Exploring the impacts of belowground plant traits on the permafrost carbon-climate feedback

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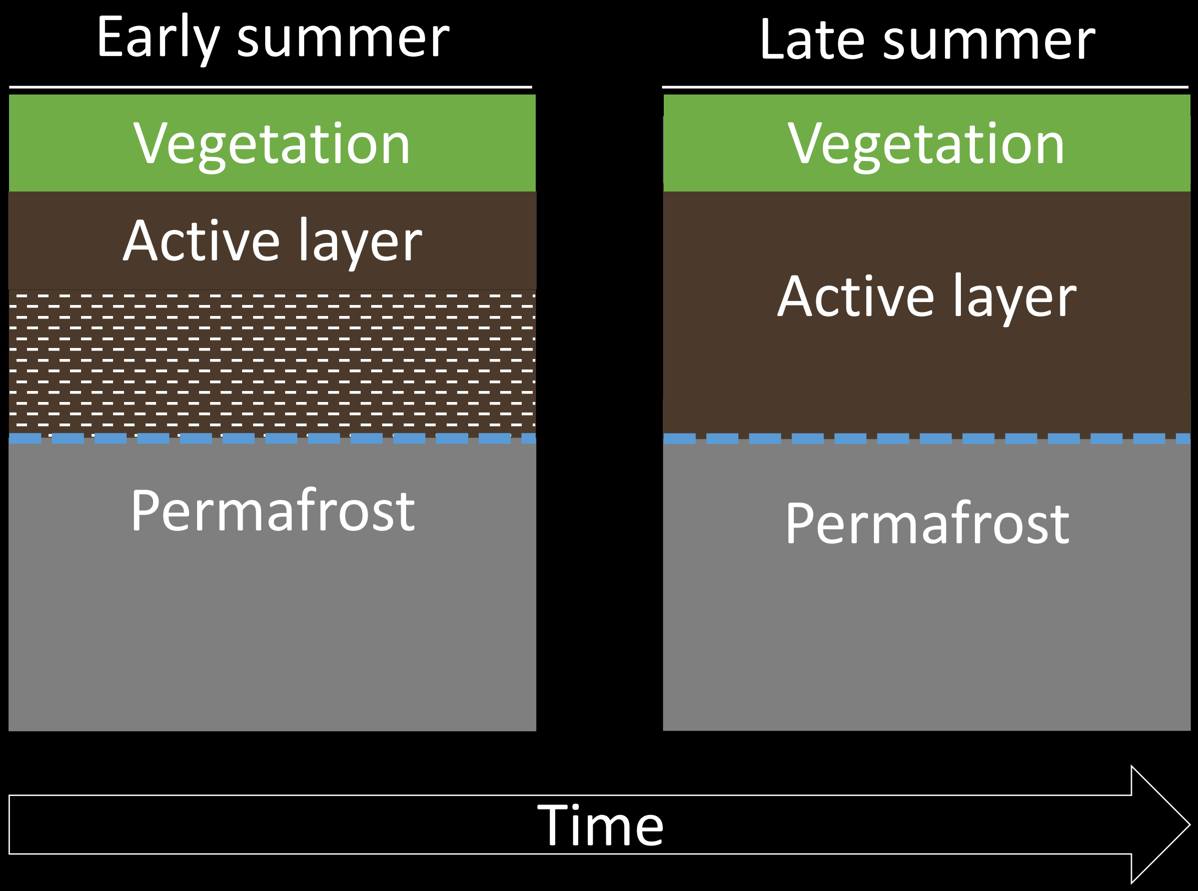
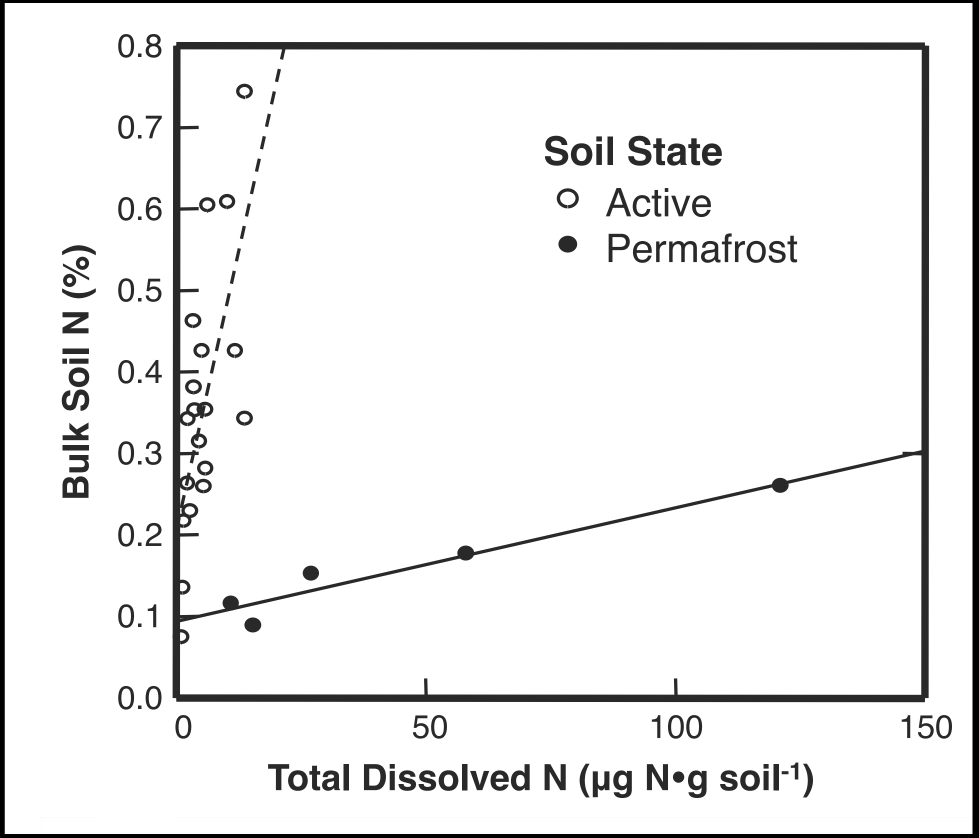
NSF ARCSS award number: 1504312

