

# Atmospheric Mercury Deposition And Impacts In The Pacific Northwest

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Mercury Deposition Network

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# Atmospheric Mercury Deposition and Impacts in the Pacific Northwest

- **NADP Mercury Deposition Network**
- **Mercury Deposition Network Annual Hg Map Summary**
- **Mercury Deposition Network Hg Deposition Trends**
- **Importance Of Monitoring Hg Deposition**
- **Mercury Deposition And Impacts In The Pacific Northwest**

# *What Is The National Atmospheric Deposition Program Mercury Deposition Network?*

- A Cooperative Monitoring Program
  - Measure wet deposition and atmospheric concentrations of pollutants
  - We monitor the rate of pollution movement into ecosystems
- North America
  - Taiwan, Mexico, South America
- Owned and operated by our members
- Decisions made by our members
- Started in 1978, 35<sup>th</sup> year
- “acid rain network”
- Over 400,000 precipitation samples

# *Long-term Monitoring Program In Support Of Research On The Effects Of Atmospheric Chemical Deposition*



NATIONAL ATMOSPHERIC DEPOSITION PROGRAM

A Cooperative Research Support Program of the  
State Agricultural Experiment Stations (NRSP-3)  
Federal and State Agencies  
and Private Research Organizations

**NADP**

**National Research Support Project #3**

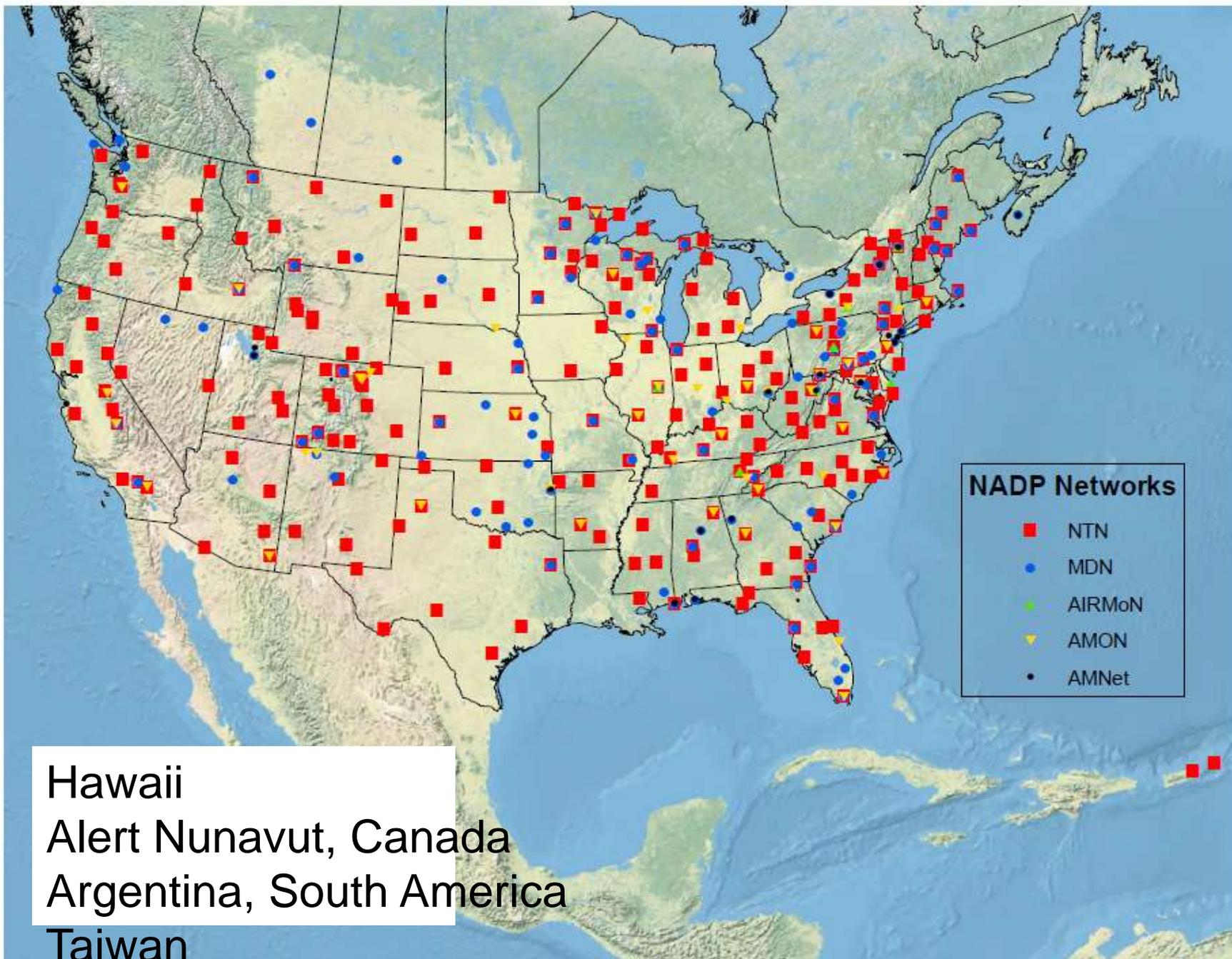
- A Long-term Monitoring Program

In Support of

Research on the Effects of Atmospheric  
Chemical Deposition

# NADP's Goal

*To monitor chemistry/contaminants in precipitation (rain and snow) and in the atmosphere, as consistently and as accurately as we can, for long periods to determine changes over time (trends).*



**NADP Networks**

- NTN
- MDN
- AIRMoN
- ▼ AMON
- AMNet

Hawaii  
Alert Nunavut, Canada  
Argentina, South America  
Taiwan



# Species Measured by the NADP

## acidic species

free acidity (or pH), sulfate, nitrate, chloride

## nutrients

nitrate, ammonium, orthophosphate

## earth crustal base cations

calcium, magnesium, potassium

## salts

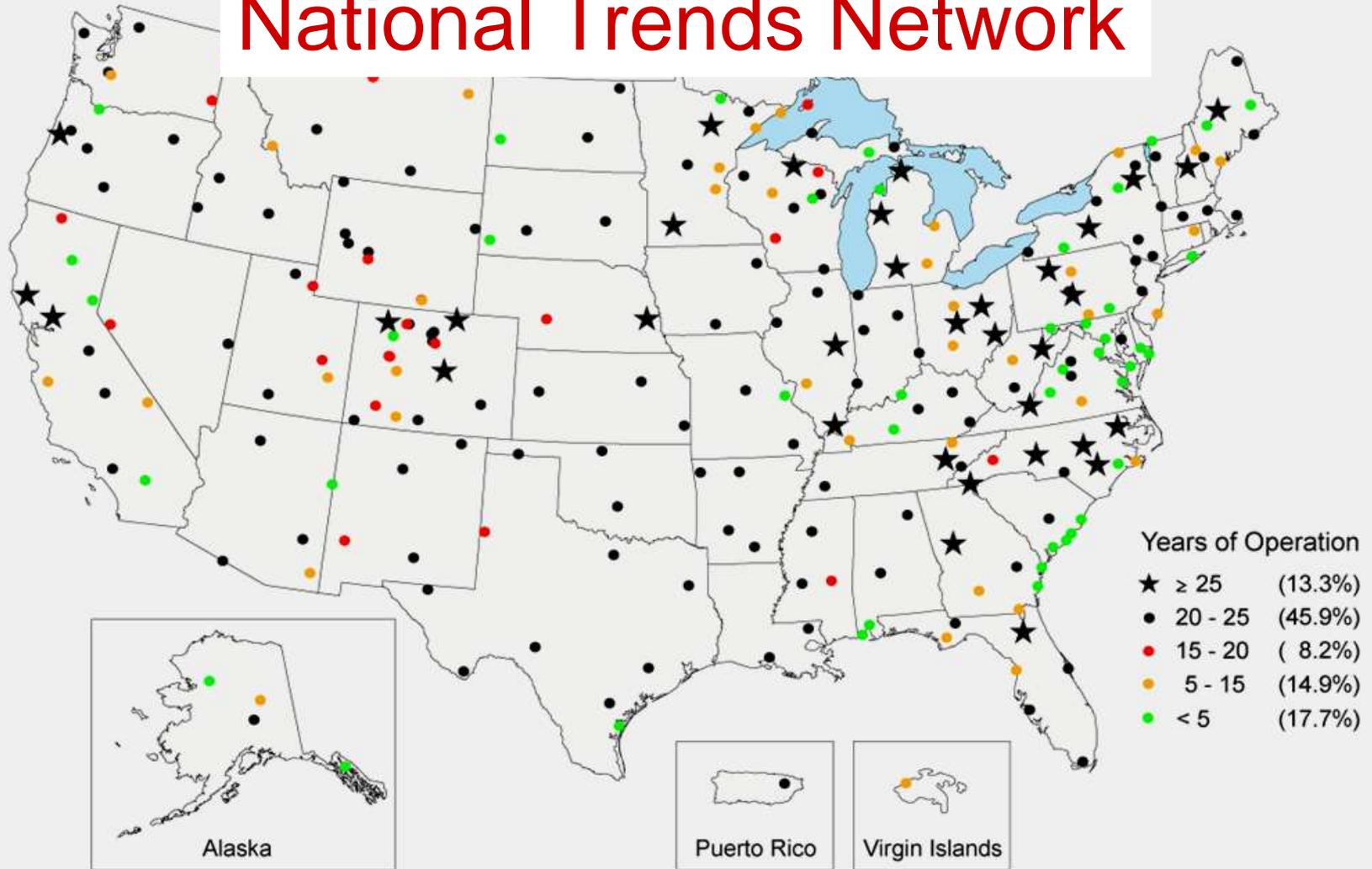
sodium and chloride

## heavy metals

mercury, trace metals (MDN)

# NADP Precipitation Monitoring Sites

## National Trends Network



~ 350 Monitoring Stations





# National Atmospheric Deposition Program

## Key To Success Of NADP

### Standardized Monitoring Network

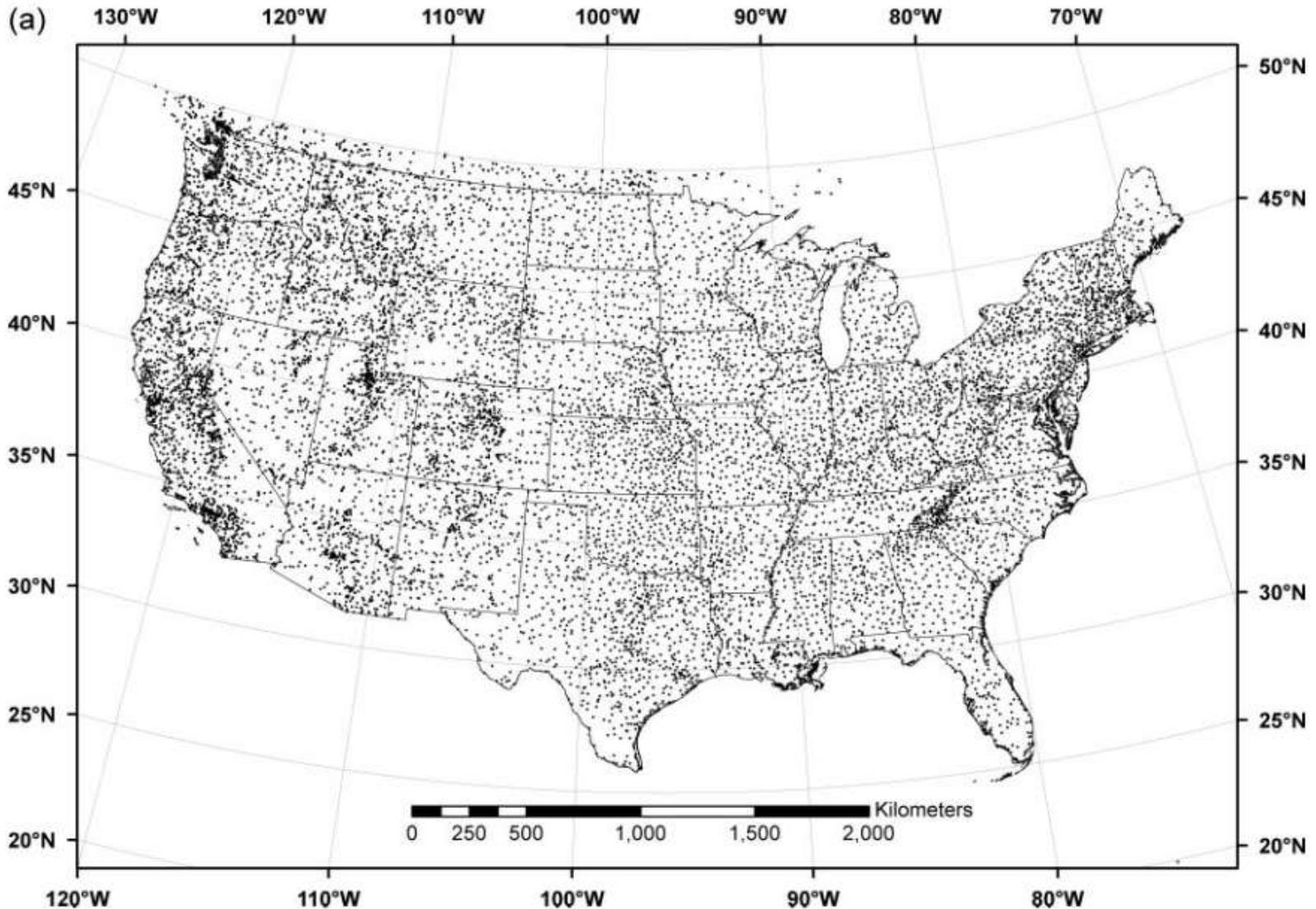
- North American Coverage (NTN Good/MDN ?)
- All Sites Conform To Same Siting Protocol
- All Sites Use Same Standardized Equipment
- All Sites Use Same Field Sampling Protocol
- All Sites Use High Quality Central Analysis Lab
- High-Level Field + Laboratory Quality Assurance
- Internal/External Quality Programs

# NADP Mercury Deposition Network Annual Hg Deposition Summary Maps

- **Each MDN Site:**
  - Measures 7-Day Integrated (weekly) Wet Deposition Precipitation Concentration
  - Measure Precipitation Volume At Each Site
  - Calculate Hg Deposition ( $\text{ng Hg/m}^2/\text{year}$ )
- **Annual Hg Deposition Summary Maps:**
  - Continuous Color Gradient Map Incorporating An External, Highly Resolved Precipitation Dataset (PRISM)



# PRISM Precipitation Depth Measurement Sites

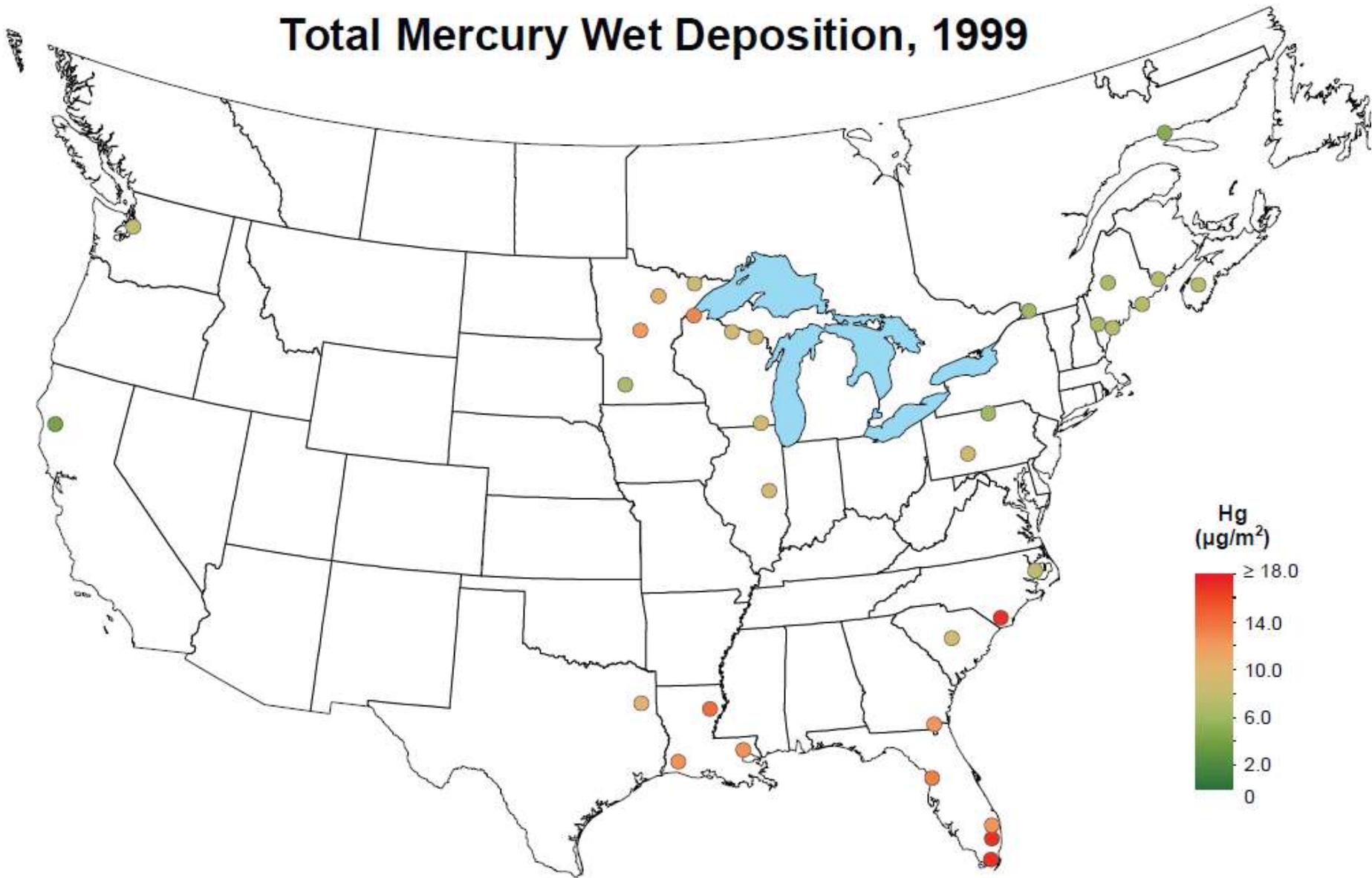


# NADP Mercury Deposition Network PRISM Precipitation Depth Monitoring

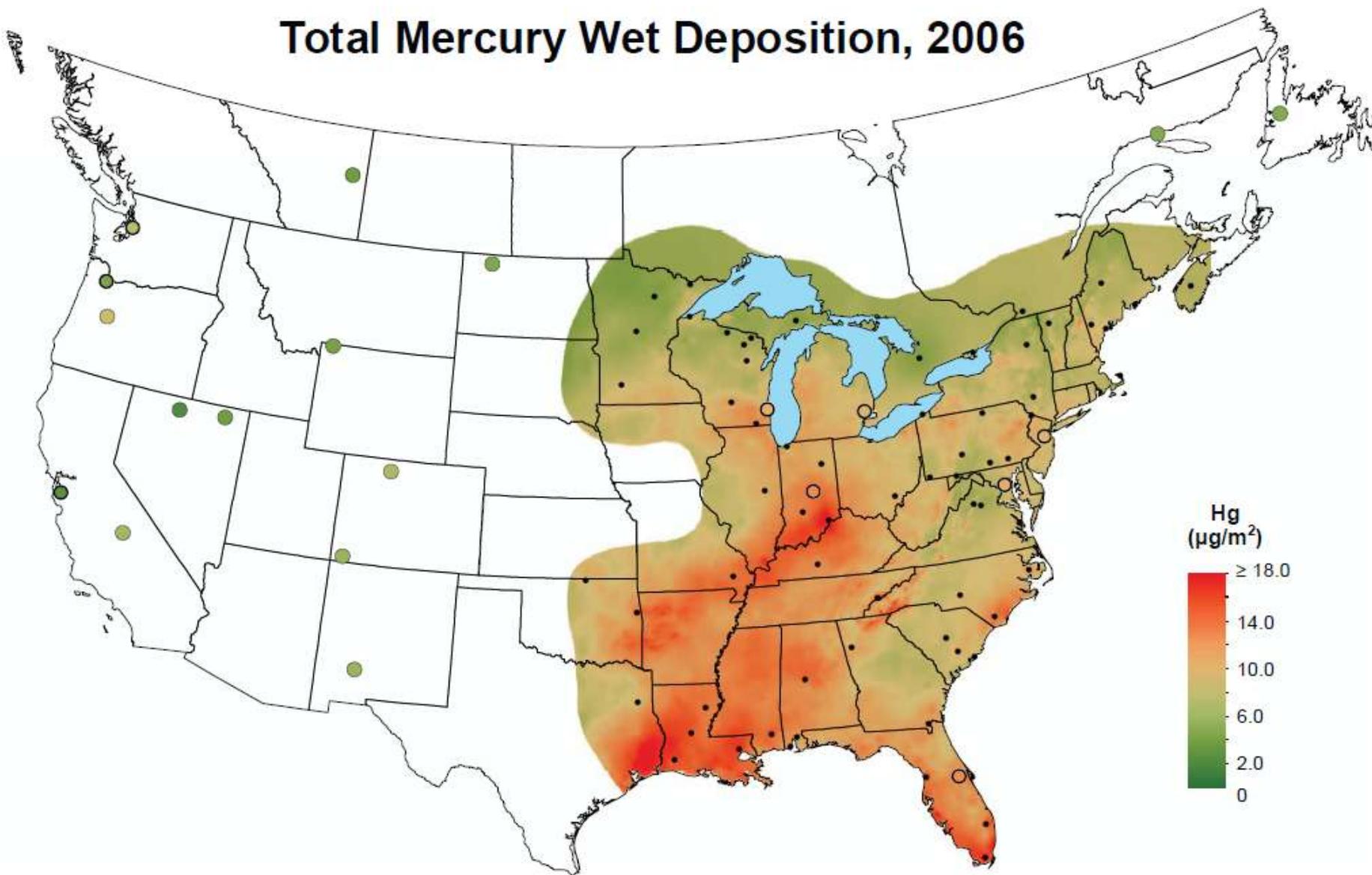
- ~7000 Precipitation Volume Monitoring Stations
- NADP annual concentration and deposition maps represent a modeled, spatial interpolation of quality-controlled point observation data from NTN and MDN sites.
- The deposition surfaces are not directly interpolated. Instead, they are generated as a product of two interpolated surfaces - the corresponding concentration surface, and a precipitation surface that combines NADP-measure precipitation values with PRISM direct and modeled estimates



