Performance of the 2013 NCEP Operational HWRF and Plans for 2014 Hurricane Season

Significant improvements in Hurricane Intensity Forecasts

Vijay Tallapragada & HWRF Team

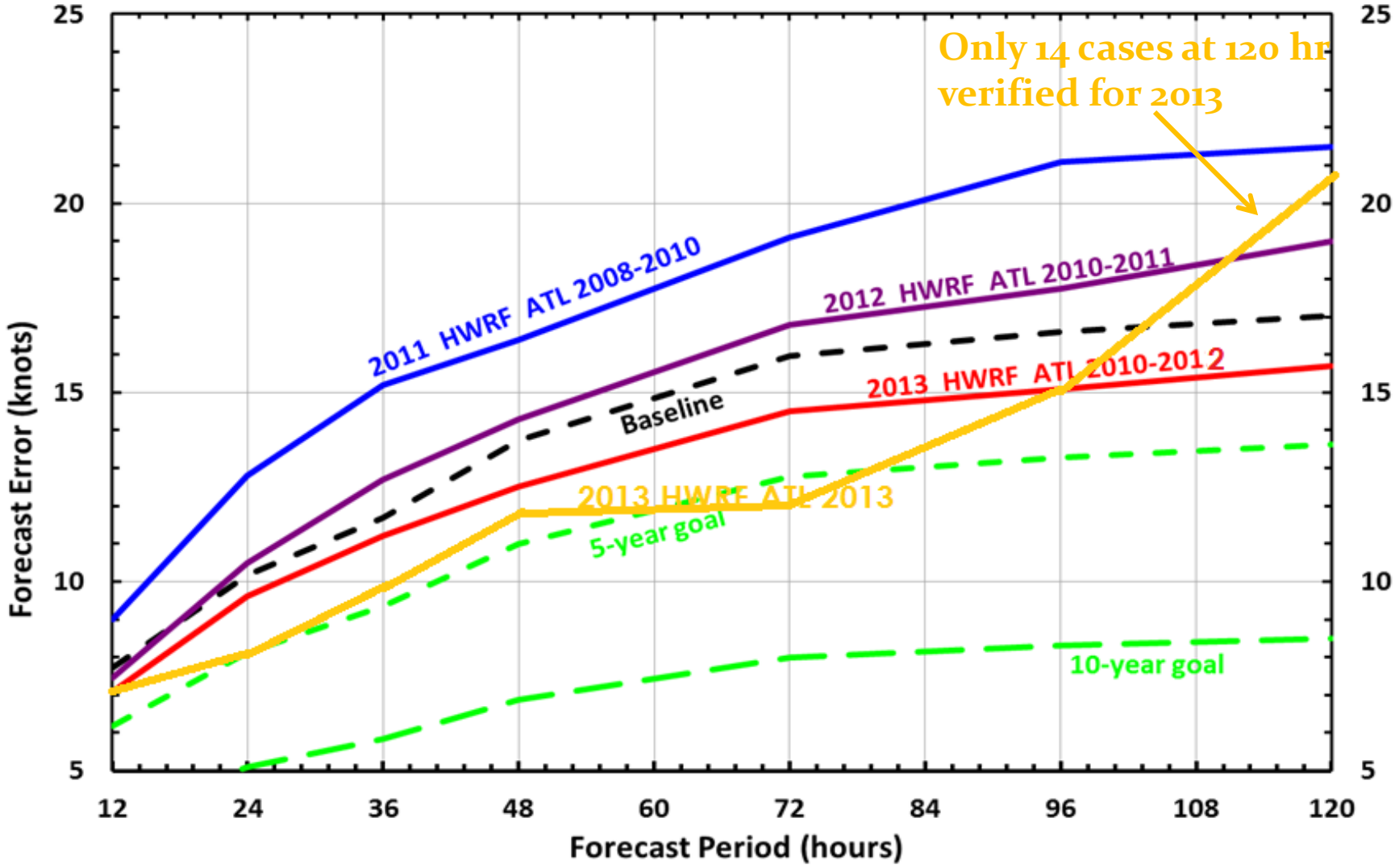
Environmental Modeling Center,
NCEP/NOAA/NWS, NCWCP, College Park, MD 20740.

68th IHC/TCRF, March 5, 2014

Outline

- Performance of current operational HWRF for 2013 season
- HFIP supported Special Projects and Real-Time Parallel HWRF Experiments
- Performance of HWRF in the North Western Pacific and North Indian Ocean basins and Southern Hemisphere
- Further enhancements to the HWRF modeling system for 2014 hurricane season

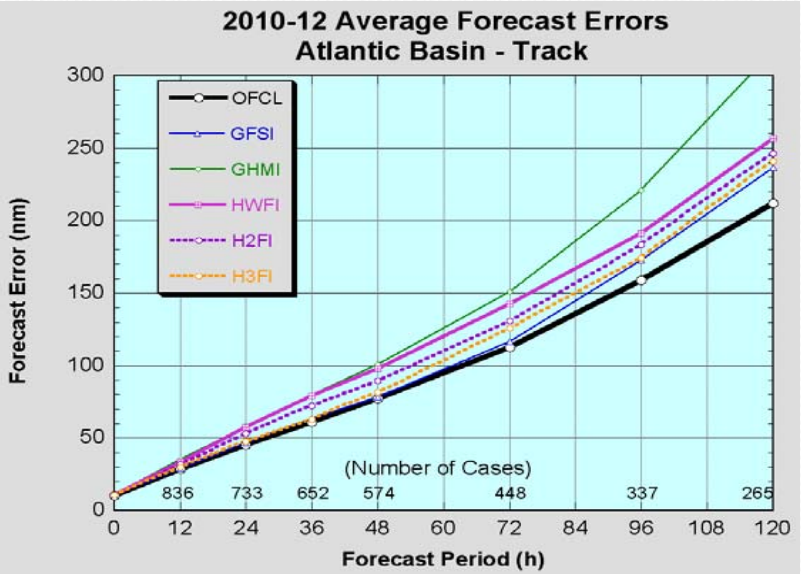
HWRF Intensity ATL Basin: Cumulative Forecast Improvements (Retrospective and Real-Time Performance)

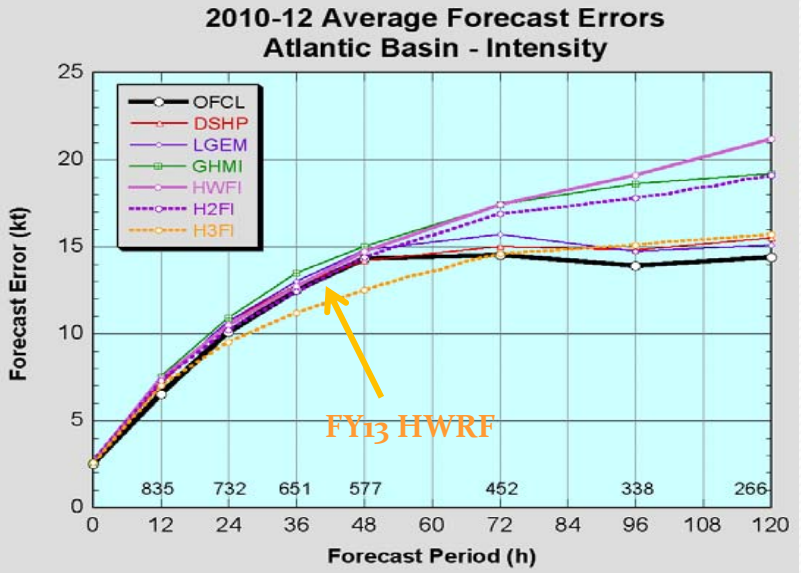


How did we get there?

Role of NCEP High-Resolution HWRF Modeling System

- **2012 HWRF: For the first time, a very high-resolution hurricane model operating at cloud-permitting 3km resolution implemented into NCEP operations during the 2012 hurricane season, a result of multi-agency efforts supported by HFIP**
- **2013 HWRF implementation on WCOSS included more advanced upgrades followed by extensive 3-season T&E**
- **Highlights of 2013 HWRF:**
- Sophisticated 9-point **nest tracking algorithm & nest parent interpolations**
- **Observations based PBL** and **Surface Layer** Physics
- **Improved air-sea fluxes for ocean coupling (POM-TC)**
- **Data Assimilation and Vortex Initialization upgrades:**
- **One-way hybrid EnKF-3DVAR data assimilation** and **assimilate real-time inner-core NOAA P3 Tail Doppler Radar datasets**
- **Improved storm size correction**, **modified filter domain** and **use of GFS vortex** when the storm is weaker than 16 m/s
- **Extensive evaluation:**
- **Three-season (2010-12) comprehensive evaluation for NATL/EPAC showing intensity skill superior to NHC forecasts**

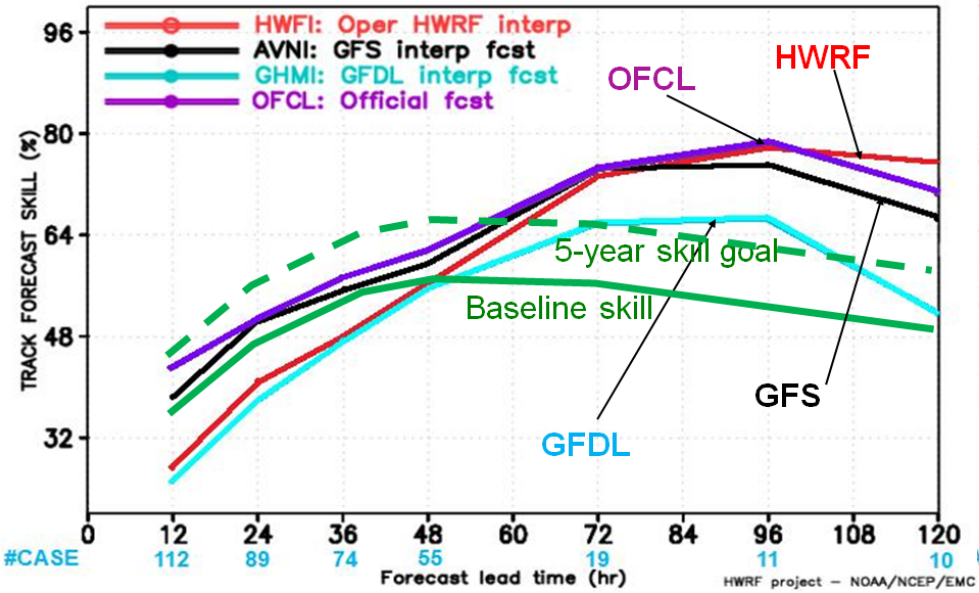




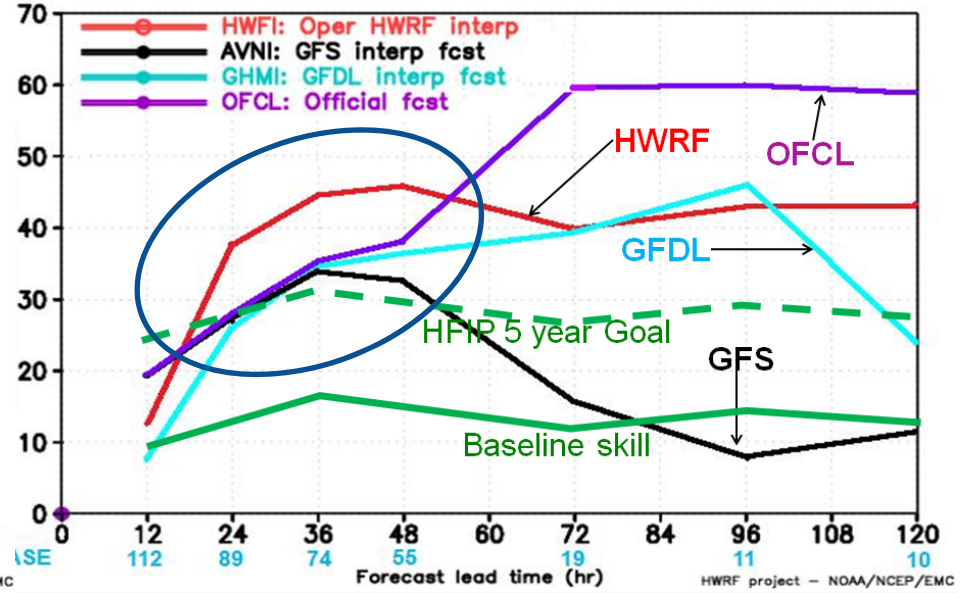
NOAA HURRICANE FORECAST IMPROVEMENT PROJECT

Performance of NCEP Models for 2013 North Atlantic Basin

Comparison of 2013 NCEP Operational Models to the 5 Year HFIP Goal: Track (Early Models)

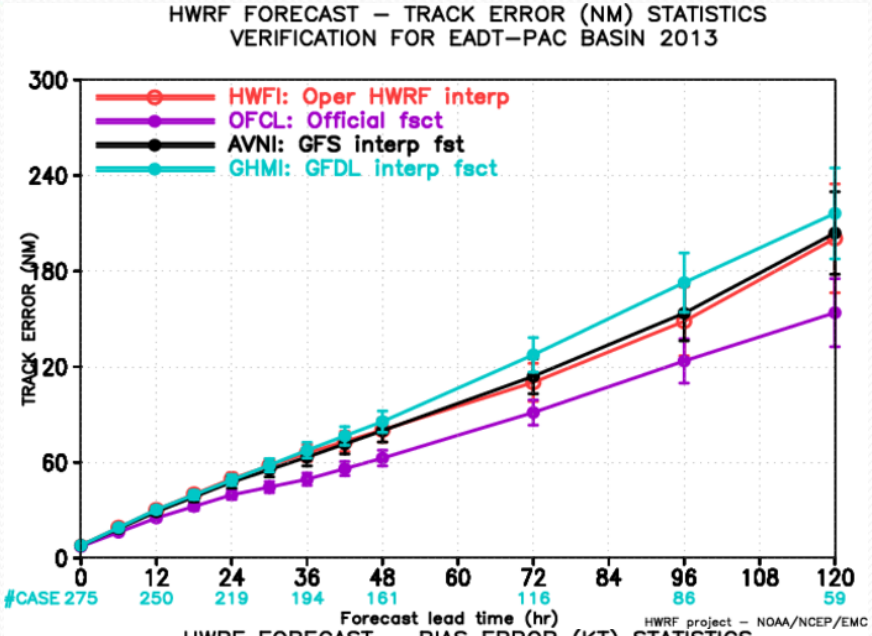


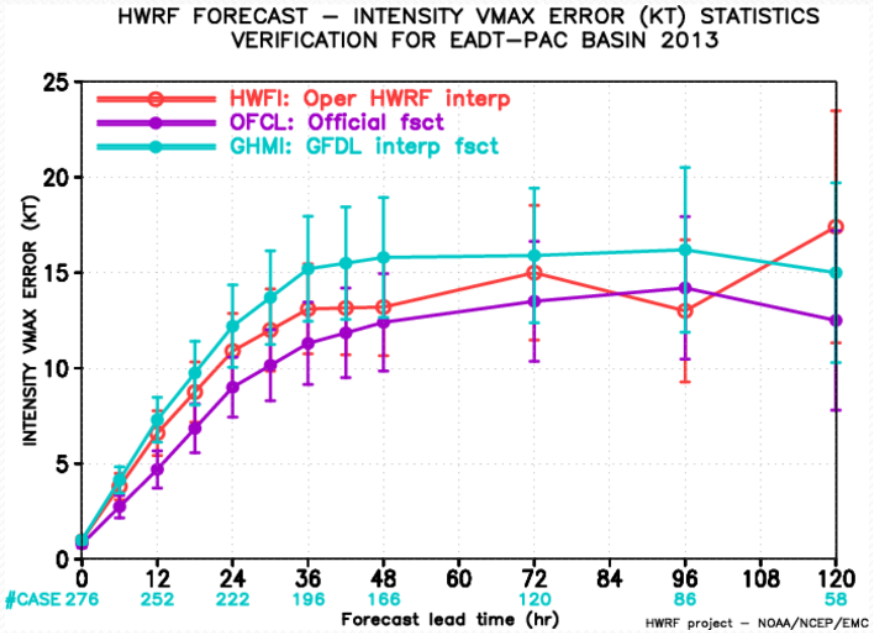
Comparison of 2013 NCEP Operational Models to the 5 Year HFIP Goal: Intensity (Early Models)

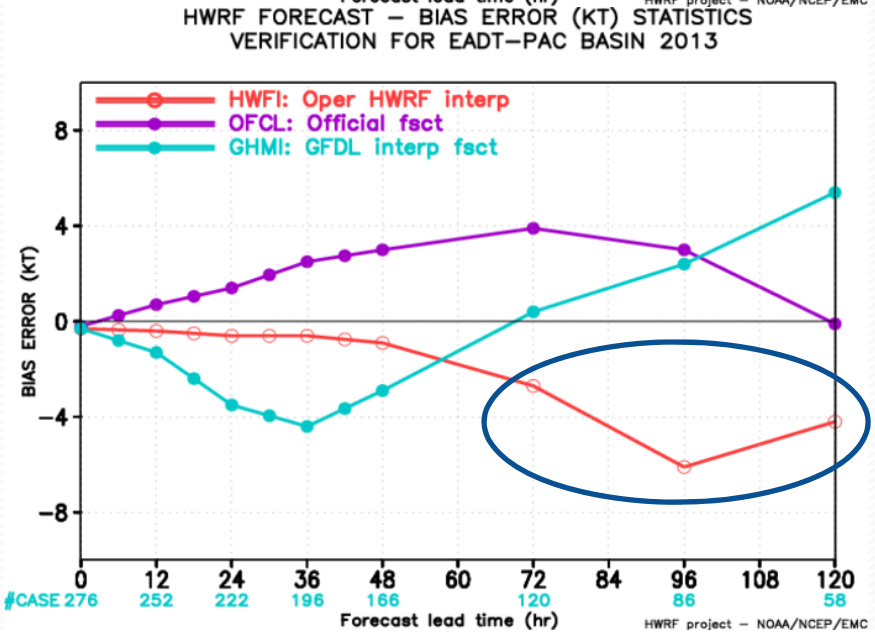


HWRF Model Real-Time Performance for 2013 Atlantic intensity forecasts match the expectations from the pre-implementation T&E

2013 East Pacific early model verification



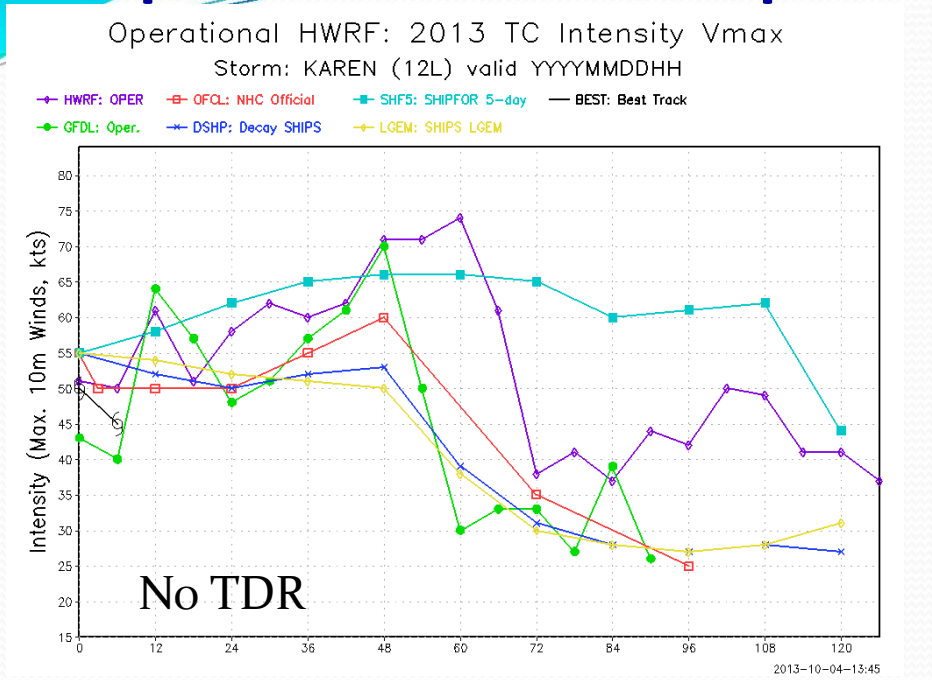


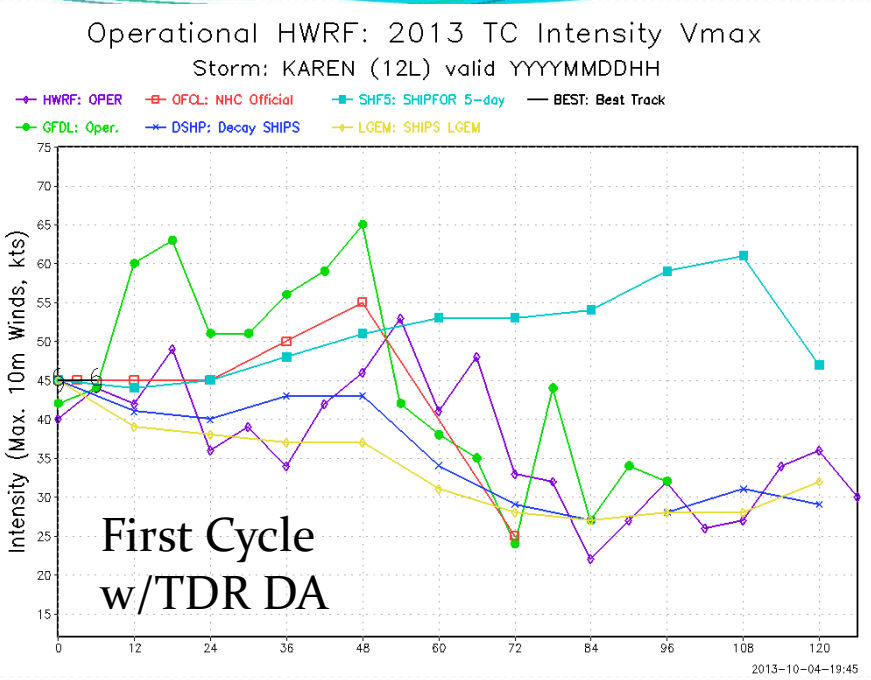


HWRF track and intensity forecasts for the Eastern Pacific basin have shown better skill compared to other NCEP models

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

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

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

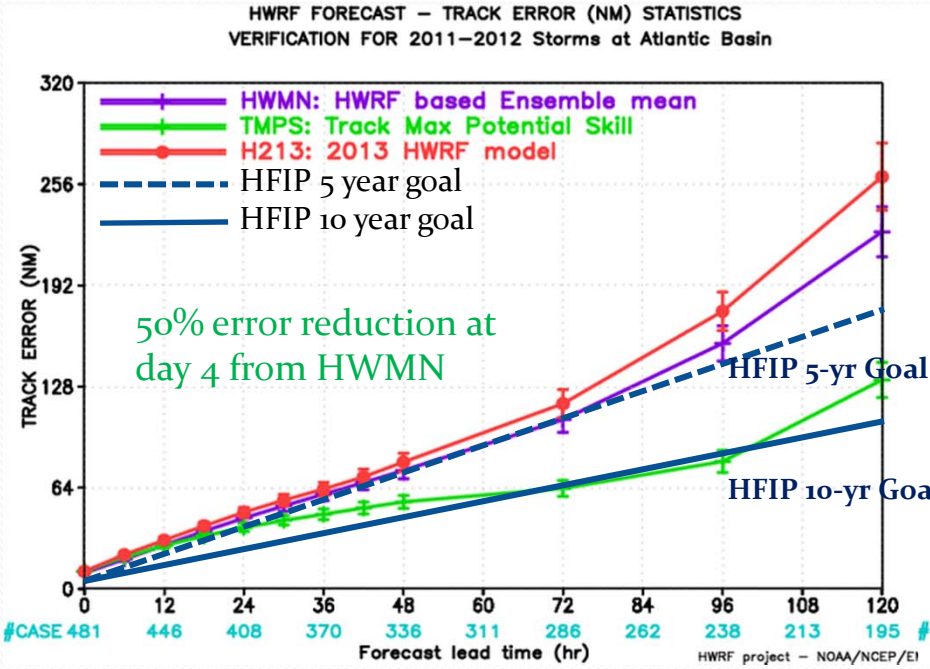
All these projects are supported by HFIP and allowed us to expand the Development Phase of operational HWRF for future upgrades.

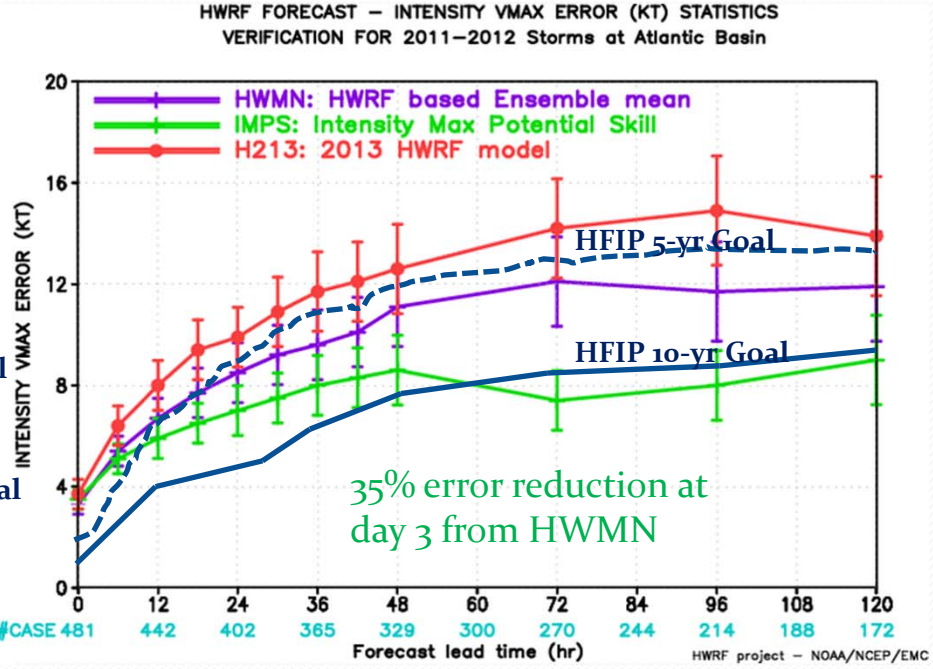
HFIP resources on Jet and NCEP resources on Zeus helped us accomplish these real-time parallel systems.

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

20-member HWRF Ensembles: HWRF Max Potential Forecast Skill (MPFS)

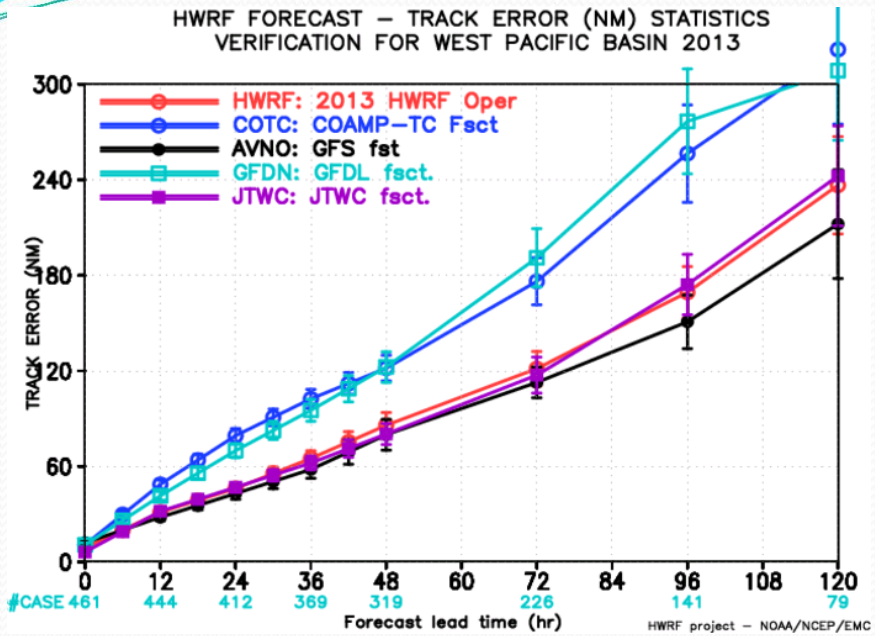
- Real-time forecasts from 20-member HWRF ensembles using large-scale perturbations from GEFS IC/BC and storm-scale perturbations using stochastic convective physics
- 2013 HWRF EPS meets or exceeds HFIP 5-year goals
- Future upgrades from HWRF should lead us to meet the HFIP 10-year goals if we can improve the vortex initialization and short-range (0-48hr) forecast problems
- Plans for High-Resolution (3km) COAMPS-TC/HWRF/GFDL multi-model regional ensemble system to provide enhanced probabilistic forecast guidance
- **More details by Zhan Zhang (S4-07)**

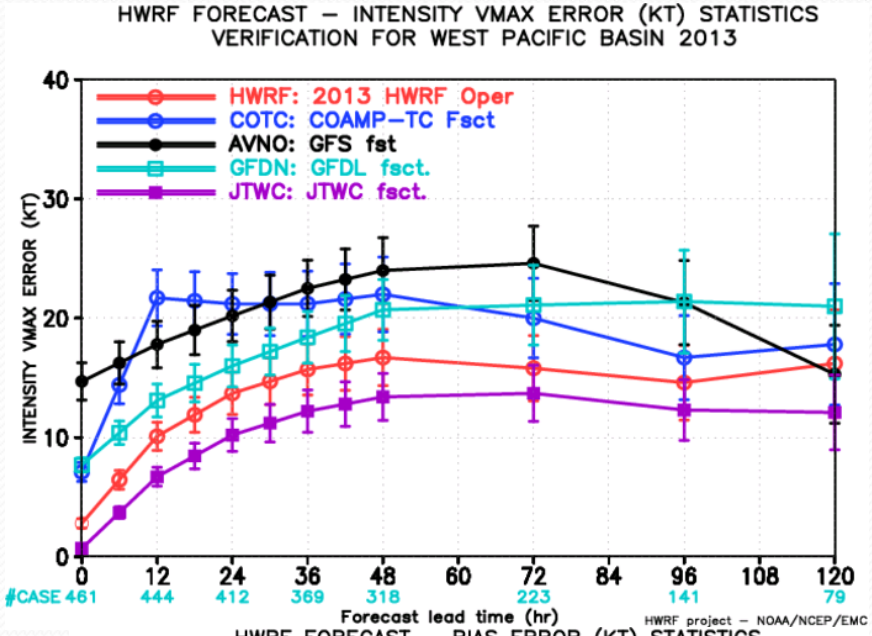




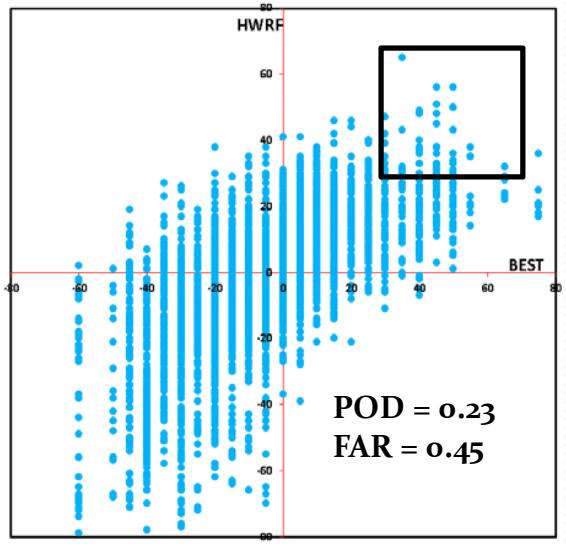
Performance of Operational HWRF for the 2013 Western Pacific Basin

More details by Sam Trahan (S4-04) and Chanh Kieu (S4-05)



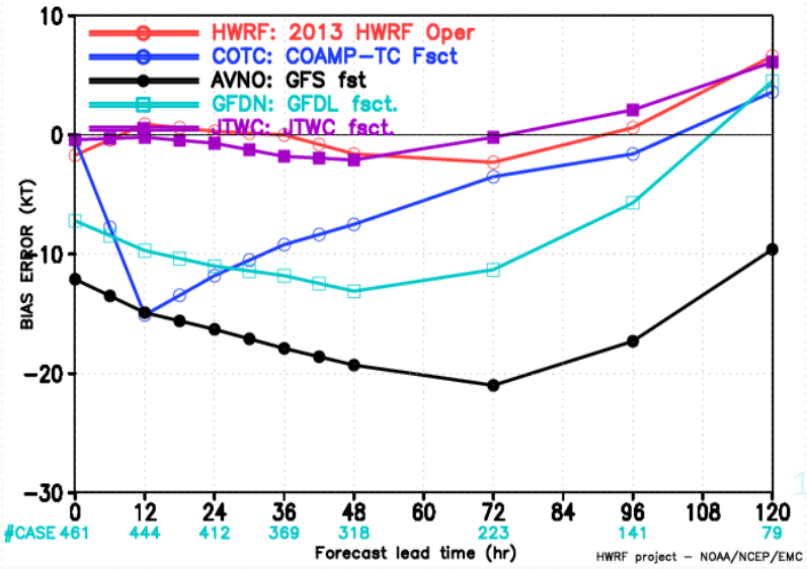


RI verification (VMAX change > 30 kt/24h)

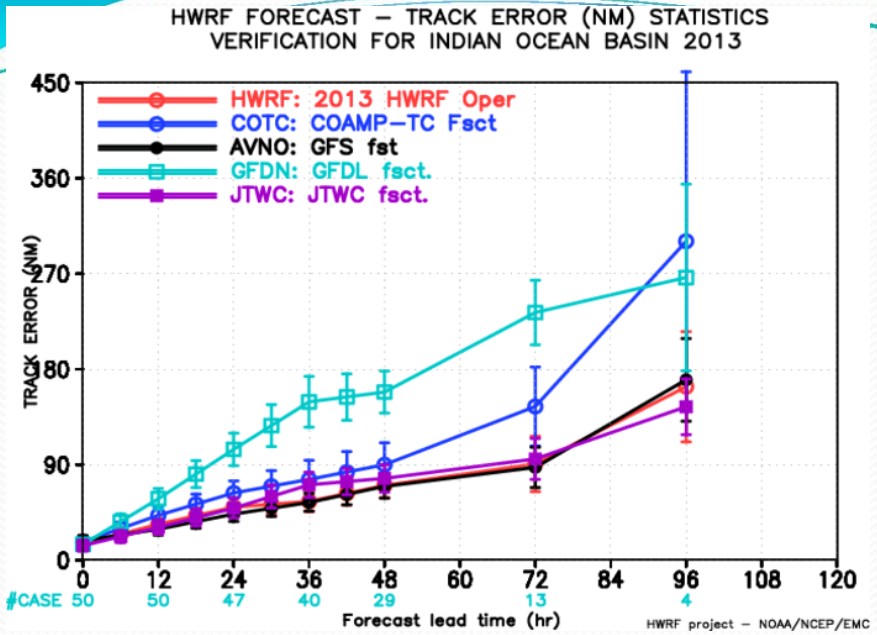


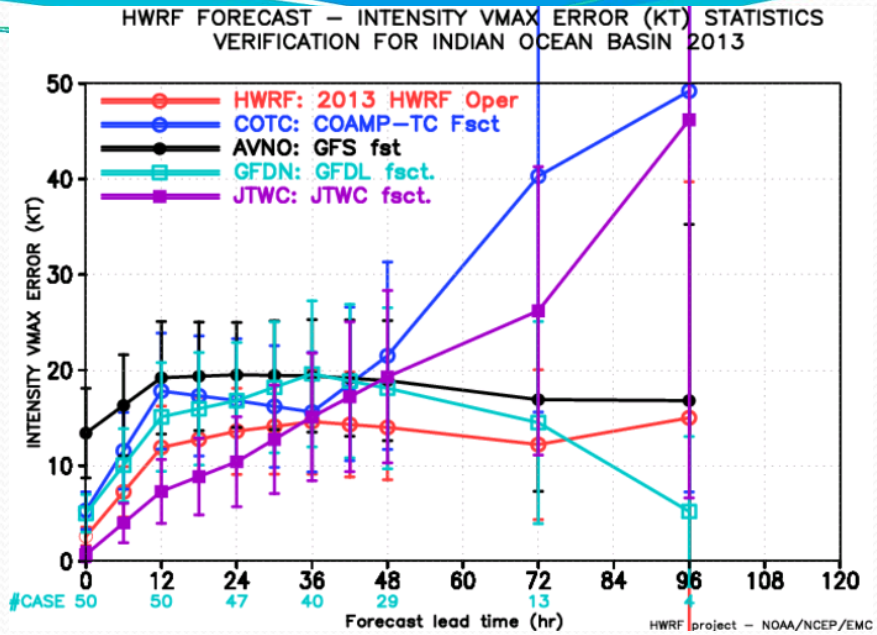
HWRF RI POD skill is ~ 23 % and by far has higher POD index as compared to other models and in other basins *(previous analysis of RI for WPAC from 2012 HWRF showed <10% skill).*

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

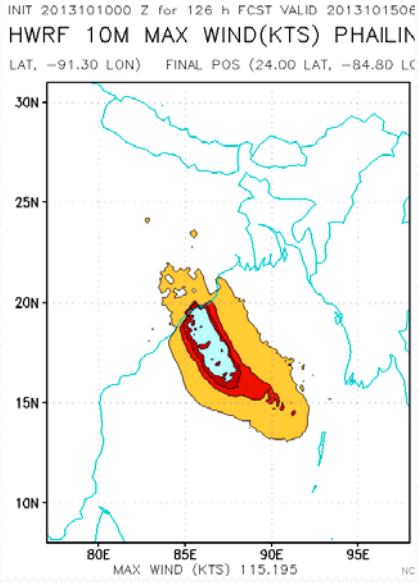


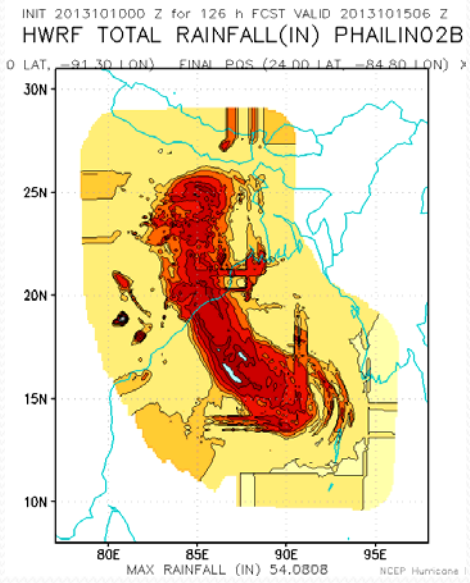
Performance of Operational HWRF for the 2013 Indian Ocean Basin

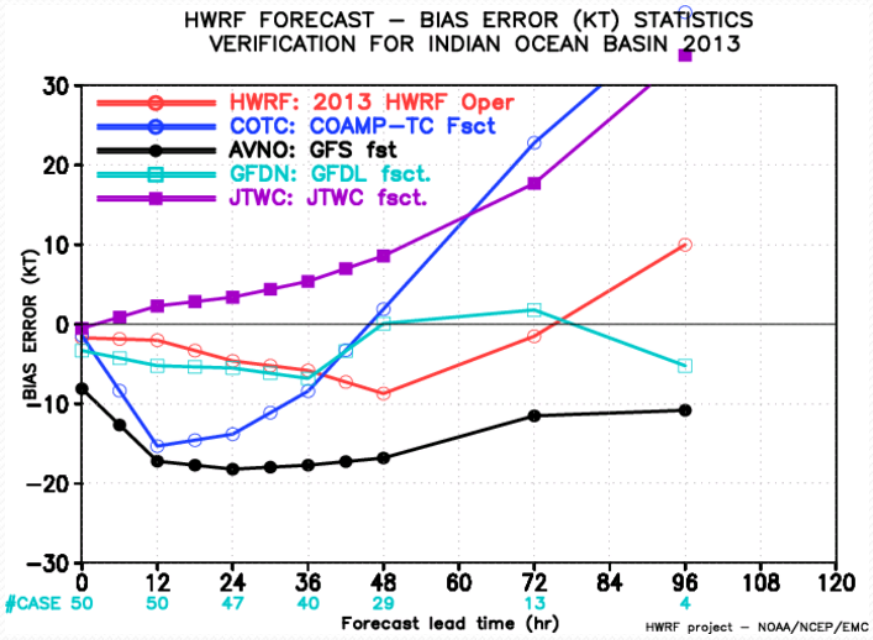




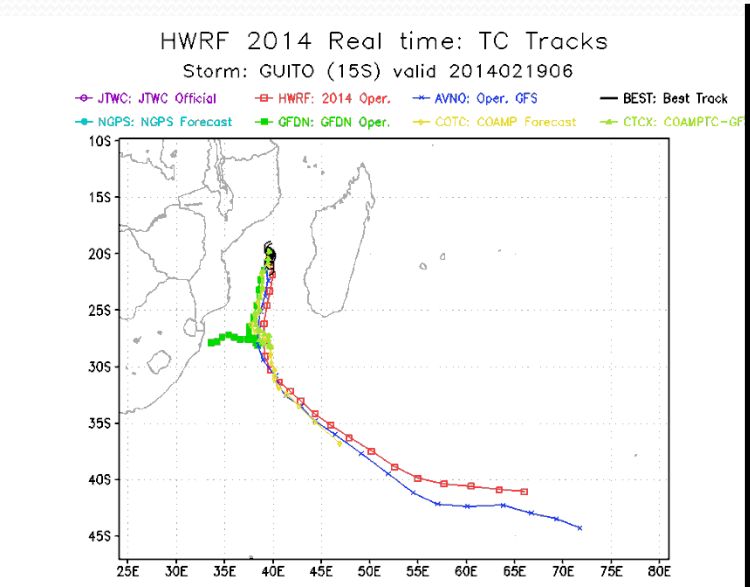
NCEP HWRF forecasts accurately captured the intensity, structure and rainfall of Phailin

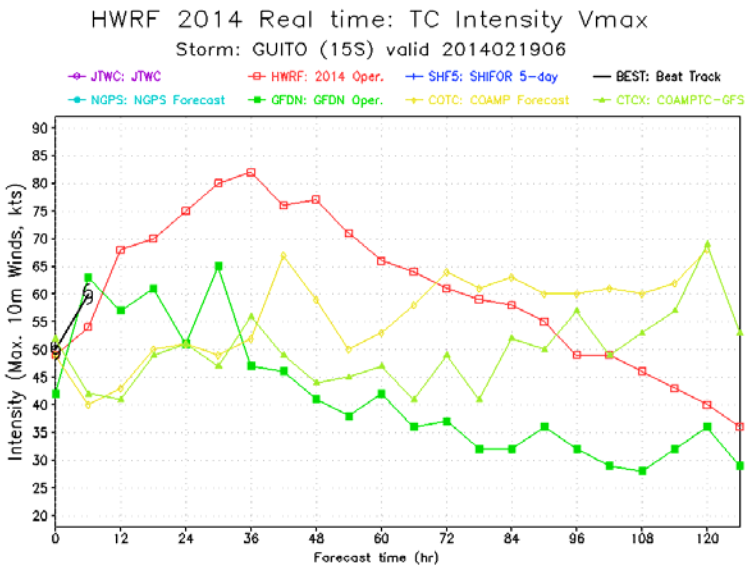


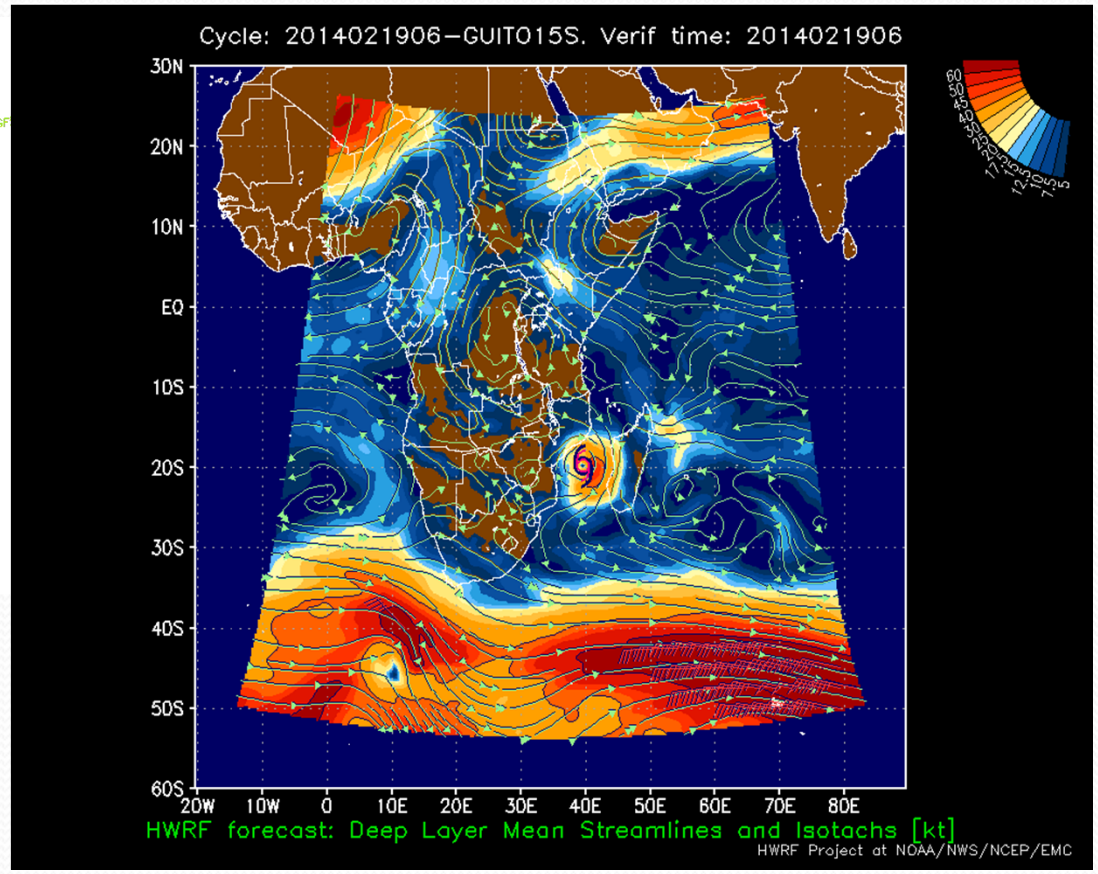




HWRF as a Truly Global High-Resolution Operational Tropical Cyclone Model: Real-Time Forecast Guidance for Southern Hemisphere TCs as of Jan 2014







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/

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 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, insufficient vertical resolution for satellite data assimilation

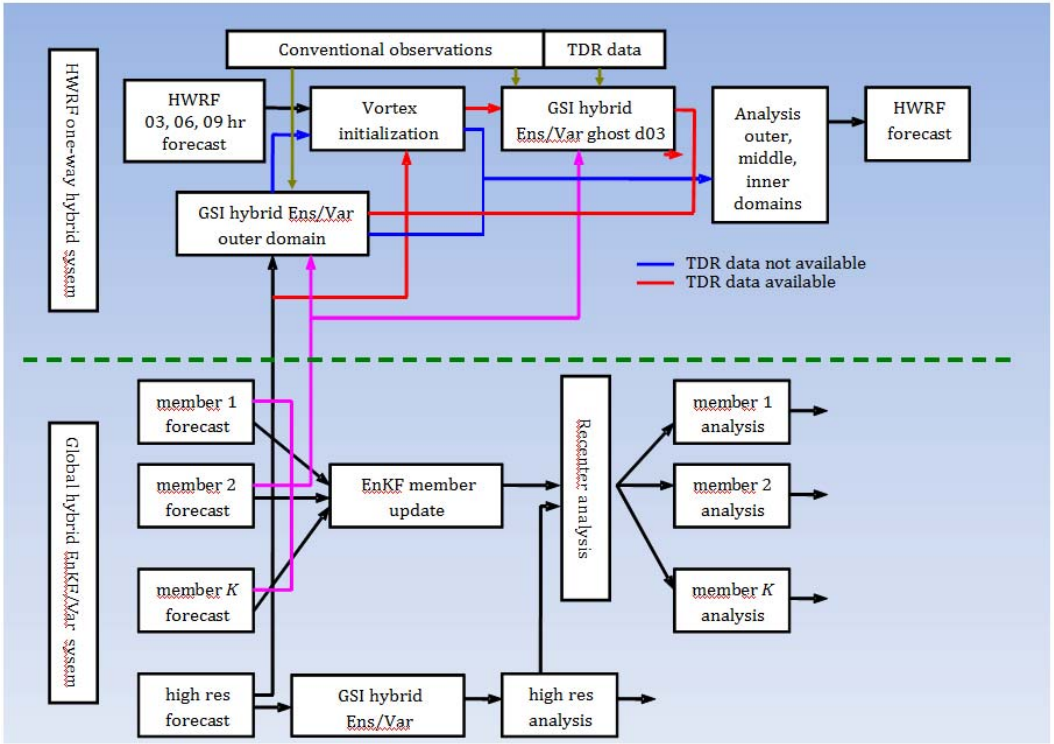
f) Coarse resolution of ocean model, inadequate conditions for choice of ocean domain in the Atlantic, 1-D coupling in the East Pacific

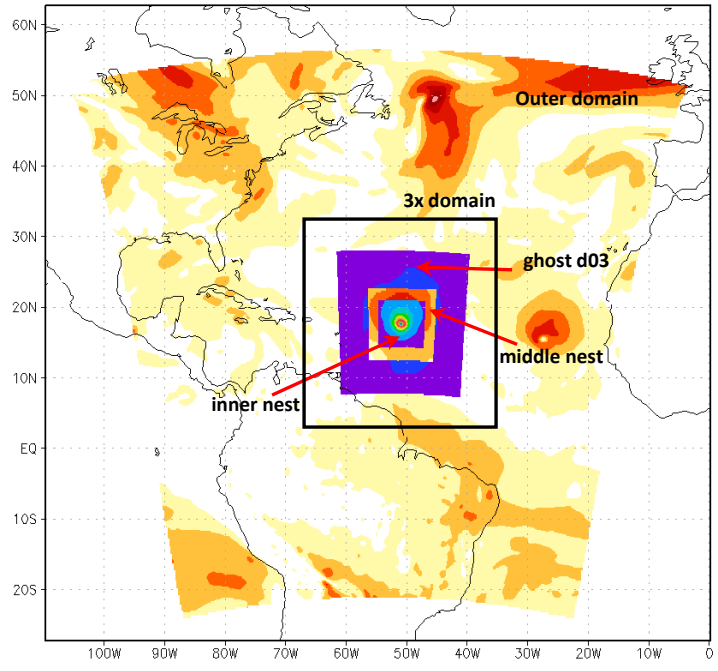
Focus areas for development, testing and evaluation

1. Increase the vertical resolution of atmospheric model to 61 levels with higher model top
2. Upgrade HWRF physics suite to include RRTM-G, Modified Ferrier MP, NOAH LSM.
3. Upgrade the ocean model (POM) to 1/12° 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 (better use of Aircraft Recon TDR and Dropsonde Data)
5. Additional operational forecast products from HWRF to include several new variables (e.g.. tornado potential fields for SPC), fields for downstream applications (hurricane wave model) and 9-minute ATCF output
6. Pre-implementation tests based on proposed Q4FY13 GFS upgrades

More details by Young Kwon (S4-03) on FY14 HWRF T&E

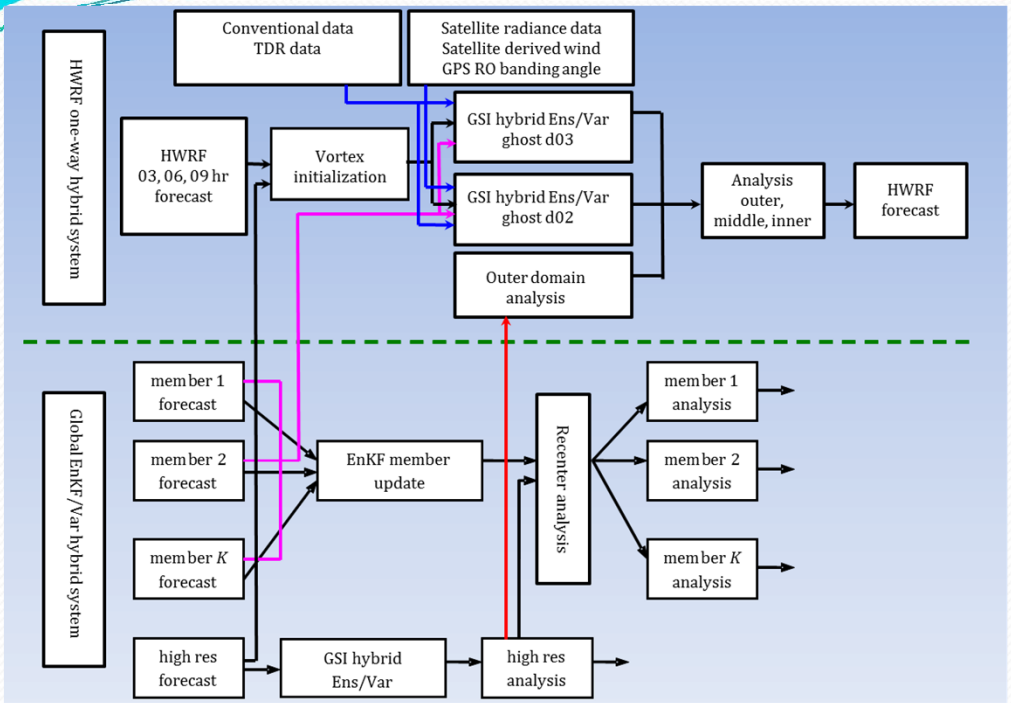
2013 Operational HWRF Data Assimilation System (HDAS)

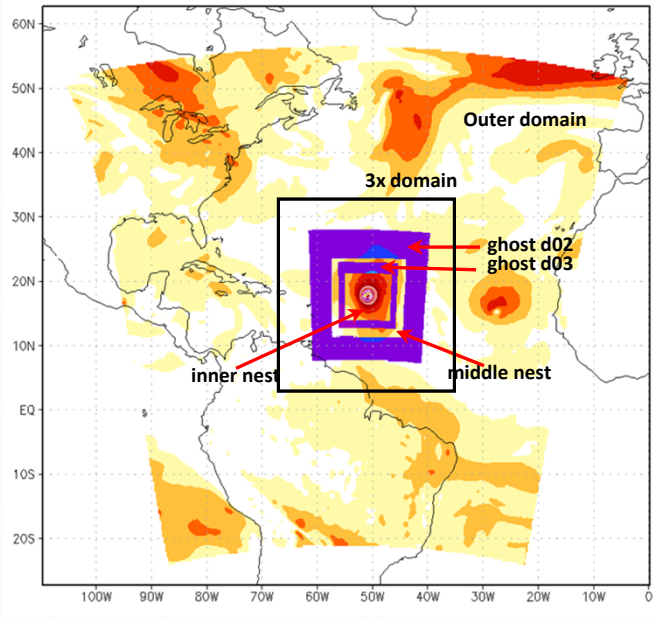




- Data assimilation performed on outer domain. When TDR data are available, data assimilation also performed on ghost d03 after vortex initialization. Vortex initialization performed on 3x domain prior to the DA.
- GSI hybrid analysis using global 80 EnKF ensemble member at T254L64.
- First guess
  - TC environment cold start from GDAS forecast
  - TC vortex cycled from HWRF forecast
  - First Guess at Appropriate Time (FGAT)
- Observational data
  - outer domain: conventional data (radiosondes, dropsondes, aircraft reports, surface ship and buoy observations, surface observations over land, pibal winds, wind profilers, VAD wind, scatterometer winds, GPS-derived integrated precipitable water)
  - ghost d03: conventional data and TDR data
  - satellite radiance, satellite derived wind and GPS RO data are **not** assimilated in the 2013 operational HWRF.

HDAS Upgrades for 2014 Implementation





- Data assimilation performed on ghost d02 (20°x20°, 9km) and ghost d03 (10°x10°, 3km) after vortex initialization. GFS analysis is used in outer domain. No DA for outer domain.
- GSI hybrid analysis using global EnKF 80 ensemble member.
- First guess:
  - TC environment cold start from GDAS forecast
  - TC vortex cycled from HWRF forecast
  - First Guess at Appropriate Time (FGAT)
- Observational data:
  - ghost d02: conventional data (including dropsonde data), TDR data and Satellite Data
  - ghost d03: conventional data (including dropsonde data) and TDR data (no satellite data for 3km analysis)

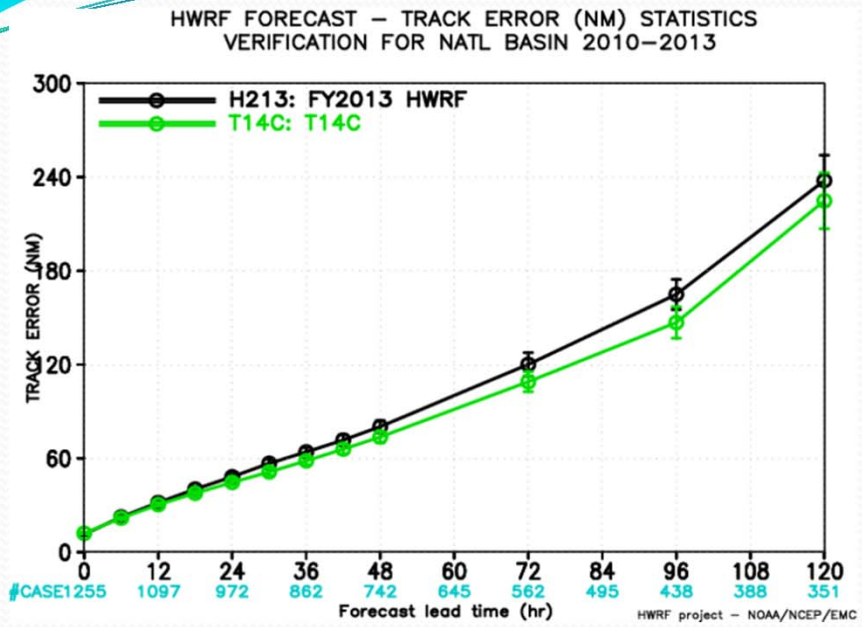
Satellite radiance assimilation for 9km (ghost_d02) domain:

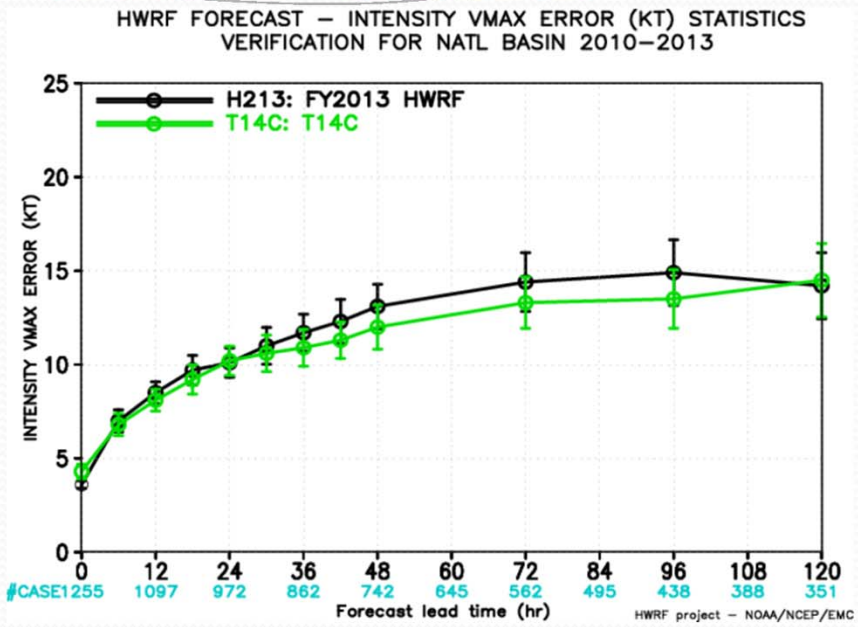
- use GFS-HWRF blended vertical coordinate (75 levels)
- use bias correction estimations from global analysis
- use GFS ozone profiles

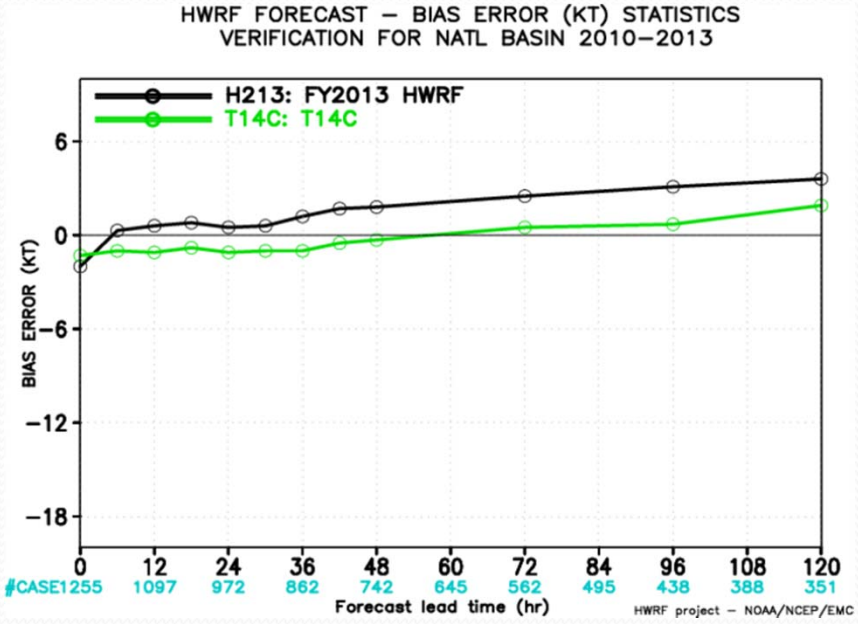
Satellite Data:

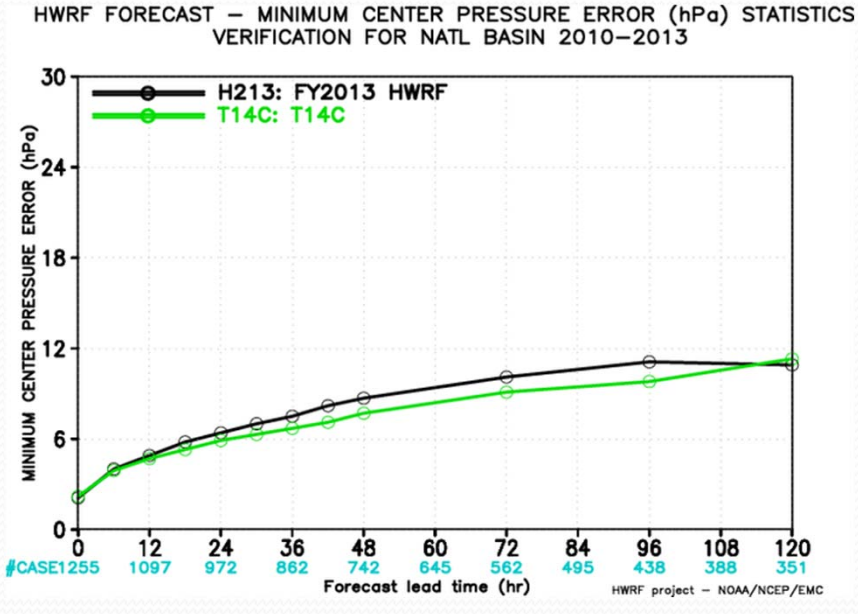
Radiances from IR instruments (HIRS,AIRS, IASI, GOES Sounders), Radiances from MW instruments (AMSU-A, MHS, ATMS), Satellite derived wind, GPS RO bending angle

Preliminary Results from FY14 HWRF Configuration with DA upgrades (without Physics upgrades) 2010-2013 ATL basin

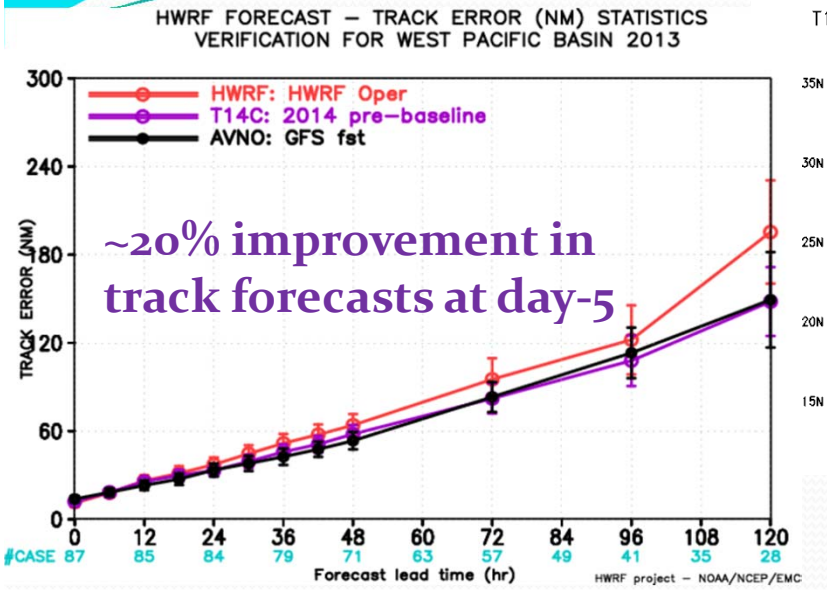


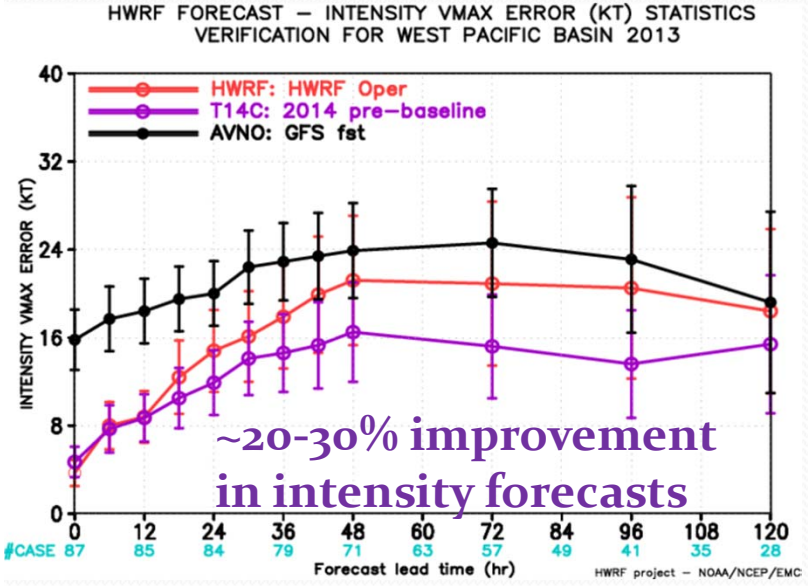


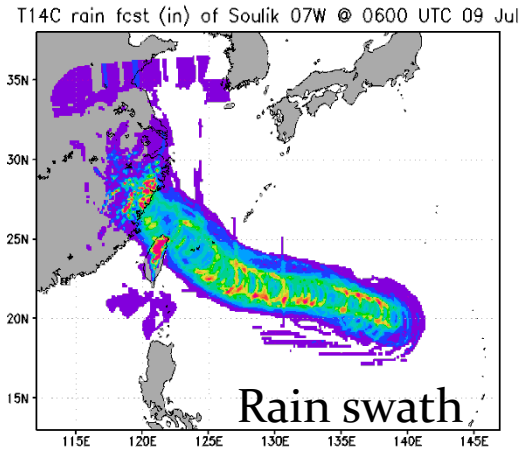


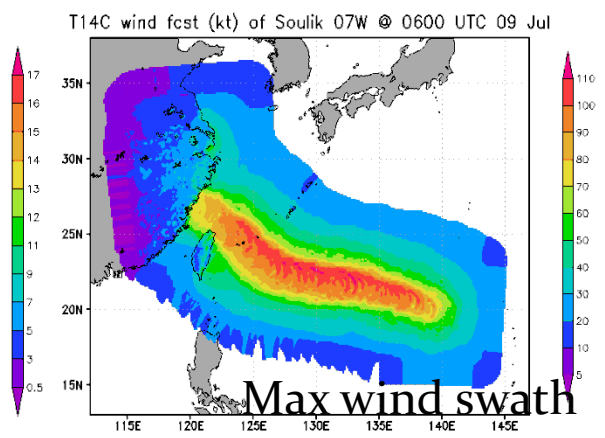


HWRF in 2014 for West Pac: Further improvements









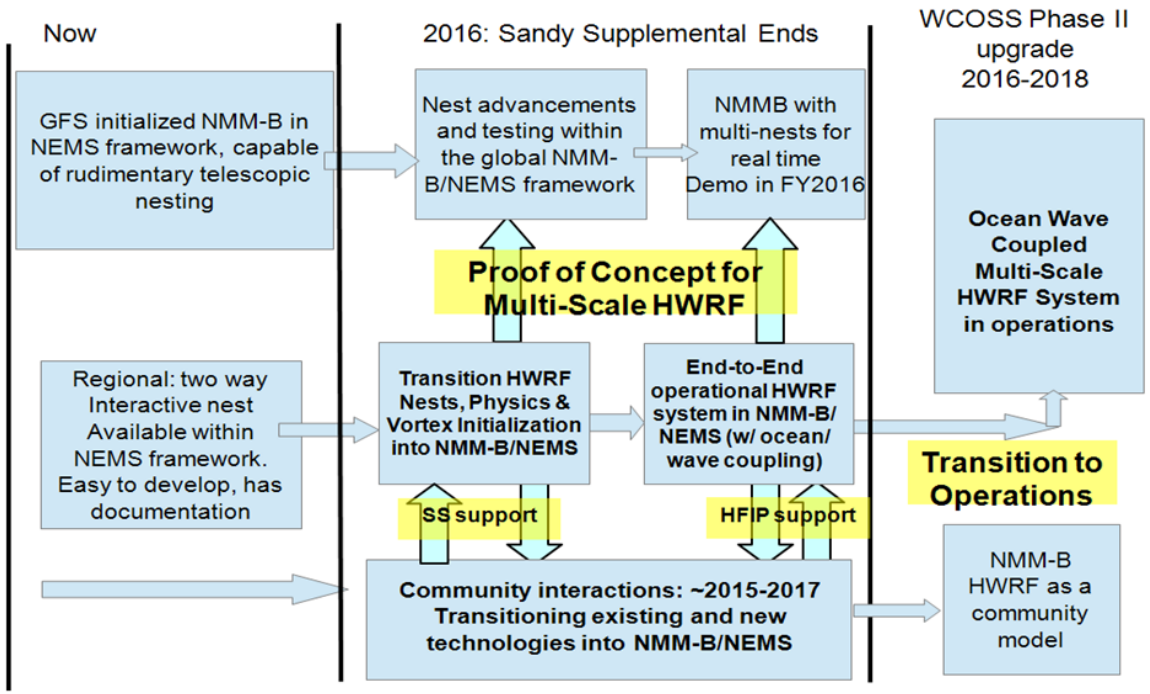
- **2014 HWRF is configured with higher vertical resolution and increased model top**
- **Further enhancements to physics and data assimilation**
- **Preliminary results indicate significant improvements in track and intensity for Western Pacific (similar performance noted for Atlantic and Eastern Pacific basins)**
- **More accurate wind and rainfall products, with possible downstream applications to include hydrology, wave and surge guidance for landfalling storms**

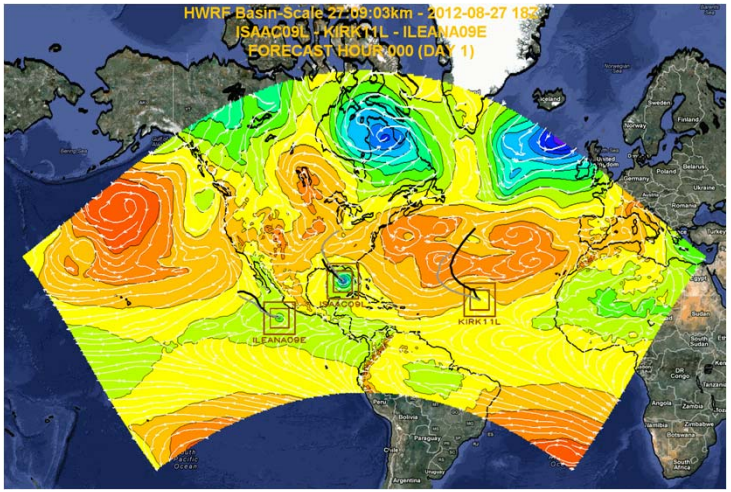
Advancements to Operational HWRF – Transition to NMM-B/NEMS Multi-Scale Modeling System

- **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**





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 HRD, NHC, DTC, GFDL, URI, CIRA, ESRL and other HFIP partners