Ensemble-based storm-scale analysis and prediction of deep convection: The 27 May 2016 hail storms over Southern Germany

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Toward a seamlessly integrated storm-scale ensemble prediction system:

- The next generation of convective- or storm-scale forecasting aims to **integrate nowcasting and NWP** into a single framework to predict the formation and evolution of **individual deep convective storms**.
- On the NWP-side we have to used **advanced data assimilation** systems, like the local ensemble transform Kalman filter (LETKF) to assimilate remote-sensing data (radar, VIS and IR satellite, lightning, GPS, etc.)
- The **NWP model has to be improved**, e.g., by going to 1 km grid spacing and using better physics, e.g., two-moment microphysics.
- Everything has to be integrated based on **probabilistic forecasting products**, because the predictability is very limited on the scale of individual deep convective storms.
- Similar efforts also at other centers, e.g., Warn-On-Forecast project at NSSL.

Convective-scale NWP at DWD: Plans for 2020

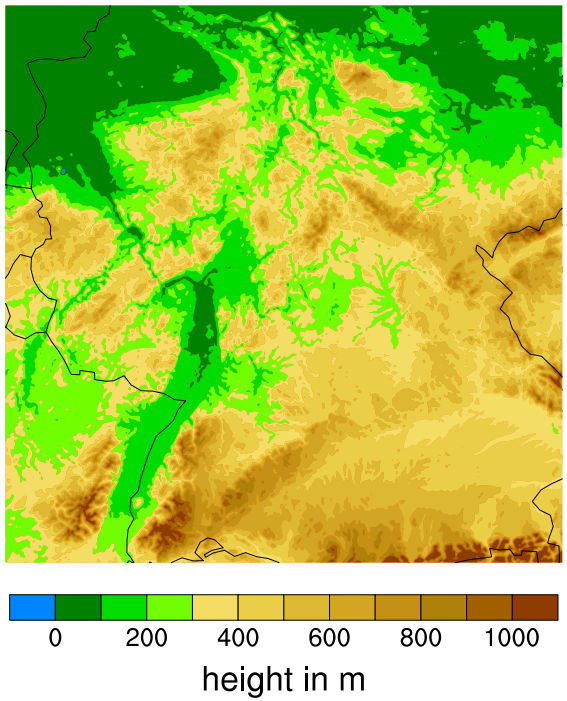
- **Storm-scale ICON-RUC-EPS:** hourly 12h ensemble forecasts based on short data cut-off (< 20 min); assimilation of 3D radar data, satellite (IR and VIS), Mode-S, etc.; 40 members for ensemble data assimilation and ensemble prediction.

- **Convective-scale ICON-LAM-EPS:** every 3 hours ensemble forecasts up to 48h

Model domain of ICON-RUC and ICON-LAM; 2 km for the full domain and a 2-way nest with a grid spacing of 1 km for Germany.

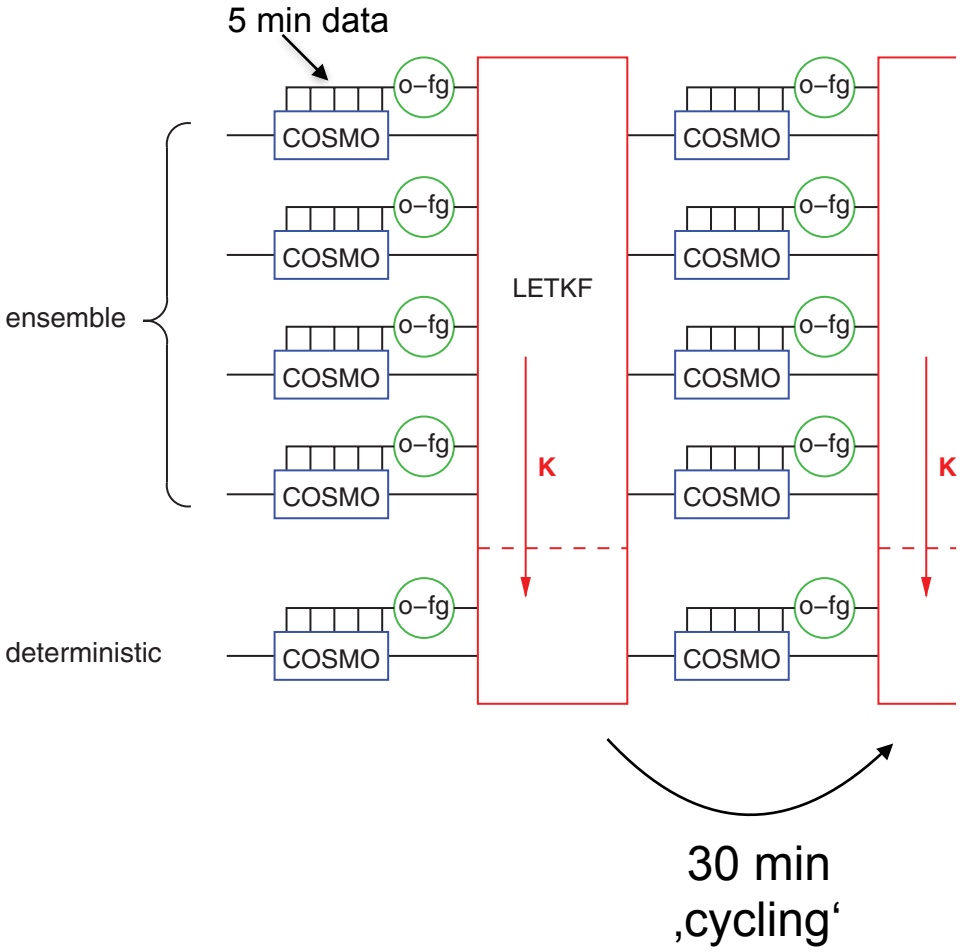
A prototype experiment with the COSMO model

- COSMO model with 1 km grid spacing focusing on Southern Germany
- Two-moment microphysics with hail (Seifert and Beheng 2006, Blahak 2008)
- Data assimilation using LETKF with 3d radar reflectivity and radial velocity (Schraff et al. 2016, Bick et al. 2016).
- Assimilation with 40 ensemble members and 30 min cycling using 5 min radar data.
- Forecasts with 20 ensemble members for 6 hours.



Model domain of COSMO1-RUC with a grid spacing of 1 km on a 480 x480 grid.

Local Ensemble Transform Kalman Filter

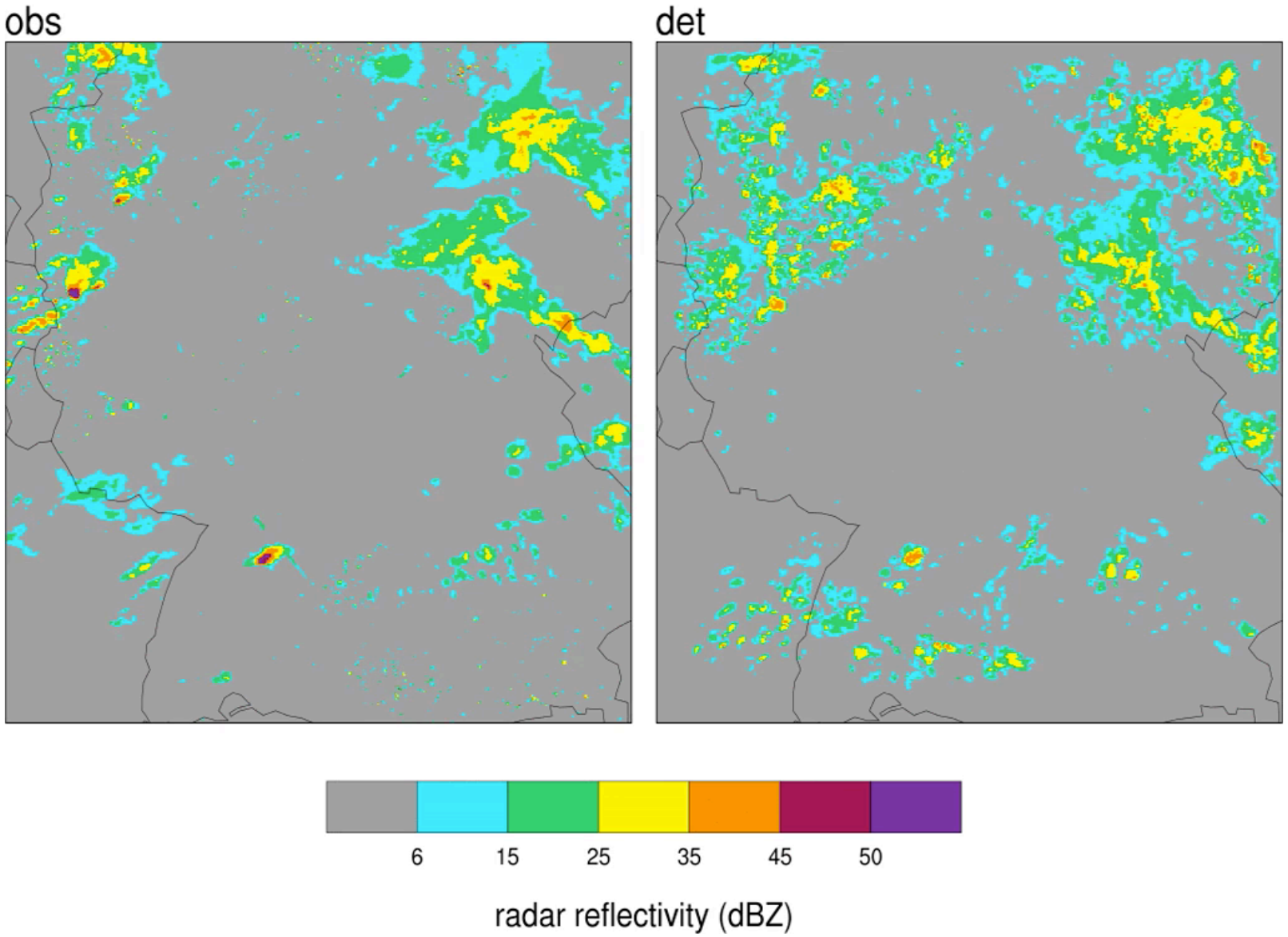


- During the COSMO runs the model is compared with observations using a forward operator (o-fg).
- LETKF estimates new 3d fields of all model variables based on covariances in the ensemble members, e.g, how w and T correlate with dBZ.

Caveats:

- Works only if observations are well covered by ensemble.
- Non-gaussian statistics are not well represented.

COSMO First Guess, 20160527, 12:00 UTC + 00 min



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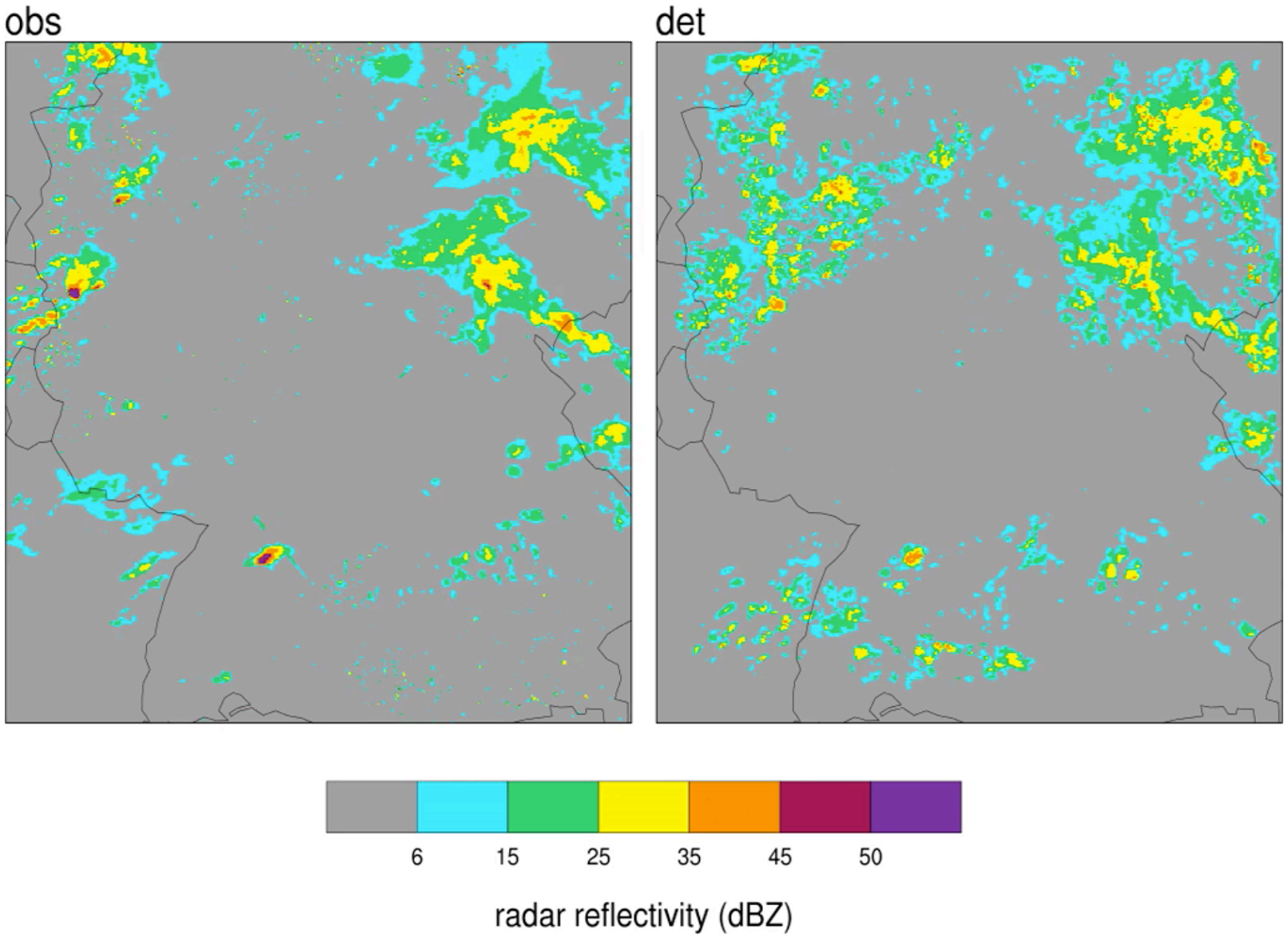
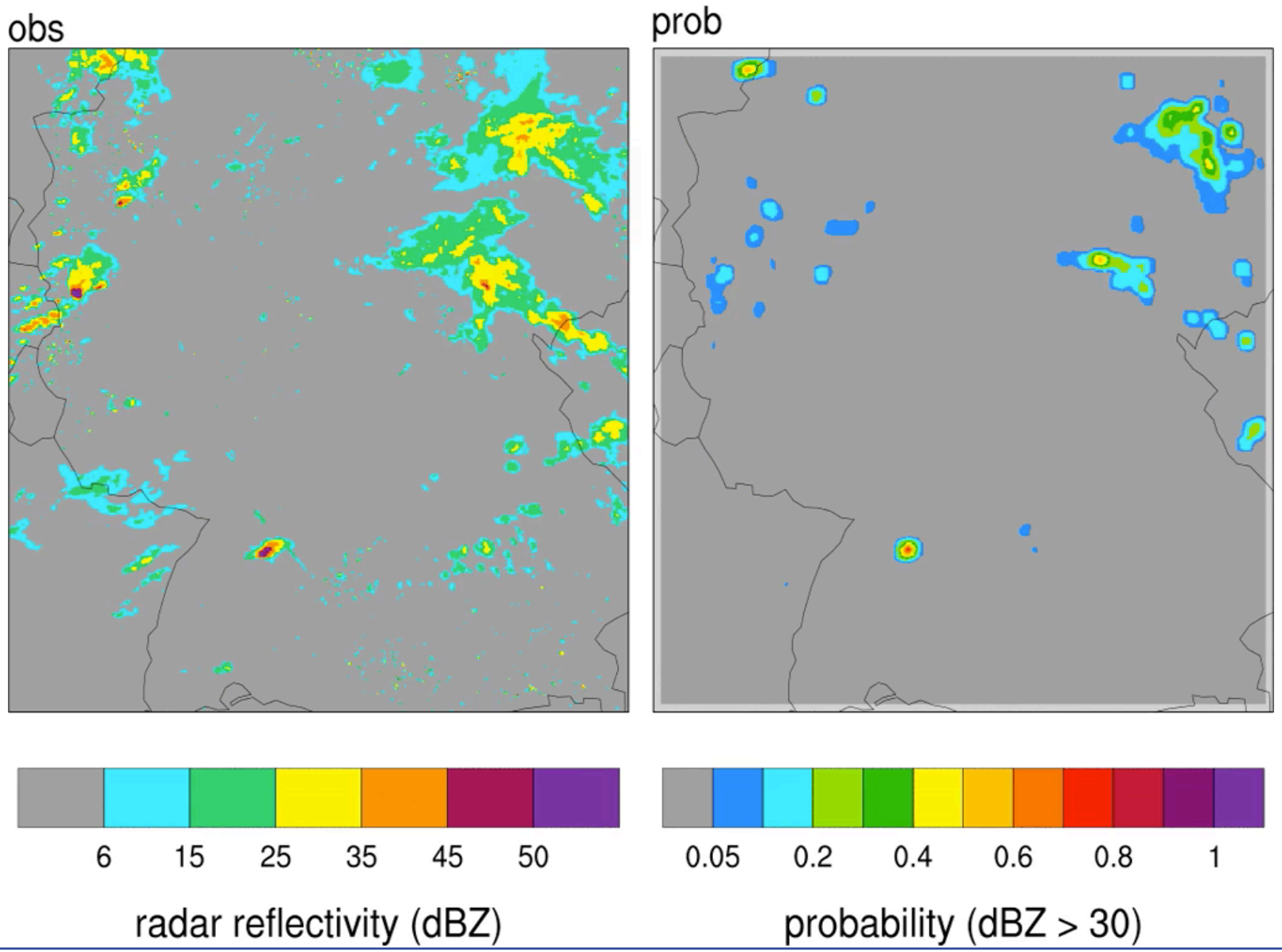
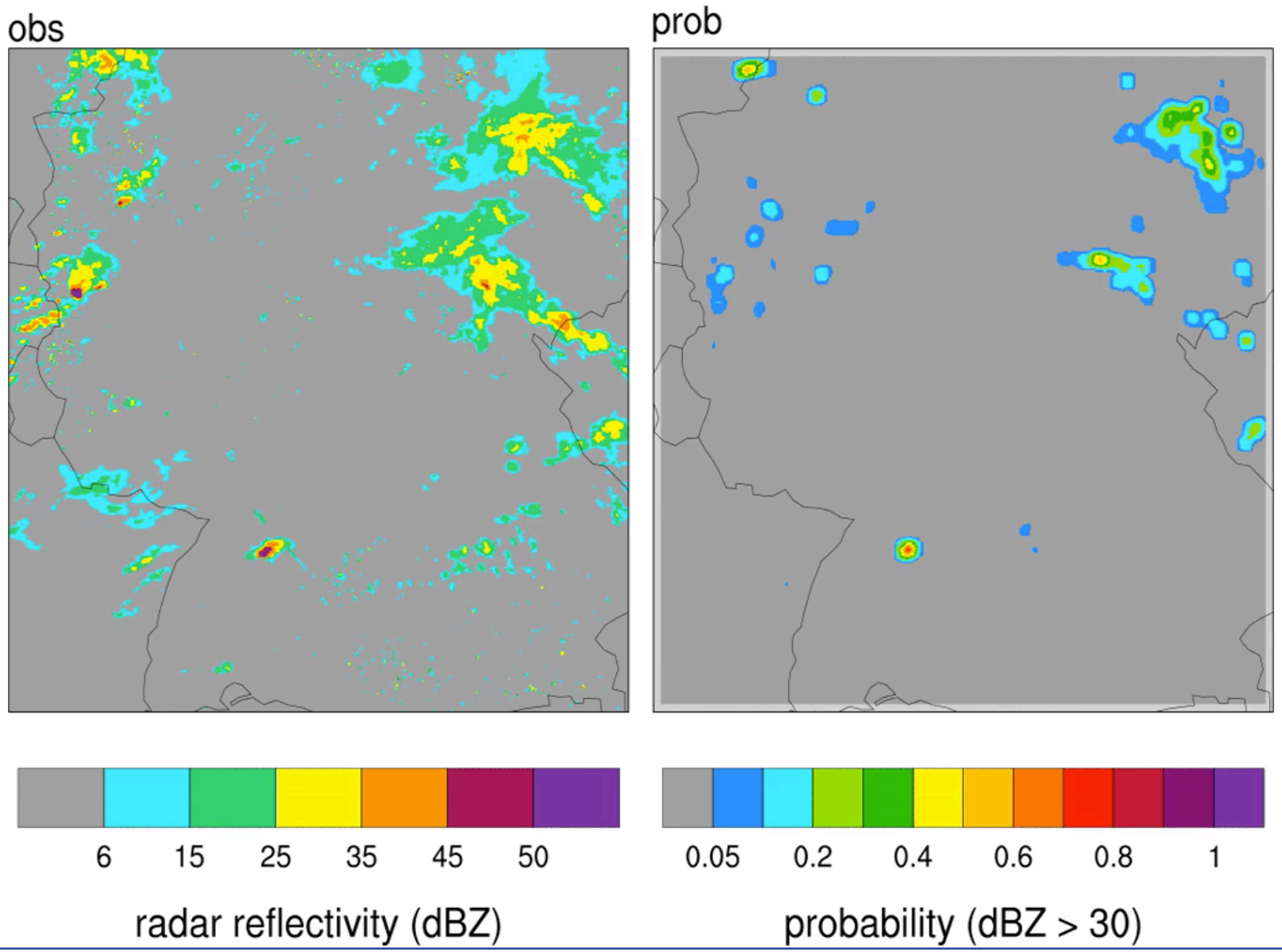



