Authors' Response to Referee #2 Comments on

"Completeness of radiosonde humidity observations based on the IGRA" by António P. Ferreira, Raquel Nieto, Luis Gimeno

Referee comments (highlighted in blue) are copied before the authors' responses.

The manuscript examines the completeness of newly released IGRA V2 humidity data. It is useful to have such a documentation to help users decide whether IGRA V2 has enough data for their own research before putting more efforts into downloading and analyzing the data. I would also like to appraise the authors for making their results (data) available and plan to update it on a two-year basis. I am little bit surprised on why the authors only look at humidity data, not including temperature and wind data. In "Introduction", the authors did not provide the rationale for only studying humidity observations, such as less humidity data than temperature data and degraded performance for hygrometers. Based on my evaluation, I think that the manuscript in current version needs some revision. Some of specific comments are listed below.

Although the present work focuses on humidity, for comparison purposes, Sect. 2 and 3 provide some information about global wind and temperature data collected in IGRA [amount of stations and daily observation of the three parameters since 1905 (Fig. 1); vertical resolution/extent of temperature and humidity observations since 1945 (Fig. 6)].

The opening paragraphs of Sect. 1 recall the significance of radiosondes in accessing atmospheric humidity, as well as the role and limitations of historical radiosonde data to humidity studies. The problem of missing humidity observations due to limitations of operational radiosonde hygrometers and reporting practices, among other factors was pointed out in Sect. 1.2 and explained Sect. 1.3. Differences in vertical coverage related to reporting practices of humidity measurements will be also briefly mentioned on P2 [please refer to our reply to Referee #2].

Nevertheless, there is a particular reason why we have examined the completeness of radiosonde humidity observations, which in fact was not expressed on the manuscript. Humidity measurements (either as relative humidity or dew-point depression) require simultaneous temperature measurements, both quantities being measured at specified pressure levels. So, radiosonde humidity observations, in fact, represent simultaneous observations of pressure, temperature and humidity. Leaving aside horizontal wind – which is indirectly measured with the aid of a tracking device – humidity observations represent the most accomplished of the radiosonde observations. We think this is worth to be remarked in the revised version, not only in Sect. 1, but also in the Abstract and the concluding Sect. 6.

Changes in the manuscript:

P1, L11-12
Where it reads:
aiming to describe the completeness of humidity observations from radiosondes
It will read:
aiming to describe the completeness of humidity observations (i.e., of simultaneous observations of temperature and humidity) from radiosondes

P3, L11 (beginning of paragraph) – Insert text:
Radiosonde humidity measurements involve the simultaneous measurements of pressure, temperature and relative humidity or dew-point depression. Therefore, except for horizontal wind – which is indirectly measured with the aid of a remote tracking device – the 'humidity observations' represent the most accomplished of the radiosonde observations.

P23, L9
Where it reads:
a dataset detailing the completeness of humidity observations
It will read:
a dataset detailing the completeness of humidity observations (RH and/or DPD together with pressure and temperature)

Specific comments:

1. P1 L16: spell out GUAN.

GUAN is now spelled right in the Abstract, except for the letter corresponding to GCOES which (like WMO) we believe is better known to most readers and is only translated the first time it appears in the main text.

P1, L16
Where it reads:
GUAN network
It will read
GCOES Upper-Air Network

2. P2 L30, add some of new references, such as Dai et al. (2011). Dai, A., J. Wang, P. W. Thorne, D. E. Parker, L. Haimberger, and X. L. Wang, 2011: A new approach to homogenize daily radiosonde humidity data J. Climate, 24, 965-991. This applies to other places in "Introduction".

Dai et al. (2011) was only cited in the concluding section; we agree it should be first mentioned in Sect. 1. [Please note that we add a few more updated refs regarding Referee #1 comments.]

P2, L29; P7, L8 – Insert citation:
Dai et al. (2011)

3. P3, L4: Durre et al. (2018, JTECH) should be used for the IGRA V2 reference.

In fact, that paper was not referred before because it was published after the submission date of our manuscript. A proper citation will be inserted in several places of the revised manuscript. We think we should also put a reference to CARDS, since it is the predecessor of IGRA v1. On P7, L24, Durre et al. (2016) refers specifically to the IGRA dataset used in our work.

Note: the information on the humidity quality checks on P8, L5-12 was kindly provided to the authors by Imke Durre; however, we have lately found that it became part of the documentation publicly available on the NOAA website for IGRA since April 18, 2018.

