

Real-time Multi-scale EnKF analyses for Forecasts at Convection- Permitting Resolution

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Background

- CAPS/OU has been producing 4-km CONUS-domain ensemble forecasts for evaluation at NOAA HWT (Hazardous Weather Testbed) since spring 2007
- Goals: To determine the **optimal design, configurations, and post-processing** of storm-scale ensemble prediction, and to provide the products for **evaluation** by forecasters and researchers, and test storm-scale **data assimilation** methods.
- Develop a hybrid MPI-OpenMP parallel algorithm for EnSRF (Wang et al. 2013)
- Case studies: 10 May 2010 tornado outbreak
- Spring 2013: Experimental single EnKF DA in the central US domain. 24-hour daily forecast.

2013 Experimental single 4-km EnKF SSEF initialized at 00 UTC

- Forecast model: WRF-ARW
- Microphysics scheme: WSM6 with perturbed Nor, Nog, ρ_g
- Multi-PBL schemes: MYJ, YSU, ACM2, MYNN, QNSE
- 40 member ensemble
- DA scheme: ARPS parallel EnSRF
- DA: single data assimilation at 0000 UTC
- 24-hour deterministic forecast from an ensemble mean analysis

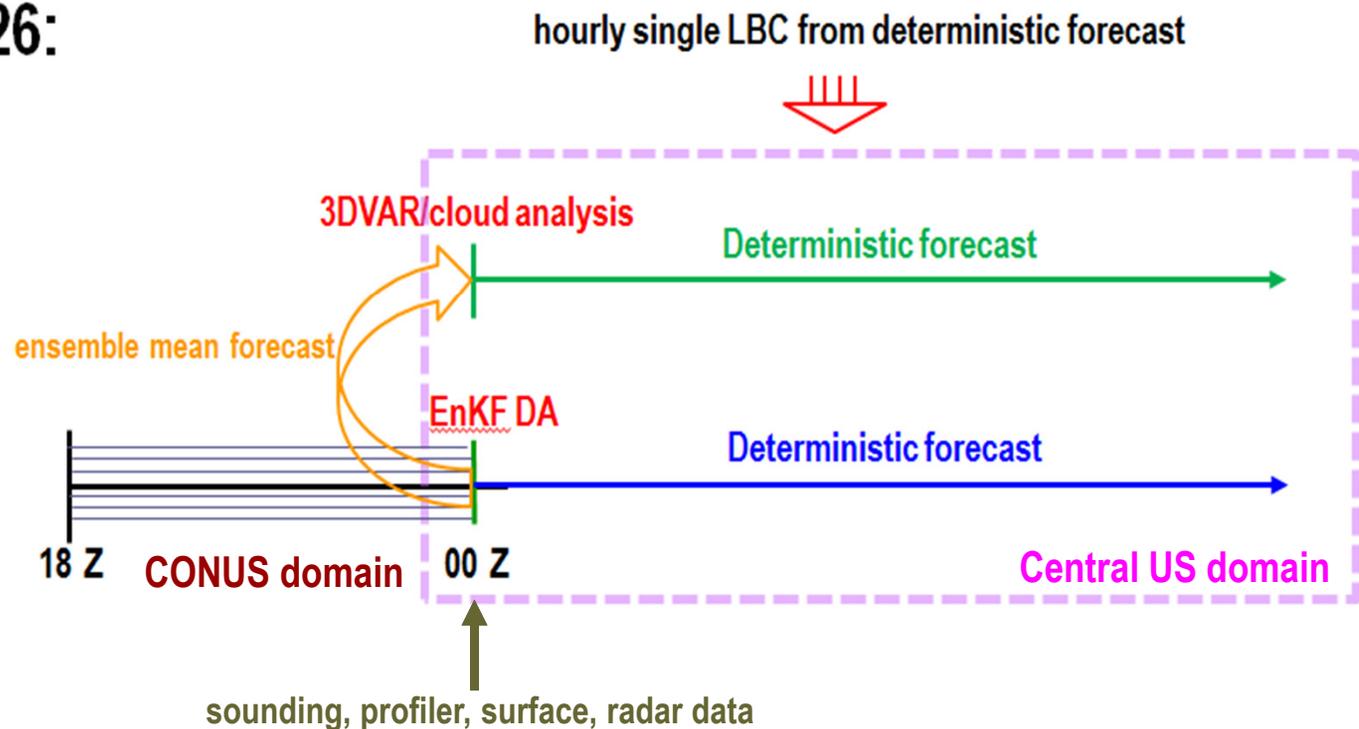
2013 Experimental single 4-km EnKF SSEF initialized at 00 UTC

- Initial conditions and lateral boundary conditions: NAM analysis + SREF perturbations
- Observations: sounding, profiler, surface, radar (Z , V_r)
- Influence radii: sounding (800 km), profiler (800 km), surface (300 km), radar (16 km)
- Covariance inflation: Relaxation-to-prior-spread (RTPS) following Whitaker and Hamill (2012) + multiplicative (Anderson 2001; Xue et al. 2005)

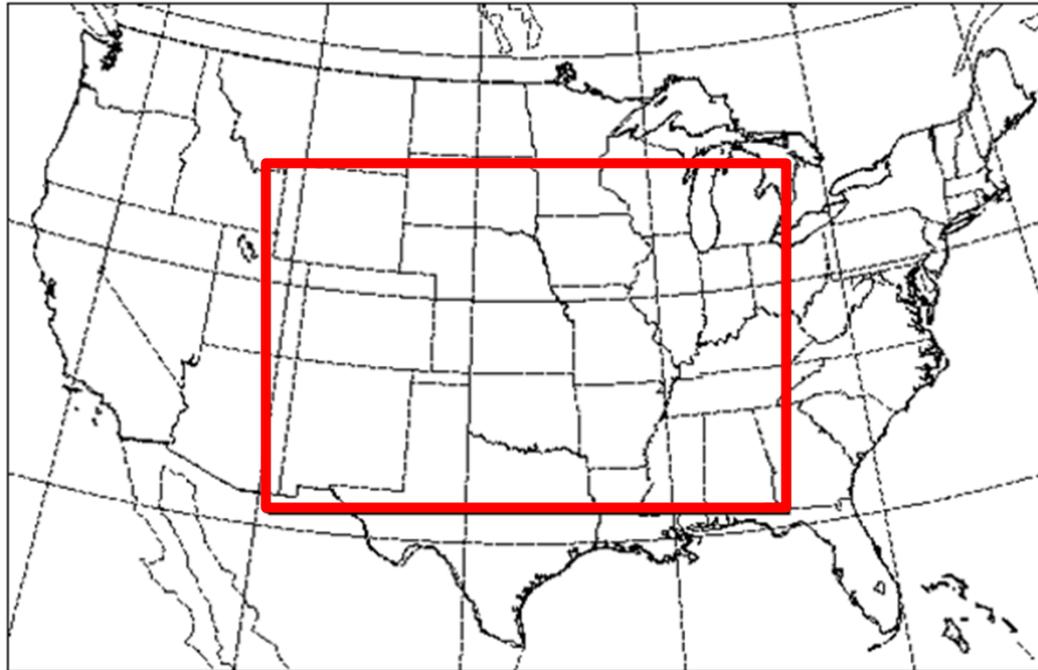
2013 Experimental 4km EnKF SSEF initialized at 00 UTC

HWT member 26:

4 km ensemble:



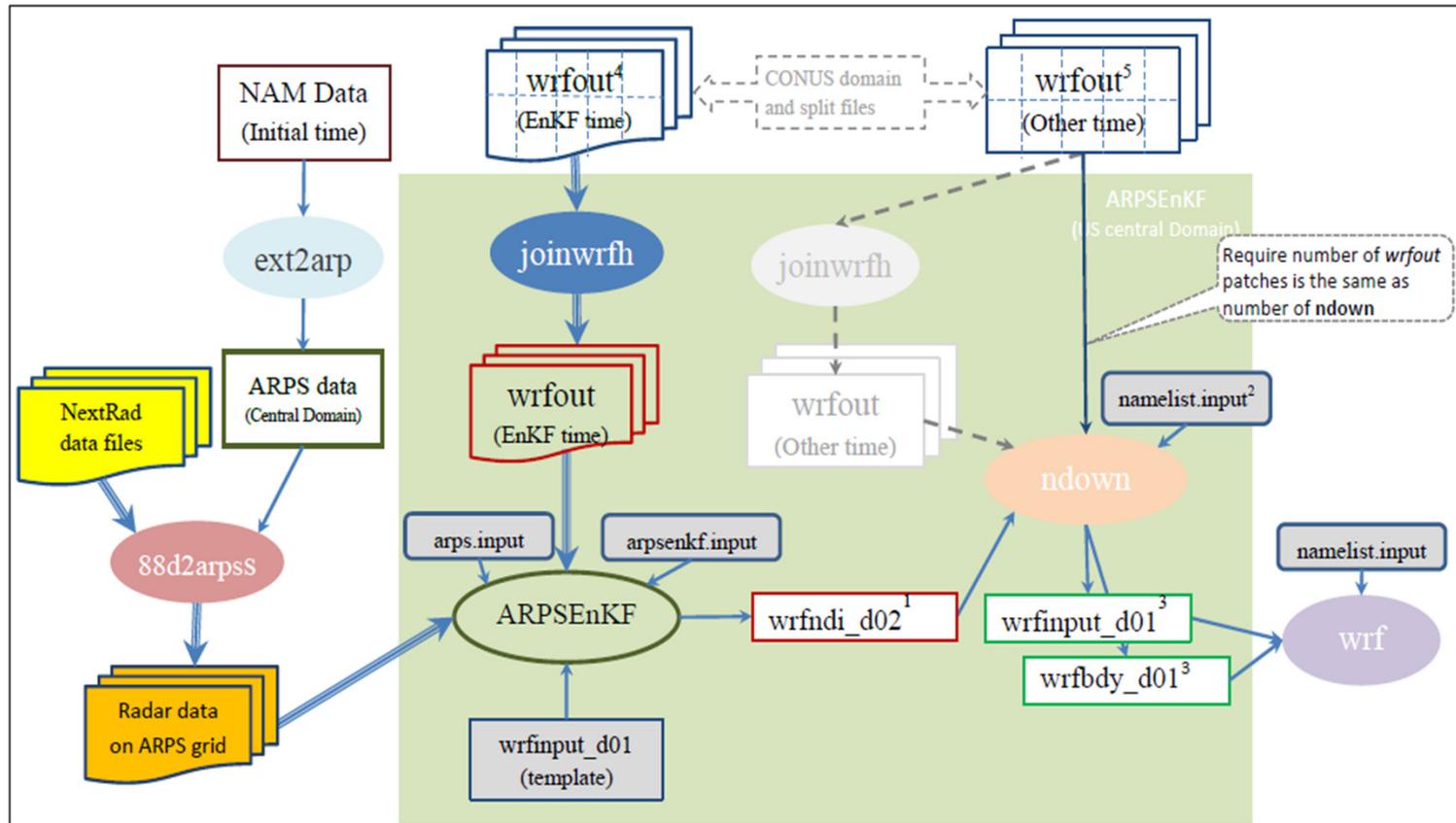
2013 Domain



CONUS domain: 1200x768

Central US domain: 600x400

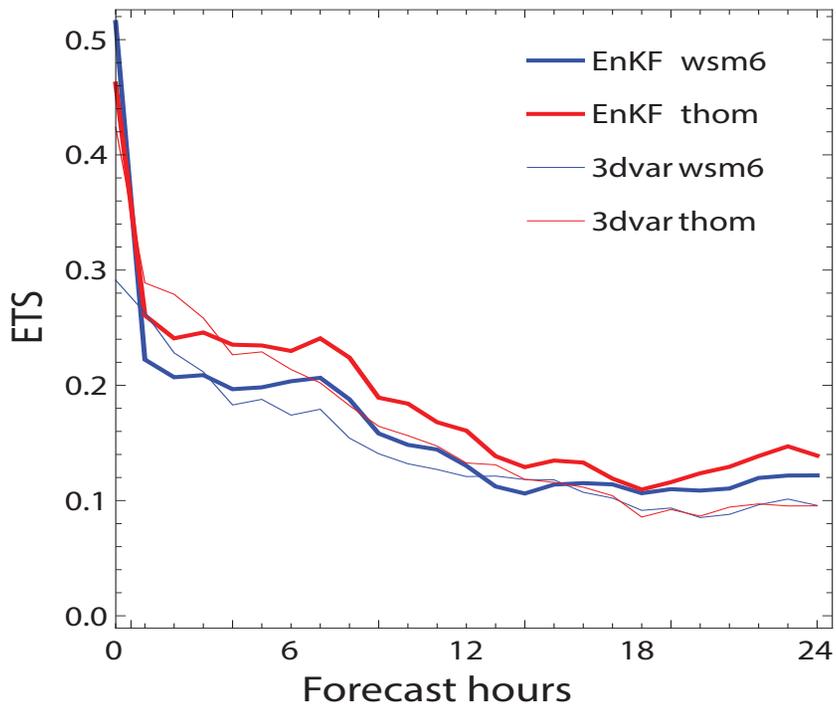
EnKF flow chart from CONUS domain to US central domain



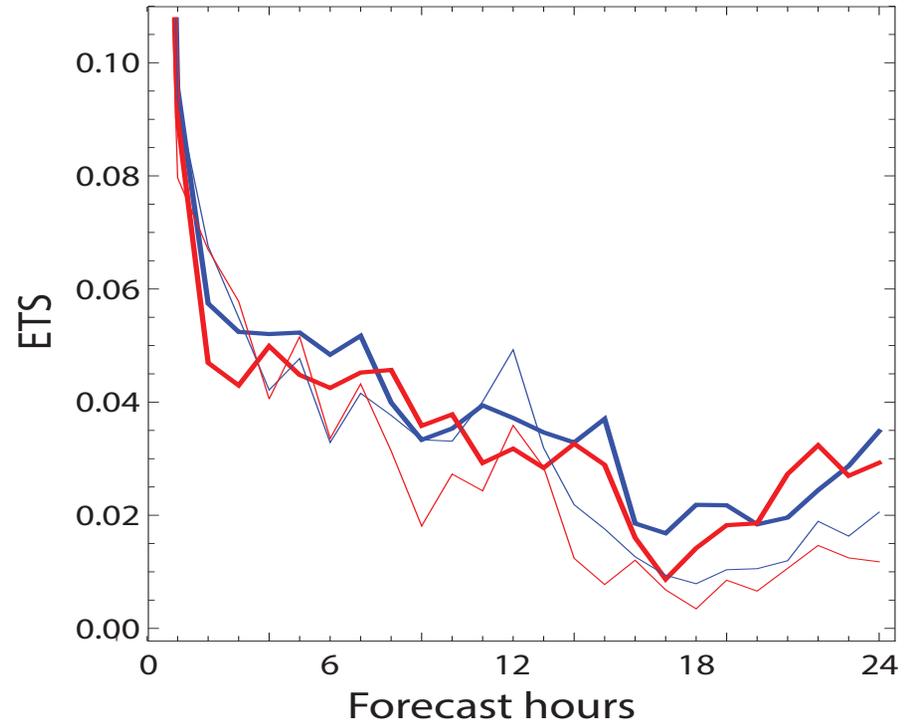
1. Output is ensemble mean and should be renamed from "wrfinput_d01" to "wrfndi_d02";
2. Set same values for two domains, *start_[year, month, day, hour, minute, second]*, *end_[year, month, day, hour, minute, second]*, *history_interval*, *e_we*, *e_sn*, *e_vert*, *dx*, *dy*, *num_metgrid_soil_levels*, *i_parent_start=1*, *j_parent_start=1*, *parent_grid_ratio=1* and *interval_seconds = 3600*, *io_form_auxinput2 = 2*, as well *grid_id = 1, 2*, *parent_id = 0, 1*;
3. Rename "wrfinput_d02" to "wrfinput_d01" and rename "wrfbdy_d02" to "wrfbdy_d01";
4. 40 Ensemble member forecast valid at 00Z;
5. HWT member 26 forecast from 00Z to 09Z.

