The impact of GLOW wind profile data on numerical simulation of a warm season convective system observed during IHOP_2002

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Backgorund

"Tropospheric winds are the number one unmet measurement for improving weather forecasts."

-- National Research Council

- **Lack of wind profile measurements in atmospheric boundary layer**

- **Challenge in the use of wind profiles from a single observational station.**

Science questions

- **The importance of moisture fields in the initiation and evolution of mesoscale convective systems has been well recognized and studied during IHOP_2002.**

- **However, the influence of wind measurements on numerical predictions of mesoscale convective systems has not been given much attention.**

Objectives

- **Examine the ability of four-dimensional variational data assimilation method in assimilating multi-time wind profiles from a single station**

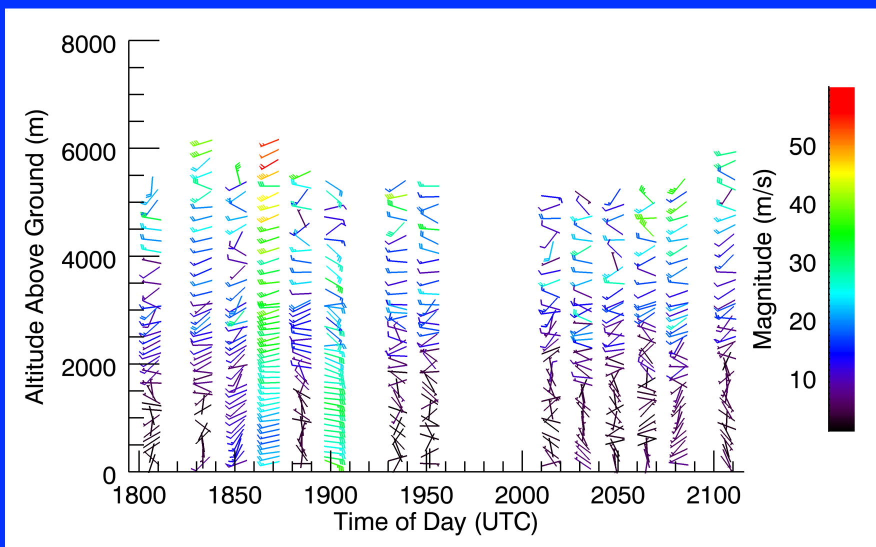
- **Demonstrate the impact of wind profiles on numerical simulation of a warm season mesoscale convective system**

GLOW (Goddard Lidar Observatory for Winds) Lidar Wind Observations

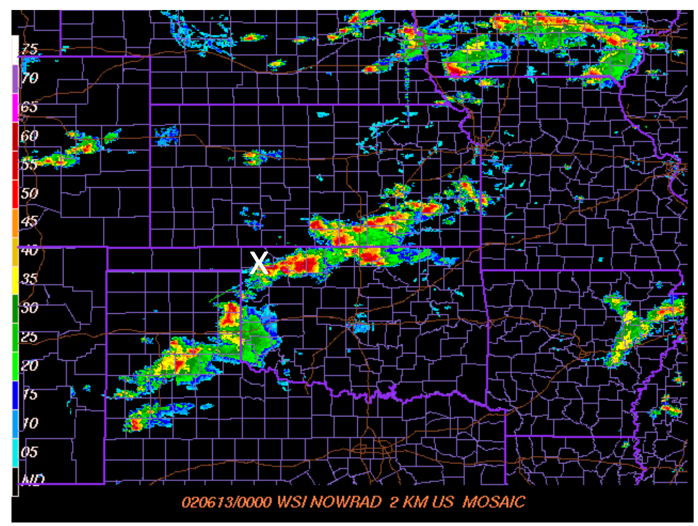
International H_2 O Program (IHOP) field program: May and June 2002

Wind profile Resolution: 10 minutes;
100m below 3km and 200m above 3km of the height

Over 240 h of data in 35 days

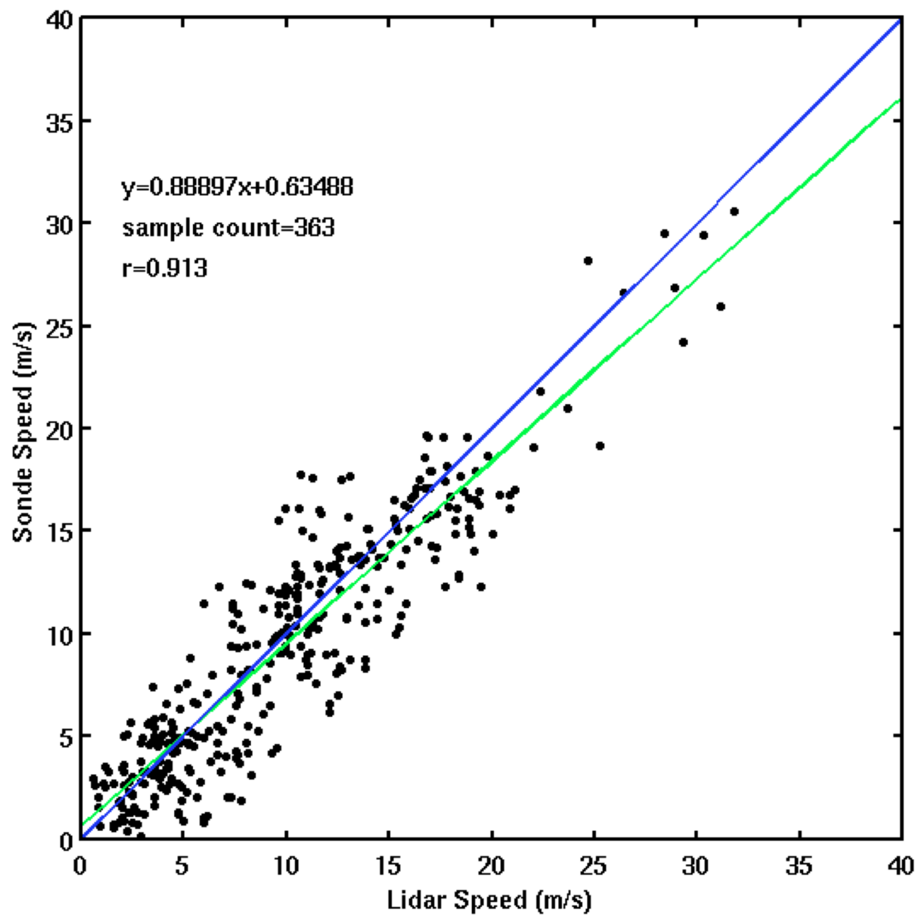


Observations at Homestead site, OK during 12-13 June 2002



Quality of the Lidar wind data

Wind speed: Lidar vs. Sonde



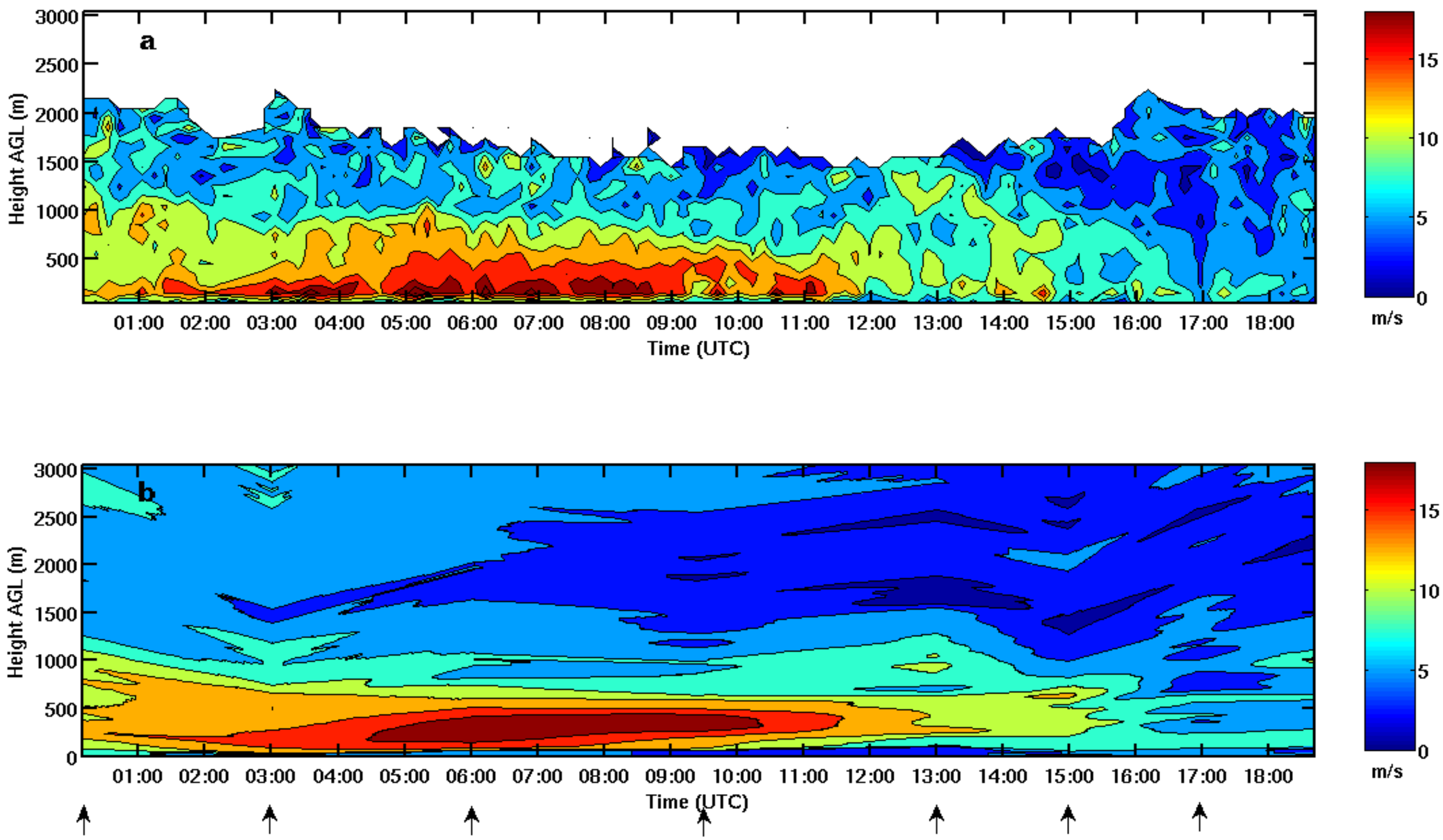
The scatter plots of wind speed of Lidar samples and Sonde samples.

