

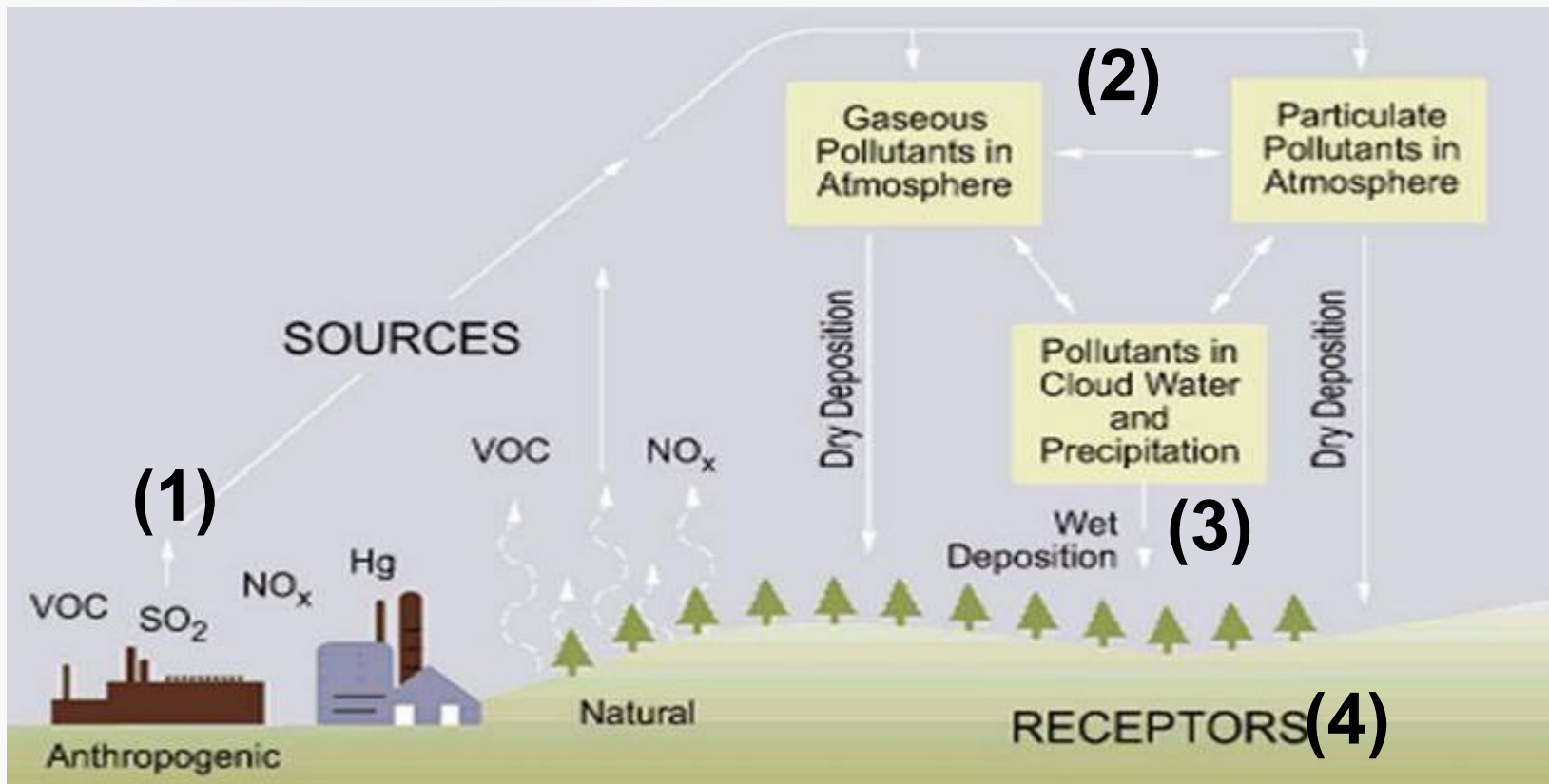


The Acid Rain Program: What it Means to Mountain Streams in Virginia

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Acid Rain



Acid Rain Program



- 26 million ton/ year SO₂ Emission in 1980¹
- 1990 Amendments of Clean Air Act
- Campaign Promises of G.W. Bush in 1988
- 1990 Amendments of Clean Air Act
 - Title I – Air Pollution Prevention and Control (NAAQS)
 - Title II – Mobile Source Emissions (OTEQ – ECA)
 - Title III – Monitoring, etc.
 - **Title IV – Acid Rain Program (ARP) & Emission Trading**
 - Title V – Permits
 - Title VI – Stratospheric Ozone

¹<http://www.epa.gov/airtrends/aqtrends.html>

Title IV - Acid Rain Program



- **Power Sector Cap & Emission Trading Program for SO₂**
- **8.95 million tons SO₂ Emission Cap by 2010**
- **Three Phase Reductions**
- **Smoke Stack Monitoring Program (CEMS)**
- **Environmental Monitoring**

Recent Programs

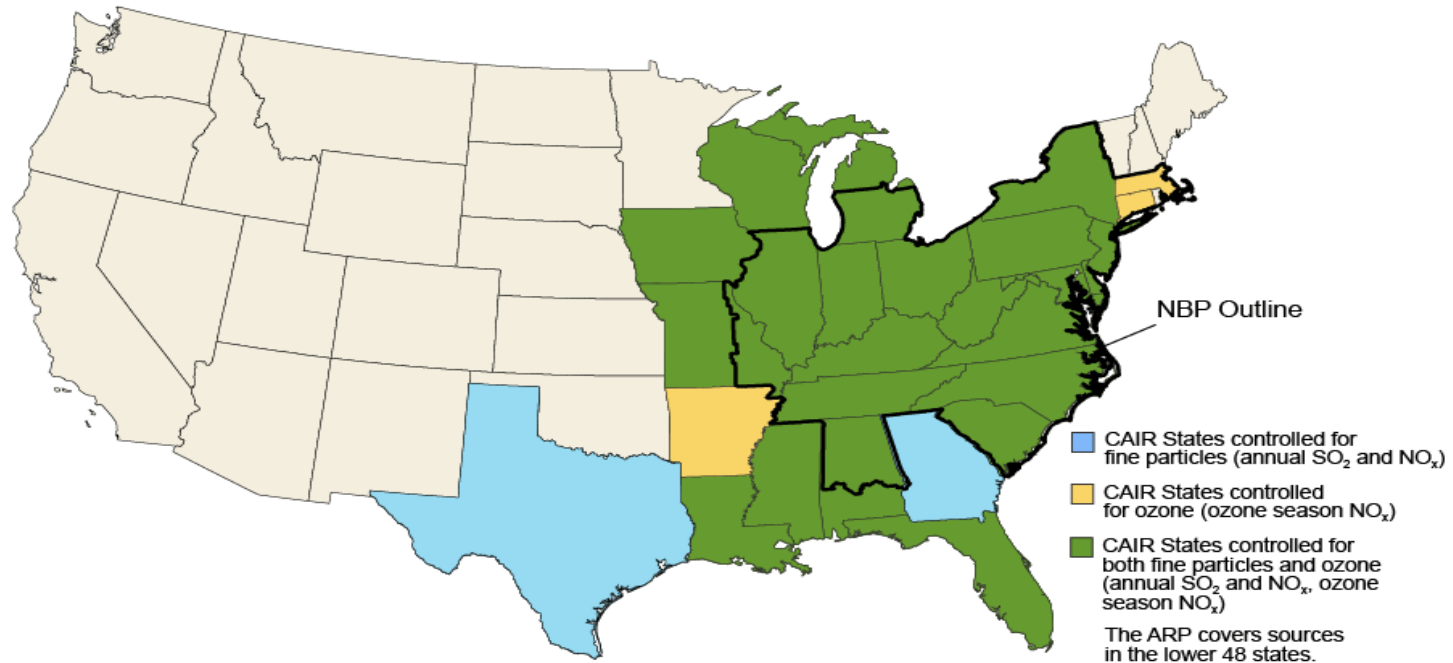


- **NO_x Budget Trading Program (NBP) 2000**
 - **Ozone season NO_x Cap and Trade Program**
- **Clean Air Interstate Rule (CAIR) 2008-present**
 - **SO₂ and NO_x Cap and Trade Program**
 - **Vacated in 2008, but D.C. Circuit remanded without vacature**
 - **3.5 and 1.33 million ton SO₂ and NO_x Caps by 2015**
- **Cross State Air Pollution Rule (CSAPR) 2012**
 - **SO₂ and NO_x Cap and Trade Program to replace CAIR**
 - **US Court of Appeals in 2012 Vacated CSAPR**
 - **U.S. Supreme Court**
 - **3.24 and 1.16million ton SO₂ and NO_x Caps by 2015**

