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ACCESS
Arctic Climate Change
Economy and Society

Policy Brief n°2

Shipping in the Arctic: Links to Air Pollution and Climate Change

Nowhere is climate change more visible than in the Arctic. What happens in the Arctic also has global impacts. With its large expanse of heat-reflecting snow and ice, the Arctic serves as the "refrigerator" of the global climate system. Melting of the sea-ice enhances the effects of climate change in the Arctic and accelerates global temperature increase. The changing Arctic landscape is opening new opportunities for transport routes and natural resource development. Ship operations in the Arctic will expand if they are safe, reliable and profitable. While this offers economic benefits, it may have repercussions on the Arctic's fragile environment, if not carefully managed.

This brief explores links between Arctic shipping, air pollution and climate change. It recaps why it matters and some policy approaches adopted or under consideration to tackle the issues.

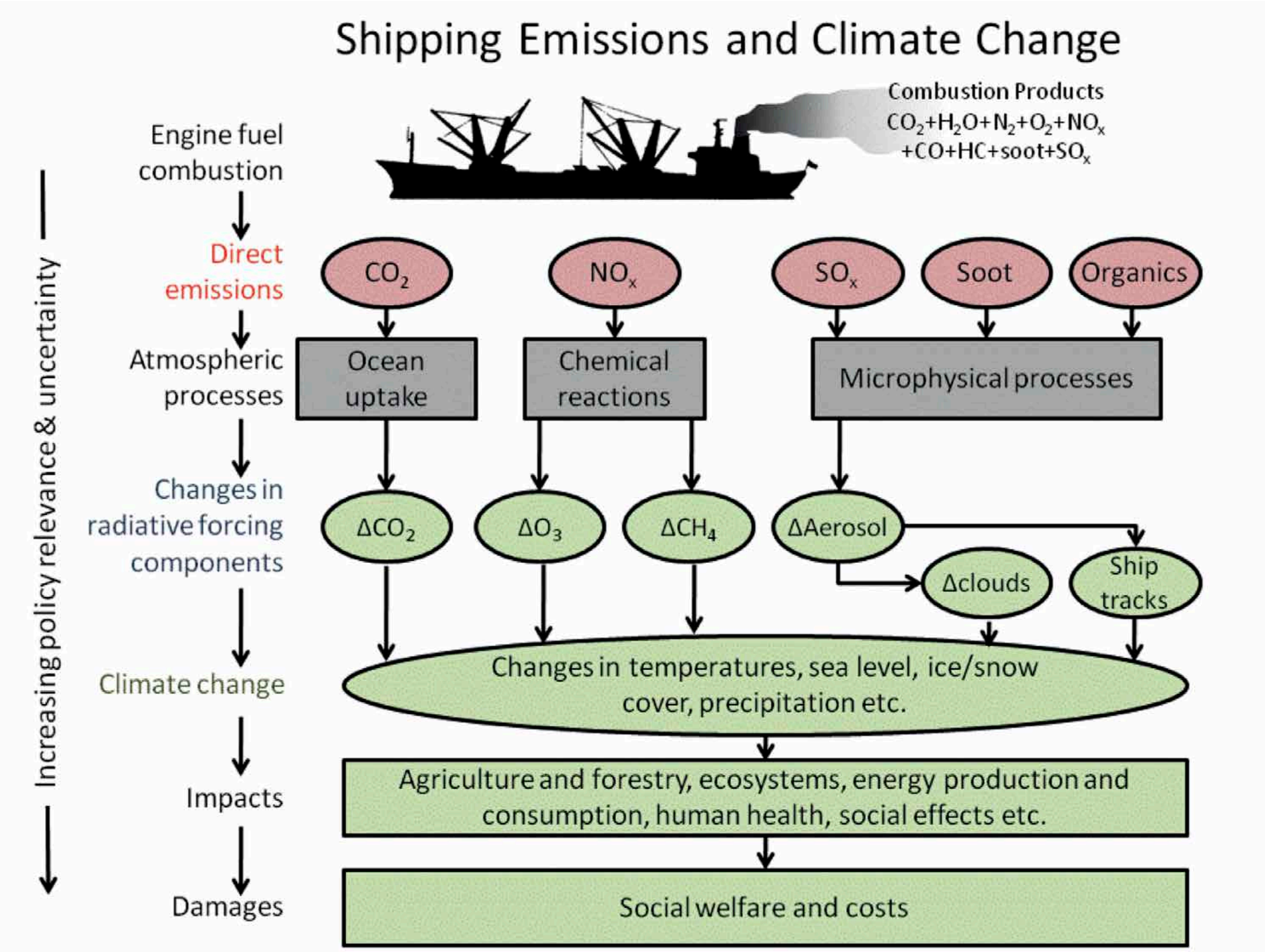

Figure 1 - Shipping Emissions and Climate Change.
Source: Second IMO GHG Study. Buhaug, Ø. et al., (2009), *International Maritime Organization, London, April 2009.*

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SEVENTH FRAMEWORK PROGRAMME

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Ship Emissions and Climate Change

Carbon dioxide (CO_2), a long-lived greenhouse gas (GHG), is emitted from ships and contributes to global warming together with short-lived climate forcers (SLCFs)[1] that remain in the atmosphere for shorter periods ranging from a few days to a few decades (Figure 1). Besides limiting climate impacts such as ice melting, SLCF reductions could reduce local air pollution and produce other co-benefits.

Emissions of SLCFs in the Arctic have a stronger effect than they do at more southern latitudes.

Black carbon (soot) - formed by the incomplete combustion of fossil fuels, biofuels and biomass - is the most strongly light-absorbing component of particulate matter. It has a warming effect both in the atmosphere and when it is deposited on snow and ice surfaces. Other emissions have a cooling effect (e.g. sulphur dioxide that forms aerosols). The net global effect of shipping emissions has been shown to be an initial cooling on timescales of decades to centuries and thereafter a warming due to accumulation of long-lived GHGs.[2] Calculating the net climate effect of increased shipping in the Arctic is not easy and depends on the projected scenarios, time horizon and location of emissions. However, some of the SLCFs have a stronger effect in the Arctic than they do at more southern latitudes.[3]

