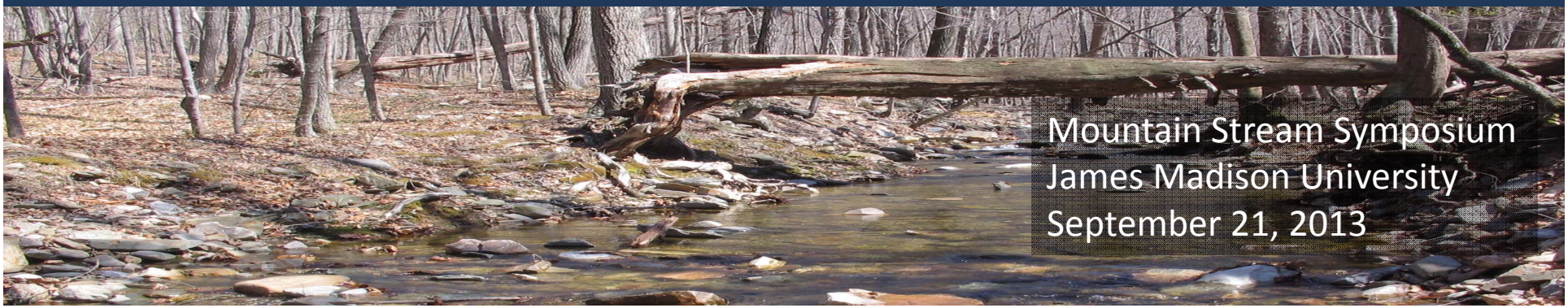
Virginia's Mountain Steams: What Thirty Years of Research tells us about Future Impacts of Acid Rain and Climate Change

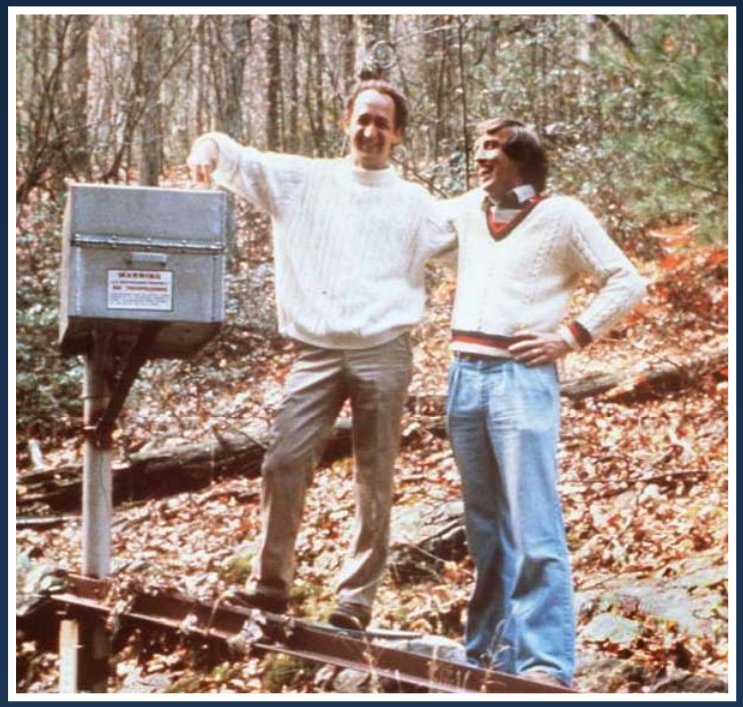
Todd Scanlon
Jim Galloway
Jack Cosby
Rick Webb
Drew Robison

Department of Environmental Sciences
University of Virginia

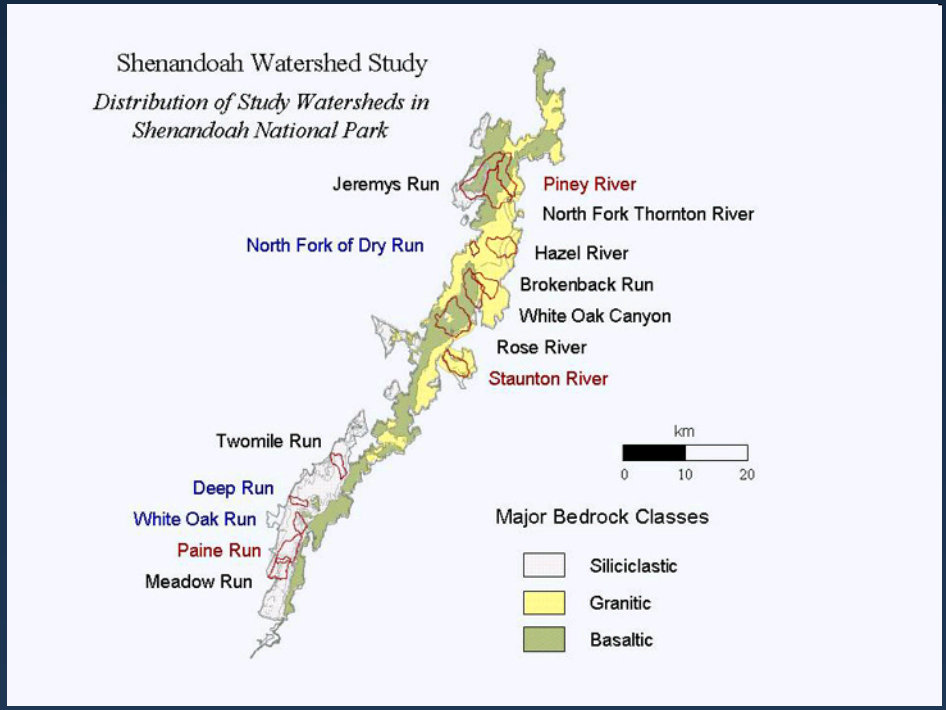


Mountain Stream Symposium
James Madison University
September 21, 2013

Shenandoah Watershed Study (SWAS)



Jim Galloway George Hornberger

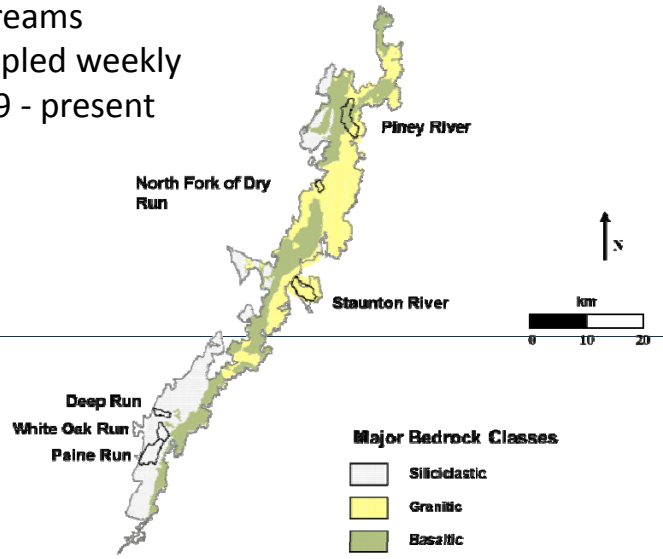


Initiated in 1979 as a cooperative research venture with the U.S. NPS

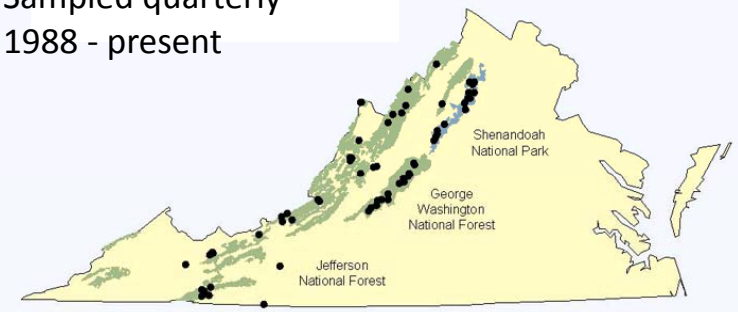
Outdoor laboratory

Hierarchy of Spatial and Temporal Scales

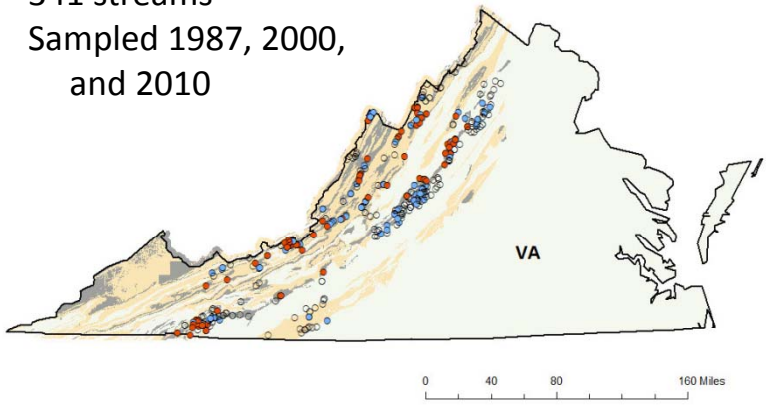
Shenandoah Watershed Study (SWAS)
5 streams
Sampled weekly
1979 - present



Virginia Trout Stream Sensitivity Study (VTSSS)
66 streams
Sampled quarterly
1988 - present



"Decadal" Survey
341 streams
Sampled 1987, 2000, and 2010



SWAS Objectives

. . . to improve understanding of ecosystem processes in the forested mountain watersheds of Shenandoah National Park and the central Appalachian region

. . . to detect and assess hydro-biogeochemical changes occurring in these relatively undisturbed ecosystems

SWAS Core Program

Watershed is the basic unit of study – framework for process-based research

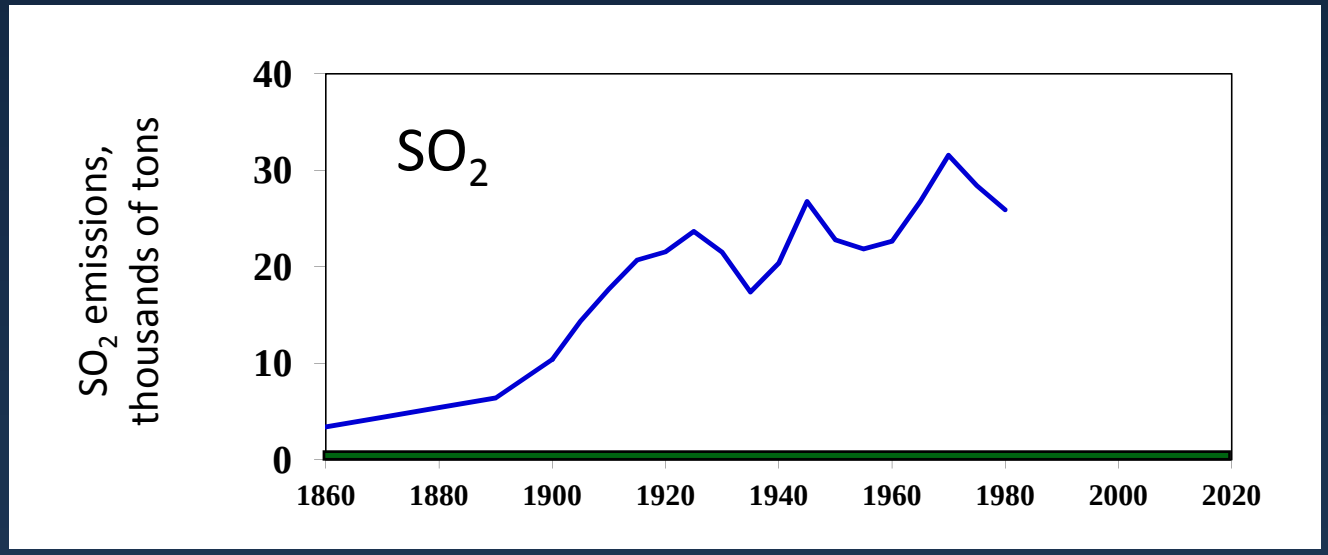
Basis for regional extrapolation

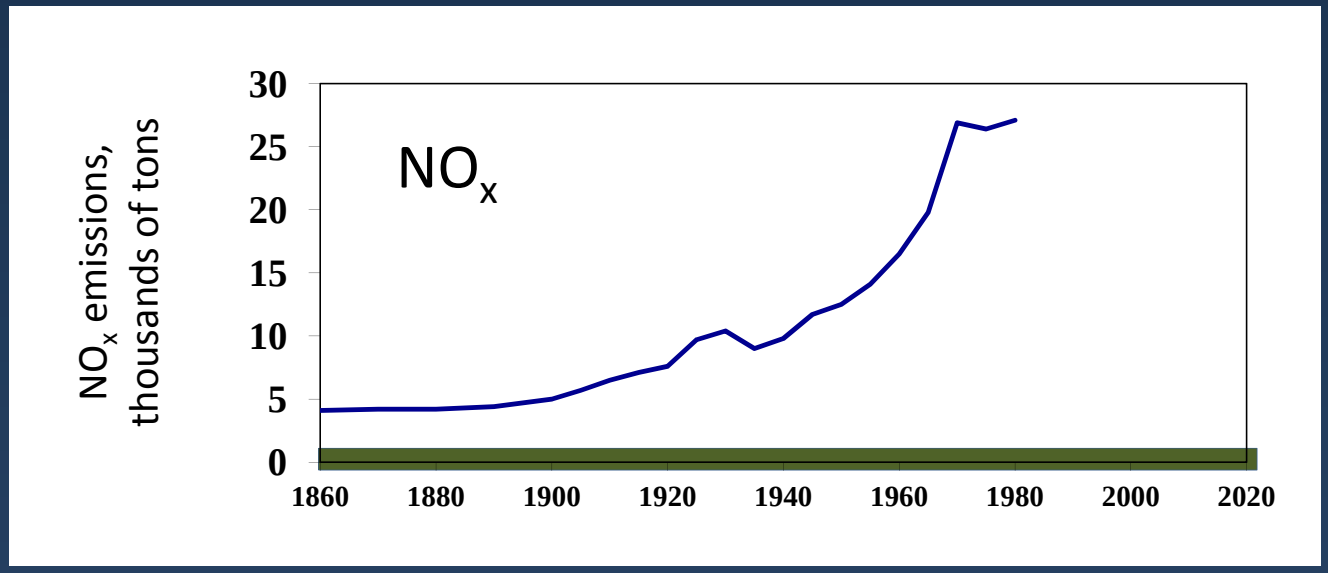
Longest watershed study in National Park system

