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Interactive comment on "A comparison between the GNSS tomography technique and the WRF model in retrieving 3D wet refractivity field in Hong Kong" *by* Zhaohui Xiong et al.

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Response to Reviewer #1:

Q1: lines 46-51: I agree that 1) the least squares scheme or the Kalman filter scheme with additional constraints or using a priori information and 2) the algebraic reconstruction algorithm or similar methods are the main ways to get the results of the tomographic inversion, but the GNSS WV tomography methods quite a bit more than the tomographic inversion. The methods to establish the tomographic region, and then to divide up this region by tomographic voxels or tomographic nodes are also very important for improving the tomographic model. For completeness, it would be of great

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benefit to the readers to say something about the other aspects of the tomographic method except the tomographic inversion.

ResponseïijŽThanks for the suggestion. We added the literature review about other aspects of the tomographic method, including voxel division, the usage of virtual reference stations, and using the rays coming from the side face of the tomography area. The details are as follows (copied from lines 51-54): “Besides the algorithm improvement, some scientists tried to optimize the voxel division (Chen and Liu, 2014) or use virtual reference stations (Adavi and Mashhadi-Hossainali, 2014) or use additional GNSS rays (Zhao and Yao, 2017) to increase the effective GNSS rays and thus improve the tomography results.”

Q2: lines 85-96: I think that the process of the GNSS data does not need to be described in such detail. The parameter settings for Bernese 5.0 software can be presented by a table in the appendix. It may not be appropriate to devote much space in the main body of the paper.

Response: According to Reviewer’s suggestion, we moved the description about the process of the GNSS data and the reconstruction of SWD to Appendix A. See lines 91 and 296-308.

Q3: lines 103-104: Do I understand it correctly that the settings of the horizontal resolution and the number of the vertical layers are defined manually? If I understand it correctly then I am not clear the actual resolutions both in horizontal and vertical of the input data. I think it would be better to provide more information about the input data.

Response: Yes, the settings of the horizontal resolution and the number of the vertical layers should be defined manually. The main input data is the ECMWF ERA-interim reanalysis whose nominal resolution is 0.125° but actual resolution is 0.75°. This has been clarified in line 102.

Q4: line 122: Are you sure that the unit of specific humidity is kg/kg.

Response: It is g/g, we have corrected it in line 114.

Q5: section 3.2: Although a reference to GNSS tomography is useful, how to achieve this also an important content for readers in this paper. The detail information about the process of the GNSS tomography is needed to add.

Response: As suggested, we have added the detailed description about our GNSS tomography algorithm in lines 148-178.

Q6: lines: 128-130: Priori information, as the initialization parameters, is the main part of the tomographic model. Line 144 shows that the background data (ECMWF ERA Interim Data) has been used in WRF preprocessing system. Some background data as NWM fields or even standard atmosphere water vapor distribution can also be used in GNSS tomography. So I think it would be better to increase a set of experiments for the GNSS tomography with the priori information (GTPI). It would be interesting to compare the results from GTPI with other experiments which were conducted in the paper.

Response: The tomography model does not necessarily depend on a priori information. The core idea of our tomography algorithm is free of a priori information (not count the constraints) and we try to make tomography algorithm an independent technique to retrieve 3D wet refractivity field. If a priori information from NWM is used, the solution will be highly correlated with the NWM data. The WRFDA output is also largely determined by the background data (also NWM data). Consequently, the tomography solution and WRFDA output will be correlated. If we make such a comparison (tomography with NWM vs. WRFDA output), it will be unfair and less meaningful. We have clarified this in lines 144-145. In addition, the NWM data has a very coarse resolution (even the latest ERA-5 data have a horizontal resolution of $\sim$30 km, basically one grid node covers our research area), which means it cannot reflect the water vapor distribution within our research area. Base on the above reasons, we choose not to do such a comparison.

Q7: lines: 139-140: You state that the reanalysis results and the radiosonde observation are interpolated to the centers of the associated tomography voxels. I am a little bit surprised by this statement. The radiosonde (RS) data are used to validate the WR derived from GNSS tomography and reanalysis in this paper. Therefore, you should avoid adjusting the original data of RS. The other reason is that the RS data also exists the potential error. Comparison of the tomographic results with corresponding interpolation results of the RS may increase the influence of RS error due to insufficient results of the comparison. To get more reliable and complete results, it would be nice to interpolate the results of GNSS tomography and reanalysis to the position of the RS. On the one hand, can you explain how did you unify the units of the layers between the reanalysis and the GNSS tomography? You don't provide any information about it. I mean that the atmosphere is vertically divided into 45 layers by different pressure for the reanalysis (in line 104). However, for the GNSS tomography, the troposphere is vertically divided into 13 layers with a constant thickness of 800 meters (in line 131). It should be followed by one paragraph description of the method to unify the units.

Response: Thank you for your suggestion. In the vertical troposphere, the tomography model has only 13 layers whose vertical resolution is only 800 m while the radiosonde has a vertical resolution of ~23 layers from 0 km to 10 km height. It means that the radiosonde data have a much better vertical resolution than the tomography results. Therefore, we think interpolating the dense radiosonde data to the sparse tomography layers in the vertical direction would be more accurate. We show the original radiosonde profiles in Figures 4 and 5 now. We convert the pressure levels to geopotential height by NCL. The heights of the tomography layers are converted to normal height. We neglect the slight difference between the geopotential height and normal height. By these efforts, we unify the units of the layers and make the different results comparable. This has been clarified in lines 182-189.

Q8: line 222: "time points" is not suitable for this case. The inversion of the tomographic WR needs GNSS data during a specific period of time. It's more like epochs than time

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points.

Response: Thank you for your suggestion. And we replaced the “time points” with “epochs” in the manuscript.

Q9: lines 229-230: The average DA-ZTD and DA-Tomo may not suit for this case. It would be better to use Mean Absolute Error (MAE) instead of the average. MAE can avoid the canceling effect of the positive and negative values.

Response: Thank you for your suggestion. Actually, the DA-ZTD and DA-Tomo are MAE in the manuscript. This has been clarified in lines 271, 275-276 in the manuscript.

Q10: lines 238-241: I am not sure that the rainy period and the rainless period present a striking contrast. Even in the rainy period, the WR derived from GNSS tomography and reanalysis only at the specific period (i.e., 0:00 and 12:00 UTC daily), at which it may not rain.

Response: Thank you for your suggestion. We replaced the ’rainy’ with ’wet’ in the manuscript. During July 20 to 26, it did not keep rainning all the time, but it was really wet. And the wet and dry (rainless) period indeed show different vertical distribution of the water vapor.

Please also note the supplement to this comment:
https://www.ann-geophys-discuss.net/angeo-2018-84/angeo-2018-84-AC4-supplement.pdf

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