



**N
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WRF in NCEP Operations

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Where the Nation's climate and weather services begin

TOPICS

- Condensed Chronologies
- WRF Post Processor
- HiResWindow
- Short Range Ensemble Forecast (SREF)
- North American Mesoscale (NAM)
- Future Plans

NMM, ARW in NCEP Operations

• Pre-WRF NMM at NCEP

- May 2000: nonhydrostatic option released in upgrade to [NCEP's workstation Eta](#)
- May 2001: NMM model equations, solution techniques & test results published in [Janjic, Gerrity, and Nickovic](#), 2001, Mon. Wea. Rev. also [Janjic](#), 2003, Meteor. & Atmos. Phys.
- February 2002: [HiResWindow](#) runs upgraded to use 8 km NMM replaces 10 km Eta (hydrostatic)
- February 2002: [On-Call Emergency Response](#) (OCER) capability begins using 4 km NMM to support HYSPLIT
- May 2003: [Fire Weather / IMET Support](#) runs implemented using 8 km NMM

• WRF-ARW at NCEP

- September 2004: [HiResWindow](#) first WRF implementation of 10 km WRF-ARW v1.3
- June 2005: [HiResWindow](#) upgraded to use 5.8 km WRF-ARW with explicit convection
- December 2005: [Short Range Ensemble Forecasting](#) system adds 3 members using 45 km WRF-ARW v2.0
- September 2007: [HiResWindow](#) expanded domain and upgraded to 5.1 km WRF-ARW v2.2.1
- **Aug-Sept 2009: SREF WRF-ARW upgraded to v2.2.1, add 2 members and increase resolution to 32 km**

WRF-NMM in NCEP Operations

- April 2004 thru present: [NSSL/SPC Spring Program](#), daily developmental run of 4.5 km WRF-NMM with explicit convection
- September 2004: [HiResWindow](#) first WRF implementation of 8 km WRF-NMM v1.3 replaces pre-WRF NMM
- June 2005: [HiResWindow](#) upgraded to use 5.1 km WRF-NMM with explicit convection
- December 2005: [Short Range Ensemble Forecasting](#) system adds 3 members using 40 km WRF-NMM v2.0
- June 2006: [NAM runs](#) use 12 km WRF-NMM v2.1 & WRF-GSI replacing Eta & Eta-3DVar
- September 2007: [HiResWindow](#) expanded domain and upgraded to 4 km WRF-NMM v2.2.1
- December 2008: final in series of NAM upgrades

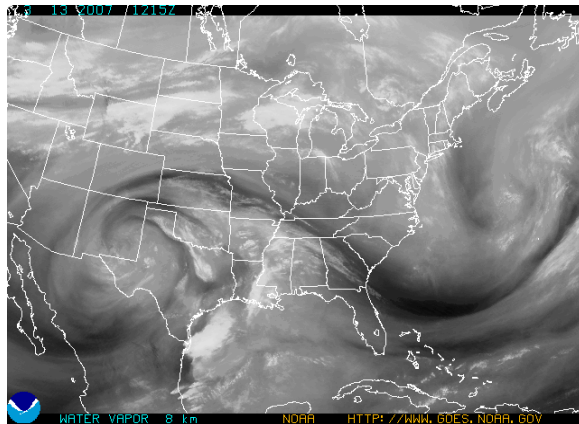
Updates to WRF Post Processor

Courtesy of Hui-Ya Chuang

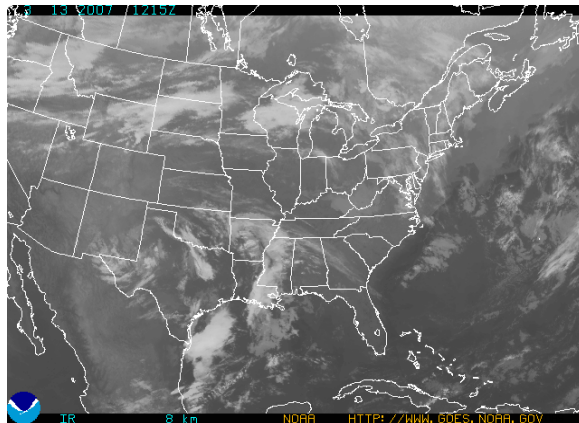
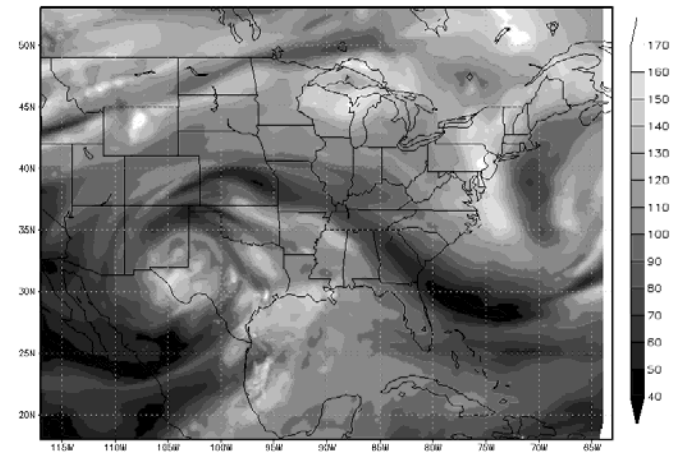
- WRF Post Processor version 3.1
 - Released on April 9, 2009 by DTC
 - Identical to NCEP's operational NAM code except
 - It does not produce simulated GOES fields due to
 - Linux compile issue for Community Radiative Transfer Model.
- The updates and bug fixes in this release include:
 - a) capability to properly treat all hydrometeor fields from NMM runs using non-Ferrier microphysics schemes;
 - b) improved speed in horizontal interpolation;
 - c) bug fixes for Polar Stereographic and Lambert Conformal projections in the Southern Hemisphere.
- Future updates will include:
 - Radar Echo Top height (requested by FAA)
 - Ri-based PBL height (to be compatible with NCEP's [verification](#) & [analysis](#) projects which are based on diagnosing PBL height from radiosonde and aircraft soundings using critical Ri ($=0.25$))

