Assimilation of GNSS ZTD with HARMONIE

J. Sánchez[1], S. Thorsteinsson[2], M. Lindskog[3] and H. Vedel[4]

[1]AEMET, Santander, Spain

[2]Icelandic Meteorological Office, Reykjavik, Iceland

[3]Swedish Meteorological and Hydrological Institute, Norrköping, Sweden

[4]Danish Meteorological Institute, Copenhagen, Denmark

Background

HARMONIE upper-air humidity data assimilation

The HARMONIE km-scale forecasting system is running daily at several HIRLAM institutes. The main components are the data assimilation system and the forecast model. The data assimilation system consists of one for surface properties and one for upper-air. The default upper-air data assimilation is based on 3-dimensional variational data assimilation, with conventional types of observations assimilated with a 3 h data assimilation cycle. Multivariate background error statistics are derived from ECMWF Ensemble Data Assimilation (EDA), downscaled with the HARMONIE km-scale model. The only direct humidity measurements are provided by vertical profile measurements from radiosondes and 2 m relative humidity measurements from SYNOP stations. Since an accurate initial humidity model state is important for short range prediction of detailed weather, an enhanced usage of humidity observations is aimed for.

Utilization of GNSS observations in HARMONIE

Zenith Total Delay (ZTD) observations obtained from a ground-based network of Global Navigation Satellite System (GNSS) receivers contains spatially dense information on the total columnar amount of water vapor. These observations are furthermore available with a temporal resolution up to fifteen minutes. The HARMONIE system has been prepared for assimilation of these types of observations. The observation handling system includes data selection, bias correction, quality control and data assimilation (in particular GNSS ZTD observation operator). Either a static bias correction or an adoptive variational bias correction (VarBC) (Dee, 2005), utilizing a constant offset value as predictor, can be applied.

Model Setup for 3D-Var tuning and Experiments

To evaluate the meteorological impact of the GNSS ZTD observations in HARMONIE cy38h1beta3, three extended parallel data assimilation and forecast experiments have been carried out over a domain covering the Iberian peninsula (Fig. 1). The time period of the experiment was from 1 to 30 of September and with a two-week spin-up period before that. Data assimilation system and the forecast model were run within a 3 h data assimilation cycle and forecasts up to+36 h were launched 4 times a day. For lateral boundary conditions hourly ECMWF forecasts were used. Conventional types of observations were derived from the ECMWF MARS archive, and GNSS ZTD observations were from the EUMETNET E-GVAP program data archive (Fig 1). The three parallel experiments, summarized below, were different only in observations used and bias correction methods applied:

- Upper-air data assimilation with conventional observations (CRL).
- Upper-air data assimilation with conventional observations and GNSS ZTD observations using static bias correction (STA).
- Upper-air data assimilation with conventional observations and GNSS ZTD observations using ZTD VarBC (VBC).

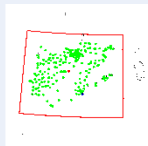

Fig. 1. Iberian peninsula model domain (red frame) and horizontal position of GNSS ZTD observations (green dots) used. Red and blue dot represents horizontal positions of GNSS station for which a single observation impact study has been carried out (red) and for which functionality of VarBC (blue) is demonstrated

Results

Single Observation Impact Study

To illustrate how a ZTD observation modifies the background state a single observation impact experiment has been carried out. The single observation was located in the inner part of Spain (40.5˚N/3.1˚W, red dot in Fig. 1), and the observed ZTD was 24 mm higher than the corresponding background value. The main impact is on the specific humidity field of the model state, but there is also a weak impact on other model variables. This influence is due to the ZTD GNSS observation operator and due to the background error statistics. The resulting horizontal and vertical spread of the ZTD observation on the specific humidity field is illustrated in Fig. 2. The current system give rather large weight to the GNSS ZTD observations and the observation minus analysis departure is 5 mm.

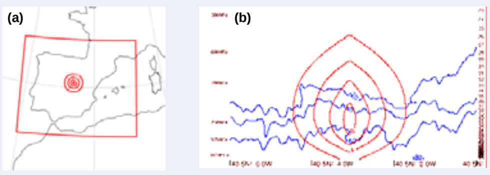

Fig. 2. Impact of single GNSS ZTD observation 236 mm higher than the background value on model specific humidity field (unit: kg/kg times 10000). Both horizontal distribution of impact at the 850 hPa level (a) and vertical/horizontal distribution of impact along a cross-section from 40.5˚N/6˚W to 40.5˚N/0˚W (b) is shown. Red iso-lines are for analysis increments and blue for the background state.

Variational Bias Correction

The functionality of the variational bias correction is illustrated by a showing the time-evolution of observation and background counterparts for one particular station (37.6˚N/0.7˚W, blue dot in Fig. 1) during the spin-up phase, when GNSS ZTD observations enter the system in passive mode only. Fig 3. demonstrates that the VarBC removes bias of observation with a adaptively time of roughly 10 days.

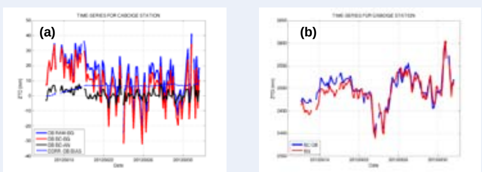

Fig. 3. Time-series from CABOIGE_ GNSS ZTD station. (a): Observation minus background departure before and after bias correction of observation, estimated observation bias to be corrected and bias corrected observation minus analysis departure. (b): Bias corrected observation and model state background equivalent. (unit: mm).

Verification Scores of Parallel Experiment

Verification scores of the three HARMONIE (cy38h1beta3) parallel experiments carried out on the ECMWF computing system ecgb/c2a are shown for the last 15 days of the run. The impact of assimilating ZTD GNSS observations and the impact of using the two bias corrections schemes is evaluated.

For most model variables, impact of GNSS ZTD data is slightly negative but there is a significant day to day variation (Fig. 4a) and for some cases there is a clear positive impact from GNSS ZTD data. For precipitation data we however find a neutral to slightly positive impact of GNSS ZTD data, as can be seen on Kuiper Skill Score plot for 12h accumulated precipitation (Fig.4b)

Further studies are ongoing with an enchained system with regard to tuning of error statistics and observation bias correction and observation thinning.

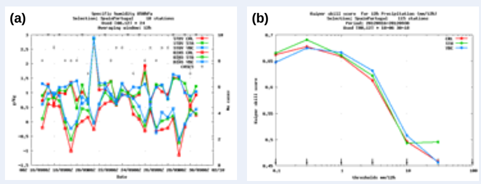

Fig. 4. Day to day verification of specific humidity forecasts (unit: g/kg) for 850hPa against 10 stations over Spain-Portugal area (a), and verification of 12 h accumulated precipitation forecast by the Kuiper Skill Score using 115 SYNOP stations over Spain and Portugal ,both figures for 16-30 September 2012.
Red curve is for CRL, green curve for STA and blue for VBC.

Conclusions & Future work

- Extended data assimilation experiments evaluating the potential impact of of ZTD GNSS observations have been carried out over an Iberian domain.
- First results are neutral to slightly negative but further experiments with and enhanced system is ongoing.

References

Dee D. 2005. Bias and data assimilation. *Q J. R. Soc. Meteorol. Soc.*, **131**: 3323-3343.

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