Quantifying Dynamical Inconsistencies in Convective Ensemble Data Assimilation

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LMU Munich

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Motivation

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Spurious convection after Radar data assimilation of thunderstorms

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Method

1. Proper characterization and quantification of spurious convection (this talk)
2. Development and testing of methods to increase “dynamical consistency” of analyses (future work)

Outline

1. LETKF OSSEs with varying length scales
   - Fine and Coarse Analysis Schemes
   - Spurious Convection
2. Quantifying Dynamical Consistency
   - Gravity Wave Noise
   - Coldpool Coupling

~~Retrieval of Perturbation Pressure~~ (in abstract, but dropped)

OSSE Setup

- Perfect model experiment:
  - 2 km horizontal resolution, sounding with high CAPE and shear
  - 1 Nature Run, 50 Members

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- Long-lived ($>$ 6h) mesoscale convective systems
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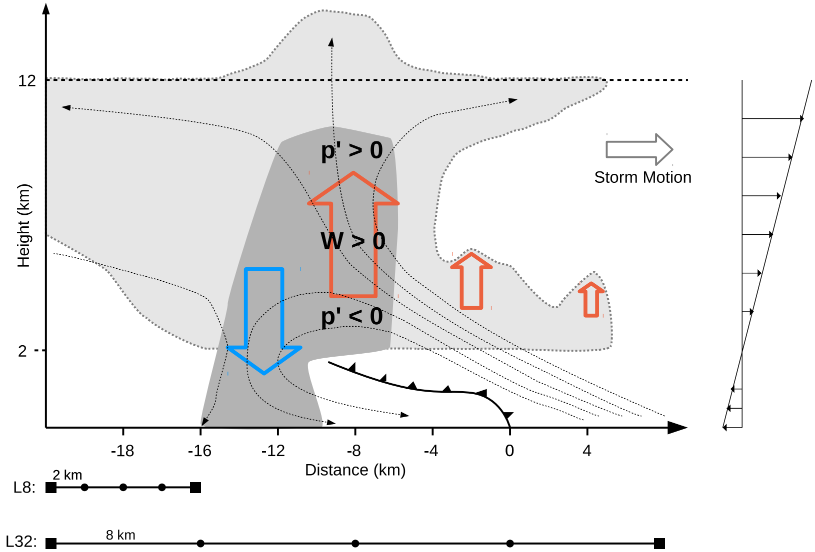
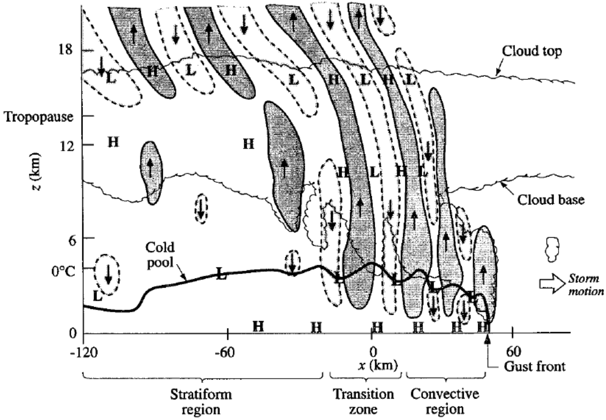
  - similarity of storms (shape, strength) due to identical sounding
- LETKF Data Assimilation
  - COSMO-KENDA System (German Weather Service)
  - Simulated observations of reflectivity and Doppler wind
  - 3 hour assimilation cycling
  - 3 hour ensemble forecast
  - Varying analysis scales to study scale dependent error growth

Multicell Storm Structure



Multicell Storm Structure

Yang and Houze, 1996: Multicell Squall-Line Structure as a Manifestation of Verztically Trapped Gravity Waves, MWR, 123, 641.



