Assimilation of GNSS tomography products into WRF using radio occultation data assimilation operator

Natalia Dymarska[1], Gregor Möller[1], Estera Trzcina[2], Witold Rohm[2], Robert Weber[1], Johannes Böhm[1]
[1]Department of Geodesy and Geoinformation, TU Wien, Vienna, 1040, Austria
[2]Institute of Geodesy and Geoinformatics, Wroclaw University of Environmental and Life Sciences, Wroclaw, 50-357, Poland

ABSTRACT

The Global Navigation Satellite Systems (GNSS) can be used to determine accurate and high-frequency atmospheric parameters in all-weather conditions. In the last years GNSS tomography development was focused on numerical methods to stabilize the solution, which has been achieved to a great extent. Our previous trials showed that tomography outputs can be assimilated into the Weather Research and Forecasting Data Assimilation model, using its three-dimensional variational assimilation (WRFDA 3DVar) system. In this study, GNSS tomography was performed by two models (TU Wien, WUELS) within the area of Central Europe during the period of 29 May - 14 June 2013, when heavy precipitation events were observed. An assimilation of the tomography refractivity in the nested domain over Europe (12- and 36-km resolution) is investigated.

GNSS TOMOGRAPHY

GNSS troposphere tomography is a novel technique that takes advantage of Slant Wet Delay (SWD) observations between GNSS receivers and satellites, traces these signals through the 3D grid of voxels and estimates by an inversion process the wet refractivity or the water vapour content within each voxel.

Tomography models	• ATom (TU Wien) • TOMO2 (WUELS)
Domain	• horizontal resolution 0.5°x0.5° • 15 vertical layers (up to 13 km)
Period	• 29 May - 14 June 2013 • time resolution of 6 hours

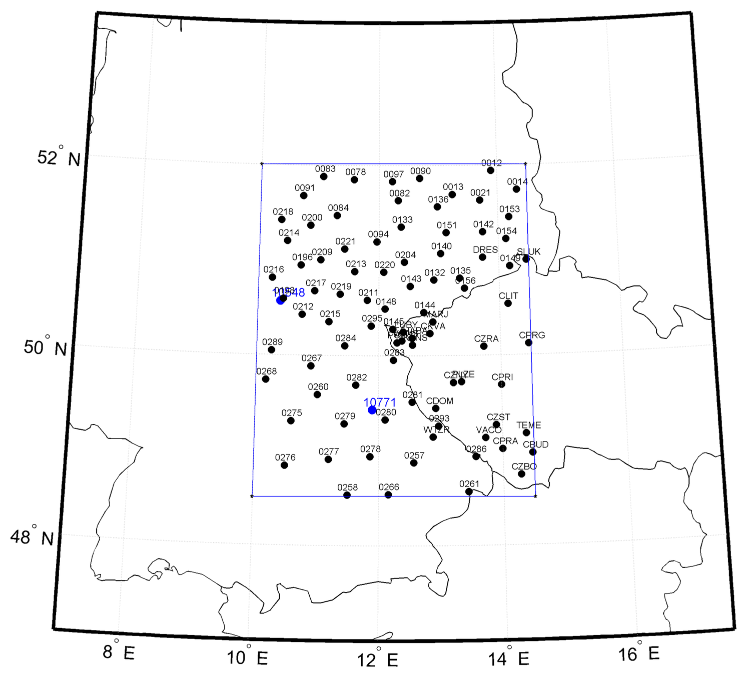

Figure 1: Location of GNSS stations in the tomographic domain.

SWD computation

SWD observations were computed in the following steps:

- Zenith Total Delays (ZTD) and horizontal gradients (GN, GE) provided by Geodetic Observatory Pecny (GOP) for 72 GNSS sites
- Removing of the Zenith Hydrostatic Delay (ZHD) computed by means of Saastamoinen model from ZTD estimates

$$ZWD = ZTD - ZHD$$

- Mapping of the ZWD, GN and GE observations into direction of the GPS and GLONASS satellites using VMF1 (for ZWD) and Chen and Herring (for GN and GE) mapping functions

$$SWD = ZWD \cdot mf_w(\varepsilon) + G_N \cdot m_{az}(\varepsilon) \cdot \cos(\alpha) + \\ + G_E \cdot m_{az}(\varepsilon) \cdot \sin(\alpha)$$

The resulting dataset of SWDs is hereafter referred to 'set0', whereas 'set1' compensates for hydrostatic anisotropic effects.

