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Climatic Factors Driving the Hydrological and Geochemical Responses of Tundra Upland Lakes to Landscape Perturbation

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W-CIRC
Water & Climate Impacts Research Centre

ArcticNet
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University of Victoria

ISSUE

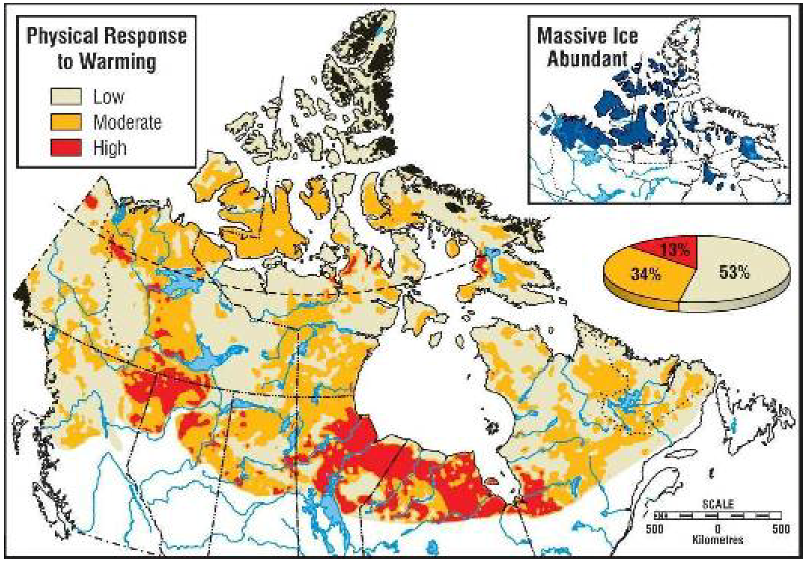
Climate Change, construction, oil/gas extraction, etc.

↓

Permafrost degradation – active layer thickening and shoreline retrogressive thaw slumping (SRTS)

↓

Potential hydro-bio-geochemical impacts



(Prowse, 2009)

“SLUMPED LAKES”

Exposure of ice-rich sediment

Thawing

Terrain instability

Collapsing shoreline

Stabilization

Burn et al. (1989)

INTEGRATIVE RESEARCH APPROACH

1. **ArcticNet/IPY Freshwater Bionet investigation - "Hydro-ecological responses of Arctic tundra lakes to climate change and landscape perturbation"**

- Permafrost degradation (Kokelj et al.)
- Timing and duration of lake-ice (Prowse et al.)
- Aquatic Biology (Wrona et al.)

⟶ Thompson et. al.

2. **Other Research**

- Stream discharge (Marsh et al.)
- Stream hydro-chemistry (Marsh et al.)
- Catastrophic drainage (Marsh et al.)
- Vegetation (Lantz et al.)
- Snowpack (Kokelj et al.)
- Contaminants (Blais et al.)
- Others

PURPOSE AND OBJECTIVES

Purpose: To investigate linkages between the hydrological and geochemical processes of the contributing basin and tundra lakes affected by landscape perturbation in the region north-east of Inuvik, NWT, Canada.

Objective 1: Create/update a historical record of **temperature** and **precipitation**

→ **annual snow pack index**
→ **spring freshet initiation**
→ **open water duration**
→ **rainfall**
→ **snowfall**
→ **evaporation**

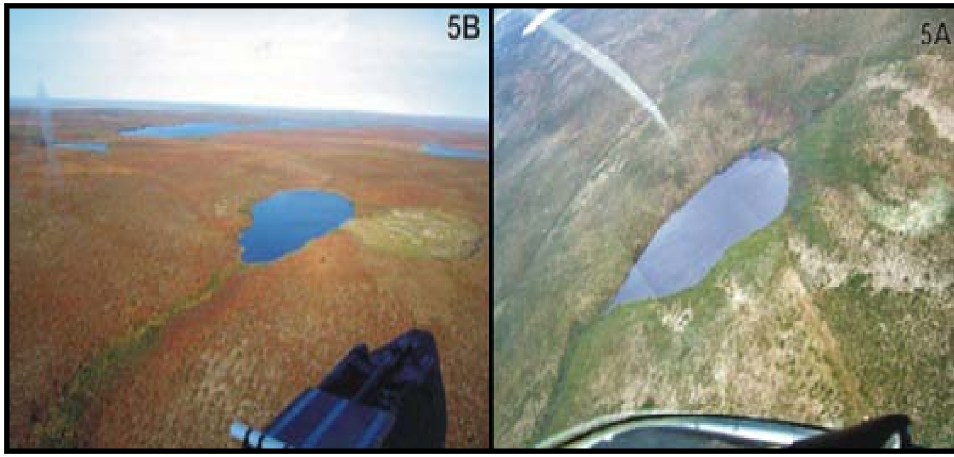
Objective 2: Assess the importance of landscape-level processes on the geochemistry of **"slumped"** and **"unslumped"** lakes.