Simulated Imagery from NAM (WRF-NMM) versus GOES observations

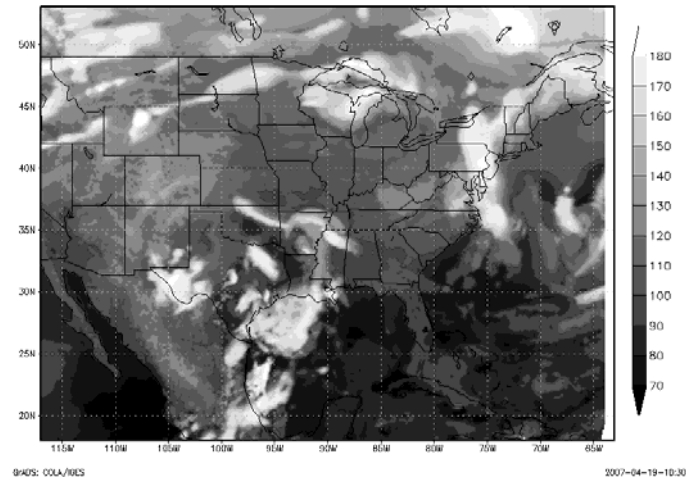
GOES water vapor channel



WRF NMM water vapor channel



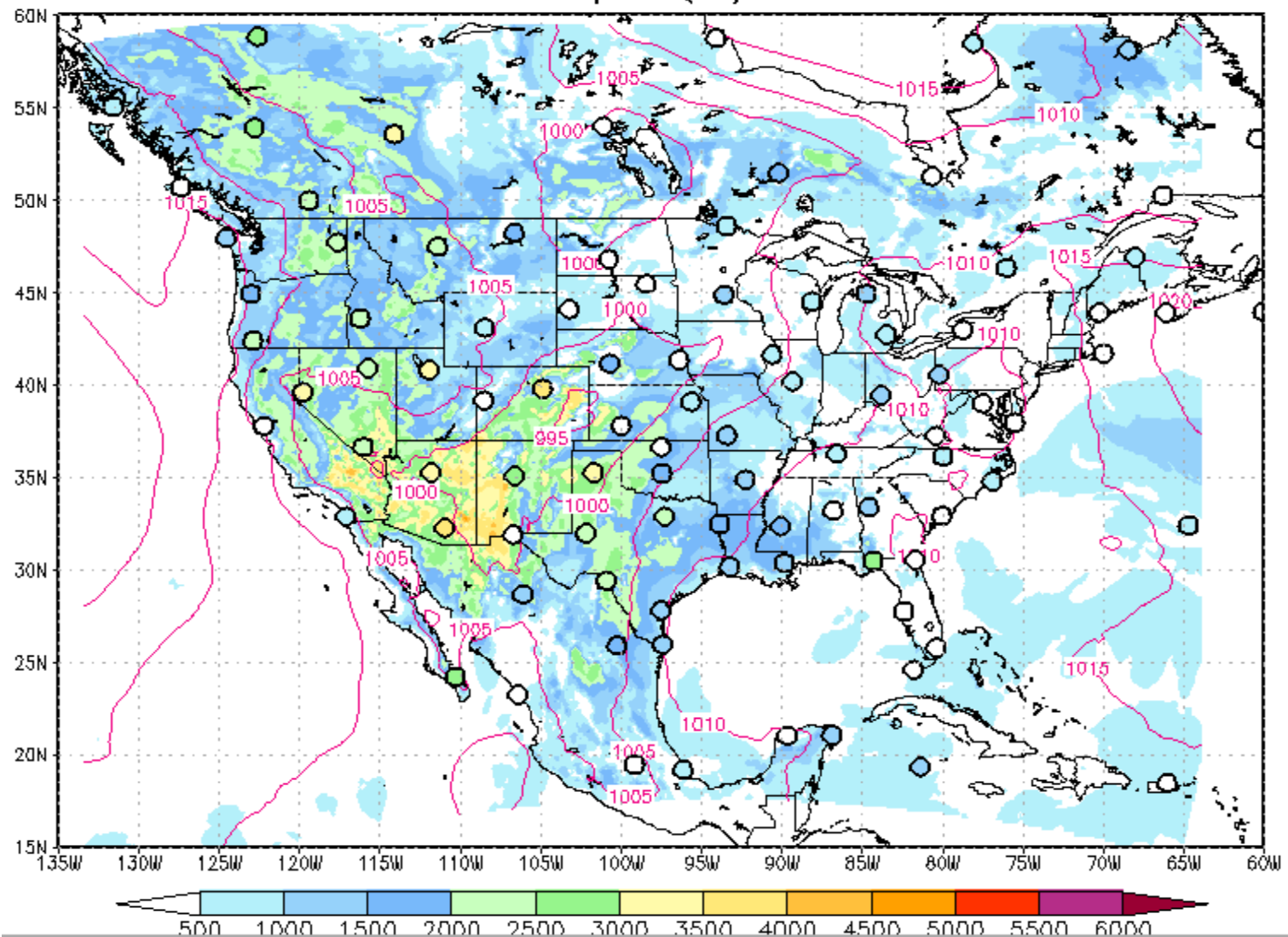
GOES IR channel



WRF NMM IR channel

NAM 12 hr Forecast Ri-Based PBL Height with Verifying RAOBs

12hr fcst NAM PBL depth (Ri) Valid 00Z19JUN2009



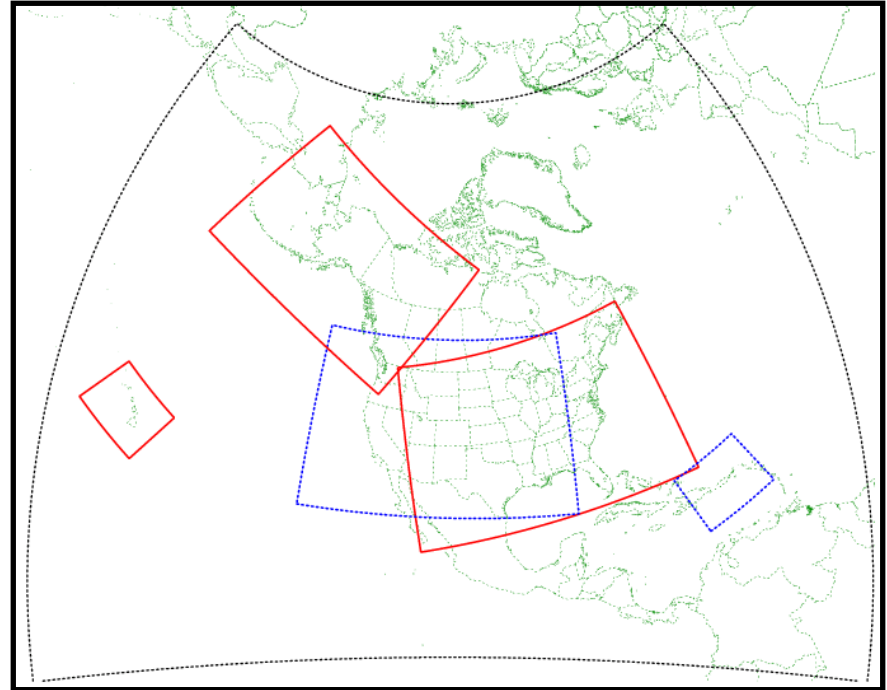
HiResWindow Updates in CY2008

- Feb 12
 - Fix WRF Post to get frozen precip included in computation of simulated reflectivity for ARW runs. (NWS Central Region)
- Apr 15
 - 1) Fix a bug in the boundary smoothing along the eastern boundary of NMM domains;
 - 2) Change compilation options for NMM and task geometry for both NMM & ARW to make codes run faster;
 - 3) Trigger prelim job from 48 h GFS forecast rather than 84 h GFS forecast;
 - 4) Change the NMM namelists to produce hourly model output (added to NAWIPS 4/18;
 - 5) Add updraft helicity to NMM output. (NCEP SPC)
- Aug 6
 - 1) Change the generating process code (PDS octet 6) from 84 to WRF core specific values of 112 (WRF-NMM) and 116 (WRF-ARW) (for AWIPS NCF);
 - 2) Add vertical motion at 200, 250, and 1000 hPa isobaric levels (for DTRA);
 - 3) Fix WRF Post to properly generate precipitation type and total cloud field percentage for the WRF-ARW.
- Sep 15
 - Generation of GRIB2 is changed so distinct GRIB records are made for wind components (AWIPS NCF).
- Nov 4
 - WRF post input code is corrected to eliminate risk of seg fault failure.

HiRes Window Fixed-Domain Nested Runs

Configuration/Schedule as of September 2007

- 4-5 km explicit runs of both NMM & ARW at same time every day - **if & only if** **no** hurricane runs are needed
- 00Z : ECentral & Hawaii
- 06Z : WCentral & Puerto Rico
- 12Z : ECentral & Hawaii
- 18Z : Alaska & Puerto Rico



- **Daily displays of both ARW + NMM are at:**
<http://www.nco.ncep.noaa.gov/pmb/nwprod/analysis/> (see next slide for example) and
<http://www.emc.ncep.noaa.gov/mmb/mmbpll/nestpage/>
- **Soon (if not already) to ‘appear’ on AWIPS-Satellite Broadcast Network and NOAA-port**

Model Analyses & Forecast Page

Now Includes Sim. Reflectivity w/Zoom

To view model images, click on the desired image resolutions in the table below.

More information is available in the [Product Description Document](#)

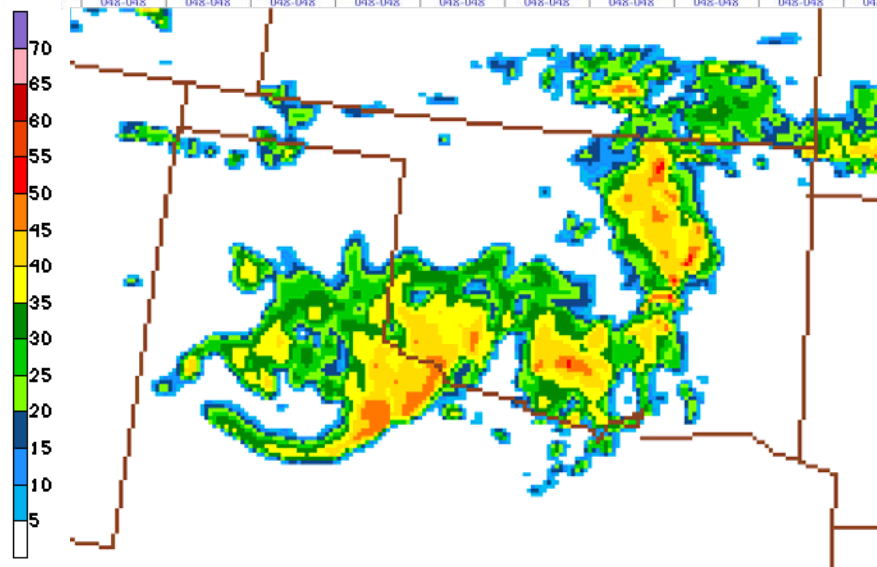
Select Region: [\[North America\]](#) [\[South America\]](#) [\[Africa\]](#) [\[Canada\]](#) [\[North Pacific\]](#) [\[Eastern Pacific\]](#) [\[Western North Atlantic\]](#) [\[Polar Ice Drift\]](#)

	00 UTC	06 UTC	12 UTC	18 UTC
NAM	coarse medium fine 4-panel charts 20-Jun-08	coarse medium fine 4-panel charts 20-Jun-08	coarse medium fine 4-panel charts 19-Jun-08	coarse medium fine 4-panel charts 19-Jun-08
GFS	coarse medium fine 4-panel charts 20-Jun-08	coarse medium fine 4-panel charts 20-Jun-08	coarse medium fine 4-panel charts 19-Jun-08	coarse medium fine 4-panel charts 19-Jun-08
GEFS	Spaghetti Charts Means & Spreads 20-Jun-08	Spaghetti Charts Means & Spreads 20-Jun-08	Spaghetti Charts Means & Spreads 19-Jun-08	Spaghetti Charts Means & Spreads 19-Jun-08
HRW	Eastern US NMM ARW 20-Jun-08	Western US NMM ARW 20-Jun-08	Eastern US NMM ARW 19-Jun-08	Alaska NMM ARW 19-Jun-08
NGM	coarse medium fine 4-panel charts 20-Jun-08		coarse medium fine 4-panel charts 19-Jun-08	
	Hurricane Graphics			
GHM	Full Domain 20-Jun-08		Nested Domain 20-Jun-08	
HWRF	Full Domain 20-Jun-08		Nested Domain 20-Jun-08	

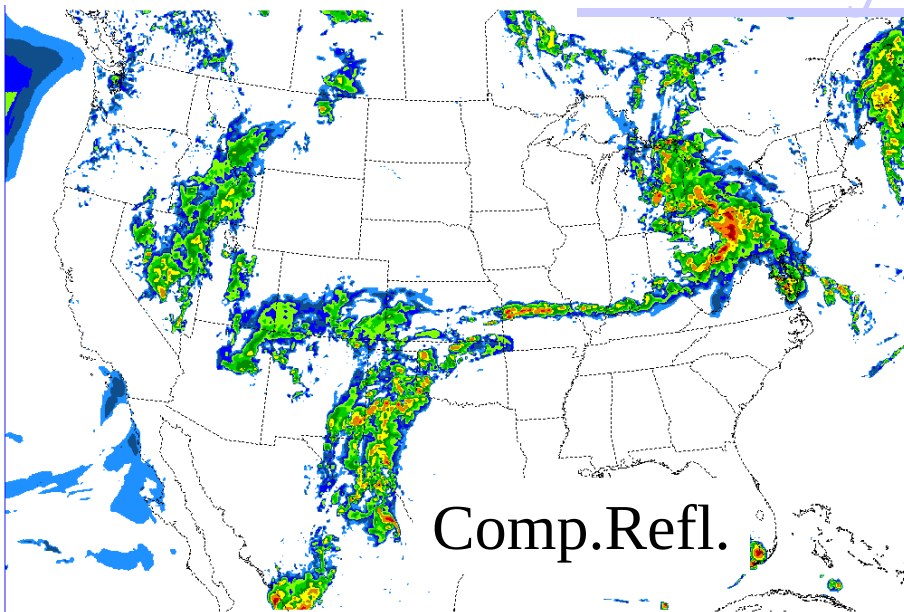
Model Analyses and Forecasts
HIRESW ARW 12 UTC

1 Hr	300mb Wind, Hr	500mb Vert. Hr	700mb RH, Hr	850mb Temp, Hr	Tot Pcpn 03 hrs	Tot Pcpn 12 hrs	Tot Pcpn 24 hrs	Tot Pcpn 36 hrs	Tot Pcpn 48 hrs	Sim. Reflectivity	MSLP 1000 - 500mb
Loop	Loop	Loop	Loop	Loop	Loop	Loop	Loop	Loop	Loop	Loop	Loop
000	000	000	000	000	000	000	000	000	000	000	000
003	003	003	003	003	003	003	003	003	003	003	003
006	006	006	006	006	006	006	006	006	006	006	006
009	009	009	009	009	009	009	009	009	009	009	009
012	012	012	012	012	012	012	012	012	012	012	012
015	015	015	015	015	015	015	015	015	015	015	015
018	018	018	018	018	018	018	018	018	018	018	018
021	021	021	021	021	021	021	021	021	021	021	021
024	024	024	024	024	024	024	024	024	024	024	024
027	027	027	027	027	027	027	027	027	027	027	027
030	030	030	030	030	030	030	030	030	030	030	030
033	033	033	033	033	033	033	033	033	033	033	033
036	036	036	036	036	036	036	036	036	036	036	036
039	039	039	039	039	039	039	039	039	039	039	039
042	042	042	042	042	042	042	042	042	042	042	042
045	045	045	045	045	045	045	045	045	045	045	045
048	048	048	048	048	048	048	048	048	048	048	048

4-Panel Charts (Hours)											
1d	300mb Wind, Hr	500mb Vert. Hr	700mb RH, Hr	850mb Temp, Hr	Tot Pcpn 03 hrs	Tot Pcpn 12 hrs	Tot Pcpn 24 hrs	Tot Pcpn 36 hrs	Tot Pcpn 48 hrs	Sim. Reflectivity	MSLP 1000 - 500mb
000-009	000-009	000-009	000-009	000-009	000-009	000-009	000-009	000-009	000-009	000-009	000-009
012-021	012-021	012-021	012-021	012-021	012-021	012-021	012-021	012-021	012-021	012-021	012-021
024-033	024-033	024-033	024-033	024-033	024-033	024-033	024-033	024-033	024-033	024-033	024-033
036-045	036-045	036-045	036-045	036-045	036-045	036-045	036-045	036-045	036-045	036-045	036-045
048-048	048-048	048-048	048-048	048-048	048-048	048-048	048-048	048-048	048-048	048-048	048-048

