Integrated Assessment of the Recovery of Surface Waters from Reduced Levels of Acid Deposition in the Catskills and Adirondacks

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science for a changing world

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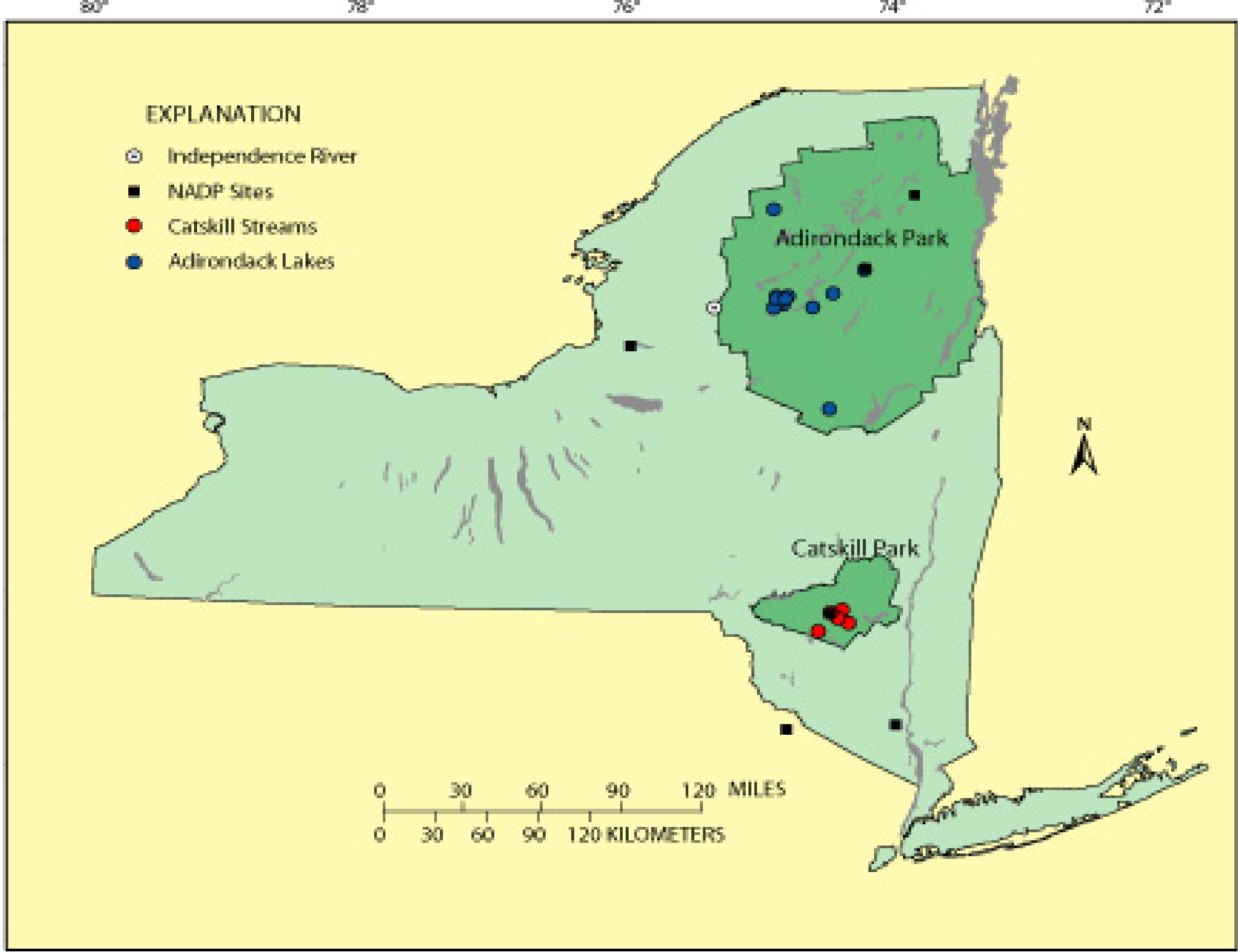
Objectives

- Compare temporal changes in surface water chemistry in the Catskills and ADKs
- Look at processes/factors affecting the N cycle across these regions – sugar maple
- Predict future surface water chemistry

