

# Current Status of NCEP Operational Model System

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**NCEP/EMC**

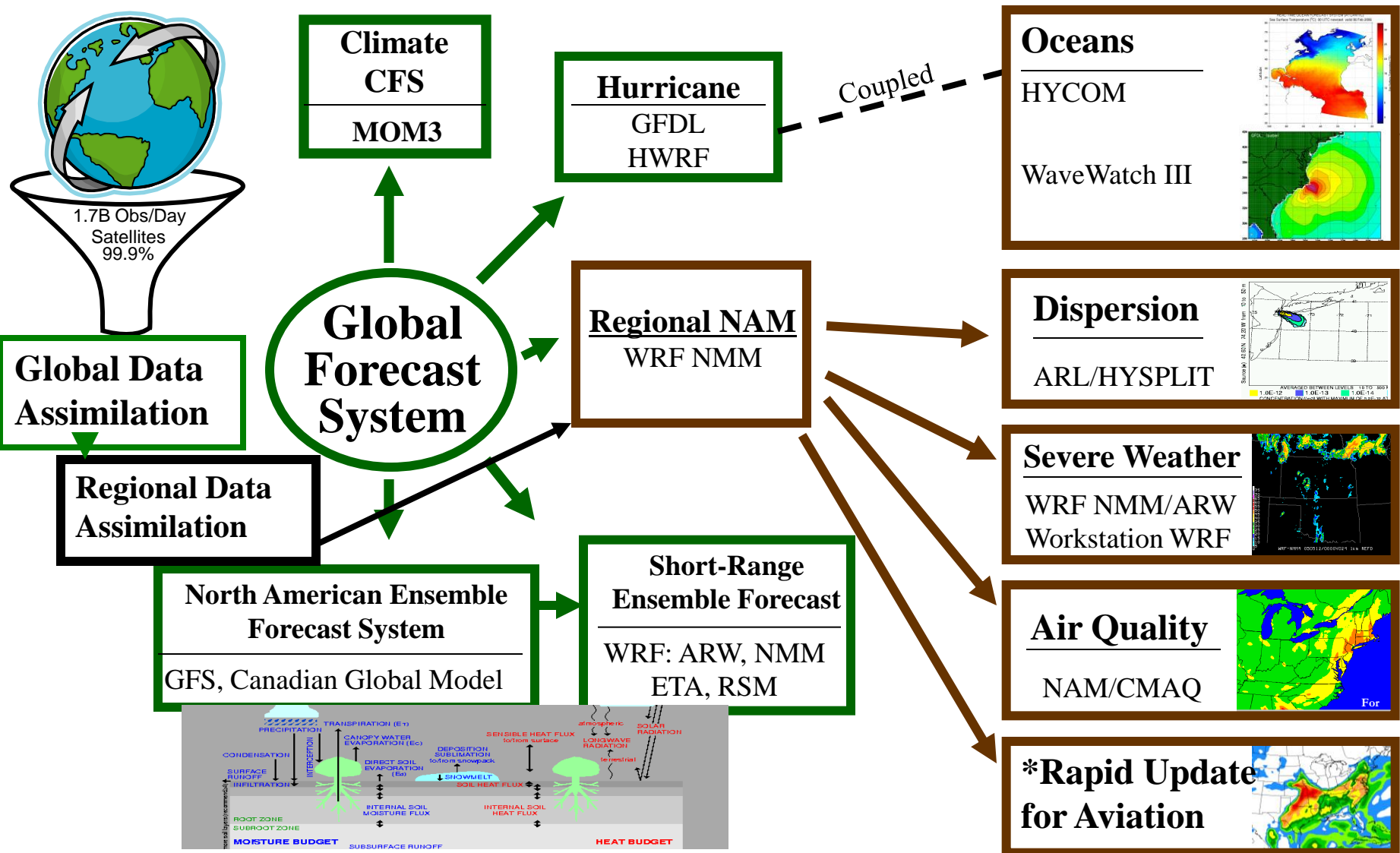
With input from:

Goeff Dimego, Matthew Pyle, Eric Rogers, Jun Du,  
Binbin Zhou, Hua-Lu Pan, and John Ward at EMC

**“Welcome to the National Weather Service's National Centers For Environmental Prediction's Environmental Modeling Center. The Environmental Modeling Center is responsible for the enhancements, transitions-to-operations, and maintenance of more than 20 numerical prediction systems comprising NCEP's operational production suite.”**



# NOAA's NWS Model Production Suite



# Recent upgrade in the operational GFS

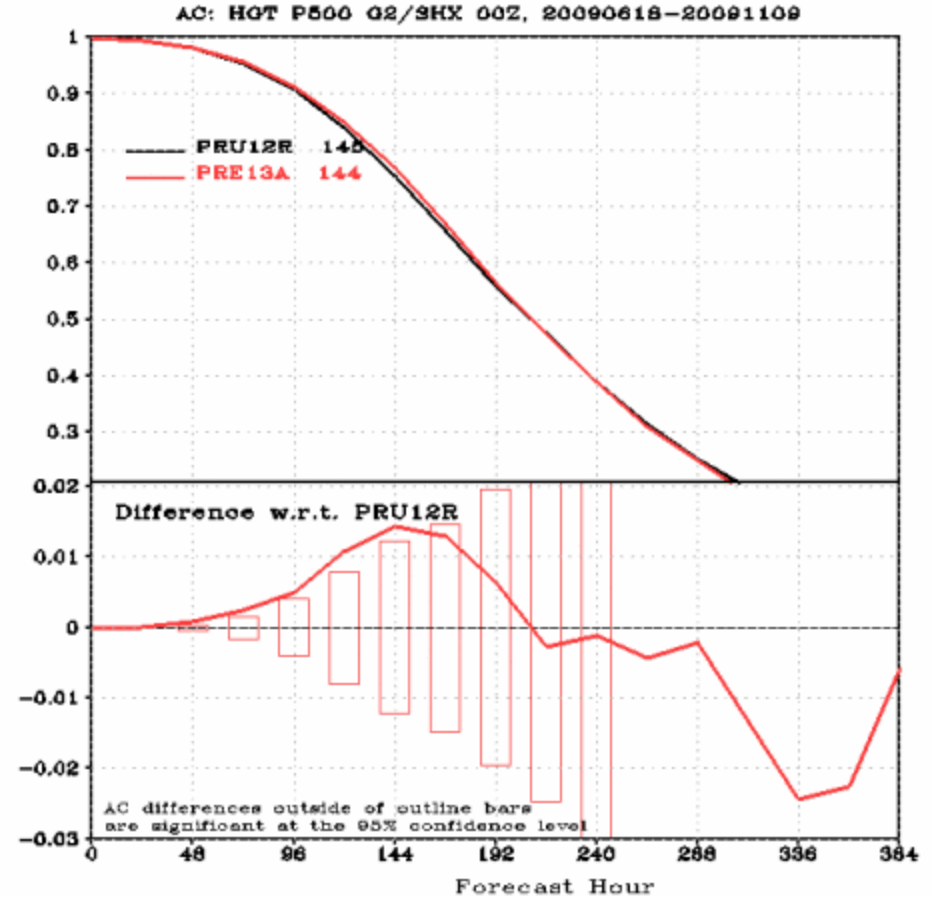
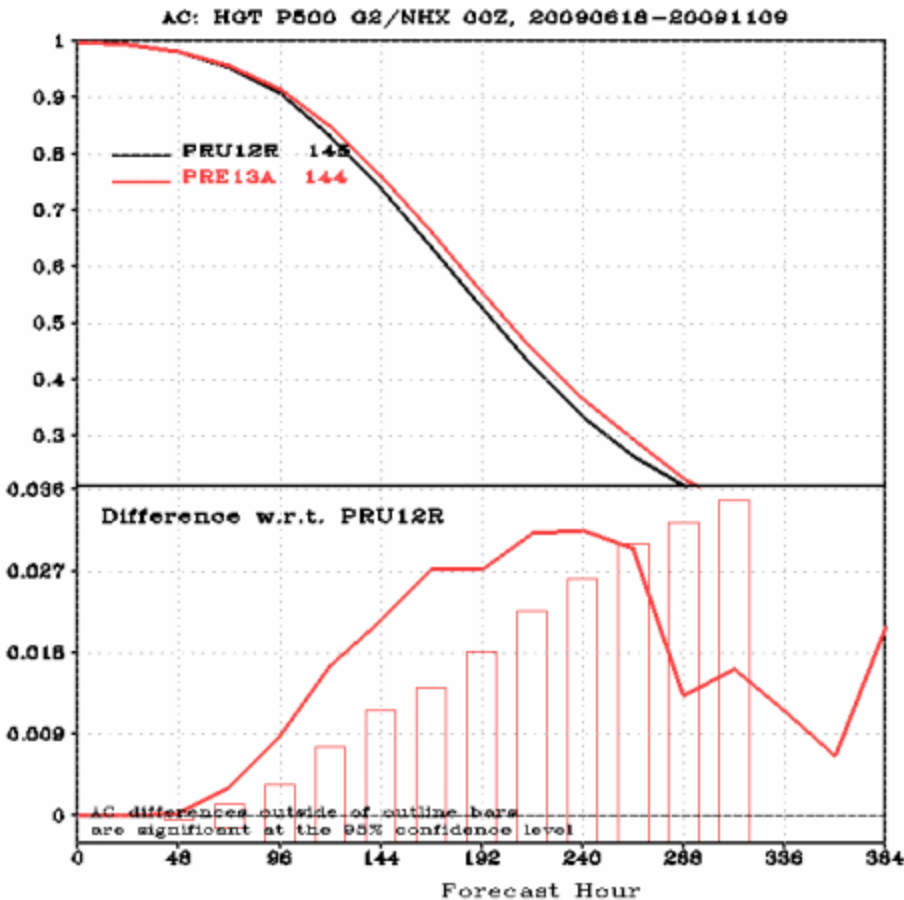
(Effective at July 27<sup>th</sup> 2010 12 UTC)

- Resolution increase: T382L64 (~35km) => T574L64 (~23km)
- Major physics change:
  - Shallow and deep convection, PBL schemes
  - Radiation:
    - SW: NCEP0 => RRTM (Rapid Radiative Transfer Model)
    - LW computation frequency: 3 hrs => 1 hr
    - SW cloud overlap: random => maximum-random overlap
  - Positive-definite vertical tracer transport scheme (remove negative water vapor)
  - Minor changes in mountain blocking parameterization

# 500 MB Anomaly Correlation

## Northern Hemisphere

## Southern Hemisphere

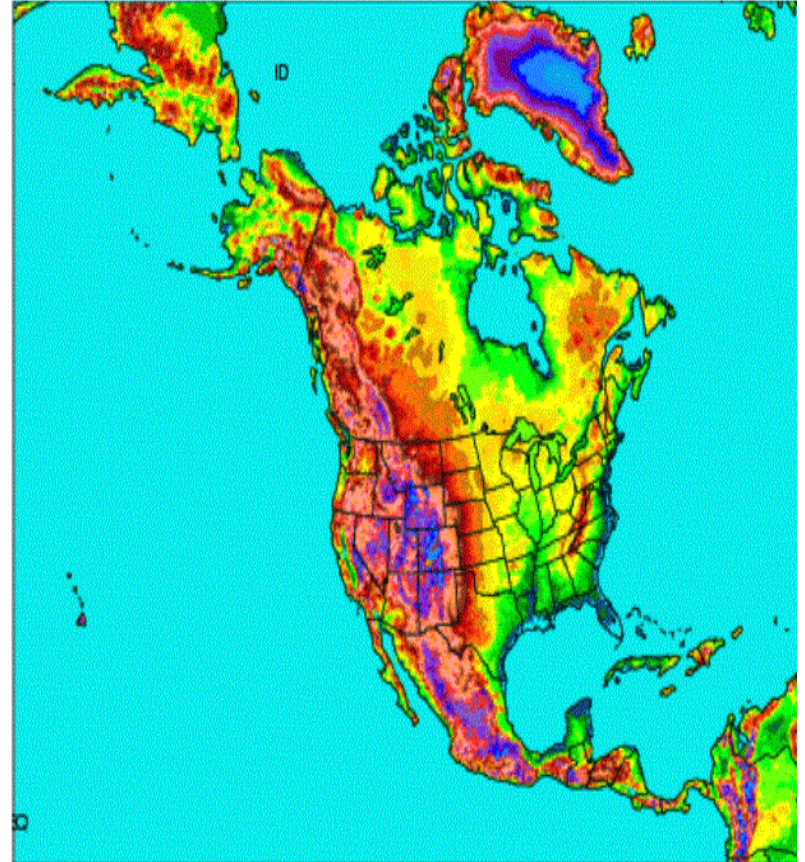


# Future GFS (2011)

- Model dynamics: T878L64 (~23km) Semi-Lagrangian
- Model physics:
  - Moist vertical mixing scheme ( $q_v, q_l, & T \Rightarrow q_t & T_l$ )
  - Include convective cloudiness
  - Stochastic sub-grid cloud radiative process (McICA: Monte Carlo Independent Column Approximation)
  - New treatment of thermal roughness length

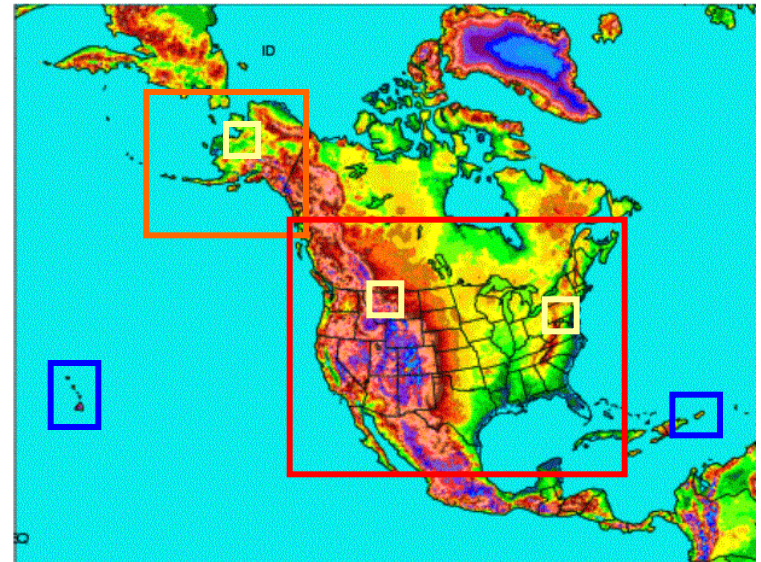
# Operational NAM

- WRF-NMM (E-grid)
  - BMJ convective parameterization
  - Noah LSM
  - Mellor-Yamada 2.5 Turbulence
  - Ferrier microphysics
- GSI analysis
- 4/Day = 6 hr update
- Forecasts to 84 hours
- 12 km horizontal
- 60 layers with 2 mb top
- 12 hr pre-forecast assimilation period with 3hr updates (catch-up)