Intercomparison between results from two models shows agreement in most of domain, with discrepancies of about 10 ppm for some voxels in the lower parts (fig. 2). Additionally, comparison with external data was made, using ZWD derived from GNSS (fig. 3) and wet refractivity vertical profiles from radiosonde data (fig. 4).

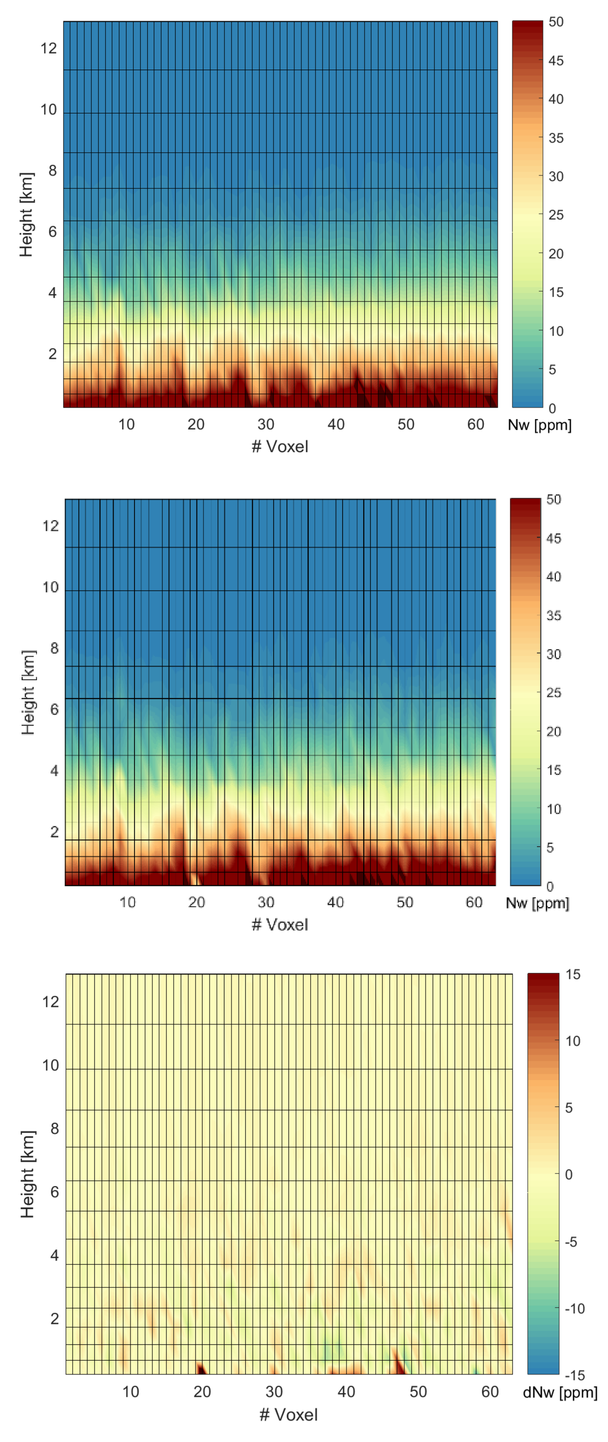

Figure 2: Wet refractivity fields (set1) and differences, as obtained for the 29th of May 2013, 18 UTC. From top to bottom: TU Wien set1, WUELS set1 and their differences (TUWien minus WUELS).