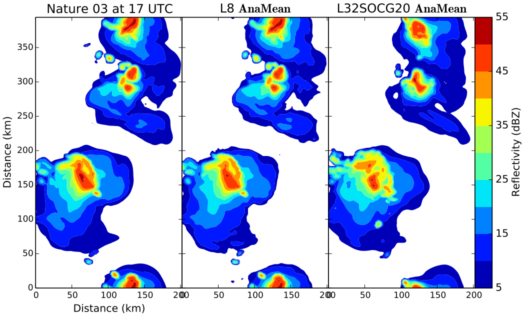
Fine and Coarse Analysis Schemes

L8

- 8 km localization
- 2 km observations
- 5 minute cycling

L32SOCG20

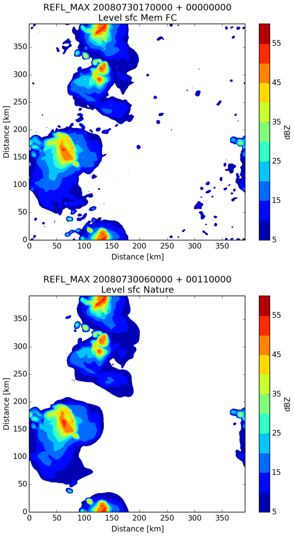
- 32 km localization
- 8 km observations
- 20 minute cycling



Lange and Craig 2014: The Impact of Data Assimilation Length Scales on Analysis and Prediction of Convective Storms, MWR, 142, 3781-3808.

First Forecast Hour: Spurious Storm Evolution

- Top: Member of **L8**
- Bottom: Nature



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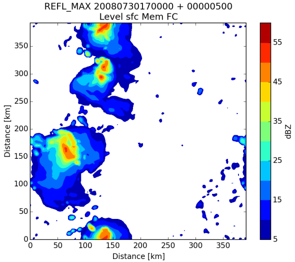

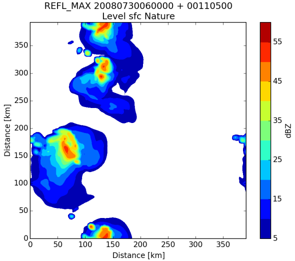

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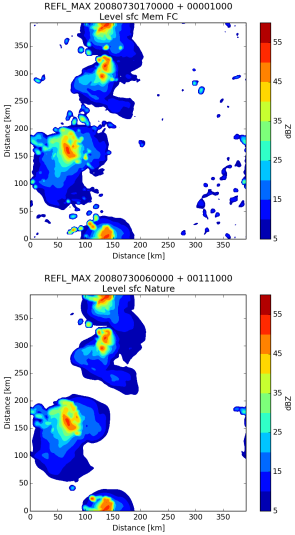

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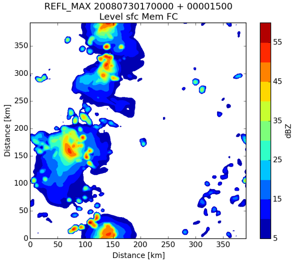

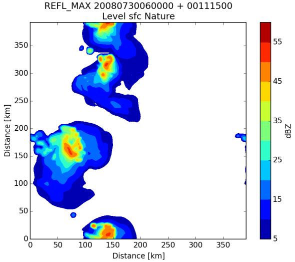

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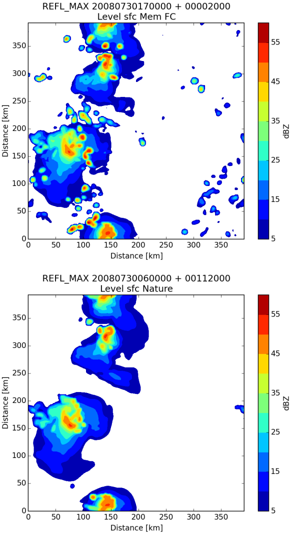

