Permafrost thaw affects mass soil erosion with potential for eutrophication of the Arctic Ocean under continued climate change

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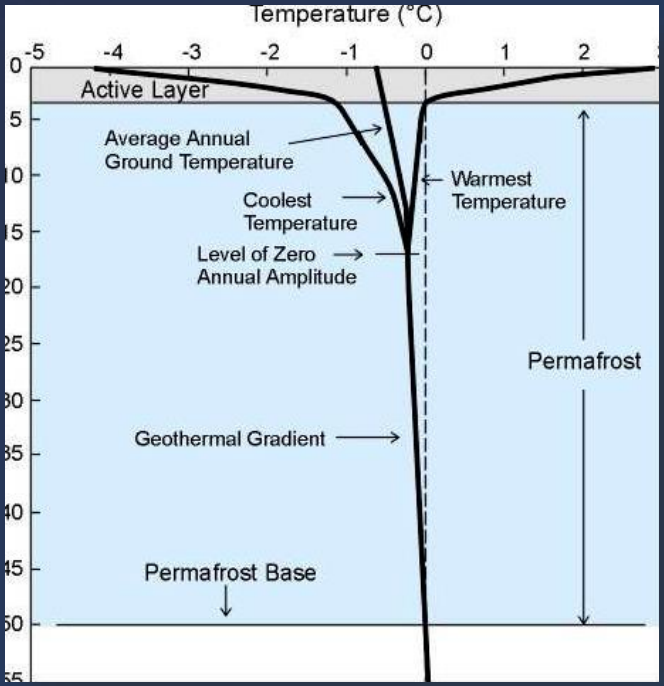
Watersheds: “canary in the coal mine”

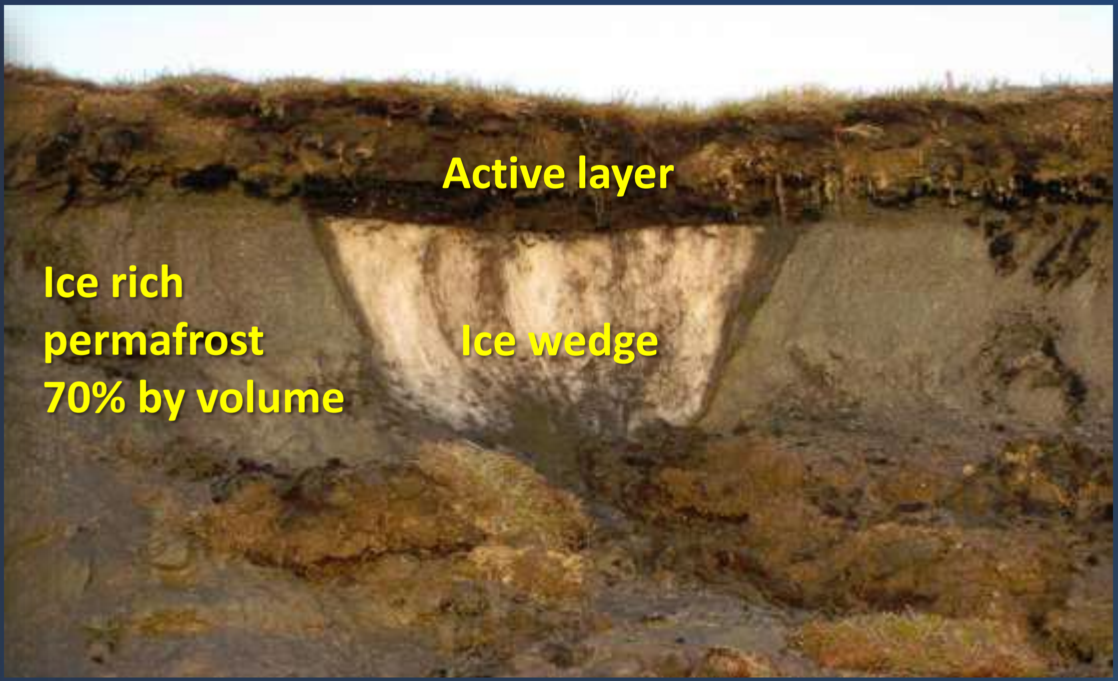
The Washington Post

The Arctic climate threat that nobody's even talking about yet

Chris Mooney April 1, 2015

In this Aug. 10, 2009, photo, a hill of permafrost "slumping" from global warming near the remote, boggy fringe of North America, 2,200 kilometers (1,400 miles) from the North Pole, where researchers are learning more about methane seeps in the 25,000 lakes of this vast Mackenzie River Delta, in the Northwest Territories, Canada.(AP Photo/Rick Bowmer)