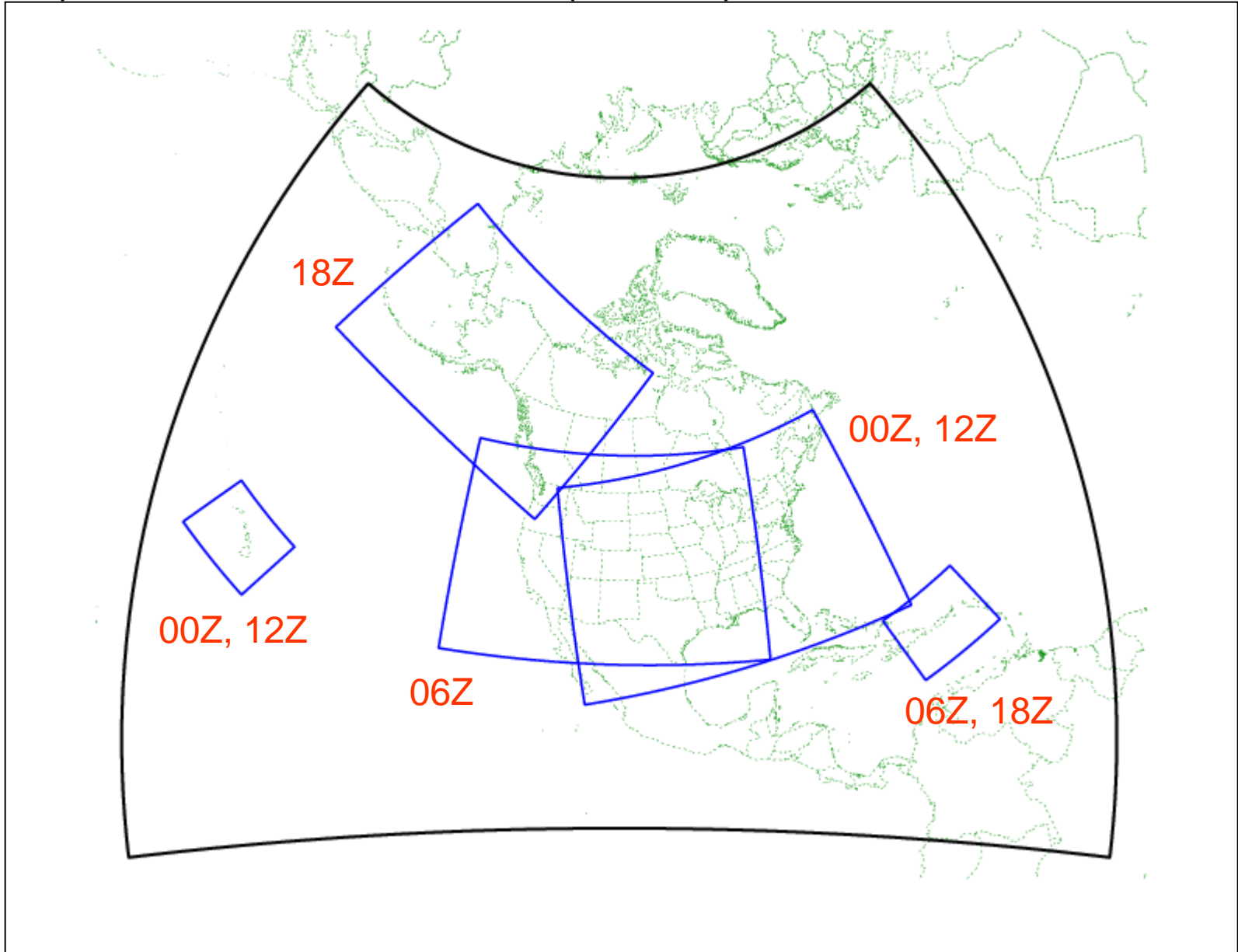


# Future NAM (spring 2011)

- NEMS based NMM
- B-grid replaces E-grid
- Parent remains at 12 km and 84-h length
- Same physics as current NAM, with refinements
- Multiple Nested domain run inside parent 12km run to 60hr:
  - 4 km CONUS
  - 6 km Alaska
  - 3 km Hawaii / Puerto Rico
  - 1.3=1.5 km on-call nest inside CONUS/Alaska domain (tentative)



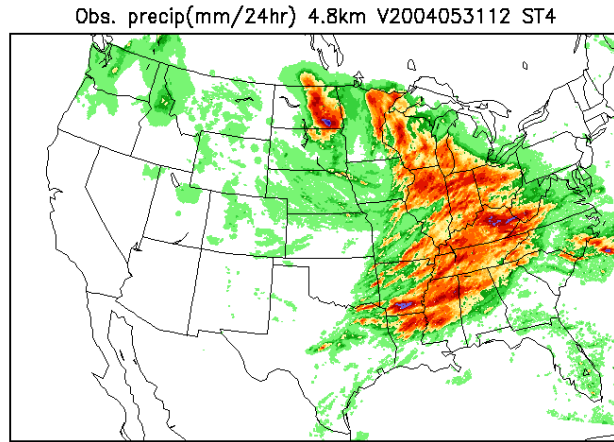
Current configuration with 3 large domains (AK, west US, east US) and 2 small domains (HI, PR) in NCEP HiresWindow



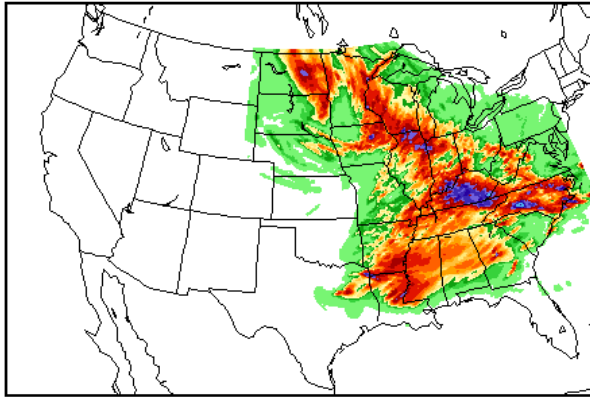
## Details for NCEP HiresWindow domains

	WRF-NMM	WRF-ARW
Horizontal grid spacing (km)	4.0	5.15
Vertical levels	35 sigma-pressure hybrid	35 sigma
PBL/turbulence	MYJ	YSU
Microphysics	Ferrier	WSM3
Land-Surface	NOAH	NOAH
Radiation (SW/LW)	GFDL/GFDL	Dudhia/RRTM
Parameterized Convection	None	None

Obs.



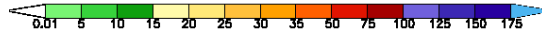
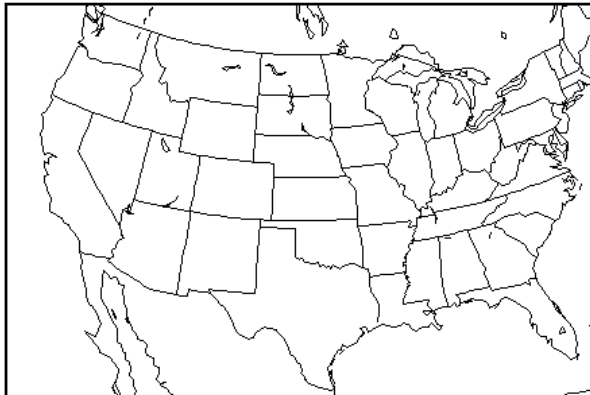
Tprp(mm/24hr) 5km V2004053112 R5



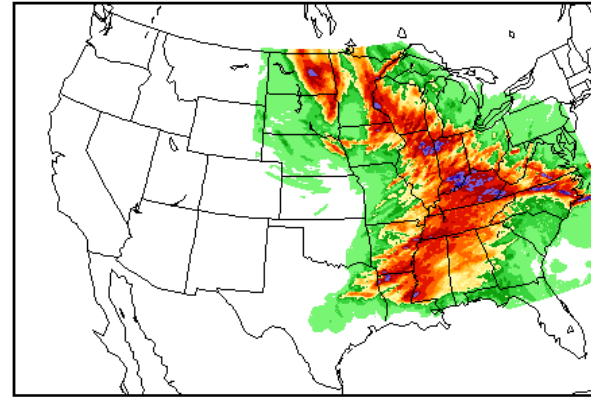
Without  
cumulus  
convection  
scheme

5km res.

Cprp(mm/24hr) 5km V2004053112 RSM-NOSAS BF f24 c2r15t5



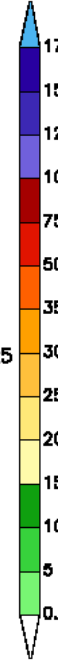
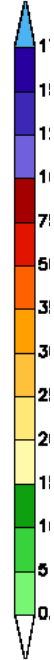
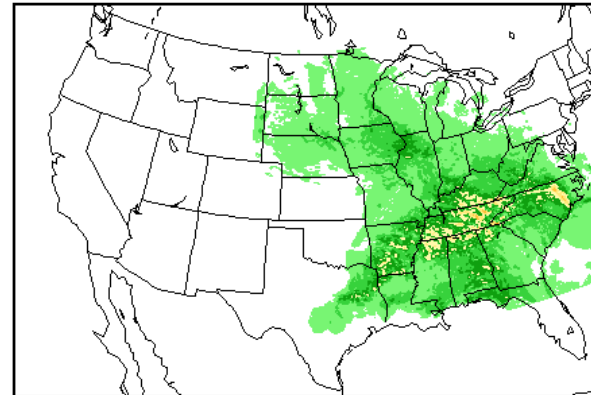
153112 RSM-SAS BF f24 c2r15t5



With  
cumulus  
convection  
scheme

5km res.

Cprp(mm/24hr) 5km V2004053112 RSM-SAS BF f24 c2r15t5

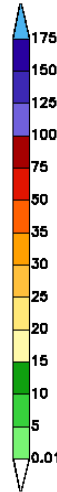
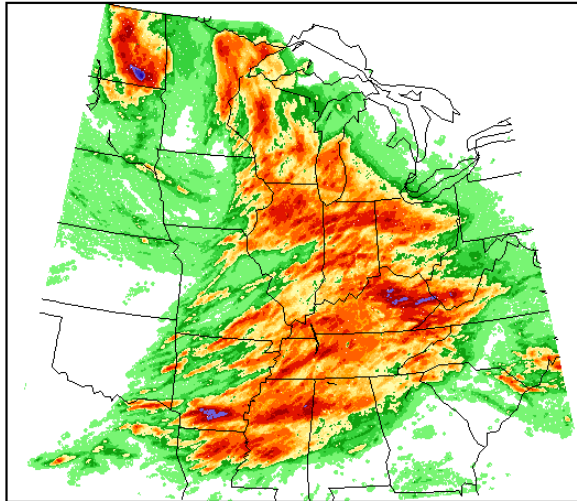


# Reply from Matthew Pyle

“In terms of objective verification, the models certainly do better with parameterized convection. **High precipitation bias in the warm season** is definitely a problem, particularly for the WRF-NMM. However, forecasters at the Storm Prediction Center (SPC) and elsewhere like seeing the detailed forecasts produced by the models without parameterized convection. **Without the smoothing action of convection, the models can produce much more realistic looking convective signatures (squall lines, etc.)**”

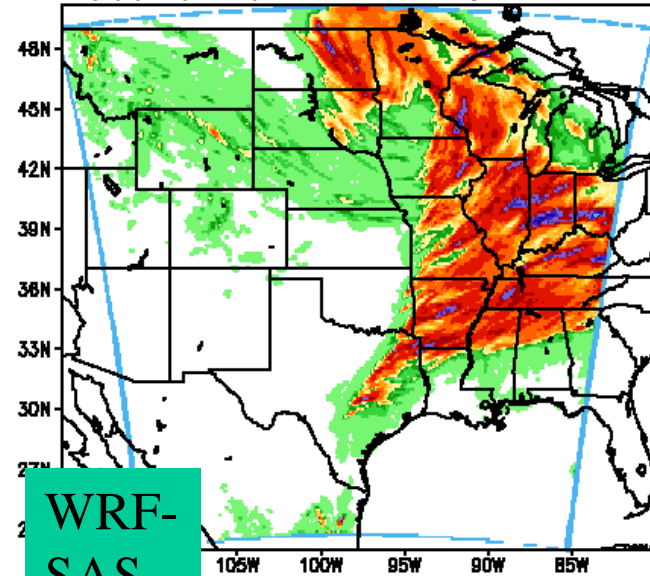
Obs.

Obs. precip(mm/24hr) 4.8km V2004053112 ST4



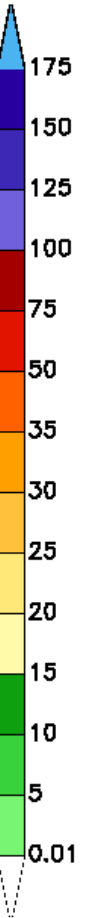
SAS CONV 24-HR FCST 4-KM

Tprp(mm/24hr) Valid 12Z 31 May04 WRF 4km



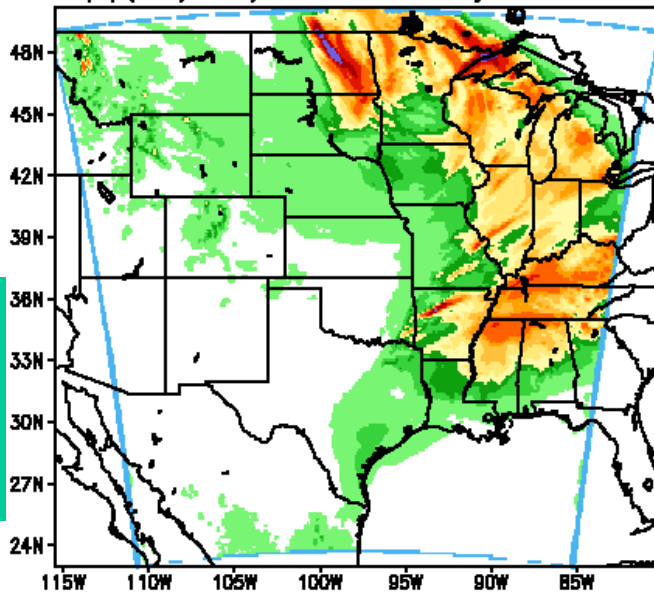
WRF-SAS

4 km



BMJ CONV 24-HR FCST 4-KM

Tprp(mm/24hr) Valid 12Z 31 May04 WRF 4km



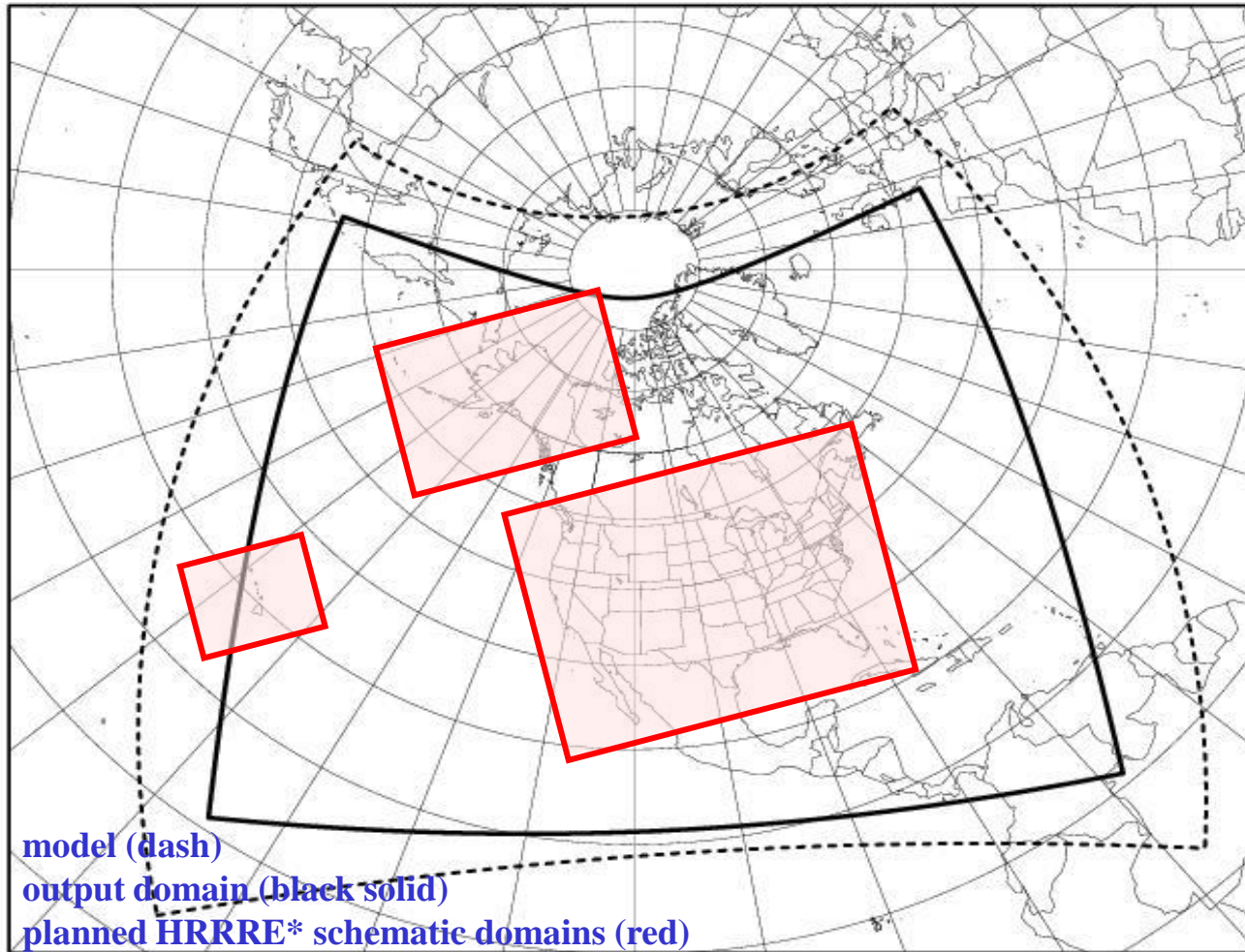
WRF-BMJ  
4 km

- Suggests that the convection scheme should be parameterized to play a diminishing role as the resolution increases, and in 4-5 km grid-resolution, contribution of parameterized convection (such as mitigating excessive precipitation) may be still important.