Li et al. 2010

Time-height variation of the wind: Lidar vs. Sonde

Lidar

Sonde



June 25 , 2002

Li et al. (2010)

4-Dimensional Variational Data Assimilation (4-D VAR)

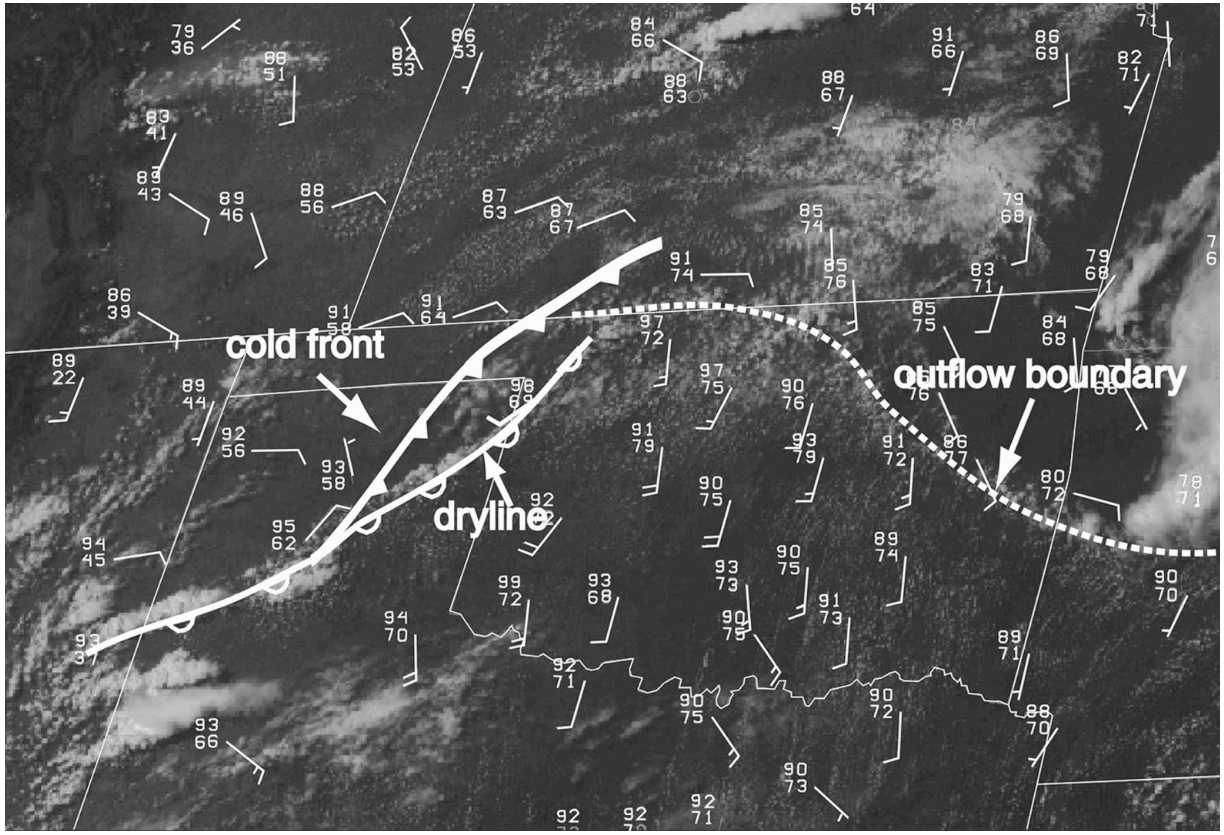
$$J(x_o) = \sum_{k=1,m} J_k + J_b$$

$$J_b = \frac{1}{2}(x - x_b)^T B^{-1}(x - x_b)$$

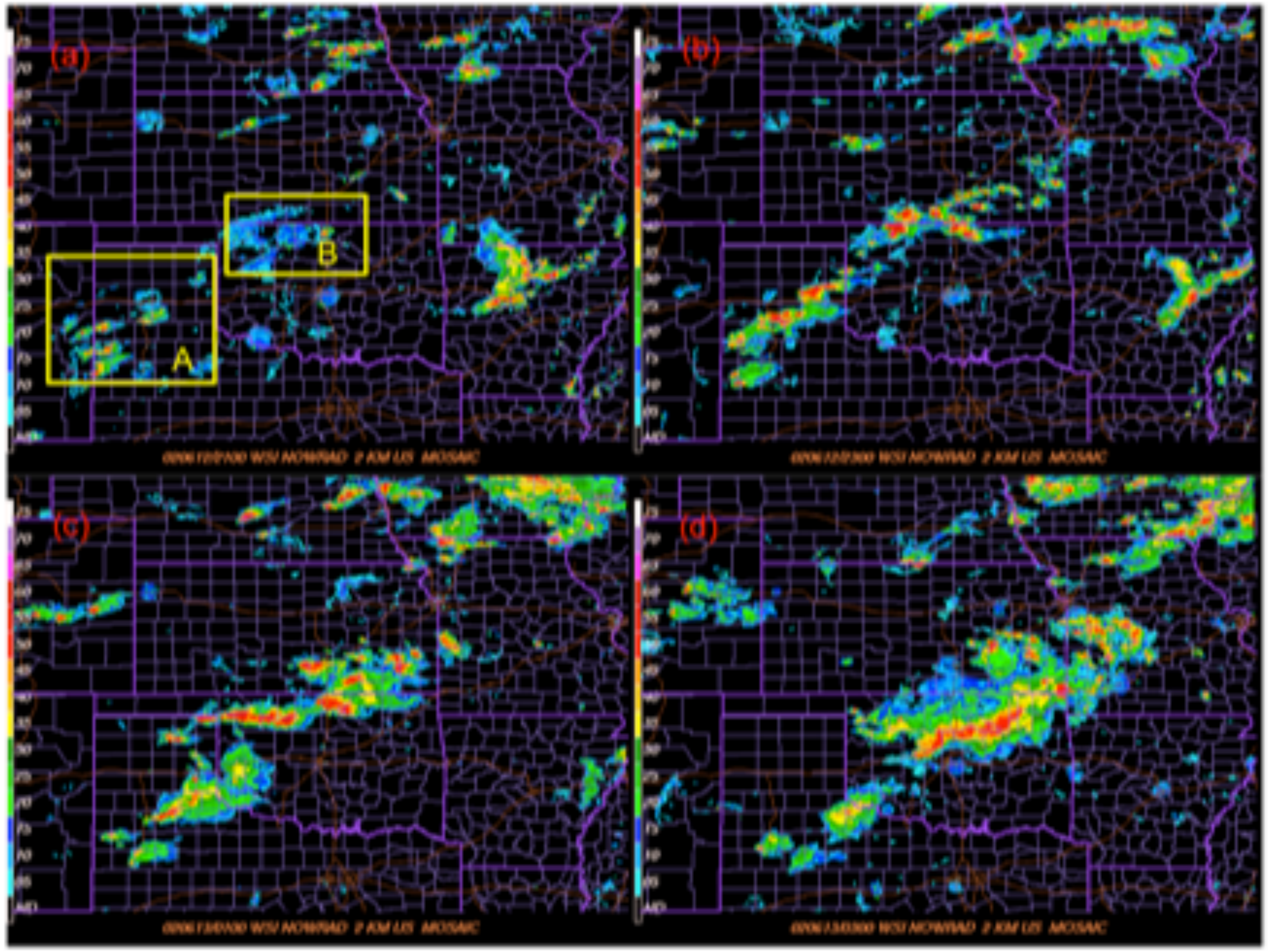
$$J_k(x_0) = \sum_{i=0,\Delta} \left(H_i(M_i(x_0)) - y_i\right)^T O^{-1} \left(H_i(M_i(x_0)) - y_i\right)$$

