Water Quality Monitoring and Atmospheric Deposition: How are they Linked?

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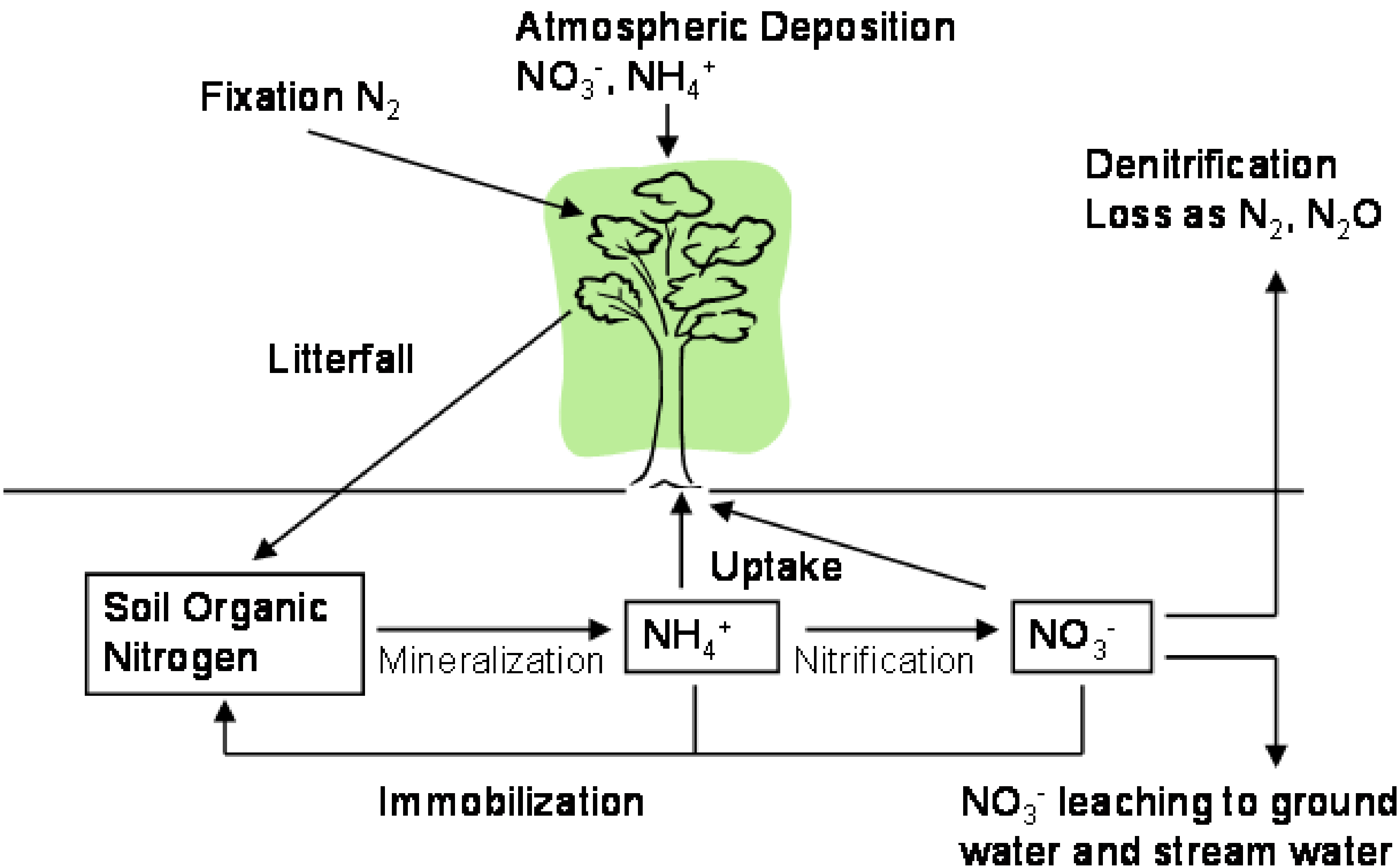
Water Quality Monitoring

