Fine and Coarse Data Assimilation and Forecasts of Thunderstorms in an Idealized Testbed (Masterarbeit, finished)

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Outline

Fine vs. Coarse Assimilation

Obstacles:

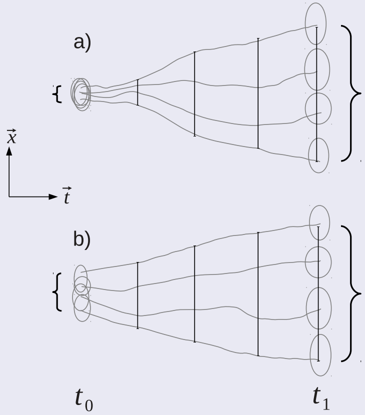
- Atmospheric predictability limited by error growth
- Forecasts tainted by model error

Question:

Is a forecast
(a) from a fine analysis
better than
(b) from a coarse analysis?

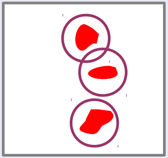
Forecast window: 3 hours

Expected behavior:

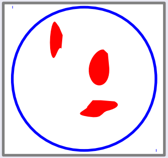


Fine vs. Coarse Assimilation

Nature Run
single cells of an elongated squall line



Analysis R8
single cells taken from best fitting member(s)



Analysis R32
coarse fit from coarsely fitting member(s)

Fine vs. Coarse Assimilation

Fine Scheme (R8)

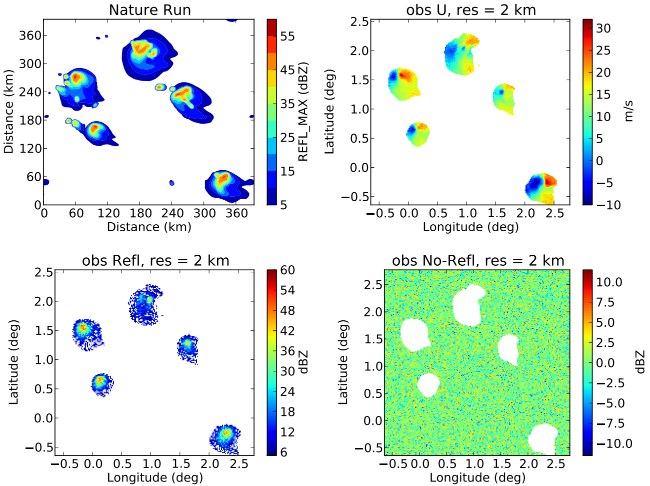
1. High-Res Observations

Coarse Scheme (R32)

1. Coarse SuperObservations

Fine vs. Coarse Assimilation

t = 14:00, $z_{synthobs}$ = 11500.0 m



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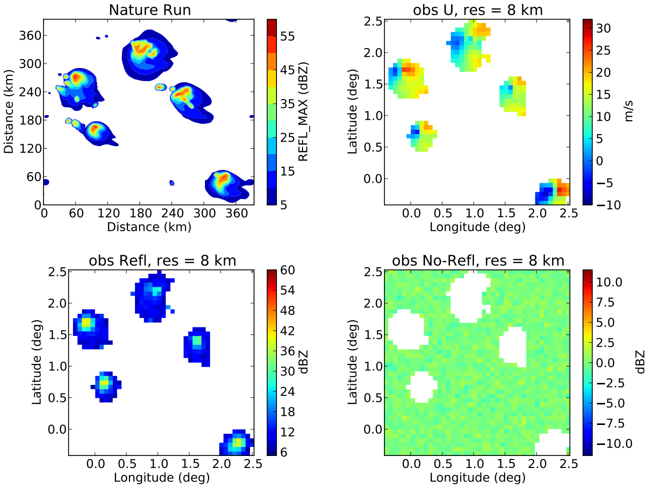

Fine vs. Coarse Assimilation

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1. High-Res Observations

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Fine vs. Coarse Assimilation

