Synthesizing Data on Stream Flow and Chemistry at Research Watersheds to Assess Effects of Atmospheric Deposition and Environmental Change

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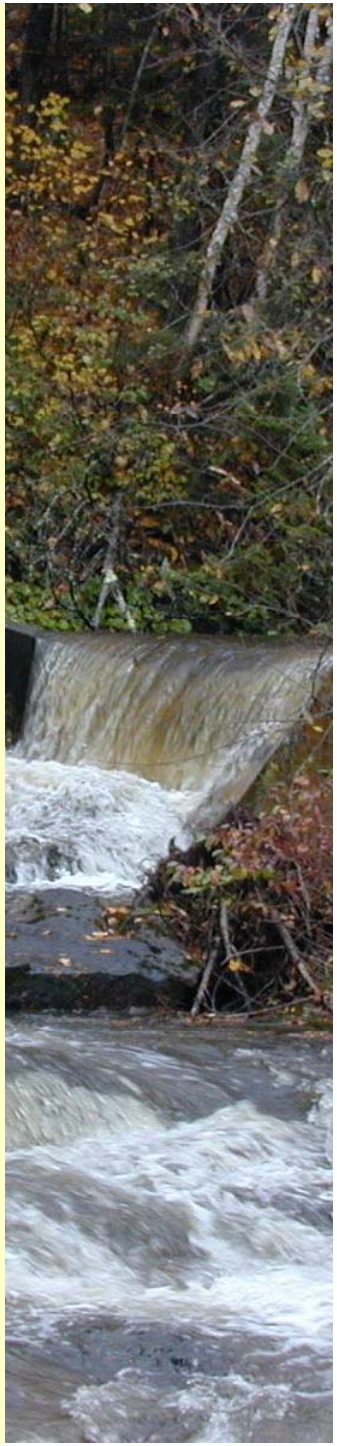
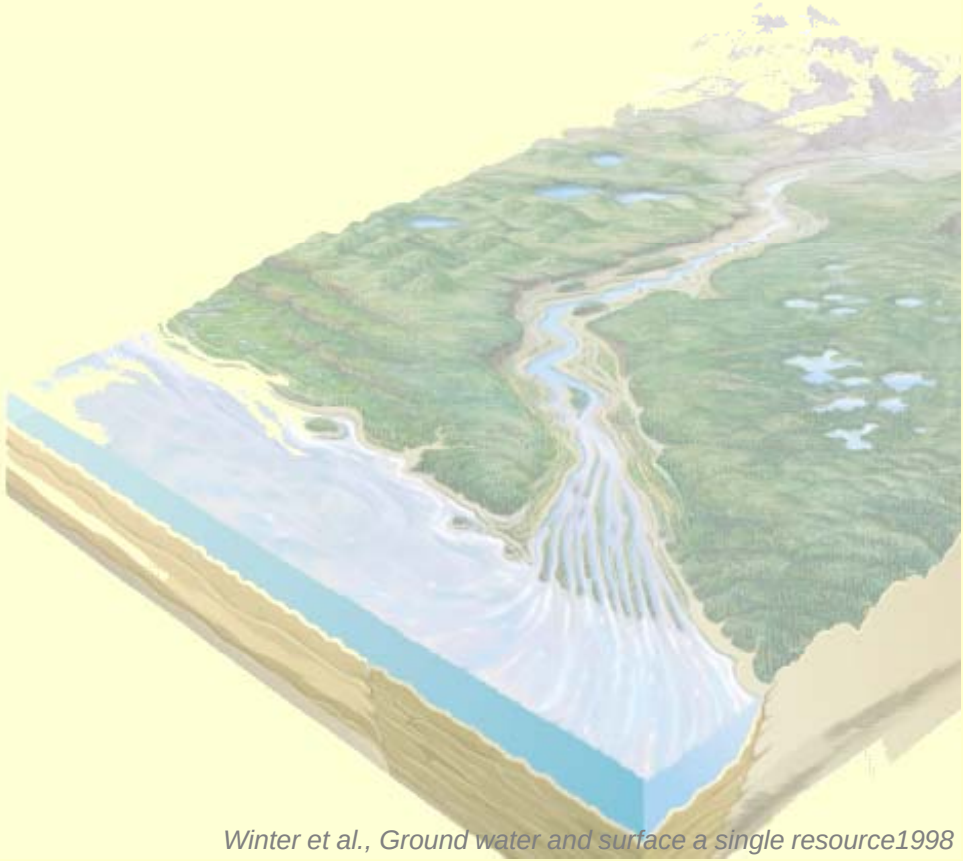
Acknowledgements

- Generations of scientists and technicians at individual sites.
- Operating funds from Forest Service Research Stations and cooperators that supports long-term monitoring at research catchments.
- All cooperators on EFR syntheses, especially Sherri Johnson, Chuck Rhoades, and George Ice. Cooperators from other research catchments.
- Funding from the Forest Service Office of Research and Development (Washington), Rocky Mountain Research Station, Northern Research Station, and the National Council on Air and Stream Improvement.
- ARRA money at Oregon State University that supports post-doctoral researchers.



Quantifying Effects on Forest Streams: A Hydrological Approach

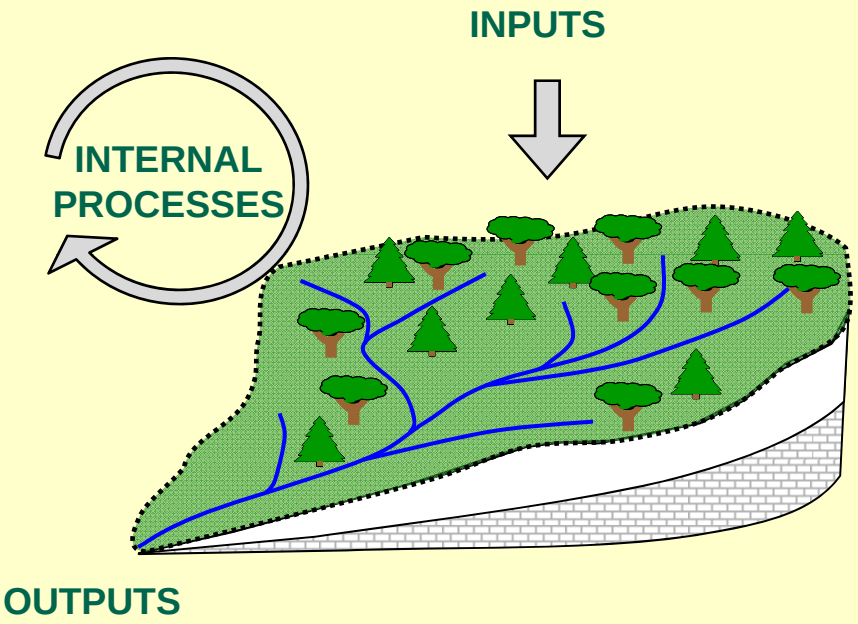
- Present examples of catchment research that have advanced our understanding of effects of atmospheric deposition on stream chemistry. Mostly Forest Service sites.
- Present examples of high temporal resolution tracers of atmospheric pollutant effects.
- Present aspects of emerging synthesis efforts that expand upon site-based research.



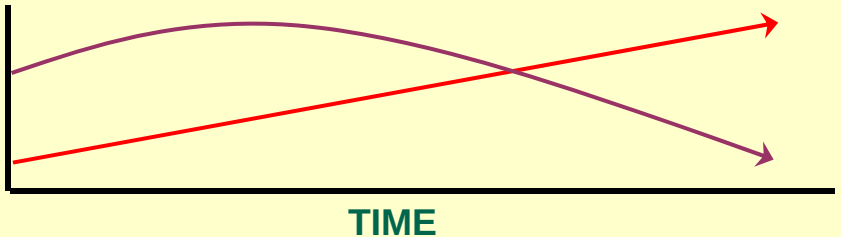
Winter et al., Ground water and surface a single resource1998

Small-Catchment Studies

- Quantify hydrology by measuring precipitation inputs and stream outflows.



