Verification of 2018 HWRF and HMON Performance

The Hurricane Project Team

NOAA/NWS/NCEP/EMC

Presented by

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**IMSG at EMC/NCEP/NWS/NOAA; [#]EMC/NCEP/NWS/NOAA; [%]HRD/AOML/NOAA*

in collaboration with

HRD/AOML, DTC, NHC, JTWC, GFDL, ESRL, URI, OU, SUNY Albany, CCU, and other HFIP/JHT PIs

HFIP Annual Review Meeting, November 5-7, 2018

GFDL Geophysical Fluid Dynamics Laboratory | DTC | THE UNIVERSITY OF RHODE ISLAND | AOML | NOAA ESRL GSD | NCAR | HFIP | NCEP | IMSG I.M. Systems Group, Inc.

NOAA HURRICANE FORECAST IMPROVEMENT PROJECT

HWRF™ The Hurricane Weather Research And Forecast System

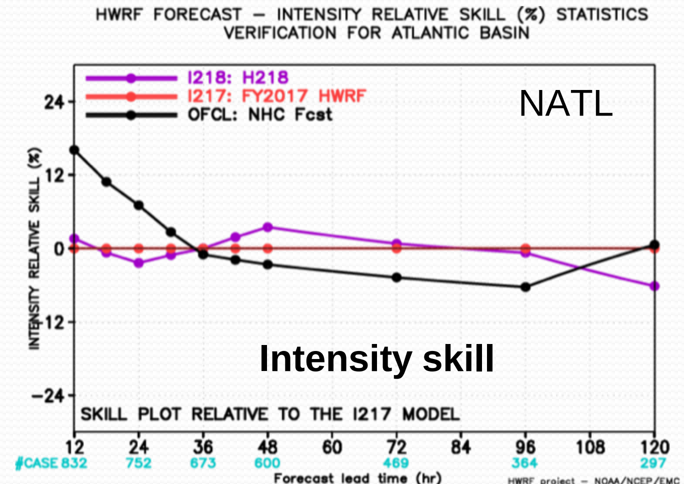
Outline

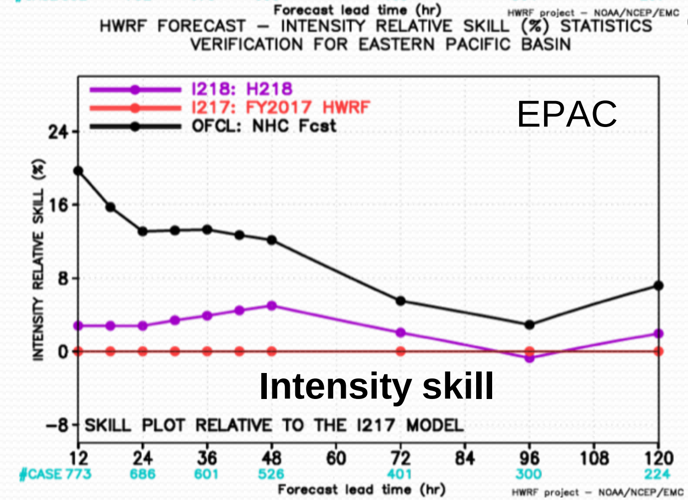
- Overview of FY2018 HWRF and HMON upgrades
- HWRF/HMON performance for different TC basins
- Highlights/discussions of model performance for individual storms
- Summary of FY2018 HWRF and HMON performance

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~~ (with HRD)
- Vortex Initialization/DA Improvements (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/G-IV)
  - Consider dropsonde drifting
- Physics Advancements
  - Adjust the horizontal diffusion and convergence damping coefficients
  - Updated RRTMG scheme with a new cloud overlap method (DTC/AER)
  - ~~In-cloud mixing modification for GFS EDMF PBL scheme~~ (Zhu, FIU)
  - ~~YSU PBL scheme~~ (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

H218 intensity forecast
for 2015-2017 NATL/EPAC storms



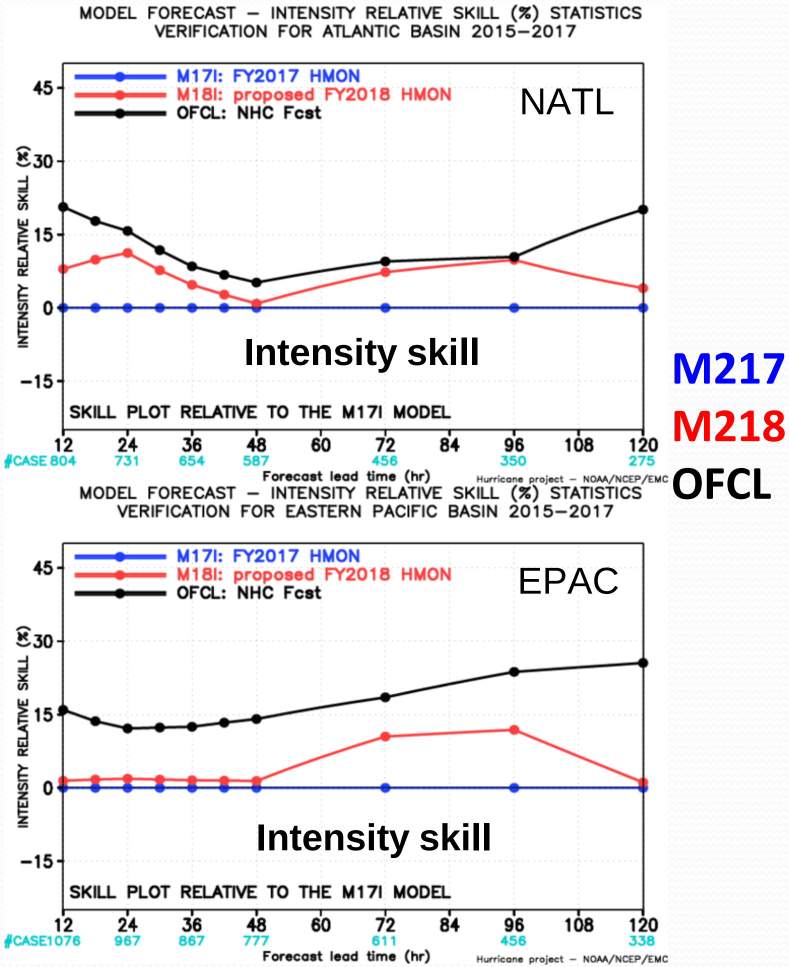


H217
H218
OFCL

Highlights of FY2018 HMON Upgrades

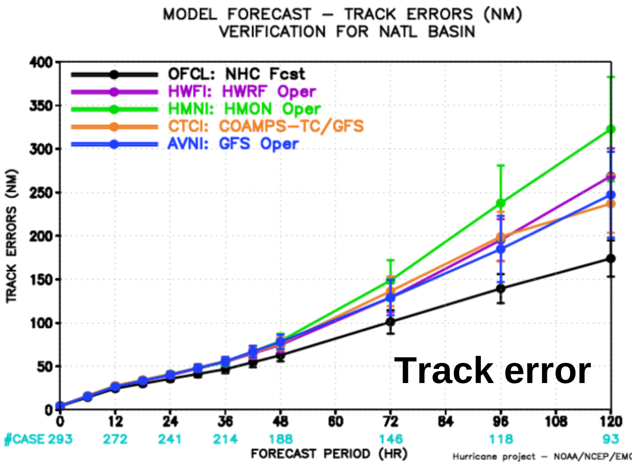
- System and Resolution Enhancements
  - Upgrade to the latest NMMB dynamic core (with bug fixes)
  - T&E with 2017 4D-Hybrid GDAS/GFS IC/BC
  - Increase vertical levels from 42 to 51 with a model top of 50 hPa
  - NMMB dynamic core optimization (IBM analyst)
  - Change diffusion parameterization
- Initialization Improvements
  - ~~Updated composite vortex~~
- Physics Advancements
  - Update momentum and enthalpy exchange coefficients
  - Use scale-aware SAS scheme
  - Use GFS-EDMF PBL scheme
  - ~~Explore using of MYJ surface layer + MYJ PBL~~
- Coupling Upgrades
  - Use unified HWRF/HMON coupler
  - Add HYCOM coupling in NATL basin

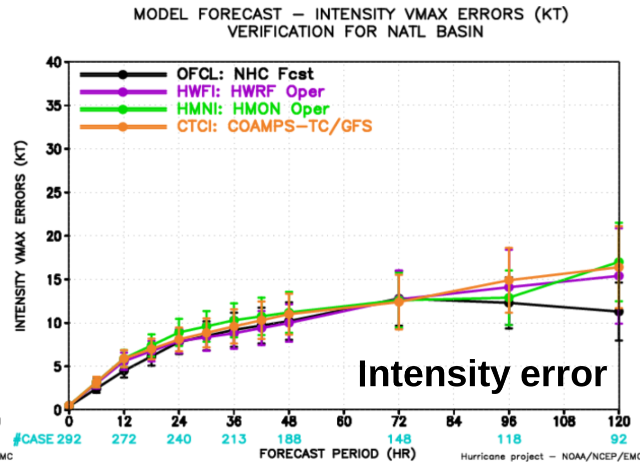
M218 intensity forecast
for 2015-2017 NATL/EPAC storms

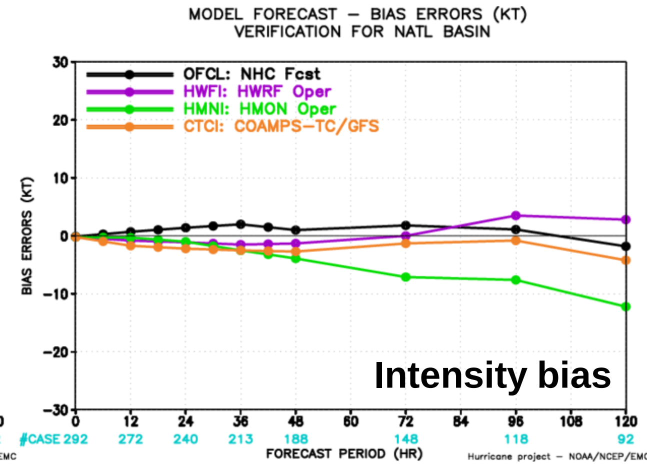


Verification for 2018 North Atlantic Basin

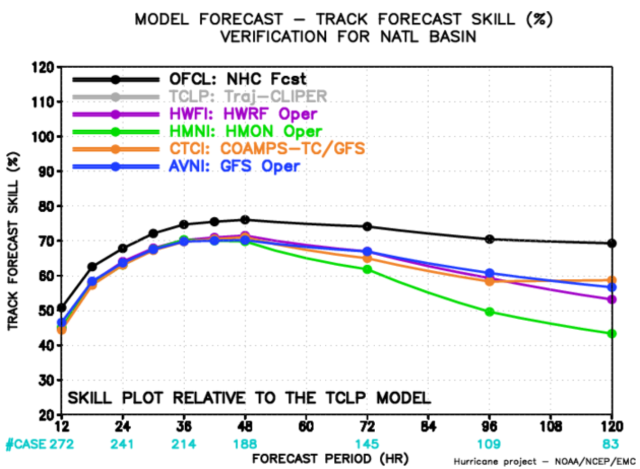
Real-Time Performance (Early Guidance)



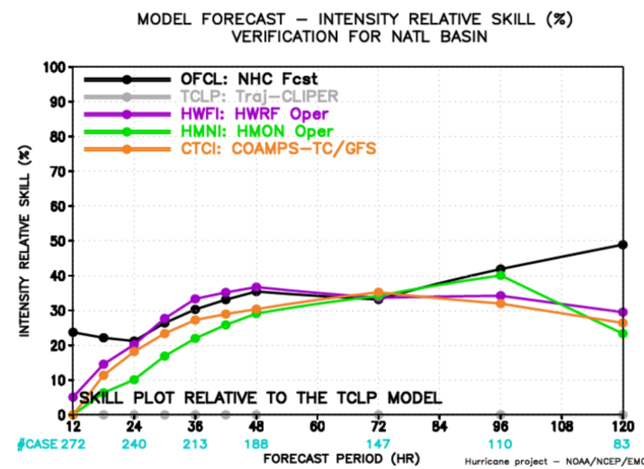




OFCL
HWRF
HMON
CTCX
GFS



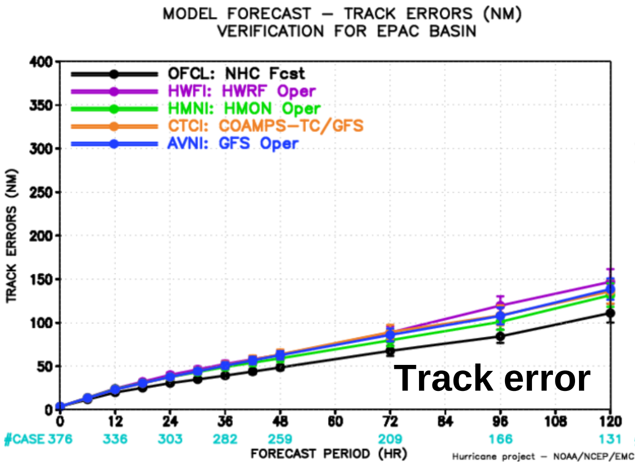
Track skill

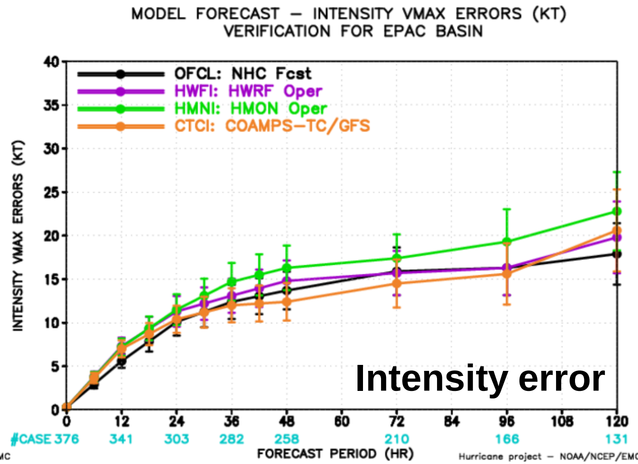


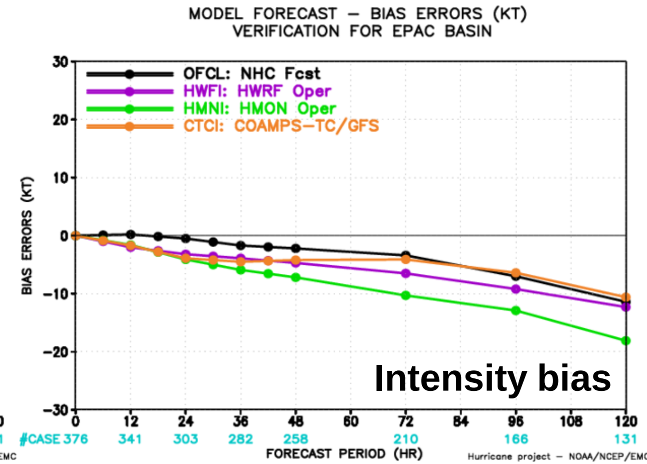
Intensity skill

Verification for 2018 Eastern Pacific Basin

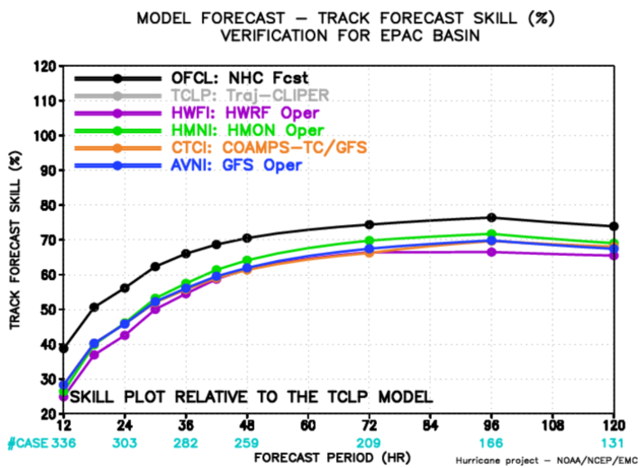
Real-Time Performance (Early Guidance)



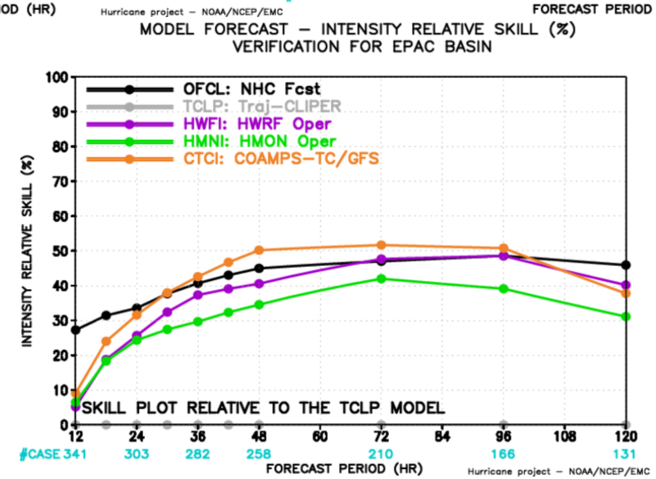




OFCL
HWRF
HMON
CTCX
GFS



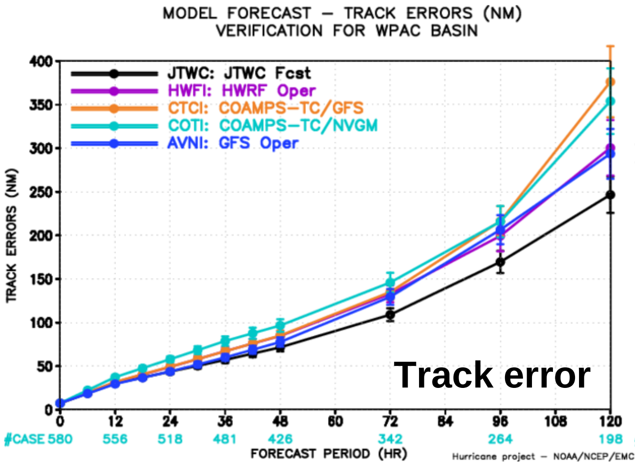
Track skill

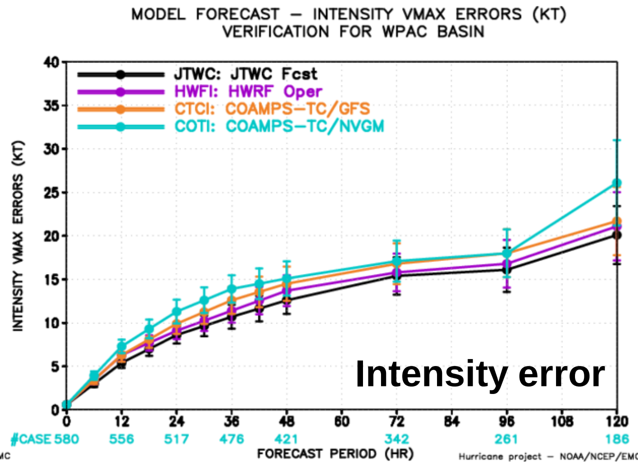


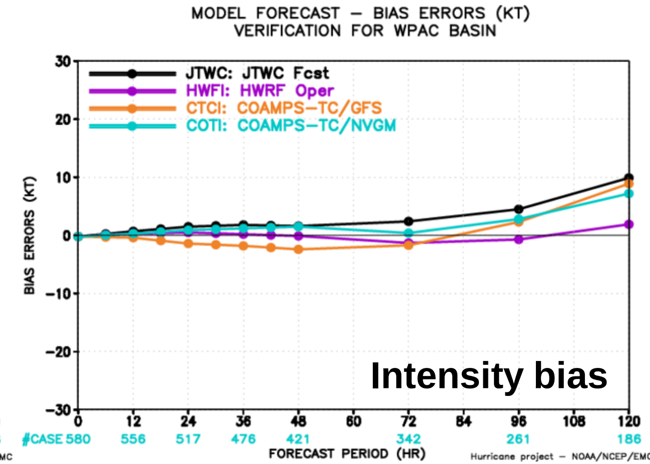
Intensity skill

Verification for 2018 Western Pacific Basin

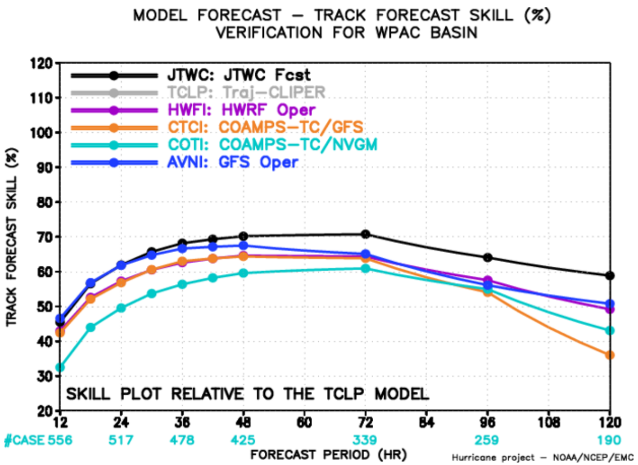
Real-Time Performance (Early Guidance)



