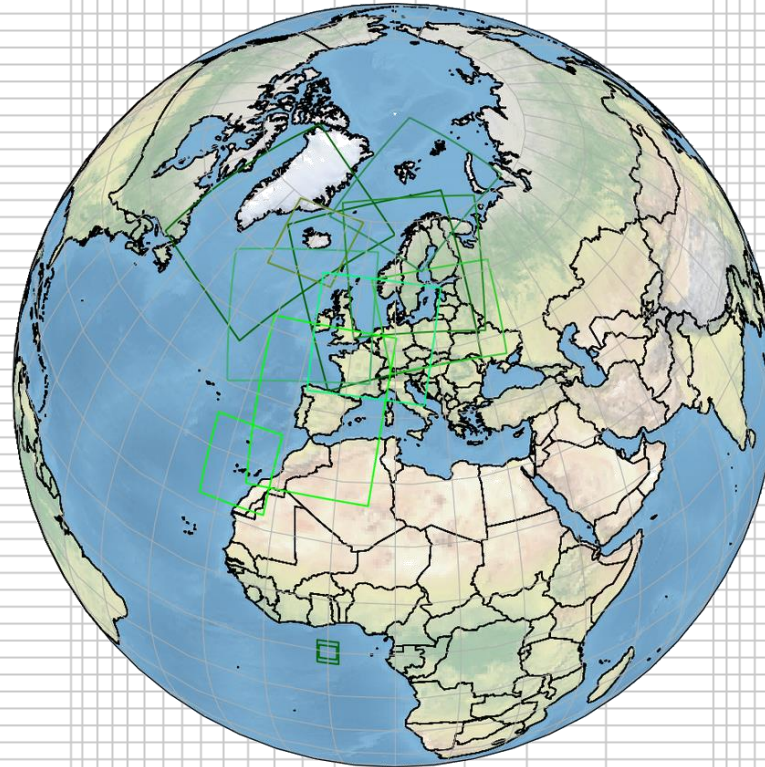


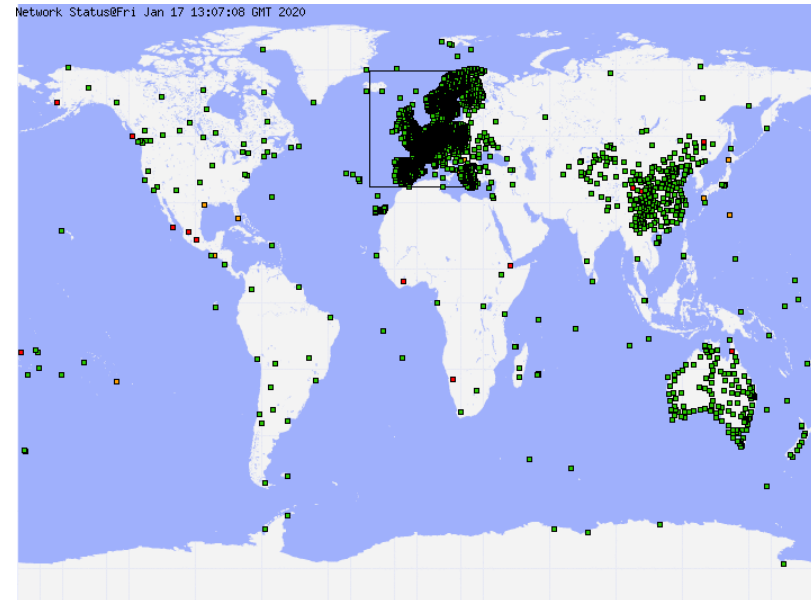
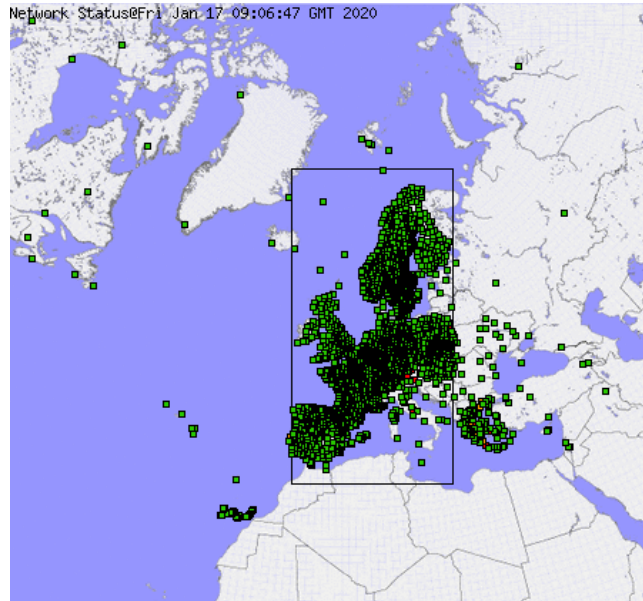
Impact of ground-based GNSS in HARMONIE-AROME



