Mesoscale WRF Surface-Data Assimilation: Spring 2007 Experiments at the National Severe Storms Laboratory

David Dowell
NCAR, Boulder, CO

David Stensrud
NSSL, Norman, OK

Nusrat Yussouf
CIMMS, Norman, OK

Mike Coniglio
NSSL, Norman, OK

Jeff Anderson
NCAR, Boulder, CO

Chris Snyder
NCAR, Boulder, CO

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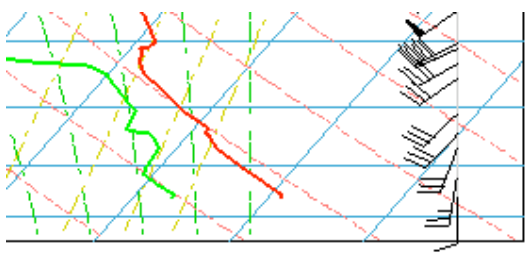
Motivation

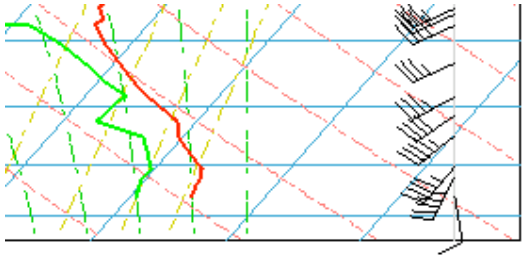
Investigate the value of assimilating surface observations for mesoscale NWP

- predictions of surface boundaries, convective storm environments
- probabilistic precipitation forecasts

Using surface obs to update the model state can be difficult

- strong gradients near the surface
- situation-dependent background-error covariances needed



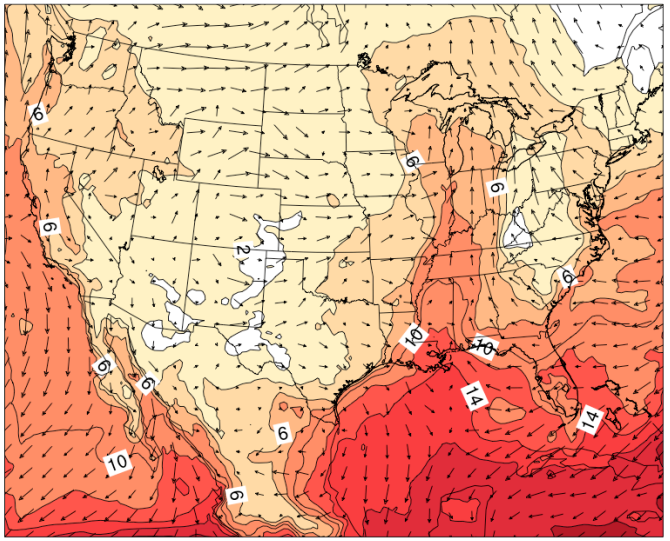


Recent work provides encouragement

- Hacker and Snyder 2005 -- significant correlations between state variables at sfc and those at heights up to several km AGL, even at night
- Fujita et al. 2007 -- improvement in 6-12 hour MM5 ensemble forecasts through assimilating surface obs for only 6 hours

Mesoscale Ensemble Forecasting (WRF-ARW 2.1)

- CONUS grid
  - 30-km horizontal grid spacing, 31 vertical levels
  - Mean initial and boundary conditions from NAM



- 30-member ensemble
  - Initial and boundary condition perturbations (from WRF-Var)
  - Parameterization diversity
    - Microphysics: Lin et al. (6 class), WSM (3 class)
    - Shortwave radiation: Dudhia, Goddard
    - PBL: YSU, Mellor-Yamada-Janjic, NCEP GFS
    - Surface layer: MM5 similarity, Eta similarity (Janjic)
    - Cumulus: Kain-Fritsch, Betts-Miller-Janjic, Grell-Devenyi

