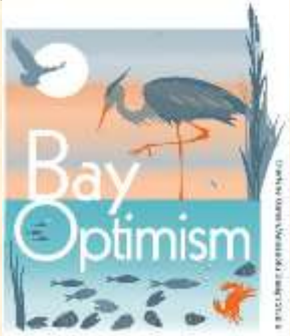
Integrating Air and Water Environmental Management in the Chesapeake Bay Program: An Encouraging Tale



SERC Lecture Series

August 15, 2017

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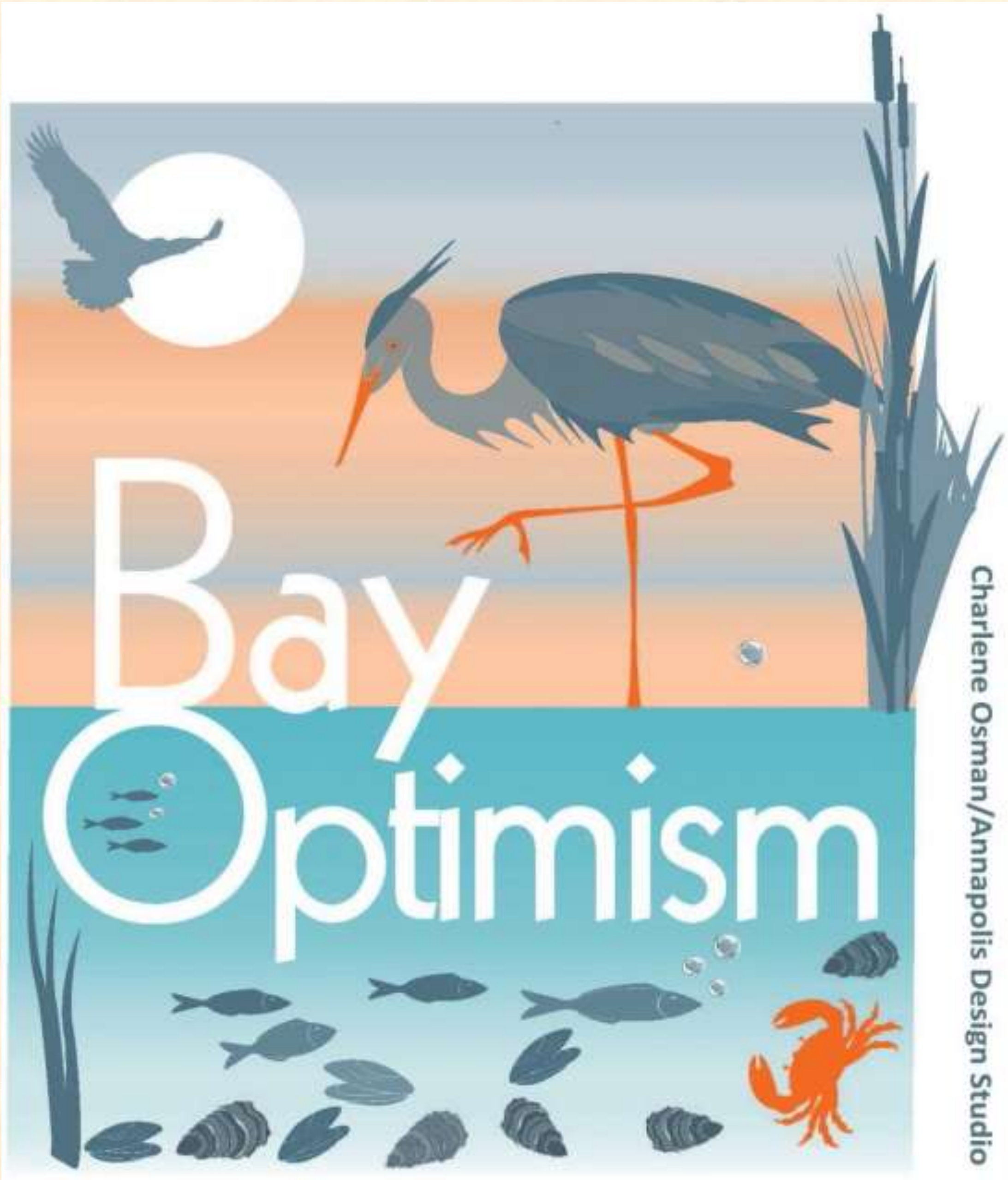
Chesapeake Bay Program
Science, Restoration, Partnership


Bay
Optimism
Charlene Osman/Annapolis Design Studio

Overview of Trends in Atmospheric Deposition

- Cleaner air means cleaner water. The Clean Air Act has helped Americans breathe easier and live healthier, reducing illnesses and premature deaths and contributing to a stronger economy and better quality of life. At the same time, the Act has helped protect our waters by reducing NOx emissions. Air pollution contributes about one third of the total nitrogen loads delivered to the lands and tidal waters of the Bay watershed.
- Load reductions tracked in the Chesapeake Bay watershed take into account the national nitrogen emission reductions and subsequent Chesapeake watershed deposition reductions that are due to national programs.
- Trends in NOx and ammonia - Loads of oxidized nitrogen (NOx) are decreasing and are estimated to continue to decrease until 2025 and beyond. Loads of reduced nitrogen or ammonia are steady or increasing.

A Short History of the Assessment of Atmospheric Deposition of Nitrogen in the Chesapeake Bay Program

1985 – “There is no atmospheric deposition of nitrogen.”

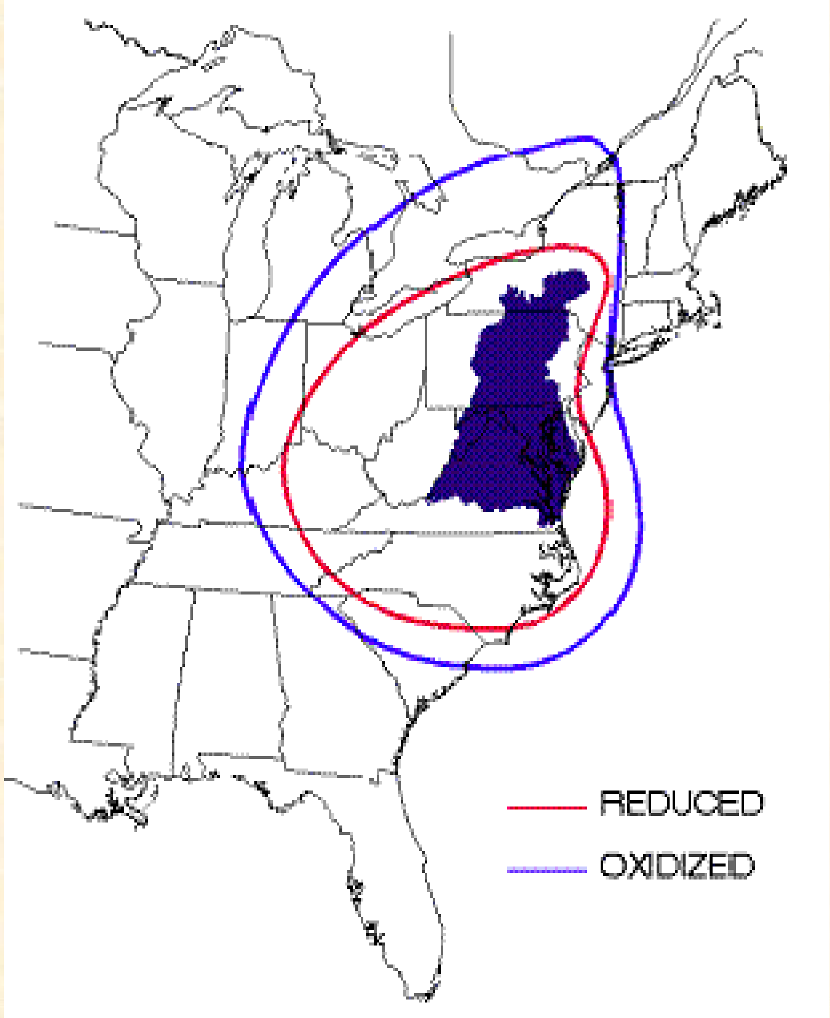
1995 – “Ok, there is some atmospheric deposition of nitrogen……but its uncontrollable.” (M. Tylor, 1988; Fisher and Oppenheimer, 1991)

2005 – “Wow! The CAA national program is sure removing a lot of nitrogen from the Chesapeake watershed.” (and other coastal watersheds too).

2015 – The atmospheric deposition of nitrogen to tidal water is an important component of the TMDL allocations. “We couldn’t have done the restoration without the air reductions.”

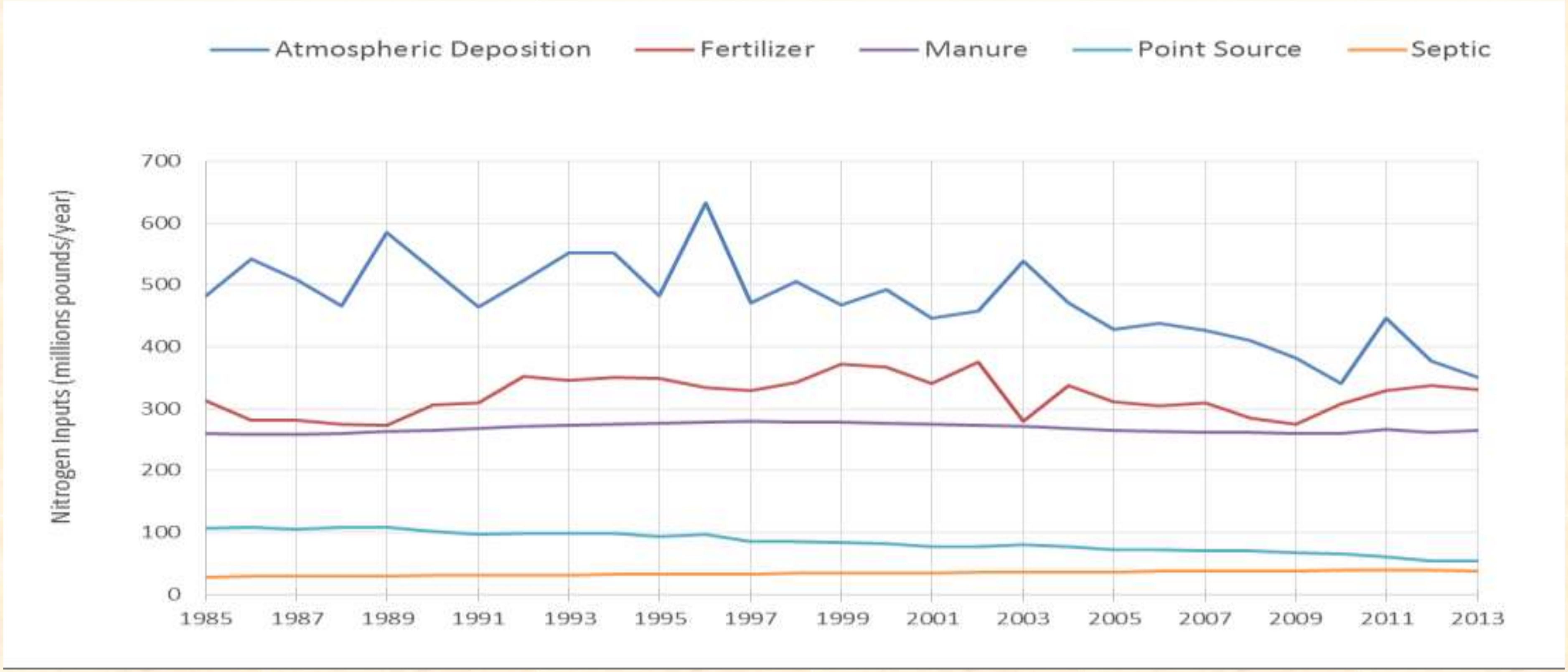
Chesapeake Bay Airshed

The Bay’s NOx airshed—the area where emission sources that contribute the most airborne nitrates to the Bay originate—is about 570,000 square miles, or nine times the size of the Bay’s watershed. About 50 percent of the nitrate deposition to the Bay is from air emission sources in Bay watershed jurisdictions. Another 25 percent of the atmospheric deposition load to the Chesapeake watershed is from the remaining area in the airshed. The remaining 25 percent of deposition is from the area outside the Bay airshed. The ammonia airshed is similar to the NOx airshed, but slightly smaller.



Atmospheric deposition is the greatest nitrogen load source to the Chesapeake

Time series of estimated atmospheric, fertilizer, manure, point source, and septic nitrogen input loads to the Chesapeake watershed and tidal waters.



Atmospheric deposition has been the highest source of nitrogen load to the Chesapeake watershed and tidal Bay, but also is the load with the most rapid rate of reduction.

The nitrogen attenuation that takes place in the delivered load to the Bay – The 1% Credit

Atmo Dep

About 70% of the emission NOx load is removed in conversion of NO_2 to units of N. Example 100 tons of emissions reduced to 30 tons.

About 52% of NOx atmo dep emitted in the CB watershed Is deposited in the CB watershed. Example: 30 tons reduced to 15 tons.

Forest, Cropland, Pasture, and Pervious Developed Land Use

The ~1% Credit

About 7% of NOx atmo dep deposited is exported to rivers and streams and delivered to the Bay. Example: 15 tons reduced to 1 ton.

Rivers and Streams

On average about 1% of NOx emissions are delivered to the Chesapeake (but additional reductions can be attributed to tidal Bay deposition).

