Application of a WRF mesoscale data assimilation system to short-range thunderstorm forecasts

HWT/DTC Collaboration Meeting

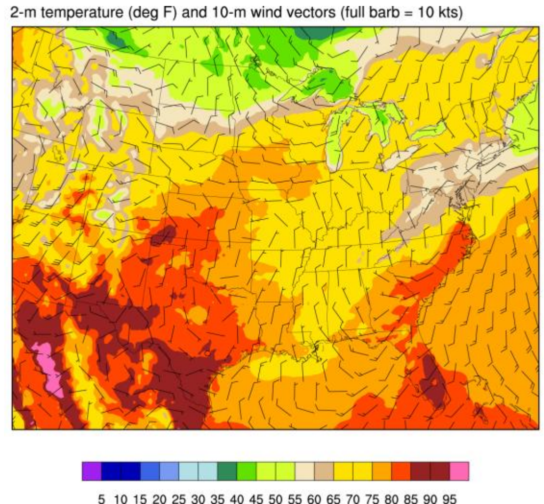
Dustan M. Wheatley
CIMMS/NSSL

David J. Stensrud and Michael C. Coniglio
NOAA/NSSL

Jidong Gao
OU/CAPS

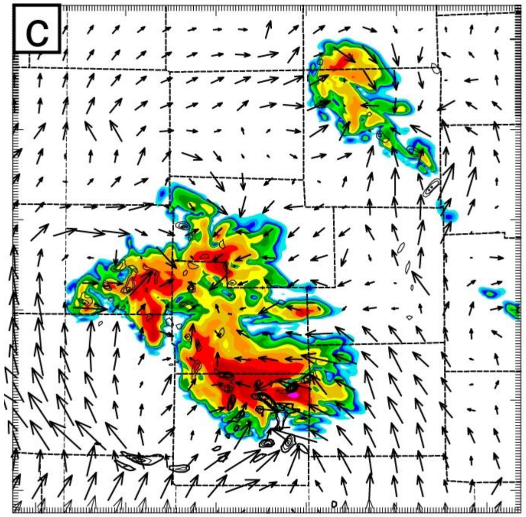
Goals

- Near-term: Evaluate the application of an EnKF mesoscale analysis/forecast system to predicting severe weather events
  - *Ability to produce realistic mesoscale structures (e.g., cold pools)*
  - *Impact on environmental characteristics such as CAPE, shear, etc*



Goals

- Long-term: Evaluate the application of convection-allowing forecasts launched from mesoscale ensemble to severe weather events
  - *Need inhomogeneous environments?*
  - *How can we best optimize computer resources?*
  - *Warn-on-forecast driven*



WRF Mesoscale Ensemble System

- WRF-ARW V2.2
  - Eastern two-thirds of CONUS
  - 20-km horizontal grid spacing; 35 vertical levels
  - Mean initial and boundary conditions from the NAM forecast cycle starting at 12Z

WRF mesoscale ensemble system (cont.)

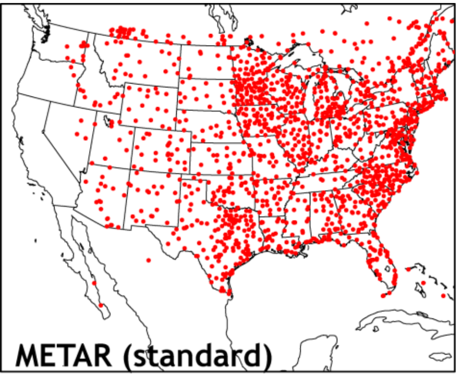
- 30-member ensemble
  - IC/BC perturbations from WRF-Var (Torn et al. 2006)
  - Random, filtered soil moisture perturbations
  - Physics diversity
    - Microphysics: WSM6, Thompson
    - Cumulus: Kain-Fritsch, Betts-Miller-Janjic, Grell-Devenyi
    - Surface layer: Similarity theory (MM5), Similarity theory (Eta)
    - PBL: YSU, MYJ, NCEP GFS
    - Shortwave radiation: Dudhia, Goddard

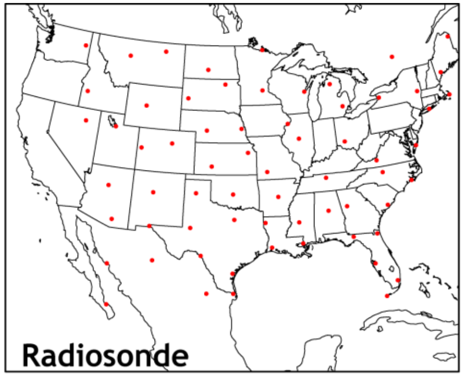
Mesoscale data assimilation

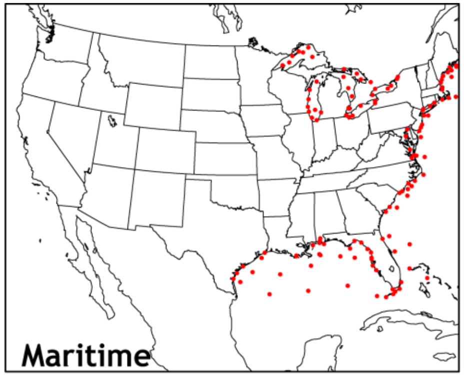
- *p (land-surface altimeter), T, T_d, u, v*

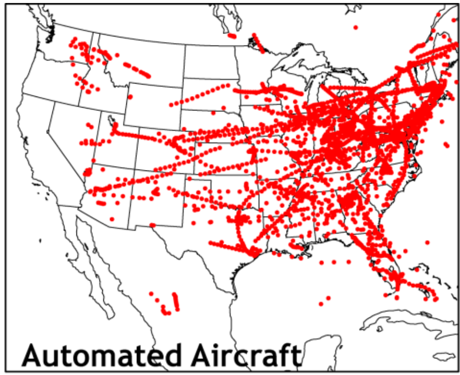
- Data Assimilation Research Testbed (DART)
  - Ensemble Kalman filter (EnKF) approach
  - See http://www.image.ucar.edu/DAReS/DART

