Shining light on Arctic river biogeochemical dynamics:

Using *in-situ* high-frequency optical sensors to constrain carbon & nitrogen exports and stoichiometry in Arctic headwaters

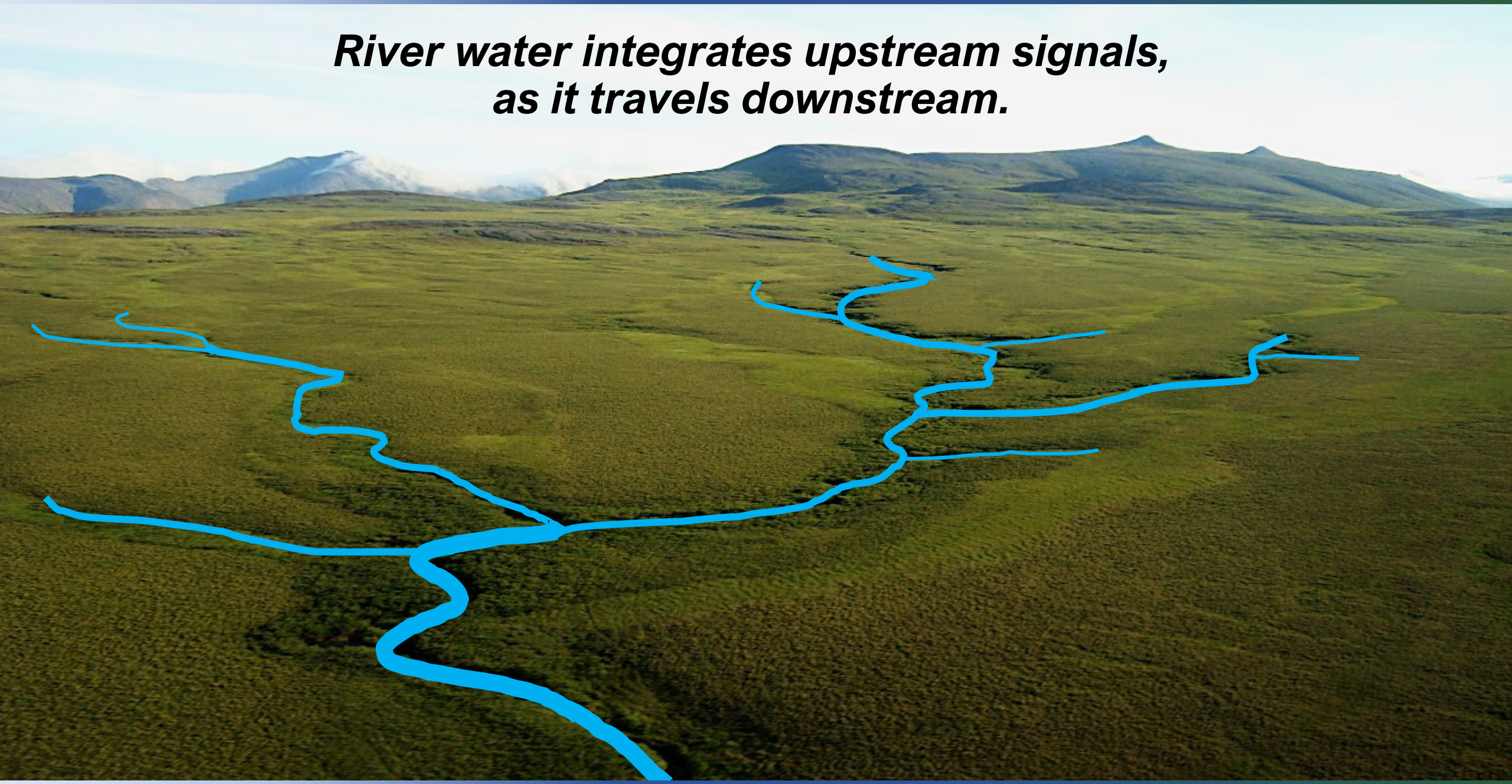
Arial J. Shogren

Assistant Professor - The University of Alabama

@DrArialShogren

What is happening to carbon and nutrients in the vast permafrost region?

River water integrates upstream signals, as it travels downstream.



River network chemistry tells a story.

River Integrated Observations through Synoptic Sampling (& Sensors) -- ***RIOS*** *for short!*

- Using repeated distributed surface water chemistry to reveal the influence of season, changing flow-paths, and landscape on lateral C & N flux (NSF 1916567) – ***data forthcoming!***

- **Using high-frequency sensors to "shine light" on <u>when</u>, <u>why</u>, & <u>how</u> Arctic watersheds release C & N (NSF 1906381).**

Spatially intensive "synoptic" sampling

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From 2016-2018 and 2021-2022, we repeatedly sampled >120 subcatchments in our three watersheds.

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- **Carbon (DOC)**
- **Nitrogen** (**NO_3^-**, NH_4+, DON)
- Phosphorus (SRP)
- Periodic table

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What can we learn?

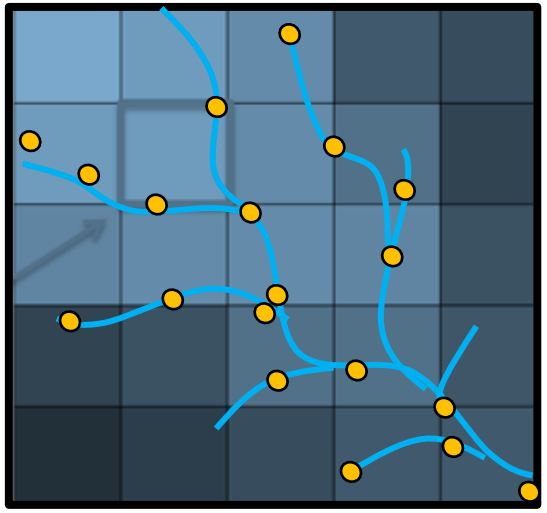
Representativeness of a given subcatchment, inference about flow paths, effects of disturbance…

Method: Repeated "synoptic" sampling… via helicopters!

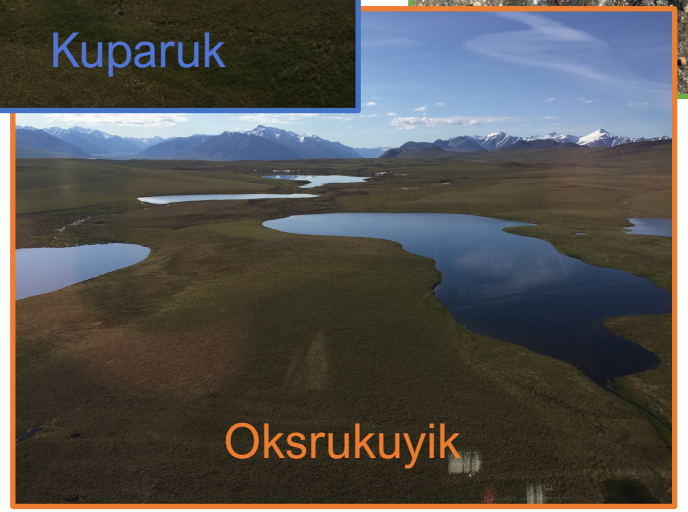
We visit >40 unique locations within each watershed within a few hours.

Gives a "snapshot" of distributed stream chemistry.

Has several benefits, including getting to see the entire watershed with a literal bird's eye view.