Overview:

- **Problem Introduction and Watershed Management Approach in the Chesapeake.**

- **Introduction To Key Models and Management Process.**

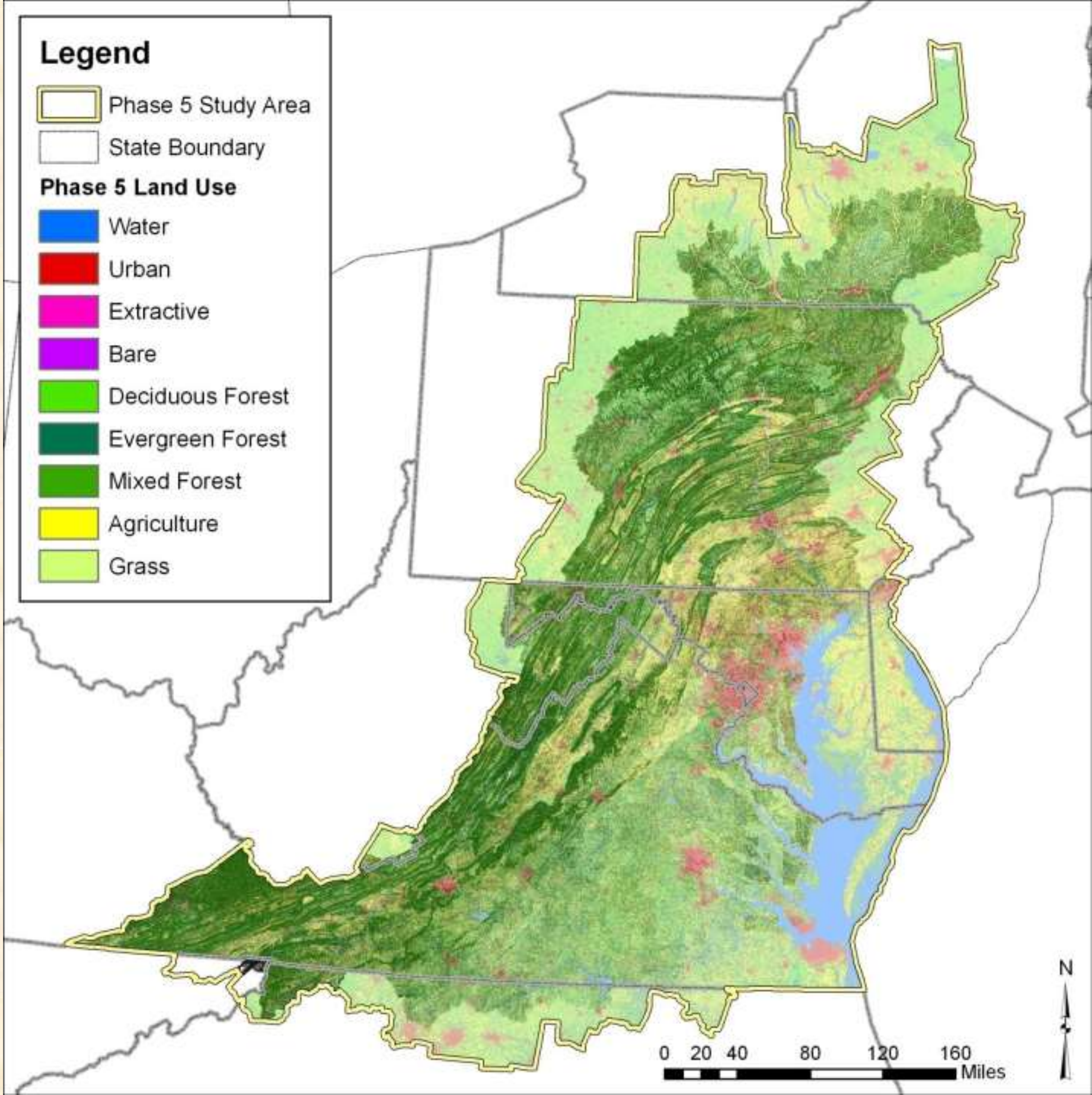
- **Trends and Results in the Chesapeake**

- **Conclusions**

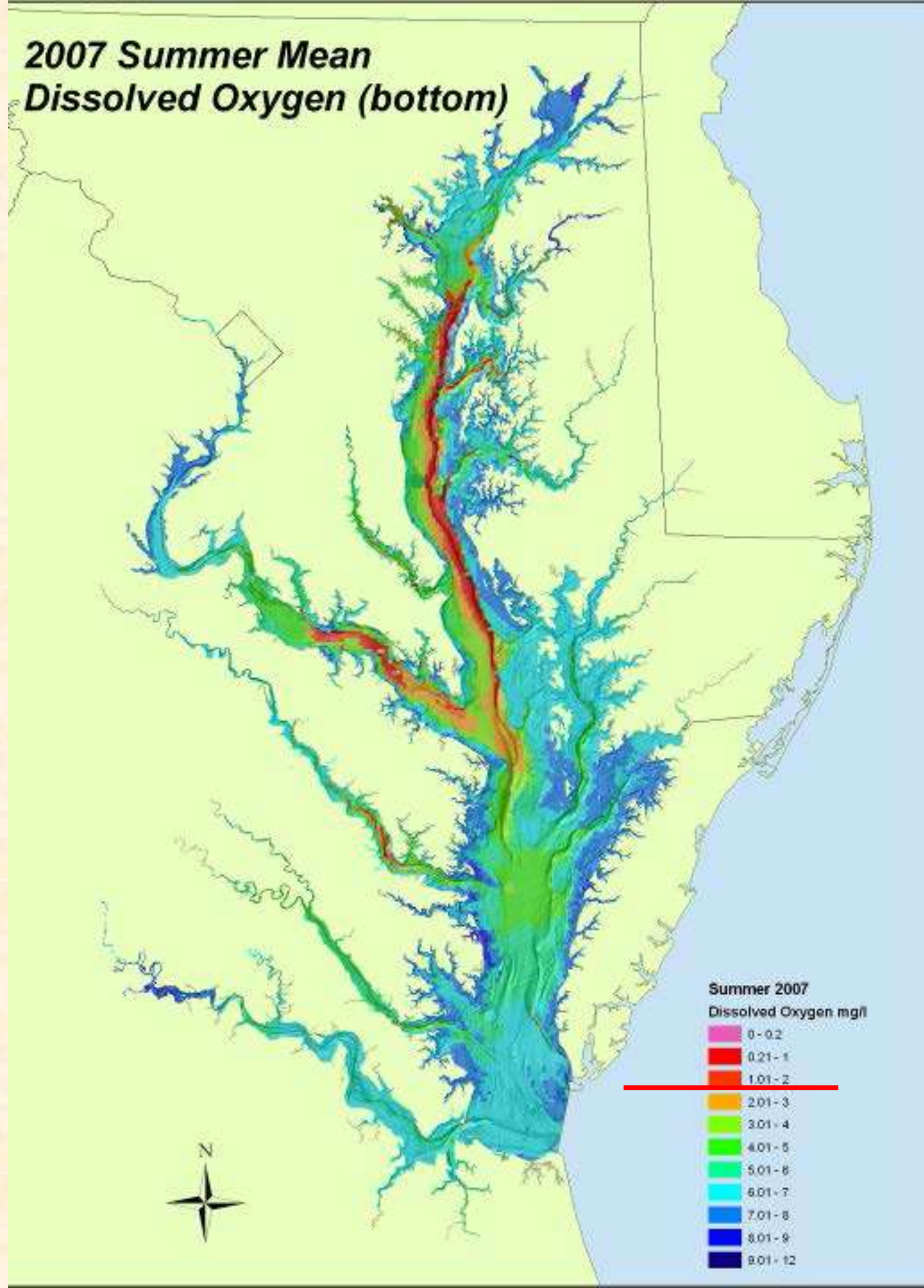
Problem Introduction and Watershed Management Approach

Photo: Chuck Gallegos/SERC, with aerial support from LightHawk

We need to view the CBP integrated models of the airshed, watershed, and tidal Bay models as a whole. Together they relate the watershed and airshed loads to water quality impairments in the Chesapeake.

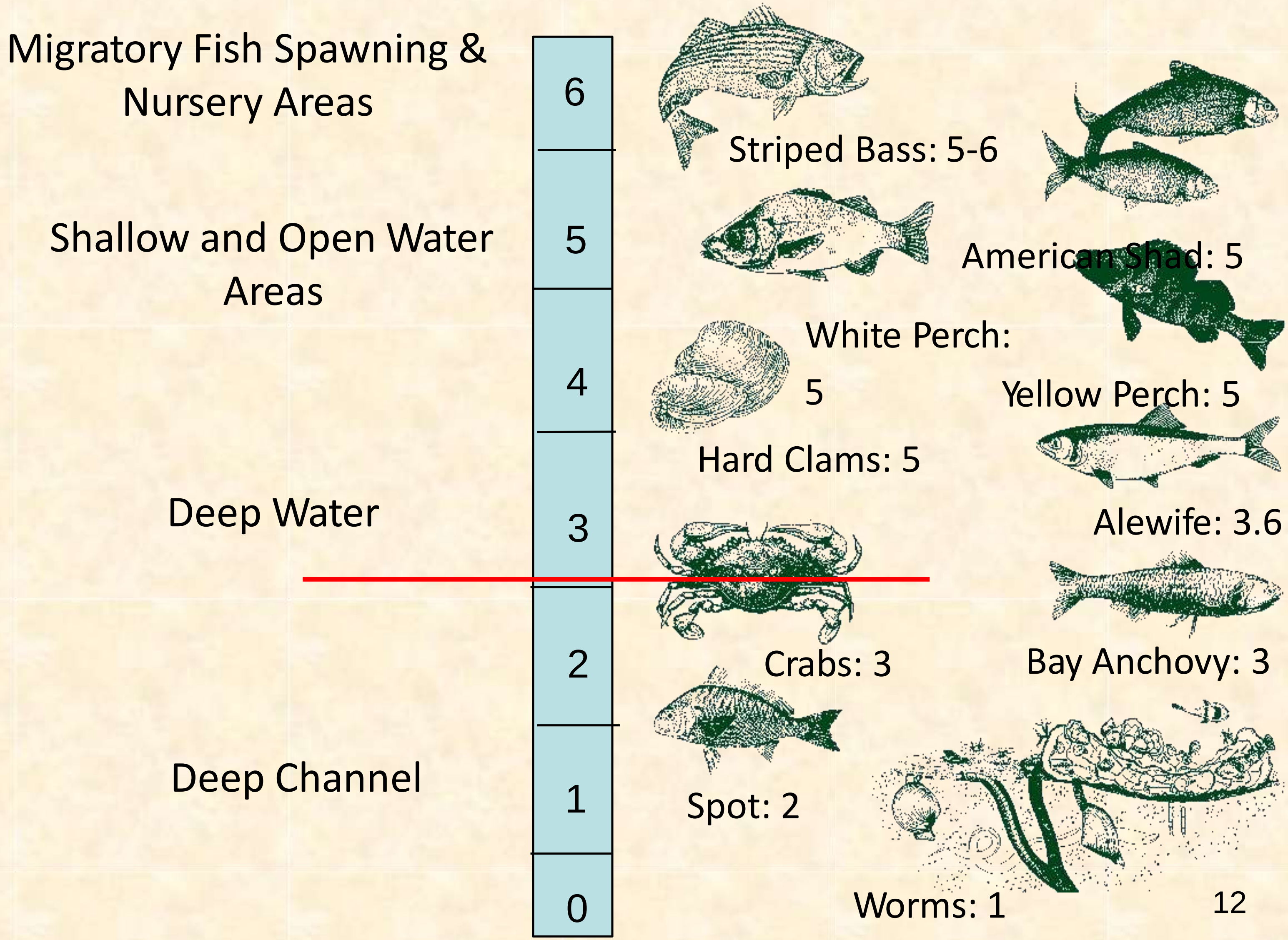


Low to no dissolved oxygen in the Bay and tidal rivers is a recurring problem every summer in the Chesapeake.

