Dear reviewer,

Thank you for reviewing our paper, we appreciate that with its length, it was a significant time commitment.

In order to respond to your comments we have kept your original comments in black, our responses are in blue, and changes to the paper are identified with underlined blue.

The paper by Malina et al. presents an ozone profile retrieval approach using CrIS thermal infrared measurements which is slightly improved by a sequential combination with TROPOMI/Sentinel 5P ultraviolet measurements. The method used in the approach and the results are sound. This is well in the scope of AMT. However, the ozone retrievals of the combined CrIS/TROPOMi approach are very similar to those from the CrIS only approach, both in terms of sensitivity and the derived ozone quantities. This mean that the contribution of the combination with TROPOMI is very limited. Since this very important aspect is not very clear in the text of the manuscript, I strongly recommend major revisions of the paper before considering publication. Moreover, the presentation of the method is not very clear and needs thorough revision.

We hope that the corrections applied to your comments, and the comments of reviewer 1 fulfil your criticism.

The principal major revisions I strongly recommend are the following:

- Title: I recommend indicating explicitely that it is a sequential approach from CrIS only to CrIS/TROPOMI and replacing “augmented by” by “and”. The augmentation from TROPOMI is very limited in order to point it out so clearly in the title.

We thank the reviewer for this point, however we respectfully disagree. A significant aspect of the paper is building the pipeline for CrIS-TROPOMI retrievals, where we make the point that when calibration on bands 1 & 2 are improved, we will be able to take advantage with minor adjustments to our algorithm. We therefore view this paper as a first step for further papers and developments in the future. Further, we point out benefits to the joint retrieval, through comparisons with MLS, and the ozonesondes.

- Abstract (major remark 1): the enhancement of CrIS-TROPOMI with respect to CrIS only approach should be clearly quantified with precise numbers. The values of degrees of freedom and precision (bias, correlation, rmse) with respect to reference measurements (ozonesondes) for both the stratosphere and troposphere should be clearly provided in the abstract for both CrIS-TROPOMI and CrIS only methods.

We have changed the abstract to read as follows:

Improved performance is characterised in the stratosphere from CrIS-TROPOMI, firstly through a modest increase in the degrees of freedom of signal (often between 0.1-0.2). Secondly, through comparisons with the Microwave Limb Sounder, where a global month long comparison shows a mean difference ~x10 lower than either CrIS or TROPOMI individually, and R^2 values 3% higher. In the troposphere, CrIS-TROPOMI and CrIS show

similar degrees of freedom for signal, with about 2 globally, but higher in the tropics partitioned equally between the lower and upper troposphere. CrIS-TROPOMI validation with ozonesondes show improved performance over CrIS-only, with a difference in the tropospheric column bias between 30 and 200% depending on the season. Cross-comparisons with satellite instruments and reanalysis datasets show similar performances in terms of correlations and biases.

- Abstract (major remark 2): it should be clearly stated that the approach is a sequential method first using CrIS only measurements, then TROPOMI data and finally CrIS and TROPOMI jointly. This information is very hard to find in the paper (it only appears in page 15) and it is essential to understand the clear similarity between CrIS only and CrIS-TROPOMI approaches. It should clearly state in the abstract and at the beginning of the presentation of the approach (current section 3).

We have modified the abstract to take this comment into account, the modified sentence is highlighted below.

"The sequential combination of TIR and UV measurements, which follows retrievals from each instrument separately, improves the ability of satellites to characterise global ozone profiles, over the use of each band individually."

- Abstract (major remark 3): The sentence "The results demonstrate that CrIS/TROPOMI retrieval have the potential to substantially improve our understanding of ozone" is too vague and unclear. The paper mainly focuses on the observation of ozone and its precision, and not on the geophysical understanding of ozone-related processes and its evolution. I recommend removing such statement and focus on the metrology aspect of the new approach.

We have updated this sentence to read as follows.

"These results demonstrate that CrIS/TROPOMI retrievals have the potential to improve global satellite ozone retrievals."

- Section 3: A change in the order and explanations in this section is clearly needed to understand the new aspects of the CrIS/TROPOMI approach. I strongly recommend providing at the beginning a clear description of the main flow of information about the ozone profile, clearly stating which is the first approach applied (CrIS only), whose results are then used as a priori of subsequent approaches, etc. This is provided in page 15 (section 3.4) and therefore it is difficult to follow. After this overall explanation, I recommend explaining the details of each box in Figure 1 (current section 3.2, then 3.3 and finally current explanations of section 3.1).

We have now swapped the CrIS-TROPOMI explanation to the beginning of this section, which outlines the pipeline steps, followed by the CrIS and TROPOMI ozone steps. The description of the algorithm follows these sections.

We do not think it is completely necessary to describe each box of figure 1, as some (e.g. non-ozone VMRs) are provided for context and information, and only have limited impact on the ozone retrievals. However, describing them in detail would require substantial more text.

- The differences between CrIS/TROPOMI and CrIS only should be clearly pointed out. Currently this is very difficult to find. For example, no statements of such kind are given for Fig. 7, although it is the global comparison of ozone retrievals.