Wood et al., 1998, JoH



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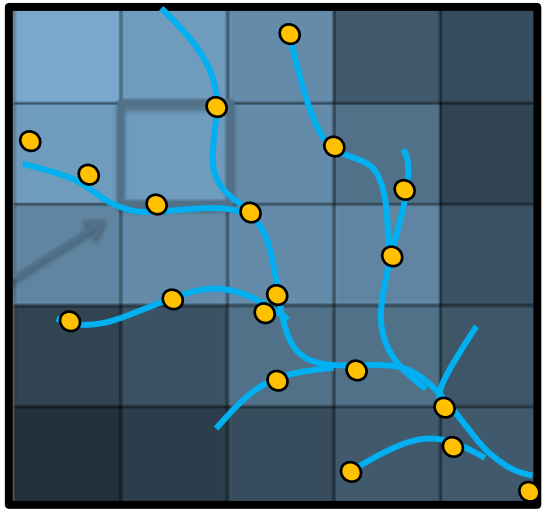

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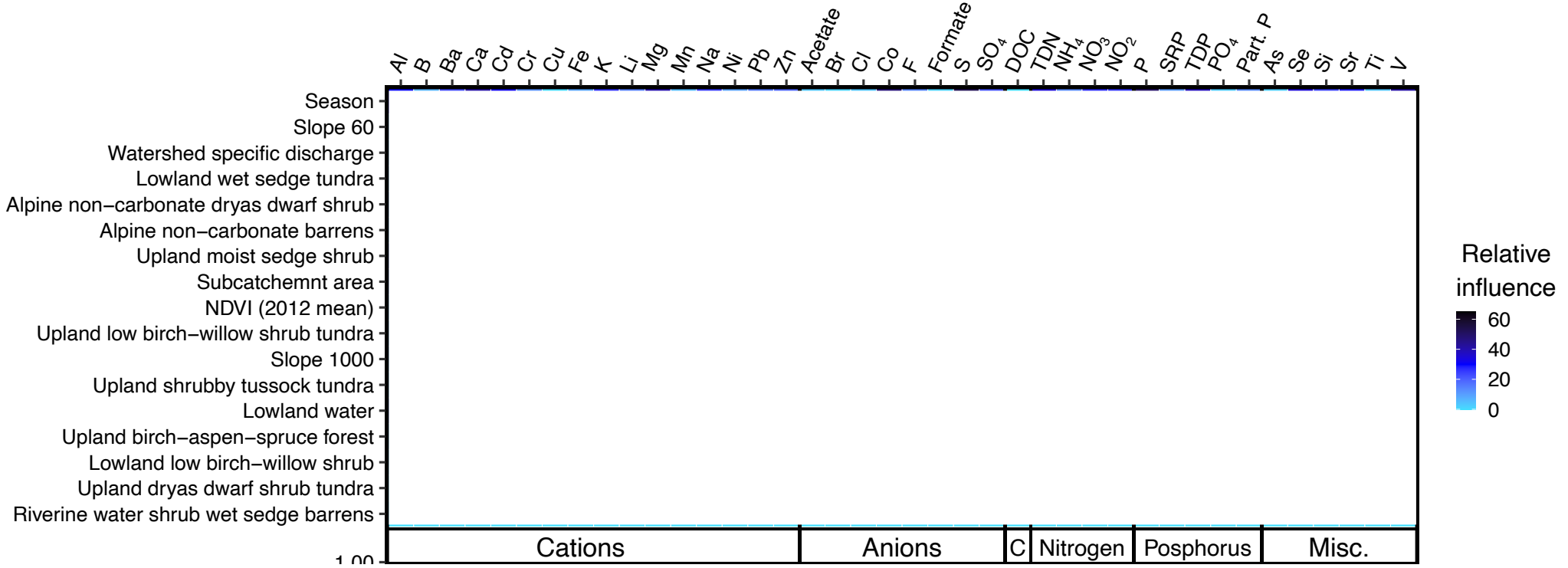
Why do we see what we see in the stream channel?

Expectation: Lateral nutrient flux will be influenced by season & veg!



Williamson, Zarnetske, Shogren et al. *In Prep*

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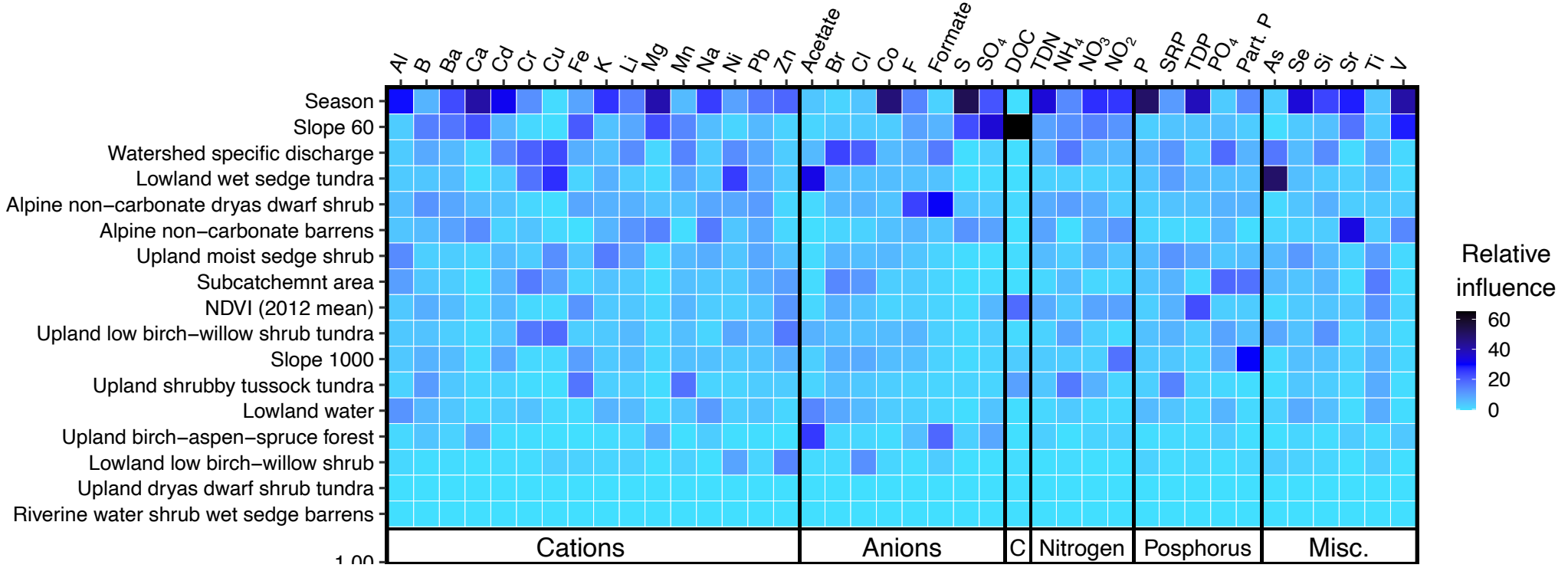

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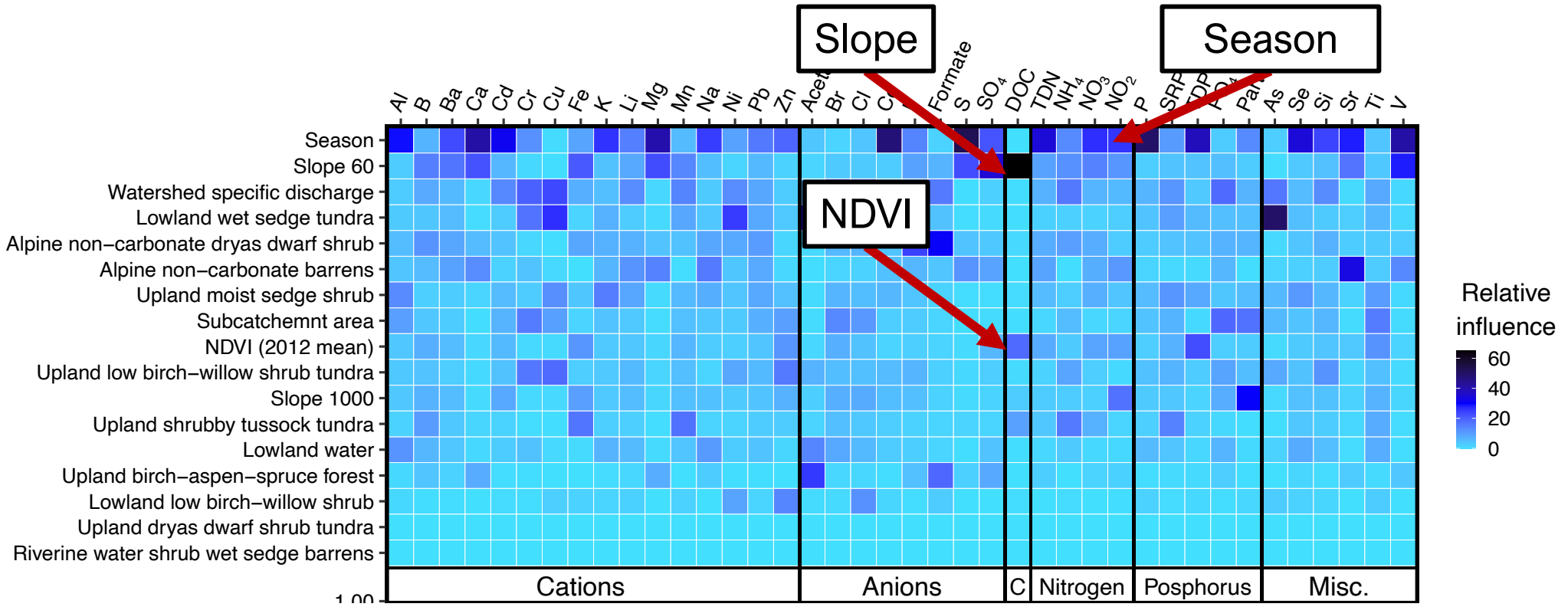