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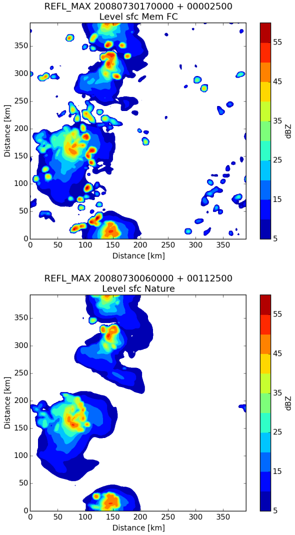

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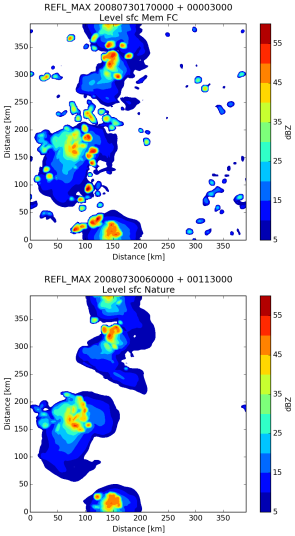

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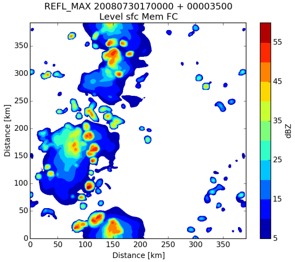

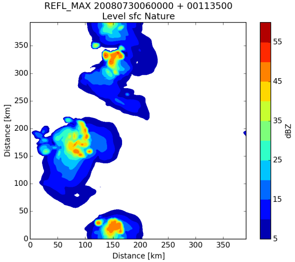

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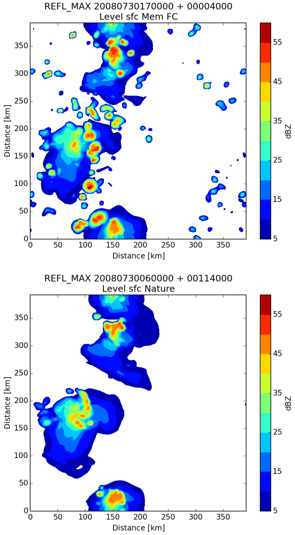

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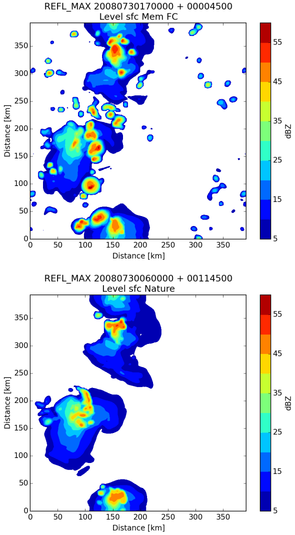

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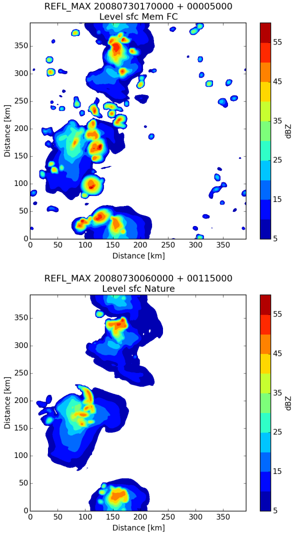

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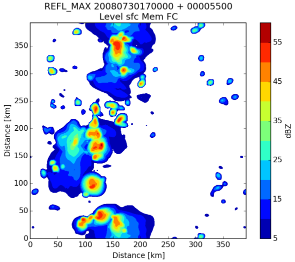

