Arctic microbiomes in a landscape of change

Jessica Ernakovich and team

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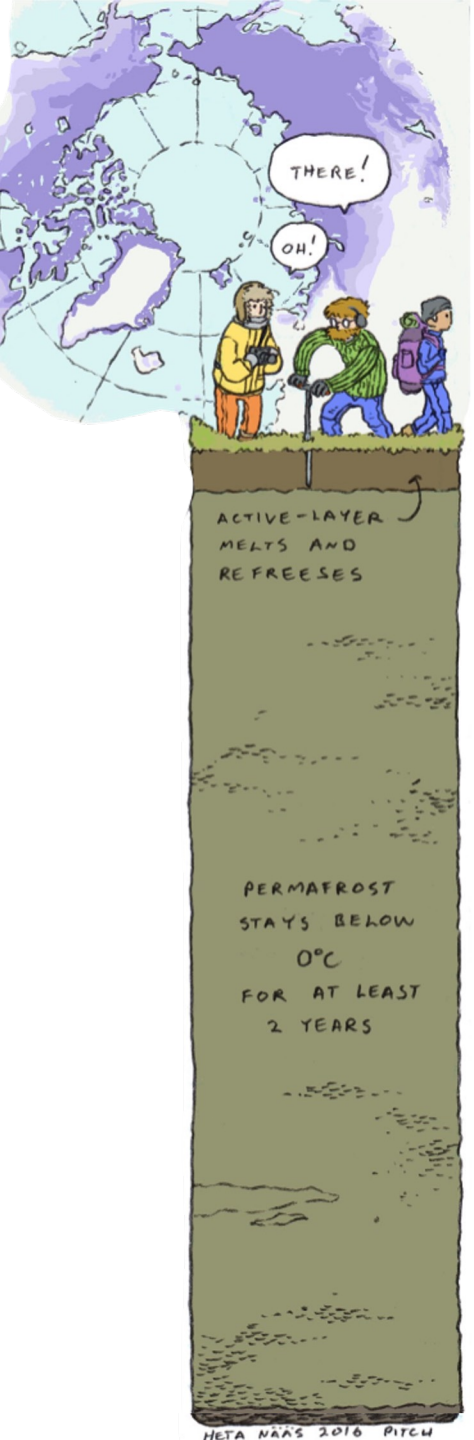
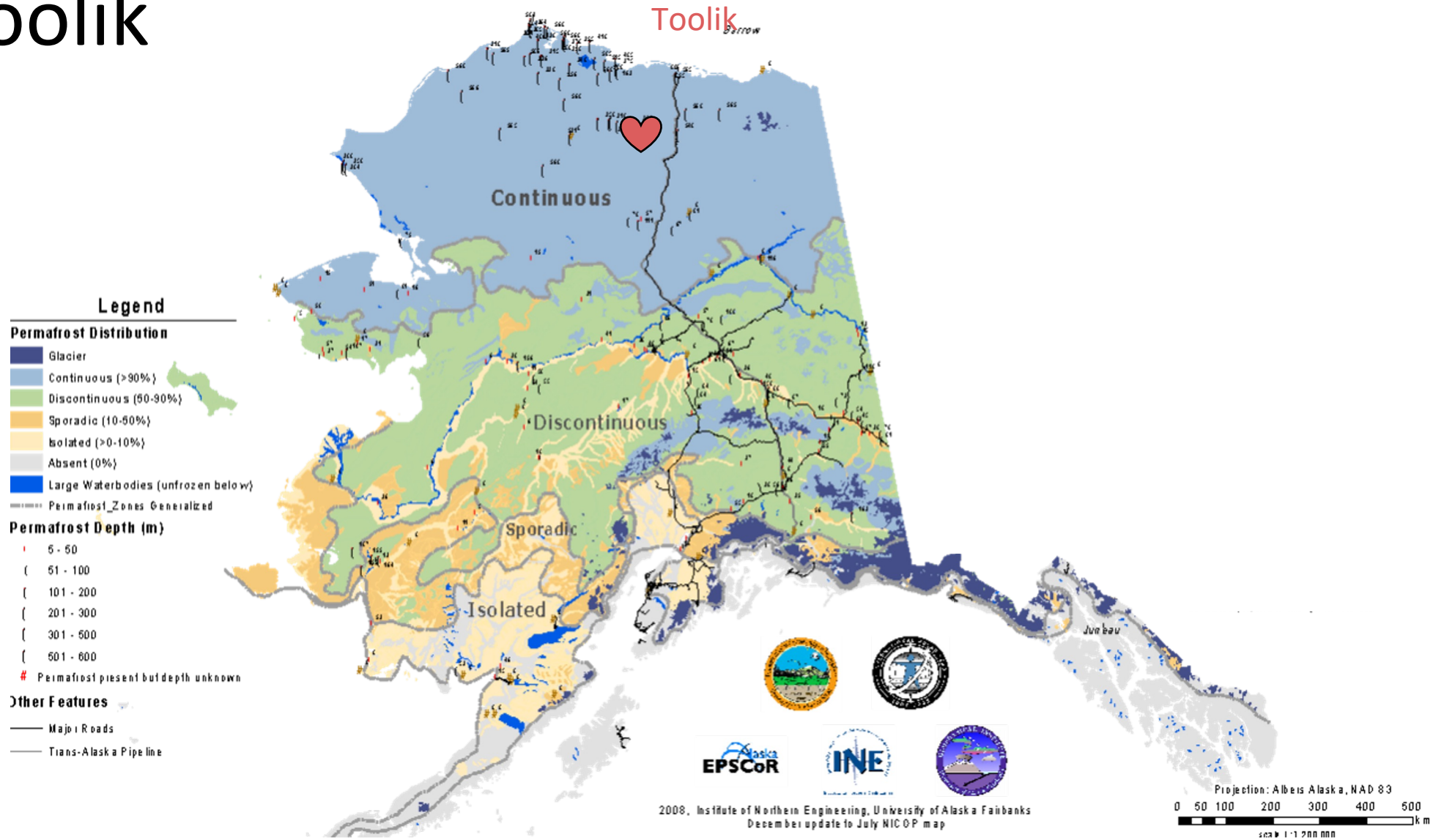
2. EMERGE Biology Integration Institute

The work discussed in this talk took place on Nunamiut homelands. We are grateful for their stewardship of the land and our ability to study it. Subsequent work was performed on the homelands of the Abenaki people.