Made possible by strong cooperation with NPS and EPA

U.S. Emissions

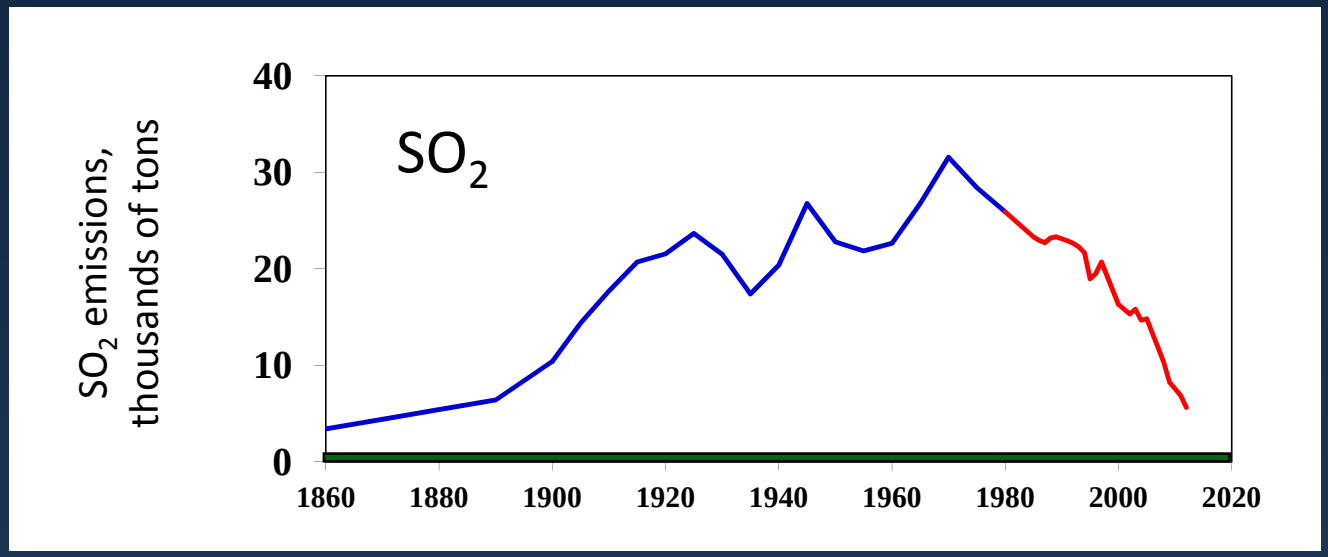
Source: EPA National Emission Inventory

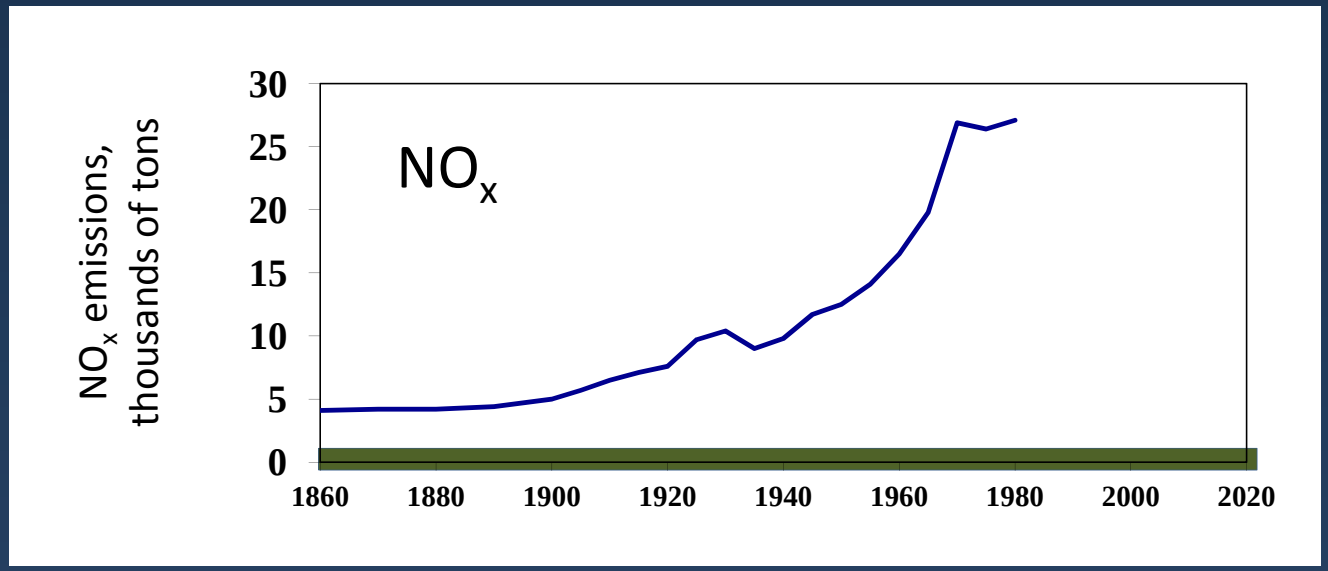




U.S. Emissions

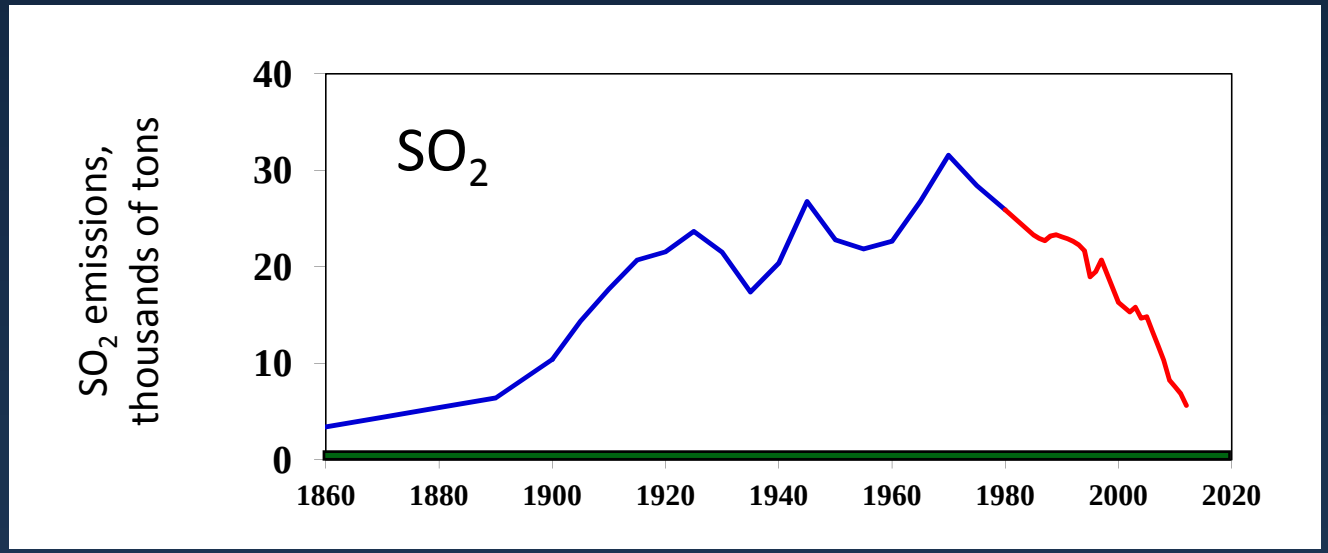
Source: EPA National Emission Inventory

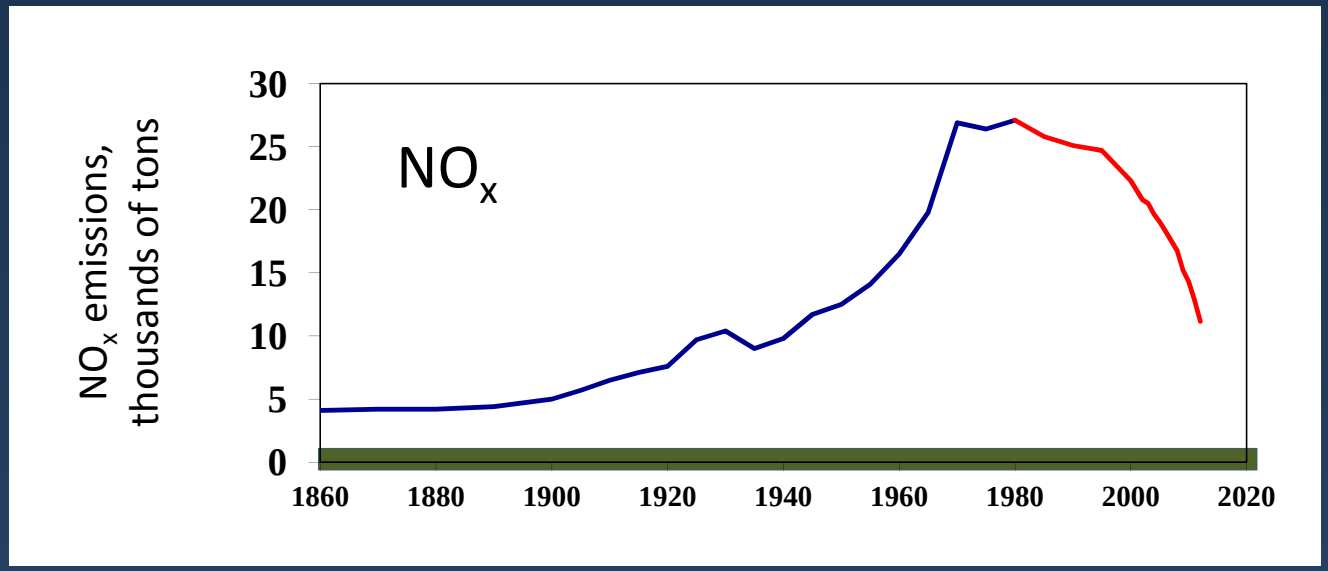




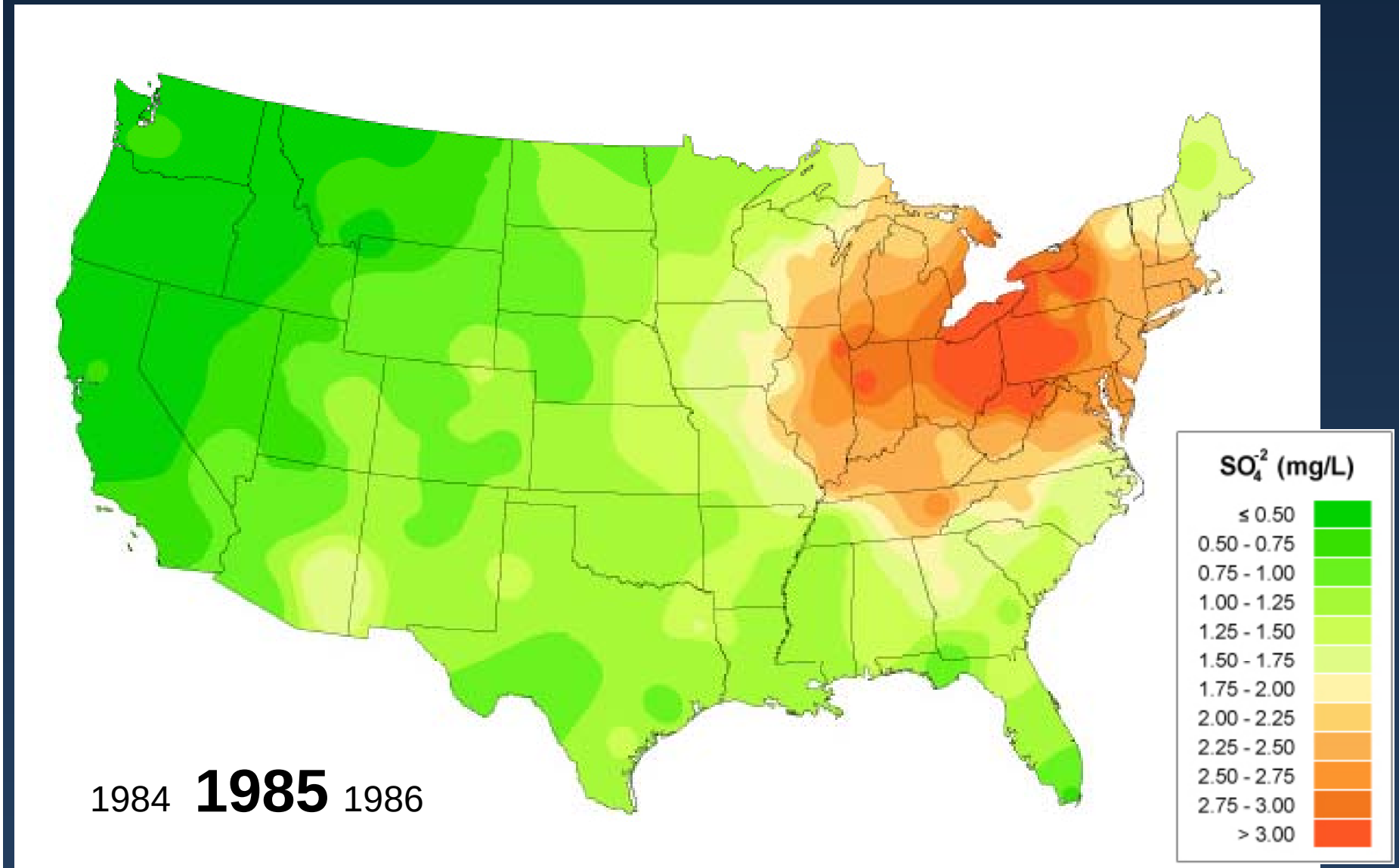
U.S. Emissions

Source: EPA National Emission Inventory



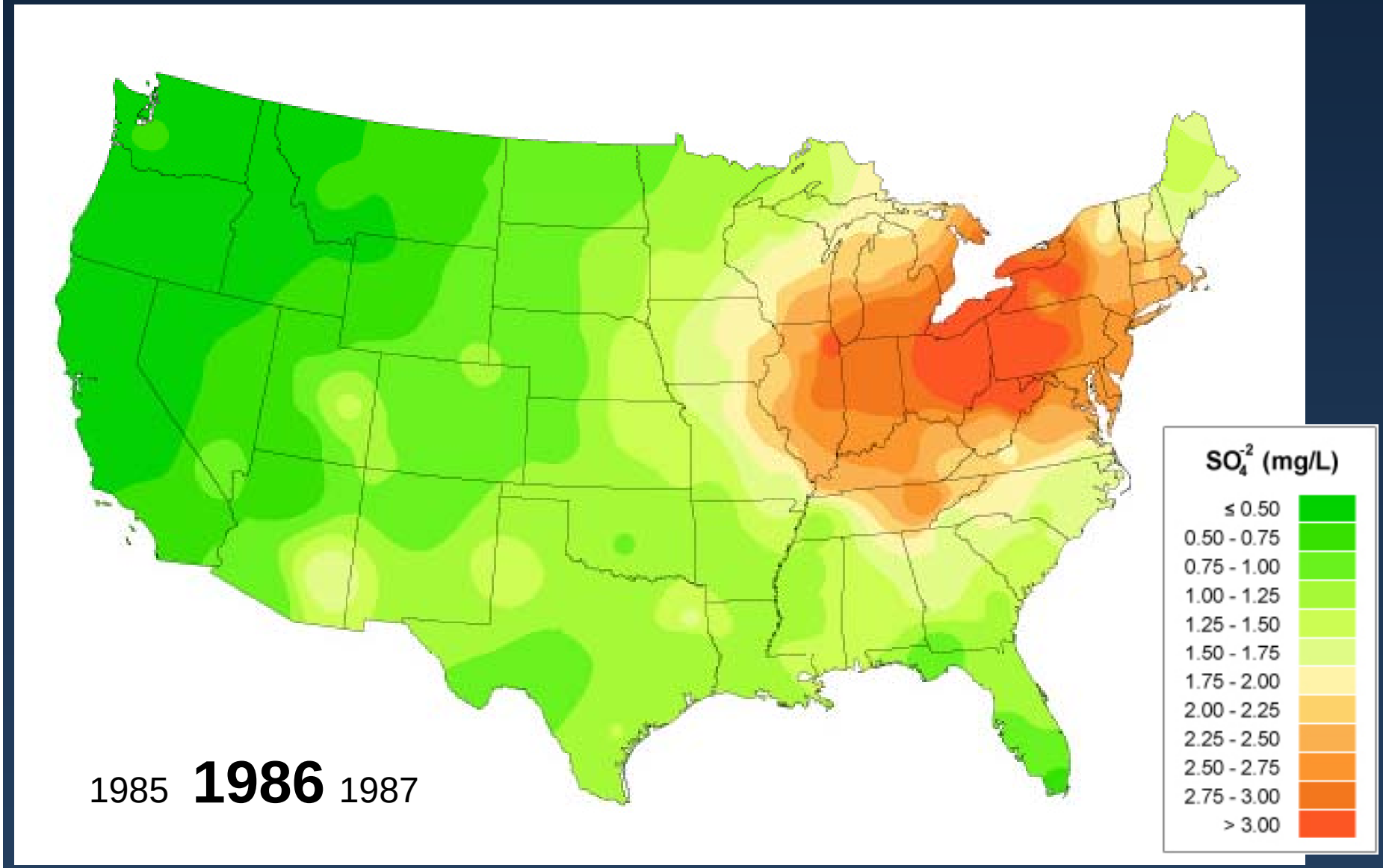


Sulfate Ion Concentrations



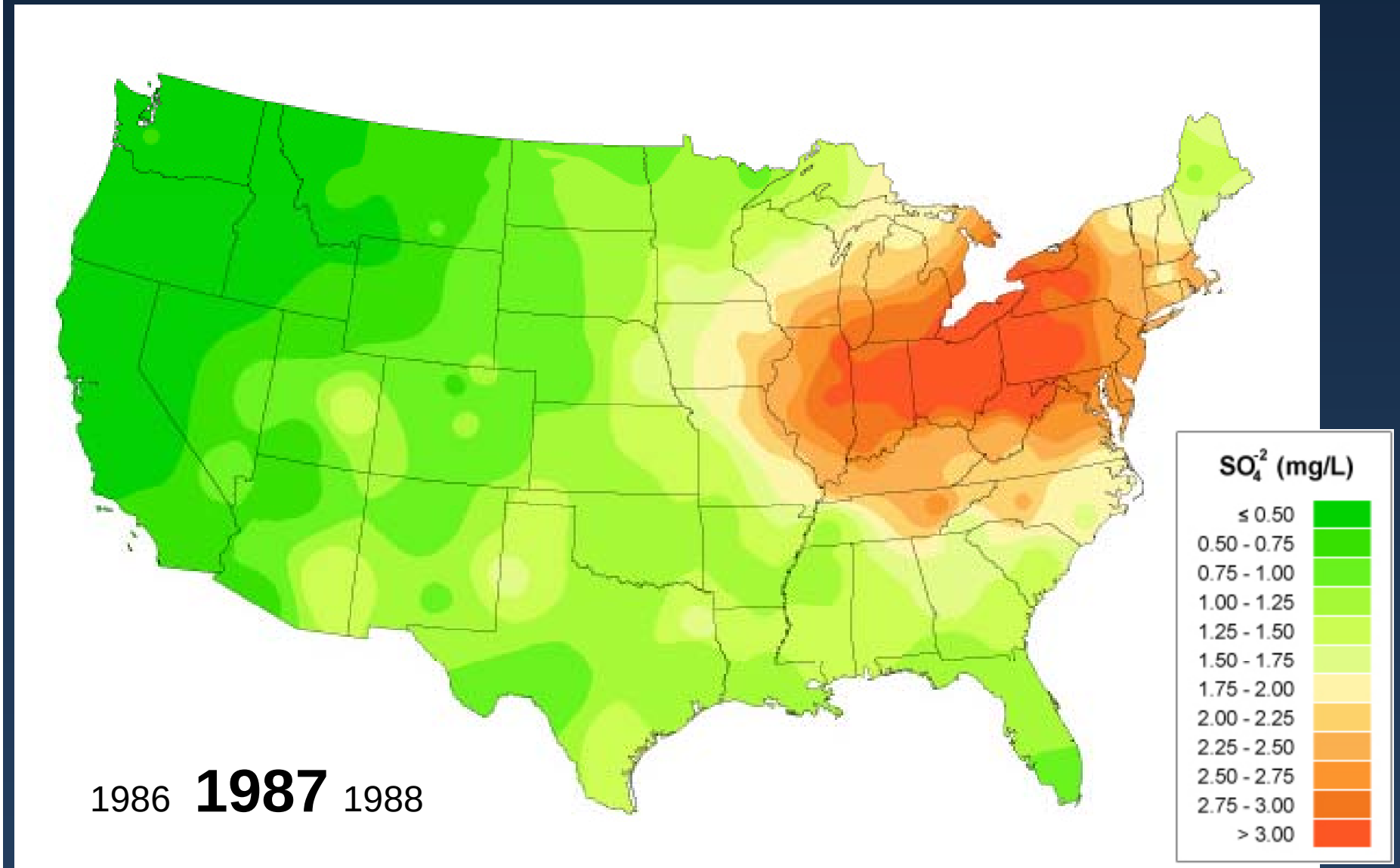
Source: National Atmospheric Deposition Program

Sulfate Ion Concentrations



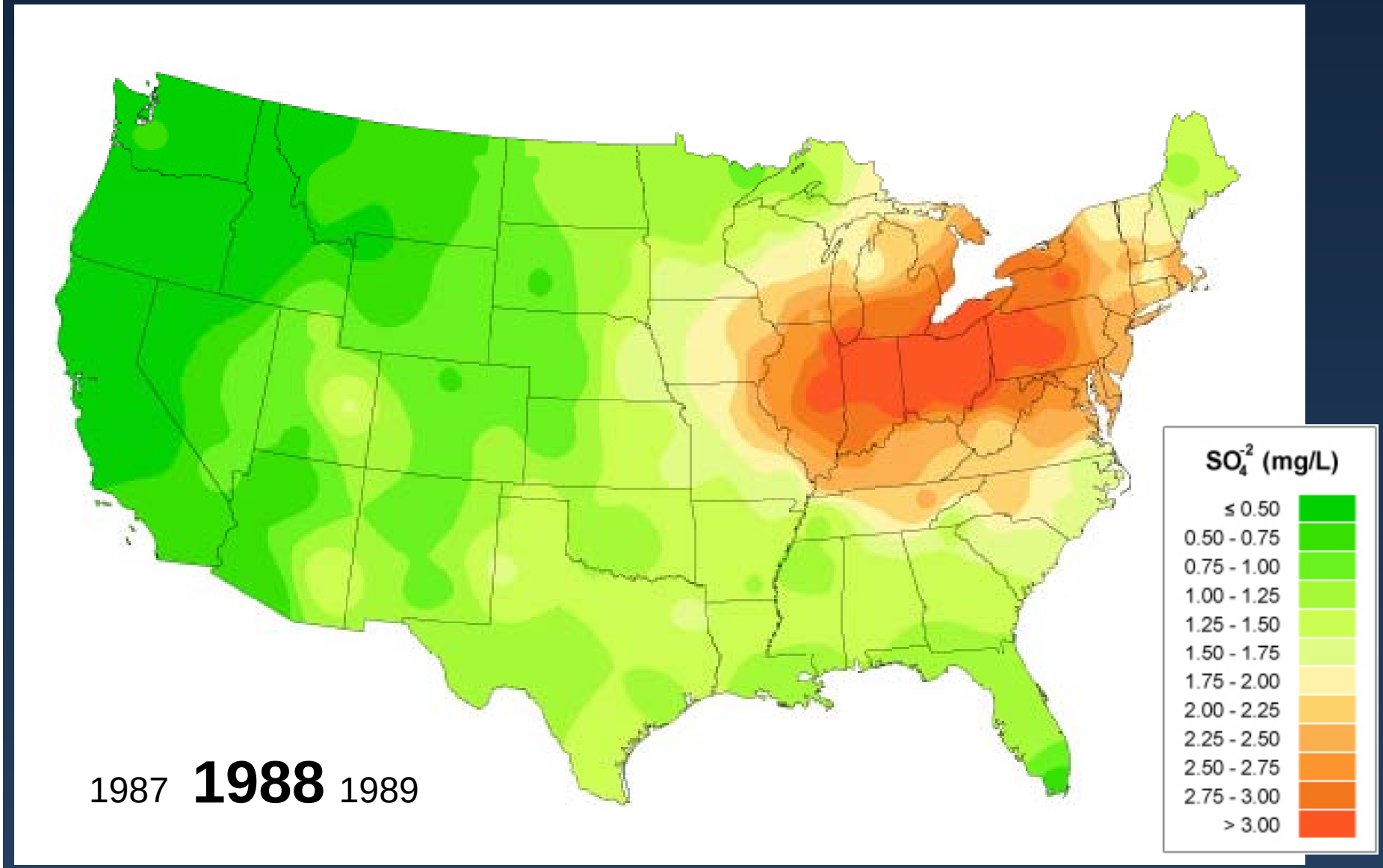
Source: National Atmospheric Deposition Program

Sulfate Ion Concentrations



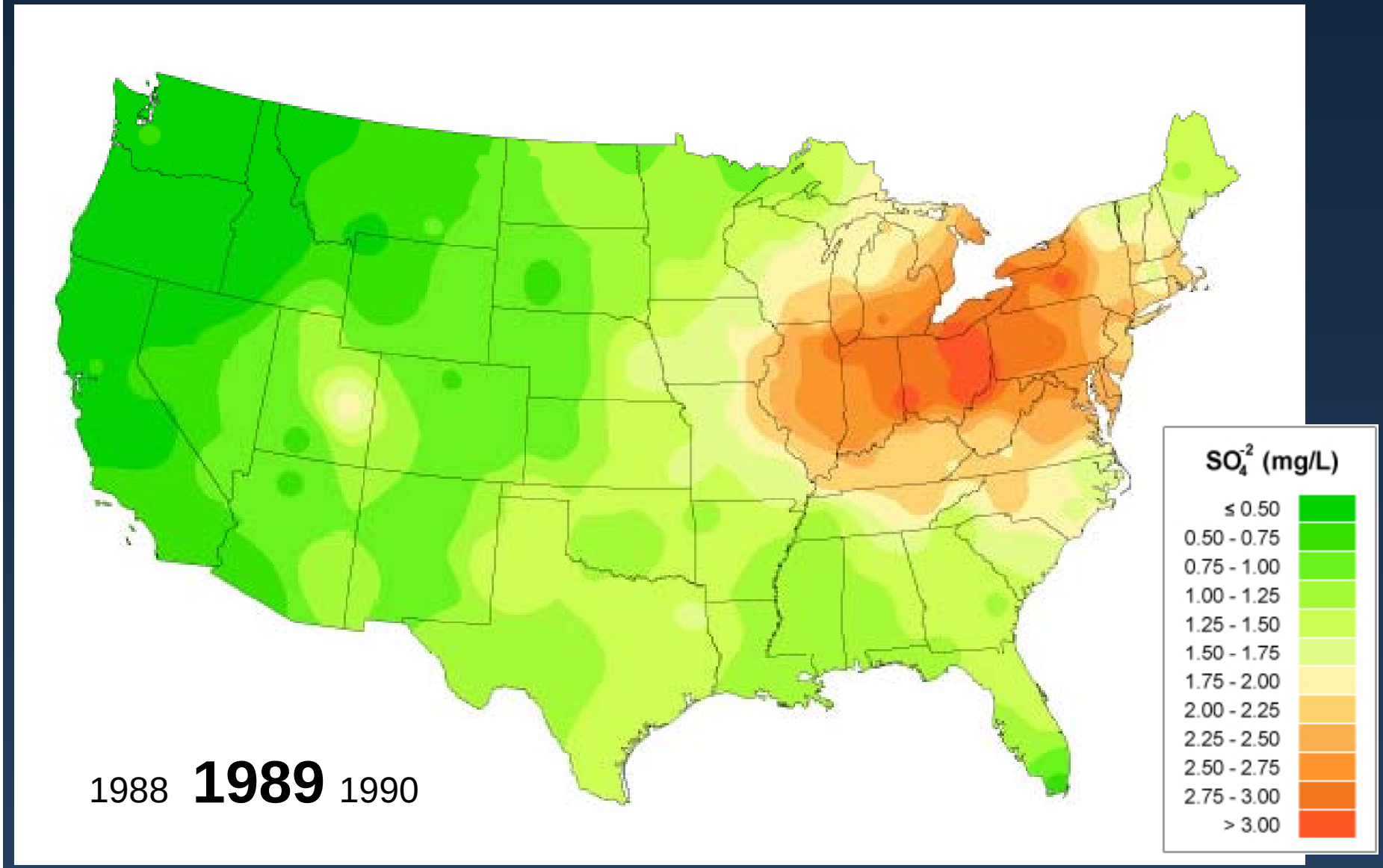
Source: National Atmospheric Deposition Program

Sulfate Ion Concentrations



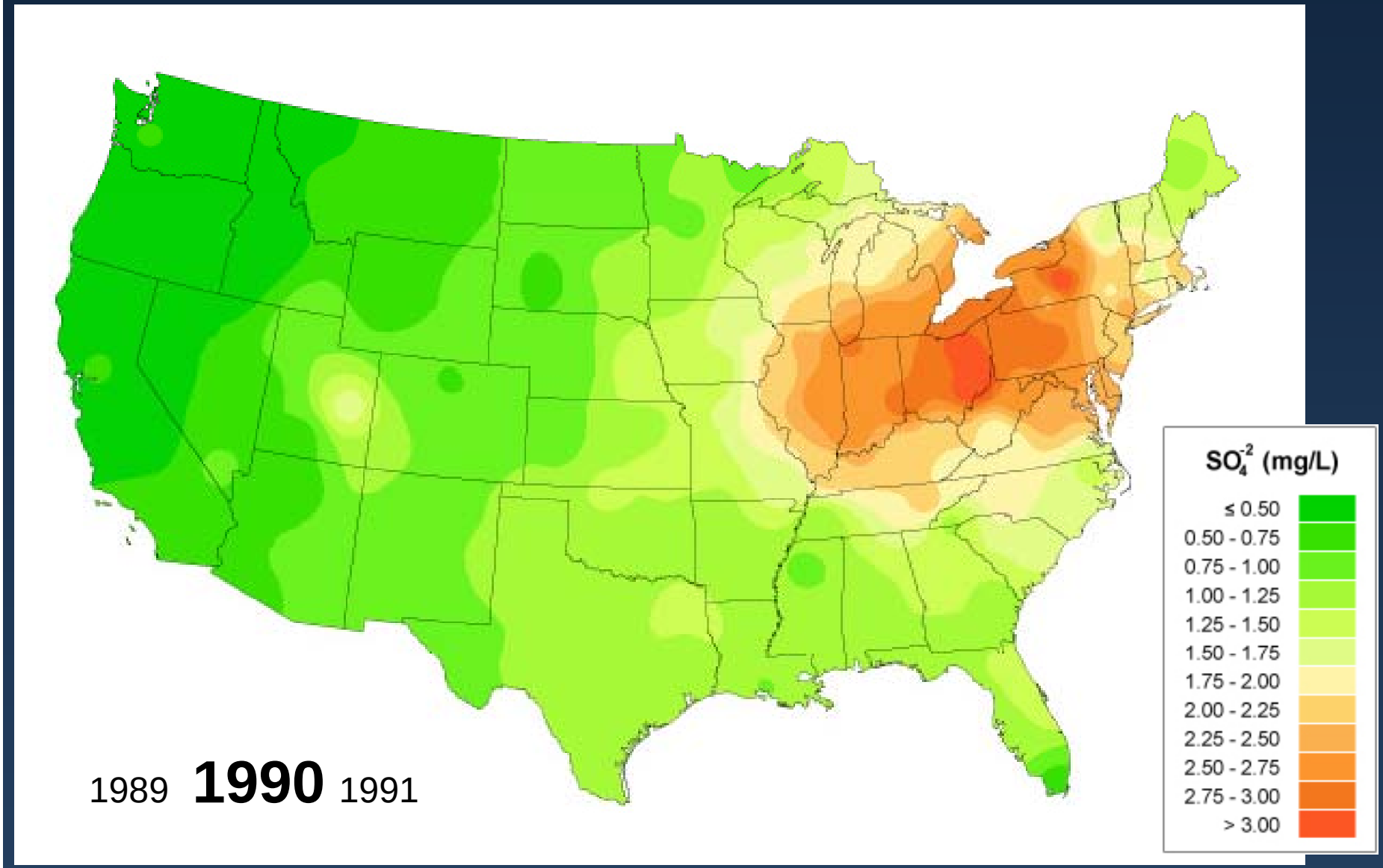
Source: National Atmospheric Deposition Program

