Water In a Warming Alpine: Surprises in the Water Quality Record of Niwot Ridge, Colorado and Beyond

Eve-Lyn S. Hinckley

Dept. of Ecology and Evolutionary Biology, University of Colorado, Boulder
Cooperative Institute for Research in Environmental Science

Environmental Biogeochemistry Group

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The Life of a Biogeochemist


Alpine

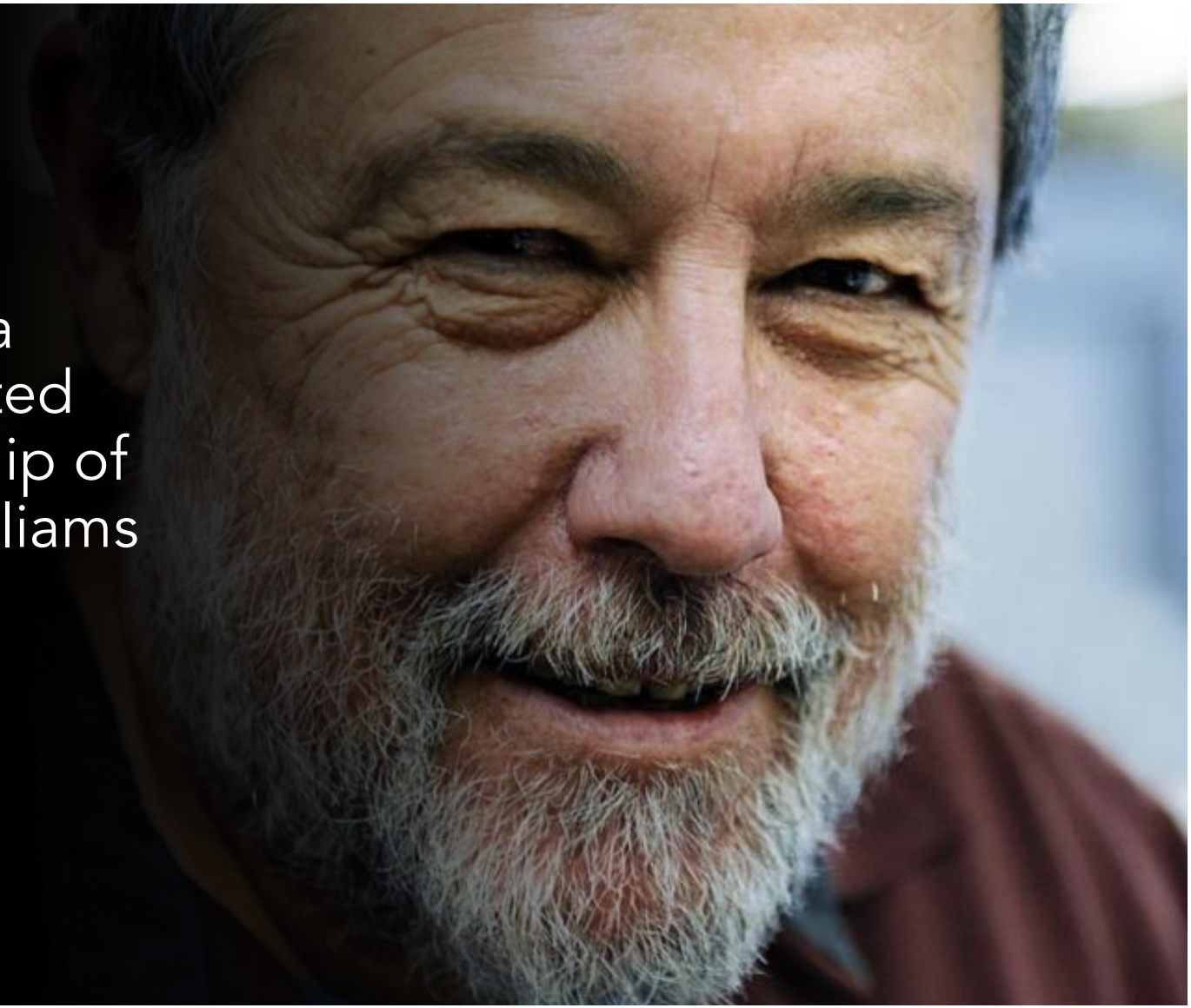

Subalpine

Today

How are global change drivers shifting in the alpine, and what are the implications for water quality and ecological communities?

- Long-term trends in global change drivers
- Focused studies in the alpine and subalpine areas
- What does it all mean?

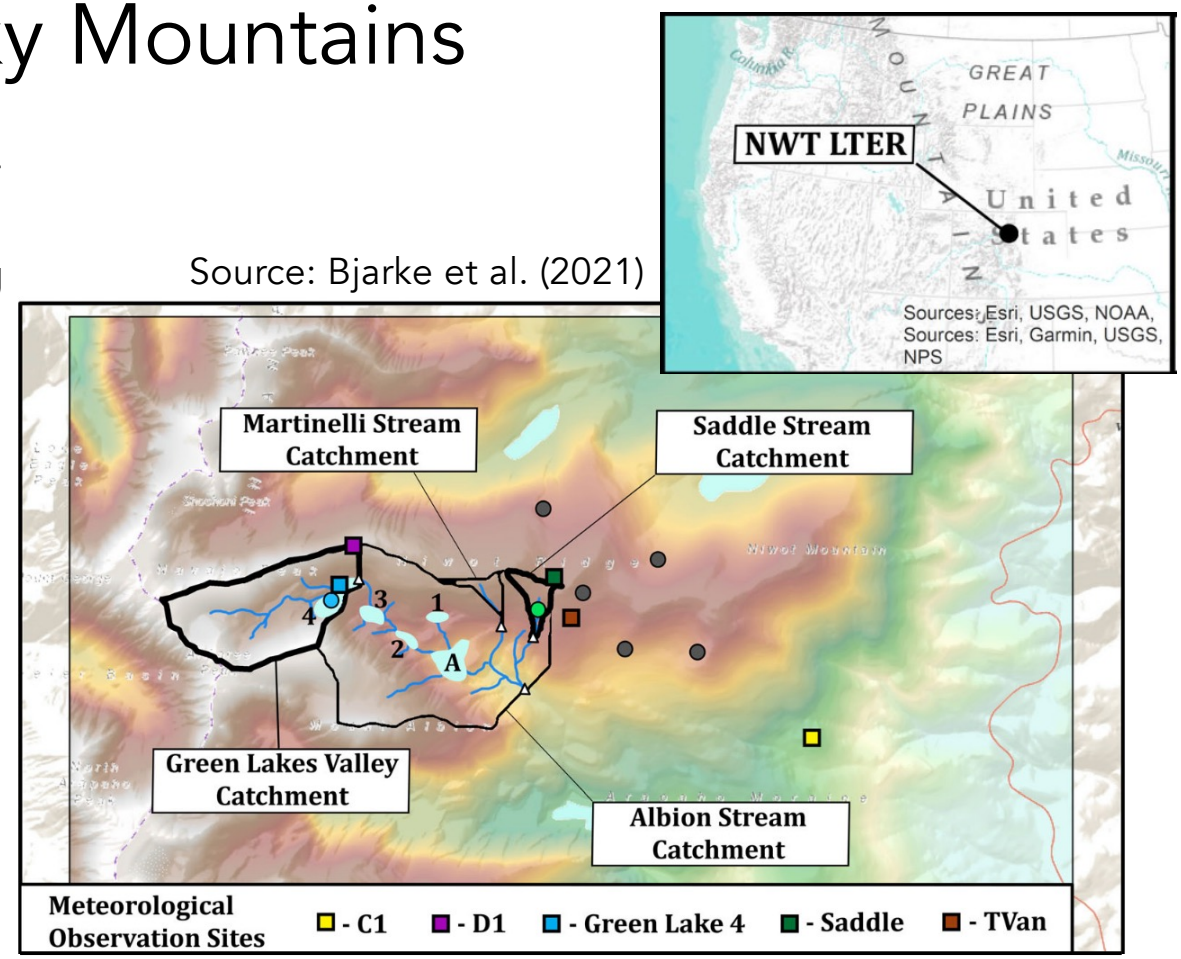
Many of these data points were collected under the leadership of Professor Mark Williams – aka Snobear



