**Referee #1**

*Reply to referee #1 for the comment on the manuscript* **amt-2023-119:**
**Version 8 IMK/IAA MIPAS temperatures from 12–15 µm spectra: Middle and Upper Atmosphere modes**

We thank the reviewer for his/her valuable comments and suggestions. We have addressed all of them. In this response, we go through the raised issues point by point and outline the changes we intend to make. Additionally, we have corrected several typos.

*Review of "Version 8 IMK/IAA MIPAS temperatures from 12-15 micron spectra: Middle and Upper Atmosphere modes" by Garcia-Comas et al.*

*General Comments:*

**Reviewer's summary:**
*This manuscript describes a new MIPAS temperature dataset from 18-115 km altitude, which the authors call version 8.03. In addition to improved calibrated spectra, the authors detail a variety of improvements to the retrieval and show several comparisons against previous versions of the data as well as comparisons against existing SABER temperature observations. The paper provides a comprehensive description of the uncertainties and overall, the figures are instructive and clear. Although the authors spend considerable effort comparing their results to SABER temperatures, comparisons with recently re-processed MIPAS temperatures using nitric oxide emission are quite limited and it is not really clear why. The manuscript is also lacking detail in some places, particularly in explaining the results in the upper altitude region of their dataset. The reviewer recommends publication provided that the authors address the concerns enumerated below.*

*Specific Comments:*

**Reviewer's suggestion**:
*Line 97 and elsewhere. The authors spend considerable effort comparing to existing SABER temperature observations. Could the authors please comment on and show how their results compare to MIPAS thermospheric temperatures derived from nitric oxide spectra at 5.3 microns (e.g. Funke et al., Atmos. Meas. Tech., 16, 2167-2196, 2023)? There is mention of day-night differences on lines 384-387 and latitude variations on lines 394-396. However, a direct comparison between the two MIPAS temperature datasets would be particularly useful for the reader. If there is a reason for this limited comparison or if this has been done in other publications then please say so and give a reference. Thank you.*

**Author's response**:
We think this is a very good suggestion.
We propose to rename Section 5 with "Consistency with NOM mode 12-15-micron and UA mode 5.3-micron temperatures" and to include the following paragraph at the end of Section 5:
"Version 8 temperature retrievals from nitric oxide spectra at 5.3 microns, obtained by MIPAS in the UA mode, are detailed in Funke et al. (2023). The a priori temperature profiles used to derive those 5.3-micron temperatures consist solely of version 8 15-micron temperatures below 110 km (presented here) and solely of corrected MSIS version 2.0 temperature profiles above 120 km (Emmert et al., 2021). A merging of the two is performed at 110-120 km, as

described in Funke et al. (2023). Moreover, retrieved temperatures are strongly regularized towards 12-15-micron  our temperatures below 110 km.
We examined the differences between our 12-15-micron temperatures and version 8 5.3-micron temperatures (not shown). Below 110 km, both temperature datasets are essentially identical for all atmospheric conditions, as expected, except for summer at latitudes poleward of 30º, where the differences are within 5K. At 115 km, the 5.3-micron temperatures are generally 5-10K smaller than our 12-15-micron temperatures, and this difference can reach 20-30K for summer at latitude poleward of 30º. Importantly, the differences do not generally depend on solar illumination. Therefore, the differences of the datasets are within our estimated systematic errors for all atmospheric scenarios."

**Reviewer's suggestion**:
*Lines 165-179. Could the authors show how the model results used for atomic oxygen compare to the recent MSIS 2.0 for atomic oxygen (Emmert et al., Earth and Space Science, 7, e2020EA001321. https://doi.org/10.1029/2020EA001321, 2020)? More importantly, how do any differences in MSIS 2.0 atomic oxygen affect the temperature retrieval?*

**Author's response**:
We thank the reviewer for this comment, that let us find a mistake in the text (Line 293). Section 3 of the manuscript describes the the temperature error sources, including those coming from the uncertainties in the atomic oxygen abundances used in our retrievals. The estimation of the atomic oxygen uncertainty above 95 km has actually been done by means of comparisons with NRLMSIS 2.0 data, and not with NRMLMSISE00 data, as it was written in the text (lines 289-295). Therefore, Fig. 4 actually shows the average uncertainty based on comparisons with MSIS 2.0 atomic oxygen above 95km merged to the estimated MIPAS V5 atomic oxygen error below 95km (note that these are daytime and nighttime averages of the distinct abundances that we took for five latitude boxes and for the four seasons). Moreover, the effect of the differences between the atomic oxygen used and that of MSIS 2.0 on the retrieved temperatures is therefore included implicitly in the O-uncertainty component of our temperature non-LTE error estimation, which is described in Section 3.2 (see blue lines in Fig. 8). We would like to emphasize that, firstly, the effect of atomic oxygen uncertainty on retrieved temperature is only important above 95 km (see Fig. 8) and, secondly, the estimated MIPAS V5 atomic oxygen uncertainty is generally larger than that based on comparisons with MSIS 2.0 below 95 km.

