Convection-allowing Numerical Weather Prediction for Hazardous Weather

Progress and Challenges

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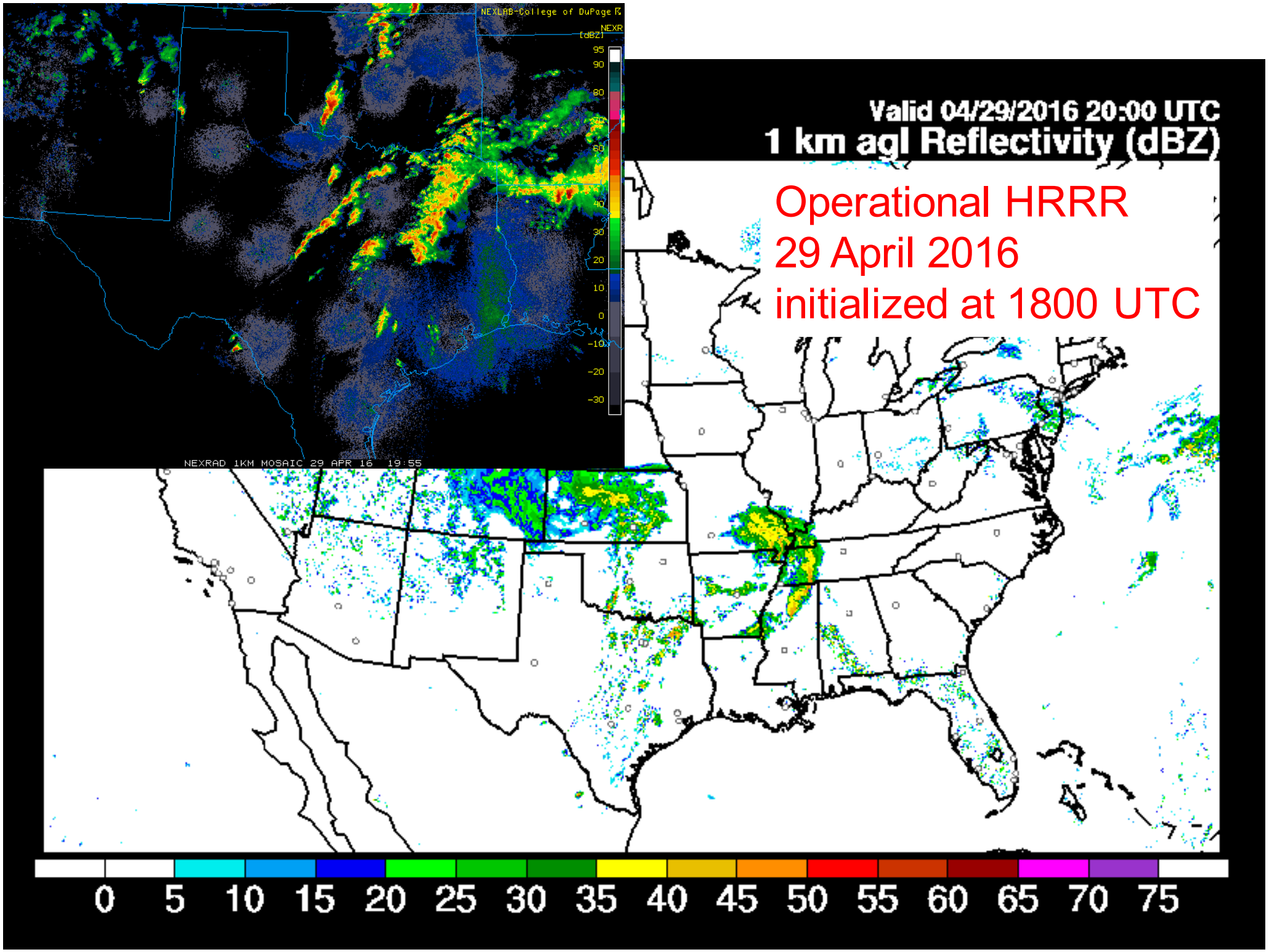
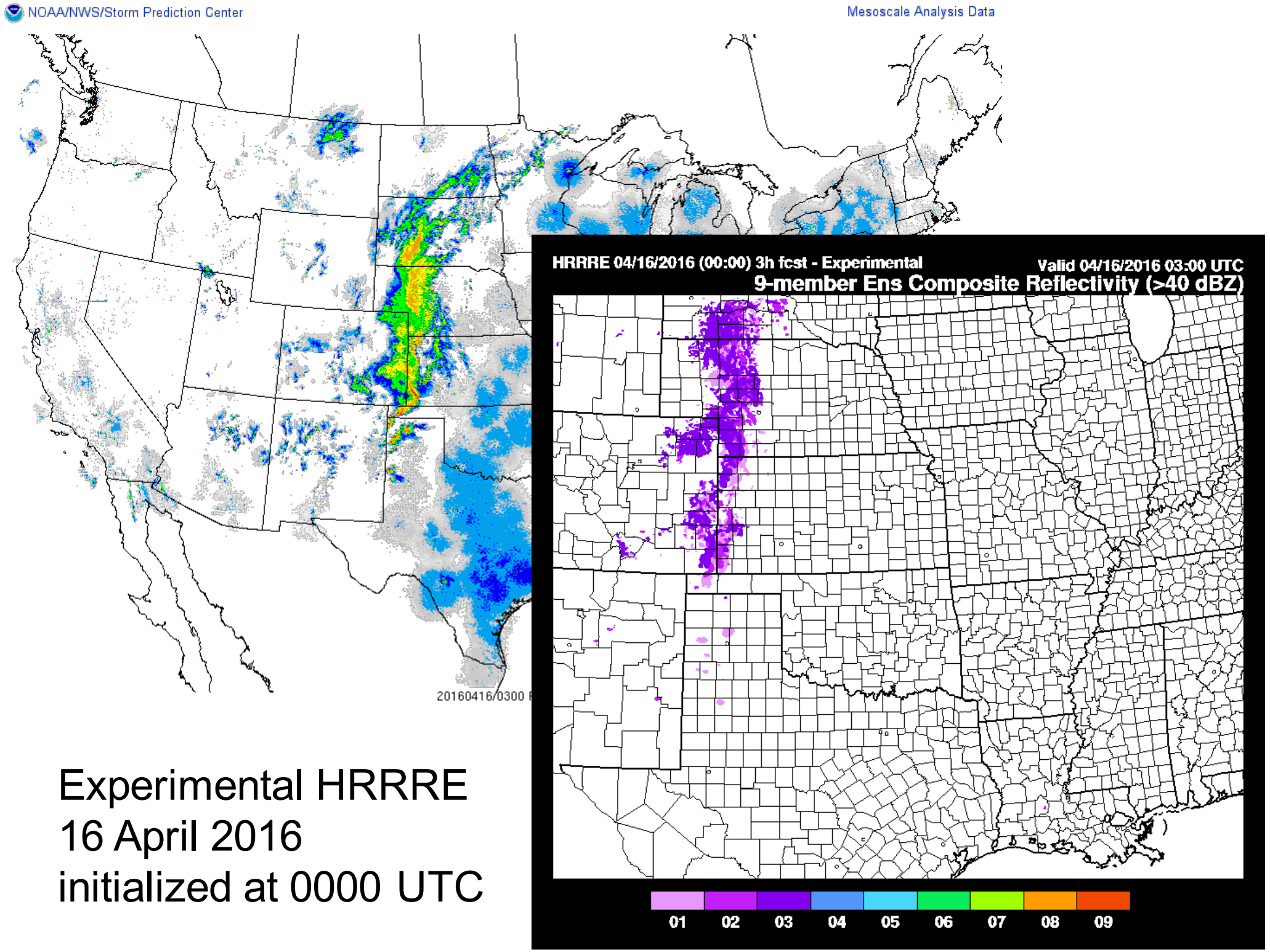
High-Resolution Rapid Refresh (HRRR)