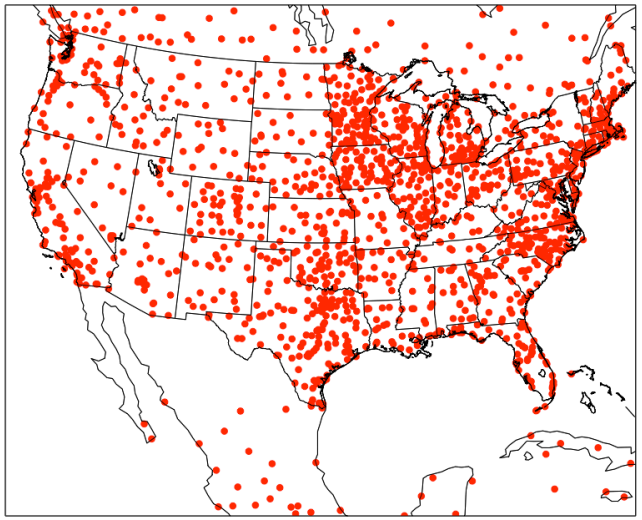
Data Assimilation Research Testbed (DART)

http://www.image.ucar.edu/DAReS/DART/

- Ensemble-based data-assimilation software developed at NCAR, available to the community
- Interfaces available for various models, big (e.g., WRF and CAM) and small (e.g., Lorenz)
- Parallel (MPI) implementation of ensemble Kalman filter

Observations

- Hourly observations from approximately 1500 sites over USA, Mexico, and Canada



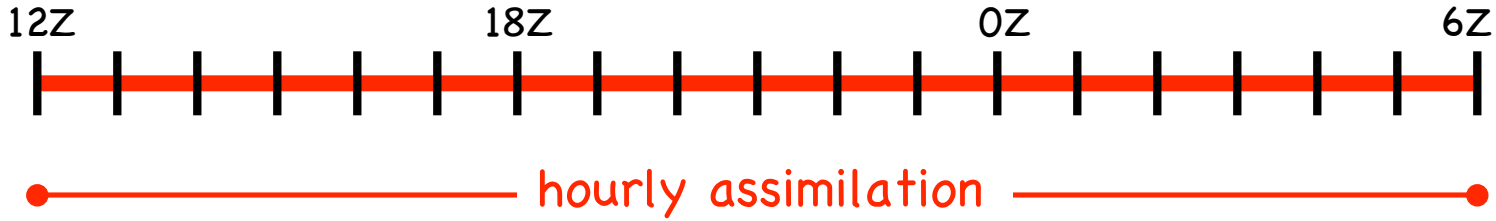
- Horizontal wind components (u and v) at 10 m AGL (2.0 m s^{-1} error)
- Potential temp. (θ) and dewpoint (T_d) at 2 m AGL (2.0 K error)

- All model state variables updated
  - 300-km (20-level) localization radius around each observation

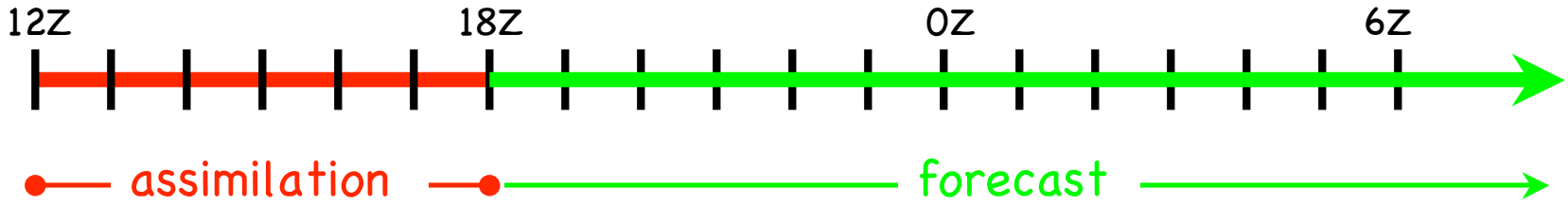
- Observations in model diagnosed through PBL and surface-layer schemes ("U10", "V10", "T2", "Q2")

Daily Experiments (March-June 2007)

