QUANTIFYING UNCERTAINTY IN ECOSYSTEM STUDIES :
Using long-term data from small watersheds

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What is QUEST?

QUEST is a research network interested in improving understanding and facilitating use of uncertainty analyses in ecosystem research.

- Currently funded project is an analysis of hydrologic input-output budgets in small headwater catchments throughout the US
- Includes researchers and students in the US, Canada, and Japan

Ecosystem Budgets have no error.

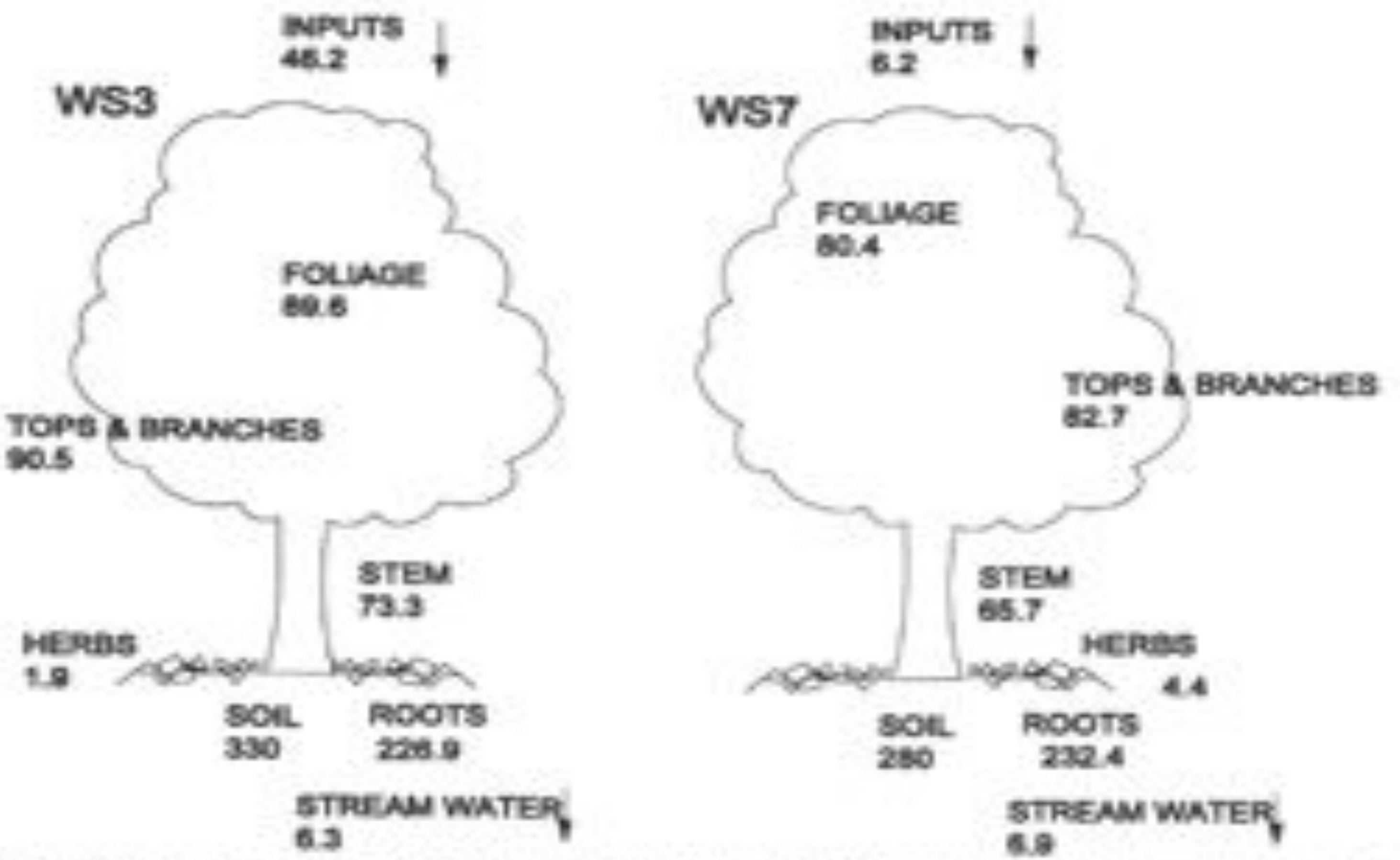
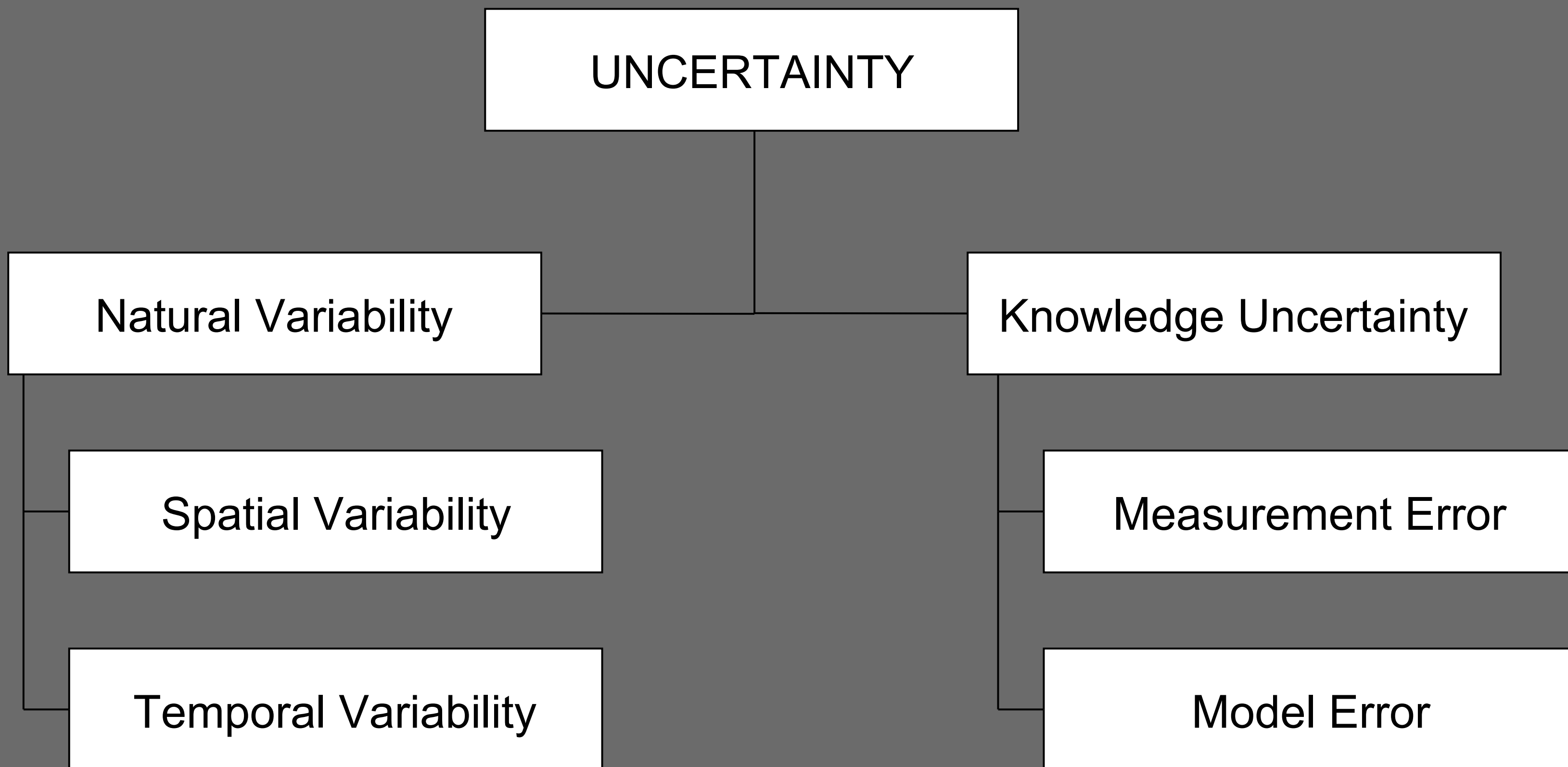


