REVIEW OF Rawat et al (2022), **Performance of AIRS ozone retrieval over the central Himalayas: Case studies of biomass burning, downward ozone transport and radiative forcing using long-term observations,**

SUMMARY & RECOMMENDATION

This paper uses AIRS (on NASA's Aqua satellite platform) long-term observations of ozone centered over the central Himalayan mountains to: (1) evaluate the AIRS ozone product with ozonesonde and other satellite observations and (2) determine sources for observed trends. The work is novel as it is a first time analysis of these products in this region using ozonesondes and satellite observations.

The paper does lack a clear, concise final interpretation of the results in the Conclusion section, which makes determining the authors' main conclusions difficult. Although one specific conclusion mentioned, which is interesting to note, is that lower differences with the ozonesondes are observed in the lower and middle troposphere and stratosphere with nominal underestimations of less than 20%. The abstract does highlight these results, so more attention is needed in the final section of the paper. Below are listed other several areas where additional information is desired and a few comments. Publication with minor revisions is the recommendation.

We thank the reviewer for careful and detailed review of the paper and very constructive feedback. We have revised the manuscript following his/her suggestions, particularly the Conclusion section. Our responses to each suggestion/comment are described below in boldfaces.

STRENGTHS OF THE PAPER

There are BLAH important elements of the analysis that make it appealing, original, and thorough:

- The careful statistical analysis of the evaluations between AIRS and the ozonesondes (ground truth) including the use of the satellite averaging kernels to make more accurate comparisons.
- The use of other widely used satellite products and other satellite IR sensors for comparison to AIRS.
- Histograms that show nicely the vertical and seasonal variability of AIRS as compared to the ozonesondes.
- The attempt to show the application of the AIRS dataset for studying observed trends. The above analyses and their interpretations explain why this paper merits publication.

We appreciate the referee for careful reading and pointing to the strengths of our manuscript.

AREAS OF IMPROVEMENT FOR THE REVISED PAPER

• Generally, there appears to be updates in the references used throughout the paper (latest revised draft), but still found the paper lacking newer publications cited. For example, there are newer publications for ozonesondes than Smit et al. (2007). There is the latest ozonesonde report that came out last year (and references therein) that should be cited: Smit, H. G. J., Thompson, A. M., & the Panel for the Assessment of Standard Operating Procedures for Ozonesondes, v2.0 (ASOPOS 2.0). (2021). Ozonesonde measurement principles and best operational practices, GAW Report 268. World Meteorological Organization. Retrieved from https://library.wmo.int/doc_num.php?explnum_id=10884.

Thank you very much. We have added these new references in the revised manuscript.

• This leads to the next comment: Has this ozonesonde data been reprocessed to make sure it accounts for an instrument-specific corrections as well as others? Were these ozonesondes EnSCI or Science Pump or something else? These corrections need to be applied to the ozonesonde data for comparisons with satellite products to be more accurate (see reference above) and this additional guidebook for data reprocessing: Smit, H. G. J., & the Panel for the Assessment of Standard Operating Procedures for Ozonesondes (ASOPOS). (2012). Guidelines for homogenization of ozonesonde data, SI2N/O3S-DQA activity as part of “Past changes in the vertical distribution of ozone assessment”. Retrieved from http://wwwdas.uwyo.edu/%7Edeshler/NDACC_O3Sondes/O3s_DQA/O3S-DQAGuidelines%20Homogenization-V2-19November2012.pdf .