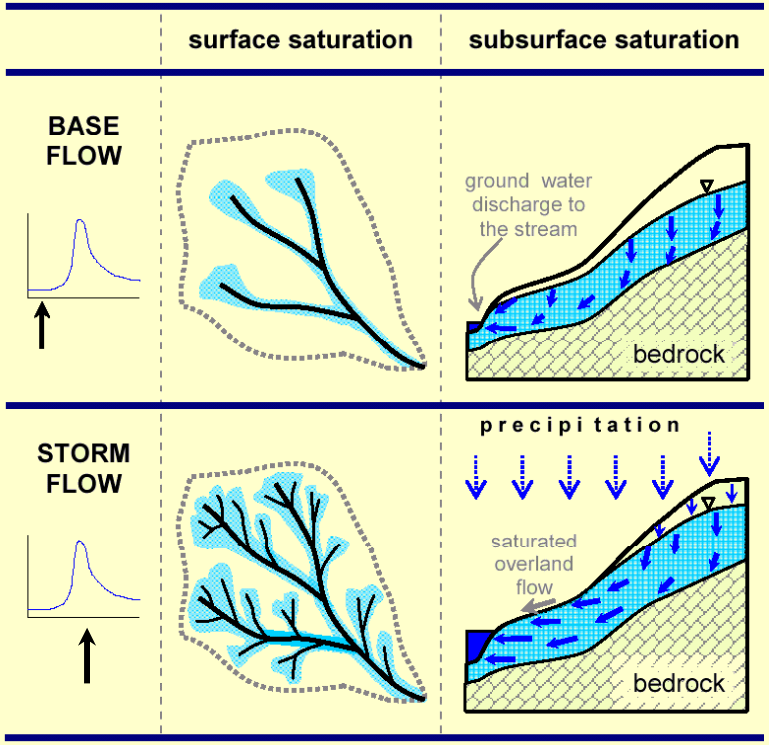
- Monitor baseline reference conditions for change.



To document ecosystem conditions, identify environmental problems, and assess effects of landscape-level management decisions.

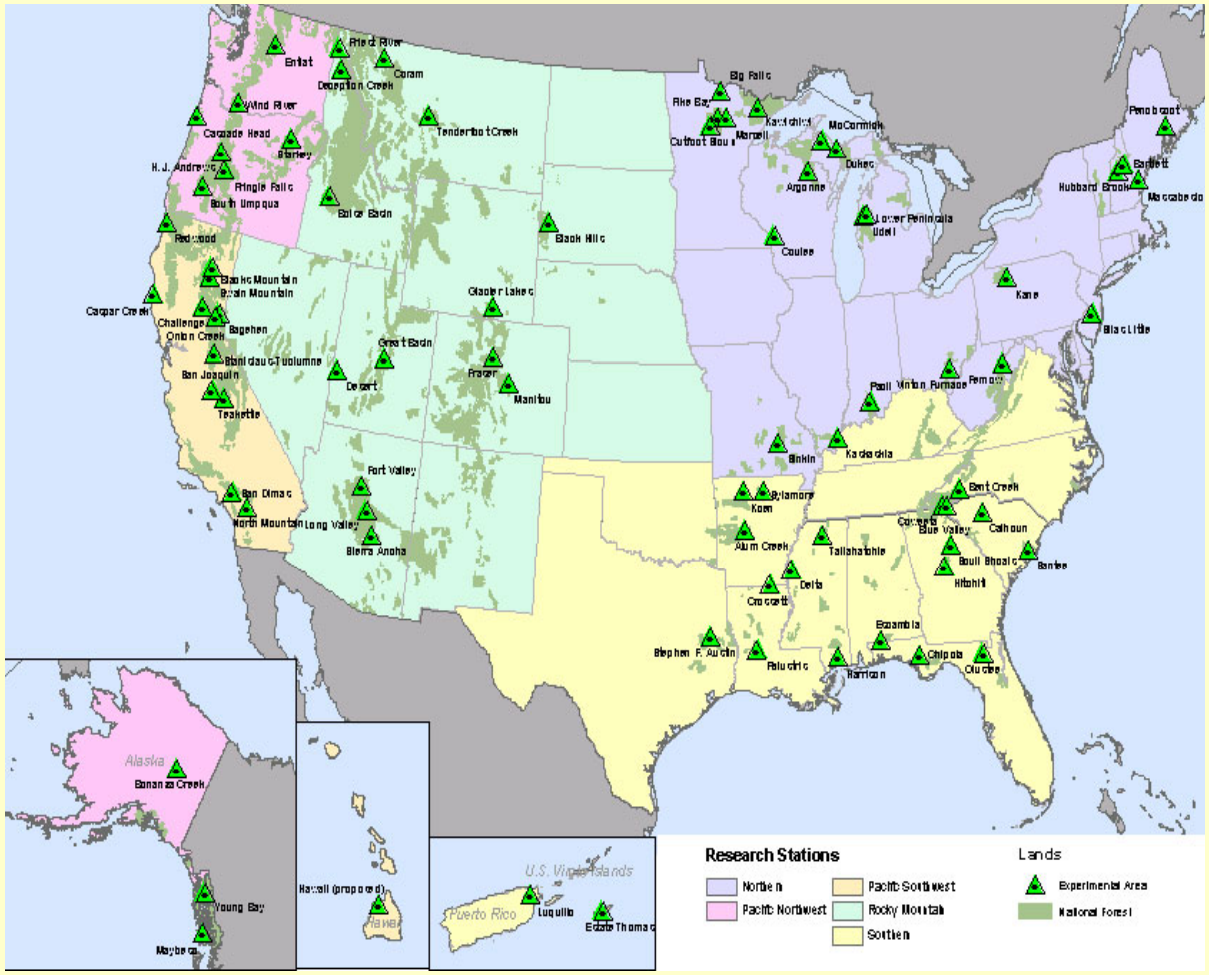
Effects of Flowpath Routing on Stream Chemistry

- Inputs, biogeochemical transformations, and hydrological processes affect solute availability in the landscape.
- The expansion of saturation links distinct landscape source areas to stream chemistry.



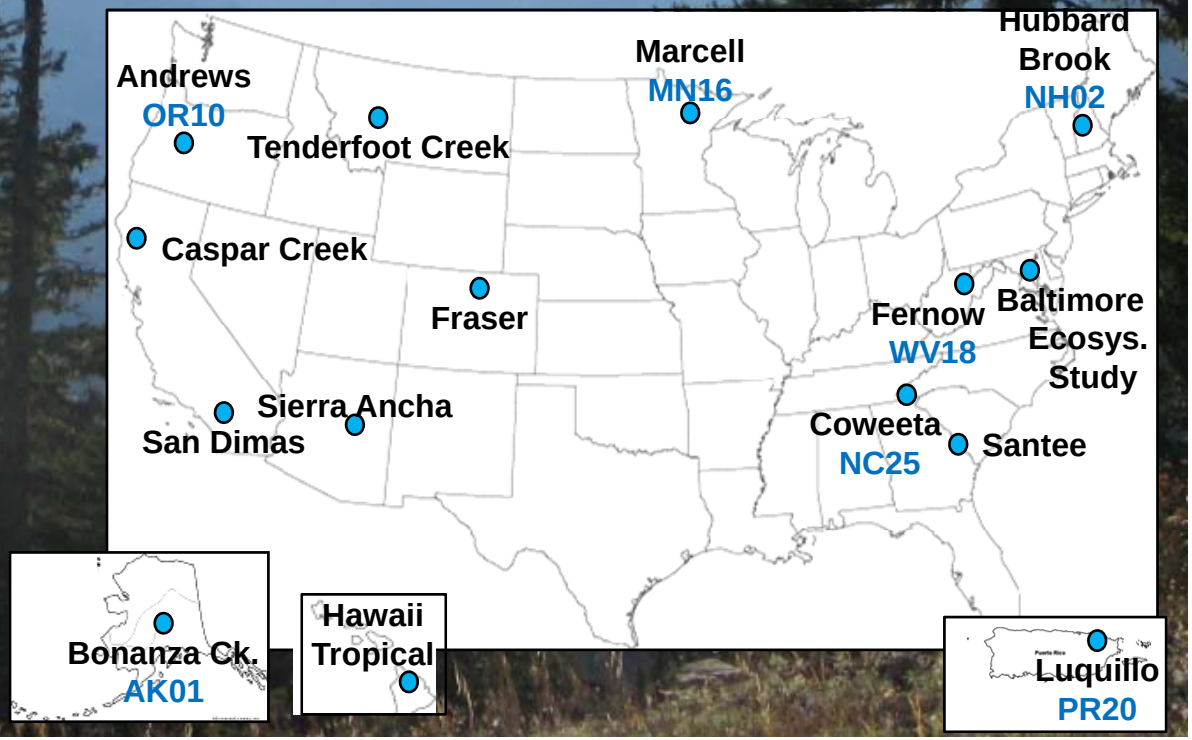
Forest Service
Experimental Forests & Ranges (EFR)

- A majority of sites are silvicultural experiments.
- A subset of sites include catchment and ecosystem research.



