LINKAGES AMONG ACIDIC AND MERCURY DEPOSITION AND CLIMATE CHANGE IN ADIRONDACK ECOSYSTEMS

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Outline

- Approach and pollutant interactions
- Recent trends in Adirondack deposition and lake chemistry
- Linkages with mercury
- Linkages with climate change
- Final thoughts
Lake Classes

- Seepage
- Drainage
  - Thin till
  - Medium till
  - Thick till
- Carbonate
Arbutus Lake – 48.2 ha
Climatic Data
- Solar radiation
- Precipitation
- Temperature

Atmospheric Chemistry
- Carbon dioxide
- Ozone

PnET
- Water balance
- Photosynthesis
- Living biomass
- Litterfall

Net Mineralization

BGC
- Aqueous reactions
- Surface reactions
  - Cation exchange
  - Adsorption
  - Humic binding
  - Aluminum dissolution/precipitation

Shallow water flow
- Weathering

Deep water flow
- BGC – Surface water
  - Aqueous reactions
Mercury Deposition

SO$_4^{2-}$, NO$_3^-$, H$^+$, Hg$^{2+}$

DOC, H$_2$SO$_4$, NO$_3^-$, H$_2$Al

Hg$^{2+}$, MeHg

Ca$^{2+}$, Al, H$_2$SO$_4$, NO$_3^-$, DOC

H+, ANC, Hg$^{2+}$

Ca$^{2+}$, Al, Hg$^{2+}$, MeHg

MeHg, Al, Hg$^{2+}$

SO$_4^{2-}$, NO$_3^-$, MeHg
Climate Drivers

- $\text{SO}_4^{2-}$, $\text{NO}_3^-$, $\text{H}^+$
- $\text{DOC}$, $\text{ANC}$
- $\text{Ca}^{2+}$, $\text{Al}$

Temperature
Precipitation
$\text{CO}_2$
TRENDS IN WET DEPOSITION
AND LAKE CHEMISTRY
48 Long Term Monitoring Lakes
1992-2008

Change (ueq/L-yr, umol/L-yr)

SO4  - n=47
NO3  - n=19
Ca   - n=39
ANC  - n=34
ALIM - n=35
HION - n=28
SO4 + NO3 - n=46
CB   - n=29

Min - Mean - Max
48 Long Term Monitoring Lakes
1992-2008

Min - Mean - Max

DOC - n=22

Change (umol C/L-yr)
Change in pH

-0.04  -0.02  0.00  0.02  0.04  0.06

Change in DOC (umol/L-yr)

-10      -5    0      5     10     15     20     25

Change in pH

pH 4.0  4.5  5.0  5.5  6.0  6.5  7.0  7.5

Change in DOC (umol/L-yr)
Cumulative Frequency Diagram for Ca (cmol$_c$/Kg)
Ca Normalized to C (Oa Horizon)

Cumulative Frequency Diagram for Exch. Al (cmol$_c$/Kg)
Exch. Al Normalized to C (Oa Horizon)
LINKAGES WITH MERCURY DEPOSITION
DOC (mg C L\(^{-1}\))

HBEF \(r^2 = 0.67\)
Sleepers River \(r^2 = 0.78\)
Beaver Meadow \(r^2 = 0.86\)
Lake Inlet \(r^2 = 0.92\)
$y = 6.67x^{-2.40}$
$r^2 = 0.49; P < 0.0001; n = 131$
LINKAGES WITH CLIMATE CHANGE
AOGCM
- Hadley (high sensitivity)
- GFDL (mid sensitivity)
- PCM (low sensitivity)

Low CO$_2$ = 550 ppm
High CO$_2$ = 970 ppm
at 2100
Stream Flow (HF-HadCM3)

Great Precipitation and Runoff, more uniform seasonal discharge

- Earlier Summer Discharge (Snowmelt)
- Later Snow pack Development

Ave. Monthly Flow (Cm)

Month

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<th>1983-2000</th>
<th>2083-2100</th>
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Streamwater NO₃⁻
With CO$_2$ Fertilization
Acidification Recovery

- **Deposition**
  - Sulfate
  - Nitrate
  - Acidity

- **Forests**
  - Soil
  - Calcium
  - Sugar Maple
  - Red Spruce

- **Lakes**
  - Sulfate
  - Nitrate
  - ANC
  - DOC
  - Fish

**Statuses**:
- Strongly Recovering
- Moderately Recovering
- Uncertain
- Deteriorating
Final Thoughts

- NADP can play a critical role in assessing interactions among acidic and mercury deposition and climate change.

- Long-term meteorological, deposition and watershed data are essential for hypothesis generation and testing models.

- A key research need moving forward is evaluating the linkages between atmospheric and watershed models.
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- National Science Foundation (NSF); and
- USDA Forest Service - NSRC
## Climate Projections (HWF)

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<th>1970-1999</th>
<th>Mean Change 2070-2099</th>
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<tr>
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<td>PCM B1</td>
<td>PCM A1</td>
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<td><strong>Temperature (°C)</strong></td>
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<td>4.4</td>
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<td><strong>Annual Precipitation (cm)</strong></td>
<td>101</td>
<td>+21.2</td>
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<td><strong>PAR (mmol m(^{-2}) s(^{-1}))</strong></td>
<td>618</td>
<td>+21.0</td>
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Low CO\(_2\) = 550 ppm by 2100  
High CO\(_2\) = 970 ppm by 2100  
Current CO\(_2\) = 370 ppm  
In 1800 CO\(_2\) = 280 ppm
Streamwater $\text{SO}_4^{2-}$