Arctic sea ice: source or sink for nitrous oxide?

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INTRODUCTION

An important climate active gas still misunderstood

Nitrous oxide (N_2O) is a greenhouse gas 300 times more effective than CO_2 on a per molecule basis, and is the dominant ozone-depleting substance emitted in the 21st century. Since the beginning of the industrial age it has increased in the atmosphere at a rate of 0.2 to 0.3% per year. Bacterial activities, such as nitrification and denitrification, are the only known natural processes that produce or consume N_2O. Globally, oceans are a source of N_2O for the atmosphere. However, N_2O still remains poorly-known and there are possibly unidentified sources affecting the atmospheric concentrations.

The arctic is a region in change, characterised by the presence of an ocean covered by sea ice part of the year. Atmospheric N_2O concentrations over the arctic region are known to have higher seasonal variability than at lower latitudes. Currently, there are no published data on N_2O dynamics in the Arctic Ocean and its sea ice cover.

DATASETS AND METHOD

We measured:

1- N_2O concentrations in the bottom 10 cm of drifting and landfast Arctic sea ice.

2- N_2O concentrations in the underlying surface water (USW) during the vernal ice algal bloom.

Methodological considerations:

- We test three techniques to sample bulk N_2O concentrations in sea ice.

- Melting bulk sea ice in an **air-tight glass syringe** gives the most reliable results.

From bulk N_2O concentrations in sea ice we estimate:

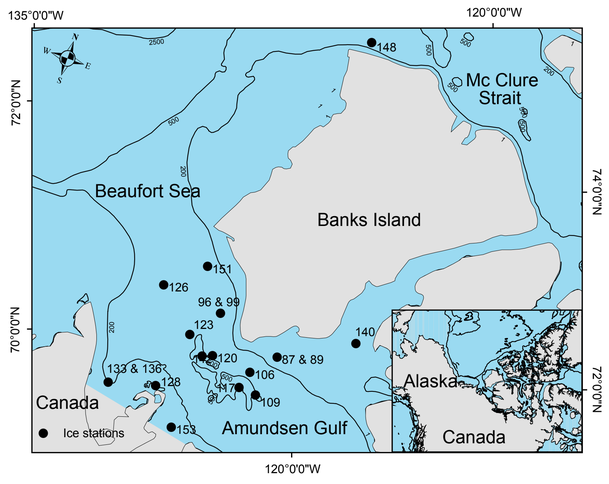
1- Bulk N_2O saturations in sea ice with respect to atmospheric concentrations.

2- N_2O concentrations and saturations in brine sea ice based on the salinity.

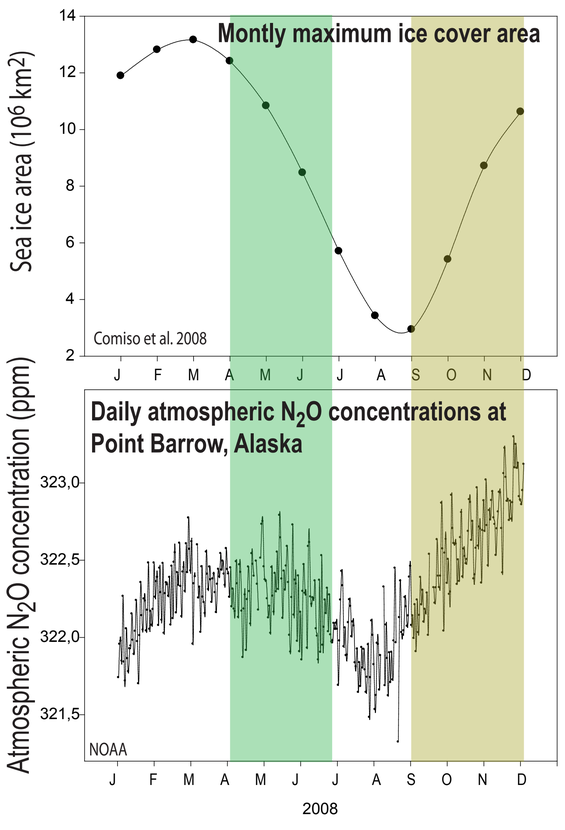
STUDY AREA

As part of the **Circumpolar Flaw Lead (CFL)** System Study and of the **International Polar Year (IPY)**, we collected samples in the **Amundsen Gulf and McClure Strait** (Canadian Archipelago).

On board of the Canadian Ice-Breaker CCGS Amundsen from 28 March to 2 June 2008.



