



The NOAA Operational Numerical Guidance Suite:

Status and Future Plans

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Presentation Outline



- **Why NOAA Conducts Operational Numerical Weather Prediction**
- **Model Development**
 - **Computational Aspects**
 - **Global Forecast & Data Assimilation System Priorities**
 - **CONUS Mesoscale**
 - **Regional Hurricane**
- **Transition of Research to Operations**



NOAA Operational Numerical Guidance Supports the Agency Mission



- Numerical Weather Prediction at NOAA

- Required for agency to meet service-based metrics

- National Weather Service GPRA* Metrics

- (* Government Performance & Results Act)

- Hurricane Track and Intensity

- Winter Storm Warning

- Precipitation Threat

- Flood Warning

- Marine Wind Speed and Wave Height

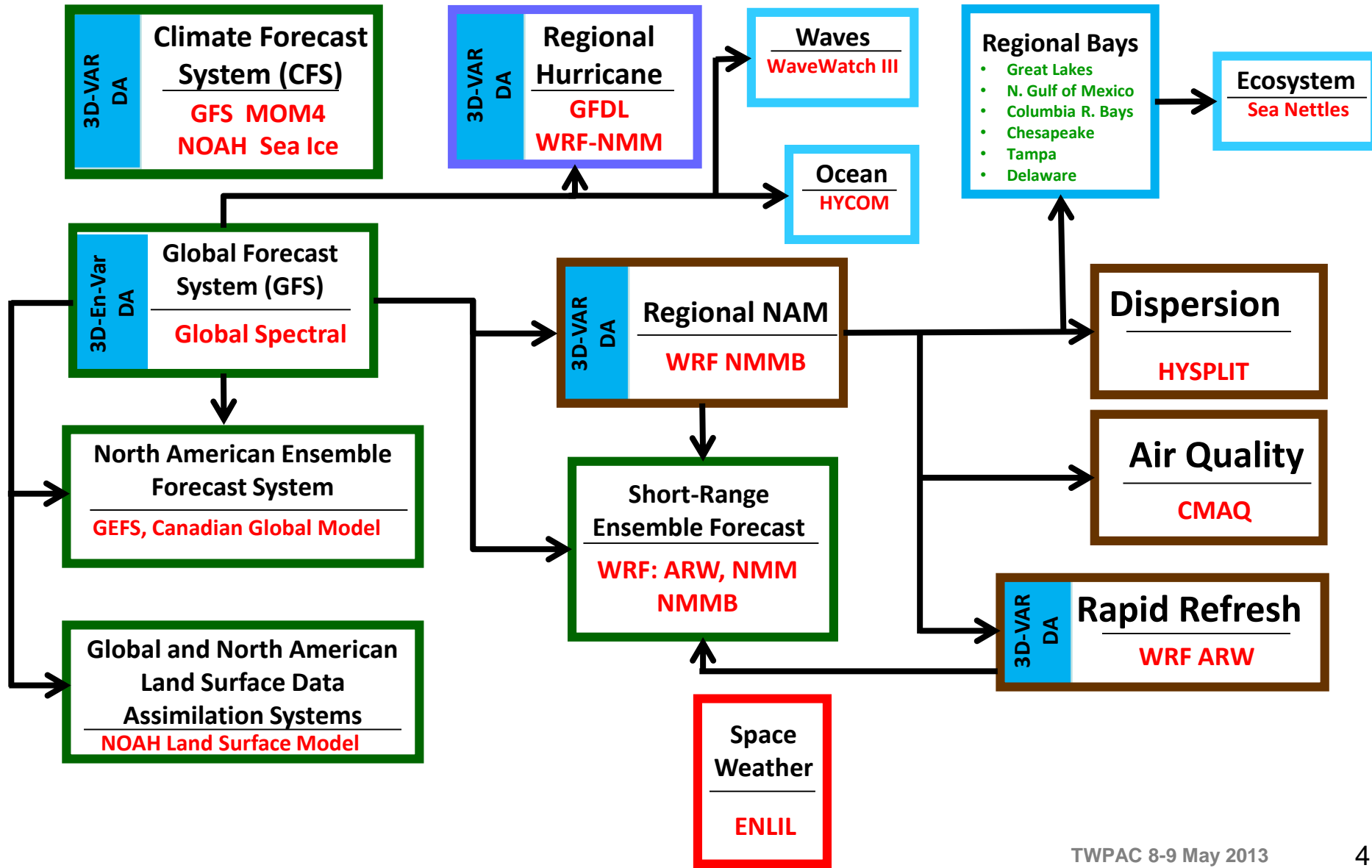
**Lead Time
and
Accuracy!**

- Operational numerical guidance:

- Foundational tools used by Government, public and private industry to improve public safety, quality of life and make business decisions that drive US economic growth