Temporal Change Across Regions

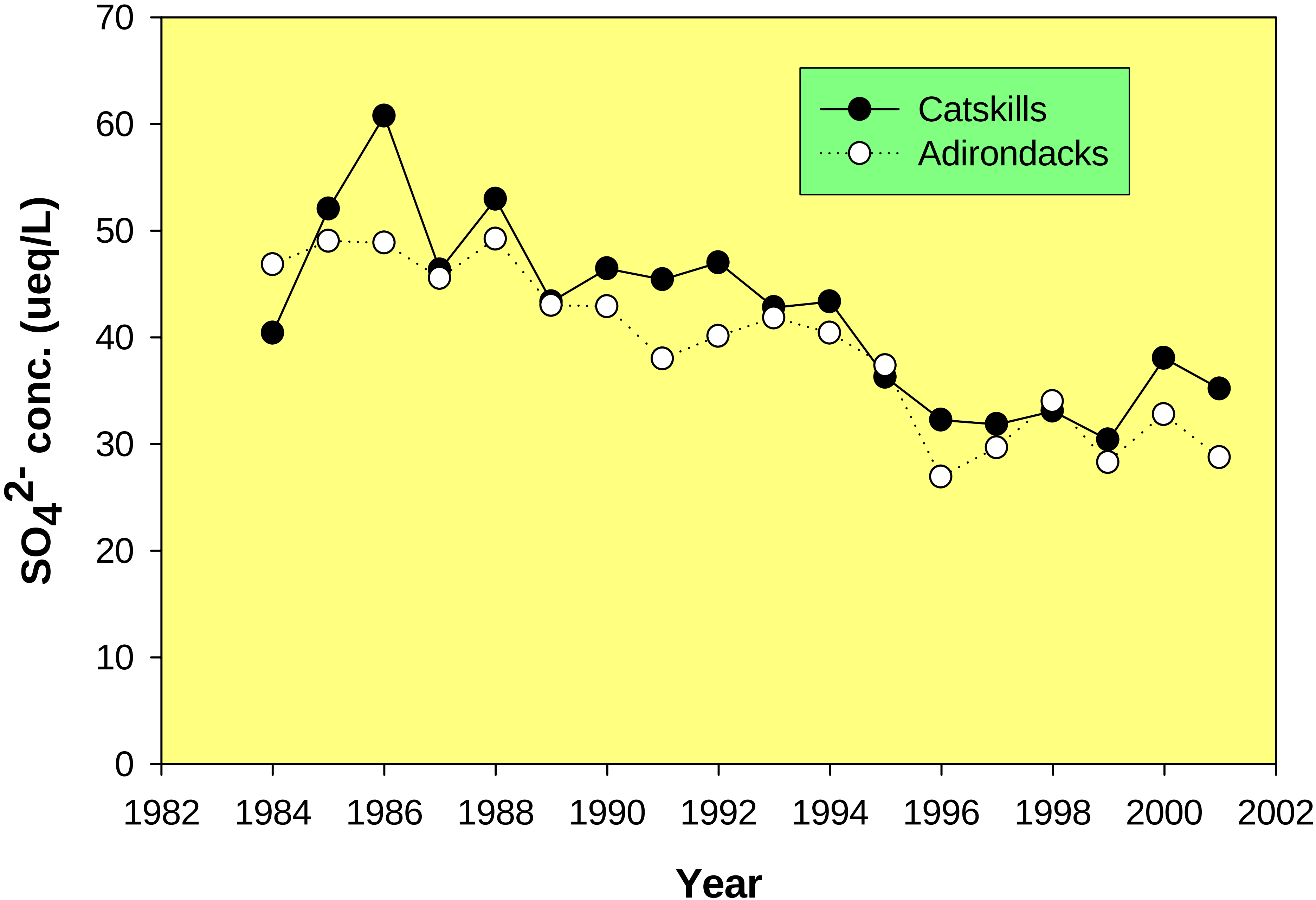
- Trend analysis – Seasonal Kendall test
- Precipitation chemistry – 3 NADP sites near each region, 1984-2001, 1992-2001
- Surface water chemistry – 5 Catskill streams, 12 ADK lakes, 1992-2001
- Flow correction vs. no flow correction
- Synchronicity of trends



80°
78°
76°
74°
72°
45°
43°
41°
EXPLANATION
Independence River
NADP Sites
Catskill Streams
Adirondack Lakes
Adirondack Park
Catskill Park
N
0 30 60 90 120 MILES
0 30 60 90 120 KILOMETERS

