Regional Modeling of Atmospheric Deposition with CMAQ as a tool for Ecosystem Based Management

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Regional Modeling of Atmospheric Deposition with CMAQ as a tool for Ecosystem Based Management

Organization of Talk:

What is CMAQ

(Community Multiscale Air Quality model)

How does it perform regionally

What does N deposition look like across the A-P region

Species of nitrogen deposition?

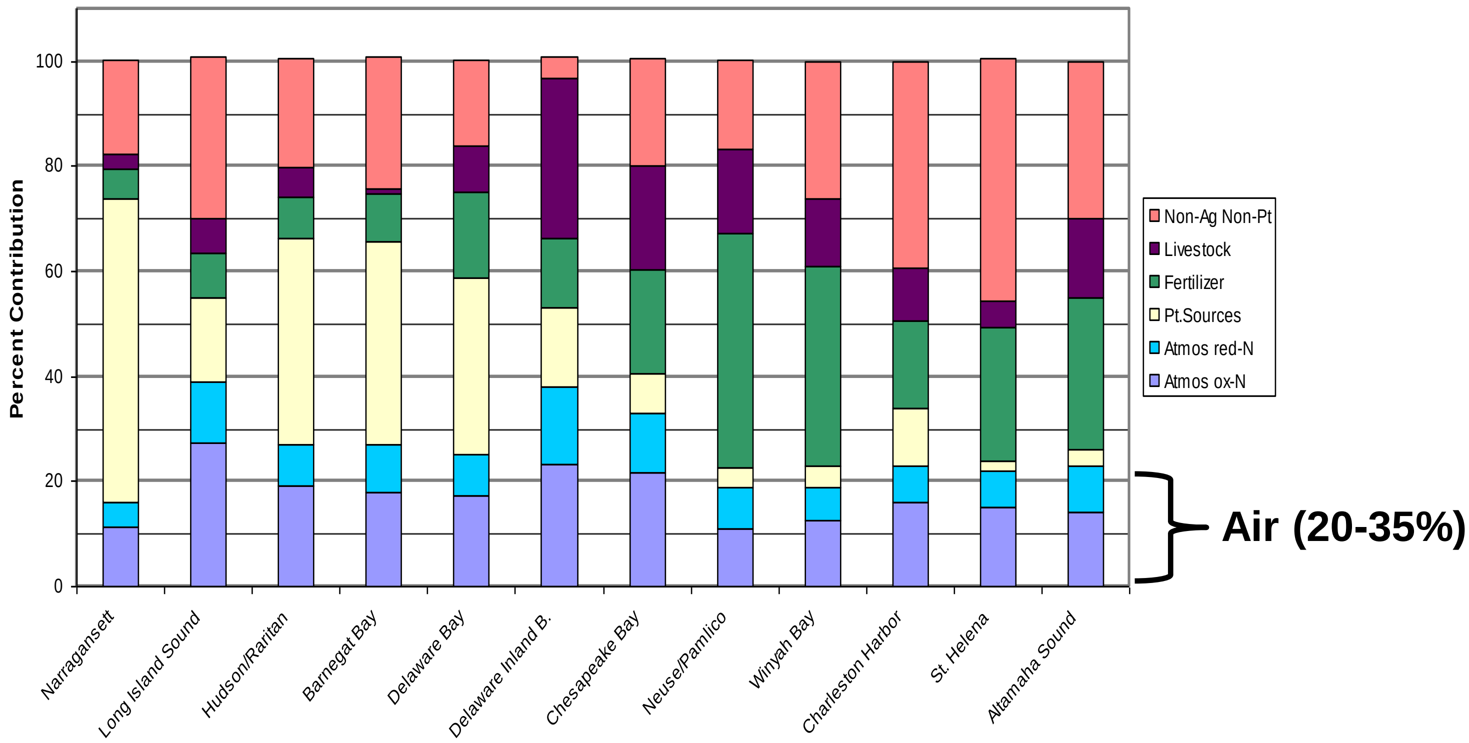
What are the sources?

The special case of ammonia

What deposition levels do we expect in 2020 compared to 2002

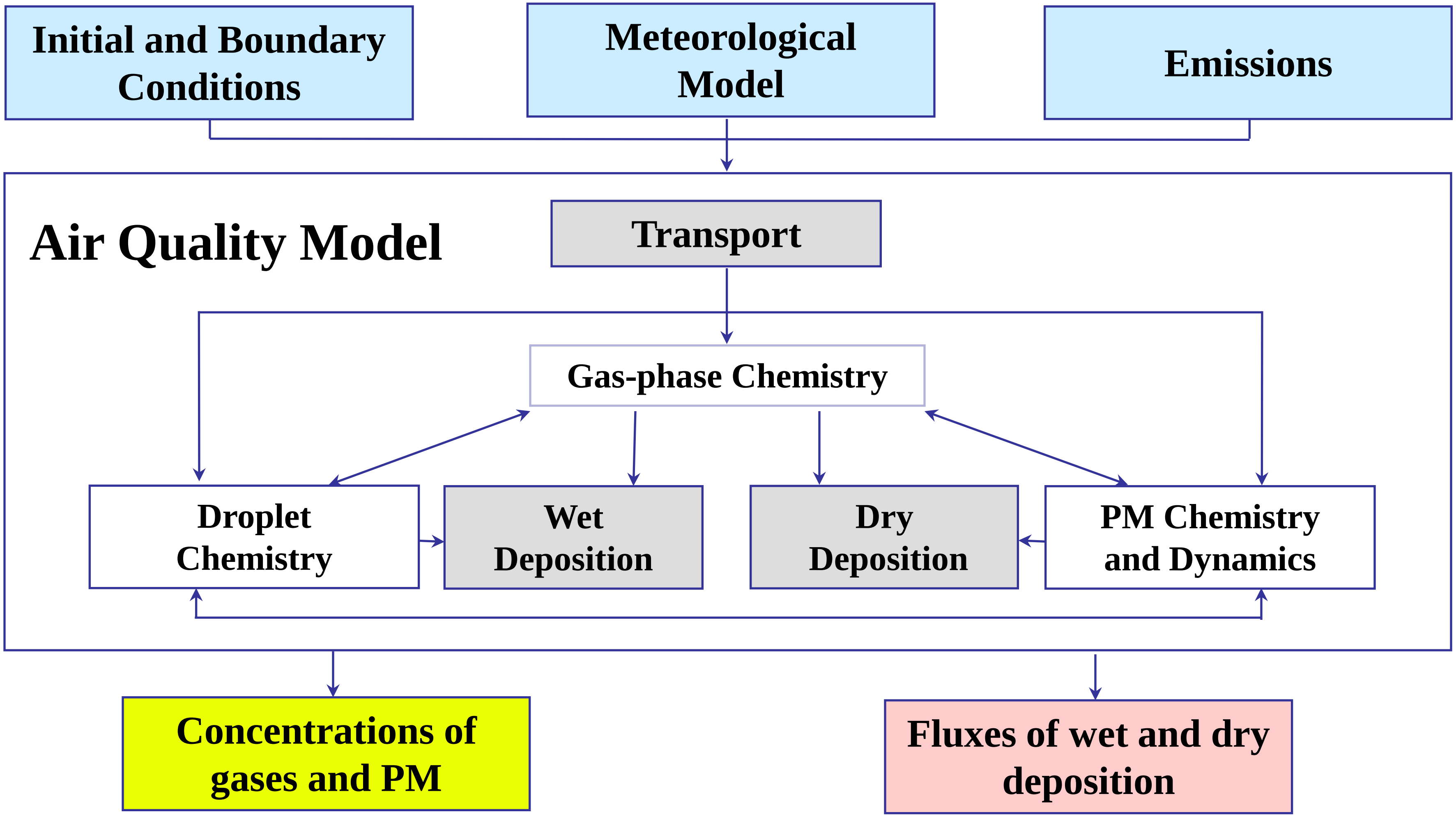
Atmospheric Nitrogen Deposition - Eutrophication

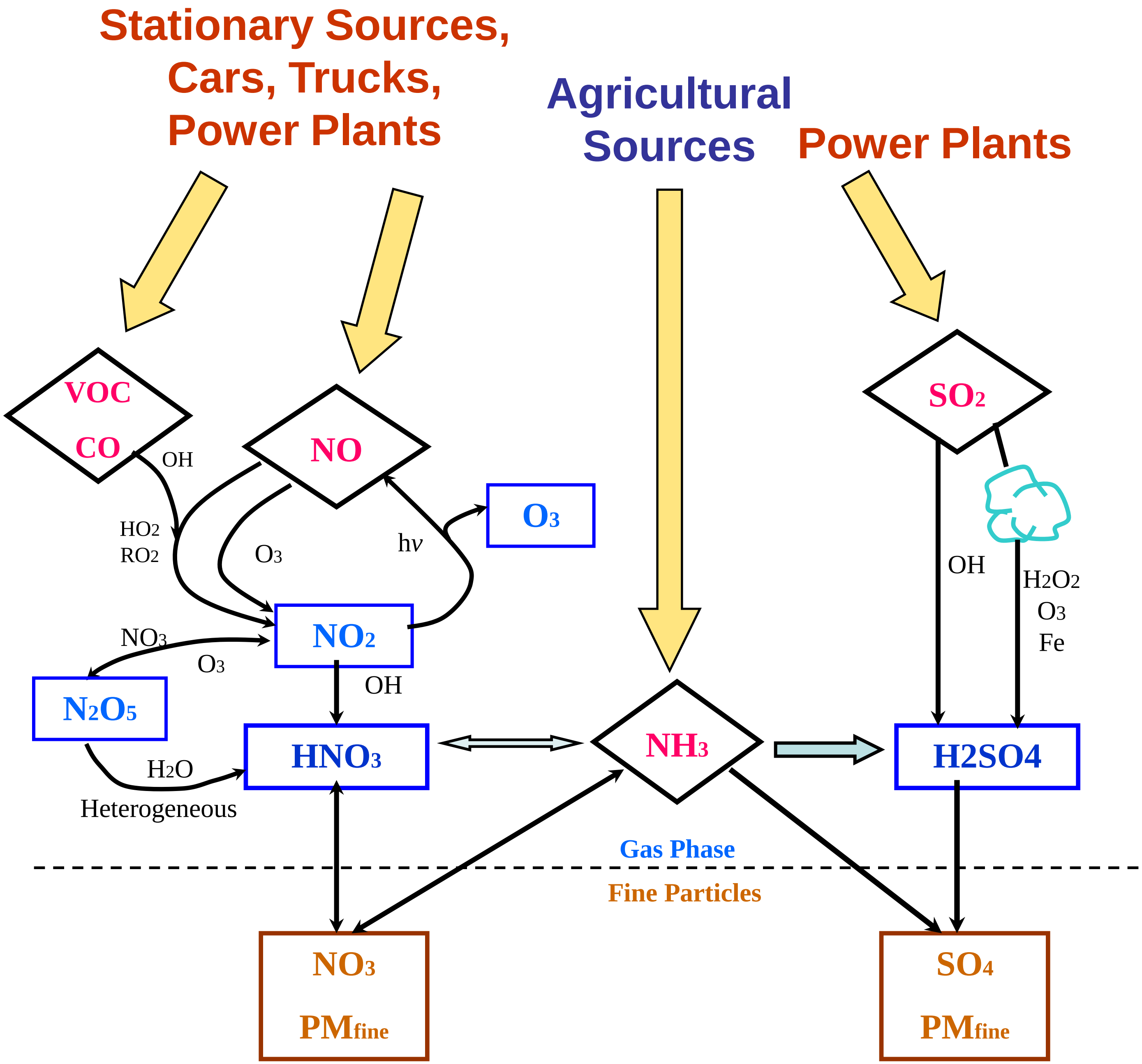
Nitrogen Loading to Estuaries by Source Type



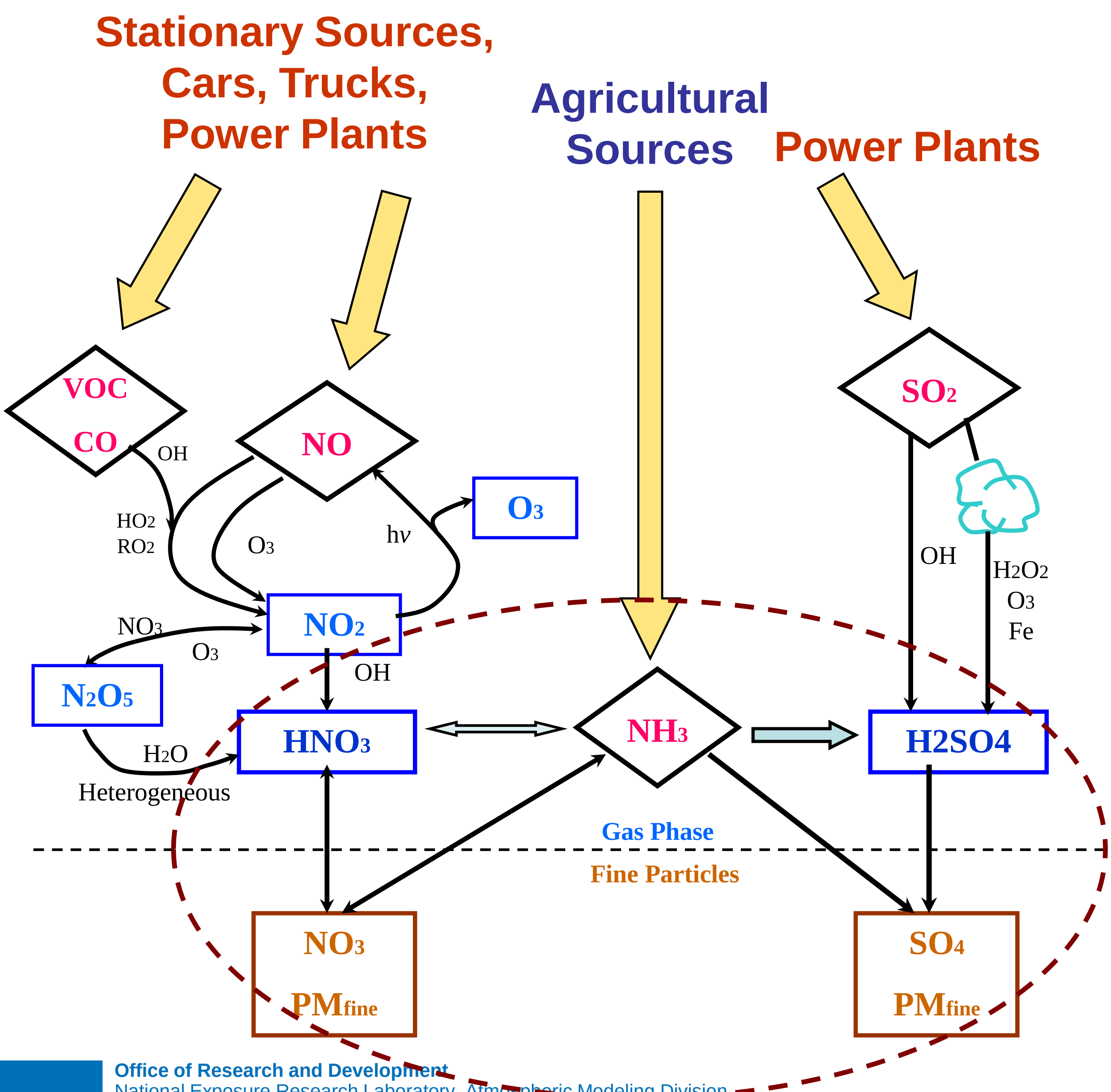
- **Air accounts for 20-35% of N loading to estuaries (both indirect and direct)**
- **Chesapeake Bay & Neuse: Air accounts for ~30% of N loading**
- **A regional atmospheric deposition model can provide useful information for Ecosystems Based Management regarding these deposition inputs**