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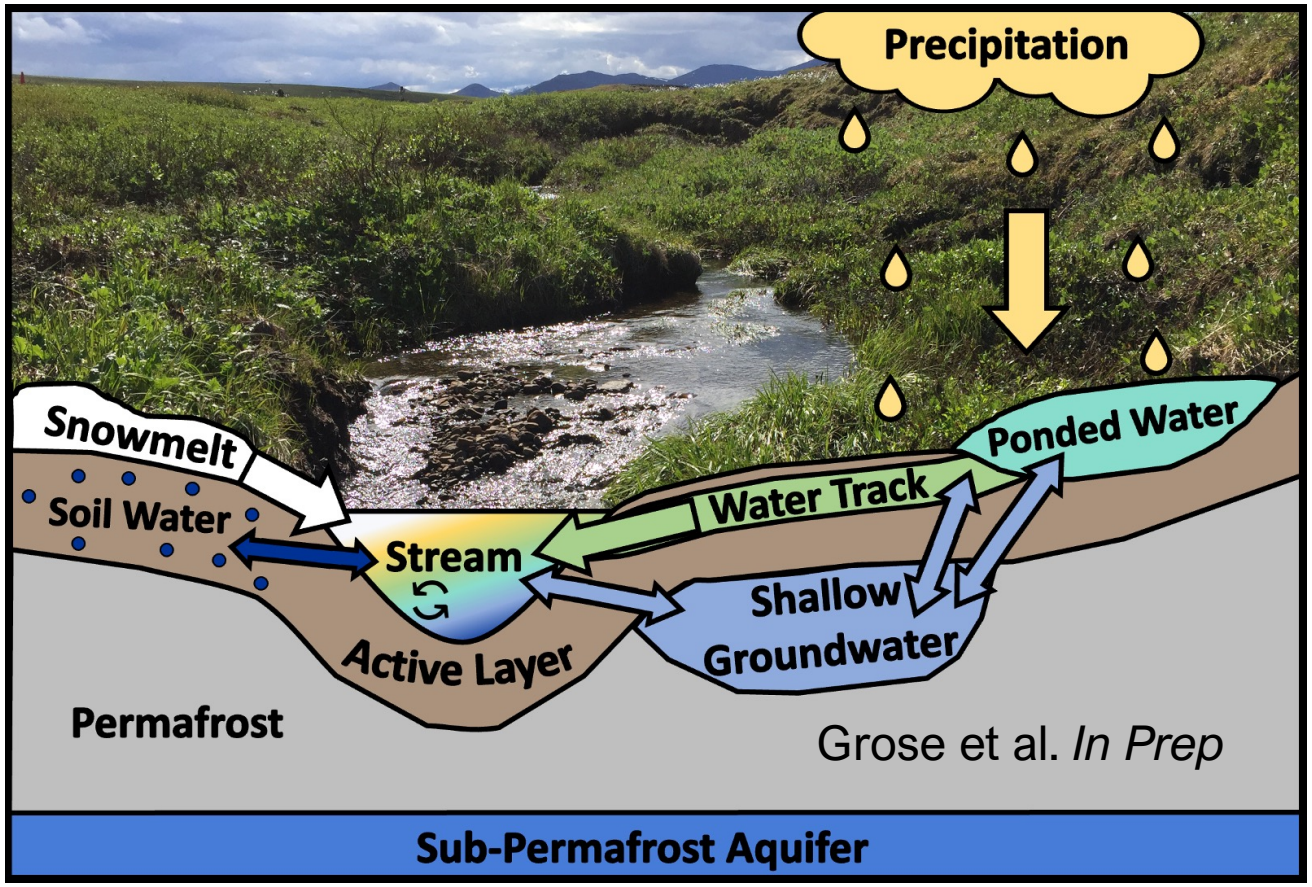

Let's use water tracers to constrain how flow-paths & source areas change!

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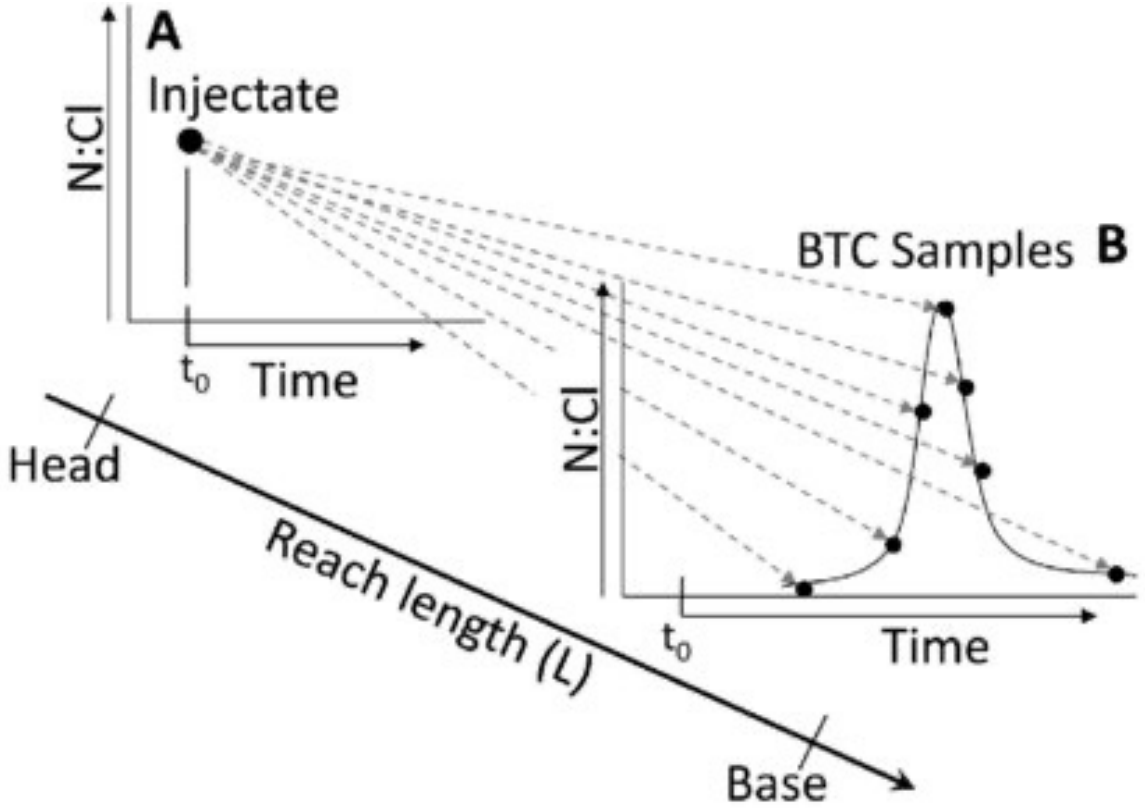
Expectation: Lateral nutrient flux will be influenced by uptake capacity!