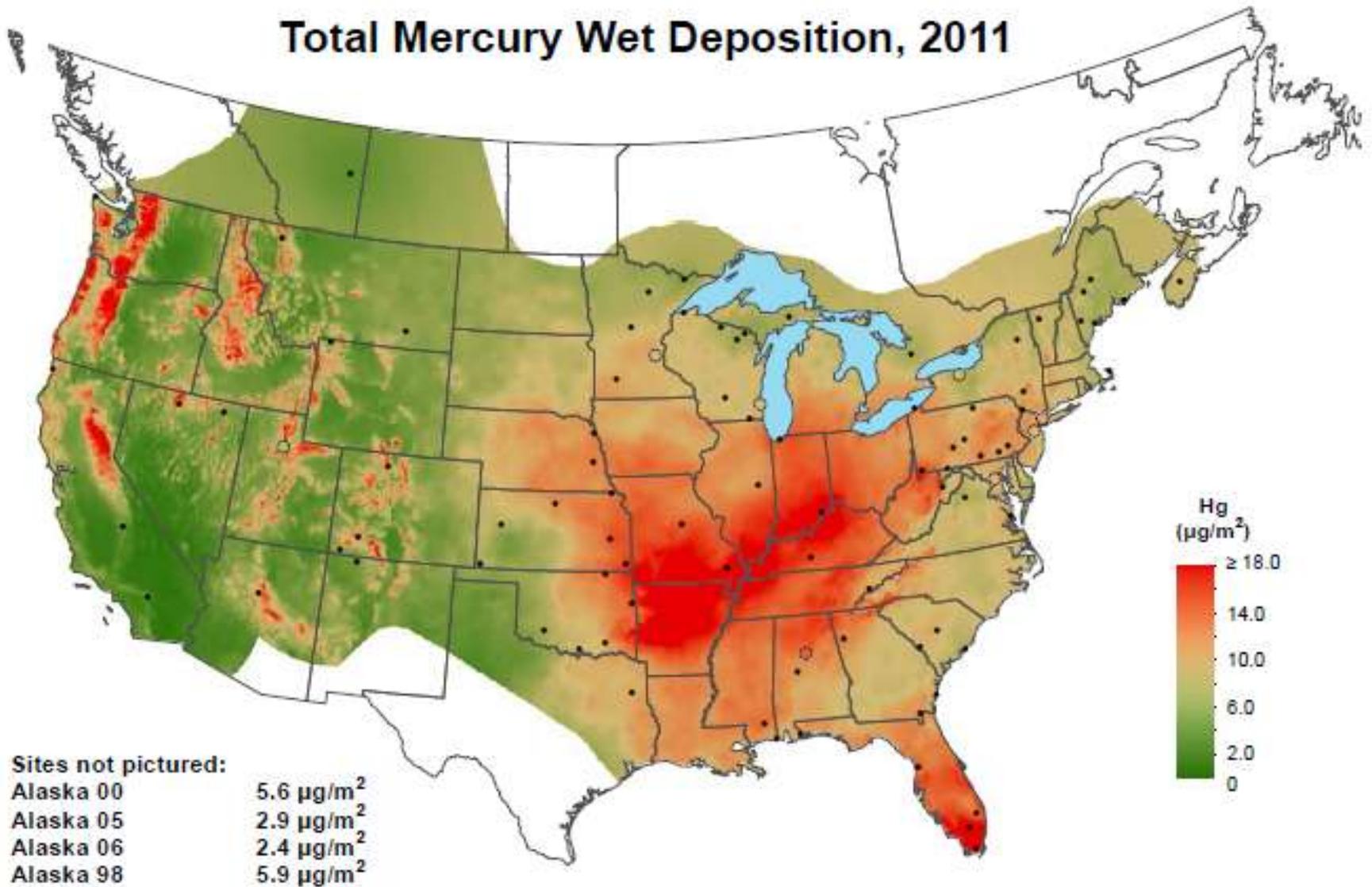
# Total Mercury Wet Deposition, 1999



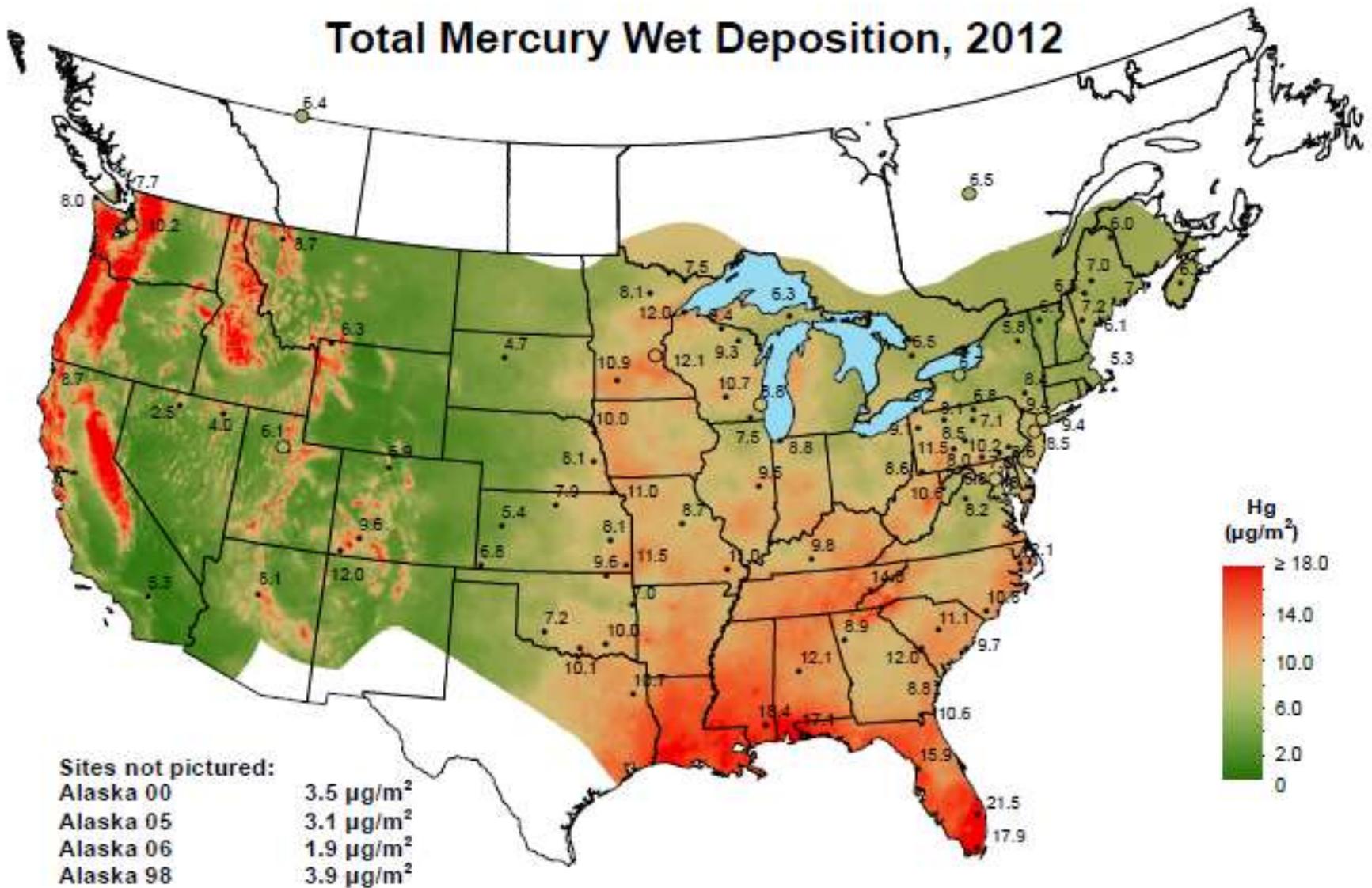
# Total Mercury Wet Deposition, 2006



# Total Mercury Wet Deposition, 2011

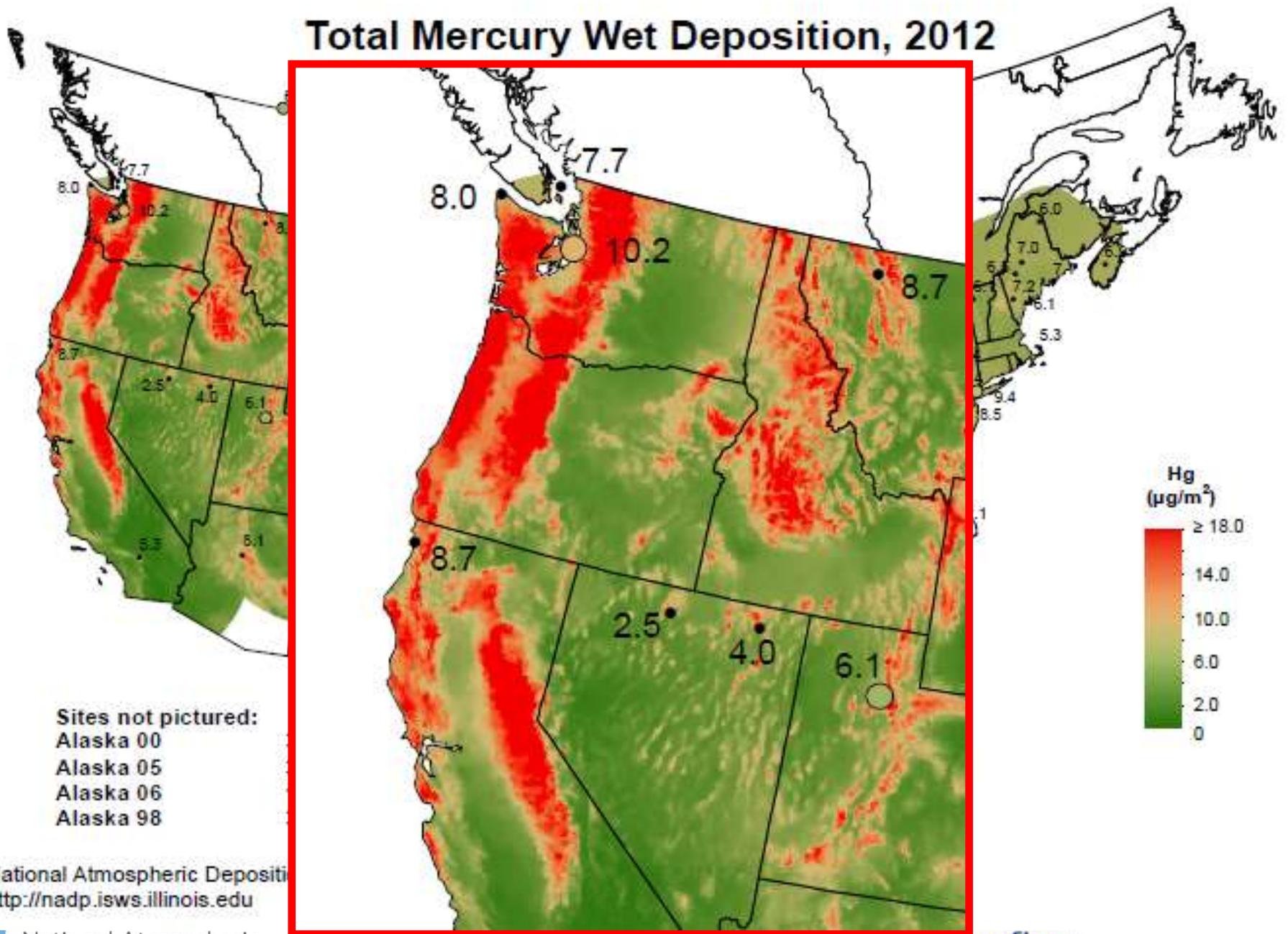


# Total Mercury Wet Deposition, 2012



National Atmospheric Deposition Program/Mercury Deposition Network  
<http://nadp.isws.illinois.edu>

# Total Mercury Wet Deposition, 2012



Sites not pictured:  
Alaska 00  
Alaska 05  
Alaska 06  
Alaska 98

National Atmospheric Deposition Program  
<http://nadp.isws.illinois.edu>

# Wet Deposition Hg Trend Methods (USGS)

- Seasonal Kendall Test for Trends
- Seasonal Kendall Slope Estimator
  - From the “Mann Kendall” as extended by van Belle and Hughes, 1984
  - non-parametric, normality not assumed
  - allows for seasonality and multiple stations
  - allows for missing data
  - from “Statistical Methods for Environmental Pollution Monitoring”, R. O. Gilbert, 1987
- Examines differences over time
  - Difference (obs1 – obs2) > 0, then =+1
  - < 0, then =-1
  - = 0, then = 0

# Mercury Deposition Network – Trends Analysis Of Precip Hg Concentration

Concentration Trend Results for Northwest Sites  
Prime values, Trends for All Seasons Together

Obs	site	SmPr	var_SmPr	ZmPr	Test_90	Test_95
1	WA18	-2410	277305.67	-4.57654	SIGN	SIGN
2	BC06	-137	4147.67	-2.12725	SIGN	SIGN
3	ID03	-86	1672.00	-2.10320	SIGN	SIGN
4	BC16	-40	1624.67	-0.99238	....	....
5	CA72	-65	6284.33	-0.81994	....	....
6	CA97	-11	458.00	-0.51400	....	....
7	WA03	-49	11324.67	-0.46045	....	....
8	ID99	-7	1204.00	-0.20174	....	....
9	ID98	1	707.67	0.03759	....	....
10	CA20	5	10660.33	0.04843	....	....
11	OR01	56	6317.67	0.70455	....	....
12	OR10	80	9640.67	0.81477	....	....
13	NV02	250	15207.00	2.02730	SIGN	SIGN

WA18: Local Incinerators Shut Down  
 BC06: Sig Down (not enough data)  
 ID03: Sig Down (not enough data)  
 ID98: Slight Up (not enough data)  
 ID99: Slight Up (not enough data)  
 OR01: Up (not enough data)  
 OR10: Up (not enough data)  
 NV02: Sig Up (good data set)

# Mercury Deposition Network – Trends – Hg Deposition & Precipitation

**Deposition Trend Results for Northwest Sites**  
Prime values, Trends for All Seasons Together

Obs	site	SmPr	var_SmPr	ZmPr	Test_90	Test_95
1	WA18	-1347	275854.00	-2.56465	SIGN	SIGN
2	ID99	-51	1204.00	-1.46980	SIGN	....
3	BC06	-84	4147.67	-1.30430	SIGN	....
4	CA97	-19	458.00	-0.88781	....	....
5	BC16	-21	1624.67	-0.52100	....	....
6	ID03	2	1672.00	0.04891	....	....
7	NV02	44	15207.00	0.35680	....	....
8	CA72	54	6284.33	0.68118	....	....
9	ID98	25	707.67	0.93978	....	....
10	CA20	100	10660.33	0.96853	....	....
11	WA03	138	11324.67	1.29678	SIGN	....
12	OR10	180	9640.67	1.83324	SIGN	SIGN
13	OR01	181	6317.67	2.27719	SIGN	SIGN

**Precipitation (subppt) Trend Results for Northwest Sites**  
Prime values, Trends for All Seasons Together

Obs	site	SmPr	var_SmPr	ZmPr	Test_90	Test_95
1	ID99	-89	1696.00	-2.16111	SIGN	SIGN
2	BC06	-37	4831.00	-0.53233	....	....
3	CA97	-3	574.67	-0.12514	....	....
4	WA18	44	342941.67	0.07514	....	....
5	BC16	8	2460.33	0.16128	....	....
6	NV02	25	22004.00	0.16853	....	....
7	OR10	68	10185.67	0.67377	....	....
8	CA72	72	7729.67	0.81894	....	....
9	ID03	59	3476.00	1.00072	....	....
10	ID98	31	759.33	1.12498	....	....
11	CA20	179	13674.00	1.53075	SIGN	....
12	WA03	188	13500.67	1.61801	SIGN	....
13	OR01	212	6829.67	2.56529	SIGN	SIGN

# The Mercury Problem



1) Elemental Gaseous Hg Is Emitted Into The Atmosphere through either combustion emissions or natural process (i.e. forest fires)

2) Some forms of Hg will fall once it is emitted.

3) Elemental Gaseous Hg can travel hundreds/thousands of miles until it is oxidized and falls out as wet Hg or dry Hg deposition

4) Once Hg wet/dry deposited to aquatic ecosystems these systems can convert the mercury to the toxic, bioaccumulative form of Methyl Mercury.

5) Mercury enters the food chain and works its way into fish, wildlife and humans.



# Importance Of Monitoring Mercury Deposition

## Global Mercury Emissions Treaty

### *- United States Signs and Ratifies Minamata Convention*

- 140 Countries, Legally Binding
- Deals with world-wide emissions and discharges of a pollutant that threatens the health of millions,
- Agreed risk to human health and environment was so significant that accelerated action needed
- Toxic, persistent and subject to long-range transport
- High levels of mercury in certain fish / human health concern

### Global Treaty on Mercury Pollution Gets Boost From United States



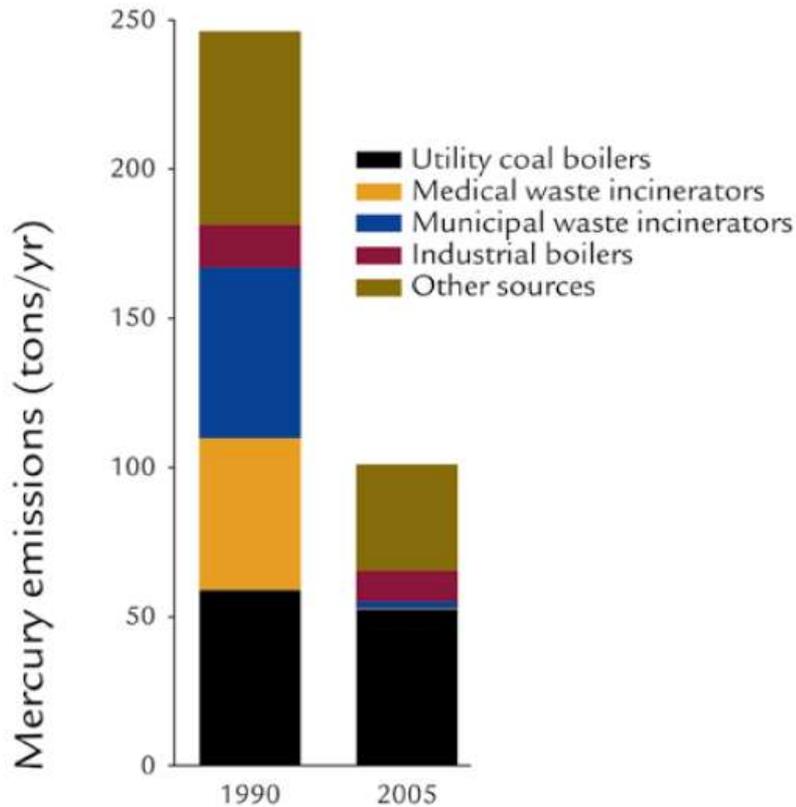
**UNEP's Achim Steiner Welcomes First Ratification of the Minamata Convention on Mercury.**

**Nairobi, 7 November 2013** - The United States has strengthened the international effort to bring down emissions and releases of a notorious heavy metal after simultaneously signing and ratifying the Minamata Convention on Mercury.

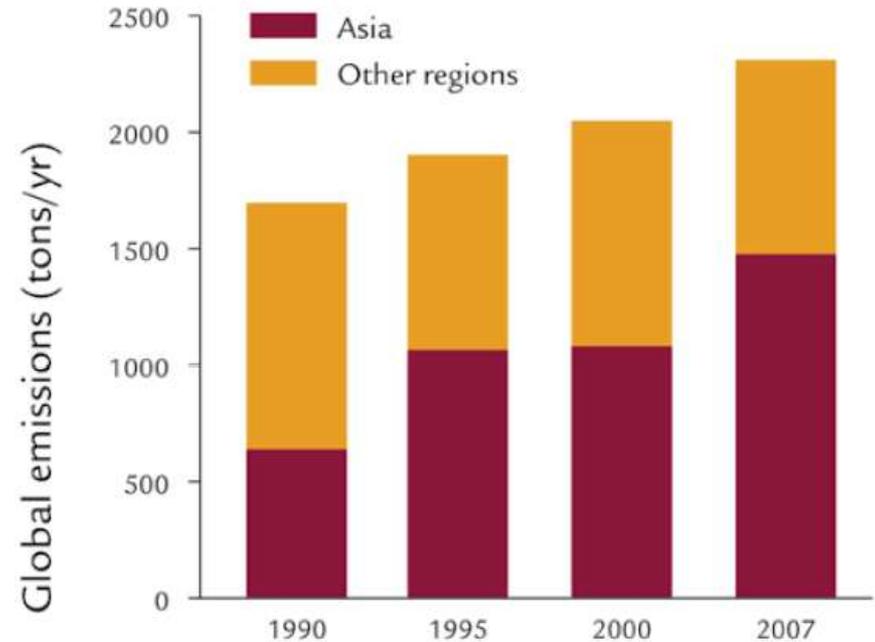
# Specific US Sources, Asian Growth

Total U.S. and Global Mercury Emissions from Human Activities

3a



3b



# Importance Of Monitoring Hg Wet Deposition

## EPA Mercury Air Toxics Standards (MATS)

- Released :February 16, 2012
- Start Date: April 16, 2015
- Coal and Oil Fired Electric Generating Units
- 90% Hg Emissions Reductions Required By 2018
- Recently Challenged



Chicago Tribune  
NEWS

### **U.S. Appeals Court Upholds Hazardous Air Pollution Rule**

Lawrence Hurley and Valerie Volcovici

Reuters

12:39 PM CDT, April 15, 2014

WASHINGTON (Reuters) - In a victory for the Obama administration, a U.S. appeals court on Tuesday upheld a regulation that would limit emissions of mercury and other hazardous pollutants mainly from coal-fired power plants, starting next year.

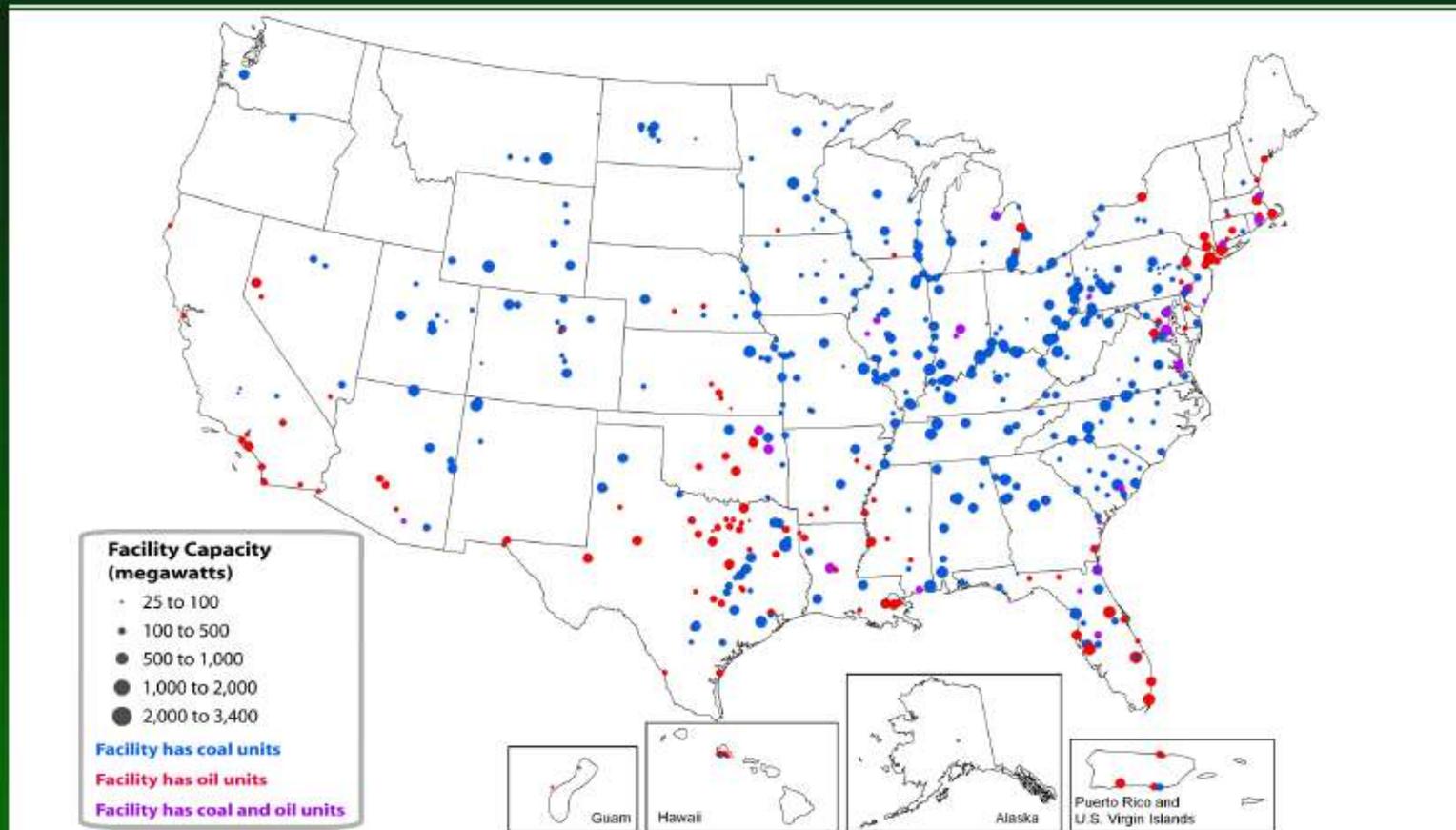
The EPA's Mercury and Air Toxics Standard (MATS) applies to 1,400 of the country's largest power plants and would come into force in 2015, or in some cases, 2016.

