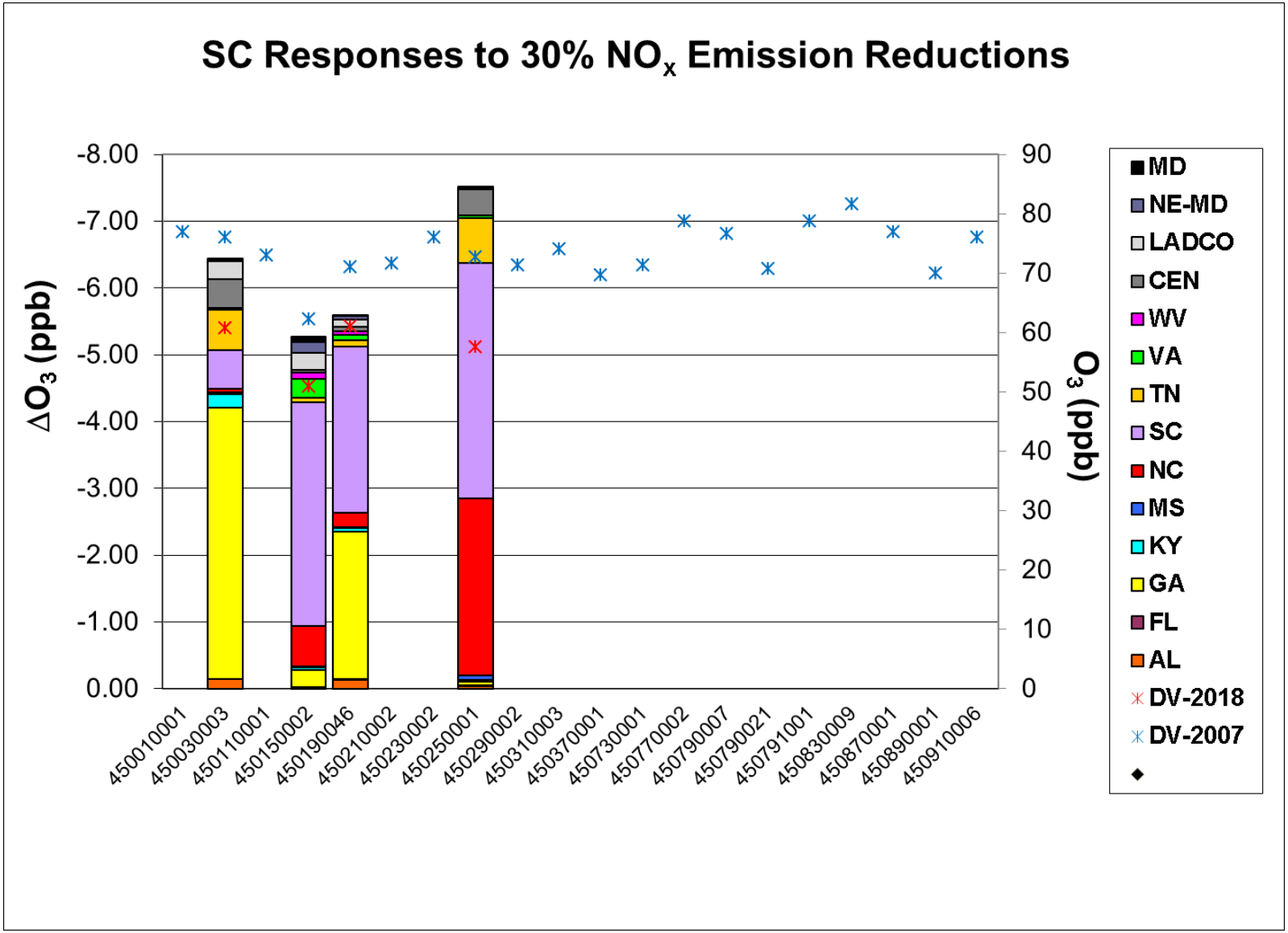


Figure 5-42 Relative NO_x sensitivities at South Carolina sites

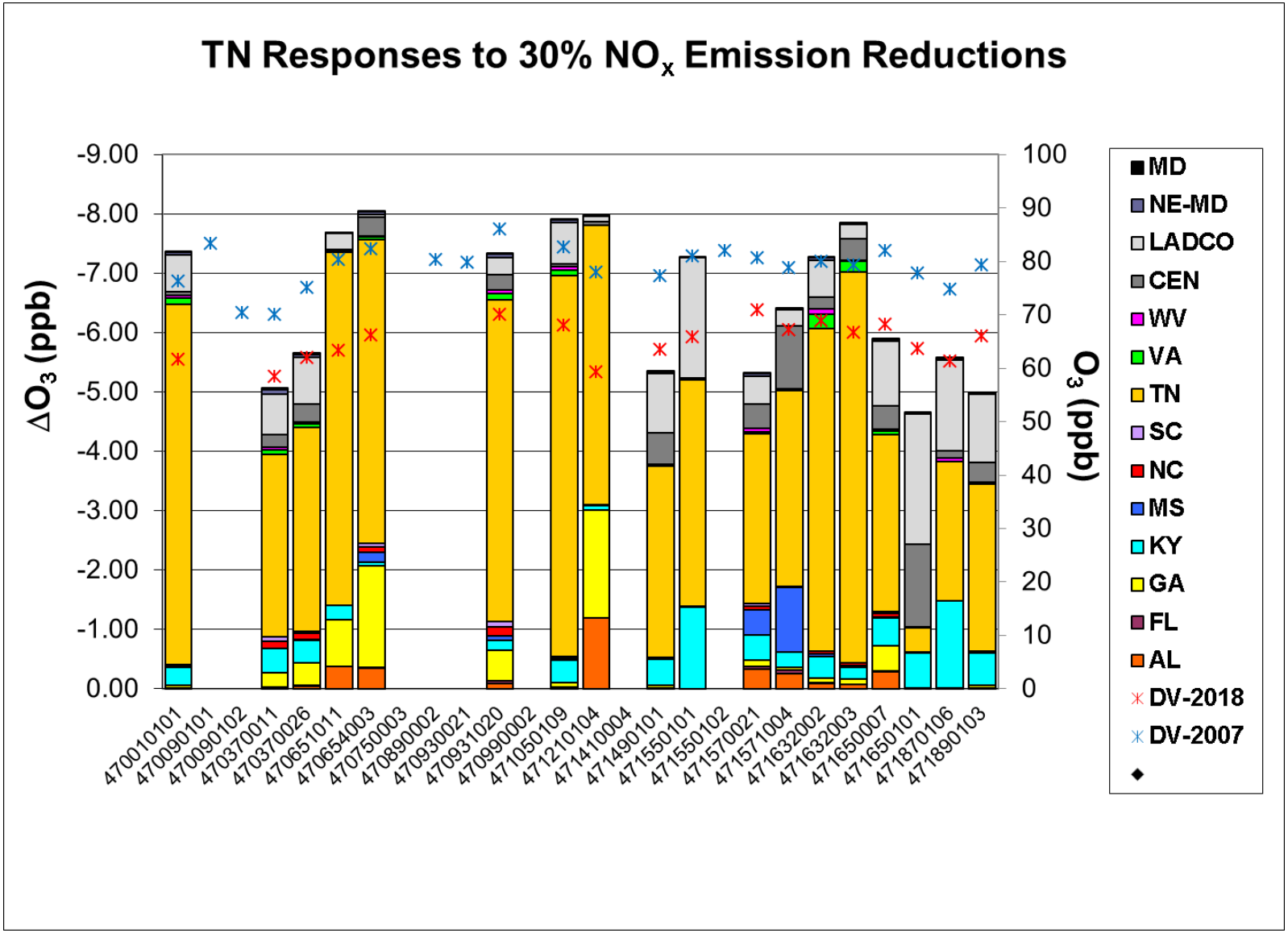


Figure 5-43 Relative NO_x sensitivities at Tennessee sites

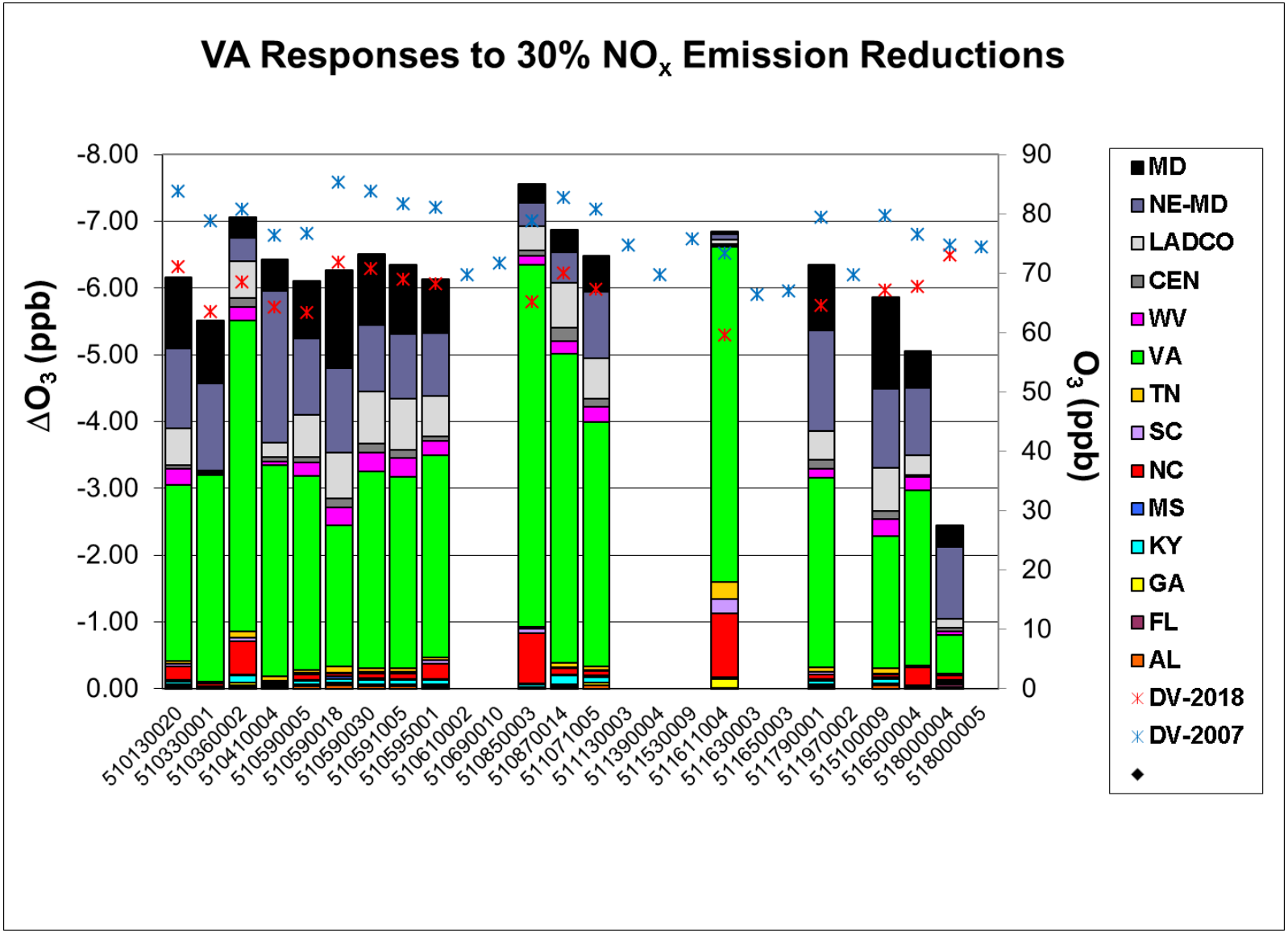


Figure 5-44 Relative NO_x sensitivities at Virginia sites

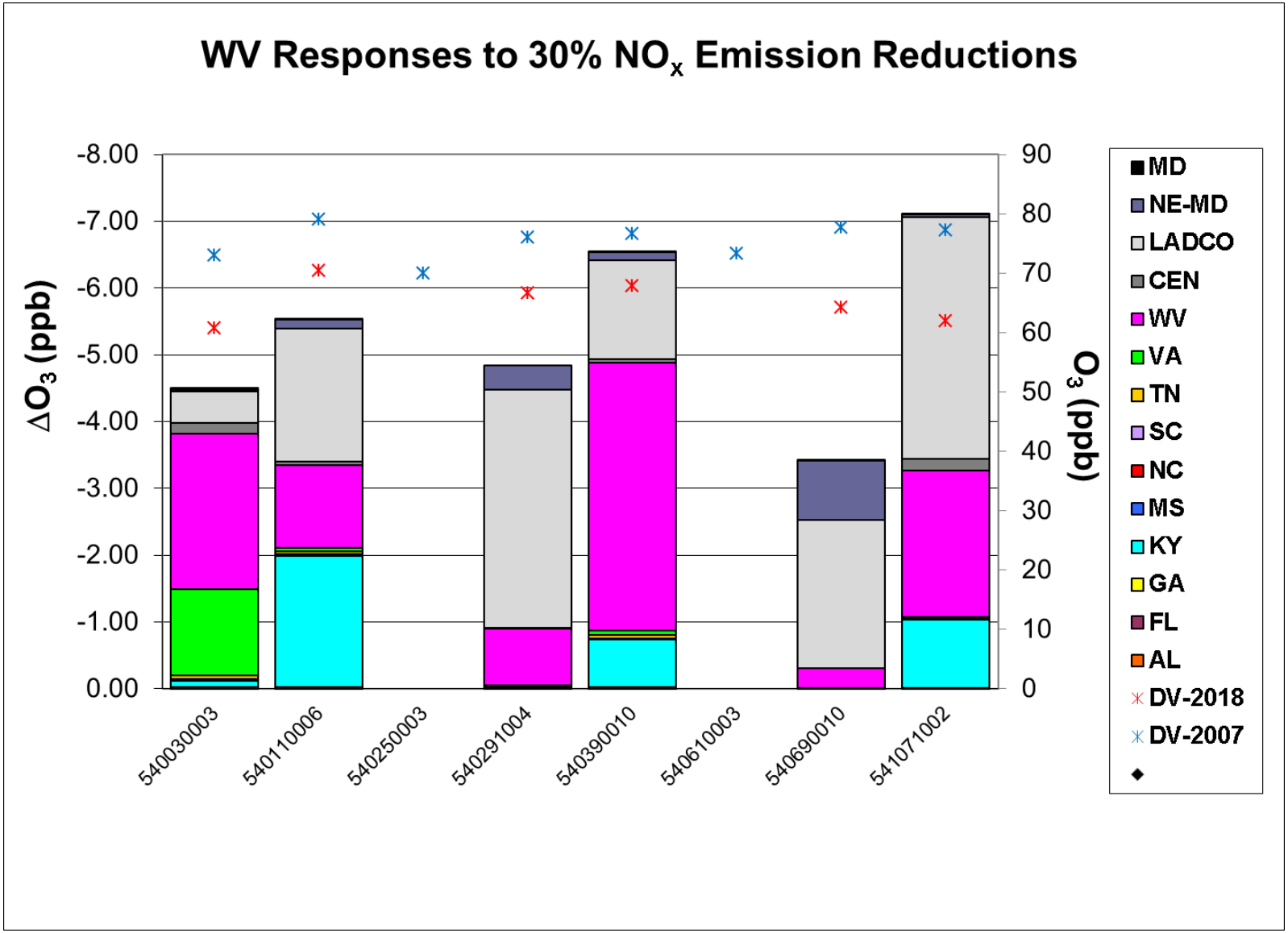


Figure 5-45 Relative NO_x sensitivities at West Virginia sites

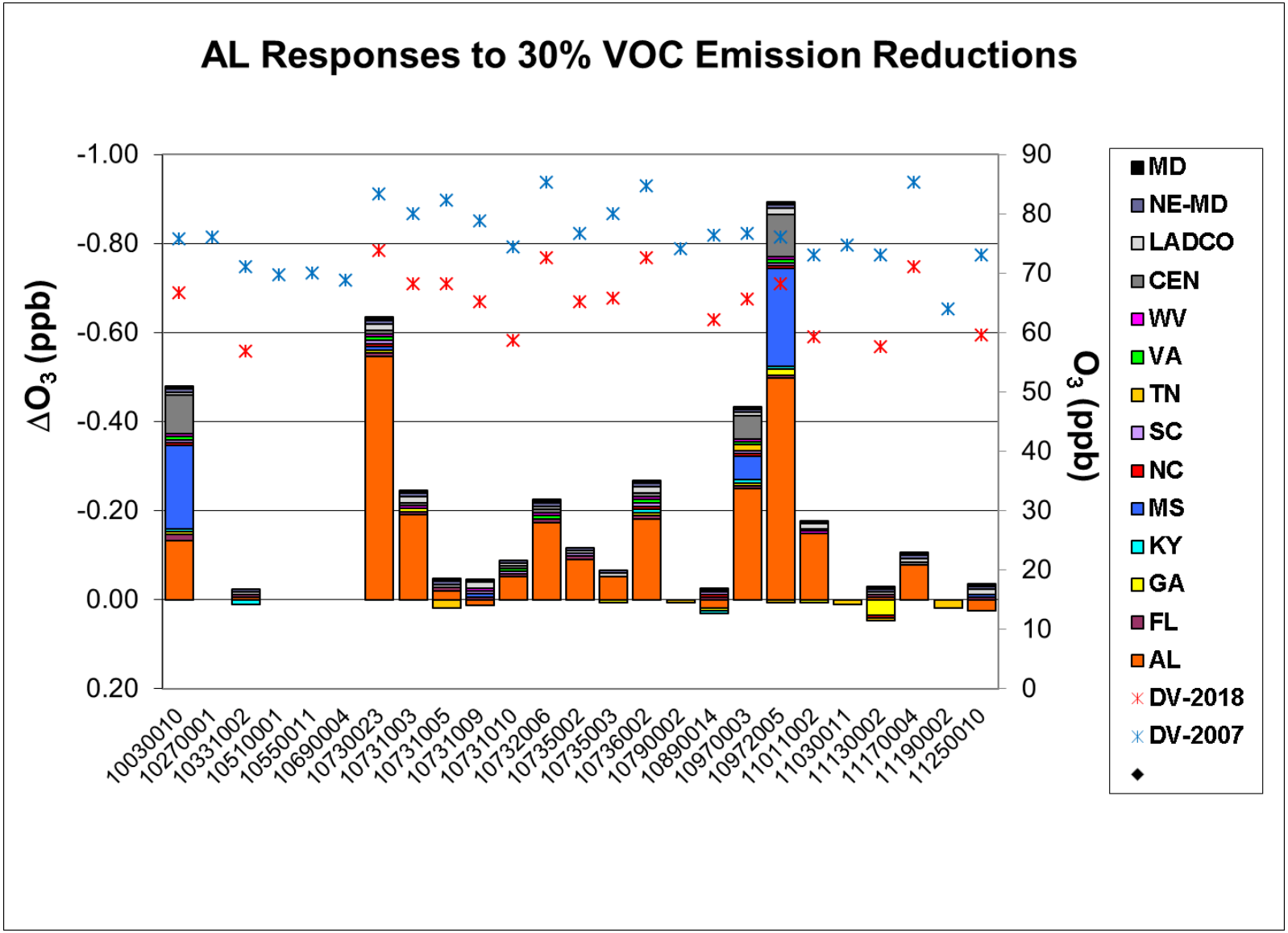


Figure 5-46 Relative VOC sensitivities at Alabama sites

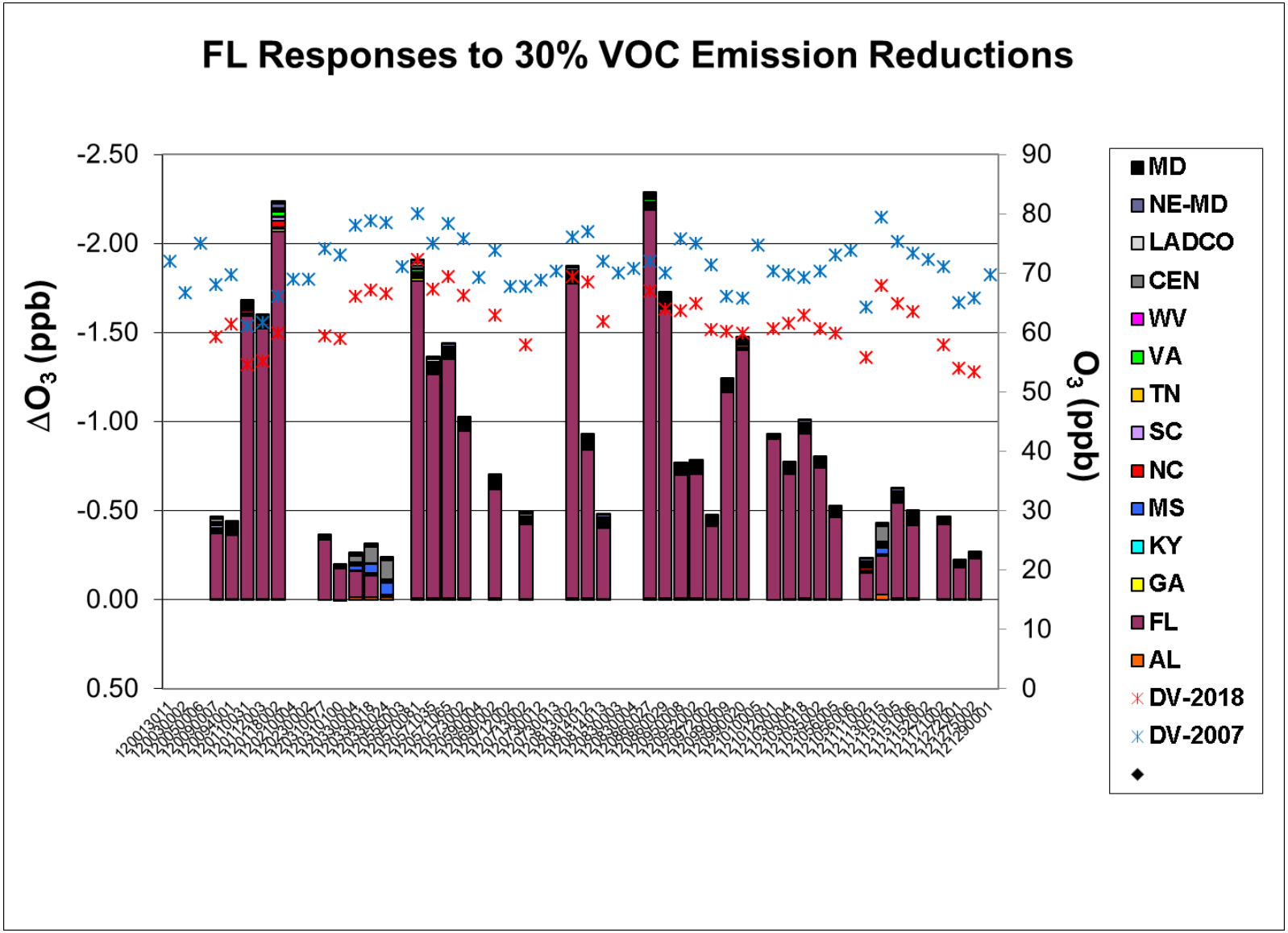


Figure 5-47 Relative VOC sensitivities at Florida sites