Annett.Bartsch@polarresearch.at
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LIVERPOOL BAY AND TUKTOYAKTUK PENINSULA, CANADA
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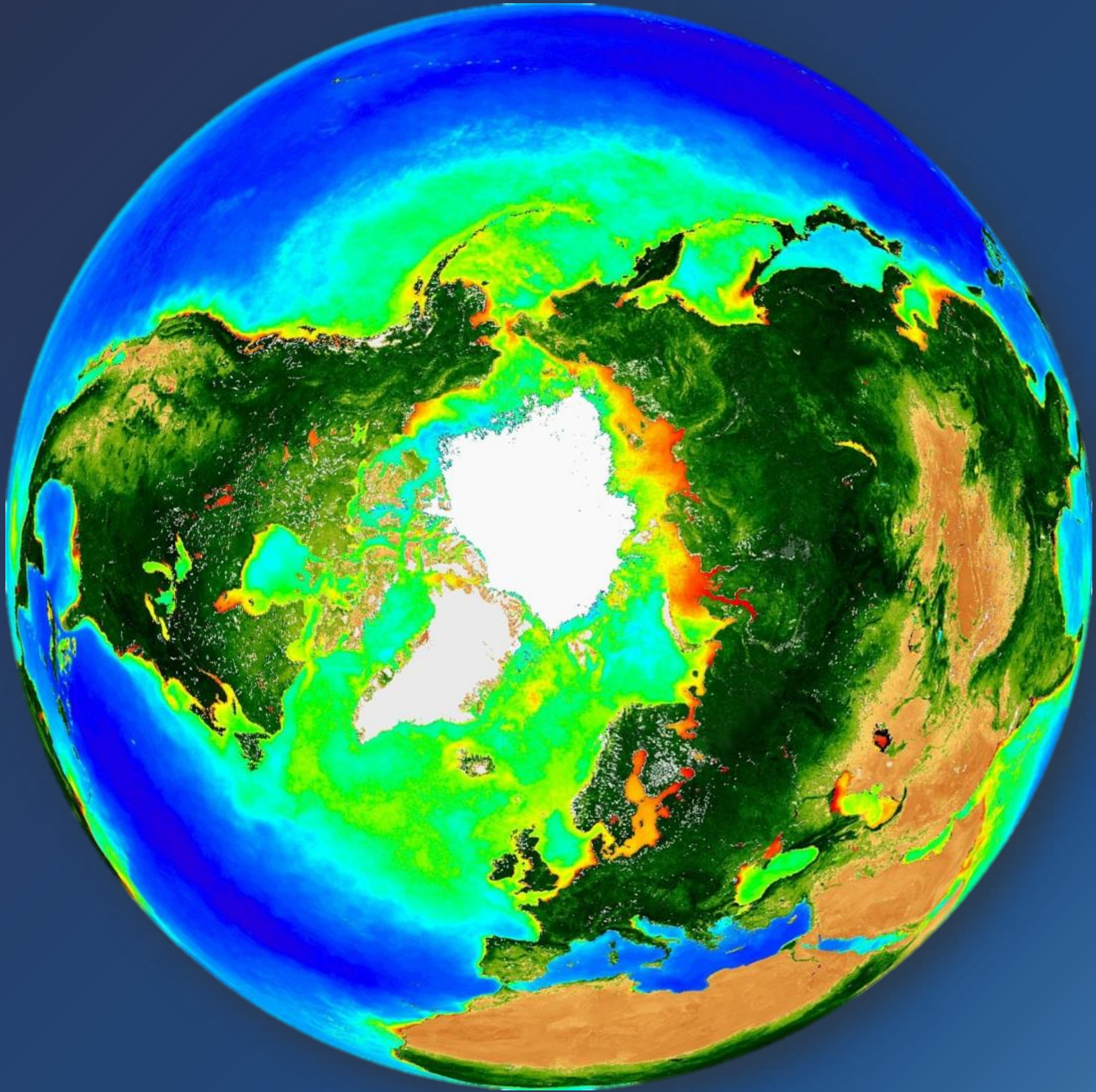

http://oceancolor.gsfc.nasa.gov/cgi/biosphere_globes.pl

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Reduction in areal extent of high-latitude wetlands in response to permafrost thaw

Christopher A. Avis[1]*, Andrew J. Weaver[1] and Katrin J. Meissner[2]

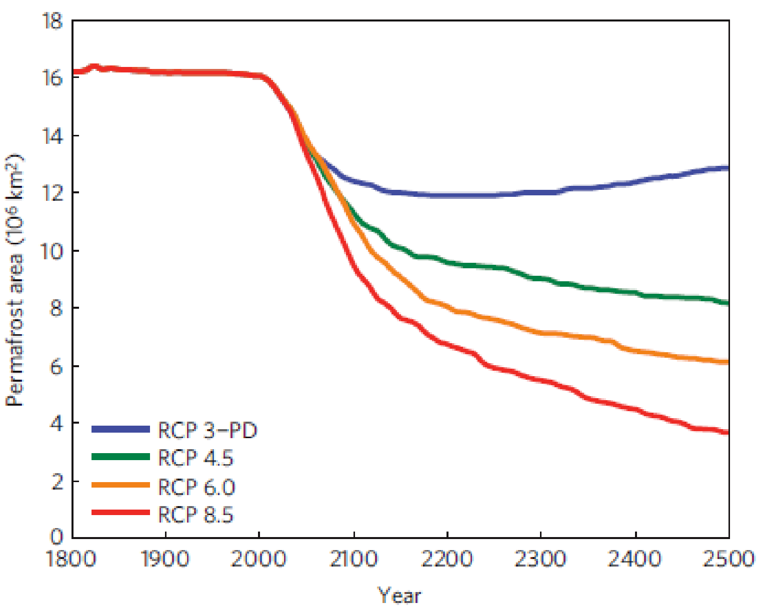
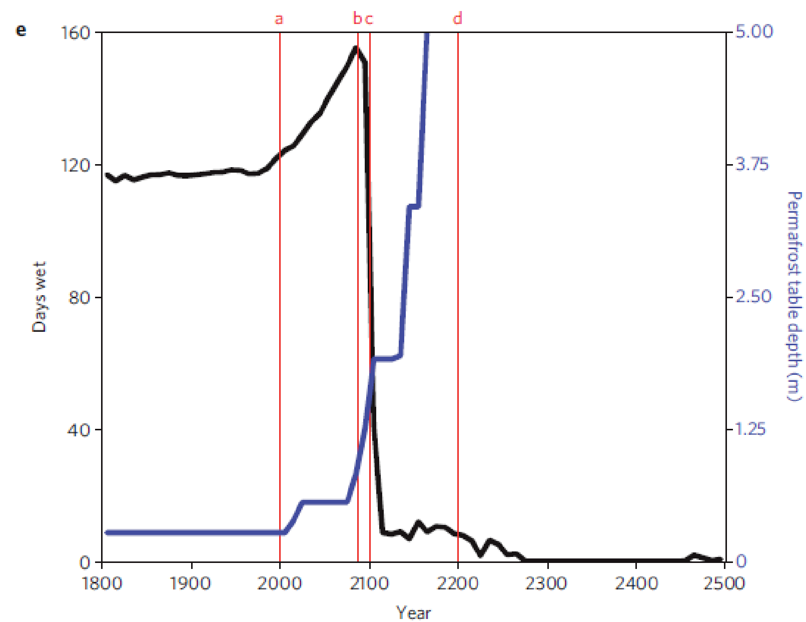


Figure 1 | Evolution of Northern Hemispere permafrost extent under RCP scenarios. The plot shows the areal extent of permafrost in the Northern Hemisphere simulated by the UVic ESCM under four RCP forcing scenarios. We note that the model identifies permafrost within grid cells at depths to 250 m and therefore near-surface permafrost will degrade at a faster rate than indicated in this figure.