Forest Service Experimental Catchments

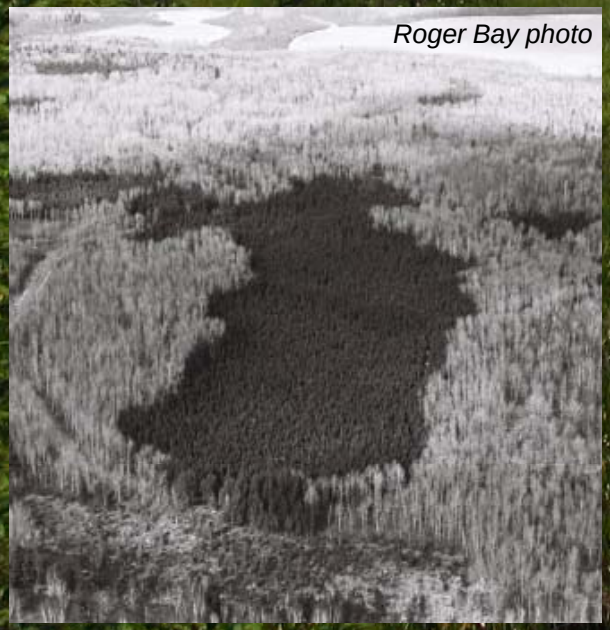
A network of primarily steep, mountainous research catchments that spans the USA.



Lowland Catchments with Wetlands

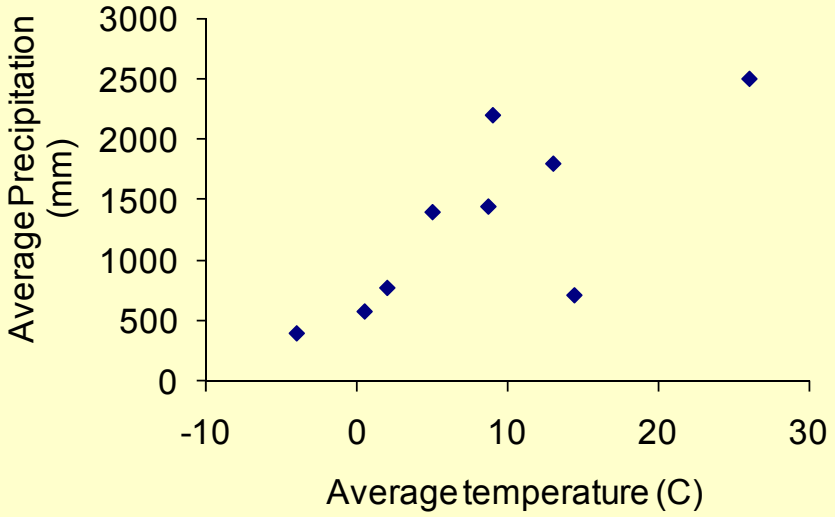
Marcell EF: Boreal peatlands in northern Minnesota

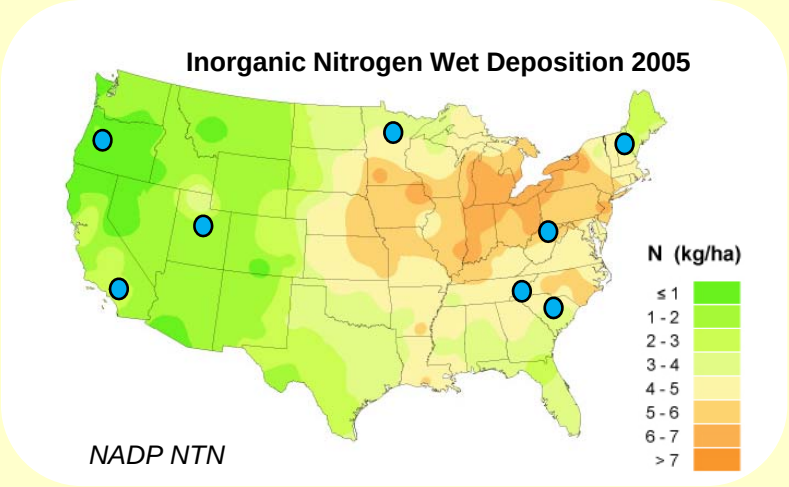
Santee EF: Coastal wetlands in South Carolina



A Research Platform

- Data from sites that encompass the nation's forest types, climates, and gradients of disturbance regimes.
- The longest running records of stream chemistry and atmospheric deposition at control and experimental catchments (10^1 to 10^3 ha basins). Typically sampled at weekly to biweekly intervals.
- Evolving research agendas provide the flexibility to address emerging questions via collaborative research.





