Reviewer 1

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.

Reviewer 2

The manuscript presents a balloon-borne instrument measuring SO2, based on the well-known ozonesonde. The technique is really promising, definitely a step forward to the dual-sonde method, and the manuscript reads very well. It provides a good background on atmospheric SO2, the ozonesonde technique, the dual-sonde method, and the measurement principle of the new technique is well described and illustrated. Tests done with the SO2 sonde underline the potential of this new technique.

*The manuscript can be therefore accepted after some **minor revisions**:*

- *Comment 1: The structure of the manuscript, and in particular the description of the tests (field deployments), could be possibly improved. Now, those sections follow a rather chronological order, like the reader is taking part in the development phase of the instrument, and this might not be the best way to present it. In the paper, you should present the state-of-the art SO2 sonde, and a reader might be less interested in intermediate versions of the instrument (e.g. without sample dryer). Therefore, alternatively, you might present the final instrument and its different components, and illustrate the importance of every component by means of those field deployments (e.g. the importance of the sample dryer).*

Response: The authors agree that the structure of the manuscript can be improved to highlight all major modifications for the final version of the SO_2 sonde instead of a chronological development. A dryer filter section is included in the instrumentation section following the description of the first two modifications (i.e., biased current and O3 removal filter). The field testing/results section highlights the importance of all the components of the final single-sonde SO_2 system. The updated manuscript reflects these changes.

- *Comment 2: In studies about ECC-ozonesonde measuring ozone, quite often the formula to convert the current to ozone partial pressure is included, illustrating which factors (e.g. background current, temperature of the pump, pump flow rate, pump efficiency, conversion efficiency) impact the measurement of the ozone concentration. Would it be feasible to come up with a modified version for the SO2 sonde as well? This would, to my opinion, nicely demonstrate which factors contribute to the SO2 measurement, and to which extent (in some sense).*

Response: Please refer to our response to Reviewer #1's Comment #3, which discusses important factors that impact the SO_2 sonde measurement.

- *Comment 3: The weak point of the study is the lack of validation/comparison of the SO2 tropospheric profile measurements of the SO2 sonde by another reference instrument. Does such a reference instrument exist? Could the SO2 total column data of the SO2 sonde be compared with TROPOMI overpass data? Please comment in the manuscript on possible (future) validation/intercomparison studies.*

Response: The authors agree that validation of the SO_2 sondes vertical profiles with other *in situ* measurements and/or validation with satellite measurements (TROPOMI) would provide greater support for the single SO_2 sonde system. A Pandora was deployed with the SO_2 sonde in Hawaii and a preliminary analysis shows a good agreement of the two. A separate manuscript will focus on the Pandora and satellite comparison. This has been mentioned in the manuscript and included below. Satellite column SO_2 retrievals depend significantly on accurate plume height identification. Furthermore, the ratio of the field of view of the satellite to the horizontal scale of the plume can make comparisons with columns determined from in situ profiles challenging for a single flight. An ensemble approach is probably warranted. Such an approach is beyond the scope of this paper given the limited nature of the field deployment samples.

P12ln336 "Additionally, future manuscripts topics include intercomparison studies of the SO_2 sonde's vertical profile measurements with other column measurements (i.e., Pandora) and satellite measurements and more in-depth analysis of the SO_2 sonde measurements at the various field deployments."

- *Comment 4: On page 10, line 285, you mention a descent profile of the SO2 sonde, which triggers my curiosity. Have you gathered all the descent profile data of your SO2 sonde launches? And if yes, what could be learned from the comparison of the ascent and descent profiles (taking the trajectories of the volcanic SO2 plumes and the balloon into account)?*

Response: Each free-release balloon SO_2 sonde measurement has an ascent profile and a corresponding descent profile. The authors agree it would be interesting to include comparisons of the ascent to descent profiles to better understand changes in the SO_2 volcanic plumes. However, the authors have designated this manuscript to focus on the development of the single SO_2 sonde system and present select field measurements that best highlight the importance of each modification that converted the original En-Sci ozonesonde to the single SO_2 sonde and potential limitations the current version might have. The authors are planning another manuscript that is the more "science" paper that will provide in depth analysis of the various field deployments. This has been mentioned in the manuscript and included below.

P12ln336 "Additionally, future manuscripts' topics include intercomparison studies of the SO_2 sonde's vertical profile measurements with column measurements (e.g., Pandora) and satellite measurements and more in-depth analysis of the SO_2 sonde measurements at the various field deployments."

- *Comment 5: I follow the other reviewer in his/her comment that the magnitude of the bias current is in some sense the hocus pocus of the technique and deserves more attention. How can you prevent a profile like in Fig. 7(d), where the SO2 sonde saturates? What is the price of imposing a very high default magnitude of the bias current for every SO2 sonde?*

Response: Please refer to the response to Reviewer #1's comment.

Technical comments *(other than from the other reviewer):*

- *Comment 6: Page 6, lines 157-158: shouldn't "white background" and "grey background" be reversed?*

Response: Yes, the reviewer is correct. The colors of the backgrounds were swapped and have been updated.

P7ln171 "The testing included measurements with (gray background) and without (white background) the O_3 removal filter."

- *Comment 7: Page 7, line 196: is it really necessary to mention which team conducted the free release flight?*

Response: The authors agree with the reviewer that the team does not need to be mentioned. The text has been updated and included below.

P9ln245 "On March 23, 2018, a traditional SO_2 dual-sonde payload (Morris et al., 2010) as well as the SO_2 sonde v1.0 were launched using a free-release balloon flight from the Universidad de Costa Rica's campus in San Jose (approximately 31 km downwind of Turrialba Volcano)."

- *Comment 8: Page 8, line 215: additional laboratory testing on the dual-sonde?*

Response: The authors have agreed to exclude this sentence as authors have no plans to conduct testing of the dual-sonde.