# Mercury Air Toxics Standard (MATS)

## Implementation Date: April 2015



The Toxics Rule Facilities  
National Electric Energy Data System (NEEDS 4.10 MATS) (EPA, December 2011)



# Atmospheric Transport and Deposition Of Mercury To Water Bodies Is Dominant Pathway

## ➤ Input Of Mercury To Water Bodies

“Between 40%-75% is likely by wet deposition”

(Sorensen et al., 1997; Scherbatskoy et al., 1997; Lamborg et al., 1995; Mason et al., 1997; Landis and Keeler, 2002; Mercury 2006 Committee Statement)



# Importance Of Measuring Mercury Deposition

## 1) Decrease In Mercury Deposition?

➤ *Important To Measure Potential Hg Reductions In Wet Deposition To Assess Policy and If Expected Billions Of Dollars Of Emission Controls Are Working*

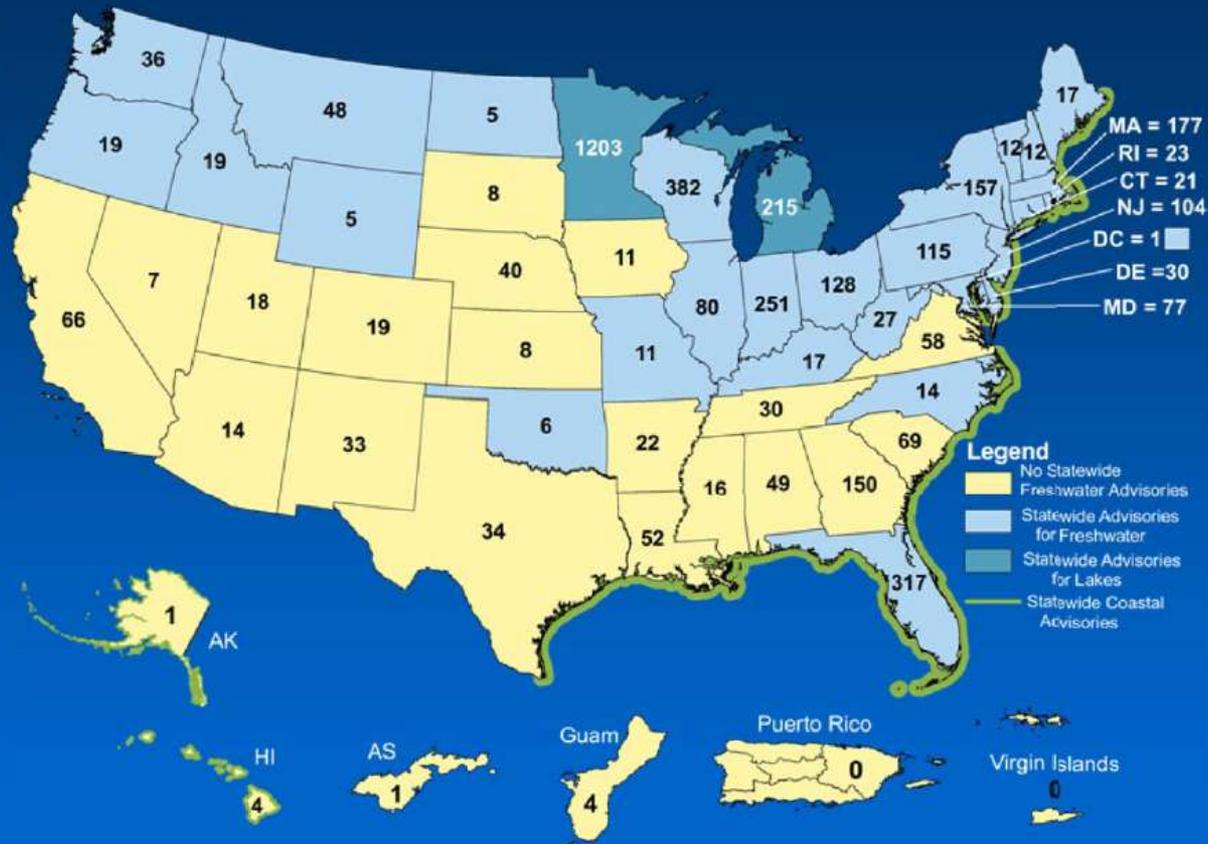
**\*\* Mercury Deposition Network Is The Only National Scale Network In Place To Measure The Affects Of Hg Emission Reductions In The Environment**

## 2) No Hg Deposition Reductions?

➤ *No Hg Reductions is an equally important find and could indicate that other mercury sources are at play (i.e. global (non-US based) sources of mercury).*

# Need For Mercury Deposition Network

## Total Number of Fish Consumption Advisories – 2008



**NOTE:** This map depicts the number of fish advisories issued by the states as of December 2008. Because only selected waterbodies are monitored, this map does not reflect the full extent of chemical contamination of fish tissues in each state or territory.

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# *Monitoring Mercury Deposition*

*A Key Tool to Understanding the Link between Emissions and Effects*

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**State and Provincial Hg fish consumption advisories have increased to include:**

- 4,249 advisories in 50 states which represent:**
  - 43% of the Nation's total lake acres**
  - 39% of the Nation's total river miles**
  - 42% of the Nations coastal waters and**
  - 100% of the Great Lakes**



# Impacts Of Hg Deposition In The Pacific Northwest

## EPA National Rivers And Streams Assessment



## National Rivers and Streams Assessment

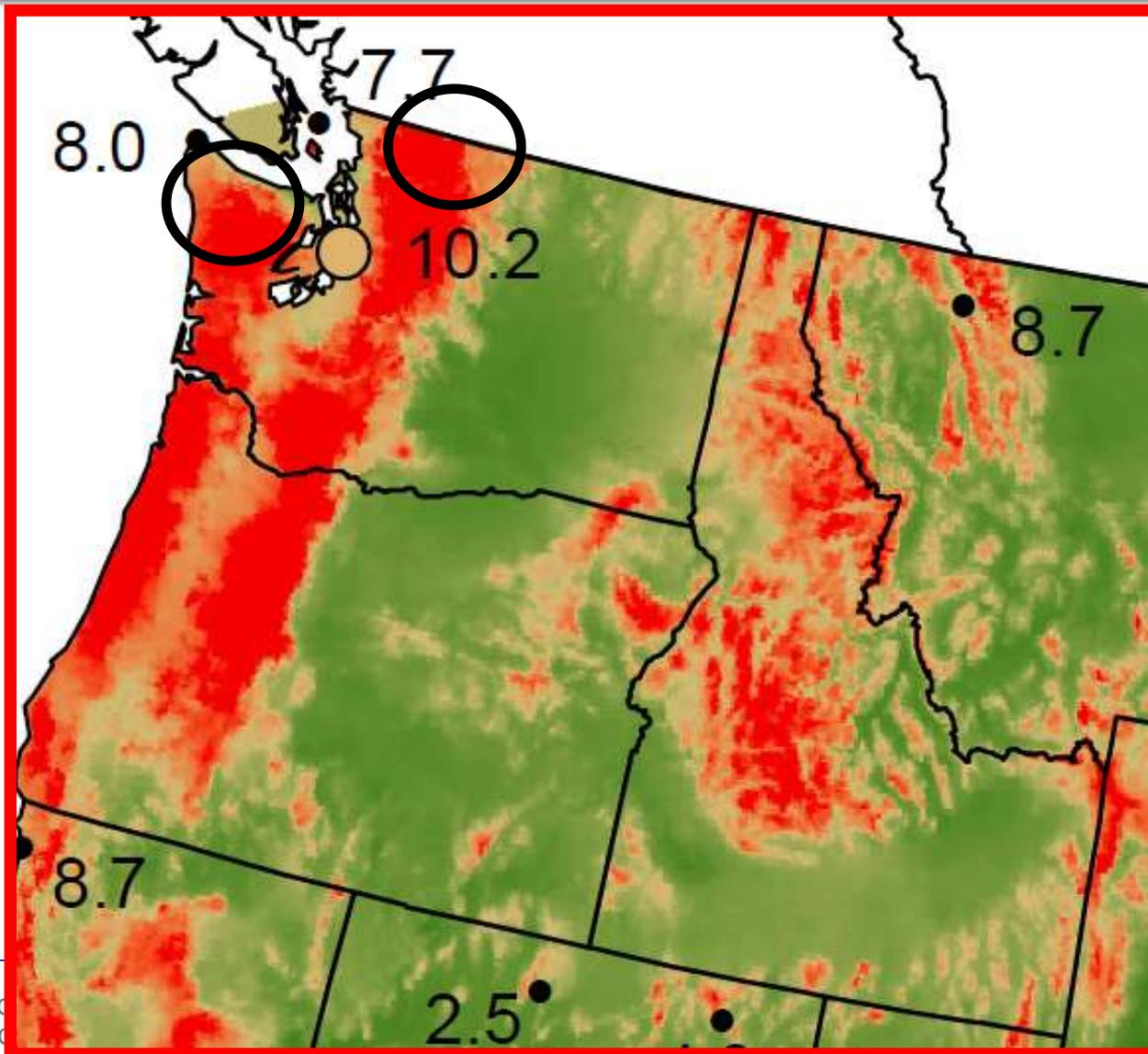
### 2008–2009

#### A Collaborative Survey

All fillet samples analyzed for the NRSA contain quantifiable levels of mercury. Fish tissue results indicate that 13,144 river miles have concentrations above the 300 parts per billion human-health-based water quality criterion for mercury; 38,400 river miles do not. Figure 23 summarizes the target and sampled populations for the fish tissue indicator.

Elevated mercury levels in fish are the leading cause of fish consumption advisories in the U.S. Urban river results showed that mercury concentrations occurred above the 300 ppb human health screening value at about a quarter of the assessed urban river miles. These results demonstrate the pervasive nature of mercury deposition in watersheds of the U.S. and mercury's subsequent accumulation in fish. PFCs are recognized as contaminants of emerging concern because they are toxic, ubiquitous,

# NPS WCAP Hg Study 2002-2007



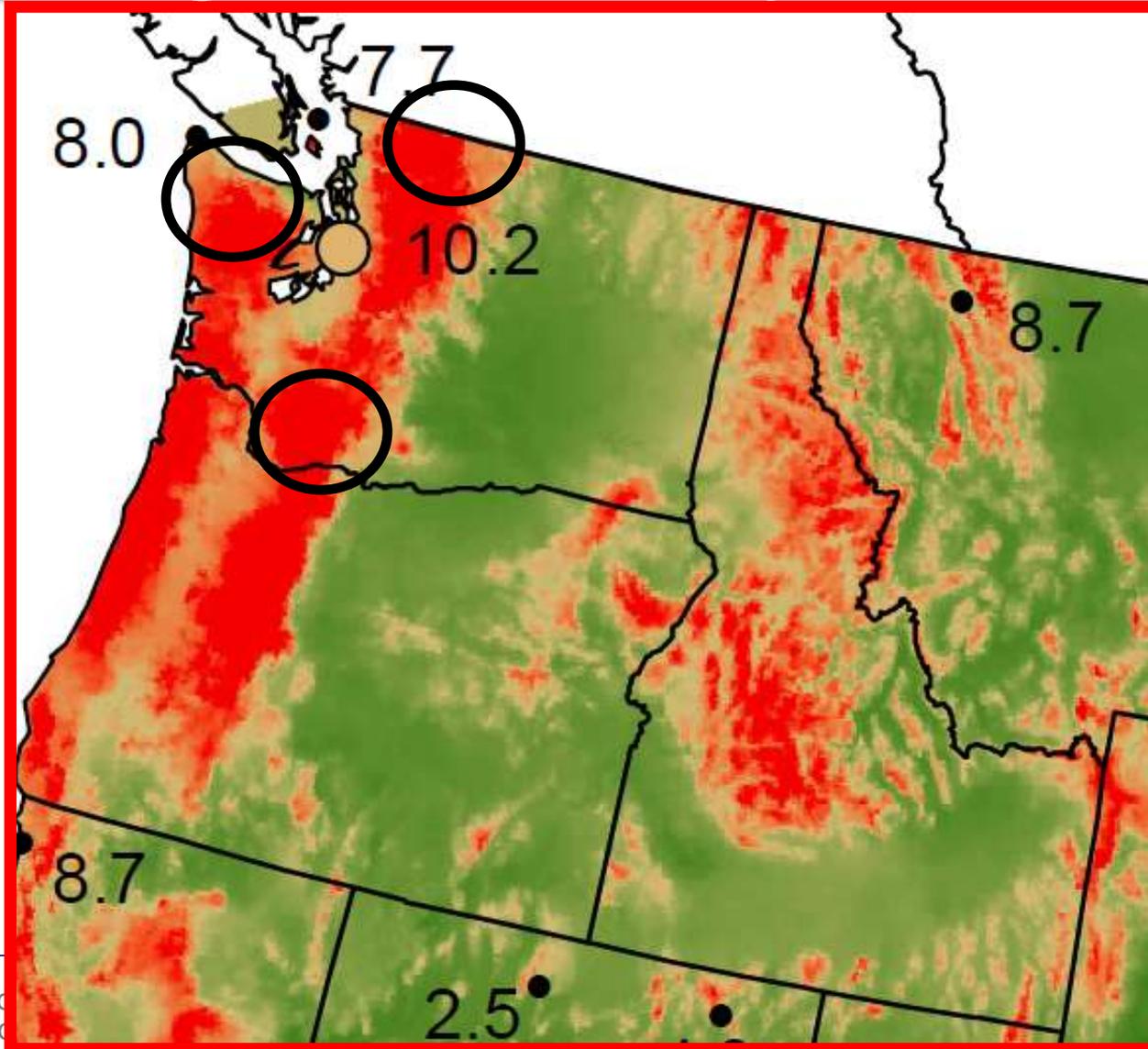
# Western Airborne Contaminants Assessment Project National Park Service (2002-2007)

- 7 Ecosystems Monitored Across Western US  
(Including Hoh Rainforest National Park)
- Contaminants Tended To Accumulate At Higher Elevations
- Some Of The Highest Hg Concentrations In Fish At High Alpine Lakes

## Although Hg Deposition Relatively Low In Pacific Northwest Arctic Parks

- **“In-Lake Biological processes vary among lakes/eco-regions and likely contributes to higher rates of mercury bio-accumulation in Fish”**
- **“Mercury concentrations in fish exceeded contaminant health thresholds for fish-eating wildlife at various parks**
- **“Sources are from as far away as Europe and Asia and as near as the local county.....(some study locations have) “deposition is primarily influenced by global atmospheric transport”**

# USGS High Alpine Lakes Hg In Fish Study 2007



# Tissue Contaminants and Associated Transcriptional Response in Trout Liver from High Elevation Lakes of Washington

Patrick W. Moran,<sup>\*†</sup> Neelakanteswar Aluru,<sup>‡</sup> Robert W. Black,<sup>†</sup> and Mathilakath M. Vijayan<sup>‡</sup>  
U.S. Geological Survey, Washington Water Science Center, Tacoma, Washington 98402, and Department of Biology, University of Waterloo, Waterloo, Ontario, Canada

*Environ. Sci. Technol.*, 2007, 41 (18), pp 6591-6597

DOI: 10.1021/es070550y

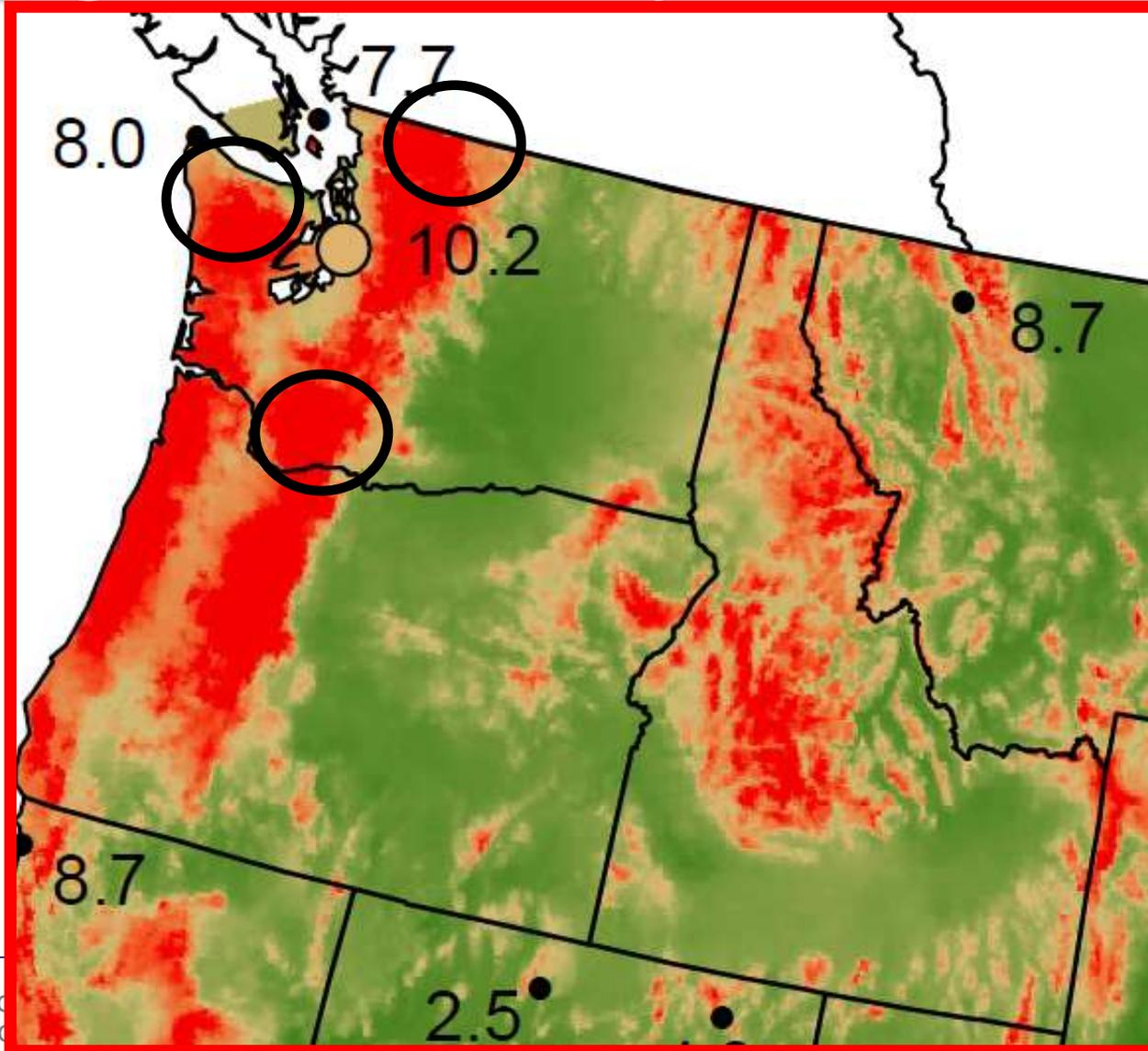
Publication Date (Web): August 14, 2007

Copyright © 2007 American Chemical Society

- The consistent cold temperatures and large amount of precipitation in the Olympic and Cascade ranges of Washington State are thought to enhance atmospheric deposition of contaminants.
- Mercury was detected in trout from all lakes sampled (15 to 262  $\mu\text{g}/\text{kg}$  ww)
- median total and methyl mercury were 30.4 and 0.34  $\mu\text{g}/\text{kg}$  dry (ww),
- our results suggest that local urban areas contribute to the observed contaminant patterns in these high elevation lakes,
- Evidence that mercury disrupts genetic information in fish

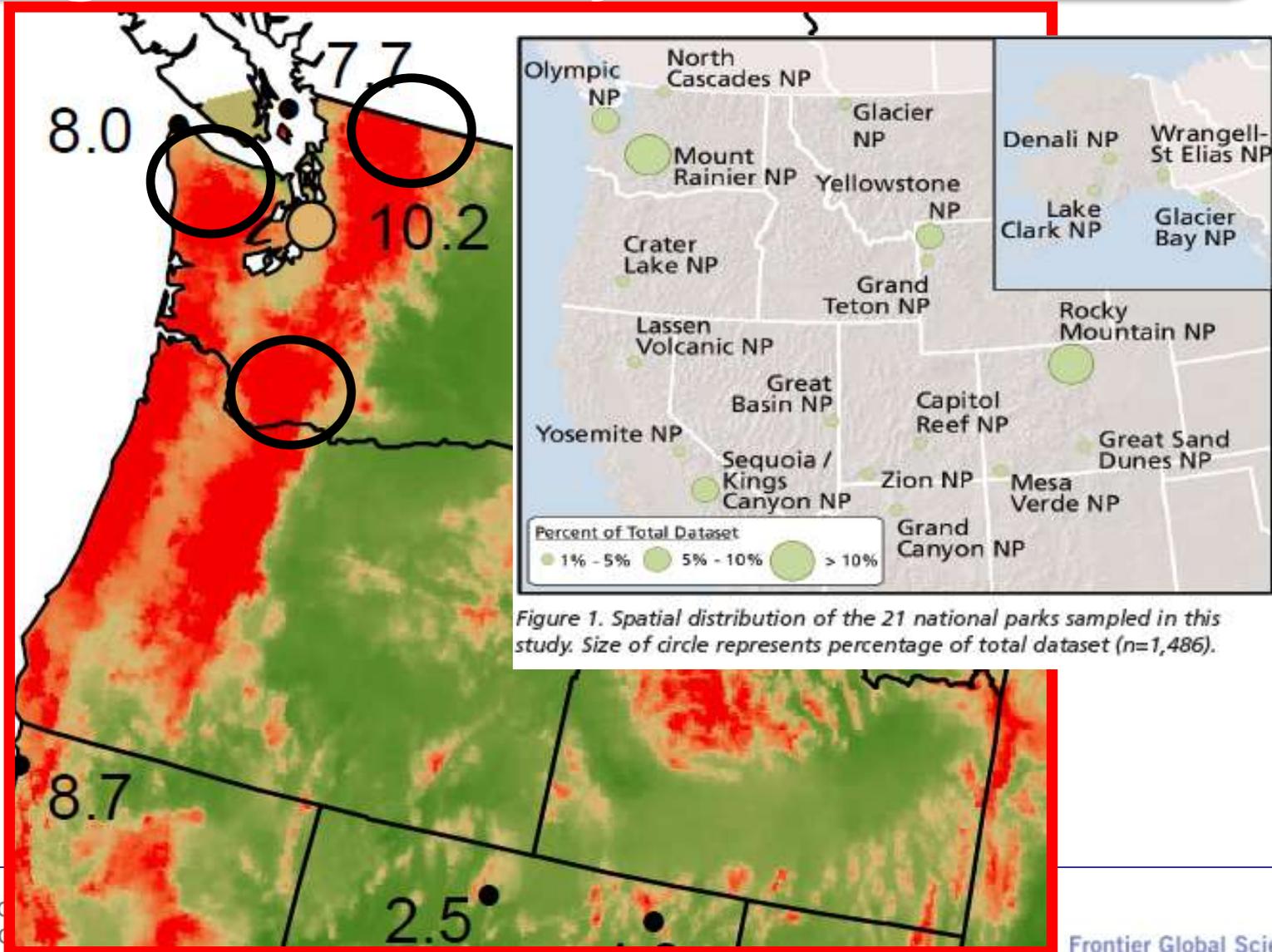
# NPS/USGS

## Hg In Fish Study 2013-2014

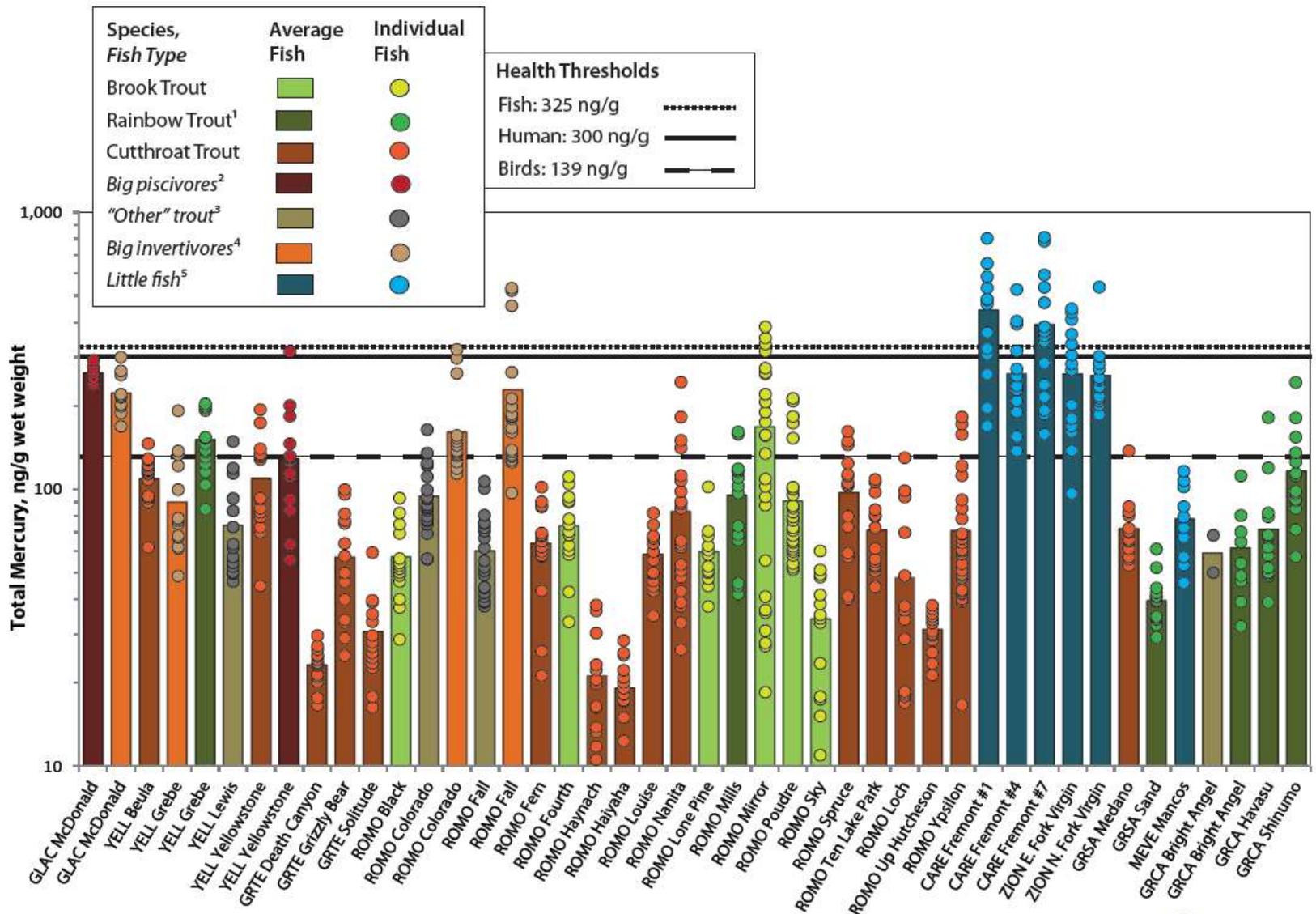


# NPS/USGS

## Hg In Fish Study 2008-2012



# NPS/USGS Hg In Fish Study 2008-2012



# NPS/USGS

## Hg In Fish Study 2008-2012

“Airborne Hg enters environmental cycles in complex ways, resulting in the contamination of even remote places

“There is concern that atmospherically deposited Hg could threaten the ecological integrity of aquatic communities in the parks and the wildlife that depend on them.