Figure 2. July nitrogen budgets for WS3 (treatment watershed) and WS7 (control watershed), Fernow Experimental Forest. Values are kg ha^{-1}.

Adams et al. 1995

What contributes to uncertainty in nutrient budgets?



Sources of Uncertainty in Stream Export of Nutrients

Measurement Uncertainty

- Uncertainty in analysis of water chemistry

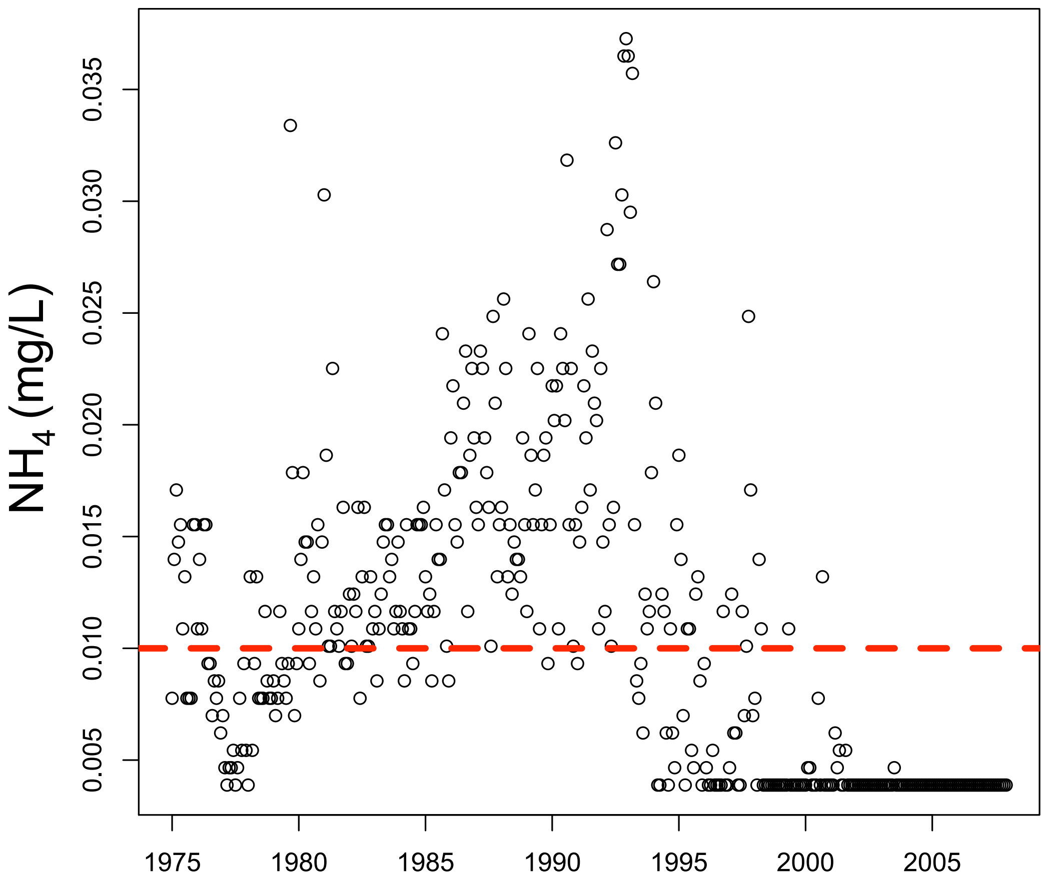
Analysis of water chemistry

Precision over range (POR): repeatability

Method detection limit (MDL): lowest detectable concentration

Note:

Uncertainties are generally small except near detection limits.