WMO 7th Workshop on the impact of various observing systems on NWP

Magnus Lindskog, Jana Sánchez Arriola, Henrik Vedel,
Siebren de Haan, Roger Randriamampianina, Martin Ridal
Ynvild Sauge, Sigurdur Thorsteinsson

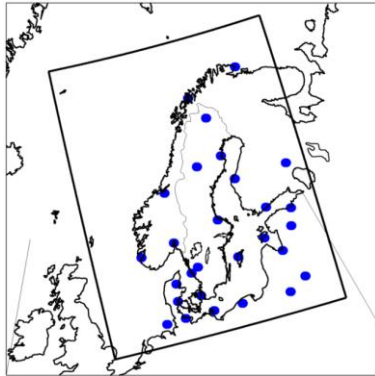
- **Ground-based GNSS data**
- **Model results**
- **Conclusions and future plans**



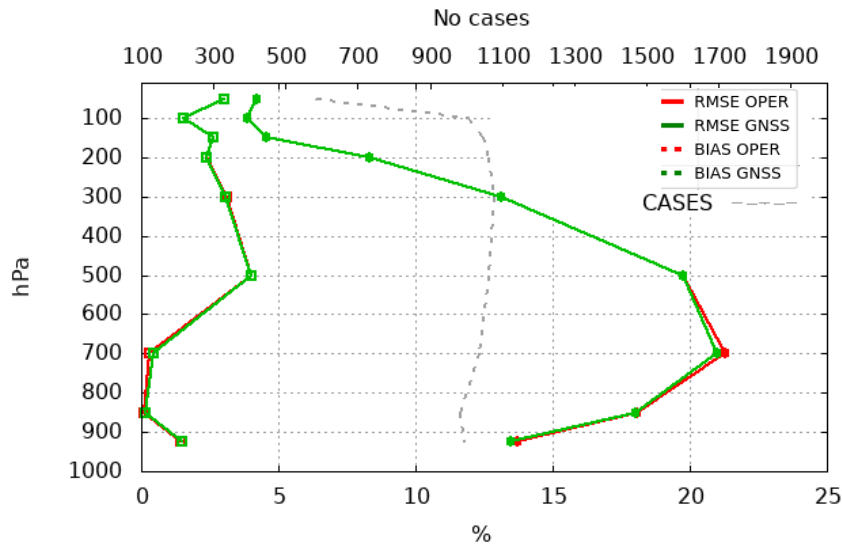
- E-GVAP (EUMETNET GNSS Water Vapour programme) gather ZTDs (Zenith Total Delays) estimated from raw ground-based GNSS data, mainly owned and processed by geodetic institutions.
- Most ZTD data are uploaded hourly, with a timeliness of about 90 min.
- Sub-hourly ZTD uploads are being introduced for rapid update NWP and nowcasting. Enable timeliness down to about 10-15 min.
- Operational data are available via GTS – distributed by UK Met Office in BUFR format. All data are available via institute specific password restricted ftp in a simple ascii format.
- Future enhancements include distribution of additional information that can be derived from the same basic GNSS measurements: ZTD gradients and Slant Total Delays (STD) towards individual GNSS satellites.

