Responses to Referee #2

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As expressed in the title, the manuscript developed a dataset which contains high quality integrated water vapour dataset from 12,552 ground-based GPS stations in 2020. Such dataset provides better accuracy in IWV than the current operational GPS IWV dataset also provide by Nevada Geodetic Laboratory. The enhanced IWV have been validated by comparing with the ones given by the operational GPS IWV and with nearby Radiosonde-derived IWV. The error budget of enhanced IWV has been briefly discussed and the quality of the ERA5, which provides the weighted mean temperature and pressure for the conversion of ZWD to IWV, has also been validated by comparing with the RS data. Such dense network of enhanced IWV product is import to study both the temporal and spatial variations of the water vapour and is useful for a validation with IWVs given by other techniques. The manuscript is well written with a good structure. I would suggest that the manuscript should be published after a minor revision.

Reply: Thanks a lot for your comments. Our replies are shown with blue Arial font type. The related texts copied from the revised manuscript are shown with green Times New Roman font type.

Some minor comments:

1. Line 44: remove "precise". radiosonde-derived IWV suffers from errors caused by the sensor characteristics that vary in time and space. It is better here just saying Radiosondes can provide vertical distribution of water vapour.

Reply: Removed as suggested.

2. Line 69: “valule” → “value”

Reply: We modified it as follows:

An enhancement of NGL’s operational GPS IWV product will provide more accurate IWV estimates and thus **it can be more valuable** for many applications

3. Line 88: Are those constraints recommended by GipsyX? Are those values suitable for all stations since you are processing data globally? Can you comment on such issue.

Reply: In NGL’s current GPS data processing strategy, the constraints of ZWD and two horizontal gradient parameters are set as 3 and 0.3 mm $h^{-1/2}$, respectively. These constraint values are employed according to Bar-Sever et al. (1998). We acknowledge that the optimal constraint values can be diverse in different regions under different weather conditions. Hence, NGL is addressing this issue as presented by Young et al. in the AGU Fall Meeting in December 2022. It is reported that using a loosed ZWD constraint of 6 mm $h^{-1/2}$ can generally reduce the variability of global GPS stations’ vertical positions. Moreover, the variability of vertical positions

can be further reduced if the constrains are optimized individually for each station. It is therefore recommended to use station-specific optimal constraints of tropospheric delays in future.

We add the following sentences in the last paragraph of Section 6 Summary and outlook:

The GPS data processing strategy can also be further improved. For example, station-specific optimal constrains on the tropospheric delays and horizontal gradients can be applied to accommodate various weather conditions in different regions. Hence there will be a second-order enhancement of the IWV product. To do this goes beyond the scope of this work, but we suggest it as a promising extension of our investigation.

Reference:

Bar-Sever, Y. E., Kroger, P. M., and Borjesson, J. A.: Estimating horizontal gradients of tropospheric path delay with a single GPS receiver, Journal of Geophysical Research: Solid Earth, 103, 5019–5035, https://doi.org/10.1029/97JB03534, 1998.

Young Z., Blewitt G., and Kreemer C.: Application of Variable Random Walk Process Noise to Improve GPS Tropospheric Path Delay Estimation and Positioning at Local and Global Scales. https://agu.confex.com/agu/fm22/meetingapp.cgi/Paper/1162048. AGU Fall Meeting 2022 (Oral presentation).

4. Line 98: “three-dimensional station coordinates every 24 hours” → “daily three-dimensional station coordinates”

Reply: Modified as suggested.

5. Figure 1: In capital, “cyan” → “blue”

Reply: Modified as suggested. Moreover, in response to the comment from Frank Fell (Community), we divided the GPS stations into two subsets (coastal and inland stations) with a threshold of 20 km on their distances to sea. The coastal and inland GPS stations are displayed as blue and red dots in Fig. 1, respectively, as can be seen in our response to that comment.

6. Line 108: “distances” –> “differences”

Reply: We are sorry for the ambiguous description in the original manuscript, and we modified it as follows:

We blacklisted 57 stations as **the changes of their positions over time** were larger than 10 m in vertical or 100 m in horizontal.

7. Line 135: “IWV” → “ZTD”

Reply: Modified as suggested.

8. Line 154: "," → "."

Reply: Modified as suggested.

9. Line 196: remove "-"

Reply: Removed as suggested.