CAIR, ARP, and NBP States



CAIR, ARP, and NBP States

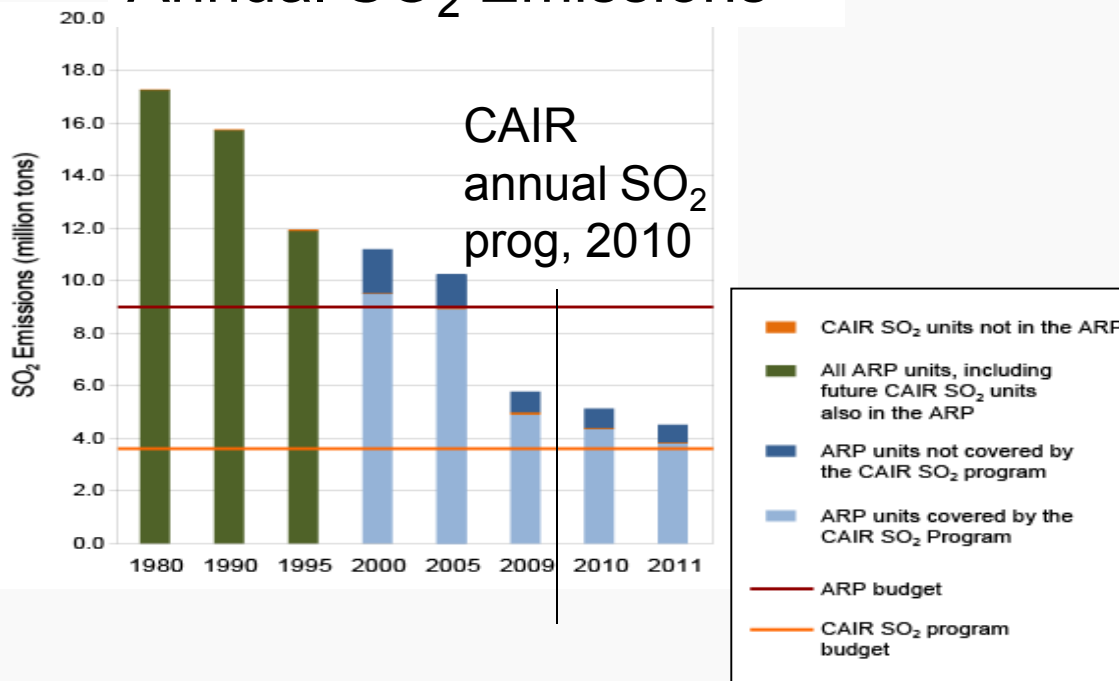


Source: EPA, 2012

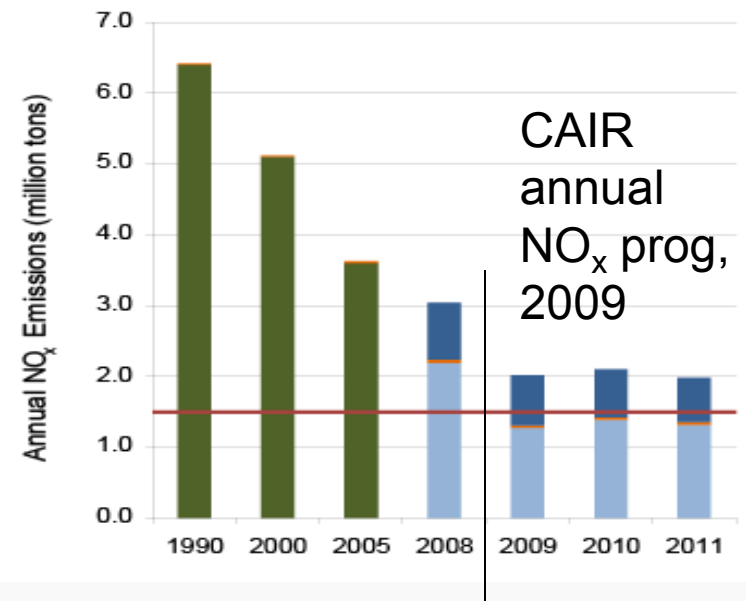
Emissions from Power Sector



Annual SO₂ Emissions



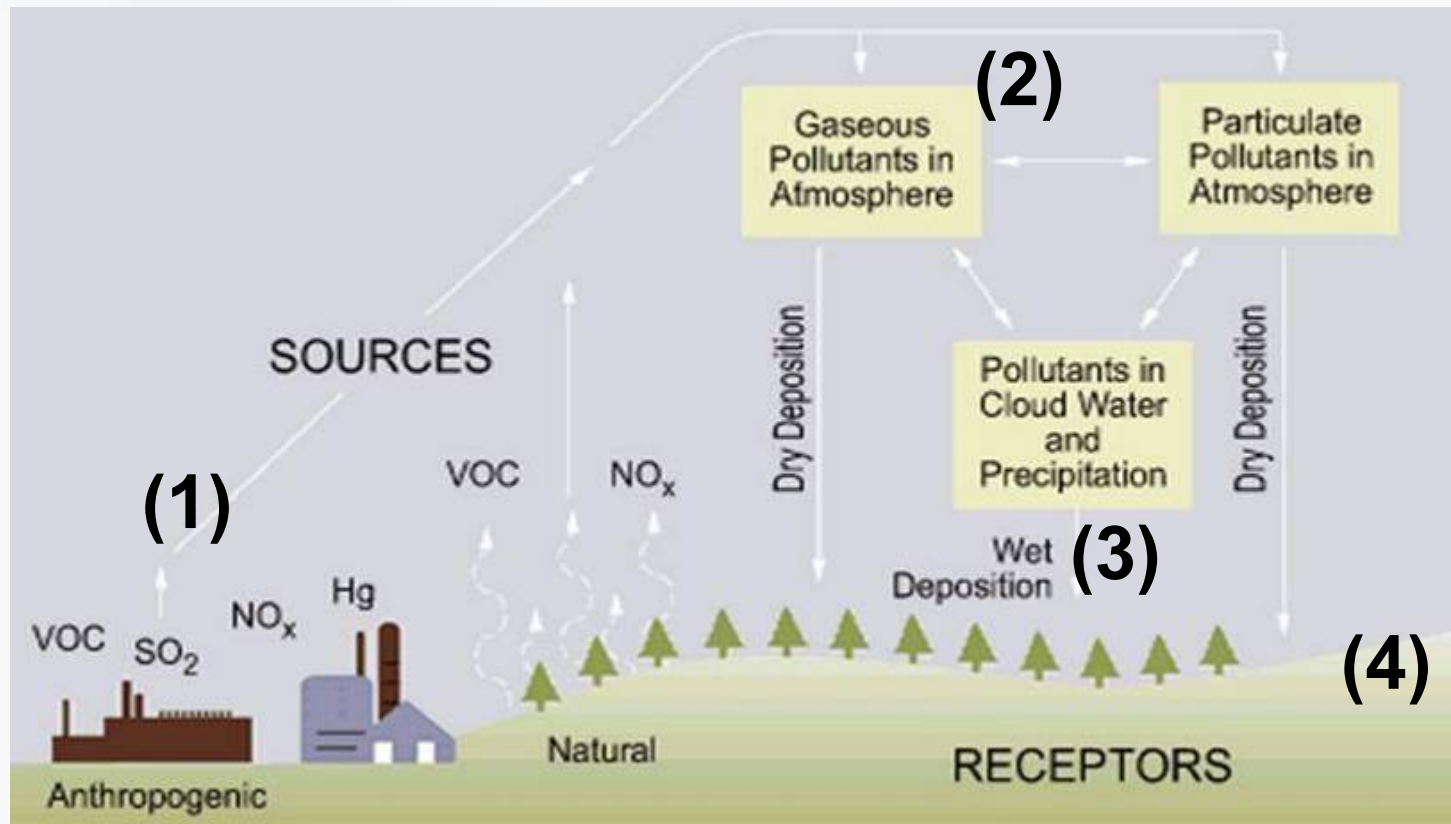
Annual NO_x Emissions



Summary



- **CAIR and ARP Annual SO₂ Emissions:** 4.5 million tons (71 percent below 1990) today
- **CAIR and ARP Annual NO_x Emissions:** 2.0 million tons (60 percent below 1990) today



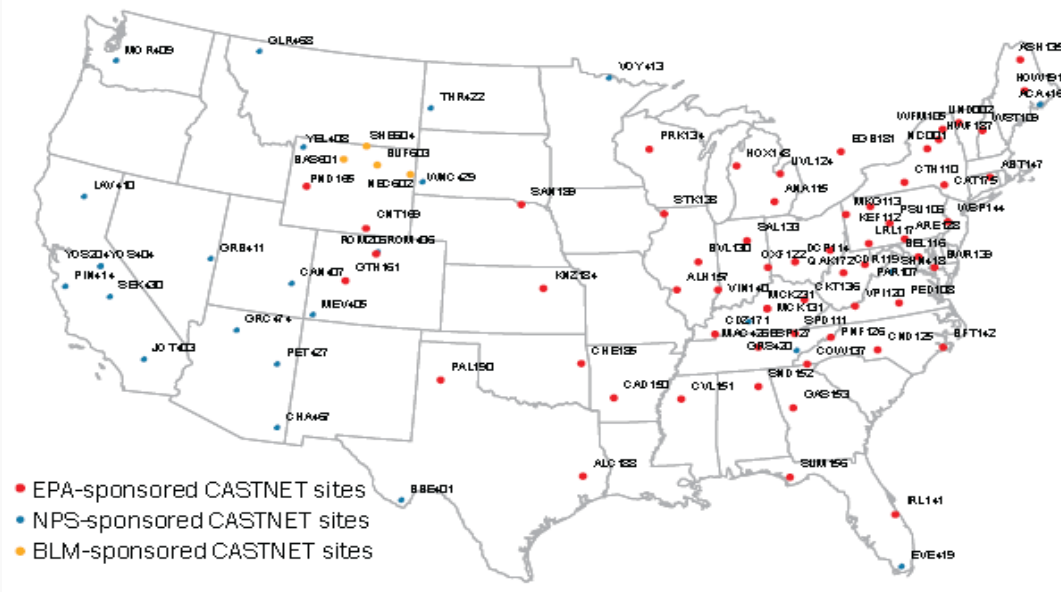
Clean Air Status and Trends Network (CASTNET)



