The NCAR high resolution ensemble

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Support: NCAR's MMML and CISL;
Collaborators: Ryan Torn, Greg Thompson, Stan Trier, Morris Weisman, Dave Ahijevych, Davide Del Vento, NOAA's NSSL, SPC

NCAR's history in real-time convection-allowing forecasts

- NCAR MMM first demonstrated convection-allowing forecasts in real-time with WRF in support of 2003 BAMEX field campaign
  - Showed potential of improved depictions of convective systems for forecast guidance
  - The success of this system inspired other teams to join NCAR in high resolution prediction

- Forecast continued in following springs, and began for other seasons/phenomena, but a new revolution left NCAR's real-time efforts behind…

Convection-allowing ensembles

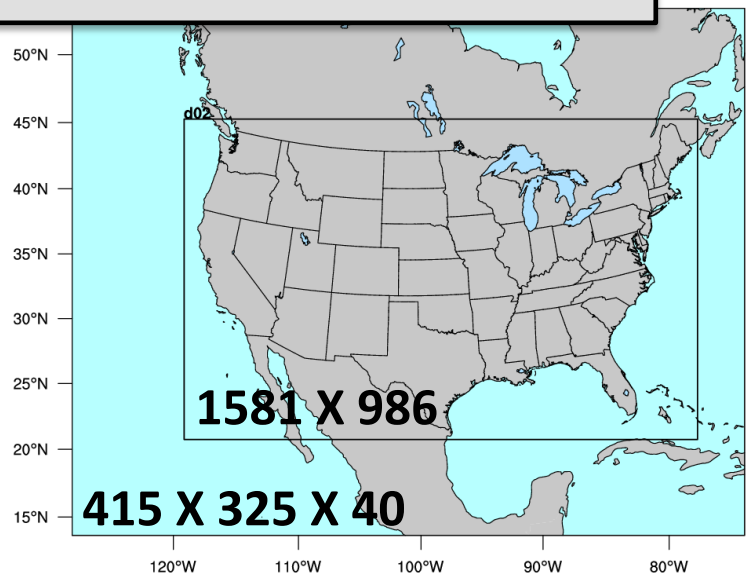
- CAPS began storm-scale ensembles in 2007, later joined by AFWA, UKMet, NSSL, plus informal conglomerates of deterministic forecasts (SSEO)
  - Initialization typically drawn from down-scaled operational models
  - Largely ad hoc methods for spread from + perturbations, multi-analysis, multi-physics, multi-model
- NCAR began development of EnKF initialized forecasts in 2011, first real-time ensemble in spring 2013
  - Demonstrations tied to field campaigns in spring season
  - Data Assimilation Research Testbed (DART)
  - Ensemble variance ≈ certainty in initial conditions

WRF model configuration options

- Tiedtke cumulus parameterization (15-km domain only)
- Thompson microphysics
- RRTMG Short and Longwave radiation
  - includes aerosol and ozone climatology

All members of the ensemble use the same physics, BY DESIGN!

- 75 s (18.75 s) time step
- Perturbed GFS forecasts for lateral boundary conditions

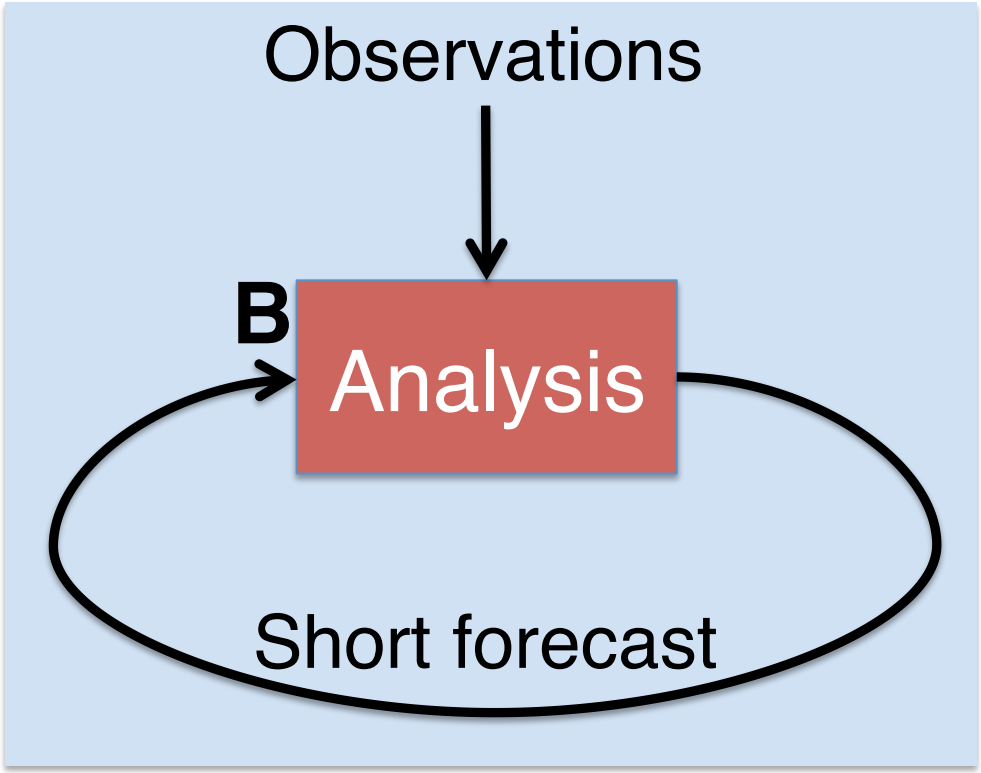


DA primer: continuously cycled analysis

Continuous cycling is 'best practice'

First guess (**B**) for analysis is short forecast from prior analysis

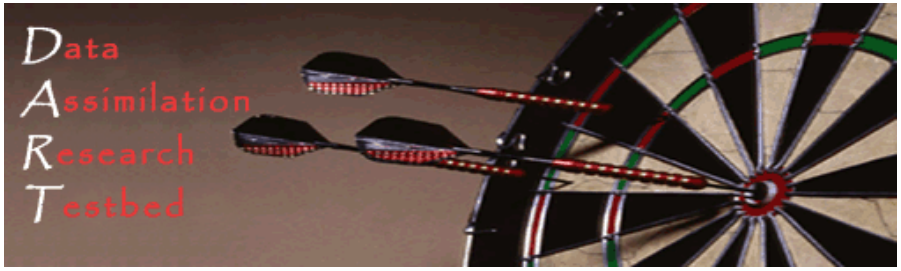
No 'spinup' needed, on the model attractor