Primary Study Sites:

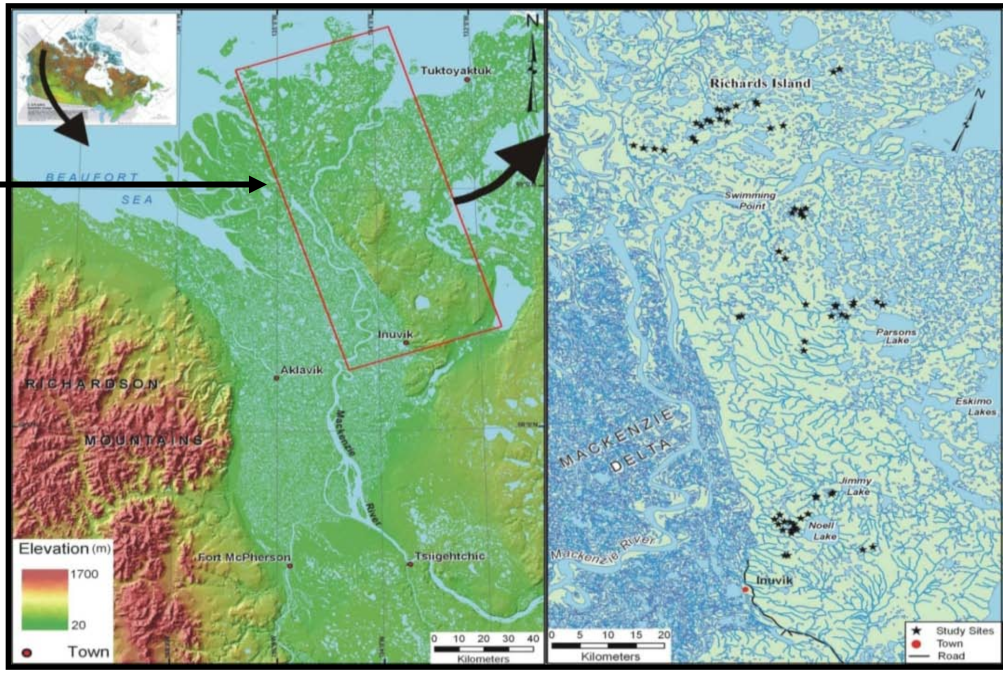
Unslumped: Lake 5A
Catchment area = 0.21 km^2
Lake area = 0.03 km^2
Lake depth = 10.9 m

Slumped: Lake 5B
Catchment area = 0.28km^2
Lake area = 0.03 km^2
Lake depth = 9m

LAKE 5B **LAKE 5A**



Proposed Mackenzie Valley Natural Gas Pipeline



- 66 paired lakes (control and affected)
- Chosen by Indian and Northern Affairs Canada (INAC)

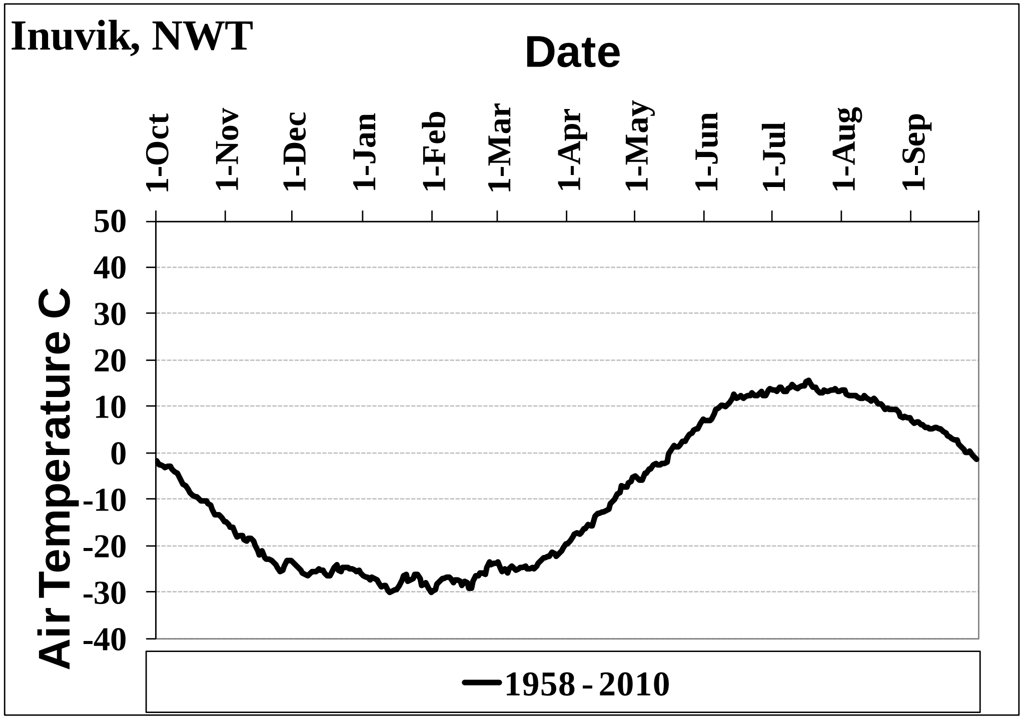
Average Daily Air Temperature:

- In 2009 and 2010 (two primary study years) snowmelt was initiated 2-3 weeks early

- Temperature ↑ above 0 in a matter of days

- By May 1st much of the snowpack had ablated

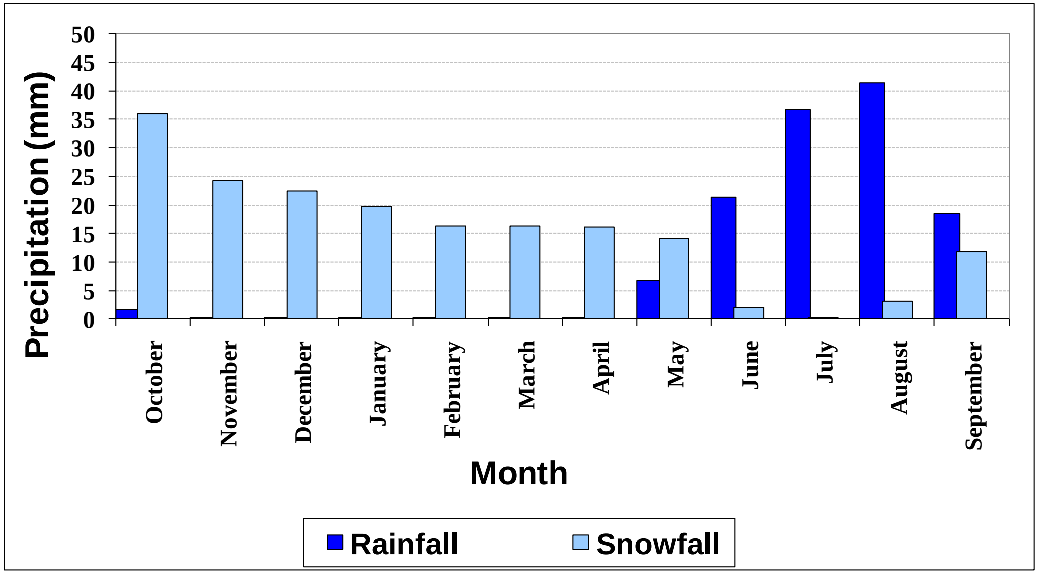
- Rarely has this happened before



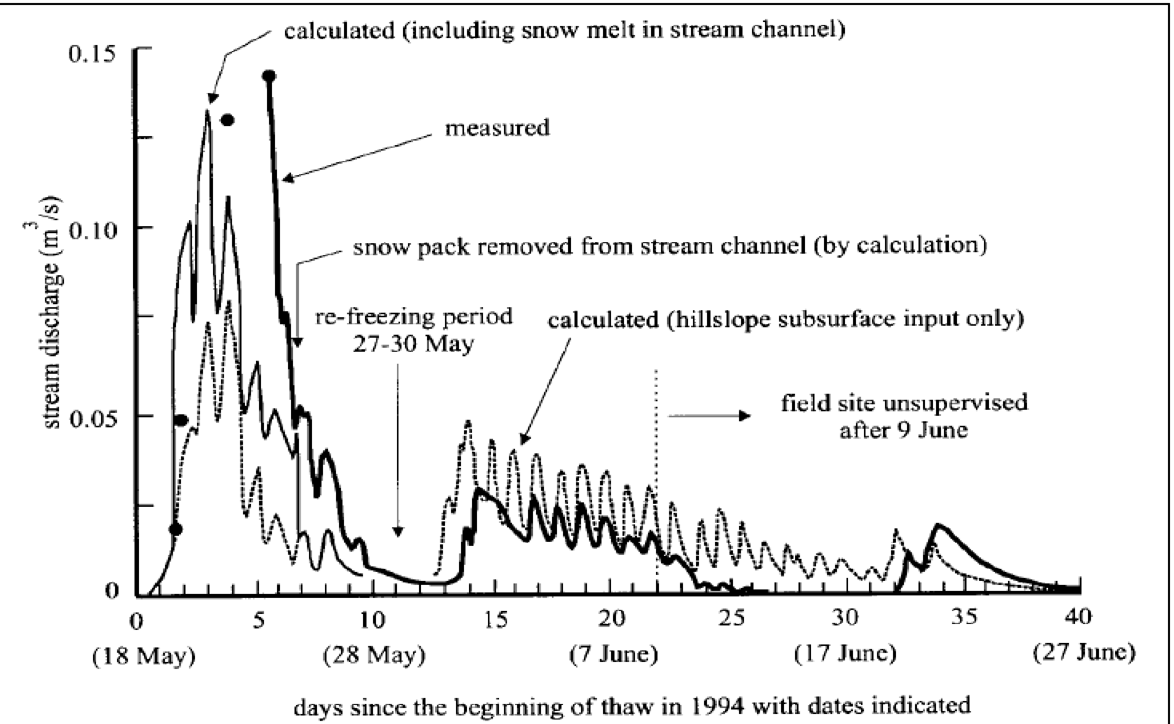
Precipitation:

- Snowfall dominates October – May

- Rainfall dominates June – September



High inter-annual variability in stream flow…







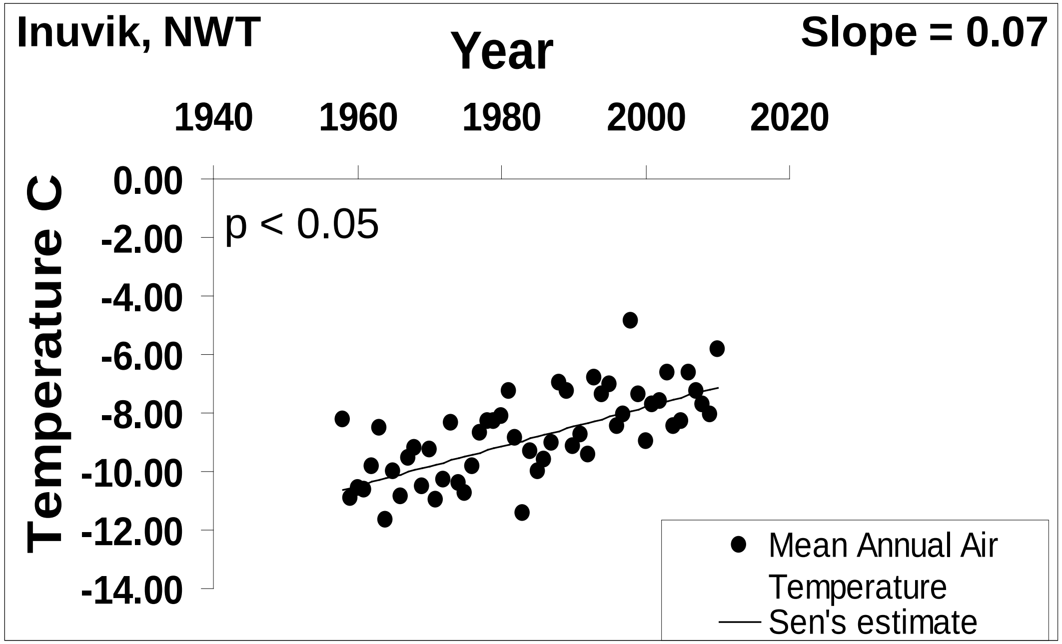

Spring:
- Rapid melt rates
- Low vertical infiltration
- Overland flow dominates

Summer/Fall:
- Snowpack has mostly ablated
- High vertical infiltration
- Subsurface flow dominates

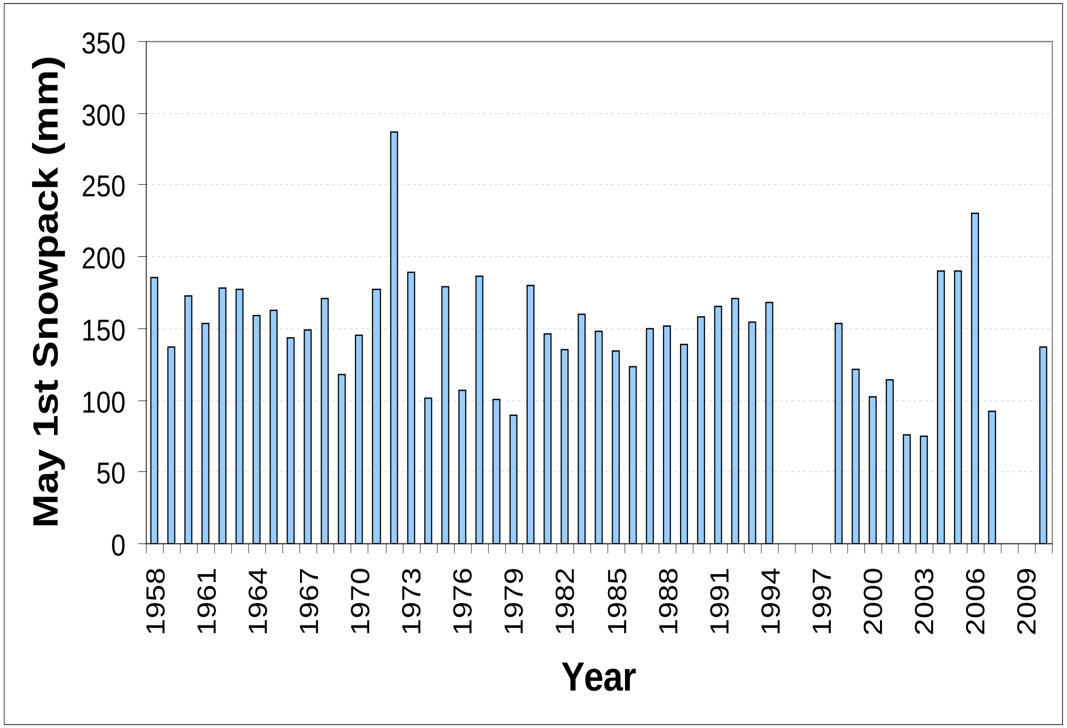
Winter
- Snowpack forming
- Little to no vertical infiltration
- Low stream flow