Air Concentrations SO_2 & $\text{NO}_x \rightarrow$ Model Dry Deposition



Figure 1: CASTNET Site Map





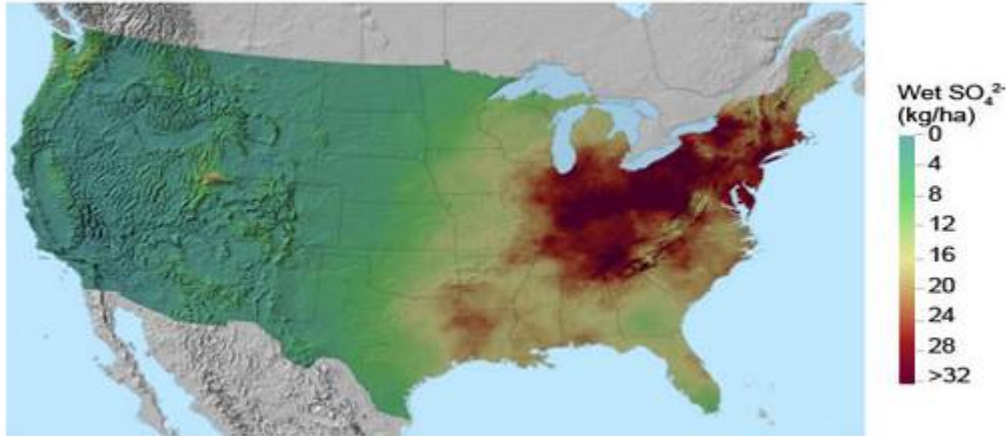
National Atmospheric Deposition Program



Deposition in Precipitation



1989–1991



2009–2011



Source: EPA, 2013

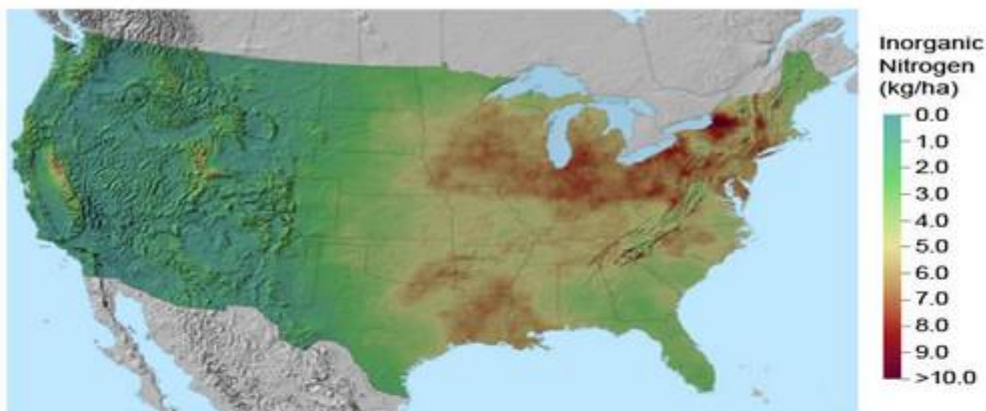


Three-Year Mean Wet Sulfate Deposition

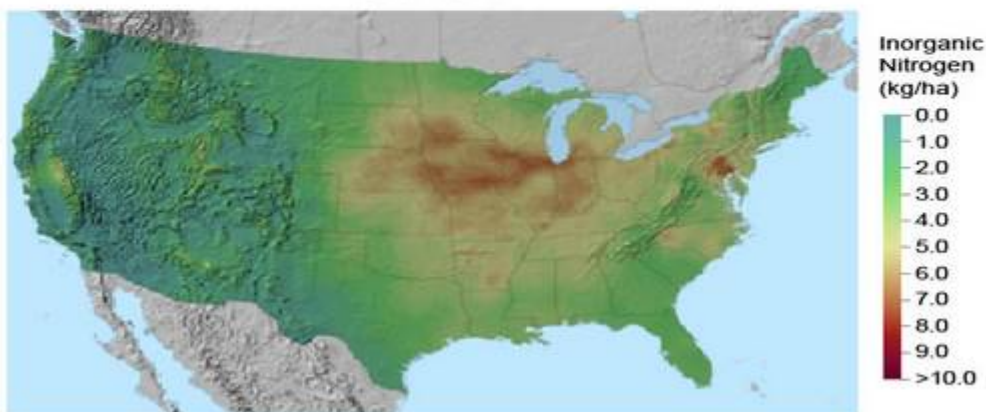
Parameter-elevation
Regressions on Independent
Slopes Model (PRISM)