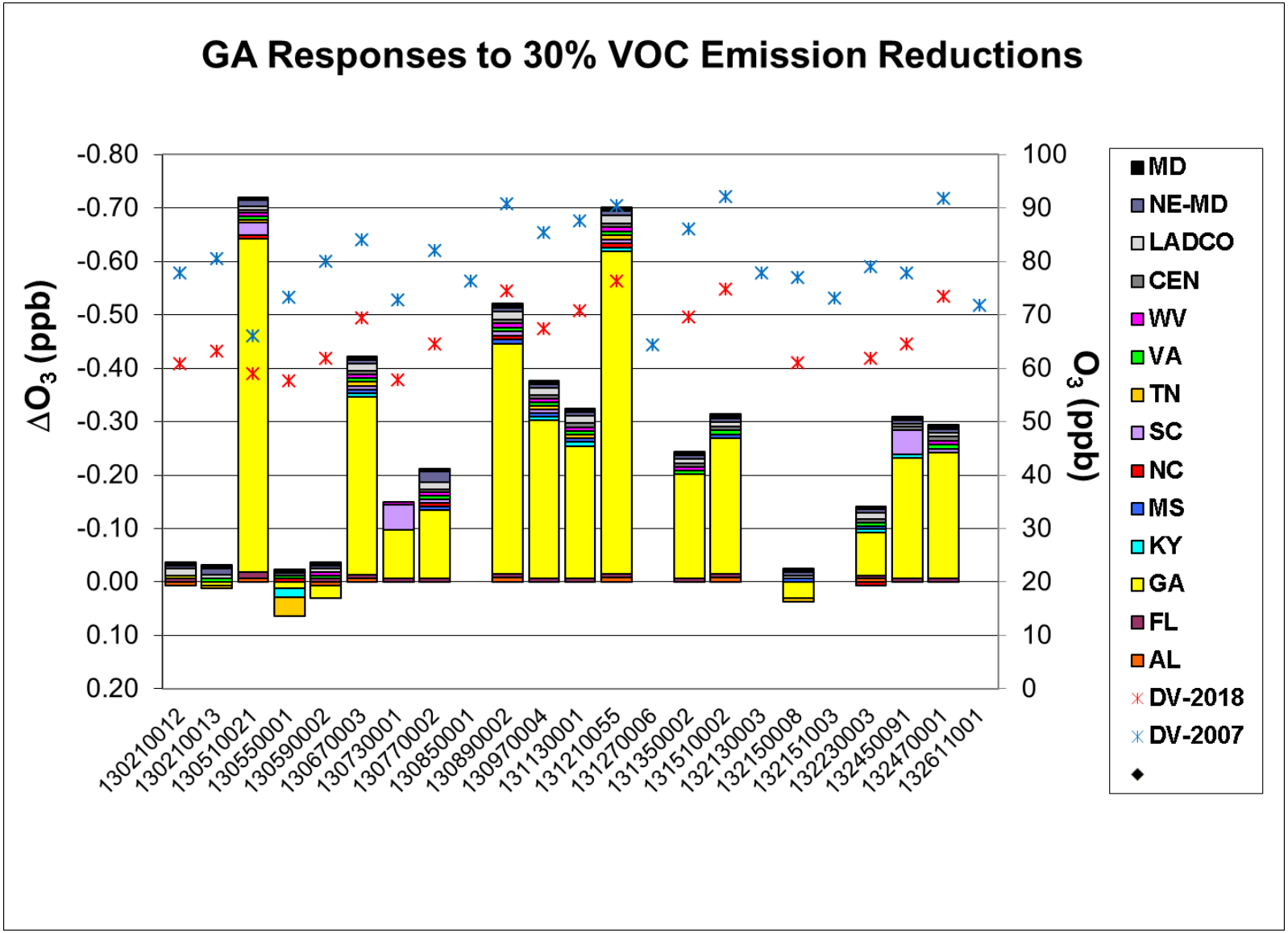


Figure 5-48 Relative VOC sensitivities at Georgia sites

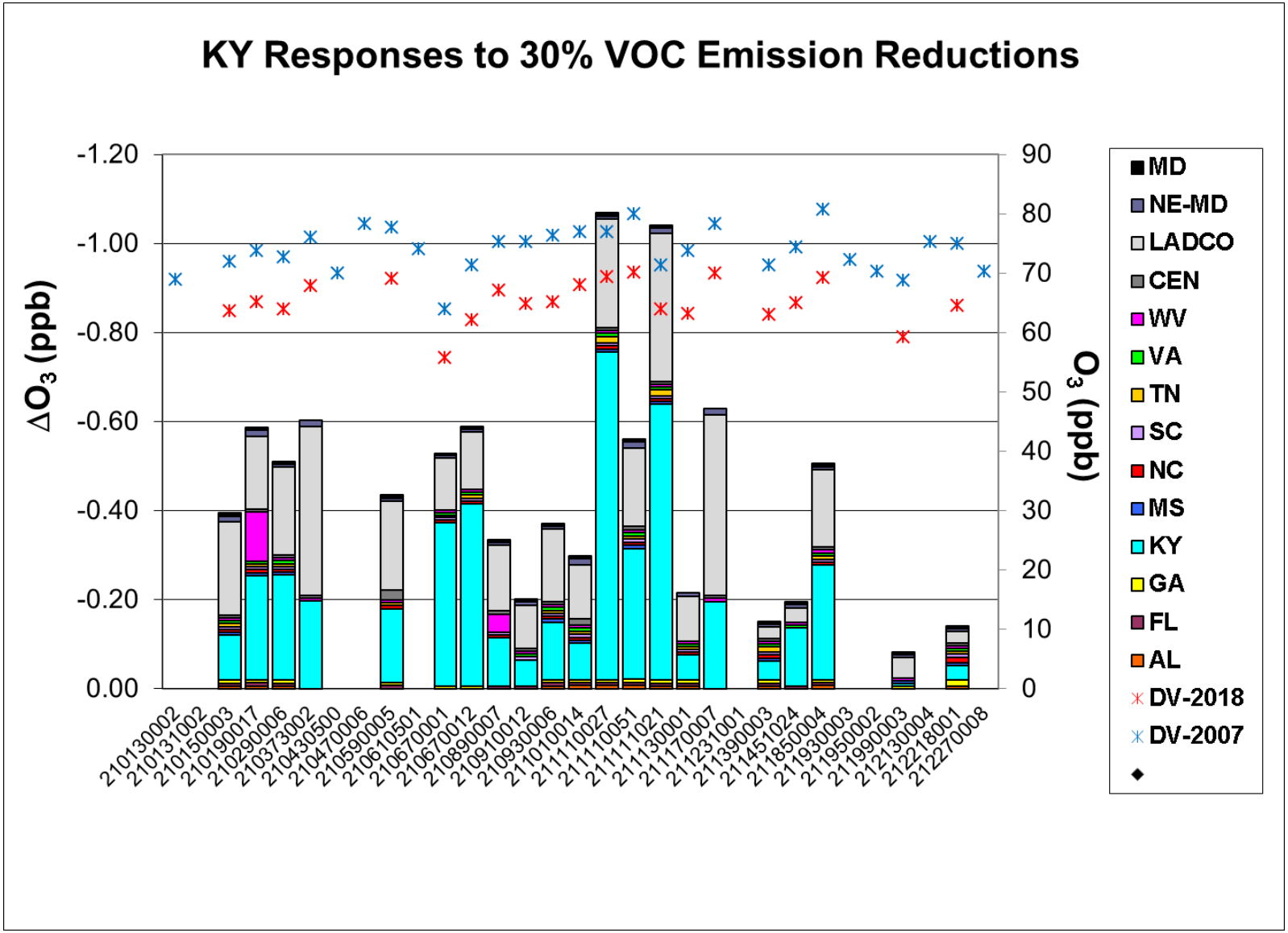


Figure 5-49 Relative VOC sensitivities at Kentucky sites

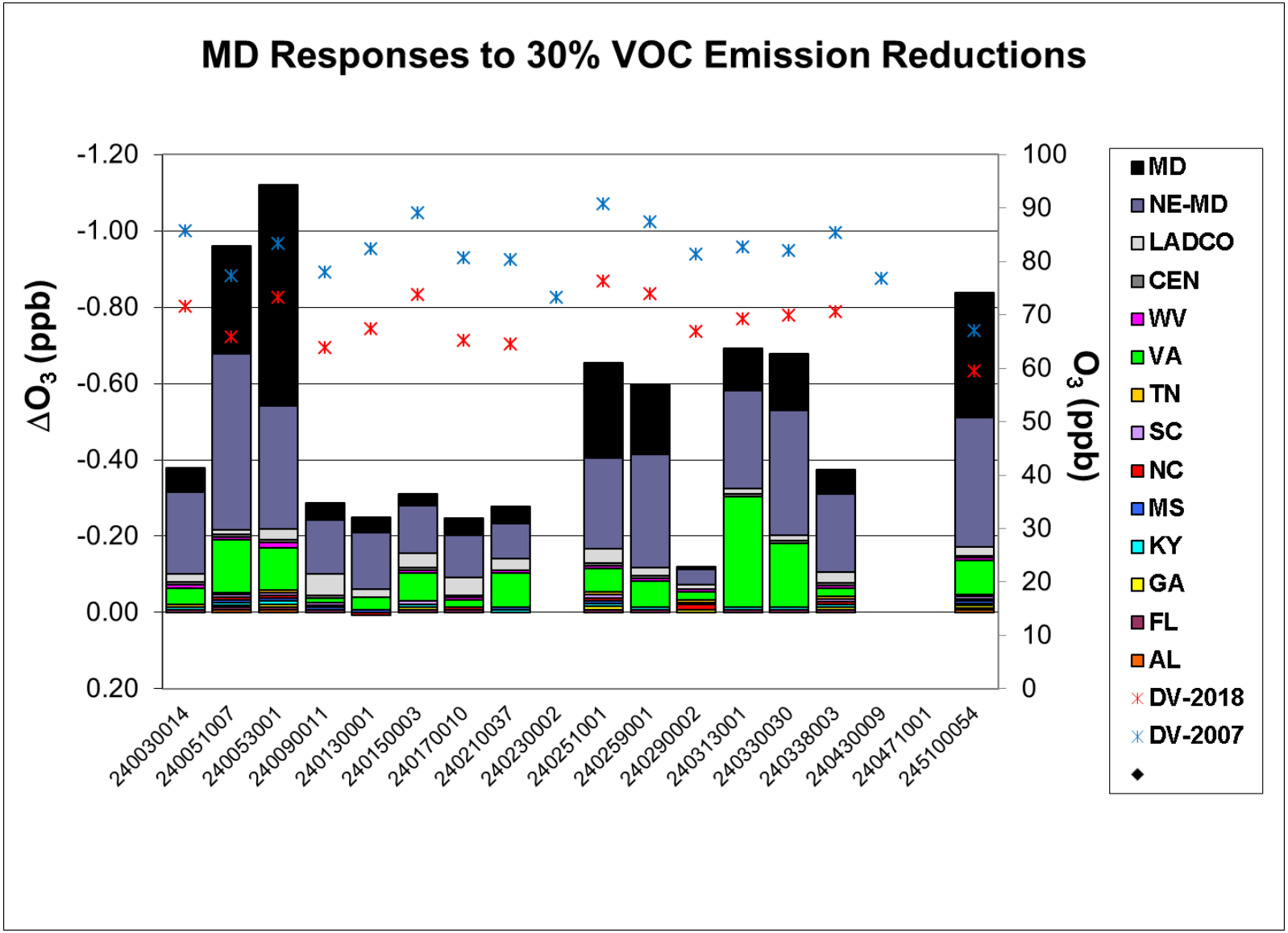


Figure 5-50 Relative VOC sensitivities at Maryland sites

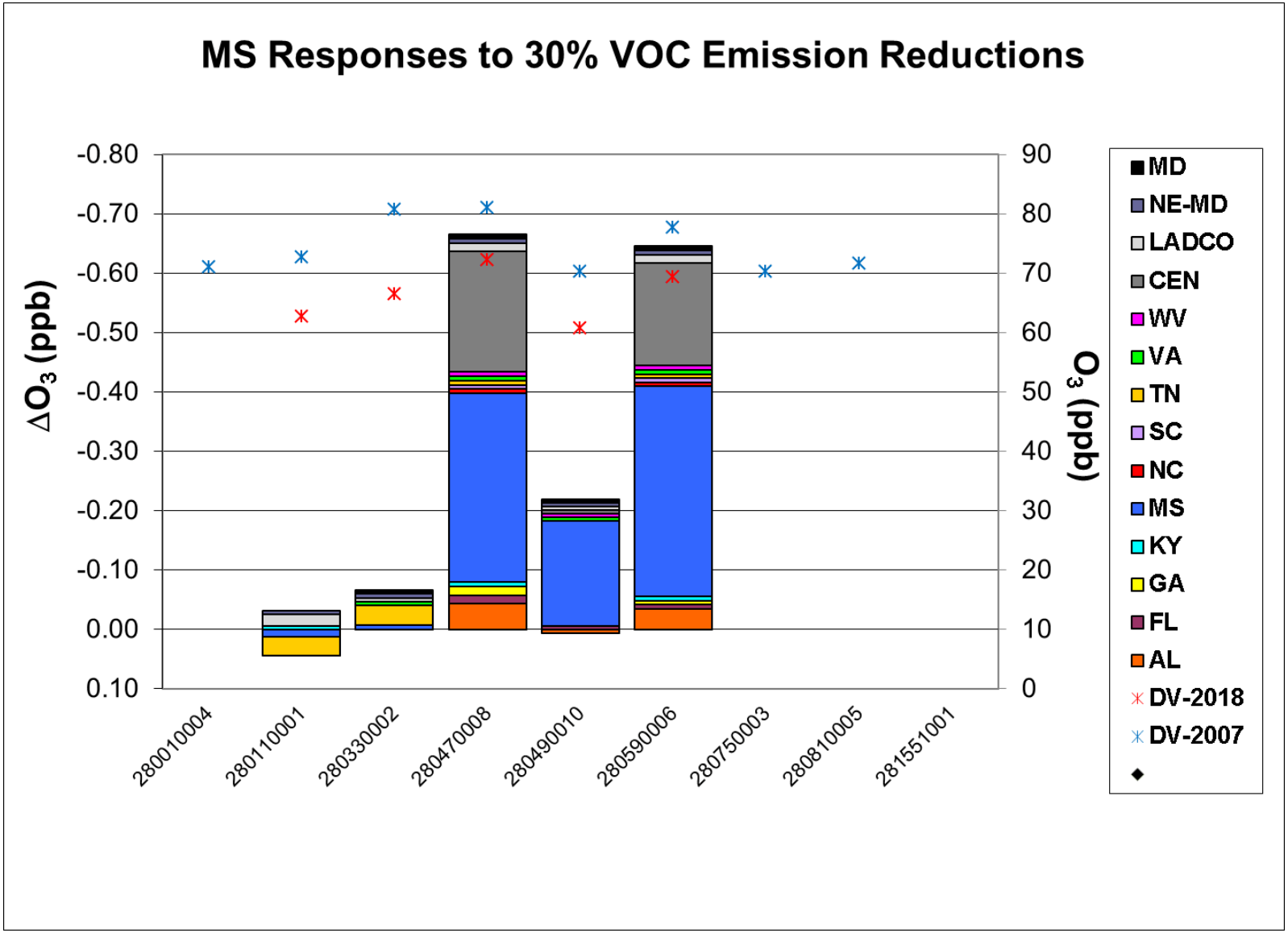


Figure 5-51 Relative VOC sensitivities at Mississippi sites

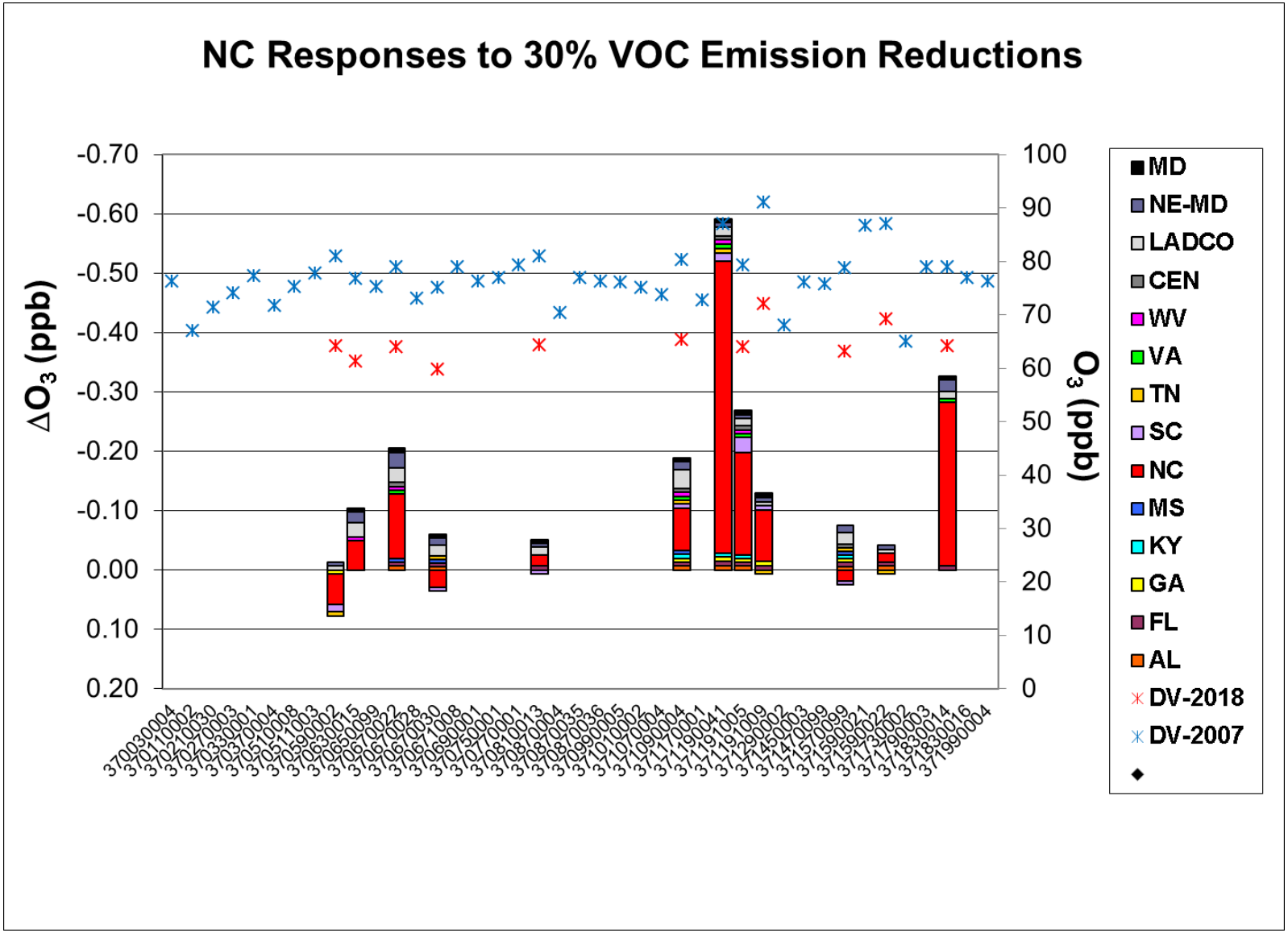


Figure 5-52 Relative VOC sensitivities at North Carolina sites

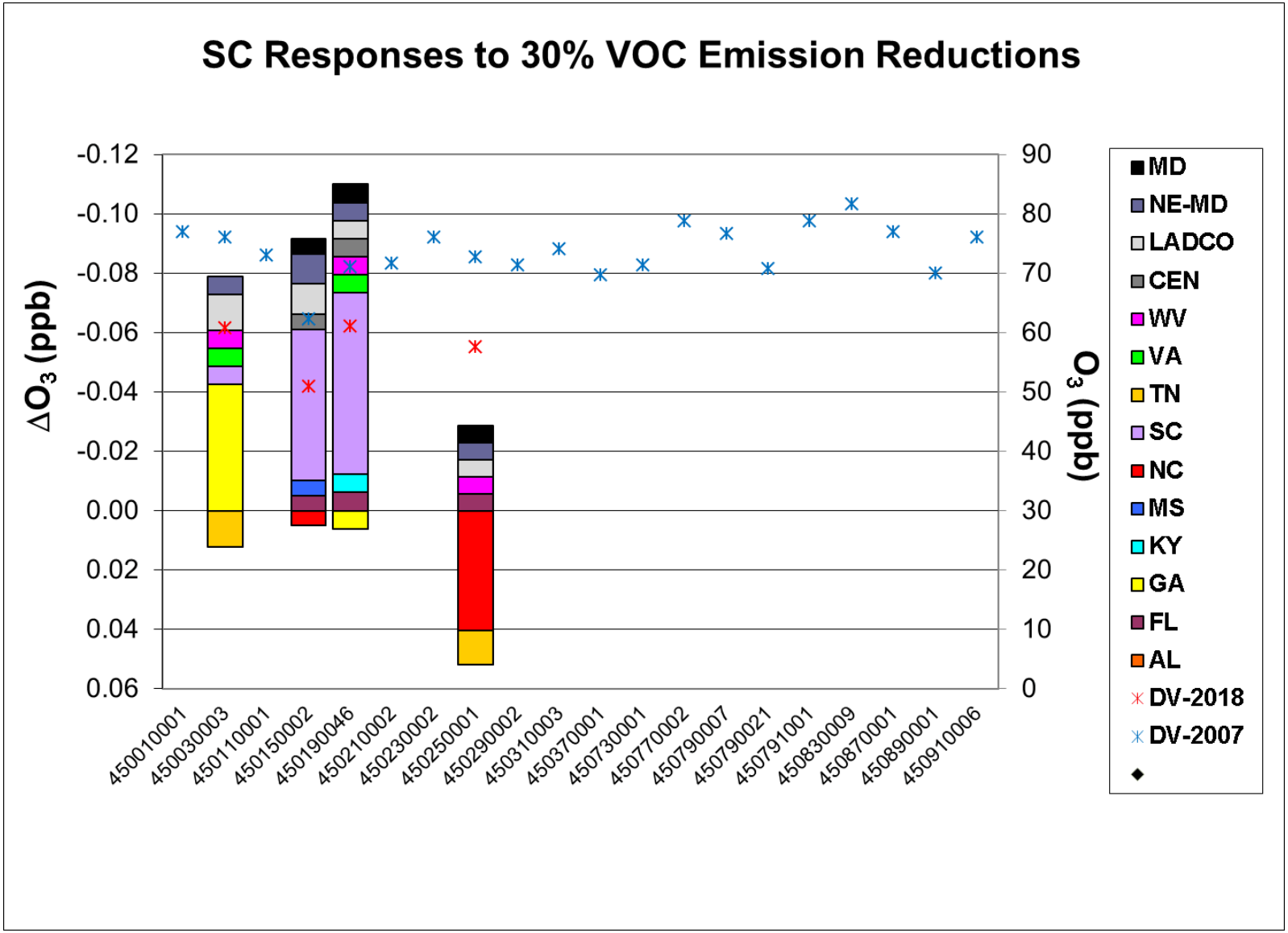


Figure 5-53 Relative VOC sensitivities at South Carolina sites

