Estimating Loads and Trends of Atmospheric Nitrogen Deposition in the Chesapeake Watershed and Tidal Waters

STAC Workshop on the
The Peculiarities of Perviousness

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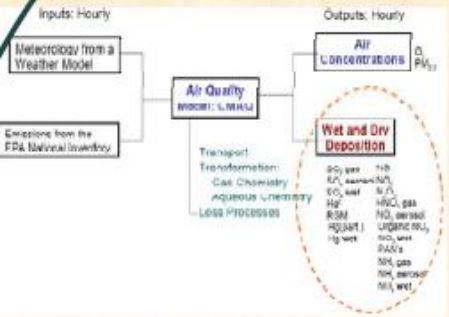
Overview:

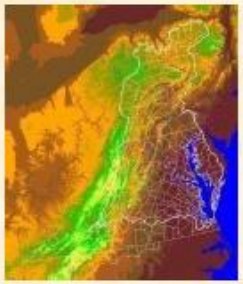
- Methods and Approaches in CBP Airshed Modeling
- Trends in Chesapeake Nitrogen Deposition
- Future Directions

Nutrient Allocation Decision Support System

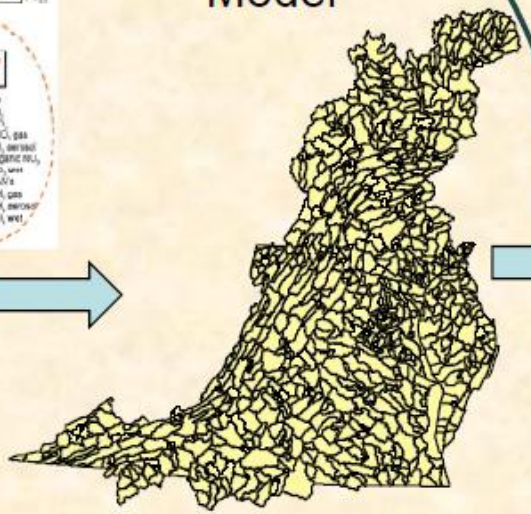
Used to Develop Allocations

Airshed Model



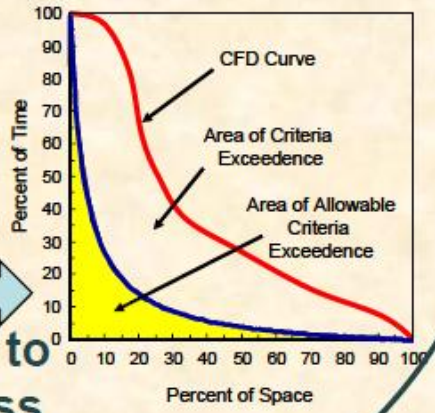


Watershed Model



Bay Model

Criteria Assessment Procedures



Used to Assess TMDL Achievement

Land Use Model

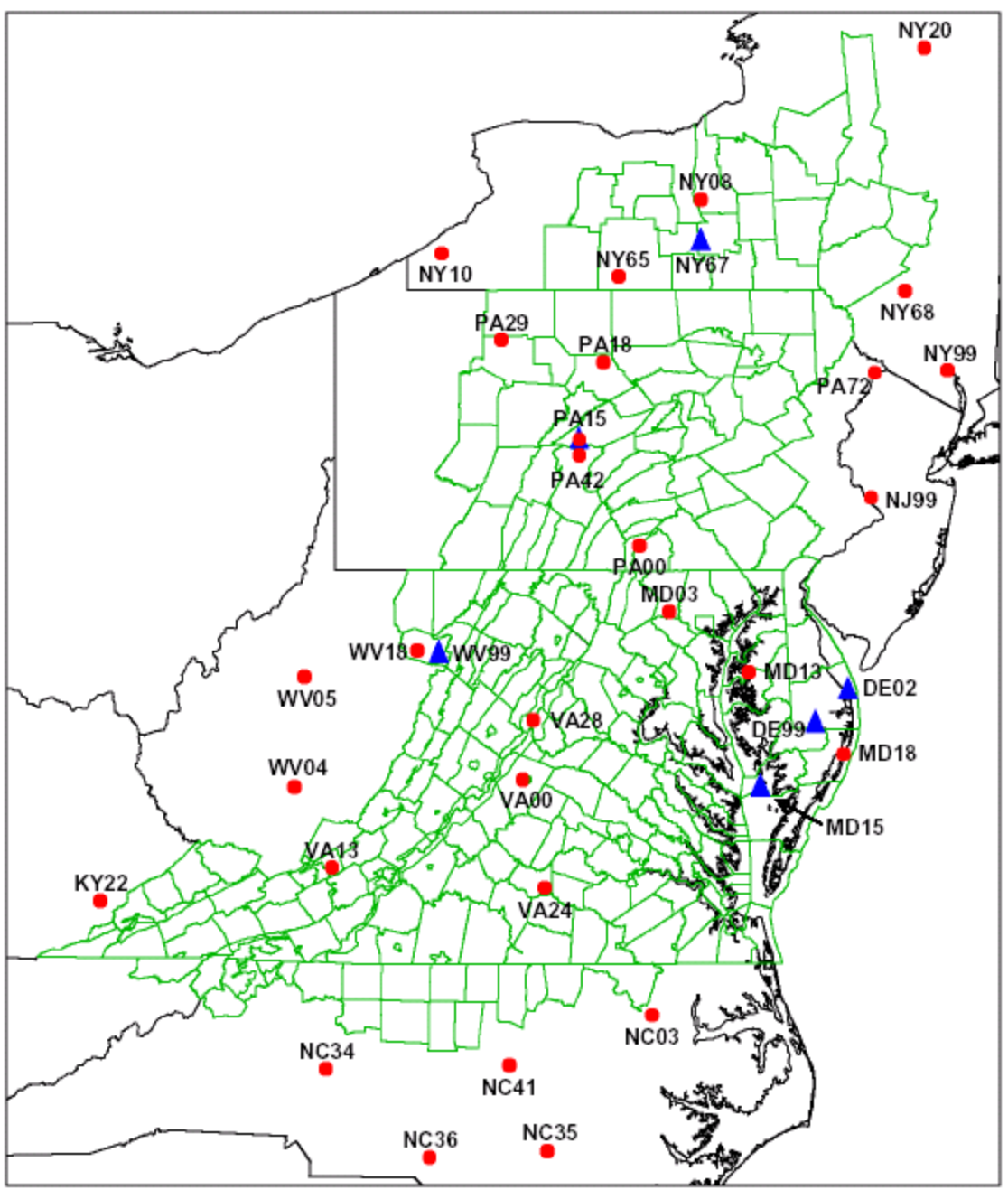
Effects

Allocations

Models and Methods:

A regression model developed by Grimm and Lynch was used to estimate hourly loads of wet deposition for the 1985 to 2005 simulation period.

Locations of the 39 NADP/NTN (circle) and 6 AIRMoN (triangle) precipitation chemistry monitoring sites used for development of the wet-fall regression model. Also shown are the land-segments of the Watershed Model, which are the smallest spatial units of atmospheric deposition estimates used in the Chesapeake TMDL.

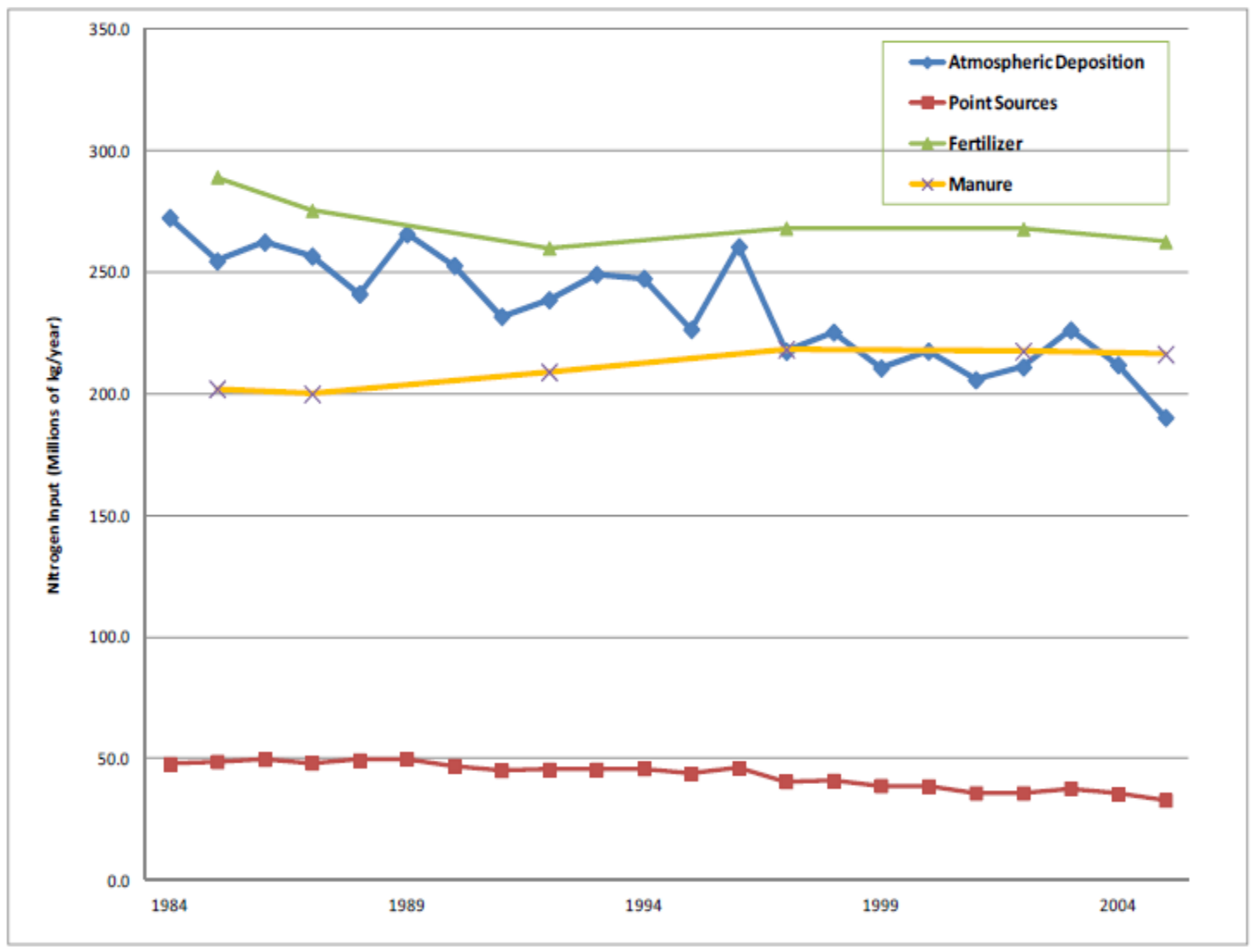


Models and Methods:

The 12-km CMAQ model grid over the Chesapeake Bay basin and also showing watershed model segments (Dennis et al. 2007).

