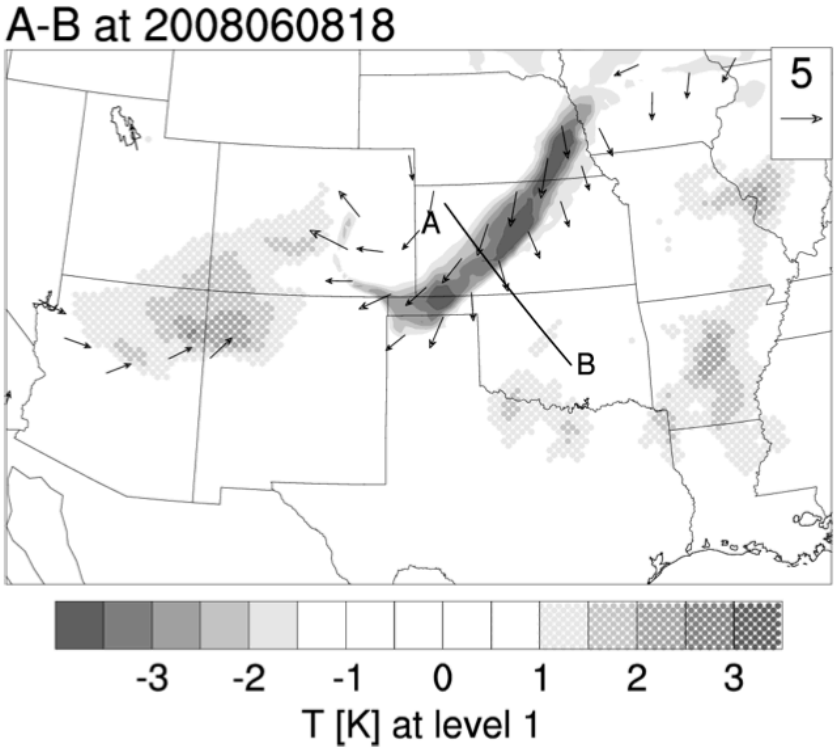
Recent Developments in Mesoscale Data Assimilation with WRF/DART



Chris Snyder, NCAR [MMM and IMAGe]

NCAR is supported by the US National Science Foundation

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Thanks to Soyoung Ha, Terra Thompson (OU), Glen Romine

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WRF/DART

Data Assimilation Research Testbed (DART)

- Provides algorithm(s) for ensemble Kalman filter (EnKF)
- General framework, used for several models
- Parallelizes efficiently to 100's of processors
- Developed by Jeff Anderson and team; see (and download from) http://www.image.ucar.edu/DAReS/DART/

WRF/DART

- WRF-specific interfaces
- obs operators: conventional, GPS, radar, surface observations

Why Ensemble DA?

Covariances estimated from ensemble of forecasts

- Reflect character, dynamics of recent flow
- Don't depend on assumed balances (e.g. geostrophic)

Analysis ensemble that approximates analysis uncertainty

- Reflects location, quality of recent observations
- Basis for EF system as well

Little dependence on model

- Easy to use new configurations/physics

Update multiple, nested grids simultaneously

Relation of EnKF and Variational Schemes

WRF/DART EnKF ~ WRFDA with alpha CV

… two ways to solve same problem, given same f/c ensemble

WRFDA as released does not generate analysis ensemble
(but see T. Auligné)

Key Element of Ensemble DA

Assume that covariances are small at sufficiently large spatial separation

- e.g., Seattle uncorrelated with Miami

Covariance localization

- Multiply covariance estimated from ensemble by factor that depends on separation distance
- Factor = 0 beyond specified distance: “localization radius”

Main tuning parameter, typically comparable to length scale of flow

Mesoscale Analyses

Model bias limits performance of cycling DA system

- Romine et al (2013), real-time convection-permitting forecasts
- Torn and Davis (2012), tropical cyclones on large Atlantic domain
- Improvements to model of equal importance to details of DA

Surface observations abundant, informative but under-utilized

Assimilation of Surface Observations

Assimilate METAR U10, V10, T2, Td2 over CONUS

- 45- and 15-km domains, two-way nested, 3-h cycling
- Evaluate against (unassimilated) mesonet observation

