Assimilation of zenith total delays in the AROME France convective scale model: a recent assessment

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Abstract

The Zenith Total Delay (ZTD) derived from Global Navigation Satellite Systems (GNSS) observations is increasingly assimilated in numerical weather prediction (NWP) models worldwide. This helps to improve the knowledge of the initial state of the atmosphere and subsequent forecasts. The convective scale NWP model AROME is operational at Méteo-France since December 2008. It has a resolution of 2.5 km and uses the three-dimensional variational (3-D) data assimilation scheme with a Rapid Update Cycle (RUC) of 3 hours.

This study presents a recent assessment of the impact of assimilation of the GNSS ZTD observations into the AROME 3-D var model. Two data assimilation experiments have been performed for a recent summer period of July 18, 2013 to August 20, 2013. The first experiment uses the ZTD from the stations centered within the AROME domain while the second experiment involves an additional dataset provided by the University of Luxembourg and is assimilated into E-GVAP. The network of stations processed by UL contains stations located all over Europe with a densification over Luxembourg and the Greater Region. Figure 1 shows the Europe-wide network of GNSS stations processed by the E-GVAP analysis centers.

At Méteo-France, a convective permitting NWP model AROME is operational since December 2008. The model has a three-dimensional variational (3-D) data assimilation system with a Rapid Update Cycle (RUC) of 3 hours and a dedicated background error covariance matrix allowing assimilation of data at mesoscale. The AROME domain covers a significant part of Western Europe. The horizontal resolution is 2.5 km on a Lambert projection centered at 46.4° North and 2.2° East with 750 and 720 physical grid points in the east-west and north-south directions respectively. The domain is vertically divided in 60 layers with the center of the uppermost layer located at 1 hPa. Figure 2 shows the domain of the AROME model. The colored dots in Figure 2 show the GNSS stations processed by various E-GVAP analysis centers used for the assimilation of ZTD in AROME.

The goal of this study is twofold. First, a recent assessment of the impact of assimilation of GNSS ZTD in the current version of the operational 3-D variance data assimilation system for the AROME model (which has undergone various upgrades and improvements since the past assessment studies) has been provided. The second impact of increasing the GNSS network through the addition of the UL01 solution has been examined.

Impact Assessment

The impact assessment of GNSS ZTD assimilation was carried out in two parts i.e. studying the impact on the model analysis and studying the impact on model forecasts.

Impact on Analysis

Figure 4 shows the distributions of the analysis difference (the difference from the equivalent without the GNSS ZTD assimilation) for the first guess departures for 12 h after the ZTD and the model equivalent ZTD computed from the 3-hour AROME forecast for the whole period of the experiment. The a priori data selection allows the first guess departures to follow a Gaussian distribution (which is an underlying hypothesis of the data assimilation optimisation). Then E-GVAP experiments outside three standard deviations are considered as outliers and rejected from what is called a “background check”. When more than one processing center is available for a given station, the choice is made on the one that is using the best statistics available in the “white list”.

Figure 4(a) and 4(b) show the distributions of analysis and first-guess departures, respectively, of all the ZTD observations from both the operational EGVAP solutions whereas Figures 4(c) and 4(d) show the distribution of analysis and first-guess departures, respectively, of ZTD observations from only the UL01 solution. It could be seen that the UL01 solution’s analysis and first-guess departures follow a Gaussian distribution and that the distribution is ‘more standard’ (i.e., higher relative impact) after assimilation showing that the 3-D var has brought the model state closer to the ZTD observations. Even though the shape of the distribution is smoother with the EGVAP solution since the sample is larger than that of UL01, the means and standard deviations are very close to each other. Therefore the 3-D var system behaves the same way for assimilating ZTD EGVAP or UL01.

Impact on Forecast

Forecast scores were computed from the three experiments to study the effect of assimilating various GPS ZTD datasets on atmospheric forecasts for the period of July 18, 2013 to August 20, 2013. Figure 5 shows the bias and the standard deviation of the forecast scores for 2-meter temperature and Figure 6 shows the bias for 2-meter relative humidity averaged over the whole domain of the AROME model. The scores have been computed by comparing the forecasts to a dedicated 2-meter analysis using surface observations from SYNOP and RADOME networks. It shows that both are very close but rather neutral. The GPS ZTD data seems to slightly bias the bias in relative humidity but increases the bias in temperature. The impact of assimilating UL01 ZTD observations in addition to EGVAP is either neutral or slightly negative.

Conclusions

An impact assessment of the assimilation of GPS derived ZTD observations in the AROME 3-D var NWP model was conducted by experiments without GPS ZTD assimilation, with the assimilation of operational EGVAP ZTD solutions, and with the assimilation of ZTD observations from UL01 in addition to EGVAP solutions.

The analysis and first-guess departures of the ZTD observations selected for assimilation from the UL01 solution were found to be almost unbiased and following a Gaussian distribution comparable to the ZTD EGVAP data and in agreement with underlying hypotheses of the 3-D var assimilation system. The mean and standard deviation of the analysis departures of UL01 ZTD was found to be slightly higher than those of the EGVAP only solution. From the three assimilation experiments, 3-h forecasts of the AROME model were run. Forecast scores for 2-meter temperature and 2-meter relative humidity were computed over the whole domain and rather neutral results were found. The GPS ZTD data seems to slightly reduce the bias in relative humidity but increases the bias in temperature. The assimilation of UL01 ZTD observations in addition to EGVAP solutions seems to have either a neutral or relative impact on the forecast scores. These preliminary forecast scores will be complemented by precipitation scores for specific severe weather events that took place during the period.

Methodology

This study has been conducted by performing three forecast experiments using the AROME 3-D var NWP model for the period of July 18 – August 20, 2013. Table 1 shows some characteristics of these experiments.

<table>
<thead>
<tr>
<th>Experiment Name</th>
<th>NCOGPS</th>
<th>EGVAP</th>
<th>UL01</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNSS Networks Used for ZTD Assimilation</td>
<td>E-GVAP Operational Solutions only</td>
<td>E-GVAP Operational Solutions</td>
<td>UL01 Test Solution</td>
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The experiment without the assimilation of GNSS ZTD observations was performed to serve as a baseline for the experiments in which GNSS ZTD assimilation was conducted and to provide a recent impact assessment of assimilating GNSS ZTD in the AROME 3-D var model. The two experiments with the GPS ZTD assimilation were performed for studying the impact of assimilating the ZTD estimates from the UL01 solution in addition to the operational EGVAP ZTD solutions. From the output of these three experiments, various parameters were extracted and statistic for the computations between those were calculated.

Figure 3 shows the flowchart for the EGVAP and UL01 experiments i.e. the experiments in which GNSS ZTD data has been assimilated.

References

4) http://demosciences.meteo-france.fr/

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