- Principal assessment tool for evaluating effects of air pollutants on ecosystems
- **Indirect indicator** – really interested in biota, but quicker and easier than biological monitoring
- Based on understanding of **chemical tolerance range** and **thresholds** for biota – i.e. ANC=0

Assumptions

- Biota will reflect "**chemical conditions**"
- Water quality will reflect atmospheric deposition levels
- Explore these assumptions with examples of Sulfur, Nitrogen, and Mercury deposition studies

Forest Nitrogen Cycle



Some Challenges

- Storage pools are quite large relative to deposition in a given year
- Pools may be responding to other factors – climate, insect defoliation, etc.
- Other loss pathways – gaseous fluxes
- Expect **time lags** between changes in atmospheric deposition and water quality

Hubbard Brook, NH

Compartment or Flux	Sulfur (kg/ha)	Nitrogen (kg/ha)
Annual Input (wet dep.)	12.7	6.5
Annual Output	17.6	3.9
Above Ground Vegetation	42	351
Below Ground Vegetation	17	181
Forest Floor	124	1256

Annual S output < 10% of storage (probably less)

Annual N output < 1% of storage

Likens and Bormann, 1995

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Alpine Ecosystem – Niwot Ridge

Compartment or Flux	Nitrogen (kg/ha)
Annual Input (wet + dry dep.)	6.1
Annual Output	1.6
Above Ground Vegetation	8
Below Ground Vegetation	53.5
Microbial Biomass	5
Soil	681

Annual N output < 1% of storage

Bowman and Seastedt, 2001

Mercury – Experimental Lakes, Canada

Compartment or Flux	Hg (µg/m^2)
Input (throughfall + litterfall)	19
Output (stream)	2.3
Above Ground Vegetation	84.7
Soil	960

Annual Hg output < 2% of storage

Krabbenhoft et al., 2005
Harris et al., 2007

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Other Challenges – Sources and Processes

- Natural sources – i.e. sulfide minerals, N fixation, Hg-bearing minerals
- Multiple human sources – agriculture, human waste
- Incomplete understanding of some biogeochemical processes – semi-irreversible adsorption of S in southern soils
- Quantify sources, rates of key processes
- Tools – isotope tracers, experiments, models

