Atmospheric Measurement Techniques Discussions

Atmos. Meas. Tech. Discuss., referee comment RC2
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Comment on amt-2022-22

Anonymous Referee #1

Referee comment on "Can state-of-the-art infrared satellite sounders and reanalyses detect moisture inversions in the Arctic?" by Giovanni Chellini and Kerstin Ebell, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2022-22-RC2, 2022

The mauscript of Chellini and Ebell illustrates the results of a study aiming to answer the question of whether humidity profiles retrieved from infrared satellite (nadir) sounders and ECMWF reanalyses can be used for the detection of moisture inversion layers in the Arctic.

The authors have substantially ignored my initial comments, therefore, I am sorry that I have to repeat them here and, still, I cannot recommend the manuscript for publication in the Atmospheric Measurement Techniques journal. The motivations will be clear from the comments included hereafter.

General comments

1) Independently of the vertical grid that may have been used for profile retrievals, at low altitudes (0 – 10 km), the vertical resolution (i.e. the full width at half maximum of the averaging kernels) of IASI water vapour profiles is of the order of 3 – 5 km. For this sole reason, one would not even try to use the profiles retrieved from these missions to detect moisture inversions in 100 hPa layers. A more sound question would be: which is the minimum size (in terms of strength and depth) versus altitude, of moisture inversions that can be detected from IASI and AIRS retrieved profiles? To my opinion the work could be re-organized in the attempt to answer this question. As it is now, the manuscript only shows that the trivial answer (no) to the question set in the title (at least the part regarding satellite sounders) is really true.

2) By ignoring the averaging kernels of IASI and AIRS measurements, the authors do not allow for the strong correlations existing between retrieved profile grid points. The peaks of the averaging kernels of nadir sounders are overlapping each other, therefore, adapting the radiosonde vertical resolution with simple, non-overlapping, “box” kernels is not adequate. This is the reason why the authors find a substantial disagreement between the moisture inversion statistics determined from satellite and from adapted-radiosonde

profiles. This makes very critical (and to my opinion unacceptable) the content of Section 4.3 of the manuscript.

3) As far as the presentation form is concerned, in scientific papers there is no need for lengthy text descriptions of the behavior of the lines shown in the plots: plots, on their own, are a tool to summarize the results. The text could be significantly shortened and should rather focus on the interpretation of the observed results (discrepancies, in this case).

Specific comments

L. 231: Which is the vertical resolution (FWHM of AKs) of AIRS retrieved humidity profiles? How many are the degrees of freedom?

L. 233: the profile inversion in the AIRS support product shown in Fig. 1C could be an artifact easily originated by the regularization used in the retrieval. Do you use the retrieval diagnostic to assign a "confidence level" to the detected humidity inversion layers?

L. 242: different statistics of AIRS and IASI measured profiles also due to the different strategy to handle cloudy measurements in AIRS and IASI retrievals. The two instruments / retrievals also smooth differently the horizontal structures in the atmosphere: the averaging area is 12 km for IASI and 39 km for AIRS. How do you account for these differences in the statistics presented later?

L. 289: why don't you apply the same criterion based on measurement error also to IASI and AIRS profiles? Note that, while radiosonde profile grid points are mostly independent from each other, IASI and AIRS retrieved profile grid points are strongly correlated to each other, thus the correlations should be properly taken into account in this case.

L. 293: is this part of the analysis useful? Note that the procedure described is not equivalent to degrading the radiosonde profiles to the same vertical resolution of the satellite nadir sounders. To do that, averaging kernels of the related nadir retrievals should be used.

L. 294: "vertical grid" or "vertical resolution" ? I guess the vertical resolution is relevant in this context. Of course, vertical sampling must be adequate to the actual vertical resolution (see the Nyquist theorem).

L. 336 – 360: this lengthy descriptive text is not useful, a look at Fig. 3 already conveys all the information given in the text. The text is useful only when provides a physical interpretation of the results shown in the figure.