For regional models – nearly all centers use 'partial' cycling – periodically replacing the background from another (often global) analysis

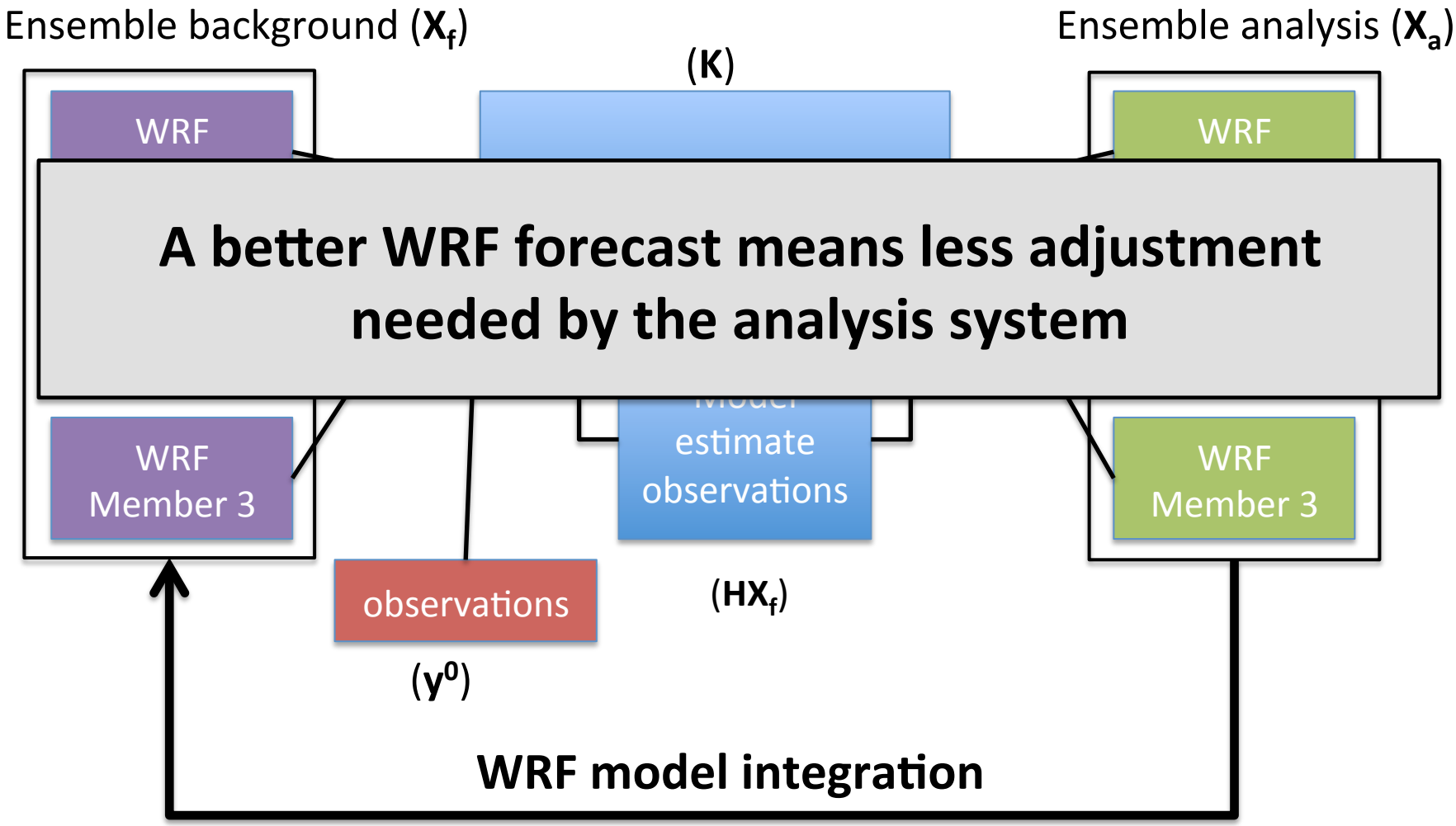
DART ensemble analysis configuration options

- Data Assimilation Research Testbed toolkit (Lanai)
- **Continuously cycled** (initialized mid-March 2015)
- Ensemble Adjustment Kalman Filter
- **50-member** analysis
- Updated every **6 hours**
- Localization: 1270 km horizontal
  1.5 scale height vertical
- Adaptive prior inflation, sampling error correction
- Assimilate **conventional observations**:
  Radiosonde, METAR, select Mesonet,
  cloud motion vectors, ACARS, Marine

