

# Lessons from cross-site studies of forested watersheds: trends in water quality and effects of disturbances

[Alba Argerich](#)<sup>1</sup> and Sherri Johnson<sup>2</sup>

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## Introduction

### Forested watersheds

80% of our nation's freshwater resources originate from forest watersheds

### Forest management

activity in the headwaters has the potential to affect downstream or "WE ALL LIVE DOWNSTREAM"

### Nitrogen (N)

essential nutrient

water quality parameter

human alteration of the nutrient cycles  
= eutrophication



# Stream Chemistry Synthesis Project

<http://web.fsl.orst.edu/streamchem/>

## Participant sites:

Bonanza Creek /Caribou-Poker, AK  
H.J. Andrews, OR  
San Dimas, CA  
Tenderfoot, MT  
Fraser, CO  
Marcell, MN  
Fernow, WV  
Coweeta, NC  
Santee, SC  
Hubbard Brook, NH  
Luquillo, PR



## Collaborators:

Mary B. Adams, *Fernow Experimental Forest*; Devendra M. Amatya, *Santee Experimental Forest*;  
John L. Campbell, *Hubbard Brook Experimental Forest*; George G. Ice, *NCASI, Inc.*; Sherri L.  
Johnson, *HJ Andrews Experimental Forest*; Jeremy B. Jones, *University of Fairbanks, AK*; Jennifer  
D. Knoepp, *Coweeta Experimental Forest*; Gene E. Likens, *Cary Institute of Ecosystem Studies*;  
William H. McDowell, *University of New Hampshire*; Charles C. Rhoades, *Fraser Experimental  
Forest*; Stephen D. Sebestyen, *Marcell Experimental Forest*; Peter M. Wohlgenuth, *San Dimas  
Experimental Forest*; David K. Wright, *Tenderfoot Experimental Forest*

# Stream Chemistry Synthesis Project

<http://web.fsl.orst.edu/streamchem/>

## Objectives:

### Comparison of long term data across sites. Synthesis papers:

- 1) Effects of forest disturbance on stream chemistry dynamics, concentrations and fluxes
- 2) Trends in N concentrations in reference watersheds
- 3) Influences of sampling strategy and calculation methods on stream solute flux estimates: A comparison of methods used in long-term catchment studies
- 4) Addressing nutrient criteria using reference basin data

**Create a database for stream chemistry data** (Standardize units, document analytical and sampling methods)

# Stream Chemistry Synthesis Project

<http://web.fsl.orst.edu/streamchem/>

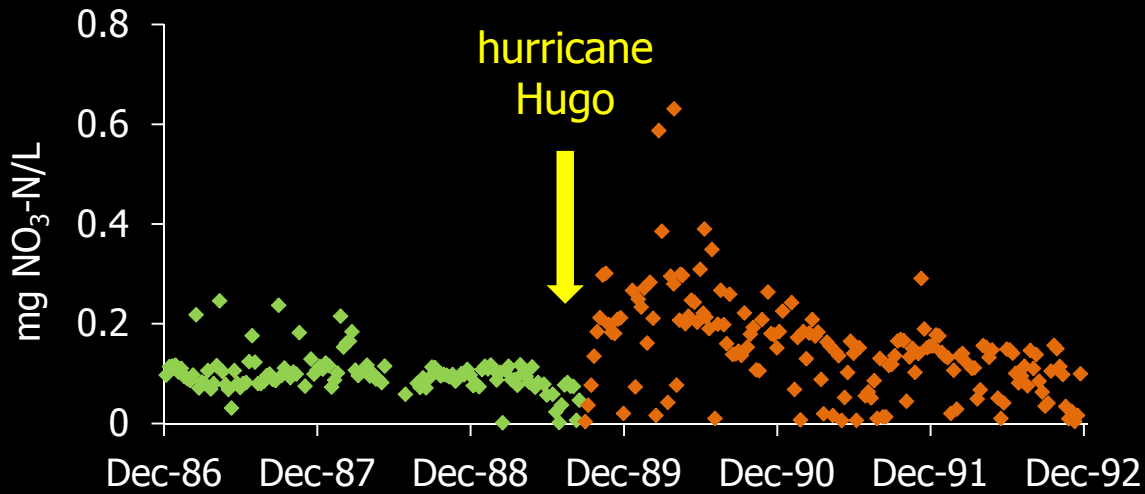
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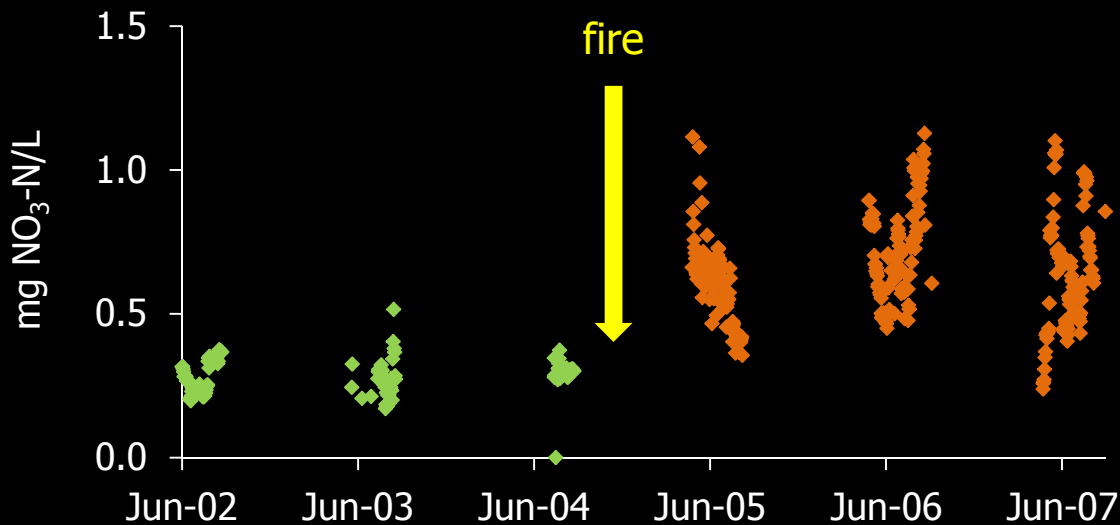
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# Do NATURAL disturbances lead to similar responses?

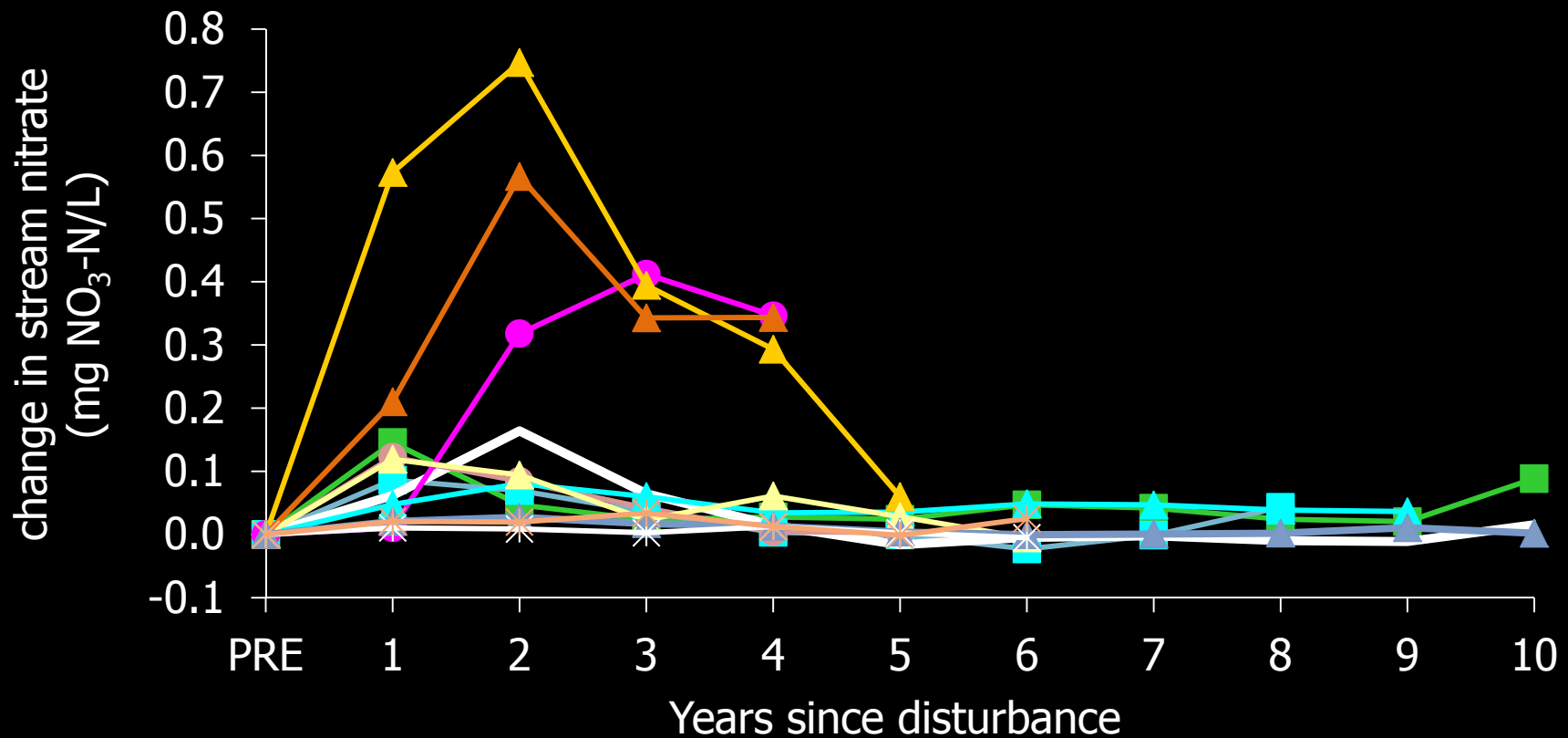


Luquillo Exp. Forest -  
Quebrada Sonadora  
Puerto Rico



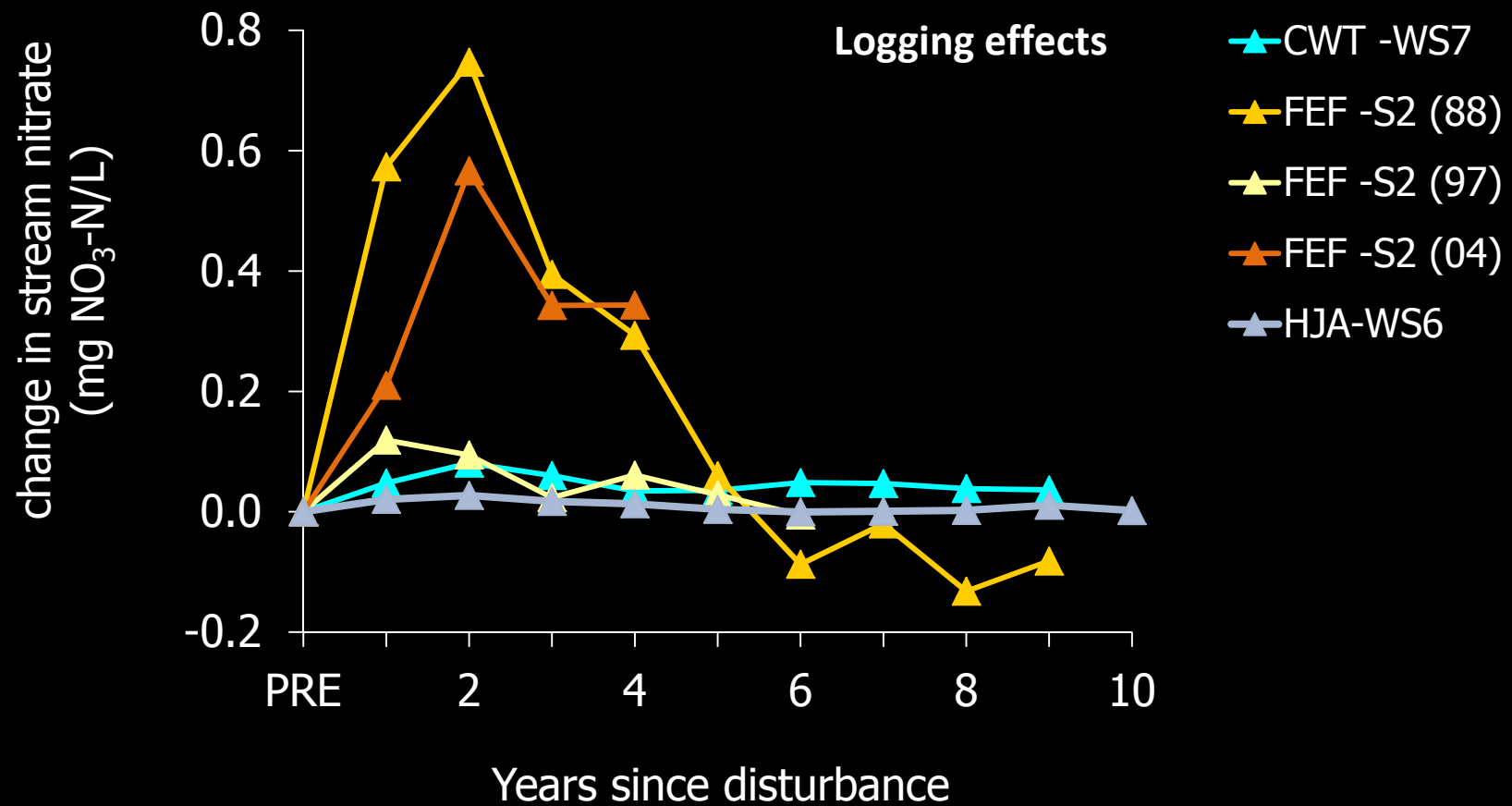
Caribou-Poker Creek –  
P6 watershed  
Alaska