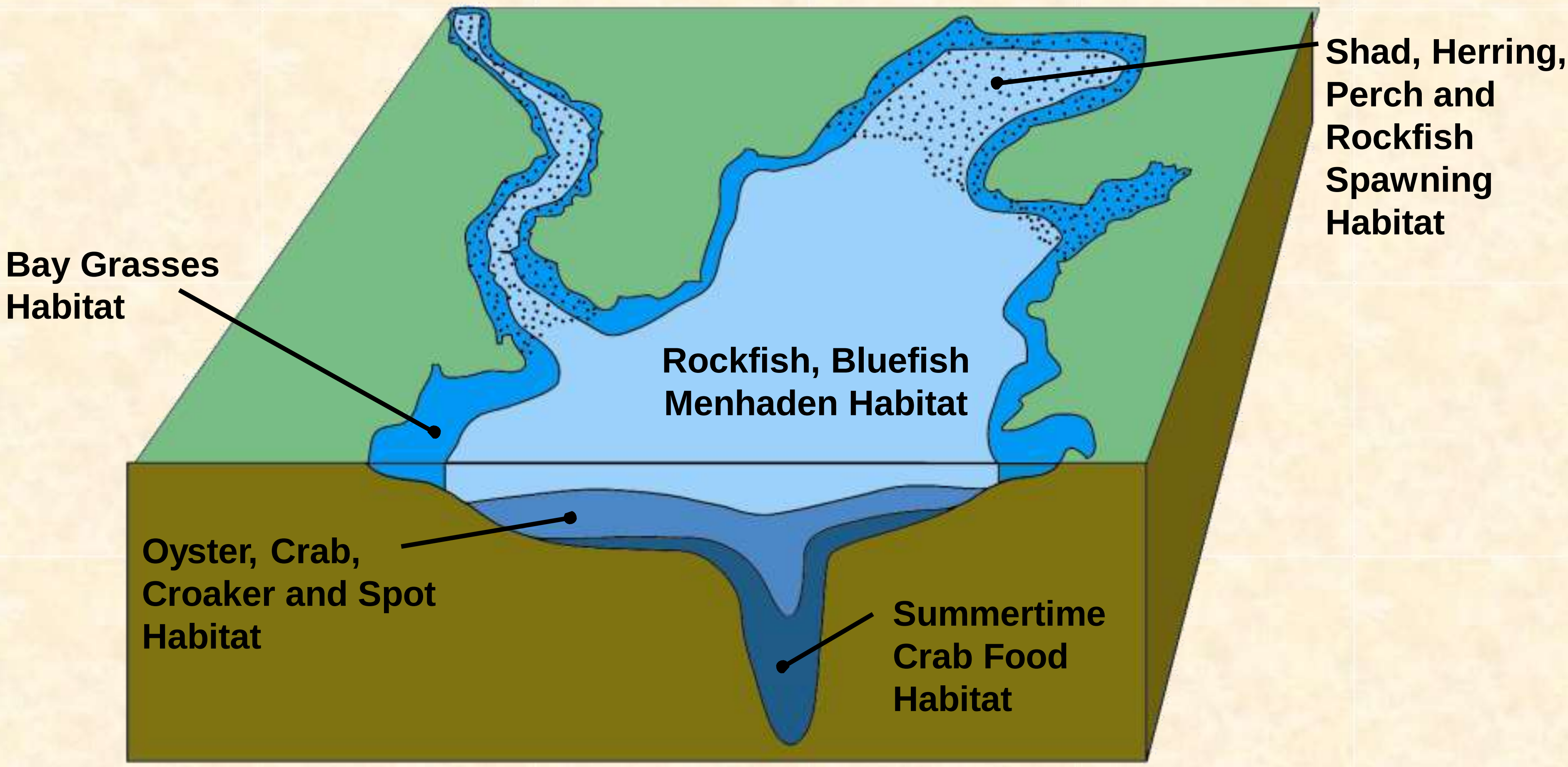


Bay Dissolved Oxygen Criteria

Minimum Amount of Oxygen (mg/L) Needed to Survive by Species



Local "Zoning" for Bay and Tidal River Fish, Crab and Grasses Habitats



Chesapeake Bay TMDL: December 2010

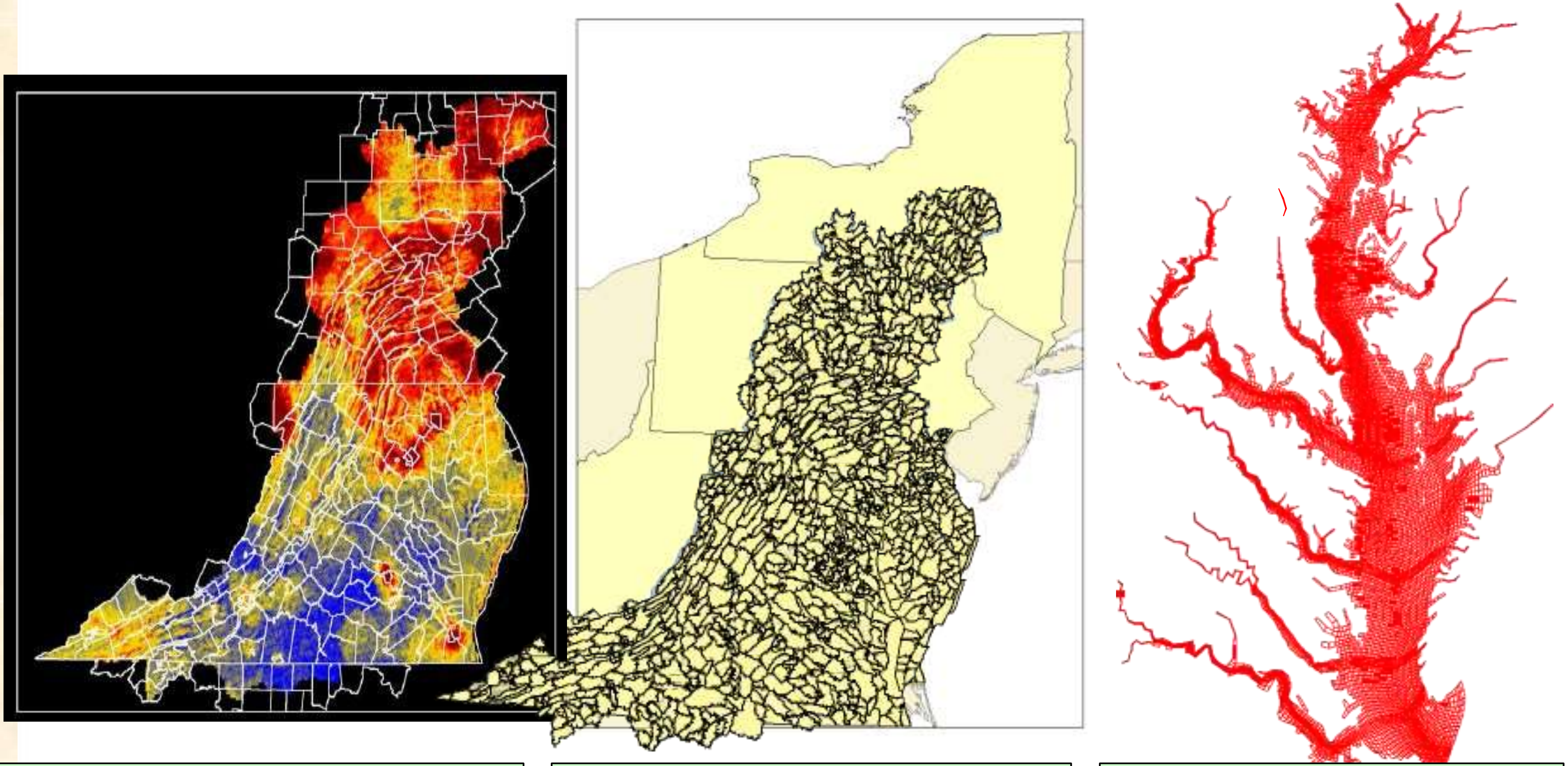
- **Since water quality standards are not met in the Chesapeake, a Total Maximum Daily Load (TMDL) is used to calculate and allocate the maximum amount of a nitrogen allowed to enter the tidal Bay, so that the Chesapeake will meet living resource based quality standards.**
- **Bay TMDL is the most comprehensive roadmap for restoration we have ever had for Chesapeake Bay.**
- **Addresses all sectors and major sources of nutrient and sediment pollution.**
- **Designed with rigorous accountability measures to ensure that all pollution controls needed to restore Bay are in place by 2025, with 60 percent by 2017.**
- **Restoration activities will protect and enhance the economic value of the Bay and rivers, and be a driver for local economies.**

Photo: SERC

Introduction To Key Models and Process

Photo: Chuck Gallegos/SERC, with aerial support from LightHawk

An Overview of the CBP Integrated Models:
Current Chesapeake Bay Modeling Structure

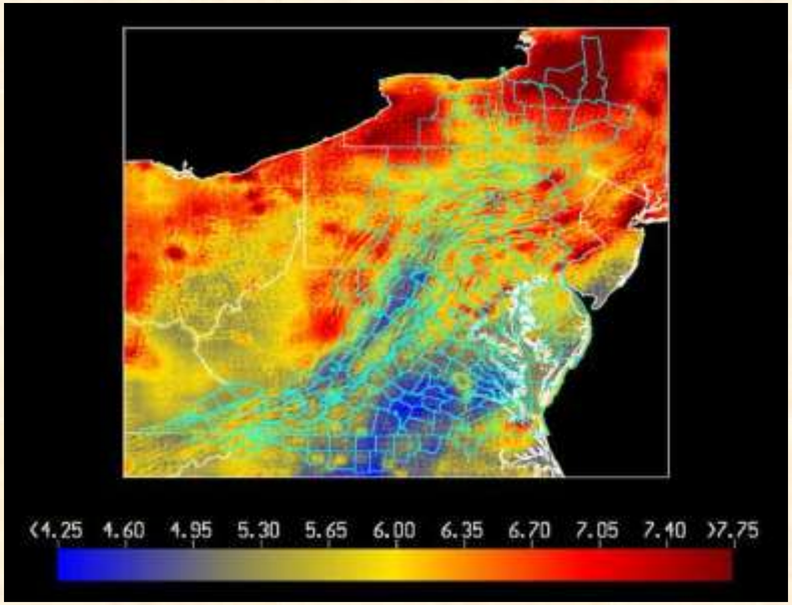


Nitrate and ammonia deposition from improved <u>Daily Nitrate and Ammonium Concentration Models</u> using 35 monitoring stations over 18 simulation years. Adjustments to deposition from the <u>Community Multi-scale Air Quality (CMAQ) Modeling System</u>

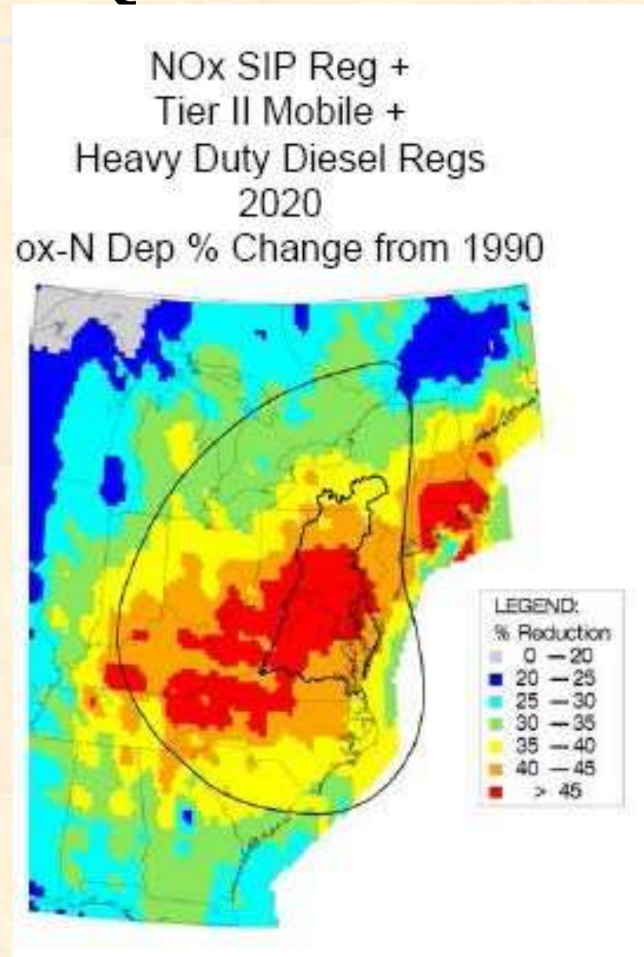
<u>Phase 5 Watershed Model</u>
Year-to-year changes in land use and BMPs; 899 segments; 24 land uses; 296 calibration stations; 21 simulation years; sophisticated calibration procedures; calibration demonstrably better in quality and scale

<u>Chesapeake Bay Estuary Model</u>
Detailed sediment input; Wave model for resuspension, Full sediment transport; Filter feeder simulation; Simulation of Potomac algal blooms; 54,000 model cells; 18 simulation years

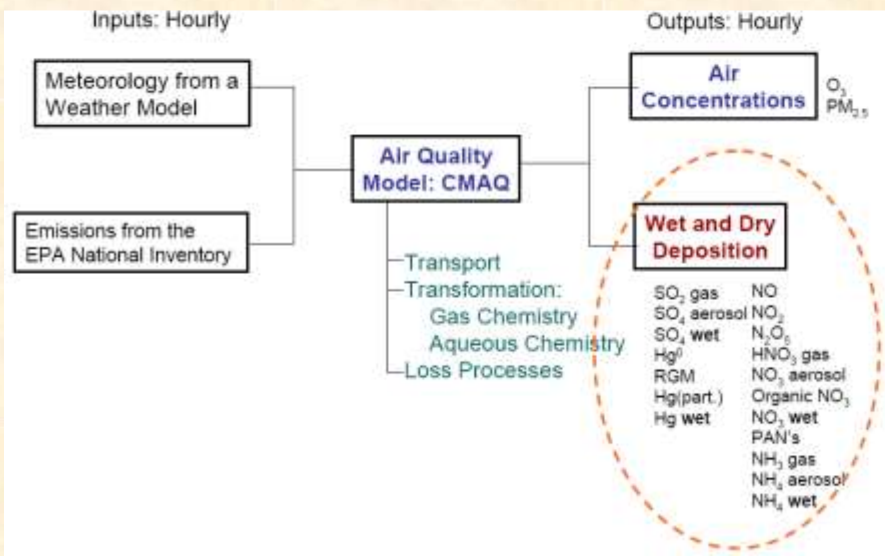
The Airshed Model - CMAQ



Combining a regression model of wetfall deposition...



…with CMAQ estimates of dry deposition for the base…



…and using the power of the CMAQ model for scenarios.

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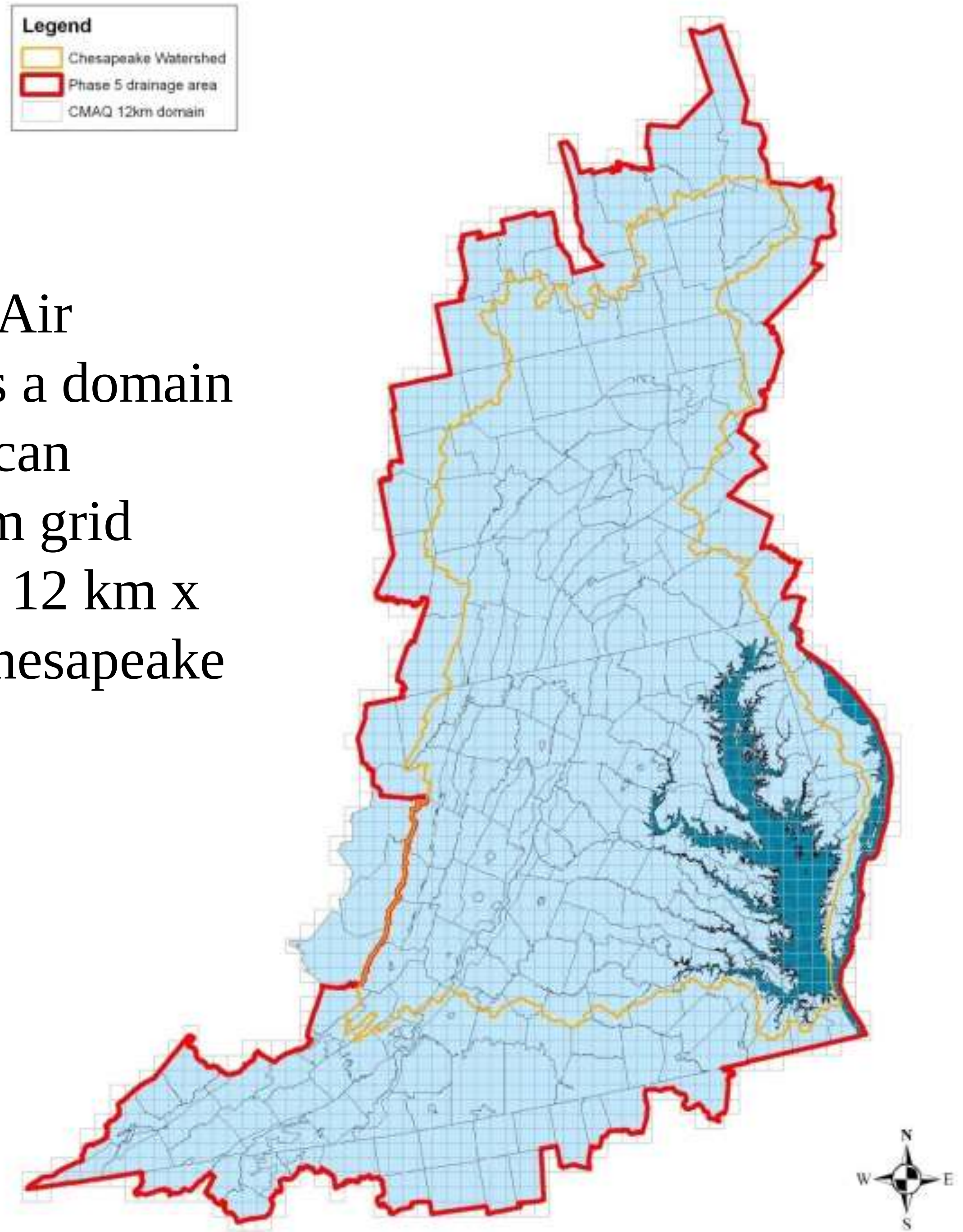
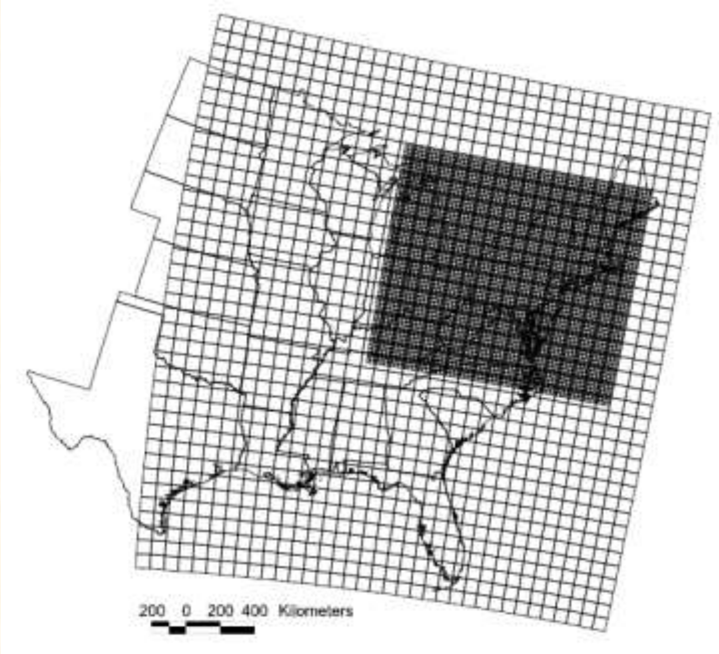
CMAQ Model