ETS for composite

Z ≥ 20 dBZ

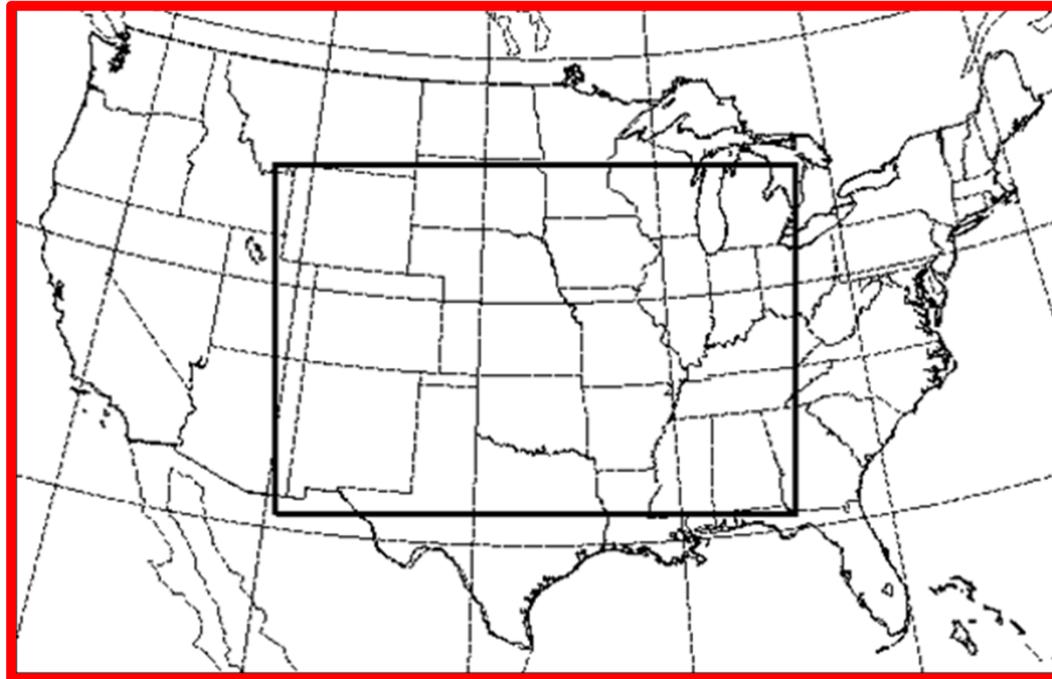


Z ≥ 40 dBZ



ETSs averaged over 14 forecast days for deterministic forecasts starting from the EnKF mean analysis