Tundra is nutrient limited

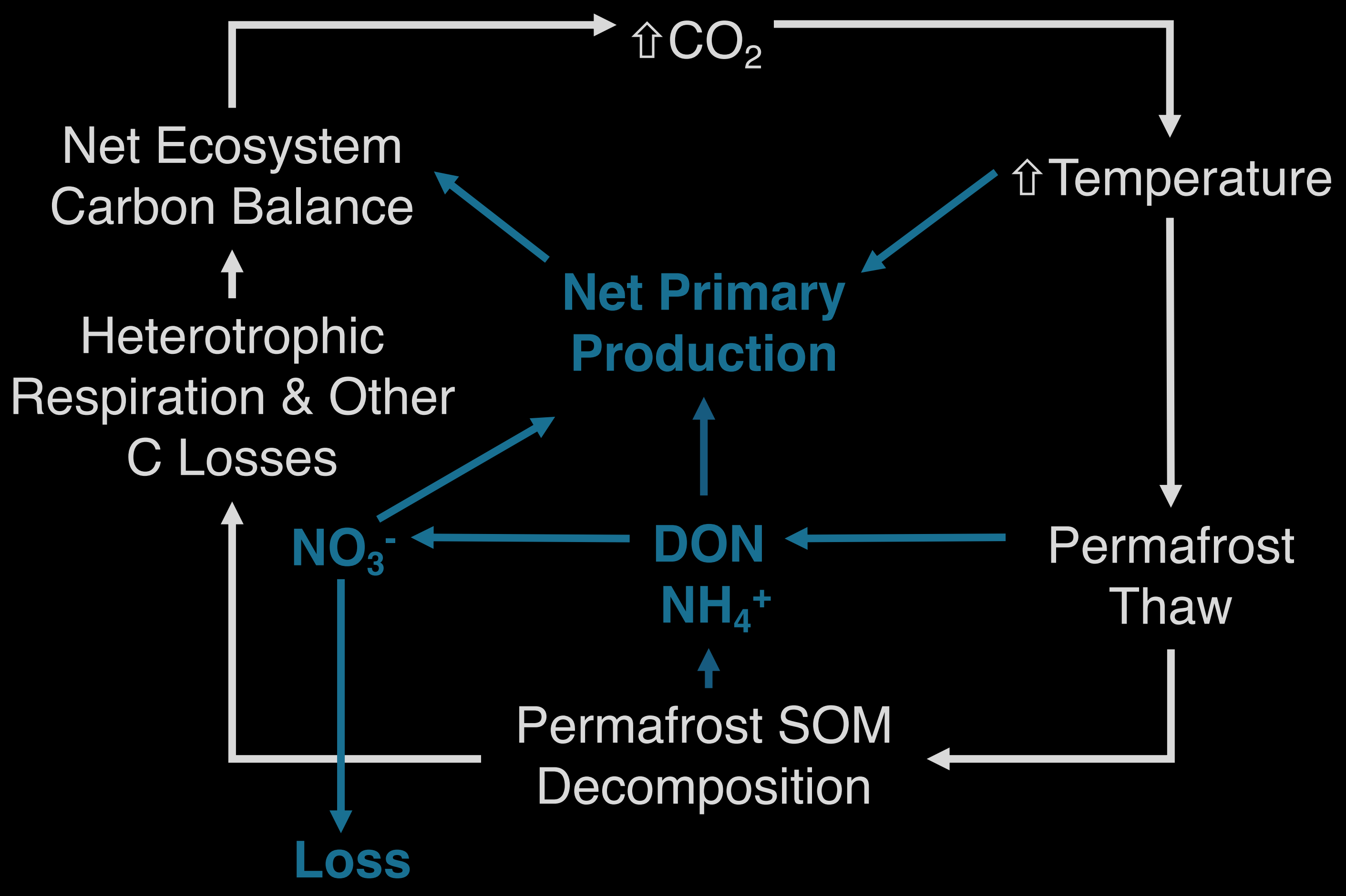
Permafrost nitrogen





Mack unpubl. data

Coupled C and N cycling



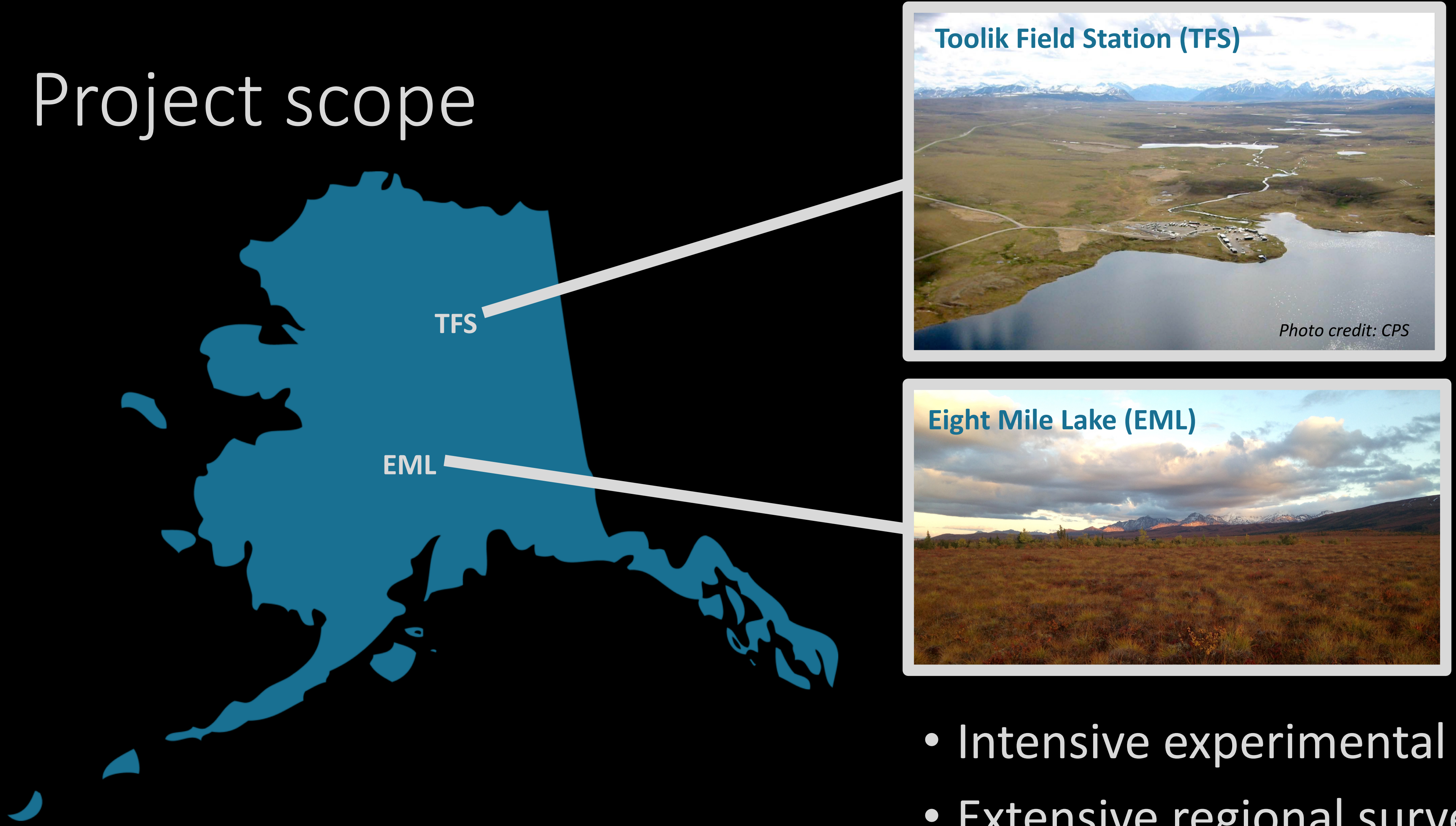
Do belowground traits dictate nutrient uptake as permafrost thaws?

Hypothesis: Permafrost N will be acquired by plants with

- roots that can grow ***deep*** and stay active ***late***
- ***mycorrhizal symbionts*** that forage at the thaw boundary

Goals: Characterize species rooting profiles & determine whether there is active uptake of deep N when thaw depths are deepest

Project scope



- Intensive experimental sites
- Extensive regional survey sites
- Regional modeling with TEM

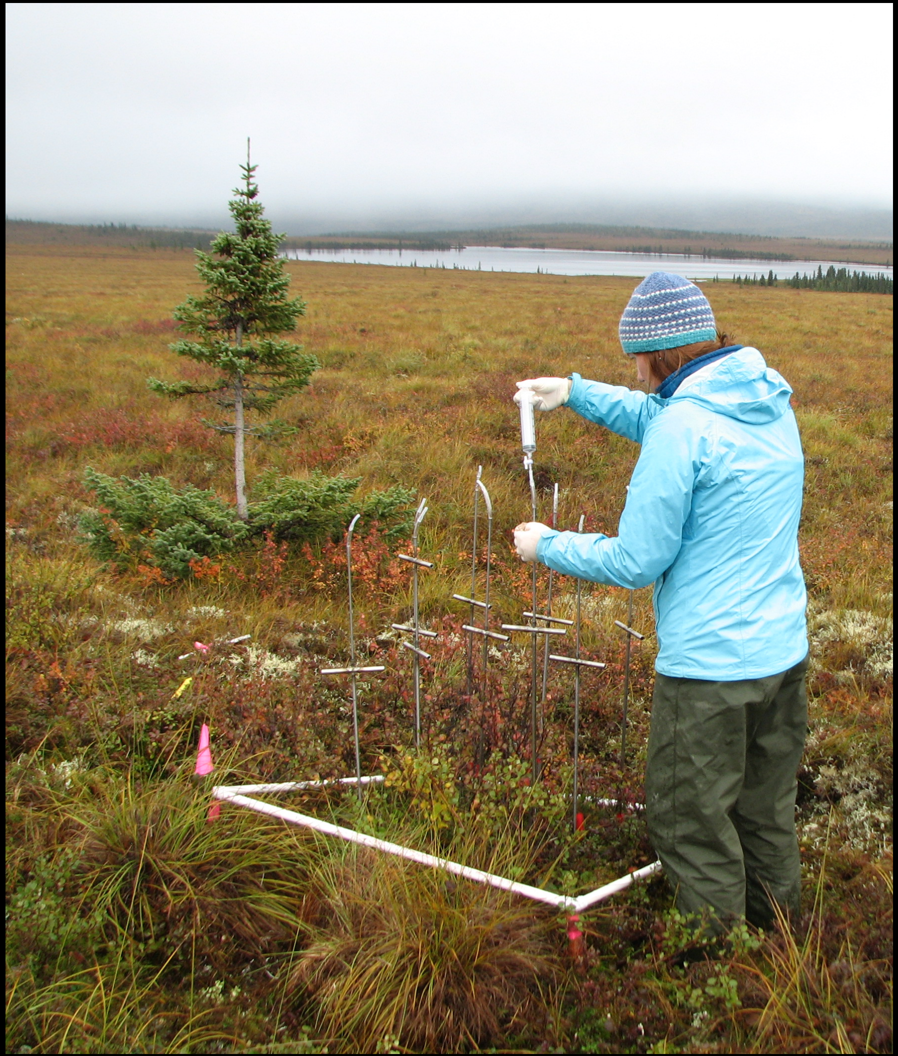
Warming at Toolik yields conditions similar to Eight Mile Lake