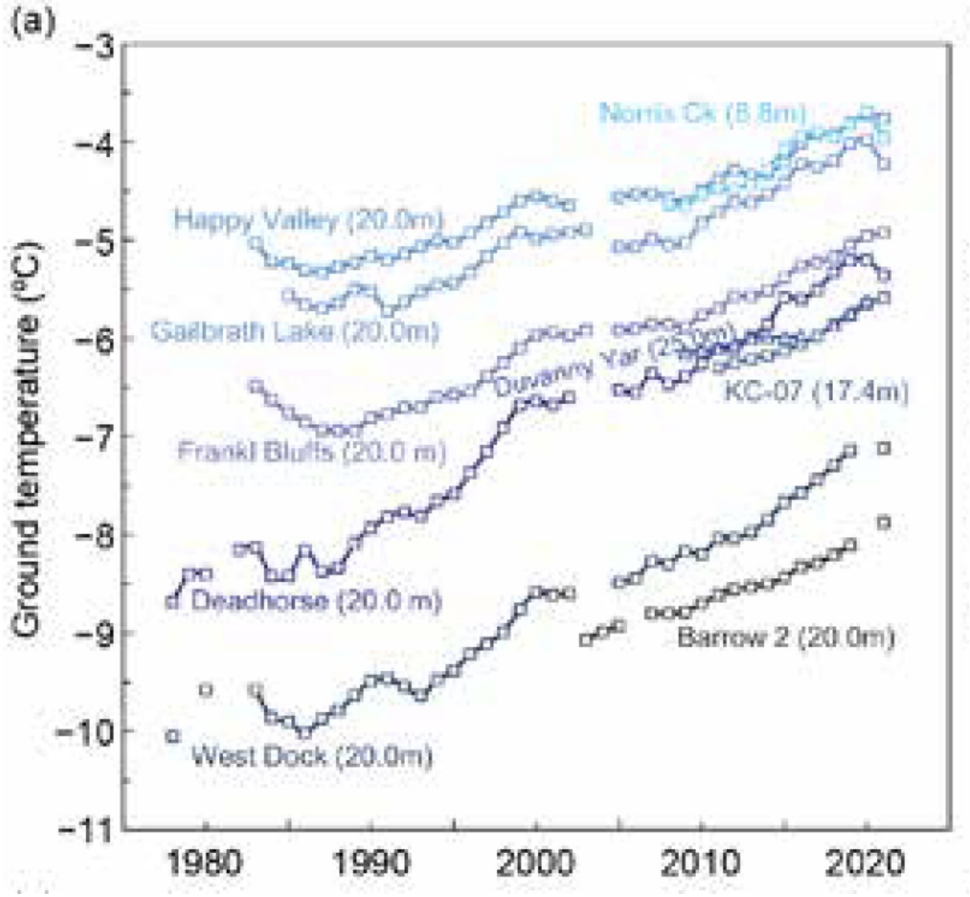
Permafrost shapes the environment of Toolik

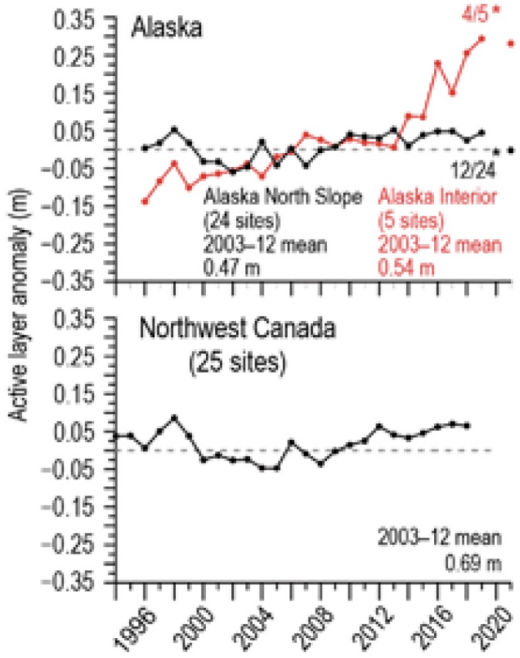




Jorgenson et al., 2008

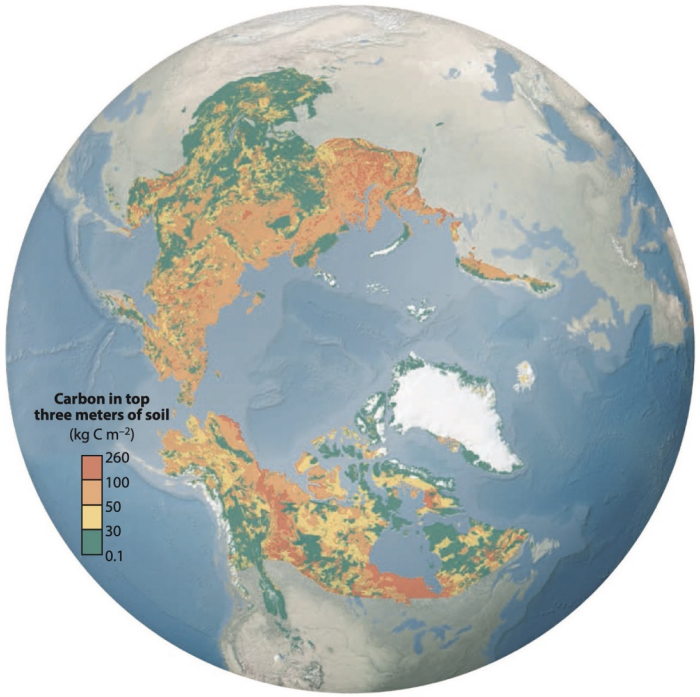
Permafrost temperatures are warming & thawing (in some cases)



