Responses to Referee #1

We thank the referee #1 for the insightful comments and constructive suggestions. We have addressed all their comments in the revised manuscript. Below are our responses to the referee's critical comments (*Italics*). The page and line numbers in our responses refer to those in the revised manuscript.

a. Function-based tomography is the direct calculation of water vapor density using signal delays at arbitrary points and it is independent of the voxel-based method. In this paper, the voxel-based tomography has been used to model the water vapor density at each voxel and water vapor density has not been calculated directly at arbitrary points. Therefore, the use of the phrases "function based model" or "function based tomography" is not correct.

Authors: Thanks for the reviewer's reminding, the phrases "function-based model" and "function-based tomography" in our new proposed model has been revised and deleted. The title has changed into "An improved pixel-based water vapor tomography model". Only the future work of the function-based tomography model in the conclusion part has been preserved in this paper. These phrases has been revised throughout the manuscript.

b. Why did not authors use the function based method directly and without voxel-based tomography? In other words, why the slant tropospheric delay (SWD) of the signals is not considered as a function of the geographical location?

Authors: Thanks for the reviewer's question, to our knowledge, since the tropospheric tomography has been proposed, there are few pure function-based water vapor tomography models in the previous research. It's too challenging to obtain the water vapor density directly from the slant tropospheric delay of the signals so far. In this paper we just try to find out if the function part could be used in the tropospheric tomography model. As now the results of this paper turn out to be good, in the near future we will dedicate ourselves to building the pure function-based water vapor tomography model, which would consider the SWD of signals as a function of the geographical location.

c. In this paper, the polynomial function is used for interpolation. This interpolation method causes fluctuations between interpolation points. Due to the small size of the study area, these fluctuations increase the error of interpolation results between interpolation points. In these cases, other interpolation functions or method with less variation between interpolation points could be used.

Authors: Thanks for the reviewer's reminding, however, as for the function part of the interpolation method, we did try some other interpolation methods using the 1stOpt (First Optimization) software in previous preparations for the experiments. The results of other interpolation methods were similar with or a little worse than that of the polynomial function. Since the Hong Kong Satellite Positioning Reference Station Network (SatRef) is a flat GNSS network (Zhang et al., 2017), there is no large difference in tomography results between the polynomial function and other interpolation methods while the polynomial function has the easier and more convenient expression. So in this paper we choose the polynomial function for the interpolation.

Reference: Zhang Bao, Fan Qingbiao*, Yao Yibin, Xu Caijun and Li Xingxing. An Improved

Tomography Approach Based on Adaptive Smoothing and Ground Meteorological Observations. Remote Sensing, 2017, 9, 886, DOI:10.3390/rs9090886.

d. In order to show the efficiency of the proposed method, it is better to give the map of water vapor density from voxel-based tomography and from the paper method.
Authors: Thanks for the reviewer's reminding, the maps of water vapor density from the traditional tomography model and the proposed tomography model have been presented (Page 10, Line 332, Lines 338-340; Page 11, Figure 2).

e. Due to the presence of the radiosonde station in the study area, it is necessary to compare the results of voxel-based tomography and result of the paper method with radiosonde observations to show that the proposed method in this paper is more efficient than voxel-based tomography.
Authors: Thanks for the reviewer's suggestion, the water vapor comparison with radiosonde data section has been added. The comparison results showed that the proposed tomography model was not as good as the traditional tomography model on RMSE and we analyzed the reasons. The main reason could be due to systematic differences between the training source ECMWF data and the radiosonde data as well as the location of the radiosonde station being close to the HKSC GNSS station, leading to the voxels for the location of the radiosonde station having GNSS rays penetration, which is not suitable for the improved tomography model to show its good advantage in the scenario of voxels without GNSS rays penetration. However, the water vapor profiles of the improved model almost match that of the traditional model (Page 17, Figure 6), indicating that the improved model still has the advantage of the convenient and efficient expression (Page 1, Lines 29-30; Page 10, Lines 315-317; Page 16, Line 457 to Page 17, Line 490; Page 18, Lines 503-504).

f. In this paper, many self-citations have been used. Also, in the introduction section authors did not refer to the new and valid articles, which used new techniques in different steps of tomography such as choosing the best dimensions for Voxels, Applying 3d ray tracing, using AIRS measurements, for example: "HajiAghajany, S., Amerian, Y. (2017). Three-dimensional ray tracing technique for tropospheric water vapor tomography using GPS measurements. Journal of Atmospheric and Solar-Terrestrial Physics, Volume 164, 2017, Pages 81-88. "
Authors: Thanks for the reviewer's reminding, the introduction section has been rewritten. Some self-citations were deleted and the paper of Haji Aghajany, S. and Amerian, Y. was cited. Besides, we added some new and valid articles for reference in the introduction section (Page 2, Line 54, Lines 67-72).

*g. The first and appropriate references for virtual stations topics are the follows: * Vollath U, Buecherl A, Landau H, Pagels C, Wager B (2000) Multibase RTK positioning using virtual reference stations.In: Paper presented at the Proceedings 13th International Technical Meeting of the Satellite Division of the US Institute of Navigation, ION GPS-2000, Salt Lake City, September, 19–22. * Marel H-v-d (1998) Virtual GPS reference stations in the Netherlands. In: Paper presented at the Proc 11th International Technical Meeting of the Satellite Division of the US Institute of Navigation, ION GPS-98, Nashville, TN, September 15–*

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Authors: Thanks for the reviewer's reminding, the references for virtual stations topics as you suggested have been rewritten (Page 2, Lines 72-74).