Sulfate Ion Concentrations



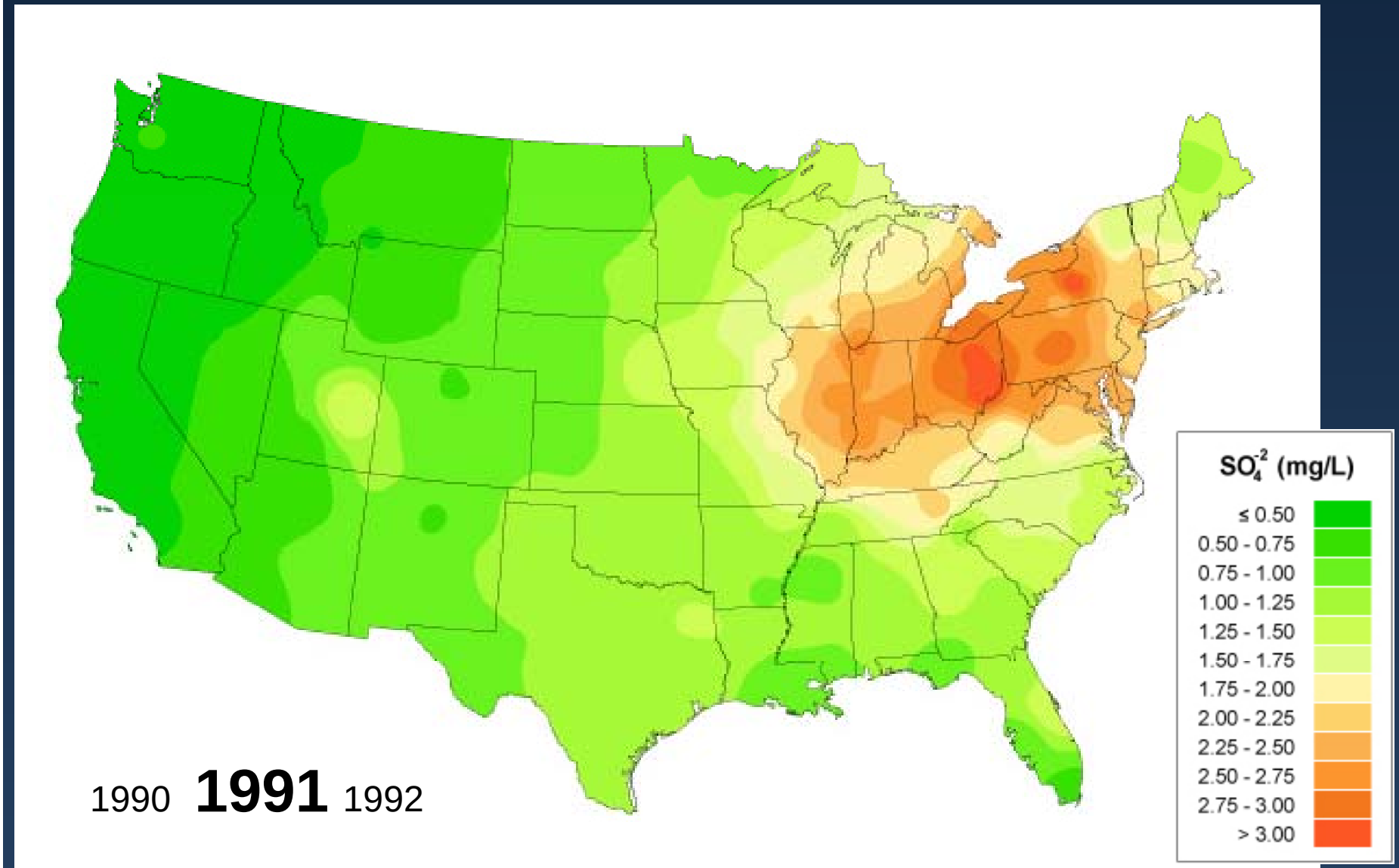
Source: National Atmospheric Deposition Program

Sulfate Ion Concentrations



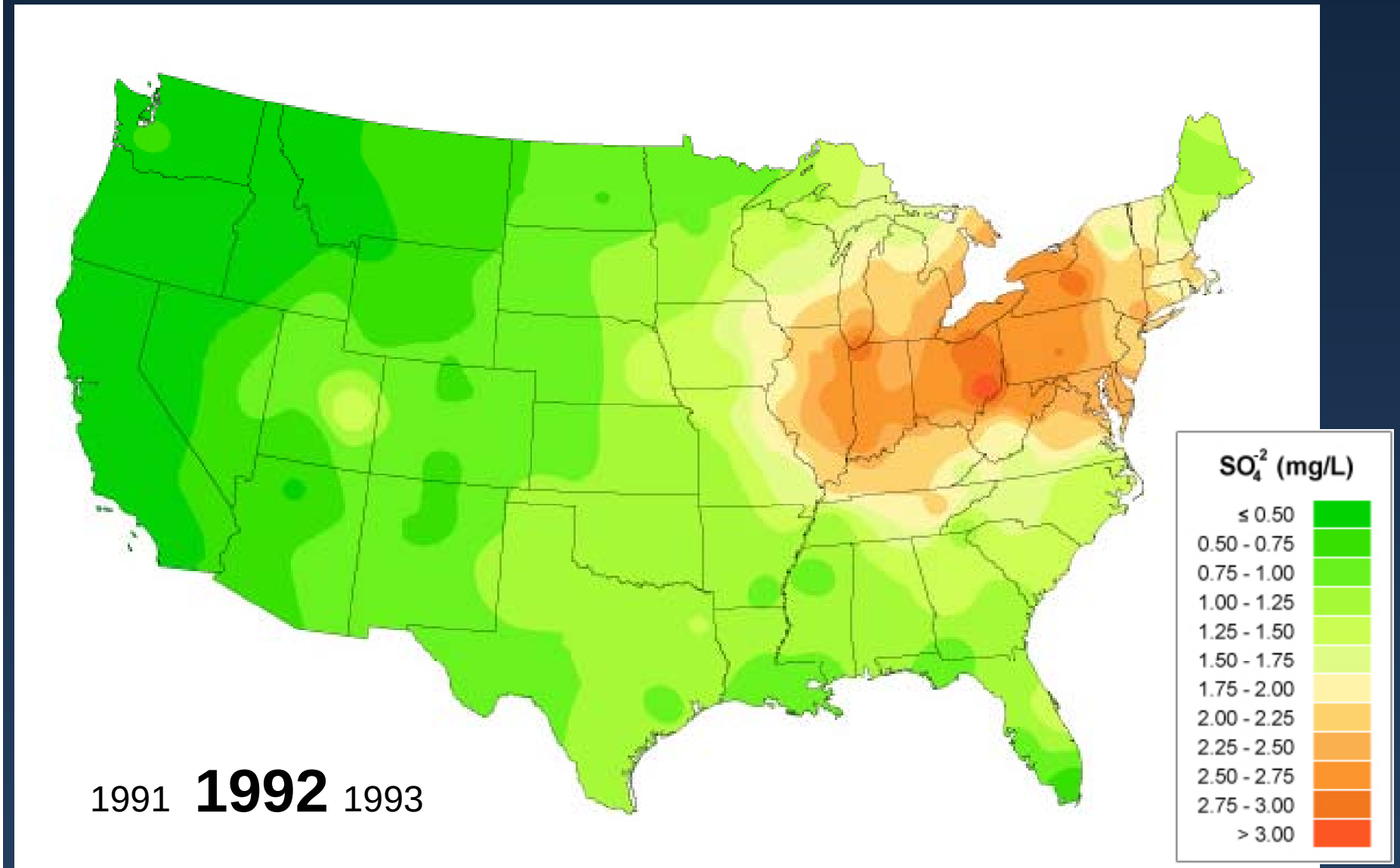
Source: National Atmospheric Deposition Program

Sulfate Ion Concentrations



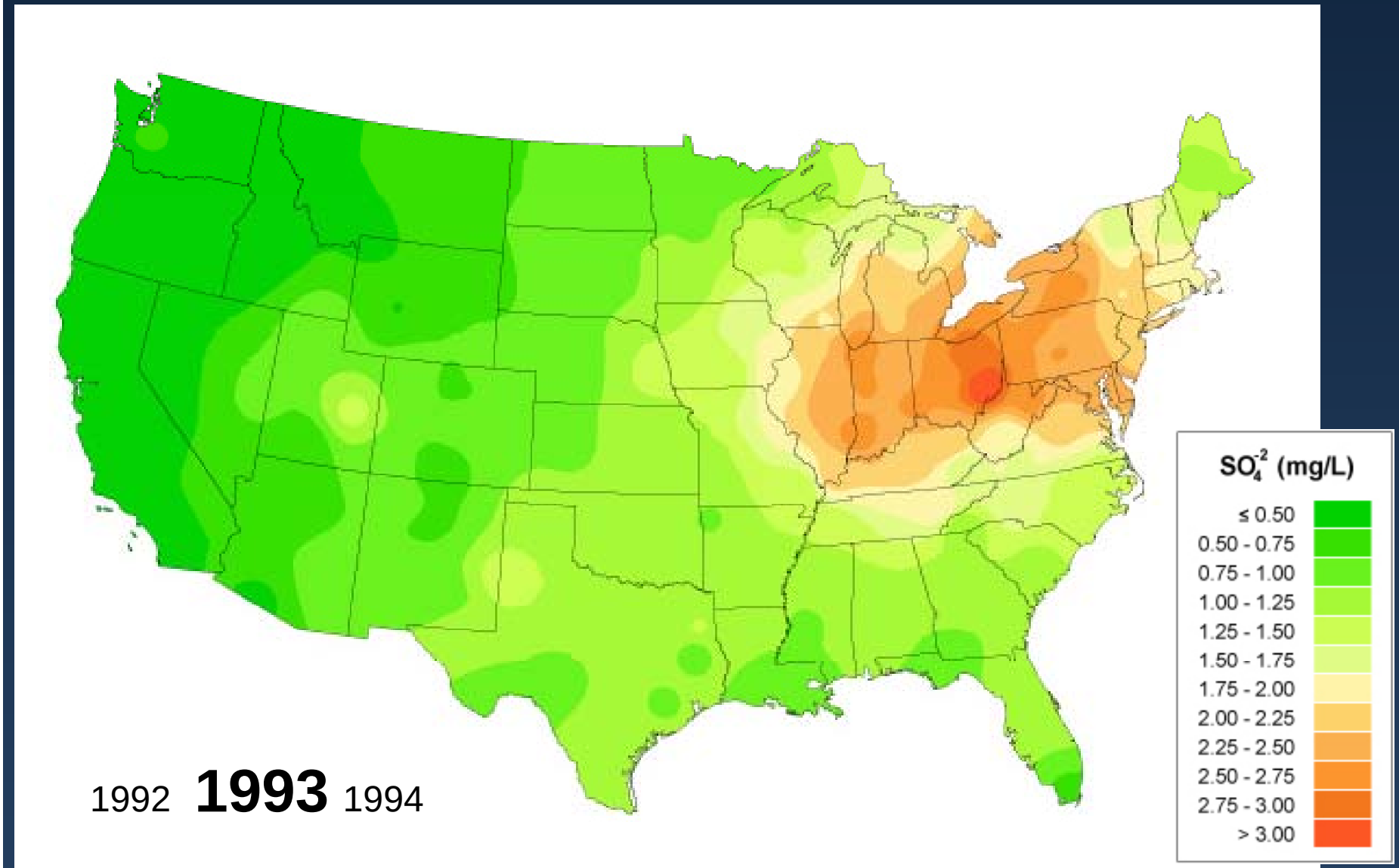
Source: National Atmospheric Deposition Program

Sulfate Ion Concentrations



Source: National Atmospheric Deposition Program

Sulfate Ion Concentrations



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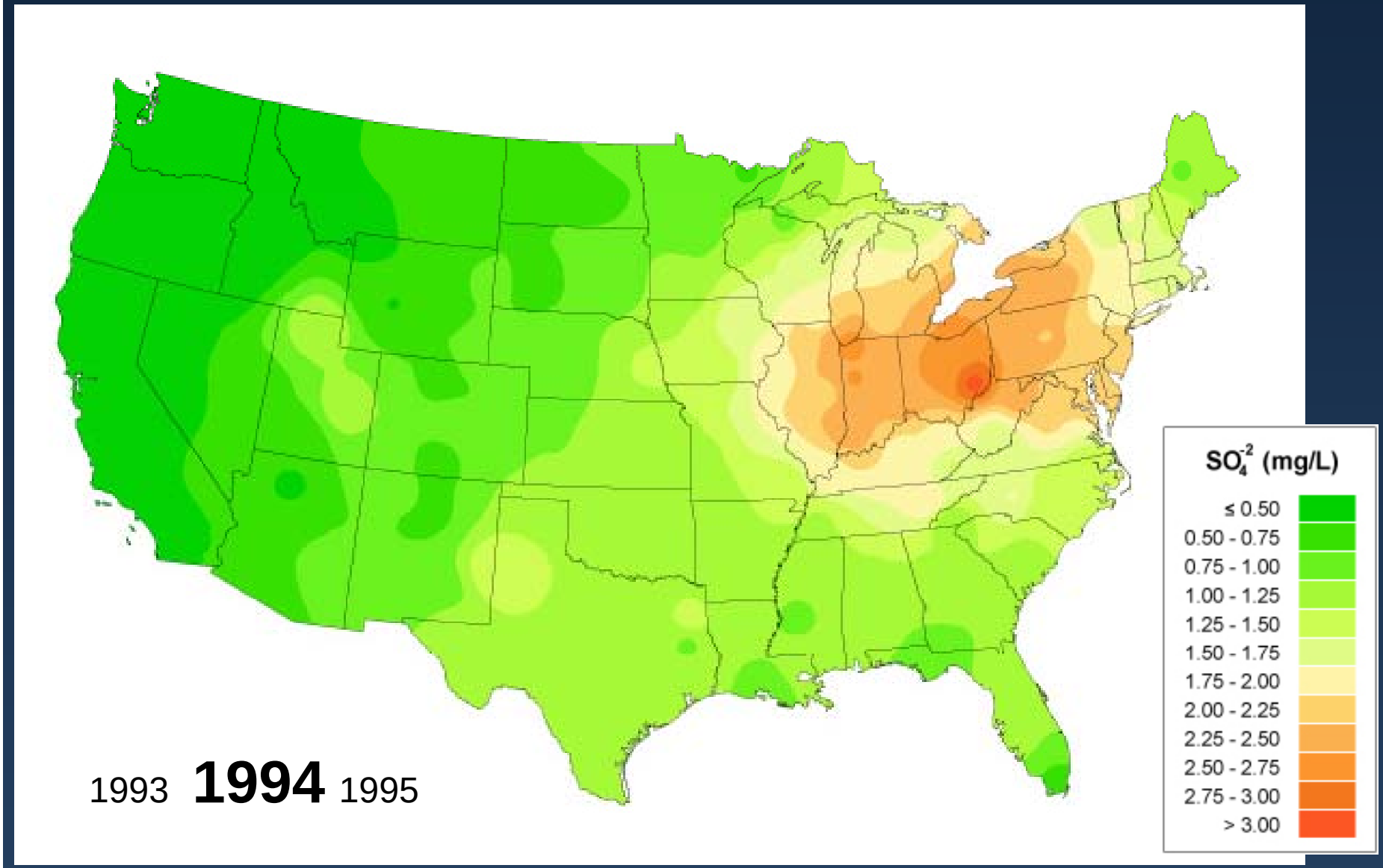
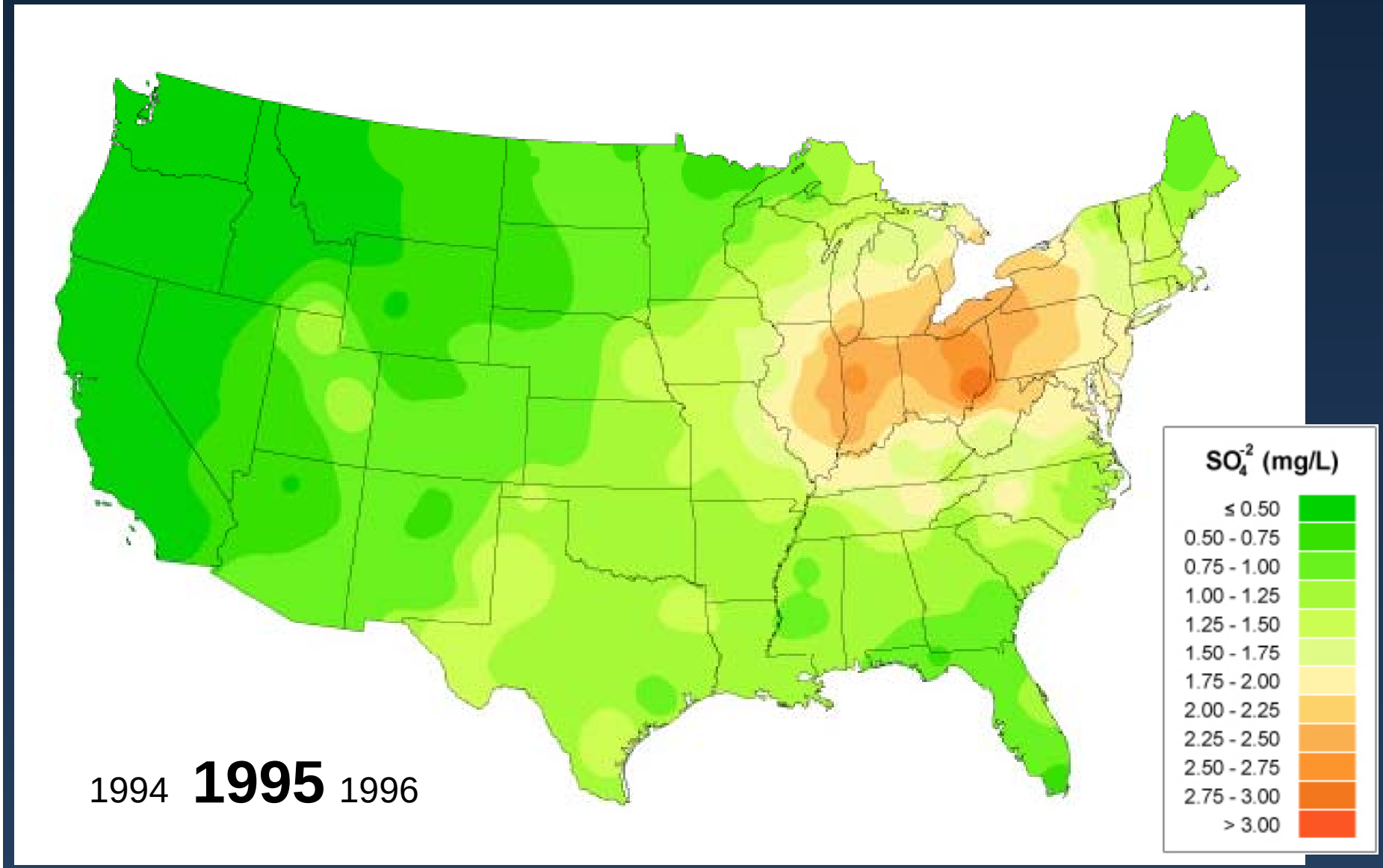
Sulfate Ion Concentrations



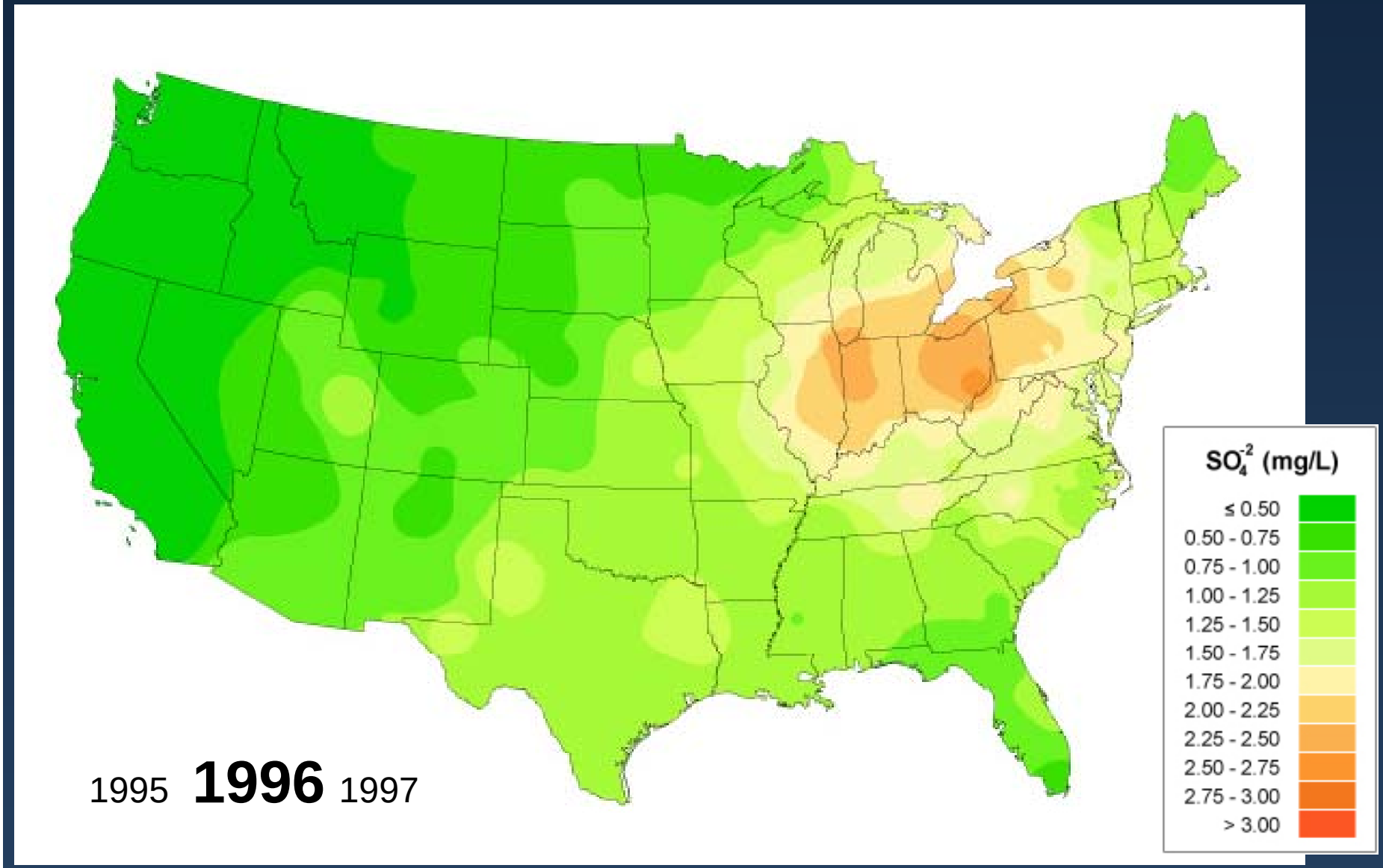
Source: National Atmospheric Deposition Program