- Observation platforms…

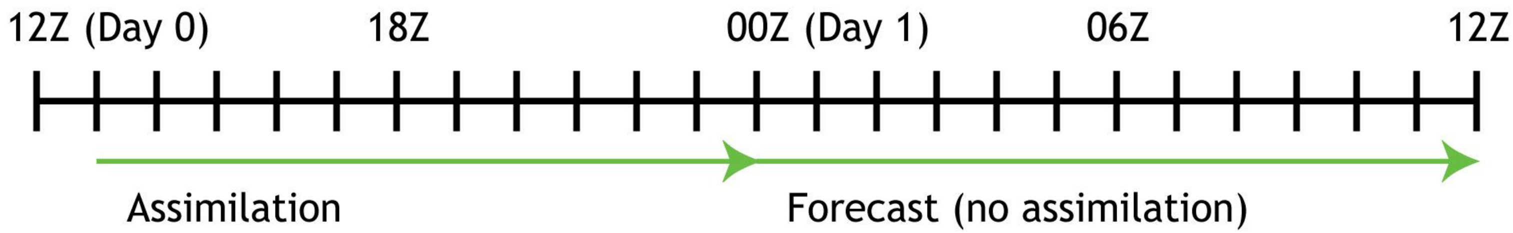






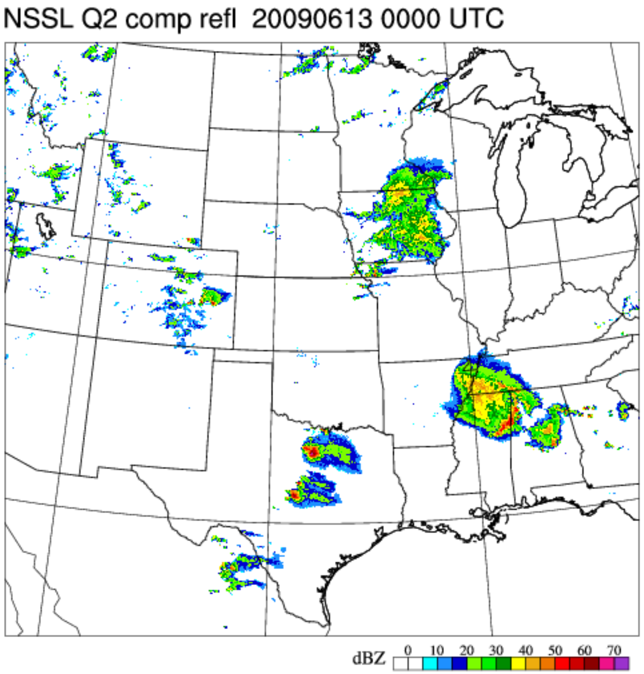


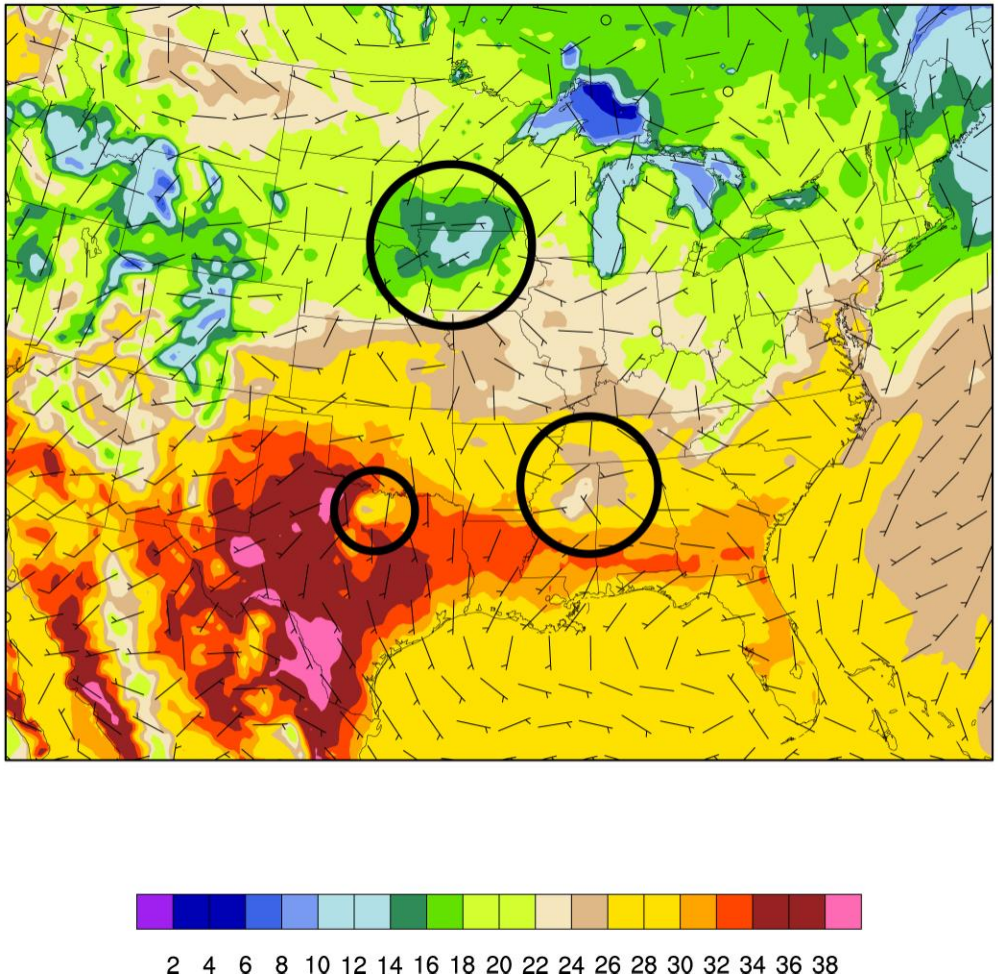
Design of experiments



- Resultant analyses and forecasts compared against a pure ensemble forecast (with no data assimilation)