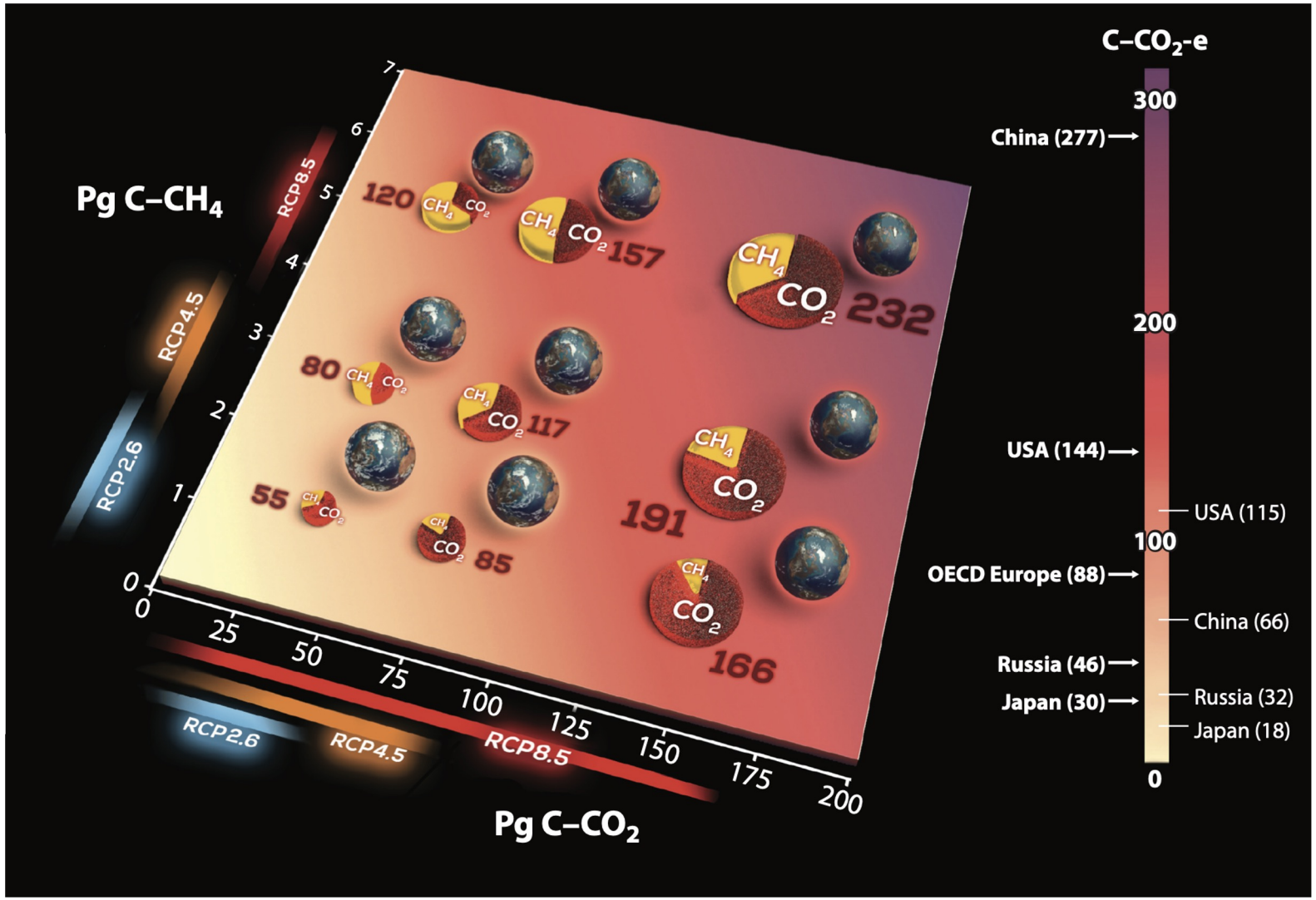


State of the climate in 2021: The Arctic // Permafrost: Smith et al.
Image credit: https://www.unavco.org/highlights/2009/toolik.html

