

A Data Assimilation Testbed using KENDA and idealized COSMO Ensembles

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COSMO User Seminar
Data Assimilation Session
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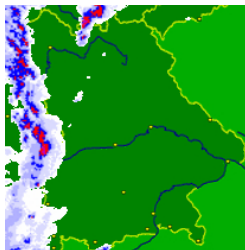
Outline

- 1 idealized COSMO-KENDA
 - Convective-scale Data Assimilation
 - Nature Run and Synthetic Observations

- 2 Experiments: LETKF Cycling and Ensemble Forecasts
 - Analysis Ensemble Convergence
 - Forecast error growth
 - Results, Conclusions, Outlook

Thunderstorm Prediction

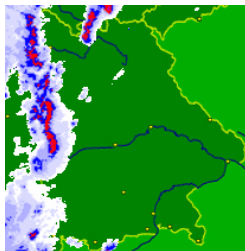
Large-scale phenomena (e.g. low-pressure systems) more predictable than small scales (convection, thunderstorms)



$\Delta t = 1 - 3 \text{ h} \rightarrow$ difficult predictability for $\rightarrow \Delta x = 20 \text{ km}$

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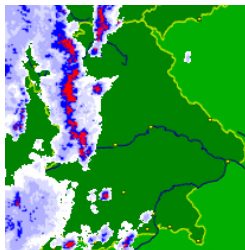
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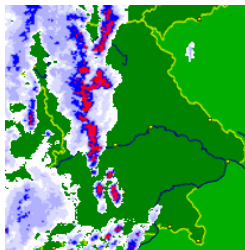
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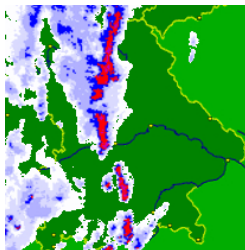
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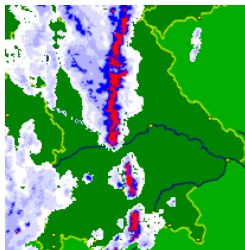
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- chaotic nature of atmosphere taken into account
- ensemble forecasts more useful than deterministic forecasts:
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- decision of DWD for operation of KENDA:
 - Kilometre-scale ENsemble Data Assimilation
 - Local Ensemble Transform Kalman Filter (LETKF) coupled with convection-permitting German forecast model COSMO-DE

Data Assimilation of Convection

Experiments for Ensemble Data Assimilation of Convection:

- **Perfect model** experiments (with nature run) to understand LETKF filter algorithms
- **Convection only**: no large scales
- **Simulated Doppler Radar** as realistic observation system

Nature Run and Ensemble

COSMO model setup (based on Daniel Leuenberger's work)

Domain: $198 \times 198 \times 50$ gridpoints
periodic lateral boundaries conditions

Resolution: 2 km horizontally

Initial state: Horizontally homogenous sounding,
 $CAPE = 2200 \frac{\text{J}}{\text{kg}}$,
random white noise on T (0.02 K) and W ($0.02 \frac{\text{m}}{\text{s}}$)
in the boundary layer

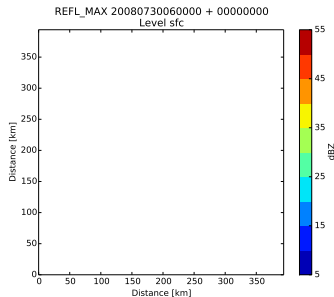
Model: Full COSMO physics with active radiation scheme

Forecast: 8 hour spinup until convection evolves:

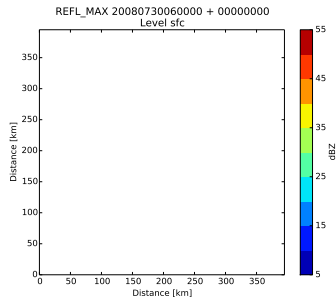
- long-lived cells, lifetime ≥ 6 h
- horizontal position *fully random* in ensemble

1 km Resolution vs. 2 km

$\Delta x = 2$ km

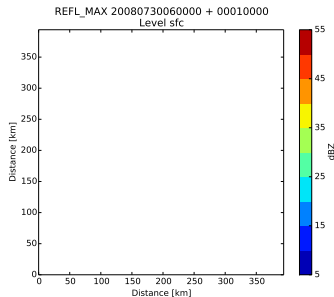


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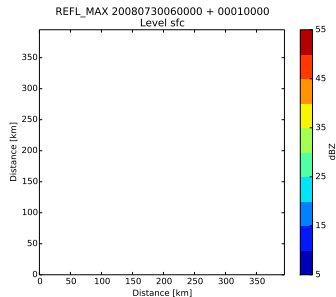


