# Dependence of ship-engine aerosol emissions on fuel type: trace metals, black carbon, and light absorption

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Shipping emissions represent a rare source of aerosol pollution in the relatively-clean marine atmosphere. The radiation and cloud interactions of these polluting aerosols are influenced by their content of light-absorbing carbon, which includes both black carbon (BC) and light-absorbing organics (Mueller et al., 2015). The production and emission of these species by a ship engine depends on the composition of the fuel, which has traditionally been the sulfur-rich residual fuel Heavy Fuel Oil (HFO).

Since 2010, European regulations have required low-sulfur distillate fuels like Marine Gas Oil (MGO) or diesel to be used in and around European ports (Jonson et al., 2015). Relative to HFO, the lower sulfur content as well as the lighter-hydrocarbon composition of distillate fuels like MGO lead to different fractions of BC and organics being produced (Mueller et al., 2015), and potentially to fundamentally different BC properties due to changes in combustion chemistry.

This study focuses on the shift in particulate matter (PM) properties for emissions of the same engine run on HFO, MGO, or diesel fuel. To characterize the trace-metal content of the PM, an Aerodyne High-Resolution Aerosol Mass Spectrometer equipped with a laser vaporizer at 1064 nm (SP-AMS) was employed. To quantify BC mass and mixing state, a Single-Particle Soot Photometer (SP2) was used; optical properties were simultaneously measured by the Aerodyne CAPS PM-ssa (extinction and scattering) and an aethalometer (wavelength dependence of absorption).

The SP-AMS detected such trace metals as V, Fe, Ba, and Ni at significant concentrations in the HFO exhaust. Ratios of these trace metals, often used to identify ship emissions, varied over time. The distillate fuels MGO and DF emissions contained negligible amounts of trace metals; the possibility of using other mass spectral features for source apportionment will be discussed. These discussions will incorporate aerosol light absorption measurements, which for HFO indicated a domination of light absorption by organic carbon ("brown carbon").

Measurements were performed as a function of engine load for all three fuels. The relationship between trace-element emission and aerosol optical properties across these loads for all three fuels will be discussed. These data provide a basis for the understanding of atmospheric shipping emissions, and the prediction of the climate and health-effect response to a switch from HFO to MGO or diesel fuel.

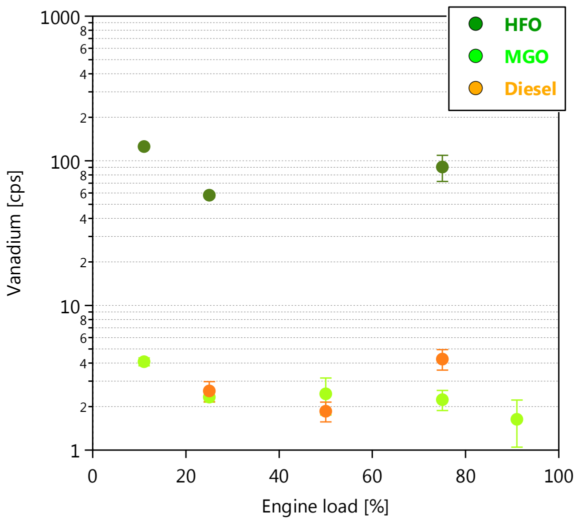


*Figure 1:* SP-AMS vanadium signal for the three fuels as a function of engine load.

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Mueller et al., Applied Energy 155, 204–217, 2015.
Jonson et al., Atmos. Chem. Phys. 15, 783–798, 2015.