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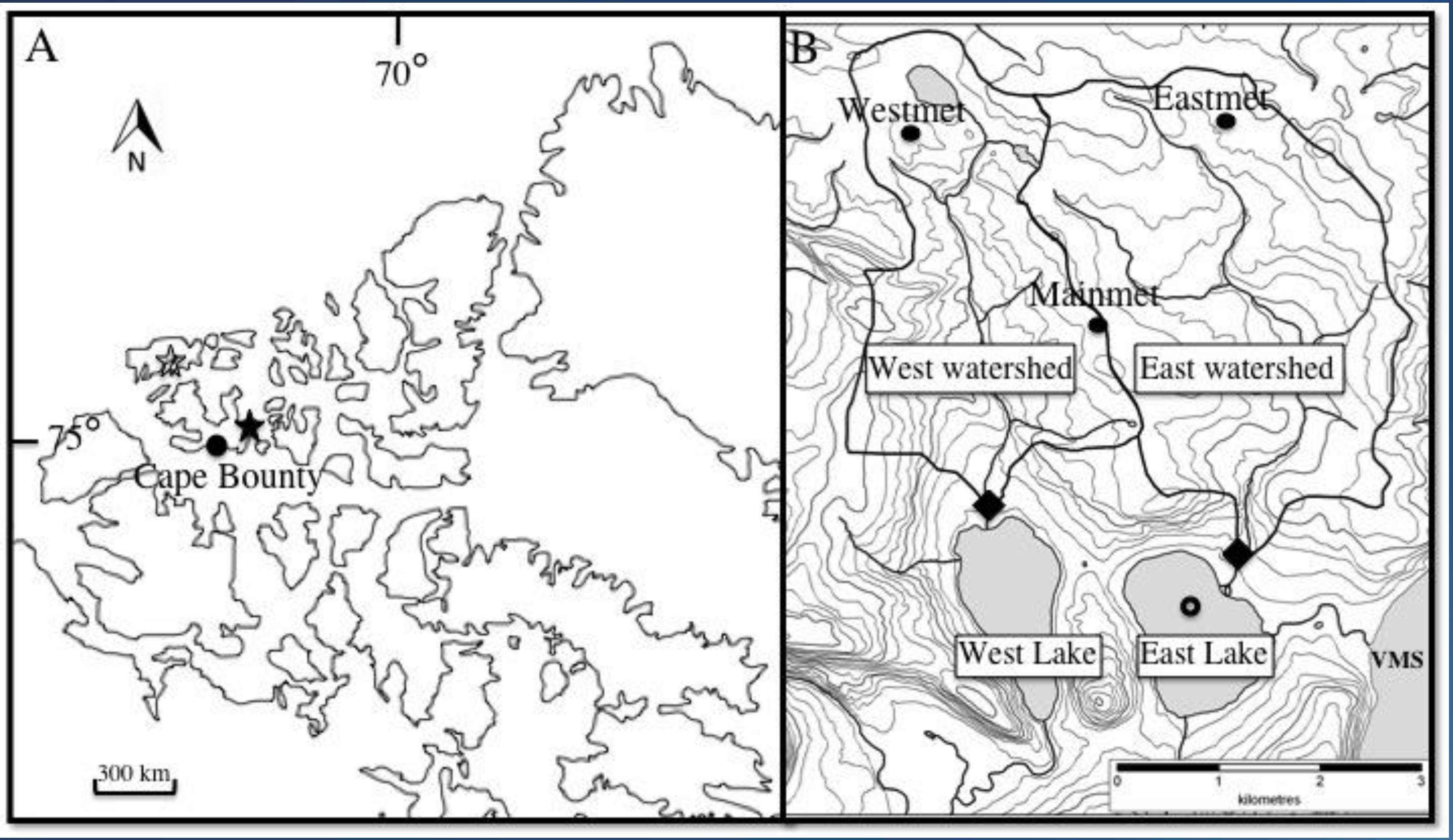
Arctic Landscapes in Transition: Responses to Thawing Permafrost

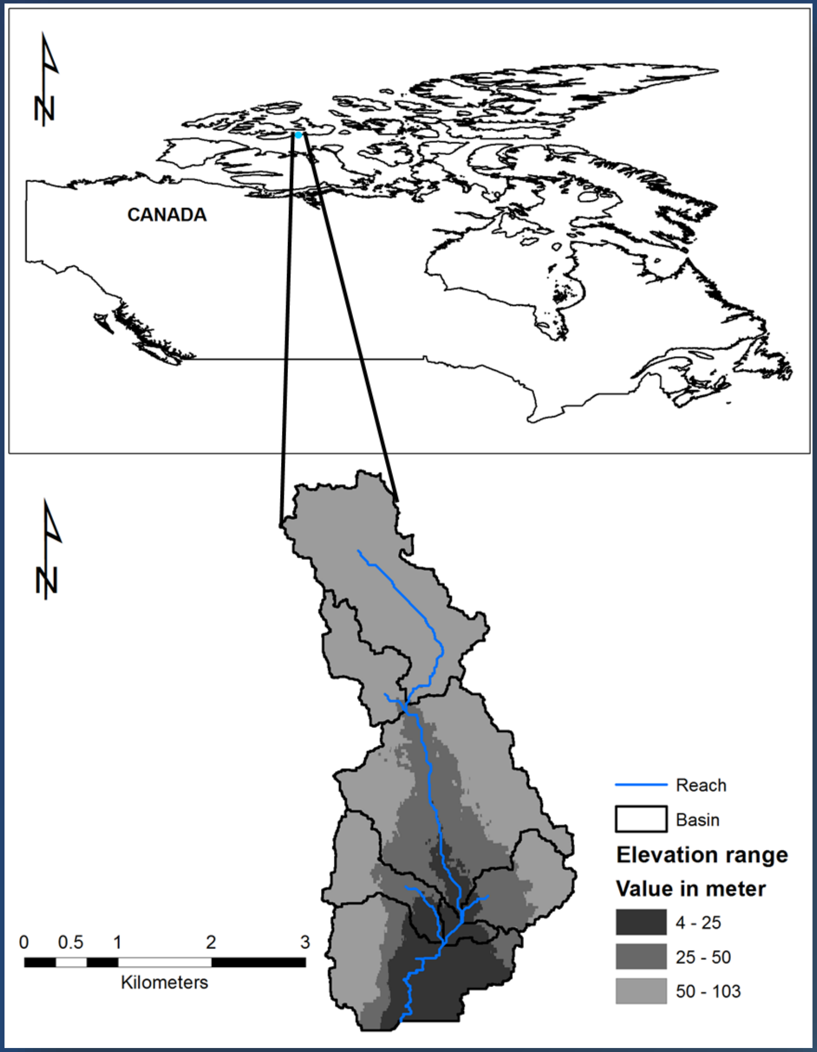
By J. C. Rowland, C. E. Jones, G. Altmann, R. Bryan, B. T. Crosby, G. L. Geernaert, L. D. Hinzman, D. L. Kane, D. M. Lawrence, A. Mancino, P. Marsh, J. P. McNamara, V. E. Romanovsky, H. Toniolo, B. J. Travis, E. Trochim, and C. J. Wilson