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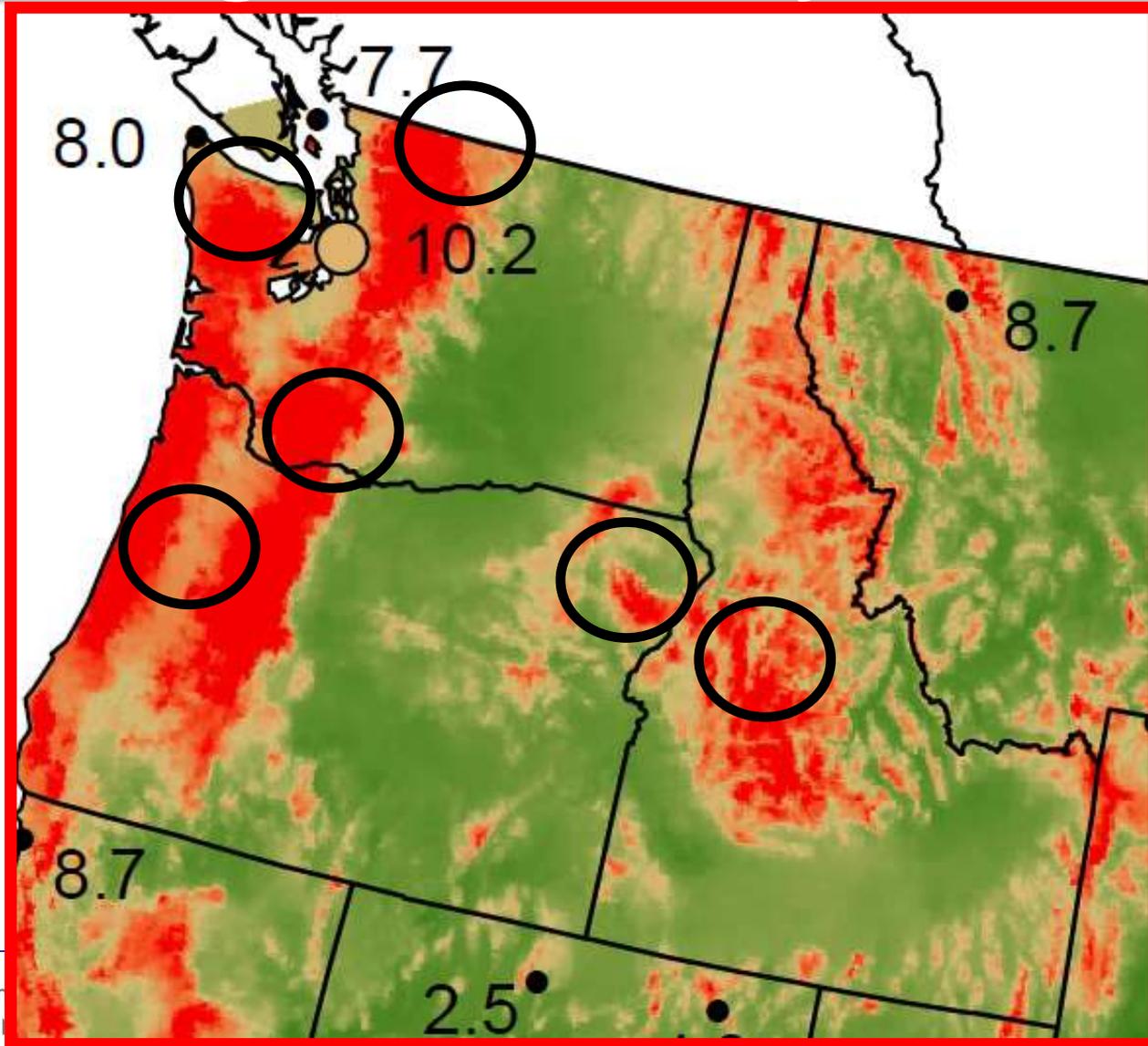
### Where does mercury come from?

Although there are natural sources of mercury such as volcanoes, most of the Hg that affects parks comes from burning fossil fuels like coal in power plants. Waste incinerators, oil and gas wells, and mining operations are other human-caused sources of mercury. In the atmosphere, Hg

travels long distances as tiny particles and gases. It settles to the ground by falling in rain and snow or landing as dust particles. In the environment and particularly in wetlands, Hg is transformed into a more toxic form, methylmercury, that can bioaccumulate and biomagnify in organisms.

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# NPS/USGS Hg In Fish Study 2013



# NPS/USGS

## Hg In Fish Study 2013

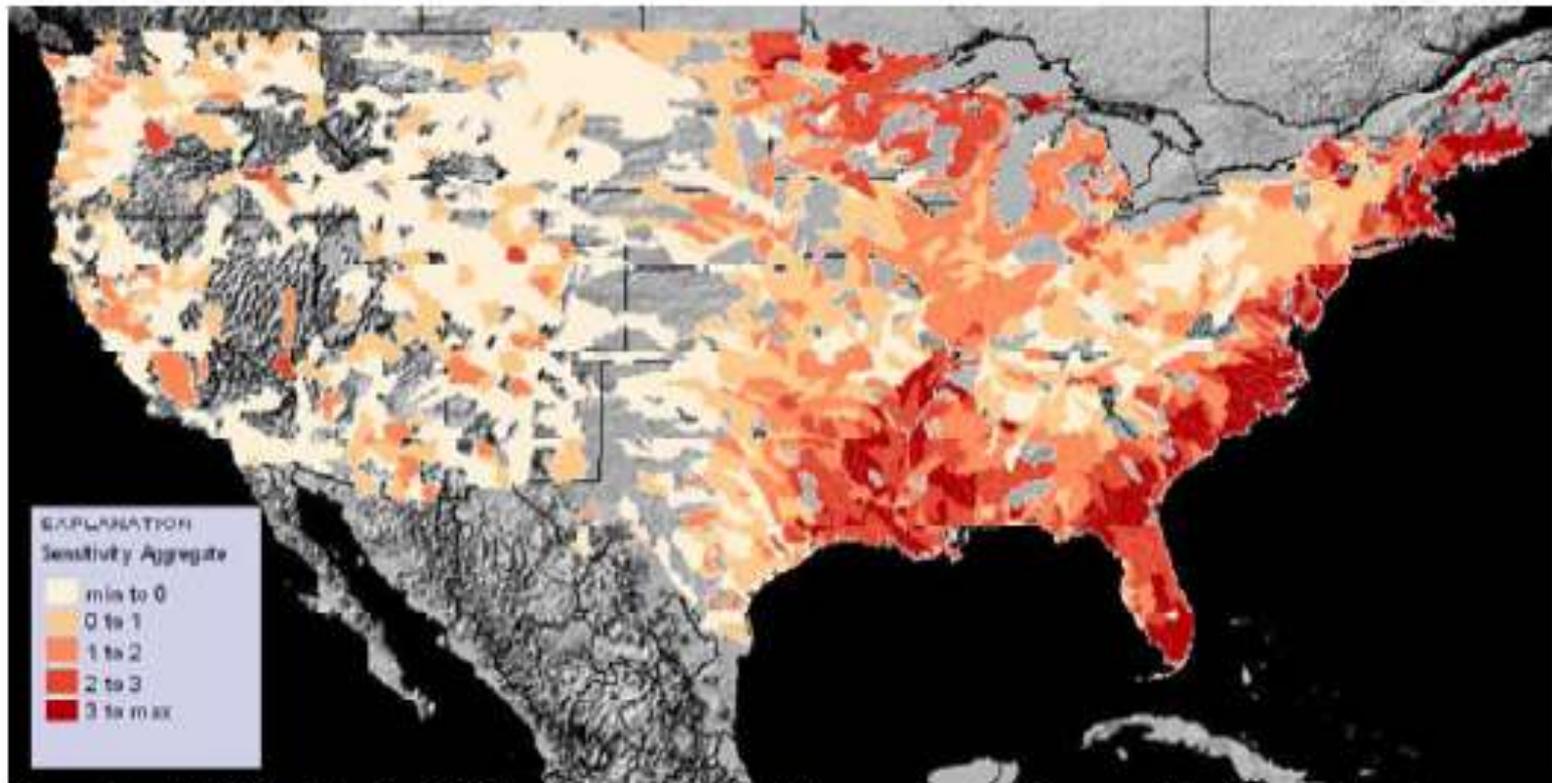
### Mercury Bioaccumulation in Fishes from Subalpine Lakes in the Wallowa-Whitman National Forest, Northeastern Oregon and Western Idaho

By Collin A. Eagles-Smith, Garth Herring, Branden L. Johnson, U.S. Geological Survey, and Rick Graw, U.S. Forest Service

- 27 Lakes Samples (177 Fish)
- 1 Fish Exceeded EPA Human Health (0.3 mg/Kg)
- 54% Exceeded ODEQ Tissue Residue Criteria (0.04 mg/Kg)
- 25-68% Exceeded Levels For Mink and Kingfisher
- “Total Hg May Be Present In These Lakes At Levels Associated With Ecological Risk”

# Does “Lower” Mercury Wet Deposition Impact Our Area?

## *USGS Mercury Methylation Sensitivity Map for Aquatic Ecosystems (Preliminary)*



Based on USGS data for TOC, pH, aquatic sulfate concentration, and hydric soils. Areas not colored are missing data for one or more of these indicators.



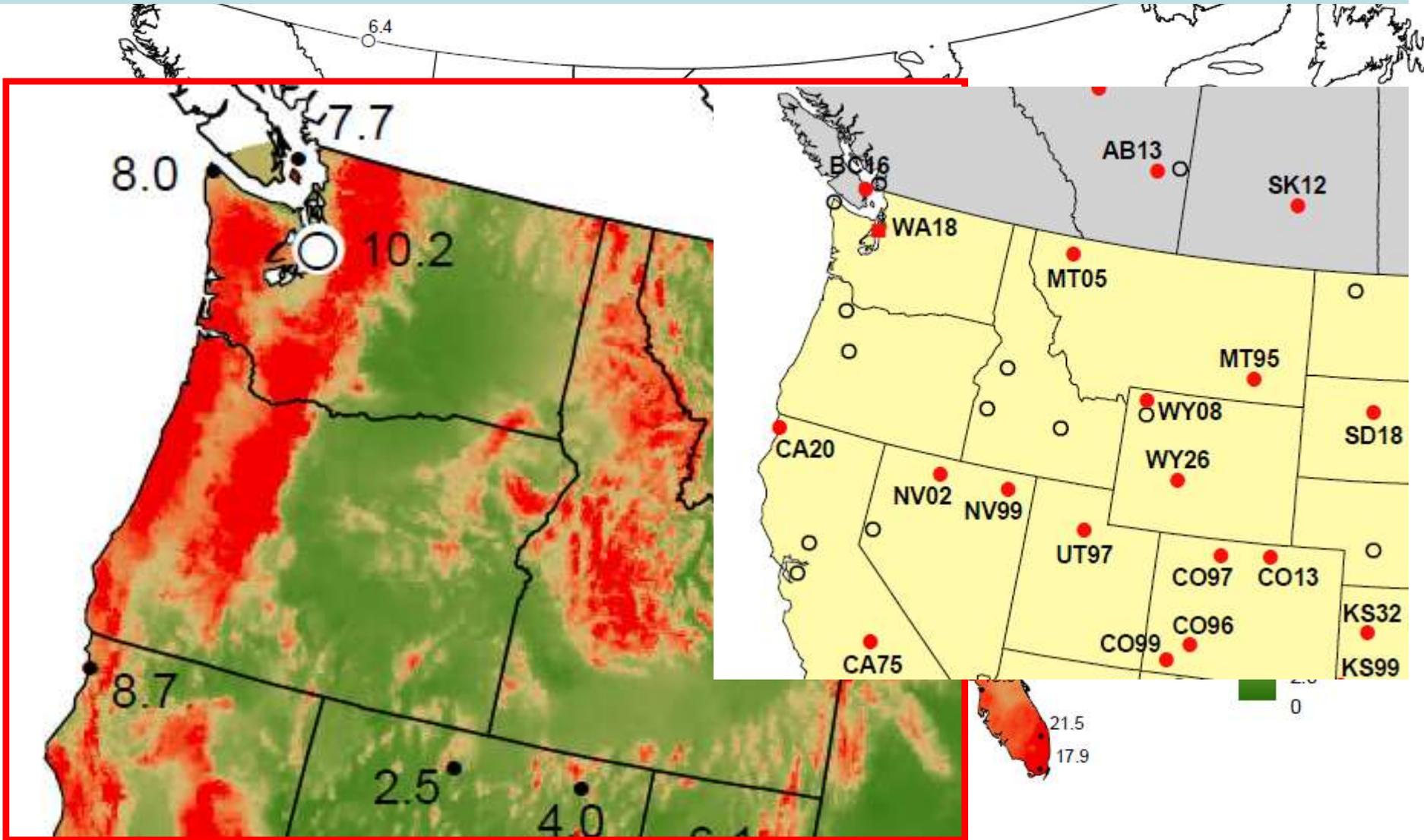
# How Much Mercury In Wet Deposition Will Impact Our Area?

Western Airborne Contaminants Assessment Project  
National Park Service (2002-2007)

**Although Hg Deposition Relatively Low In Pacific Northwest Parks**

- **“In-Lake Biological processes vary among lakes/eco-regions and likely contributes to higher rates of mercury bio-accumulation in Fish”**
- **“Sources are from as far away as Europe and Asia and as near as the local county.....(some study locations have) “deposition is primarily influenced by global atmospheric transport”**

# EPA Region 10 States – MDN Site Loss

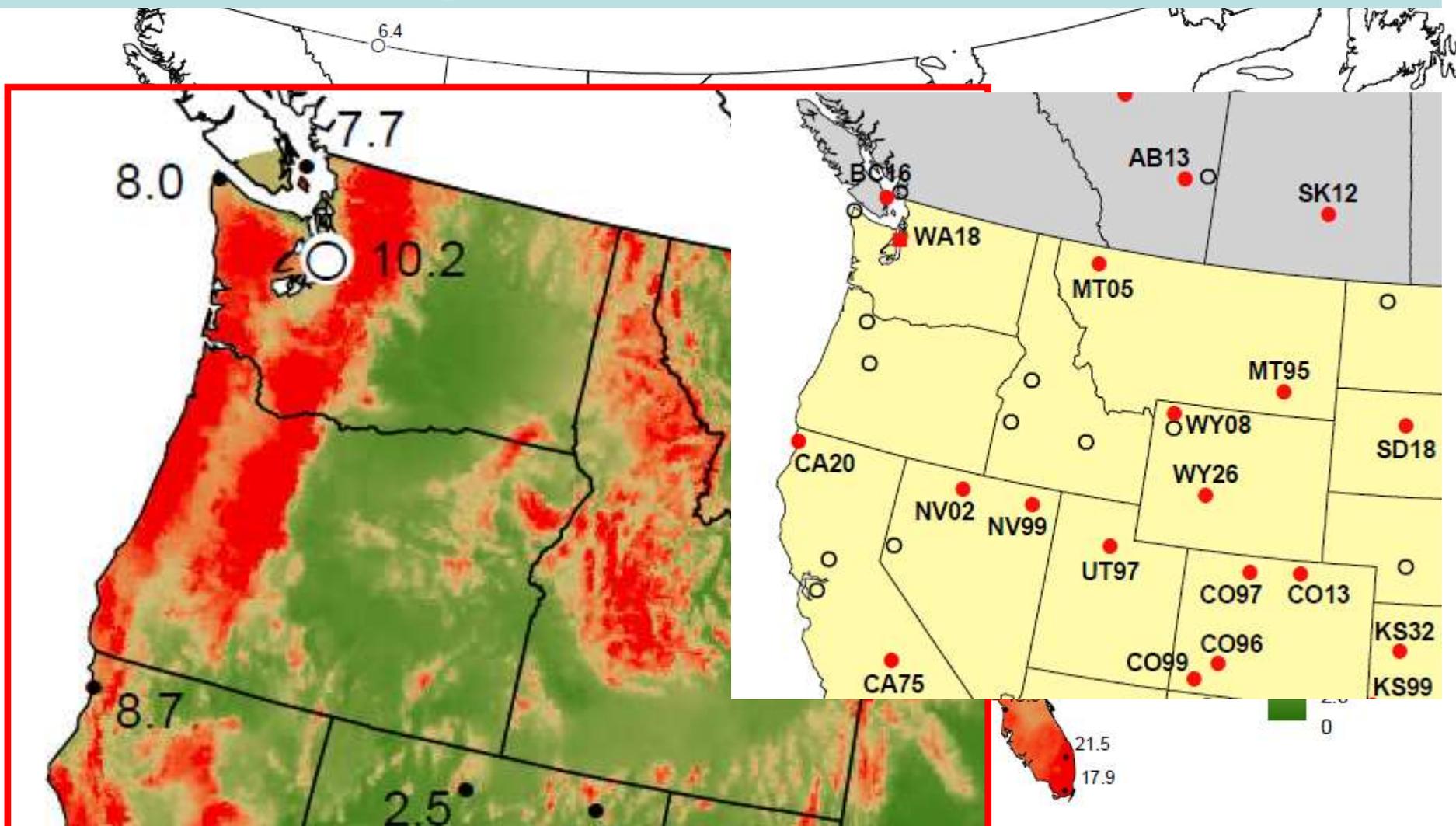


National Atmospheric Deposition Program/Mercury Deposition Network  
<http://nadp.isws.illinois.edu>

# Priority List Of Monitoring Needs

- Washington 03 (Makah Nation) upwind of all US sources; Asian input, national background. Currently Unfunded.
- High Elevation WA/OR we are predicting some of the highest deposition levels in the country; fish concentrations in these regions are also considered correspondingly high (WACAP, USGS, other)
- State of Oregon - no coverage since OR01 and OR10 have stopped
- State of Idaho - no coverage since ID03 has been stopped
- Important Effect Of Increase In Hg Emissions (East Asia) and Upcoming US Based Reductions = Critical To Monitor Now

# EPA Region 10 States – MDN Site Loss



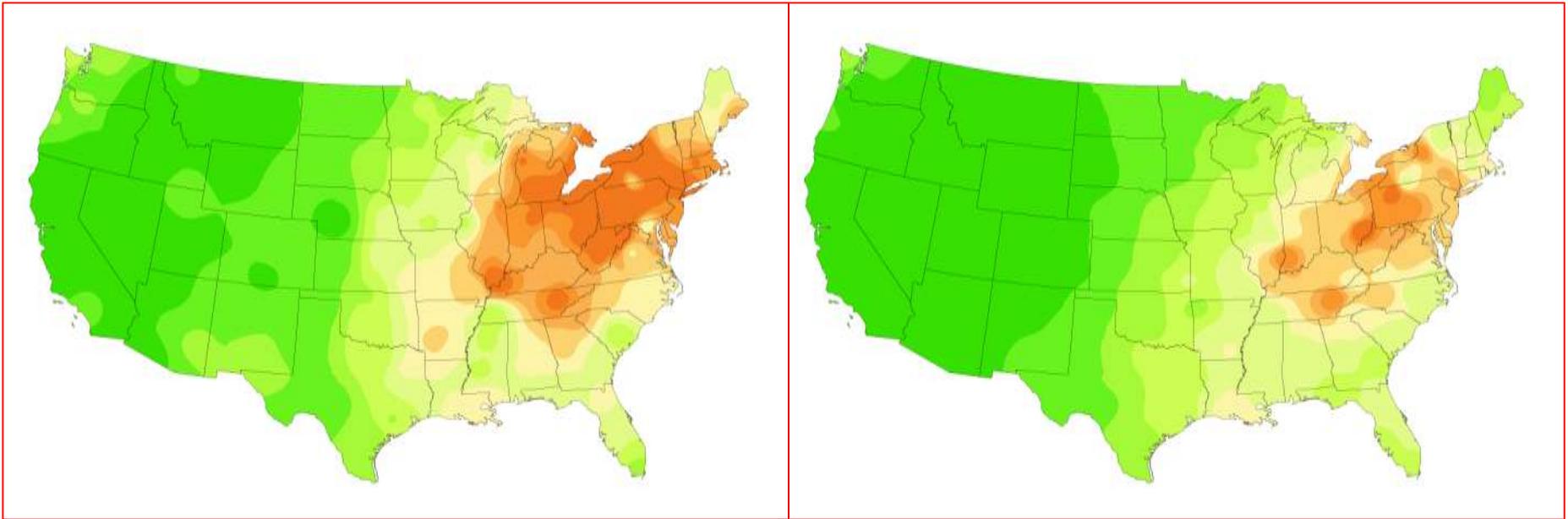
***If No Monitoring In Oregon and Idaho, the NADP Mercury Deposition Maps will essentially have no data therefore leaving these areas “blank”***