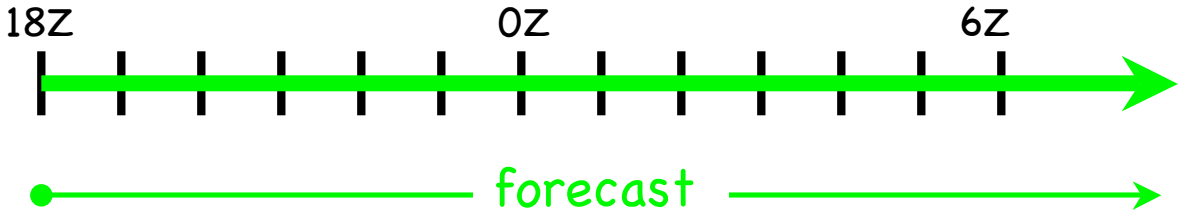
- Hourly mesoanalyses



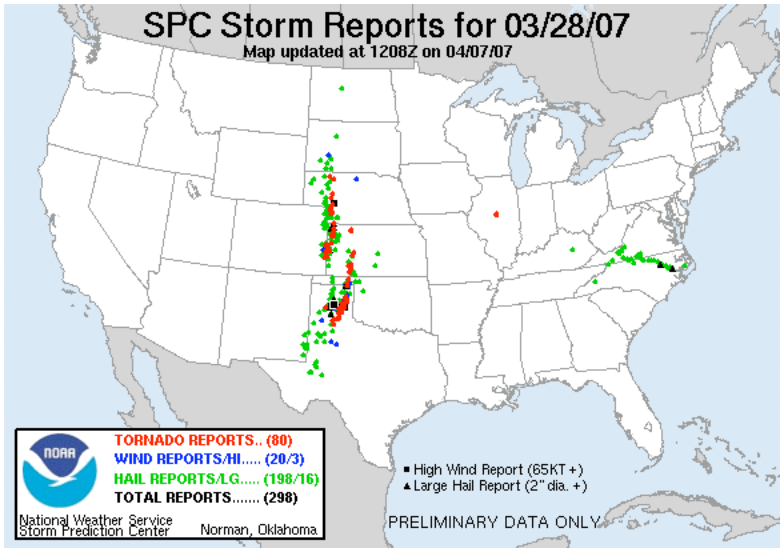
- Ensemble forecasts with surface-data assimilation

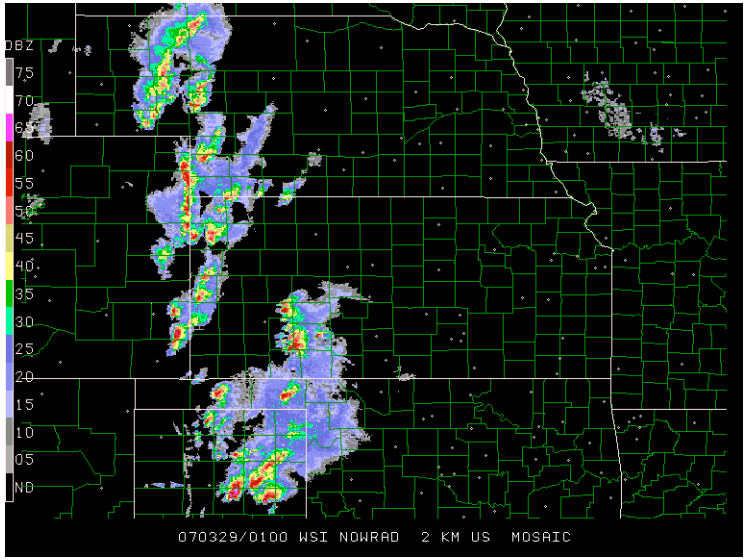


- Ensemble forecasts without surface-data-assimilation
  - NAM 18Z analysis + i.c. and b.c. perturbations + parameterization diversity

