

Assimilating 3D radar reflectivity with an Ensemble Kalman Filter on a convection-permitting scale

International Symposium on Data Assimilation 2015

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Special thanks to U. Blahak (DWD), H. Reich (DWD), C. Schraff (DWD), Y. Zeng (LMU)

February 26, 2015

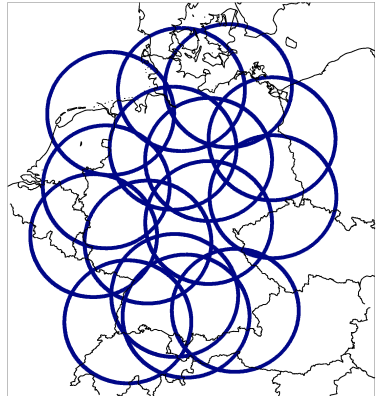
Motivation

Goal

- ▶ Improve short-term model forecasts of convective events

Radar data

- ▶ High resolution in both space + time, dense coverage
- ▶ 3D information
- ▶ Potential future benefit from polarimetric moments (mixing ratios)



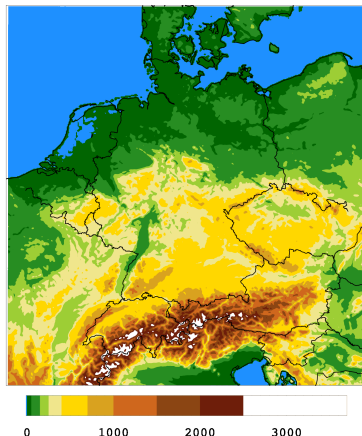
COSMO-DE and LETKF

COSMO-DE

- ▶ Convection-permitting numerical weather prediction model
- ▶ Horizontal grid spacing 2.8km, 50 vertical layers

KENDA

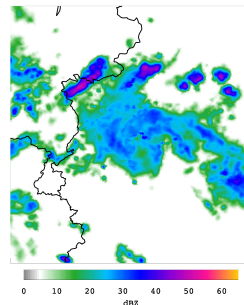
- ▶ Local Ensemble Transform Kalman Filter (**LETKF**) for COSMO-DE (developed at DWD, following Hunt et al., 2007)
- ▶ 40 ensemble members + 1 deterministic run



Radar forward operator

Simulate synthetic 3D radar scan based on COSMO-DE model fields (EMRADSCOPE, developed at DWD/KIT)

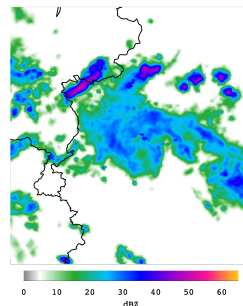
- ▶ **No-reflectivity:** set all values below 5 dBZ to 5 dBZ
- ▶ **Superobbing:** achieve relatively homogeneous horizontal data distribution
 - Reduce computational costs
 - Relax necessity of direct match between model and obs (double penalty problem)



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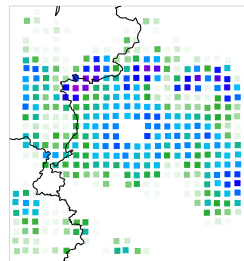
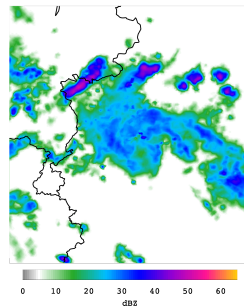
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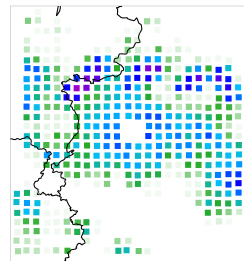
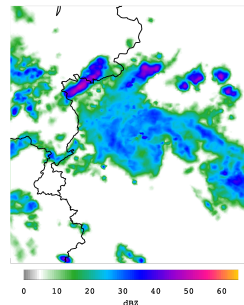
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Cycling study

Case study: May 26th 2014

- ▶ Spinup from 0-12 UTC (no data assimilation)
- ▶ 3h cycling (12-15 UTC) followed by 6h free forecast (15-21 UTC)

CONV

Assimilated obs:
conventional (synop, temp,
airep)

