

We would like to thank Bruce Ingleby for his careful reading of the paper and his valuable comments. Our answers appear in blue below.

Comments by Dr. Bruce Ingleby

p4 111 : 'The GRUAN RS92 profile for humidity does not vary greatly from Vaisala's default processing below the upper troposphere' Vaisala's processing changed at version 3.64 of DigiCora III.

This is the 'Dec 2010' change described at

<http://www.vaisala.com/en/meteorology/products/soundingsystemsandradiosondes/soundingdatacontinuity/RS92-Data-Continuity/Pages/humiditymeasurementimprovedalgorithm.aspx>

Note that practical implementation can be delayed - for example German and UK stations only implemented it in 2015 and a few countries have DigiCora I or II which don't have the radiation and time-lag corrections for humidity. In TEMP code there is no indication which version of DigiCora III is in use but for BUFR reports generated by Vaisala software the information is provided, see <https://software.ecmwf.int/wiki/display/TCBUF/Radiosonde>.

NB. Radiosonde reports include humidity as dew point temperature. At low temperatures (below about -40C) it matters which saturation vapour pressure equation is used in conversions to RH or specific humidity http://cires1.colorado.edu/_voemel/vp.html gives a useful overview. Vaisala radisondes assume the Hyland and Wexler formula. The WMO CIMO Guide (2014 edition, <http://www.wmo.int/pages/prog/www/IMOP/IMOP-home.html>) recommends several similar formulae (Hyland, Hyland and Wexler or Sonntag) for processing radiosonde humidities.

We are aware of that dependence and agree that it is important to take properly into account the saturation vapour pressure equation when converting specific humidity into RH (and vice-versa).

However, we don't think it is relevant to discuss that in the present case: if everything is properly converted, with the right units, then no error can be attributed to the phase of water.

Moreover, if an error was performed in the saturation vapour pressure calculation then it would affect the upper tropospheric layers and not the lower layers.

p8 237 humidity corrections ... Agusti-Panareda et al 2009 :

The Agusti-Panareda/Vasiljevic (AP09) correction was developed at ECMWF and is used at various European NWP centres (not the Met Office who trialled it and decided not to use it). One problem is that (as mentioned above) there are some RS92 reports bias corrected at the station and others not and no way (from TEMP) to distinguish them. Another problem is that the AP09 method assumes homogeneous background error biases - probably less warranted for humidity than temperature. The bias correction of radiosonde humidity is currently under investigation at ECMWF.

Thanks a lot for pointing that to us!

We have rephrased the text to that this comment into account and so now it reads

"The RAOBS are not bias corrected by a VarBC scheme but using static corrections, as the one proposed by Agusti-Panareda et al. (2009) with a standardization to night-time RS92 observations. Even though such static corrections have known weaknesses (difficulty to separate RS92 reports bias corrected at the station from others, assumption of homogeneous background error biases), these measurements are used to anchor the bias correction and the final humidity analysis in NWP systems"

p10 291 'The differences in Table 2 show consistent results' The point that strikes me from Table 2 is that all the instruments show rather a jump from the first channel (most positive difference) to the

next channel. However I note that the second SAPHIR channel $f_0 \pm 1.1$ is more negative than the $f_0 \pm 1$ channels on the other instruments.

Indeed, but it is important to recall that these numbers are calibration differences that need to be compared to the radiometric sensitivity of each channel and each sensor.

p11 317 'new Vaisala RS41 probes, which are likely to be even more accurate than the RS92'

Yes, because there is a temperature sensor within the humidity sensor there is no need for a radiation bias correction to the humidity (eg Jensen et al, 2015)

Comparison of Vaisala radiosondes RS41 and RS92 at the ARM Southern Great Plains Site M. P. Jensen, D. Holdridge, P. Survo, R. Lehtinen, S. Baxter, T. Toto, and K. L. Johnson Atmos. Meas. Tech. Discuss., 8, 11323-11368, doi:10.5194/amtd-8-11323-2015, 2015

We have added the reference to Jensen et al. (2015) in this part of the paper.

p11 319 'in-situ' - 'laboratory and ground-based' might be clearer I presume that in a laboratory it is difficult if not impossible to obtain a good simulation of clouds - perhaps making it more likely that clouds are a significant part of the discrepancy.

We have thus modified "laboratory measurements and the atmospheric results" by "laboratory and ground-based in-situ results" in order to clarify the discussion.

Table 1 and Figure 1. I found the description of frequency and bandwidth very confusing.

It became clear after email discussion with the lead author: each "channel" is actually the combination of two channels. For example the third SSMIS channel is given as 183.31 ± 6.6 in Table 1. It has a lower side channel "looking" at the range [175.21, 178.21] while the upper side channel looks at the range [188.41, 191.41]. These two parts are then averaged to form 1 measurement (they basically do that to lower the noise, and reach the required radiometric sensitivity). - An example like this should be provided to clarify matters.

In Figure 1 only the upper side channels are represented. - If raw data for the separate side channels are available these might help in understanding the spectral characteristics better.

We agree that the reader needs to be aware of this specificity to understand the difference between the bandwidths and the frequencies. We have thus provided more details in the legend of Table 1. It now reads:

“Table 1: List of satellites, sensors and their channels located in the $f_0 = 183.31$ GHz absorption line. To reach the required radiometric accuracy, the sensors are double-sided channels (except channel 3 of MHS), with the same bandwidth on each side : for each channel, radiation is measured over each side and averaged.”

Moreover, concerning the representation in Figure 1: we would need to separate the sensor measurements in order to represent each side. This is a complex task since we get the average of the two sides from the satellite ground segment. The separation is easy with RTMs, but not with the satellite data. Anyhow, we added the following sentence in the legend of Figure 1 in order to avoid confusion:

“For simplicity, only one side of the absorption line is represented.”

Figure 2b 'Suomi' misspelt in the top line of the title.

This typo was corrected.

Personally, I would like to see typical humidity weighting functions for typical midlatitude and tropical profiles - perhaps for SAPHIR channels.

A lot of typical weighting functions are available in the literature, but we added a reference to Brogniez et al. (2011) that shows weighting functions for SAPHIR and AMSU-B-like sounders.