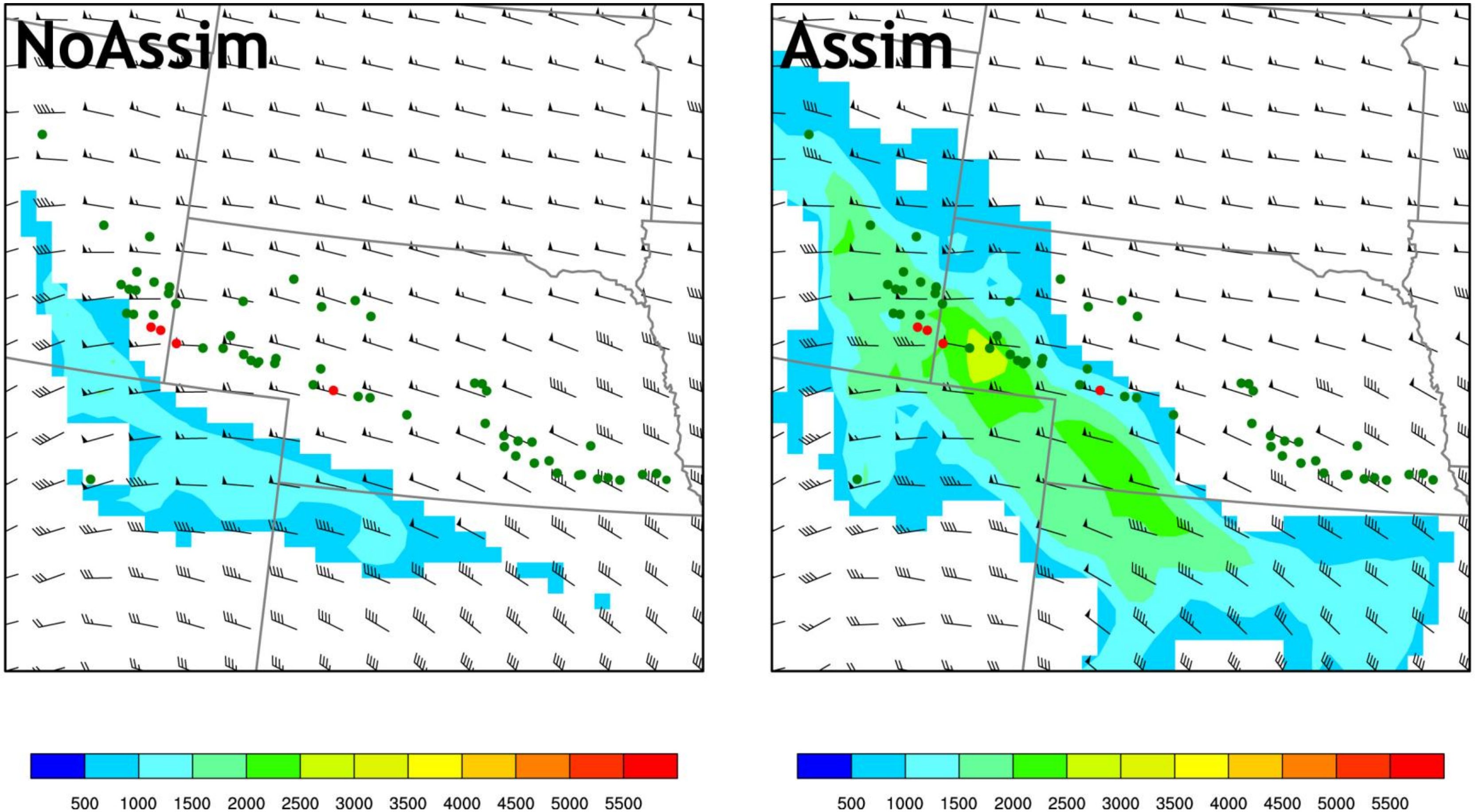
0000 UTC 13 June 2009





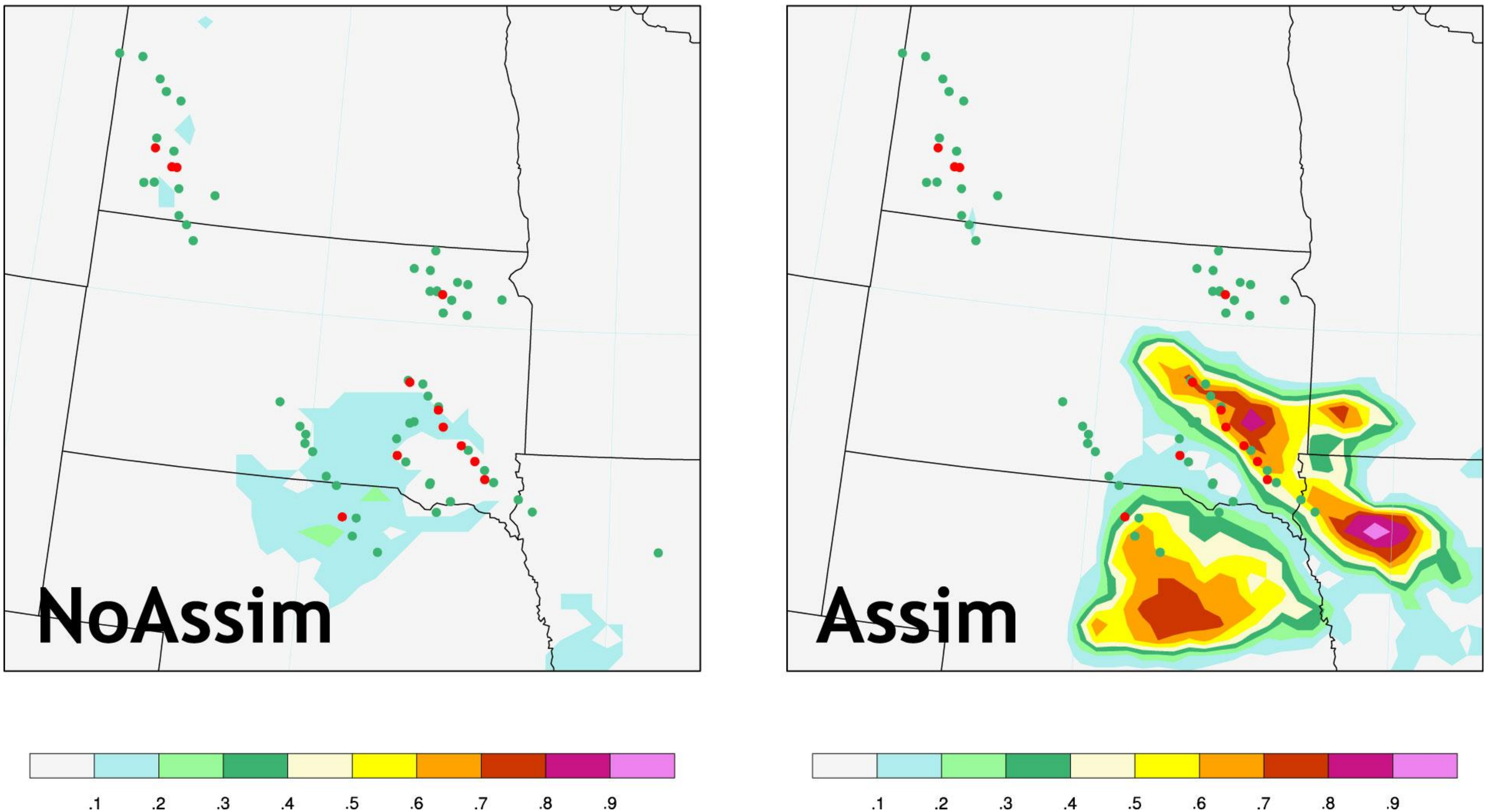
Associated cold pools reproduced in ensemble mean 2-m temperature

0000 UTC 6 June 2009
CAPE / 0-6-km shear



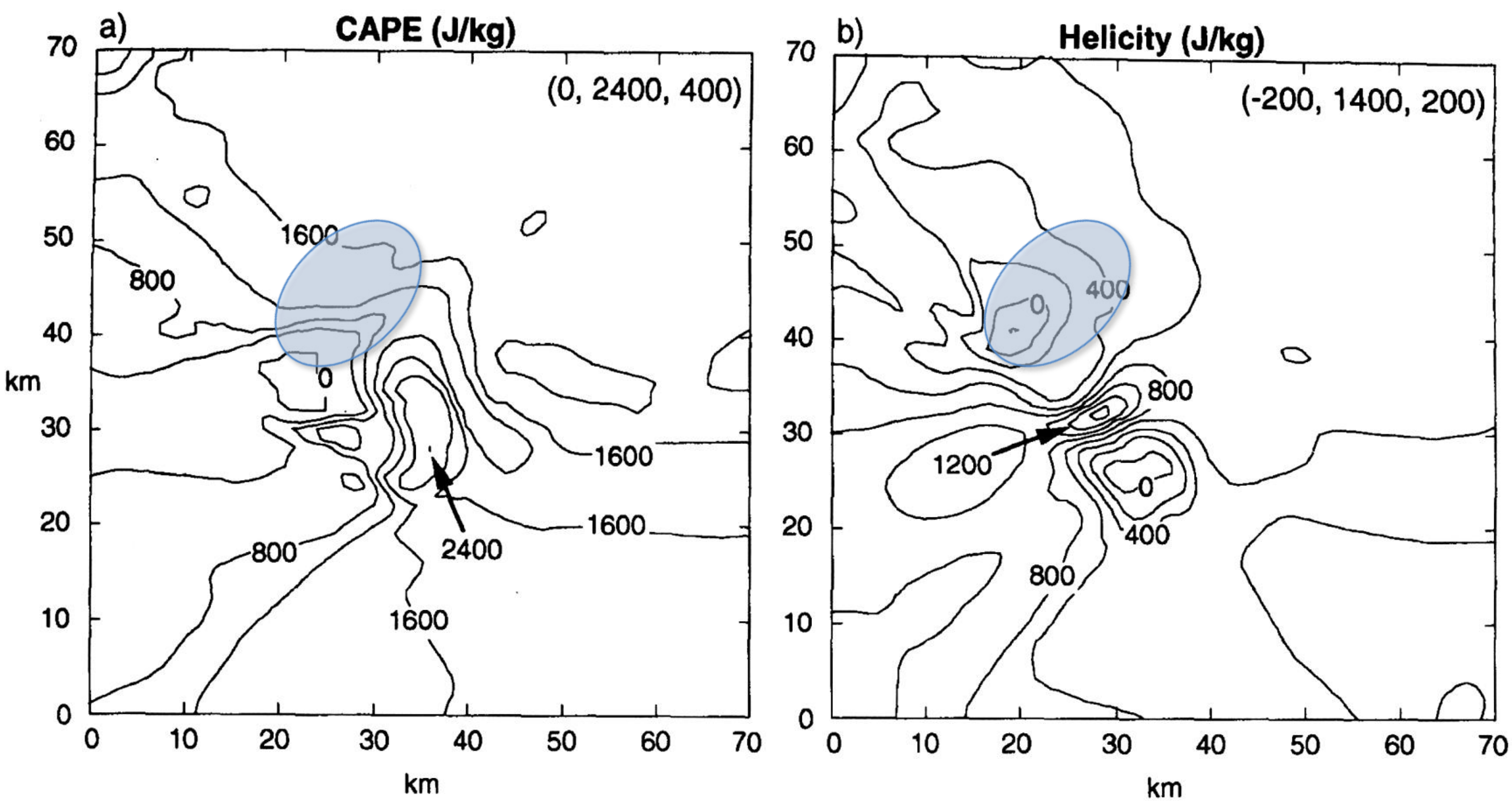
CAPE axis improved in Assim

0200 UTC 25 June 2009
Significant Tornado Parameter



Values improved in Assim

Storm-scale experiments- How important is horizontal environmental variability on convective scale?