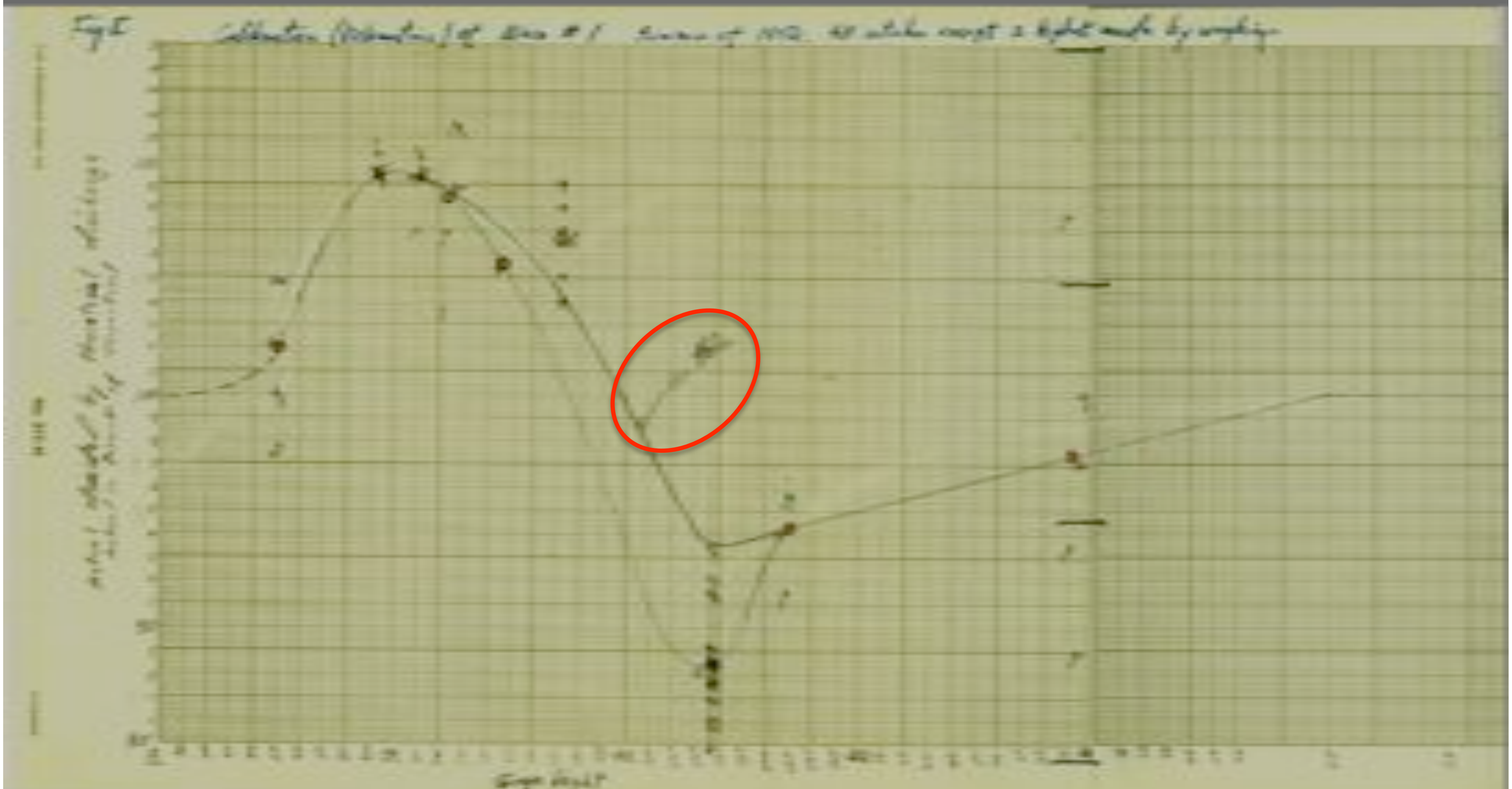
Sources of Uncertainty in Stream Export of Nutrients

Measurement Uncertainty

- Uncertainty in analysis of water chemistry
- Uncertainty in height-discharge relationship at the weir

Height-discharge relationship

At Hubbard Brook, discharge was measured at low flow and compared to the predictions of the theoretical curve ($Q = 2.49H^{2.48}$). The rating table is corrected according to this hand-drawn curve.



There are no such validation measurements at high flows.