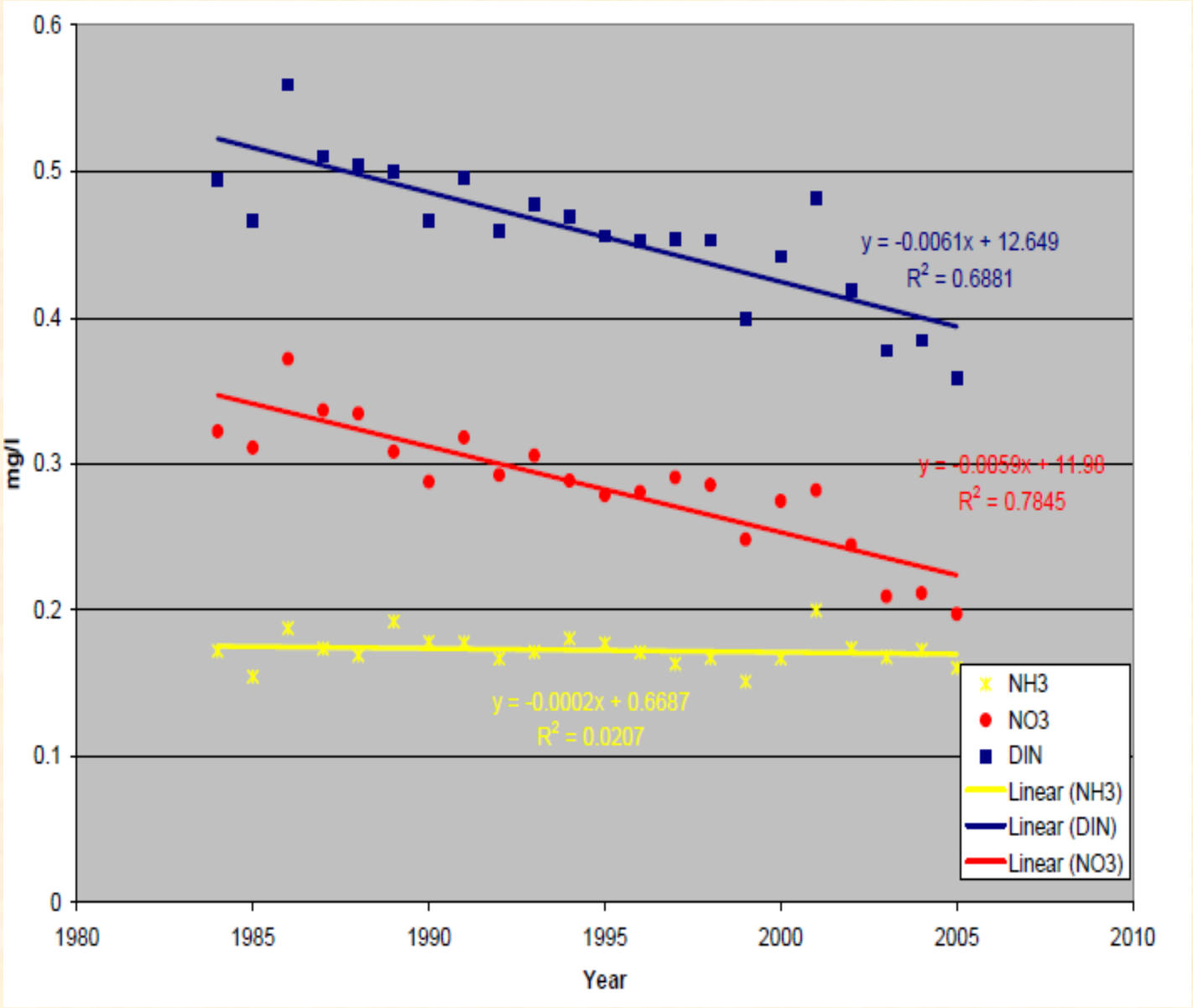
Models and Methods:

Time series of estimated atmospheric, fertilizer, manure, and point source total nitrogen input loads to the Chesapeake Bay.



Models and Methods:

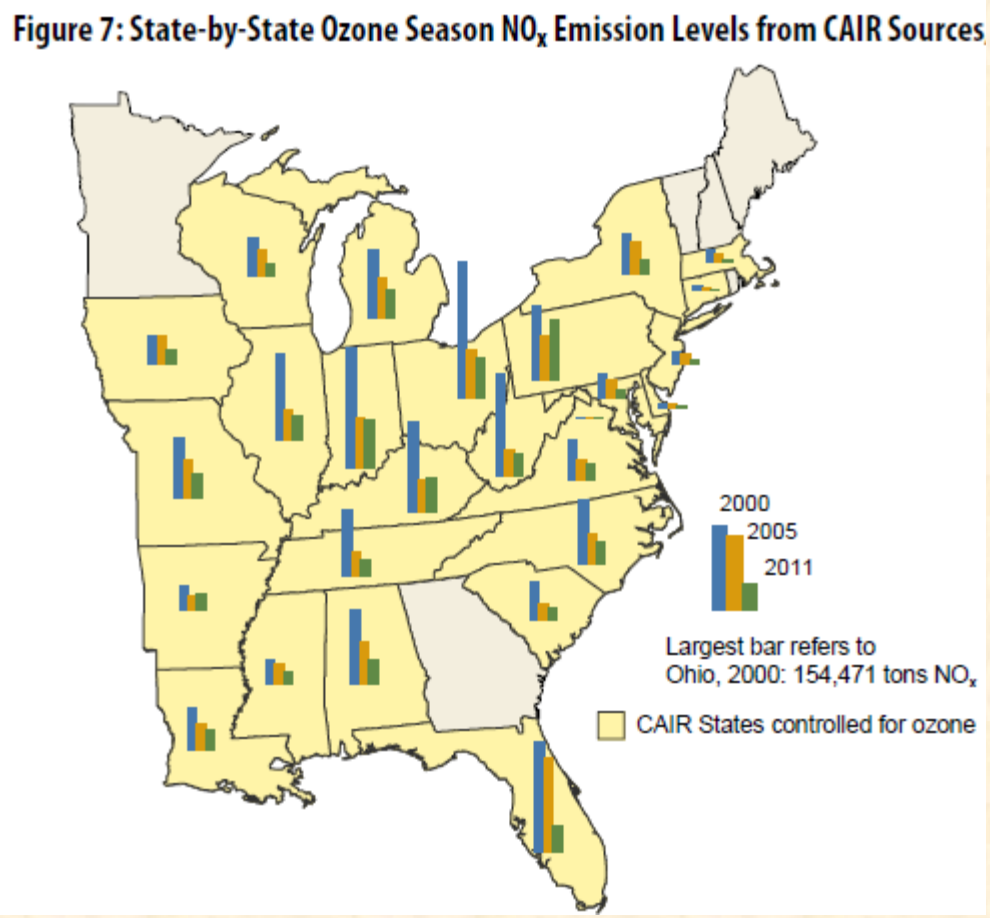
Trend of estimated average nitrate and ammonia deposition concentrations to the Chesapeake watershed.



Trends - Key Messages:

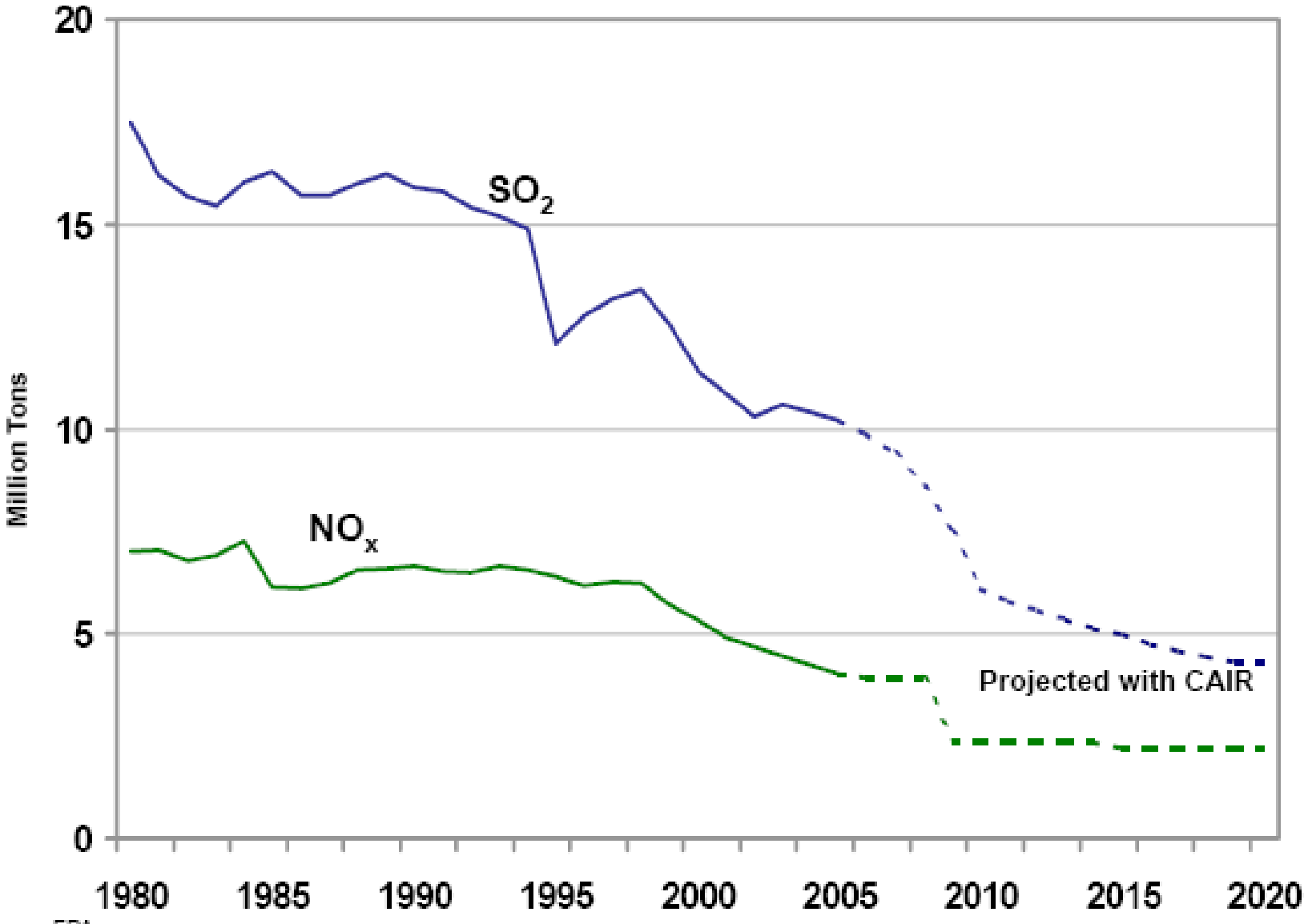
- Significant CAA driven emission reductions over the past two decades
  - Illustration: decadal record of declining emissions
- Long term decreasing trends in atmospheric nitrogen deposition concentrations and loads across Bay watershed
  - Illustration: nationwide maps of declines in nitrate concentrations
  - Illustration: long term declining nitrogen trends at select Bay watershed NADP stations.
- Reflected in widespread achievement of air quality standards
  - Illustration: histograms of ozone non-attainment days over time
- Nitrogen concentrations in headwater streams are also decreasing as a direct result
  - Illustration: graphics from Eshleman et al., 2013 ES&T paper
- Nitrogen concentrations in Bay watershed's largest rivers continue to decline (e.g., Potomac, Susquehanna)

Key Message: NO_x Emissions Declining



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

CAIR Accelerates 35 Years of Clean Air Progress:
Nationwide SO_2 and NO_x Emissions from the Power Sector



Source: EPA

Key Message: NO_x Emissions Declining

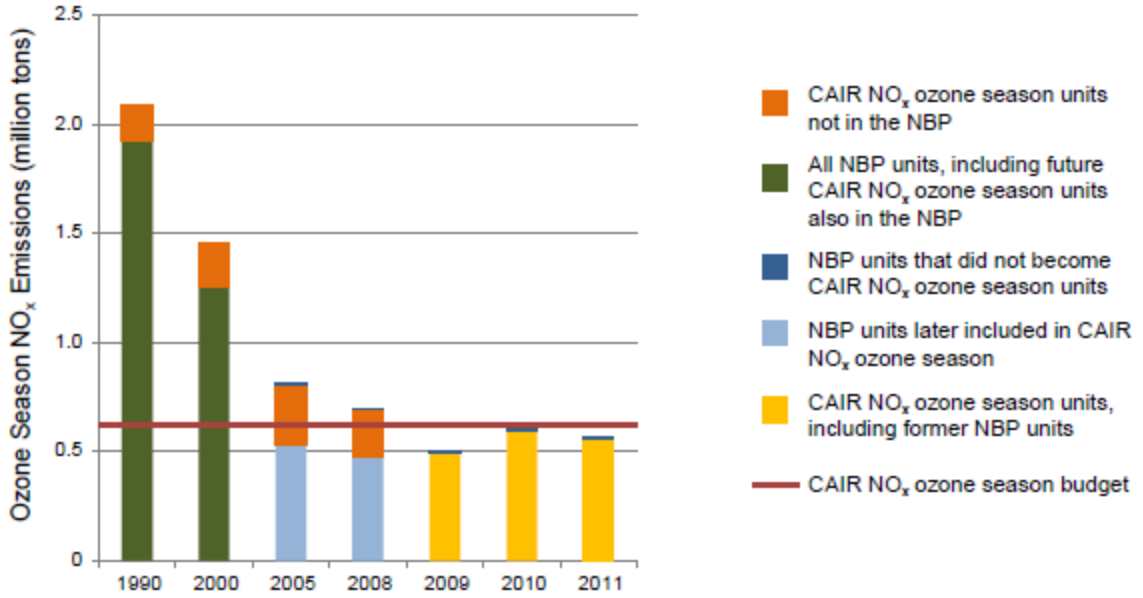
Units of percent and millions of kilograms in parentheses.