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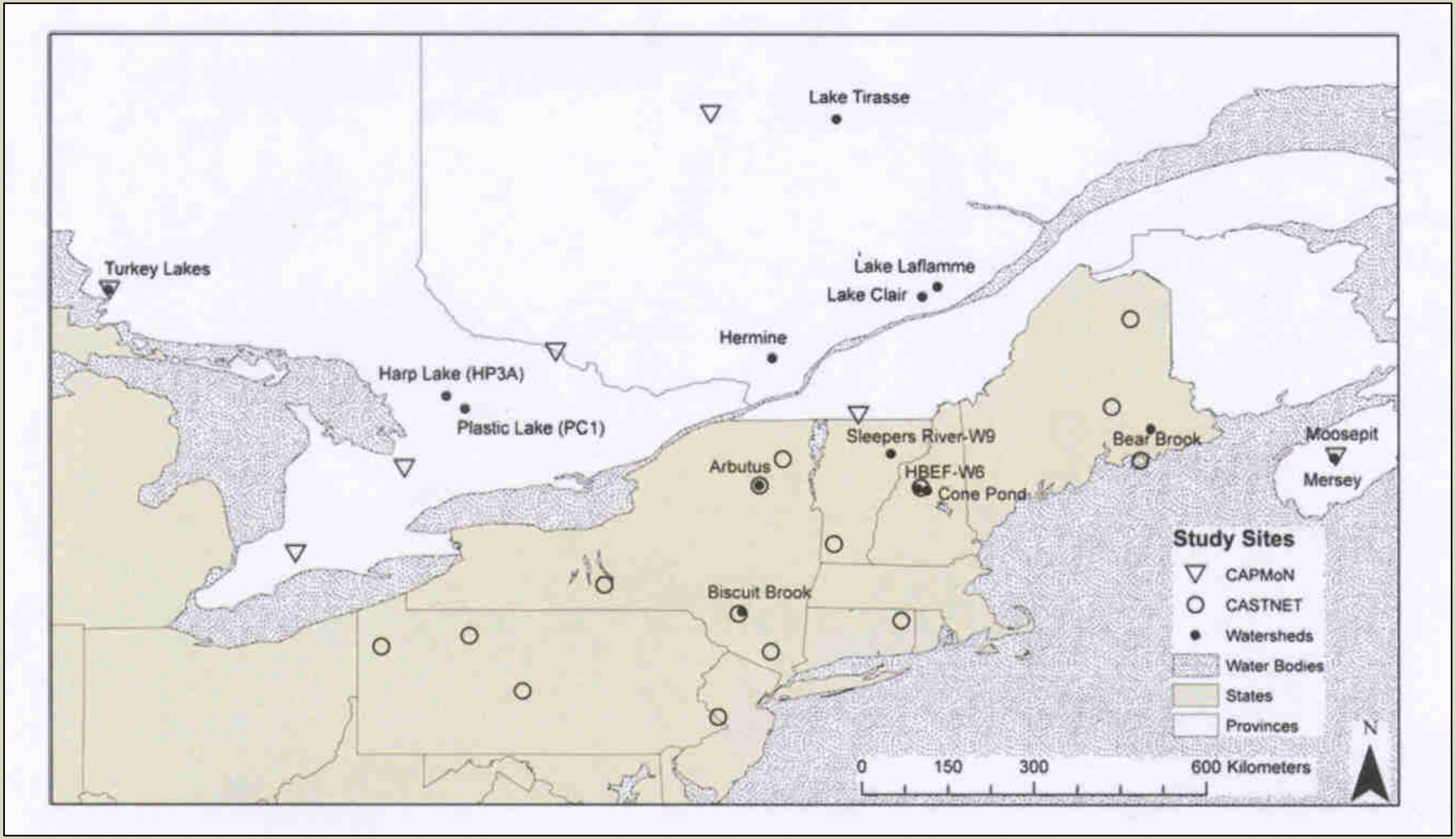
