The Effects of Winter Pulsed Warming and Snowmelt on Nitrogen Cycling in Agricultural Soils: A Lysimeter Study

Danielle Green[1], Fereidoun Rezanezhad[1], Sean Jordan[2], Claudia Wagner-Riddle[2], Hugh Henry[3], Stephanie Slowinski[1], Philippe Van Cappellen[1]
[1]Ecohydrology Research Group, Department of Earth and Environmental Sciences, University of Waterloo
[2]School of Environmental Sciences, University of Guelph, Guelph, Ontario, Canada
[3]Department of Biology, Western University, London, Ontario, Canada
E-mail: dcgreen@uwaterloo.ca

Background and Scope

In cold regions, climate change is expected to result in warmer winter temperatures and increased temperature variability. This can decrease soil insulation by reducing snow cover, exposing soils to colder temperatures and more frequent and extensive soil freezing and thawing.

Motivation: Freeze-thaw events can exert an important control over winter soil processes and the cycling of nitrogen (N), with consequences for soil health and nearby water quality. These impacts are especially important in agricultural soils.

Objective: Determine the impact of winter warming and freeze-thaw cycles on N cycling in agricultural soils, comparing the impact on two soil textures, silt loam and loamy sand.

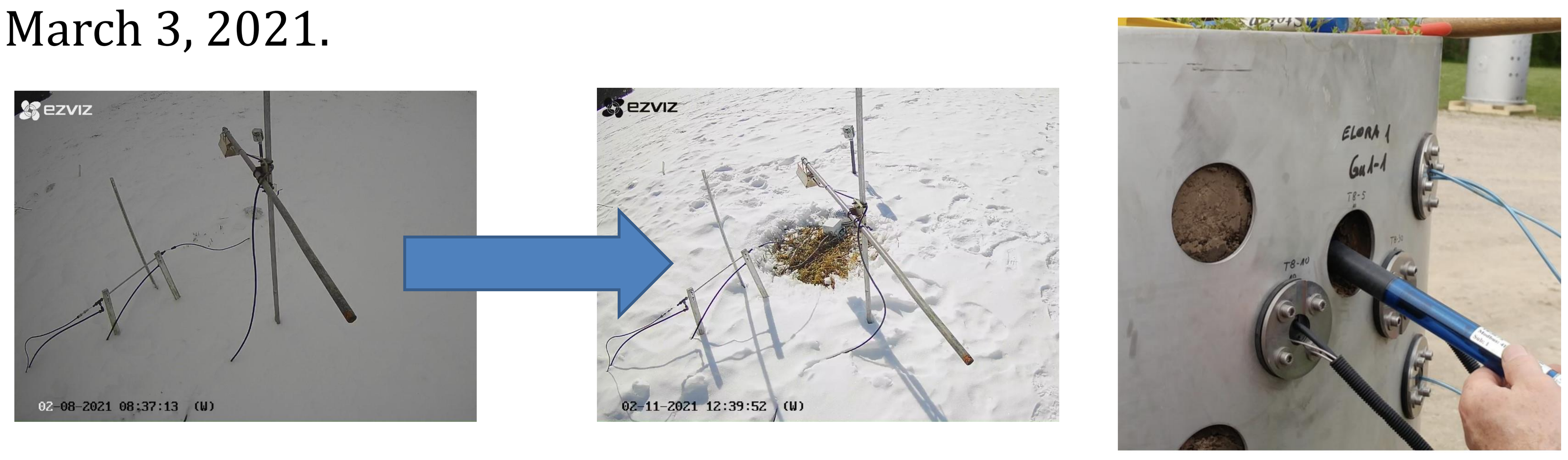
Methodology

Study Site: An agricultural site within the University of Guelph's Elora Research Station. This experiment occurred between December 1st, 2020 and April 30th, 2021 using 4 weighted cylindrical lysimeters.

Environmental Parameters: Air temperature and precipitation were recorded by the Elora weather station hourly.

Soil Type: 2 of the lysimeters contained silt loam soil and 2 contained loamy sand soil.

