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Comment on amt-2021-302

Anonymous Referee #2

Referee comment on "Time evolution of temperature profiles retrieved from 13 years of infrared atmospheric sounding interferometer (IASI) data using an artificial neural network" by Marie Bouillon et al., Atmos. Meas. Tech. Discuss.,
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Review of amt-2021-302: "Time evolution of temperature profiles retrieved from 13 years of IASI data using an artificial neural network" by Marie Bouillon et al.

In this paper, the authors describe the creation of a global temperature dataset derived from IASI satellite observations. A new retrieval method based on using an Artificial Neural Network (ANN) to retrieve vertical profiles of atmospheric temperature is applied globally for 13 years of IASI data from 2006-2018 at 11 pressure levels throughout the troposphere and stratosphere. They then verify their derived temperatures against ERA5 reanalyses globally and ARSA radiosonde observations in selected locations. They find that their new retrieval typically deviates less than 0.5 - 1K from these reference data. Finally they fit linear trends to their retrieved temperatures to show global warming/cooling rates in the troposphere and stratosphere, providing further important evidence and quantification of our changing climate.

Overall, the paper and its dataset appear to be of very high quality and are potentially very useful to the scientific community. The manuscript is well written and in general there is sufficient detail to describe the method. Figures are generally clear and the analysis is sufficient to support the conclusions. The temperature dataset itself is very well presented and archived on a freely accessible website and easily downloaded from an FTP server.

I have some minor comments below that the authors may like to consider in a revised manuscript.

Below these, I have also included some typographic and stylistic suggestions that they may also like to consider. I do not require a point-by-point response to these typographic/style suggestions.

Minor Comments

1. The manuscript could benefit from a short "Data" section where the IASI instruments and radiances, the ERA5 reanalyses and the ARSA radiosonde data are briefly described. This would greatly improve flow in the results sections where the ATPs are compared to ERA5 and IASI, without needing to introduce and describe them in the text there.

2. Did the authors notice and difference in the accuracy or noise levels in their retrieval during day or night conditions? Possibly, I might expect a local nighttime retrieval to be better constrained than daytime because local thermodynamic equilibrium can be assumed at night, however this might not be a problem for this retrieval because of the machine learning method applied. The authors could simply regenerate Fig. 3 once for ATPs derived during local daytime and again for local nighttime conditions, and see if there are any differences. They can just report this in the manuscript if there is/isn't any difference, no need to include the figures. There is another temperature retrieval for the NASA AIRS satellite developed by Hoffmann and Alexander (2009) who found a large difference between day/night, but theirs was a different method to the one applied here.

3. Sect. 2.2, see also I.171-174 - Is it a problem that the training dataset output (ERA5) actually assimilates IASI radiances, so it sounds like the later comparison to ERA5 could be a bit circular? I don't think this presents a problem, but the authors should briefly explain why this is not a problem.

4. I.144 - "More information on ERA5 temperatures..." this is where a dedicated Data section would be more helpful.

5. I.149 - I could be wrong about this, but I think what is plotted in Fig. 2 would be better described as the "weighting functions", "kernel functions" or "sensitivity functions" of the selected IASI channels. These channels, or rather their sensitivity functions with pressure, are arranged into a Jacobian matrix, but the channel sensitivity profiles themselves are not necessarily "Jacobians". Terms like "weighting function" are commonly used to describe these sensitivity functions for hyperspectral imagers, so I might suggest either using this, or clearly explaining why they are being described as Jacobians here. As I said, I may be wrong, but some more explanation around the chosen terminology is required to clear this up.

6. Fig. 2 - Related to point 2 above, do these sensitivity functions change significantly under day/night conditions? If so, could this affect the true height of the retrieved temperature? I don't expect this effect to be very large, but the authors could comment on this.

7. Sect. 3.1, I.168-171 - This information for example would be better in a new "Data" section.

8. I.178 and elsewhere - [Important] I cannot find anywhere in the manuscript where it is clearly stated whether these differences are "IASI minus ERA5" or "ERA5 minus IASI". As a result, it's not clear for sure which dataset has a warm/cold bias with respect to the other. This is the same for Figs. 3, 6, 7 and S1. I would suggest simply writing (IASI minus ERA5) or similar in the figure caption, that would be enough to clarify.

9. I.191 - This first sentence is not clear, please rephrase. How about "At 2hPa, differences range from -2K to 2K globally", or similar?