Sulfate Ion Concentrations



Source: National Atmospheric Deposition Program

Sulfate Ion Concentrations



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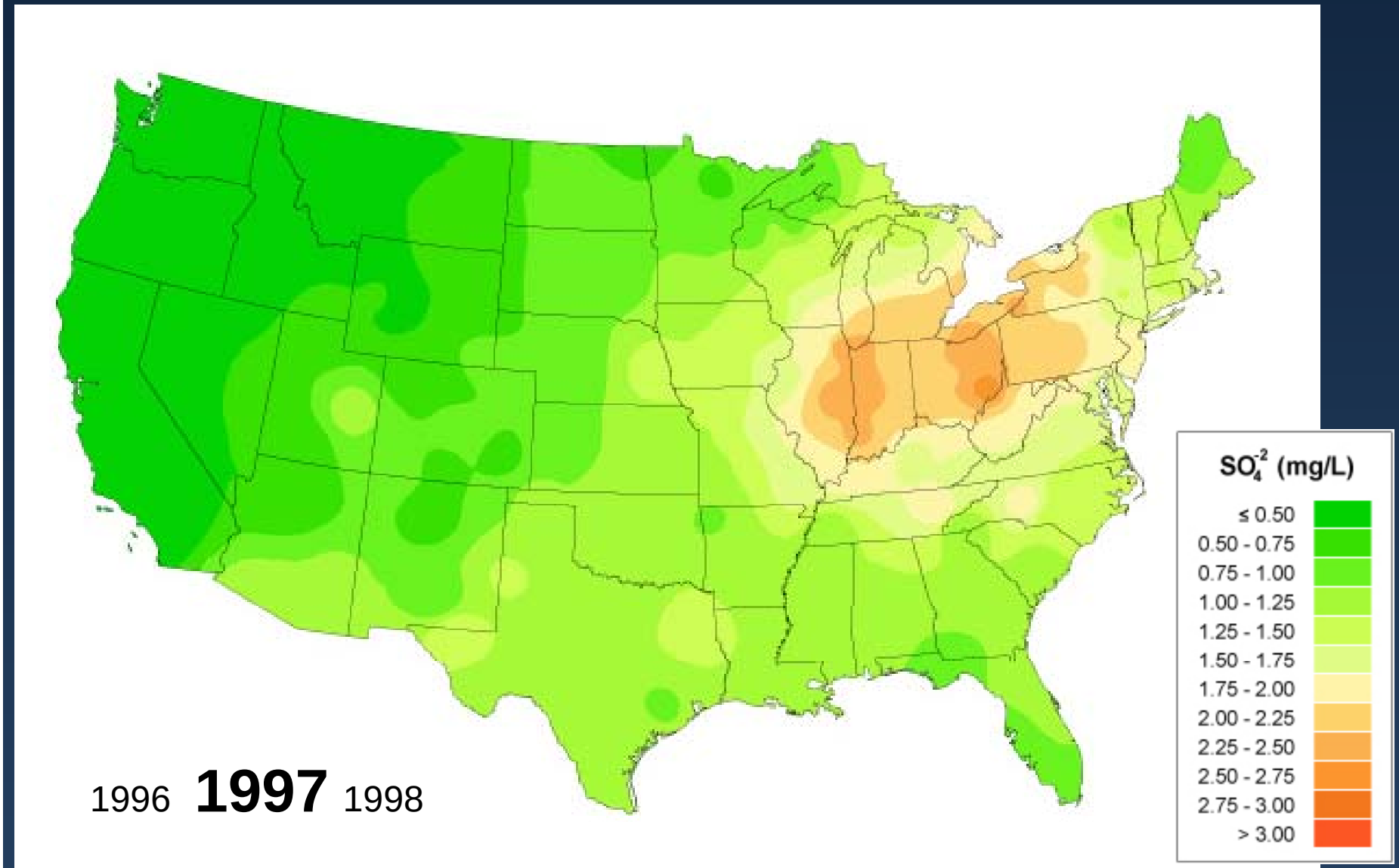

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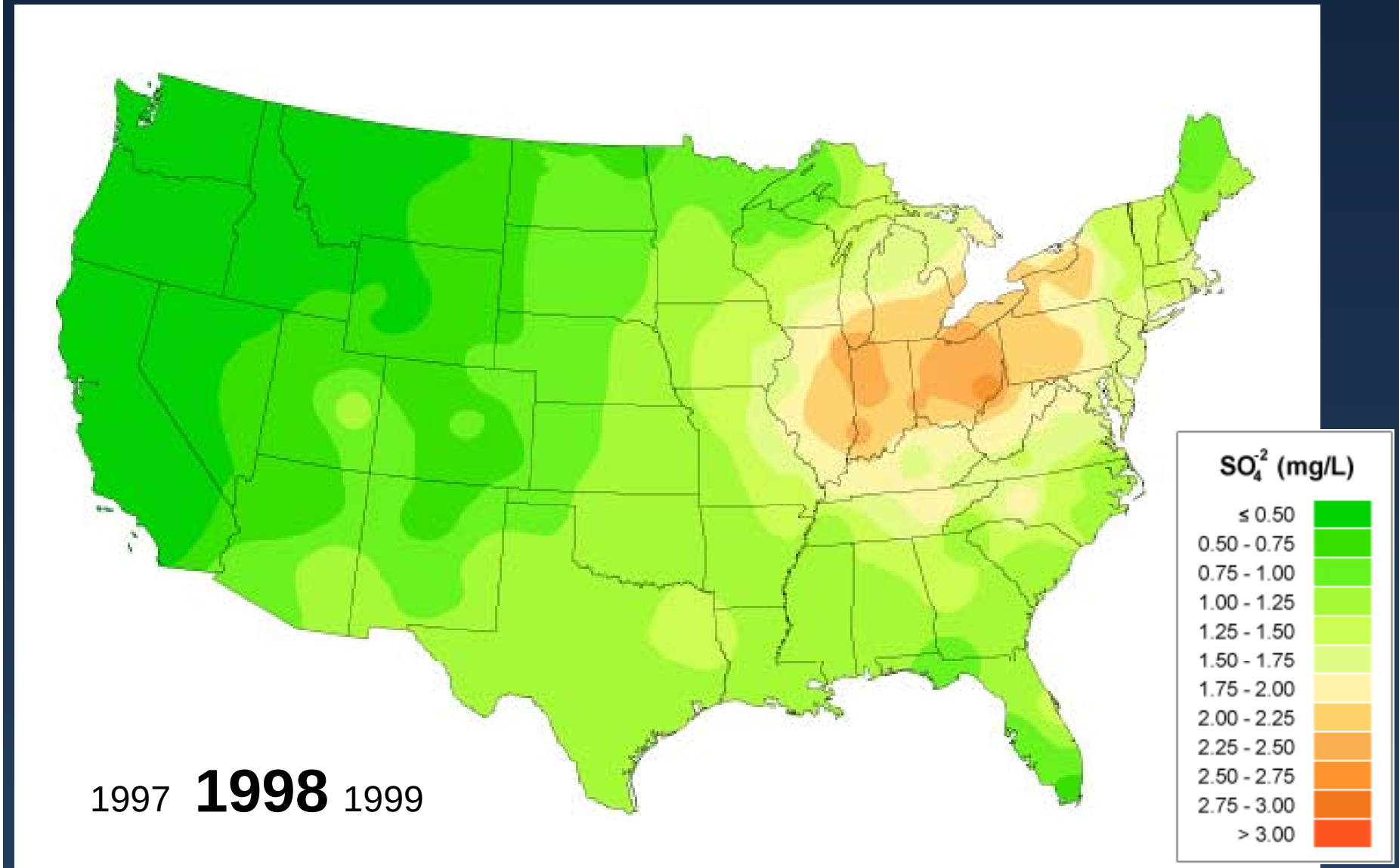
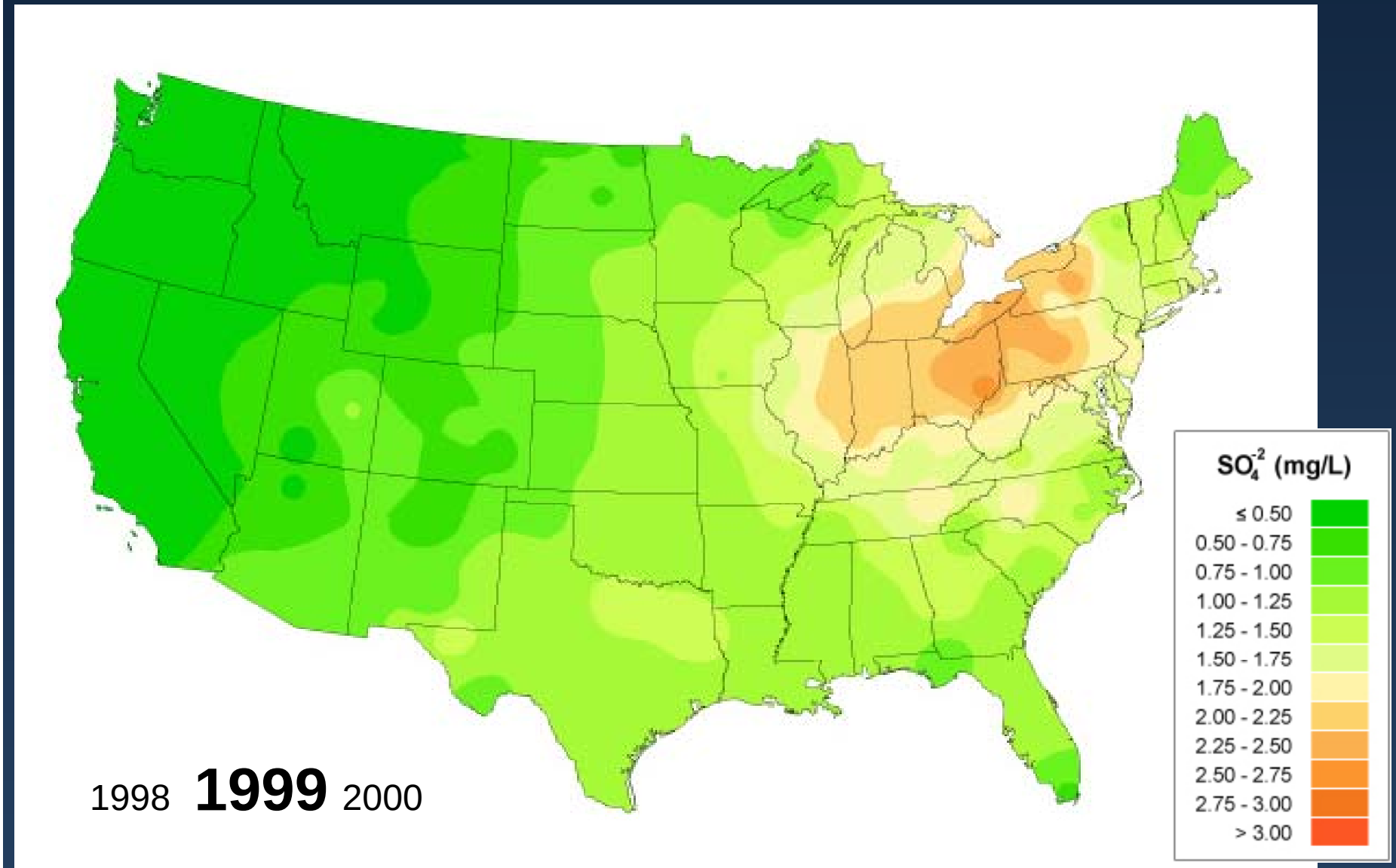
Sulfate Ion Concentrations



Source: National Atmospheric Deposition Program

Sulfate Ion Concentrations



Source: National Atmospheric Deposition Program

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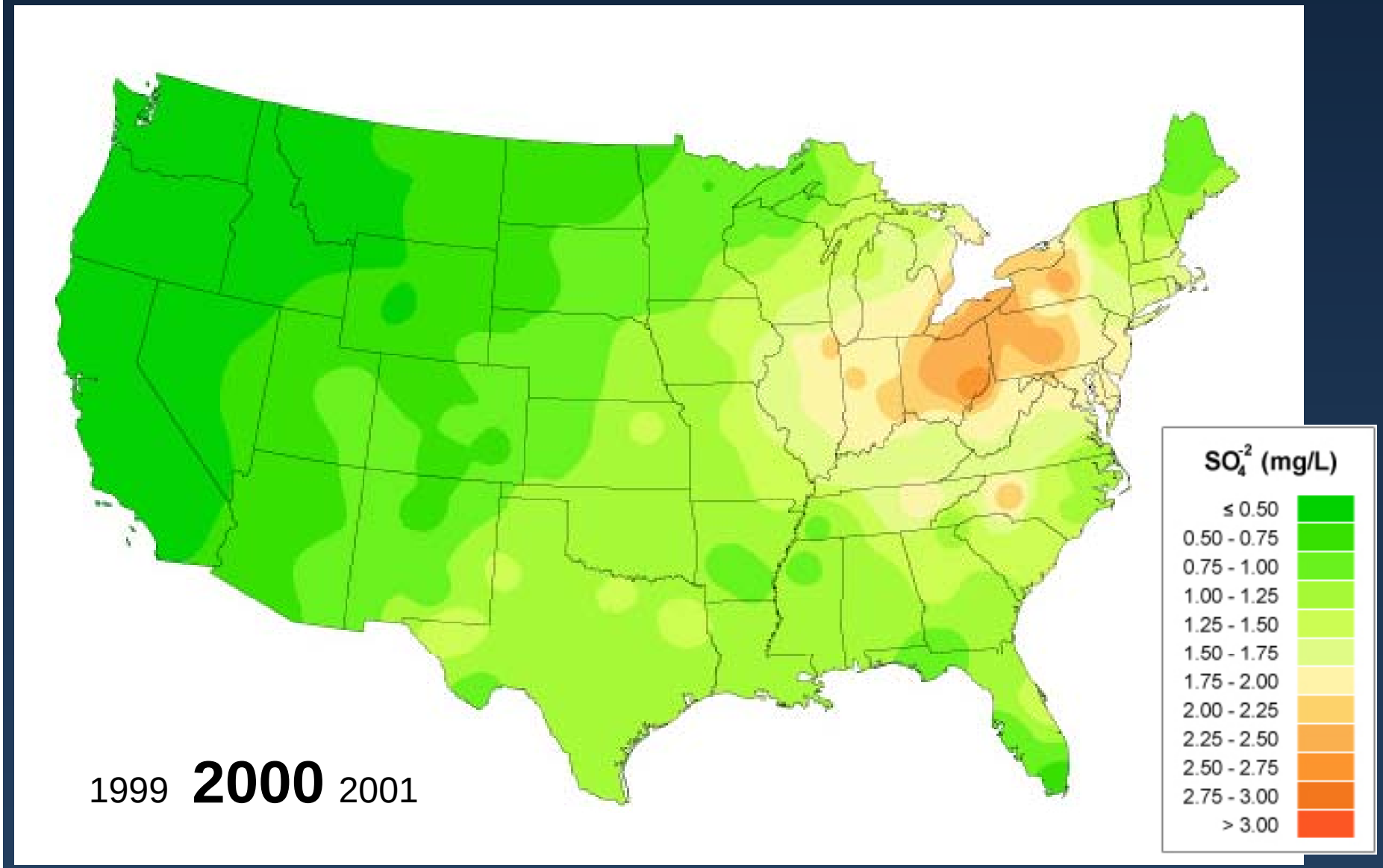
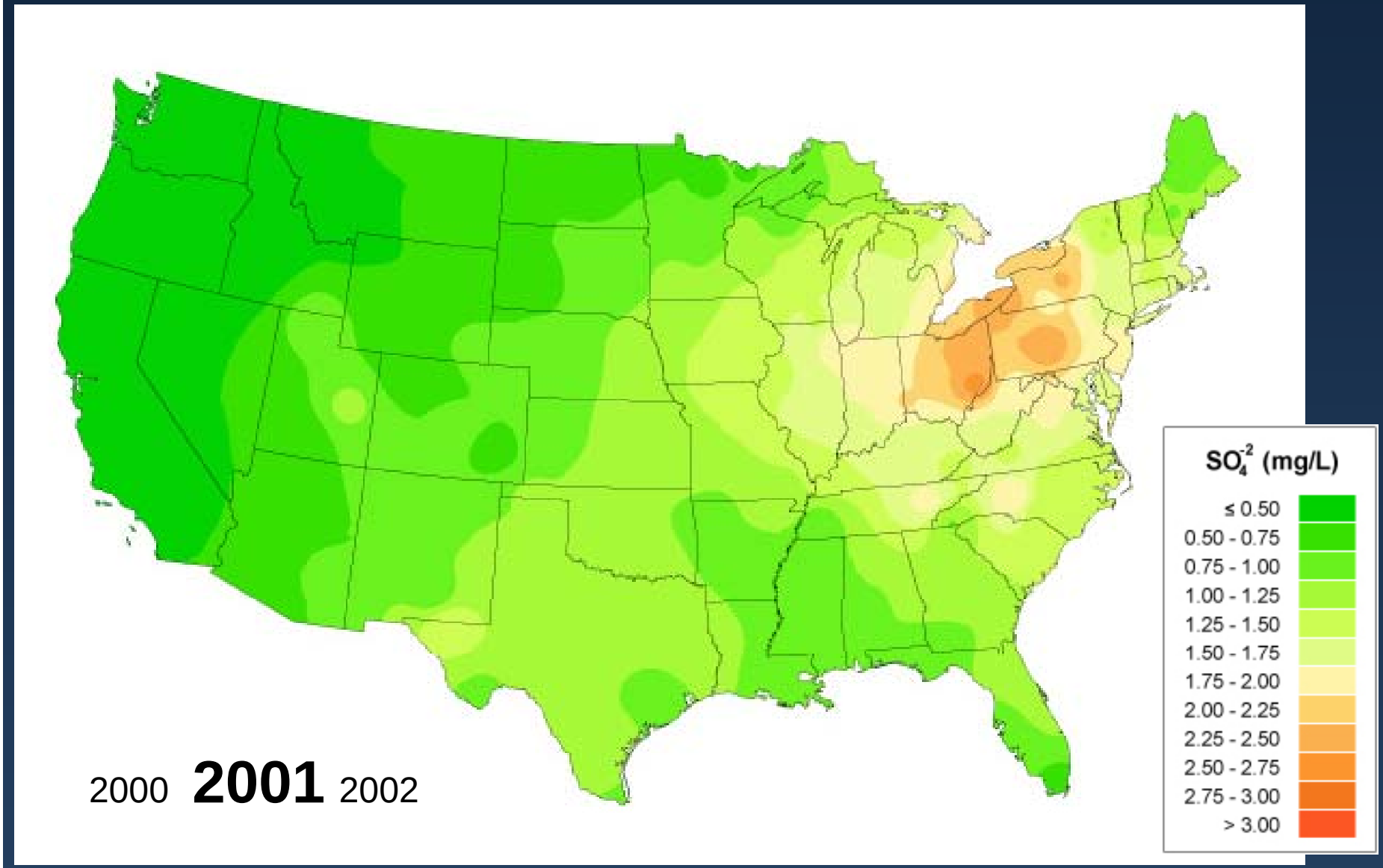


Source: National Atmospheric Deposition Program

Sulfate Ion Concentrations



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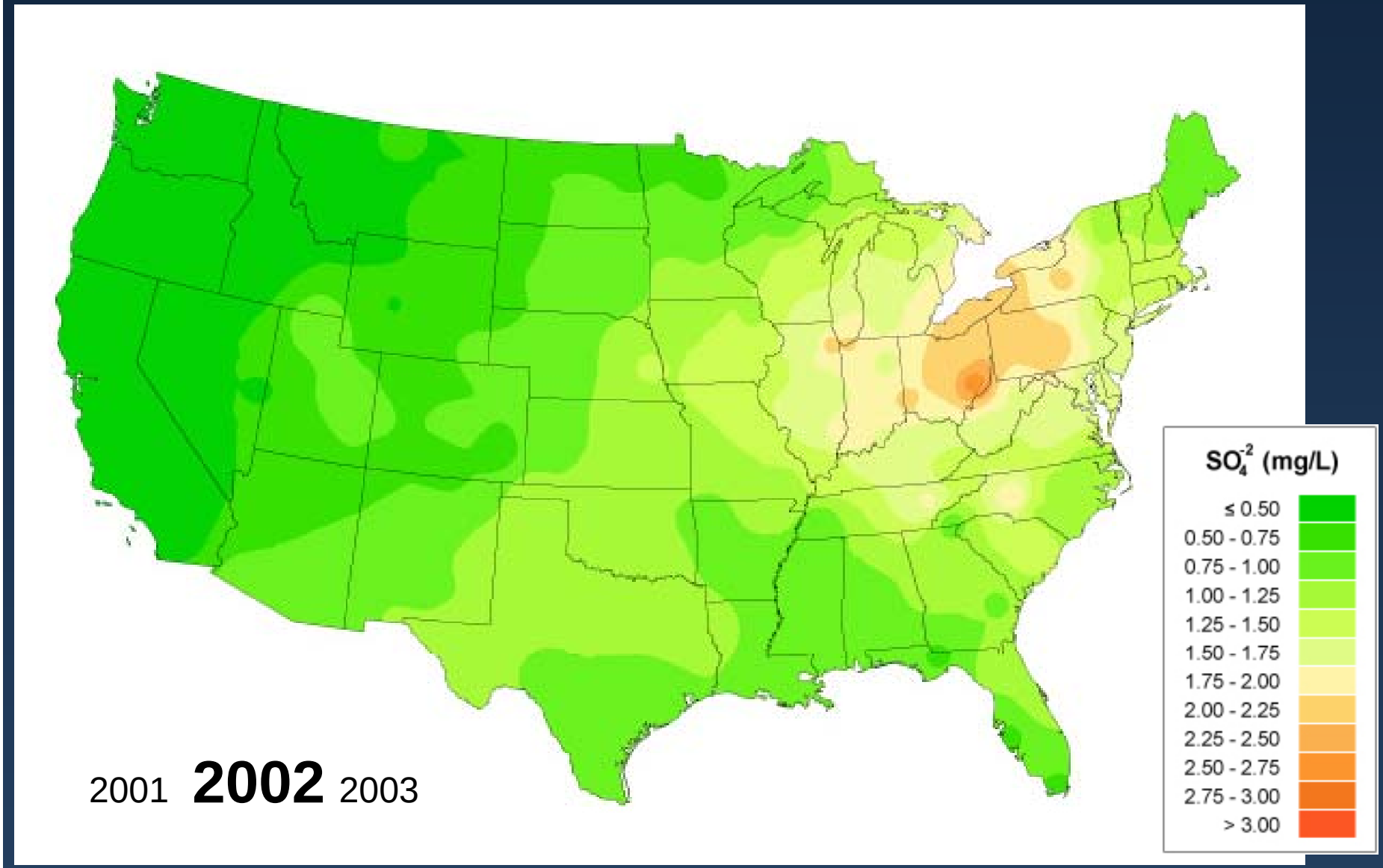