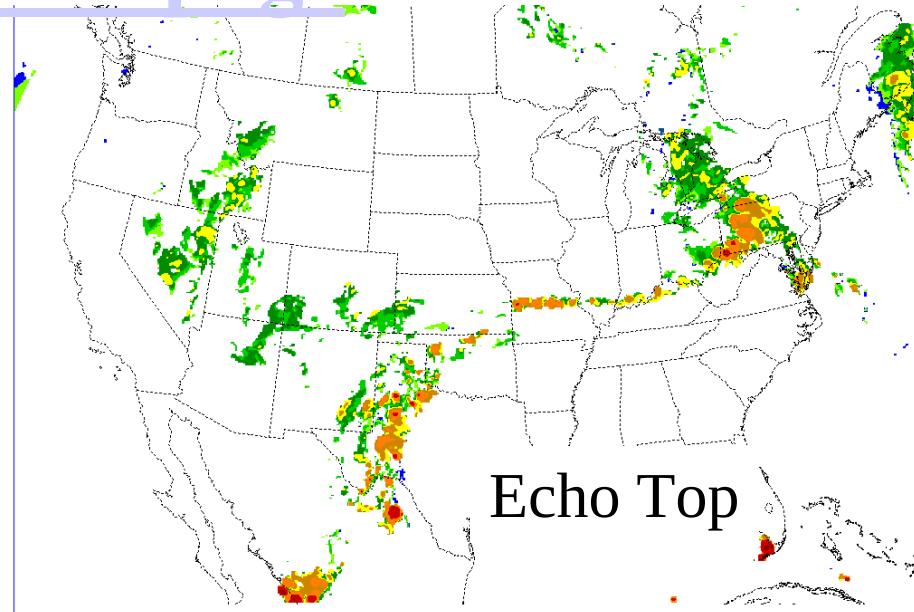


Matt Pyle Webpage



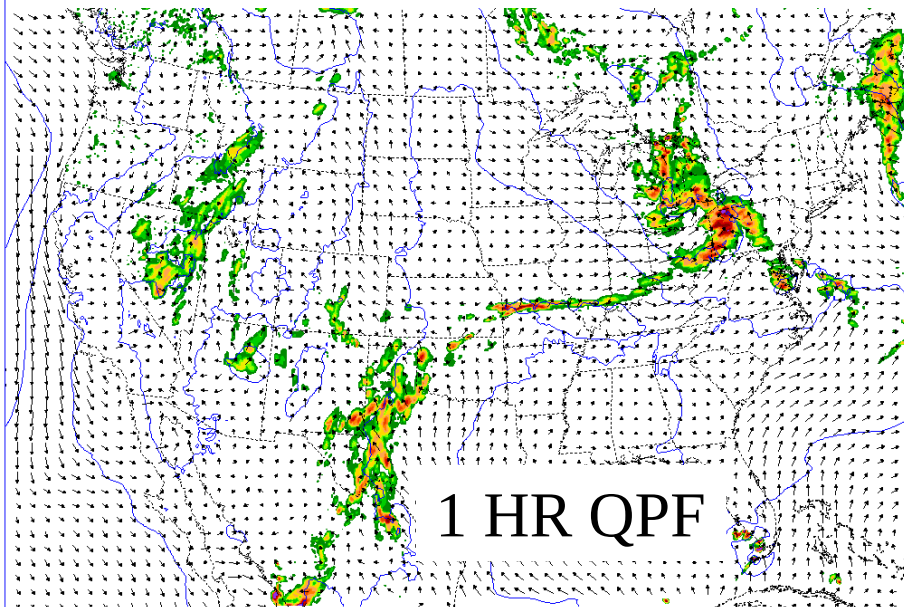
Comp.Refl.

090620/1200V012 SFC REFC
5 10 15 20 25 30 35 40 45 50 55 60 65



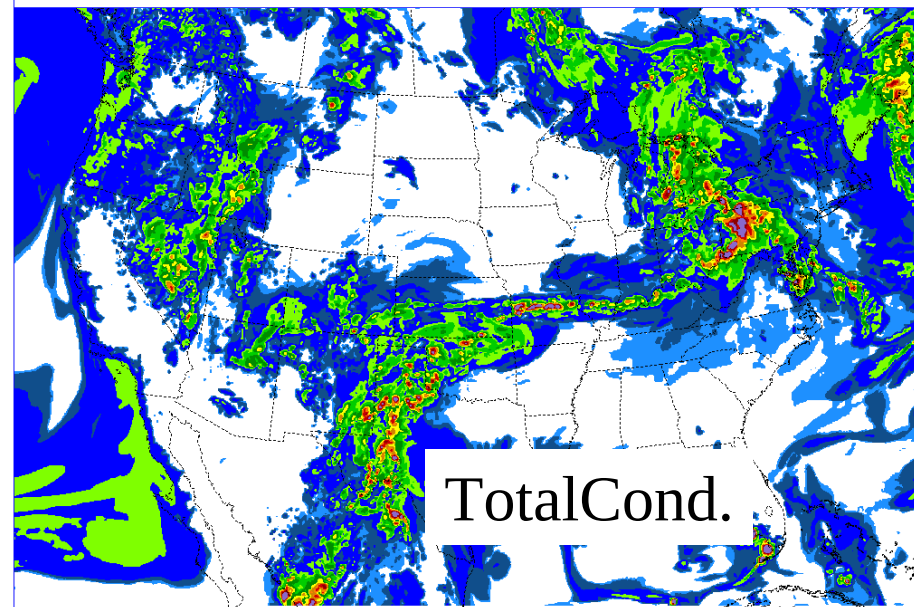
Echo Top

090620/1200V012 SFC ECHTOP
1000 3000 5000 7000 9000 11000 13000 15000 17000



1 HR QPF

090620/0000F012 P01I, EMSL, 10 m winds
.01 .05 .10 .15 .20 .30 .50 .75 1.00 1.50 2.00
20 KTS →



TotalCond.

090620/1200V012 SFC TCOLC
.001 .010 .100 .500 1.000 2.000 4.000 6.000 8.000 10.000 15.000 20.000

Plans for HiResWindow

- Improve initial conditions (Liu & Parrish)
 - Apply GSI analysis (as 3rd ‘outer-loop’)
 - Using radial winds only
 - Sharpen background error covariances
 - Apply Diabatic Digital Filter (ala RUC)
 - Force latent heating from 88D reflectivity mosaic
- Improve resolution to $\sim 2\text{-}3$ km
- Replace NMM with NMMB

Short Range Ensemble Forecast (SREF) System

- Four-per-day runs started July 2006
- Bias Correction added December 2007
- Routine displays etc. are available at:
<http://wwwt.emc.ncep.noaa.gov/mmb/SREF/SREF.html>
<http://www.nco.ncep.noaa.gov/pmb/nwprod/analysis/>
- Fall 2008 Upgrade was delayed until after NCEP's new computers are accepted (~Aug 2009)

SREF FALL-2008/9 Upgrade

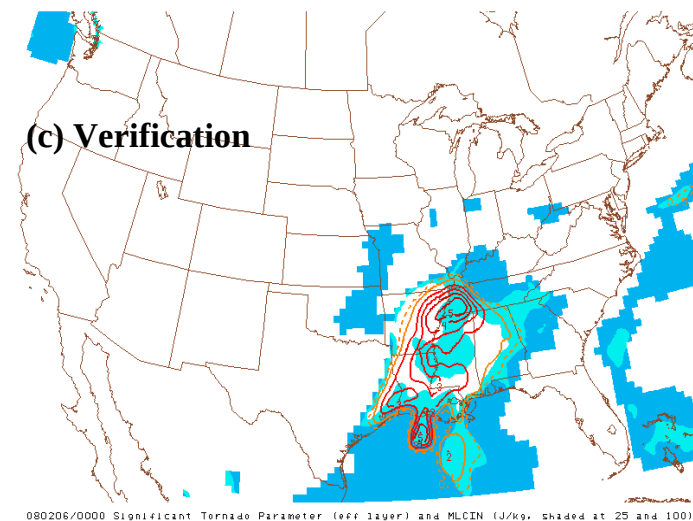
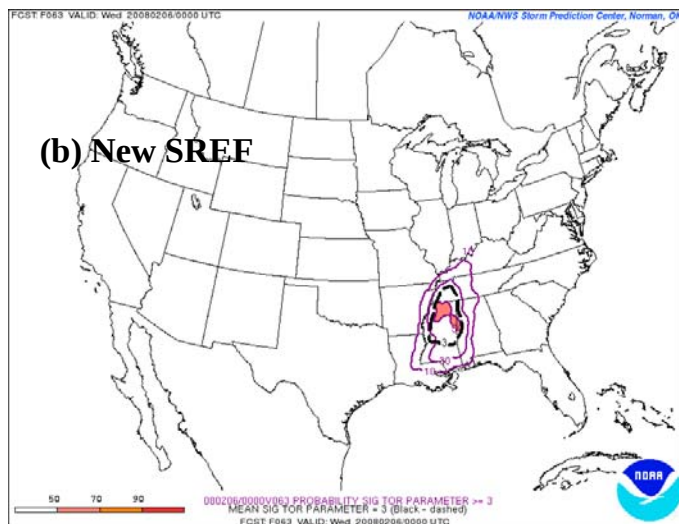
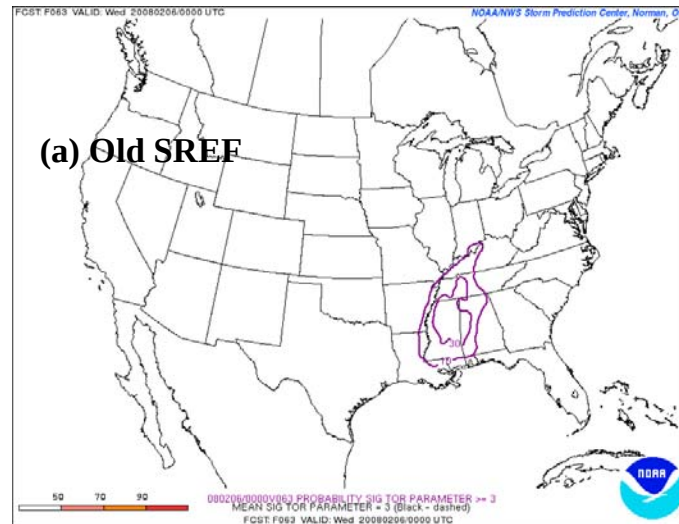
SREF System:

- Upgrade WRF version from 2.0 to 2.2
- Increase horizontal resolution NMM (40->32km) , ARW (45->32km)
- Increase WRF membership from 6 to 10
- Decrease Eta membership from 10 to 6
- Replace Zhao with Ferrier for 3 RSM SAS members
- Use global ET perturbations for 10 WRF members

SREF Products

- Increase output frequency to hourly out to 39 hr
- Add hourly BUFR soundings out to 87 hr
- Add cloud base, composite 88D reflectivity, echo top, Ri based PBL height
- Add wind-variance fields (for dispersion modeling)

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 ≥ 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)

