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Atmospheric Measurement Techniques Discussions

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Interactive comment

Interactive comment on "Using reference radiosondes to characterise NWP model uncertainty for improved satellite calibration and validation" *by* Fabien Carminati et al.

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We would like to thank the referee for addressing his/her recommendations to improve the quality of our study. Each of the four questions is addressed in order below and manuscript changes are documented accordingly.

Referee:

Clarify the time range to match the raob and model fields, is it typically between 3-9h as currently done in NWP? It is said that only a small fraction is in slot 0-3-h. Is it then representative of 6-h forecast? I would think most of the time differences is in range 4-8 h?

Authors:

The radiosonde observations are interpolated between T+n and T+(n+3) where n is the model forecast time (or analysis if n=0) preceding the radiosonde observation time. For example, the radiosonde launched from Lindenberg on 2016-12-31T16:47:14 UTC (LIN-RS-01_2_RS92-GDP_002_20161231T180000_1-000-001.nc) has been interpolated between the Met Office forecasts T+3 (2016-12-31T15:00:00) and T+6 (2016-12-31T18:00:00), noting that in this example the analysis T+0 (2016-12-31T12:00:00) is not used.
However, because the interpolation is applied to each observation of the profile, with a 15-second step, it is possible that by the time a balloon reach its bursting point the observations in the upper part of the profiles are interpolated in the successive time window with respect to those in the lower part: e.g. in a hypothetical radiosonde profile with an observation made at T17:30:00 near the surface and one at T18:30:00 near the ceiling, the former observation will be interpolated between model T+3 and T+6, while the latter will be interpolated between T+6 and T+9 forecast lead times (from the analysis T12:00:00).
In the 2016 case study presented in the paper, out of 1160 MetOffice – GRUAN matchups, 13 (1.1%) have a launch time in the T+0 – T+3 window, and 1147 (98.9%) in the T+3 – T+6 window. For ECMWF – GRUAN matchups, 8 (0.7%) are the T+0 – T+3 window, 567 (48.9%) in the T+3 – T+6, 5 (0.4%) in the T+6 – T+9, and 580 (50%) in the T+9 – T+12 window. Note that the ECMWF model has more forecast windows because only two analyses are available per day (compare to four at the MetOffice).
In a subsequent study, we will investigate the model error as a function of the time window, but this is however out of scope of the present paper.

Manuscript change:

Line 269: changed “T+(n+1)” to “T+(n+3)”

Referee:

Clarify if the balloon drift is taken into account. This is important as shown, e.g. by Laroche and Sarrazin, Weather and Forecasting, 2013, 772-782.

Authors:

The Balloon drift is taken into account in this study. This is stated on lines 218-219 as follows: “Note that all collocations presented in this paper account for the radiosonde drift.” Details of the spatio-temporal interpolation are describe in section 3.3.

Referee:

Total uncertainty for ATMS channels 18-22 shown in Fig. 6 increases from about 1.5 (ch 18) to 2.5 K (ch. 22). However values obtained at NWP centres are significantly lower than this for observed minus background (O-B), i.e. $\sim$0.4-0.8 K lower (for observation accepted for assimilation). Perhaps adding such stats for the two NWP centres would be good, plus explain differences.

Authors:

It is important to differentiate bias (referred to as error in this study) and uncertainty. The mean O-B statistics obtained in NWP centres characterise the observation bias in radiance space (assuming an unbiased model background). In practice it is not easy to disentangle the bias associated with the observation and that associated with the background. In the section 4 of our study, we try to estimate the bias associated with the background by calculating NWP – GRUAN statistics for the Met Office and ECMWF datasets. In the humidity channels it is found within $\pm$ 0.46K during night-time (Table 1).

GRUAN profiles are bias corrected by the GRUAN lead-centre to the best of their knowledge and the profiles of uncertainty relate to the uncertainty associated with this correction. Those uncertainty profiles are used in section 5 to calculate the overall uncertainty of the difference NWP – GRUAN, which is found to vary from 1.5 to 2.5K in the humidity channels.

With a total uncertainty greater than the error, eq. (1) is satisfied and the measurement can be deemed statistically consistent (according to Immler et al., 2010).

At the Met Office, the mean background departure (O-B) for ATMS observations accepted for assimilation is within $\pm$0.9K in the 18-22 humidity channels. It means that the bias in the background potentially contributes up to half of the calculated O-B. This, however, will require further work (such as the uncertainty analysis of the satellite observations minus background difference) that is beyond the scope of this paper.

Comparing satellite observations-based O-B statists, as suggested by the referee, to the simulated Tb-based NWP-GRUAN statistics presented in this study may be confusing for the readers and (we think) is not an added value to this study since we are not investigating their difference.

Referee:

Add basic info, reference on bias correction to radiosonde. It is said that the bigger part of the bias is linked to model error.

Authors:

The following paragraphs will be added to section 2.2 and 2.3, respectively:

Manuscript change:

Line 181:
In the Met Office NWP system, the interpolation of background fields is performed twice, once for all observations and later just for those observations to be assimilated. The radiosonde profiles are averaged over the vertical model layers. Latitude, longitude, and time at each level are used in the first interpolation of background values, but fixed coordinates are used in the latter interpolation. A bias correction of radiosonde profiles is in place on a per station basis but is generally not applied where RS92 are used. As noted by Ingleby and Edwards (2015), radiation corrections are now often directly applied by the radiosonde manufacturer such as Vaisala, which reduces the need for correction in NWP system. Bias correction and quality controls operationally applied to radiosonde at the Met Office are detailed in the appendix 1 of Ingleby and Edwards (2015).

Line 199:
The treatment of radiosondes in the ECMWF system differs from that of the Met Office in that there is no average on model levels and each level is treated as a point value. In addition, the balloon drift in space and time was not accounted for in 2016 (i.e. the ascension was assumed instantaneous and vertical). The treatment of the

radiosonde drift (from BUFR reports) has been introduced in the operational system in 2018 (Ingleby et al., 2018). Also in contrast to the Met Office, radiosondes at ECMWF are bias corrected for temperature and humidity. The correction, described by Agusti-Panareda et al (2009), uses monthly statistics of background departure based on night-time RS92 and is applied as a function of radiosonde type, pressure, and solar elevation angle.

Line 879:

Agusti-Panareda, A., Vasiljevic, D., Beljaars, A., Bock, O., Guichard, F., Nuret, M., Garcia Mendez, A., Andersson, E., Bechtold, P., Fink, A., Hersbach, H., Lafore, J.-P., Ngamini, J.-B., Parker, D.J., Redelsperger, J.-L., Tompkins, A.M.: Radiosonde humidity bias correction over the West African region for the special AMMA reanalysis at ECMWF, Q.J.R. Meteorol. Soc., 135 : 595-617. doi: 10.1002/qj.396, 2009.

Line 939:

Ingleby, B., Isaksen, L., Kral, T., Haiden, T., Dahoui, M.: Improved use of atmospheric in situ data, ECMWF Newsletter, number 155, Page 20-25, https://www.ecmwf.int/node/18208, doi:10.21957/cf724bi05s, 2018.

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