## Fall 2009 NCEP SREF System (21 members)

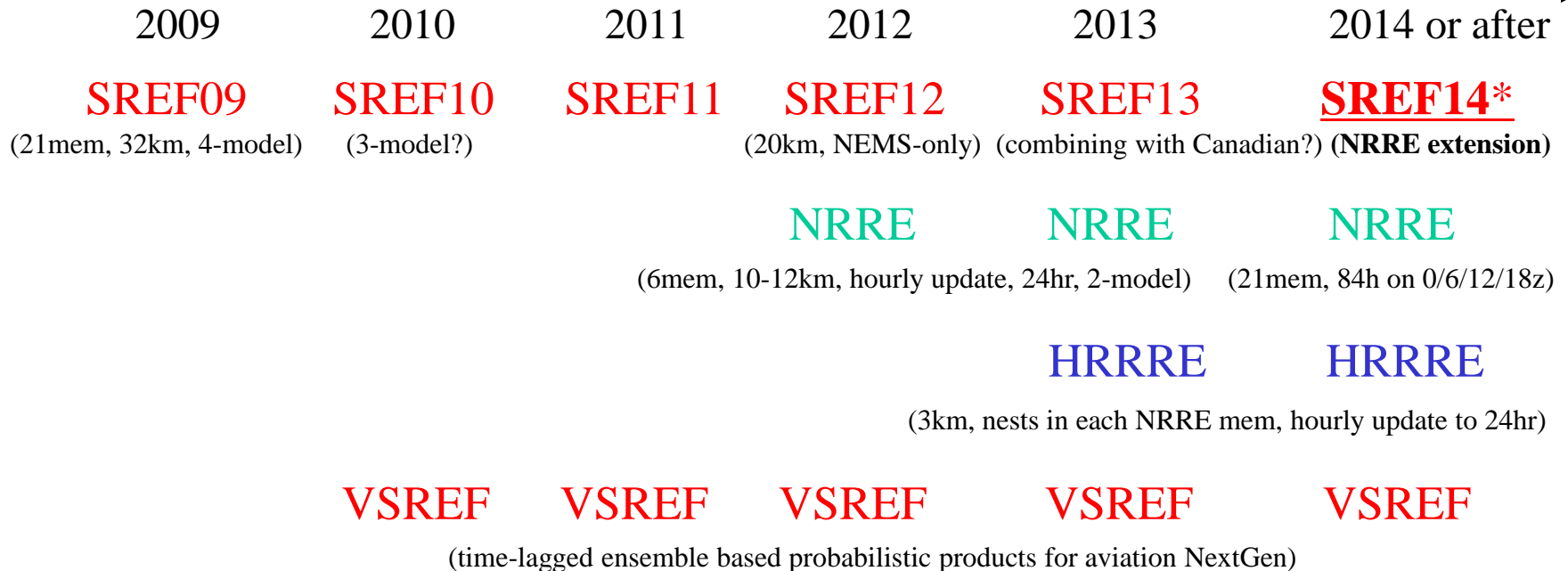
<b>Model</b>	<b>Membership</b>	<b>Resolution</b>	<b>Forecast Hours</b>	<b>IC/IC perturbation</b>	<b>LBC/LBC perturbation</b>	<b>Output Frequency for pgrb files</b>	<b>Output Frequency for bufr soundings</b>
Eta_BMJ	3 (ctl1, n1, p1)	32km	87hr (4 times, 3, 9, 15, 21z)	ndas/regional BV	GFS/GEFS	1hrly to 39hr, 3hrly afterward	1hrly and breakdown to sites
Eta_KF	3 (ctl2, n2, p2)	32km	87hr (4 times per day)	ndas/regional BV	GFS/GEFS	1hrly to 39hr, 3hrly afterward	1hrly and breakdown to sites
RSM_SAS_Ferrier	3 (ctl1, n1, p1)	32km	87hr (4 times per day)	GFS 3hr fcst/regional BV	GFS/GEFS	1hrly to 39hr, 3hrly afterward	1hrly and breakdown to sites
RSM_RAS_Zhao	2 (n2, p2)	32km	87hr (4 times per day)	GFS 3hr fcst/regional BV	GFS/GEFS	1hrly to 39hr, 3hrly afterward	1hrly and breakdown to sites
NMM	5 (ctl, n1, p1, n2, p2)	32km	87hr (4 times per day)	GFS 3hr fcst/global ET	GFS/GEFS	1hrly to 39hr, 3hrly afterward	1hrly and breakdown to sites
ARW	5 (ctl, n1, p1, n2, p2)	35km	87hr (4 times per day)	GFS 3hr fcst/global ET	GFS/GEFS	1hrly to 39hr, 3hrly afterward	1hrly and breakdown to sites

# SREF Domains



\* HRRRE = High-Resolution Rapid Refresh Ensemble

# SREF Future Plans



- 
- \*NEMS = NOAA Environmental Modeling System (a unified modeling framework)
  - \*SREF (32→20km→10/12km, 6-hrly update to 84h for general weather forecasts)
  - \*NRRE = NAM Rapid Refresh Ens (10-12km, hrly update to 24h for aviation)
  - \*HRRRE = Hi-Res Rapid Refresh Ens. (3km, nested in NRRE, hrly update to 24h for high-impact events for targeted CONUS, AK and HI domains)
  - \*VSREF = Very Short-Range Ens Forecast for aviation NextGen prob products

Questions?  
Comments?



**The current GFS (Control):**

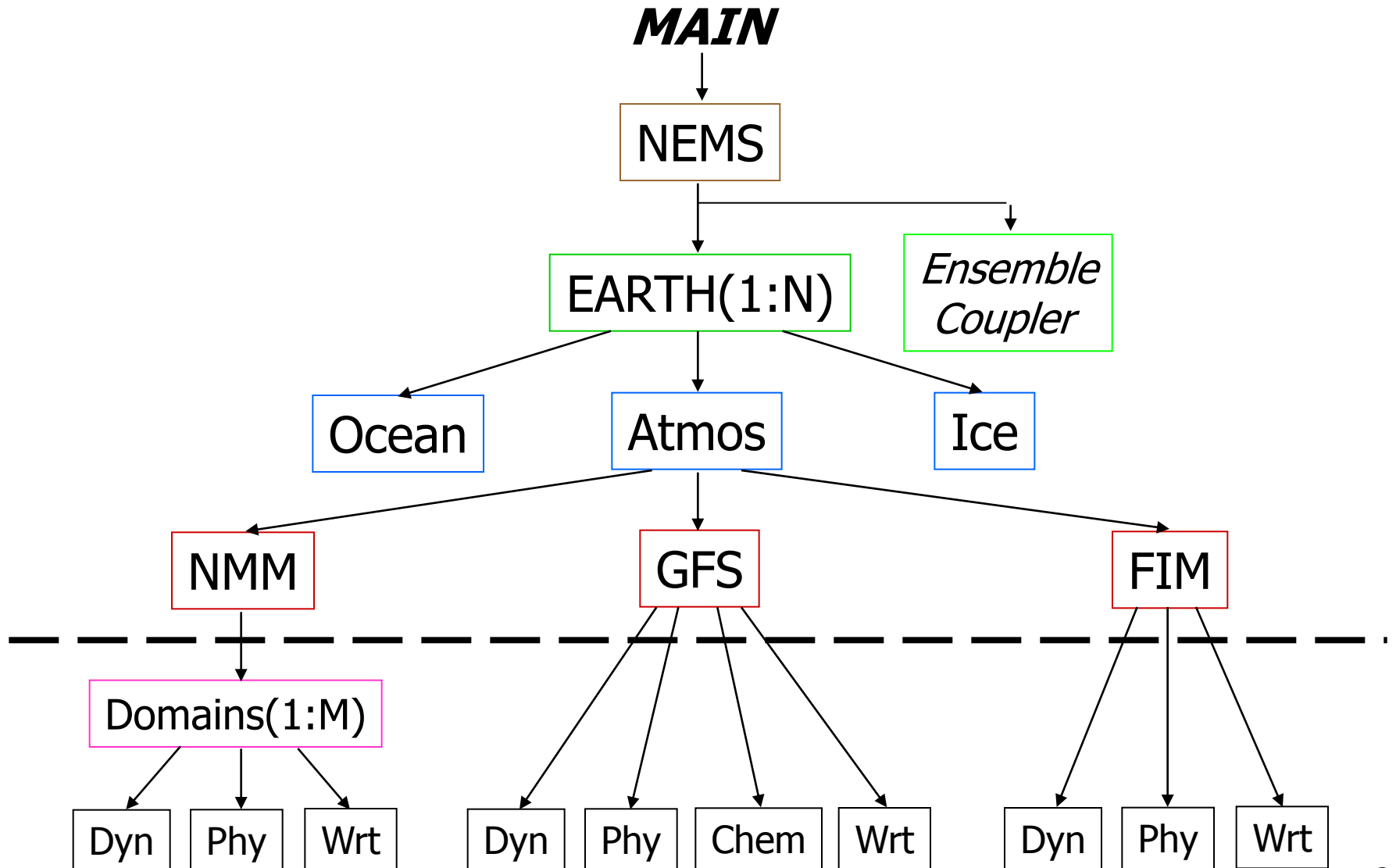
$$Z_{ot}/Z_{om}=1$$

**The tested GFS:** from Zeng (1998)

$$Z_{ot} = Z_{om} * \{ \exp[(-b_1 Re^{**0.25}) - b_2] \}$$

where  $Re$  is the roughness Reynolds number,  $b_1$  and  $b_2$  are tuneable parameters.

# NEMS 3.0 Component Structure

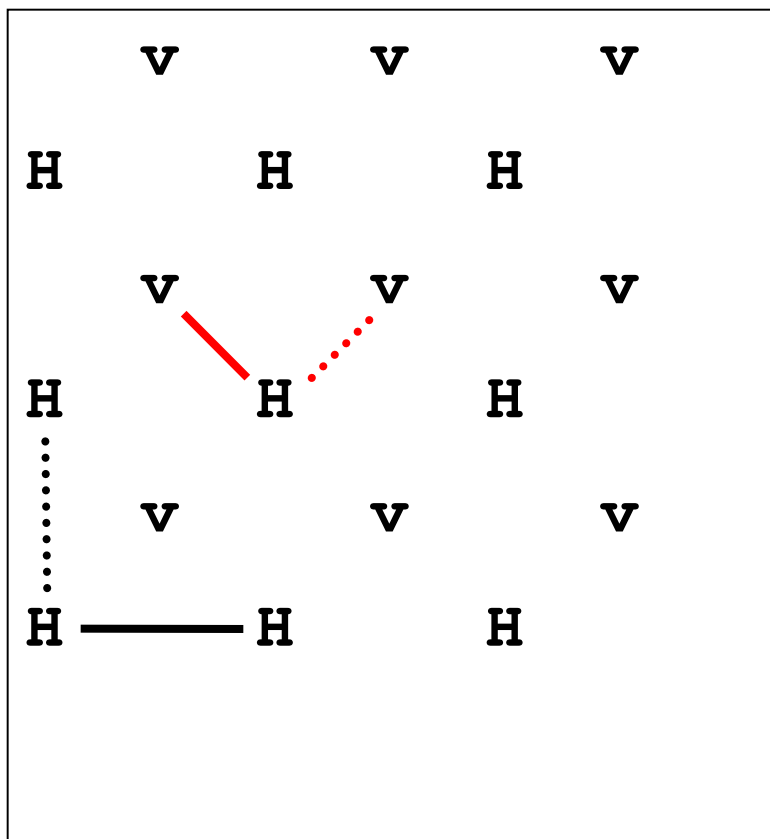


***Below the dashed line the cores can be organized as best suits their own needs.***

# NAM Plans for Spring 2011

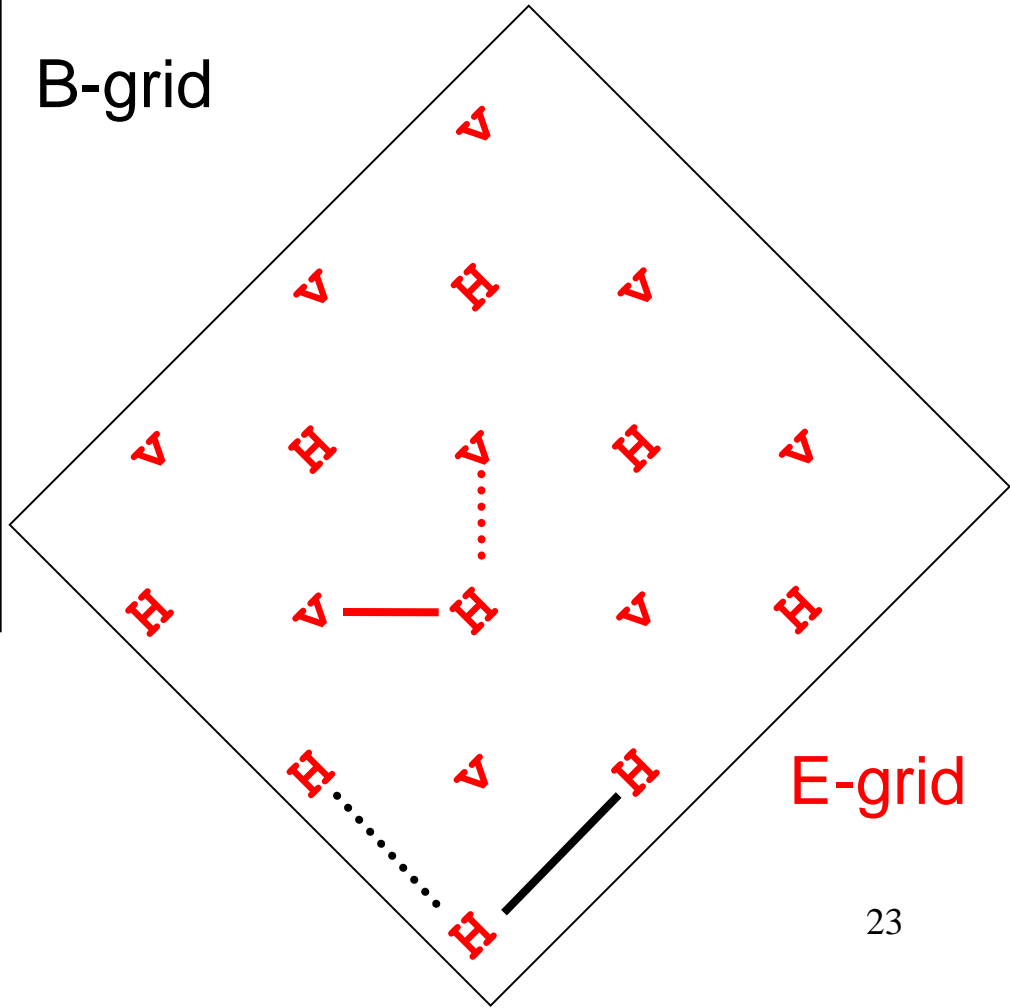
- NEMS-based NMMB system replacing WRF-based NMM
- Parent run remains at 12 km/60 level resolution out to 84-h
- Add CONUS, Alaska, Hawaii, and Puerto Rico nests to every NAM
  - Nests run to 60 hours
  - Nested guidance similar to HiResWindow except:
    - Available every NAM run – no hurricane preemption
    - Available 4 times per day – no intermittent availability
    - Available ~3 hours earlier than HiResWindow output
- Tentative; add on-call 1.3-1.5 km nested run inside CONUS/Alaska nest to 36-h for support of fire weather, Homeland Security, and other situations as needed