INTERPRETATION



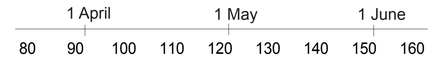
Strong relationship between:

- Sea ice cover area
- Seasonnal variability in atmospheric N_2O concentrations

In fall (sea ice formation): atmospheric N_2O concentrations increase.

In spring (sea ice melting), atmospheric N_2O concentrations decrease.

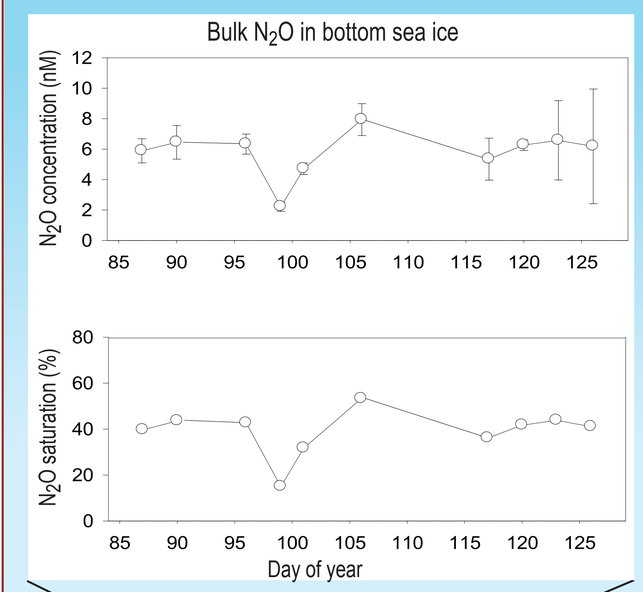
RESULTS



Measured sea ice bulk N_2O

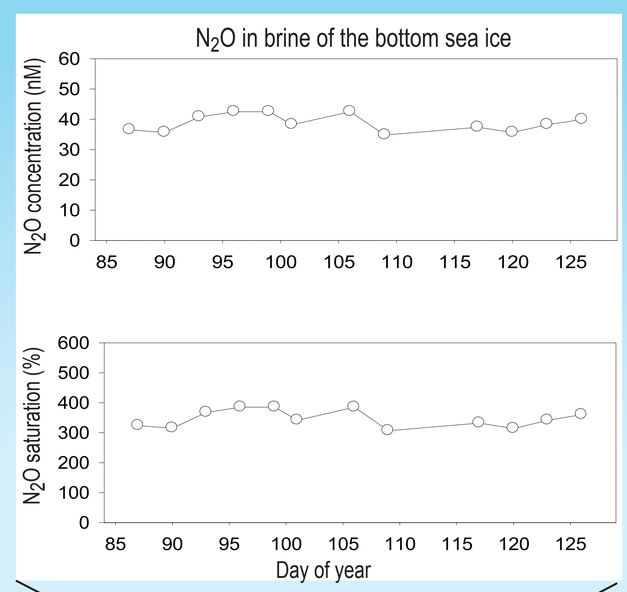
- Concentrations relatively constant among stations.