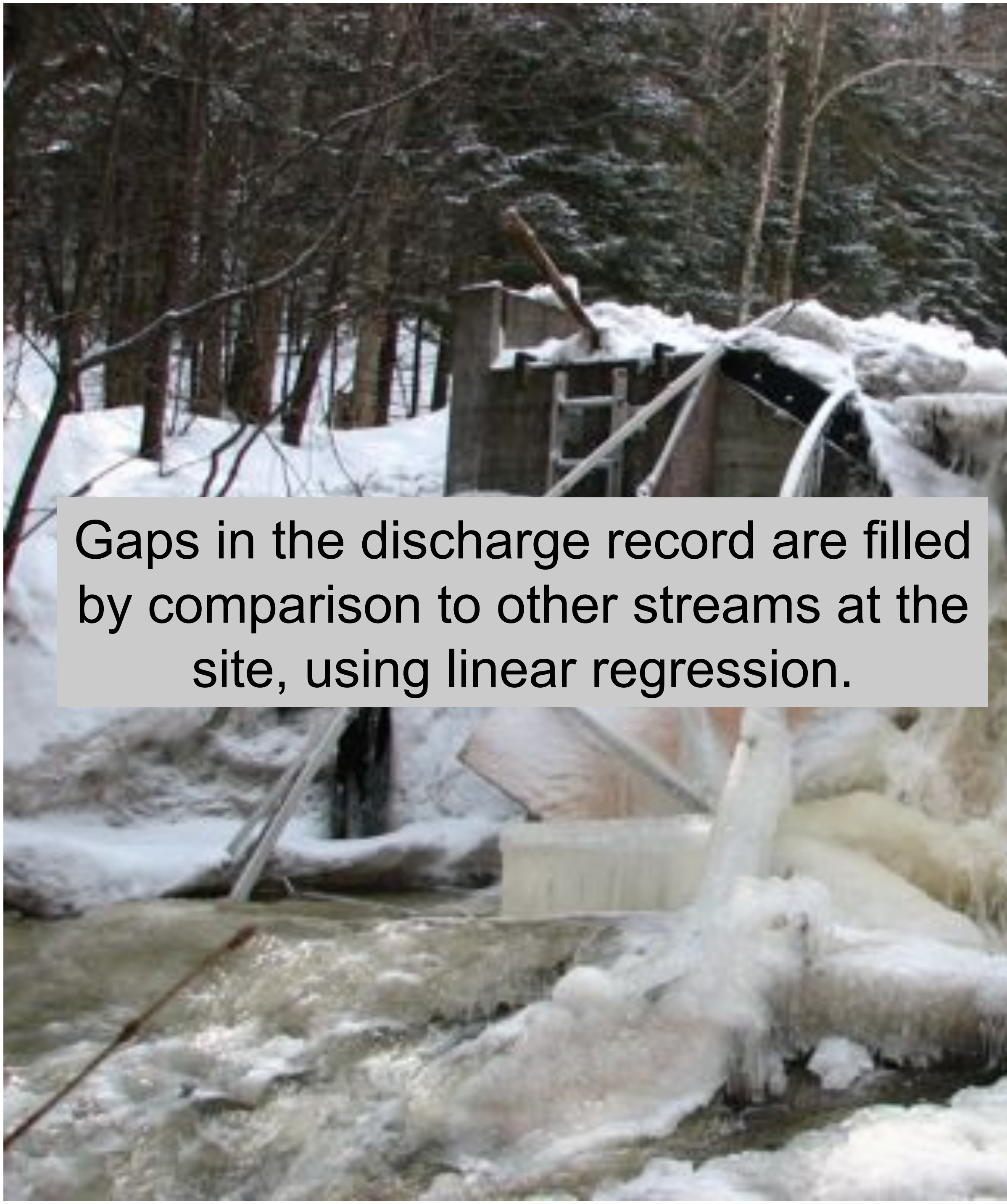
Sources of Uncertainty in Stream Export of Nutrients

Measurement Uncertainty

• Uncertainty in analysis of water chemistry

• Uncertainty in height-discharge relationship at the weir

• Uncertainty in filling gaps in the discharge record



Gaps in the discharge record are filled by comparison to other streams at the site, using linear regression.

Sources of Uncertainty in Stream Export of Nutrients

Measurement Uncertainty

- Uncertainty in analysis of water chemistry
- Uncertainty in height-discharge relationship at the weir
- Uncertainty in filling gaps in the discharge record
- Uncertainty in watershed area

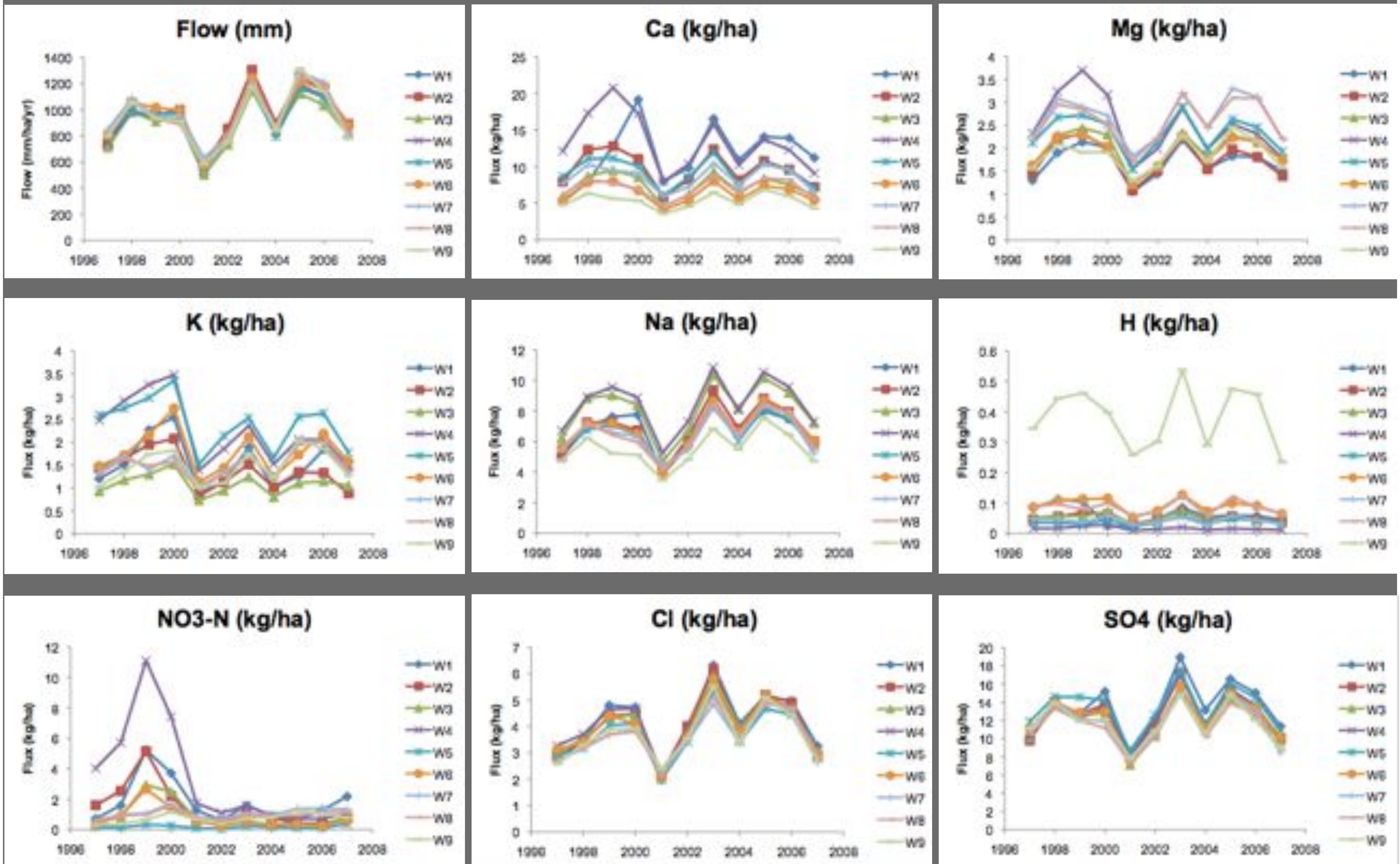
Sources of Uncertainty in Stream Export of Nutrients