Long-Term Monitoring

Precipitation

Air and soil temperature

Streamflow

Groundwater levels

Soil moisture

Water chemistry

Atmospheric deposition

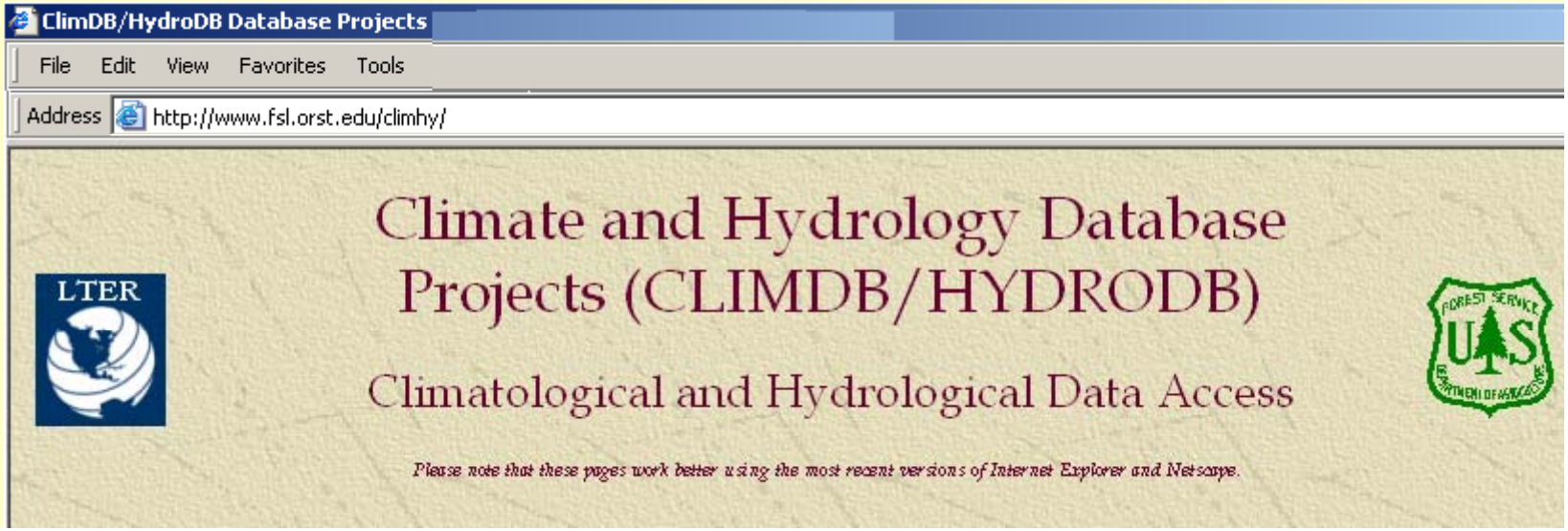
Soil properties

Aboveground woody biomass

Plus more…

A Fundamental Role in Ecosystems Research

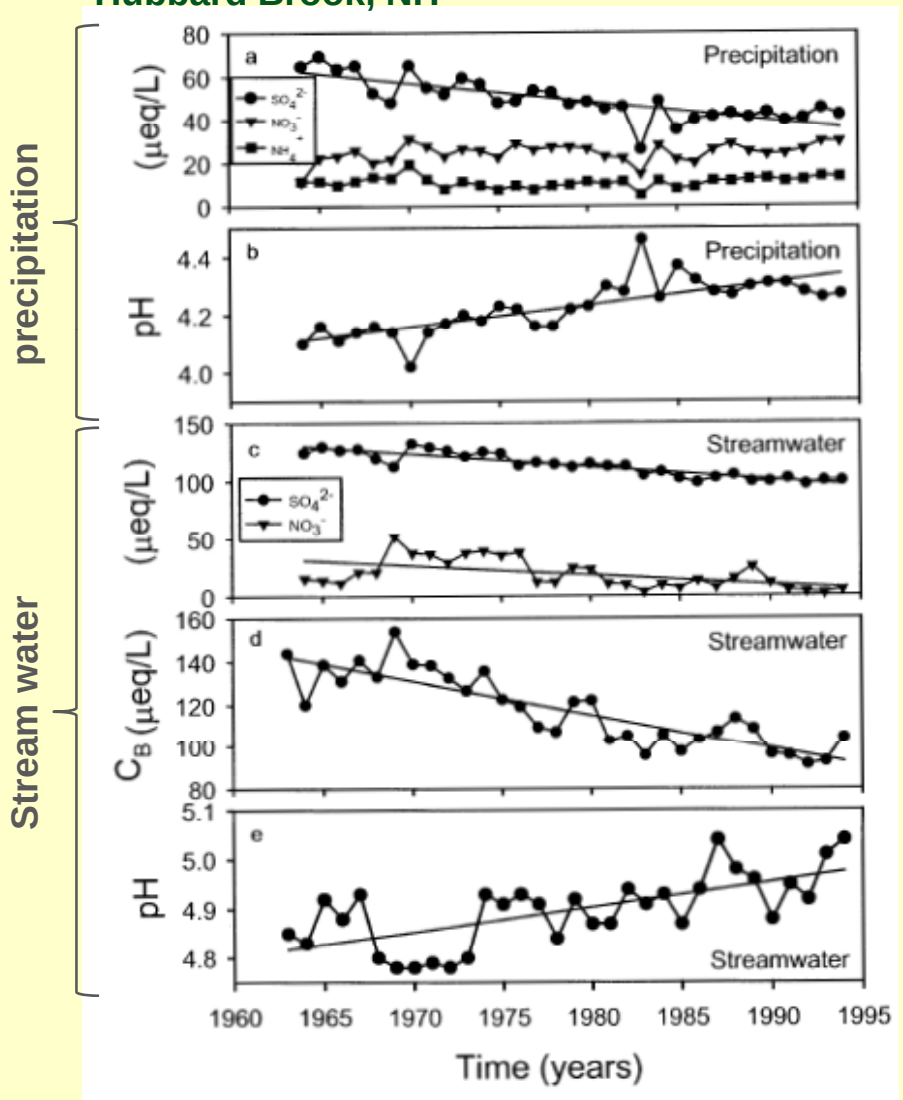
- Long-term data on streamflow and meteorology collected at many sites are publicly-available, important records of climate and hydrology.
- To date, chemistry data have typically been used to answer site-specific questions. The data have not been as available as the hydrological and climate data.



A Legacy of Findings at Individual EFR Sites

Effects of ecosystem acidification, soil calcium depletion, and recovery following regulations on emissions.

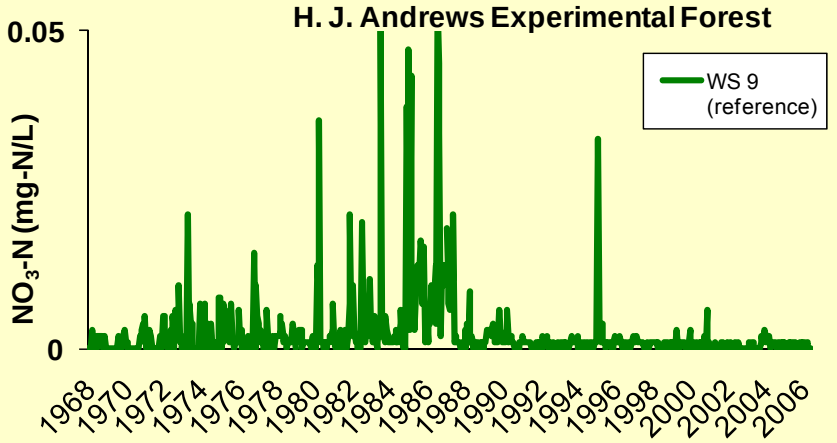
Hubbard Brook, NH

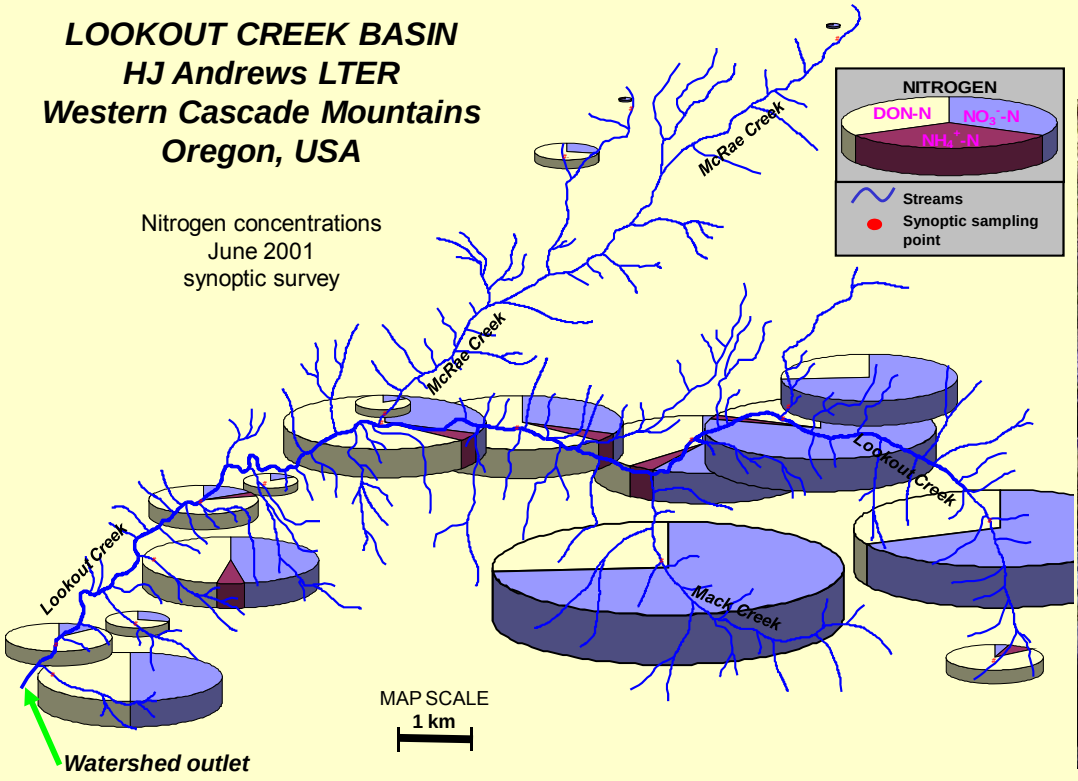


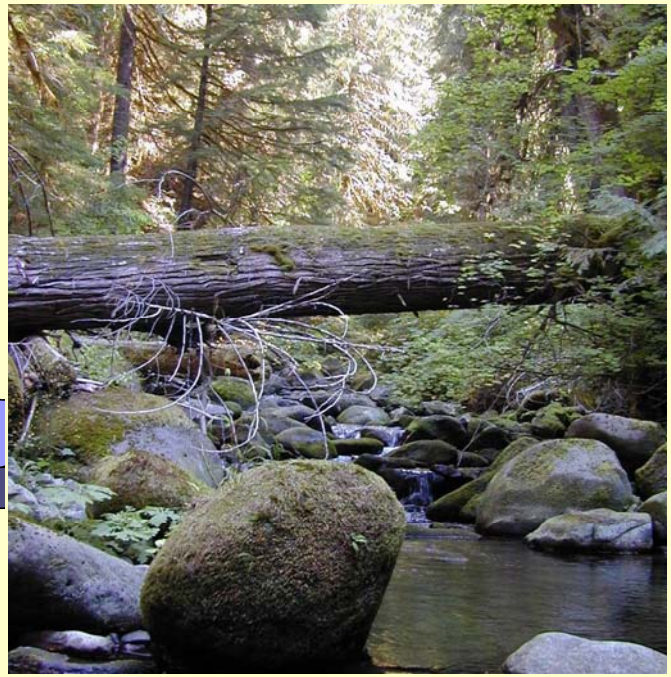
From Driscoll et al. 2001. Bioscience 51:180-198

A Legacy of Findings

Baseline data on N concentrations in least impacted catchments.