Covino et al. 2010

How does the instream processing potential change across the thaw season?

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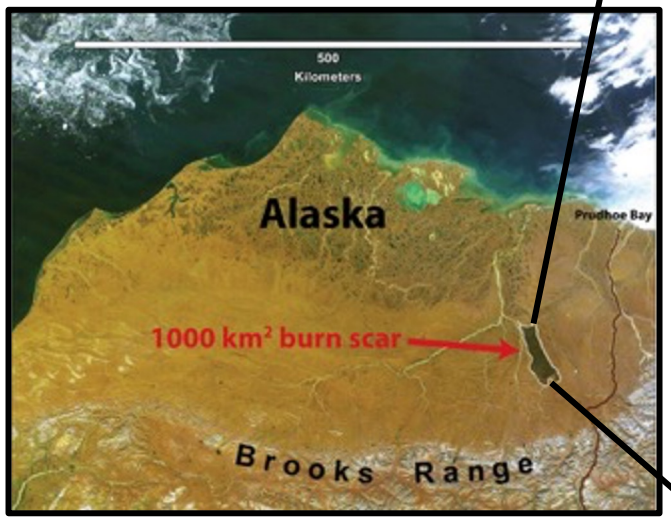
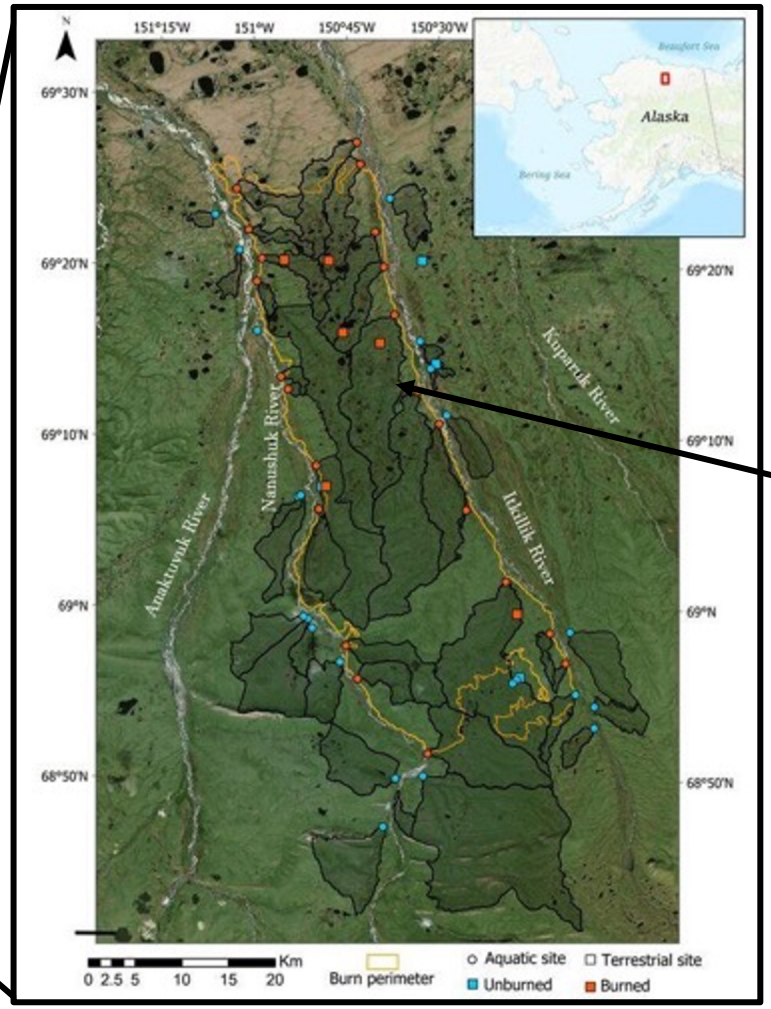


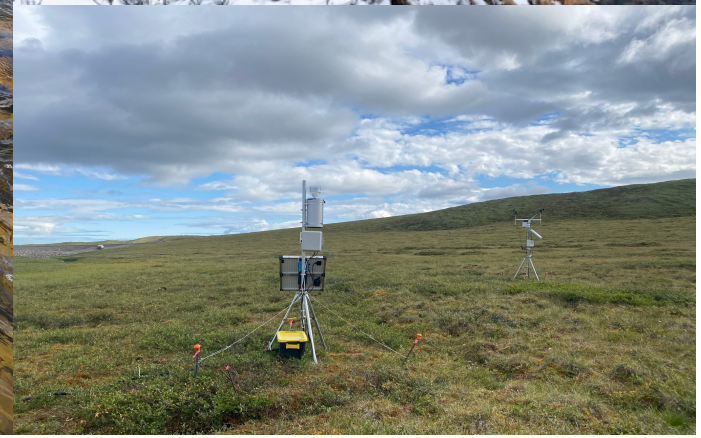


Abbott, Zarnetske, Shogren et al. *Global Change Biology* 2021

High-Frequency Monitoring

When, where, and how are Arctic landscapes most “leaky” to C and N?

Capturing snowmelt & storms using traditional “grab” sampling approaches can be challenging & dangerous.



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- Total Dissolved Nitrogen (TDN)
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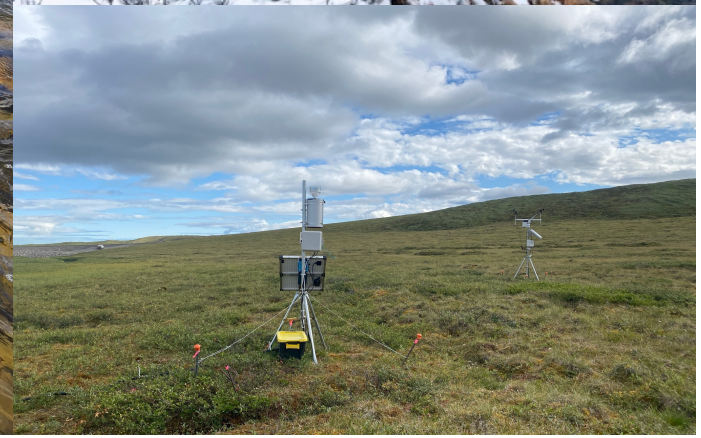

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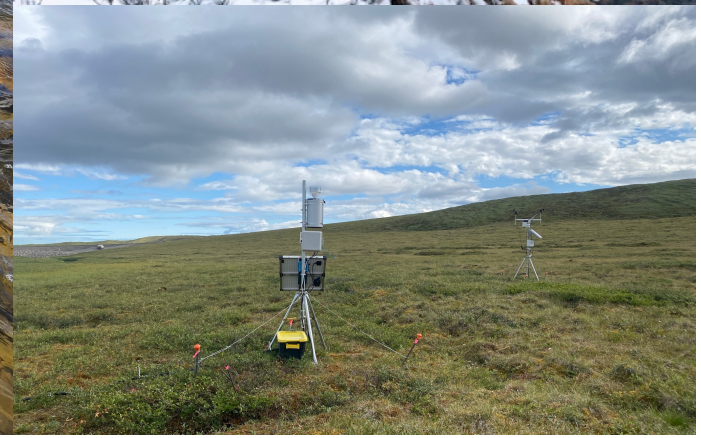
What can we learn?
Dominant seasonal & landscape influences on biogeochemical exports.



Arctic Study Sites: Toolik Field Station

High frequency monitoring at each watershed outlet allowed us to compare export patterns across three distinct landscape archetypes of the North Slope.

