Airborne measurements of ship emissions

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Keywords: ship emissions, health, climate, aerosol
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Baltic Sea and North Sea, including the English Channel, were designated as SOx Emisson Control Areas (SECA) in May 2006 and November 2007 by the International Maritime Organization. In these sea regions the maximum sulphur content of marine fuels was restricted to 1.5% (weight/weight) and further reduced to 1.0% from July 2010 in SECA countries. These actions have significantly reduced the ship emitted SOx and sulphur containing fractions of particulate matter thus mitigating some of the detrimental effects to human health. Further, from Jan. 1st, 2010 a requirement for the use of 0.1% of sulphur (0.1%S) fuel in the European port areas became effective. From the beginning of 2015 sulphur is to be removed from marine fuels and only the use of 0.1%S marine gas oil is allowed in SECAs according to the new EU directive (2012/33/EC), whereas shipping globally have to switch to 0.5%S fuel by 2020. There should exist methods how to monitor the fuel sulfur content of the ships. One method is to measure gas phase SO_2 and CO_2 ratio from ship plume.

The analysis of costs and effects of the sulphur reductions have mostly included only the effects on human health, but they can also have impacts on the climate (Lauer *et al*., 2009). Emissions of sulphate aerosol are thought to have significant climate cooling impacts, either directly by scattering incoming solar radiation or indirectly by acting as cloud condensation nuclei and thus modifying cloud albedo. On the other hand, black carbon (BC) aerosol can warm the climate when it absorbs solar radiation in the atmosphere as well as by reducing the surface albedo in snow and ice covered regions, such as the. The emissions of these two aerosol types were recently connected to ship fuel sulphur content and the operational conditions of marine engines (Lack and Corbett, 2012). Current widely available ship emission inventories offer only limited support in assessing the climate impact of international shipping, because they lack the information how and where the ships are run during voyages and port stays. Significant uncertainties can exist in determining the time spent at sea, engine load profiles used, emission factors applied and emissions occurring during port operations.

Recently, Jalkanen *et al.* (2009) introduced the Ship Traffic Emission Assessment Model (STEAM) which uses Automatic Identification System (AIS) and is able to track individual vessels with unprecedented accuracy. However, in order to model the effects of fuel sulphur content, engine load profiles and ship operations accurately, a solid experimental groundwork is needed. Comprehensive studies, especially experimental, on ship emissions are rare (Murphy et al., 2009).

We had two major goals in this study; to test the method to monitor marine fuel sulphur content and to make detailed measurements on aerosol properties to gain better understanding on climate and health effect of ship emitted aerosols now and in the future. We studied ship emission with various flying platforms with different kind of instrumentation. Used platforms were one engine Cessna 172, two engine SHORT SC-7 Skyvan and AS350 helicopter. In Cessna and helicopter had the most simple instrumentation since the instrumentation are run by batteries, whereas Skyvan is prepared to carry heavier loads, like aerosol mass spectrometer. It has also electricity available on board.

With the basic instrumentation gas phase CO_2, CH_4, H_2O and SO_2 and particle number concentration (>4 nm), temperature and humidity was measured. In figure 1 is example from one flight in ship plume with Cessna. It shows that this method could be developed to a standard method to monitor the sulphur content of the ship fuel as well as for detailed studies of chemical, physical and optical properties of ship plumes.

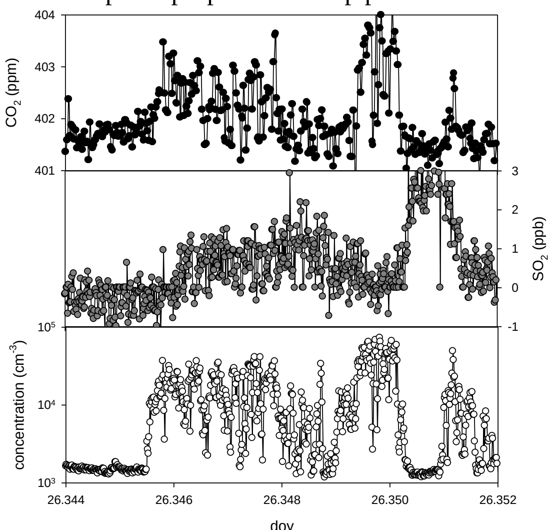

Figure 1. CO_2, SO_2 and aerosol number concentration in ship plume when approaching a vessel.

The work was supported by the European Regional Development Fund, Central Baltic INTERREG IV A Programme (project SNOOP). We would like to thank Airspark Oy, Aalto University Skyvan team and Helitour for flying platforms.

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