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FACULTY OF SCIENCE

Season matters: Lateral flux of nitrate in the permafrost landscape

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Introduction

Plant-available N in soil solution is a key parameter linking nutrient input, soil organic matter turnover and plant nutrient uptake and growth .In the N-limited Arctic ecosystems, downslope movement of nitrate (NO_3^-) is a potentially under-studied source of ecosystem N. In the permafrost landscape snowmelt water will run off on top of the frozen surface, bringing dissolved compounds downslope. In the early thaw season, nutrients mineralized over winter are mobilized at the same time as snow melt supplies water, which moves on the still shallow frozen surface. This study investigates

- how much of released NO_3^- , supplied from upslope on the frozen surface, which is retained in a receiving ecosystem, and how much passes for further transport.
- which parts of the receiving ecosystem the NO_3^- moves, and how these depend on the season progression, thus thaw depth.
- We model the ecosystem and estimate the consequences of increased NO_3^- release in the future.

Study site

A semi-permanent snow fan, which supplies moisture throughout most of the summer, is located on a slope in Blæsedalen, a glacially carved valley in southern Disko Island, Western Greenland (69° 18′40.9″N; 53° 30′40.9″W). The climate is Low arctic and the slope is classified as mesic tundra heath dominated by *Salix arctica*, *Betula nana* and *Cassiope tetragona* (see figure 1).

Figure 1: Overview of the studied slope with a semi-permanent snow fan. Five reception area plots were established on the footslope..Photo: Laura Helene Rasmussen.

Experimental setup

- Five replicate monitoring plots were established on the footslope, positioned on a line perpendicular to the slope.
- For each monitoring plot, two adjacent tracer experiment plots were established

Monitoring plots

Parameters measured in the Reception area monitoring plots:

- Soil moisture and temperature was logged continuously in 0, 10, 20, 40 and 60 cm depth.
- Soil water chemistry in 10-20 and 20-30 cm depth was measured using extracts from soil water suction cups
- Soil gas was extracted from 20, 30 and 40 cm.
- Vegetation was analyzed once/season
- CO_2 and N_2O fluxes were measured over the growing seasons 2018 and 2019

Methods

A tracer solution was injected on top of the frozen surface upslope of the tracer plots in early July (30 cm depth) and in early August (90 cm depth), respectively (figure 2).

Solution:
100 ml 99.9% D_2O dissolved in 1000 ml local water.
Additionally, 99.99% ^{15}N as $K_2NO_3^-$, in amounts that correspond to 0.15 g ^{15}N m^{-1}