Estimated Portion of Deposited NO_x Loads on the Chesapeake Watershed in Millions of Kilograms.		
Year	**1990**	**2020**
Power Plants (EGUs)	40% (100)	17% (25)
Mobile Sources (on-road)	30% (75)	32% (46)
Industry	8% (20)	20% (29)
Other (off-road-construction Residential and commercial)	21% (53)	31% (45)

Estimated portion of deposited NO_x loads on the Chesapeake watershed from four sectors including EGUs, mobile sources, industry, and all other sources in 1990 and 2020. **Total annual deposited nitrogen loads to the Chesapeake watershed are estimated to be 250 million kilograms in 1990 and 145 million kilograms in 2020**.

Key Message: NO_x Emissions Declining

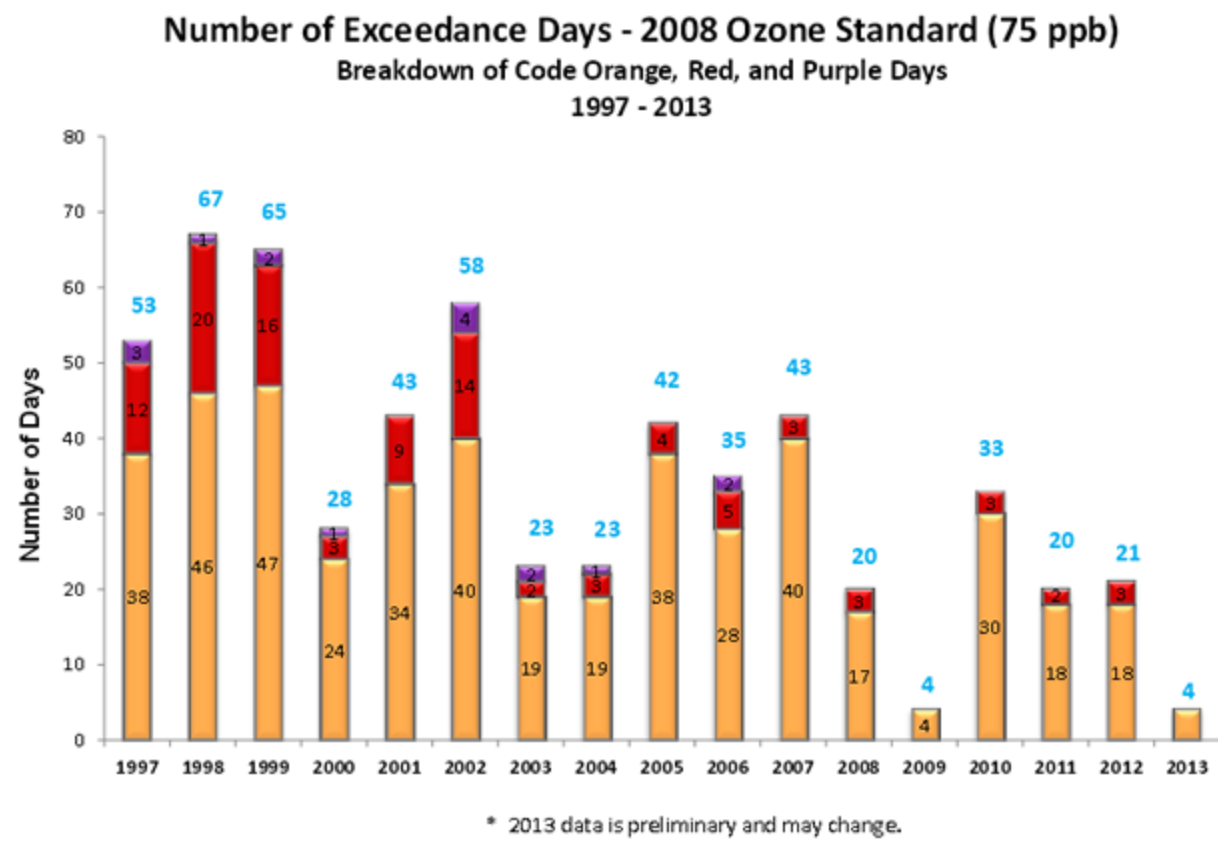
Figure 6: Ozone Season NO_x Emissions from CAIR and NBP Sources, 1990–2011



Note: For CAIR units not in the NBP, the 2008 NO_x emissions were applied retroactively to 1990 and 2000 if the unit operated in the previous year's ozone season.
Source: EPA, 2012

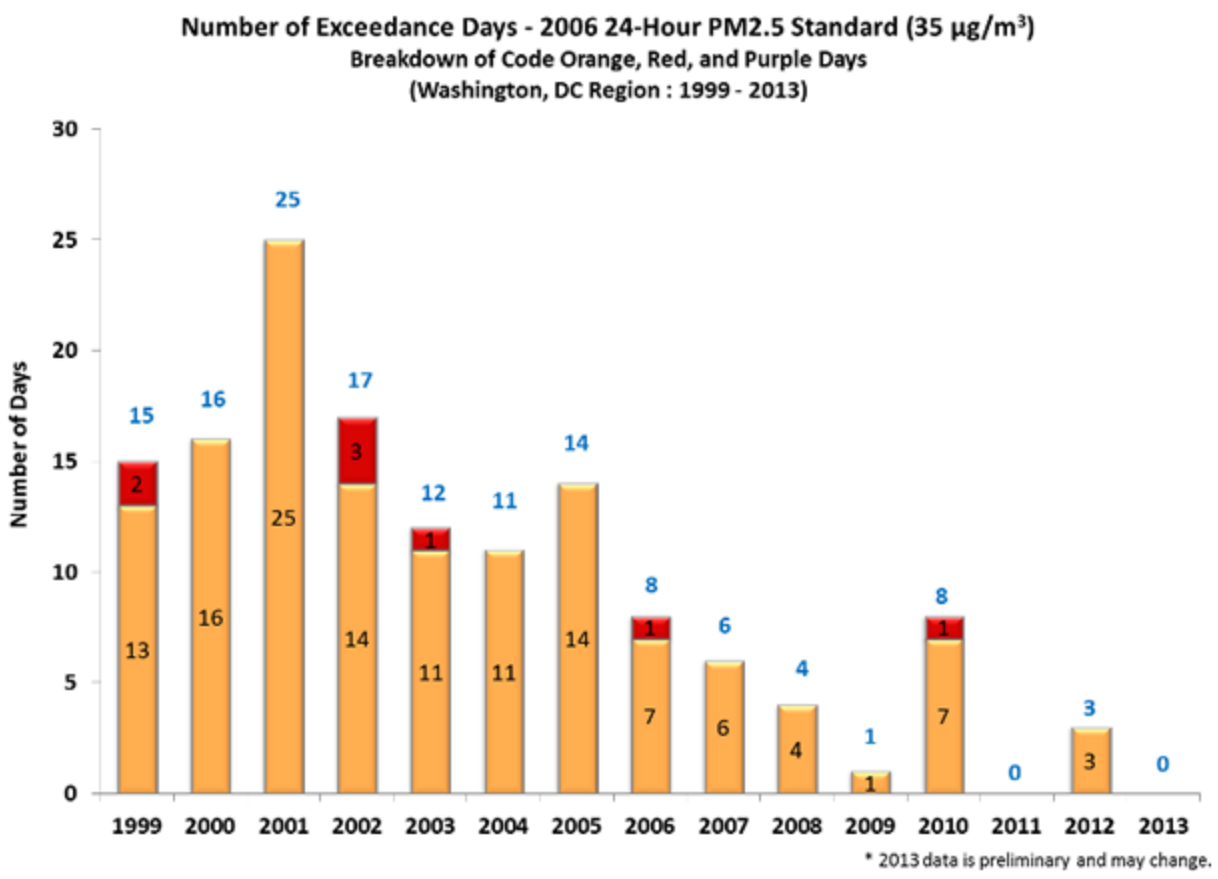
Source: U.S. EPA "SO2 and NOx Emissions, Compliance, and Market Analyses" 2013.

Key Message: Air Quality Improving



Source: Washington Post “Breathing easier: Washington, D.C.’s remarkable improvement in air quality” by Jason Samenow. September 26, 2013.

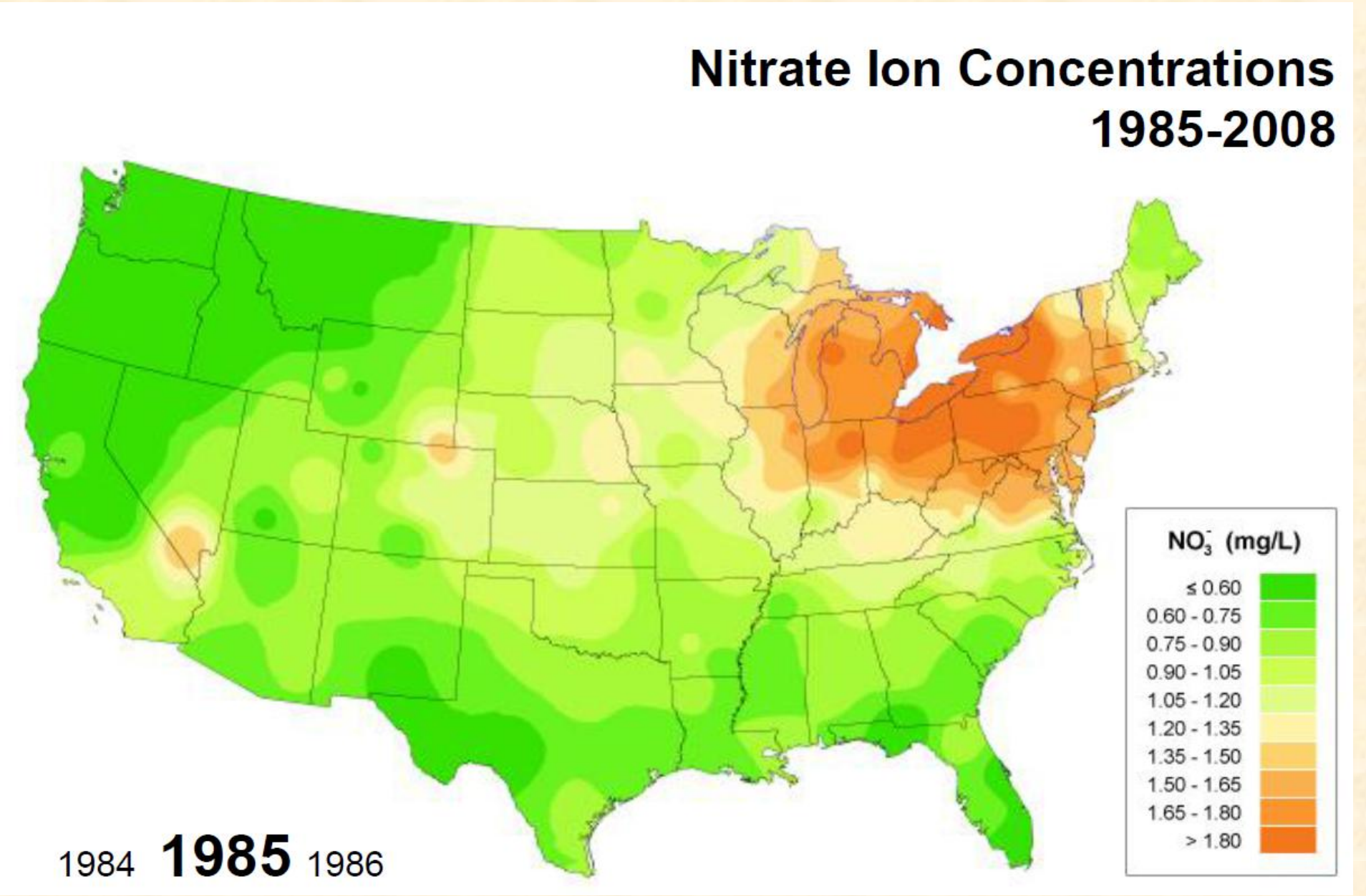
Key Message: Air Quality Improving



Source: Washington Post "Breathing easier: Washington, D.C.'s remarkable improvement in air quality" by Jason Samenow. September 26, 2013.

