



**N
C
E
P**

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



SREFv6.0.0 (16km, Aug, 2012)



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

SREFv1.0.0 (48km, Apr, 2001)



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:

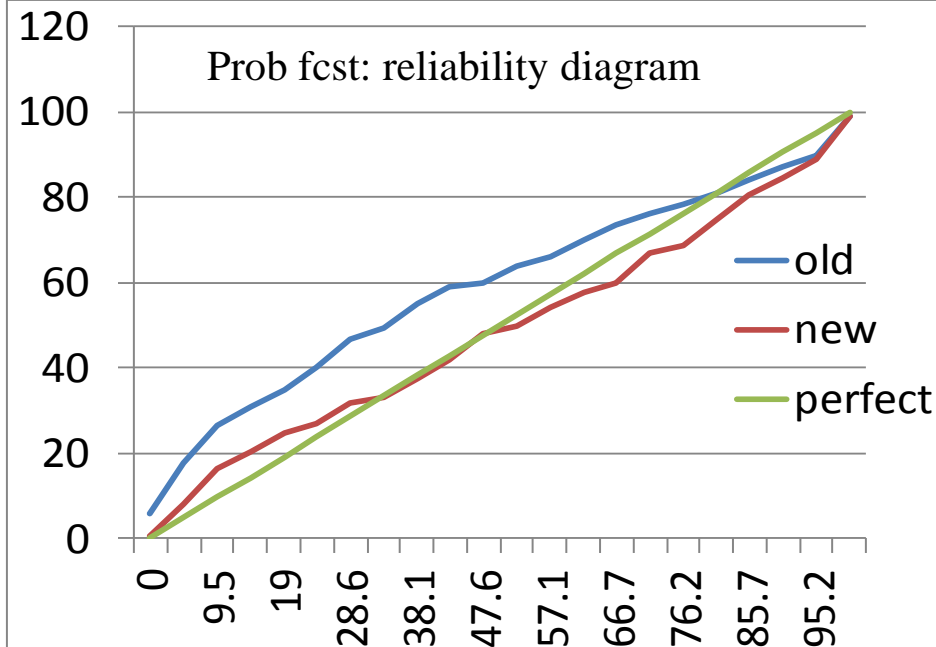
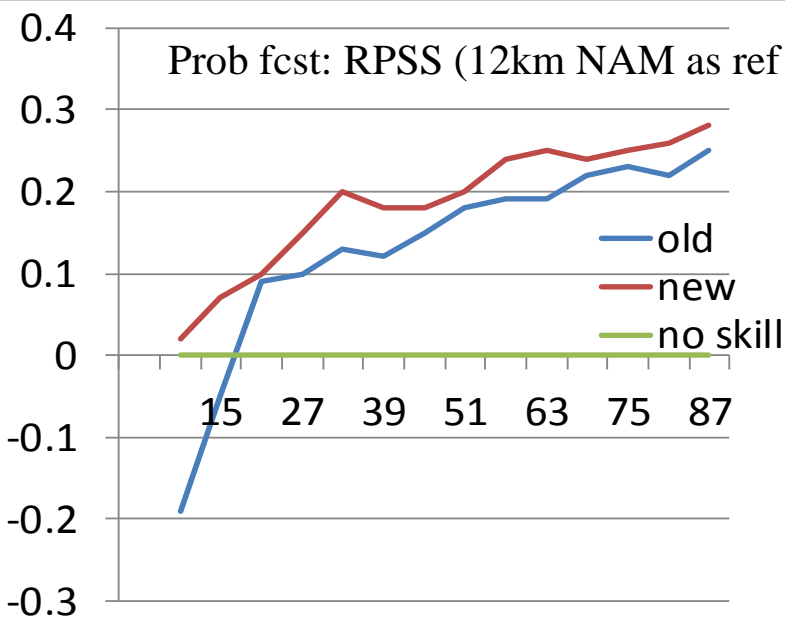
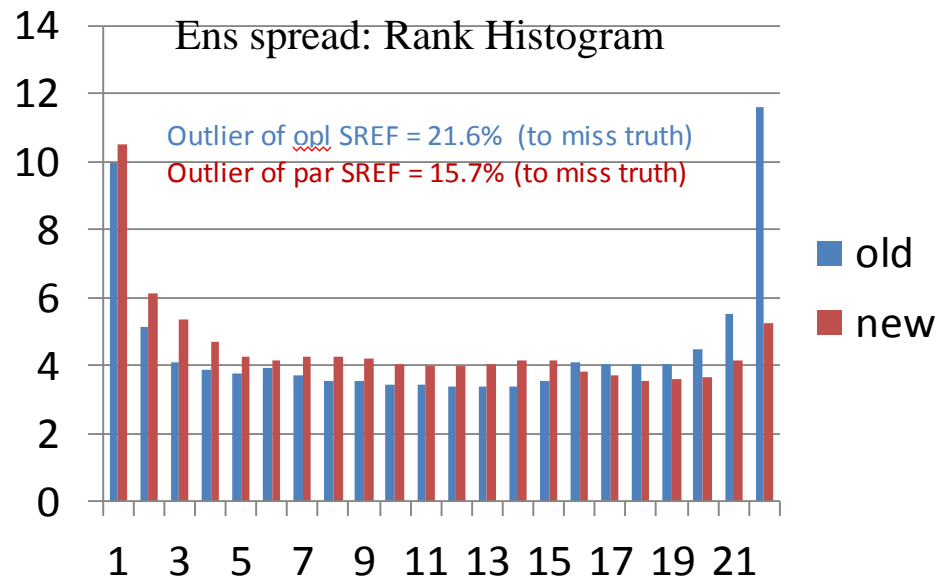
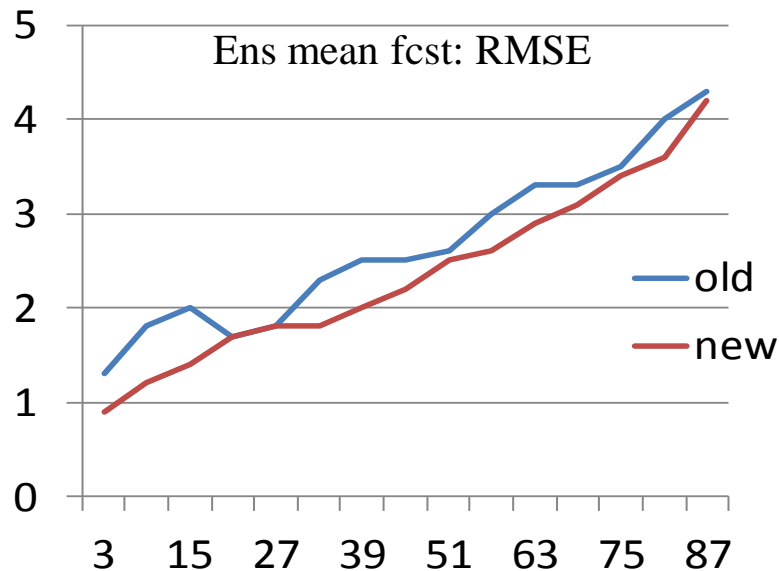
- (1) Multi-model (16km): NMMB, WRF_NMM, WRF_ARW
- (2) Multi-physics: various flavors from NMM, NCAR, GFS, RR
- (3) Stochastic parameterization (Teixeira and Reynolds 2008) in NMMB model is in place but not turned on (more verification)
- (4) Stochastic kinetic energy backscatter (SKEB) scheme in WRF-ARW 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:

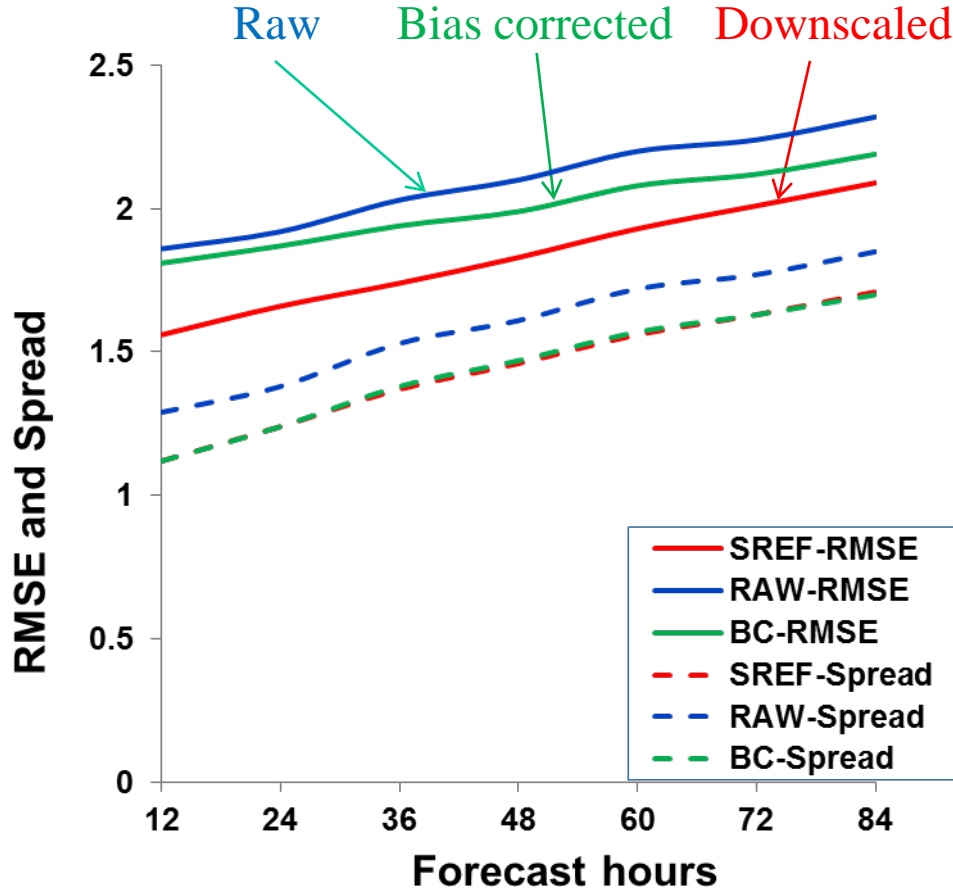
- (1) Decaying-average method for bias correction for basic atmospheric variables (1st moment only)
- (2) Frequency-matching method for precipitation bias correction (1st moment only)
- (3) Downscaling of surface variables to 5km by applying the difference between lower-res and higher-res analysis
- (4) clustering
- (5) member performance ranking (different weights for different members)

What we need:

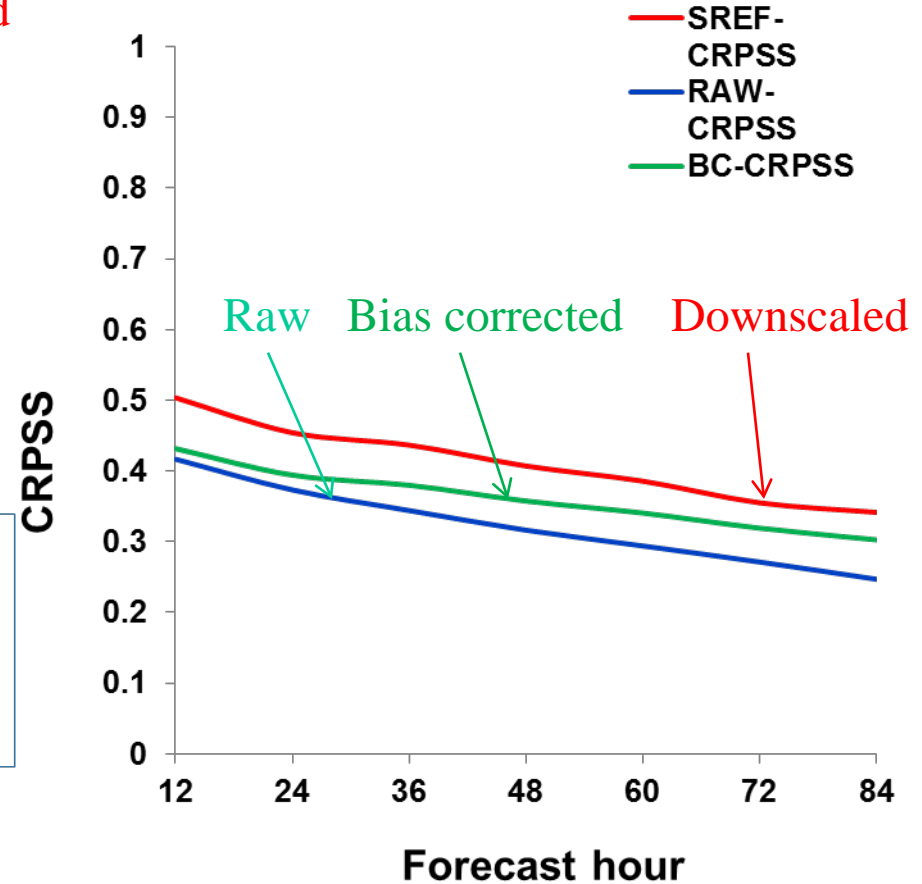
- (1) Bias correction of model variables directly on model native grid (before model post), so everything else produced by model post thereafter will be automatically bias corrected
- (2) 2nd moment (spread) calibration (Decaying-average Bayesian Model Averaging/MDL)
- (3) Higher-moment: e.g. calibrating 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)

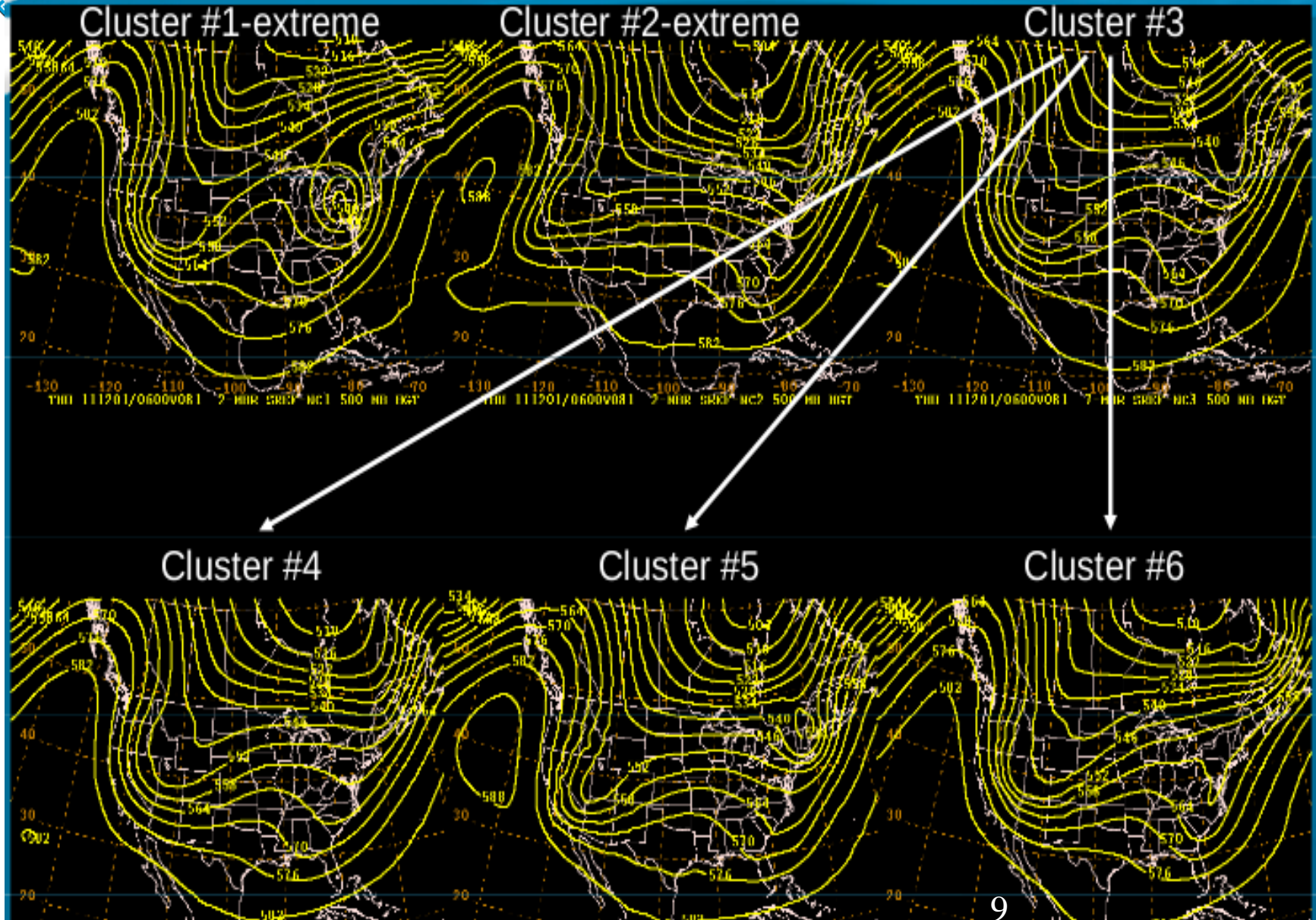


Ens mean (T2m)