- Multi-time observations, asynoptic data
- Forecast model as strong constraint
- The adjoint equation is applied during minimization

June 12 2002 Convection Case



Visible satellite imagery at 2045 UTC 12 Jun 2002, with surface observations overlaid. (from Liu and Xue, *Mon. Wea. Rev.*, 2008)



2100 UTC
12 June
2002

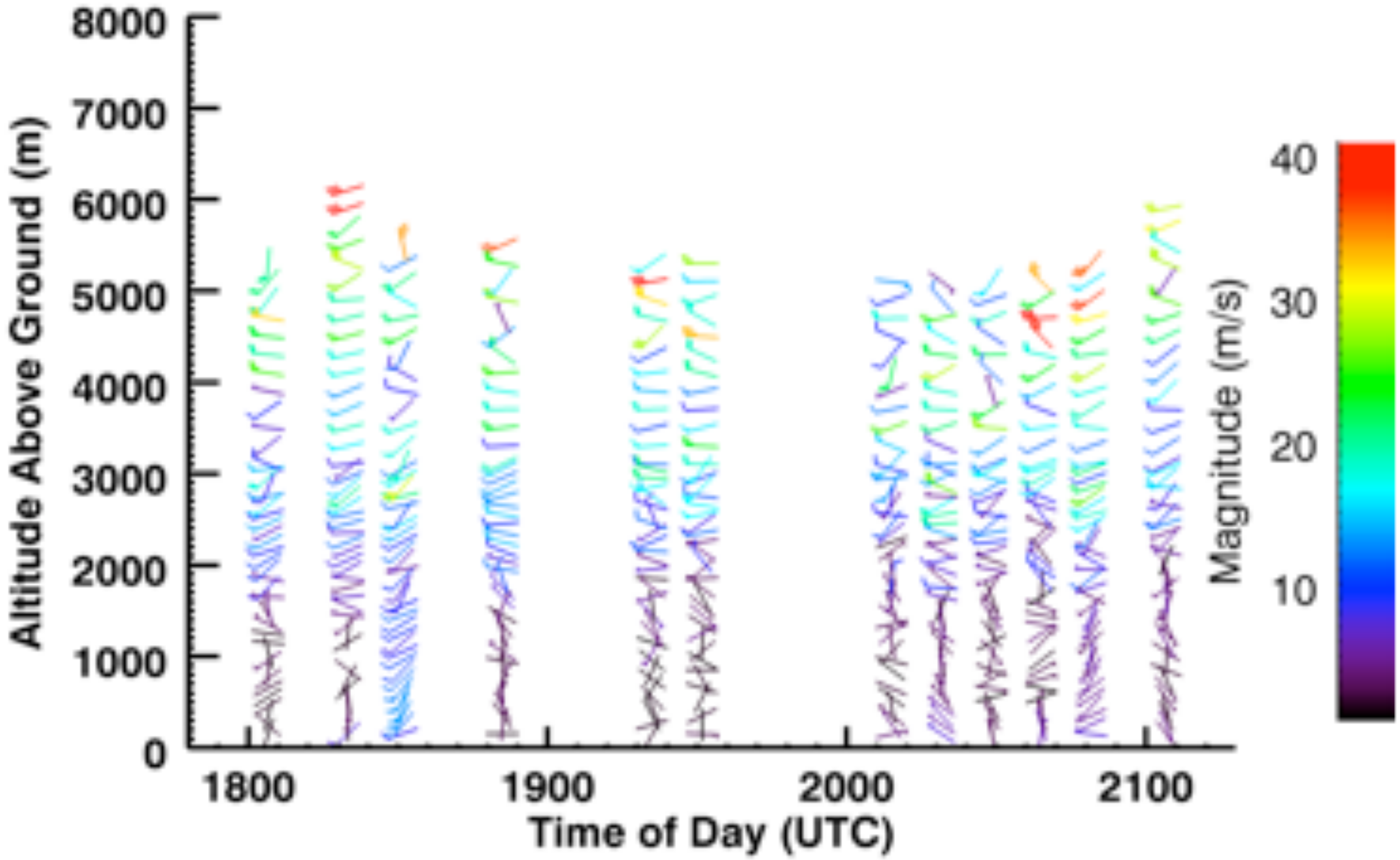
2300 UTC
12 June
2002

0100 UTC
13 June
2002

0300 UTC
13 June
2002

Composite radar reflectivity observations at (a) 2100 UTC 12 June 2002, (b) 2300 UTC 12 June 2002, (c) 0100 UTC 13 June 2002, (d) 0300 UTC 13 June 2002.
(Data from WSI IHOP 2002 2-km resolution sector mosaic reflectivity imagery dataset)

GLOW wind profiles from 1800 UTC to 2100 UTC June 2002



Time series of GLOW wind profiles at Homestead profiling site (36.558° N, 100.606° W) from 1800 UTC to 2100 UTC June 2002. Colors represent the different magnitudes of wind speeds.

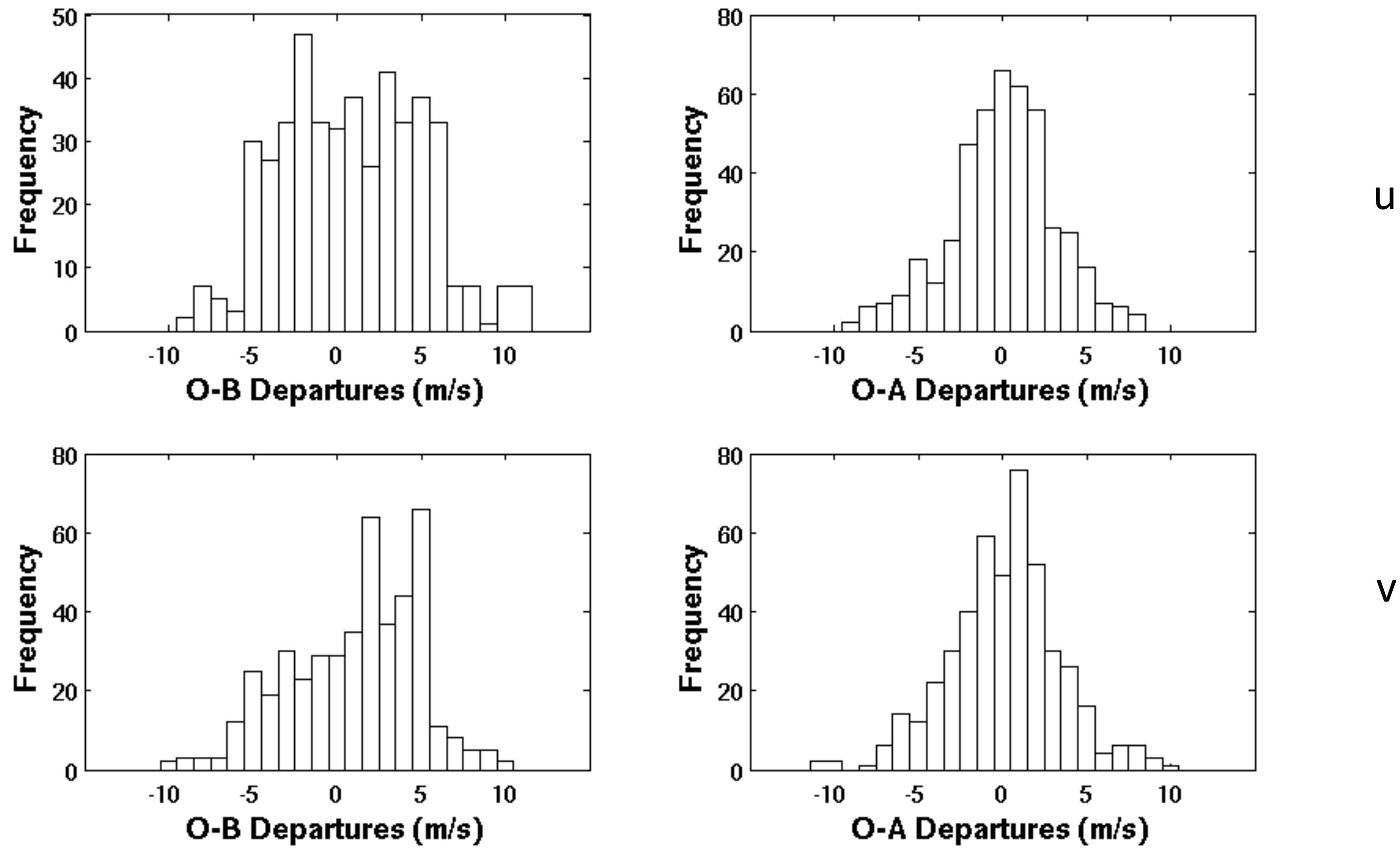
Experimental set up

Model: **A advanced research version of the weather research and Forecasting (WRF) model (Skarmorock et al. 2008)**

