Vermont EPSCoR

Opportunities in Watershed Research Made Possible by Emerging Technologies and Approaches

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22nd National NSF EPSCoR Conference
Coeur d'Alene, Idaho
25 October 2011

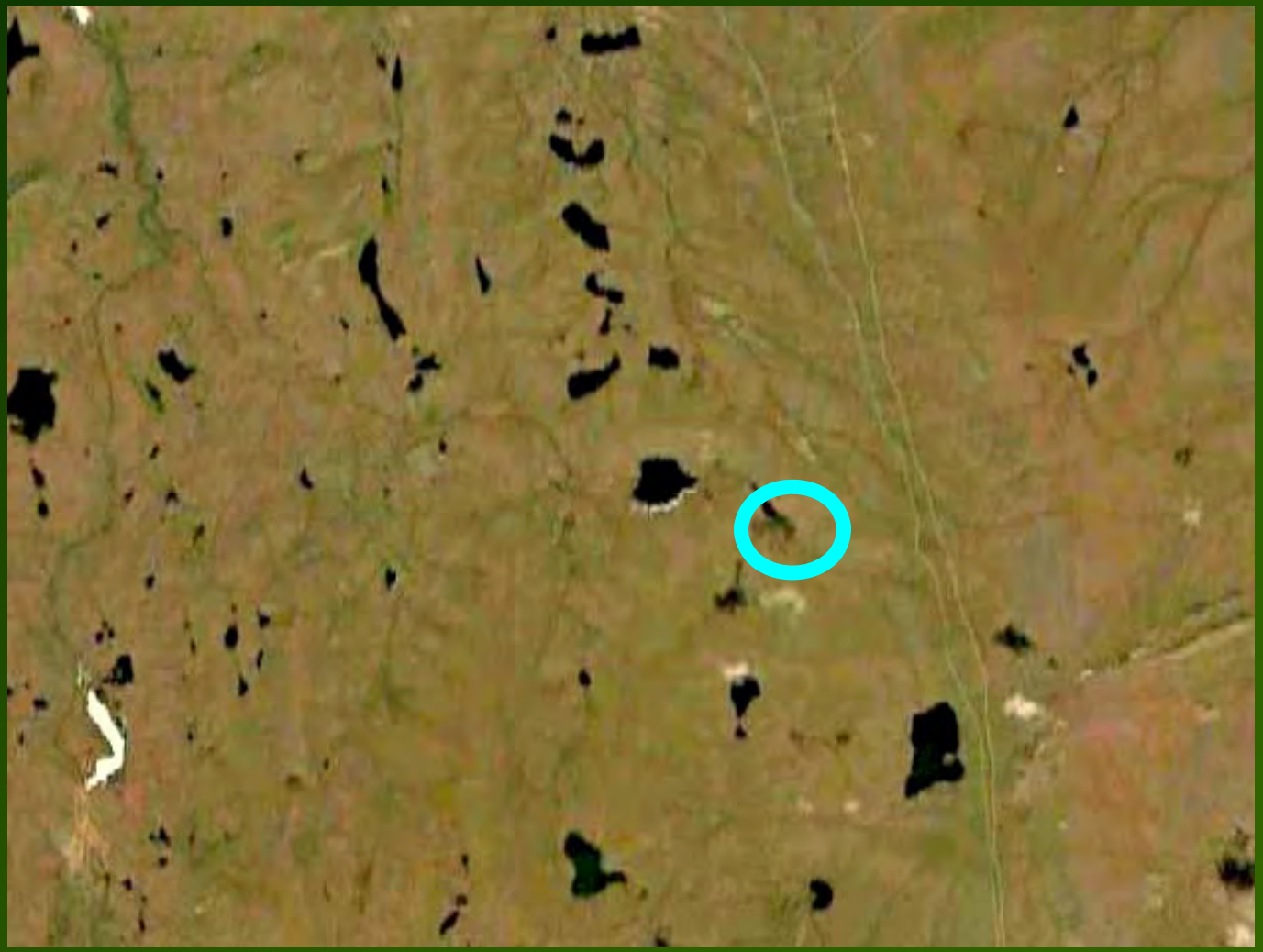
What is the challenge?

Matching the scale of observation to the scale of interest

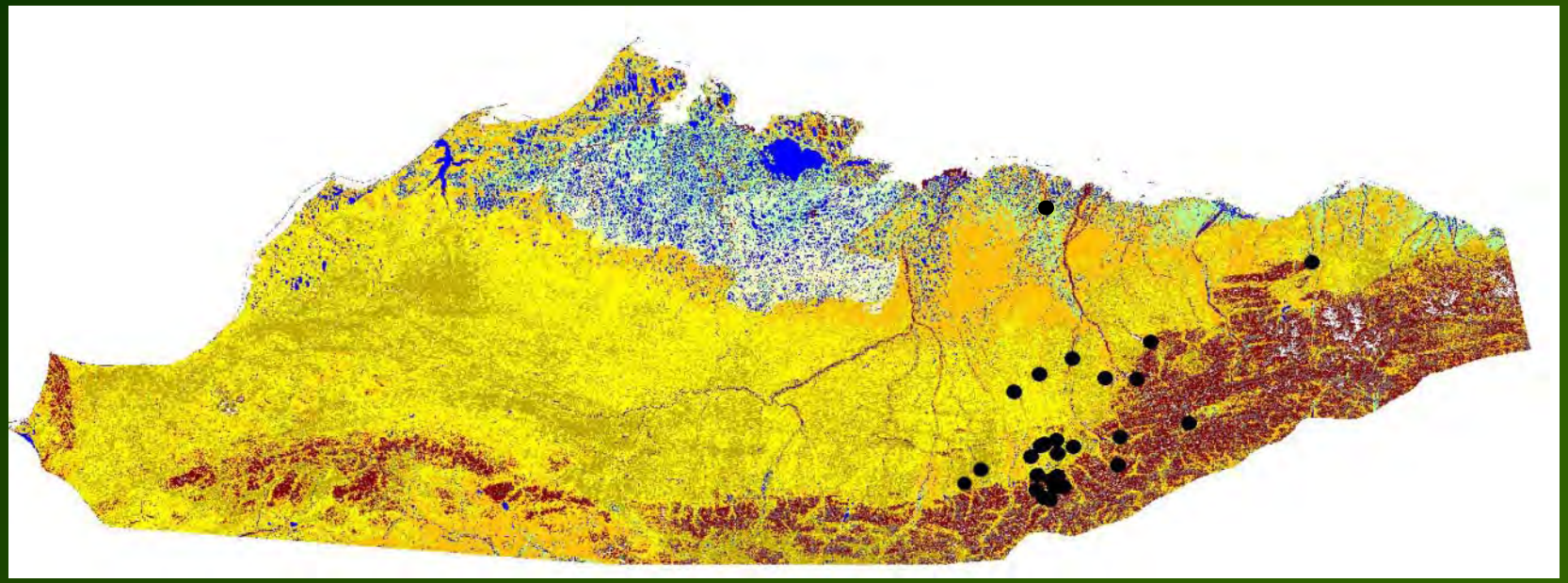
- Manual sampling measures separated points in time
- Instruments typically measure separated points in space
- Increasing interest in continuous observation over large regions

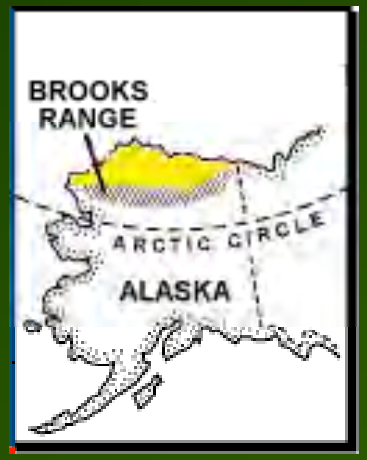
The Measurement Scale

The Landscape Scale



The Regional Scale





- Dry Prostrate-Shrub Tundra and Barrens
- Moist Graminoid, Prostrate-shrub Tundra (MGPT; nonacidic)
- Moist Dwarf-shrub, Tussock-graminoid Tundra (MDTT; typical tussock tundra):
- Moist Low-Shrub Tundra and other Shrublands (MLTS):
- Wet Graminoid Tundra (WGT:
- Water:
- Clouds and ice:
- Shadows:
- Moist Tussock-graminoid, Dwarf-shrub Tundra (MTDT; cold acidic):
- No Data

Focus of this Talk

- Addressing the Temporal Dimension
  - Opportunities in sensor technologies
- Addressing the Spatial Dimension
  - Opportunities in observing technologies
- Addressing the Communication Challenge
  - Opportunities for data transmission
- Addressing the Synthesis Challenge
  - Opportunities in modeling approaches

