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Nitrogen biogeochemical cycle in the chemocline of perennially ice-covered Lake Untersee, East Antarctica

DANIEL FILLION[1], HAROLD J BRADBURY[2], DENIS LACELLE[3], DALE T ANDERSEN[4], LUDOVIC PASCAL[1], LORIE DEMERS-PERREAULT[1], STEPHANIE KUSCH[5] AND ANDRE PELLERIN[1]

[1]Institut des Sciences de la Mer de Rimouski
[2]The University of British Columbia
[3]University of Ottawa
[4]SETI Institute
[5]Institut des sciences de la mer - Université du Québec à Rimouski

Meromictic basins in perennially ice-covered Antarctic lakes are extreme environments that may serve as analogs for biogeochemical dynamics in Earth's primitive and low-oxygen oceans. We investigated N cycling in the euxinic basin of Lake Untersee (East Antarctica) to constrain the dominant metabolisms and quantify N transformations and their role in the C cycle. Previous genomic research revealed the putative presence of N assimilation and nitrification, but quantitative information on N transformations is lacking. Here, we present high-resolution water column data of physicochemical parameters and key redox species and use a 1-D reactive-transport model (RTM) to constrain the N metabolic pathways.

Despite the remarkably stable conditions observed over 20+ years of monitoring of the interface between the anoxic bottom waters in the basin and the overlying oxic waters, turbulent mixing results in eddy diffusivity (Kz) of up to three orders of magnitude above molecular diffusion. The vertical gradient of Kz across the chemocline balances upward fluxes of reduced species, including ammonium (NH_4^+) and methane (CH_4), with downward oxygen fluxes from overlying waters, thereby quantitatively constraining the N transformations. The RTM results suggest that the measured N_2 excess in the anoxic waters requires NH_4^+ loss through canonical nitrification-denitrification. Simulations including anaerobic oxidation of ammonium (anammox) showed an accumulation of nitrite (NO_2^-) at the oxycline (~0.10–1.0 µM) that we did not detect in the water samples. Other microbial pathways, such as nitrate-dependent anaerobic methane oxidation (n-damo) and H_2S-dependent denitrification, if present, can only play a minor role in N transformations to be reconciled with the observed redox species profiles. This suggests that aerobic recycling of an abundant NH_4^+ pool governs N removal, leaving little room for alternative pathways, such as anammox and n-damo, with implications for Earth's past oceans.