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Response to Anonymous Referee #2 (RC2):

We would like to thanks the second referee for the positive feedback and valuable suggestions. Please find below the original comments, the authors' response (in blue) and the amendment made to the manuscript (*in italic*). Note that figure and line numbers refer to the original manuscript.

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General comments:

Two similar microwave ozone instruments that have been measuring from nearby sites in Switzerland for decades, but the data has been processed with different retrieval codes. The authors do a nice job of harmonizing these datasets. The content is appropriate for publication in AMT. Below are a number of suggestions which I hope may improve the manuscript.

Throughout this study there is a disturbing emphasis on "reducing discrepancies" or "improving the agreement" between instruments. No scientific study should ever have this goal. The goal is to harmonize various stages of the data processing so that these stages do not, by themselves, introduce differences.

Regarding the reduction of discrepancies, the authors agree with the second referee on the substance. We believe that this impression arose from sentences found in the abstract, introduction and methods and we have modified a number of them. It should help to make clear that the goal of the study was focused on the harmonization of the data processing and that no further corrections were applied on the resulting ozone profiles to "improve their agreement".

The most obvious information missing in this manuscript is any comparison of the tropospheric opacities at each site. While the sites are physically close in stratospheric terms, and the altitudes are similar, the tropospheric conditions at the two sites may be very different, yet there is no information presented on this topic. Even if the tropospheric opacities are quite similar, a small figure making this point would be nice.

Following the suggestion of the two reviewers, the authors would like to suggest the two following main changes to the original manuscript:

Manuscript structure:

Reduction of the number of figures and reorganisation of the figure order. In particular, Fig. 3 and 4 have now been integrated into a single figure to show the error and resolution from both instrument together. The uncertainties budget figures have also been merged together to keep only 2 figures, one for the low opacity case and one for the high opacity case. Last, Fig. 10 has been moved upward to avoid introducing it before Fig. 8 and 9.

Opacity:

Addition of a new figure (Figure A) in the Appendix to show the difference in opacities between the two sites. In addition, the authors would suggest to extend the discussion on the opacity and its potential role in the stratospheric ozone seasonal differences between the two sites. In particular, the authors would suggest to rewrite the opacity discussion in section 4.1 as follows:

During the summertime the warmer and wetter troposphere results in a higher opacity. This attenuates the ozone spectral line and thus decreases the retrieval sensitivity during summer. As discussed in section 3.3, a higher tropospheric opacity also results in larger uncertainties in the retrieved ozone profile. In case of very hot and humid conditions, the troposphere can become optically thick at 142 GHz which can prevent the retrieval of ozone profiles. It is confirmed by Fig. A1 which shows higher tropospheric opacity in summertime than during the other seasons.

However, Fig. A1 also shows that the difference in tropospheric opacity at the two sites remains constant, independent of the season. In addition, we investigated the correlations between GROMOS and SOMORA considering only profiles measured at low tropospheric opacity ($\tau \leqslant 1$) and did not see any significant changes in the results. For these reasons, we believe that the summer bias does not result from the higher tropospheric opacities affecting this season.

The reasons for the summer seasonal bias remains unclear but we assume that they result from seasonal temperature and humidity cycle in the troposphere. Indeed, despite controlled room temperature for both instruments, the higher summer temperature still influences room and window temperatures and consequently the instruments (e.g. receiver noise temperature). We believe that the hardware components of GROMOS and SOMORA have different sensitivity to such influences, which could explain the seasonal patterns observed in their relative differences and the lower correlation of the ozone profiles during summer.