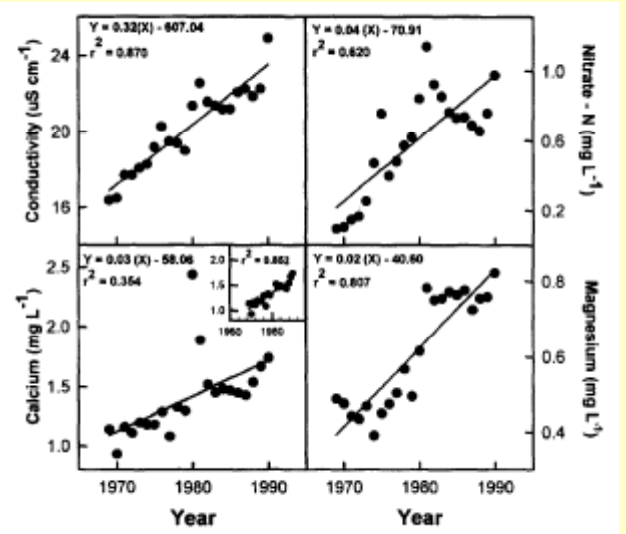




A Legacy of Findings

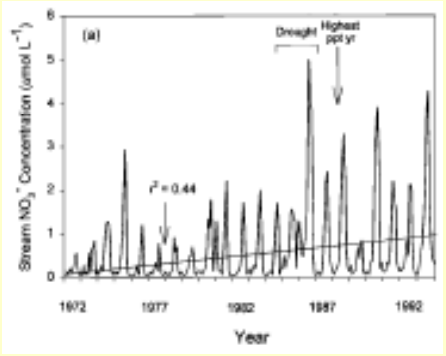
Documenting changing nitrogen status and nitrogen saturation in catchments.

Fernow Experimental Forest, WV



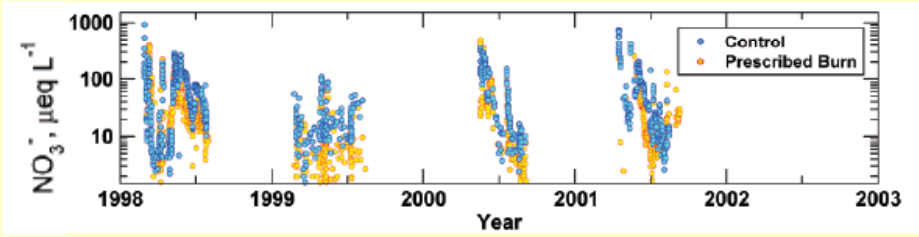
From Peterjohn et al. 1996. Biogeochem 35:507-522

Coweeta Hydrologic Laboratory, NC



From Swank & Vose. 1997. Global Biogeochem Cycles 11:657-671

San Dimas Experimental Forest, CA

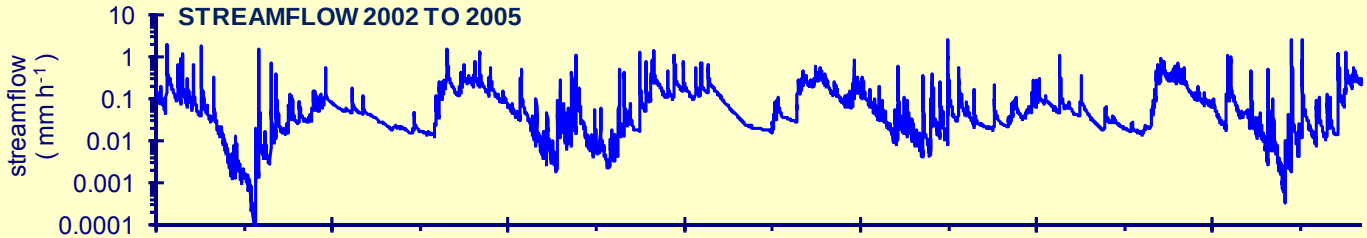


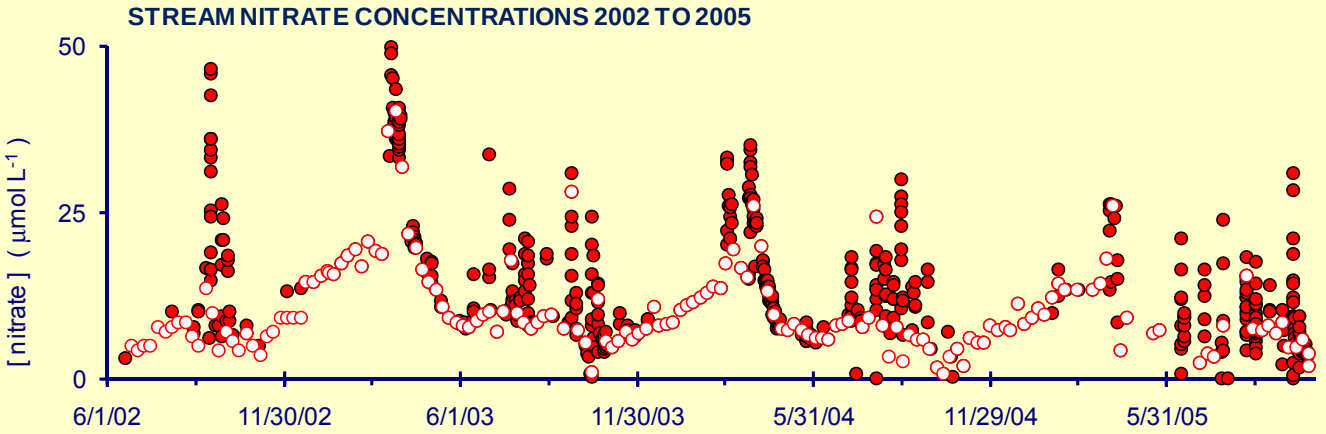
From Meixner et al. 2006. ES&T 40:2887-2894

Targeted Studies to Document Stream Nitrate Sources

How are patterns of high nitrate concentrations during stormflow related to nitrate sources, processing, and transport in landscapes?

Sleepers River Research Watershed
USGS Water, Energy, and Biogeochemical Budgets Program