Precipitation Chemistry Trends, 1984-2001

- pH increased 0.01 to 0.02 yr^{-1}
- SO_4^{2-} conc. decreased 1 to 1.5 $\mu eq\ L^{-1}\ yr^{-1}$
- NO_3^- conc. decreased 0.33 $\mu eq\ L^{-1}\ yr^{-1}$ (5 of 6 sites)
- Fewer trends during 1992-2001 – only pH trends persistent



Catskills
Adirondacks
SO_4^{2-} conc. (ueq/L)
Year
0
10
20
30
40
50
60
70
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002

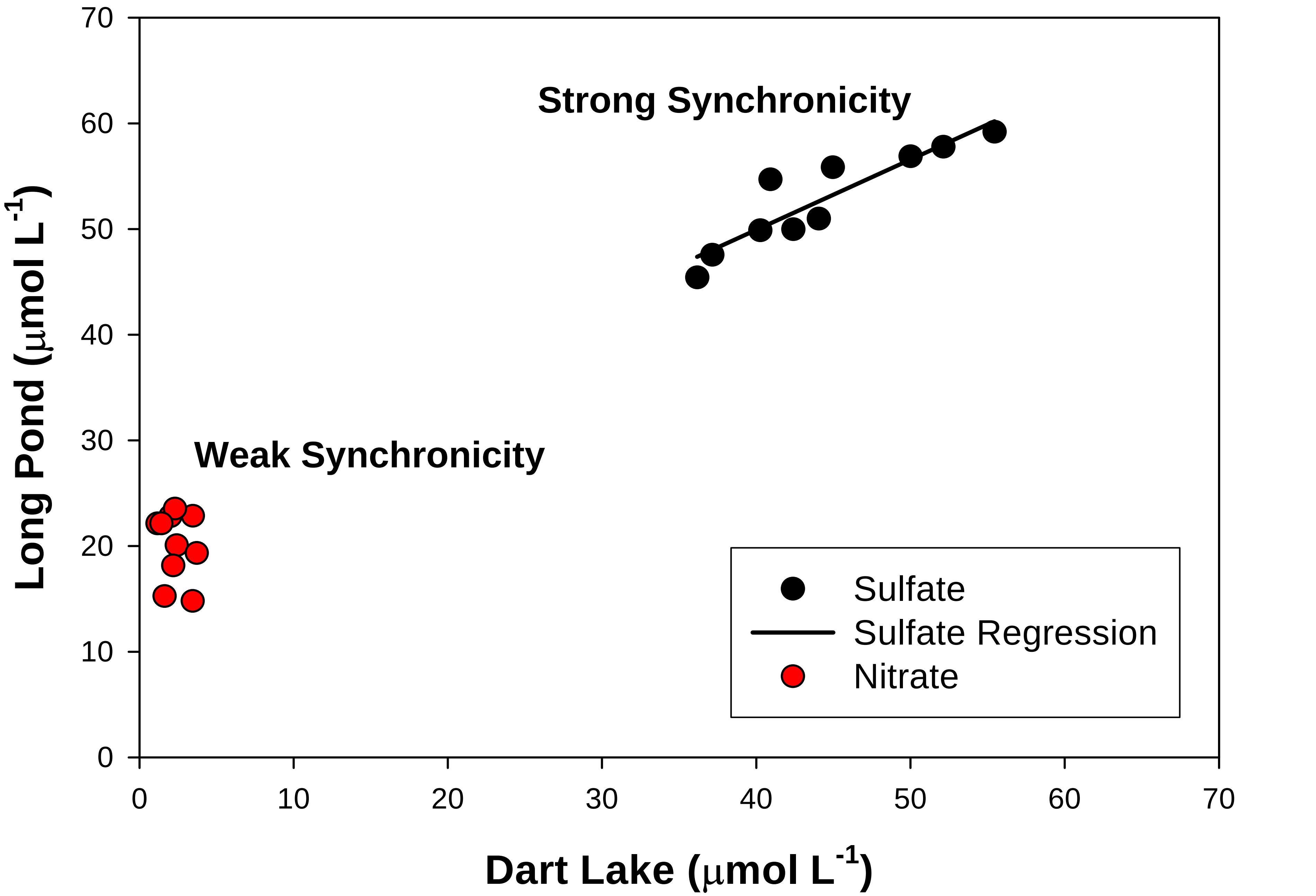
Surface Water Chemistry Trends, 1992-2001