Kuparuk
(Tundra)

Low gradient
↑ Biomass
↓ N, ↑ C
92 km²

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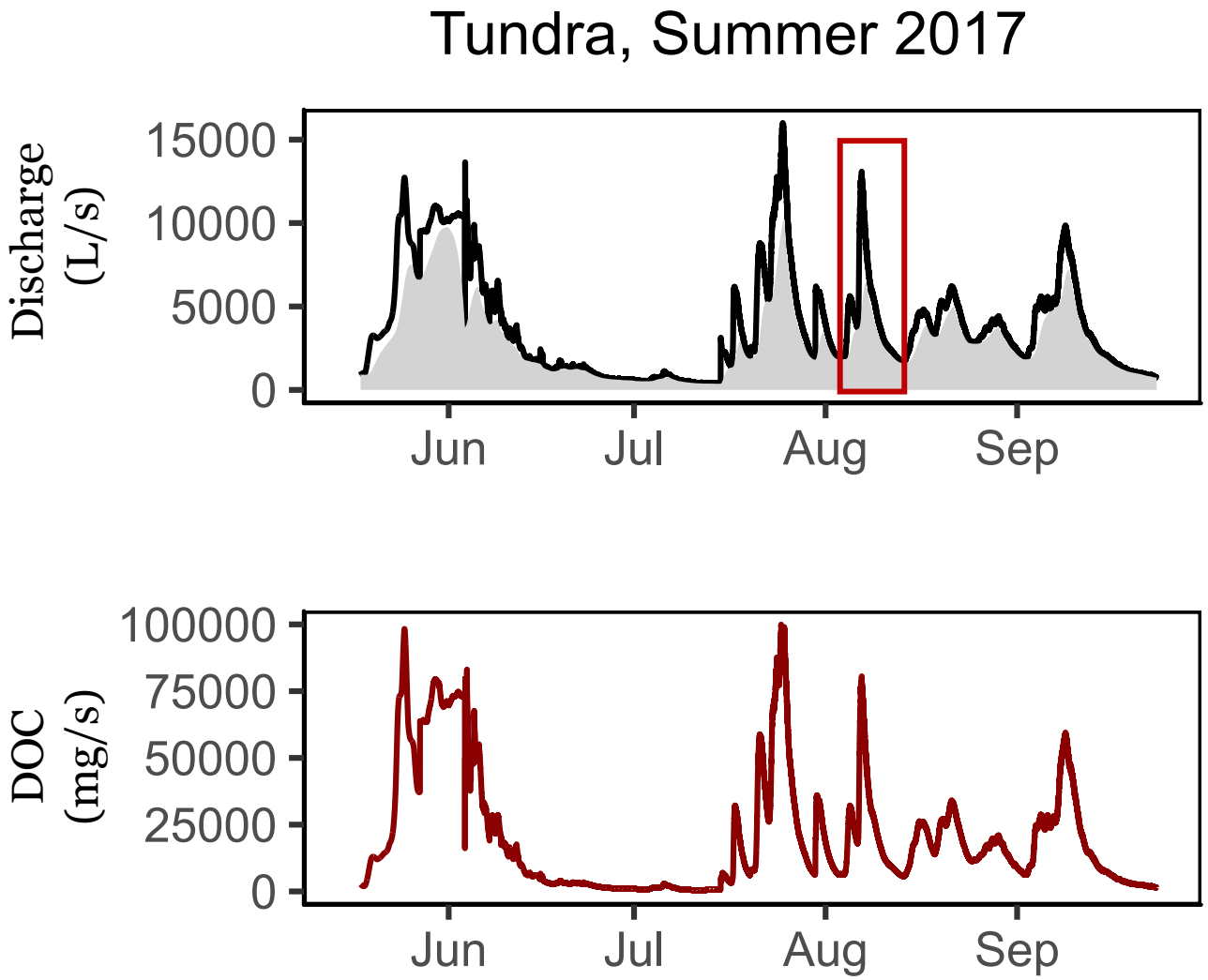
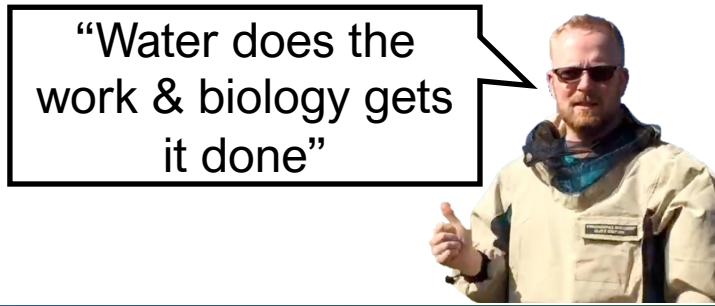
Trevor Creek
(Alpine)

High gradient
↓ Terrestrial biomass
↑ N, ↓ C
42 km²

Analysis: Event-scale Concentration-Discharge (CQ) Responses

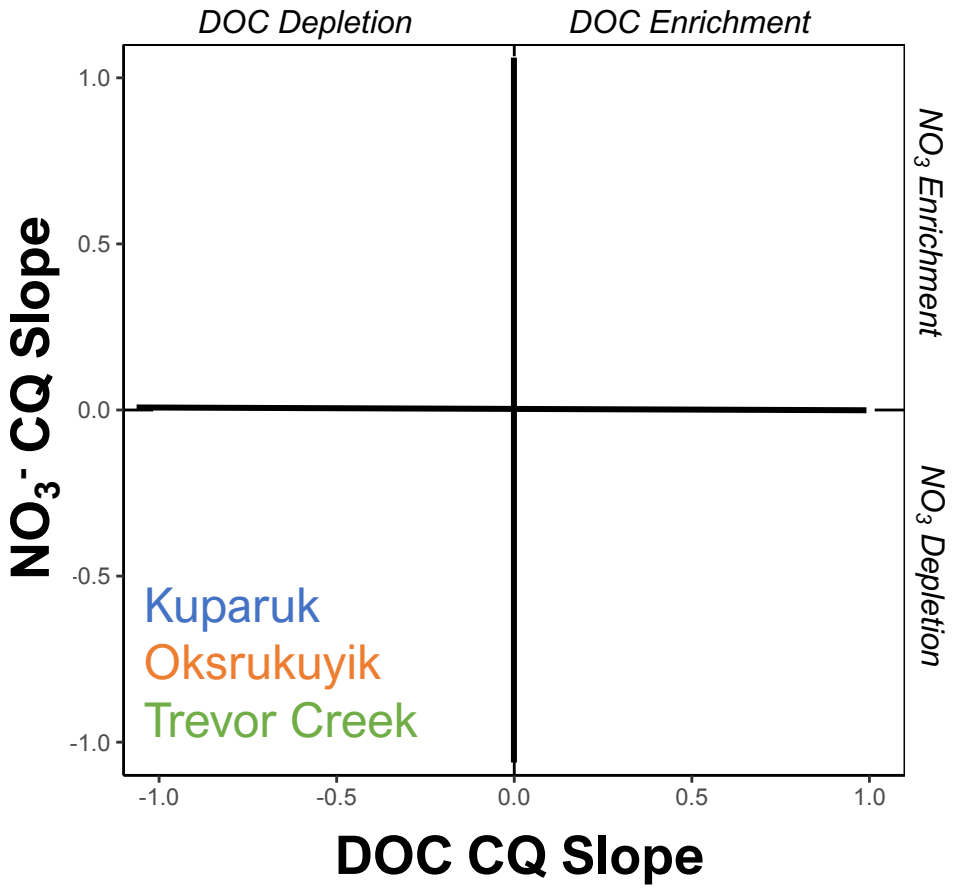


For each event, we estimate the CQ slope (β), which is like taking the watershed's pulse.



Where, when, and how are Arctic landscapes most "leaky" to C and N?

Result: CQ patterns clustered predictably by landscape topography.



Shogren et al. *2021 L&O*

Does the watershed template control material transport?