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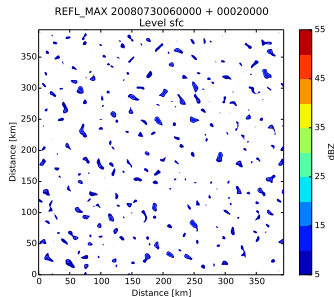


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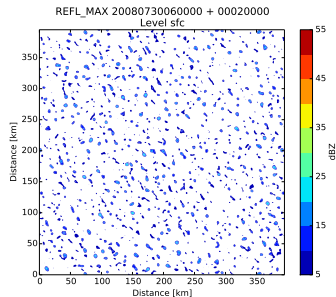


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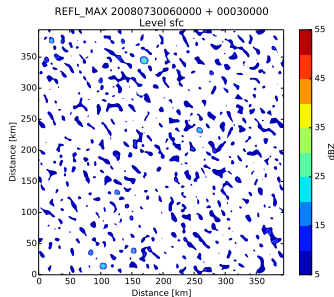


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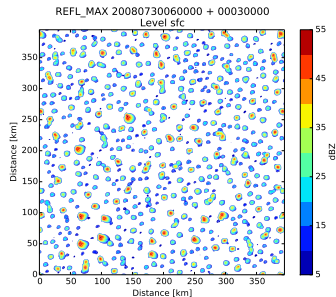


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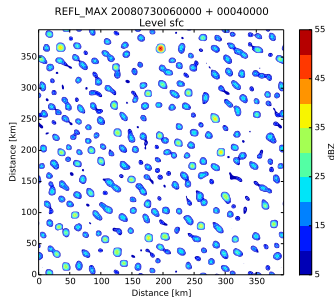


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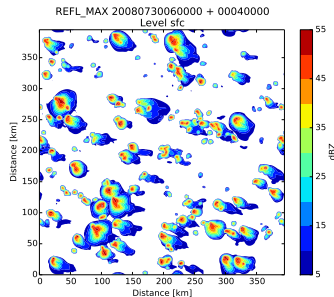


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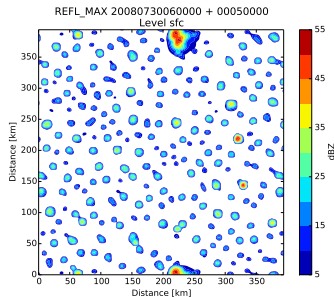


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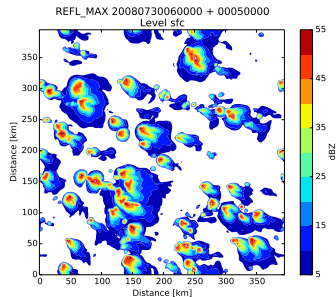


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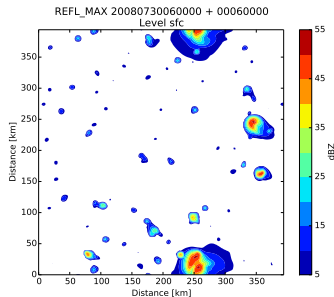


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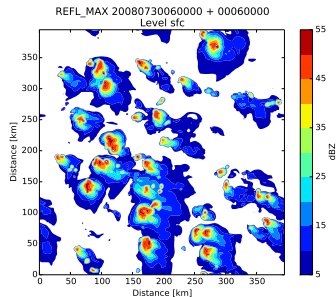


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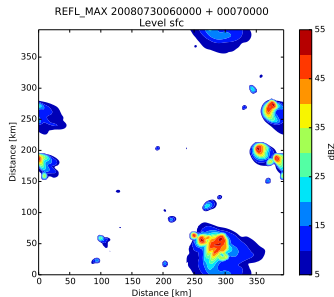


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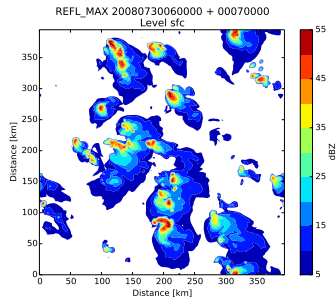