The “country of permafrost” has big climate implications

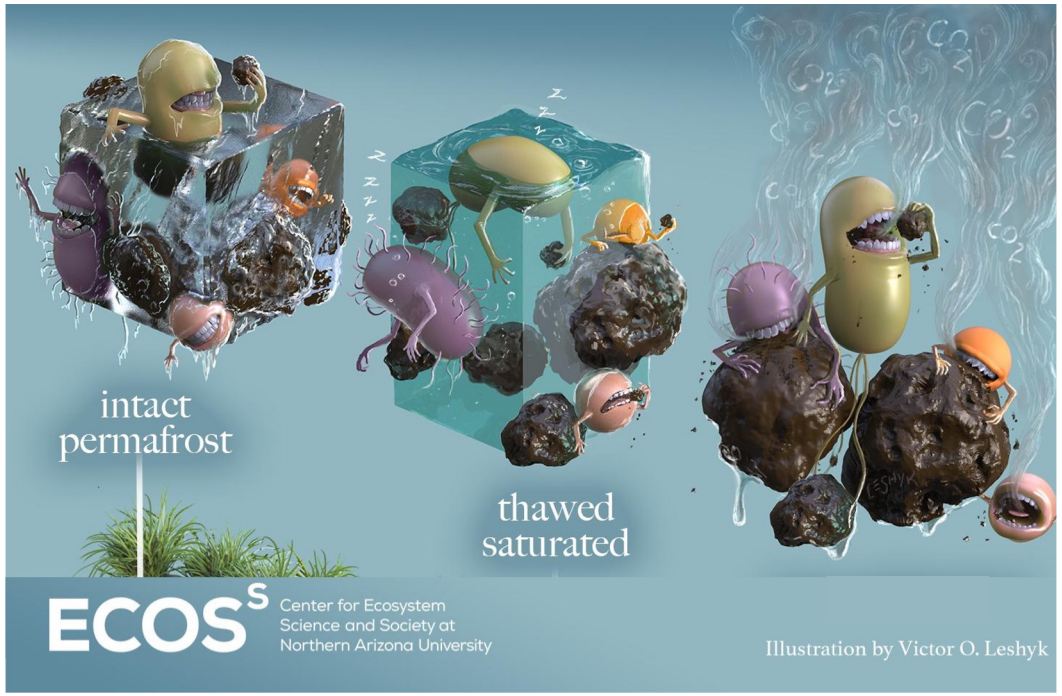


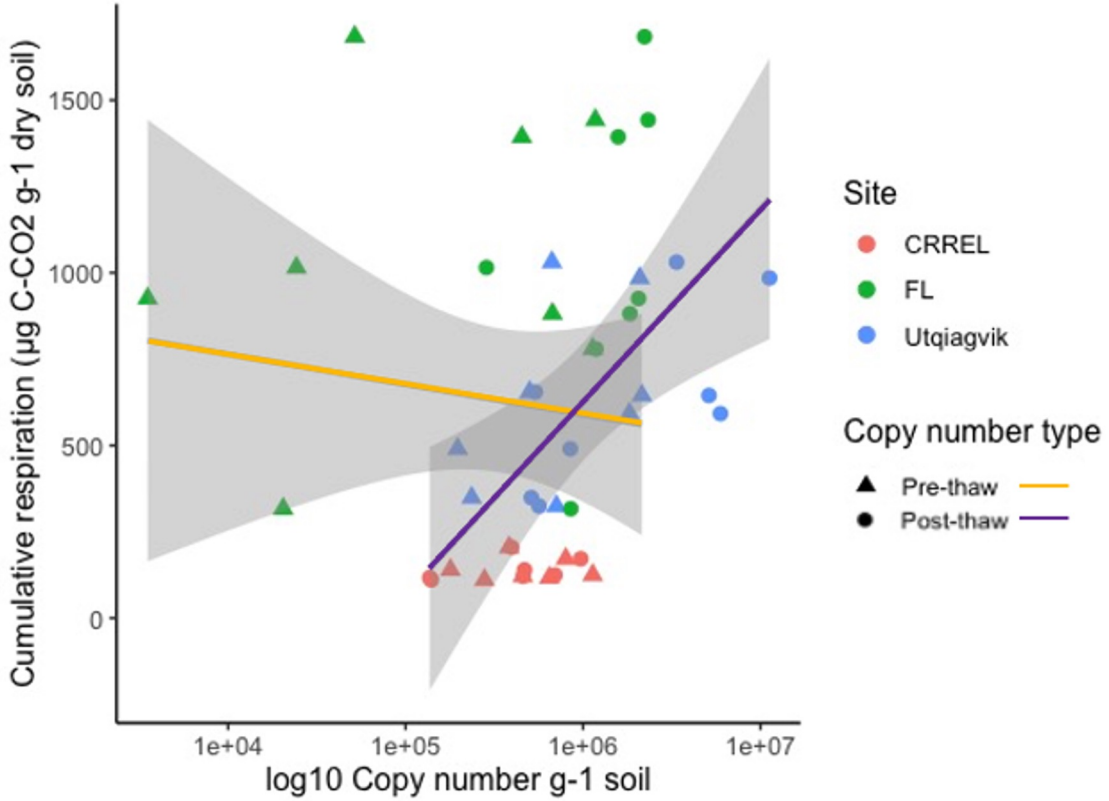
Permafrost contains 2x as much C as the preindustrial atmosphere



Schuur et al., 2022 ARER

Microbes are (largely) a missing link in understanding the permafrost-climate feedback





The amount of CO2 produced is correlated to biomass after thaw

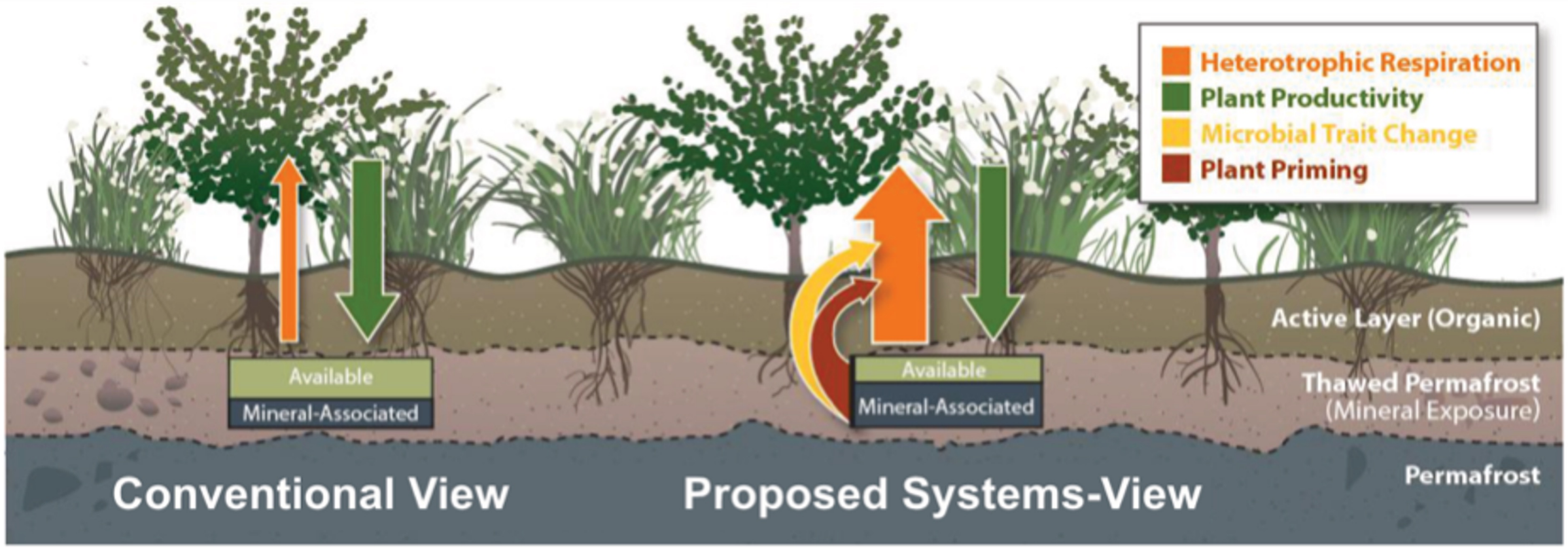
O'Brien, 2022 masters thesis

We have two projects working to address this knowledge gap:

#1: Resolving plant-microbe-mineral interactions to address permafrost-climate feedbacks

#2: Predicting the post-thaw microbiome using assembly theory

#1: Resolving plant-microbe-mineral interactions to address permafrost-climate feedbacks



Collaborative Research: Permafrost climate feedbacks: How interactions among plants, microbes, and minerals affect biogeochemical projections in a changing Arctic (Award # 2031253) – PIs: Ernakovich, Hicks Pries, Wieder, Grandy

#1: Resolving plant-microbe-mineral interactions to address permafrost-climate feedbacks

Overarching Q: How will feedbacks between plants and soils (e.g., minerals and microbes) affect arctic soil carbon balance in response to global change?

1. Determine how soil microbial communities and mineralogy affect the fate of plant exudates and the vulnerability of native SOM to priming in thawed permafrost.
2. Determine how plants influence permafrost soil C balance under elevated CO_2.
3. Project future arctic soil C dynamics in a warmer and more CO2-enriched world by integrating MIMICS-CN—which considers feedbacks among plants, microbes, and minerals—into the CLM.