N:  
ht



# Sulfate Deposition Reductions: 1985-2008

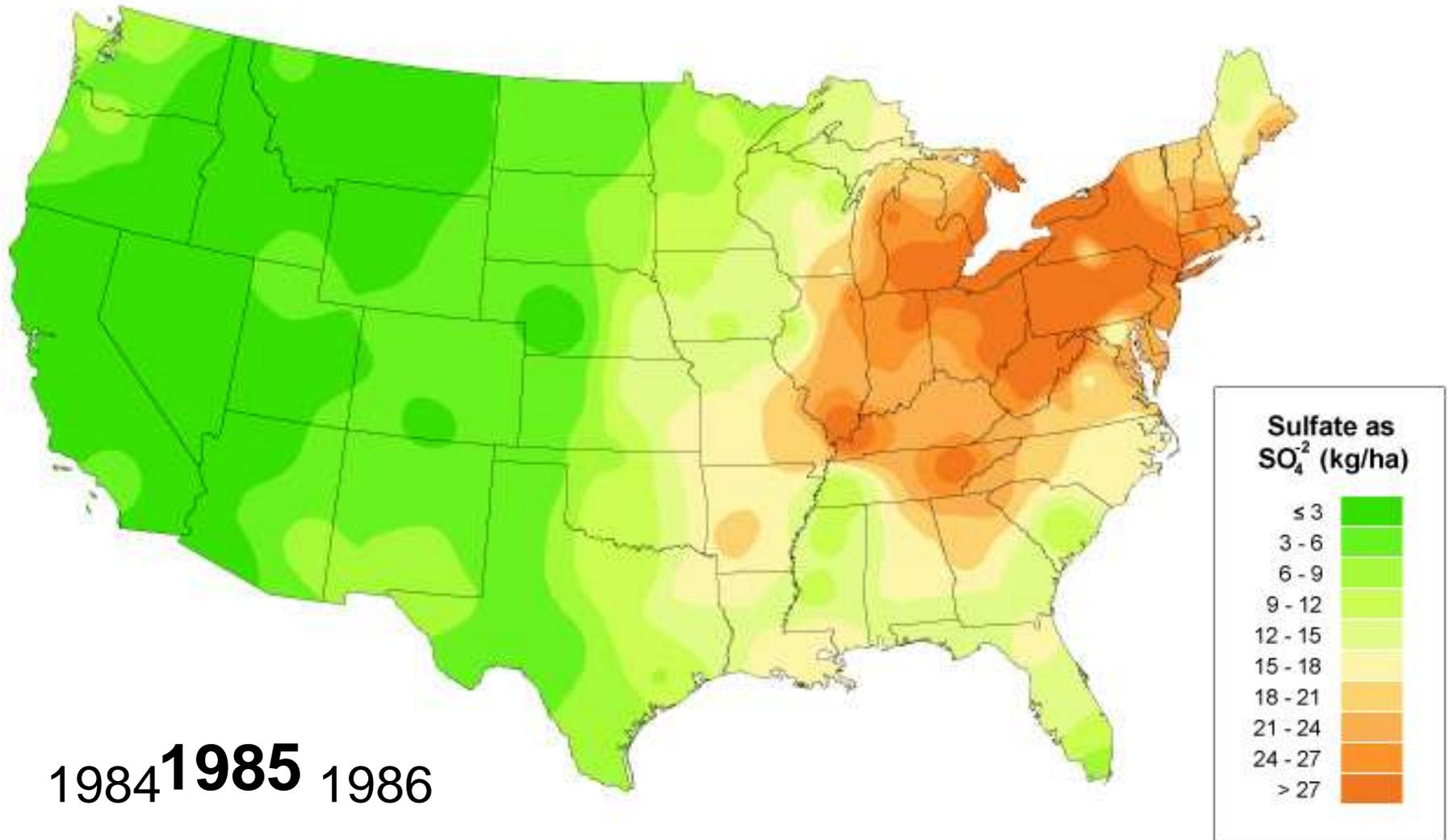
*Will We See The Same Reductions For Mercury After The Mercury Air Toxics Standards (MATS)?*



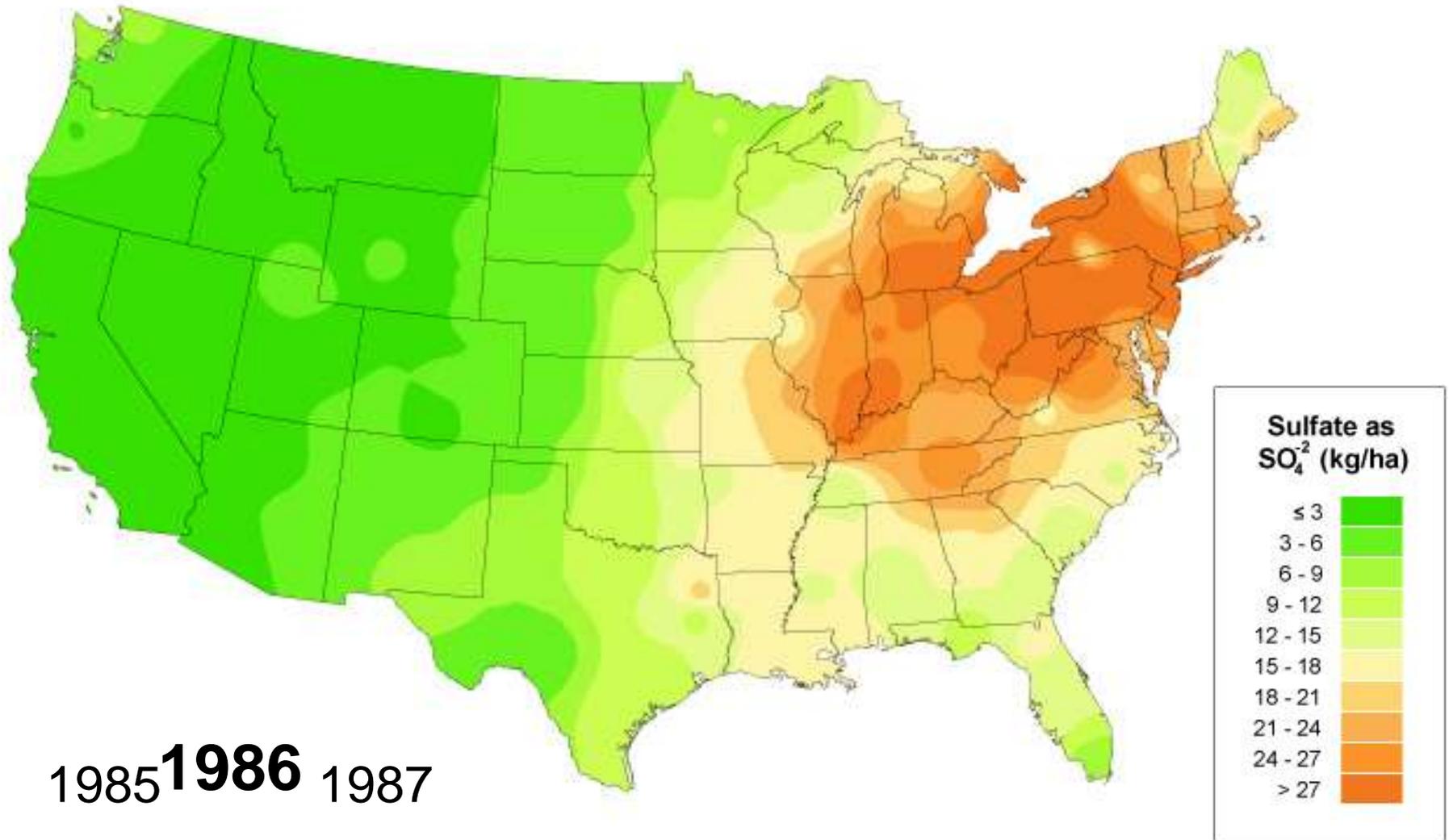
National Atmospheric  
Deposition Program

**Mercury Deposition**

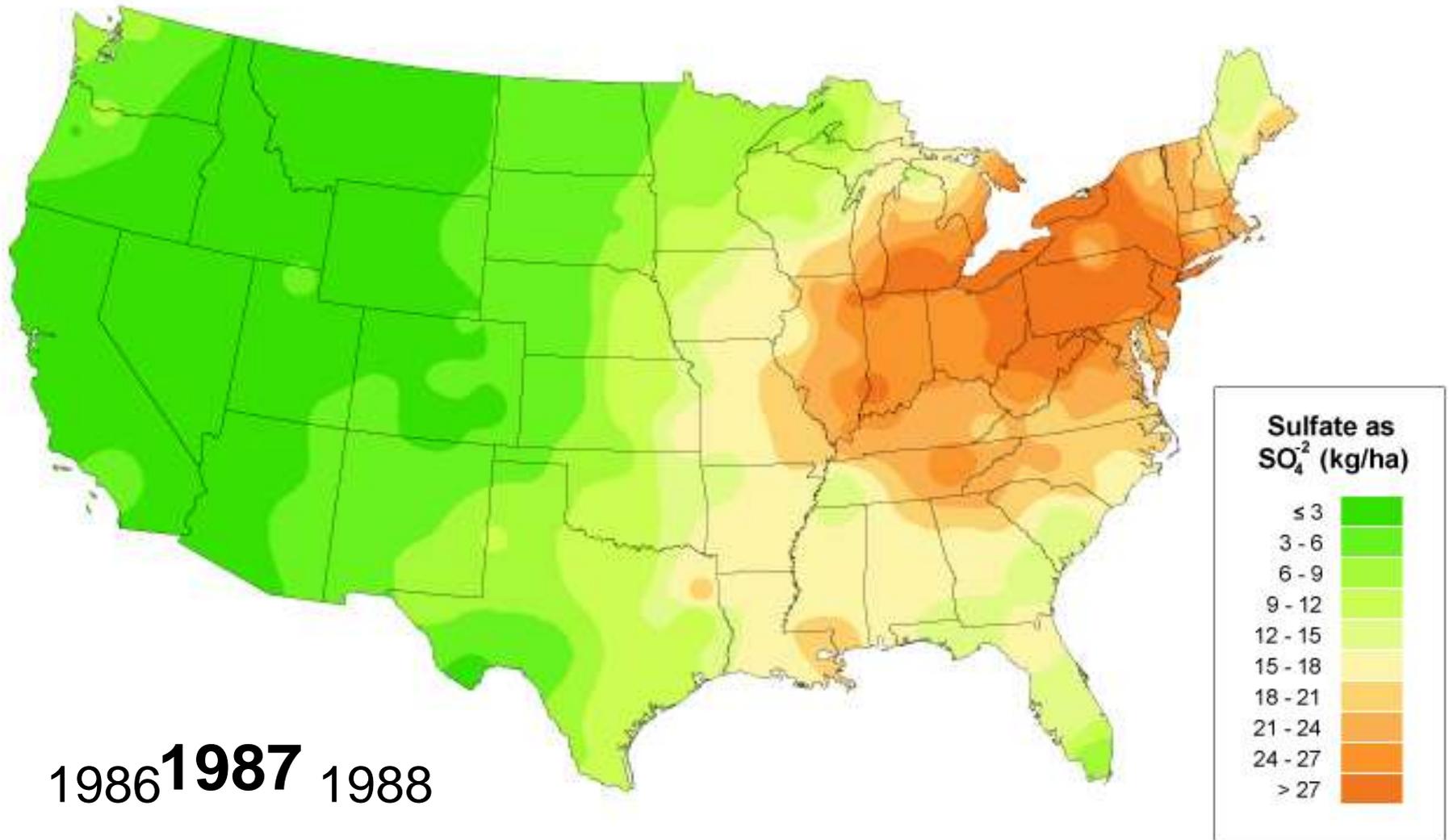
# Sulfate Ion Wet Deposition 1985-2008



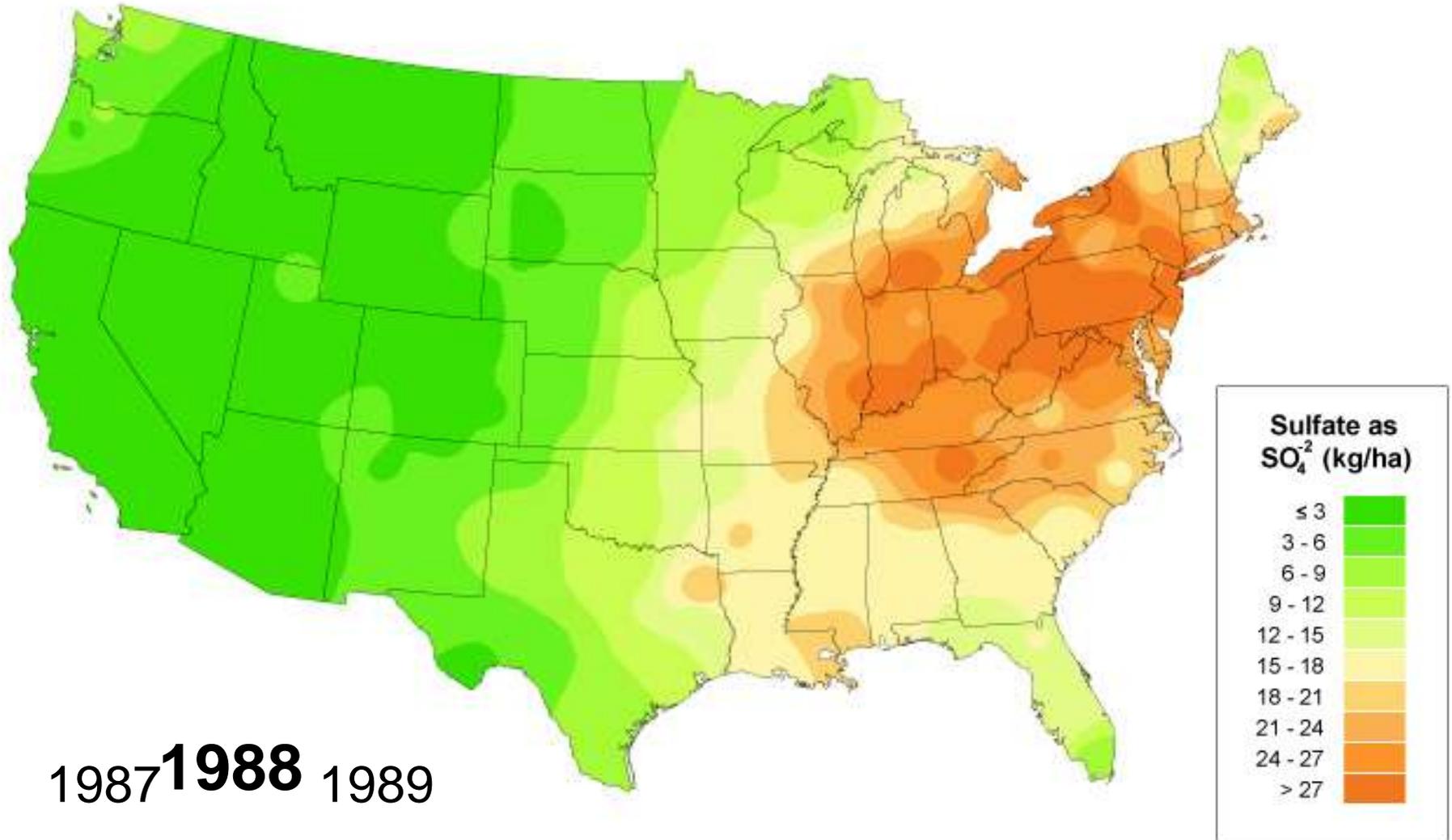
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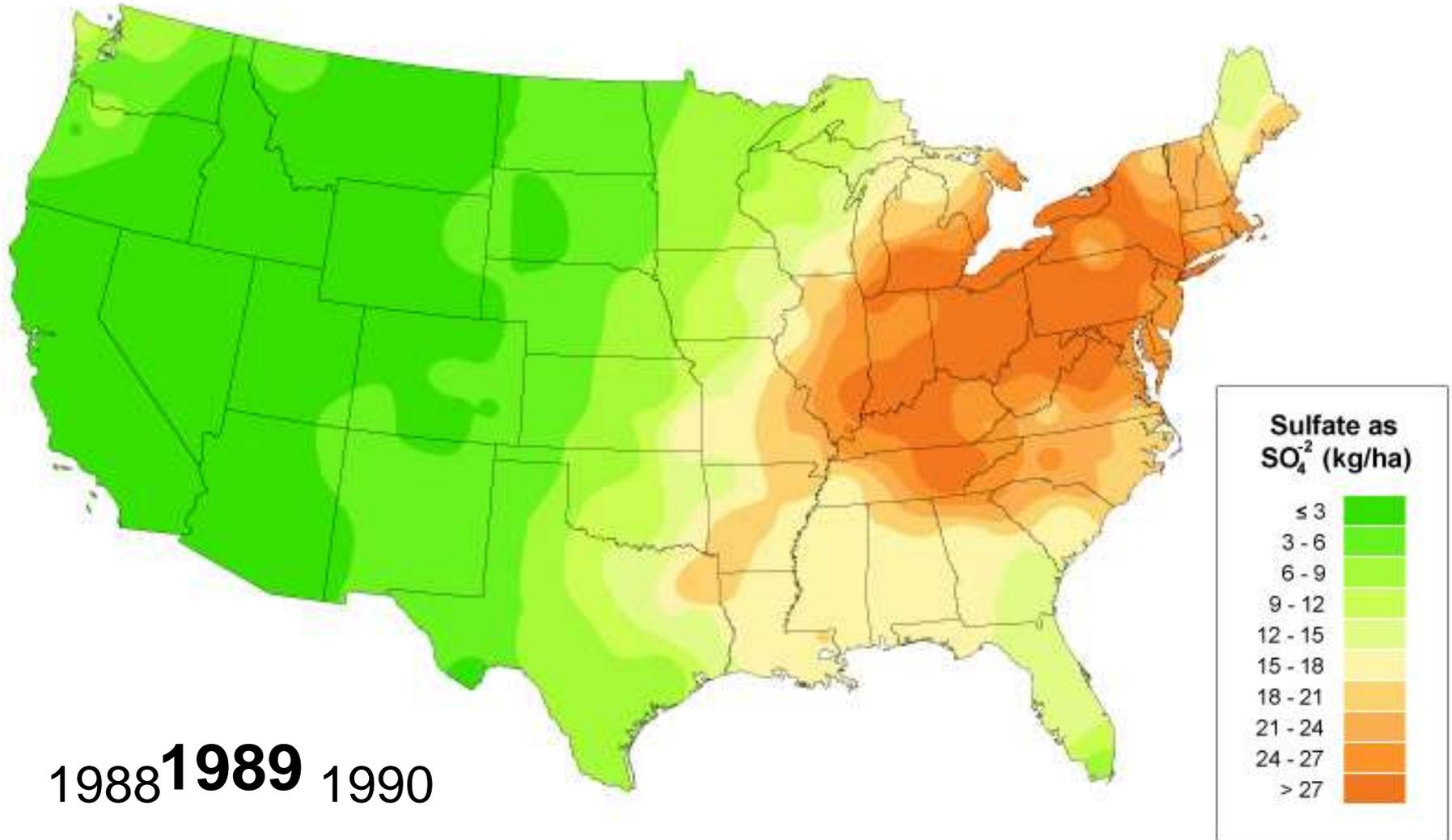
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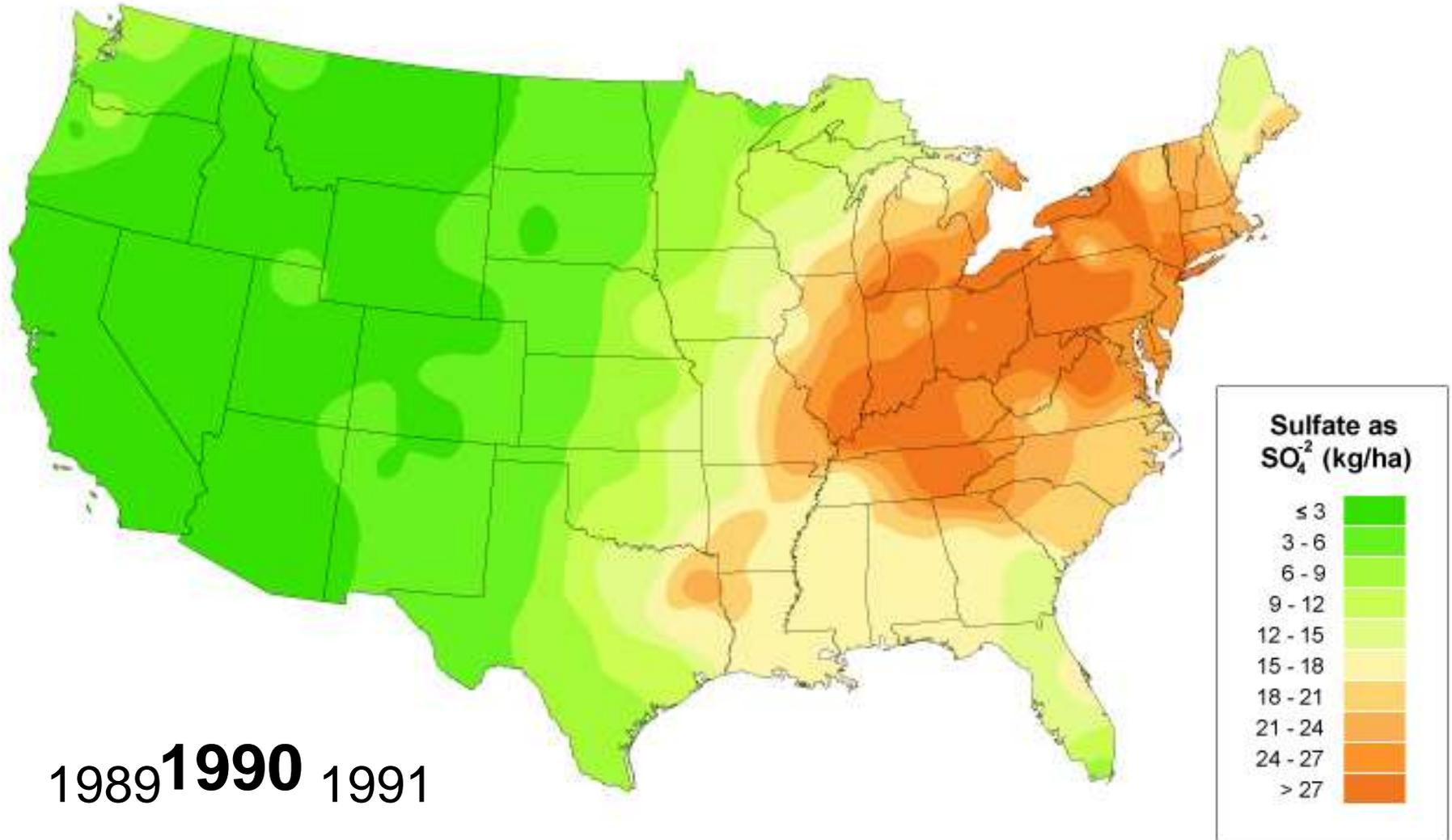
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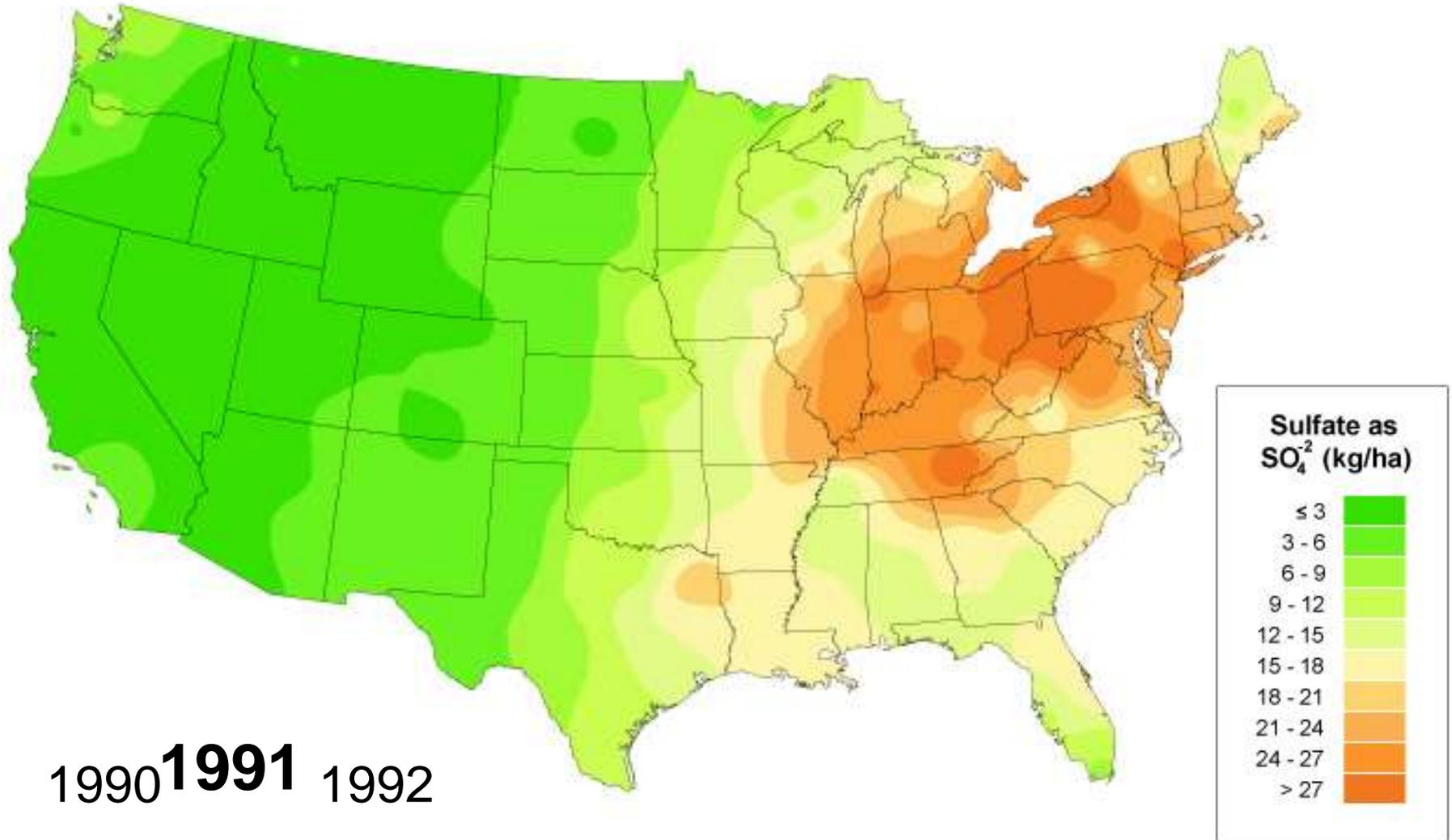
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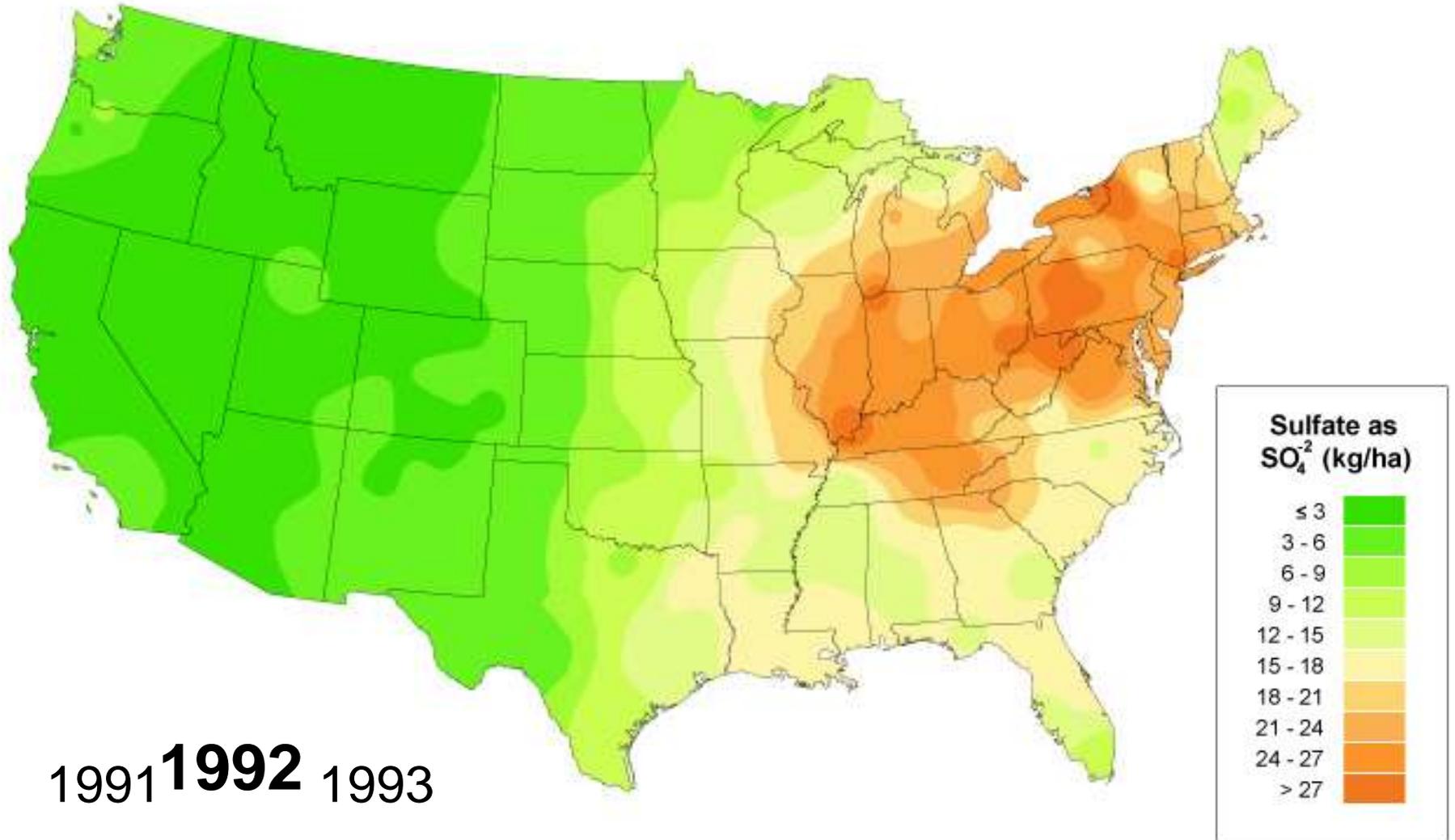
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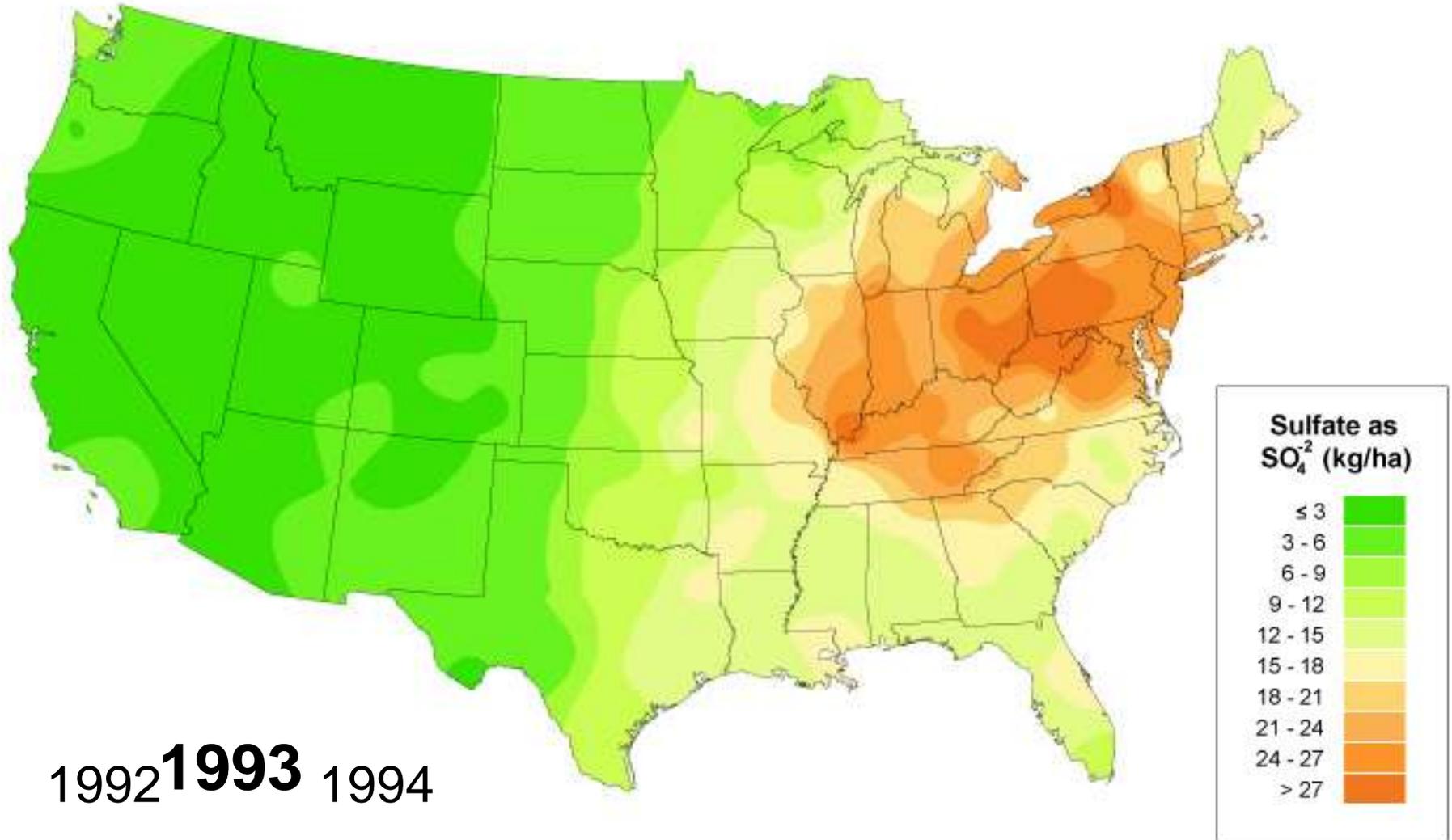
# Sulfate Ion Wet Deposition 1985-2008