Outlook for Impacts on Climate from Increases in Arctic Shipping: ACCESS Research

Predicted Impacts on Radiative Forcing from Increased Arctic Shipping[4]

This ACCESS research calculates impacts of future shipping in the Arctic and worldwide with a particular focus on black carbon emissions. The Oslo CTM2, a global chemical transport model, and a radiative forcing model were used to study the evolution of chemical constituents causing impacts. Two datasets for ship emissions are used to characterise the potential impact from shipping: a high scenario and a low scenario with maximum feasible reduction (MFR) of black carbon. In MFR, black carbon emissions in the Arctic are reduced, with 70 % due to technology improvements. Counteracting the growth in shipping traffic in both scenarios is the phase-in of regulations resulting in reduced emissions factors of sulphur and organic aerosols.

Today's net impact from SLCFs from shipping is a cooling.

Over time the net climate impact of SLCFs might be a warming or a cooling depending on emissions distribution and regional atmospheric conditions. The current net impact of SLCFs from shipping both globally and in the Arctic is a cooling.

The study predicts that shipping will contribute to Arctic and global warming in the period 2004 - 2030. This is mainly due to reduced cooling impact of sulphate aerosols and clouds as sulphur emissions from ships are reduced due to the phase-in of IMO regulations. Analysis indicates that the regulations are efficient in reducing particle pollution in the Arctic and worldwide. The trade-off is that it leads to a warming.

Sulphur limits reduce particle pollution, but with a trade-off that leads to warming.

Though black carbon emissions from shipping are small, measures to cut emissions can improve air quality and result in a cooling effect. The study finds an important contribution from black carbon in the Arctic in 2030, especially deposits on snow and ice which efficiently absorb solar radiation thereby warming the surface. The climate warming from black carbon associated with Arctic shipping is reduced by 60 % in the MFR scenario. The effect on ozone (O_3) is rather large and the compensating NOx - induced methane cooling is small in the Arctic. Therefore, regulations of NOx in the Arctic could also be favourable both for air quality and climate, but further studies are needed. Research should quantify the effect of small-scale processes in the ship plumes possibly reducing the NOx lifetime and associated impacts on the GHGs, ozone and methane.

1 - SLCFs typically include methane (CH_4), black carbon, hydro-fluorocarbons (HFCs) and tropospheric ozone (O_3).