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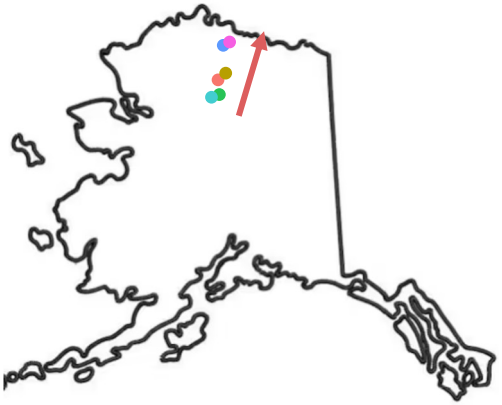
Project updates:



Deglaciation gradient ranging from 11K – 4.5 mi yo

- samples collected
- Plant-associated microbiomes are nearly all surveyed
- C and mineral analysis coming along
- Retrofitting of isotope labeling plant growth chamber nearly complete

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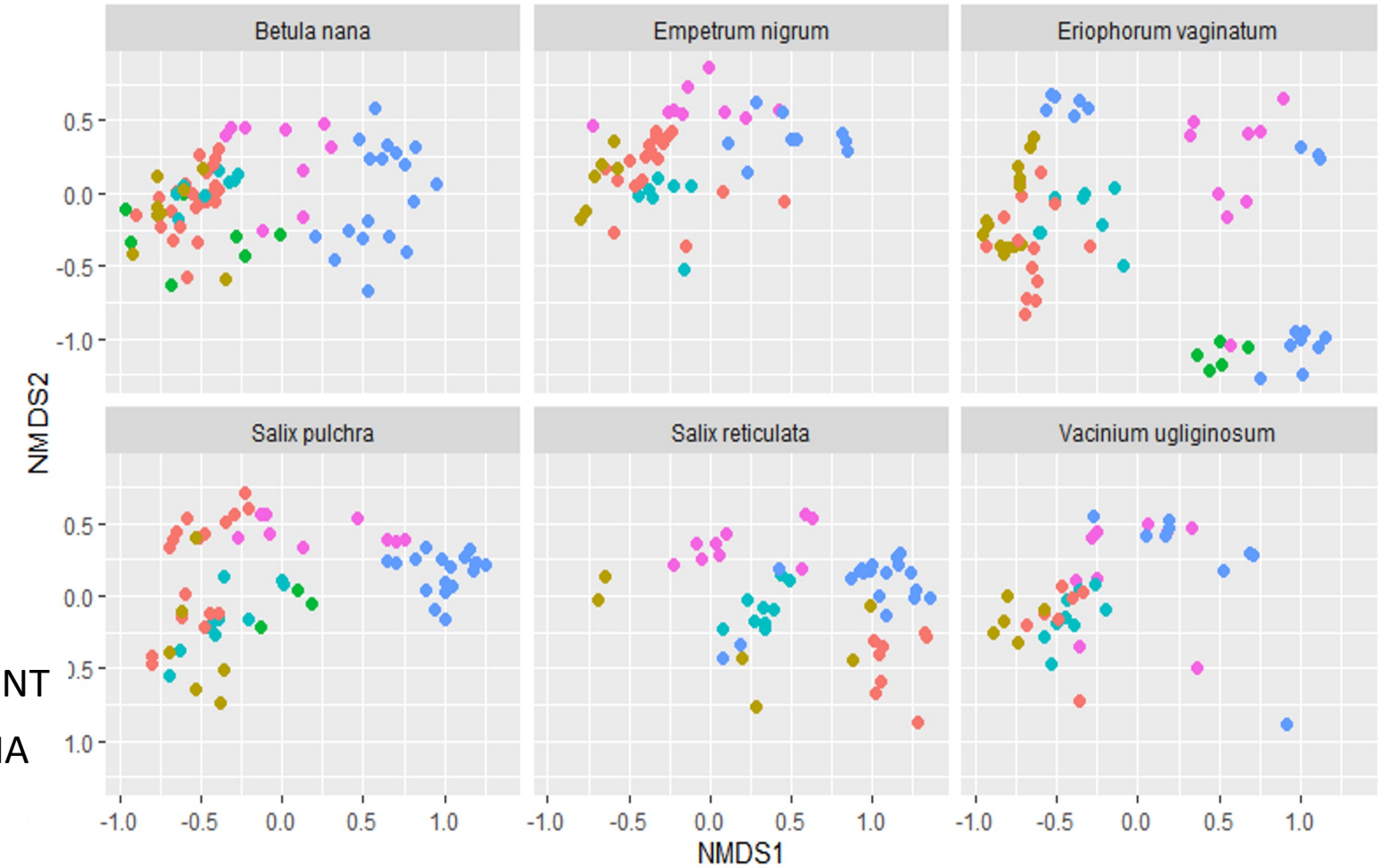
Plant-associated microbiomes: Soil type is a stronger driver of bacterial rhizosphere communities than host plant

Deglaciation gradient ranging from 11K – 4.5 mi yo

Site

- E. Toolik MAT
- Kuparuk MAT
- S. Dalton MAT
- S. Dalton MNT
- Sagwon Hills MNT
- Sagwon Hills MAT



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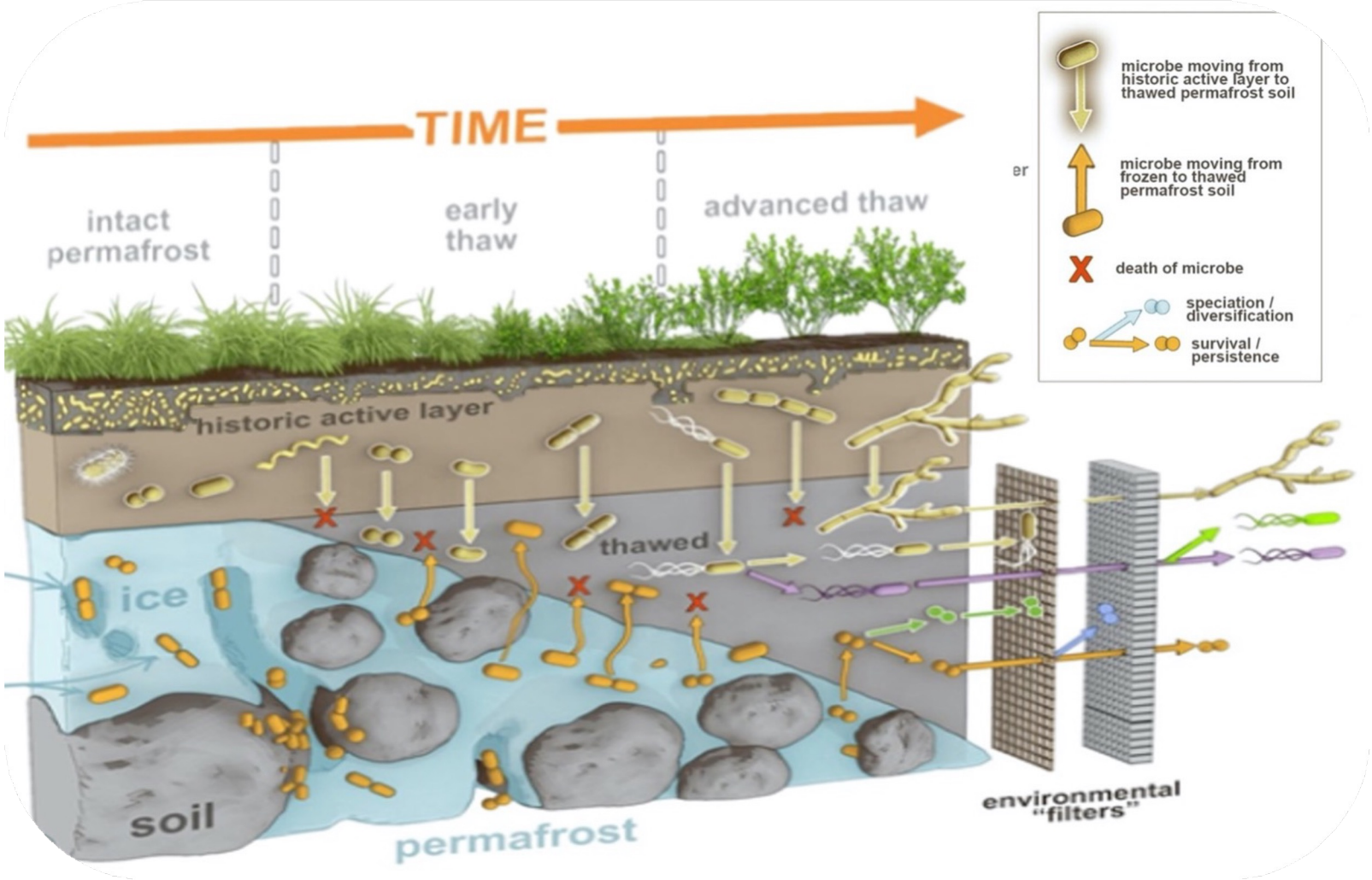
#2: Predicting the post-thaw microbiome using assembly theory