Total deposition (wet +dry)
75% for Mid-Atlantic

1989–1991



2009–2011



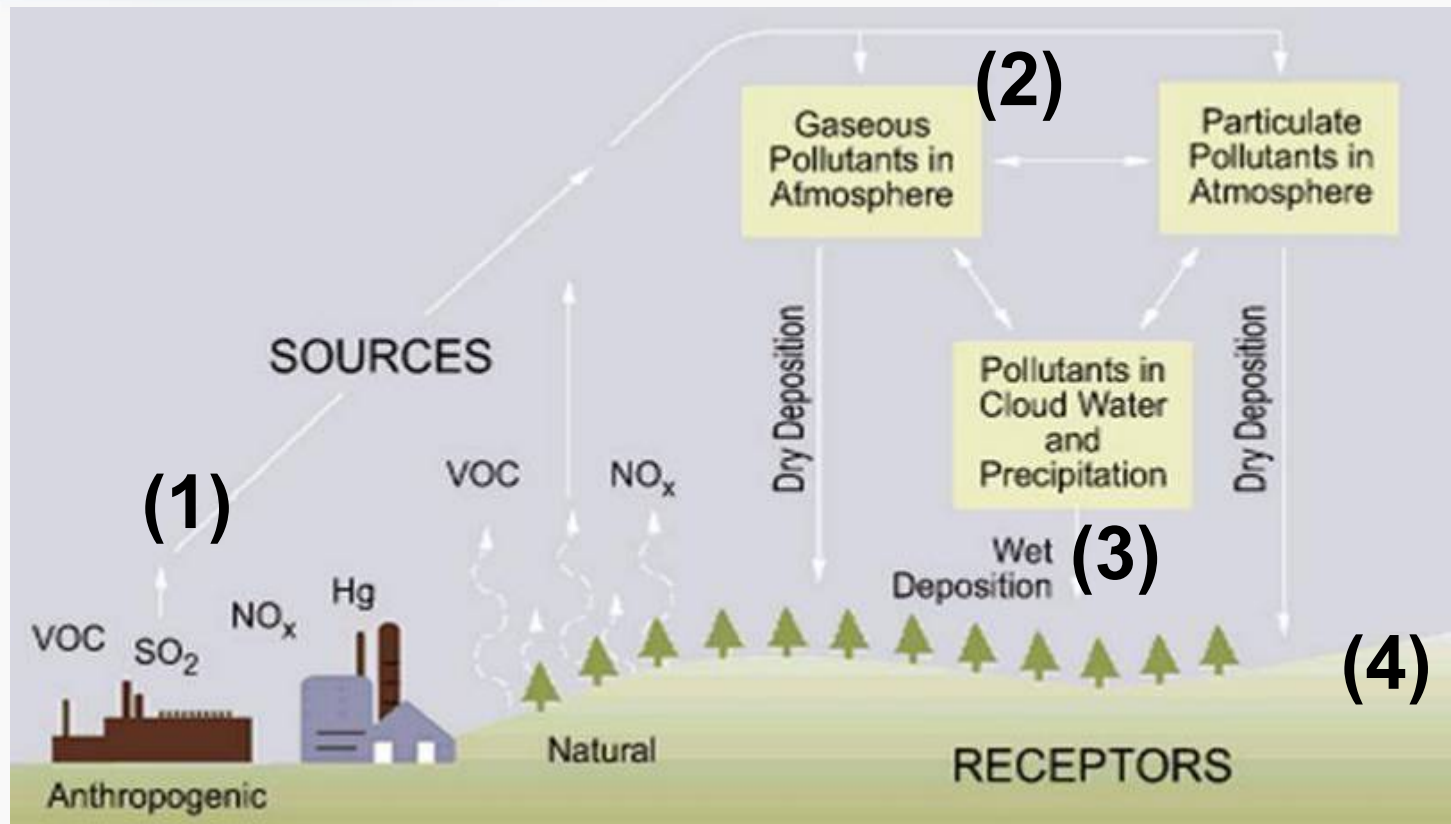
Source: EPA, 2013



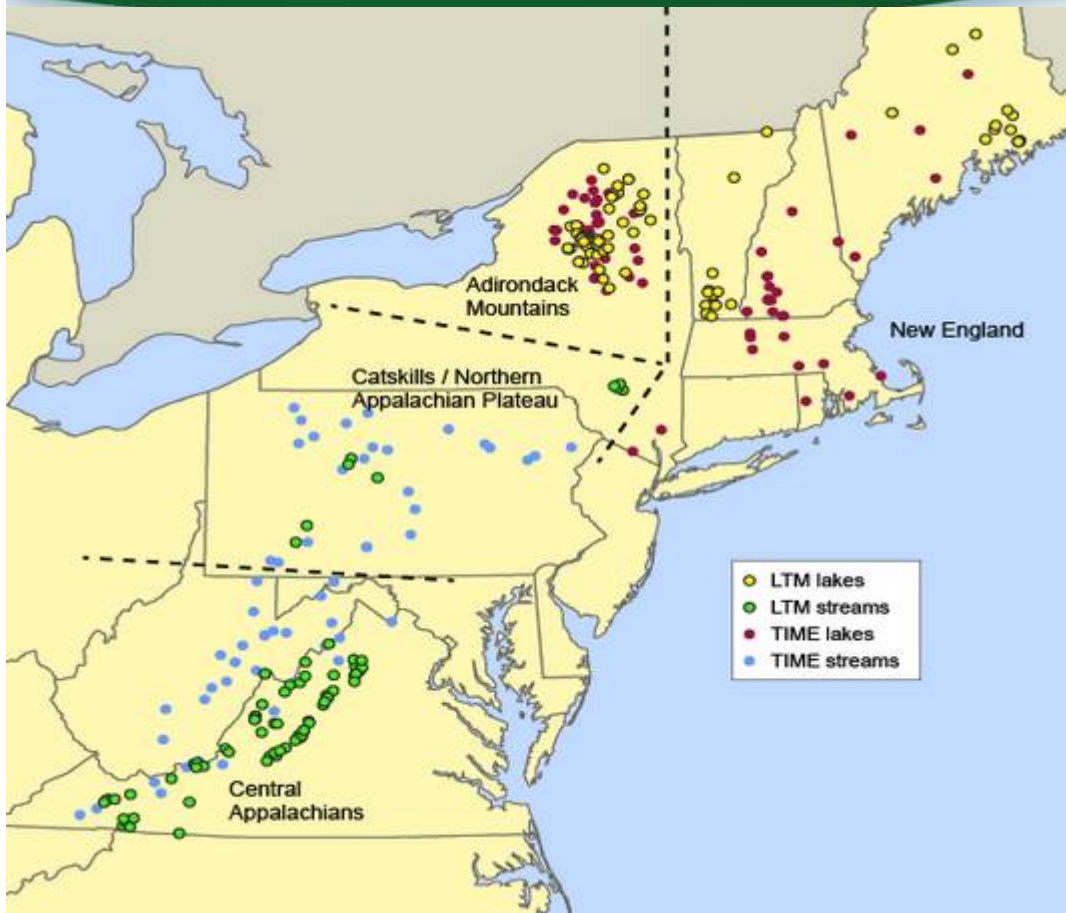
Three-Year Mean Wet Inorganic Nitrogen Deposition

Parameter-elevation
Regressions on Independent
Slopes Model (PRISM)

Total deposition (wet +dry)
63% for Mid-Atlantic

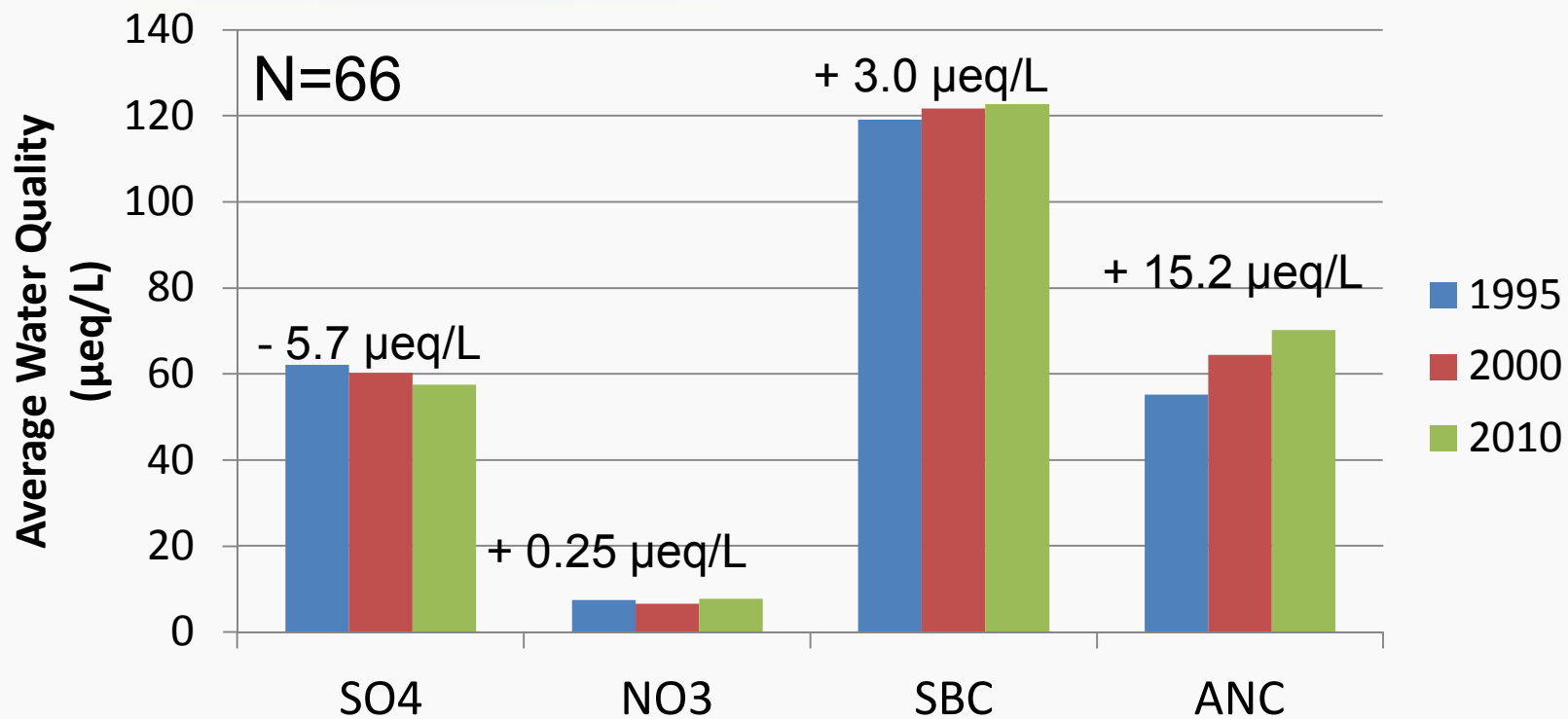


Long Term Monitoring

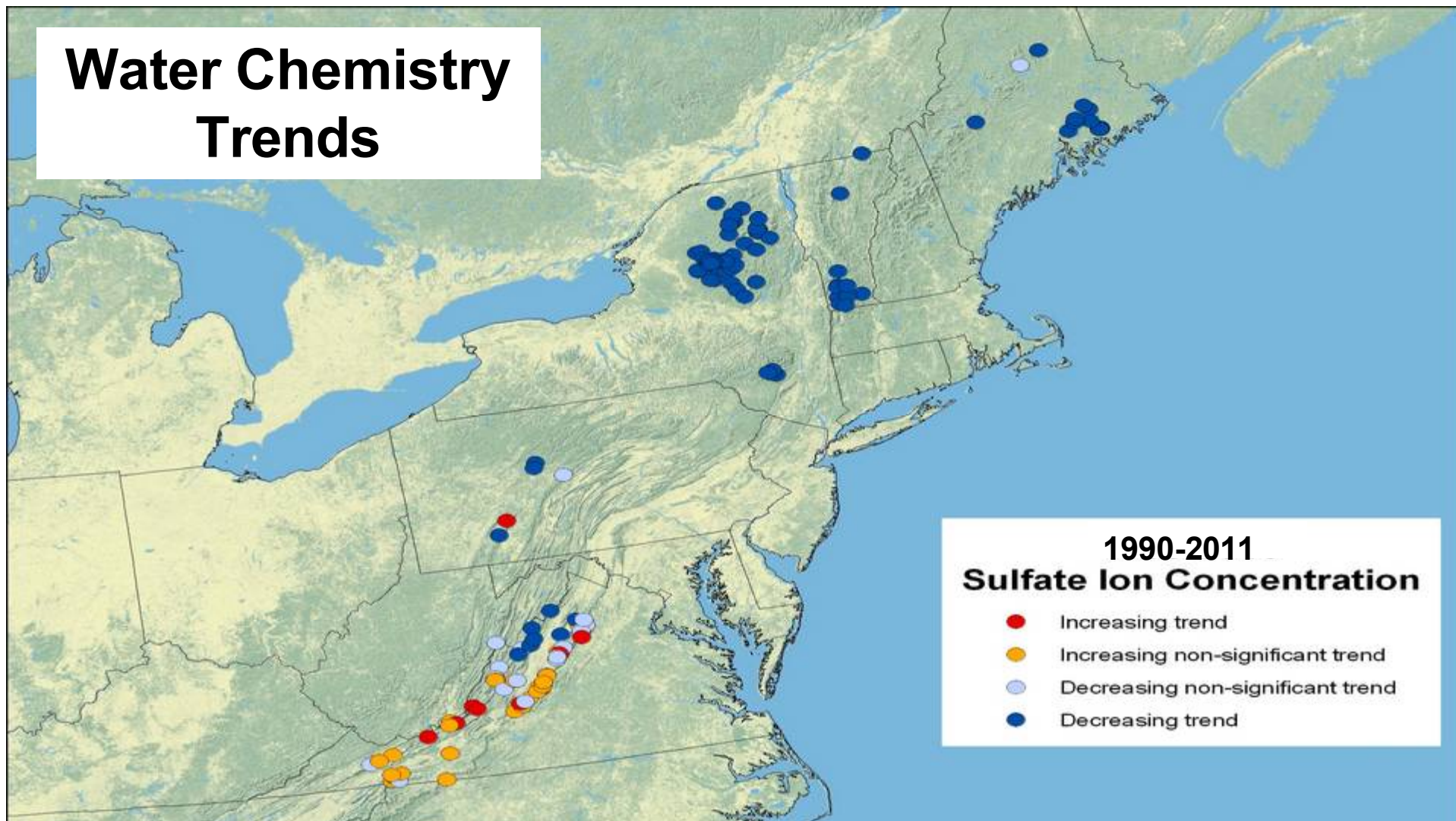


- 154 active sites
- Sampled monthly-quarterly
- Lakes (NE)
- Streams (Mid-Atlantic)
- Data record, 1980s-present
- SO_4^{2-} , NO_3^- , (Acid Anions)
- ANC, Base Cations
- SWAS-VTSSS