Niwot Ridge Long-term Ecological Research Site – Colorado Rocky Mountains

- A place to leverage long-term climate and ecological observations to investigate how the alpine is changing

Source: Bjarke et al. (2021)



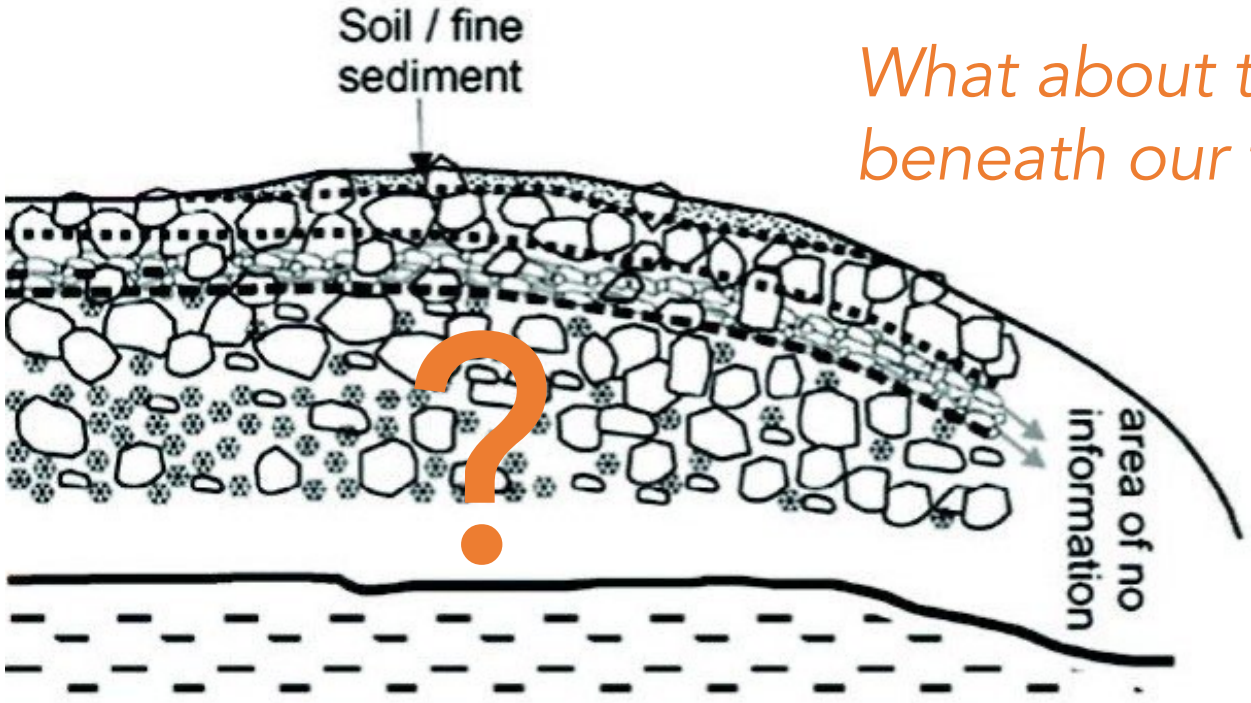
Niwot Ridge Long-term Ecological Research Site – Colorado Rocky Mountains

- A place to leverage long-term climate and ecological observations to investigate how the alpine is changing

- Local findings provide insights into how alpine zones are changing around the world

Source: www.theguardian.com

Niwot Ridge Long-term Ecological Research Site – Colorado Rocky Mountains



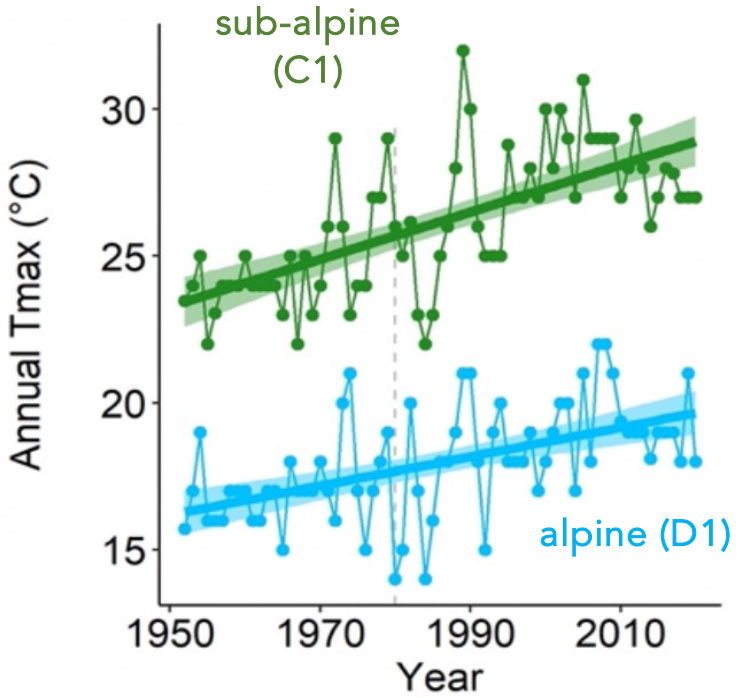
What about the world beneath our feet?