COSMO First Guess, 20160527, 12:00 UTC + 00 min
obs
prob
6
15
25
35
45
50
radar reflectivity (dBZ)
0.05
0.2
0.4
0.6
0.8
1
probability (dBZ > 30)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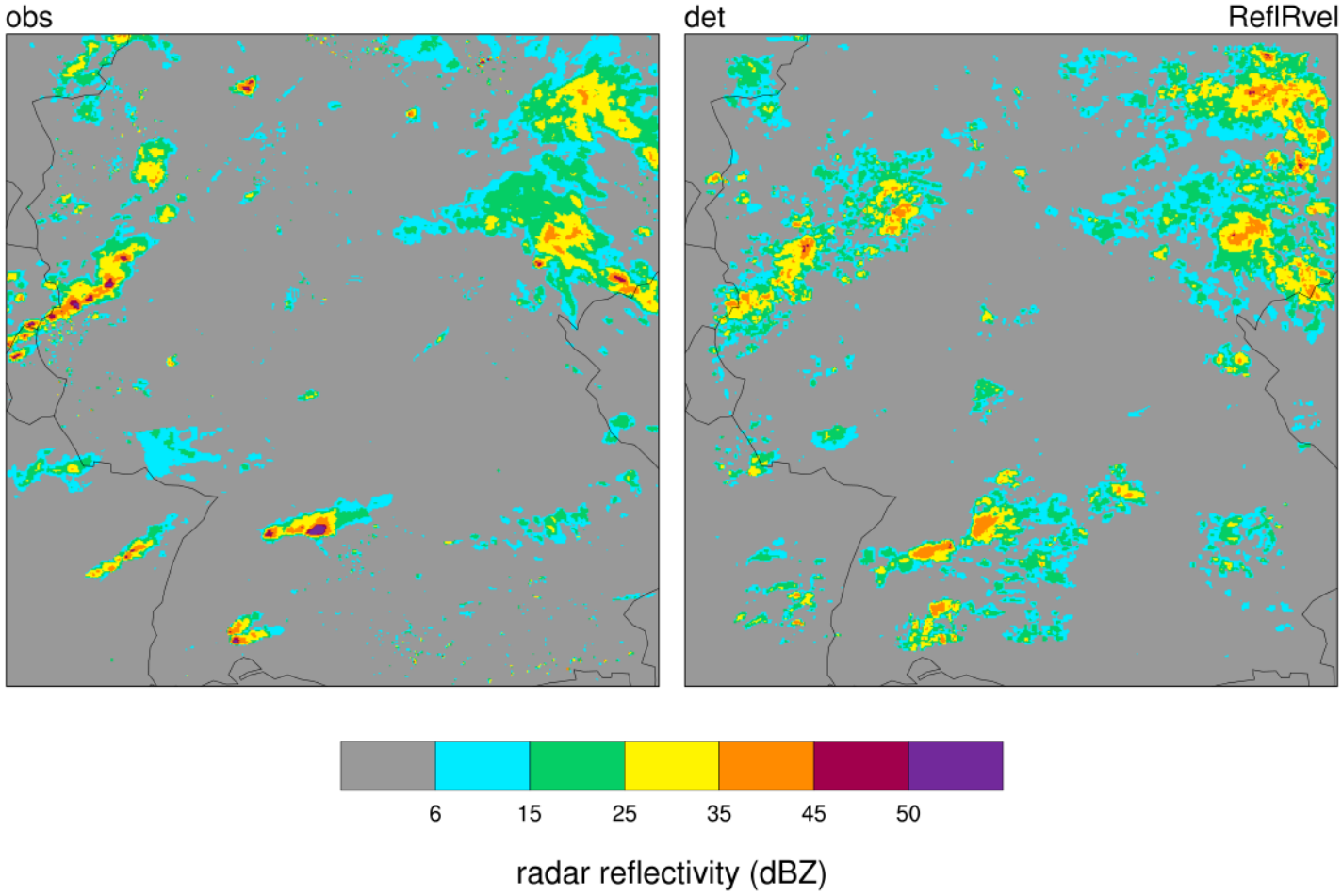
Results of the assimilation experiment

- The LETKF can assimilate individual deep convective storms like supercells.
- The pulsating behavior shows that model and LETKF provide slightly inconsistent solutions. This is unavoidable, because the LETKF is a purely statistical method that does not take into account the actual model equations.
- The model recovers quite quickly from the analysis increments and can built up reasonable storms.
- Some noise has to be accepted in this approach and some noise is actually necessary to retain ensemble spread. Difficult to distinguish good noise from bad noise!