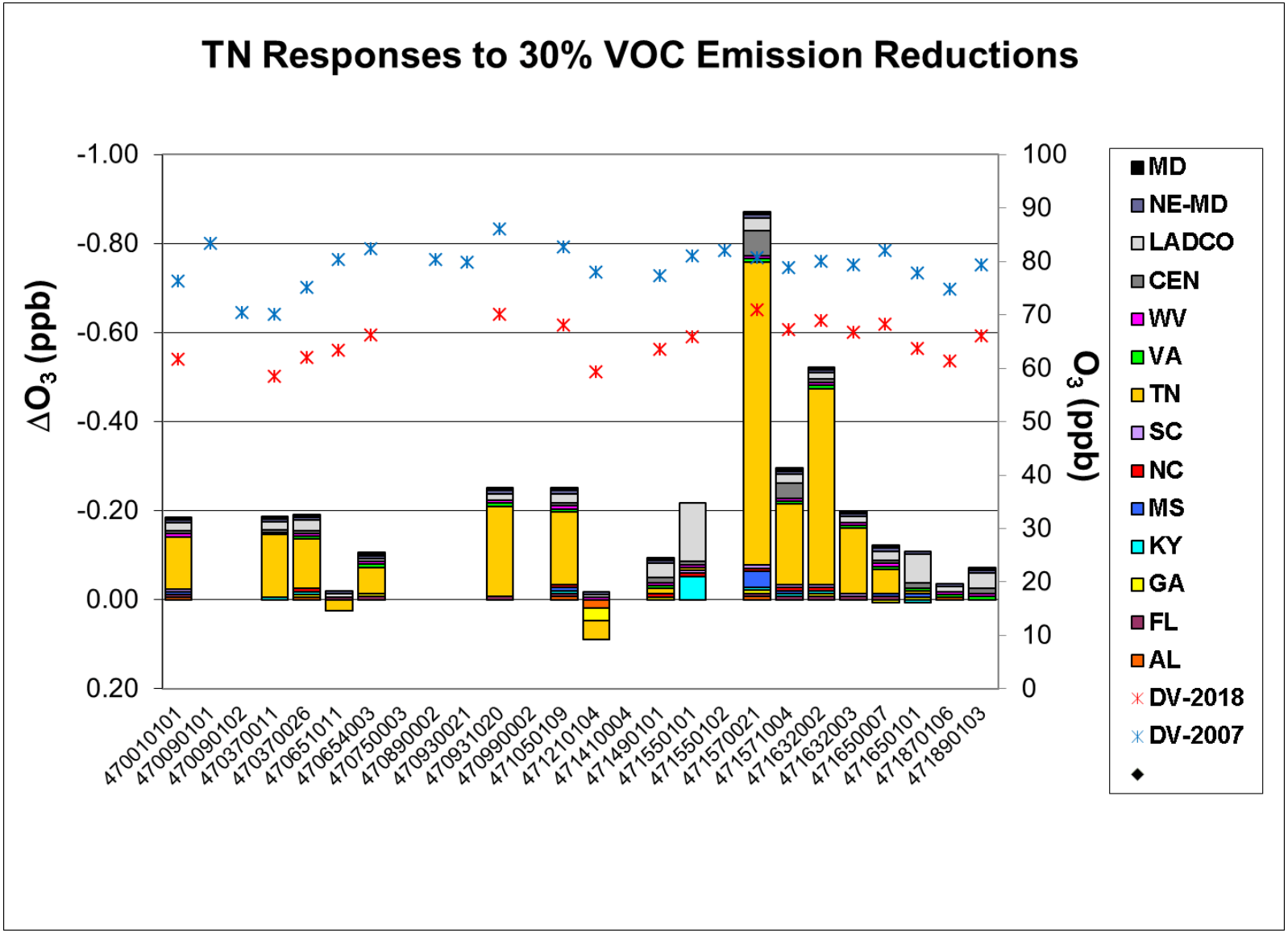


Figure 5-54 Relative VOC sensitivities at Tennessee sites

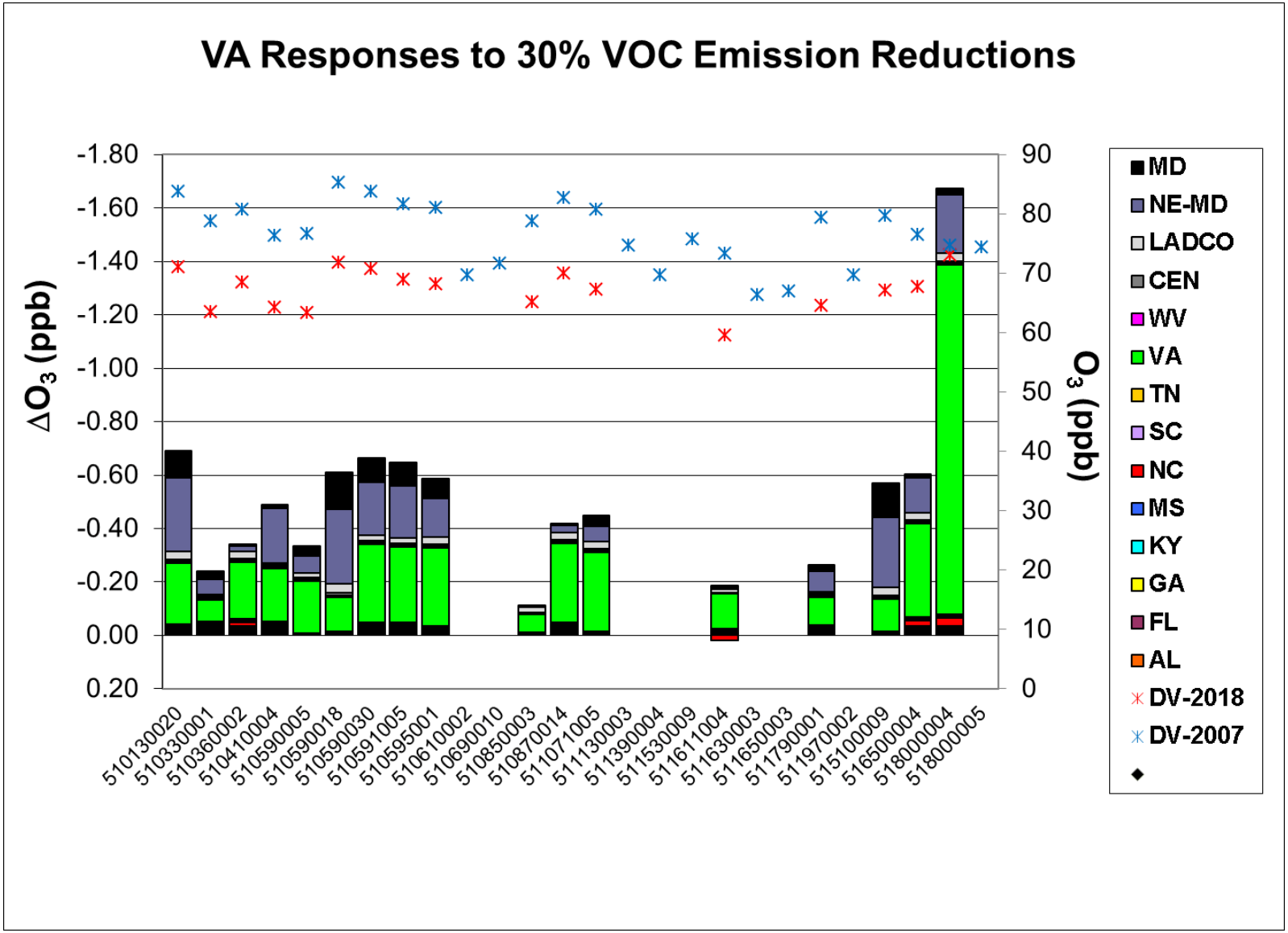


Figure 5-55 Relative VOC sensitivities at Virginia sites

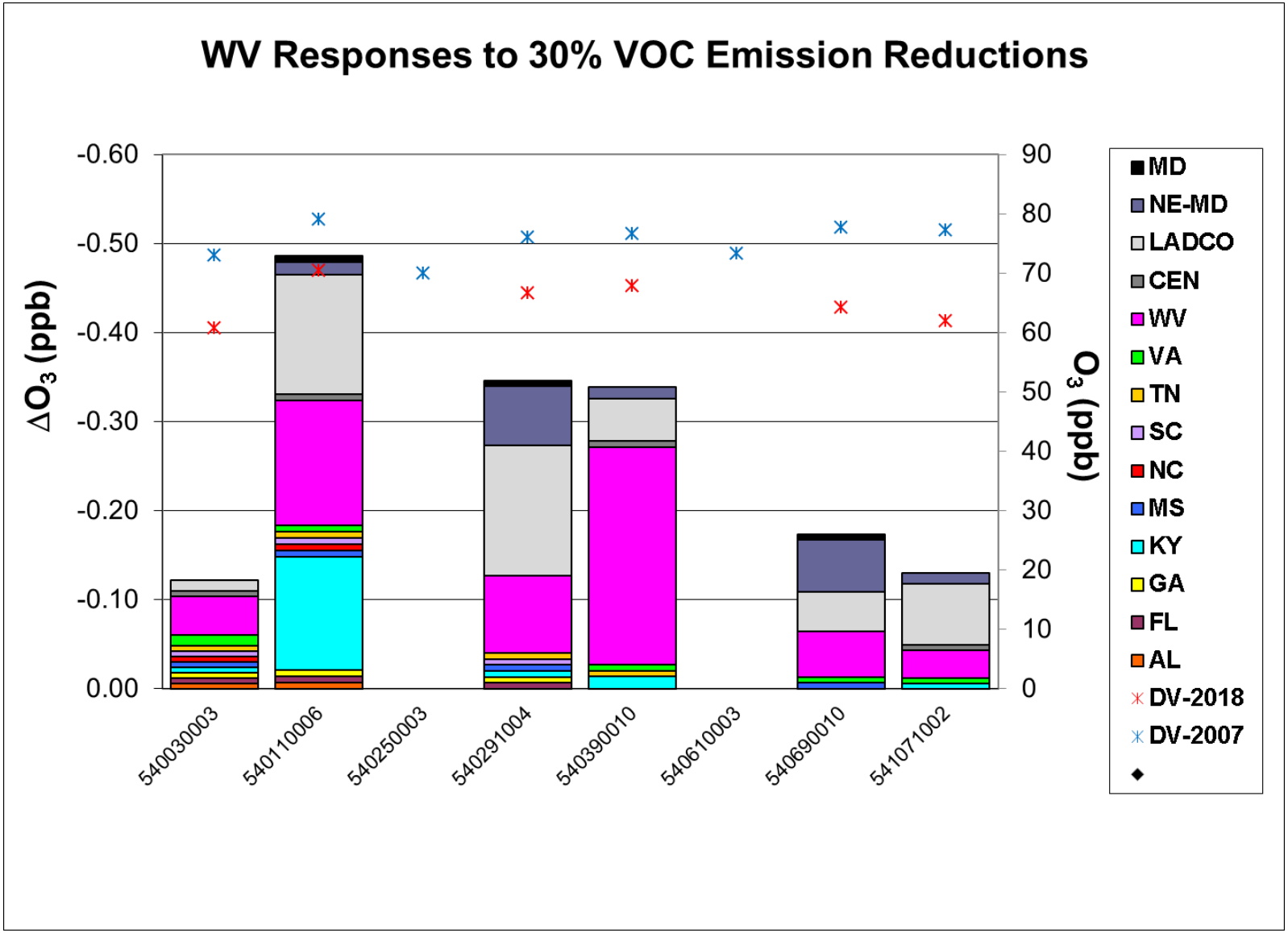


Figure 5-56 Relative VOC sensitivities at West Virginia sites

5.5 Normalized Sensitivities

Normalized NO_x and VOC sensitivities were calculated for each monitor by dividing the relative sensitivities to the home state's NO_x or VOC emissions by the amount of emission reductions in the home state listed in

Table 5-4. Normalized NO_x and VOC sensitivities were stacked in a bar for each monitor and all the monitors in a state were grouped in a chart. Figure 5-57 through Figure 5-66 show the normalized NO_x and VOC sensitivities at the monitors of the 10 SESARM states (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Virginia and West Virginia).
In general, the normalized NO_x sensitivities are an order of magnitude larger than the normalized VOC sensitivities. This means that one ton of NO_x reduction is at least ten times more beneficial than one ton of VOC reduction. But there are several exceptions to this rule. First and foremost, in Florida the normalized VOC sensitivities are of the same order of magnitude as normalized NO_x sensitivities at several sites and even larger at some sites. Then at some Kentucky sites and one Virginia site normalized NO_x or VOC sensitivities are of the same order of magnitude. NO_x or VOC reductions are sometimes disbeneficial; in those cases the normalized sensitivity is positive. The ratio of normalized NO_x sensitivity to normalized VOC sensitivity was calculated for each monitor. This ratio is typically larger than 10 except at several coastal sites and some sites along the borders of the SESARM states with CENRAP, LADCO and MANE-VU (Figure 5-67).