- SO_4^{2-} conc. decreased at all sites

  Catskills = $-2.5\ \mu eq\ L^{-1}\ yr^{-1}$

  ADKs = $-3.3\ \mu eq\ L^{-1}\ yr^{-1}$
- BC conc. decreased at ~ 95% of sites
- NO_3^- conc. decreased at ~ 50% of sites
- pH and ANC increased at ~ 60% of sites

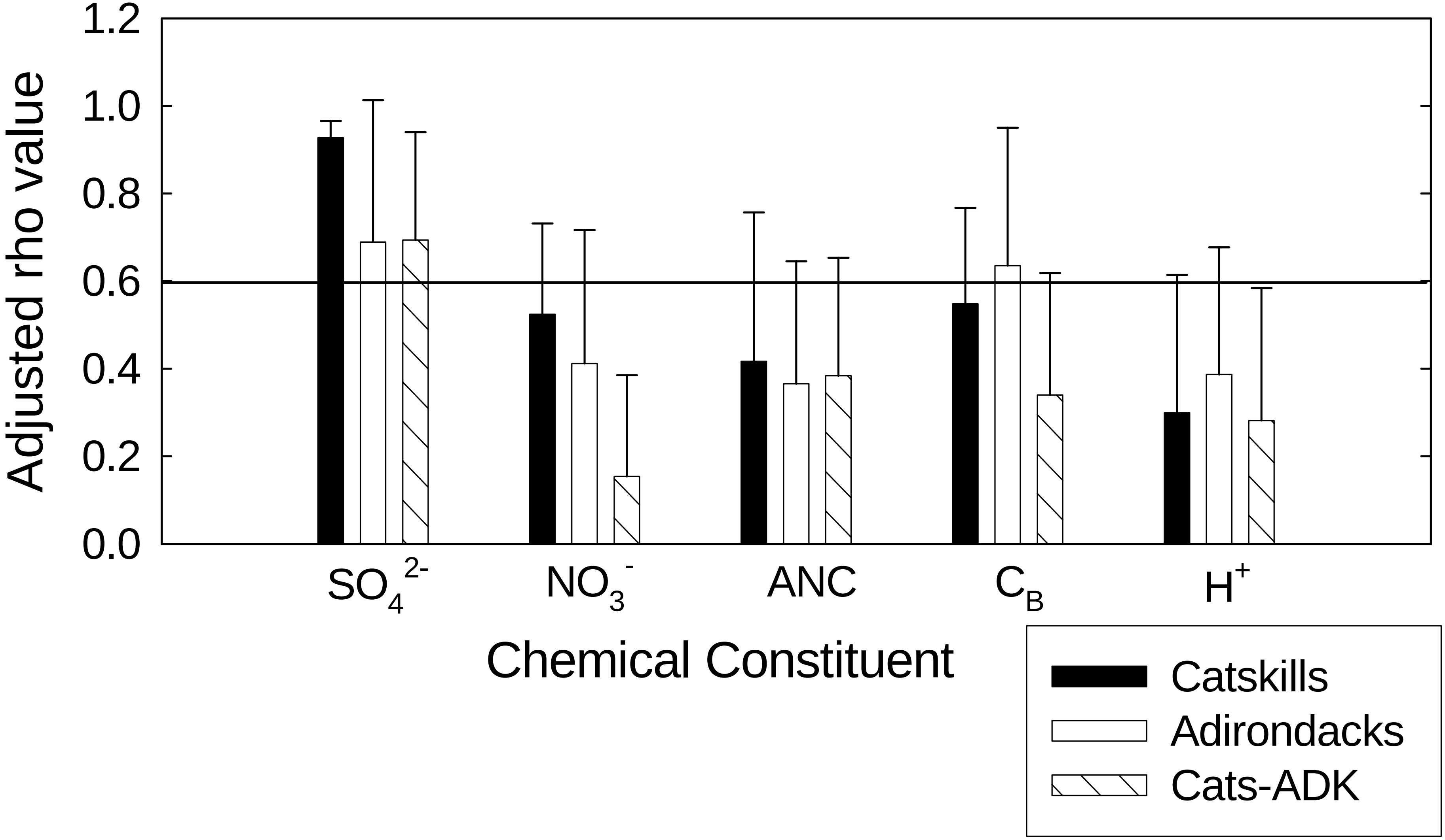
What is Trend Synchronicity? – An Example