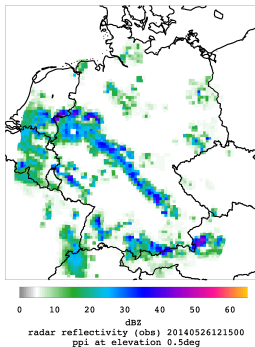
RADAR+CONV

Assimilated obs:
reflectivity, no-reflectivity,
conventional

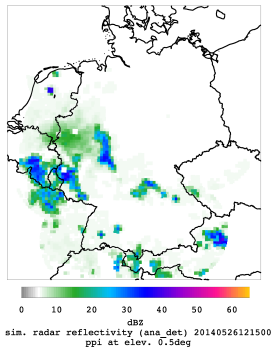
- ▶ Study influence of update frequencies: **5, 15, 30, 60 minutes**
- ▶ Consider all available data since last analysis

Det run 15min update: Analysis cycle (Reflectivity)

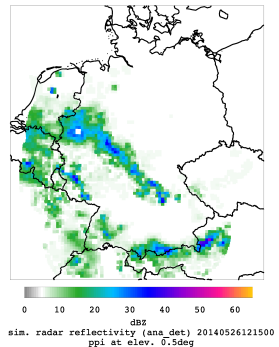
Observation:



CONV:

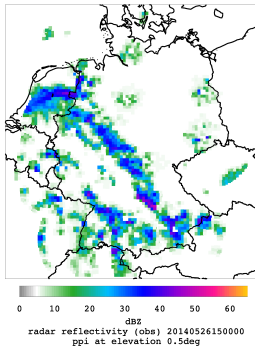


RAD+CONV:

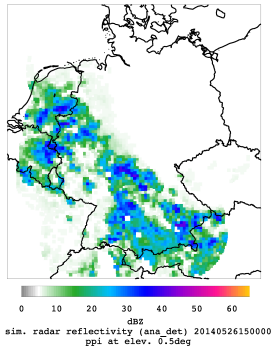


Det run 15min update: Forecast window (Reflectivity)

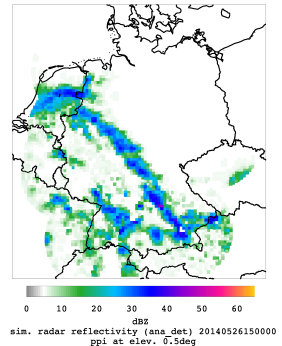
Observation:



CONV:

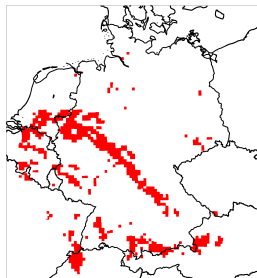


RAD+CONV:



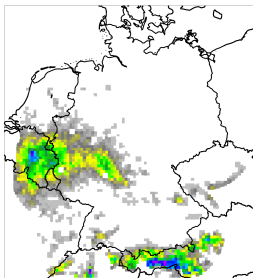
FG ensemble 15min update: Analysis cycle (#ens members > 20dBZ)

Obs (> 20dBZ):



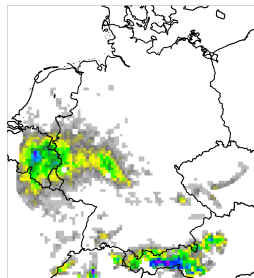
obs exceeding 20dBZ
20140526121500
ppi at elev. 0.5deg

CONV:



#fg_ens_members exceeding 20dBZ
20140526121500
ppi at elev. 0.5deg

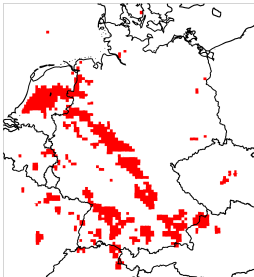
RAD+CONV:



#fg_ens_members exceeding 20dBZ
20140526121500
ppi at elev. 0.5deg

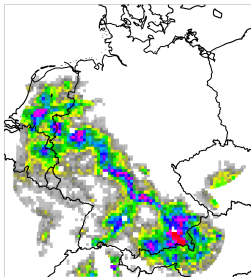
FG ensemble 15min update: Forecast window (#ens members > 20dBZ)

Obs (> 20dBZ):



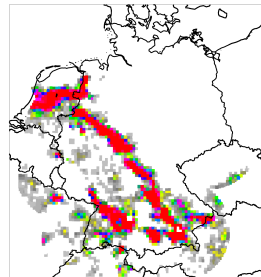
obs exceeding 20dBZ
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CONV:



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RAD+CONV:



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First verification

In observation space: Fraction Skill Score

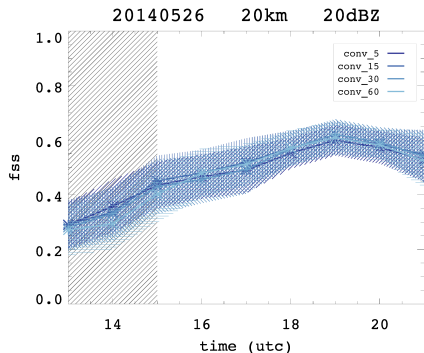
- ▶ compares model and observation based on exceedance of a dBZ threshold
- ▶ ranges from 0 to 1, perfect score 1

In model space: Equitable Threat Score

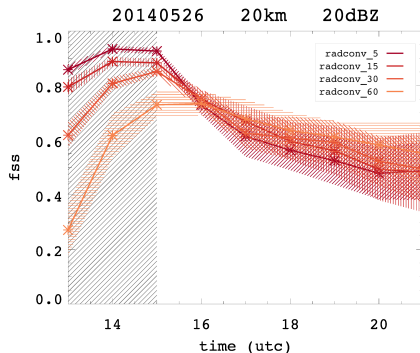
- ▶ compares precipitation rate from the model against radar derived precipitation rate (mm/h)
- ▶ ranges from -1/3 to 1, perfect score 1

Fraction Skill Score

CONV:

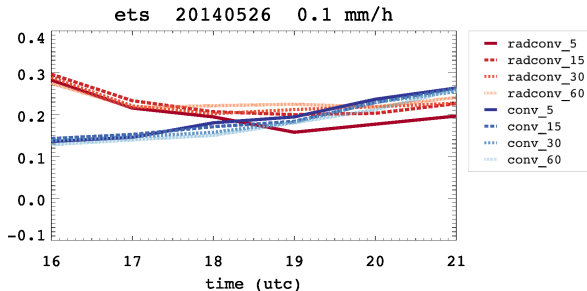


RADAR+CONV:

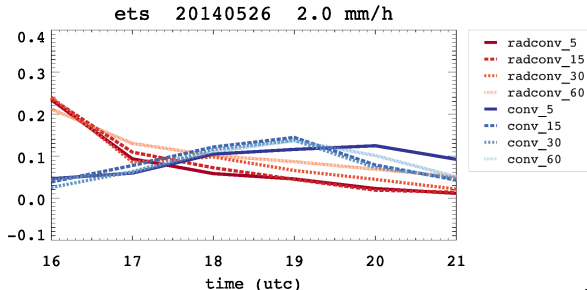


Equitable threat score

0.1 mm/h:



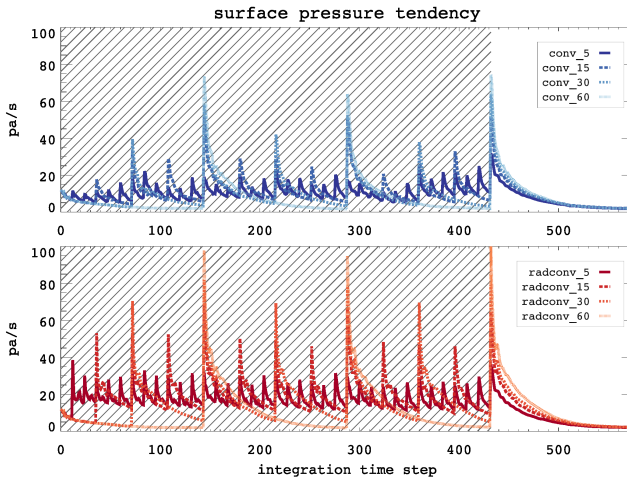
2.0 mm/h:



(Forecast initialized
at 15 UTC)

Surface pressure tendency during assimilation

A measure of noise in a model:



Summary: Radar reflectivity assimilation in KENDA

- ▶ So far we investigated only 1 case study
- ▶ In terms of FSS, assimilating radar reflectivity yields very good agreement between analysis and observation
- ▶ Forecast impact is visible during first 2-4 hours in both FSS and ETS
- ▶ Underestimation of precipitation intensity in all experiments
- ▶ After 1h forecast, 60 min update seems superior to 5 min update
- ▶ Rapid updates do not allow the model to adjust from changes introduced by data assimilation

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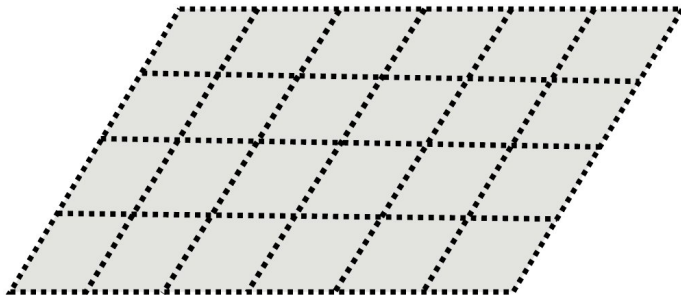
LETKF Parameters