# NMMB stands for Nonhydrostatic Multiscale Model on B-grid

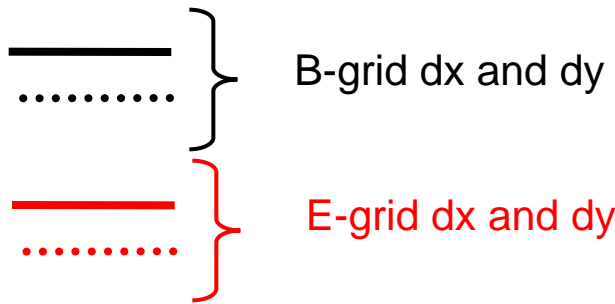


B-grid is just an E-grid rotated 45 degrees (and vice-versa)

B-grid



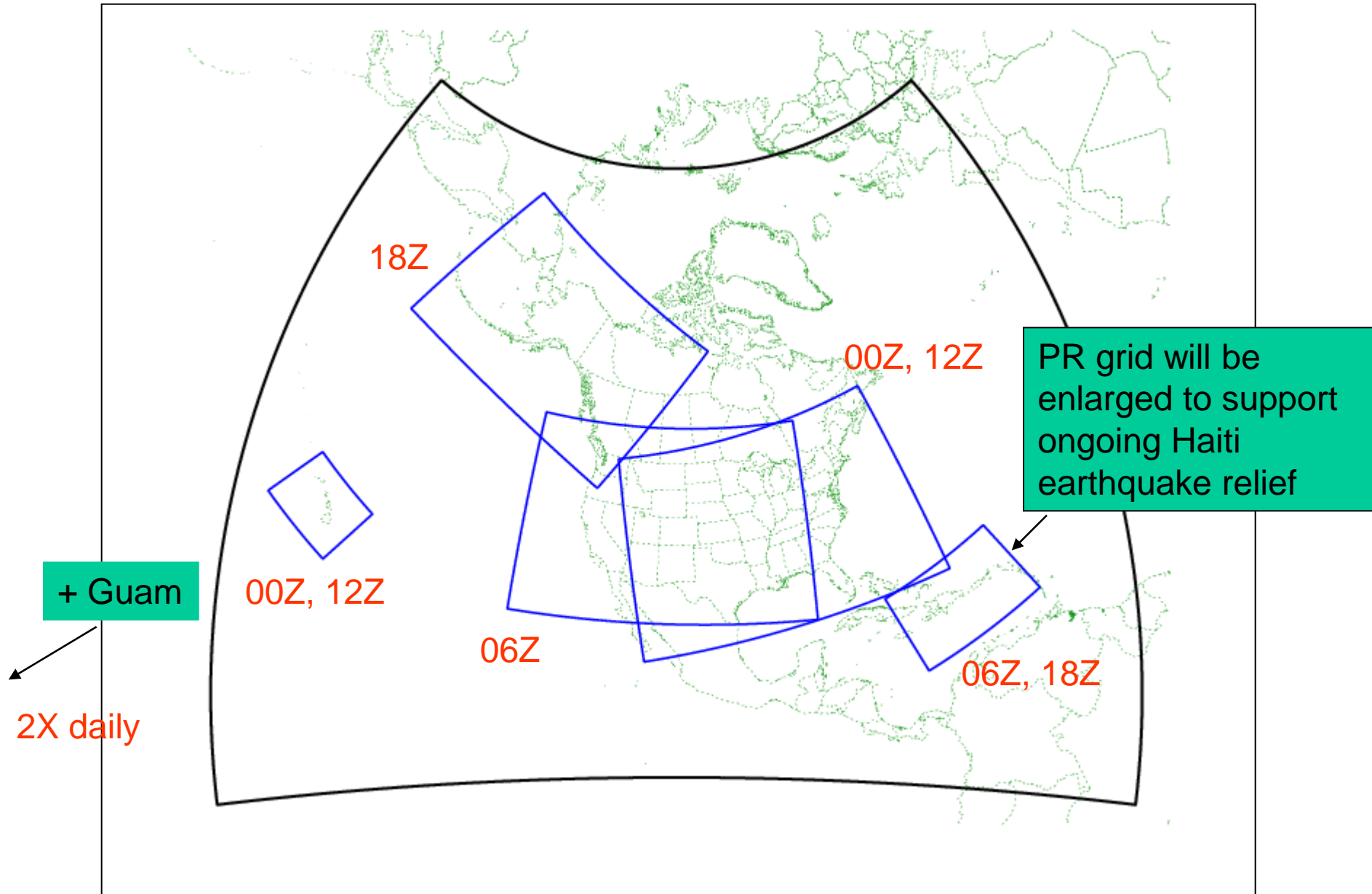
E-grid



# B-grid Advantages

- These are the main B grid advantages:
  - The B grid requires narrower halos, i.e. less communications;
  - On the global scale, the polar filtering on the B grid is more effective and the polar boundary condition is more straightforward;
  - E grid code is more complex, indirect addressing (slower too) and is more difficult for debugging and maintenance;
  - The B grid is better for application of the model in idealized 2D studies, e.g. in the x-z plane;
  - Streamlined physics interfaces compared to WRF infrastructure, facilitating development, debugging and maintenance.
- Other NMMB differences / enhancements
  - New Eulerian positive-definite monotonic tracer advection scheme which is much more conservative & even a little cheaper
  - New generalized hybrid vertical coordinate
  - RRTM radiation option
  - GFS physics option

# Future configuration with 3 large domains (AK, west US, east US) and 3 small domains (HI, Haiti/PR, Guam)



## NCEP Hires Window overview

- Based on the Weather Research and Forecasting (WRF) system. Both dynamical cores (WRF-ARW and WRF-NMM) are utilized.
- Makes 48 h integrations over five smaller “windows” at higher (4-5 km) resolution than the 12 km NAM model.
- Currently utilizing old WRF V2.2 code, but an upgrade to WRF V3.2 code is scheduled for December 2010.
- After Dec 2010 upgrade, both cores will utilize their respective versions of positive-definite moisture advection (improved warm-season precipitation bias).

# Recent Upgrades to the SREF system

(Implemented on 27 Oct. 2009)

- **Upgrade models: WRF-NMM, WRF-ARW and RSM**
- **Increase horizontal resolution:**
  - ARW (45 km to 35 km)
  - NMM (40 km to 32 km)
  - RSM (45 km to 32 km)
- **Total Membership = 21:**
  - Adding 4 WRF
  - Eliminating 4 Eta
- **For the 3 RSM members: replace Zhou cloud with Ferrier**
- **Use Global Ensemble Transform (ET) perturbations for the 10 WRF members**
- **Increase output frequency from every 3 hr to hourly for 1st 39hr (mem, CONUS)**
- **Add/fix/unify variables in SREF output**
  - wind variance products (for DTRA)
  - radar (composite reflectivity + echo top) (for FAA)
  - unify PBL height diagnosis with critical Ri (aviation)
  - Icing, turbulence, flight restriction (mem, prob) and ceiling (mem, mean, spread and prob) (aviation)
  - BUFR broken out into individual station time-series (SPC)

# SREF Methodology

## IC aspect:

- Multi-analysis (gdas and ndas)
- Perturb ctl anal (bred vector, global ET, regional ET)
- Perturbed LBCs (from global EPS)
- Land surface initial states such as soil moisture and temperature (tested)

## Model aspect:

- Multi-model (Eta, RSM, NMM, ARW)
- Multi-physics (various convection and cloud schemes)
- Stochastic physics (tested)

## Residual Part:

- Post processing including:
  - bias correction
  - downscaling (tested)

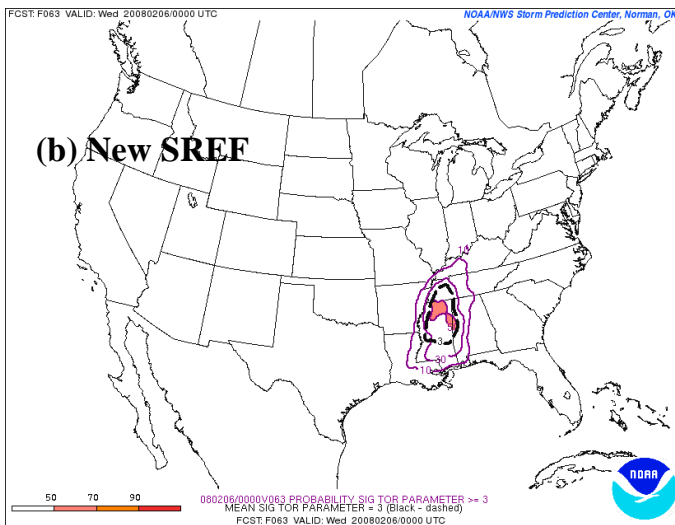
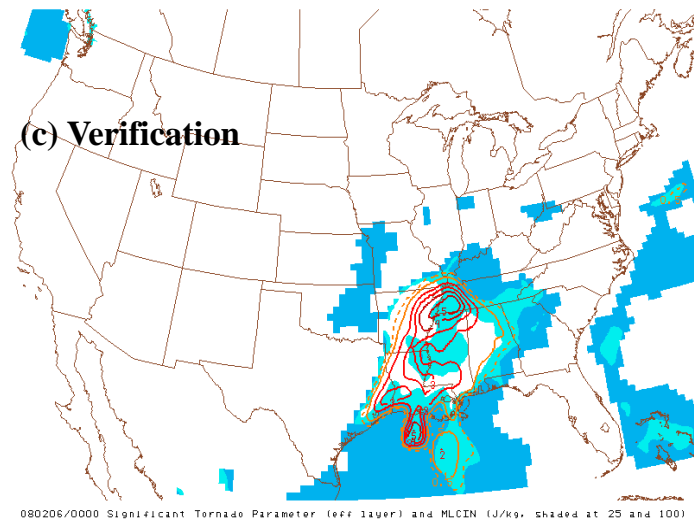
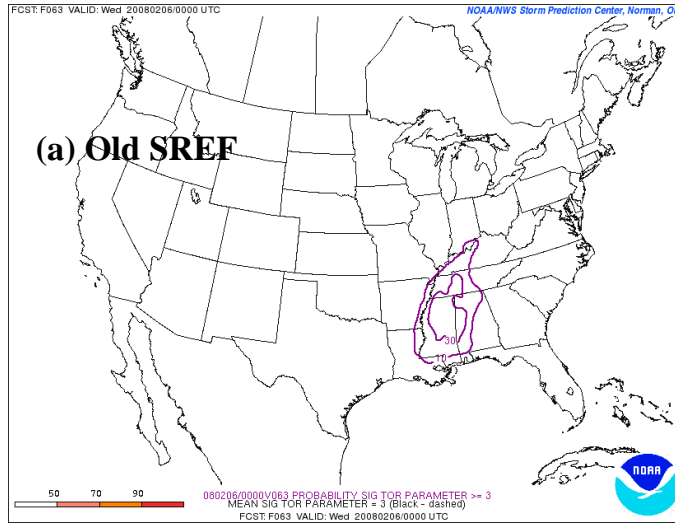
# **Q1 FY2010 SREF Changes - 1**

- **Upgrade model versions for NMM (2.2), ARW (2.2) and RSM (2008)**
- **Increase horizontal resolution for non-Eta members (Eta members run at 32km):**
  - To 32km from 40km for NMM (2x)
  - To 32km from 45km for RSM (2.8x)
  - To 35km from 45km for ARW (2.1x)
- **Keep membership at 21 members, but:**
  - Add 4 WRF members from 6 to 10 (5 NMM + 5 ARW)
  - Remove 4 Eta members from 10 to 6 (3 BMJ + 3 KF)
- **Add more initial condition diversity using ET method instead of breeding**
  - WRF members use 10 different GEFS initial conditions
  - GEFS uses ET method instead of breeding

# **Q1 FY2010 SREF Changes - 2**

- **More physics diversity:**
  - Replace Zhao with Ferrier in 3 SAS members for RSM
  - Replace Ferrier with WSM3 in all members for ARW
- **SREF Output:**
  - Add hourly output of each member
  - Fix serious bug in ARW's BUFR skin-temperature
  - Breakout single bufr file into individual station time-series used by forecaster's
  - Upgrade the WRFBUFR code to use MPI I/O
  - Fix ceiling height coming out of WRF
  - Icing, turbulence, flight restriction (mem, prob) and ceiling (mem, mean, spread and prob) for aviation
  - Unify PBL height diagnosis with critical Ri (aviation)
  - Add wind-variance fields for DTRA
  - Add radar composite reflectivity & echo top (for all members except Eta) for FAA
  - Add tropical cyclone tracking
- **Implemented 27 October, 2009**

Fig. 5: Day 3 SREF 09z 3 Feb 2008: 63-hr forecasts valid at 00 UTC 6 Feb 2008 (Super Tuesday Tornado case, provided by David Bright of SPC)

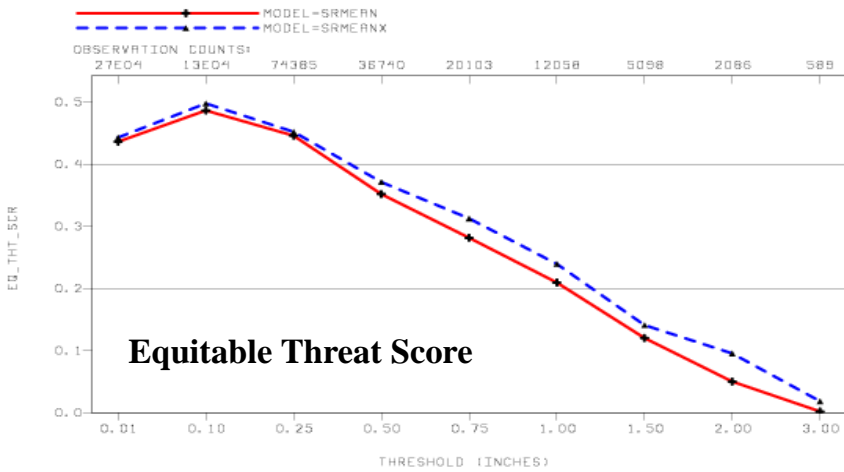


SREF Forecasts of Probability of Sig. Tornado Parameter  $\geq 3$

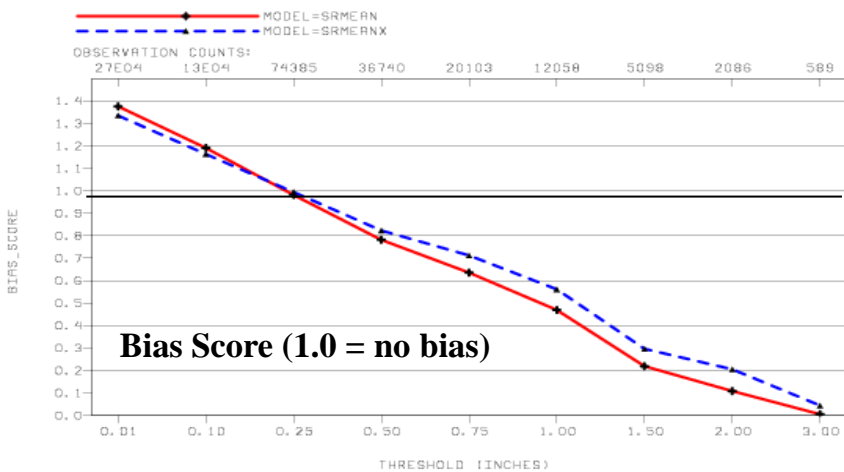
New SREF indicates higher probability over lower MS Valley (also note mean STP = 3 contour in new SREF but not in old SREF)

**Fig. 7: Equitable Threat score (ETS) and Bias score of 24h-accumulated precipitation forecasts of ensemble mean over CONUS, averaged over the period of Oct. 15 – Nov. 16, 2008. New SREF is in dash line and old SREF in solid line. Both ETS and Bias score improved, smaller bias and larger ETS for all thresholds especially heavier precipitation, for the new SREF (against Stage-II precip analysis)**

