Interactive comment on "The use of GNSS zenith total delays in operational AROME/Hungary 3D-Var over a Central European domain" by Máté Mile et al.

We would like to thank referee #2 for his/her valuable suggestions. In the following, you will find our responses, separately for each comment/concern. We are confident, that we can provide a revised version of the manuscript, which is trying to address all of your points.

In black: referee observations
In blue: our response

Anonymous Referee #2

This paper presents the results on the impact studies of assimilating GNSS ZTD observations together with conventional observations, radar reflectivities and Doppler winds, and radiances from satellites with an experimental AROME/Hungary system over a domain in central Europe for two periods. The pre-processing, the description of the experiments , and the results are explained in detail. And the impact shown seems to be consistent with previous published studies. My recommendation is to accept the publication once minor modifications suggested below are taken into account:
- A map of the GNSS stations coverage before and after the 20km thinning could be recommended to include.
The figure of NWP domain and orography is replaced by figure 1 below which includes all GNSS stations inside the NWP domain as well.

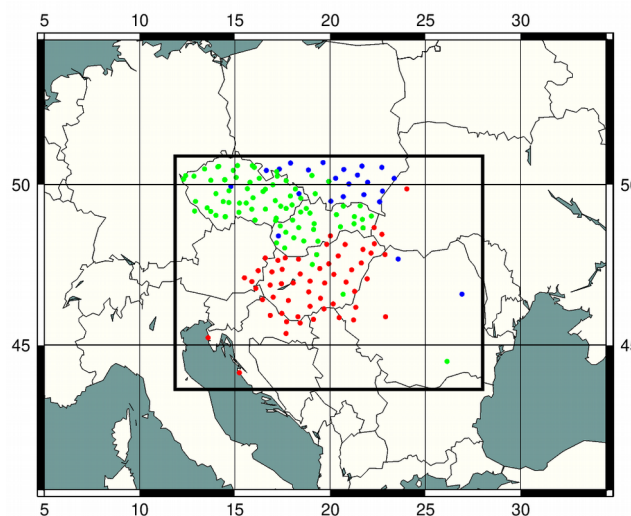
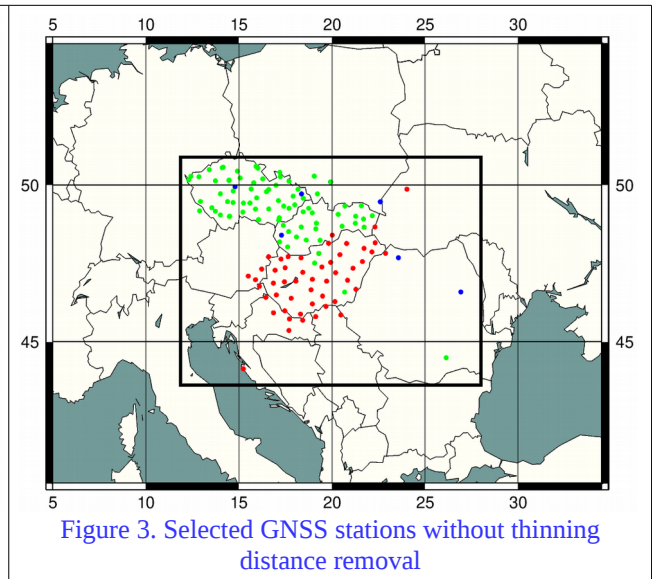
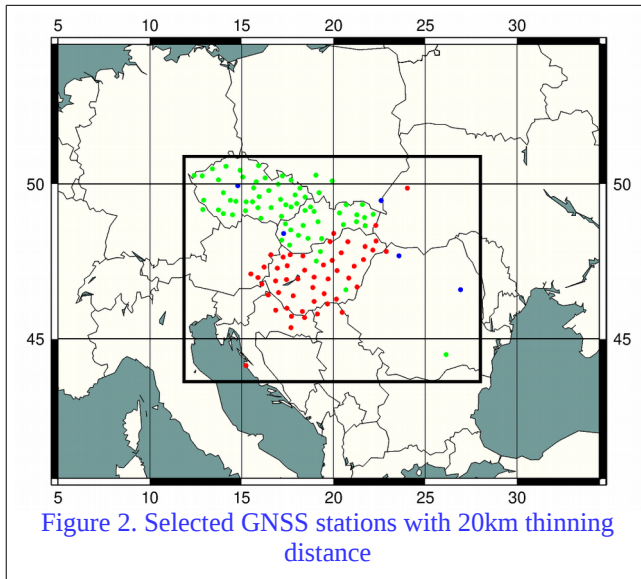



Figure 1. All GNSS stations inside the AROME/Hungary's NWP model

Another figure is added to the manuscript which shows the selected stations with 20km thinning distance (see figure 2 below). Furthermore a third figure (figure 3 below) is prepared (but not inserted to the manuscript for the time being) which shows reliable stations without 20km thinning. The biggest differences between figure 2 and 3 can be observed over Czech Republic (e.g. around Prague). If the reviewer can agree, we would like to propose putting only the first and the second figures which show the stations before and after the pre-selection procedure. The third figure – we believe – can be less illustrative for a reader.