Data assimilation system: **WRF 4-dimensional variational data assimilation (4DVAR) system (Huang et al. 2009)**

Model resolution: **27km/9km/3km**

Histograms of wind departures from lidar wind observations



Analysis Increments

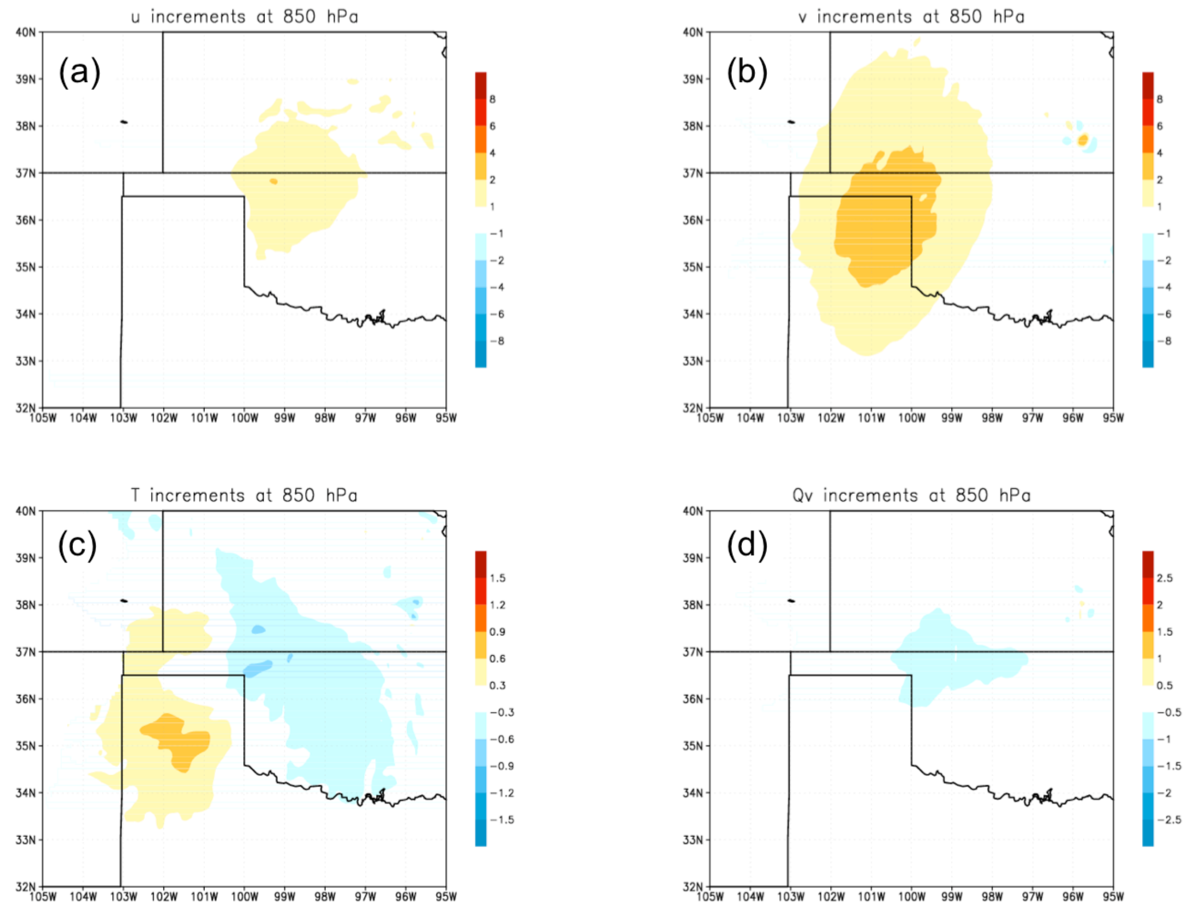
850 mb; Beginning of DA window

u

v

T

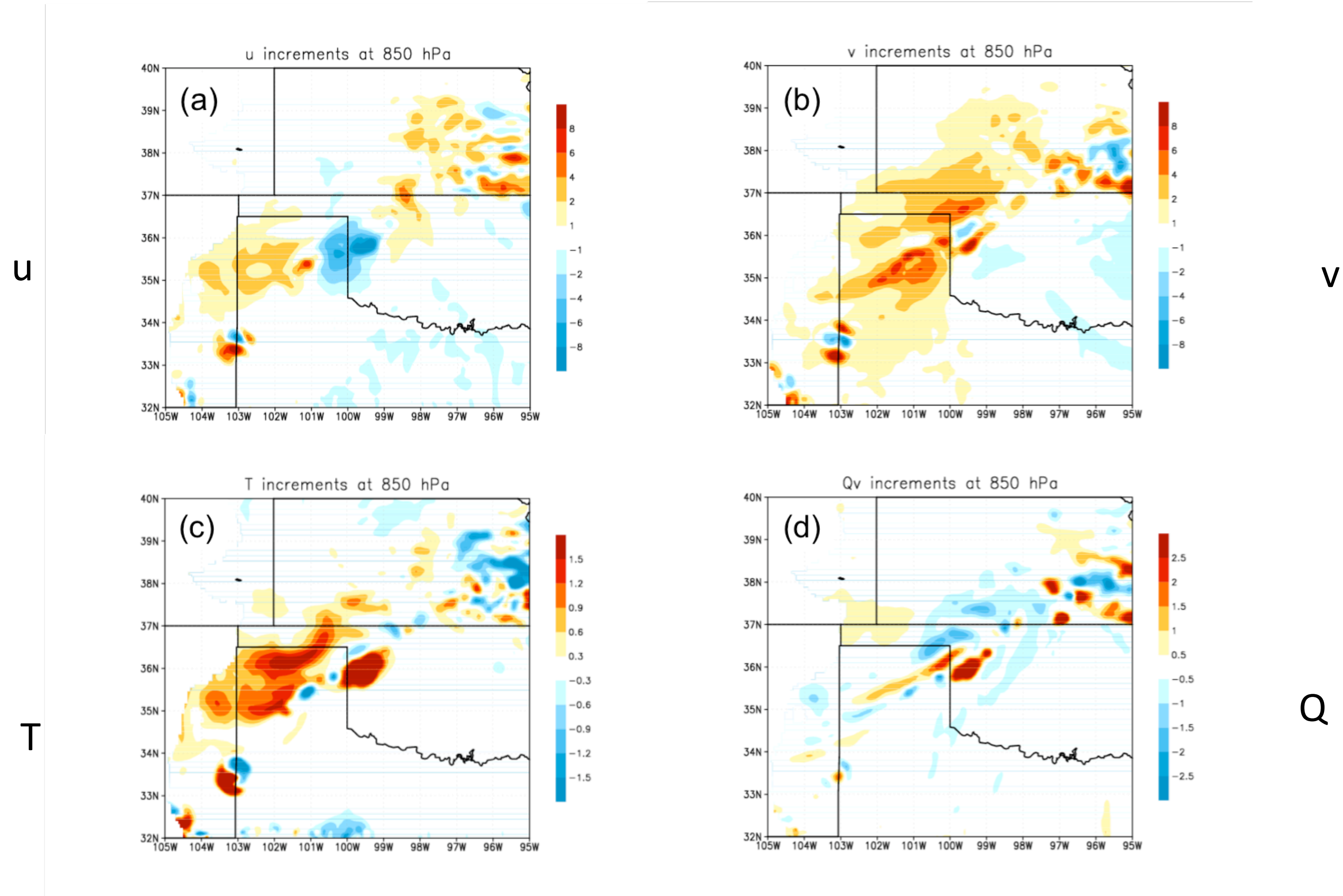
Q



Analysis increment of u, v, T, Qv, 2100 UTC 12, June

Analysis Increments

850 mb; End of DA window

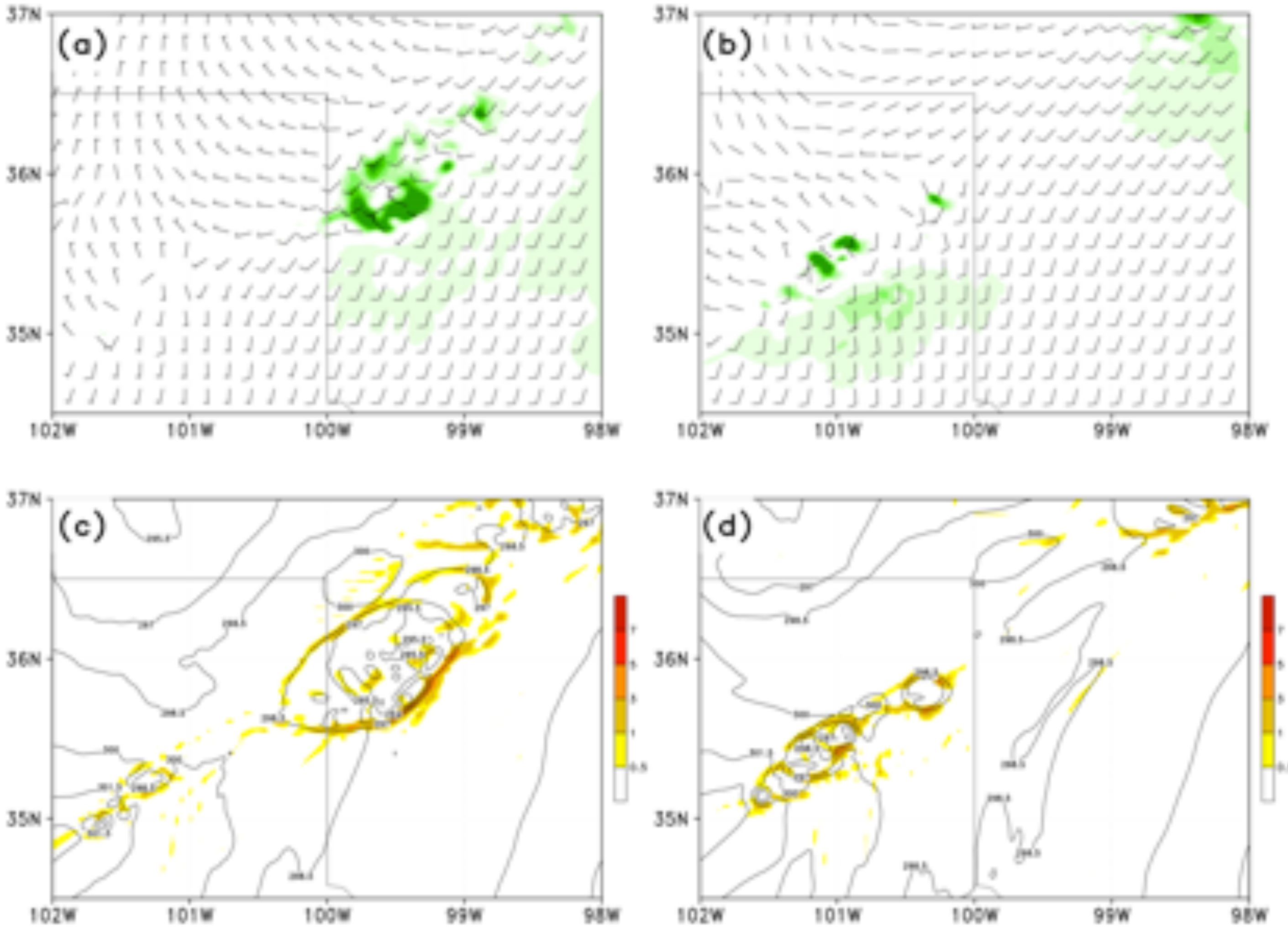