COSMO Forecast, 20160527, 13:00 UTC + 00 h



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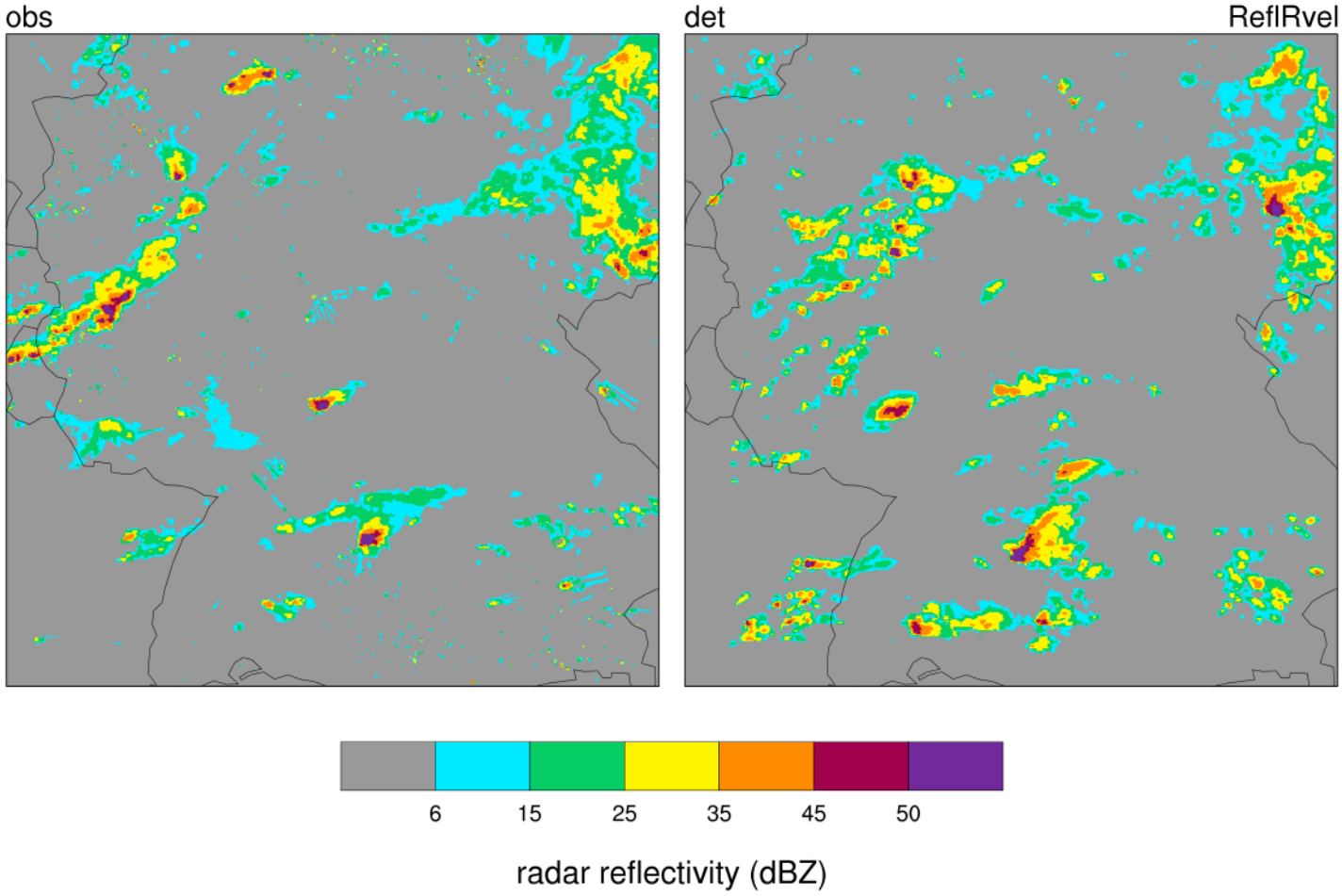