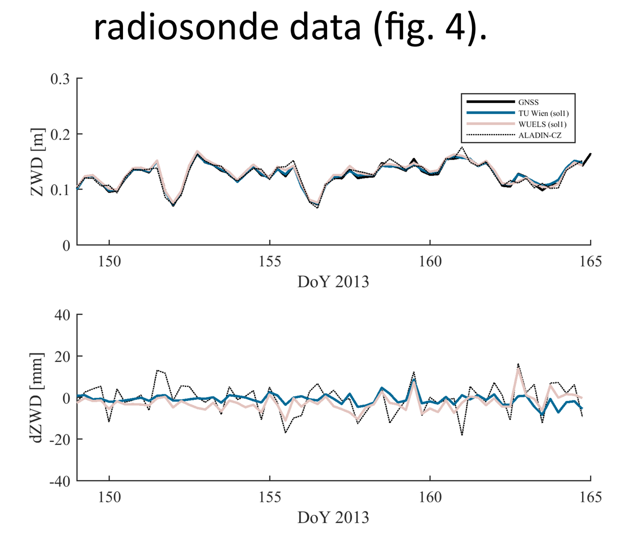

Figure 3: GNSS derived ZWD and integrated ZWD times series at GNSS site WTZR. The top plot shows the absolute values and the bottom plot highlights the ZWD differences with respect to the GNSS derived ZWDs.

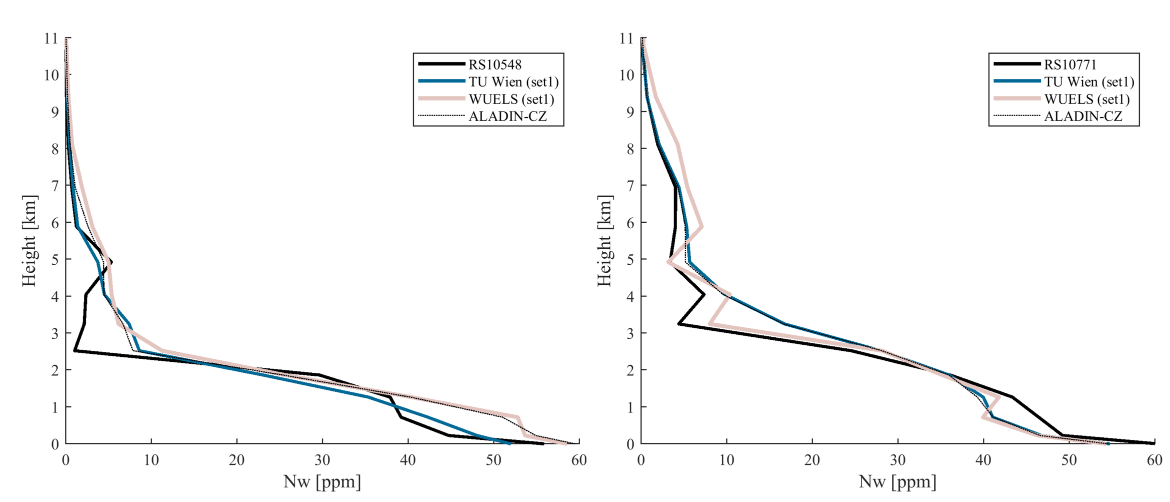

Figure 4: Wet refractivity profiles derived from radiosonde launches, ALADIN-CZ 6 hour forecast data, TU Wien and WUELS tomography solution 1 for 6th of June 2013, 12 UTC (left) and 13th of June 2013, 00 UTC (right), respectively.

WRF ASSIMILATION

WRF SETTINGS

Forecast	
Forecast length	24 (an assimilation at 6 hour of the forecast)
Forecast period	2013-05-29 00 – 2013-06-14 23
Grid size in x/y axis	70/80 (parent), 55/58 (nested)
Resolution of the grid in x/y axis	36 km (parent), 12 km (nested)
Vertical dimension	35
Assimilation	
System	WRFDA 3DVar
Window	1 hour
Time	00, 06, 12, 18 UTC (6 hours after forecast run)