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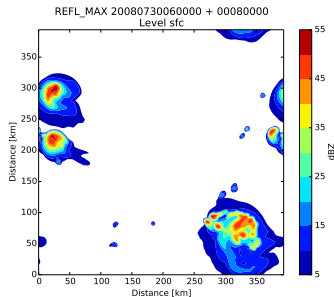


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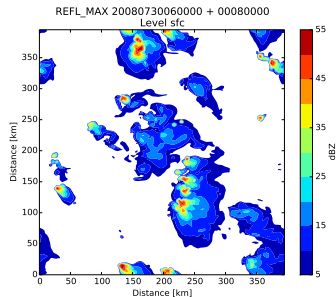


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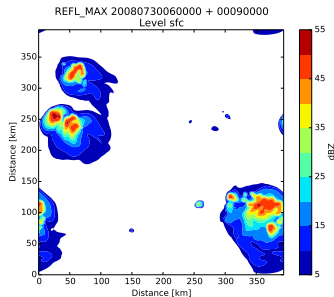


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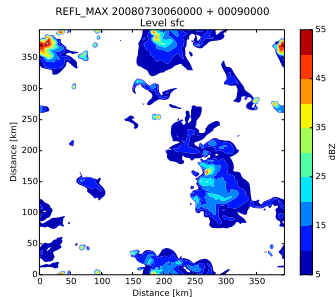


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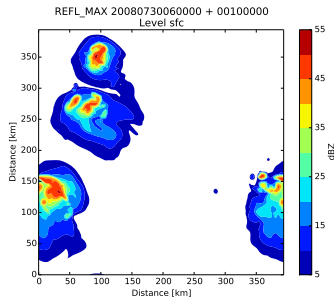


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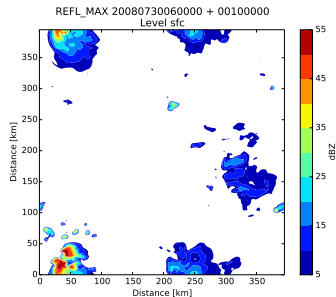


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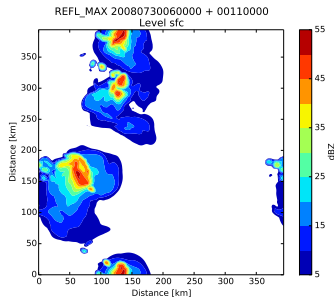


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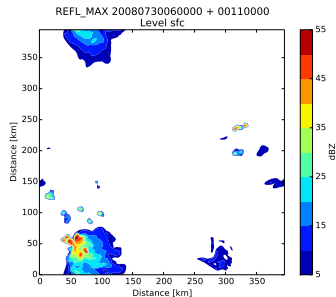


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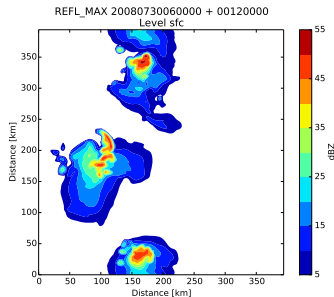


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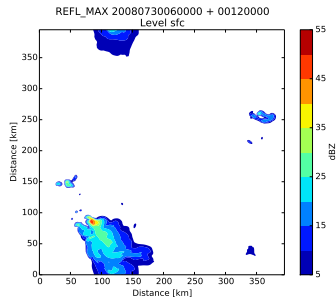


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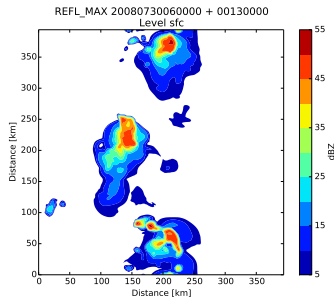


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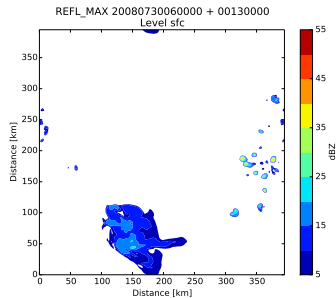


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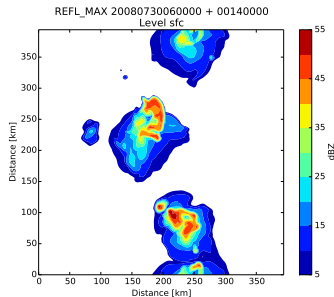