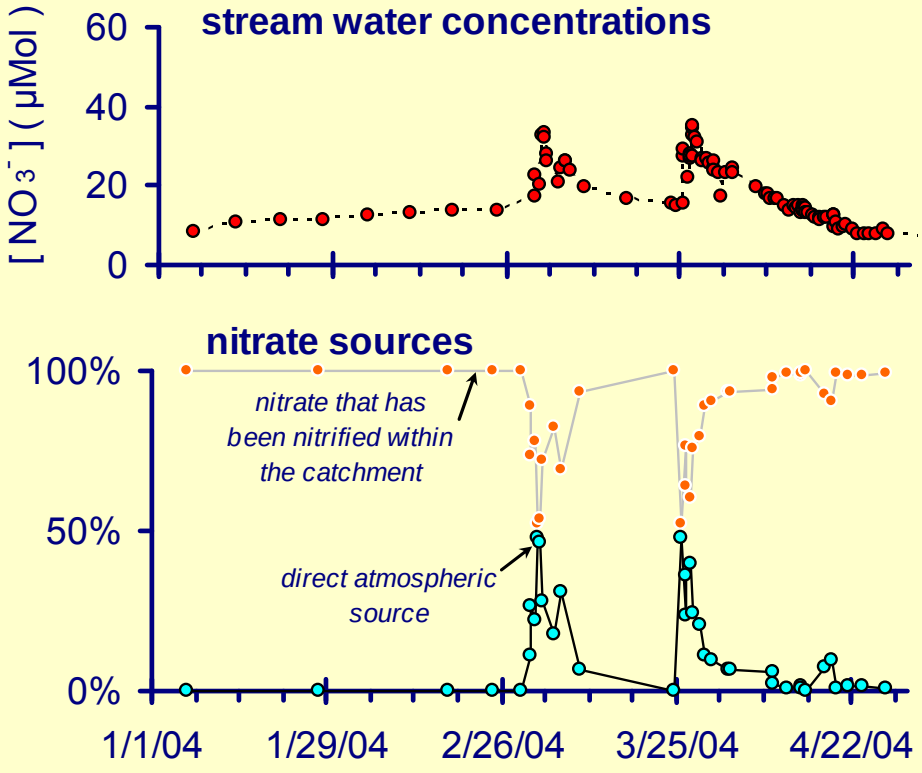




From Sebestyen et al. 2009. JGR-Biogeosciences 114:G02002

Apportioning Sources of Stream Nitrate

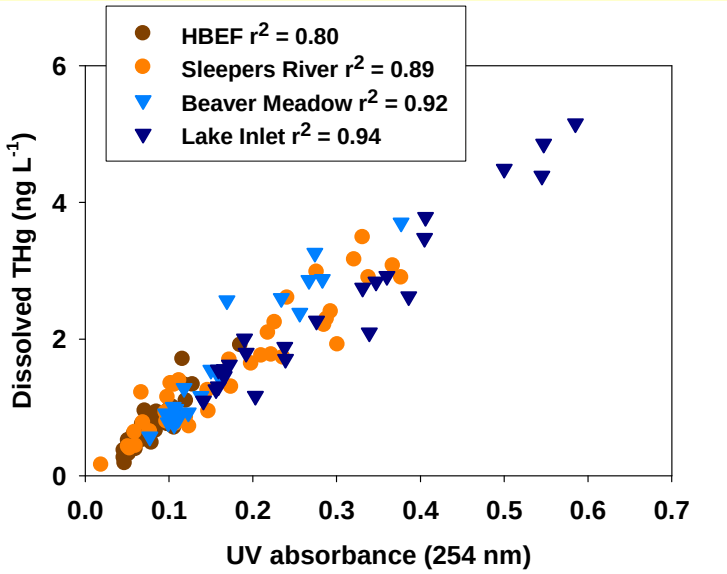
- Nitrate isotopes ($\delta^{18}O$) reveal the timing and magnitude of direct inputs of nitrate from atmospheric sources to streams.
- The terrestrial processes that retain atmospherically deposited nitrate may be bypassed during storm flow.

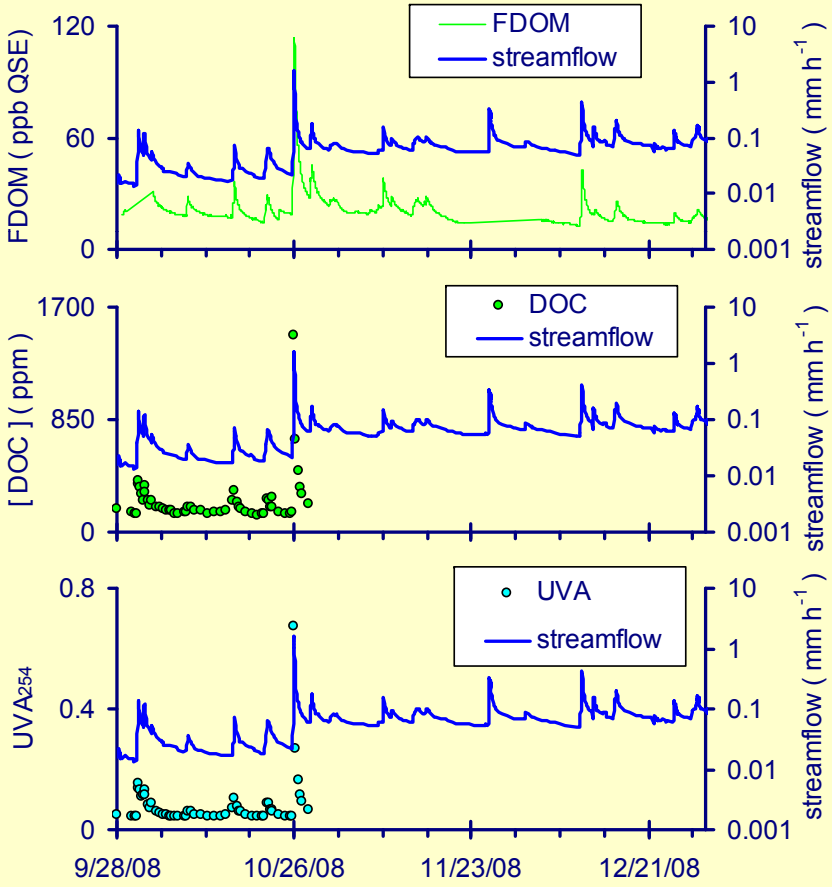


From Sebestyen et al. 2008. WRR 44:W12410

Investigating Effects of Accumulated Hg Inputs

Application of high temporal resolution optical sensors may allow more accurate quantification of Hg yields from catchments.

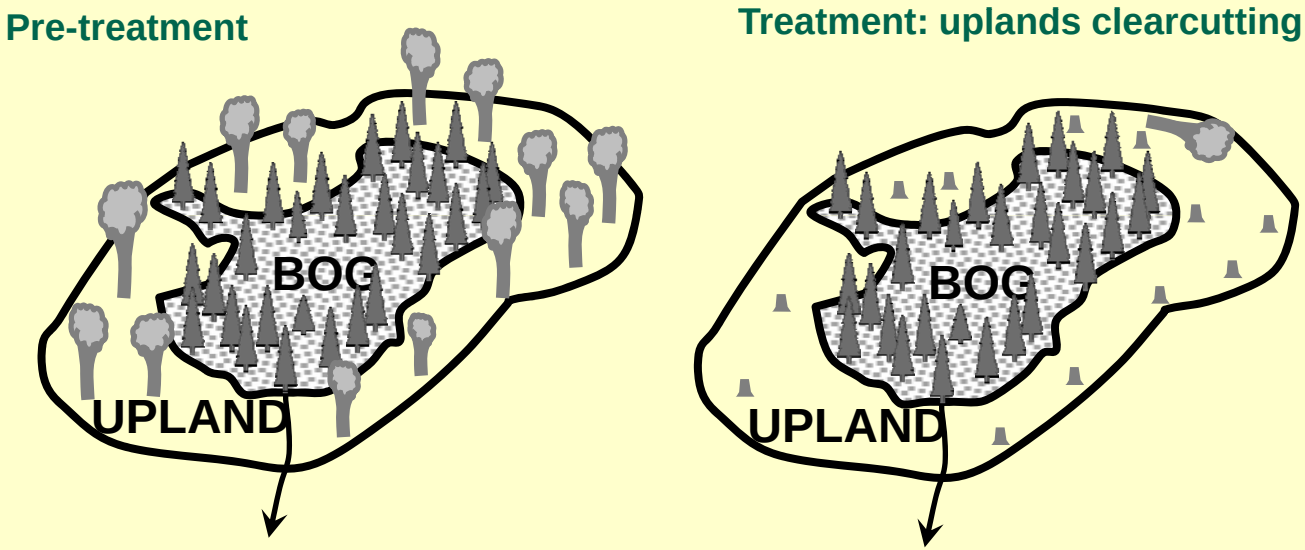




Data from Shanley, Pellerin, Saraceno, Aiken, Driscoll, and Sebestyen

Paired-Watershed Study Design

- Compare hydrological, hydrochemical, and ecological responses of manipulated catchments to similar but unmodified catchments.
- Experimentally manipulate ecosystems at “meaningful” spatial and temporal scales for land management decisions.