Variable	Toolik	Toolik greenhouses	EML
Mean annual temperature	-7.0°C	-6.0°C	-1.0°C
Surface permafrost temperature	-5.0°C	-4.0°C	-0.7°C
Average active layer depth	~40 cm	~60 cm	~60 cm

*Conditions at EML are close to those predicted for Toolik Lake by 2100

Exploring deep roots and deep N

- Research at Eight Mile Lake on belowground root traits and deep N uptake was recently published in Journal of Ecology
- Finishing a manuscript exploring how mycorrhizal fungi may be an important mechanism for dwarf shrub access to deep N



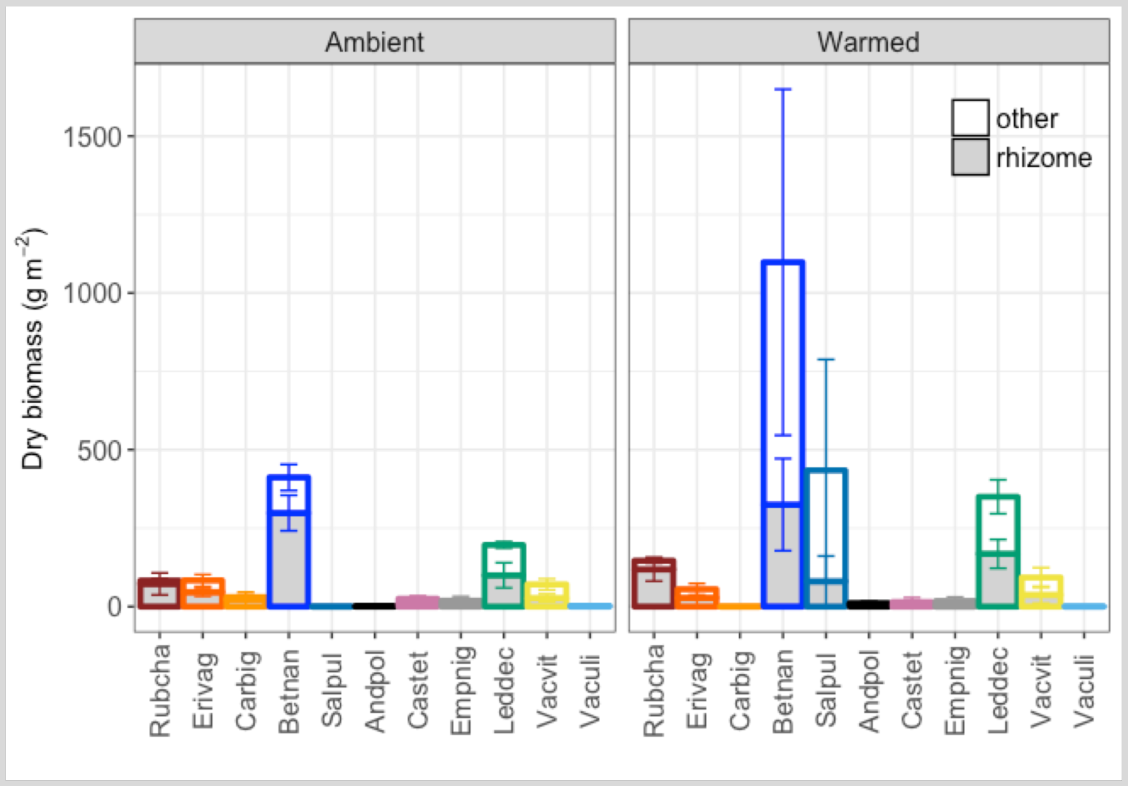
Focus at and near Toolik Field Station

Experimental site

Regional survey

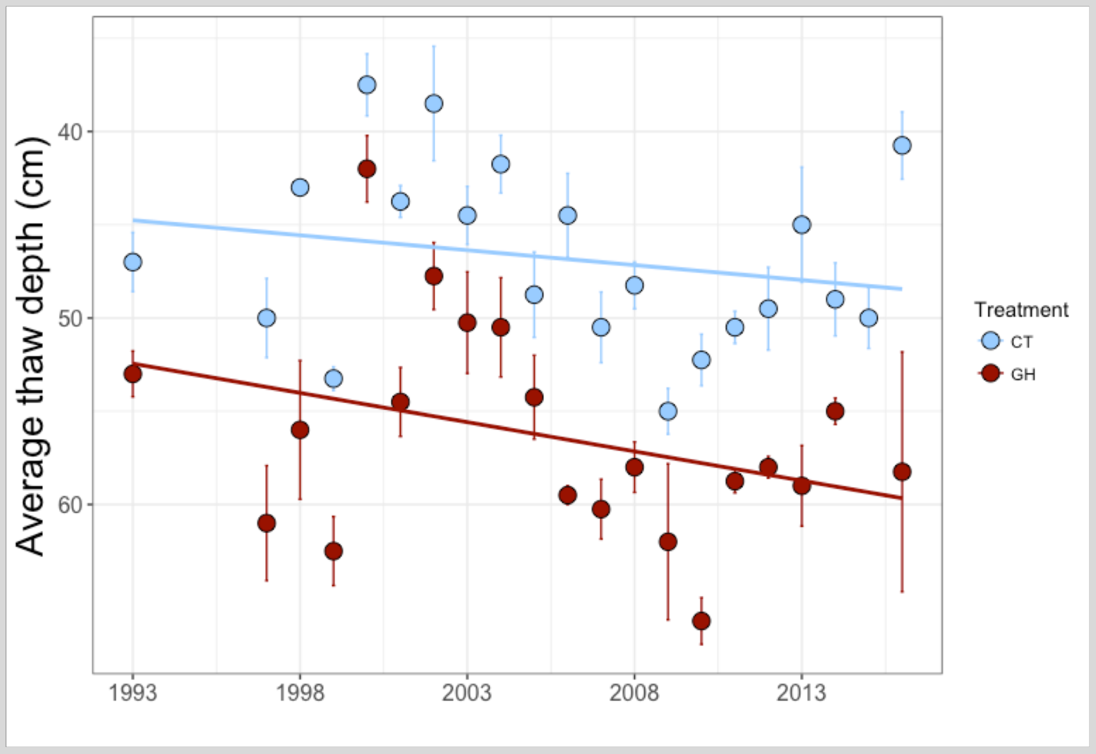
Effects of experimental warming

LTER warming experiment: aboveground vascular plant biomass 2016

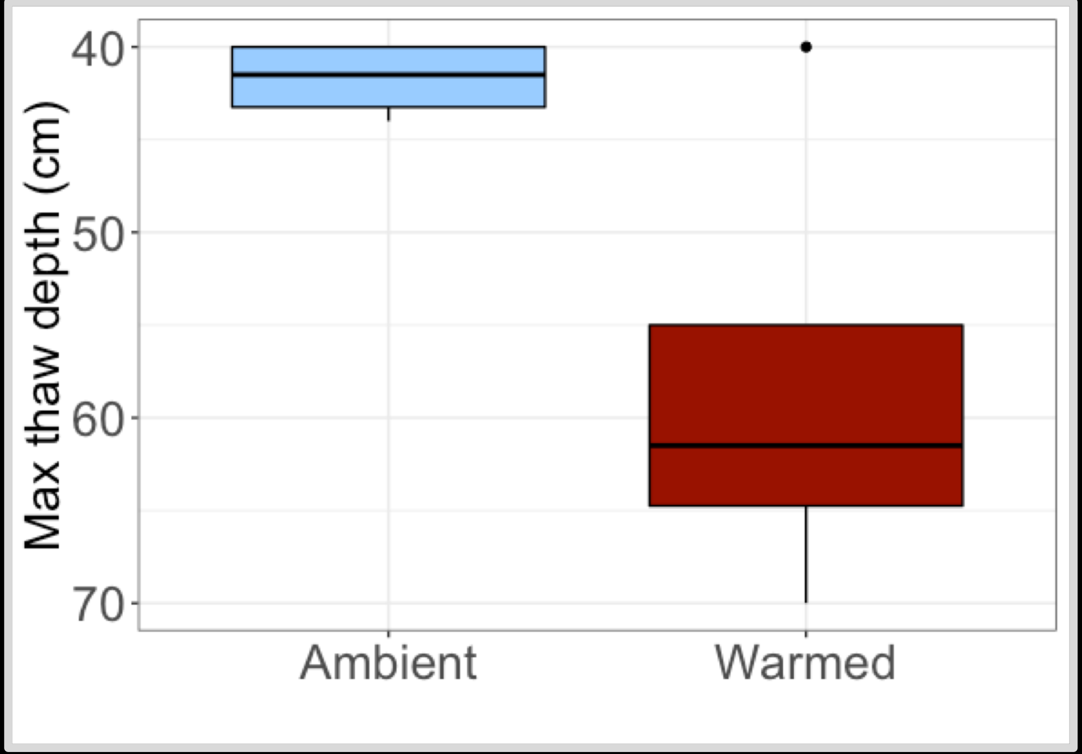


Effects of experimental warming