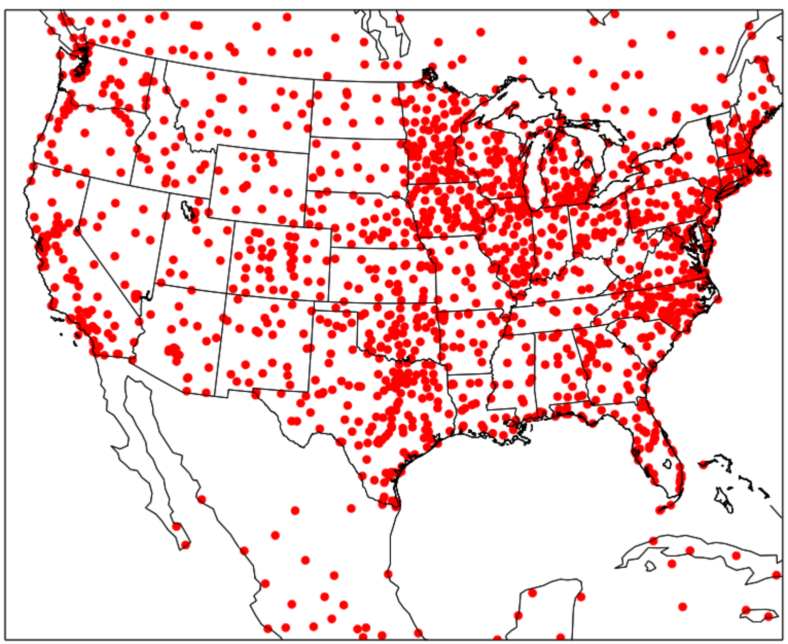


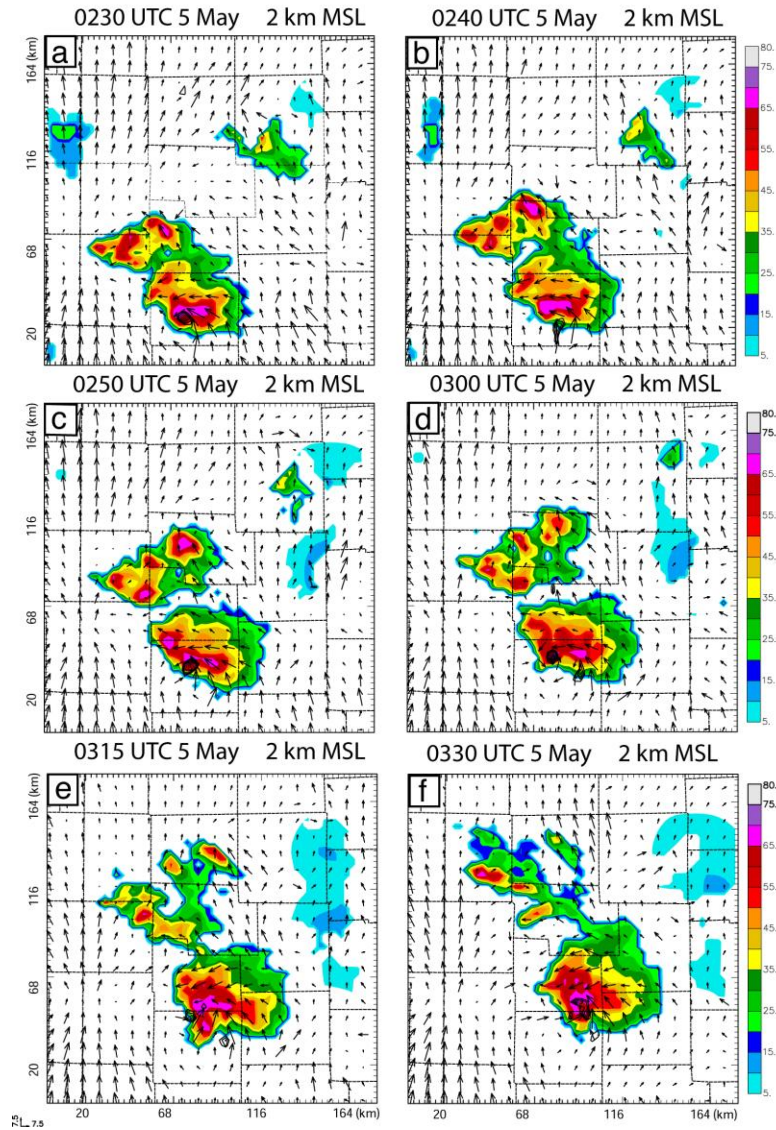
Cooper et al. (1994)

4-5 May 2007

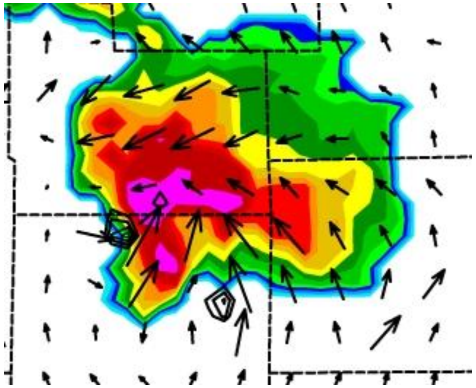
Mesoscale Ensemble

- Assimilate surface observations from 1300 4 May to 0230 UTC 5 May (theta, dewpoint, u, v)



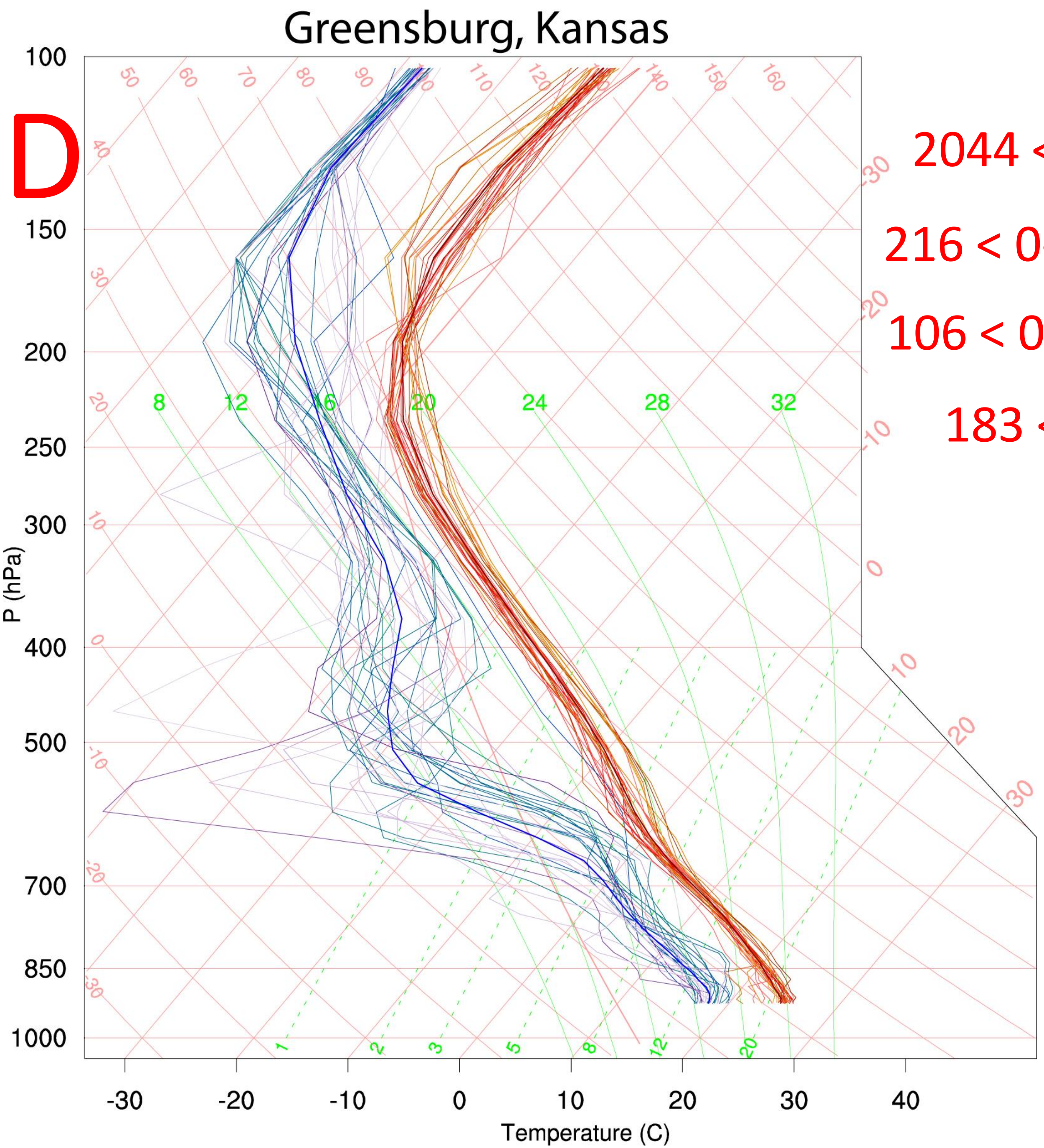


Convection-allowing ensemble



- ARPS model
  - 1 km grid spacing, 47 vertical levels to 20 km
  - LFO microphysics
  - 1-h forecast starting at 0230 UTC
- Two sets of initial conditions
  - SND – 30 vertical soundings from mesoscale ensemble
  - 3D – 30 three-dimensional fields from mesoscale ensemble
- Radar data assimilation
  - ARPS 3DVAR scheme (Gao et al. 2004) and cloud analysis
  - Reflectivity and radial velocity data from 6 nearby radars at 0230 UTC
  - No cycling

