PAME I-2015 Agenda Item 4.8 (b)

AMSA Recommendation II (H)

Annotated List of Studies and Assessments on Ship Air Emissions and the Effect of Such Emissions on the Arctic Marine Environment

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Background

AMSA Recommendation II (H) provides:

> *"That the Arctic states decide to support the development of improved practices and innovative technologies for ships in port and at sea to help reduce current and future emissions of greenhouse gases (GHGs), Nitrogen Oxides (NOx), Sulfur Oxides (SOx) and Particulate Matter (PM), taking into account the relevant IMO regulations."*

Contained within the PAME II-2014 records of decision is an invitation for member governments to "submit to the (PAME) Secretariat information on studies and assessment, both existing and ongoing, on ship air emissions (in particular black carbon) in the Arctic, methodologies for measuring emissions, and the effect of such emissions on the Arctic marine environment." Accordingly, Canada submits the following annotated list of relevant studies and assessments:

1. Aliabadi, A. A., Staebler, R. M., and Sharma, S. (2014). Air quality monitoring in communities of the Canadian Arctic during the high shipping season with a focus on local and marine pollution. Atmos. Chem. Phys. Discuss (14), 29547-29613. doi:10.5194/acpd-14-29547-2014.

In an effort to characterize the relative impact of shipping on air quality in the North, two monitoring stations have been installed in Cape Dorset and Resolute, Nunavut, and have been operational since 1 June 2013. The impact of shipping and other sources of emissions on NOx, O3, SO2, BC, and PM2.5 have been characterized for the 2013 shipping season from 1 June to 1 November. In addition, a high resolution Air Quality

Health Index (AQHI) for both sites was computed. Shipping consistently increased O3 mixing ratio and PM2.5 concentration. Ship-influenced air masses consistently exhibited degraded air quality by an increase of 0.1 to 0.3 in the high resolution AQHI compared to no ship-influenced air masses. Continued air quality monitoring in the above sites for future shipping seasons will improve the statistics in the analysis as well as characterize repeating seasonal patterns in air quality due to shipping, local pollution, and long-range transport.

2. Mjelde, A.; Martinsen, K.; Eide, M.; Endresen, Ø. (2014). Environment accounting for Arctic shipping – a framework building on ship tracking data from satellites. Marine Pollution Bulletin, Vol 87 (Issue 1/2), p22-28.

This paper describes a framework for environmental accounting. A cornerstone in the framework is the use of Automatic Identification System (AIS) ship tracking data from satellites. When merged with ship registers and other data sources, it enables unprecedented accuracy in modeling and geographical allocation of emissions and discharges. This paper presents results using two of the models in the framework; emissions of black carbon (BC) in the Arctic, which is of particular concern for climate change, and; bunker fuels and wet bulk carriage in the Arctic, of particular concern for oil spill to the environment. Using the framework, a detailed footprint from Arctic shipping with regards to operational emissions and potential discharges is established.

3. Dalsøren, S. B., Samset, B. H., Myhre, G., Corbett, J. J., Minjares, R., Lack, D., Fuglestvedt, J. S. (2013). Environmental impacts of shipping in 2030 with a particular focus on the Arctic region. Atmospheric Chemistry & Physics, Vol 13 (Issue 4), p1941-1955.

The authors of this article quantify the concentrations changes and Radiative Forcing (RF) of short-lived atmospheric pollutants due to shipping emissions of NOx, SOx, CO, NMVOCs, BC and OC using high resolution ship emission inventories for the Arctic that are more suitable for regional scale evaluation than those used in former studies. A chemical transport model and a RF model are used to evaluate the time period 2004-2030, when we expect increasing traffic in the Arctic region. Two datasets for ship emissions are used that characterize the potential impact from shipping and the degree to which shipping controls may mitigate impacts: a high (HIGH) scenario and a low scenario with Maximum Feasible Reduction (MFR) of black carbon in the Arctic. In MFR, BC emissions in the Arctic are reduced with 70% representing a combination technology performance and/or reasonable advances in single-technology performance. In 2030 the authors found increased concentrations of all pollutants in large parts of the Arctic.

