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# Climate impacts of shipping and petroleum extraction in an unlocked Arctic ocean

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Reductions in sea ice extent are expected to open up the Arctic region to increased volumes of ship traffic and petroleum extraction activities. Both of these potentially entail changes in concentrations of short-lived climate forcers (SLCFs) such as aerosols and ozone, which may impact the future climate. The response of the Arctic to SLCF emissions is however not well constrained, as the annual cycle, solar irradiation, surface albedo and ambient temperature are special to this region.

The present study investigates the effects of SLCF emissions in the Arctic in 2004, as well as in 2030 and 2050. An emission inventory is used for present day activities, while future emissions are taken from models of the global energy market and shipping fleet. Atmospheric concentrations are input to the OsloCTM2 chemical transport model, and radiative forcings (RFs) are calculated using a multi-stream radiation transport code. Climate impacts are quantified via RFs and Global Warming Potentials of the various emitted components, in addition to estimates of the first indirect aerosol effect and the snow albedo effect from black carbon (BC).

For present day emissions we calculate a net negative RF from shipping, mainly driven by the indirect aerosol effect, and a net positive RF from petroleum extraction, mainly due to the BC snow albedo effect. For future emissions the general results remain similar, but the total RFs develop with changes in emission volume and composition. We discuss the sensitivity of the Arctic region to emissions in terms of normalized RFs as function of season and geographical location.