Geophysical Research Abstracts
Vol. 14, EGU2012-7155, 2012
EGU General Assembly 2012
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Particles from a Diesel ship engine: Mixing state on the nano scale and cloud condensation abilities

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Transport by ship plays an important role in global logistics. Current international policy initiatives by the International Maritime Organization (IMO) are taken to reduce emissions from ship propulsion systems (NO and SO, primarily). However, particulate emissions (e.g. soot) from ships are yet not regulated by legislations. To date, there is still a lack of knowledge regarding the global and local effects of the particulate matter emitted from ships at sea. Particles may influence the climate through their direct effects (scattering and absorption of long and shortwave radiation) and indirectly through formation of clouds.
Many studies have been carried out estimating the mass and particle number from ship emissions (e.g. Petzold et al. 2008), many of them in test rig studies (e.g. Kasper et al. 2007). It is shown that particulate emissions vary with engine load and chemical composition of fuels. Only a few studies have been carried out to characterize the chemical composition and cloud-nucleating ability of the particulate matter (e.g. Corbett et al. 1997). In most cases, the cloud-nucleating ability of emission particles is estimated from number size distribution.
We applied measurements to characterize particulate emissions from a MAN B&W Low Speed engine on test bed. A unique data set was obtained through the use of a scanning mobility particle sizing system (SMPS), combined with a cloud condensation nucleus (CCN) counter and a thermodenuder - all behind a dilution system. In addition, impactor samples were taken on nickel grids with carbon foil for use in an electron microscope (EM) to characterize the mineral phase and mixing state of the particles. The engine was operated at a series of different load conditions and an exhaust gas recirculation (EGR) system was applied. Measurements were carried out before and after the EGR system respectively.
Our observations show significant changes in number size distribution and CCN activity with varying conditions. Results of transmission electron microscopy revealed salt condensates of nanometer size attached to soot particles. High resolution structural analysis of single particles shows that three different phases (graphitic soot, crystalline salt and amorphous condensed organic matter) may be present in the same particle volume. A closure between CCN activation curves, EM samples, and SMPS size distribution will be presented and used to identify climate active parts in single particles.

ACKNOWLEDGEMENTS

We thank the Danish Agency for Science, Technology and Innovation for support through the NaKIM project (www.nakim.dk).

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