Schematic Representation of the Community Multiscale Air Quality (CMAQ) Model





Fossil Fuel Combustion that Produces Nitrogen and Sulfur Oxides (NO_X and SO_X) and Agricultural Production that Produces Ammonia are are the Main Sources of Inorganic $PM_{2.5}$ and Nitrogen Deposition



The Partitioning Between Gases and Particles, Which Is Determined by Ammonia Availability, Greatly Affects Concentrations of aNO_3^- and $aSO_4^=$ Which Have Low Rates of Dry Deposition

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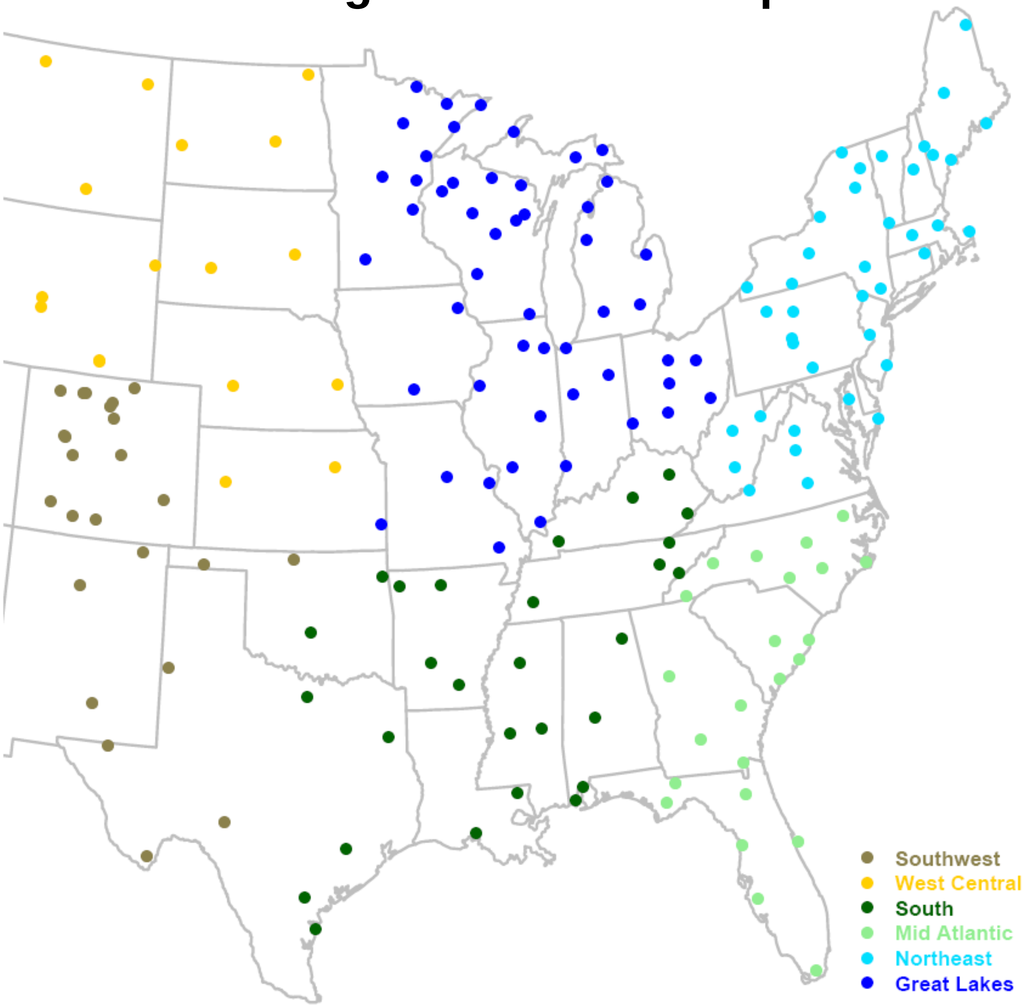
Color coding used for scatter plots



182 NADP monitoring sites

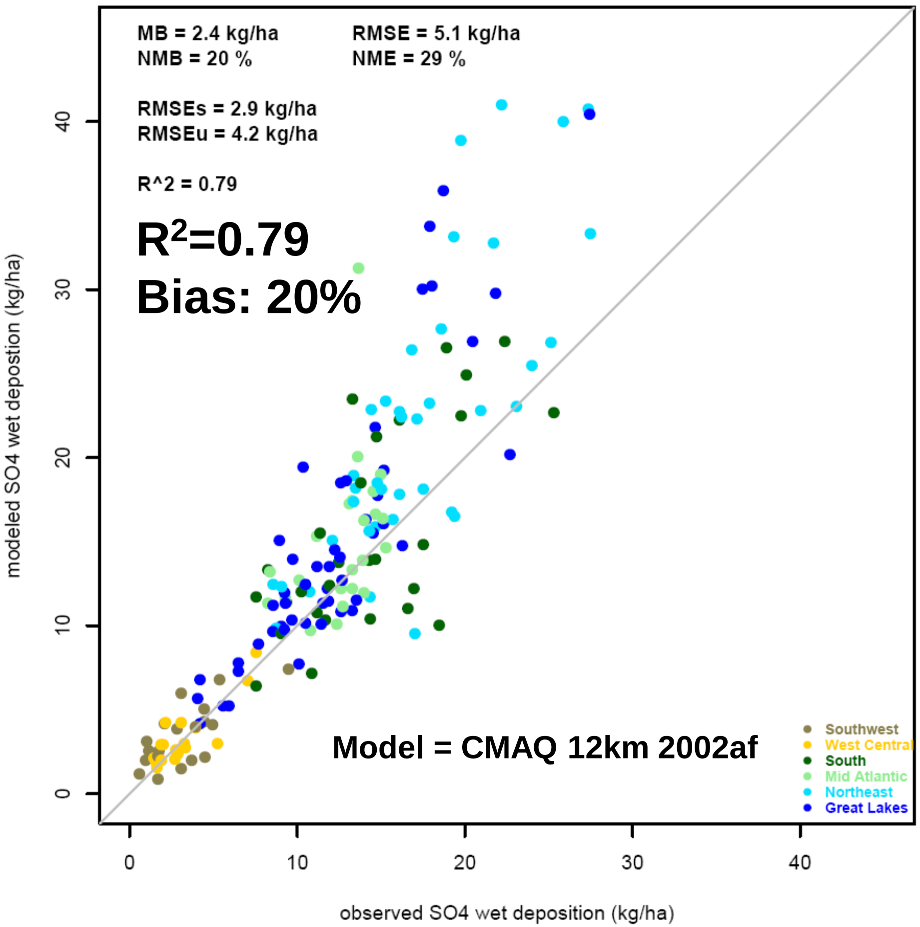
How well does CMAQ perform?

Compare model wet deposition estimates against NADP wet deposition measurements

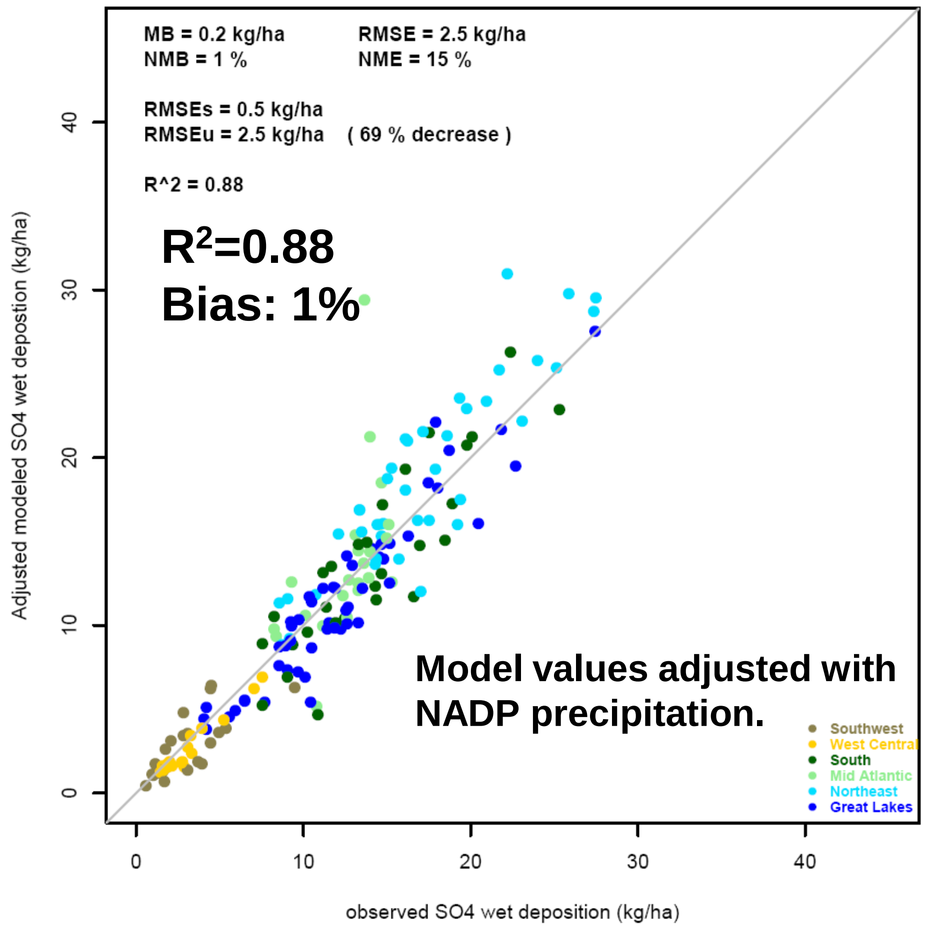
Correct for precipitation error

Precipitation-Corrected Wet Deposition SO_4: Has the least uncertainty

Observed vs. Modeled Wet Deposition SO_4



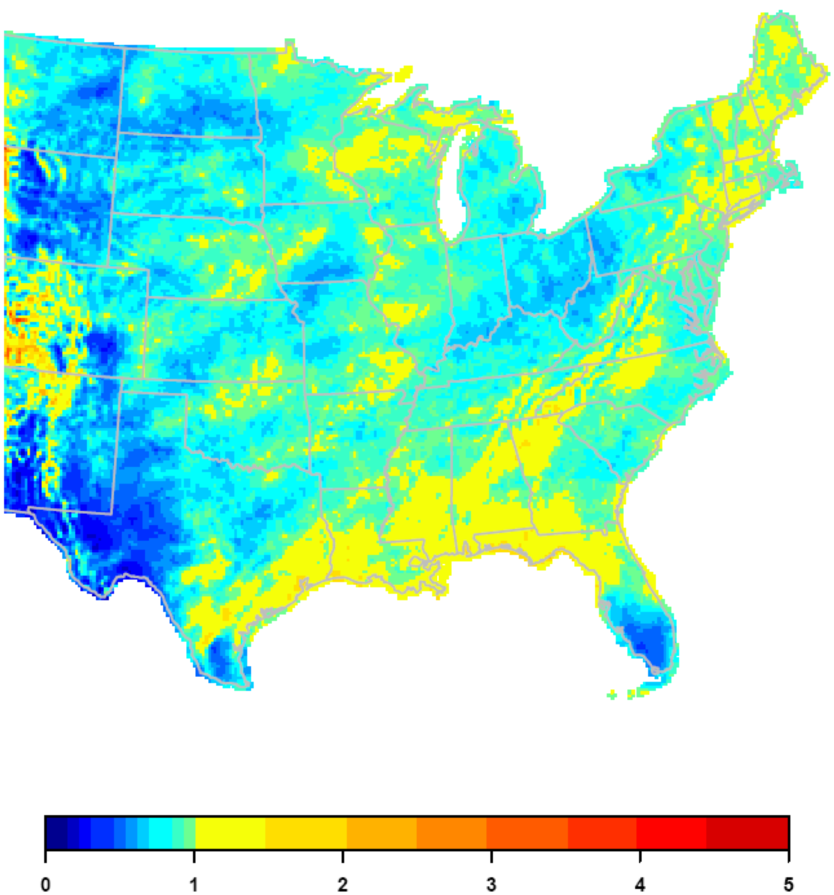
Observed vs. Adjusted Modeled Wet Deposition SO_4