- Convection-allowing forecasts produced hourly and extend out 18+ h
  - WRF/ARW
  - Horizontal grid spacing of 3 km, 50 levels
  - CONUS domain
  - Thompson microphysics, RUC-Smirnova LSM, MYNN PBL scheme, RRTM longwave, Goddard shortwave
  - Run operationally by NOAA


NEXLAB-College of DuPage
NEXR
[dBZ]
95
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
NEXRAD 1KM MOSAIC 29 APR 16 19:55
Valid 04/29/2016 20:00 UTC
1 km agl Reflectivity (dBZ)
Operational HRRR
29 April 2016
initialized at 1800 UTC
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75



Experimental HRRRE
16 April 2016
initialized at 0000 UTC

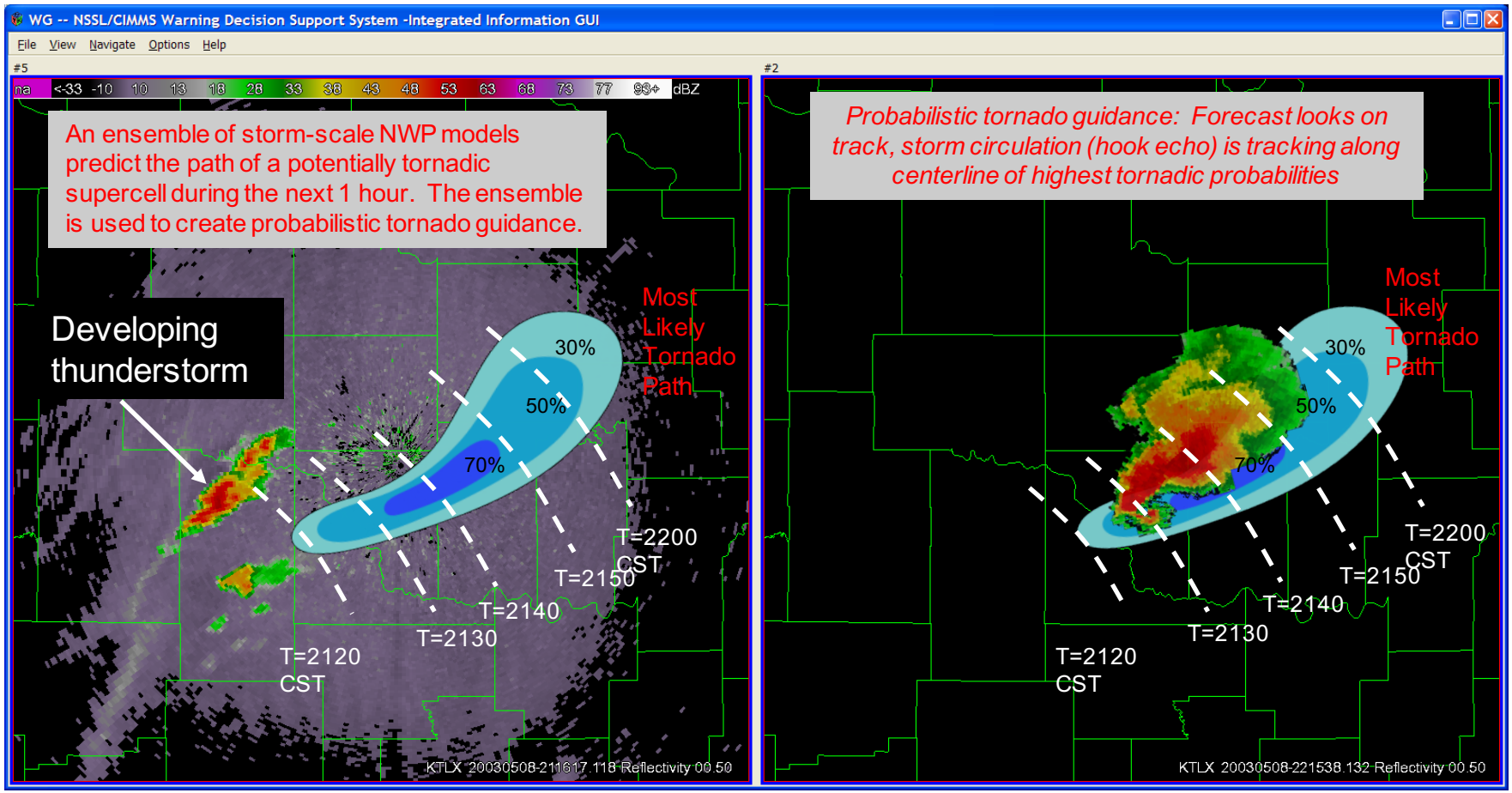
Progress and Challenges

- Useful predictions of convective mode (i.e., isolated, supercell, line of convection, bowing line of convection)
- Initiation time often close to reality
- Overall evolution good, details not so much
- Occasional amazing forecast!
  - When to believe, when not to believe?

