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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_3 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 pre-cursor 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_3).

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_x) 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, Scandanavian Coast and the Baltic Sea results in annual NO_x emissions of between 0.2-1Gg N/yr along ship tracks and ports. Table 1 provides the annual integrated NO_x surface emissions from non-transport, road and ship. The total anthropogenic Arctic NO_x 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_x from urban centres out into the more pristine MBL

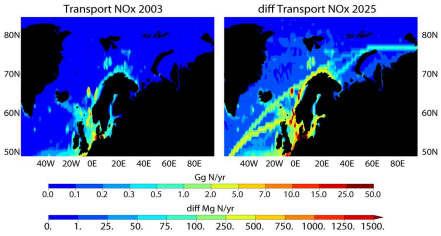

Figure 1: A1B shipping NOx emissions for 2000 and the estimated growth for 2025 in Mg N/yr.

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_x 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

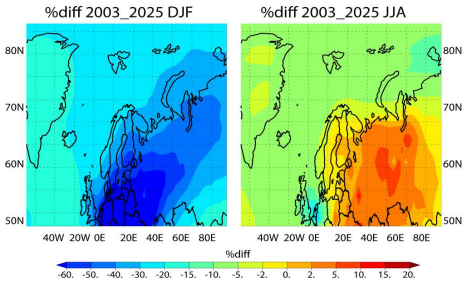

Figure 2: Percentage differences in near-surface O3 over the Arctic between 2003 and 2025.

Figure 2 shows the percentage differences in near-surface O_3 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_x emissions titrating O_3. On the other hand, for June-July-August (JJA), when photochemistry is active, the higher background CH_4 in the future A1B scenario increases the NO_x recycling efficiency enhancing tropospheric O_3 formation [6].

Figure 3 shows the regional distribution in near-surface O_3 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_3 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_3 formed during DJF (JJA), although in absolute terms near-surface O_3. 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.

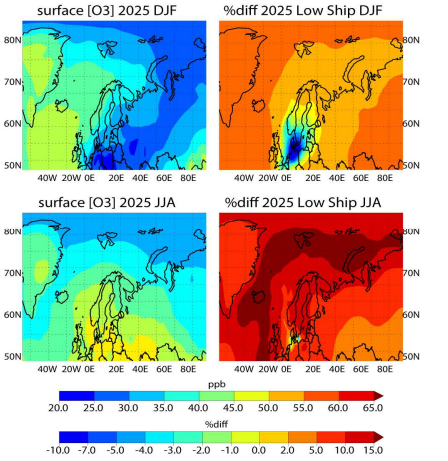

Figure 3: Seasonal distribution in near surface O_3 during 2025 and the estimated contribution due to shipping emissions.

References

[1] Hoor, P., et al., The impact of traffic emissions on atmospheric ozone and OH: results from Quantify, *Atms. Chem. Phys.*, 9, 3113-3136, 2009.
[2] Myhre, et al, Radiative forcing due to changes in ozone and methane caused by the transport sector, *Atms. Environ.*, 45, 387-394, 2011.
[3] Hodnbrog, et al, Future impact of non-land based traffic emissions on atmospheric ozone and OH – an optimistic scenario and a possible mitigation strategy, *Atms. Phys. Chem. Discuss.*, 11, 16801-16859, 2011.
[4] Houweling, S., F. J. Dentener and J. Lelieveld, The impact of non-methane hydrocarbon compounds on tropospheric chemistry, *J.Geophys.Res.*, 103(D9), 10673-10696, doi:10.1029/97JD03582, 1998.
[5] Endresen. O., et al, A historical reconstruction of ships fuel consumption and emissions, J. Geophys. Res., 11, p.17, 2007.
[6] Williams, J. E. and Van velthoven, P. F. J., Uncertainty in the Future distribution of Tropospheric Ozone over West Africa due to variability in Anthropogenic Emissions Estimates between 2025 and 2050, Int. J. Geophysics, 2011, Article ID 324359, doi: 10.1155/2011/324359.

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