Cape Bounty Arctic Watershed Observatory (CBAWO), Melville Island

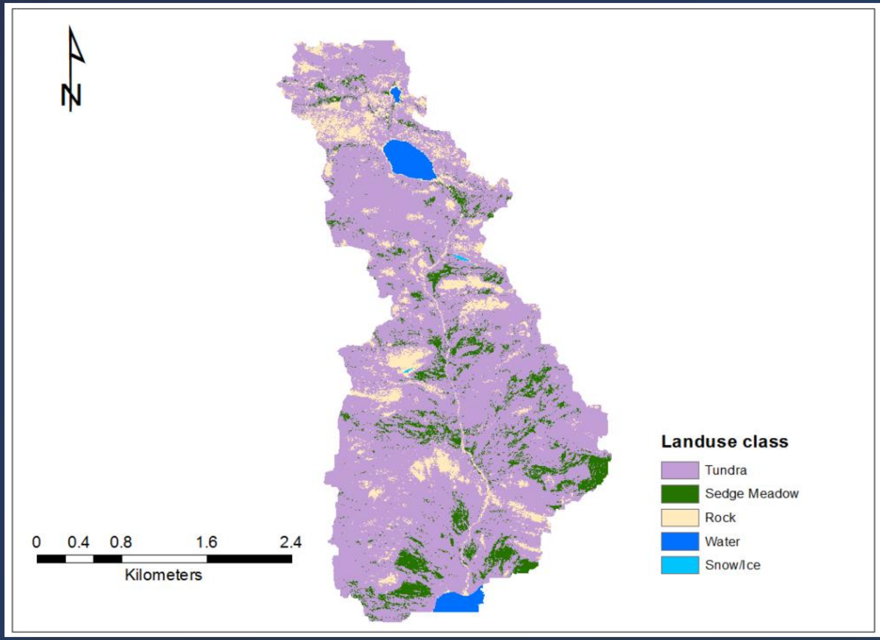


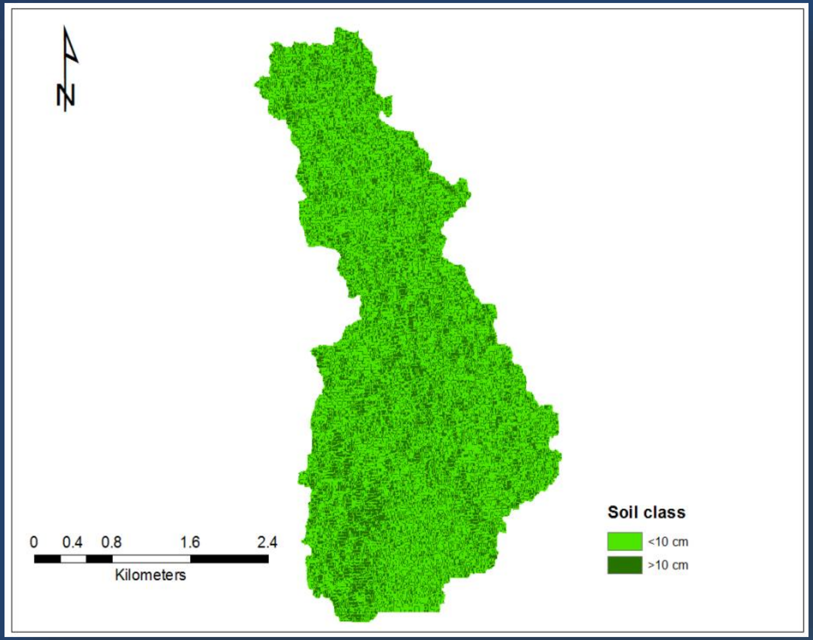
Background

- Cape Bounty Arctic Observatory, Melville Island, Nunavut
- Understand continued climate change impacts of terrestrial to marine sources of carbon and nutrients from Arctic watersheds
- Use of SWAT to assess potential fluxes in an experimentally challenging environment