Quinton et al. (1999)

- **Mean Annual Air Temperature**
- High inter-annual variability
- Overall, ↑ by 0.07 °C every year

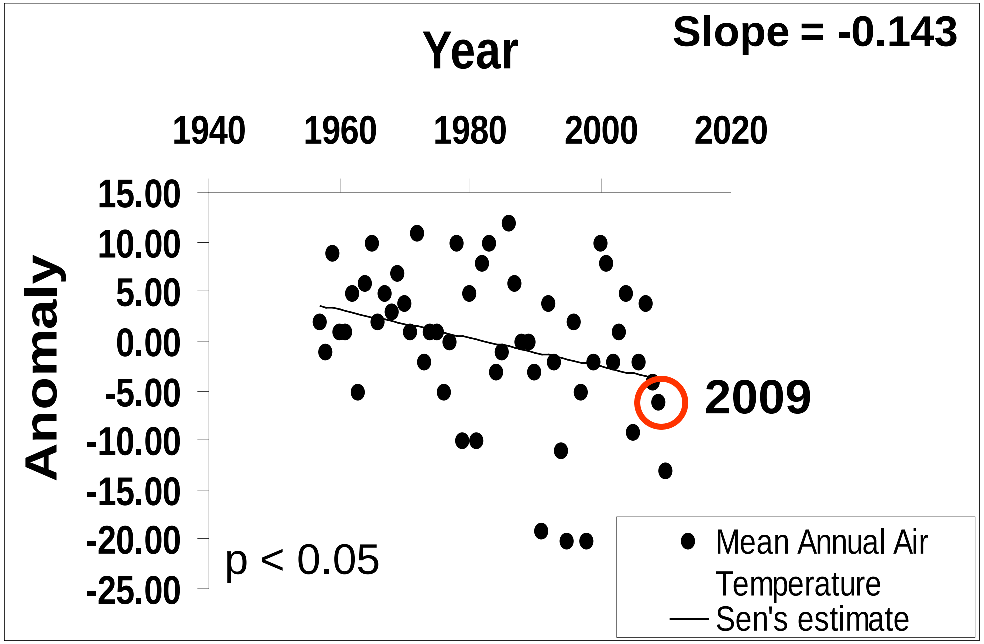


- **May 1st snowpack** – Precipitation (mm) that fell between October 1st and April 30th
- High inter-annual variability in snowpack depth
- Significant implications for the hydrology of our two primary study lakes



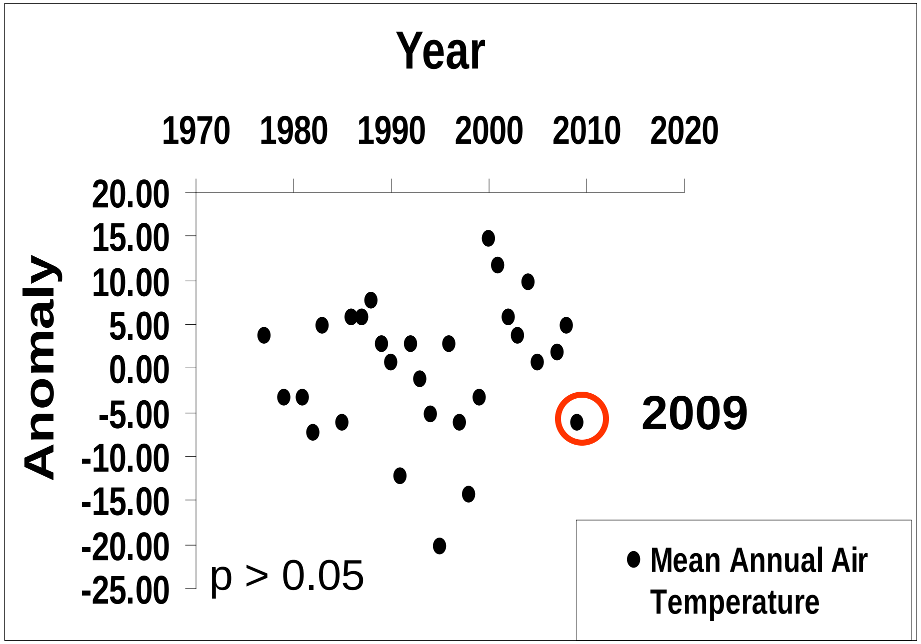
SPRING 0°C ISOTHERM

Mean = 136 (May 15th)