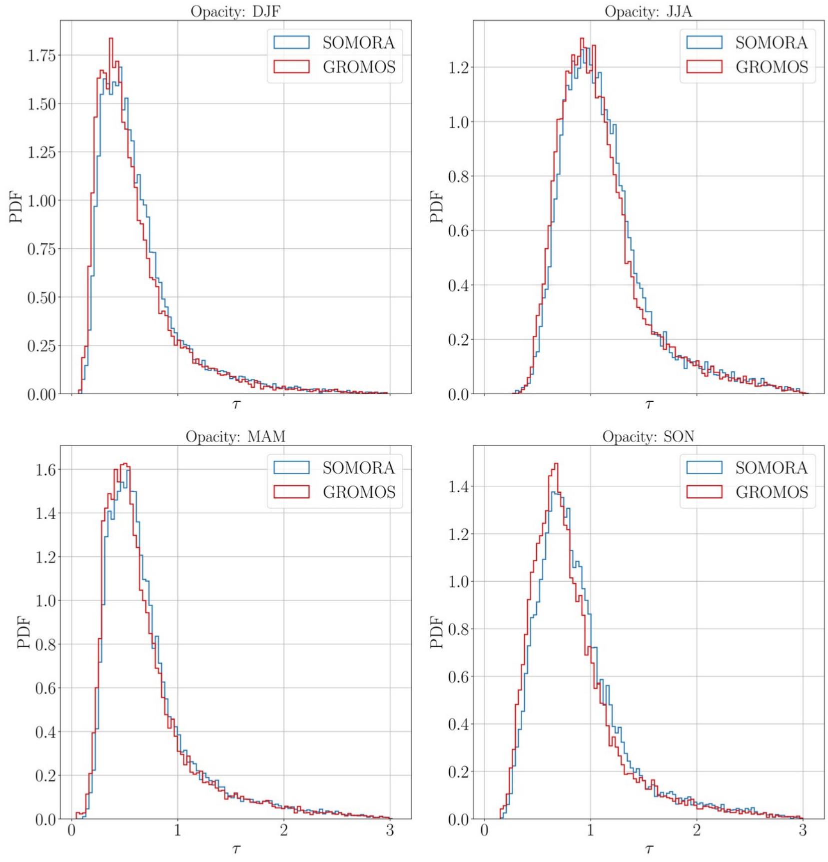

Figure A: PDF of tropospheric opacities at the 2 sites.

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Specific comments:

Line 40 – “close to each other”. Please give a physical distance somewhere in this paragraph.

We have added the physical distance between the two instruments as follows:

In Switzerland, two ozone MWRs are operated since more than 20 years in the vicinity of each other (ca. 40 km): the GROund-based Millimeter-wave Ozone Spectrometer (GROMOS) in Bern and the Stratospheric Ozone MOnitoring RAdiometer (SOMORA) in Payerne (Fig. 1).

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Line 69 and 70 – This sentence sounds rather odd. It sounds like you’re measuring the atmosphere with a measurement that is insensitive to the atmosphere. I assume the word troposphere belongs somewhere in here.

We agree and as suggested by both reviewer, we therefore modified the entire paragraph as:

Passive microwave radiometry uses the electromagnetic radiation emitted and transmitted in the microwave frequency region to derive geophysical quantities of interest. It makes this technique suitable for both earth's surface observation from space and sounding of atmospheric trace gases, temperature or winds from satellites or ground-based instruments. Unlike other techniques, MWRs do not require UV/VIS emitting sources (e.g. sun or stars) and are able to measure during day and night. In addition, the pressure broadening effect at microwave frequencies enables to retrieve vertical profiles of temperature, winds and abundances (e.g. Parrish et al., 1988; Connor et al., 1994; Rüfenacht et al., 2012; Krochin et al., 2022).

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Line 99 – “no way to confirm the amplitude of the effect of the bias”

We have changed this sentence as follows:

“no way to confirm the amplitude of the bias”

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Line 115 – “Due to their high sensitivity, the operation of microwave radiometers requires continuous calibration”. I don’t understand this statement. Continuous calibration is required because the receivers are not perfectly stable, not because they are highly sensitive.

We agree that sensitivity was not the correct word to use here and have changed this sentence as follows:

The operation of microwave radiometers requires continuous calibration because their receivers are never perfectly stable [...]

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Line 134 – I assume what the authors are trying to say here is that they “provide good quality spectra for 87% and 89% of measurements”, but I’m not quite sure if that is what is meant. Please rephrase.

