Slope hydrology and permafrost: The effect of snowmelt N transport on downslope ecosystem

Laura Helene Rasmussen¹, Per Ambus¹, Wenxin Zhang¹,², Per Erik Jansson¹,³, Anders Michelsen¹,⁴, and Bo Elberling¹

¹University of Copenhagen, Institute for Geosciences and Natural Resource Management, Center for Permafrost, København K, Denmark (lhr@ign.ku.dk)
²Department of Physical Geography and Ecosystem Science, Lund University, Sölvegatan 12, Lund, Sweden
³KTH Royal Institute of Technology, Stockholm, Sweden
⁴Department of Biology, University of Copenhagen, Denmark

In the permafrost-affected landscape, surface and near-surface water movement links areas of higher elevation with lowlands and surface water bodies. Water supply is dominated by snow melt and is thus highly seasonal, as most water moves on the frozen surface in spring, passing only a thin layer of thawed soil. Soluble nutrients mobilized by soil thaw may thus be transported laterally from upslope to downslope ecosystems, which in nutrient-limited cold ecosystems may affect vegetation, ecosystem respiration and surface-atmosphere interaction. In a nitrogen (N) limited ecosystem, however, released inorganic N may in reality not travel far downslope.

This study quantifies the potential effect of the snowmelt water nutrient transport by tracing dissolved N in meltwater moving downslope on the frozen surface in a W Greenlandic slope with a snow fan supplying meltwater throughout most of the summer. We use the stable isotopes ¹⁵N and D applied simultaneously on top of the frozen surface upslope in a combined solution to investigate the behavior of water and dissolved N flow patterns. We further address the effect of season by tracing N supplied in the early thaw season (30 cm to the frozen surface) and in the late thaw season (90 cm to the frozen surface). Monitoring the slope in detail, we then use the numerical coupled heat-and-mass transfer Coup model to simulate the biotics and abiotics of the receiving ecosystem and study the importance of the lateral N input and the effect of increased N transport in a warmer future.

About 50 % of the N tracer was retained in the ecosystem immediately below injection in the early growing season (30 cm active layer), whereas about 35 % was retained in the later growing season (90 cm active layer). Most of the applied ¹⁵N was rapidly immobilized by microbes and into the bulk soil, whereas only a few percentages was taken up by the vegetation. D recovery seemed to follow the pattern of microbial N uptake, suggesting that N and D moved physically from the frozen surface and to the immediate subsoil together.

Modelling the ecosystem based on measured N and C pool sizes, meteorology, soil temperature and moisture revealed a large N constrain on vegetation growth. The current observed vegetation could not be explained with the measured pools alone, suggesting an “invisible” source
of N to support the observed vegetation. We conclude that a substantial fraction of lateral N input is transported further downslope, but that increases in N release and transport might not affect vegetation immediately, as most supplied N ends in the soil pool. Vegetation in the receiving ecosystem relies on an external N source, which could be dissolved N transported by snowmelt water on the frozen surface. Snowmelt redistribution of N in the landscape may thus be a factor to account for when studying N cycling in a spatial context.