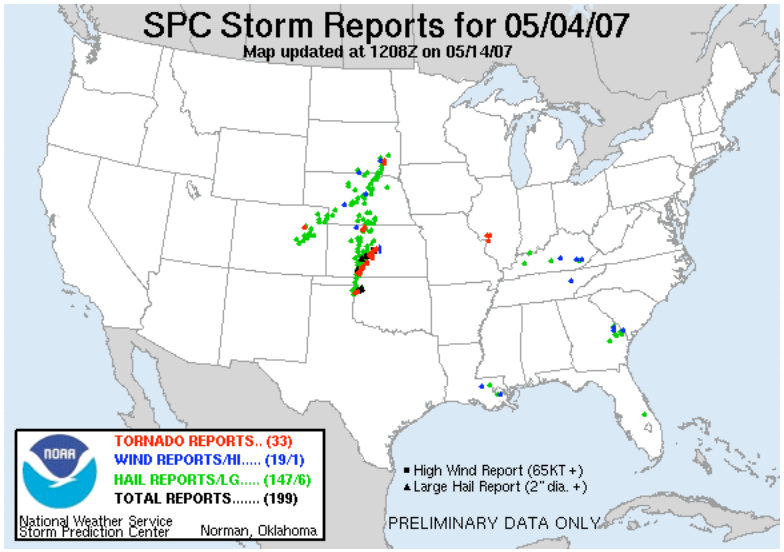


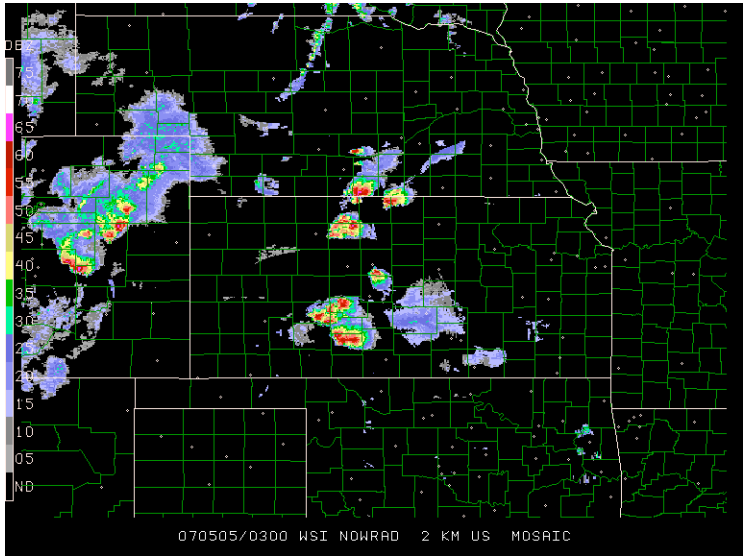
March 28 Tornado Outbreak





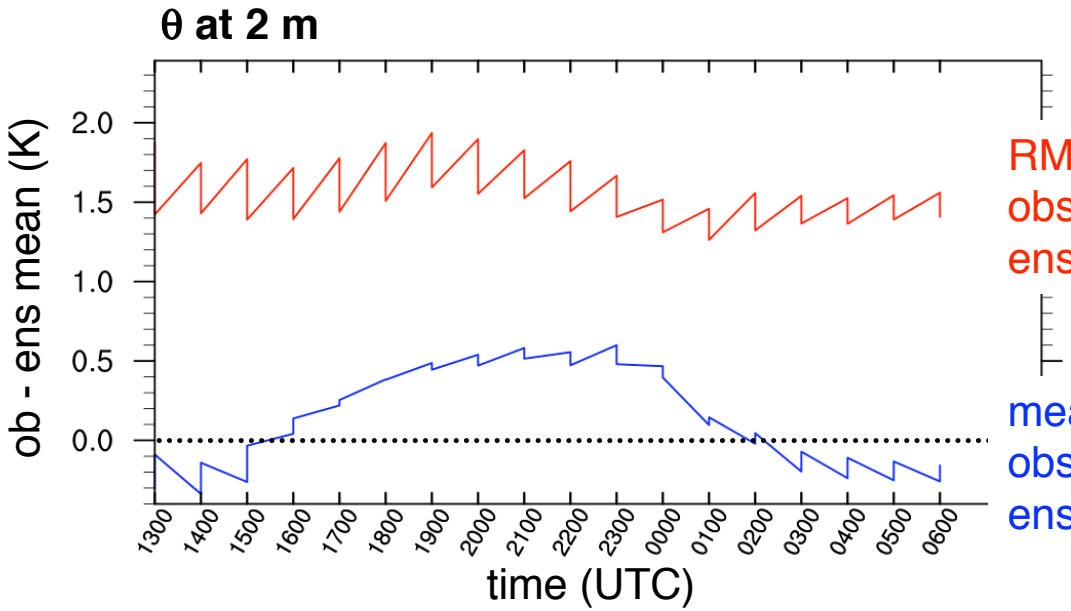
May 4 (Greensburg, KS) Tornado Case