10. Figure 5: Use kgm^{-2} as the unit of IWV in the figure to be consistent to the rest parts of the manuscript.

Reply: Modified as suggested. As we added a figure in the revised manuscript, the original Figure 5 is changed to Figure 6 as below:

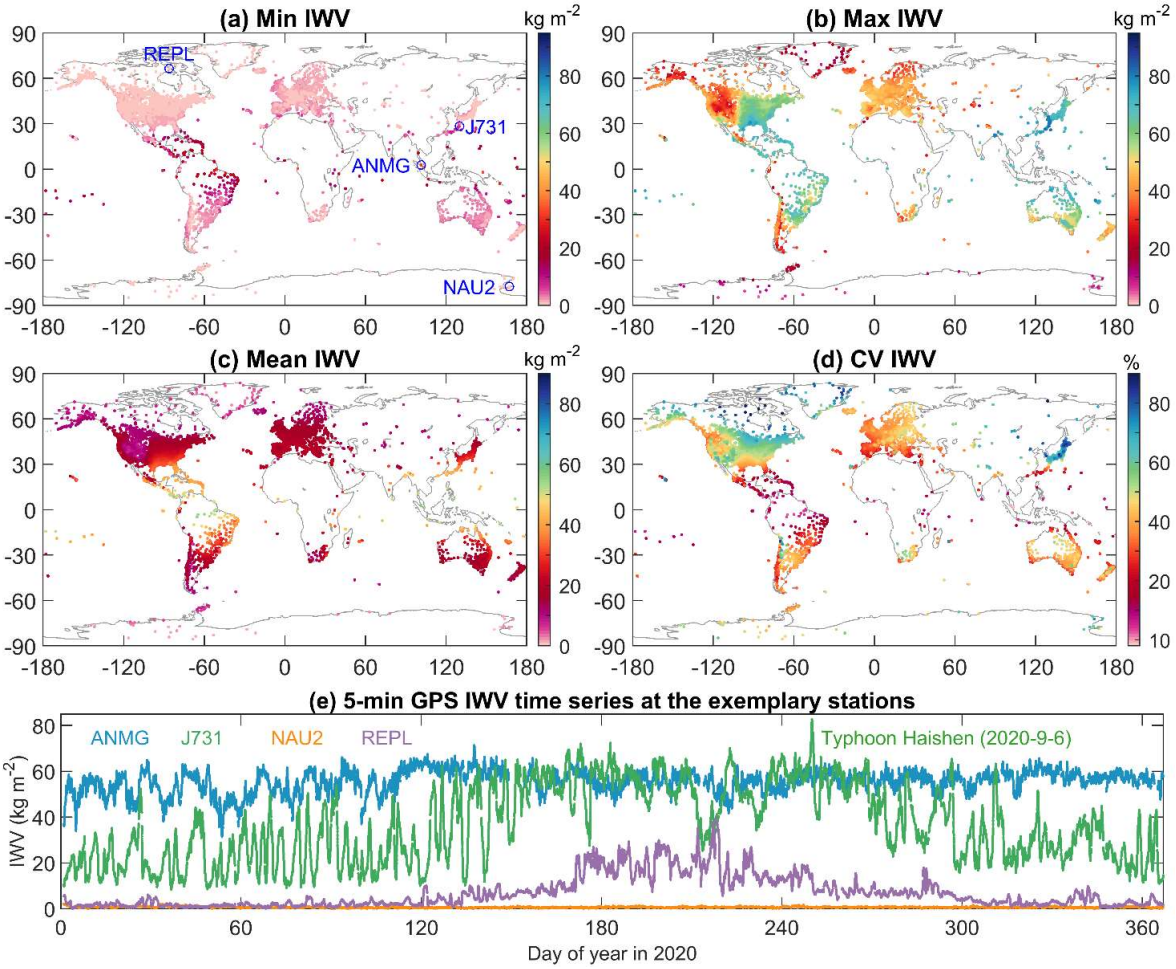

Figure 6. Minima (a), maxima (b), mean values (c), and coefficients of variations (d) of the 5-min enhanced GPS IWV time series in 2020 at 9,418 stations. (e) IWV time series of four exemplary stations.

11. Line 305: "weak" → "small"

Reply: Modified as suggested.

12. Line 309: “weak” → “small”

Reply: Modified as suggested.

13. Line 317: “have” → “has”

Reply: Modified as suggested.

14. Line 318: Change to “1 mm ZHD bias can result in a IWV bias ranging from 0.12 to 0.17 kgm^{-2} ”

Reply: Modified as suggested.