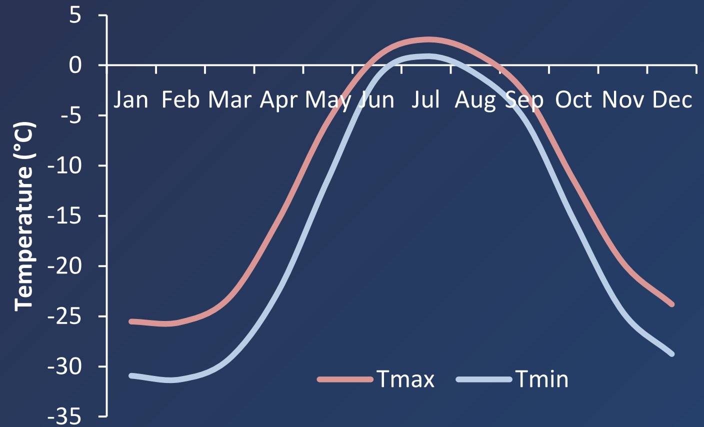


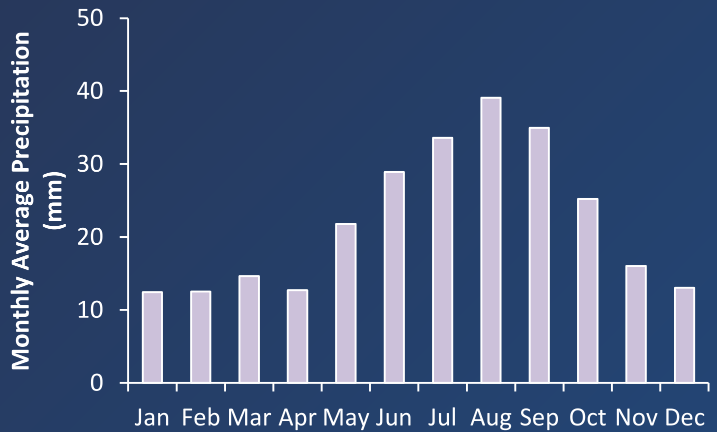
SWAT Data

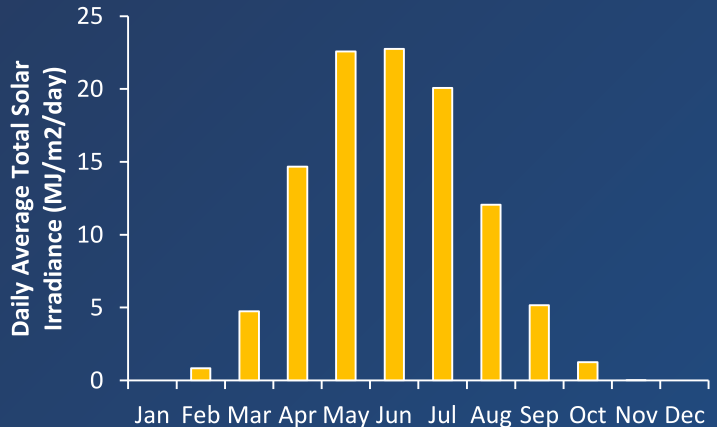




- Landcover – IKONOS 2008, F. Gregory (200MSc thesis, Queens Univ)
- DEM used to derived topographic soil index as a surrogate for soil depth (max depth set @ 50 cm)
- Daily meteorology derived from NCEP reanalysis
  - Station located at 74.79° W 108.75 ° N
  - Includes min/max temperature, precipitation, solar irradiance, and wind
  - 1979-2010







Not the actual station!

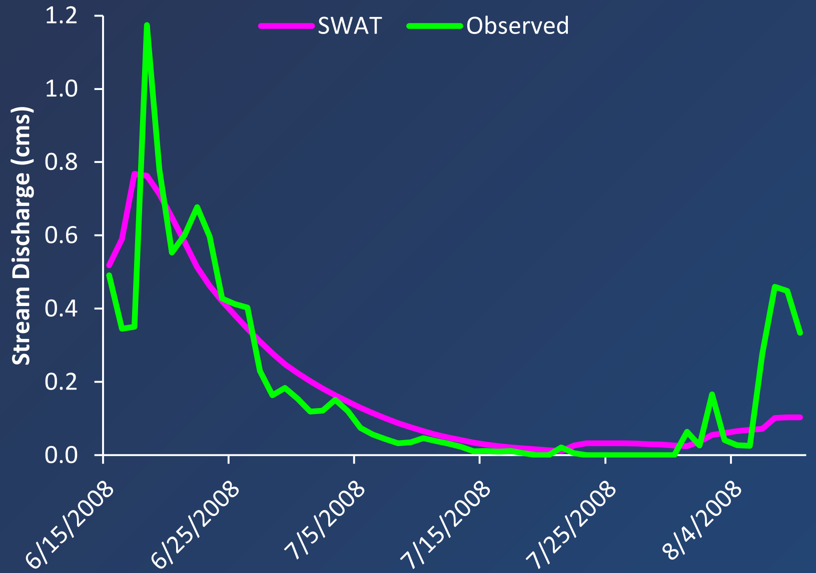
http://globalweather.tamu.edu/

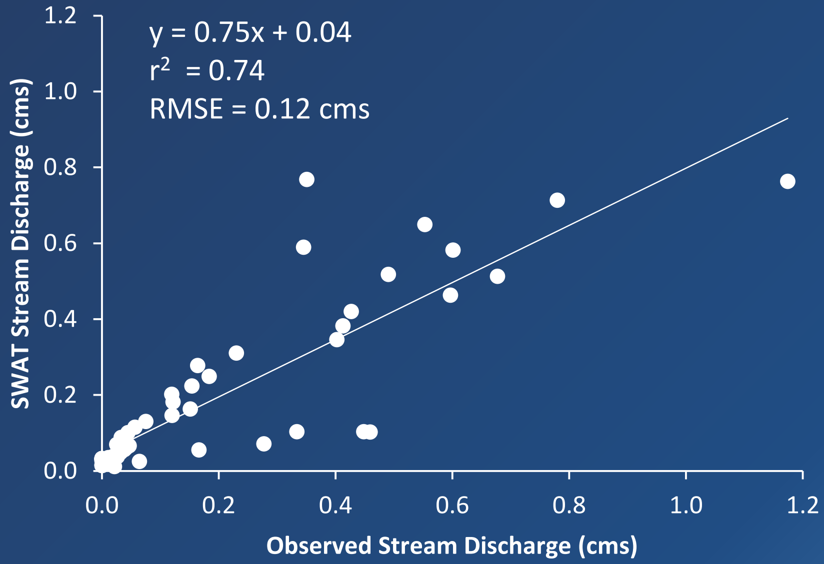
Usersoil

Soil Characteristic	**Value**	**Reference**
Bulk Density g/cm3	*1.0*	*Michaelson et al.1996*
Available Water Content (mm H2O/mm soil)	*0.034*	*Bölter et al. 2003*
Saturated Hydraulic Conductivity (mm/hr)	*8.82*	*Derived from Clapp and Hornberger (1978) based on %sand, silt, clay*
Organic Carbon Content (%)	*1.9*	*Bölter et al. 2003*
Clay Content (%)	*29*	*Bölter et al. 2003*
Silt Content (%)	*45*	*Bölter et al. 2003*
Sand Content (%)	*26*	*Bölter et al. 2003*
Rock Fragment Content (%)	*60*	*Bölter et al. 2003*
Moist soil albedo	*0.16*	*Chapin et al. 1999*
USLE K (Mg m2 hr/m3 Mg cm)	*0.31*	*Computed based on Wischmeier and Smith (1978)*

