

Plans for Operational Hurricane Modeling in FY20

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(with ongoing collaborations from AOML, DTC, NHC, GFDL, ESRL, FIU, OU, AER and others)

¹*Environmental Modeling Center*
NOAA / NWS / NCEP

HFIP Annual Review Meeting, November 5, 2019



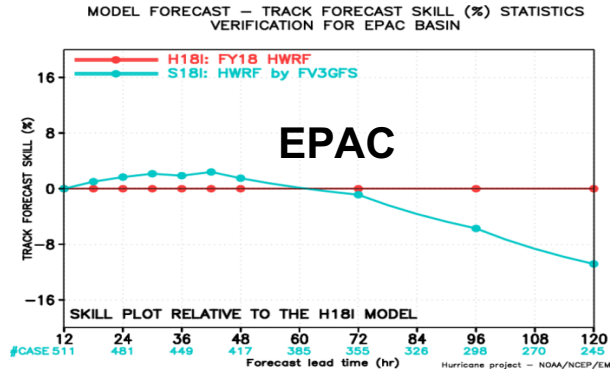
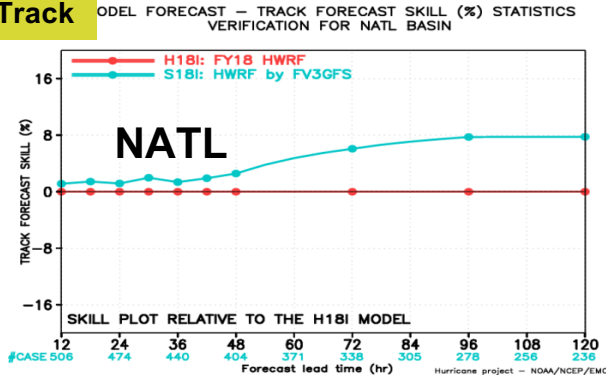
FY19 HWRF/HMON Performance



FY18 HWRF Testing with FV3GFS

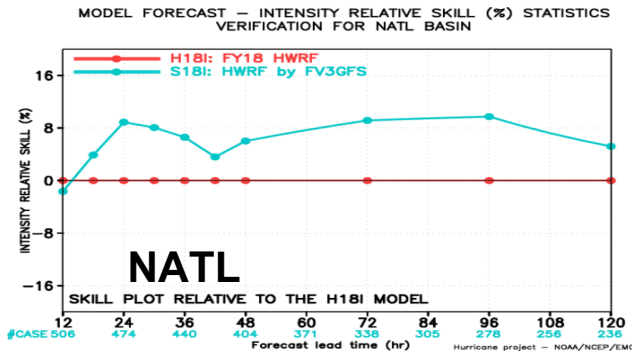
NATL and EPAC Track and Intensity Skill Using Priority Storms from 2015-2018, Early Model Results

Track

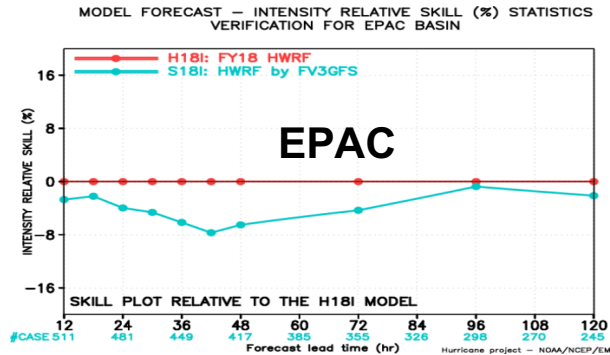


Intensity

HWRf w/Legacy GFS
HWRf w/FV3GFS



HWRf w/Legacy GFS
HWRf w/FV3GFS



ATL: There is good improvement in track skill especially for longer lead times Intensity skill improvements are evident at all lead times

