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Interactive comment on "Comparison of GNSS integrated water vapor and NWM reanalysis data over Central and South America" *by* Laura Isabel Fernández et al.

Anonymous Referee #1

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General Comments:

In this paper integrated water vapour (IWV) data from GNSS are compared to data from two numerical weather models (ERA-Interim from ECMWF and MERRA-2 from NASA). In this context, a correction for differences in surface geopotential heights is proposed and successfully applied. Except for some details mentioned below the methods used and the results of the comparisons are well described. My major concerns are related to the height correction as shown in the comments below.

1. Novelty of the correction approach and related results:

I think the application of a surface altitude correction is not new. It it commonly used e.g. in the satellite community if model data are taken as input for a retrieval. However, I must admit that I did not find a proper reference for this – it is (silently) assumed as obvious that such kind of correction is required. Furthermore, it is also obvious that structures smaller than the model spatial solution cannot be resolved and that therefore any correction will be less good in case of sea/land edges, small islands or large topographic changes within one model grid box.

2. Application of correction:
It should be explained why the correction is not applied to data with small height differences. In this case the correction should be small but still give an improvement, and it would not be necessary to have a (somewhat artificial) criterium on ΔZ to decide if the correction should be applied or not.

3. Definition of correction:
At several places in the manuscript it is mentioned that the correction for different surface geopotential heights is subtracted or added to the data depending on the sign of the height difference. It would be much clearer to have corrections with different signs and a fixed definition on how the correction is applied (either added or subtracted to IWV_{GNSS} or IWV_{NWM}). This would also be more consistent with the results (positive and negative differences) shown e.g. in Fig. 4.

4. Computation of correction (section 3.2):
As explained in section 3.2 the correction is derived from an integration of (interpolated) NWM profiles over the geopotential height difference range. Especially for smaller height differences this integration should depend on the vertical interpolation (or maybe even extrapolation) of the profiles. A good indication for a valid integration would be a comparison between the gridded IWV and the corresponding integral over q at a model grid point. Since for the correction q and T profiles are interpolated to the GNSS station position, why not determine the

IWV directly from the integral of q over height (starting at station height)? This would not require additional IWV grid information from the NWMs. This should be discussed.

5. Temporal interpolation:
   It seems that model data are only spatially interpolated to the locations of the GNSS stations. How are temporal differences handled? Are only GNSS data used close to the model grid times (assuming which maximum time difference)? How do temporal differences affect the results? Please explain.

Specific Comments:

1. p. 1, l. 22–23:
   "the correction procedure is not advisable either for a coastal station and/or stations in islands"

   Actually, islands are not specifically mentioned in the main part of the manuscript. This should be aligned.

2. p. 2, l. 22:
   "That is because of a misrepresentation of ECMWF analysis"

   This formulation is unclear. This sounds like the authors did something wrong in interpreting the ECMWF data which is probably not what is meant here. Please clarify.

3. p. 3, l. 21–22:
   "resulted from a geodetic process of (GPS + GLONASS) data"

   What is meant with "geodetic process" - please explain. Alternatively, you could remove this part of the sentence if you just refer to the data product from Bianchi et al. (2016a).

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4. p. 4, section 2.1: Also here the "geodetic process" is mentioned several times without explanation. Other formulations are unclear and terms remain unexplained, e.g. (l. 13): "The GNSS observations were processing at a double-difference level" or (l. 17–18): "The comparison of ZTD results shows the expected consistency between estimations from the homogeneous but independent analysis." What does the latter mean for the quality of the data product?

It seems that the authors use a previously published GNSS data product for the study. Therefore I suggest to reformulate this section such that it mainly refers to this underlying study and only explains the principle of the retrieval method and the basic properties of the data set (like temporal resolution, expected accuracy) without going into details.

5. p. 6, eq. 5:
What is the pressure calculated by this formula used for? Is it for the integration of q in eq. 6? The NWMs should also provide pressure (consistenly with q) - why are these data not used here? Is the lapse rate λ assumed to be independent from height? If yes, for which altitude range is this assumption valid?

6. p. 7, l. 22:
What is meant with "inter-annual averages"? Do you mean an average over the complete time series? Please clarify.

7. Section 4.1:
I suggest to add plots of the content from Table 2 (e.g. station vs. IWV$\pm$SD for the different data sets, possibly ΔZ vs. IWV) to facilitate the interpretation of the results.

8. p. 8, l. 8:
"model failures" is the wrong term here. You cannot expect from a model that it provides perfect results for points not on the model grid. Please reformulate.

9. p. 8, l. 9:
   "...the disagreement is the greatest for the stations classified as Critical"

   This statement is obvious, the sentence can be deleted.

10. p. 9, l. 29 (and eq. 5): Is δZ and ΔZ the same quantity? If not, explain the difference, otherwise adapt notation.

11. p. 10, l. 3:
    "MERRA-2 generally overestimates IWV_{GNSS}"

    Is this a new finding (in this case it should be emphasised more) or something already known (then give references)?

12. p. 18, Fig. 1:
    I think this figure is not absolutely necessary as it just visualises the bi-linear interpolation which is a standard method.

Technical Corrections:

1. p. 1, l. 22:
   grid point → grid points

2. p. 2, l. 3:
   Keyboards → Keywords

3. p. 4, l. 9:
   come → comes

4. Section 2.1.1 should probably be section 2.2

5. p. 8, l. 1:
   fulfill → fulfills

6. p. 8, l. 20:
   exceed → exceeds

7. p. 8, l. 23:
   better than a → better than

8. p. 8, l. 24:
   have to be added → has to be added

9. p. 21, Fig. 4:
   The y axis of the plots should be labelled (e.g. "IWV difference") and not only show a unit.