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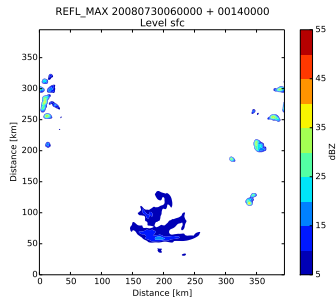


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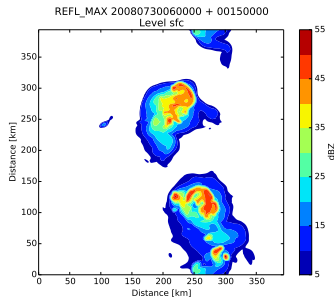


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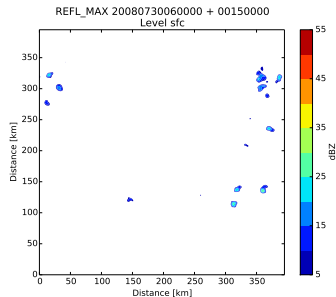


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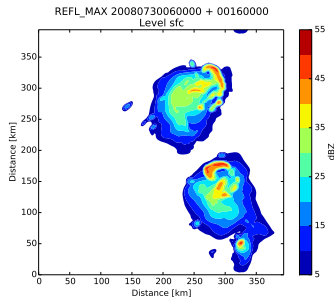


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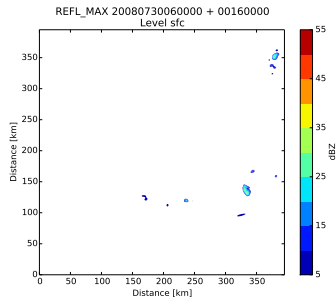


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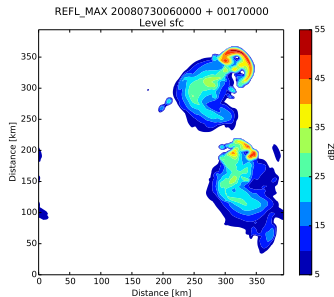


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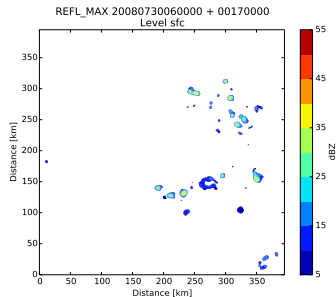


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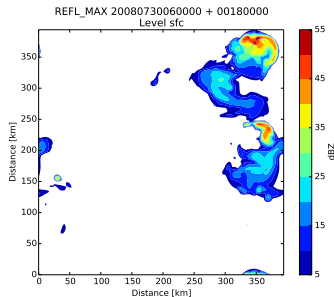


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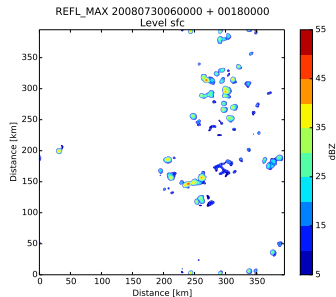


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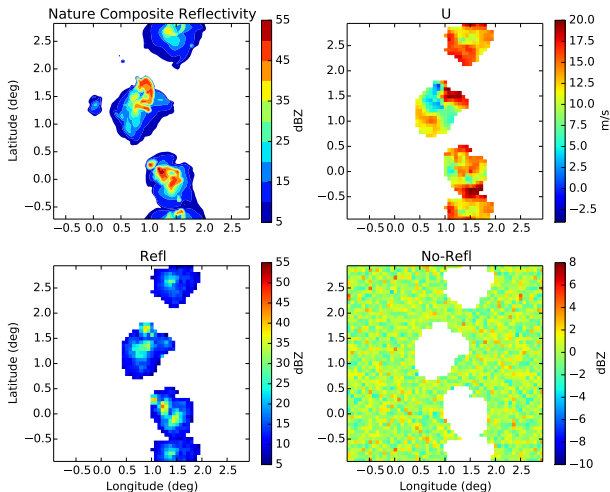