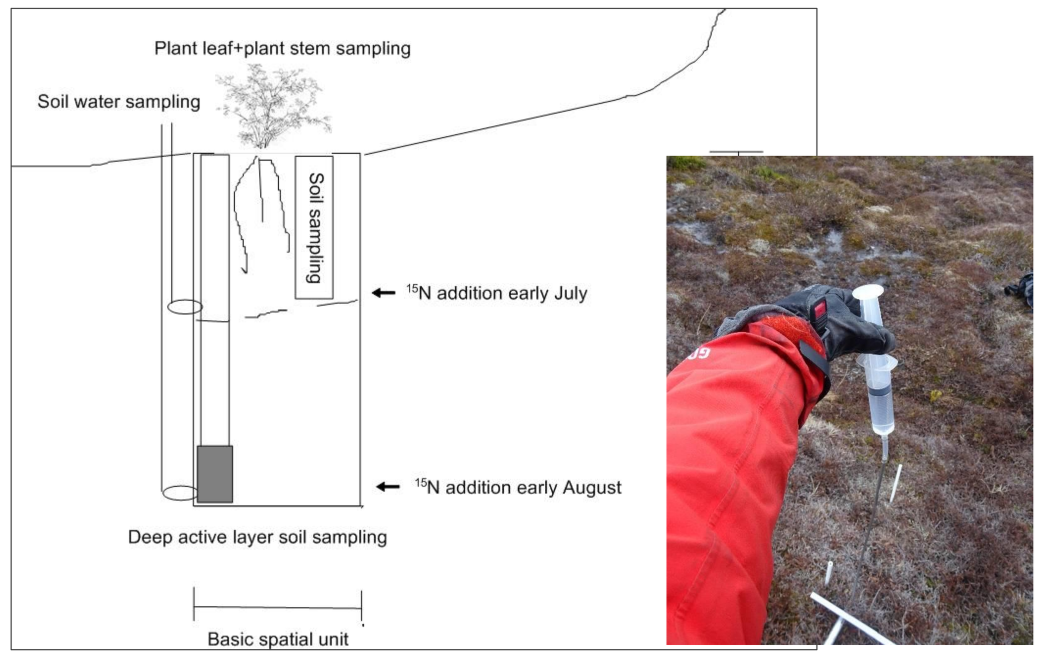

Figure 2: Left: Conceptual figure of the tracer exoerment setup,. Right:: Action picture from injection of tracer solution. Credit: Laura Helene Rasmussen.

Sampling:

On day 1, day 3, day 7 and day 25 sfter tracer injection, following samples were obtained (figure3):

- Bulk soil N+C in 0-10, 10-20 and 20-30 cm
- Microbial N+C in 0-10, 10-20 and 20-30 cm
- Root N+C in 0-10, 10-20 and 20-30 cm
- Aboveground vegetation N+C divided into root and stem pool for each species

Figure 3: View of tracer plot on sampling day 25. Photo: Laura Helene Rasmussen.

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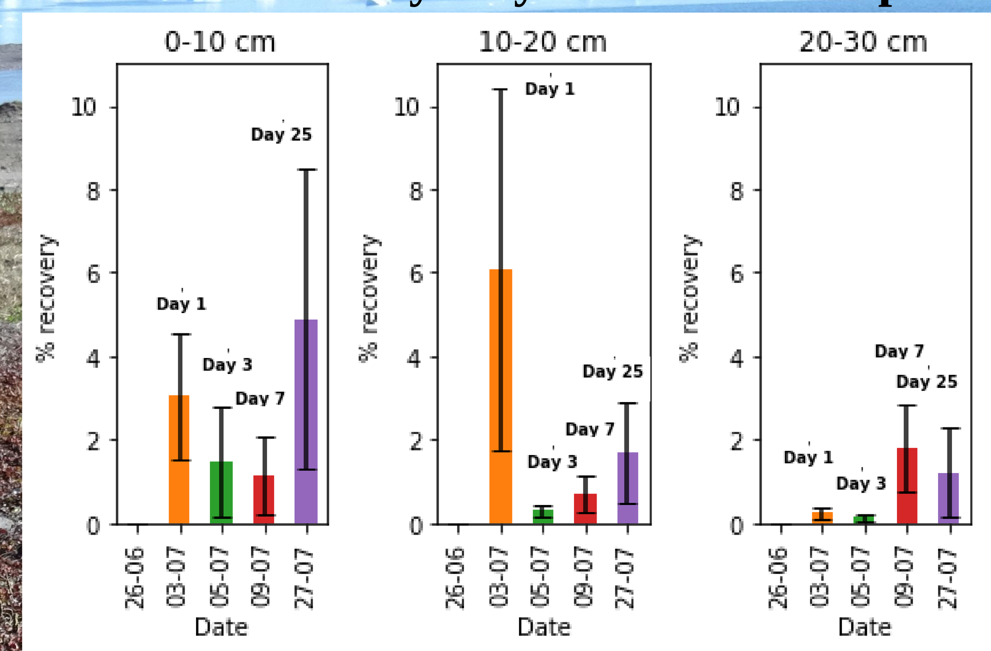
So how much nitrate was retained – and where did it go in the ecosystem?