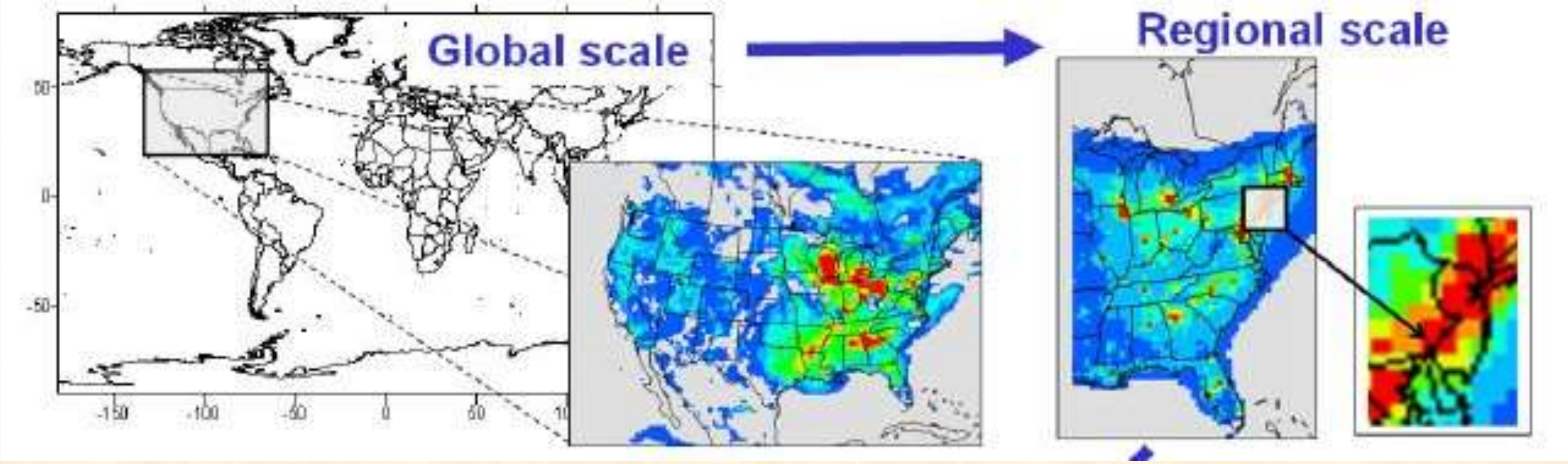
The Community Multiscale Air Quality Model (CMAQ) has a domain that covers the North American continent at a 36 km x 36 km grid scale and is nested at a finer 12 km x 12 km grid scale over the Chesapeake watershed and Bay.



History of CBP Airshed Model

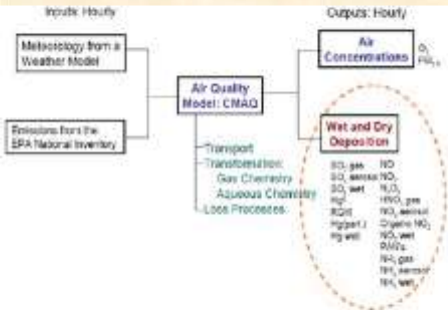


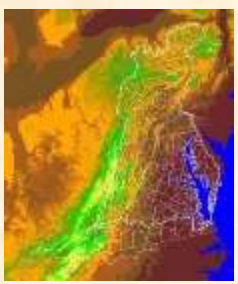
The 1st generation CBP Airshed Model (RADM) covered only the Eastern US. The current 2nd generation CBP Airshed Model, CMAQ, is a continental scale "one-model" design and uses a nested grid of 36 km in the US and a 12 km fine grid for the Chesapeake watershed.



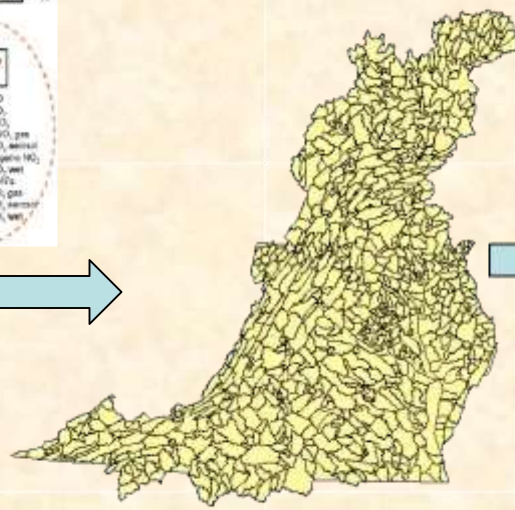
Nutrient Allocation Decision Support System

Airshed Model



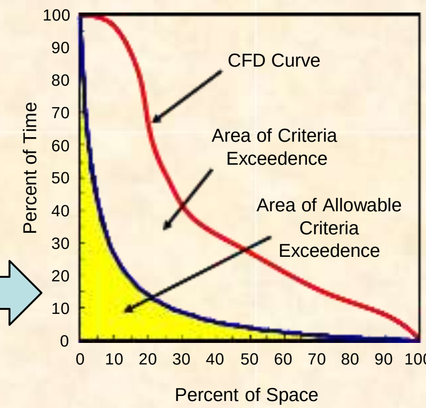


Watershed Model



Bay Model

Criteria Assessment Procedures



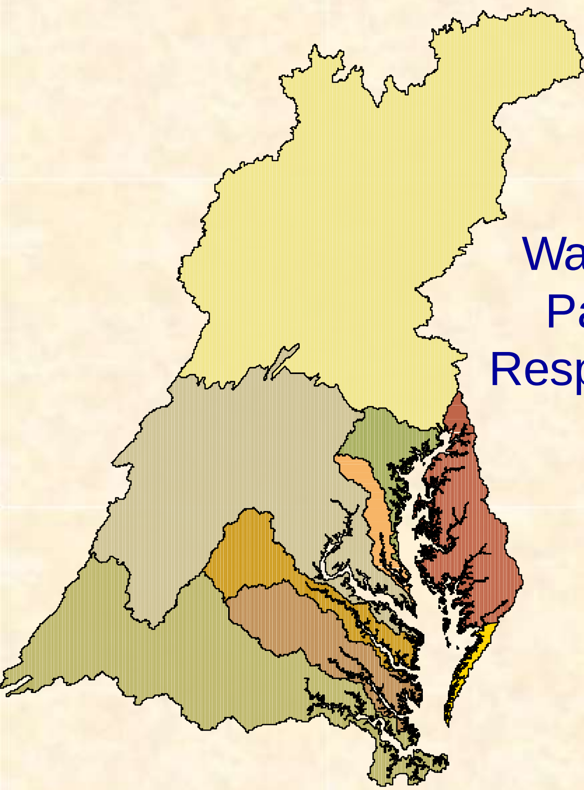
Effects

Allocations

20

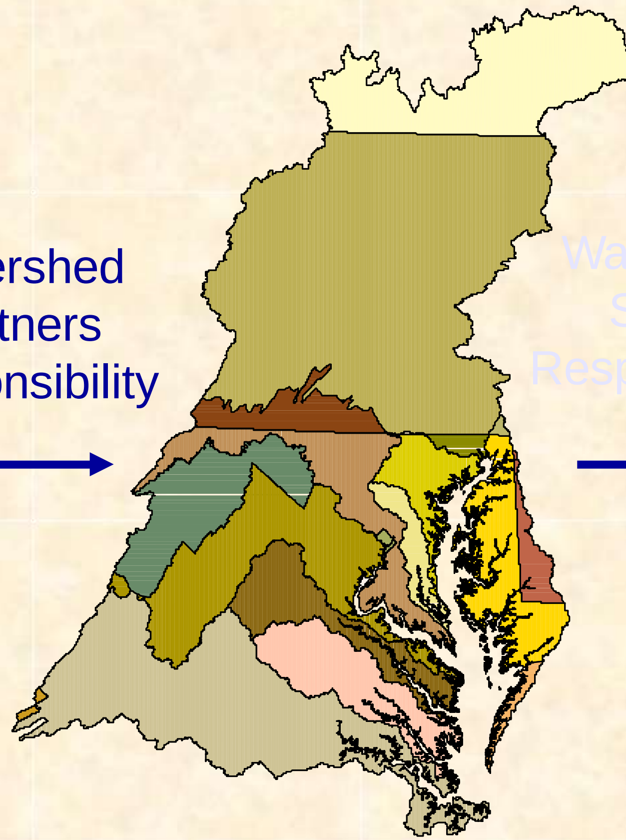
Load Allocation Process

By **9** major river basins



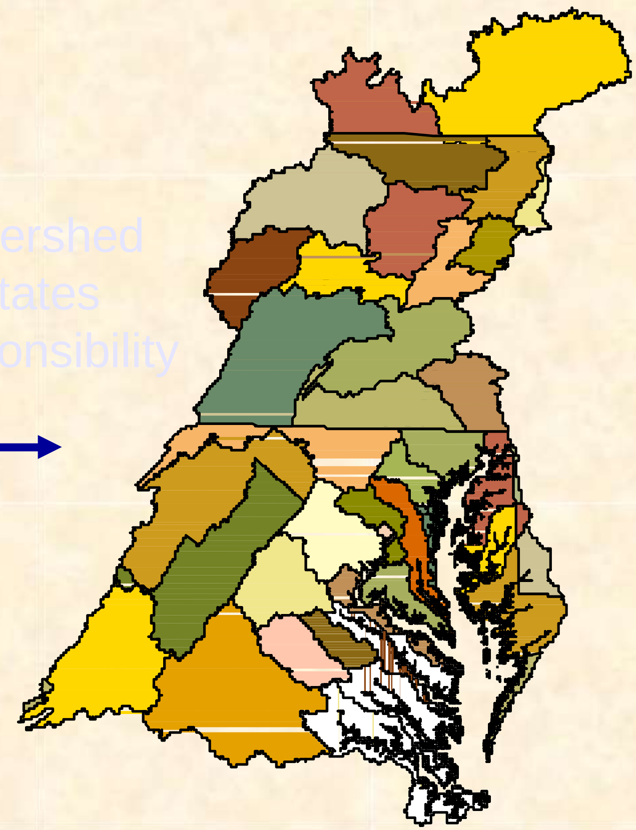
Watershed Partners Responsibility

...then by **20** major tributary basins by jurisdiction



Watershed States Responsibility

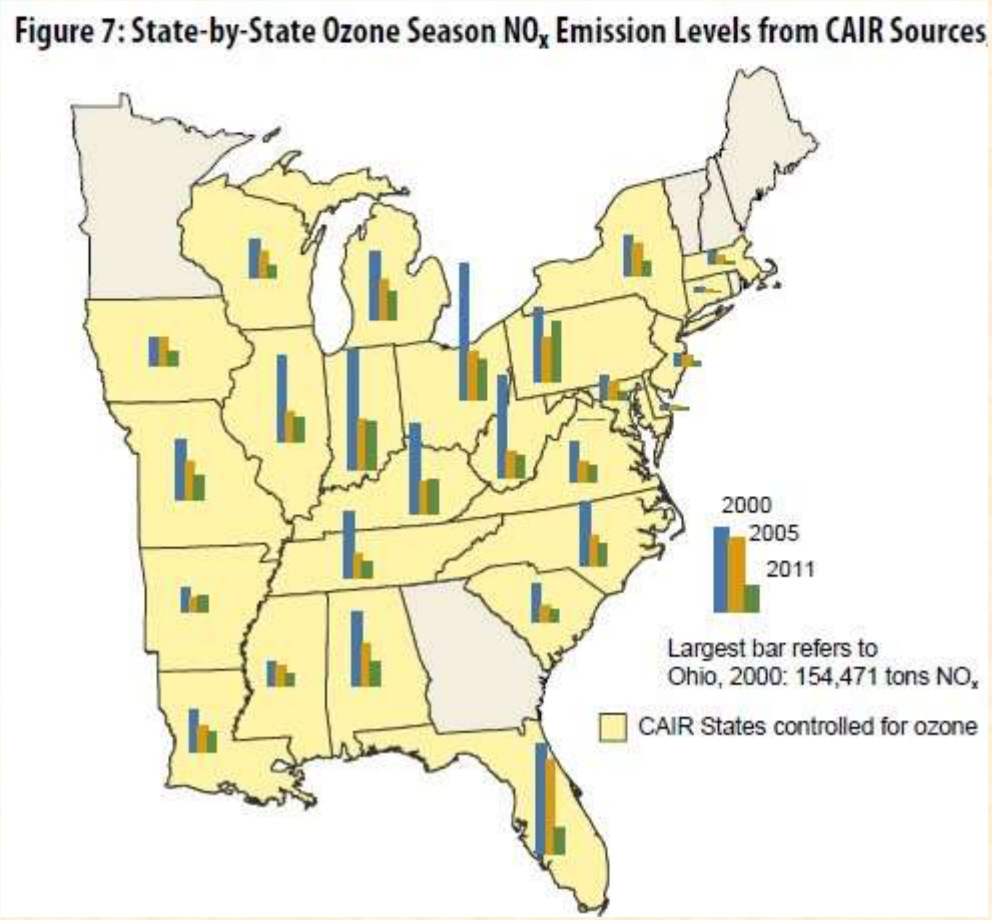
…then by **44** state-defined tributary strategy subbasins