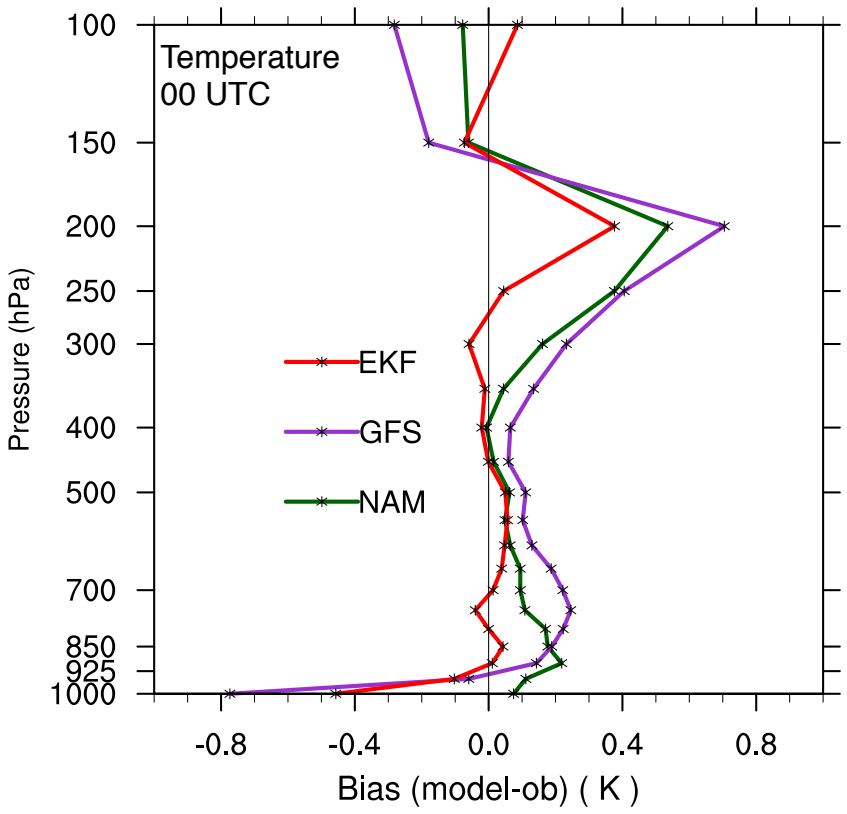


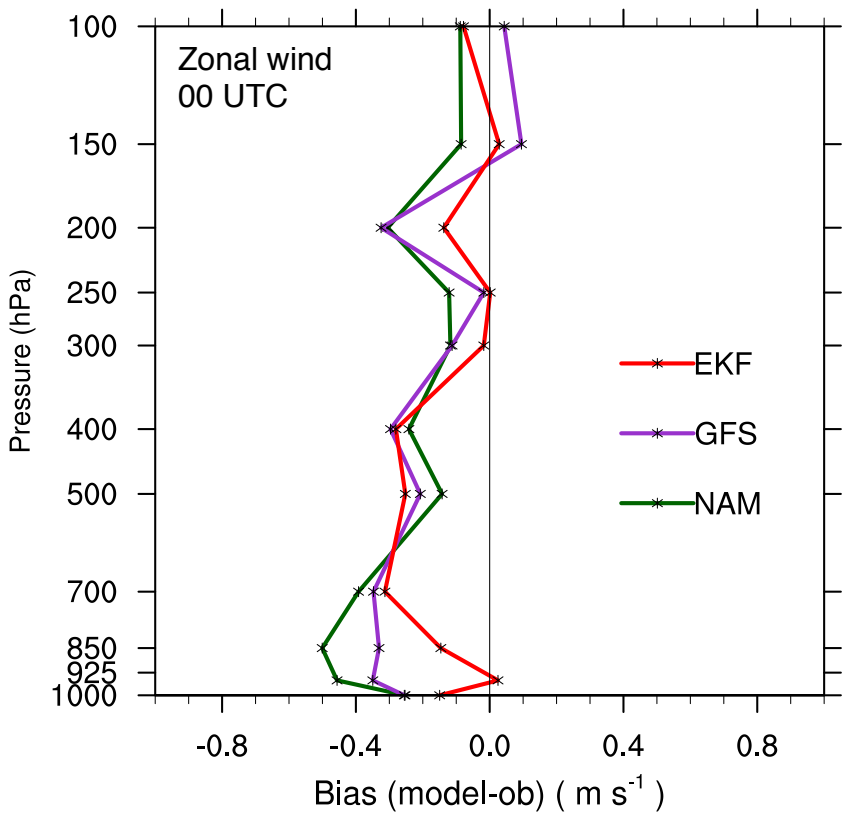
Block diagram of ensemble cycled analysis (DART)

$$\mathbf{X_a = X_f + K[y^0 - HX_f]}$$



Analysis bias comparison: DART, NAM, GFS





DART analysis fit is similar to (or better than) NCEP operational analyses against radiosonde observations on the NCAR grid

Real-time forecast system

NCAR ENSEMBLE – http://ensemble.ucar.edu

PRODUCT EXAMPLES

Ensemble mean: average forecast state from all ensemble members
- smooth, 'best forecast'

Probability matched mean: remapping of ensemble mean
- improved magnitudes over ensemble mean, may be unrepresentative

Ensemble spread: variability metric among the member forecasts
- representativeness of the ensemble mean

Ensemble max/min: shows the extreme values at a given location
- quick look for high impact events, little information on likelihood

Paintball (spaghetti) plot: Gives location and structure information
- overlap indicates qualitative agreement, single threshold shown

Postage stamp: small plots with full contour range for each forecast member
- insight on member scenarios

Probability threshold: raw likelihood from ensemble of event occurrence
- summary of ensemble information at a given point, limited skill on grid scale

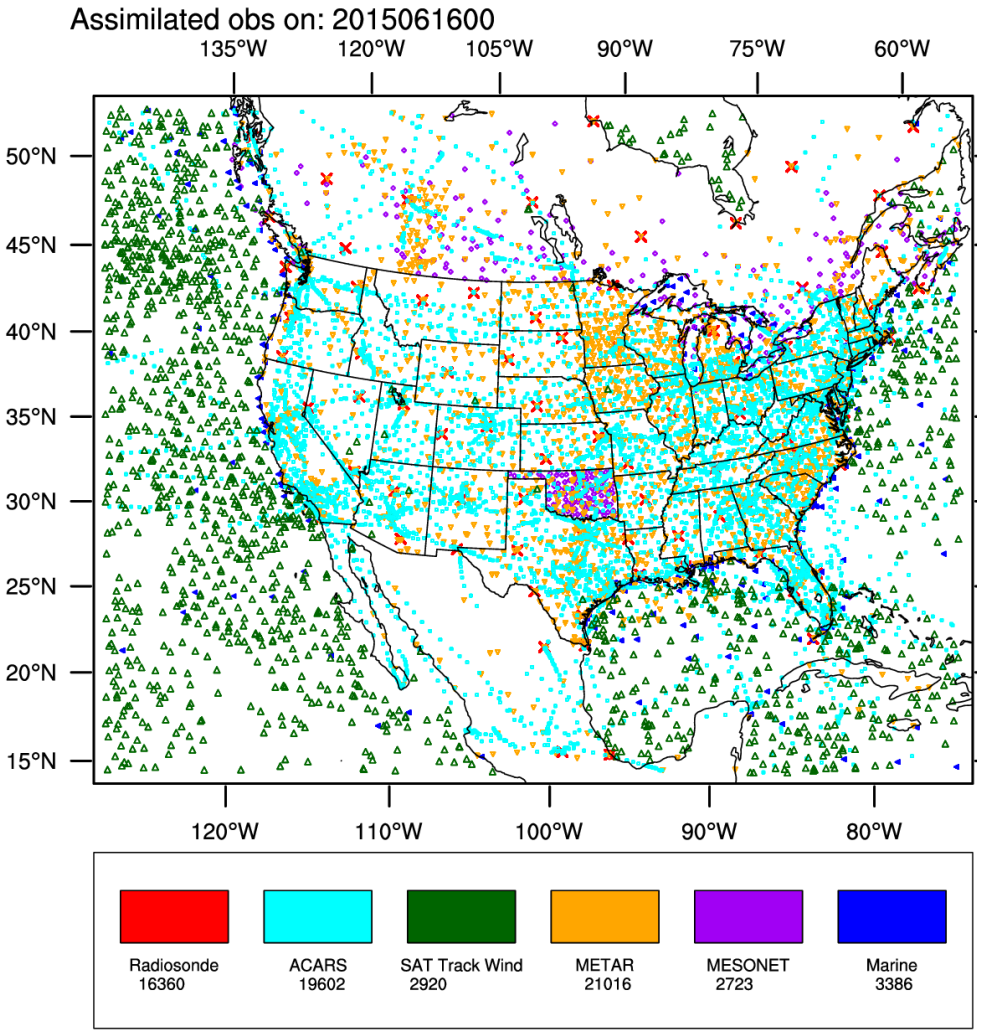
Neighborhood probability: relaxes event occurrence to local area
- better representation for extreme events