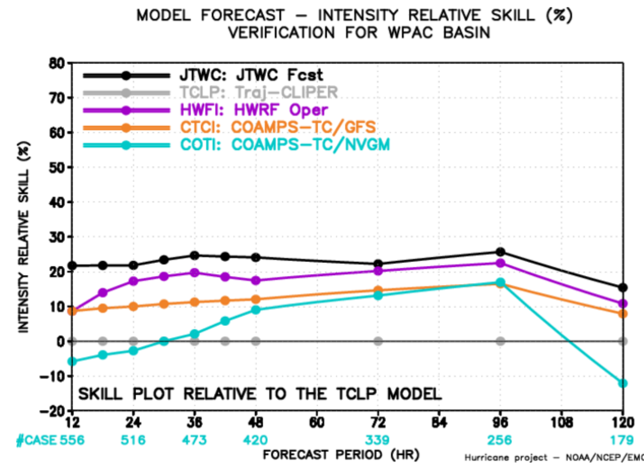




JTWC
HWRF
COTC
CTCX
GFS



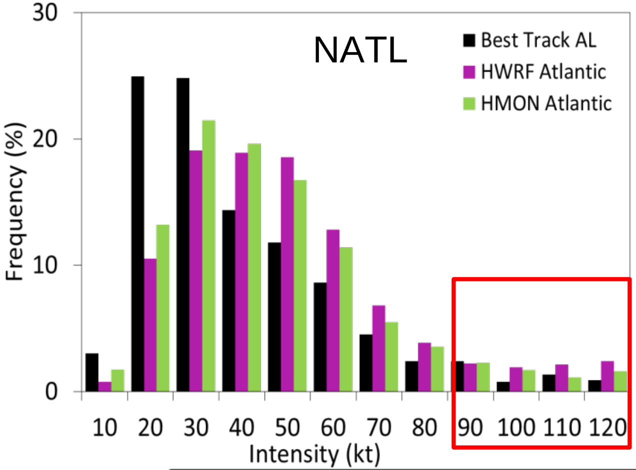
Track skill

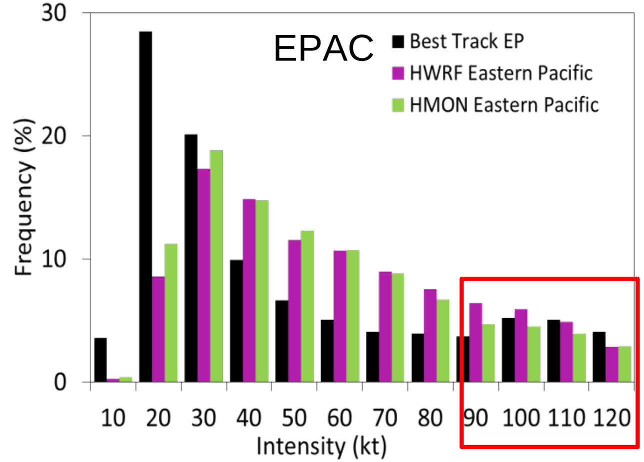


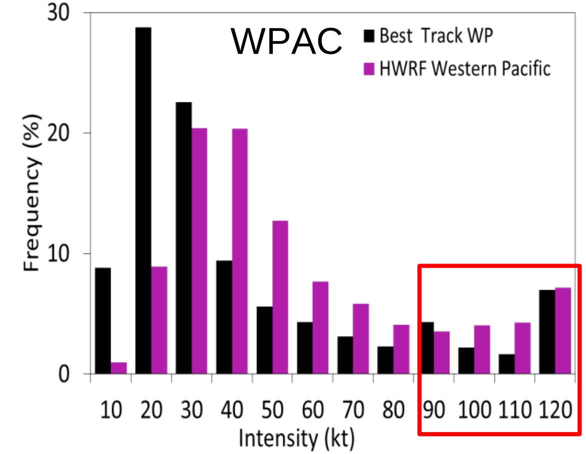
Intensity skill

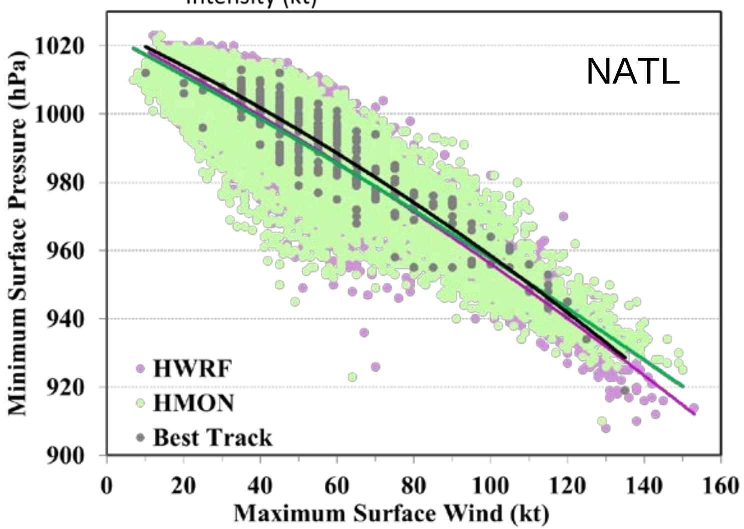
Intensity Distribution and Wind-Pressure Relation

2018 HWRF/HMON Performance

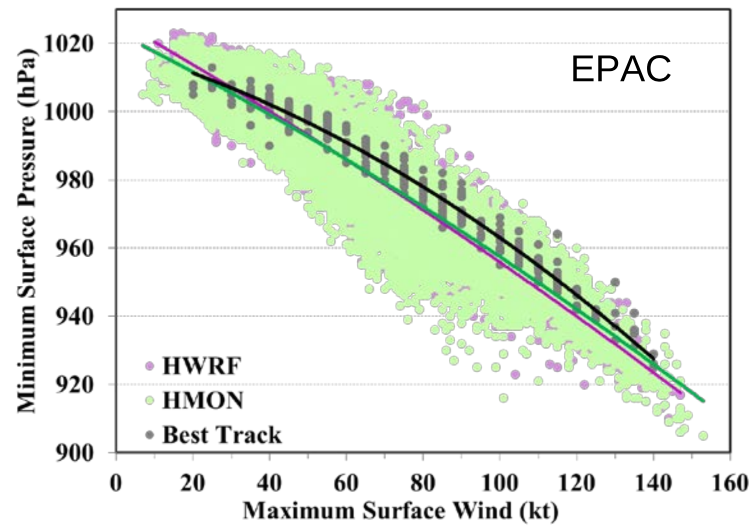




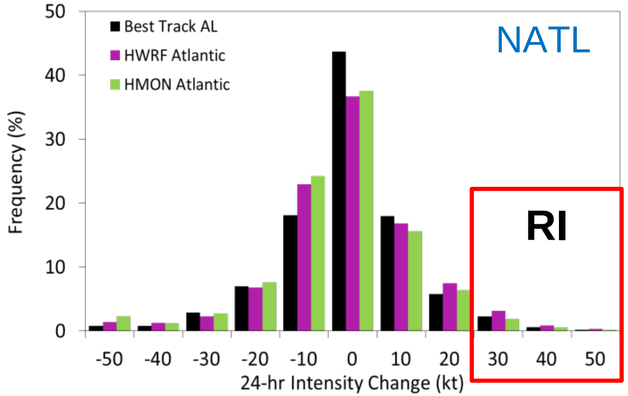


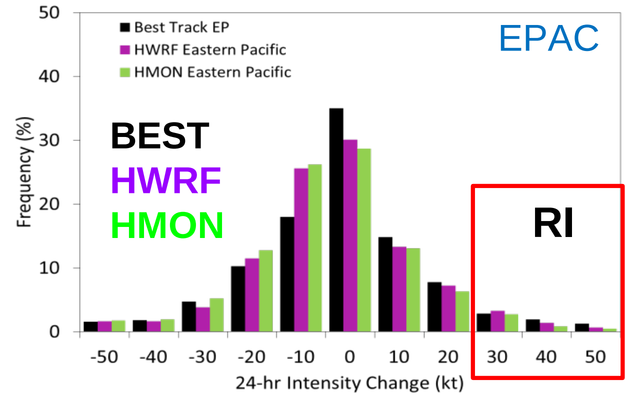


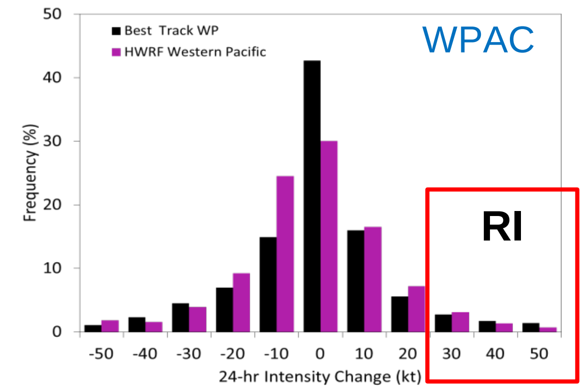
BEST
HWRF
HMON



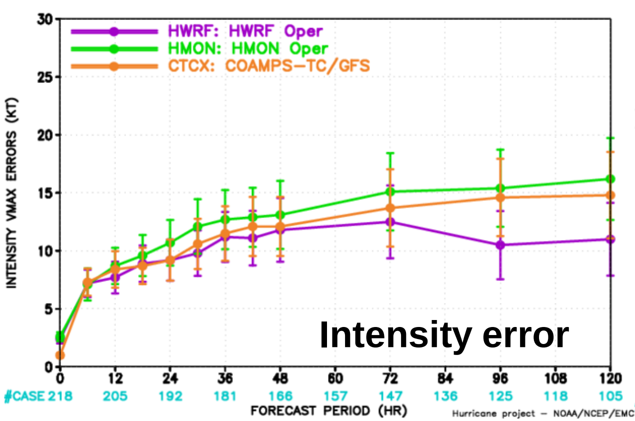
24hr Intensity Change Distribution and Model Performance for RI Storms

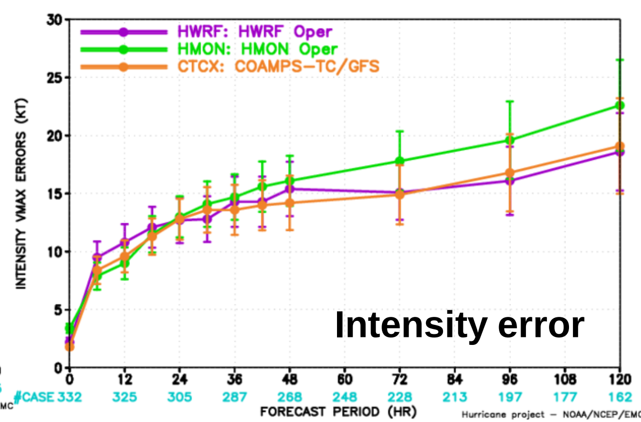


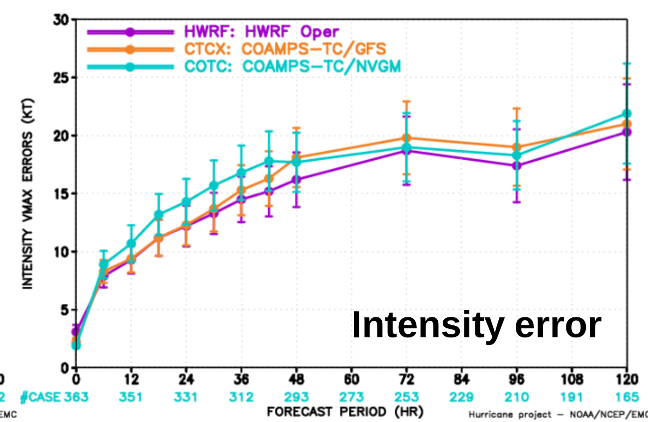




Intensity errors for 2018 NATL/EPAC/WPAC storms experienced rapid intensification





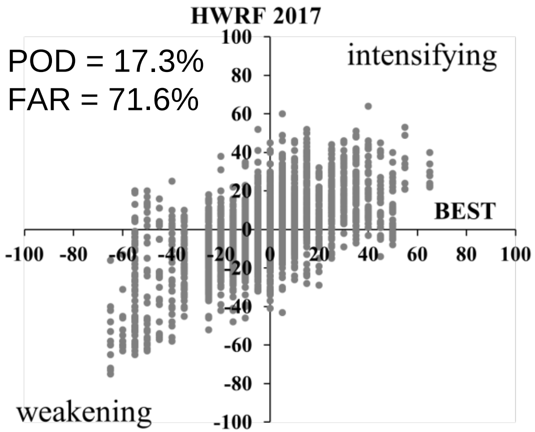


HWRF HMON COTC CTCX

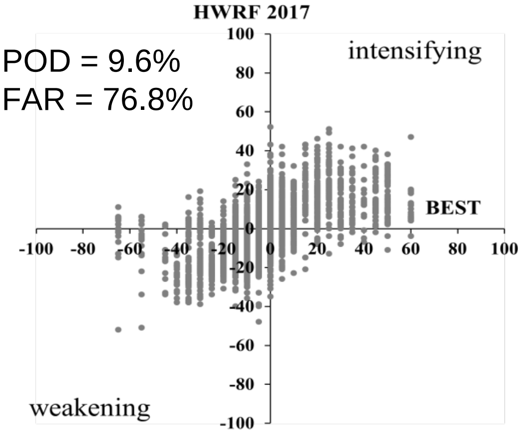
Rapid Intensity Change Forecast Performance

HWRF POD and FAR for RI

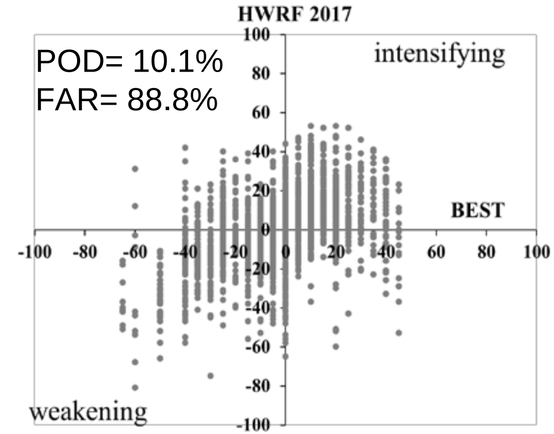
2017 HWRF



NATL

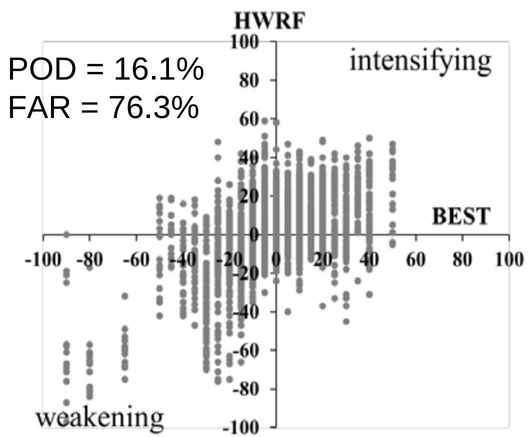


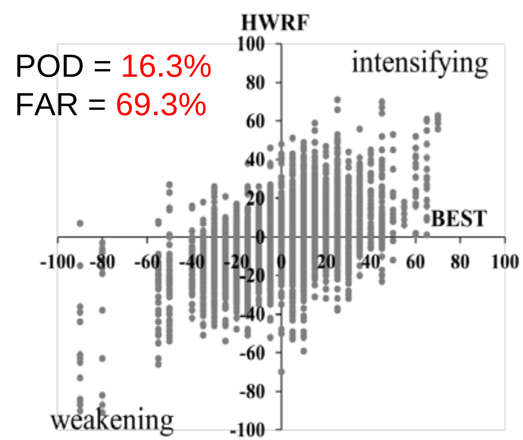
EPAC

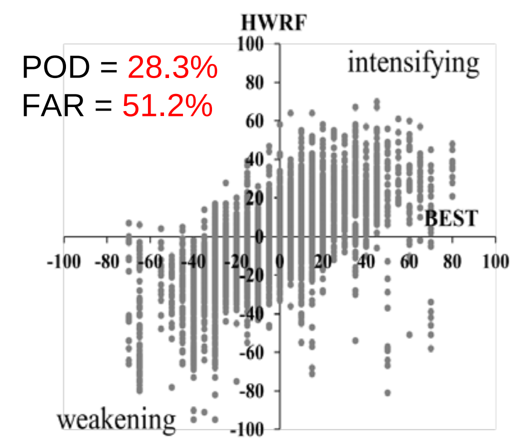


WPAC

2018 HWRF





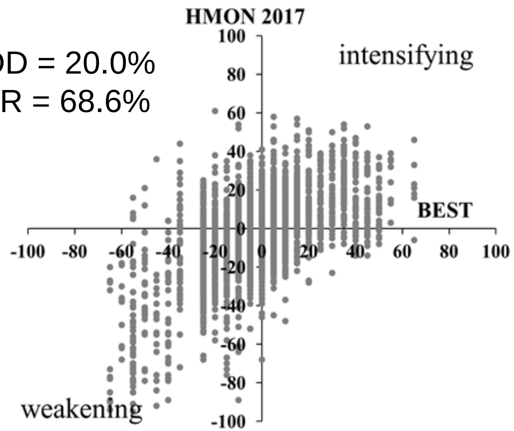


Rapid Intensity Change Forecast Performance

HMON POD and FAR for RI

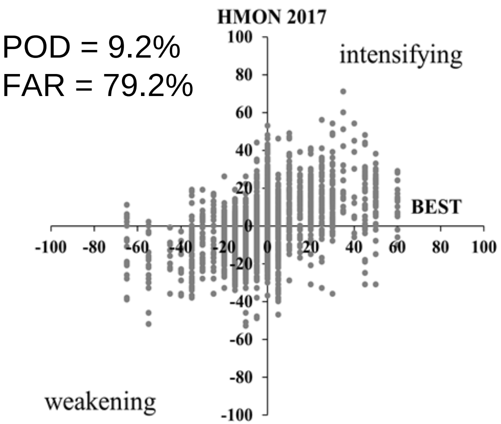
2017 HMON

POD = 20.0%
FAR = 68.6%



NATL

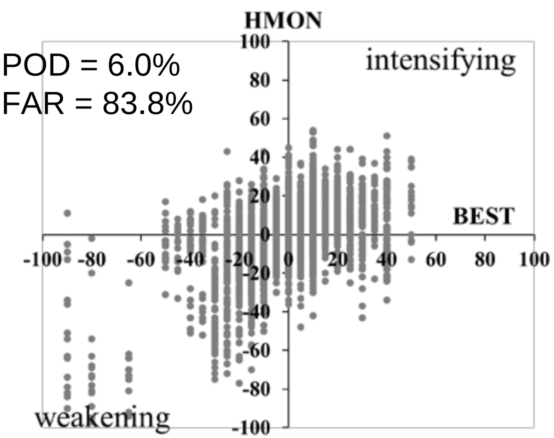
POD = 9.2%
FAR = 79.2%



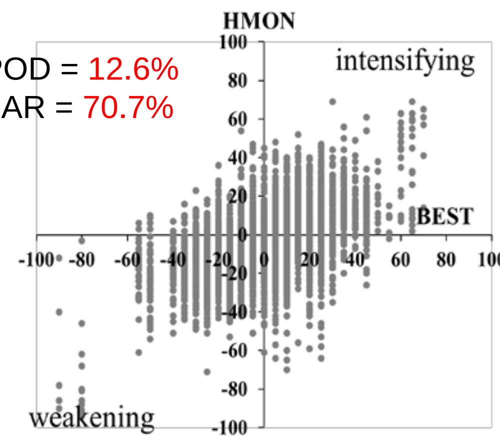
EPAC

2018 HMON

POD = 6.0%
FAR = 83.8%

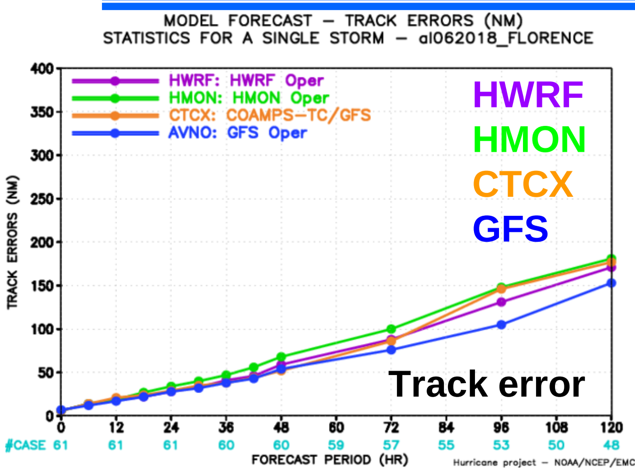


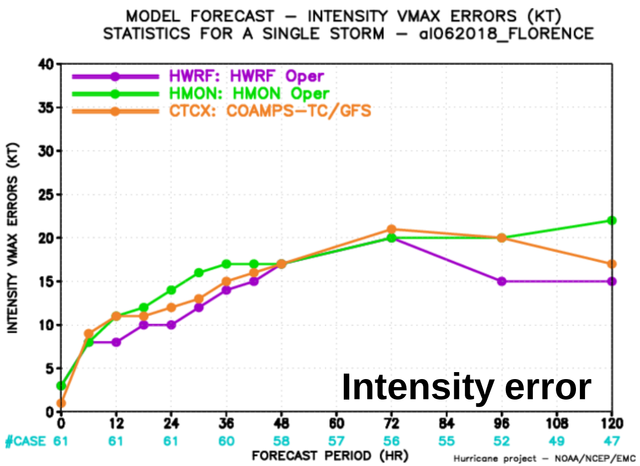
POD = 12.6%
FAR = 70.7%



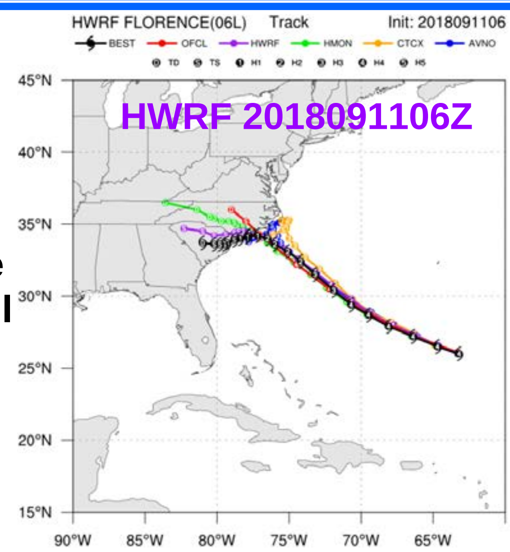
HWRF/HMON Forecast for Florence (06L)

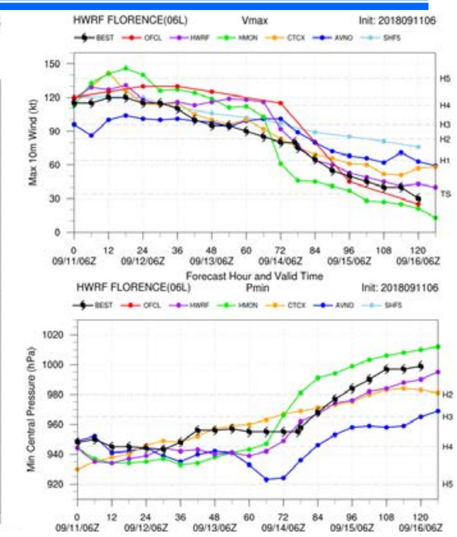
Track, intensity and rainfall forecast



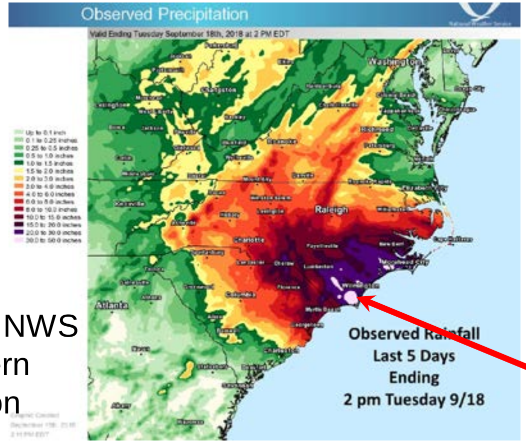


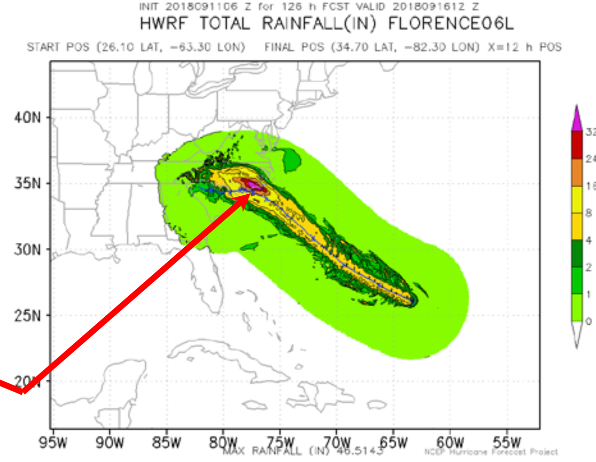
78-hr before landfall





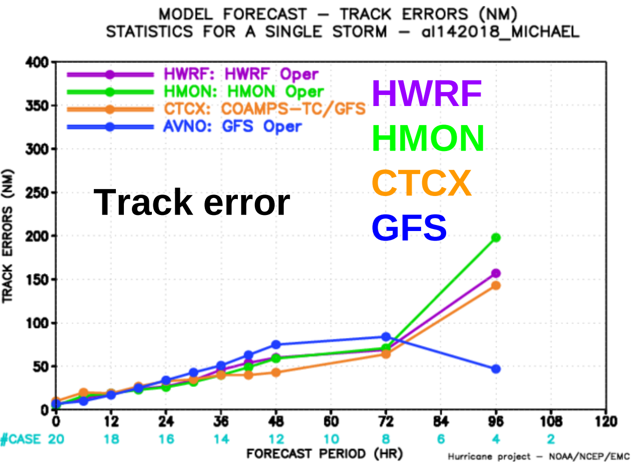
From NWS Eastern Region

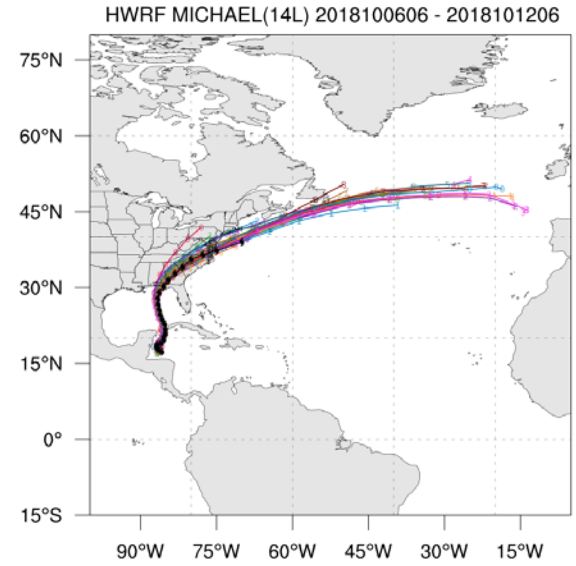




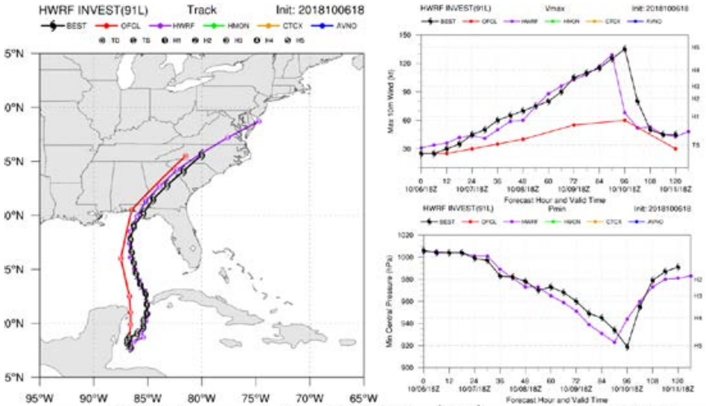
HWRF/HMON Forecast for Michael (14L)

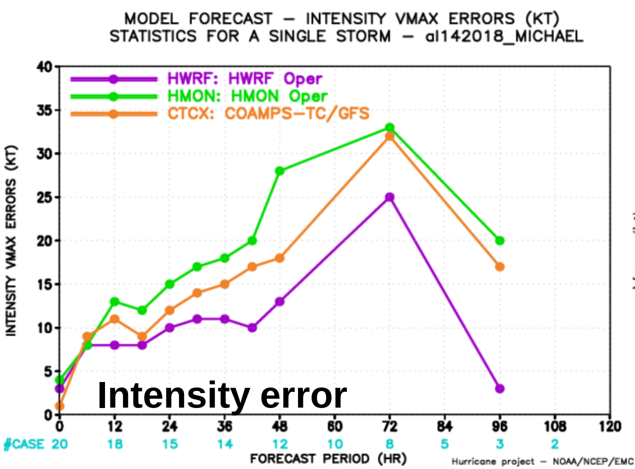
Track and intensity errors and composites

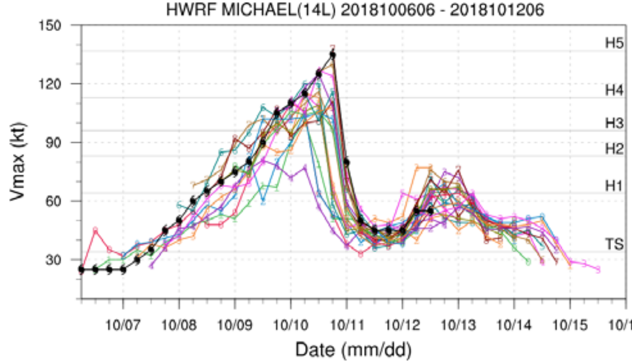


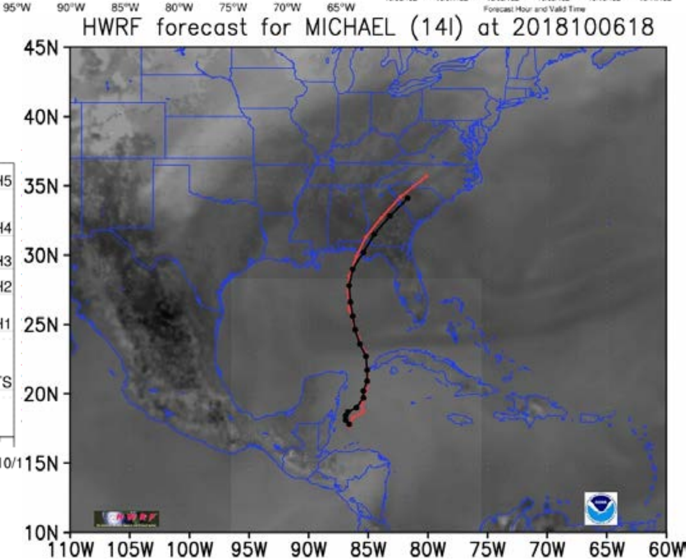


HWRF forecast at 96-hr before landfall





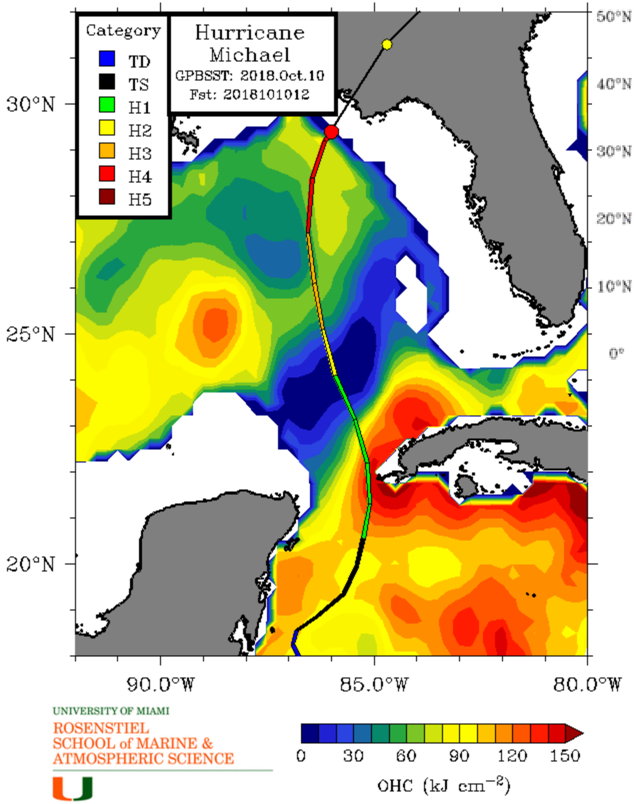




HWRF Forecast for Michael (14L)

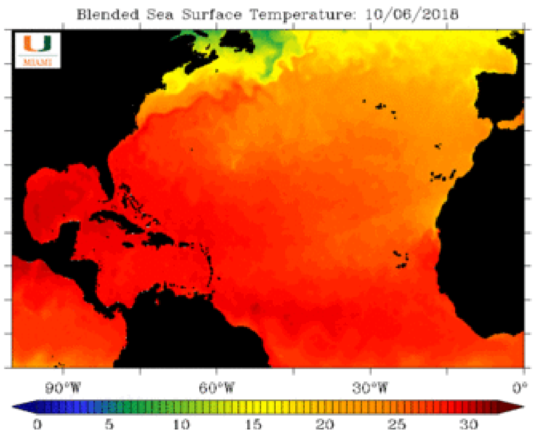
HWRF ocean initialization and coupling

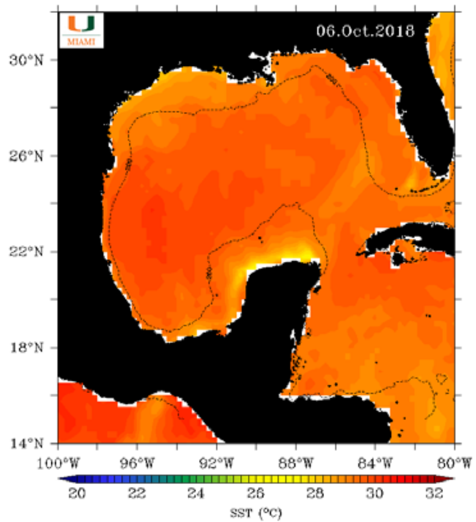
OHC of 20181010



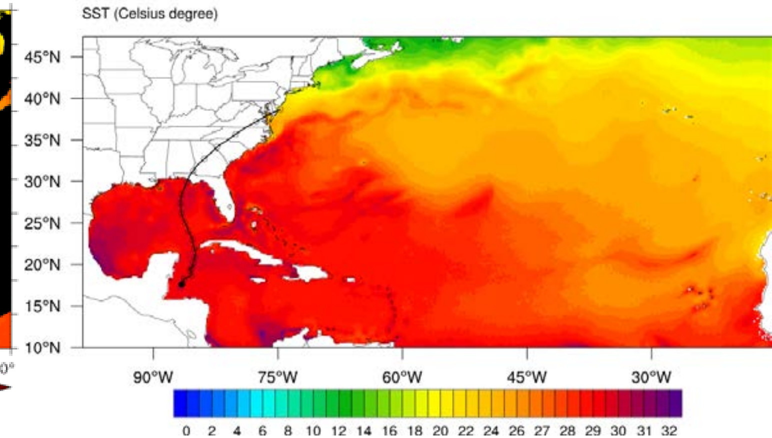
Satellite-derived OHC and SST from UM RSMAS

SST of 20181006

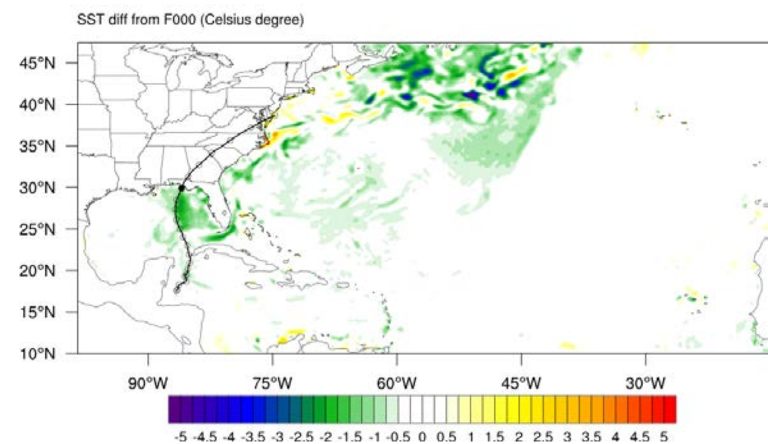




HWRF SST 2018100618Z F000

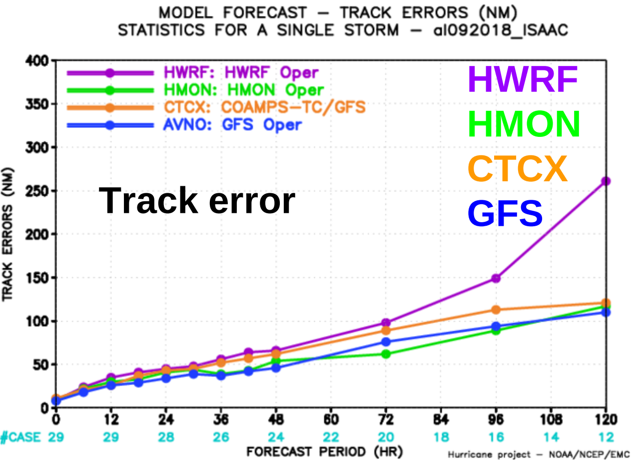


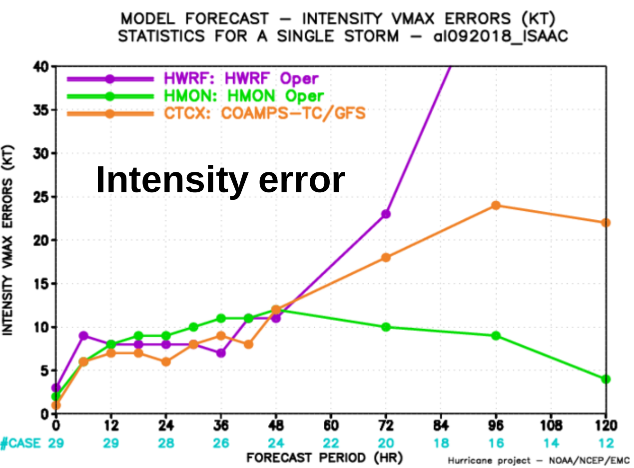
HWRF SST Cooling 2018100618Z F090

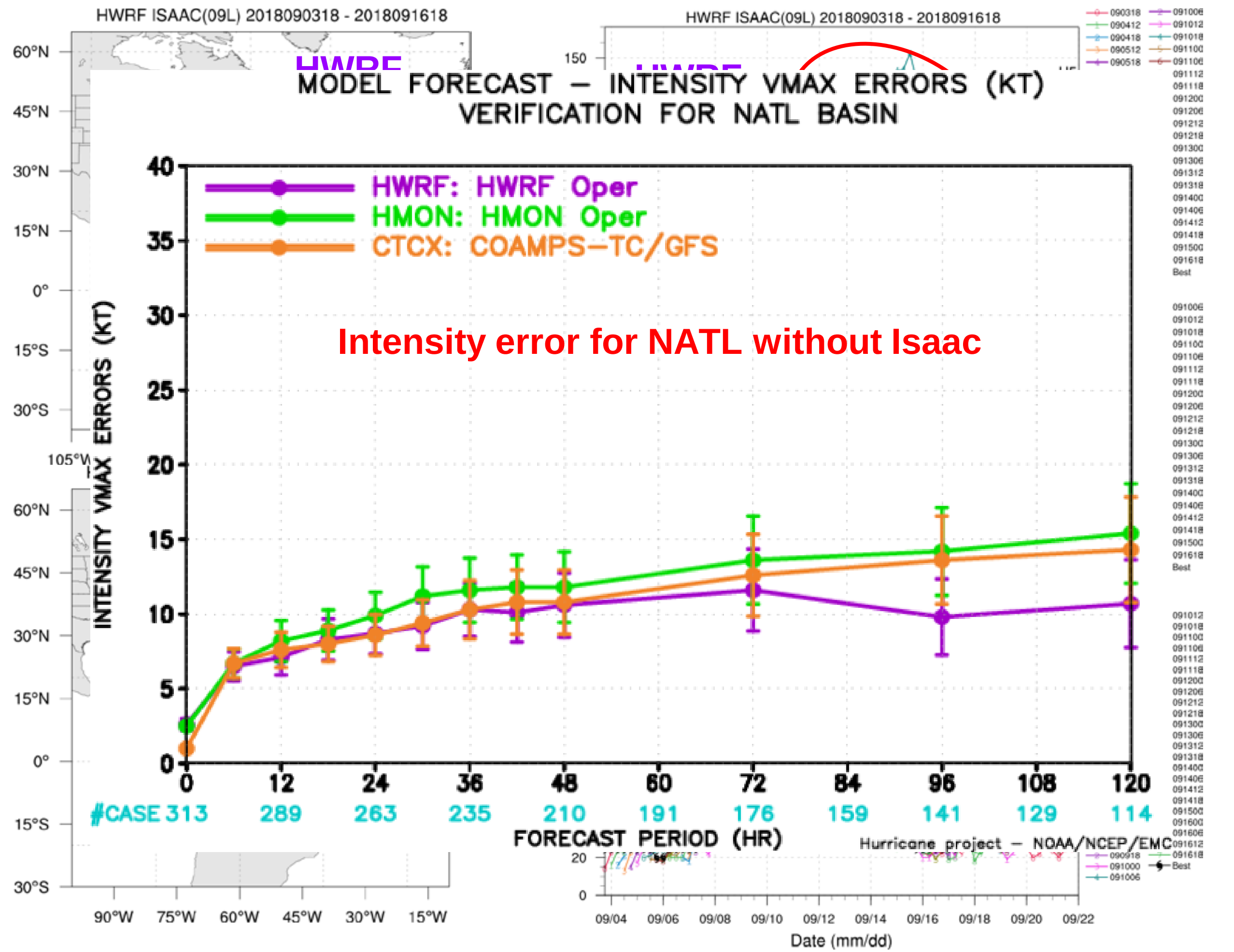


HWRF/HMON Forecast for Isaac (09L)

Track and intensity errors and composites

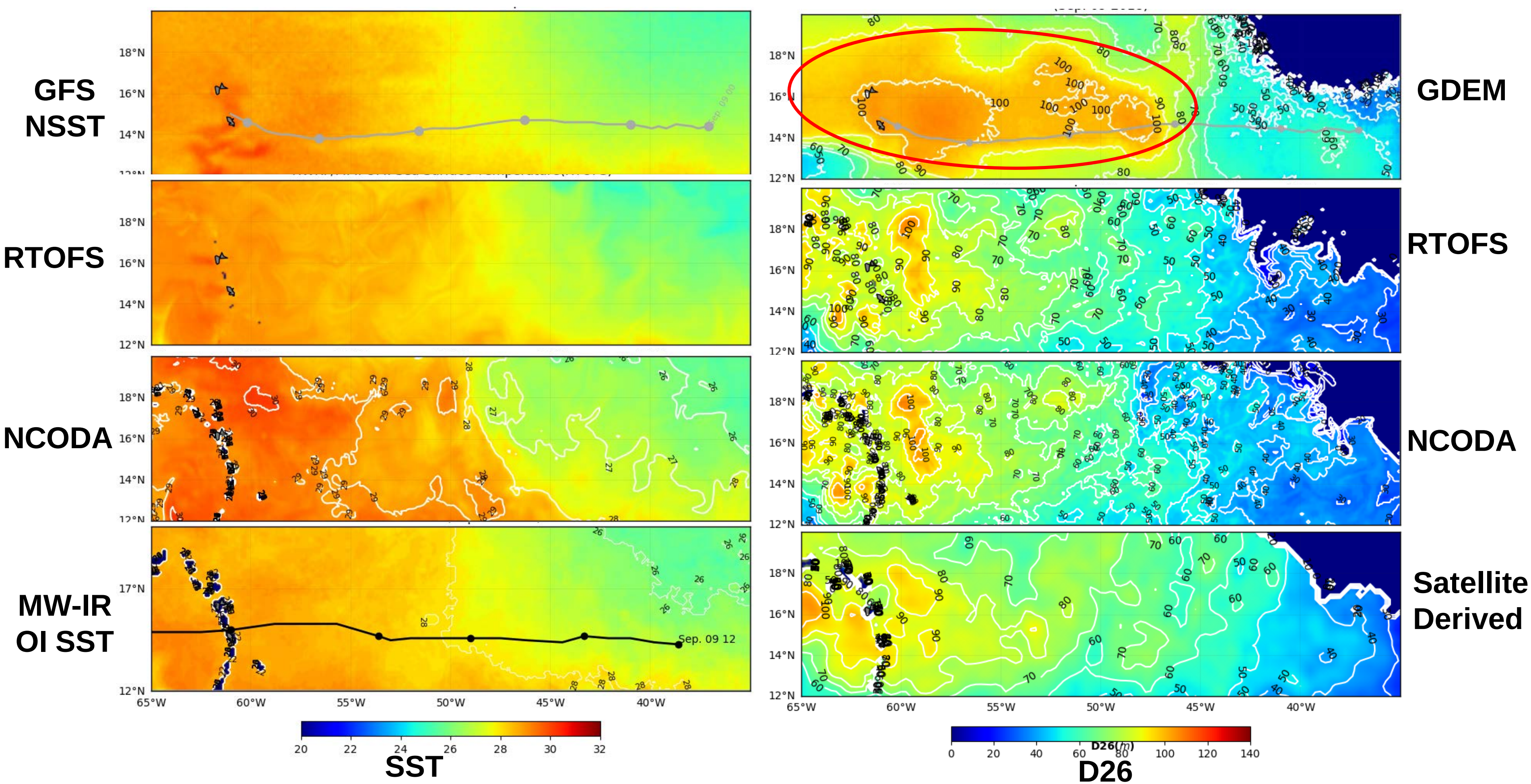




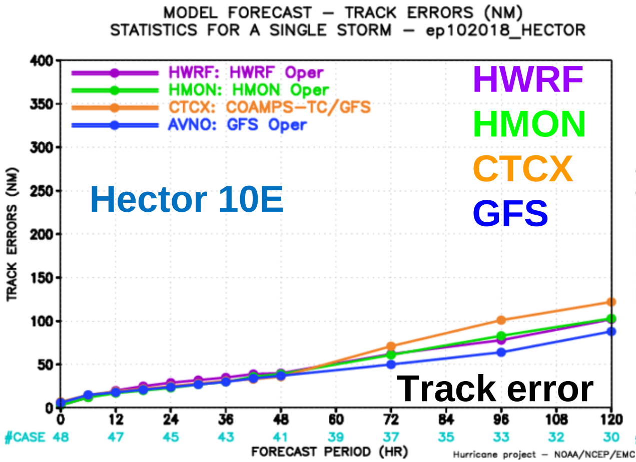


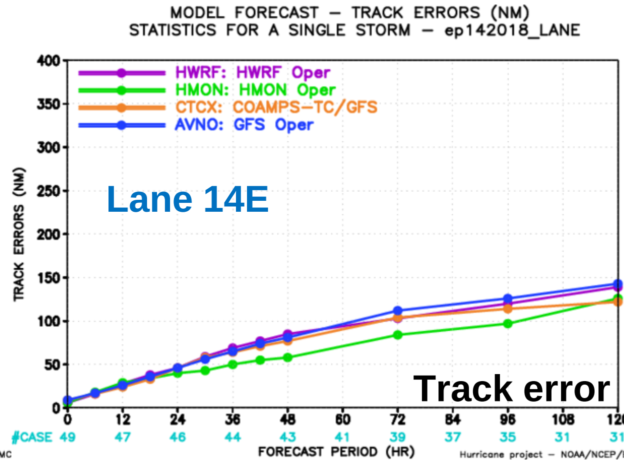
HWRF Ocean Initialization for Isaac (09L)

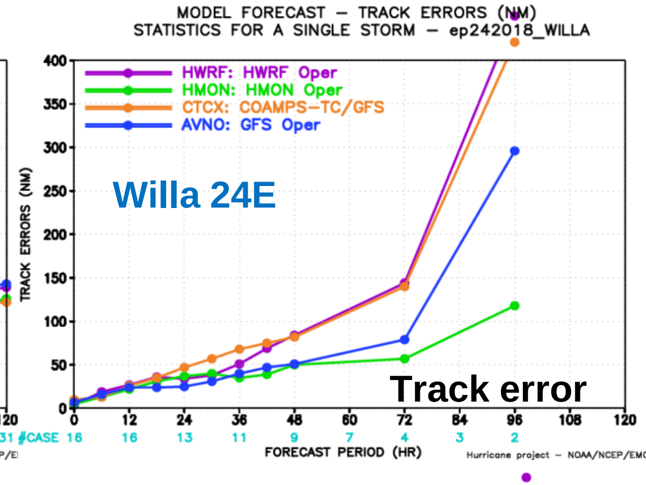
SST and D26 valid at 2019090900Z

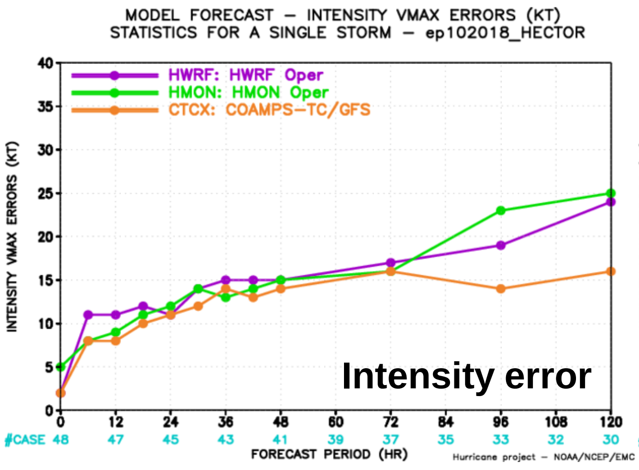


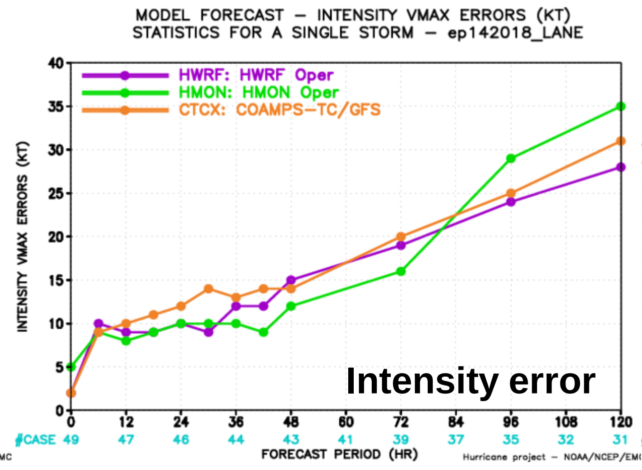
HWRF/HMON Forecast for Some EPAC Storms Hector (10E), Lane (14E) and Willa (24E)

