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Repeat measurements of methane and nitrous oxide distributions across the North American Arctic Ocean from 2015–2018

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Rapid environmental change across the Arctic Ocean has the potential to alter the cycling and sea-air exchange of greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O). Predicting how climate change will affect CH_4 and N_2O distributions is challenging due to a lack of published data on these gases in the Arctic across broad spatial scales and multiple years. Here we present four years of summertime CH_4 and N_2O concentration profiles collected throughout the North American Arctic Ocean (1000 measurements per year from 2015–2018) as well as a year-round time-series of CH_4 and N_2O in the coastal Arctic from 2017–2018. By integrating multiple years of data at repeat stations, we are able to evaluate the impact of year-to-year variability in physical and biogeochemical conditions, such as ice cover, water masses, and nutrients, on the distribution and sea-air fluxes of these gases.

Our results show that the dominant source of N_2O across the North American Arctic Ocean is sedimentary nitrification and denitrification in the Bering and Chukchi Sea shelf regions, with elevated N_2O in 2016 compared to other years correlated with an increased presence of Pacific Winter Water in the sampling region. As this water mass flows eastward, elevated N_2O in subsurface waters persists for thousands of kilometers because N_2O has no known sinks in oxygenated waters. CH_4 distributions are more spatially and temporally variable, suggesting more localized sources and active water column oxidation of this gas. Summertime sea-air fluxes of both gases are relatively low in magnitude and similar to other oceanic regions.

We collected a year-round time-series from 2017–2018 in the coastal Arctic (Cambridge Bay, Nunavut) and an adjacent river system. During the freshet, we observed elevated CH_4 concentrations associated with river inflow for a $\sim$2-week period, with maximum surface CH_4 concentrations of 10 000 nM (250 000 % saturation) in the river, and 1000 nM (25 000 % saturation) in the Cambridge Bay estuary. By comparison, background CH_4 concentrations were 10 nM in the estuary for the remainder of the year. In 2018, we used the ChemYak autonomous surface vehicle to map the spatial and vertical distributions of CH_4 and CO_2 during the freshet period in Cambridge Bay, sampling from the river mouth to the receding ice edge. Surface concentrations of CH_4 and CO_2 in open water decreased with time over a 5-day period, suggesting rapid ventilation of these greenhouse gases to the atmosphere. Our results demonstrate that sampling during the freshet period are required to accurately estimate annual greenhouse gas emissions from this and similar systems. Such sampling will be necessary to resolve how future changes in the seasonal timing and volume of Arctic river inflow and ice melt may alter greenhouse gas emissions from these regions. Our measurements from coastal to open ocean regions of the Arctic Ocean establish a benchmark against which future changes in CH_4 and N_2O distributions can be evaluated.