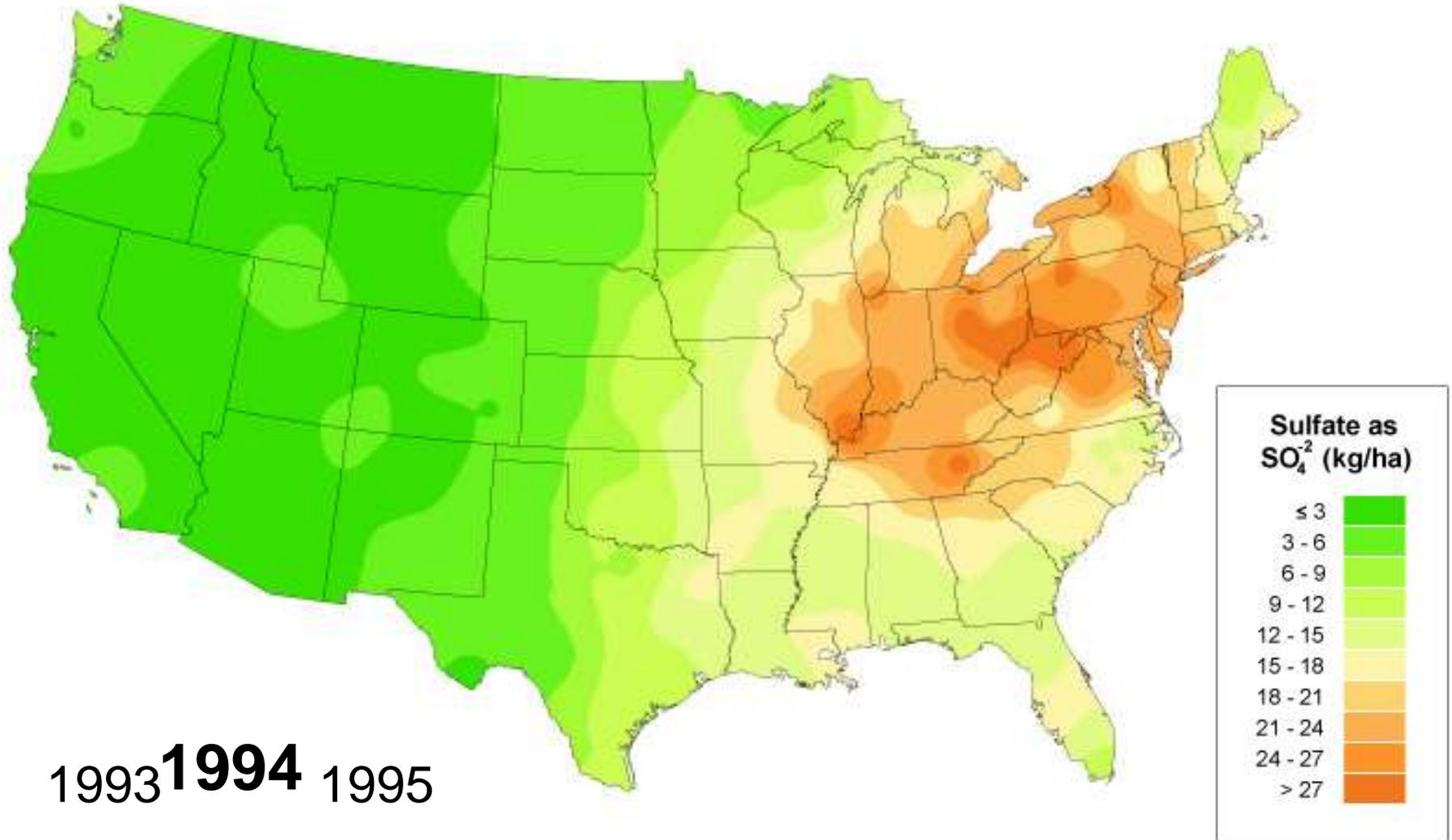
# Sulfate Ion Wet Deposition 1985-2008



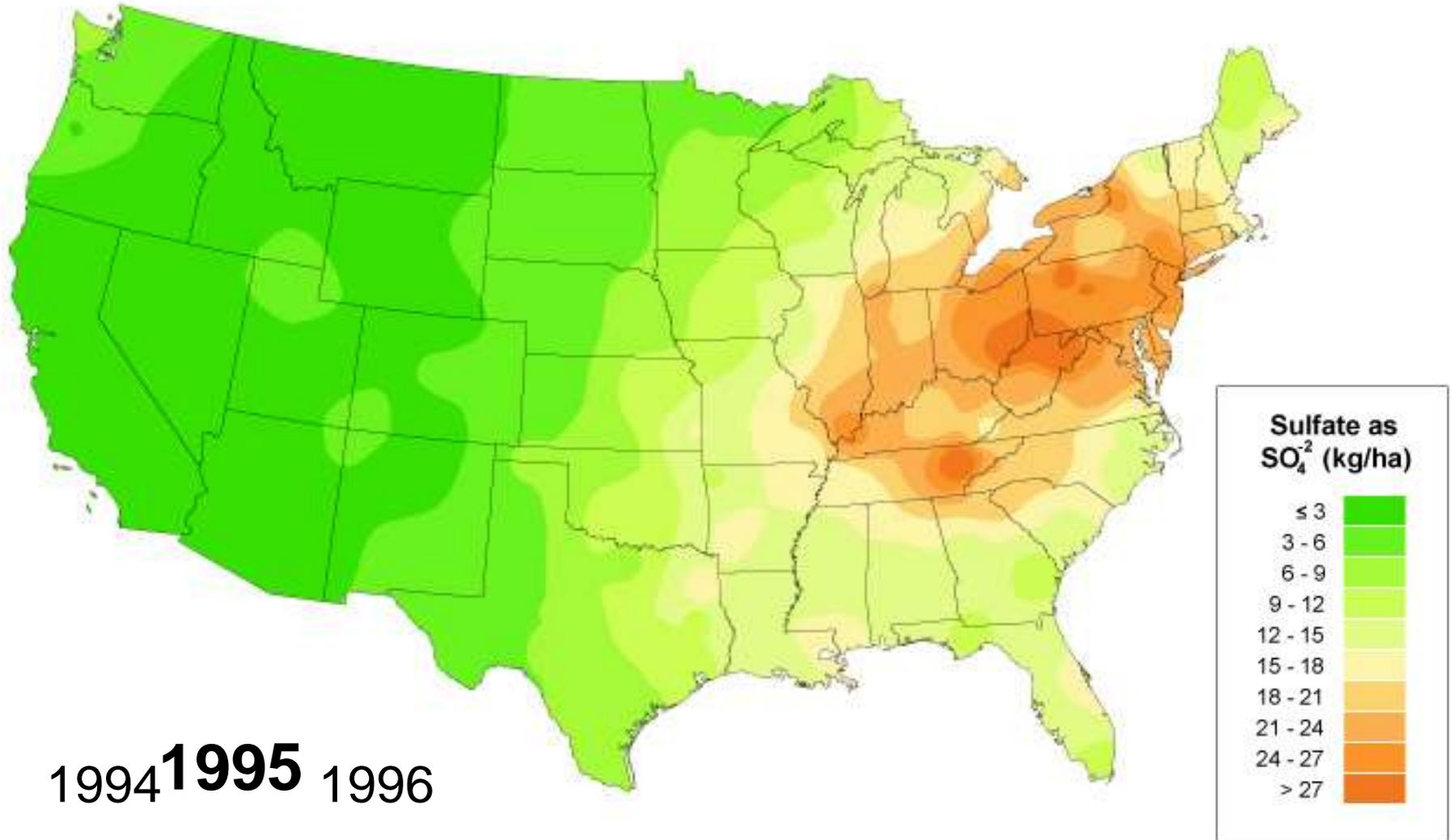
# Sulfate Ion Wet Deposition 1985-2008



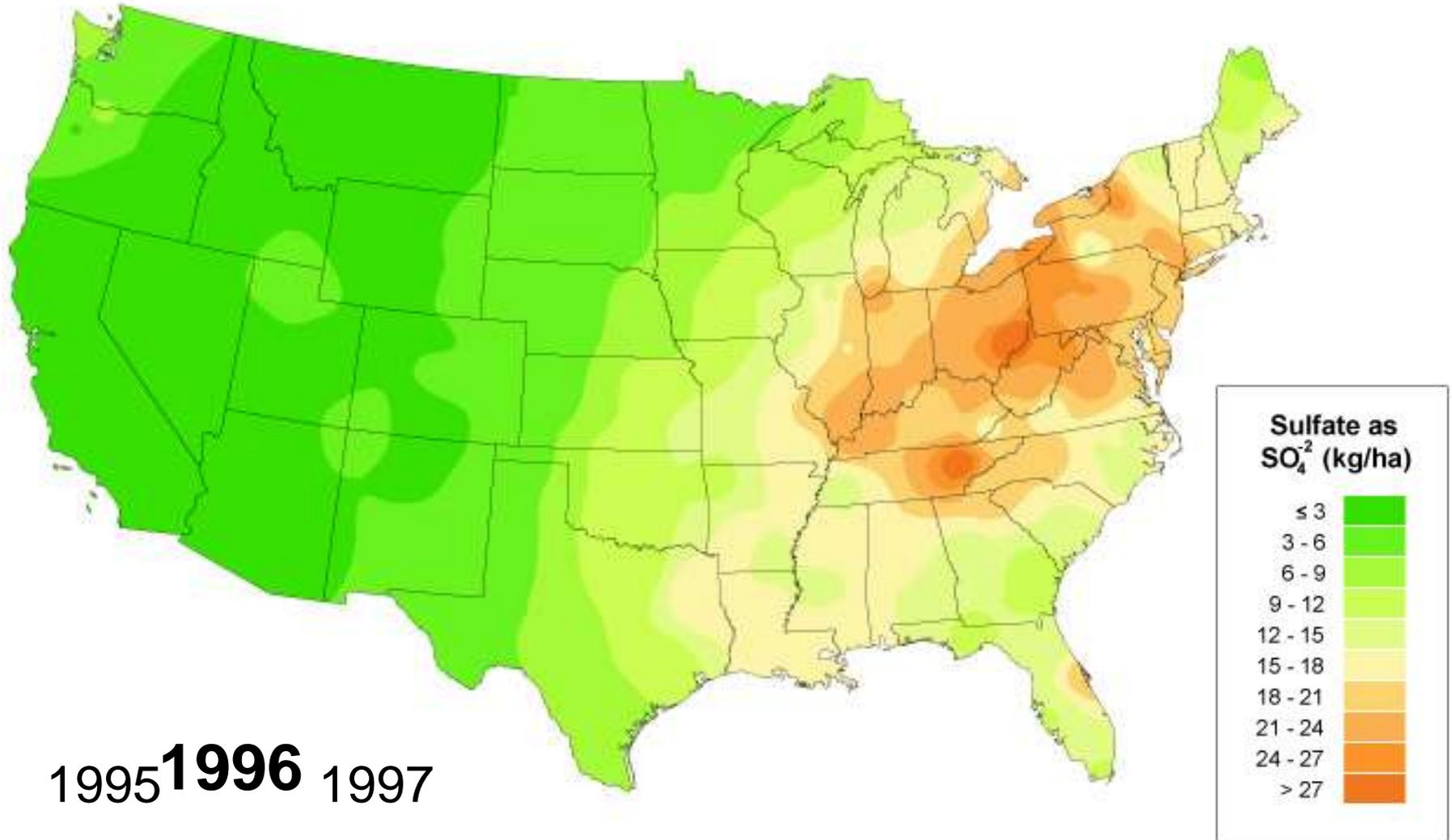
# Sulfate Ion Wet Deposition 1985-2008



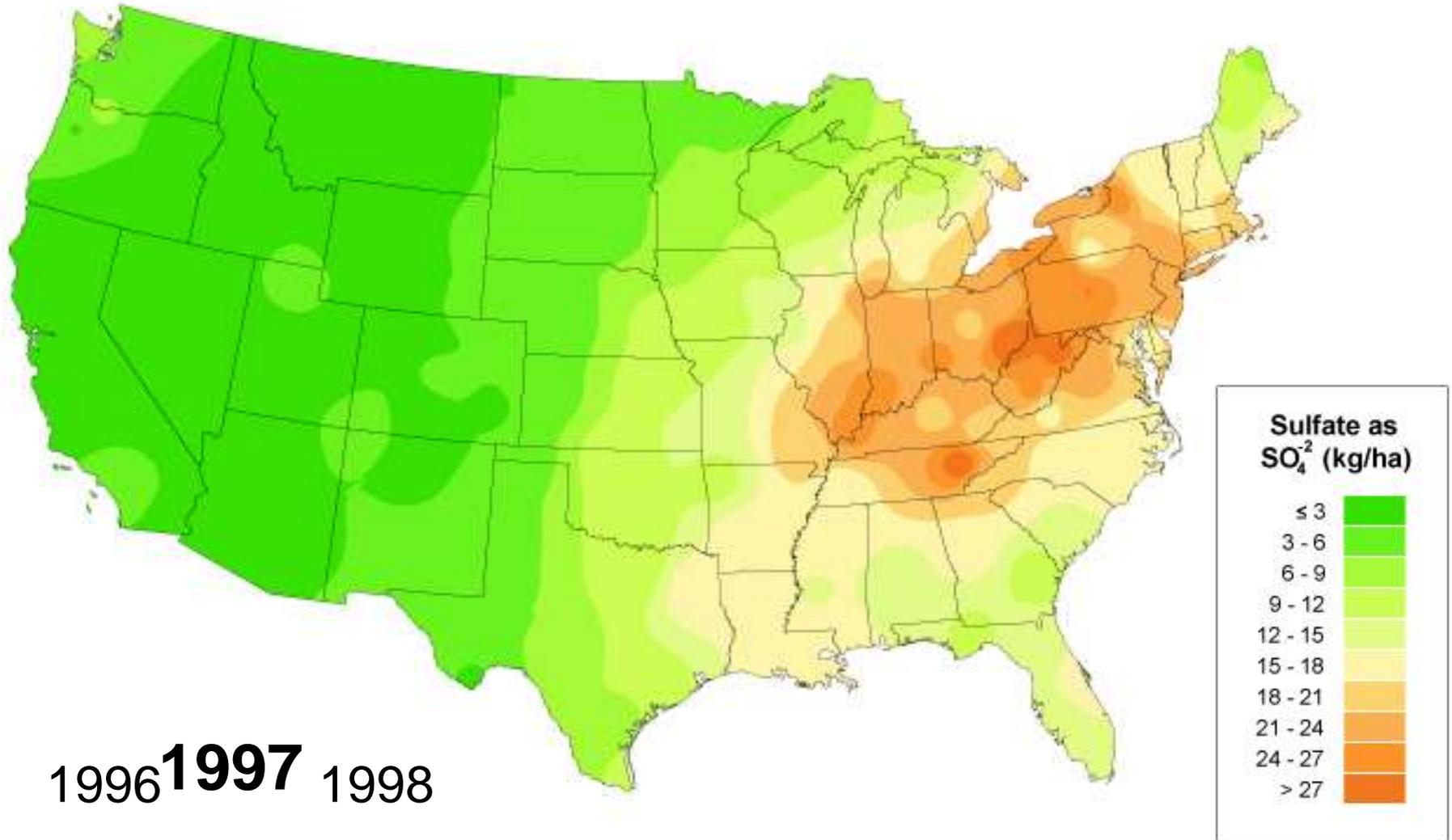
# Sulfate Ion Wet Deposition 1985-2008



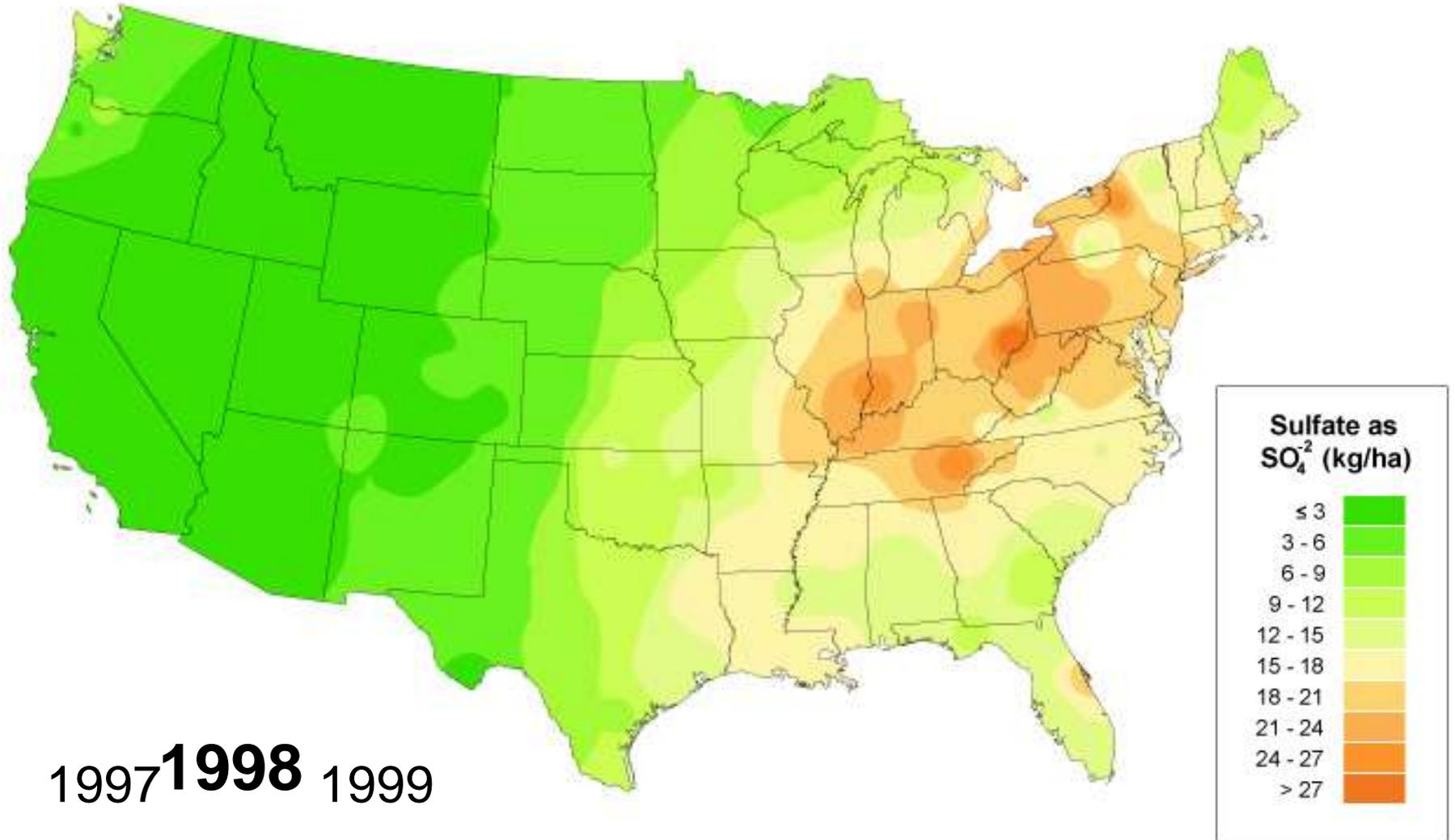
# Sulfate Ion Wet Deposition 1985-2008



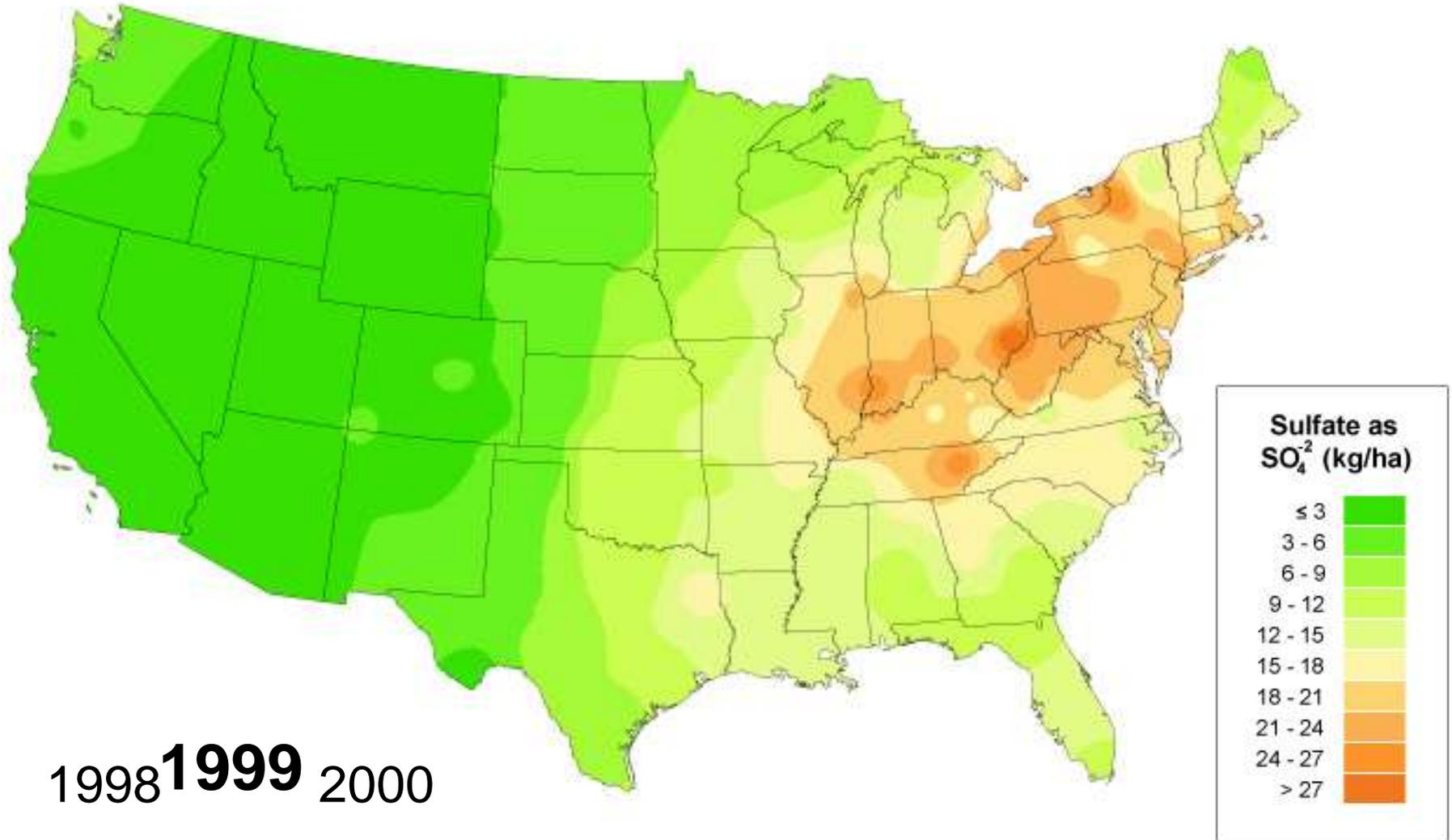
# Sulfate Ion Wet Deposition 1985-2008



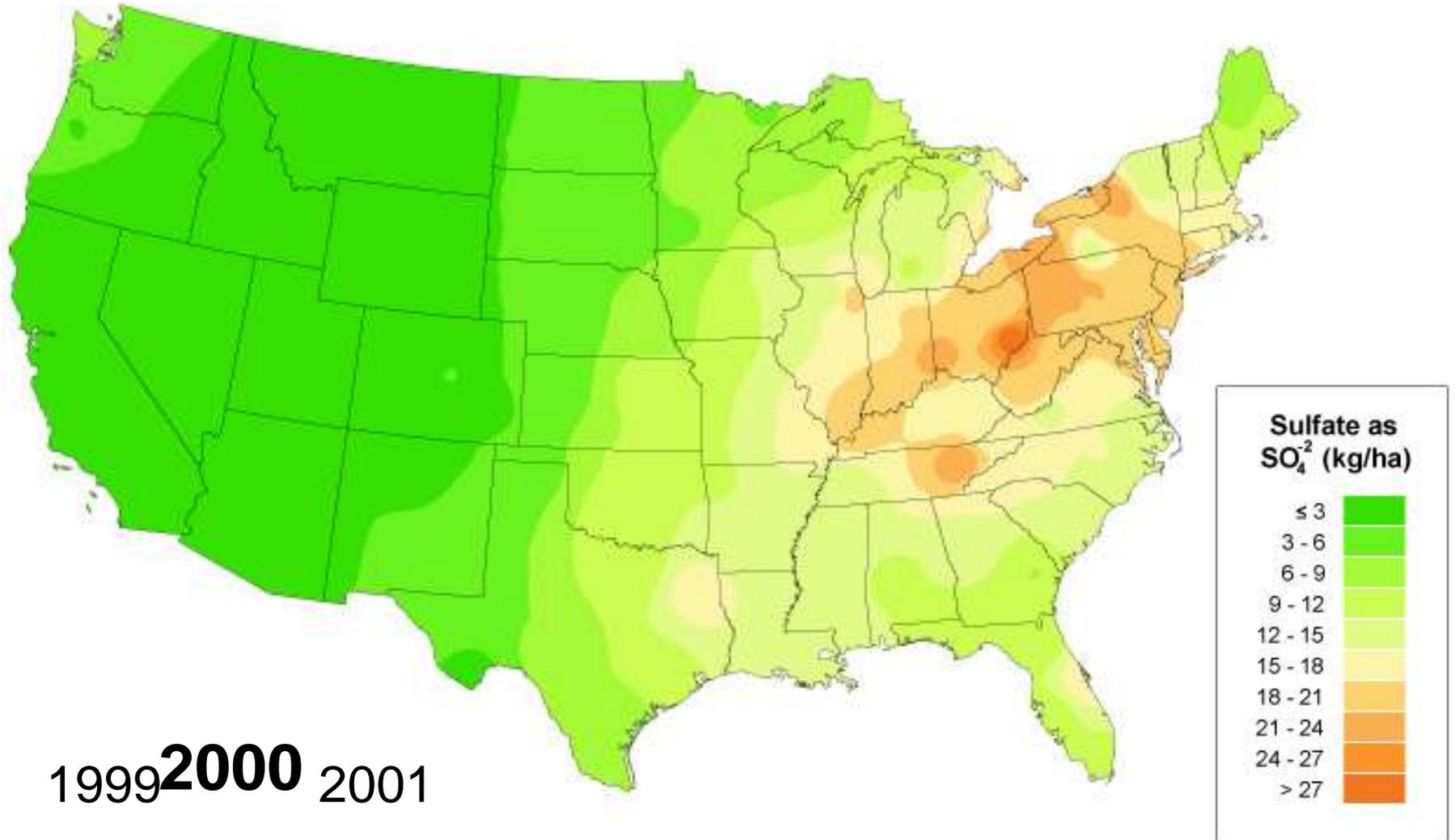
# Sulfate Ion Wet Deposition 1985-2008



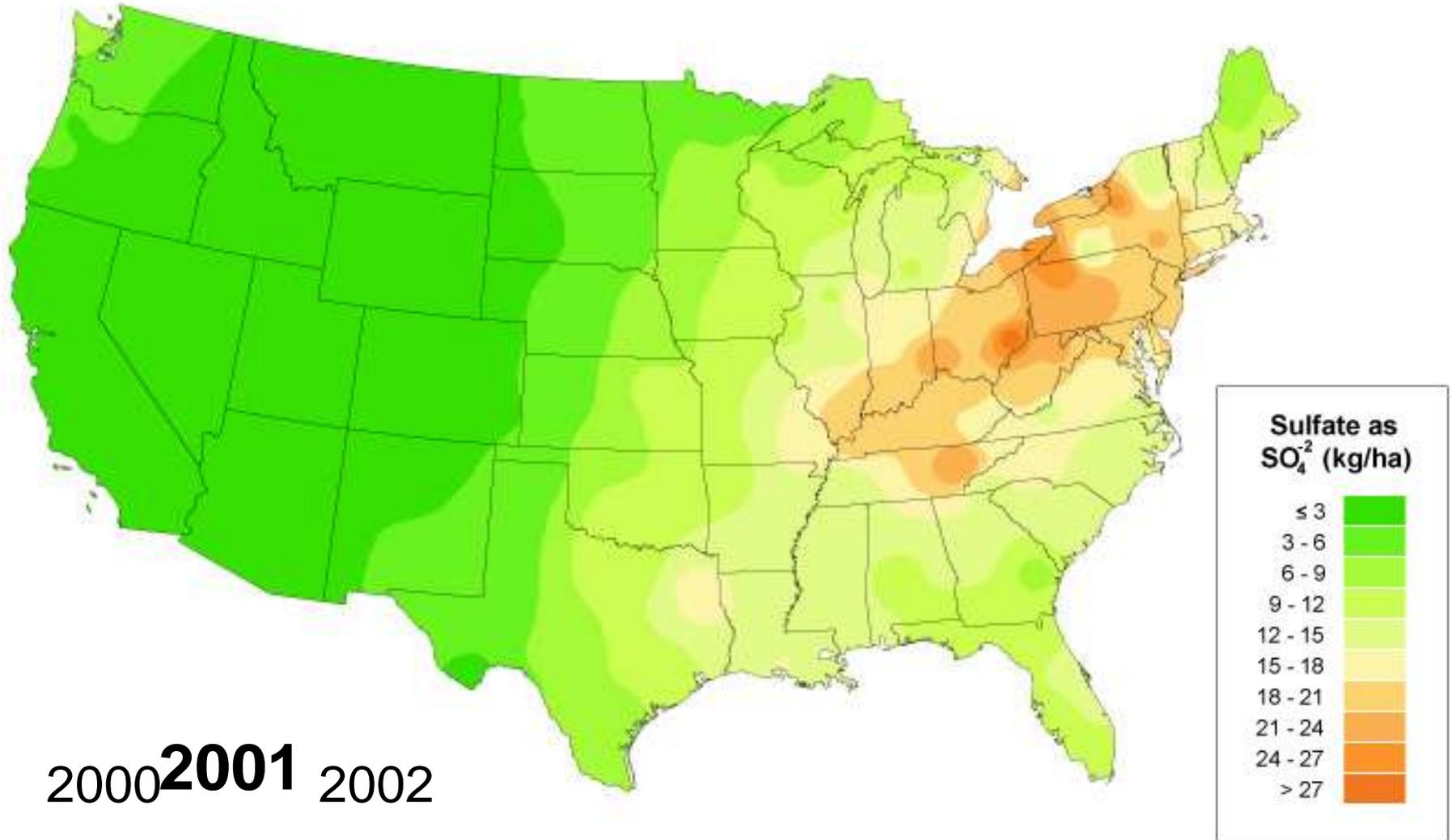
# Sulfate Ion Wet Deposition 1985-2008



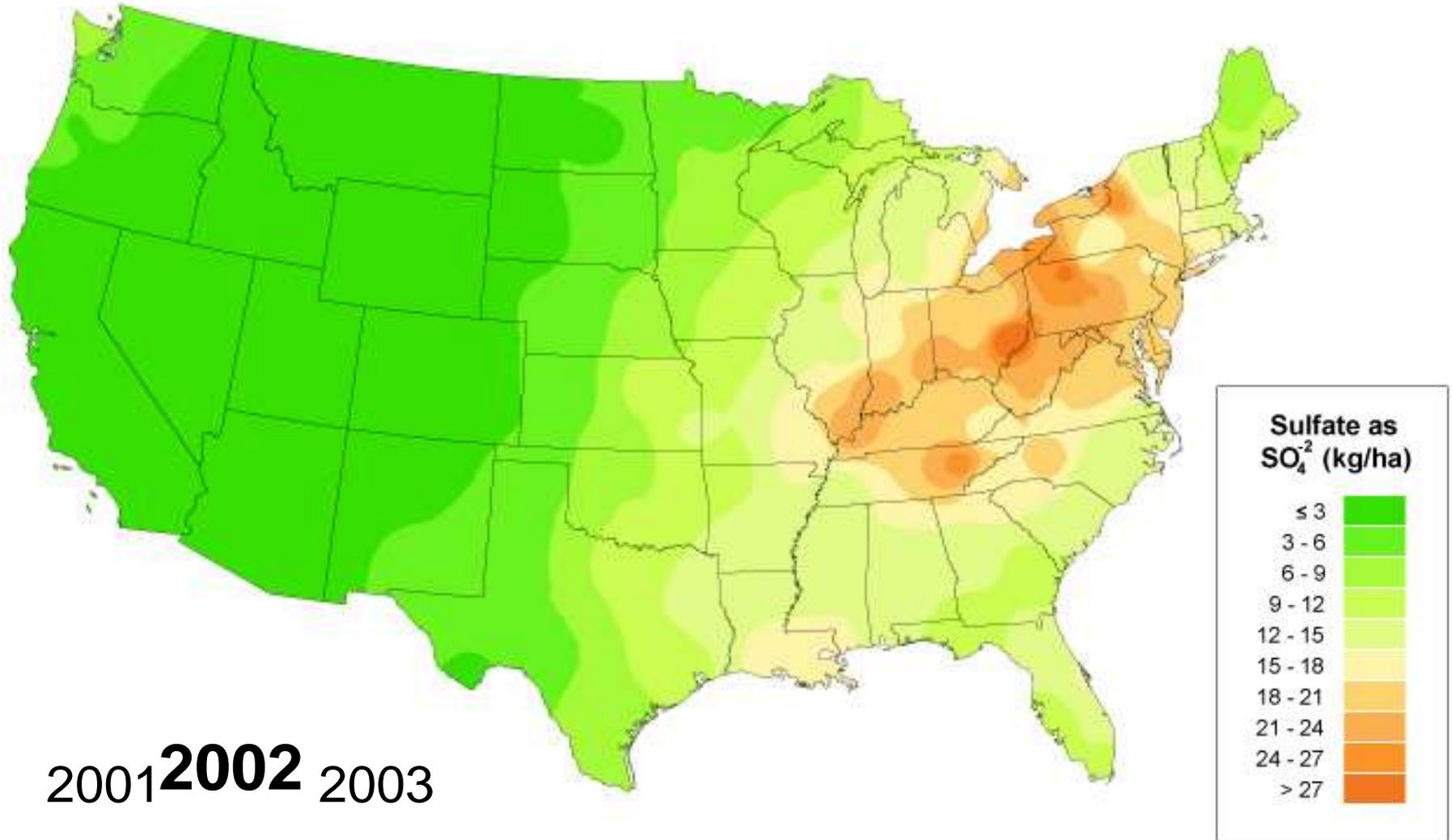
# Sulfate Ion Wet Deposition 1985-2008



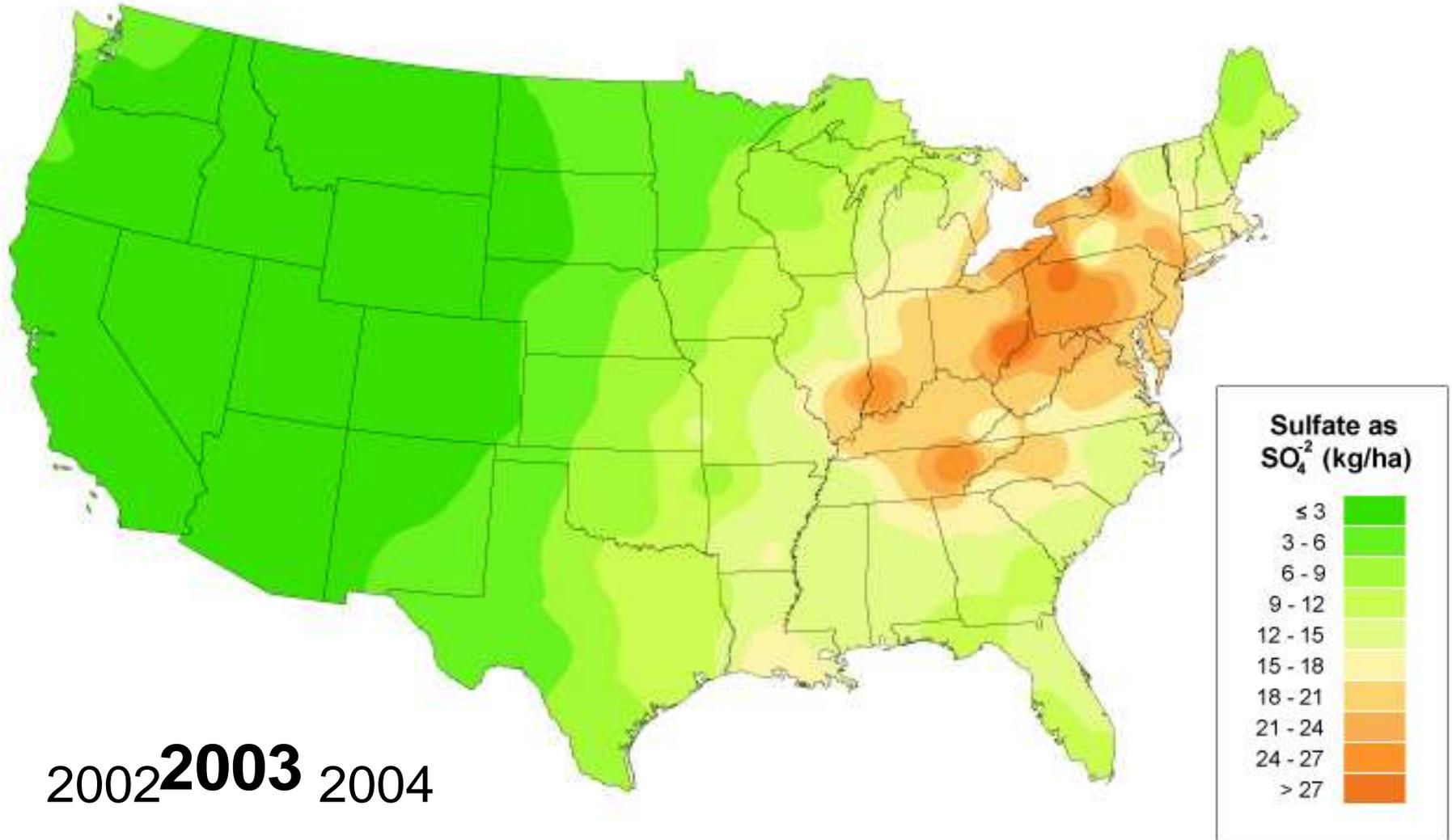
# Sulfate Ion Wet Deposition 1985-2008



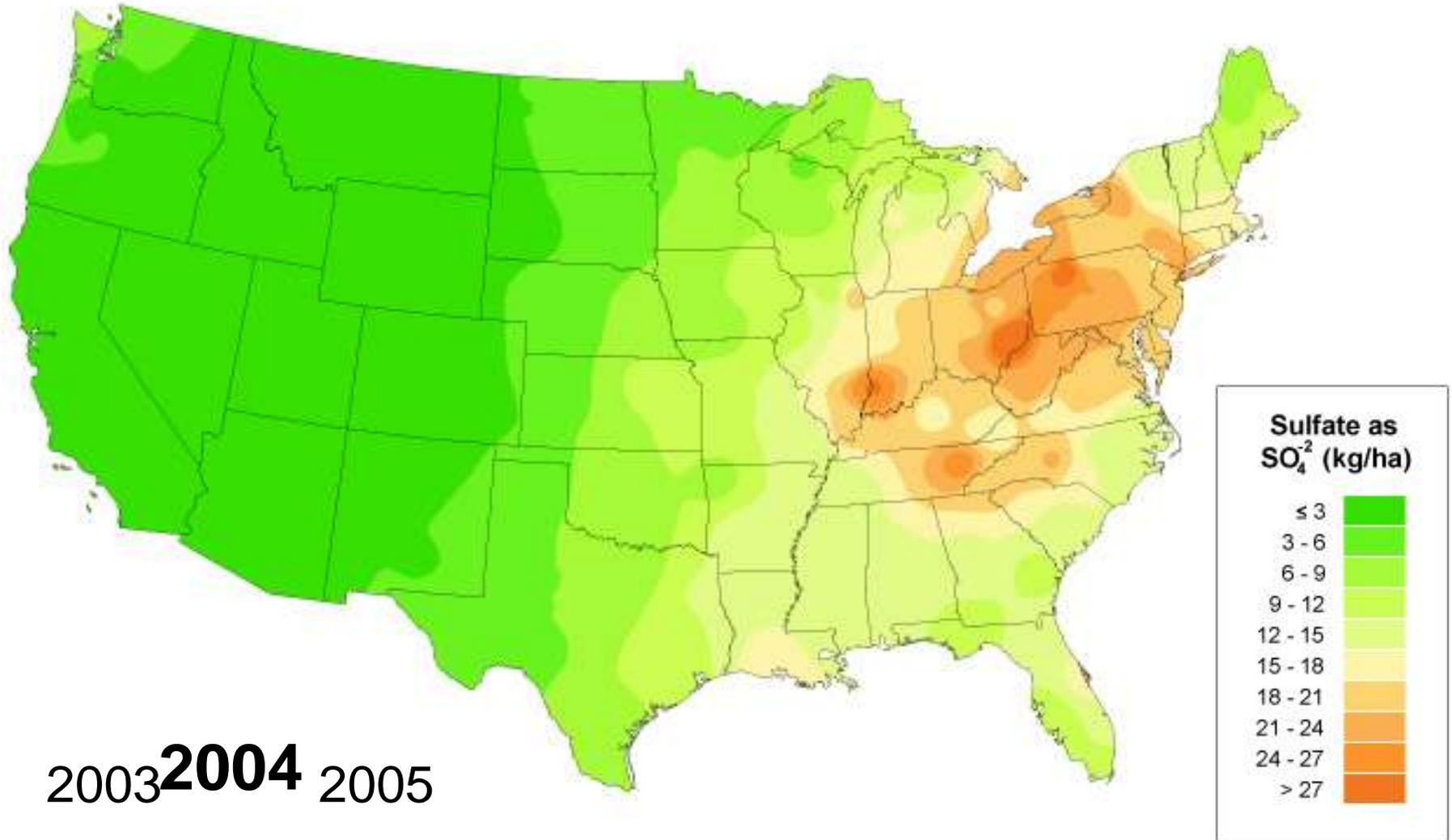
# Sulfate Ion Wet Deposition 1985-2008



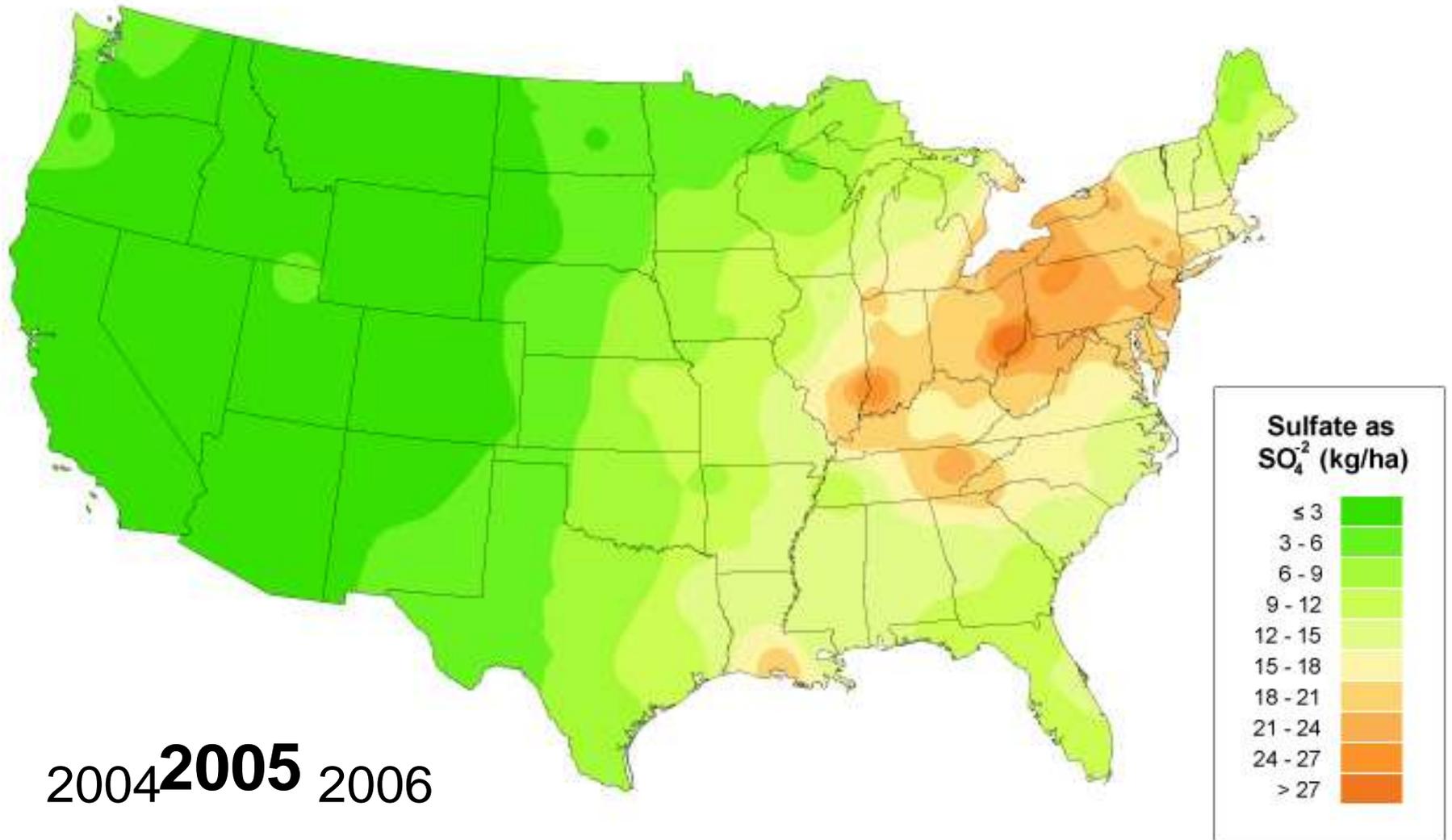
# Sulfate Ion Wet Deposition 1985-2008



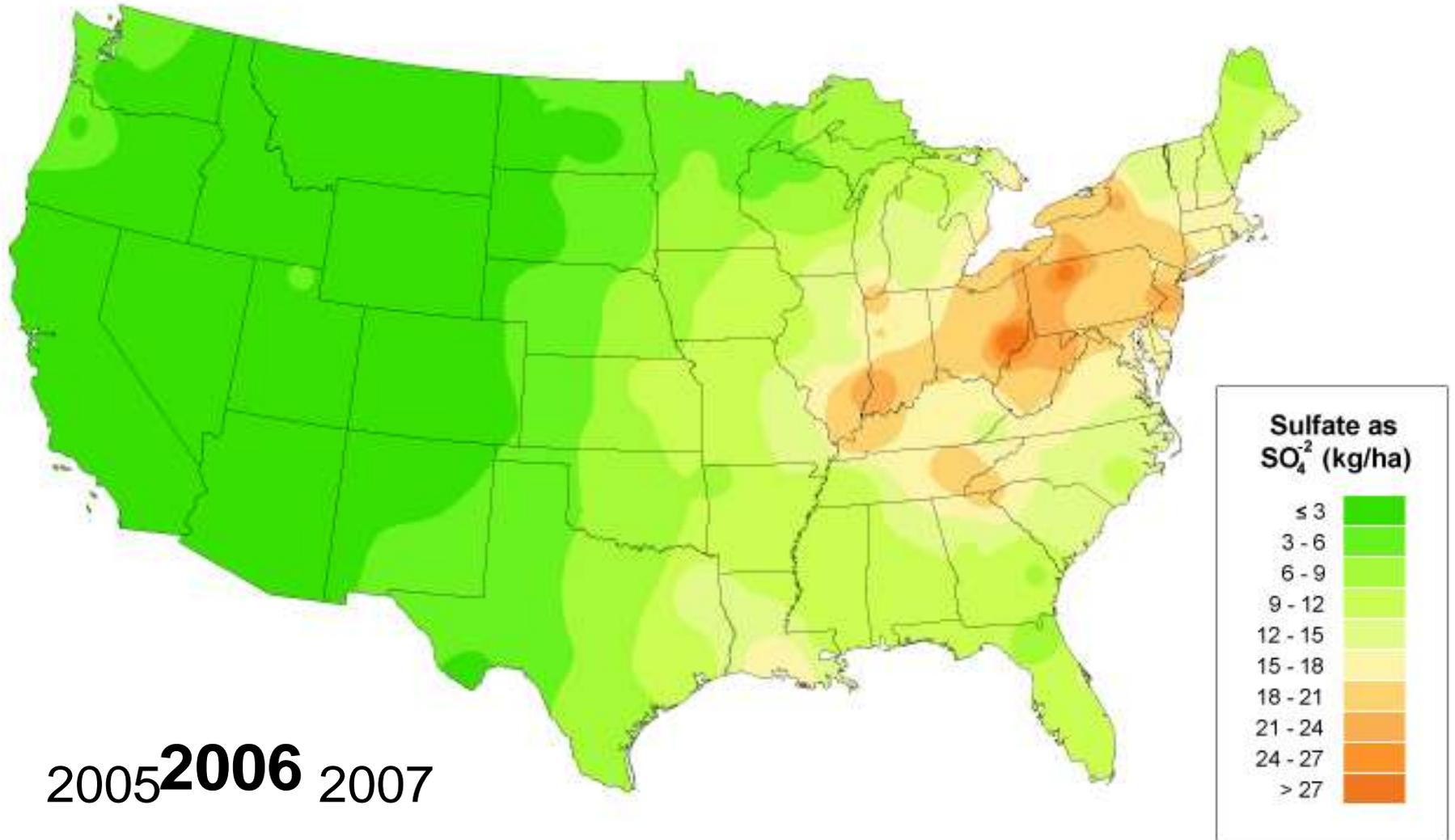
# Sulfate Ion Wet Deposition 1985-2008



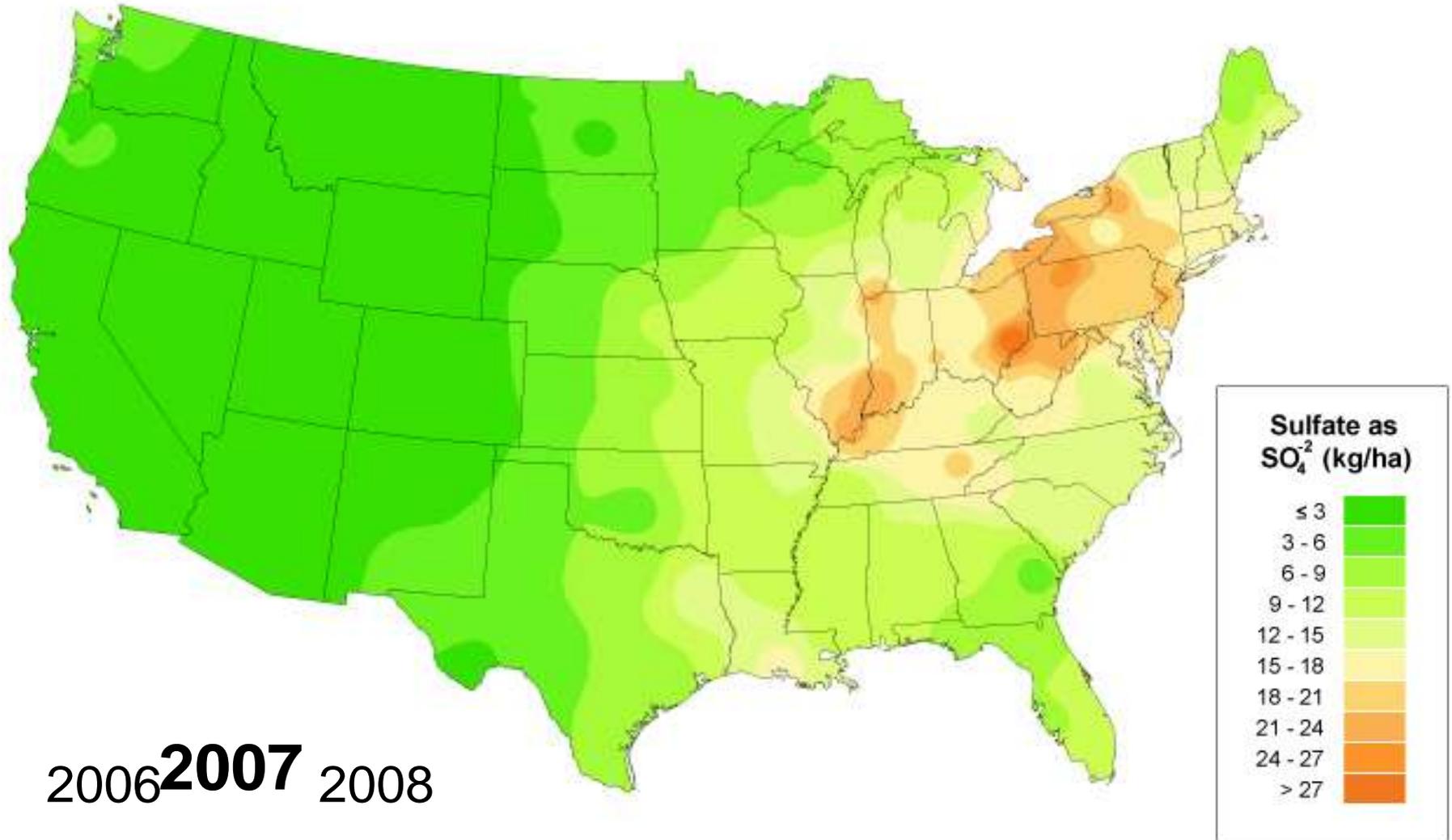
# Sulfate Ion Wet Deposition 1985-2008



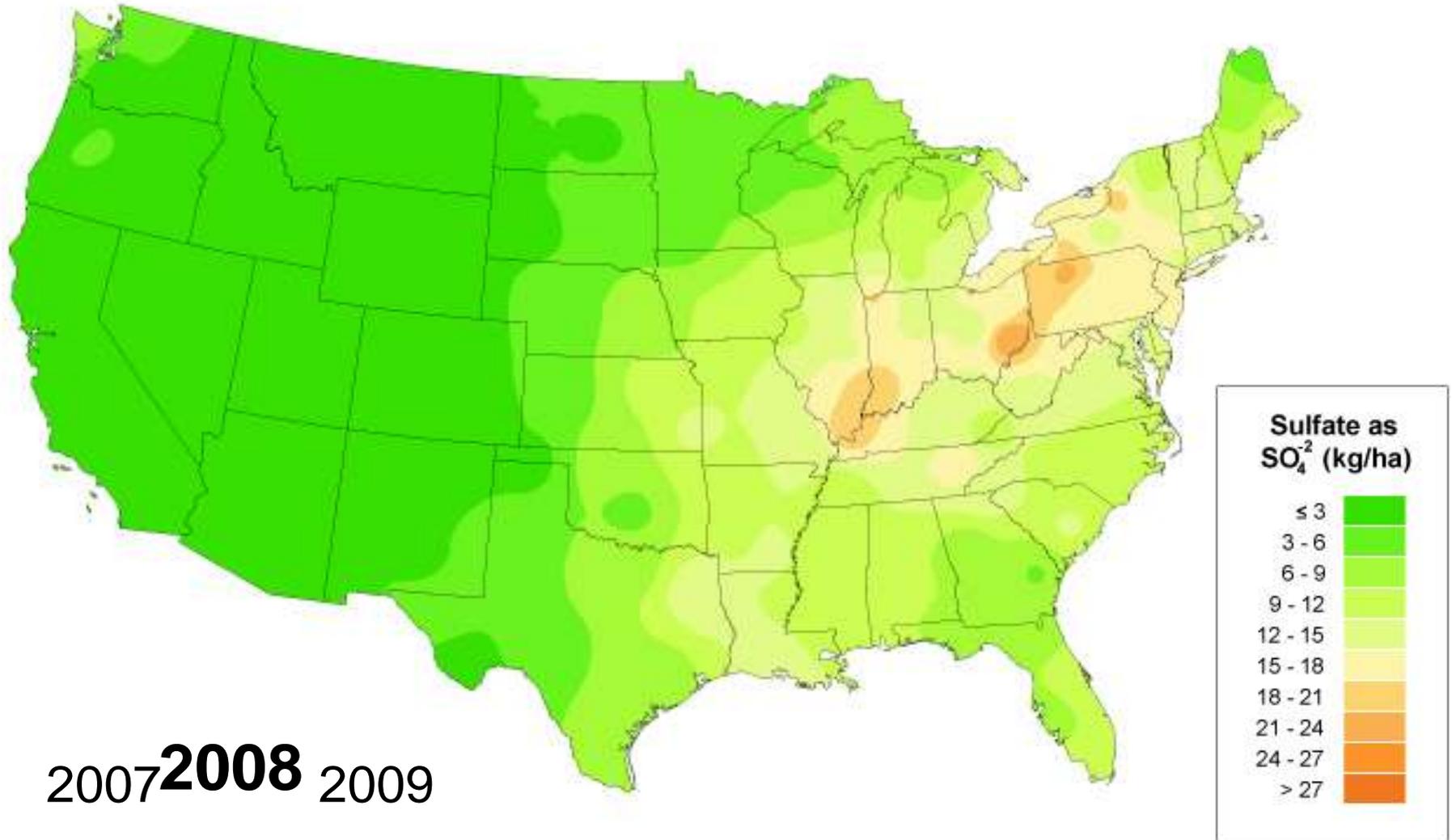
# Sulfate Ion Wet Deposition 1985-2008



# Sulfate Ion Wet Deposition 1985-2008



# Sulfate Ion Wet Deposition 1985-2008



# NADP Mercury Deposition Network 1996-2011

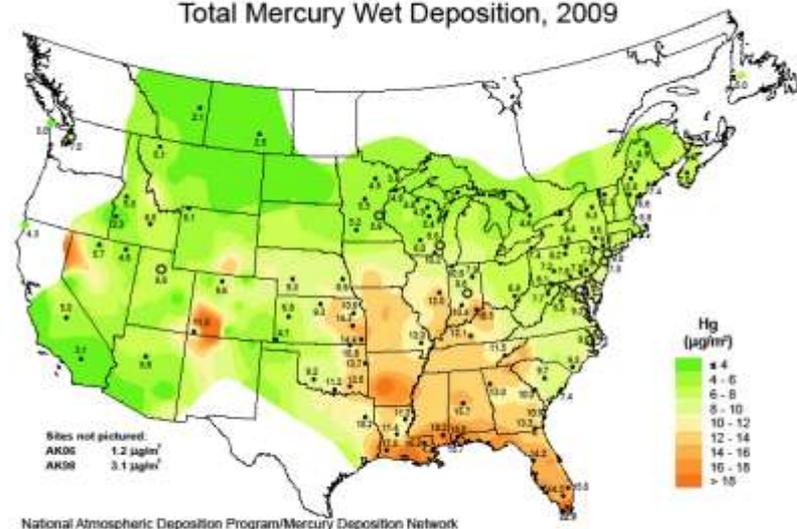