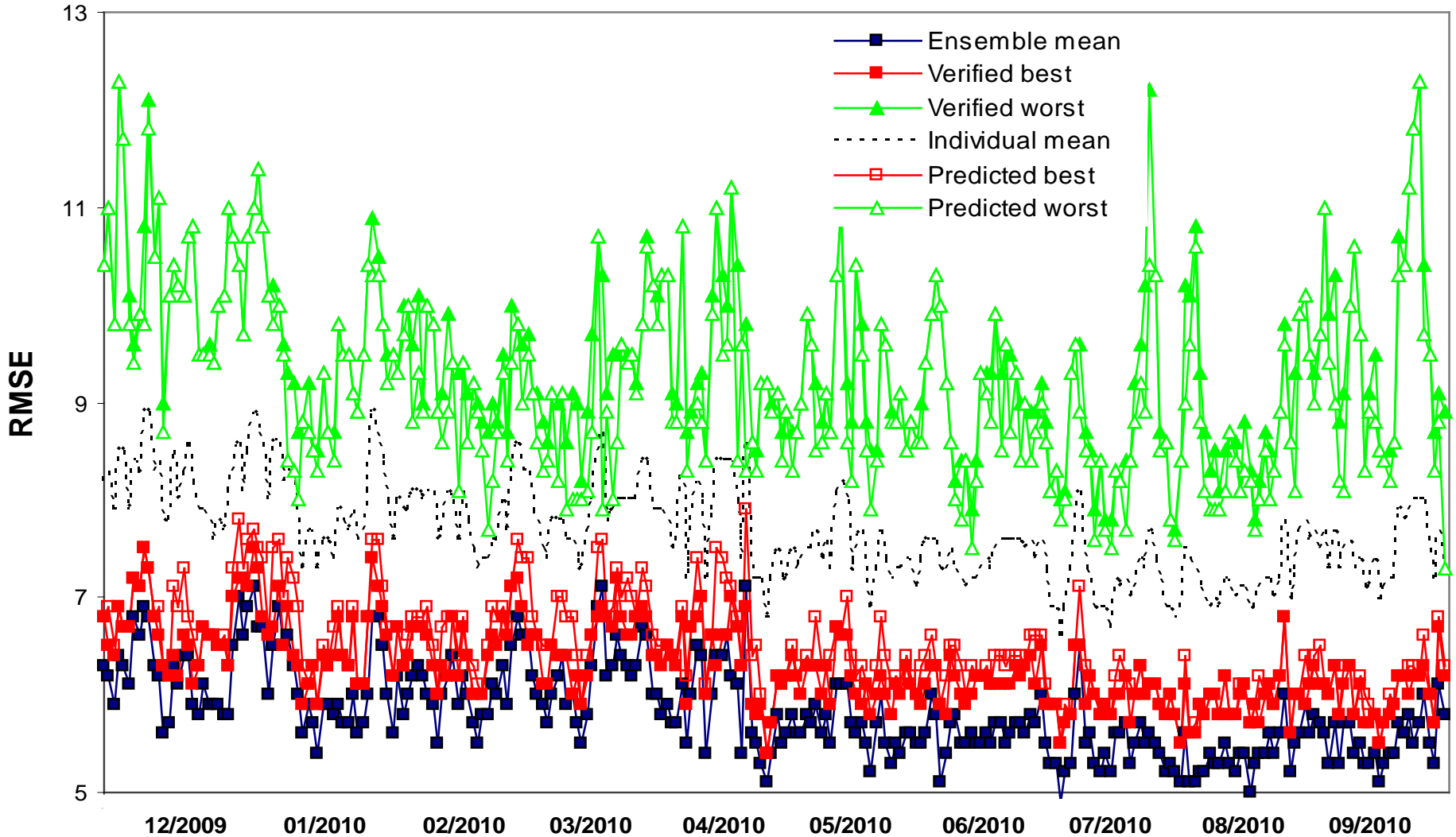
Probability

Example of Ensemble Clusters



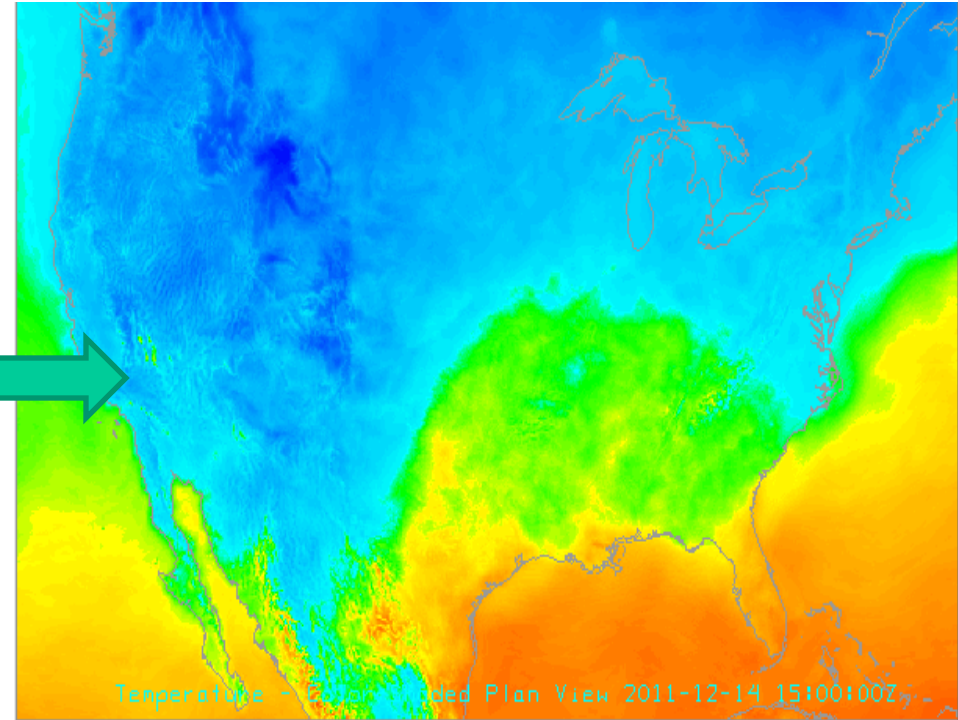
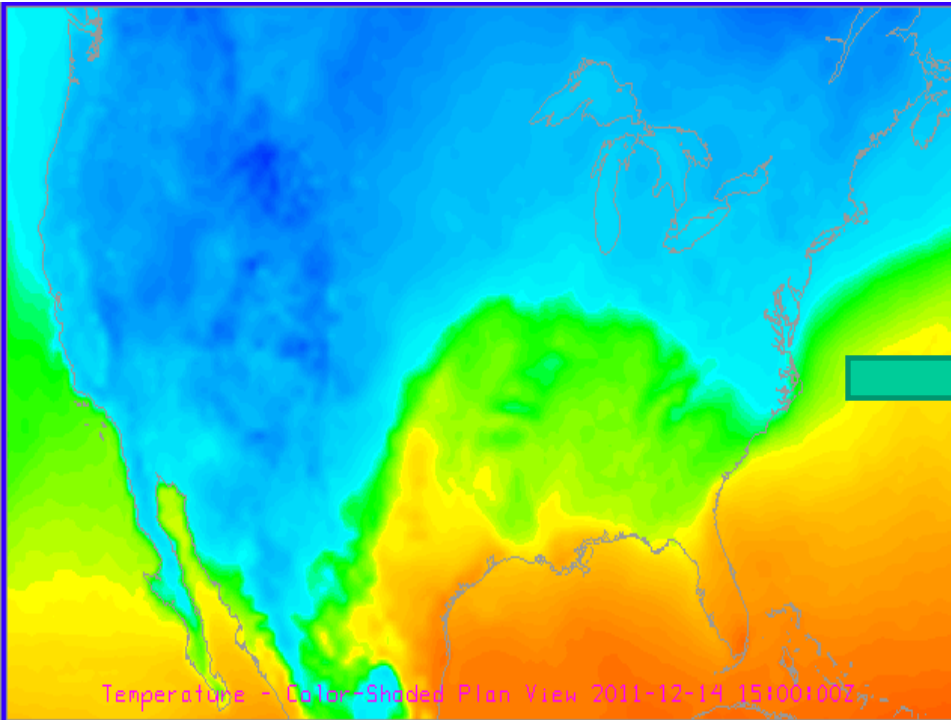


Individual member' performance ranking (weights for each members): Du and Zhou 2011 MWR





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



Before (40km)

After (5km)

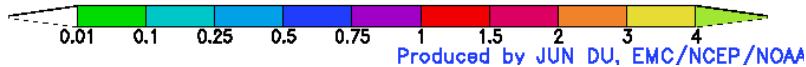
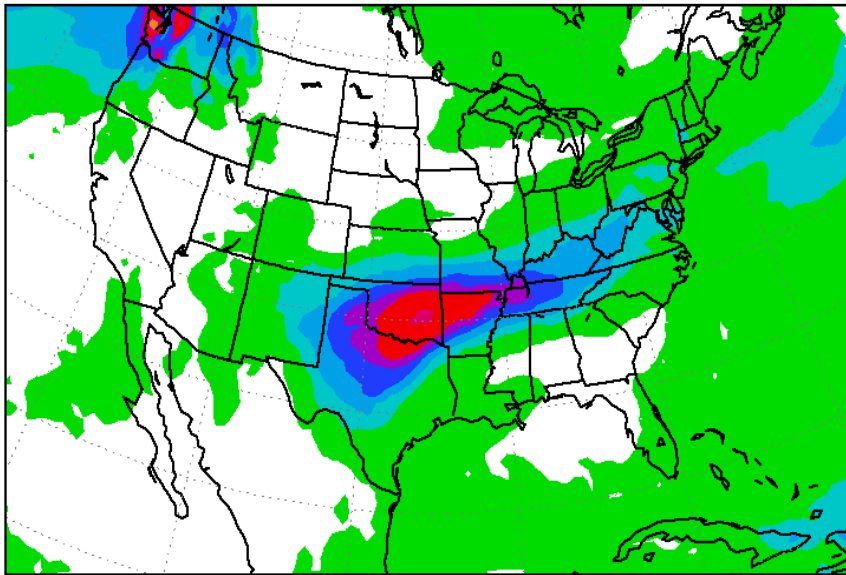


Bias correction can effectively remove over-predicted light precipitation and enhance under-predicted heavier precipitation



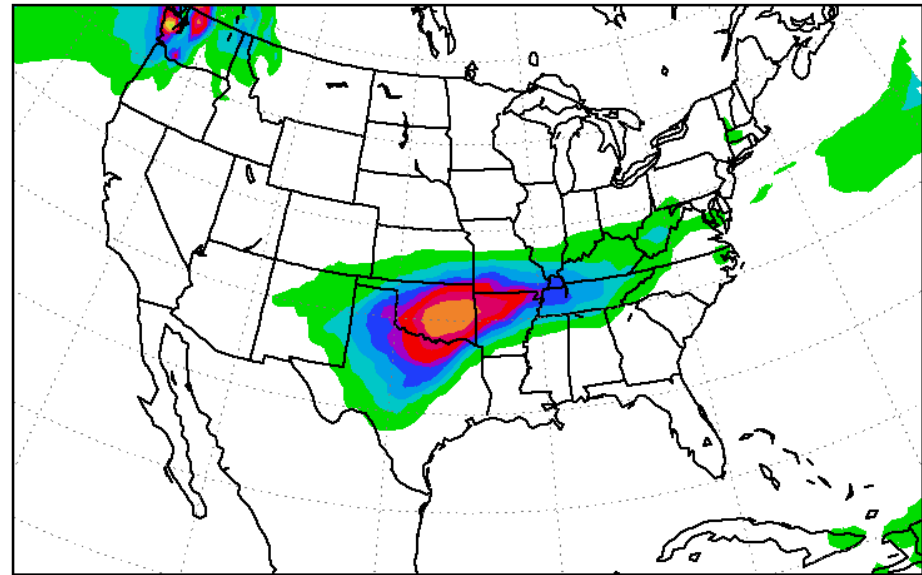
16km SREF mean (raw)

COM_US 03h-apcp (in) 87H fcst from 21Z 18 NOV 2011 (mem 1)
verified time: 12z, 11/22/2011



16km SREF mean (bias corrected)

COM_US 24h-apcp (in) 87H fcst from 21Z 18 NOV 2011 (mem 1)
verified time: 12z, 11/22/2011





Ensemble products

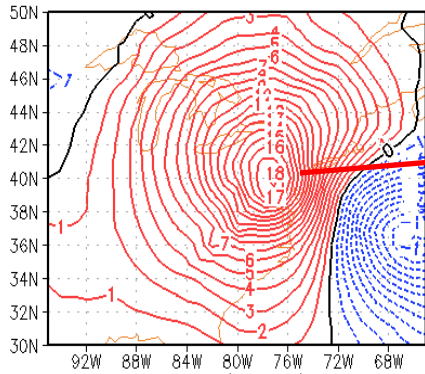
What we have:

- (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)

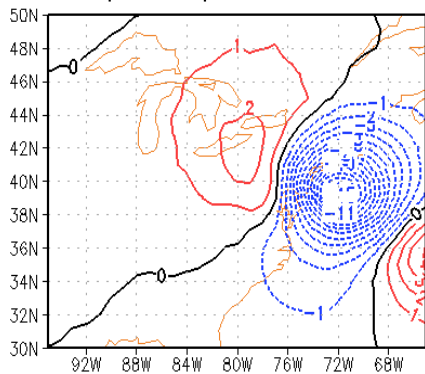
What we need?

- (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 visualization of uncertainty information

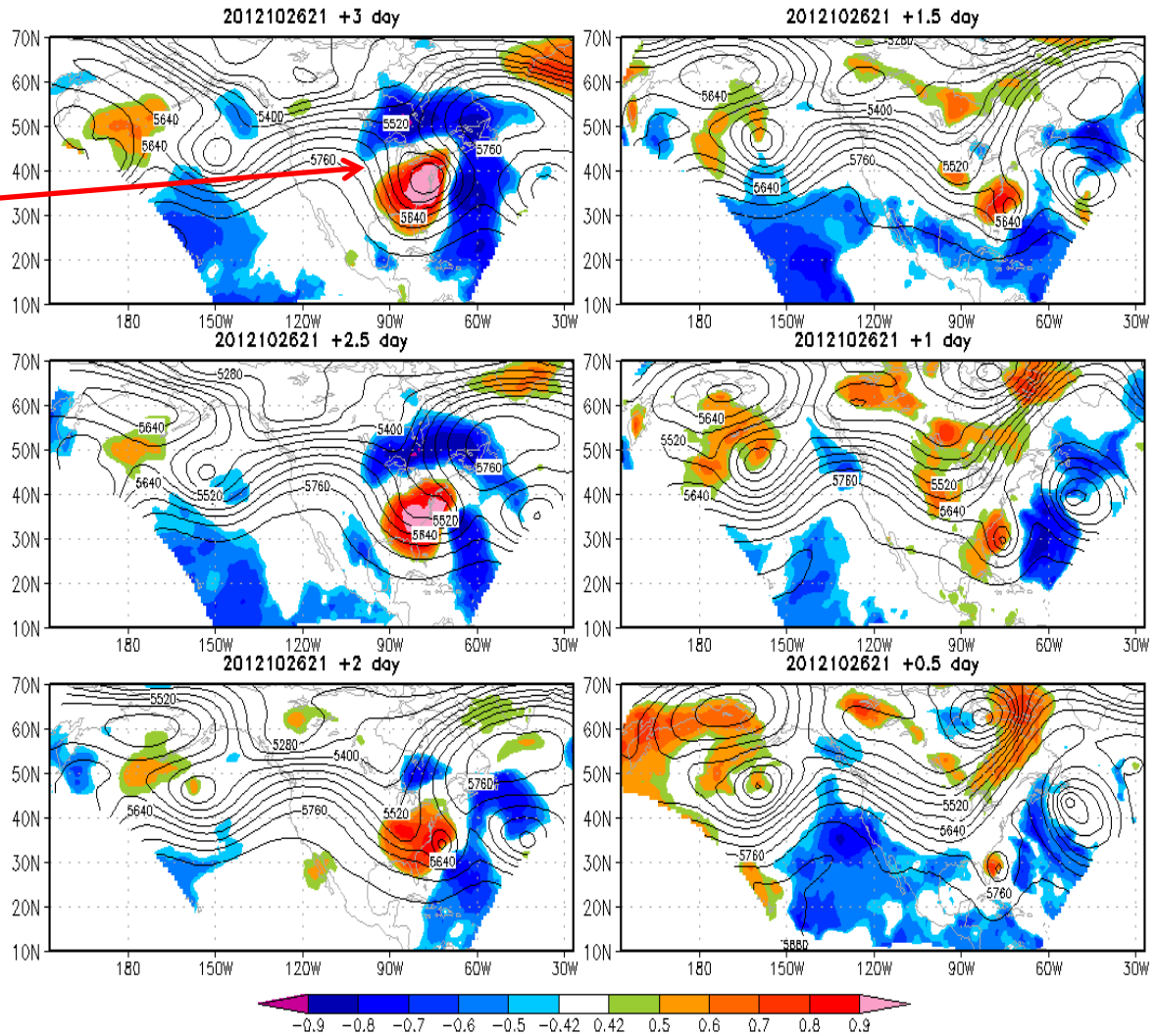
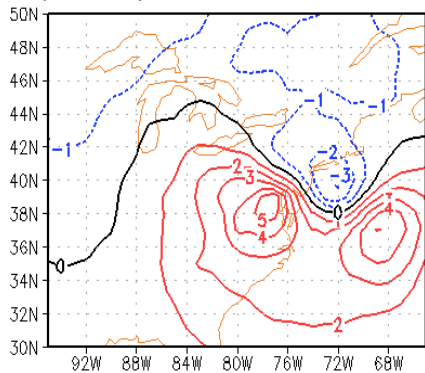
EOF1 pattern, explained variance: 70.9%