Warn-on-Forecast Vision

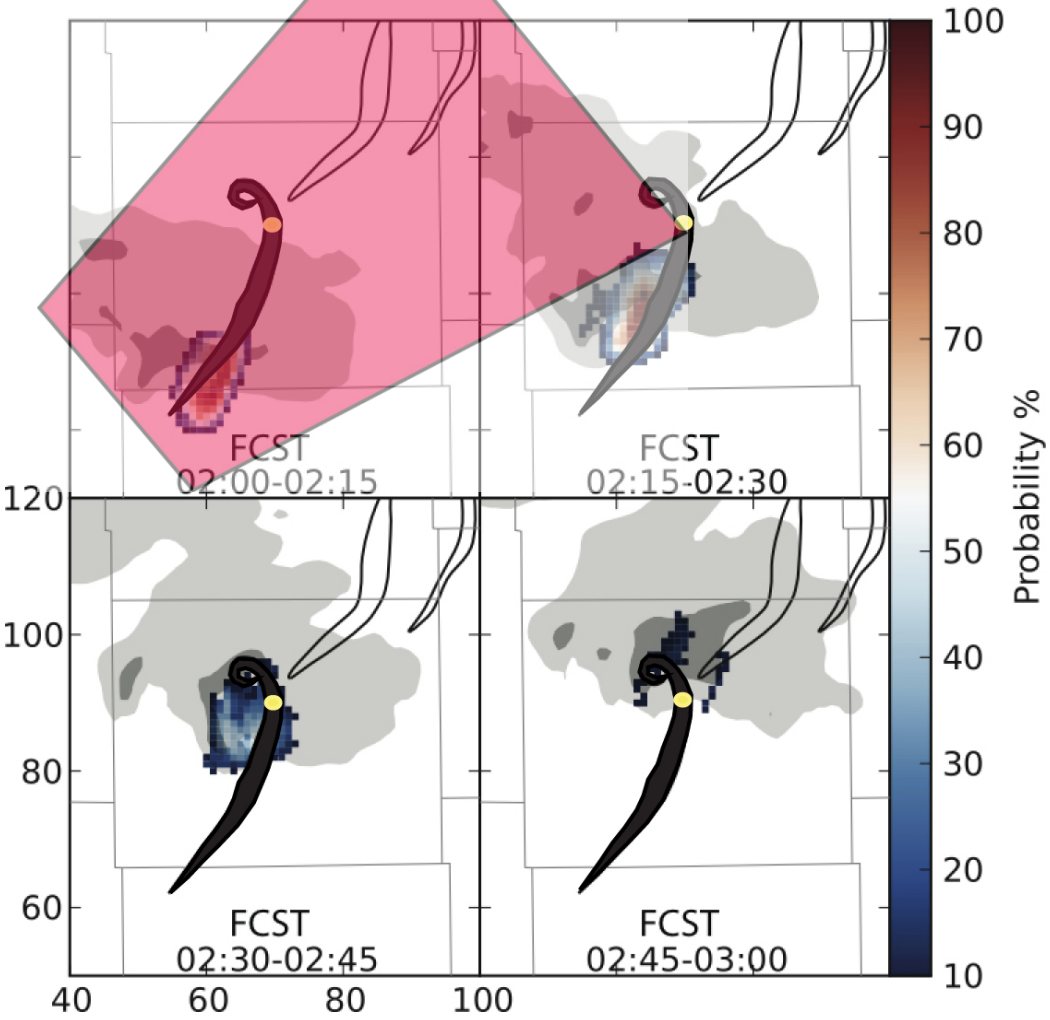
Radar and Initial Forecast at 2100 CST

Radar at 2130 CST: Accurate Forecast



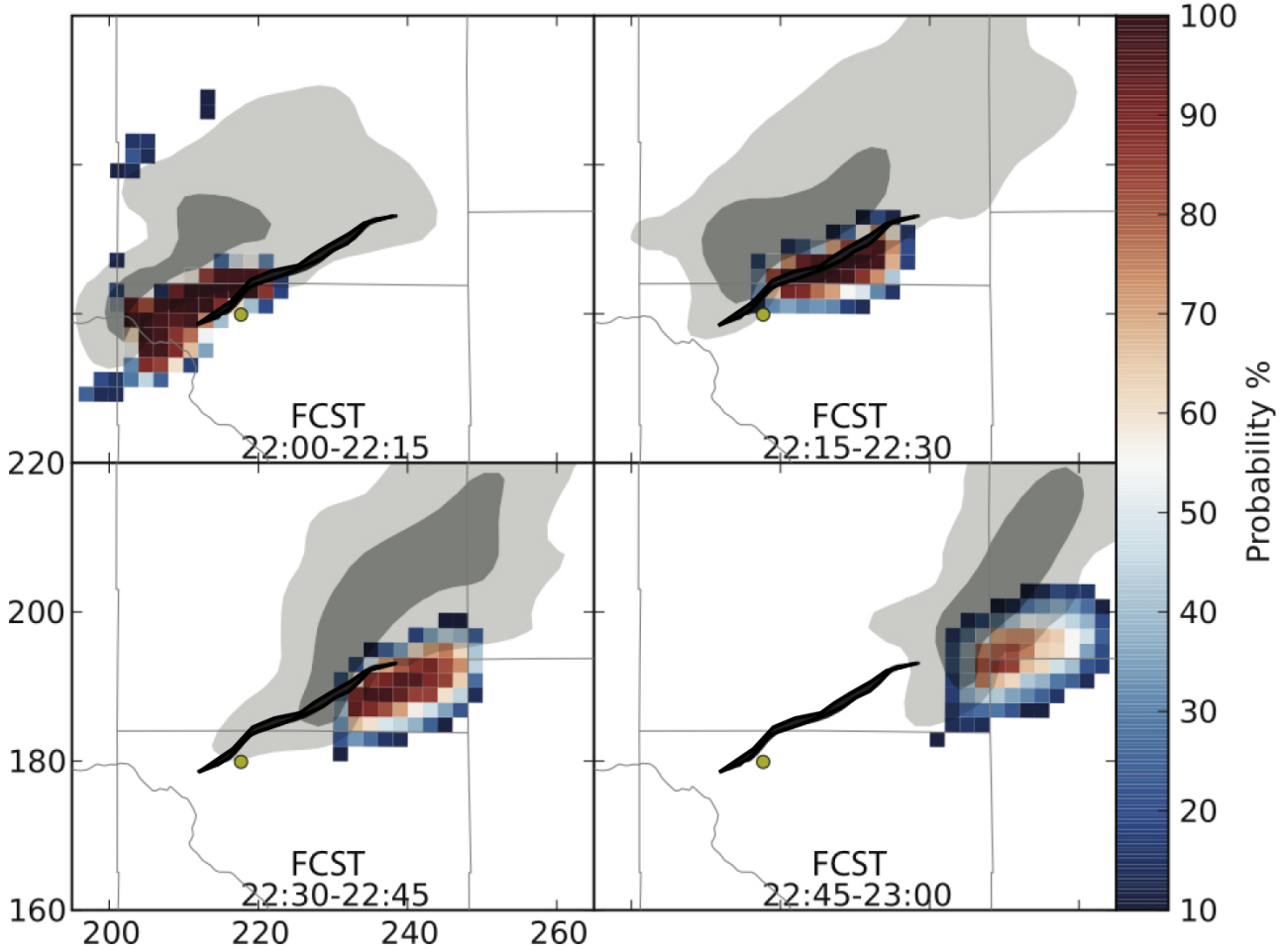
Stensrud et al. 2009 (October *BAMS*)