Further info: <http://egvap.dmi.dk> egvap@dmı.dk

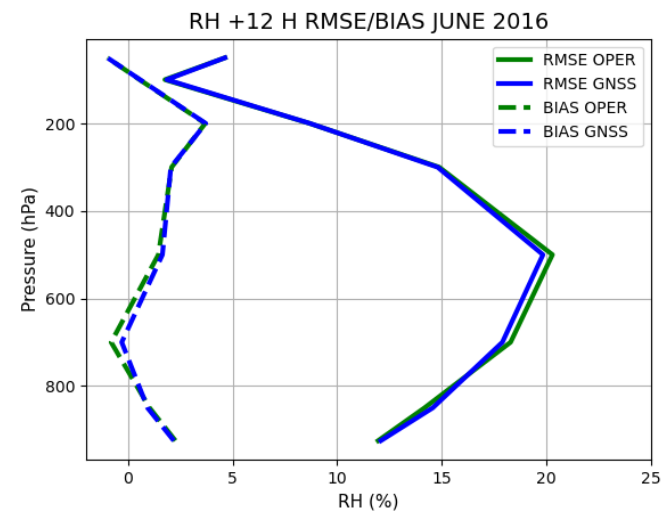
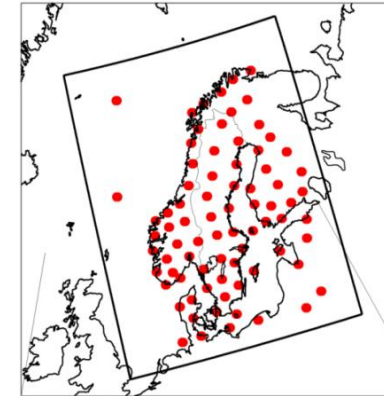
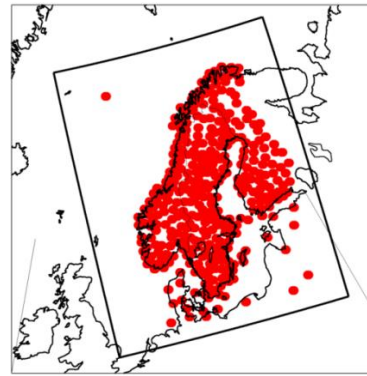
Pos. impact impact of GNSS ZTD on humidity, cloud and precipitation forecasts.



15 stations Selection: ALL
Relative Humidity Period: 20141218-20150113
Used {00,12} + 12 24

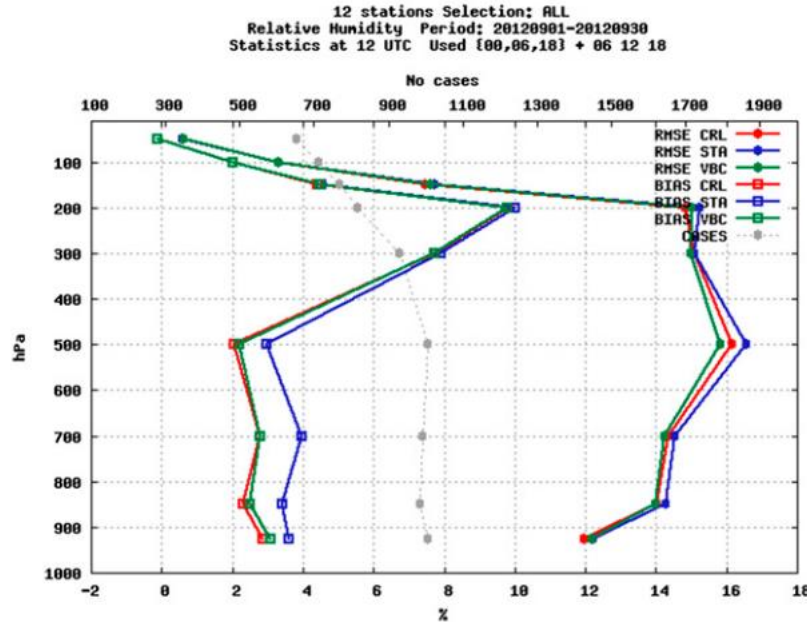
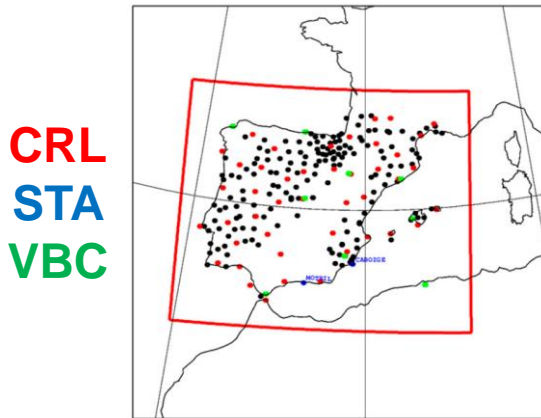