Source: Litaor (2022)

Niwot Ridge Long-term Ecological Research Site – Colorado Rocky Mountains

<u>Global Change Drivers</u>

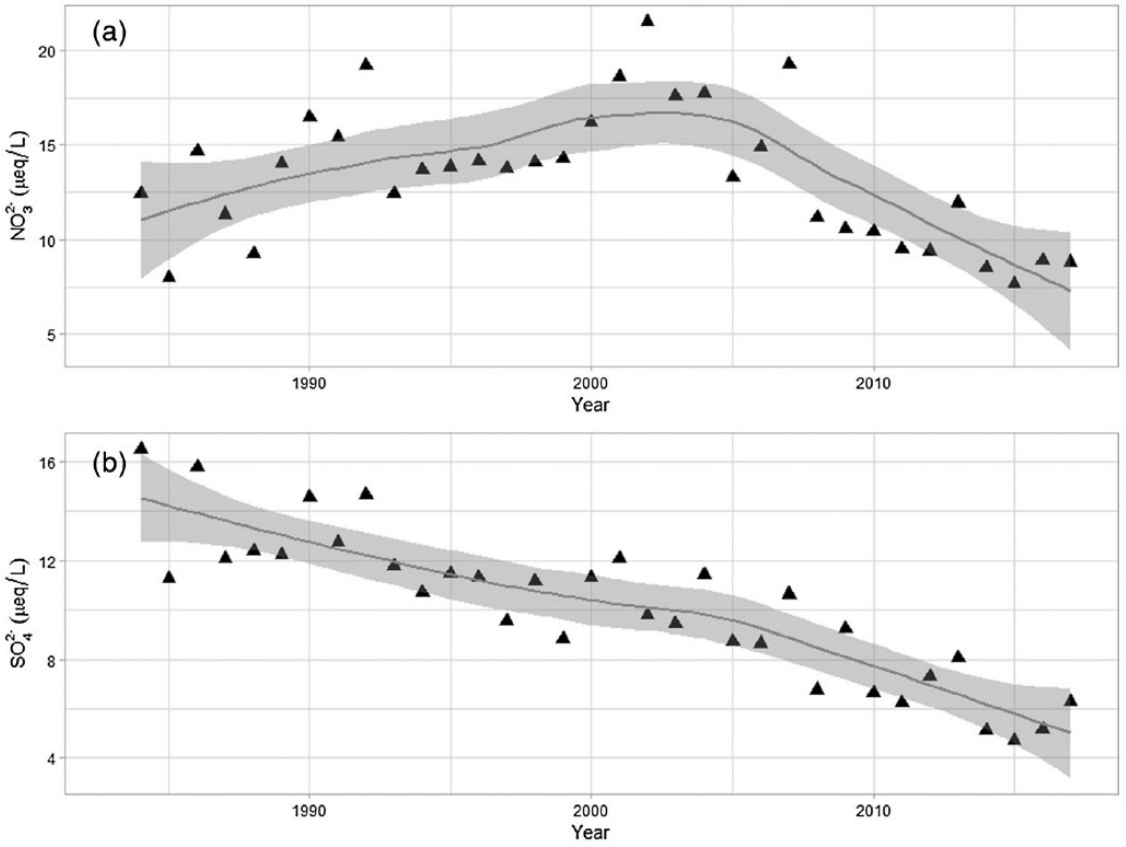
- Air temperature is increasing



Niwot Ridge Long-term Ecological Research Site – Colorado Rocky Mountains

<u>Global Change Drivers</u>

- Air temperature is increasing
- Atmospheric deposition of nitrate (NO_3^-) and sulfate (SO_4^{2-}) is decreasing