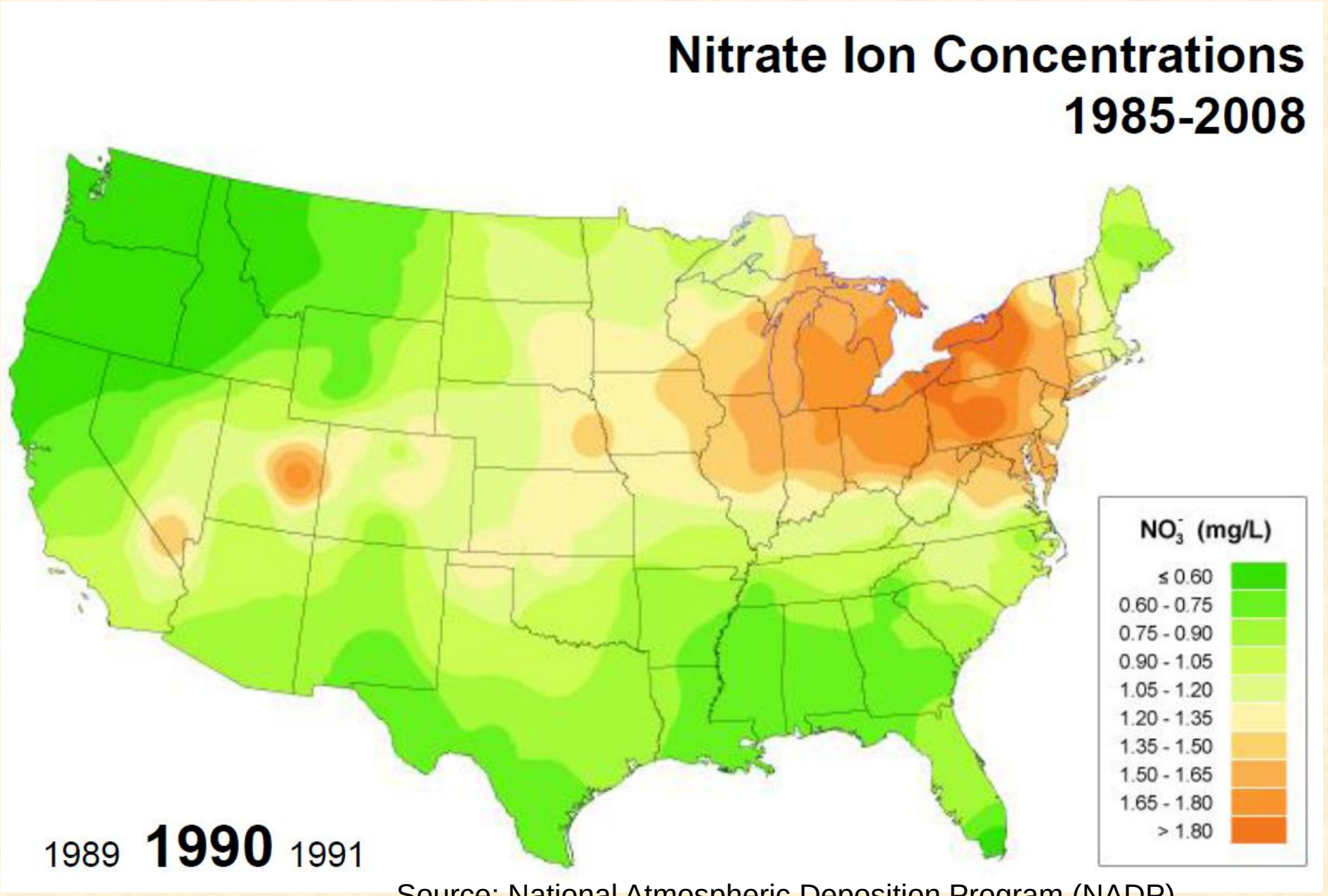
But, we have now largely met the regions air quality standards and the trend will now flatten out as the emphasis is on maintaining air standard achievements. **"Past performance is not indicative of future results."**

Key Message: NADP Nitrate Deposition Declining



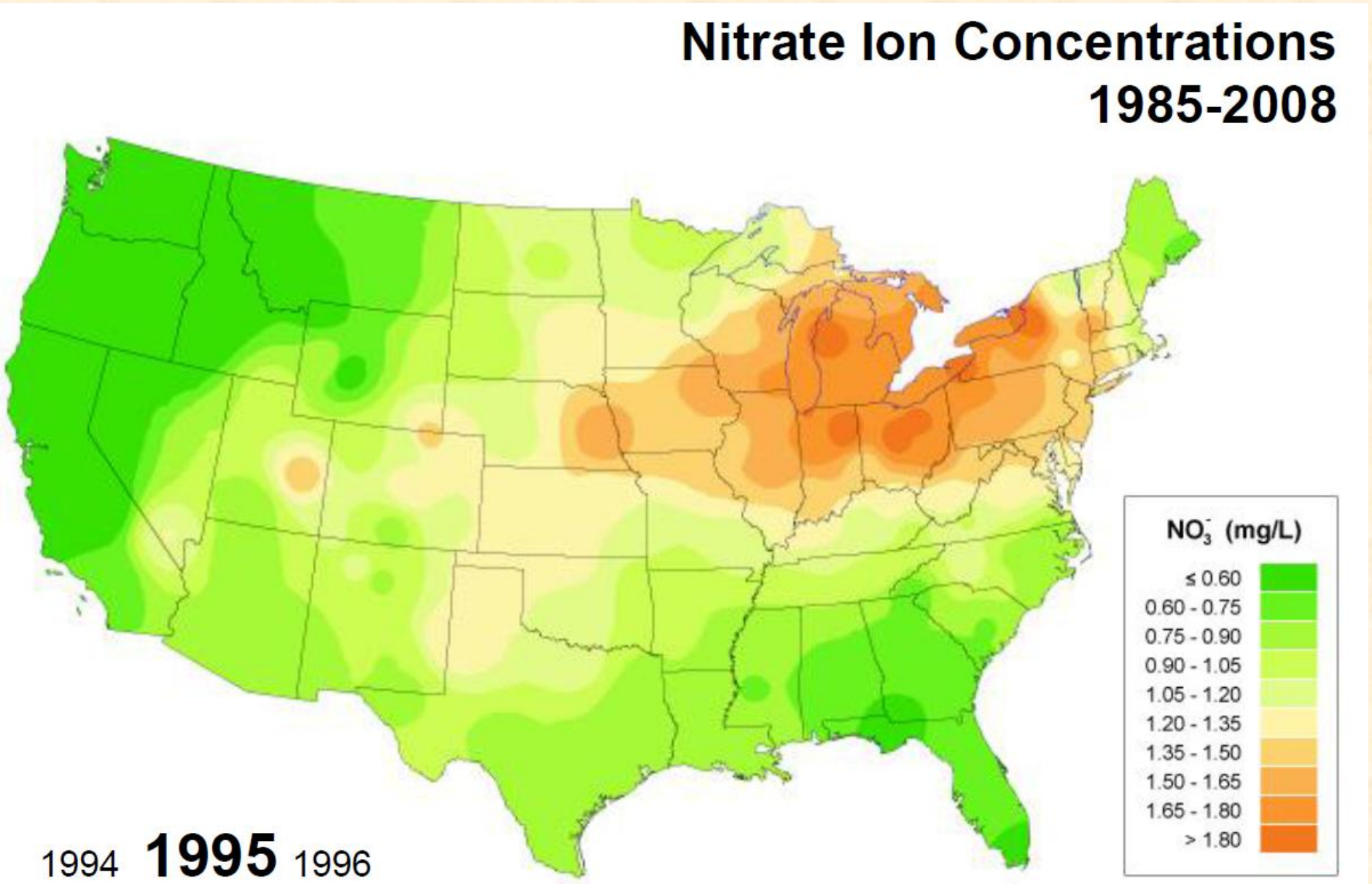
Source: National Atmospheric Deposition Program (NADP)

Key Message: NADP Nitrate Deposition Declining



Source: National Atmospheric Deposition Program (NADP)

Key Message: NADP Nitrate Deposition Declining



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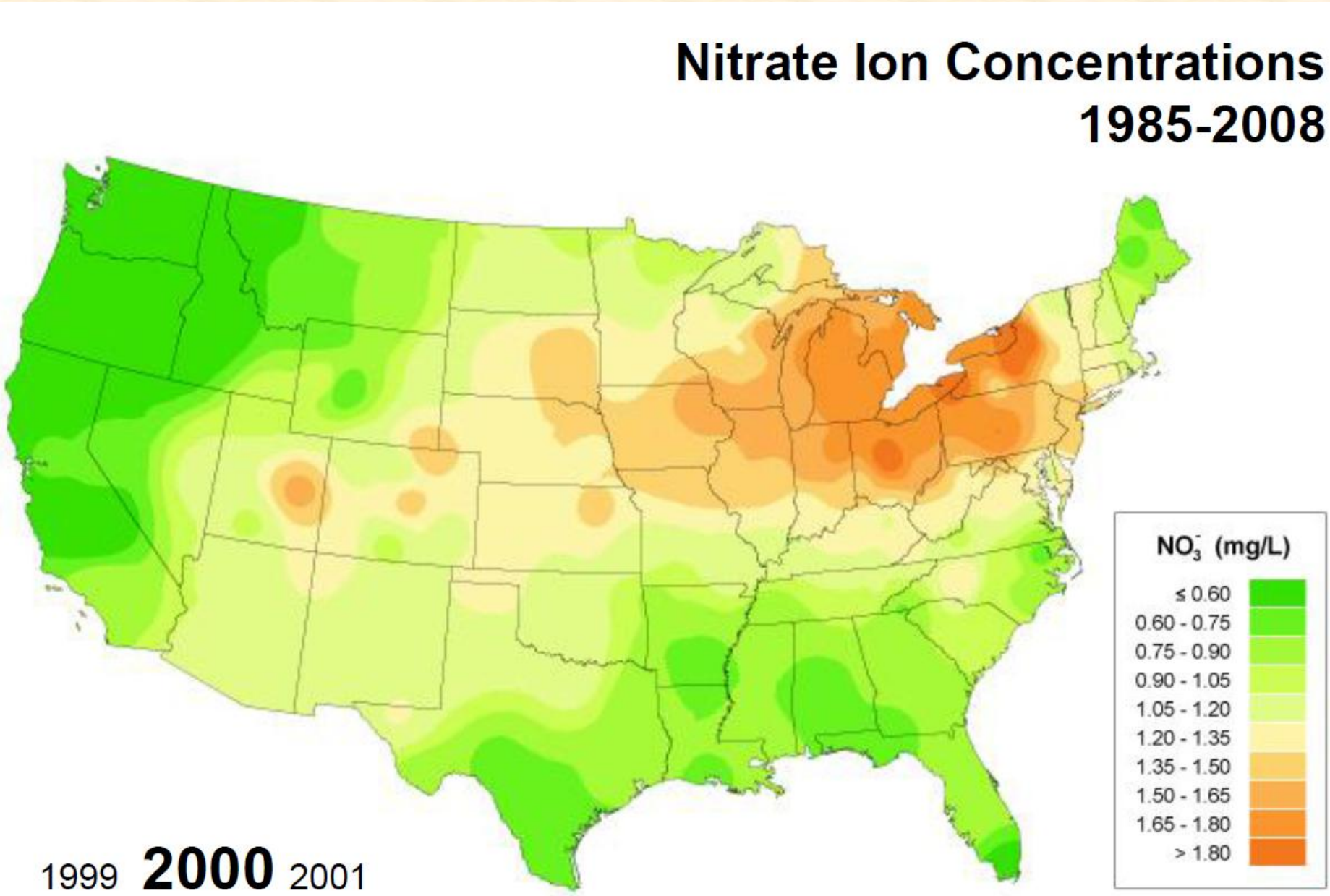
Key Message: NADP Nitrate Deposition Declining