STAT=FHO PARAM=APCP/24 FHOUR=27+33+39+45+51+57+63+69+75+81+87 V\_RGN=G212/RFC  
 VYMDH=200810150000-200811162300

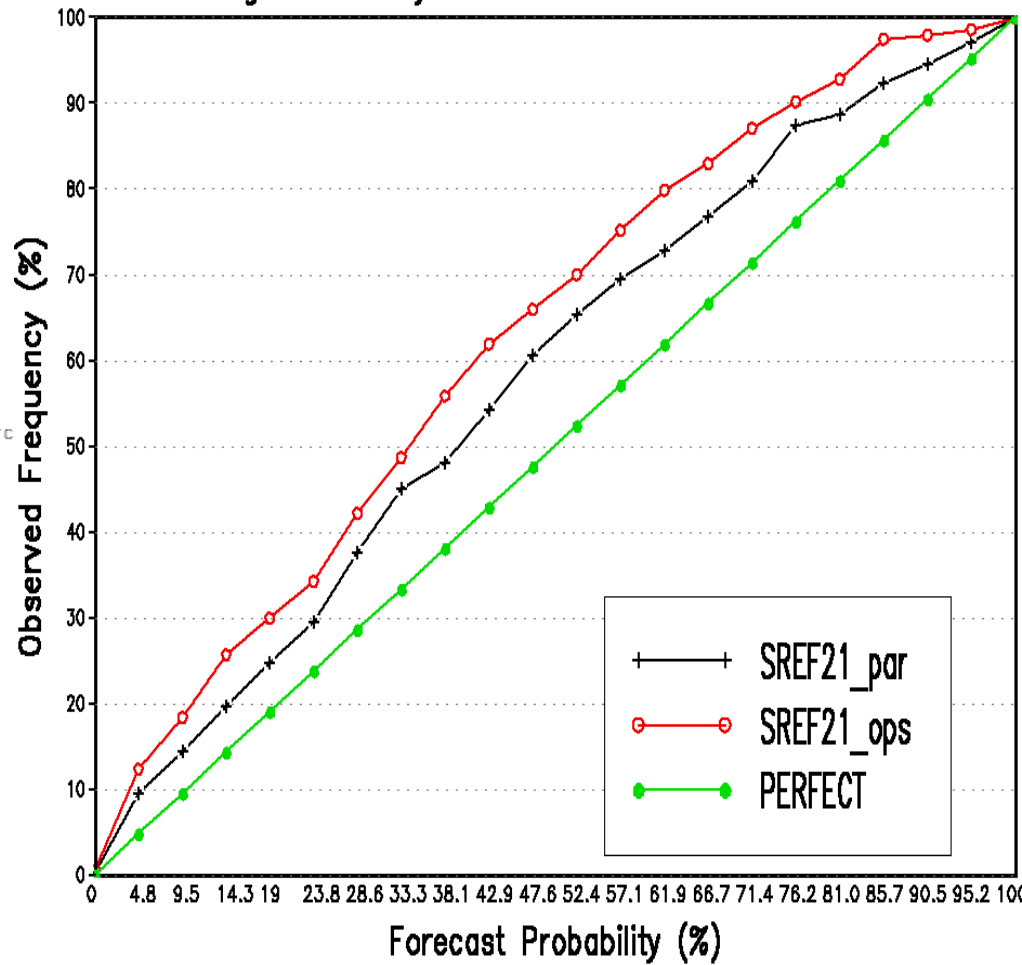


STAT=FHO PARAM=APCP/24 FHOUR=27+33+39+45+51+57+63+69+75+81+87 V\_RGN=G212/RFC  
 VYMDH=200810150000-200811162300

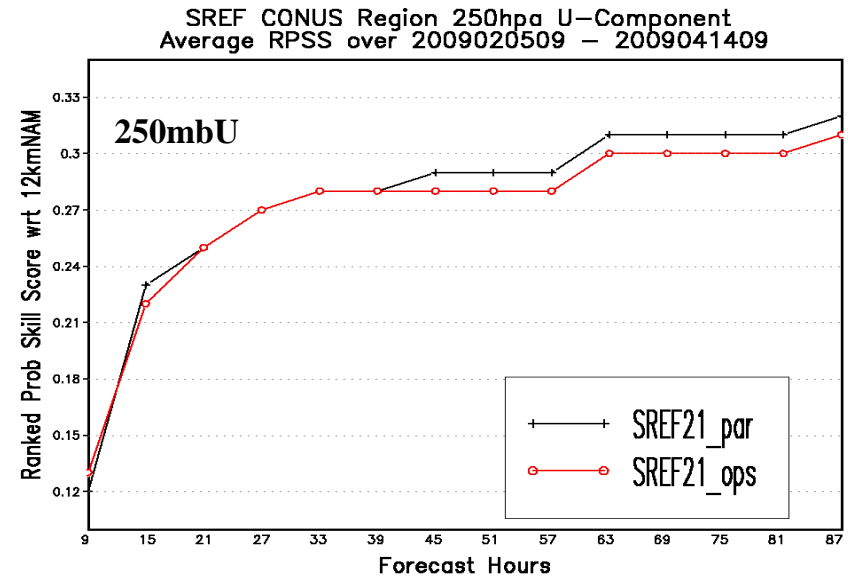
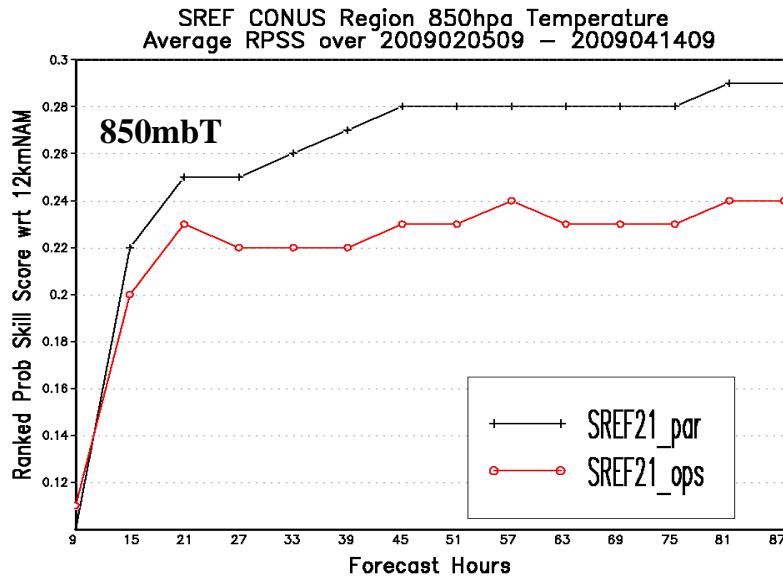
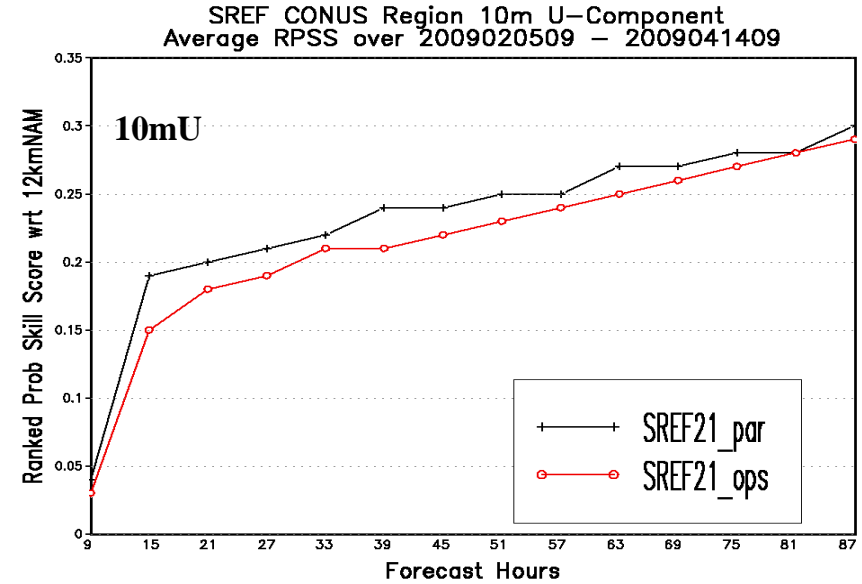
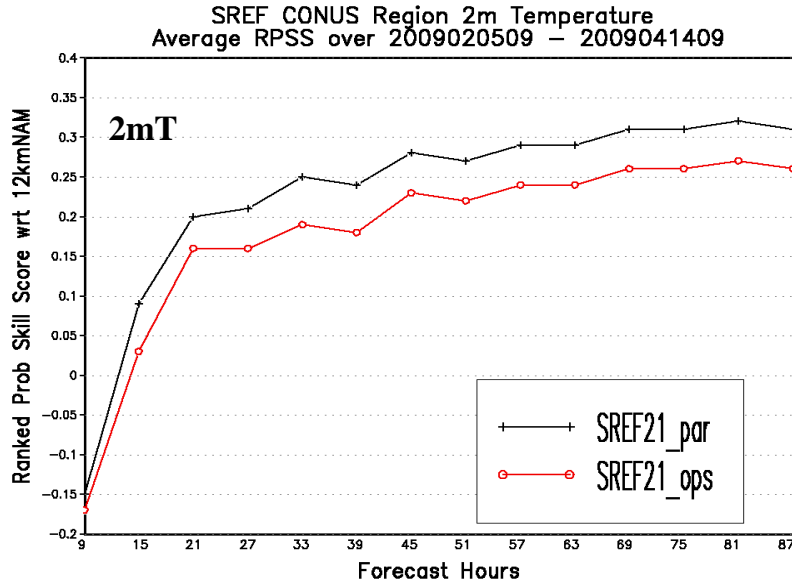


**Fig.9: Reliability diagram of 2m-temperature probabilistic forecast at 87hr, averaged over the period of Feb. 5 – April 14, 2009: new SREF in black and old SREF in red, the closer to the green line, the better**

**SREF CONUS Region 2m Temperature  
 Average Reliability For 2009020509 – 2009041409**

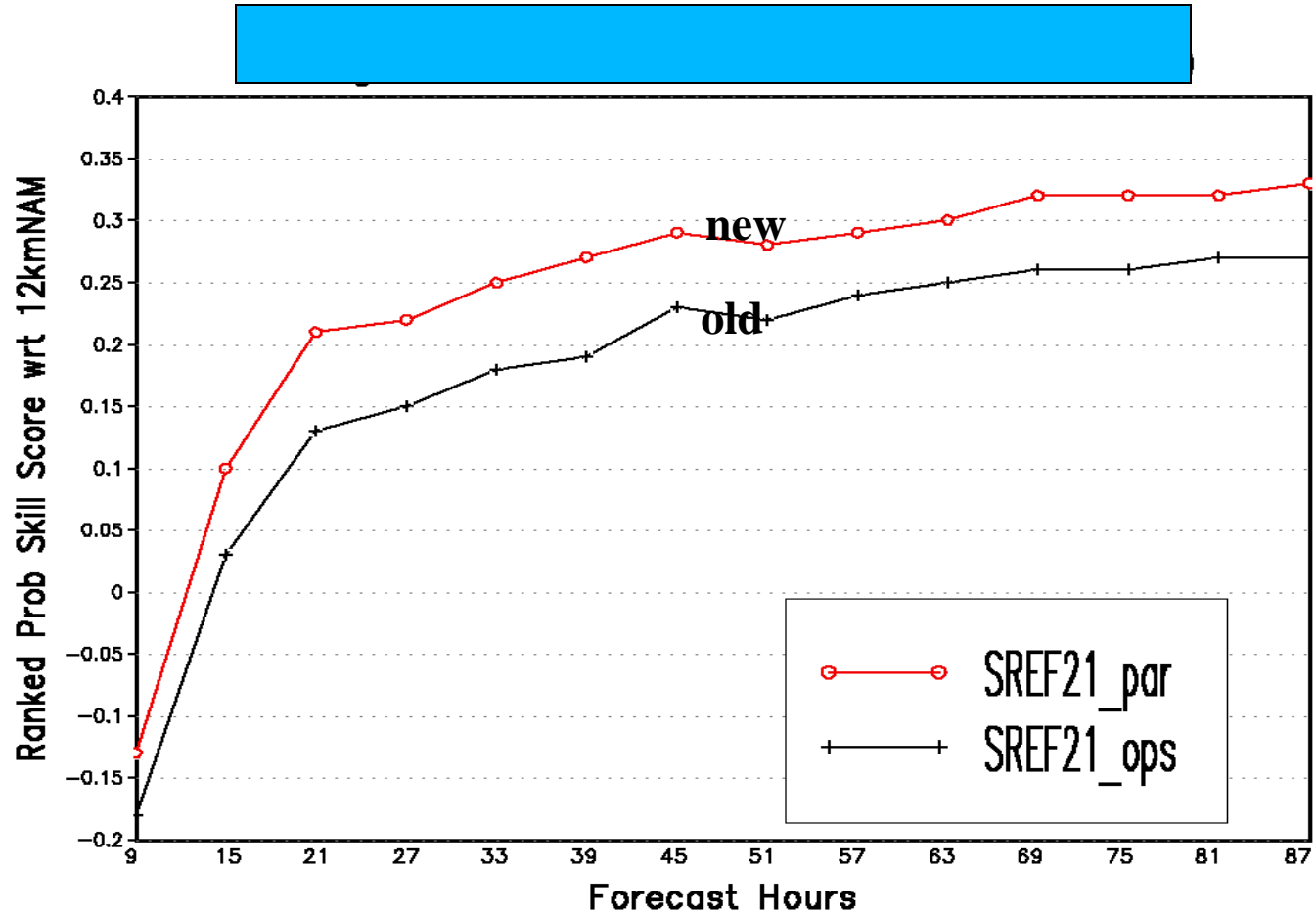


# Fig 8: Probabilistic forecast measured by RPSS: large improvement for all fields (Feb. 5 – Apr. 14, 2009)



# Ranked Probabilistic Skill Score

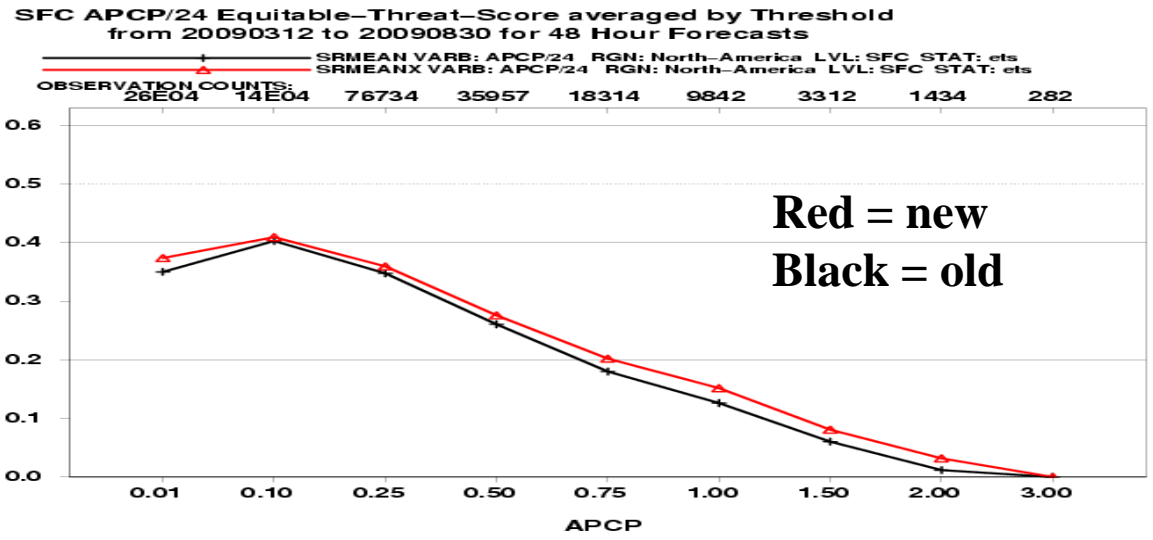
**CONUS 2 meter temperature**  
**02 February – 10 August 2009**