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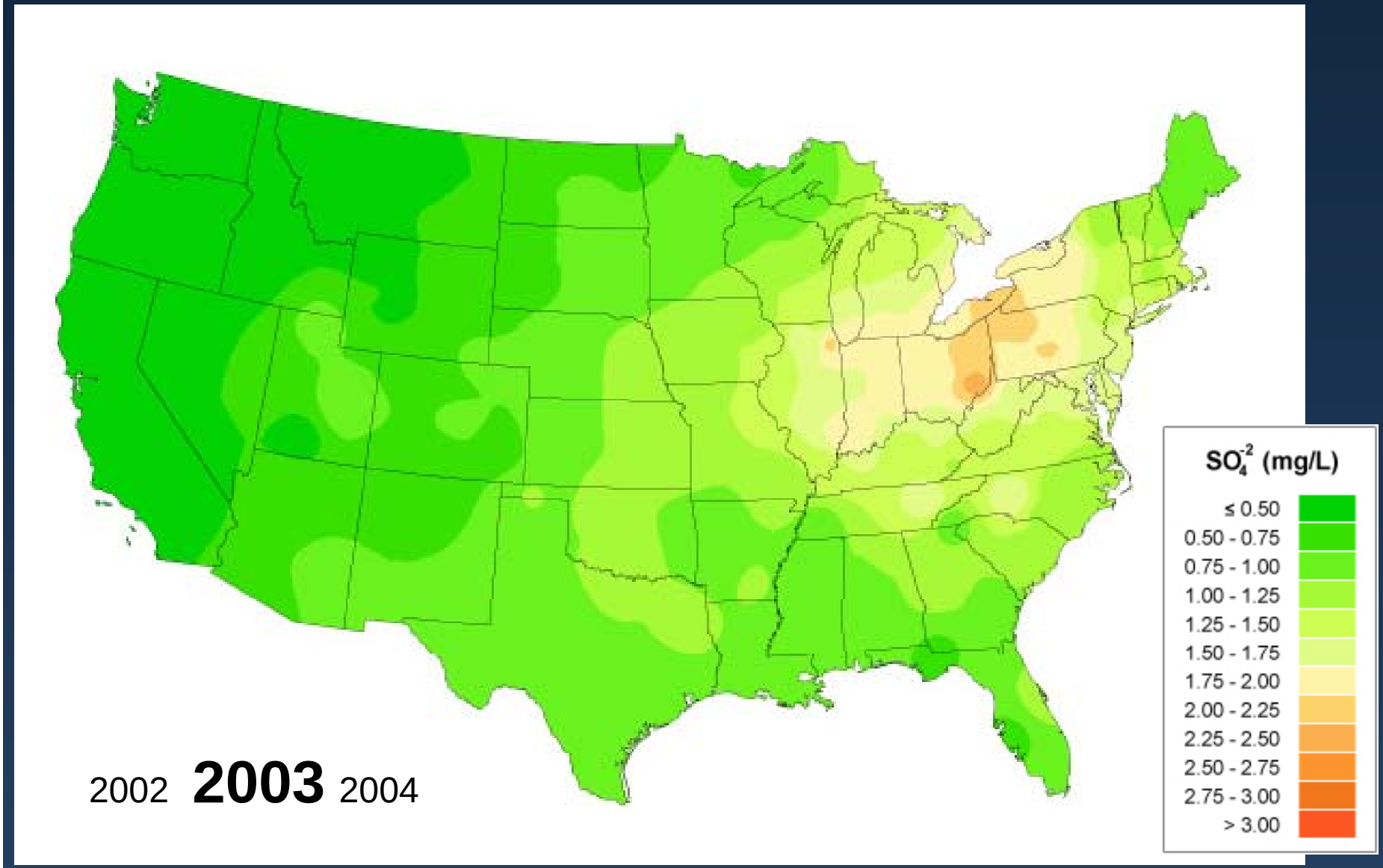
Sulfate Ion Concentrations



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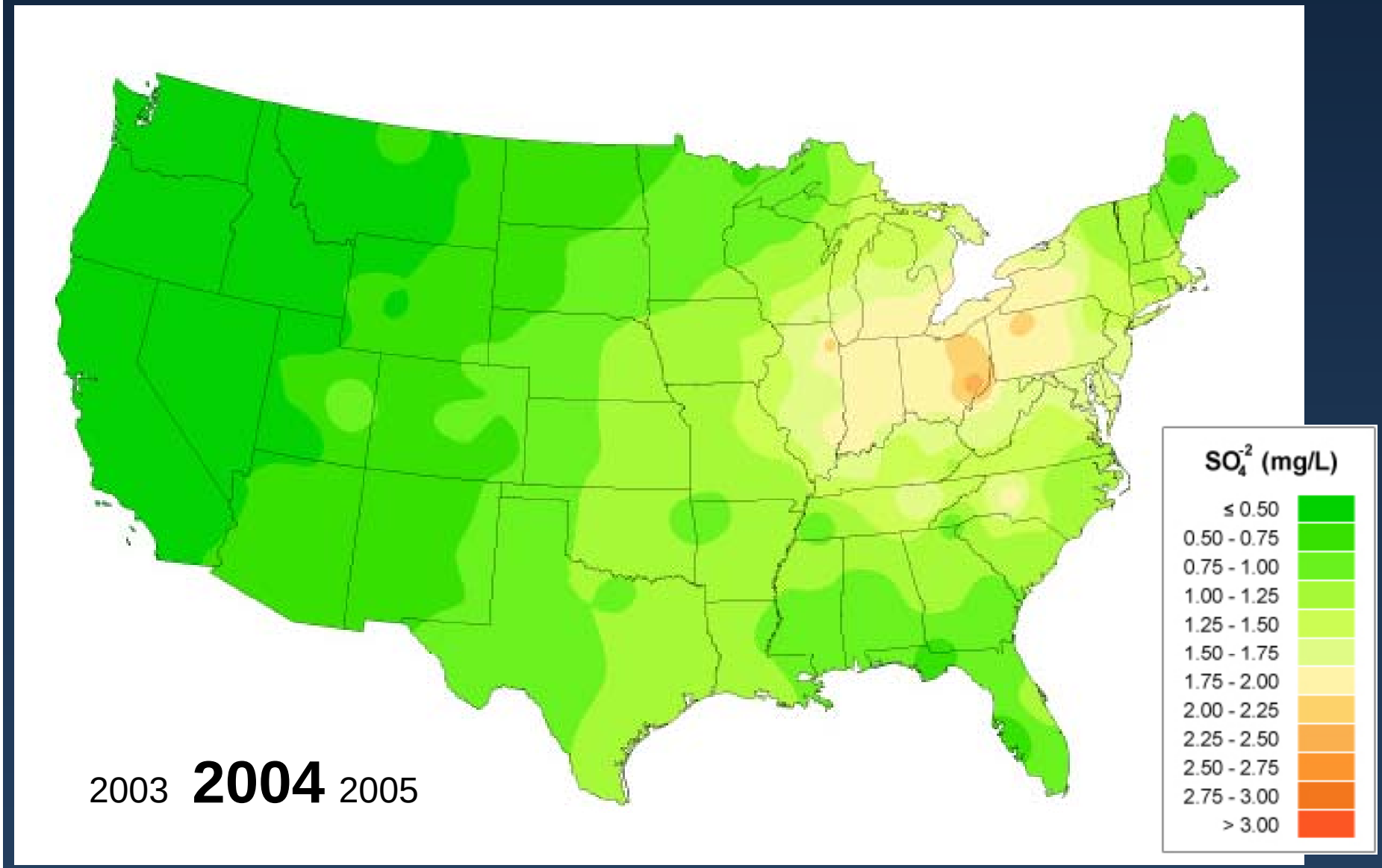
Sulfate Ion Concentrations



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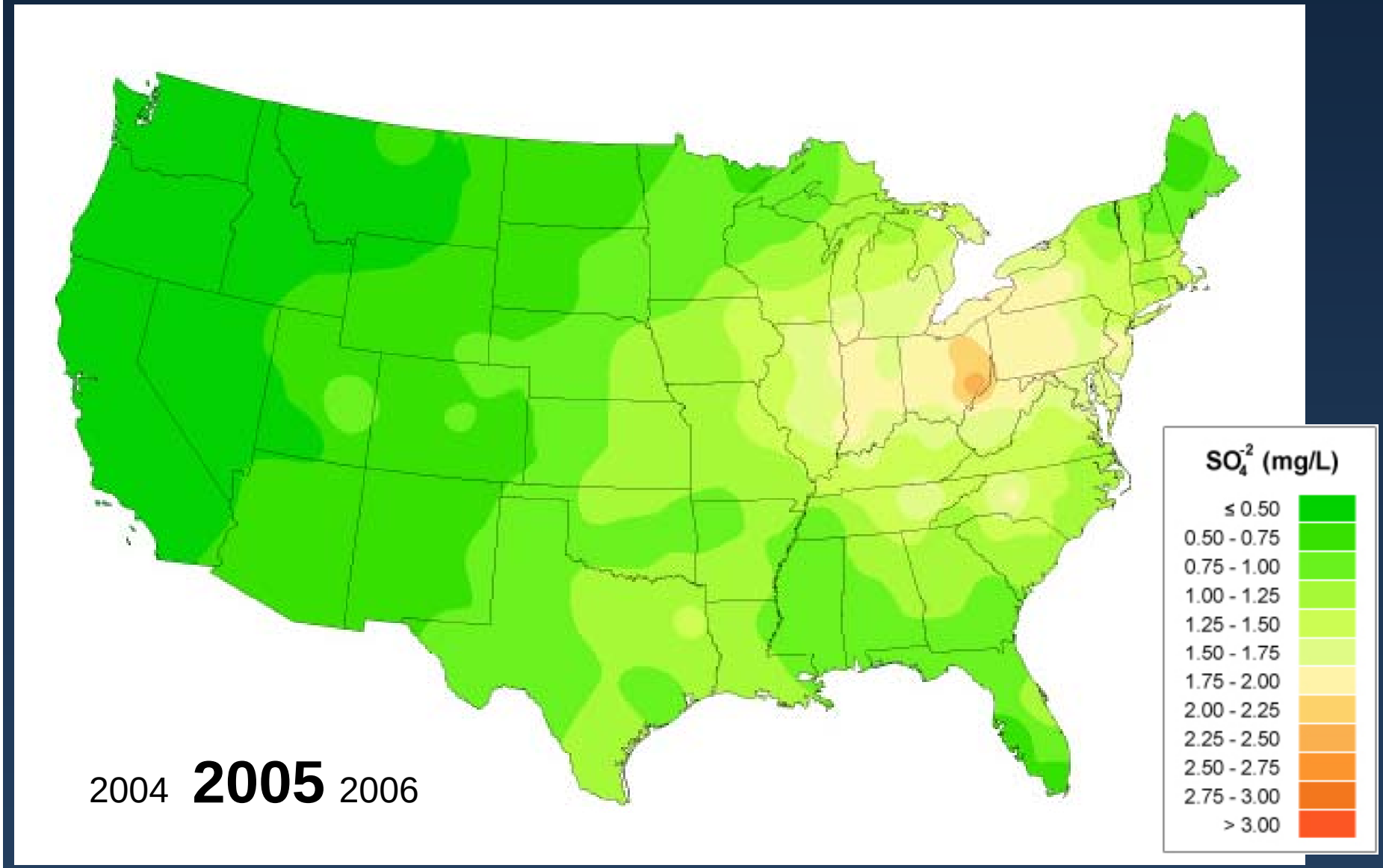
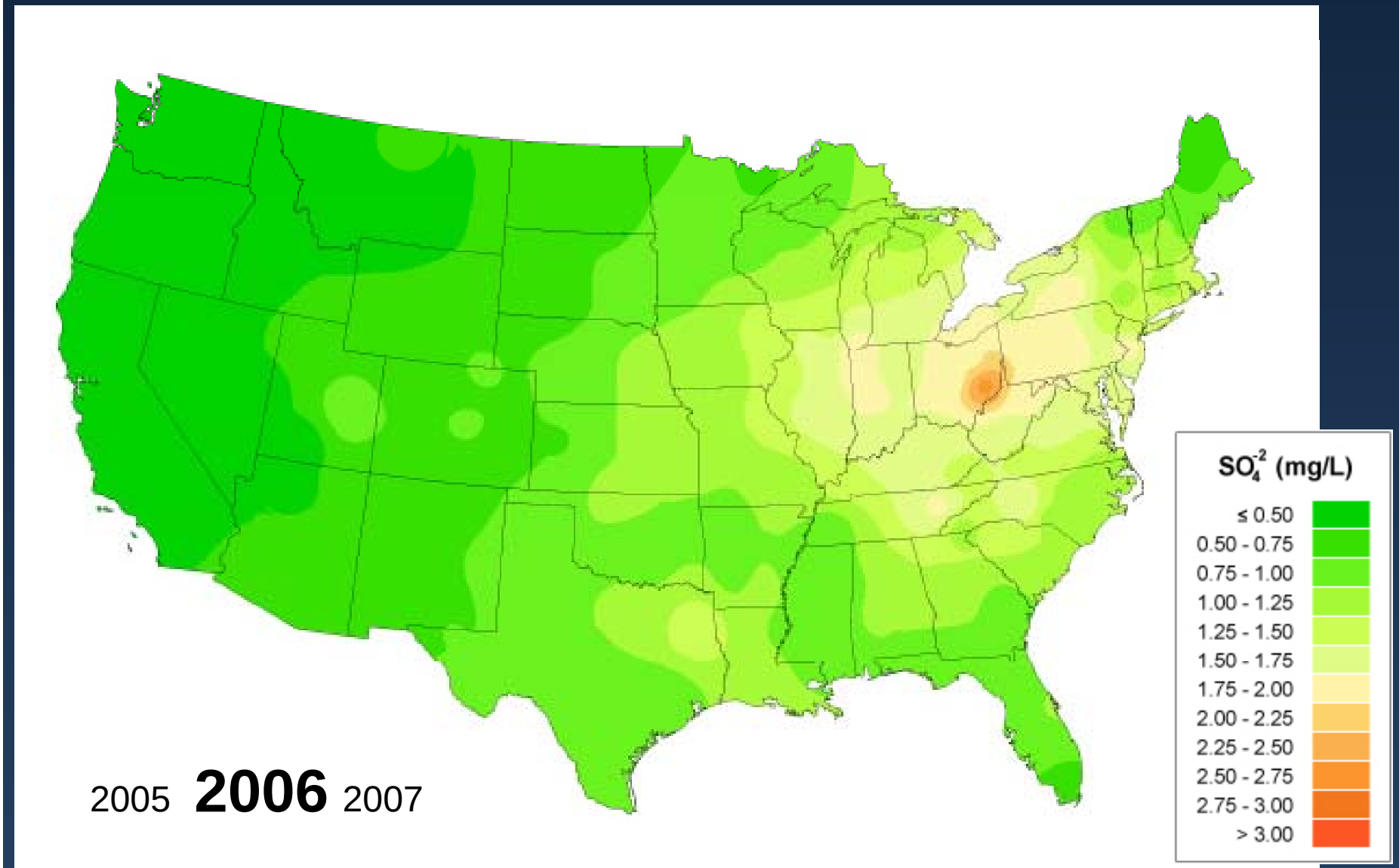
Sulfate Ion Concentrations



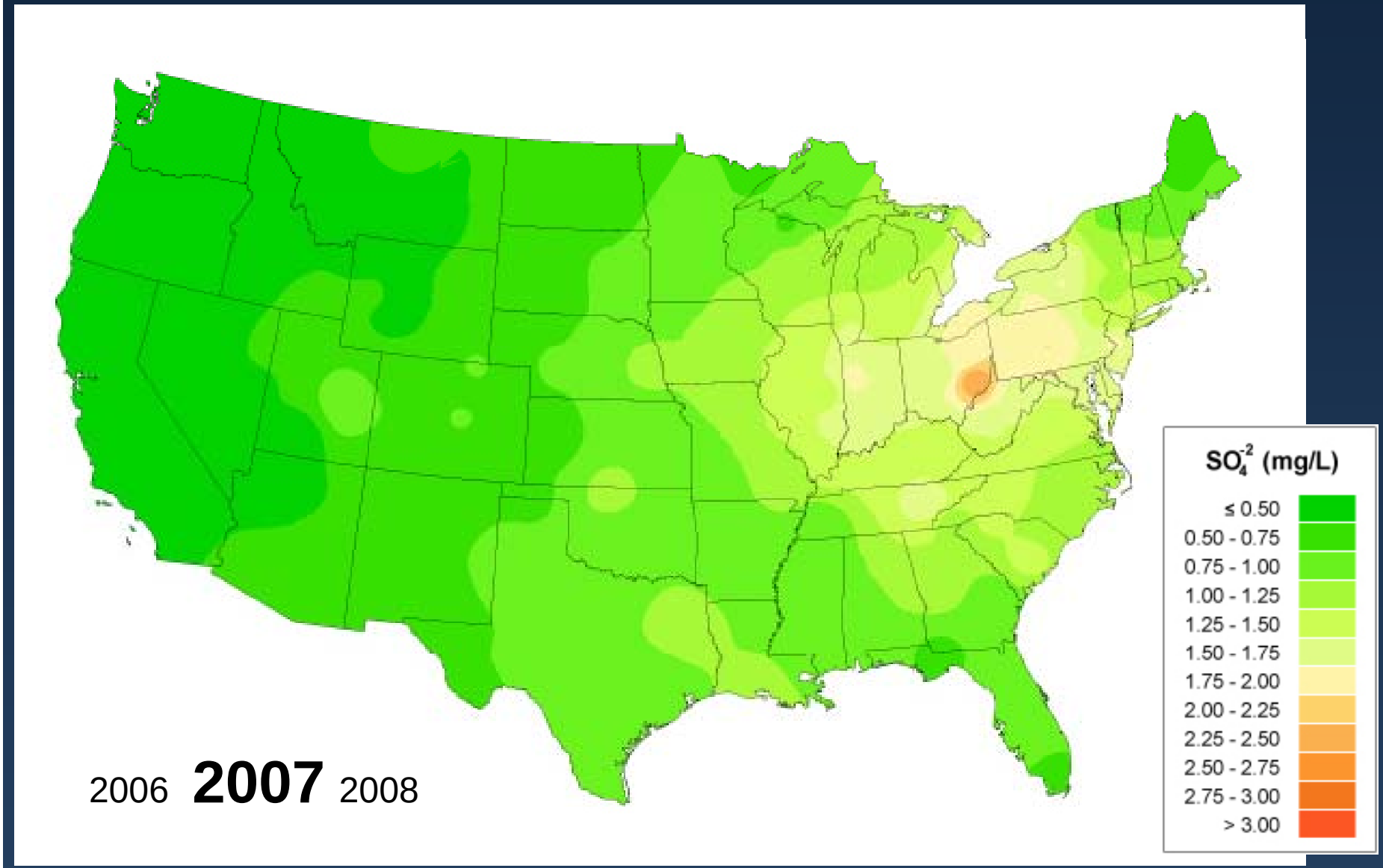
Source: National Atmospheric Deposition Program

Sulfate Ion Concentrations



Source: National Atmospheric Deposition Program

Sulfate Ion Concentrations



Source: National Atmospheric Deposition Program

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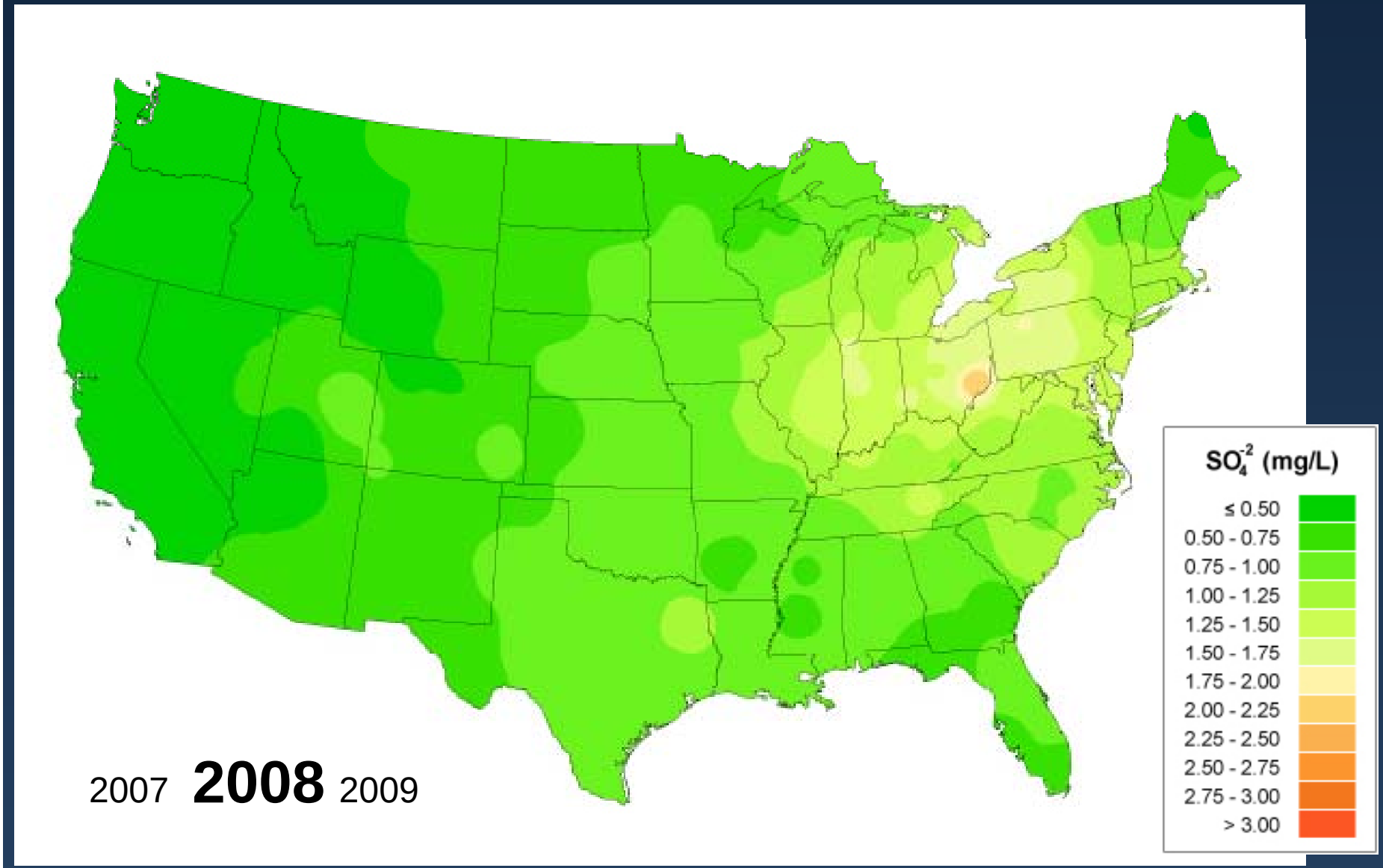
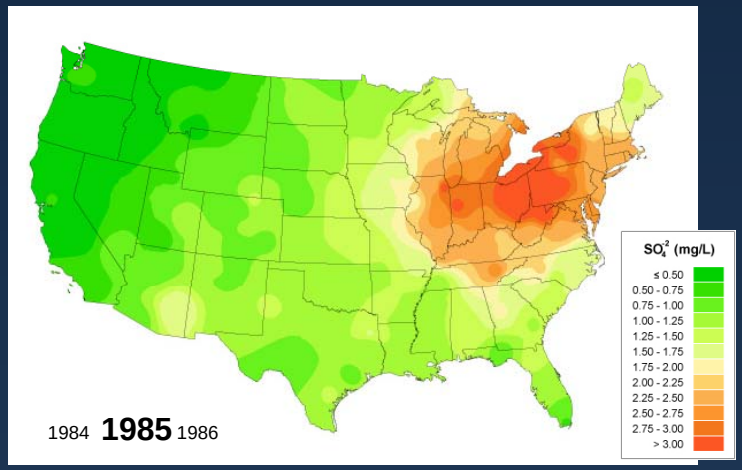