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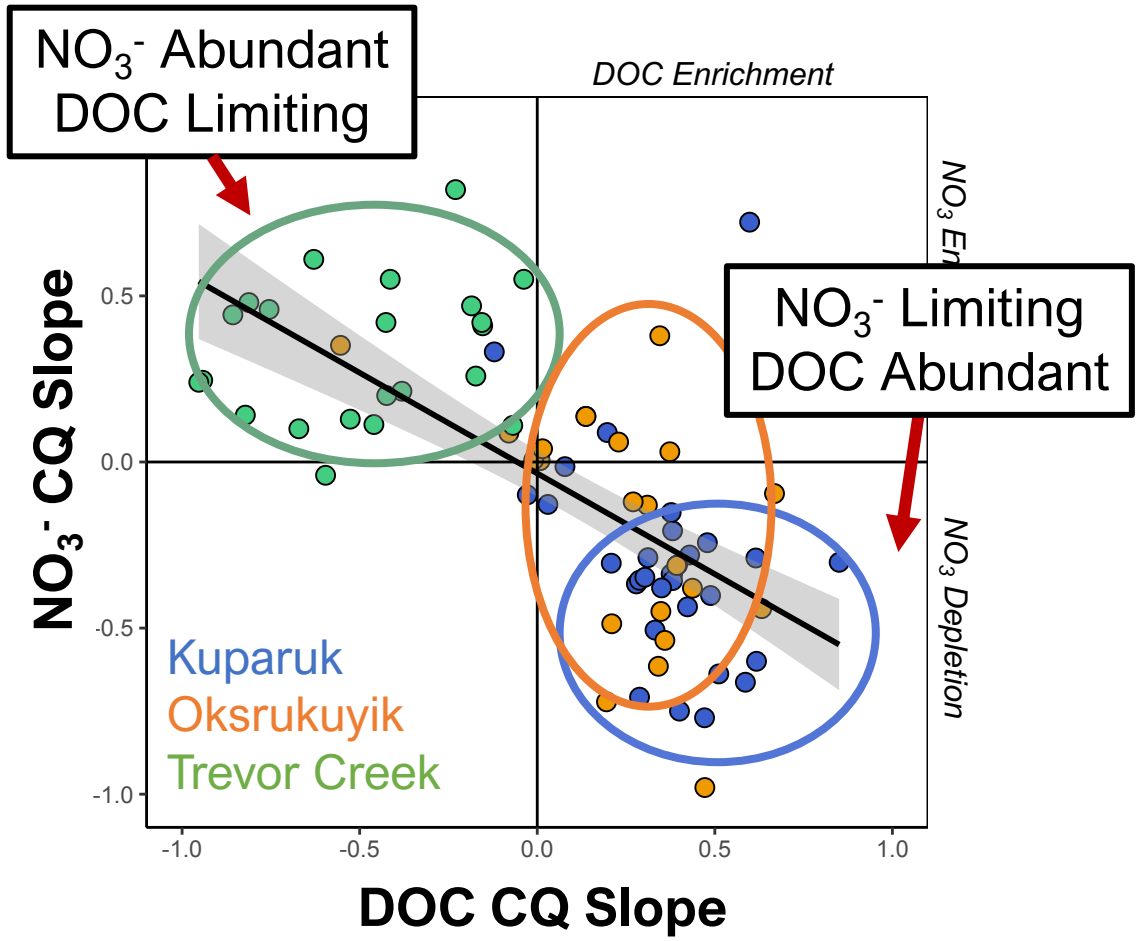


Trevor (Alpine): storms can deplete organic matter pools relative to N stores.

Kuparuk (Tundra): storms flush available NO_3^- pools and elevate DOC flux from land to water.

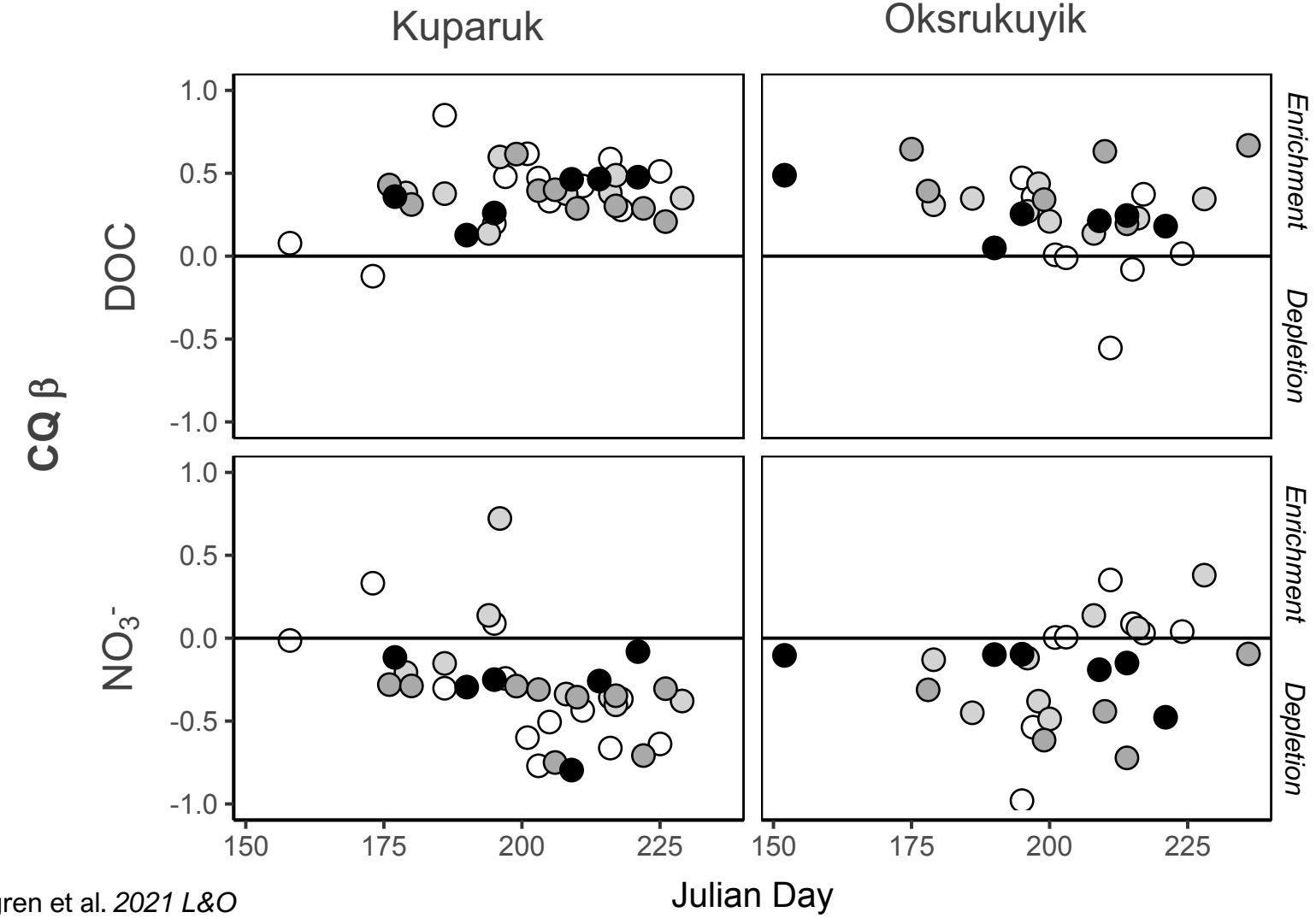
Oksrukuyik (Lake-influenced): storms consistently flush DOC, but NO_3^- behavior "buffered" by lake influence.

Landscape Matters!

Shogren et al. *2021 L&O*

Where, **When**, and how are Arctic landscapes most "leaky" to C and N?

Result: No significant seasonal trends in CQ behavior.