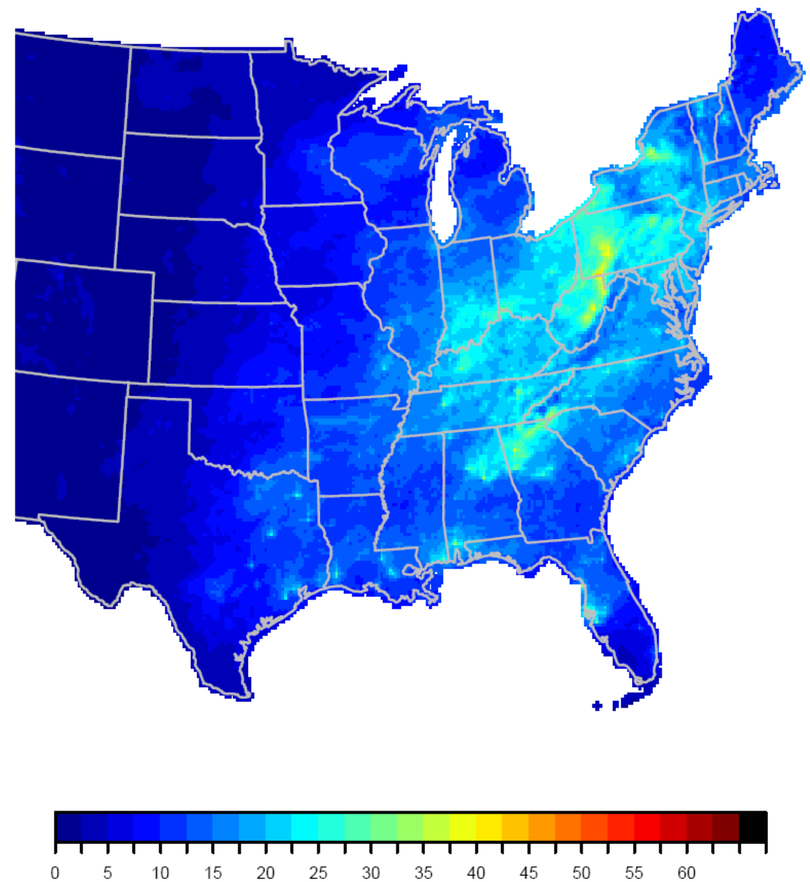


PRISM orographic enhancements are evident

Adjusted CMAQ Wet Deposition SO_4 (kg/ha)

Precipitation Ratio: PRISM / CMAQ

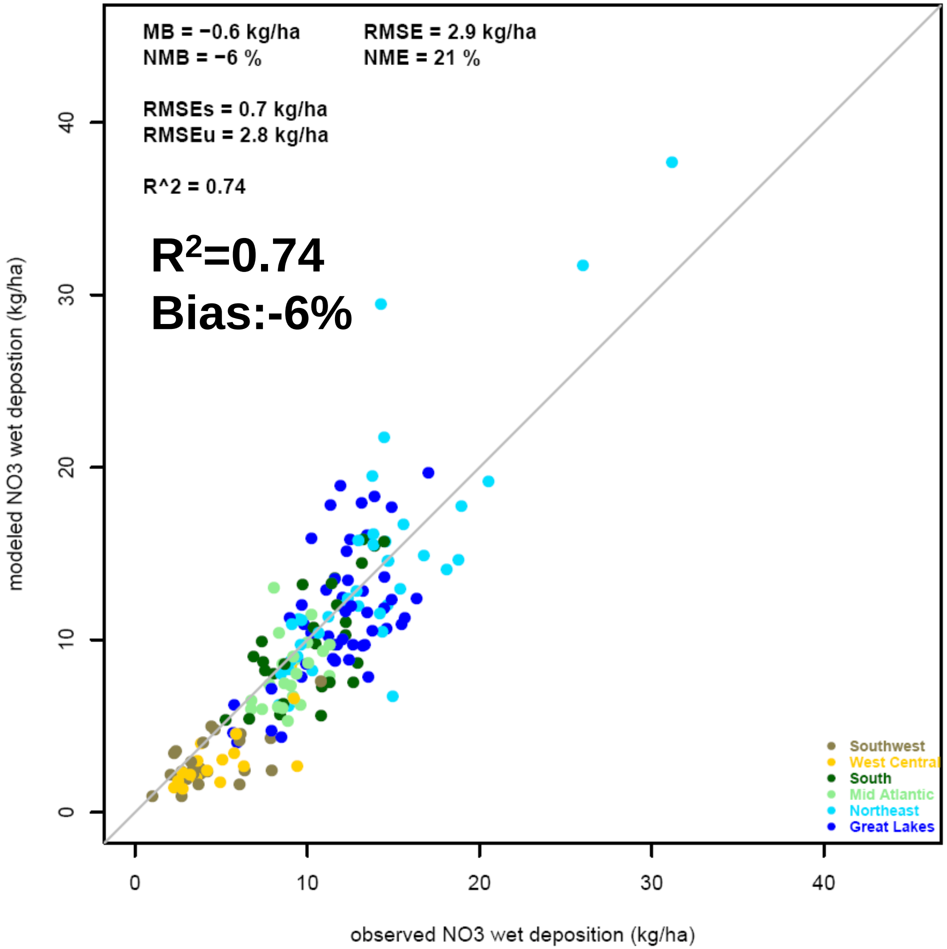




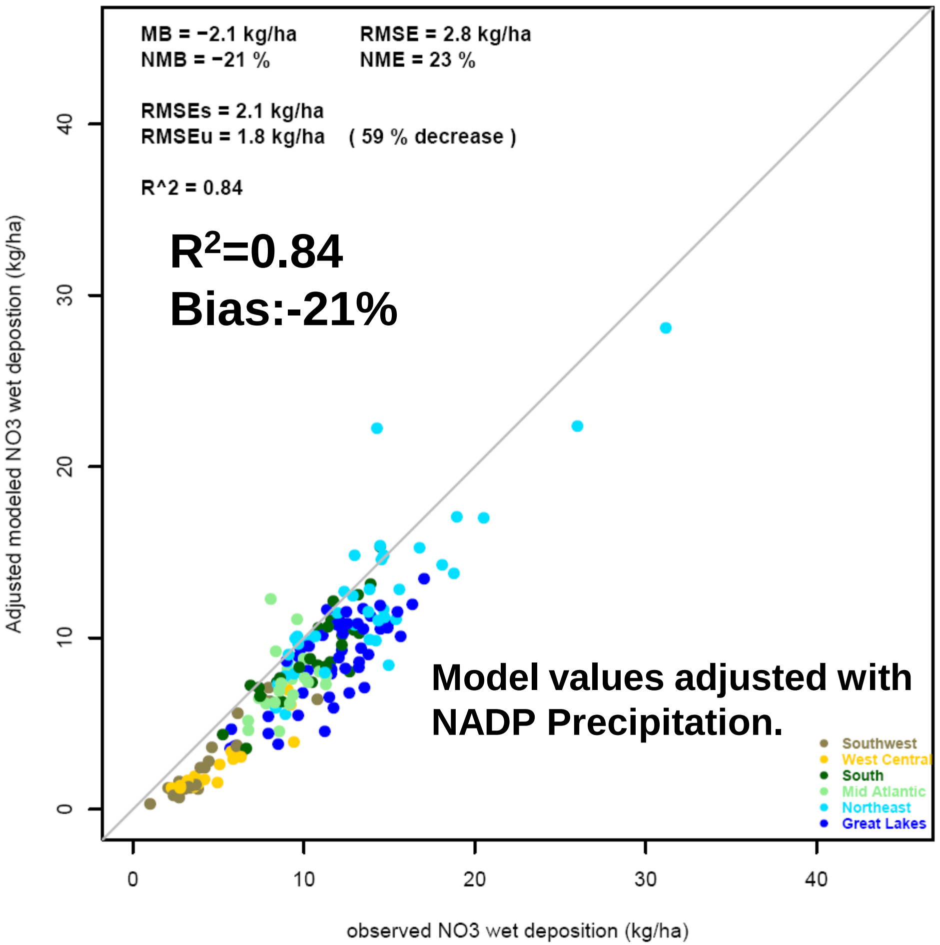
Model values adjusted with PRISM precipitation.