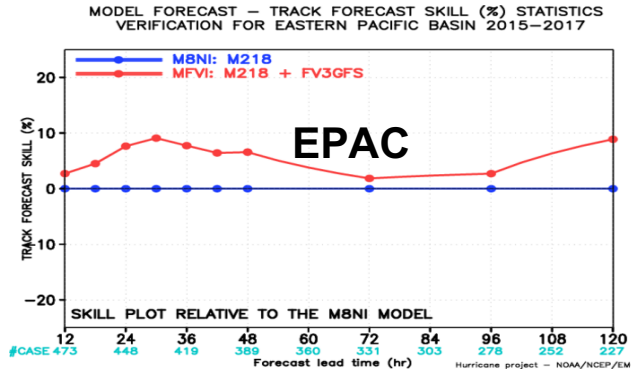
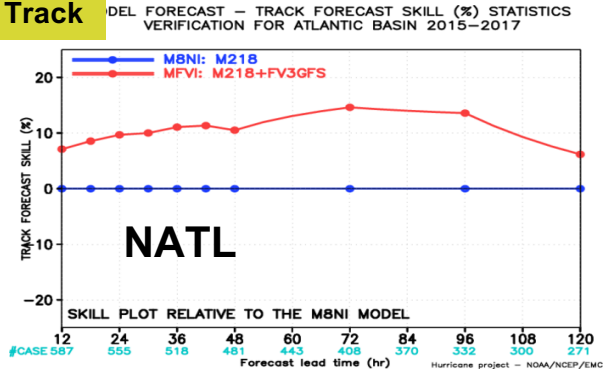
EPAC: Track skill is improved for the first 2 days, behind for Days 4 and 5. Intensity skill is behind for the first 3 days, neutral beyond.



FY18 HMON Testing with FV3GFS

NATL and EPAC Track and Intensity Skill Using Priority Storms from 2015-2018, Early Model Results

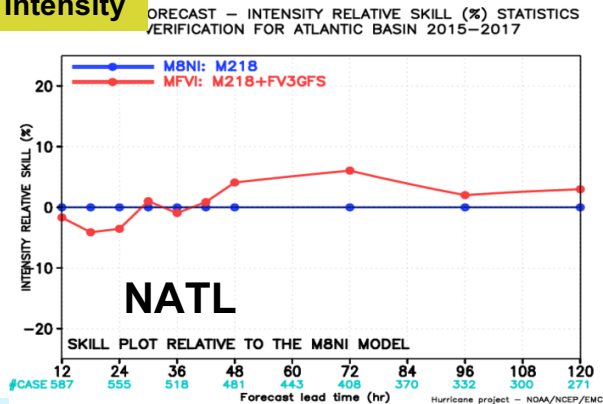
Track



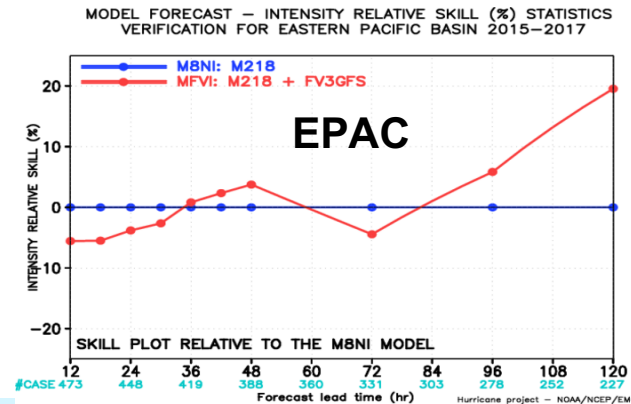
ATL: There is good improvement in track skill for all lead times. Intensity skill is behind for the first 24 hrs, neutral to improved beyond.

Intensity

HMON w/FV3GFS HMON w/ Legacy GFS



HMON w/FV3GFS HMON w/ Legacy GFS



EPAC: Track skill improvements are evident at all lead times. Intensity skill is behind for the first 36 hrs, neutral thereafter till Day 3 and good improvements for Days 4 and 5.



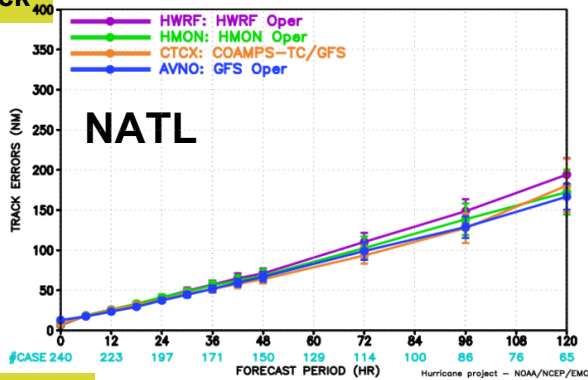


Operational HWRF vis-à-vis Dynamic Models: Track and Intensity Errors for 2019 till date (Late Results)

