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Lateral taliks drive winter dissolved organic carbon transfer to aquatic systems in permafrost regions: approach using silicon isotopes

MAËLLE VILLANI[1], PHILIPPE ROUX[1], MAUD HENRION[1], SEBASTIEN FRANÇOIS[1], ELÉONORE DU BOIS D'AISCHE[1], LAURENCE MONIN[1], ALBERTO BORGES[2], ALLISON K KELLEY[3], JUSTIN LEDMAN[3], GILLES DENIS[4], EDWARD A.G SCHUUR[3] AND SOPHIE OPFERGELT[1]

[1]UCLouvain
[2]ULiège
[3]Northern Arizona University
[4]Nanok expedition (IMAQA)

Warmer winter in permafrost regions alters subsurface hydrology and biogeochemical cycling during a season traditionally assumed to be inactive. Taliks, unfrozen portions of soil that persist in winter, are often studied using thermal and physical parameters but biogeochemical processes occurring in these taliks remain understudied. Taliks can be either, closed and are surrounded by frozen ground, or lateral and may form lateral water flow pathways, enabling the transfer of dissolved organic carbon (DOC) from soils to aquatic systems, which may contribute to winter permafrost carbon emissions. Thus, the distinction between closed and lateral taliks is important in determining biogeochemical connectivity.

Fieldworks were conducted during winter (February–March) in 2024 and 2025 along a water track near Eight Mile Lake, Alaska (USA). Soil cores were collected upstream, downstream, and outside the water track to sample soil pore waters from both frozen part of the soil and taliks. Silicon isotopes ($\delta^{30}Si$) were measured in soil pore waters to distinguish talik types (closed vs. lateral): in a closed talik, silicic acid concentration is increasing upon freezing, leading to amorphous silica precipitation that induces Si isotope fractionation with ^{28}Si preferentially incorporated into the colloidal amorphous silica, leaving the residual solution enriched in ^{30}Si. In a lateral talik, the saturation for amorphous silica precipitation is not reached, which does not lead to Si isotope fractionation. Soil pore water and local headwater chemistry (pH, conductivity and DOC concentrations) was measured to study DOC transfer from lateral taliks to aquatic bodies.

Our results show that by comparing soil pore waters $\delta^{30}Si$ from frozen parts of the soil and taliks ($\Delta_{Frozen\text{-}Talik}\ \delta^{30}Si$), closed taliks form upstream and outside the water track ($\Delta_{Frozen\text{-}Talik}\ \delta^{30}Si < 0$), whereas lateral taliks develop downstream ($\Delta_{Frozen\text{-}Talik}\ \delta^{30}Si > 0$). In soil pore waters from taliks, DOC concentrations are twice higher in the lateral than in the closed taliks. Moreover, a winter 1.9 °C warmer in 2025 compared to 2024 was associated with a 57% increase of DOC concentration in the river in 2025 compared to 2024, highlighting a potential higher transfer of DOC from lateral taliks to river with interannual climate variability.