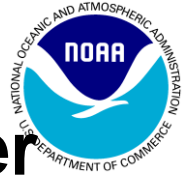


NOAA's Operational Numerical Guidance Suite

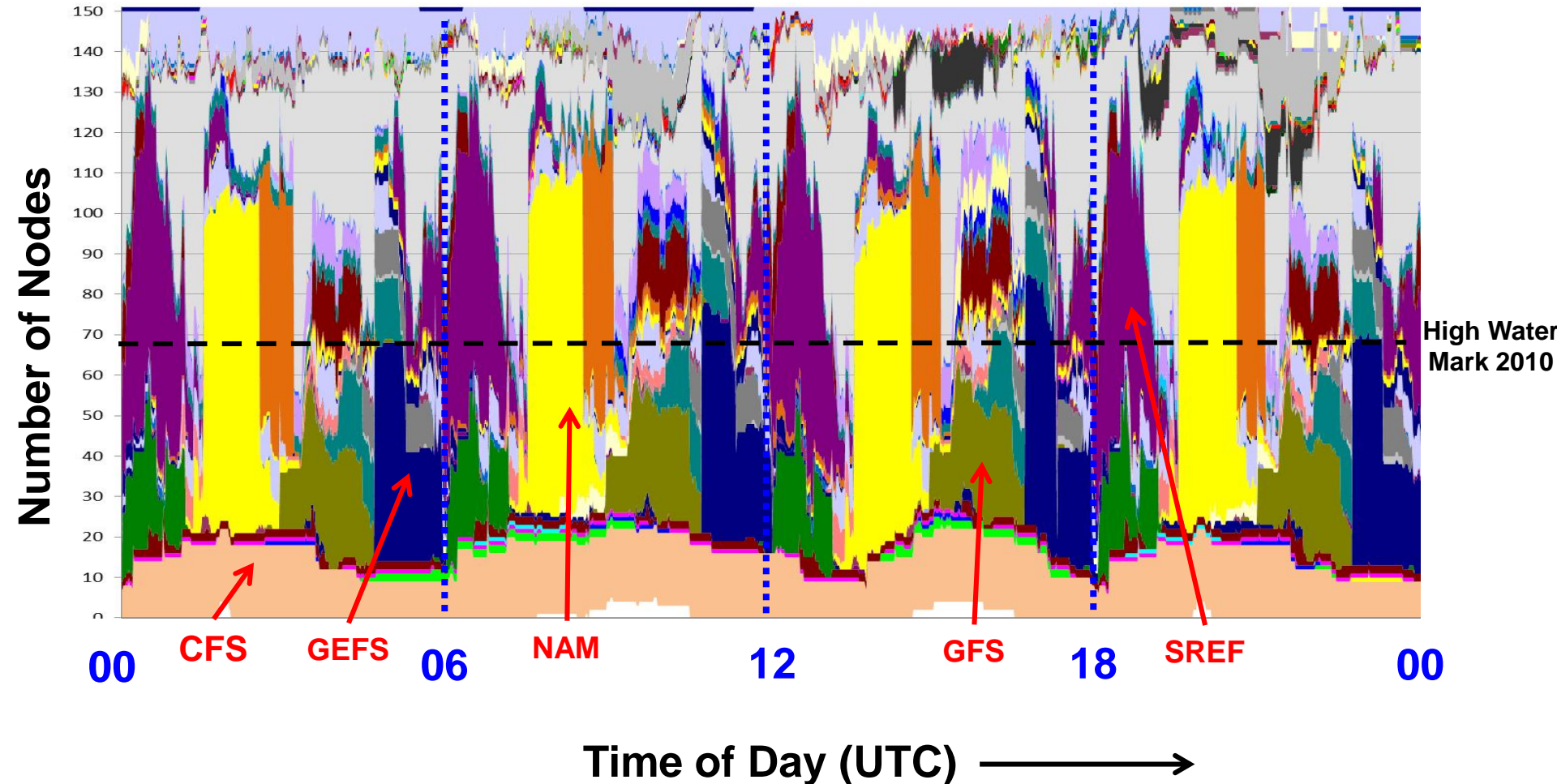




Numerical Guidance Suite Execution on the Operational NOAA Supercomputer



24-h Snapshot 20 August 2012





NOAA Operational Computing: IBM iDataPlex System



Location

- Primary
 - Reston, VA (IBM provided facility)
- Backup
 - Orlando, FL (IBM provided facility)

Configuration

- Identical Systems (per site)
 - IBM iDataPlex/Intel Sandy Bridge/Linux
 - 208 trillion calculations/sec
 - 10,048 processing cores
 - 2.59 petabytes of storage
- Performance Requirements
 - Minimum 99.9% Operational Use Time
 - Minimum 99.0% On-time Product Generation
 - Minimum 99.0% Development Use Time
 - Minimum 99.0% System Availability
 - Failover tested regularly

Inputs and Outputs

- Processes 3.5 billion observations/day
- Produces over 15 million products/day

Significance

- Where United States weather forecast process starts for the protection of lives and livelihood
- Produces model guidance at global, national, and regional scales

Examples:

- Hurricane Forecasts
- Aviation / Transportation
- Air Quality
- Fire Weather

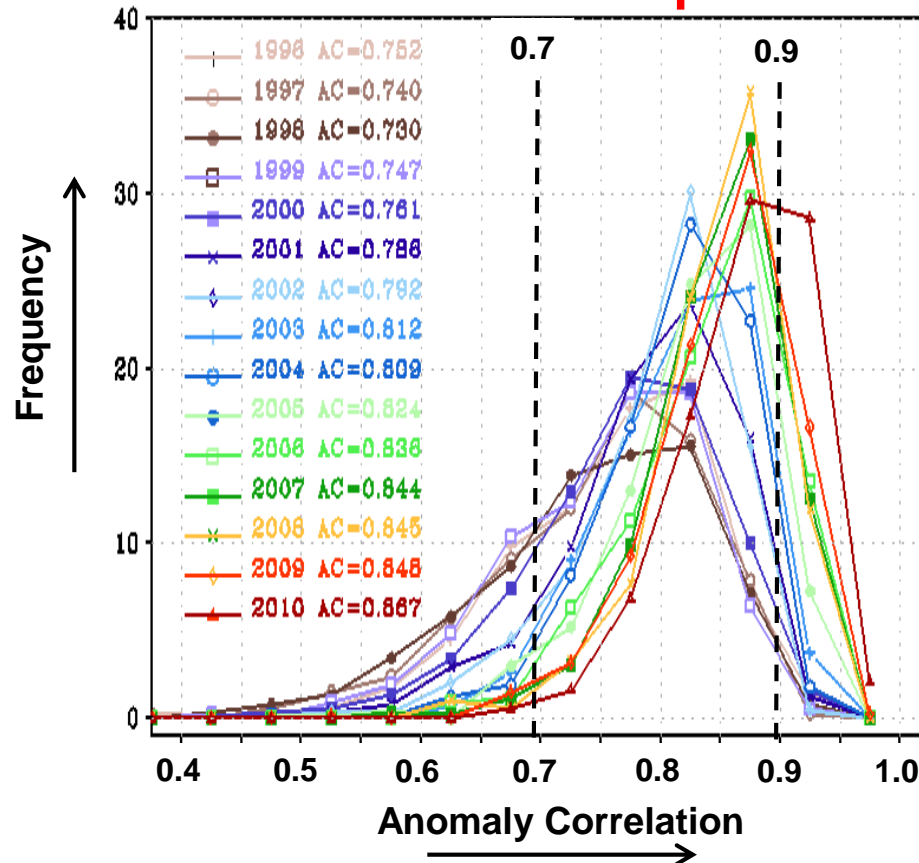




GFS 500-hPa Height Anomaly Correlation Frequency Distribution (1996-2010)