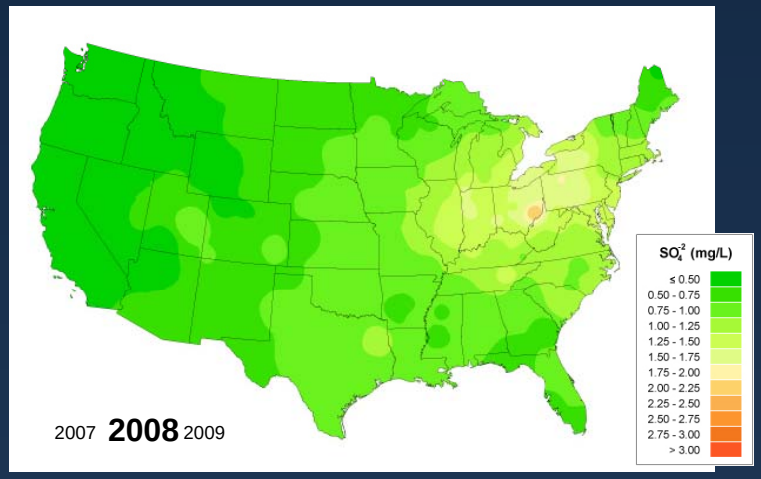
Source: National Atmospheric Deposition Program

Trends in atmospheric deposition

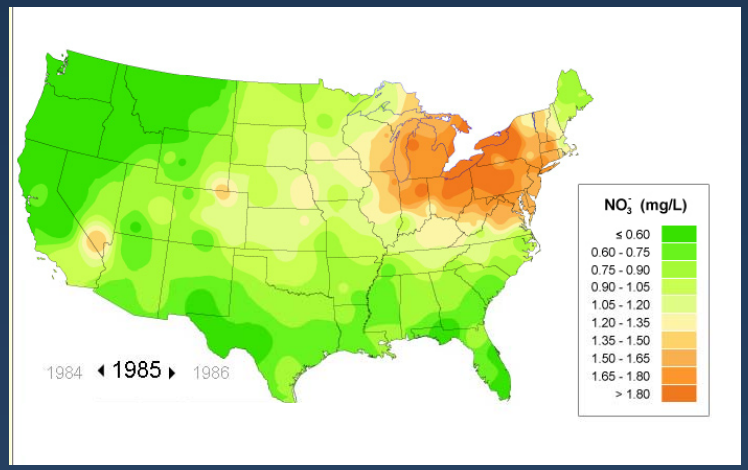
Source: National Atmospheric Deposition Program

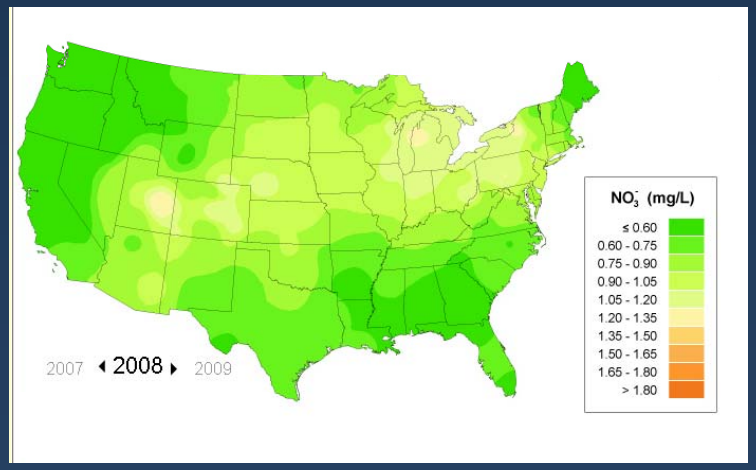
Sulfate Ion Concentration



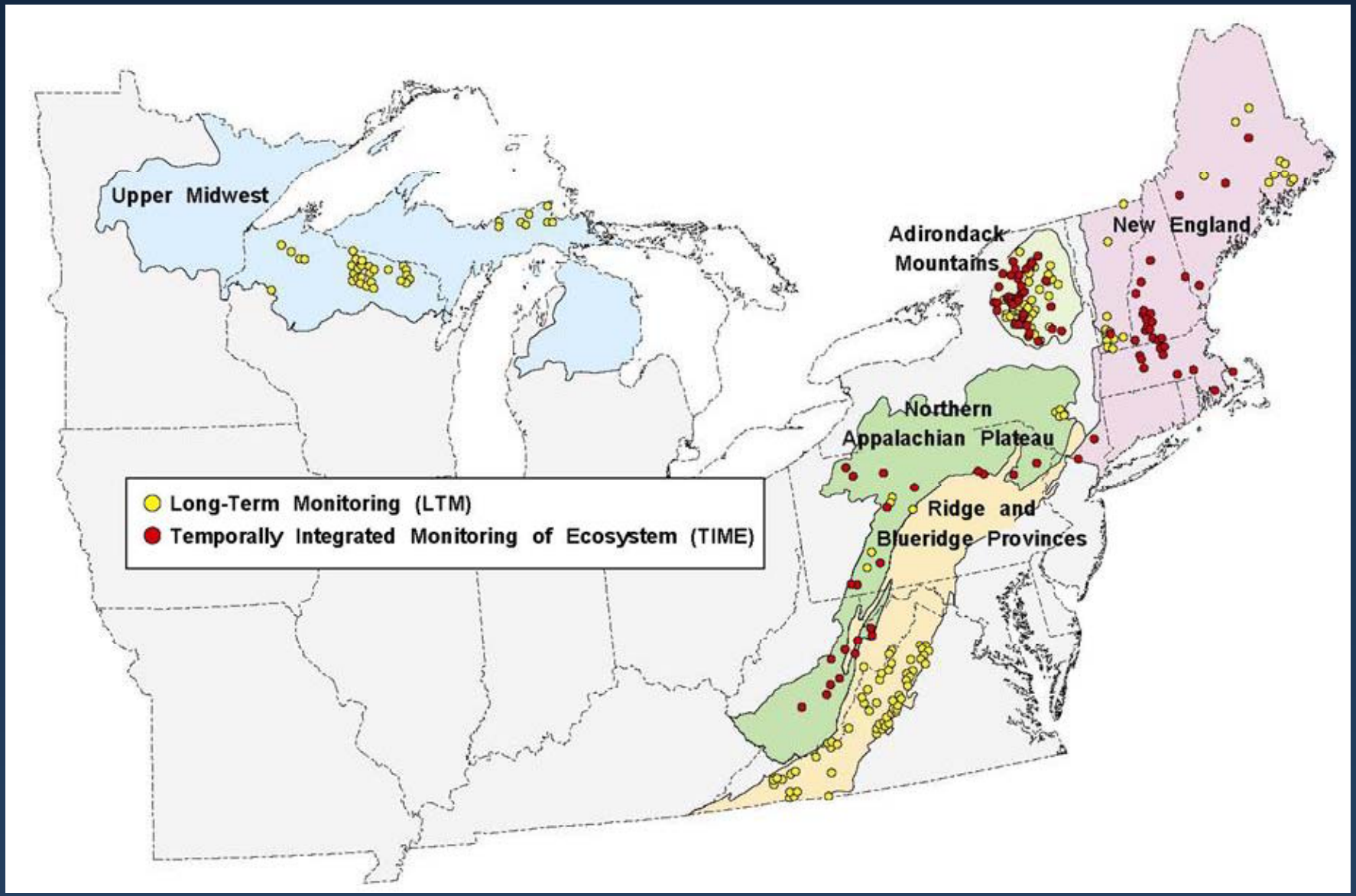


Nitrate Ion Concentration

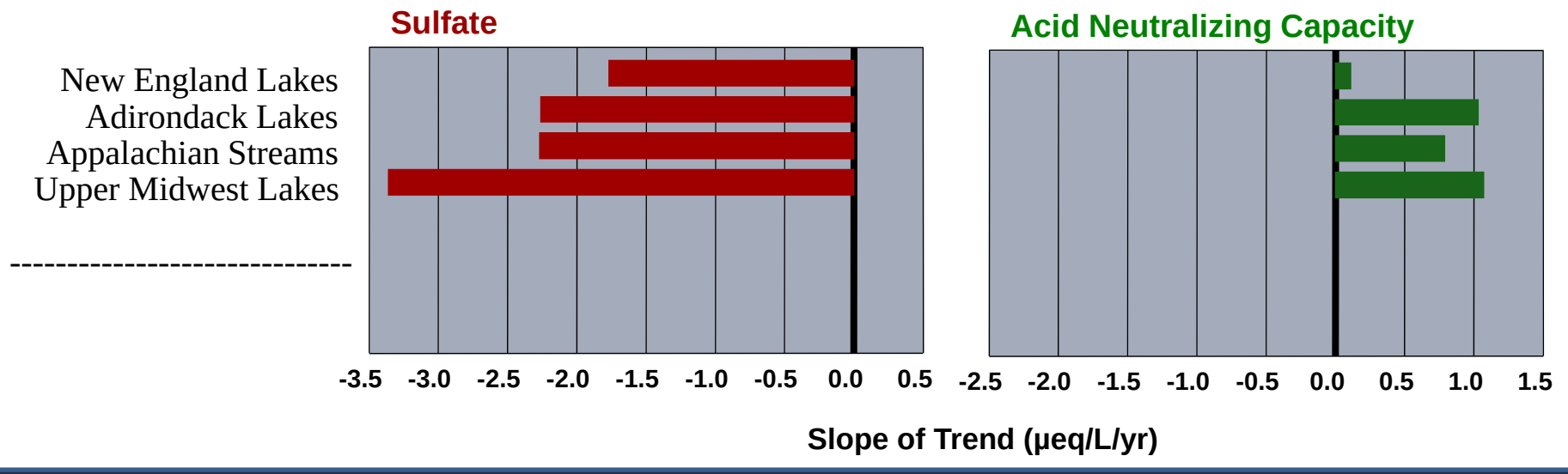


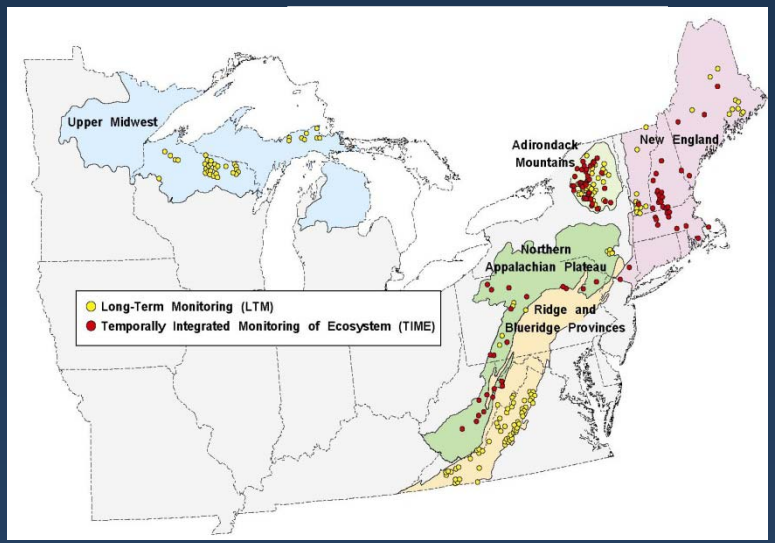


Stream / Lake water monitoring



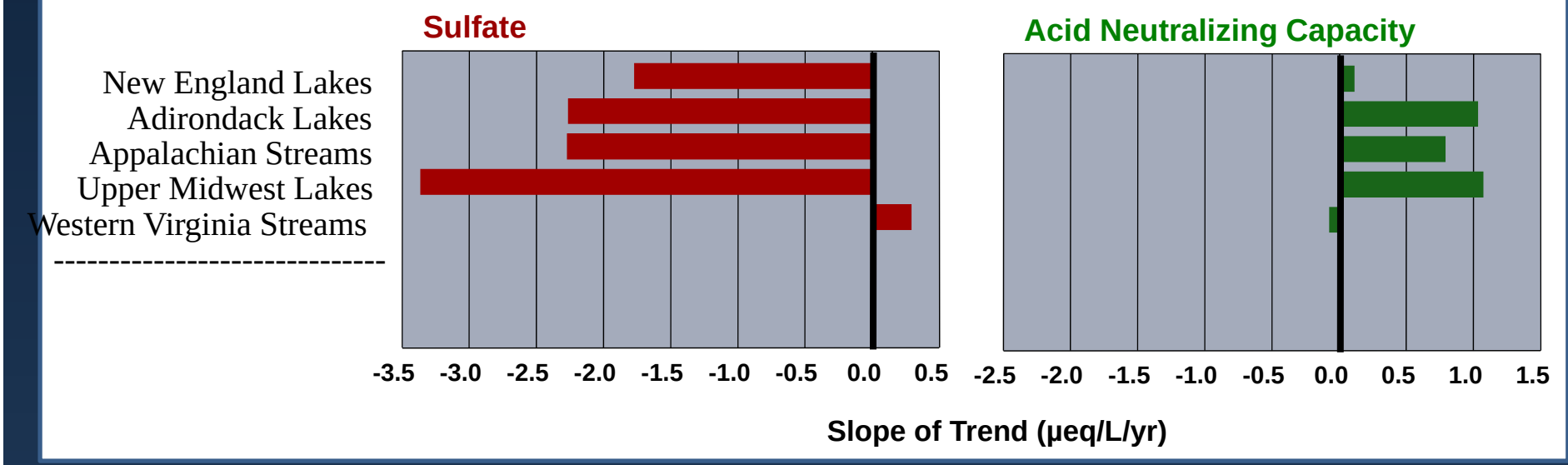
Trends in stream & lake composition (1990 - 2000)

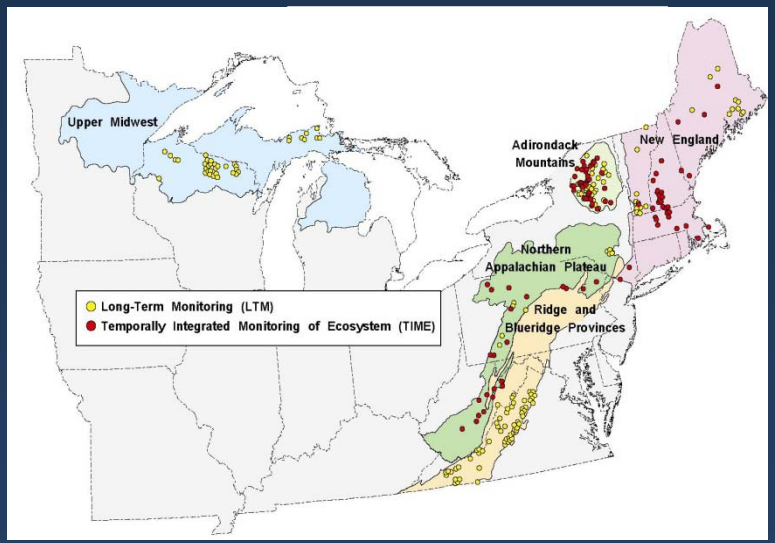




- Sulfate concentrations and acidity of surface waters in most regions have decreased in response to decreased sulfur emissions

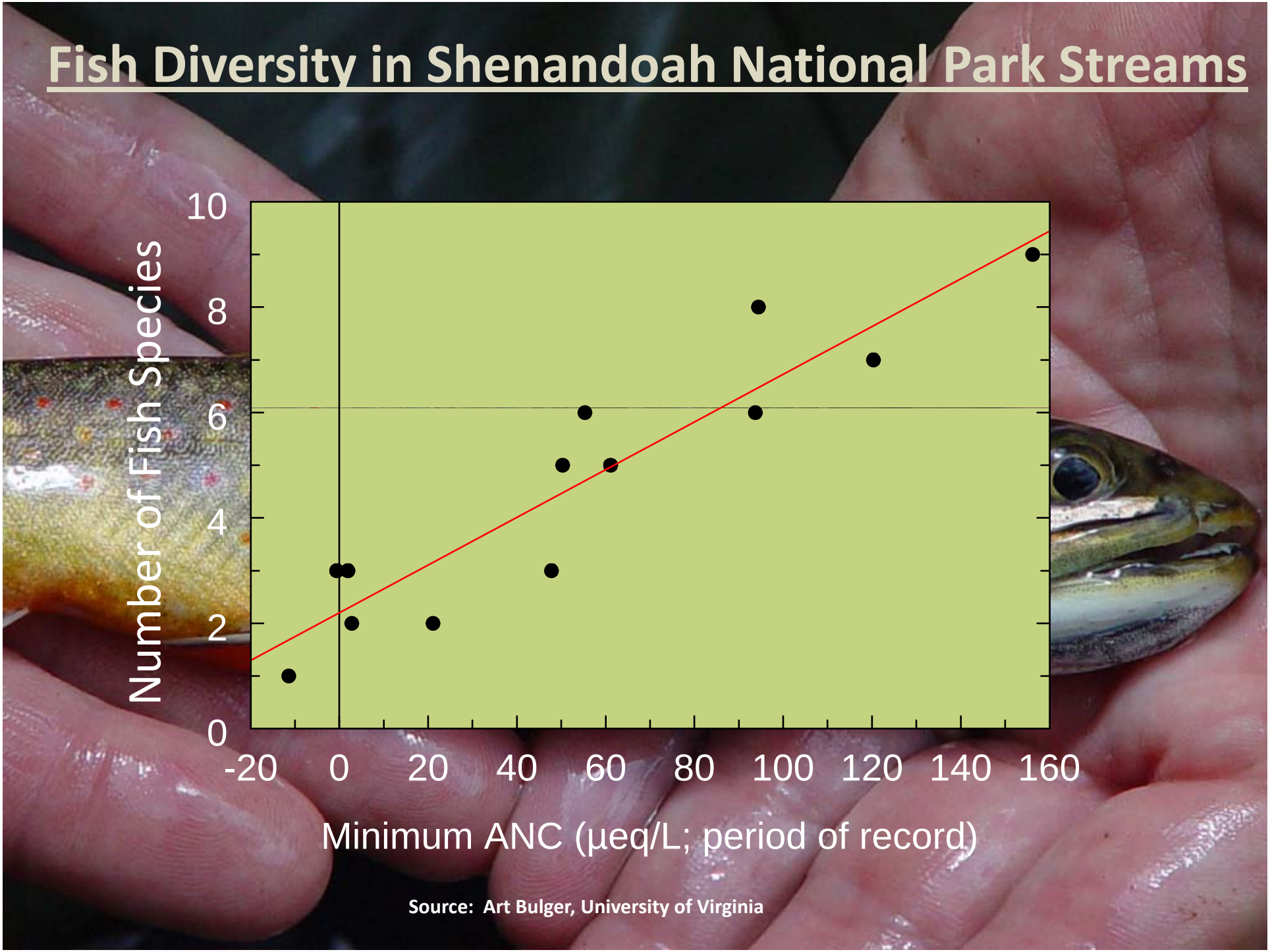
Trends in stream & lake composition (1990 - 2000)





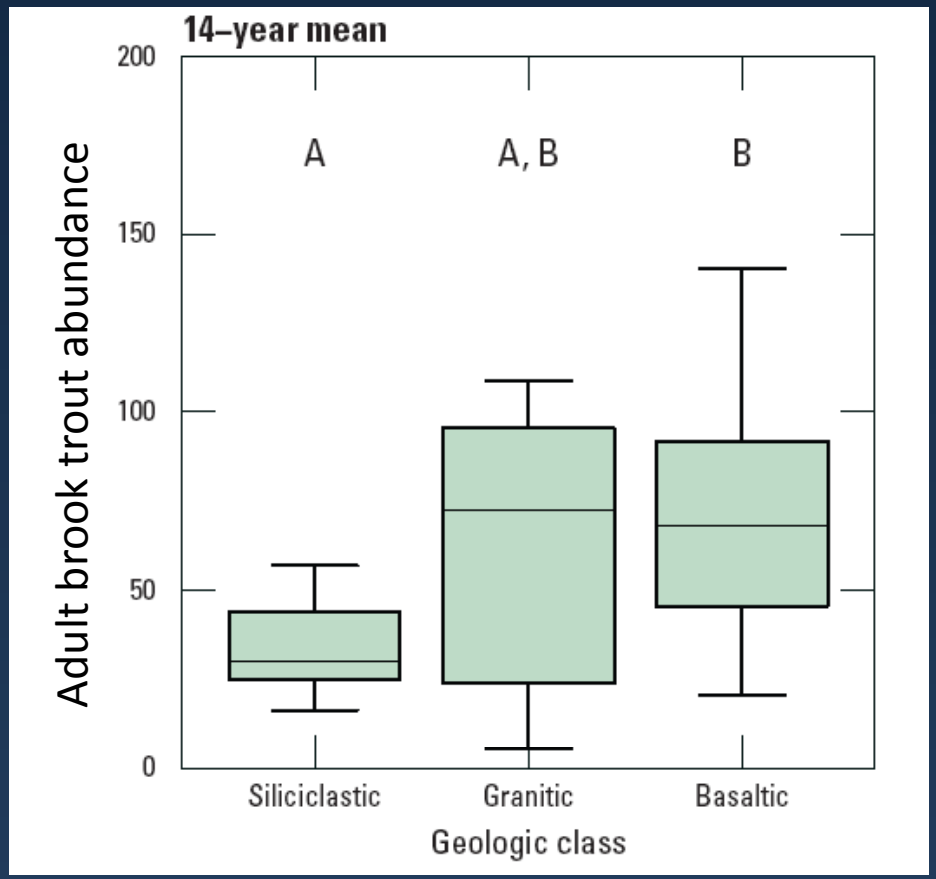
- Sulfate concentrations and acidity of surface waters in most regions have decreased in response to decreased sulfur emissions
- But not in western VA.
- In 2002 EPA told Congress that this should be a ‘red flag’ to regulators.