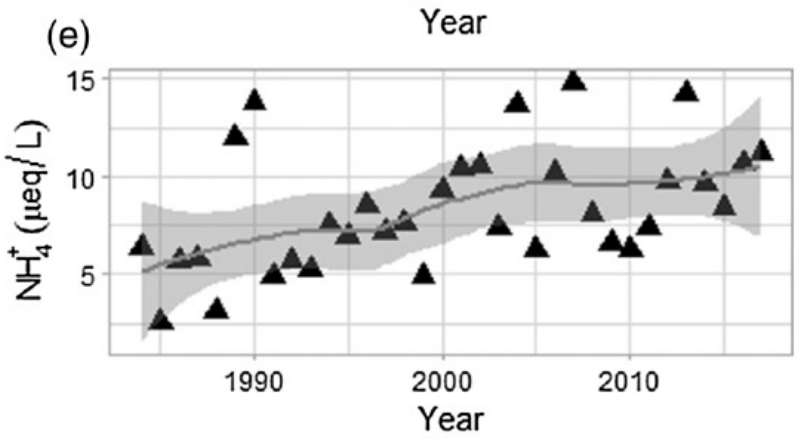


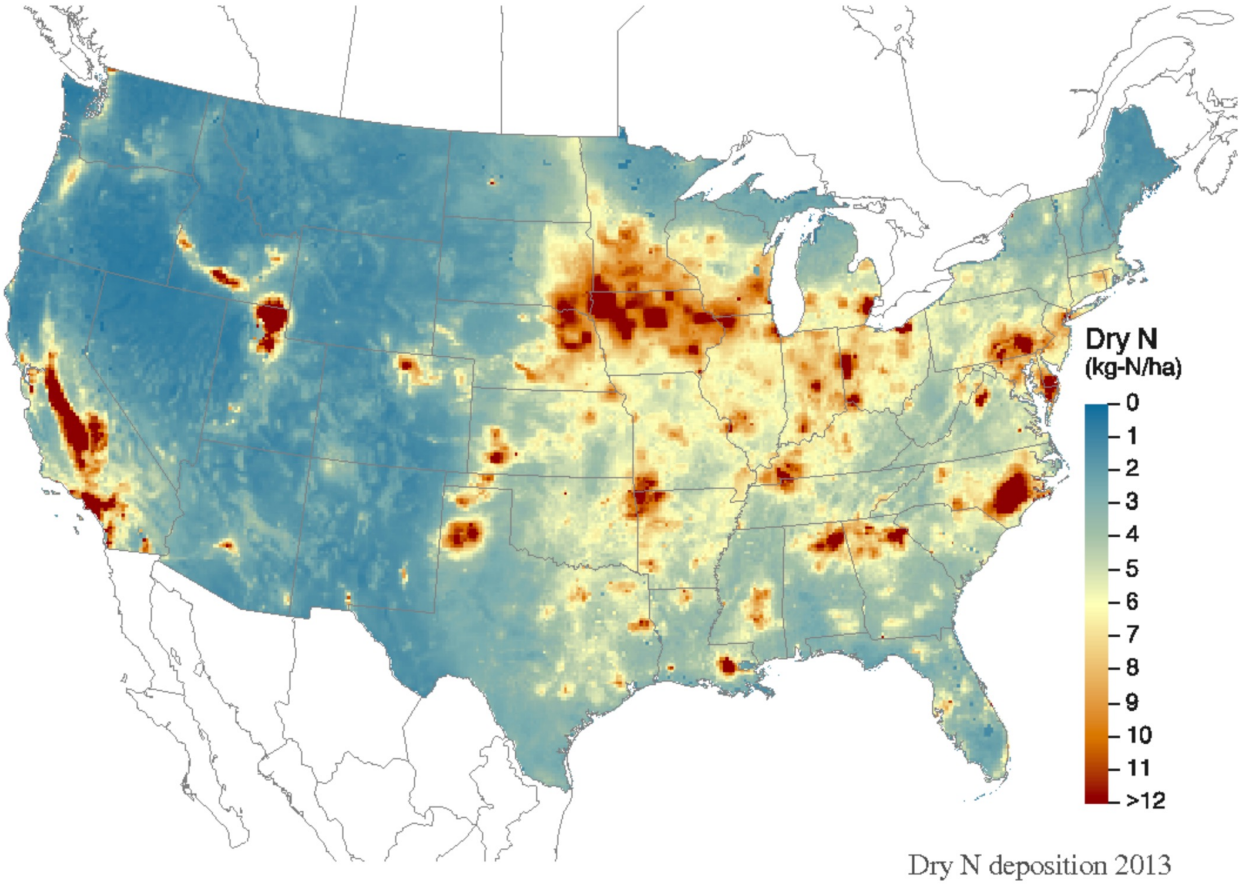

Regulation works!
nrdc.org

Niwot Ridge Long-term Ecological Research Site – Colorado Rocky Mountains

<u>Global Change Drivers</u>

- Air temperature is increasing
- Atmospheric deposition of nitrate (NO_3^-) and sulfate (SO_4^{2-}) is decreasing
- But! Atmospheric deposition of ammonium (NH_4^+) is increasing





Dry N deposition 2013

Source: CASTNET/CMAQ/NTN/AMON/SEARCH

USEPA 10/15/14

Focused studies in the alpine and subalpine areas

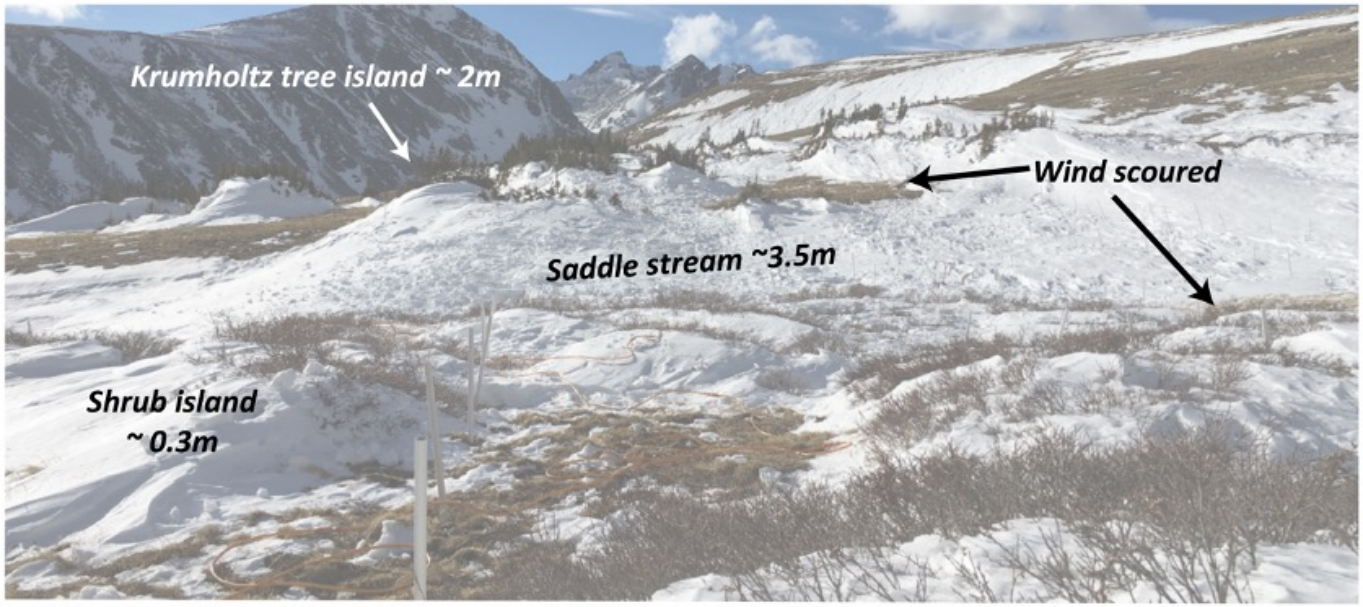
1. Subsurface imaging: What is the subsurface structure and ice extent? How is it changing?

2. Mapping hydrological zones and connectivity: How much of the landscape is connected by water and how will it change over time?

