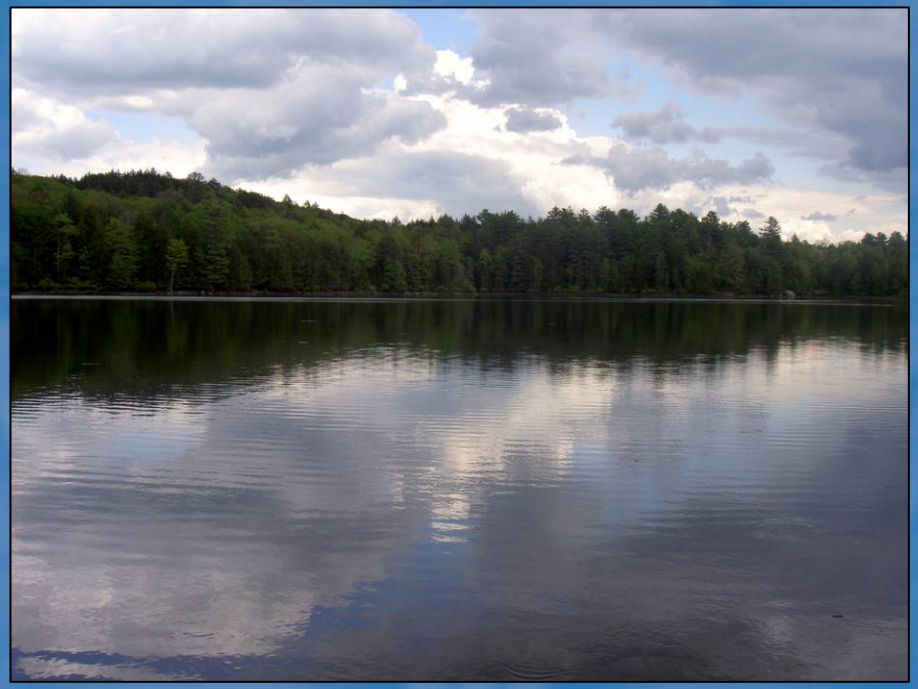
Watershed Nitrogen Modeling: Coupling Diverse Approaches Using a Case Study from New York State



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Sixth National Monitoring Conference
20 May 2008

Collaborators

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Consequences of nitrogen inputs to watersheds

(after Driscoll et al. 2003)

Air Quality Impacts

✓Elevated ground-level ozone
✓Increased particles in the air
✓Reduced visibility
✓Increased acid rain and nitrogen deposition

↕

Forest Impacts

✓Increased acidity of forest soils (& calcium depletion)
✓Nitrogen saturation of forest ecosystems
✓Ozone damage to forests

↕

Water Quality Impacts

✓Elevated acidification of lakes and streams
✓Groundwater contamination
✓Over-enrichment of coastal ecosystems

Challenge:

(1) Understanding spatial variations in NO_3-N across multiple, diverse catchments and linkages to landscape controls under varying seasonal conditions

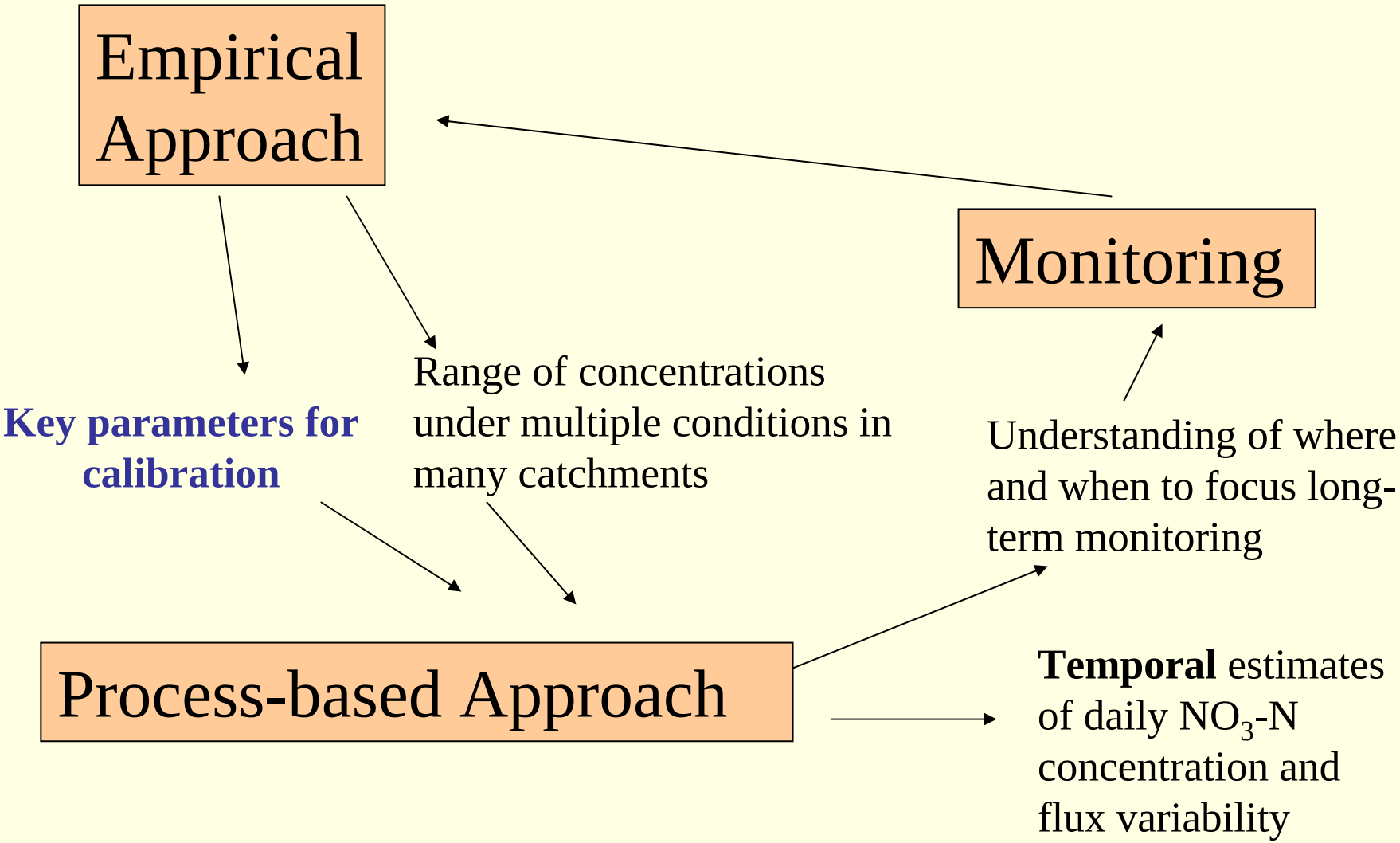
(2) Fitting an appropriate NO_3-N model for rapid assessment of multiple catchment concentrations contributing to large surface water systems