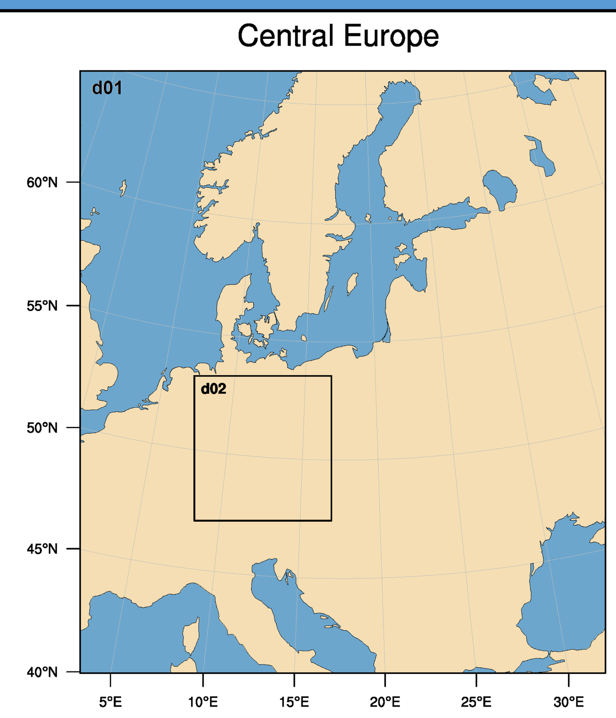

Figure 5: WRF domains location.

ASSIMILATION RESULTS

In order to check an impact of wet refractivity fields assimilation, we conducted several comparisons. This study presents results for 1st of June 2013. Total precipitation fields from both runs (TU Wien, WUELS) are shown on fig. 6. Other meteorological parameters, such as wind components, water vapor mixing ratio, and temperature are presented on fig. 7. Vertical profiles of wet refractivity, calculated from radiosonde observations data, tomography outputs, and forecast 6 hours after assimilation have been shown on fig. 8.

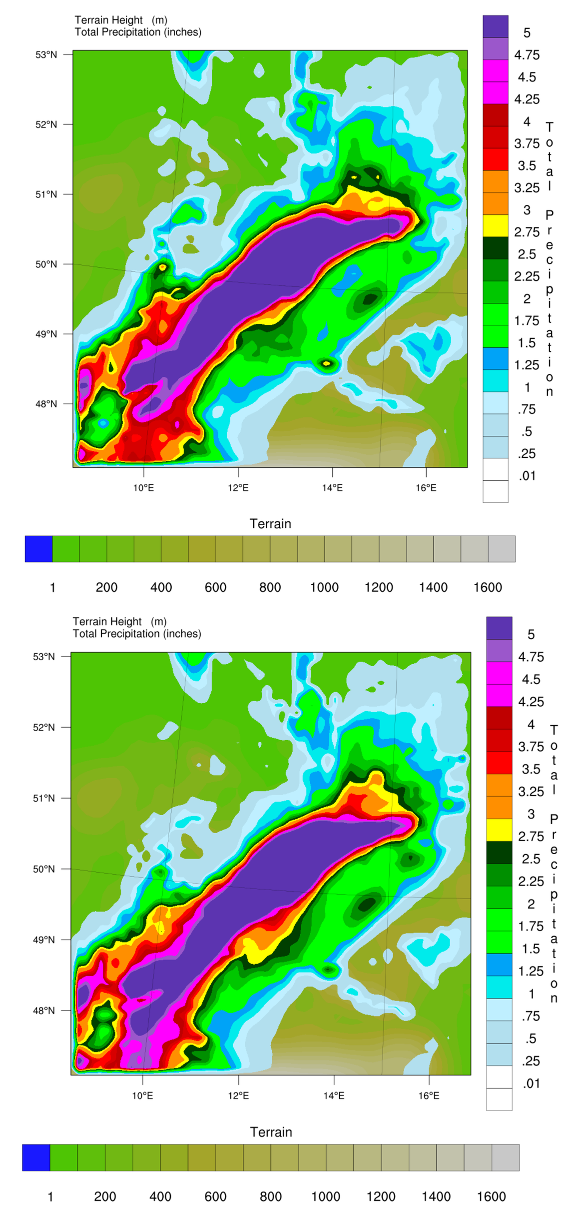

Figure 6: Total precipitation in the nested domain, as obtained for the 1st of June 2013, 12 UTC, i.e. 6 hours after assimilation of Nw estimated by TU Wien set1 (top) and WUELS set1 (bottom).