Analysis increment of u, v, T, Qv, 2100 UTC 12, June

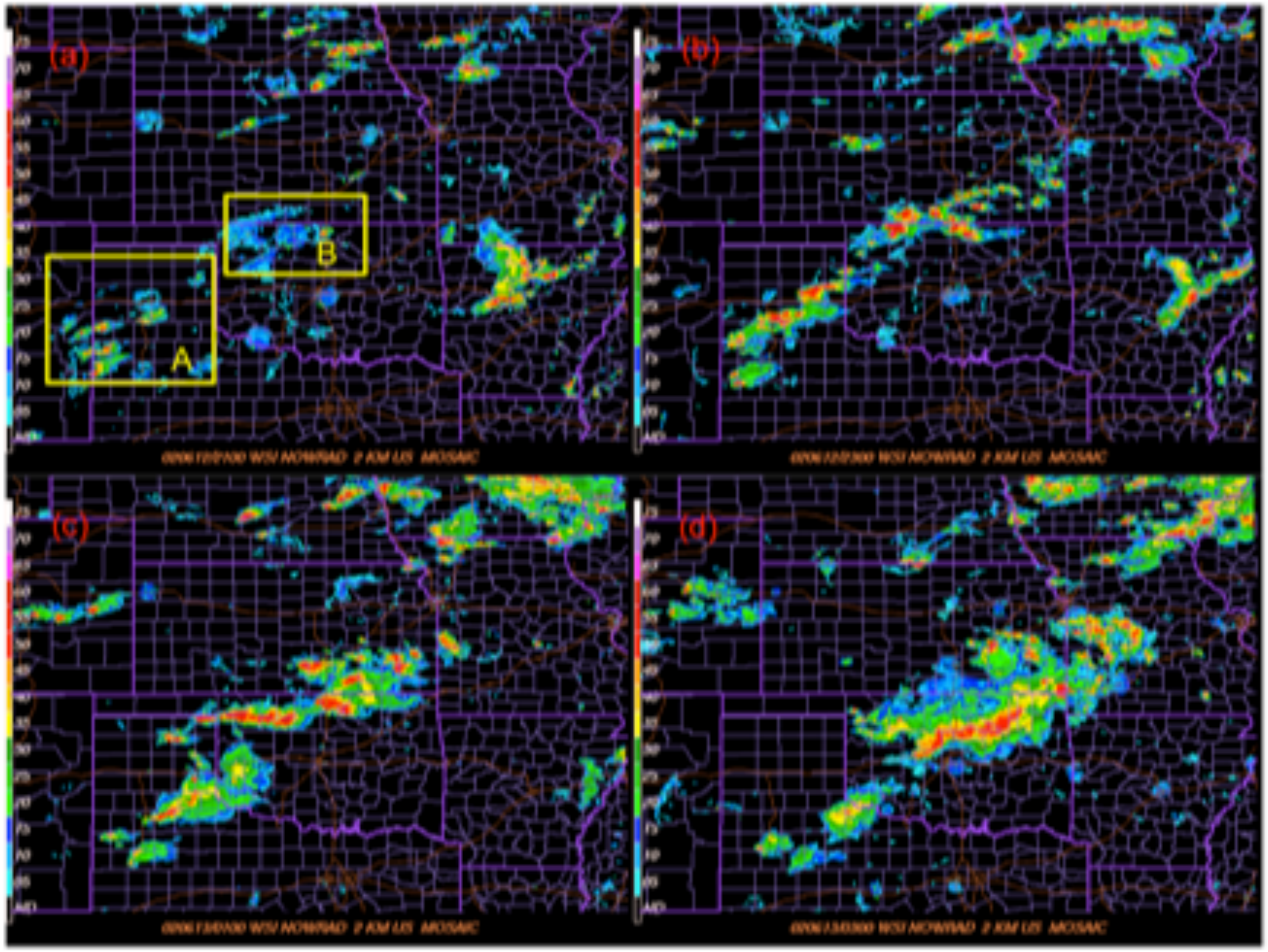
CTRL Vs. 4DVAR

(u,v) Winds

W



2100 UTC 12 June 2002 850 mb; End of DA window



2100 UTC 12 June 2002

2300 UTC 12 June 2002

0100 UTC 13 June 2002

0300 UTC 13 June 2002

Composite radar reflectivity observations at (a) 2100 UTC 12 June 2002, (b) 2300 UTC 12 June 2002, (c) 0100 UTC 13 June 2002, (d) 0300 UTC 13 June 2002.
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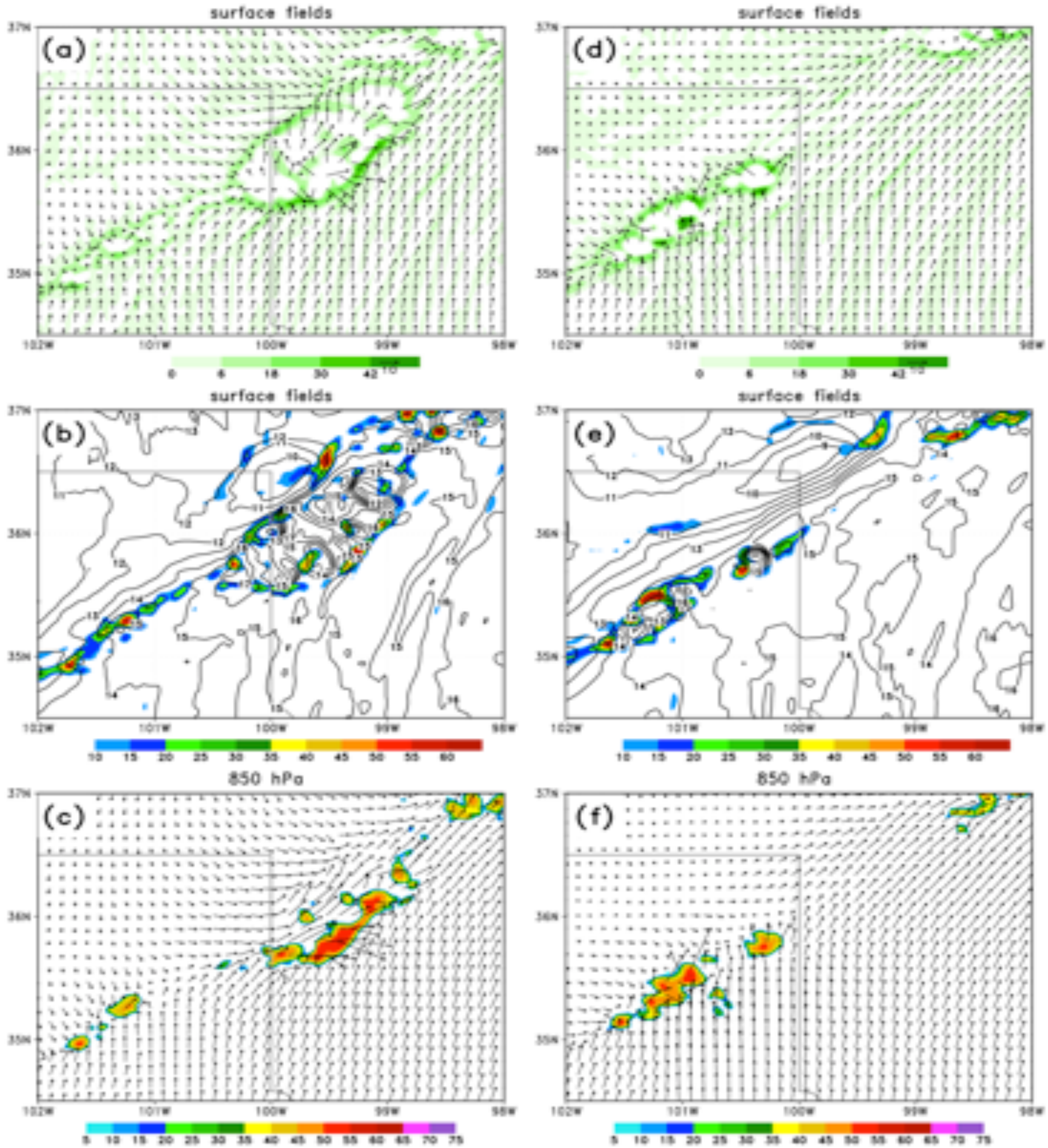
CTRL Vs. 4DVAR