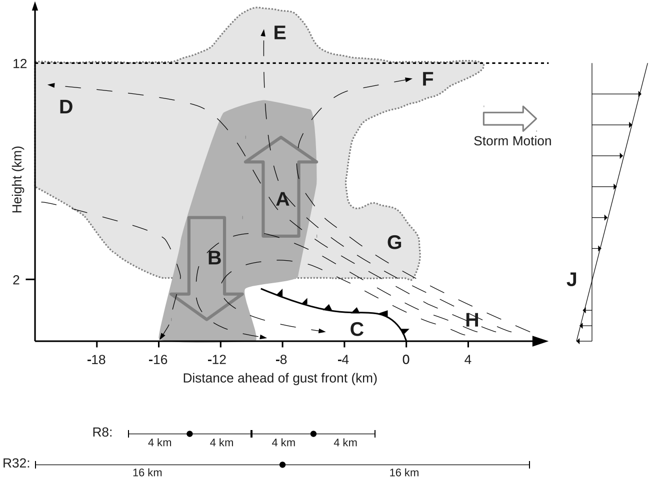
Fine Scheme (R8)

1. High-Res Observations
2. Small Localization Radius

Coarse Scheme (R32)

1. Coarse SuperObservations
2. Large Localization Radius

Fine vs. Coarse Assimilation



Fine vs. Coarse Assimilation

Fine Scheme (R8)

1. High-Res Observations
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Coarse Scheme (R32)

1. Coarse SuperObservations
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Fine vs. Coarse Assimilation

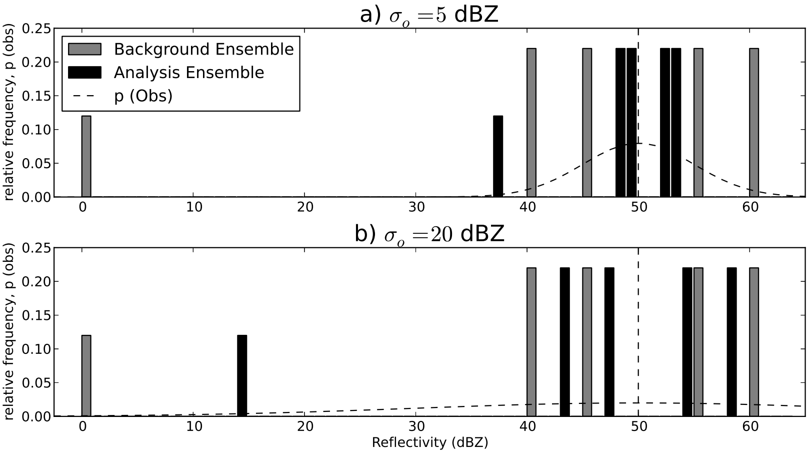
Fine Scheme (R8)

1. High-Res Observations
2. Small Localization Radius
3. Small **R**-entries σ_o^2

Coarse Scheme (R32)

1. Coarse SuperObservations
2. Large Localization Radius
3. Large **R**-entries σ_{SO}^2

Fine vs. Coarse Assimilation



Fine vs. Coarse Assimilation

Fine Scheme (R8)

1. High-Res Observations
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1. Coarse SuperObservations
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Fine vs. Coarse Assimilation

Fine Scheme (R8)

1. High-Res Observations
2. Small Localization Radius
3. Small **R**-entries σ_o^2
4. Short forecast interval

Coarse Scheme (R32)

1. Coarse SuperObservations
2. Large Localization Radius
3. Large **R**-entries σ_{SO}^2
4. Longer forecast interval

Fine vs. Coarse Assimilation

Fine Scheme (R8)

1. High-Res Observations
2. Small Localization Radius
3. Small **R**-entries σ_o^2
4. Short forecast interval

Analysis properties:

- Ensemble collapse onto observed clouds
- No spurious clouds
- Small error and variance

Coarse Scheme (R32)

1. Coarse SuperObservations
2. Large Localization Radius
3. Large **R**-entries σ_{SO}^2
4. Longer forecast interval

Analysis properties:

- Position of clouds roughly coincident with observations
- Spurious clouds possible
- Larger error and variance

