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Atmospheric Measurement Techniques Discussions

Interactive comment on "Tropospheric profiles of wet refractivity and humidity from the combination of remote sensing datasets and measurements on the ground" *by* F. Hurter and O. Maier

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The paper "Tropospheric profiles of wet refractivity and humidity from combination of remote sensing datasets and measurements on the ground" by F. Hurter and O. Maier presents interesting rigorous approach to fuse data stemming from various sources. The neat mathematical description of the fusion problem by means of collocation with special emphasis on proper handling of the correlation between observations have to be highly appreciated. This paper is a result of cross discipline understanding and a good example on how to bridge a gap between geodesy and meteorology.

Despite high standard of the presented work, authors have not discussed several major issues linked with weather prediction, GNSS meteorology and data fusion:

1. My understanding of fusion is that the fused data set should has all strengths of each data set combined and inherit limited noise, providing there is no bias in the original data set. This is very ambitious target, however it might not be feasible to apply in real world meteorological networks where the systematic errors are of unknown magnitude and need to be removed before incorporating the data into the observation system. Therefore my concern in regards to the fusion is that it might not be in position to replace the assimilation systems currently present in the Numerical Weather Prediction systems. The basic difference between assimilation and fusion would be that fusion finds optimal state between observations while assimilation finds solution that agrees the most with the background model state. This actually prevents introducing new systematic errors. Would it be interesting to know authors opinion as to how address this issue. Maybe, post processing of NWP outputs in particular for severe weather events is a solution to obatain short term forecasts?

2. I was reading the paper twice trying to pick up how authors are taking into account the fact that not all of the observations are taken in the same time and have different latency (GPS RO, radiosonde, ground-based GNSS, automatic weather stations). The analysed parameters (ZWD, e, p) have the deterministic part as

well as stochastic part time dependent, that is true but what is the time resolution of the collocation is unclear to me. In this regard the Kalman filter seems to be bit more applicable. The reason why I would choose to use Kalman filter instead of fitting procedure (collocation) is that it would allow me to use all the elements of covariance matrices (15,16), as a measurement and process noise. Moreover, the clear time step procedure of Kalman filter will help to address the issue with latency and non time collocated measurements, additionally the short term prediction would be available from Kalman filter, the question remains if the quality would be comparable to the one obtained from extrapolation of collocation field.

3. In the discussion section authors compare the solution obtained from collocation to the GNSS tomography, concluding that the same accuracy has been demonstrated for both methods. Therefore, authors question the applicability of tomography principle and use of slant GNSS observation instead propose to use only zenith integrated values. I have to agree that tomography solution could carry very little information if use with to many constraints. What I can't agree is the pointless of using slant delays, there are couple of very good reasons to use it:

   (a) The azimuthal non homogeneity will manifest itself especially priori severe weather conditions and this information might become essential for proper now casting of severe weather event. I would rather encourage authors to apply slant observation in their collocation software, however there would be modifications needed in the equation (9). The figure 6 shows clearly that the collocation is not performing well especially in the height around 2km and during summer months on the Northern Hemisphere. This is the time when there is much more water vapour present in troposphere (carried in mid latitudes by weather fronts). In contrary to the collaction results, tomography at precisely this height and with this type of events perfoms best. The AWATOS2 model, developed at the ETH Zurich, proved to be very effective

in estimating the storm surge in Victoria, Australia (Manning et al., 2012), showing all synoptic and mesoscale features of Mesoscale Convective System.

   (b) The tomography models in generally suffers from over constraining that is used as a remedy for unconditioness and ill possedness of the inverse problem. However, the use of unconstrained model (Rohm, 2013) with strict observations selection policy (Robust Kalman Filter) produces results with an accuracy of 5-6 mm/km (paper submitted to ANGEO). Simulations suggests that the accuracy of tomography retrieval might be even 5 times better (1 mm/km) (Rohm and Bosy, 2009), but in order to achieve that high quality of results the noise in the input observations should be 0.001 mm. The question remains if this is achievable.

   (c) The tomography models might be improved with RO measurements that goes across vertical domain of tomography model and therefore improve the geometry of the problem. Therefore, I believe there is still a room for further development of tomography models.

I admit that this paper is important achievement in the field of geodesy and meteorology, the methodology applied, especially in regards to the covariance matrices is very effective. I'm looking forward to future works of authors showing impacts of slant observations and possible conversion of their methodology to Kalman filter (e.g. Zeng and Zhang (2010)). I agree that usually tomography suffers from over constraining, however in the severe weather conditions the tomography models could be quite useful. The unconstrained tomography method is feasible to produce accurate results without additional artificial parameters, which makes it competitve to the models currently used.

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