4. Eckhardt, S., Hermansen, O., Grythe, H., Fiebig, M., Stebel, K., Cassiani, M., Baecklund, A., Stohl, A. (2013). The influence of cruise ship emissions on air pollution in Svalbard – a harbinger of a more polluted Arctic? Atmospheric Chemistry & Physics Discussion, Vol 13 (Issue 1), p3071-3093.

In this study the authors analyzed whether tourist cruise ships have an influence on measured sulphur dioxide (SO2), ozone (O3), Aitken mode particle and equivalent black carbon (EBC) concentrations at Ny Ålesund and Zeppelin Mountain on Svalbard in the Norwegian Arctic, during summer. When ships with more than 50 passengers cruise in the Kongsfjord, measured daytime-mean concentrations of 60-nm particles and EBC in summer show enhancements of 72 and 45% relative to values when no ships are present. Even larger enhancements of 81 and 72% were found for stagnant conditions. In contrast, O3 concentrations were 5% lower on average and 7% lower under stagnant conditions, due to titration of O3 with the emitted nitric oxide (NO). The results may be taken as a warning signal of future pan-Arctic conditions, if Arctic shipping becomes more frequent and emission regulations are not strict enough.

5. Winther, Morten, Christensen, Jesper H., Plejdrup, Marlene S. Ravn, Erik S. Eriksson, Ómar F.,Kristensen, Hans Otto. (2014) Emission inventories for ships in the arctic based on satellite sampled AIS data. Atmospheric Environment, Vol 91, p1-14.

This paper presents a detailed BC, NOx and SO2 emission inventory for ships in the Arctic in 2012 based on satellite AIS data, ship engine power functions and technology stratified emission factors. Emission projections are presented for the years 2020, 2030 and 2050. Furthermore, the BC, SO2 and O3 concentrations and the deposition of BC are calculated for 2012 and for two arctic shipping scenarios – with or without arctic diversion routes due to a possible polar sea ice extent in the future. In 2012, the largest shares of Arctic ships emissions are calculated for fishing ships followed by passenger ships, tankers, general cargo and container ships. In 2050, the Arctic diversion routes highly influence the calculated surface concentrations and the deposition of BC in the Arctic. During summertime navigation contributions become very visible for BC (>80%) and SO_2 (>1000%) along the arctic diversion routes, while the O_3 (>10%) and BC deposition (>5%) additional contributions, respectively, get highest over the ocean east of Greenland and in the High Arctic.

6. Corbett, J. J., Lack, D. A., Winebrake, J. J., Harder, S., Silberman, J. A.,Gold, M. (2010). Arctic shipping emissions inventories and future scenarios. Atmospheric Chemistry & Physics Discussions, Vol 10 (Issue 4), p10271-10311.

Arctic shipping is an important contributor to the region's anthropogenic air emissions, including black carbon - a short-lived climate forcing pollutant especially effective in accelerating the melting of ice and snow. These emissions are projected to increase as declining sea ice coverage due to climate change allows for increased shipping activity in the Arctic. To understand the impacts of these increased emissions, scientists and modelers require high-resolution, geospatial emissions inventories that can be used for regional assessment modeling. This paper presents 5 km×5 km Arctic emissions inventories of important greenhouse gases, black carbon and other pollutants under existing and future (2050) scenarios that account for growth of shipping in the region, potential diversion traffic through emerging routes, and possible emissions control measures. Arctic shipping may increase climate forcing due to Arctic ships by at least 17% compared to warming from these vessels' CO_2 emissions. The paper also presents maximum feasible reduction scenarios for black carbon in particular. These emissions reduction scenarios will enable scientists and policymakers to evaluate the efficacy and benefits of technological controls for black carbon, and other pollutants from ships.

7. Browse, J., Carslaw, K. S., Schmidt, A., and Corbett, J. J. (2013) Impact of future Arctic shipping on high-latitude black carbon deposition. Geophysics Research Letters, Vol 40 (Issue 16), p4459-4463.

