On the scale and magnitude of surface precursors to simulated isolated convective initiation

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Dense Surface Observations

Pressure Observation Locations at 2014072800 (total=1101)
Dense Surface Observations

Pressure Observation Locations at 2014072800 (total=7113)
Role of Surface in Convective Initiation (CI)

• Scale dependence of precipitation predictability is small-scale variability of low-level humidity, wind and temperature (Weckwerth 2000)

• Low-level convergence 15-90 minutes before CI (Weckwerth and Parsons 2006)

• Horizontal Convective Rolls and Misocyclones have surface signature (e.g. Weckwerth et al. 1996, Kain et al. 2013)

• Surface observations able to constrain boundary layer well (Hacker et al. 2007, Hacker and Snyder 2005)
Question

How well can assimilating dense surface observations constrain model forecasts of convective initiation?
Experiments

• Directly examine the impact of surface observations on convective initiation, beyond the larger mesoscale

• 30 cases
• May-October, 2014
• “Air-mass” storms absent large-scale forcing
• ALL cases associated with at least one severe storm report
Experiments

• Simulations with CM1 \textit{(r17)} (Bryan and Fritsch 2002; Bryan 2002)
  • Initialize at 12Z with real soundings
  • Fixed surface fluxes
  • 0.2 K random T perturbations at start
  • 104km x 104km x 18km domain
  • 200m resolution “truth” run (e.g. Nowatarski et al 2014)
    • 50m dz in PBL
  • 1 km resolution—100 member ensemble
    • 150m dz in PBL
  • YSU PBL, NASA-Goddard MP and radiation
KFFC June 11, 2014

http://www.mmm.ucar.edu/imagearchive/

http://weather.uwyo.edu/
Object-based tracking

- Based on the Method for Object-based Diagnostic Evaluation (MODE) (Davis et al. 2006/2009; Wolff et al. 2014)
- Thresholding based on Kang and Bryan 2011
Storm Objects

Total Precipitating Storms
200m → 14
1km → 8-18
Surface Field Composites (1km)

• 1256 precipitating storms from 100 ensemble members (1km)
• Centered at location where precipitation begins
• Examine surface fields from 90 minutes before convective precip
Composite CREF [dBZ] (t = -90 min.)

Composite of Precipitating Objects

< CREF

T2 →

90 min
To Precip.

< PSFC

U10 →

1km res.
Composite of Precipitating Objects

\( \leftarrow \text{CREF} \rightarrow \text{T2} \)

60 min To Precip.

\( \leftarrow \text{PSFC} \rightarrow \text{U10} \)

1 km res.
Composite of Precipitating Objects

£ CREF
T2 ➔

40 min
To Precip.

£ PSFC
U10 ➔

1km res.
Composite of Precipitating Objects

$\leftarrow$ CREF
T2 $\rightarrow$

30 min To Precip.

$\leftarrow$ PSFC
U10 $\rightarrow$

1 km res.
Composite of Precipitating Objects

$\leftarrow$ CREF

$\rightarrow$ T2

20 min To Precip.

$\leftarrow$ PSFC

$\rightarrow$ U10

1km res.
Composite of Precipitating Objects

\( \leftarrow \text{CREF} \rightarrow \text{T2} \)

10 min To Precip.

\( \leftarrow \text{PSFC} \rightarrow \text{U10} \)

1 km res.
Composite of Precipitating Objects

:\textarrow{\leftarrow}{CREASE} \rightarrow{T2}

0 min To Precip.

:\textarrow{\leftarrow}{PSFC} \rightarrow{U10}

1 km res.
Composite of Precipitating Objects

\[ \text{CREF} \leftarrow \text{T2} \rightarrow \]

10 min
After Precip.

\[ \text{PSFC} \leftarrow \text{U10} \rightarrow \]

1 km res.
Composite of Precipitating Objects

CREF \leftarrow \quad \text{T2} \quad \rightarrow \quad \text{PSFC}

20 min After Precip.

\leftarrow \quad \text{PSFC} \quad \rightarrow \quad \text{U10}

1 km res.
Surface Field Composites (200m)

- 14 storms from single 200m “truth” run
- Small sample size $\rightarrow$ noisier
Composite of Precipitating Objects

$\leftarrow$ CREF $\rightarrow$ T2

50 min To Precip.