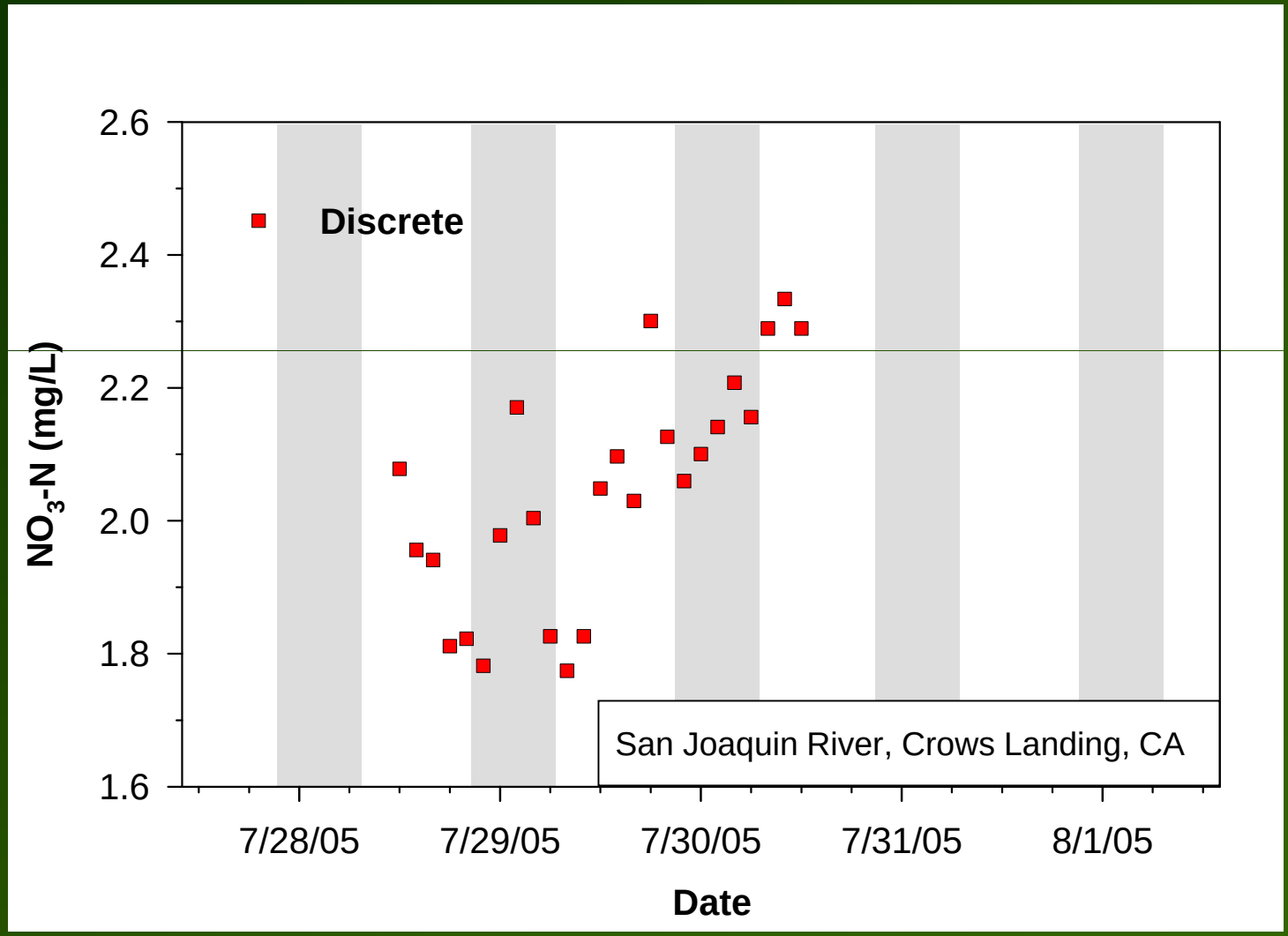
The Temporal Challenge

Optical Sensors

Satlantic, ISUS Nitrate Sensor

WET Labs, WET Star Flow-Through FDOM Fluorometer

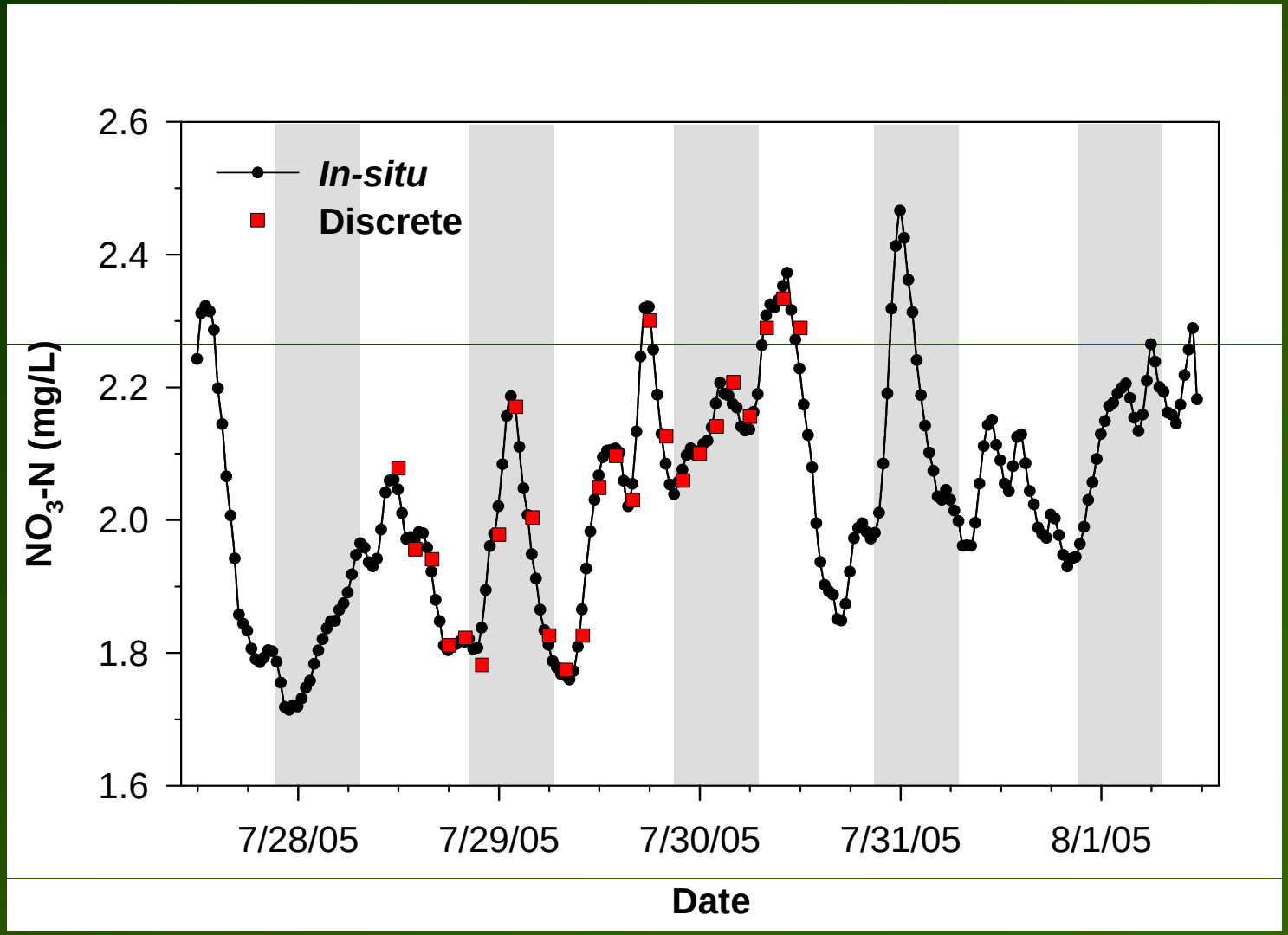
Insights into Nutrient Patterns



USGS science for a changing world

Pellerin et al., 2009

Insights into Nutrient Patterns



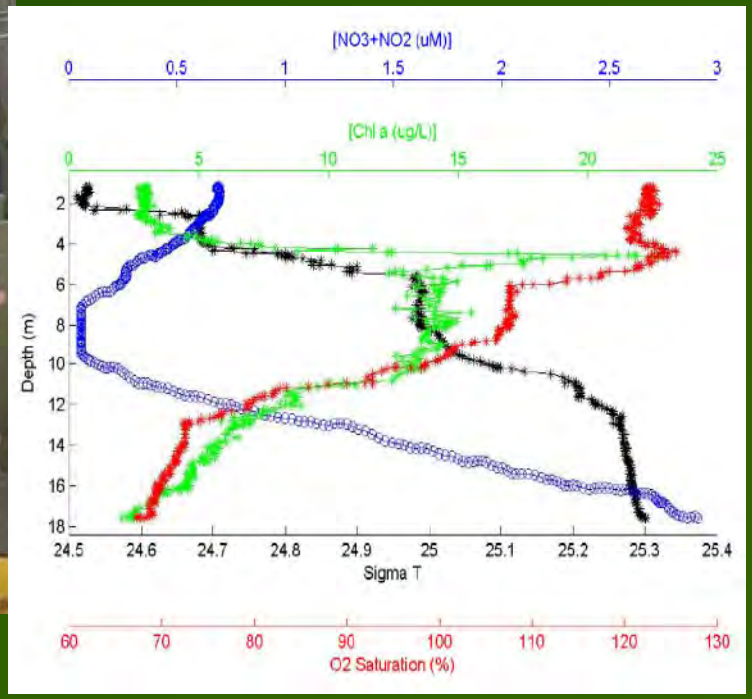
USGS science for a changing world

Pellerin et al., 2009

Challenge of Simultaneous Nutrient Analysis

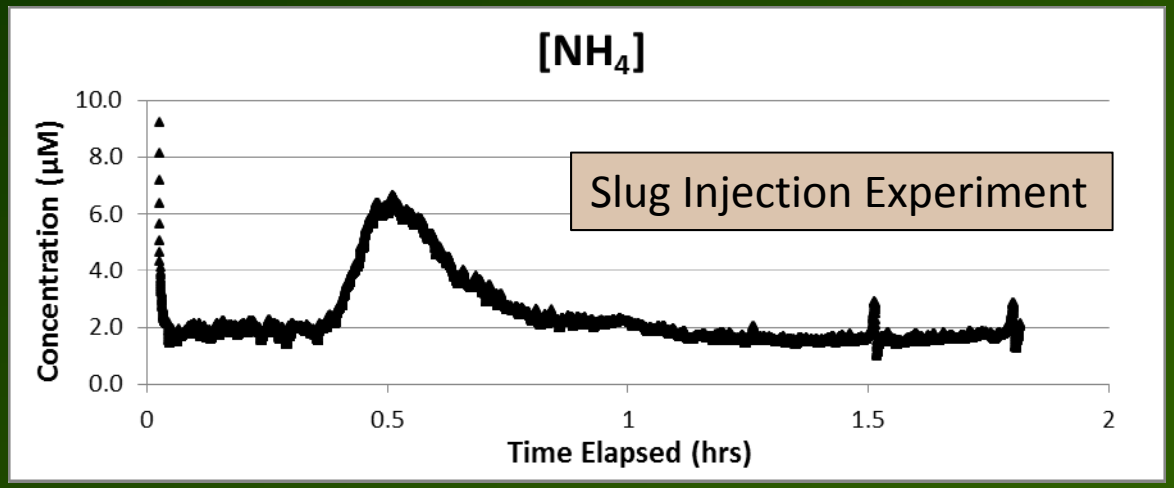
Automatic Profiling Nutrient Analyzer (APNA)

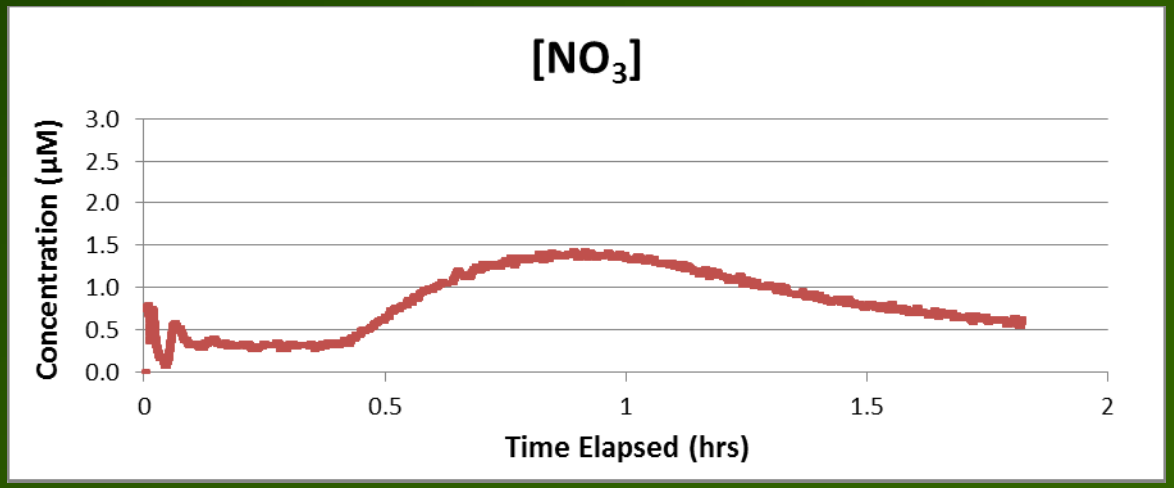
SubChem APNA



Egli et al. (2006)