Sandy Verry photo

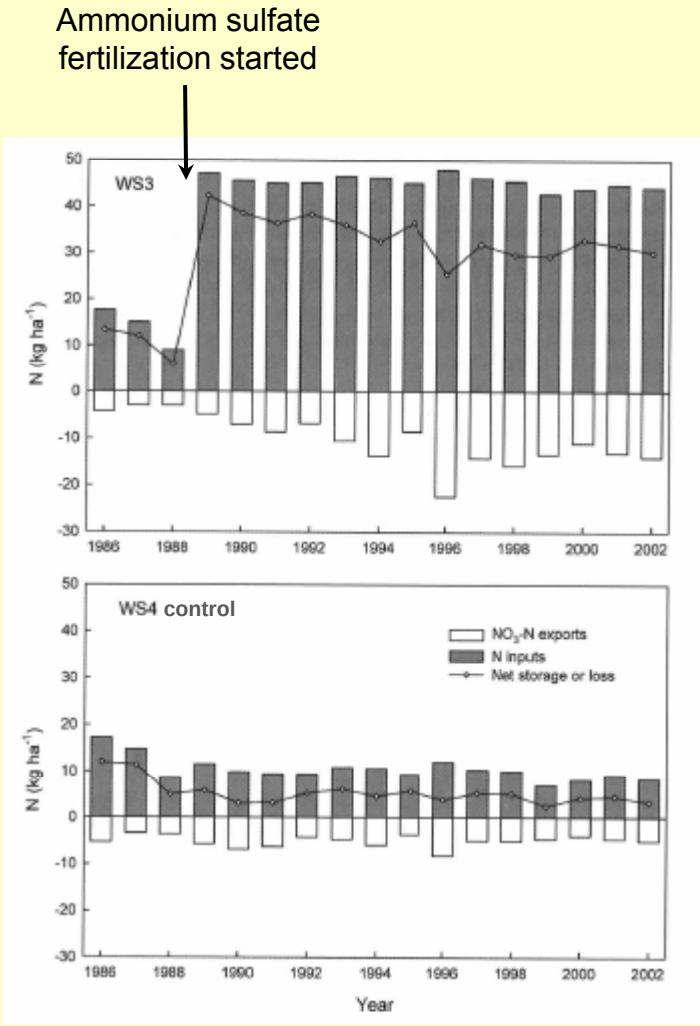
Catchment Experiments

- Starting with the Wagon Wheel Gap study in 1919, numerous forests have been harvested, converted, or otherwise manipulated to study responses of streamflow and water chemistry.
- Large-scale ecosystem manipulations and long-term studies are now a hallmark of EFR research.

Effects of Nitrogen Deposition

at the Fernow Experimental Forest, WV

- Ammonium sulfate added to triple ambient deposition and to study effects of catchment acidification.
- Stream nitrate concentrations at WS3 tripled relative to the WS4 control – with effects that were immediate and persisted throughout the duration of the additions.

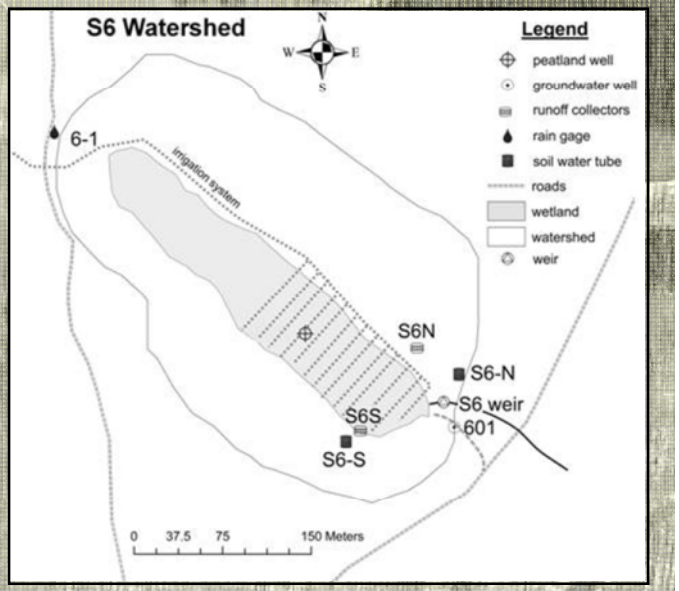


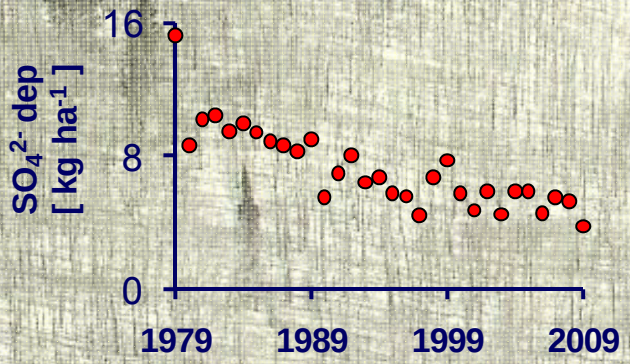
from Adams et al. 2006. The Fernow Watershed Acidification Study

Effects of Sulfate Deposition on Mercury

at the Marcell Experimental Forest, MN

- Sulfate was added to a bog to quadruple wet deposition and evaluate effects on MeHg production in peatlands.
  - Mimics levels of 1979.
- Production of MeHg is stimulated by sulfate deposition. *see Jeremiason et al. 2006. ES&T 40:3800-3806*
  - Stream MeHg yield doubled when sulfate was added to 11% of the catchment area.
- The "recovery" phase is now being monitored.

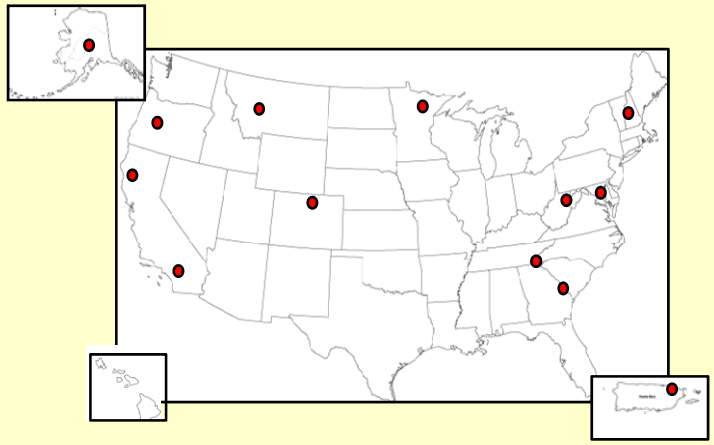




Roger Bay photo

Advancing EFR Research

- Syntheses on the longest records of stream flow and chemistry from a network of sites that span gradients of:
  - Elevation.
  - Aspect.
  - Climate regimes.
  - Biomes
- Stream chemistry data from more than 40 control catchments.
- Disturbances ranging from:
  - Forest harvesting (paired-watershed studies).
  - Meteorological events (droughts, floods).
  - Atmospheric deposition.
  - Wildfire.
  - Climate change.



Stream Chemistry Syntheses of EFR Data

- A collaboration to synthesize stream chemistry data from 10 EFR sites
  - Individual sites choose to share data and participate in any particular synthesis.
  - Syntheses are proceeding as collaborations among sites.
- Ongoing synthesis projects will:
  - Evaluate long-term stream chemistry trends and drivers of change.
  - Consider the utility of long-term EFR stream chemistry data for evaluating numeric nutrient criteria for small, headwater streams.
  - Compare methods used to estimate stream solute yields.
  - Culminate in the development of a web-accessible StreamChemDB for all sites that are willing to contribute data.

COORDINATORS	
Sherri Johnson	HJ Andrews
Chuck Rhoades	Fraser
Stephen Sebestyen	Marcell
Alba Argerich	post-doc
Effie Greathouse	post-doc
George Ice	NCASI
Jennifer Knoepp	Coweeta

COOPERATORS / CO-AUTHORS	
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John Campbell	Hubbard Brook
Jeremy Jones	Bonanza Creek
Pam Edwards	Fernow
Gene Likens	Hubbard Brook
Bill McDowell	Luquillo
Phillip Riggans	San Dimas
Pete Wohlgemuth	San Dimas
David Wright	Tenderfoot Creek
and others	

Long-term Stream Chemistry Syntheses

- Evaluate why the forms and concentrations of stream nitrogen vary among sites having similar atmospheric inputs?
- Evaluate how other drivers of environmental change affect stream nitrogen responses to atmospheric inputs.