3. Export of reactive elements: Are the mass balances of reactive elements changing over time?

4. Wetland investigation: Are these small areas key to storage and/or reaction of elements?

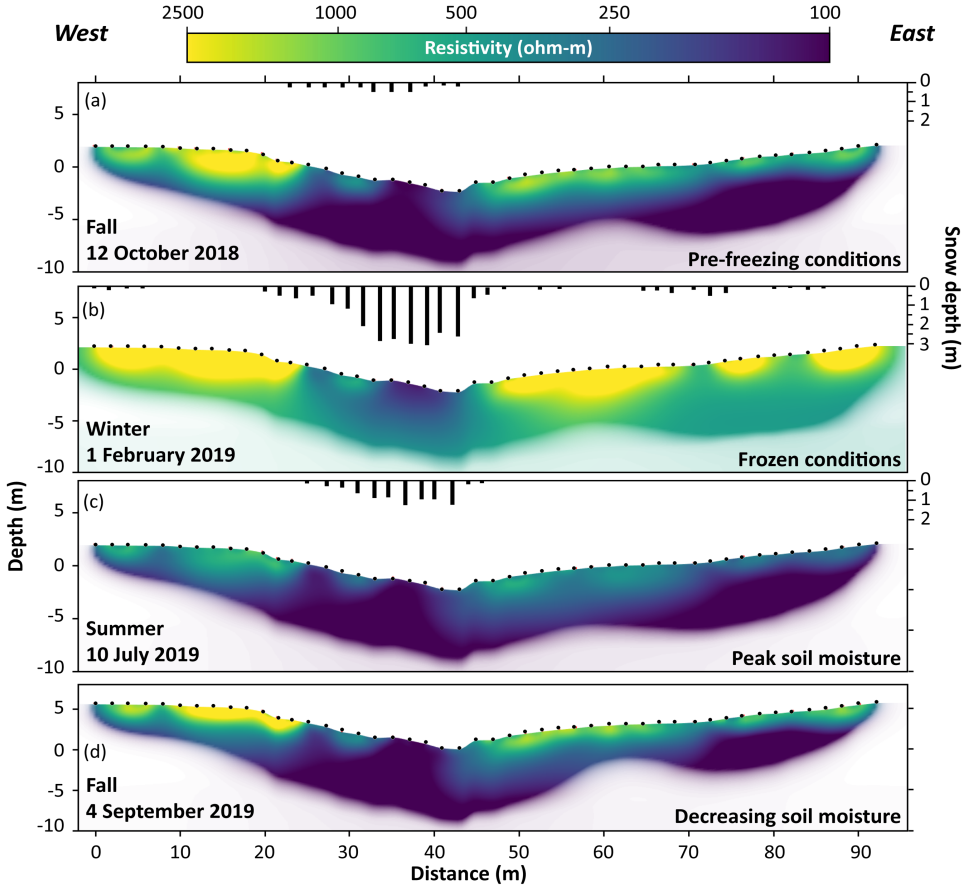
1. Subsurface imaging

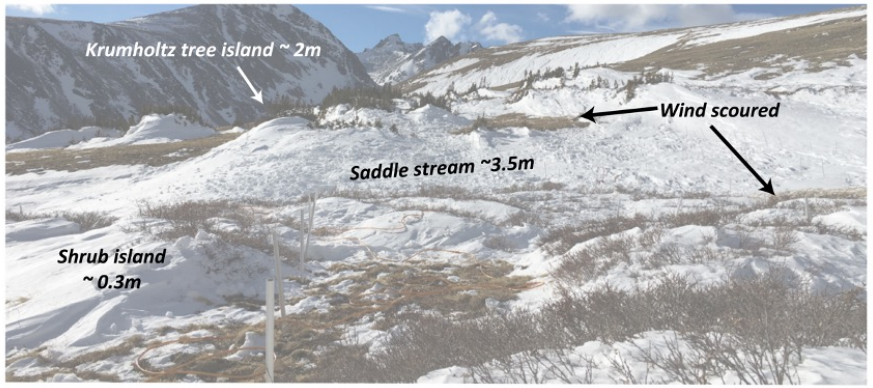


Rey, Hinckley, Walvoord, and Singha (2021) *HP*

1. Subsurface imaging

Electrical Resistivity Tomography (ERT)

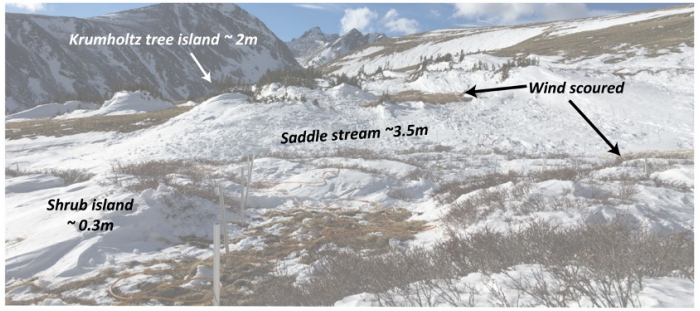




Shallow snow depth = deeper freezing depth

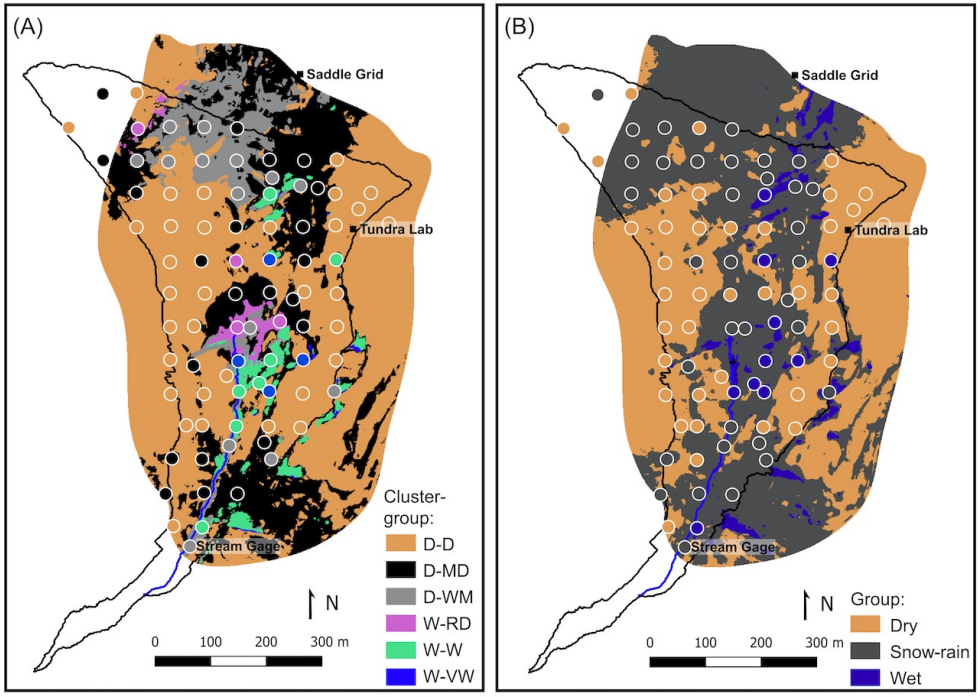
Rey, Hinckley, Walvoord, and Singha (2021) *HP*

2. Mapping hydrological zones and connectivity



- Combines ground-based and airborne observations, machine learning, and statistical clustering to identify hydro groups, after Wainwright et al. (2015)
- About half of the catchment remains dry and disconnected for most of the year
- Wetter areas are a much smaller area, but likely play a big role in element cycling, support of organisms, water export

