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# Future Arctic shipping routes and European air quality in 2025

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Future emissions projections (A1B) for 2025 in the Arctic regions estimate that the importance of the shipping sector increases thus shifting direct emissions from the land to over the oceans. Here we perform large-scale simulations to investigate the effect on regional air quality. We find there is a strong seasonality in the near-surface O<sub>3</sub> at high northern latitudes, with shipping contributing upto 15%.

## 1. Introduction

The emission of trace gases from shipping into the Marine Boundary Layer (MBL) has been shown to be important for both global air quality and radiative forcing [1, 2]. The declining coverage of Arctic sea ice will make new transport routes at high latitudes economically viable. The associated increases in the emission of both particles and precursor gases in the Arctic region has the potential to alter regional air quality in both Europe and the Arctic circle [3]. Here we perform large-scale chemistry transport simulations using projected emission estimates for 2025 to assess potential effects towards tropospheric ozone (O<sub>3</sub>).

## 2. Model Description

The version of the global TM4 atmospheric chemistry model used here employs a vertical resolution of 34 levels, a horizontal resolution of 3° x 2° and is driven by ECMWF meteorological data fields. It has recently participated in multi-model studies and performs close to the model ensemble average [3]. For the chemistry component the modified CBM4 scheme is adopted, which has recently been updated with the most recent recommendations for the reaction data [4]. The emission scenarios employed are estimates for 2000 and follow the A1B scenario for 2025 as supplied in the EU-QUANTIFY project, with shipping emissions being taken from Endresen et al [5]. Biomass burning and biogenic contributions are fixed throughout in order to focus on anthropogenic effects. The meteorological data for 2003 is used for all simulations therefore the possible effects due to climatic change are not included in the study. We compare simulations with a 5% perturbation (reduction) in estimated shipping emissions to differentiate the effects of this transport sector.

## 3. Increases in Arctic shipping emissions

Figure 1 shows the present distribution of nitrogen oxides (NO<sub>x</sub>) from shipping around Europe and the projected increase by 2025 in the European part of the Arctic. The high shipping activity around the English Channel, Scandinavian Coast and the Baltic Sea results in annual NO<sub>x</sub> emissions of between 0.2-1Gg N/yr along ship tracks and ports. Table 1 provides the annual integrated NO<sub>x</sub> surface emissions from non-transport, road and ship. The total anthropogenic Arctic NO<sub>x</sub> emission

decreases between 2000 and 2025 (A1B) due to mitigation practices of industrial processes and road emissions. The fraction due to shipping activity increases significantly from ~20% to ~38%. This shifts the emission of anthropogenic NO<sub>x</sub> from urban centres out into the more pristine MBL

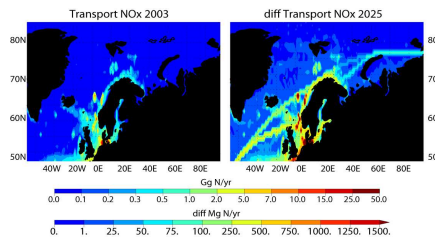


Figure 1: A1B shipping NO<sub>x</sub> emissions for 2000 and the estimated growth for 2025 in Mg N/yr.

Year	Total	Road	Ship	BB/Ind
2000	4.69	1.17	0.58	2.94
2025	3.57	0.58	0.82	2.17

Table 1: Integrated annual surface NO<sub>x</sub> emissions for the European Arctic region (60°W-80°E, 50-80°N) for 2000 and A1 2025 given in Tg/N yr.

## 4. Effect on Arctic air quality

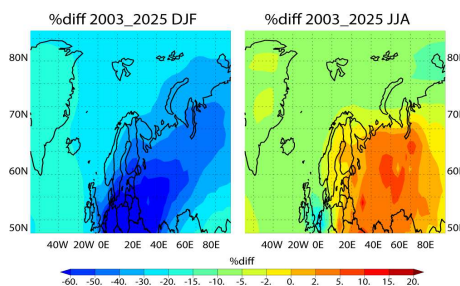


Figure 2: Percentage differences in near-surface O<sub>3</sub> over the Arctic between 2003 and 2025.

Figure 2 shows the percentage differences in near-surface O<sub>3</sub> as calculated using the A1B 2025 emission estimates. There is a stark contrast between seasons. Decreases occur during December-January-February (DJF) due to the higher NO<sub>x</sub> emissions titrating O<sub>3</sub>. On the other hand, for June-July-August (JJA), when photochemistry is active, the higher background CH<sub>4</sub> in the

future A1B scenario increases the NO<sub>x</sub> recycling efficiency enhancing tropospheric O<sub>3</sub> formation [6].

Figure 3 shows the regional distribution in near-surface O<sub>3</sub> for seasons DJF and JJA using the 2025 A1B scenario, along with the projected increases due to the shipping sector. A seasonality exists in the near-surface O<sub>3</sub> concentrations due to the longer days increasing photochemical activity during JJA, where maxima occur near Benelux and Northern Germany. The 5% perturbation simulation shows that shipping emissions account for between 0-5% (5-15%) of the near-surface O<sub>3</sub> formed during DJF (JJA), although in absolute terms near-surface O<sub>3</sub> decreases by a few percent compared to the present day due to the expected mitigation of emissions from other sectors. A significant increase occurs in the new shipping lanes north of Scandinavia.

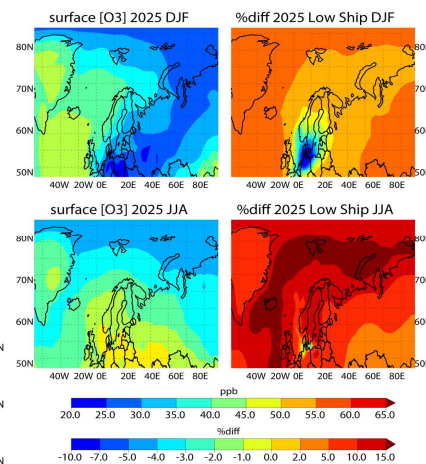


Figure 3: Seasonal distribution in near surface O<sub>3</sub> during 2025 and the estimated contribution due to shipping emissions.

## References

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