Marine Black Carbon emissions: an instrument comparison

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As the Northwest Passage through the Arctic Ocean is becoming more navigable and more ships take this route, the International Maritime Organization (IMO) has become interested in assessing the impact of Black Carbon (BC) emissions due to shipping on climate forcings in the Arctic.

The IMO agreed to use the definition laid out in Bond et al. (2013) and asked its members to do measurement campaigns to get familiar with this definition of BC in the context of Marine emissions. BC emissions from ships should be measured with different measurement methods, marine engines, engine conditions and marine fuels. In this study, we focus on the behaviour of different measurement techniques in varying engine conditions and fuels.

Emissions from a 2-Stroke DDC 6-71N engine with an in-line 6 cylinder configuration, a maximum rated speed of 2100 RPM (range 1100-2100), a BMEP of 641 kPa, and a power of 210 Hp at 2100 RPM mounted on a test-bed were measured. Three different fuels were used: DMA (distillate with low sulphur content), RMA-12 (residual with low sulphur content), and RMG-380 (residual with high sulphur content). The latter was representative of the fuels typically used outside controlled areas.

A suite of BC-specific instruments as well as many ancillary instruments were used to measure engine emissions. The Black Carbon instruments reported here are: Semi-continuous OC/EC, OC/EC filters, Laser-Induced Incandescence (LII), Micro-Soot Sensor (MSS), Smoke Meter (FSN), and Multi-Angle Absorption Photometer (MAAP) and Aethalometer. The spread in responsivity of these instruments was quite broad, varying by about a factor of two.

A Conditioning System (CS) consisting of a catalytic stripper and sulphur adsorbers was used in roughly half of the tests to strip emissions off of organic vapours that might have otherwise affected the response of the various BC instruments. The sample conditioning system proved effective in reducing OC and sulphate as shown by Teflon filter analysis and by TEM images of emitted particles having passed through, or bypassed, the CS. The effect on the BC instruments' response, however, was not immediately evident.

Noting the broad spread in instrument responsivities, we applied a post-hoc calibration to the BC instruments based on their response to the DMA fuel and tested to see if this calibration improved agreement for the tests run with the two residual fuels. We calculated the spread in slopes for all BC instruments (except the MAAP and Aethalometer because of their non-linear behaviour) before and after applying the post-hoc calibration and saw a reduction in the spread from around 30-40% before to around 15% after for both RMA-12 (Fig. 1) and RMG-380 emissions. The spread was further reduced to around 10% when applying the post-hoc calibration to conditioned emissions.

These measurement campaign results suggest that instrument calibrations with a marine-relevant source and the use of a conditioning system have potential to improve agreement between instruments and further testing of these strategies is encouraged in future marine engine measurement campaigns.

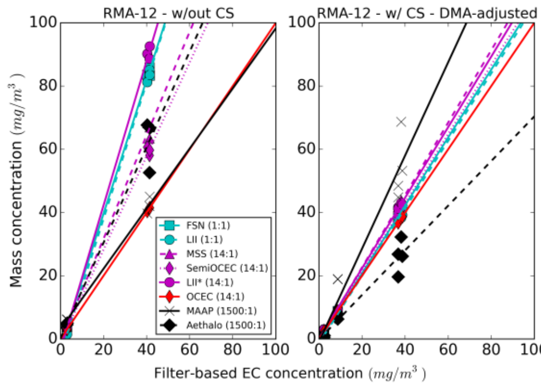

Figure 1. Mass concentration of engine emissions running on RMA-12 as measured by BC instruments. Left panel: as measured without the CS and no calibration. Right panel: as measured with the CS and with DMA-based calibration.

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Bond et al. (2013), *J. Geophy. Res.* **118**, 5380–5552.