10. I.196-199 and Fig. 3 - The information in these lines and Figure 3 could be easily summarised in a line plot that could be included neatly into the bottom right hand corner of Fig. 3. The additional panel could show the time-averaged difference (x-axis) against latitude (y-axis) for each of the 11 pressure levels considered, which could be colour coded. This would be a very useful summary of the information contained in Fig. 3.

11. I.201-204 - Does the fact that a latitude-longitude gridding is being used affect the RMS calculation? Obviously, a 1x1 degree lat-lon bin is much smaller at high latitudes than in the tropics, so there will be fewer IASI data points going into it. Are there sufficient numbers of points in each bin that the RMS is not likely to be affected by this?

12. I.206-207 - The increased RMS above mountain ranges could also be due to atmospheric gravity wave (GW) activity. If there are orographic GWs present over the mountains in the IASI measurements that are even slightly different from those simulated in ERA5 in terms of phase, amplitude, intermittency or location, this will likely result in a higher RMS value than a region with low GW activity.

13. Sect 3.2 I.214-234 - Firstly, the description of the ARSA radisondes could go in a Data section. Secondly, there is a long paragraph here from I.216-231 where it is not entirely clear what processes are applied to the radisonde datasets by whom and which of these steps are relevant for the present study. I.231 onwards "ARSA provides a 43 pressure-level profile..." should be near the top of the paragraph for readability, or even in the Data section. The authors should also decide how best to describe the relevant quality controls and extrapolation steps applied to the ARSA data for readability, because at the moment it is a little confusing which parts are relevant.

14. I.233 - I think the authors mean "substitute ERA-Interim for ERA5"?

15. I.250 and Fig. 6 - Normally it is good to show the highest time resolution possible, but would these figures be better simply showing the monthly averaged differences? This also would help to overcome the poor time coverage of the high latitude radisonde stations. The figures are also not high enough resolution to see individual daily differences anyway.

16. Fig. 6 - As mentioned above, the information in Fig. 6 would be very well summarised by a line plot showing time-averaged temperature differences (x-axis) against altitude (y-axis) for each radisonde region. The different lines for the different regions could be neatly colour-coded like the authors have done in Fig. S3. I think this could be very clear and may be worth including.

17. I.264-265 - How much of this persistent positive temperature difference at 2hPa could be due to biases in the ARSA dataset, and not due to the IASI retrieval? Looking at Fig. S1, there is a very similar positive bias when the ARSA radisondes are compared to ERA5. There could therefore be a small temperature bias at these altitudes in the ARSA data, perhaps due to the additional datasets that are used to extrapolate or constrain the radisonde data at these altitudes?

18. I.269-272 - Related to the point above, it would be very useful to include in the supplementary material the exact same figure as Figs. 6 and S1 but for the differences between IASI and ERA5 for each region. This could help the authors to more confidently assess some of the observed temperature differences in different the regions.

19. Fig. 7 - [Important] The authors should explain, or at least discuss, the thin vertical red stripes that appear in some of the panels in Fig. 7 (such as in the 30hPa panel). They should clarify whether these are artefacts that result from their analysis or if they are physical. I did wonder if they were due to re-initialisations of the EUMETSAT retrieval, or perhaps even due to sudden stratospheric warmings. The authors should discuss.

20. I.320 - "...although the areas of strongest warming are slightly different." It would be useful to briefly describe what these differences are if the authors are going to mention the Shangguan et al. (2019) study.

21. I.342-345 - The DOIs listed do not appear to be working correctly, please check. Also, the authors could consider using the accepted short doi service for readability (<https://shortdoi.org/>).

22. I.354 - Are both of these southern warming regions in Fig. 8 due to ozone hole recovery or just the region over the pole?

23. One final general point, it might be very useful for the community if the authors could say something about the vertical resolution of their retrieval. Naturally, the retrieval is evaluated on 11 pressure levels, but if the authors were able to estimate the vertical resolution of the retrieved temperature at for each of these levels that would be very useful if other researchers wanted to investigate gravity wave observations in the dataset, in a similar to what has been done in many studies for AIRS (Hoffmann and Alexander, 2009). Further to this, are the retrieved ATPs also archived on the satellite scantrack or is only the global 1x1 degree grid available?

Typographic and style suggestions

I.44 - "are" >> "can be"

I.53 - "A second instrument, and then a third, were launched in 2012 and 2018 respectively, and..."

I.56 - "insured" >> "ensured" (insured is only used to relate to (e.g.) car insurance)

I.56-57 - "are ensured and the construction of a long-term climate data record becomes possible."