Impact enhanced when adding more GNSS ZTD observations until ~50 km



On the importance of bias correction

Static versus adaptive



Adaptive variational bias correction gives better results than static.

Adding one more VARBC predictor

OFFSET
OFFSET+1000-300 thickness
OFFSET+TCWV

$$\mathbf{b}(\beta, \mathbf{x}) = \sum_{i=0}^{N_p} \beta_i \mathbf{p}_i(\mathbf{x})$$

No improvements from adding one more predictor.

Impact of adding other observations: Iberia radar reflectivity+gnss

3 experiments:

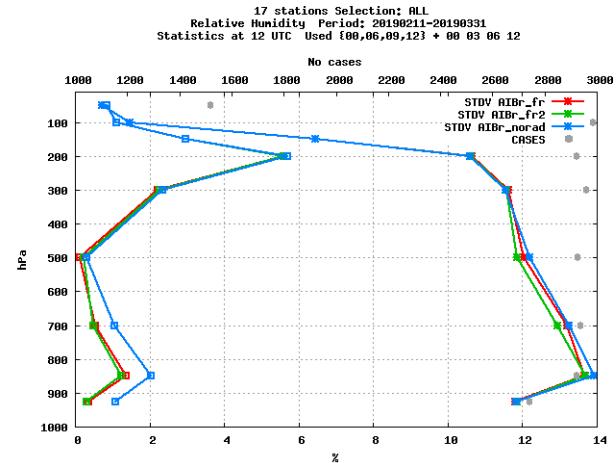
AIBr_norad: NO RADAR,
sigmao_gnss=20mm

AIBr_fr: radar reflectivities,
sigmao_gnss=20mm

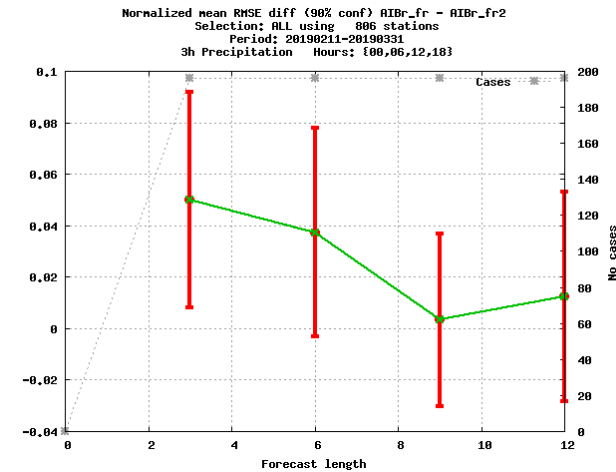
AIBr_fr2: radar reflectivities,
sigmao_gnss=30mm

Scores for precip and humidity related variables improve when radar reflectivity is introduced and even more if the weight of gnss is decreased (fr2)