Real-time analysis statistics

Analysis page details:

- Observations assimilated
- Analysis state
- Analysis system performance
  - observation space
  - state space

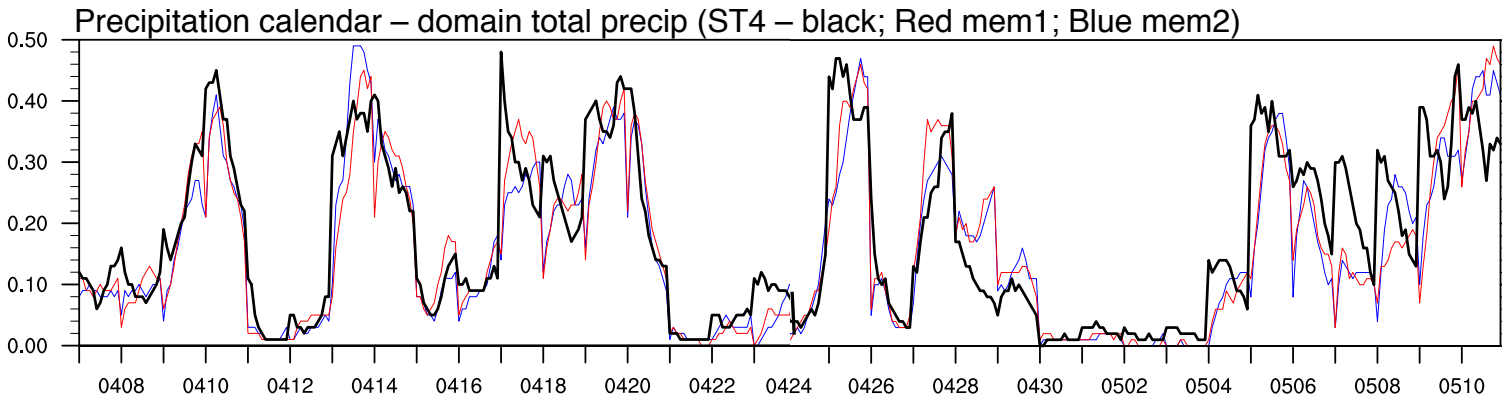
http://www.image.ucar.edu/wrfdart/rta/index.php