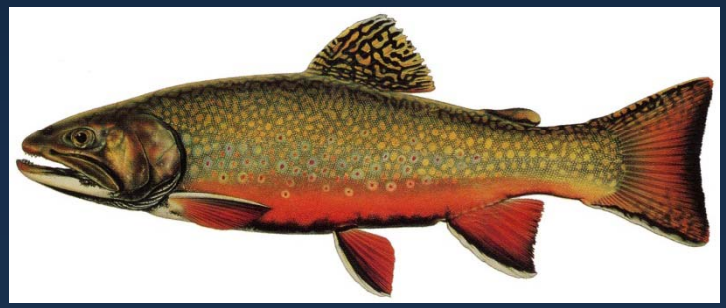
Fish Diversity in Shenandoah National Park Streams

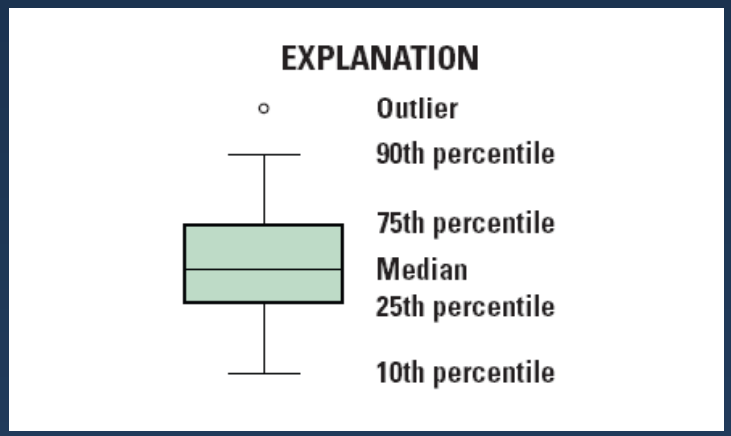


Source: Art Bulger, University of Virginia

ANC effect on Brook Trout populations

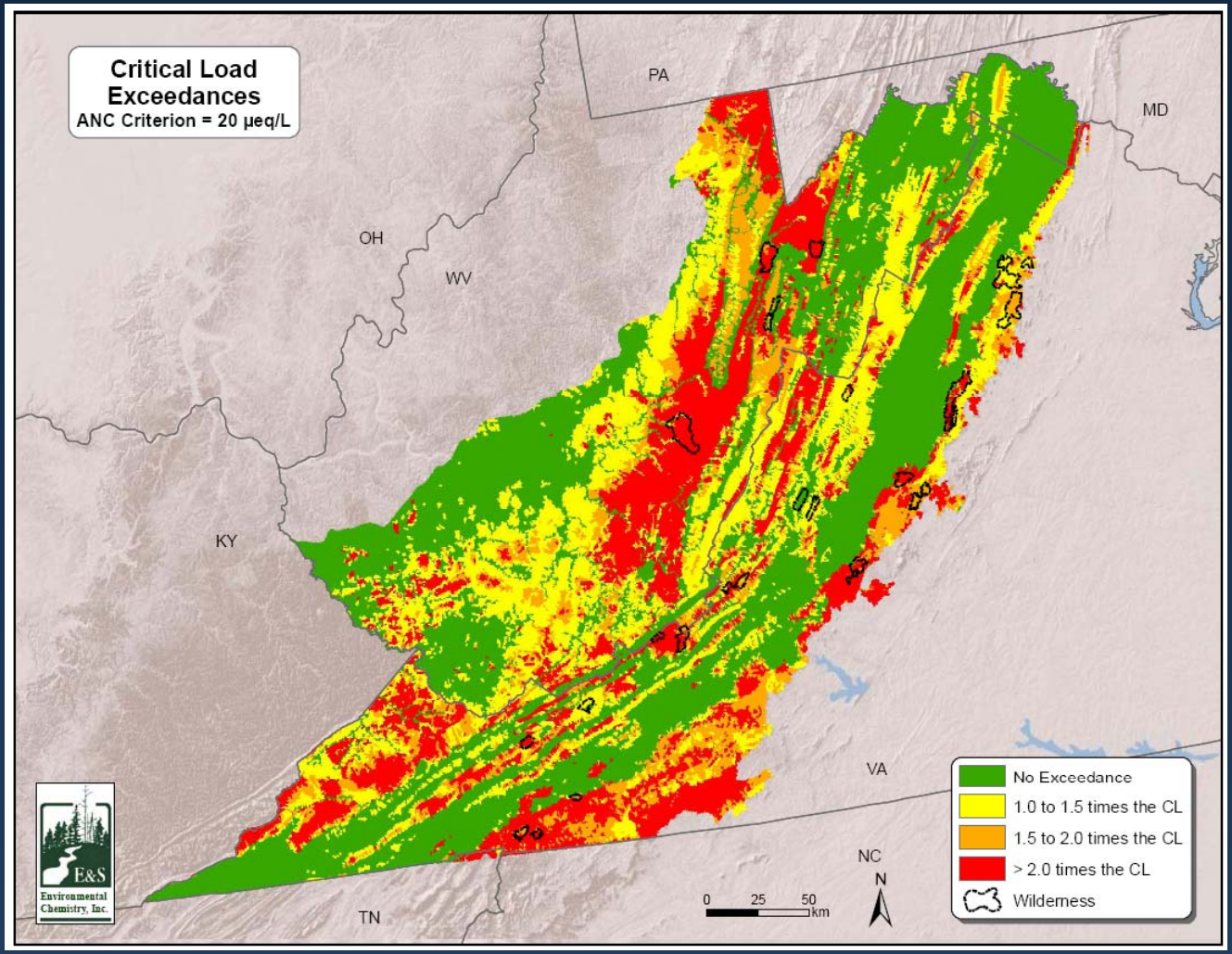






Jastram et al., 2013

Estimated Critical Loads



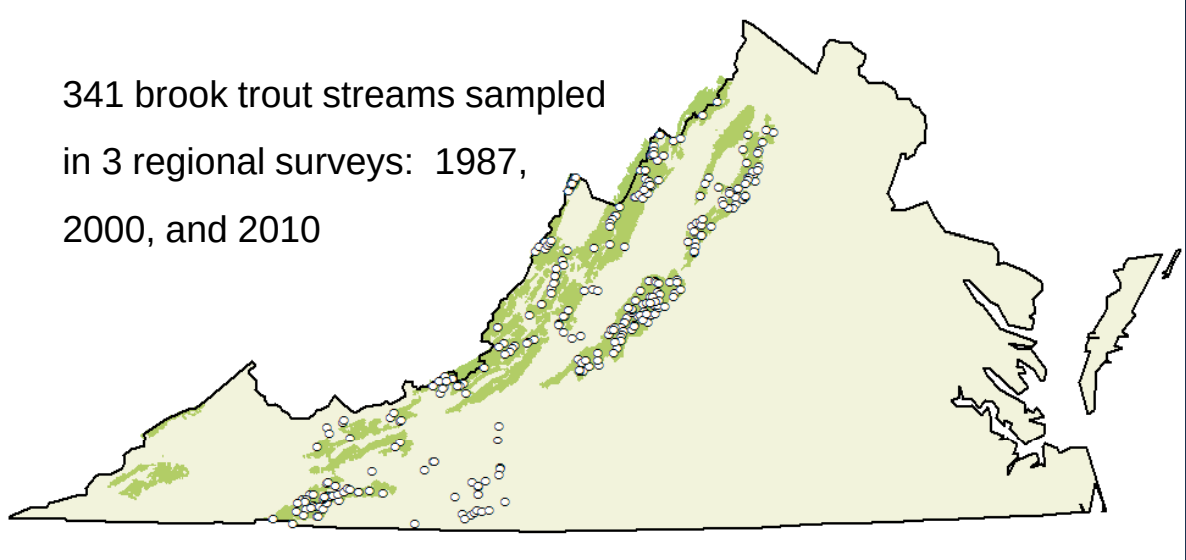
Webb, 2012

Long-term damage to base cation states of soils

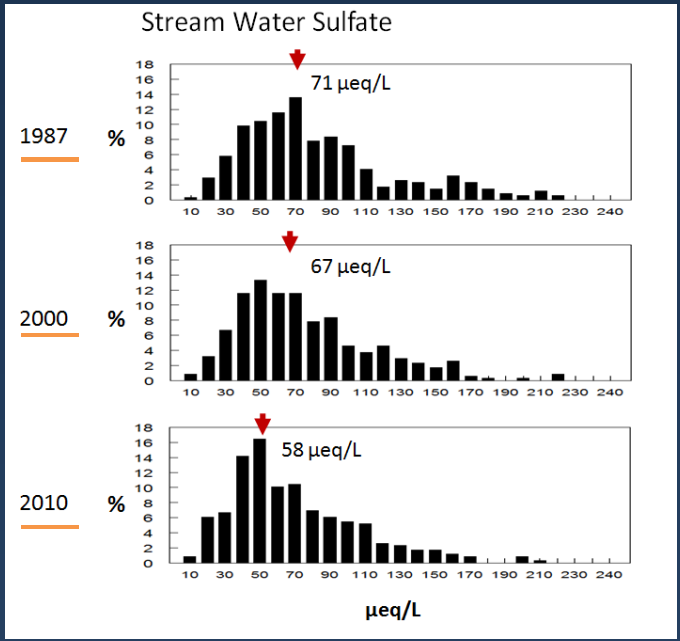
Some locations may take centuries to recover, based on model estimates

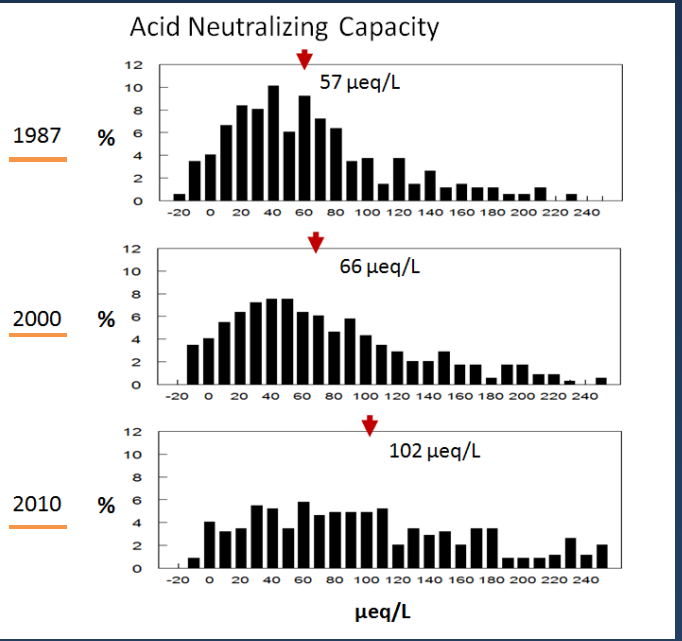
MAGIC used for estimates (Cosby)

Now for some positive news …



Regional survey data:



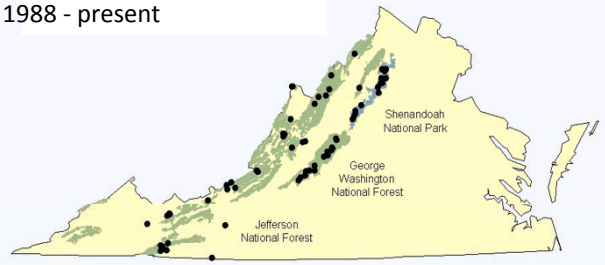


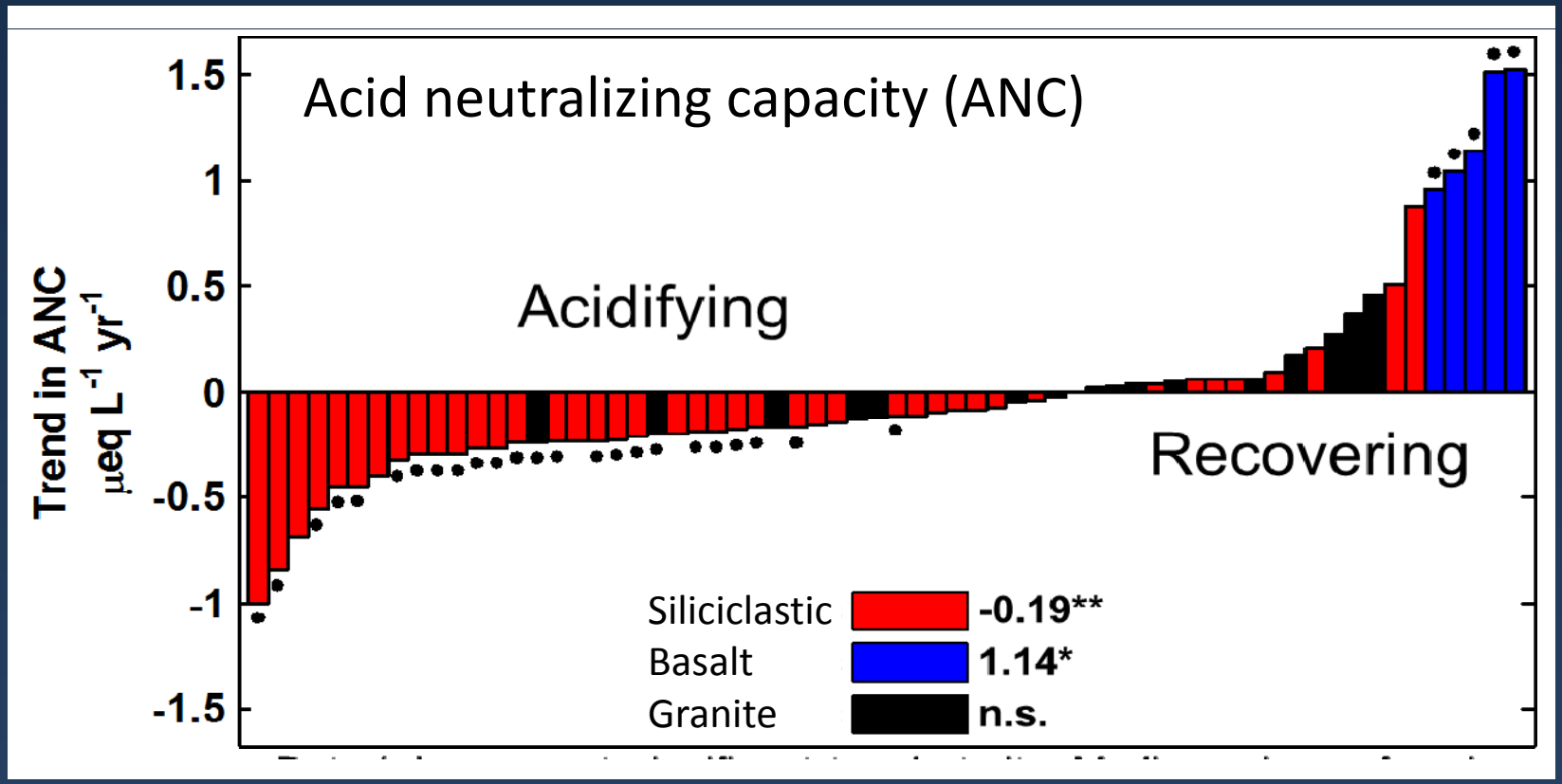
Quarterly sampling trends

Rich getting richer (basaltic)

Poor getting poorer (siliciclastic)

Virginia Trout Stream Sensitivity Study (VTSSS)
66 streams
Sampled quarterly
1988 - present

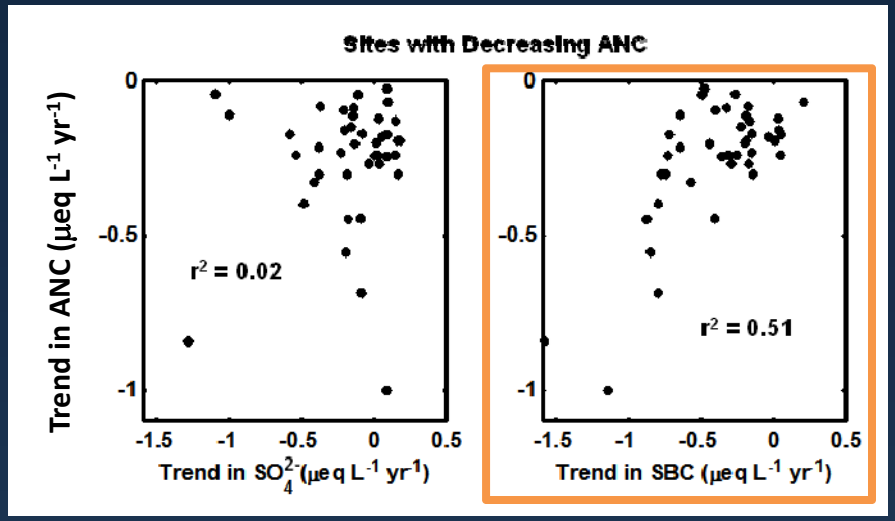




Quarterly sampling trends (continued)

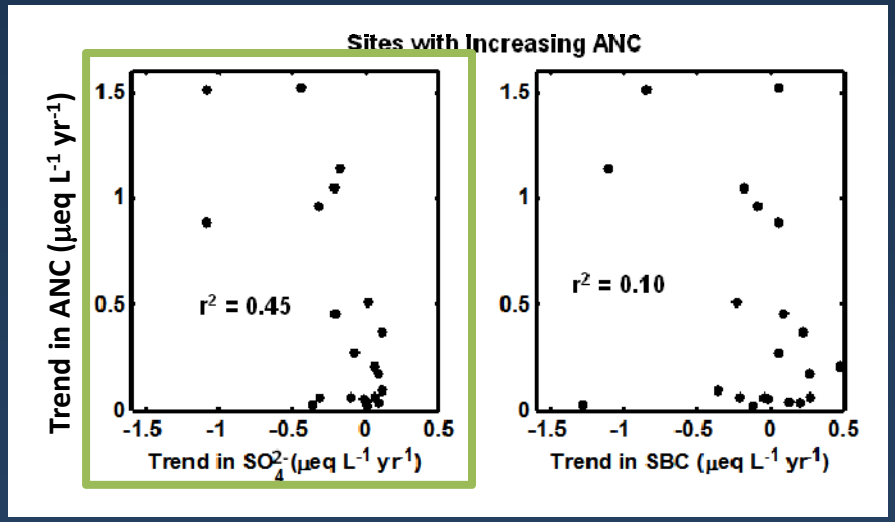
Streams with decreasing ANC (Continued Acidification)

Continued acidification is driven by declines in base cations.



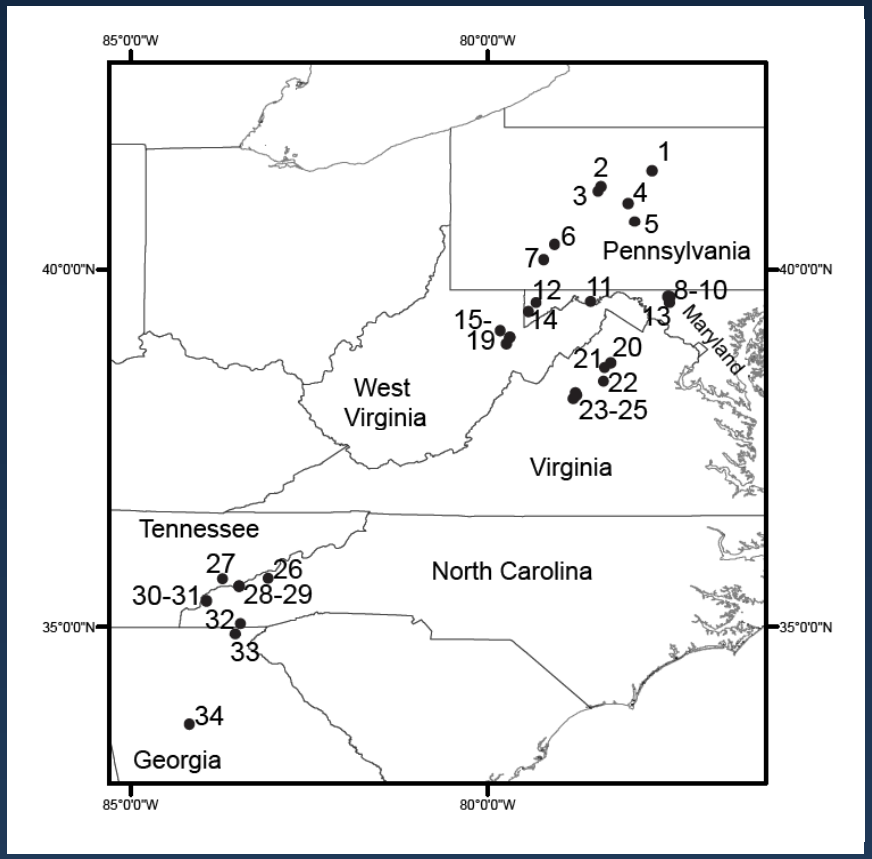
Streams with increasing ANC (Acid Recovery)

Acid recovery driven by declines in stream sulfate.