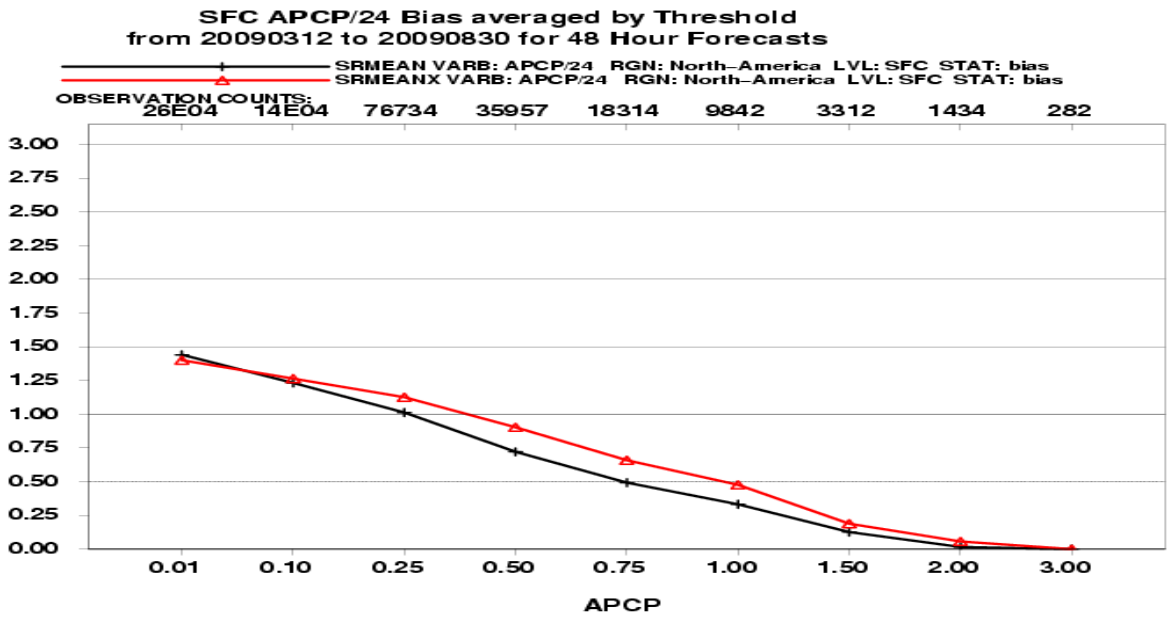
**New SREF is more skillful than the old SREF**

# Warm season 24h Accumulated Precip from EMC parallel (Mar. 12 – Aug. 30, 2009)

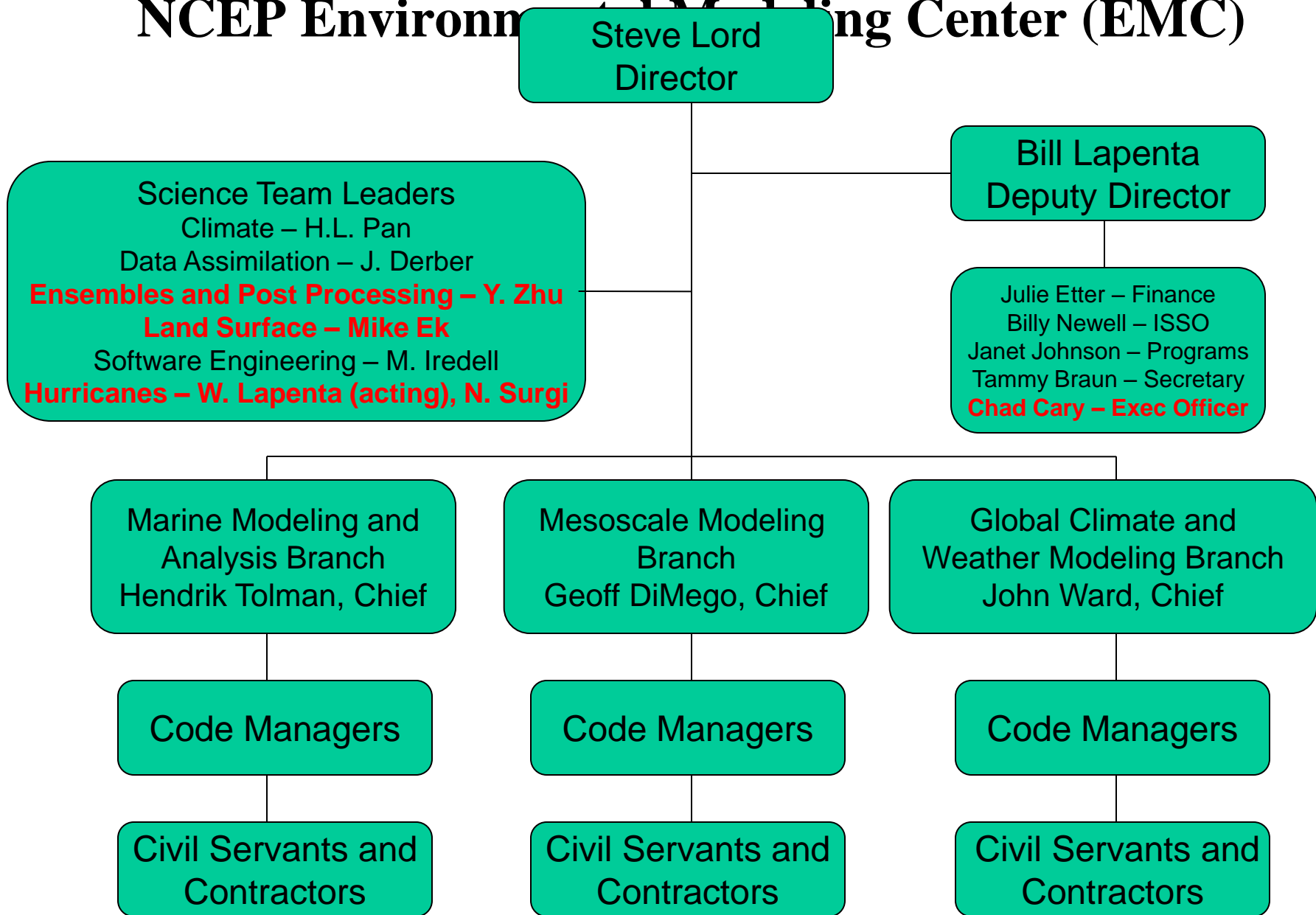
**ETS**



**BIAS**

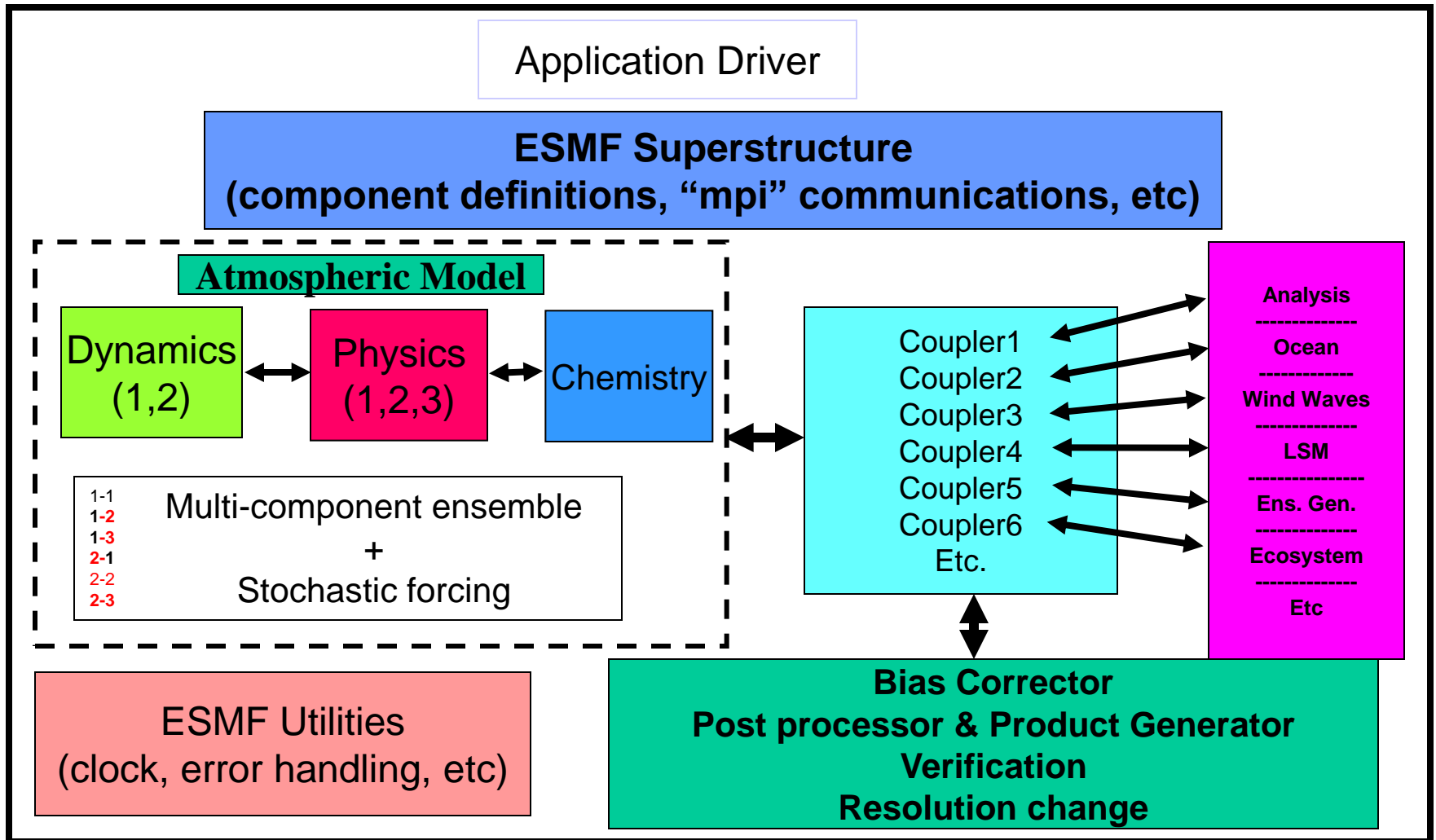


# NCEP Environmental Modeling Center (EMC)



# NOAA Environmental Modeling System (NEMS)

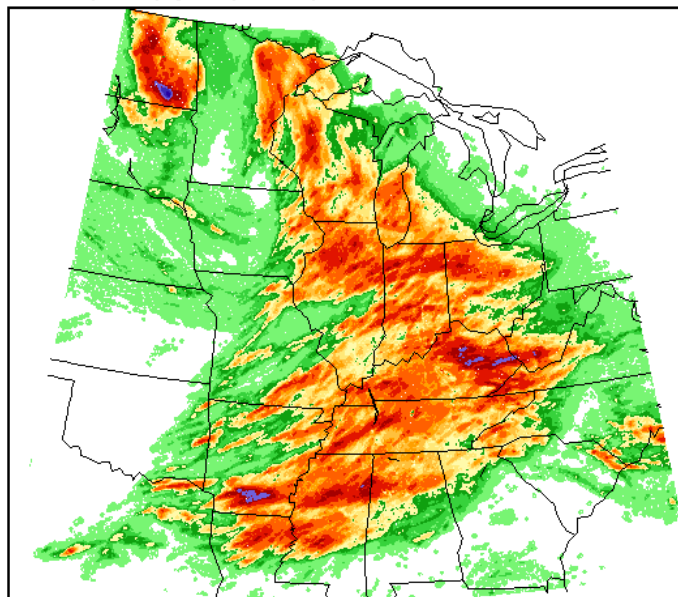
(uses standard ESMF compliant software)



\* Earth System Modeling Framework (NCAR/CISL, NASA/GMAO, Navy (NRL), NCEP/EMC), NOAA/GFDL  
 2, 3 etc: NCEP supported thru NUOPC, NASA, NCAR or NOAA institutional commitments  
 Components are: Dynamics (spectral, FV, NMM, FIM, ARW, FISL, COAMPS...)  
 Physics (GFS, NRL, NCAR, GMAO, ESRL, GFDL...)

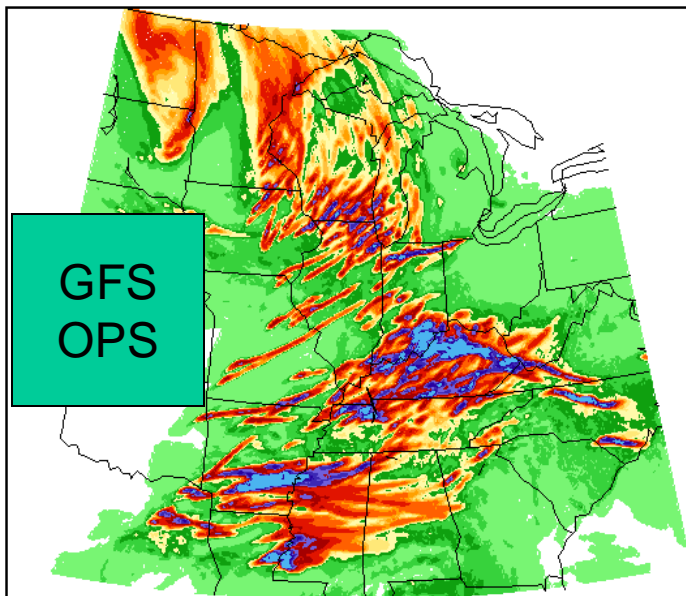
NHC, HPC, OPC, CPC, AWC and SPC  
for their timely evaluations

Obs. precip(mm/24hr) 4.8km V2004053112 ST4

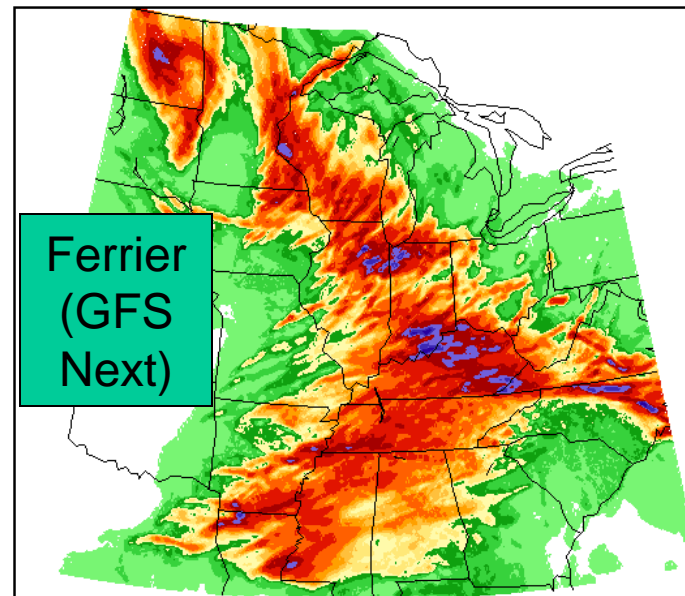


**Impact  
Of  
Microphysics  
5 km  
(RSM)**

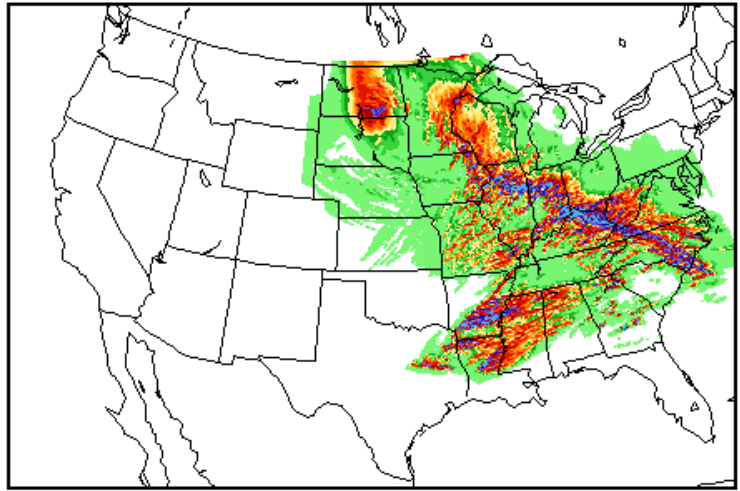
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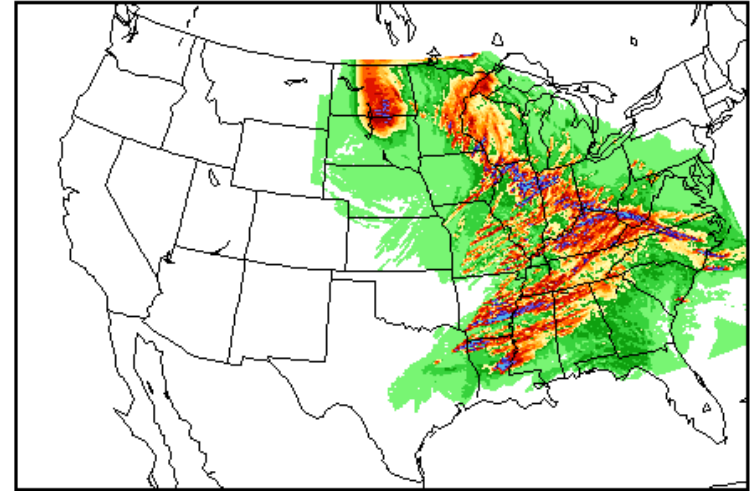
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Tprp(mm/24hr) 4km Valid 12Z 31 May04 RSM-noconv fh=48