This sentence was indeed not very clear and we have rephrased as follows:

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Considering instrumental issues and technical interruptions for maintenance (e.g. for LN2 refilling or instrument repairs), GROMOS and SOMORA provided good quality hourly spectra for respectively 87 % and 89 % of the measurements performed between 2009 and 2021. It results in more than 80'000 hours of comparable retrieved ozone profiles.

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Line 186 – "a modulation"

Thank you, we corrected the typo.

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Paragraph starting at 195 – Have the fitted baselines been removed in the spectra shown in the following figures?

No, the baseline are still present in the measured spectrum and are included in the fitted spectrum. As a result, they are "suppressed" in the residuals. However, the examples shown in the paper did not contain high amplitude sine baselines. In Figure B below, the reviewer can find an example with higher amplitude sine baselines (with the blue line indicating the full baseline retrievals (sine + 2nd order polynomial). In this case, a sine baseline is still present in the residuals but much reduced compared to the case without baseline (Figure C)

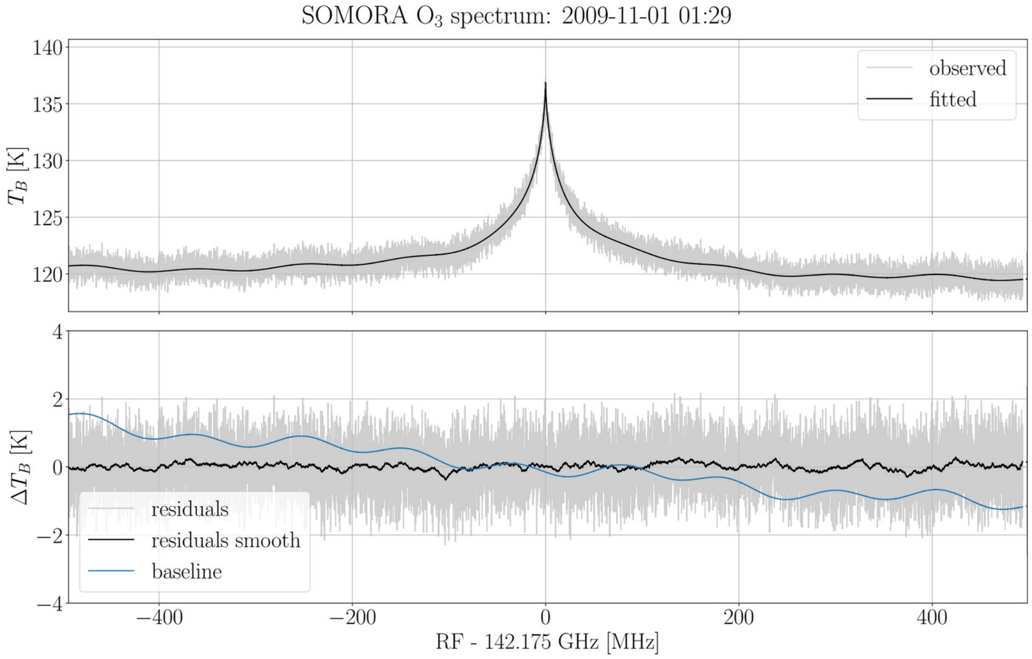

Figure B: Example of SOMORA spectrum with high sinusoidal baselines.