Measurement Uncertainty

Natural Variability

- Spatial variation (multiple streams sampled at each site)
- Temporal variation (multiple years of sampling)

Natural variability: Temporal and Spatial



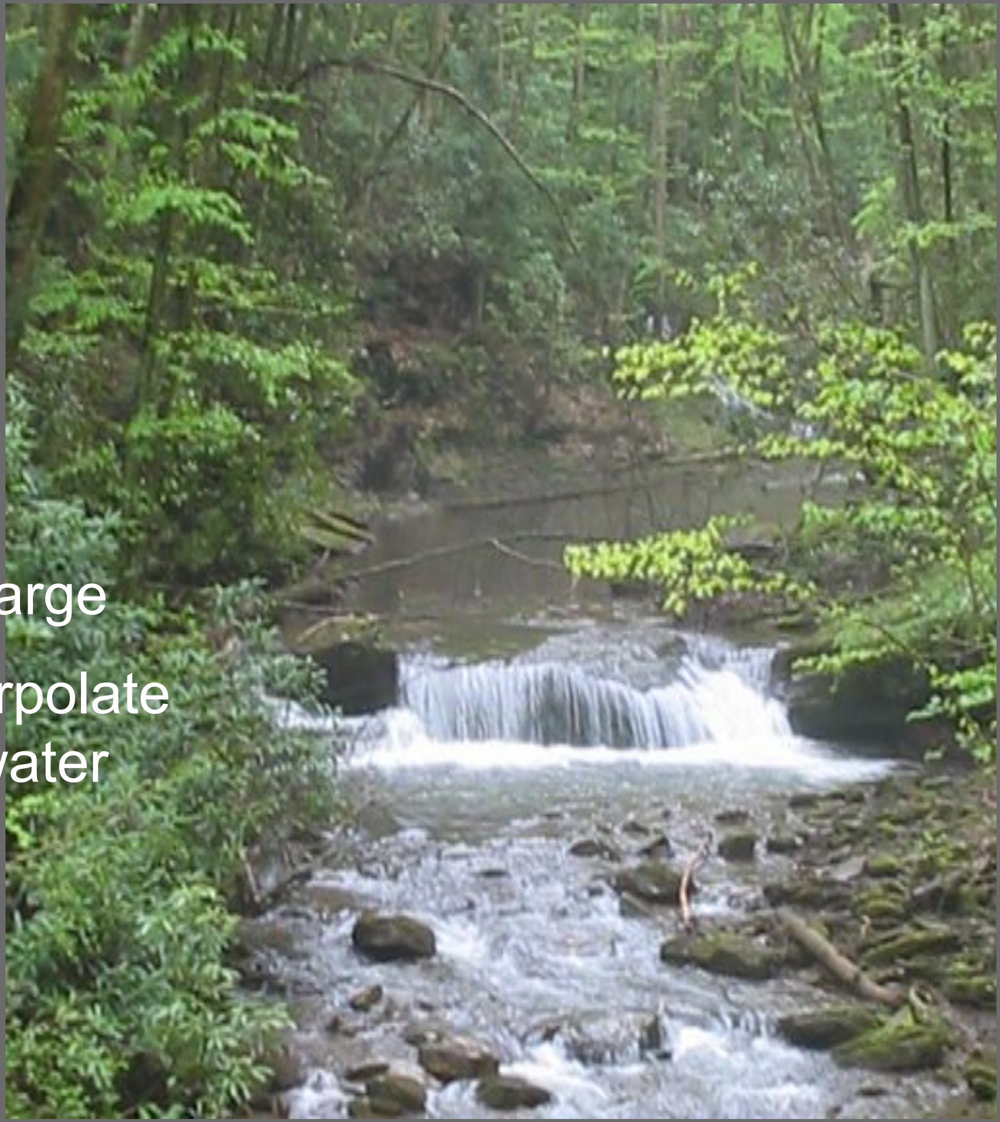
Sources of Uncertainty in Stream Export of Nutrients