CAREER: A research foundation to improve understanding of the post-thaw permafrost microbiome via collaboration networks and experiential learning (Award # 2144961) – PI: Ernakovich (collaborators: Dorrepaal, Schuur, Rich, Johansen, Sannel)

#2: Predicting the post-thaw microbiome using assembly theory

The objective of this research is to understand the factors shaping post-thaw microbiome composition and function.

Research aims:

1. Assess the state of the science by synthesizing published and yet unpublished data on post-thaw microbiomes
2. Quantify the contribution of stochasticity to the post-thaw microbiome composition over space, time, and disturbance intensity using a field sampling approach
3. Assess the mechanisms of assembly at play in post-thaw microbiomes using highly controlled laboratory incubations performed across many ecological axes

Currently seeking postdoc for this!

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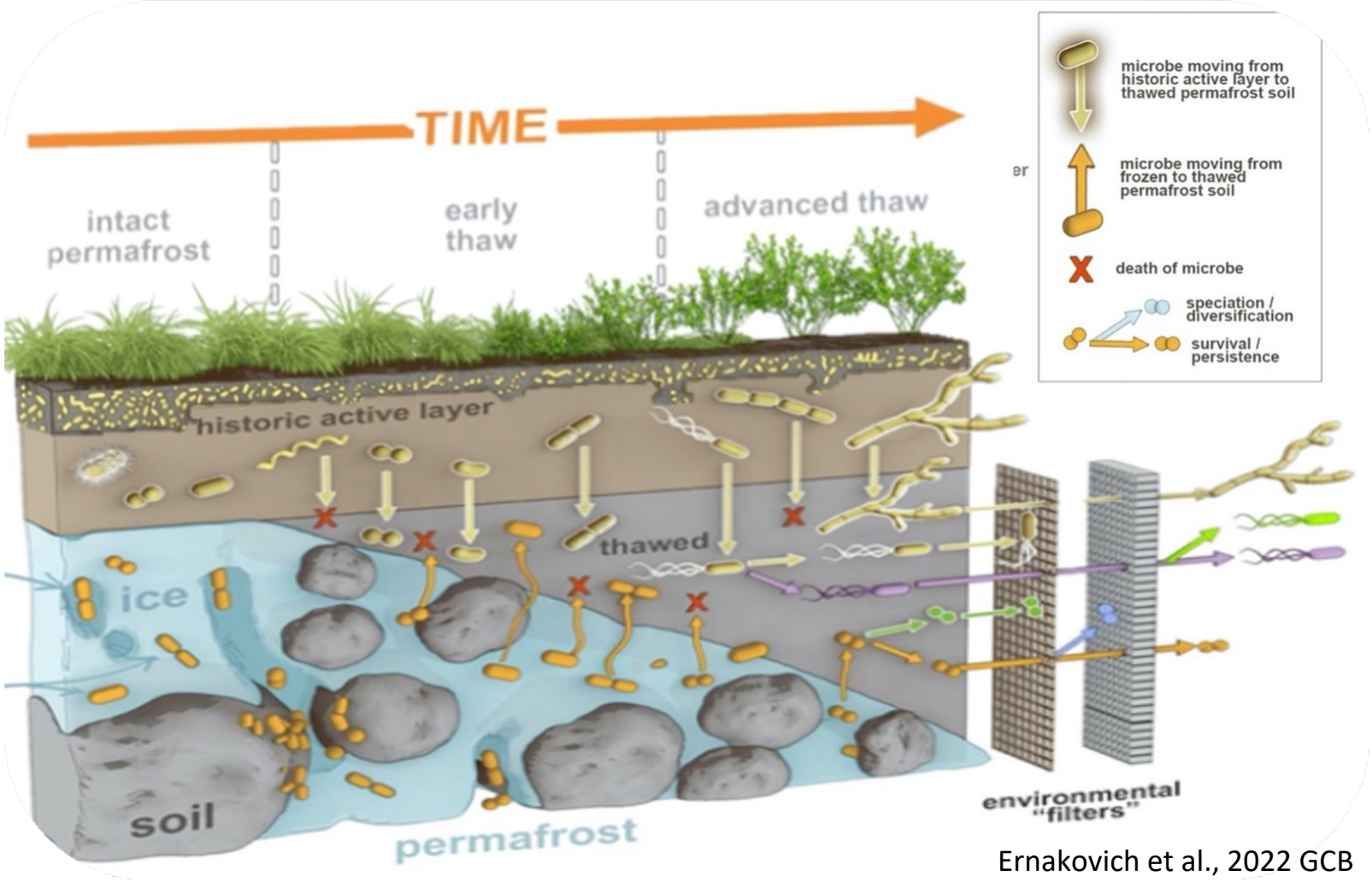