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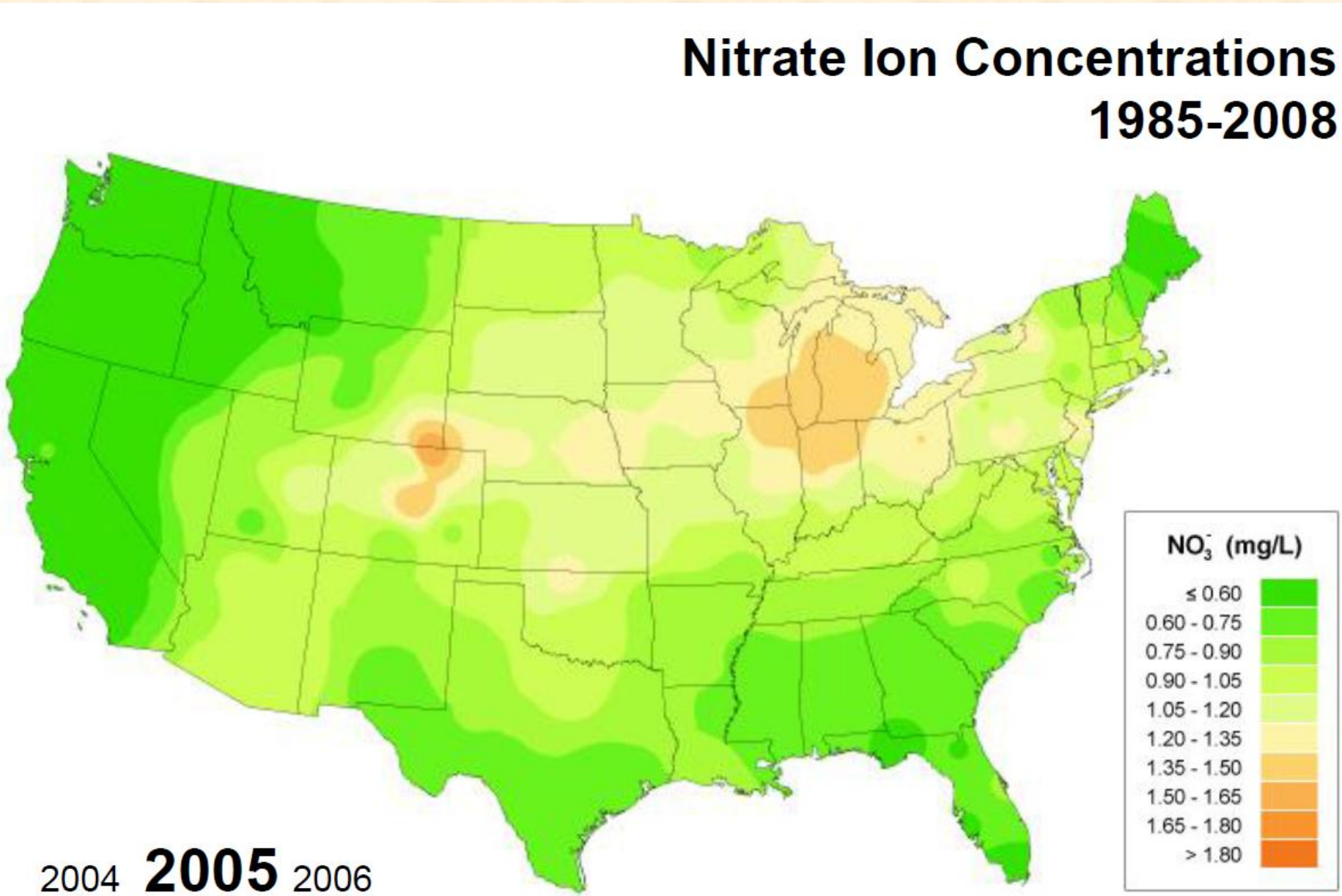

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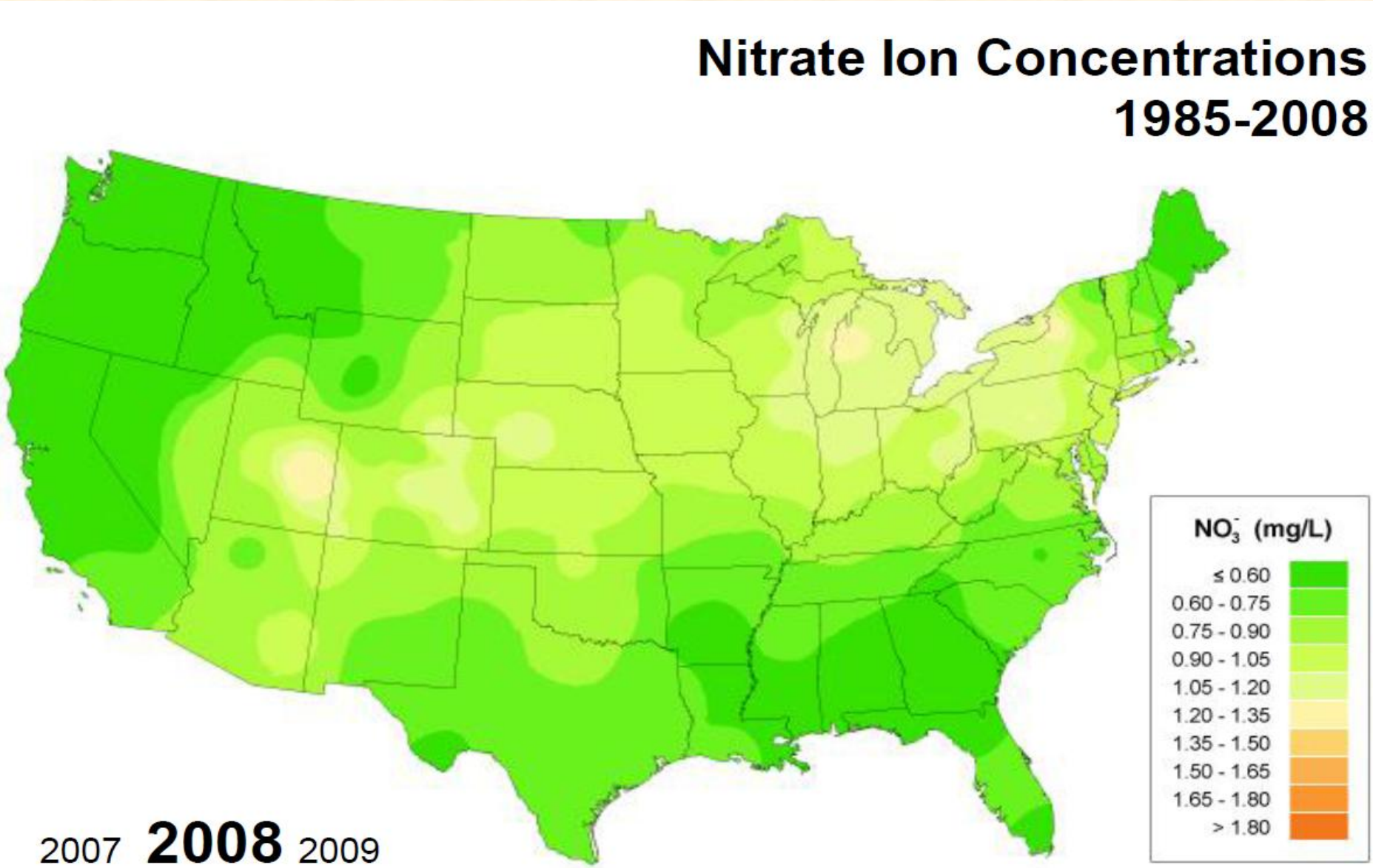
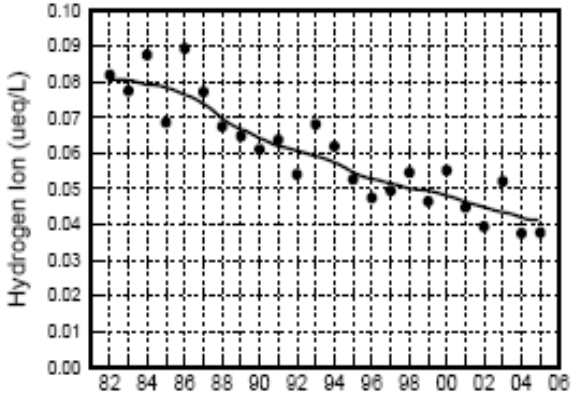
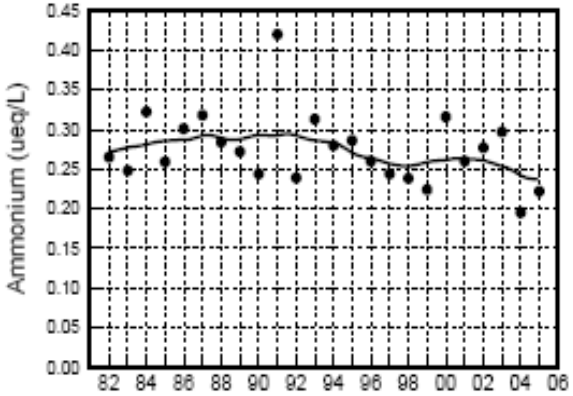
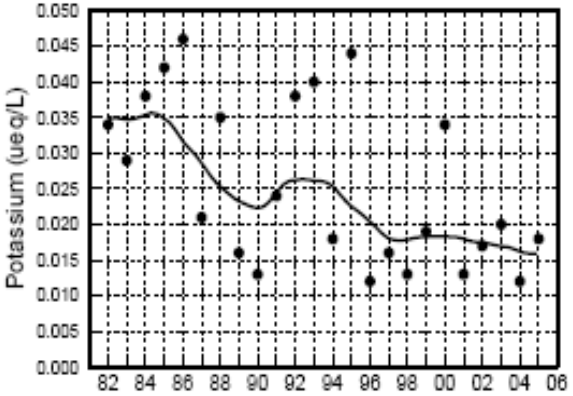


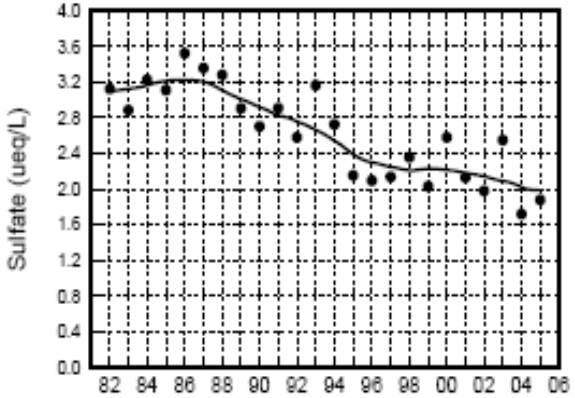
Source: National Atmospheric Deposition Program (NADP)

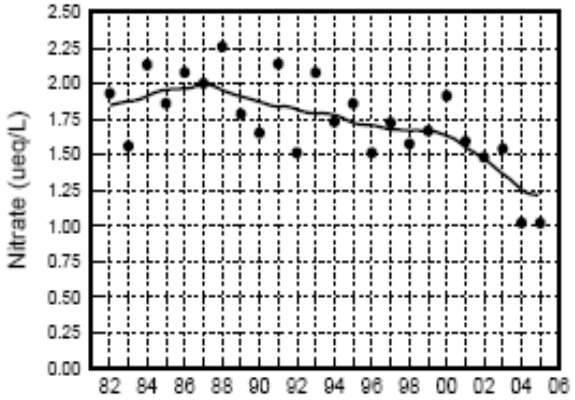
Kane Experimental Forest - NADP/NTN: 2005 Annual Concentrations