AIB_fr2 less bias and STDV RH

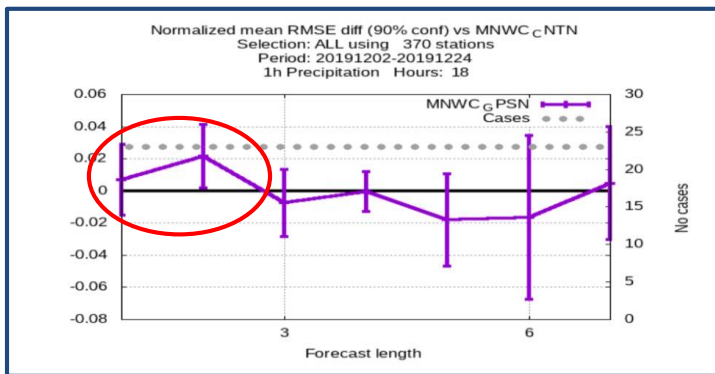
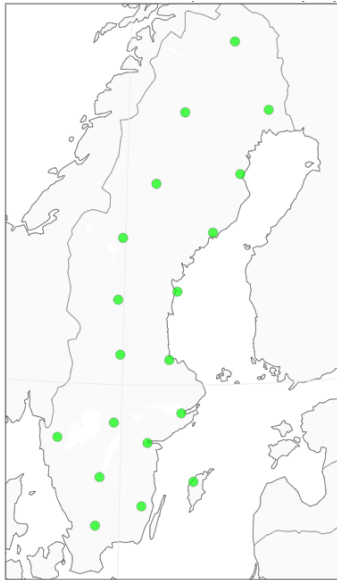


AIB_fr2 less RMSE for 3h acc pco



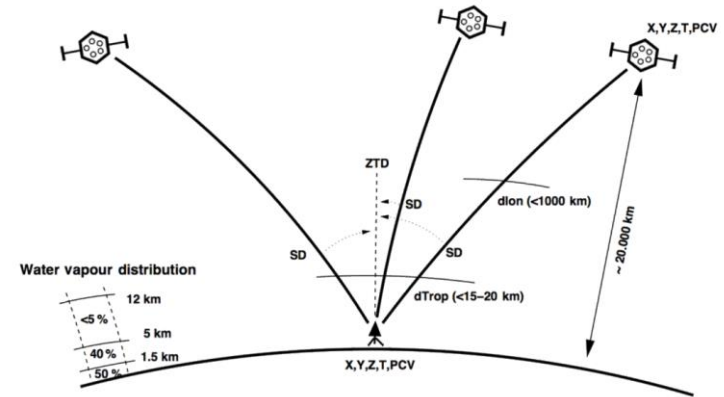
Anchoring capabilities of AMDAR Q?

Use of short timeliness ground-based GNSS ZTD for Nowcasting

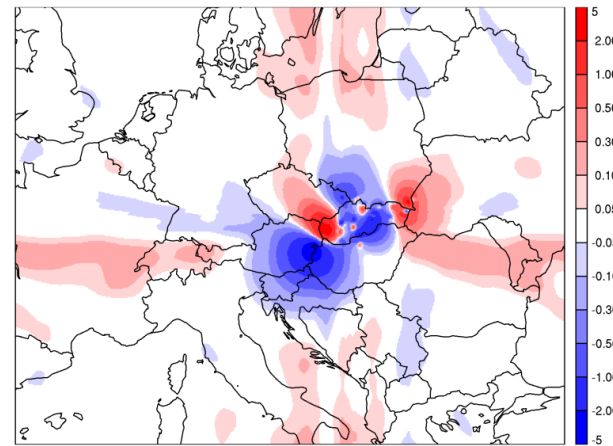


Use of GNSS resulted in improved short-range accumulated precipitation forecasts.

Assimilation of STD



Schematic picture of slant total delays from Guerova et al. (2016).



Model level 60 specific humidity assimilation increments (0.1 gkg^{-1}) due to 714 STDs (work by Martin Imrisek, LACE).

- Ground-based GNSS ZTD have been demonstrated to have a positive impact on HARMONIE-AROME regional NWP forecast.
- We have studied the importance of thinning, bias correction procedure and interaction with other types of observations assimilated. In addition we have demonstrated the importance (not shown) of a more general data-assimilation developments, such as refined background error statistics and data assimilation algorithm.
- Focus is shifting towards NWP based nowcasting with an increased interest in short timeliness GNSS data.
- We see a potential of a future assimilation of ZTD gradients and STD for km scale data assimilation and there is on-going work in such a direction.