We are unclear in what the reviewer means exactly here, we point out in many locations in the paper that CrIS-TROPOMI has improved performance in the stratosphere through comparisons with MLS, and the comparisons with ozonesondes show improved performance in the troposphere. We accept that there is little obvious difference in Figure. 7, however, this would be difficult to see for any global comparison, since CrIS-only does a good job of capturing both the troposphere and the stratosphere. We argue that any obvious deviation between CrIS-TROPOMI and CrIS would indicate a problem with the retrievals. There are cases where significant differences occur, but these tend to be filtered out in the quality control.

- The comparison with ozonesondes is expected to be presented before that with respect to other datasets (models, other retrievals) as they are reference measurements.

While we understand the point of the reviewer here, we do not agree. We put the stratospheric comparison first because this is where the most change is seen in the CrIS-TROPOMI retrievals. MLS is the main standard for comparisons in the stratosphere and not ozonesondes, hence why we put the satellite comparisons first in this section.

- It is very important to show correlation coefficients and global scores of the comparison between CrIS/TROPOMI and single band retrievals with respect ozonesondes (Tables 8 and 9)

We have added correlation coefficients to table 8, however table 9 is used purely to show and contrast the impact of not applying the satellite operators to the ozonesonde measurements. We are therefore not convinced as to the benefit of adding correlation coefficients for this table. Our analysis here is as previous papers from our group have shown, e.g. Fu et al. (2018).

Other important remarks:

- Panels in Figures: I recommend assigning different letters for each panel of the figures. Currently many panels are indicated by the same letter, which is then difficult to point out without ambiguity

Thank you for this point, we are however not sure where the difficulty lies. Each panel is clearly labeled with the relevant instrument/instrument combination, we feel this is more obvious than the many labels required by individual alphabetical labelling.

- Figures 4, 5 and 6: differences between CrIS only and CrIS/TROPOMI are very tiny. I recommend providing clear statements with quantified differences.

Thank you for this point. For Figure 4 we feel this has already been made clear, through the statistics highlighted on the figure.

For Figure 5 we have added the following text.

"However, we note that CrIS-TROPOMI shows numerous cases where DFS values have a larger magnitude than CrIS, especially over mid-latitudes."

For Figure 6, there is an explanation in the related text which describes the total error variability of CrIS-TROPOMI is smaller than that of CrIS.

- Quality assessment: Lines 397-400: what about convergence to small spectral residuals of the CrIS/TROPOMI retrieval as compared to CrIS only? How it is possible to have a pass rate of 39% for TROPOMI only and (slightly) larger (40%) for CrIS/TROPOMI which is subsequential step?

Although CrIS-TROPOMI is a subsequent step of TROPOMI, the retrievals are non-linear in nature, and there may be cases where an edge case failure for TROPOMI yields a pass for CrIS-TROPOMI, due to the differences in the retrievals.

- Figure 7: too many tiny panels. I recommend using 2 pressure levels and much bigger panels, as well as indicating in the text the clear similarity between CrIS only and CrIS/TROPOMI retrieved ozone amounts.

We have removed one of the pressure levels in order to make the figure bigger. We have also highlighted in the corresponding text the similarity between the retrievals. For example:

"Note that as shown in the AKs, there are no clear differences between CrIS-TROPOMI/CrIS-only retrievals in the troposphere"

"In general there are few obvious differences between any of the retrieval cases in the stratosphere, with minor differences in magnitude apparent."

Minor revisions:

- Line 273: panel c) of Fig. 1?

We're not sure what the reviewer means here, there is no panel c) of figure 1 and we can't find the text the reviewer is referring to.

- 5 b) TROPOMI: color scale is saturated. It should be changed.

The issue here is that the DFS values for the TROPOMI-only retrievals are almost identical across the whole globe, so we would receive the same result, no matter what colour scale we apply.

- Figure 15: problem with panel indicators

We're not sure what the problem with the indicators is, please elaborate.

Added References

Fu, D., Kulawik, S. S., Miyazaki, K., Bowman, K. W., Worden, J. R., Eldering, A., Livesey, N. J., Teixeira, J., Irion, F. W., Herman, R. L., Osterman, G. B., Liu, X., Levelt, P. F., Thompson, A. M., and Luo, M.: Retrievals of tropospheric ozone 6 profiles from the synergism of AIRS and OMI: Methodology and validation, Atmospheric Measurement Techniques, 11, 5587-5605, https://doi.org/10.5194/amt-11-5587-2018, 2018.

Moré, J. J. (1978). *The Levenberg-Marquardt algorithm: Implementation and theory*. https://doi.org/10.1007/bfb0067700.

Zavyalov, V., Esplin, M., Scott, D., Esplin, B., Bingham, G., Hoffman, E., Lietzke, C., Predina, J., Frain, R., Suwinski, L., Han, Y., Major, C., Graham, B., & Phillips, L. (2013). Noise performance of the CrIS instrument. *Journal of Geophysical Research: Atmospheres*, *118*(23), 13,108-13,120. https://doi.org/10.1002/2013JD020457