SPRING FRESHET INITIATION

Mean = 144 (May 29th)



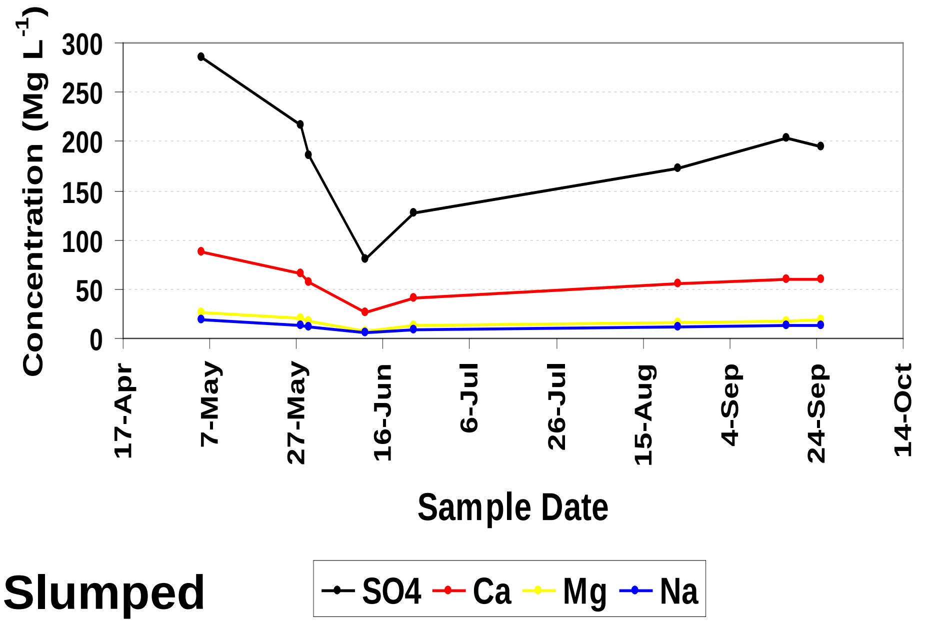
Bonsal and Prowse (2003)

- **Good for analysis of spatial/inter-annual variability in ice-on and ice-off dates**
- **More robust methods required for open-water duration**

Burn et al. (2006)

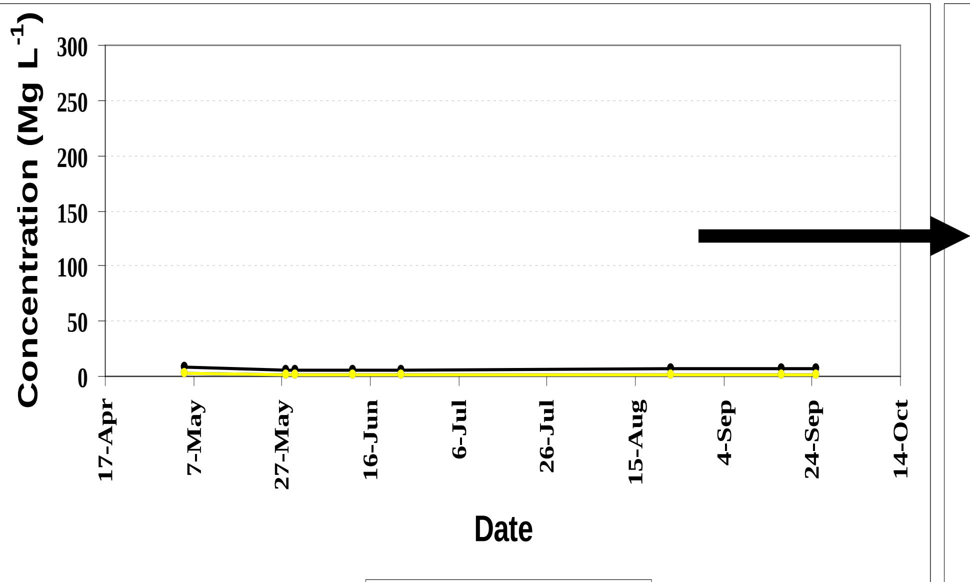
- **Trail Valley Creek can act as a surrogate for our primary study lakes**