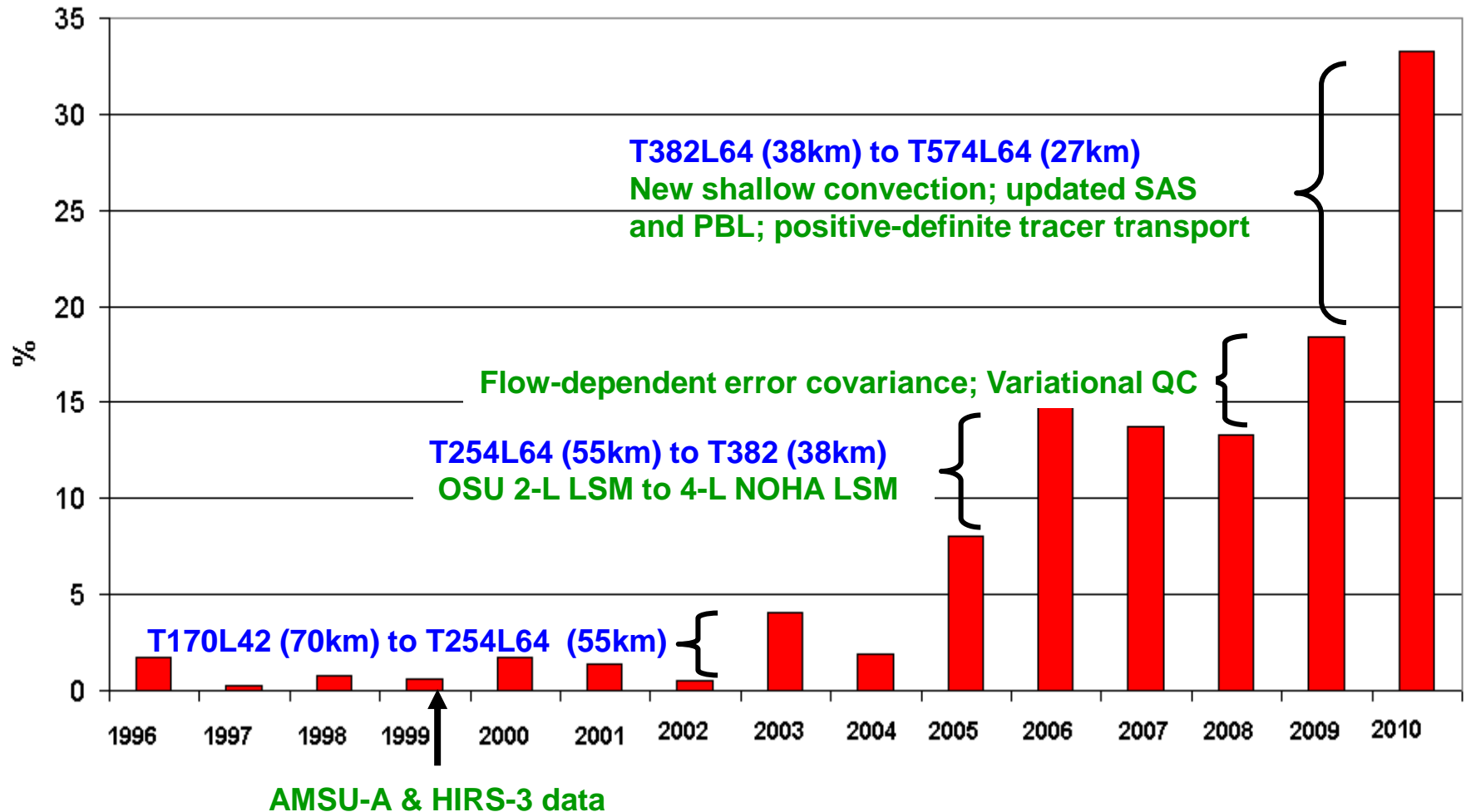
00Z Cycle GFS Day-5 Forecast Northern Hemisphere



- Frequency of poor forecasts ($AC < 0.7$) decrease
- Frequency of good forecasts ($AC > 0.9$) increase



Percentage of Good Forecasts GFS 5-Day 500mb AC > 0.9 v.s. Model Upgrades





Global Data Assimilation System Upgrade



Implemented 22 May 2012

- **Hybrid system**
 - Most of the impact comes from this change
 - Uses ensemble forecasts to help define background error
- **NPP (ATMS) assimilated**
 - Quick use of data 7 months after launch
- **Use of GPSRO Bending Angle rather than refractivity**
 - Allows use of more data (especially higher in atmos.)
 - Small positive impacts
- **Satellite radiance monitoring code**
 - Allows quicker awareness of problems (run every cycle)
 - Monitoring software can automatically detect many problems
- **Partnership between research and operations**
 - (NASA/GMAO, NOAA/ESRL, Univ OK, and NOAA/NCEP)
- **Consolidation across systems**
 - Unify operational data assimilation system for global, regional and hurricane applications
 - Cost effective—O&M
 - Configuration management