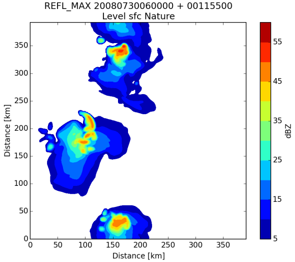

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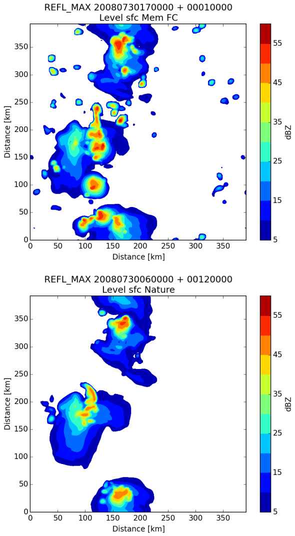
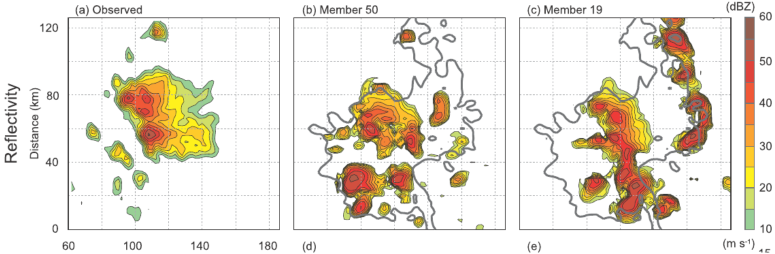


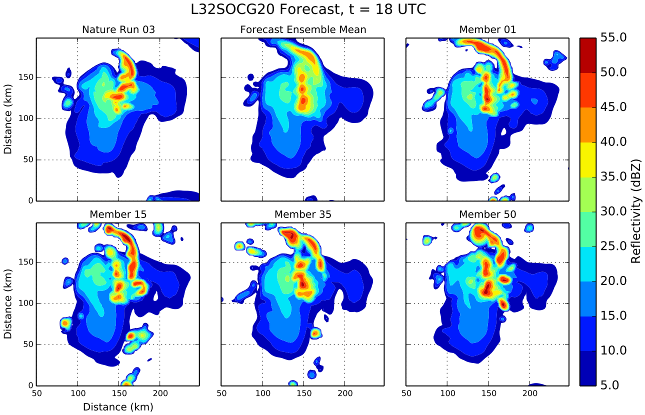
Spurious convection with other people

Aksoy et al, 2010: A Multicase Comparative Assessment of the Ensemble Kalman Filter for Assimilation of Radar Observations. Part II: Short-Range Ensemble Forecasts, MWR, 138, 1273.



1h Forecasts in L32

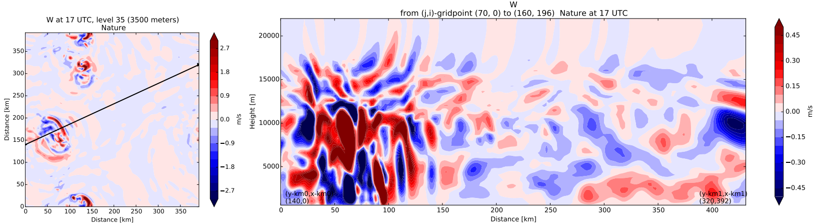
Less spurious convection in L32 → more “dynamical consistency”?



Outline

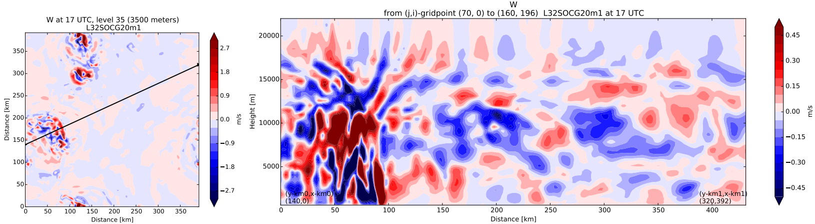
Gravity Wave Noise (last analysis)

Nature Run



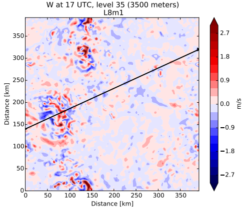
Gravity Wave Noise (last analysis)