SWAS-VTSSS



Water Chemistry Trends



1990-2011 LTM Trends



Region	Water Bodies Covered	% of Sites with Improving Sulfate Trend (-)	% of Sites with Improving Nitrate Trend (-)	% of Sites with Improving ANC Trend (+)
Adirondack Mountains	50 lakes	100%	56%	68%
New England	26 lakes	100%	18%	32%
Catskills/N. Appalachian Plateau	9 streams	80%	40%	45%
Central Appalachians	66 streams	15%	59%	36%

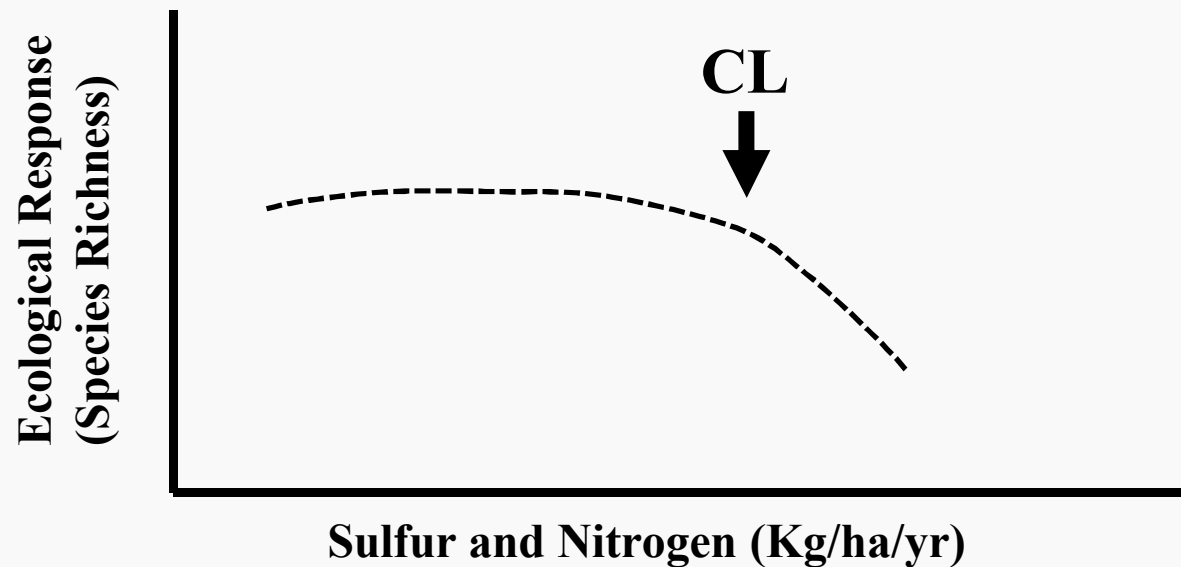
Notes:

- Trends are determined by multivariate Mann-Kendall tests.
- Trends are significant at the 95 percent confidence interval ($p < 0.05$).
- Sum of Base Cations assumes neutral salt, (Ca+Mg+K).

Critical Loads



- The level sulfur and nitrogen deposition below which ecosystems are believed to be protected according to present knowledge.



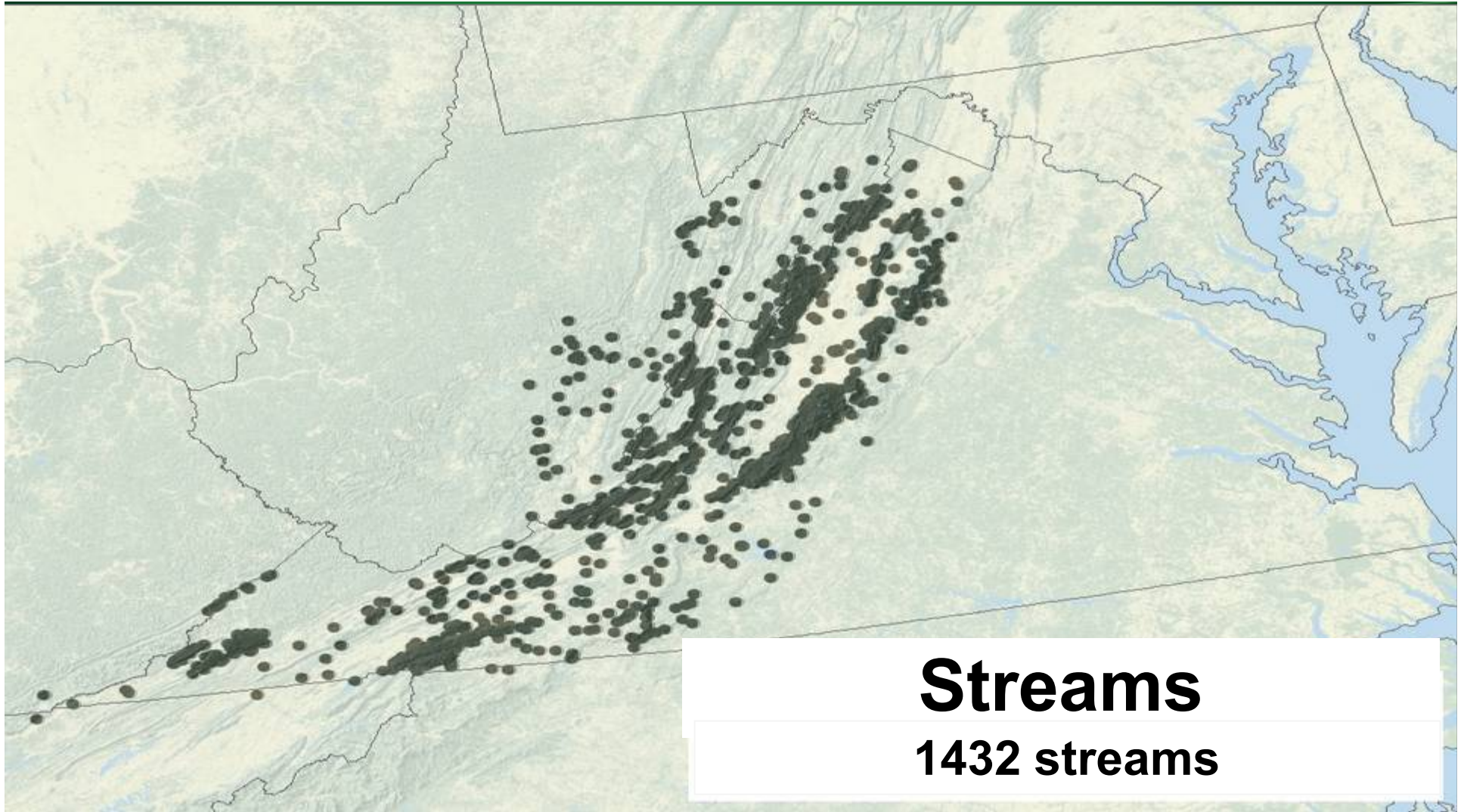
- **Surface Water Acidity**
- **Soil Acidity**
- **Forest growth**
- **Species Diversity**
- **Lichens Abundance**



What are Critical Loads?



- **Mass Balance Relationships Base on Water Chemistry Measurements**
- **Buffering of the Watershed**
- **Biota Protection - Acid Neutralizing Capacity (ANC) of 50 $\mu\text{eq/L}$**
- **Exceedances”** where Total Deposition is **Greater** than Critical Load
 - **Assumed ANC Falls Below 50 $\mu\text{eq/L}$**
 - **1990 – Before Emission Reduction Programs (e.g. ARP/CAIR)**
 - **2001 & 2011 – After Emission Reduction Programs**
 - **Time is not Considered in Critical Load Analyses**