2 - Eide, M. *et al.* (2013), "Reducing CO_2 from Shipping – Do non-CO_2 Effects Matter?", *Atmos. Chem. Phys., 13*, 4183-4201.

3 - Ødemark, K. *et al.* (2012), "Short-lived Climate Forcers from Current Shipping and Petroleum Activities in the Arctic", *Atmos. Chem. Phys.*, 12, 1979-1993; Dalsøren, S. *et al.* (2013), "Environmental Impacts of Shipping in 2030 with a particular Focus on the Arctic Region", *Atmos. Chem. Phys.*, 13, 1941-1955.

4 - CICERO (2014), *Radiative Forcing Estimates for Perturbation in the Arctic of Short-lived Climate Compounds*, ACCESS report D1.71, forthcoming.

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While emissions from shipping are at their maximum in the summer-early autumn (the season with less ice), the maximum radiative forcing in 2030 is predicted to be in spring-early summer coinciding with the melting season. This makes it essential to consider how extended sailing seasons in years beyond 2030 may accelerate sea-ice and snow cover melt in the Arctic.

Arctic Transit Shipping versus Suez Route: Radiative Forcing and Temperature Responses [5]

The melting of Arctic sea-ice may open new shipping routes between Europe and Asia. The Arctic route is shorter than the traditional Suez Canal route and could result in significant fuel savings and lower emissions (for the same volume of cargo transported). This research investigates the climate impact of a shift in shipping traffic from lower latitudes to the Arctic.

A gradual increase in container traffic on a new Arctic route from Europe (Rotterdam) to Asia (Yokohama) is considered using ship emission inventories for 2030 and 2050.[6] Arctic transits occur in the period July-November when it is feasible and profitable. Fuel savings and lower emissions are, however, somewhat offset by increased fuel consumption per kilometre to break through ice, especially in 2030. Using the Arctic route reduces the travel time by 37 % in 2030 and 43 % in 2050 and cuts fuel use by 29 % and 37 %.

The impacts of short-lived climate forcers depend on the location of the emissions.

The different atmospheric conditions and sensitivity to emissions at high and low latitudes determine the resulting climate impact of SLCFs. Shifting shipping from Suez to Arctic routes initiates SLCF responses of very different magnitudes and signs. Reducing emissions at lower latitudes and introducing new emissions in the Arctic gives a net positive global radiative forcing (warming) from changes in SLCFs in 2030 and 2050. The impacts of CO_2 and other long-lived GHGs do not depend on location of the emissions. The net reduction in CO_2 emissions has a global cooling impact that grows over time due to the long response time of atmospheric CO_2. Overall, this results in a warming for the first one-and-a-half centuries due to SLCFs, which then switches to cooling due to the long response time and dominant effect of CO_2. Thus, shifting shipping to the Arctic poses questions in terms of short-term versus long-term climate effects.

Quantifying Emissions from Shipping [7]

ACCESS research quantifies Arctic ship emissions and their impact on regional air pollution and climate. For the first time, SLCFs (e.g. ozone, aerosols and their precursors) were measured in ship pollution plumes in the Arctic, where particular meteorological/operating conditions exist, as well as from several offshore (hydrocarbon) and onshore (smelting) facilities. ACCESS aircraft flights determined pollutant emission factors for vessels likely to operate in the Arctic (cargo, passenger, fishing vessels) using both heavy fuel oil and marine gas oil. The percentage of non-volatile particles (mostly soot and ash), based on several ship plume samplings, ranged from 49 % to 74 %, which is similar to large container ships operating further south. In addition, the flights around offshore oil extraction facilities revealed an abundance of storage and shuttle tankers. Emissions from such ship types need to be taken into account in current and future Arctic emission inventories.

This ACCESS research has provided new data and a glimpse of emissions from shipping and hydrocarbon operations in one area. It is being used to validate emission inventories and, in combination with model simulations, to quantify impacts of such local pollution on regional air quality. Studies examining future impacts need to take into account how emissions patterns will change as adopted regulations have effect and technology advances are adopted. Clearly, further studies are needed to profile and better quantify local pollutant sources, including shipping, in the Arctic.

5 - Fuglestvedt, J. *et al.* (2014), "Climate Penalty for Shifting Shipping to the Arctic", Accepted *Environmental Science & Technology*.