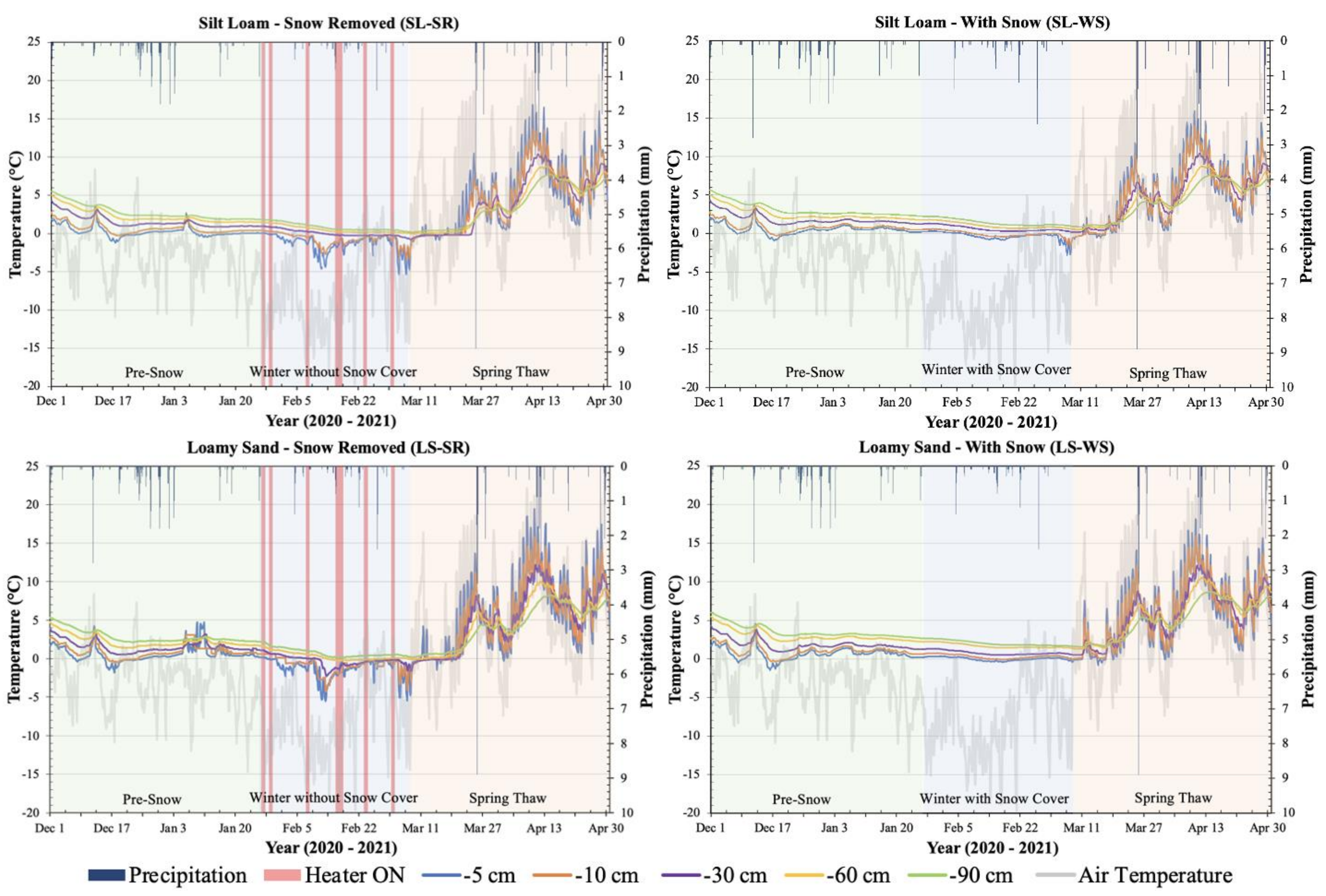
Winter Warming: Winter warming was applied to 2 lysimeters using a ceramic infrared heater. Heaters were turned on to melt fallen snow then turned off to allow soil to freeze between January 27, 2021 and March 3, 2021.



Soil Parameters: Soil temperature and moisture were measured every 10 minutes and pore water samples were collected weekly at -5, -10, -30, -60, and -90 cm below the lysimeter surface. N_2O fluxes at the lysimeter surface were measured every 2 hours.