Measurement Uncertainty

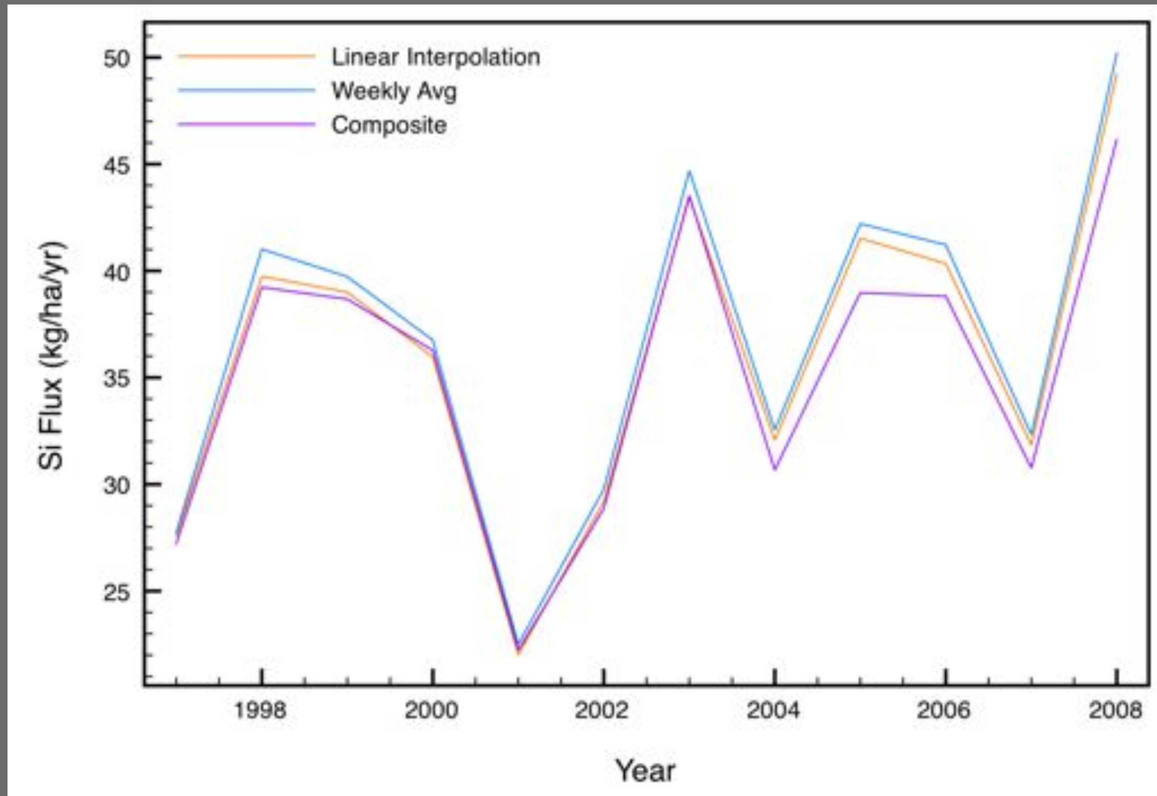
Natural Variability

Model Uncertainty

- Flux = concentration * discharge
- Model selection: how to interpolate between sampling dates for water chemistry



Uncertainty in streamwater chemistry estimates: Methods comparison



Comparing methods for estimating flux of Si at Hubbard Brook:

- **Linear interpolation**: concentrations for the week are linearly estimated between the two sampling dates
- **Weekly average**: One value applied to the entire week (many ways to do this)
- **Composite method:** model including a concentration-discharge relationship which is driven through the measured points