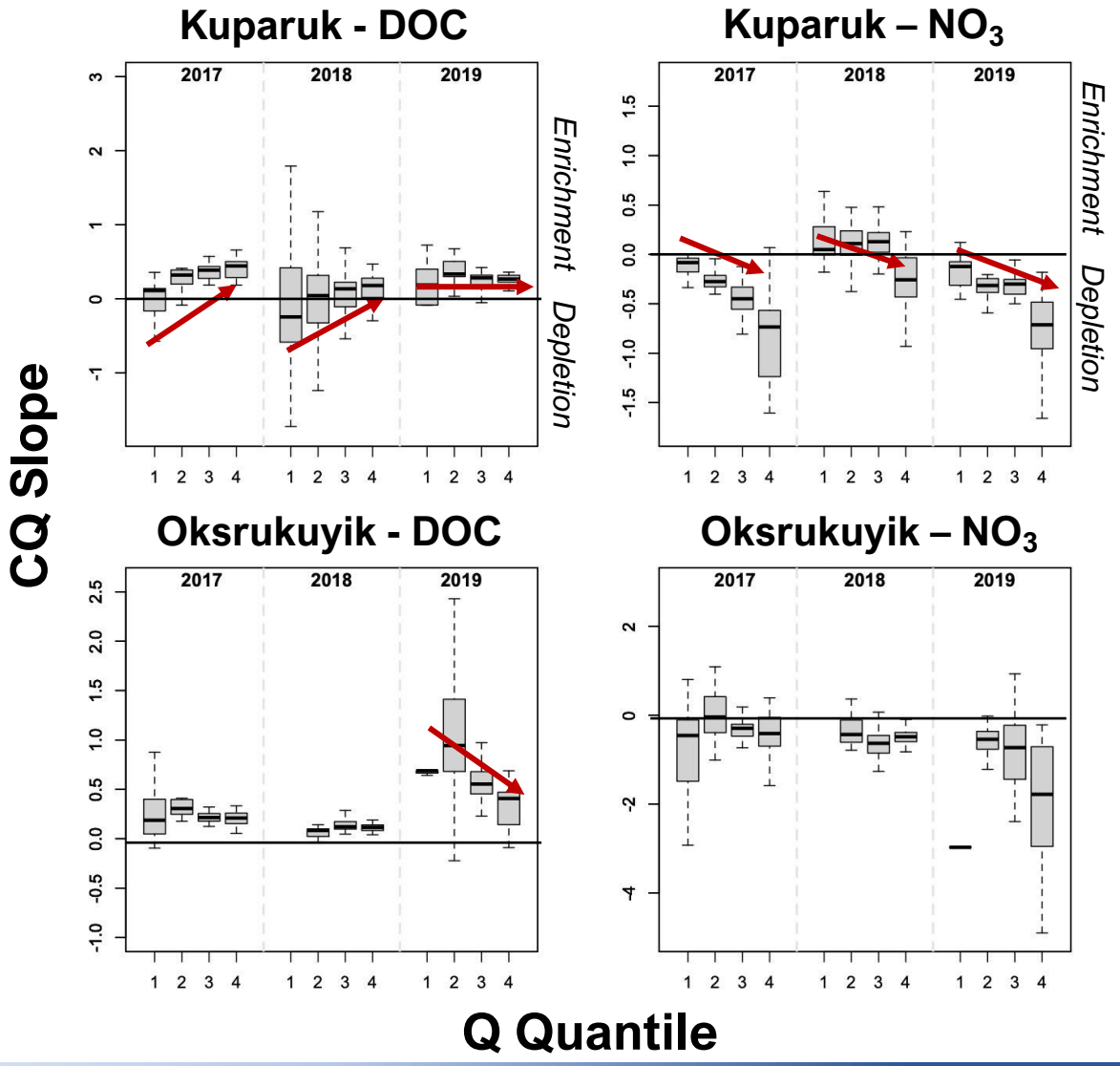


At the watershed scale, we do not observe a clear influence of seasonal ALT.

Shogren et al. *2021 L&O*
Shogren et al. *In Prep* for JGR Biogeosciences

When, Where, and **How** are Arctic landscapes most "leaky" to C and N?

Result: Event size controls the magnitude of the CQ response



Kuparuk (Tundra): In most years, larger storms have a larger impact on NO_3^- slope and can also influence DOC.

Oksrukuyik (Lake-influenced): No difference in CQ slopes across discharge quantiles.

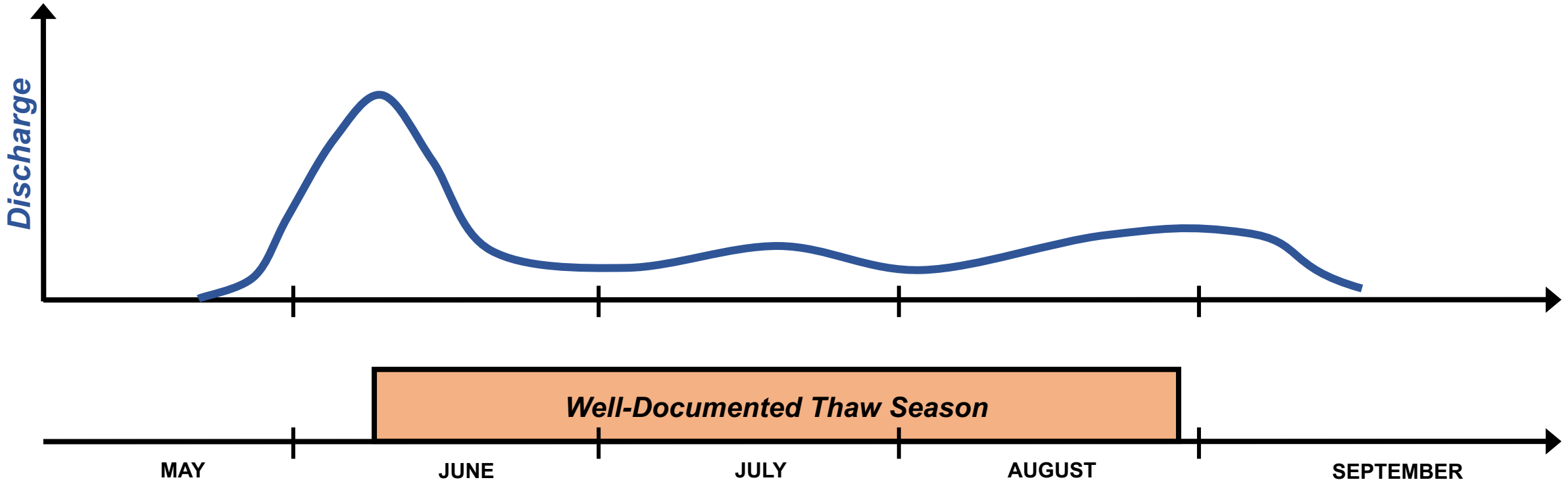
More water = more C mobilization & stronger N depletion.

When, Where, and How are Arctic landscapes most “leaky” to C and N?

Shogren et al 2020 ERL, Ernakovich et al. 2019

When, Where, and How are Arctic landscapes most "leaky" to C and N?

This region is rapidly experiencing the impacts of climate change, resulting in intensified hydrology (when & how water flows).



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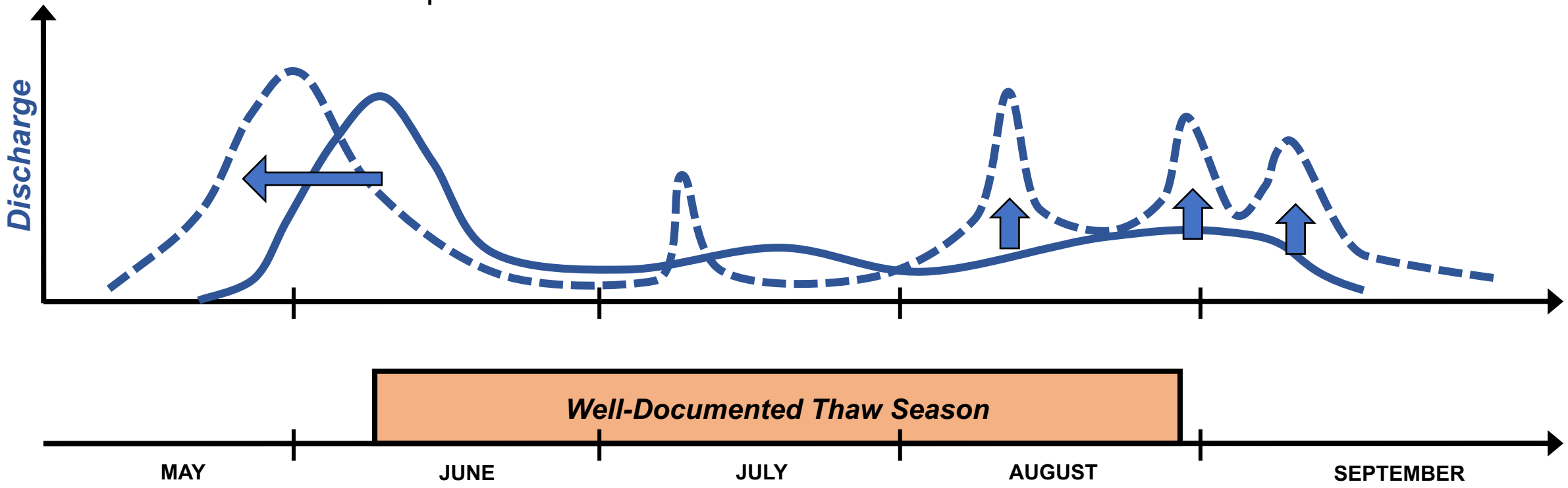
When, Where, and How are Arctic landscapes most "leaky" to C and N?