Nature Run

COSMO setup

Domain: 198 x 198 x 50 gridpoints
periodic lateral boundaries conditions

Resolution: 2 km horizontally

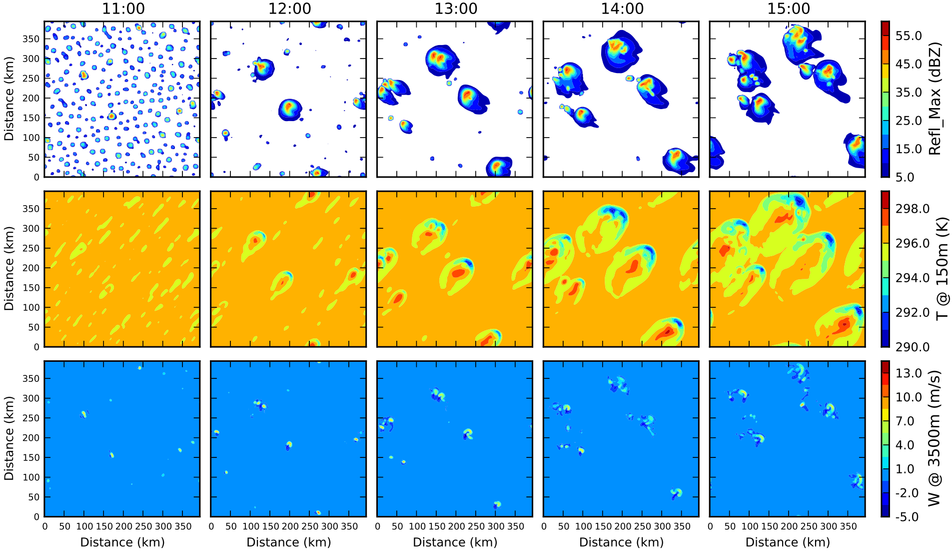
Initial state: Horizontally homogenous sounding
random T and W whitenoise in the boundary layer

Sounding: $CAPE = 2200\,\mathrm{J/KG}$
Steering wind from $\approx 225\,^{\circ}$

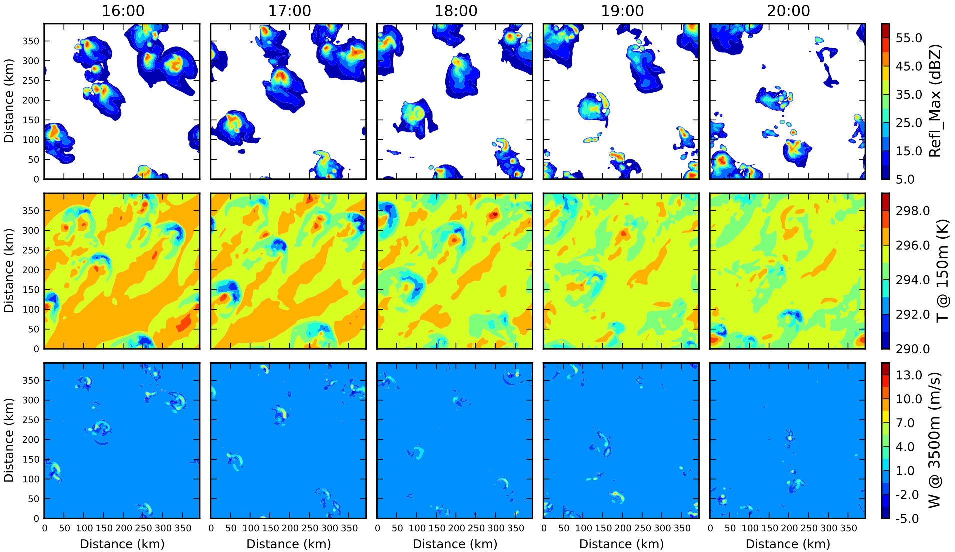
Forecast time: Start at 06:00, runs for 24 h

Model physics: Full COSMO physics with active radiation scheme

Nature-Run: Time series



Nature-Run: Time series

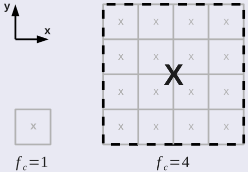


Synthetic Doppler Radar Observations

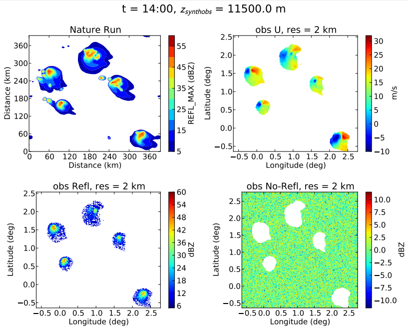
Doppler radar observations:

1. Reflectivity ($> 5\,\mathrm{dBZ}$)
2. No-Reflectivity (where *refl* $< 5\,\mathrm{dBZ}$)
3. U-wind (where *refl* $> 5\,\mathrm{dBZ}$)

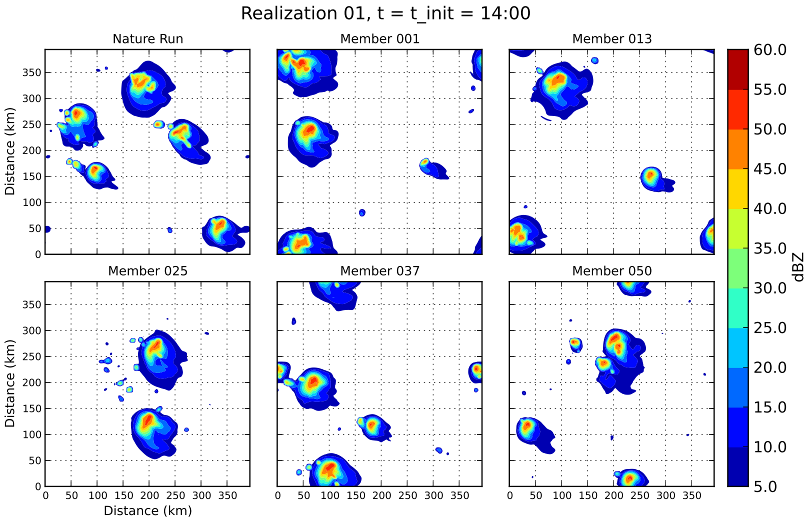
Coarse SuperObservations for R32:



Nature Run and Synthetic Obs:



Nature Run vs. Ensemble



LETKF Setup

Idealized LETKF

Localization: 8 / 32 km horizontally (R8/R32), 3-5 km vertically

ObsRes: 2 / 8 km horizontally (R8/R32), 1 km vertically

Coarse Grid: Factor 1 / 4 (R8/R32)

Interval: 5 / 20 minutes (R8/R32)

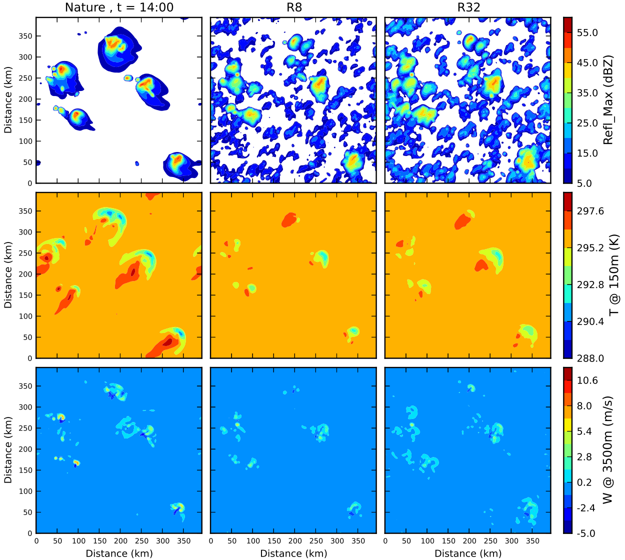
Inflation:

- **R**-inflation with factor 4 / 16 (R8/R32)
- inflation factor $\rho = 1.05$

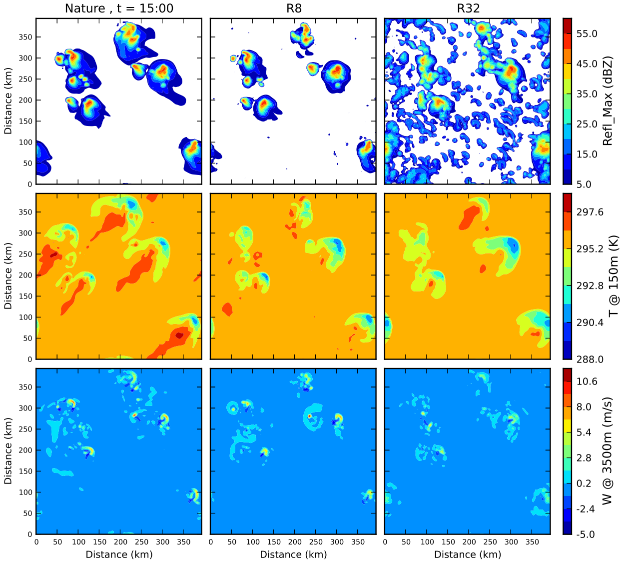
Timesetup:

- 06:00 - 14:00 Model spinup
- 14:00 - 17:00 Assimilation cycling
- 17:00 - 20:00 Ensemble forecasts

Assimilation Results: Nature vs. Analysis Ensemble Means



Assimilation Results: Nature vs. Analysis Ensemble Means



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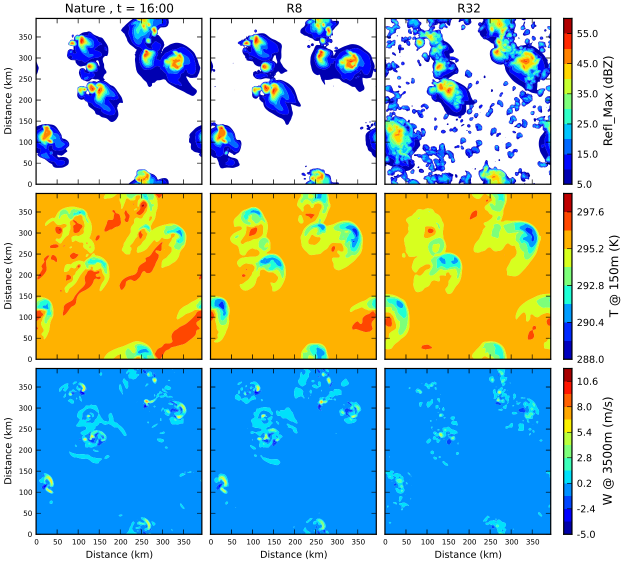