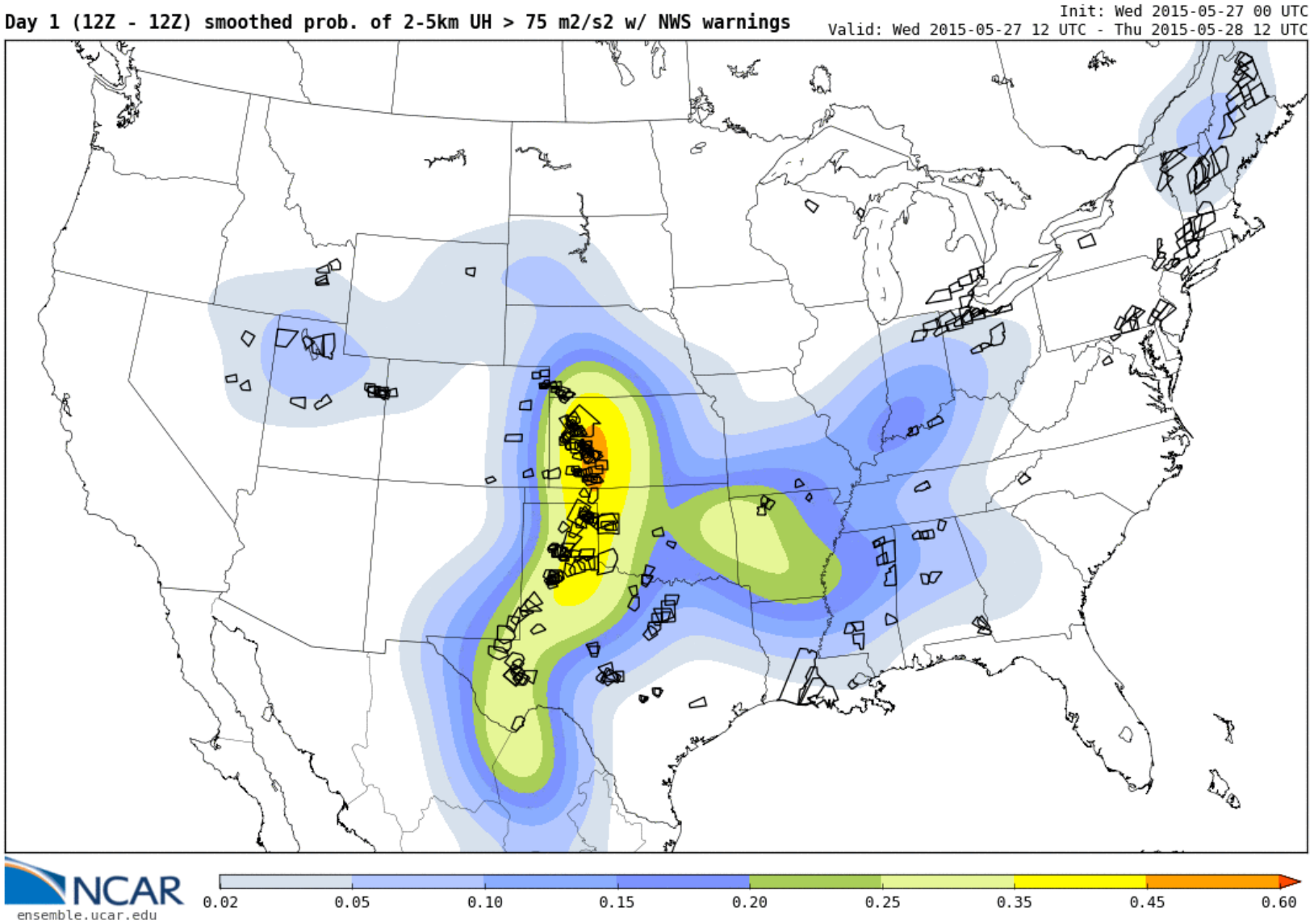
Real-time forecast system verification

Investigating forecast performance in several ways:

- Precipitation verification (intensity, location, timing)
- Observation space verification (use DA system to evaluate forecasts)
- Storm surrogate value for prediction of weather hazards (e.g. UH vs. storm reports)
- Analysis system performance (observation fit to priors, mean analysis increments, planning to look at physics tendencies)