EOF2 pattern, explained variance: 13.5%



EOF3 pattern, explained variance: 6.100000000000001%



Sensitivity of EOF PC1 to Z500 field (Shaded)

SREF ensemble mean Z500 (Contour); unit(mb); IT:2012102621

Valid area: LON from 95W to 65W, LAT from 30N to 50N; VT: 2012102921

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	<ul style="list-style-type: none"> • 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 	<ul style="list-style-type: none"> • 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, 700, 600, 500, 300, and 250mb • Thickness 218600m, 12900m, 18005m • Thickness of 1000-850, 1000-500, 850-700mb
Prob	<ul style="list-style-type: none"> • 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 	<ul style="list-style-type: none"> • 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

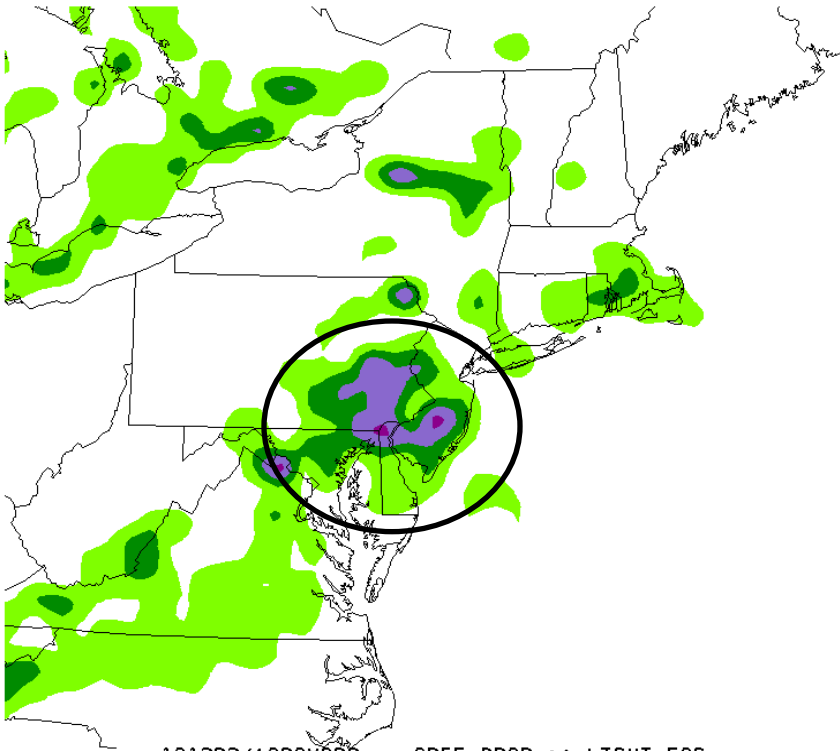
Max	<ul style="list-style-type: none"> • T2m • SLP • 10m U, V • Ceiling • Visibility 	<ul style="list-style-type: none"> • T at 700, 600, 500, 300 mb • height at 1000, 850, 700, 600, 500, 300, 250mb • U, V at 1000, 850, 700, 600, 500, 300, 250mb • RH at 850, 700, 600, 500, 300, 250mb • Td at 850, 700, 500, 300mb
Min	<ul style="list-style-type: none"> • T2m • SLP • 10m U, V • Ceiling • Visibility 	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • T2m • SLP • 10m U, V • Ceiling • Visibility 	<ul style="list-style-type: none"> • 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%	<ul style="list-style-type: none"> • T2m • SLP • 10m U, V • Ceiling • Visibility 	<ul style="list-style-type: none"> • 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%	<ul style="list-style-type: none"> • T2m • SLP • 10m U, V • Ceiling • Visibility 	<ul style="list-style-type: none"> • 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%	<ul style="list-style-type: none"> • T2m • SLP • 10m U, V • Ceiling • Visibility 	<ul style="list-style-type: none"> • 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%	<ul style="list-style-type: none"> • T2m • SLP • 10m U, V • Ceiling • Visibility 	<ul style="list-style-type: none"> • 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%	<ul style="list-style-type: none"> • T2m • SLP • 10m U, V • Ceiling • Visibility 	<ul style="list-style-type: none"> • 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



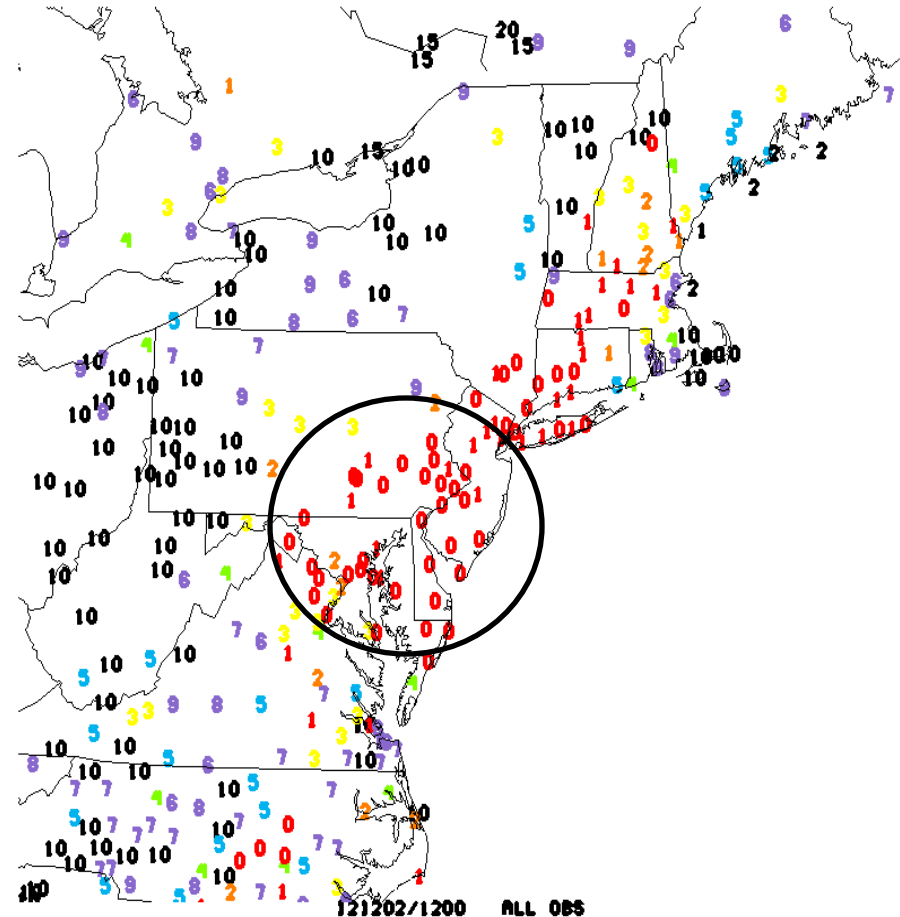
SREF fog product (the Dec. 2/Sunday dense fog case in the east coast: general signal is there but magnitude is underdone likely due to not enough vertical levels within boundary layer of the SREF models)



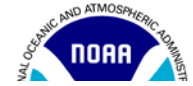
SREF-based 9h prob forecast of fog (<1 mile) from 03z, 12/2/12, Sunday



