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Assimilation of radial winds in an Ensemble Kalman Filter on the Convective Scale

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Overview:

With the Kilometer Scale Ensemble Data Assimilation System KENDA the German Weather Service (DWD) and the Consortium for Small Scale Modeling (COSMO) have developed an Ensemble Kalman Filter (EnKF) for Data Assimilation on the convective scale (cf. Schraff et al, QJRMS 2016).
The current setup of the KENDA system is a hybrid approach. It consists of the ensemble data assimilation (EDA) system for conventional observations over central Europe in combination with the assimilation of RADAR data based on latent heat nudging (LHN, Stephan et al 2008). It is currently in parallel routine and scheduled to become operational in Q4 2016.

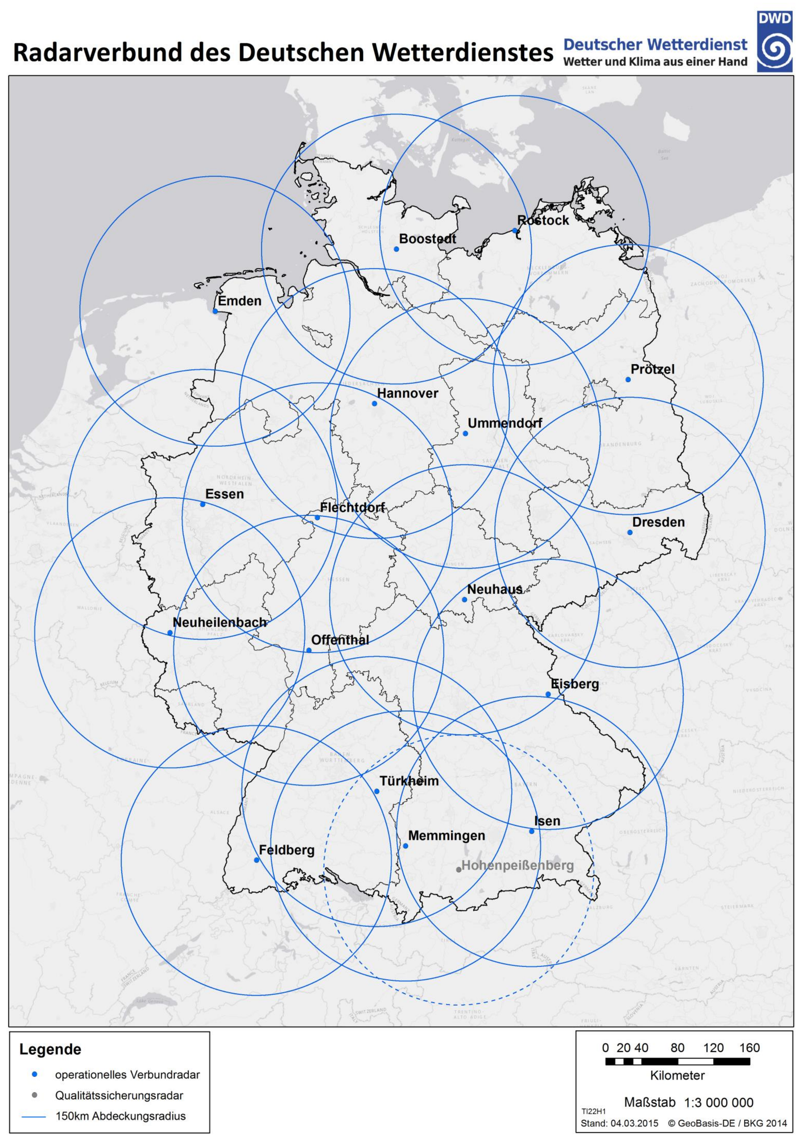
The new weather radar network of the DWD provides a complete coverage over Germany and offers unique 3-dimensional informations such as reflectivities and radial winds. The assimilation of radar reflectivities within the KENDA system has been successfully tested by Bick et al, QJRMS 2016. The assimilation is based on the EMVORADO 3D-RADAR forward operator developed by Zeng and Blahak (cf. Zeng 2014).