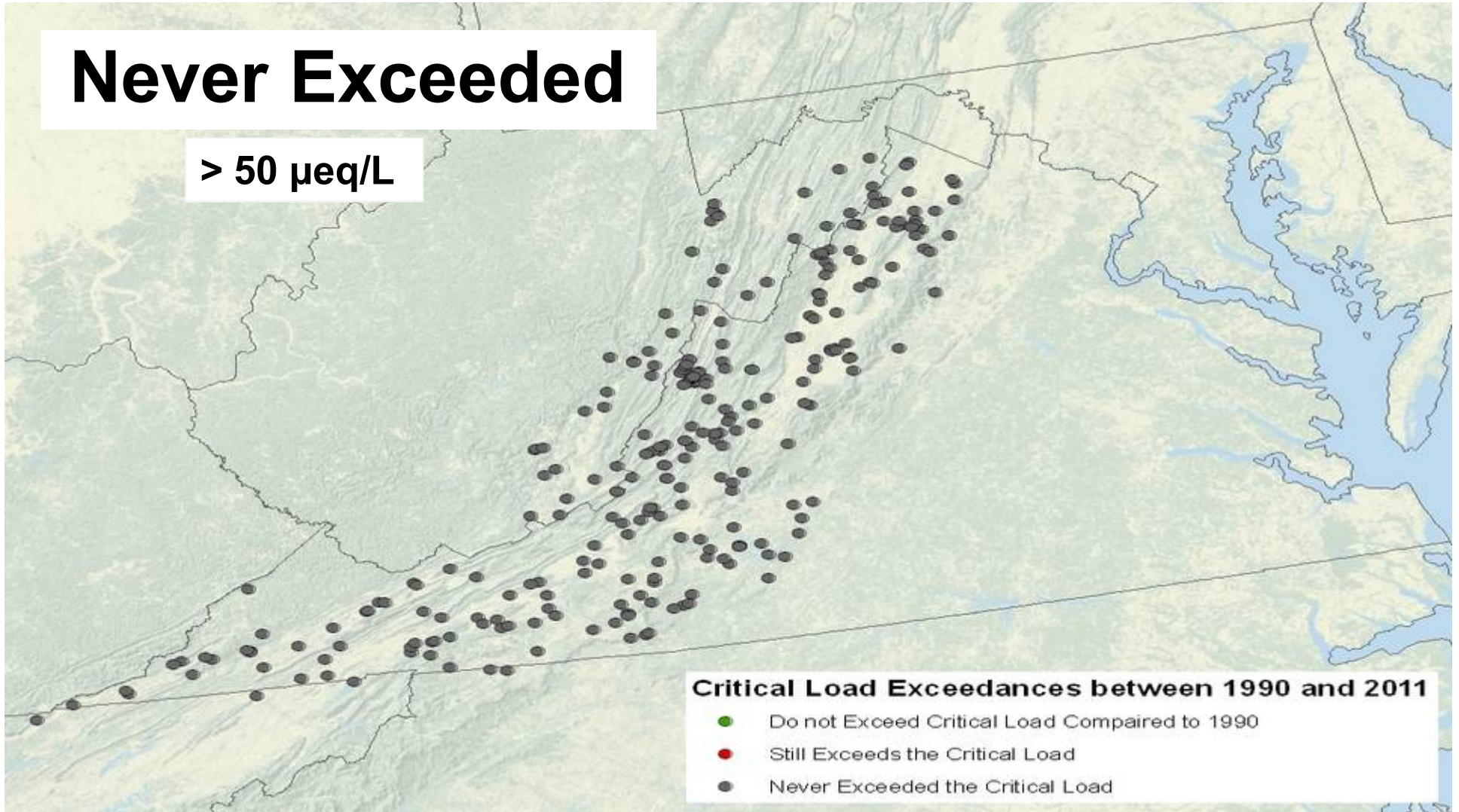


Never Exceeded

> 50 $\mu\text{eq/L}$

Critical Load Exceedances between 1990 and 2011

- Do not Exceed Critical Load Compared to 1990
- Still Exceeds the Critical Load
- Never Exceeded the Critical Load

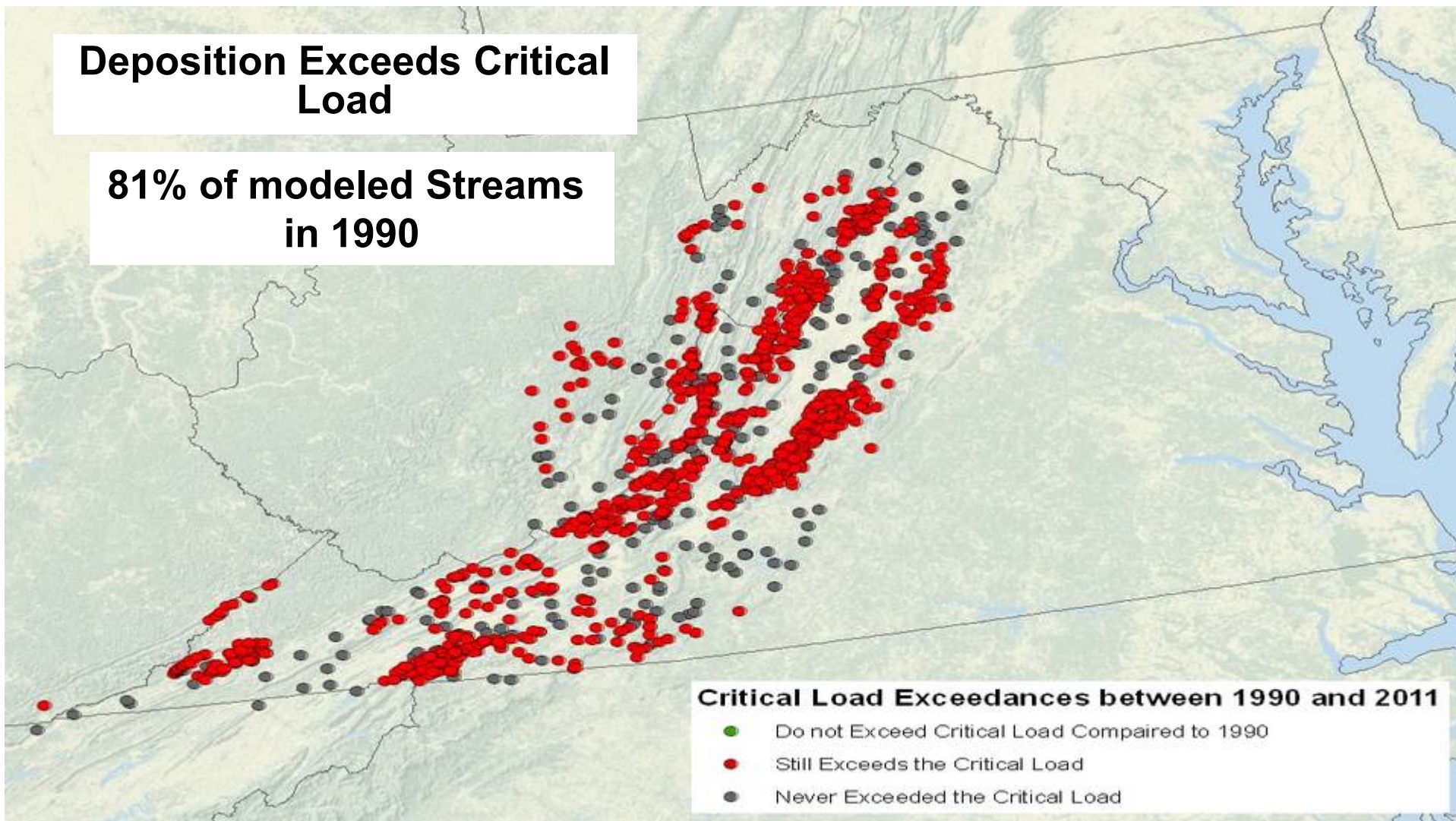


Deposition Exceeds Critical Load

**81% of modeled Streams
in 1990**

Critical Load Exceedances between 1990 and 2011

- Do not Exceed Critical Load Compared to 1990
- Still Exceeds the Critical Load
- Never Exceeded the Critical Load

