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Atmospheric Measurement Techniques Discussions

AMTD

Interactive comment

# *Interactive comment on* "Monitoring compliance with fuel sulfur content regulations of sailing ships by unmanned aerial vehicle (UAV) measurements of ship emissions in open water" *by* Fan Zhou et al.

**Anonymous Referee #2**

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The paper by Zhou et al. reports on fuel sulfur content (FSC) compliance monitoring of sailing ships with unmanned aerial vehicles (UAV). Measurements were carried out in the Yangtze River Delta close to Shanghai in China, which is selected as an domestic emission control area (DECA) in China having a FSC limit of 0.5% (m/m). Since measurements of the FSC and therefore compliance monitoring from sailing ships are sparse, the topic is of interest not only for the scientific community. The manuscript is in general clearly written and I recommend it for publication in AMT. However, to better demonstrate the quality of the instrumentation and the methods used in this study more details should be given in the paper.

Instrumentation:

- There are no details on the custom sensors for $SO_2$ and $CO_2$ given. At least a link to a data sheet (in English) or better a table with specifications is needed.

- I am wondering about the short response time of the modules ($T90 < 1s$) which is much better than every electrochemical sensor I know. Looking to figure 5 this response time is very unlikely. $SO_2$ and $CO_2$ measurements of the same plume are out of phase (at least 10 to 15 s) having also completely different gradients.

- Please give more information on the method water vapor was filtered out. What about contamination with particles/soot . . .?

- Have the authors investigated cross-sensitivities to e.g. NO and $NO_2$?

- Measurements were carried out close to the funnel. Therefore, temperatures of the air sucked into the system are highly variable. How this is accounted for?

- Give information on the calibration methods used in this study to ensure long-term data quality. Since sensors used in this study are completely different to those used in Zhou et al. 2019 a simple plot showing the outcome of the sensors when using standard gas mixtures (e.g. 5 and 0 ppm $SO_2$) would be nice.

- The UAV used in this study is the same as in Zhou et al., 2019. What does it mean for the off-shore measurements? What is the operation time under typical weather conditions having e.g. a wind speed of 5 m/s? What is the maximum reasonable distance to a sailing ship? Please add a table with specifications of the whole UAV system.

Methods and uncertainties:

- The authors used peak values of $SO_2$ and $CO_2$ after applying a running mean of 10 s to the measurements to calculate the FSC. Looking to Figure 5 b it is not clear to me, how this could give reasonable results. As already mentioned above the gradients (and therefore real response times of the sensors) look completely different even for averaged values. At least one example proving and illustrating this method is needed.

- Simply taking into account the given accuracies for the sensors (5 and 3 % on measuring ranges respectively) an error of at least 0.03 % (m/m) can be calculated. Within this calculation no other errors e.g. due to the measurement procedure are included. Therefore, the reported total uncertainty of 0.03 for low FSC levels sounds quite optimistic to me.

- Please give details or an illustration what is meant with good- and poor-quality data.

Minor corrections:

- 2.1. Instrumentation: I guess, dimensions of the pod are given in cm.

- Figure 5: More details needed, which values are used for the calculation of the FSC (see above)

- Tables 1 and 2: Please always give FSC Values in % (m/m) using only the number of meaningful digits. "True value" implies that the analysis of fuel samples have no error which is of course not the case. Please refer to e.g. fuel sample analysis and give the typical error for this method (should be roughly 0.01 % (m/m))

- Table 2: Add values for the fuel sample analysis when available.

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