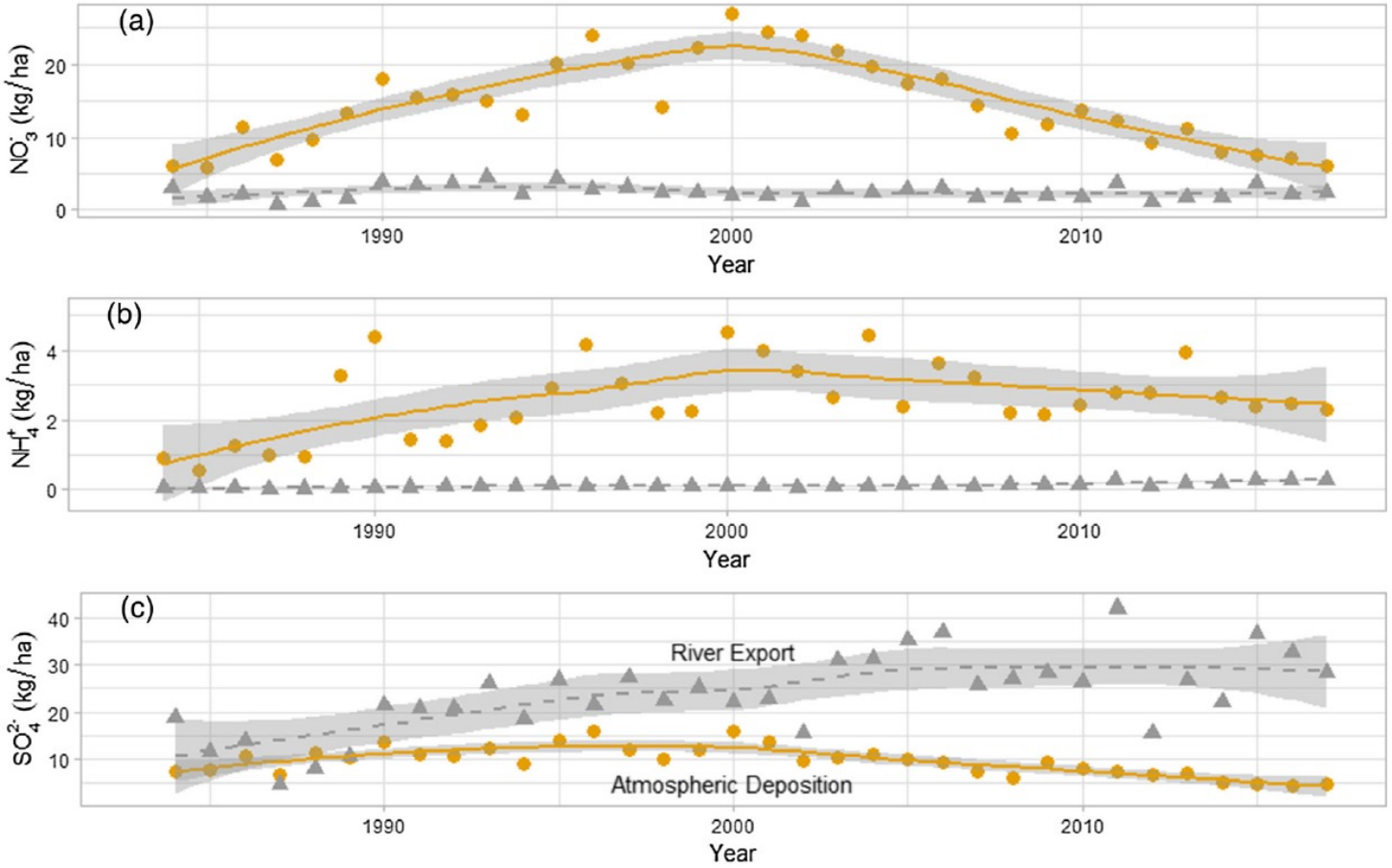
Hermes et al. (2020) *Frontiers in Water*



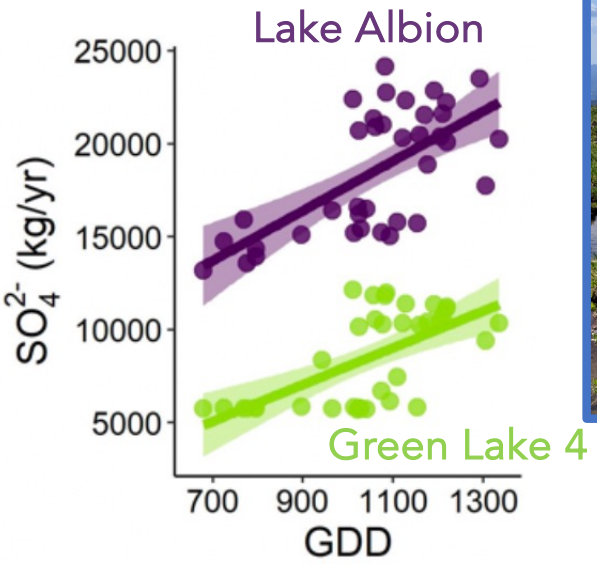
3. Export of reactive elements - streams

Area-normalized trends tell an interesting story

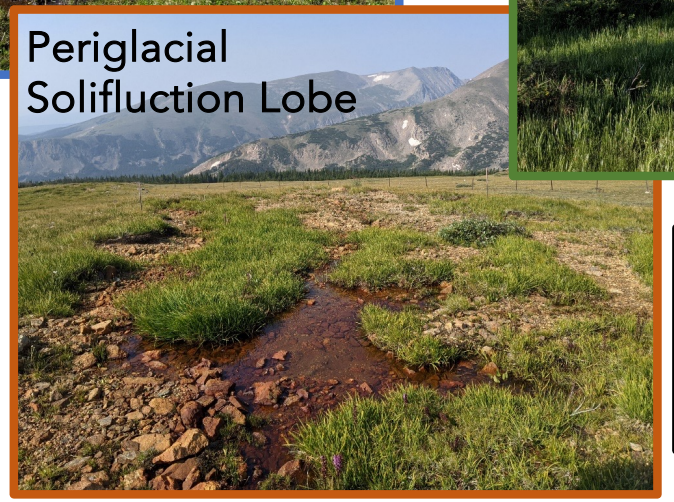
- Nitrate down to background
- Ammonium from ag? It is staying in soils or moving to streams and lakes?
- Sulfate is higher in streams than in deposition-–there's an internal source