Innovation Analysis: Potential Temperature at 2 m AGL

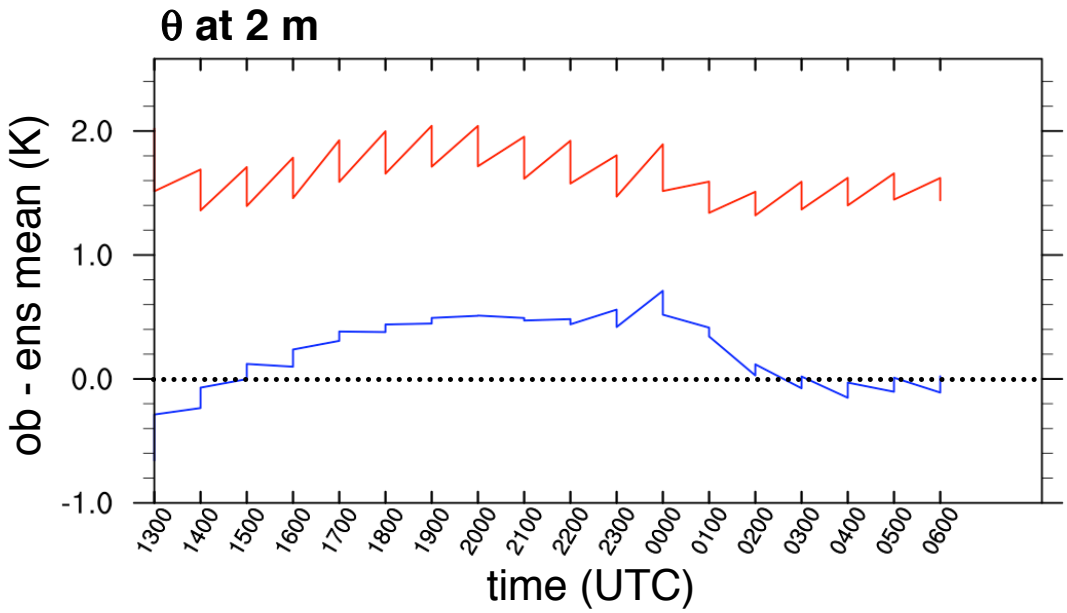
March 28



RMS diff. between observation and ensemble mean

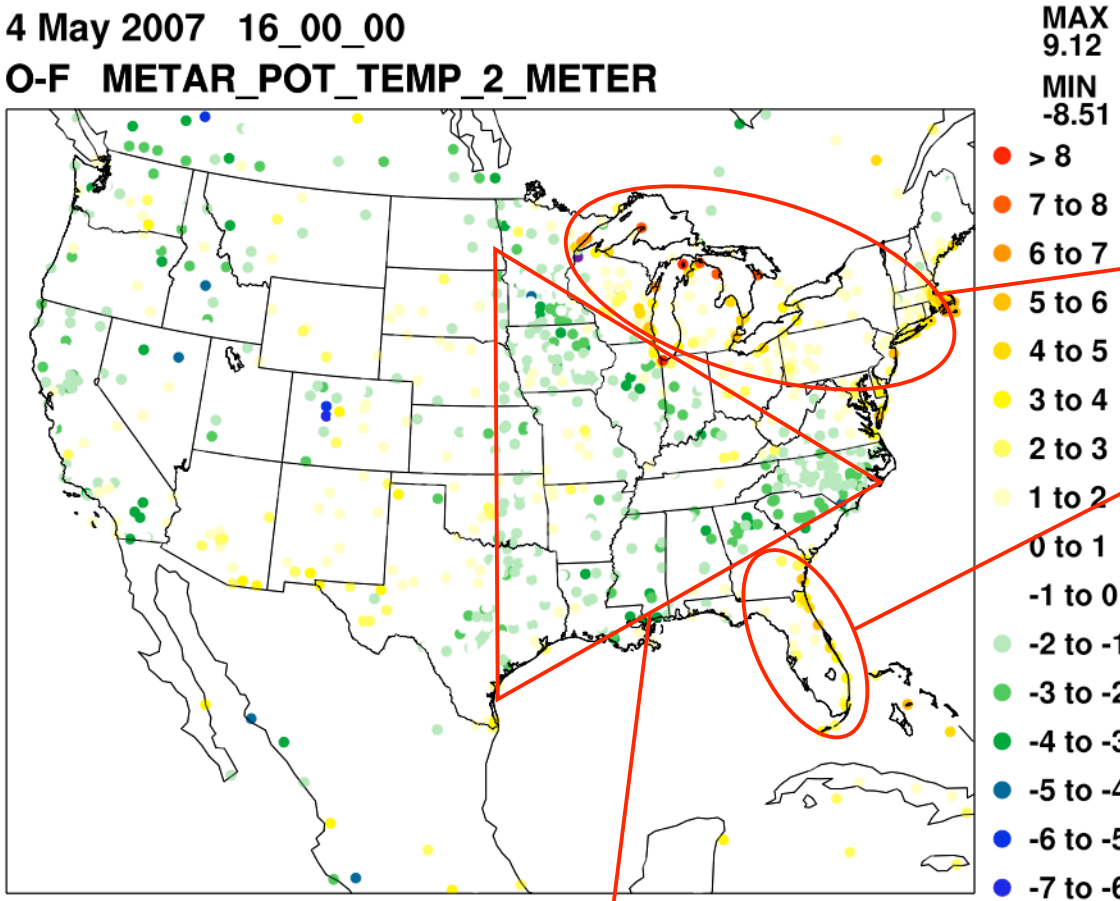
mean diff. between observation and ensemble mean

