

Atmos. Meas. Tech. Discuss., community comment CC1  
<https://doi.org/10.5194/amt-2020-519-CC1>, 2021  
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## Comment on amt-2020-519

Bruce Ingleby

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Community comment on "Characterizing and correcting the warm bias observed in Aircraft Meteorological Data Relay (AMDAR) temperature observations" by Siebren de Haan et al., Atmos. Meas. Tech. Discuss., <https://doi.org/10.5194/amt-2020-519-CC1>, 2021

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Characterizing and correcting the warm bias observed in AMDAR temperature observations

General

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This manuscript addresses an important issue and provides some hope that aircraft temperature biases can be addressed at source.

It should be noted that the bias correction methods applied at NWP centres are imperfect (Eyre, 2016) - partly because NWP models have their own biases. These methods work best when the proportion of anchor observations is large: pre-Covid aircraft numbers were increasing whilst the numbers of anchor obs (radiosondes and GPS-RO) were static. In the ECMWF system the largest bias corrections are applied to US-AMDAR. These have been found to interact with Weak Constraint 4DVar (essentially a model bias correction) and because of this the Weak Constraint can only currently be applied in the stratosphere. If aircraft temperature biases can be removed prior to the NWP system they could become anchor observations - part of the solution rather than part of the problem.

The choice of papers referenced could do with some improvements.

Detailed comments

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line 17 'Upper air observations from aircraft are an important source of information for numerical weather prediction (NWP).'

Possibly reference Ingleby et al (2021).

line 21,22 'ECMWF has introduced an aircraft and flight phase dependent temperature correction (Cardinali et al., 2004).'

The ECMWF bias correction of aircraft temperatures was announced in a short newsletter item by Isaksen et al (2012, see below), an update is given in Ingleby et al (2019). Cardinali et al (2004) did not discuss aircraft temperature biases.

I think the work at NCEP by Zhu et al (2015) should also be mentioned.

line 29 'The formal difference is slightly smaller than 0.4K (Painting, 2003).'

I'm not sure what this means - clarify or delete.

It might be worth mentioning the EUFAR workshop on aircraft temperature measurements (Nov 2020):

[https://www.eufar.net/shared\\_subjects/s/3fa8510de42844d6b30ca0a6980d01eb/](https://www.eufar.net/shared_subjects/s/3fa8510de42844d6b30ca0a6980d01eb/)

(I particularly remember the presentation by Bob Sable on TAT sensors - it seems the industry preoccupation is with avoiding icing of the sensors in extreme conditions and accuracy was a secondary consideration.)

line 40 'Aircraft sensors'

I recommend that the book by Wendisch and Brenguier (2012) is referenced in this section.

line 70ff 'Aircraft temperature measurement'

This is key and should probably be expanded slightly - to mention the conversion of kinetic energy to temperature (mainly by adiabatic compression within the TAT probe). Perhaps mention typical differences between  $T_a$  and  $T_i$ . Section 2.5 of Wendisch and Brenguier is useful - it derives equations like (4). WMO seems to be encouraging use of WMO No. 8 'Guide to Meteorological Instruments and Methods of Observation' rather than Painting (2003).

line 91 '2.5 Numerical weather prediction model data'

Either here or earlier the geographical domain being used should be mentioned.

line 115,116 'Since generally an atmospheric profile has a temperature lapse rate of -6.5 K/km'

'Since average tropospheric profiles have ...' would be more accurate.

line 123,124 'the temperature is really biased assuming that the bias not

related to the time difference, is independent of the flight phase'

perhaps 'there is an additional bias term, which may be independent of the flight phase'

line 145 What is the typical time difference  $\tau$ ? How much does it vary?

Is it linked to aircraft type and/or airline?

line 147 'possible' - 'possibly'

line 161 'Thus, when we have an (estimate) of the mapping  $f^{-1}$  we can correct the temperature measurement.'

Either remove the brackets or extend them: '(an estimate of)'.

More fundamentally I haven't fully understood this mapping, any extra explanation would be welcome. From Figure 1 I think that larger corrections are needed at lower airspeeds - is this correct (and true of other aircraft)?

line 190,191 'Radiosondes are generally launched at the main hours (00, 06, 12, 18 UTC), as required by WMO, with the majority of launches around 00 and 12 UTC (these timestamps represent the observation at a level of 500 hPa at the whole hour)'

'before the main hours' (often about 45 minutes before, but different NMSs vary).

