Nitrous oxide dynamics in sea ice

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Fluctuations in greenhouse gases (GHGs) concentration alter the energetic budget of the climate system. There is high confidence that natural systems related to snow, ice and frozen ground (including permafrost) are affected. Nitrous oxide (N_2O) is one of the potent GHG naturally present in the atmosphere, but witch has seen his concentration growing since industrial era. N_2O has a lifetime in the atmosphere of 114 years and a global warming potential (GWP) of 298 to be compared to carbon dioxide that has a GWP of 1. N_2O is also describe as the dominant ozone-depleting substance emitted in the 21st Century. Yet, there are still large uncertainties and gaps in the understanding of the cycle of this compound through the ocean and particularly in sea ice. Sources and sinks of N_2O are therefore still poorly quantified.

The main processes (with the exception of transport processes) involved in the N_2O cycle within the aquatic environment are nitrification and denitrification. To date, only one study by Randall et al. present N_2O measurements in sea ice. Randall et al. pointed out that sea ice formation and melt has the potential to generate sea-air or air-sea fluxes of N_2O, respectively.

Study on ammonium oxidation and anaerobic bacterial cultures shows that N_2O production can potentially occur in sea ice. Denitrification can act as a sink or a source of N_2O. In strictly anaerobic conditions, N_2O is removed by denitrification. However, denitrification can also occur in presence of O_2 at trace level concentrations (>0.2 mg L^{-1}), and in these conditions there is a large N_2O production.

Recent observations of significant nitrification in Antarctic sea ice shed a new light on nitrogen cycle within sea ice. It has been suggested that nitrification supplies up to 70% of nitrate assimilated within Antarctic spring sea ice. Corollary, production of N_2O, a by-product of nitrification, can potentially be significant. This was recently confirmed in Antarctic land fast ice in McMurdo Sound, where N_2O release to the atmosphere was estimated to 4 $\mu mol.m^{-2}.yr^{-1}$. This assessment is probably an underestimate since it only accounts for dissolved N_2O while a significant amount of N_2O is likely to occur in the gaseous form like N_2, O_2 and Ar.

Finally, nitrification produces little N_2O in oxygenated waters but the N_2O production yield from nitrification strongly increases as O_2 levels decrease. Hence, it is not possible to distinguish the sources of N_2O solely based on bulk N_2O concentrations or environmental conditions, while deepened knowledge of processes is needed to well understand N_2O emissions.

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