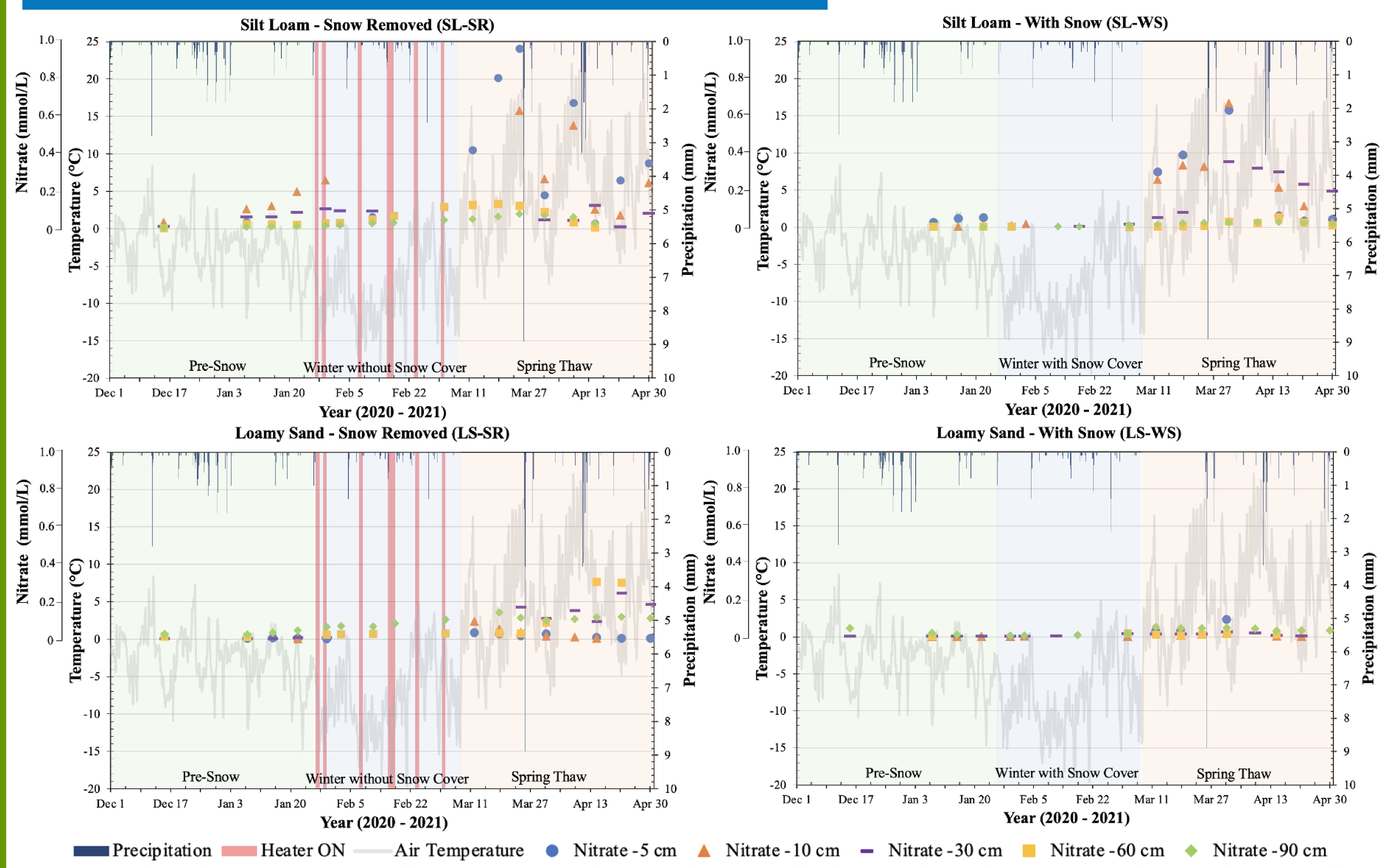
Porewater Geochemistry and Analytical Techniques: Pore water samples were filtered, subsampled, and analyzed for ammonium (NH_4^+), total dissolved nitrogen (TDN), nitrate (NO_3^-), and nitrite (NO_2^-).