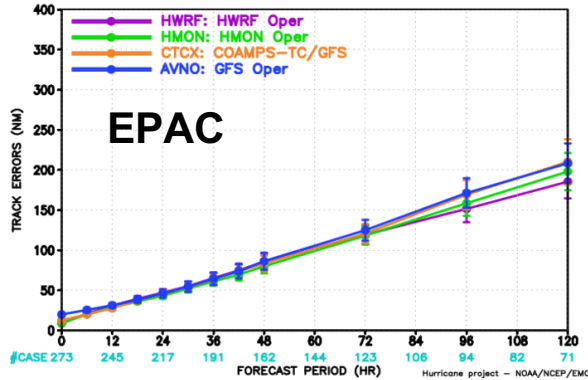


Track

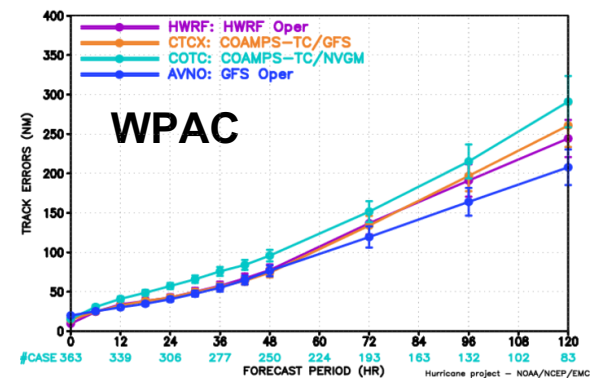
MODEL FORECAST – TRACK ERRORS (NM)
VERIFICATION FOR NATL BASIN



MODEL FORECAST – TRACK ERRORS (NM)
VERIFICATION FOR EPAC BASIN

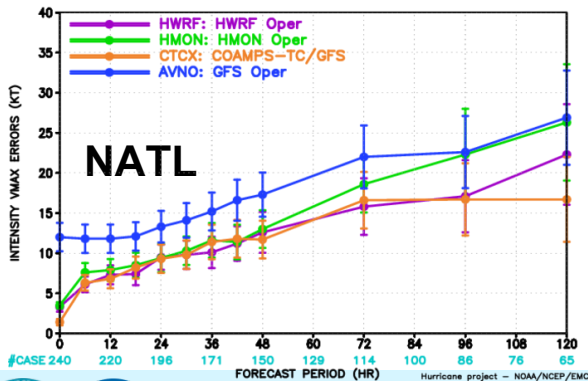


MODEL FORECAST – TRACK ERRORS (NM)
VERIFICATION FOR WPAC BASIN

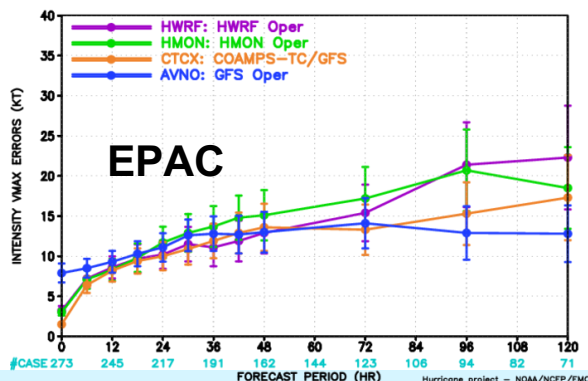


Intensity

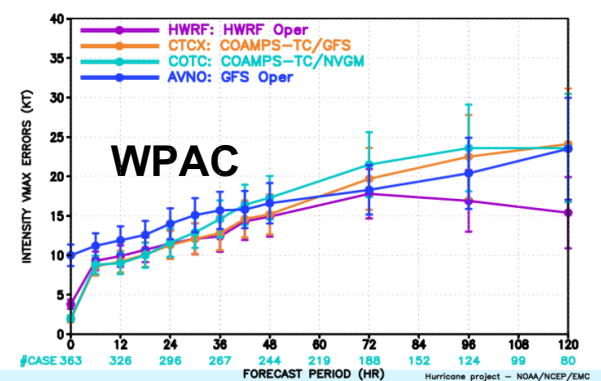
MODEL FORECAST – INTENSITY VMAX ERRORS (KT)
VERIFICATION FOR NATL BASIN