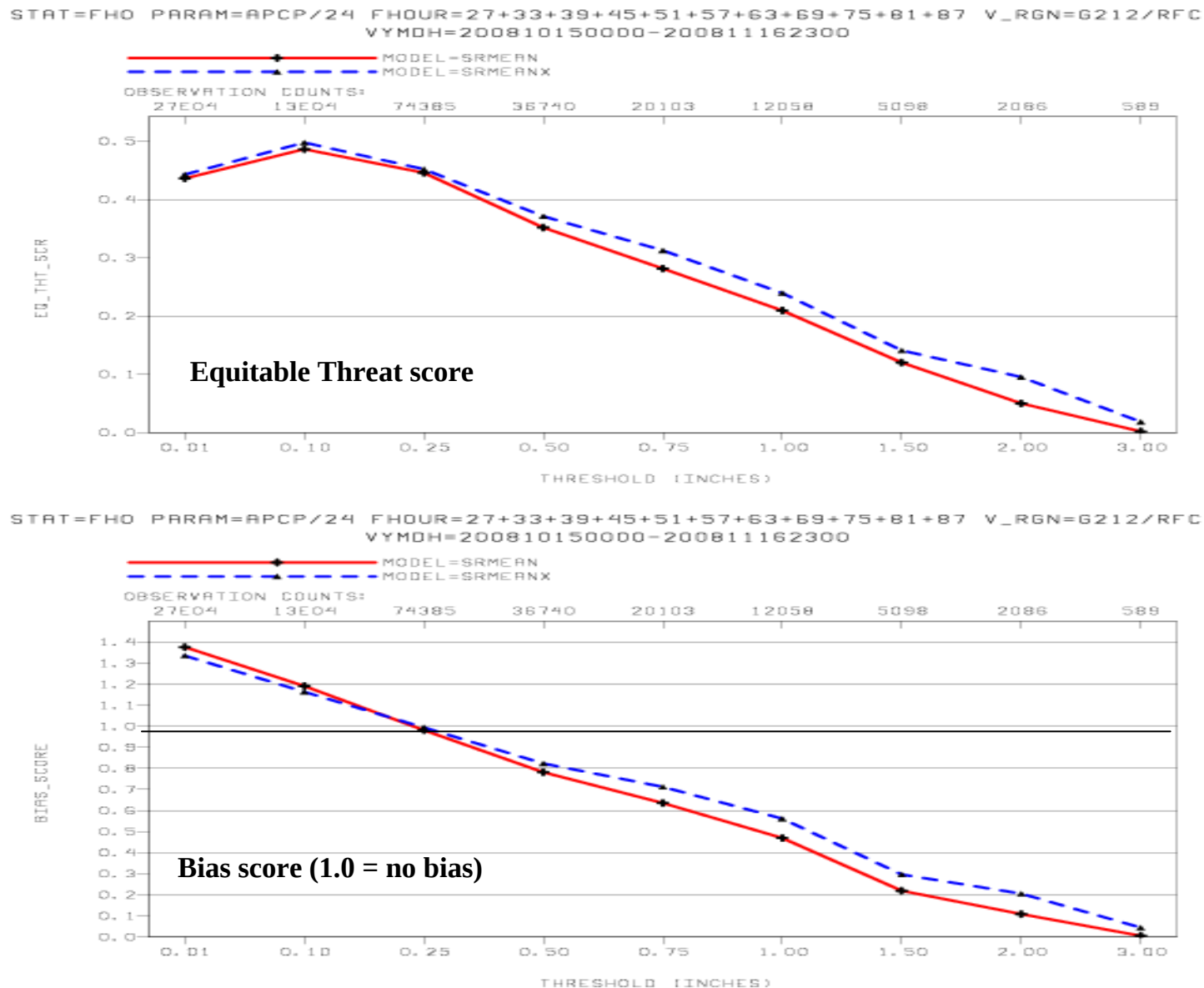
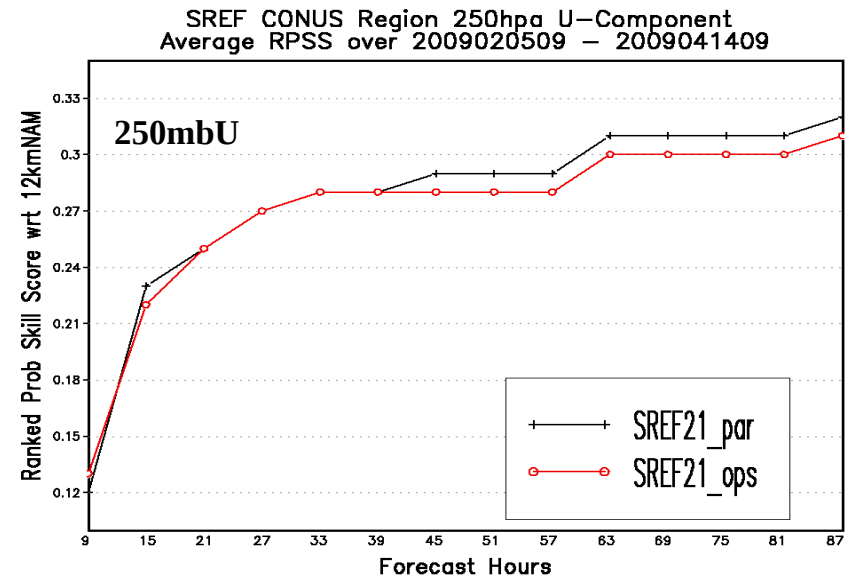
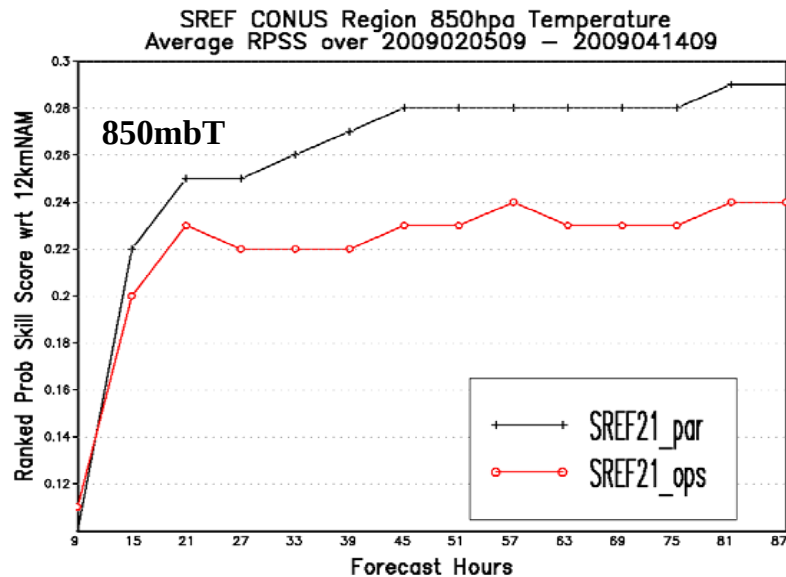
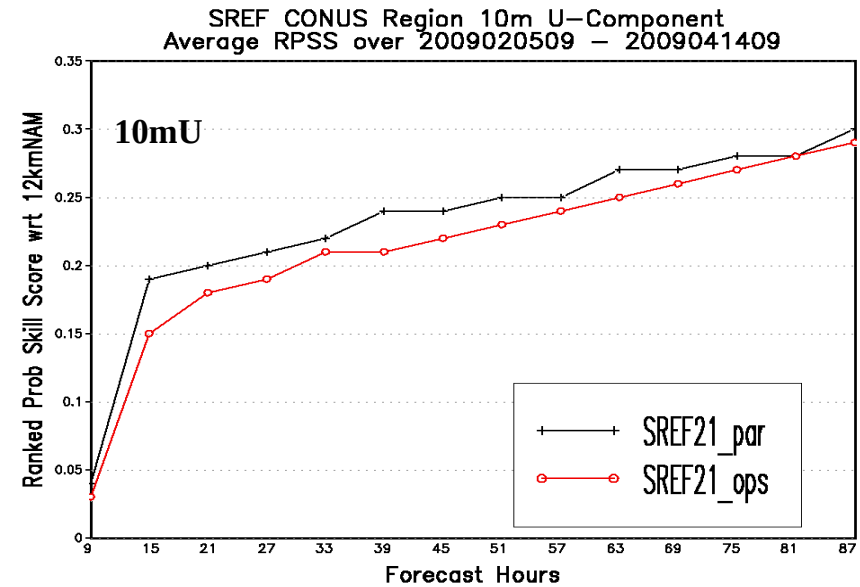
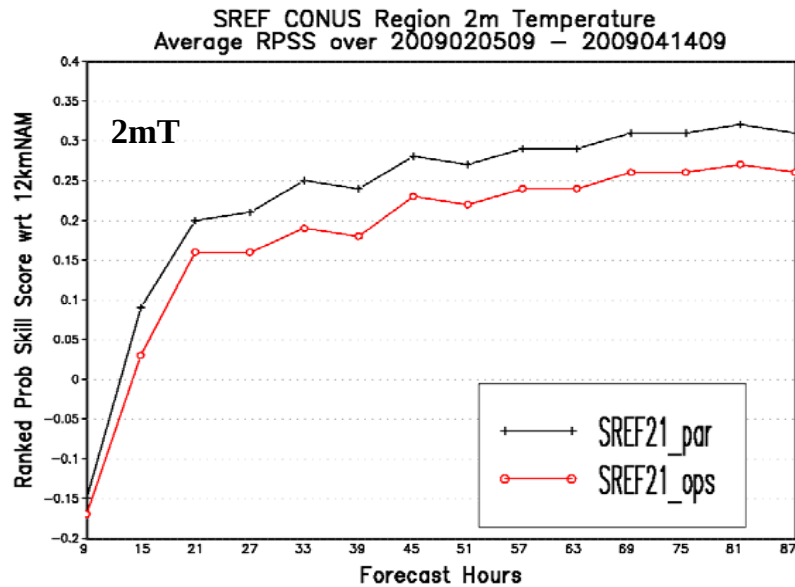