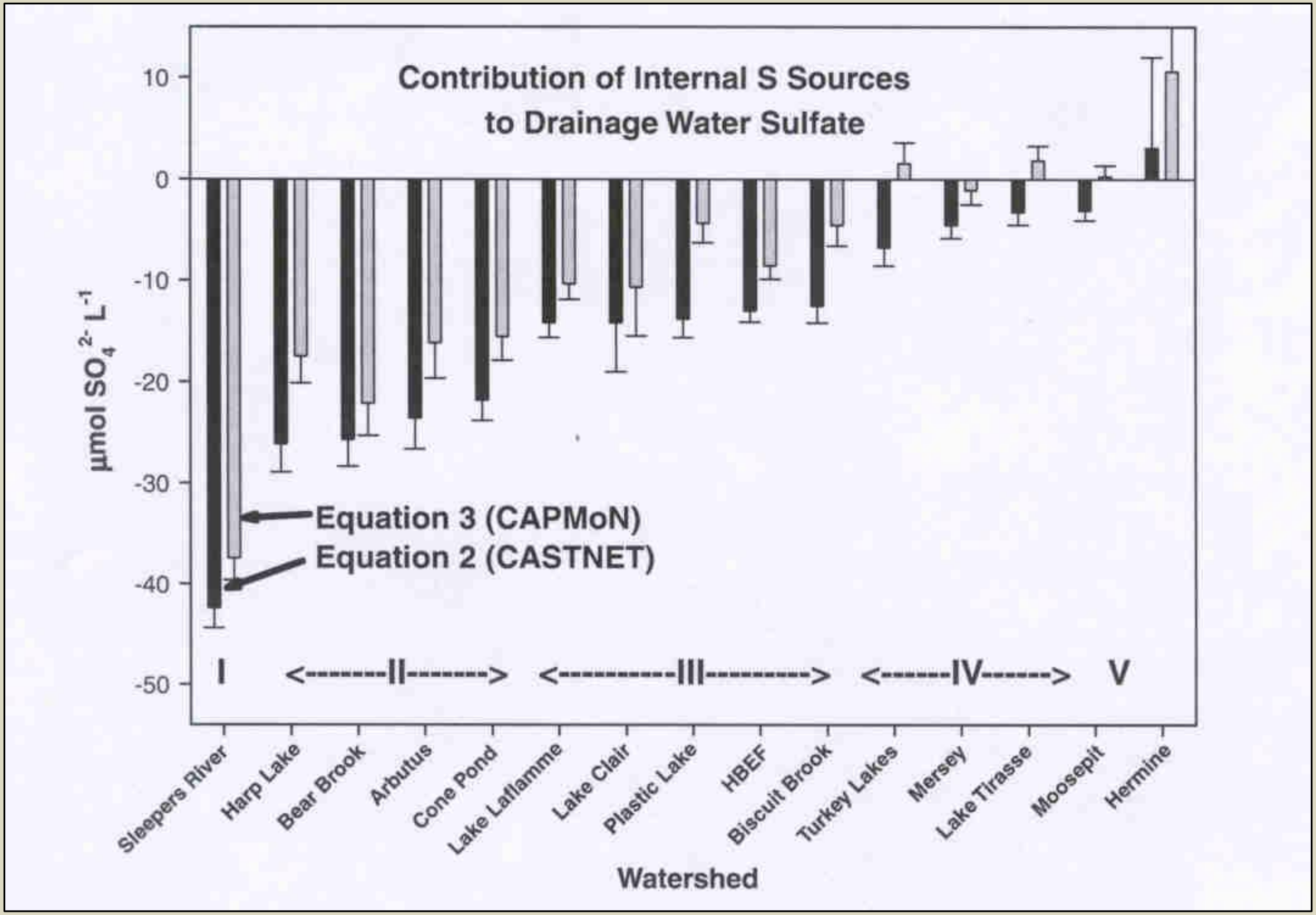
Sulfur Budgets Northeastern North America