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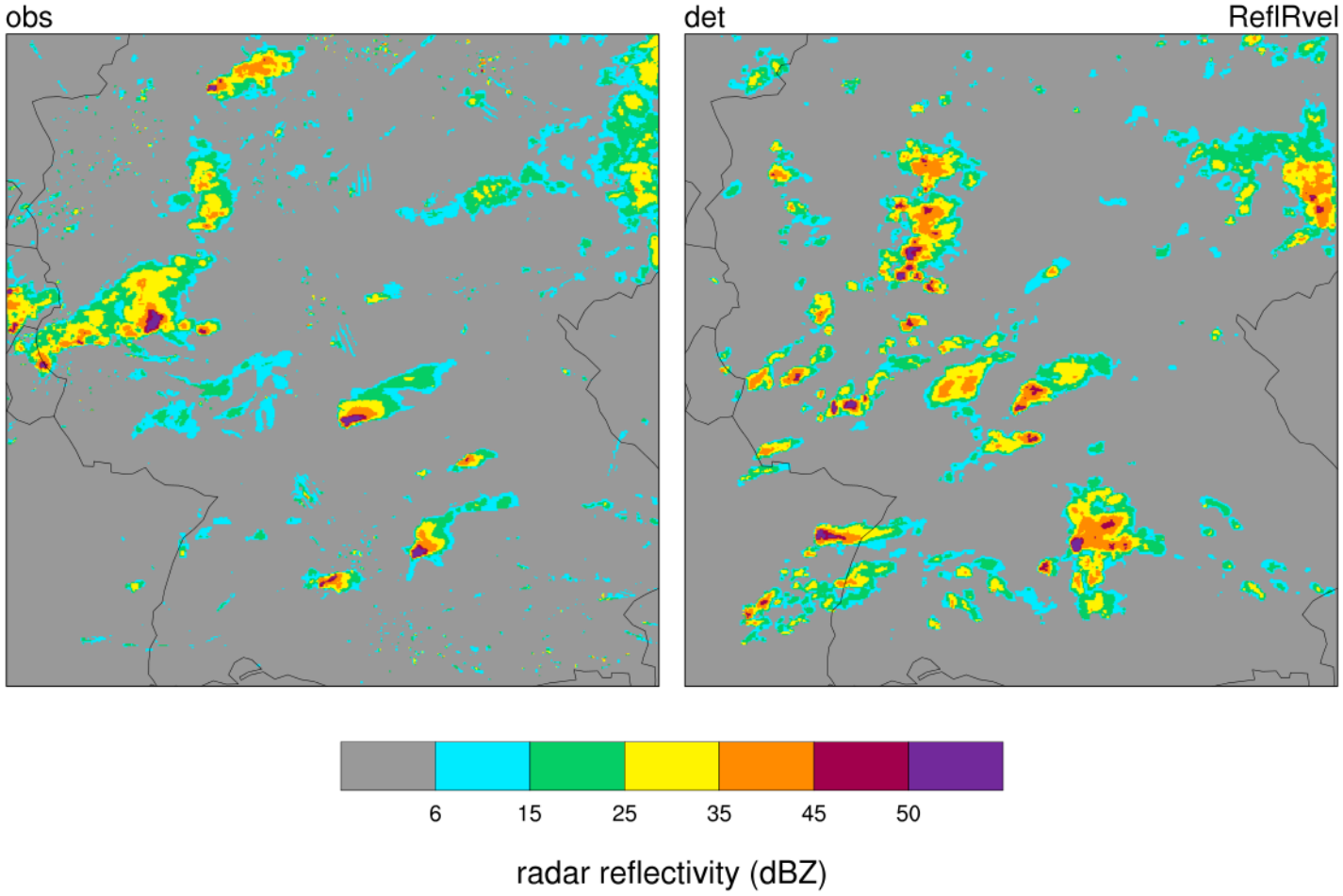
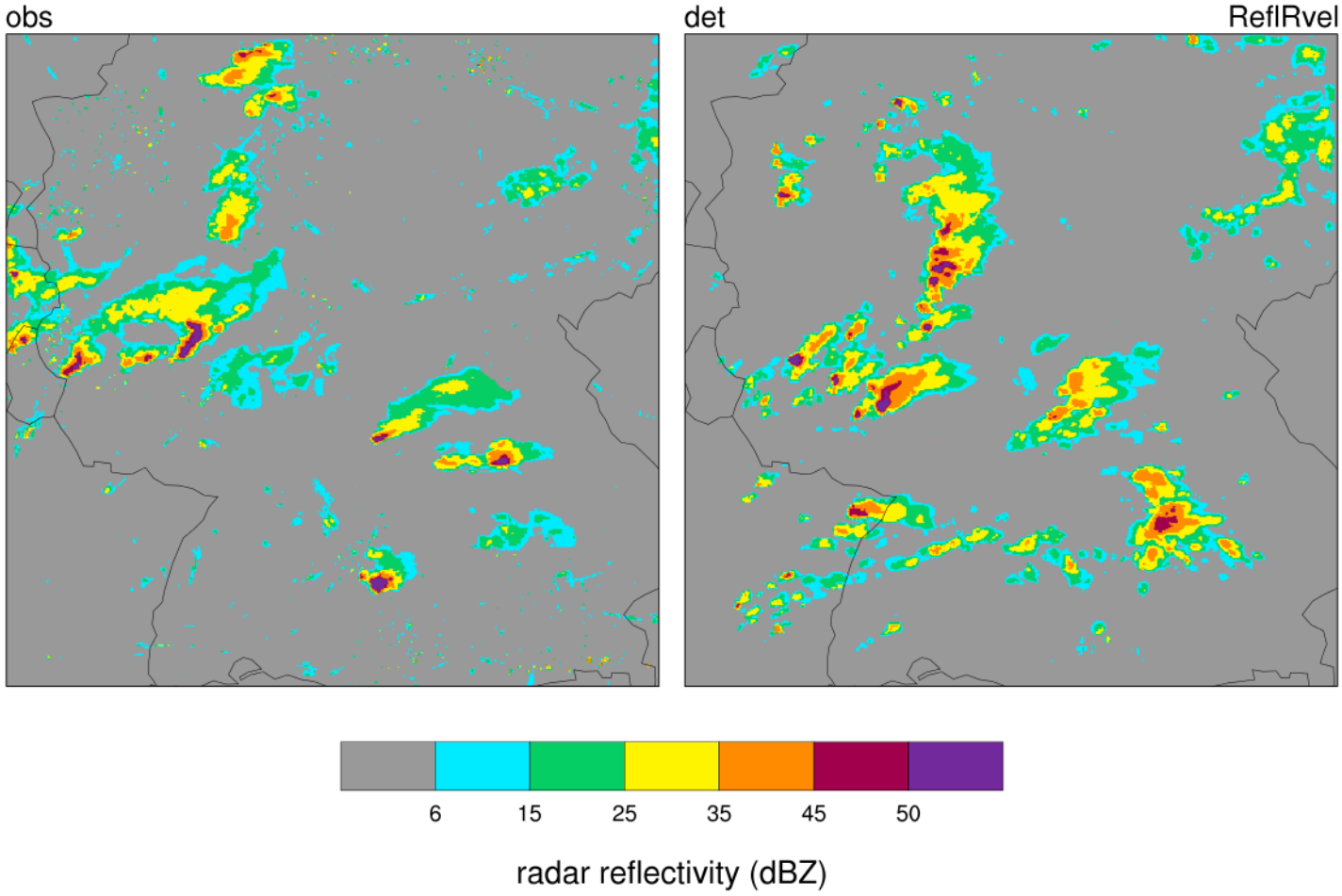
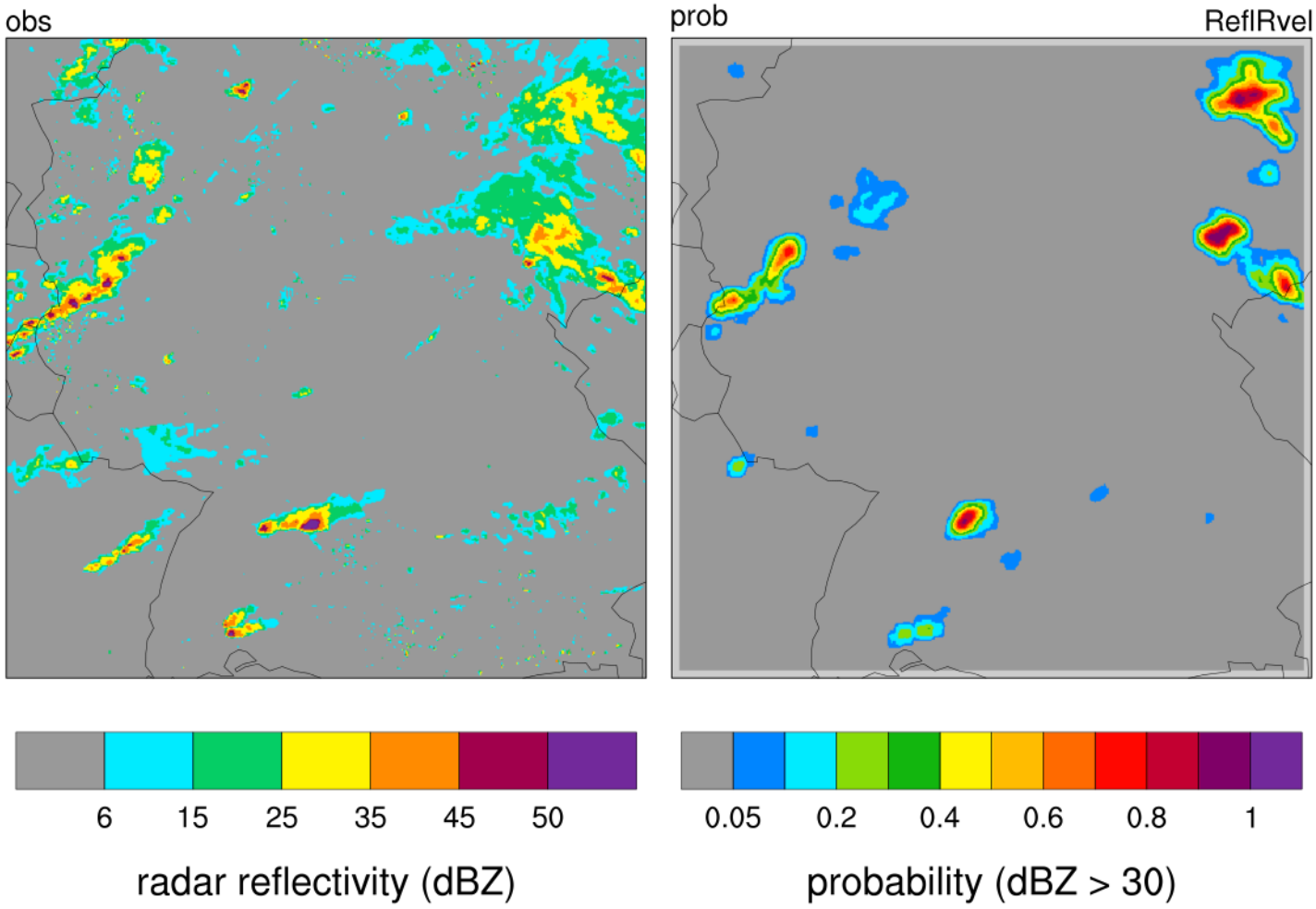


COSMO Forecast, 20160527, 13:00 UTC + 03 h



COSMO Forecast, 20160527, 13:00 UTC + 00 h



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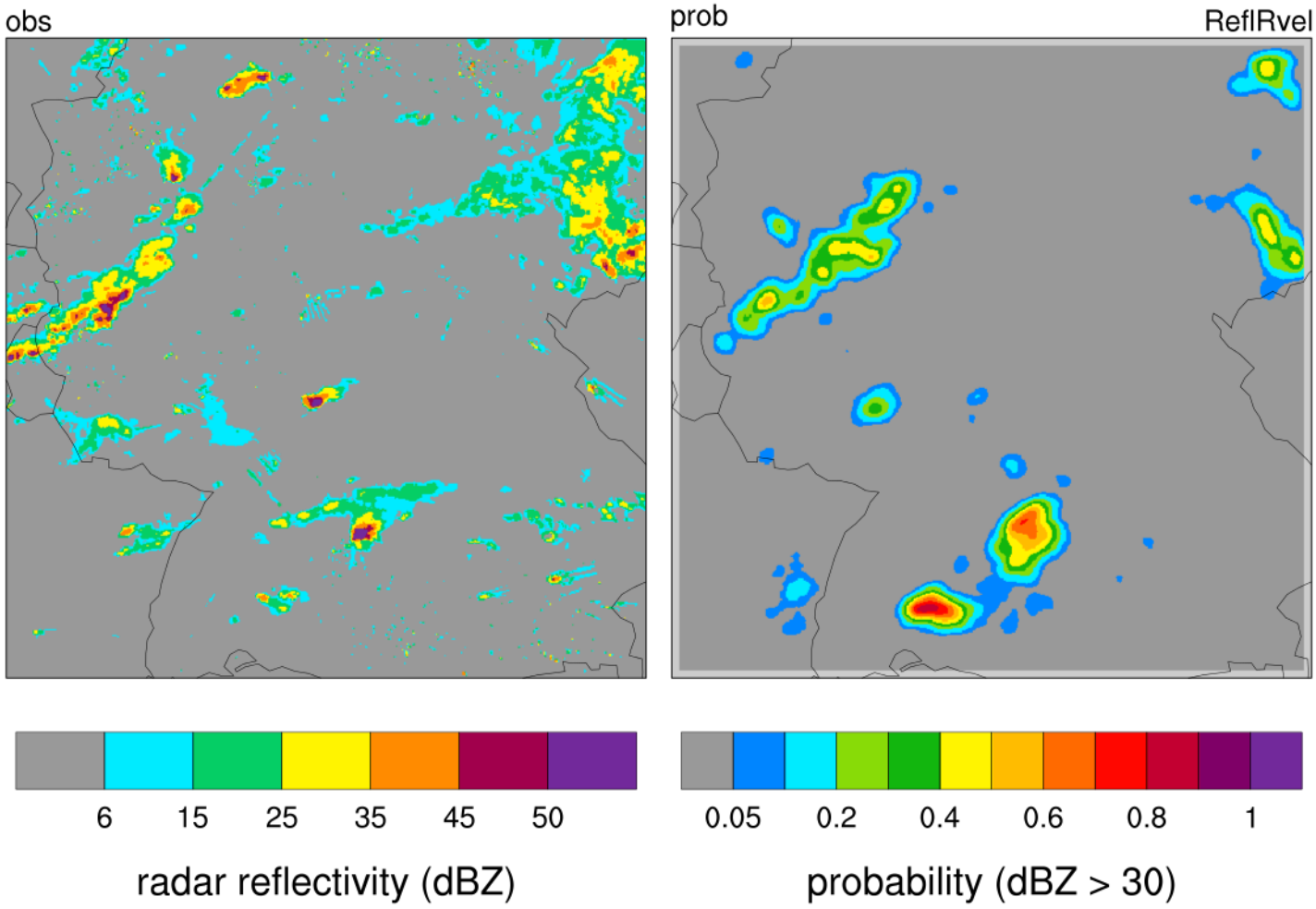