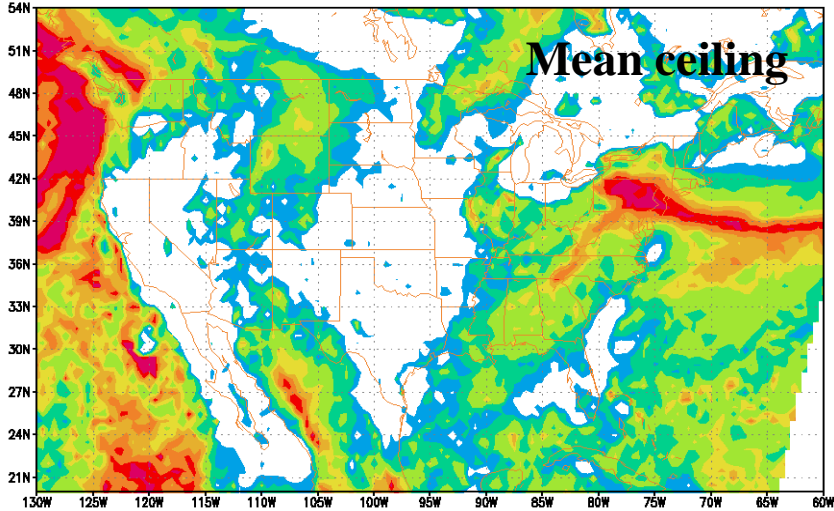
Observed visibility



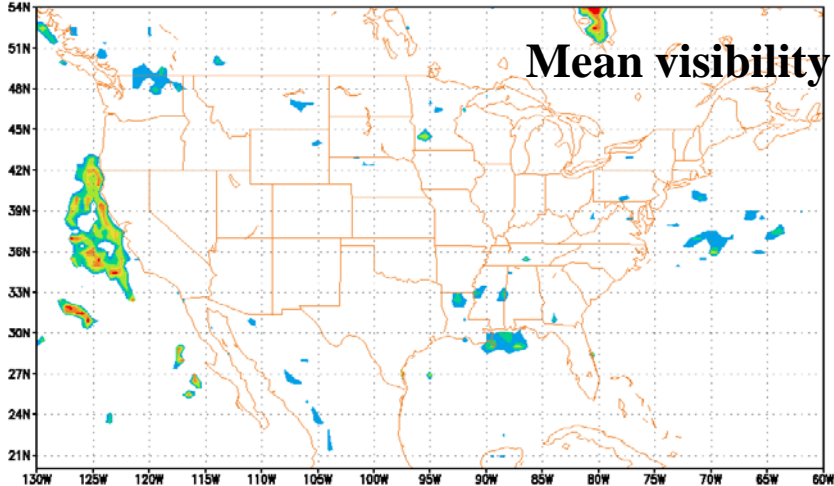
Ensemble products for aviation weather



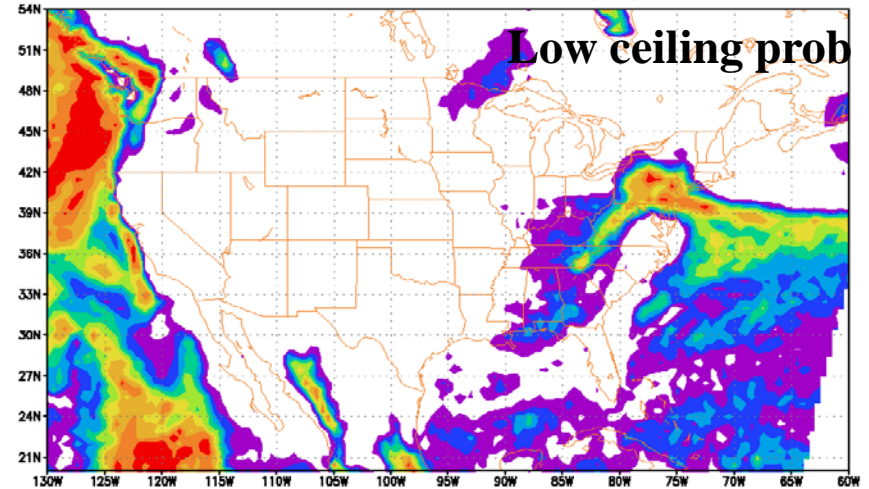
SREF: Mean Ceiling height (m) 24H FCST
from 21z Jul 19 2012. Verified Time: 21z 07/20/2012



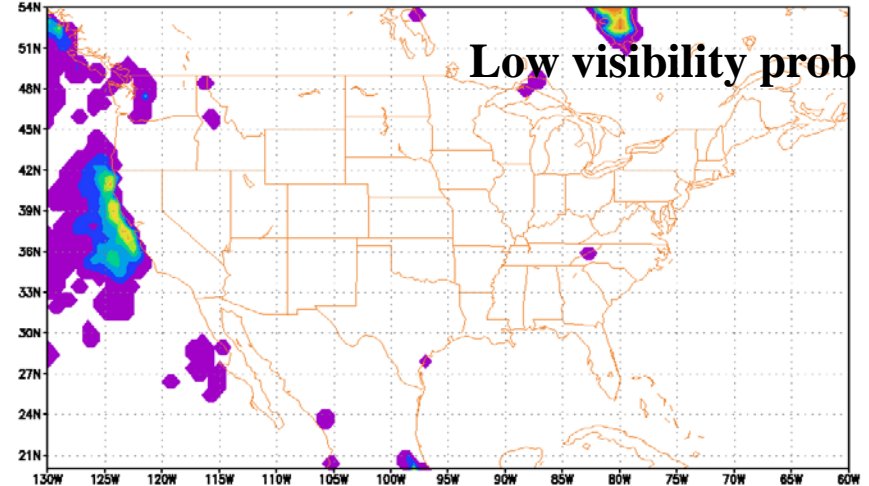
SREF: Mean Visibility (m) 24H FCST
from 21z Jul 19 2012. Verified Time: 21z 07/20/2012



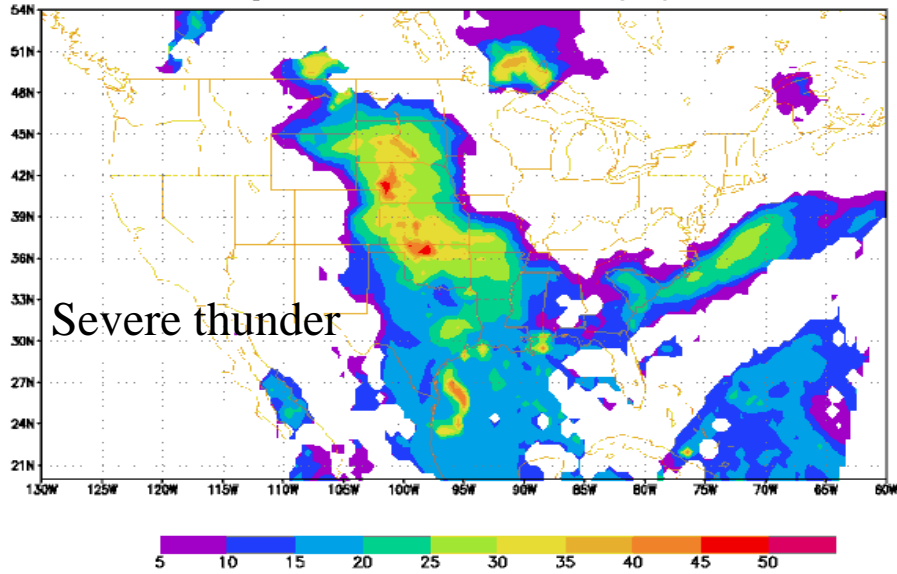
SREF: Probability of ceiling < 600 m 24H FCST
from 21z Jul 19 2012. Verified Time: 21z 07/20/2012



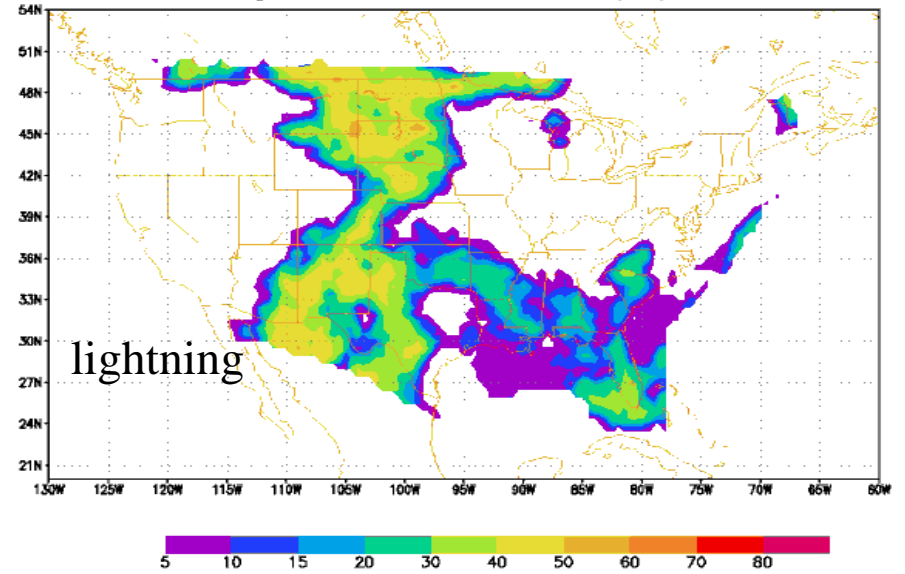
SREF: Probability of Vis < 1600 m 24H FCST
from 21z Jul 19 2012. Verified Time: 21z 07/20/2012



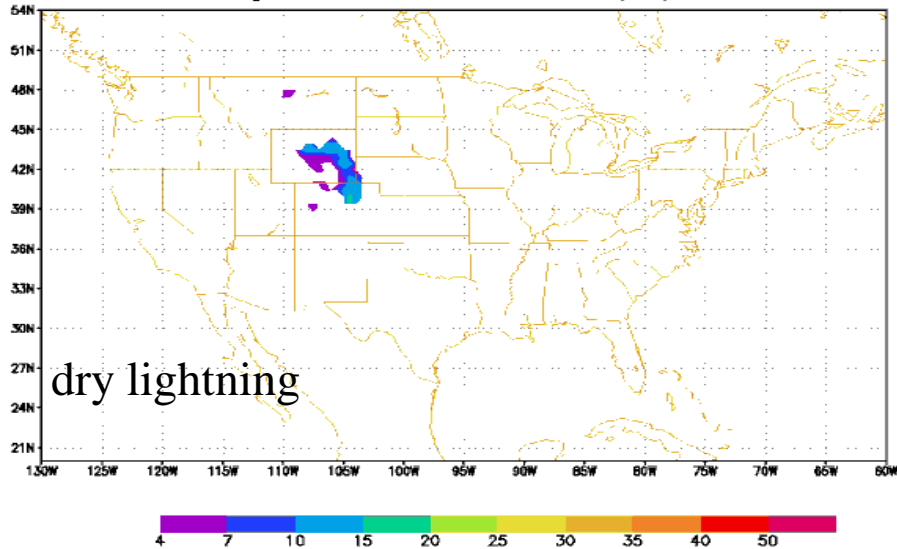
SREF: Probability of Severe Thunder Storm 12H FCST
from 15z Aug 11 2011. Verified Time: 03z 08/12/2011



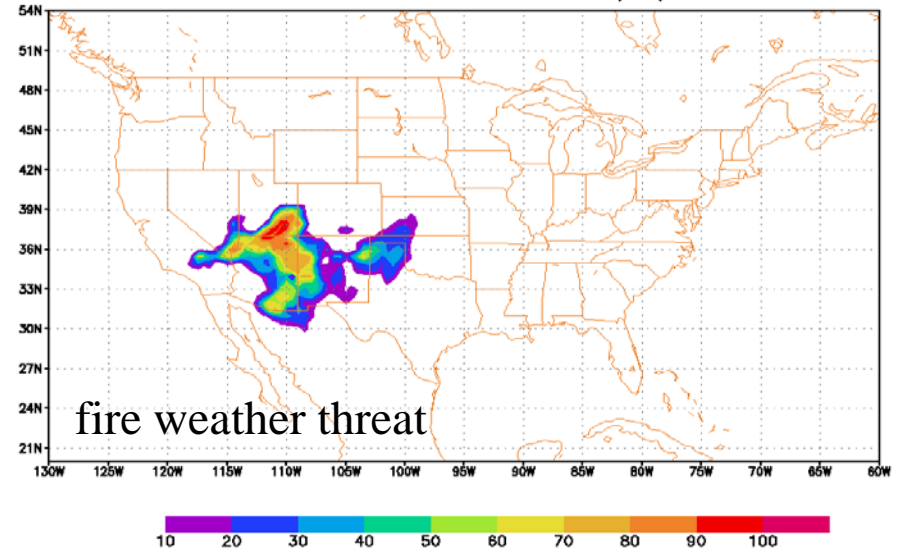
SREF: Probability of Lightning Hrly Rgn3 12H FCST
from 15z Aug 11 2011. Verified Time: 03z 08/12/2011



SREF: Probability of Lightning Dry 09H FCST
from 15z Aug 11 2011. Verified Time: 00z 08/12/2011

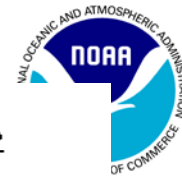


SREF: Probability of Fire-Weather 36H FCST
from 09z Jun 15 2011. Verified Time: 21z 06/16/2011