Trend in late season thaw depth

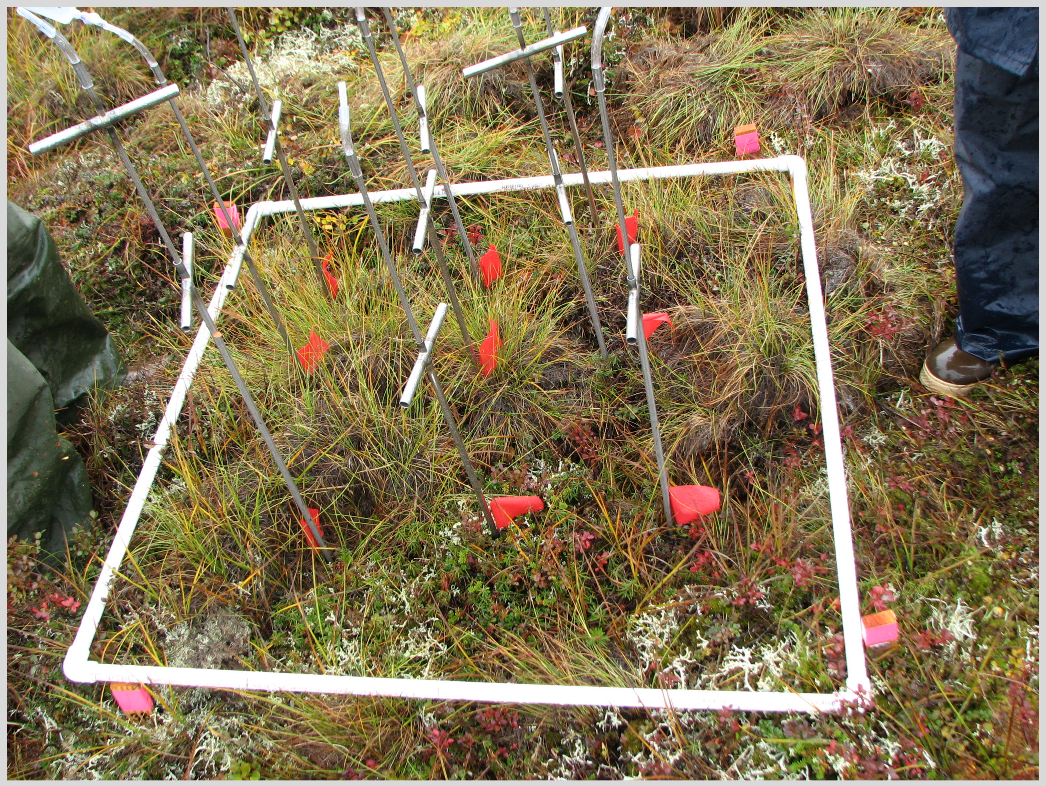


Thaw depth during our harvest



Methods overview

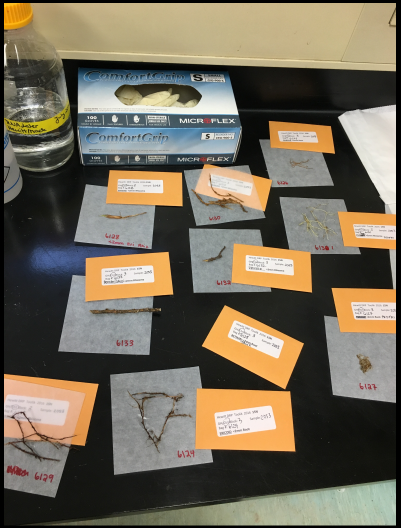
Deep Isotope addition



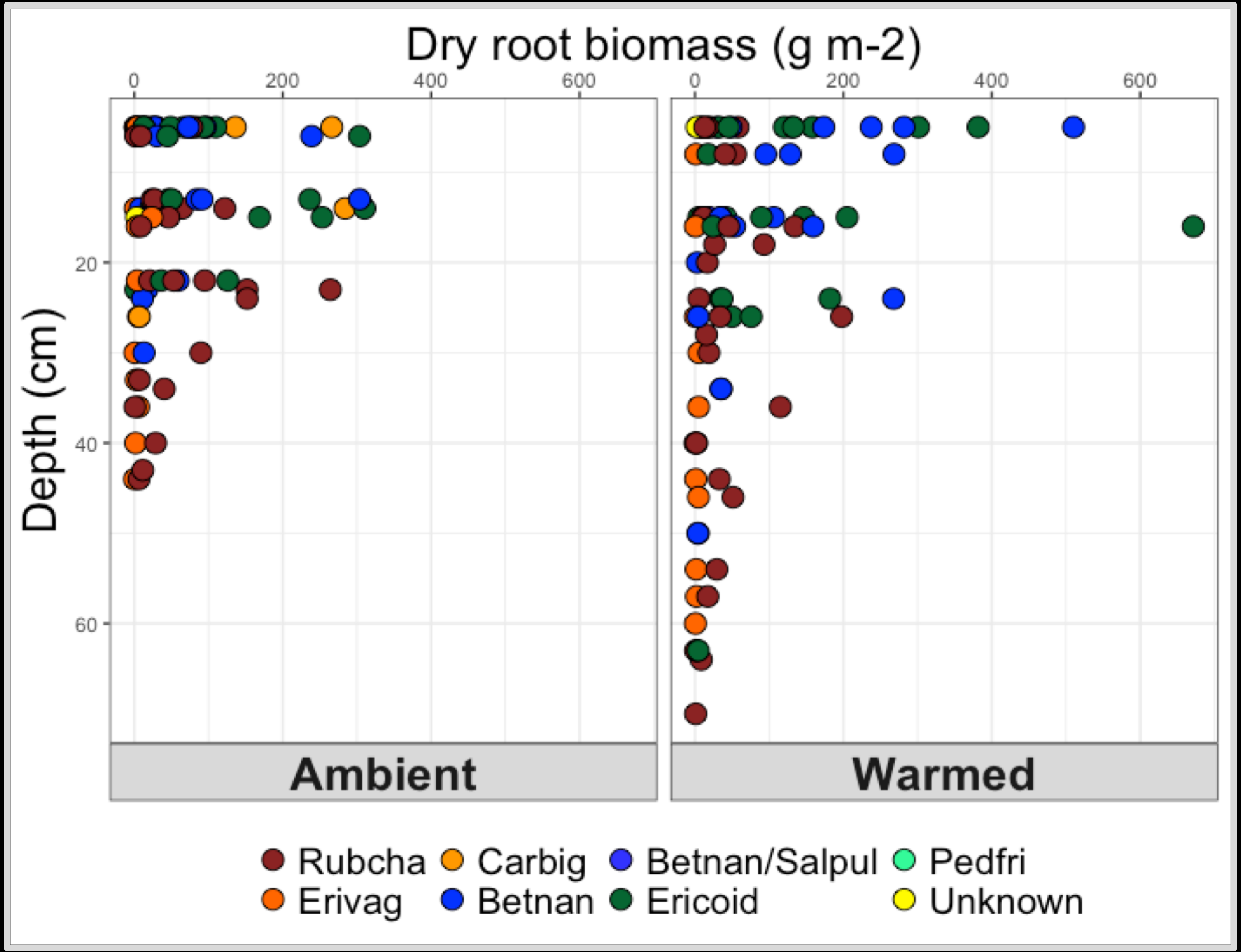
Fate of the tracer

Aboveground

Belowground

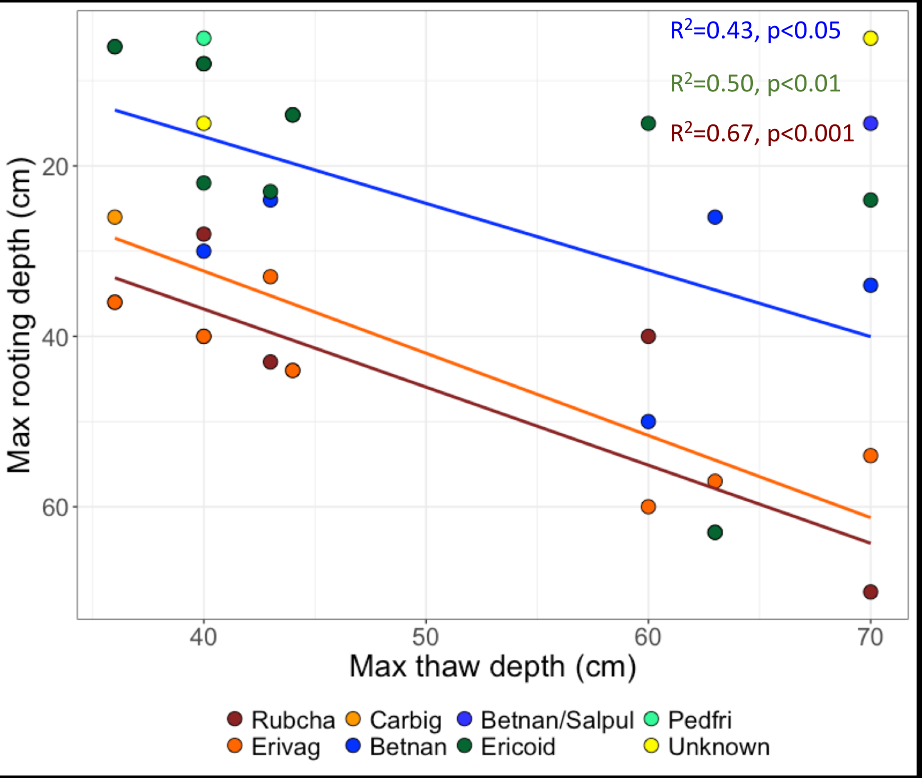


Fine root profiles

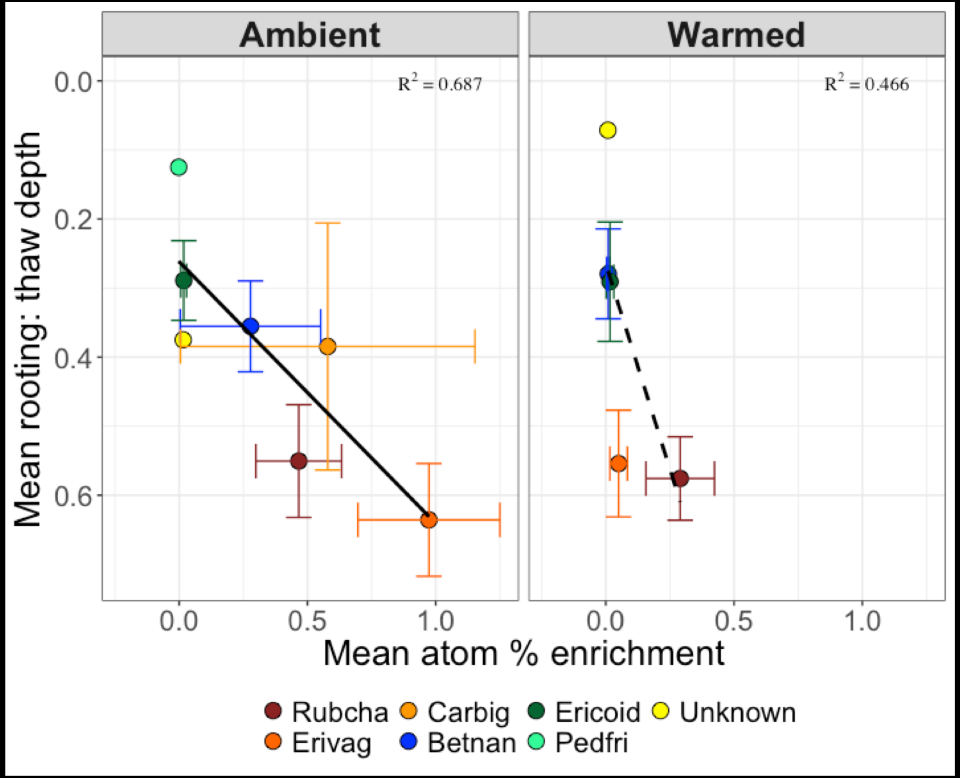


Rooting plasticity and acquisition of permafrost N

Rooting plasticity

