Performance of the 2013 Operational HWRF

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HFIP Annual Review Meeting, February 19, 2014

Outline

- Performance of current operational HWRF for 2013 season
- HFIP supportedd Special Projects and Real-Time Parallel HWRF Experiments
- Performance of HWRF in the North Western Pacific and North Indian Ocean basins
- Evolution of HWRF as a unique tropical cyclone model for all tropical oceanic basins

Priorities for 2013 HWRF Upgrades

Known Issues:

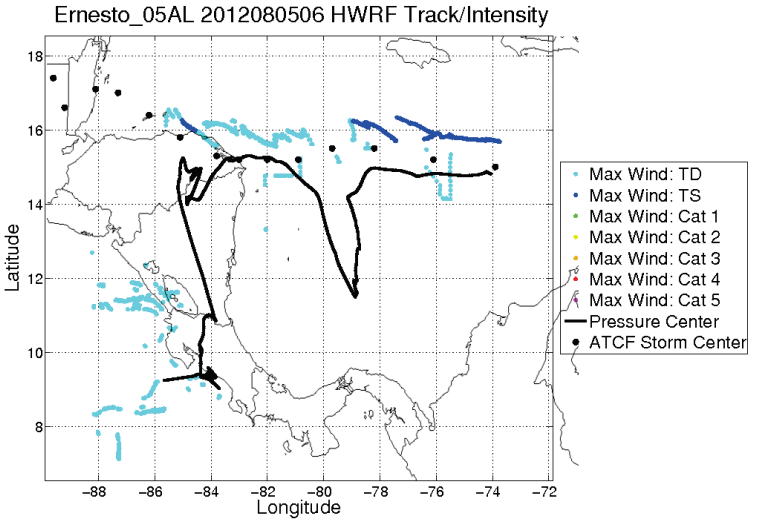
- Nest size, movement, feedback and domain discontinuities
- physics time steps too large
- Weaker storms continue to pose difficulty
- Convection scheme differences degrade synthetic satellite products, PBL height evaluation indicated problems over land

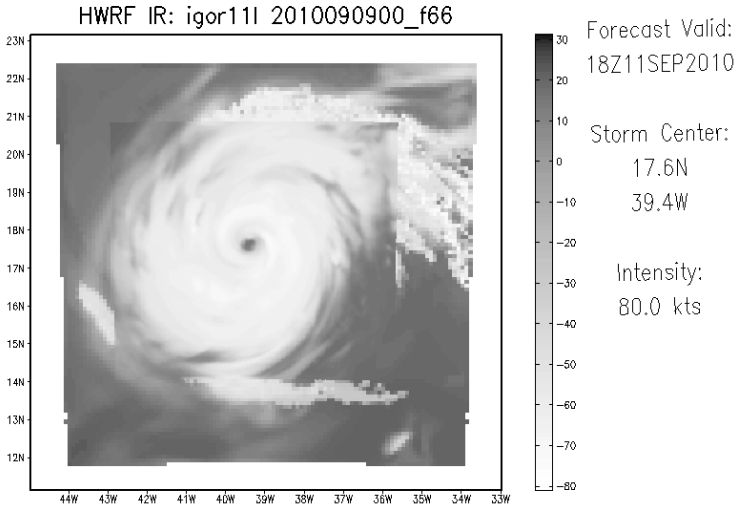
Implementation Plan:

- Address nest size, movement and nest-parent interpolation issues; increase frequency of physics calls
- Modify vortex initialization for weaker storms and implement one-way hybrid EnKF-3DVAR DA, include inner-core NOAA P3 TDR data when available
- Test and evaluate various physics upgrades (PBL, Convection and Radiation)
- Conduct 3-season testing

Goals (addressing NHC's Wish List for 2013):

- **Increase intensity forecast skill by 20% without degrading track skill and improve quality of products**



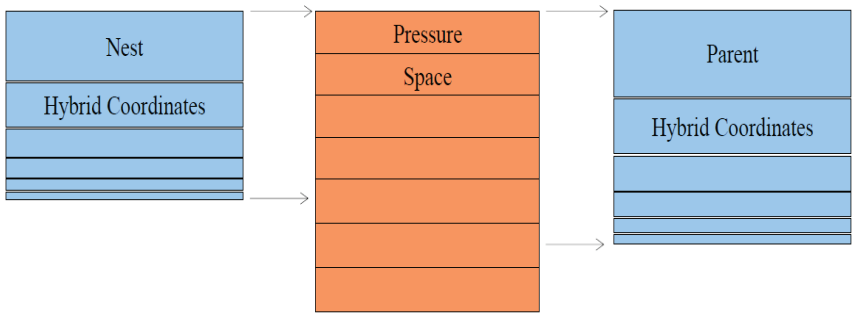


2013 HWRF pre-implementation Test Plan

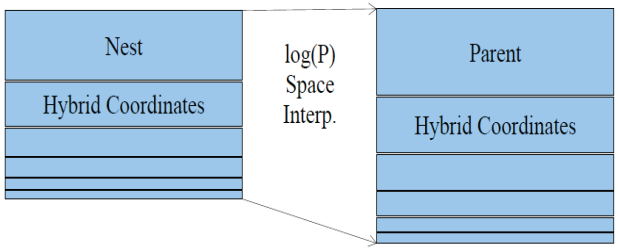
EXP	Description	Comments	Platform/# of cases
Pre-Baseline Experiments			
TDRP	FY12 HWRF + One-Way Hybrid GSI + TDR DA when available	Real-time demo during 2012 season	CCS, All 2012 ATL and EP, 821 cases
HDFL	FY12 HWRF + Flux truncation into POM	DTC's contribution for R2O innovation	Jet, All 2012 ATL 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 + New nest movement algorithm	Revised nest-parent interpolations and improved treatment of variables at nest boundaries. Improved nest tracking based on membrane MSLP and Tim's tracker.	Jet, All 2012 ATL and EP and 6 others from 2010-11; 988 cases
HHPC	FY12 HWRF + High Frequency Physics Calls	Increased Physics calling frequency from 180 sec. to 30 sec. Third nest size increased by about 30% from	Jet, A few selected storms from 2012
Baseline Experiment			
H130	All modifications from pre-baseline experiments	2013 HWRF baseline is based on positive outcome from the pre-baseline experiments described above.	Jet/Zeus/WCOSS, All 2010-2011-2012 1870 cases
Physics Upgrades			
H131 (Final)	H130 + PBL changes	HWRF PBL to include variable critical Richardson number	Jet, All 2010-12, 1870 cases

Systematic T&E of about 10 different configurations, more than 15000 simulations from 80 storms of 2010, 2011 and 2012 hurricane seasons on CCS/Jet, Zeus and WCOSS, thanks to support from HFIP PO for Jet usage, and from NCO for usage on CCS/WCOSS. Results from these experiments are on HWRF website: http://www.emc.ncep.noaa.gov/gc_wmb/vxt/baseline.

New Nest Parent Interpolation Method



New Method: Single Step



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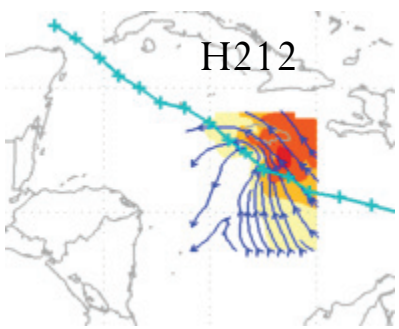
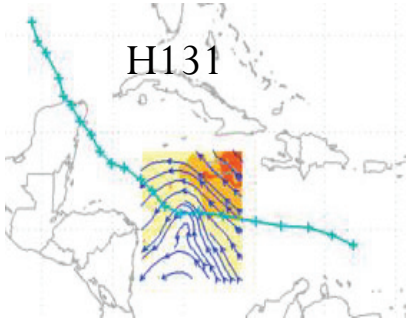
New Nest-Parent Interpolation method in WRF-NMM is computationally advantageous (accurate and faster) and allows us to experiment with more sophisticated microphysics schemes and 100% feedback from nest to parent

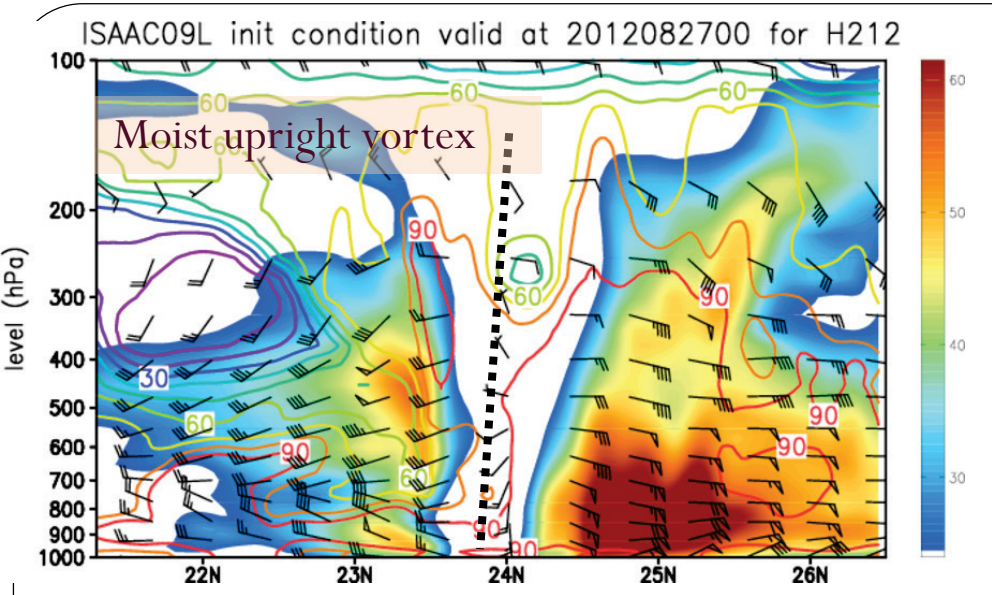


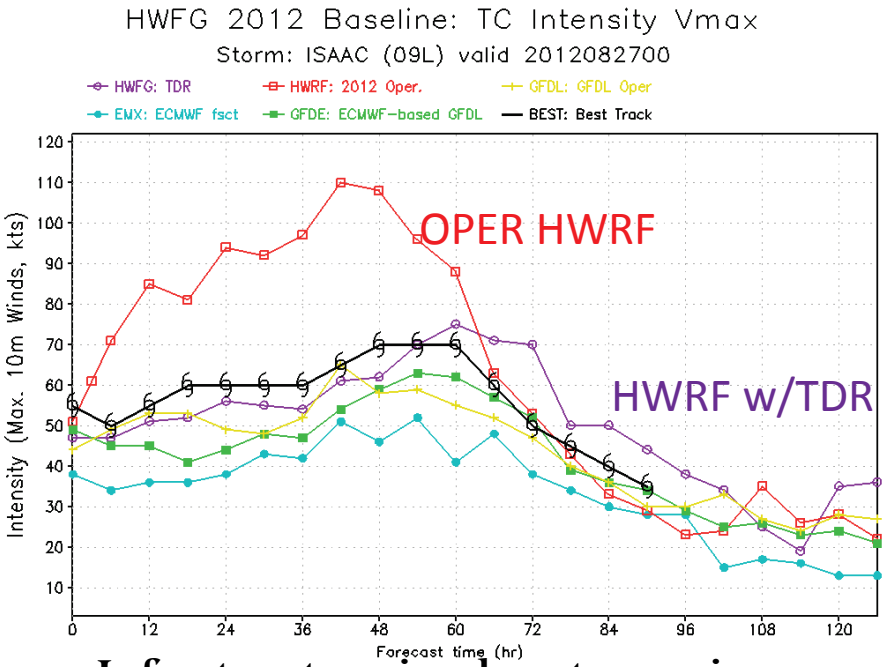


Nest Motion Solution: Nine Field Tracker

- **MSLP or PDYN alone is not enough, Centroid methods have limited value for weak and sheared systems.**
- **Track nine thermodynamic and wind fields and use Membrane MSLP (NCEP tracker) at every nest movement time step (3 min)**
- **rallelized, modified for E grid rotated lat-on**

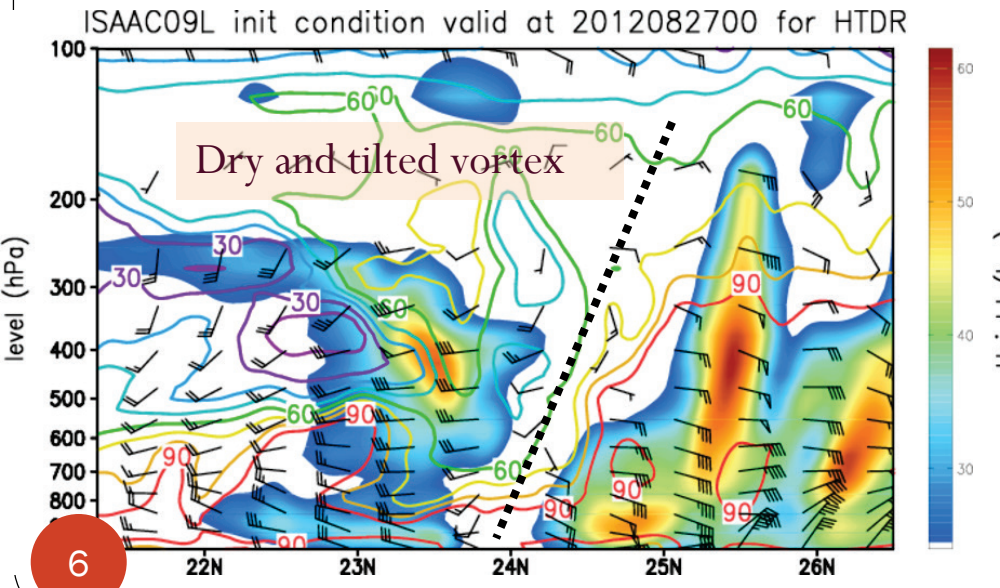
- **Prevent the nest loosing the storm**
- **Have the nest centered over the storm more accurately.**
- **This is a significant improvement over centroid based methods.**