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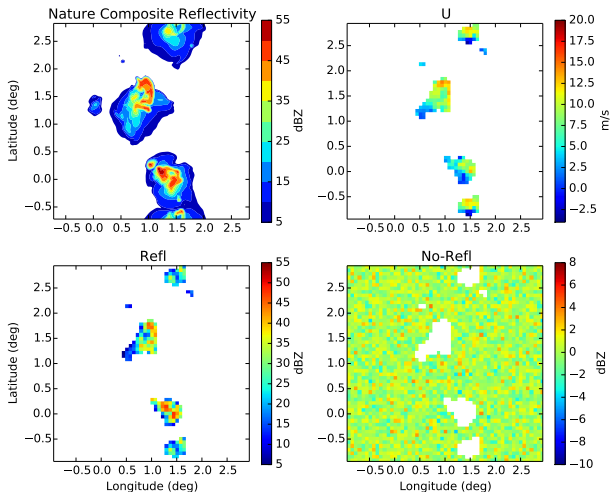
Synthetic Observations

20 UTC: Synthetic Observations at $z = 9776$ m

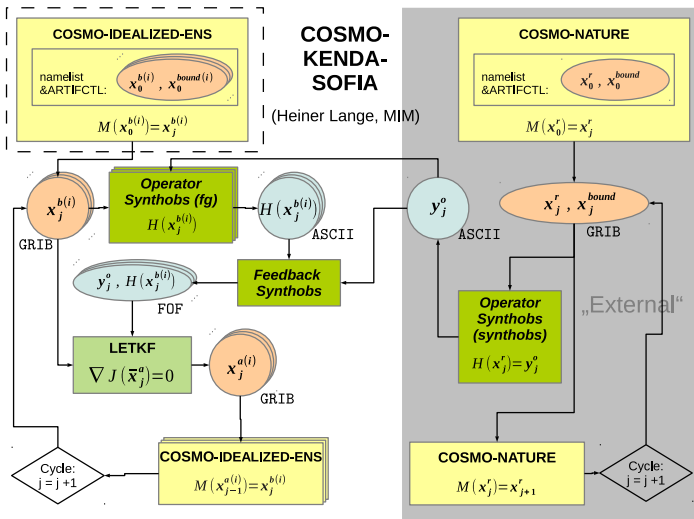


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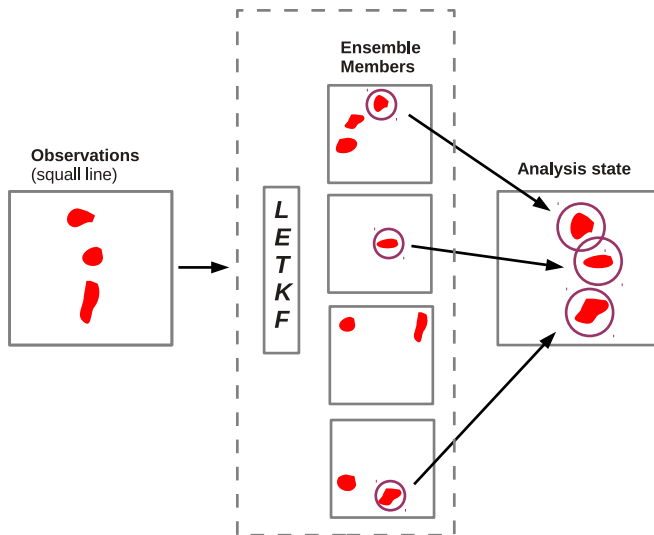
20 UTC: Synthetic Observations at $z = 514$ m



LETKF-Flowchart



LETKF - How it works



LETKF-Setup 1/2

Assimilation setup

- 50 member ensemble (perfect model)
- Python-simulated observations of *radial wind* and *(no)-reflectivity*
- periodic LETKF-solution
- Python-cycling environment