Thanks. We are using EN-SCI ozonesonde, which was developed by Dr. Komhyr (Komhyr, 1969; Komhyr et al. 1995), and this sensor is being used extensively worldwide. Briefly, EN-SCI ECC ozonesonde coupled with iMet radiosondes are operated under the standard operating procedures (SOPs) as documented by EN-SCI documentation and described elsewhere. The ASOPOS recommended sensing solution type for ENSCI with 0.5% KI half buffer (SST0.5) is used. The ozonesonde sensor's successful performance is assured before launch (about 3 - 7 days before launch) as part of advance preparation and during the day of launch by maintaining and reviewing the records for background current, pump flow rate, response time, etc. Here we have also checked the background current variation during 2011 - 2017, and it was below 0.08 µA with an average of 0.025 ± 0.012 µA, which is as suggested (Smit & ASOPOS Panel, 2020; Ancellet et al., 2022) for acceptable launch. Furthermore, the total ozone normalization factor (NF) is exclusively used to screen the overall quality of the ozonesonde ozone profile. These details are already made available in earlier publications (Rawat et al., 2020) and we missed to mention them here. Now we have added this information briefly in the revised MS (section 2.14).

According to ASOPOS recommendation, if NF lies in the following range 0.9<NF<1.2, the data is considered of good quality (Smit & ASOPOS Panel, 2020). We have now calculated the total ozone normalization factor for our ECC ozonesonde with collocated OMI total ozone as reference. The total ozone from ECC ozonesonde is estimated by integrating ozone up to burst altitude and then using a balloon burst climatology from McPeters and Labow (2012). Figure 1 below shows the variation of the total ozone normalization factor for our ozonesonde from 2011 to 2017 and the respective frequency distribution on the right side.

This factor is well within the ASOPOS recommendation with an average of 1.0 ± 0.04, which implies the reasonable quality of our ozonesonde. The use of such correction factors has been in debate for a long time as ECC ozonesonde are used as the independent measurements of ozone (Smit & ASOPOS Panel, 2020), however used for quality checks. Additionally, ozonesonde observations from present site have also been utilized in various campaigns based studies [SUSKAT (Bhardwaj et al., 2018), StratoClim (Brunamonti et al., 2018)] and in other studies (Ojha et al., 2014; Ojha et al., 2017). We have now added this information in the revised manuscript (section 2.1.4).

Ancellet, G., Godin-Beekmann, S., Smit, H.G., Stauffer, R.M., Van Malderen, R., Bodichon, R. and Pazmino, A. Homogenization of the Observatoire de Haute Provence electrochemical concentration cell (ECC) ozonesonde data record: comparison with lidar and satellite observations. *Atmospheric Measurement Techniques*, *15*(10), pp.3105-3120, 2022.

Ojha, N., Pozzer, A., Akritidis, D., and Lelieveld, J.: Secondary ozone peaks in the troposphere over the Himalayas, Atmos. Chem. Phys., 17, 6743–6757, https://doi.org/10.5194/acp-17-6743-2017, 2017.

(Here, references do not present in the manuscript are provided)

