Airborne Measurements of Emissions from Oil and Gas Exploration and Production Activities in the Norwegian Sea

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Over the past few decades, a rapid decline in Arctic sea ice has been observed. Unlocking of the Arctic Ocean is expected to promote hydrocarbon extraction in the Arctic, which in turn will increase emissions of climate-relevant pollutants such as black carbon (Ødemark *et al*, 2012). Despite the anticipated impact, there are still insufficient in-situ measurements of emissions from oil and gas activities.

In July 2012, an aircraft campaign based in northern Norway was conducted, as a part of the EU ACCESS (Arctic Climate Change Economy and Society) project, to investigate impacts of different pollution sources on the Arctic atmosphere. Among 13 flights performed, the flight on 19 July focused on measuring emissions from various oil/gas platforms, drilling rigs and tankers in the Norwegian Sea.

The DLR research aircraft Falcon was extensively equipped with aerosol instrumentations: Condensation Particle Counters to measure total, non-volatile and nucleation mode particle number concentrations, Optical Particle Counters, Ultra-High Sensitivity Aerosol Spectrometer, Passive Cavity Aerosol Spectrometer Probe and Forward Scattering Spectrometer Probe to measure particle size distributions across a wide range of particle sizes, Particle Soot Absorption Photometer to measure absorption coefficient and Single Particle Soot Photometer to measure black carbon concentrations. Aerosol measurements were complemented by measurements of trace gas (NO_x, SO_2, O_3 and CO) concentrations and meteorological parameters.

Particle size distributions measured within exhaust plumes from all facilities showed large enhancement in the number concentrations for particles < ~150 nm, which is characteristic of combustion emissions. However, different types of facilities emitted plumes with distinct chemical compositions as can be seen in Fig 1 as an example. Plumes from shuttle tanker and condensate storage tanker (*e.g.* Åsgard C in Fig 1) operating on fuel oil were characterised by high SO_2 concentration and high fraction of non-volatile particles (> 45%). Drilling rigs (*e.g.* Deepsea Bergen in Fig 1) were also high emitters of non-volatile particles.

On the other hand, oil/gas platforms (*e.g.* Heidrun in Fig 1), which combust large amounts of fuel gas, emitted low levels of SO_2 and mostly volatile particles with non-volatile particle fractions < 10%. Also, a significant increase in the nucleation mode particle concentration (up to 50% of total particle concentration) was observed which suggests new particle formation in the plumes, possibly due to high levels of co-emitted VOC. Especially high particle concentrations (> 20,000 cm^{-3} but < 2% non-volatile fraction) were measured for a platform which was flaring at the time of the measurement.

In addition to the freshly emitted plumes, relatively aged (1.5 – 2.5 hour old) pollution plumes were also sampled. Even in the aged plumes, total particle concentrations were more than 6 times higher than the background concentration. Therefore, emissions from oil and gas activities are expected to have a significant impact on the local air quality.

The results from this study will be used to improve current emission inventories and to validate regional and global chemical transport models. This will ultimately allow better prediction of future Arctic air pollution and associated warming.

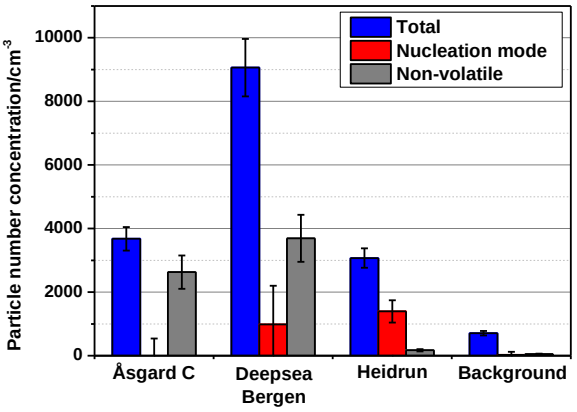

Figure 1. Maximum particle number concentrations measured in the pollution plumes from different oil/gas facilities (*n.b.* plume dilutions have not been taken into account yet). Average background concentrations measured in the marine boundary layer are also shown.

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