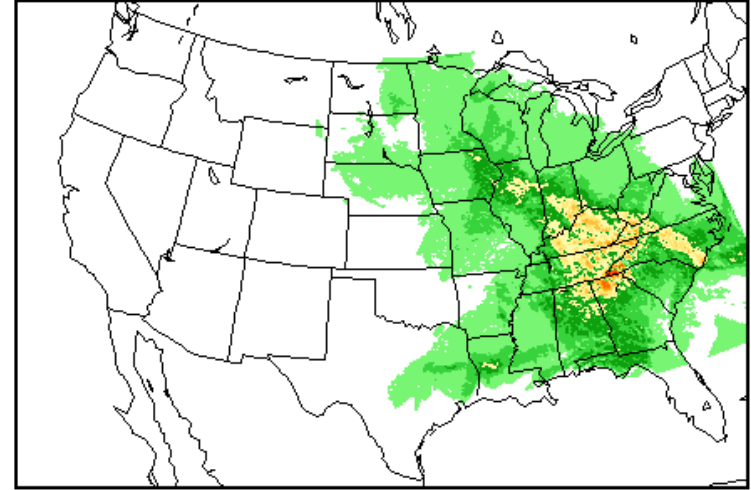
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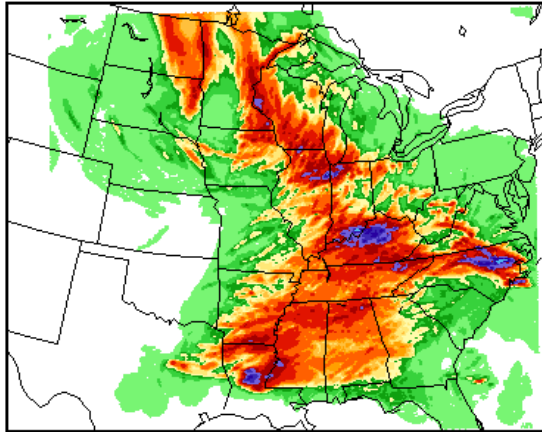
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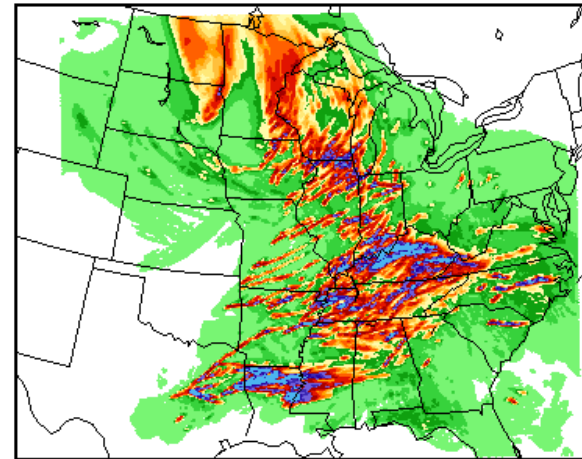
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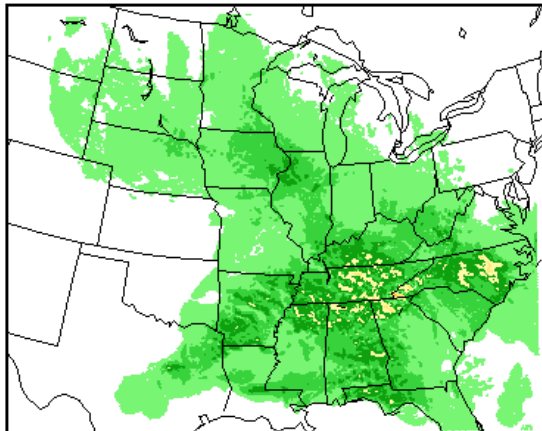
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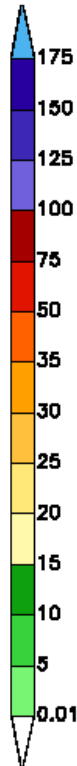
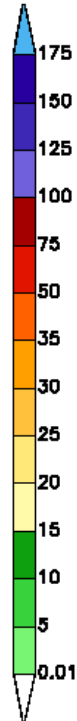
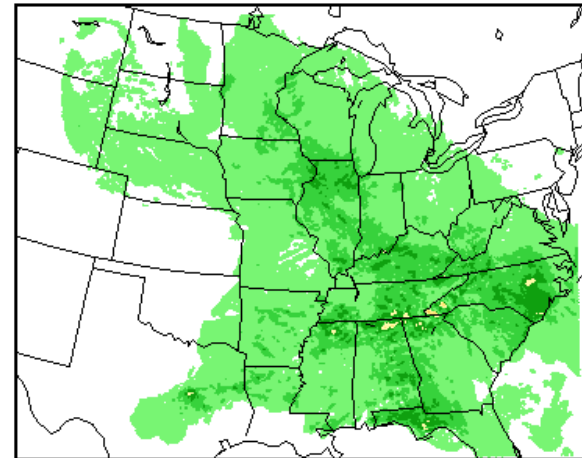
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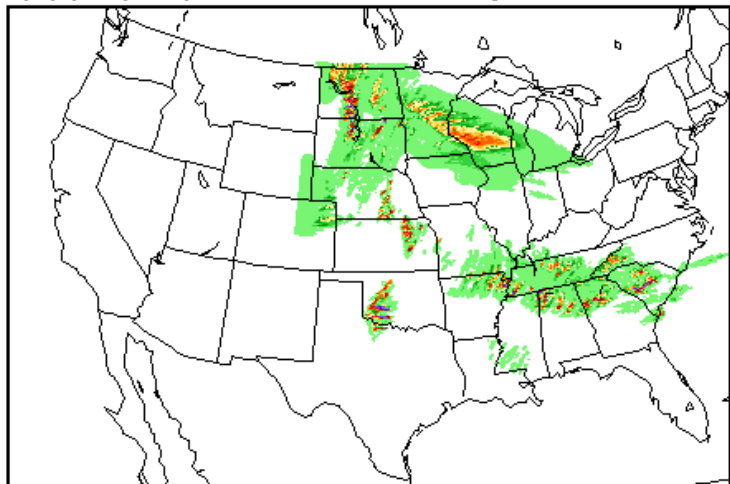
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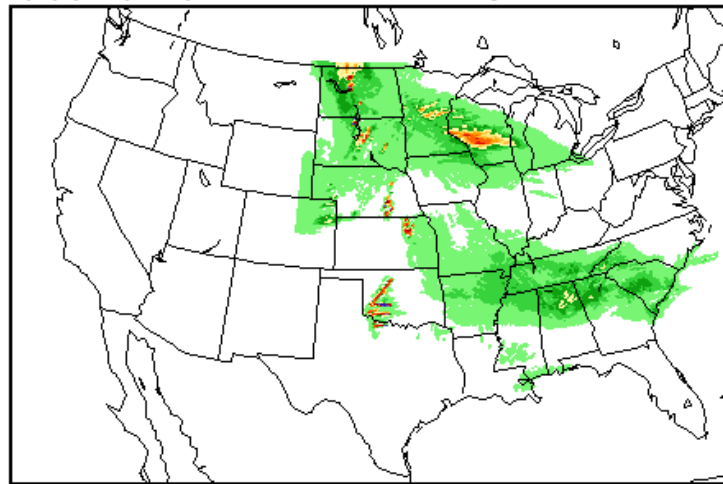
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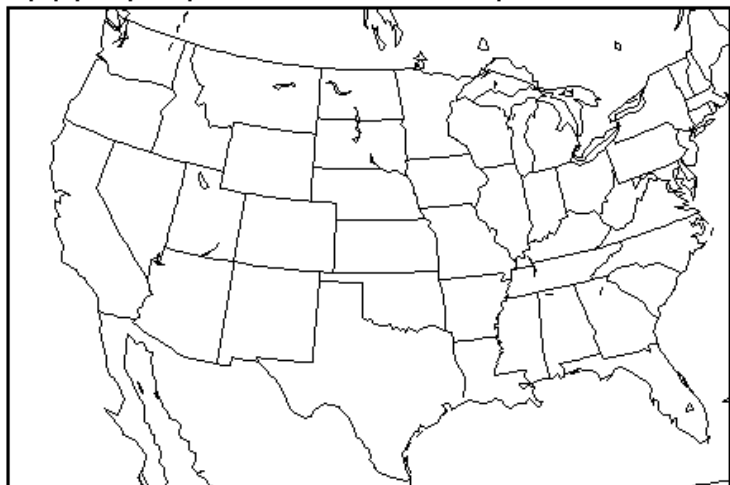
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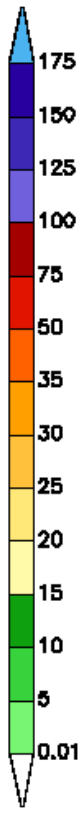
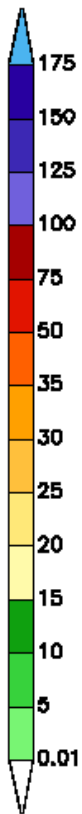
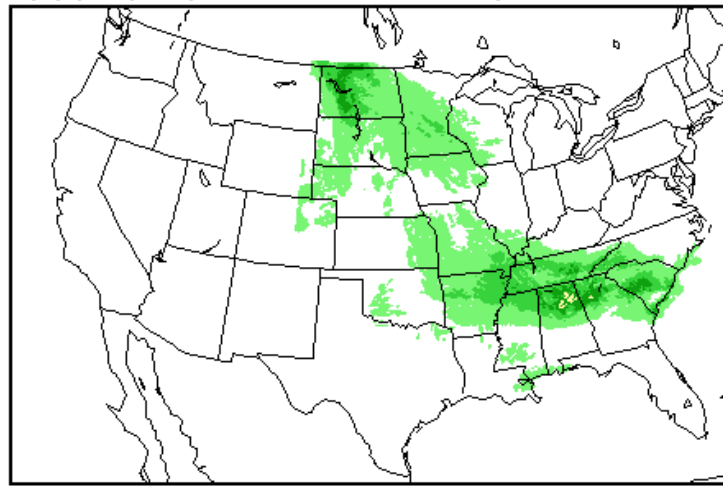
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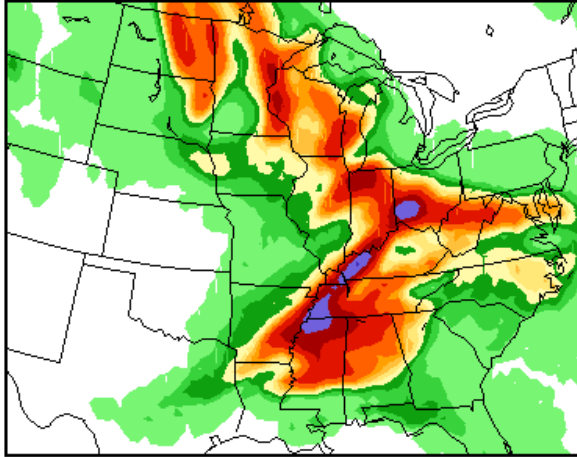
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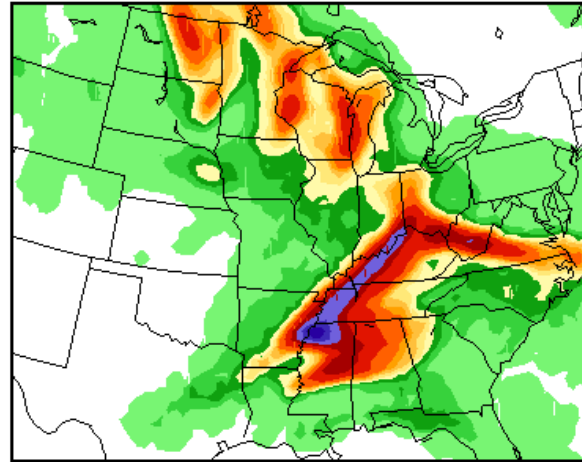
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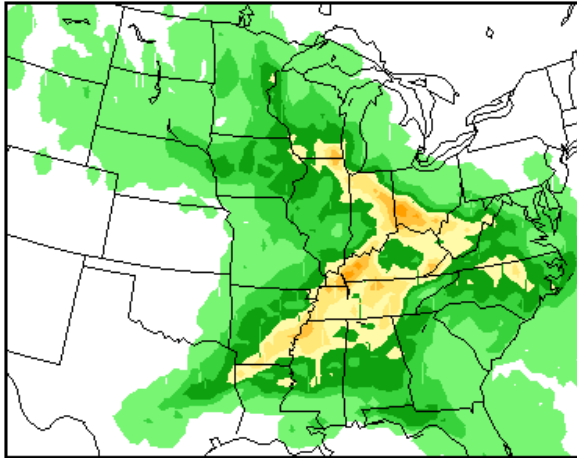
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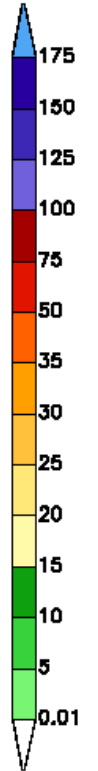
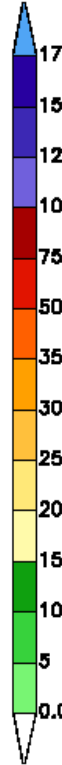
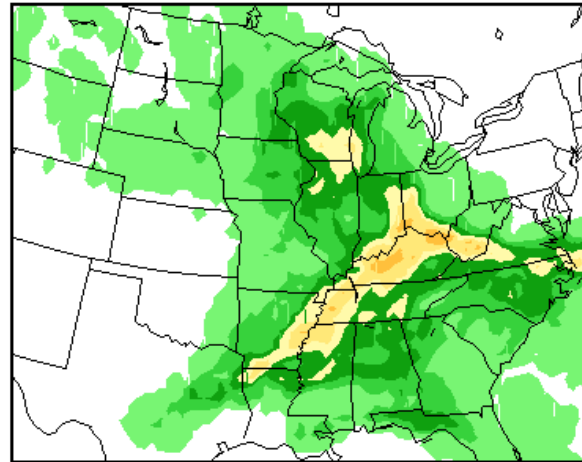
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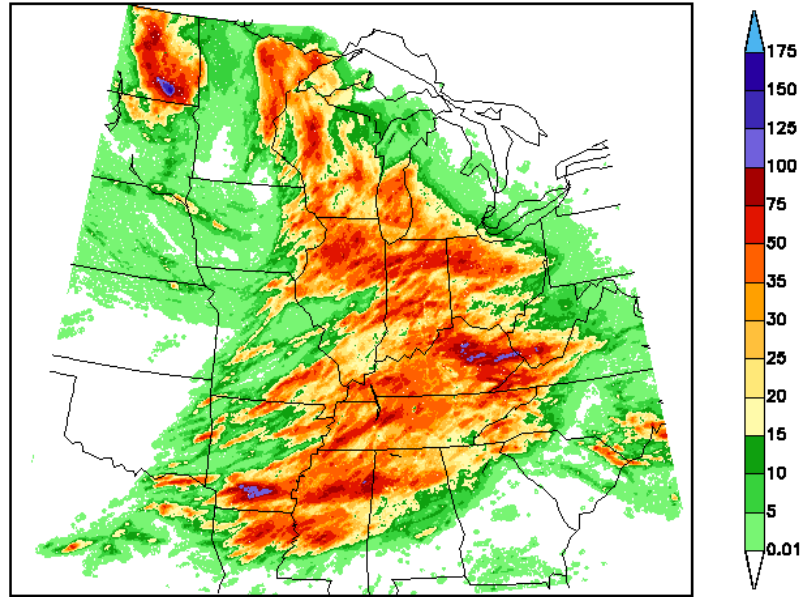
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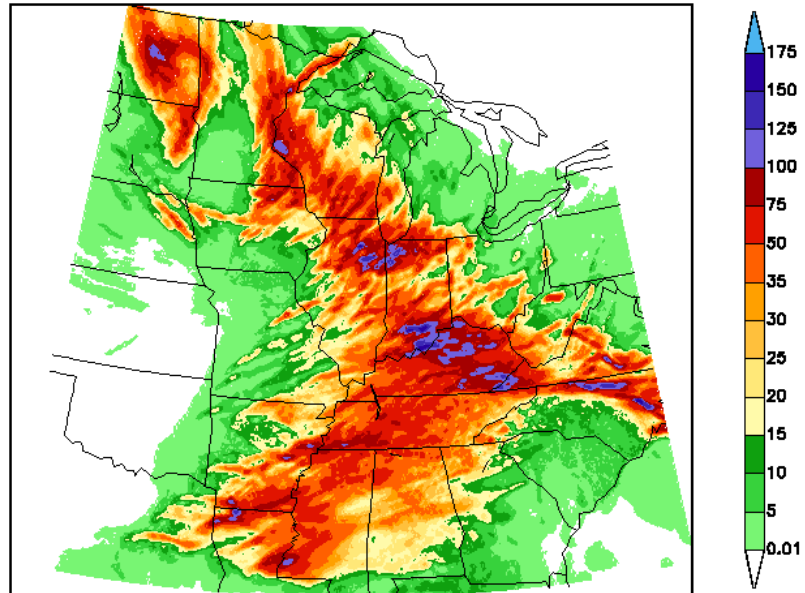
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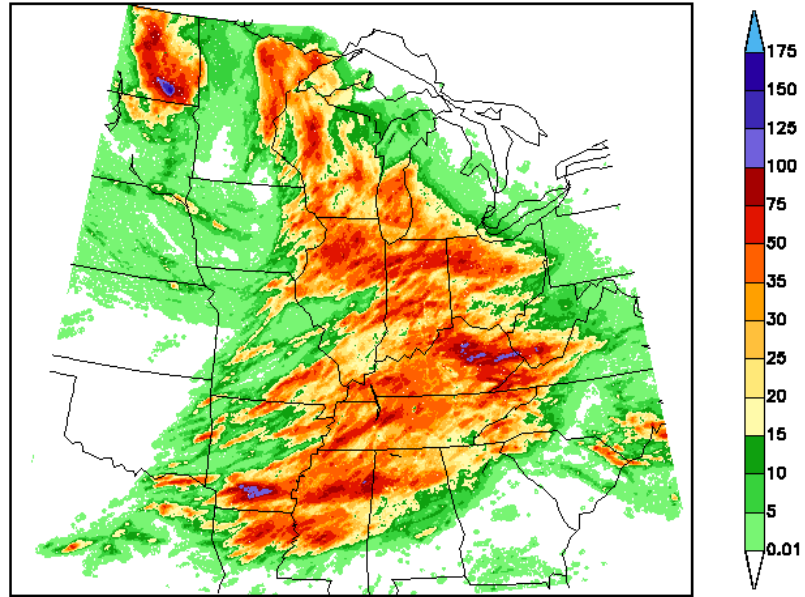
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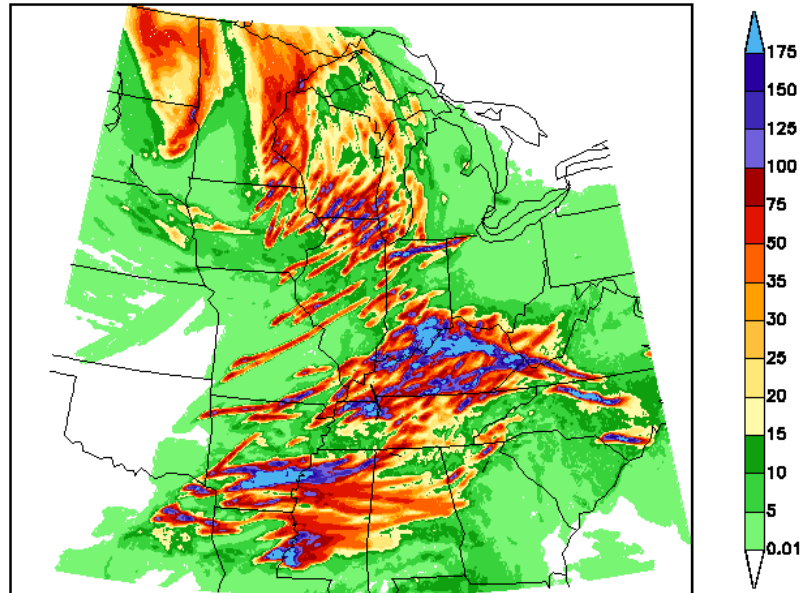