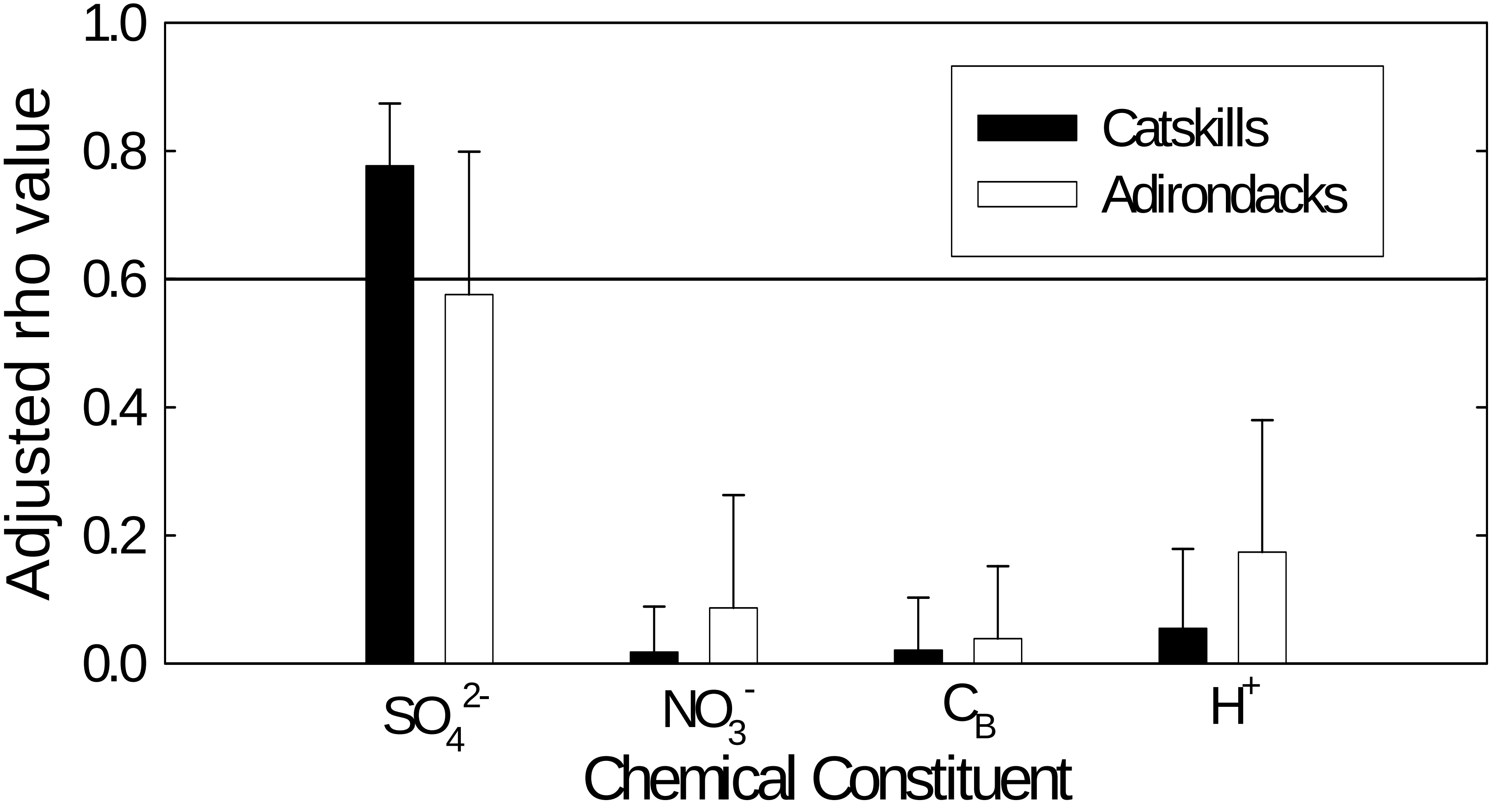
Trend Synchronicity

- Pairwise comparisons of sites – by region, across regions, mean annual volume-weighted conc.
- Rho (r) value – linear regression
- Statistical significance – $p < 0.05$, $r > 0.609$
- Strong synchronicity – drivers of element cycling processes are fairly uniform across the region
- Weak synchronicity – drivers vary among the sites