Trends and Results

Photo: Chuck Gallegos/SERC, with aerial support from LightHawk

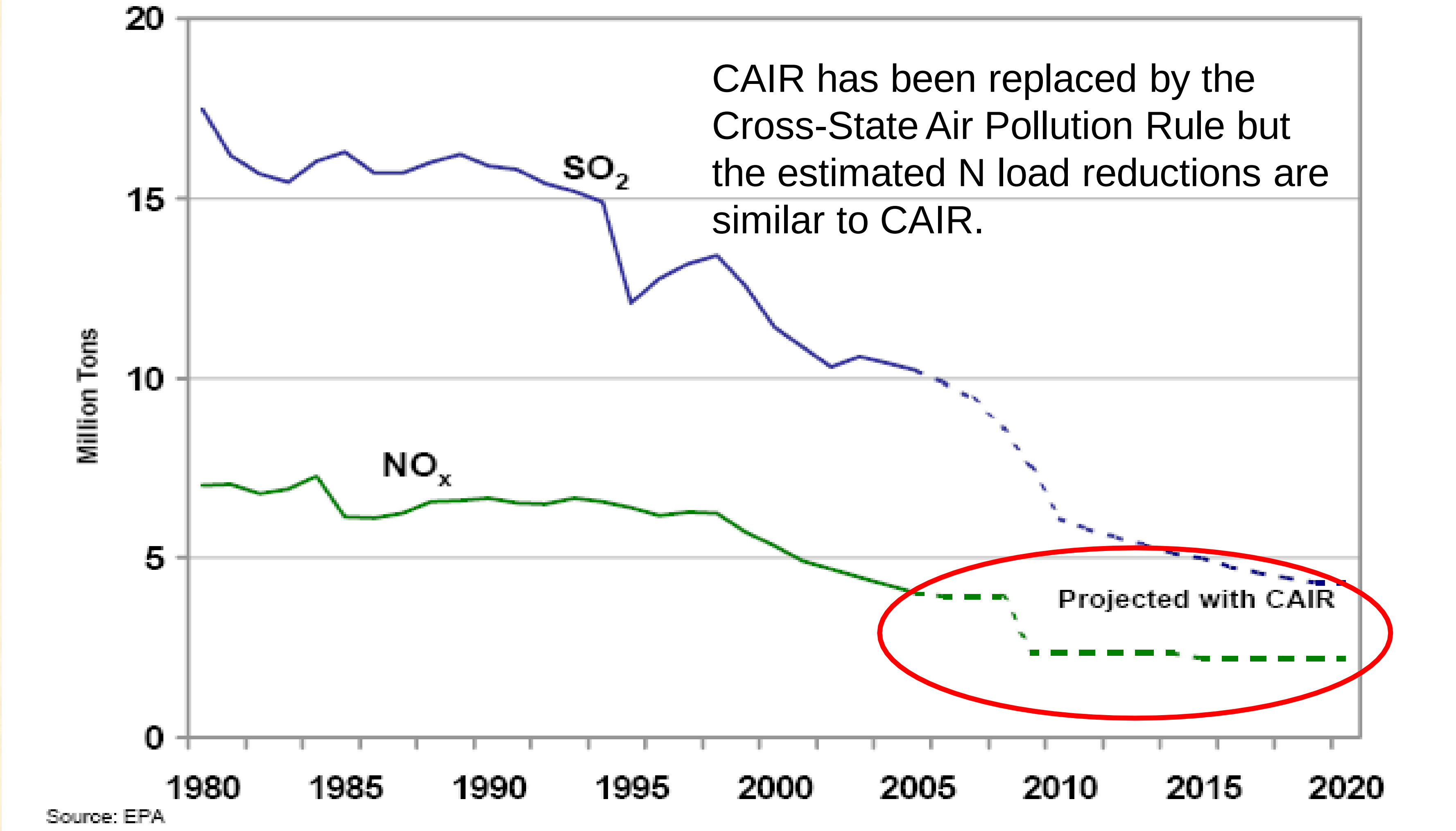
Progress Storyline: air emissions declining



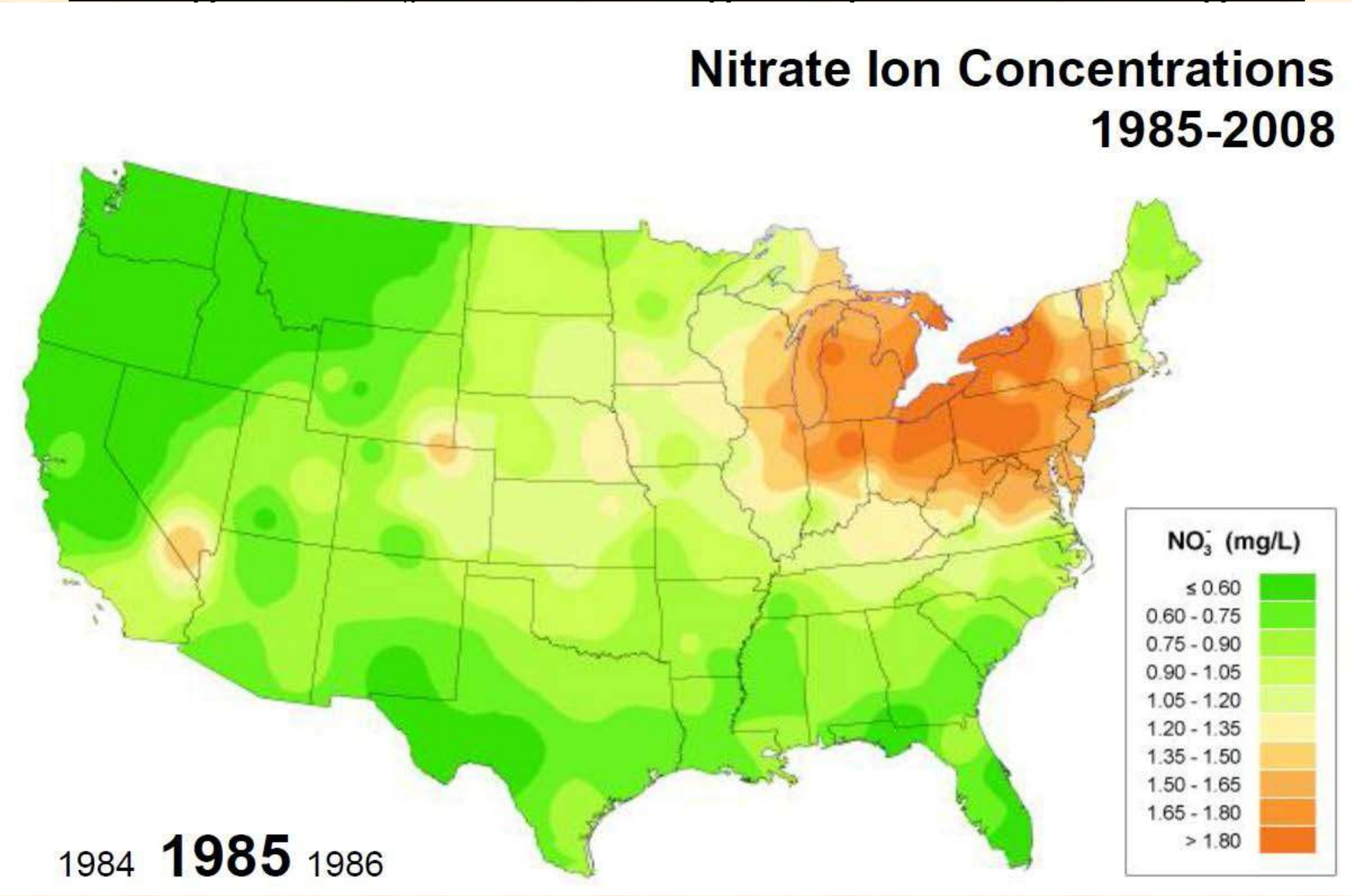
Source: U.S. EPA "SO2 and NOx Emissions, Compliance, and Market Analyses" 2013.

But atmospheric loads of NOx are decreasing

Estimated nationwide emissions of NOx and SO_2 from electric generating units (EGUs) since 1980 and estimated emissions to 2020.