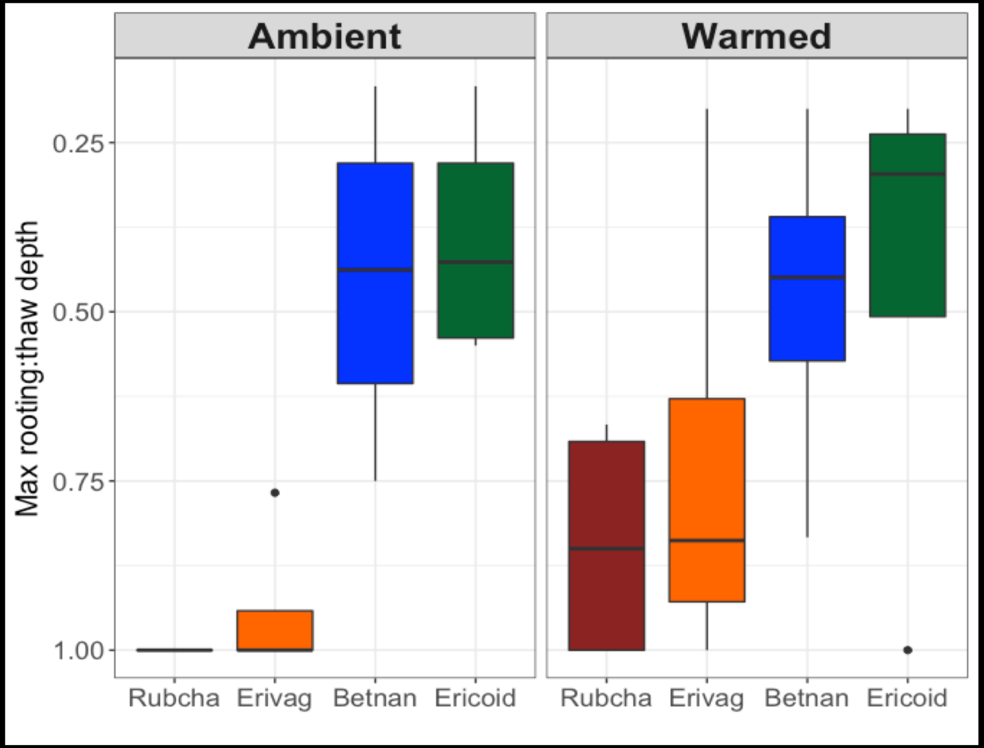


Deep N acquisition

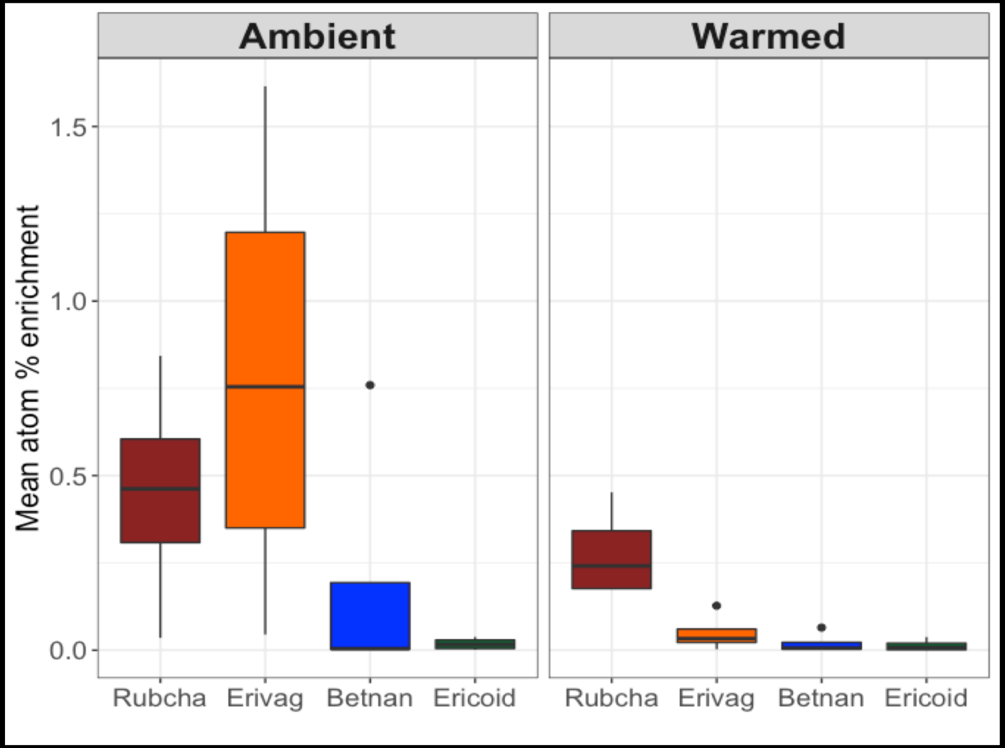


Rooting plasticity and acquisition of permafrost N

Rooting plasticity

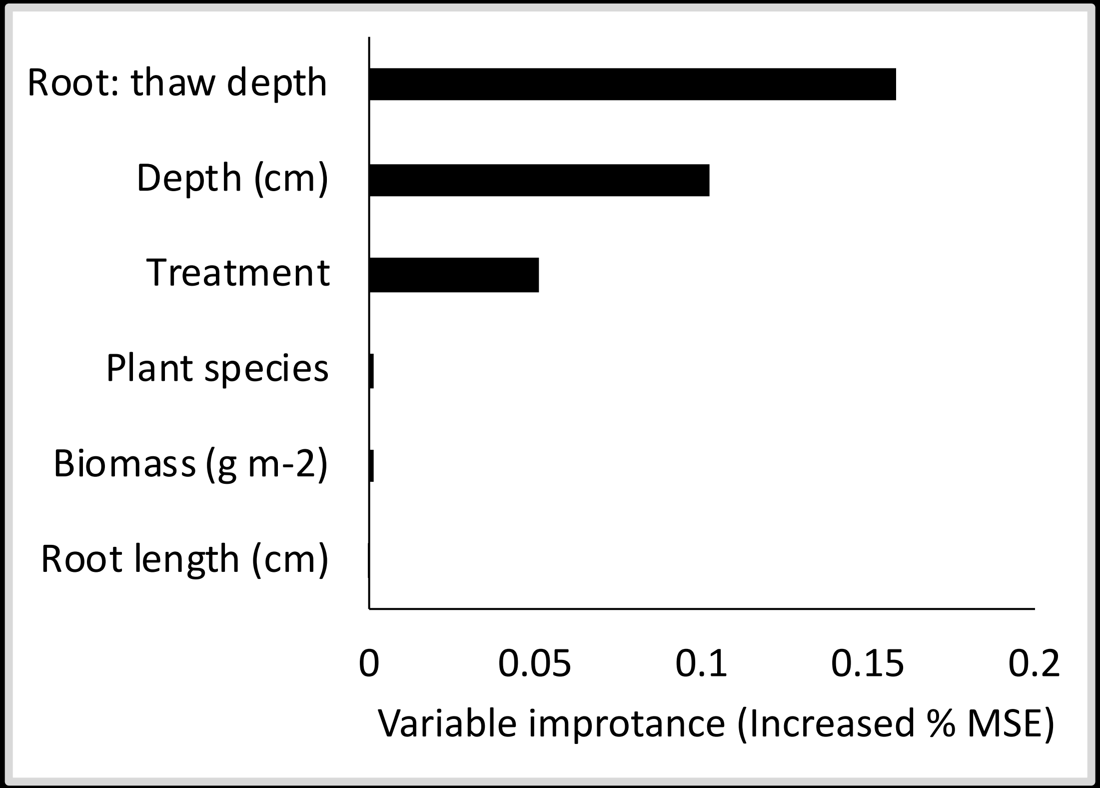


Deep N acquisition



Plant acquisition of permafrost N

Variable importance explaining fine root isotope enrichment



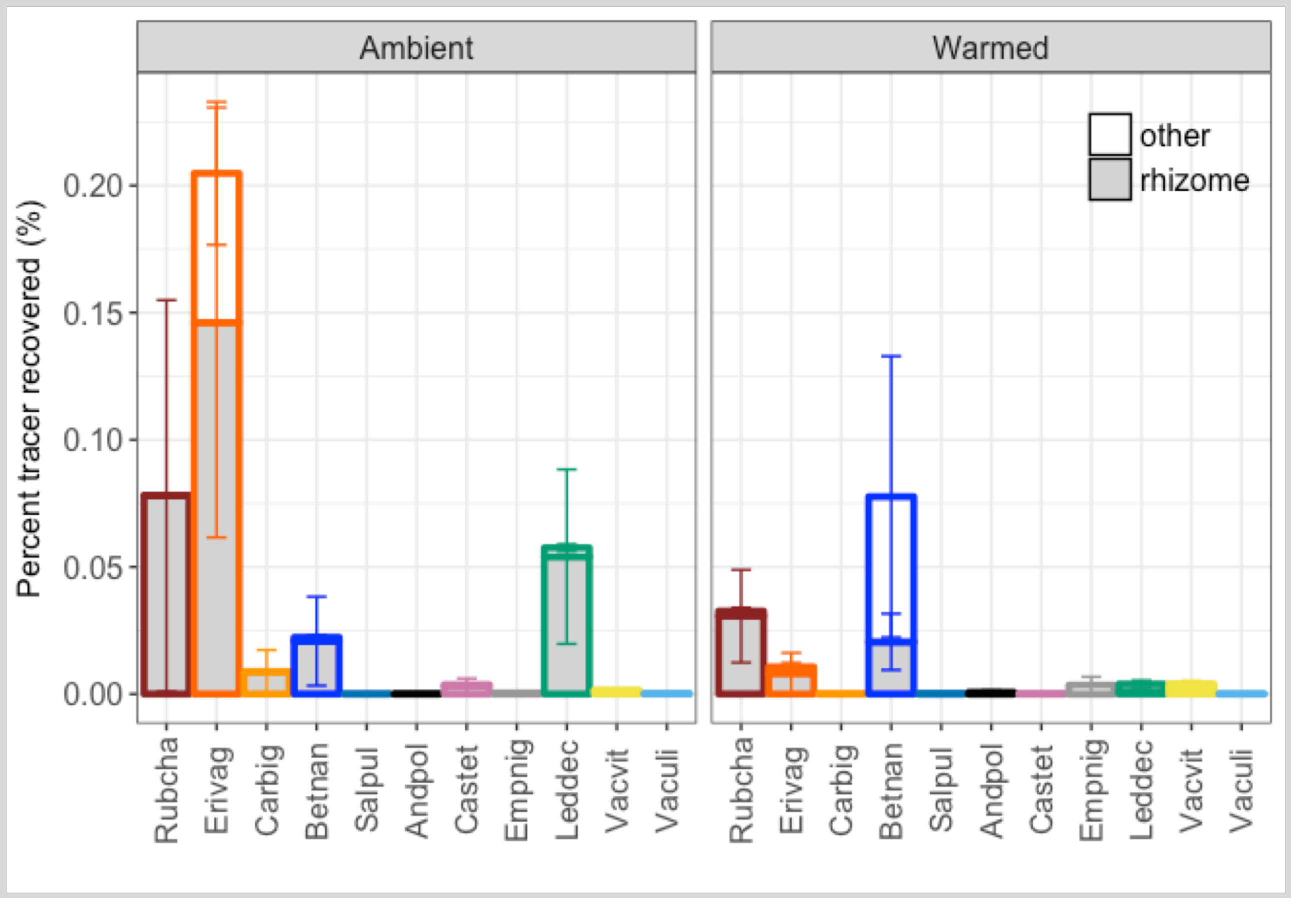
Deep N acquisition by fine roots