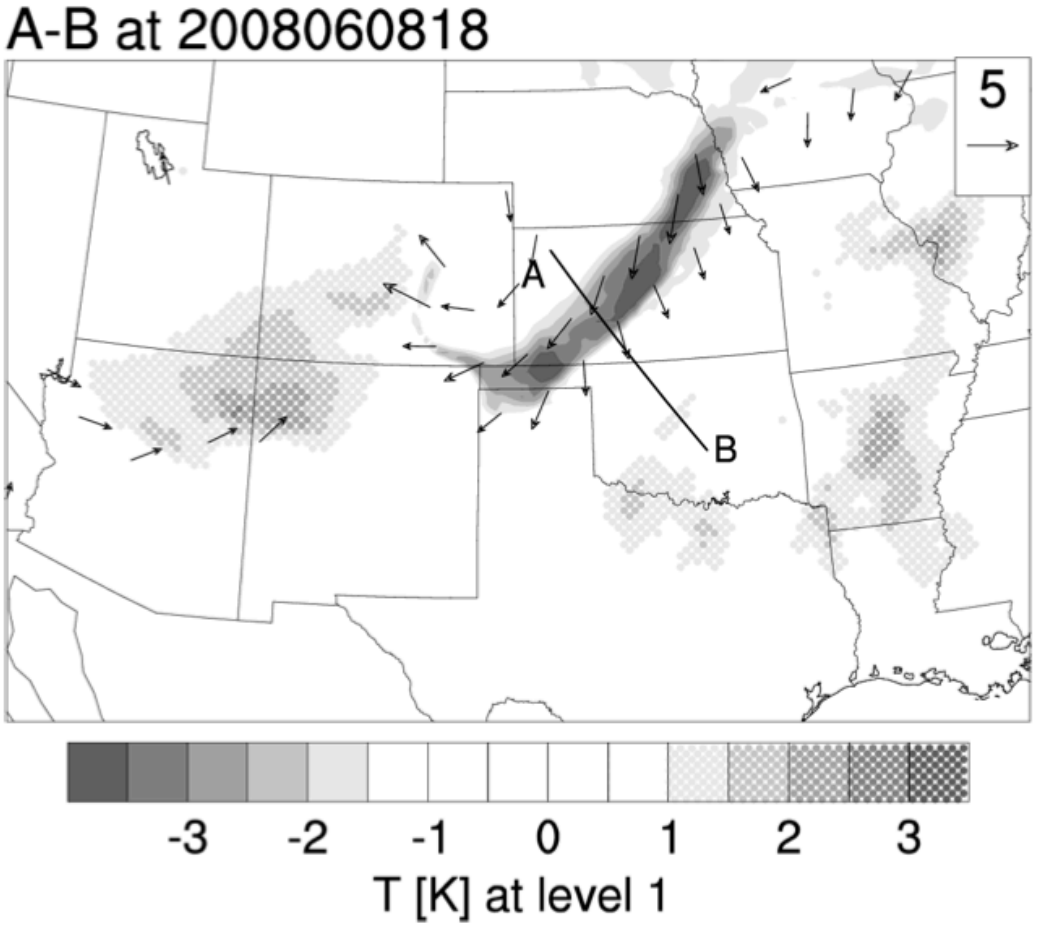
Localization radius for EnKF is ~600 km

Significant improvements in:

- Surface analyses
- 3-h forecast fits to METAR and radiosondes
- Error relative to RUC analyses for forecasts < 6 h