MODEL FORECAST – INTENSITY VMAX ERRORS (KT)
VERIFICATION FOR EPAC BASIN



MODEL FORECAST – INTENSITY VMAX ERRORS (KT)
VERIFICATION FOR WPAC BASIN



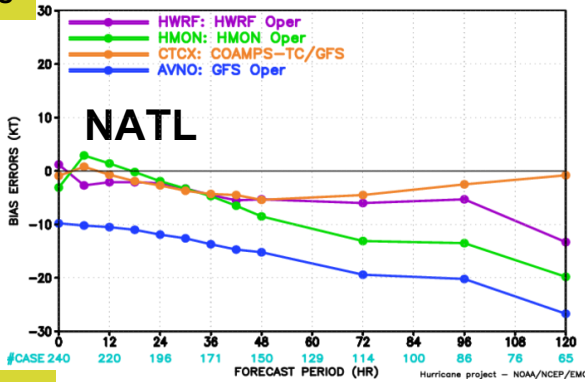


Operational HWRF vis-à-vis Dynamic Models: Intensity Bias and MSLP Errors for 2019 till date (Late Results)

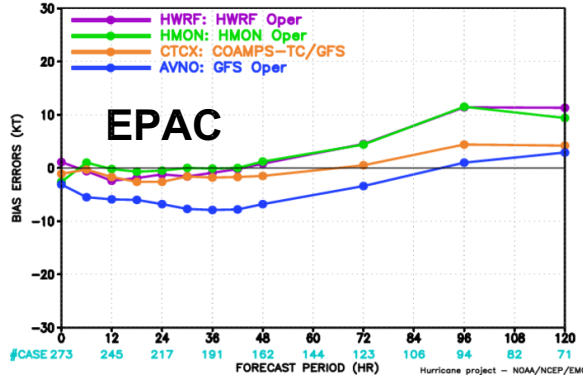


Bias

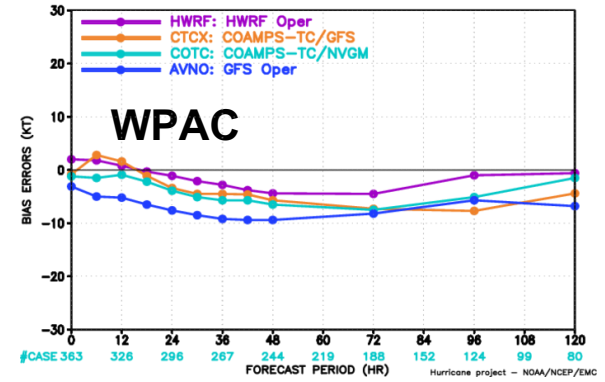
MODEL FORECAST – BIAS ERRORS (KT)
VERIFICATION FOR NATL BASIN