# Do natural AND ANTHROPOGENIC disturbances lead to similar responses?



- LUQ - QS (hurricane)
- HBEF -W6 (ice storm)
- BNZ -P6 (fire)
- ▲ FEF -S2 (logging)
- ▲ FEF -S2 (logging)
- \* CWT -WS36 (insect infestation)
- CWT -WS7 (hurricane)
- SEF-W77 (fire)
- ▲ CWT -WS7 (logging)
- ▲ FEF -S2 (logging)
- ▲ HJA-WS6 (logging)
- \* FRA- E. St. Louis (insect infestation)

Do same type of disturbances lead to similar responses?



Do same type of disturbances lead to similar responses?

**Different magnitude and duration of the responses**

**Definition of PRE conditions?**



Disturbed  
catchments

VS.

Reference  
catchments or  
pre-conditions

*non stationary?*



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# Trends in stream nitrogen concentrations for forested reference catchments across the USA

A Argerich<sup>1</sup>, S L Johnson<sup>2</sup>, S D Sebestyen<sup>3</sup>, C C Rhoades<sup>4</sup>,  
E Greathouse<sup>1</sup>, J D Knoepp<sup>5</sup>, M B Adams<sup>6</sup>, G E Likens<sup>7,8</sup>,  
J L Campbell<sup>9</sup>, W H McDowell<sup>10</sup>, F N Scatena<sup>11</sup> and G G Ice<sup>12</sup>

<http://iopscience.iop.org/1748-9326/8/1/014039>

video abstract



## 7 sites & 22 reference catchments

without major land use changes in the last 60 years

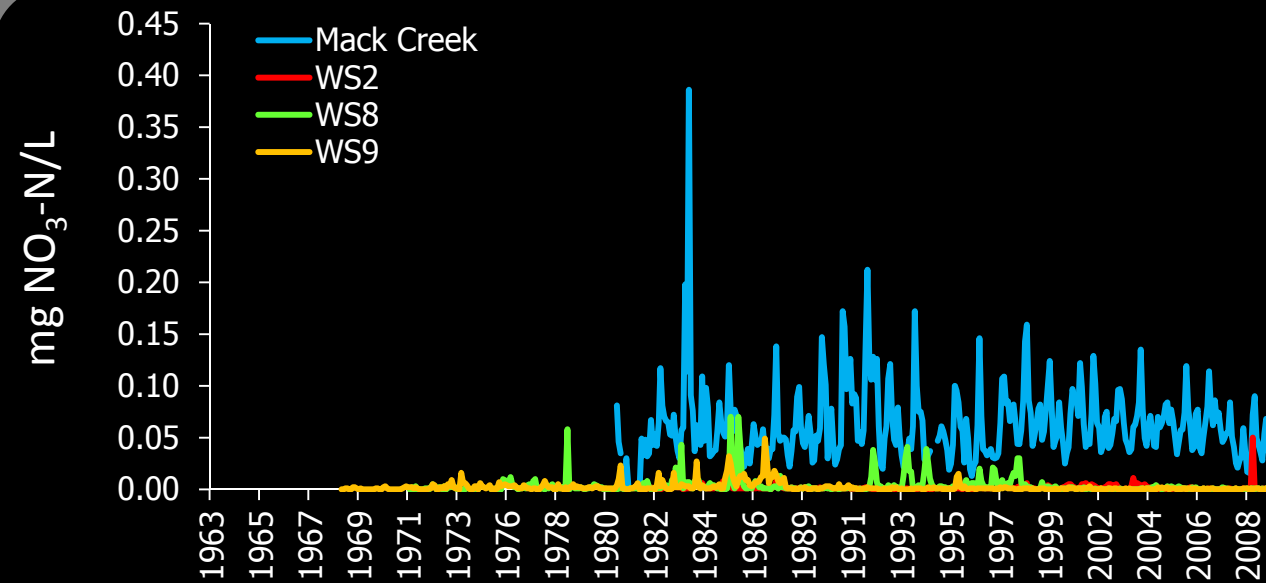
≥ 12 years of data (1996-2007)

chemistry sampling intervals < 3 weeks

daily Q measurements



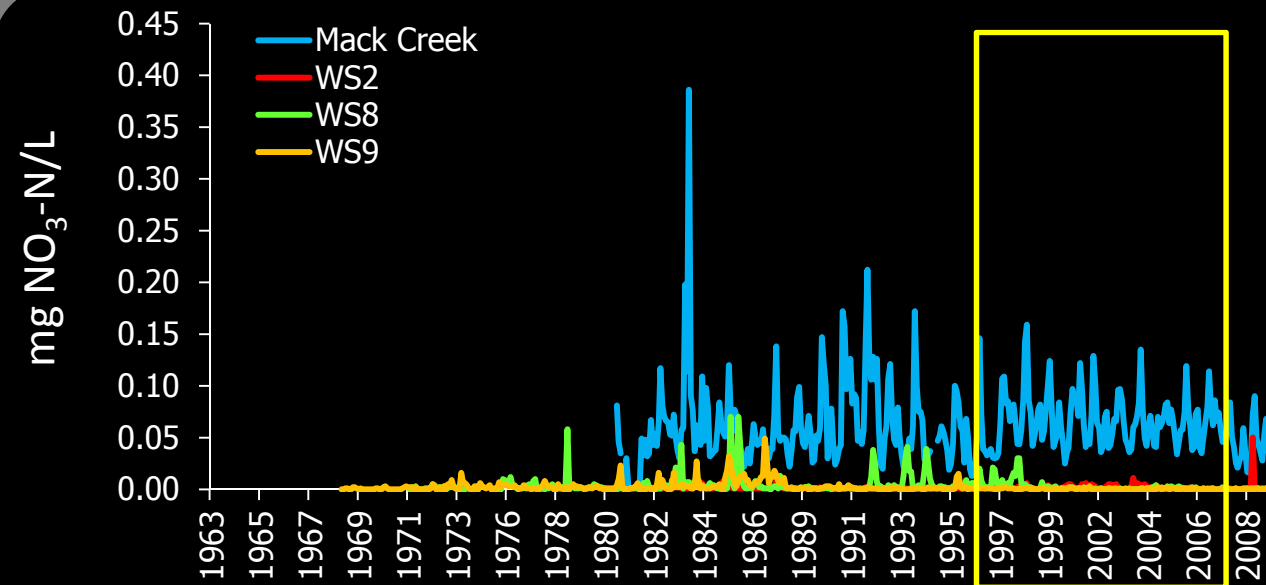
## Trends in N concentrations: natural variability