Insights into Nitrogen Dynamics in Arctic Streams



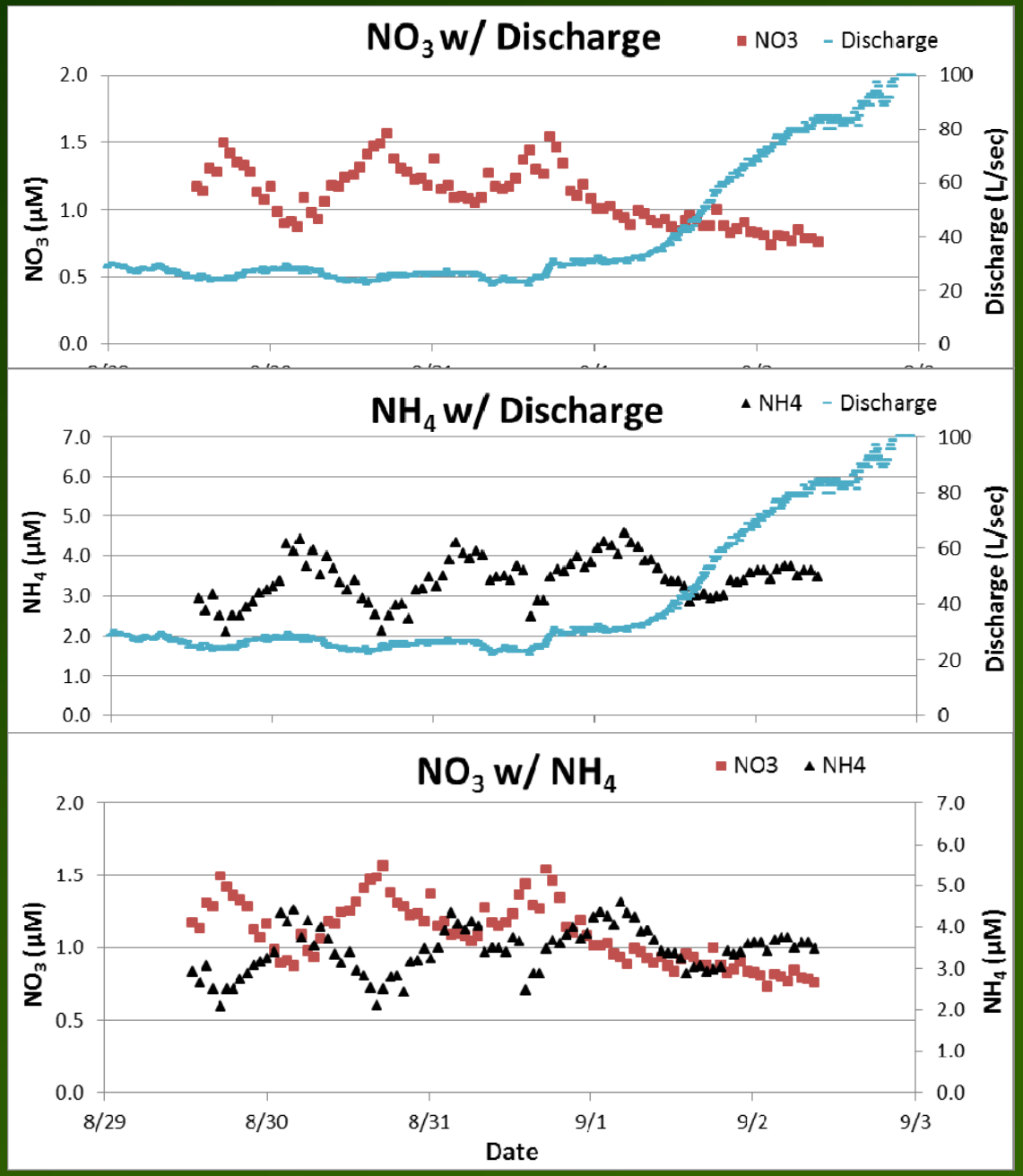


Snyder and Bowden, unpublished data (2011)

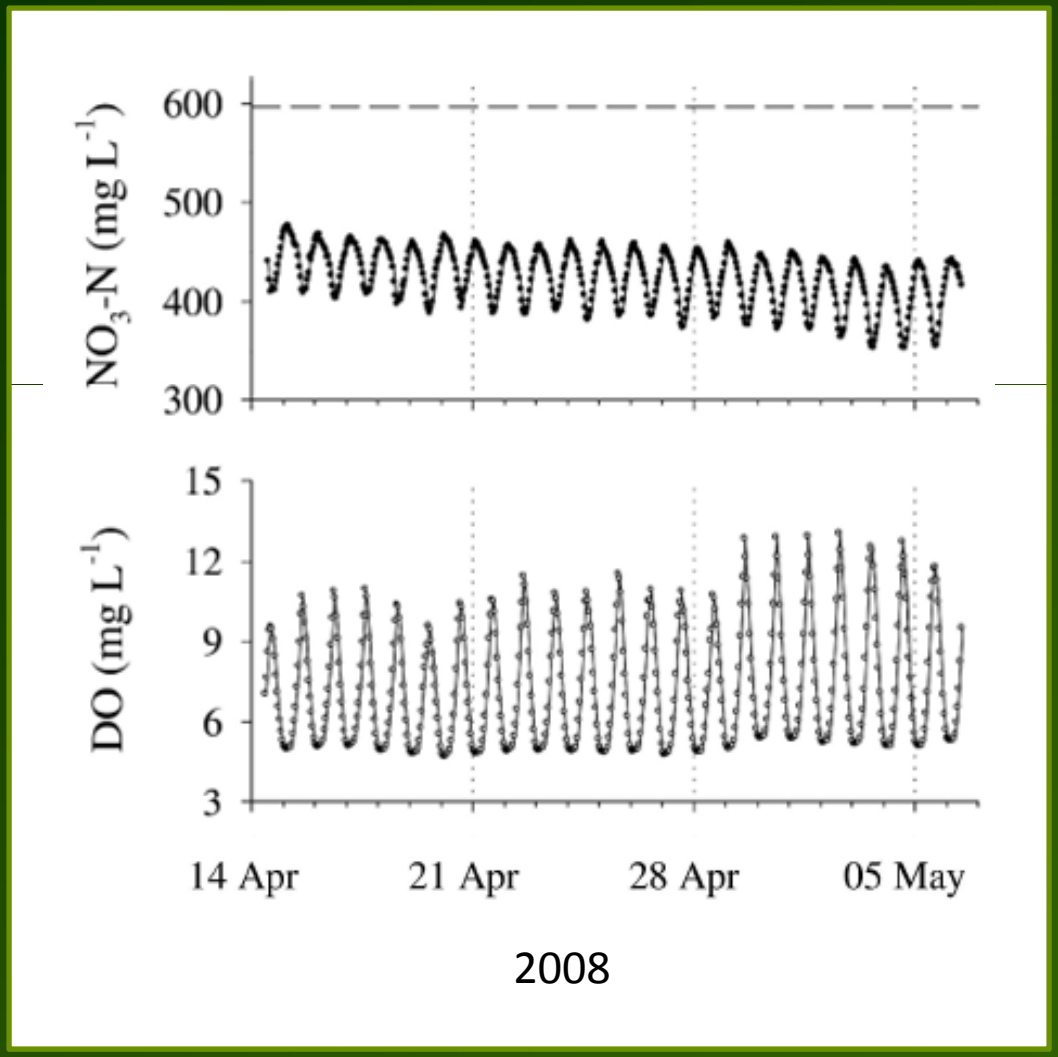
Insights into Nitrogen Dynamics in Arctic Streams

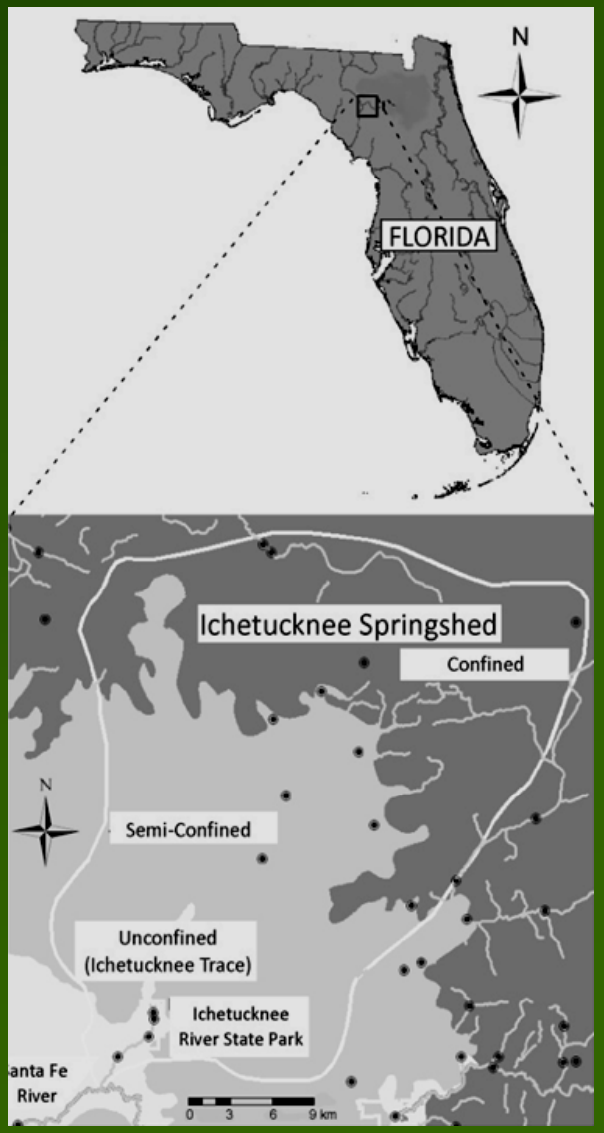
Ambient Experiment

Snyder and Bowden, unpublished data (2011)