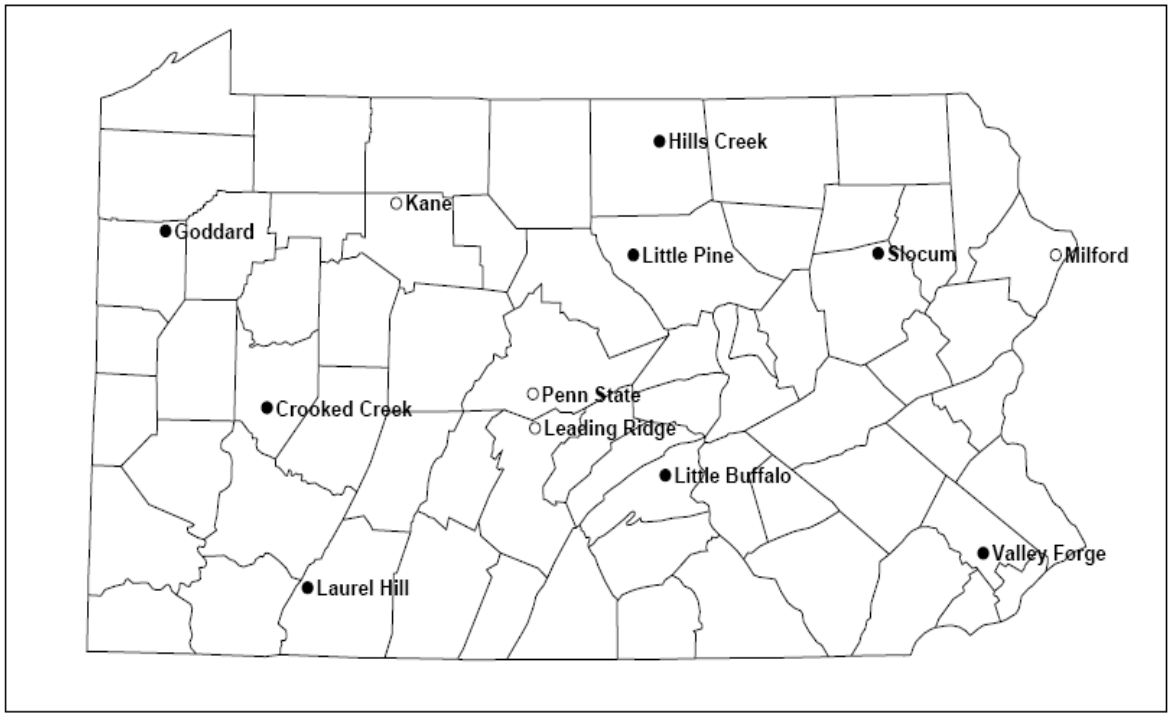




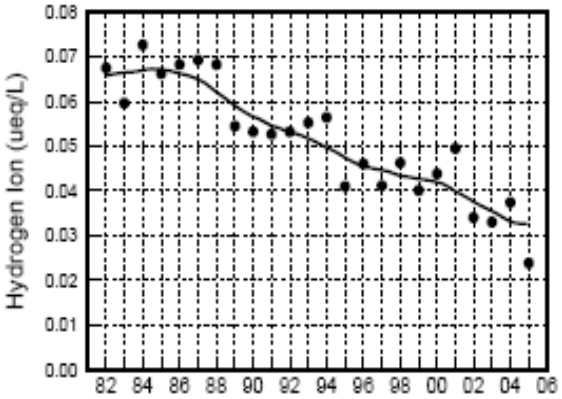


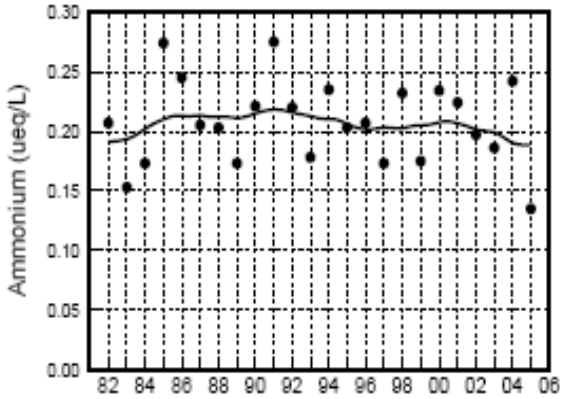


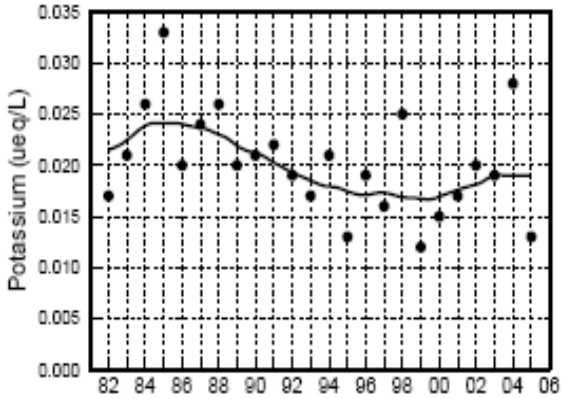
Pennsylvania Atmospheric Deposition Monitoring Network

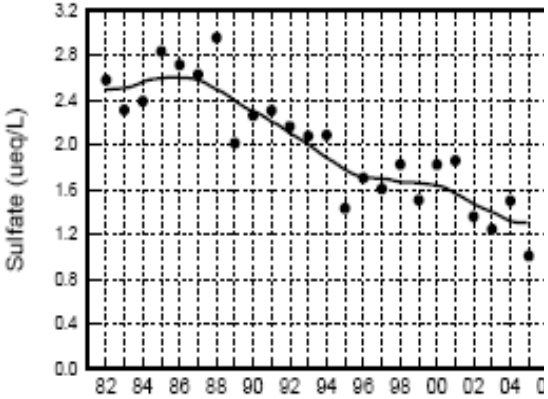


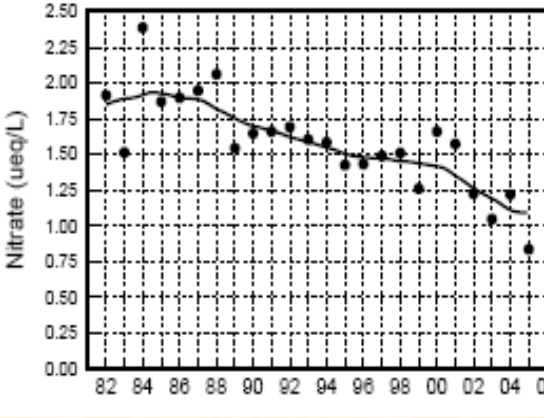
Milford - Forest Service - NADP/NTN: 2005 Annual Concentrations











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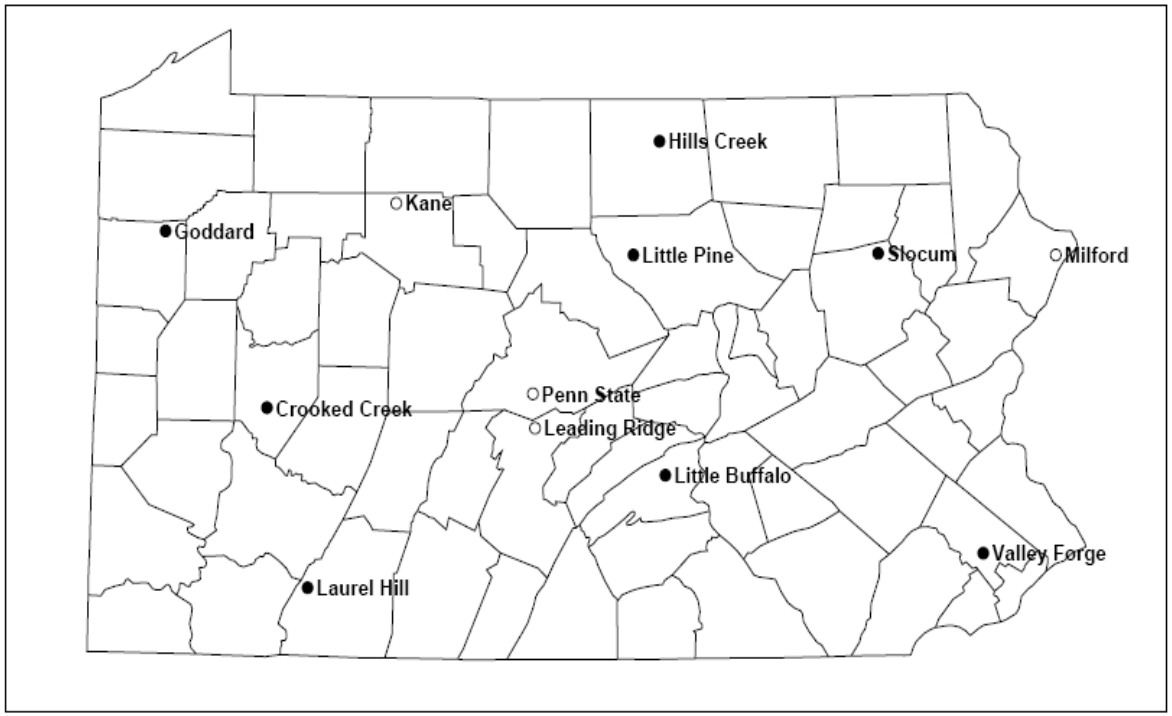
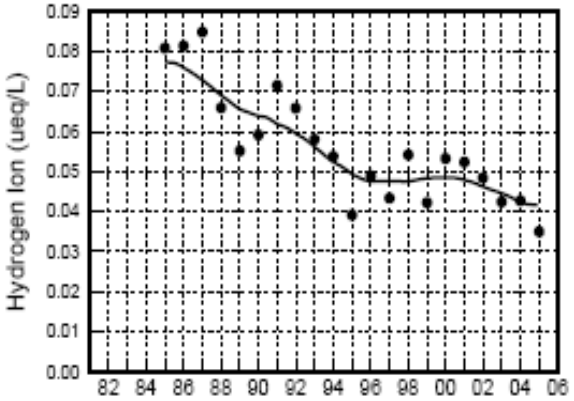
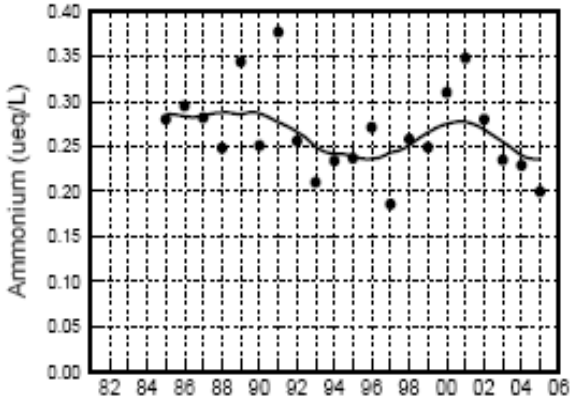
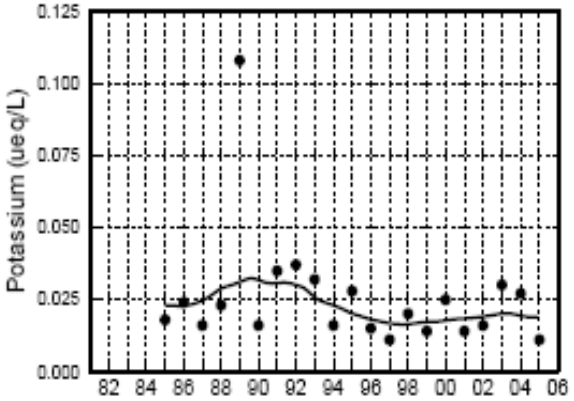
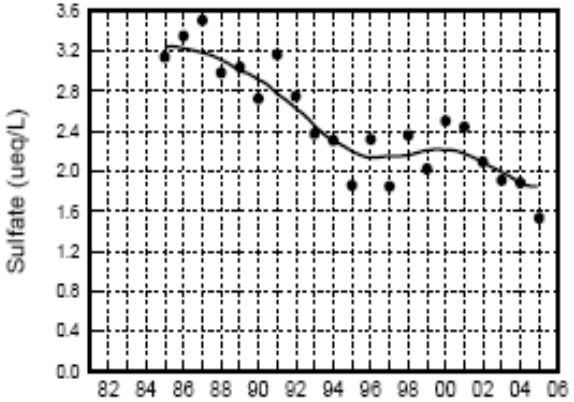


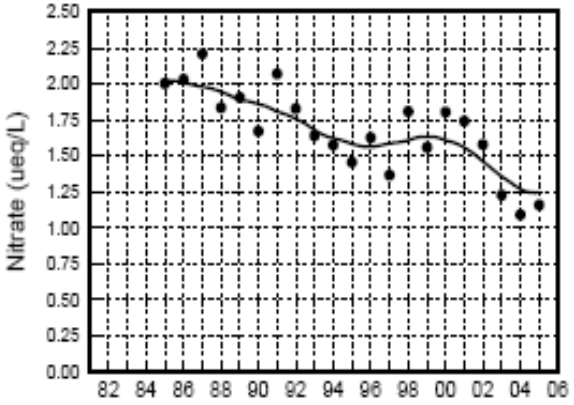
Pennsylvania State University - NADP/NTN: 2005 Annual Concentrations