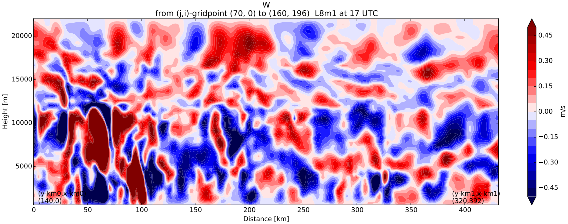
L32 Member



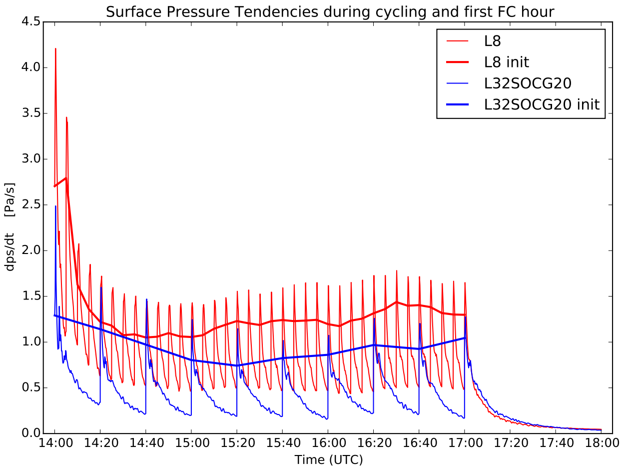
Gravity Wave Noise (last analysis)

L8 Member





Surface Pressure Tendencies

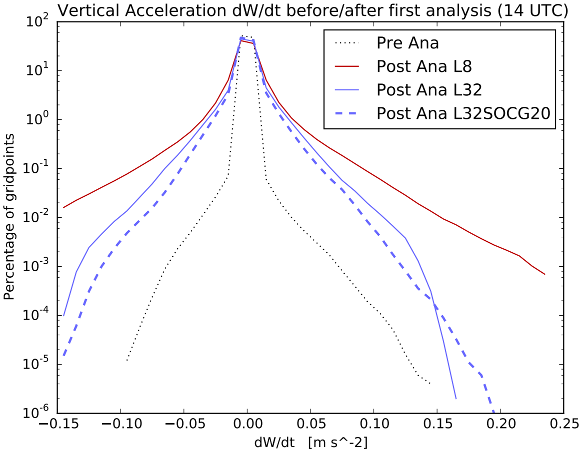


Surface Pressure Tendencies Results

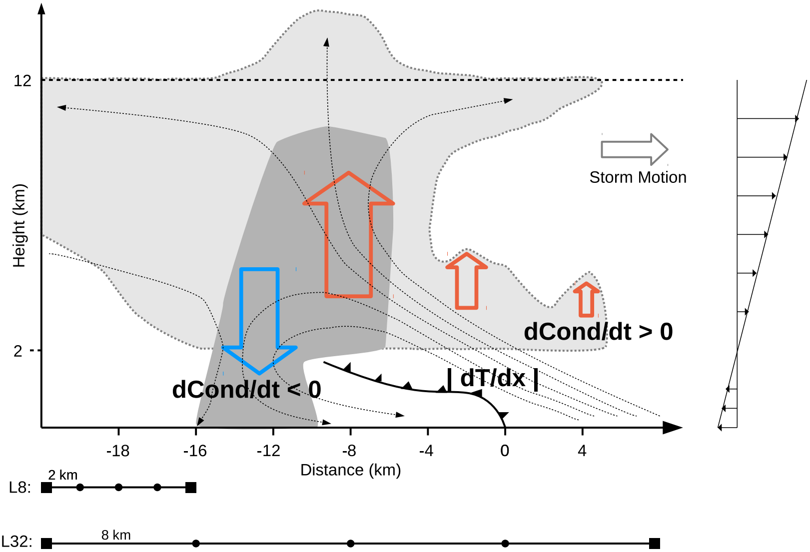
Surface pressure tendencies

- larger in L8, especially at first analysis
- incomplete relaxation within the cycling (L8 and L32)
- only bulk indication for “dynamical consistency”

Vertical Acceleration Histograms



Coldpool Coupling



Cold Pool Coupling

Question

"How closely is the future convection coupled to the present cold pool edges?""