## H. J. Andrews Exp. Forest



## Trends in N concentrations: natural variability

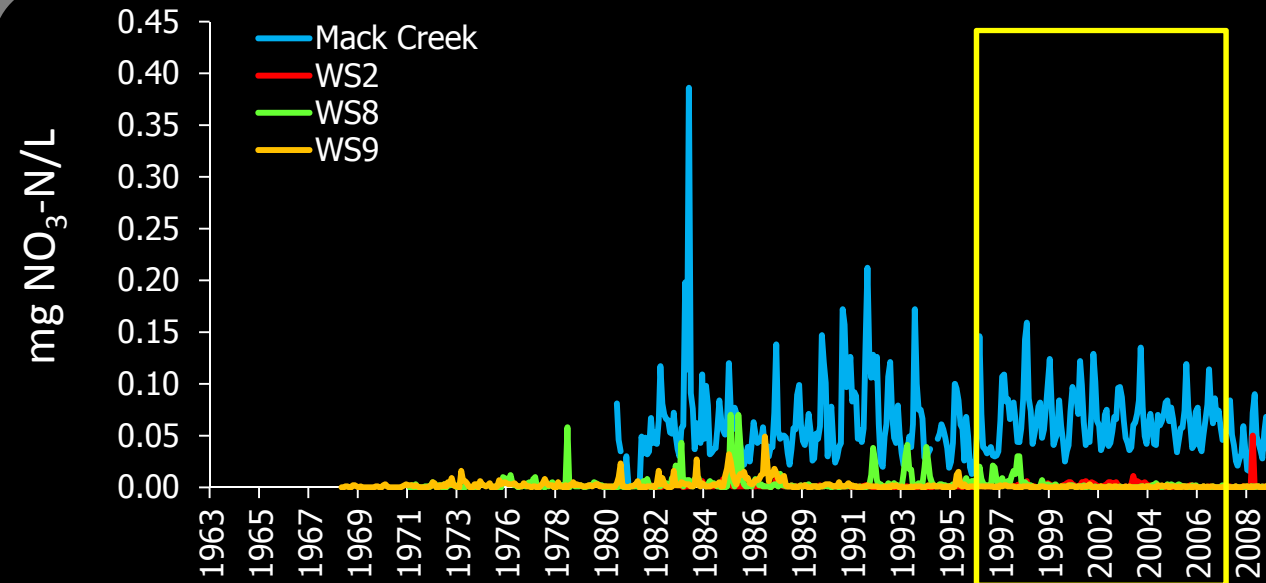


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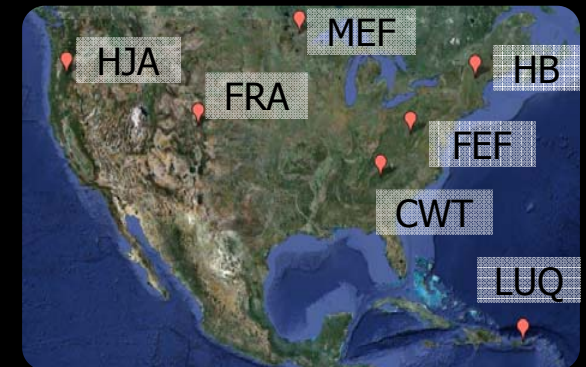
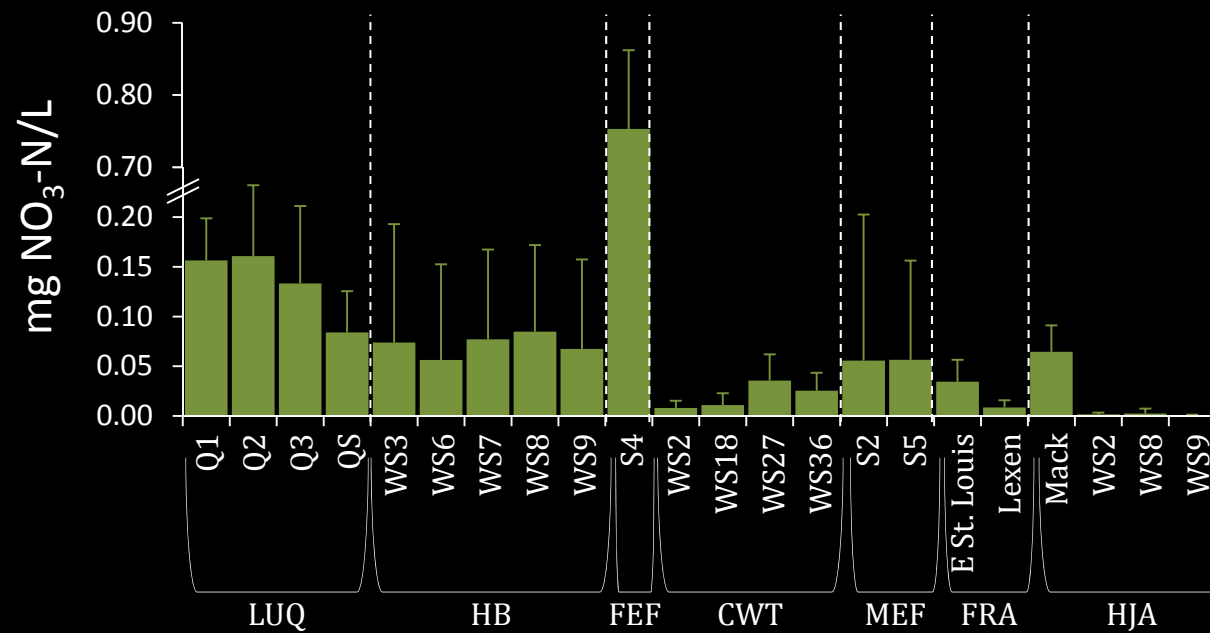


Period of 1996-2007

# Trends in N concentrations: natural variability



H. J. Andrews Exp. Forest



Period of 1996-2007

# Trends in N concentrations: natural variability

1. Is there more variation among Experimental Forests sites than among basins within an Experimental Forest?



Temporal variation:  
● intra-annual

# Trends in N concentrations: natural variability

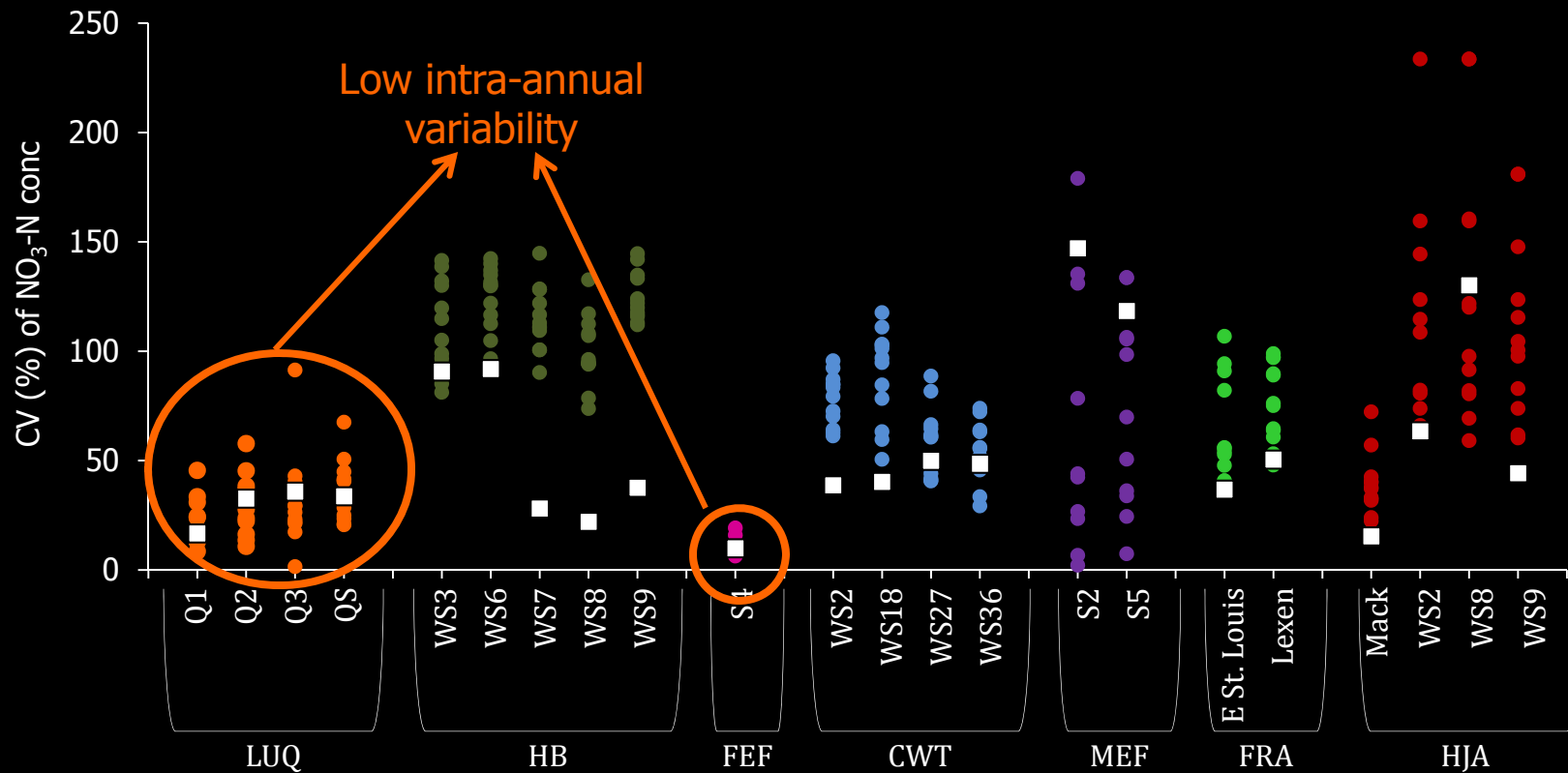
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Temporal variation:  
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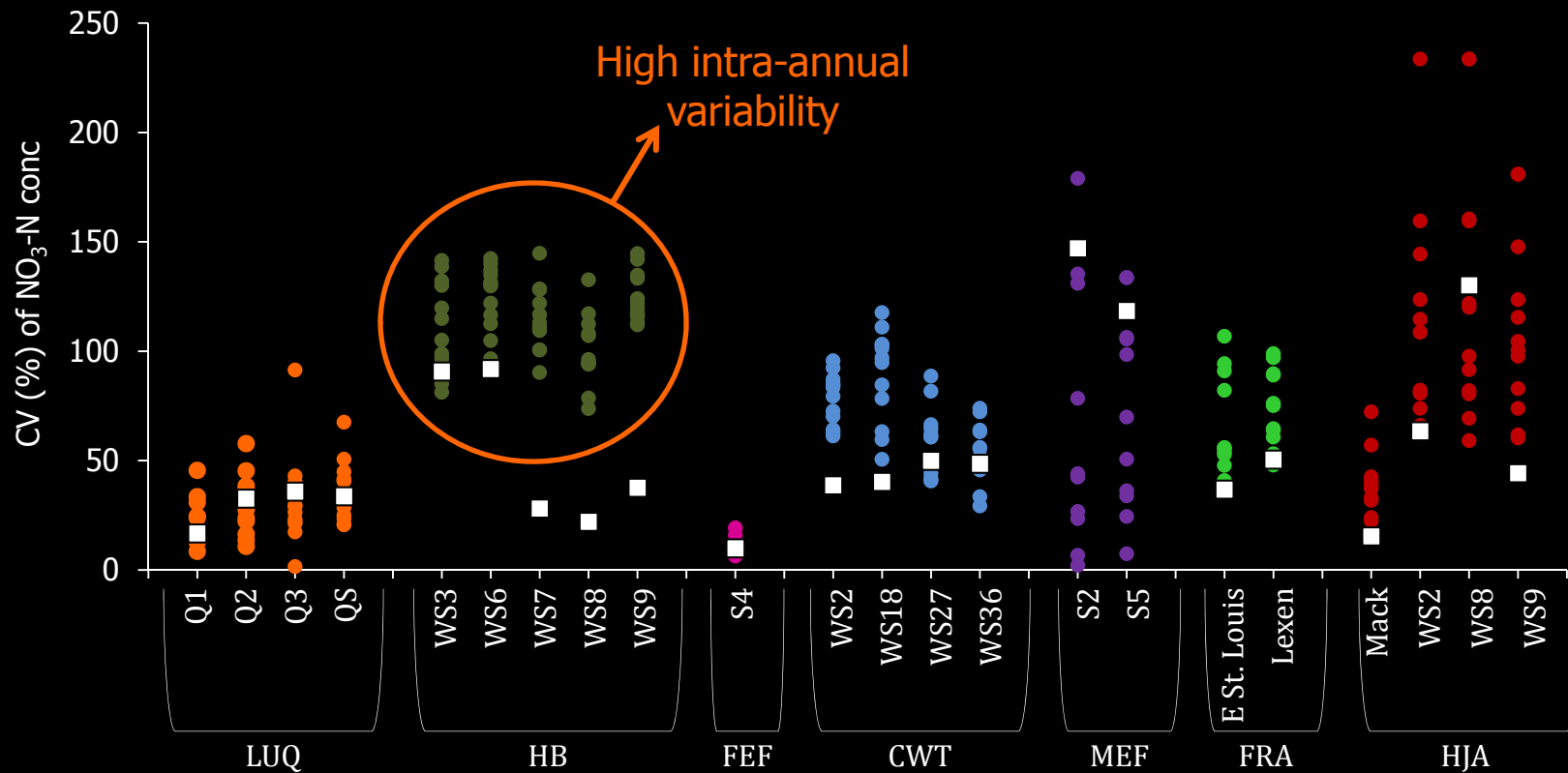
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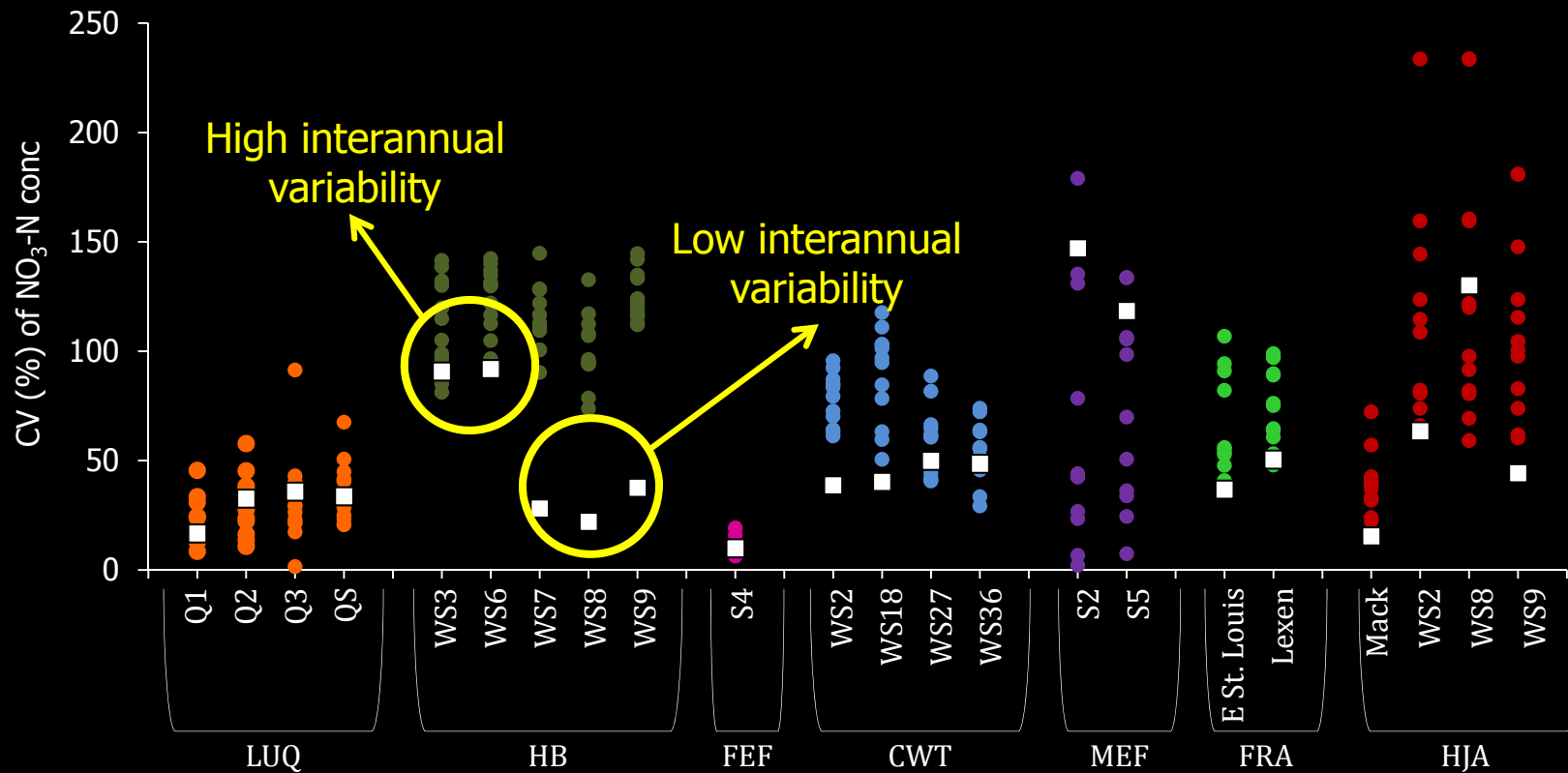
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Temporal variation:

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- interannual

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Temporal variation:  
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Spatial variation:  
— within sites

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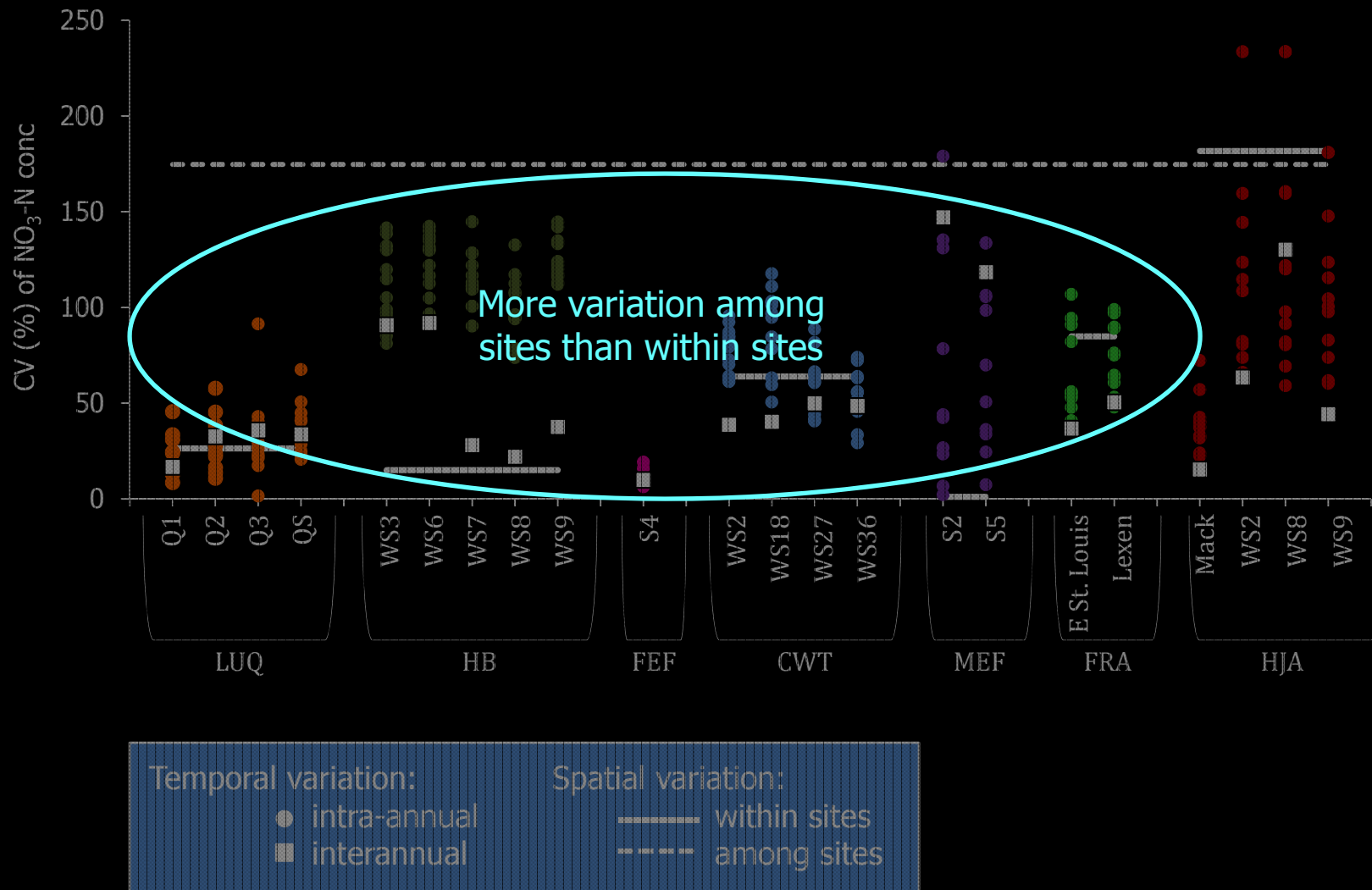


Temporal variation:  
● intra-annual  
■ interannual

Spatial variation:  
— within sites  
- - - among sites

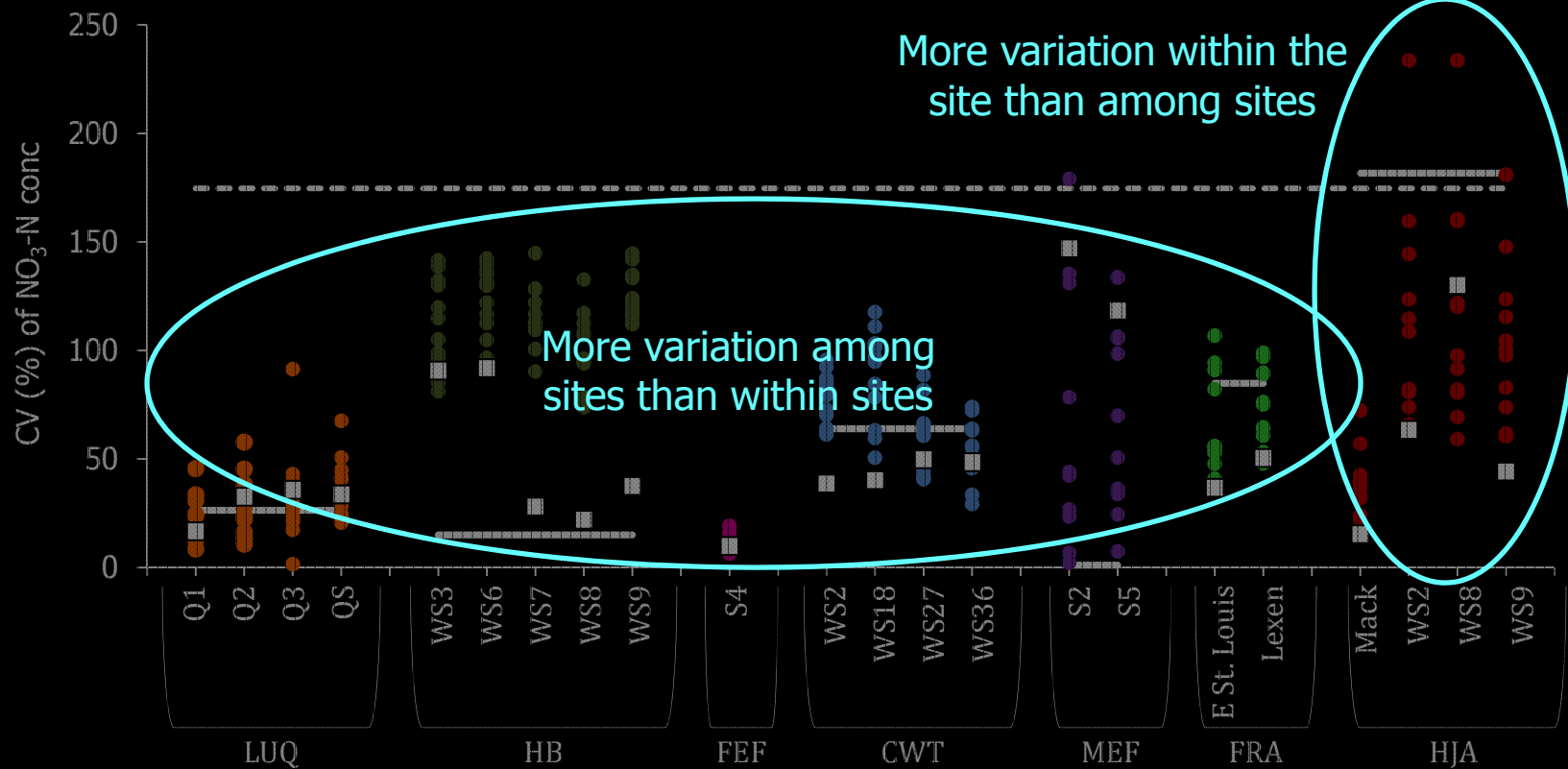
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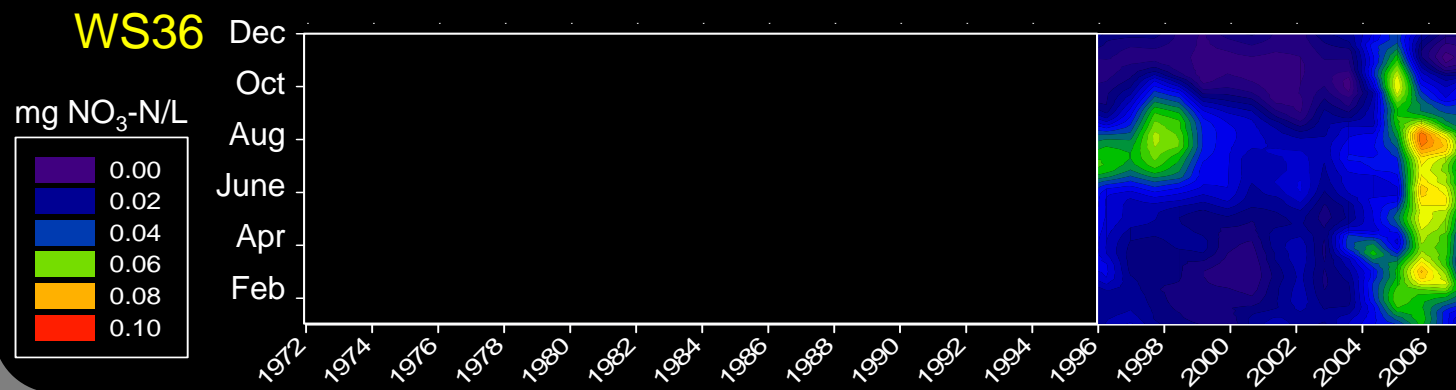


