Monitoring ship emissions with continuous onshore SMPS measurements

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The accumulated emissions from ship traffic are cooling the climate mainly due to reduced methane lifetime caused by NOx emissions and also due to the direct and indirect climate effects of the particles emitted. There is, however, a lot of uncertainty in the magnitude of this cooling effect. According to our knowledge there are no long data series of detected aged ship emissions that are dispersed wider in the atmosphere.

Therefore, we measured the particle number size distribution at a background site approximately 35 km downwind of a heavy trafficked ship lane, representative of roughly 1-3 hours aged ship plumes. The site Høvsøre (56°27' E, 8°09' N, 2m a.s.l) is positioned on the western coast of Jutland peninsula in Denmark. It is located in flat terrain approximately 1.8 km inland from the shoreline. The measurements were conducted using a Scanning Mobility Particle Sizer (SMPS), covering particle diameter range 12 - 500 nm. The measurement period was from March 9th to July 23rd 2012.

We also studied air mass back trajectories (Draxler and Hess, 1998) arriving at the site. During 28% of the measurement days the air had constantly arrived from the sea and passed over the ship lane in last couple of hours. These days were examined further.

During most of these days we observed a large number of clear short-duration peaks above the background particle number concentration (Figure 1). During occurrence of the peaks the number concentration increased typically by several thousand particles cm^{-3}, but during some days with very low background particle concentration the increase was only some hundreds of particles cm^{-3}. The peaks were assumed to be formed by emissions from individual ships on the ship lane. The peak diameters (in dN/dlogD_p above background level) were typically at 40-50 nm and a weakly elevated accumulation mode concentrations were observed. When particle size distributions were converted to dV/dlogD_p, the peak diameters increased to 60-80 nm, and a second mode was often found with peak diameter around 200 nm. Counting statistics for the larger particles were not sufficient for calculating the relative contribution of the second peak to the total particulate volume in the plume.

These peaks were compared to reported emissions from individual ships near Gothenburg harbor (Jonsson *et al.*, 2011). The number concentrations at Høvsøre were found to be two orders of magnitude lower than in Gothenburg, which was expected because of the longer transport time and therefore much stronger dilution of the plume at Høvsøre. The peak diameters observed at Høvsøre were also slightly higher than those at Gothenburg, indicating further growth of the particles in the plume during aging.

The number of separable peaks per day was usually 20-40 (Figure 1), which is clearly less than the average number of ships per day (about 100) on that ship route. This indicates that we are missing a large number of ships on any given day. Potential reasons for this could be 1) coinciding peaks; 2) stronger dilution of the plumes originating from the further edge of the ship lane; 3) some of the plumes pass over our measurement site at higher altitude or 4) a fraction of the ships are not emitting enough particles to be identified at Høvsøre.

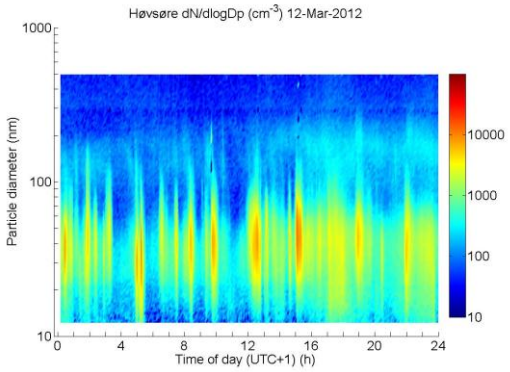

Figure 1. The particle number size distribution at March 13th, 2012 at Høvsøre. Ship plumes are seen as elevated number concentrations at sub-100nm size range.

Already at this stage of the research we can conclude that we do observe a lot of plumes from individual ships at approximately 35 km distance to the ship. These plumes should represent the aging of ship induced emissions, as well as their climate impact better than emissions measured on a ship itself or in near vicinity of one. We can also conclude that we are unable to observe plumes from every individual ship.

The next stage of the research is to use automatic ship identification system to connect the plumes to individual ships, and to investigate the effect of different meteorological parameters and background particle concentrations on the plume peaks. More results on these issues are expected before the EAC 2013 conference.

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Draxler, R. R. and Hess, G. (1998), *Australian Meteorological Magazine* **210**, 295-308.

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