NCEP Closing the International Gap

June, July, August (JJA) 500hPa Geopotential RMSE

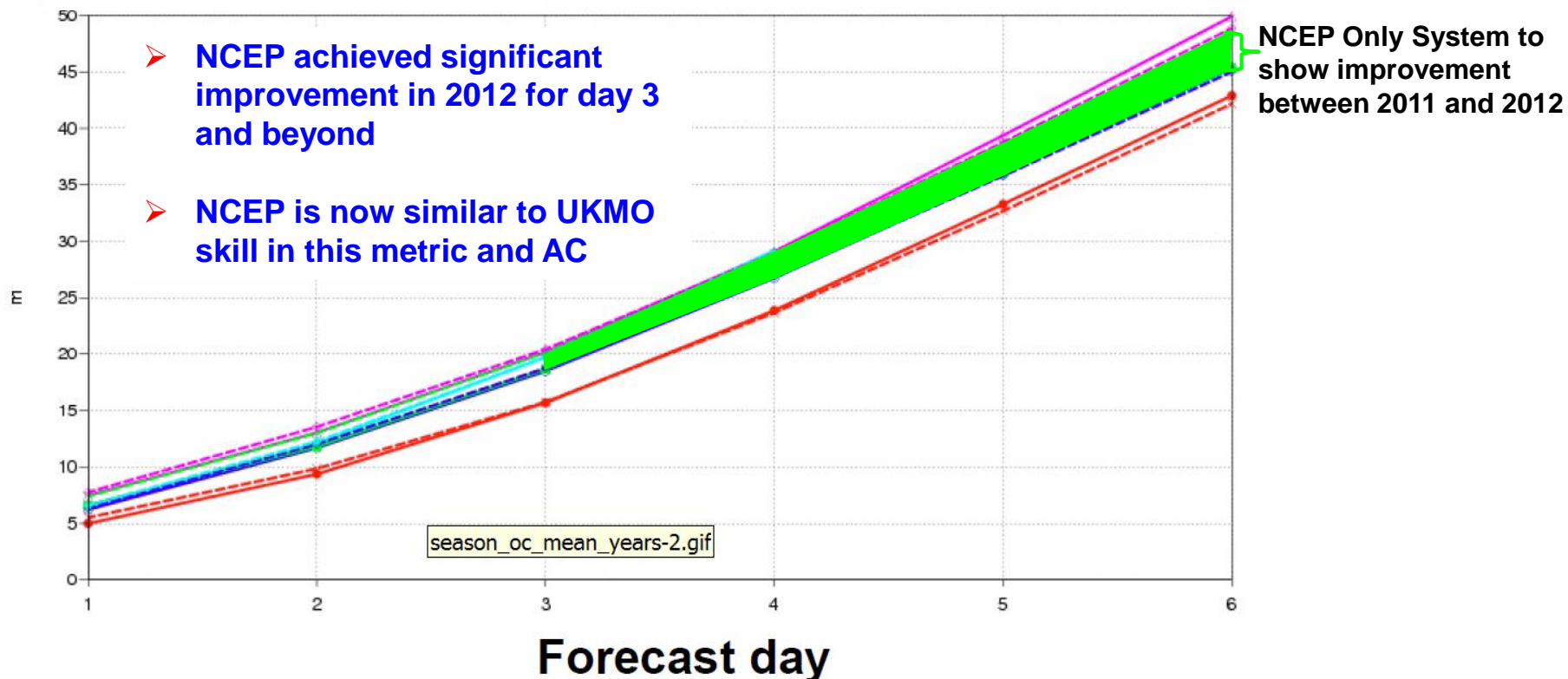


Comparison with other forecasting centres

500hPa geopotential
Root mean square error
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)

	2011	2012
Meteo-Fr	--- (cyan)	— (cyan)
CMC	--- (magenta)	— (magenta)
NCEP	--- (green)	— (green)
UKMO	--- (blue)	— (blue)
ECMWF	--- (red)	— (red)

Solid line lower than dashed indicates improvement between 2011 and 2012





Looking Forward...

GDAS/GFS & GEFS Into 2015



System	Feb 2012	Q2FY14	Q3FY15
GDAS	3D En-VAR Dual Res	3D En-VAR Dual Res	4D En-VAR Dual Res
	80 Members @ T254 (55 km)	80 Members @ T574 (27 km)	80 Members @ T574 (27 km)
	Analysis @ T574 (27 km)	Analysis @ T1148 (16 km)	Analysis @ T1500 (13 km)
	64 Vertical Levels	64 Vertical Levels	128 Vertical Levels
System	Feb 2012	Q2FY14	Q3FY15
GFS	T574 (27 km) 0 to 7.5-d	T1148 (16 km) 0 to 10 d	T1500 (13 km) 0 to 10 d
	T254 (55 km) 7.5 to 16-d	T574 (27 km) 10 to 16-d	T574 (27 km) 10 to 16-d
	64 Vertical Levels	64 Vertical Levels	128 Vertical Levels
		Semi-Lagrangian	Extend top for space weather
System	Feb 2012	Q2FY14	Q3FY15
GEFS	T254 (55 km) 0 to 8-d	T574 (27 km) 0 to 16-d	T878 (22 km) 0 to 16-d
	T190 (70 km) 8 to 16-d		
	42 Vertical Levels	64 Vertical Levels	128 Vertical Levels
		Semi-Lagrangian Use EnKF/ETR perturbations	Use EnKF perturbations



National Multi-Model Ensemble (NMME) Project



- Facilitated by the NOAA Climate Test Bed
- NMME as a Modeling Test-Bed
 - Seasonal to Interannual Time Scales
 - Predictability Research: e.g., South East US Drought
 - Model Evaluation and Development
 - Initialization Strategies: e.g., Land, Ocean
 - Fosters interaction between research and operations
 - Provides experimental guidance products to Climate Prediction Center
- Participating Organizations:
 - University of Miami - RSMAS
 - National Center for Atmospheric Research (NCAR)
 - Center for Ocean---Land---Atmosphere Studies (COLA)
 - International Research Institute for Climate and Society (IRI)
 - Canadian Meteorological Centre (Soon)
 - NASA – GMAO
 - NOAA/NCEP/EMC/CPC
 - NOAA/GFDL
 - Princeton University
 - University of Colorado (CIRES)



Data are available at: <http://iridl.ldeo.columbia.edu/SOURCES/.Models/.NMME/>

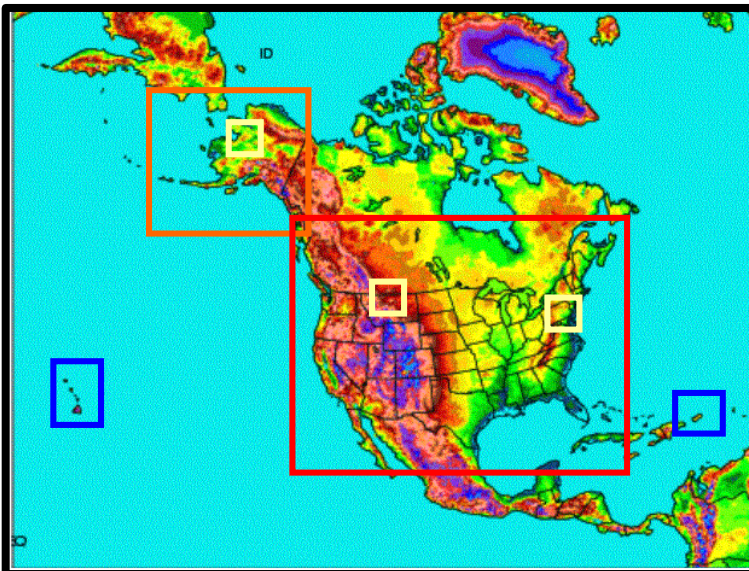


Operational Mesoscale Modeling for CONUS:



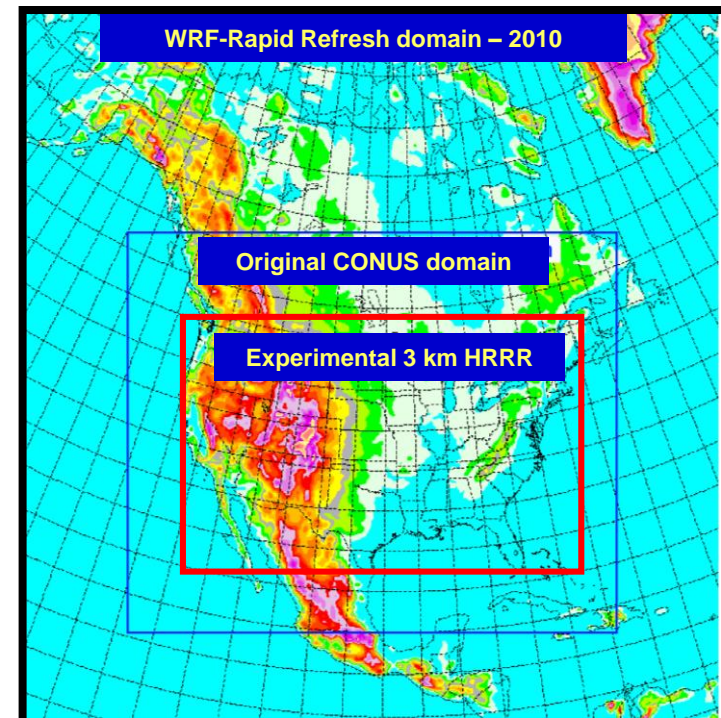
North America Model (NAM)

- *Implemented 18 October 2011*
- NEMS based NMM
- Outer grid at 12 km to 84hr
- Multiple Nests Run to ~48hr
 - 4 km CONUS nest
 - 6 km Alaska nest
 - 3 km HI & PR nests
 - 1.3km DHS/FireWeather/IMET



Rapid Refresh (RAP)

- *Implemented 1 May 2012*
- WRF-based ARW
- Use of GSI analysis
- Expanded 13 km Domain to include Alaska
- Experimental 3 km HRRR



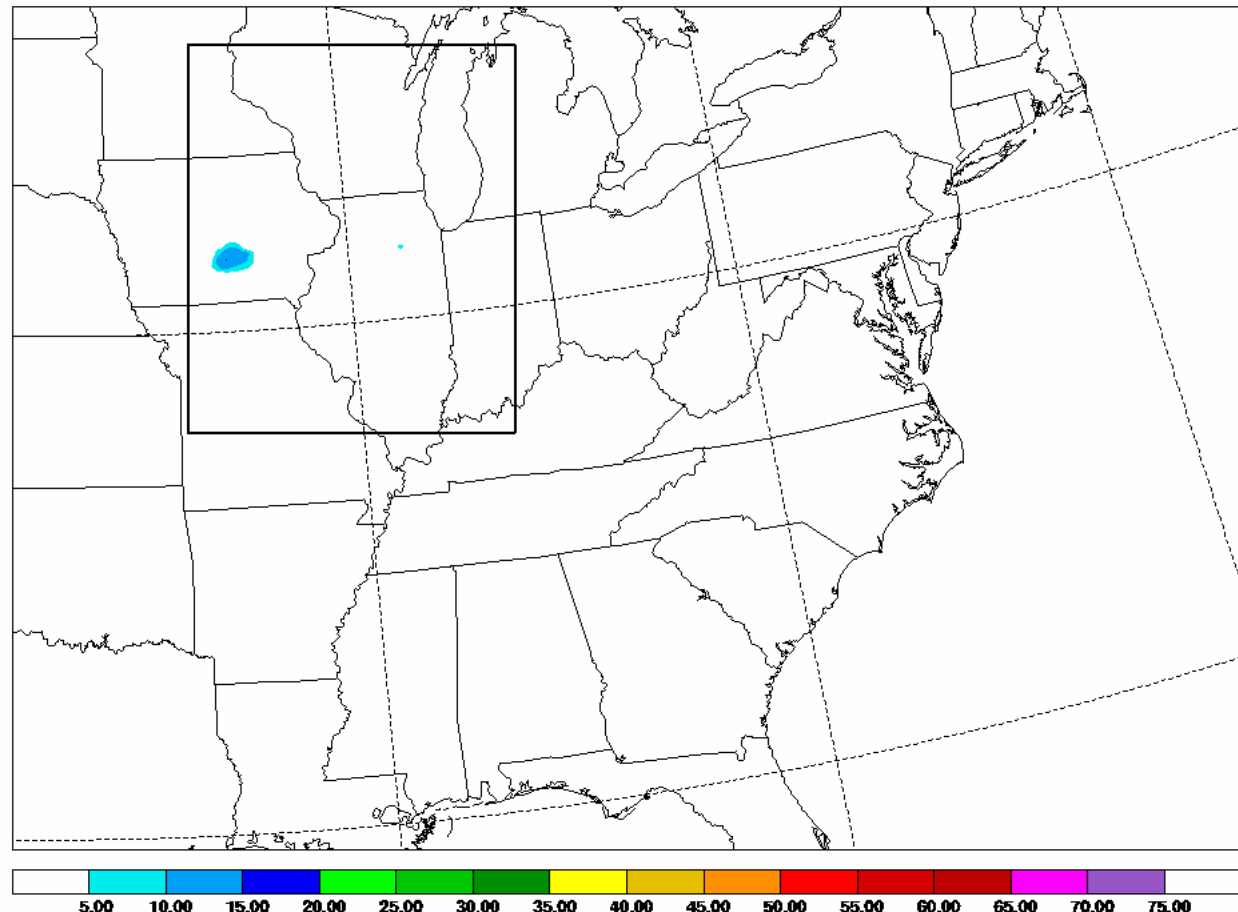


NAM Application to High Impact Weather



1.3 KM NMM Moving Nest applied to 29 June 2012 Derecho Simulated maximum composite radar reflectivity

Maximum/Composite radar reflectivity [dbZ] (atmos col)
20120629 15h 00m 0.00s



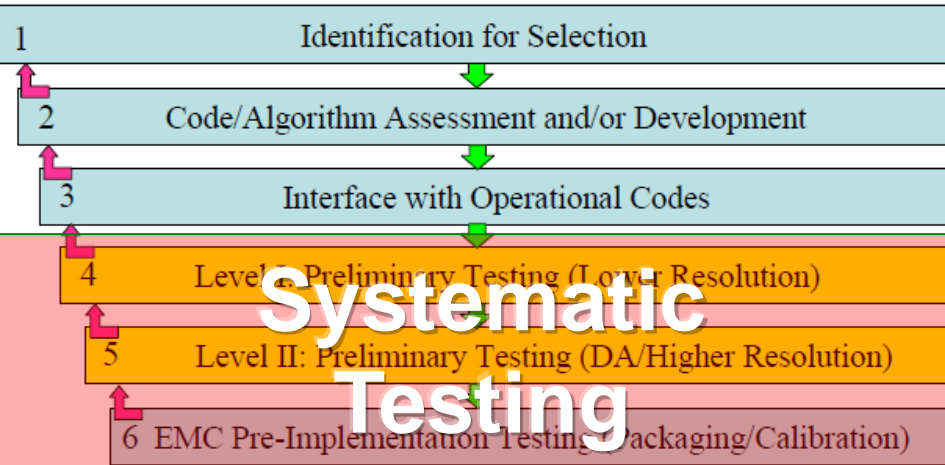
- Initialized with RAPv2 analysis
- 12km parent domain with 1.3km moving nest
- Nest motion perscribed
- Output every 10 minutes
- Supports NOAA WoF and WRN inititaves
- Ongoing development:
 - Nest movement based on phenomena of interest
 - 2-way nesting for hurricane applications
 - Computationally efficient



Process to Transition Research into NOAA Operational Model Suite



R&D and Pre-Implementation Phase



EMC Change Control Board

- Scientific Integrity
- Product Quality
- EMC Mgmt Approval
- ACCOUNTABILITY**

- Generate RFC's
- Submit RFC's to NCO

Implementation Phase

- SPA's build NCO parallel from RFC's
- 30-day NCO parallel
 - Test code stability
 - Test dataflow
 - Products to NCEP Centers and EMC code developers
- NCEP Centers
 - Evaluate impact
 - Assessments to NCEP OD

- 30-day NCO parallel stable
- NCEP centers approve
- ACCOUNTABILITY**

- Briefing to NCEP Director for final approval
- ACCOUNTABILITY**

Implementation



Example of R&D and Pre-Implementation Testing



HWRF 2011 Upgrade

HR20	HR30*	HR21 ¹	H20J	HRDI	HR25/HR28	HR28
V3.2 Baseline (POM)	V3.2 Baseline (HYCOM)	GFS deep convection	New GFS data	Updated vortex initialization	GFS deep convection + modifies surface physics	Final 2011 package
HWRFV3.2 Include all 2010 upgrades	Couple V3.2 (HR20) to HYCOM	Uses GFS deep convection scheme implemented in July 2010	Use new 2011 GFS data for initial and boundary conditions	Use two parameters to modify storm size, use model consistent pressure and no composite storm for cycle	Enthalpy exchange coefficient is the same as drag coefficient over V=40m/sec	All combinations of 2011 implementation + new HWRF-UPP
Test cases: All 2008, 2009, 2010 at both AL and EP	All ATL 2008/2009/2010*	All 2008, 2009, 2010 at both AL and EP*	All 2010 cases	All 2008, 2009, 2010 at both AL and EP *	All 2008, 2009, 2010 at both AL and EP	All 2010 cases
Nov. 1, 2010	Jan. 31, 2011	Jan. 31, 2011	Jan. 15, 2011	Jan. 31, 2011	Feb. 28, 2011	Mar. 15, 2011

Suggested priority cases: ATL: Fay(33), Ike(51) (2008), Bill(34), Erika(10) (2009), Alex(23), Earl(41), Tomas(35) (2010): total 227 runs; EPAC: Jimena(24), Linda(19) (2009), Celia(37) (2010): total:80 runs
All test cases: ~700 runs

- Potential upgrades are tested for ~700 cases for each config.
- Final configuration with combined upgrades are chosen in concert with NHC.

*Withdrawn from 2011 implementation

2013 HWRF pre-implementation Test Plan

EXP	Description	Comments	Platform/# of cases
Pre-Baseline Experiments			
TDRP	FY12 HWRF + One-Way Hybrid GSI	Run in real-time during 2012 hurricane season (Stream 2.0 Demo). Also included real-time TDR data for 19 cases.	CCS, All 2012 ATL and EP 821 cases
HDFL	FY12 HWRF + Flux truncation into POM	DTC performed these tests to evaluate the impact of 25% reduction of heat, momentum and radiative fluxes in the operational coupled HWRF-POM	Jet, All 2012 ATL and EP 821 cases
P160	FY12 HWRF + Initialization Changes	Improved size correction, modifications to filter domain and use GFS vortex when initial storm intensity less than 16 m/s	Jet, All 2012 ATL and EP 821 cases
HNPI	FY12 HWRF + New nest-parent interpolations	Revised nest-parent interpolations and improved treatment of variables at nest boundaries	Jet, All 2012 ATL and EP and 6 others from 2010 -11; 988 cases
HNTT	HNPI+ New nest movement algorithm	Improved nest tracking based on membrane MSLP and Tim's tracker. Choice of 8 storms that had difficulty tracking the nest properly	Jet, 8 Selected storms 168 cases
HHPC	FY12 HWRF + High Frequency Physics Calls	Increased Physics calling frequency from 180 sec. to 30 sec. Third nest size increased by about 20% from 5.5x5 to 7x6.5	Jet, A few selected storms from 2012; 100 cases
Baseline Experiment			
H130	All modifications from pre-baseline experiments	2013 HWRF baseline is based on positive outcome from the pre-baseline experiments described above. Run on three different platforms.	Jet/Zeus/WCOSS, All 2010-2011-2012 ATL and EP 1870 cases each
Physics Upgrades			
H131 (Final)	H130 + PBL changes	HWRF PBL (GFS based scheme) is upgraded to include variable critical Richardson number for improved treatment of PBL height in all weather conditions.	Jet/Zeus/WCOSS, All 2011-2012 and August - October 2010 ATL and EP 1870 cases