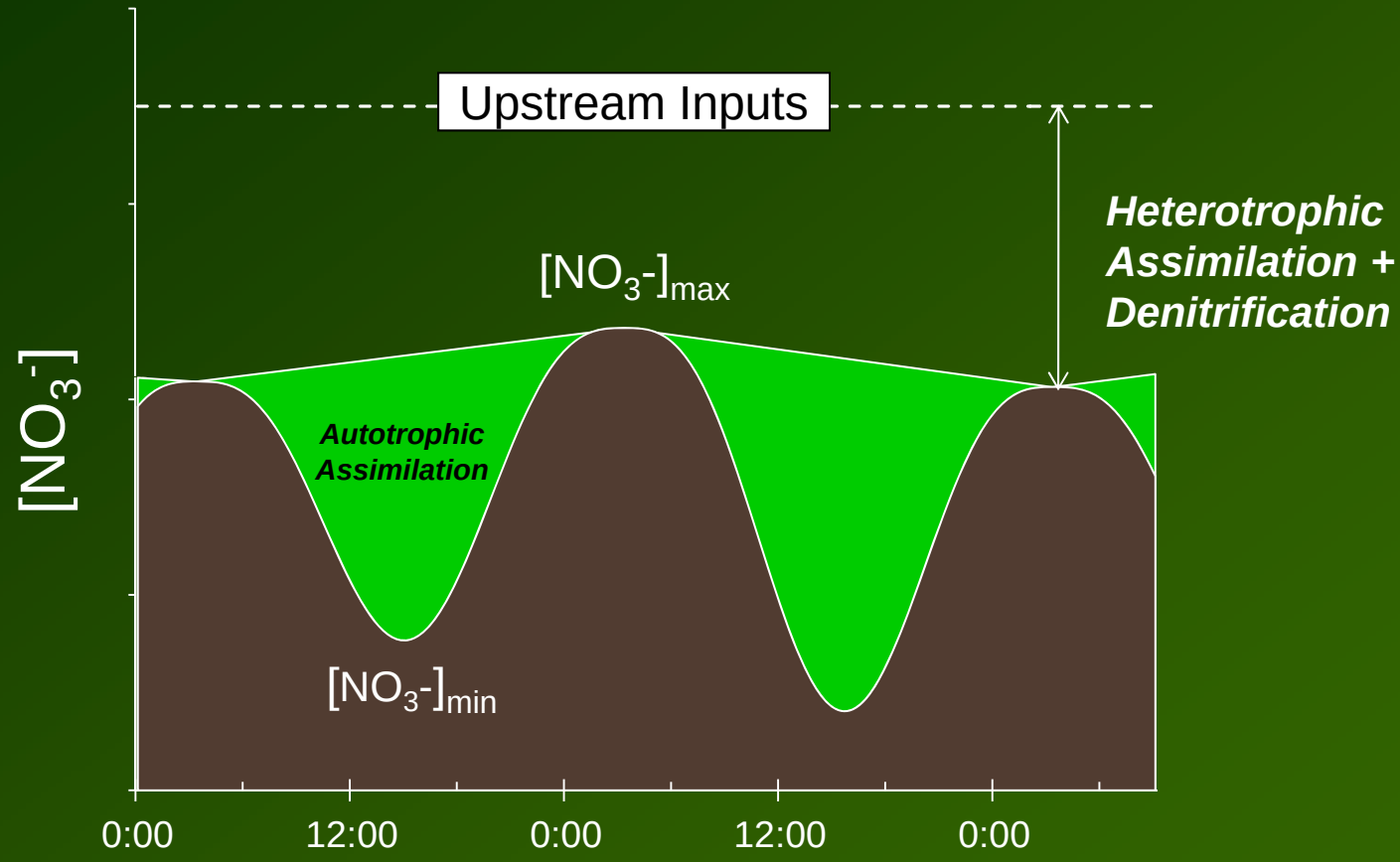
Diel Patterns in Nitrate and Oxygen





Heffernan and Cohen (2010)

Connecting Patterns to Processes

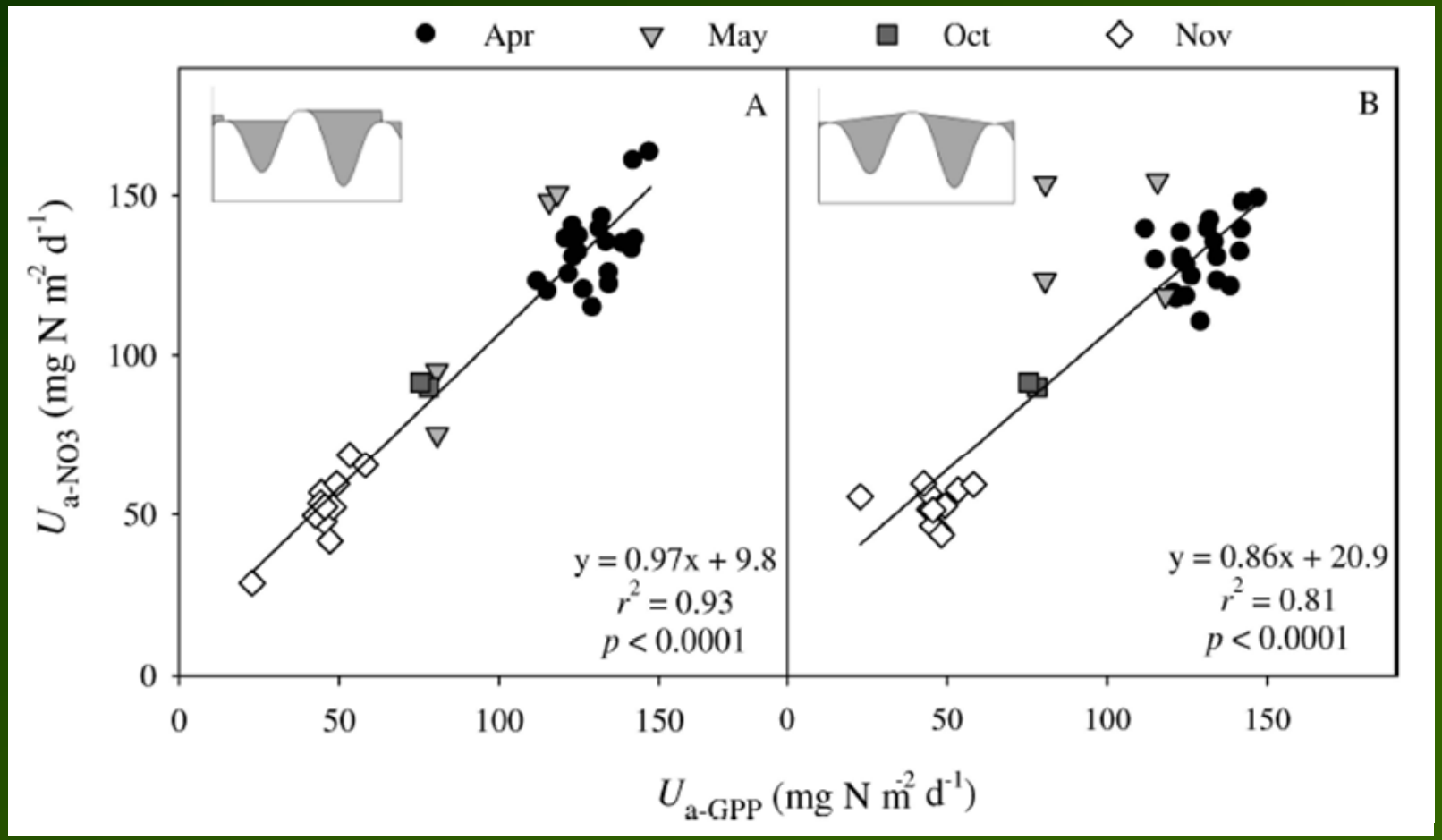


Assumptions: No autotrophic assimilation at night (at $[NO_3^-]_{max}$)
Other processes, other N species are constant

Heffernan and Cohen (2010)

Uptake of Nitrate Based on Diel Patterns versus Primary Production Demand

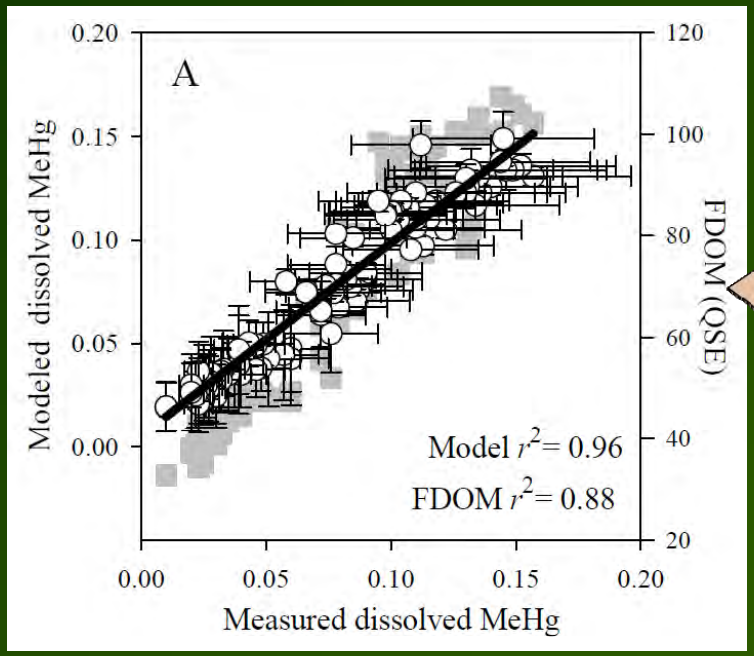
Uptake inferred from diel nitrate patterns