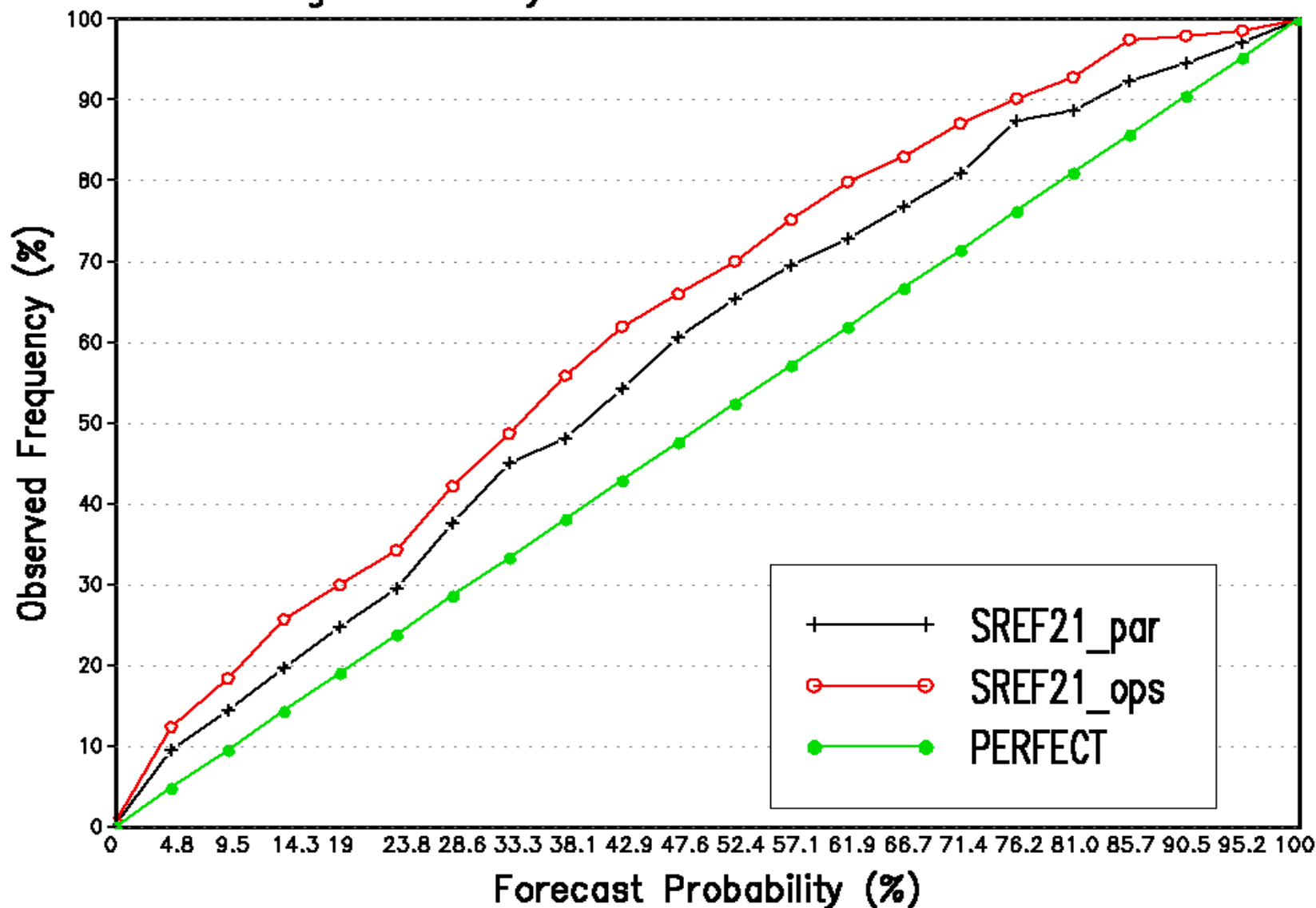
Fig 8: Probabilistic forecast measured by RPSS: large improvement for all fields (Feb. 5 – Apr. 14, 2009)



Reliability diagram for 2 m Temperature

Probabilistic Forecast at 87 hr

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



North American Mesoscale (NAM)

- All operational NAM changes to WRF-NMM and WPS through the December 2008 implementation, including GWD, have been committed to NCAR/DTC repository and are in the v3.1 release.
- Bug-fixes (not implemented in NAM yet due to moratorium) were also included in v3.1 release
 - First layer advection of w and z missing factor of 2
 - Initialize constant in turbulence scheme
 - Pass separate cloud & hydrometeor fields to radiation
- Displays etc. are available at:
<http://www.emc.ncep.noaa.gov/mmb/mmbpll/opsnam/>
<http://www.nco.ncep.noaa.gov/pmb/nwprod/analysis/>

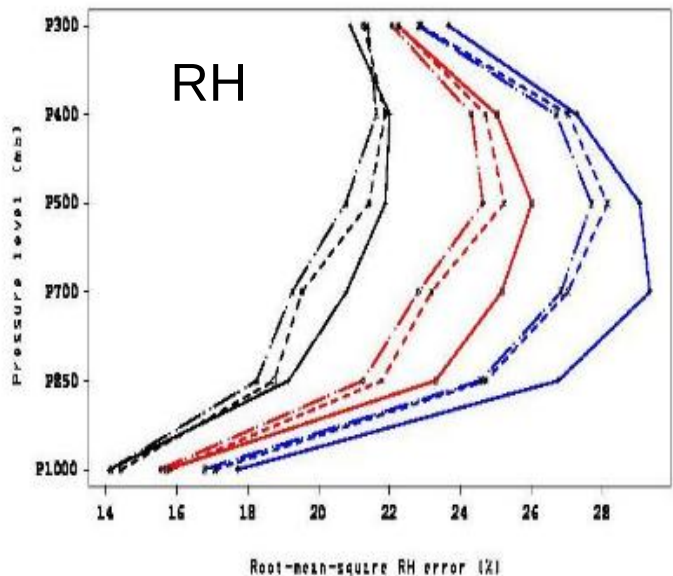
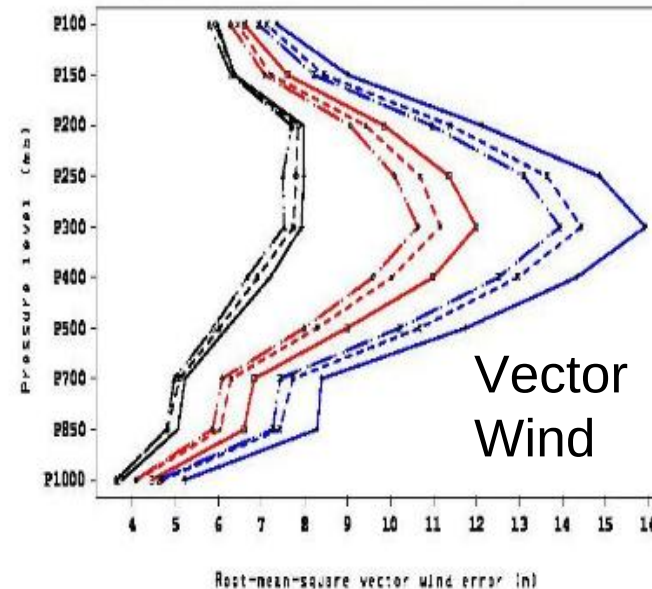
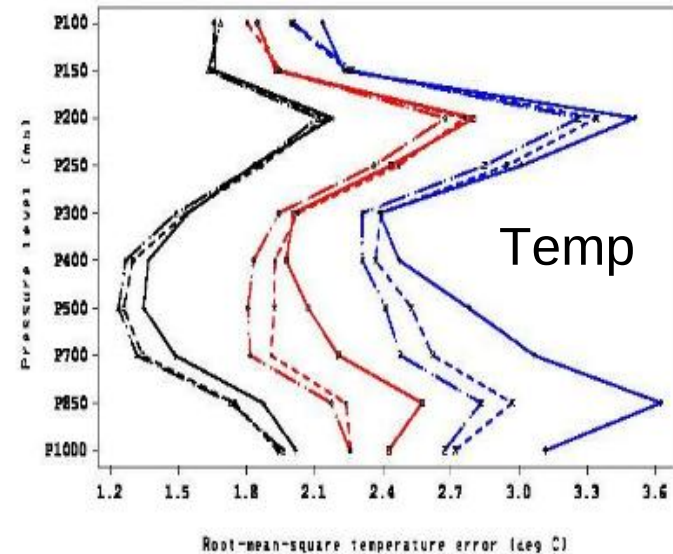
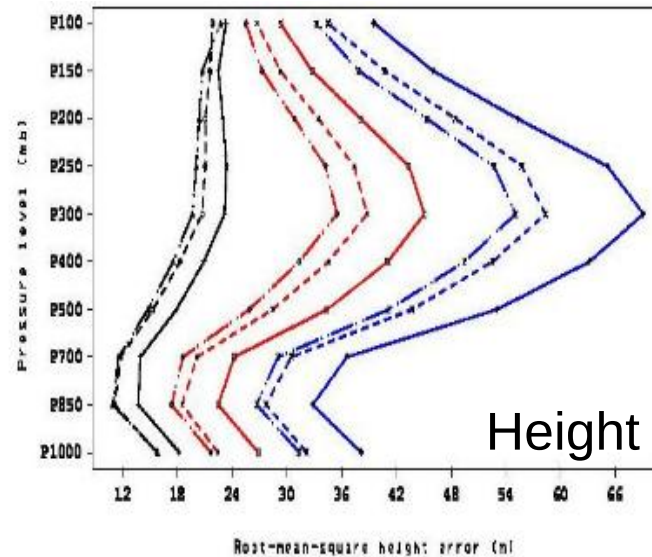
DECEMBER 2008 CHANGES

- NDAS “Partial Cycling”
- NMM Model Changes
 - Vertically mix/diffuse each hydrometeor species
 - Radiation change : double absorption coefficients for water and ice in clouds
 - Land-sfc model changes to address problematic 2-m dew point temps over snow cover
- GSI Analysis Changes
 - New observations : MetOp-a radiances and TAMDAR/AMDAR aircraft data
 - New version of radiative transfer model w/default climatology
- Use hi-res (23 km) AFWA snow depth analysis

Impact of partial cycling : vertical profile of cumulative RMS errors from Dec 07 – Feb 08

- Solid = Ops NAM
 - Dash = PII NAM
 with 3/08 changes
 - Dash-dot = PII
 NAM with 3/08
 changes + NDAS
 Partial Cycling

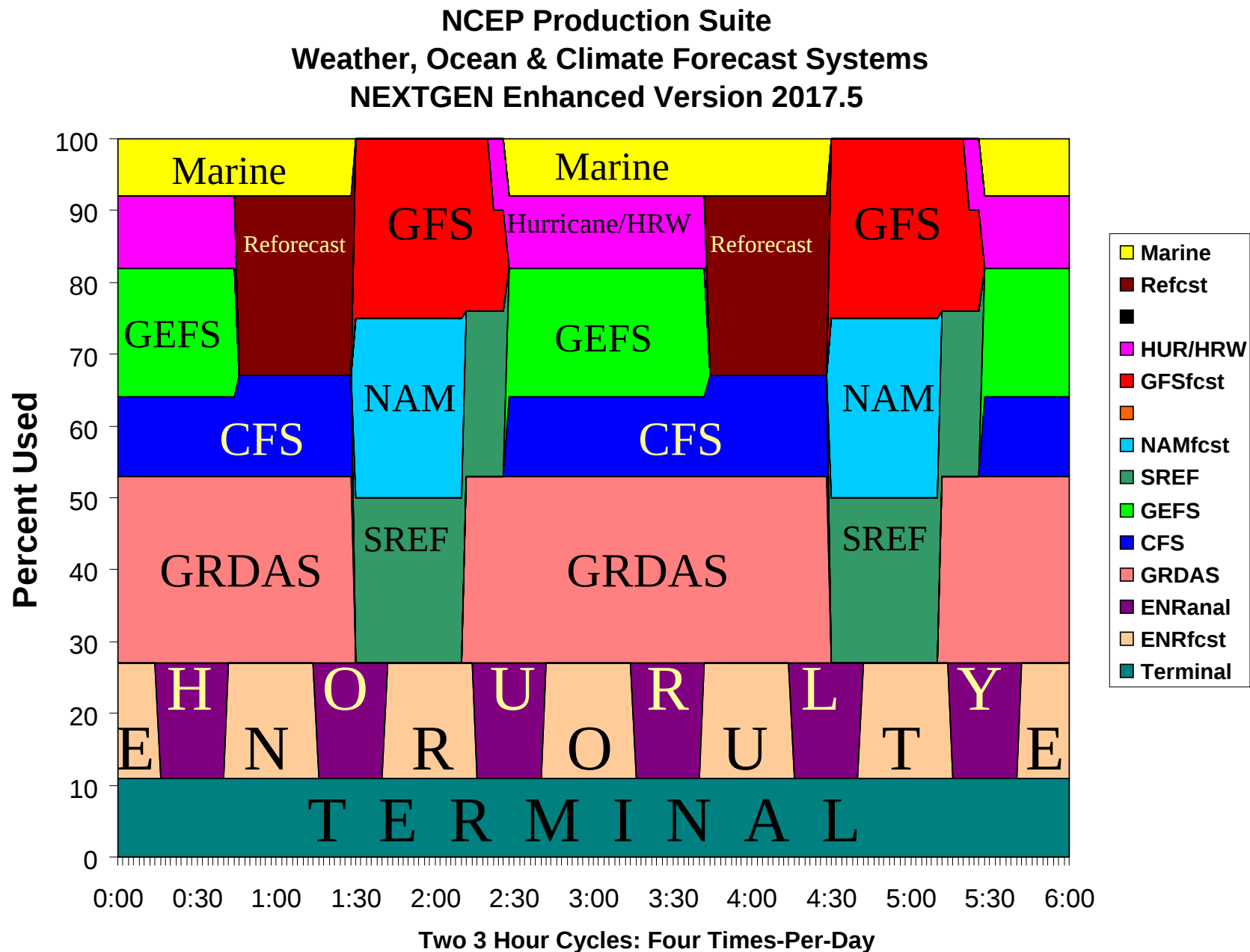
Black = 24-h Fcst
 Red = 48-h Fcst
 Blue = 72-h Fcst