- ▶ Reflectivity obs error: 10 dBZ
- ▶ Reflectivity horizontal localization radius: 16km (Gaspari Cohn parameter)
- ▶ Conventional obs horizontal localization radius: 80km (Gaspari Cohn parameter)
- ▶ Inflation: Relaxation to prior spread

Superobservations

Step 1: Construct a horizontal cartesian grid over the model domain

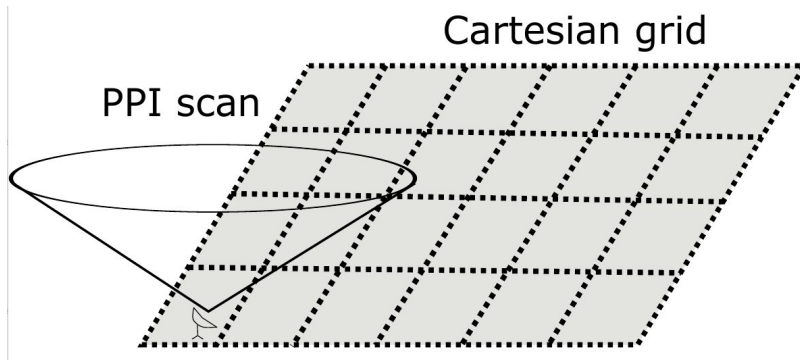
Cartesian grid



Courtesy Y. Zeng

Superobservations

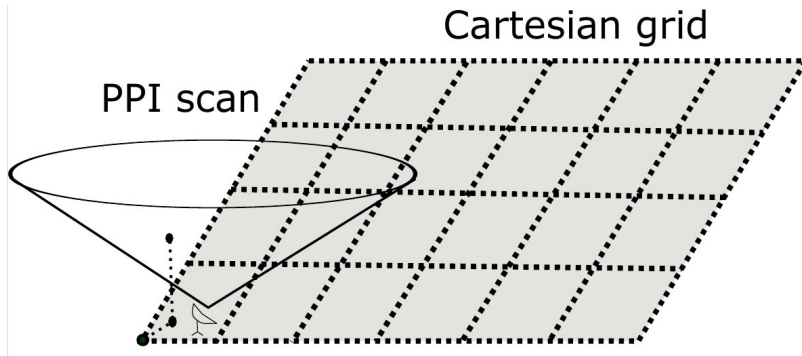
Step 2: Start with the lowest PPI scan from one radar station



Courtesy Y. Zeng

Superobservations

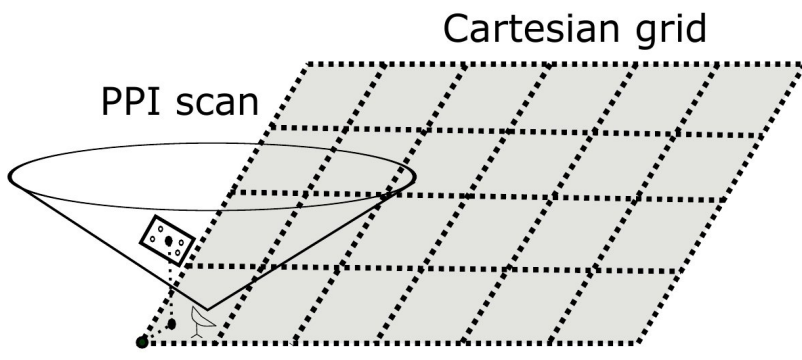
Step 3: loop over cartesian grid points, for each cartesian grid point find the radar bin on the PPI scan whose projection onto the horizontal plane is closest to this cartesian grid point.