SWAT Calibration

Discharge Data, West Lake, Jun 15 – Aug 9, 2008

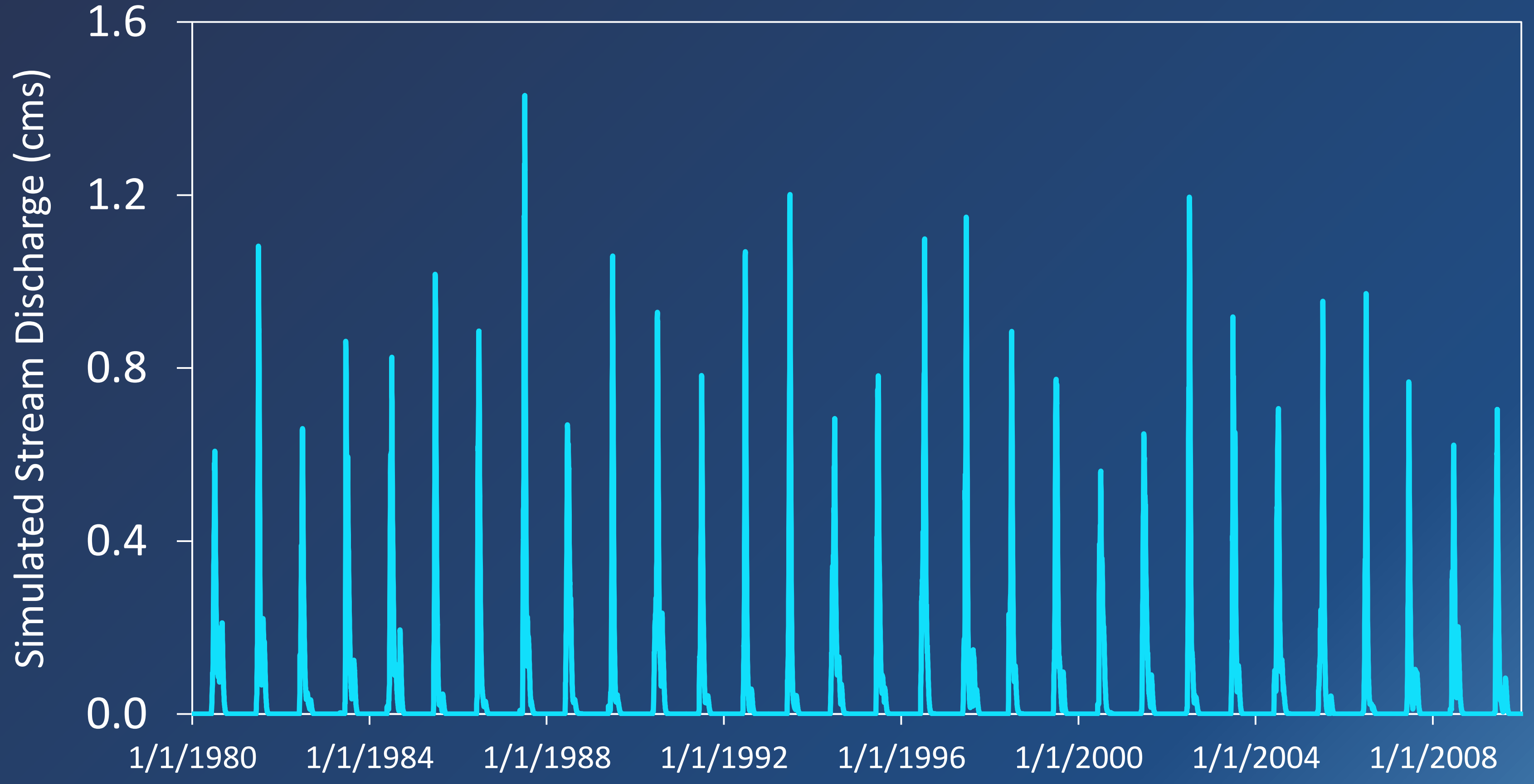




Description	SWAT Default	Calibrated
Baseflow alpha factor (Days)	0.048	0.300
Deep aquifer percolation fraction	0.05	0.01
Groundwater delay time (Days)	31	1
Hydraulic conductivity in channel alluvium (mm/hr)	0	480