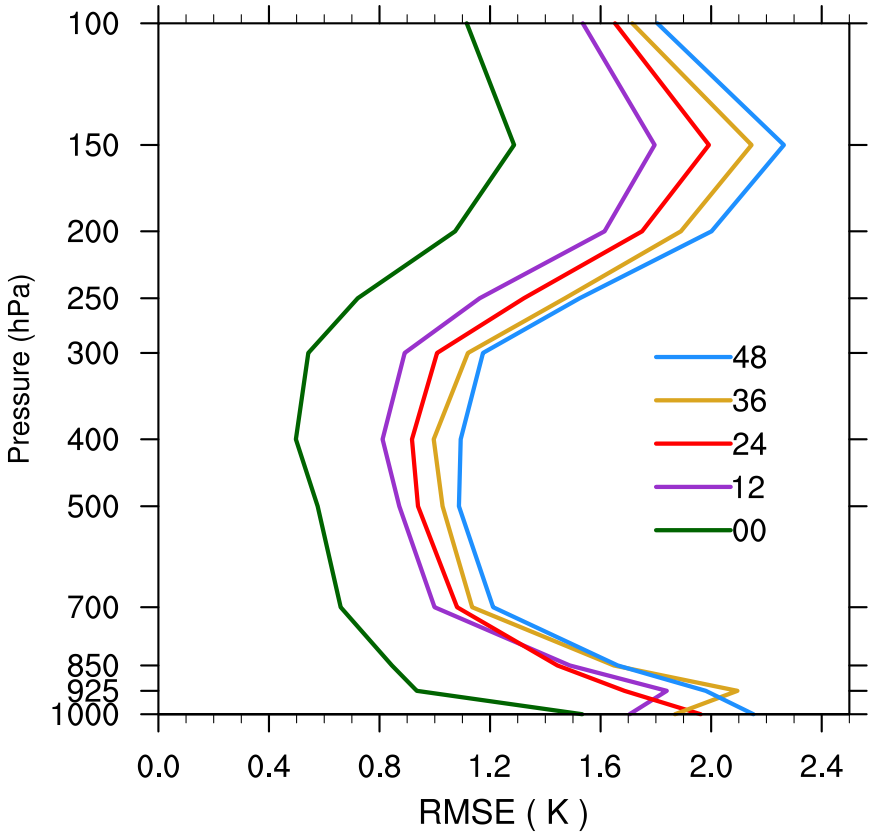


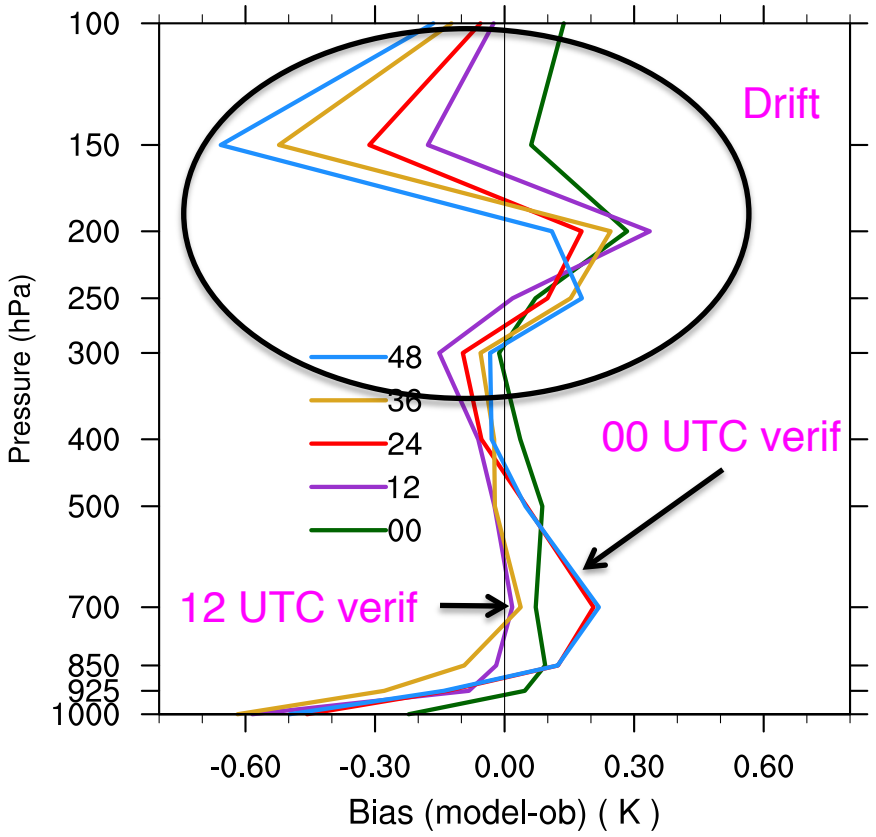
Real-time forecast system verification



NWS warning polygons overlain on daily supercell surrogate probabilities

Real-time forecast system verification



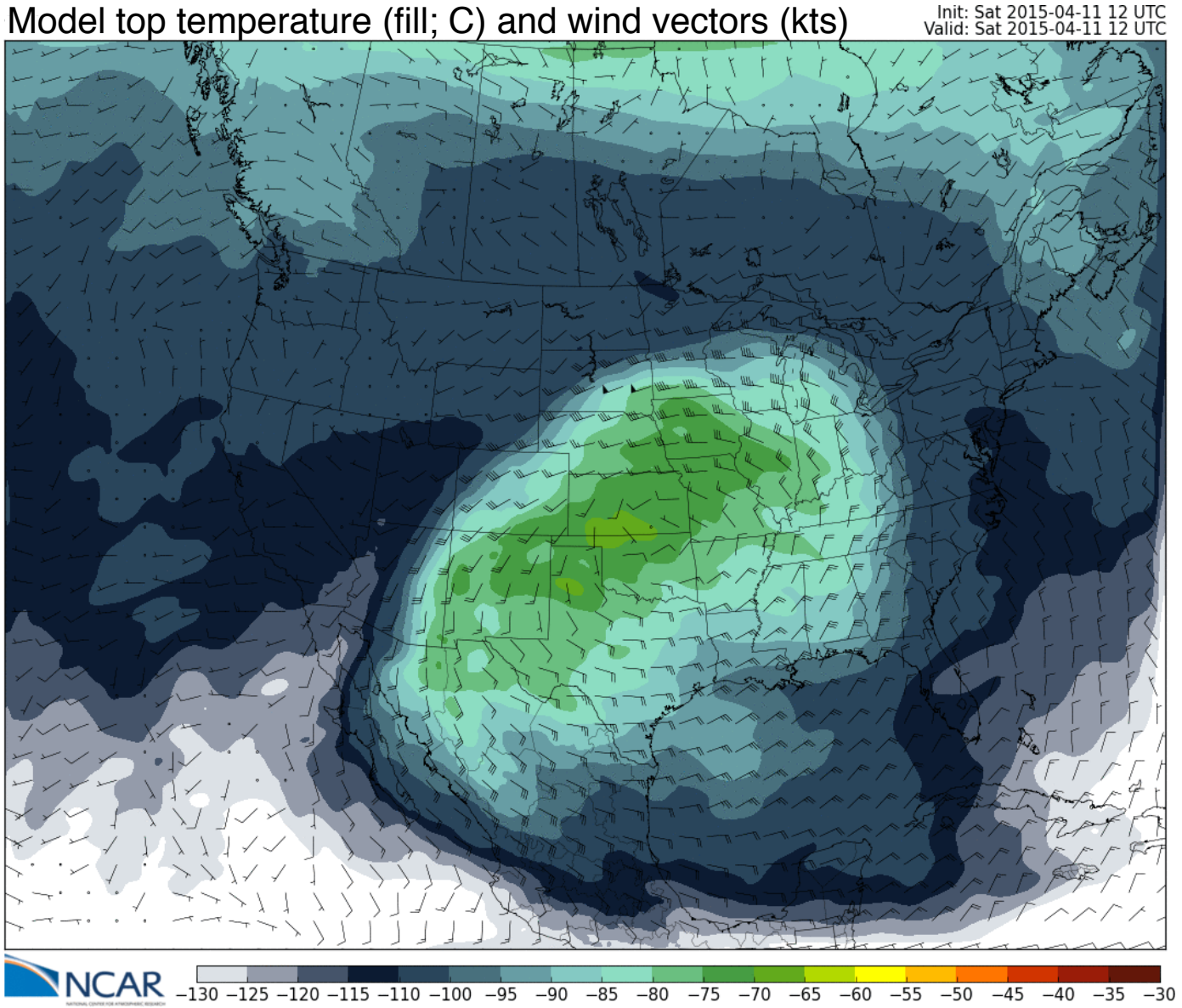


3-km ensemble forecast verification against radiosondes

