Atmos. Meas. Tech. Discuss., 6, C4561–C4563, 2014
www.atmos-meas-tech-discuss.net/6/C4561/2014/

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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Received and published: 2 March 2014

Main objection.

I thank the reviewer for raising important issues with the paper, which I have tried to rectify in my response and my revisions.

The reviewer has noticed that there is a mixed message in the paper concerning the accuracy of the method. This was not intended. Rather I tried to show that using the camera with just one filter is not sufficient to achieve the "theoretical" accuracy obtainable. So there are two messages that I need to make more clear. First, given good viewing conditions and the right optical configuration it is possible to achieve 20-40% accuracies. Second, the current configuration was limited and may only achieve

these accuracies when conditions are close to ideal, viz. close proximity to a 'clean' ship plume, good sunlight, no clouds. The m/s will be revised to reflect this much more clearly. I have removed a statement from the Abstract concerning the quantitative errors found, as suggested.

Details.

Abstract. Row 18. Agreed.

P9470, row 10. Change made.

P9470, row 20. I did not wish to repeat the results presented in the Balzani paper, but agree further comments are needed here. According to Fig. 10 of Balzani et al. the Stena Hollandica emission rate (measured and modeled) is close to 22 g/s, whereas that reported by the UV camera is 23 g/s, so it is not always that the UV camera measurements are in such bad disagreement. But on the whole the UV camera did produce higher values and this was attributed to particles. A quantification of the overestimation of SO2 mass loading due to black carbon is included in the revision.

P9478, row 17. This should read 10 ppm*m and has been changed.

P9491, row 18, eq.7. Agreed. Change made.

P9482, row 6. The WMO standard for screen-height measurements is between 1.25 and 2 m. I chose 1.5 m as an average value for use in the formula. The actual height of the wind data was not provided.

P9482, row 15. It is true that wind uncertainty represents a large error term. Wind speed fluctuations can be quite high and the atmosphere downwind of the ship is disturbed by the ship. On the day in question winds were light (3-5 m/s). So a wind speed error of 1 m/s is reasonable (at screen height). The mean wind on 18.09.2009 was $\sim$4 m/s (the apparent wind was between 6-12 m/s) and the standard deviation (20,000 data points) was 1 m/s. I have assumed that the error does not change with height; a perfect model, so the error could be larger. A measurement at 10 m would indeed be

preferable, however as stated in the paper the camera can provide a far better estimate by feature tracking or using optical flow models. In at least on case analysed the true wind must have been strong as the apparent wind is in the direction of the ship movement and so in this case errors could be greater. I have done the wind analysis for a few ships using camera images and found the estimates to match the values given in the paper quite well (within 20%) but there are insufficient examples to make any definitive statements.

P9482, row 5 and Table 3. See comments above. The error estimates refer to a low wind speed (at screen level). Consecutive UV images seem to show that the apparent wind was quite steady. The wind direction was also quite constant ($\sim$50$\pm$20°) on this occasion, so the Table is reporting properly the results presented for this work and is not to be considered as a general result. The impact of particles has been acknowledged as a large source of bias error–by assuming no particles the retrieved values will always be biased high (30% or more) and this certainly explains some of the differences found between the UV camera and the lidar. Water droplets are only weakly absorbing in the UV and generally this effect is regarded as negligible.

P9483, row 13. Clearly some ships have much dirtier plumes than others and unfortunately because this was not quantified during the experiment it remains difficult to make a definitive statement that this is the source of bias. (It may be that there are other sources of bias, not fully recognized). I can see that readers of the paper may get the wrong impression about the errors as reported. I have revised the paper in line with the reviewer's comments and tried to make it clear that the camera has potentially a high error rate provided certain factors are taken into account (e.g. corrections for particulates) and measurement conditions are benign. I have also included an appendix in the revision to quantify the effects of particles on the SO2 retrieval. This may be as low as 2% or as high as 30%.

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