May 4



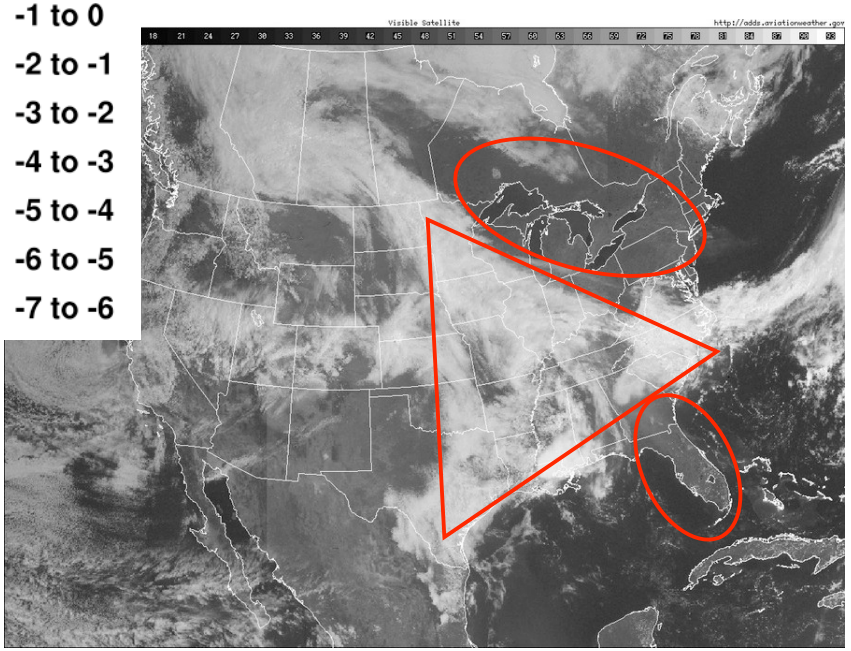
model too cool daytime, too warm nighttime