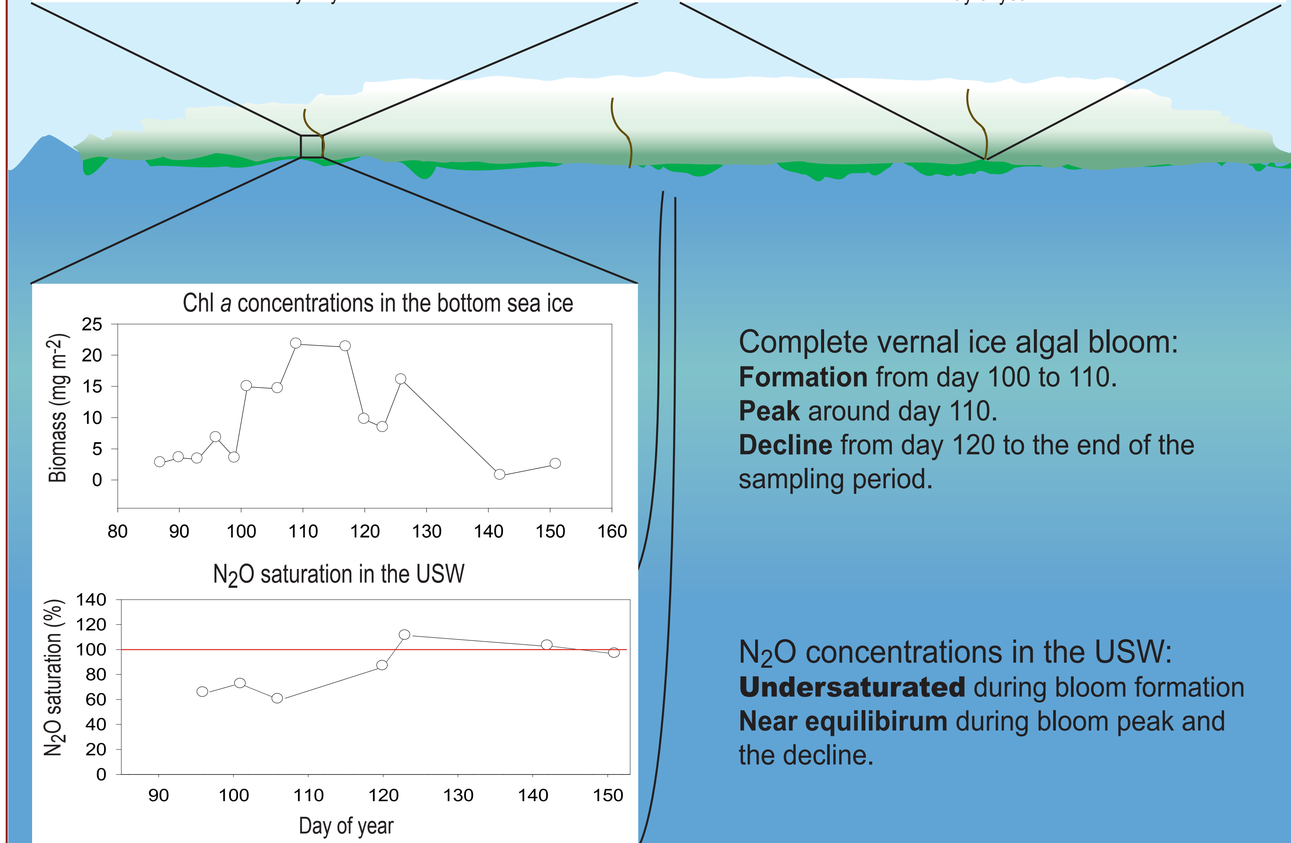
- Undersaturated with respect to the atmosphere (ca. 40%).



Estimated sea ice brine N_2O

- 660-676% higher than those in bulk sea ice.
- Super-saturated with respect to the atmosphere (ca. 322.9%).
- Volume of brine in bulk sea ice are about 0.12-0.24%.





Complete vernal ice algal bloom:
Formation from day 100 to 110.
Peak around day 110.
Decline from day 120 to the end of the sampling period.

N_2O concentrations in the USW:
Undersaturated during bloom formation
Near equilibirum during bloom peak and the decline.

Based on our undersaturated bulk N_2O concentrations measured in arctic sea ice, we suggest that the seasonal variability of atmospheric N_2O concentrations can be affected as follows :

In fall

During sea ice formation, N_2O can be ejected from frozen water via brine expulsion as observed for other impurities (salts, nutrients, gases; Killawee et al., 2002).

This results in undersaturated bulk concentrations in sea ice which persist through winter.

N_2O from brine ejection can either be ventilated from sea ice to the atmosphere, contributing to the increase of atmospheric concentrations observed in fall.

Alternatively, N_2O can be mixed into the USW, contributing to the increase of N_2O concentrations observed during winter (Maranger, pers. comm.)

In spring

During sea ice melting, undersaturated N_2O concentrations in bulk sea ice probably become equilibrated with the atmosphere, resulting in a sink for atmospheric N_2O.

This sink can contribute to the decrease of atmospheric concentrations observed in spring.

The USW, the ice edge and the marginal ice zone could act as a weak source.

CONCLUSIONS

Arctic sea ice could play an active role in seasonal variability of N_2O concentrations

During sea ice formation in fall: ejection of brine liquid rich in N_2O can contribute to the increase of N_2O concentrations in the atmosphere or in the USW.

During melting of the sea ice cover in spring: bulk sea ice which is undersaturated with respect to the atmosphere can act as a sink for atmospheric N_2O.

Dynamic N_2O variation in the underlying surface water during vernal ice algal bloom

Levels of N_2O in the USW are undersaturated or near equilibrium and could represent either a sink during bloom formation or a minor source during its decline.

So... Is the arctic sea ice a sink or a source for atmospheric N_2O ?

We suggest that arctic sea ice can be a source in fall and a sink in spring for N_2O in the atmosphere and therefore contribute to the seasonal variability in atmospheric N_2O concentrations.

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Nitrous Oxide data from the NOAA/ESRL halocarbons in situ program.