Figure 2. Selected GNSS stations with 20km thinning distance

Figure 3. Selected GNSS stations without thinning distance removal

- As it is well explained in this study, the winter period has been carried out without the previous adaptation of the bias coefficients and then the impact is more neutral. It could be reconsidered here the possibility to include a study of these bias values in the period itself to check if they have already stabilized, as it is suggested in the text, or even if it is necessary to include this period in this work due to showing the impact of assimilating GNSS ZTD observations and also the impact of using variational or static bias corrections (as Sanchez-Arriola et al. 2017) with the domain and nwp system selected might be enough.

Due to the observation error and bias were not updated for winter assimilation runs, it is difficult to make clear conclusion from the winter OSE's verification scores. Therefore, we agree to remove this winter impact study from the manuscript (in accordance with the reviewer's comment). The related results were criticized by other reviewers as well. Additionally, we would like to propose to add one more verification result (dew point temperature forecast) to the summer trial which also indicates the significant improvement of the GNSS ZTD assimilation.

Other suggestions are:
P1L2: replace "numerial" by "numerical"
Replaced.
P1L4: replace "ZTDs" by "ZTD"
Replaced.
P1L8: replace "ZTDs" by "ZTD"
Replaced.
P2L33: You may probably have forgotten to add the TOUGH
(Targeting Optimal Use of GPS Humidity Measurements in Meteorology) Project in
the list that took place just after COST 716 and before EGVAP (http://tough.dmi.dk/)
Added.
P3L10: replace "ZTDs" by "ZTD"
Replaced.
P3L16: replace "ES1206" by "COST ES1206"
Replaced.
P3L22: replace "Applied" by "Description of the"
Replaced.
P3L27: replace "Meso-NH(?)" by "Meso-NH (Lac et al., 2018)"
Replaced. Another reference was also added.

Lafore, J.-P., Stein, J., Asencio, N., Bougeault, P., Ducrocq, V., Duron, J., Fischer, C., Héreil, P., Mascart, P., Masson, V., Pinty, J. P., Redelsperger, J. L., Richard, E., Vilà-Guerau de Arellano, J.: The Meso-NH atmospheric simulation system. Part I: Adiabatic formulation and control simulations. Ann. Geophys., 16, 90–109., 1997.

P3L50: Assimilated satellite observations could be more explained

The satellite and RADAR observations were assimilated only for DFS diagnostic purposes and those non-conventional observations were not taken into account in GNSS ZTD OSEs. It is now explained in the manuscript more clearly. The use of satellite observations in DFS diagnostic is also explained with more details in the text.

"The non-conventional satellite and RADAR observations were added to AROME experimental analyses solely for diagnostic study and they were not considered in the GNSS ZTD observing system experiments."

P4L18: replace "COST Action ES-1206" by " COST ES1206"

Replaced.

P4L35: replace "ZTDs" by "ZTD"

Replaced.

P5L5: replace "station multiplication " by "stations that are processed by more than one Analysis Centre"

Replaced. "Considering that particular stations can be processed by several analysis centre (we can call it station multiplication) that station/processing centre pair is selected which has the smallest standard deviation of OMF."

P5L10: replace "consist 197" by "consist of 197"

Replaced.

P7L25: Figure 7 could be a little bit more explained.

One more sentence is added about bias results and the result of dew point temperature is also mentioned here.

"For these surface parameters the error reduction with respect to the reference during the first 6 hours in AROME forecast is apparent by the use of ZTD observations with both static and variational bias correction. Nevertheless, the temperature bias is slightly overestimated, but dew point temperature and relative humidity bias are remained more or less the same for short forecast ranges. The most important is that the error reduction is statistically significant for the short-, very short-range ..."

P7L: replace "consist 197" by "consist of 197" Cannot Figure 9 and Figure 10 be after Figure8 and before the Conclusions?

Replaced. The manuscript was compiled by Latex editor with "amtd" document class. The figure's location is more or less determined by Latex software. The current version is only for review process and for discussion (e.g. one column template), therefore the position of figures can be changed later.