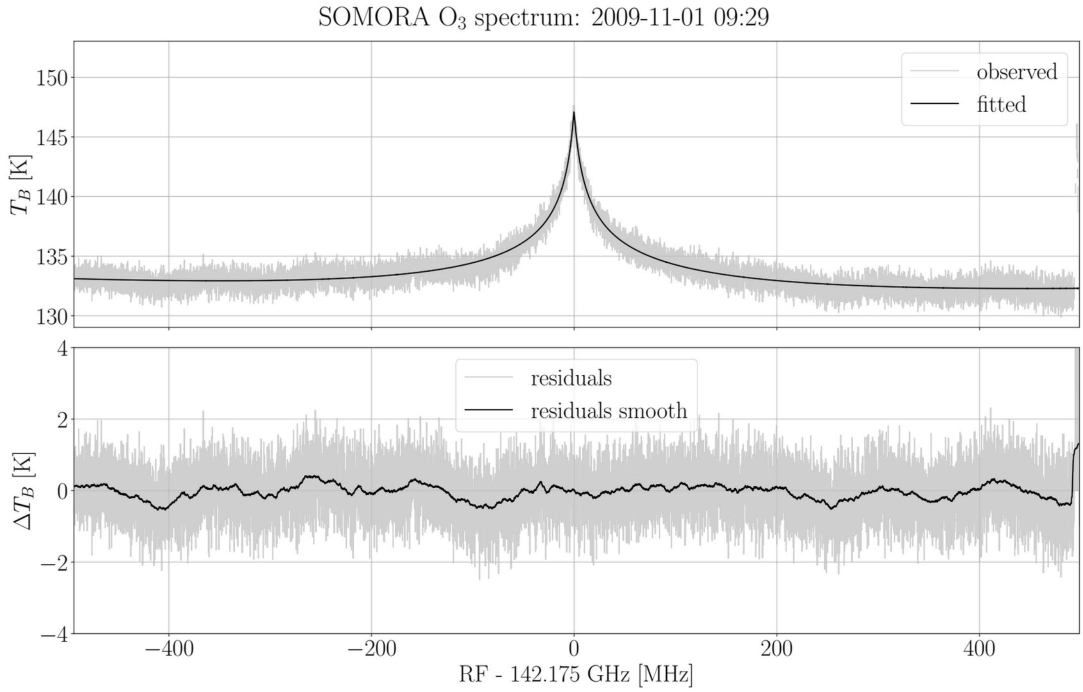

Figure C: Same as Figure B but without retrieval of the sine baselines.

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Figures 3 and 4 seem to be almost identical. While I realize that the authors are trying to make this point, there is no need for a two 4-panel figures to make this point. It would be nice to see the errors and resolutions of both instruments on the same plot (perhaps one with symbols and the other with a lines).

Thanks for this comment, we agree that this was not the most efficient way to visualize these data and that errors and resolutions should go into a single figure for the two instruments. We also think that it is important to show the AVKs for the two instruments even if, as mentioned later, they are more dependent on tropospheric conditions: this is a necessary condition so that we can compare the instrument directly in the rest of our manuscript.

In that sense, we would like to suggest Figure D as replacement of Figures 3 and 4:

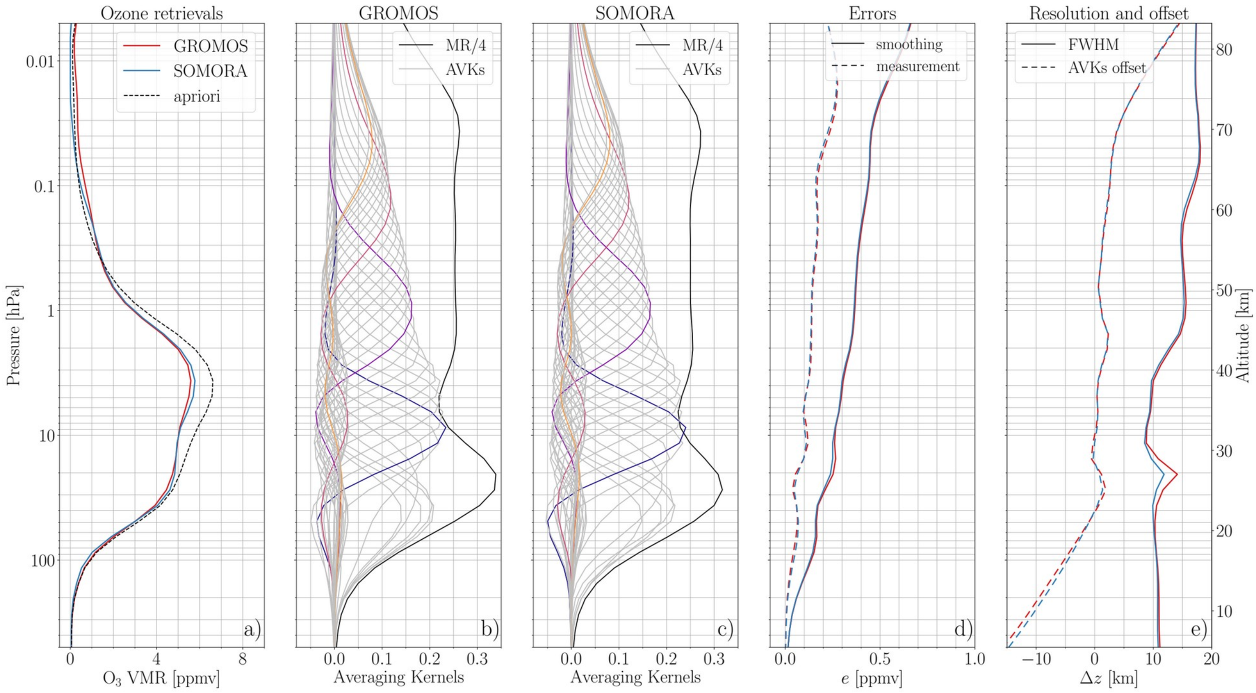

Figure D: Example of hourly retrievals diagnostics for GROMOS and SOMORA

Perhaps I’ve missed it, but why is there a large spectroscopy error at the top in Figure 5 but not in Figure 6?

This is hard to say why it appears on GROMOS only but it might be because the retrieved ozone profile for GROMOS is zero at these altitudes whereas the SOMORA profile still retrived a tiny amount of ozone there. Given the amplitude of the measurement and smoothing errors at this altitude, we believe that it is difficult to track the exact effect of spectroscopic parameters changes up there. In fact, the uncertainties become dominated by the measurement noise above approx. 2 hPa so that we do believe that the larger spectroscopy error appearing up there is an artifact from the GROMOS retrievals.

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The authors show high and low tropospheric opacity cases, but they do not mention the opacities of these cases, nor do they give any indication of how representative each case is. I assume that the difference in AVKs between high and low opacity cases is larger than that between the two instruments in the low opacity case. I don’t think that there is any need to show the AVKs for both instruments in the low opacity case since the exact AVK is probably much more opacity-dependent than instrument-dependent.

We agree and have added opacities value to define our “low” and “high” opactity cases. Combined with the new figure (Figure A), it should provide a context on how representative are these two opacity cases for GROMOS and SOMORA. In addition, we suggest to extend the discussion in Section 4.1 to discuss the opacities at the two sites and the implication of this on the seasonal bias.

Regarding the AVKs, it is correct that they are opacity dependent but we still believe that it is important to show the AVKs from the two instruments. In the original manuscript, we showed two examples of AVKs corresponding to rather low opacity (τ=0.4). We did not mention the opacity of the cases shown and did not discuss the effect of higher opacities on the AVKs. Therefore, we also suggest to add the opacity value to the retrieval diagnostics (Figure D) and discuss the implication of higher opacity on the AVKs and the retrievals in general in section 3.3.

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Figure 12 would be much more helpful if it were deseasonalized. Or perhaps just shrink the y-axes ranges a bit to make it easier to distinguish the lines.

We agree that the original figure was a bit difficult to read and as recommended, we suggest to shrink the y-axis and modify the temporal resolution (1 week instead of 2 days) of the time series to get Figure E as a replacement for Fig. 12. We also did a deseasonalized version (Figure F) but we think that the good capture of the seasonal cycle by the two instruments is important and therefore we would prefer to keep Figure E.