- **Early July - shallow thaw layer:**
  50 % of injected ^{15}N tracer was retained, whereas 50 % continued downslope.
- **Early August- deeper thaw layer:**
  35 % of ^{15}N tracer was retained.
- **Most of the ^{15}N was retained in the microbes and bulk soil pools**
- **Only 1-3 % was retained by vegetation pools, even with a shallow thaw layer**

Microbial recovery July: 30 cm thaw depth



Microbial recovery August: 90 cm thaw depth

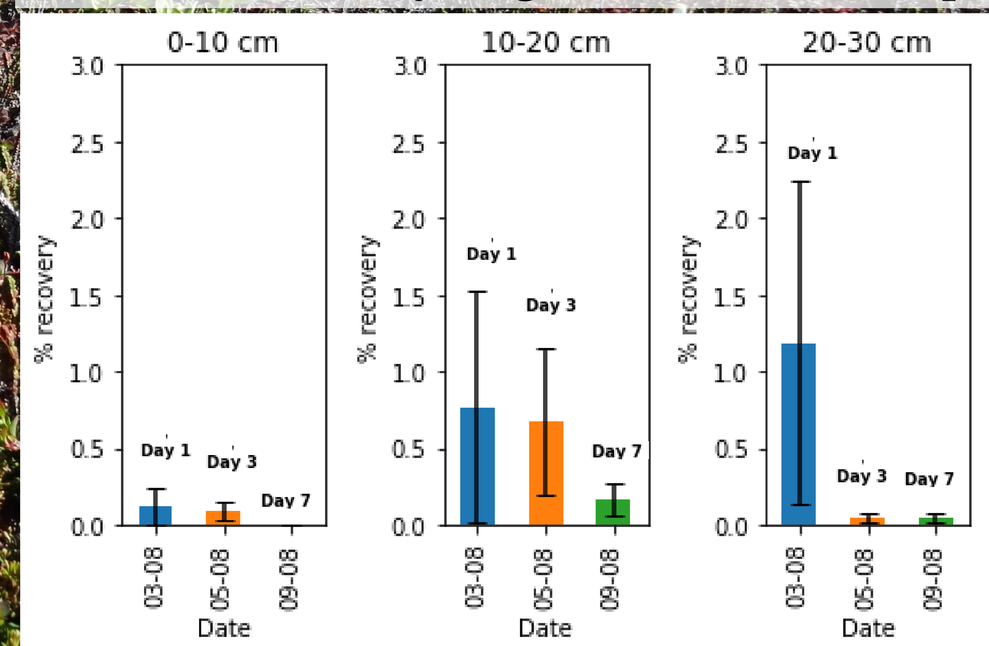


Figure 4: Microbial nitrate-^{15}N recovery divided into day after tracer injection for (upper) early season (July, 30 cm thaw depth) and (lower) late season (August, 90 cm thaw depth).

Conclusions from the field:

There is a potential for downslope lateral N transport on the frozen surface, even in the early season

Lateral N input is mainly retained in the soil, thus only indirectly reaching vegetation

Lead to Model questions:

Does the laterall N input matter for the ecosystem compared to the internal N cycling?

Does this change if N input increases in response to higher winter temperatures, thus winter mineralization?

Approach:
Control run with inflow from the side with a flow rate and a concentration of NO_3^- corresponding to measured values
Experimental runs with increased lateral N input in the inflow water