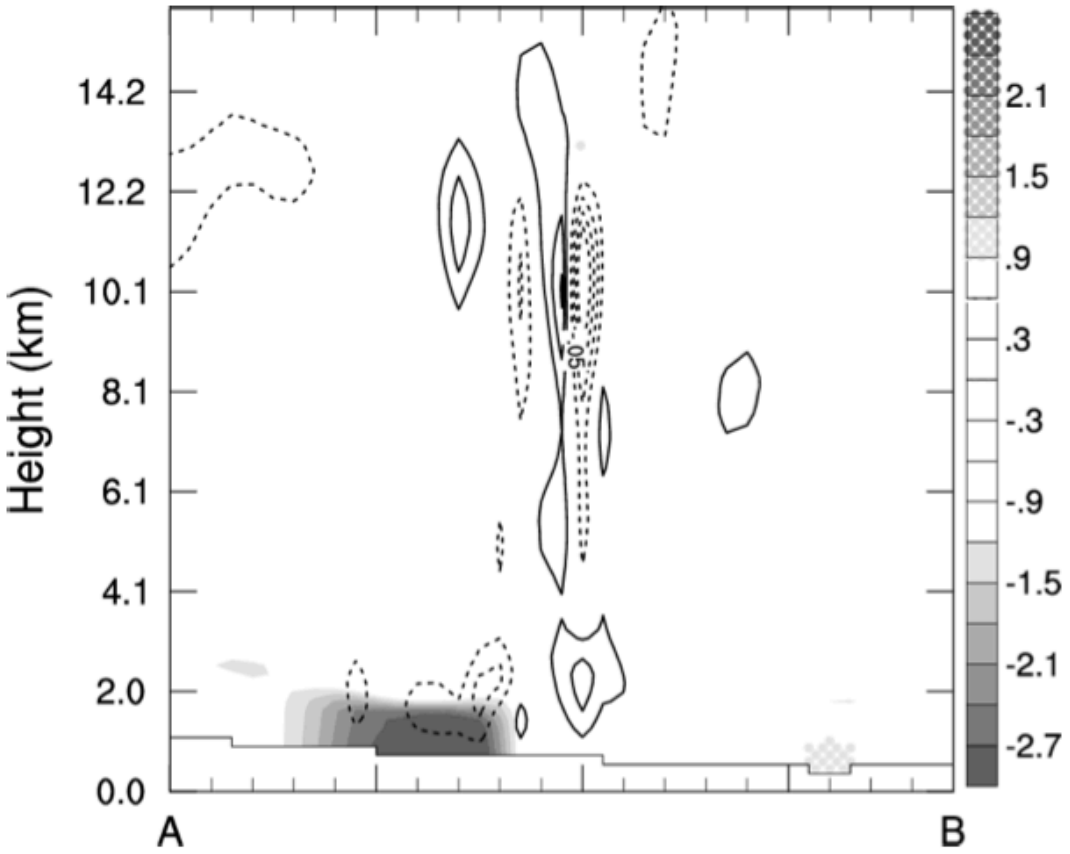
Effect of Surface Observations

- Analysis increment from assimilation of METAR



Effect of Surface Observations (cont.)