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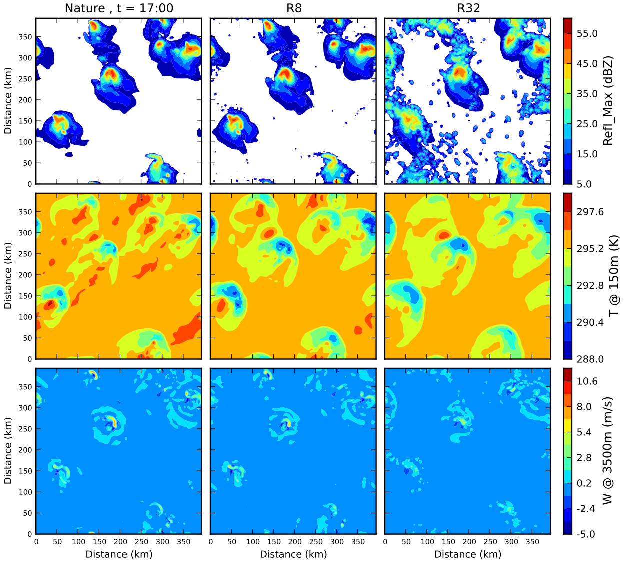
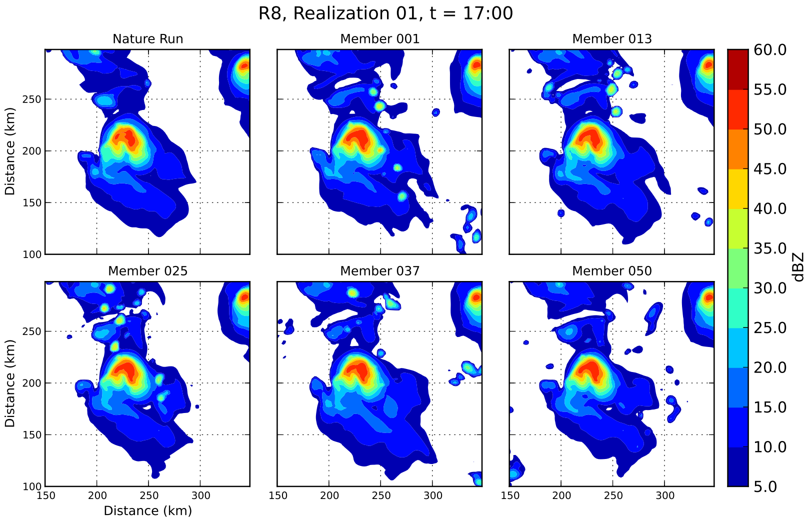
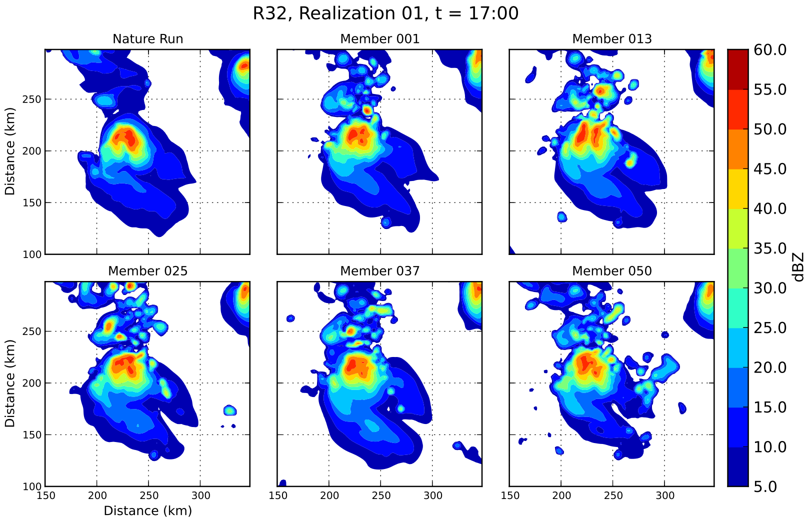