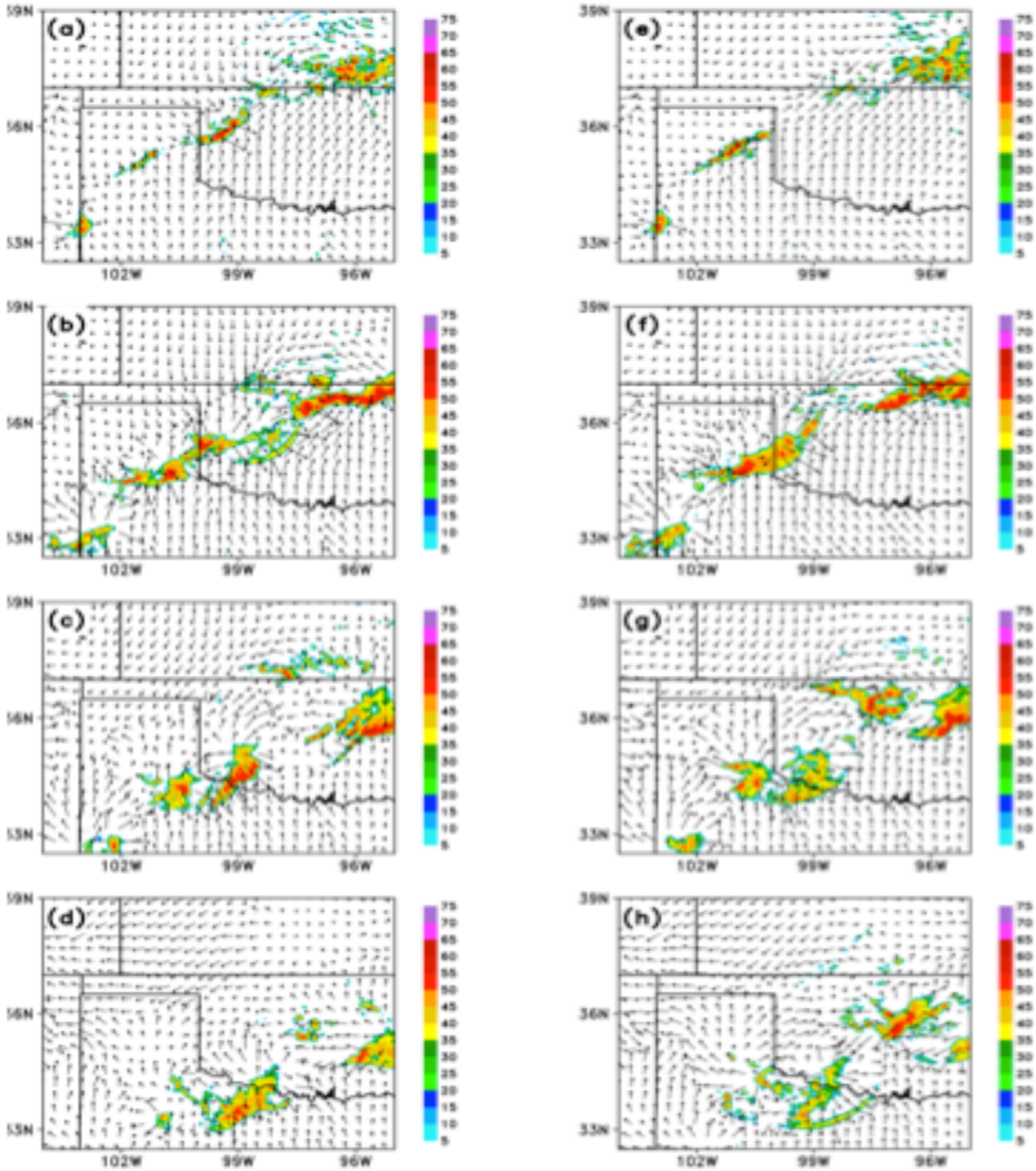
2100 UTC 12 June 2002



Moisture convergence and convection

Radar Reflectivity

CTRL Vs. 4DVAR



2100 UTC
12 June

2300 UTC
12 June

0100 UTC
13 June

0300 UTC
13 June

CTRL Vs. 4DVAR

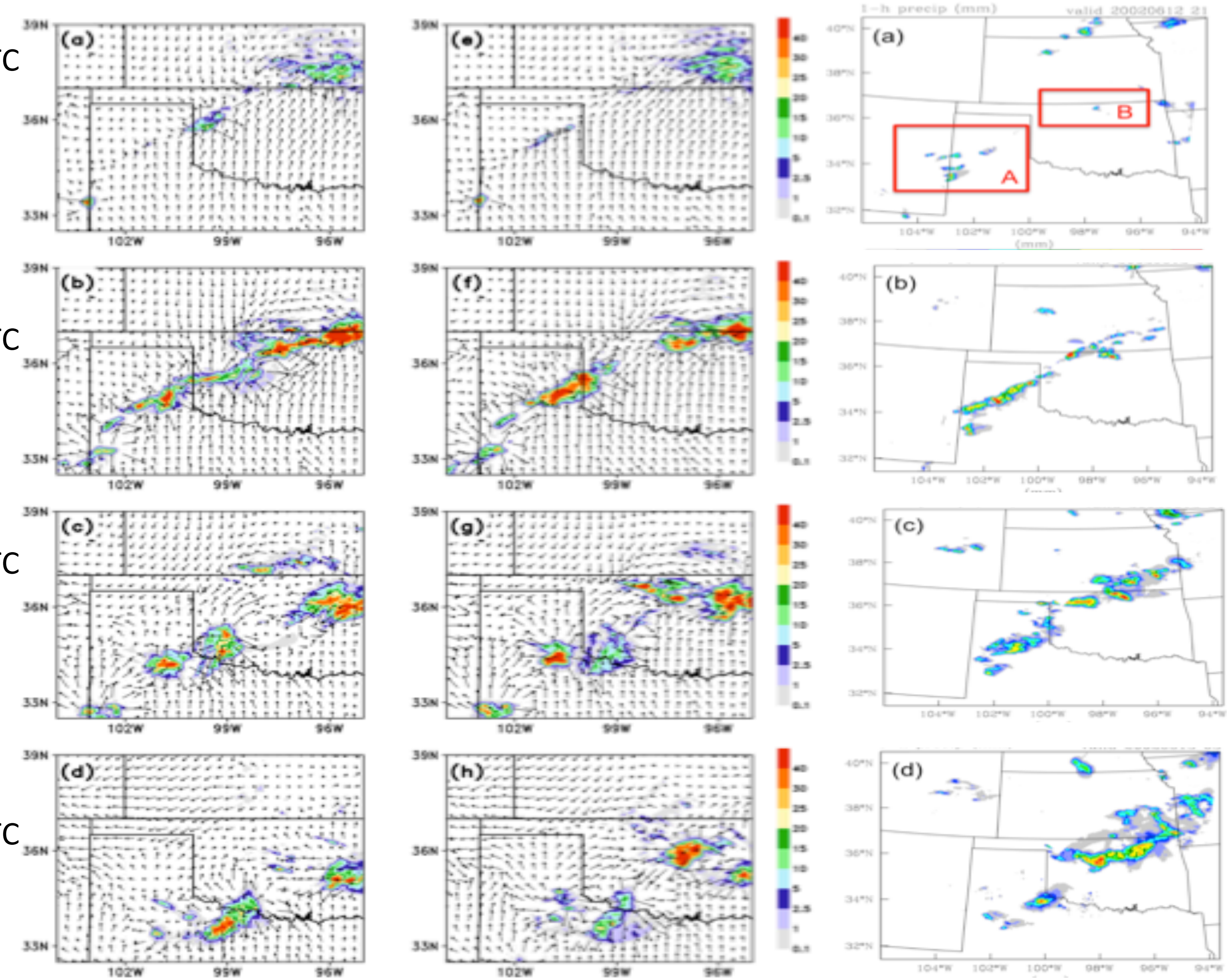
Hourly precip. OBS

2100 UTC
12 June

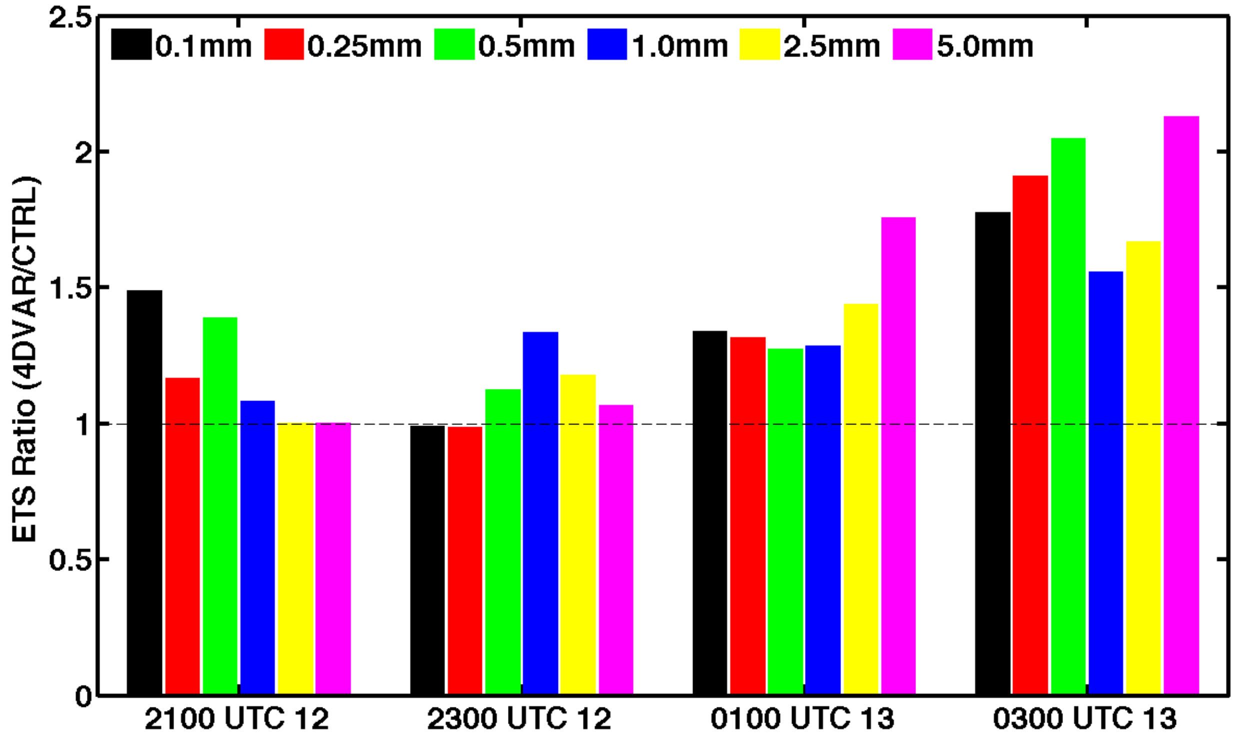
2300 UTC
12 June

0100 UTC
13 June

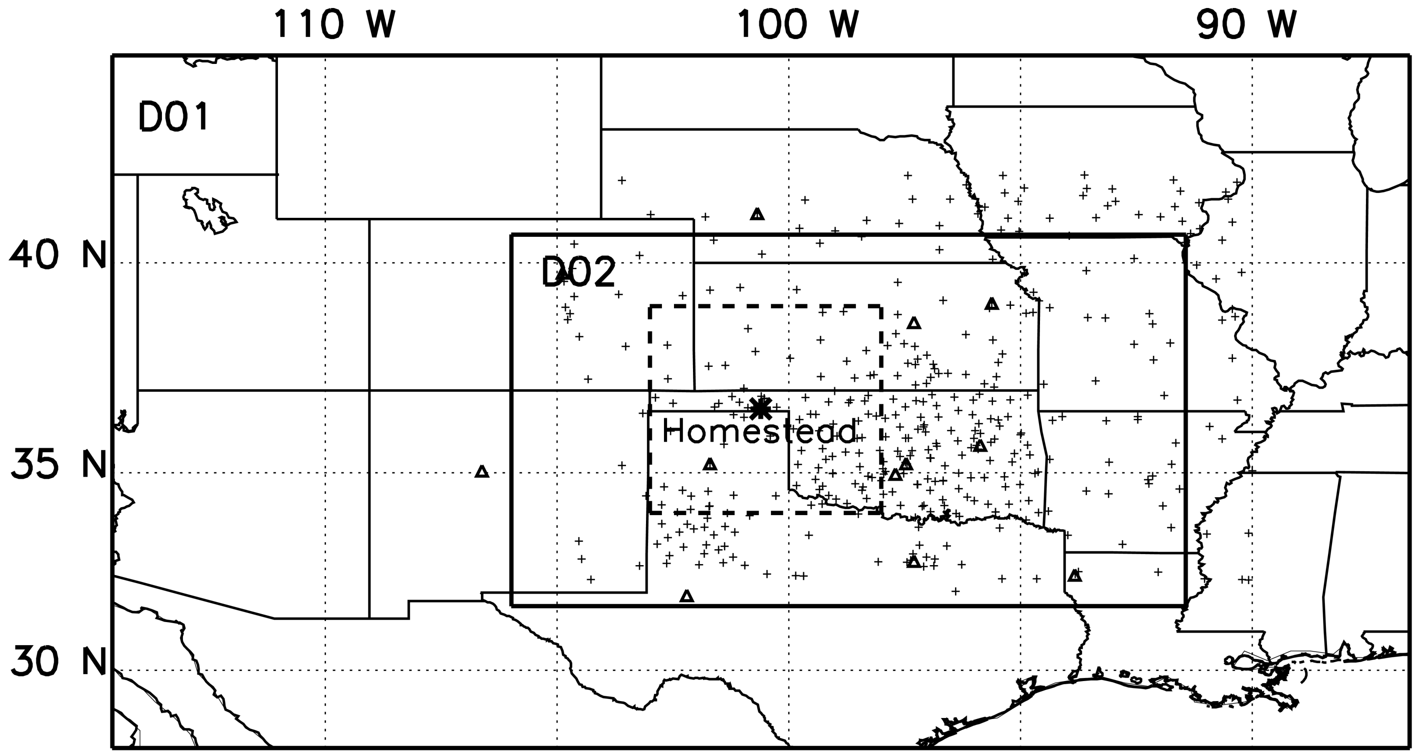
0300 UTC
13 June