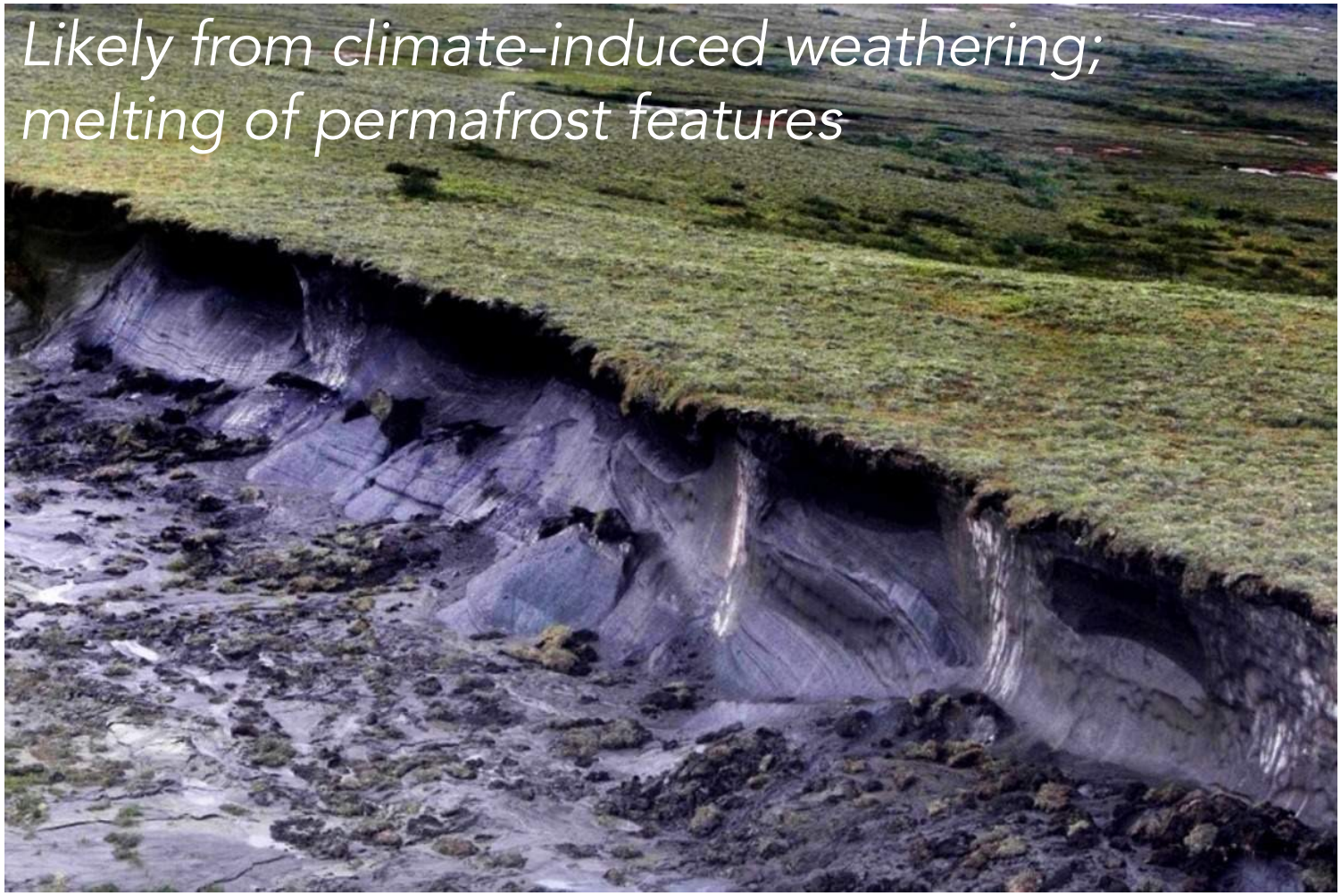
3. Export of reactive elements – lakes and wetlands



Evidence of increasing sulfate export with greater number of warm days



Do the wetlands have disproportionately higher rates of C, N, S, and Hg cycling?


Likely from climate-induced weathering; melting of permafrost features

4. Wetlands: Element Storage and Reactivity

Lower [S], atmospheric signal

Snowpack
(Mast et al. 2001, *Atmos. Environ.*)

Precipitation
(Bao 2003, *J. Geophys. Res.*)

Bedrock
(Mast et al. 2011, *Biogeochemistry*)

Alpine Wet Meadow

Periglacial
Solifluction Lobe

Higher [S], geologic signal

Atmospheric deposition

Geologic weathering

$\delta^{34}S\text{-}SO_4^{2-}$ (‰)

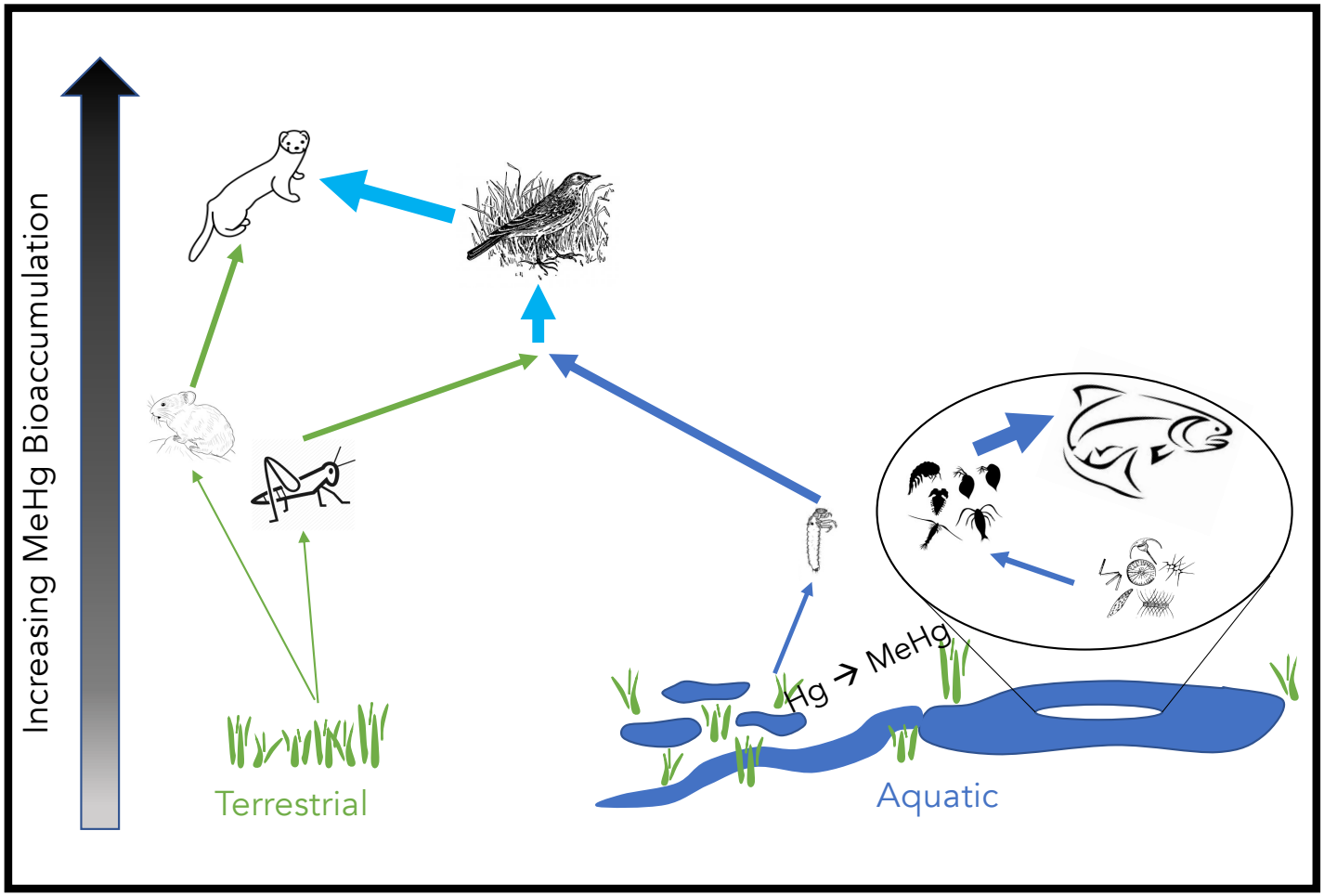
10
5
0
-5
-10

0
20
40

$SO_4^{2-}\text{-}S$ (mg L^{-1})