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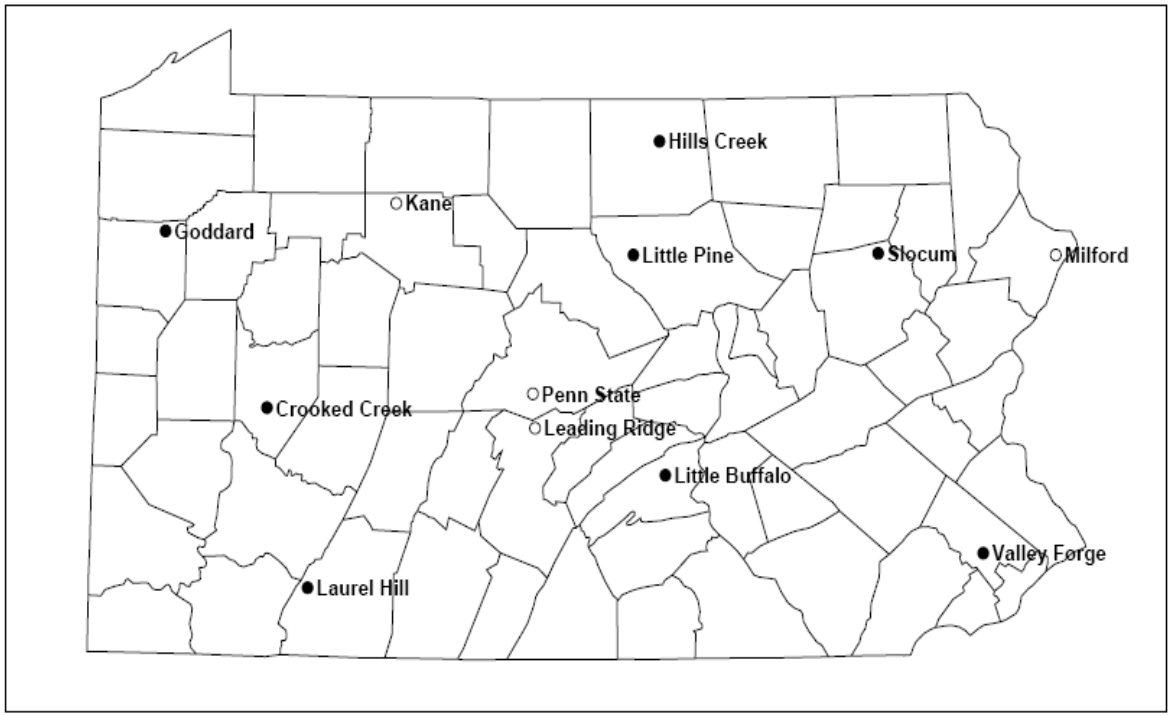
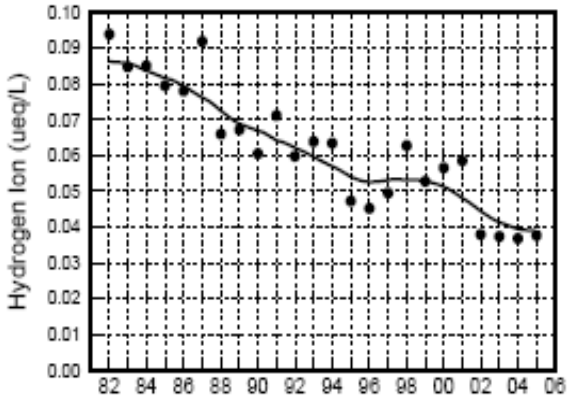
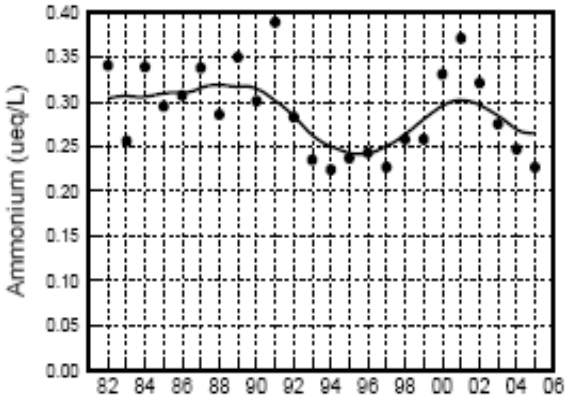
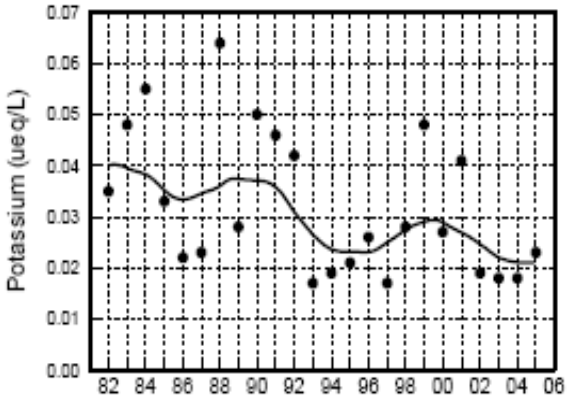
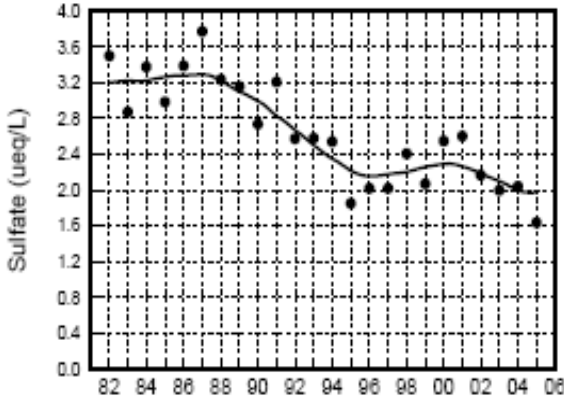


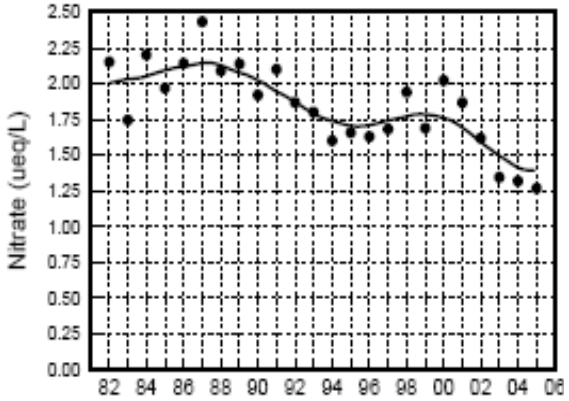
Leading Ridge - NADP/NTN: 2005 Annual Concentrations











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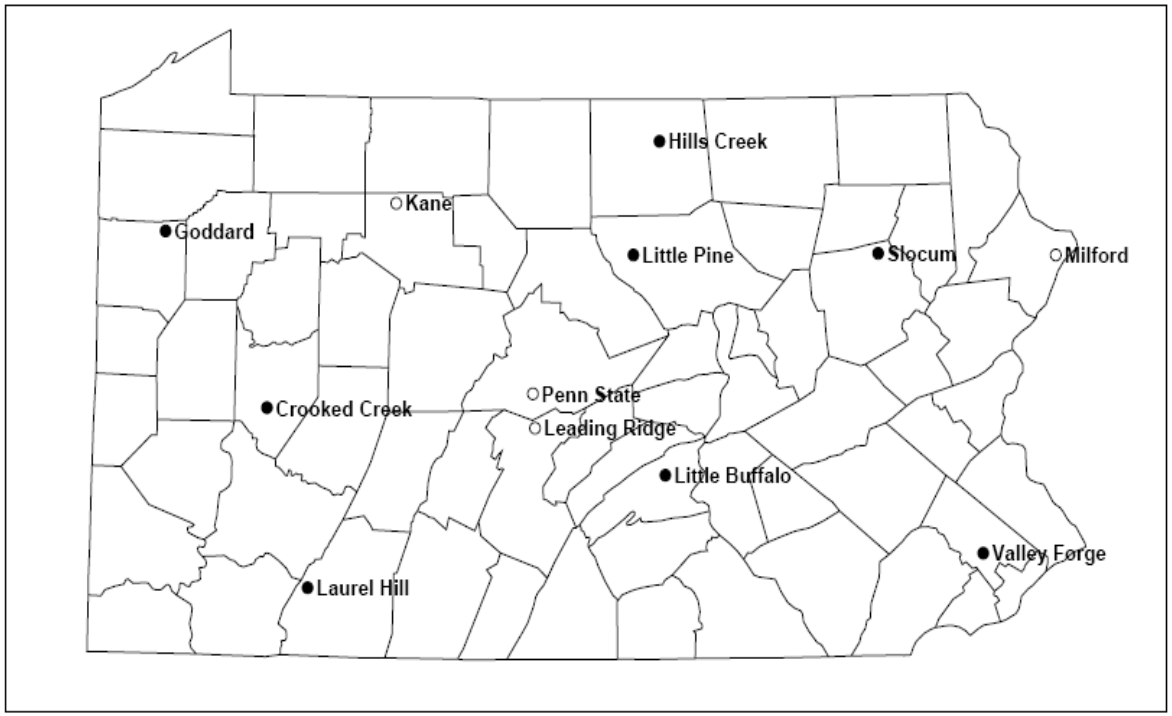


Key Message: Better Than Expected Responses

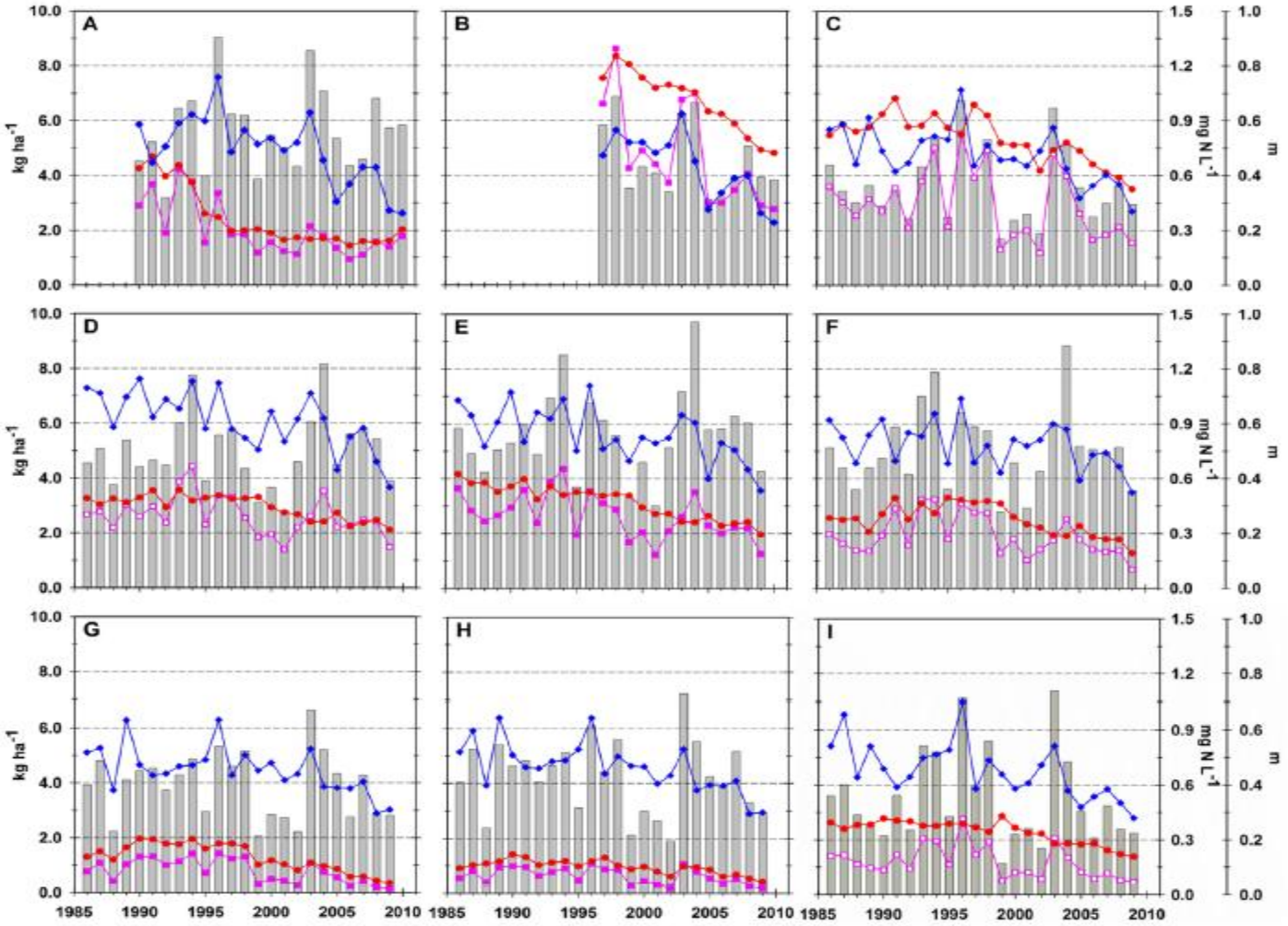


Figure 2. Temporal patterns (1986–2009) in annual (1) nitrate-N yields (kg ha^{-1}, pink lines/squares), (2) areal N deposition (kg ha^{-1}, blue lines/diamonds), (3) nitrate-N concentrations (mg N L^{-1}, red lines/circles), and (4) runoff (m, gray bars) for the nine study; letters correspond to watersheds 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]