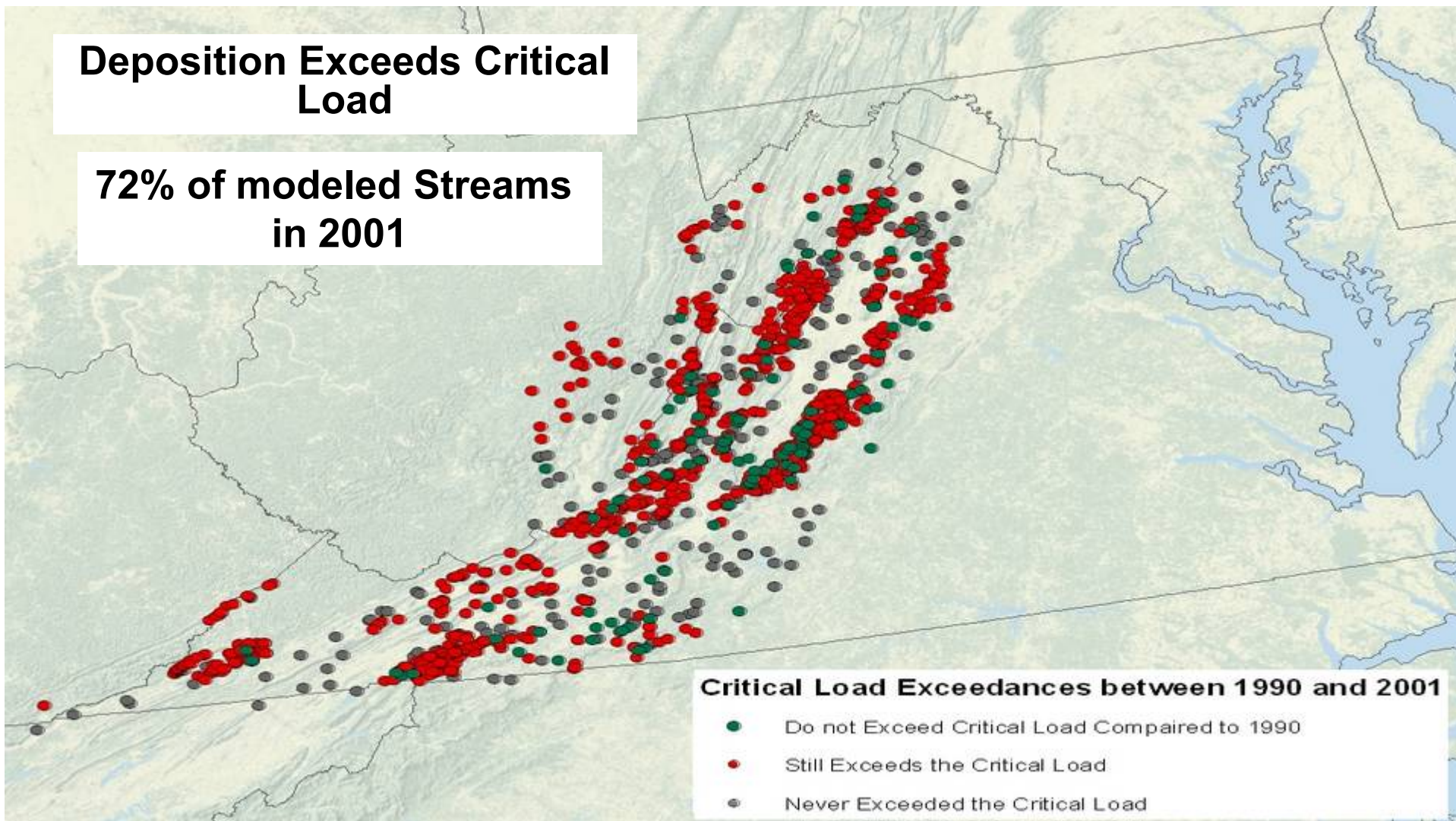


Deposition Exceeds Critical Load

**72% of modeled Streams
in 2001**

Critical Load Exceedances between 1990 and 2001

- Do not Exceed Critical Load Compared to 1990
- Still Exceeds the Critical Load
- Never Exceeded the Critical Load



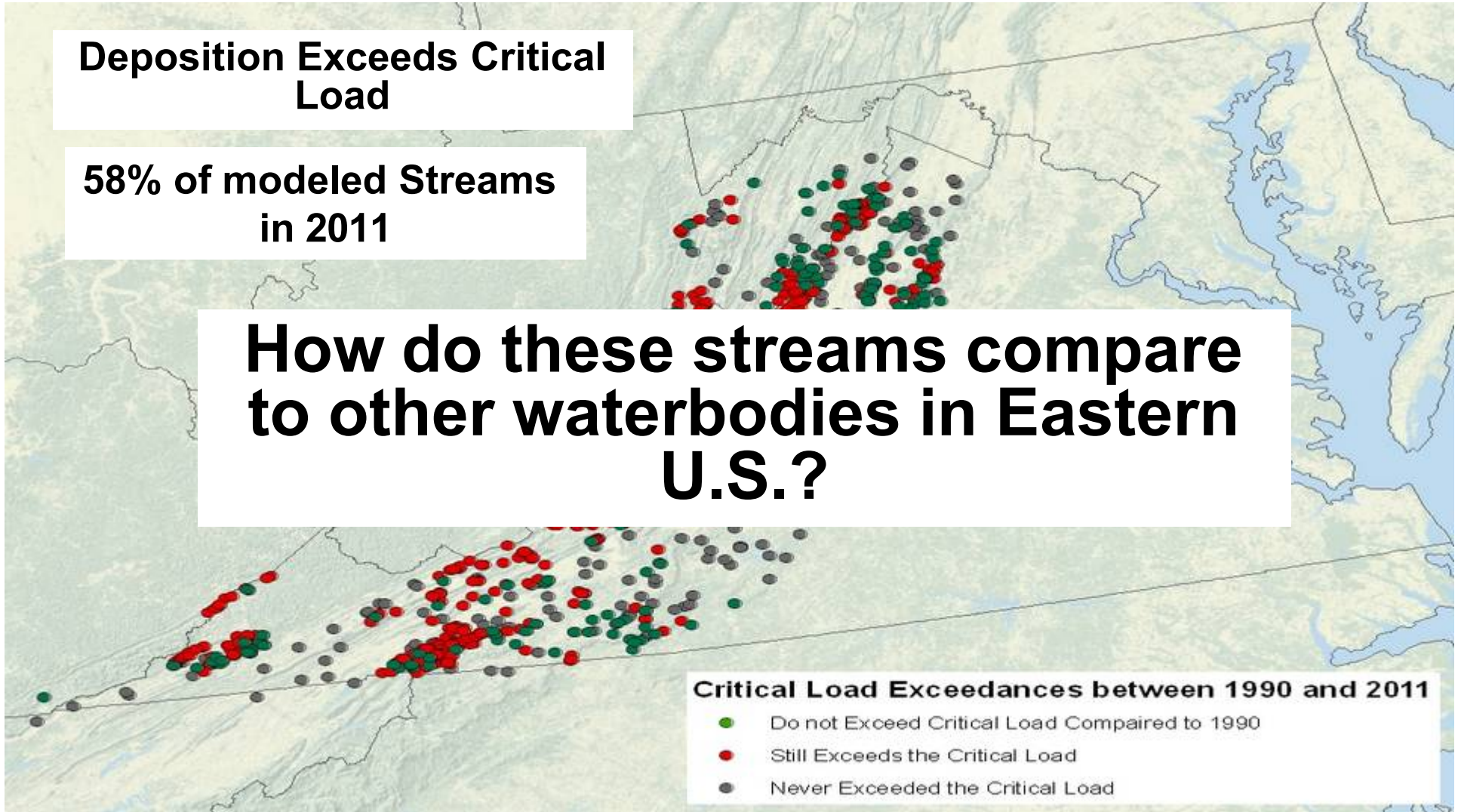
Deposition Exceeds Critical Load

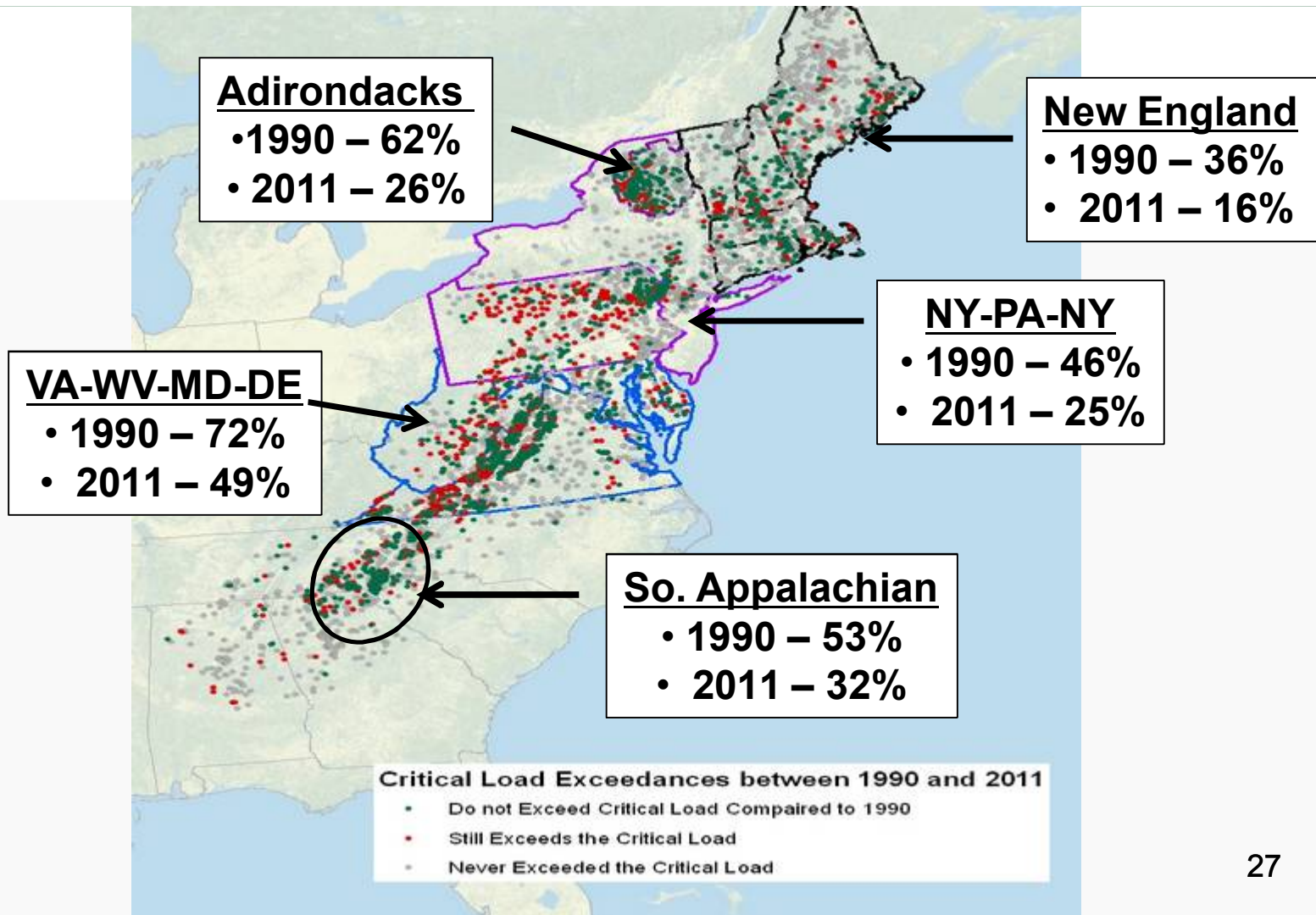
**58% of modeled Streams
in 2011**

**How do these streams compare
to other waterbodies in Eastern
U.S.?**

Critical Load Exceedances between 1990 and 2011

- Do not Exceed Critical Load Compared to 1990
- Still Exceeds the Critical Load
- Never Exceeded the Critical Load