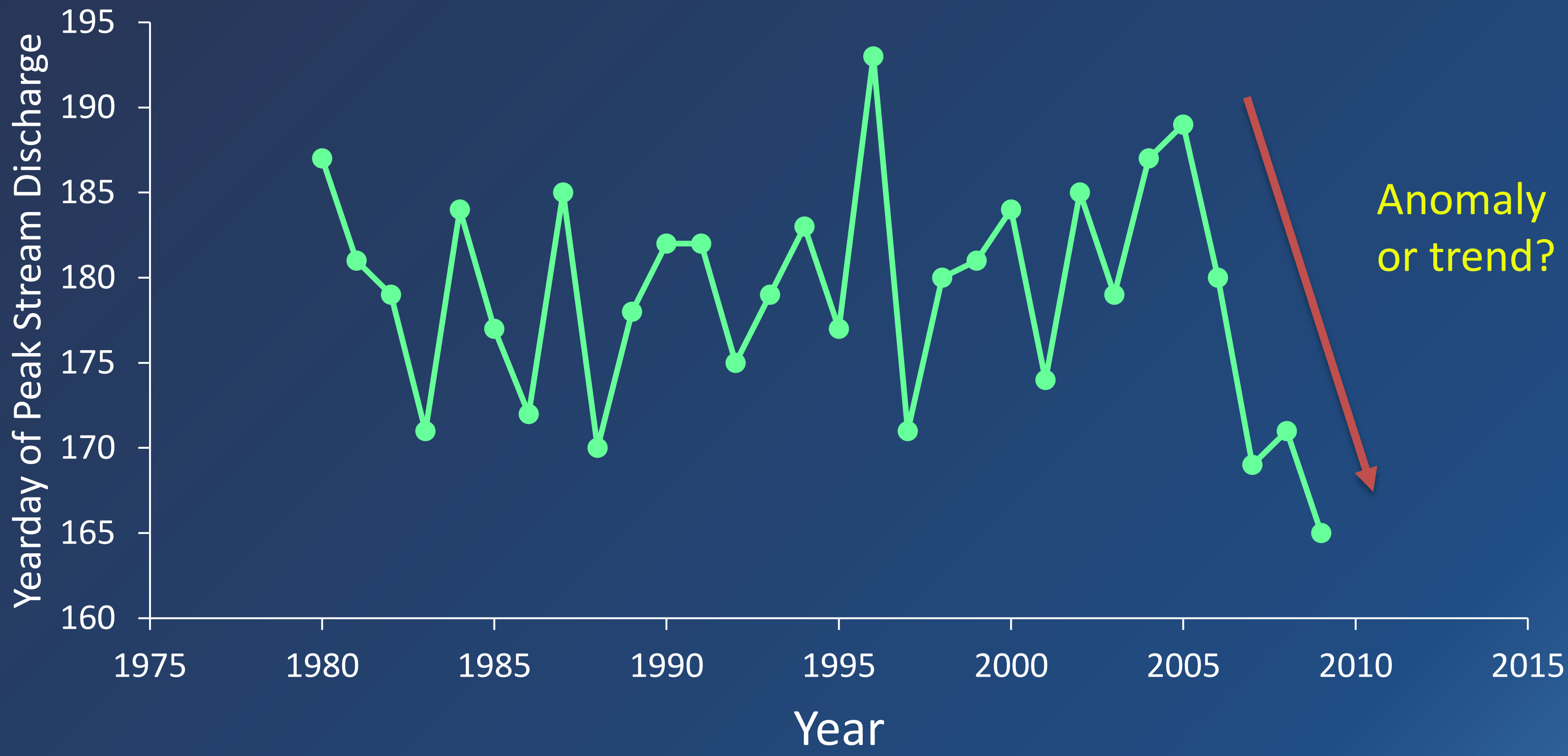
SWAT Stream Discharge

West Lake 1980-2010



SWAT Peak Flow Day

West Lake 1980-2010

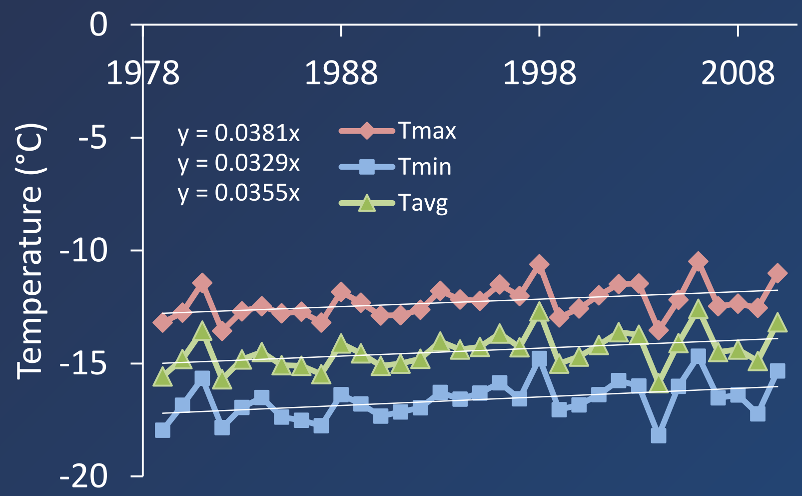


- Pre-2006, mean peak flow June 29
- Post-2006, mean peak flow June 21

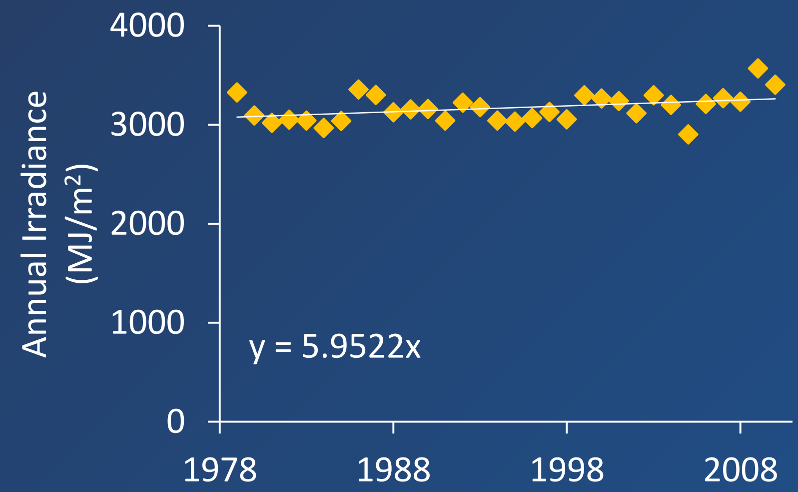
SWAT Meteorological Variables

Met Station 74.79° W 108.75 ° N

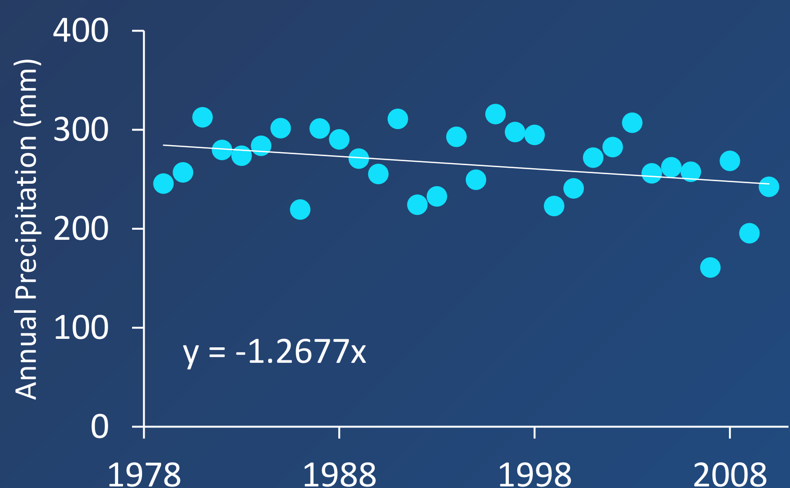
Temperature



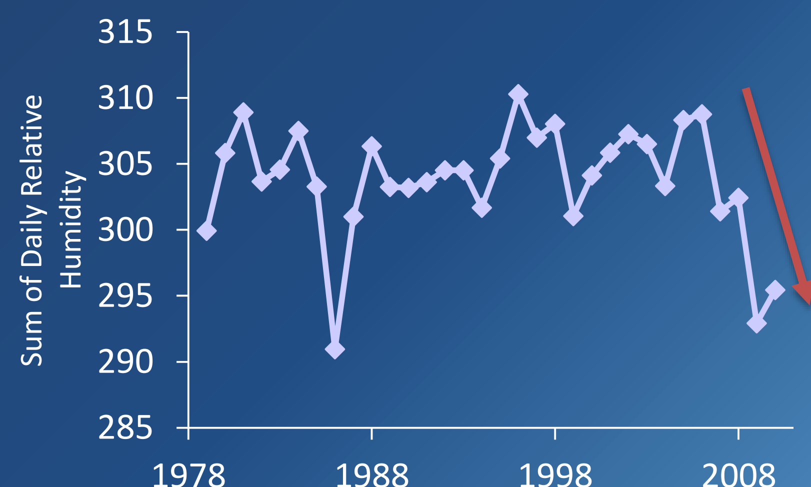
Solar Radiation



Precipitation

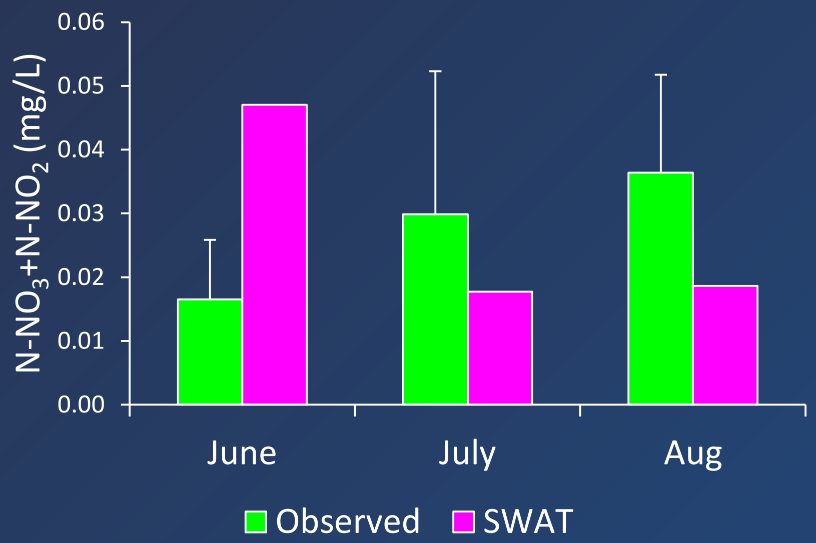


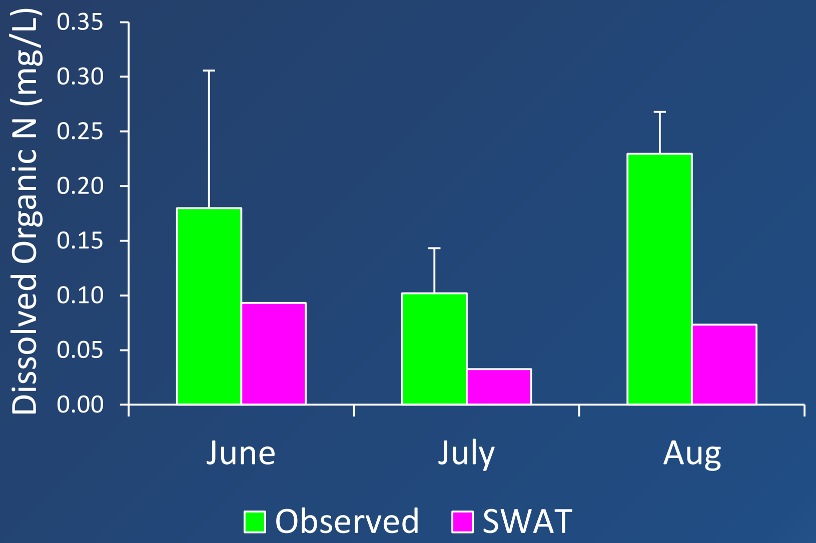
Humidity

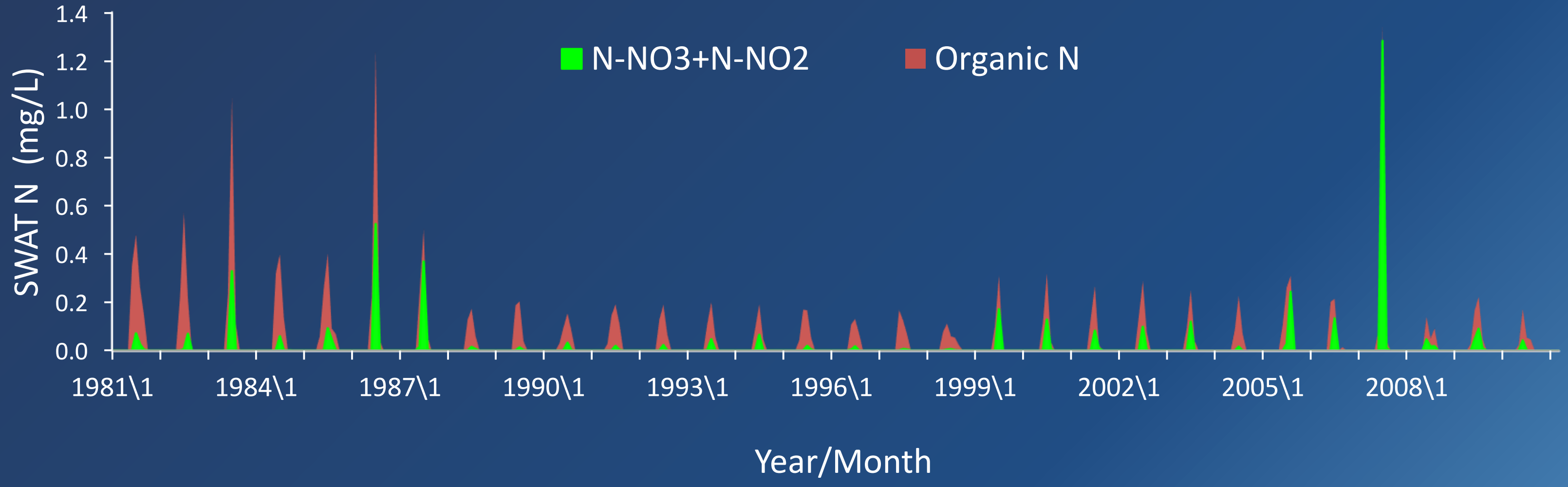


Initial Nutrient Results

Solute Data, West Lake, Jun 15 – Aug 9, 2008







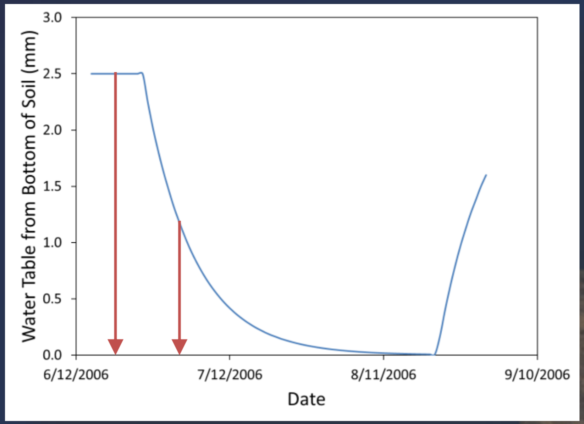
Factor of Safety (F_s)

Lewkowicz and Harris (2005)

$$F_s = \frac{c' + z(\gamma - m\gamma_w)\cos^2\beta\tan\phi'}{z\gamma\sin\beta\cos\beta}$$

- c' - effective cohesion (assumed 5 kPa)
- z – depth of slip (m)
- γ – unit weight of soil
- γ_w – unit weight of water
- m – ratio of height of water table above slip to depth of slip surface (z)
- β – slope angle (°)
- ϕ' – effective angle of friction (assumed 27°)

SWAT-derived F_s Prediction



Summary

- Stream discharge declining over time; day of peak flow recently earlier
  - Current model does not assess melting permafrost inputs
- Climate warmer, less precipitation, sunnier, drier
  - Conditions lead to less snowpack with lower isothermal conditions for melting
- Model prediction of nitrogen sources similar, though underestimating organic decomposition
- Soilfluction processes approximated through depth to water table; controlled by depth to permafrost