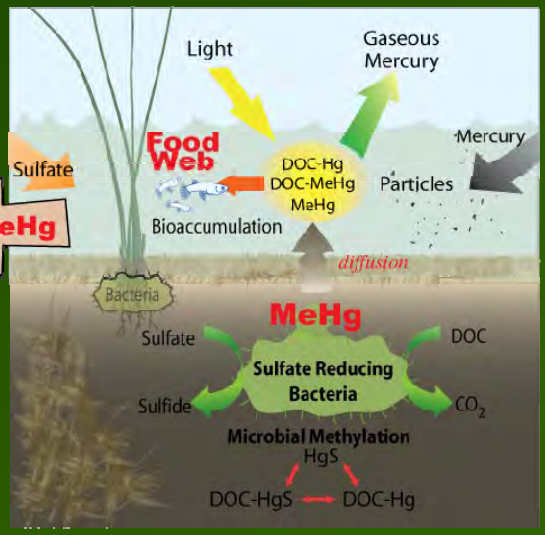


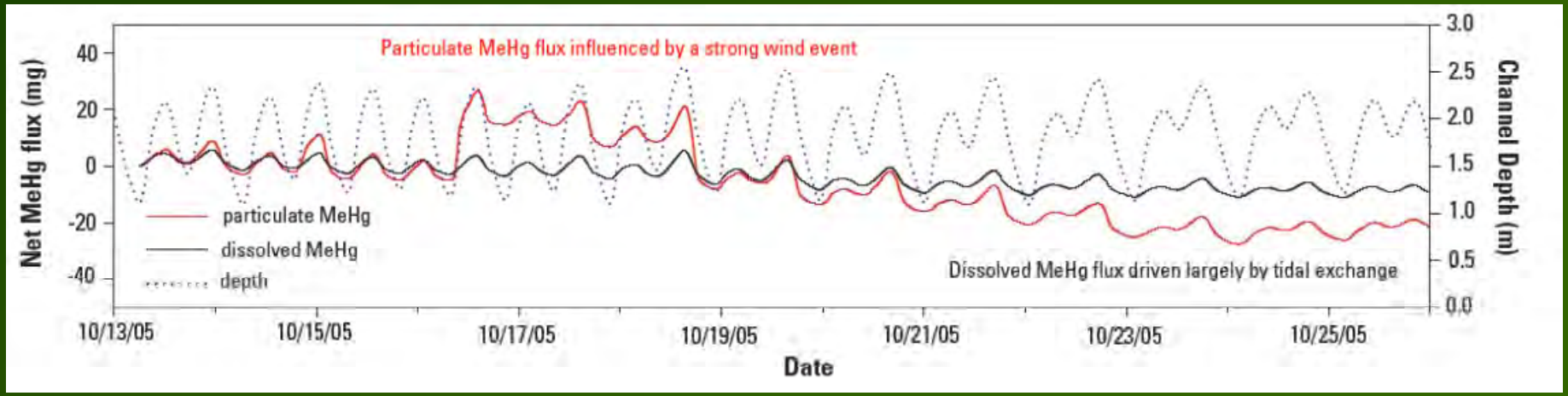
Uptake inferred from primary productivity & expected N demand (stoichiometry)

Heffernan and Cohen (2010)

Methyl Mercury Fluxes from Tidal Wetlands

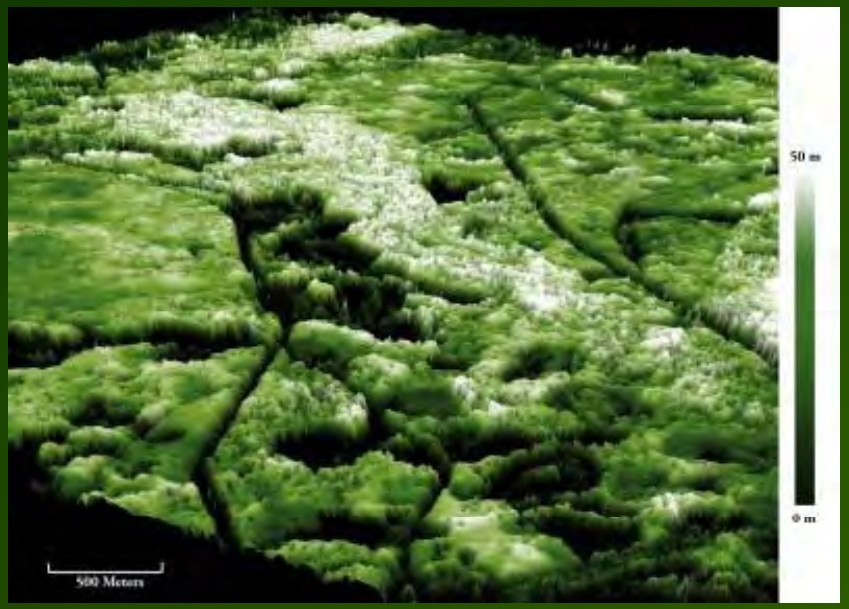




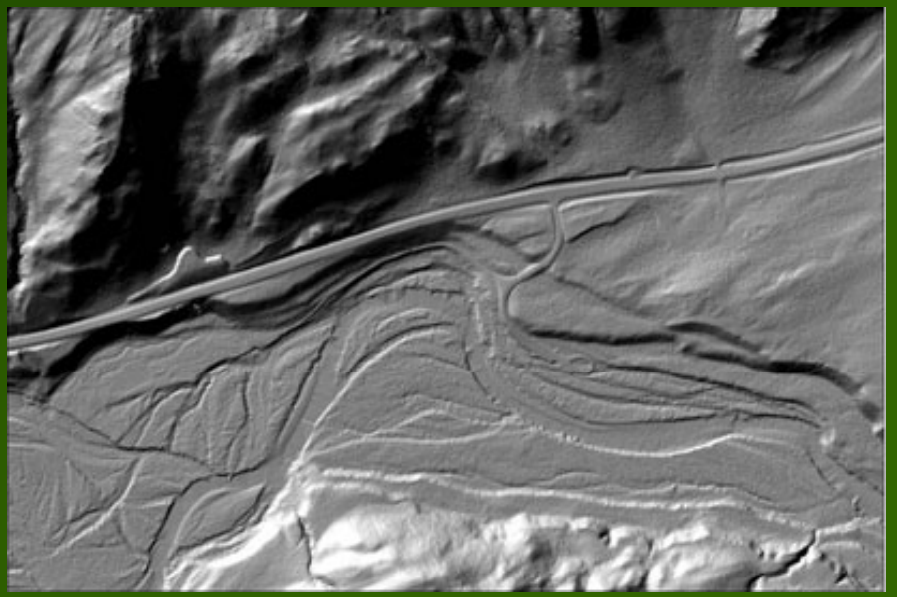


Bergamaschi et al., 2011

Addressing the Spatial Challenge
e.g. Light Detection and Ranging Radar (LiDAR)



LiDAR image of forest canopy height in the Patuxent National Wildlife Refuge. Goetz et al. (2007)



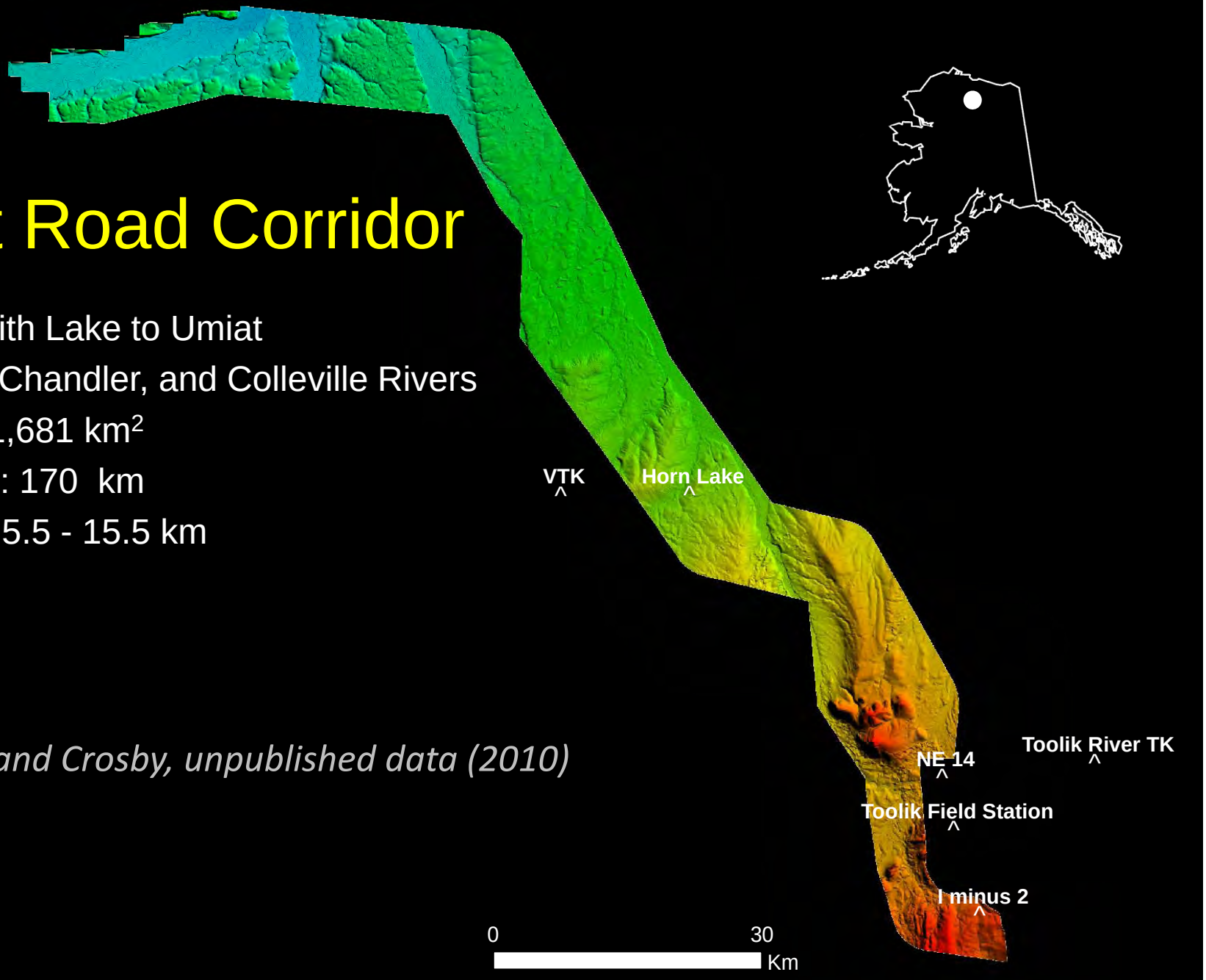
LiDAR Services International, Inc. (2011)

Arctic permafrost thaw failures - *thermokarst*

Photo credits: WB Bowden and AW Balser

Umiat Road Corridor

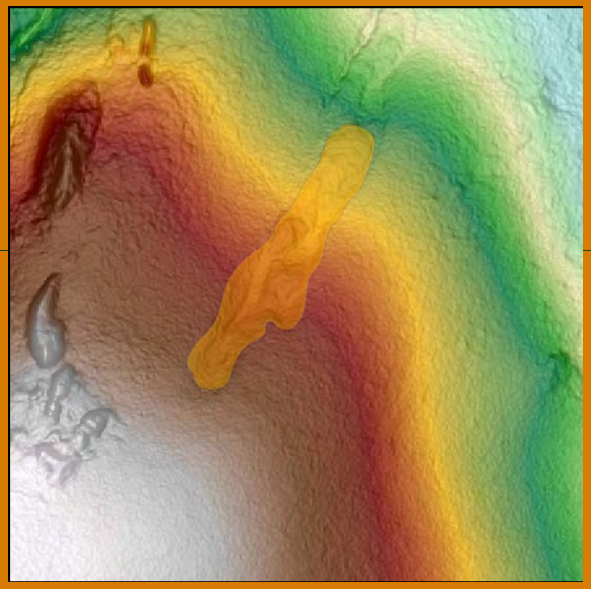
- Galbraith Lake to Umiat
- Itkillik, Chandler, and Colleville Rivers
- Area: 1,681 km^2
- Length: 170 km
- Width: 5.5 - 15.5 km



