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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 #2

Page 11035, Line 9: abbreviation of ft is not clear.

Answer: We have changed this to "foot".

Page 11036, line 10: What is mean by 'certified instruments'?

Answer: The instruments are certified according to directives of the European Union for air quality measurements: EN 14212 for SO2, EN14211 for NOx, and EN14625 for

O3. We have added this to the manuscript.

Page 11036, line 23: unclear what is meant by: difference of total NO. Should it be NOx and NO without conversion?

Answer: Yes, it should be NOx and we have changed this in the manuscript.

Page 11037, line 15 – 22: Why the AIS data is not used to identify all peaks?

Answer: We could associate every NO peak to an individual ship with the AIS data before analysing the CO2 and SO2 signal, but we would have to exclude those peaks without clear signals later anyway and would not gain any additional information.

Page 11037, line 22-25: It seems difficult to calculate the peak area since the response times of SO2 analyser and the CO2 analyser are so different and the data collection frequency is 1 min-1 i.e. the response time of the SO2-analyzer, frequency of the data collection and the duration of the peak concentrations are of the same order of magnitude. Please explain in more detail how the peak areas are calculated?

Answer: We calculate the peak area for each gas individually. After subtracting the background for the gas, we identify the peak maximum, and the start and end points of the peak. All values from start to end are added up to be the peak area. Using 1 minute data collection frequency is a compromise between better accuracy of our instruments with their longer response times (especially SO2) and easier data analysis on the one hand and better resolution of the peaks and better assignment of ships to peaks close together on the other hand.

Page 11037, line 23: How to define the background with respect of the peaks?

Answer: Please see the answer to reviewer 1. We have changed the manuscript to: "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."

Page 11039, line 4: There are uncertainty sources that have different contribution for different analysers: moisture, cross interferences by other chemical species. How, e.g. the contribution of NO on SO2 measurements has been taken into account?

Answer: We do have cross sensitivity with NO and we have reanalysed our data to include this effect. Please see the answer to reviewer 1. We have changed the explanation of peak analysis to: "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. For all peaks the individual peak area above the background concentration is determined. This accounts for the difference in peak width for each gas due to different time resolutions of the respective instruments. 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."

Page 11039, line 16: How to end up the uncertainty of measurements of 15 %. This may be too low estimation especially at the range of 10 ppb.

Answer: The uncertainty of 15 % is the best case scenario where the peaks are large compared to the background noise and a well-mixed plume is assumed with a conversion efficiency of 1 % from sulphur to SO2. Our measurements lie well within the range of 15 to 30 percent uncertainty especially for sulphur contents around 0.1% and higher.

Page 11040 line 10. Rounding the 0.1 % limit up to 0.15 % may be speculation and cause a 50 % increase from the limit. Please explain is this assumption in consistent with the legislation?

Answer: This is just a suggestion on how to handle information about sulphur content obtained by in situ instruments such as our system and give a value to define what is compliant with the regulations or not. We have chosen this value of 0,15 % which exceeds our uncertainty, to be sure that we do not accuse ships of a regulation violation which was caused by the uncertainty of our measurement, and also such that other groups with potentially higher uncertainty of their measurement systems can still

compare their results with ours.

Page 11041 line 14-15. The reader gets very easily the idea that 95.4 % of ships follows the rules for sulphur content of ship engine fuel while you were able to measure 10 to 40 % of the whole ships? Please clear the sentence. Does this method apply if the ship is using different fuel (LNG), use heavy oil but scrubbing technique? Please discuss this issue.

Answer: We have rephrased the sentence to be clearer about the number of compliant ships in accordance to the number of measured ships: "Our data shows that the vast majority (95.4 %) of all the ships we have measured are indeed complying with the new regulation of 0.1 % sulphur fuel content." Since we do not know about the fuels the ships are using or if they use scrubber techniques, we can only estimate a potential sulphur content assuming the ships burn fuel with that sulphur content. Therefore, this method could be used to estimate whether different techniques such as LNG or scrubber technique have comparable results of SO2 reduction to the use of low sulphur fuels. However there are still few ships who use alternative methods and this issue would need further research.

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