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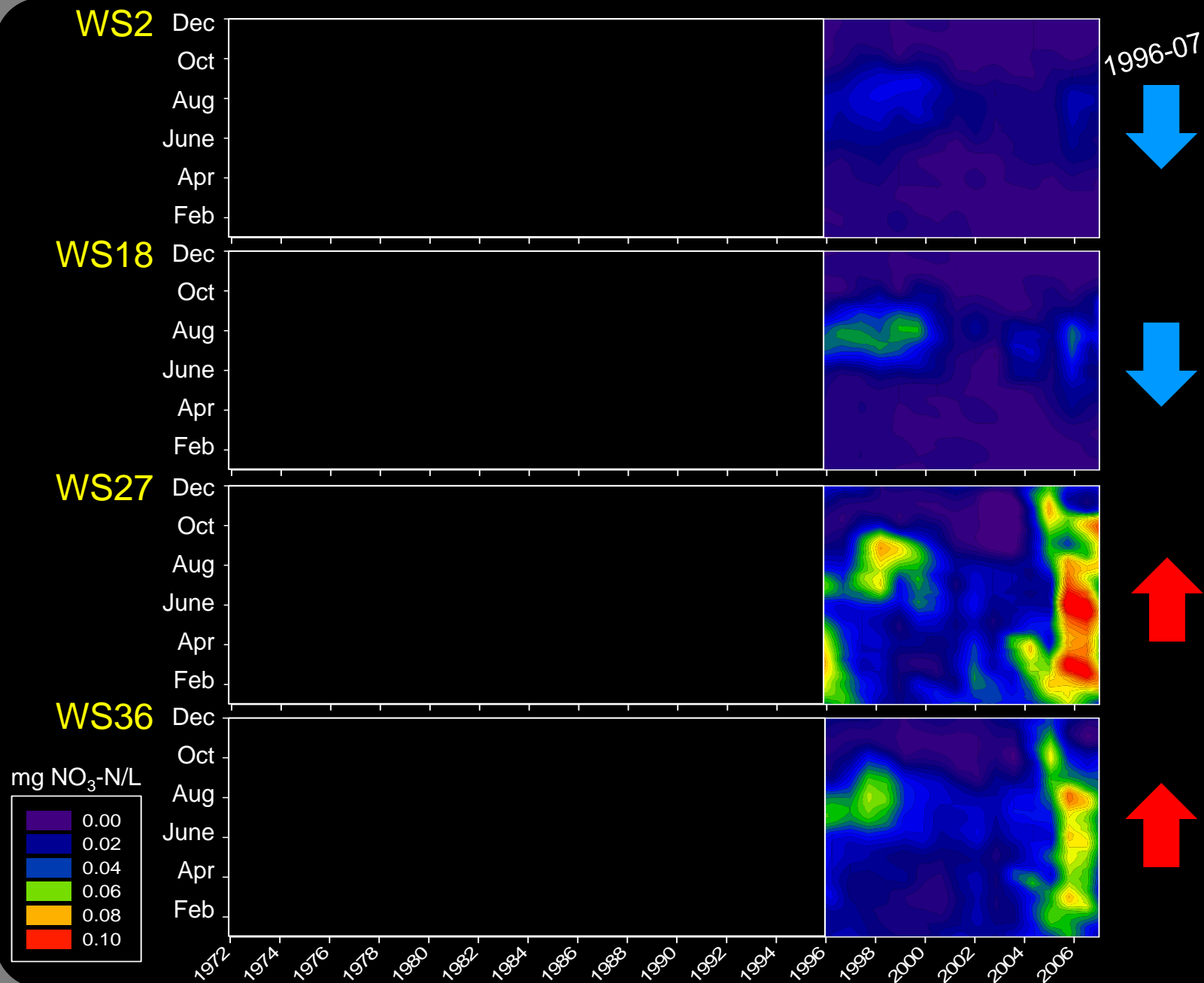
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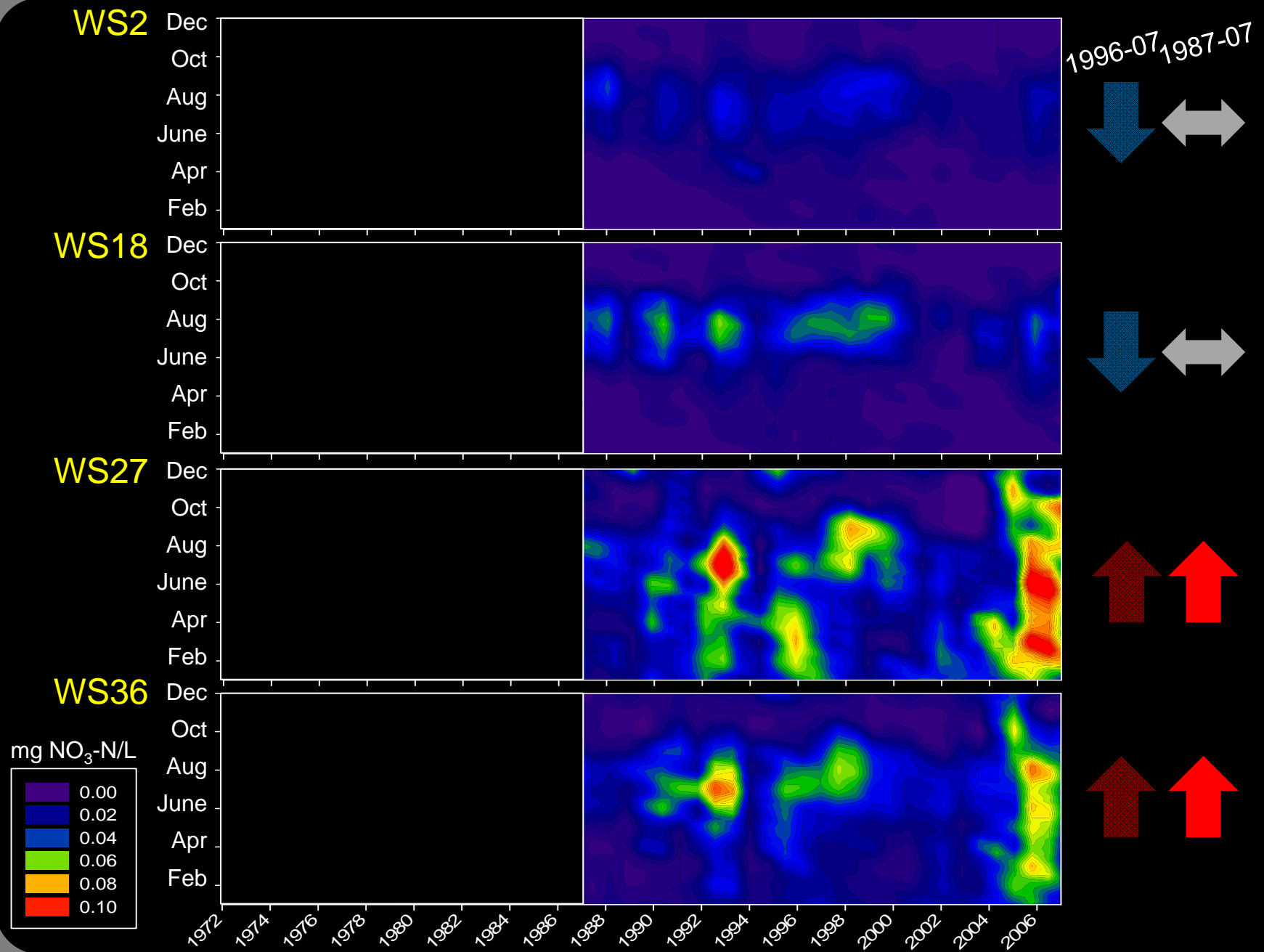
# Trends in N concentrations: nitrate in Coweeta



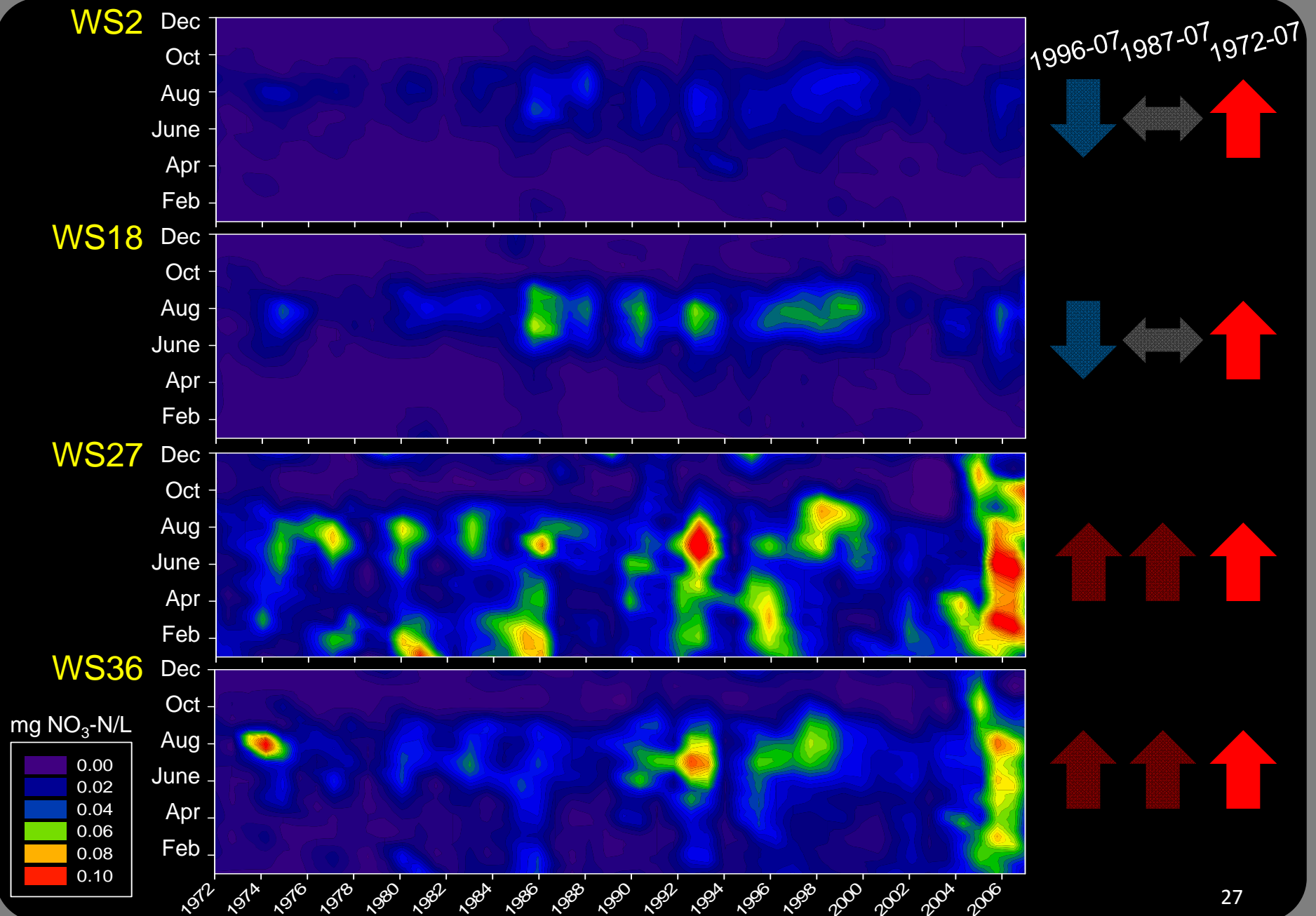
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# Trends in N concentrations: nitrate in Coweeta



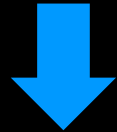
# Trends in N concentrations: nitrate in Coweeta



# Trends in N concentrations: all sites

NO<sub>3</sub>-N

1996-07 (12 y)   1987-07 (21 y)   1972-07 (36 y)