This region is rapidly experiencing the impacts of climate change, resulting in intensified hydrology (when & how water flows).

As snowmelt occurs earlier and late-season storm events become more common, potential to move more material from land to water.



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What is happening in between these states?
What are we missing?

Water quality sensors can help us fill these gaps!

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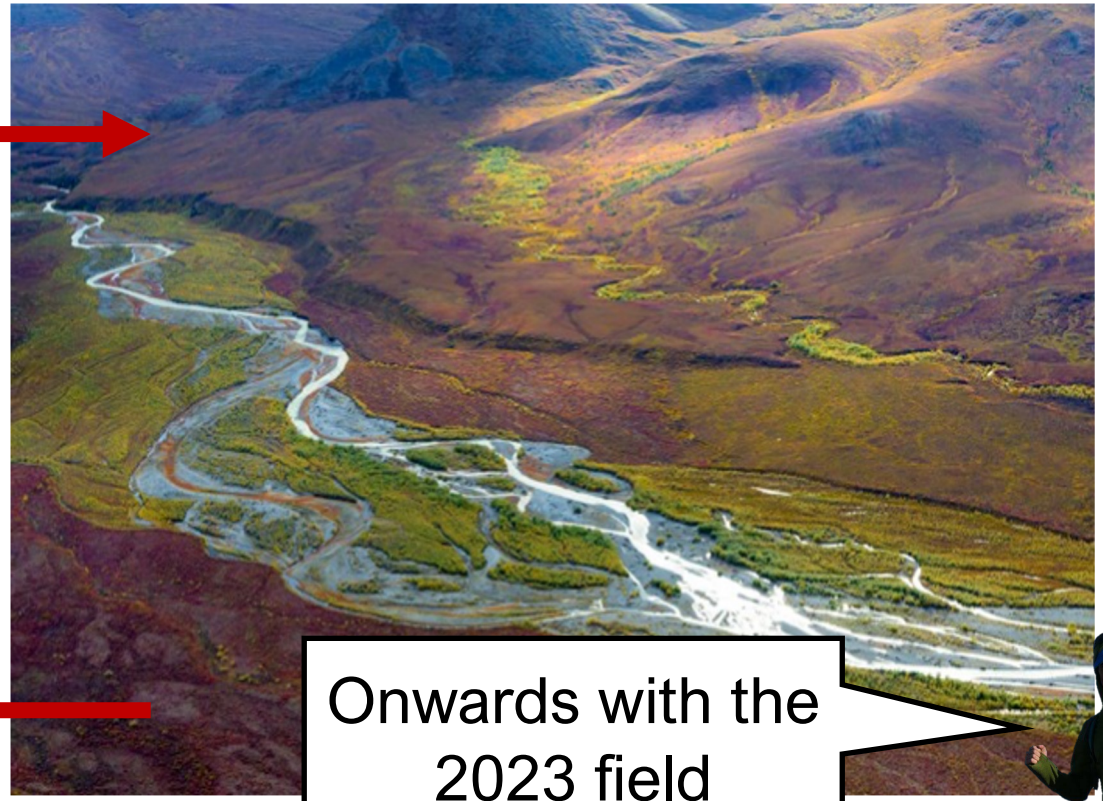
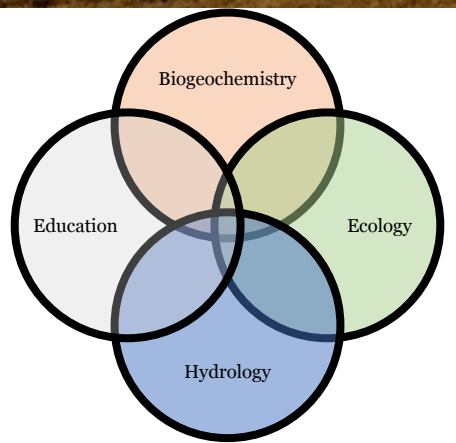


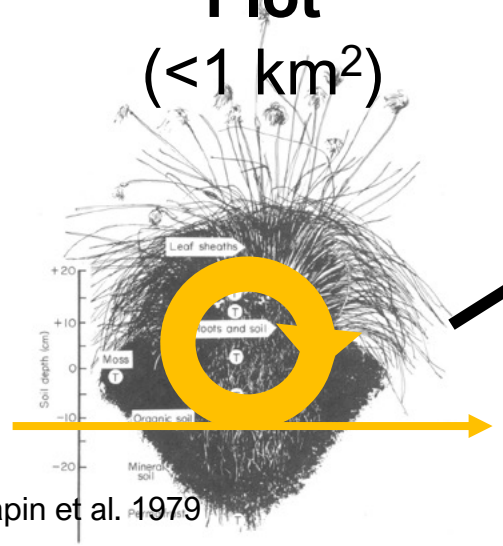
Onwards with the 2023 field season!



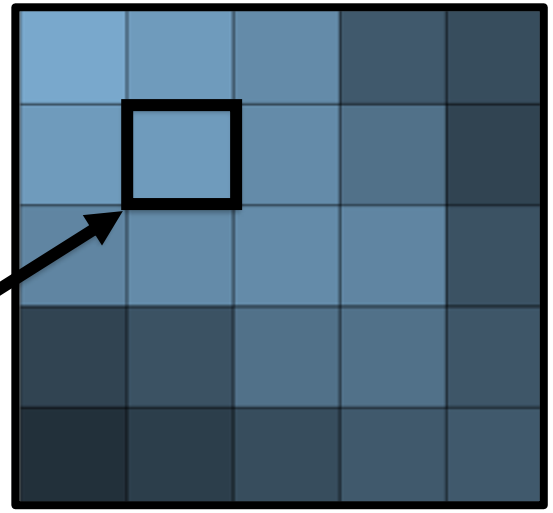
Collaborators, Students, & Other Support: Benjamin Abbott, Breck Bowden, Jon O'Donnell, Jay Zarnetske, Sam Bratsman, Brian Brown, Sam Cairns, Julie Doll, Megan Duda, Rebecca Frei, Natasha Griffin, Kara Haas, Emma Haines, Frances Iannucci, Joseph Lee-Cullin, Alex Medvedeff, Jansen Nipsko, Abigail Rec, Liz Schultheis, Rachel Watts, Toolik EDC, Qiwen Zhang, *and many others!*

What is happening to carbon and nutrients in the vast permafrost region?

Plot
(<1 km^2)



Chapin et al. 1979



Wood et al., 1998, JoH

Regional
(>10,000 km^2)

Ecologically "Closed"
Tight Nutrient Cycling

Chapin et al. 1978, Shaver et al. 2014, Liu et al. 2018, others

Ecologically "Open"
Net Nutrient Loss

Tank et al. 2016, Toohey et al. 2016, McClelland et al. 2007, Wild et al. 2019