Courtesy Y. Zeng

Superobservations

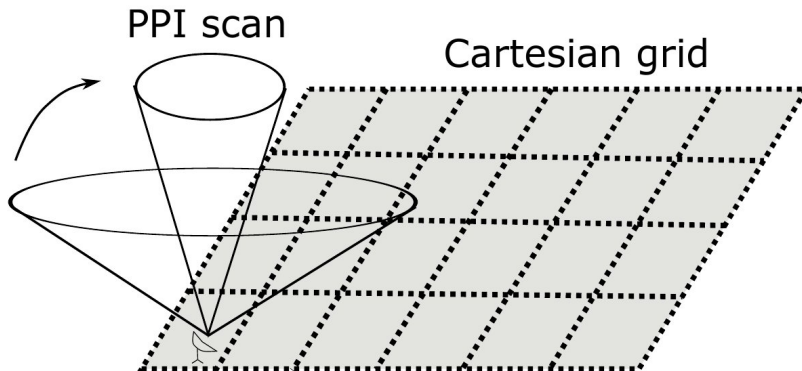
Step 4: define the local area around the radar bin for superobbing, calculate the average of values within the local area



Courtesy Y. Zeng

Superobservations

Step 5: when the loop over all cartesian grid points is done, go to the next PPI scan



Courtesy Y. Zeng

Fraction Skill Score

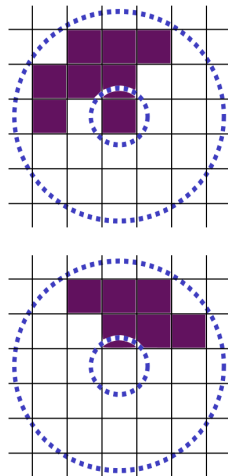
The FSS is a variation of the Brier Skill Score:

$$FSS = 1 - \frac{FBS}{FBS_{worst}},$$

$$FBS = \frac{1}{n_{rad}} \sum_{j=1}^{n_{rad}} (O_j - M_j)^2$$

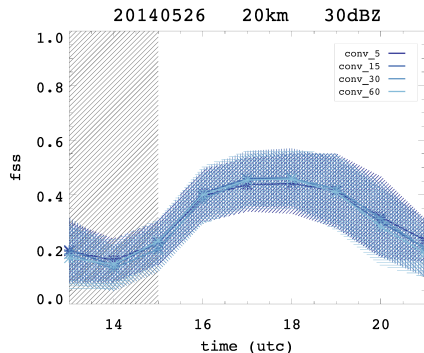
$$FBS_{worst} = \frac{1}{n_{rad}} \left[\sum_{j=1}^{n_{rad}} O_j^2 + \sum_{j=1}^{n_{rad}} M_j^2 \right]$$

The FSS ranges from 0 to 1 (perfect score 1).

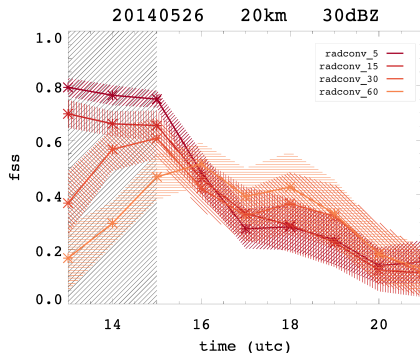


Fraction Skill Score

CONV:



RADAR+CONV:



Equitable Threat Score

The ETS indicates how well the forecast occurrence of events agrees with the observed occurrence of events:

$$ETS = \frac{\text{hits} - \text{hits}_{\text{random}}}{\text{hits} + \text{misses} + \text{false alarms} - \text{hits}_{\text{random}}}, \quad \text{where}$$

$$\text{hits}_{\text{random}} = \frac{(\text{hits} + \text{misses})(\text{hits} + \text{false alarms})}{\text{total}}$$

The ETS ranges from -1/3 to 1 (perfect score 1).

Runtime of 3h assimilation cycle at DWD's Cray

Experiment	Elapsed time (h:min)			# COSMO/LETKF runs
	Total	COSMO	LETKF	
RADAR_5	8:07	0:08	0:06	36
RADAR_15	4:48	0:09	0:11	12
RADAR_30	3:45	0:14	0:20	6
RADAR_60	3:14	0:23	0:38	3

COSMO:

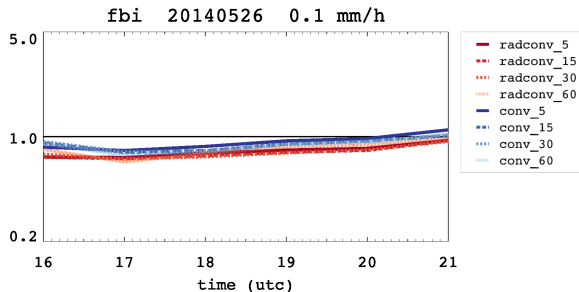
- ▶ 120 PEs
- ▶ Memory 1536M

LETKF:

- ▶ 160 PEs
- ▶ Memory: 6144M

Frequency bias

0.1 mm/h:



2.0 mm/h:

