Hurricane WRF: 2018 Operational Implementation and Community Support

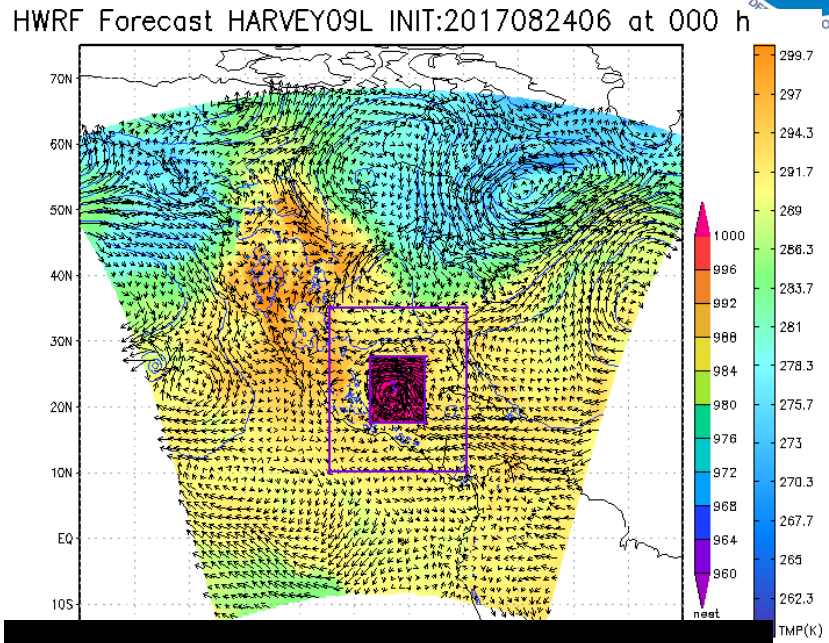
B. Liu, A. Mehra, Z. Zhang, K. Newman, E., Kalina, S. Abarca, L. Bernardet, M. Biswas, L. Carson, J. Dong, J. Frimel, E. Grell, H.-S. Kim, Q. Liu, Z. Ma, J. Meixner, D. Sheinin, J. Sippel, B. Thomas, W. Wang, H. Winterbottom, K. Wu, L. Zhu, and V. Tallapragada

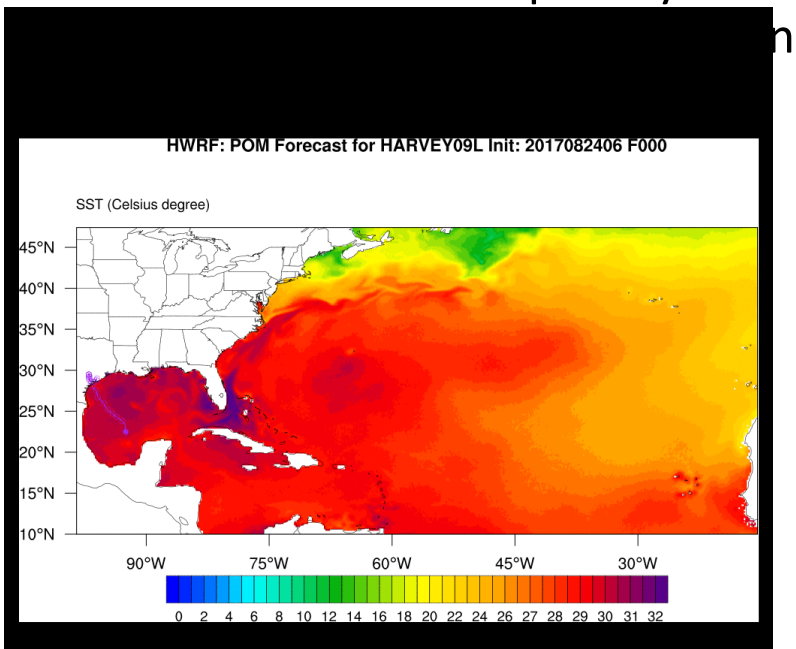
2018 Joint WRF/MPAS Users' Workshop, June 11-15, 2018

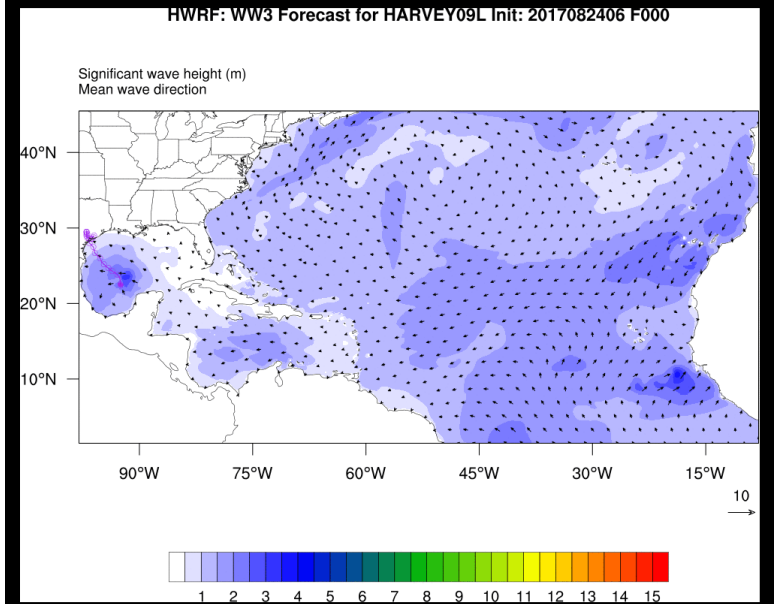
HWRF Overview

- HWRF is the NCEP operational hurricane model providing model guidance to global tropical cyclones
- Built within WRF infrastructure and based on WRF-NMM dynamic core
  - Rotated lat-lon projection
  - Arakawa E-grid
  - Hybrid sigma-pressure vertical coordinate
  - Triple nested vortex following domains
- HWRF is an air-sea coupled system

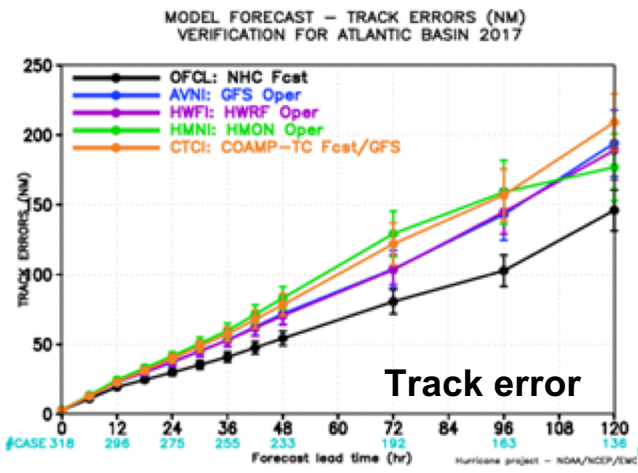
ng

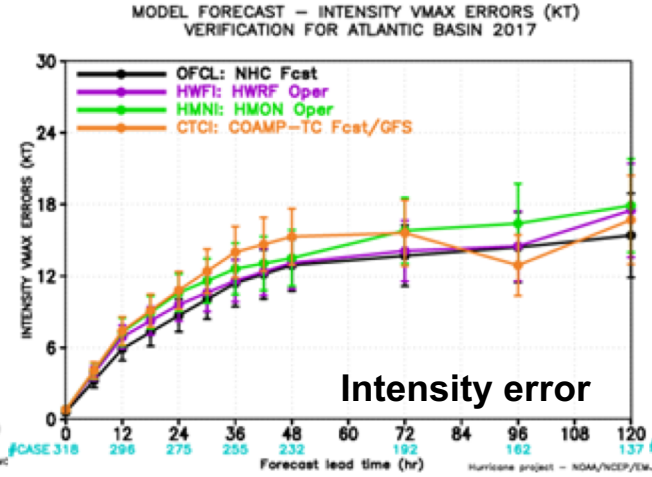


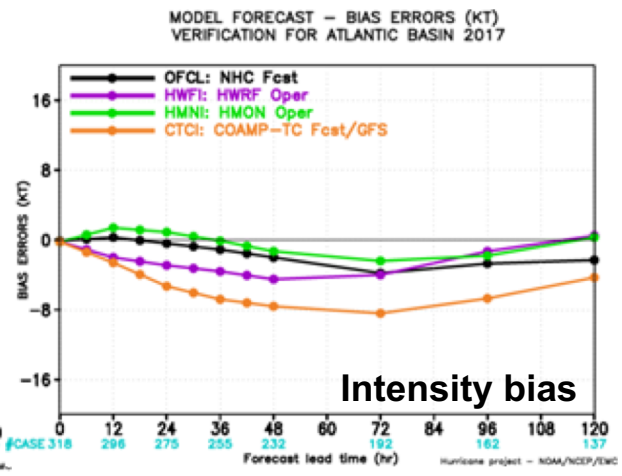


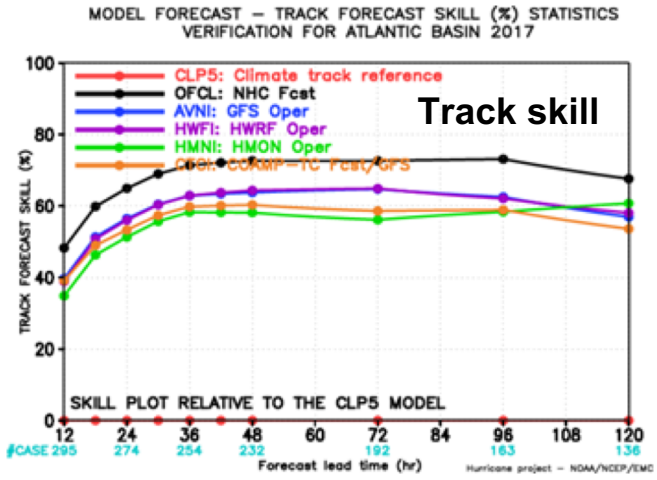


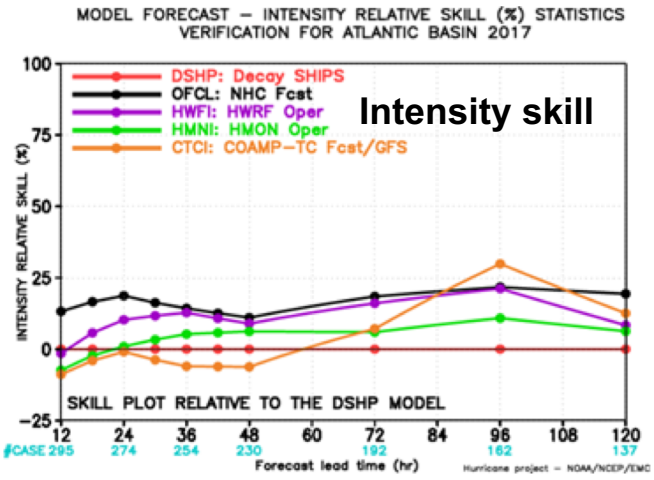
FY2017 HWRF for 2017 NATL Storms
Real-Time Performance (Early Guidance)







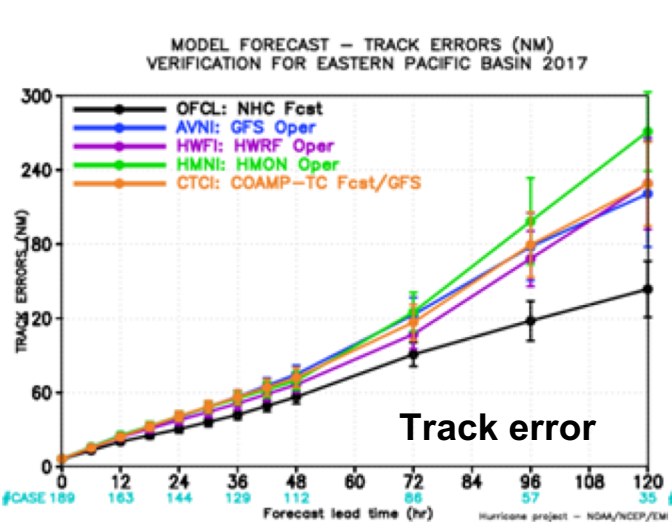


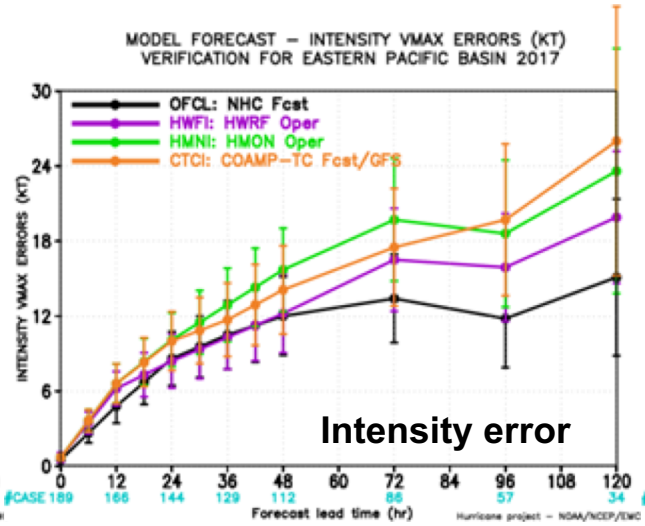


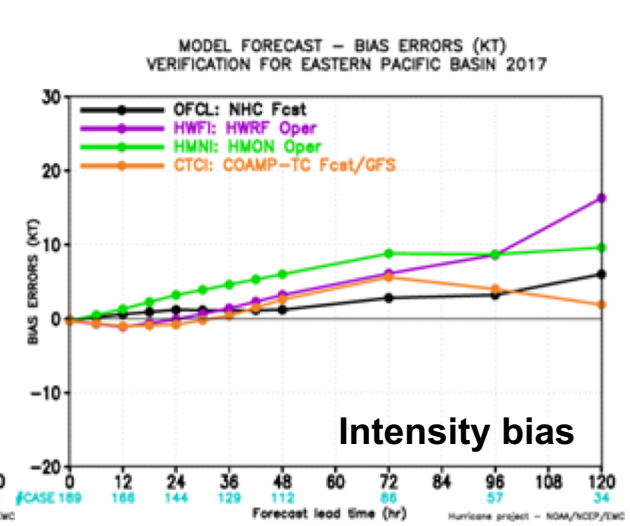
HWRF
HMON
CTCX
GFS
OFCL

Track guidance close to GFS forecast
Best intensity forecast among dynamical guidance models

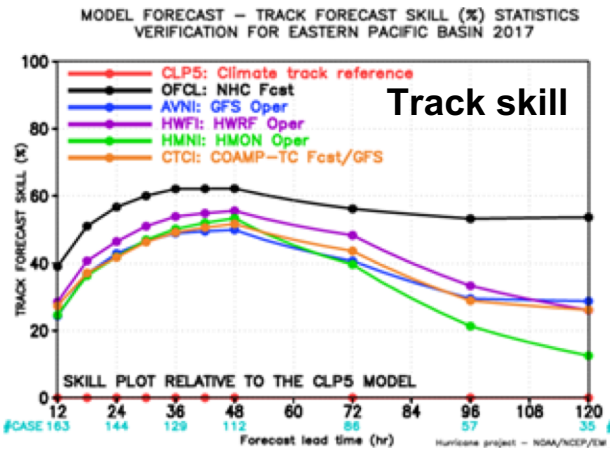
FY2017 HWRF for 2017 EPAC Storms Real-Time Performance (Early Guidance)

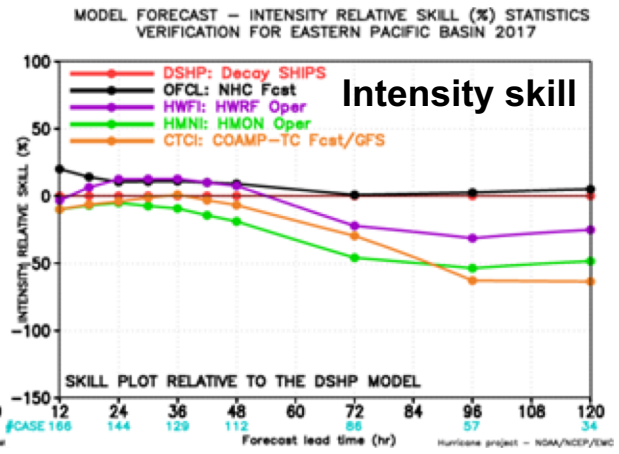






HWRF
HMON
CTCX
GFS
OFCL





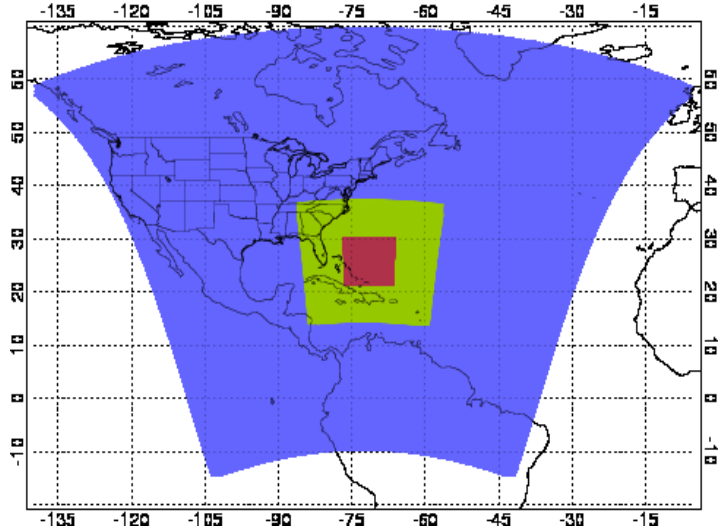
Better track forecast than GFS and other regional guidance models
Best intensity forecast among dynamical guidance models

Highlights of FY2018 HWRF Upgrades

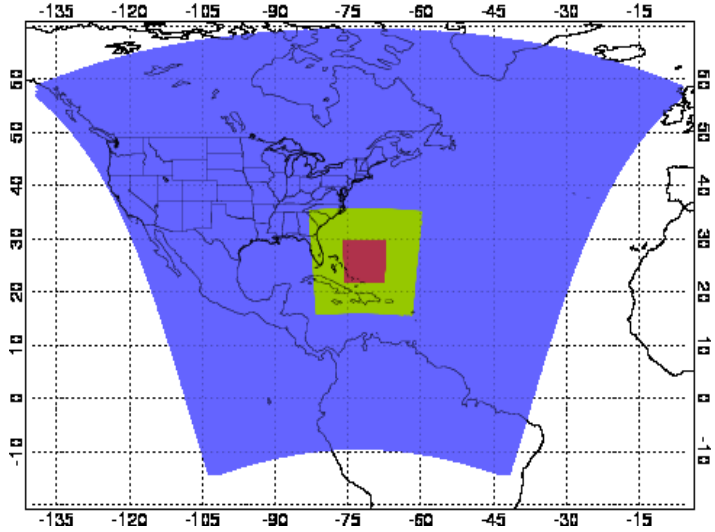
- Infrastructure Enhancements
  - Upgrade dynamic core from WRF3.8.1a to WRF3.9.1 (with bug fixes)
  - T&E with 2017 4D-Hybrid GDAS/GFS IC/BC
  - Increase horizontal resolution from (18/6/2-km) to (13.5/4.5/1.5-km)
  - Slightly reduced domain sizes for the two nested domains
  - Unify the vertical level configuration for all global TC basins (L75 with a model top of 10 hPa)
  - ~~Increase parent domain size~~ (collaboration with HRD)
- Vortex Initialization/DA Improvements (collaboration with HRD)
  - GSI code upgrades and disable SSMI channel 2 data
  - Stochastic physics for self-cycled DA ensemble members
  - Admit new data sets (GOES-16 AMVs, NOAA-20, SFMR, TDR from G-IV)
  - Considering dropsonde drifting
- Physics Advancements
  - Adjust the horizontal diffusion and convergence damping coefficients
  - Upgrade the RRTMG scheme with a modified cloud overlap method (DTC visitor program)
  - ~~In-cloud mixing modification for GFS EDMF PBL scheme~~ (collaboration with Zhu, FIU)
  - ~~YSU PBL scheme~~ (collaboration with Fovell, University at Albany - SUNY)
- Air-Sea Interaction and Coupling
  - Unified HWRF/HMON coupler with double precision coordinates from the HWRF component
  - Add a POM ocean domain for the CPAC basin
  - Enable ocean coupling (with HYCOM) for Southern Hemisphere basins
  - Sea surface wave initial condition from global wave model

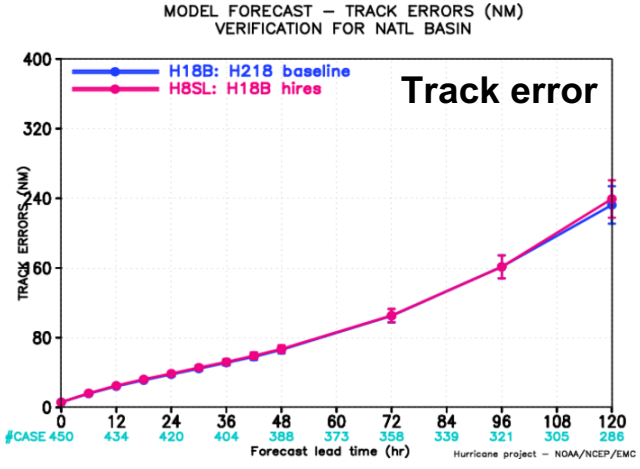
Toward High Resolution Convection Resolving Modeling in Operational HWRF

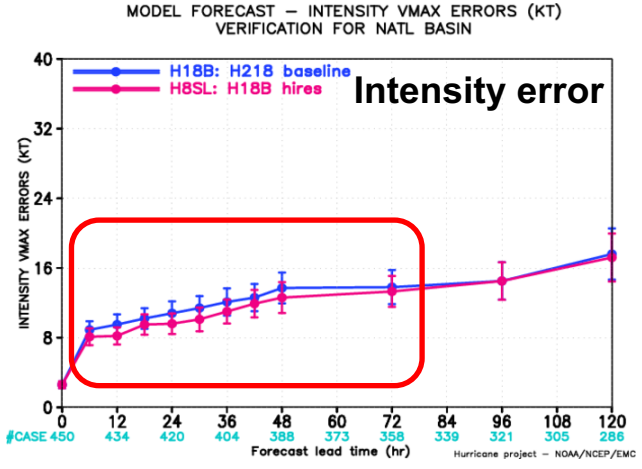
FY2017 HWRF: 18/6/2 km

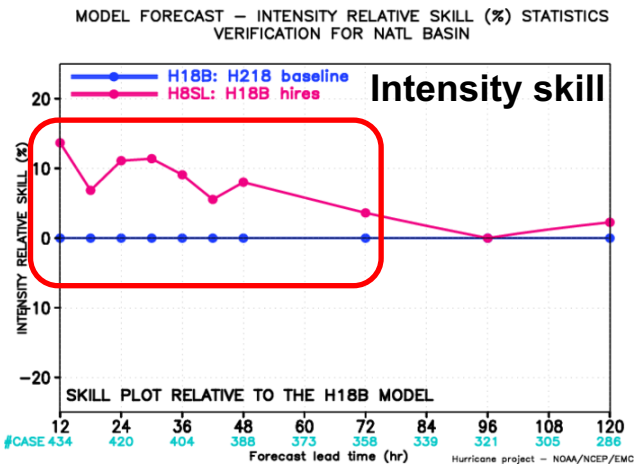


FY2018 HWRF: 13.5/4.5/1.5 km



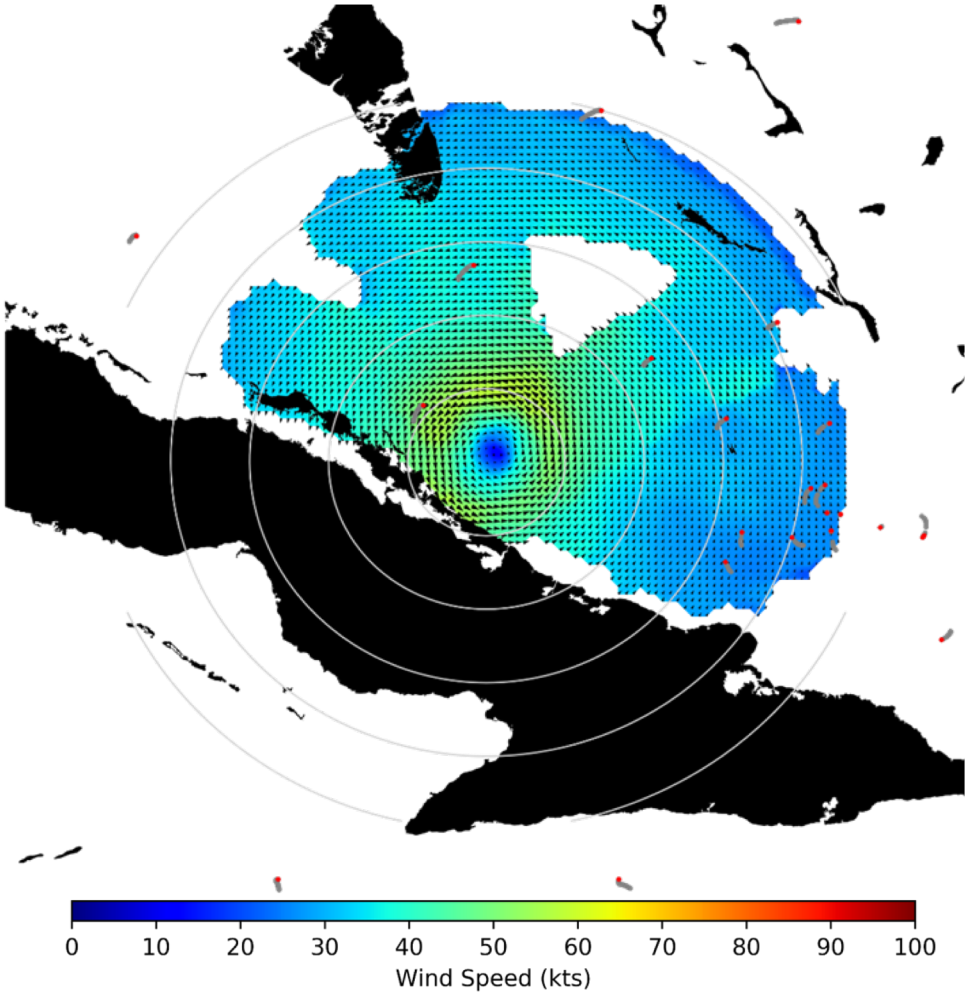




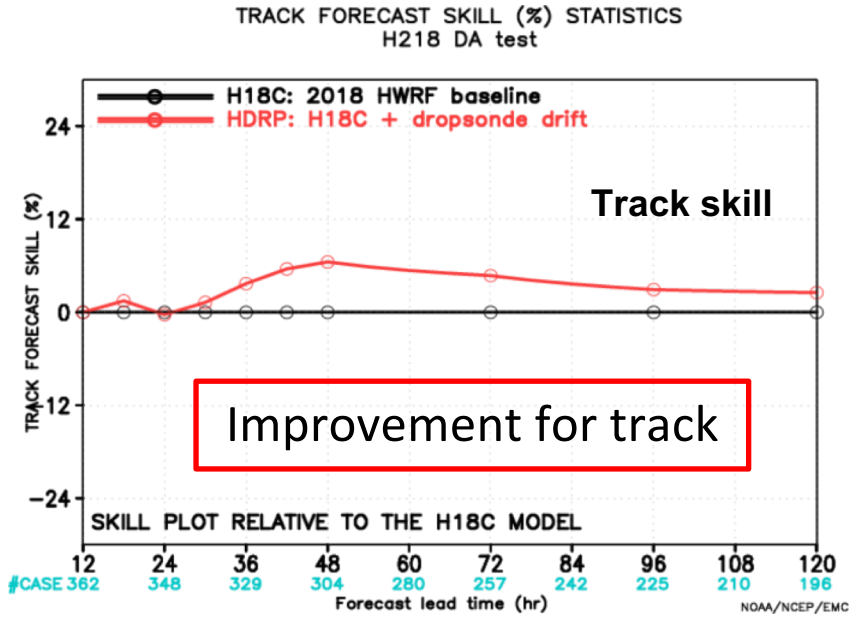


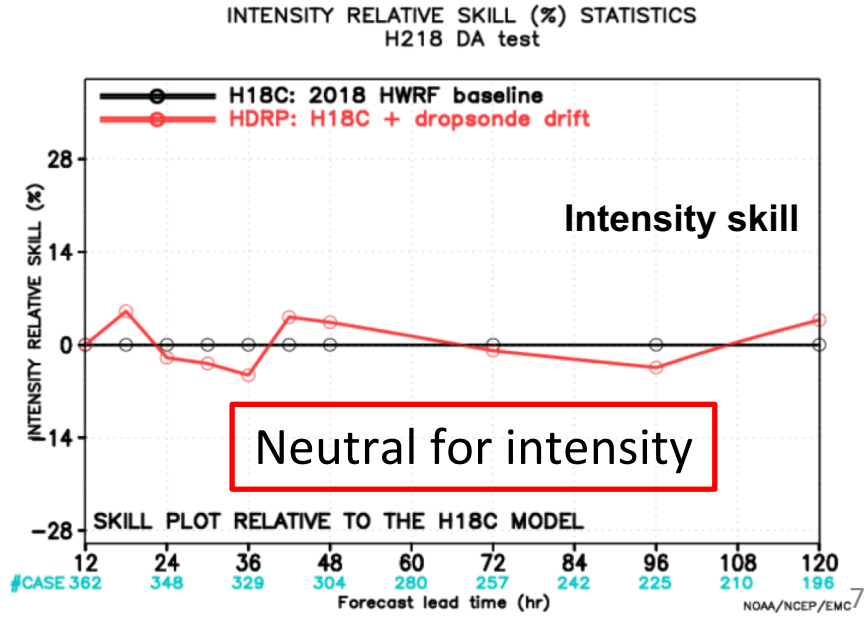
Overall neutral impact for track while substantial improvements for intensity

Considering Dropsonde Drifting



Observed radar winds (shaded) and wind vectors (arrows), and the dropsonde release locations (red), and subsequent computed dropsonde advection trajectories (grey) for Hurricane Irma (11L2017) on 08 September.





Modified Cloud Overlap Method for RRTMG Radiation Scheme

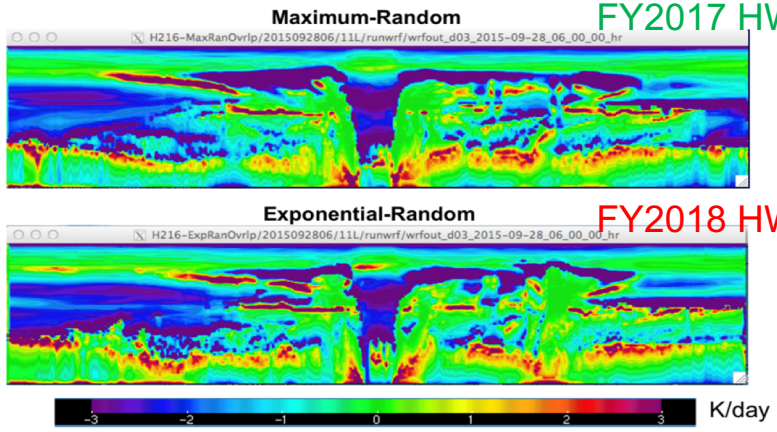
"Maximum-random" (FY2017 HWRF)

- Continuous cloud layers overlap as much as possible; blocks of cloud layers with clearance between are oriented randomly

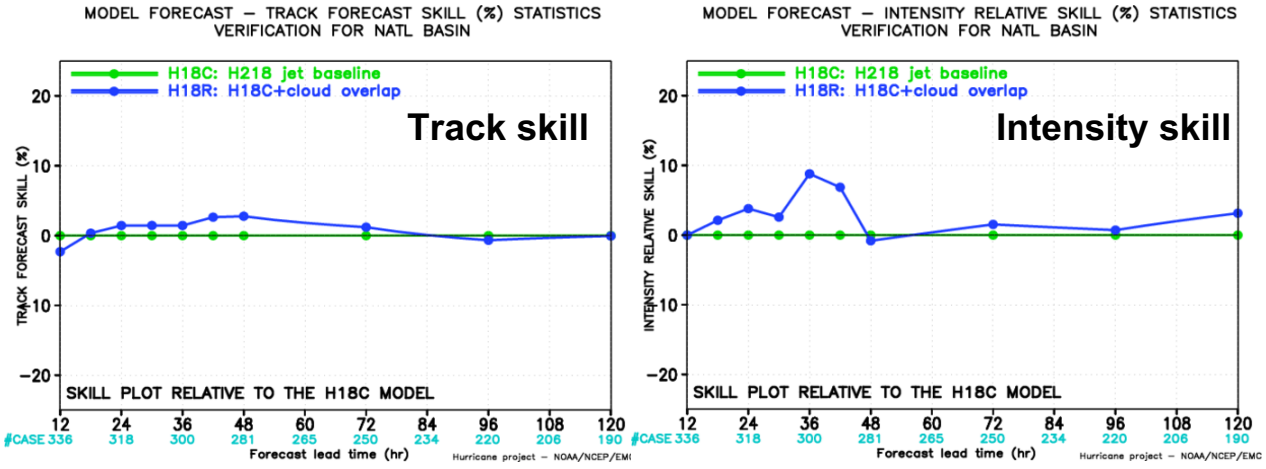
"Exponential-random" (FY2018 HWRF)

- Continuous cloud layers use overlap that transitions exponentially from maximum to random with distance through clouds, blocks of cloud layers with clearance between are oriented randomly
- Constant decorrelation length (Z_0 = ~1-2 km) controls rate of exponential transition

Radiative Heating Rates - LW

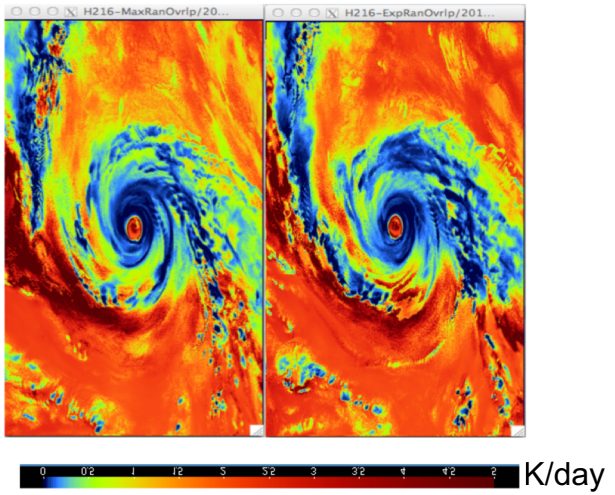


Vertical west-east slice: through Joaquin eye



Radiative Heating Rates - SW

Maximum-Random **Exponential-Random**



FY2017 HWRF FY2018 HWRF

Inner nest at ~900 hPa, Joaquin

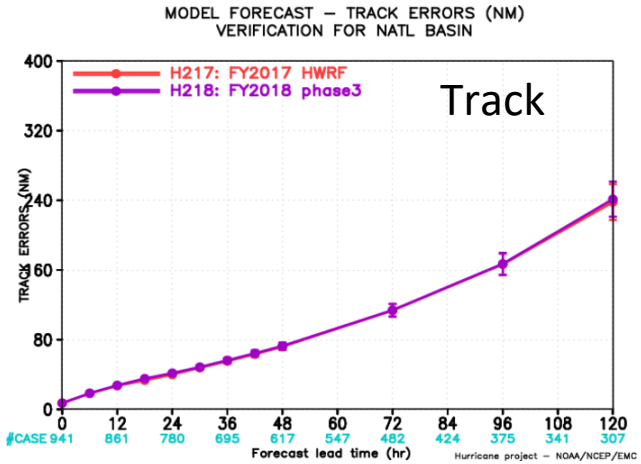
Overall positive impacts for both track and intensity

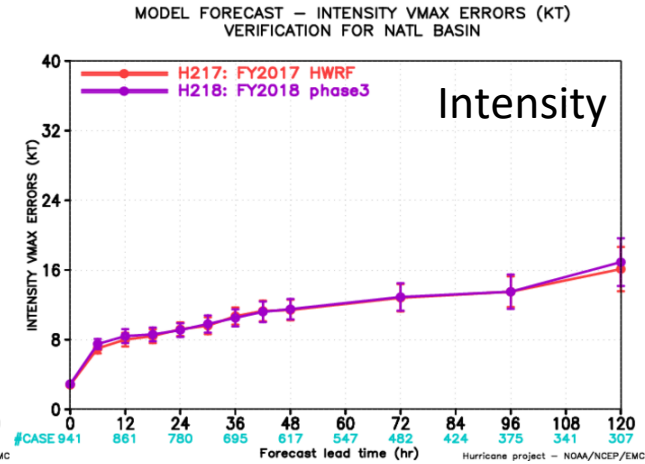
FY2018 HWRF Configurations for Different TC Basins

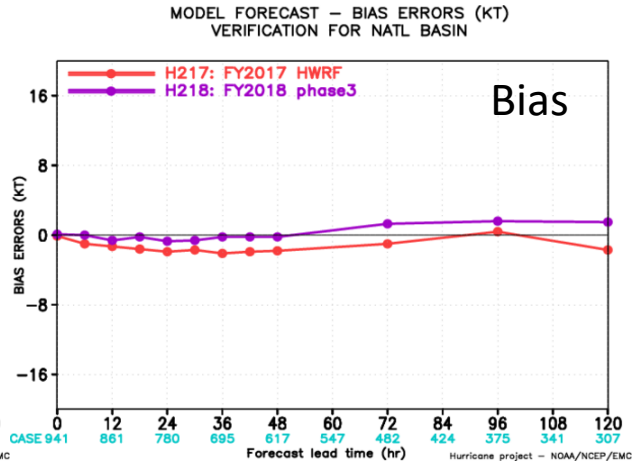
Basin	Ocean Cpling	Wave Cpling	Data Assimilation	Ensemble DA	Vertical	Top
NATL	POM GDEM/GFSSST	WW3 1-way	Always	TDR/priority storm	75 level	10 mb
EPAC	POM RTOFS	WW3 1-way	Always	TDR/priority storm	75 level	10 mb
CPAC	POM RTOFS	WW3 1-way	None	None	75 level	10 mb
WPAC	HYCOM	None	None	None	75 level	10 mb
NIO	HYCOM	None	None	None	75 level	10 mb
SIO	HYCOM	None	None	None	75 level	10 mb
SPAC	HYCOM	None	None	None	75 level	10 mb

- EnKF self-cycled DA system for one TDR or priority storm
- 75 vertical levels with 10-hPa top for all global TC basins
- Ocean coupling for all global TC basins (POM for NHC basins, HYCOM for JTWC basins)
- POM RTOFS initialization for EPAC/CPAC basin
- One-way coupling to wave model for NATL, EPAC, and CPAC
- Sea surface wave IC/BC come from global wave model

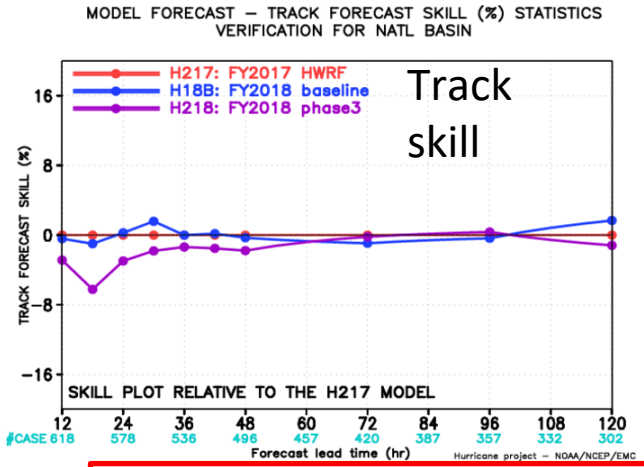
H218 Performance for NATL (2015-2017 storms)

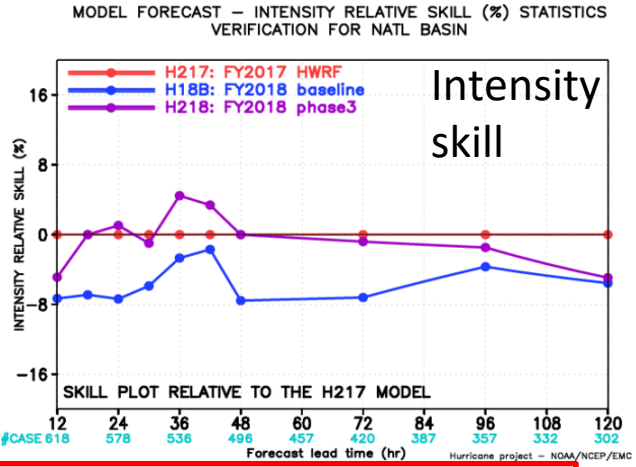






H217
H218
H18B

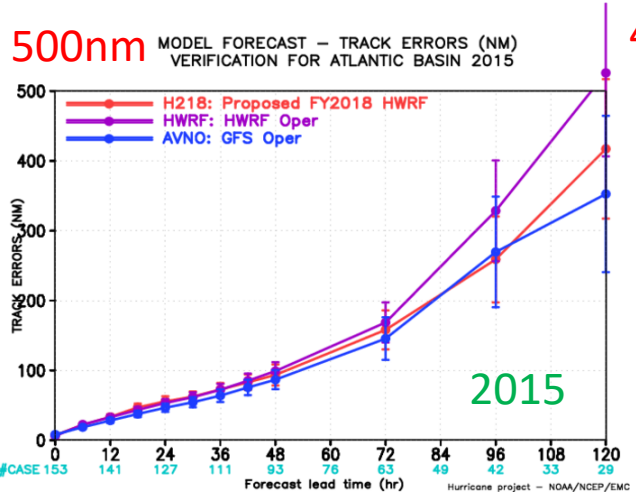




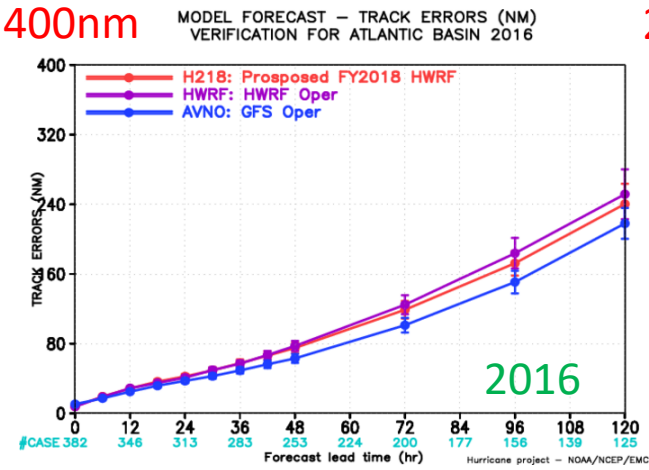
Similar track errors compared to H217 and H18B
Intensity error overall neutral to H217 except day 5, whereas substantially better than H18B
Overall improved intensity bias compared to H217

Continuously Improved Track Forecasting H218 vs Operational HWRF for NATL

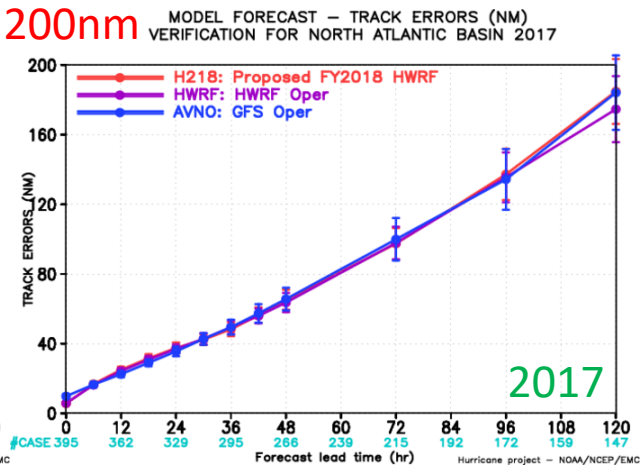
500nm



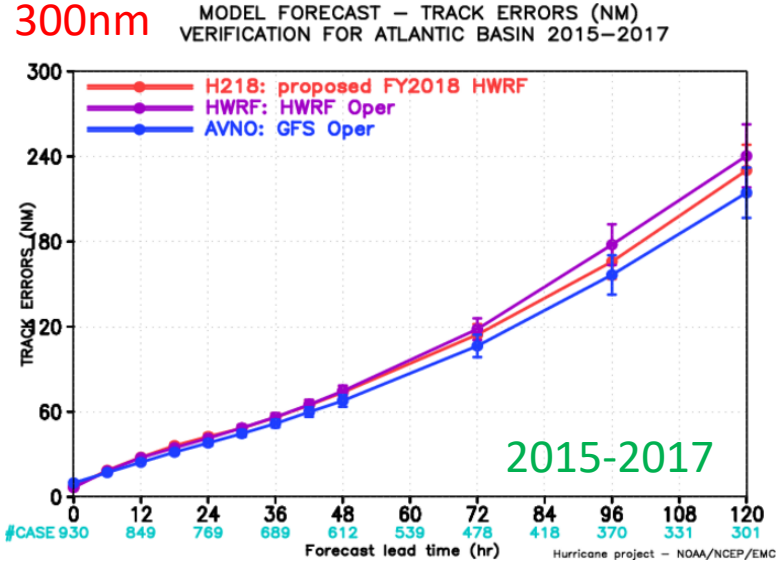
400nm



200nm



300nm



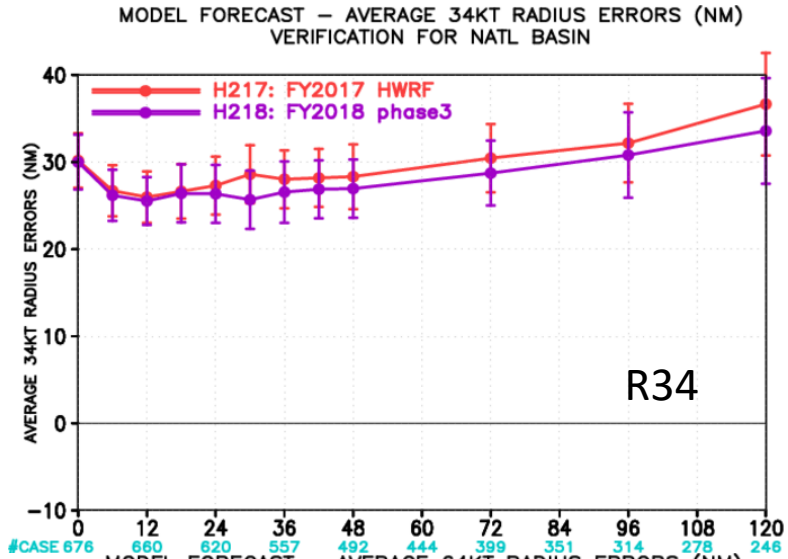
H218 HWRF
Oper HWRF
Oper GFS

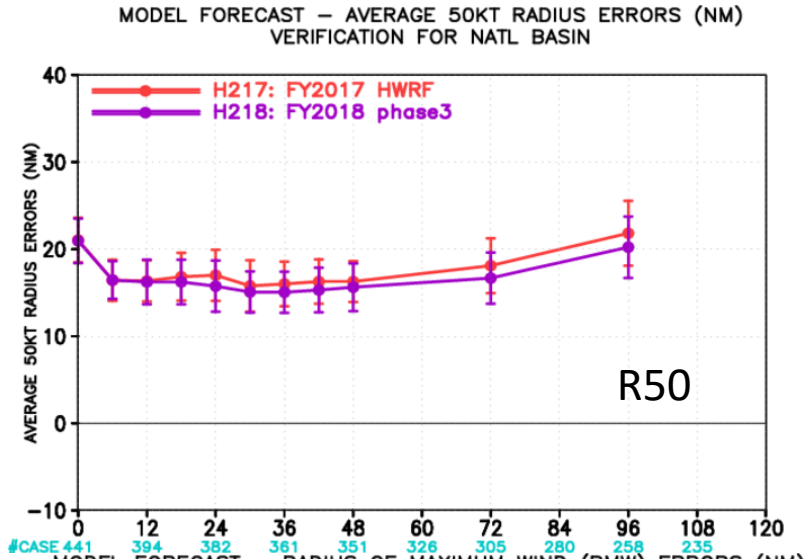
Operational HWRF continuously improves track forecasts for the past three seasons, catching up GFS's track forecasts
H218 maintains track error improvements over operational HWRF

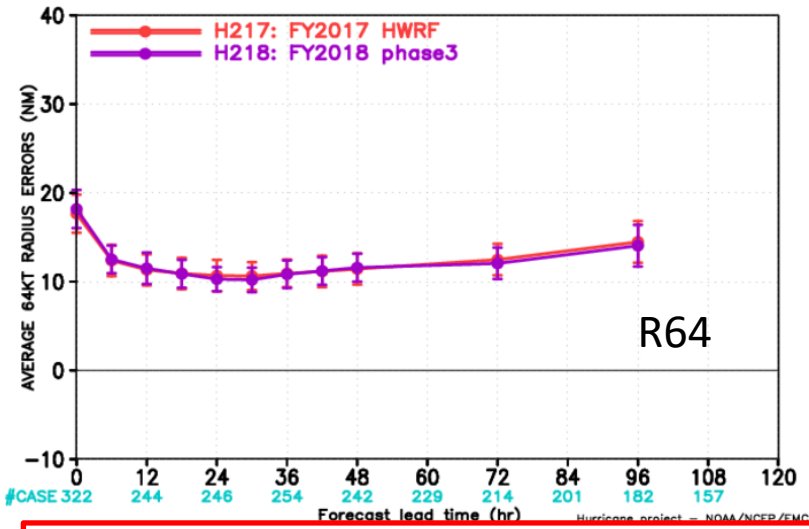
H218 Performance for NATL
(Storm size errors)

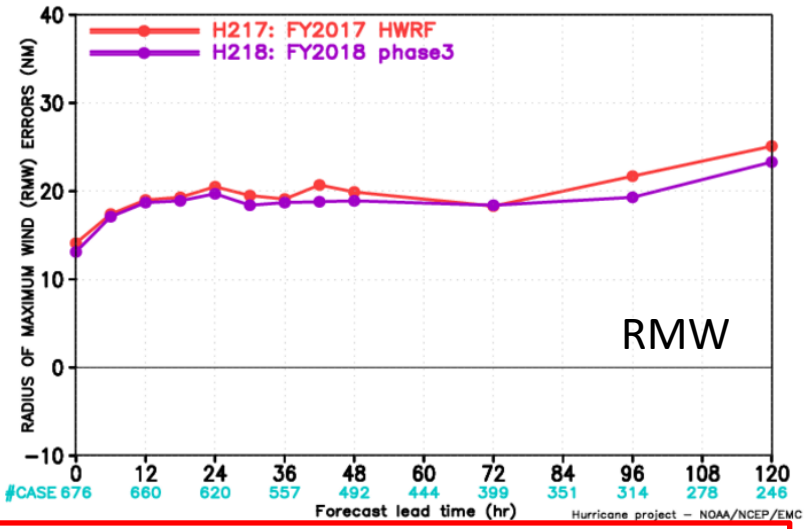
H217

H218



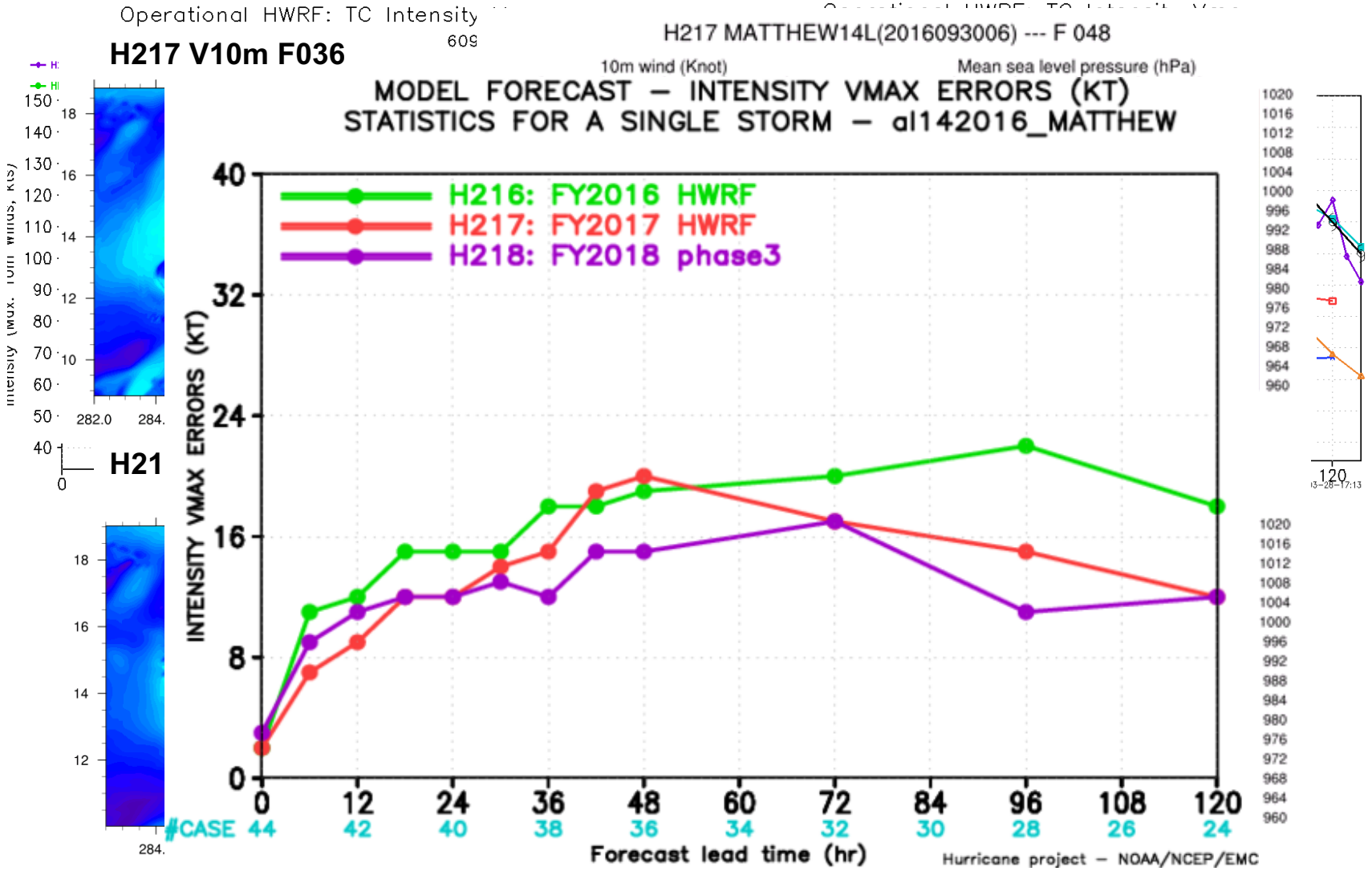




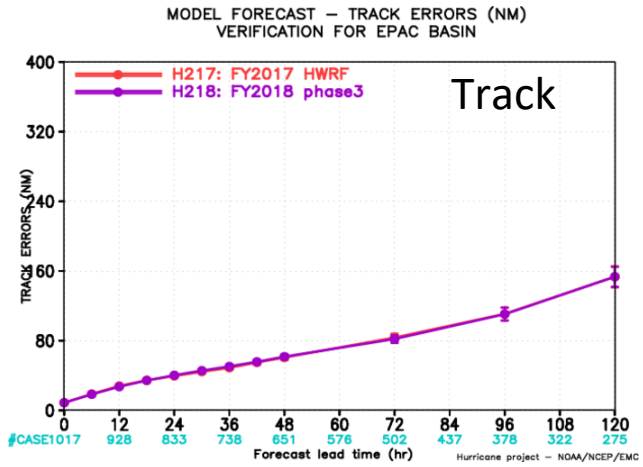


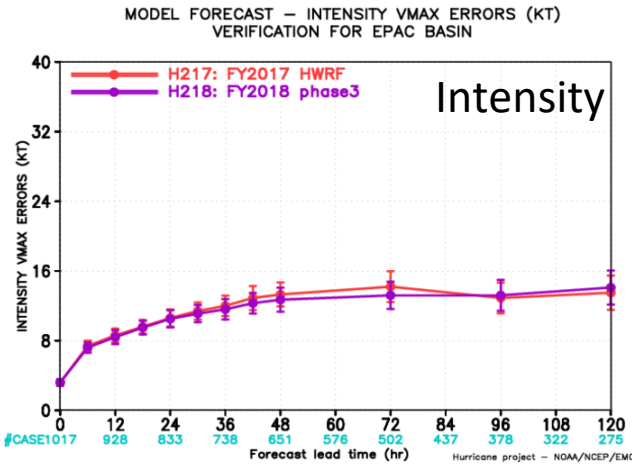
Storm size errors were further reduced in H218 for almost all lead times

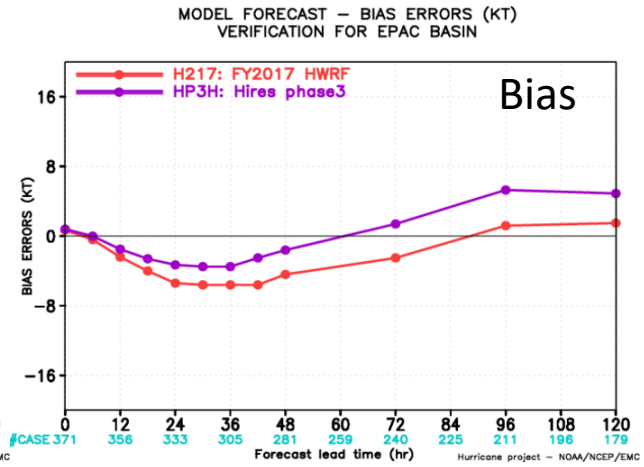
H218 Performance for Matthew (14L2016) Intensity Oscillation



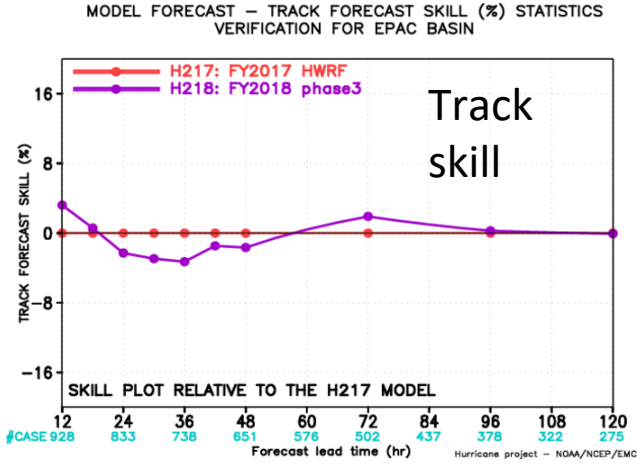
H218 Performance for EPAC (2015-2017 storms)

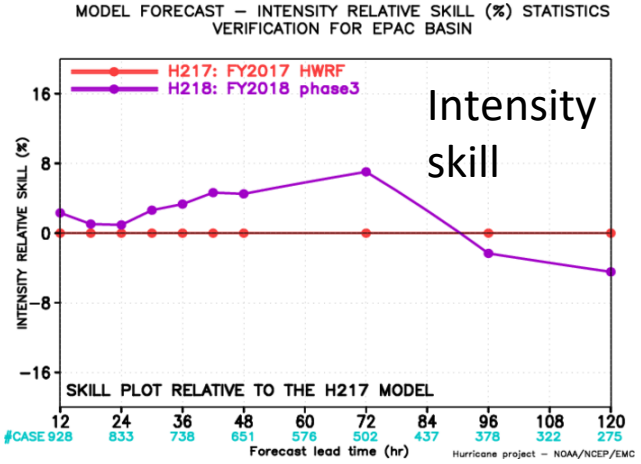






H217
H218

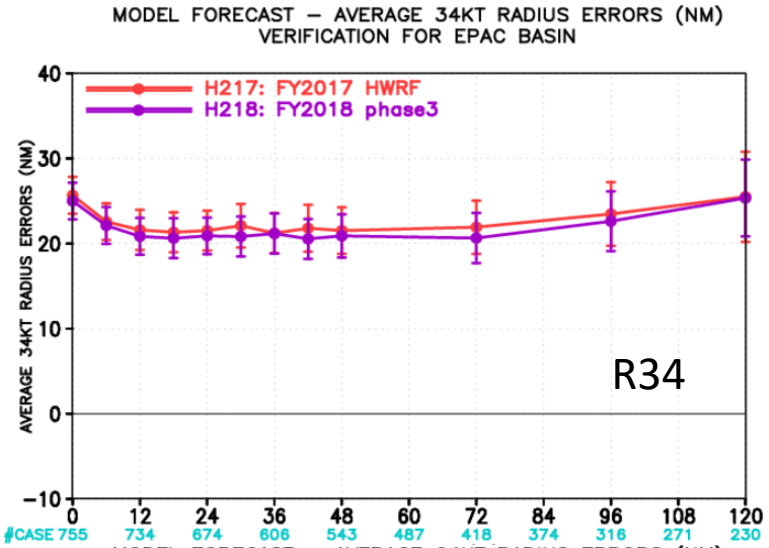


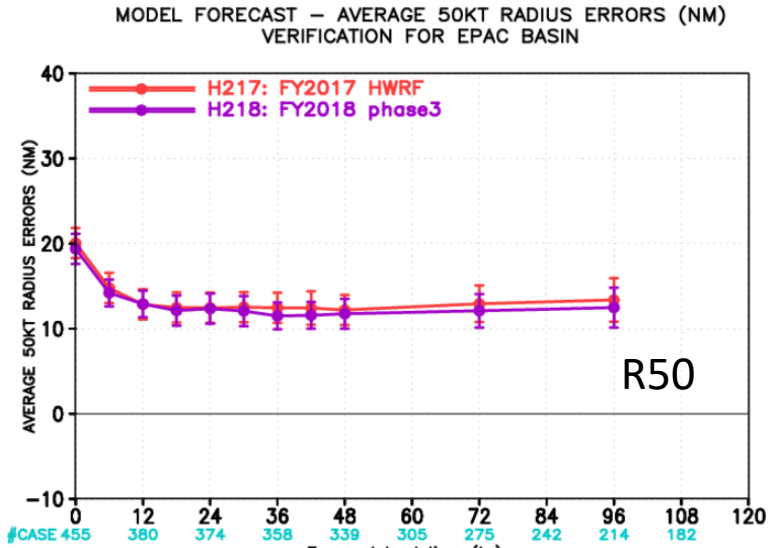


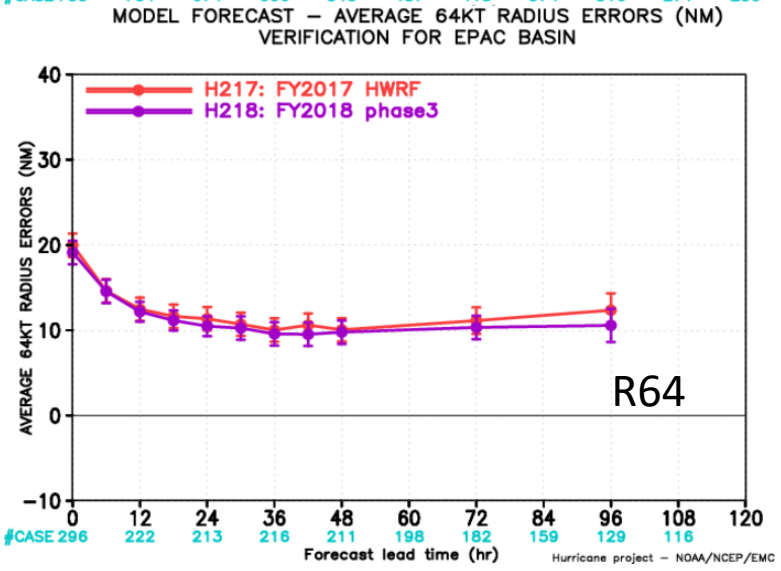
Overall neutral impact for track forecast
Improved intensity error and bias up to day 3, with some degradation for days 4-5

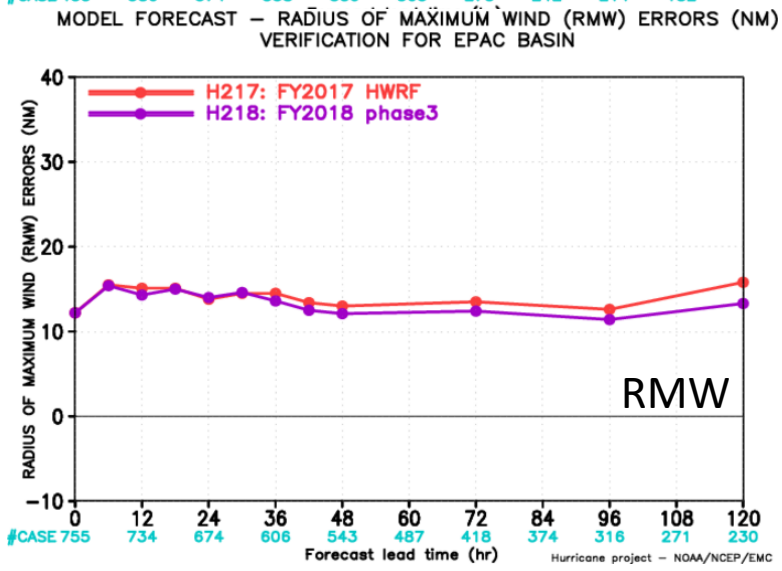
H218 Performance for EPAC
(Storm size errors)

H217
H218





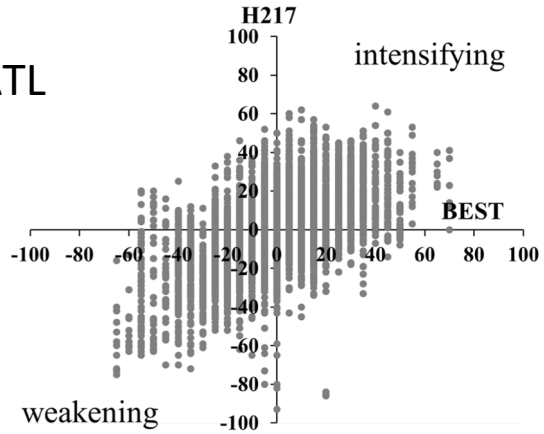




Storm size errors were further reduced in H218 for almost all lead times

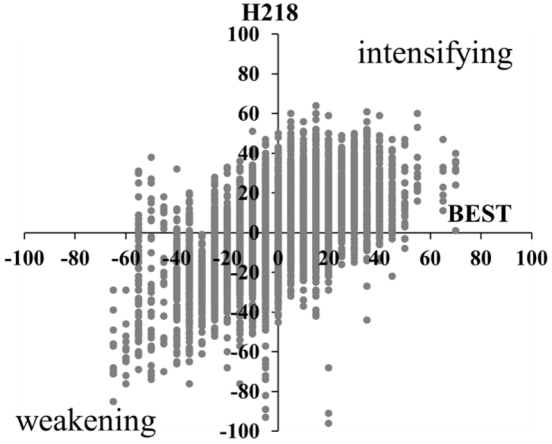
H218 Performance for NATL/EPAC
(Rapid intensification forecast)

NATL



OBS / H217	Yes	No
Yes	79	261
No	396	7894

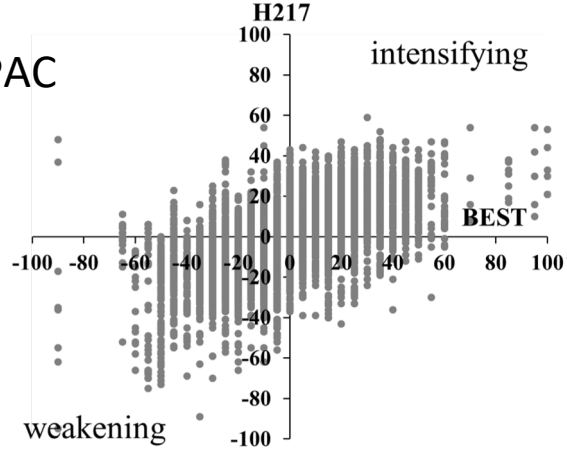
POD = 16.6%
FAR = 76.8%



OBS / H218	Yes	No
Yes	92	356
No	368	7959

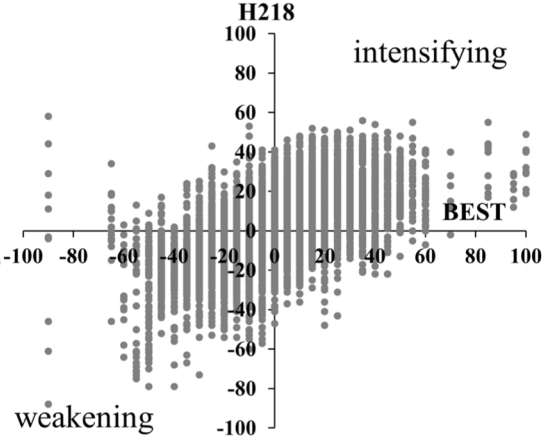
POD = 20.0%
FAR = 79.5%

EPAC



OBS / H217	Yes	No
Yes	93	166
No	647	7114

POD = 12.6 %
FAR = 65.6%



OBS / H218	Yes	No
Yes	113	293
No	668	7699

POD = 14.5 %
FAR = 72.2%

H217 H218

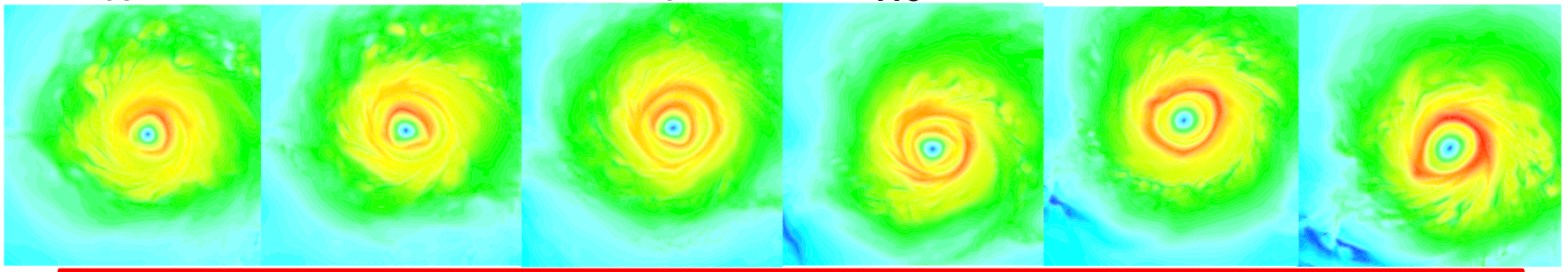
POD: Probability Of Detection
FAR: False Alarm Rate

H218's PODs for the both basins (NATL: 20.0%; EPAC: 14.5%) are improved from H217(NATL: 16.6%; EPAC: 12.6%)
Meanwhile H218's FARs are also higher than H217

Secondary Eyewall Formation in H218

Hurricane Maria (2017), forecast cycle initialized on 20170920 12Z

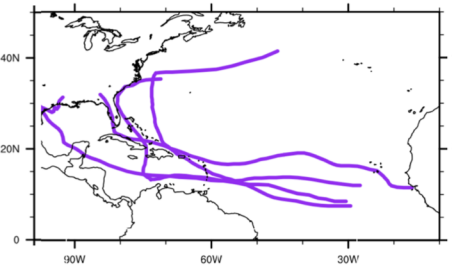
$Vmag_{2km}$ [ms^{-1}]



H218 shows SEs in 82% of the Maria cycles, and multiple SEs in 6% of those cycles

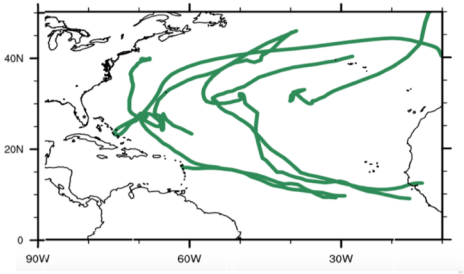
Major Hurricanes (2015-2017)

With SEs



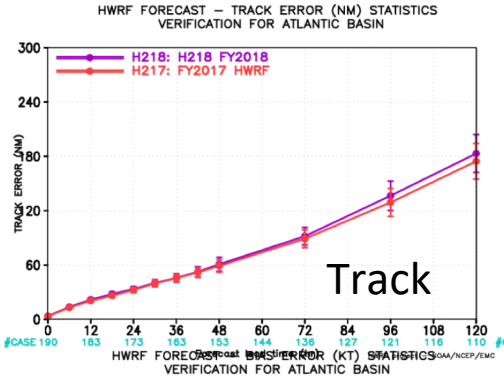
201614L Matthew
201709L Harvey
201711L Irma
201715L Maria

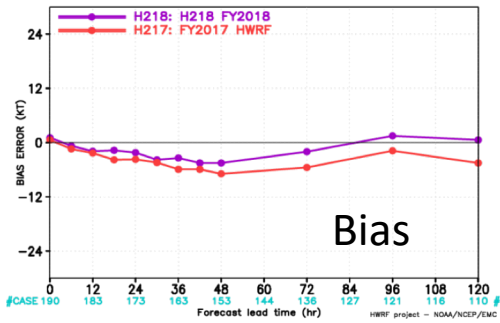
Without SEs



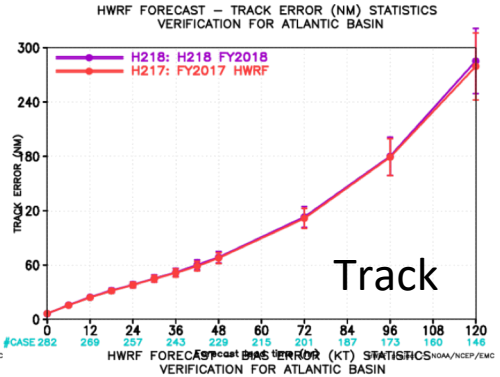
201504L Danny
201511L Joaquin
201615L Nicole
201607L Gaston

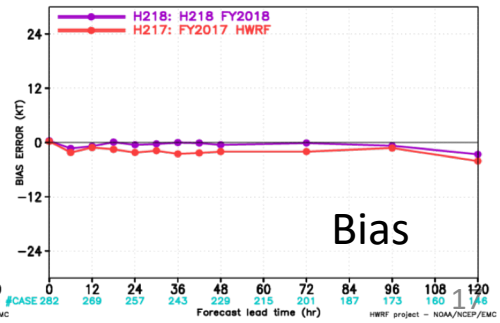
With SEs





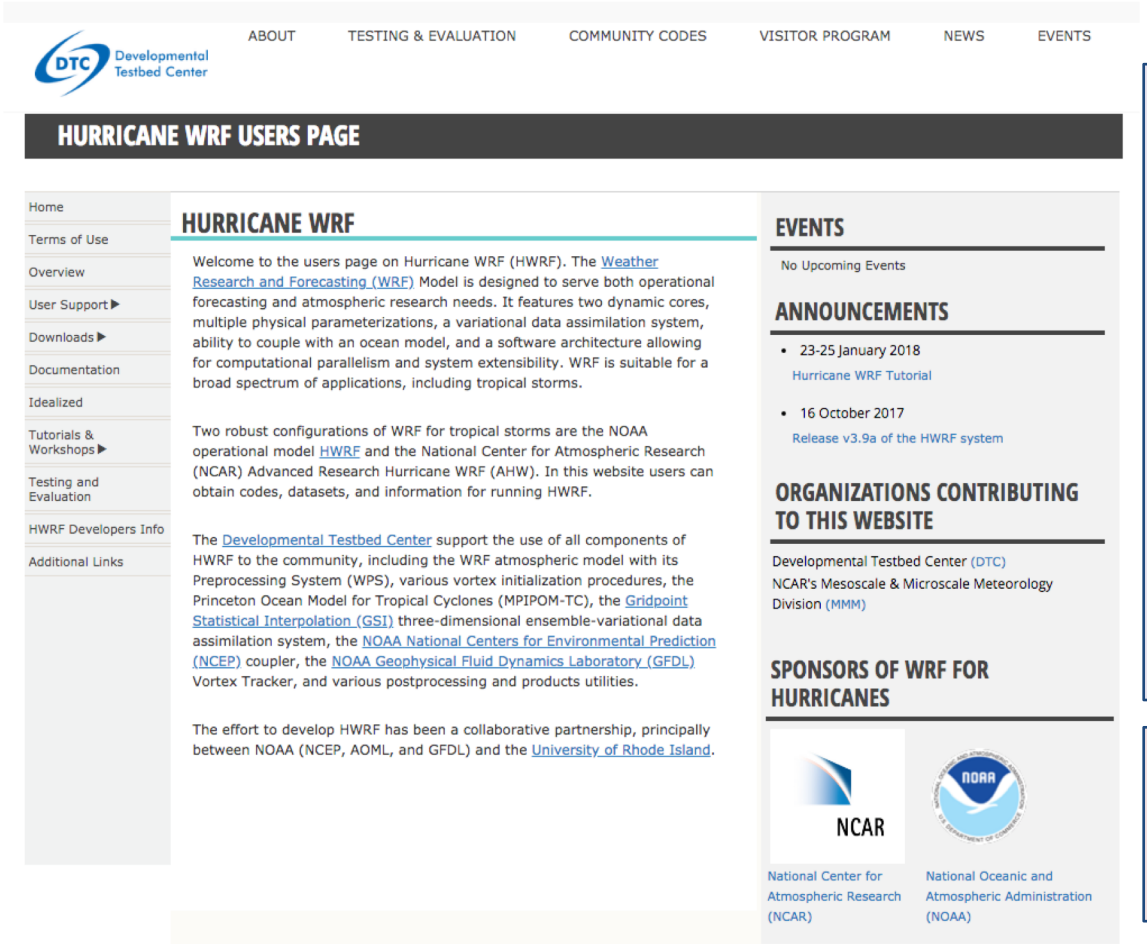
Without SEs





Developmental Testbed Center Support

www.dtcenter.org/HurrWRF/users



- Yearly releases, code downloads, datasets, documentation, online tutorial, helpdesk
- 1600+ registered users
- Stable, tested code
- Benchmarks available

Support to HWRF developers in code management

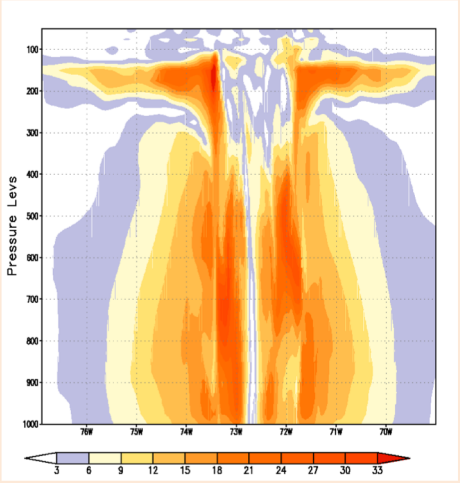
Current release: HWRF v3.9a (2017 operational) - October 2017
Next release: HWRF v4.0a (2018 operational) - planned September 2018

Developmental Testbed Center

HWRF Community Code

HWRF public release

- End-to-end atmosphere-ocean coupled HWRF system corresponding to operational model of the year
  - Freely available and fully supported
- Additional research capabilities
  - Idealized tropical cyclone w/ landfall
  - Compatible with previous operational configurations
    - 27/9/3 km domain
    - d02/d03 grid sizes
    - vertical levels
    - model top
  - Alternate physics schemes
  - Alternate configurations (i.e.: DA, ocean, input datasets)
- Supported for all oceanic basins



HWRF developer support

DTC provides specialized support for HWRF developers using repository code

Streamlines transition of new developments to the HWRF model

DTC visitor program

The DTC is interested in engaging with the community about new developments that could be evaluated for HWRF

http://www.dtcenter.org/visitors/

Summary of FY2018 HWRF Upgrades

- FY2017 HWRF real-time performance
  - Track forecast skill is substantially improved comparing to FY2015-2016 HWRF performance for NATL (similar to GFS track forecast skill)
  - Continues providing very good intensity model guidance (close to official intensity forecast guidance for NATL storms)
- Highlights of FY2018 HWRF upgrades include:
  - Increased horizontal resolution from (18/6/2-km) to (13.5/4.5/1.5-km)
  - Unified vertical level configuration for all basins (L75)
  - Updated RRTMG scheme with a modified cloud overlap method
  - Stochastic physics for self-cycled DA ensemble members
  - Admitting new data sets and considering dropsonde drifting in DA
- FY2018 HWRF retrospective tests demonstrated that:
  - Track forecasts of H218 and H18B are very similar and neutral to H217
  - Intensity forecast of H218 is substantially better than the baseline experiment for NATL storms and better than H217 for EPAC storms
  - Storm size errors are further reduced at all lead times
- Ocean coupling with HYCOM for Southern Hemisphere storms
- One-way coupling to WW3 with surface wave IC/BC from global wave model

Thank you!

Real-time NCEP operational model guidance for all global TCs

HWRF: http://www.emc.ncep.noaa.gov/HWRF

HMON: http://www.emc.ncep.noaa.gov/gc_wmb/vxt/HMON