LETKF-Setup 1/2

Assimilation setup

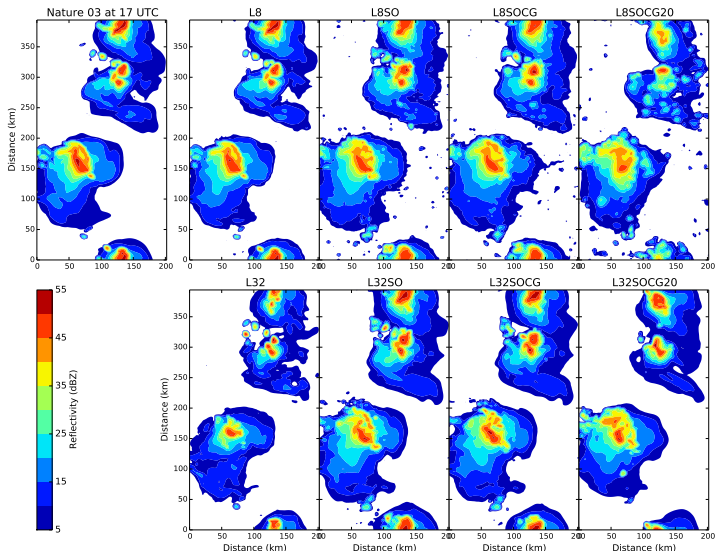
- 50 member ensemble (perfect model)
- Python-simulated observations of *radial wind* and *(no)-reflectivity*
- periodic LETKF-solution
- Python-cycling environment
- 3 hours cycled assimilation
- 3 hours ensemble forecast

LETKF-Setup 2/2

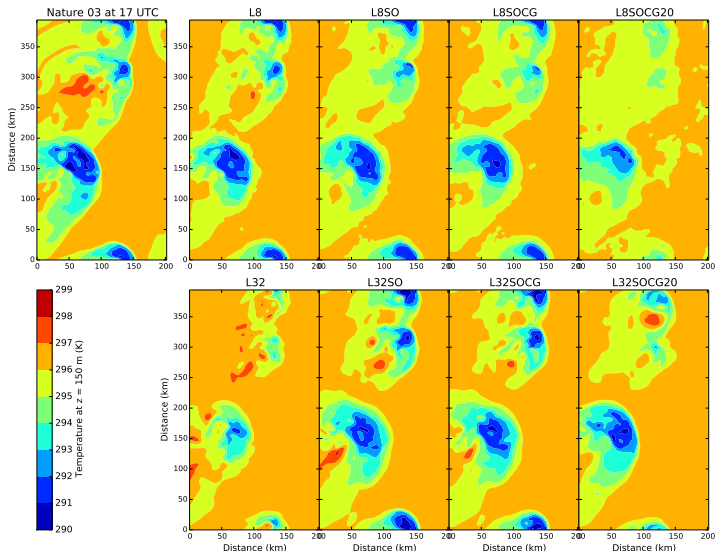
Assimilation settings

- Observation Resolution 2 and 8 km (superobservations SO)
- LETKF coarse grid on 2 and 8 km (coarse grid CG)
- Assimilation interval 5 and 20 minutes (20)
- Horizontal localization 8 and 32 km (L8 and L32)

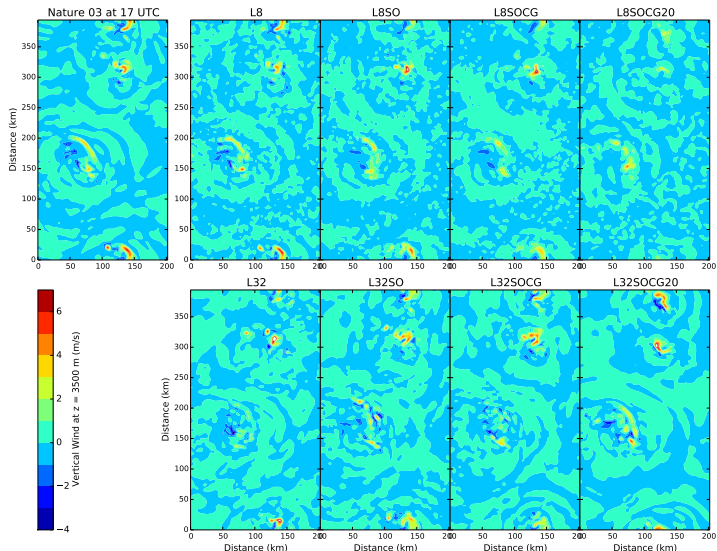
Assimilation Results: Nature vs. Analysis Ensemble Means