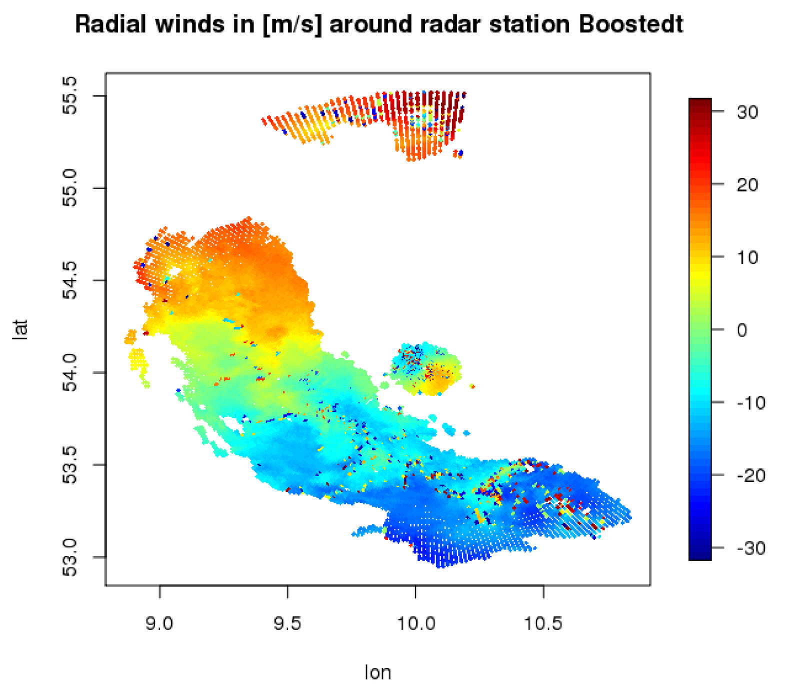
Ongoing work is now the assimilation of 3D-RADAR radial winds by the ensemble Kalman filter of the KENDA system, based on the EMVORADO forward operator of Zeng and Blahak (see above) (using an ODE based ray tracer).
The KENDA system in use combines a Local Ensemble Transform Kalman Filter (LETKF) and a deterministic run, which is updated by using the Kalman gain matrix for the ensemble mean analysis. Currently, the ensemble consists of 40 members and the analysis is done hourly.

Radar observations are very dense, especially close to the radar station. Such a high density is not necessarily beneficial. Therefore, several radar bins are averaged (a process called superobbing) to reduce the density.

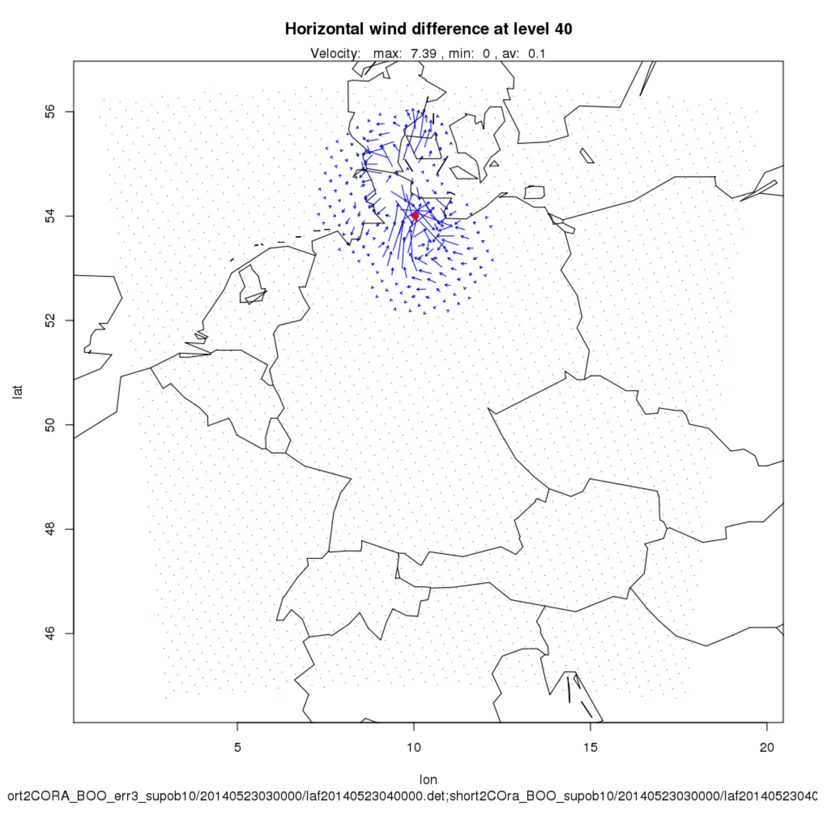
Radar Observation System:

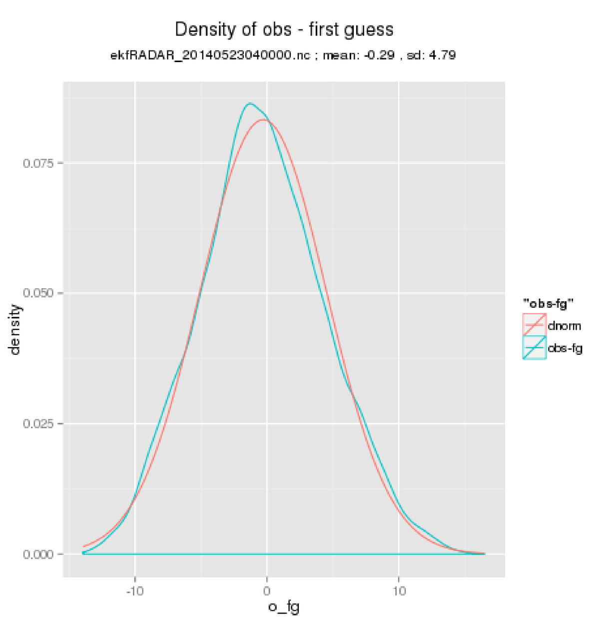
The new weather radar network of the German Weather Service (DWD) consists of 17 radars (dual-polarimetric C-Band Doppler radars) which cover Germany completely.
Radar stations record dynamical and microphysical characteristics of precipitating clouds (reflectivities and radial winds) in a high spatial and temporal resolution.





The observation data for radial winds are obtained by Doppler volume scans which last each about 5 minutes. Measurements are taken at 10 elevations (between 0.5° and 25°) with an azimuthal resolution of 1° and a range resolution of 1 km.