Changes in the manuscript:

P3, L3-4
Where it reads:
The first version contained practically data after 1945 (Durre et al., 2006). The IGRA Version 2 used in this paper (Durre et al., 2016), extends back in time as early as 1905
It will read:
The first version of IGRA (a successor of the the Comprehensive Aerological Reference Data Set (CARDS; Eskridge et al., 1995) contained practically data after 1945 (Durre et al., 2006). The IGRA Version 2 used in this paper, very recently documented in Durre et al. (2018), has enhanced data coverage and extends back in time as early as 1905

P8, L11-12
Where it reads:
(i) for RH (with the later introduction of this variable in the archive) and (iii)–(iv) were added in IGRA 2 (Imke Durre, personal communication, April 12, 2018)
It will read:
(ii) for RH (with the later introduction of this variable in the archive) and (iii)–(iv) were added in IGRA 2.

P8, L26 (before "NB") – Insert text:
For a description of data coverage and data sources of IGRA 2, a full description of quality assurance of data, and further detail on the differences between IGRA 1 and IGRA 2, the reader should see Durre et al. (2018) published after the submission date of this work.

Additions to the reference list:

Durre, I., X. Yin, R.S. Vose, S. Applequist, and J. Arnfield, 2018: Enhancing the Data Coverage in the Integrated Global Radiosonde Archive. J. Atmos. Oceanic Technol., 35, 1753–1770, doi:10.1175/JTECH-D-17-0223.1

Eskridge, R. E., O. A. Alduchov, I. V. Chernykh, Z. Panmao, A. C. Polansky, and S. Doty, 1995: A Comprehensive Aerological Reference Data Set (CARDS): Rough and systematic errors. Bull. Amer. Meteor. Soc., 76, 1759–1775, doi:10.1175/1520-0477(1995)076<1759:ACARDS>2.0.CO;2.

4. P4, L29: "although most of the soundings did not reach beyond 700 hPa", I think that this is outdated. Most of modern radiosonde soundings can reach above 700 hPa.

The phrase, inside parenthesis at the end of a sentence, reports to the earliest soundings in IGRA, coincident with the earliest upper-air temperature data at Lindenberg station. We will rephrase it for clarity.

P4, L29
Where it reads:
most of the soundings
It will read
most of those soundings

5. P7, L2: China doesn't use goldbeater skin anymore. Again, this info is outdated.

Nor Russia (!), according to the very recent Bruce Ingleby's report "An assessment of different radiosonde types 2015/2016, ECMWF Technical Memorandum 807 (2017). We believe that fast-response hygristors are not yet completely outdated (e.g., GTS1-1 radiosonde).

Changes in the manuscript:

Where it reads:

Although the capacitive thin-film sensors have been widespread (with Vaisala radiosondes), two older sensor types are still in use: the carbon hygristor (in VIZ radiosondes) and the goldbeater's skin sensor, introduced in 1950s and still used in radiosondes made in Russia and China; this peculiar sensor responds too slowly to be useful at temperatures lower than –20 °C and suffers from hysteresis following exposure to low humidity (Nash, 2015; Moradi et al., 2013).

It will read

Although the capacitive thin-film sensors have been widespread (with Vaisala radiosondes RS80 and RS92) two old humidity sensor types continued in use for many years: the carbon hygristor (in VIZ/Sippican radiosondes, currently in disuse, and in the GTS1 radiosonde, in use in China) and the goldbeater's skin sensor introduced in 1950s and used in some radiosonde types made in Russia and China until a few years ago; this peculiar sensor responded too slowly to be useful at temperatures lower than –20 °C and suffered from hysteresis following exposure to low humidity (Nash, 2015; Moradi et al., 2013). For the current radiosonde types, see Ingleby (2017).

Addition to the reference list:

Ingleby, B. An Assessment of Different Radiosonde Types 2015/2016; ECMWF Technical Memorandum No. 807; European Centre for Medium Range Weather Forecasts: Reading, UK, 2017, http://www.gaia-clim.eu/system/files/publications/17551-assessment-different-radiosonde-types-20152016.pdf

6. P13, L3: 500 hPa threshold might be too high for high elevation sites. I think that it would be 300 hPa.

Yes, most likely. However, according to usual practice, we take 500 hPa as minimal requirement to estimate PWV for all stations. A very few studies have extended this upper limit to 400 hPa and even 300 hPa (without making any distinction between low and elevated stations). Evidently that turns out to be too restrictive for past radiosonde observation. For a first approach, we think it's necessary to pay more attention to the vertical resolution up to the 850-hPa level, since the estimation of PWV is known to be particularly sensible to the humidity profile in that region.

7. Fig. 4: Is decreasing of radiosondes stations in 35-65N due to reducing number of radiosonde launches in Europe given the budget constrain?

We really don´t know. The related trends at other latitudes, after 1990, seem more significant on a global perspective. A detailed analysis by country would probably give more information. However, this is out of the scope of the current analysis.