## Monitoring Hg And Metals In Precipitation

*Will we see the same reductions for mercury  
as we did with Sulfur?*

National Atmospheric Deposition Program  
Mercury Deposition Network



Total Mercury Wet Deposition, 2009





# National Atmospheric Deposition Program

**2014 Fall Meeting and Scientific Symposium**

**Hilton Indianapolis Hotel & Suites, Indianapolis, Indiana, October 21-24, 2014**

**Announcement and Call for Abstracts**

**Due August 15, 2014**

## **THE GLOBAL CONNECTION OF AIR AND WATER**

NADP is an internationally recognized cooperative program that provides long-term, high-quality precipitation chemistry and other measurements to evaluate temporal and spatial trends in atmospheric deposition. NADP monitoring networks measure acids, nutrients, base cations, and mercury in precipitation plus atmospheric concentrations of gaseous ammonia, and gaseous oxidized, particulate-bound, and elemental mercury. Data provided by NADP can be augmented with data from other networks such as CASTNET, IMPROVE, and SEARCH to support research on multi-pollutant source/receptor relationships, the potential for deposition effects on terrestrial and aquatic ecosystems, and biogeochemical cycling of pollutants.





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## THE GLOBAL CONNECTION OF AIR AND WATER

For abstract submission, registration, and more information, see <http://nadp.isws.illinois.edu/nadp2014/>

**Abstracts are due August 15, 2014.** Oral and poster presentations are invited on all aspects of deposition monitoring, networks, equipment, sampling and analytical methods, modeling, research linking data to ecological responses, and the application and use of data for management and policy decisions. Oral presentations will be grouped by these themes:

- International atmospheric, deposition, and climate monitoring and models
- Mercury deposition and effects
- Urban air chemistry and deposition
- Critical loads of nitrogen and mercury
- Agriculture and atmospheric deposition
- Measurements and models of wet and dry atmospheric deposition

For questions about the NADP fall meeting and scientific symposium, contact the coordinator, Martin Risch, U.S. Geological Survey, (317) 600-2763, [mrrisch@usgs.gov](mailto:mrrisch@usgs.gov). For other inquiries, contact Lisa Volk at the NADP Program Office, (217) 333-0887, [lisavolk@illinois.edu](mailto:lisavolk@illinois.edu).



# ICMGP KOREA 2015

The 12th International Conference on  
Mercury as a Global Pollutant

June 14-19 2015 Jeju, Korea