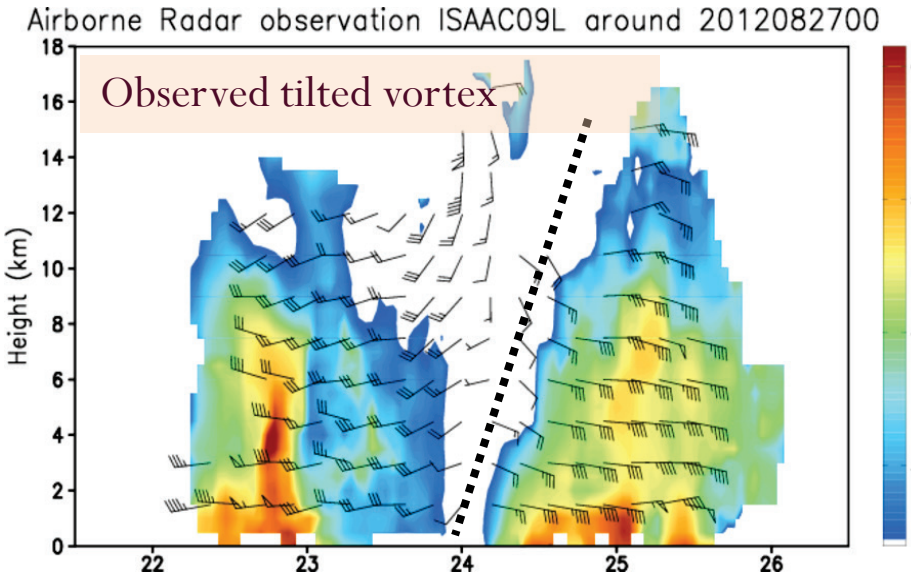




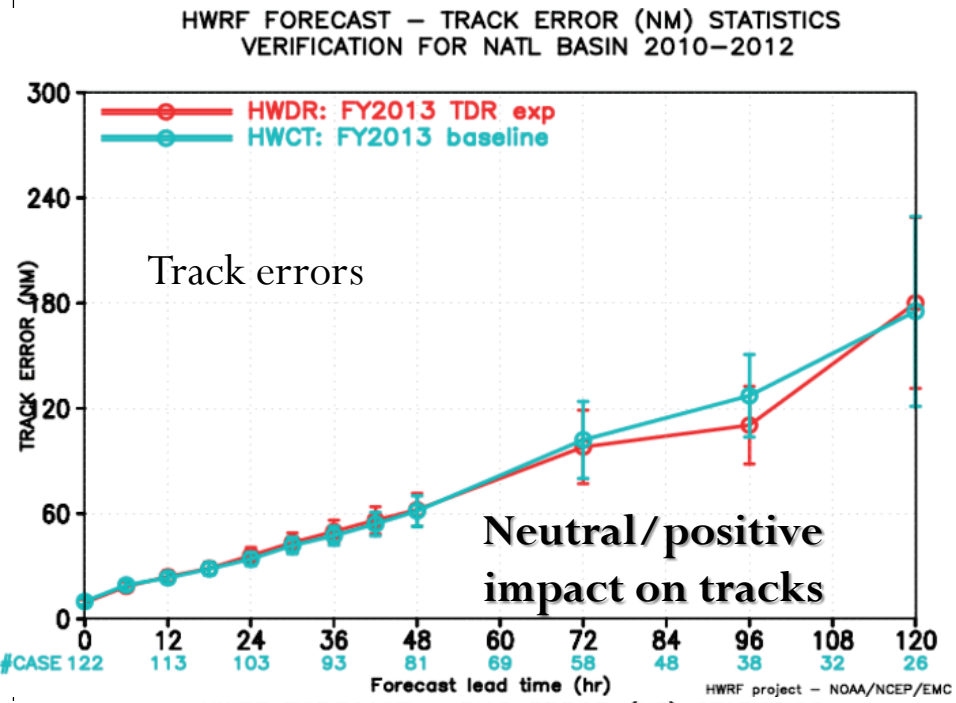
Significant impact of TDR Data Assimilation on Initial Vortex Structure

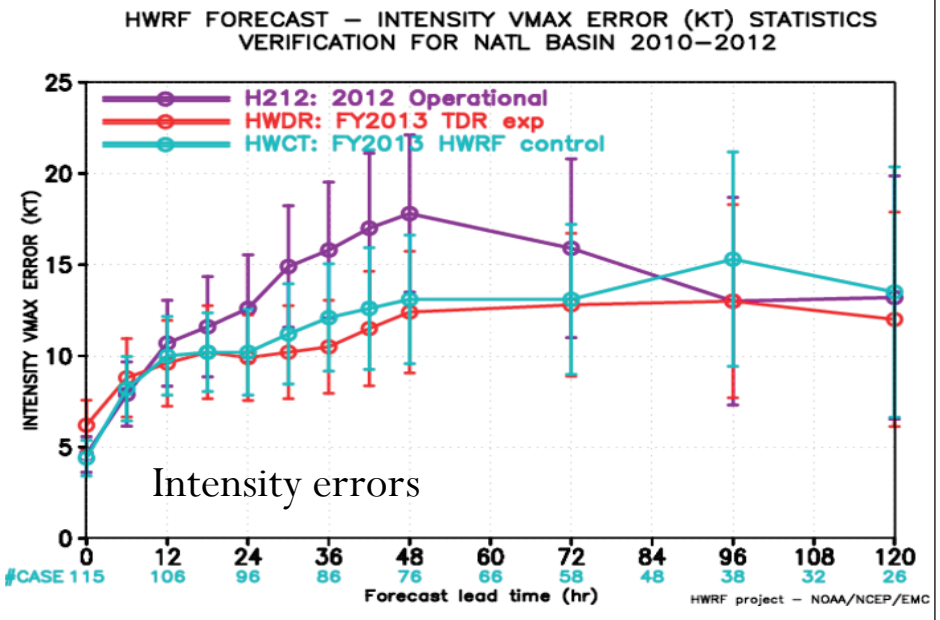
Infrastructure in place to receive NOAA P3 TDR data in real-time

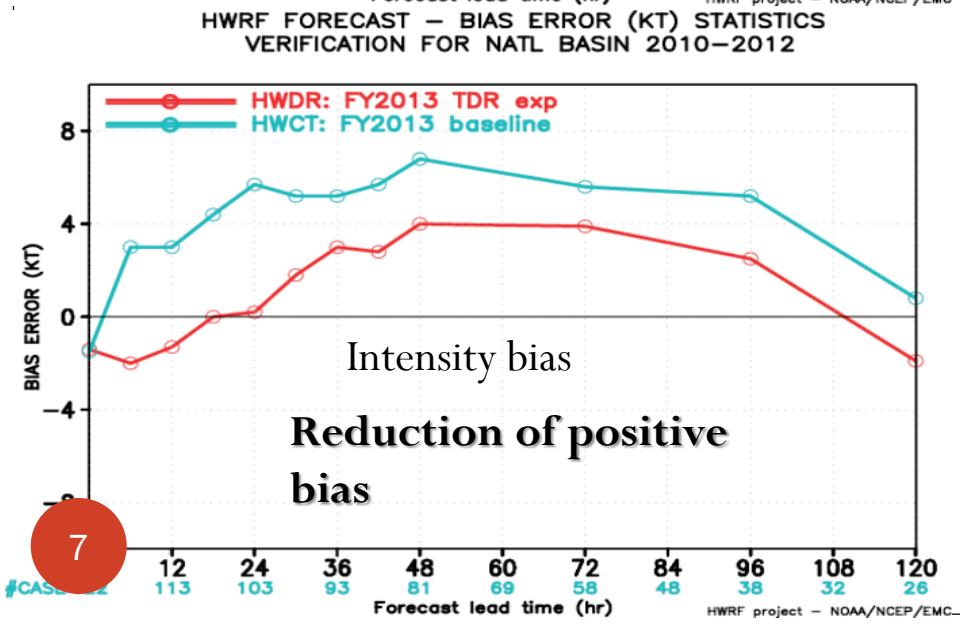




Results from TDR DA Experiments (2010-2012)





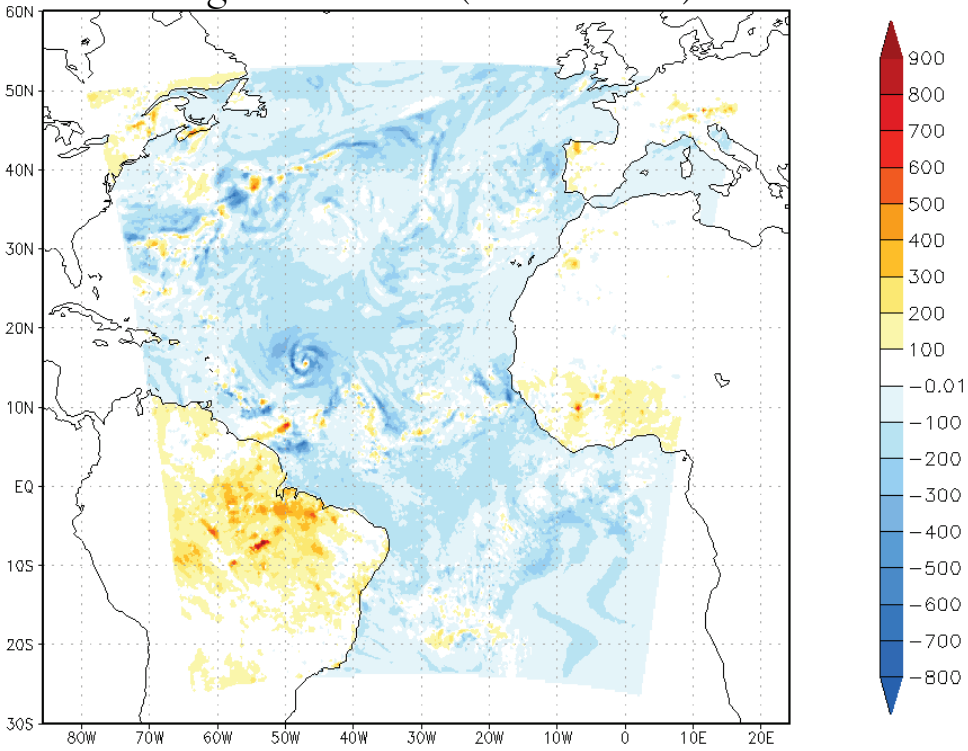


Intensity forecasts with TDR data assimilation showed about 30-40% improvement over 2012 HWRF, 10-15% over 2013 HWRF Control (includes direct and indirect impacts due to vortex cycling)

Enhancements to HWRF/GFS PBL Scheme with variable Ric

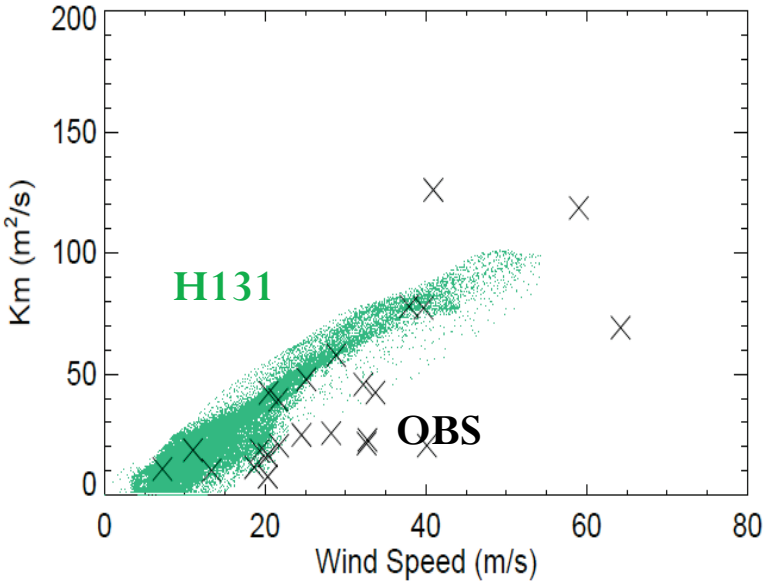
Hurricane Katia (20110829018+96hr)

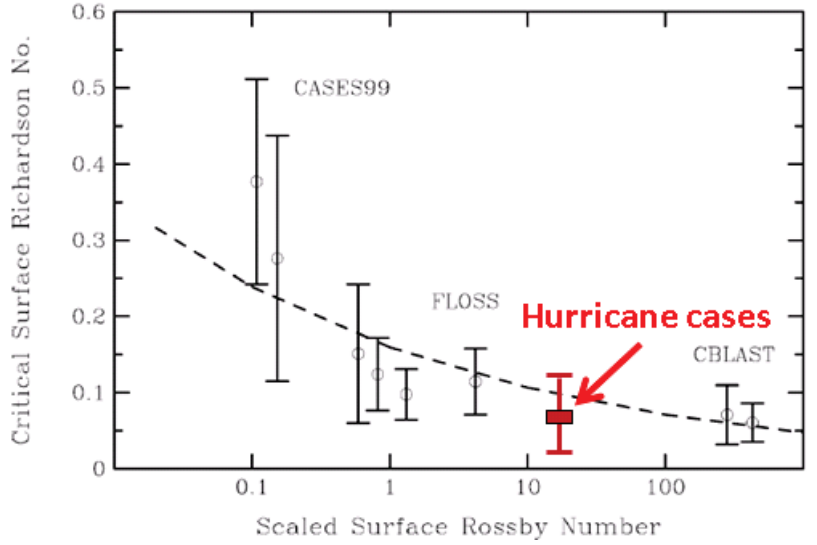
PBL height difference (H131-H212)



PBL height over the ocean and hurricane area becomes shallower while that over land area becomes deeper