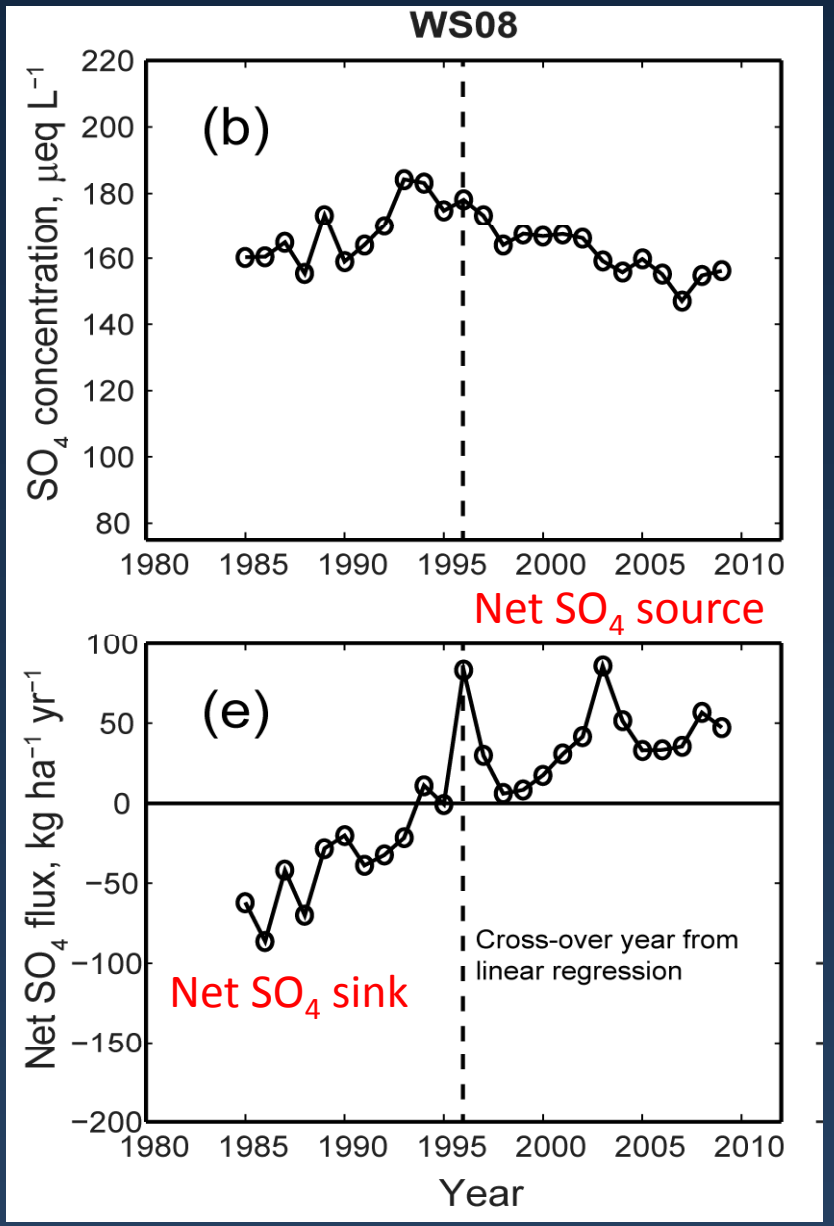
Robison et al., in review

Predicting declines in sulfate (weekly data)

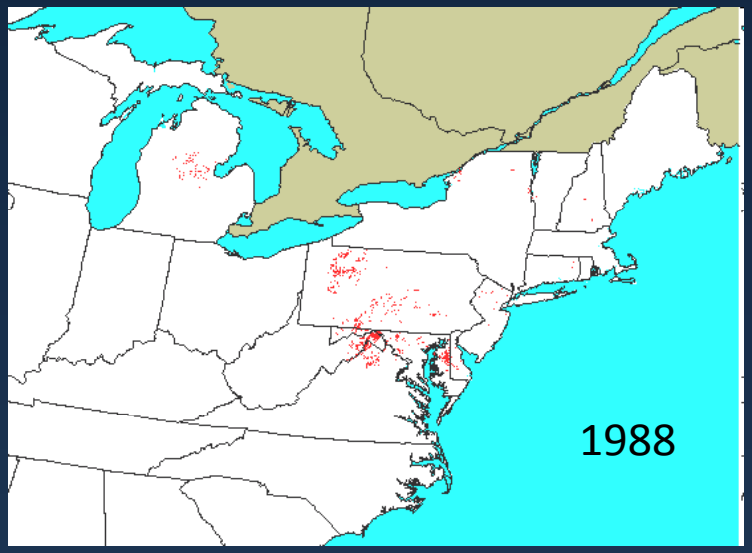


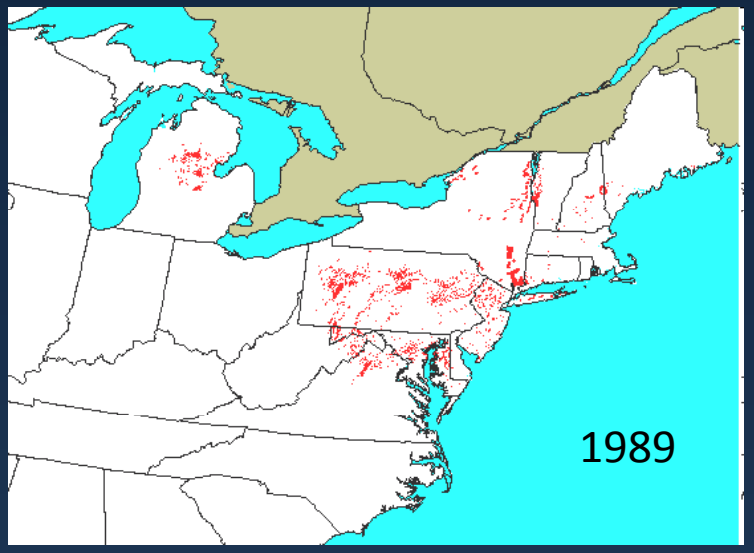
"Cross-over" dates for SNP streams

PAIN:	2015
PINE:	2012
STAN:	2016
WOR1:	2021
DR01:	2017

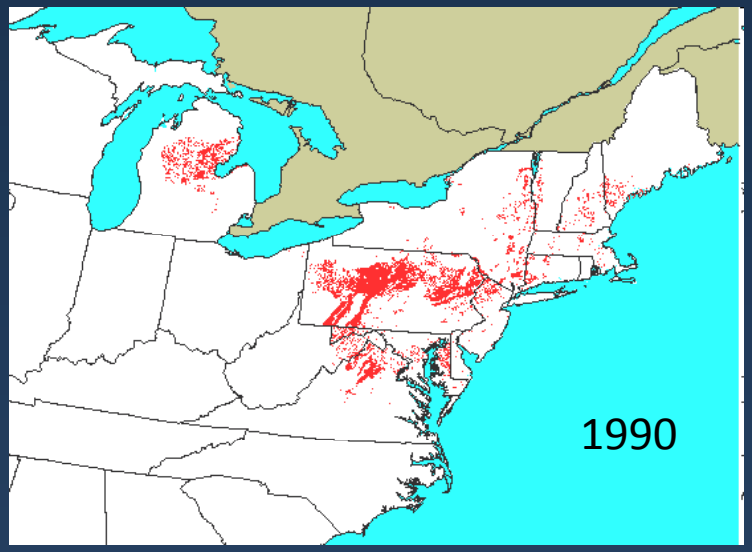


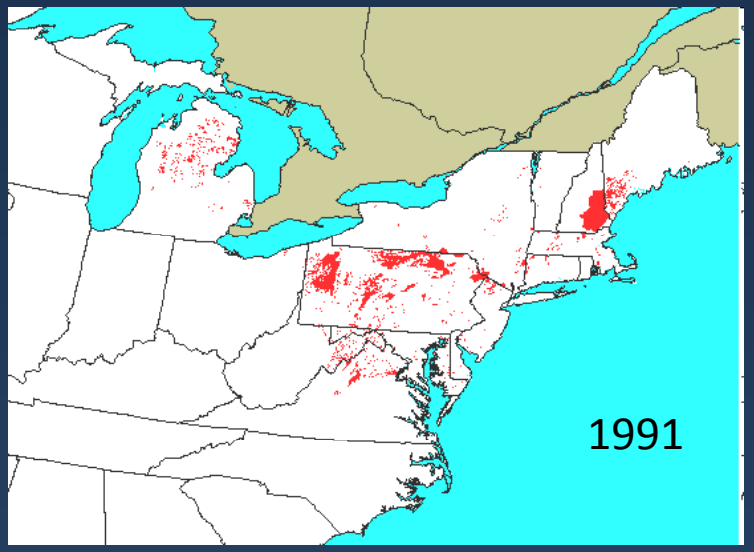
Unexpected events: Gypsy moth defoliation





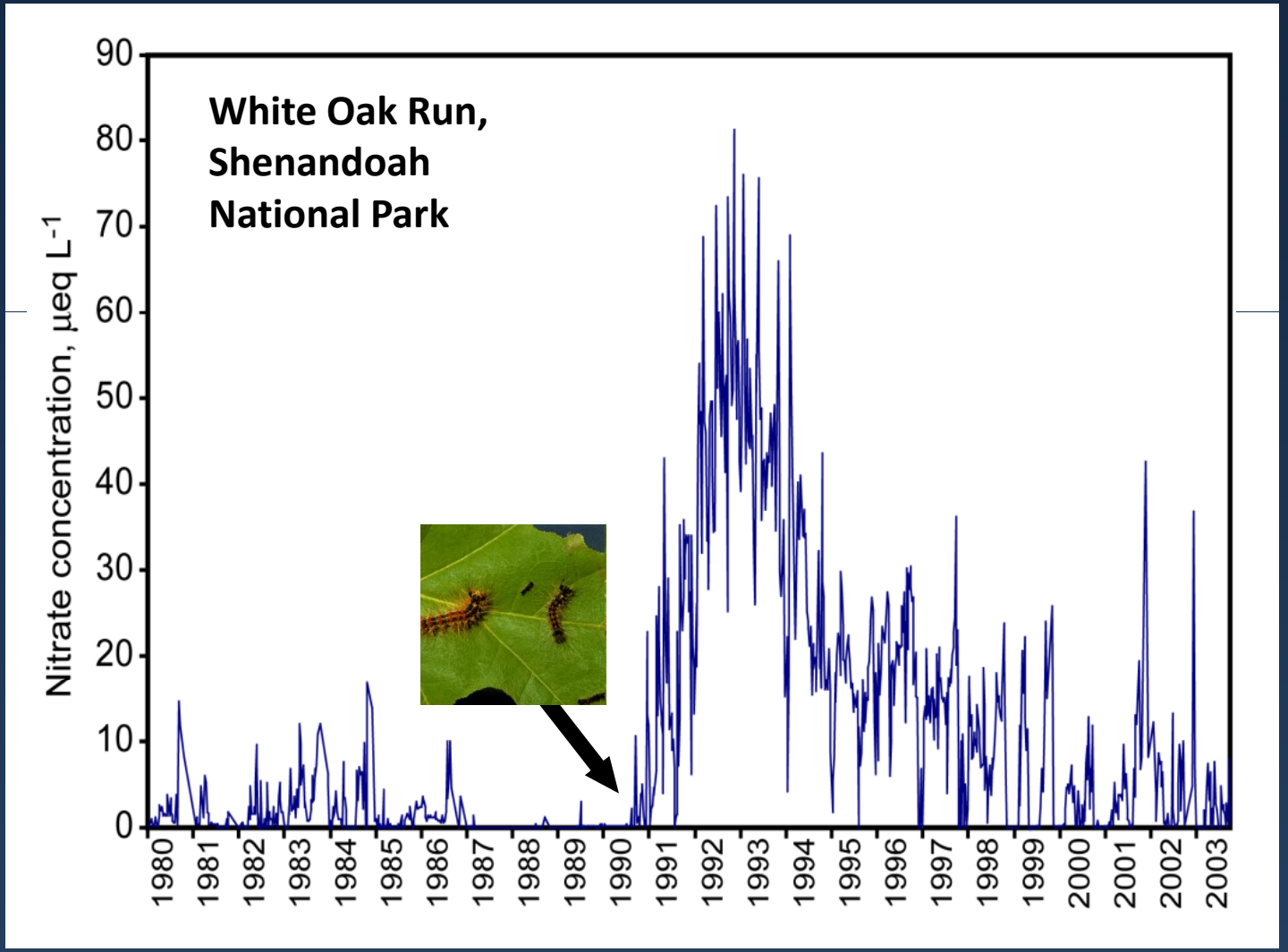
Gypsy Moth
Lymantria dispar



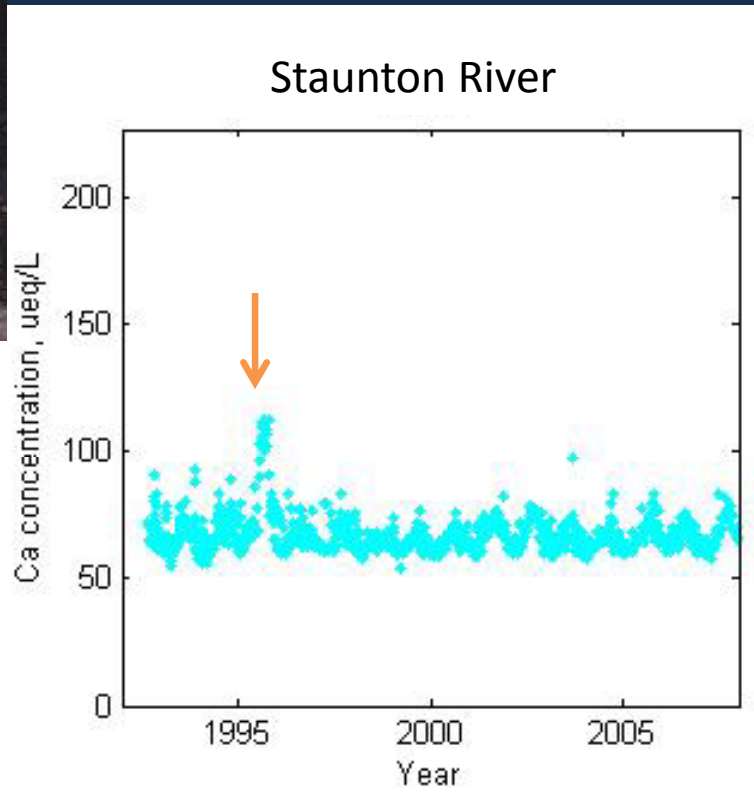


Source: U.S. Forest Service

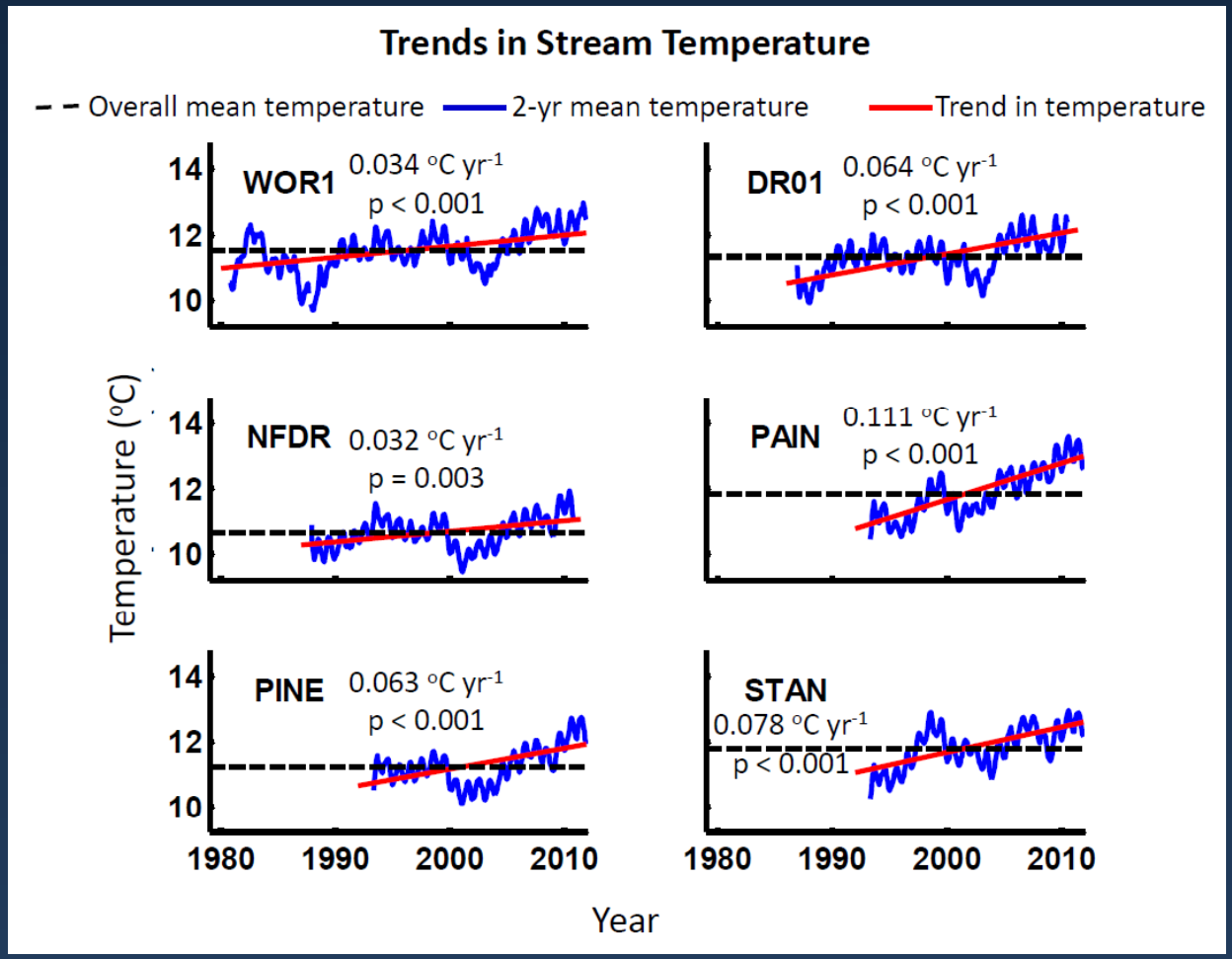
Unexpected events: Gypsy moth defoliation



Unexpected events: Rapidan flood (1995)



Emerging Issue: Climate Change



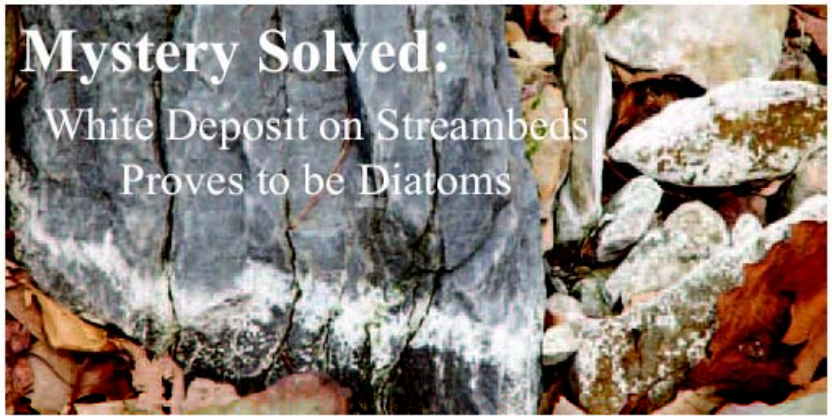
Possible Impacts:

Range of brook trout

In-stream metabolism

Affect on acid/base status

Watersheds as outdoor laboratories



By Rick Webb and Karen Rice

In the late winter and spring of 2006 an unusual white deposit was observed on rocks and margins of streambeds in a number of park streams. Inquiries were made to park staff and scientists studying water resources in the park as to what the deposit was and did it pose any type of risk. A number of explanations were proposed, but it was not until samples were collected and examined with a scanning electron microscope that the identity of the deposit was definitively determined.

The mystery deposit consists of diatoms.

Diatoms are single-celled, photosynthetic algae found in both marine and freshwater habitats, as well as in other damp environments. Diatoms are notable for their intricately structured cell walls, or frustules, which are made of silica. Although diatoms are microscopic, they are extremely abundant and an important part of the food web. It is estimated that diatoms are responsible for 20% to 25% of all organic carbon fixation on the planet. Although the silica cell walls of diatoms settle in large deposits on the ocean floor, deposits in freshwater streams such as those observed in the park generally do not occur.

So, why were there diatom deposits on park stream beds in the early spring of 2006? A couple of factors may have been involved.

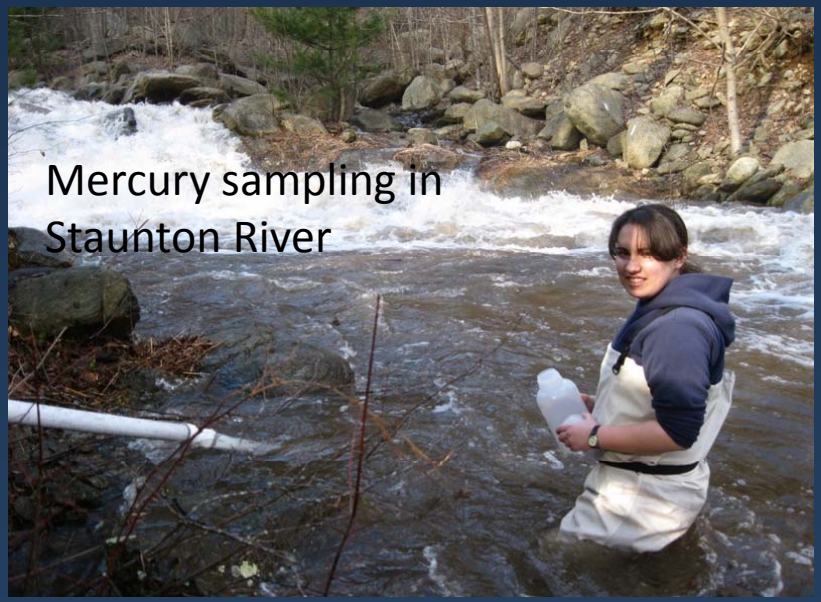
One factor is that stream flows were unusually low for the season, leaving diatoms vulnerable to desiccation on dry streambeds. An increase in algal growth is often observed in park streams in the winter and early spring when the forest canopy is open and streams are exposed to sunlight. Later in the growing season algal growth diminishes as the canopy leafs-out and less sunlight reaches the streambeds. The spring of 2006 appears to have been unusual because water levels dropped during the period when algae were growing rapidly.

Supporting evidence for the low-flow explanation is provided by examination of the Palmer Drought Severity Index (PDSI), which is a measure of relative dryness based on temperature and rainfall information. During the first 15 weeks of 2006, the PDSI for the three western Virginia climate divisions that include the park changed from "Abnormally Moist" in January to "Abnormally Dry" in early April (SRCC, 2007).

Another possible factor is that diatom populations in park streams may be increasing. Trend analysis using

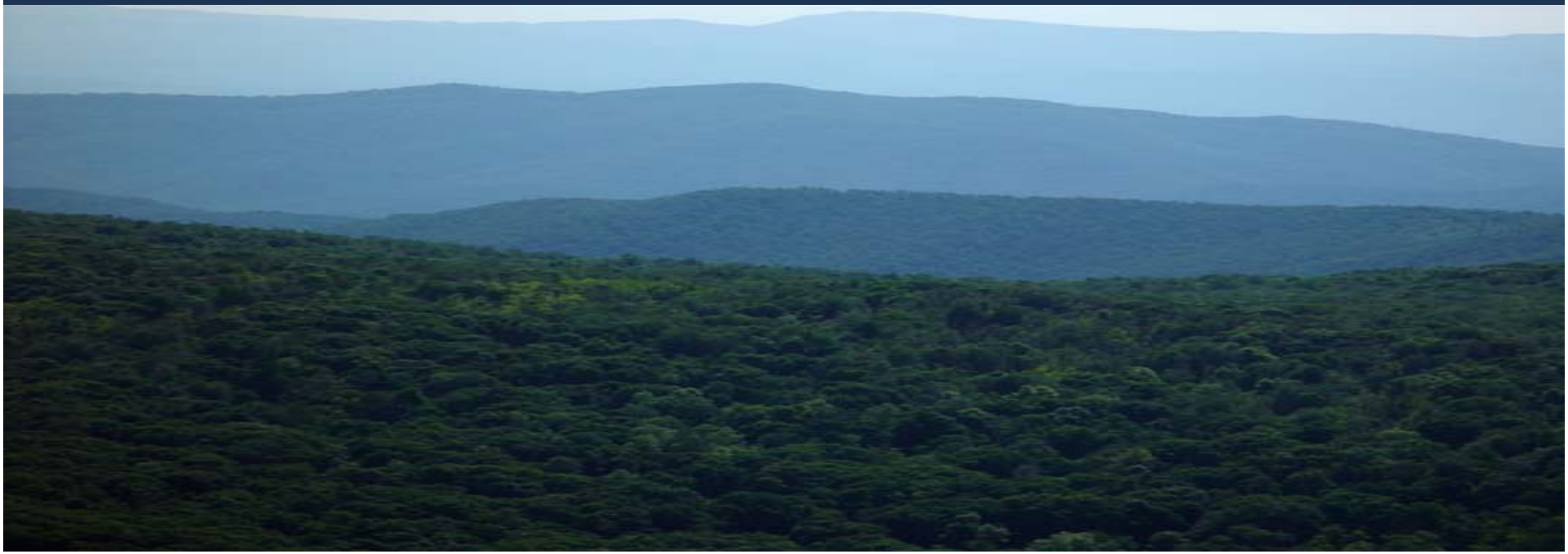
Above: A view of the white deposit. Samples were collected from the Big Run and Moormans River watersheds. A scanning electron microscope was used to determine the structure and composition of the material. Photo by Rick Webb.

Below: The white deposit observed on rocks in a dry streambed in the Big Run watershed. Photo by Rick Webb.



Future Plans

- **Make data accessible online**
- **Deployment of in situ sensors**
- **Make data accessible in real time (satellite transmission)**



Acknowledgments

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Acknowledgments

Sulfur Dioxide (SO_2) Emissions in U.S.