Mitchell et al., 2010

Most Sites Show "Bleeding" out of Stored Sulfur



Mitchell et al., 2010

Multiple Nitrogen Sources

- Models based on land use export coefficients (SPARROW) or biogeochemical processes (Chesapeake Bay Model, CENTURY)
- Isotopes – ^{15}N and ^{18}O
- How much of N transport attributed to atmospheric N deposition?
- How much of NO_3^- in undisturbed watersheds is directly-deposited from atmosphere?

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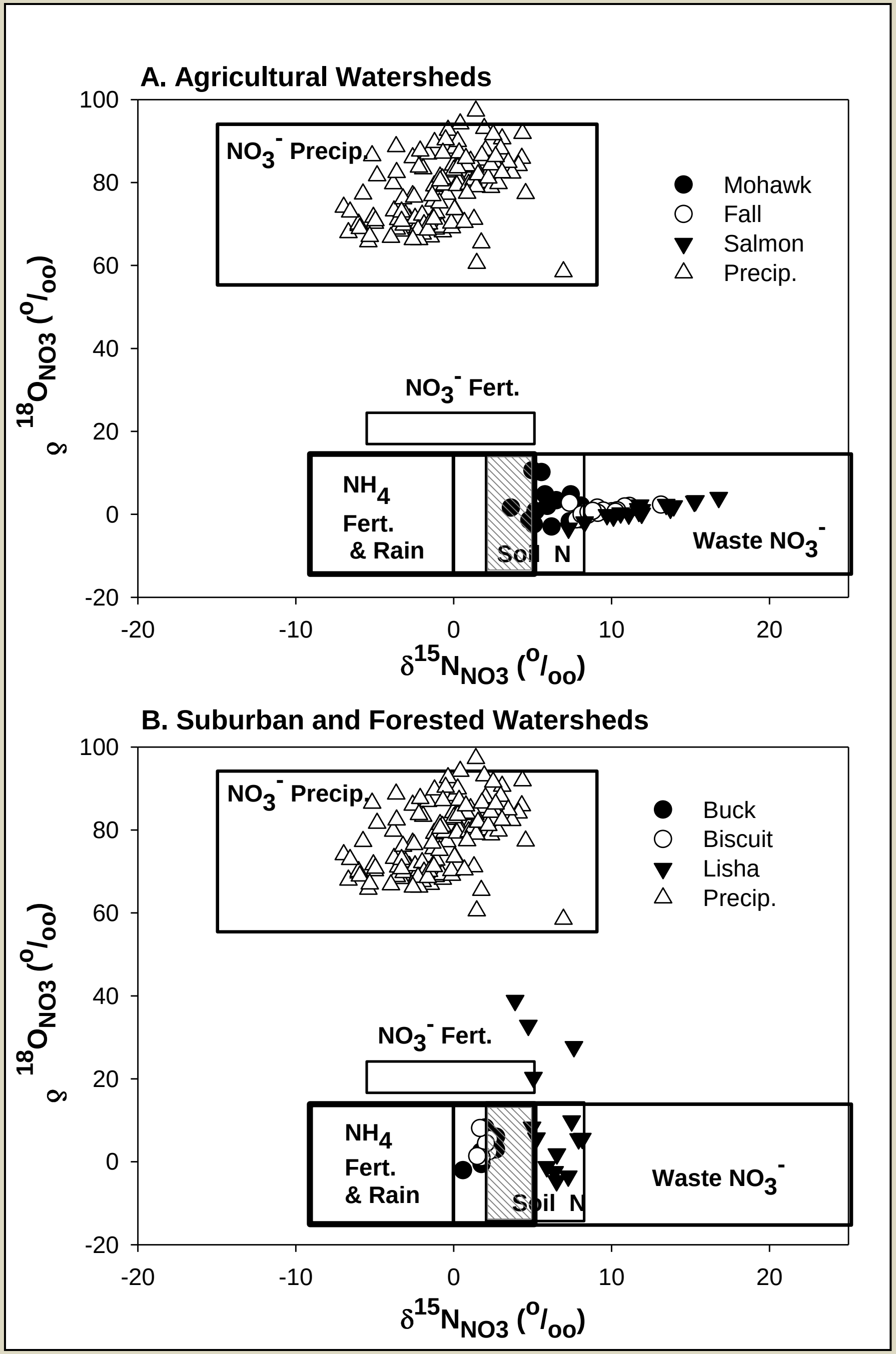
Nitrate Isotopes as Tool for Determining Sources

- Precipitation has high $\delta^{18}O$-NO_3 values
- Waste has high $\delta^{15}N$-NO_3 values
- Possible to observe where denitrification rates are high
- Usually not possible to quantify relative sources



Burns et al., 2009

Mercury

- Large soil stores – bioavailability?
- Large gaseous fluxes - ~10 – 20% of annual inputs
- Isotopes promising new tool – early stages of application
- Experiments – METAALICUS results suggest fish in lakes respond rapidly to decreases in Hg deposition

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Current Focus of Water Quality Monitoring

- Recovery – S, N, and Hg deposition have been decreasing over North America in recent decades
- Is surface water chemistry (biota) responding in kind?
  1. Sulfur – yes in northeast, little response in southeast
  2. Nitrogen – small response in some regions
  3. Mercury – mixed results among fish studies

Water Quality Monitoring Networks

- LTM/TIME – Adirondack and New England lakes, Northern App. Plateau, Blue Ridge
- LTER sites – Hubbard Bk, Coweeta, Niwot Ridge
- Federal agencies – USGS (HBN,WEBB), USFS (Experimental Forests), NPS (RMNP, Acadia, Shen, Smokies), NOAA (estuaries)
- State programs – ALSC, MA, MD, NH, PA, others