Synchronicity - Surface Water Chemistry



Synchronicity – Precip. and Surface Water Chemistry



Synchronicity Results

- SO_4^{2-} shows strong synchronicity among surface waters within each region and across regions
- S cycle processes fairly uniform and strongly linked with changes in precip. SO_4^{2-} conc.
- NO_3^- shows weak synchronicity
- N cycle is affected by a myriad of factors, which differ within each region and across regions
- pH and ANC not synchronous - affected by changes in SO_4^{2-}, NO_3^-, base cations, and others

Nitrogen Cycle

- NO_3^- trends in surface waters do not parallel those in precip.
- N is in high biological demand relative to its supply, more tightly cycled than S
- Factors – land use history, fires, wetlands, tree species, soil organic matter

Role of Sugar Maple

- Both regions dominated by northern hardwood forest – American beech, yellow birch, sugar maple, red maple
- Sugar maple soils - higher rates of nitrification, higher NO_3^- conc. in drainage waters than other northern hardwoods
- Any changes in the relative amount of sugar maple will change NO_3^- conc.

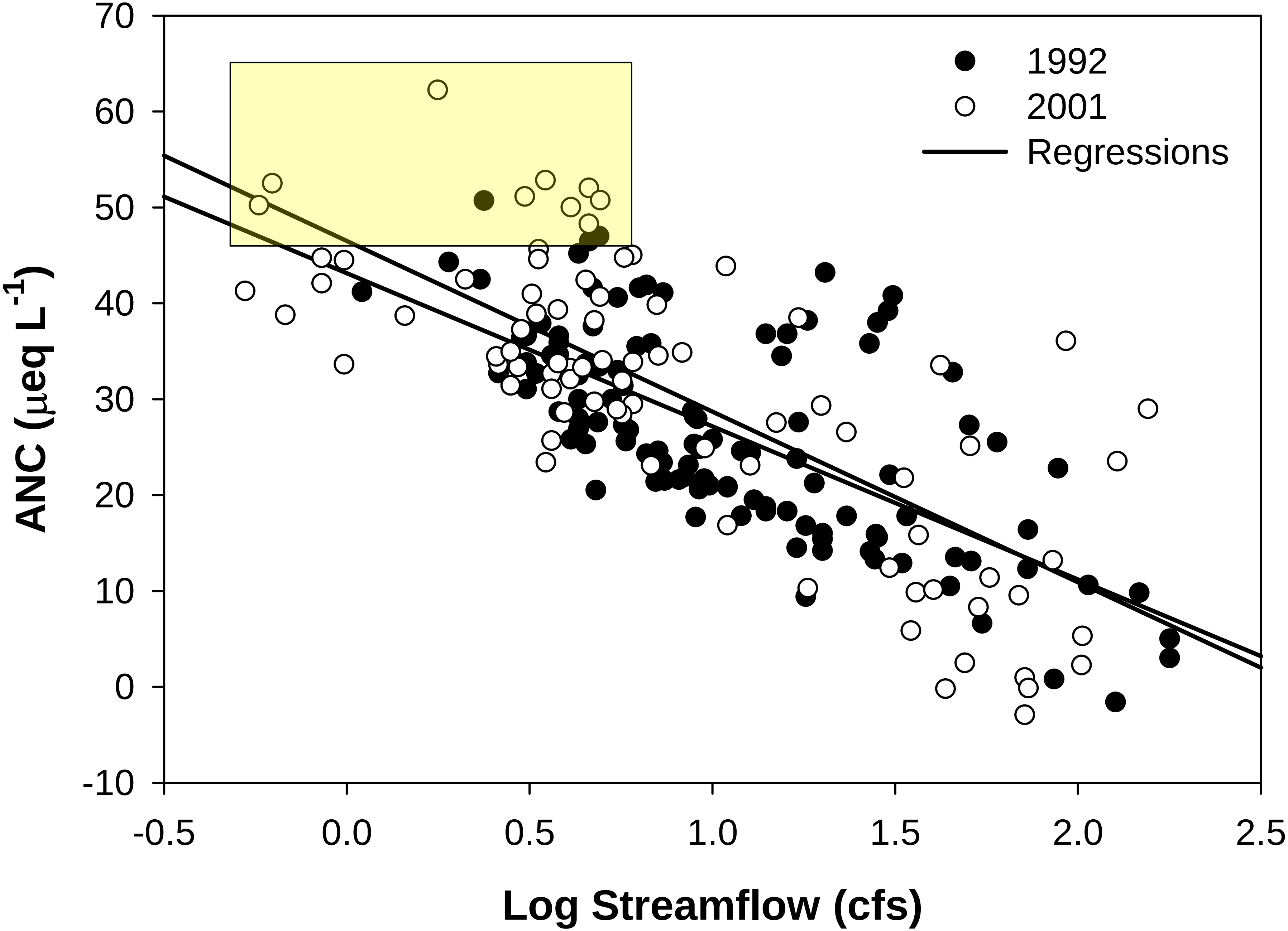
Factors that might Affect Future Sugar Maple Abundance