- Proximity to deep N affords the greatest uptake more so than biomass or root length

Plant acquisition of permafrost N

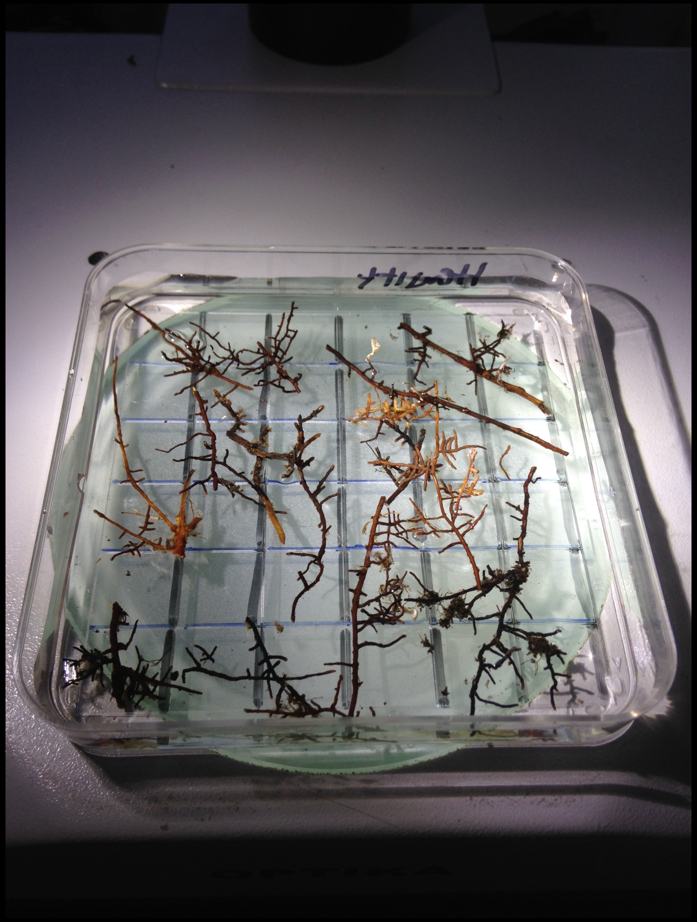
Aboveground harvest

Aboveground harvest: % isotope recovered



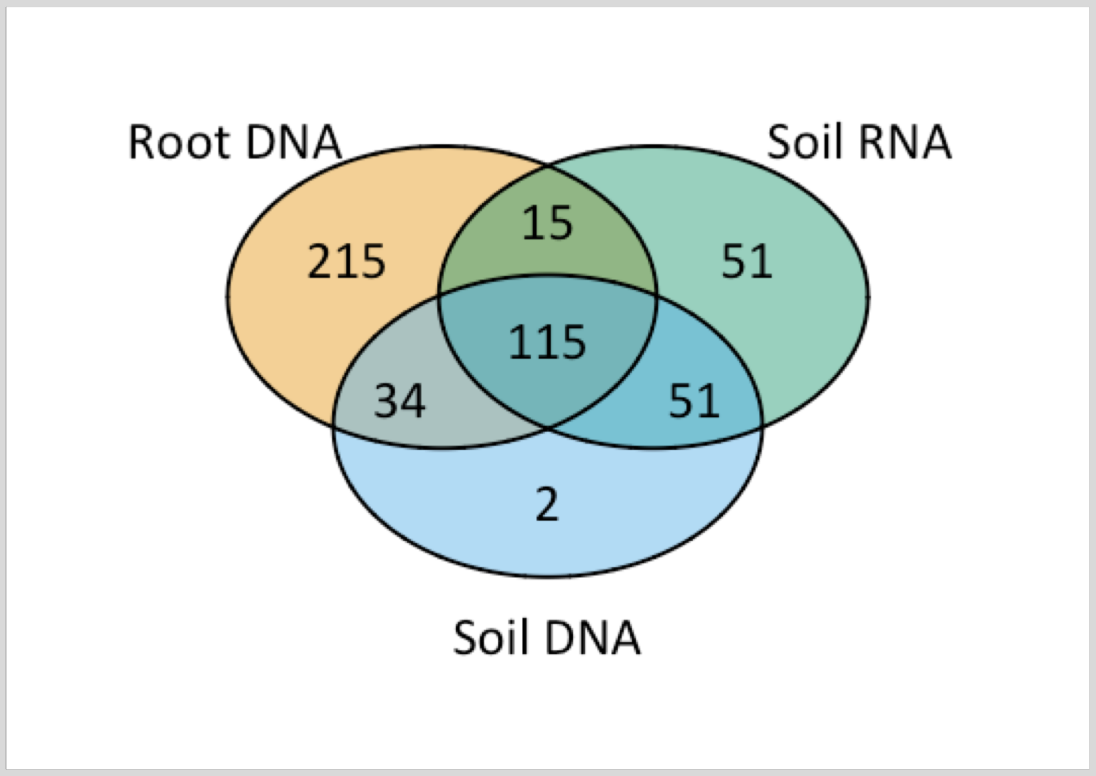
Next steps: the role of mycorrhizal fungi

- Molecular characterizations:
  - Fungal depth profiles
  - Fungal connection between rooting zone and thaw front
    - Root DNA
    - Thaw front RNA