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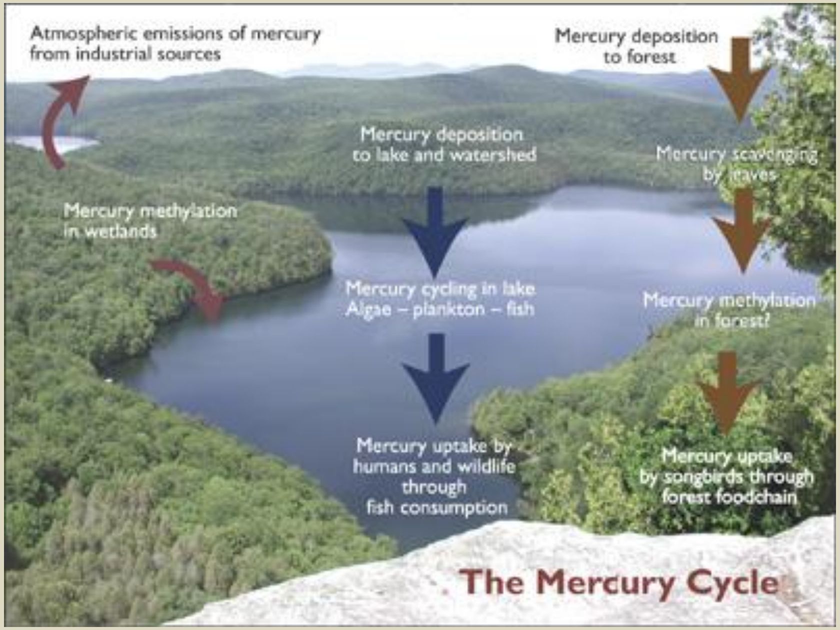
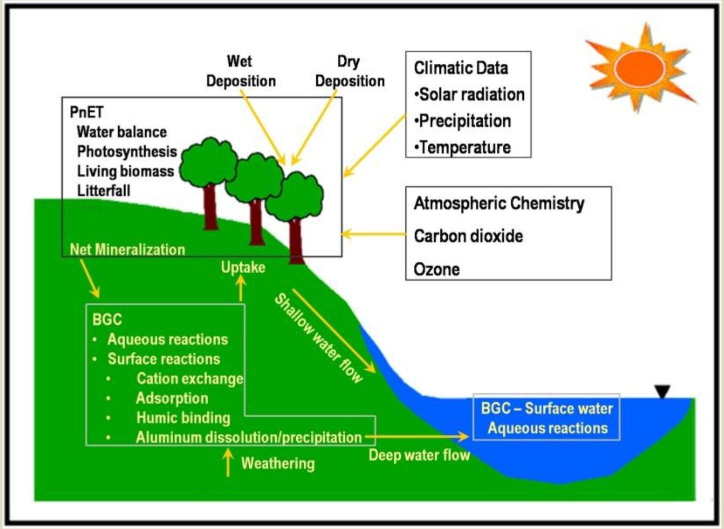
No Mercury Monitoring Network

- Several states periodic assessments of fish Hg
- **MercNet** – strategy for environmental monitoring of Hg, including water chemistry, no funding



Models

- Biogeochemical processes from deposition to surface water chemistry – MAGIC, PnET-BGC, WARMF, others
- Applications - Critical loads, future water chemistry
- Reflect state-of-science
- Challenge - Knowledge of processes & rates incomplete



“Holes” in our Knowledge

- Reversibility of SO_4^{2-} adsorption – southeast
- How do nitrogen pools respond to other disturbances?
- How much of Hg storage is semi-permanent?
- Lags in response to changes in atmospheric deposition
- Soils – important research focus

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Do Biota Always Reflect Water Quality?

- Qualified yes, but time lags
- Recovery from acidification
  1. Acid tolerant communities – competition
  2. Dispersal
  3. Some, but not all chemical conditions may recover - calcium
- Sharp chemical thresholds not always evident
- Restoration of original species

Climate Change Muddying the Waters

- Most biogeochemical processes temp. and moisture dependent – chemical weathering, nitrification, etc.
- DOC may increase due to warming – implications for Hg, acidification recovery
- Increased frequency and intensity of climatic events – drought, large rain storms
- Conceptual understanding and models must consider these climate change factors

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Conclusions

- Water quality reflects atmospheric pollutant deposition
- Soils are important stores of these pollutants – buffer between atmosphere and waters
- Tools to help us understand sources and processes – models, isotopes, experiments
- Expect lags in response – soils
- Biota will not always reflect water quality