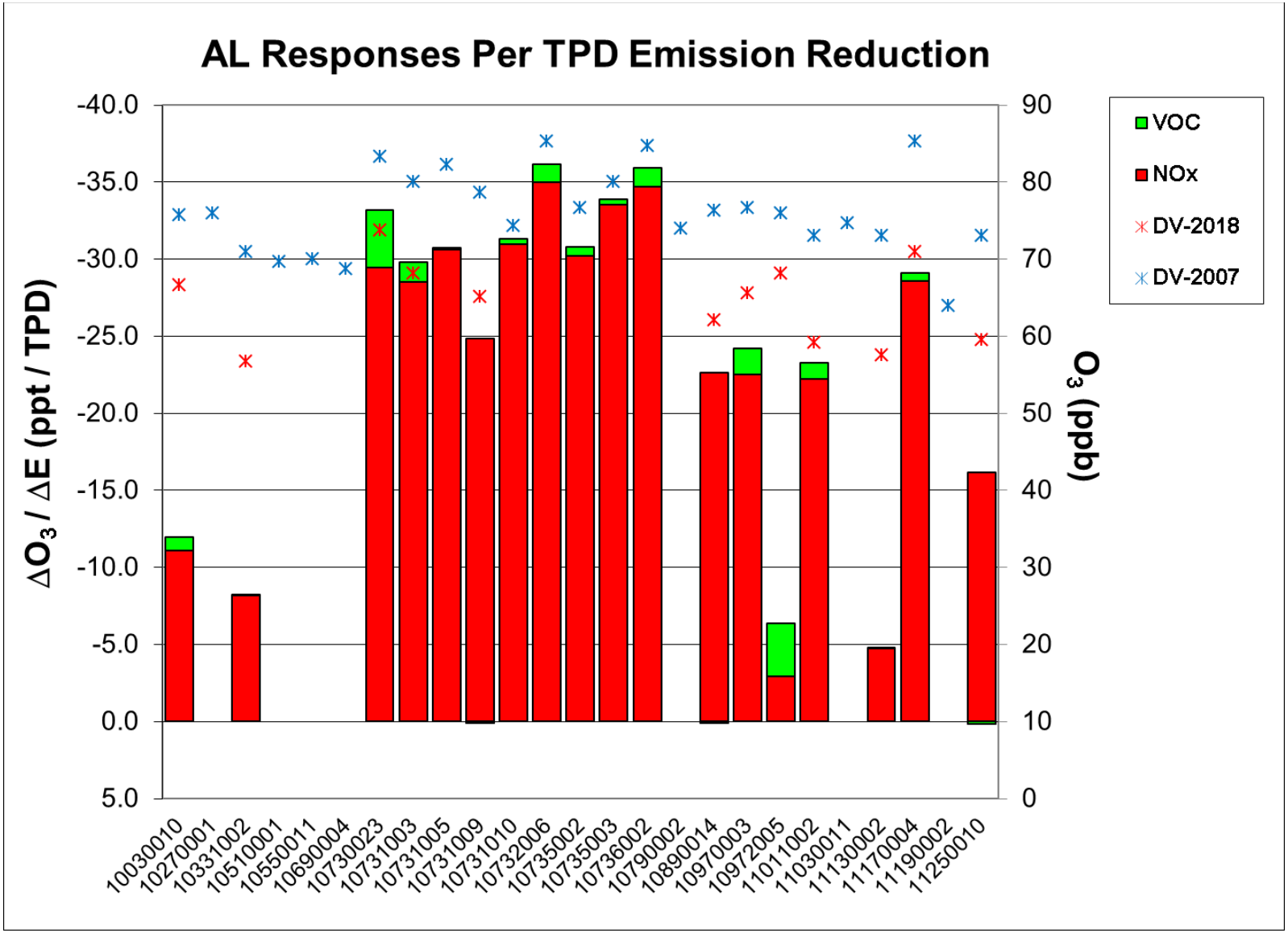


Figure 5-57 Normalized NO_x and VOC sensitivities at Alabama sites

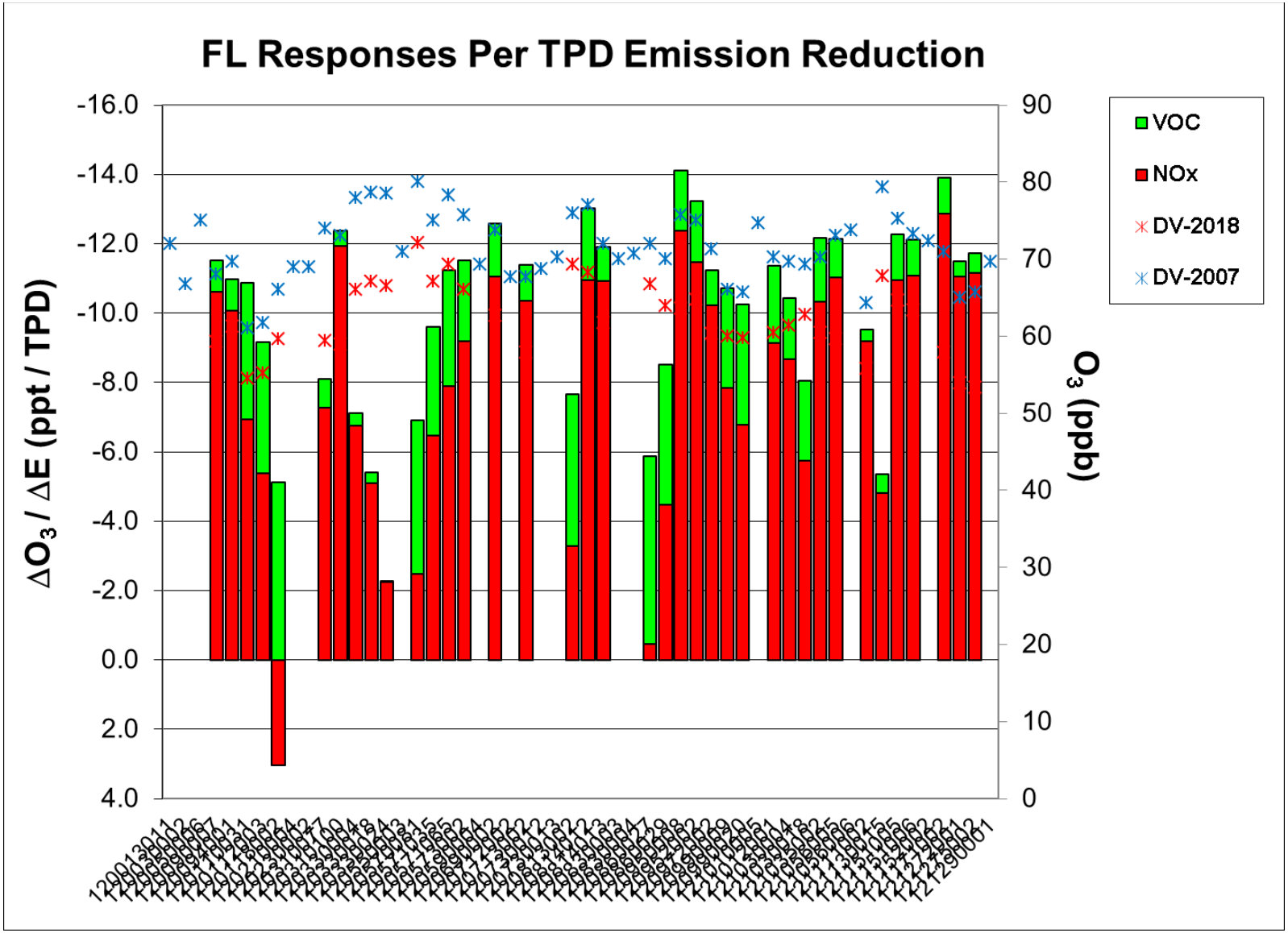


Figure 5-58 Normalized NO_x and VOC sensitivities at Florida sites

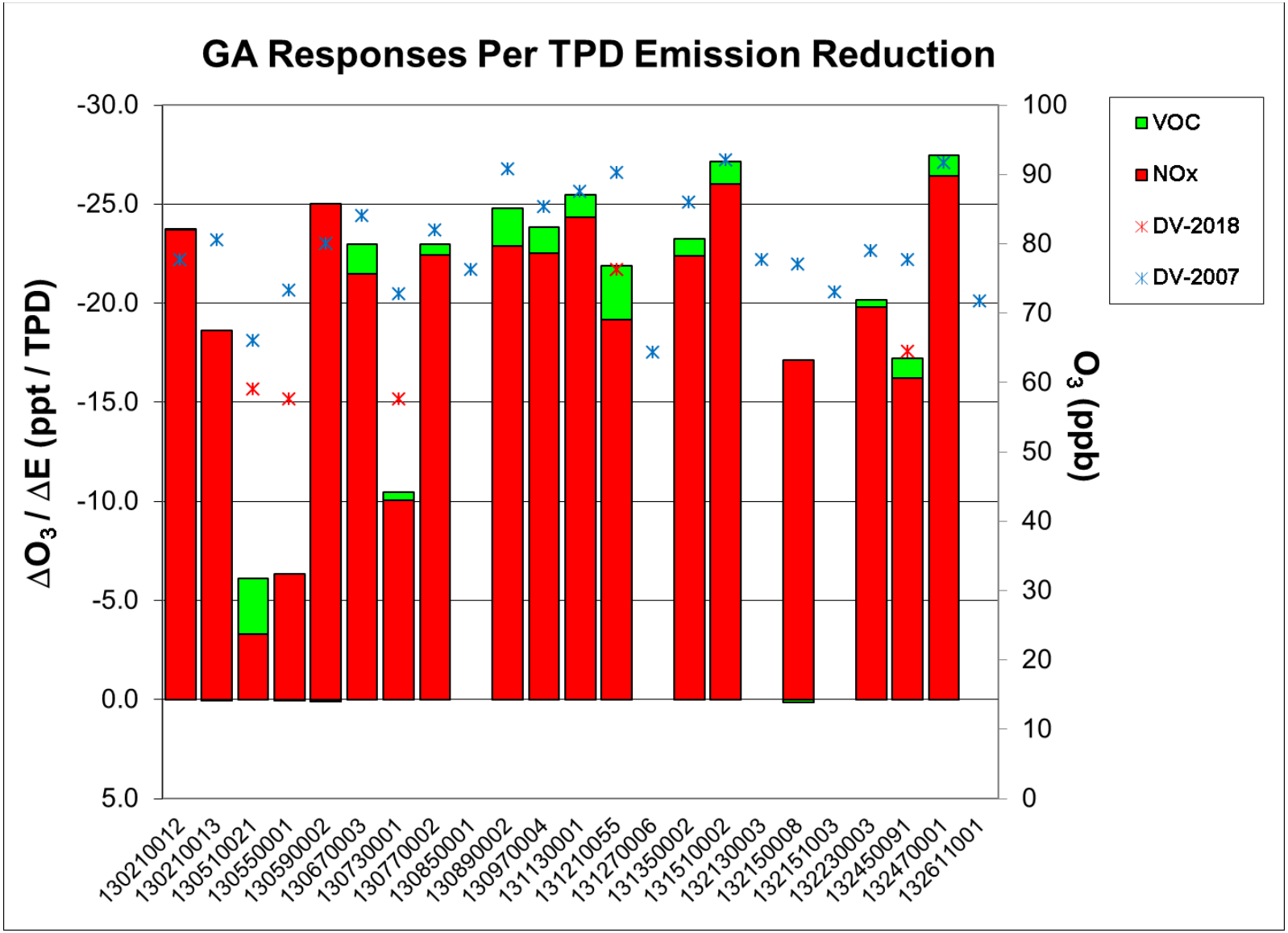


Figure 5-59 Normalized NO_x and VOC sensitivities at Georgia sites

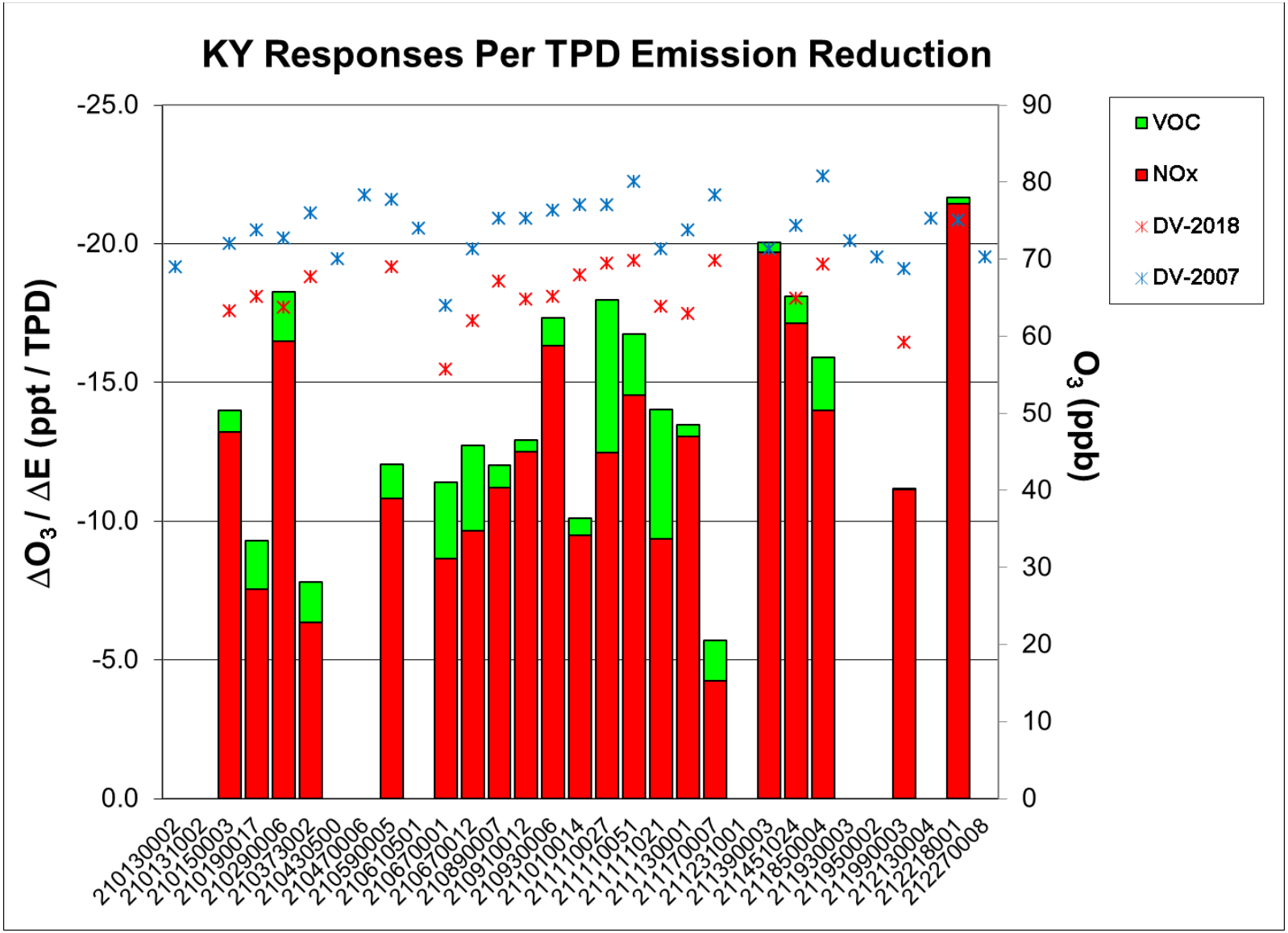


Figure 5-60 Normalized NO_x and VOC sensitivities at Kentucky sites

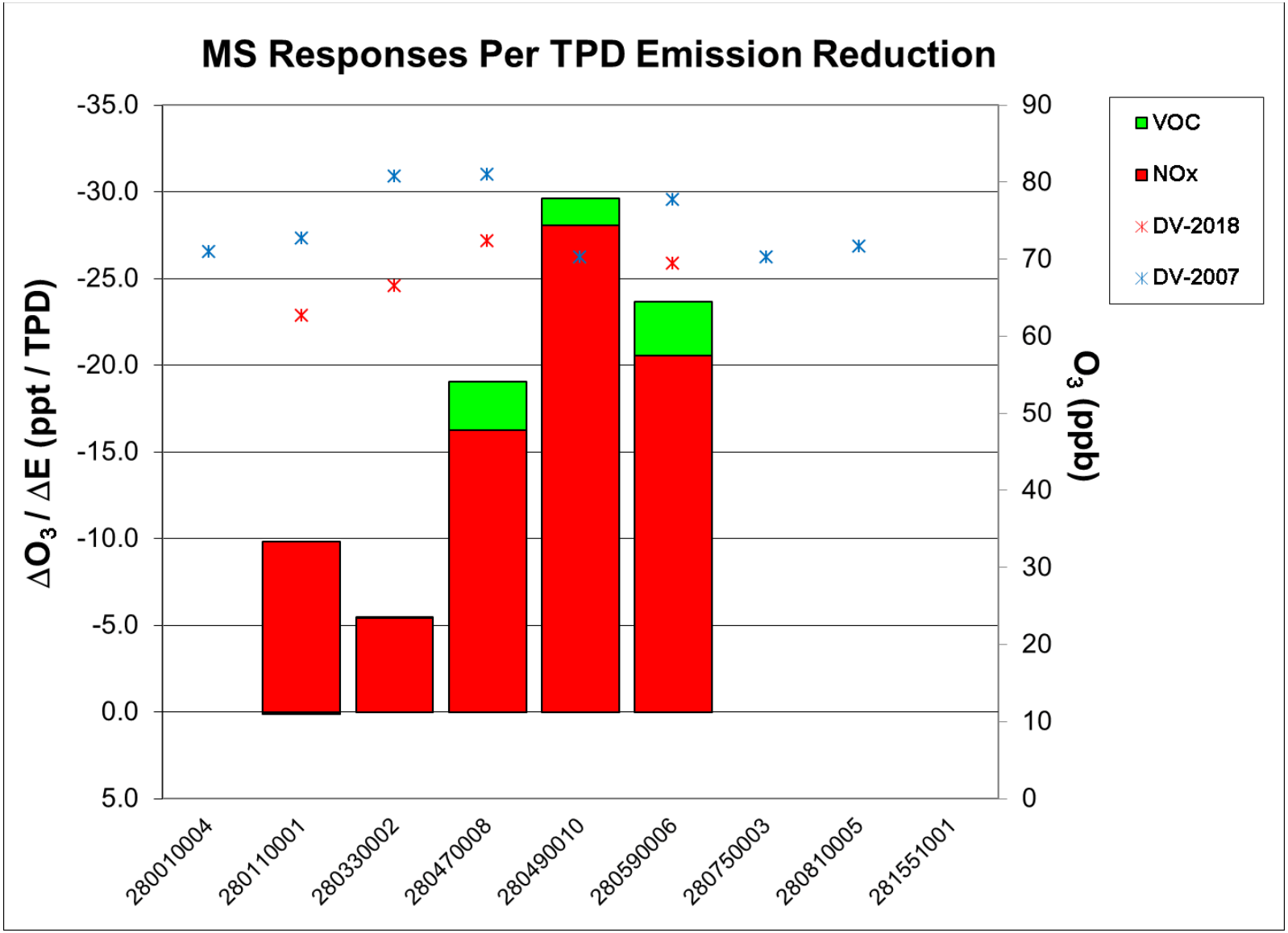


Figure 5-61 Normalized NO_x and VOC sensitivities at Mississippi sites

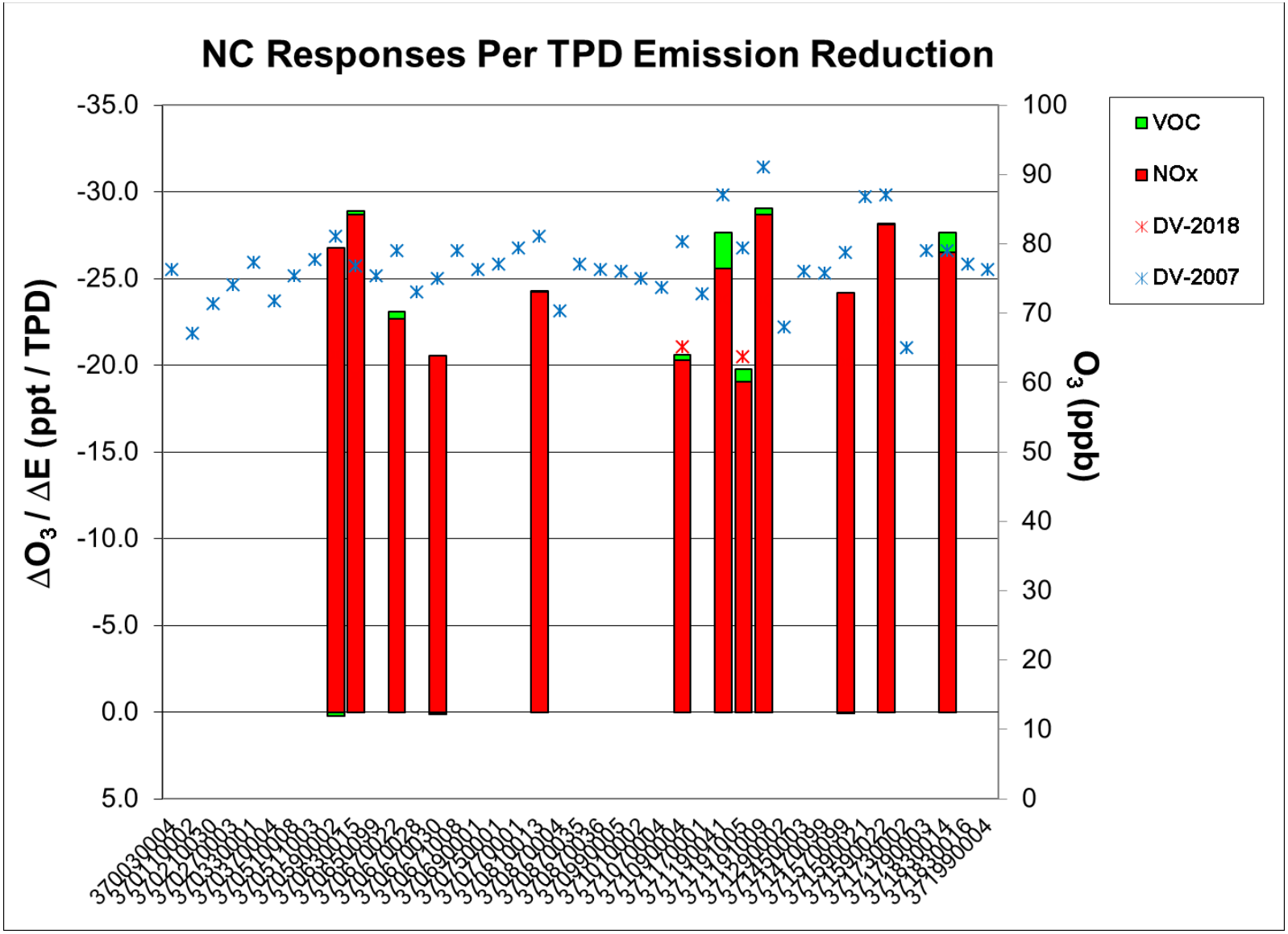


Figure 5-62 Normalized NO_x and VOC sensitivities at North Carolina sites

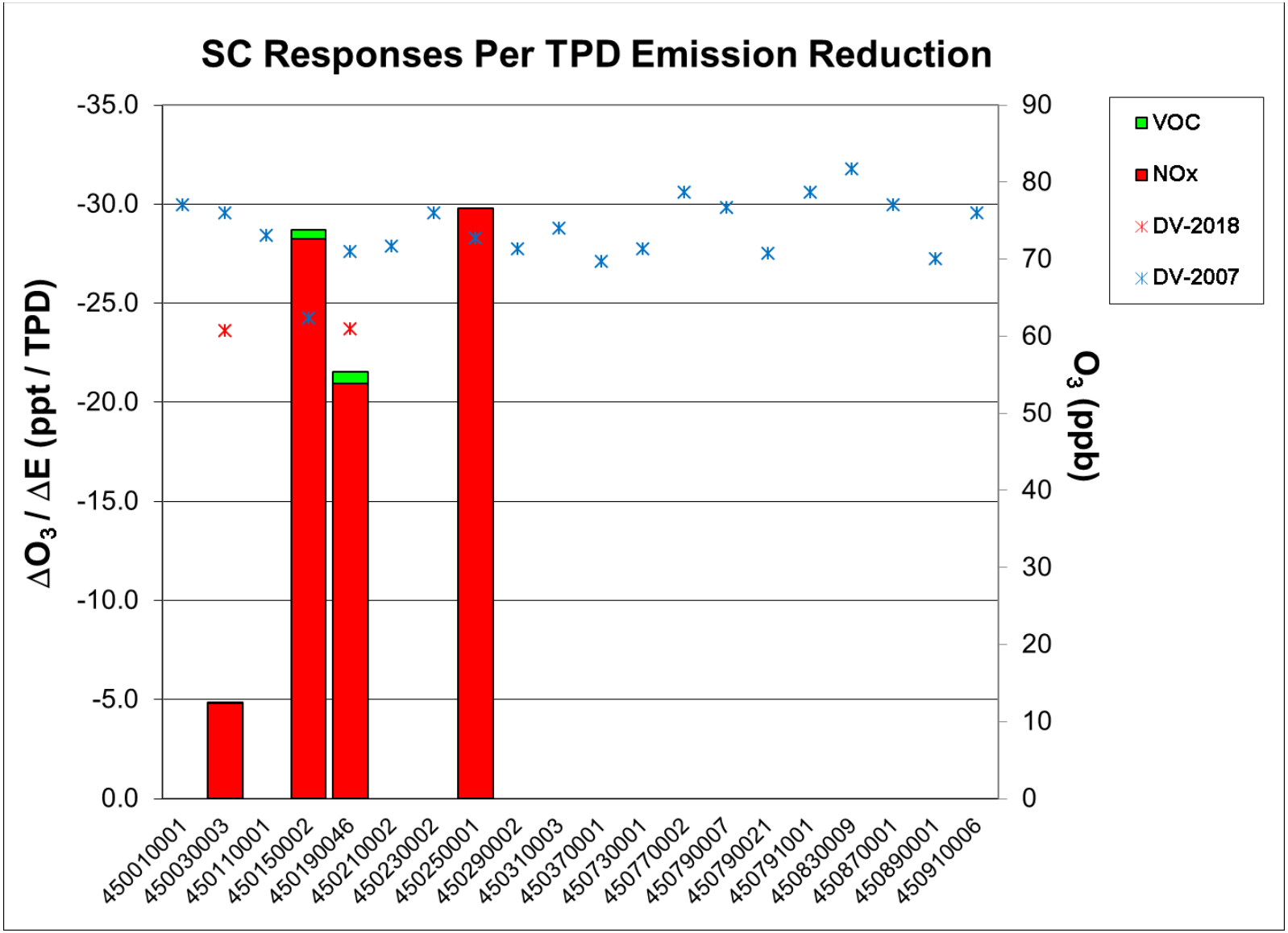


Figure 5-63 Normalized NO_x and VOC sensitivities at South Carolina sites

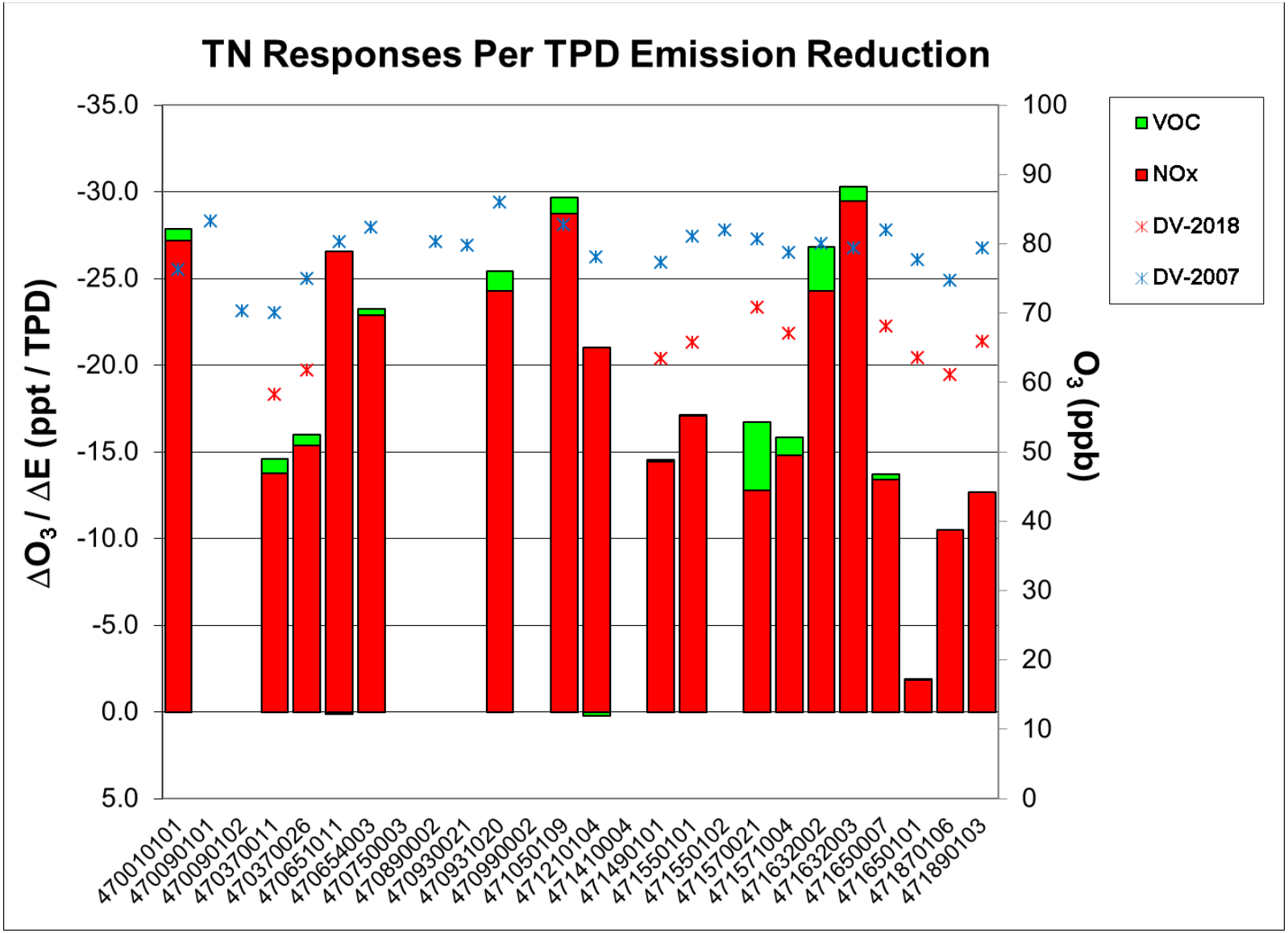


