Which of the **increasing aerosol species** in polar regions will be most important for **mixed-phase clouds**?

Motivation

Clouds are the greatest contributor of uncertainty to climate projections, and mixed-phase clouds are among the least well-understood. Mixed-phase (non-convective) clouds occur predominantly in polar regions, where the atmospheric aerosol burden has historically been very low. This means that even small increases in aerosol concentrations are likely to have a significant effect on regional cloud behaviour. While anthropogenic aerosol emissions are projected to decrease globally, ship and industrial emissions are likely to increase in the Arctic, where rapidly increasing temperatures are also contributing to an increase in naturally occurring aerosols across a range of species. Similarly, sea ice loss and warming in the Southern Ocean is likely to increase sea salt and biogenic aerosols in the region, which may also see increased transport of dust and biomass burning emissions.

Methodology

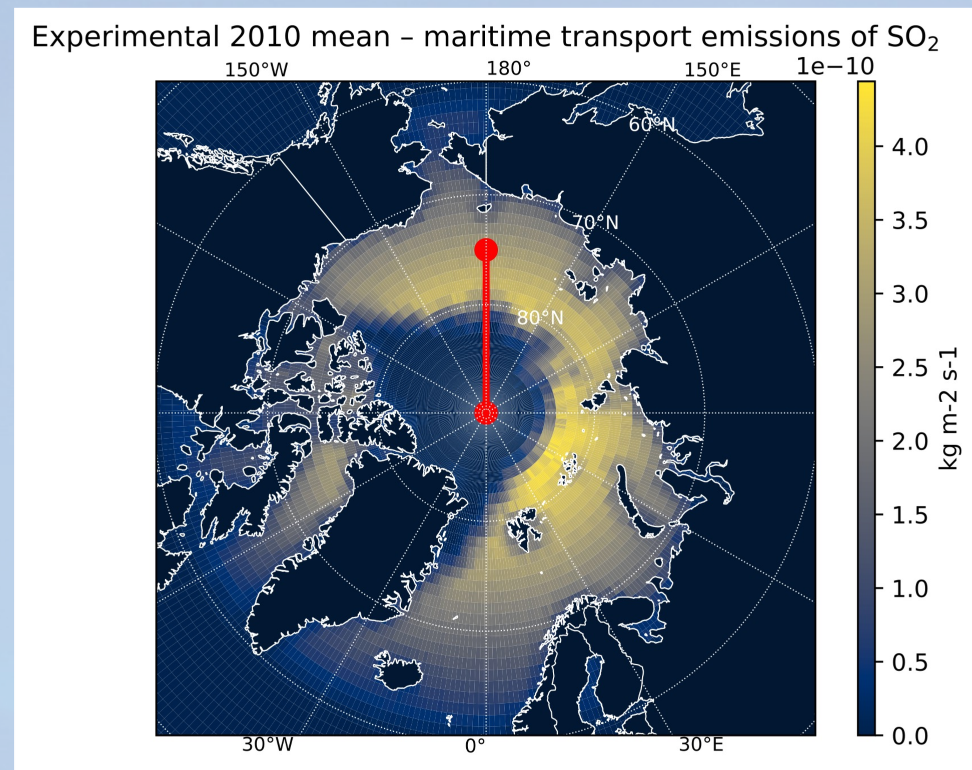
This research uses the global aerosol–climate model **ICON-A-HAM2.3** to investigate the effects of four main aerosol contributors:

- Increased sulphate, black carbon and organic carbon from **maritime shipping** (Arctic Ocean only)
- Increased sea salt, dimethyl sulphide, and biogenic organic carbon from **warmer oceans**
- Increased black carbon and organic carbon from **wildfires**
- Increased dust from **biomass burning, glacial retreat,** and **drought**

How will each of these changes affect **cloud phase and lifetime** in polar regions? And what happens when they all increase simultaneously, as is occurring in the present day?

25-year free-running simulations with prescribed (but shrinking) sea ice, 2025–2050.

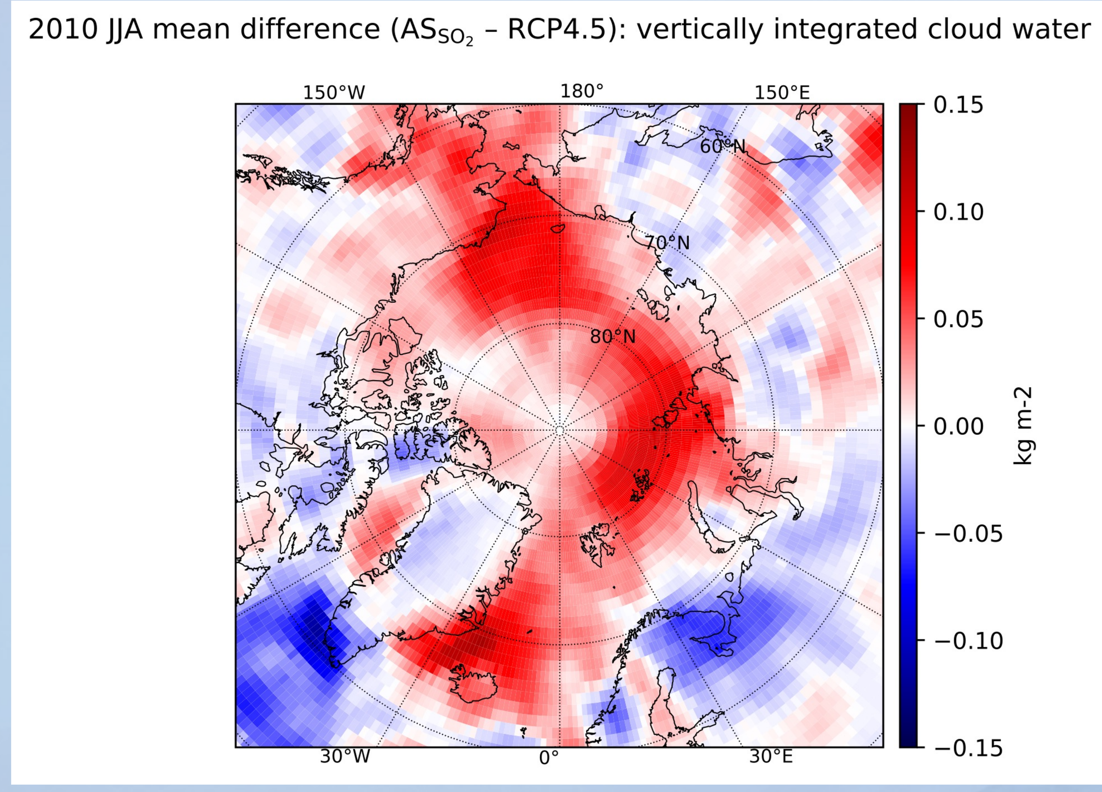
Emissions separated by sector (CMIP6 SSP585) and spatially modified (e.g. oceanic dimethyl sulphide increased poleward from 60°N/S in line with sea ice loss).



A baseline run from 2000–2025 is used to evaluate cloud ice, water, ice fraction coefficient, albedo, lifetime, and precipitation efficiency against observations.

Results

Arctic shipping. Initial high-SO_2 simulations are in agreement with Stephenson et al. (2018)[1] that an increase in summer Arctic ship traffic would increase the prevalence and persistence of liquid-phase clouds – an unintentional **marine cloud brightening effect.**



Next question: what happens when the modelled SO_2 emissions are reduced in line with the 2020 International Maritime Organisation regulation of shipping fuels?

1. Stephenson, Scott R., et al. "Climatic responses to future trans-Arctic shipping." *Geophysical Research Letters* 45.18 (2018): 9898-9908.

Aerosol–cloud interactions in polar mixed-phase clouds

Kallista Angeloff, *Atmospheric, Oceanic, and Planetary Physics*

UNIVERSITY OF OXFORD