SND



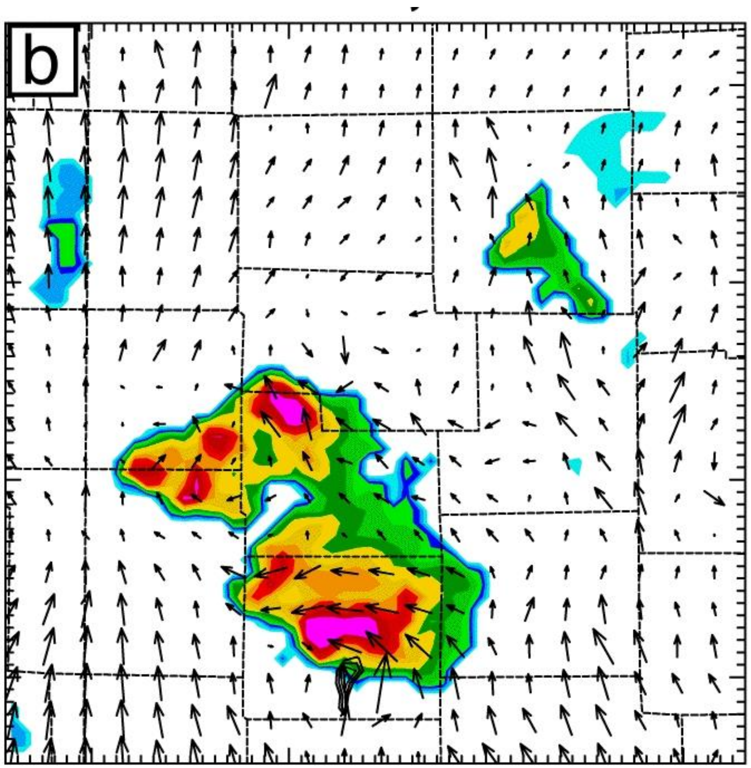
2044 < CAPE < 4832

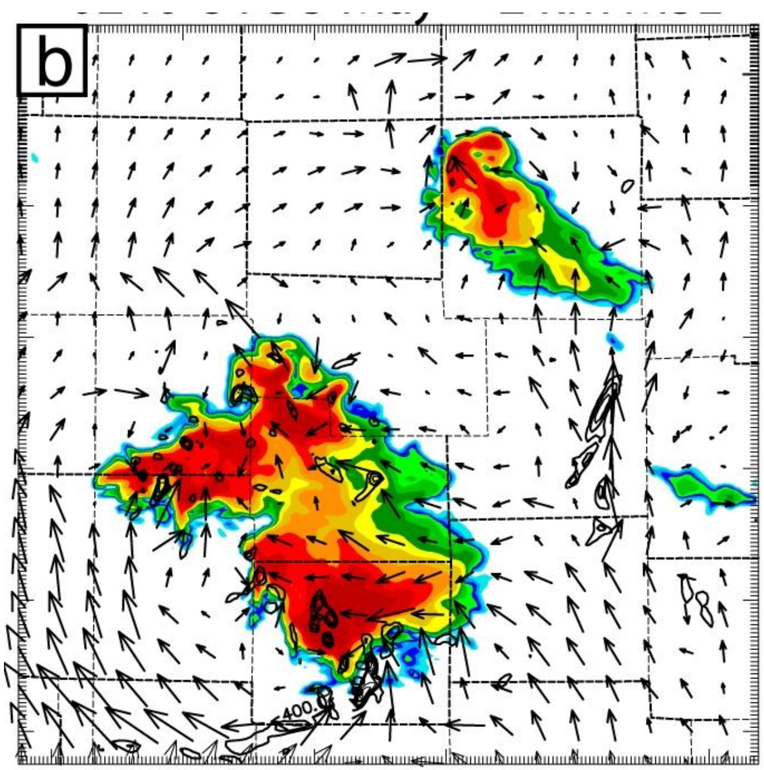
216 < 0-3 SREH < 525

106 < 0-1 SREH < 392

183 < LCL < 1077

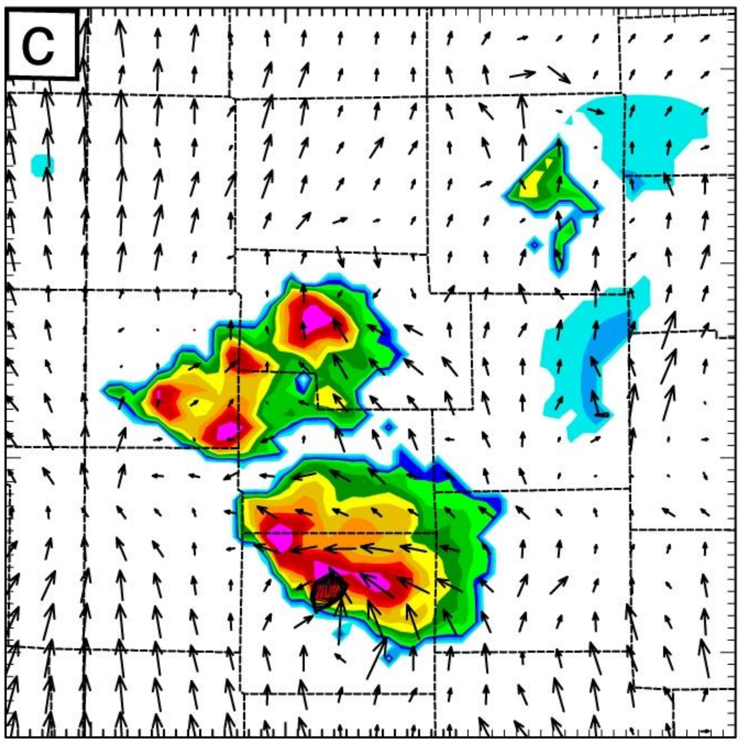
SND Forecasts – member 3

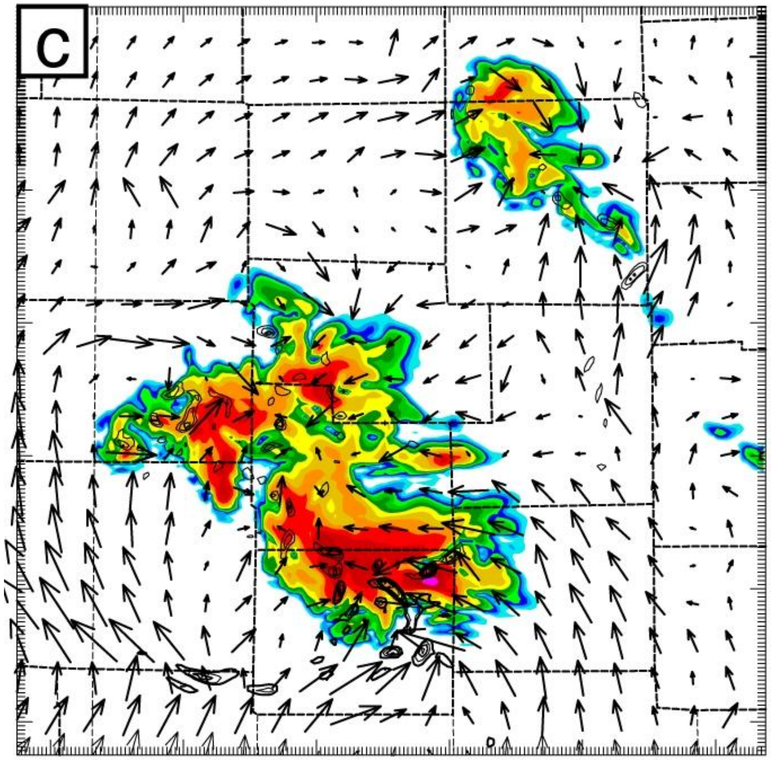




10 minutes

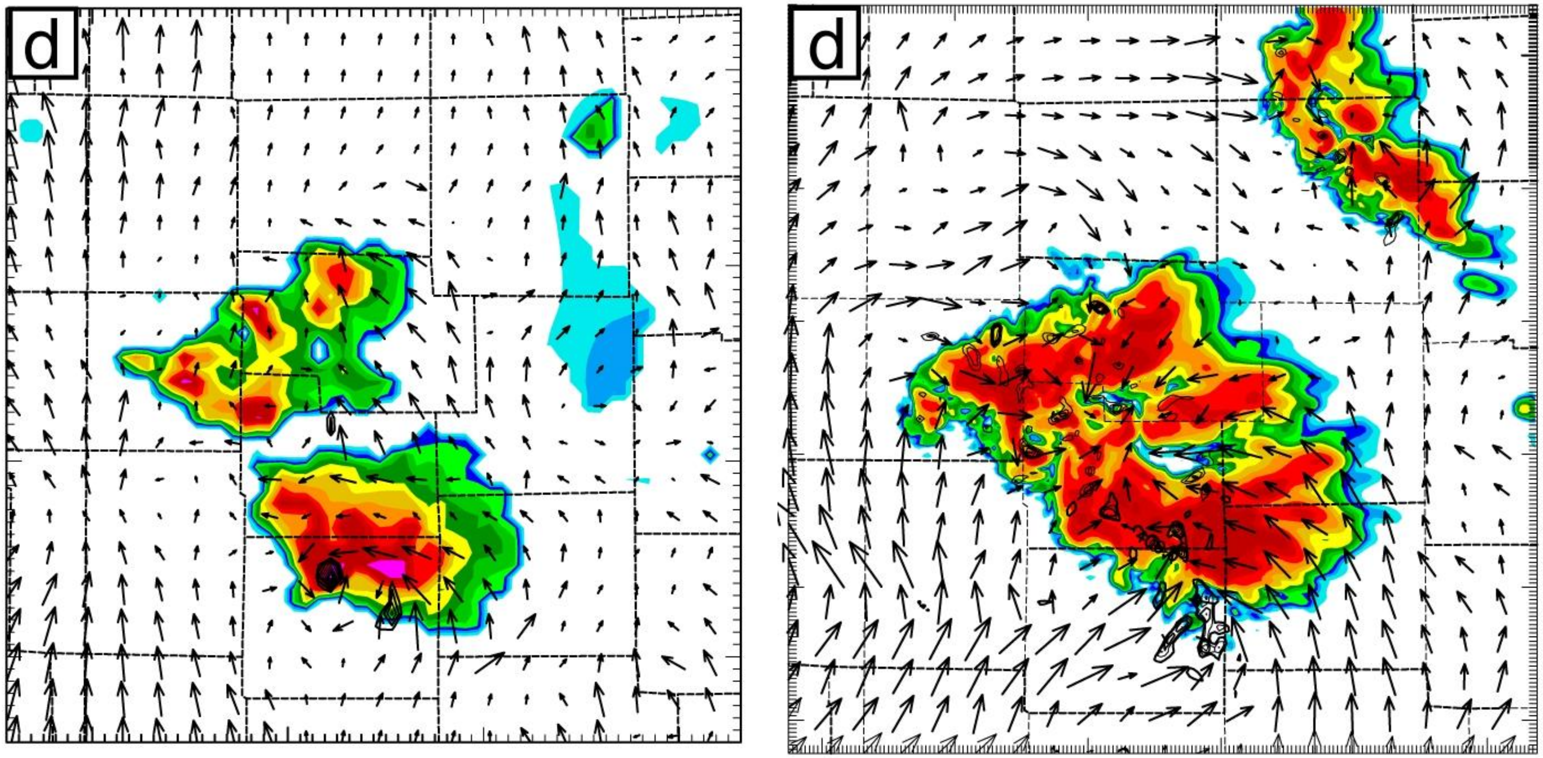
SND Forecasts – member 3





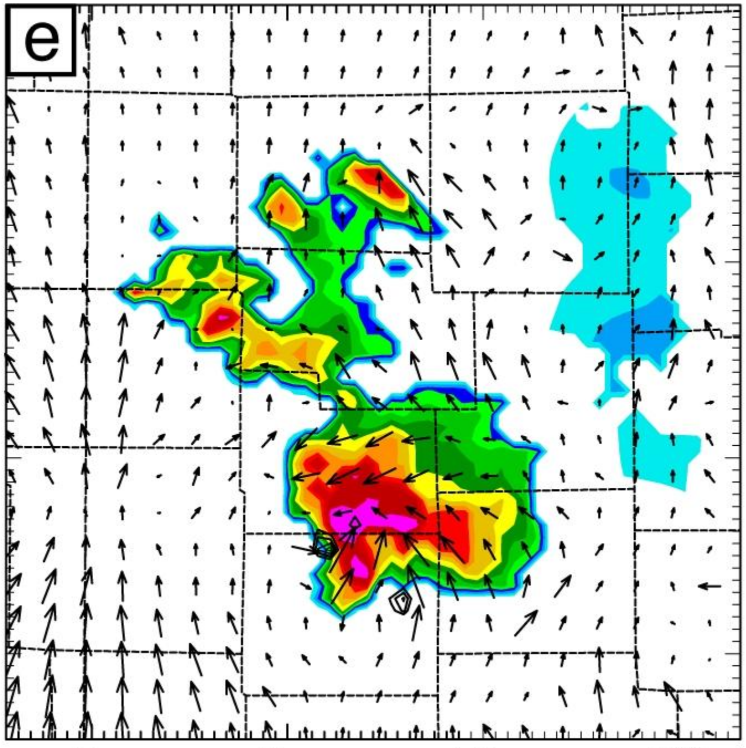