The authors use recently compiled Arctic shipping emission inventories for 2004 and 2050 together with a global aerosol model to quantify the contribution of future Arctic shipping to high-latitude BC deposition. The results show that Arctic shipping in 2050 will contribute less than 1% to the total BC deposition north of 60°N due to the much greater relative contribution of BC transported from non-shipping sources at lower latitudes.

8. Pizzolato, L., Howell, S. E. L., Derksen, C., Dawson, J., and Copland, L. (2014) hanging sea ice conditions and marine transportation activity in Canadian Arctic waters between 1990 and 2012. Climate Change, Vol 123 (Issue 2), p161.

Declining sea ice area in the Canadian Arctic has gained significant attention with respect to the prospect of increased shipping activities. To investigate relationships between recent declines in sea ice area with Arctic maritime activity, trend and correlation analysis was performed on sea ice area data for total, first-year ice (FYI), and multi-year ice (MYI), and on a comprehensive shipping dataset of observed vessel transits through the Vessel Traffic Reporting Arctic Canada Traffic Zone (NORDREG zone) from 1990 to 2012. Links to surface air temperature (SAT) and the satellite derived melt season length were also investigated. Between 1990 and 2012, statistically significant increases in vessel traffic were observed within the NORDREG zone on monthly and annual time-scales coincident with declines in sea ice area (FYI, MYI, and total ice) during the shipping season and on a monthly basis. Similarly, the NORDREG zone is experiencing increased shoulder season shipping activity, alongside an increasing melt season length and warming surface air temperatures (SAT). Despite these trends, only weak correlations between the variables were identified, although a step increase in shipping activity is apparent following the former summer sea ice extent minimum in 2007. Other non-environmental factors have also likely contributed to the observed increase in Arctic shipping activity within the Canadian Arctic, such as tourism demand, community re-supply needs, and resource exploration trends.

9. Quinn, P. K., Bates, T. S., Baum, E., Doubleday, N., Fiore, A. M., Flanner, M., Fridlind, A., Garrett, T. J., Koch, D., Menon, S., Shindell, D., Stohl, A., and Warren, S. G. (2007) Short-lived pollutants in the Arctic: their climate impact and possible mitigation strategies. Atmospheric Chemistry & Physics Discussion, Vol 7, (Iss 6), p15669-15692.

Several short-lived pollutants known to impact Arctic climate may be contributing to the accelerated rates of warming observed in this region relative to the global annually averaged temperature increase. Here, the authors present a summary of the short-lived pollutants that impact Arctic climate including methane, tropospheric ozone, and tropospheric aerosols. For each pollutant, the authors provide a description of the major sources, the mechanism of forcing, seasonally averaged forcing values for the Arctic, and the corresponding surface temperature response. Strategies are suggested for reducing the warming based on current knowledge and discuss directions for future research to address remaining uncertainties.

10. Smith, L. C. and Stephenson, S. R. (2014). New Trans-Arctic shipping routes navigable by mid century. Proceedings of the National Academy of Sciences of the United States of America, Vol 110 (Iss 13) p1191-1195.

Recent historic observed lows in Arctic sea ice extent, together with climate model projections of additional ice reductions in the future, have fueled speculations of potential new trans-Arctic shipping routes linking the Atlantic and Pacific Oceans. However, numerical studies of how projected geophysical changes in sea ice will realistically impact ship navigation are lacking. To address this deficiency, the authors analyze seven climate model projections of sea ice properties, assuming two different climate change scenarios and two vessel classes, to assess future changes in peak season (September) Arctic shipping potential. By mid-century, changing sea ice conditions enable expanded September navigability for common open-water ships crossing the Arctic along the Northern Sea Route over the Russian Federation, robust new routes for moderately ice-strengthened (Polar Class 6) ships over the North Pole, and new routes through the Northwest Passage for both vessel classes. Although numerous other nonclimatic factors also limit Arctic shipping potential, these findings have important economic, strategic, environmental, and governance implications for the region.