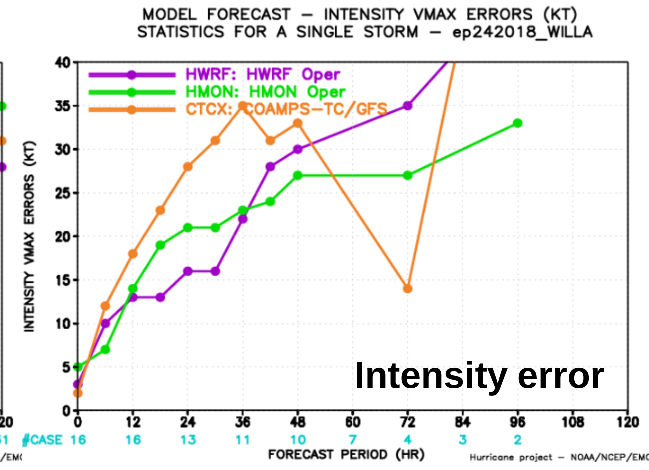




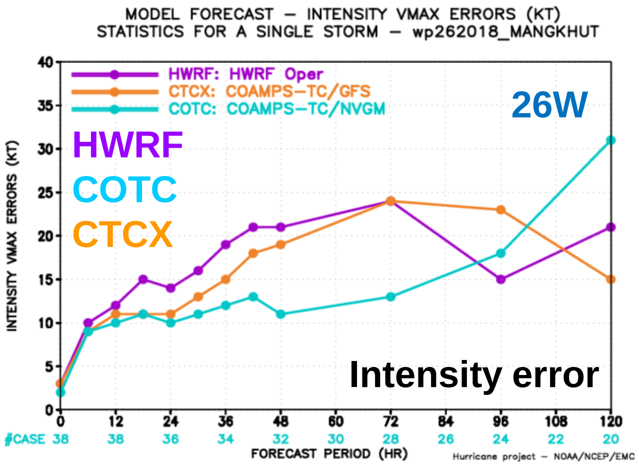


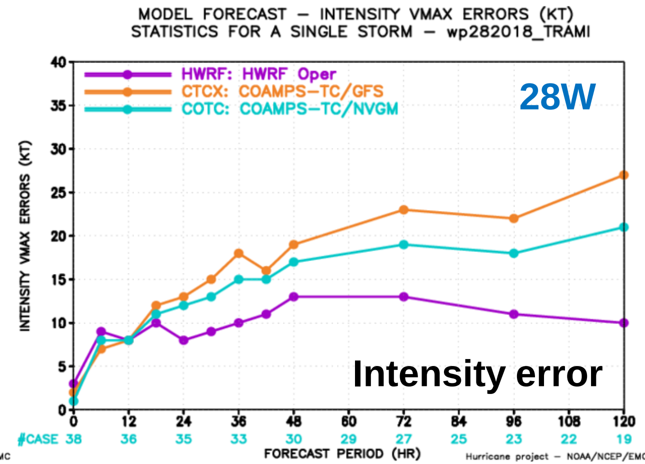


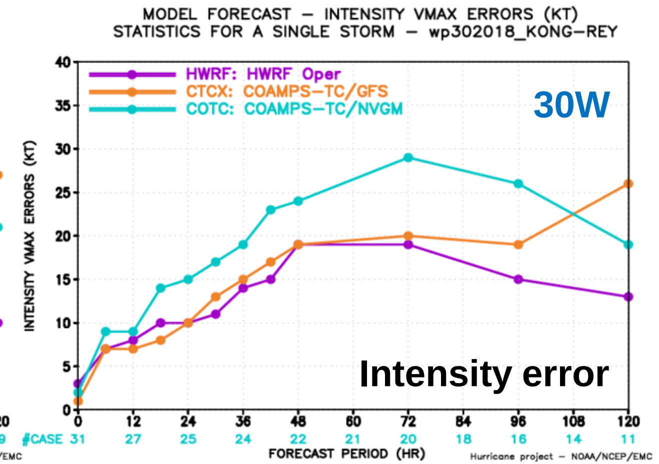




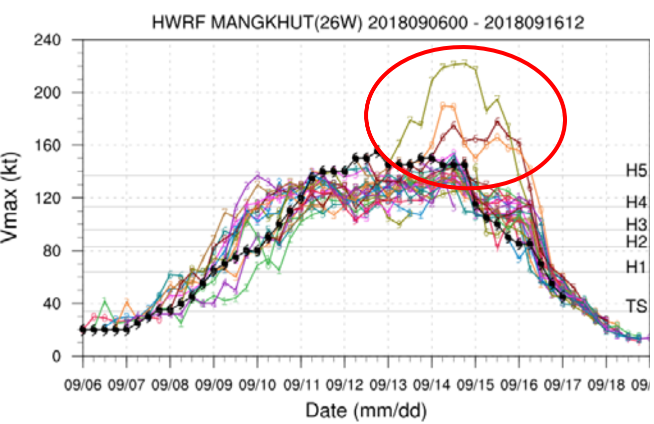
HWRF Forecast for Some WPAC Storms Mangkhut (26W), Trami (28W), and Kong-Rey (30W)

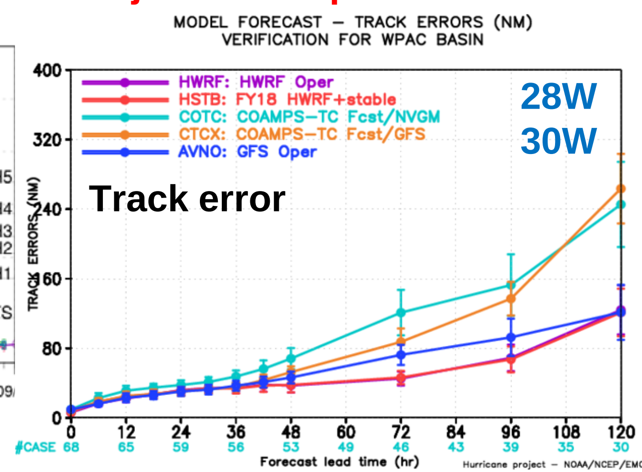


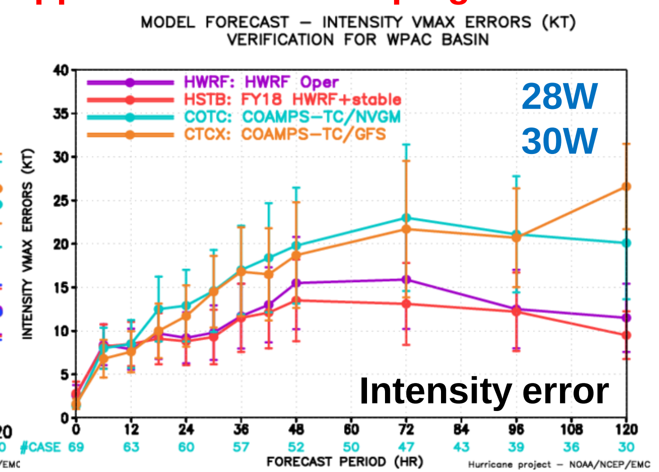




Adjust codamp coefficient and upper level dwdt damping levels







Summary for HWRF Performance

- FY2018 HWRF continues to be one of the best dynamical intensity guidance models. HWRF's intensity forecast skill is very close to OFCL guidance within day 3 for NATL storms; though is overall behind OFCL and CTCX for EPAC storms. For WPAC, HWRF's intensity is better than other dynamical intensity guidance models, while being slightly behind JTWC's official forecast.
- For intensity forecast of RI storms, HWRF performed very well for all three basins (NATL/EPAC/WPAC), especially with much improved POD/FAR for RI forecasting of WPAC storms.
- For track forecast skill, HWRF is overall very close or slightly behind its parent model GFS.
- There were some over-intensification cycles for Isaac (09L) and other storms. Also several cycles of Mangkhut (26W, a very strong WPAC storm) experienced numerical instability issue.

Summary for HMON Performance

- FY2018 HMON implementation was the first upgrade after it replaced the legacy GFDL hurricane model last year.
- HMON performed very well for track forecast of EPAC storms, even better than its parent model (GFS). Whereas, for NATL storms, its track forecast was somewhat behind other models.
- For intensity forecast, HMON was overall a little behind HWRF, and struggled for both NATL and EPAC basins, with overall weaker intensity biases especially for longer forecast lead times.
- For individual storms/forecast cycles, HMON and HWRF provided mixed track and intensity forecast skills. For example, HMON performed very well for Isaac (09L), while HWRF struggled for lots of cycles for this storm.

Thank you!

Real-time NCEP operational model guidance for all global TCs

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

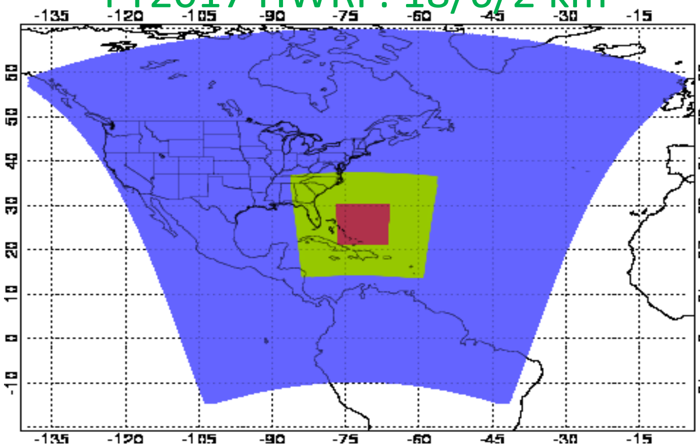
HMON: http://www.emc.ncep.noaa.gov/gc_wmb/vxt/HMON

FY2018 HWRF/HMON Configurations

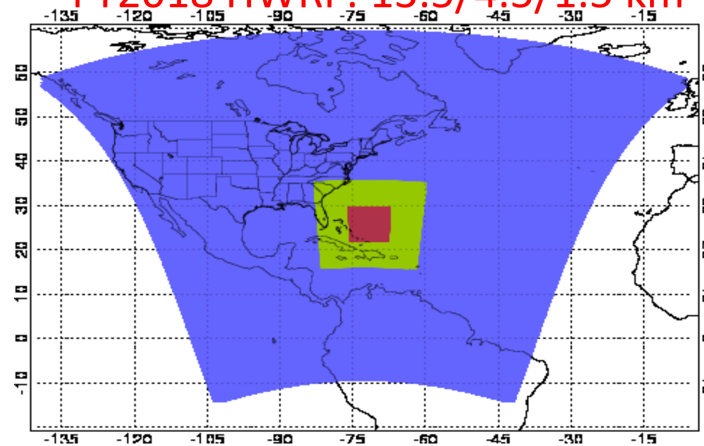
	HWRF	HMON
Dynamic core	Non-hydrostatic, NMM-E	Non-hydrostatic, NMM-B
Resolution and nesting	13.5/4.5/1.5 km; 77°/18°/6°; L75(10mb top); two-way nesting and vortex-following	18/6/2 km; 75°/12°/8°; L51(50mb top); two-way nesting and vortex-following
Data Assimilation and Initialization	Vortex relocation & adjustment; self-cycled hybrid EnKF-GSI with inner core DA (TDR)	Modified vortex relocation & adjustment; no DA
Physics	Updated surface (GFDL); NOAH LSM; GFS-EDMF PBL; scale-aware SAS; Ferrier-Aligo; Modified RRTMG	Surface (GFDL); NOAH LSM; GFS-EDMF PBL; scale-aware SAS; Ferrier-Aligo; RRTMG
Coupling	Unified NCEP coupler; MPIPOM/HYCOM; RTOFS/GDEM; one-way coupling to WW3	Unified NCEP coupler; HYCOM; RTOFS/NCODA; no wave coupling
Post-processing	NHC interpolation method; updated GFDL tracker	NHC interpolation method; GFDL tracker
NEMS/NUOPC	No	Yes with moving nests
Computation cost for forecast job	81 nodes in 98 mins	26 nodes in 95 mins