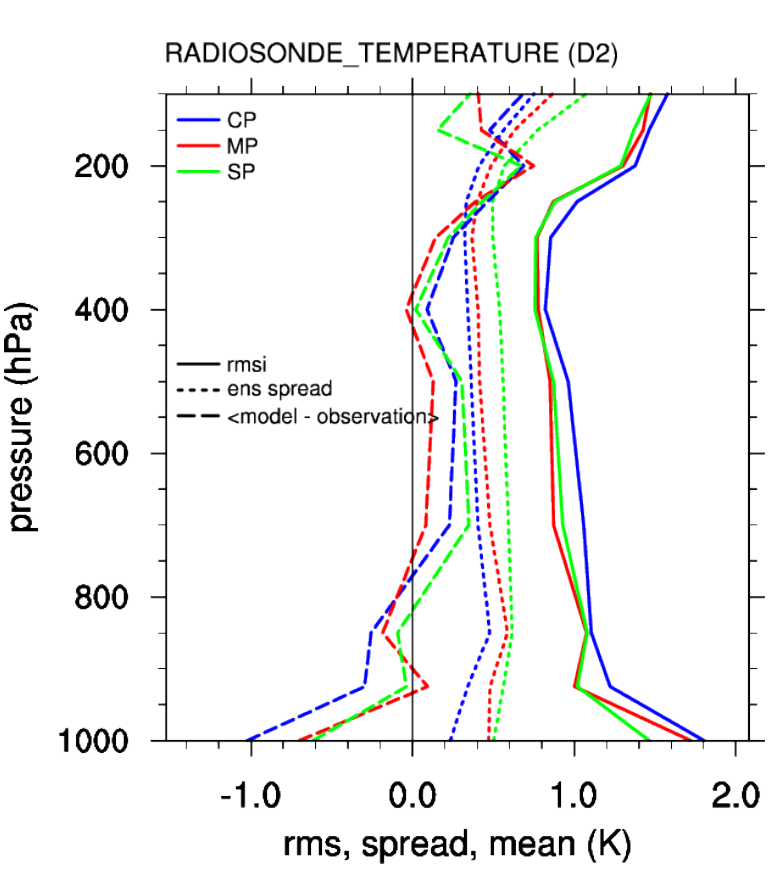
- Cross section of analysis increment

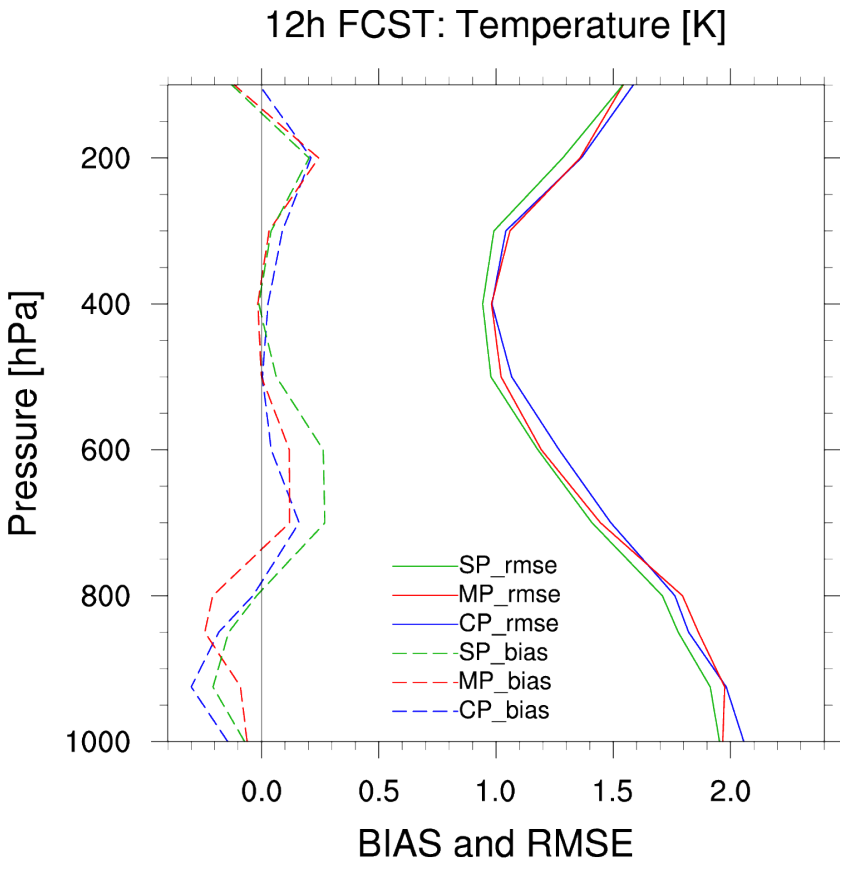


Accounting for Model Error

WRF is imperfect. Crucial to account for this in DA scheme.

- Multi-physics ensemble (red)
- Ensemble with stochastic backscatter (SKEBS; green)





Ensemble DA for Convective Scales

Standard approach, at present:

- Assimilate obs from single Doppler radar
- Resolution of 1-2 km on small domain, O(200 km x 200 km)
- Start with uniform environment (“single sounding”) before radar assimilation
- E.g., Dowell et al. (2004), Aksoy et al. (2009), Marquis et al. (2013)

Radius of localization ~ 10 km

Ensemble DA for Convective Scales (cont.)

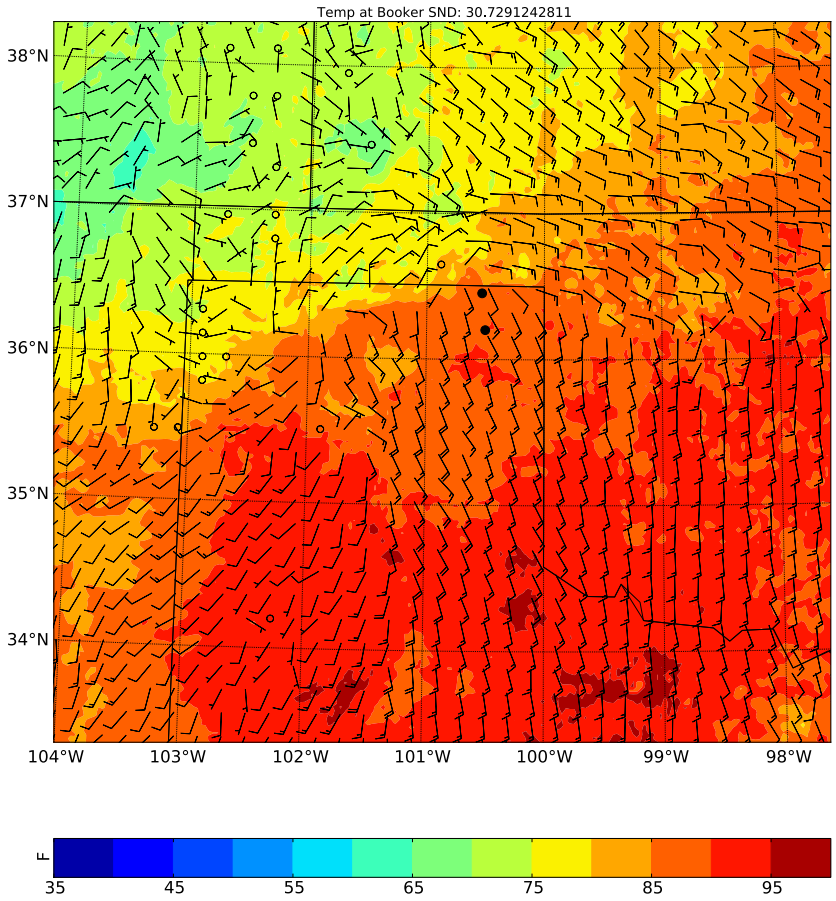
Would like to incorporate radar obs and convecitve-scale detail into mesoscale analyses

