Atmospheric Measurement Techniques Discussions

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Comment on amt-2022-66

Anonymous Referee #1

Referee comment on "Development and testing of a novel sulfur dioxide sonde" by Subin Yoon et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2022-66-RC1, 2022

Review of "Development and Testing 1 of a Novel Sulfur Dioxide Sonde" by Yoon, et al.

Summary:

The manuscript by Yoon et al. describes novel measurements using an ECC sensor modified for sensing SO2. The measurement principle is similar to that of the measurements of ozone using potassium iodide solutions.

The authors describe the efficiency of the ozone filter, which is needed to completely remove ozone from the sampled air. They also describe the importance of the dryer, which minimized the removal of SO2 by water in the filter. They show the results of several field campaigns, which indicate the validity of their approach.

The paper is an important contribution for vertical profiling of SO2 and I would recommend publication after some modifications.

Major comments:

The paper refers to Flynn and Morris, which I assume is a reference to a patent. For clarity

for readers not as familiar with ECC sondes, I would recommend including a schematic of the ECC and how the bias current is applied.

In the context of this manuscript, the authors should explain the role of the magnitude of the bias current. The authors mention a few times that an instrument was configured for a specific measurement range. The magnitude of the bias current sets the upper detection limit, but this was not very clear. The authors should then point out, what the price is for selecting a high bias current. Figure 7d indicates that selecting a bias current that is too low can still lead to saturation of the sensor. How should the bias current be selected without a priori knowledge of the amount of SO2 that will be measured? Why does a high bias current increase the lower limit of detection?

The authors might also discuss what the uncertainties of their approach are. To what level of confidence can SO2 be measured using this approach, and what factors contribute to the measurement uncertainty?

Line 154: The proprietary O3 filter is not described in the reference. For this publication, the details of the selective O3 filter are essential. Figure 2 seems to indicate that the filter is not 100% efficient in removing ozone. (This Figure does not contain blue lines, even though the legend refers to them. What is meant here?)

Line 164ff: This sentence seems to contradict the statements just before and are not supported by the Figures shown. I understand that humidity is the limiting factor, which needs to be better discussed at this point. The supplemental Figure S1 is essential and needs to be included in the main text. It would be best if the authors had a Figure similar to Figure 2 using the dryer. In addition, it would be better to restructure the manuscript and discuss the RH dependence prior to the field deployments. I would suggest merging section 5 with the instrumental description, i.e. make it Section 3.4, then merging the two field deployment Sections into one single field deployment section.

Minor comments:

The authors use the terms “bias current,” “biased background current,” and “background current” interchangeably. The authors probably just refer to the biasing of the cathode cell, i.e. this is just a “bias current” and not a background.

I would suggest defining the sensitivity of the sensor as how many uA of current are generated per incoming ppbv of SO2, which is the inverse of what the authors use. With that definition a higher sensitivity is better.

This sensitivity of the sensor depends on some of the same factors as those of the ozone ECC, i.e. pump flow rate and conversion efficiency. In addition, the SO2 sonde has the transmission efficiency of the ozone filter. The chemical conversion efficiency in the cell is probably similar to that of the ozone reactions; and the flow rate is measured. The authors could point out that without dryer, calibrating the filter is essential; in fact, the comparisons they show are exactly that. In addition, this approach must assume that the filter humidity does not change much during the time of measurement. The authors could then strengthen the point, that using the dryer, calibrating the filter is less critical and the stability probably much better. Although this is in the text, the authors could highlight that the decreased need for calibration prior to launch is an essential feature of using the dryer. As suggested above, this could be discussed in a new Section 3.4.

Line 266: I am not sure, whether the authors have shown the capability for sub ppbv detection limits. That would require a better uncertainty discussion. Figure 1 indicates that the chemistry exhibits some significant time response. This is not discussed.

Unless there are additional differences, I would suggest that the authors refer to the SO2 sonde "without dryer" and "with dryer", rather than v1.0 and v1.1. If there are other important differences, then these should be explained.

Section 3.2: It would be good to show a diagram of the sonde and of how the cathode cell is biased. It is not clear how the bias current is regulated. The text implies a fixed resistor between battery and electrode, which would make the current dependent on the battery voltage. The text also mentions a voltage regulator. Where is it used? Is the bias current through the cell regulated?

In Figure 1, phase F, the SO2 concentration exceeds that of the biased current. Can the authors explain, why the measured cell current does not go to zero? Does that indicate a baseline issue?

Line 231: I would say Figure 5 supports a variation of the transmission efficiency of 5%, not 1%.

Line 278: Why does the reduction in pressure "significantly" affect the LLOD? Can the authors elaborate?

Technical comments:

In the abstract, the authors refer to a standard deviation of the sensitivity in %. I would have expected the same units, i.e. ppbv/uA. What does this standard deviation refer to?

Line 36f: I assume the authors mean “cooling effect on the surface climate”.

Line 49: I assume they refer to “Small UAV”. Large UAV, such as Global Hawk, could even measure stratospheric plumes.

Line 87: replace “but” with “which is”

Equation 2 is not quite correct.

Line 92: Better use “pumped” instead of “diffused”.

Line 95: Better write “To rebalance the electrochemical potential of the cell …”

Line 99: Delete opening clause and move references to the end of this sentence.

Equation 6 should probably only be 1 SO42- instead of 2 SO42-

Lines 114 and 115: Do the authors mean averaging over 5 meter or 5 min?

Line 123: The reference to Flynn and Morris (2020) only includes the title and no reference.

Lines 135f: Delete “to a signal of”, to 90 ppbv add “of ozone”.

Lines 145f: Better “in a decrease in cell current, …”

Line 157: What do the authors mean by “stepwise dilution”?

Line 176: Change “escalated” to “increased”

Line 214: Change “may” to “is likely to”

Line 247: Was the campaign conducted in Ft. McMurray or Fr. MacKay? I would suggest removing one of the two names unless there was activity in both places.

Line 254: Although scientifically irrelevant, I would recommend adding that the LERZ eruption destroyed more than 700 homes in Puna, HI, and displaced thousands of residents.

Lines 286ff: Why do the authors refer to HYSPLIT for the wind direction? Isn’t it directly measured by the sondes?

Figure 6: The caption to Figure 6 indicates 20 s averaging; the main text indicates 10 meter averaging. Which is it? The caption indicates the bias current and the lower limit of detection. How the latter was determined?