Warn-on-Forecast: 4 May 2007 Greensburg, Kansas, Tornado



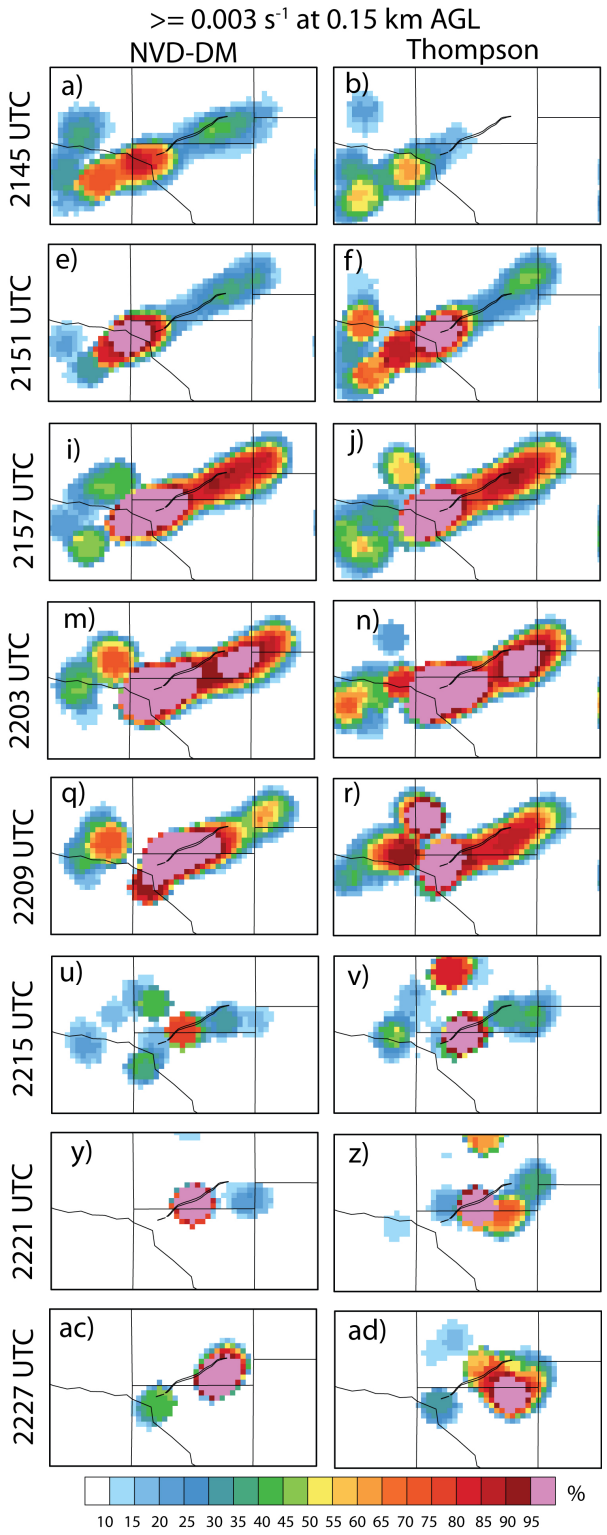
Dawson, Wicker, Mansell and Tanamachi, 2012 (MWR)
COMMAS model, 1 km horizontal grid spacing, 50 vertical levels,
Ensemble Kalman filter assimilation of WSR-88D observations, 30 ensemble members

Warn-on-Forecast: 8 May 2003 Oklahoma City Tornado



Yussouf, Mansell, Wicker, Wheatley and Stensrud 2013 (MWR)
WRF model, 2 km horizontal grid spacing, 50 vertical levels, DART ensemble Kalman filter assimilation of WSR-88D observations, 45 ensemble members

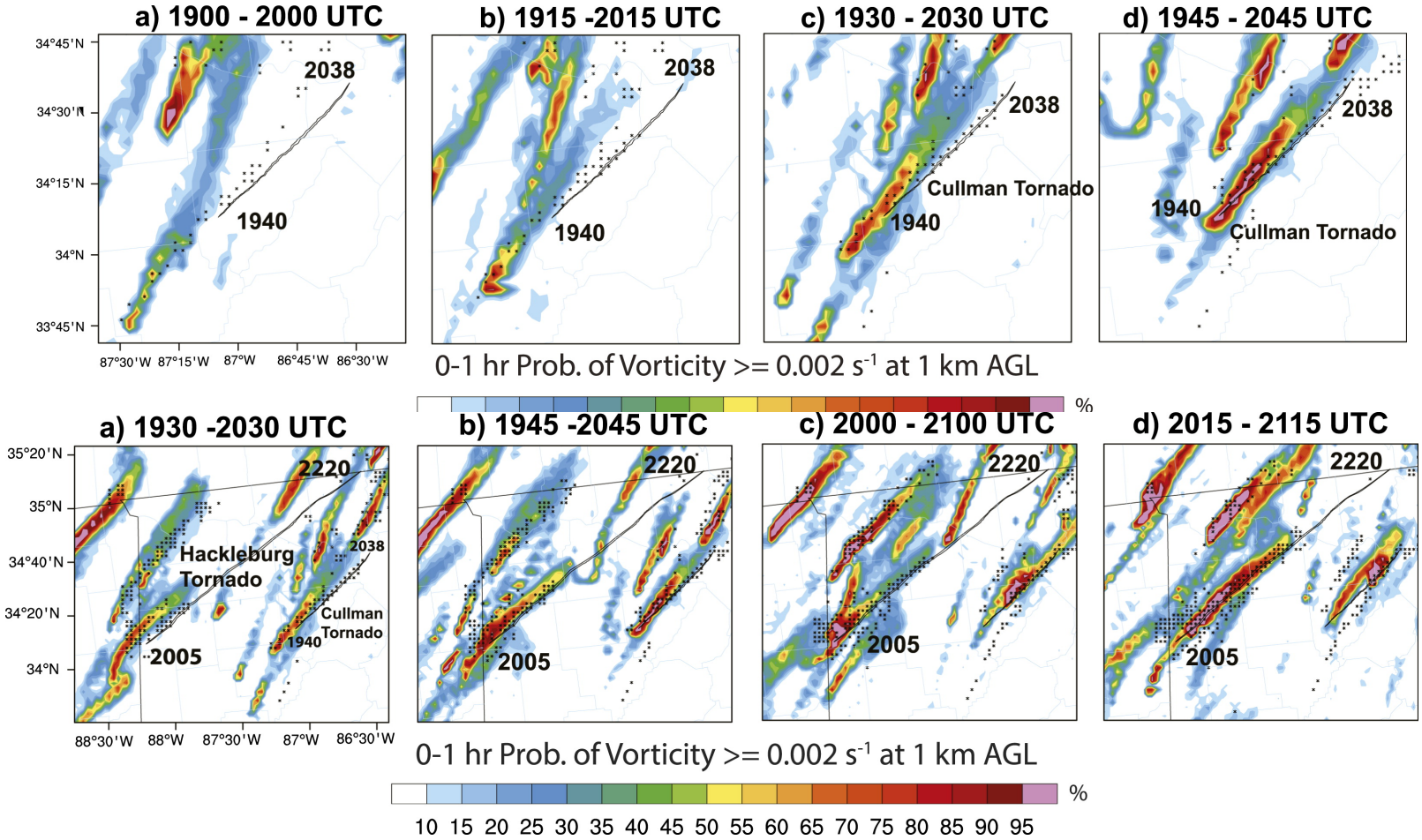
Cycled forecasts are consistent and robust – higher predictability after convection initiation



Forecasts out to 2300 UTC generated by rapidly updated analyses from 2145 UTC to 2227 UTC