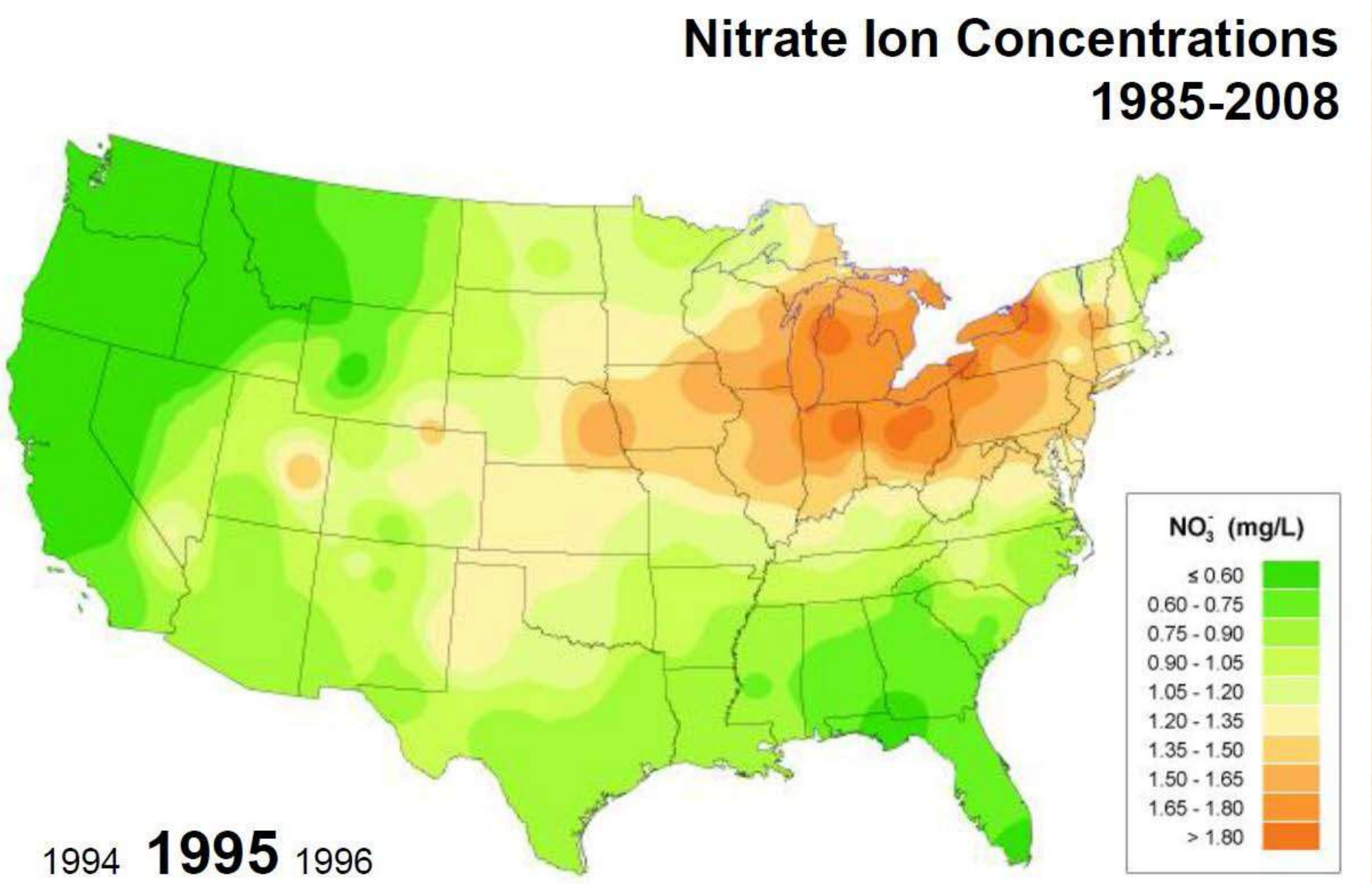


Progress Storyline: air nitrogen deposition declining



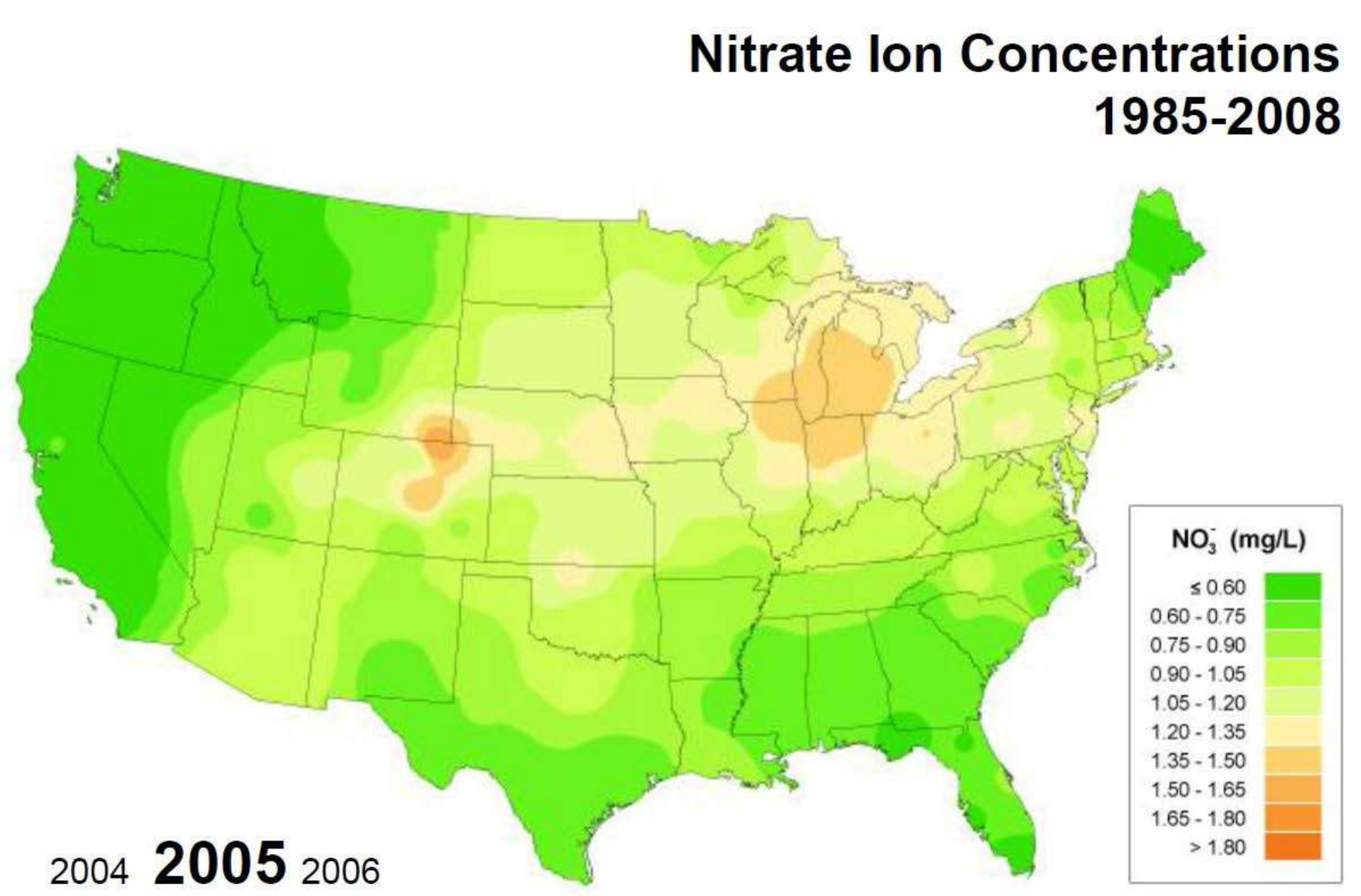
Source: National Atmospheric Deposition Program (NADP)

Progress Storyline: air nitrogen deposition declining



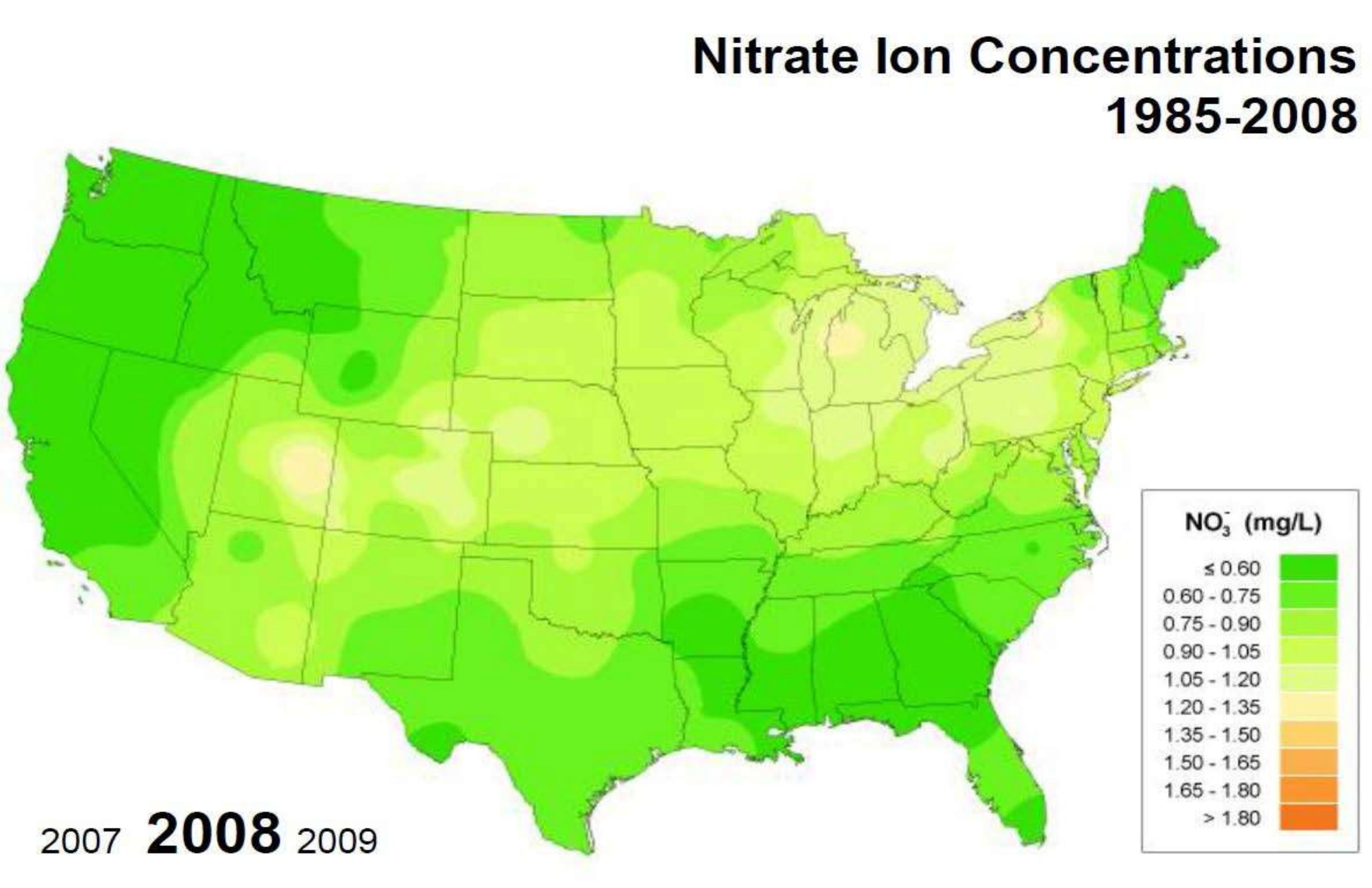
Source: National Atmospheric Deposition Program (NADP)

Progress Storyline: air nitrogen deposition declining



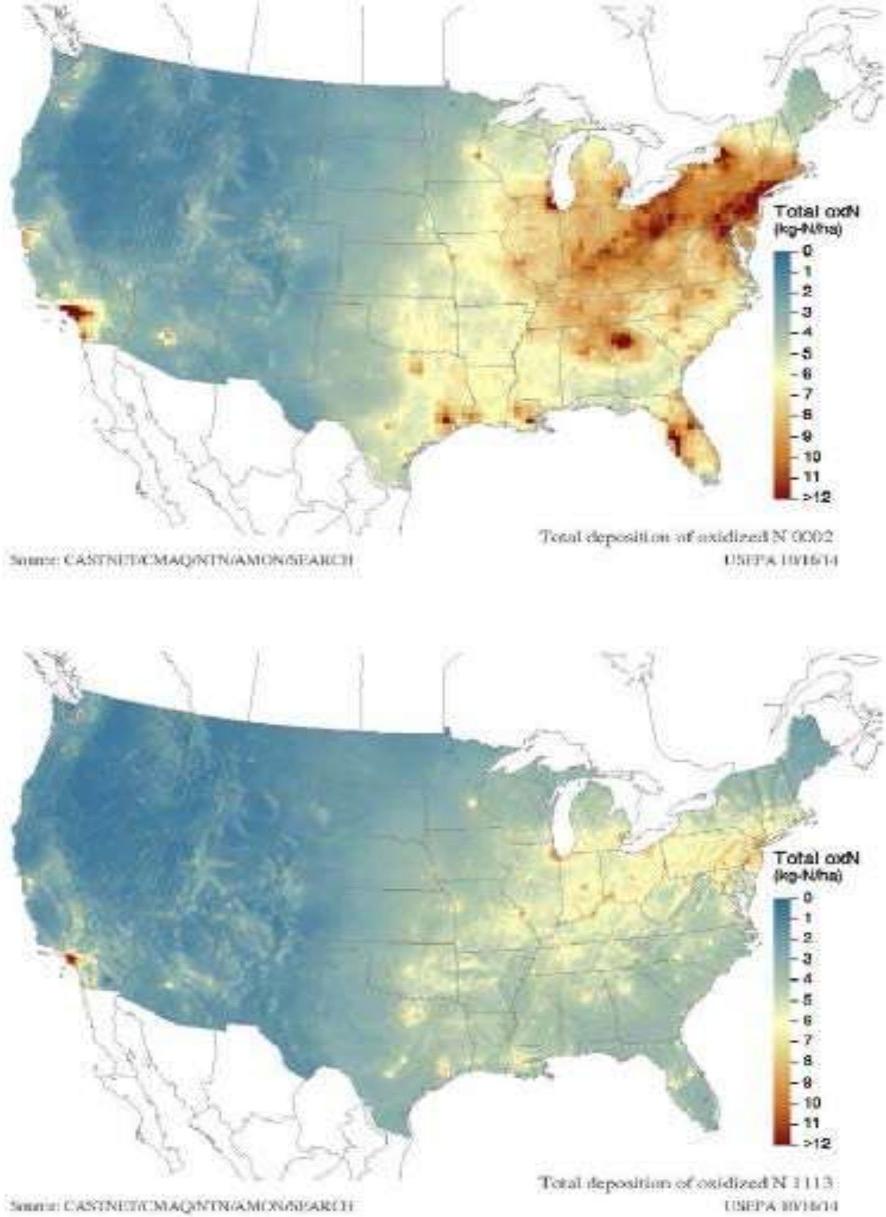
Source: National Atmospheric Deposition Program (NADP)

Progress Storyline: air nitrogen deposition declining



Source: National Atmospheric Deposition Program (NADP)

Source: Integrated Science Assessment for Oxides of Nitrogen, Oxides of Sulfur, and Particulate Matter—Ecological Criteria (First External Review Draft) EPA/600/R-16/372 February 2017 www.epa.gov/ncea/isa

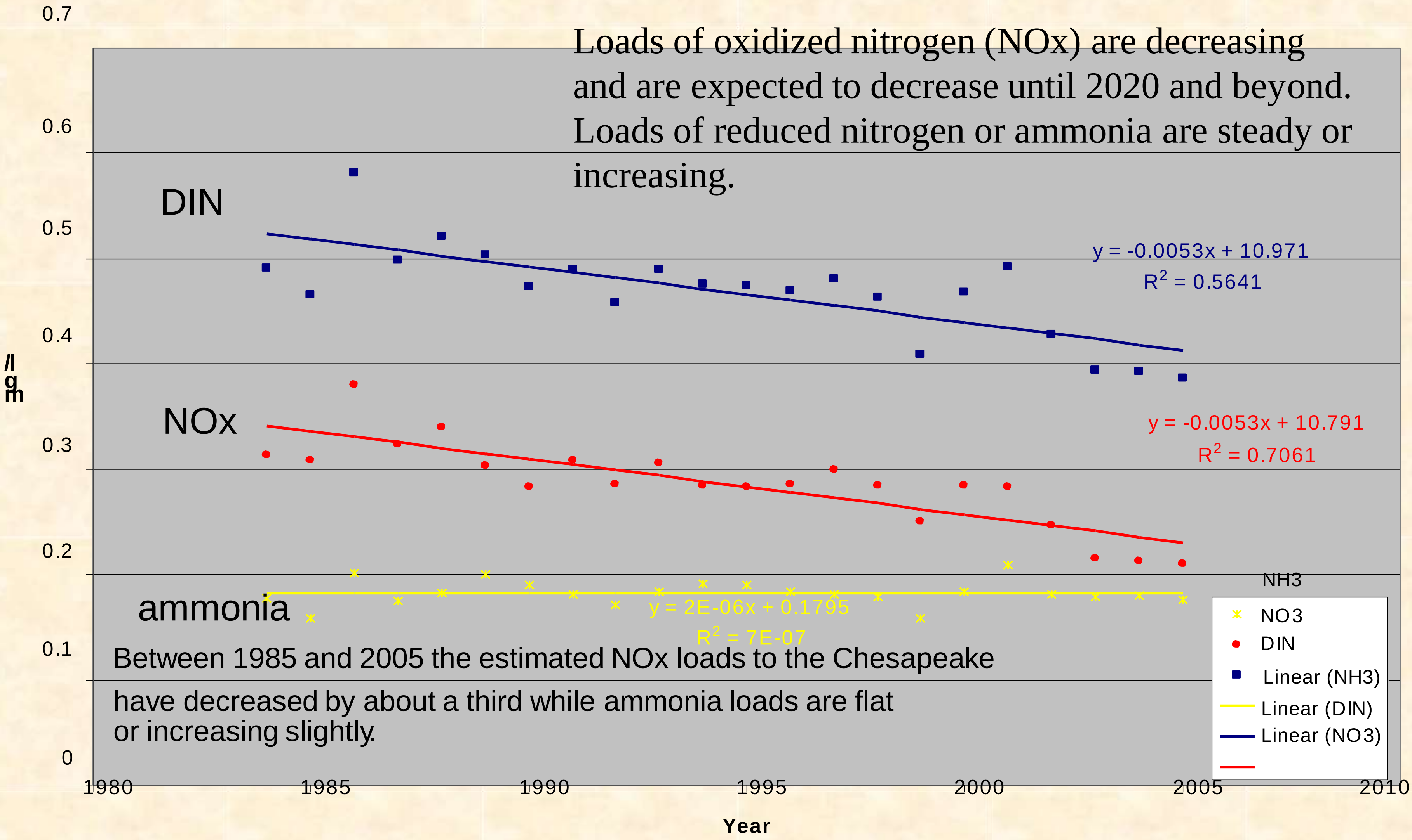


oxN = oxidized nitrogen.
Source: CASTNET/CMAQ/NTN/AMON/SEARCH.