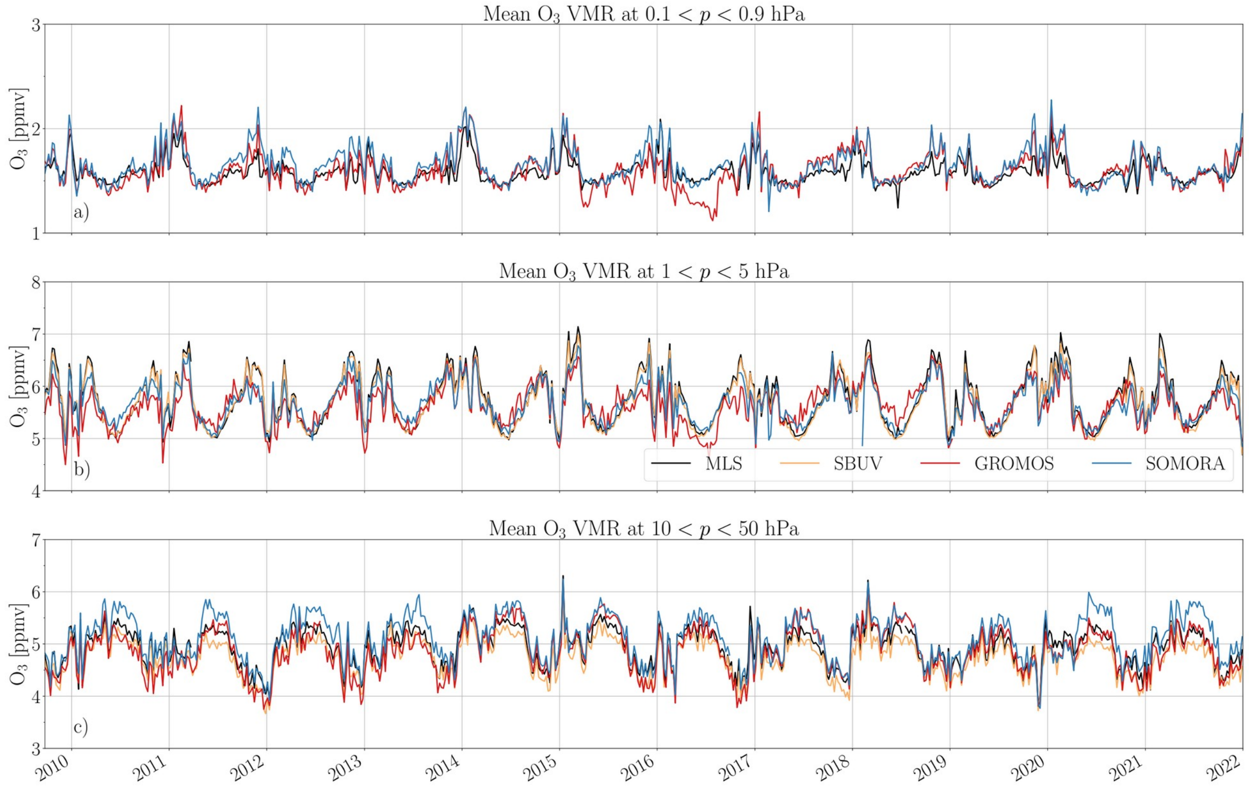

Figure E: Ozone time series, now weekly averaged for clarity.