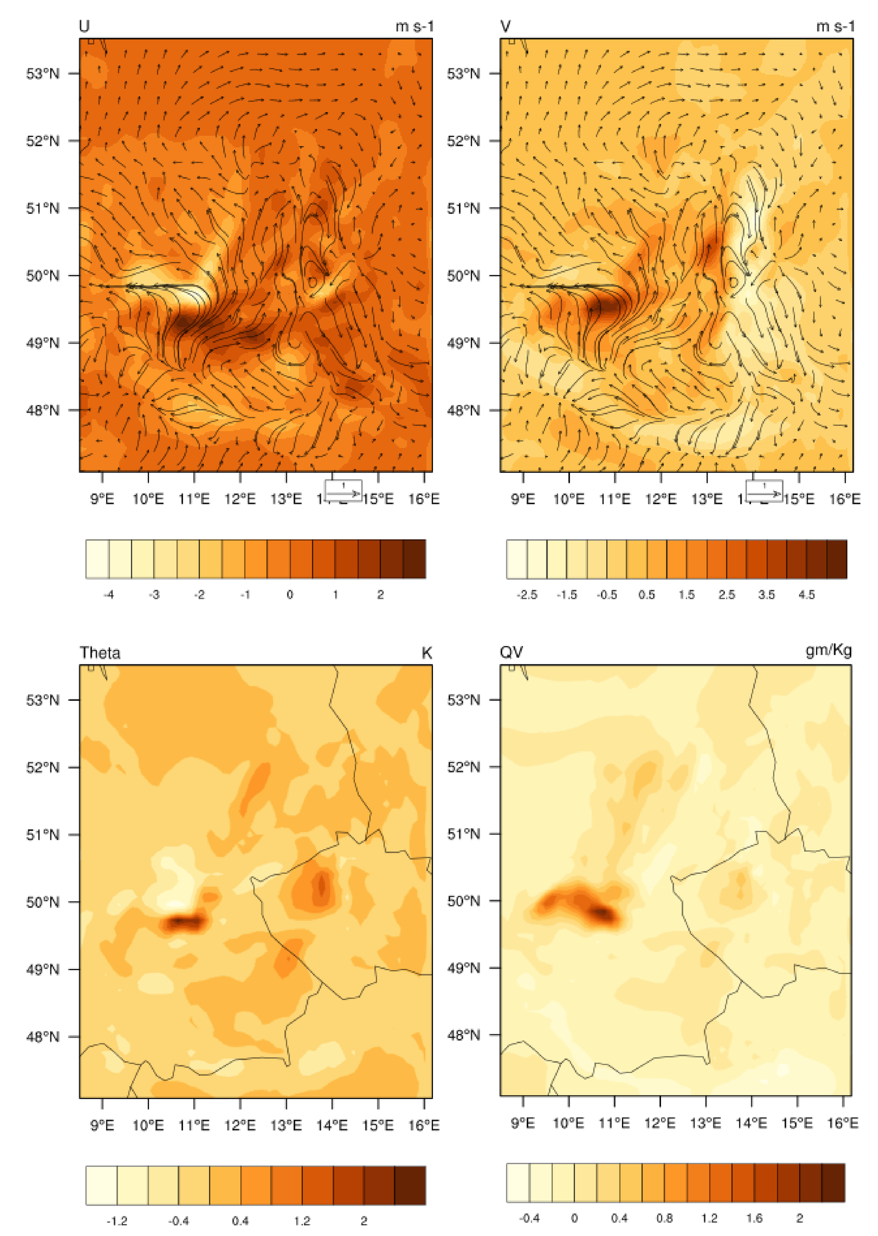

Figure 7: Horizontal cross-section of differences (TU Wien minus WUELS) at sigma level 11, for wind components (top), temperature (Theta, left-low corner), and water vapor mixing ratio (QV, right-low corner) in the nested domain, as obtained for the 1st of June 2013, 12 UTC, i.e. 6 hours after Nw assimilation.

