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Evidence from silicon isotopes for pulses of sub-ice microbial activity during winter in the Lena River

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Large Arctic rivers are key locations for nitrogen processing, which controls the supply of this limiting nutrient to the Arctic Ocean. In a warming Arctic, longer ice-free periods increase riverine productivity and modulate nitrogen consumption and delivery to the ocean. In this study, the annual variability of nitrate concentrations at the Lena River outlet (Samoylov station) was investigated. Significantly higher nitrate concentrations in water were observed sub-ice (winter) than in the open water (summer), and the higher nitrate concentrations follow phases of colder air temperature at the Lena catchment scale (ERA5 reanalysis data). We hypothesize that colder phases result in thicker river ice leading to darker under-ice conditions preferred by nitrifying microbial communities, thereby inducing increasing sub-ice nitrification. We tested this hypothesis using silicon isotopes known to fractionate upon freezing. The high nitrate concentrations in the winter are associated with heavier silicon isotope compositions in river water. This can be explained by the supersaturation and precipitation of amorphous silica preferentially incorporating the lighter silicon isotopes, leaving the water isotopically heavier. Supersaturation of amorphous silica can result from thicker ice formation upon colder air temperature at catchment scale. The silicon isotope data support phases of thicker ice formation, and indirectly support darker sub-ice conditions at the river base creating pulses of increasing nitrification. Our hypothesis is also supported by a change in the value of an index for dissolved organic carbon aromaticity (SUVA) during the colder phases: this suggests that conditions favour the decomposition of dissolved organic matter during periods of thicker river ice. Air temperature, nitrate concentration, silicon isotopes and SUVA are supporting evidence for pulses of sub-ice microbial activity in the river during winter. It follows that decreasing ice cover duration throughout the catchment is likely to decrease winter nitrate fluxes from the Lena River to the Arctic Ocean.