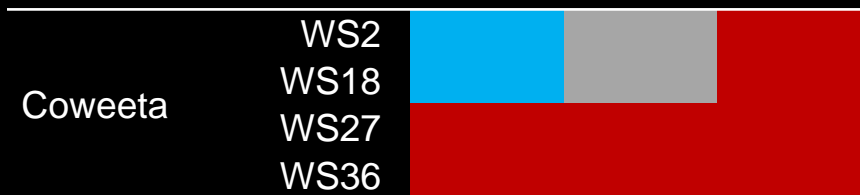
decreasing trend



no significant trend



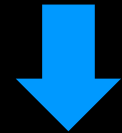
increasing trend



# Trends in N concentrations: all sites

## NO<sub>3</sub>-N

		1996-07 (12 y)	1987-07 (21 y)	1972-07 (36 y)
Luquillo	Q1	*		
	Q2	*		
	Q3	*		
	QS	*		
Hubbard Brook	WS3			
	WS6			
	WS7			
	WS8			
	WS9			
Fernow	S4			
Coweeta	WS2			
	WS18			
	WS27			
	WS36			
Marcell	S2			
	S5			
Fraser	Lexen			
	E St. Louis			
H. J. Andrews	Mack			
	WS2			
	WS8			
* 1997-07				
		WS9		



decreasing trend

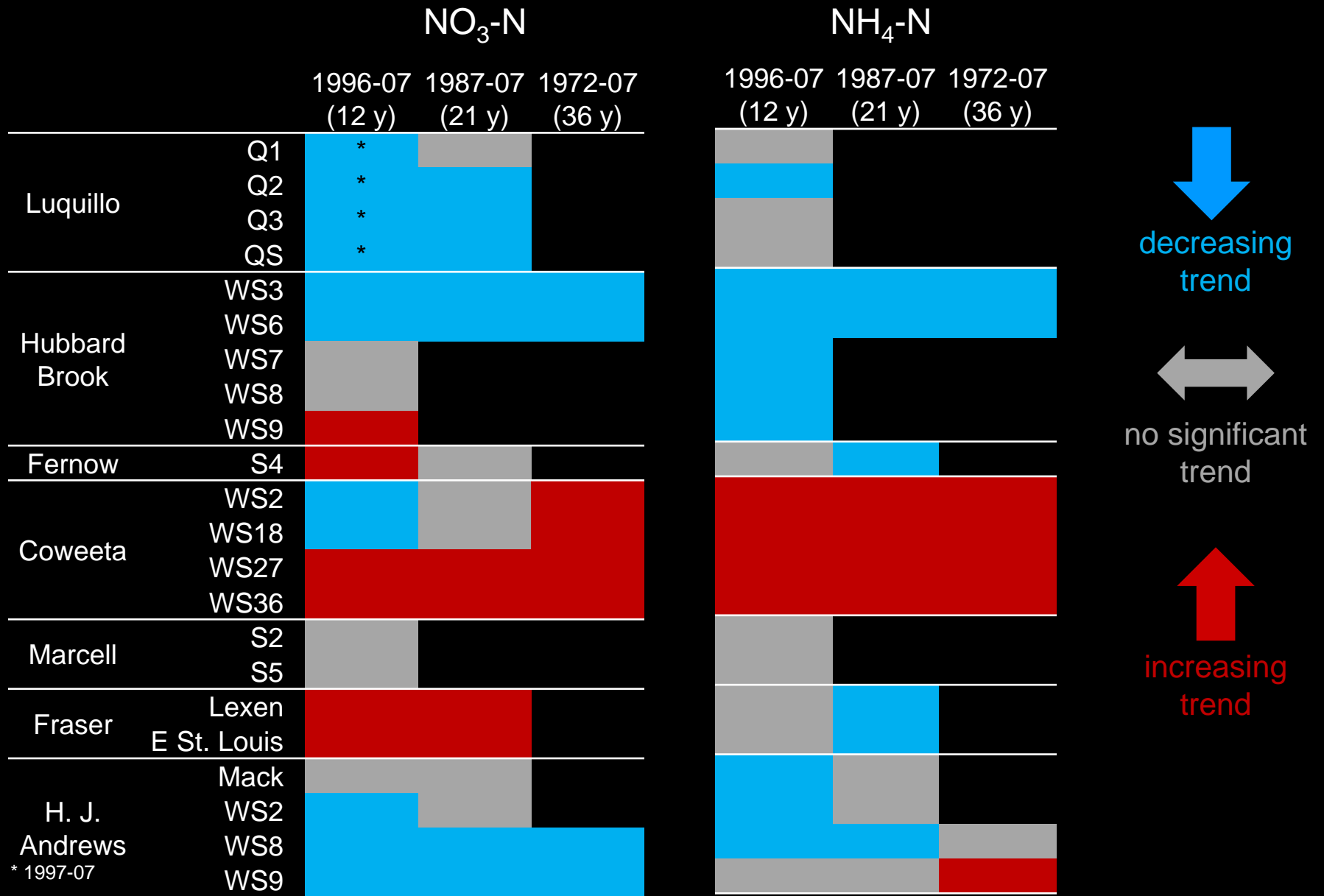


no significant trend

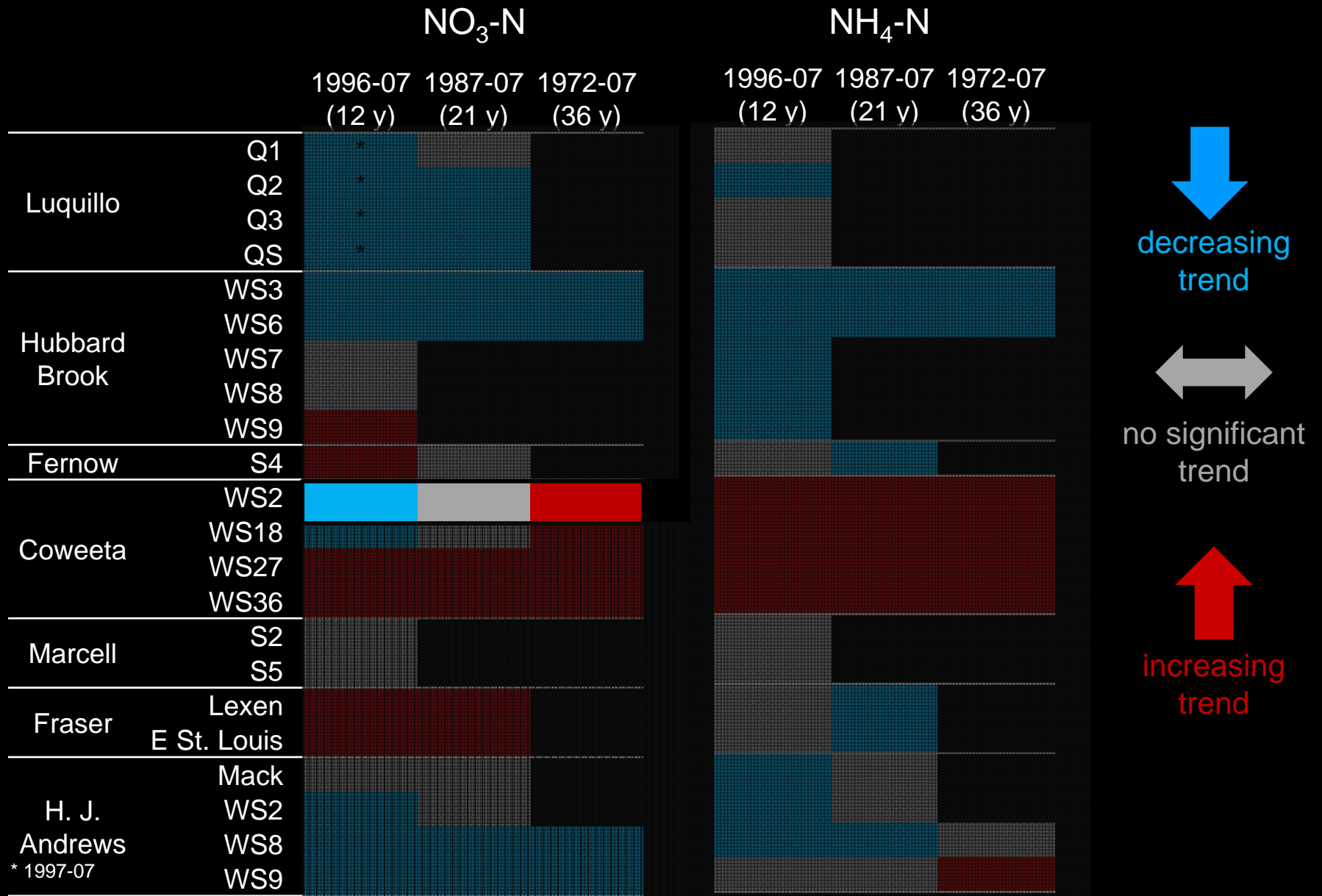


increasing trend

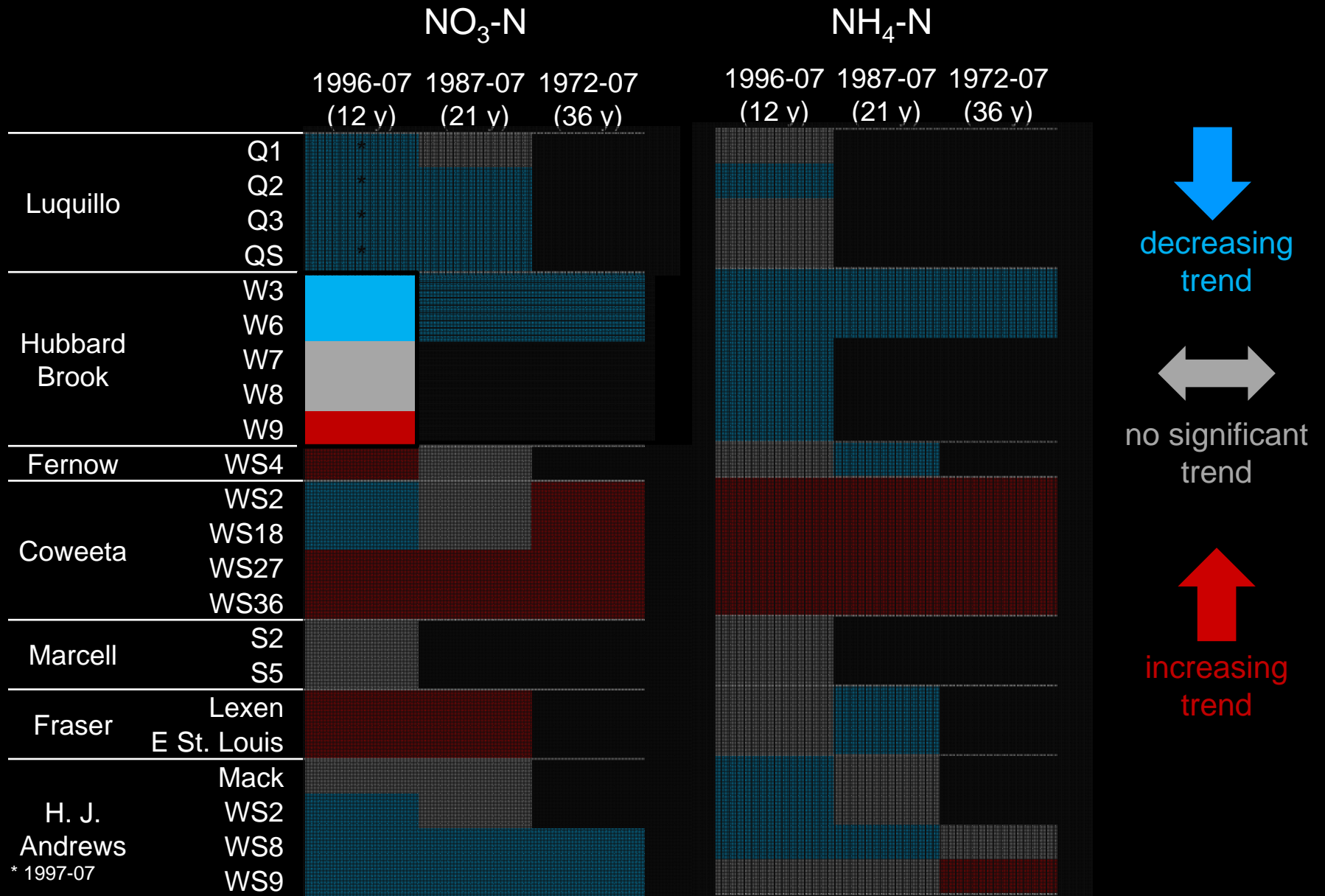
# Trends in N concentrations: all sites



# Trends in N concentrations: all sites



# Trends in N concentrations: all sites



\* 1997-07

# Trends in N concentrations: all sites

## Trends in wet NO<sub>3</sub>-N deposition

1996-07 (12 y)    1987-07 (21 y)    1978-07 (30 y)