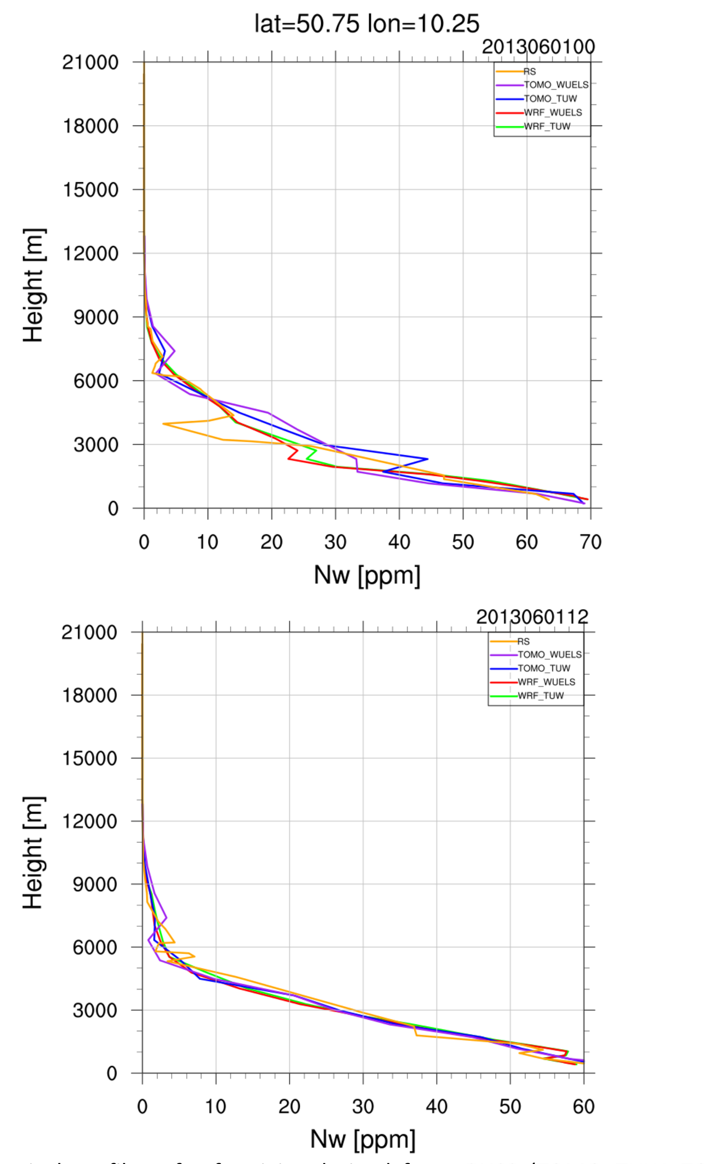

Figure 8: Vertical profiles of refractivity derived from GNSS (TOMO_TUW, TOMO_WUELS), radiosonde launches, and WRF forecasts (6 hours after assimilation, WRF_TUW, WRF_WUELS), as obtained for the 1st of June 2013, 00 and 12 UTC .

SUMMARY

In this study we conducted the GNSS troposphere tomography for the area of Central Europe. Wet refractivity fields have been estimated in the period of 29th of May and 14th of June, 2013. The comparison between two tomography models (TU Wien and WUELS) reveals the high level of constistancy of both solutions. Some small discrepencies of about 10 ppm can be seen mainly in the lower part of the domain. The GNSS troposphere tomography results have been assimilated into the nested domain of WRF model, using its data assimilation (WRFDA) system. Because of the vartical character of wet refractivity observations (3D data), the assimilation was performed using the GPSREF observation operator. Presented results show that there are only slight differences between the weather forecasts after both tomography output assimilation. However, the assimilation of the tomography products is complex as this procedure requires a proper characterisation of the observation errors. Future improvements to the assimilation method are discussed.