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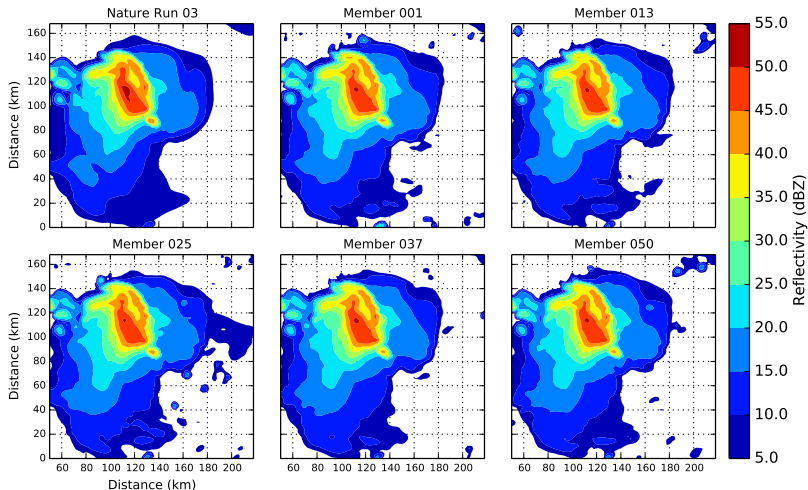


Assimilation Results: Nature vs. Analysis Ensemble Means



Analysis Members L8

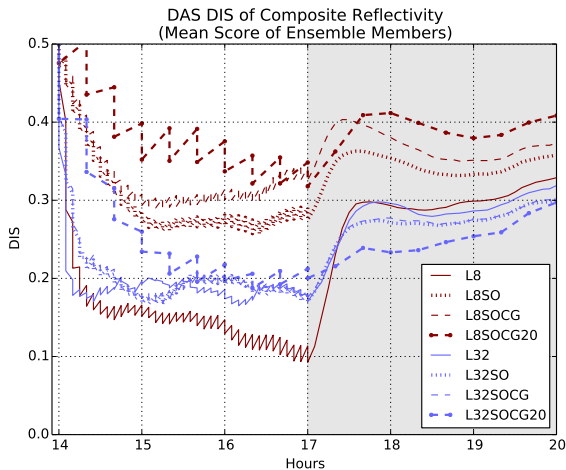
L8 Analysis, $t = 17$ UTC



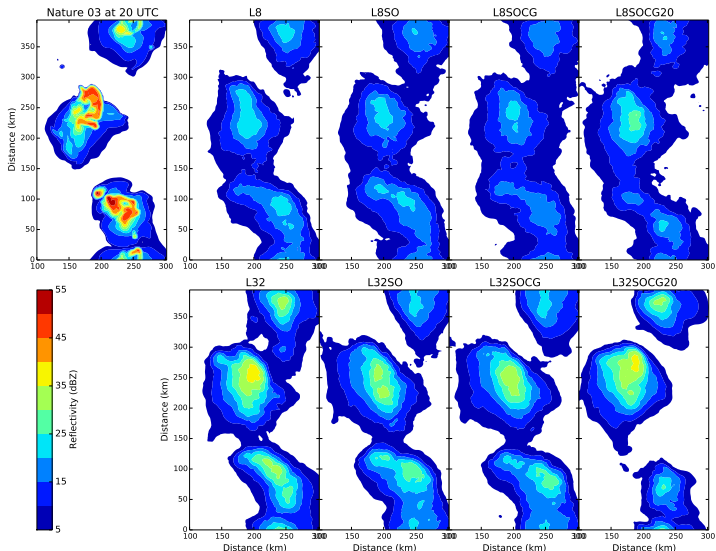
L32SOCG20 Analysis, t = 17 UTC



Forecast error growth (displacement of storms)



Forecast Results: Nature vs. Forecast Ensemble Means



Results and Conclusions

Assimilation Results

- Observation resolution of $4 \times \Delta x_{model}$ sufficient for analysis
- Update of temperature through covariances: problematic!
- Less noise introduced with $\Delta t_{ass} = 20$ minutes

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Forecast Results

- Very fast displacement error growth
- Bias issues with spurious convection
- Forecast quality limited by:
 - Predictability of convection
 - Dynamical imbalance of initial states (= LETKF analyses)

Outlook 1/2

Idealized KENDA

- Creative sandbox to study assimilation properties:
 - arbitrary types of convection (idealized COSMO)
 - free choice of ensemble spread / biases / model error
 - free choice of observation types, coverage and errors (very simple Python operator)
- KENDA-in-a-box: One Python cycling script (namelist-controlled) steers everything

Outlook 2/2

Further idealized studies

- Stability and imbalance in convective DA due to
 - strong ensemble convergence (observation errors and scale)
 - biases from strong localization
 - nonlinear observation operators
- Assimilation of convection in bad environmental soundings