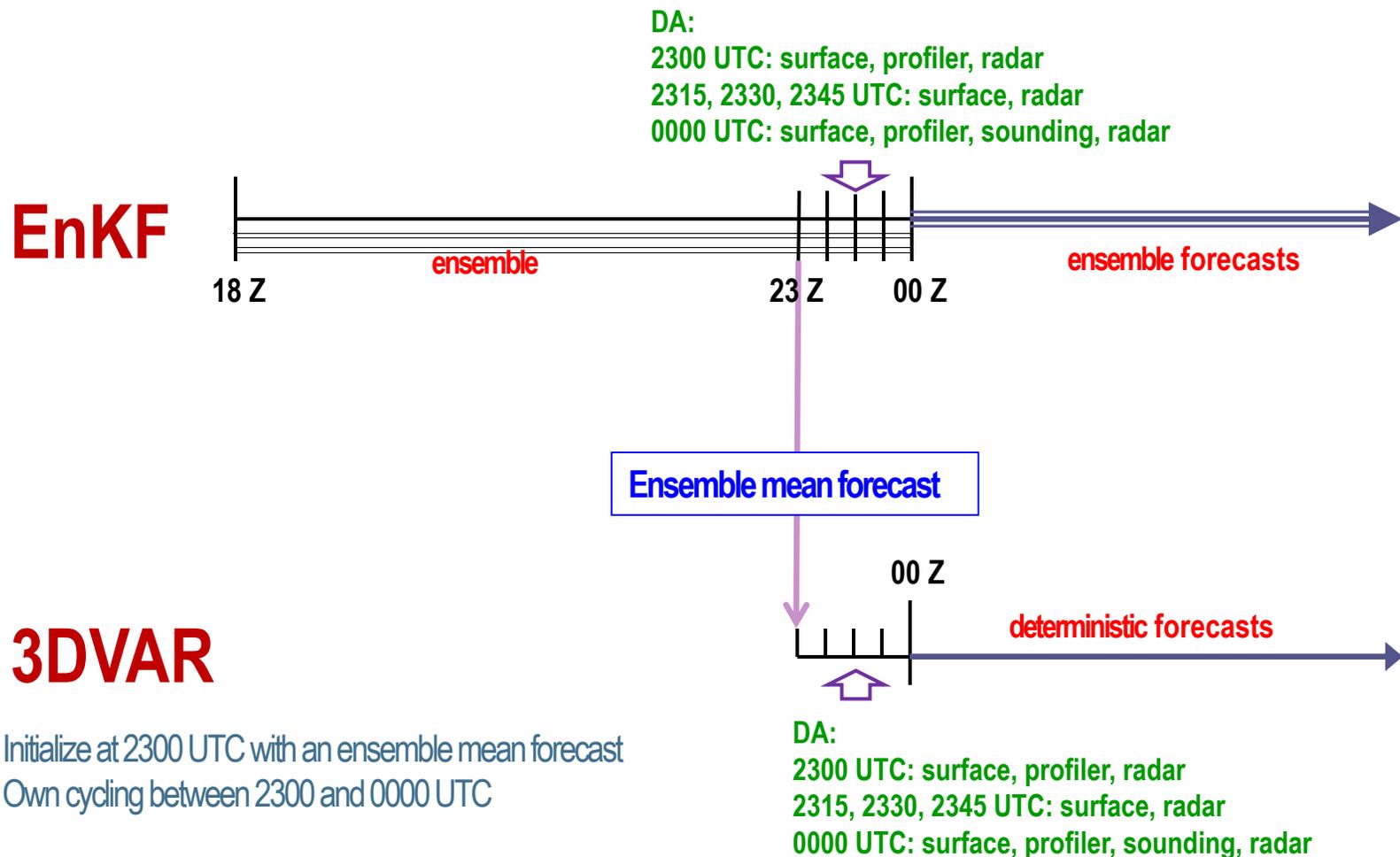
2014 Domain

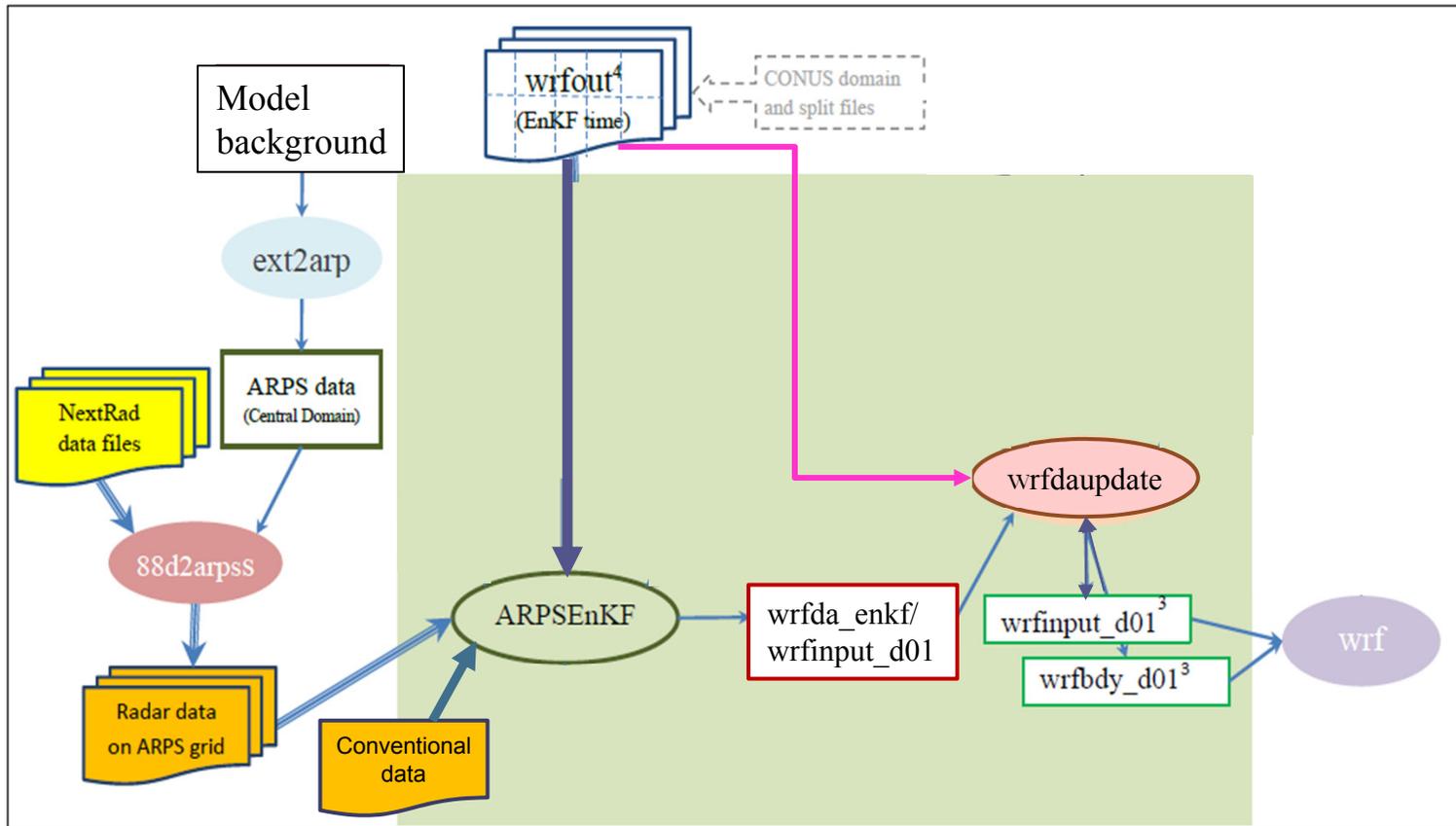


CONUS domain: 1200x768

Central US domain: 600x400

2014 1-hour cycled 4-km EnKF SSEF initialized at 00 UTC





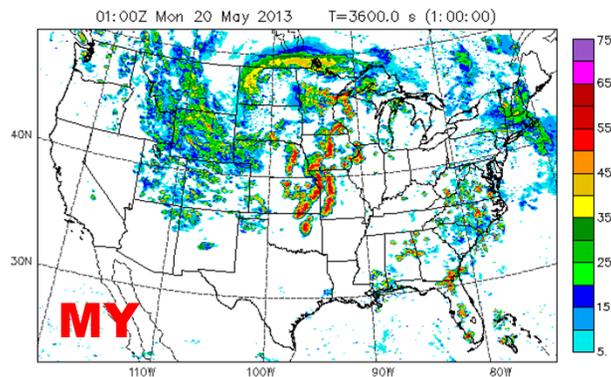
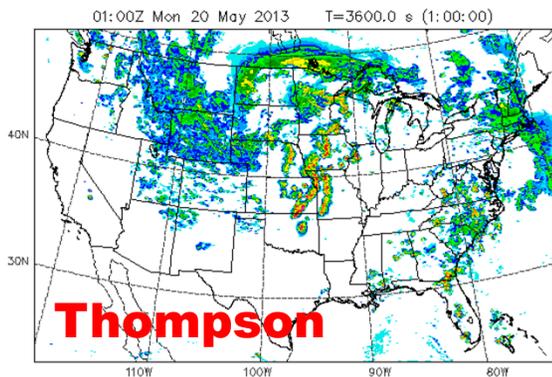
Simplified flow chart for the 2014 SE

Comparison with 2013 HWT forecasts for the tornado outbreak of 20 May 2013

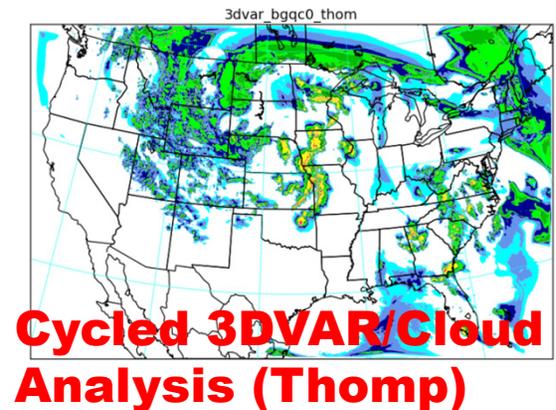
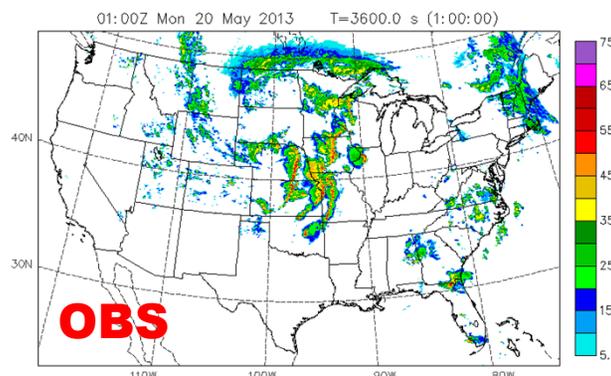
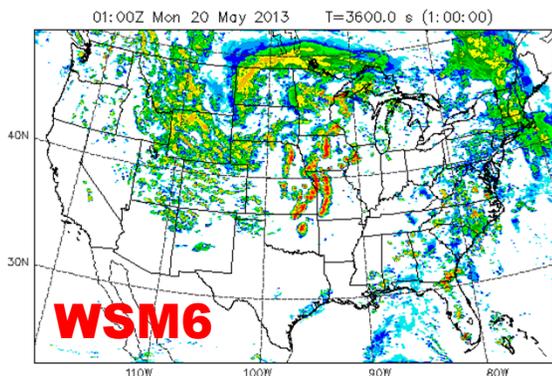
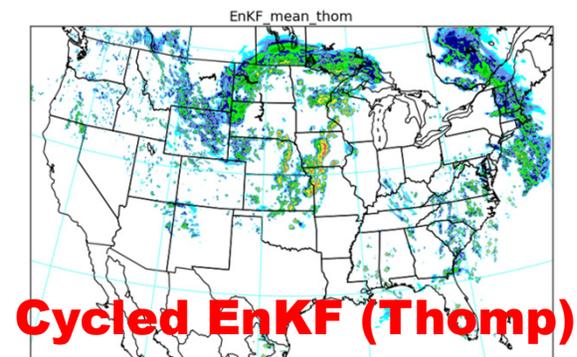
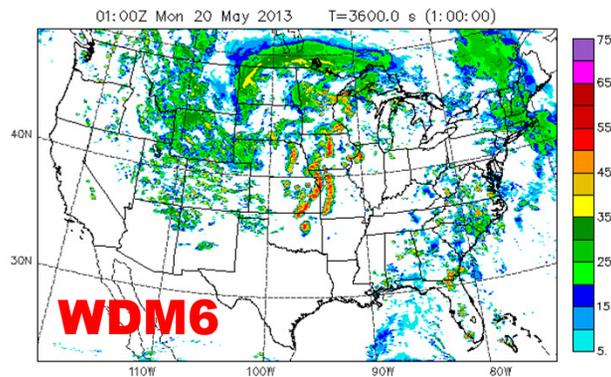
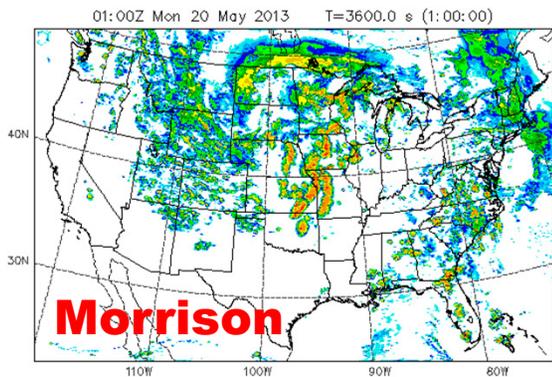
Member	IC	BC	Radar	Micro	LSM	PBL
arw_cn	ooZAPRSa	ooZ NAMf	yes	Thompson	Noah	MYJ
arw_m20	ooZAPRSa	ooZ NAMf	yes	M-Y	Noah	MYJ
arw_m21	ooZAPRSa	ooZ NAMf	yes	Morrison	Noah	MYJ
arw_m22	ooZAPRSa	ooZ NAMf	yes	WDM6	Noah	MYJ
arw_m26	ooZAPRSa	ooZ NAMf	yes	WSM6	Noah	MYJ
EnKF mean	ooZ EnKFa	ooZ NAMf	yes	Thompson	Noah	MYJ
3DVAR +cloud	ooZ ARPSa	ooZ NAMf	yes	Thompson	Noah	MYJ