Site	Station	1996-07 (12 y)	1987-07 (21 y)	1978-07 (30 y)
Luquillo	Q1	Grey	Grey	Red
	Q2	Grey	Grey	Red *
	Q3	Grey	Grey	Red *
	QS	Grey	Grey	Red *
Hubbard Brook	W3	Blue	Blue	Blue
	W6	Blue	Blue	Blue
	W7	Blue	Blue	Blue
	W8	Blue	Blue	Blue
	W9	Blue	Blue	Blue
Fernow	WS4	Blue	Blue	Blue
Coweeta	WS2	Grey	Grey	Blue
	WS18	Grey	Grey	Blue
	WS27	Grey	Grey	Blue
	WS36	Grey	Grey	Blue
Marcell	S2	Grey	Grey	Blue
	S5	Grey	Grey	Blue
Fraser	Lexen	Grey	Grey	Black
	E St. Louis	Grey	Grey	Black
H. J. Andrews	Mack	Grey	Grey	Grey
	WS2	Grey	Grey	Grey +
	WS8	Grey	Grey	Grey +
	WS9	Grey	Grey	Grey +

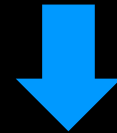
\*1985-2007

+1980-2007

1996-07 (12 y)    1987-07 (21 y)    1972-09 (38 y)

Site	Station	1996-07 (12 y)	1987-07 (21 y)	1972-09 (38 y)
Luquillo	Q1	Grey *	Grey	Black
	Q2	Grey *	Grey	Black
	Q3	Grey *	Grey	Black
	QS	Grey *	Grey	Black
Hubbard Brook	W3	Blue	Blue	Blue
	W6	Blue	Blue	Blue
	W7	Blue	Blue	Blue
	W8	Blue	Blue	Blue
	W9	Blue	Blue	Blue
Fernow	WS4	Blue	Blue	Blue
Coweeta	WS2	Grey	Grey	Blue
	WS18	Grey	Grey	Blue
	WS27	Grey	Grey	Blue
	WS36	Grey	Grey	Blue
Marcell	S2	Grey	Grey	Blue
	S5	Grey	Grey	Blue
Fraser	Lexen	Blue	Grey	Black
	E St. Louis	Blue	Grey	Black
H. J. Andrews	Mack	Blue	Blue	Blue
	WS2	Blue	Blue	Blue
	WS8	Blue	Blue	Blue
	WS9	Blue	Blue	Blue

## Trends in streamflow



decreasing trend



no significant trend



increasing trend

## Trends in N concentrations in reference catchments across US

### Is there more variation among sites than among basins within a site?

Yes, except at HJA. Stream nitrate and ammonium in reference catchments show great temporal and spatial variabilities that must be considered when evaluating loads and establishing nutrient criteria.

### Are there generalized long term trends in stream $\text{NO}_3$ and $\text{NH}_4$ ?

No, forested reference catchments across the country show both increasing and decreasing trends in stream nitrogen.

Catchments within a site do not necessarily present the same trends.

The length of record examined can result in differing trends which highlights the importance of long-term studies.

### Are trends associated with changing deposition or discharge?

Stream nitrate and ammonium increase when streamflow decreases.  
Stream ammonium increases when atmospheric ammonium wet deposition increases.

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**Create a database for stream chemistry data** (Standardize units, document analytical and sampling methods)

## Effects of sampling strategy and calculation methods on solute flux estimates

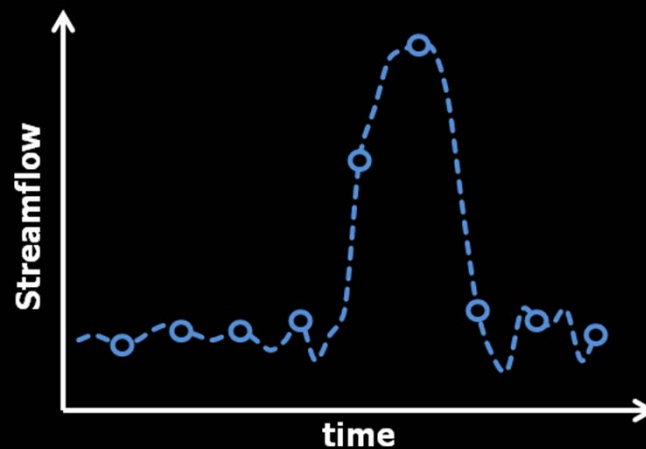
Flux= mass of N that passes a given point on the river over a given period of time

$$\Sigma(Q \times \text{conc})$$

(kg N/year)

# Effects of sampling strategy and calculation methods on solute flux estimates

Grab samples, fixed sampling intervals



Period-weighted methods

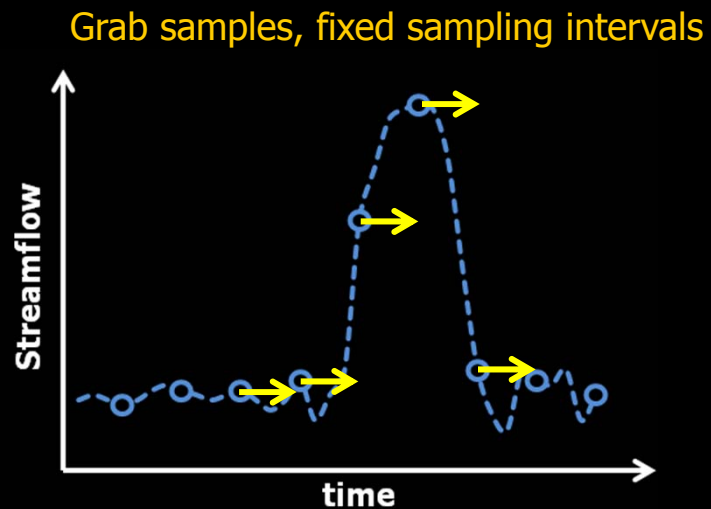
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Period-weighted methods



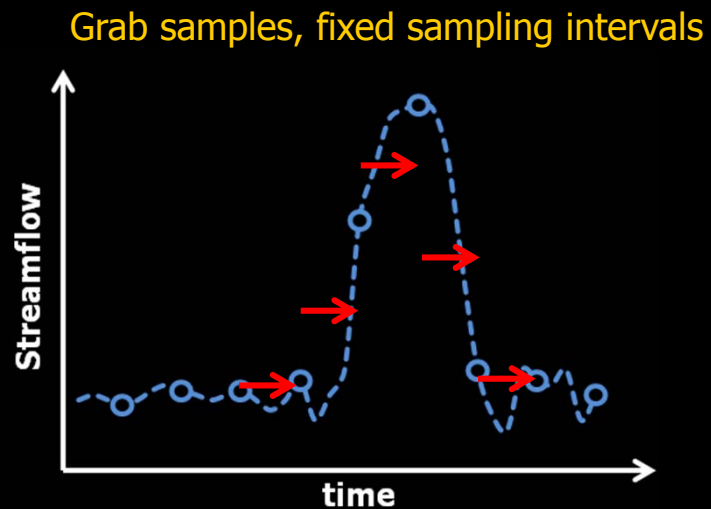
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Period-weighted methods



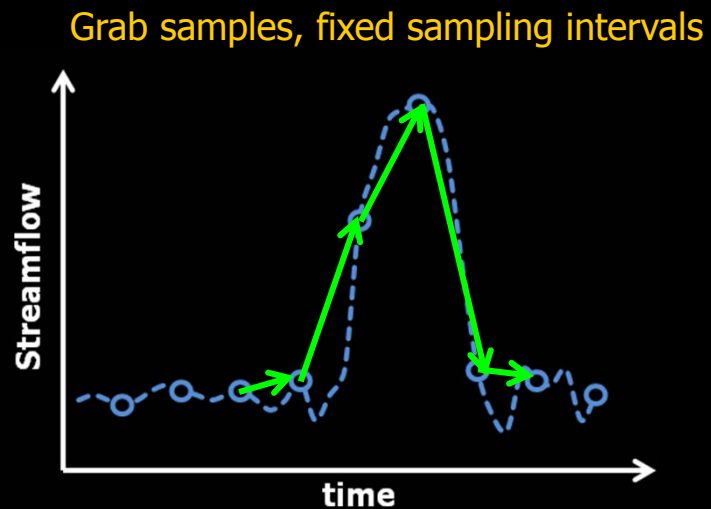
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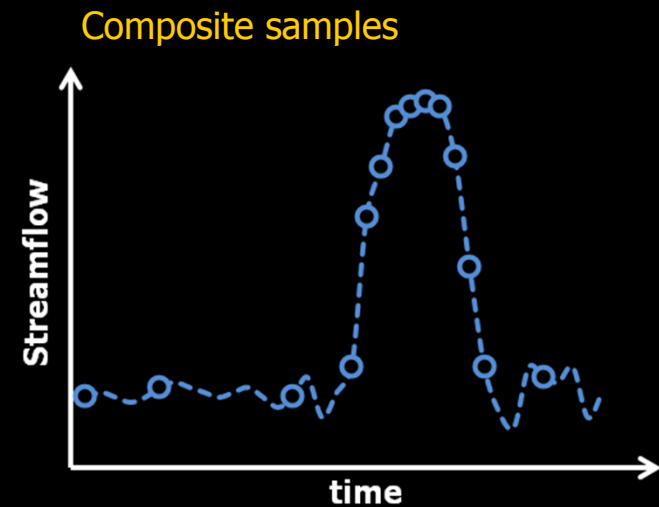
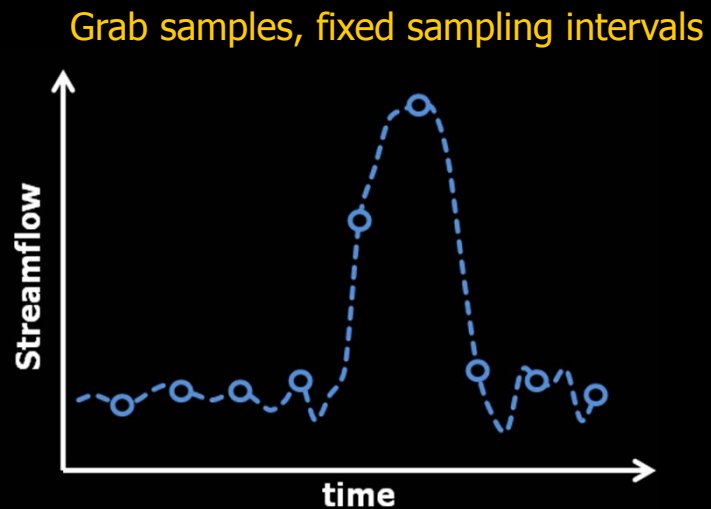
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Period-weighted methods