Ernakovich et al., 2022 GCB

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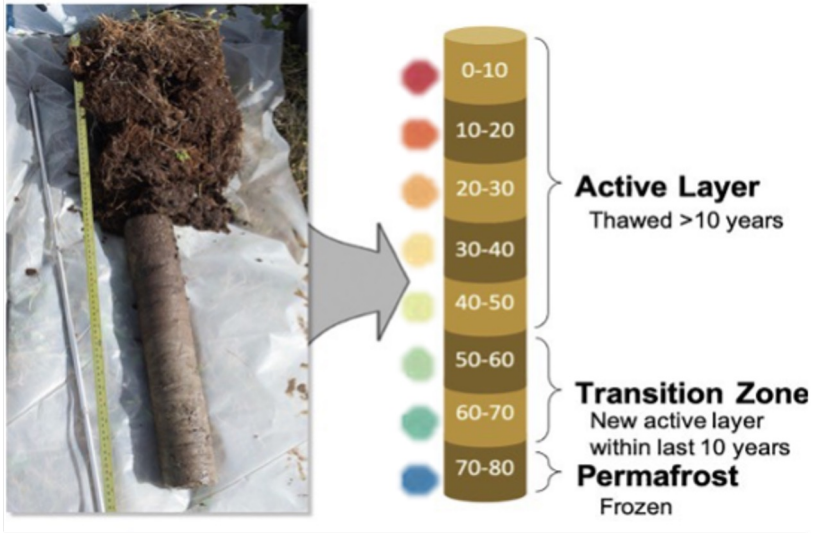
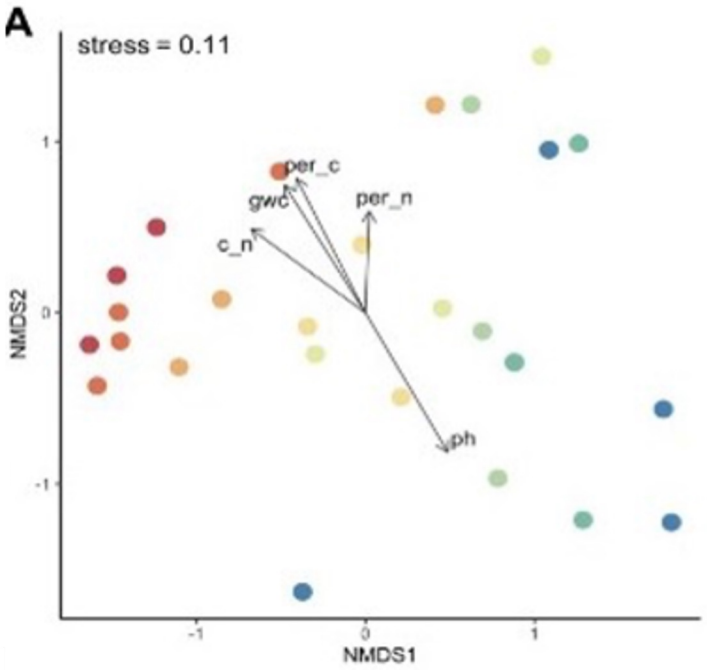
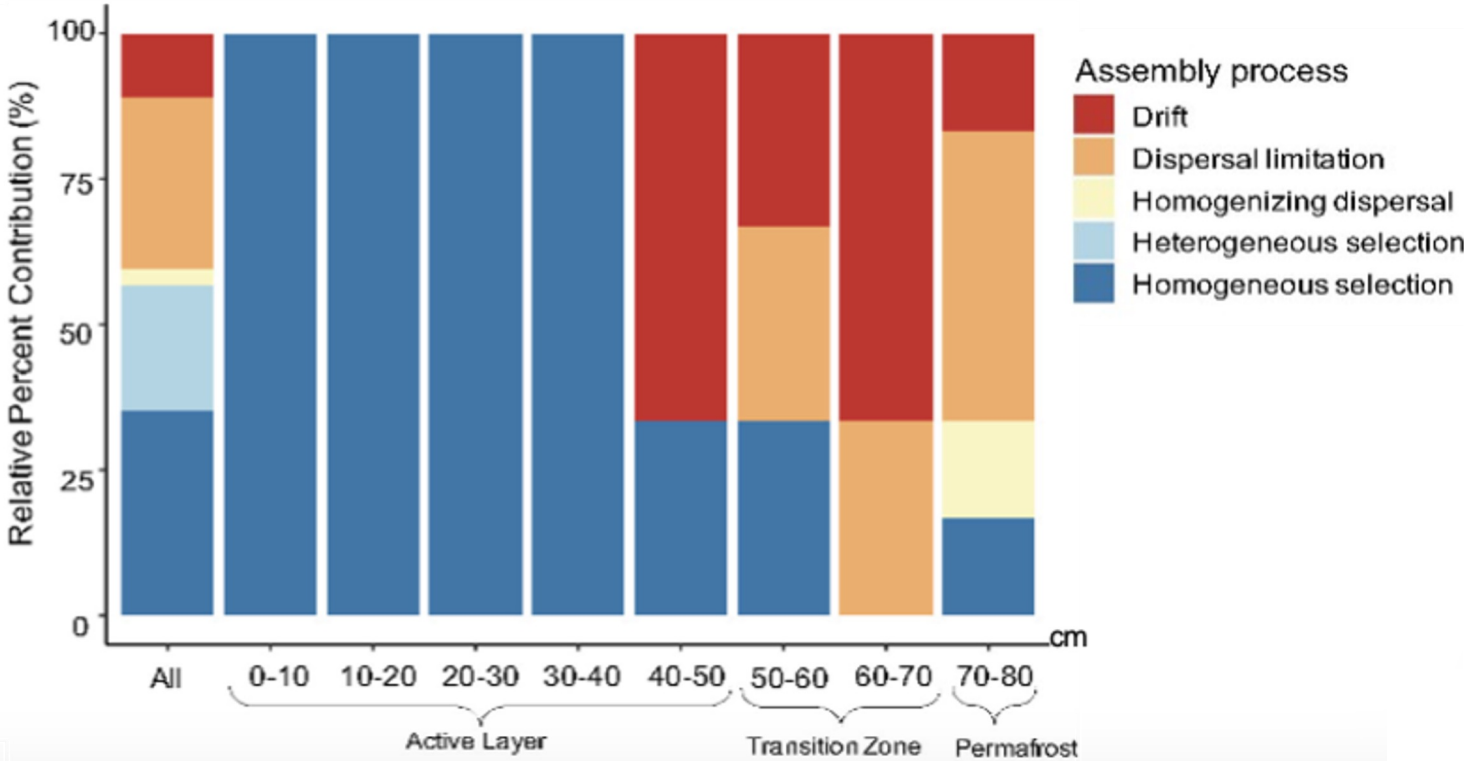
preliminary evidence from thawing permafrost peatland in Sweden:

stochasticity dominates short-term and selection dominates long term



Doherty et al., 2020





Using multiple study sites, we will test hypotheses about impact of time and disturbance intensity on factors underlying community composition