MODEL FORECAST – BIAS ERRORS (KT)
VERIFICATION FOR EPAC BASIN

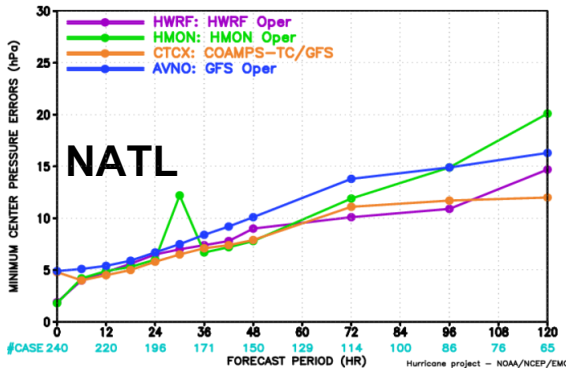


MODEL FORECAST – BIAS ERRORS (KT)
VERIFICATION FOR WPAC BASIN

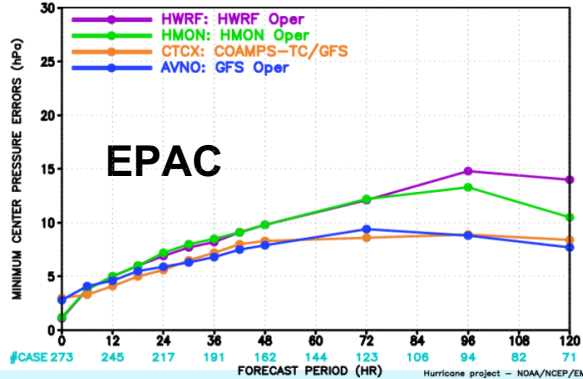


MSLP

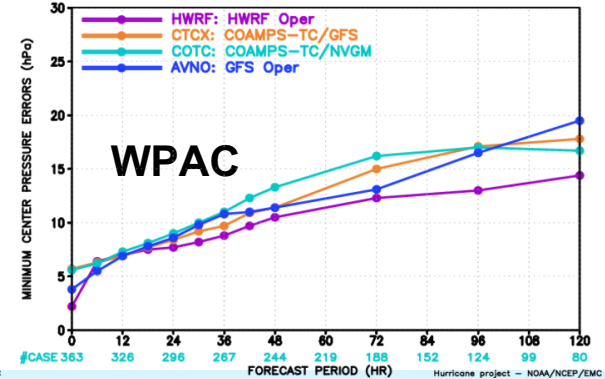
MODEL FORECAST – MINIMUM CENTER PRESSURE ERRORS (hPa)
VERIFICATION FOR NATL BASIN

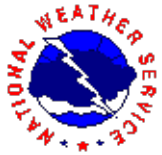


MODEL FORECAST – MINIMUM CENTER PRESSURE ERRORS (hPa)
VERIFICATION FOR EPAC BASIN



MODEL FORECAST – MINIMUM CENTER PRESSURE ERRORS (hPa)
VERIFICATION FOR WPAC BASIN





Operational HWRF and HMON for 2019 Season: Highlights



❖ NATL Basin:

- HWRF has large track errors (**retrospective evaluation with FV3GFS showed Improvements at extended lead times**)
- HWRF has the best intensity skill till Day 4, comparable to CTCX. Errors were higher than normal at day 5.
- HMON has better track skill than HWRF, large intensity errors beyond Day 2 (**retrospective evaluation with FV3GFS showed otherwise**)

❖ EPAC Basin:

- Operational HWRF has good track skill for all lead times (**retrospective evaluation with FV3FS showed degraded track at Days 4-5**)
- HWRF has the best intensity skill till day 2, and unusually high intensity errors beyond day 3 due to high positive bias (**retrospective evaluation with FV3GFS showed negative bias**)
- HMON has good track skill but still behind HWRF, intensity errors are large for extended lead times (**retrospective evaluation with FV3GFS showed otherwise**)

❖ WPAC Basin:

- Operational HWRF has good track skill till Day 2
- Operational HWRF has the best intensity performance for extended lead times beyond Day 2



FY20 HWRF v13.0.0 Potential Upgrades



Scope of FY20 HWRF Upgrades

➤ System & Resolution Enhancements

- Framework upgrade to WRFV4.0 with bug fixes
- T&E with 2019 FV3GFS/GDAS (v15.1) IC/BC
- Enable using 3-hourly (instead of 6-hourly) lateral BC's
- **High Resolution land-sea mask**

- Increase vertical resolution
or
- Increase domain size (do1, do2, do3) (resources?)
- Test with GRIB2 inputs (vs. NEMSIO)

-- Green:

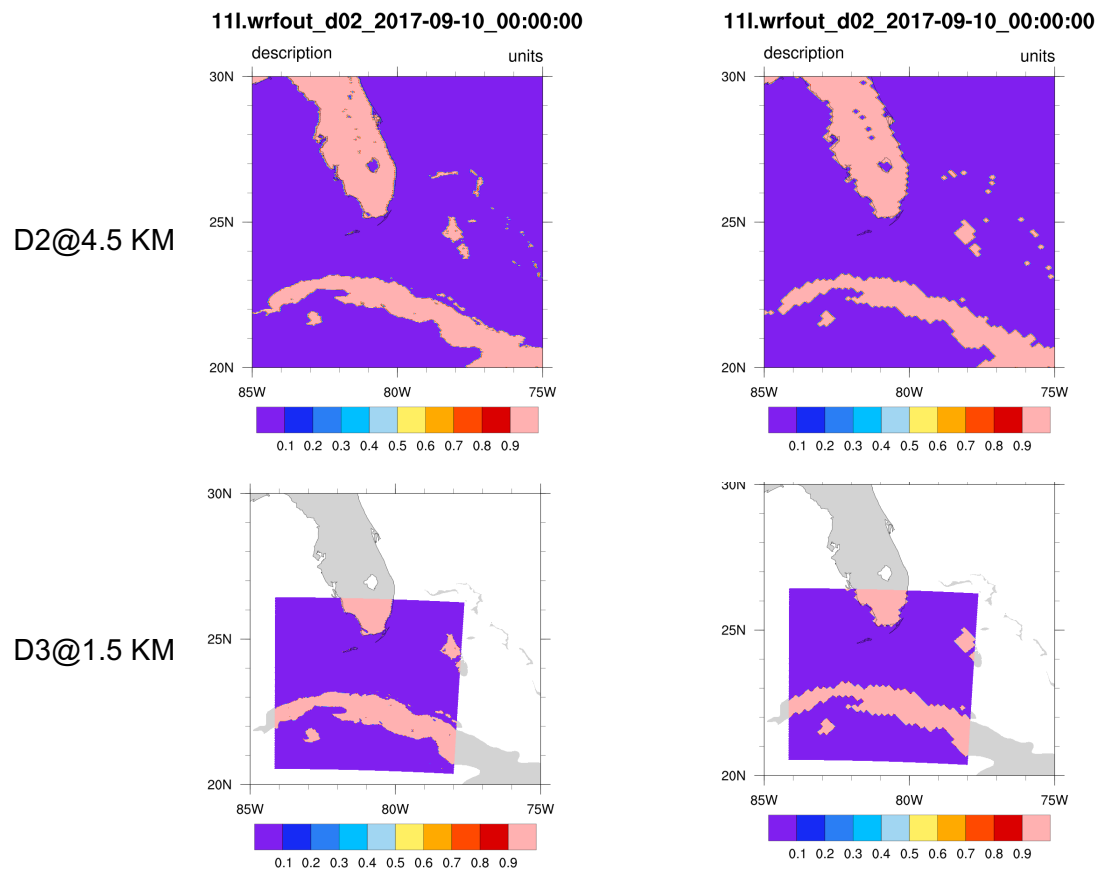
-- Orange:

Included in Baseline/H220

Tested separately as an option



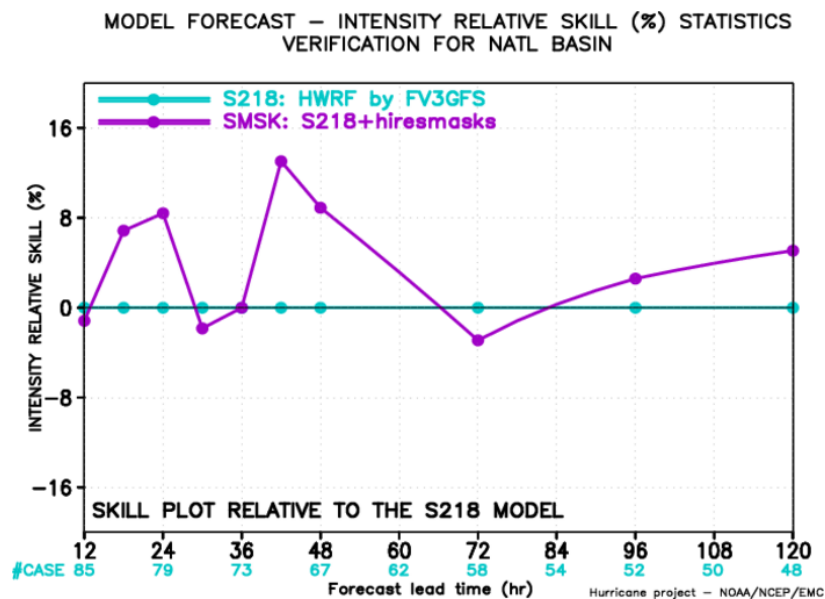
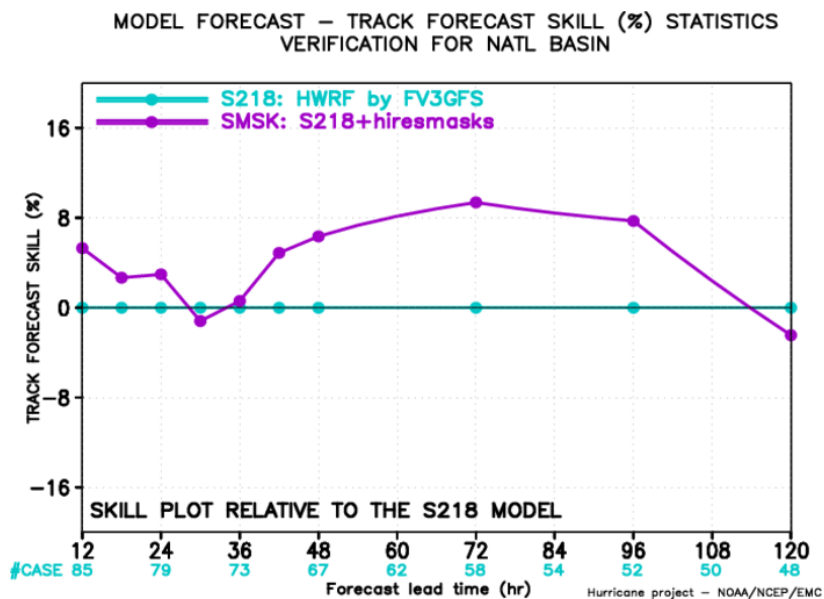
Hurricane Irma: Comparison of coastlines for the HWRF nested domains with and without high-resolution mask