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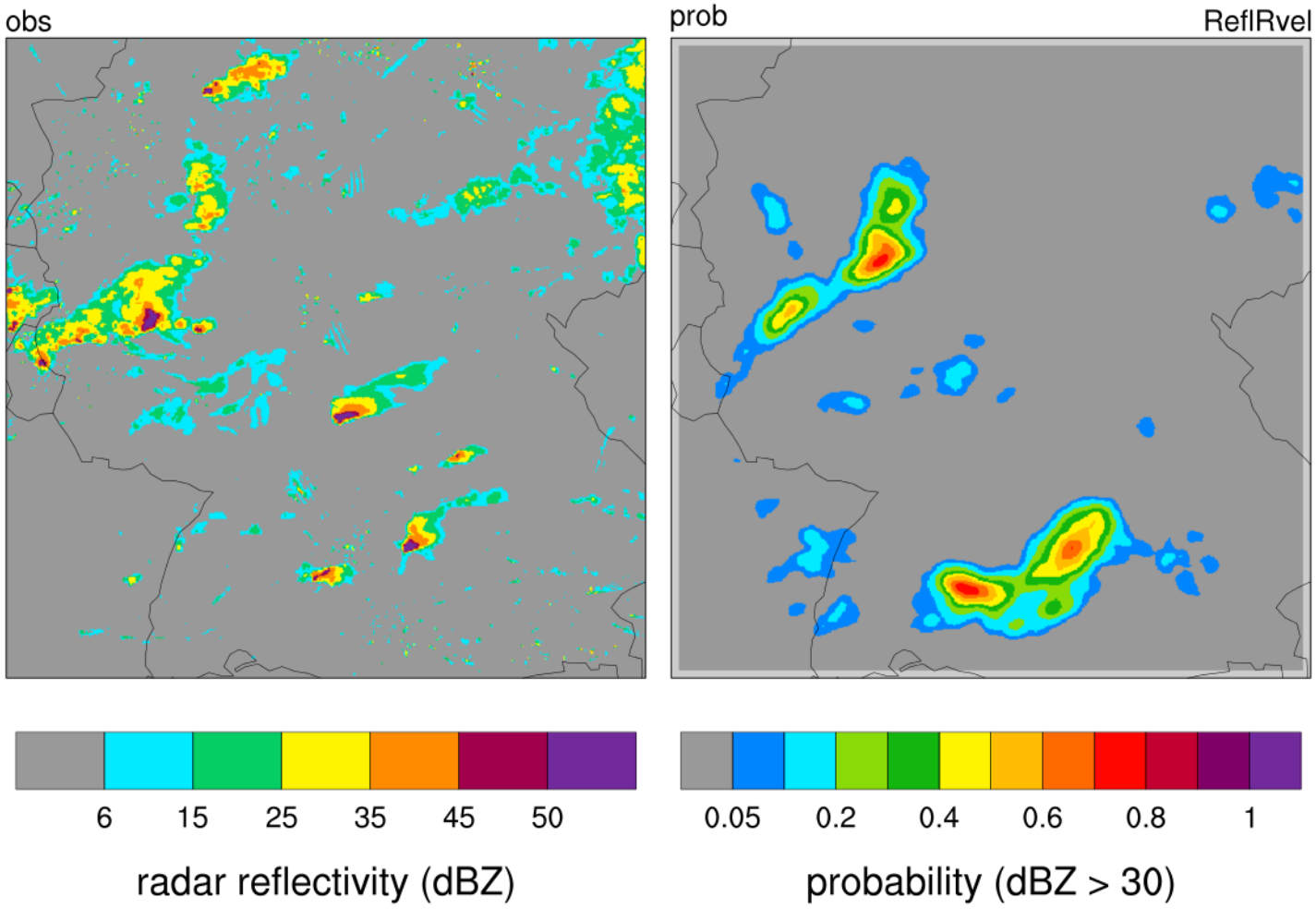
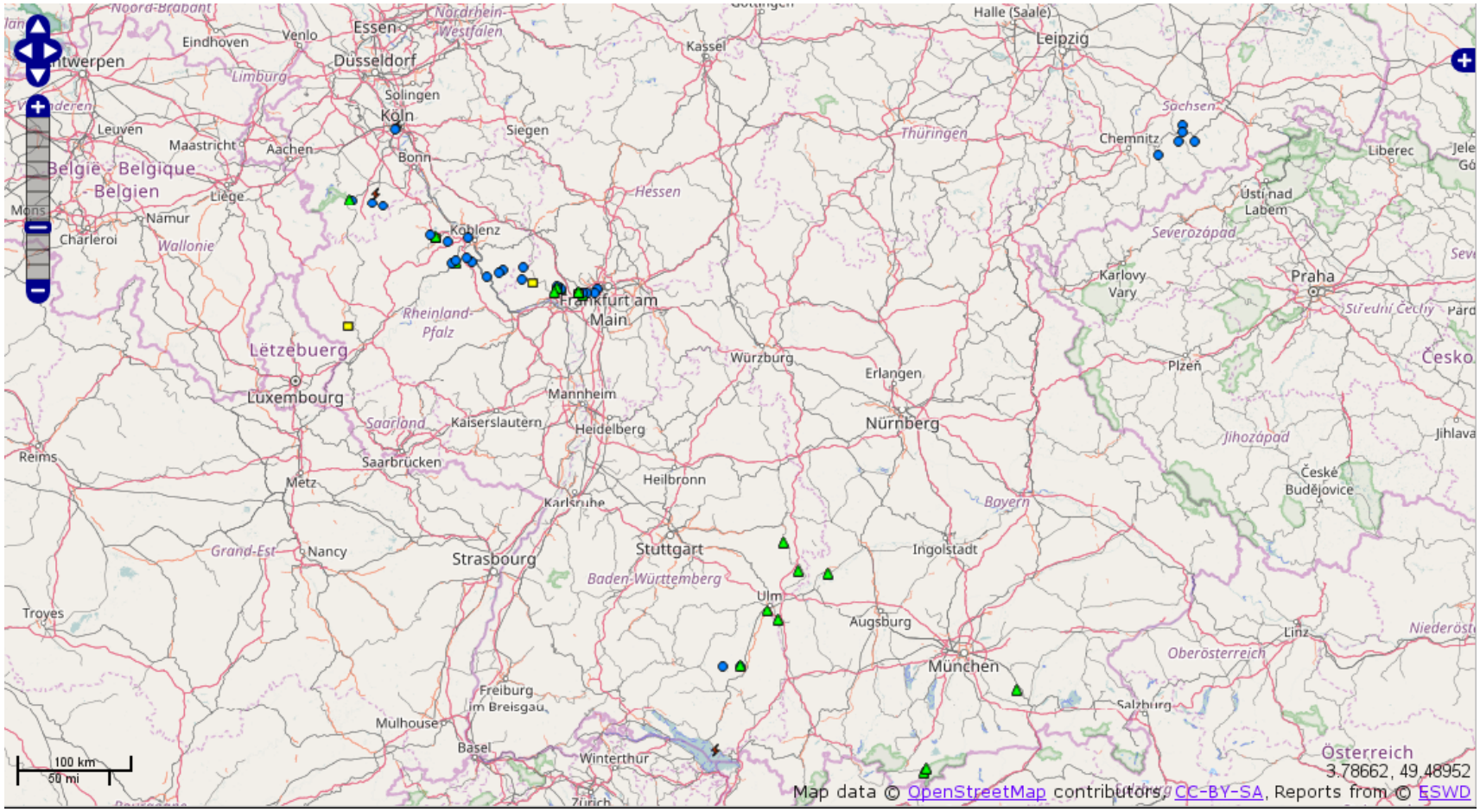
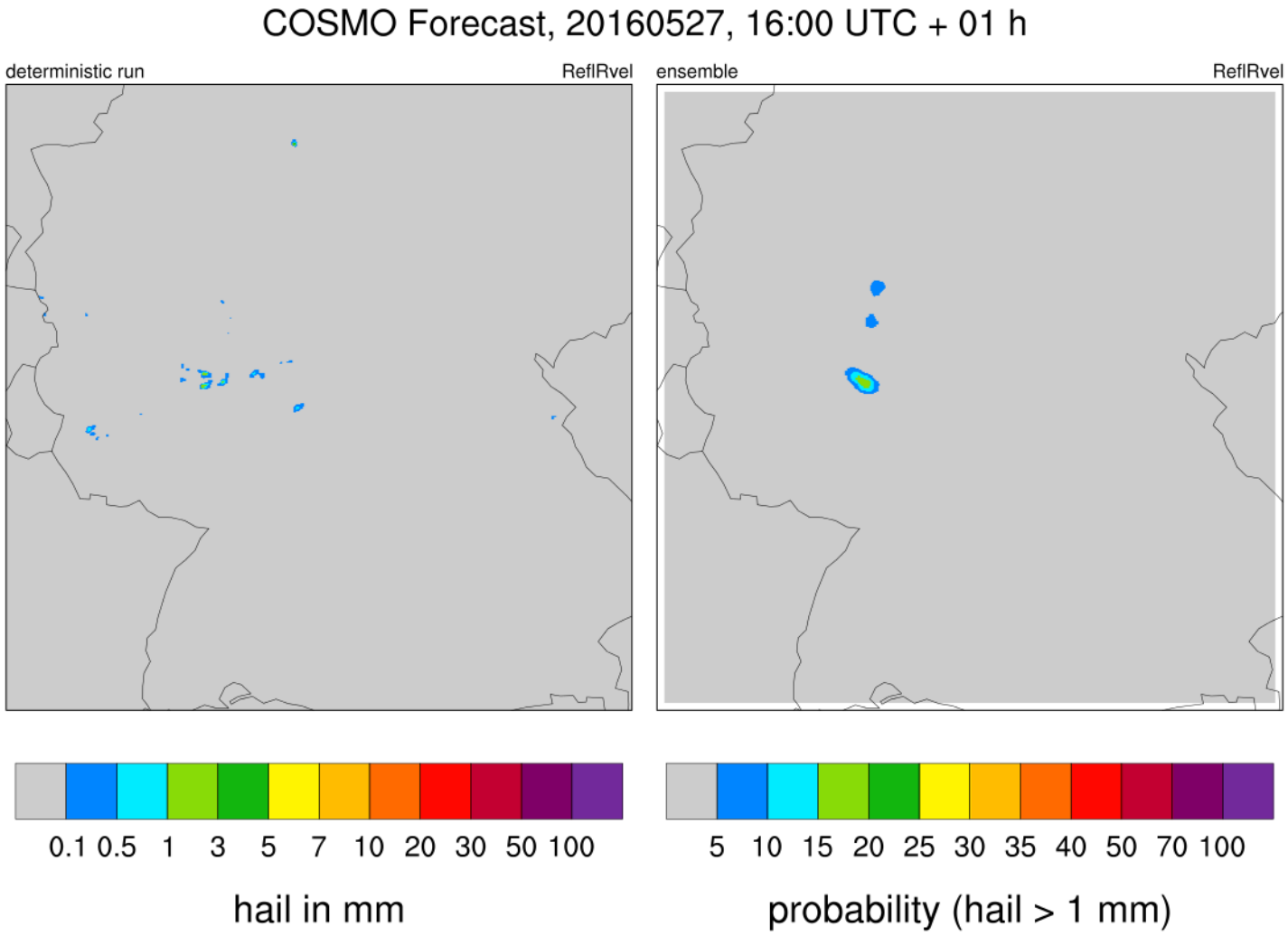