20 minutes

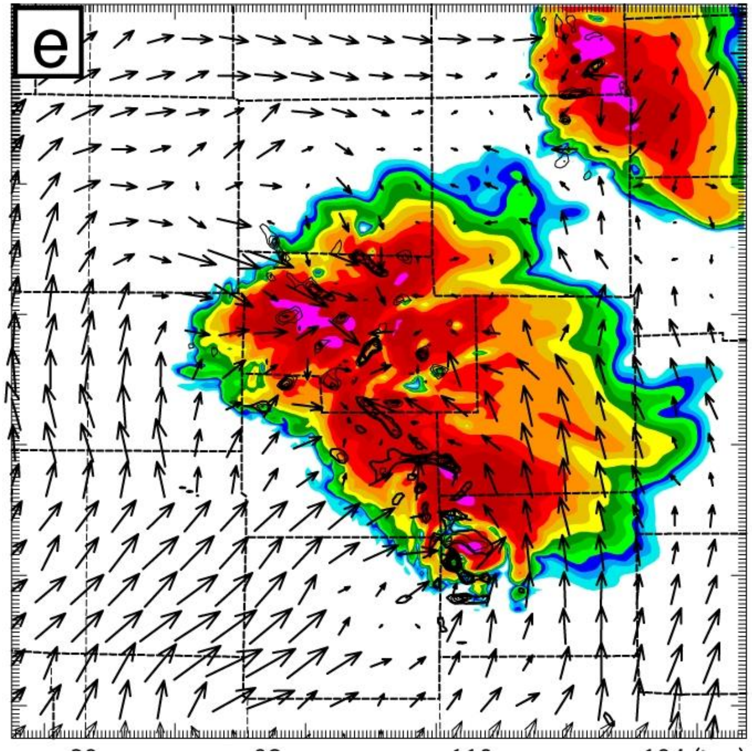
SND Forecasts – member 3



30 minutes

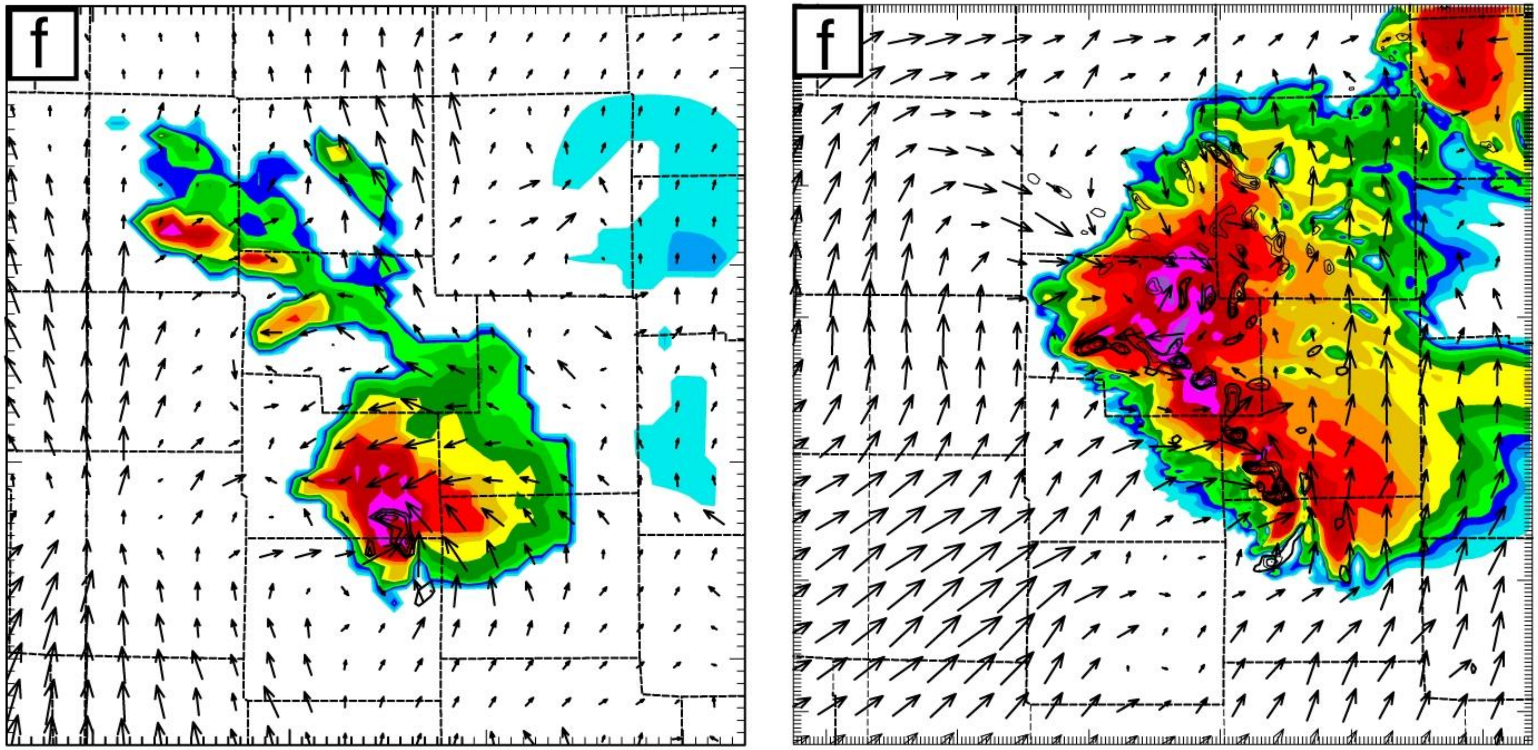
SND Forecasts – member 3





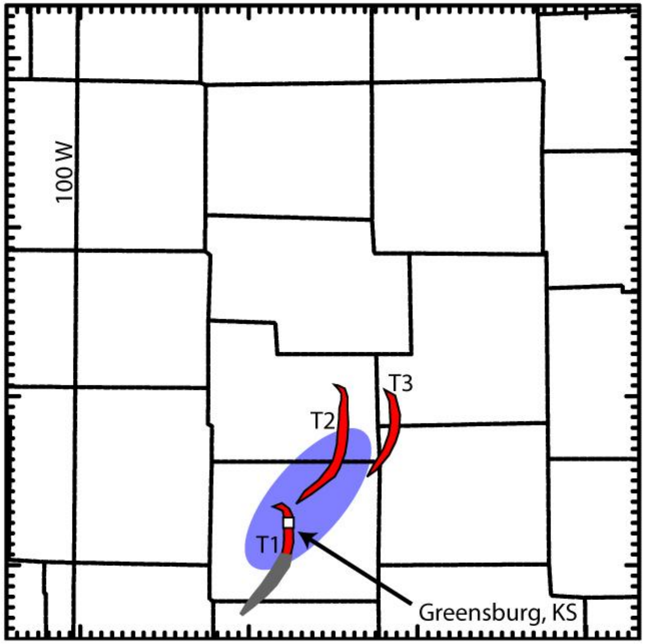
45 minutes

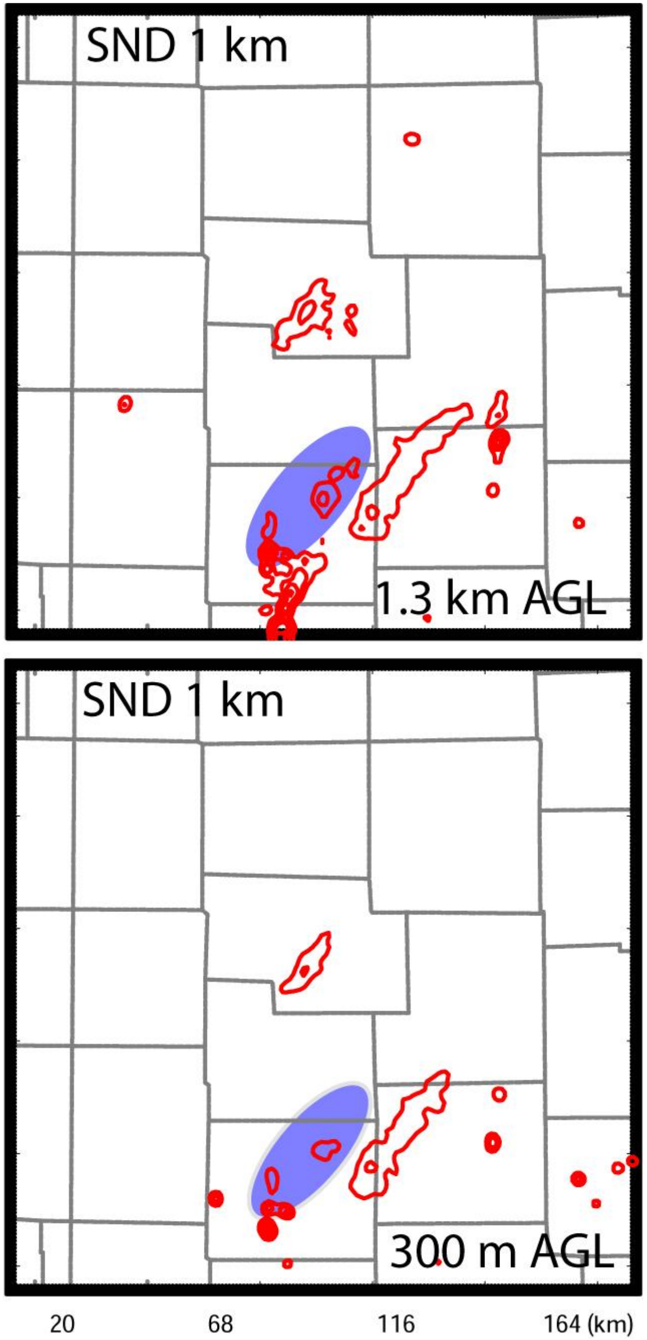
SND Forecasts – member 3



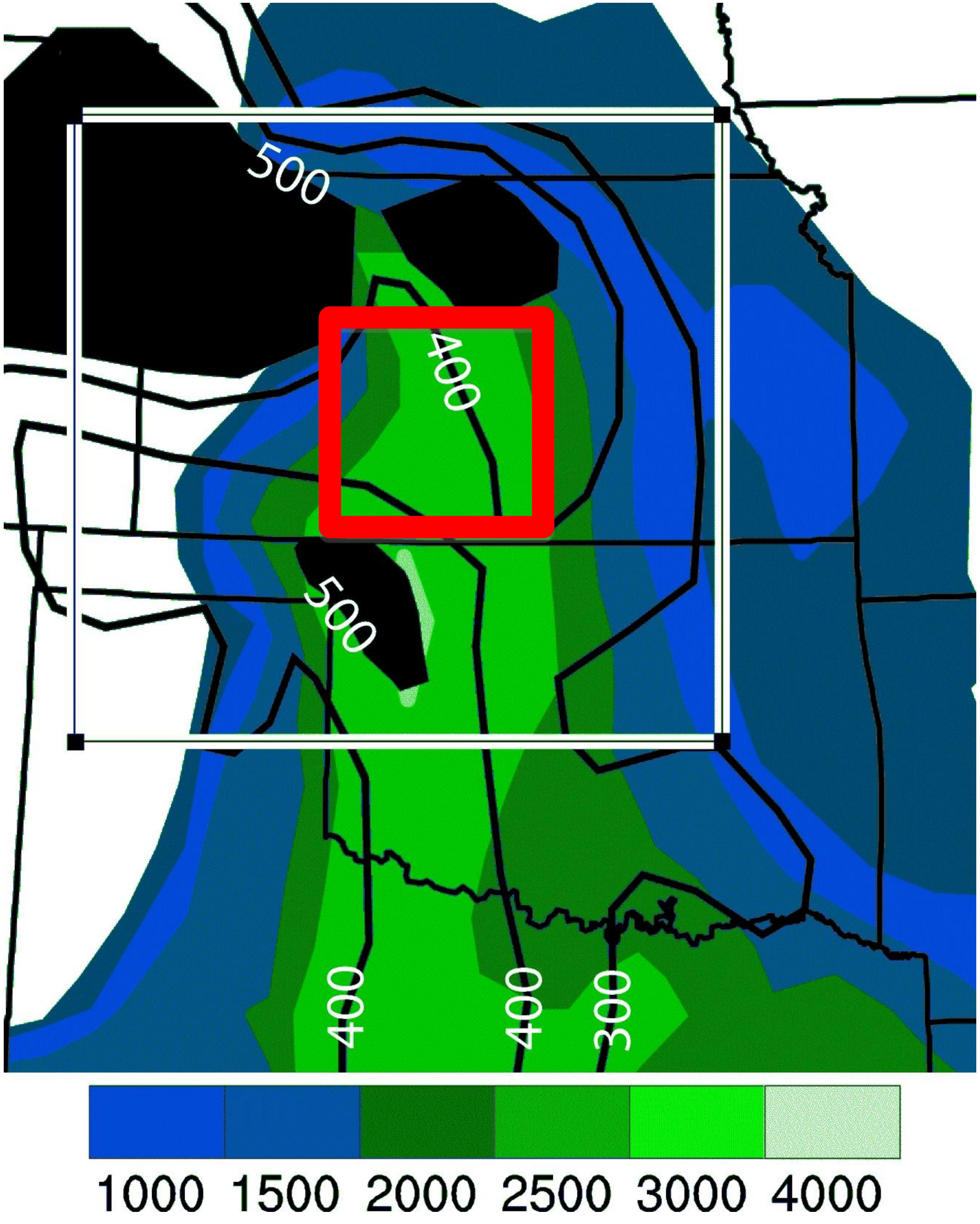
60 minutes

SND ensemble forecast initialized with radar data

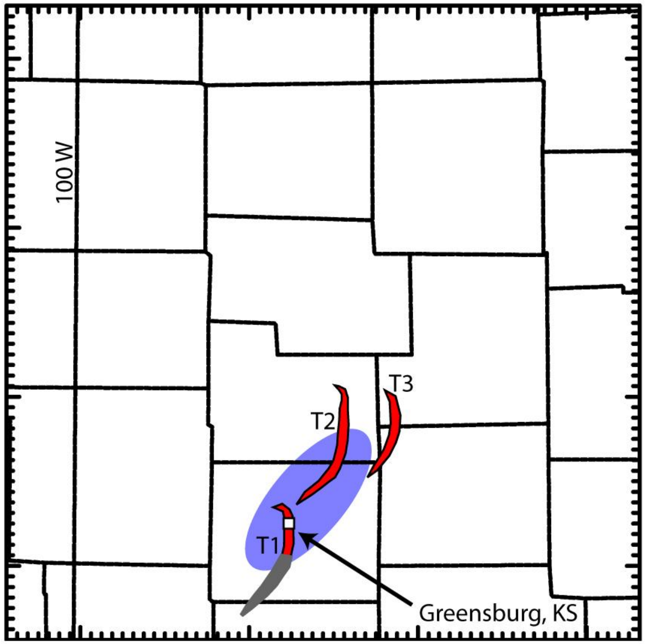


