Quantifying Dynamical Inconsistencies in Convective Ensemble Data Assimilation

Heiner Lange, George C. Craig, Tijana Janjić

Hans-Ertel-Centre for Weather Research, Data Assimilation Branch LMU Munich

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Motivation

Problem

Spurious convection after Radar data assimilation of thunderstorms

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Cause

Dynamically inconsistent DA analyses as initial states of forecasts

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Spurious convection after Radar data assimilation of thunderstorms

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Dynamically inconsistent DA analyses as initial states of forecasts

Method

- Proper characterization and quantification of <u>spurious</u> <u>convection</u> (this talk)
- Development and testing of methods to increase "dynamical consistency" of analyses (future work)

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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)

(4月) トイヨト イヨト

OSSE Setup

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

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- 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

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Fine and Coarse Analysis Schemes

Multicell Storm Structure



Fine and Coarse Analysis Schemes Spurious Convection

Multicell Storm Structure

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



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Fine and Coarse Analysis Schemes Spurious Convection

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: <u>The Impact of Data Assimilation Length Scales on</u> Analysis and Prediction of Convective Storms, MWR, 142, 3781-3808.

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Fine and Coarse Analysis Schemes Spurious Convection

First Forecast Hour: Spurious Storm Evolution

REFL MAX 20080730170000 + 00000000 Level sfc Mem FC 350 300 250 [km] Distance [150 187 100 Distance [km] MAX 20080730060000 + 00110000 Level sfc Nature 350 300 E 250' 9 200 R7 Distan 150 100 50 200 300 Distance [km] イロト イヨト イヨト イヨト

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

Fine and Coarse Analysis Schemes Spurious Convection

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REFL MAX 20080730170000 + 00000500 Level sfc Mem FC 350 300 250 250 200 200 150 , SB 100 Distance [km] MAX 20080730060000 + 00110500 Level sfc Nature 350 300 E 250' 35 8 200 1B7 Distance 150 25 100 50 150 200 250 300 Distance [km] イロト イヨト イヨト イヨト

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REFL MAX 20080730170000 + 00001500 Level sfc Mem FC 350 300 250 [w] 200 200 15f R7 100 Distance [km] MAX 20080730060000 + 00111500 Level sfc Nature 350 300 E 250' 35 8 200 R7 150 25 100 50 150 200 250 300 Distance [km] イロト イヨト イヨト イヨト

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REFL MAX 20080730170000 + 00002000 Level sfc Mem FC 350 300 E 250' Distance Distance 1B7 Distance [km] MAX 20080730060000 + 00112000 Level sfc Nature 350 300 E 250' Distance R7 25 100 50 150 200 250 300 Distance [km] イロト イヨト イヨト イヨト

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REFL MAX 20080730170000 + 00002500 Level sfc Mem FC 350 300 250 [w] 200 200 150 1B7 10 Distance [km] L MAX 20080730060000 + 00112500 Level sfc Nature 350 300 E 250' Distance 150 R7 25 100 50 100 150 200 250 300 Distance [km] イロト イヨト イヨト イヨト

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REFL MAX 20080730170000 + 00003500 Level sfc Mem FC 350 300 250 200 200 150 , SB 100 Distance [km] REFL MAX 20080730060000 + 00113500 Level sfc Nature 350 300 E 250' 8 200 1B7 Distance Dis 25 100 50 100 200 250 300 Distance [km] イロト イヨト イヨト イヨト

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REFL MAX 20080730170000 + 00005000 Level sfc Mem FC 350 300 250 200 200 150 , SB 25 100 Distance [km] REFL MAX 20080730060000 + 00115000 Level sfc Nature 350 300 250 200 200 150 35 **18**Z 100 50 100 150 200 250 300 350 Distance [km] イロト イヨト イヨト イヨト

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REFL MAX 20080730170000 + 00005500 Level sfc Mem FC 350 300 250 200 200 150 **18**Z 25 100 Distance [km] REFL MAX 20080730060000 + 00115500 .evel sfc Nature 350 300 250 200 200 150 35 **18**Z 100 50 150 200 250 300 350 Distance [km] イロト イヨト イヨト イヨト

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Spurious convection with other people

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



Fine and Coarse Analysis Schemes Spurious Convection

1h Forecasts in L32

Less spurious convection in L32 \rightarrow more "dynamical consistency"?



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Gravity Wave Noise Coldpool Coupling

Gravity Wave Noise (last analysis)



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Gravity Wave Noise Coldpool Coupling

Gravity Wave Noise (last analysis)



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Gravity Wave Noise Coldpool Coupling

Gravity Wave Noise (last analysis)

L8 Member



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Gravity Wave Noise Coldpool Coupling

Surface Pressure Tendencies



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Gravity Wave Noise Coldpool Coupling

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"

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Gravity Wave Noise Coldpool Coupling

Vertical Acceleration Histograms



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Gravity Wave Noise Coldpool Coupling

Coldpool Coupling



Cold Pool Coupling

Question

"How closely is the <u>future convection coupled</u> to the <u>present cold</u> 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

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Gravity Wave Noise Coldpool Coupling

Cold Pool Coupling: 1 hour Ensemble Forecasts

Correlation of Temperature-Gradient to Condensation Rate



Top to bottom:

- Nature
- L8
- L32

Left: behind storm Right: ahead of storm

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Cold Pool Coupling Results

Measure for "dynamical inconsistency":

New storms uncoupled to cold pool edges and their gust fronts.

Spurious convection in L8:

- $\bullet\,$ 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

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Gravity Wave Noise Coldpool Coupling

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

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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

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Summary and open questions

Statement:

Spurious convection: An embarassment for convective scale DA.

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Present OSSE setup: Sensible or chasing its own errors?

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Done so far:

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?

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Surface Pressure Tendencies: Perturbed Nature Run