- Climate warming – retreat
- Beech bark disease
- Acid precipitation – Ca^{2+} depletion
- Deer browsing – prefer maple to beech
- Pests – Asian long-horned beetle

Flow Correction of Trends

- Most studies of trends have not used flow correction
- Compared trend results with and without flow correction
- Flow not monitored in most ADK lakes – Independence River
- Flow correction important because changes in flow alone can cause trends

Why do Trends Need to be Flow Corrected?



Did Flow Correction Change Conclusions About Trends?

- No change in trend direction
- No change in SO_4^{2-} trends
- 3 NO_3^- and 4 ANC trends

  Significant $\longrightarrow$ No trend
- Flow-related climate variation can affect trends flow-sensitive species
- Greater availability of flow data at ADK lakes would improve trend detection

DOC Trends

- Increasing trends at 75 – 80% of sites

  Catskills = 4.7 μmol L^{-1} yr^{-1}

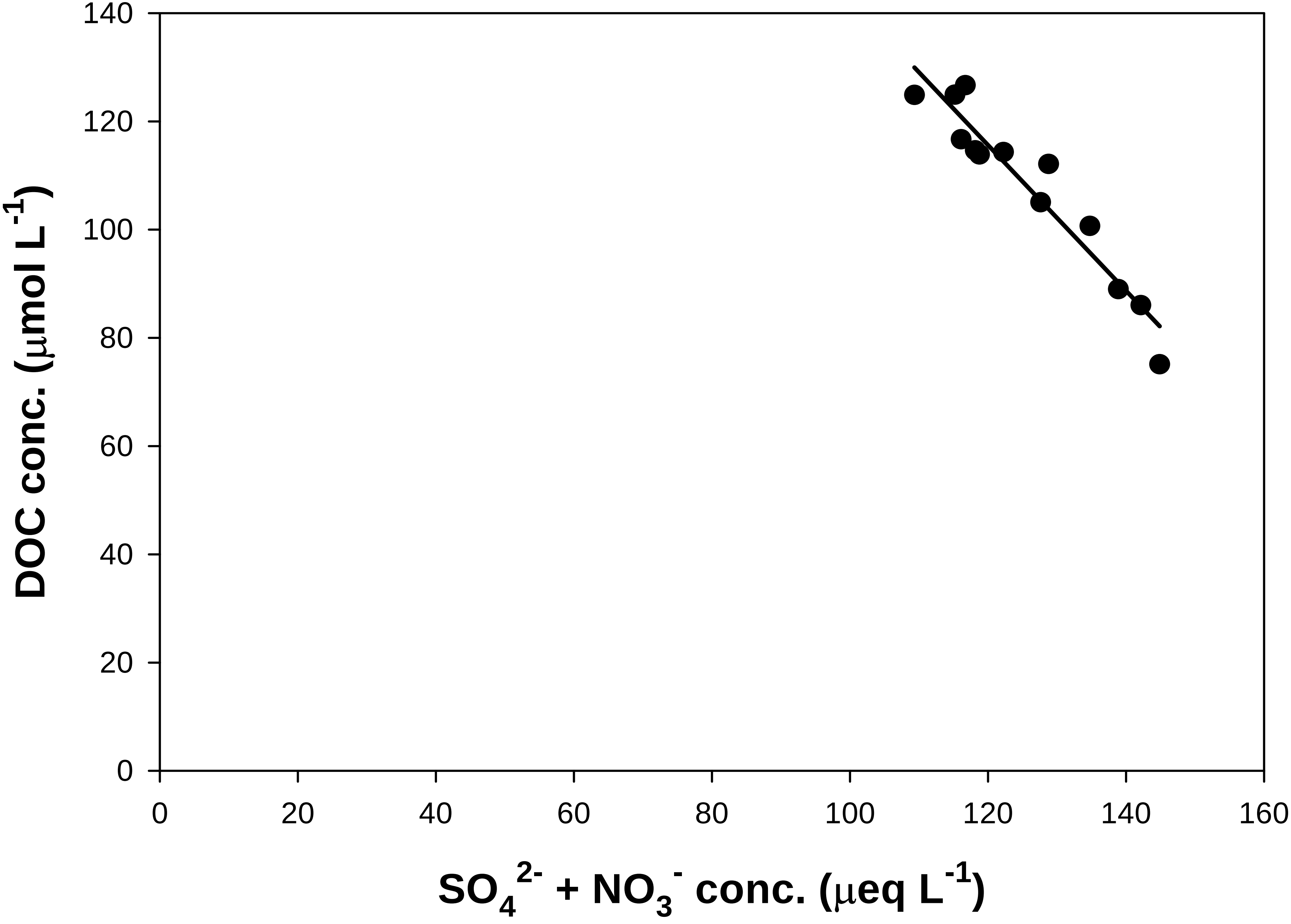
  ADKs = 7.6 μmol L^{-1} yr^{-1}

- Similar trends found in many other studies
- Importance – organic acids affect pH and ANC, forms of Al present, aquatic productivity

Why is DOC Increasing?

- Warmer temperatures stimulate microbial decomposition processes
- Increasing pH
- Decreasing ionic strength
- Chronic N deposition
- Decreasing snowmelt
- Increasing cloudiness

Biscuit Brook – Low Flow Samples 1992 - 2004



DOC Increasing - Hypothesis

- As S and N deposition decrease – “bleeding out” of organic forms of S and N from soil organic matter
- Many watersheds in NE and Europe show greater export than import of S
- As long as SO_4^{2-} and NO_3^- declining, then DOC will continue to increase
- Organic acidity replacing inorganic acidity