L. 367: Note that radiosonde profiles should be adjusted both to the vertical resolution and to the vertical grid of the IASI and AIRS Support retrievals. These adaptations can be achieved by convolving the radiosonde profiles with the averaging kernels of the retrieved IASI and AIRS profiles. Adaptation of the vertical grid only (as described in Sect. 3.2) is useless and the subsequent analysis highlights exactly this problem.

L. 372: If convolution with the averaging kernels is out of the scope of this work, then I suggest to remove this comparison: in general it is better to omit something rather than presenting something wrong.

L. 374 – 375: the number of 7 retrieval grid points (constant) is not similar to 2.5 degrees of freedom that IASI and AIRS profiles may show in polar regions. In case of 2.5 degrees of freedom, the 7 averaging kernels of the retrieved grid points may easily show overlapping peaks, thus they are not similar to the box functions that you are using to degrade the radiosonde profiles (see sect. 3.2).

L. 394 – 400: if the discrepancy in frequencies of inversion detection between HRRS and IGRA depends on how you processed HRRS measurements, why don't you correct the procedure such that the same algorithm can be applied to profiles from all the considered sources?

Figure 4: the disagreement between HRRS and IGRA radiosondes (due mainly to different processing for inversion detection, see above) is rather concerning and casts doubts about the suitability of the two datasets to detect moisture inversions. Conversely, the other behaviors are rather obvious: as you degrade the profile sampling grid and vertical resolution, the sharp profile features become harder to detect and, even if detected, these show anyhow a reduced intensity due to the smoothing applied. Panel c) for $p > 950$ hPa seem to show and exception (see also line 387 of your paper) to this general, expected, behavior: do you have an explanation for it?

L. 421 – 446: the wordily description of the curves presented in Fig. 5 is not useful, one can just look at the figure and rapidly learn the results.

Section 4.2: Again, there is no point to compare IASI and AIRS statistics to that of "IGRA adjusted to AIRS" radiosonde profiles. First, the adjustment is not done with the correct kernels. Secondly, considering that the presence of clouds and humidity inversions are likely to be correlated, the comparison of IASI / AIRS statistics should be made towards that of the "matching and adjusted" radiosonde profiles and in similar cloud coverage

conditions. I suggest to remove this section from the paper if you are not willing to correct these issues.

L. 450: the low vertical resolution of IASI and AIRS is not linked to the fact that they are passive sensors. It is rather linked to the nadir sounding technique used.

L. 498 – 500: to see if ERA5 is a suitable dataset to evaluate the statistics of humidity inversions, I would have started by comparing, at the various pressure levels, the width of the distribution of profile inversion depths (as obtained from radiosondes) to the actual vertical resolution of the ERA5 model. The fact that ERA5 performs better than IASI and AIRS (because of higher vertical resolution) is not surprising as the ECMWF model assimilates both IASI (MetOp-A/B) and AIRS measurements.

L. 525 and ff: this sentence is like saying that sharp vertical profile features cannot be detected using measurements with low vertical resolution. This is largely expected, it is not a "discovery" as presented here.

L. 537, "low vertical humidity information content of the passive remote sensing instruments": this is not true, please delete this sentence. The fact that IASI and AIRS measurements are not suitable for your study is uniquely due to the coarse vertical resolution of IASI and AIRS profiles as compared to the vertical extension of the features you want to observe. The low vertical resolution of IASI and AIRS is related to the nadir sounding technique employed, e.g. passive limb sounding remote sensing measurements have a much finer vertical resolution.

L. 552 – 553: Does this mean that you can infer the correct statistics of humidity inversions if you correct for the effect of the insufficient vertical resolution of ERA5? I don't think so. I think it would be better to re-phrase the sentence.

Technical / minor corrections

p. 5, fig. 1: please specify if the time is UTC or local.

L. 411: "rather large" with respect to what ?