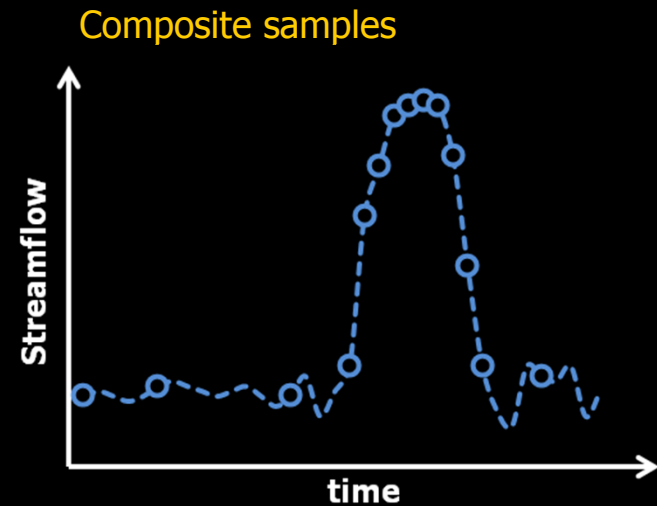
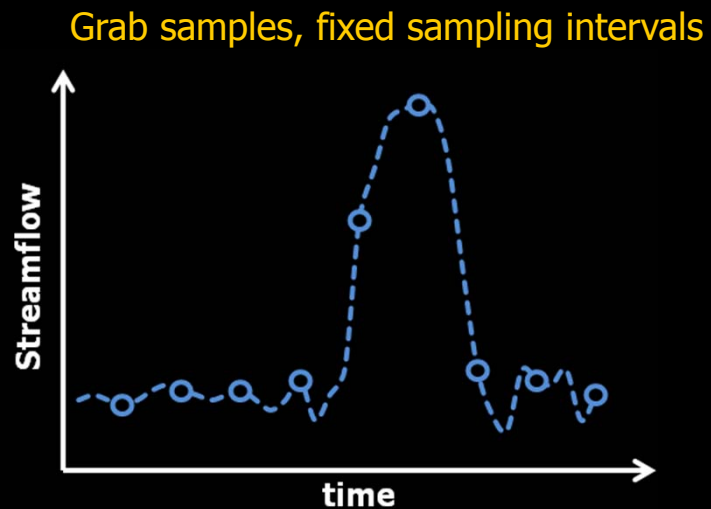
Flux= mass of N that passes a given point on the river over a given period of time

$$\Sigma(Q \times \text{conc})$$

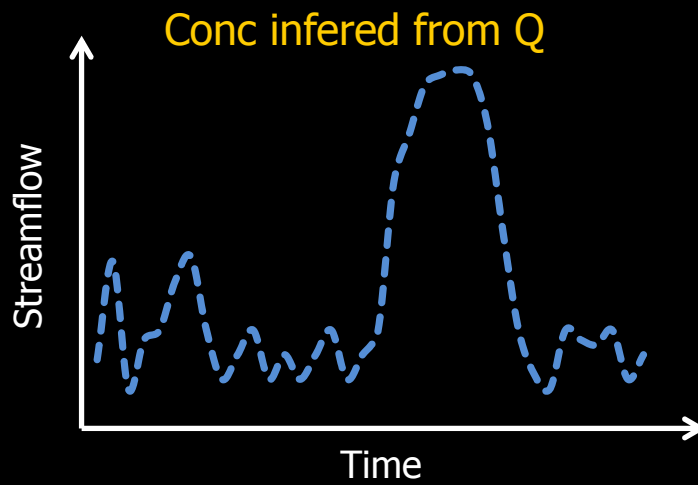
$$(\text{kg N/year})$$

# Effects of sampling strategy and calculation methods on solute flux estimates

Period-weighted methods



Regression methods



Flux= mass of N that passes a given point on the river over a given period of time

$$\Sigma(Q \times \text{conc})$$

$$(\text{kg N/year})$$

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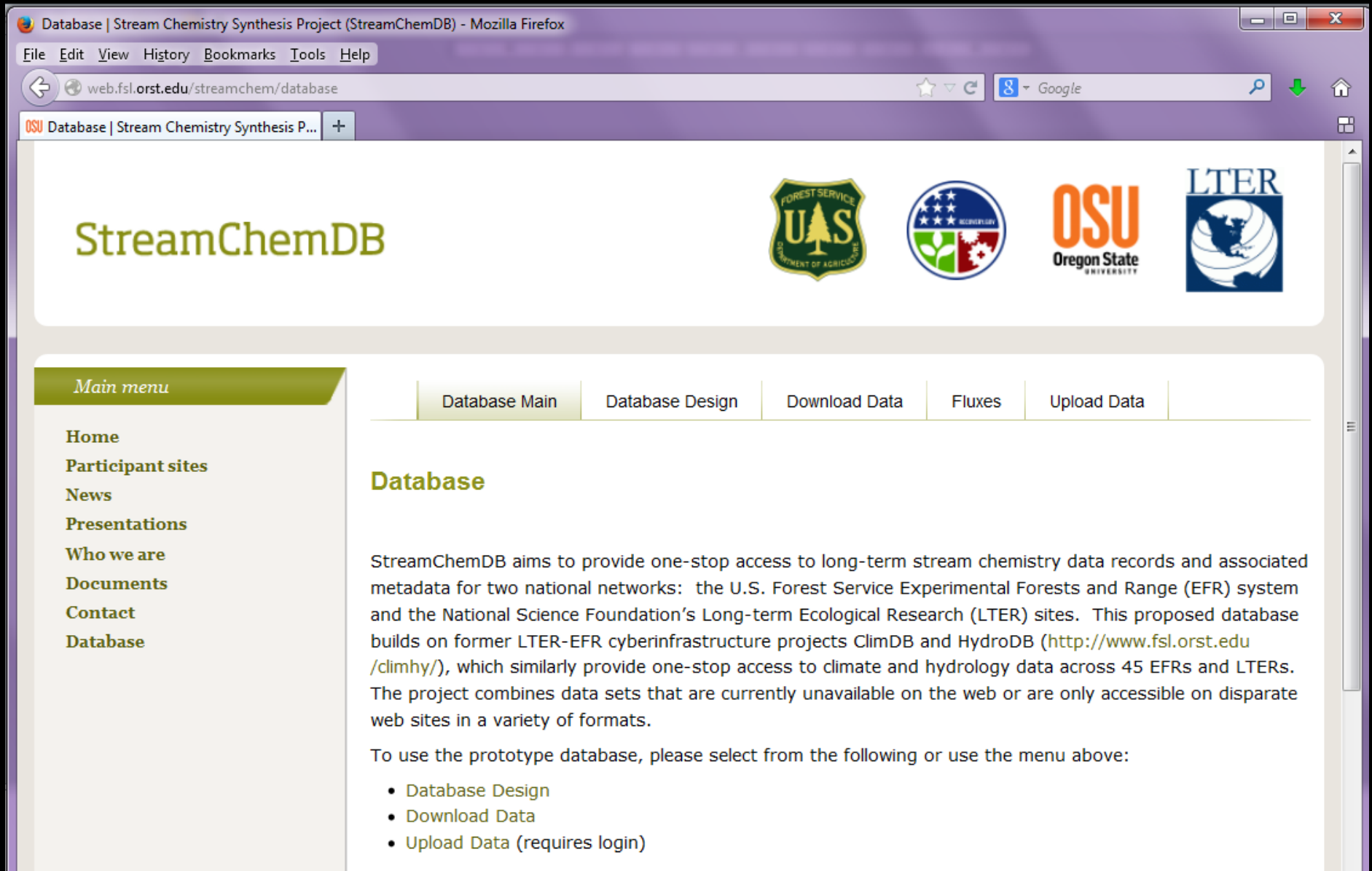
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# StreamChemDB

<http://web.fsl.orst.edu/streamchem/database>



The screenshot shows a Mozilla Firefox browser window displaying the StreamChemDB website. The browser's address bar shows the URL [web.fsl.orst.edu/streamchem/database](http://web.fsl.orst.edu/streamchem/database). The website header features the StreamChemDB logo and logos for the U.S. Forest Service, the National Science Foundation (NSF), Oregon State University (OSU), and the Long-term Ecological Research (LTER) program. A main menu is located on the left side, and a secondary navigation bar is positioned above the main content area. The main content area includes a title 'Database', a descriptive paragraph about the project's goals and data sources, and a list of links for users to interact with the database.

Database | Stream Chemistry Synthesis Project (StreamChemDB) - Mozilla Firefox

File Edit View History Bookmarks Tools Help

web.fsl.orst.edu/streamchem/database

OSU Database | Stream Chemistry Synthesis P... +

StreamChemDB

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

NSF

OSU Oregon State UNIVERSITY

LTER

Main menu

Home

Participant sites

News

Presentations

Who we are

Documents

Contact

Database

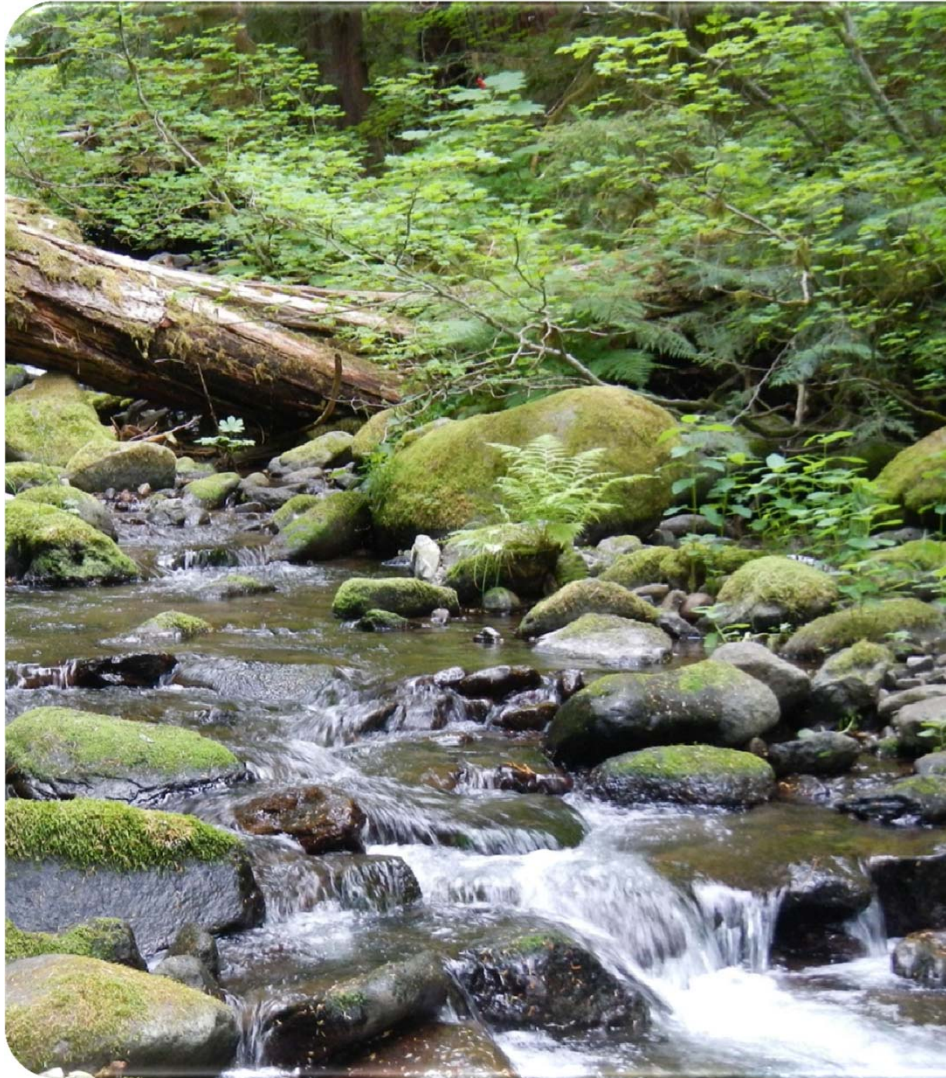
Database Main Database Design Download Data Fluxes Upload Data

## Database

StreamChemDB aims to provide one-stop access to long-term stream chemistry data records and associated metadata for two national networks: the U.S. Forest Service Experimental Forests and Range (EFR) system and the National Science Foundation's Long-term Ecological Research (LTER) sites. This proposed database builds on former LTER-EFR cyberinfrastructure projects ClimDB and HydroDB (<http://www.fsl.orst.edu/climhy/>), which similarly provide one-stop access to climate and hydrology data across 45 EFRs and LTERs. The project combines data sets that are currently unavailable on the web or are only accessible on disparate web sites in a variety of formats.

To use the prototype database, please select from the following or use the menu above:

- Database Design
- Download Data
- Upload Data (requires login)



For more information:  
[web.fsl.orst.edu/streamchem/](http://web.fsl.orst.edu/streamchem/)  
[alba.argerich@oregonstate.edu](mailto:alba.argerich@oregonstate.edu)

Questions?