Quantitative Precipitation Forecasting Scores

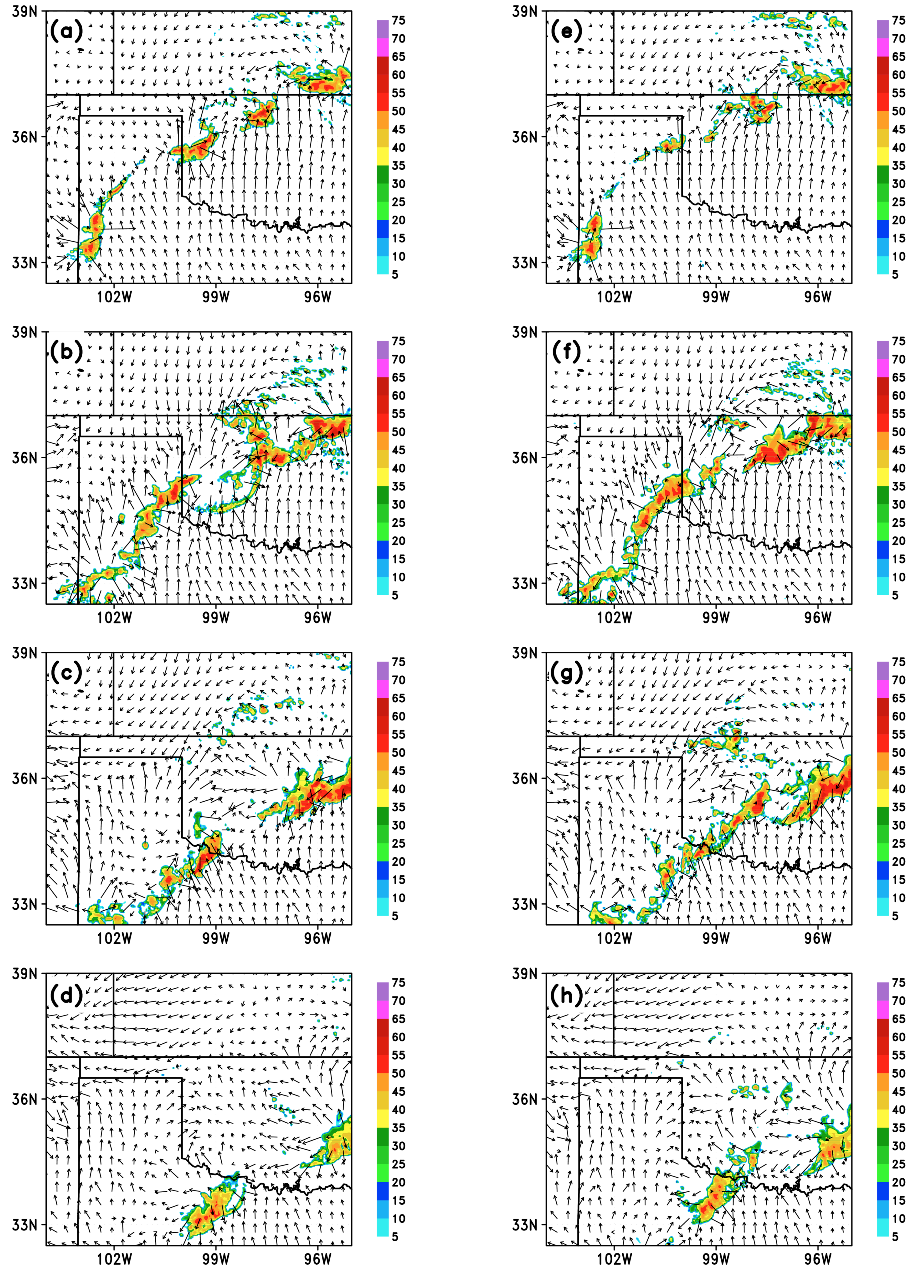


Equitable threat scores (ETS)
4DVAR vs. CTRL



110 W
100 W
90 W
40 N
35 N
30 N
D01
D02
Homestead

Assimilation of Conventional Data



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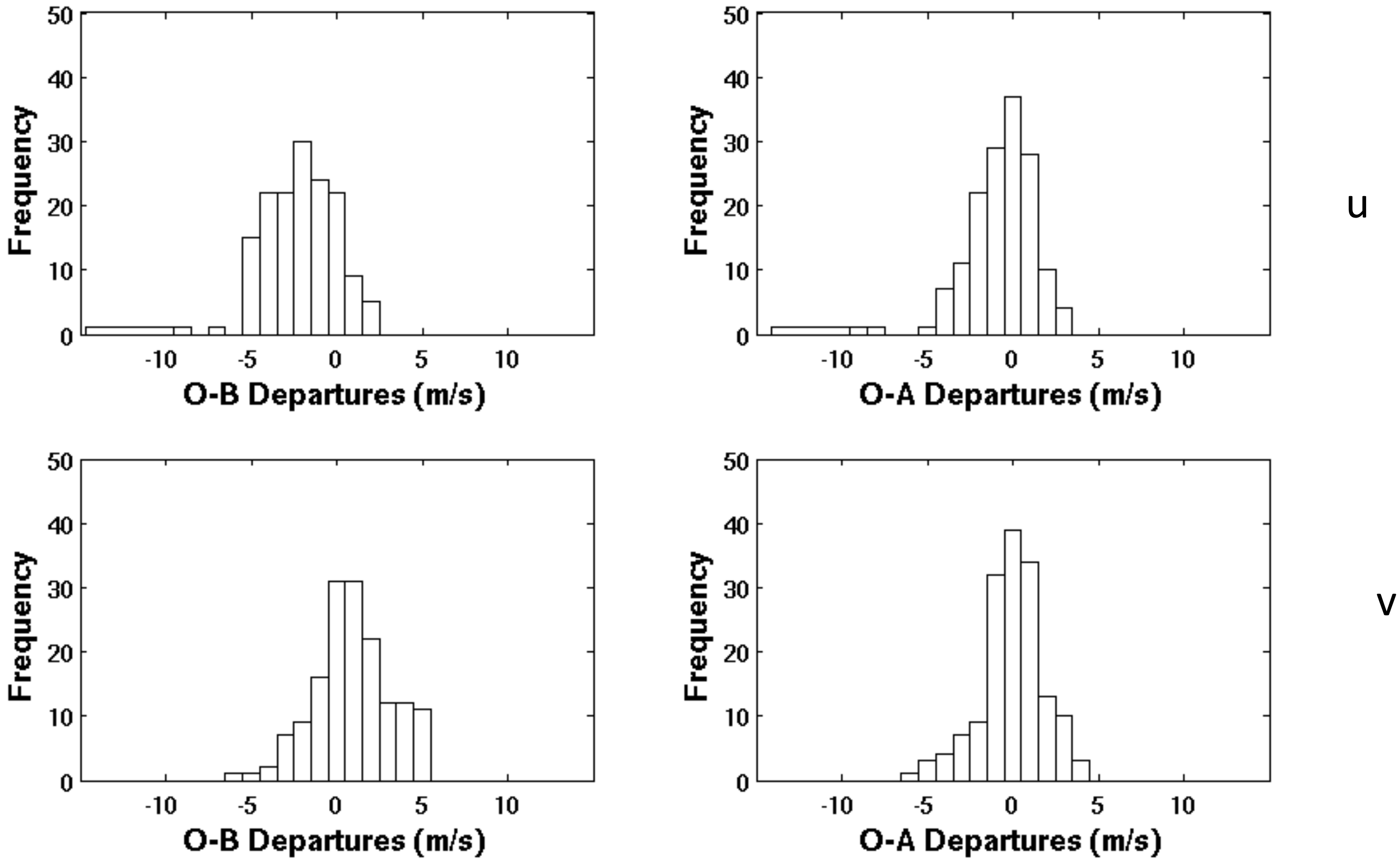

Concluding Remarks

- **Doppler Wind Lidar (DWL) profiles could be very useful data sources for improving forecasts of mesoscale convective systems**

- **4DVAR is capable of assimilating multi-time wind profiles from a single station**

- **Combining conventional observations with GLOW wind profiles did not result in obvious impact on the analysis and forecasts, mostly because the background field is too close to the conventional data thus leave little rooms for further improvements. However, results have a implication for designing future mesoscale profiling networks.**