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Atmospheric Measurement Techniques Discussions

Interactive comment on "Airborne emission measurements of SO_2, NO_x and particles from individual ships using sniffer technique" *by* J. Beecken et al.

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We thank Jan Duyzer for his comments on our paper. As these comments refer to the pre-print version for the technical review some of the comments have already been addressed in the discussion paper. Our replies are given in italic style in the section below.

Abstract - line 15 The +/- signs read as if these are error bounds. Perhaps the can be describes as range. It denotes the standard deviations.

- line 19 I suggest to be less bold and say that the fraction off ships observed complying

with the IMO limits has increased. Rather than claiming that the sulphur emission has decreased. This would require a statistical proof that the sample is representative. The main incentive of this statement was to show that with the reduction of the SECA limit in 2010 also the emission of SO2 decreased. It was not meant to show any change in compliance. This is clarified now in the manuscript.

Paper - Perhaps the term submicron is more common than sub micrometer This is changed now.

- P 4 line 5 the term flight modified. If important; please explain. This is briefly explained now.

- P 4 line 17 The term VMR is not quite common. Perhaps ppb We disagree, this is a quite common term in atmospheric science. While ppb or ppm are only units.

- P 5 line 8 the monitoring . delete the. This is corrected now.

- P 6 line 23 the Steam model STEAM is now addressed consequently as a model now.

- P 7 line 7 Density of soot is a difficult one. Large particles could be way below 1 etc. Adds to the uncertainty of the PM emission factor. Please caveat. We made it now clearer that this density is arbitrarily chosen on bases of the findings of earlier test bed combustion studies (Barone et al., 2011;Virtanen et al., 2002). Concerning the uncertainties of the particle measurements it is explicitly stated in the uncertainty section that a quantification for particles has not been performed.

- P 8 is the difference in accuracy really significant in view of assumptions etc. This was already corrected in the discussion paper.

- P 8 line 27 etc. I think this is only one reference and we should be careful to use the number of 14%. And it is strange that this would only be true with sniffer measurements. This suggest it is an artefact. Please discuss. This is now clarified:"Earlier studies show that not all of the sulfur in the fuel is emitted as SO2. It was found that 1% to 16% of the sulfur in the fuel is emitted in other forms, possibly SO3 or SO4

(Schlager et al., 2006;Agrawal et al., 2008;Moldanova et al., 2009;Balzani Lööv et al., 2013;Moldanová et al., 2013). Hence the assumption that all sulfur is emitted as SO2 yields an underestimation of the true sulfur content in the fuel."

- P11 line 12 The overall distribution is 18% higher. . ...That is a strange way of putting. Please describe as average or median. I also suggest to conclude by saying which fraction of the ships now have a S content according to IMO limits. How does the magnitude of the sample (or in fact both samples ie the old sample) relate to the total number. And is the distribution of ship types representative and comparable with the old sample. Please discuss. We agree with the referee about the phrasing and clarified this now. In both cases more than hundred ships of different types were analyzed. So we assume that this is a good base for statistics. The number of ships is presented in Figure 5 now. Concerning the compliance and distribution of ship types, we prefer not discuss the matter in detail yet, since the manuscript (Mellqvist and Berg, 2014) is still under preparation. But it was seen that the most abundant types, I.e. passenger, cargo and tanker ships emitted about the same amount of SO2 per unit fuel.

- P 11 line 24 I don't think instantaneous is meant here. Please check English. Short term? It was meant "at an arbitrary time". This is changed now.

- P12 line 9 The half width of the distribution. . .. That is not a common parameter I think. The mean diameter or geometrical standard deviation. And also looking at the number of bins: how significant is this change? Please show a graph or provide more detail. It is an interesting result showing that coagulation is important. Now it is rather vague. Thank for recognizing this. The full width at half maximum was meant instead of the term "half width". We appreciate it as a very intuitive measure for the spread of the peak distribution. The bins are chosen to contain at least 30 samples for a certain significance where possible except for the last bin from 5-8 km because the interval width would be too large. The coagulation is discussed in section 4. This was pointed out even more now.

- P12 line 17 Standard deviations are in the order of their averages. This could be ok and perhaps not so strange for lognormal like distributions. And what is the meaning of this statement? We agree and thank the referee for his careful review. We decided to put the discussion about the correlation of particle to SO2 emissions in another paper together with data from other measurement campaigns to give significantly more statistical weight in the findings.

- P 12 line 21 the conclusion based on the intercept is a bit fast. Perhaps some explanation This is not part of this paper anymore. This will be discussed in more detail in another paper.

- P13 and general PM is often understood as PM10. Perhaps it is better to specify. We agree that the usage of PM is ambiguous. Yet, since this paper only deals with particles below 560 nm and PM is either or both used in context with mass units or in close textual neighborhood to the unambiguous PN annotation we would prefer to keep this expression as it is.

- P12 line 27 Suction hopper dredgers are commercial as well I would think The conclusion seems to be misleading and should not be seen as a significant result of this paper. So this statement is removed now.

- P13 line 12 Please provide some numbers rather than saying "in agreement" The numbers are given now for easier interpretation.

- P13 line 17 match well with (rather than of) This is corrected now.

- P14 line 30 I can imagine people may consider aircraft costly. . . The costs issue is mentioned now.

- Table 5 Why is this not converted into a graph? Table 5 from the pre-print version was converted to Figure 7 in the discussion paper.

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Interactive comment on Atmos. Meas. Tech. Discuss., 6, 10617, 2013.