We will correct the MSIS model version number in the text and will include the corresponding reference (Emmert et al., 2020) in the revised version.

**Reviewer's suggestion**:
*Line 230 and Figure 2. Are these kernels available to the reader? They would be useful for comparing with models or other datasets, but it is not clear from the data availability statement at the end of the paper that they are available. Note also that the reviewer could not connect using the link to the supplement at the end of the paper.*

**Author's response**:
Our data server does not regularly provide the individual averaging kernels for each temperature profile, due to the excessive volume of these data. Nevertheless, they can be provided upon request. In the data availability statement of the revised version, we will therefore state:" Due to their data volume, averaging kernels can be made available upon request."
The link to the supplement will be updated.

*Technical Corrections:*

**Reviewer's suggestion**:
*There are many acronyms throughout this abstract that are not spelled out. Please correct these when first mentioned. Thank you.*

**Author's response**:
We will try to find all acronyms and spell them out when first mentiones in the revised manuscript. We note here that we will replace "V8" and "V5" with "version 8" and "version 5".

**Reviewer's suggestion**:
*Lines 25-26. Please give a number here (+/- X K) and indicate the altitudes at which this applies. SABER faces similar non-LTE challenges in that temperature retrieval. From Figures 12-15 the agreement gets worse and the combined systematic uncertainties get much larger above 90 km so the authors need to be more explicit about this in the abstract.*

**Author's response**:
We will replace the last sentence in the abstract by the following sentences:
"The comparison of this V8 temperature dataset with co-located SABER temperature measurements shows an excellent agreement, with differences typically within 1.5 K below 90 km, 1–3 K at 90–95 km, 1–5\,K at 95–100 km, 1–8 K at 100–105 km and 1–10 K above, that is, all falling within the combined errors. The agreement with SABER improves with respect to previous MIPAS IMK/IAA versions."

**Reviewer's suggestion**:
*Line 30. Please give a reference for these v5 spectra.*

**Author's response**:
We will include the reference in the revised version.

**Reviewer's suggestion**:
*Line 80. A brief paragraph describing the Envisat mission, as well as the orbital inclination and the equator crossing local times would be very helpful to the uninitiated reader here in order to give valuable context to the dataset.*

**Author's response**:
We will include the following sentences at the beginning of the second paragraph in Section 1:
"The ENVISAT satellite was placed into a polar Sun-synchronous orbit, with an inclination of 81.5º and an altitude of approximately 800 km. The orbital period was about 101 minutes, enabling the satellite to complete a global Earth coverage in 14.3 daily orbits. The Equator crossing local times were approximately 10:00 and 22:00."

**Reviewer's suggestion**:
*Line 149. What do the authors mean by "bias-corrected"? Is this a bias in the model and if so, why is this done? Given the importance of atomic oxygen in the temperature retrievals, one or two sentences explaining this would be helpful.*

**Author's response**:
We are not sure if the Line number indicated by the Reviewer is correct because that line describes the a priori temperature. Since the reviewer explicitly mentions atomic oxygen in

this question, we think he refers to Line 167, where the bias-correction related to atomic oxygen is discussed.
The description of the "bias-correction" performed to the WACCM4 Ox to derive the atomic oxygen used in the temperature retrievals is actually written in the three paragraphs in Lines 168-179. To emphasize these all, describe the bias-correction, we have combined the three paragraphs into one.
In order to provide a justification for this correction, we will include the following sentence: "This approach is made to preserve the transient variability as provided by WACCM4 while retaining the climatological atomic oxygen as derived from MIPAS measurements in the previous version".