$\leftarrow$ PSFC $\rightarrow$ U10

200m res.
Composite of Precipitating Objects

CREF \leftarrow T2 \rightarrow

40 min To Precip.

PSFC \leftarrow U10 \rightarrow

200m res.
Composite of Precipitating Objects

\[\text{CREF} \leftarrow \text{T2} \rightarrow \text{PSFC} \quad \text{U10} \rightarrow \]

30 min
To Precip.

200m res.
Composite of Precipitating Objects

← CREF
T2 →

20 min
To Precip.

← PSFC
U10 →

200m res.
Composite of Precipitating Objects

⇠ CREF

T2 ➤

10 min To Precip.

⇠ PSFC

U10 ➤

200m res.
Composite of Precipitating Objects

[CREF CREF] [T2 T2] [PSFC PSFC] 0 min To Precip.

[PSFC PSFC] [U10 U10] 200m res.
Composite of Precipitating Objects

← CREF
T2 →

10 min After Precip.
← PSFC
U10 →

200m res.
Compositing Summary

- Observable, coherent anomalies apparent 45-60 minutes before precipitation
  - 1-2 hours speculated predictability limit
    (Droegemeier 1990, Weckwerth 2000)
- $\sim 1$ K temp, 1.5 m/s U, 0.1 hPa PSFC
  - Consistent with observed CBL variability preceding Cl
- Scale on order of 3-5 km (200m)
- Weak anomalies in moisture (not shown)
- Similar anomalies at both resolutions!
Horizontal Correlations

• Evaluate the most effective parameters for data assimilation
  • How dense do observations need to be?
  • How sensitive do observations need to be?
• To summarize impact, compute average *ensemble* correlations and regressions of surface variables to estimated PBL height
• Common CI criterion $\rightarrow$ HPBL=LCL (LFC for precip.) (Kang and Bryan 2011)
2m Temp. and HPBL
Pre-CI

Avg. Correlation of t2 to hpb1  Time: 70

Avg. Regression Slope of t2 to hpb1
~Time of Cl

Avg. Correlation of t2 to hpbl  Time: 90

Avg. Regression Slope of t2 to hpbl
Post-Ci

Avg. Correlation of t2 to h0

Time: 105

Avg. Regression Slope of t2 to h0

10km

10km
Correlations Summary

• Covariances capture horizontal convective roll structure in pre-convective environment (~20km decorrelation length)
• Rapid decrease in length scale as storms begin developing
• After storm development, cold pool dynamics apparent
Summary

- Increasing availability of dense surface observations from a variety of sources
- Experiments with idealized ensembles show promise
  - *Observable* anomalies in surface fields 45-60+ minutes prior to onset of precipitation
  - Surface observations strongly correlate through the depth of the CBL at feasibly observable length scales
    - Horizontal correlations vary with time → ensembles!
Next Steps

• Complete analysis for remainder of cases
  • How does correlation length scale vary with the environment?
  • How long are perturbations recognizable before onset of precipitation?
• Cycle the ideal ensembles
  • Does the data assimilation actually lead to improved forecast of CI?
  • Will model spin-up negate impact?
• Full-scale OSSE and OSE experiments
  • Can we realize improvements with large-scale dynamics included?
  • How well do our dense surface observations live up to expectations?
References


Extra Slides
U-wind and HPBL
Pre-CI
~Time of CI
Post-CI

Avg. Correlation of u10 to hpbl  Time: 105

Avg. Regression Slope of u10 to hpbl
Vertical Profile of Adjustment

Pre-CI

Largest adjustments made to temperature at top of boundary layer
Vertical Profile of Adjustment

Time of CI

- Large adjustments at and above BL
- Surface increments becoming large
- Anvil and gravity wave correlations

Graph showing vertical increments with variance and mean increment data.
Vertical Profile of Adjustment

Post-CI

Strong adjustments limited to surface (cold pools)
Fractions Skill Score

REDO FIGURE
Missing Link

Synoptic-Scale Conditions

Large Mesoscale Features

Traditional Data Assimilation

Dense Surface Observations

Storm Evolution

Nowcasting

Radar Data Assimilation

Initial Formation of Storms