Tornado on the ground from 2210 to 2238 UTC

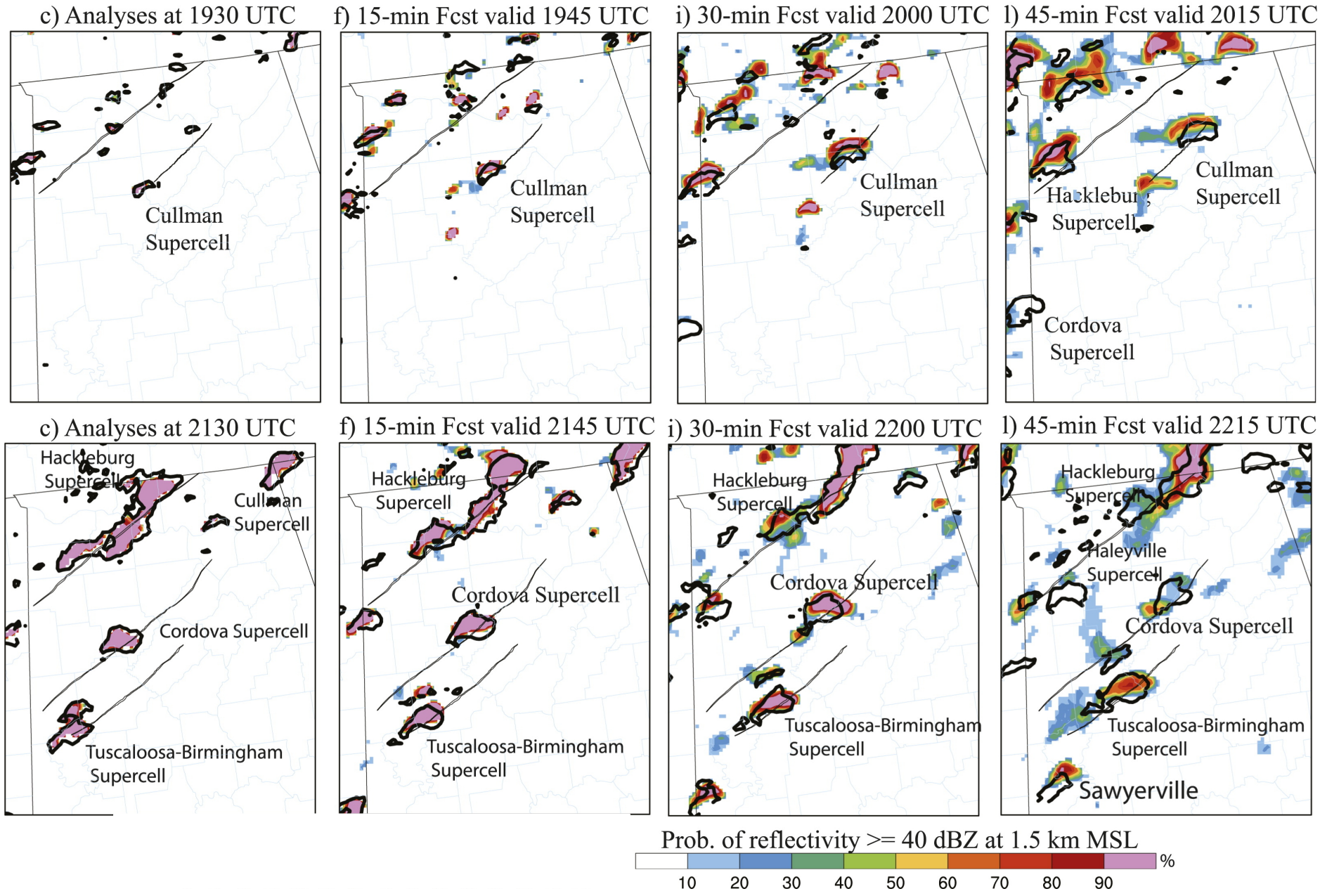
Yussouf et al. (2013)



Results of the 27 April 2011 Southeast Outbreak show good ensemble vorticity forecasts for dominant supercells, although spurious storms also develop. Takes a while to lock onto solution.

Yussouf, Dowell, Wicker, Knopfmeier and Wheatley 2015 (MWR)

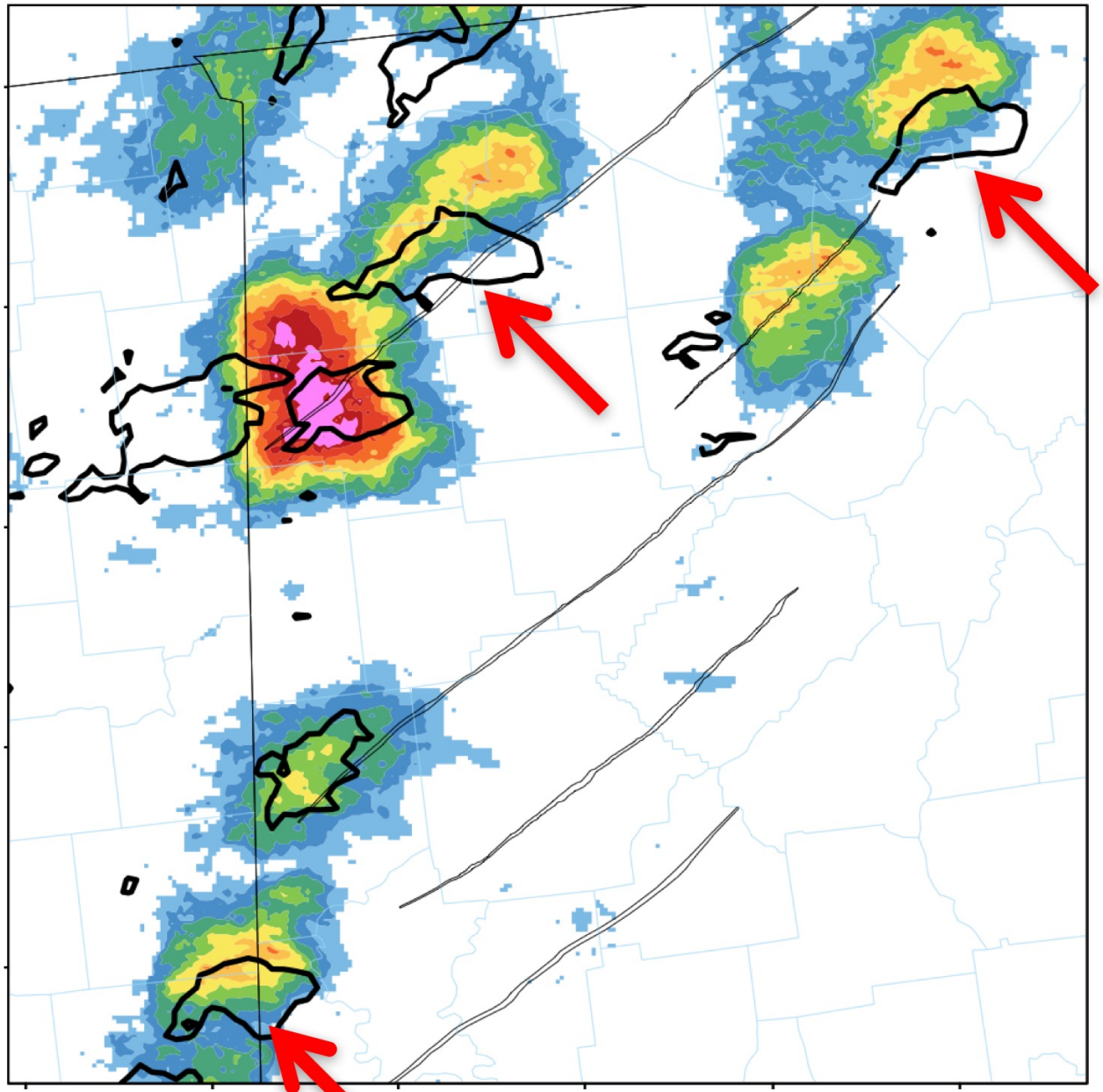
WRF model, 3 km horizontal grid spacing, 51 vertical levels, DART ensemble adjustment Kalman filter assimilation of WSR-88D radar observations + MADIS observations, 36 members



Results from Yussouf et al. (2015) suggest that there are errors in storm motion that influence forecast accuracy.

