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Denitrification kinetics support high nitrous oxide emissions in West Siberian cryoturbated tundra

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High N_2O emissions have been reported from West Siberian cryoturbated tundra soil, so called peat circles (Repo et al. 2009). However, the processes behind the high N_2O emissions are not known. We studied denitrification kinetics, N_2O production rates and carbon mineralization in soil from both the cryoturbated peat circle without vegetation and the surrounding non-turbated peat with vegetation (0-5 and 15-20 cm depth, 3 field replicates each). Peat circle soil was visually more decomposed, had higher nitrate contents but similar low pH (3.1) as compared with non-turbated peat.

When incubated anaerobically as loose soil, the cryoturbated peat produced much higher amounts of N_2O than the non-turbated peat. In addition, the N_2O product ratio for denitrification (as inferred from incubation with and without 10 vol% acetylene) was much higher in cryoturbated than in non-turbated peat, suggesting that instantaneous nitrous oxide reductase (N_2OR) activity in cryoturbated soil is absent or low. Significant N_2 production in cryo-turbated soil occurred only after all nitrate was consumed, illustrating that the peat circle denitrifier community can express N_2OR. Albeit at much lower rates, the non-turbated soils showed a more balanced denitrification upon oxic-anoxic transition characterized by instantaneous N_2 production with little N_2O accumulation. Unbalanced denitrification in peat circle soil was also indicated by μmolar NO accumulation whereas no measurable NO production was found in the non-turbated soil. Contrasts in denitrification performance persisted when incubating the soils as anoxic soil slurries and adding nitrate and glucose to the non-turbated soil to equalize substrate concentrations. Together, our findings suggest that the active denitrifying communities in the two soils represent distinct denitrification phenotypes; active denitrifiers in the N-abundant cryoturbated soil appear to be more sloppy in regulating electron flow resulting in higher N loss in form of NO and N_2O. The non-turbated denitrifying community, in contrast, tightly regulates electron flow to N-oxides, which probably reflects the scarcity of N-oxides in tundra soil. Molecular studies are on its way to clarify taxonomic denitrifier composition in cryoturbated and non-turbated tundra soil (Palmer, K. et al.).

To test the hypothesis that higher denitrification rates in cryoturbated peat are due to accelerated in situ mineralization, we also studied CO_2 production in a long-term incubation experiment with fresh loose soil (90d, 15 $^{\circ}$C). The cryoturbated soil exhibited much lower C mineralization rates than the top soil of the non-turbated tundra, most probably reflecting the absence of fresh organic carbon in this vegetation-free soil. Nevertheless, the low CO_2 production in the peat circles is in contrast to the high denitrification rates and illustrates a decoupling of C and N cycling in long-term turbated arctic soil. Apparently, the gradual decline of the C/N ratio in cryo-turbated soil (Repo et al. 2009) has fostered a viable denitrifier community through increasing net release of mineral nitrogen. Carbon limitation together with abundant N-oxide availability, in turn, may be one reason for the observed low instantaneous N_2O reductase activity in the peat circle soil.

References: Repo M, Susiluoto S, Lind SE, Jokinen S, Elsakov V, Biasi C, Virtanen T, Martikainen PJ. 2009. Large N2O emissions from cryoturbated peat soil in tundra. Nature Geoscience 2: 189-192.