Krieger and Crosby, unpublished data (2010)

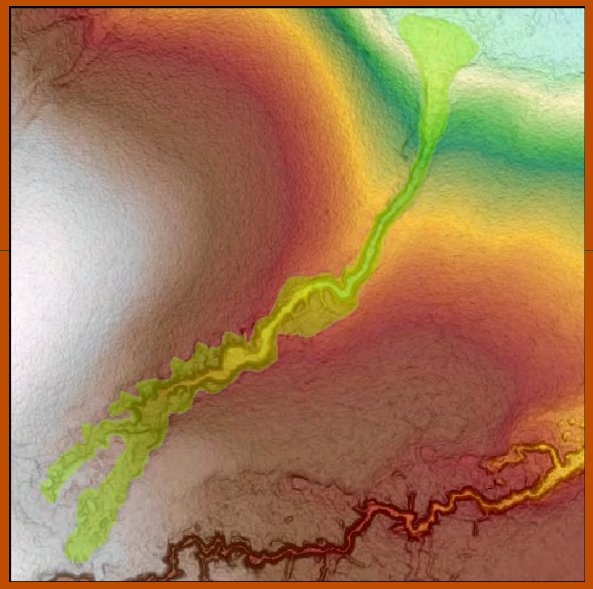
Thermal Erosional Feature Types

Active Layer Detachment



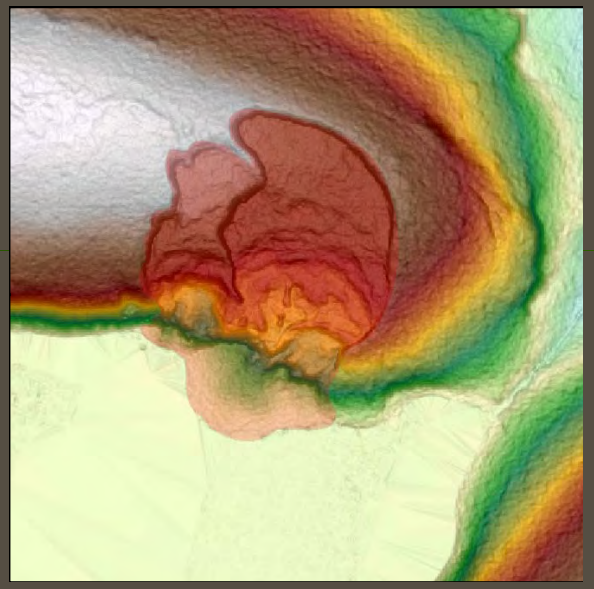
- Narrow
- Linear
- Depositional Lobe

Thermal erosion Gully



- Narrow
- Change Direction
- Spurs

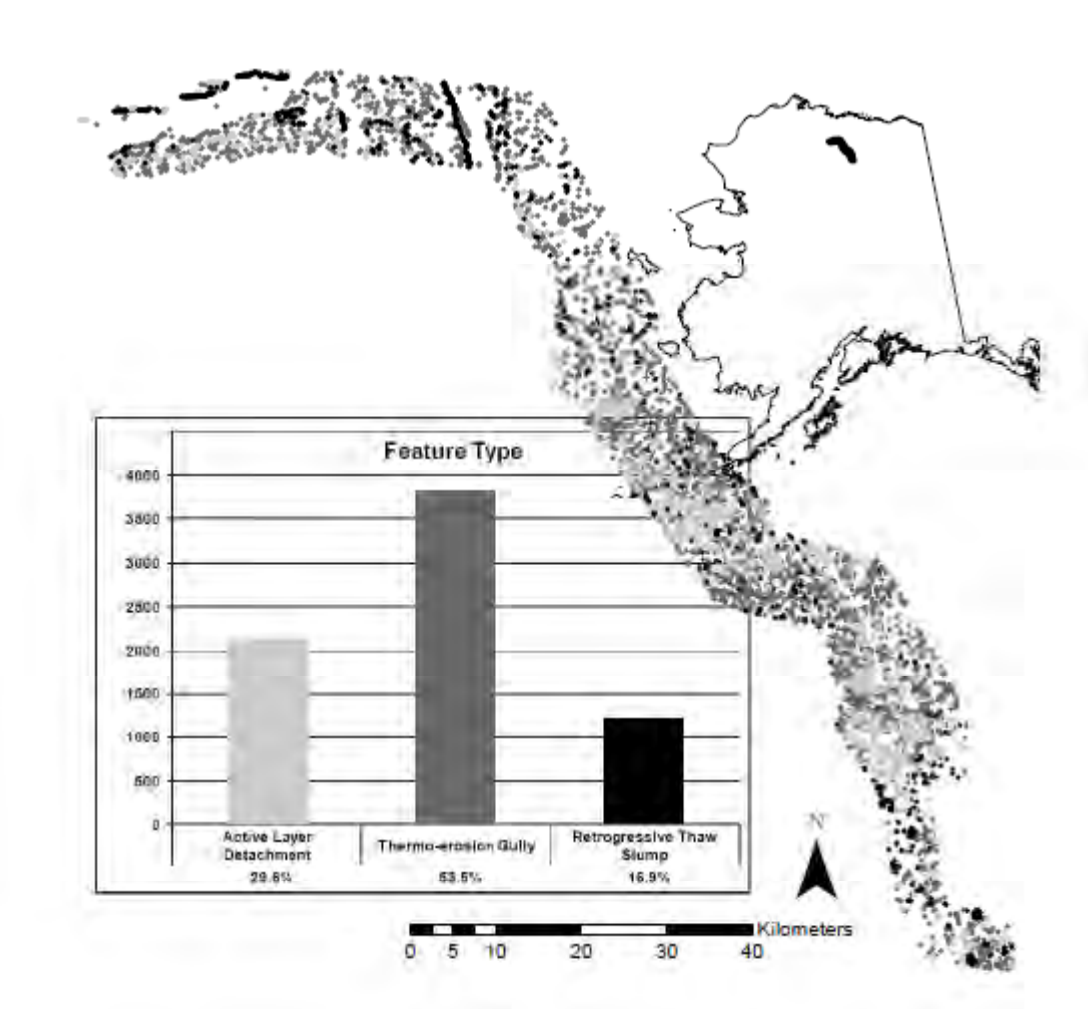
Retrogressive Thaw Slump



- Wide
- Arcuate Headwall
- Hummocky Floor

Krieger and Crosby, unpublished data (2010)

Distribution of Thermokarst Features in the Umiat Road Corridor

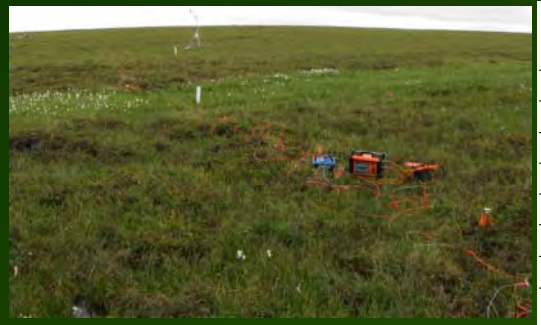


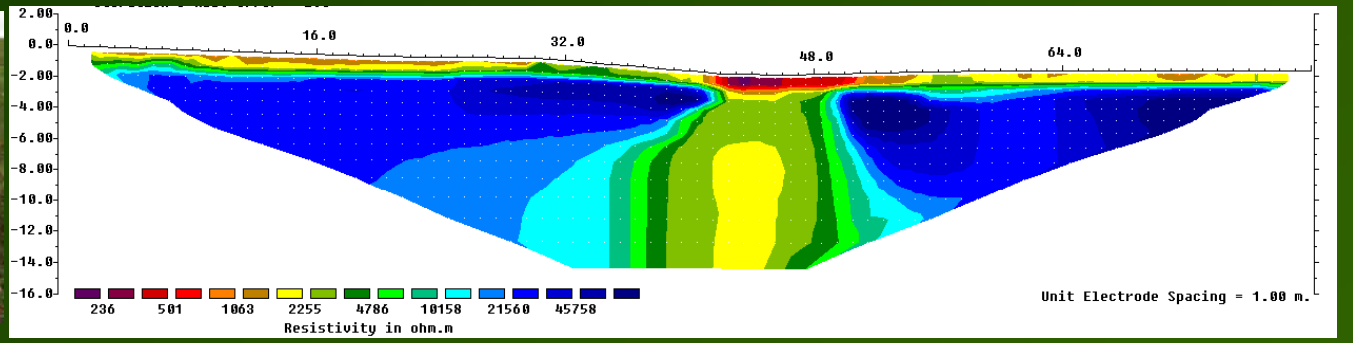
- 7000 features
- 4+ per square km
- ~2% of landscape
- type associated with landscape topography

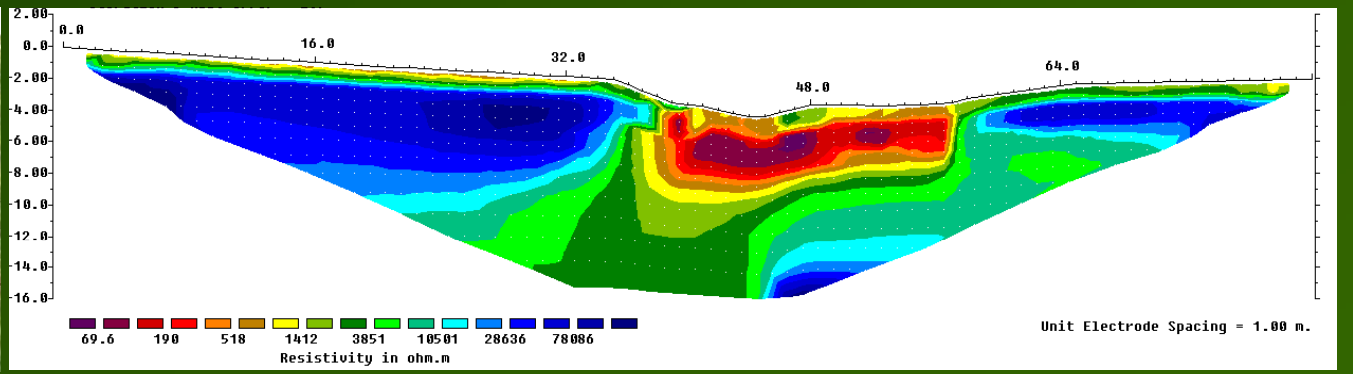
Krieger and Crosby, unpublished data (2010)

Geophysical Tools

Making the Invisible Visible







Electrical Resistivity imaging of a “talik” (thawed layer) beneath an arctic tundra stream in permafrost (Lewkowicz and Gooseff, unpublished data, 2010)