Precipitation-Corrected Wet Deposition NO_3: Intermediate uncertainty

Observed vs. Modeled Wet Deposition NO_3

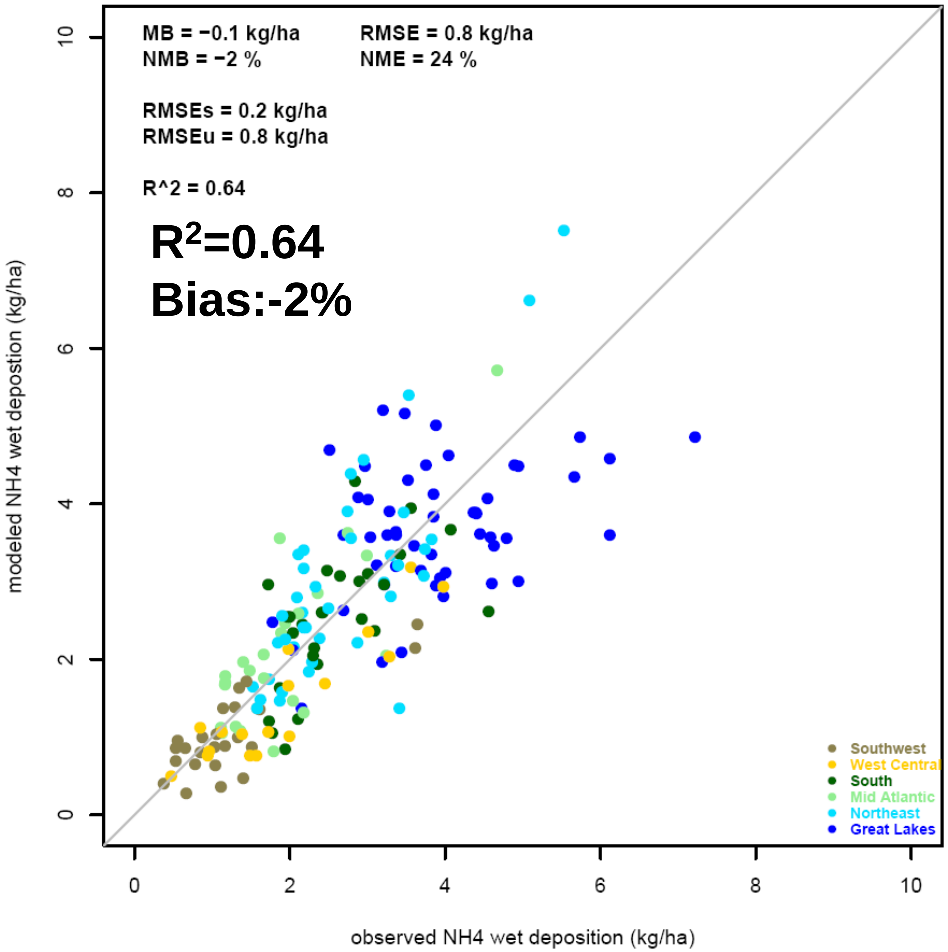


Observed vs. Adjusted Modeled Wet Deposition NO_3

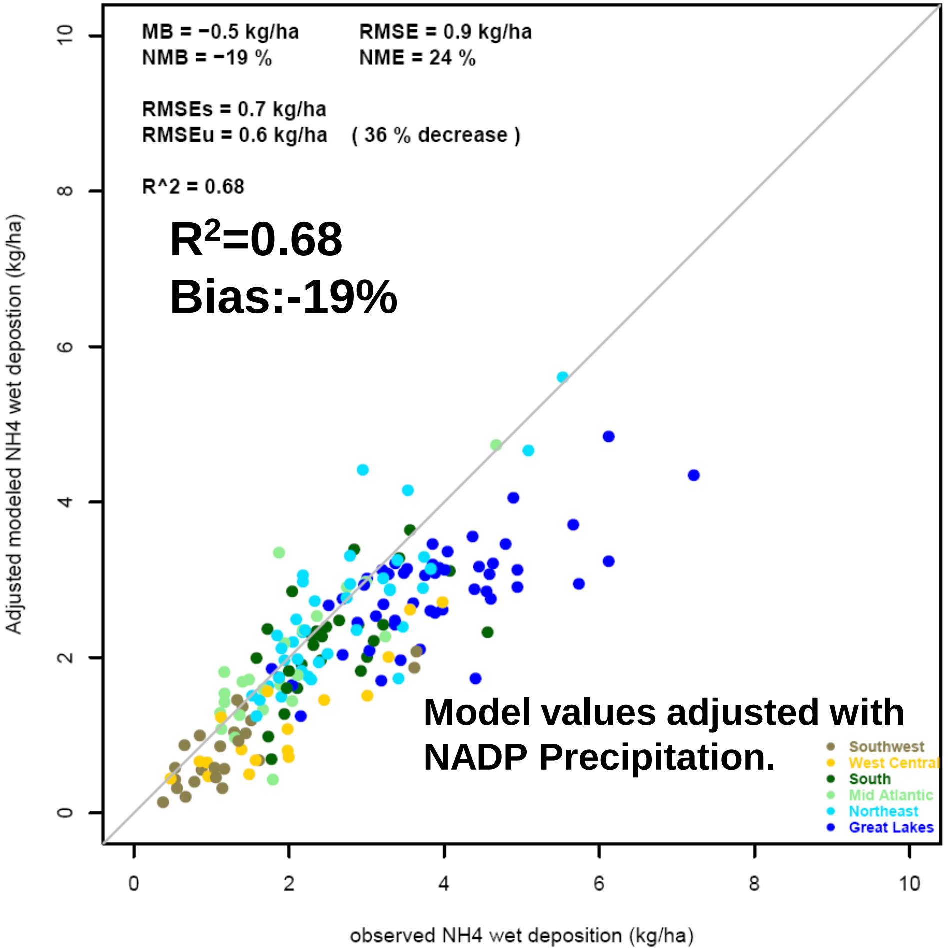


Precipitation-Corrected Wet Deposition NH_4: Has the most uncertainty

Observed vs. Modeled Wet Deposition NH_4



Observed vs. Adjusted Modeled Wet Deposition NH_4



Resultant Wet Deposition Fields for NO_3 and NH_4

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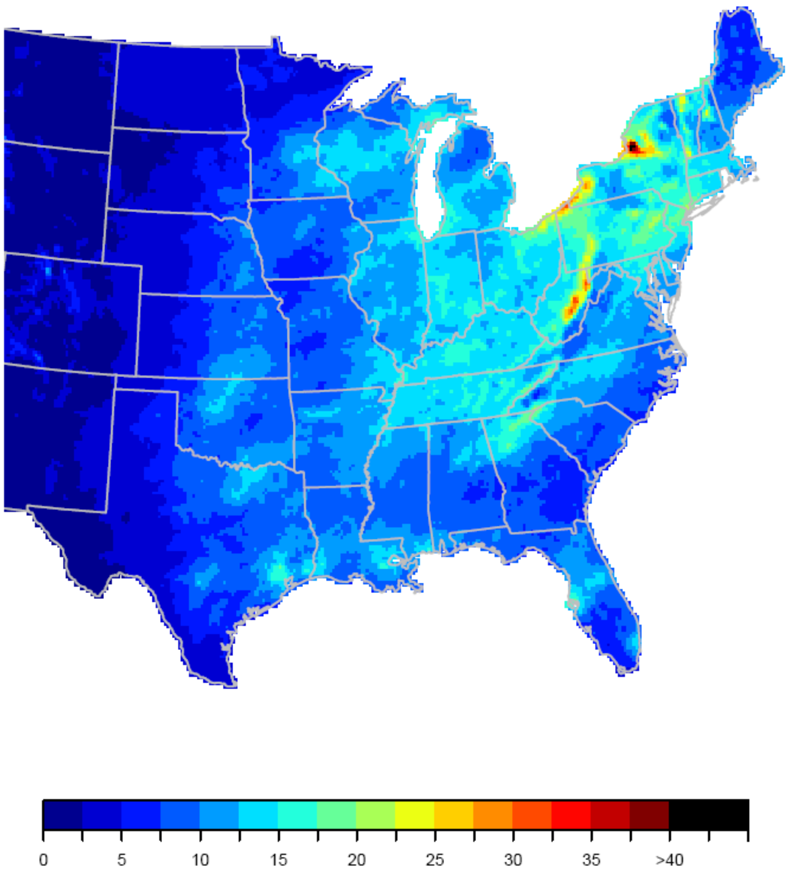
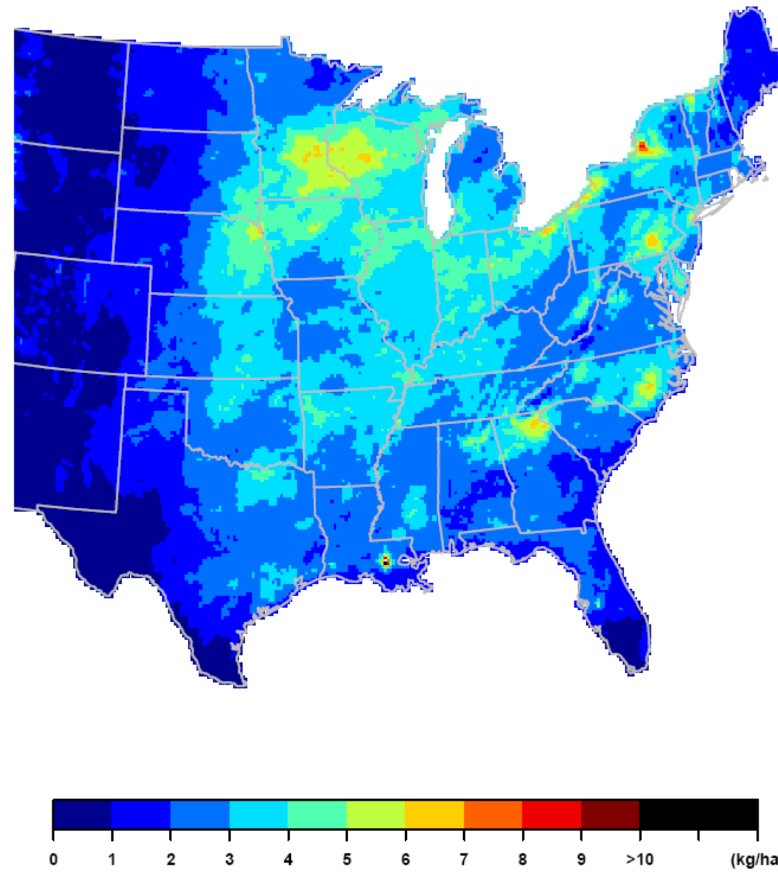
Adjusted CMAQ Wet Deposition NO_3 (kg/ha)



Model values adjusted with PRISM precipitation and then bias adjusted.

Adjusted CMAQ Wet Deposition NH_4 (kg/ha)



Model values adjusted with PRISM precipitation and then bias adjusted.

CMAQ is able to capture local concentration gradients of key species in NC (2004 data)

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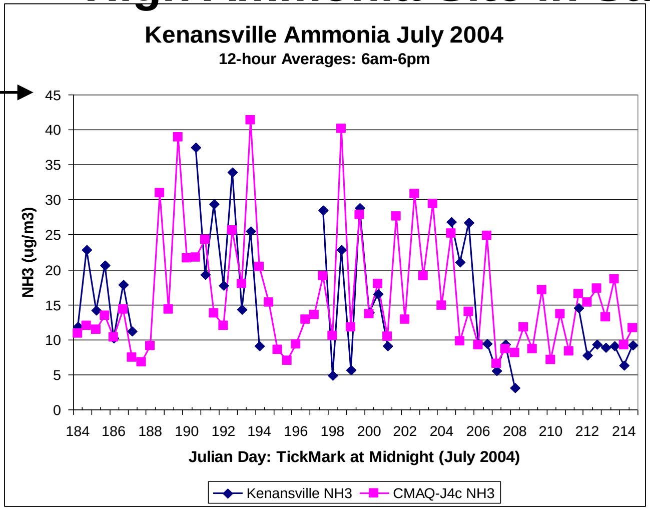
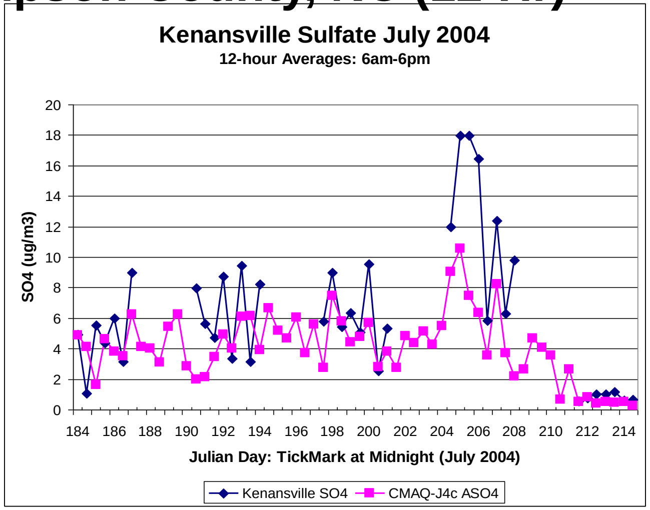
High Ammonia Site in Sampson County, NC (12-Hr)

Ammonia

45 µg/m^3 →





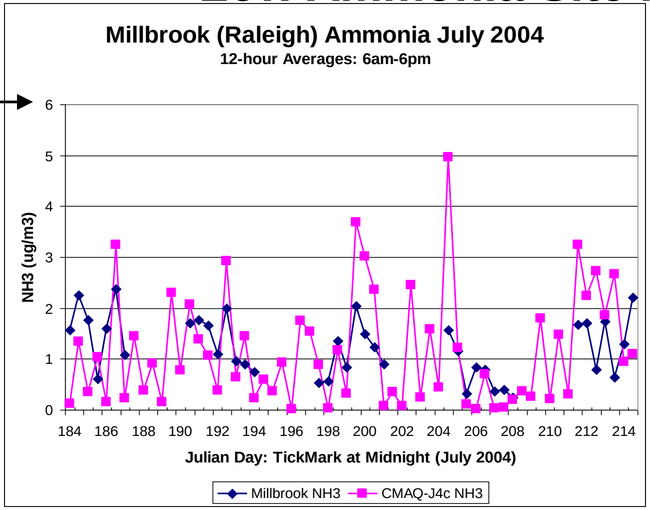
Sulfate

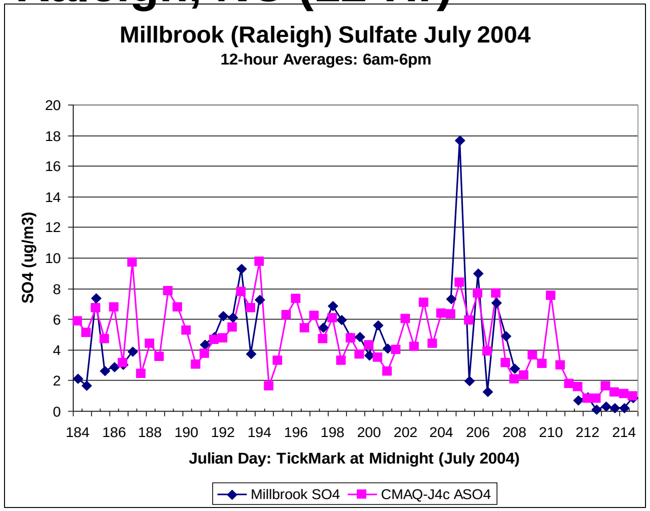
20 µg/m^3

Low Ammonia Site in Raleigh, NC (12-Hr)

