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GNSS tropospheric tomography in Near-Real Time mode as a valuable data source for Numerical Weather Prediction models

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GNSS tropospheric tomography is a technique that aims to obtain spatial distribution of wet refractivity in the lower atmosphere based on satellite signal delay. These estimates, strictly related to the water vapor amount in atmosphere, can be assimilated in Numerical Weather Prediction (NWP) models. These observations are very valuable for the weather prediction process. Water vapor amount in the troposphere is one of the most important factors forming weather conditions. Moreover it is highly variable in time and space, thus should be monitored with high spatio-temporal resolution. Vertical distribution of the water vapor in the atmosphere is usually obtained by balloon-based radiosonde sounding. This approach is very common, but also expensive. Spatial and temporal resolutions of these measurements are rather poor in comparison to the NWP models. In contrast, resolution of the GNSS tomography can be similar to the NWP models with no additional costs, especially on the areas equipped with well-developed GNSS stations networks. Previous studies on GNSS tomography indicates that the accuracy of the results is satisfactory and might be applied in meteorology.

Tropospheric tomography is a very promising technique for the weather prediction because of the slant satellite observations utilization – Slant Wet Delays (SWD) or Slant Integrated Water Vapor (SIWV). Due to the slant trajectories of the GNSS signals crossing atmosphere and tomography inverse processing the vertical profiles of humidity can be estimated. In this study an effort was made to meet two major preconditions for tomographic data assimilation in NWP: 1) adjusting tomography model to near-real time (NRT) observation and 2) reaching required accuracy of the solution. Moreover the first attempt of assimilation tomographic data in NWP model was made using refractivity profile operator (GPS_REF).

GNSS tomography model $TOMO_2$ was adjusted to use NRT troposphere observation by using predicted orbits, ZTDs and gradients from NRT GNSS estimation, WRF forecasts as an first guess in selected parts of the model. The results were compared with the Weather Research and Forecasting (WRF) model in order to determine if tropospheric tomography in NRT mode is a technique that could find application in assimilation to NWP models. Verification was based on comparison with meteorological observations from the Universal Rawinsonde Observation Program (RAOB) stations. The results show that the root mean square error (RMSE) of the $TOMO_2$ solution in the lower troposphere (altitude below 5250 m) is 11.53 ppm for wet refractivity and 1.66 gm 3 for water vapor density. The same errors for WRF model are 14.34 ppm and 2.12 gm 3. For higher altitudes (5250 – 12000 m) RMSE for tomography are 3.70 ppm and 0.58 gm 3, for WRF model 1.63 ppm and 0.23 gm 3. Due to the results obtained, GNSS tomography in NRT mode could find application in assimilation to NWP models for the altitudes below 5250 m. First attempt of assimilation tomographic data in WRF model show that assimilation leads to changes in the wind field, temperature and humidity.