Huber et al., *in prep*

4. Wetlands: Element Storage and Reactivity



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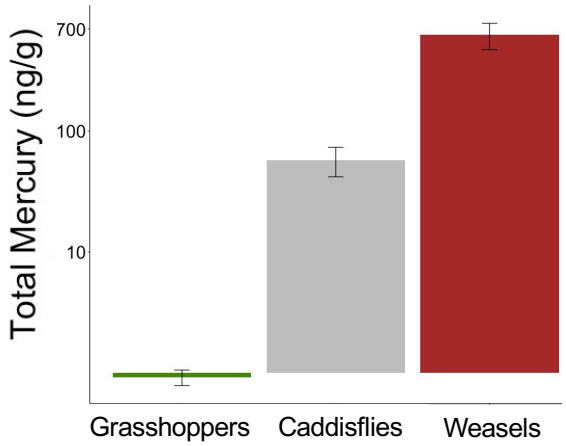

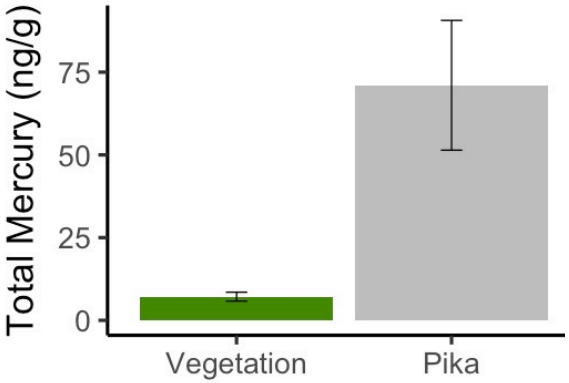

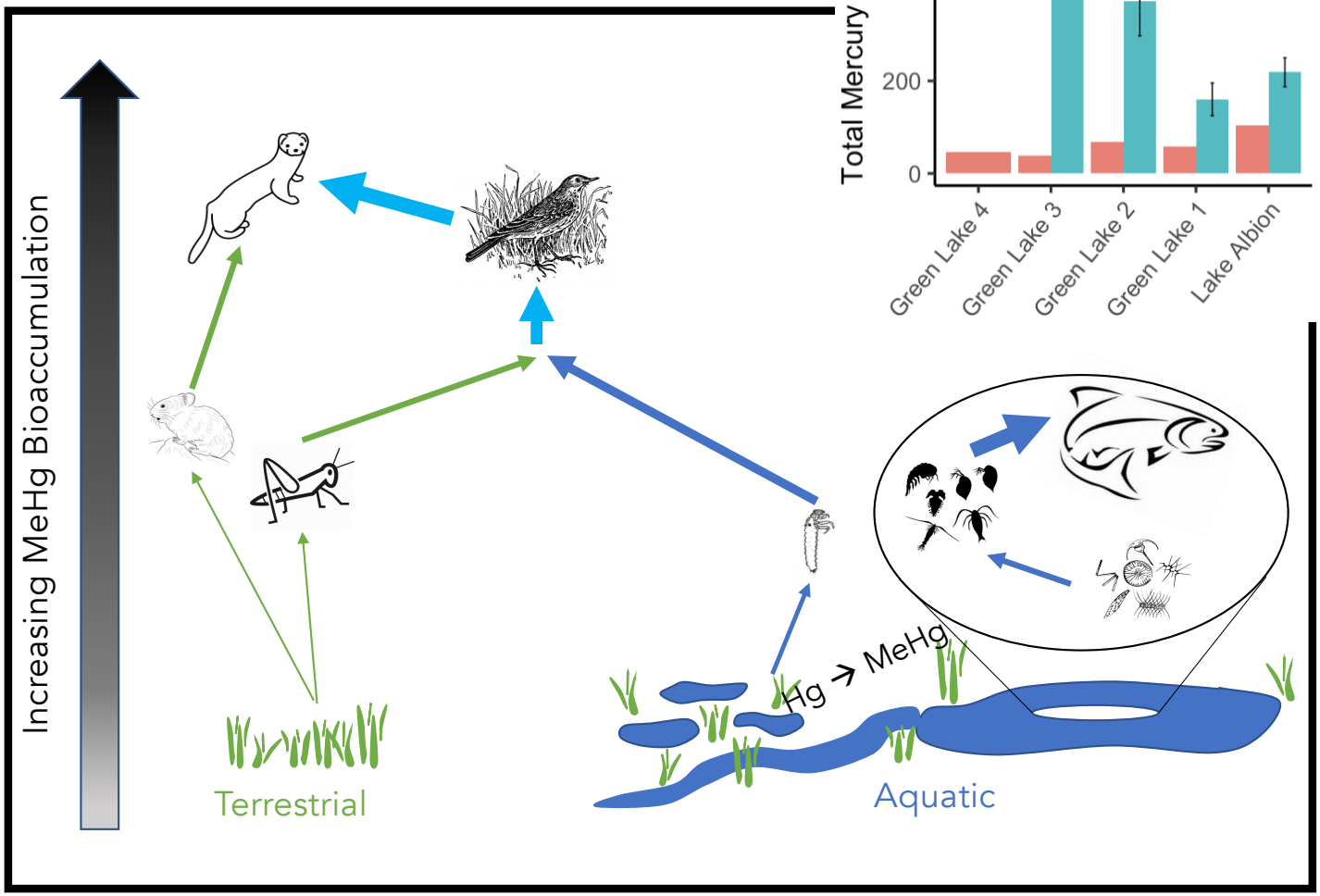

Integrating Multiple Lines of Evidence to Understand the Changing Alpine

Arikaree Glacier, Niwot Ridge (Source: Niwot LTER)

- Global change drivers are a "mixed bag"
- Ice features are thawing; dynamic throughout the year
- Long-term trends in element mass balances are changing—atmospheric NH_4^+ deposition is increasing, and export of SO_4^{2-} is increasing
- Wetter portions of the landscape are small, but may be biogeochemical "reactors" on the landscape
- Different S pools and sources among wetlands – potential for variability in biogeochemical dynamics and role of these features in the alpine

Acknowledgments

Environmental Biogeochemistry Group

My collaborators in the research shown today

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Contact

eve.hinckley@colorado.edu
www.ebgscience.org

(Source: Niwot LTER)