**Reviewer's suggestion**:
*Figure 2 caption. To what does 30 degrees refer?*

**Author's response**:
The words "latitude of" before the number were missing.

**Reviewer's suggestion**:
*Line 270. The reviewer does not understand how CO2 uncertainties can be calculated from the WACCM results. Why can this uncertainty not be estimated by ACE and/or SABER data alone? Please explain in the text.*

**Author's response**:
The uncertainties are estimated from WACCM CO2 (at MIPAS geolocations) by means of comparisons with ACE and SABER observations because that is the WACCM CO2 abundance that we use as input for these temperature retrievals, as written in Line 163. Nevertheless, for clarity, we have added "at MIPAS geolocations" after WACCM CO2 in this sentence.

**Reviewer's suggestion**:
*Lines 289-295. Again, the reviewer does not understand how an atomic oxygen uncertainty can be calculated from the WACCM results. Please explain in the text. Furthermore, it is well known that the NRLMSIS00 atomic oxygen values above 90 km are inaccurate (e.g. Sheese et al., J. Geophys. Res., 116, D01303, doi:10.1029/2010JD014640). The reviewer requests that the authors either crop their Fig. 4 at 97 km or use the newer more accurate values from MSIS 2.0 (Emmert et al., 2020).*

**Author's response**:
We estimated our atomic oxygen uncertainties in the lower thermosphere by means of comparisons of our atomic oxygen input (WACCM) with other datasets (MSIS). We will try to better specify this in the paragraph.
Regarding the MSIS version, there was a mistake in the text. We actually used NRLMSIS 2.0 atomic oxygen (and not NRLMSISE-00) to estimate the uncertainties (see answer to the specific comment above).
Besides correcting the model version, we will re-order the sentence:
"Above 95 km, we have estimated the uncertainty in the atomic oxygen used in our retrievals, coming from WACCM, from comparisons with NRLMSIS 2.0 atomic oxygen (Emmert et al., 2020).

**Reviewer's suggestion**:
*Line 355-356. How is does the quenching rate used compare to what is used by SABER? Please state this quenching rate here and state both if different.*

**Author's response**:
They are the same. This is specified in Line 450 in Section 6: Comparison with SABER.

**Reviewer's suggestion**:
*Figure 9 caption. If the "M61" title is V8 and "M21" is V5 then please say so in the caption.*

**Author's response**:
We will do so.

**Reviewer's suggestion**:
*Lines 383-387. Given the importance of tidal variability, it would be important here to (re)state the equatorial crossing local times of the Envisat orbit.*

**Author's response**:
We will restate this in the revised version.

**Reviewer's suggestion**:
*Lines 431-432. Do the authors mean +/- 1000 km and +/- 2 hours? Please be explicit. Also, if "2 hours" means 2 hours in Universal Time rather than Local Time, the authors should say that as well. Given the importance of tides in the MLT, if "2 hours" means +/-2 hours UT then a statement in the text or the captions about the local times used for the MIPAS data and those used for the SABER data would also be useful.*

**Author's response**:
We will write "+/- 1000 km and +/- 2 hours UT'

**Reviewer's suggestion**:
*Line 450. Here it would also be helpful to the reader to also state how CO2 densities and O densities, as well as their diurnal variations, are specified in the MIPAS and SABER datasets. A few sentences with references would be very useful in diagnosing the comparisons between the two instruments. This is particularly important for altitudes above 100 km and also particularly important if the values used are different.*

**Author's response**:
In the revised version, we will specify the input used in SABER 2.0 retrievals, that is, CO2 from WACCM3 climatologies, and O abundances derived from SABER ozone measurements below 95 km and taken from NRLMSISE-00 data above that altitude (Mlynczak et al., 2022 and references therein).

**Reviewer's suggestion**:
*Figures 12-15. In all of these figures, the reader cannot see the extent of the combined systematic errors at the top. Please either crop the figures at the top or expand the x-axes so the reader can see how big these are.*

**Author's response**:
We will expand the x-axes in all plots in Figures 12-15.

**Reviewer's suggestion**:
*Figures 12-15. To what does the "Nc" refer? If these are the number of coincident profiles, then please say so in the caption. Also, does that mean that the coincidences are pairs such that there are exactly Nc SABER profiles and Nc MIPAS profiles? If there are different numbers of*

*profiles that fall within the coincidence criteria then please state that explicitly. If the numbers of profiles are different for each instrument then please give both.*

**Author's response**:
"Nc" refers to the number of co-located individual MIPAS and SABER pairs. This will be specified in the caption of the figure in the revised version.