Ob. - Forecast Temperature at 2 m AGL: May 4



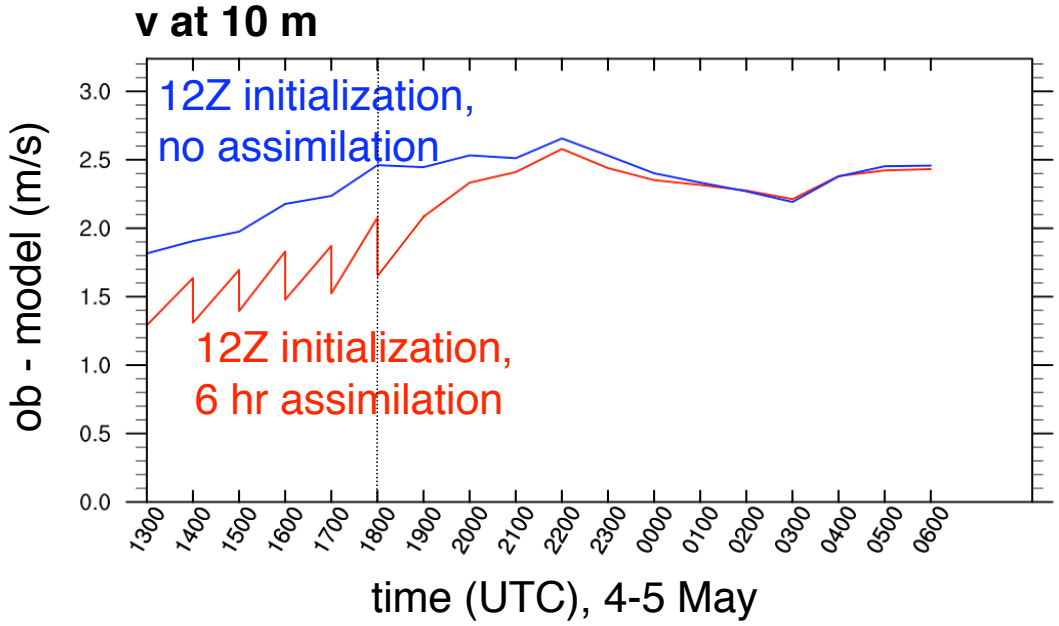
model-diagnosed
sfc. temp. too low
in sunny areas

model-diagnosed
sfc. temp. too high
in cloudy areas

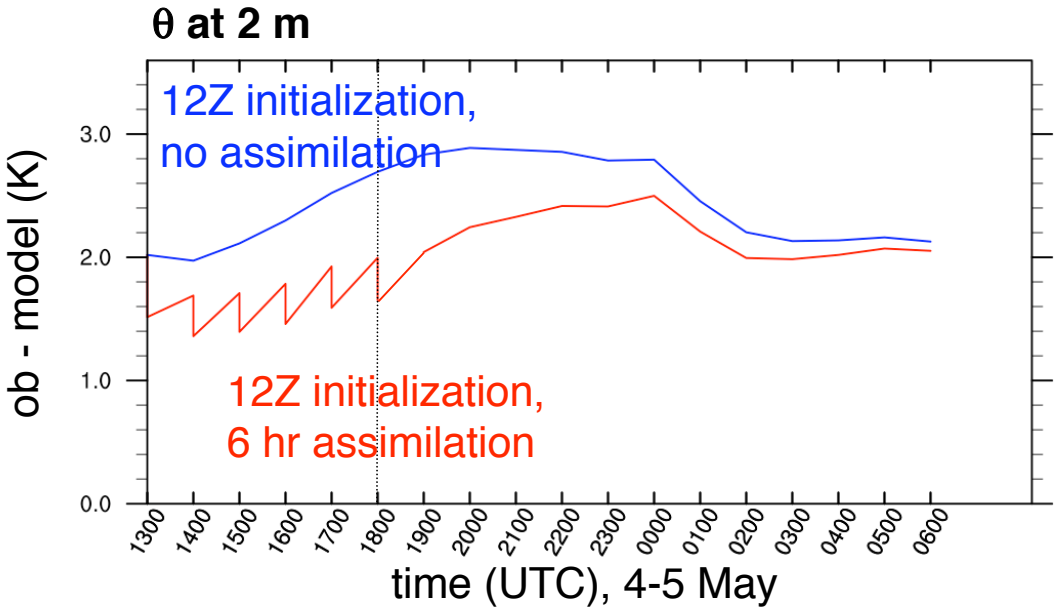


Impact of Surface-Data Assimilation on Forecasts: RMS Difference between Obs and Ensemble Mean