3DVAR+Cloud Analysis



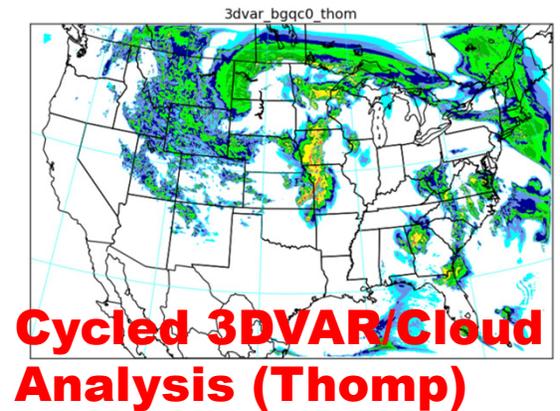
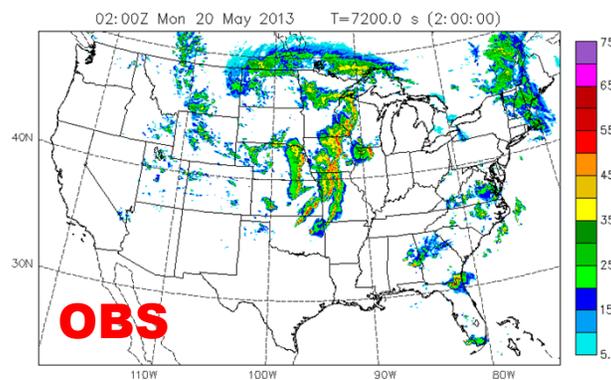
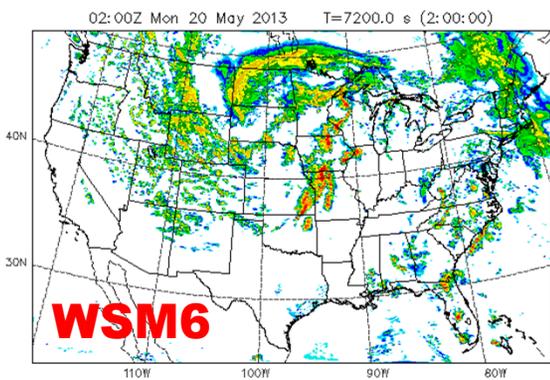
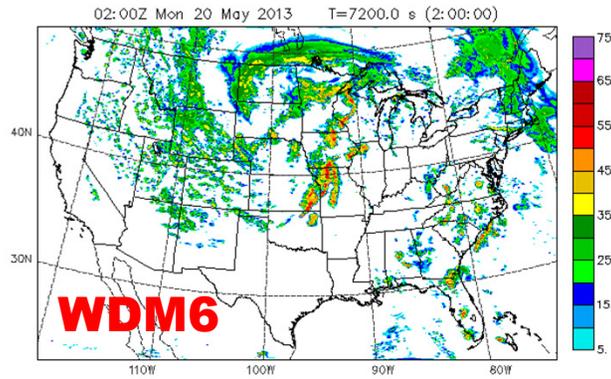
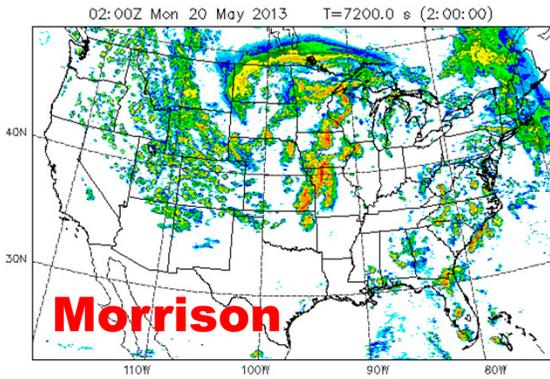
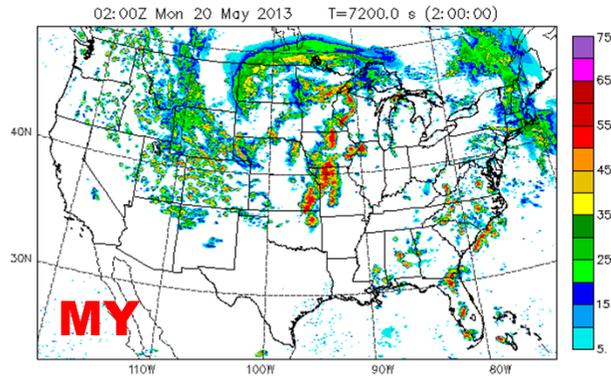
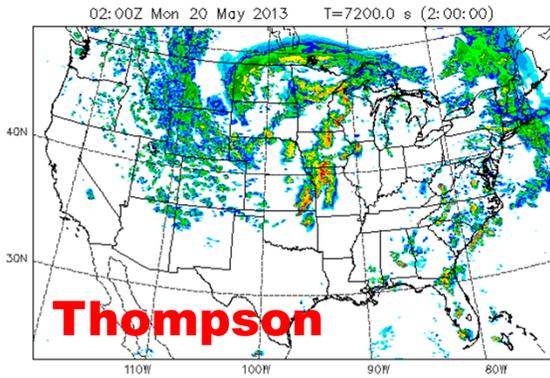
**1 hr forecast
Valid at 0100 UTC
20 May 2013**