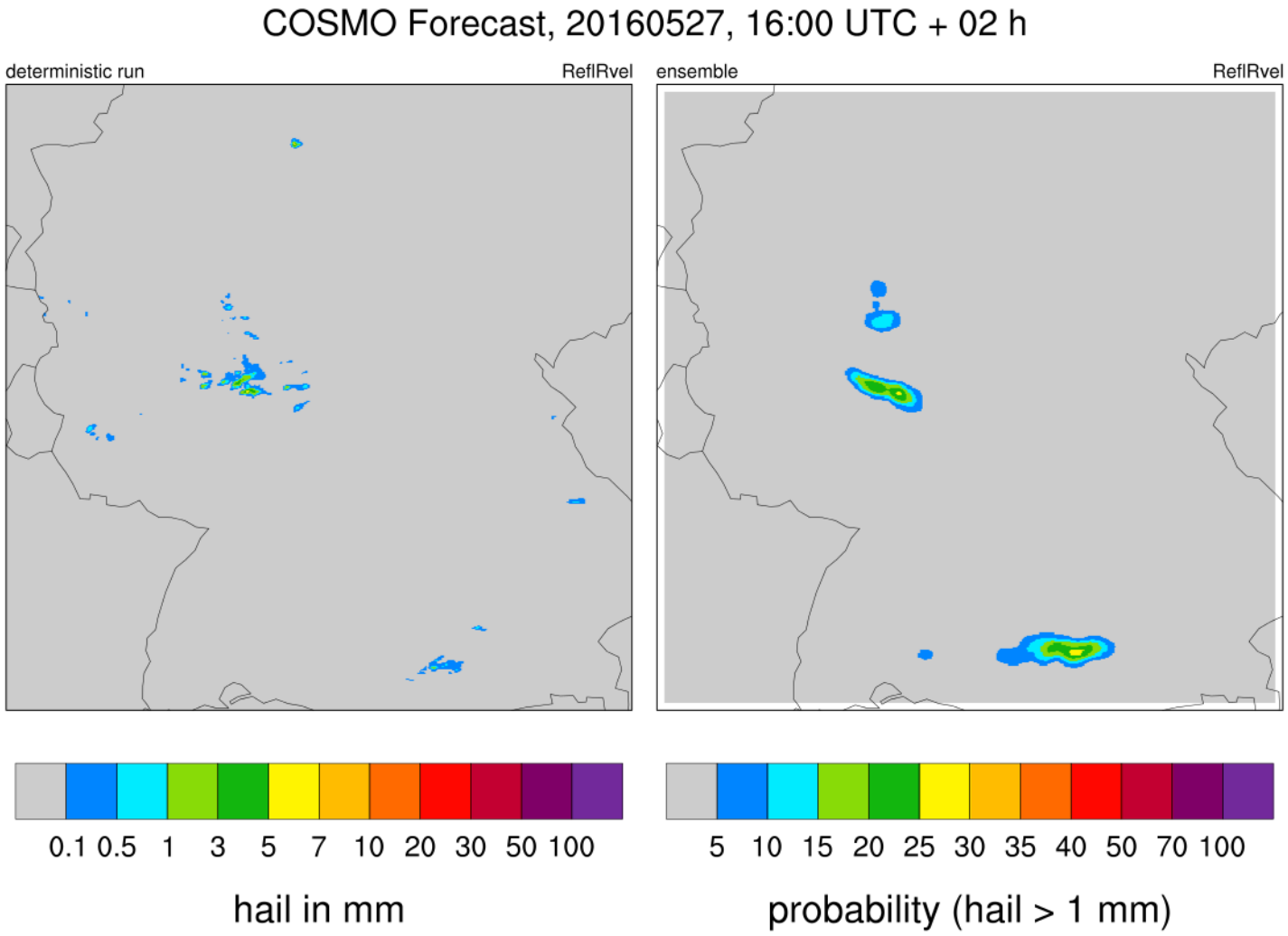
Can we hope for some explicit hail forecasts?