Challenges: Errors in Storm Motion

75-min Forecast
Valid 2045 UTC
27 Apr 2011



Courtesy
David
Dowell

Observed 40-dBZ Reflectivity Contour at 1.5 km MSL

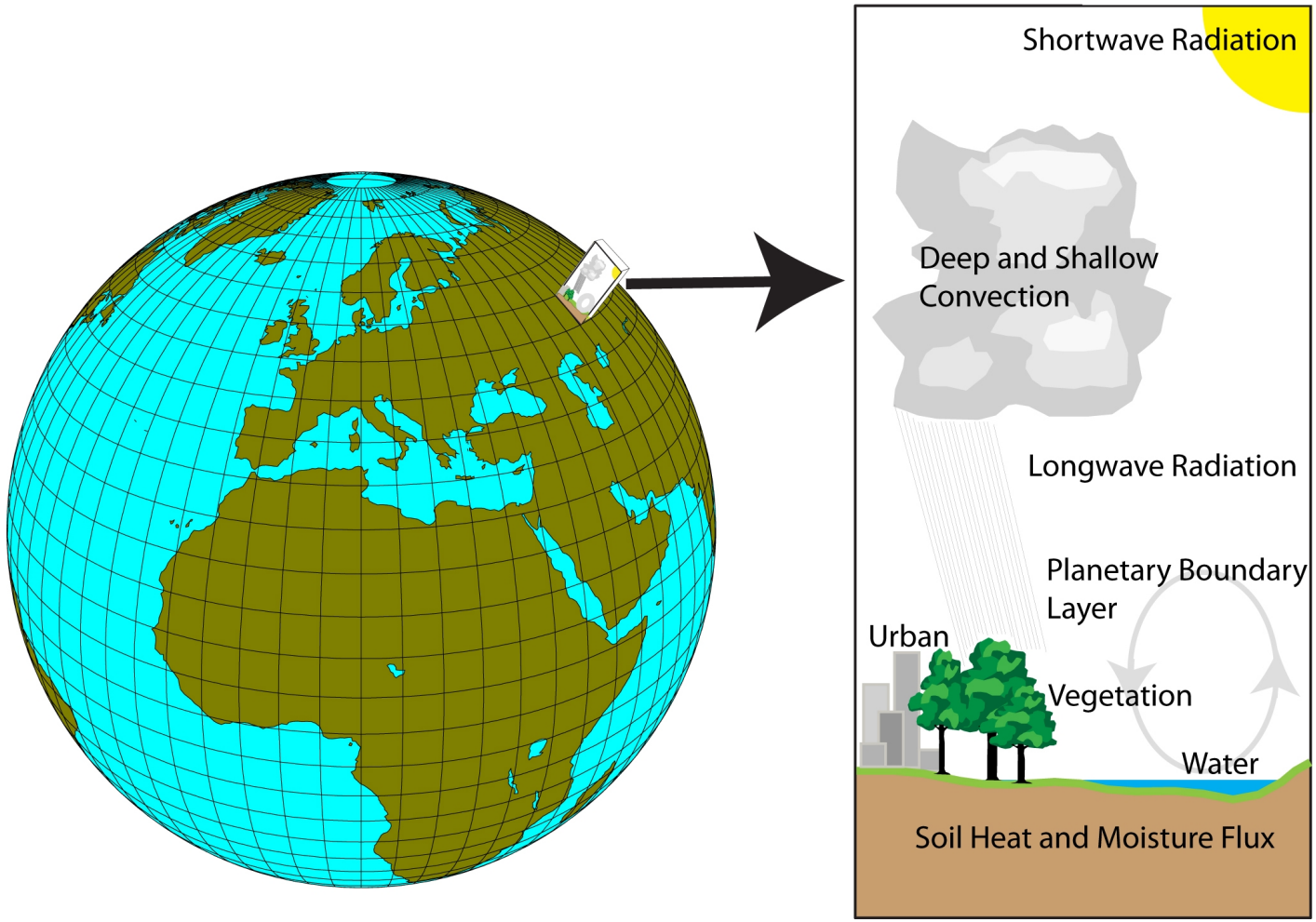
Prob. (%) of reflectivity >= 40 dBZ at 1.5 km MSL