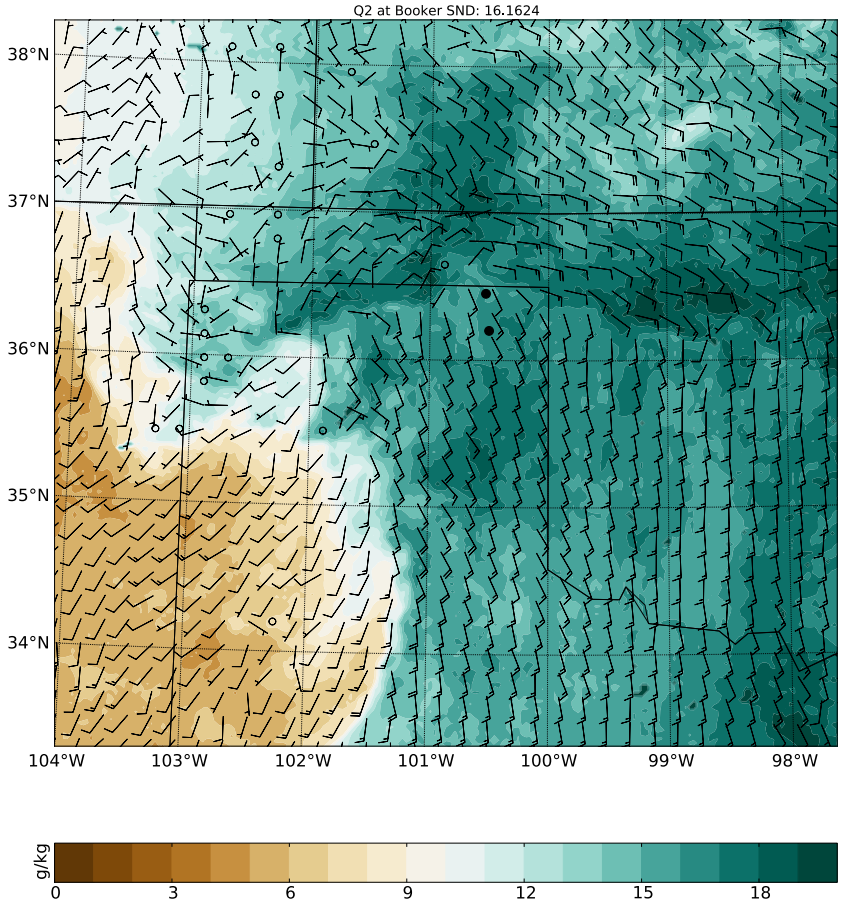
Thompson et al., ongoing work for VORTEX2 case:

- Begin by cycling CONUS domain, 15- and 3-km domains, conventional obs
- 1-hourly cycles starting day of event
- Taking initial and lateral boundary conditions from 3-km domain, assimilate obs from 4 radars on 3- and 1-km domains, 15-min cycling. Decrease localization radius.
- Finally, plan to include VORTEX2 obs near time of tornadogenesis

Ensemble DA for Convective Scales (cont.)