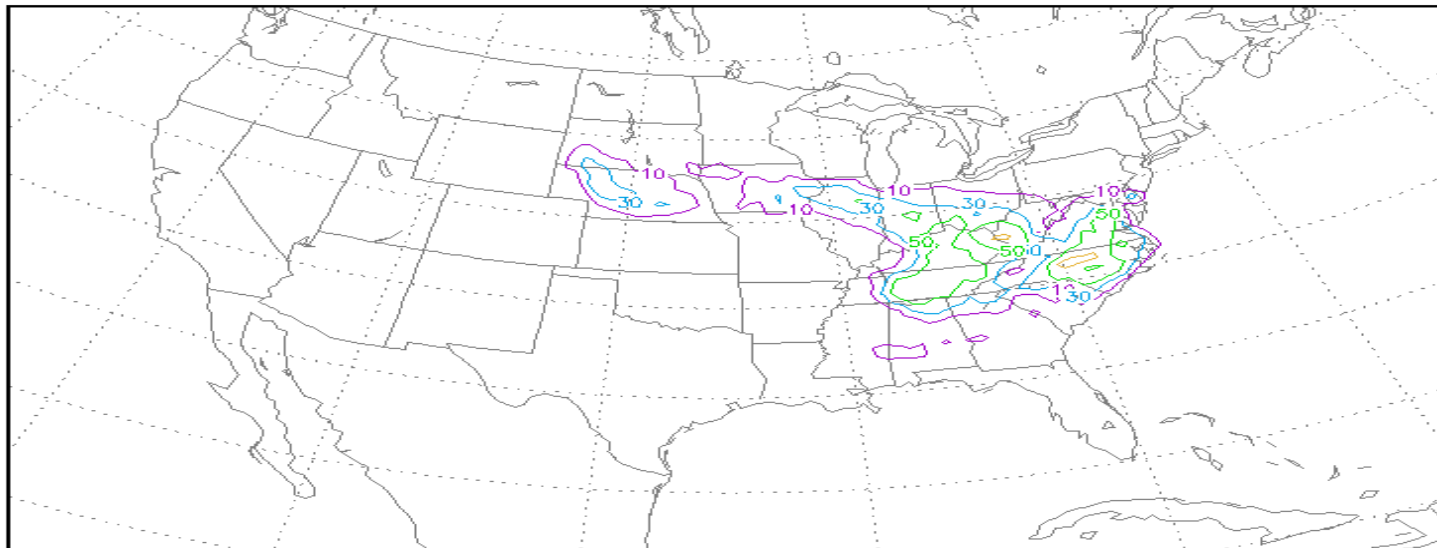




18h-forecast of prob of CAPE > 4000 J/kg (valid at 03z, 6/30/2012)



COM_US Prob CAPE > 4000 J/kg 18H fcst from 09Z 29 JUN 2012
verified time: 03z, 06/30/2012



June 29, 2012 Midwest to East Coast Derecho
Radar Imagery Composite Summary 18-04 UTC
~600 miles in 10 hours / Average Speed ~60 mph



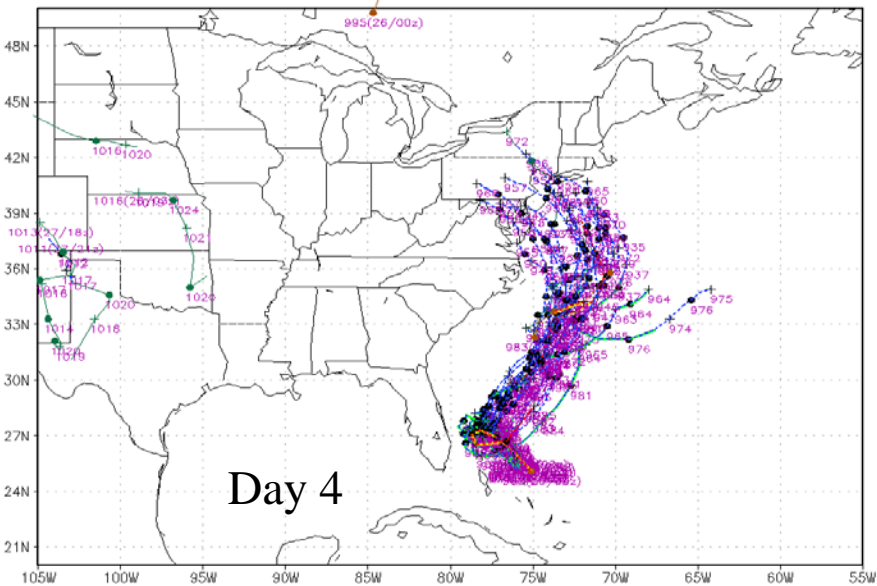
Over 500 preliminary thunderstorm wind reports indicated by *
Peak wind gusts 80-100mph. Millions w/o power.

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)

