Comment on amt-2021-412
Anonymous Referee #2

In this work on the “Combined UV and IR ozone profile retrieval from TROPOMI and CrIS measurements” Mettig et al. provide a first account on the joint retrieval of TROPOMI UV and CrIS IR measurements using their own TOPAS algorithm. This promising work is of scientific value, but its overall presentation and interpretation of results could be improved. Especially regarding the application of averaging kernel smoothing and its effect on the (interpretation of) comparison results the text should be revised.

Major comments:

Lines 46-48: “While the major challenge for the profiles from UV measurements is the low vertical resolution in the altitude range below 20 km, ozone profiles from IR measurements provide more information about the troposphere, but typically do not retrieve ozone above about 30 km (Bowman et al., 2002).” The physical reasons why this is the case, and hence why a joint retrieval might be beneficial regarding vertical sensitivity, are somewhat missing in the introduction. Please provide a brief discussion and references on the wavelength-dependence of light’s atmospheric penetration as a motivation for this work.

Lines 101-102: “But in comparison to IASI, CrIS has a lower noise. Hence, the ozone information content depending on both, spectral resolution and noise, it should be similar for CrIS and IASI.” This is quite a blunt statement that seems to be based on a wild guess only. Please be quantitative, including references, or be more cautious in the formulation, e.g. in terms of “possibly compensating effects”.

Lines 138-143: Better explain that interpolation matrix L has size coarse x fine (therefore requiring a pseudo-inverse) and provides an interpolation form the coarse to the fine grid. More importantly, however, this would also be the place to discuss that you are applying averaging kernel smoothing as well in your comparisons, with formulas. The current statement on lines 269-270 is too brief and incomplete: Regridding already accounts for a different vertical resolution in terms of representation on a grid; the kernel smoothing induces a vertical convolution, i.e., an effective smoothing over several retrieval levels. And most importantly, the statement in lines 271-274 – “where the combined retrieval is sensitive and a single retrieval is not, the former might appear to be worse. This is because the difference between retrieval and the reference profile multiplied by the AK
matrix by definition approaches zero in altitude ranges where the retrieval has low sensitivity, i.e. AKs are close to zero.” – and its disturbing effect on the further analysis could be avoided: If a distinction is made between using the AK matrix merely as a vertical smoothing matrix on one hand, and the application of averaging kernel smoothing as a method for accounting for retrieval differences on the other hand, this issue does not occur. The first requires a multiplication with a normalized AK matrix \( x' = A_{\text{normalized}} x_{\text{ref}} \), the second a weighted sum of reference and prior profiles \( x' = A x_{\text{ref}} + (I-A) x_{\text{prior}} \); see for example Section 4.2 and “averaging kernel smoothing” in Section 4.3.1 of Keppens et al., 2019, respectively. Finally, the retrieval ‘sensitivity’ is often mentioned in the text and used as an explanatory ingredient in the comparison results. From Figure 3 and the accompanying text, however, the total vertical sensitivity is hard to interpret. Please provide integrated vertical sensitivities (AK matrix row sums) in Figure 3, and explain their significance in the text, before using them in the results discussion.

Section 3: The UV and IR retrievals are well explained, but it is less clear how exactly they are combined into a single joint retrieval. An additional few sentences seem to be required on this.

Minor comments:

Quantitative results should be included in the abstract, e.g. for the MLS comparisons the mentioning of an ”improvement” is insufficient. Results for the ozonesonde validation are even missing in the abstract.

Line 24: Provide indicative numbers and/or references for “poorer”

Lines 30-34: The goal of this listing is unclear, nor is its intention of being exhaustive or not.

Line 66: Replace “is” by ”was found to be” (or something similar) and again add references.

Lines 87-88: “The smaller TROPOMI pixels are binned together to match the coarser spatial resolution of CrIS.” Provide more details already here, in the form “in x by x bins to x by x km^2”

Line 92: “July 2018 to October 2019” Make clearer that this is also the time range of the data under study.

Line 104: “in the validation” is unclear. The validation in this work or in the provided reference?

Line 130: “an excellent option” is not a scientific statement.

Lines 150-151: Be more specific on “for instance, the secondary calibration among others”

Table 1: Some retrieval settings are not discussed in the main text. Briefly mentioning these would be helpful in situating the retrieval.

Table 1 and lines 169-170: “Above 20 km, the Tikhonov parameter is constant and is 0.02. Below, the values are linearly interpolated between the altitudes 16, 10, 6, and 1 km. Values are: 0.06, 0.1, 0.06 and 0.02, respectively.” Please provide some clarification or references on how these values are obtained.
Line 182: Provide a reference for the ECMWF ERA-5 reanalysis.

Line 221: It is agreed that “This approach represents the most straightforward way to analyse the impact of combining both spectral ranges.” but could you, e.g. with reference to Mettig et al., 2021, indicate to what extent the retrievals thus differ from the ideal individual retrieval settings?

Lines 234-235: “The vertical resolutions of the three retrievals, which are given by the inverted main diagonal of the averaging kernel (AK) matrix” Please explain why this is the case and/or provide a reference.

Lines 251-252: “This may be due to the lower spectral resolution of CrIS compared to IASI and TES.” Could this be verified (possibly in future work) by artificially increasing the resolution? Please add a note on this.

Line 283: “The standard deviations for all comparisons are similar to those of the a priori profile.” Please briefly explain what this learns about the data.

Line 290: The term “retrieval layer” suggests rather a retrieval of partial columns, which I understood not to be the case here. Please mention the retrieval units explicitly and possibly change ‘layer’ to ‘level’ accordingly.

Line 291: Please provide a reference for the “2 PVU definition”

Figure 5: It might be more insightful to use the same vertical scale for our four plots.

Lines 332-334: “The mean collocated ozone profiles from NASA’s operational CrIS level 2 product for the same ozonesonde measurements are also shown. For the comparison with CrIS, it must be taken into account that the NASA operational retrieval provides only about 2 DOFs.” This dataset is not mentioned in Section 2.3.

Lines 344-345: “Because the UV-only retrieval has a low vertical resolution between 10 and 15 km, it remains close to the climatology.” Would you mean low vertical sensitivity here, which seems to be a more appropriate explanation? Please anyhow refer to the latter as well (as is done in the conclusions on lines 448-449), based on the total vertical sensitivity profiles requested in the major comments.

Editorial:

Line 12: “From the comparison with tropospheric lidars both…” into “In their comparison with tropospheric lidars, both…”

Line 39: “MetoP” into “Metop”

Line 41: Remove “instrument” before the reference.

Line 61: “combinations” plural

Lines 70-76: Adding references to the subsequent sections might help in providing a structured reading.

Line 76: “CrIS”

Lines 81-82: Be more specific than “next year”
Line 83: “UVIS” into “UV-VIS” or “VIS”

Line 173: “Frauenhofer” into “Fraunhofer”

Caption of Figure 2: “The time difference is 25 minutes...”

Figure 3: Add color bar legend.

Line 373: “received from” into “obtained with”

Line 388: Correct “is yields”

Line 392: “example”

Lines 419-420: “are by about 20% smaller” is a strange formulation

Line 452: Rephrase “an example one day”