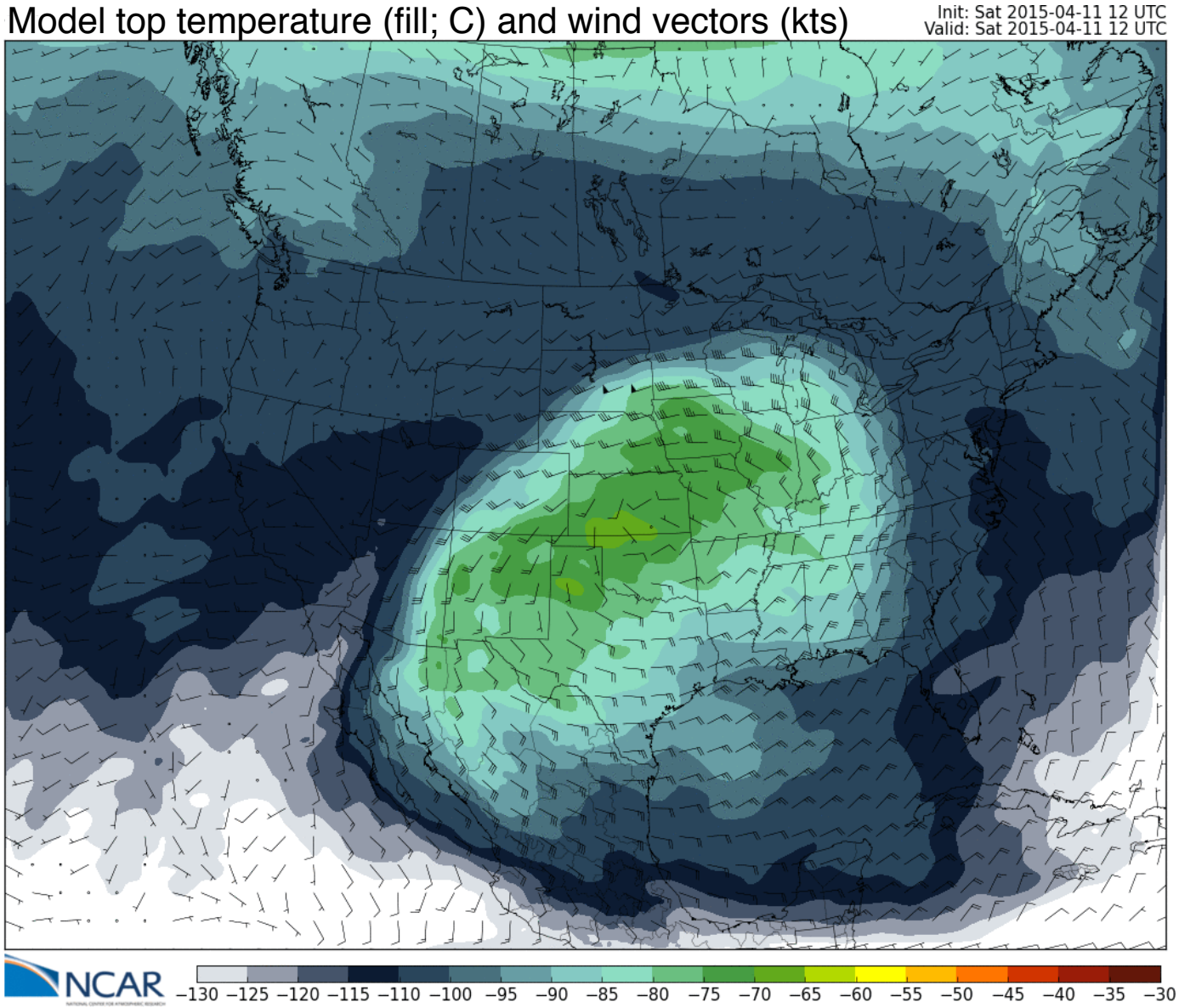
40 forecasts (late April to early June)

Initial down-scaling, diurnal bias in mid- and lower-troposphere, drift near tropopause

WRF model challenges – model top drift

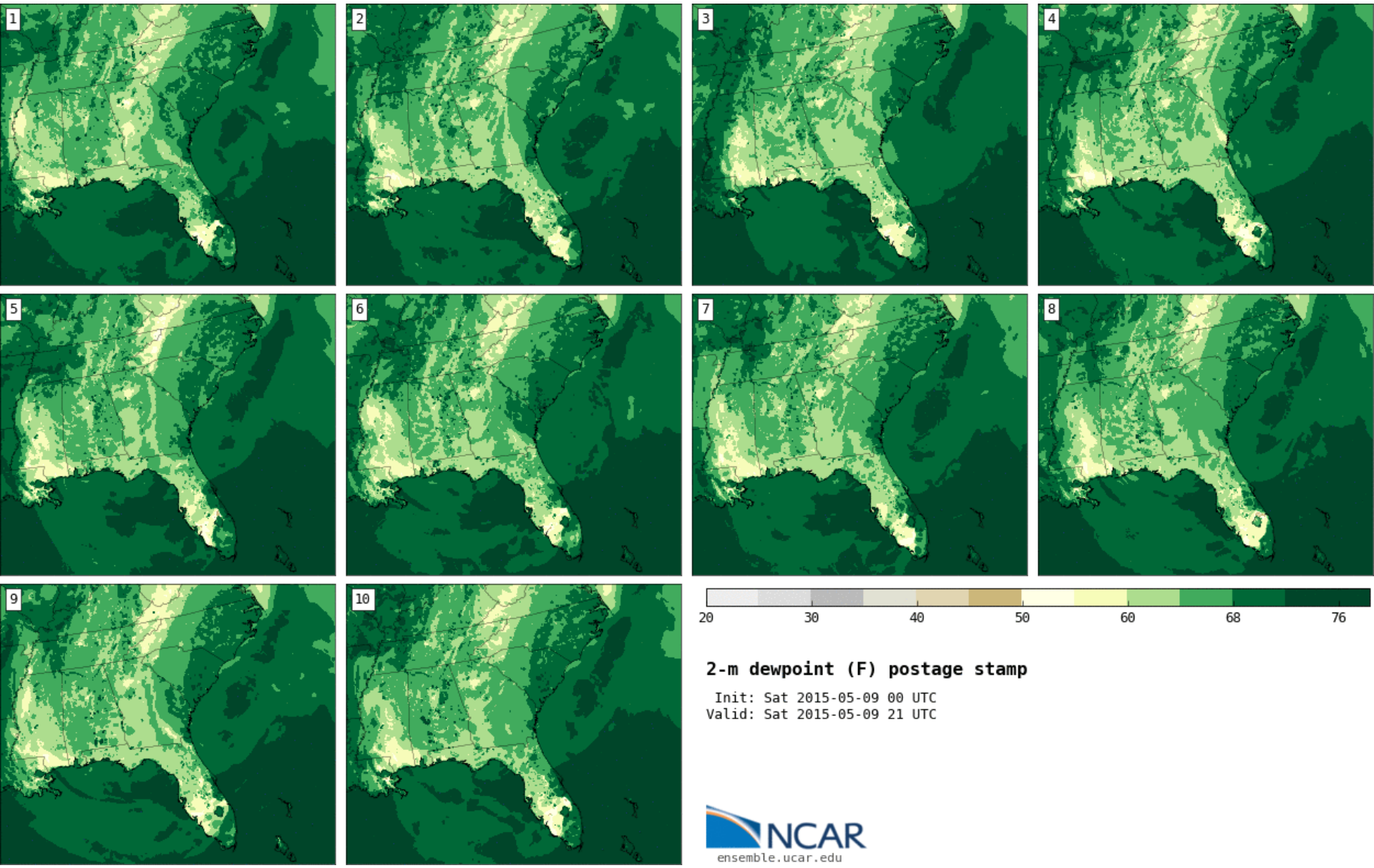


WRF model challenges – model top drift



Suggestion: Avoid a 50 mb top – try 20 mb instead?