Site & collaborator	Location	GPS	Permafrost type; age	Thaw treatment	Disturbance age	Max thaw
Active layer deepening						
Avni transect - Rich & Abisko LOC	Stordalen Mire, Sweden	68° 21.3050 N, 19° 2.6300 E	peat; Little ice age	"Natural"	ND	ND
CiPEHR - Schuur LOC	Eight Mile Lake, AK	63°52'59' N, 149°13' 32' W	loess[8]; early Pleistocene[2]	snow fence & warming	2008[1]	~60 cm[3]
Ice Cut - Dorrepaal LOC & Toolik LOC	55 km North of Toolik, AK	69°048' N, 148°836' W	loess; Pleistocene	snow fence	2014	ND
Storflaket snow fence - Johansson & Abisko LOC	~6 km E of Abisko, Sweden	68◦20'48' 'N, 18◦58'16' E[4]	peat; Little ice age	snow fence	2005	>150 cm
Thermokarst						
I-minus 1 - Schuur & Toolik LOC	Toolik Lake, AK	68°65'N, 149°58'W	loess; Pleistocene	"Natural"	472[7]	ND
Tavvavuoma-Sannel & Bolin Center LOC	Tavvavuoma, Sweden	68°28' N, 20° 54' E	Peat; 600-100 cal. BP[6]	"Natural"	ND	60 cm[5]

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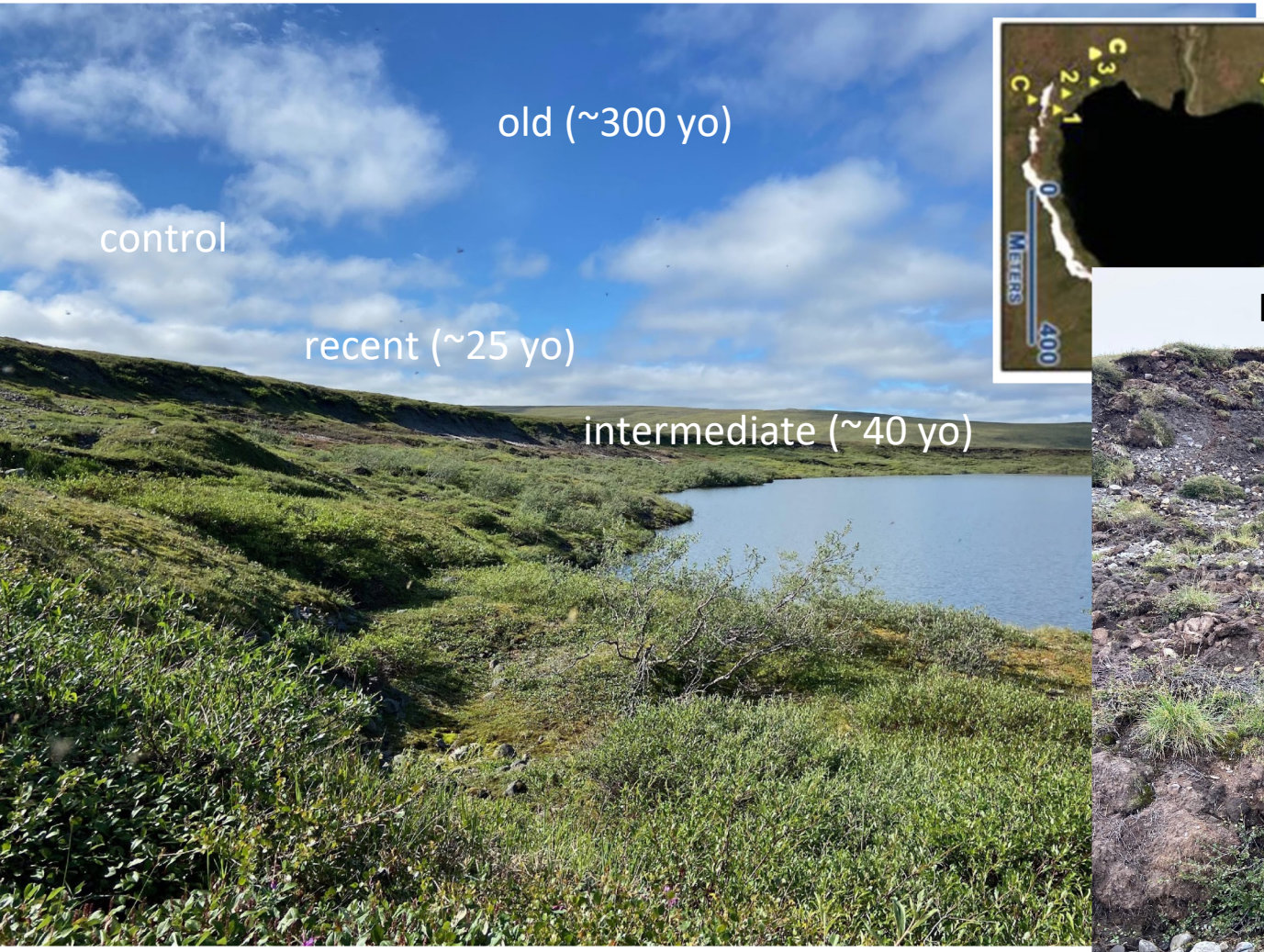
Sampling @ I-1: July/August 2022



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and experiential learning (Award # 2144961) – PI: Ernakovic

In summary: Our overarching goal (in our funded work) is to

inform understanding of changing permafrost landscapes by studying how microbes interact with their environment and by measuring and modeling gas feedbacks to climate

We are also actively learning how to ethically interact with local communities to do scholarship meaningful at the local scale

Please join the USPA Diversity, Equity, and Inclusion Committee for a workshop titled "Working in Indigenous Communities" on Tuesday, February 7th from 1 - 3pm AK.

If you are looking for a PhD position addressing local questions bringing many disciplines and Indigenous expertise to bear, please check out UNH's CARPE NRT program.

Thanks! And questions?

The field team for our plant-microbe-mineral project
Sagwon Hills, August 2022