Luquillo Experimental Forest, CO

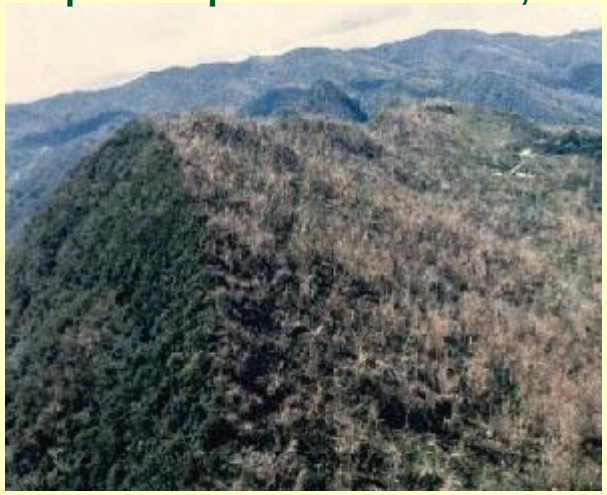


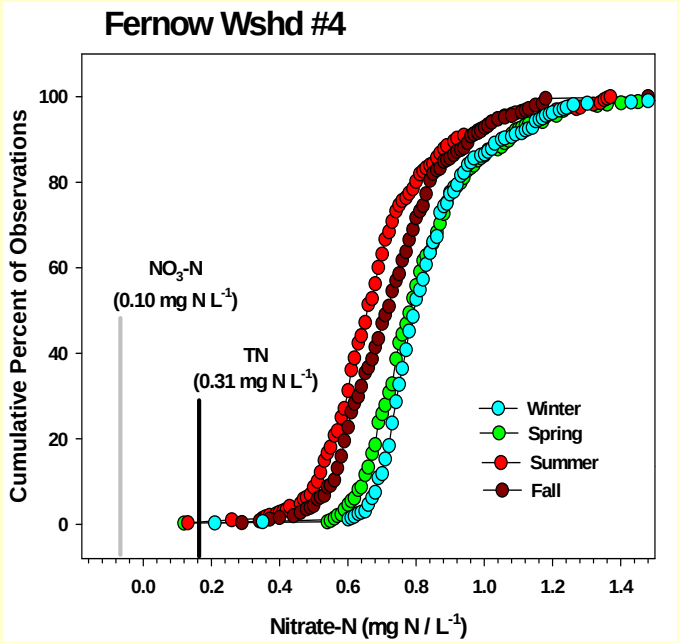
Photo by MC Larsen and AJ Torres Sanchez, pr.water.usgs.gov

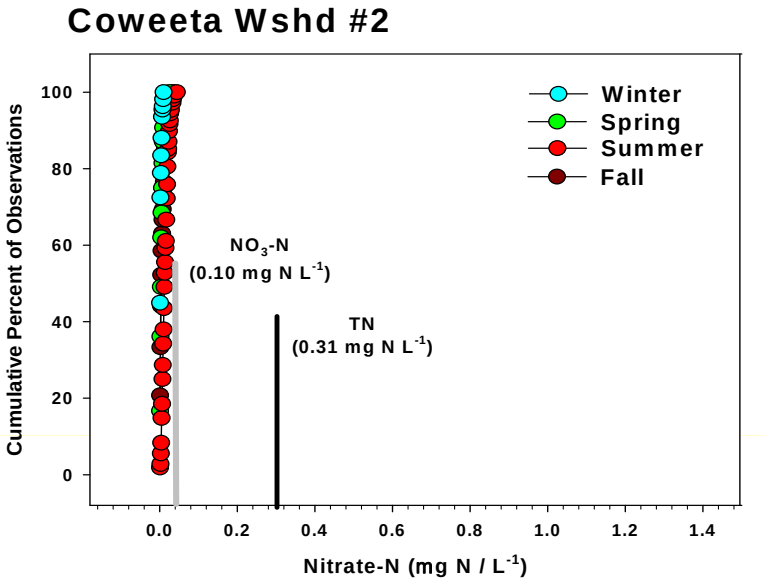
Fraser Experimental Forest, CO

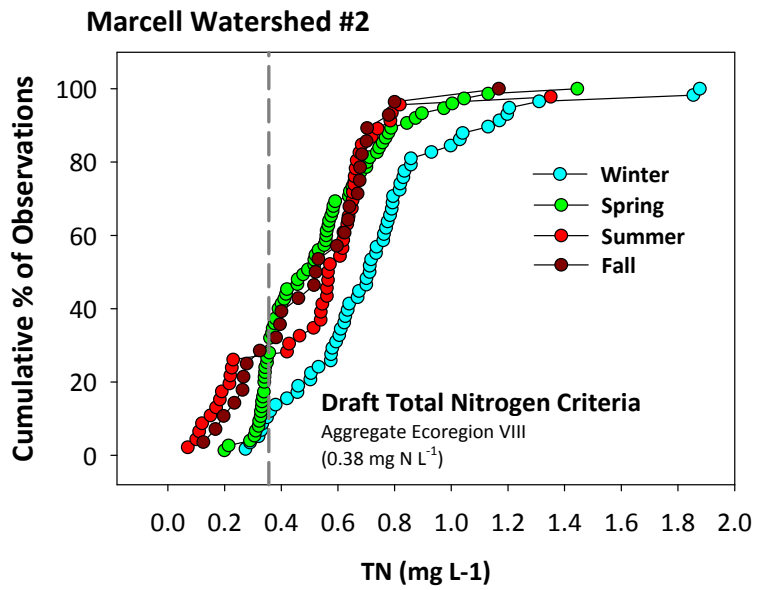
Photo courtesy of CC Rhoades

Informing Numeric Nutrient Criteria

Evaluate N and P concentrations for undisturbed and managed forests in relation to numeric nutrient criteria that have been proposed for streams.





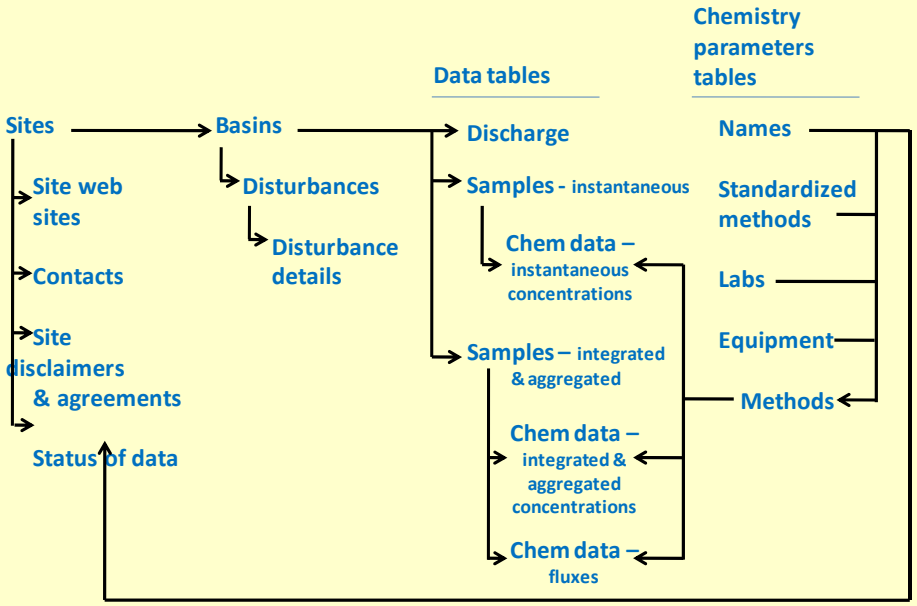


Figures developed by CC Rhoades

StreamChemDB

A web-accessible StreamChemDB for sites that contribute data.

- To be prototyped with concentration and yield data from 10 EFR's.
  - Standardized data (units).
  - QA/QC.
    - Designed for addition of data and sites.
- Funding for development and initial syntheses continues for another year.



		Bonanza Creek/ Caribou-Poker	San Dimas	Fraser	Marcell	Tenderfoot	Santee	Hubbard Brook	Fernow	Coweeta	H. J. Andrews	Luquillo
Nitrate		x	x	x	x	x	x	x	x	x	x	x
Ammonium		x	x	x	x	x	x	x	x	x	x	x
Kjeldahl N	Dissovled				x		x				x	
	Unfiltered				x	x					x	
Total N	Dissolved	x		x	x		x	x		x	x	x
	Unfiltered				x						x	
Sol. Reactive P		x			x		x	x			x	x
Ortho-P by IC				x	x					x		
Total P	Dissolved	x			x		x				x	x
	Unfiltered				x	x				x	x	

Figures developed by E Greathouse

Summary

- Long-term studies and large scale manipulations yield unique insight, some of which may reveal unexpected results.
- Via original research and collaborations, EFR (and other catchment) studies foster investigations of ecosystem responses. These sites have the potential to host new, innovative studies that address fundamental science and management questions.
- Efforts are currently underway to synthesize EFR watershed studies.
  - There is tremendous potential for cross-site collaborative research, especially studies of catchment hydrology, ecology, and biogeochemistry at an established network of sites.


Questions?
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