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

Douglas Burns
U.S. Geological Survey
Troy, NY
Co-Principal Investigators

• Mike McHale, USGS
• Charley Driscoll, Syracuse Univ.
• Gary Lovett, Inst. Ecosystem Studies
• Karen Roy, NYSDEC
• Myron Mitchell, SUNY-ESF
• Kathie Weathers, Inst. Ecosystem Studies
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
Precipitation Chemistry Trends, 1984-2001

- pH increased 0.01 to 0.02 yr\(^{-1}\)
- SO\(_4^{2-}\) conc. decreased 1 to 1.5 µeq L\(^{-1}\) yr\(^{-1}\)
- NO\(_3^-\) conc. decreased 0.33 µeq L\(^{-1}\) yr\(^{-1}\) (5 of 6 sites)
- Fewer trends during 1992-2001 – only pH trends persistent
Surface Water Chemistry Trends, 1992-2001

- $\text{SO}_4^{2-}$ conc. decreased at all sites
  - Catskills = $-2.5 \ \mu\text{eq L}^{-1} \ \text{yr}^{-1}$
  - ADKs = $-3.3 \ \mu\text{eq L}^{-1} \ \text{yr}^{-1}$
- 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

Sulfate Regression

Strong Synchronicity

Weak Synchronicity

Dart Lake (µmol L⁻¹)

Long Pond (µmol L⁻¹)
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

Chemical Constituent

- $\text{SO}_4^{2-}$
- $\text{NO}_3^-$
- ANC
- $C_B$
- $H^+$

Adjusted rho value
Synchronicity – Precip. and Surface Water Chemistry

Chemical Constituent

- $SO_4^{2-}$
- $NO_3^-$
- $CB$
- $H^+$

Adjusted rho value
Synchronicity Results

• $\text{SO}_4^{2-}$ shows strong synchronicity among surface waters within each region and across regions
• $\text{S}$ cycle processes fairly uniform and strongly linked with changes in precip. $\text{SO}_4^{2-}$ conc.
• $\text{NO}_3^-$ shows weak synchronicity
• $\text{N}$ 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 $\text{SO}_4^{2-}$, $\text{NO}_3^-$, base cations, and others
Nitrogen Cycle

- $\text{NO}_3^-$ trends in surface waters do not parallel those in precip.
- $\text{N}$ is in high biological demand relative to its supply, more tightly cycled than $\text{S}$
- 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 $\text{NO}_3^-$ conc. in drainage waters than other northern hardwoods

• Any changes in the relative amount of sugar maple will change $\text{NO}_3^-$ 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 $\text{SO}_4^{2-}$ trends
- 3 $\text{NO}_3^-$ and 4 ANC trends
  - Significant $\rightarrow$ 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 conc. (µmol L⁻¹) vs. SO₄²⁻ + NO₃⁻ conc. (µeq L⁻¹)
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

<table>
<thead>
<tr>
<th>Model Scenario</th>
<th>Reduction in SO$_2$ Emissions by 2010</th>
<th>Reduction in NO$_x$ Emissions by 2010</th>
<th>Change in ANC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990 CAAA base case</td>
<td>40</td>
<td>5</td>
<td>+3.4 ± 1.8</td>
</tr>
<tr>
<td>Moderate control</td>
<td>55</td>
<td>20</td>
<td>+9.4 ± 4.3</td>
</tr>
<tr>
<td>Aggressive control</td>
<td>75</td>
<td>30</td>
<td>+19.1 ± 4.9</td>
</tr>
</tbody>
</table>
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 $\text{NO}_3^-$ leaching
- Flow correction can affect trend significance $\text{NO}_3^-$ and ANC
- DOC increasing – deserves greater attention
- Modeling shows increasing ANC of $\sim 0.1 \mu\text{eq L}^{-1} \text{ yr}^{-1}$ 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