Plans for Future

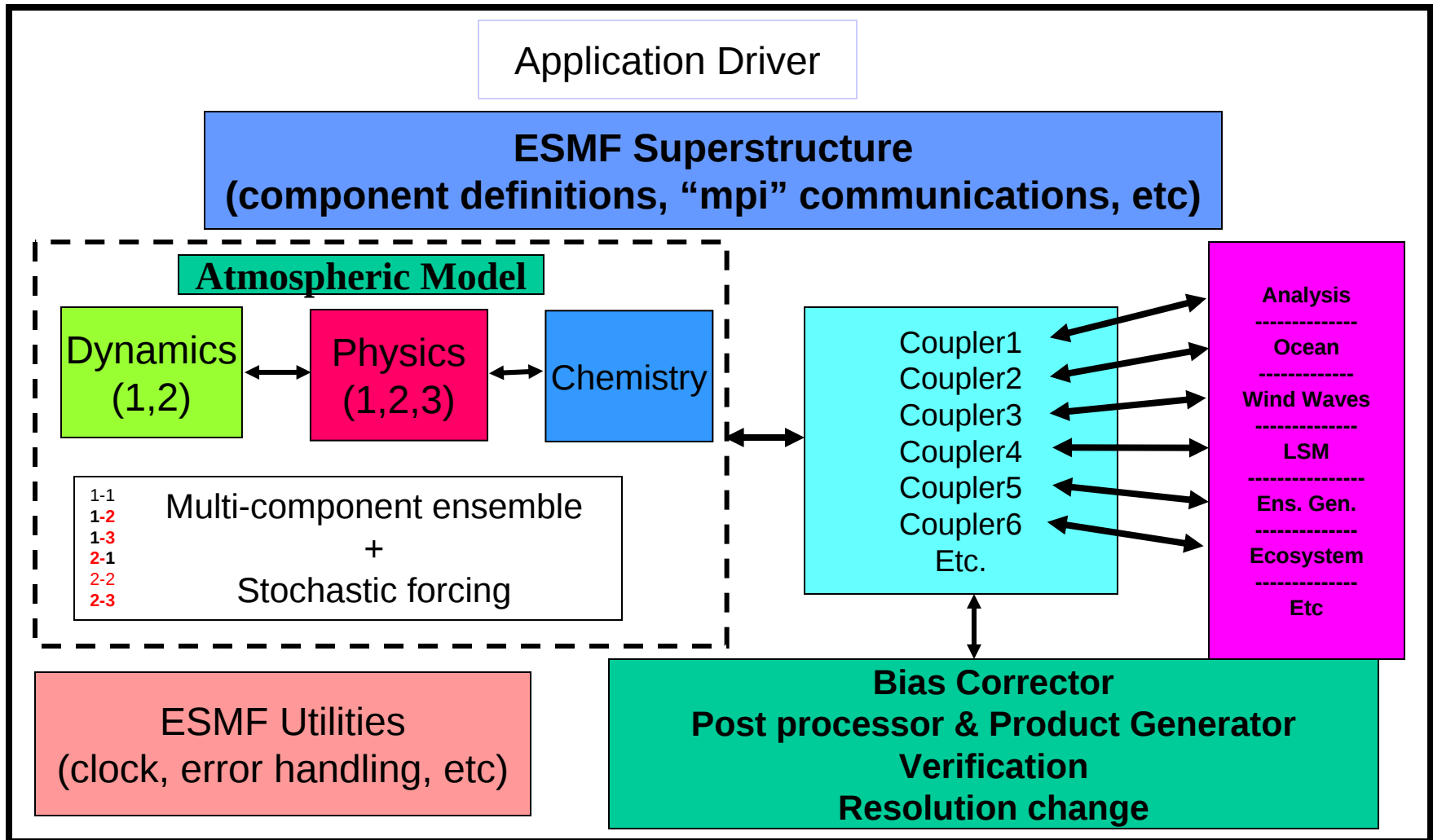
- NOAA Environmental Modeling System (NEMS)
 - Need to run GFS, NAM, SREF, GDAS/NDAS etc. concurrently and with minimal data motion
- ESMF-based, to be used NOAA-wide
 - NCEP/EMC (NAM, GFS, HYCOM etc.)
 - ESRL/GSD (Rapid Refresh, FIM, NIM)
 - OAR/GFDL (coupled climate)
- National Unified Operational Prediction Capability (NUOPC) ... subject to the availability of funds ^_^

A Possible Production Suite 2017.5 If NextGen Supports It



NOAA Environmental Modeling System (NEMS)

(uses standard ESMF compliant software)



* Earth System Modeling Framework (NCAR/CISL, NASA/GMAO, Navy (NRL), NCEP/EMC, NOAA/GFDL)

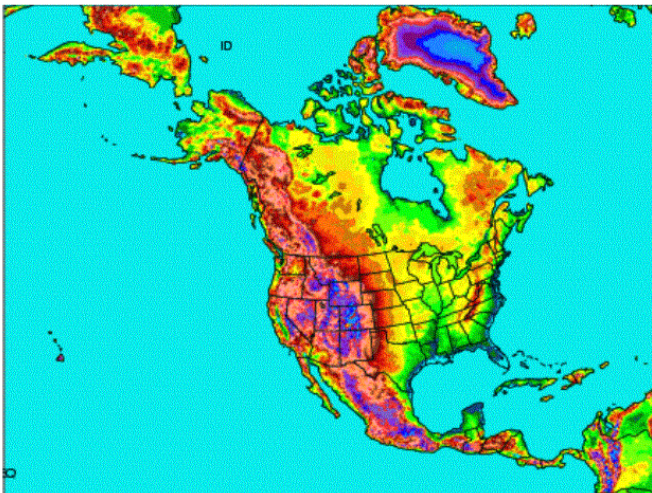
2, 3 etc: NCEP supported thru NUOPC, NASA, NCAR or NOAA institutional commitments

Components are: Dynamics (spectral, FV, NMM, FIM, ARW, FISS, COAMPS...)

Physics (GFS, NRL, NCAR, GMAO, ESRL, GFDL...)

NAM

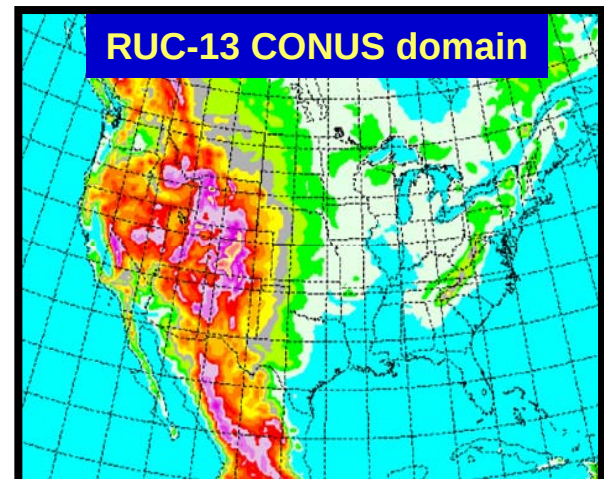
- WRF-NMM (E-grid)
- GSI analysis
- 4/Day = 6 hr update
- Forecasts to 84 hours
- 12 km horizontal
- 60 layers with 2 mb top
- 12 hr pre-forecast assimilation period with 3hr updates (catch-up)



2009

RUC

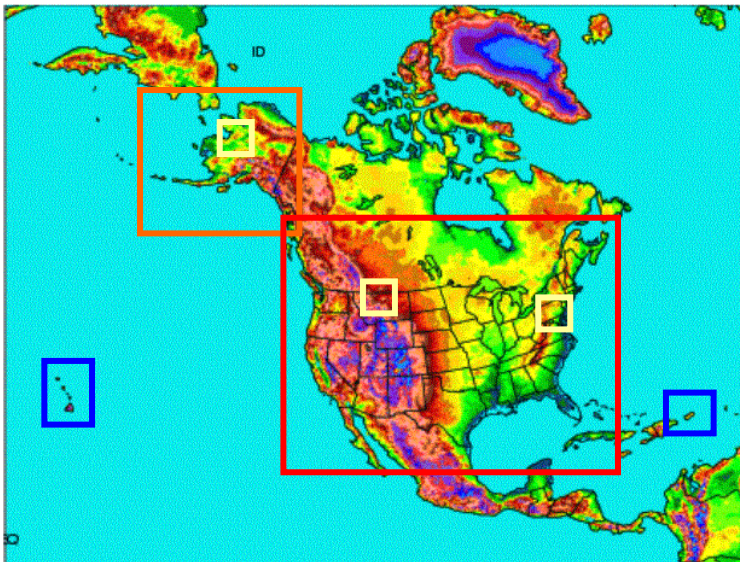
- Non-WRF RUC model
- RUC 3DVAR analysis
- 24/Day = hourly update
- Forecasts to 18 hours
- 13 km horizontal
- 50 layers with 50 mb top
- Continuous forward cycle with no pre-forecast assimilation period