- 3-km analysis, before radar DA; surface T (left) and water vapor (right)

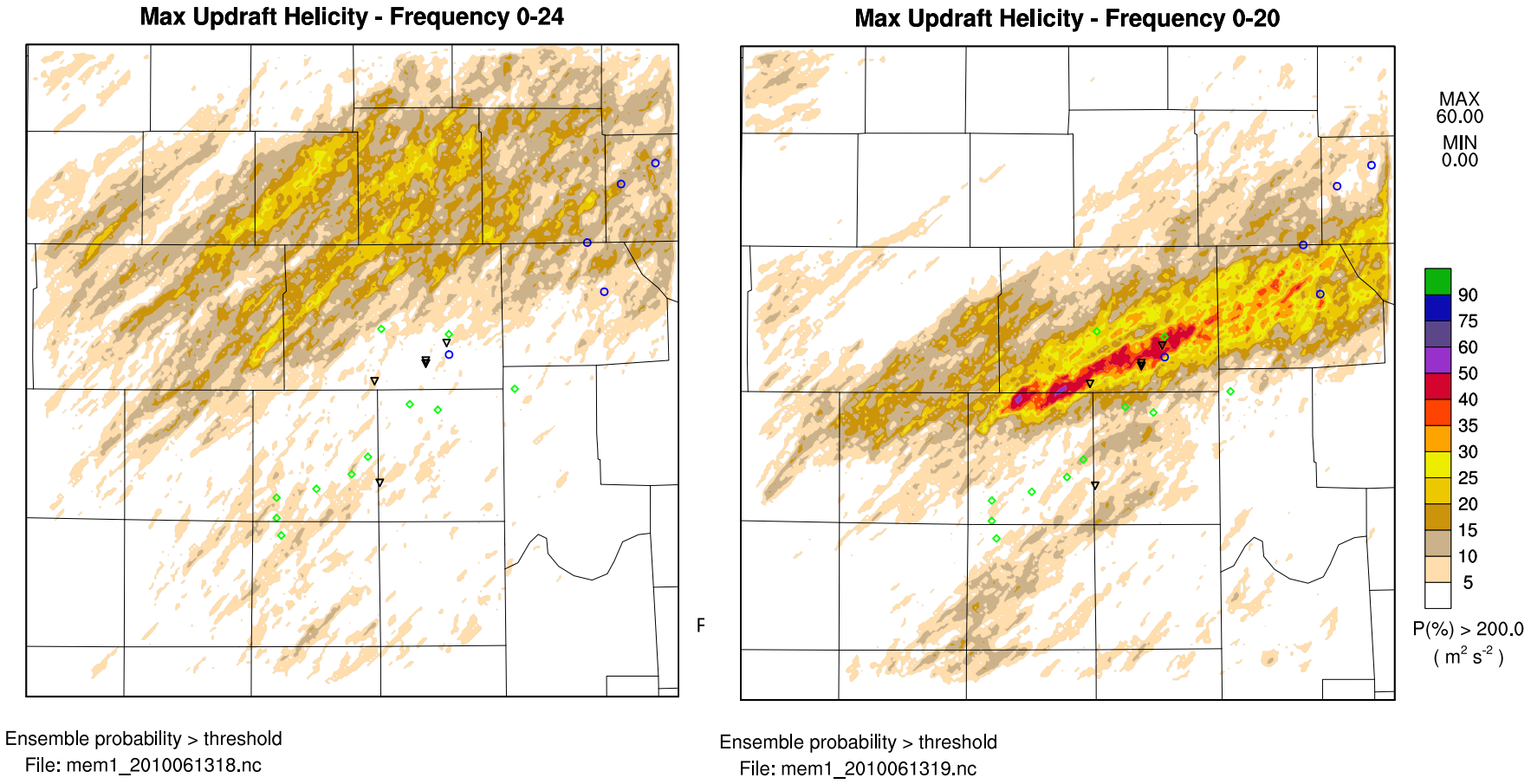




Courtesy T. Thompson

Ensemble DA for Convective Scales (cont.)

- Forecasts before (left) and after (right) 4 cycles of radar DA



Courtesy T. Thompson

Summary

WRF/DART is applicable to a range of scales and phenomena, with minimal tuning.

Goal for WRF/DART is DA for high-res., short-term prediction.

Key research issues (both ensemble and variational schemes):

- accounting within DA for uncertainty/error of forecast model
- Identifying and correcting bias in forecast model
- Role of land surface (or ocean) in mesoscale DA
- DA schemes capable of spanning multiple spatial and temporal scales

Collaboration on these issues is welcome.