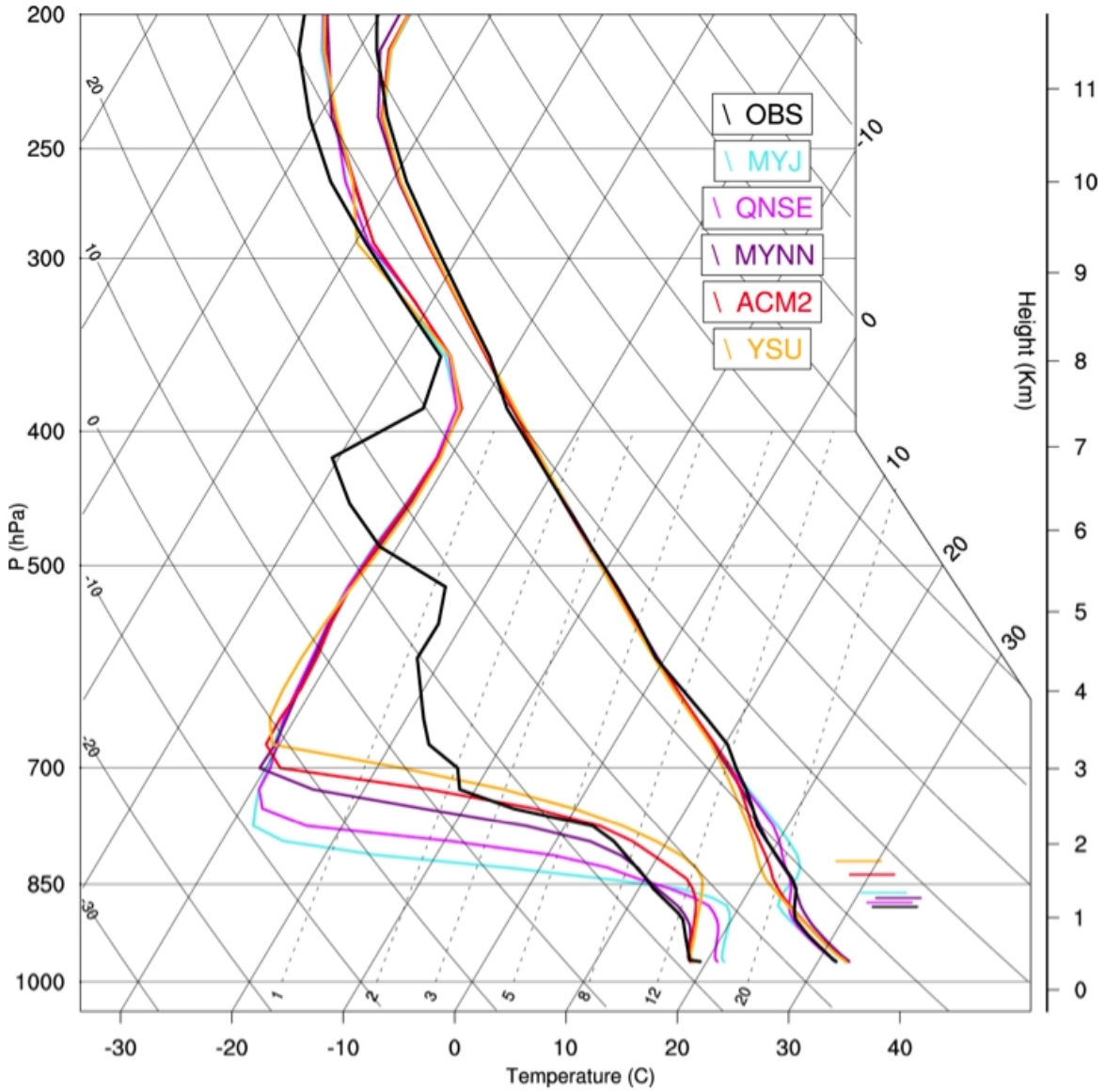
10 20 30 40 50 60 70 80 90 95

Progress and Challenges

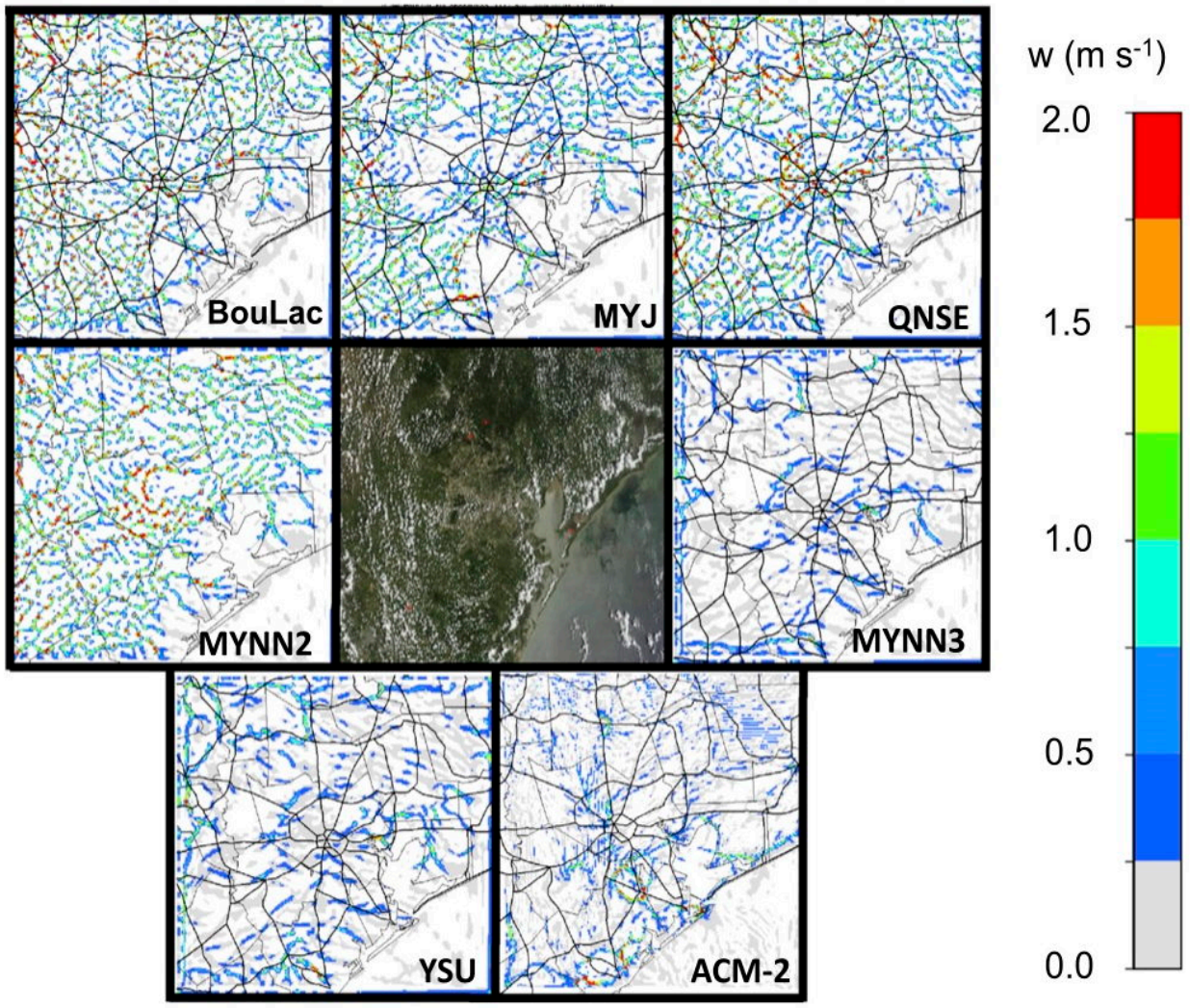
- Ensemble data assimilation successful in creating storms in model initial conditions
- Forecasts out to 45-90 minutes often provide very good guidance
- Storm motion errors show up routinely
- Ability to discriminate between tornadic and non-tornadic supercells is not clear