3DVAR/Cloud Analysis

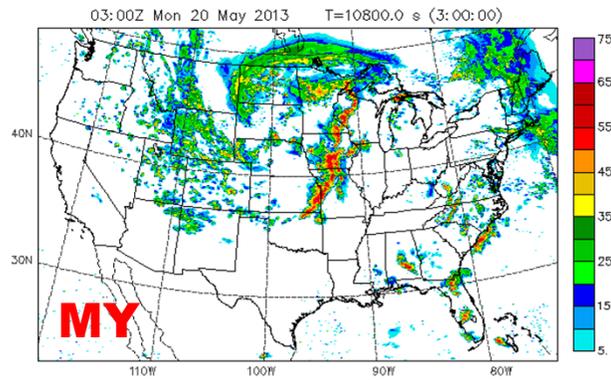
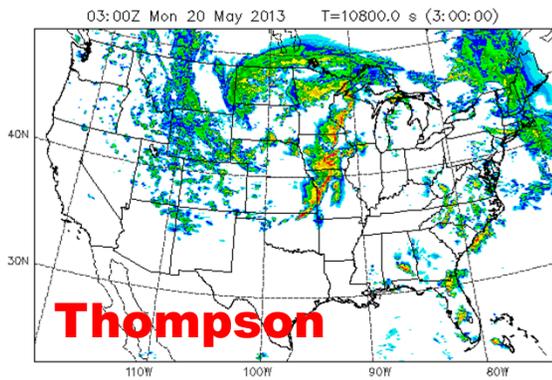
Min=0.00 Max=66.3

2 hr forecast Valid at 0200 UTC 20 May 2013

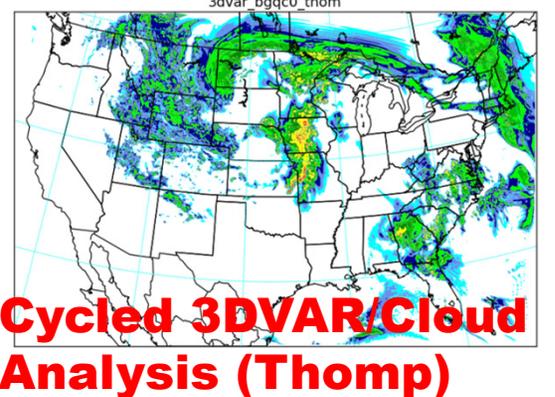
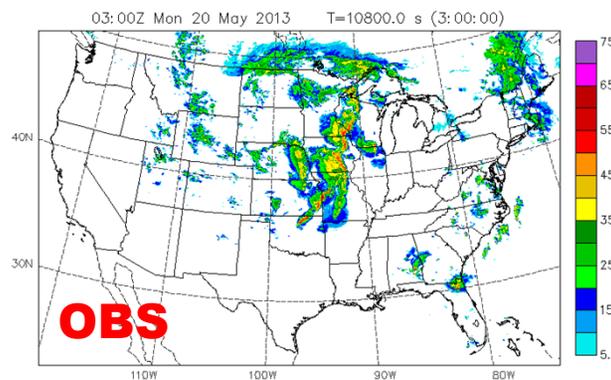
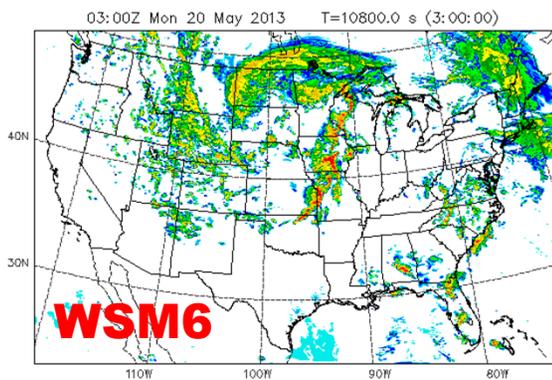
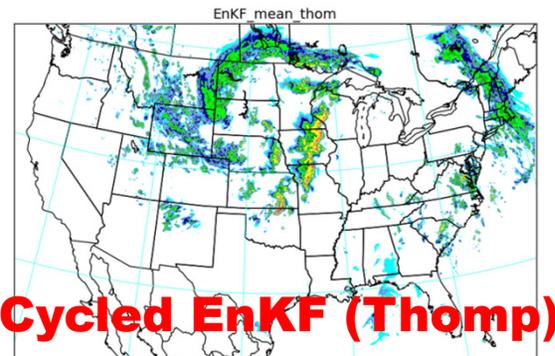
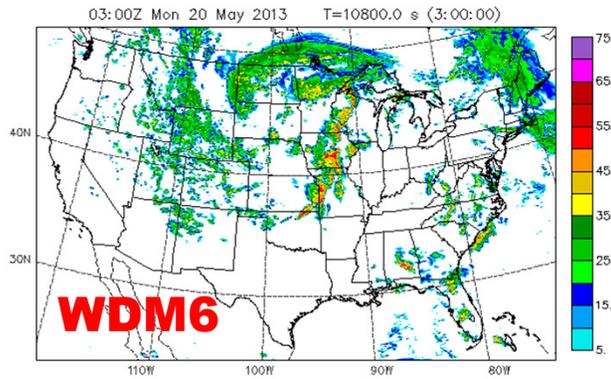
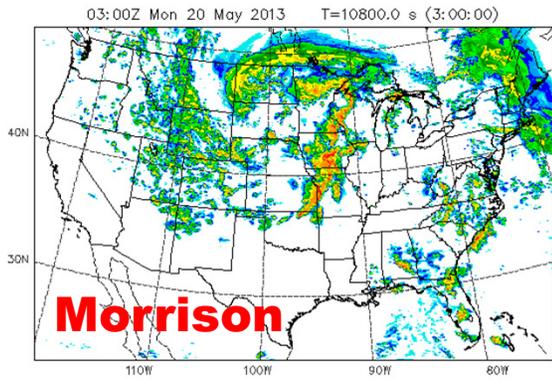


3DVAR/Cloud Analysis

Min=0.00 Max=63.9

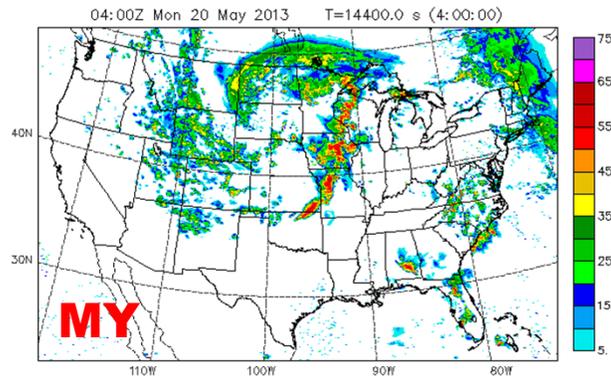
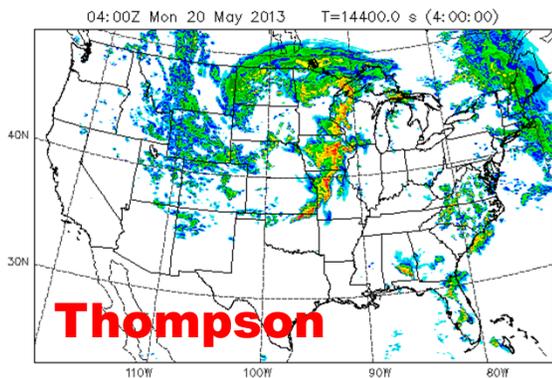