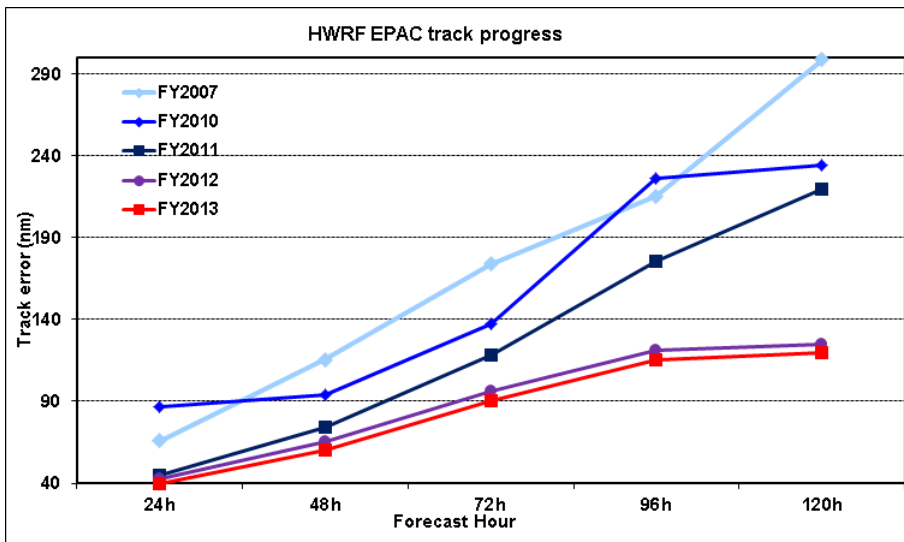


Continuous Improvement by Effective Transition of Research to Operations

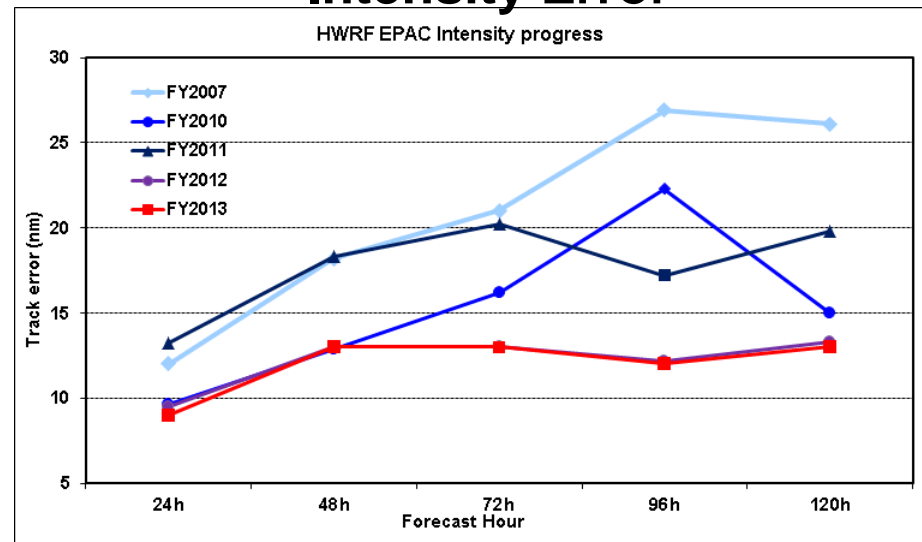


Historical Operational HWRF Eastern Pacific Track and Intensity Errors

Track Error



Intensity Error

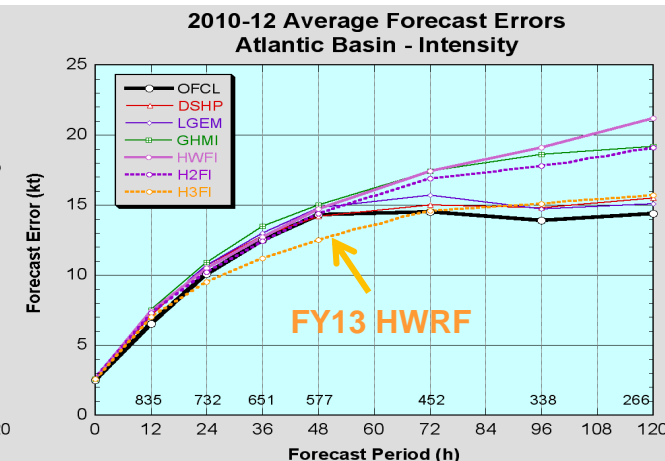
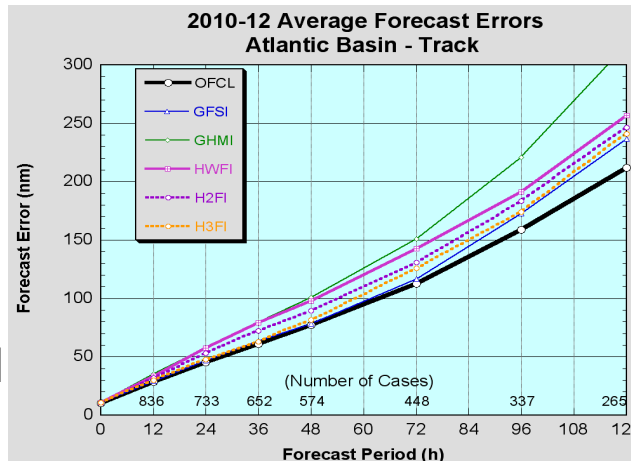
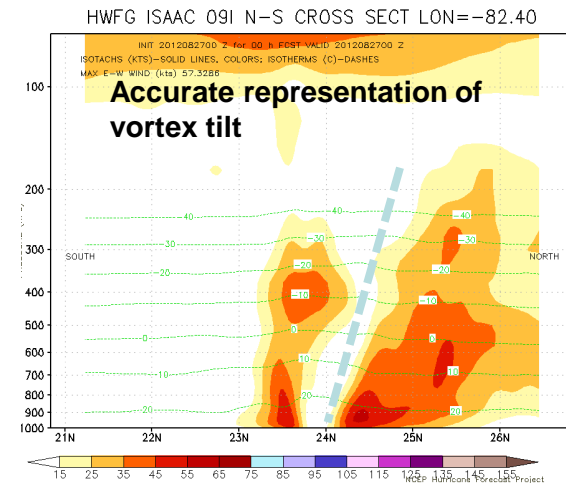
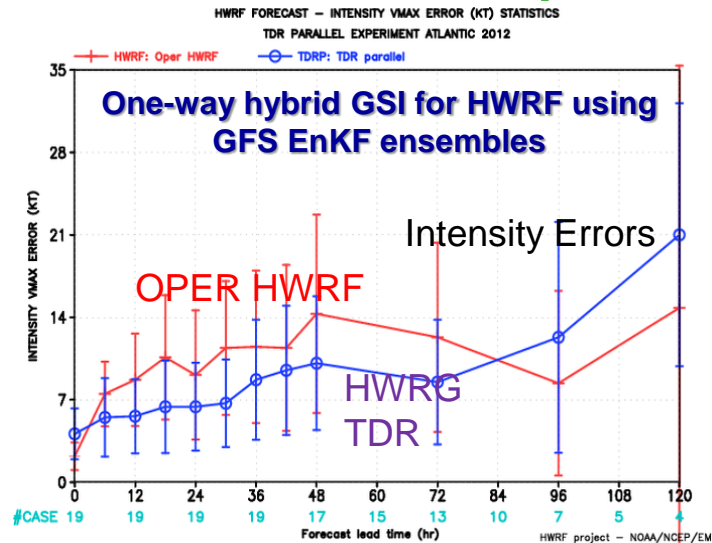




Further advancements to FY13 HWRF for improved track, intensity and structure forecasts

Advanced High resolution (3km) Triple Nested HWRF for 2013 Hurricane Season to be implemented on WCOSS

- Implementation of One-Way Hybrid Global EnKF-Regional 3DVAR GSI DA
- Improved vortex initialization, nest motion algorithm and nesting techniques
- Improved physics and air-sea interactions
- Improved product quality and enhanced synthetic satellite imagery
- Track Skill comparable to GFS, Intensity Skill superior to Official forecasts and statistical models





Global Systems Under Consideration:

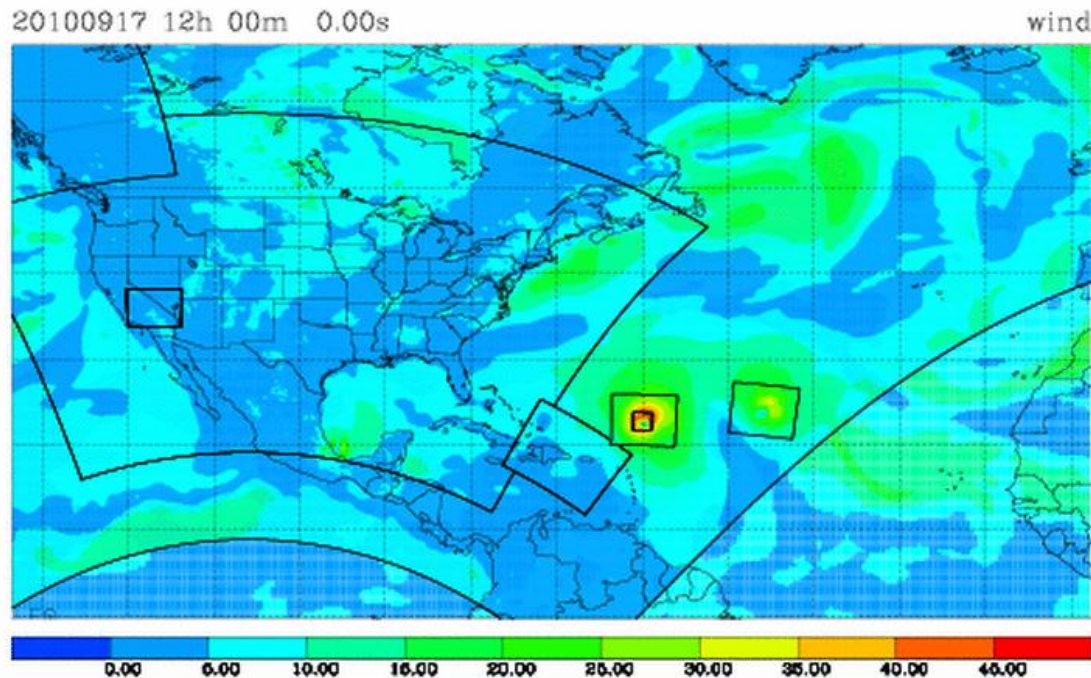


- The next-generation GFS must:
 - Provide skillful guidance for all NOAA operational applications
 - Demonstrate at least the computational efficiency of the current GFS
 - Provide the flexibility to meet future demands
- Candidate Models Currently Under Development
 - GFS Global Spectral Model (hydrostatic, spectral)
 - Non-Hydrostatic Multiscale Model (NMM) (non-hydro, grid point, nesting)
 - Flow Following Icosahedral Model (FIM) (hydro, icos A-grid, GFS physics)
 - Non-hydrostatic Flow Following Icosahedral Model (NIM) (non-hydro, FIM)
 - Cubed-Sphere Finite Volume (non-hydro, conservative)
 - Model for Prediction Across Scales (MPAS) (non-hydro, Icos C-grid, adaptive grid)
- Must be applicable across weather and climate (ISI) scales
- Balance between Science and Technology (i.e., HPC accelerators)

Is a Unified Modeling Approach Possible at NOAA?

Example Global, CONUS & Hurricane Applications

84-hour forecasts from 12Z 17 Sep 2010
Lowest model layer winds (m/s).



- Global NMM-B in the outermost domain
- NAM/NMM-B inside the global domain
- CONUS nest inside the NAM
- Moving nests of Hurricanes Igor and Julia
- Configuration within a single executable