Physical Process Parameterization Schemes

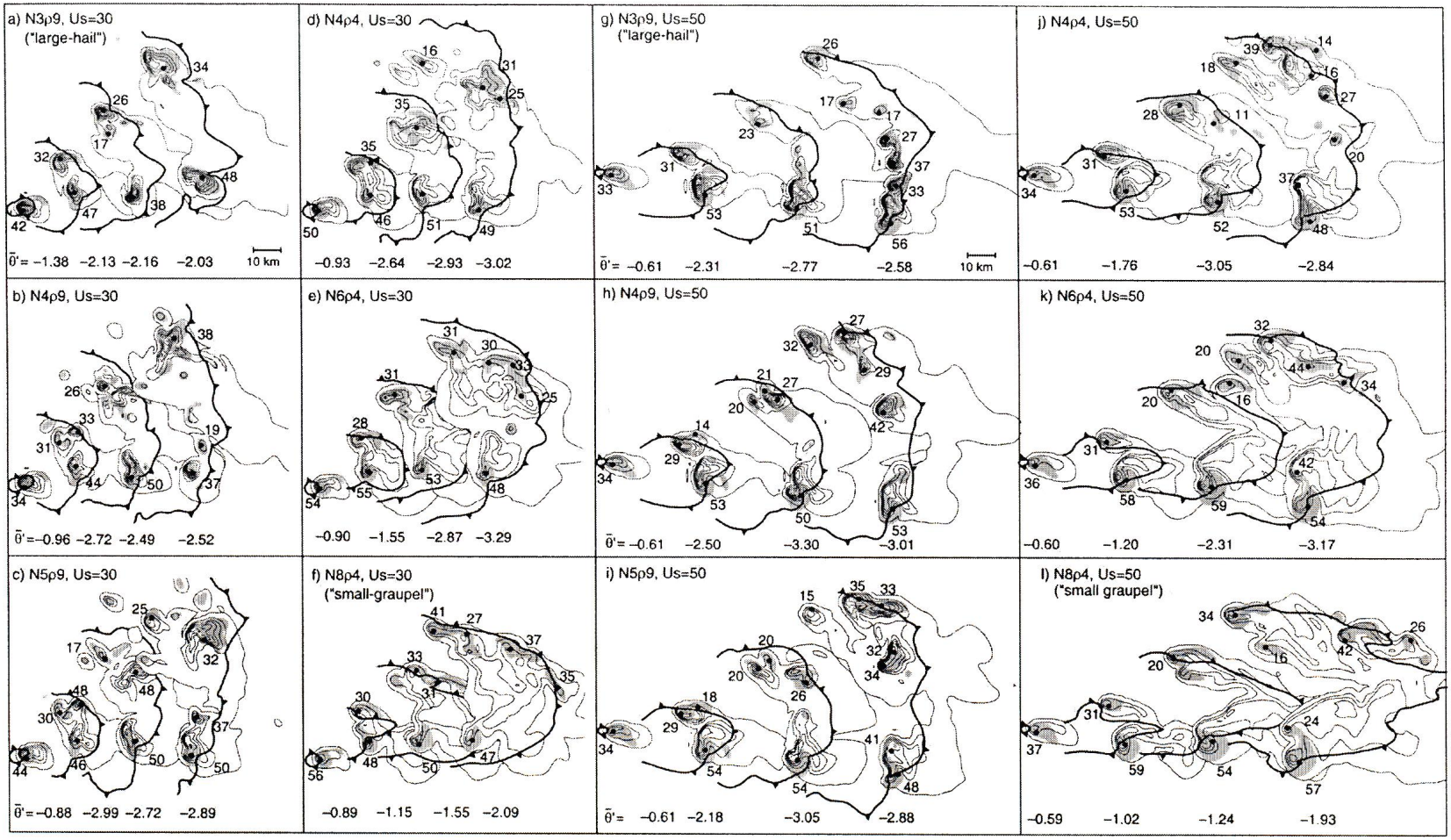




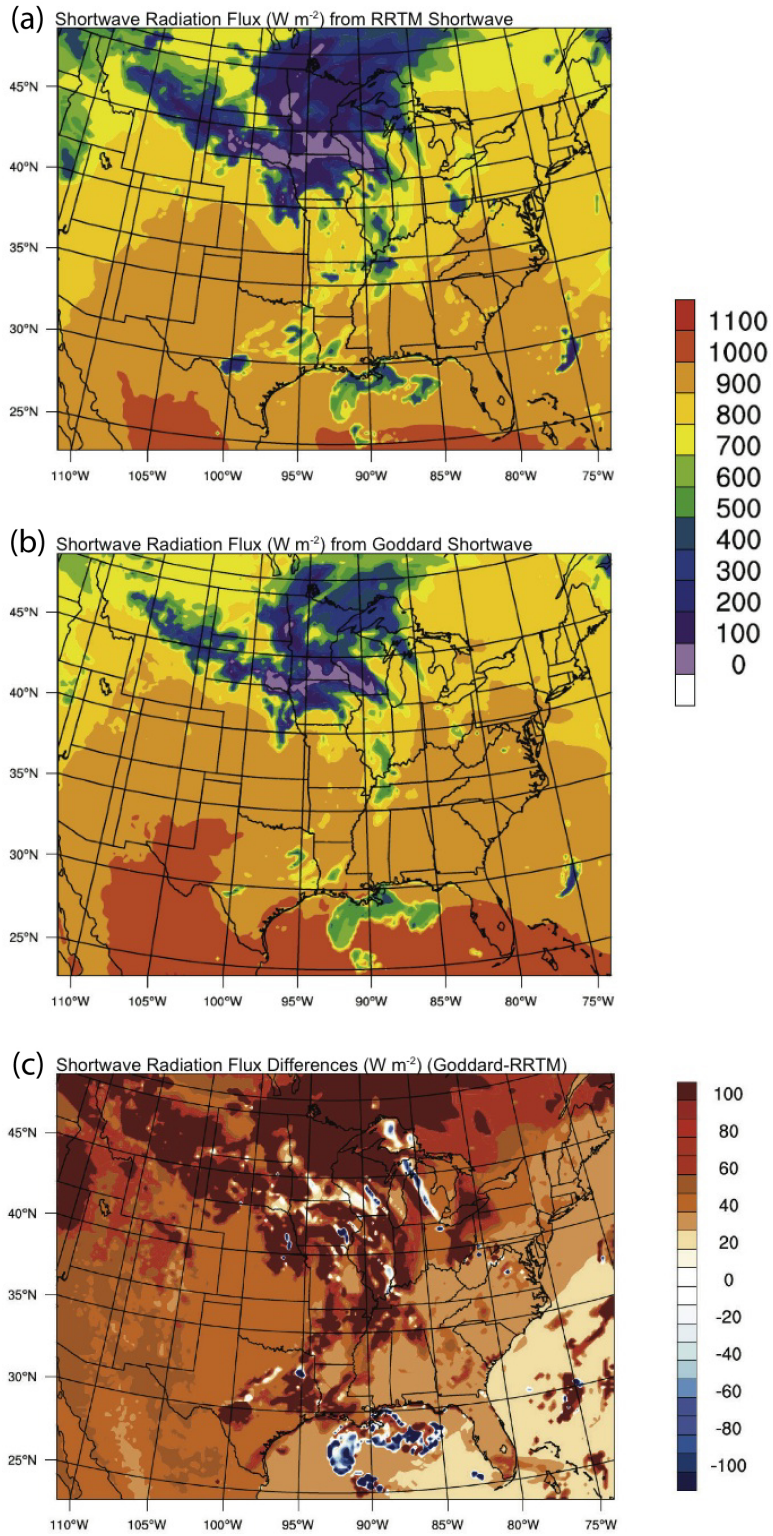
Skew-*T* log *p* diagram of an observed sounding taken at Topeka, Kansas at 2306 UTC 10 May 2011 (black line) and the corresponding profiles from five 23-h WRF model forecasts that vary only by PBL scheme. Forecasts produced by the 4-km SSEF system run by the Center for Analysis and Prediction of Storms. From Stensrud et al. (2015).



Positive vertical motion (m s^{-1}) at 125 m above ground level from CAM simulations using different PBL schemes (BouLac, MYJ, QNSE, MYNN2, MYNN3, YSU, ACM-2) along with a concurrent visible satellite image. From Ching et al. (2014).

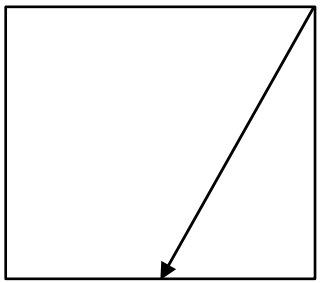


Results from Gilmore et al. (2004) indicate that changing graupel density and intercept paramters for single-moment microphysics scheme produces different convective evolutions.

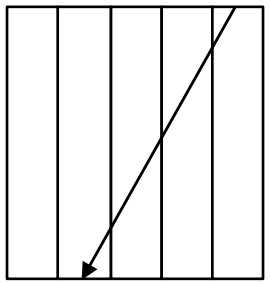


Shortwave radiation flux (W m^{-2}) reaching the Earth's surface at 1800 UTC 2 April 2006 (6-h forecast) calculated using the WRF model with 20 km grid spacing with the (a) rapid radiative transfer model (RRTM) and (b) Goddard shortwave parameterizations. The difference (Goddard – RRTM) is shown in (c).

From Stensrud et al. (2015).



20 km dx



4 km dx

Progress and Challenges

- Physical process parameterization schemes are more realistic and more capable
- Horizontal grid spacing below 4 km results in additional challenges:
  - PBL schemes not designed for this grid spacing
  - Microphysics schemes sensitive to choices, moving us toward higher moment schemes and greater computational expense
  - Radiation schemes a whole other concern, as process not contained within a single vertical grid column

Thoughts

- Convection-allowing models more capable and provide value
  - Parameterization schemes need significant attention
- Ensemble data assimilation effective
  - Still takes a number of assimilation cycles to correctly reproduce storms in models
- Ensemble design largely unexplored territory on convective-scale

Warn-on-Forecast Partners

Questions?

PennState