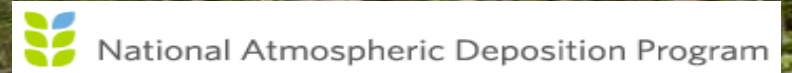


Conclusions



- **Large Reductions in SO₂ and NO_x Emissions**
- **Considerable Improvements in Acidic Deposition**
- **Only lead to modest improvements in water quality**
- **Based on critical load analysis, ~28% of streams that exceeded their critical loads pre- ARP implementation, do not under present deposition loads**
- **However, many streams in Virginia Mountains still remain at risk from current deposition levels**
- **Sulfate retention in soils will play an important role in the future recovery of Virginia's streams**

Thank You



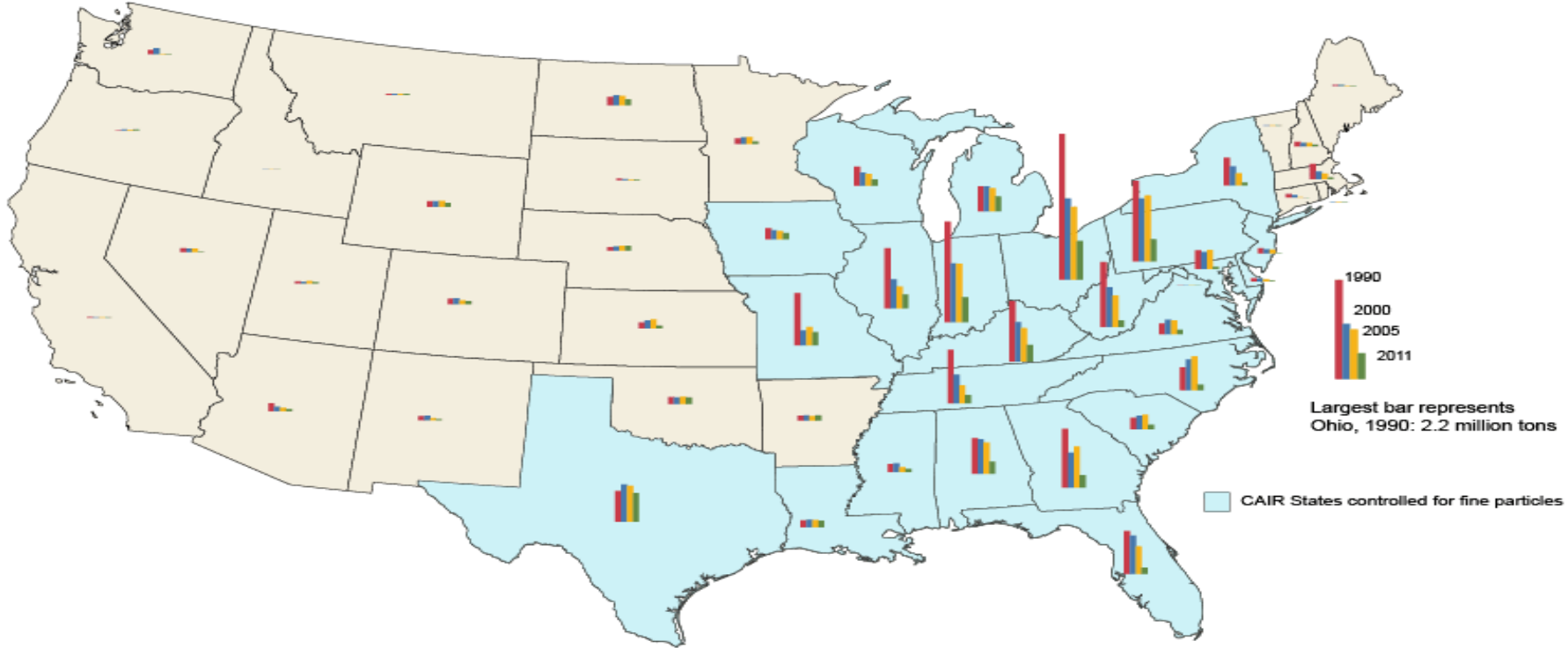
<http://www.epa.gov/airmarkets/>

<http://www.epa.gov/airmarkets/assessments/surfacewater.html>



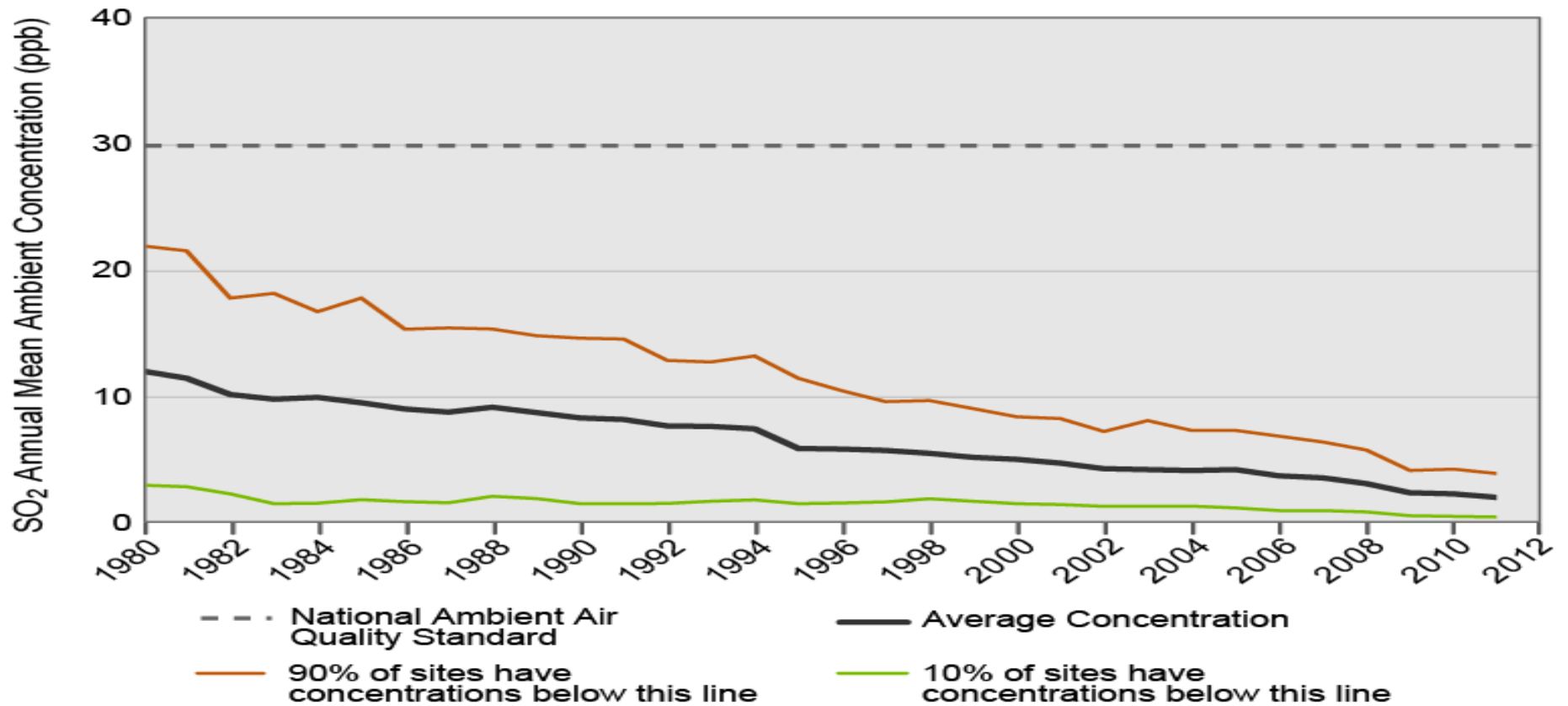
Supporting Information

State-by-State Annual SO₂ Emission For CAIR & ARP Sources, 1990 - 2011



Source: EPA, 2012

National SO₂ Air Quality, 1980–2011



Source: EPA, 2013

Based on Biological Effects



Category Label	ANC Level	Expected Ecological Effects
Acute Concern	0 micro equivalent per Liter ($\mu\text{eq/L}$)	Near complete loss of fish populations is expected. Planktonic communities have extremely low diversity and are dominated by acidophilic forms.
Elevated Concern	0–50 $\mu\text{eq/L}$	Fish species richness is greatly reduced (more than half of expected species are missing). On average, brook trout populations experience sub-lethal effects, including loss of health and reproduction (fitness).
Moderate Concern	50–100 $\mu\text{eq/L}$	Fish species richness begins to decline (sensitive species are lost from lakes). Brook trout populations are sensitive and variable, with possible sub-lethal effects.
Low Concern	> 100 $\mu\text{eq/L}$	Fish species richness may be unaffected. Reproducing brook trout populations are expected where habitat is suitable. Zooplankton communities are unaffected and exhibit expected diversity and distribution.



Relate Water Chemistry to Biological Health

Stream ANC above 50 $\mu\text{eq/L}$