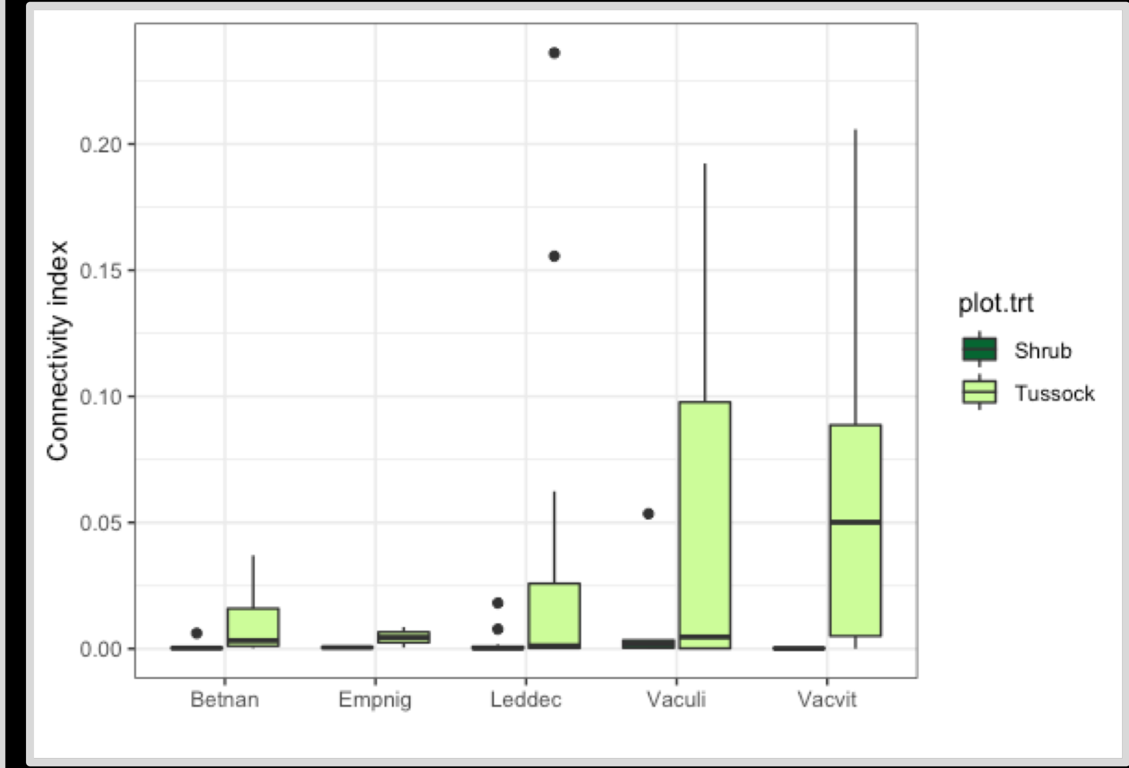


EML: fungal connection to the thaw front

Root and permafrost thaw front fungi

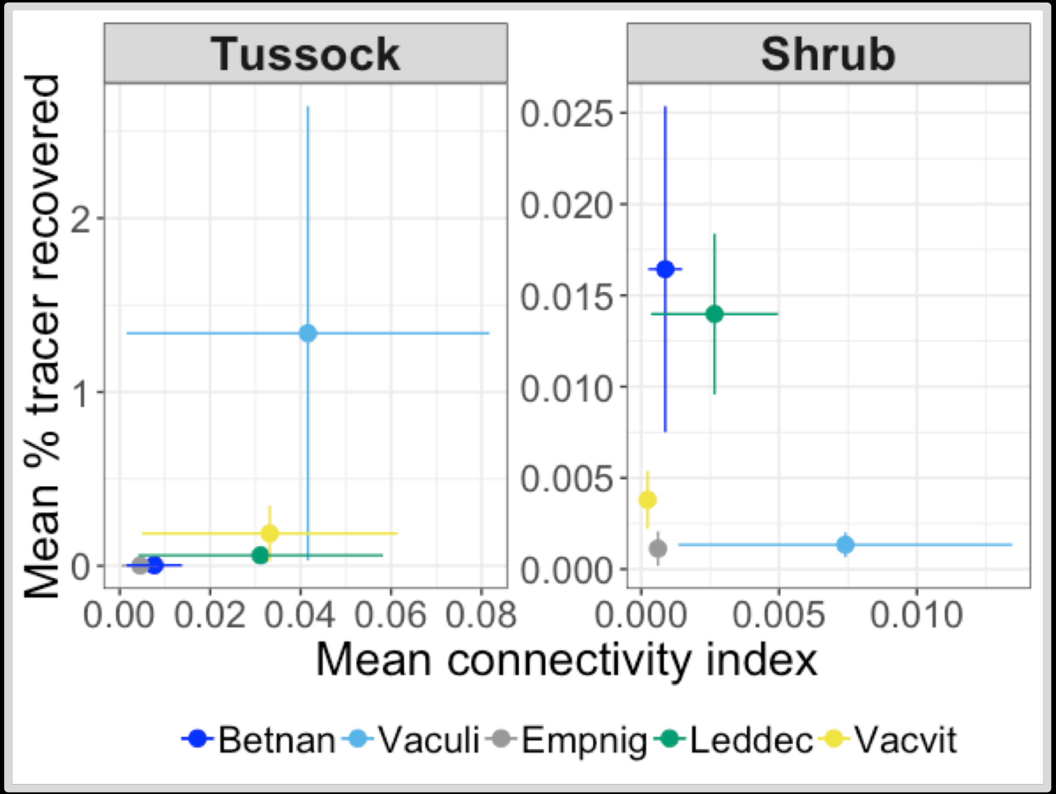


Fungal connection to the thaw front

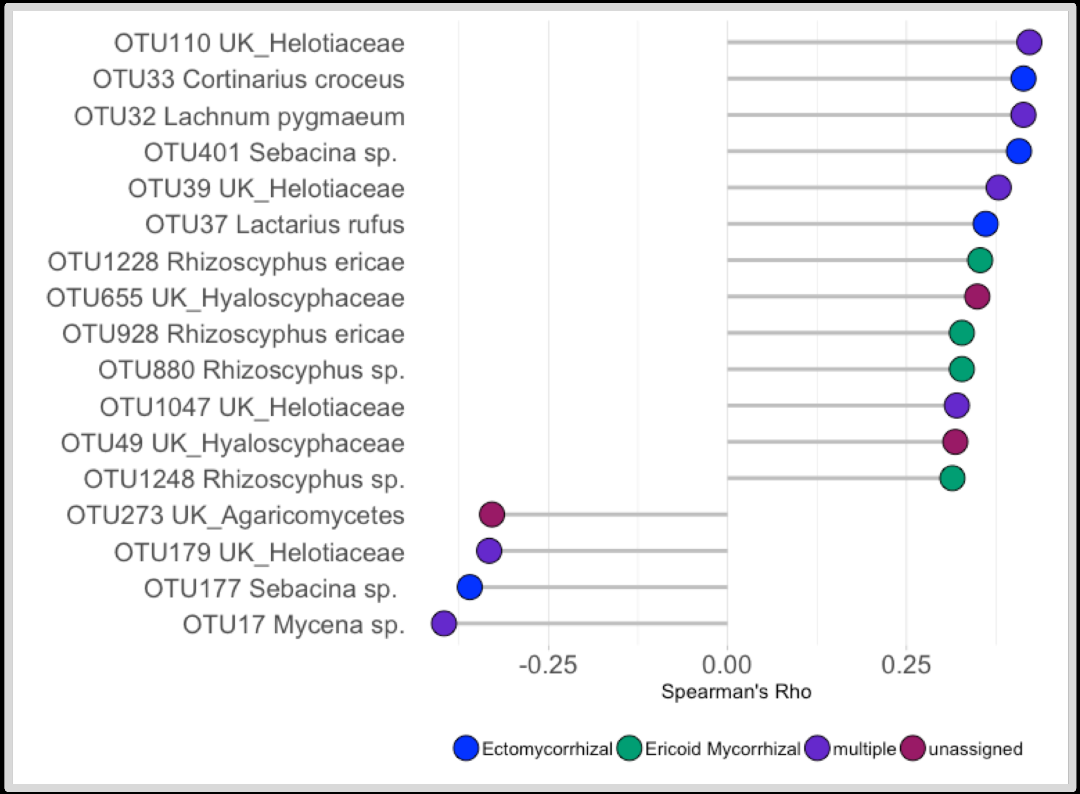


EML: fungal-connection effect on deep N access

Fungal connection to the thaw front and percent tracer recovered



Taxon-specific fungal access to deep N



Summary

- Thaw depth is an important predictor of belowground dynamics
- Forb, sedge, and deciduous shrub PFTs forage more deeply with increasing thaw
- *R. chamaemorus* and *E. vaginatum* have the deepest roots and the greatest uptake of ^{15}N
- *E. vaginatum* and *B. nana* showed some tracer recovery in their leaves within 24 hours.
- Mycorrhizal fungi may be an important mechanism of deep N access for shallowly rooted shrubs

Belowground ecology informs predictions for the Arctic

- Long term fate of permafrost N
  - Stimulation of productivity?
  - Allocation, turnover, persistence in ecosystem materials
- Deep N immobilization in fungal biomass
  - Saprotrophs vs. mycobionts
  - Quantification of uptake, turnover, stability of fungal pool
- Linking microbial community dynamics to flux measurements
  - Moving towards absolute not relative abundances
  - Heterogeneity of organisms and environment

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