Operational HWRF – Plans for 2014 and beyond.

Vijay Tallapragada & HWRF Team

Environmental Modeling Center,
NCEP/NOAA/NWS, NCWCP, College Park, MD 20740.

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Priorities for Operational HWRF for 2014 hurricane season

Address known problems/issues identified during the season:

a) Weak storms continued posing significant challenge

b) Moisture initialization in the model less than optimum

c) Cold start (very first cycle for a numbered storm) cases behave different (worse) than the warm start

d) Land interactions and cold temperature bias over land

e) Too small inner most domain to contain large storms

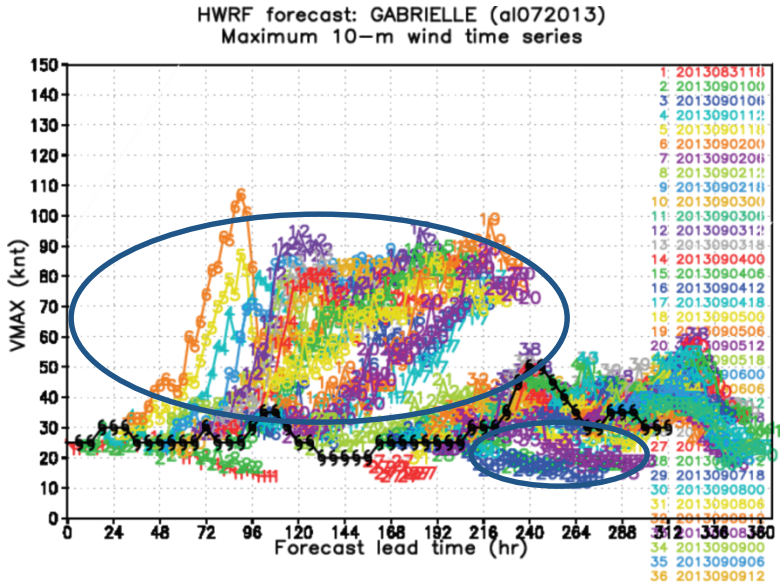
f) Insufficient vertical resolution for satellite data assimilation

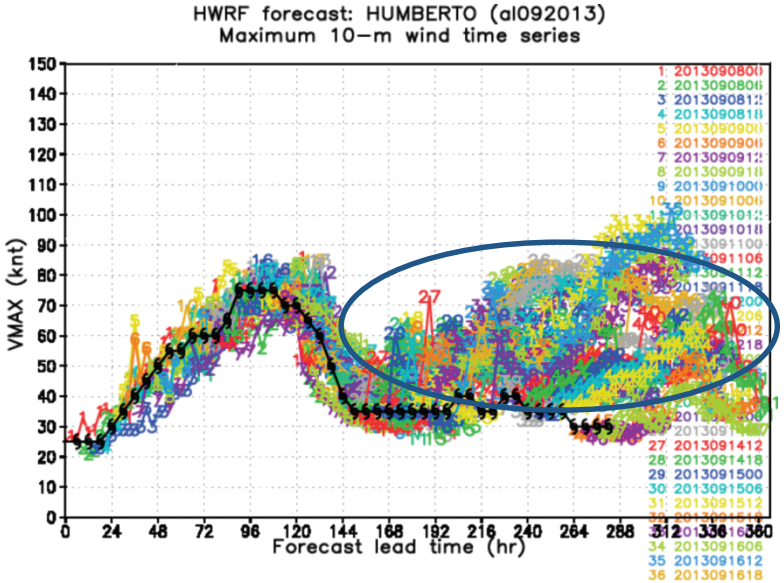
g) Coarse resolution of ocean model, inadequate conditions for choice of ocean domain in the Atlantic, 1-D coupling in the East Pacific

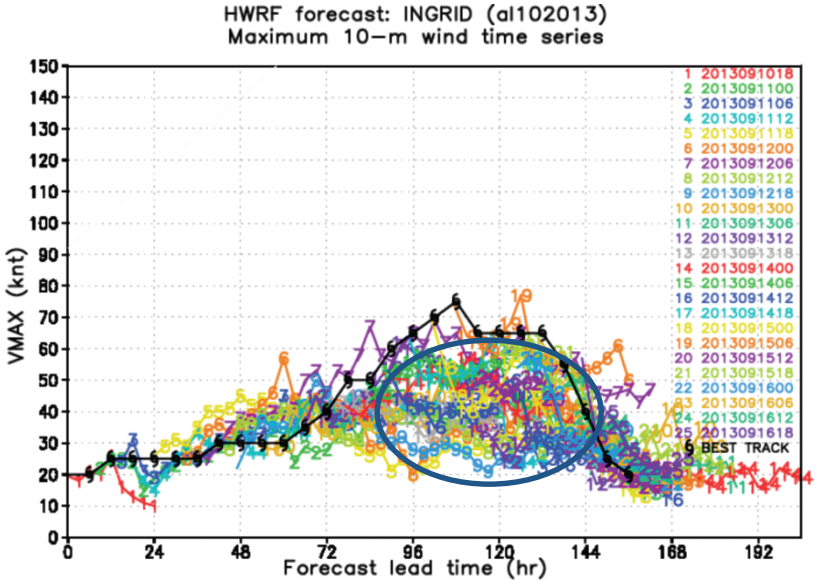
Focus areas for development, testing and evaluation

1. Increase the vertical resolution of atmospheric model to 61 levels with higher model top of 2 hPa
2. Upgrade HWRF physics suite to include RRTM-G, Modified Ferrier microphysics, NOAH LSM.
3. Upgrade the ocean model (POM) to 1/12^{o} MPI POM with unified trans-Atlantic basin and 3D ocean for Eastern Pacific basin. Upgrade the coupler to run on multiple processors.
4. Further improvements to HWRF vortex initialization scheme and HWRF Data Assimilation System
5. Additional operational forecast products from HWRF to include simulated brightness temperatures for new satellite sensors, several new variables for downstream applications and 9-minute ATCF output Many bug fixes and enhancements for the vortex tracker.
6. Pre-implementation tests based on proposed Q4FY13 GFS upgrades

Problematic Storms for Intensity Forecasts





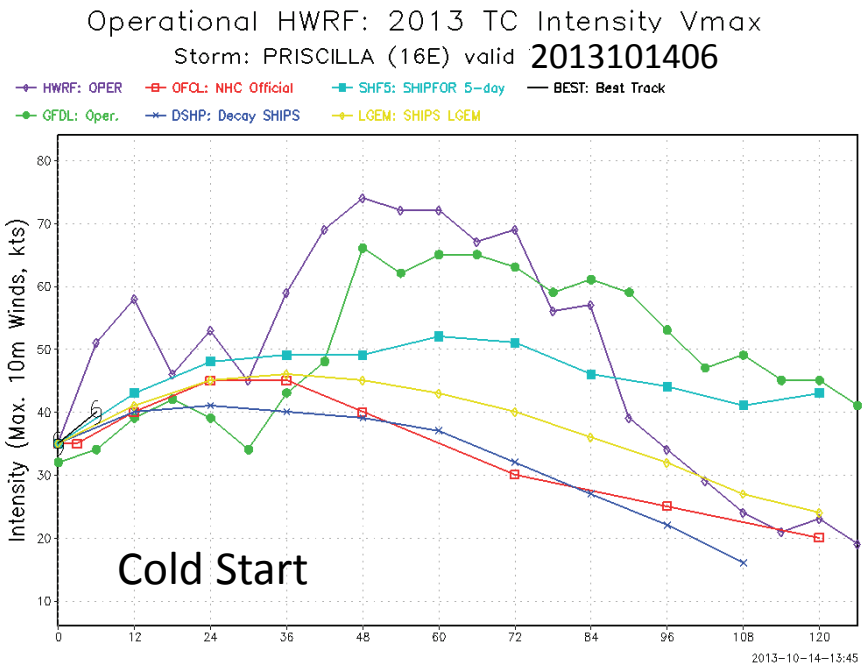


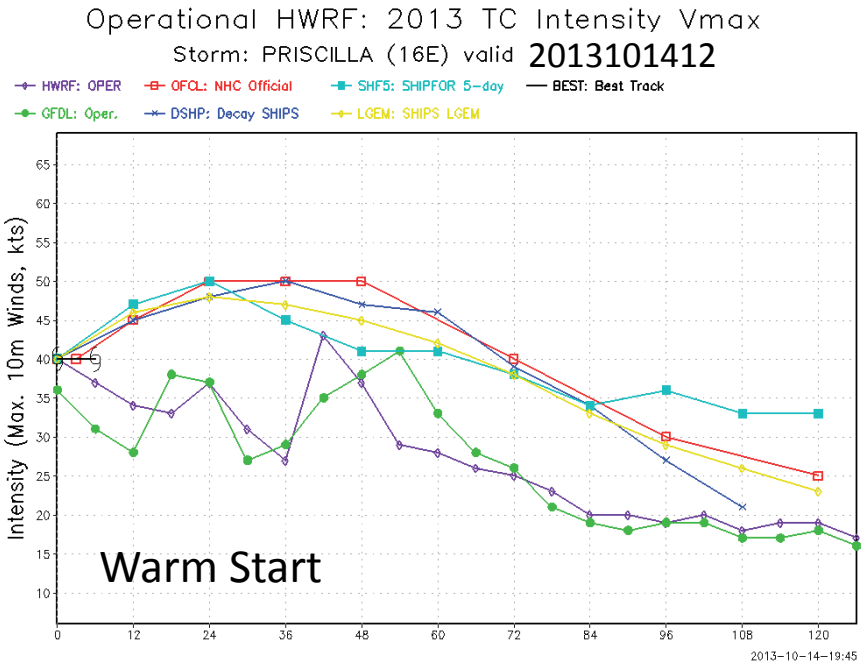
Weak storms still pose a significant challenge for HWRF.

Land interactions also impacted a few intensity forecasts for H. Ingrid

Potential initialization issues for cold start

Intensity forecasts for Cold Start



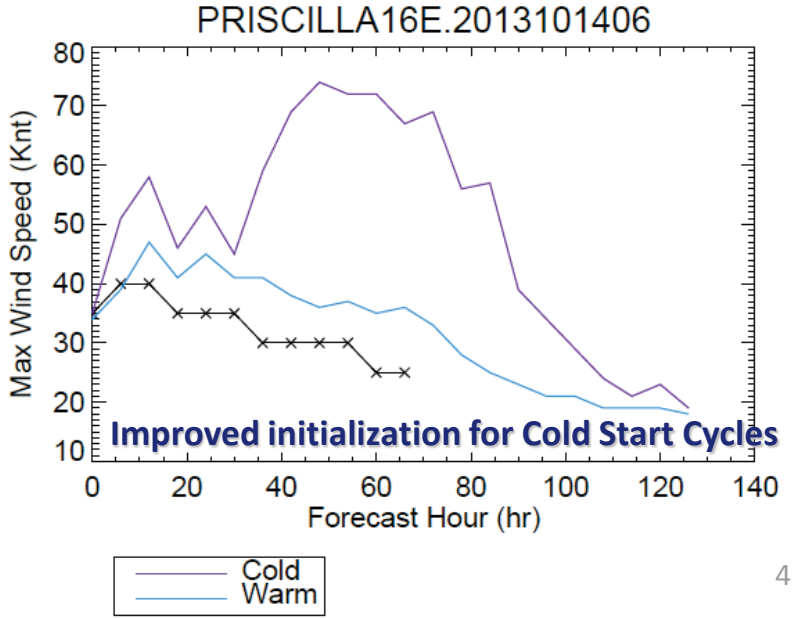


Invest 95E became Priscilla 16E on 2013101406

Cold start (bogus) intensified the storm significantly

Warm start cycles well behaved

Could we cycle the vortex from Invest 95E for first cycle of Priscilla?

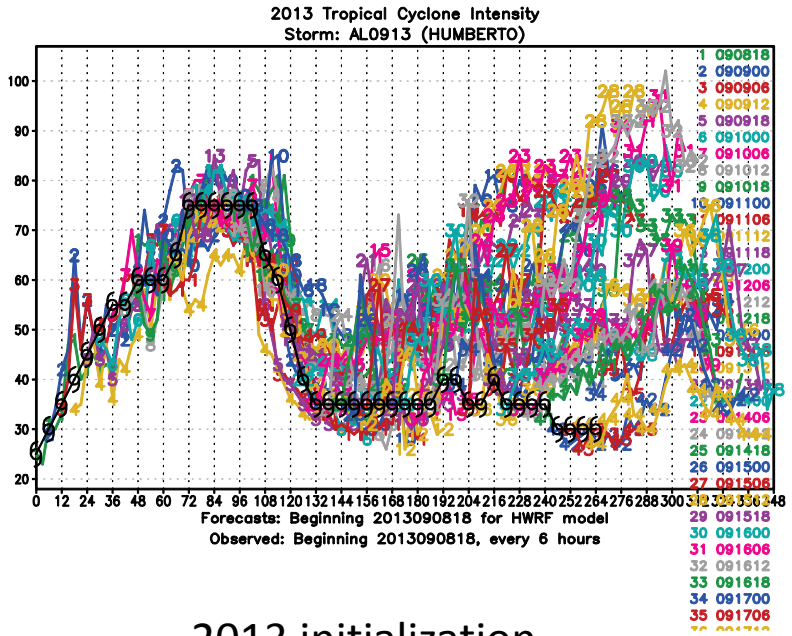


Initialization upgrades

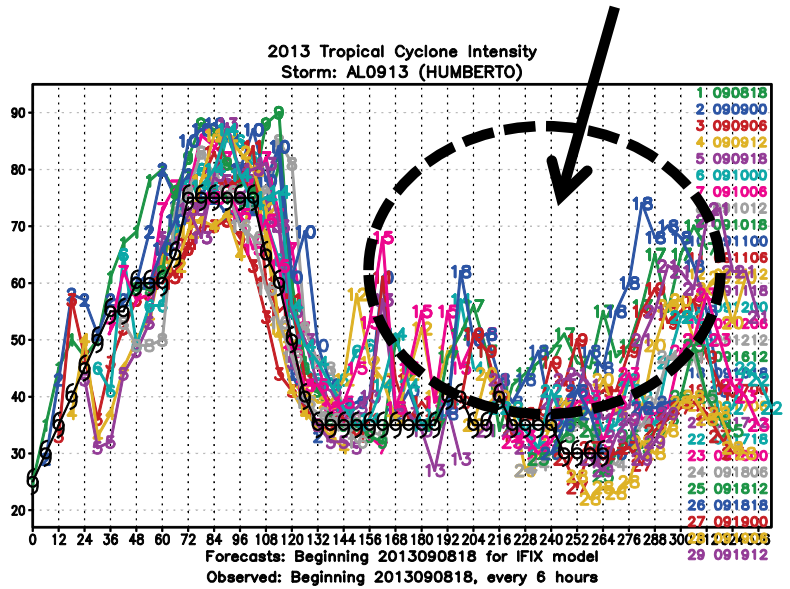
1. Match the initial maximum wind speed over the lands
2. Fix the bug of calculating south-west corner of initialization domain
3. Storm center is used in the procedure instead of using parent domain center
4. Remove the vorticity discontinuity along the filter domain
5. Avoid cold starts for the first cycle of named/numbered storm through cycling of vortex from Invest cases

Preliminary results (Humberto)

Strong intensity bias reduced

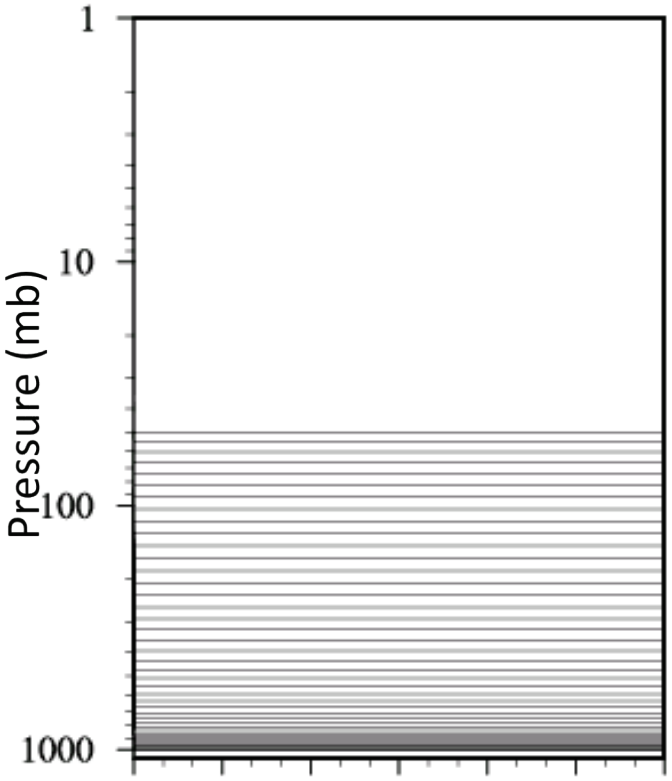


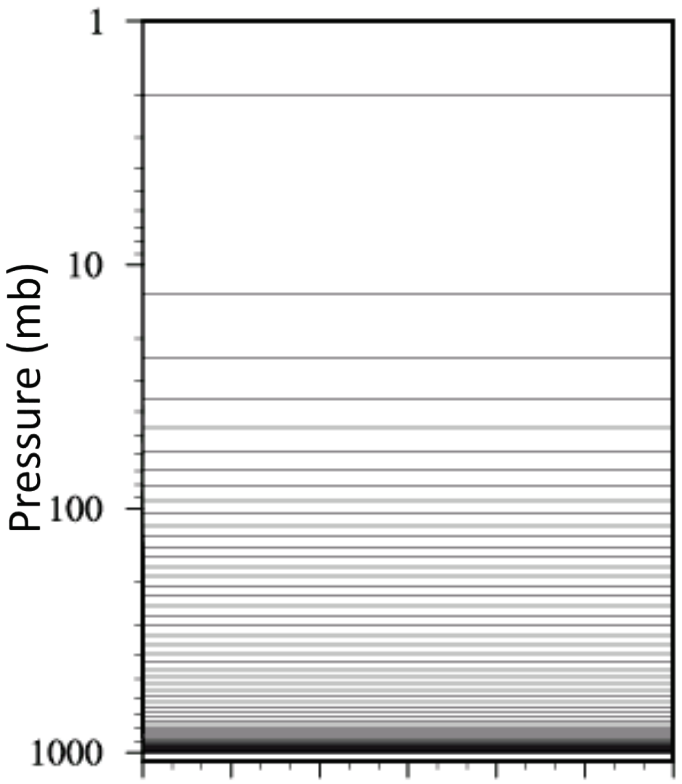
2013 initialization



Proposed upgraded init.

Increased model vertical levels (43 to 61) with higher model top (50mb to 2mb)





Operational HWRF **(43level, pt=50mb)**

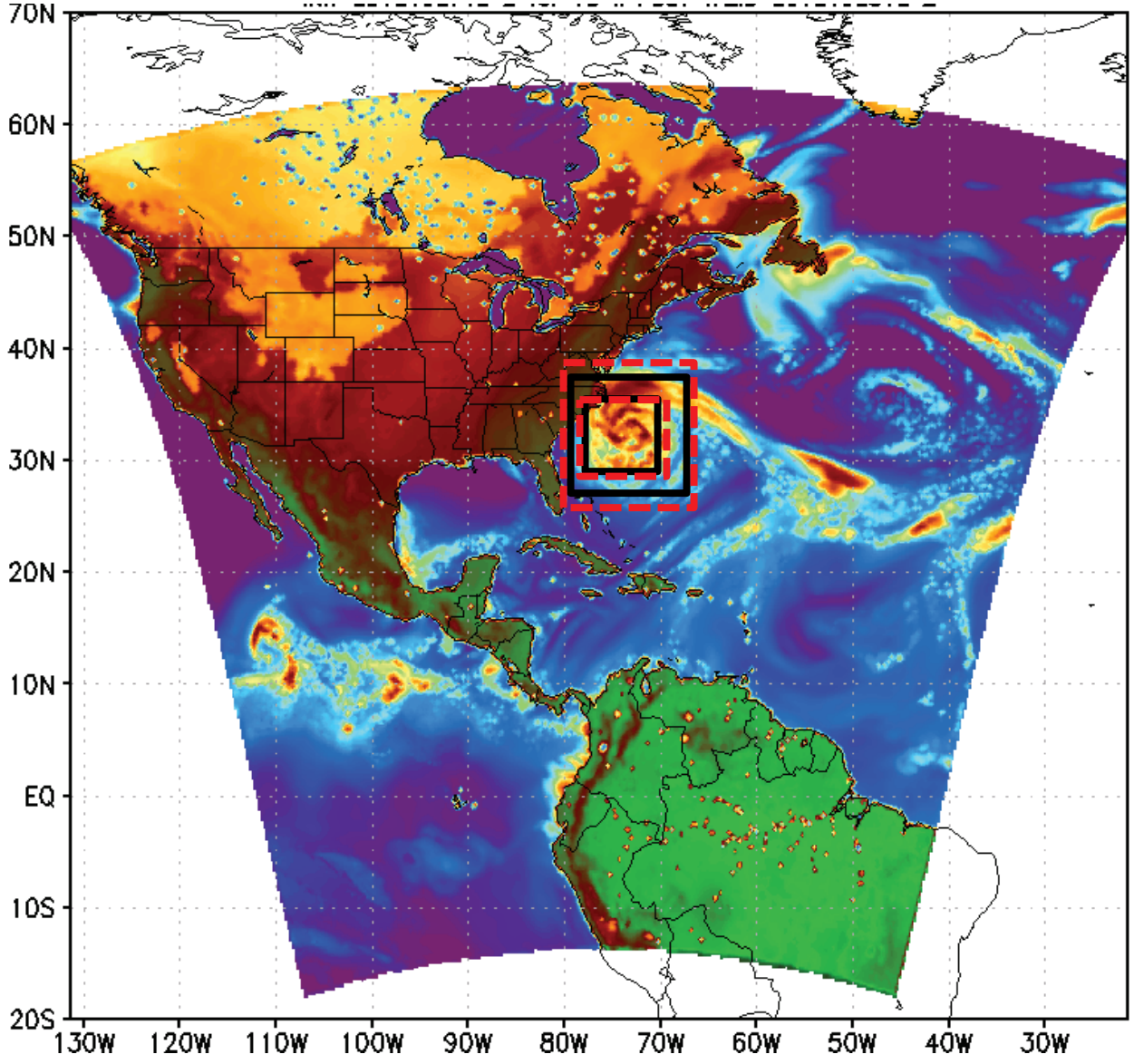
new HWRF **(61level, pt=2mb)**

Extended nest domains

Hurricane Sandy (2012102718 +18hr fcst)

d02: 20% extended
10°X10° to 12°X12°

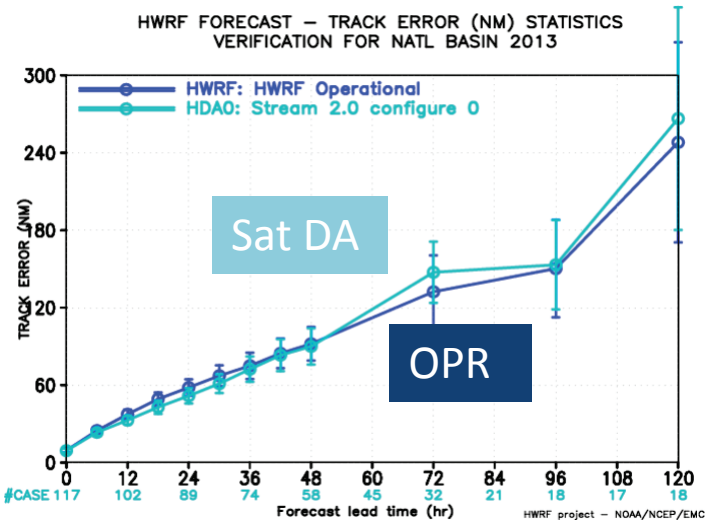
d03: 10% extended
6.5°X6.5° to 7.1°X7.1°



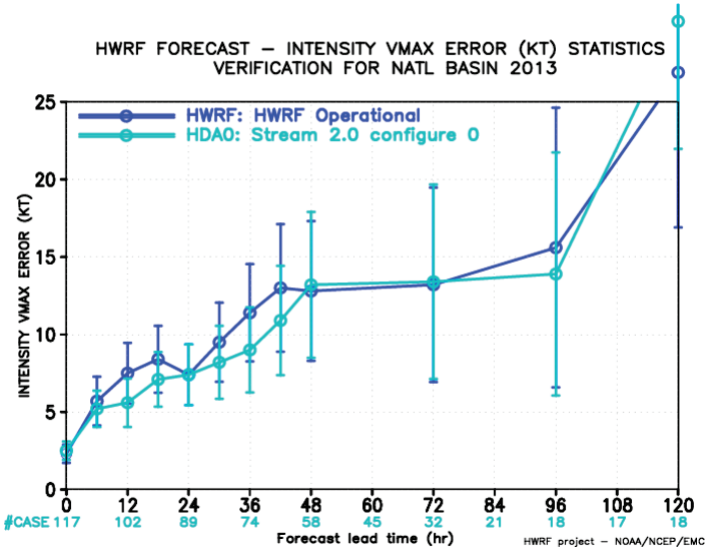
Data assimilation upgrades (Trial 1)

1. Apply regional hybrid GSI analysis for both D1 and ghost domains
2. Assimilate the conventional data and TDR, dropsondes (including inner core from aircraft recon), GSPRO, satellite derived wind, **brightness temperature from IR instruments (HIRS, AIRS, IASI, GOES Sounder) and MW instruments (AMSU-A, MHS, ATMS)**
3. Set satellite thinning box to 90 KM for IR instruments, and 45 KM for MW instruments
4. Increase model vertical levels to 61 and model top from 50mb to 2mb in order to assimilate more satellite data
5. Change 3-hourly FGAT to hourly FGAT – provide more accurate first guess fields, especially for fast moving and developing storms **(withdrawn due to resource issue)**

Results from HFIP Stream 2.0 Satellite DA Impact Tiger Team



Track Error



intensity Error

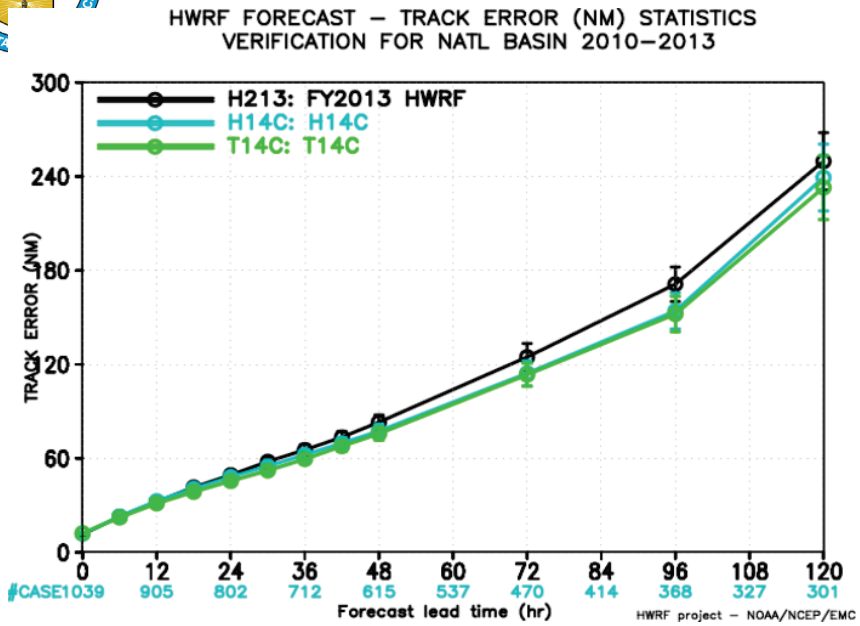
2014 HWRF pre-implementation test plan

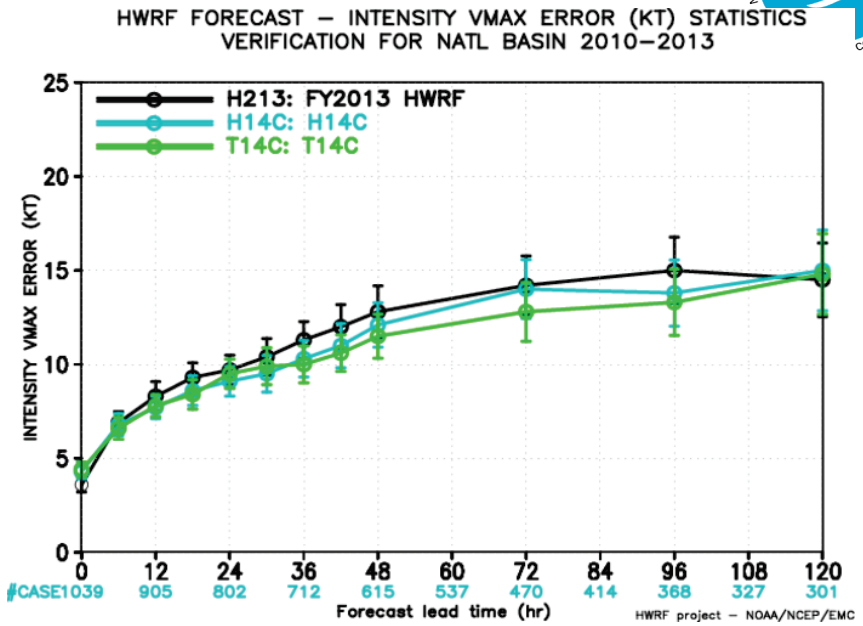
	Infrastructure/DA upgrades				Dynamics/Physics upgrades					Final
	H14A	**H14B**	**H14C**	**T14C**	**Nest motion (H140)**	**NOAH LSM (H141)**	**Upgraded Ferrier (H142)**	**RRTMG (H143)**	**Ocean (H144)**	**H214**
Description	1. Sat Da with more vertical levels 2. Extended d2/d3 3. Upgraded vortex initialization 4. GSI upgrade 5. Invest cycling	1. No Sat DA	Sat DA only for D01	Same as H14C except no DA in d01, use GFS analysis	New nest motion and high-freq. products	NOAH LSM	Separate species, Frime advection with other upgrades	Radiation	MPI-POM with new coupler	Combination of Best Performing components *need to do test runs with new GFS in WCOSS
Person	All	All	All		Sam	Young	Weiguo	Chanh	Zhan/URI	All
Cases	Whole 2011,2012 and 2013 storms 2008, 09, 10 TDR cases	As in H14A	As in H14A		Priority cases	Priority cases	Priority cases	Priority cases	Priority cases	Whole 2011,2012 and 2013 storm
Due date	Feb. 15	Feb. 15	Feb. 15		Feb. 15	Feb. 15	Feb. 15	Feb. 15	Feb. 15	March 31
Platform	Jet	Jet	Jet		Jet	Jet	Jet	Jet	Jet	Jet/WCOSS

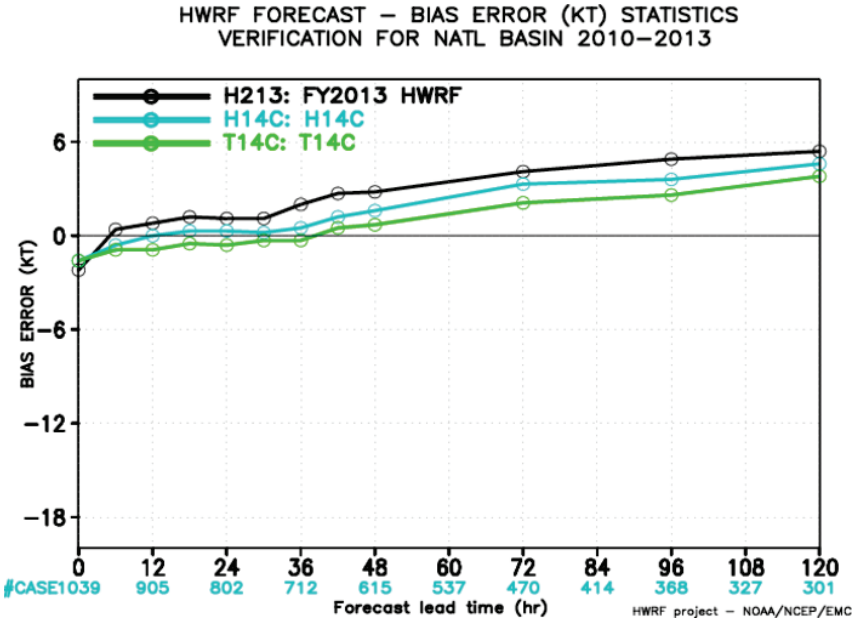
2010-2013 stats

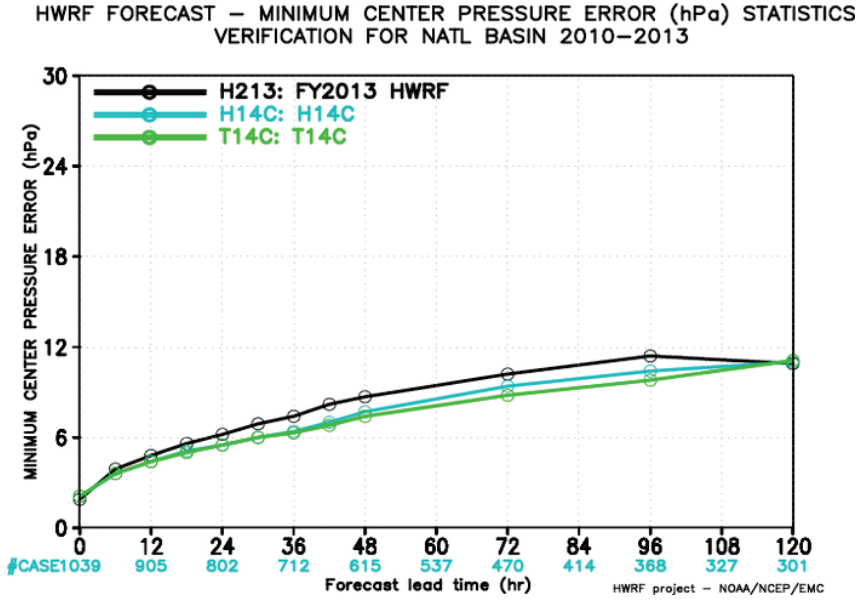
- 2014 HWRF Configuration with infrastructure/DA upgrades:
- Increased vertical resolution from 42 to 61 levels
- Increased model top from 50 hPa to 2 hPa
- Expanded 9/3 km nest domains (about 20% more)
- Modified vortex initialization
- Improved DA using inner core TDR and dropsonde data (when available), and clear sky satellite radiance data
- Two configurations:
  - H14C: Assimilate conventional data and satellite data in the outer domain using TC relocated GDAS forecasts as first guess
  - T14C: Use GFS Analysis for parent domain (no GSI for outer domain), use TC relocated GDAS forecasts as first guess for high-resolution DA (ghost) domains
- T14C is chosen as the candidate for physics testing (4 separate experiments)
  - Radiation (RRTM-G); LSM (NOAH-LSM); Advected Ferrier Microphysics and MPIPOM-TC
- Expected benefits:
  - About 10-15% improvement in Atlantic Track and Intensity forecasts
  - Neutral or positive impact on Eastern Pacific Track and Intensity forecasts
- 4-season test results to follow (comparing H14C/T14C to 2013 HWRF)

2010-2013 ATL basin

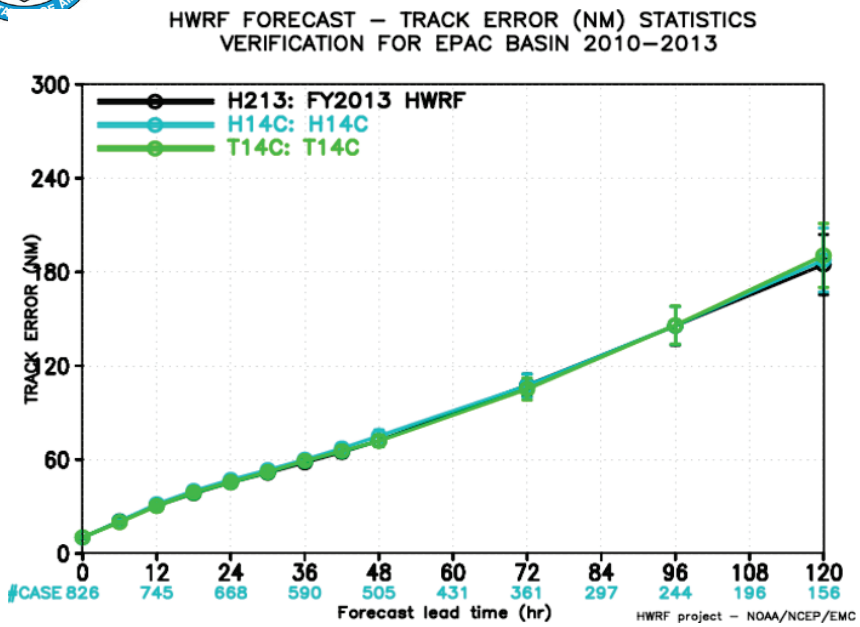


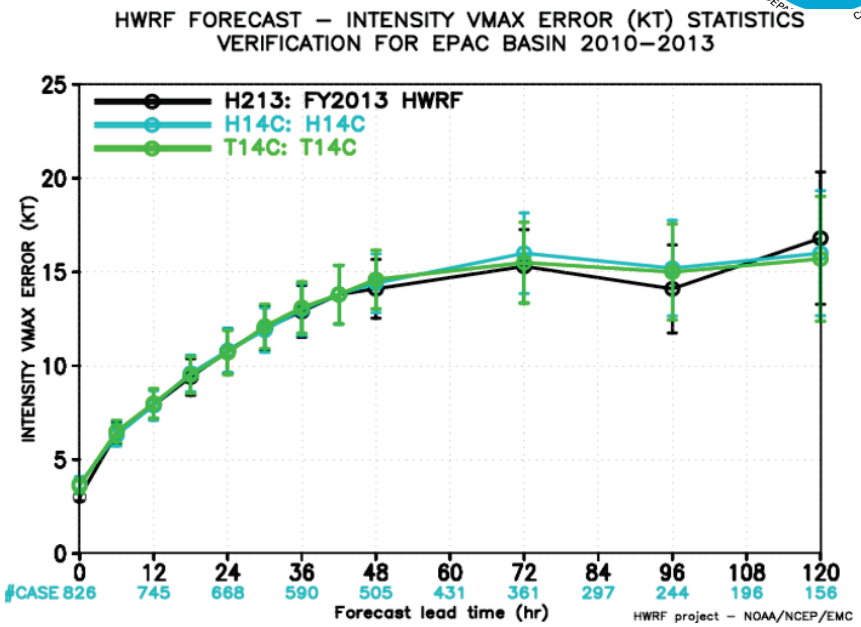


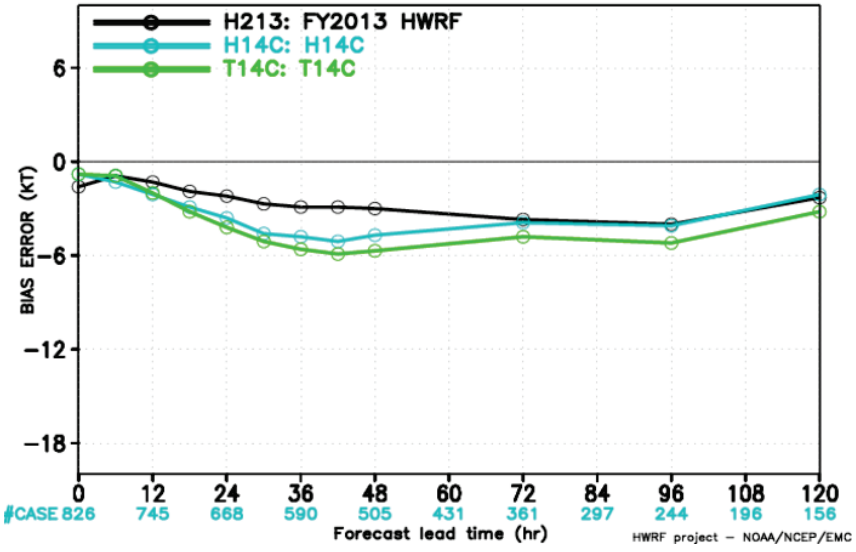


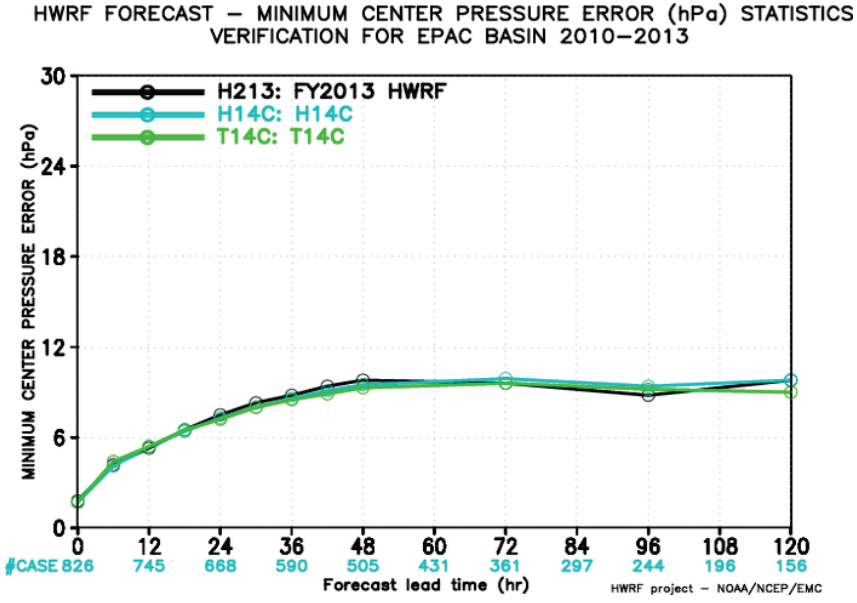


2010-2013 EP basin

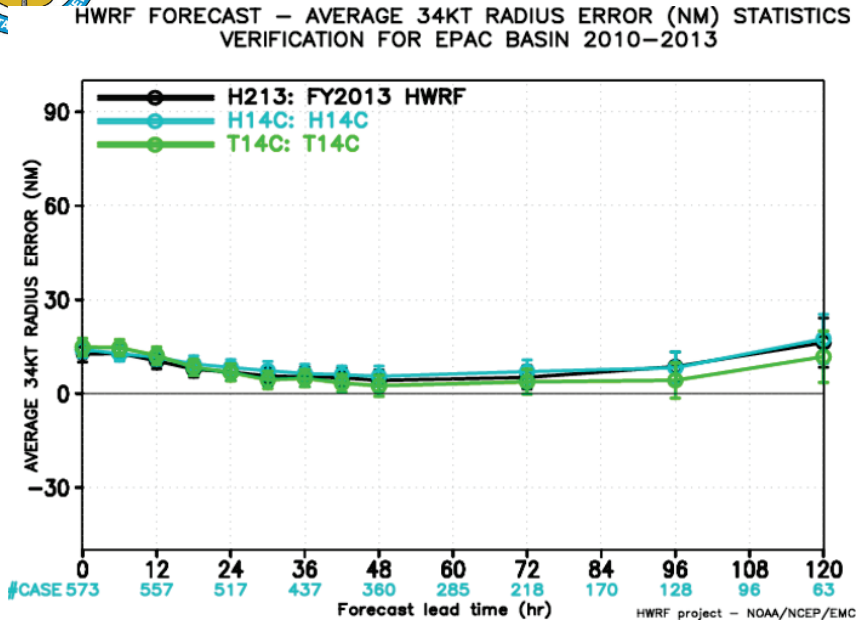


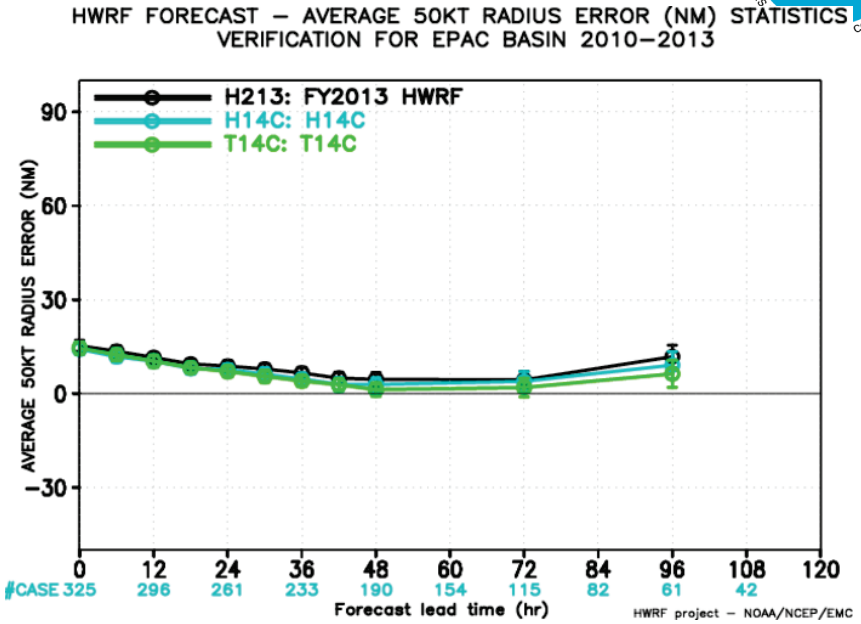


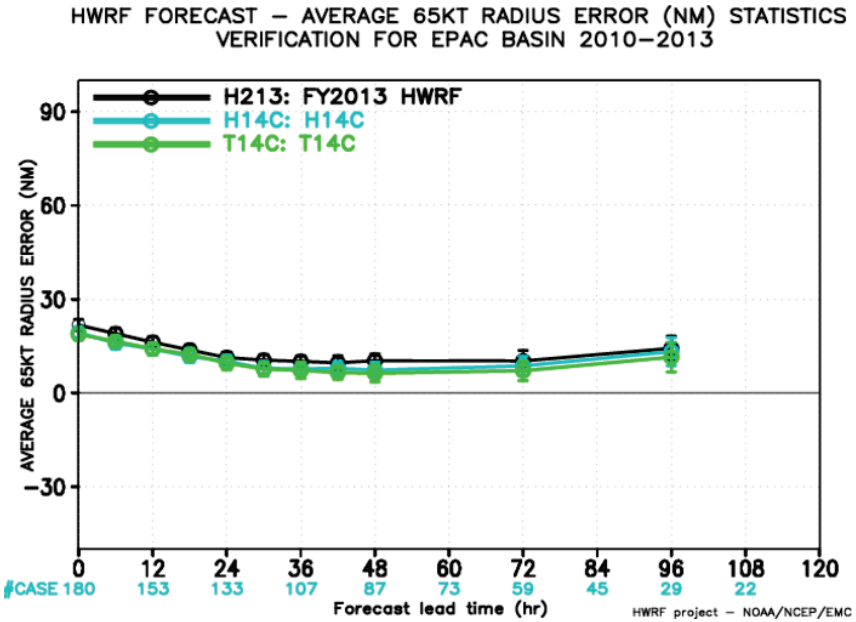


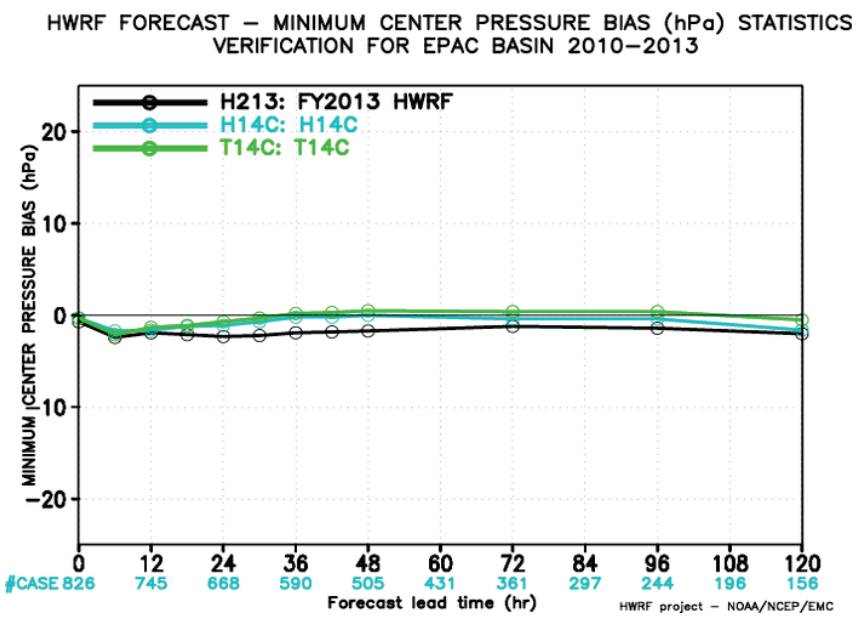


2010-2013 EP basin









What it takes in operations to run 2014 HWRF

- Resource requirements:
  - 30% more compute nodes (increase from 146 to 192)
  - 15 minutes additional run-time (increase from 75 to about 90 minutes)
  - Delivery time will move from t+5.45 to t+6.00 for each synoptic cycle
- Process optimization:
  - Process and job unification using python based scripts
  - Single pre-processing job and single post-processing job
  - Reduced I/O by eliminating several intermediate files
  - In-built swath generators for rainfall and max. wind (model will directly accumulate the fields during the integration)
  - Fully functional GRIB2 support
  - Additional output includes variables requested by SPC, 2-D grids for Hurricane Wave Models and 9-minute ATCF style storm vitals

HFIP Multi-Model Regional Ensemble Prediction System

1. **20-member HWRF Ensembles (Stream 1.5):**
   - Use FY2014 HWRF configuration and Additional stochastic perturbations to microphysics
   - Use control member's vortex for all ensemble members (no independent cycling) to increase the reliability and on-time delivery of forecasts

2. **Joint COAMPS-TC/HWRF/GFDL Multi-Model High-Resolution Regional Ensemble System (Stream 2.0):**
   - NRL scientists (Doyle and Reinecke) in collaboration with EMC (Tallapragada and Zhang) designed a plan for the HFIP multi-model ensemble using both HWRF and COAMPS-TC at 3 km horizontal resolution in an ensemble mode, consisting of at least 10 members for each model.
   - A set of cases (approximately 460 in the W. Atlantic) will be used to evaluate the performance of the 3-km COAMPS-TC and HWRF ensemble performed in a retrospective mode.
   - The GFDL ensemble system may be included in the analysis as well.
   - The joint HWRF and COAMPS-TC ensemble system will be demonstrated in real time during the 2014 season for the W. Atlantic (likely 1 Aug-30 Oct). The ensemble forecasts will be displayed and made available on the web through HFIP.

HWRF based Stream 1.5/Stream 2.0 Real-Time Parallels

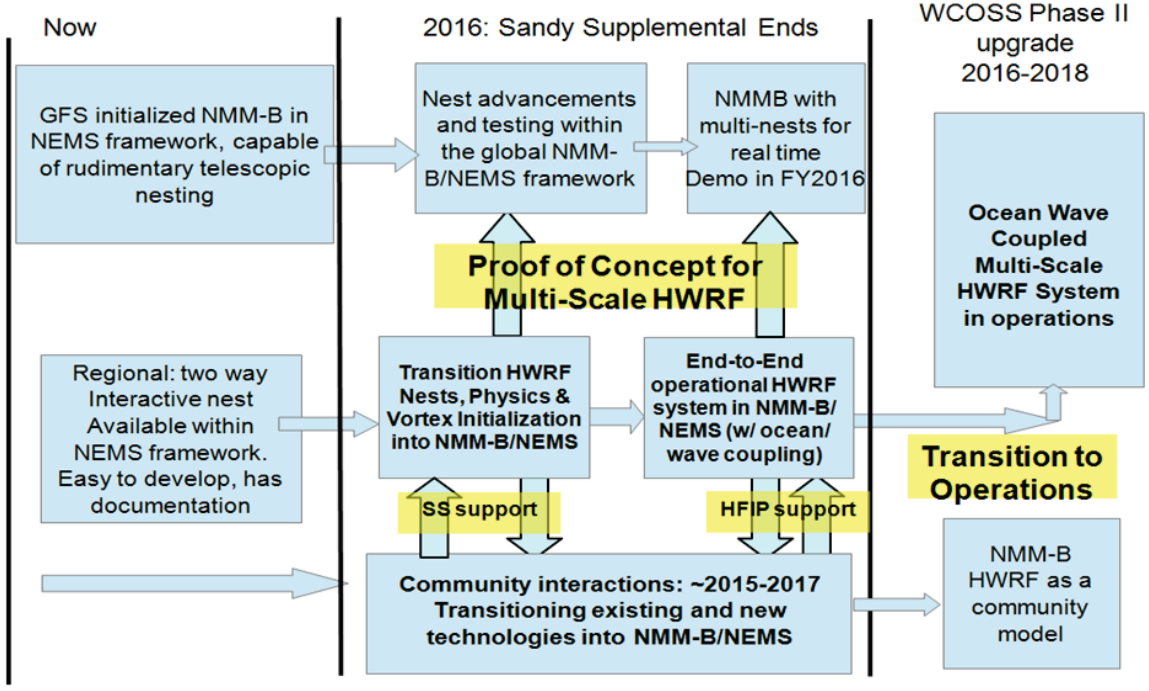
- **HWRF-HYCOM Parallel Experiments (Stream 1.5 or Stream 2)**
  - Conduct retrospective and real-time experiments
- **High-Resolution Physics experiments**
  - Continue exploring alternate physics suite for HWRF. Run real-time demo of HWRF with advanced physics options
- **HWRF-POM/HYCOM-WaveWatchIII 3-way coupled system experiments (Stream 2.0)**
  - Collaborative effort with URI/GFDL. Conduct real-time demo experiments for selected storms
- **HWRF for Global Tropical Oceans (Stream 1.0)**
  - Use FY2014 HWRF configuration (if fits on Jet)
  - Continue providing real-time forecasts for all storms requested by JTWC (including SH)

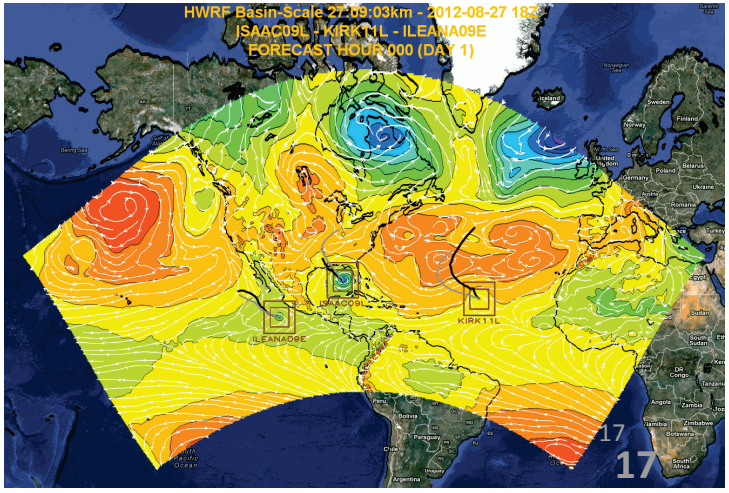
Advancements to Operational HWRF – Transition to NMM-B/NEMS Multi-Scale Modeling System

- **NCEP/AOML Collaborative effort supported by OAR Sandy Supplemental High Impact Weather Prediction Project (HIWPP) and leveraged by NOAA's HFIP support**
- **Take advantage of NMMB in NEMS infrastructure for developing next generation global-to-local-scale modeling system for tropical cyclone forecasting needs and for comprehensive solutions for landfalling storms**
- **Planned development, testing and evaluation leading to potential transition to operations in the next 3-5 years**

Scientific advancements include:

- **Scale aware and feature aware physics for high-resolution domains and for multi-scale interactions**
- **Advanced techniques for inner core data assimilation with use all available aircraft recon data including TDR, FL, SFMR, and satellite radiance data**
- **High-resolution ensembles for prediction of RI/RW**
- **Enhanced land-air-sea-wave-hydrology coupled system**





HWRF Evolution to 2018

System	Current (Q3FY13)	Q3FY14	Q3FY15	Q3FY18
Atmosphere	Triple nested WRF NMM, storm centric	Triple nested WRF NMM, storm centric	Triple nested WRF, storm centric	High-resolution Hurricane nests within the basin-scale/global model (NMM-B/NEMS)
	27:9:3km horizontal, 42 Levels	27:9:3km horizontal, 61 Levels, higher model top and expanded nested domains	18:6:2km horizontal, 64L (could be 15/5/1.67 to get closer to GFS resolution	2km or higher resolution hurricane nests with 128 Levels, global model top, with 10 member ensembles for each storm
Ocean	POM (3D ATL and 1 D EPAC) 1/6° resolution 23 levels	POM (Combined Trans-Atlantic domain at 1/12° resolution, 23 levels and 3D ocean for East Pacific)	HYCOM (1/12° resolution 32 levels)	Global HYCOM (1/12° resolution, 100 levels)
Waves	None	None	Wave Watch III	Wave Watch III
Data Assimilation	One-Way Hybrid EnKF-3DVAR with vortex init., inner core NOAA-P3 TDR DA	One-Way Hybrid with inner core aircraft recon data (TDR/FL) ~~and clear sky satellite radiance DA~~	One-Way Hybrid with inner core recon data (TDR/FL); clear and inner core cloudy radiance DA	Two-way hybrid 3D/4D En-Var with inner core aircraft and all sky satellite radiance DA
Hurricane Physics	Ferrier Microphysics with explicit convection in 3km domain	Advanced Microphysics with high-resolution convection scheme, NOAH LSM and RRTMG Radiation	Advanced Microphysics, and land-air-sea-wave interactions	Scale and feature aware physics coupled to wave, hydrology, surge and inundation models
Basins	NATL, EPAC, CPAC	NATL, EPAC, CPAC	NATL, EPAC, CPAC	All Tropical Ocean basins
Max. storms	5	5	5	All existing tropical storms including genesis forecasts out to 7 days

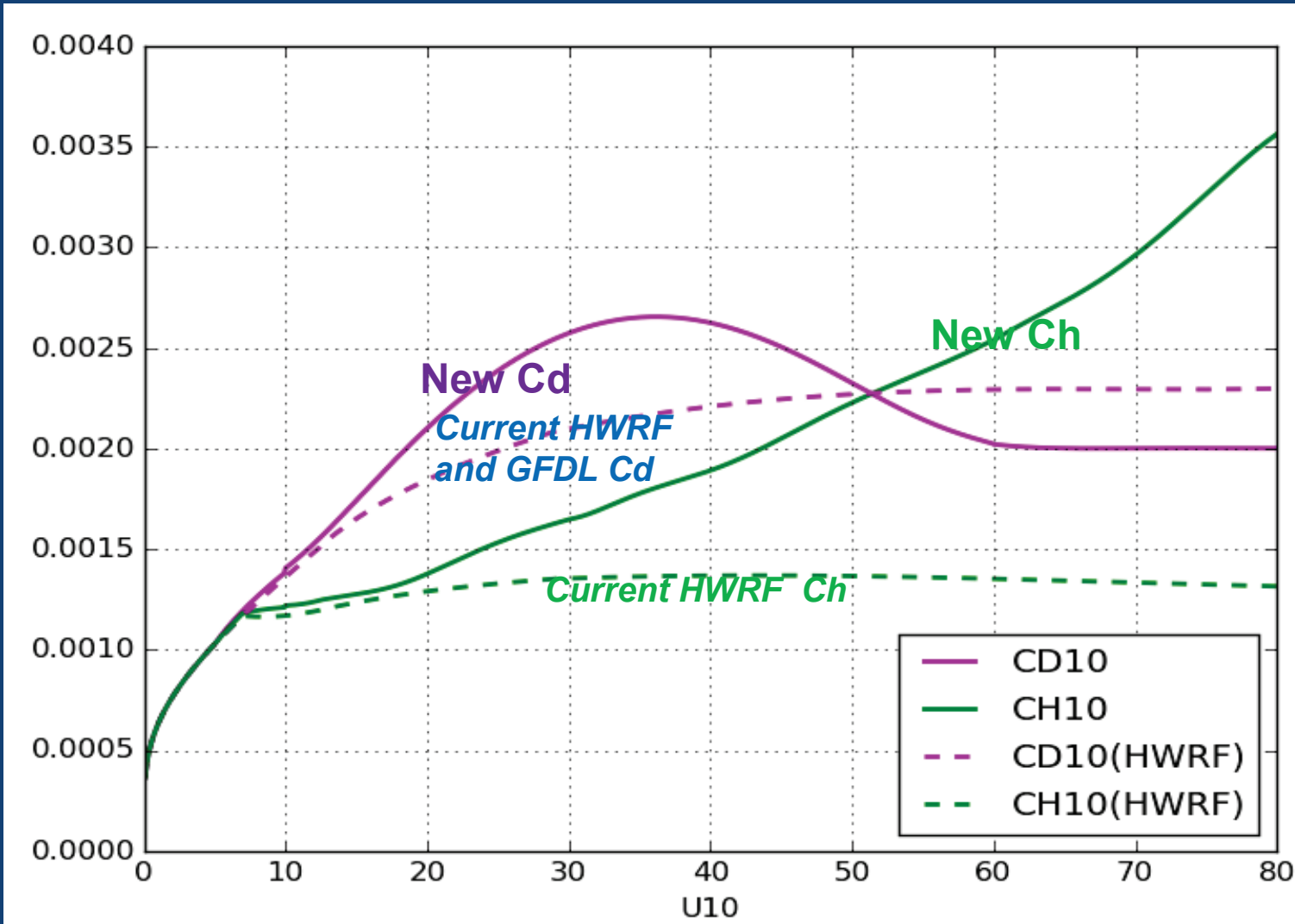
Future Outlook 5 to 25 years??????

	5-10 years	2020+
Resolution/ Infrastructure	Basin-Scale HWRF with multiple moveable nests (at cloud resolving resolutions) and high-resolution HWRF ensembles Downstream applications (including landfall related storm surge, waves, flooding and inundation)	Global to Local Scale Modeling to capture multi-scale interactions High-Resolution Ensembles for events of interest
Physics	Observations based physics Incorporate effects of sea-spray, aerosols, waves, boundary layer rolls – explicit representation of inner core processes	Ensemble based physics approach
DA/ Vortex Initialization	Hybrid/EnKF with 4-D VAR Vortex initialization within the DA, focus on assimilation of all-weather radiances and aircraft data	Part of the data assimilation for global system
Ocean/Wave/ Land	Fully coupled ocean-wave-land-atmosphere system	
Products & Downstream applications	Meeting the next-generation needs of Hurricane Specialists at NHC and JTWC	

GFDL 2014 Hurricane Model Upgrade

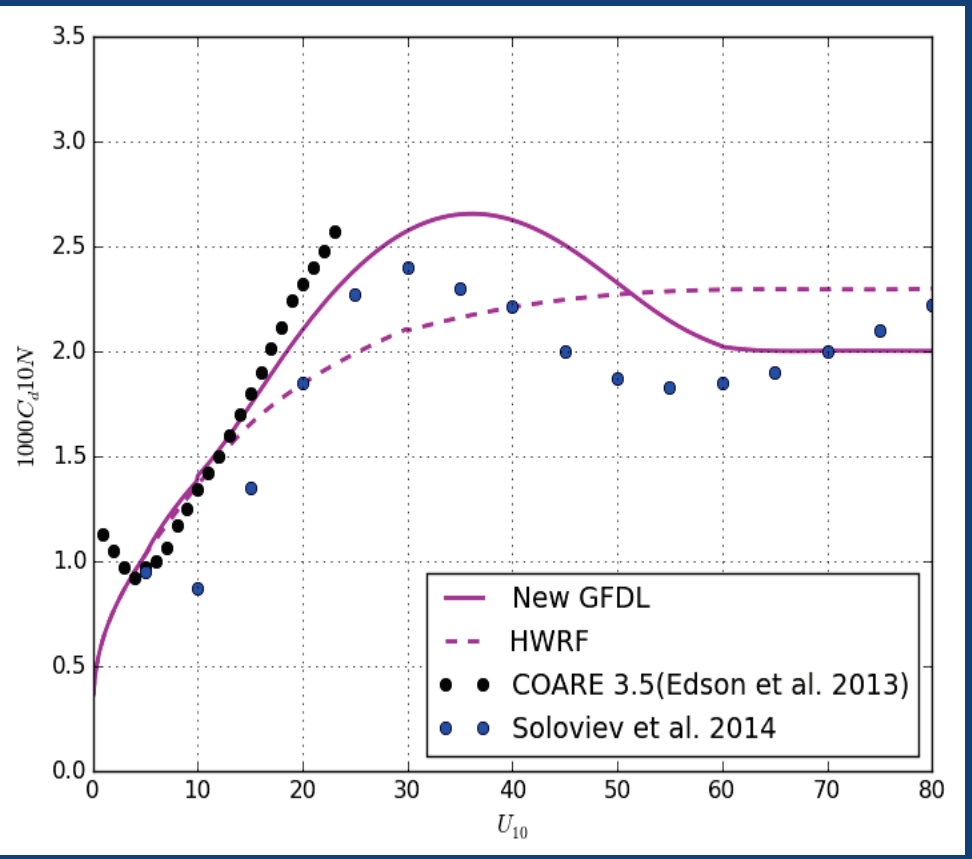
- **Increased horizontal resolution of inner nest from 1/12th to 1/18th degree with reduced damping of gravity waves in advection scheme**
- **Improved specification of surface exchange coefficients (*ch, cd*) and surface stress computation in surface physics**
- **Improved specification of surface roughness and wetness over land.**
- **Modified PBL with variable Critical Richardson Number.**
- **Advection of individual micro-physics species.**
- **Improved targeting of initial storm maximum wind and storm structure in initialization. (Reduces negative intensity bias in vortex specification)**
- **Remove of vortex specification for storms of 40 knots and less**
- **Upgrade ocean model to 1/12th degree MPI POM with unified trans-Atlantic basin and 3D ocean for Eastern Pacific basin**
- **Remove global_chgres in analysis step (direct interpolation from hybrid to sigma coordinates)**

New Cd and Ch formulation

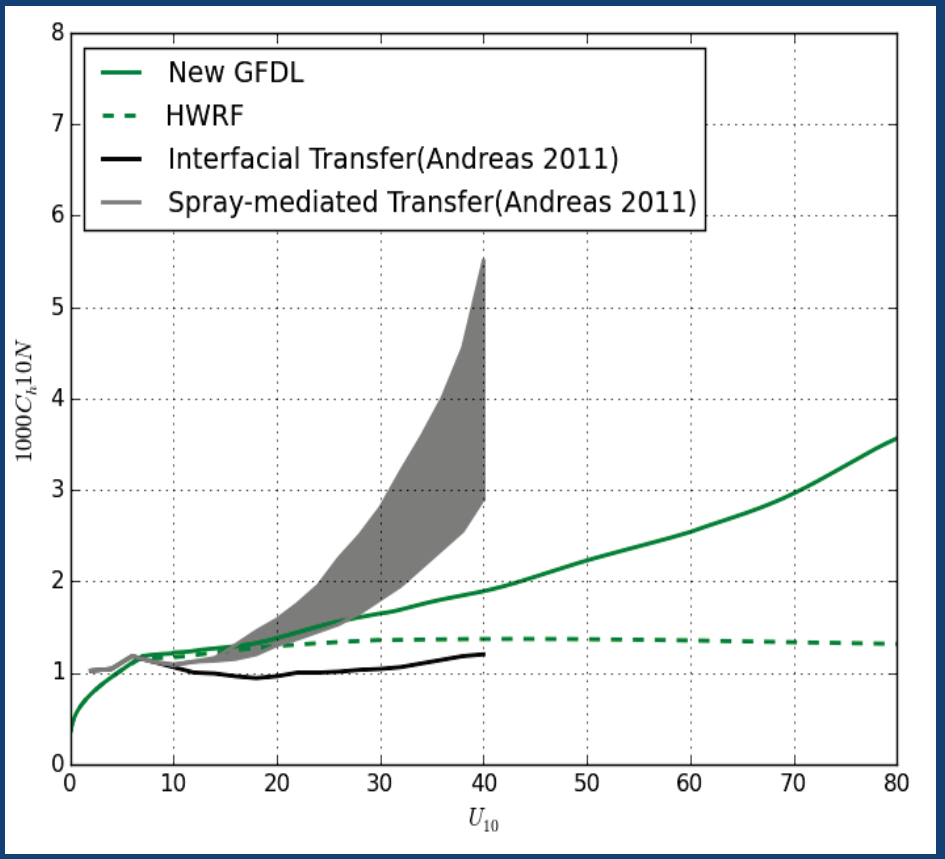


Comparison of New cd and ch with Recent Referenced Studies

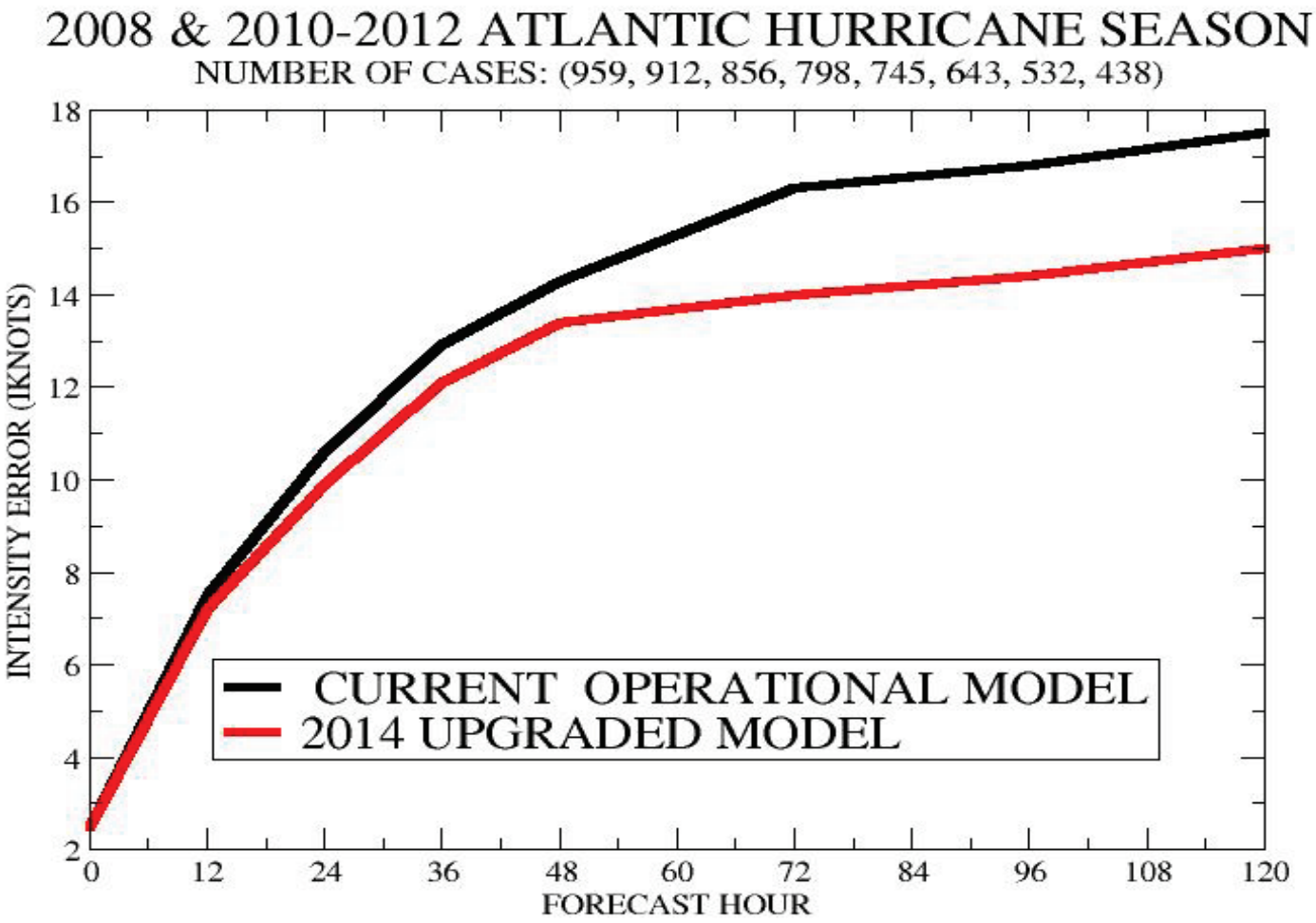
Cd



Ch

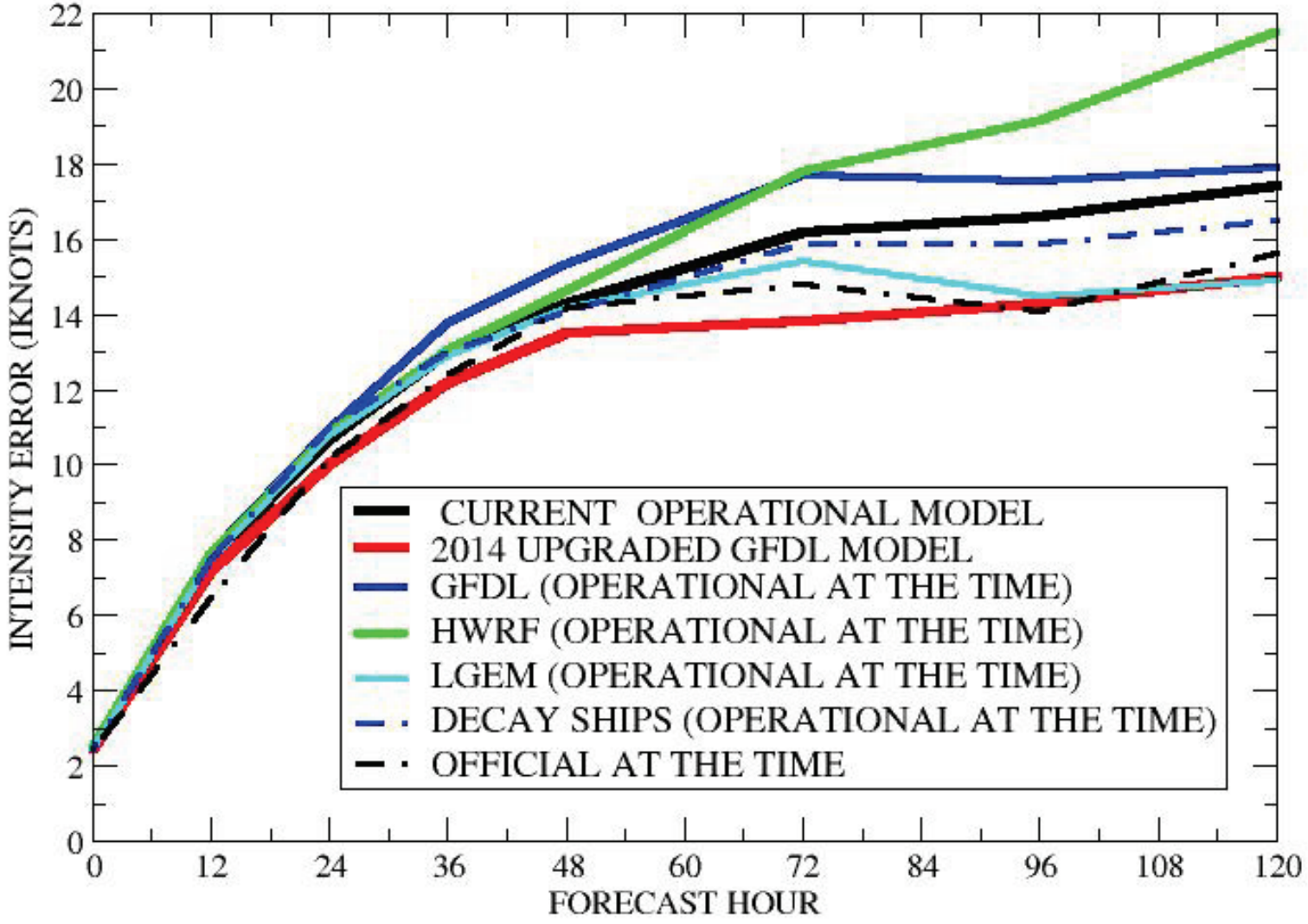


New GFDL Model Significantly Improved Intensity Skill at all Time Levels

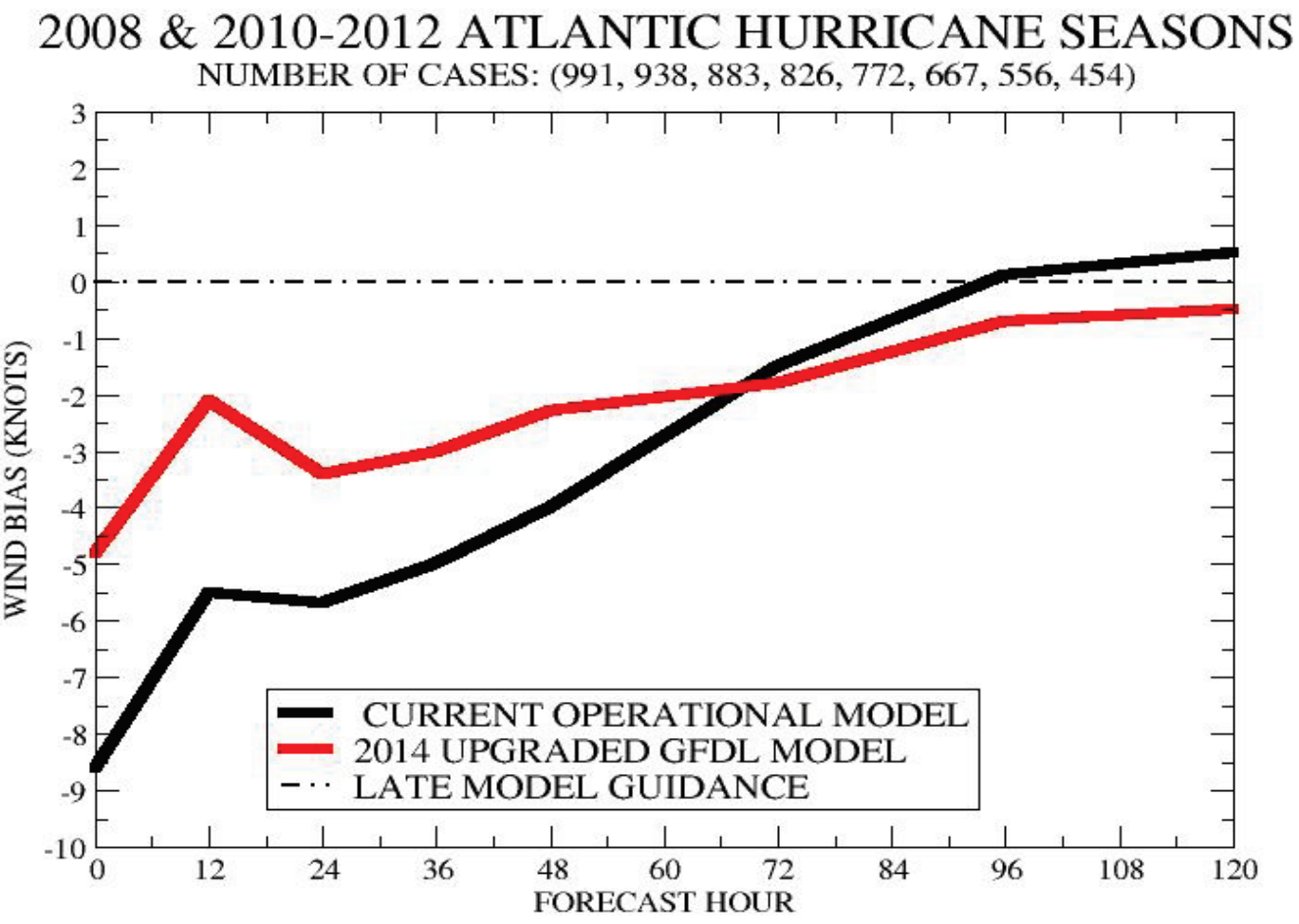


2008 & 2010-2012 ATLANTIC HURRICANE SEASONS

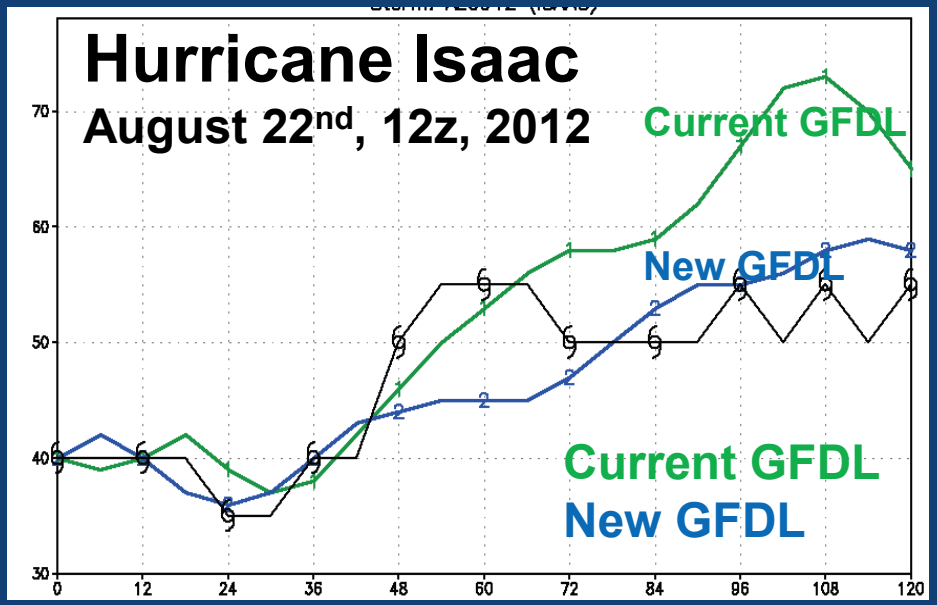
NUMBER OF CASES: (934, 891, 839, 782, 731, 631, 519, 426)

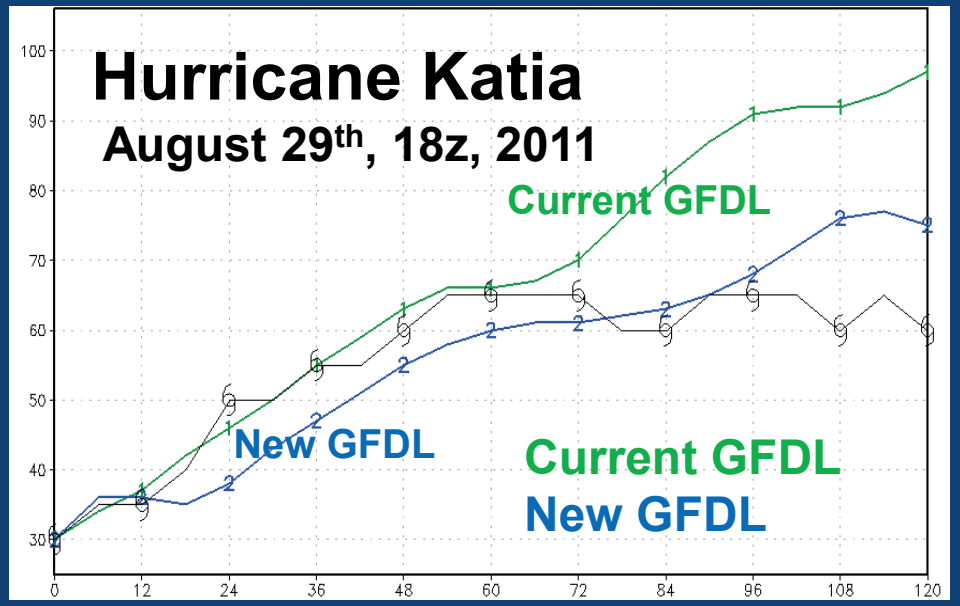


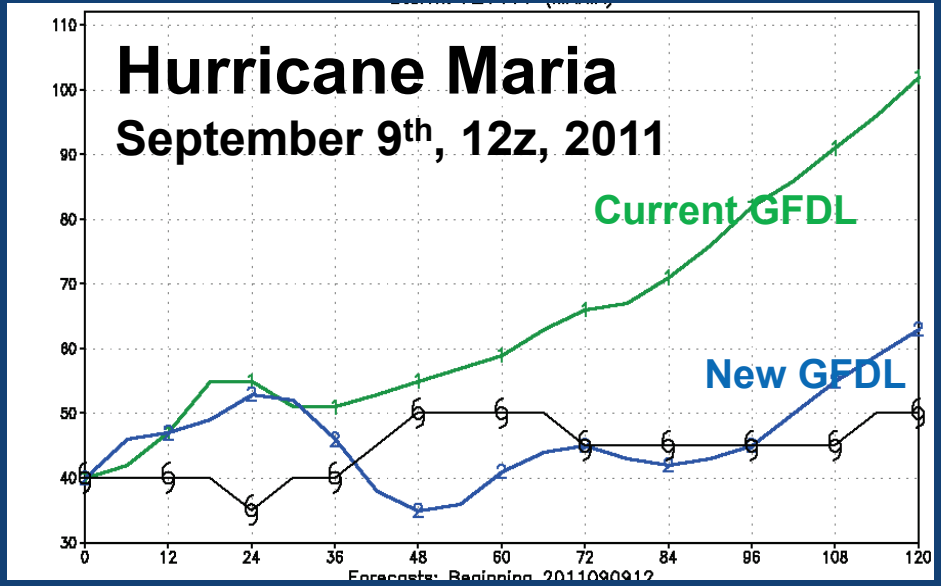
Reduced Intensity Bias with New GFDL Model

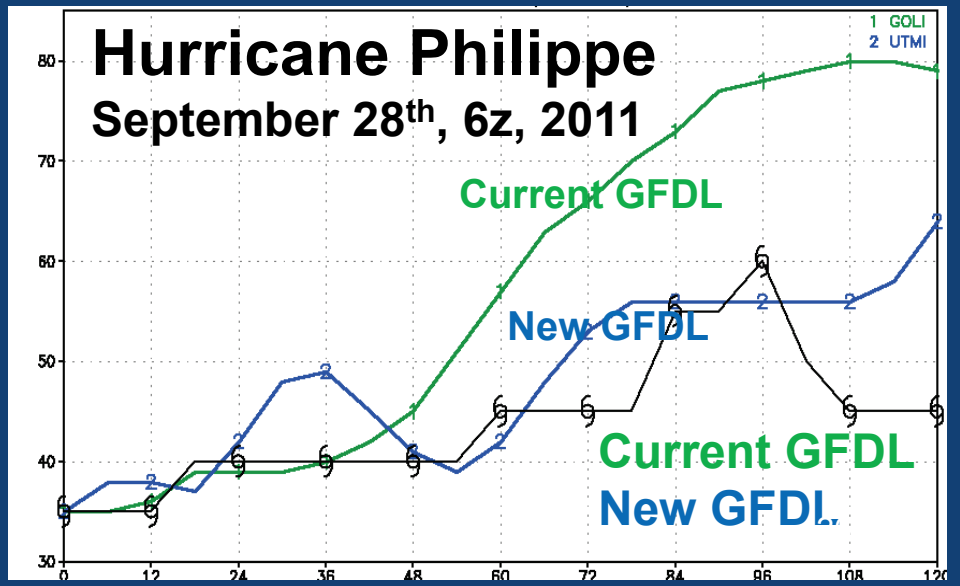


Reduced Over-Intensification Tendency for Weaker Storm Intensity with New Model

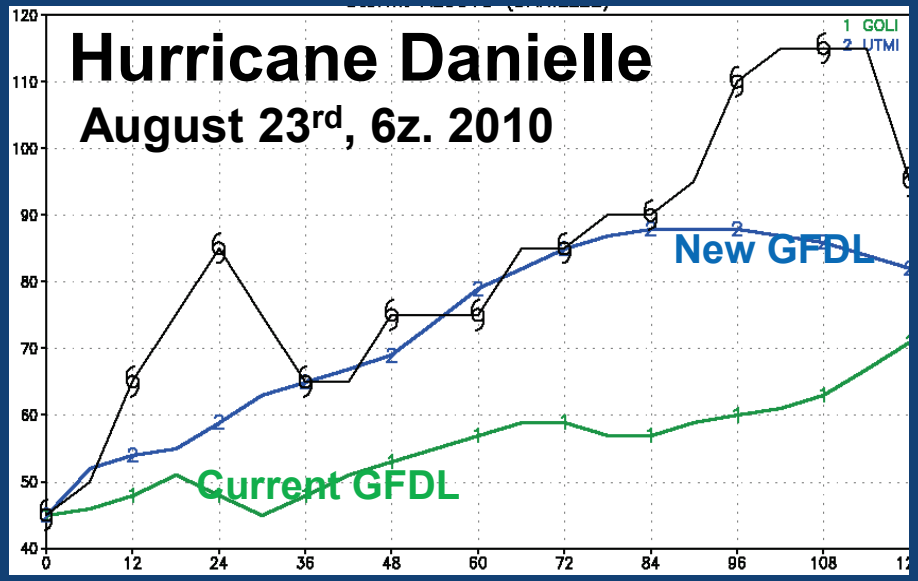


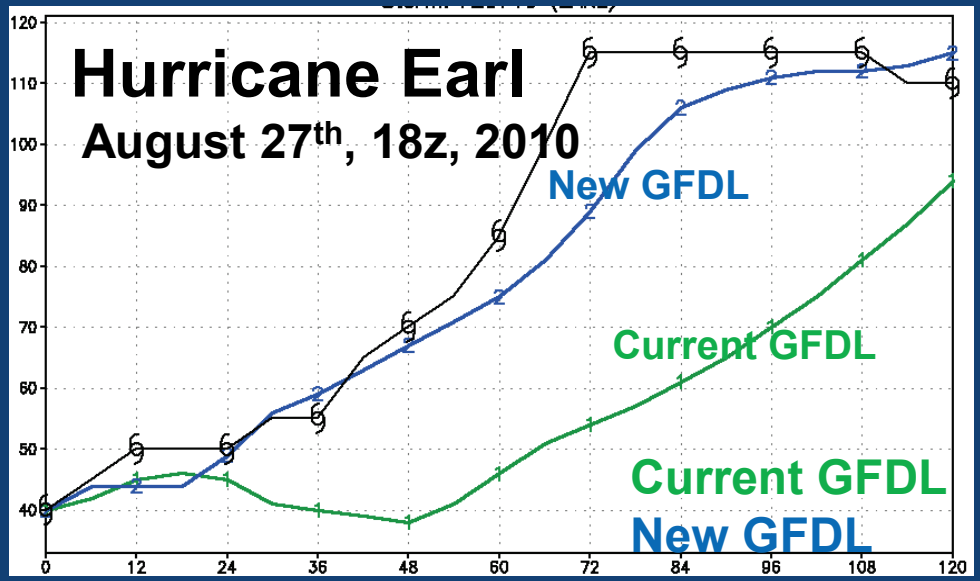


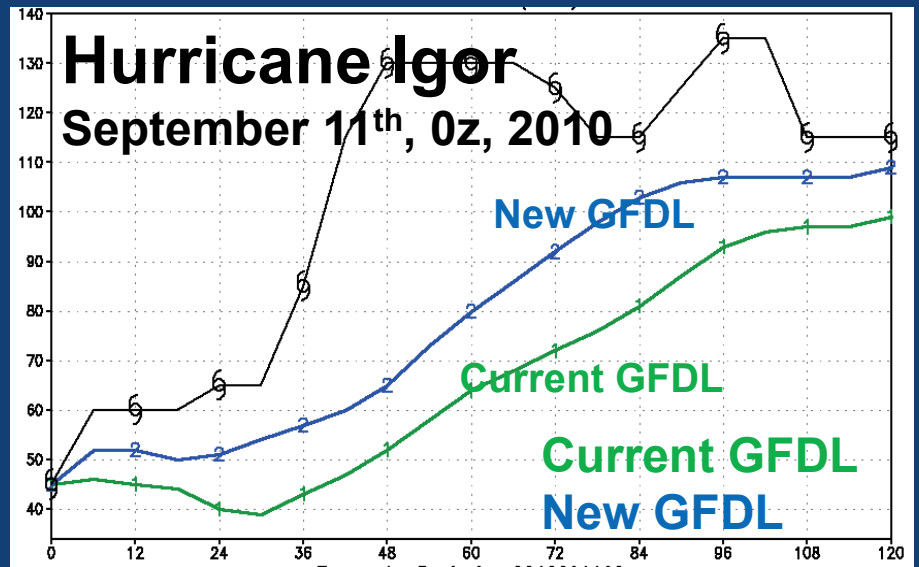


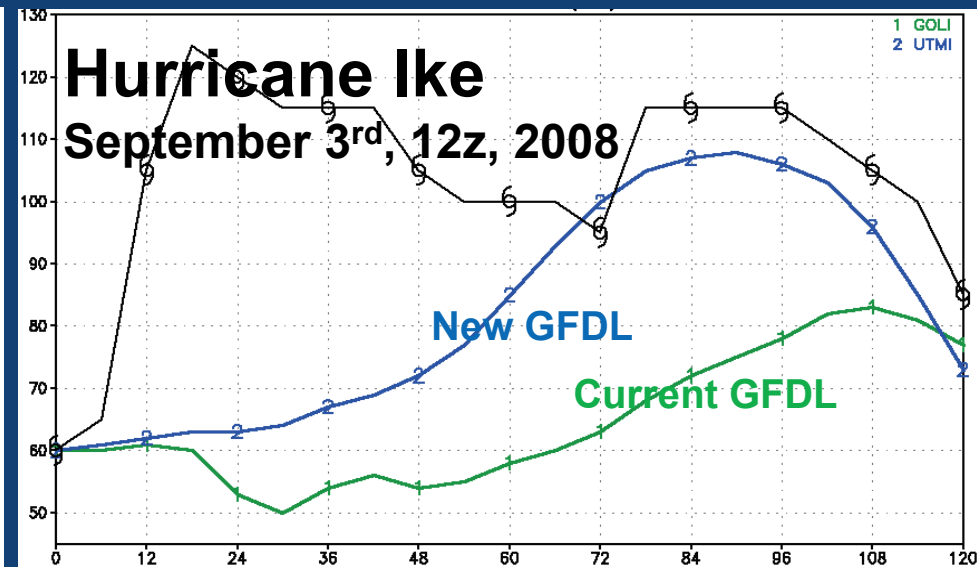


Improved Intensification for Developing Hurricanes with New GFDL Model

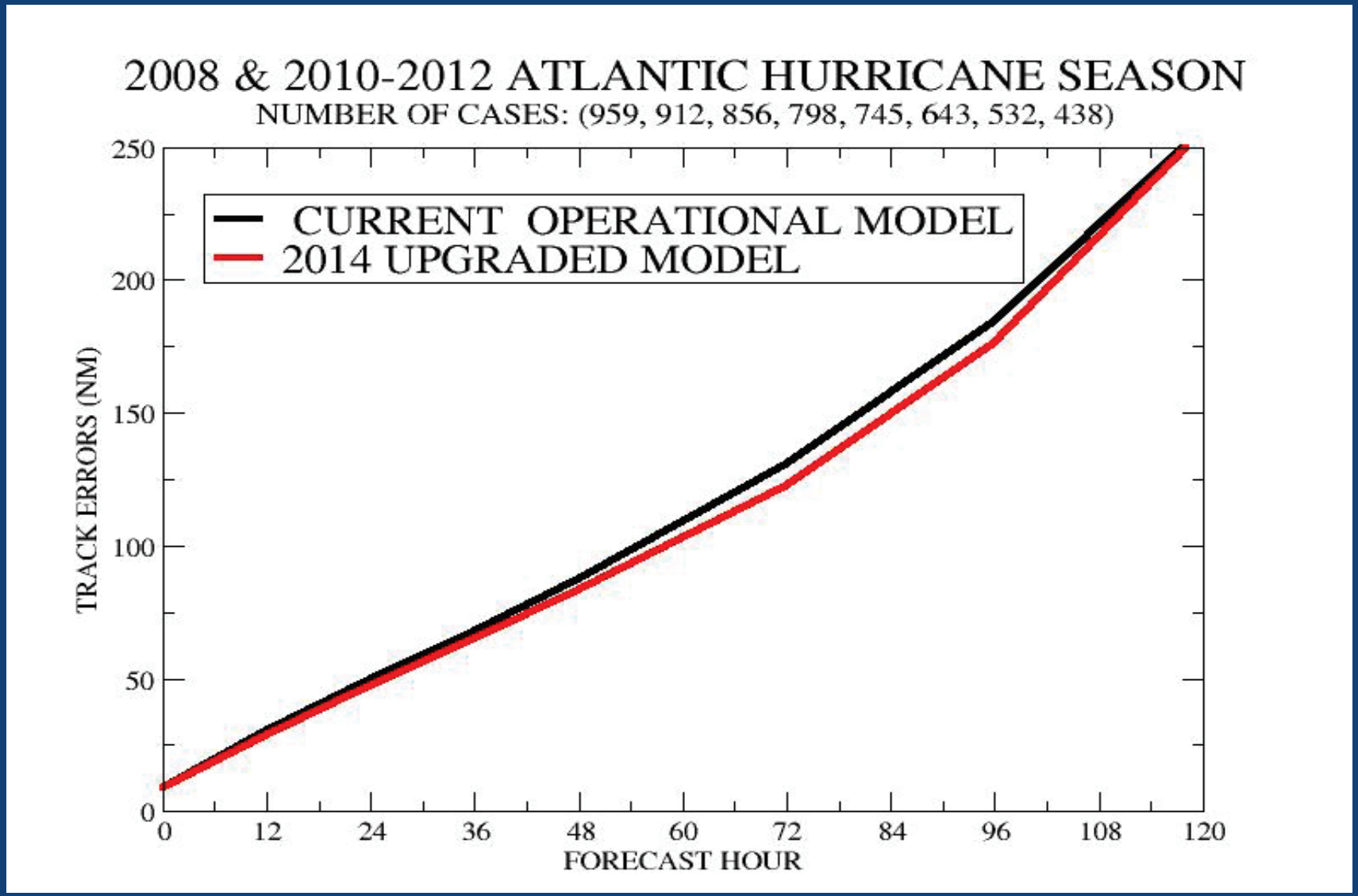




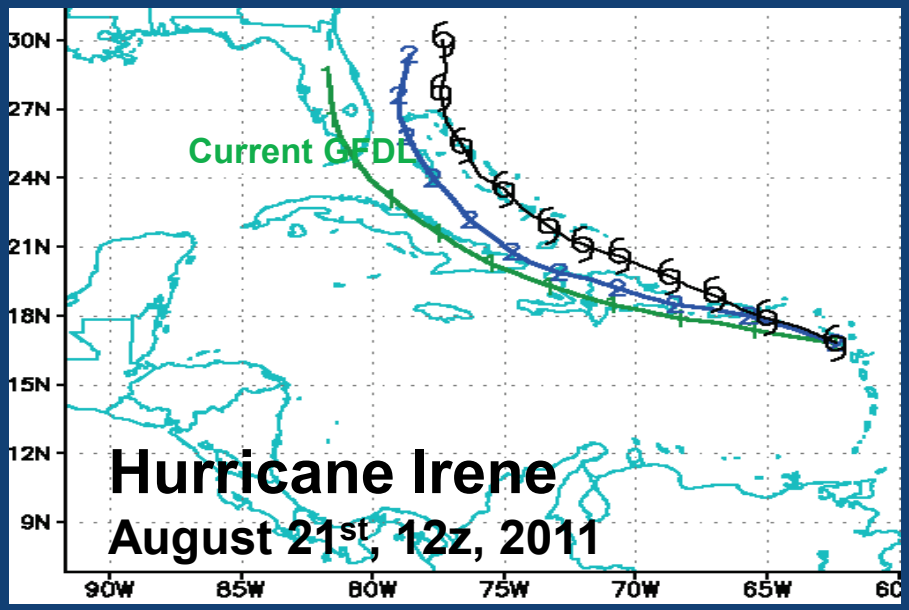


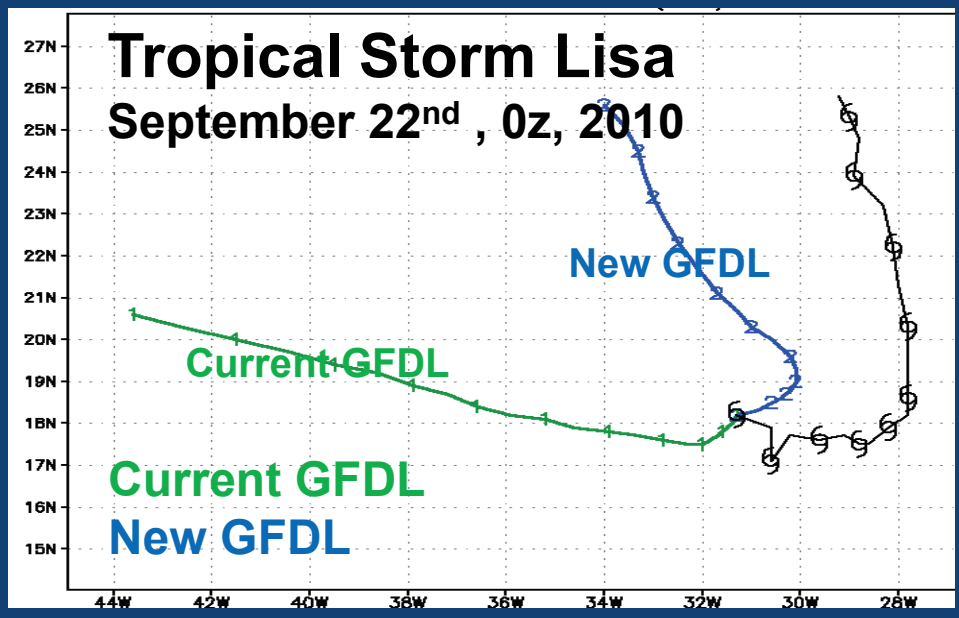


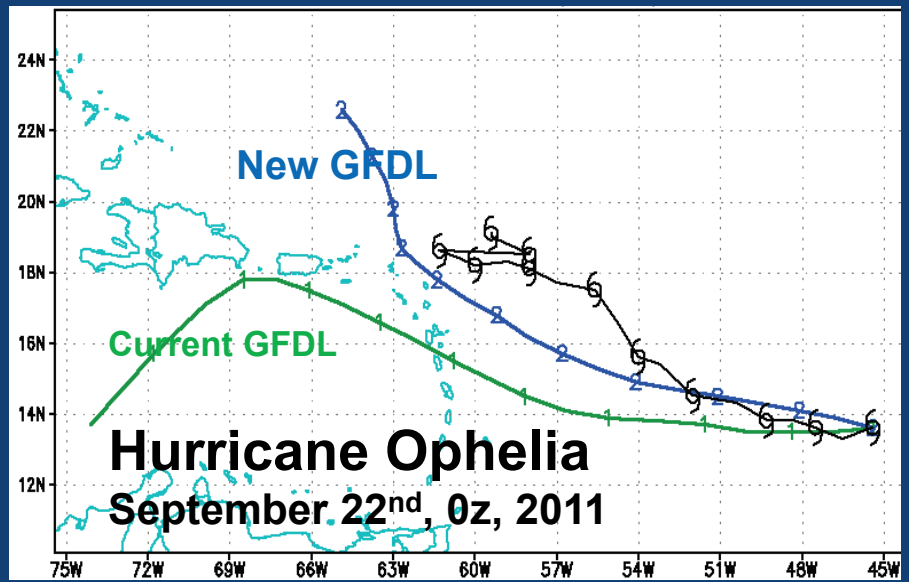
Modest Reduction in Track Errors

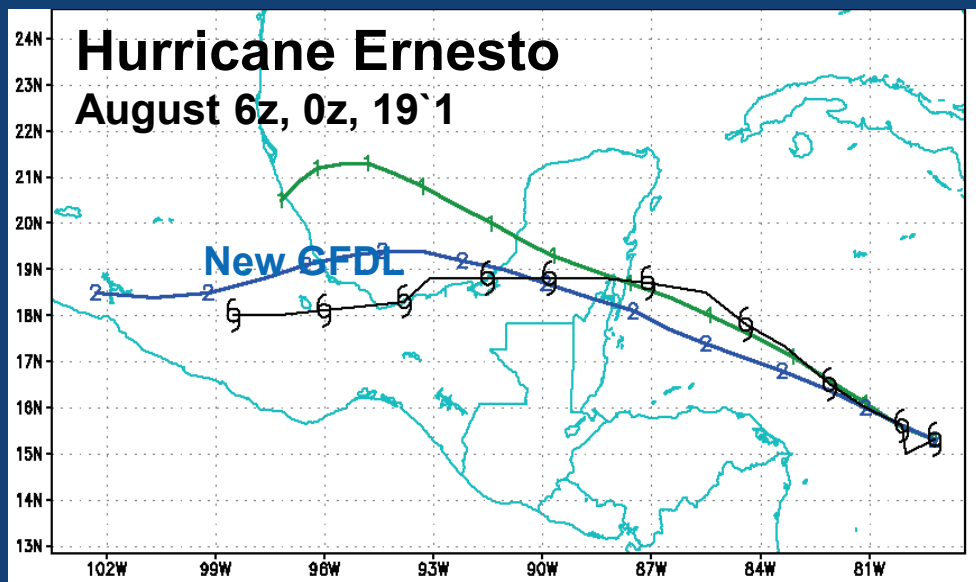


Largest Track Improvement for Developing Systems with New GFDL

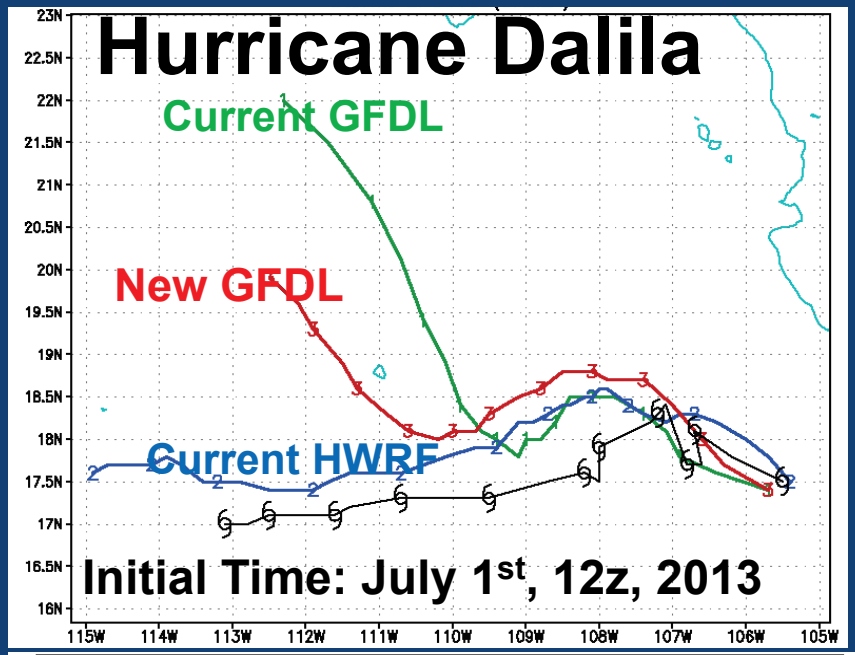


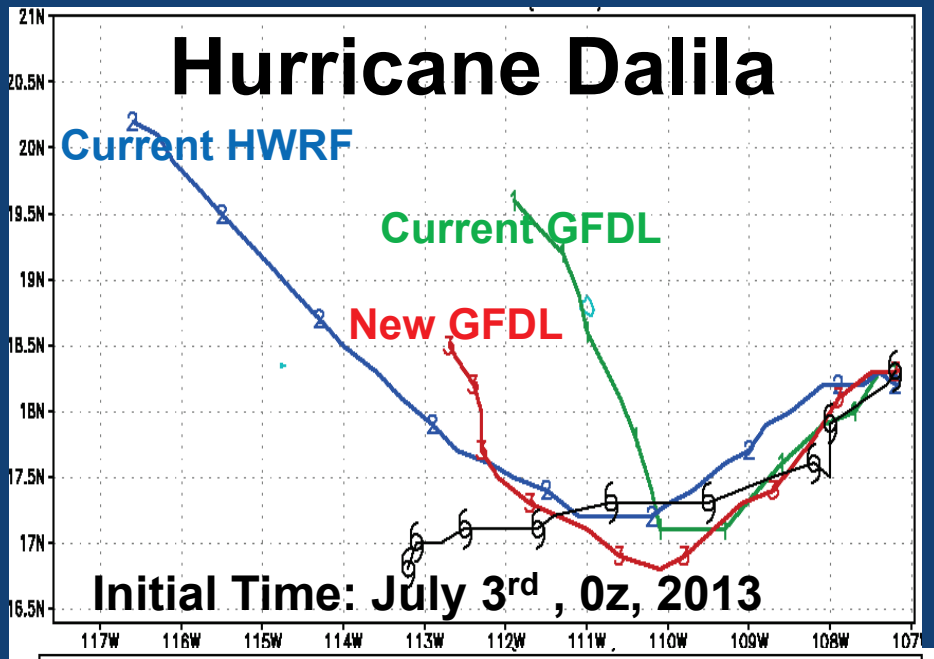


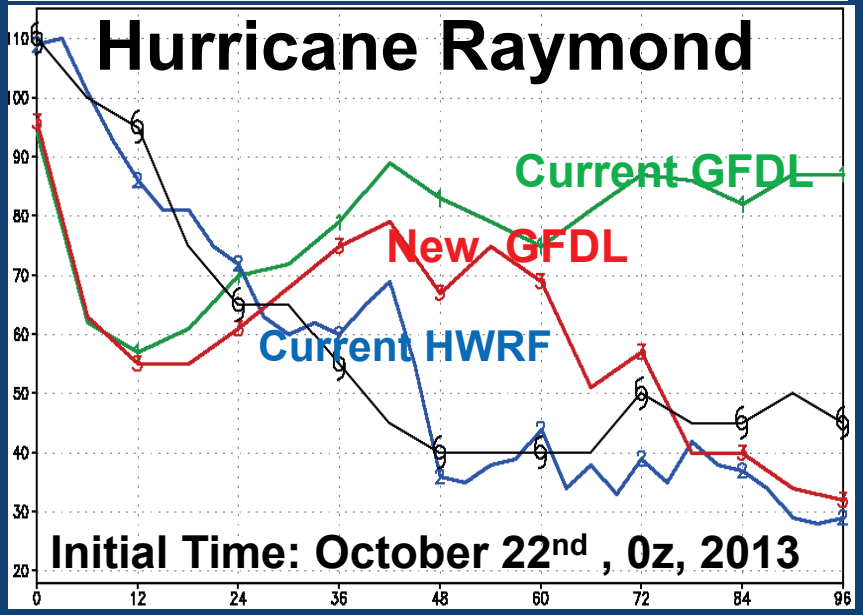


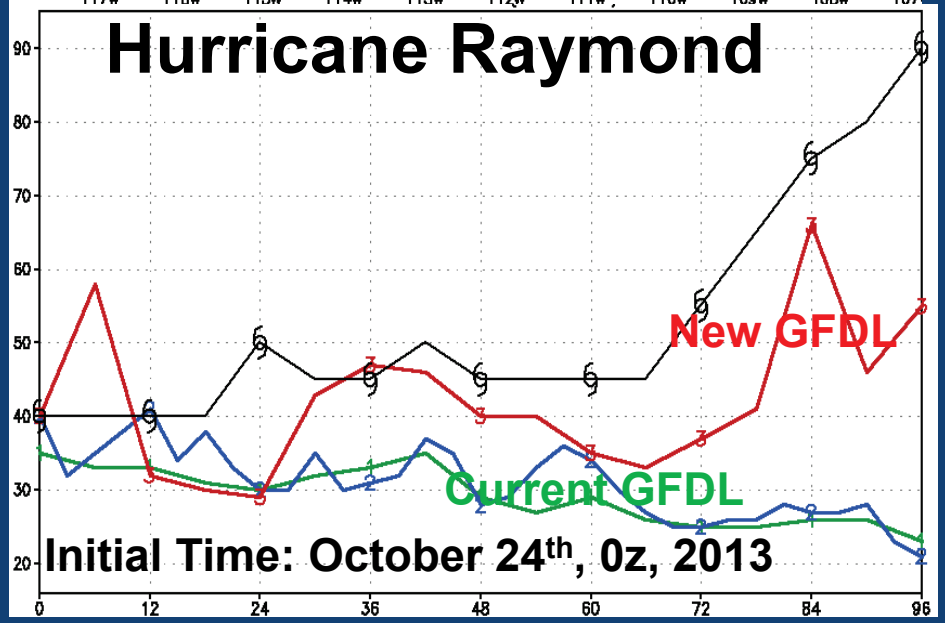


Preliminary Eastern Pacific Results









Real-time and pre-implementation T&E HWRF products:

http://www.emc.ncep.noaa.gov/gc_wmb/vxt/index.html

Thanks for your attention

Questions?

Acknowledgements:

HWRF team at EMC

EMC and HFIP Management

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