Ammonia

6 µg/m^3 →

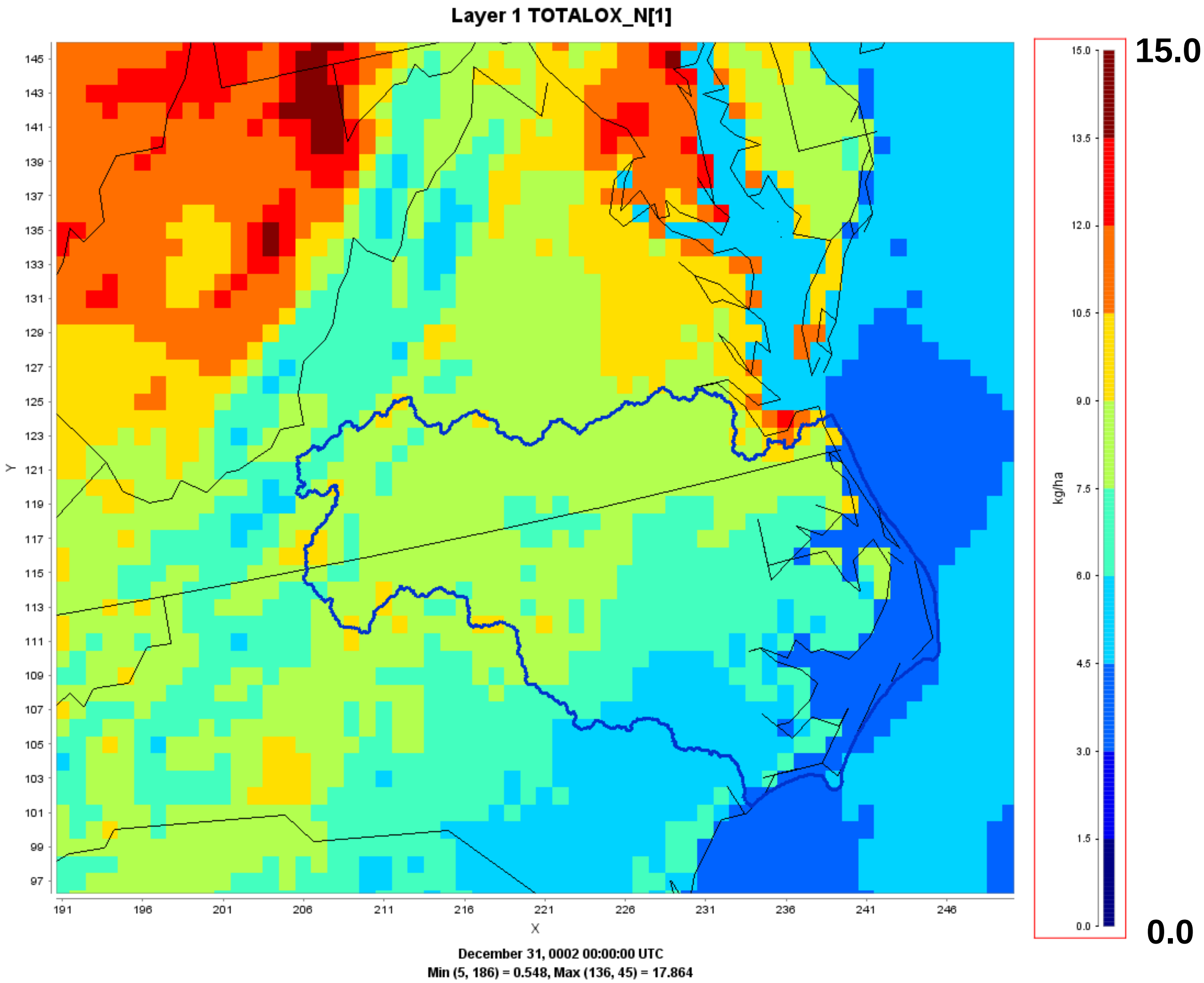




Sulfate

20 µg/m^3

What does the deposition look like across The A-P region: 2002 Total oxidized-N



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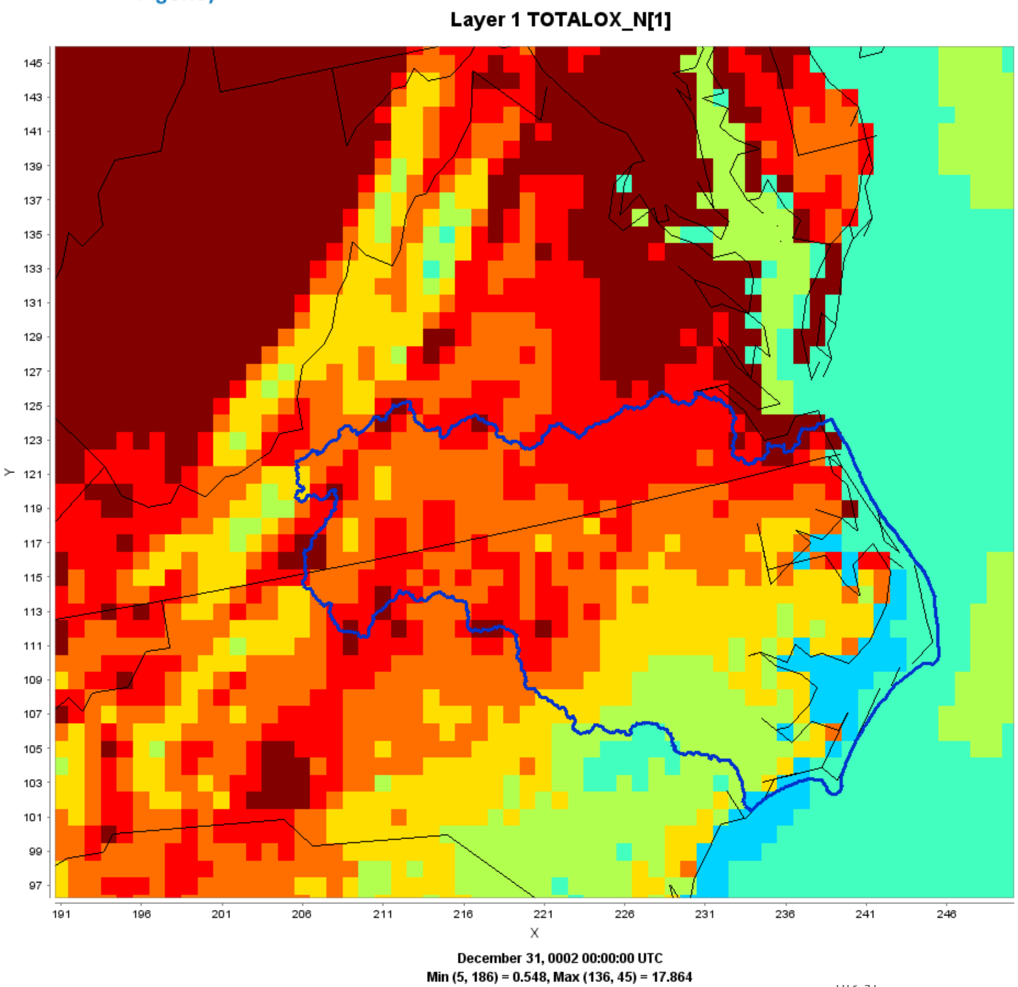
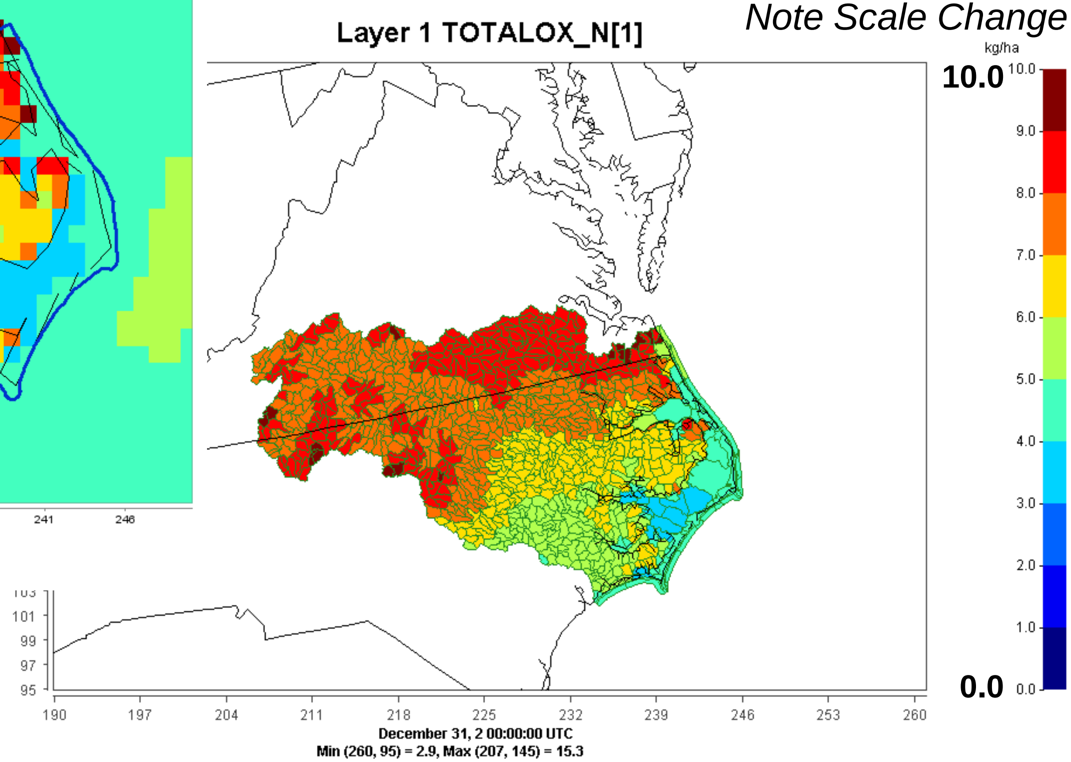
United States Environmental Protection Agency

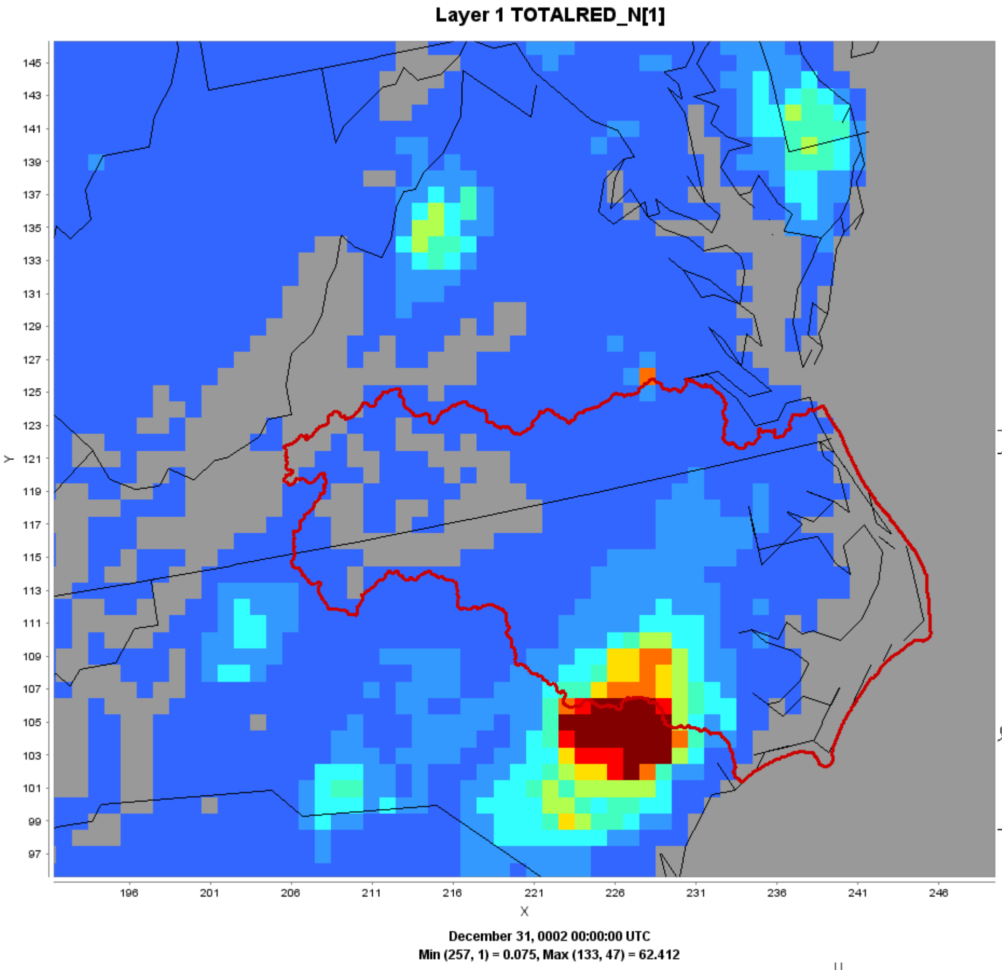


With Watershed Tool we can map CMAQ 12-km results to 12-digit HUCS

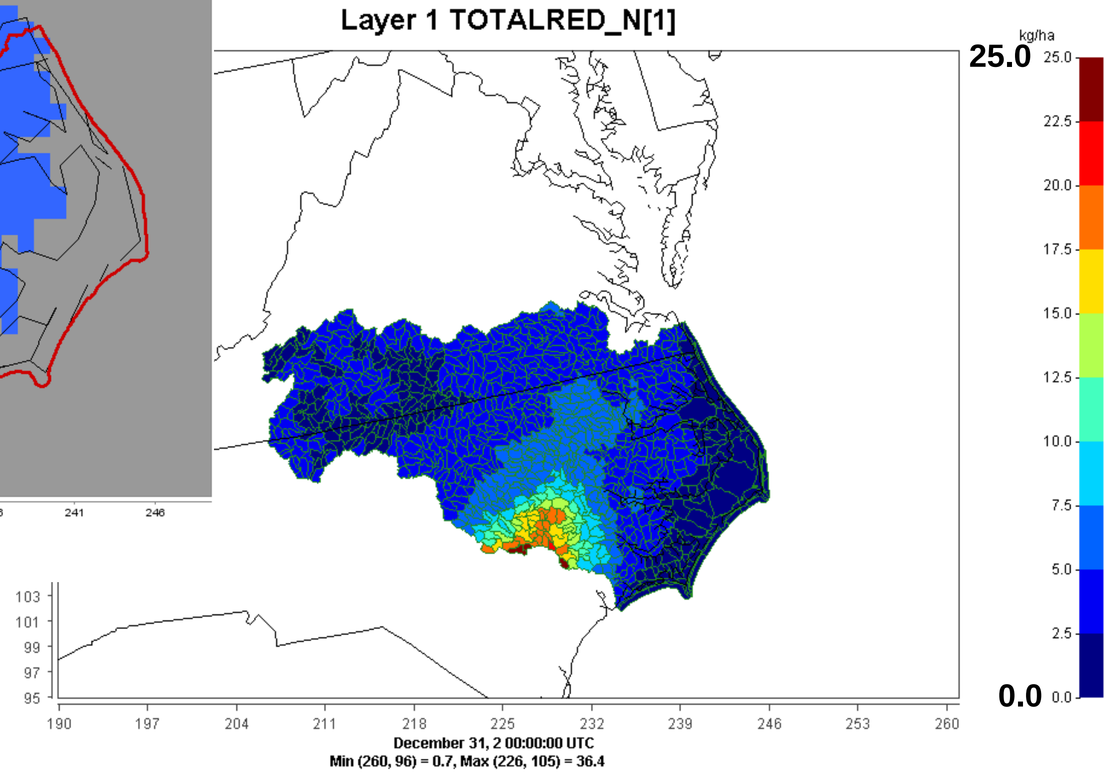
Note Scale Change



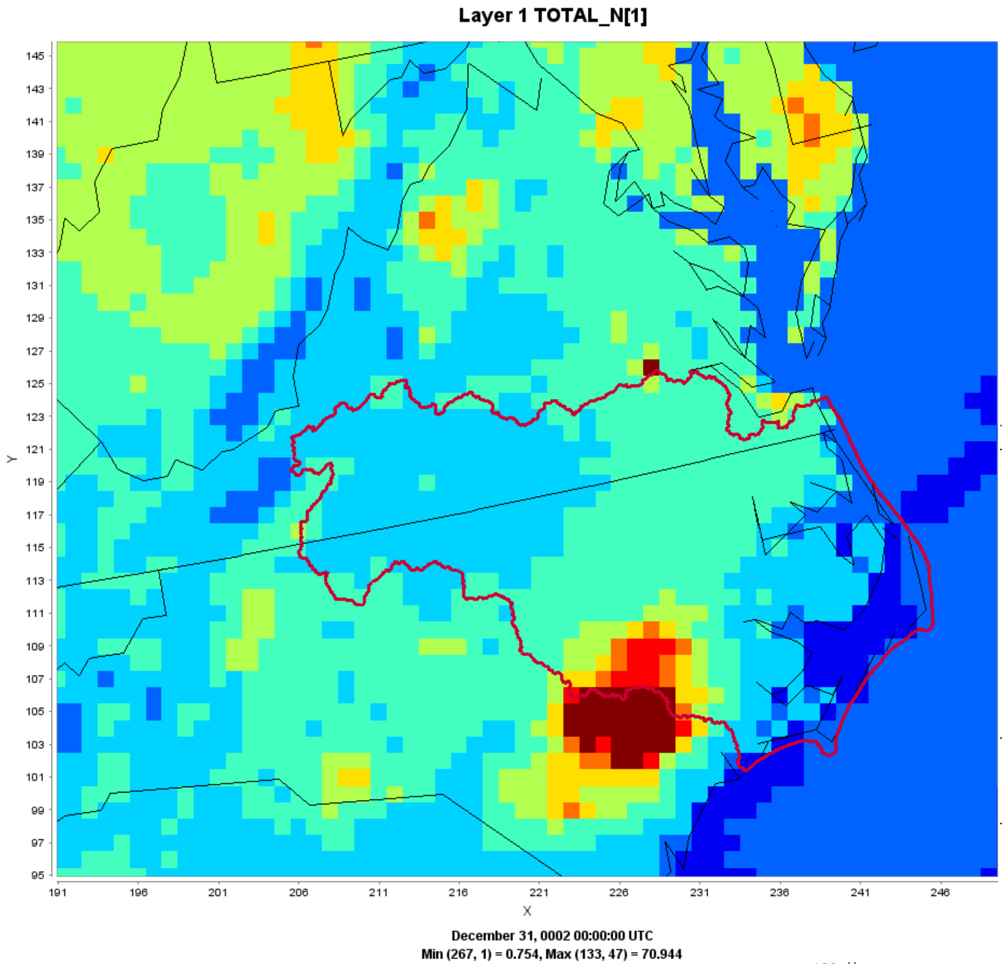
What does the deposition look like across The A-P region: 2002 Total reduced-N