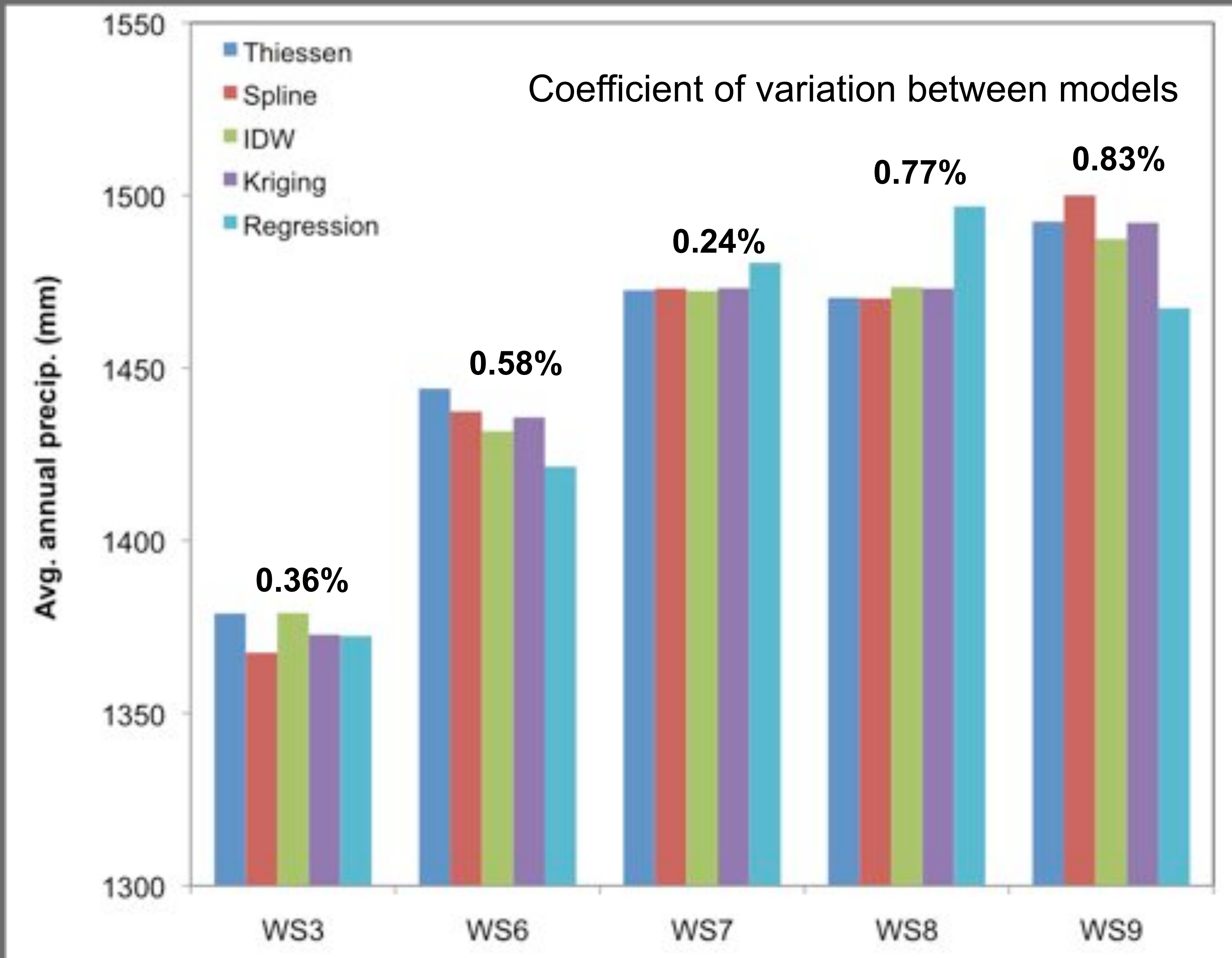
- Annual Si fluxes varied by ~5%

Sources of Uncertainty in Precipitation

Precipitation:

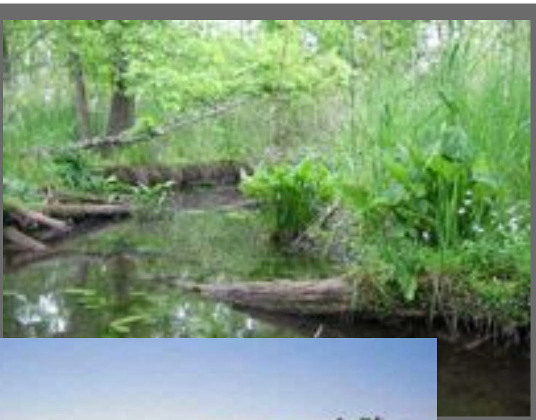
- Most uncertainty is in spatial variability.
- Varies with landscape factors; often shows orographic effects
- Low temporal uncertainty: generally measured cumulatively, most uncertainty in this area arises from analytical error
- Many spatial models can be used to predict precipitation amount in watersheds

Alternative spatial models for precipitation in the Hubbard Brook Valley

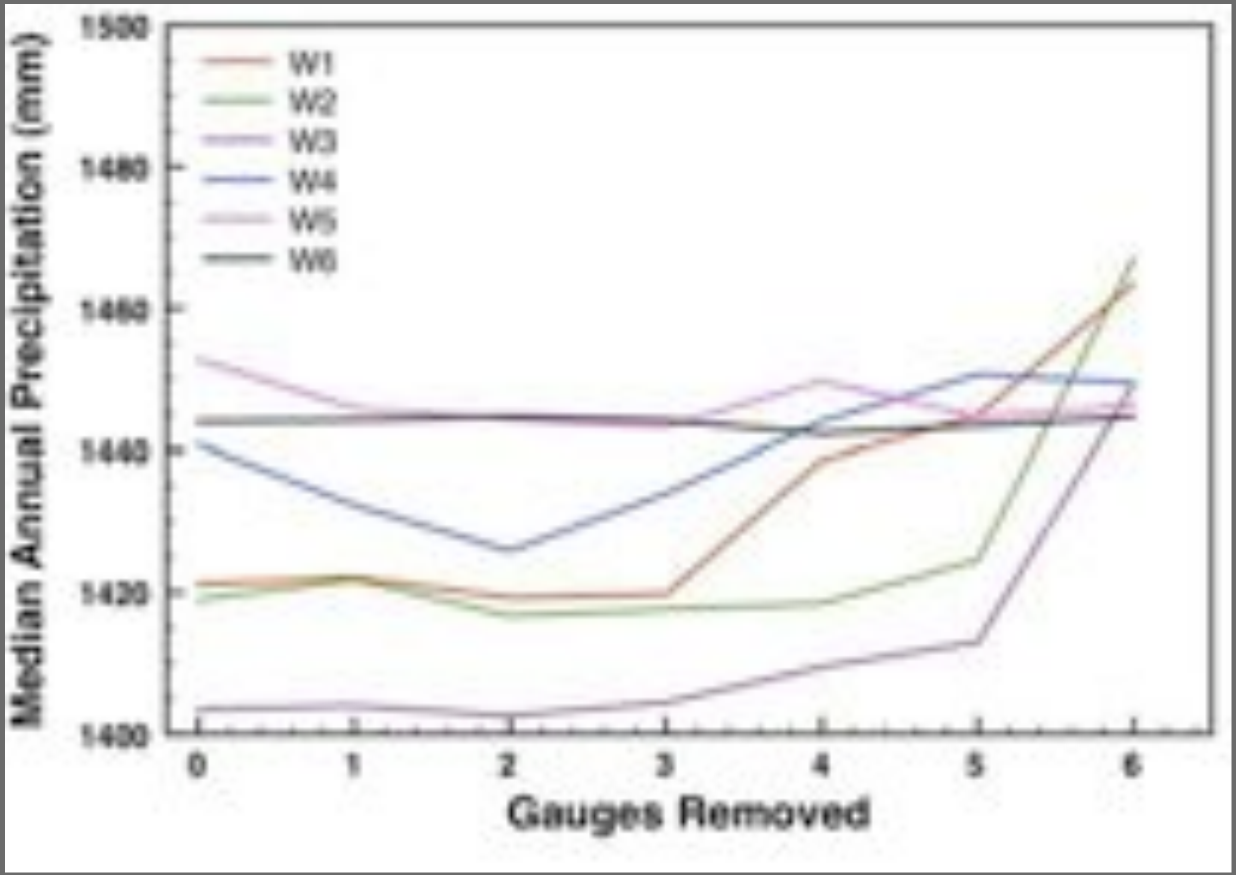


Uncertainty and Monitoring Efficiency

- Long-term monitoring (LTM) data sets are very important for detecting change over time
- Uncertainty analysis can be a tool for assessing the efficiency and coverage of LTM programs
- Want to determine if current monitoring efforts are:
  - **Excessive:** requiring more effort than is justified by the results produced
  - **Inadequate:** producing results that are not sufficiently accurate or precise to meet science or policy needs