Geophysical Tools

Making the Invisible Visible

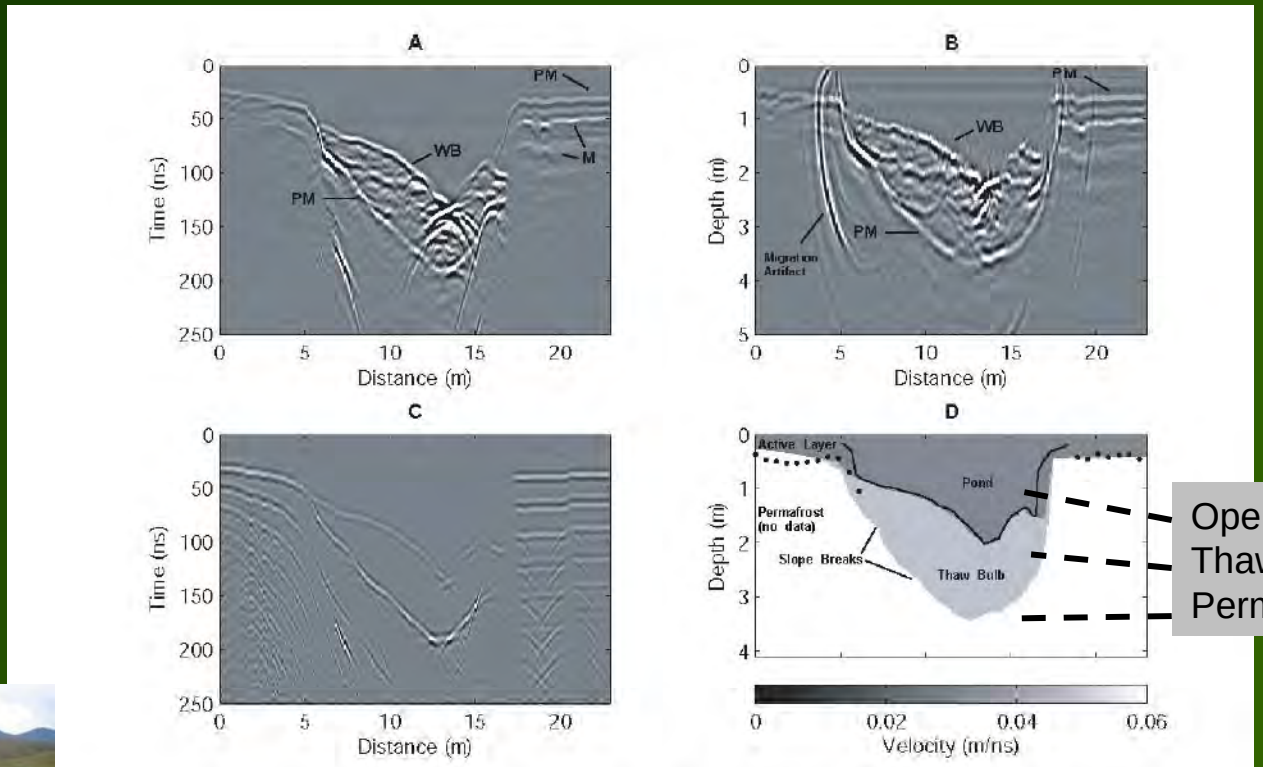
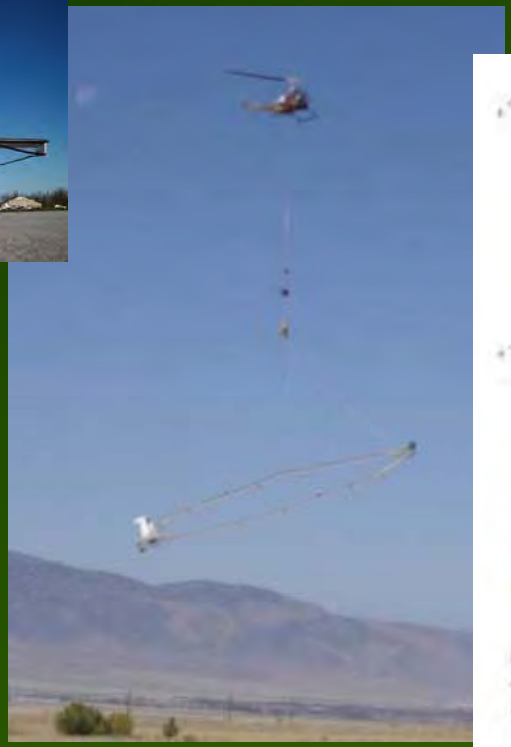


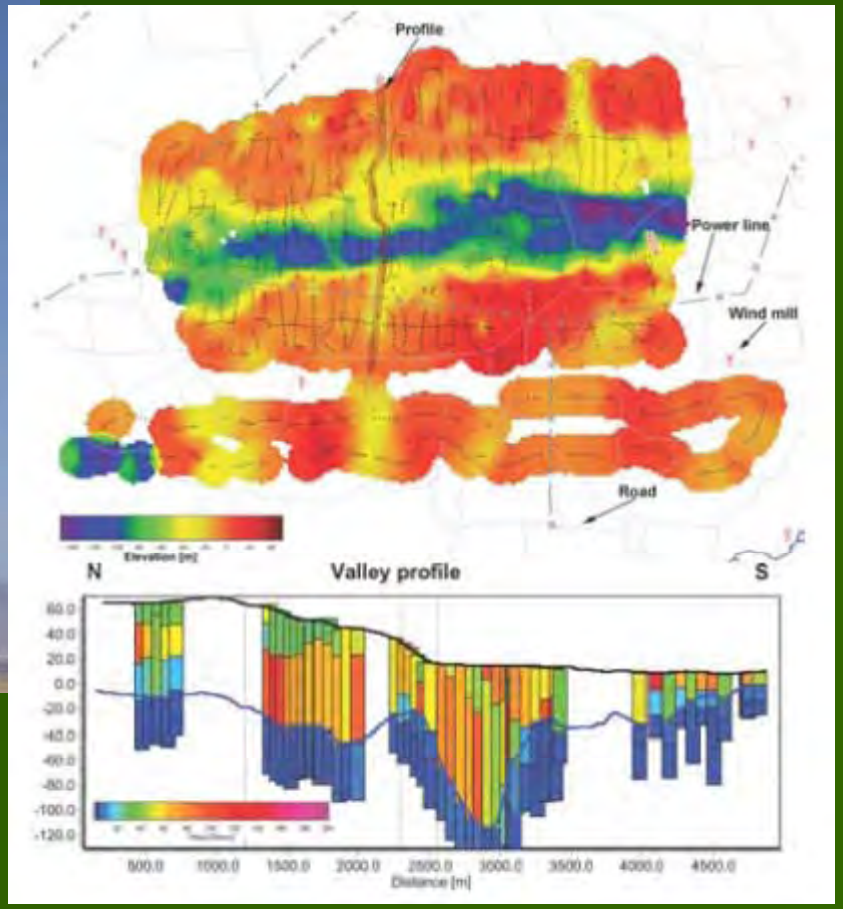
Figure 5. A) Pre-processed data from Site 2, B) depth migrated image, C) synthetic data generated using the migration velocity model, and D) migration velocity model. Note the slope breaks along the permafrost boundary that correlate with substream stratigraphic boundaries. (– –) interpreted water bottom. (•) permafrost depth using a metal probe. (PM) permafrost reflection, (WB) water bottom reflection, (M) permafrost multiple.

Ground-Penetrating Radar image of hyporheic zone in arctic stream flowing over permafrost (Bradford et al. 2005)

Geophysical Tools

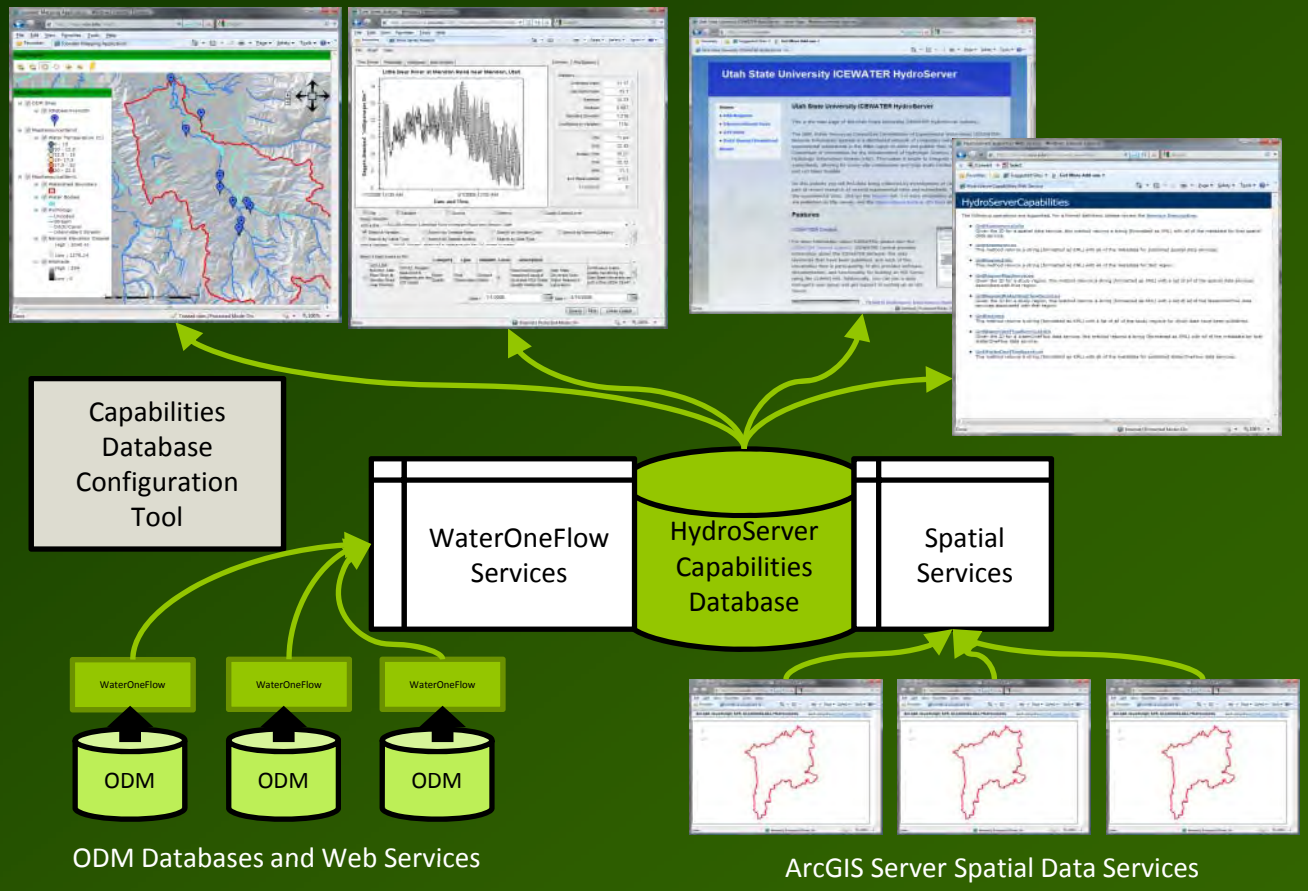
Making the Invisible Visible





Airborne Time-Domain Electro Magnetic Mapping (Robinson et al. 2006)

New Opportunities for Data Acquisition and Sharing



Horsburgh et al. (2010) CUAHSI "ICEWATER" Hydrologic Information System

New Opportunities for Data Acquisition and Sharing

van Houten et al. (2011)

New opportunities for data synthesis

1. **Scoping Models**

   High generality, low resolution, broad participation by all stakeholder groups.