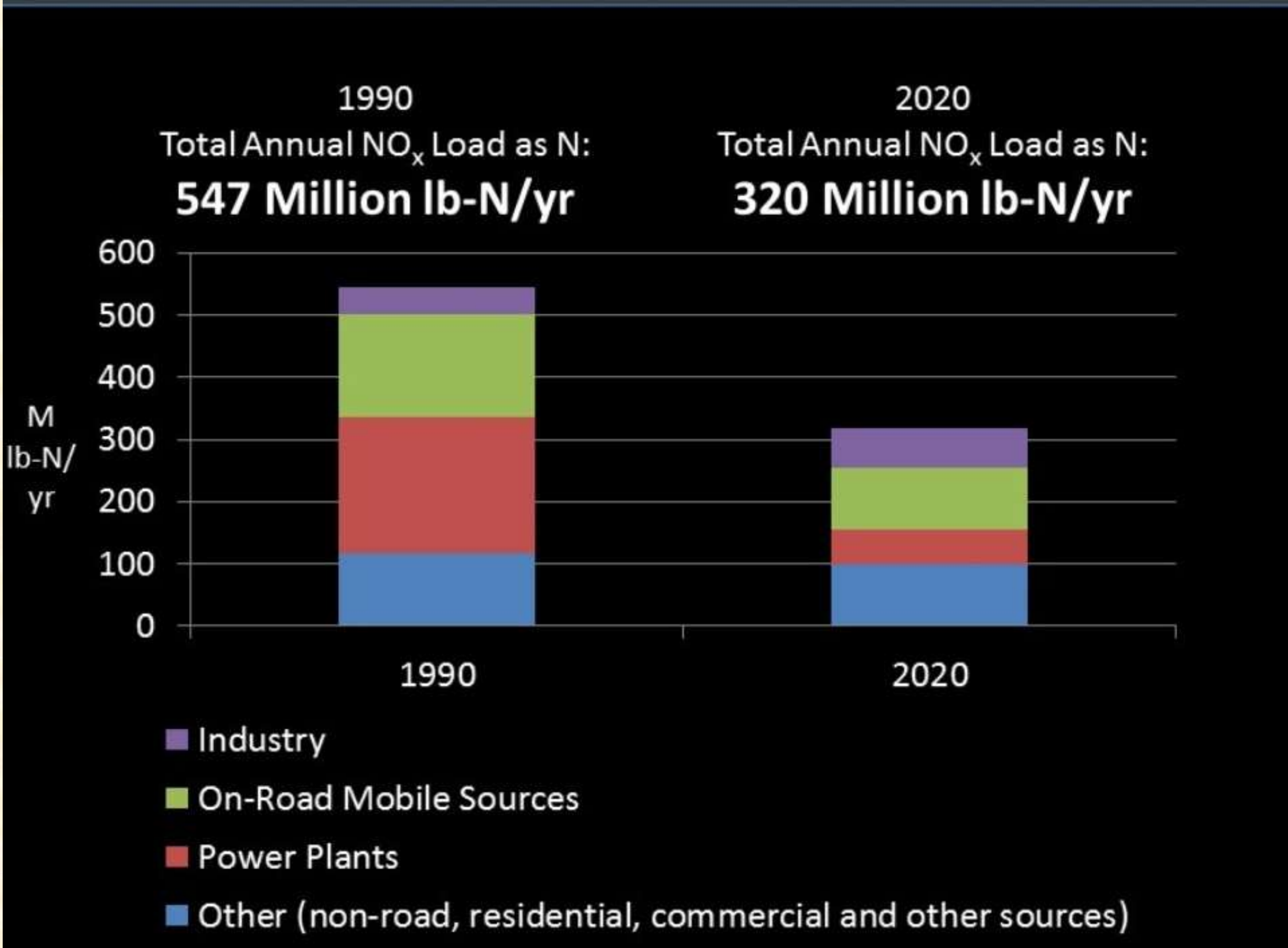
Figure A-5 **Wet plus dry deposition of oxidized nitrogen over 3-year periods. Top: 2000−2002; Bottom: 2011−2013.**

Trend of estimated average nitrate and ammonia deposition concentrations to the Phase 5 domain:

Loads of oxidized nitrogen (NOx) are decreasing and are expected to decrease until 2020 and beyond. Loads of reduced nitrogen or ammonia are steady or increasing.



Between 1985 and 2005 the estimated NOx loads to the Chesapeake have decreased by about a third while ammonia loads are flat or increasing slightly.


1990
Total Annual NO_x Load as N:
547 Million lb-N/yr
2020
Total Annual NO_x Load as N:
320 Million lb-N/yr
600
500
400
300
200
100
0
M lb-N/ yr
1990
2020
Industry
On-Road Mobile Sources
Power Plants
Other (non-road, residential, commercial and other sources)

Progress Storyline: better than expected responses

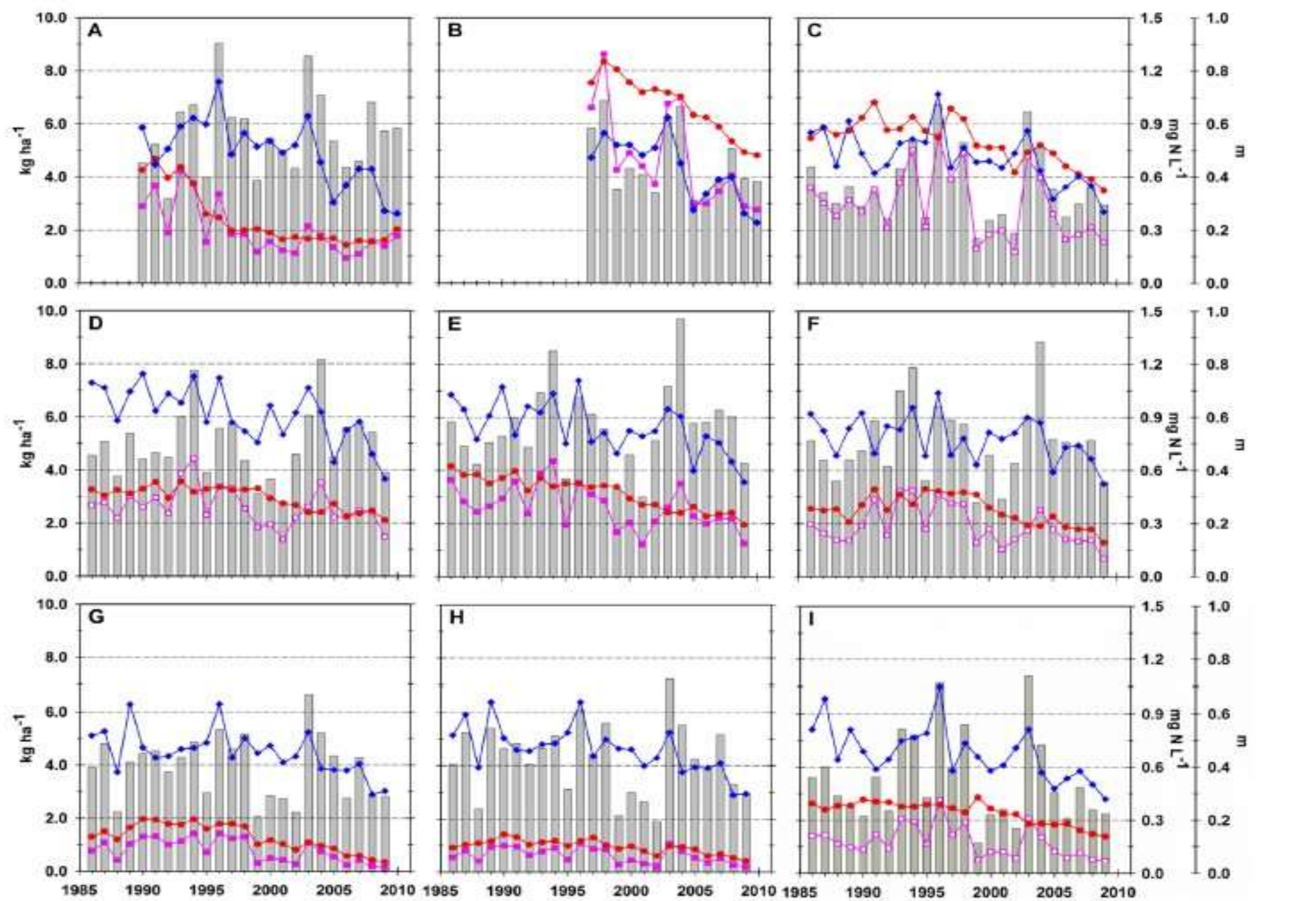


Figure 2. Temporal patterns (1986–2009) in annual (1) nitrate-N yields (kg ha^{-1}, pink lines/squares), (2) areal N deposition (kg ha^{-1}, blue lines/diamonds), (3) nitrate-N concentrations (mg N L^{-1}, red lines/circles), and (4) runoff (m, gray bars) for the nine study; letters correspond to watersheds identified in Figure 1. Time series illustrated with solid symbols produced statistically significant linear trends (see details in Table S2, Supporting Information).

Source: Eshleman et al. 2013. Surface Water Quality is Improving due to Declining Atmospheric N Deposition. *Environmental Science and Technology 47:12193-12200.*

Telling the Story to Scientific/Technical Audiences

JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION

AMERICAN WATER RESOURCES ASSOCIATION

COMPUTING ATMOSPHERIC NUTRIENT LOADS TO THE CHESAPEAKE BAY WATERSHED AND TIDAL WATERS[1]

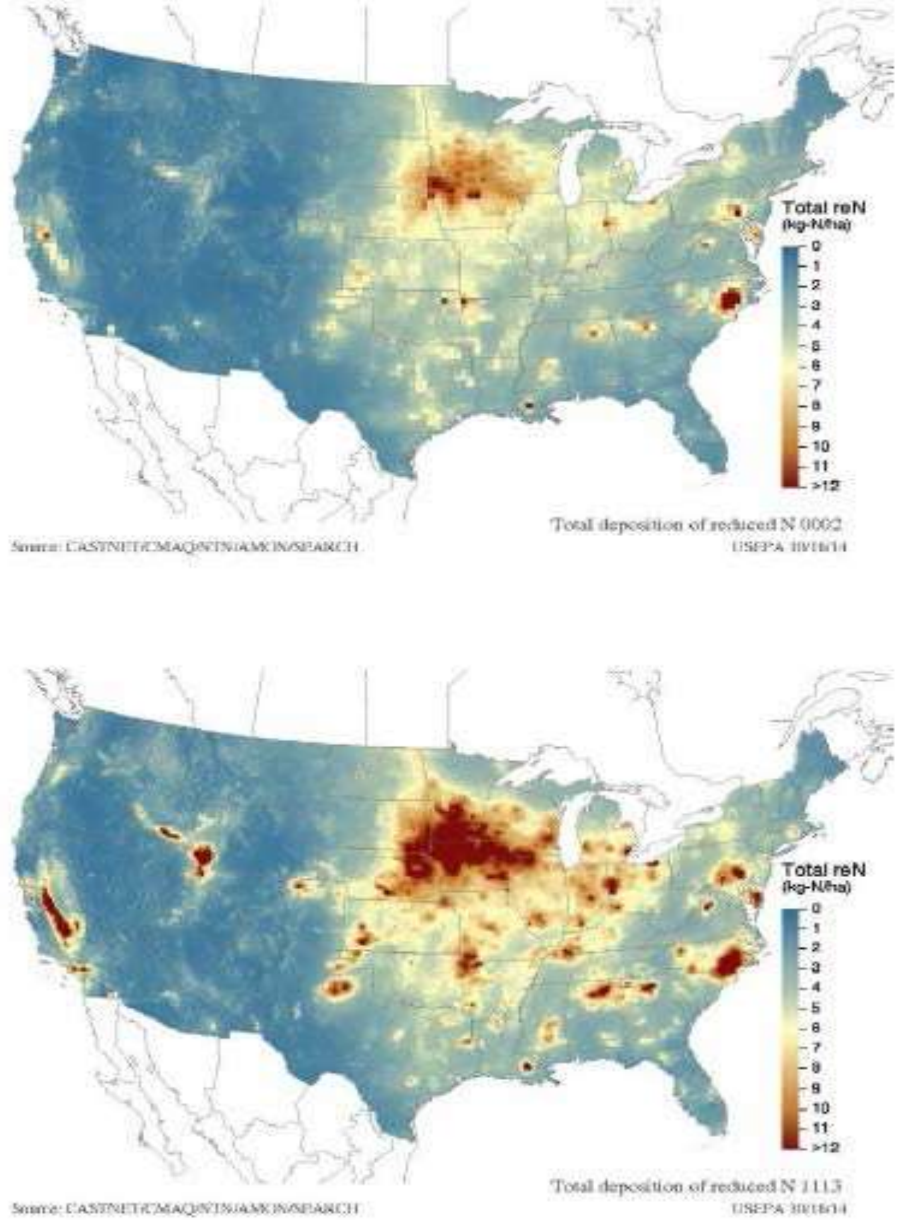
Lewis C. Linker, Robin Dennis, Gary W. Shenk, Richard A. Batiuk, Jeffrey Grimm, and Ping Wang[2]

ABSTRACT: Application of integrated Chesapeake Bay models of the airshed, watershed, and estuary support air and water nitrogen controls in the Chesapeake. The models include an airshed model of the Mid-Atlantic region which tracks the estimated atmospheric deposition loads of nitrogen to the watershed, tidal Bay, and adjacent coastal ocean. The three integrated models allow tracking of the transport and fate of nitrogen air emissions, including deposition in the Chesapeake watershed, the subsequent uptake, transformation, and transport to Bay tidal waters, and their ultimate influence on Chesapeake water quality. This article describes the development of the airshed model, its application to scenarios supporting the Chesapeake Total Maximum Daily Load (TMDL), and key findings from the scenarios. Key findings are that the atmospheric deposition loads are among the largest input loads of nitrogen in the watershed, and that the indirect nitrogen deposition loads to the watershed, which are subsequently delivered to the Bay are larger than the direct loads of atmospheric nitrogen deposition to Chesapeake tidal waters. Atmospheric deposition loads of nitrogen deposited in coastal waters, which are exchanged with the Chesapeake, are also estimated. About half the atmospheric deposition loads of nitrogen originate from outside the Chesapeake watershed. For the first time in a TMDL, the loads of atmospheric nitrogen deposition are an explicit part of the TMDL load reductions.

(KEY TERMS: water policy; simulation; total maximum daily load (TMDL); watershed management; nitrogen; Chesapeake Bay; Community Multiscale Air Quality Model; atmospheric deposition.)