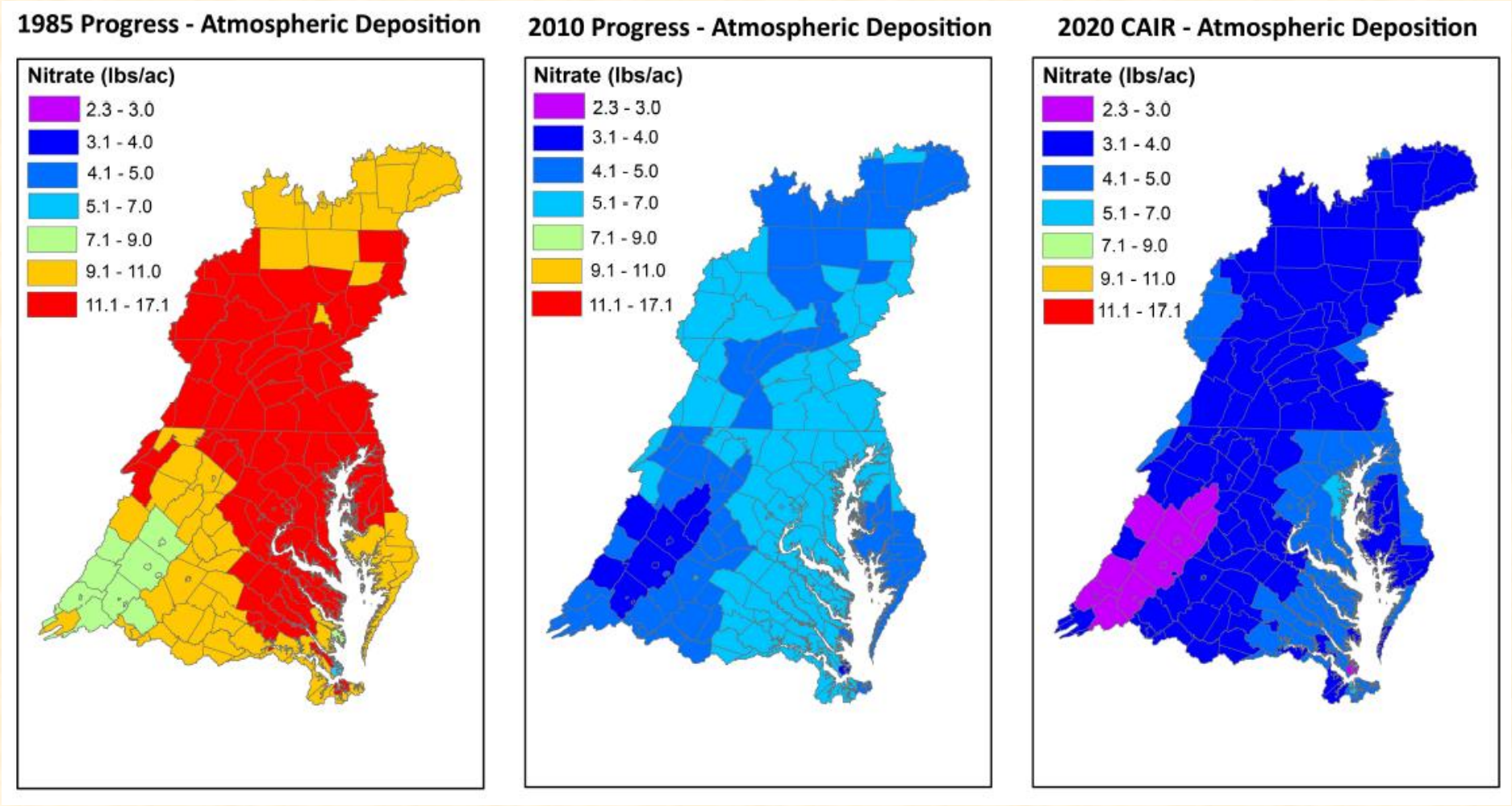
Lewis C. Linker, Robin Dennis, Gary W. Shenk, Richard A. Batiuk, Jeffrey Grimm, and Ping Wang[2]

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

Models and Methods:



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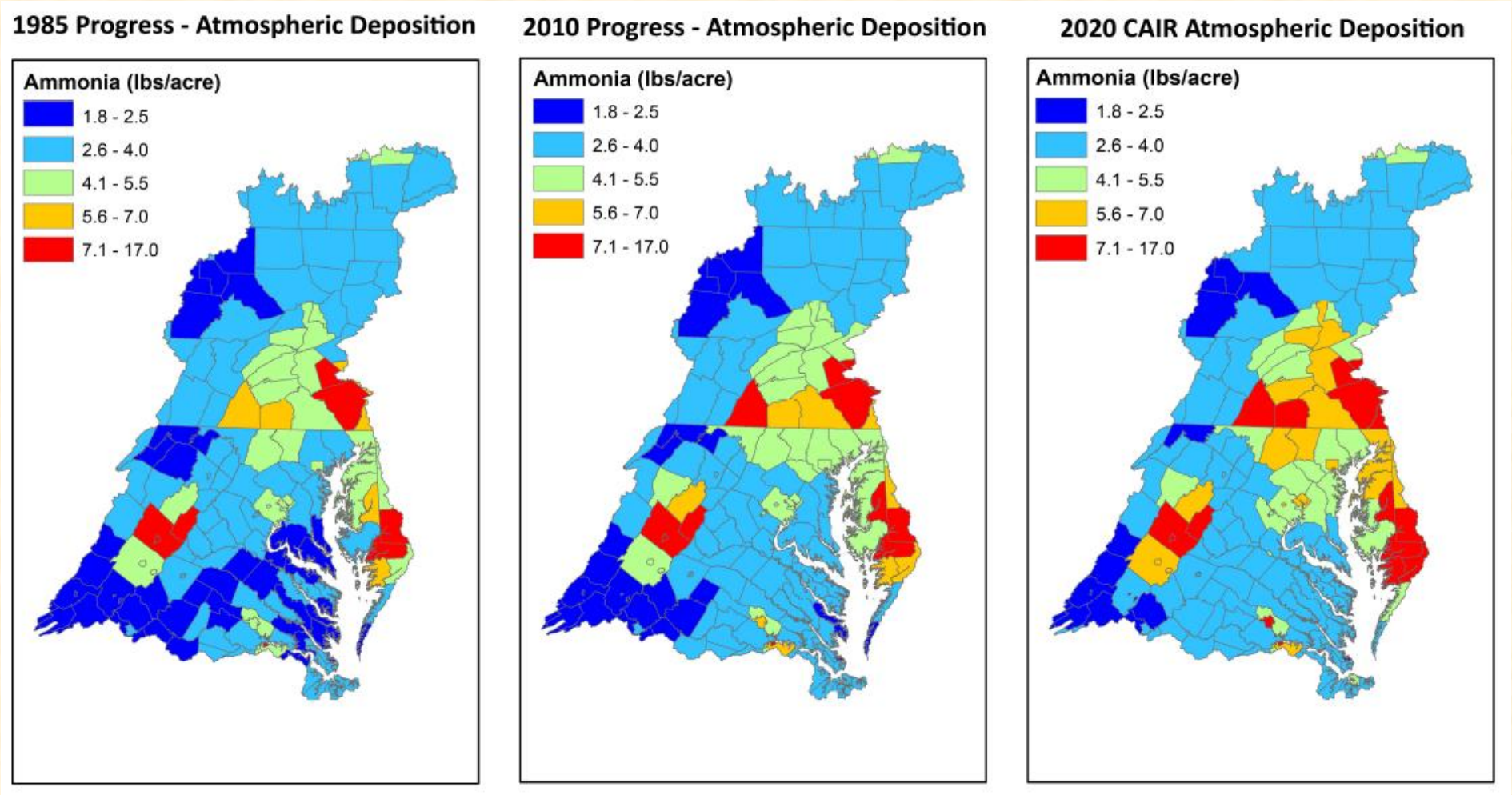

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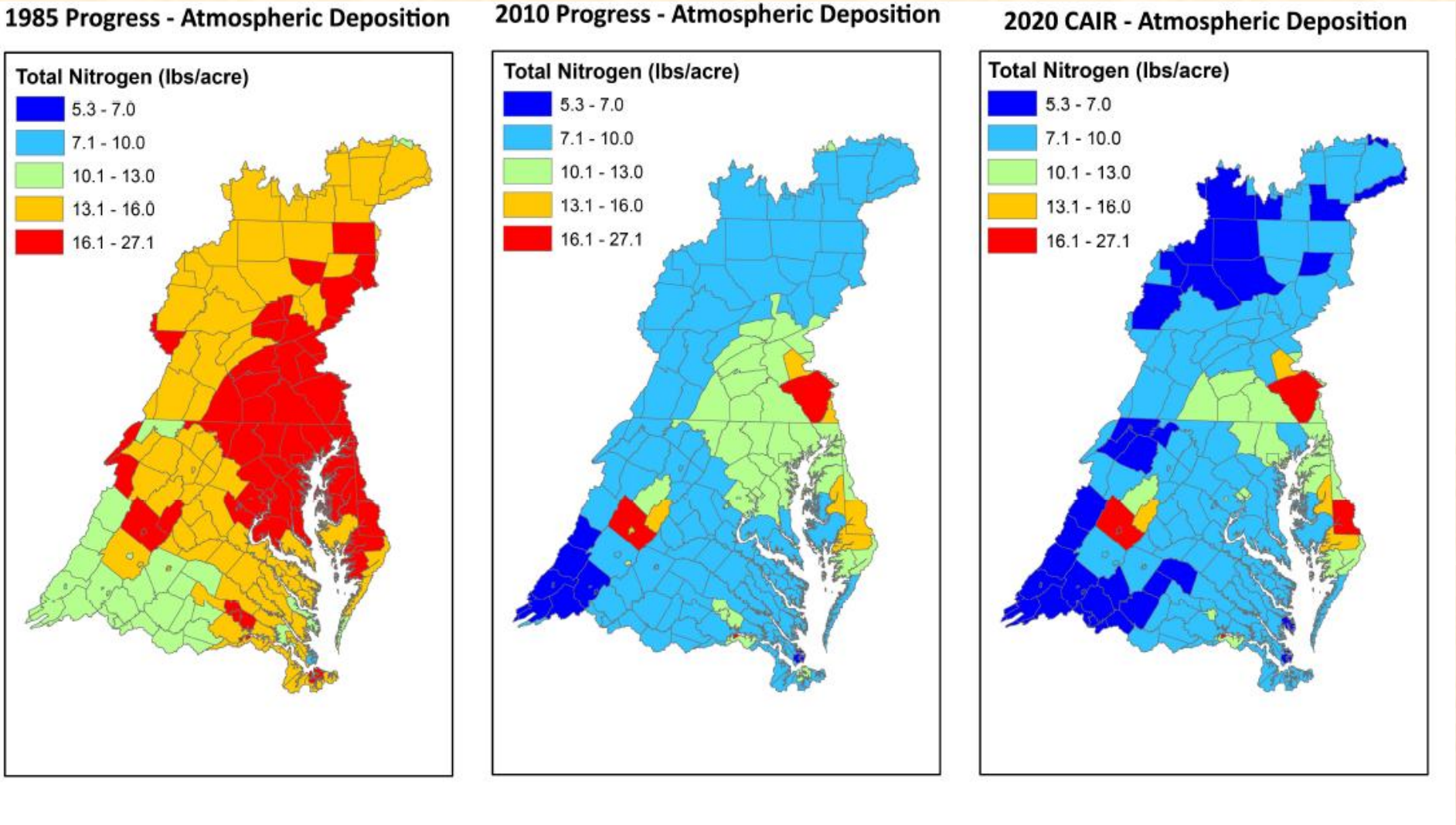

Conclusions:

- Atmospheric deposition reductions in NOx emissions are driven by national air quality standards based on human health concerns.
- Significant reductions in NOx deposition has been observed in the Chesapeake watershed. Between 1985 to 2005 there was an estimated 30% reduction in NOx deposition in the watershed.
- Trend in ammonia deposition is estimated to be unchanged watershed wide but increasing in regions with high animal populations.
- Trend in reduction will flatten out as more air quality monitors record attainment of ozone and PM2.5 standards. “Past performance does not guarantee future results.”
- On the other hand, there has been coverage in the national press that the ozone air quality standard now set at 75 ppb, could go down to between 60-70 ppb. The NAAQS was last revised to 75 ppb in 2008, and environmental groups have sued the agency seeking firm deadlines for a new standard based on the latest available scientific and technical information.