**3 hr forecast
Valid at 0300 UTC
20 May 2013**

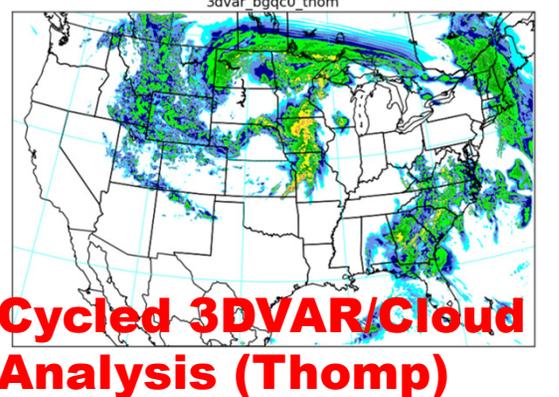
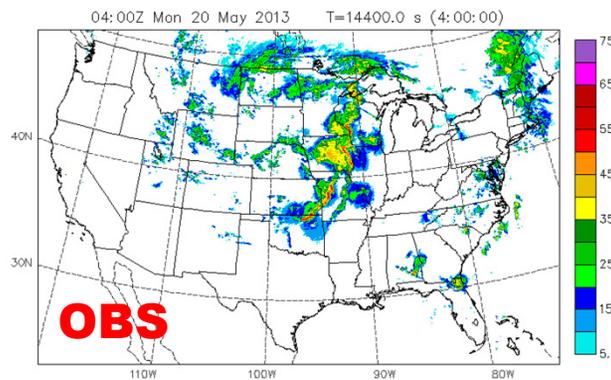
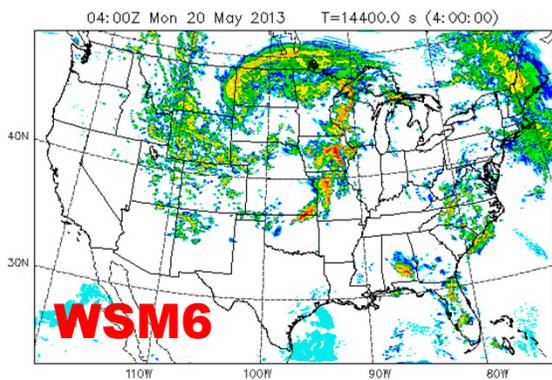
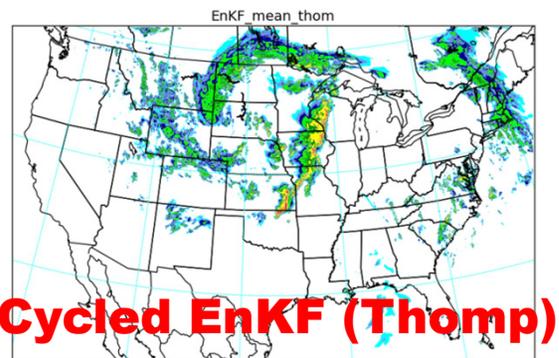
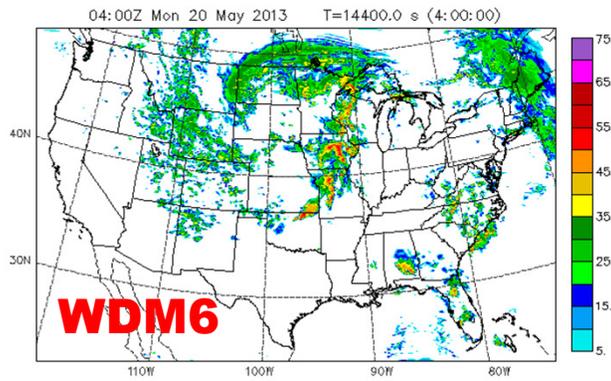
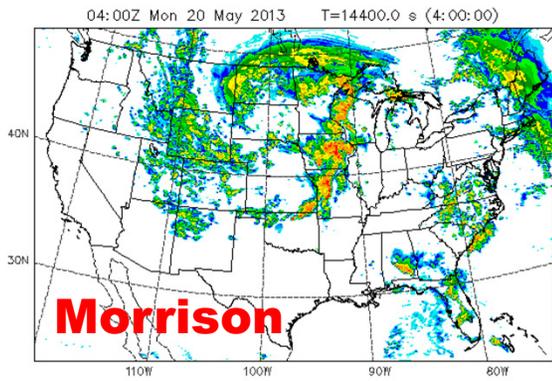


3DVAR/Cloud Analysis

Min=0.00 Max=63.2

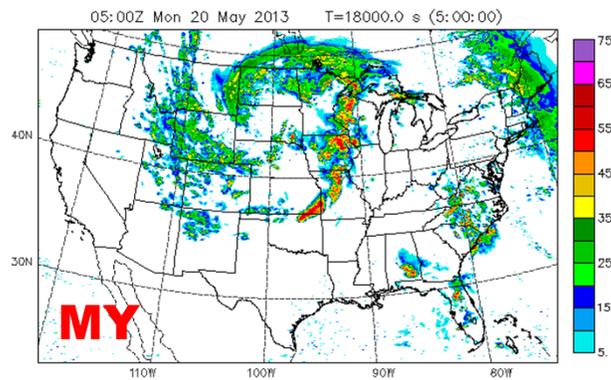
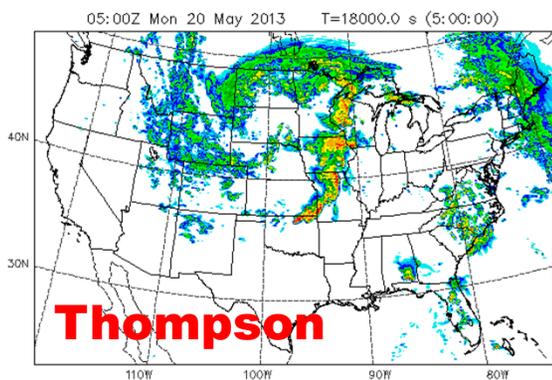


**4 hr forecast
Valid at 0400 UTC
20 May 2013**

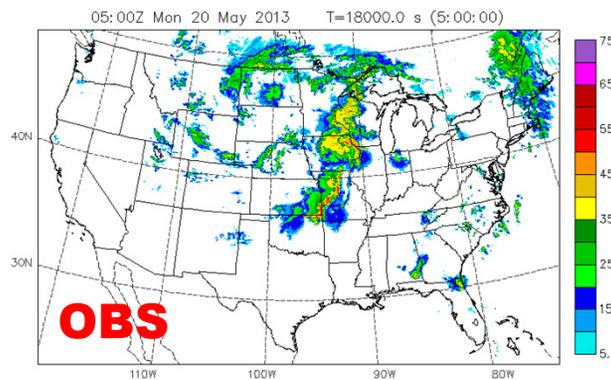
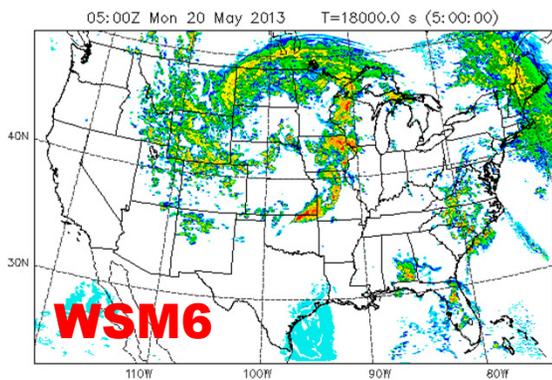
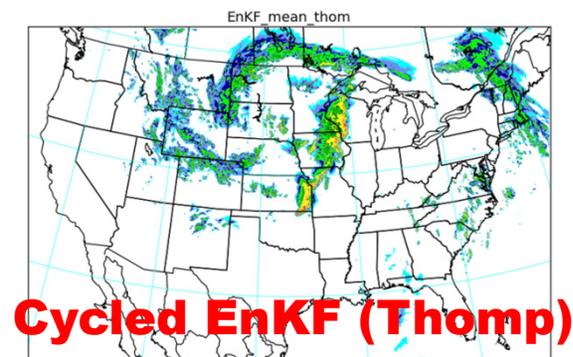
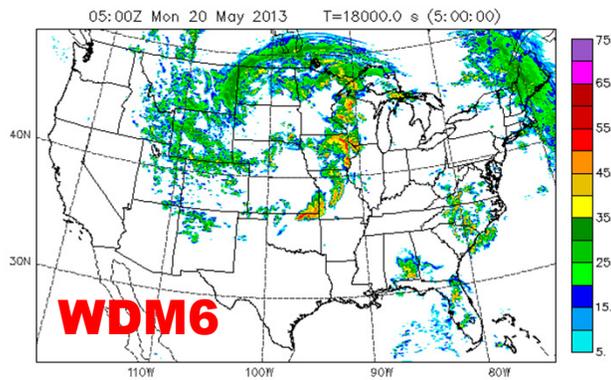
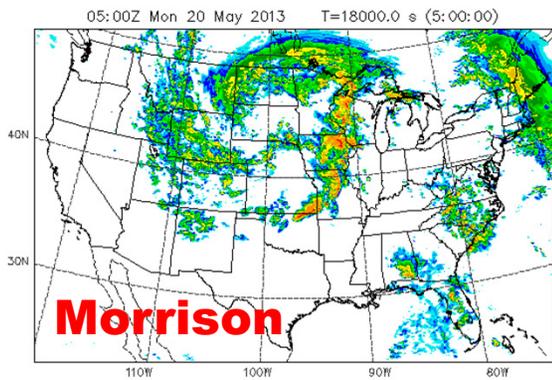