2010-2011

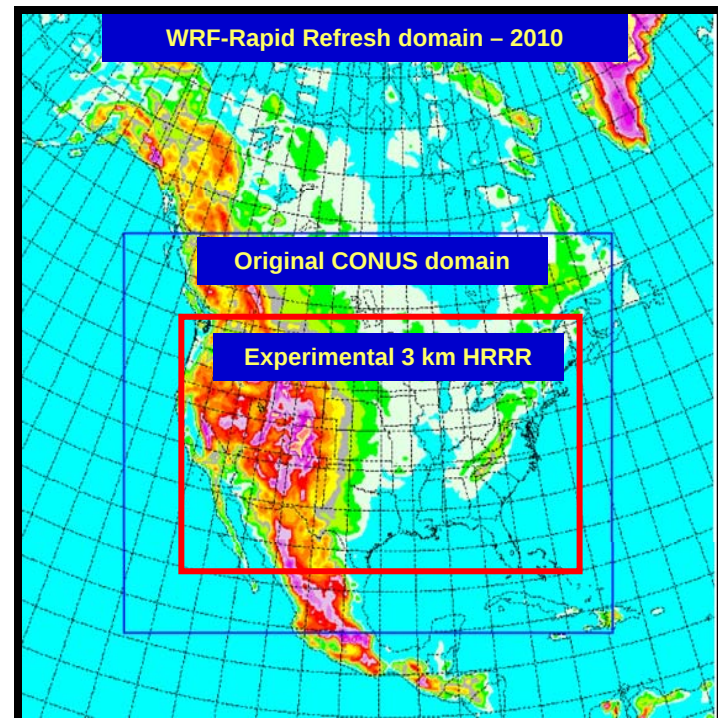
NAM

- NEMS based NMM
- B-grid replaces E-grid
- Parent remains at 12 km
- Multiple Nests Run to 48hr
 - ~4 km CONUS nest
 - ~6 km Alaska nest
 - ~3 km HI & PR nests, and/or a ~1.5-2km DHS/FireWeather/IMET

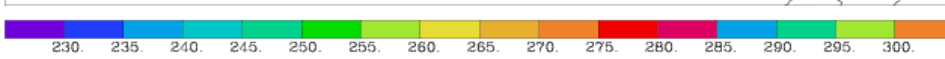
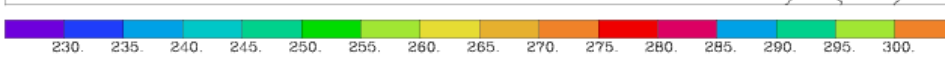
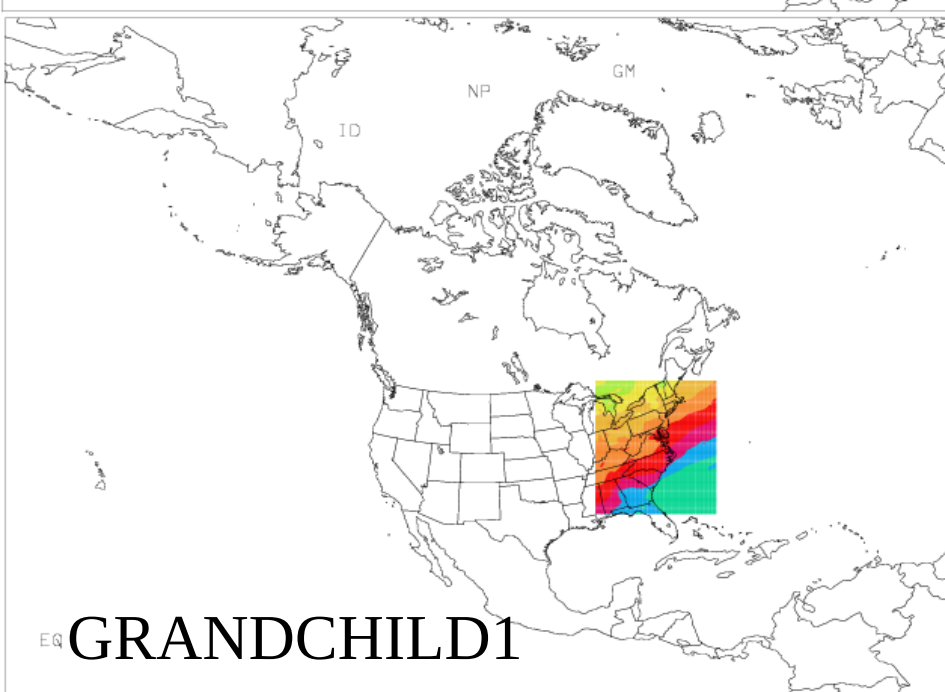
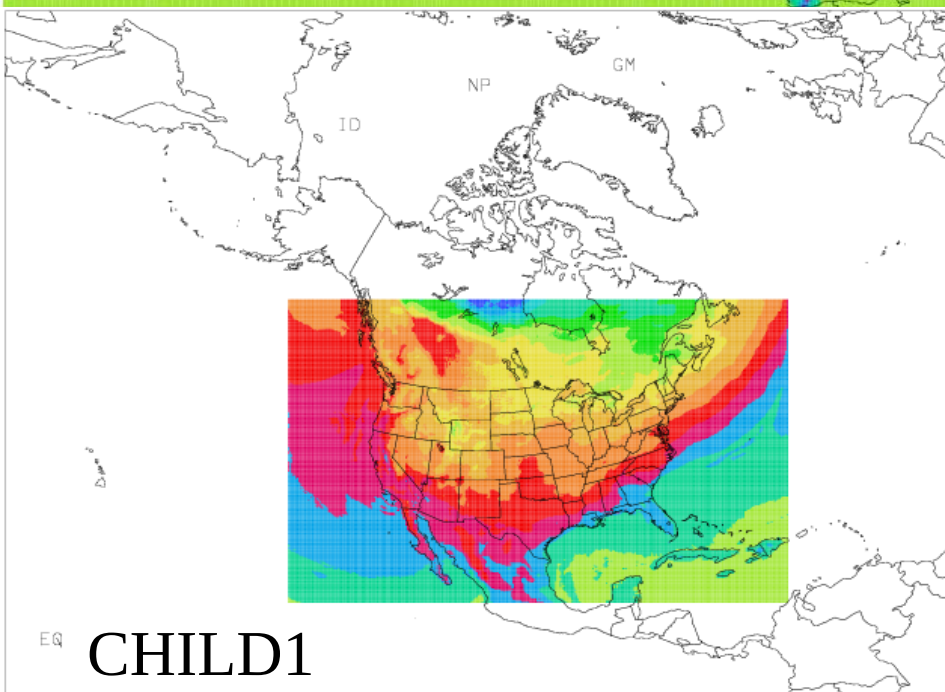
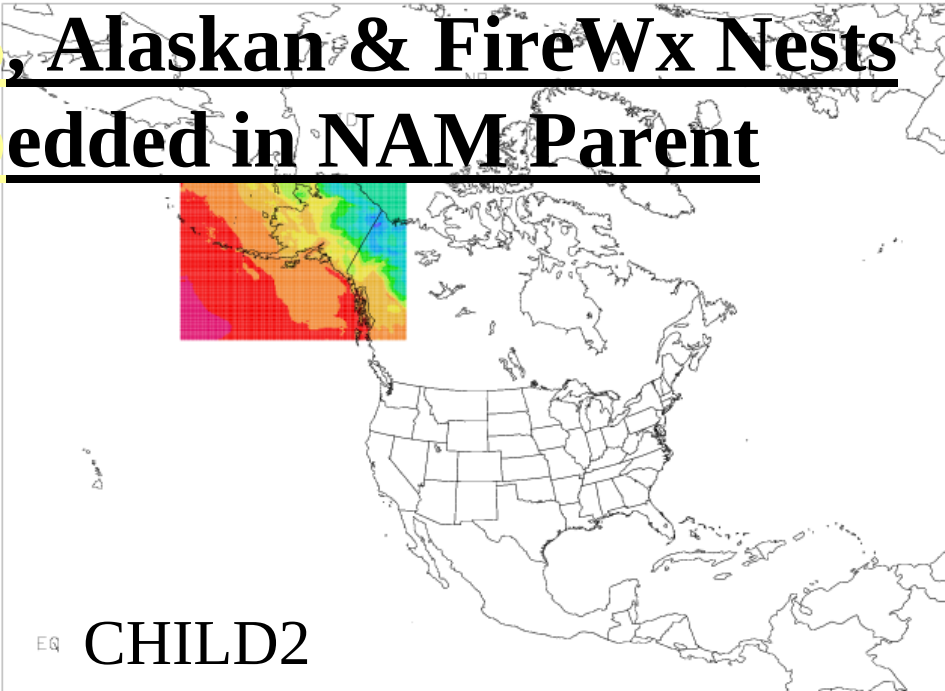
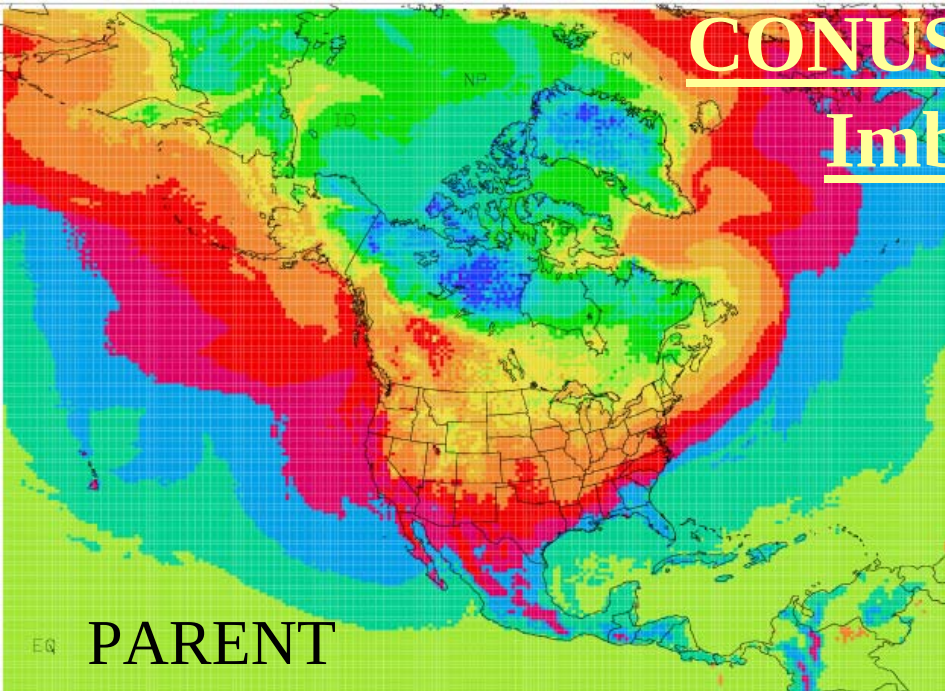


Rapid Refresh

- WRF-based ARW
- Common GSI analysis
- Expanded 13 km domain to include Alaska
- Experimental 3 km HRRR