Vertical Diffusivity K_m

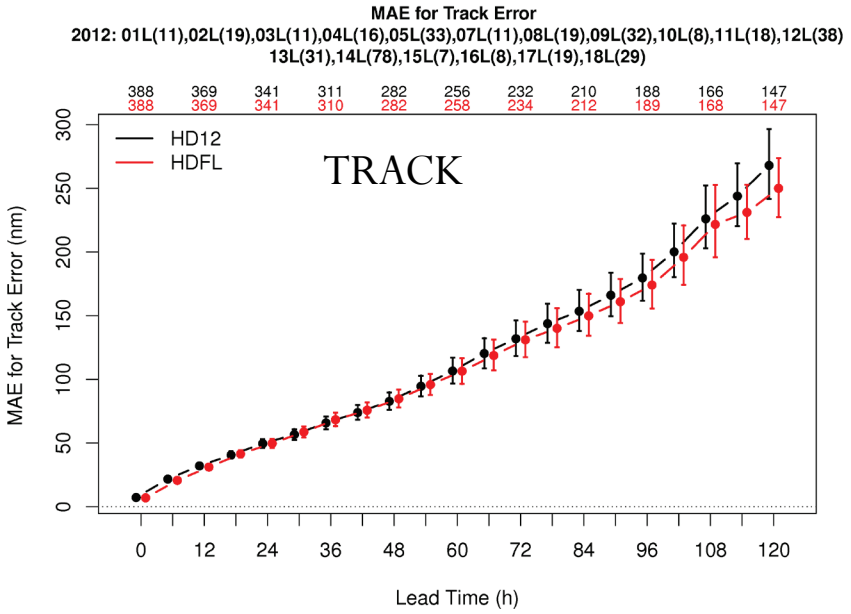


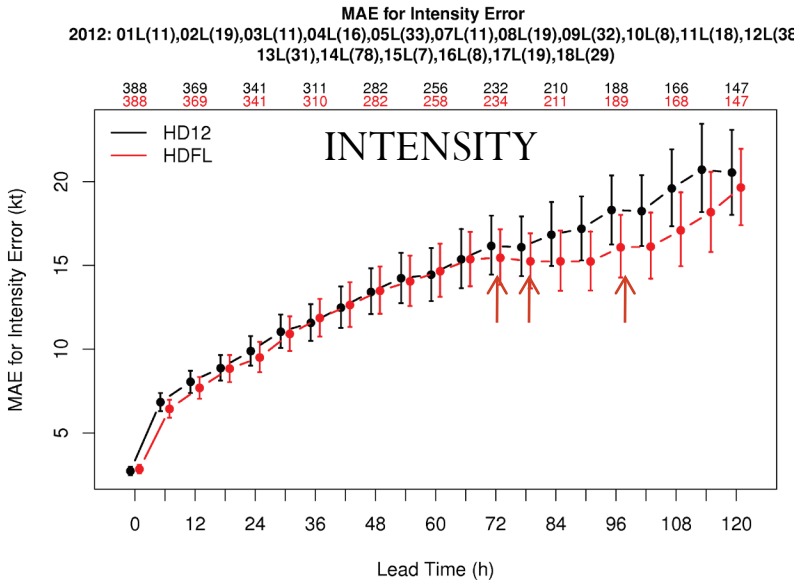


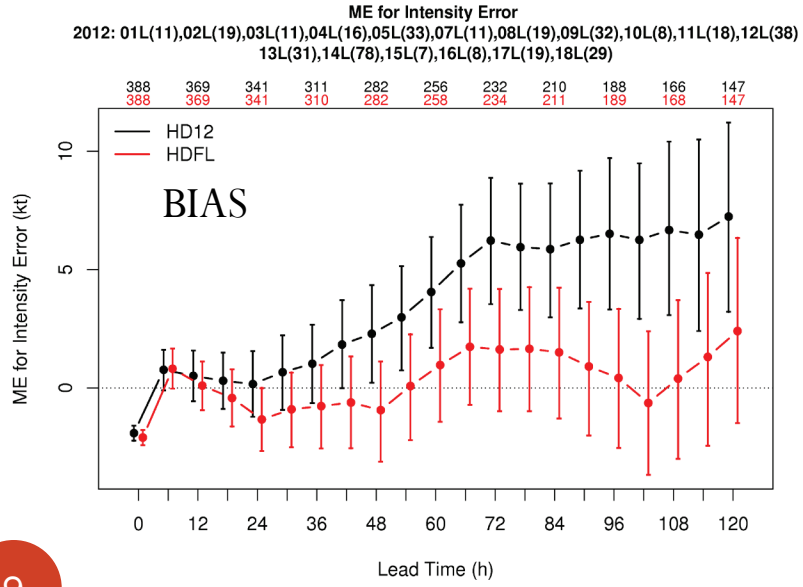
$$R_{ic} = 0.16(10^{-7}\frac{U_{10}}{fz_o})^{-0.18}$$

kers & Mahrt, 2003)

Ocean upgrades: Removal of heat & momentum flux truncation







- Remove artificial truncation of surface fluxes sent to the ocean
- Overall the impact of the change in fluxes seem beneficial.
- This is DTC's contribution to R2O for 2013 HWRF upgrades.

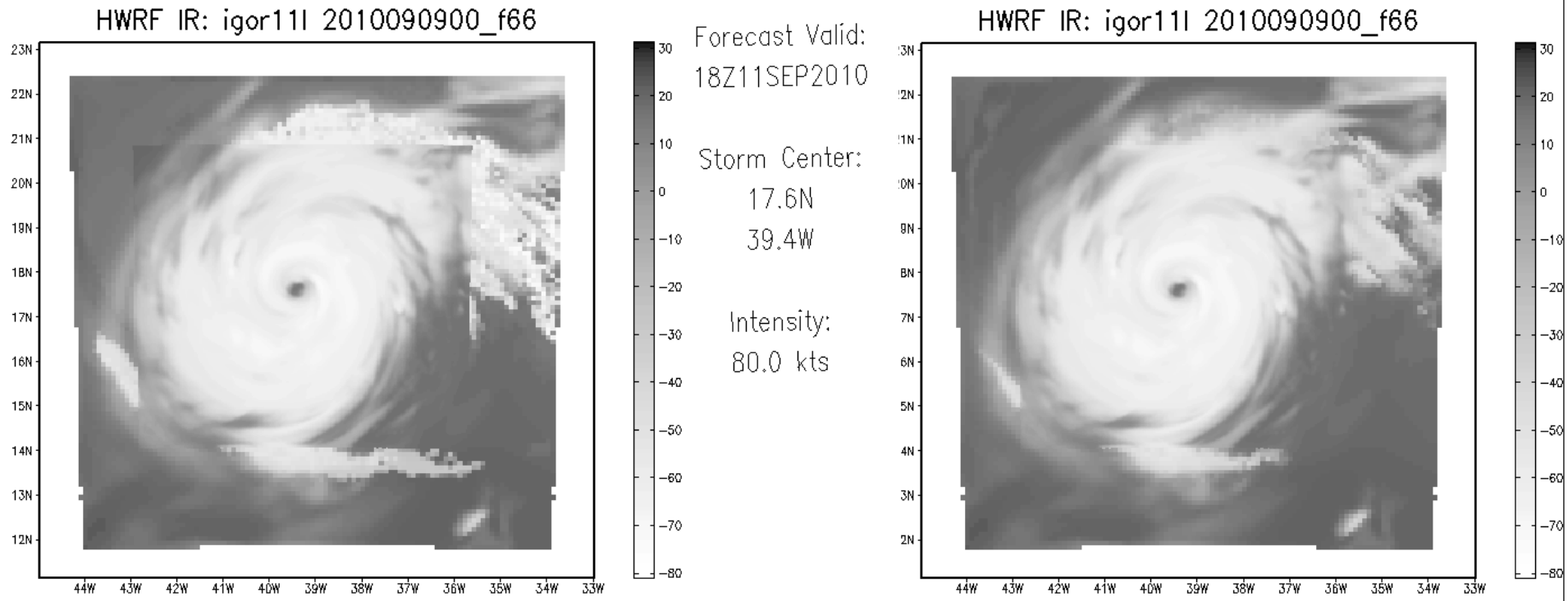
Courtesy: Ligia Bernardet, DTC

Product Enhancements: Synthetic Satellite Geostationary Imagery

H212

H131

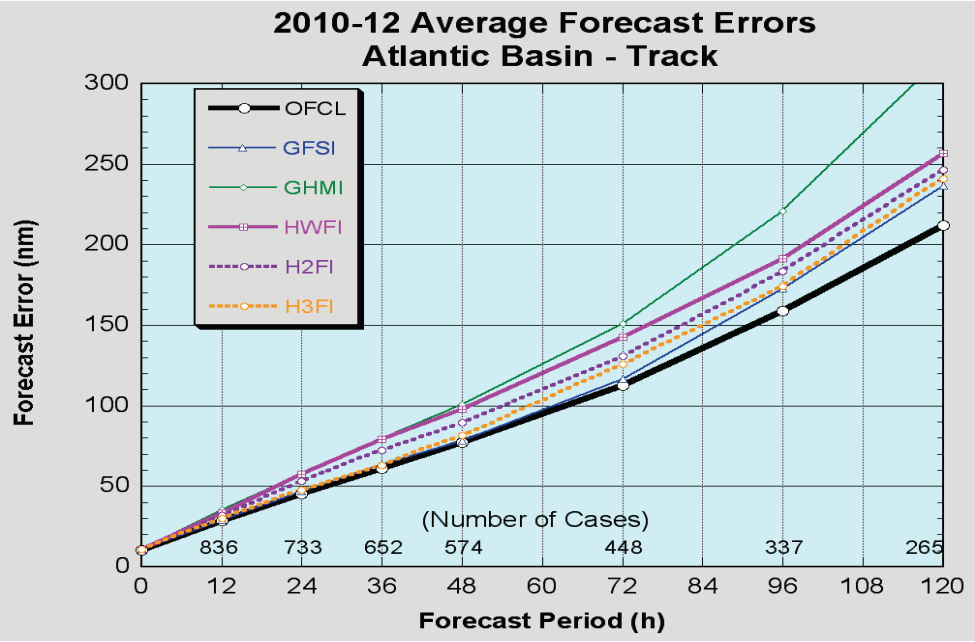
IGOR 11L 2010090900 F66, Domain 2+3

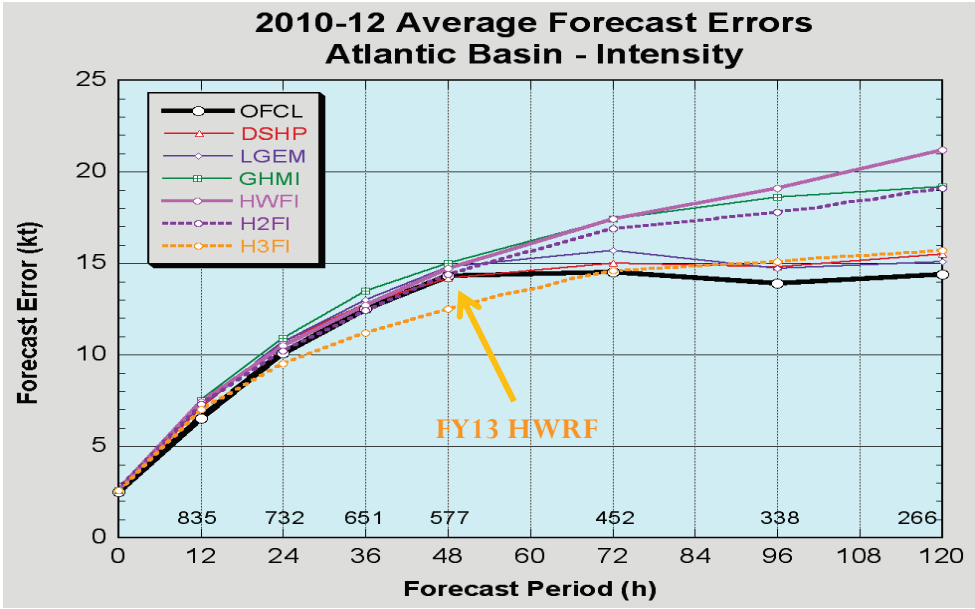


Significant reduction in domain discontinuities

Courtesy: Dave Zelinsky, NHC

Retrospective performance of FY2013 High-Resolution Triple-Nested HWRF





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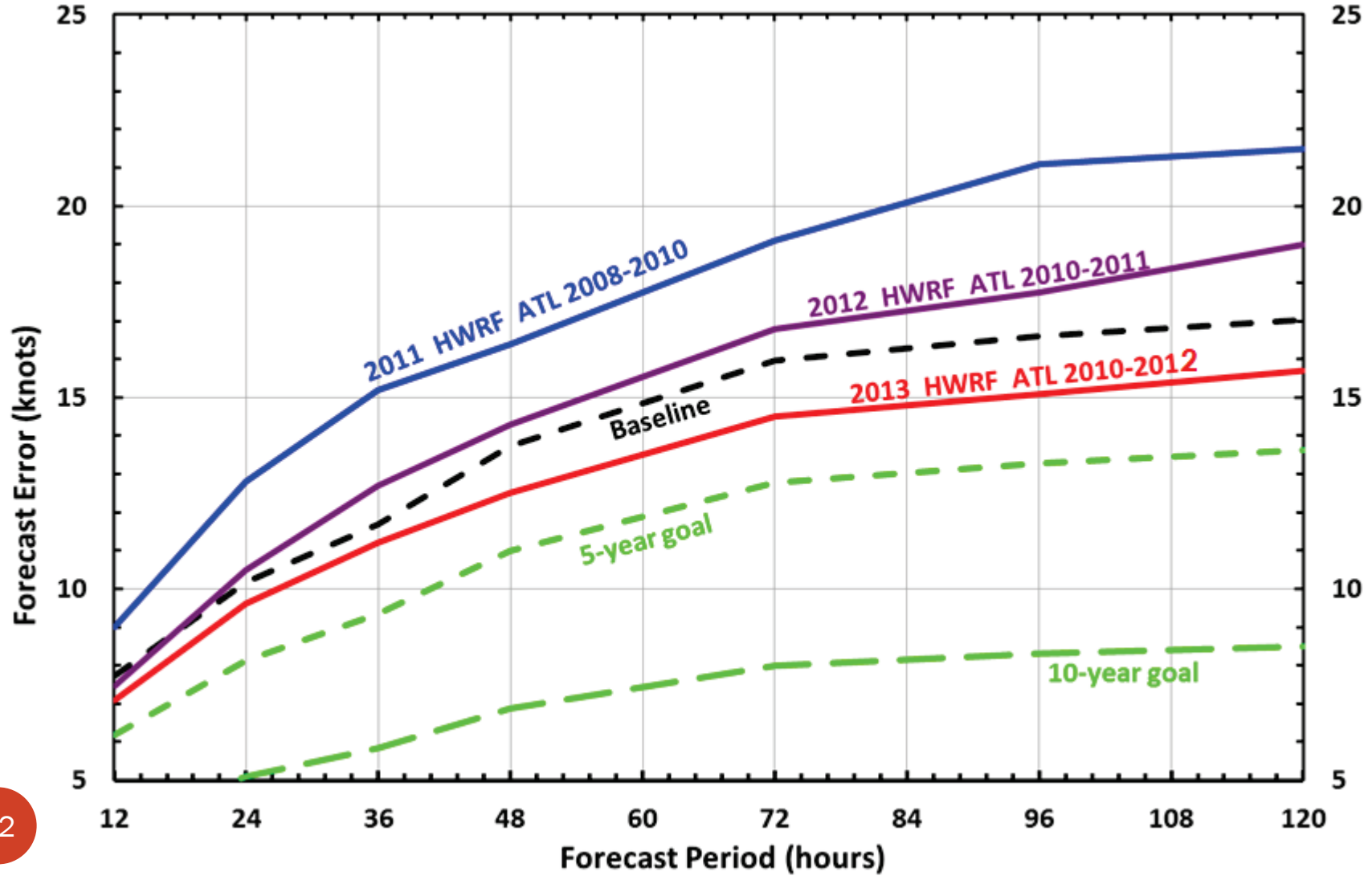
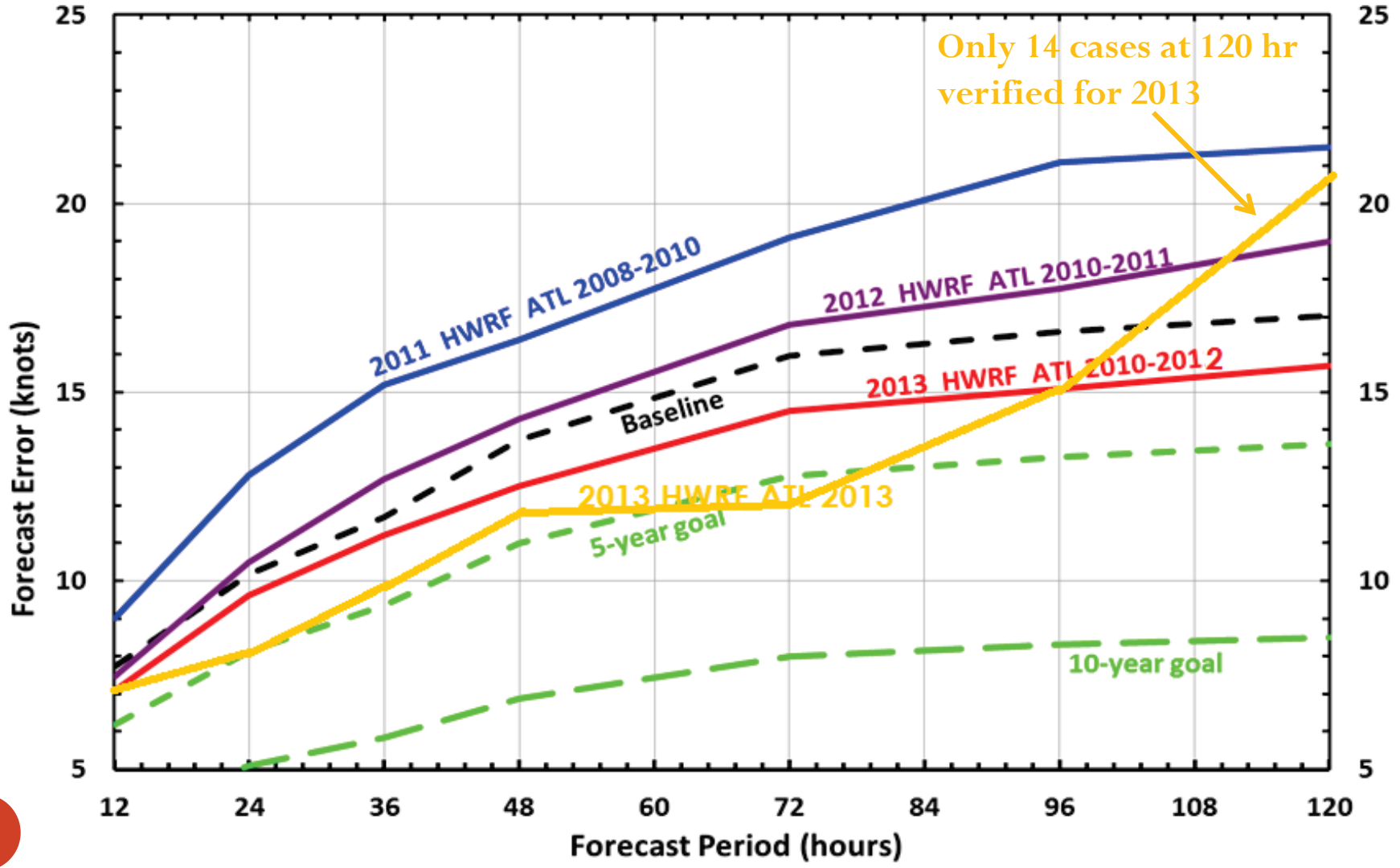
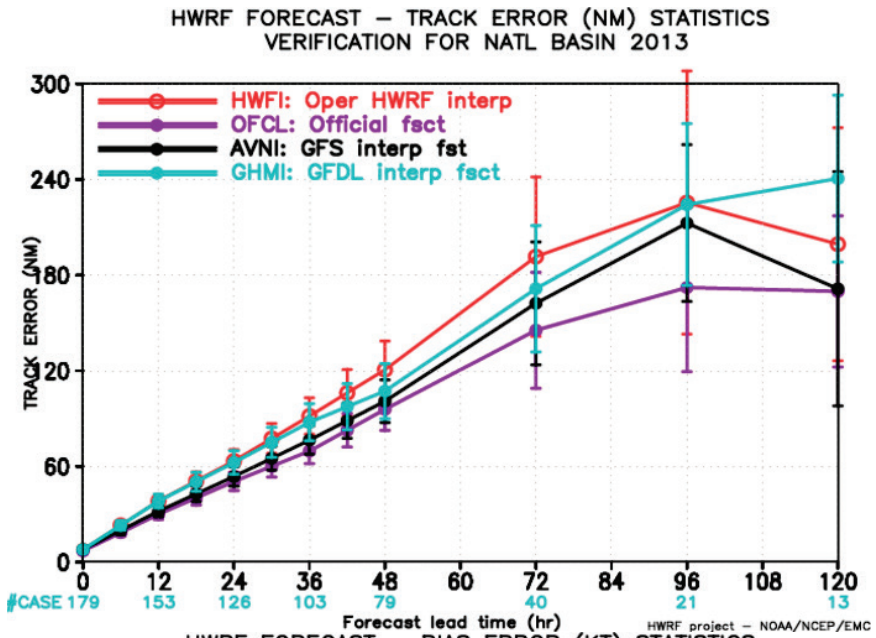
HWRF Intensity ATL Basin: Cumulative Forecast Improvements (Retrospective performance)

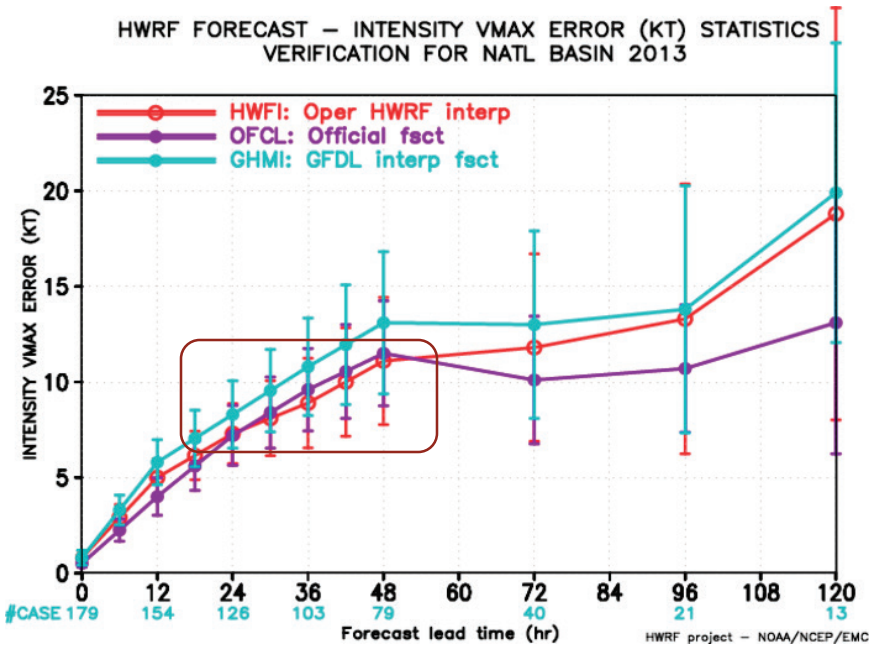


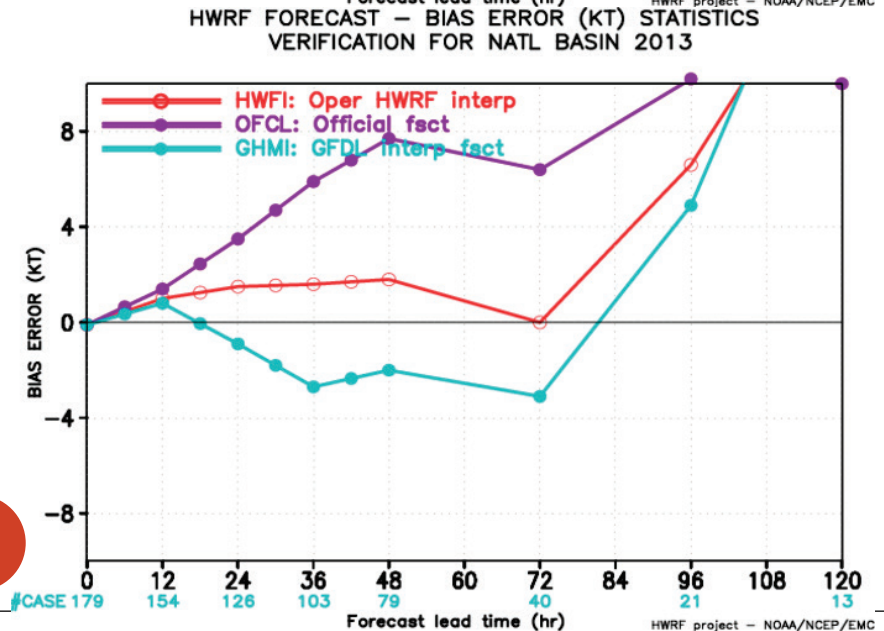
HWRF Intensity ATL Basin: Cumulative Forecast Improvements (Real-Time Performance)



2013 North Atlantic early model verification



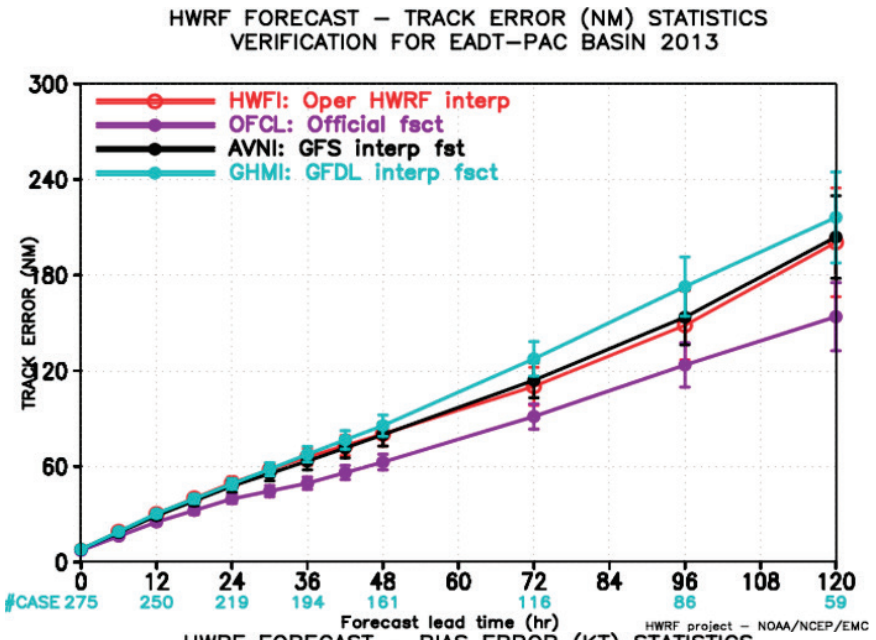


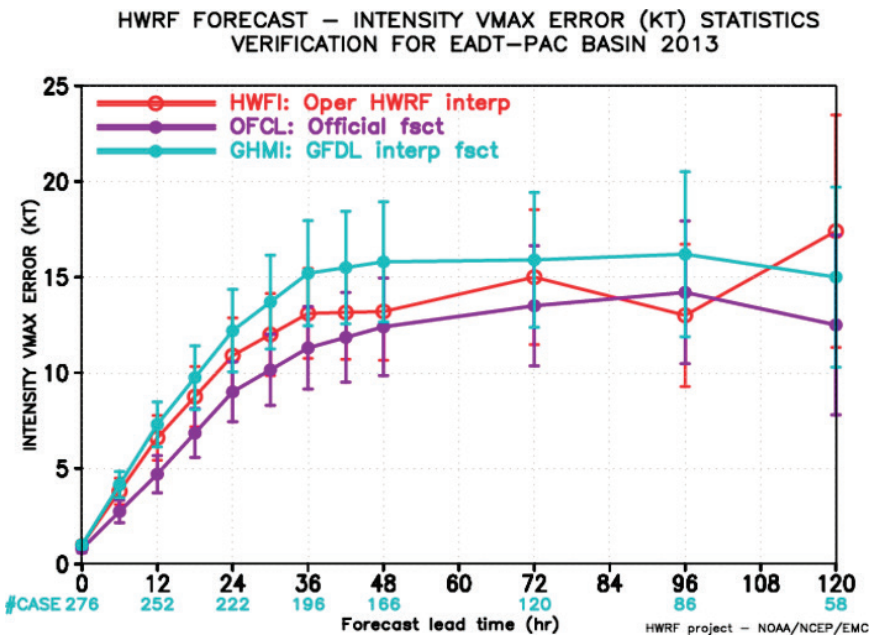


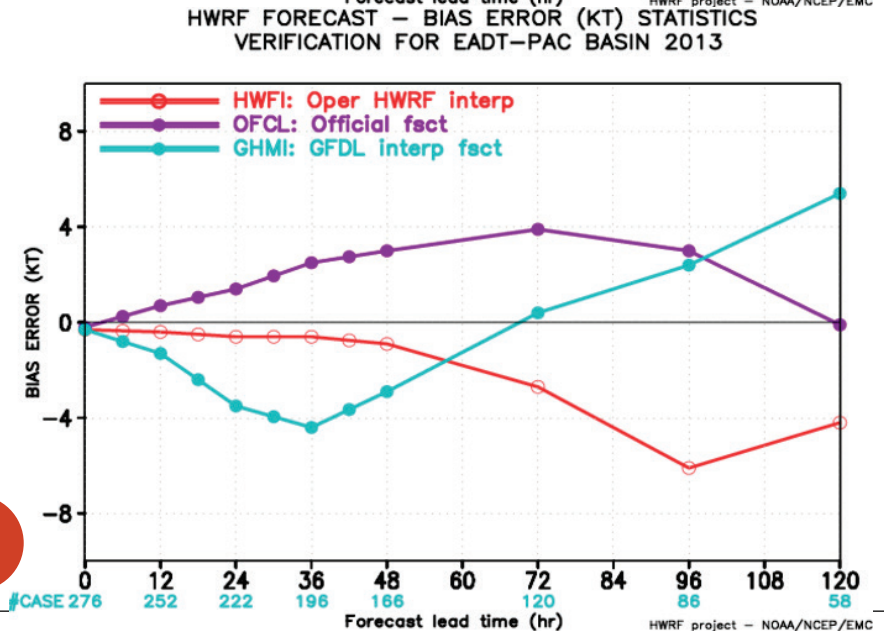
Intensity bias and errors from operational HWRF showed similar improvements noted in the retrospective evaluation. Neutral intensity bias through 72-hr lead time.

Season dominated by short lived and weaker storms.

2013 East Pacific early model verification



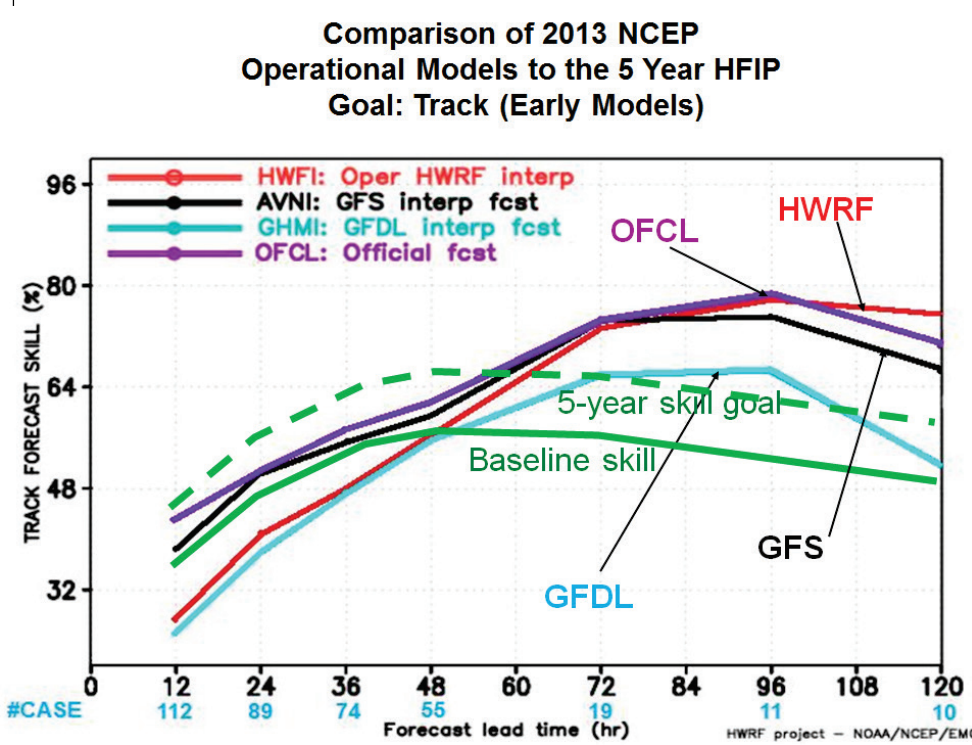


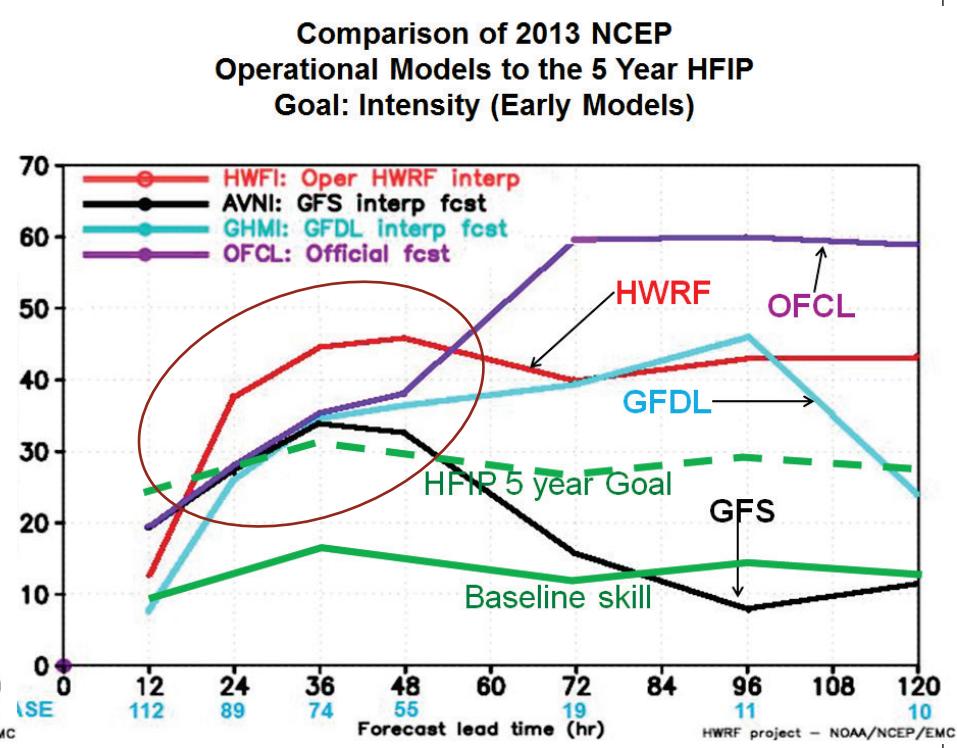


HWRF track and intensity forecasts for the Eastern Pacific basin have shown better skill compared to other NCEP models

Neutral intensity bias through 48-hr lead time, negative bias at later forecast hours.

Performance of NCEP Models for 2013 North Atlantic Basin

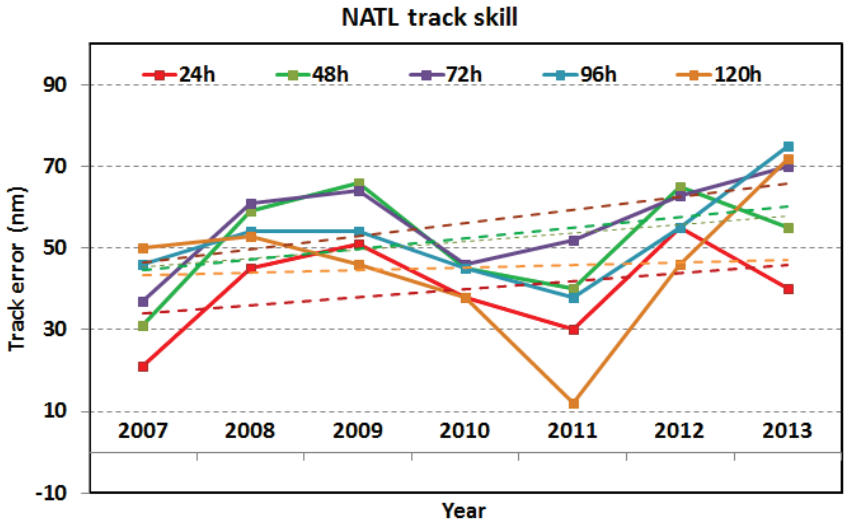




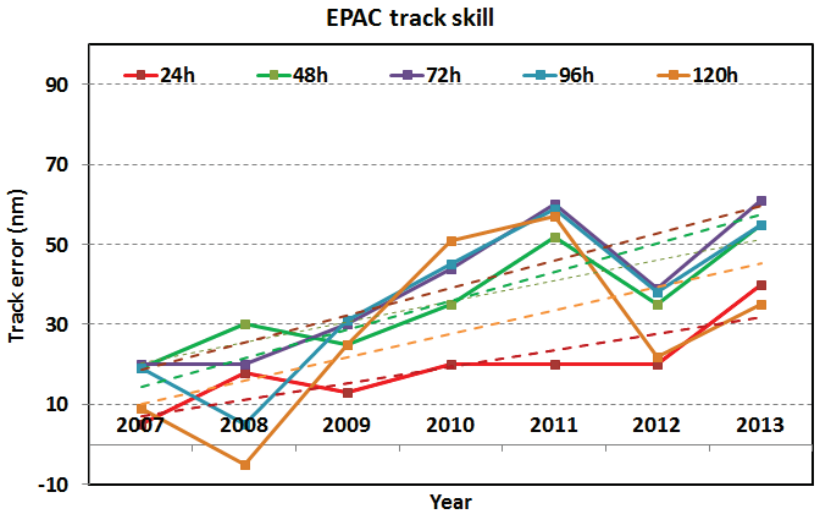
HWRF Model Real-Time Performance for 2013 Atlantic intensity forecasts match the expectations from the pre-implementation T&E

HWRF Forecast Skill Progress & Improvement w.r.t 2012

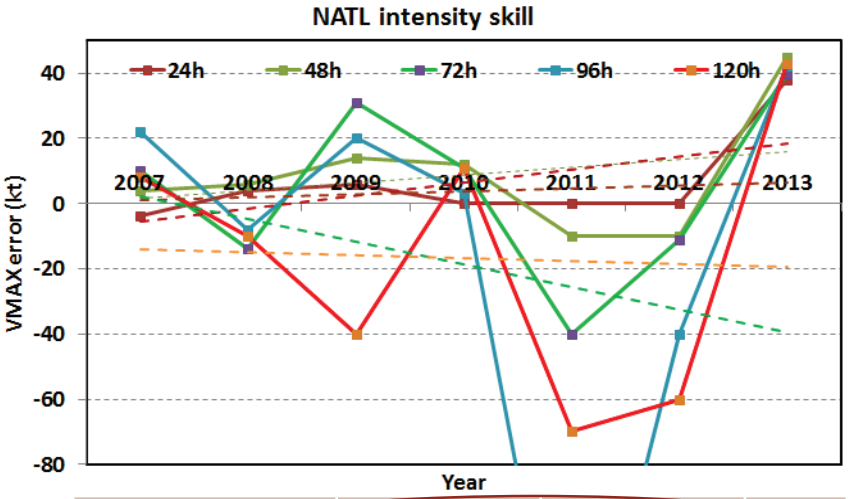
(FY2013 Operational Goals: 10% improvement in track and intensity skill at all times)



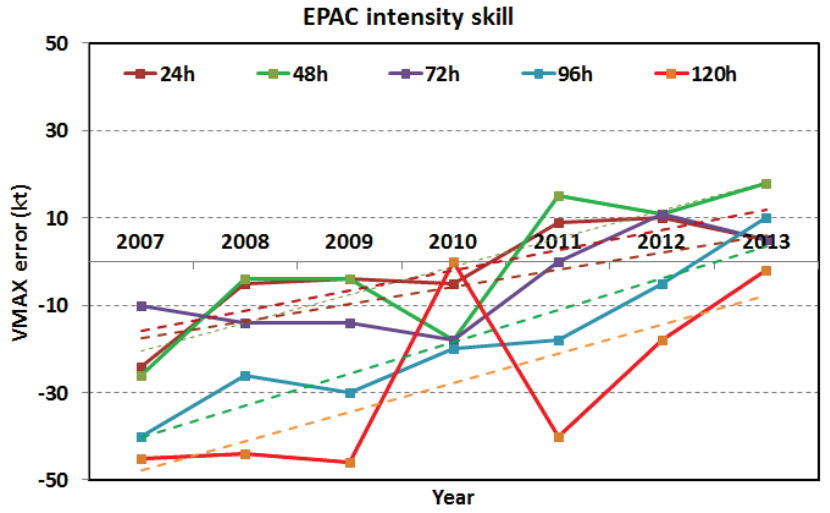
Lead time	24	48	72	96	120
improvement	-15	-10	7	20	26



Lead time	24	48	72	96	120
improvement	20	20	22	17	13

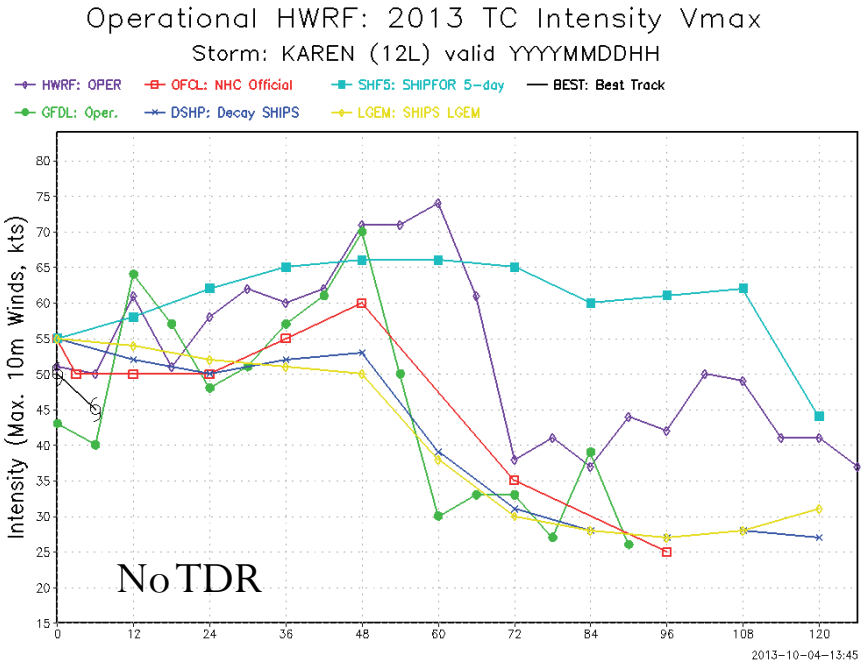


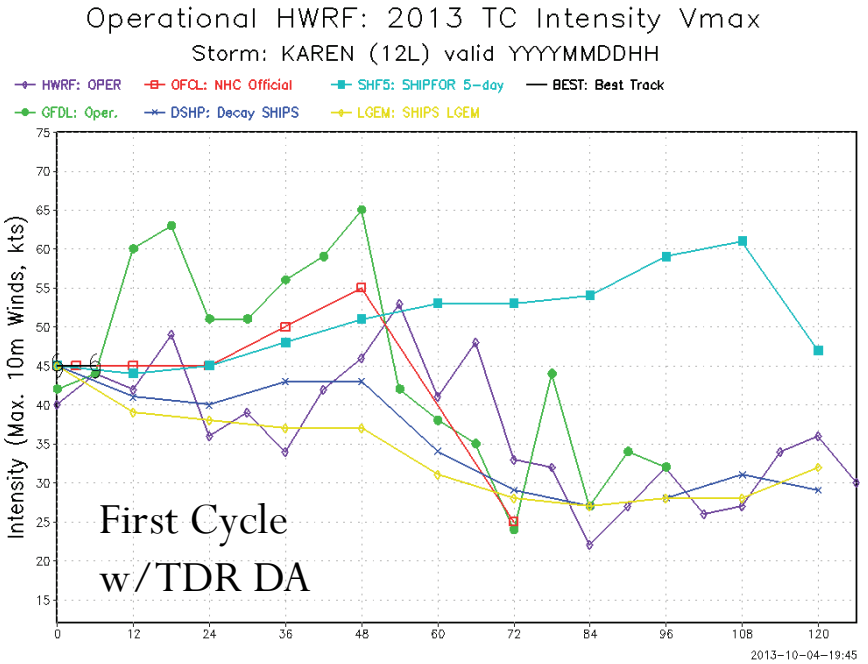
Lead time	24	48	72	96	120
improvement	**33**	**55**	**51**	**82**	**103**



Lead time	24	48	72	96	120
improvement	-5	7	-6	15	16

Impact of TDR DA on operational HWRF for TS Karen:





Impact of HWRF forecasts with TDR DA on NHC Operational Forecasts

NHC Forecast Discussion on October 4, 5 PM:

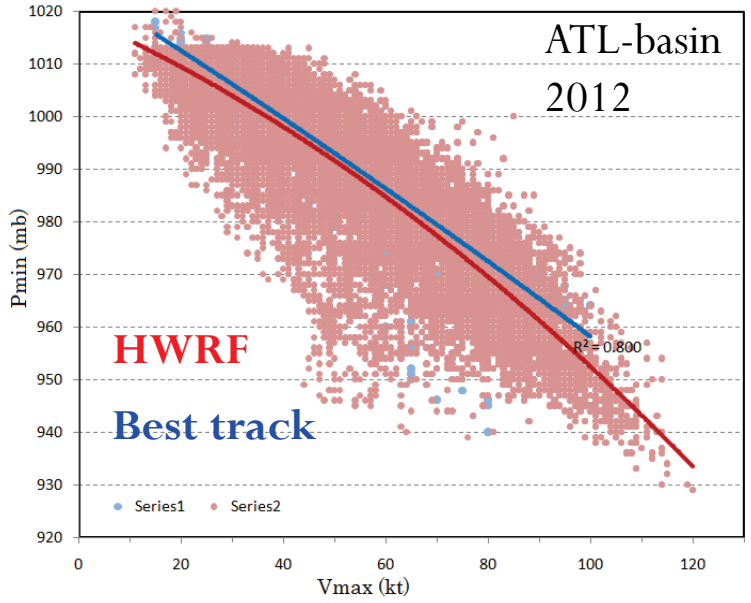
- **THE 12Z HWRF RUN SHOWED CONSIDERABLY LESS INTENSIFICATION WITH KAREN COMPARED TO PREVIOUS RUNS AFTER ASSIMILATING DATA FROM THE FROM THE NOAA P-3 TAIL DOPPLER RADAR. THIS MARKS THE FIRST TIME DOPPLER RADAR DATA HAVE BEEN ASSIMILATIED INTO AN OPERATIONAL HURRICANE MODEL IN REAL TIME.**

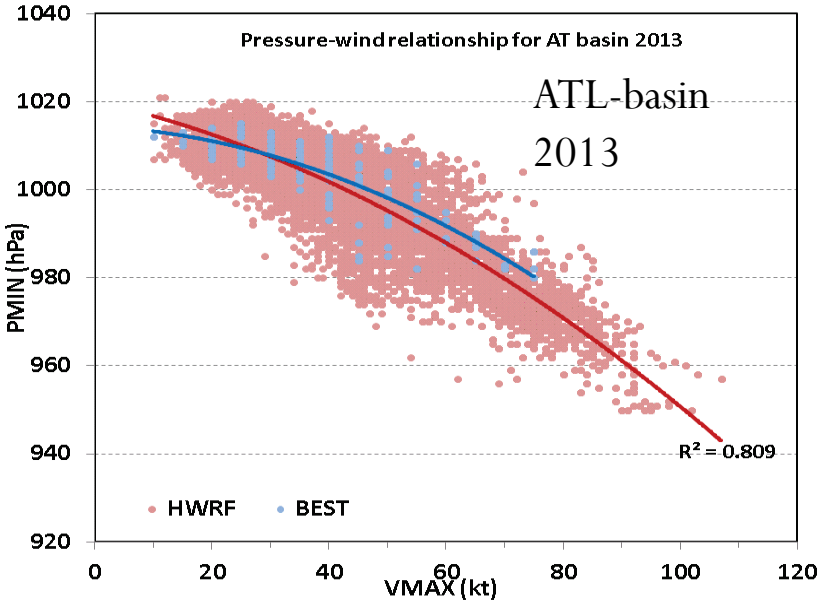
-- Forecaster Brennan

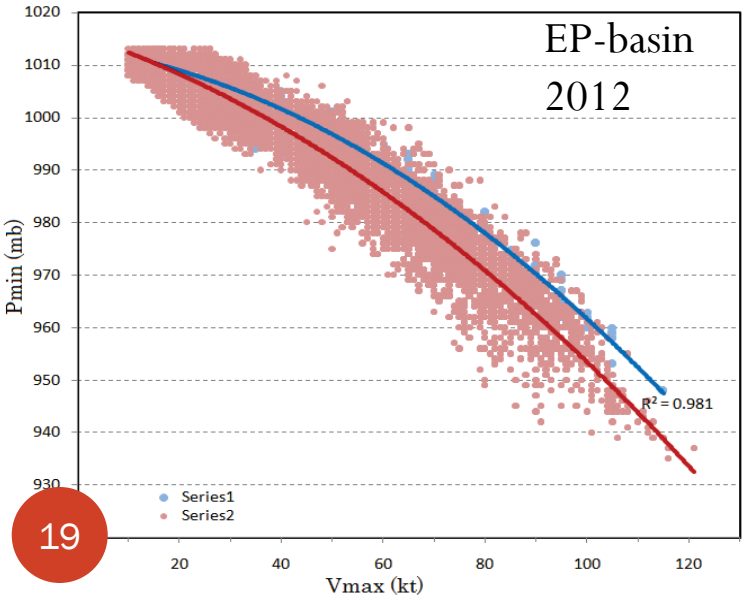
Real-time assimilation of NOAA P3 TDR DA for operational HWRF – A First in many years of flying.

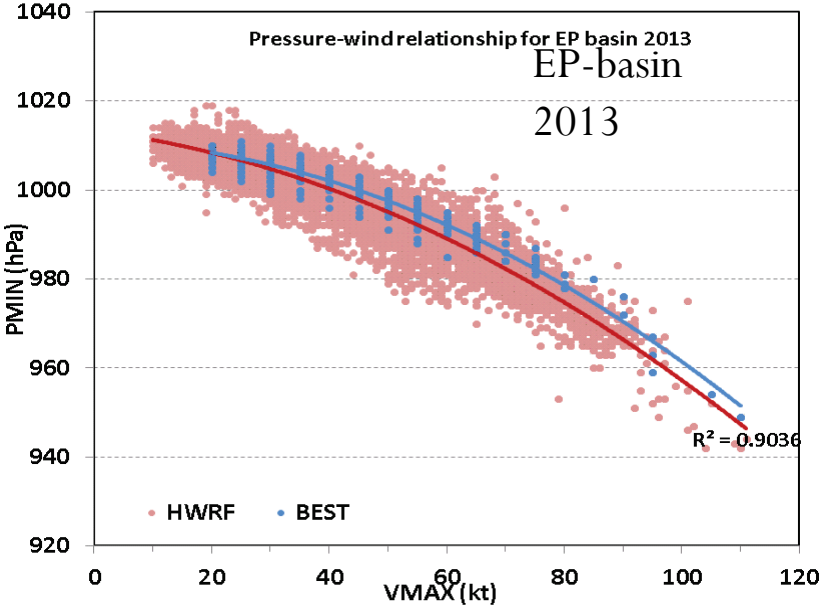
- Fix issues related to transmission of TDR data to NCO (storm id mismatch etc.)
- Conduct experiments to maximize the effective utilization of inner core data

Wind-Pressure relationship: Much improved vortex structure from 2013 HWRF









Special Real-Time Projects supported by HFIP

- **HFIP Stream 1.5 Demo: 20-member HWRF Ensembles**
- **Experimental Real-time HWRF forecasts for Western Pacific and North Indian Ocean (in support of JTWC and IMD)**
- HFIP Stream 2 Demo: Alternate physics suite
- HFIP Stream 2 Demo: Assimilation of Satellite Data
- HFIP Stream 2 Demo: Basin-Scale (hemispheric) HWRF (with multiple moveable domains, collaboration with HRD)
- HFIP Stream 2 Demo: HWRF-HYCOM

All these projects are supported by HFIP and allowed us to expand the Development Phase of operational HWRF for future upgrades.

HFIP resources on Jet and NCEP resources on Zeus helped us accomplish these real-time parallel systems.

Cross-platform compliancy through strict code management protocols and subversion based repository (supported by DTC) are pivotal for these efforts.

20-Member HWRF Ensembles for Stream1.5 Demo

➢Model Physics Perturbations (sub-grid scale):

Stochastic Convective Trigger

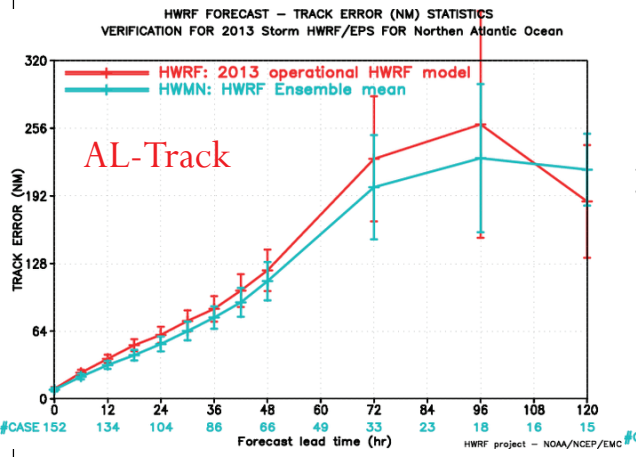
P_{CSL}-P_{LFC} <= DP(w) + Rr (n)

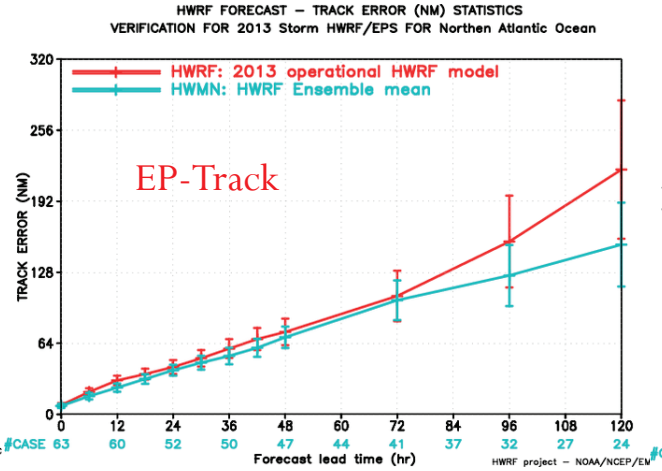
Rr is white noise, ranging from -50hPa to +50hPa, n is nth ensemble member, used as random seed. No spatial and temporal correlations

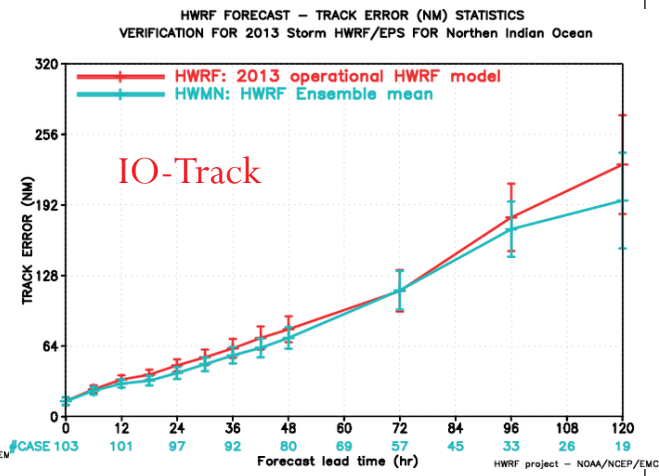
➢IC/BC Perturbations (large scale):

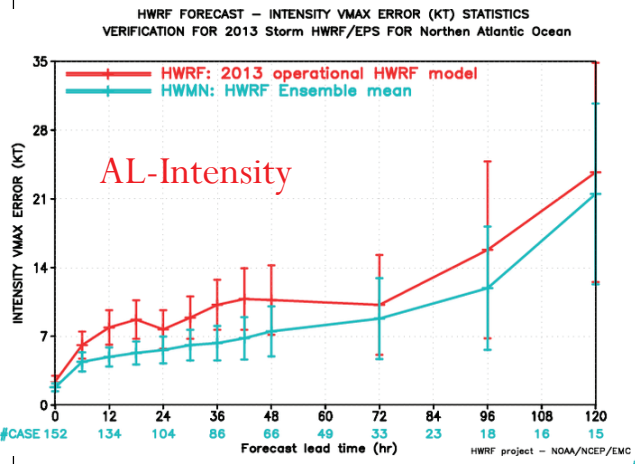
20 member GEFS.

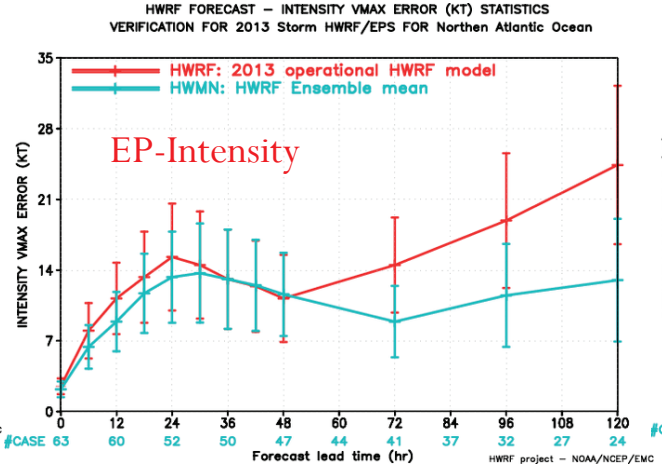
HWRF/EPS Verifications for 2013 Storms

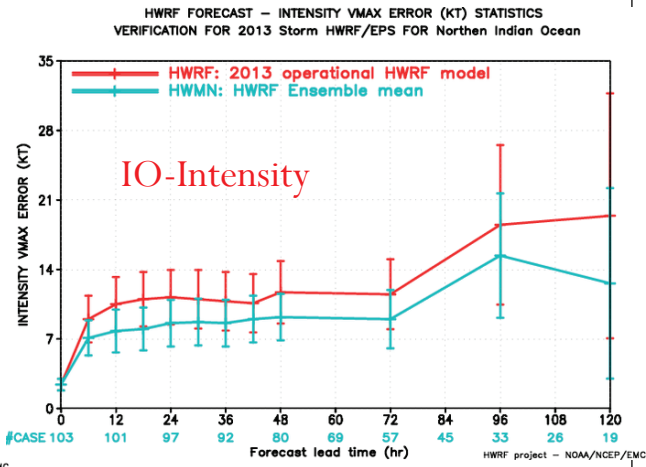








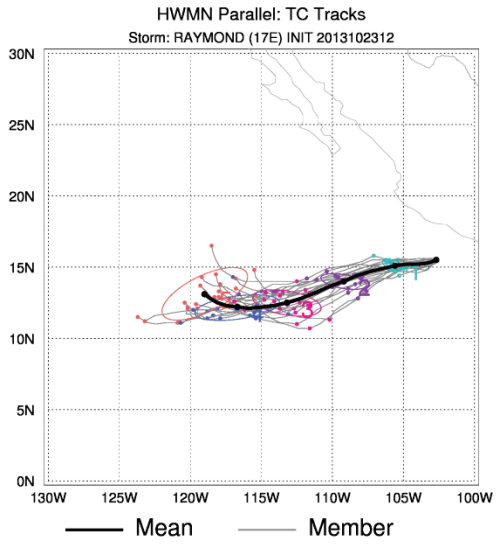


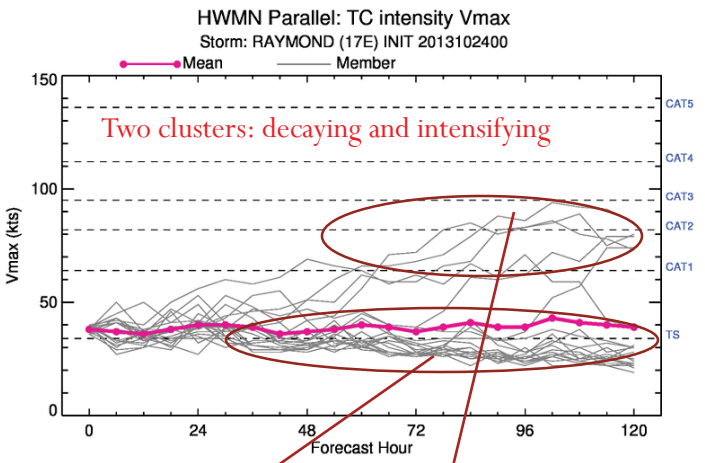


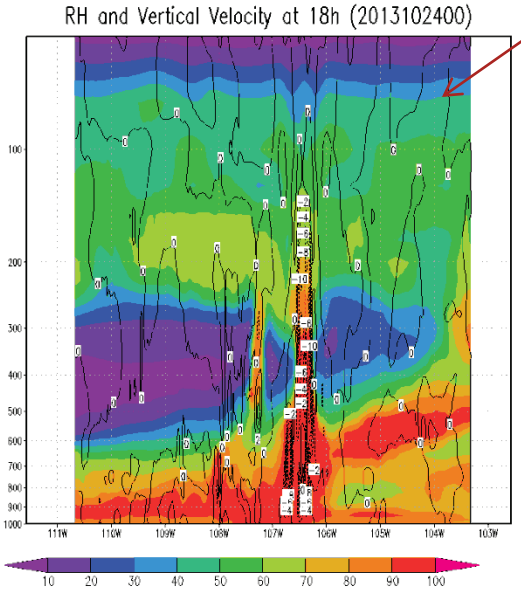
HWRF Ensemble Prediction for Hurricane Raymond, 20121024 00Z

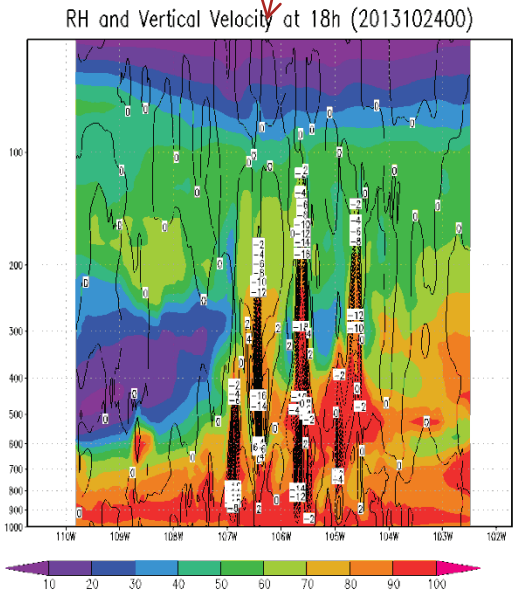
Large differences in predicted storm intensity due to sub-grid uncertainties in model physics:
stochastically perturbed cumulus convection scheme in HWRF

Dry air at mid-level suppressed storm development in one member, while active convective cells overcome the dry air, storm intensified in anther member.









HWRF as an operational forecast guidance tool for JTWC & IMD

- Starting in 2012, EMC HWRF team has been experimenting real-time forecasts for the WPAC basin, using NCEP Operational HWRF system, thanks to the support from NOAA's Hurricane Forecast Improvement Project (HFIP).

- ~ 85-90% reliability in delivering forecast products to JTWC was accomplished using dedicated resources (three sets of infinite reservations) on HFIP machines in Boulder. **Continued de** **ern Pa**

Impact of HWRF forecasts on JTWC Consensus (Official) Forecast Skill:

2013 season: Whopping 5% improvement in skill, 1 kt in bias. That is huge.

Whatever you are doing, keep doing it!

-- Buck Sampson, NRL

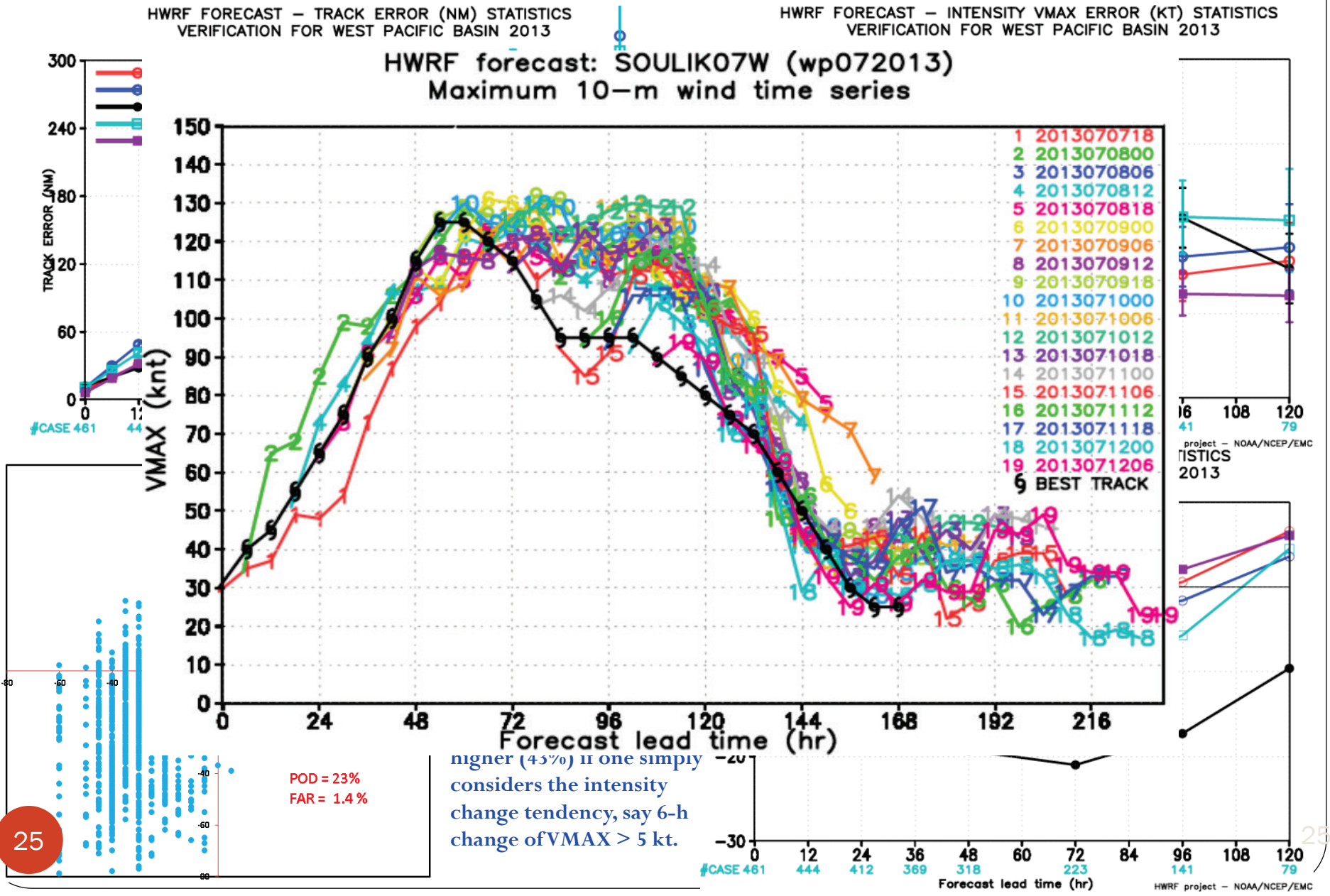
- ***"P*** ***sity gu*** ***013.*** ***Th*** ***ned oti*** ***pid intensification events that occurred in the Western North Pacific this year"***

--Bob Falvey, Director, JTWC

- ***A preliminary analysis of the performance of various models indicate that the performance of NCEP HWRF model was very good. It was a very useful product in terms of track, intensity and landfall forecast guidance as well as rainfall. Its performance was better that that of IMD HWRF.***

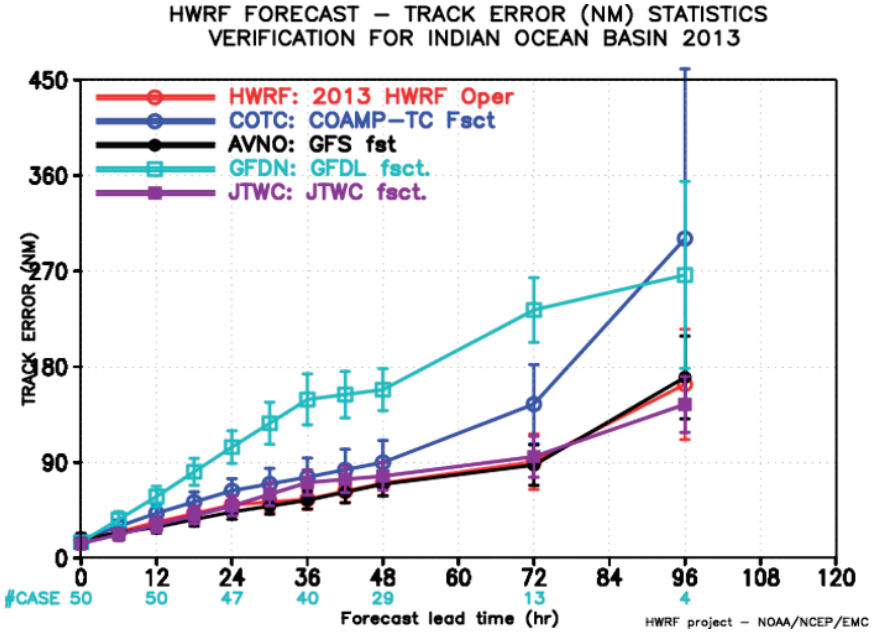
-- Dr. Mohapatra, Director, Cyclone Warning Division, IMD, India

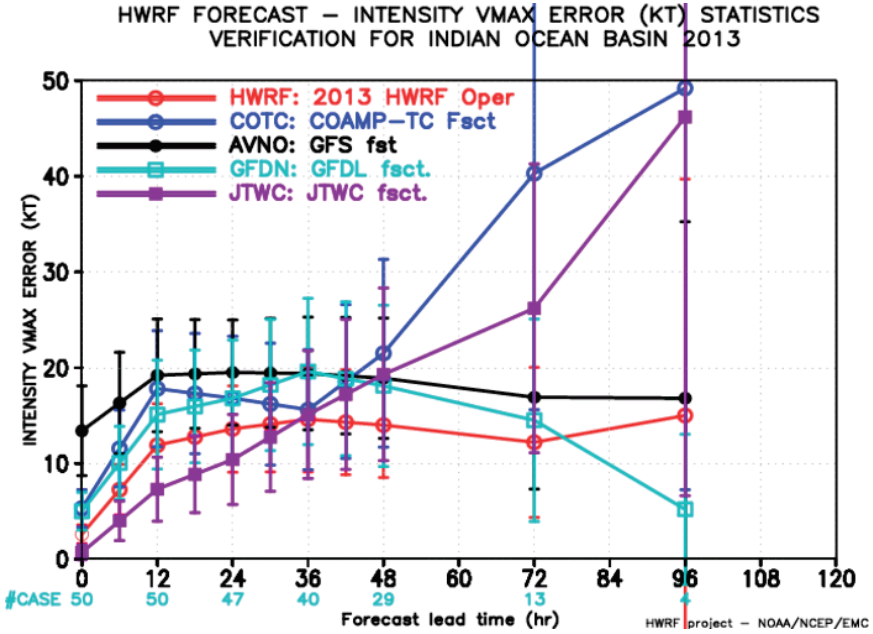
Performance of Operational HWRF for the 2013 Western Pacific Basin



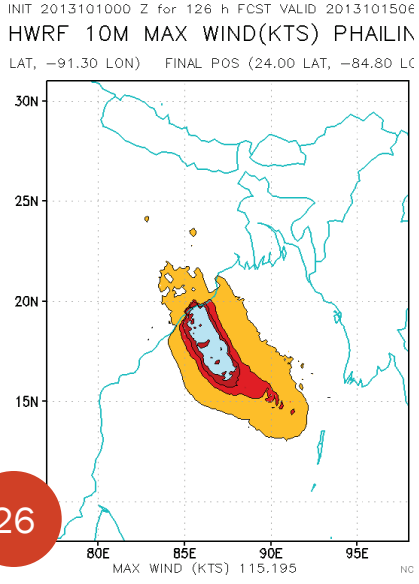
higher (43%) if one simply considers the intensity change tendency, say 6-h change of VMAX > 5 kt.

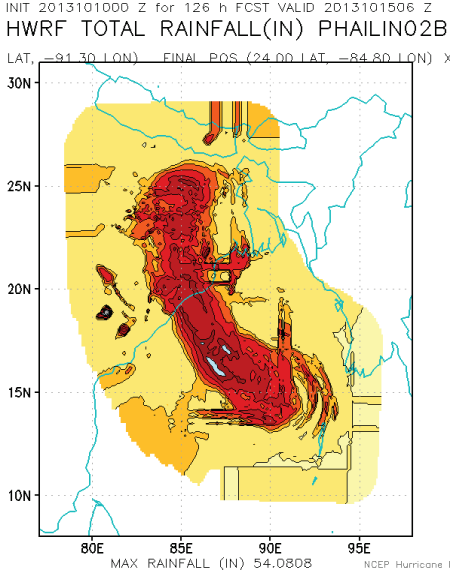
Verification for Indian Ocean for 2013

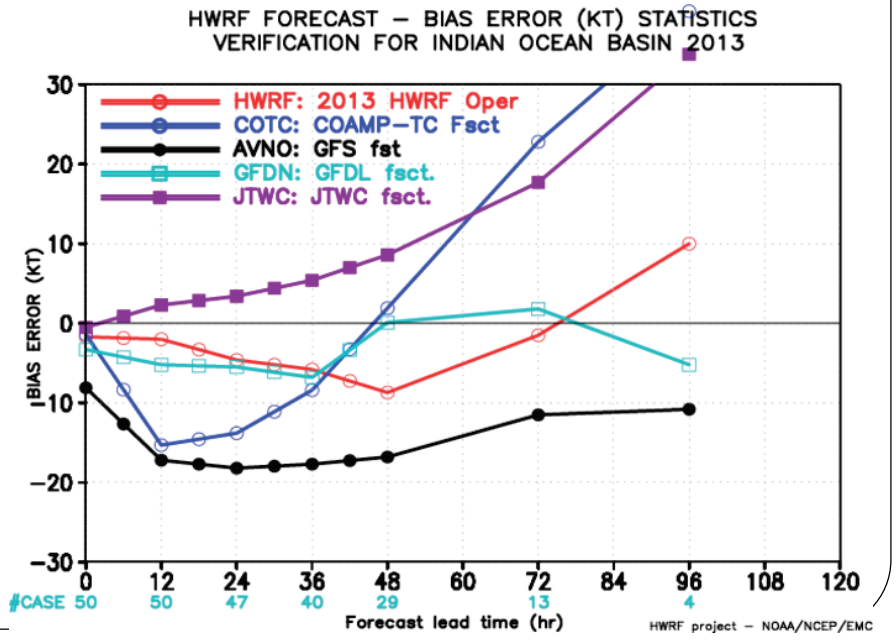




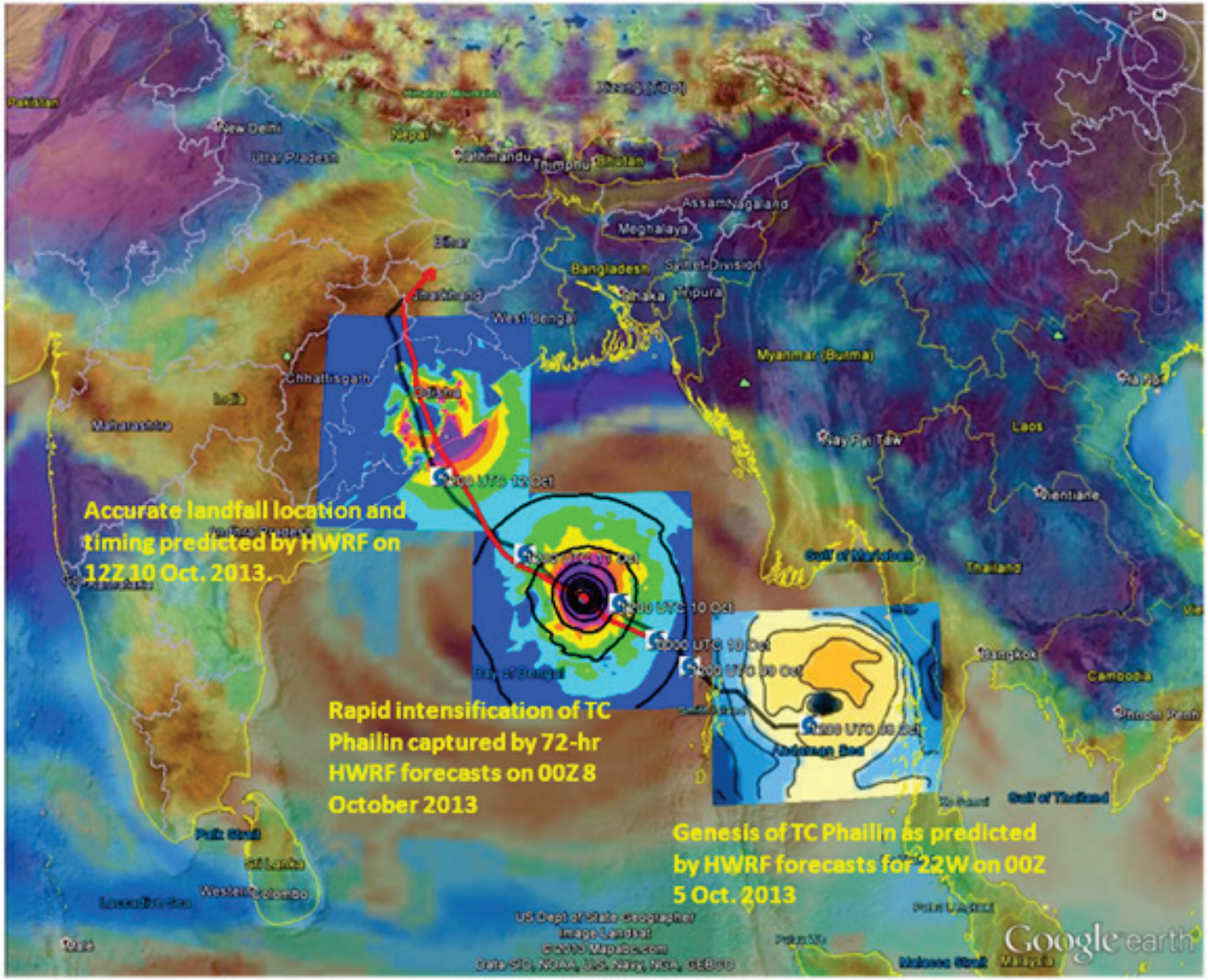
NCEP HWRF forecasts accurately captured the intensity, structure and rainfall of Phailin



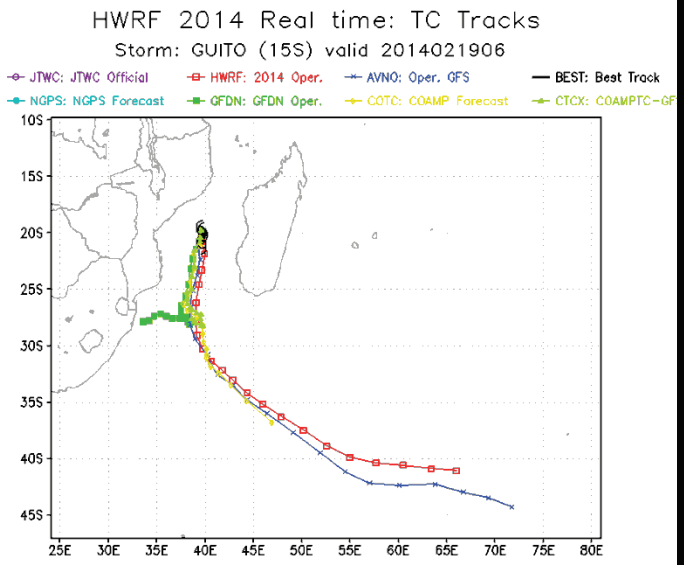


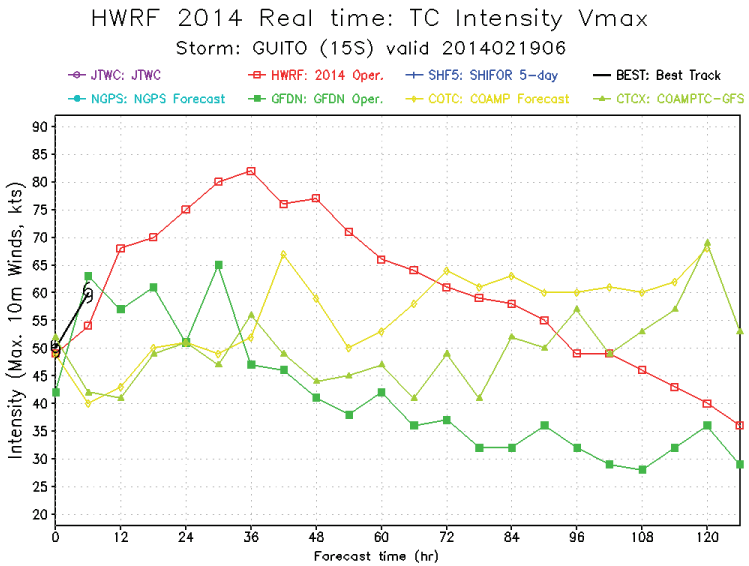


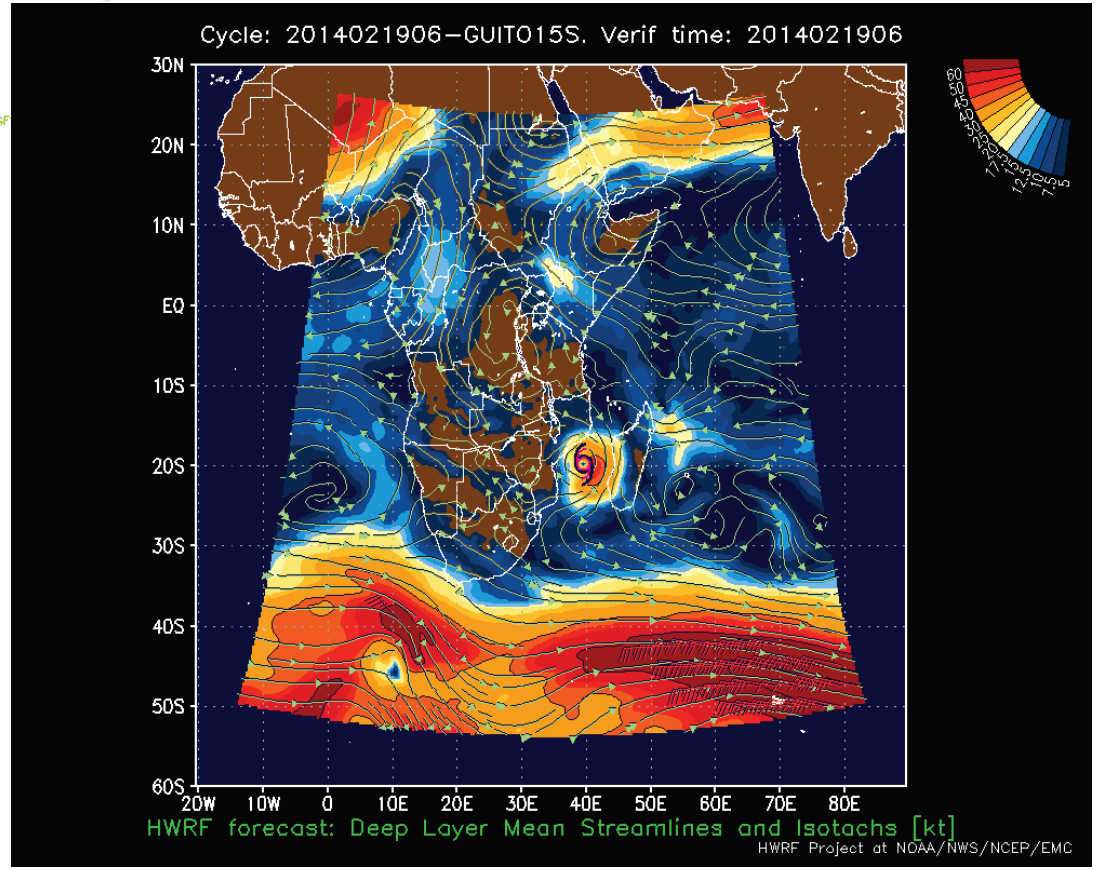
Accurate HWRF Forecasts for Very Severe Tropical Cyclone Phailin from Genesis to Dissipation



HWRF as a Truly Global High-Resolution Operational Tropical Cyclone Model: Real-Time Forecast Guidance for Southern Hemisphere TCs as of Jan 2014







Globalization of NCEP Operational HWRF allowed the HWRF team to provide real-time forecast guidance for Southern Hemispheric Storms starting on Jan 14, 2014, in support of JTWC. All real-time products are accessible from http://www.emc.ncep.noaa.gov/gc_wmb/vxt/

HWRF as a Global Tropical Cyclone Forecast Model: International Collaborations

- **JTWC**: As of Jan. 14, 2014, HWRF team at NCEP/EMC has been delivering real-time tropical cyclone forecasts **for all oceanic basins of the world including Southern Hemisphere** in support of forecasters at JTWC using dedicated computational resources provided by HFIP.
- **HWRF in India: HWRF is operational at IMD.** *MoU extended through October 2018. 2013 HWRF to be implemented in June 2014.*
- **HWRF in China:** Experimental implementation at STI in 2013; at CMA in 2014. *NOAA/CMA 18th JWG included collaboration on HWRF in Dec. 2013*
- **HWRF in Vietnam**: *Experimental implementation in 2014*
- **HWRF in Taiwan**: *Using HWRF as part of the operational suite at Central Weather Bureau since 2013*
  - ***Hosting full-pledged EMC/DTC/HFIP HWRF tutorial at Taipei, Taiwan in May 2014***
- **HWRF in Oman**: Experimental implementation of HWRF in 2014
- **HWRF in Korea**: *Expressed interest in use of HWRF at Korea Typhoon Institute*
- **Academic/Research Institutes:** Users from more than 30 Universities and several Govt/Private research institutes around the world registered with DTC and getting community support on operational HWRF.

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

Collaborations with NHC, DTC, HRD, GFDL, URI, CIRA and other HFIP partners