With Watershed Tool we can map CMAQ 12-km results to 12-digit HUCS



What does the deposition look like across The A-P region: 2002 Total N



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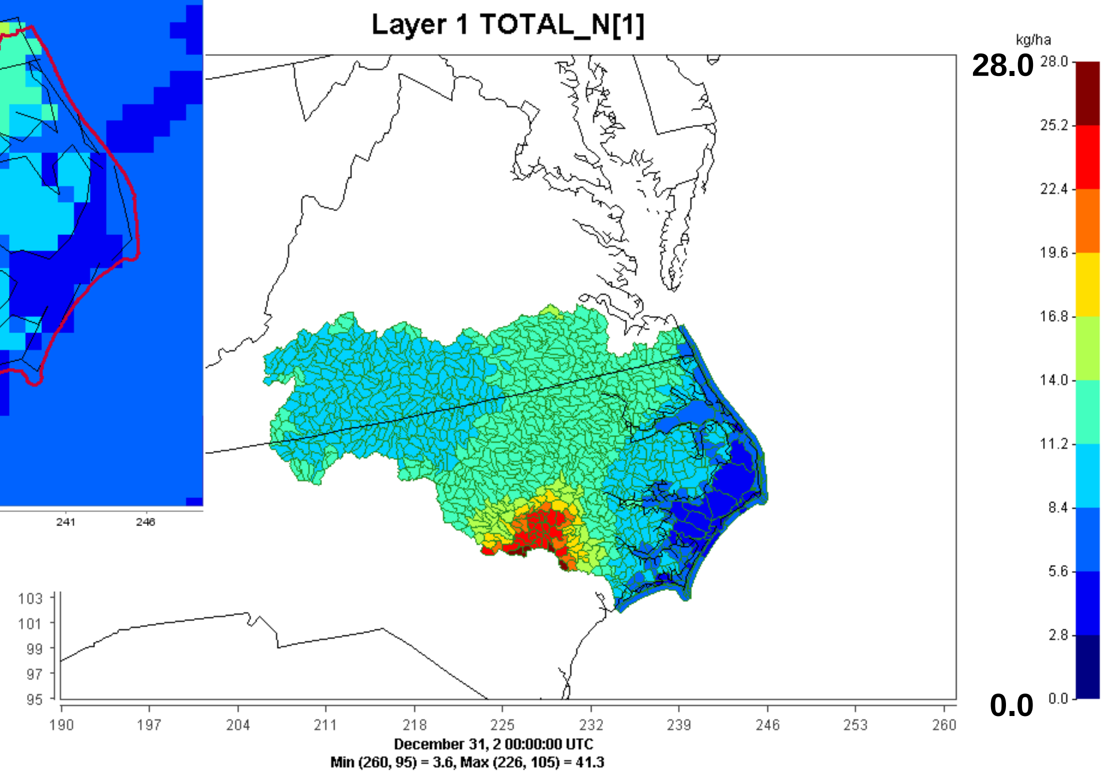
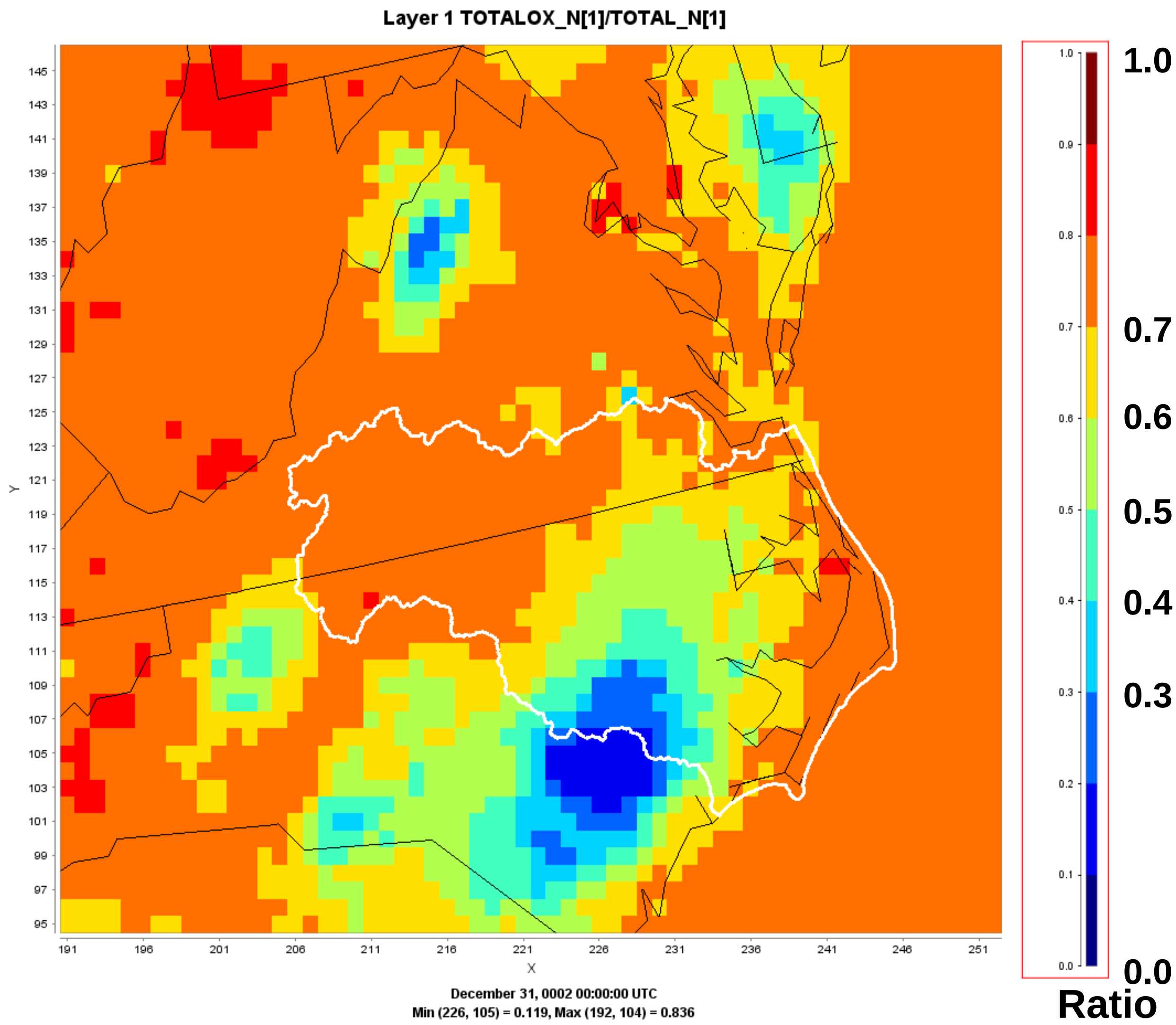


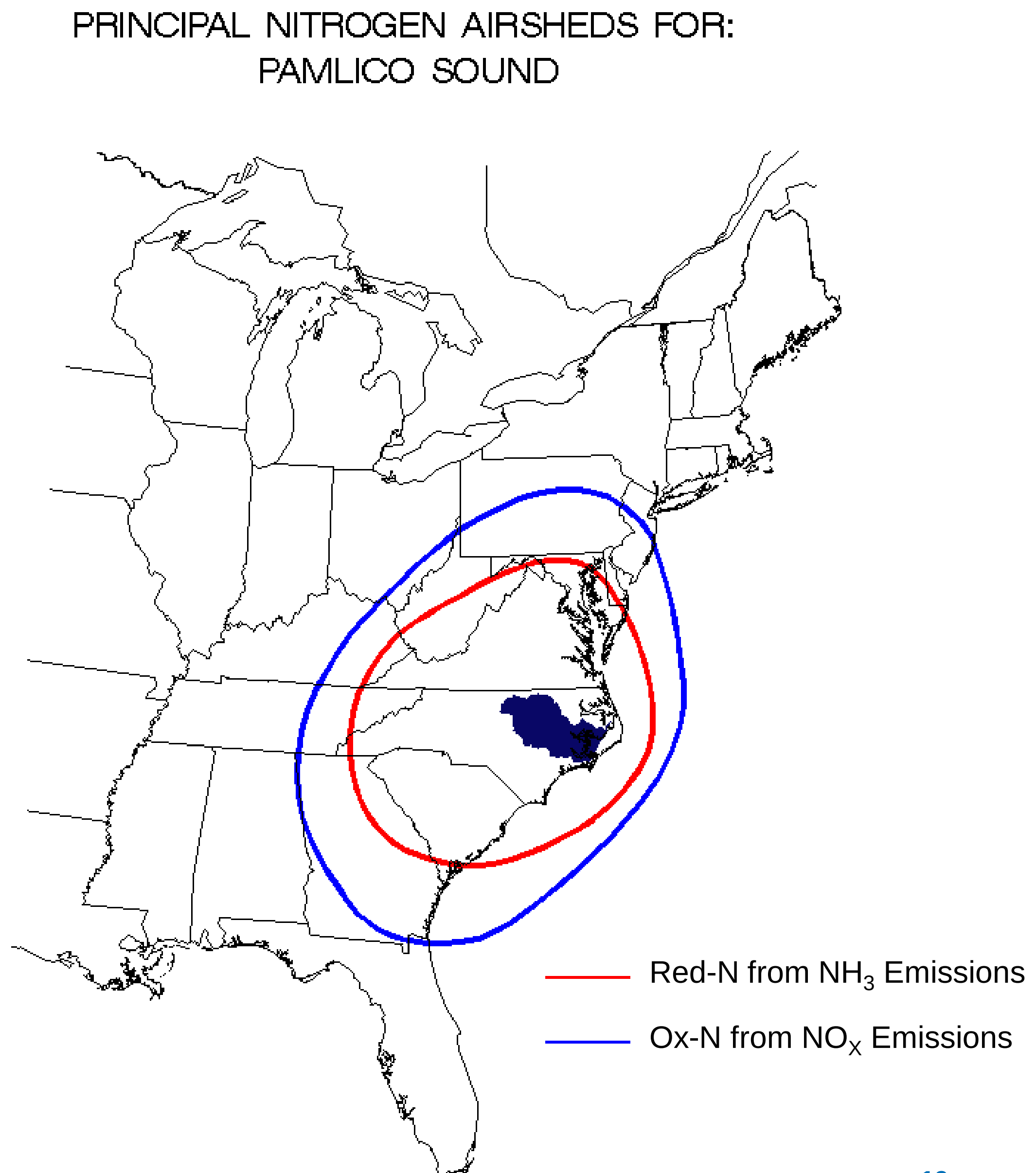
Where is the relative contribution of ox-N deposition to total N deposition important across the A-P region: It's in the headwaters



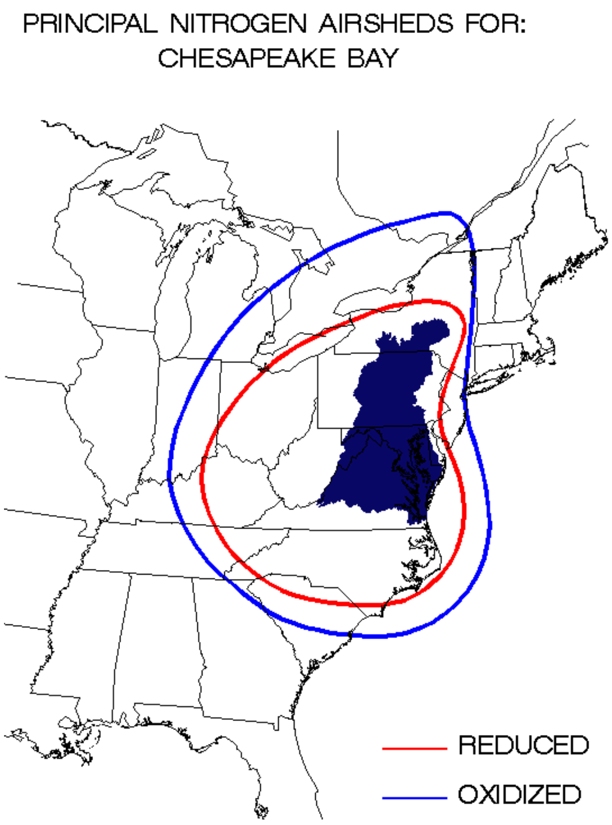
Where is the Nitrogen Coming From?