I have heard it said that they should reach 100 hPa at about the main hour.

BUFR radiosonde reports have the time of each individual level.

line 214 'The most left panel' - 'The left-most panel'

line 215,217 'The reason for the difference in bias with the time of day is not understood. Assuming that the AMDAR bias is constant we observe that the radiosonde bias, changes over the day from overestimation at 06 UTC to neutral at 12 UTC and underestimation at 18 UTC to slightly underestimation at 00 UTC.'

Radiosondes are mainly available at 00 and 12 UTC as already stated. Apart from low levels the sample at 00 UTC is quite small - because there are fewer flights at night. The proportion of cargo flights at night may well be higher? Given the sampling issues for both aircraft and radiosondes I would advise against suggesting a diurnal cycle in radiosonde biases. Radiosondes have larger uncertainty in the \_stratosphere\_ in sunlight (Dirksen et al, 2014).

line 218 'Figure 4' - interesting variation with aircraft type  
Looking at the ECMWF bias corrections by aircraft type I see even larger biases for some B787 aircraft (US-AMDAR) and small negative (cool) biases for some Airbus aircraft.  
Please increase the size of the text labels in figure 4 to improve clarity.

line 225 'the second is an accuracy related correction.'  
perhaps 'the second comes from the interconnected nature of aircraft measurements: there is a Mach number correction to the temperature and a temperature correction to the Mach number and it appears that avionics systems do not iterate to convergence.'

line 236,237 'The Mode-S EHS information can be applied to correct the AMDAR temperature bias, for those air spaces where Mode-S EHS information is available.'  
This is not a long-term solution. The meteorological community needs to persuade the aviation industry to improve their avionics/measurements.

line 258 'Painting, J. D.: WMO AMDAR Reference Manual, WMO-no.958, WMO, Geneva, <http://www.wmo.int>, 2003.'  
<http://www.wmo.int> no longer exists and WMO regard this document as superseded, see <https://community.wmo.int/activity-areas/aircraft-based-observations/resources/manuals-and-guides>

Possible extra references  
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Dirksen, R.J., M. Sommer, F.J. Immler, D.F. Hurst, R. Kivi, and H. Vomel, 2014: Reference quality upper-air measurements: GRUAN data processing for the Vaisala RS92 radiosonde. *Atmos. Meas. Tech.*, 7, 4463-4490, <https://doi.org/10.5194/amt-7-4463-2014>.

Eyre, J. R. (2016), Observation bias correction schemes in data assimilation systems: a theoretical study of some of their properties. *Q.J.R. Meteorol. Soc.*, 142: 2284-2291. doi:10.1002/qj.2819

Ingleby, B., L. Isaksen, and T. Kral, 2019: Evaluation and impact of aircraft humidity data in ECMWF's NWP system. ECMWF Technical Memorandum No. 855, <http://dx.doi.org/10.21957/4e825dtiy>.

Ingleby, B., B. Candy, J. Eyre, T. Haiden, C. Hill, L. Isaksen, D. Kleist, F. Smith, P. Steinle, S. Taylor, W. Tennant, and C. Tingwell, 2021: The impact of COVID-19 on weather forecasts: a balanced view. *Geophys. Res. Lett.*, <https://doi.org/10.1029/2020GL090699>.

Isaksen, L., D. Vasiljevic, D. Dee, and S. Healy, 2012: Bias correction of aircraft data implemented in November 2011. ECMWF Newsletter, No. 131, ECMWF, Reading, UK, p. 6, <https://www.ecmwf.int/en/eLibrary/14591-newsletter-no-131-spring-2012>.

Wendisch, M and Brenguier, J-L eds, 2013: Airborne measurements for environmental research: methods and instruments. Weinheim : Wiley-VCH Verlag GmbH, Pp.xxxii+655

WMO, 2018: Guide to Meteorological Instruments and Methods of Observation, Volume III - Observing Systems (WMO No. 8)

Zhu, Y., J. Derber, R. Purser, B. Ballish, and J. Whiting, 2015: Variational correction of aircraft temperature bias in the NCEP's GSI analysis system. Mon. Wea. Rev., 143, 3774-3803. doi: <http://dx.doi.org/10.1175/MWR-D-14-00235.1>