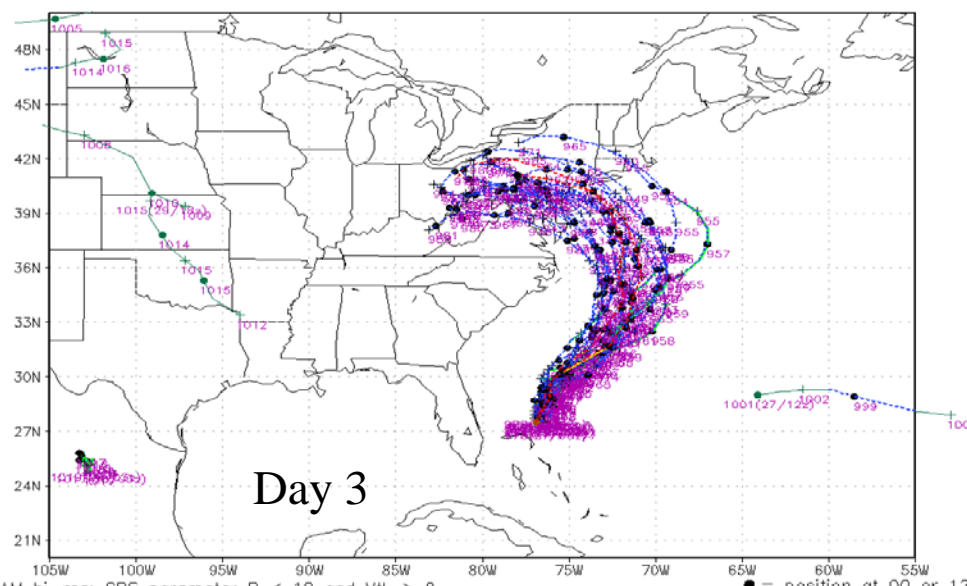


Model Forecast Storm Tracks
For forecast with initial time = 2012102603



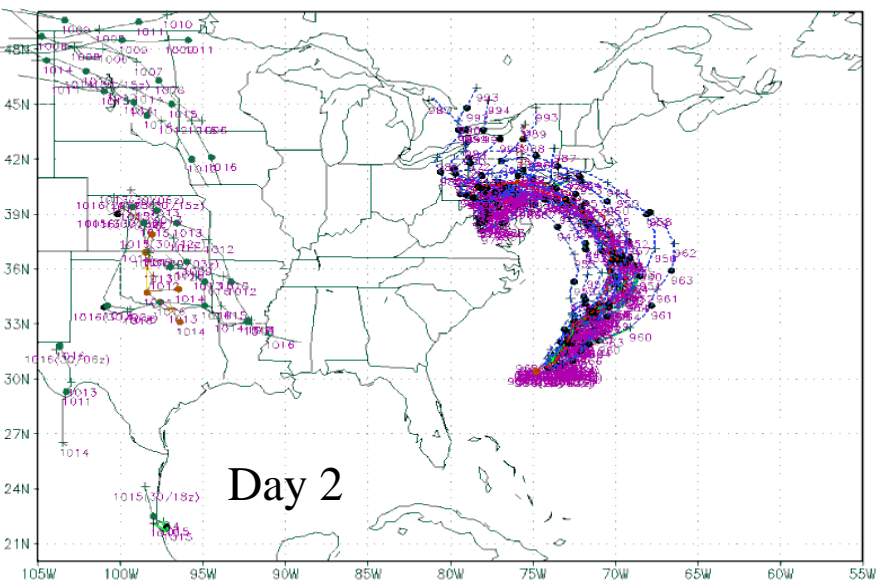
Day 4

Model Forecast Storm Tracks
For forecast with initial time = 2012102703



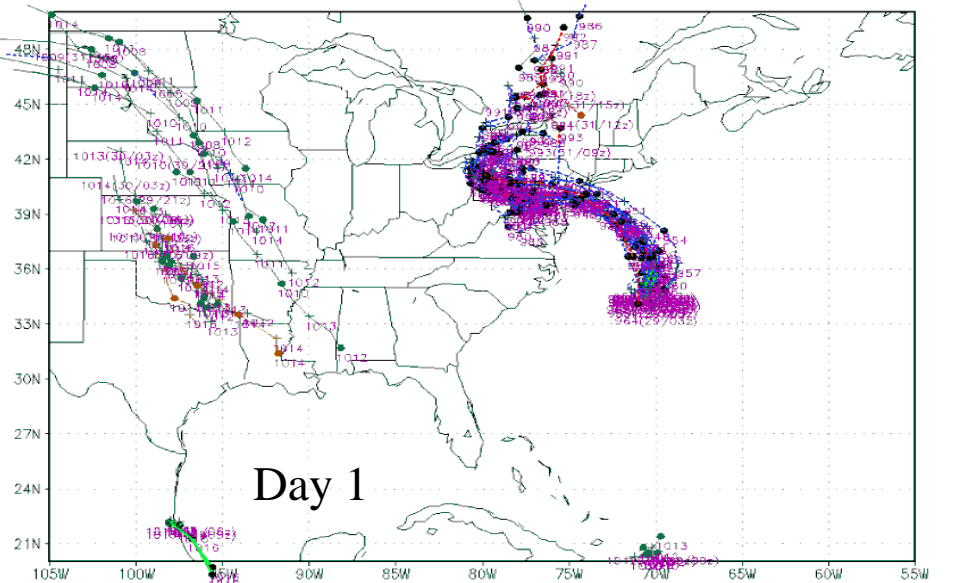
Day 3

Model Forecast Storm Tracks
For forecast with initial time = 2012102803



Day 2

Model Forecast Storm Tracks
For forecast with initial time = 2012102903

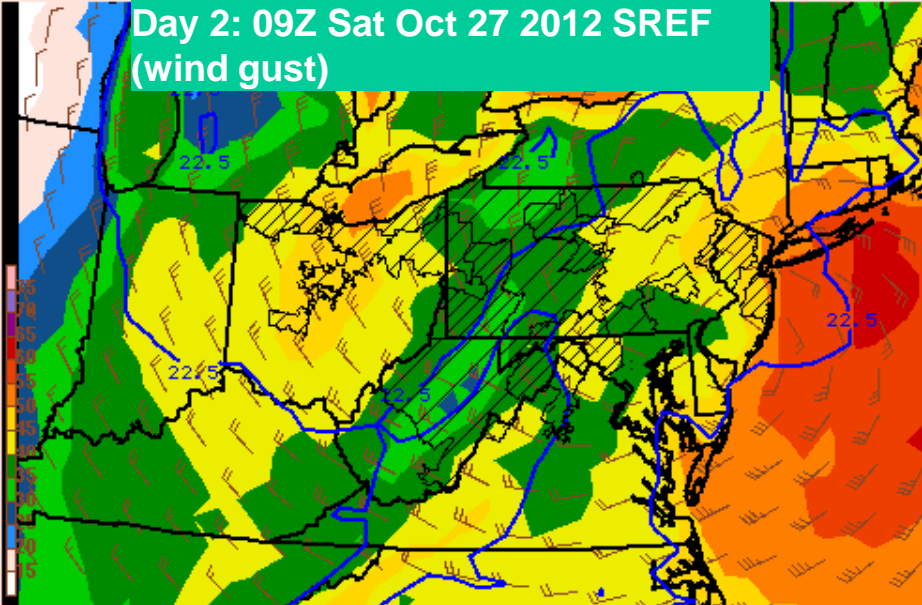


Day 1

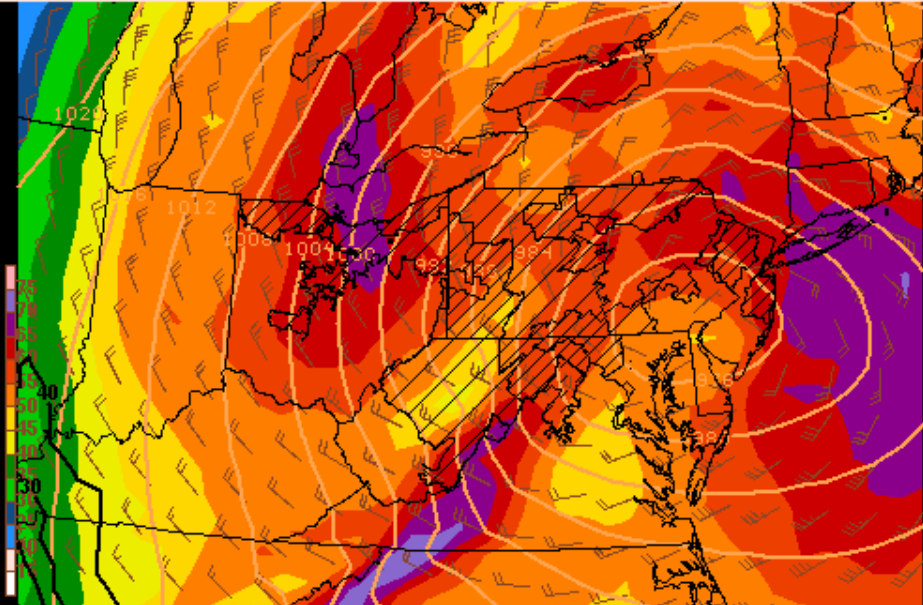
■ NAM hi-res: CPS parameter B < 10 and VTL > 0
— NAM hi-res: 1K closed contour warm core in 300–500 mb layer
— NAM hi-res: a low without full TC characteristics
● = position at 00 or 12
+ = position at 06 or 18
 Date (dd/hh) = first track

■ NAM hi-res: CPS parameter B < 10 and VTL > 0
— NAM hi-res: 1K closed contour warm core in 300–500 mb layer
— NAM hi-res: a low without full TC characteristics
● = position at 00 or 12
+ = position at 06 or 18
 Date (dd/hh) = first track

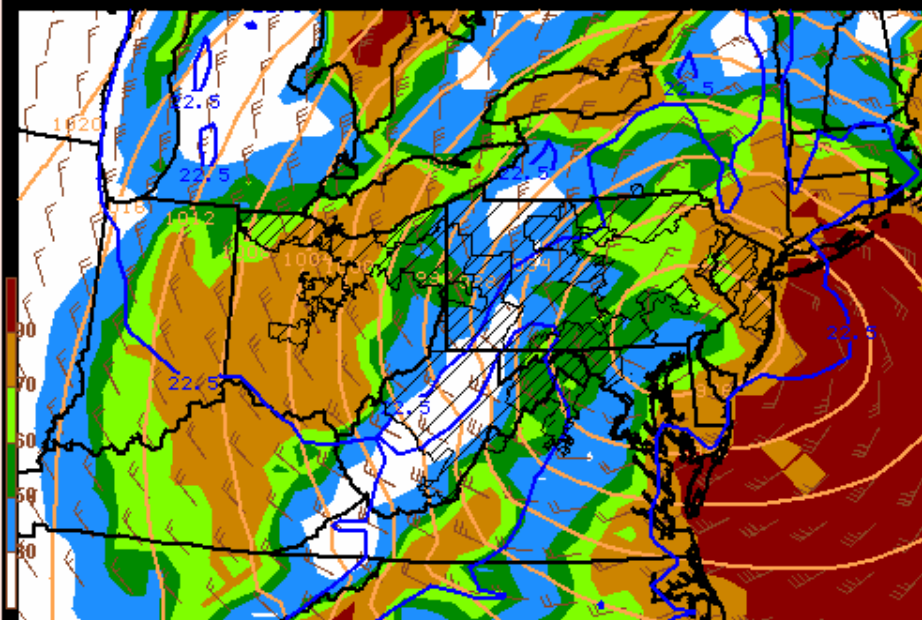
Day 2: 09Z Sat Oct 27 2012 SREF
(wind gust)



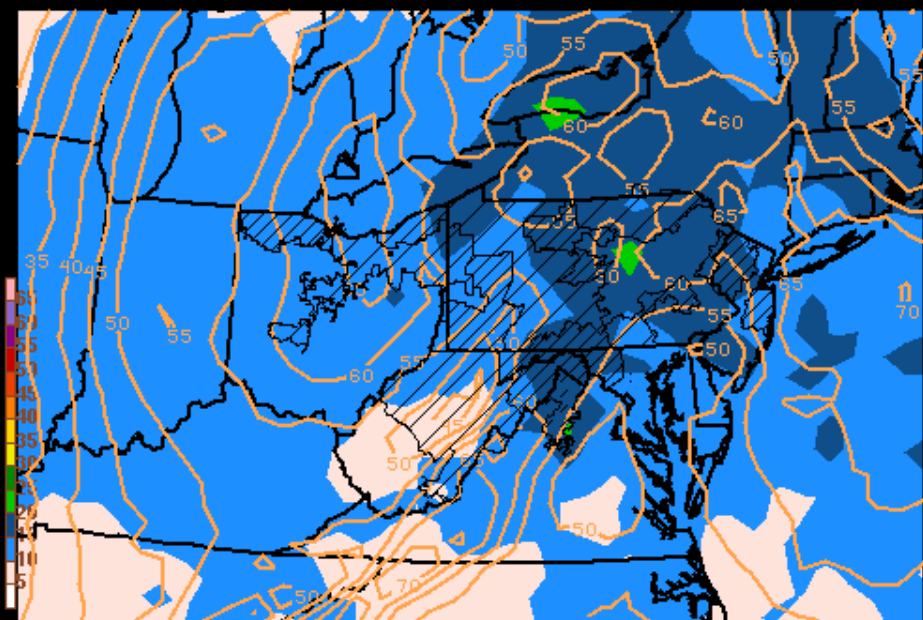
MN LYR WIND MPH FM GUST LVL TO SFC (SHADED), BARBS AVG SPEED AND DIR
F63 VALID 8PM MON OCT-29-2012 (2012102709F63 NOAA/SREF)



MAX WIND GUST MPH (SHADED), BARBS ARE AVG SPEED AND DIR
cloud cover less than 41% in black
F63 VALID 8PM MON OCT-29-2012 (2012102709F63 NOAA/SREF)

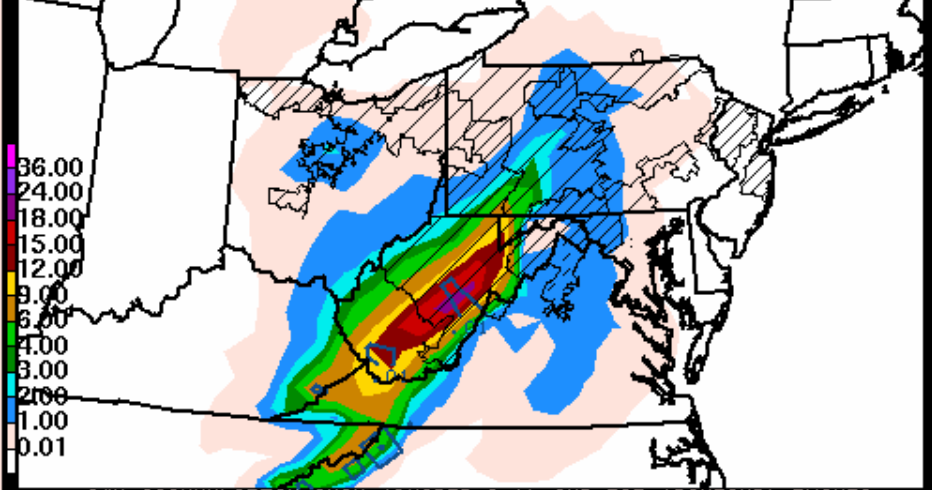


PROB(%) MN LYR GUSTS 40+ MPH (SHADED) THIN CONTOUR SUSTAINED 25MPH
F63 VALID 8PM MON OCT-29-2012 (2012102709F63 NOAA/SREF)

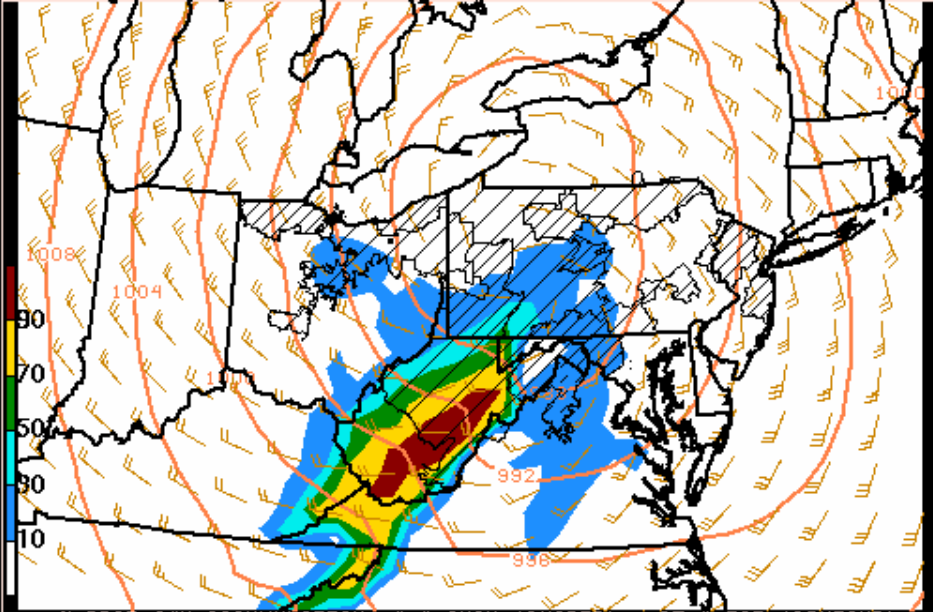


MAX MPH FM GUST LVL TO SFC (CONTOUR), UNCERTAINTY (SPREAD) MPH SHADED
F63 VALID 8PM MON OCT-29-2012 (2012102709F63 NOAA/SREF)