The emissions that contribute most to the deposition in the A-P region come from many states, not only NC

Any action to reduce atmospheric deposition to the A-P region will require regional, multi-state reductions in NO_X and NH_3 emissions



Oxidized Nitrogen Deposition State Responsibility



Deposition to Chesapeake Bay Watershed		
	1990	2020
Delaware		1.2%
Maryland	9.1%	7.9%
New York		4.6%
Pennsylvania	16.8%	16.4%
Virginia	10.4%	14.9%
West Virginia		4.6%
Six State (calculated as a group)		49.3%

What Sectors are Responsible For the Nitrogen Emissions

	2002 NO_X Emissions in NO_X Airshed (8 States) % by Sector	2002 NH_3 Emissions in NH_3 Airshed (4 States) % by Sector
Mobile	38.5 %	8.9 %
NonRoad	14.4 %	0.1 %
Power Plants	28.0 %	0.3 %
Industrial Points	10.3 %	2.3 %
Area Sources	6.3 %	0.9 %
Agriculture/Biology	1.8%	86.8 %
Other	0.71 %	0.6 %

Mobile + Power Plant sources responsible for 2/3^{rds} of NO_X emissions

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What States are Responsible For the Nitrogen Emissions

	2002 NO_X Emissions in NO_X Airshed (8 States) % by State
Delaware	1.6 %
Georgia	18.6 %
Maryland	8.3 %
North Carolina	17.3 %
Pennsylvania	21.7 %
South Carolina	10.2%
Virginia	14.5 %
West Virginia	7.7 %

	2002 NO_X Emissions in NH_3 Airshed (4 States) % by State	2002 NH_3 Emissions in NH_3 Airshed (4 States) % by State
Maryland	16.6 %	10.7 %
North Carolina	34.4 %	57.4 %
South Carolina	20.2 %	12.4 %
Virginia	28.8 %	19.5 %

A Special Look at Ammonia

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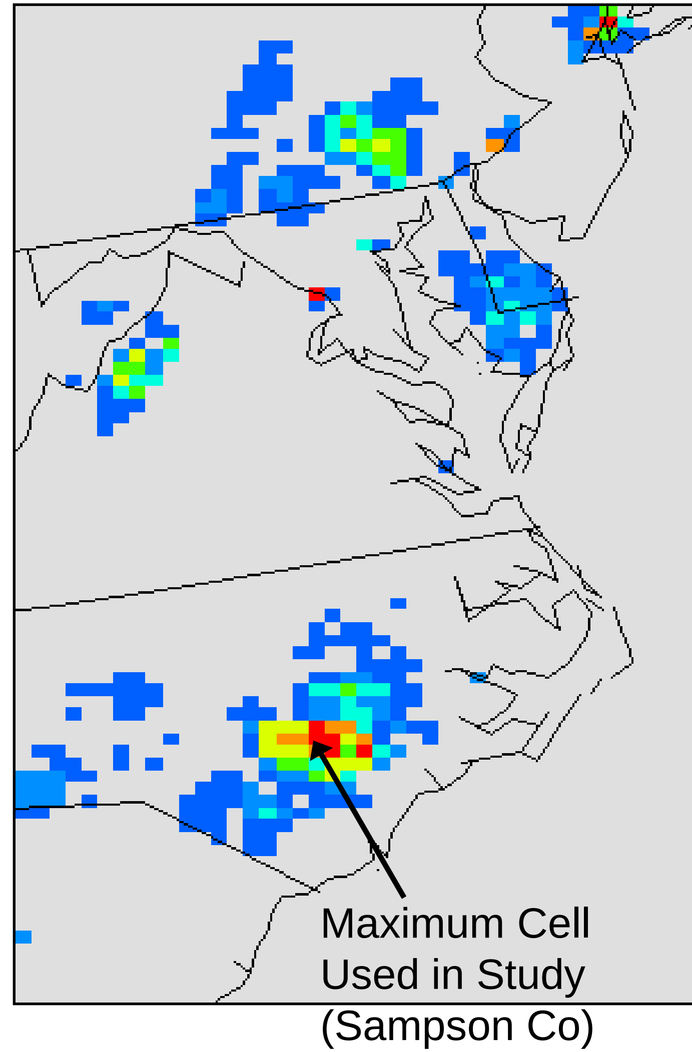
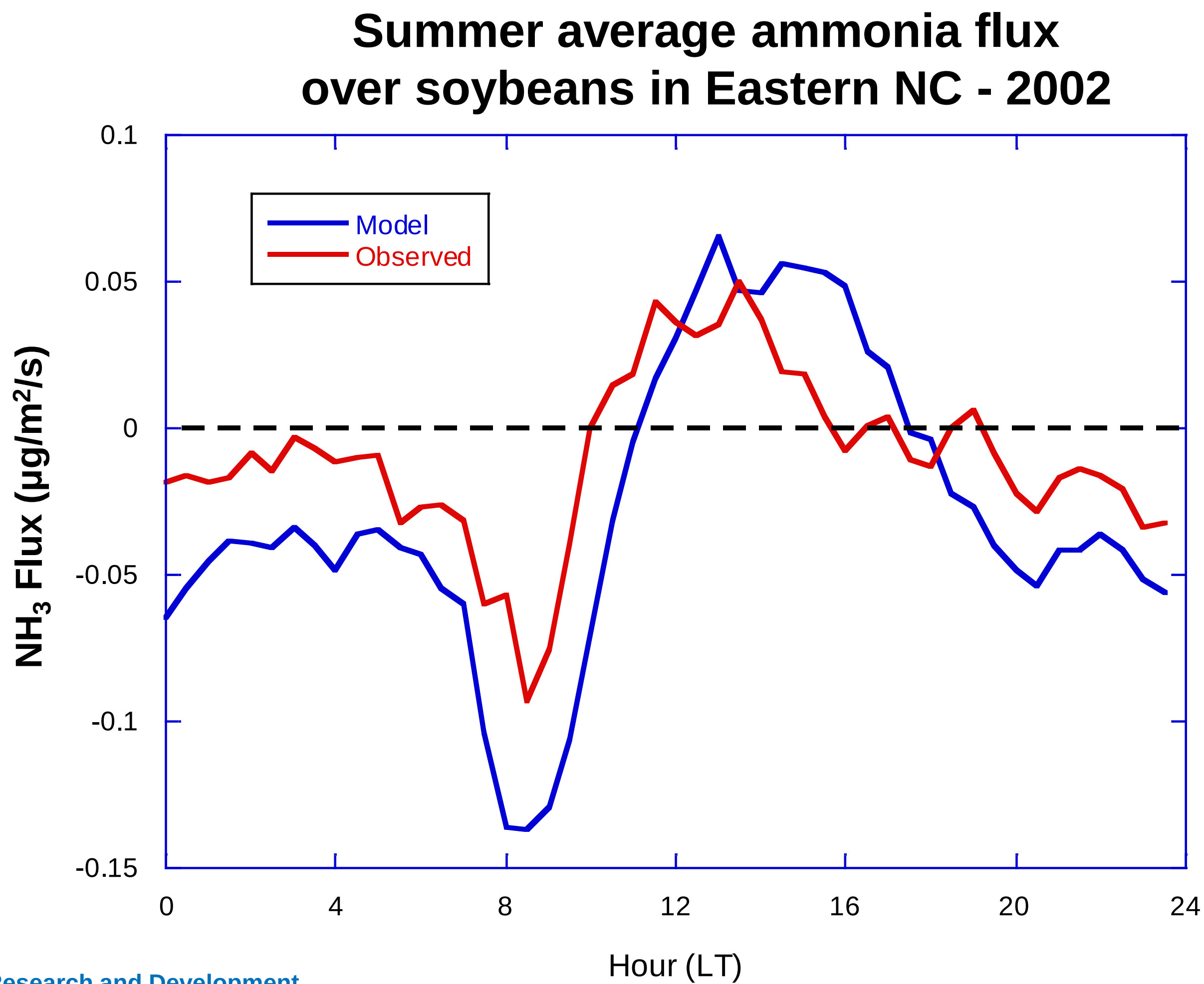
- Ammonia is important and there is a conventional wisdom among some that all ammonia emissions deposit very near the point of emission, i.e. locally.

- This is incorrect. We have conducted some model NH_3 budget studies for NC conditions to estimate the appropriate NH_3 fate (according to CMAQ). The CMAQ results are very consistent with semi-empirical studies carried out in NC by John Walker (EPA) and Wayne Robarge (NCSU).

- We particularly examined:
  - The budget of a high-emitting cell at the surface, and
  - The range of influence of the emissions from a single, high-emitting cell



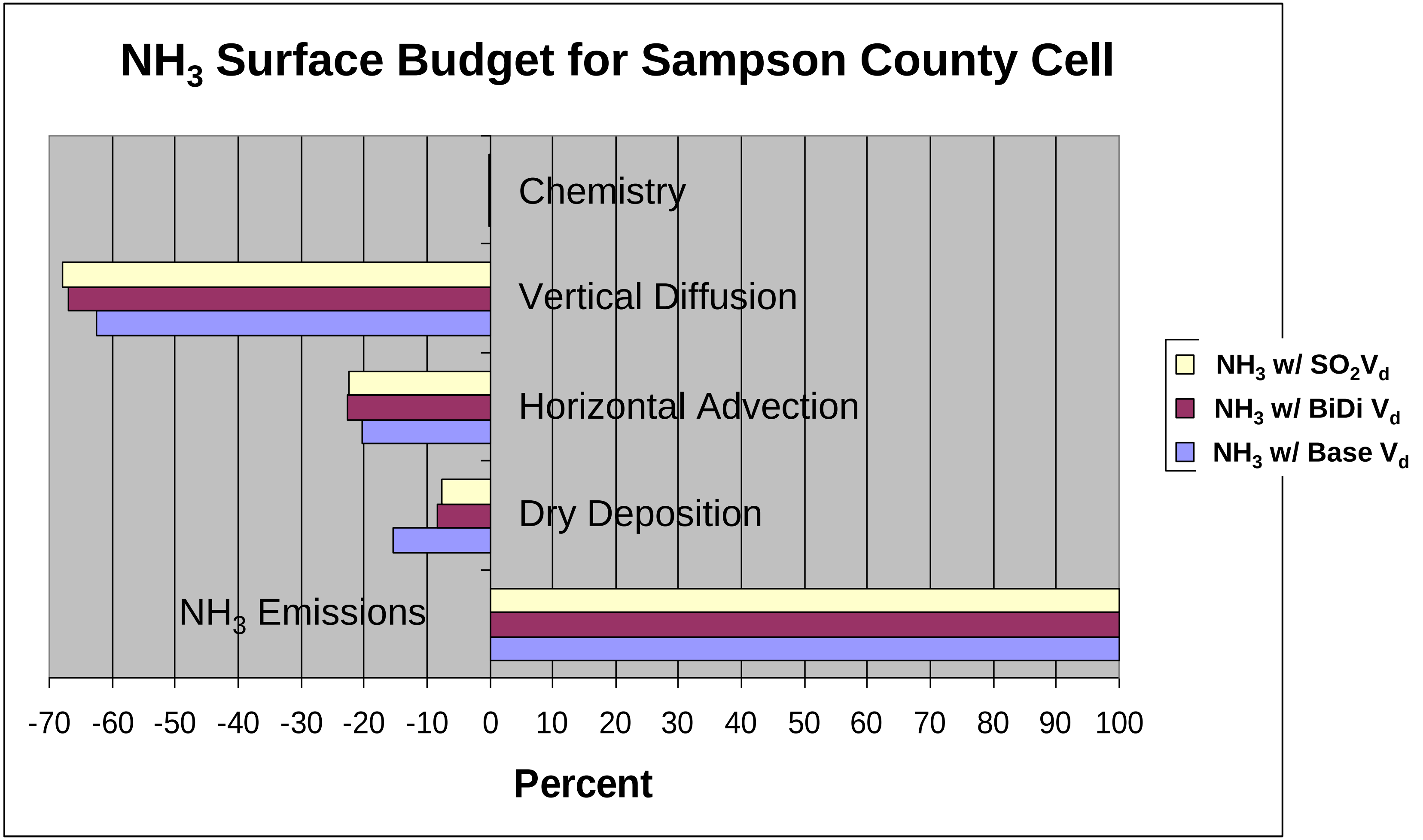
Ammonia is also more complex than most species because its air-surface exchange is bi-directional, not unidirectional. So we performed our NH_3 budget studies with three different estimates of the rate of air-surface exchange



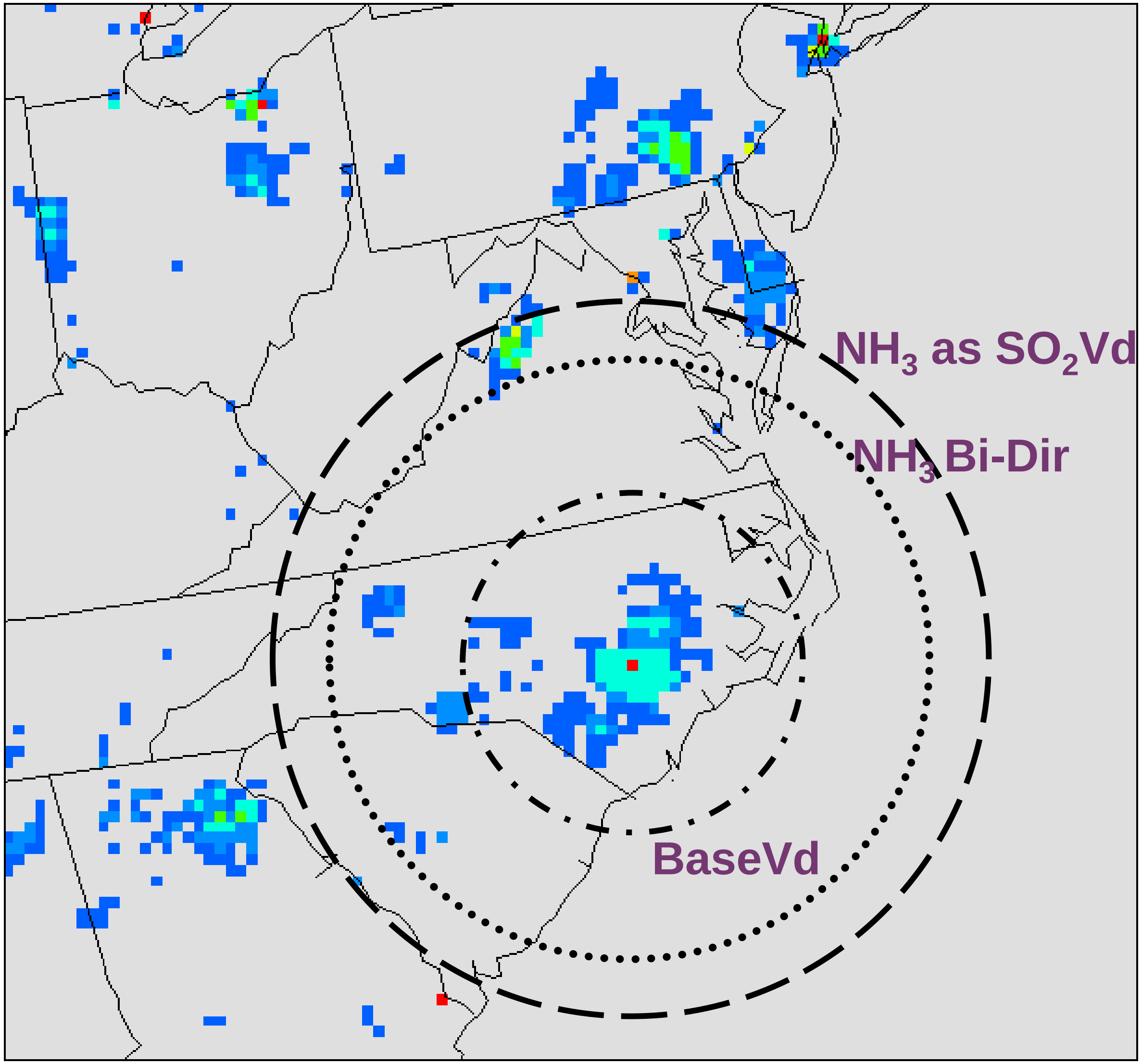
Only about 10% of the Local NH_3 Emissions Deposit Locally