PRELIMINARY DATA: LAKE GEOCHEMISTRY

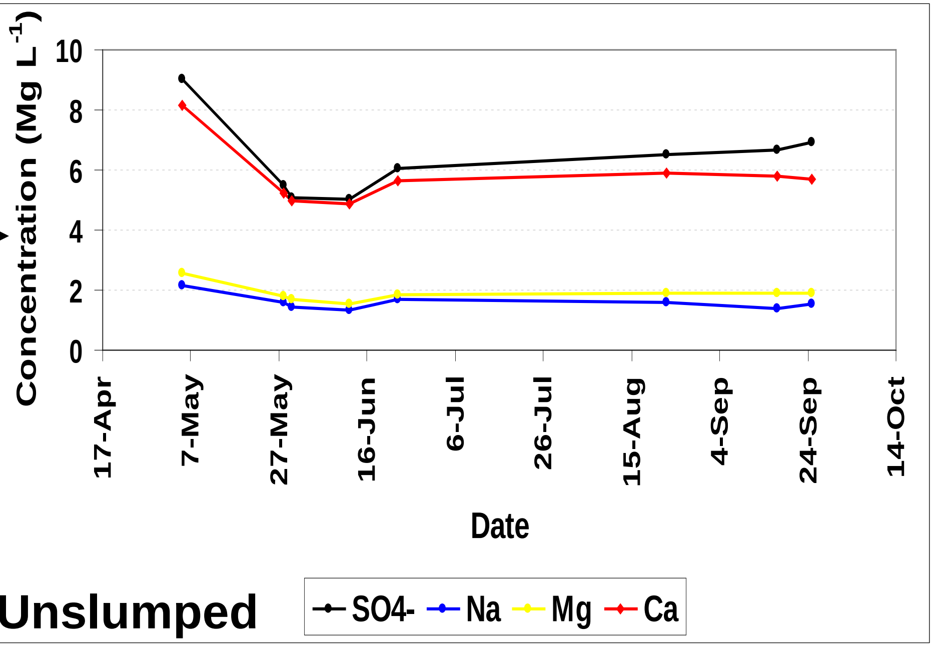


Slumped

- Observed seasonal variability in “slumped” lake chemistry
- Observed difference between **“Slumped”** and **“Unslumped”** lakes – Higher concentrations of SO_4, Ca, Mg, and Na in “Slumped” lakes
- Confirms results of Kokelj et al. (2009)
- Similar seasonal variability observed at “Unslumped” lake – at lower concentrations