Linker, Lewis C., Robin Dennis, Gary W. Shenk, Richard A. Batiuk, Jeffrey Grimm, and Ping Wang, 2013. Computing Atmospheric Nutrient Loads to the Chesapeake Bay Watershed and Tidal Waters. *Journal of the American Water Resources Association* (JAWRA) 1-17. DOI: 10.1111/jawr.12112

Source: Integrated Science Assessment for Oxides of Nitrogen, Oxides of Sulfur, and Particulate Matter—Ecological Criteria (First External Review Draft) EPA/600/R-16/372 February 2017 www.epa.gov/ncea/isa



reN = reduced nitrogen.
Source: CASTNET/CMAQ/NTN/AMON/SEARCH.

Figure A-14 **Wet plus dry deposition of reduced (inorganic) nitrogen over 3-year periods. Top: 2000−2002; Bottom: 2011−2013.**

Overview:

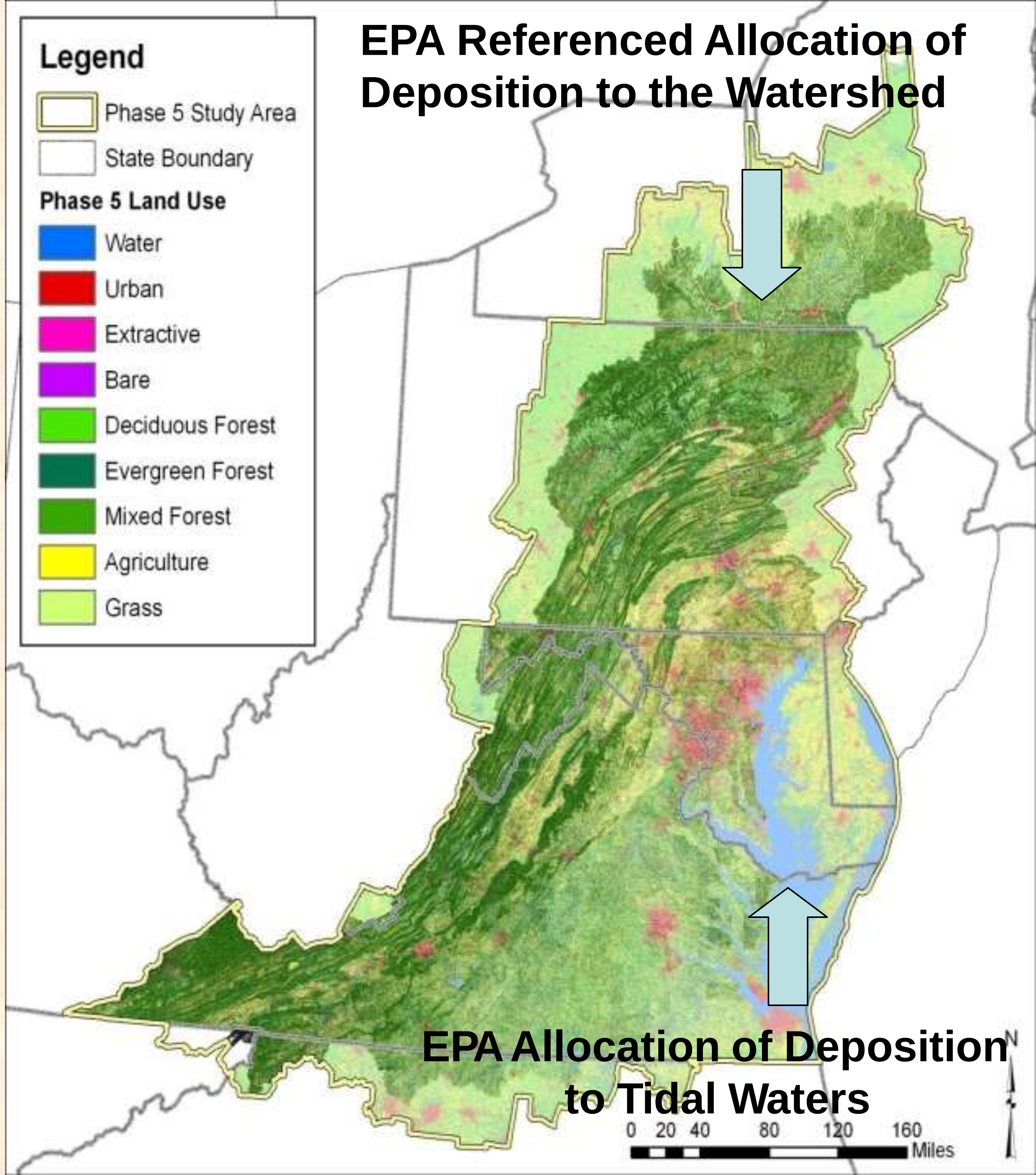
•For the Chesapeake Bay Restoration the EPA has developed a specific Chesapeake TMDL air load allocation **of 15.7 million pounds** for the tidal waters of the Chesapeake Bay (and also to account for air deposition of nitrogen in the load allocations to the watershed).

•The TMDL air allocation reflects the modeled nitrogen deposition to the Bay, taking into account the reduction in air emissions expected from sources regulated under existing or planned federal Clean Air Act (CAA)-authorized programs.

•By including air deposition in the TMDL load allocations, the TMDL accounts for the emission reductions achieved by Bay states as well as those achieved by other states within and beyond the airshed.

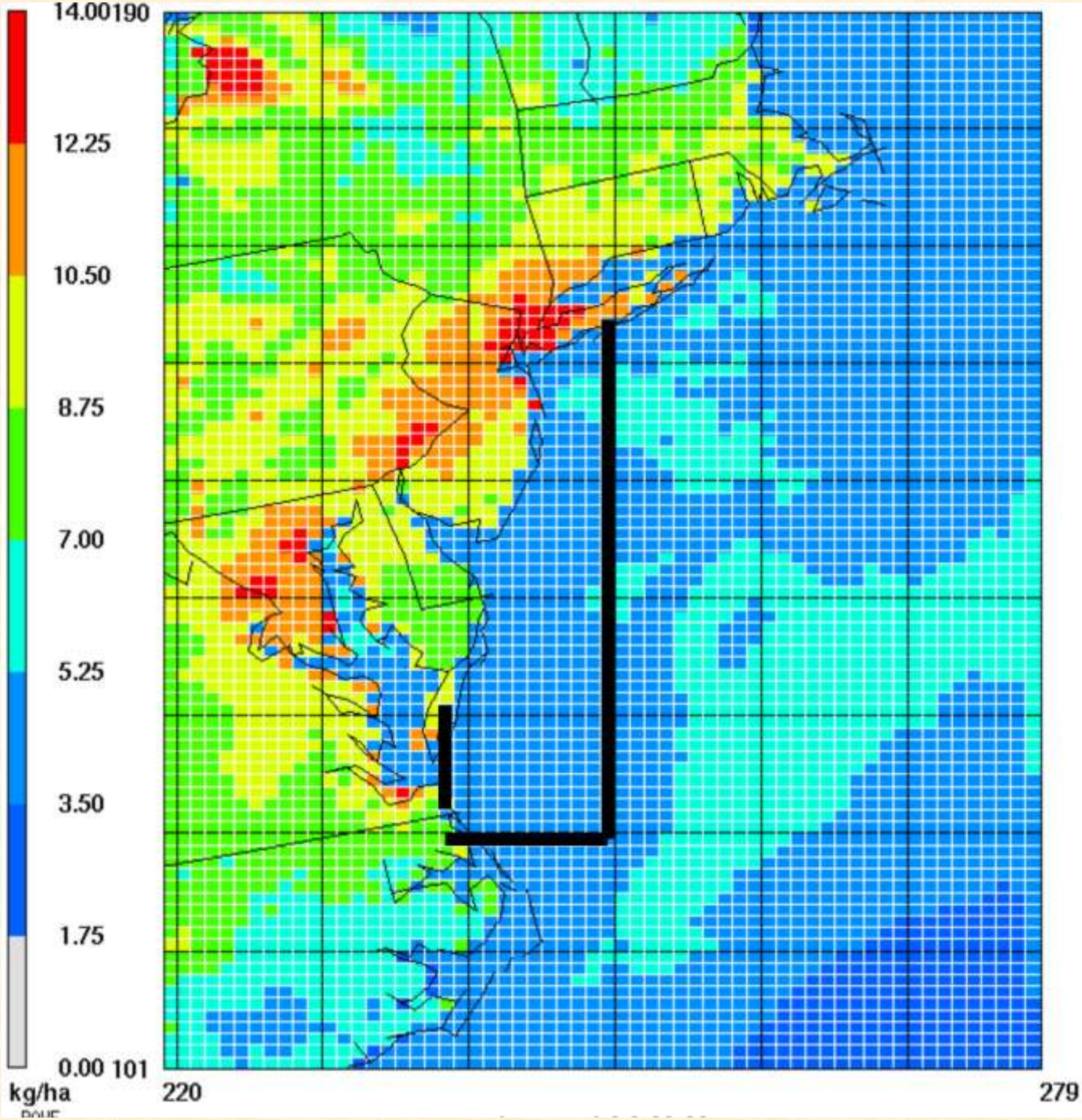
• This is the first time EPA has included air loads in a TMDL based watershed restoration.

The EPA air allocation are the load reductions up to and including the 2020 Air Allocation Scenario. The EPA Air Allocation is 15.7 million pounds to the tidal waters of the Chesapeake Bay. The 2020 Air Allocation loads are already factored into the State WIPs through the “referenced allocation” in the watershed.



Boundaries of the coastal ocean region used to adjust the ocean boundary conditions in the WQSTM.

Emission reductions resulting in reduced loads to the coastal ocean are also estimated as an adjustment to the ocean boundary loads in the CBP models.



Chesapeake Bay Program
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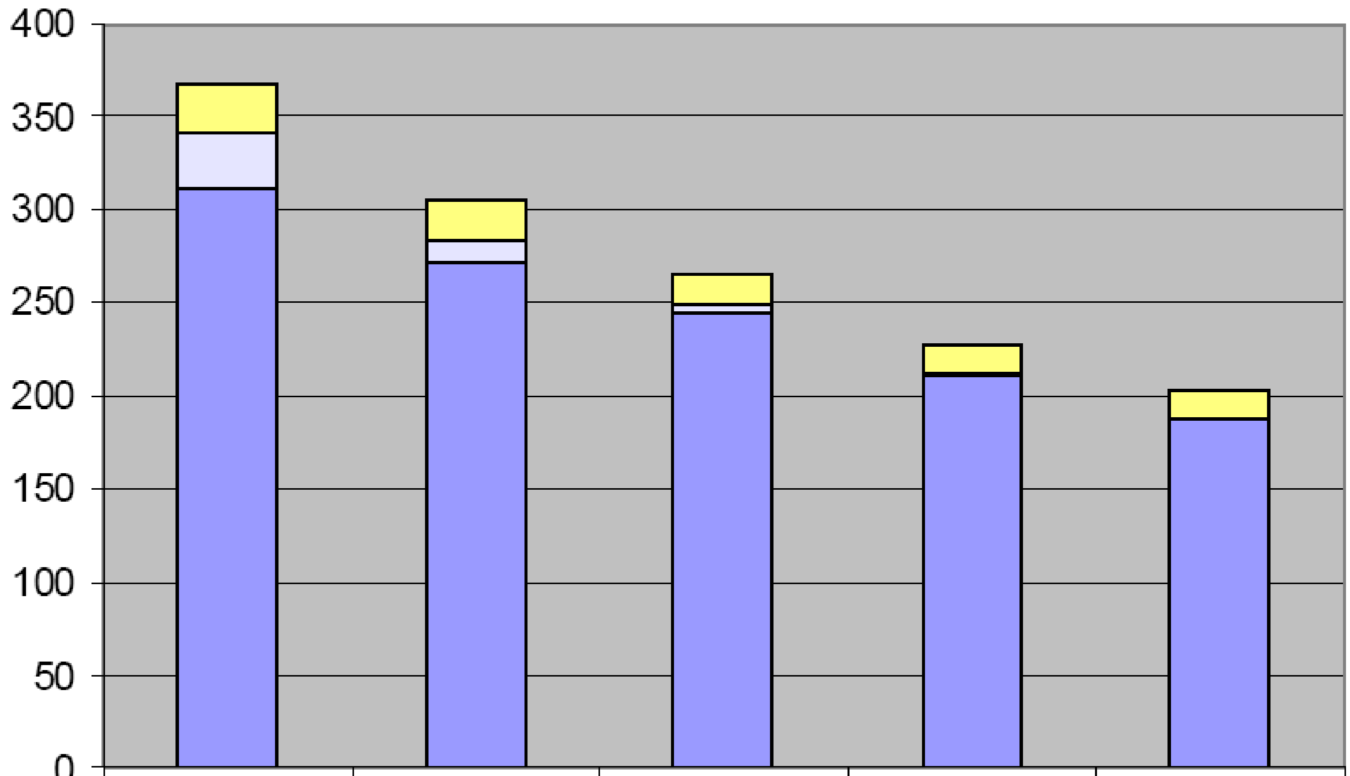
Model-Simulated Total Nitrogen Load to Bay (million pounds/year)



	1985	2002	2009	2017*	2025 Draft Allocation (7/1/2010)
EPA Responsibility: Model-simulated Total N Loads Delivered to Bay from atm. Dep. of N to tidal water****	26.08	21.59	17.42	16.39	15.70
EPA Responsibility: Model-simulated Total N Loads Delivered to Bay from atm. Dep.of N to watershed in excess of the 2020 CAIR***	31.43	12.78	3.45	1.38	0
State Responsibility: Model-simulated Total N Loads Delivered to Bay from all watershed sources, including atm. dep. of N to watershed that has not been/will not be reduced from CAA**	310.41	271.09	244.49	210.26	187.44

Conclusions:

Chesapeake Bay Program

Science, Restoration, Partnership

- Air and water program integration creates: Increased cooperation among parties.
  Better integration of Federal and State programs providing better environmental protection at least cost.
  Results that are more equitable and protective.
  More useful and accurate models/management assessment systems.
- Model integration makes complete analysis of issues:
  Environmental fate and transport among different media.
  Improving environmental management and understanding by taking into account cross-media effects.
- More complete economic analysis of benefits and costs.
- Improved understanding of all impacts of actions and policies

Additional Resources:

This is an interactive visualization of air-water management in the Chesapeake Bay Program: http://gis.chesapeakebay.net/air/

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And this is a video that can be looped: http://www.chesapeakebay.net/videos/clip/bay_101_air_pollution

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