(consistent with semi-empirical studies)

June 2002

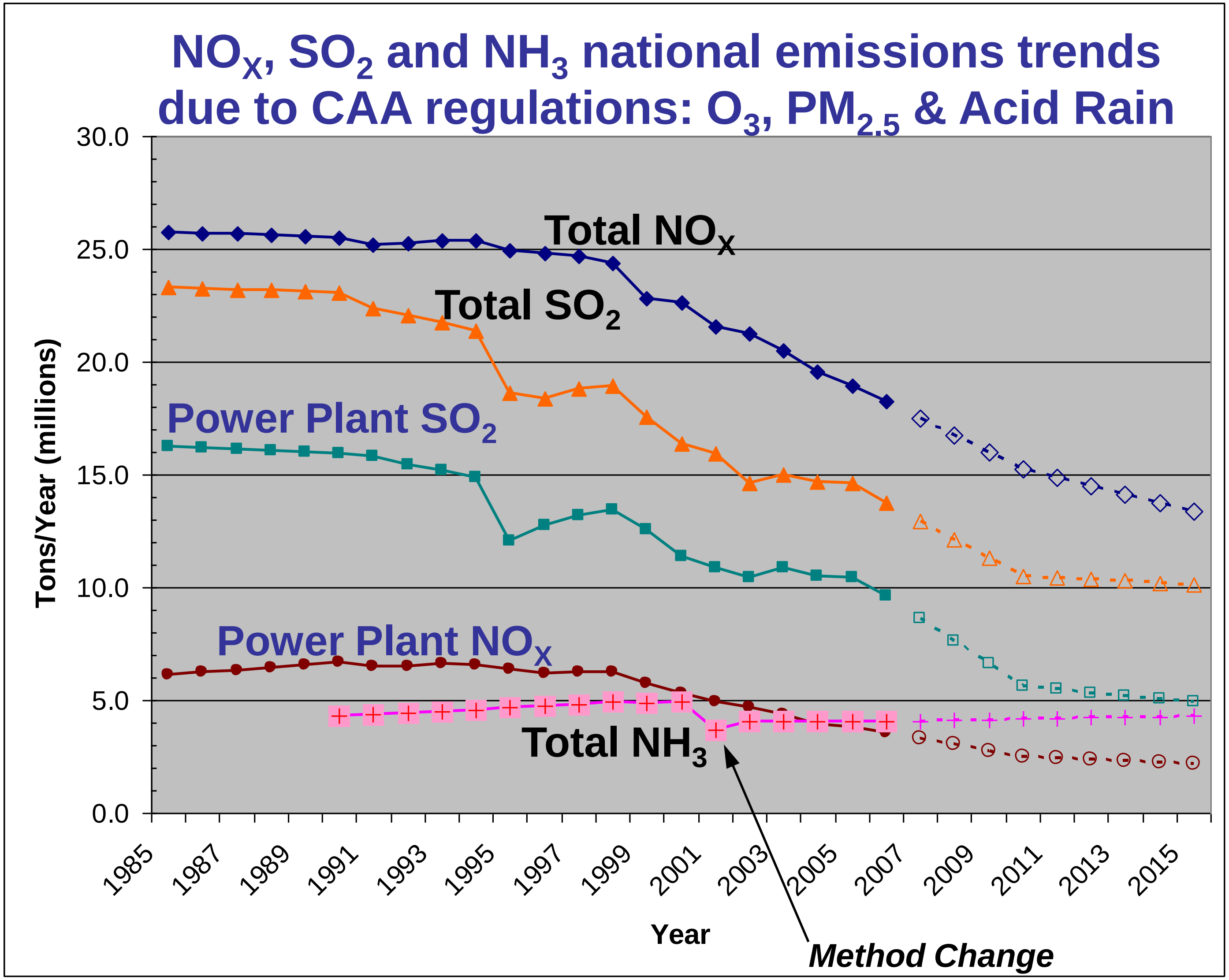


Range of Influence: Single NC Maximum Cell



The Range of Influence of NH_3 Emissions is Influenced by the Dry Deposition Formulation. It Increases With a Change from the Base CMAQ to the Bi-directional Flux Formulation for NH_3

What is Expected to Happen to Deposition In the Future out to 2020



Does Responsibility for Oxidized Nitrogen Emissions Change in 2020 With CAA Reductions

Sectors	2002 NO_X Emissions in NO_X Airshed (8 States) % by Sector	2020 NO_X Emissions in NO_X Airshed (8 States) % by Sector
Mobile	38.5 %	20.7 %
NonRoad	14.4 %	18.7 %
Power Plants	28.0 %	21.9 %
Industrial Points	10.3 %	18.6 %
Area Sources	6.3 %	14.3 %
Biologenics	1.8%	4.2 %
Other	0.71 %	1.6 %

States	2002 NO_X Emissions in NO_X Airshed (8 States) % by State	2020 NO_X Emissions in NO_X Airshed (8 States) % by State
Delaware	1.6 %	1.8 %
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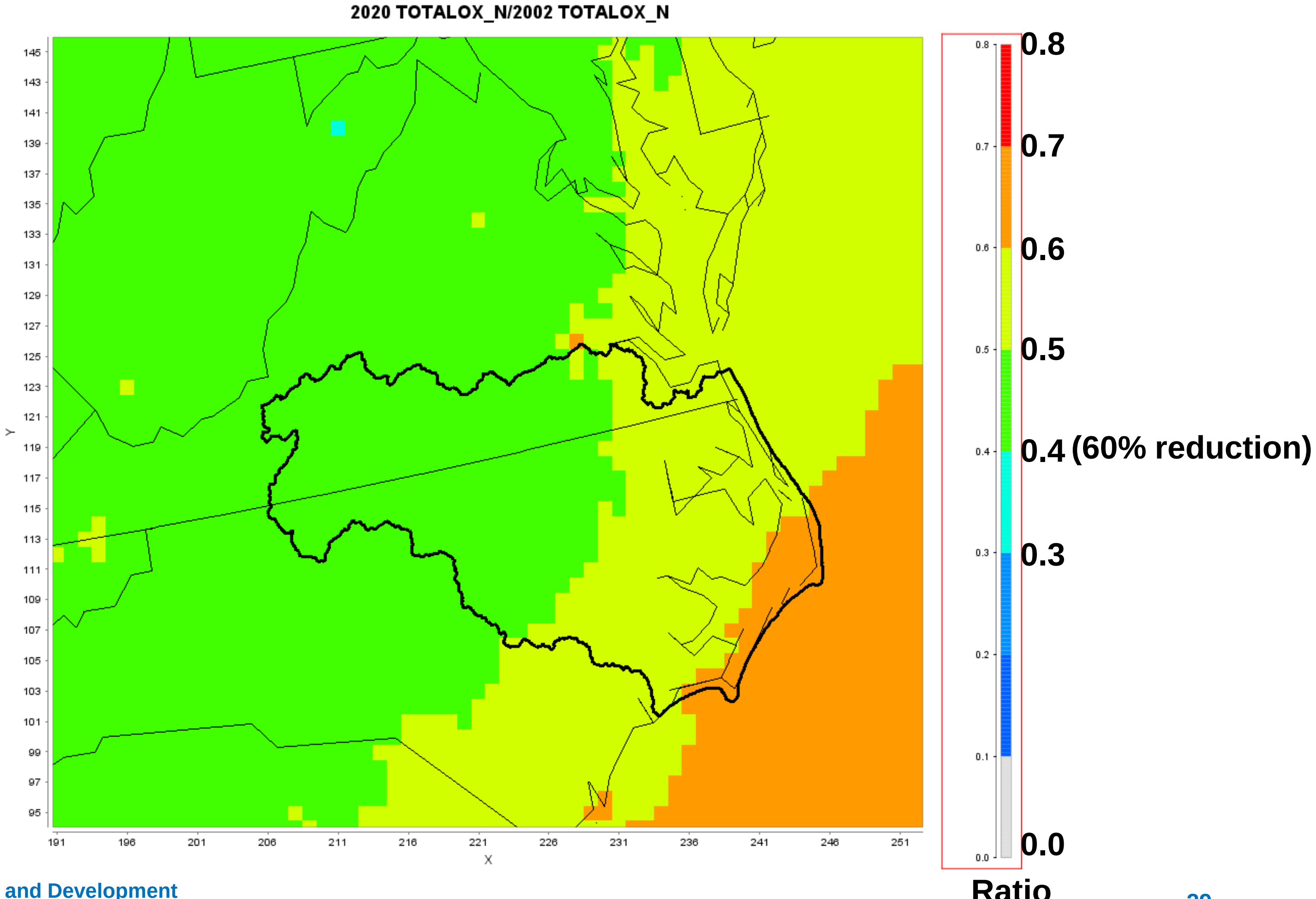
Pennsylvania	21.7 %	21.4 %
South Carolina	10.2%	10.0%
Virginia	14.5 %	15.9 %
West Virginia	7.7 %	8.6 %

The emissions reductions stemming from CAA regulations aimed at reducing human health risk are expected to significantly reduce oxidized nitrogen deposition by 2020



The 2020 reduction in total nitrogen deposition is much less than the ox-N reduction due to lack of change or increases in red-N deposition

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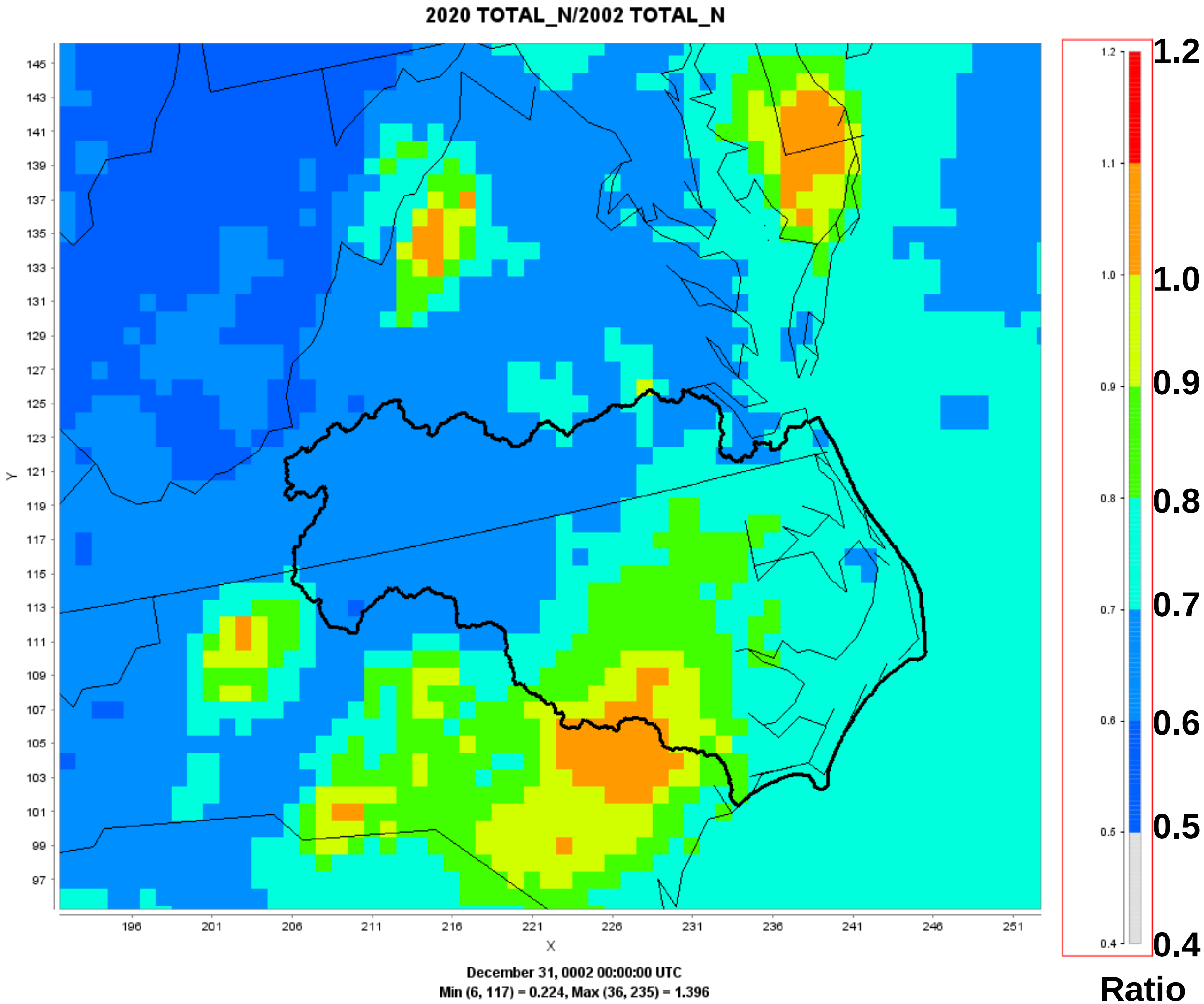

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- Regional atmospheric deposition models, like CMAQ, can provide useful information for ecosystem based management (EBM) related to the questions of how much, what form, and where from

- To fully realize the potential to contribute to EBM the air models need to be linked with ecosystem / water-shed / biogeochemical cycling models. This is not a trivial exercise and we are working on the linkage issues

- We are also working on approaches to downscale meteorology for climate change analyses in ways to support the study of the impacts on ecosystems