WRF model challenges – surface moisture

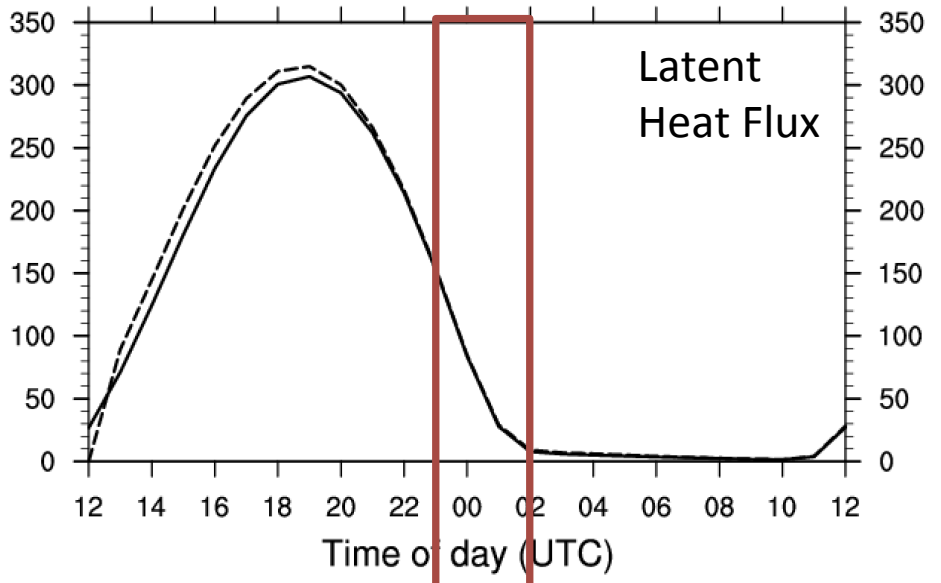


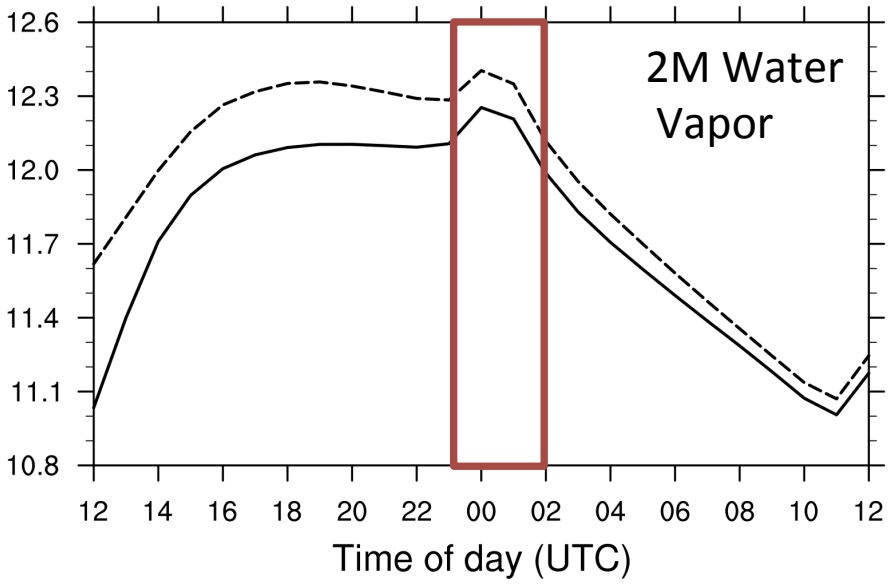
WRF model challenges – surface moisture

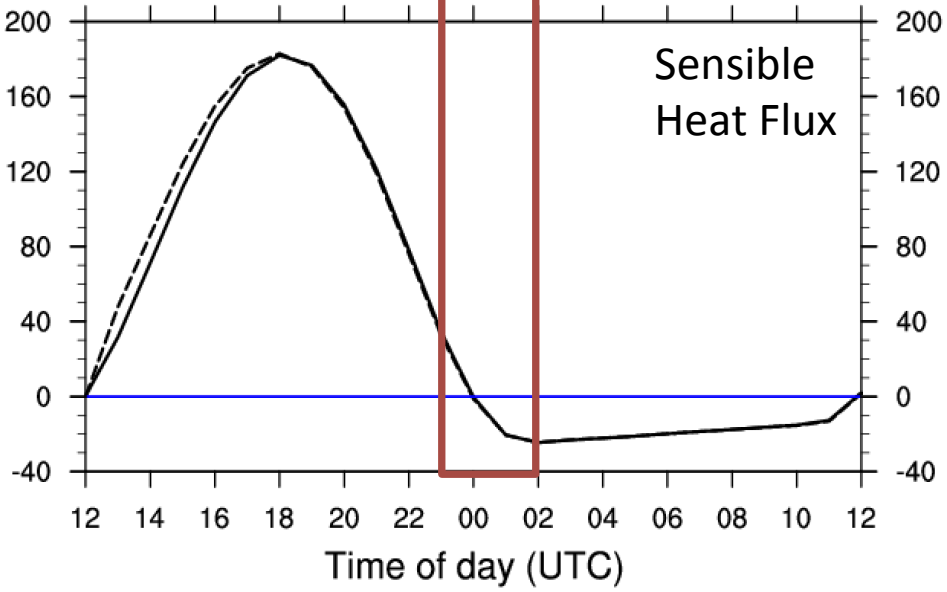
From 2013 real-time system investigation:

Spike in surface moisture owes to decoupling PBL while latent heat flux is still positive

Most prominent in vegetated areas with calm winds







NCAR Ensemble - Expected Outcomes

- Demonstration of the operational suitability of a WRF/DART based analysis and forecast system

- Larger data set of convection-allowing ensemble forecasts to understand strengths/weaknesses in system configuration – focus on hazard prediction

- Analysis increments, climatology, physics tendencies
  - **Improving WRF = better analyses and forecasts**!

- In the future – develop capability for analysis on the **3-km grid**

- We welcome collaborators!
  - Contact us at ensemble@ucar.edu

Thompson microphysics – effective particle sizes to RRTMG