Soil Temperature Dynamics

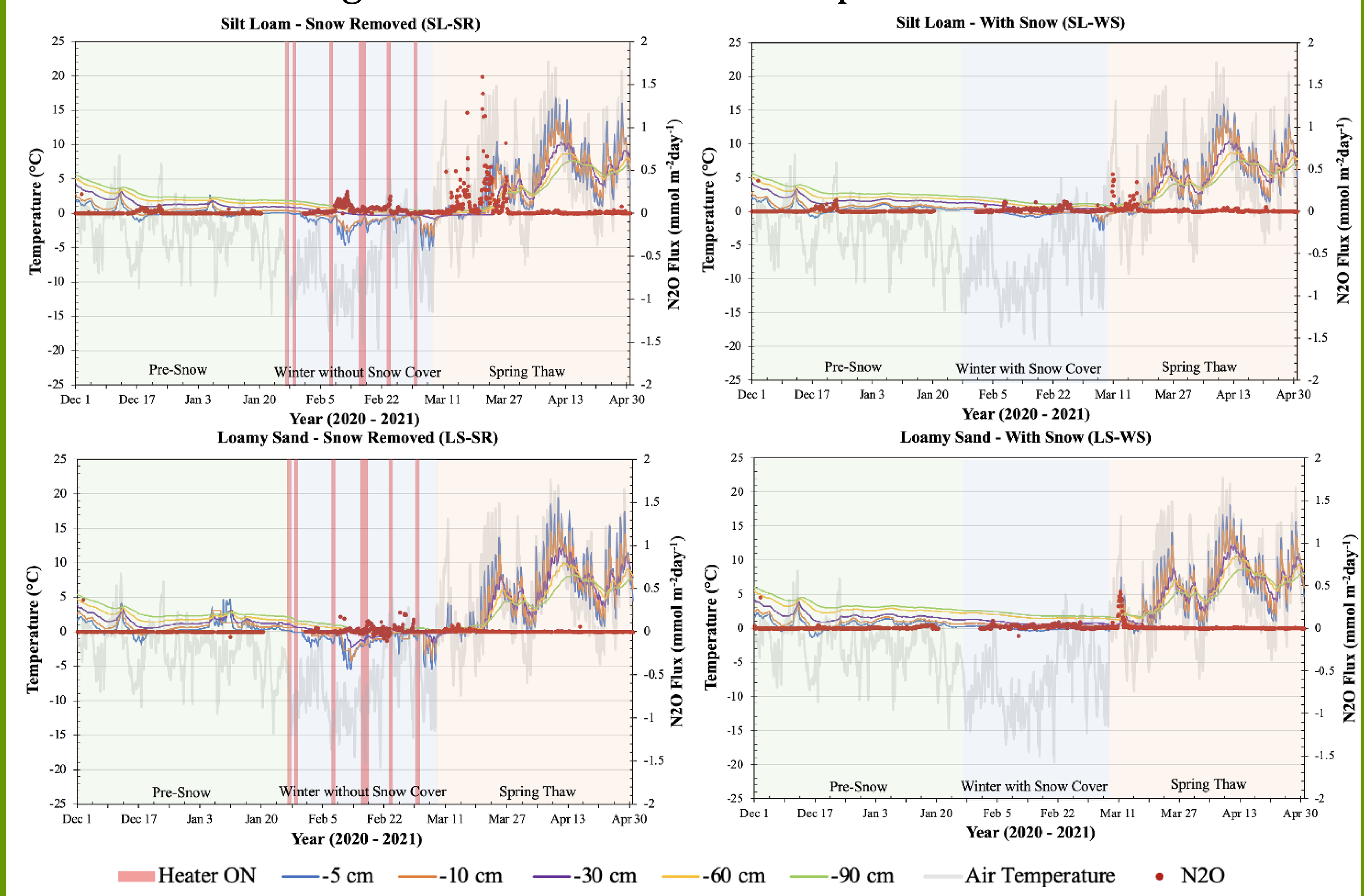


- Snow removal resulted in lower soil temperatures and increased occurrence of freeze thaw cycling.

Trends in NO_3^- and N_2O Flux



- In the loamy sand system, the released dissolved N was lost from the system via NO_3^- leaching.
- In the loamy sand, warming pulses increased soil temperatures, which led to higher water and solute transport rates.



- In the silt loam system, the released dissolved N was lost from the system as N_2O.
- The higher water retention capacity of silt loam caused increased N residence time, allowing for denitrification and/or nitrification reactions.

Conclusions

- N losses from the lysimeter systems were higher in the treatments where snow was removed because there were more freeze-thaw cycles which caused dissolved N release from soil N pools and subsequent loss of dissolved (NO_3^-) or gaseous (N_2O) N species from the systems.
- Soil type influenced soil temperature and moisture, dissolved N species concentrations, discharge, NO_3^- leaching rates, and N_2O fluxes in the lysimeters.

Acknowledgments

We would like to acknowledge the lab supplies provided by the Canada Excellence Research Chair (CERC) program in Ecohydrology and Natural Sciences and Engineering Research Council Grant (Discovery Grant to Rezanezhad: RGPIN-2015-03801). We thank Marianne Vandergriendt and Dr. Shuhuan Li (Ecohydrology Research Group, University of Waterloo) for assistance with laboratory analyses and Sean Jordan (University of Guelph) for assisting with the porewater sampling.