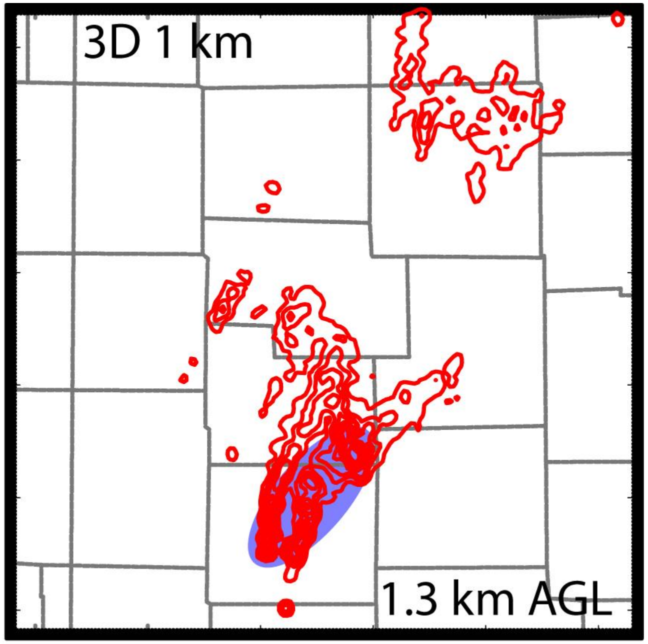


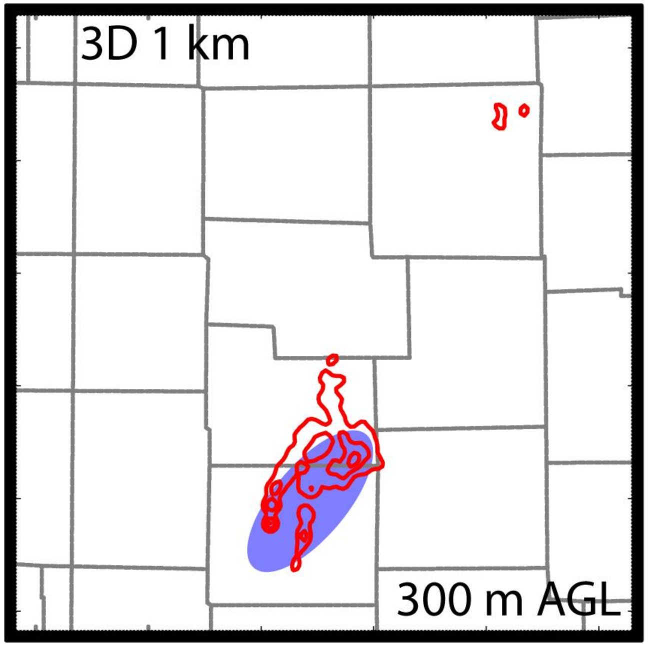
3D



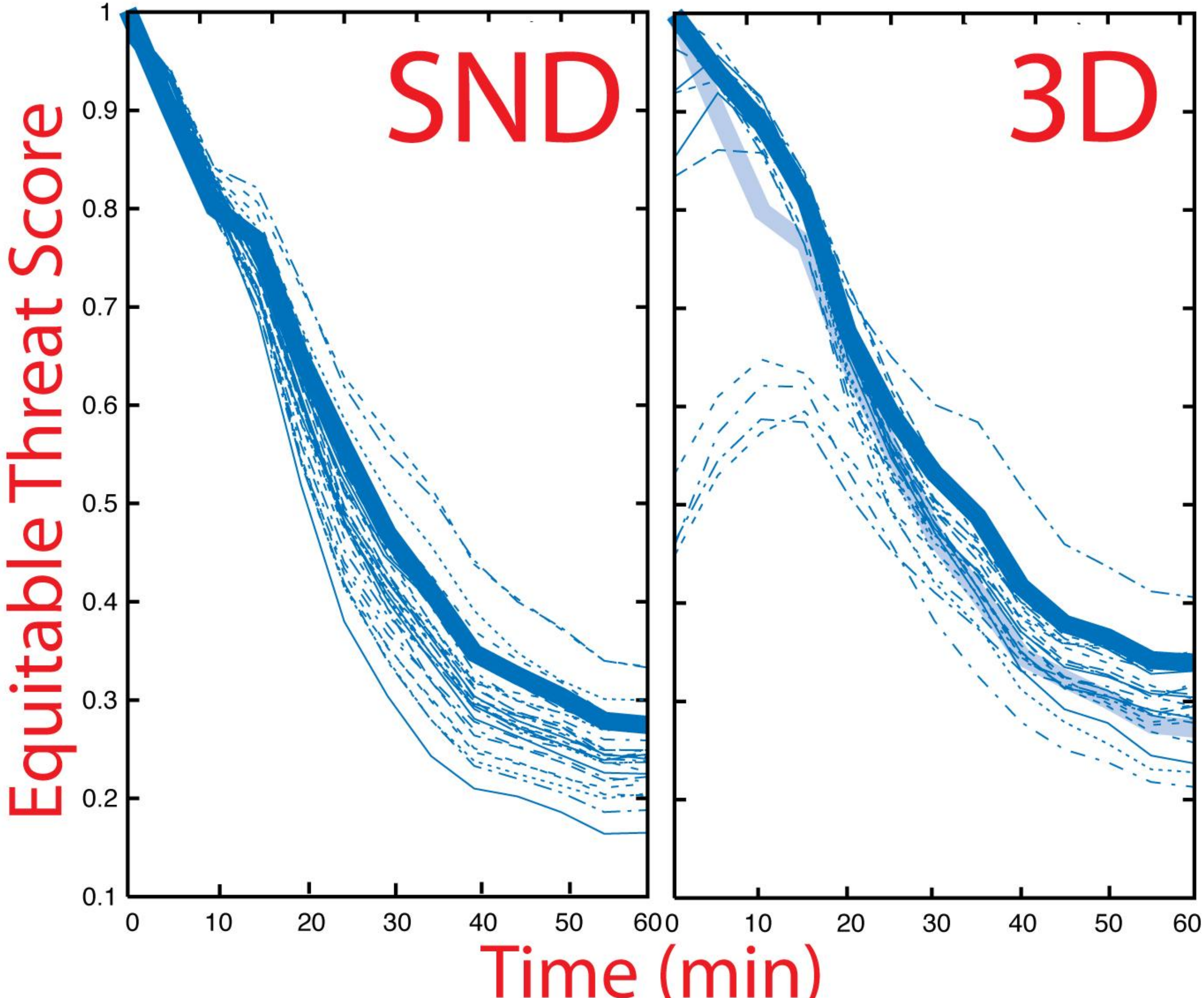
3D ensemble forecast initialized with radar data







Low-level vorticity forecasts improved with 3D fields


SND
3D
Equitable Threat Score
Time (min)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
60

Preliminary Conclusions

- Uncertainty not just the from microphysics!
- Need to use three-dimensional initial/boundary conditions for real data cases or storm evolution may be incorrect

Plans

- Run mesoscale ensemble in analysis & forecast mode in Spring 2010 for V2
- Continue collaboration with CAPS to explore/evaluate methods of sfc & radar data assimilation
- Collaborate with NCAR on proposed Front-Range Convection experiment (D. Dowell, G. Romine)