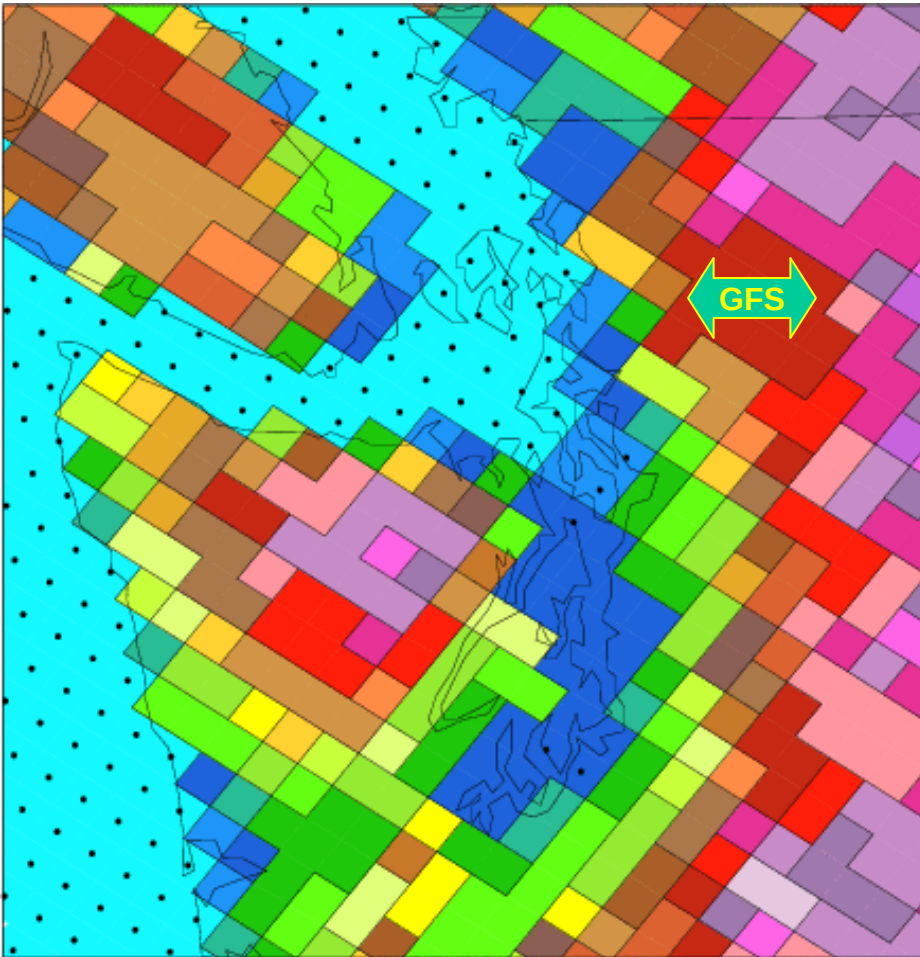


CONUS, Alaskan & FireWx Nests Imbedded in NAM Parent

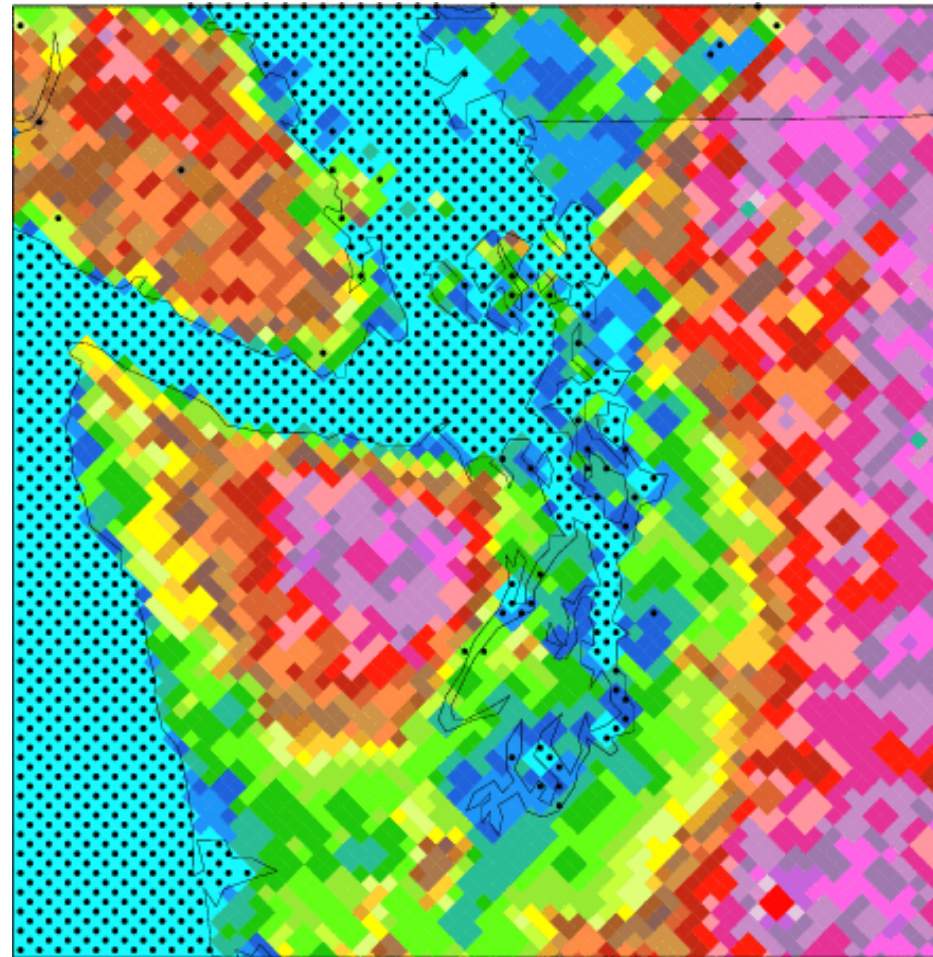


Dots represent water points Domain is Puget Sound

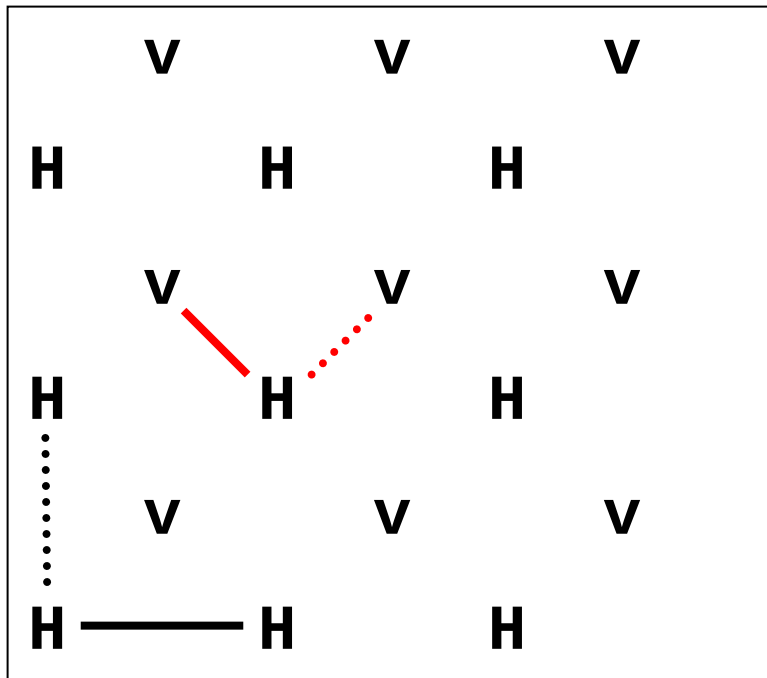
12 km Terrain



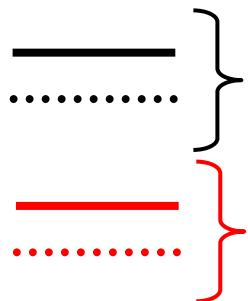
4 km Terrain



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

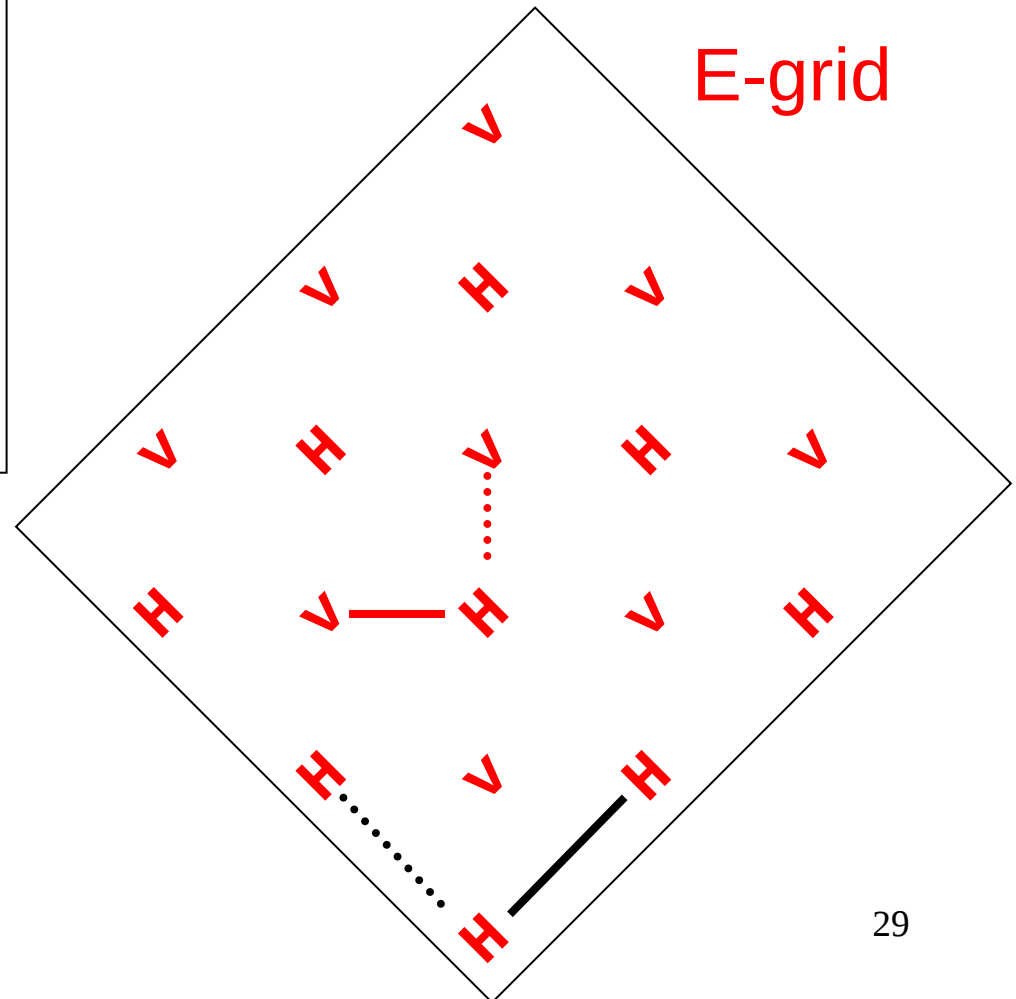


B-grid



B-grid dx and dy

E-grid dx and dy



E-grid

2012-2013

NAM/Rapid Refresh ENSEMBLE **(NRRE)**

- NEMS-based NMMB/ARW models & GSI analysis
- Common NAM parent domain at 10-12 km
- Initially ~6 member ensemble made up of equal numbers of NMMB- & ARW-based configurations
- Hourly updated with forecasts to 24 hours
- NMMB & ARW control assimilation cycles with 3 hour pre-forecast period (catch-up) with hourly updating
- NAM 84 hr forecasts are extensions of the 00z, 06z, 12z, & 18z runs.

2012-2013

High Resolution Rapid Refresh ENSEMBLE (HRRRE)

- Each member of NRRE contains
 - 3 km CONUS and Alaskan nests
 - Control runs initialized with radar data
- Positions NWS/NCEP/ESRL to
 - Provide NextGen Enroute A N D Terminal guidance
 - Provide PROBABILITY guidance
 - Improve assimilation capabilities with radar & satellite
 - Tackle Warn-on-Forecast as resolutions evolve towards ~1 km
- NAM nests are extensions of the 00z, 06z, 12z & 18Z runs.

Both NRRE and HRRRE
Require Bigger NCEP Computer