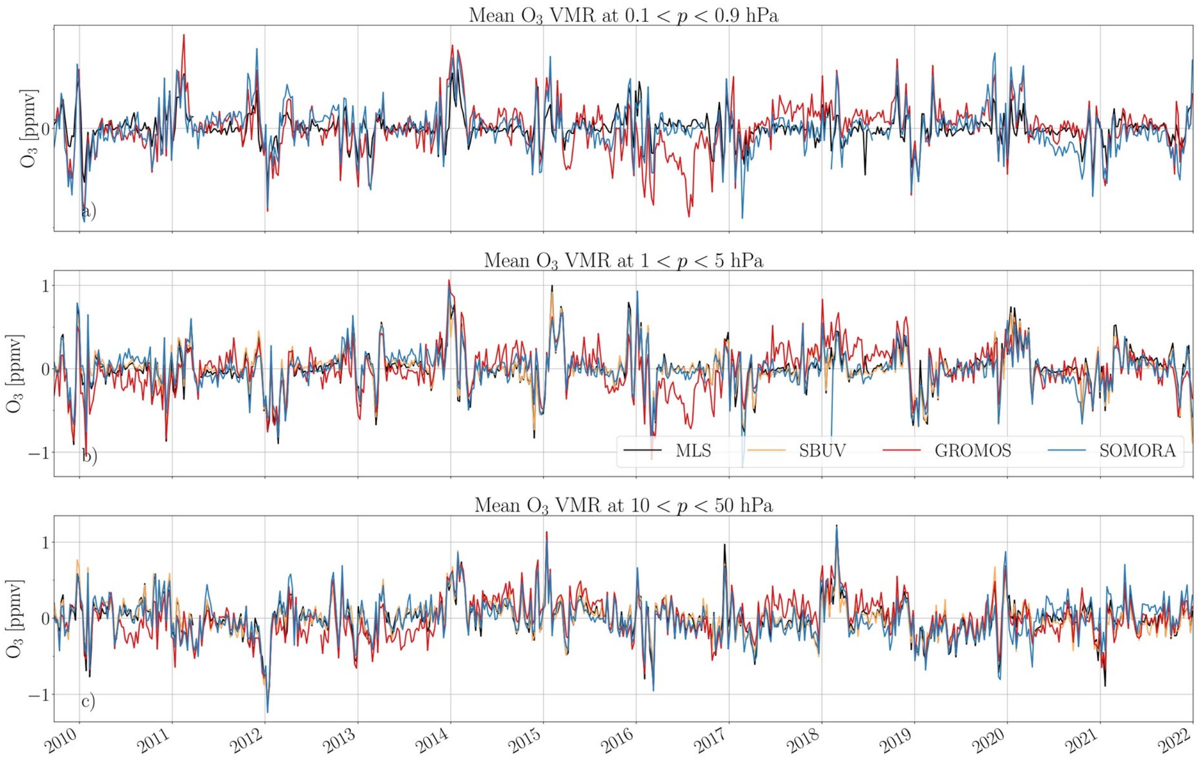

Figure F: Same as Figure D but deseasonalized.

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Are the comparisons in Figure 13 with both the daytime and nighttime MLS overpasses? Are the differences the same for both? Why are there more profiles in the unconvolved case than then convolved case?

Yes, Fig. 13, 14, B1 and B2 do not differentiate between daytime and nighttime MLS overpasses. We initially did the analysis with daytime and nighttime differences but did not see large differences, except at $p < 0.1$ hPa, where the error from both MLS and the MWRs becomes quite large.

The fact that there are more profiles available in the unconvolved cases results from numerical errors in some of the averaging kernels, producing extremely large single values at 1 or 2 altitudes. While this is not a problem for the basic comparisons, it becomes a problem during the convolution of the AVK with the corresponding MLS profile. A solution could be the interpolation of the concerned AVK but given the number of available profiles, the authors took the decision to simply filter these out which explains why the number of MLS convolved comparisons is slightly lower than the direct comparisons.

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Given that the error in Tprofile is the dominant error in Figures A1 and A2, some explanation about this would be of interest. I assume it has something to do with the calculation of opacity?

The authors agree and would suggest to rewrite as follows the paragraph of Section 3.3 where the differences between the low and high opacity cases are discussed:

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In the case of high tropospheric opacity, the ozone emission line gets more attenuated by the tropospheric water vapor absorption. The AVKs gets degraded, reducing the sensitivity of the retrievals and leading to higher uncertainties than at lower opacities. As can be seen on Fig. B1, the atmospheric temperature profile becomes the dominant contribution to the uncertainties below 1 hPa at higher opacity. It is likely due to the increased importance of the water vapor continuum retrieval, which is itself strongly dependent on tropospheric humidity and temperature. In the higher opacity case, the total relative uncertainty on GROMOS in the stratosphere is 12-15% respectively 10-12% for SOMORA.