2. **Research Models**

   More detailed and realistic attempts to replicate the dynamics of a particular system of interest, with emphasis on calibration and testing.

3. **Management Models**

   Medium to high resolution. Emphasis on producing future management scenarios. Can be exercising #1 or #2, or require further elaboration to apply management questions.

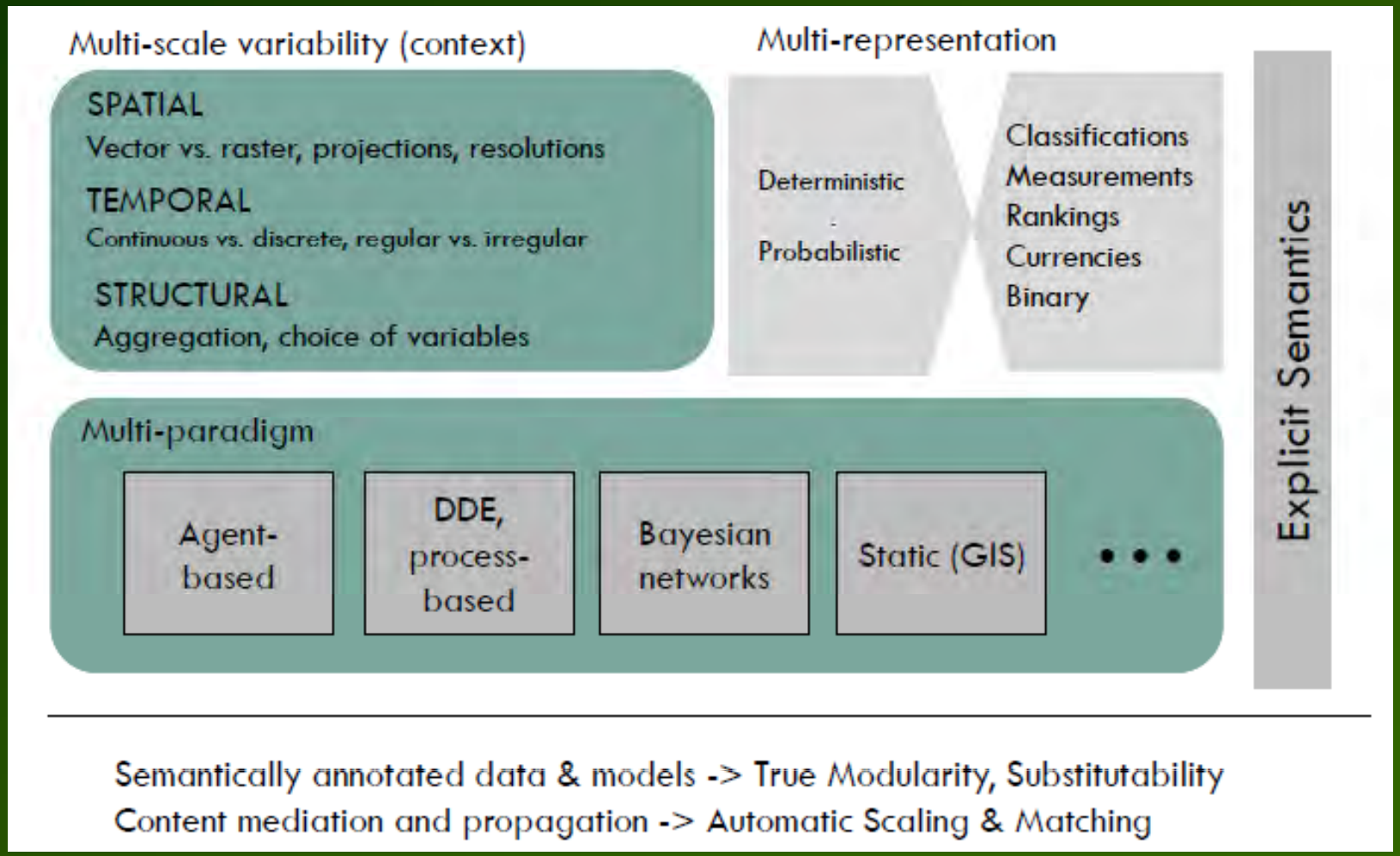
Source: Costanza, R. and M. Ruth, "Using Dynamic Modeling to Scope Environmental Problems and Build Consensus," *Environmental Management* 22: 183-195, 1998.

New opportunities for data synthesis

Moving from "complicated prediction" to "complex exploration"

- Useful rainfall-runoff models
  - SWAT, HSPF, MIKE SHE, SWMM, SLAMM, AGNPS, RHESSys
  - Process-based, parameter-intensive, data-driven
- Useful computational approaches
  - Evolutionary algorithms
  - Artificial Neural Networks
  - Self-organizing maps
- Necessary evolution
  - Swappable modeling systems
  - Seamless I/O database management & visualization

ARtificial Intelligence for Ecosystem Services (ARIES)



Erickson (2011)

Some Thoughts on the Challenges

- Addressing the Temporal Dimension
  - Continuous coverage at limited points
- Addressing the Spatial Dimension
  - Carpet coverage only occasionally
- Addressing the Communication Challenge
  - Transmission speed is probably not a problem
  - “Last mile” connectivity is a challenge
  - Management of derived data products may be
- Addressing the Synthesis Challenge
  - There is no lack of modeling tools
  - Need basic data exploration/visualization tools

Opportunities for Future Research

- Sensors as surrogates (FDOM-Hg, ADCP-TSS-TP)
- Exploration of synchronous large-scale processes (land use change)
- Exploration of signals within “noise” (short-term dynamics with long-term trends)
- Input and validation data for complex models
- Development of new sensor technologies for (phosphorus)
- Partnerships with other large-scale networks (LTER, NEON)
- Applied monitoring as a partner in basic research

Outlook

- Most of the required tools exist now
- There is a receptive “user” community
- Existing and start-up sensor developers are creating new products
- Questions important to scientist and to managers exist
- Cross-disciplinary training is occurring
- Opportunities for education are exciting
- EPSCoR is well positioned to catalyze these efforts

Thank you!

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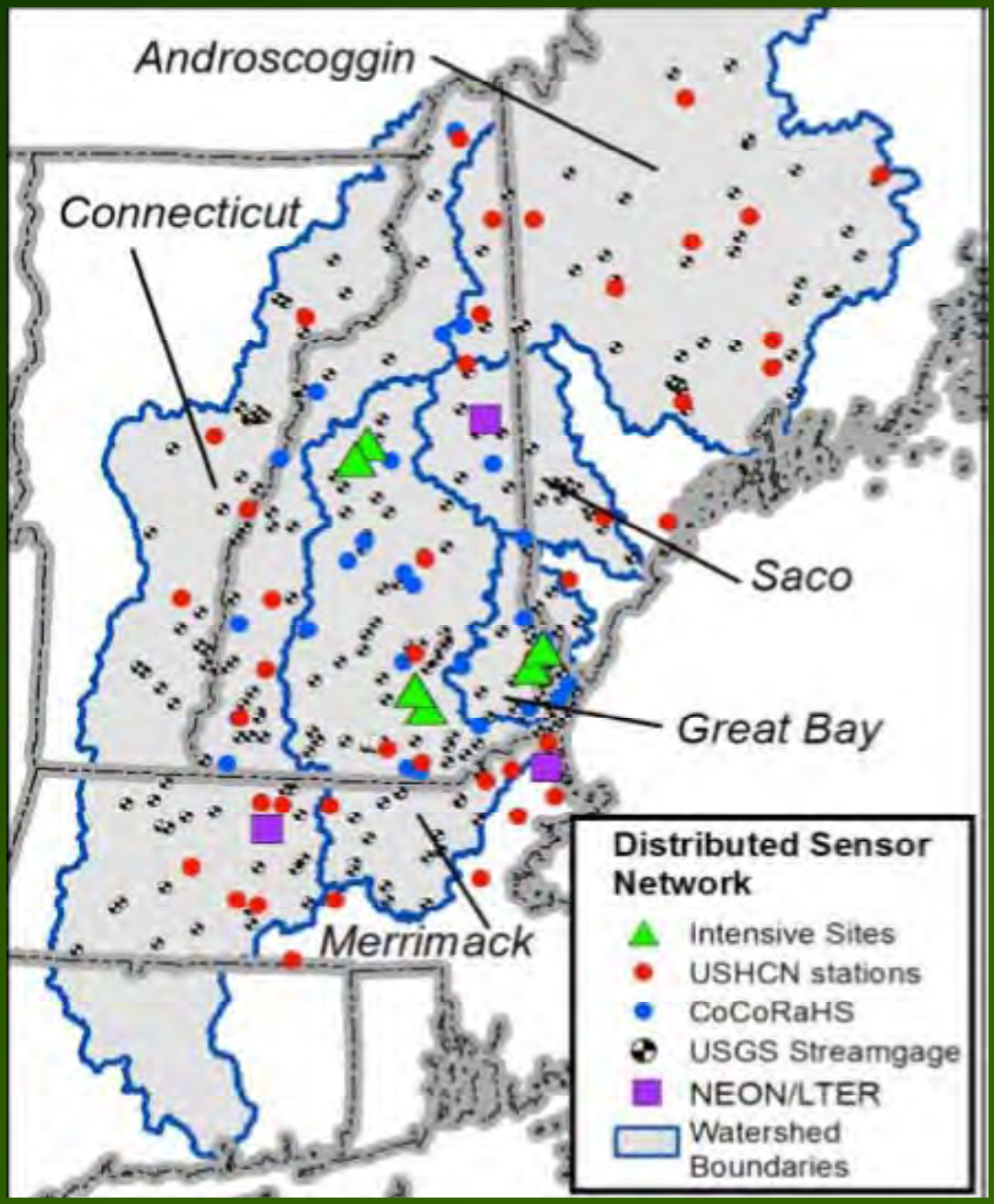
A closing thought…

- ~200 stations
- 10 metrics/station
- Reporting every second
- 173 million numbers daily



Courtesy W. McDowell (UNH)