3DVAR/Cloud Analysis

Min=0.00 Max=64.4

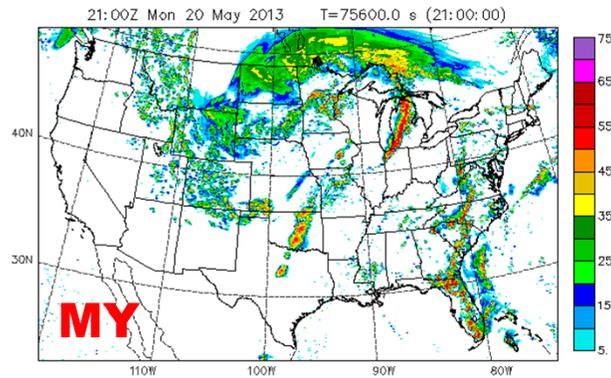
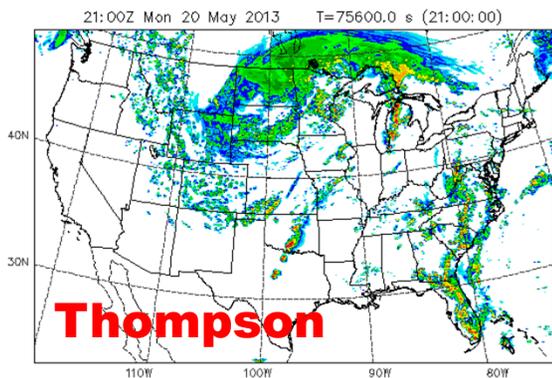


**5 hr forecast
Valid at 0500 UTC
20 May 2013**

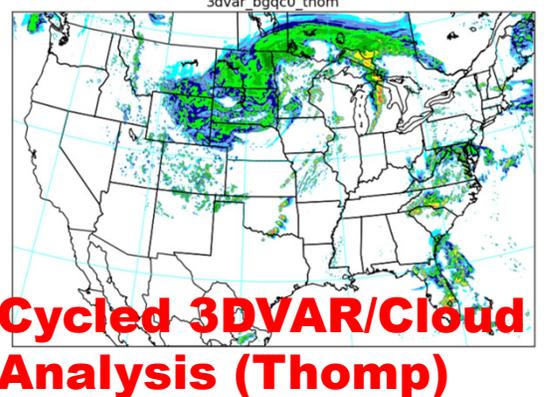
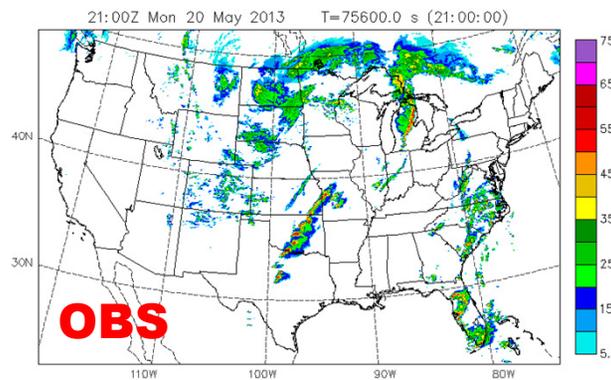
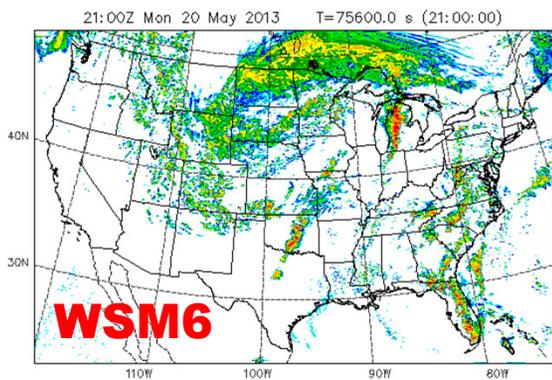
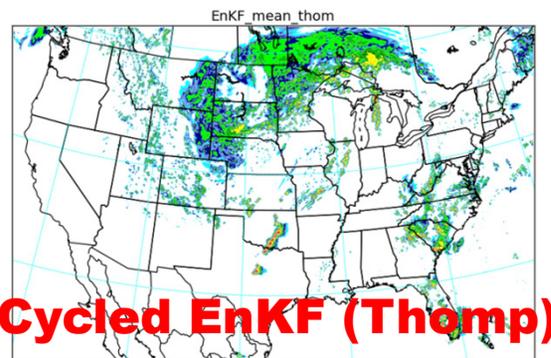
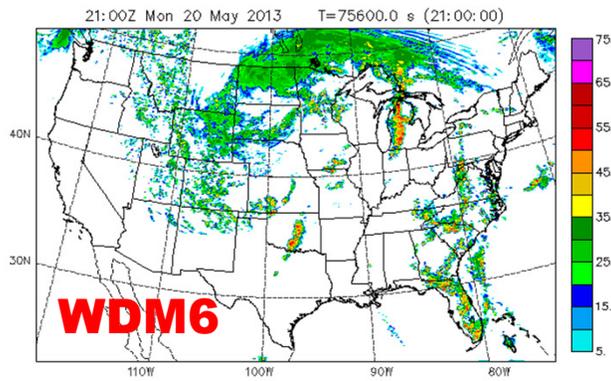
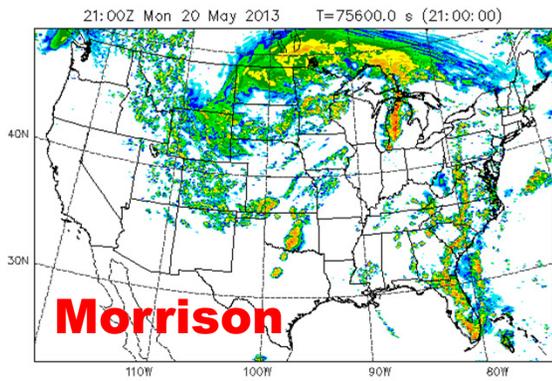


3DVAR/Cloud Analysis

Min=0.00 Max=63.0



**21 hr forecast
Valid at 2100 UTC
20 May 2013**



compst(dBZ , Shaded)

Min=0.00 Max=64.5

Performance statistics

- NICS Darter (4 PEs x 48 PEs)
 - Cray XC30 (Cascade) supercomputer
 - Two 2.6 GHz 64bit Intel 8-core XEON E5-2600 Series processors
 - Peak performance of 250 Tflops
 - Radar assimilation: ~ 7 min (2 threads, 384 cores)
 - Radar + surface assimilation: ~ 17 min (2 threads, 384 cores)
 - Radar + surface + sounding + profiler: ~ 80 min (2 threads, 384 cores)
 - 15 min forecast: ~ 4 min (192 cores)
 - 24 hour forecast: ~ 86 min (192 cores)