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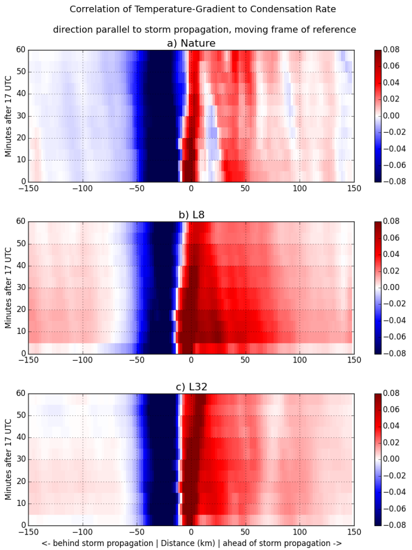
Method

Compute the spatio-temporal correlation $C(\vec{x}, t)$:

- $C(\vec{x}, t)$ of field $|\vec{\nabla} T(\vec{x}, t_0)|$ with field dCond/dt $(\vec{x}, t)$
- moving frame of reference: $|\vec{\nabla} T(\vec{x}, t_0)|$ shifted with storm propagation vector
- regard correlation parallell to storm movement

Cold Pool Coupling: 1 hour Ensemble Forecasts



Top to bottom:

- Nature
- L8
- L32

Left: behind storm

Right: ahead of storm

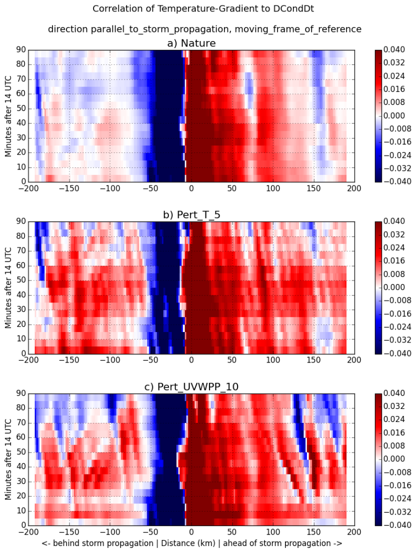
Cold Pool Coupling Results

Measure for "dynamical inconsistency":
New storms uncoupled to cold pool edges and their gust fronts.

Spurious convection in **L8**:

- triggering of long lived spurious cells immediately (< 5 min) after initialization
- mostly ahead of "true" storms
- no trace of hypothetical perturbations that "radiate" from true storms
- apperently caused by precursor cells:
  - shallow convergence patterns without rain
  - below observation threshold
    $\rightarrow$ not fully suppressed during cycling

Impact on Cold Pool Coupling: Perturbed Nature Run



Nature Run instantaneously perturbed with layerwise perturbations of background ensemble

Top to bottom:

- Nature
- Nature + Perturbed T
- Nature + Perturbed U, V, W, PP

Left: behind storm
Right: ahead of storm

Outlook: Assimilation Plans

Outlook:

Influence of EnKF-DA relaxation methods on spurious convections

- Vary localization (vertically, horizontally) and observation resolution
- Give observations less weight (inflated observation error covariance, RTPP)
- Spatial smoothing of increments
- Relating spatio-temporal parameters to GW phase speed
- Assimilate wind-only
- Gaussian anamorphosis of reflectivity observations

Summary and open questions

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Spurious convection: An embarassment for convective scale DA.

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Metrics for gravity wave noise and unbalanced storm dynamics

- Surface Pressure Tendencies
- Coldpool Coupling

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Need help with:

- Instantaneous measures for balanced states?
- Other possibilities, e.g. using ensemble sensitivities?

Surface Pressure Tendencies: Perturbed Nature Run