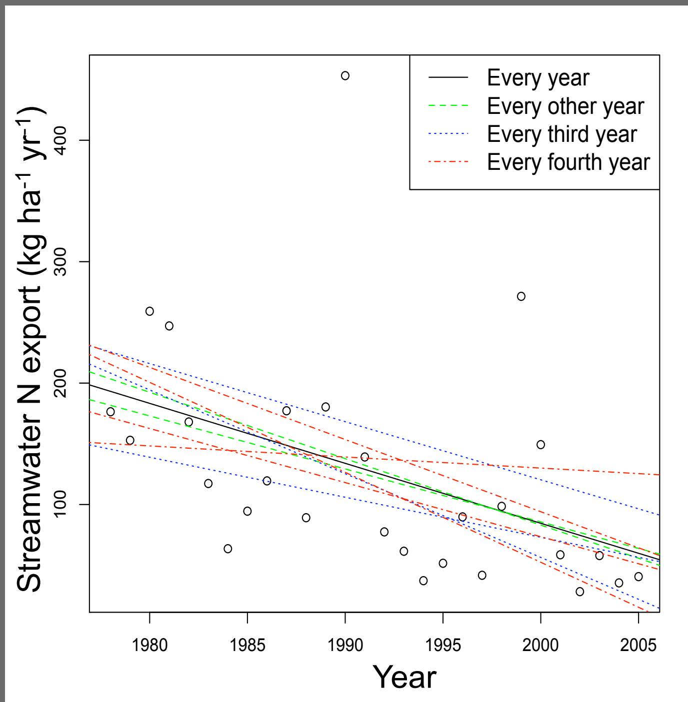

Using uncertainty to assess monitoring efficiency: Precipitation

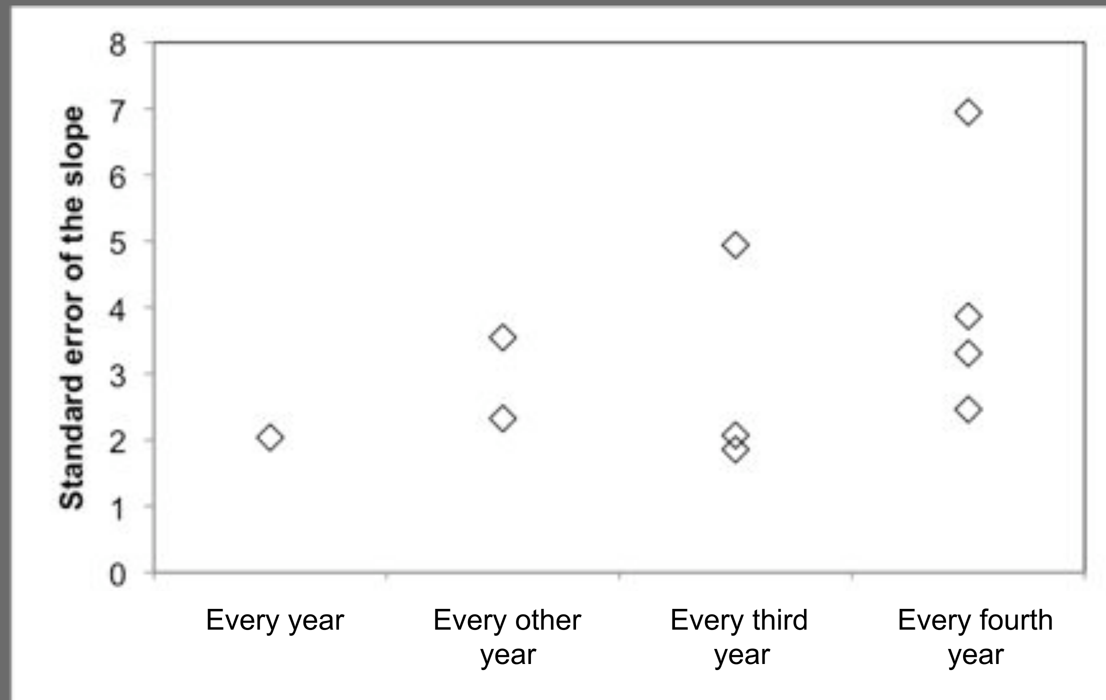


- Test how sampling intensity contributes to confidence in the annual precipitation estimates by sequentially omitting individual precipitation gauges.

- Median annual precipitation estimates varied little until five or more of the eleven precipitation gauges were ignored.

Using uncertainty to assess monitoring efficiency: Streamflow





- Standard error of the slope increases as the number of sampled years decreases
- Trade off between less sampling (lower cost) and higher error around regression

Future QUEST projects:

- Hydrologic budget of QUEST sites including uncertainty in inputs and outputs
- QUEST workshops on soils, vegetation, and ecosystem budgets
- Ecosystem nutrient budgets including uncertainty in all pools and fluxes

Be a part of QUEST!

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Quantifying Uncertainty in Ecosystem Studies
Welcome to QUEST
Ecosystem nutrient budgets often report values for pools and fluxes without any indication of uncertainty, which makes it difficult to evaluate the significance of findings or make comparisons across systems. QUEST is a research network that has evolved around the idea that uncertainty analysis should be an accepted and expected practice in the construction of ecosystem budgets.

QUEST would like to thank:

- NSF, LTER, JSPS
- All QUEST sites for contributing data and many patient and accommodating data managers
- Many people who have contributed to collection of long-term data
- Everyone who has contributed papers, example code, presentations, and links to the QUEST website

QUESTIONS?

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