NO_3^- = Important inorganic N species in soil transport and watershed management:
1. Highly mobile in terrestrial landscape
2. Typically a primary component of watershed N budgets and stream N chemistry
3. Coastal eutrophication from excess N enrichment is driving national nutrient management strategy

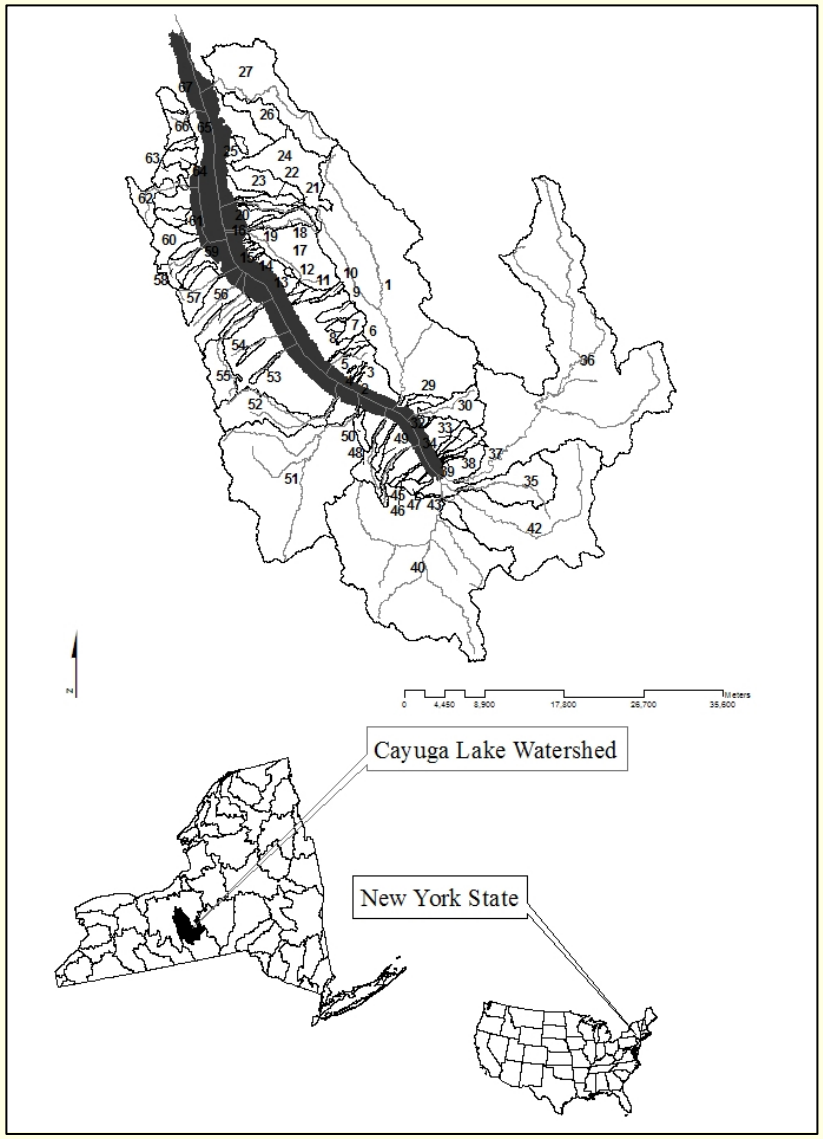
What modeling approach is appropriate for capturing **spatial variations in NO_3-N** concentrations in **multiple catchments** under **different hydrological (and biogeochemical) conditions**? Hybrid approach…

First set out to answer whether the spatial distribution of NO_3-N varies throughout the year using an empirical (data-driven) approach…

Modeling Watershed Nitrate Concentrations



Cayuga Lake Watershed

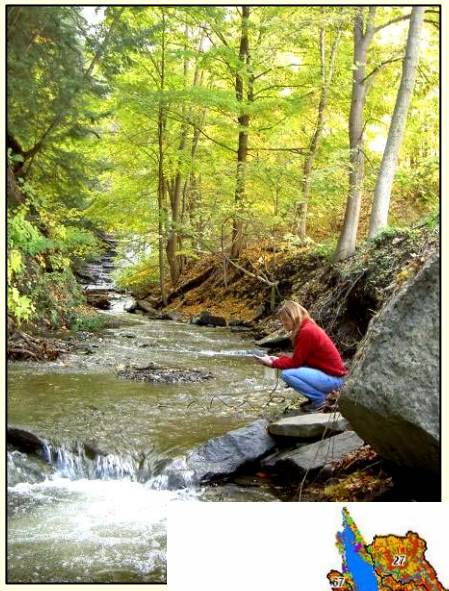


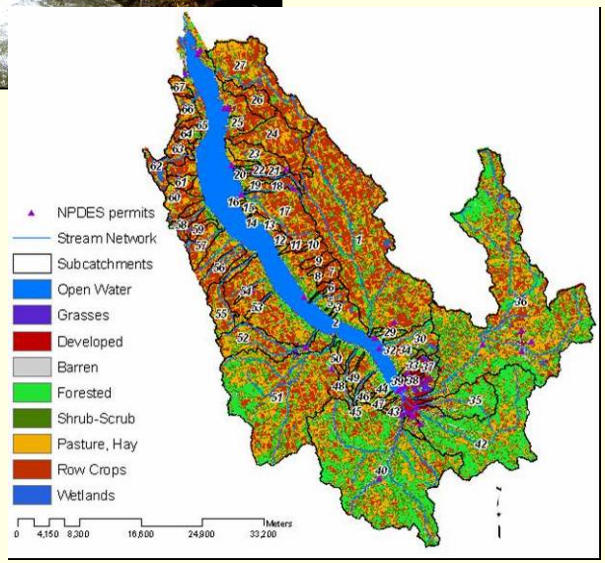
CLW: 1840 km^2 + 2081 km^2 at north outlet; 61.6 km long

Cayuga Lake Watershed, North End (Pfeiff,B)

Cayuga Lake Watershed, South End (CLWN)

Synoptic stream sampling of 77% of watershed area of Cayuga Lake:





Land Cover: Adapted from MRLC NLCD (2001)

- Varying flow regimes and seasonally available NO_3^-
- Sample at outlets to CL
- Delineate 65 subcatchments
- *Correlations* among N concentrations in streams and landscape variables (land cover, soil factors: HSG, hydric, slopes, etc.): Whole catchments & Hydrologically sensitive areas (HSAs)
- <u>Sampling periods</u>:

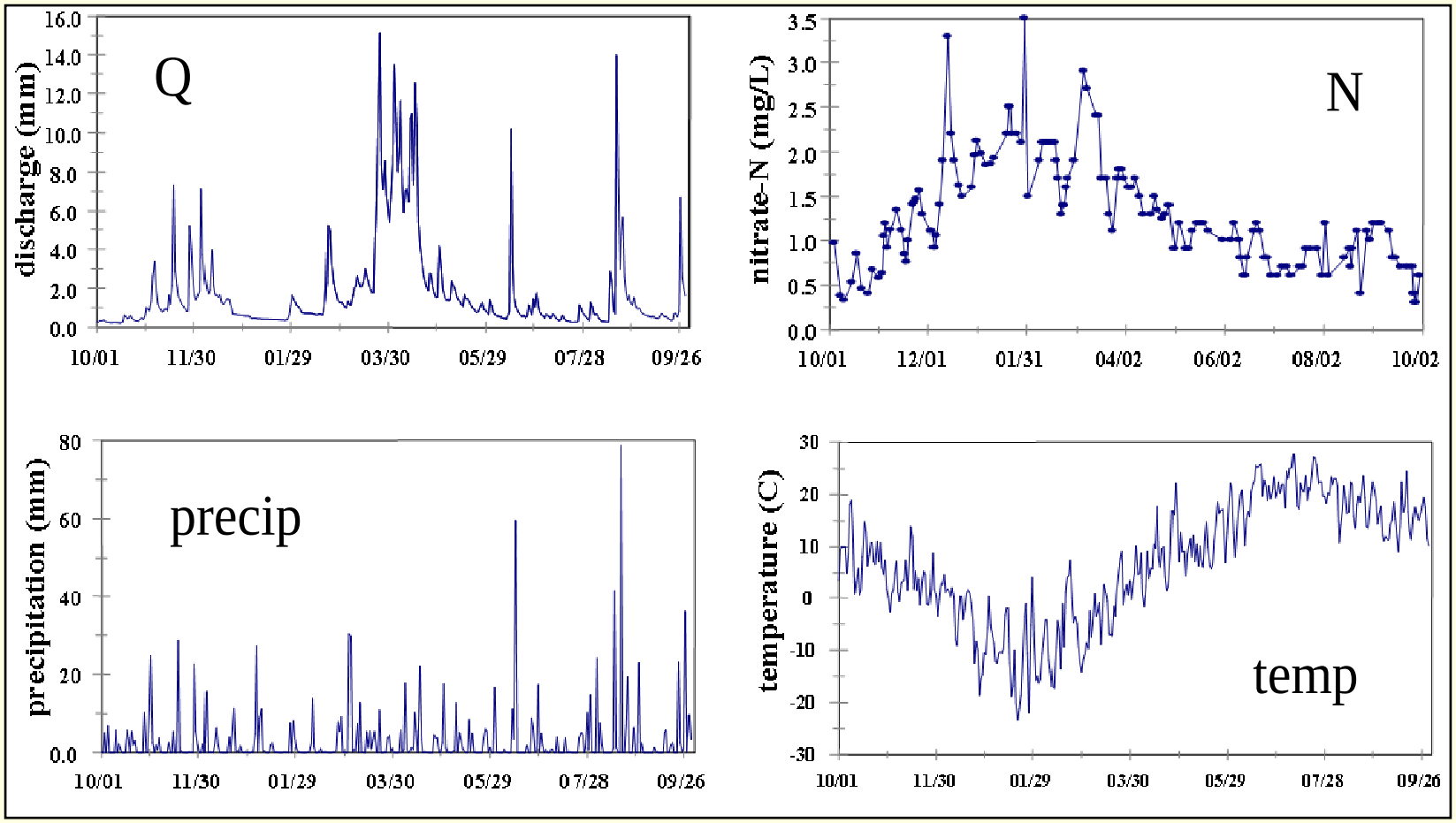
S1: 23-24 March 2005 (n=65)

S2: 19 August 2005 (n=10)

S3: 3 September 2005 (n=15)

S4: 26 & 28 October 2005 (n=65)

Seasonality of nitrate concentrations: Fall Creek, NY

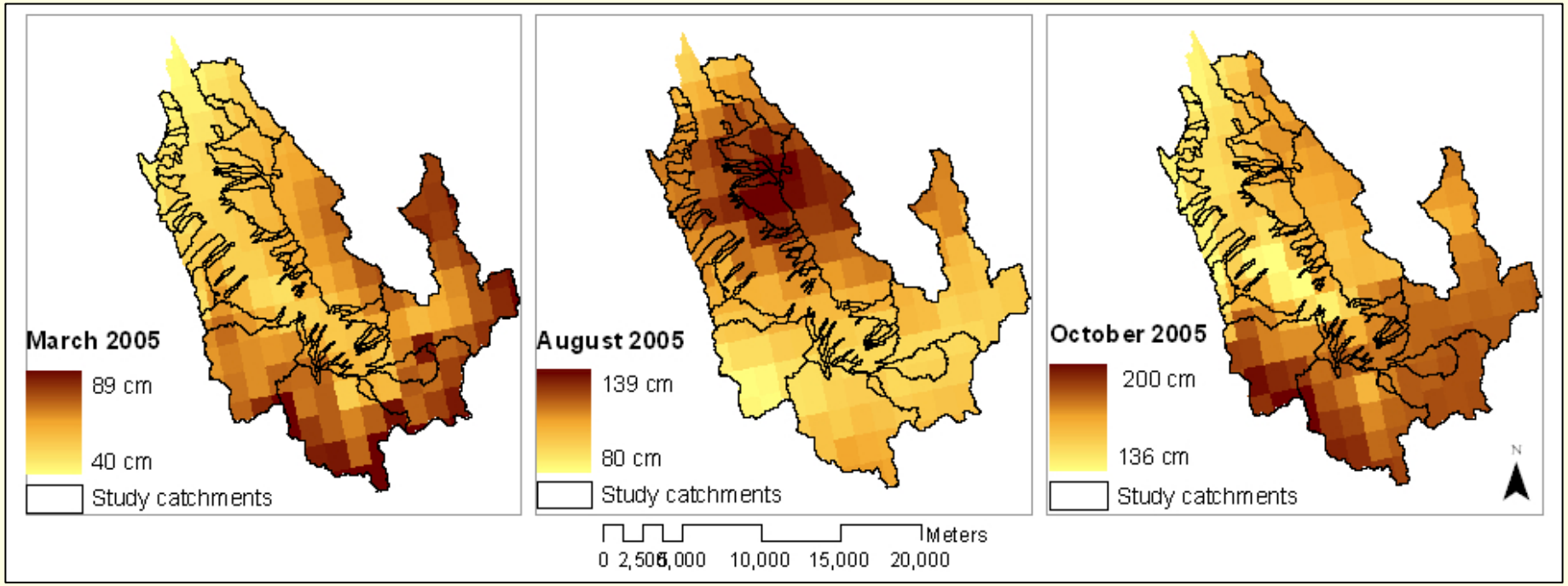


Alexander et al., 2007

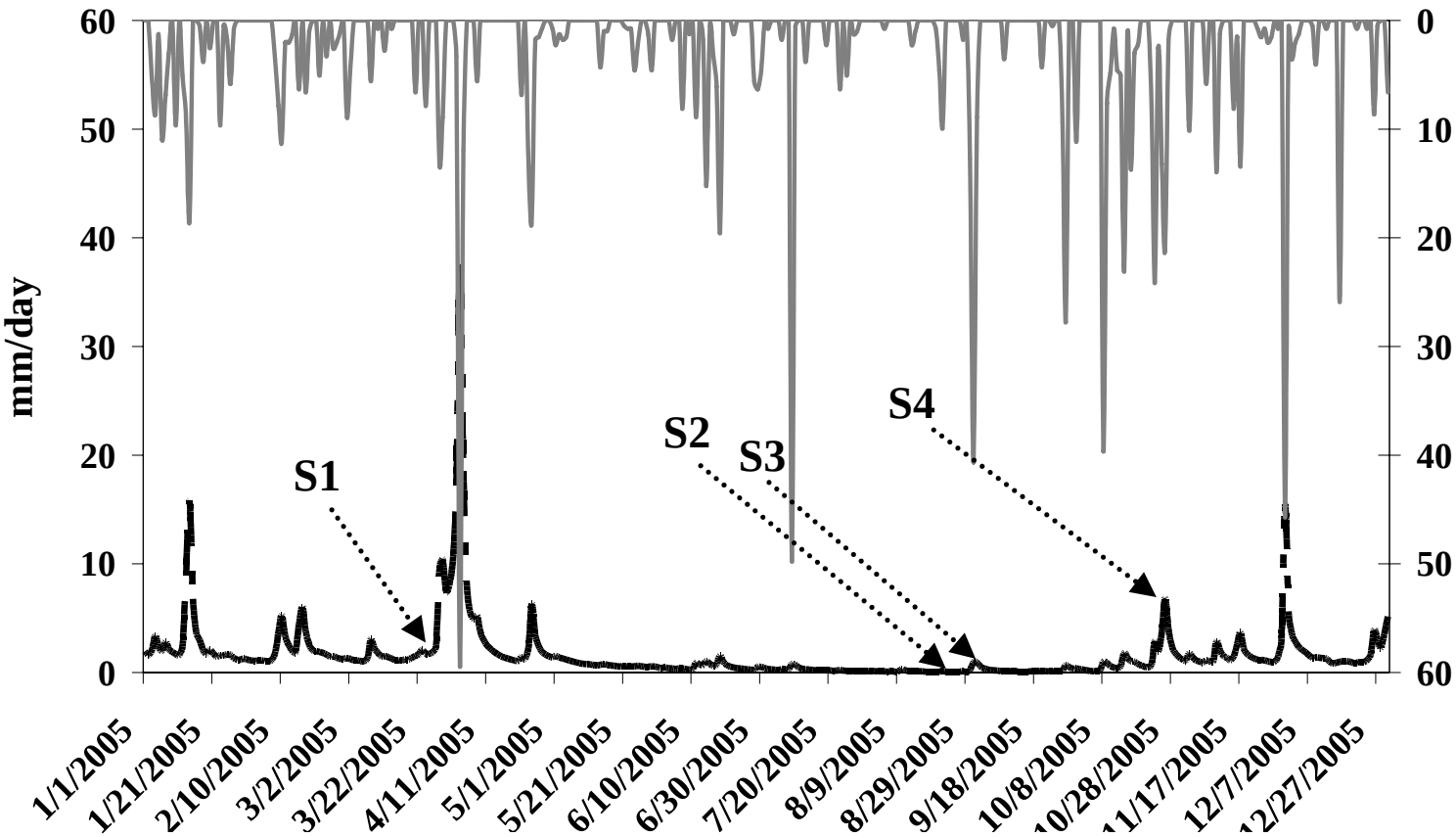
Does the rest of Cayuga Lake Watershed respond similarly???

Hydrological setting:

monthly precipitation as an indicator of variations in antecedent moisture, spatially and temporally (cm month^{-1})



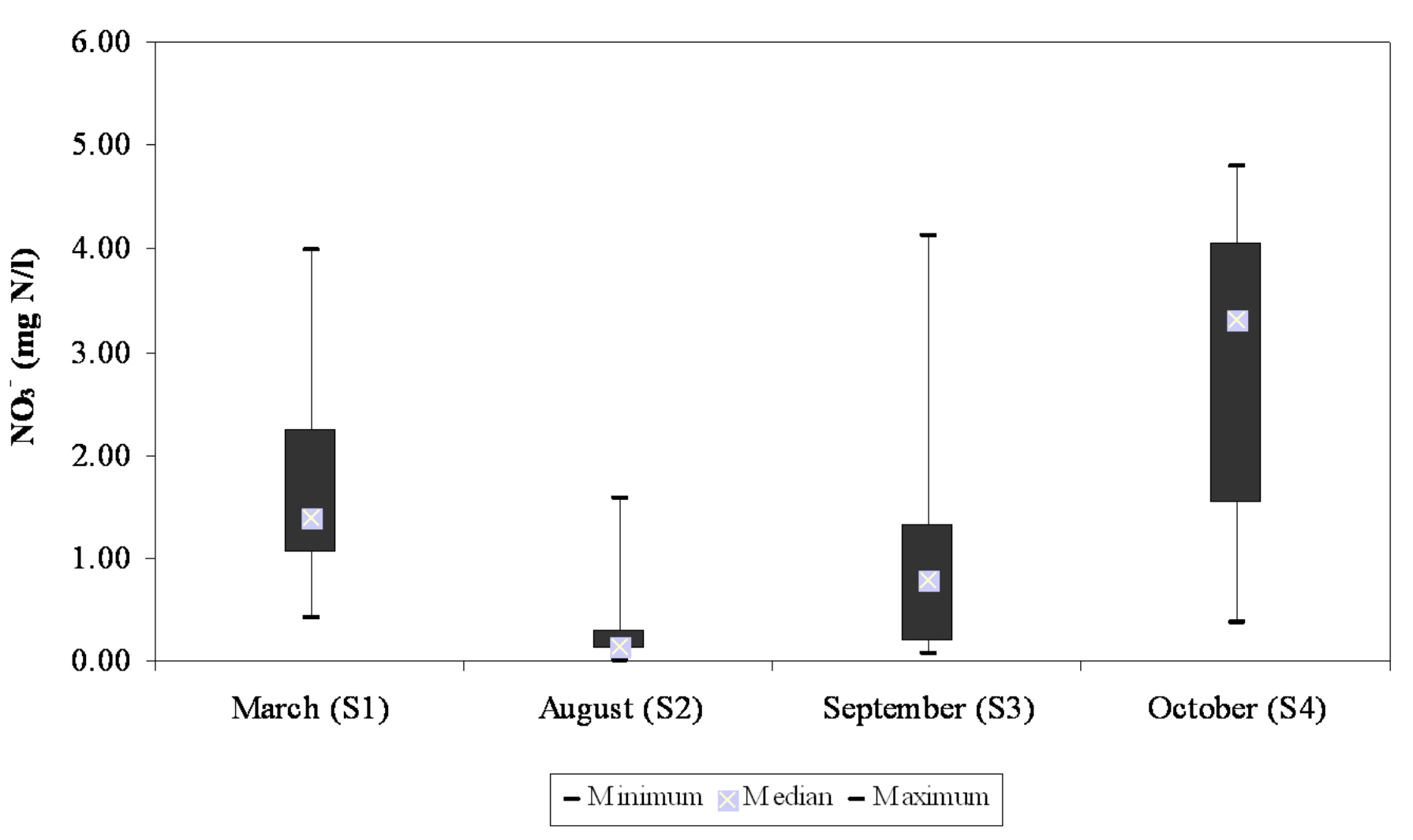
Four sampling events: Four different hydrological conditions



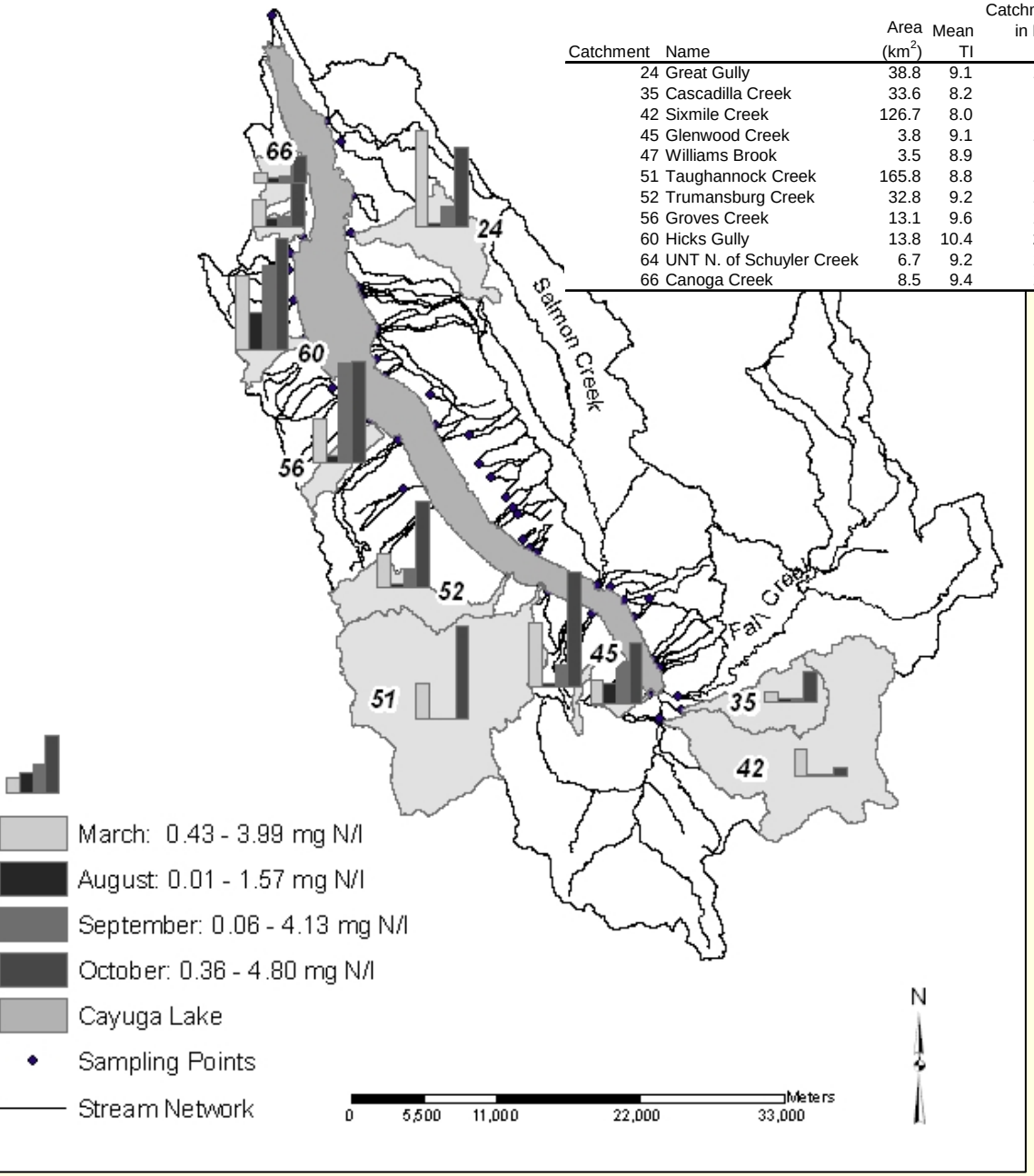
S1: 23-24 March 2005 **S2**: 19 August 2005

S3: 3 September 2005 **S4**: 26 & 28 October 2005

Seasonal variability among catchments sampled during each event

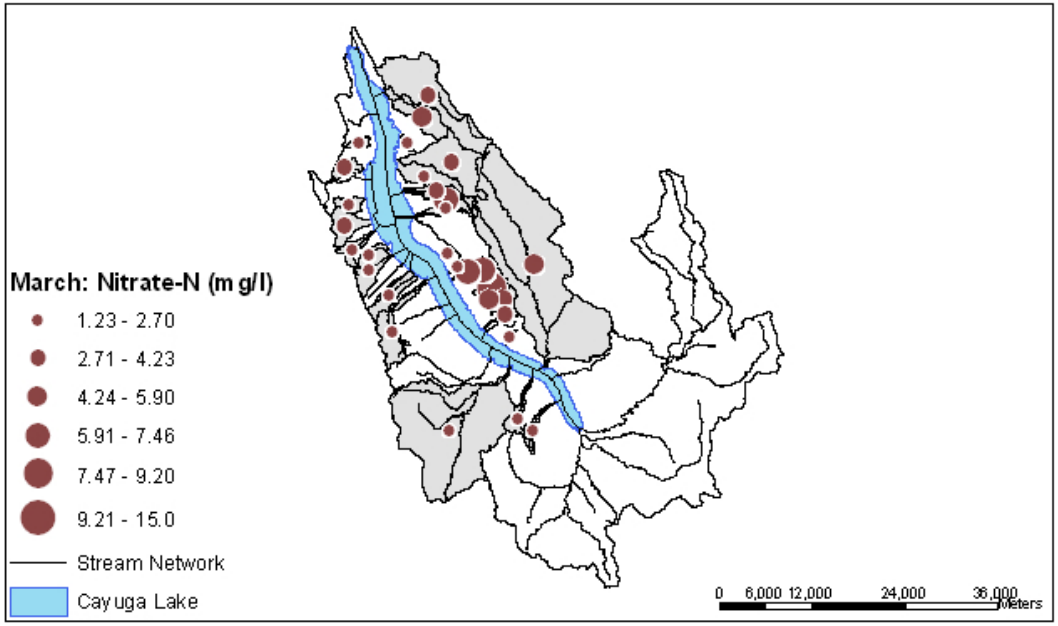


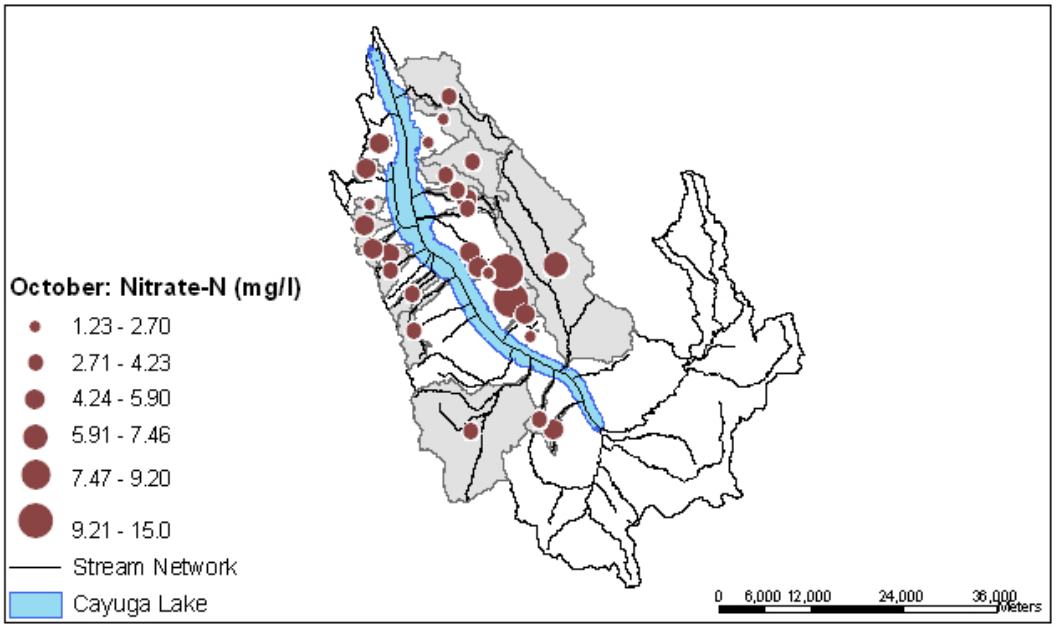
Catchment	Name	Area (km^2)	Mean TI	Catchment in HSA (%)	March Precipitation (cm/month)	August Precipitation (cm/month)	October Precipitation (cm/month)	Mean Slope (%)	Developed Land (%)	Forested Land (%)	Pasture Land (%)	Land in Row Crops (%)
24	Great Gully	38.8	9.1	12.3	55.0	128.1	168.0	4.3	0.1	10.2	26.2	54.4
35	Cascadilla Creek	33.6	8.2	8.2	68.5	92.4	180.3	10.7	3.3	55.0	17.0	5.4
42	Sixmile Creek	126.7	8.0	6.6	71.0	95.0	181.5	12.4	2.6	58.3	16.9	4.0
45	Glenwood Creek	3.8	9.1	14.2	65.3	93.9	178.1	4.1	1.7	34.2	36.1	9.6
47	Williams Brook	3.5	8.9	9.7	59.4	90.4	178.4	5.3	0.7	26.6	38.6	24.1
51	Taughannock Creek	165.8	8.8	10.0	65.5	89.7	180.9	6.0	0.5	28.9	31.9	23.3
52	Trumansburg Creek	32.8	9.2	13.3	61.3	100.5	167.4	3.9	2.0	17.1	36.8	27.6
56	Groves Creek	13.1	9.6	18.8	52.4	112.4	149.1	4.1	1.4	6.2	31.0	50.9
60	Hicks Gully	13.8	10.4	27.1	47.7	114.2	146.4	2.2	1.3	5.6	35.0	43.1
64	UNT N. of Schuyler Creek	6.7	9.2	12.8	44.6	111.2	148.5	3.0	0.0	10.6	19.1	52.7
66	Canoga Creek	8.5	9.4	13.0	43.8	107.5	146.5	2.3	0.7	6.6	41.6	38.4



Spatial variations of NO_3-N under varying hydrological and biogeochemical conditions

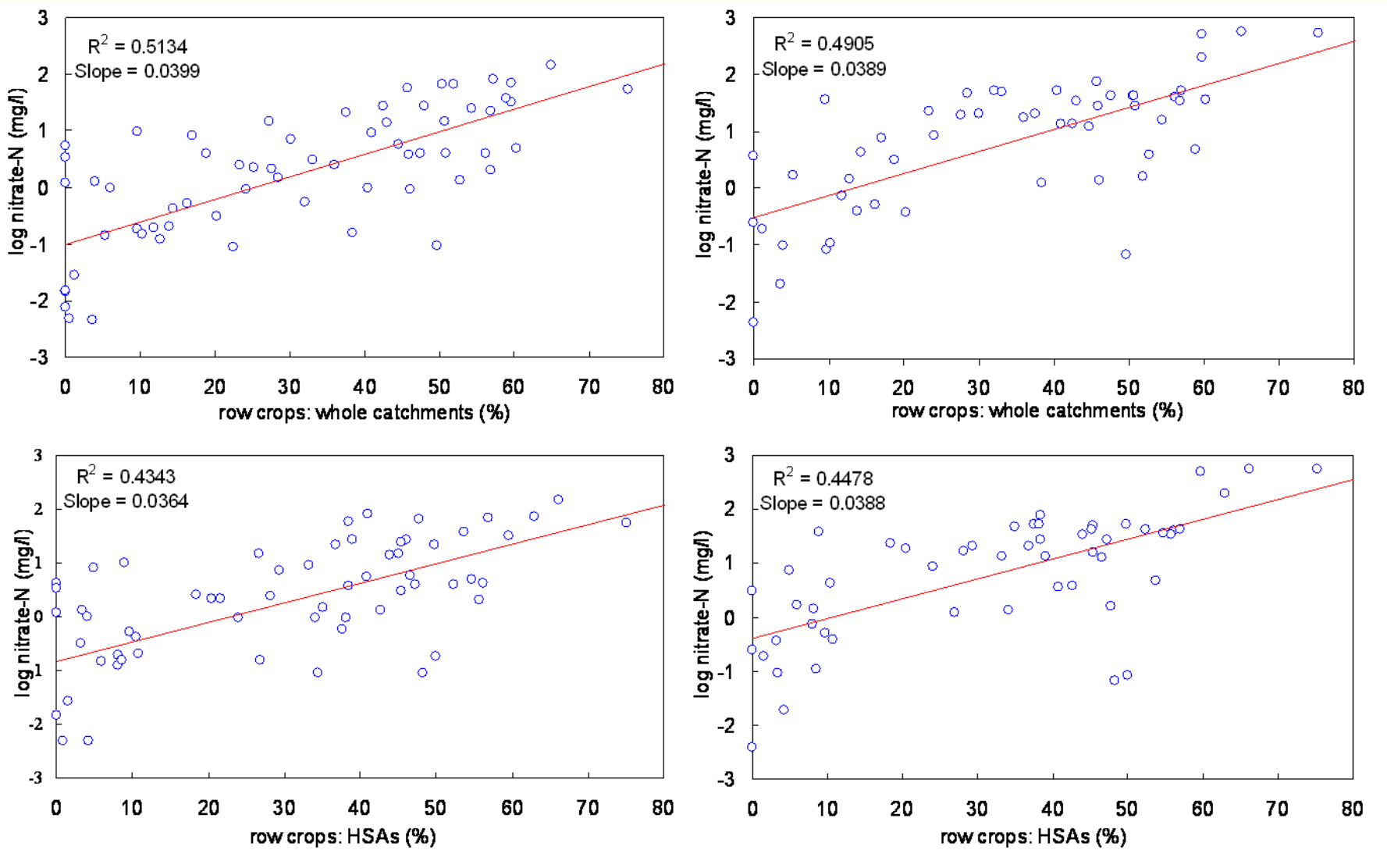
Catchment Variables	NO_3^- (mg N/l) Pearson's r S1: March *n=64*	S2: August *n=11*	S3: September *n=16*	S4: October *n=53*
Catchment Area (km2)	---	-0.8159	-0.5551	---
Mean TI	0.3089	---	---	0.0052
Precipitation (cm/month)	---	---	---	---
HSG A (%)	---	---	---	---
HSG B (%)	0.6893	---	---	0.7162
HSG C (%)	-0.6891	---	---	-0.5882
HSG D (%)	---	---	---	-0.0405
Hydric Soils (%)	---	---	---	---
Atmospheric N (kg N/ha/qtr)	---	---	---	---
Range in Elevation (m)	---	---	---	---
Average Slope (%)	-0.3595	---	-0.6020	---
Land Cover: Water (%)	-0.3255	---	---	-0.5153
Land Cover: Grasses (%)	-0.4118	---	---	-0.4533
Land Cover: Developed (%)	-0.4906	---	---	-0.4424
Land Cover: Barren (%)	---	---	---	---
Land Cover: Forested (%)	-0.4434	---	-0.5732	---
Land Cover: Scrub/Shrub (%)	-0.3505			-0.3409
Land Cover: Pasture (%)	---	---	---	---
Land Cover: Row Crops (%)	0.7166	---	0.5303	0.6522
Land Cover: Wetlands (%)	-0.3745	---	---	---
Land Cover: Impervious, 1-10	-0.4757	---	---	-0.4277
Land Cover: Impervious, 11-2	-0.4436	---	---	-0.4738
Land Cover: Impervious, 21-5	-0.4652	---	---	-0.4466
Land Cover: Impervious, 51-1	-0.3983	---	---	-0.4031





March (S1)

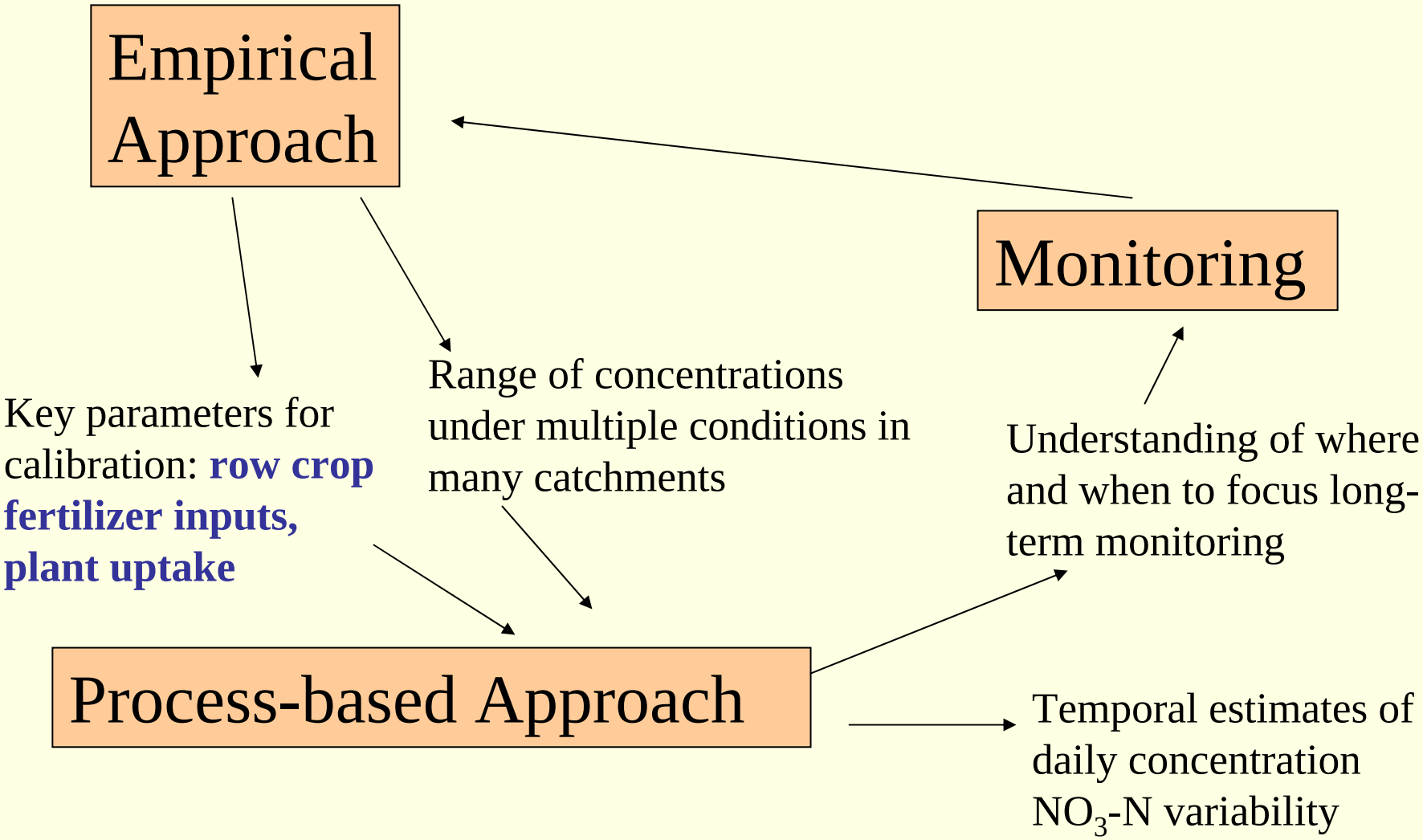
October (S4)

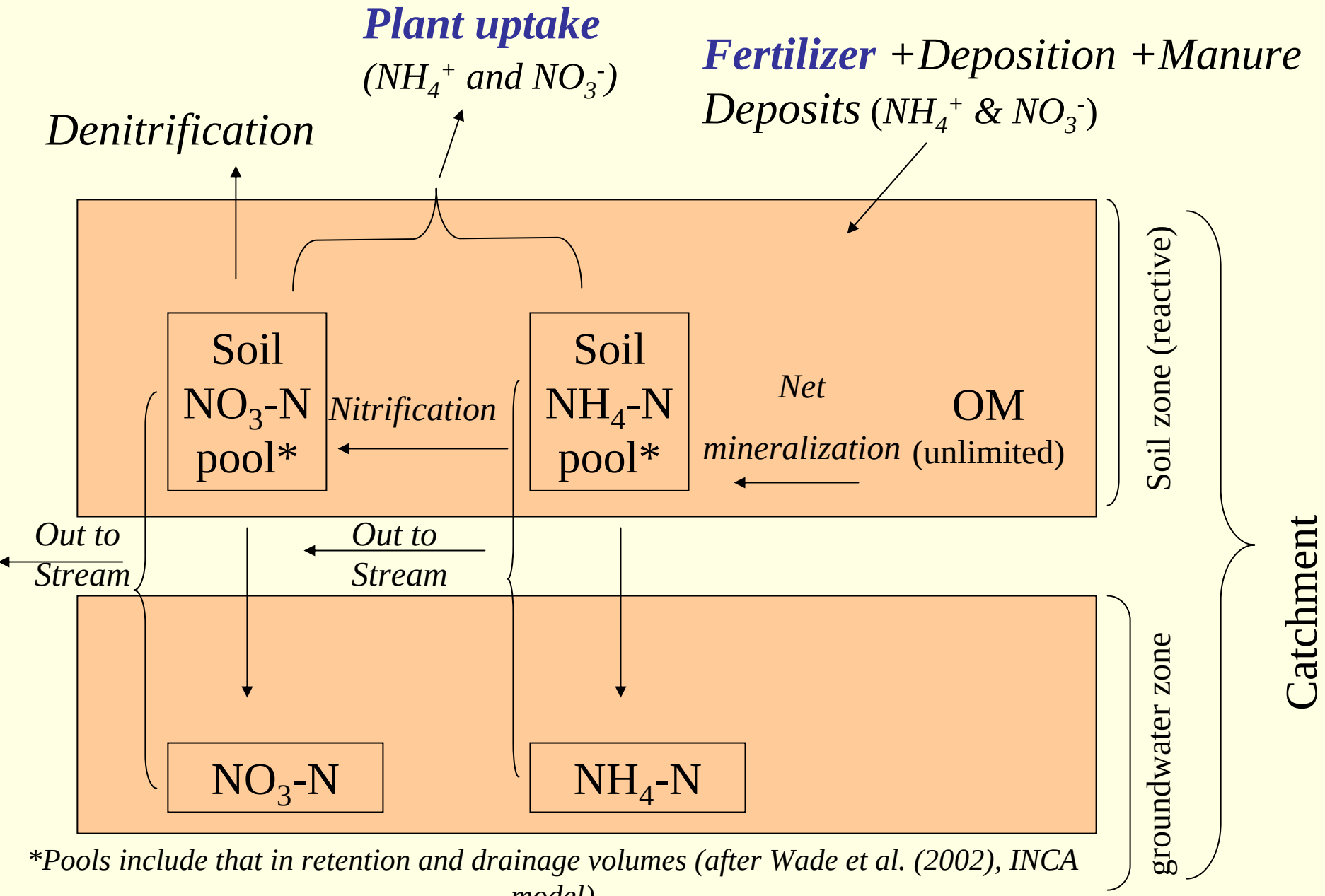


Empirical approach summary:

- The spatial variability of NO_3-N concentrations at the tributary outlets to the lake shifts under different hydrological and source availability conditions
- Row crops are significantly correlated to NO_3-N concentrations during all but the driest sampling event
- ***Need:*** A simple inorganic N process model assess how this spatial variability changes through time from *multiple catchments*, which will help to inform management decisions in the basin

Modeling Watershed Nitrate Concentrations





*Pools include that in retention and drainage volumes (after Wade et al. (2002), INCA model)

Process-based approach

***Simple structure for multiple applications*:** similar to GWLF, ReNuMa, and INCA structure, processes vary

Applications:

- Initial assessments of NO_3-N loadings and concentrations for multiple, diverse catchments through time
- Modeling multiple non-nested catchments
- Beginning to explore coupled N and Hg watershed processes

Summary: advantages of coupled (hybrid) approach

- ***Empirical methods***:
  - Provided insight to key factors affecting NO_3-N delivery in catchments of this basin (can be extended to others)…informs processed-based methods
  - Suggested a nonuniform shift of concentrations under different hydrological and biogeochemical conditions…useful for model calibration
  - Provided a snapshot of the spatial distribution of NO_3-N concentrations in multiple catchments under different seasonal conditions
- ***Process-based methods:***
  - Will provide insight to the temporal shifts in the spatial distribution of concentrations throughout the basin, better informing basin managers
  - Will advance scientific understanding of NO_3-N concentrations and loads in many multi-scale catchments, particularly with predominate row crop land cover, in a rapidly repeatable manner
- Neither approach needs to be used exclusively; coupled=beneficial
- Clarification of both models through long-term and well-structured monitoring

Questions?

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