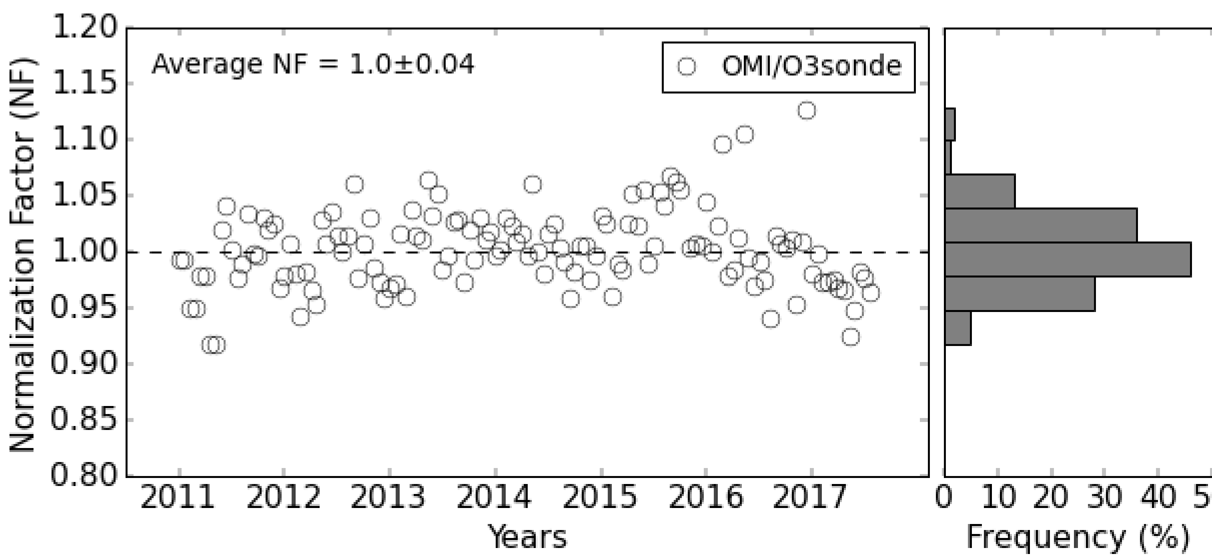

Figure 1. Estimated total ozone normalization factor of ECC ozonesonde with the Aura OMI satellite instrument. Corresponding frequency histograms are also shown on the right.

• In some of the figures, the ozonesonde data convolved with AIRS averaging kernels looked worse in comparison to AIRS than original ozonesonde data. No specific comments were noted on this so this should be addressed in the paper. For example, why would this be case?

Thank you for pointing this. Generally, for a perfect instrument and accurate retrieval algorithm, the a-priori contribution in final retrieval is assumed to be minimal, while in poor retrieval, the AKs tend to be zero metrics. Therefore, when the satellite retrieval is poor, or satellite AKs tend to be zero, it can be seen from Eq. 1 that the convolved ozonesonde will be

weighted more towards the a-priori. In such cases, the ozonesonde data convolved with AIRS averaging kernels will be different than the original ozonesonde data and may not compare well with AIRS. In the revised manuscript, in section 2.2, we have mentioned such possible profile changes of ozonesonde after applying AKs convolution.

• The satellite-derived balloon-burst climatology (McPeters et al., 1997) used to calculate the total ozone column is an outdated climatology. There is a newer one used more commonly now: McPeters, R. D., & Labow, G. J. (2012). Climatology 2011: An MLS and sonde derived ozone climatology for satellite retrieval algorithms. Journal of Geophysical Research, 117, D10303. https://doi.org/10.1029/2011JD017006. For example, Stauffer et al (2022) used this in the latest paper on the global ozonesonde network. Stauffer, R. M., Thompson, A. M., Kollonige, D. E., Tarasick, D. W., Van Malderen, R., Smit, H. G. J., et al. (2022). An examination of the recent stability of ozonesonde global network data. Earth and Space Science, 9, https://doi.org/10.1029/2022EA002459.
The use of an older climatology could explain some of the discrepancies observed in total column ozone comparisons and the recommendation is to redo this analysis with more recent climatology.

Thank you for pointing this. We are sorry for mentioning older reference. We have used the latest data of balloon burst climatology from McPeters and Labow (2012) retrieved from https://acd-ext.gsfc.nasa.gov/anonftp/toms/ML_climatology/, but by mistake we have provided the older references of 1997. We have now revised the references.

• Final recommendation: an overhaul is needed on the final section of the paper to state the final conclusions more clearly, similar to what is in the paper abstract.

Thank you for your suggestions. We have revised the conclusion section in the revised manuscript. Particularly in the revised conclusion (1) We have added the improvement in biases in percentage after applying AIRS averaging kernel information to ozonesonde during summer monsoon season (2) We have specifically mentioned the lower weighted statistical (less than 20 %) error in lower-middle troposphere and stratosphere between AIRS retrieved ozone profiles and ozonesonde compared to upper troposphere. (3) The ozone histogram differences between AIRS and Ozonesonde (AK) is added. (4) We also mentioned the higher biases in the upper troposphere for IASI and CrIS ozone retrieval. (5) AIRS capability to capture ozone enhancements of 5 -20% after biomass burning and downward transport events is explained. (6) Lastly, we have also emphasized the study's importance and improved the conclusion's last paragraph in the revised manuscript.