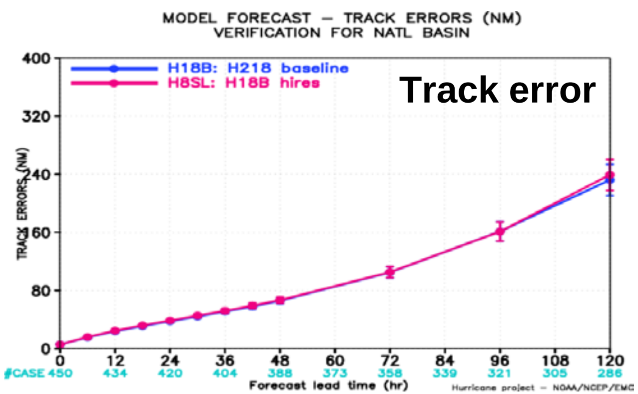
Toward High Resolution Convection Resolving Modeling in Operational HWRF

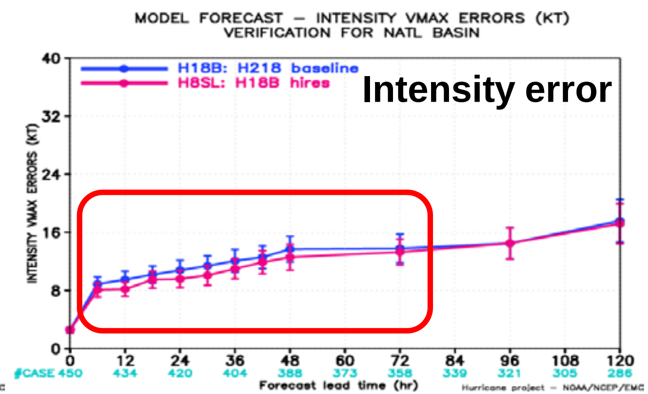
FY2017 HWRF: 18/6/2 km

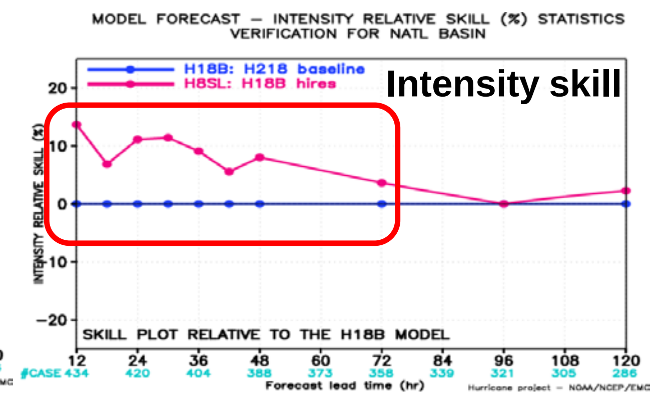


FY2018 HWRF: 13.5/4.5/1.5 km



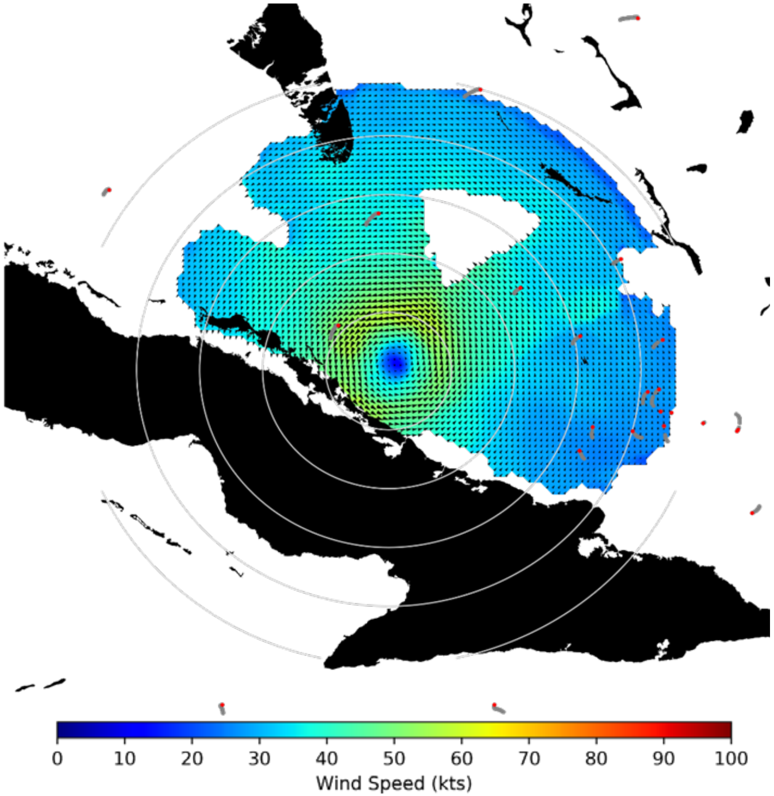




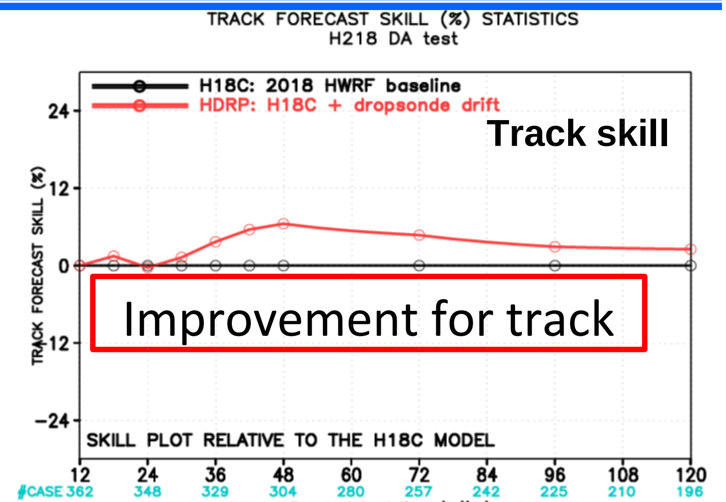


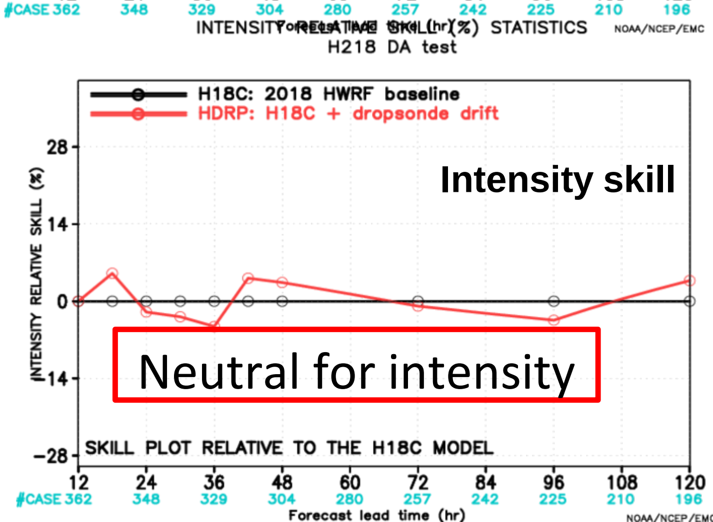
Overall neutral impact for track while substantial improvements for intensity

Considering Dropsonde Drifting in DA



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





Modified Cloud Overlap Method for RRTMG

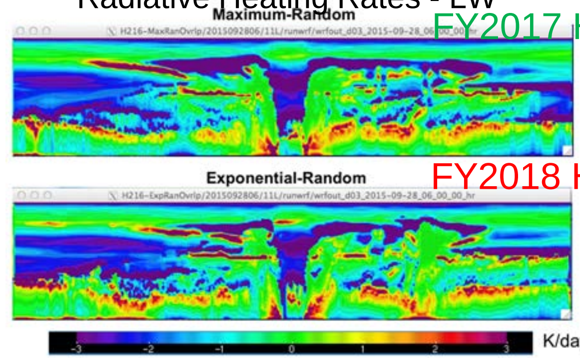
"**Maximum-random**" (FY2017 HWRF)

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

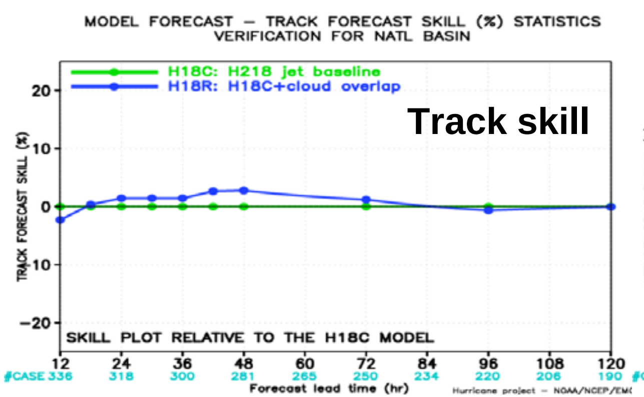
"**Exponential-random**" (FY2018 HWRF)

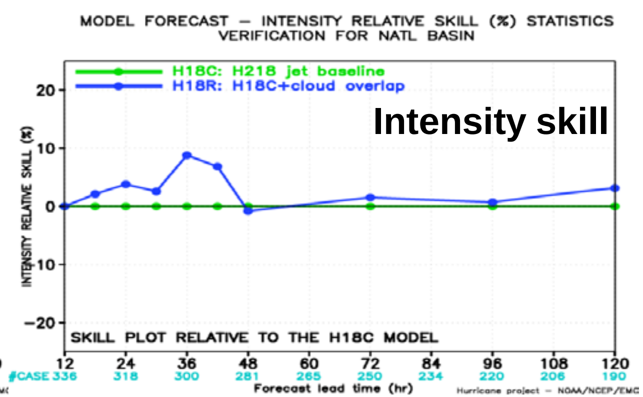
- Continuous cloud layers use overlap that transitions exponentially from maximum to random with distance through clouds, blocks of cloud layers with clearance between are oriented randomly
- Constant decorrelation length (Z_0 = ~1-2 km) controls rate of exponential transition

Radiative Heating Rates - LW

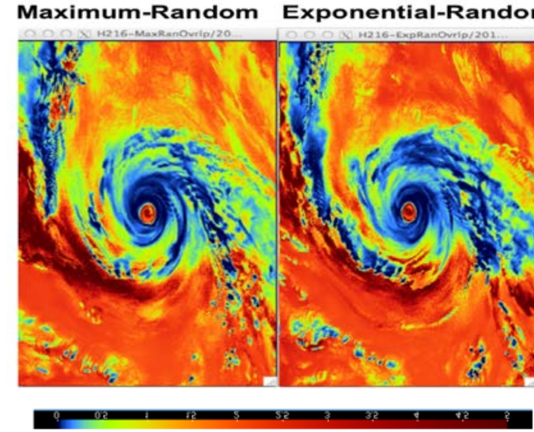


Vertical west-east slice: through Joaquin eye





Radiative Heating Rates - SW



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 Coupling	Wave Coupling	DA	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