+++ NO_3^-

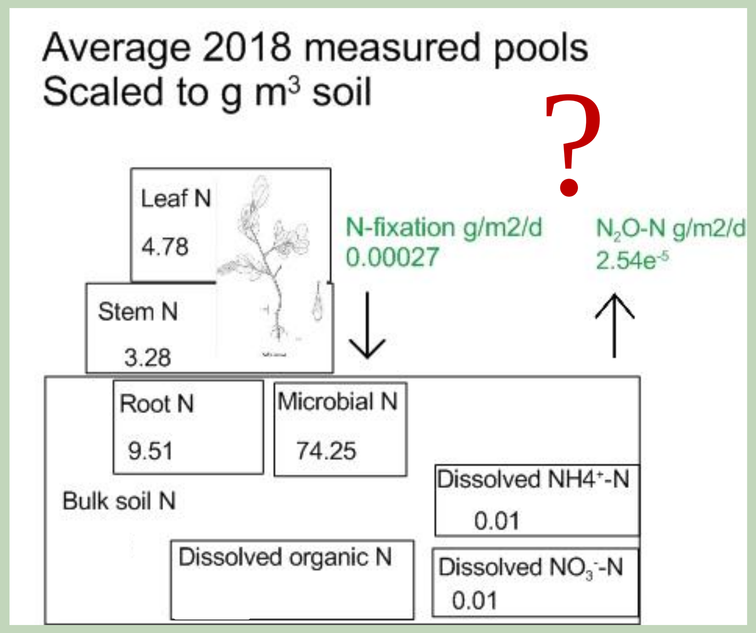
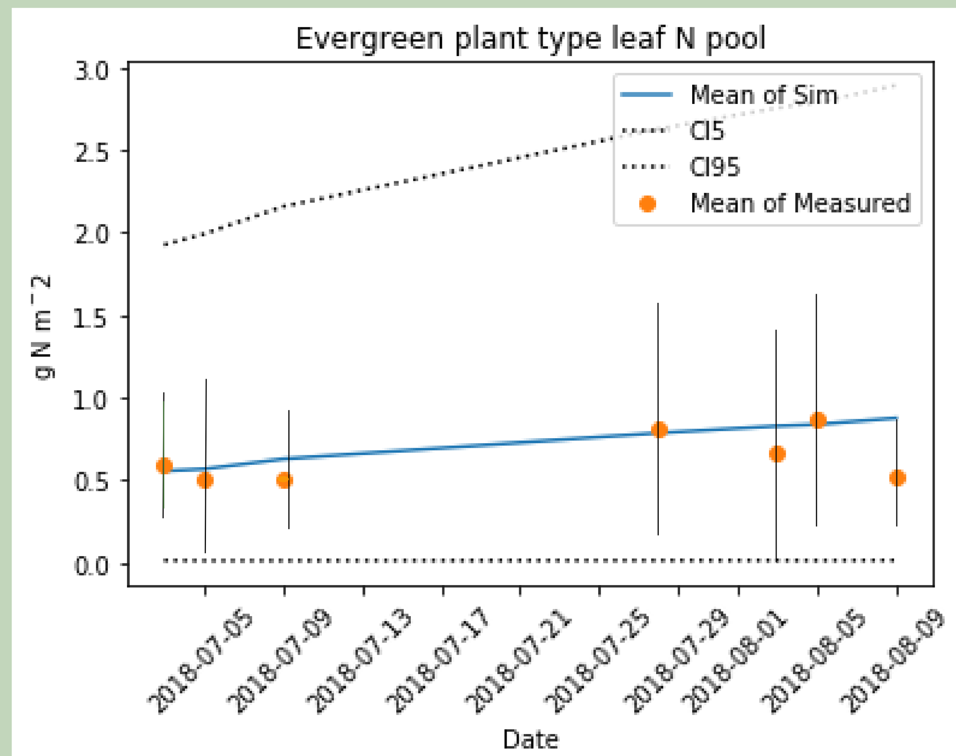


Figure 5: Conceptual figure of the model approach to testing the effect of increased lateral N input.

Coup model:
Numerical process-based ecosystem model based on a soil profile with movement of mass and energy between layers, and with the possibility of adding water movement laterally from the side (Jansson and Karlberg, 2011).



Example of model simulation:
The Coup model simulation of the Reception area site is validated based on its ability to simulate the measured pools of C and N over time correctly. To the left is an example of the current setup simulation of the Leaf N pool [g m^{-2}].

Figure 6: Coupmodel simulation of evergreen leaf N pool over the summer 2018 compared to measured leaf N pool. Bars represent standard error of the mean of the measurements.