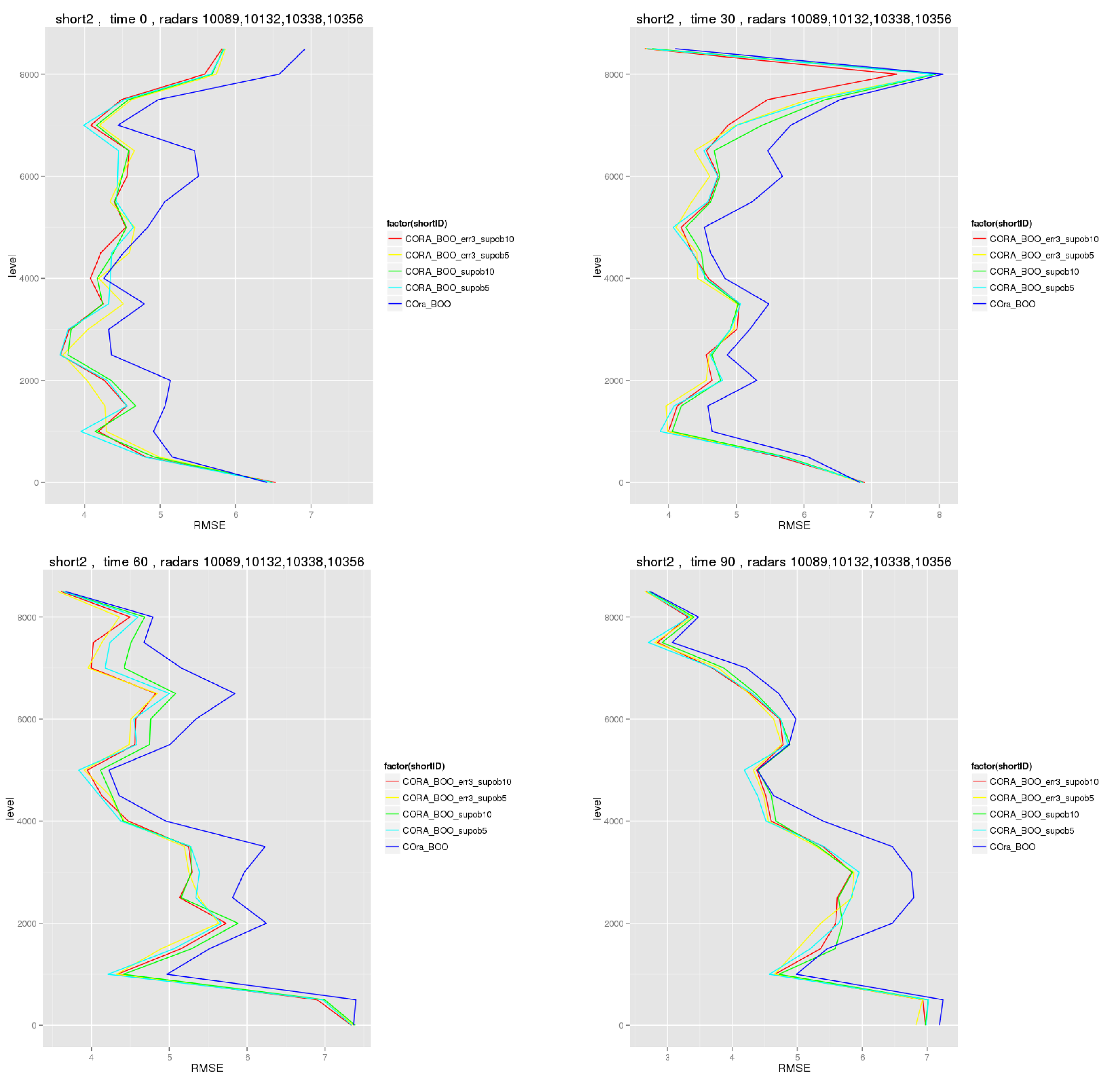




Experiments:

Short tests with different settings of radar specific parameters are running, such as modifications of observation errors (3 and 5 m/s), resolutions for superobbing (5, 10 and 20 km) or radius of vertical and horizontal localization.
Beside the assimilation of conventional data, we currently only assimilate radial wind data from one radar system (Boostedt).
The cycling period is from 3 UTC to 13 UTC, 23 May 2014. It is followed by a short forecast from 13 UTC to 17 UTC.
The tests show a positive impact of the assimilation of radial winds on the first two forecast hours (compared to the reference experiment where only conventional data is assimilated).

After the first cycle (1h):
The first figure shows the difference of the horizontal wind between the analysis with assimilation of radial wind and the analysis of the reference experiment (only assimilation of conventional data). The location of the radar system Boostedt is given by the red dot.
The second figure shows the distribution of observation minus first guess (blue) and the corresponding normal distribution (red).



Verification of the forecast against radial winds:
RMSE (observation – model equivalent) over the forecast time in 30 minutes steps.
Radial wind observations are taken from 4 different radar stations: Boostedt, Hannover, Ummendorf, Rostock. In the cycling period, only data from Boostedt was used. The dark blue line shows RMSE of the reference experiment (only assimilation of conventional data). The other lines belong to experiments where additionally radial winds are assimilated in the cycling period with different radar specific parameters: observation error 3 m/s vs. 5 m/s and superobbing 5 km vs. 10km.

References:

- C. Schraff et al. Kilometre-Scale Ensemble Data Assimilation for the COSMO Model (KENDA). *Quarterly Journal of the Royal Meteorological Society*, 2016.
- T. Bick et al. Assimilation of 3D Radar Reflectivities with an Ensemble Kalman Filter on the Convective Scale. *Quarterly Journal of the Royal Meteorological Society*, 2016.
- Y. Zeng. Efficient Radar Forward Operator for Operational Data Assimilation within the COSMO-model. *KIT Scientific Publishing*, 2014.
- K. Stephan et al. Assimilation of radar-derived rain rates into the convective-scale model COSMO-DE at DWD. *Quarterly Journal of the Royal Meteorological Society*, 2008.

DWD, Research and Development, Division FE 12 (Data Assimilation)
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