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Atmospheric Measurement Techniques Discussions

AMTD
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Interactive Comment

Interactive comment on "Ship emissions of SO₂ and NO₂: DOAS measurements from airborne platforms" *by* N. Berg et al.

Anonymous Referee #3

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The manuscript by Berg et al. describes a novel application of differential optical absorption spectroscopy by using ocean reflected stray light as light source to measure SO2 and NO2 columns in ship plumes. The columns are then converted into emission values taking relative wind speed and light path length into account. The conducted measurements are evaluated as feasibility study for potential future use of this technique to monitor ship emissions in emission controlled areas. The novelty of the approach is appealing and fits well within the scope of AMT. However, the manuscript falls short in the discussion of some relevant points, particularly in dealing with uncertainties that arise from radiative transfer and with respect to comparing this approach to other possible monitoring techniques.

General comments:

Radiative Transfer: The geometric approximation of the AMF depends, a.o., on solar zenith angle, on the local aerosol profile and in a rather complex fashion on the reflection on the water surface as well as on the optical density and spatial distribution of the ship plume. The error estimation is not complete without at least performing some basic radiative transfer model case studies. Even though the authors state that this is beyond the scope of the paper, its omission leaves the conclusion on the feasibility questionable. The discussion in Section 6.1 on light being reflected on the plume directly is too short. Depending on the optical density of the plume as well as on the single scattering albedo of the aerosol, photons could be multiple scattered inside the plume or be reflected off the plume, thus either de- or increasing the measured slant column. Looking only at the intensity is not sufficient to properly quantify this effect.

Measurement setup: Please explain why a telescope viewing angle of 30 degrees was chosen.

The roll angle of the aircraft/ helicopter will also introduce an error.

Discussion of results: An agreement between model and measurement of about 40% seems promising. However, looking at Fig. 16 that shows some rather large discrepancies between optical and in situ measurements raises the question whether the DOAS method would really be sufficiently reliable to not give false positives in the future when ships run on 0.1% SFC only. In fact testing this method on ships that indeed run only on SFC 0.1% seems advised. Also, the instrumental setup seems rather costly, which might speak against the method. A discussion of DOAS vs. other methods would be very interesting.

Specific comments:

Section 2.1: Please clarify how the operation with 2 spectrometers and 1 telescope

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works – or are there 2 telescopes?

Section 2.1: (1) Since ozone strongly absorbs in the same wavelength range as SO2, checking the sensitivity of the SO2 fit to the inclusion of ozone is advised to make sure that ozone is indeed cancelled out by the reference. (2) The fitting range that is chosen for NO2 includes a water vapor absorption band. Since emission plumes typically also contain water vapor raises the question of why is no water reference included in the NO2 fit or why is the NO2 spectral fitting region not shortened to avoid the water absorption? (3) Please include a NO2 fit picture.

p.6274, ln.17 and p.6283, ln.2: why was SO2 only detected in 60% of the plumes?

p.6278, ln.4: cite Grainger and Ring, 1962 when mentioning the Ring-effect

p.6280, ln.15: typically "AMF" is used for air mass factor. $\frac{1}{2}$ SIN(telescope angle) is a geometric approximation of the AMF. Its uncertainty does not only depend on the presence of waves, but also changes with e.g. solar zenith angle or the optical density of the plume. These inherent uncertainties should be stated. See also discussion above.

p.6286. ln.10: 3 measurements of the same ship plume are not necessarily probing the same slant columns as the diameter of the plume might change due to dilution and depending on the distance to the ship as well as the radiative transfer of the measurements might not be comparable. It is therefore not a given that the uncertainty of a measurement is reduced by repeating it 3 times.

Tables 1-3: Though appreciating the work that has gone into collecting the information contained in these tables and its value for a real emission control, most of the information is not relevant for this publication and partially contained in the histograms. The tables could be removed or shortened.

Figs 1 and 2: please use wavelength as x-scale instead of channels

Fig. 6: The background becomes negative over time in an almost systematic fashion.

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What could be the cause of that? The 3rd peak is larger than the first 2 peaks. Is that caused by measuring the plume closer to the ship? If so, then see also comment above.

Fig.14: measurement error bars are not visible

Technical corrections:

p.6276, ln.19: “obey” instead of “obeys”

p.6281, ln.17: “of the ships” instead of “for the ships” (?)

p6285, ln.8: delete “a” after SO2

p.6285, ln.24: replace “Fig.9” with the appropriate Fig. number

p.6290, ln.5: “need” instead of “needs”

Fig.3, caption, 2nd line: “outside the” instead of “outsidethe”

Interactive comment on Atmos. Meas. Tech. Discuss., 4, 6273, 2011.