6 - Peters, G. *et al.* (2011), "Future Emissions from Shipping and Petroleum Activities in the Arctic", *Atmos. Chem. Phys.*, 11, 5305-5320, doi:10.5194/acp-11-5305-2011.

7 - Roiger, A. *et al.* (2014), "Quantifying Emerging Local Anthropogenic Emissions in the Arctic Region: the ACCESS Aircraft Campaign Experiment", *Bull. Amer. Meteor. Soc.*, doi: http://dx.doi.org/10.1175/BAMS-D-13-00169.1.

SEVENTH FRAMEWORK PROGRAMME

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Regulatory and Policy Frameworks

International

The International Maritime Organization (IMO) is the United Nations specialised agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships. International air pollution standards are in Annex VI to the International Convention on the Prevention of Pollution from Ships (MARPOL).

In 2008 the IMO adopted a phased programme of fuel and engine standards that are geographically based. Areas with air quality problems are designated as Emission Control Areas (ECAs). Today there are four ECAs.[9] Ships operating in ECAs are required to meet tighter emission limits (Table 1). Beginning in 2015, both new and existing ships operating in ECAs will be required to use fuel with no more than 1000 parts per million of sulphur. Equivalent compliance methods, such as exhaust cleaning systems, are accepted.

MARPOL amendments in 2011 include energy efficiency standards for new ships which phase in from 2013 to 2025. They aim to cut fuel consumption by 30 % compared with today's vessels and hence CO_2 emissions. Beginning in 2016, new ships operating in ECAs must also have advanced technology engines designed to cut emissions of ozone-forming oxides of nitrogen (NOx).

Table 1 - IMO Fuel Oil Sulphur Limits

Outside ECA SOx and particulate matter emissions	Inside ECA SOx and particulate matter emissions
4.5 % prior to 1 January 2012	1.5 % prior to 1 July 2010
3.5 % on/after 1 January 2012	1.00 % on/after 1 July 2010
0.5 % on/after 1 January 2020 (depending on outcome of fuel availability review to be concluded in 2018)	0.10 % on/after 1 January 2015

8 - European Climate Change Programme Working Group on Ships, 2011, *http://ec.europa.eu/clima/events/docs/0047/options_addess_slcf*

9 -Baltic Sea (sulphur oxides only); North Sea, including the English Channel, (sulphur oxides only); North American (sulphur oxides, nitrogen oxides and particulate matter); US Caribbean Sea (sulphur oxides, nitrogen oxides and particulate matter.

European Union

Changes in Arctic shipping may affect the European Union (EU) including in areas of economic significance for trade and consumption, ports and shipping companies; security and safety of transport opportunities; and environmental interests. The EU is not a member of the IMO, but its competent authorities co-ordinate via member states in the IMO committees.

European Union Fuel Oil Sulphur Limits

The EU rendered mandatory IMO rules on the sulphur content of marine fuels in 2012.The limit in designated ECAs is 0.1% from 1 January 2015 and EU member states are asked to ensure that this is the case for the Baltic Sea and the North Sea. The IMO standard of 0.5% for sulphur limits outside ECAs will be mandatory in EU waters by 2020.

EU Options to Address Short-Lived Climate Forcers Emitted by Ships[8]

An EU climate change programme Working Group on Ships has proposed policy options that could be adopted to address non-CO_2 climate forcers as part of an EU instrument to reduce GHGs from shipping. While the strategy should primarily focus on CO_2 reduction, supplementary actions should also be undertaken to reduce emissions of SLCFs. Policy options suggested by the Working Group include:

- Improve estimates of SLCF shipping emissions under Arctic conditions and their impacts on climate, ecosystems and air quality.
- Adopt market-based instruments to reduce emissions in sensitive areas. While this issue will be discussed at the IMO, given its relevance for Arctic shipping and its significant transport of black carbon emissions to the Arctic, the EU should consider the early introduction of a regional measure to reduce emissions from shipping.
- Earmark a proportion of revenues for emissions abatement technologies.
- Adopt emission standards for ships, as have proven successful in the road sector.

27 participants and 10 European countries involved in ACCESS project

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For further information about ACCESS please visit our website at www.access-eu-org

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