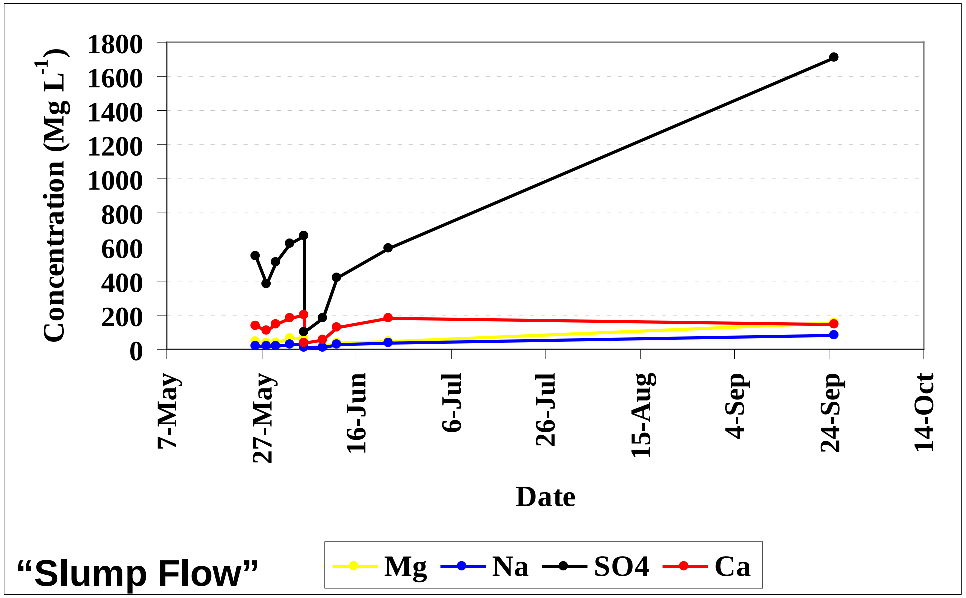


Unslumped

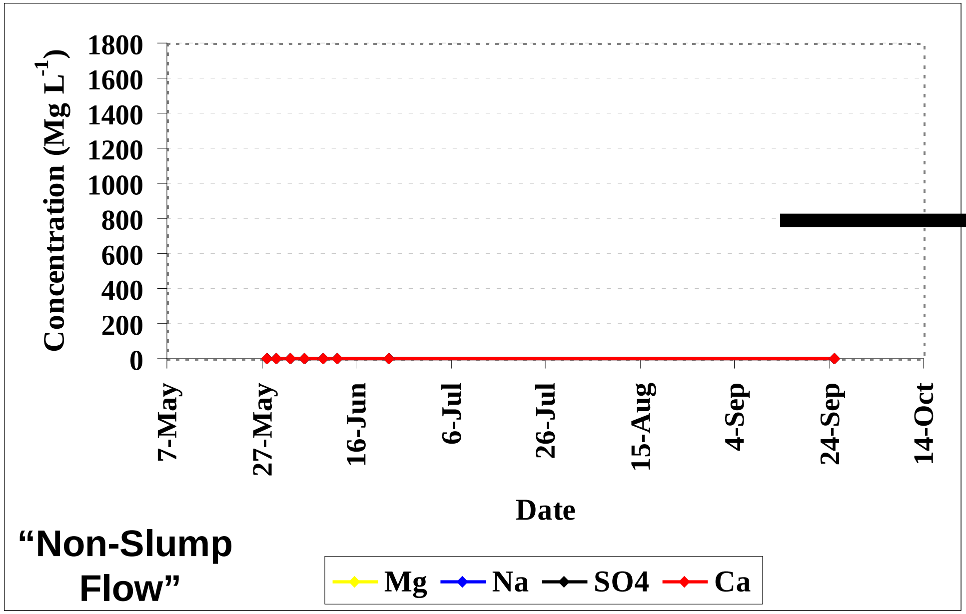


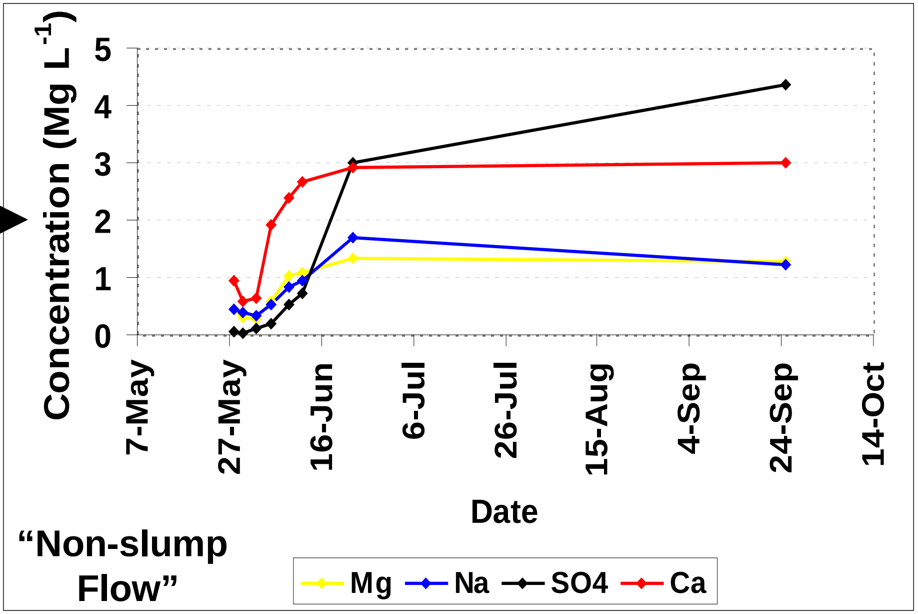
Unslumped

PRELIMINARY DATA: Surface Flow Geochemistry



- Similar seasonal trends are observed for landscape flow (e.g., ephemeral drainage channels)
- Agrees with seasonal trends in stream hydrochemistry observed at nearby Trail Valley Creek – Quinton et al. (2006)
- Observed seasonal variability in "slump flow to lake" chemistry
- "Slump flow" has higher concentrations of Mg, Na, SO_4, and Ca





Summary

- Strong inter-annual and seasonal variability in temperature controls key hydrological processes
    - Ice-on and ice-off dates
    - Spring freshet initiation
- Variability in rainfall and snowfall also have significant implications
    - Snowpack
    - Spring stream discharge
- Lake and stream water chemistry appears to be typified by the spring freshet
- Shoreline Retrogressive Thaw Slumping (SRTS) is a common feature among lakes in the upland region north-east of Inuvik, NWT
- Permafrost degradation (SRTS) appears to increase the SO_4, Ca, Na, and Mg loading to ephemeral drainage channels – increasing the ionic concentration of “slumped” lakes
- ↑ in the concentration of SO_4, Ca, Na, and Mg may affect the ecology of “slumped” lakes

FUTURE DIRECTIONS

- **Evaporation**
  - ⟶ **Detailed micrometeorological measurements taken for 2006, 2007, 2008, and 2009**
  - ⟶ **Use Priestley-Taylor to modify a simpler method**

- **Snow Water Equivalence (SWE)**
  - ⟶ **Detailed snow surveys at 5A and 5B for 2006, 2007, 2008, and 2009**
  - ⟶ **Snowpack at “slumped” vs. “non-slumped” lakes**

- **<u>Inter-annual</u> and <u>seasonal</u> variability in lake geochemistry – “slumped” vs. “non-slumped”**
  - ⟶ **Additional water chemistry data for 2007, 2007, 2008, and 2010**

- **Regional variability in lake geochemistry**
  - ⟶ **Landscape and lake geochemistry at 19 additional lakes**

- **Regional variability in soil and permafrost geochemistry**
  - ⟶ **Soil and Permafrost cores taken along the proposed transect**

- **Community outreach – NSERC Northern Research Internship**

THANK YOU!

- Tom Carter
- Donald Ross
- William Hurst
- Klaus Gantner
- Peter Di Cenzo

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Questions? E-mail me at ehille@uvic.ca