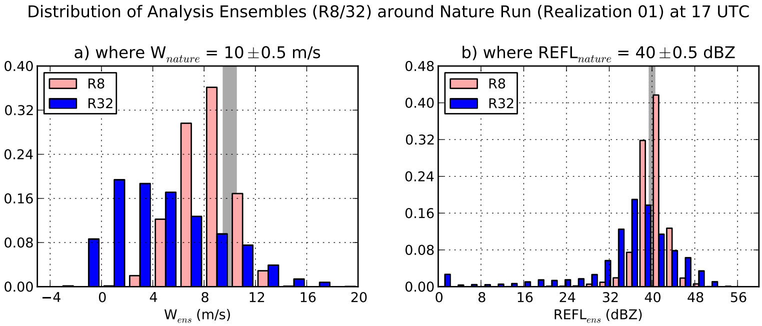
Analysis Members R8



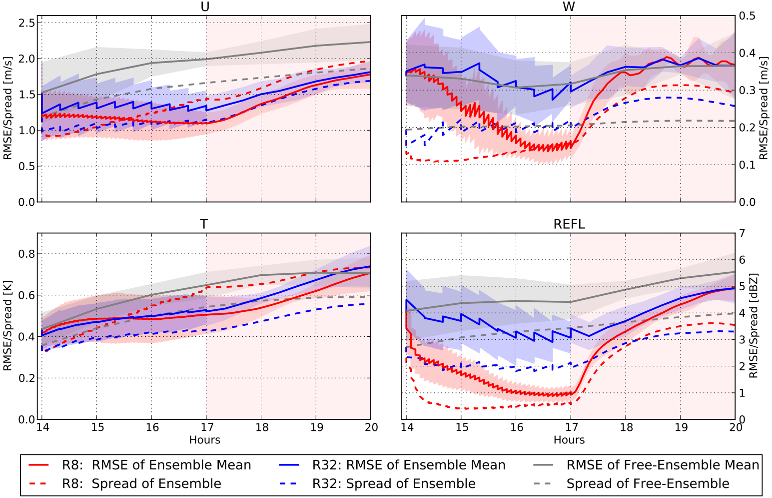
Analysis Members R32



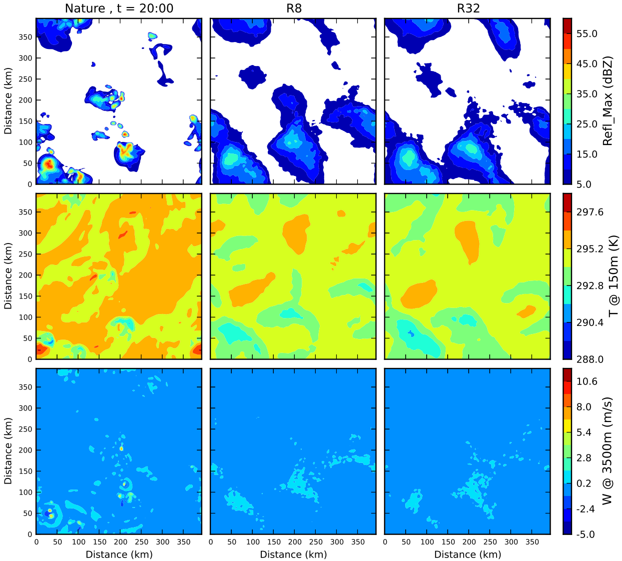
Analysis Ensemble Distributions



RMSE-Statistics: U, W, T, Reflectivity

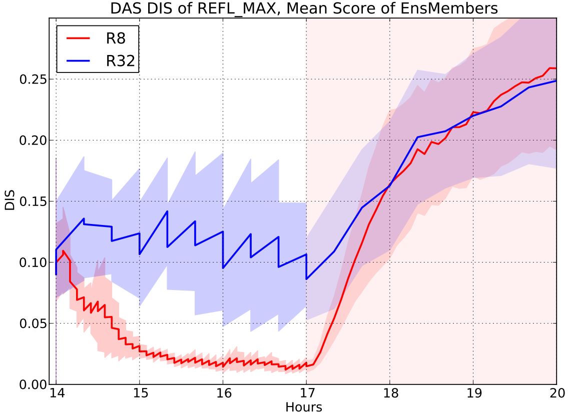


Forecast Results: Nature vs. Forecast Ensemble Means



DAS-DIS Displacement Score

Displacement of forecast field with respect to observations, measured by the amplitude of the morphing vector field:



Summary

Methods:

- Successful assimilation of long-lived convection by LETKF using only radar observations of radial wind and reflectivity
- 3 hours of cycled assimilation followed by 3-h forecast

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Fine vs. coarse scheme:

- Fine scheme produces better analyses than coarse scheme
- Coarse scheme gives equally good 3-h forecasts
- Coarse scheme needs *much less* computational power

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- Successful assimilation of long-lived convection by LETKF using only radar observations of radial wind and reflectivity
- 3 hours of cycled assimilation followed by 3-h forecast

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- Coarse scheme gives equally good 3-h forecasts
- Coarse scheme needs *much less* computational power

Problems:

- Too much convection in coarse analyses
- Bad temperature-analyses for both schemes

Conclusions

For operational forecasts:

1 hour forecast: Fine scheme advantageous

3 hour forecast: Coarse scheme probably sufficient

For operational models:

- Enhanced mesoscale predictability due to
  - Orography
  - Synoptic forcing

  → better forecasts, independent of fine/coarse initial storm state
- Advantages of coarse scheme:
  - Model-inherent convection, also if sounding forecast is wrong
  - Spurious convection possibly helpful for late detections

Outlook

Masterarbeit

publication in preparation for MWR (*Lange & Craig*)

PhD project

Assimilation of MODE-S aircraft winds in COSMO-MUC-KENDA

Basic research on LETKF in convective regimes:

- Constraints to LETKF-analyses, e.g. positivity and conservation of mass (*with Tijana*)
- Localization and dynamical stability concerns
  - introduction of spurious gravity waves through analyses
  - spectral analysis of increments
  - stability constraints on analysis possible? filtering?

Bias through humidity bounds

Setting negative values of analysed mixing ratios ("Qx") to zero is physically necessary, but introduces a wet bias: