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NCEP Short Range Ensemble Forecast (SREF) System: *what we have and what we need?*

Jun Du

NOAA/NWS/NCEP
Environmental Modeling Center

(for NSF EarthCube Workshop, NCAR, Dec. 17-18, 2012)

An evolving system

SREFv1.0.0 (48km, Apr, 2001)

SREFv6.0.0 (16km, Aug, 2012)

<u>Next generation</u>:
Convection-explicit, cloud-resolving, rapid-update-cycle (hourly) storm-scale (3km) ensemble prediction system directly coupled with data assimilation (EnKF)

Part of the purposes of this workshop: to help building such a system

Value of SREF to US economy

We have estimated that use of SREF has helped reduce duration of outages to our customers by ~16%. This means for every customer experiencing a 6 hour outage due to a damaging weather event, their power gets restored a full hour sooner than it would otherwise if we did not use SREF to help us get out in front of the event.

FirstEnergyCorp

Pete Manousos

Brian Kolts

Initial condition/LBC/land surface initial states

What we have:

(1)Multi-analysis: GFS, NAM and RR analyses

(2)Mixed IC perturbations:

*regional bred vector (7 nmmb members)

*global Ensemble Transform with Rescaling/ETR (7 wrf_arw members)

*blended perturbation of "smaller-scale bred vector + larger-scale ETR" (7 wrf_nmm members)

(3) Various LBCs from global ensembles

(4) Various land surface initial states from NAM, GFS, RR analyses

What we need:

(1)Coupling with NDAS system via EnKF perturbations

(2)Exploring new IC perturbations when model resolution goes higher and higher?

(3)Better coupling with global ensemble by perturbing LBC

(4)Directly perturbing land surface initial states

Model and physics

What we have:

(1)Multi-model (16km): NMMB, WRF_NMM, WRF_ARW

(2)Multi-physics: various flavors from NMM, NCAR, GFS, RR

(3) Stochastic parameterization (Teixeira and Reynolds 2008) in NMMB model is in place but not turned on (more verification)

(4) Stochastic kinetic energy backscatter (SKEB) scheme in WRF-ARW model is in place but not turned on (too slow)

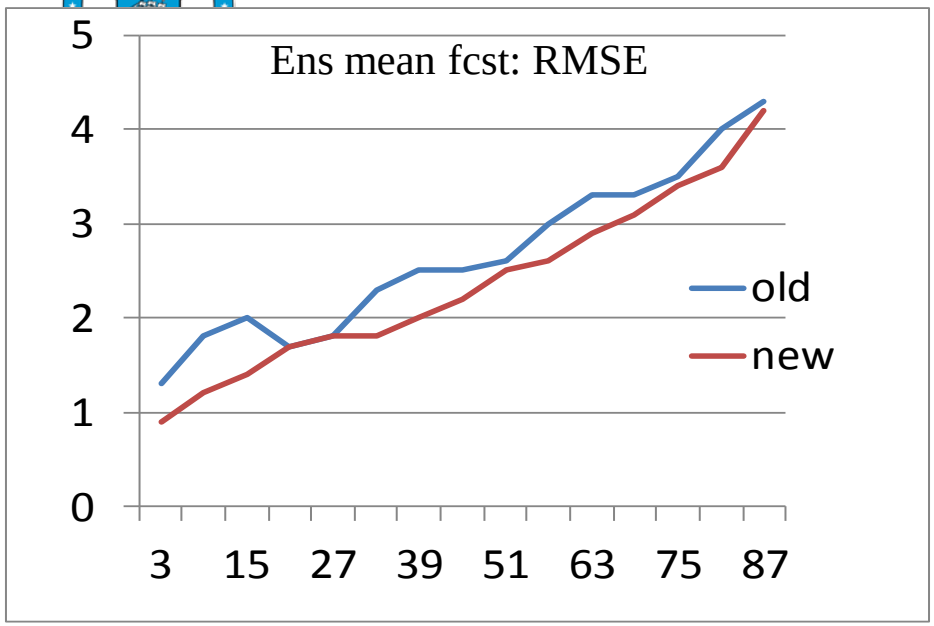
What we need:

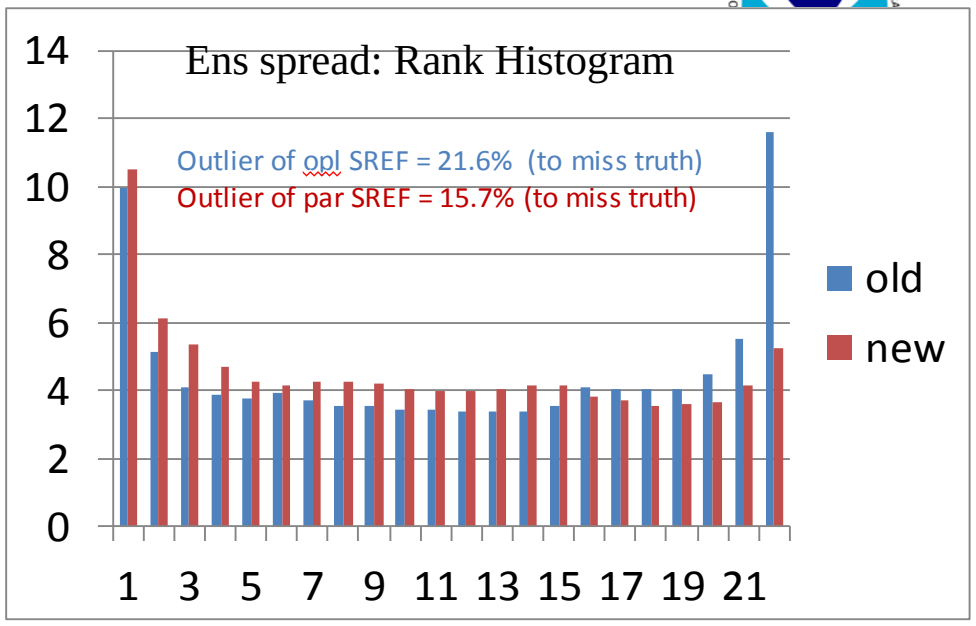
(1)Evaluating the stochastic parameterization scheme and speeding up the SKEB scheme for implementation

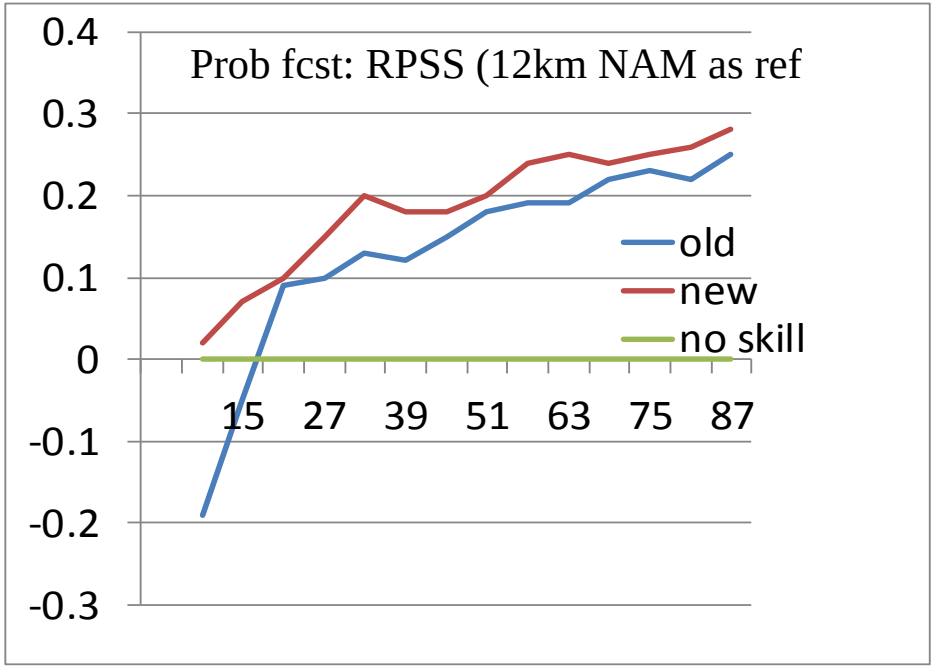
(2)Testing other stochastic physics schemes (e.g., Jeff Whitaker)

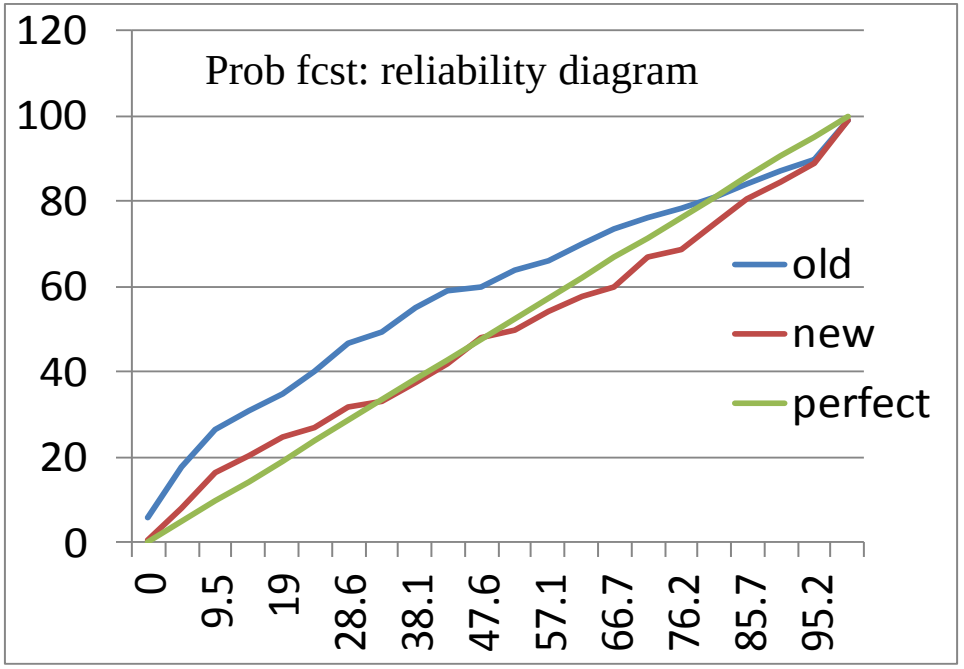
(3)Real question is to see if any stochastic physics scheme can really outperform multi-model and multi-physics approaches to eventually replace them?

General positive improvements in the Aug. 21, 2012 upgrade:
e.g., SLP (old SREF vs. new SREF, Oct. 23 – Dec. 31, 2011)









Post processing and calibration

What we have:

(1)Decaying-average method for bias correction for basic atmospheric variables (1st moment only)

(2)Frequency-matching method for precipitation bias correction (1st moment only)

(3)Downscaling of surface variables to 5km by applying the difference between lower-res and higher-res analysis

(4)clustering

(5)member performance ranking (different weights for different members)

What we need:

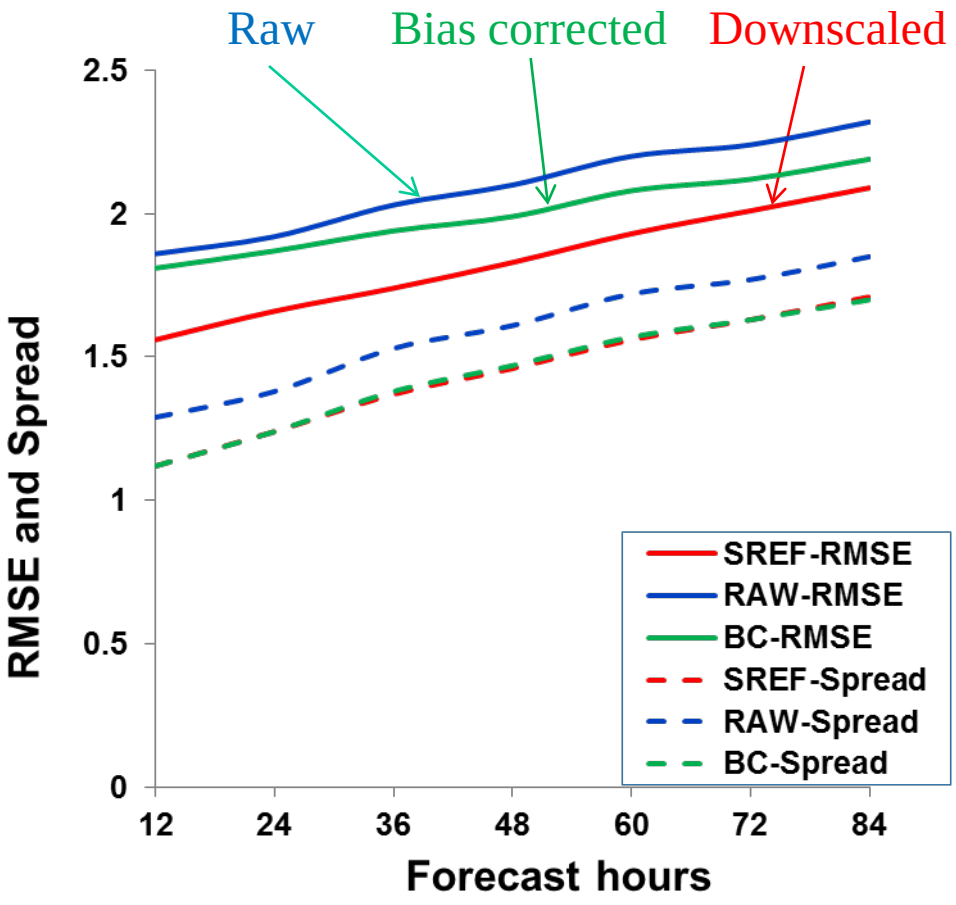
(1)Bias correction of model variables directly on model native grid (before model post), so everything else produced by model post thereafter will be automatically bias corrected

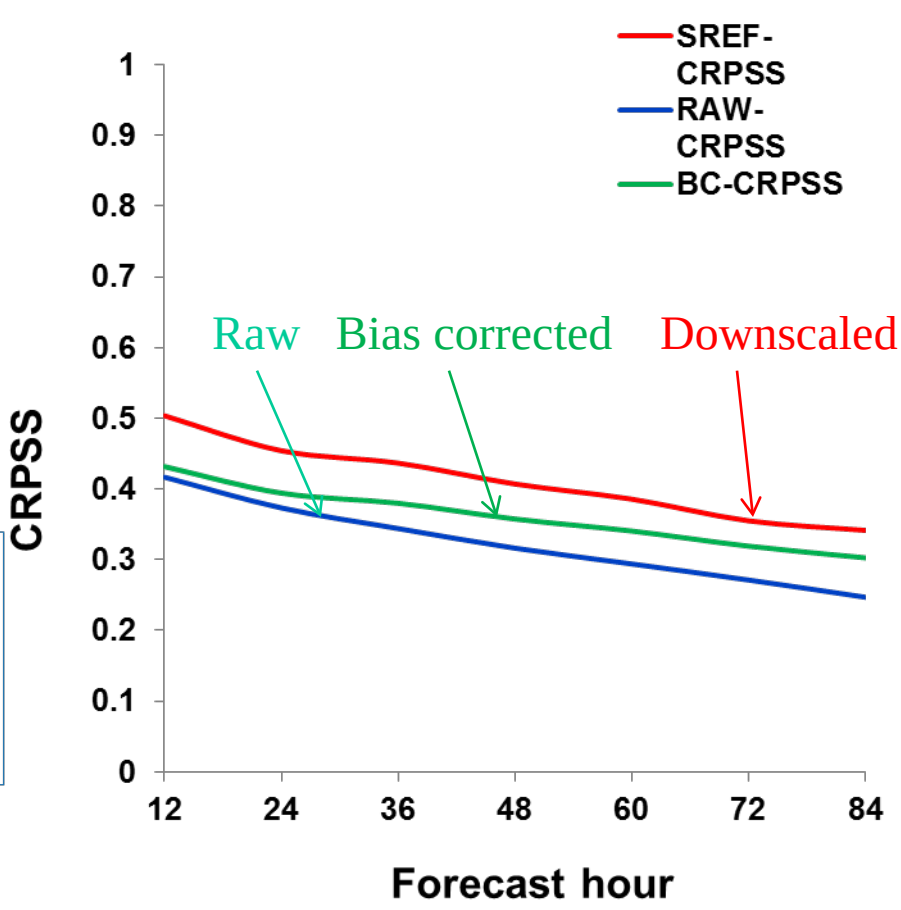
(2)2nd moment (spread) calibration (Decaying-average Bayesian Model Averaging/MDL)

(3)Higher-moment: e.g. calibrating probability as well as estimating uncertainty in probability (probability of probability)?

(4)Innovative approaches extracting and condensing ensemble information

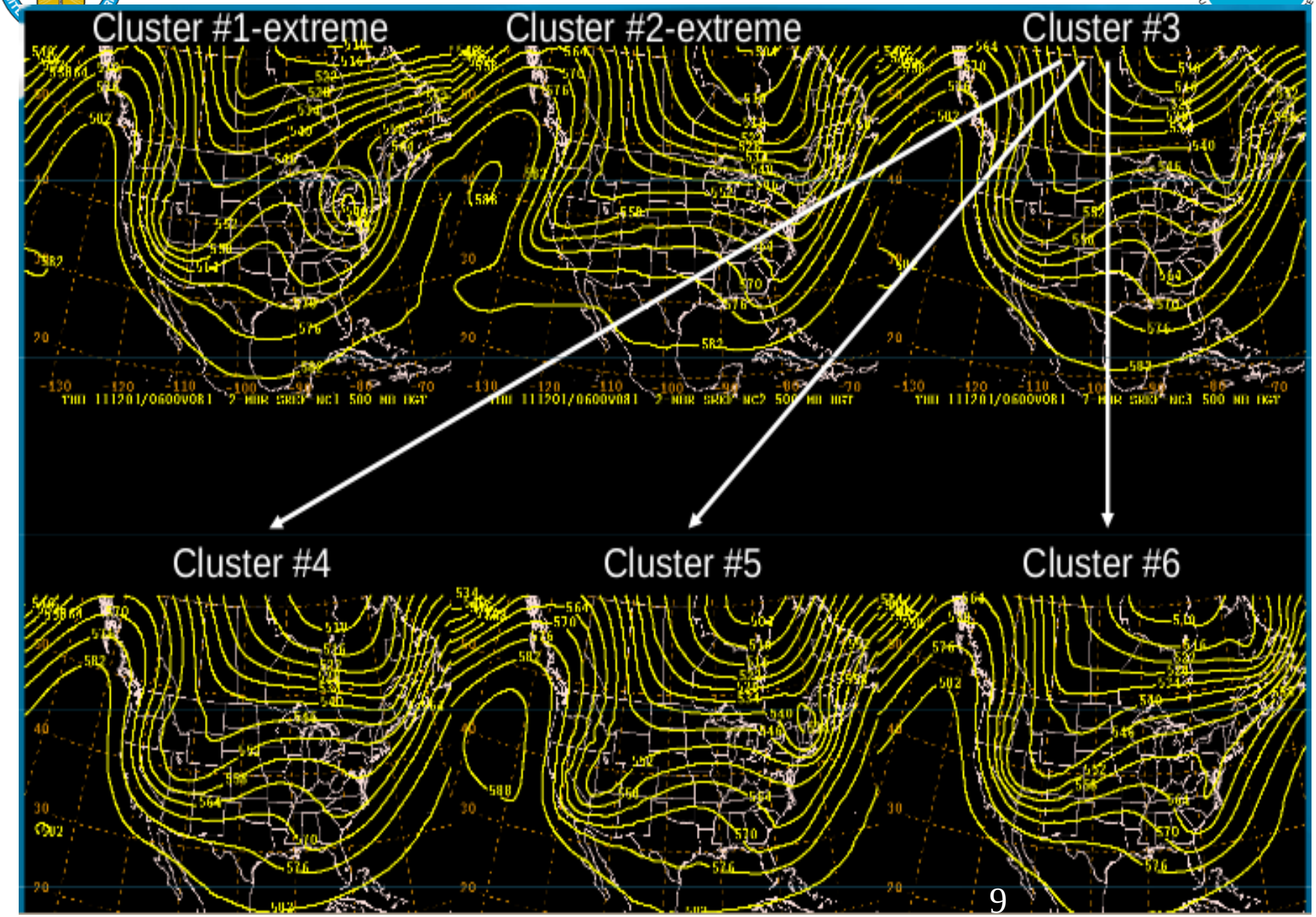
Improvements through bias correction and downscaling each step (verified against RTMA, 6/18/12 – 7/16/12)





Ens mean (T2m) Probability

Example of Ensemble Clusters



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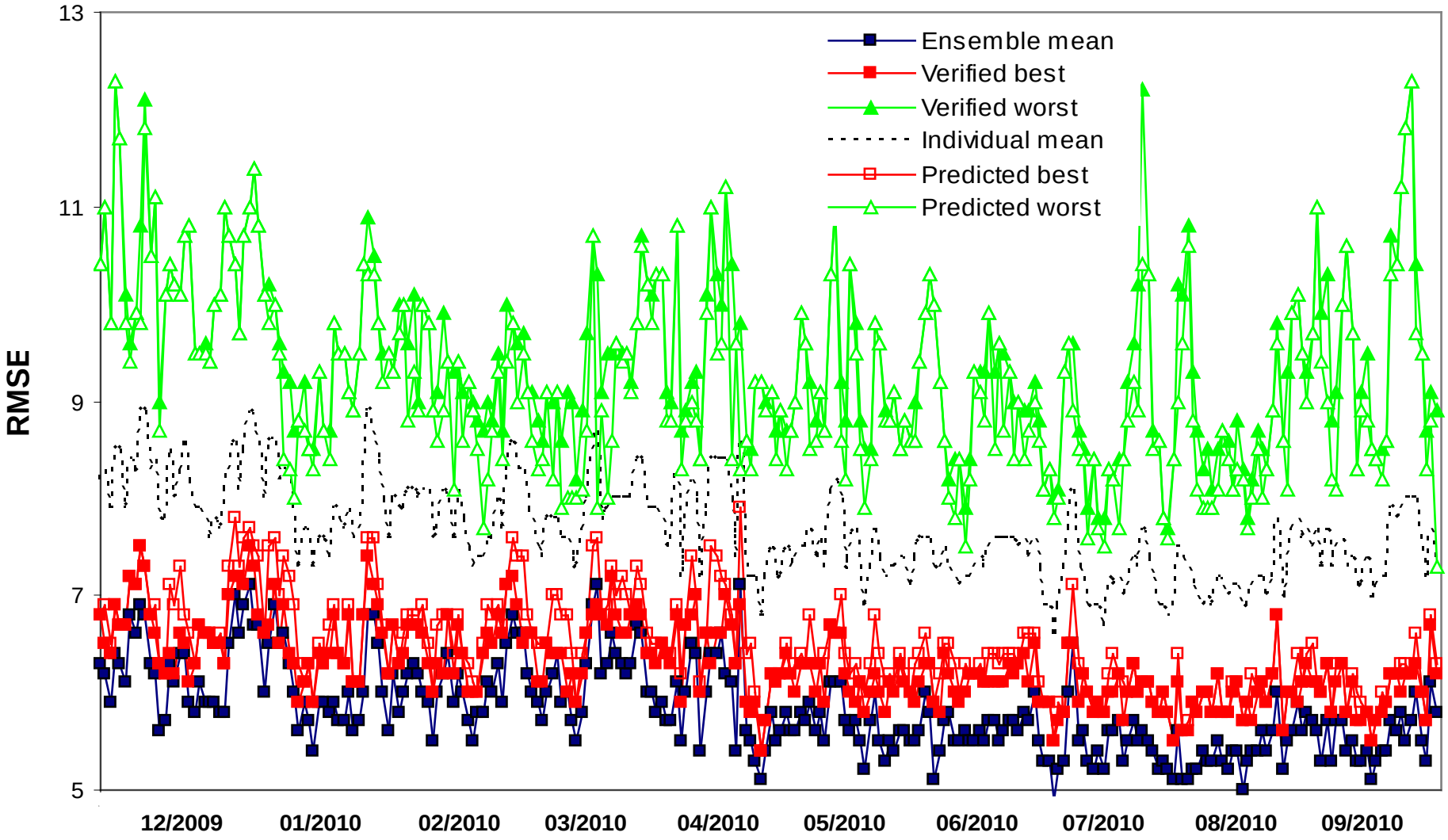
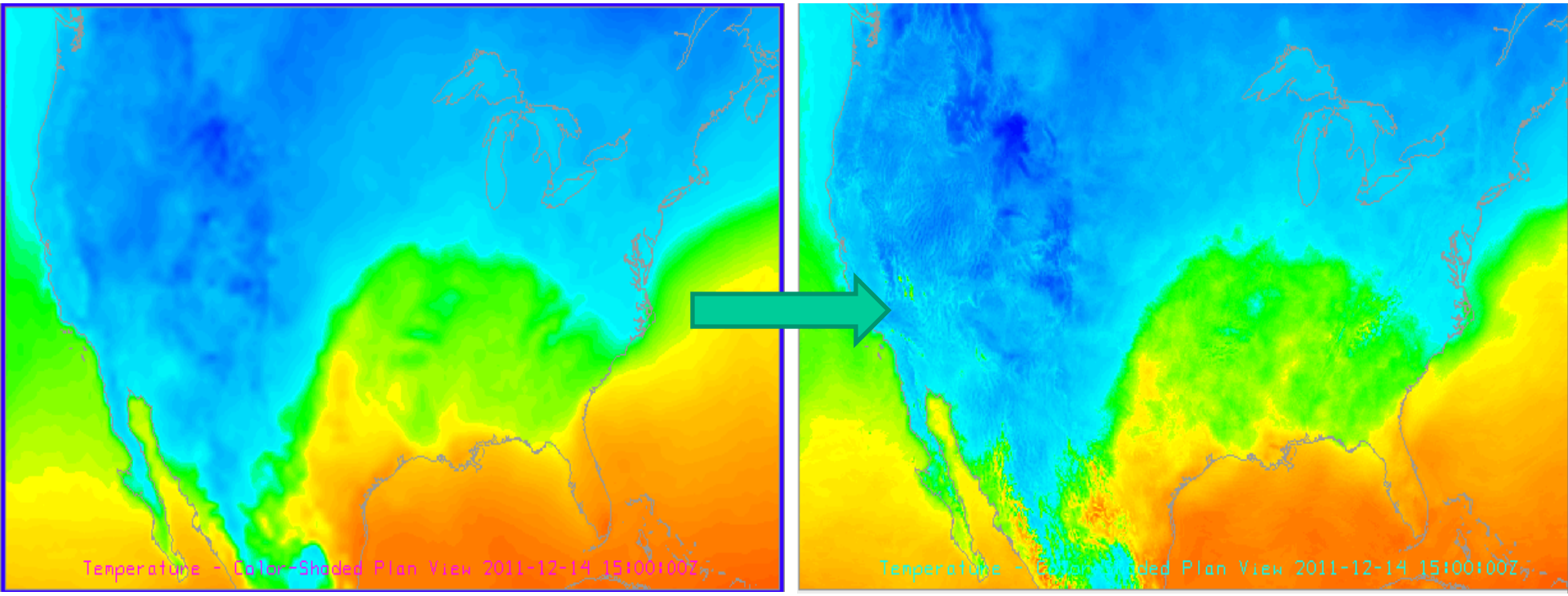
Individual member' performance ranking (weights for each members): Du and Zhou 2011 MWR



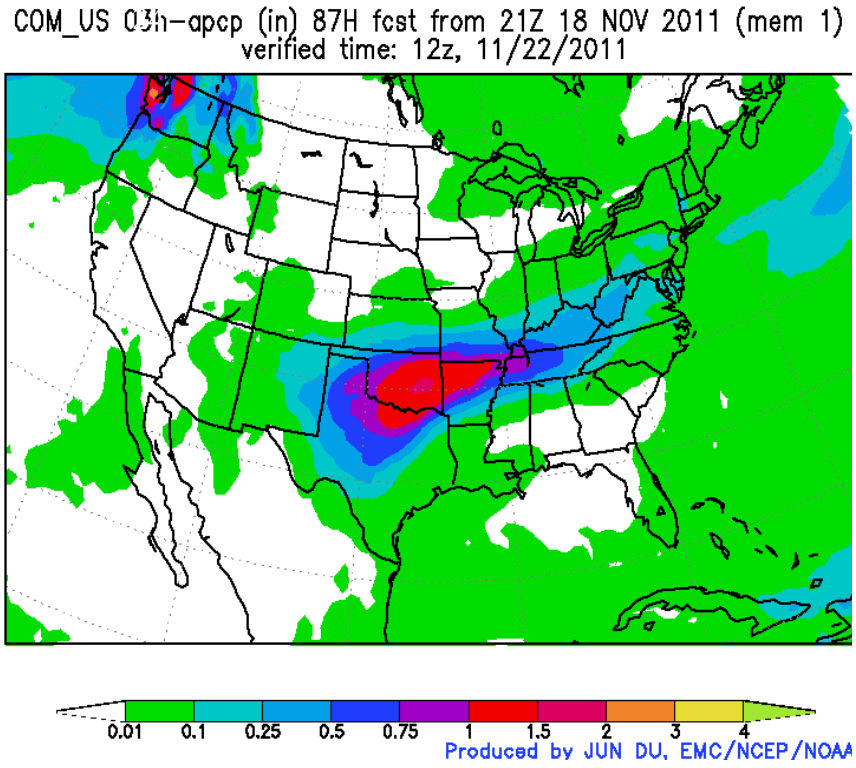
Downscaling to 5km (sample: T2m valid at 15Z, Dec. 14, 2011; DTC helped in testing)



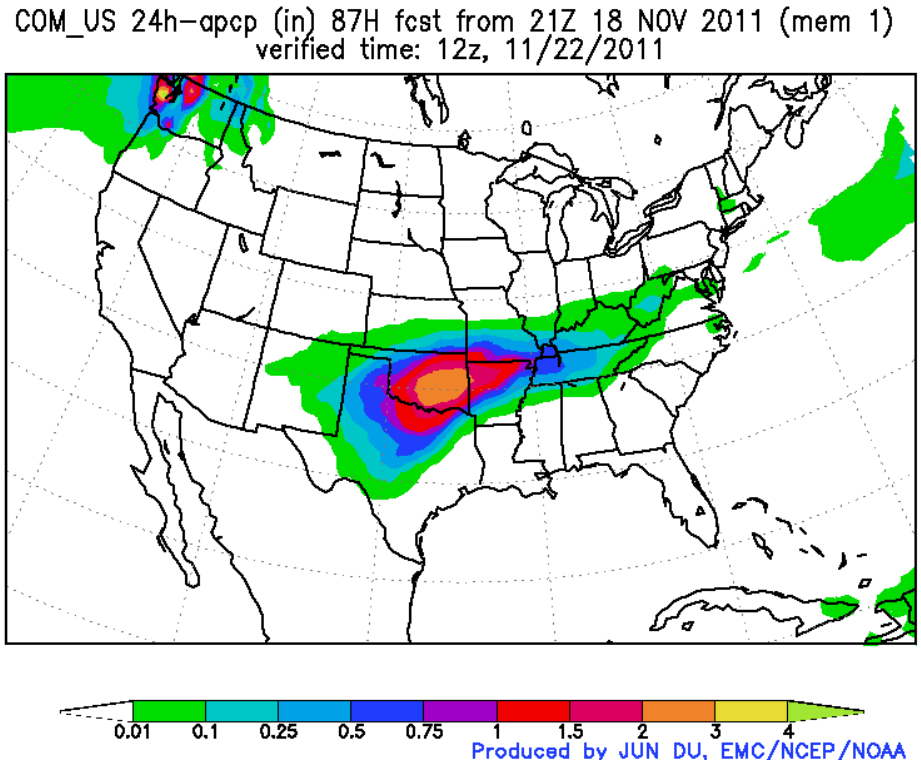
Before (40km) **After (5km)**

Bias correction can effectively remove over-predicted light precipitation and enhance under-predicted heavier precipitation

16km SREF mean (raw)



16km SREF mean (bias corrected)



Ensemble products

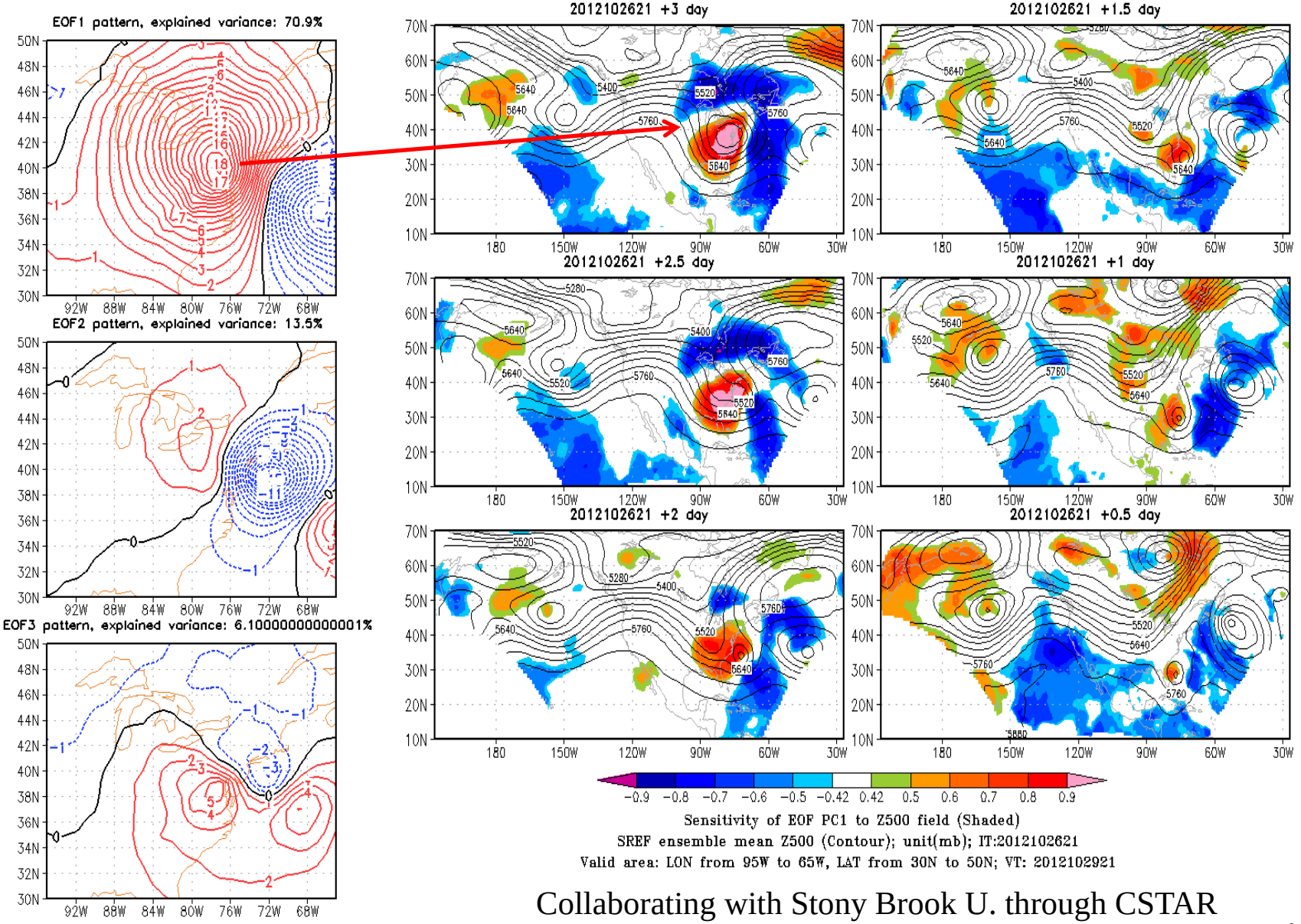
What we have:

(1)mean, spread (spgt, stamp charts, …) and probability
(2)max/min, mode, 10-25-50-75-90% percentiles
(3)Ensemble sensitivity maps (why uncertain and where targeted observation)

What we need?

(1)Better ensemble mean (weighted, probability-matching and others)
(2)Neighborhood probability (for high-res EPS)
(3)Extreme forecast index (EFI)/anomaly forecasts
(4)Special products for wind energy and dispersion uncertainty modeling etc.
(5)Better visulization of uncertainty information

SREF-based ensemble sensitivity maps (Hurricane Sandy case)



The first 3 EOF MSLP patterns for SREF fcst ; contour interval: 1mb; VT: 2012102921
Analysis is computed for valid region; LON: from 95W to 65W; LAT: from 30N to 50N

Collaborating with Stony Brook U. through CSTAR Project (Brian Colle, Edmund Chang, Minghua Zheng)

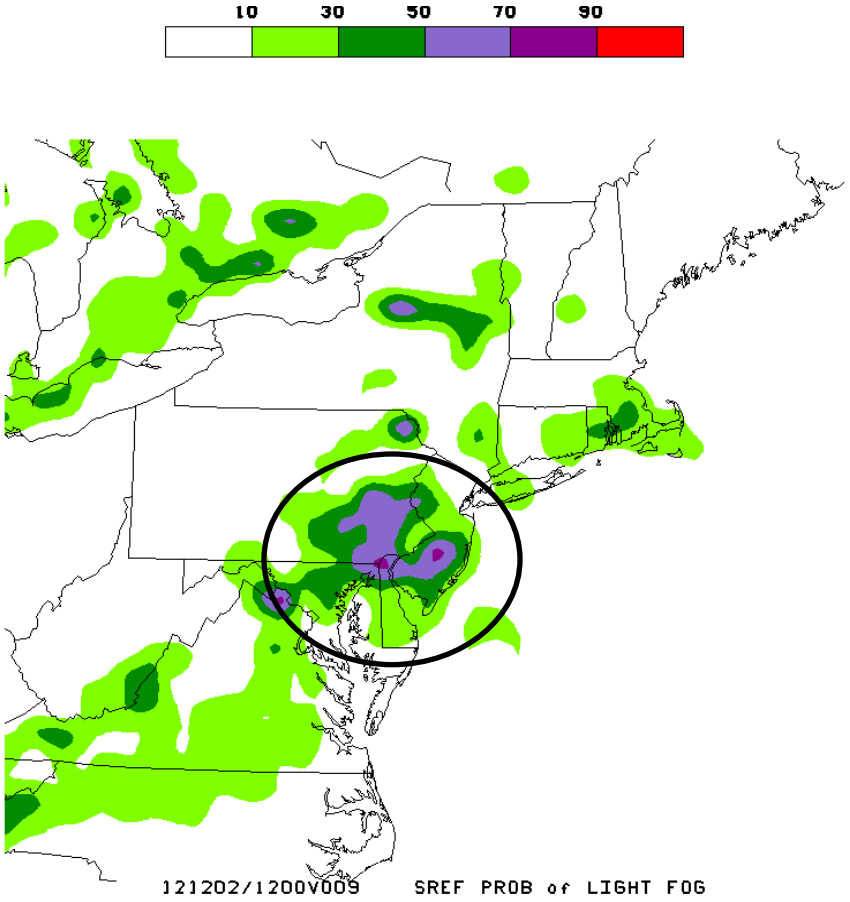
List of ensemble products

	Surface products	Upper-air products
Mean and Spread	• 10m U, V, and speed • SLP • 2m RH • 2m T • 2mTd • CAPE • CIN • PWTR • LI • 1, 3, 6, 12, and 24 hr APCP • 3, 6, 12, and 24hr acc snow • Precip type • Visibility • Fog LWC • Ceiling • Cloud top • Total cloud • LLWS	• U, V at 1000, 850, 700, 600, 500, 300, 250mb • Height at 1000, 850, 700, 600, 500, 300, 250mb • Abs Vorticity at 850, 700, 600, 500, 300, 250mb • RH at 850, 700, 600, 500, 300mb • T at 700, 600, 500, 300mb • Td at 850, 700, 500, 300mb • SREH at 7600m • Wind speed at 1000, 850,7 00, 600, 500, 300, and 250mb • Thickness 218600m, 12900m,18005m • Thickness of 1000-850, 1000-500,850-700mb
Prob	• Ceiling<500, 1000, 2000, 3000, 4000, 6000 feet • Visibility<0.25, 0.5, 1, 2, 3, 5, 6 mile • Flight condition of LIFR, IFR, MVFR,VFR • LLWS > 20knots / 2000feet • Reflectivity > 10, 20, 30, 40 dBZ • Echo-top > 3000, 9000, 15000, 21000,30000feet • Fog light, medium, dense • 10m wind speed > 20, 35, 50 knots • Precip types of rain, snow, freezing ran • 1, 3, 6, 12, 24hr APCP > 0.01, 0.05, 0.1, 0.25, 0.5, 1, 1.5, 2, and 4 inch • 3,6,12 and 24hr acc snow > 1, 2, 4, 6, 7.5, 8 , 10, 12, 14, 20 inch • T2m < 0C, > 25.8 C • CAPE > 250, 500, 1000, 2000, 3000, 4000 J/kg • CIN < -50, -100, -200, -300, -400 J/kg • LI < 0, -2, -4, -6, -8 • Total cloud = 0~20, 20~50, 50~80, 80~100	• T850mb < 0C • SREH7600 > 100, 150, 200 250 300 • Icing occurrence at 900, 800,725,650,575,500 and 400 mb • Severe, mid and light CAT at 500, 450, 400, 350, and 300, 275,225 200 mb

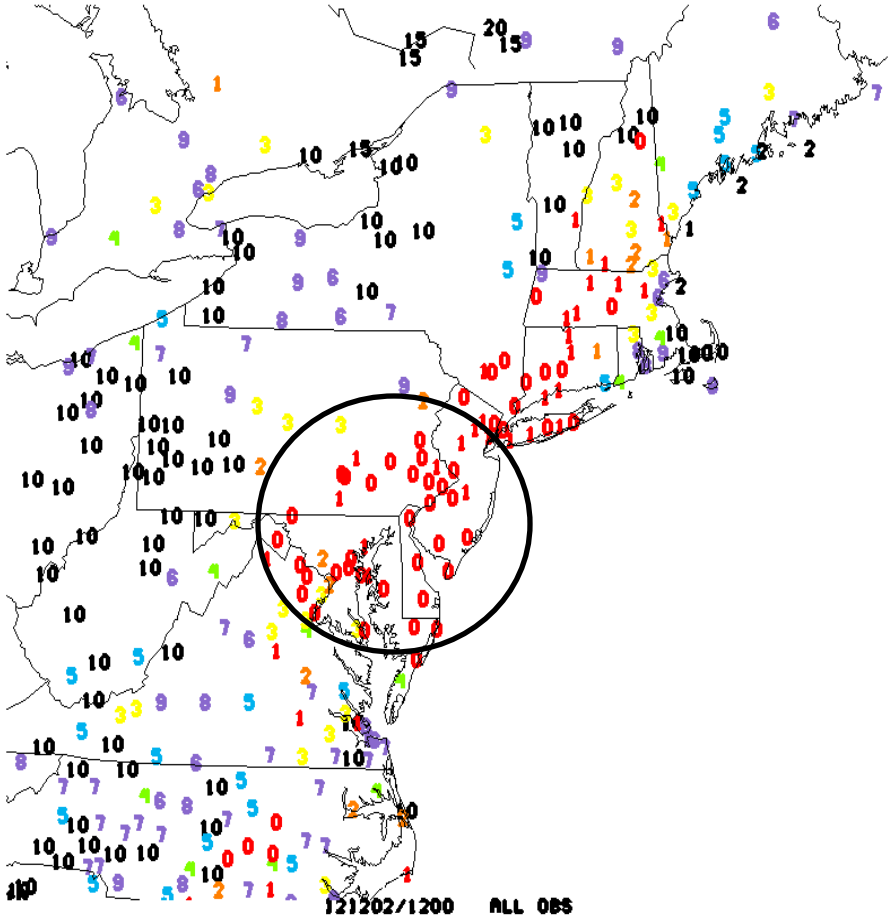
Max	• T2m • SLP • 10m U, V • Ceiling • Visibility	• T at 700, 600, 500, 300 mb • height at 1000, 850, 700, 600, 500, 300, 250mb • U, V at 1000, 850, 700, 600, 500, 300, 250mb • RH at 850, 700, 600, 500, 300, 250mb • Td at 850, 700, 500, 300mb
Min	• T2m • SLP • 10m U, V • Ceiling • Visibility	• T at 700, 600, 500, 300 mb • height at 1000, 850, 700, 600, 500, 300, 250mb • U, V at 1000, 850, 700, 600, 500, 300, 250mb • RH at 850, 700, 600, 500, 300, 250mb • Td at 850, 700, 500, 300mb
Mode	• T2m • SLP • 10m U, V • Ceiling • Visibility	• T at 700, 600, 500, 300 mb • height at 1000, 850, 700, 600, 500, 300, 250mb • U, V at 1000, 850, 700, 600, 500, 300, 250mb • RH at 850, 700, 600, 500, 300, 250mb • Td at 850, 700, 500, 300mb
10%	• T2m • SLP • 10m U, V • Ceiling • Visibility	• T at 700, 600, 500, 300 mb • height at 1000, 850, 700, 600, 500, 300, 250mb • U, V at 1000, 850, 700, 600, 500, 300, 250mb • RH at 850, 700, 600, 500, 300, 250mb • Td at 850, 700, 500, 300mb
25%	• T2m • SLP • 10m U, V • Ceiling • Visibility	• T at 700, 600, 500, 300 mb • height at 1000, 850, 700, 600, 500, 300, 250mb • U, V at 1000, 850, 700, 600, 500, 300, 250mb • RH at 850, 700, 600, 500, 300, 250mb • Td at 850, 700, 500, 300mb
50%	• T2m • SLP • 10m U, V • Ceiling • Visibility	• T at 700, 600, 500, 300 mb • height at 1000, 850, 700, 600, 500, 300, 250mb • U, V at 1000, 850, 700, 600, 500, 300, 250mb • RH at 850, 700, 600, 500, 300, 250mb • Td at 850, 700, 500, 300mb
75%	• T2m • SLP • 10m U, V • Ceiling • Visibility	• T at 700, 600, 500, 300 mb • height at 1000, 850, 700, 600, 500, 300, 250mb • U, V at 1000, 850, 700, 600, 500, 300, 250mb • RH at 850, 700, 600, 500, 300, 250mb • Td at 850, 700, 500, 300mb
90%	• T2m • SLP • 10m U, V • Ceiling • Visibility	• T at 700, 600, 500, 300 mb • height at 1000, 850, 700, 600, 500, 300, 250mb • U, V at 1000, 850, 700, 600, 500, 300, 250mb • RH at 850, 700, 600, 500, 300, 250mb • Td at 850, 700, 500, 300mb

SREF fog product (the Dec. 2/Sunday dense fog case in the east coast: general signal is there but magnitude is underdone likely due to not enough vertical levels within boundary layer of the SREF models)

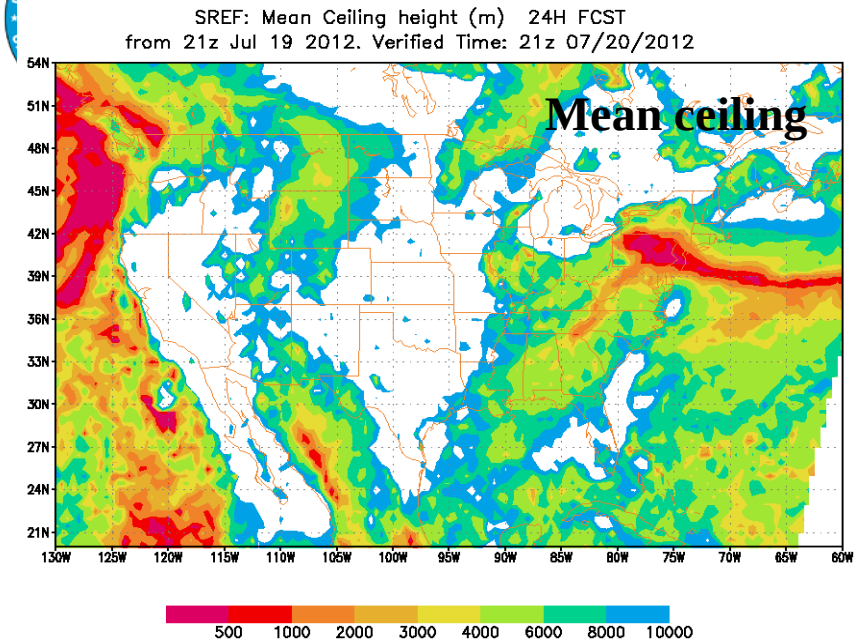
SREF-based 9h prob forecast of fog (<1 mile) from 03z, 12/2/12, Sunday

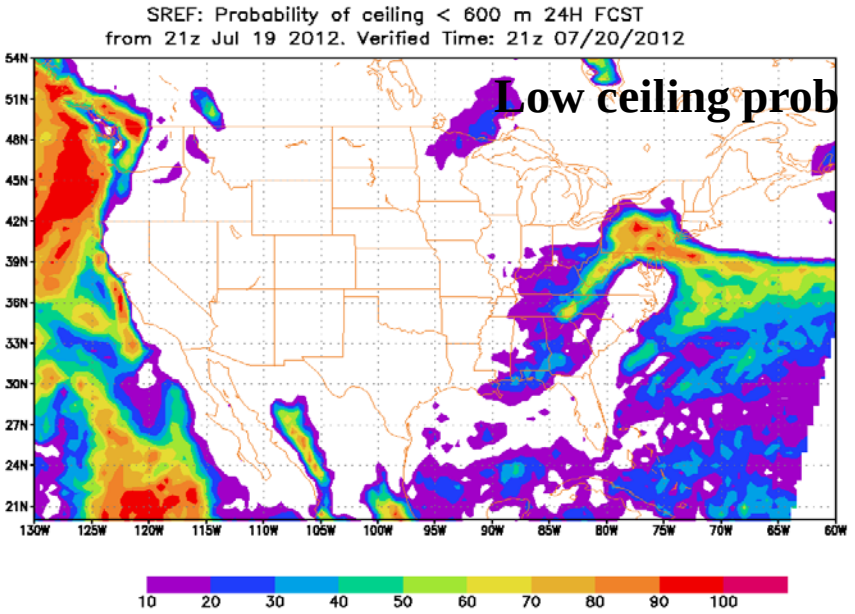


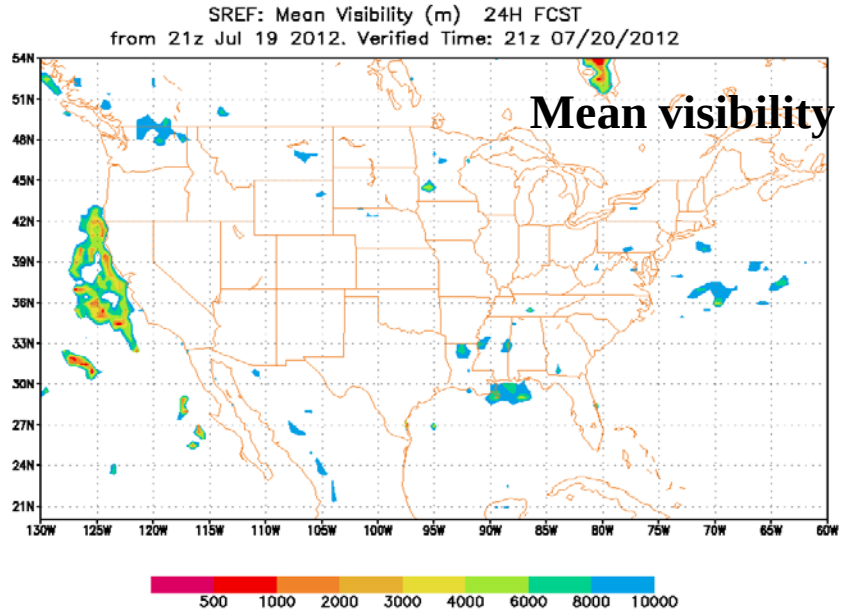
Observed visibility

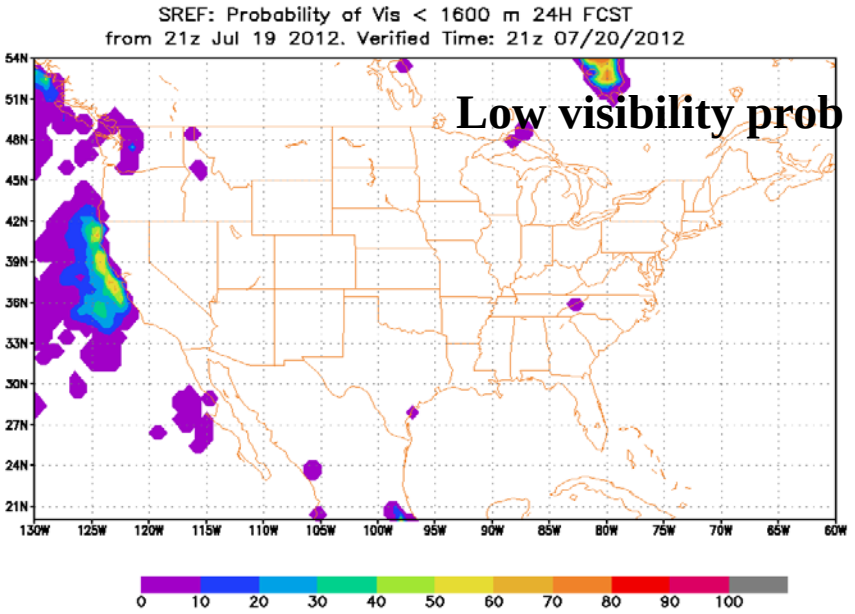


Ensemble products for aviation weather

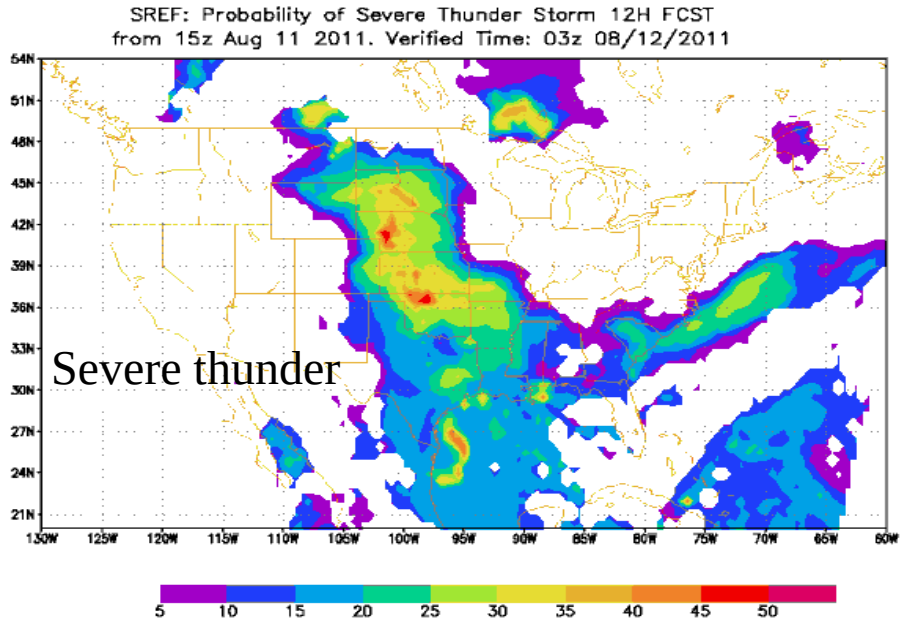


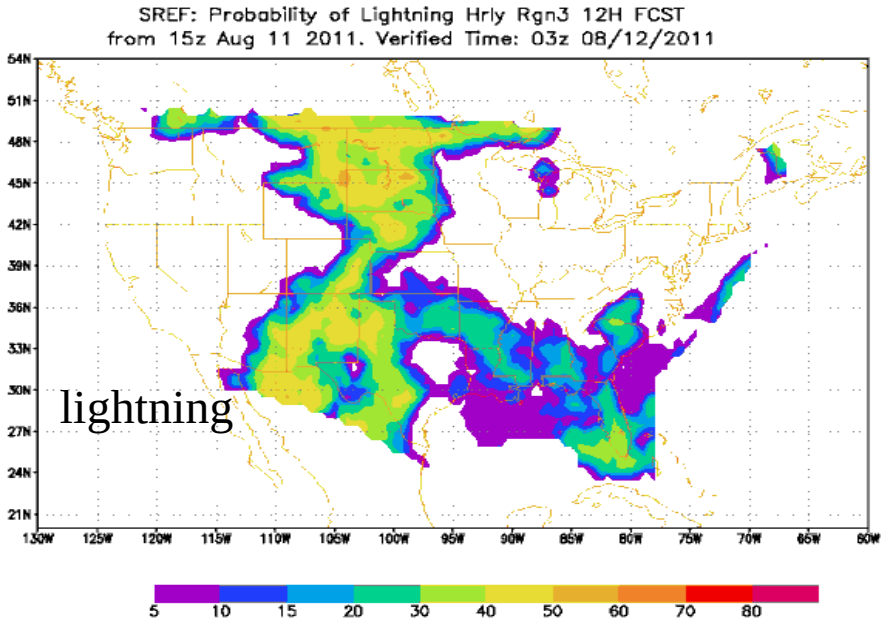


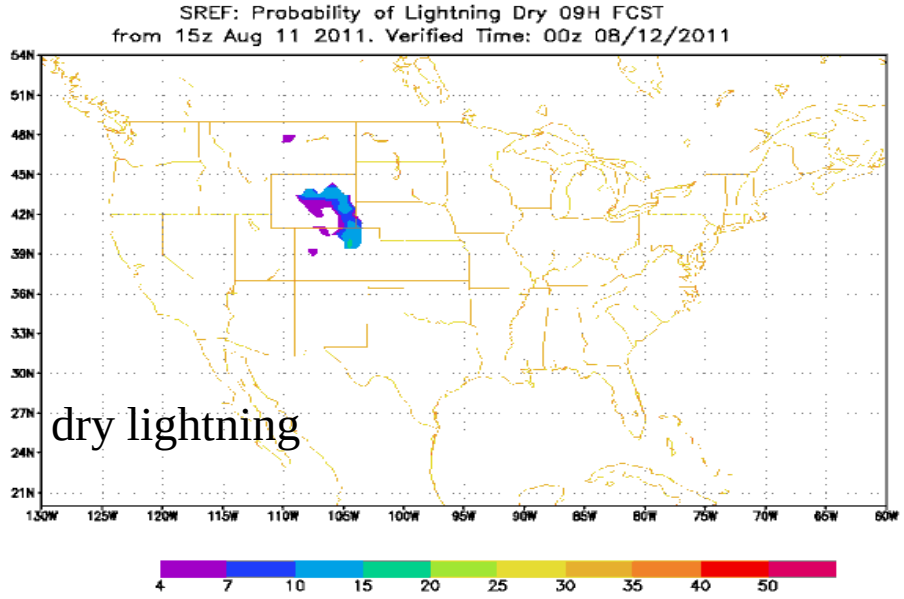


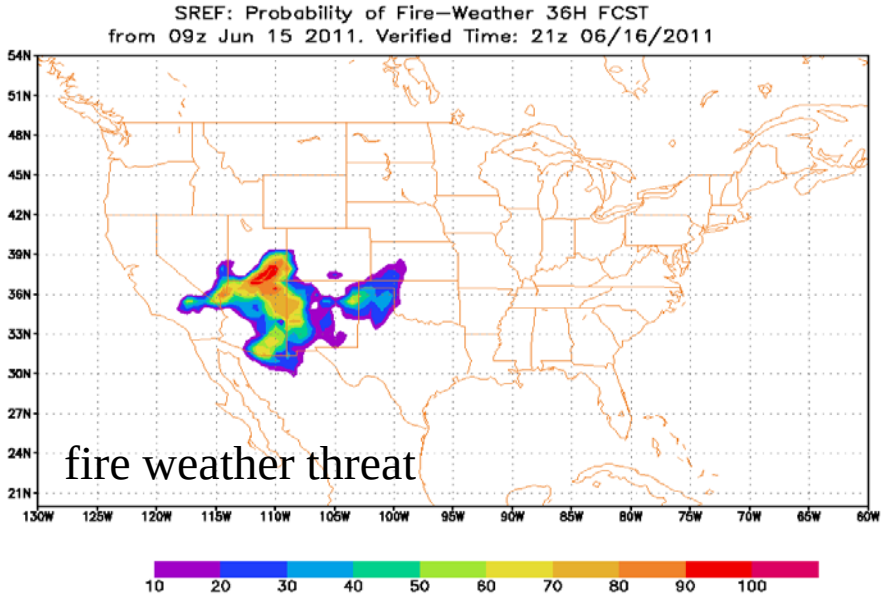


Ensemble products for convection and fire weather (SPC)

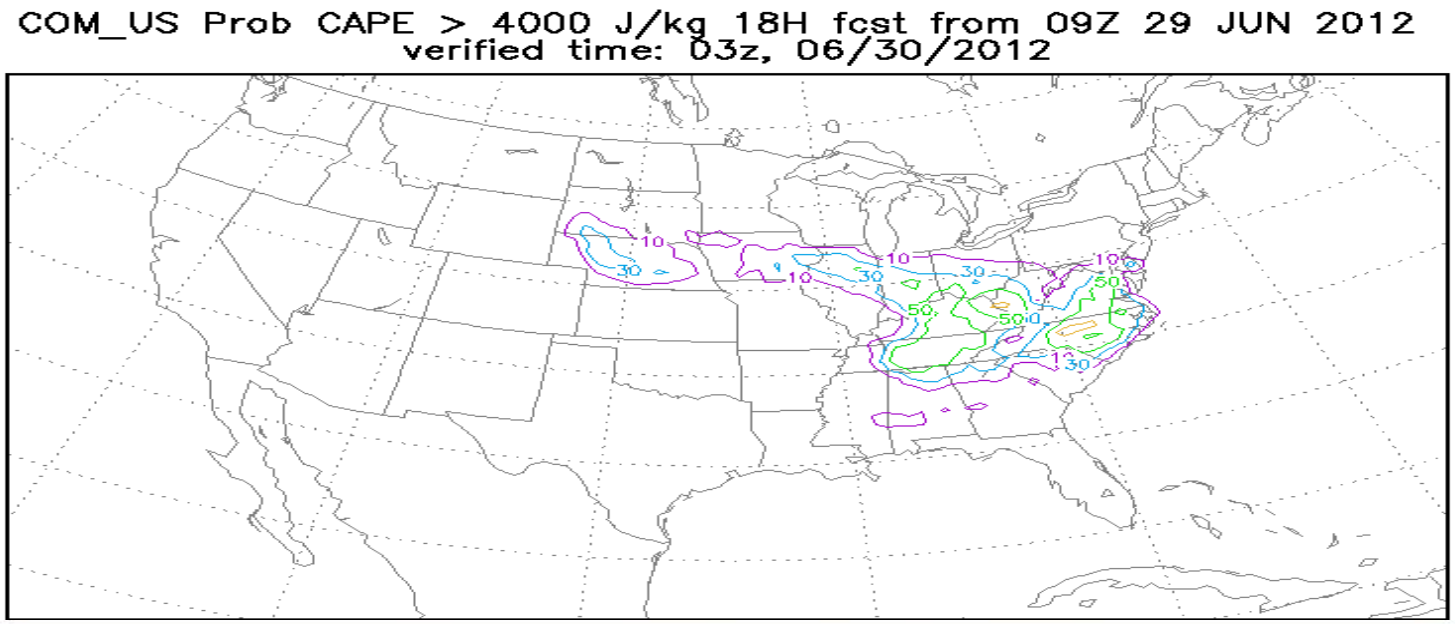


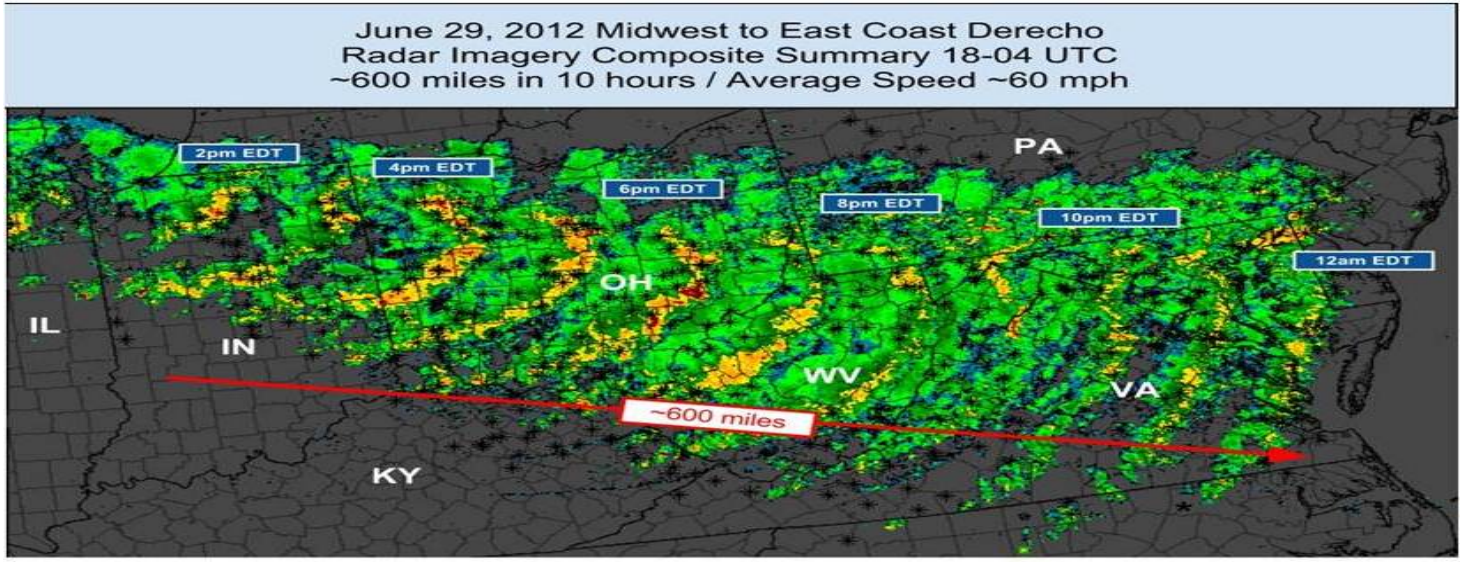






18h-forecast of prob of CAPE > 4000 J/kg (valid at 03z, 6/30/2012)

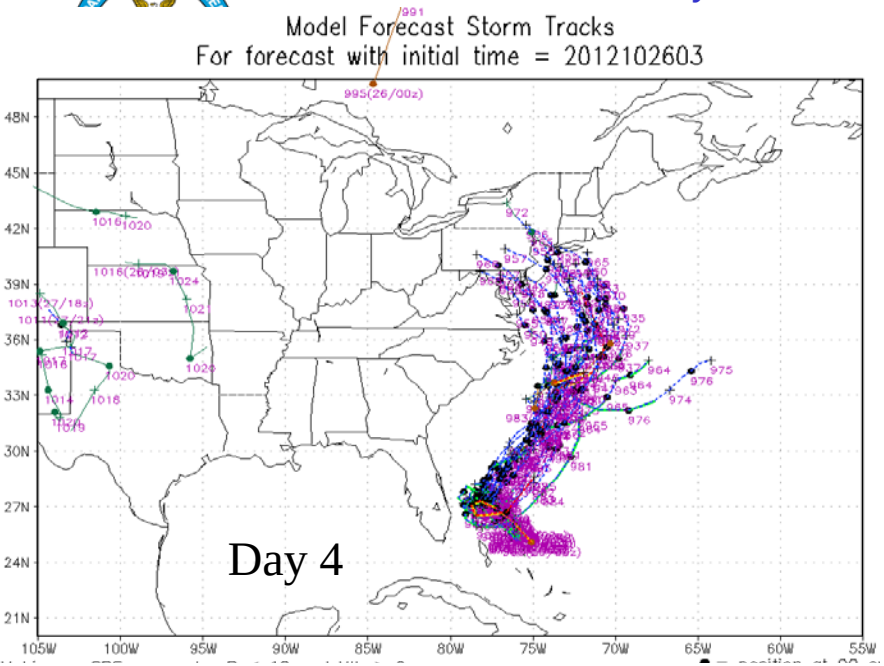


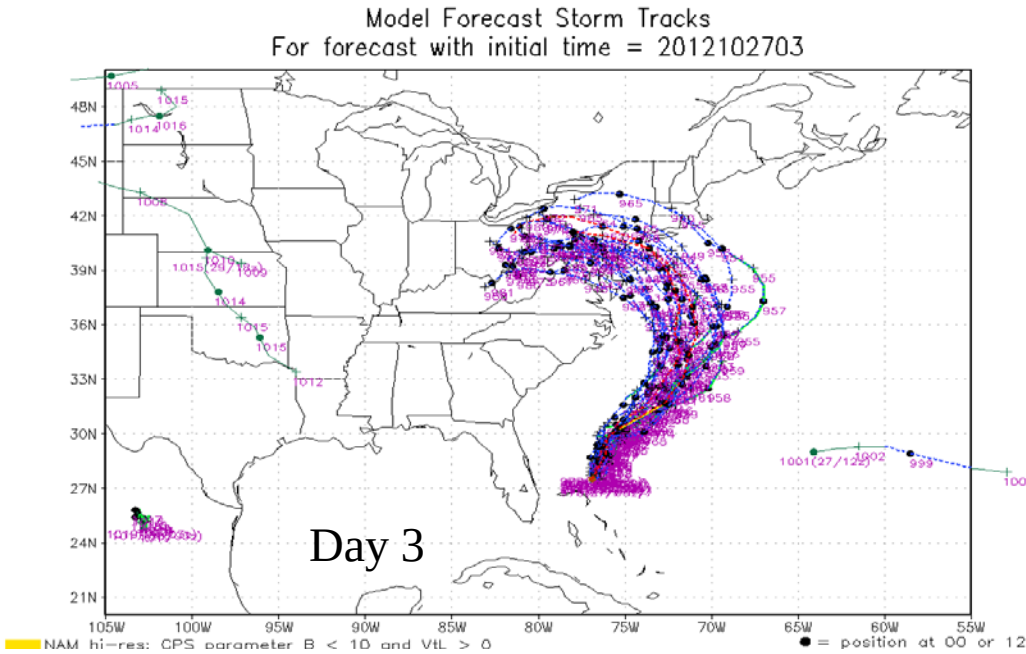


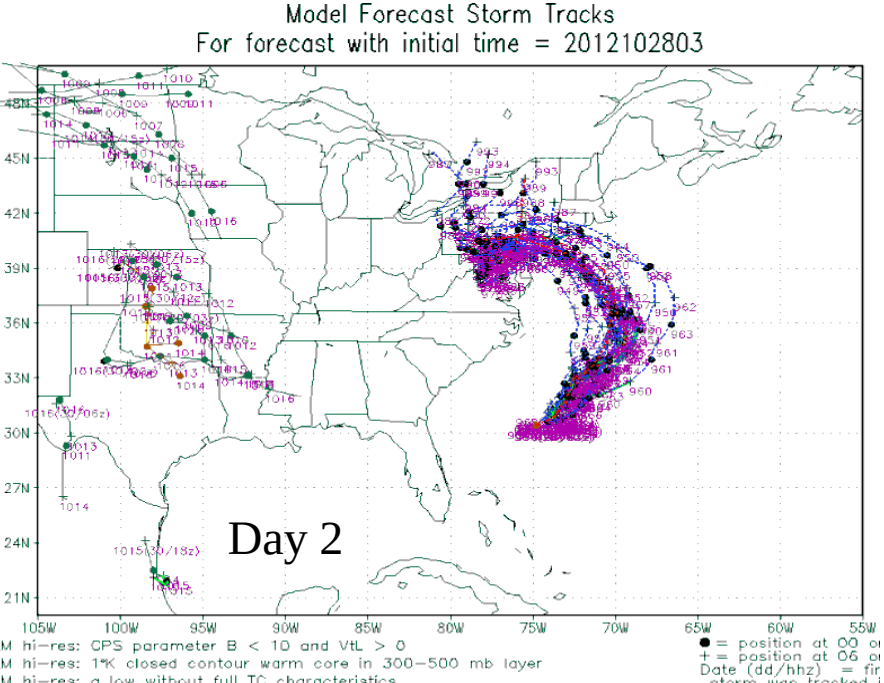
Over 500 preliminary thunderstorm wind reports indicated by *
Peak wind gusts 80-100mph. Millions w/o power.

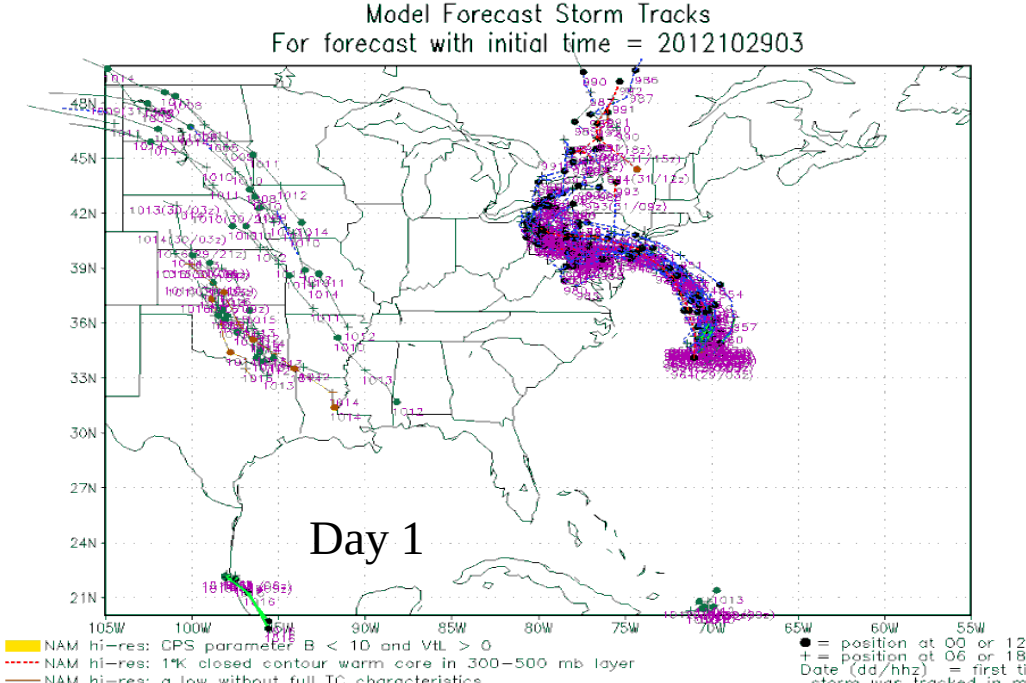
Summary Map by G. Carbin
NWS/Storm Prediction Center

NCEP SREF Track Forecasts of Hurricane Sandy (landfall near Atlantic City, New Jersey, 00z, Oct. 30, 2012)

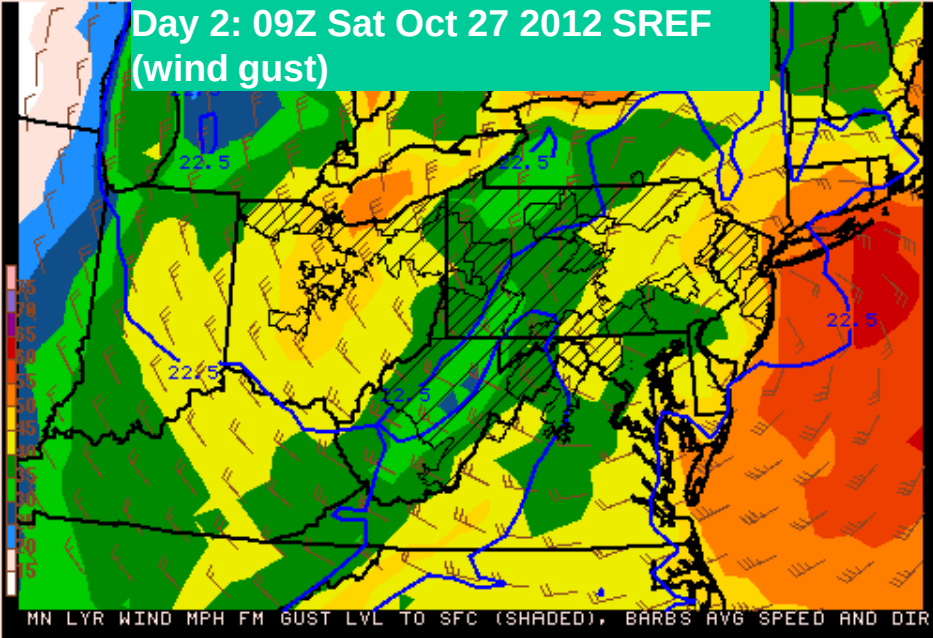


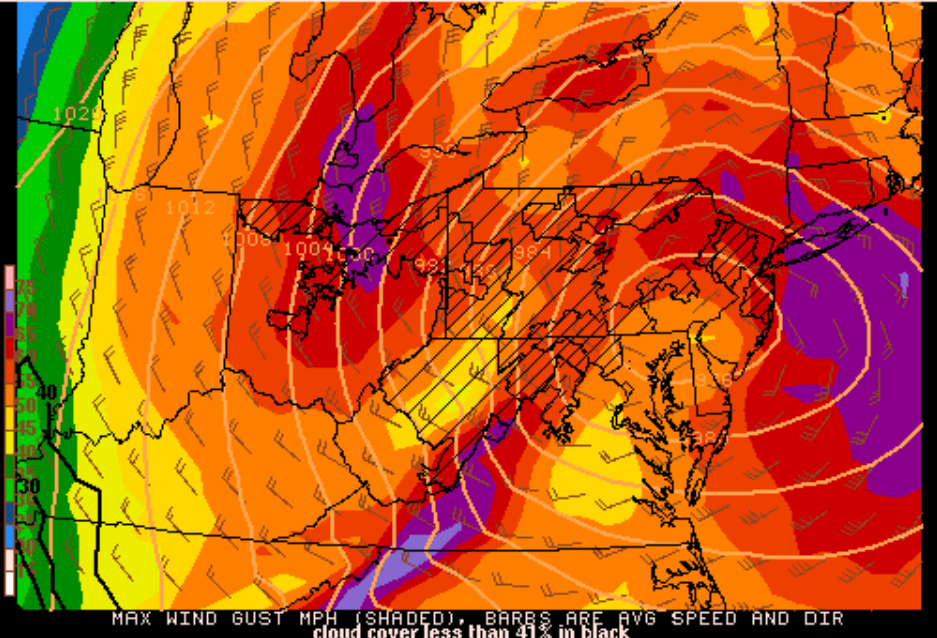


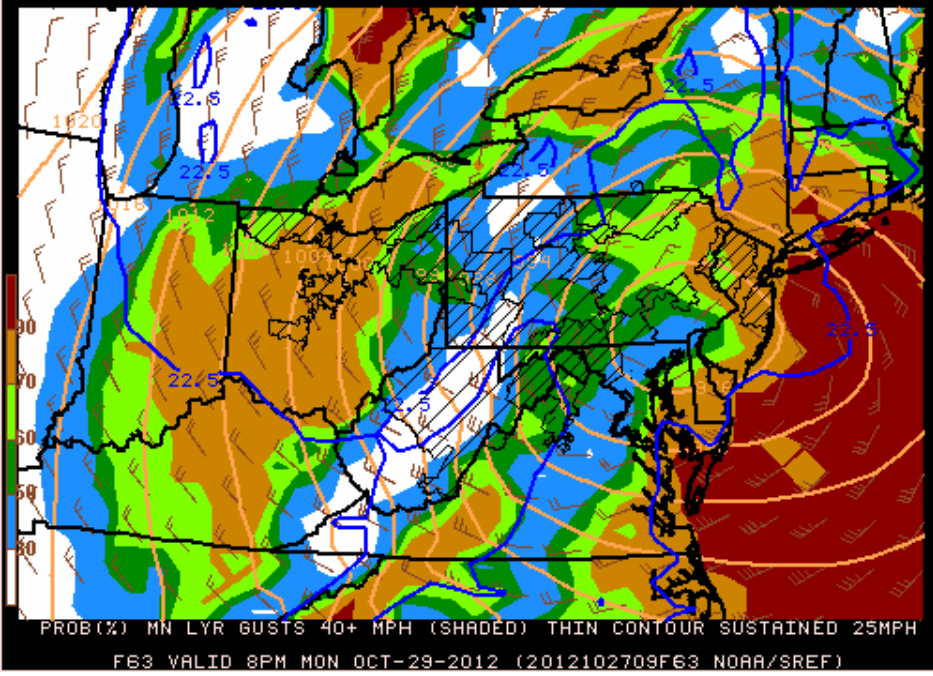


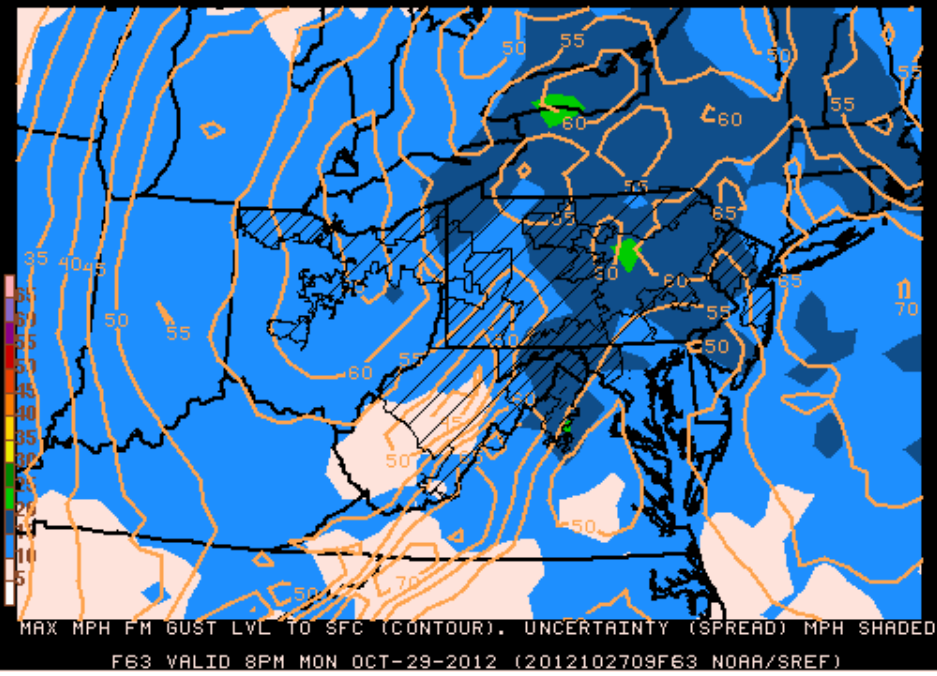


Day 2: 09Z Sat Oct 27 2012 SREF (wind gust)