- May limit increases in pH

Modeling - PnET-BGC

- PnET – ecosystem model, C, N, and water
- BGC – geochemical equilibrium model, base cations and Al
- Calibrated – compared to historical water chem., 4 ADK lakes, 1 Catskill stream
- Predicted water chem. under different deposition scenarios

Modeled Changes in ANC by 2050

Model Scenario	Reduction in SO_2 Emissions by 2010	Reduction in NO_x Emissions by 2010	Change in ANC
1990 CAAA base case	40	5	+3.4 ± 1.8
Moderate control	55	20	+9.4 ± 4.3
Aggressive control	75	30	+19.1 ± 4.9

Modeling Results

- Under 1990 CAAA 3 ADK lakes with negative ANC would remain negative
- Under aggressive control scenario, 2/3 would reach positive ANC
- Even under aggressive control scenario, increase in ANC ~ 1/3 to 1/2 of current rates (1990-2000)

Conclusions - 1

- ANC and pH increased 60% of surface waters examined in two regions
- Only SO_4^{2-} showed strong synchronicity among regions suggesting surface waters respond rapidly and uniformly to changes in deposition
- NO_3^- conc. increased 50% of waters, trends not directly related to changes in precip. NO_3^- conc.

Conclusions - 2

- Abundance of sugar maple one factor that affects NO_3^- leaching
- Flow correction can affect trend significance NO_3^- and ANC
- DOC increasing – deserves greater attention
- Modeling shows increasing ANC of ~ 0.1 $\mu eq\ L^{-1}\ yr^{-1}$ under 1990 CAAA

Publications

- **Trends** – Burns et al., in press, Hydrological Processes
- **Sugar Maple** – Lovett and Mitchell, 2004, Frontiers in Ecology and the Environment
- **Modeling** – Chen et al., 2004, Hydrological Processes; Chen and Driscoll, 2004, Atmospheric Environment
- **NYSERDA Report** – Burns et al., 2005