I.65 and elsewhere - the typesetters may require you to add these DOIs as references in the bibliography.

I.69 - [Optional] Generally, "in order to" can be shorten to simply "to" to improve readability: "...(ANN) technique to derive a homogeneous..."

I.86 - "...absorption band, because these channels are most sensitive to atmospheric temperature..."

Eqns. 2, 3, 4 and 5 - not everything in these equations needs to be bold, e.g. the 1/2 log, the number 1, the subscripts and indeces, etc.

I.103 - It might be useful to briefly define what is meant by the term "skin temperature", to help readers in other fields.

I.105 - See point above about "In order to"

I.130 - It might be useful to define what is meant by the v1 and v2 absorption bands, to help readers in other fields. Or simply remove them.

I.130 - Do you mean "in the v1 N2O absorption band"?

I.134 - Aires et al., 2002: either missing brackets (2002) or broken reference.

I.140 - "A monthly value for global CO2 concentration was also added..."

I.142 - Again, the typesetters may ask you to provide this website as a proper reference in the bibliography with a date accessed etc.

I.146 - What are these 50000 different observations? Are they ERA5 points on the IASI scantrack or are they including the ARSA radiosondes?

I.150 - "...particularly for pressures less than 10hPa..."

I.181, I.186, I.206 and throughout the results section - [Suggestion] The authors very often use phrases like smaller, larger etc. to describe the distribution of temperature differences globally between IASI and ERA5/ARSA. However, these are relative terms and on many occasions they are used quite subjectively without quantification, for example "...the differences between the two datasets are much smaller (less than 0.5 K) at mid latitudes and at the poles." Smaller than what? And what is considered a "small" difference? There are other examples. The authors could try to be more direct and quantitative in their descriptions, for example "Between 7 hPa and 100 hPa, differences between the two datasets are typically less than 0.5 K at mid latitudes and at the poles, but in the tropics (30°S to 30°N) they can be up to 1K." This is a very minor style point but it helps to make the results clearer and more direct for the reader.

I.189 - "can" >> "could"

I.194-195 - Suggest replacing sentence with "In Fig. 2, we see that the channels that peak at these pressure levels have high sensitivity, but there are fewer of them compared to other pressure levels."

I.196 - "all latitudes"

I.203 - "bin" is more appropriate than "pixel" here

I.206 - "At 750 hPa, RMS values are..."

I.208 - "...where the RMS can reach 2K."

I.212 - "coherent" >> "consistent"

I.216 - "Whenever and wherever..." >> "If..."

I.244 - "However, the Antarctic stations only have between 10 and 150 observations per year, and only two stations have more than 100 observations per year."

I.274 - This DOI should also probably be listed as a proper reference.

Fig. S2 - Check figure caption: do you really mean "computed with the outputs of ANN" as with Fig. 8 or is this a copy-paste error?

I.305 - "assets"

I.311 - "trend is"

I.317 - "At mid latitudes, the warming is weaker." Also, can this be quantified rather than just saying "weaker"?

I.321 - Check the wording here is correct. How about: "In the stratosphere, we observe a cooling trend at all latitudes northward of 40S".

I.324 - I don't think you mean "inferior", this has quite a negative connotation! Use "lower than" or "smaller than".

I.342-345 - Would these DOIs be better in the Data Availability section?

I.347 - Again, "inferior to" is not appropriate here, use "less than" instead.

I.348 - Many commas. What about: "...are similar, demonstrating that our IASI product can be used..."

I.351-354 - Phrasing is not clear, what about: "We found a warming trend in tropospheric temperatures that is strongest at the poles (1 K/decade due to arctic amplification) and in the tropics (0.7 K/decade). In the stratosphere, we find a strong cooling trend in the tropics between 30°S and 30°N, while poleward of 40°S in the southern hemisphere there are two regions with an important warming trend that are likely due to the ozone hole recovery."

I.373-378 - The websites listed in the Data Availability section for the Climate Data Store and the ARSA temperatures do work, but they are potentially cumbersome and may change with website updates. I would suggest perhaps stripping them down to <https://cds.climate.copernicus.eu> and <https://ara.lmd.polytechnique.fr>.

References

Hoffmann, L., and M. J. Alexander (2009), Retrieval of stratospheric temperatures from Atmospheric Infrared Sounder radiance measurements for gravity wave studies, *J. Geophys. Res.*, 114, D07105, doi:10.1029/2008JD011241