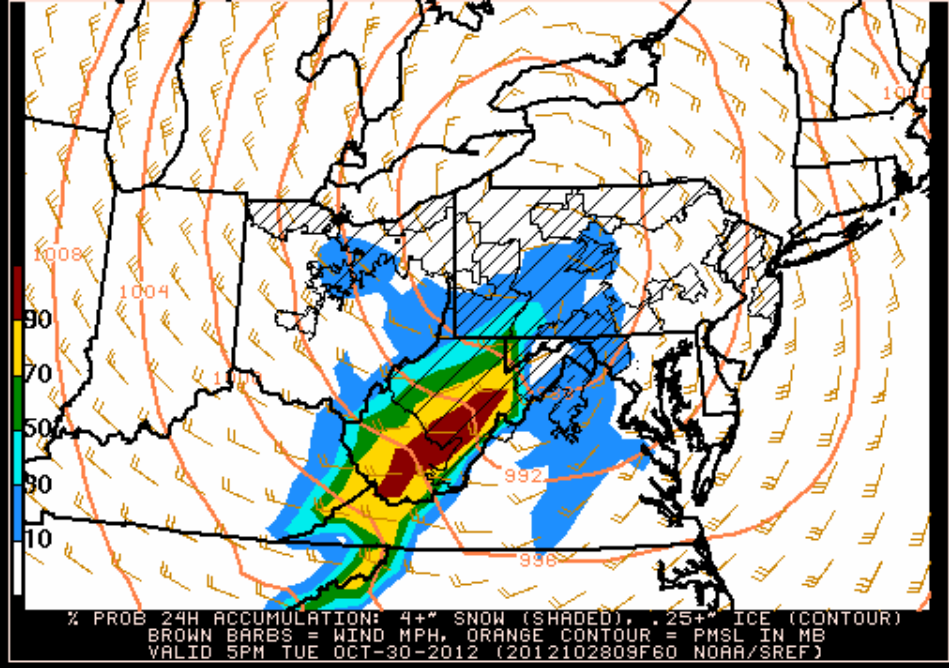


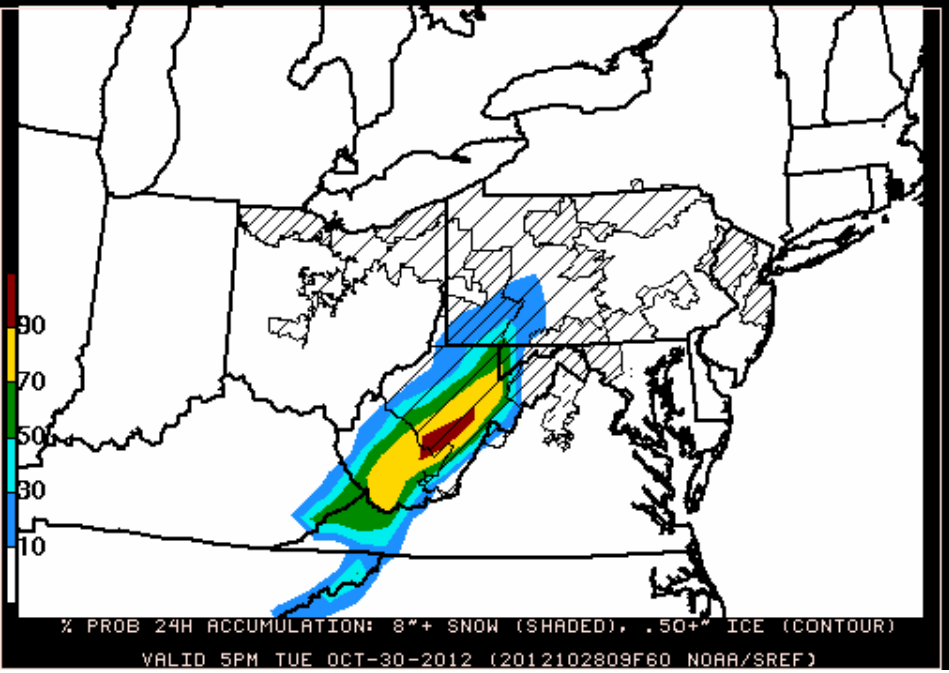


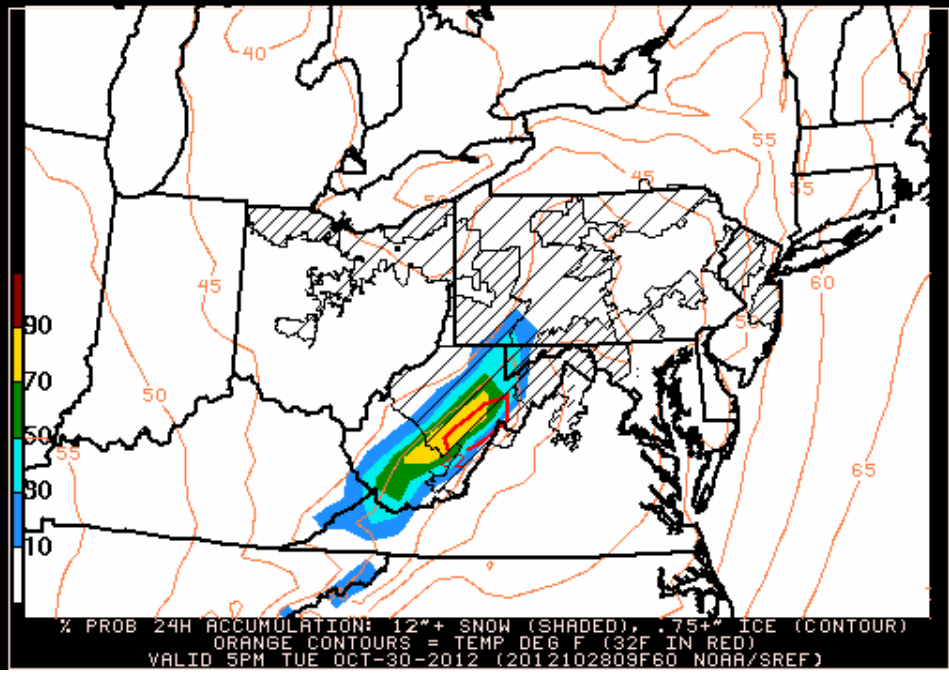




Day 2: 09Z Sat Oct 28 2012
SREF (ptype and snow acc)







Other regional ensemble systems at NCEP

What we have:

(1)NARRE-TL. North America Rapid Refresh Ensemble (NAM and RR, time lagged) for aviation: 12km, 10 members, hourly update, 12hr length (May 1, 2012)

(2)HREF. Hi-Res Ensemble Forecast (NMM, ARW and SREF) for convection: 5km, 44 members, 12hrly cycle, 48hr length (Dual-resolution hybrid ensembling method, Du 2004) (April, 2011)

(3)NSSE. NCEP Storm-Scale Ensemble for convection, aviation and dispersion (NMMB, NMMv1, NMMv2, ARW, time lagged): 4 km, 15 members, hourly update, 12h length (experimental, to be implemented in 2013)

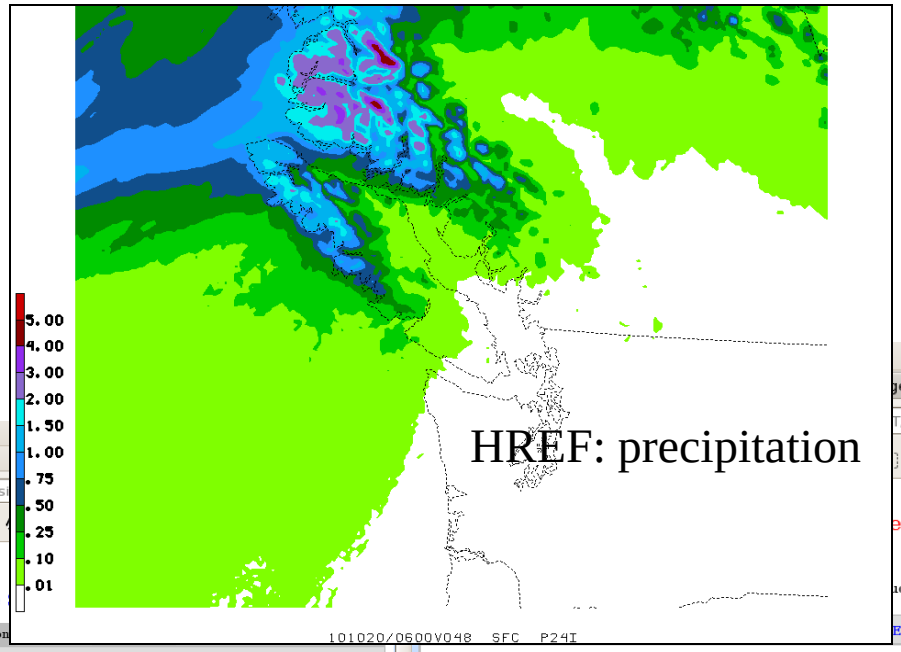
What we need:

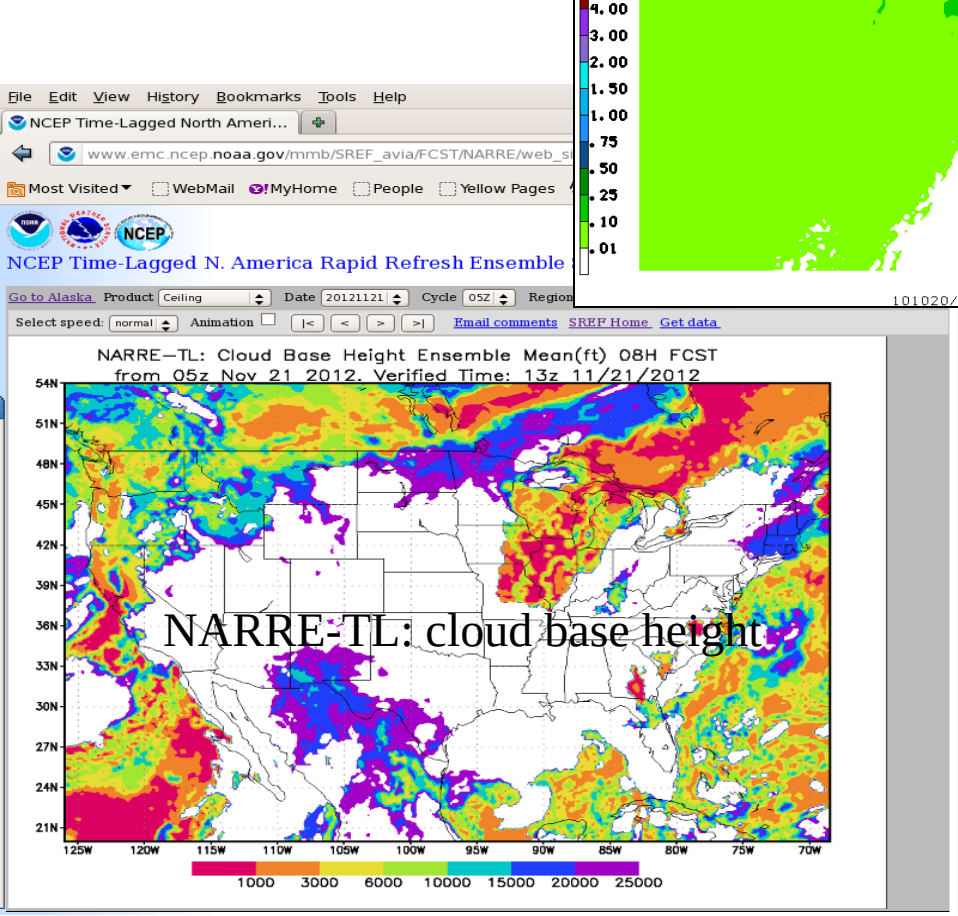
(1)Bigger and faster super-computer to actually run a 3km Hi-Res Rapid Refresh based NSSE system to replace NARRE-TL, HREF and NSSE as well as unifying all EMC regional models (NAM, RR, SREF)

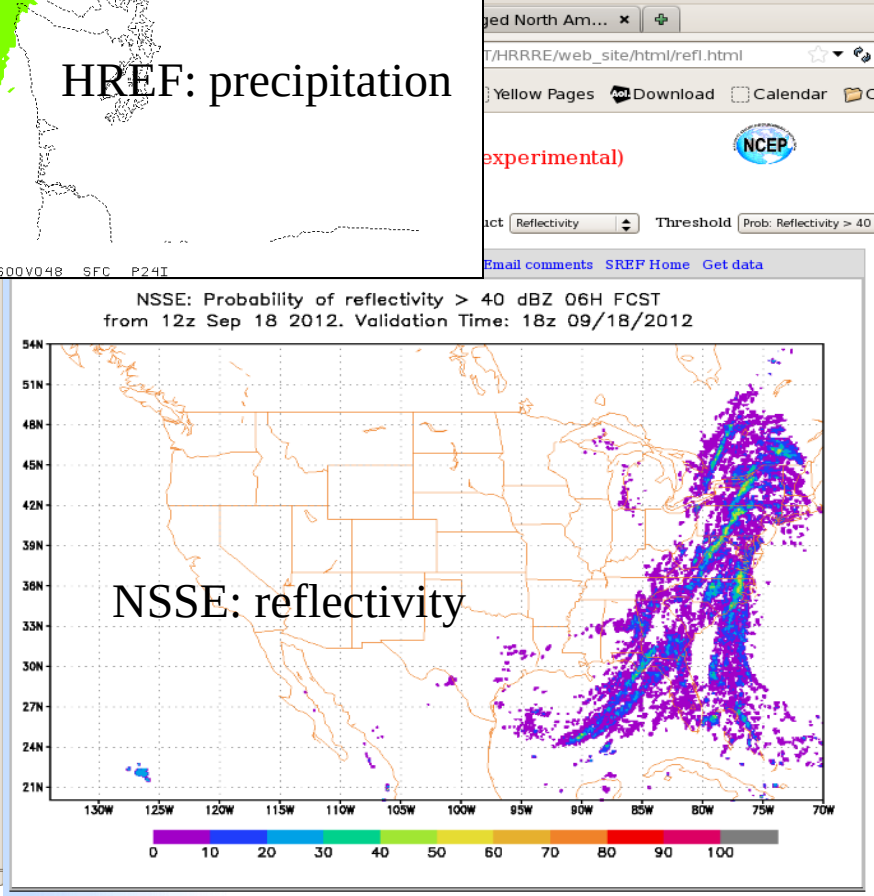
(2)New way to perturb IC and model physics?

(3)NAEFS_LAM by combining SREF with Canadian REPS

Other three regional ensemble systems at NCEP: NARRE-TL, HREF and NSSE







Last but not least:

Real-time SREF forecast data available to support community development such as the effort EarthCube by providing perturbed ICs and LBCs or as a bench mark to compare with for your research system (SREF covers North America)

- NOMADS -- http://nomads.ncep.noaa.gov/pub/data/nccf/com/sref/prod/
- ftp -- ftp://ftp.ncep.noaa.gov/pub/data/nccf/com/sref/prod/

Spatial "spread-skill relation" is a main problem of current ensemble systems: in area of small fcst error, spread is too big; for area of large fcst error, spread is not big enough; large spread exists but is not overlapping with large fcst error area → a challenge to both IC and physics perturbation scheme design