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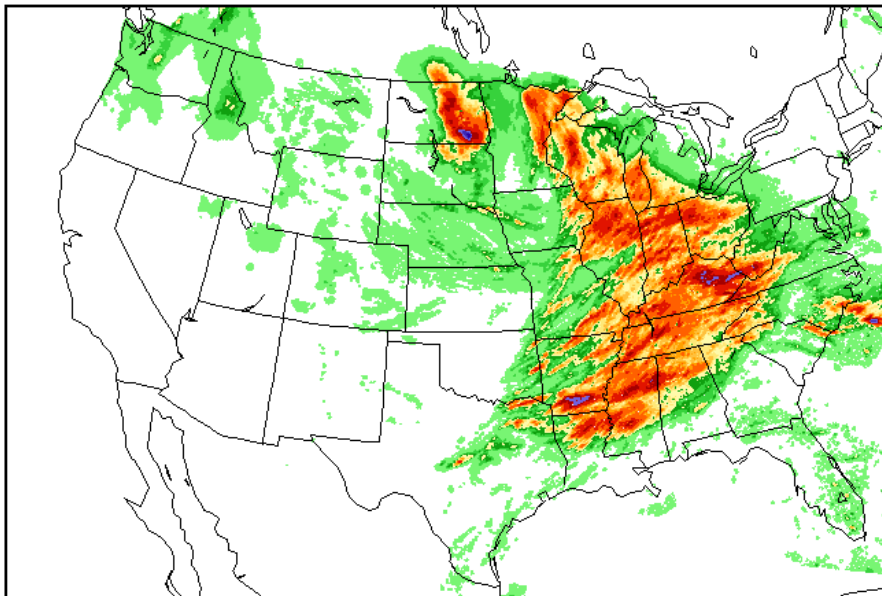
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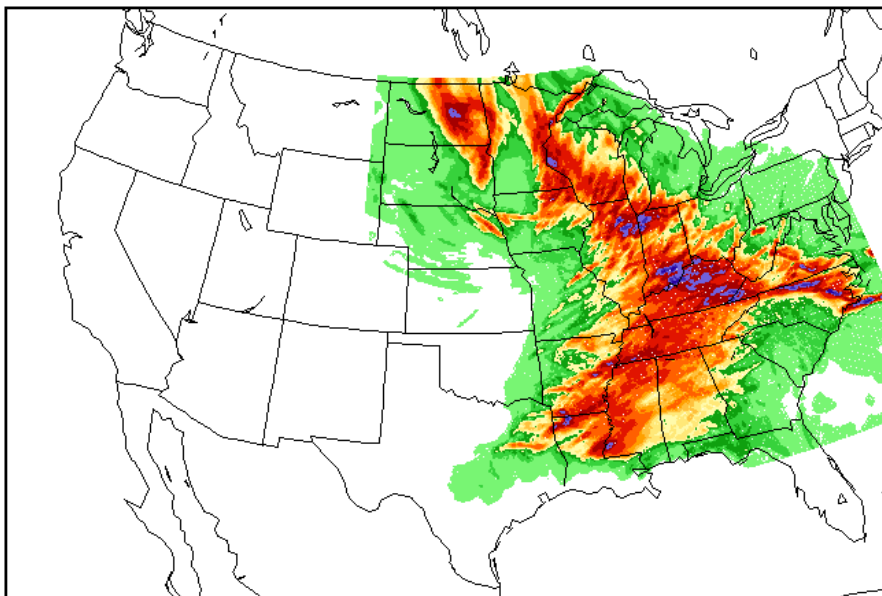
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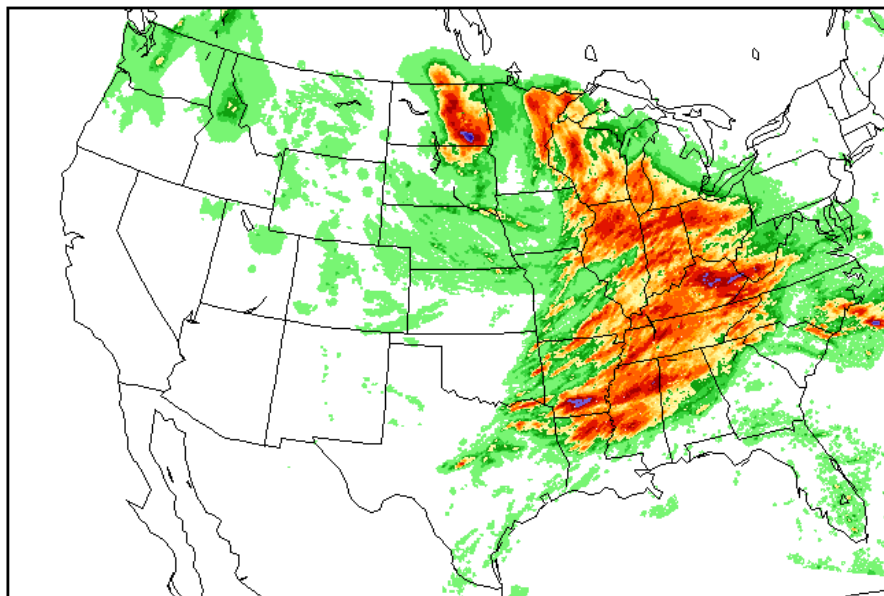
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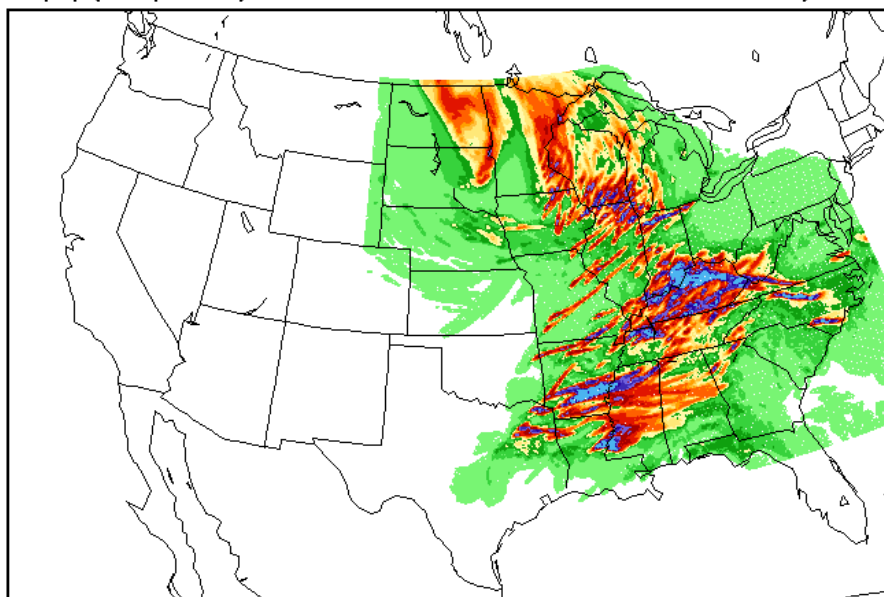
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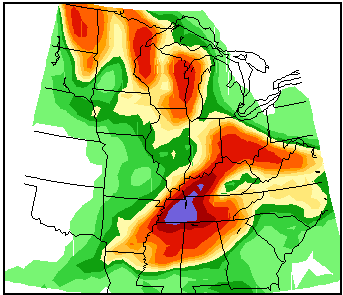
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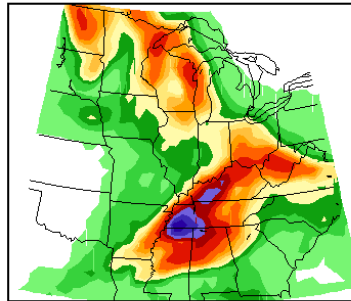
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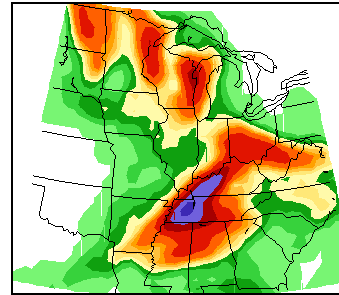
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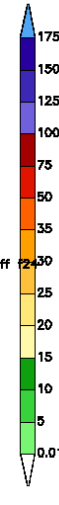
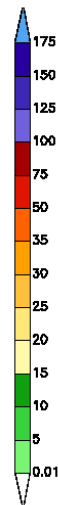
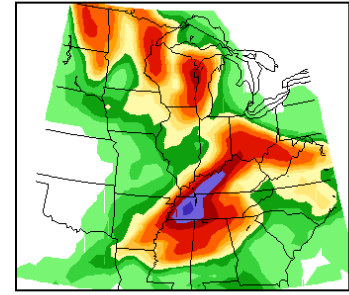
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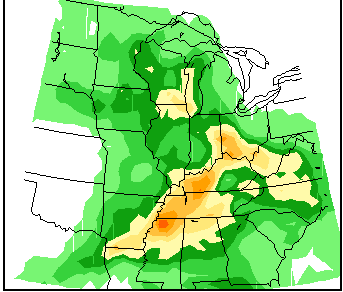
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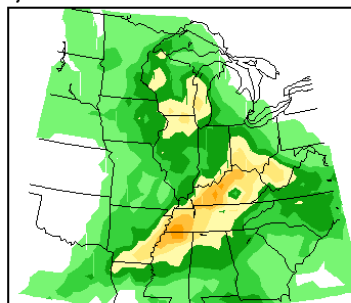
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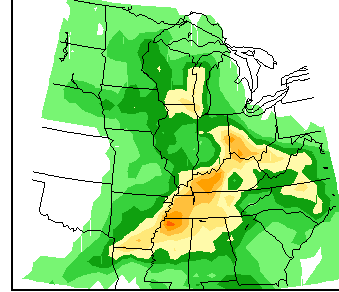
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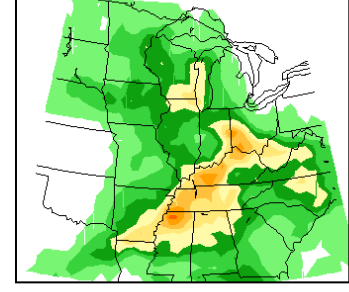
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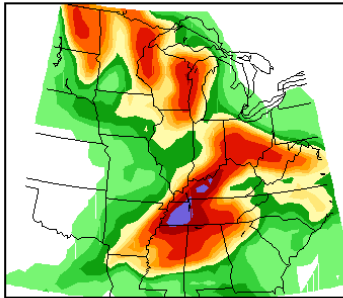
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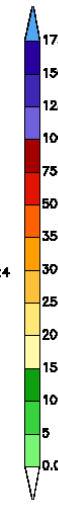
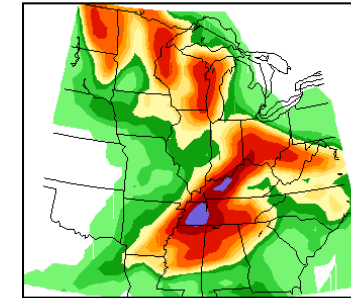
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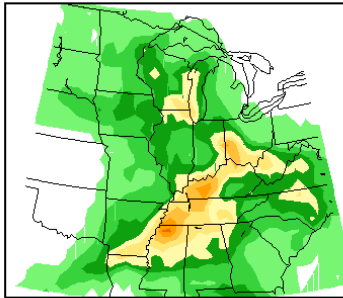
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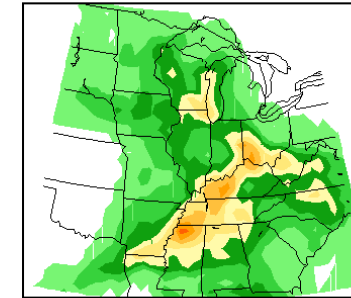
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Cprp(mm/24hr) 50km Y2004053112 NHYD RSM-SAS BF nhyd2r f24



**Thankyou!**

