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Atmospheric Measurement Techniques Discussions

Interactive comment on "Measuring SO_2 ship emissions with an ultra-violet imaging camera" *by* A. J. Prata

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General.

This is an extremely helpful and thoughtful review and I thank the reviewer for his constructive and helpful remarks.

The reviewer has pinpointed a major problem encountered with the analysis of the single-channel UV camera data in order to retrieve SO2 in ship plumes. This was also described in the paper but unfortunately perhaps with not enough emphasis. In response, I have modified the text to highlight this issue and added an Appendix that describes how to correct for the problem of soot by using a second channel, collecting UV light at a longer wavelength.

Specific comments

P9469, L15. Agreed. Reference added.

P9470, L2. Re-stated as "Preference is for S content to be below 0.5% for ships in harbours and at 0.1% for ships at berth."

P9471, L5. I wrote it in this order for two reasons: firstly this is the time order of the measurements, and secondly I wanted to convey the development from speculative measurement to feasibility study. I accept the logic of the reviewer but my personal preference is to keep the chronological order. However, I have moved the paragraph suggested by the reviewer to the Results section, as a compromise.

P9471, L20. Yes this is a good suggestion and I have made the change.

P9471, L26. Agreed. I can remove this Figure.

P9473, L1. A short paragraph has been added explaining the manual tracking method. An optical flow model has now been developed but it is beyond the scope of this paper to include a description here.

P9473, L23. Section on SIRENAS-G has been removed.

P9474, L12. Agreed. Change made.

P9474, L13. Omission fixed.

P9474, L15. Fast sampling is needed to avoid "smearing". Sentence added to clarify.

P9475, L9. "backscattered" removed.

P9475, L13. Signal-to-noise for this retrieval relies on the contrast between the plume intensity and the background. This contrast is reduced the further the camera is from the plume.

P9475, L17. Re-phrased as suggested.

P9476, L8. Removed the word “multiple”.

P9477, L16. “Schott glass” added in parentheses.

P9479, L6. The word “scattering” has been removed because as the reviewer rightly points out this process is not included in the BBL formulation. The word “vicinity” refers to the background light on either side of the plume. This has been re-worded. Finally, it is true that the camera cannot influence the radiative transfer, but the field-of-view certainly does, and this is the point of the sentence, which I think is clear.

P9479, L13. Yes I have not gone into this effect in any detail in this paper. However, I accept that it is worth mentioning and include a short sentence citing the relevant literature as suggested by the reviewer.

P9479, L15. As the reviewer has already pointed out a larger aperture leads to unwanted light variations across the CCD. Thus reducing the aperture is a good strategy. However, this means there is less light available, reducing signal-to-noise. Faster sampling simply means that sharper images can be obtained, but this is also a function of the quantum efficiency of the detector so the sentence has been modified.

P9480, L17. Sentence added to explain.

P9481, L11. I have referred to Table 1.

P9481, L15. Changed for a distance of 1 km.

P9482, L4. Change to “. . .results were best when the ship was close-by and orthogonal to the camera.”

P9482, L13. Two sentences added to add detail to the distance calibration calculation.

P9483, L14. Yes this is true, but the ships also sometimes present clean (sometimes invisible) plumes and these are the cases that were carefully selected for analysis whenever possible. In most cases, ships at Svalbard and those entering the port of Rotterdam were at low speed and the plumes were cleaner than when the engines

were at full power. Ships at berth generally use less powerful auxiliary engines. In the case of the NYK Cool, which gave very high emission rates, the plume was not obviously dirty. When possible, only plumes that appeared “clean” were analysed. This does not guarantee that the plumes are free of particulates but it reduces the problem. Nevertheless this issue is acknowledged and I have modified the text to make this point stronger, as suggested by the reviewer. The new Appendix shows how to make a correction using a second channel.

The suggested approach of analyzing quantitatively the RGB images is interesting. Some of the coloration of the visible plume is simply due to water droplets in the plume (which do not absorb appreciably in the UV, but scatter light). I feel that a detailed analysis of this kind could be pursued as a separate paper. I have determined that a dual-camera system or dual-filter, single camera may be a better approach. Such a system is under development.

P9484, L16. Yes and emphasized further as suggested.

P9485, L8. Yes really in the case described.

P9485, L9. The reasoning here is that larger distances lead to larger errors in estimating the light intensities (background and plume). Both underestimation and overestimation are possible.

P9487, L21. References added.

P9487, L24. Yes, this should be “maximizing coincidence”.

P9493, Table 3. Sentence added to explain visibility assessment.

P9495, Figure 1. Figure 1 now removed.

P9496, Figure 2. Both scales should be the same. The images have not been distorted. The Figures have been re-drawn with a single scale and the font size increased.

P9497, Figure 3. Correction made - as above.

P9503, Figure 9. This was an illustrative example. In fact this cell shown leaked (sometime later) and was not used in the calibration. As suggested, Figure 9 has been replaced showing another cell that was used in the calibration.

P9504, Figure 10. The spectrometer measurement for this cell was 982.9 ppm*m.

P9506, Figure 12. Corrections made as suggested.

P9508, Figure 14. Corrections made as suggested.

P9509, Figure 15. The caption has been corrected.

P9510, Figure 16. Corrections made as suggested.

Interactive comment on Atmos. Meas. Tech. Discuss., 6, 9467, 2013.