Soil biogeochemical processes under freeze-thaw cycles using a process-oriented experimental approach

F.REZANEZHAD[1*], T. MILOJEVIC[1], D. OH, C. T. PARSONS, C. SMEATON[1], P. VAN CAPPELLEN[1]

[1]Ecohydrology Research Group, University of Waterloo, Waterloo, ON, N2L 3G1, Canada (*correspondence: frezanez@uwaterloo.ca)

The ongoing displacement of climate zones by global warming is increasing the frequency and intensity of freeze-thaw cycles in soils at middle and high latitudes. Repeated freezing and thawing of soils changes their physical properties, geochemistry, and microbial community structure, which together affect ecosystem functioning and the biogeochemical cycling of carbon and nutrients in aquatic and terrestrial environments. A mechanistic understanding of how freezing and thawing influence soil respiration, greenhouse gas emissions, and leaching of nutrients to groundwater is necessary to predict how soil and water resources will respond to climate change. In this presentation, we present a novel approach, which combines the acquisition of integrated physical, chemical and microbial data in a newly-developed soil column system in which simulates realistic soil temperature profiles during freeze-thaw cycles. Surface and subsurface changes to gas and aqueous phase chemistry are measured to delineate the pathways and quantify soil biogeochemical processes during freeze-thaw cycles. The results indicate that the time-dependent carbon and nutrient dynamics are influenced by a combination of two key factors. Firstly, fluctuations in temperature and oxygen availability affect soil geochemical and microbial activities. Secondly, the recurrent development of a physical ice barrier prevents exchange of carbon and nutrients between the soil and atmosphere during freezing conditions; removal of this barrier during thaw conditions increases the rates of carbon and nutrients leaching and production. During freezing, oxygen levels in the unsaturated zone decreased due to restricted gas exchange with the atmosphere. As the soil thawed, oxygen penetrated deeper into the soil enhancing the aerobic mineralization of organic carbon and other nutrients. The results from this process-oriented experimental approach will help the interpretation of freeze-thaw processes in cold climate ecosystems and the prediction in models coupling soil processes to the global carbon/nutrient cycle and climate.