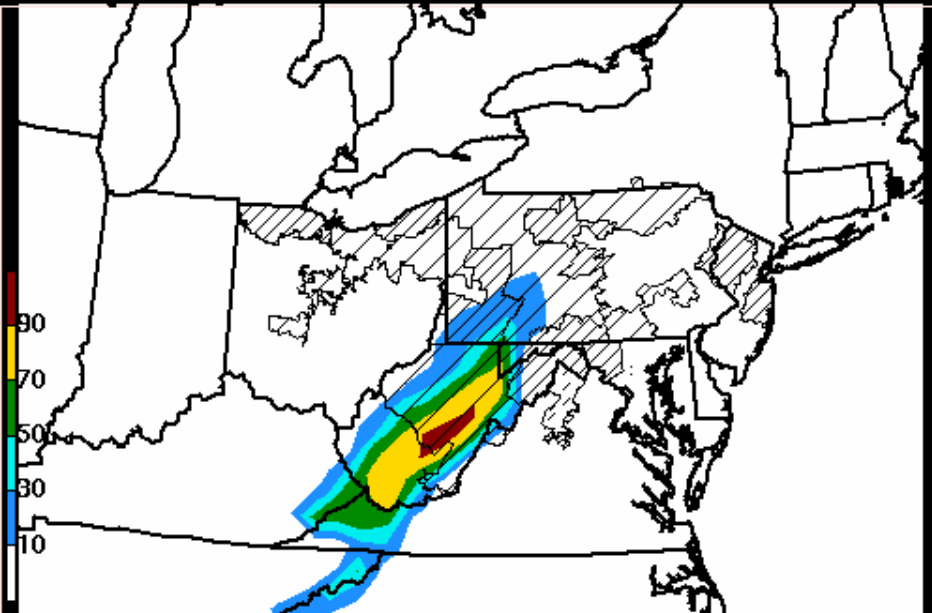
Day 2: 09Z Sat Oct 28 2012
SREF (ptype and snow acc)



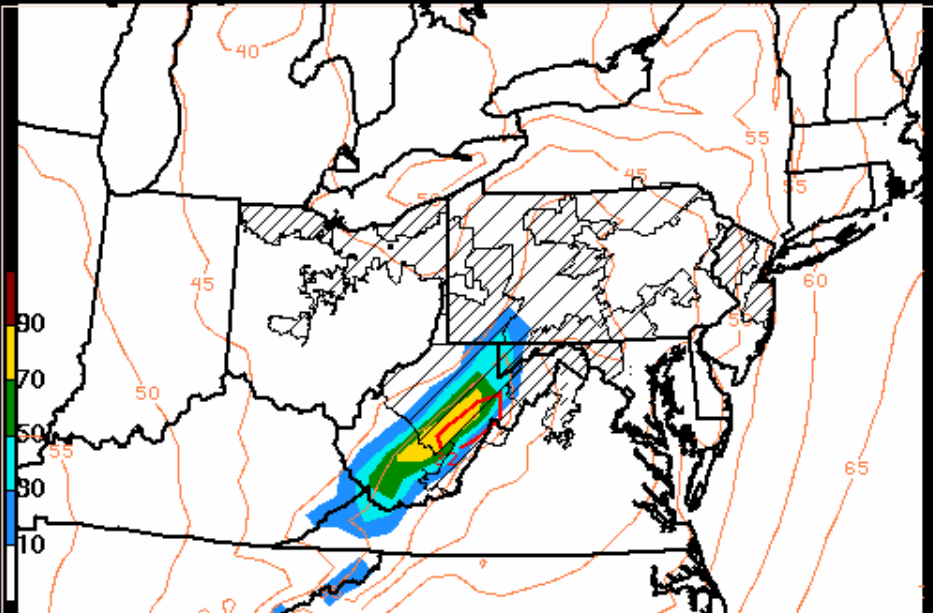
24H ACCUMULATION SNOW (SHADED 8:1) AND ICE (CONTOUR) INCHES
 VALID 5PM TUE OCT-30-2012 (2012102809F60 NOAA/SREF)



% PROB 24H ACCUMULATION: 4"+ SNOW (SHADED), .25"+ ICE (CONTOUR)
 BROWN BARBS = WIND MPH, ORANGE CONTOUR = PMSL IN MB
 VALID 5PM TUE OCT-30-2012 (2012102809F60 NOAA/SREF)



% PROB 24H ACCUMULATION: 8"+ SNOW (SHADED), .50"+ ICE (CONTOUR)
 VALID 5PM TUE OCT-30-2012 (2012102809F60 NOAA/SREF)



% PROB 24H ACCUMULATION: 12"+ SNOW (SHADED), .75"+ ICE (CONTOUR)
 ORANGE CONTOURS = TEMP DEG F (32F IN RED)
 VALID 5PM TUE OCT-30-2012 (2012102809F60 NOAA/SREF)



Other regional ensemble systems at NCEP



What we have:

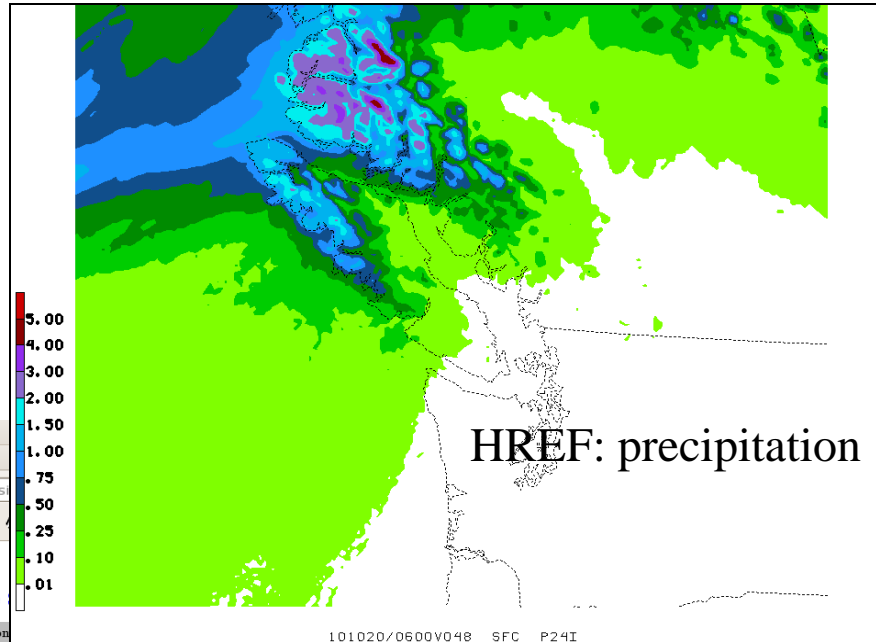
- (1) **NARRE-TL**. North America Rapid Refresh Ensemble (NAM and RR, time lagged) for aviation: 12km, 10 members, hourly update, 12hr length (May 1, 2012)
- (2) **HREF**. Hi-Res Ensemble Forecast (NMM, ARW and SREF) for convection: 5km, 44 members, 12hrly cycle, 48hr length (Dual-resolution hybrid ensembling 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



File Edit View History Bookmarks Tools Help

NCEP Time-Lagged North Ameri...

www.emc.ncep.noaa.gov/mmb/SREF_avia/FCST/NARRE/web_s

Most Visited WebMail MyHome People Yellow Pages

NCEP

NCEP Time-Lagged N. America Rapid Refresh Ensemble

Go to Alaska Product: Ceiling Date: 20121121 Cycle: 05Z Region:

Select speed: normal Animation

Email comments SREF Home Get data

ged North Am... x

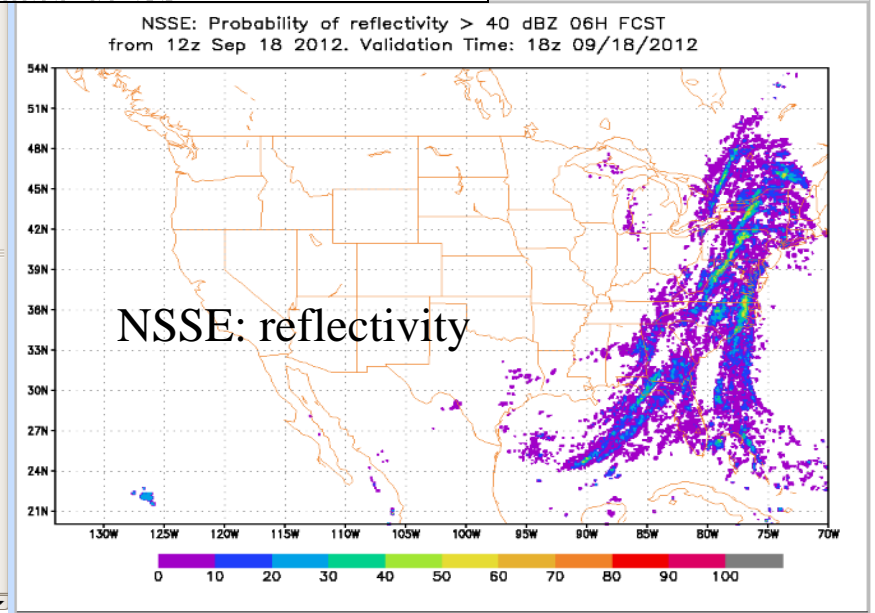
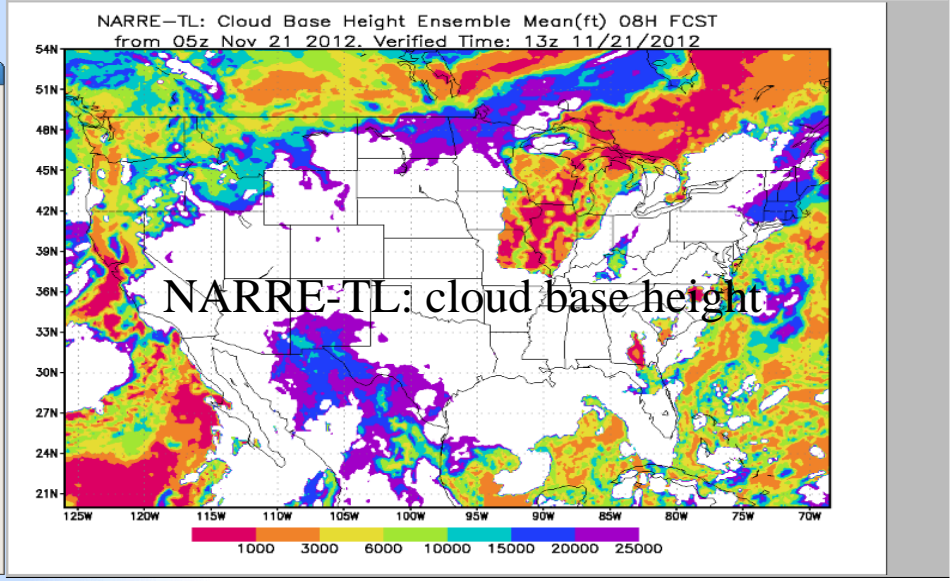
T/HRRRE/web_site/html/refl.html

Yellow Pages Download Calendar Channels

experimental) NCEP

Reflectivity Threshold Prob: Reflectivity > 40 dBZ

Email comments SREF Home Get data





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