- **On 27 May several cm of (small) hail were reported near Wiesbaden.**

Reports in ESWD




COSMO Forecast, 20160527, 16:00 UTC + 01 h
deterministic run
REFLRVEL
ensemble
REFLRVEL
0.1 0.5 1 3 5 7 10 20 30 50 100
hail in mm
5 10 15 20 25 30 35 40 50 70 100
probability (hail > 1 mm)


COSMO Forecast, 20160527, 16:00 UTC + 02 h
deterministic run
REFLRVEL
ensemble
REFLRVEL
0.1 0.5 1 3 5 7 10 20 30 50 100
hail in mm
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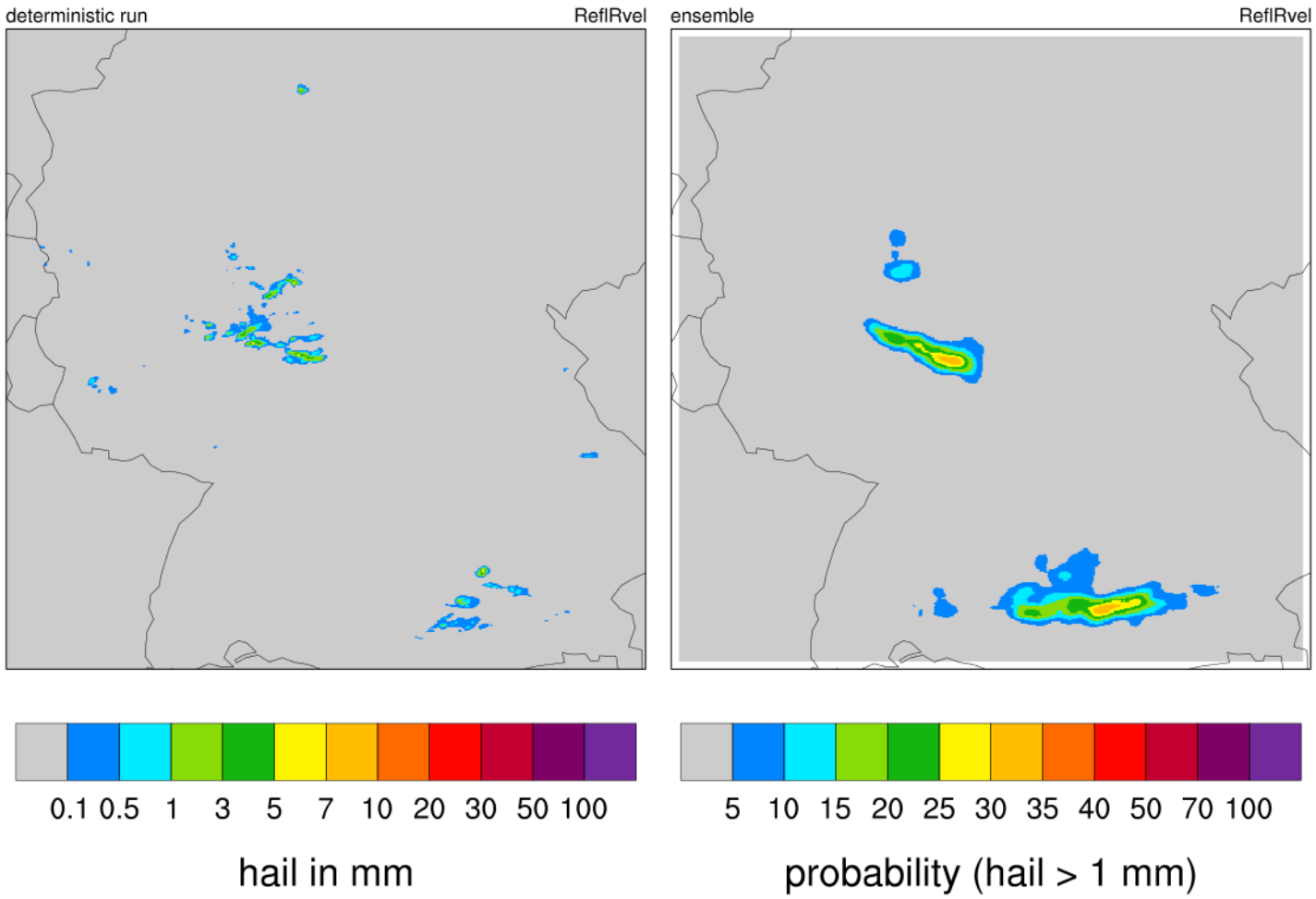
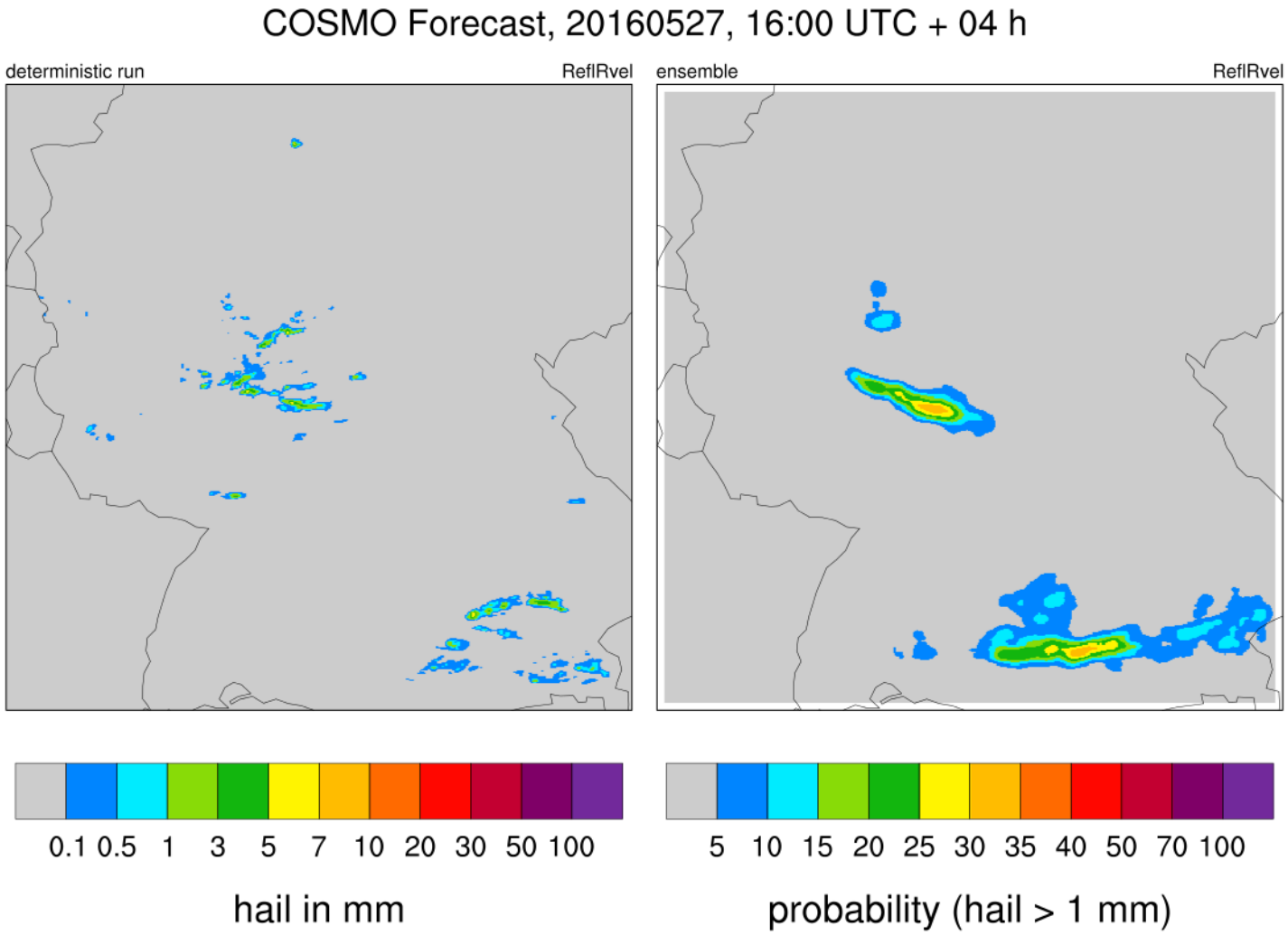
COSMO Forecast, 20160527, 16:00 UTC + 03 h




COSMO Forecast, 20160527, 16:00 UTC + 04 h
deterministic run
REFLRVEL
ensemble
REFLRVEL
0.1 0.5 1 3 5 7 10 20 30 50 100
hail in mm
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probability (hail > 1 mm)

Results of the forecast experiment

- Forecasting individual storms is difficult and further model improvements are necessary.
- The COSMO-LETKF systems has to potential to predict deep convection in more detail than the current nudging-based system.
- Forecasting hail is even more difficult. The two-moment scheme can predict hail, but biases are large and skill is low, so far. Needs more work and later on calibration of the probabilities.

Conclusions:

- Explicit assimilation and forecasting of individual convective storm is possible, but very difficult.
- Forecasting on this scale makes most sense in terms of probabilistic products.
- Still a lot to do until 2020, when we want to go operational with such a system.