Figure 5-64 Normalized NO_x and VOC sensitivities at Tennessee sites

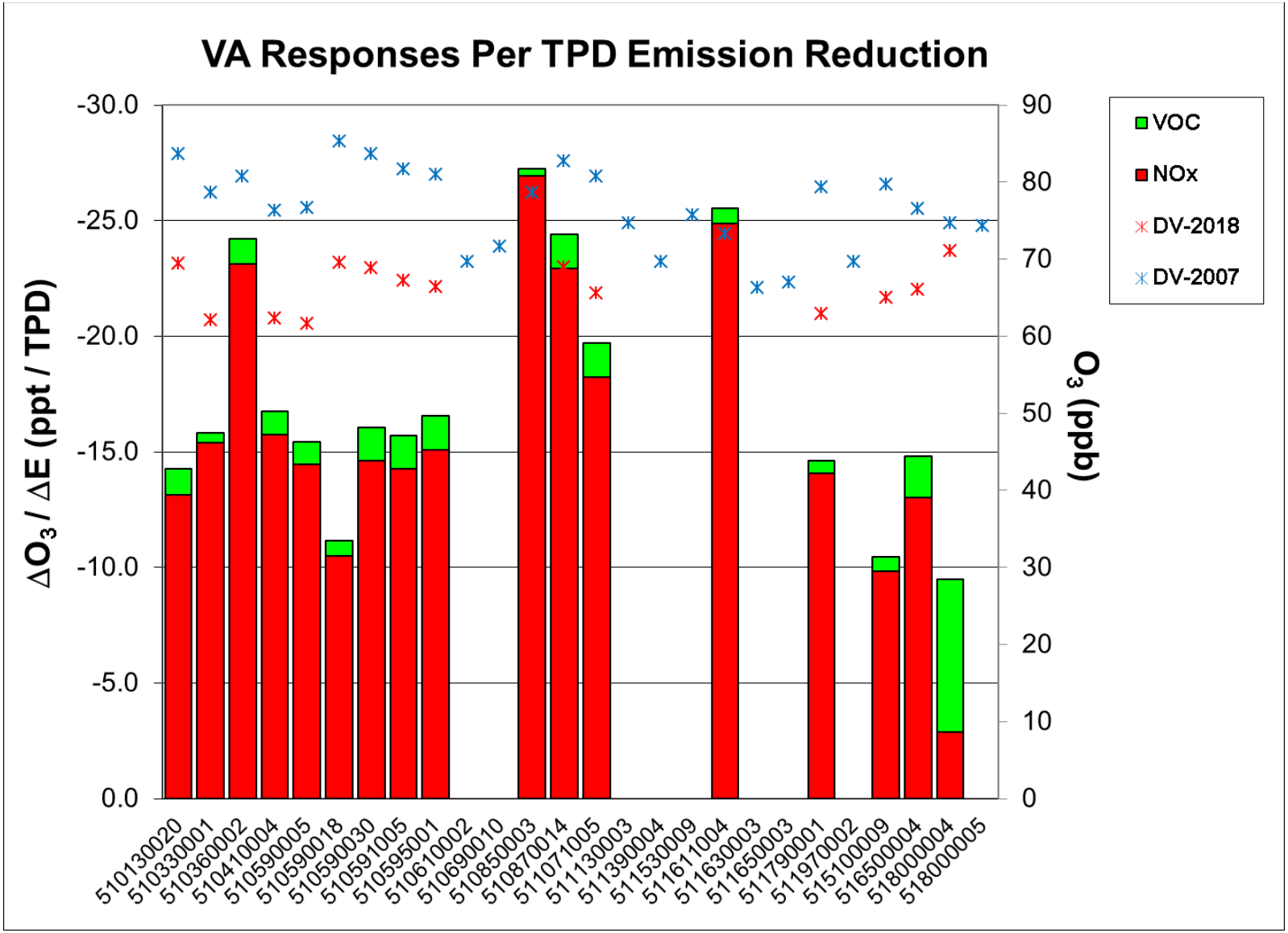


Figure 5-65 Normalized NO_x and VOC sensitivities at Virginia sites

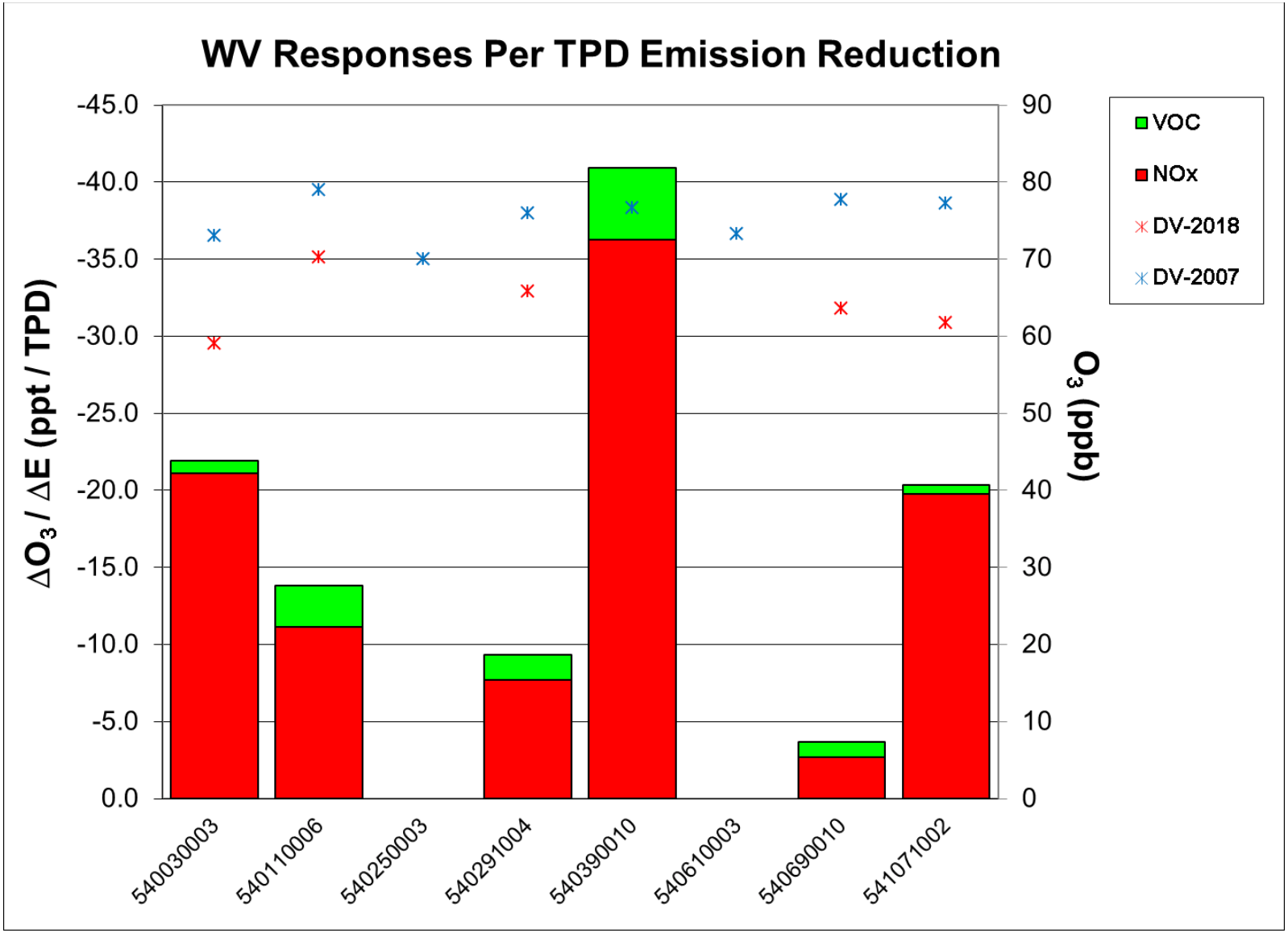


Figure 5-66 Normalized NO_x and VOC sensitivities at West Virginia sites

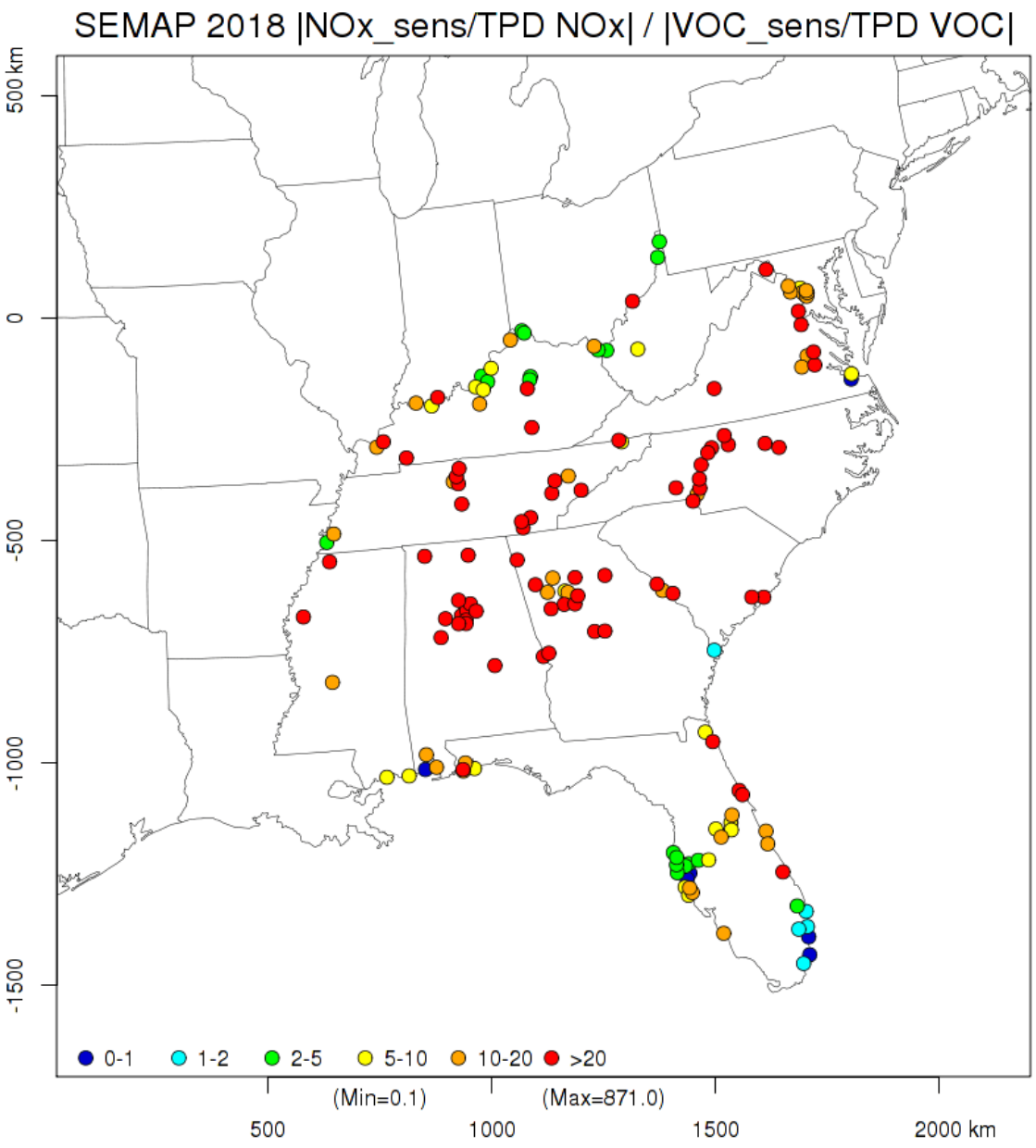


Figure 5-67 Ratios of normalized sensitivities (NO_x/VOC) at SEMAP sites

5.6 Conclusions

In general, absolute sensitivities (ΔO_3) and relative sensitivities (DDVF) of ozone to NO_x and VOC emissions are very similar. Relative sensitivities may be more reliable because they are based on 2007 measured ozone concentrations through DVCs used to derive DVFs, and the modeling results are used in a relative sense through RRFs.

Anthropogenic NO_x emission reductions are much more effective at reducing 8-hour maximum ozone concentrations in the SESARM states compared to anthropogenic VOC emission reductions. Some sites in Florida show comparable benefits from VOC and NO_x reductions.

NO_x and VOC emissions from the home states typically have the largest impact on the ozone levels of its own monitors. Neighboring states have the next largest impact. The impacts of VOC emissions from

neighboring states are much smaller than the impacts of NO_x emissions from neighboring states relative to home state impacts. The impacts of neighboring RPO's NO_x emissions to ozone in the SESARM states are significant in Kentucky (from LADCO), Mississippi (from CENRAP), Tennessee (both from CENRAP and LADCO), Virginia (from MANE-VU) and West Virginia (from LADCO). In return, the impacts of Virginia and West Virginia NO_x emissions to ozone in Maryland are significant.