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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Monitoring compliance with sulphur content regulations of shipping fuel by in-situ measurements of ship emissions" *by* L. Kattner et al.

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Answers to Referee #1

General comment: This paper describes a large set of ship emission measurements carried out downwind of by passing ships in the Elbe River. The method has been developed and used within the scientific community during the last 10 years. The paper is well written. It has focus on compliance monitoring and considering that the shipping sector has been forced to decrease their emission by an order of magnitude from January 1st 2015, by running 0.1% sulfur fuel content instead of 1 % on northern

European waters, these data are very interesting, since they correspond to one of the first data sets. For the reason above I believe the paper should be published. The paper should however be improved in the technical discussion regarding the quality etc.

Answer: We thank the reviewer for the general positive comments and the recommendation. Below, we reply point-by-point to the specific comments. As far as possible, we have considered the suggestions in the revised manuscript.

Specific comments: Row 28, p 11033: The author mentions MGO but not the fuel many ships seems to be using, i.e. desulfurized heavy fuel oil.

Answer: We have changed the manuscript to include different kinds of fuels besides MGO.

Row 7, p 11036: We have some own experience on similar measurements showing that 1 minute resolution is somewhat slow and that ship plumes drifts by rather quickly. It would be good if the author can discuss /elaborate on this issue further and include in the uncertainty discussion.

Answer: The width of our peaks is typically between one and five minutes, even if we look at the CO2 data in one second resolution. This agrees well with an example given in Beecken et al., 2014b, Figure 1, where the ground based measured plume has a width of about 2 minutes. Peaks that are too narrow will become too small when averaged to 1 minute and are thus excluded from our analysis. Increasing the resolution to seconds would probably improve the ability to detect smaller peaks as well as to distinguish between plumes of ships that are close together but not increase the accuracy of our measurements.

Row 13, p 11036: The SO2 fluorescence technique has cross sensitivity to NO. Has this been assessed and corrected for?

Answer: Yes, there is a NO cross sensitivity for our SO2 device which has been as-

sessed via calibration with six different NO concentrations ranging between 100 ppb and 450 ppb. It showed that 0.8 % of NO is measured by our SO2 instrument as a SO2 signal. With our measurements of NO parallel to SO2, we can estimate this cross sensitivity for each measured plume individually and correct the SO2 data. Since we have underestimated this effect in our analysis of the January 2015 data set, we have reanalyzed the data with NO correction and changed Figure 4 accordingly. This improves the quality of our data set but does not change the message of our manuscript. We thank the reviewer for his suggestion. We have changed the manuscript in section 2 Instrumentation to: "There is a NO cross sensitivity for SO2 which gives for 0.8 % of the NO signal an SO2 signal. We have determined this value of 0.8 % via a set of 6 calibration measurements of different NO concentration between 100 and 470 ppb." Also in section 3 Data analysis: "The peak area value of the SO2 peaks is corrected with 0.8 % of the peak area value of the NO peaks to account for the cross sensitivity." We have added the Institute for Hygiene and Environment to the acknowledgements, who help us with the additional calibration.

Row 3, p 11037: The LICOR instrument is a rather nonlinear instrument. The spa calibration carried out was rather crude from 306 to 990 ppm corresponding to a too large interval in my mind, since the instrument is nonlinear in this interval. The author should elaborate on this issue in the uncertainty discussion.

Answer: According to the specifications of our LICOR 840A instrument, its measurement range is from 0 to 3000 ppm and company calibration shows that it is linear within this range. We have chosen our calibration gases to lie within the range and have a low and a high value. Measurements of both calibration gases show within the uncertainty of the gas concentration only an offset, which is corrected for.

Row 3 to row 16, p 11039: The problem of obtaining good CO2 baseline values in a measurements site inland with long averaging time should be discussed. Also the nonlinearity of the CO2 sensor (see above).

Answer: The baseline is determined via a succession of three centered running means where peaks are excluded after each run and data is interpolated for the excluded peak. This gives a good baseline. Periods with very variable background signals where the baseline determination is not acceptable are excluded from our analysis. We have added to the manuscript: "Background signals for each gas are determined via a customized running mean filter. Only for those events with a significant CO2 peak and a clearly determinable background, SO2 signals are analysed."

Row 3 to row 16, p 11039: Since ships today run on low sulfur fuel content the precision in the SO2 measurement, and the baseline assessment etc, is more difficult since there is very little signal, especially for small ships. This should increase the SO2 uncertainty to higher than 15-30% which is the typical uncertainty found in other studies for instance by Balzani et al. Also the threshold of 0.15% is questionable in my mind for the same reason.

Answer: We have a quite strict quality control for the peaks we are analyzing to prevent the increase of uncertainty in our analysis, which is a compromise between the number of ships we can analyse and the quality of our data. For 10 % of our analysed ships we have a detection limit for the sulfur content of 0.05 % due to low CO2 values. For the rest of our data, we are confident in our uncertainty of up to 30 % and better when the peak concentrations are higher.

Row: 27 p 110039; I believe the referred paper (Beecken 2014a) is about airborne measurements on the open sea while here the measurements is an inland measurements. The authors should discuss this.

Answer: Yes, the data we referred to is measured by in-situ instruments from airplane. Although the conditions are different and measurements are more difficult, we still think the data is comparable. We have commented this in the manuscript: "This is better than previously published compliance rates of 85 % of 174 ship plumes (Beecken et al, 2014a), although it should be noted that this study did not include uncertainty consider-

ations and was measured by airplane on the open Sea. This could hint to the possibility that compliance might not be so high when no direct control is possible. Compliance rates at other locations for land based measurements show values of 90 % of 255 ship plumes and 97 % of 211 ship plumes (Beecken et al, 2014b)."

Row 12, p 12: These data are presumably the first published in ACP for 2015 data but to my knowledge there are phd dissertations including similar results.

Answer: Yes, there is a PhD dissertation from Jörg Beecken in 2015, in which first measurements of January 2015 are presented. We have referenced this phd thesis and changed the phrasing in our manuscript: "There are preliminary results for first SFC measurements in January 2015 presented in Beecken, 2015, which are comparable with our measurements, although with slightly higher uncertainty and lower compliance rates."

Row 17, p 11041: Even though the oil price is so low that MGO now has the same price as HFO last year the difference between the two still remains.

Answer: That is true, but the low prices might still help with the acceptance of the new regulations. We have rephrased this sentence: "It should be noted that the global oil price and thus MGO costs for the needed sulphur quality in January 2015 was the lowest since 2009, which could have a positive influence on the acceptance of the new regulation."

Figure v2. Is the data NO (as written in labels and text) or NOx. Why not NOx?

Answer: We have shown in Figure 2 the comparison between NO data in 2014 and January 2015 since NO is a parameter which we are using in our analysis. We could use NOx data as well but it would show similar behavior.

Technical Corrections: The paper is well written in most places.

Answer: Thank you!

Row 15. P 110033: insert which between and which are basically Row 9 p 11034: change to "and, when suspicion is raised, take. . . "

Answer: Changed as suggested.

Interactive comment on Atmos. Chem. Phys. Discuss., 15, 11031, 2015.