v wind component

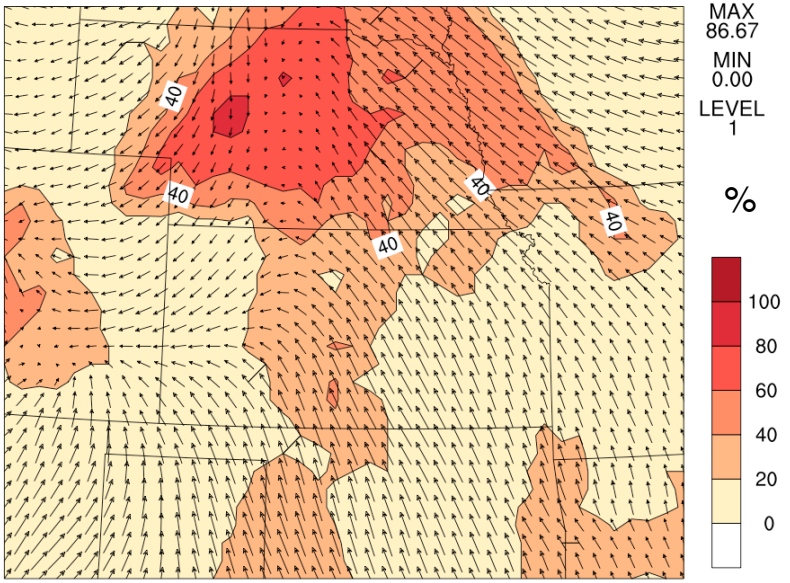


temperature

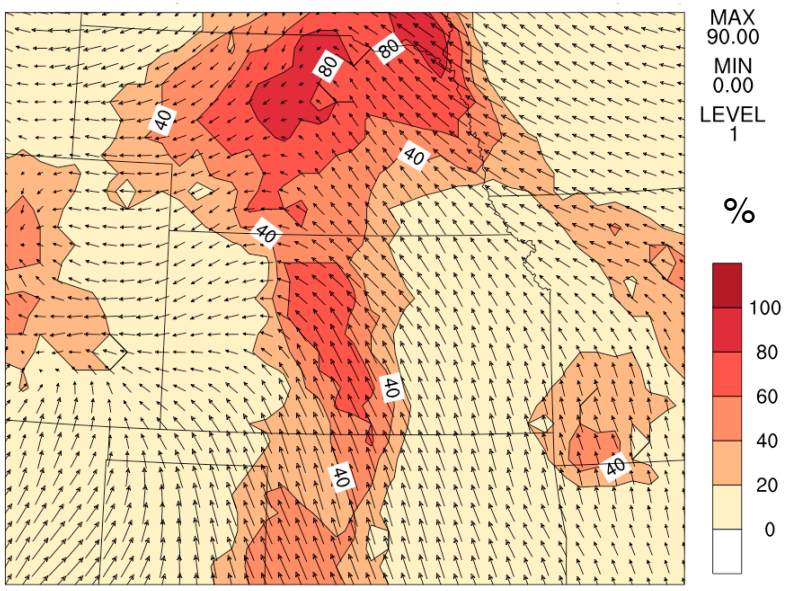


Probability (1-hr convective precip. > 1 mm)

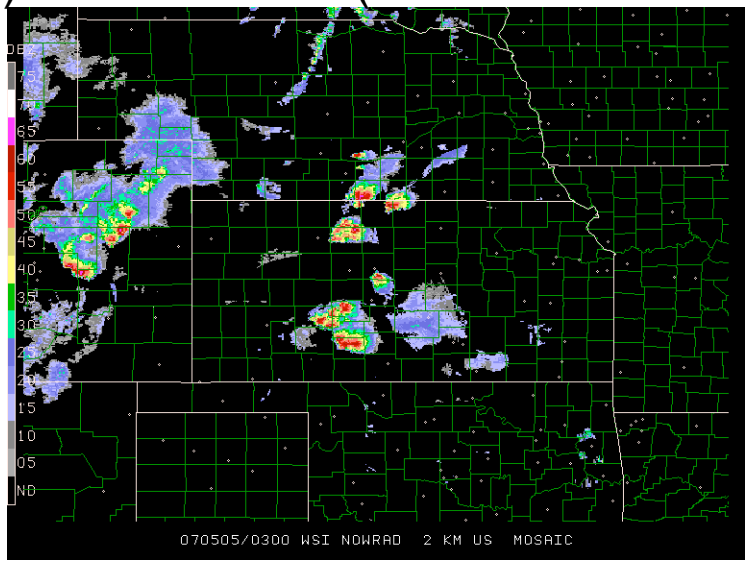
0300 UTC 5 May 2007



9-hr forecast without assimilation
(18Z initialization)



9-hr forecast with assimilation
(12Z initialization + 6 hr assimilation)



Future Work

- More analysis of spring 2007 cases
  - Verification at Oklahoma Mesonet sites
  - Sounding verification
  - Statistics stratified by ensemble-member characteristics (e.g., PBL scheme)
- Higher-resolution ensemble forecasting
- Longer assimilation windows