Using Hurricane Irma (2017) as an example, high-resolution land-sea masks are compared for outer nest domain (D2) (top left panel) with operational HWRF (top right panel) and for inner nest domain with high-resolution mask (bottom left) with operational HWRF (bottom right).

The high-resolution mask provides a much improved representation of coastlines (and orography) for Florida, Cuba and the Bahamas.

HWRF with High-Resolution Mask: Much Improved track and Intensity skill for Hurricanes Irma and Harvey



Based on results for Hurricanes Irma and Harvey, there is good improvement in track skill (left panel) and intensity skill (right panel) when high-resolution mask is introduced in the HWRF configuration.

Scope of FY20 HWRF Upgrades

➤ Physics Advancements

- Upgrade to the latest version of the F-A microphysics scheme with bug fixes
- Updates to the cloud overlap method in RRTMG (AER)
- **Test variable mixing length modifications; test other PBL schemes (MYNN; YSU)**
- Test latest version of SAS
- Consider Thompson for microphysics
- G-F cumulus scheme (ESRL)
- Adjust surface flux exchange coefficients

-- Green:

Included in Baseline/H220

-- Orange:

Tested separately as an option



Hurricane Harvey: Flow Dependent Variable Horizontal Mixing Length Scale

Horizontal eddy diffusivity, K_h :

$$K_h = L_h^2 |D_h| \text{ where}$$

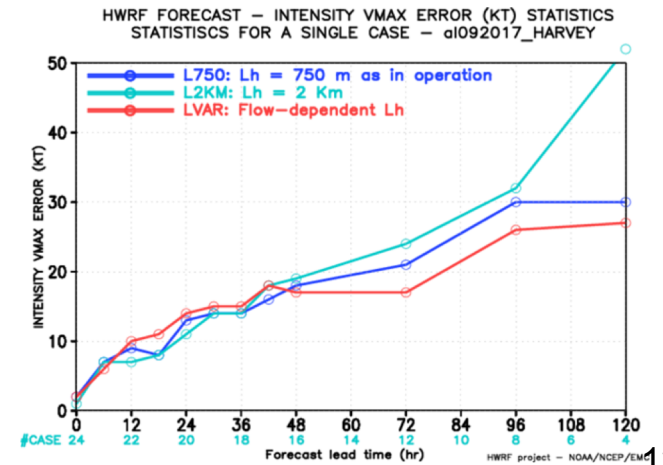
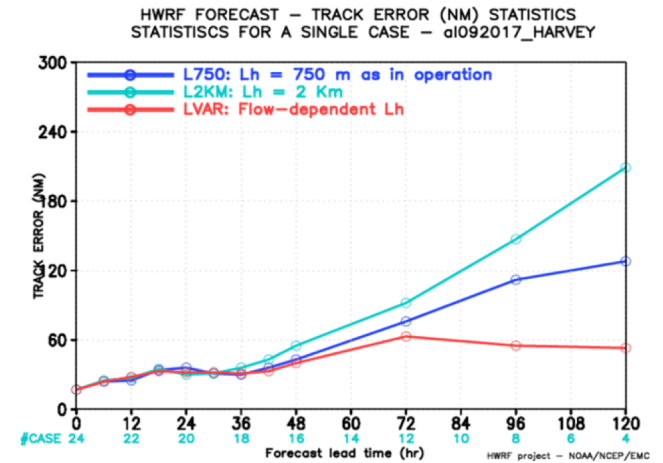
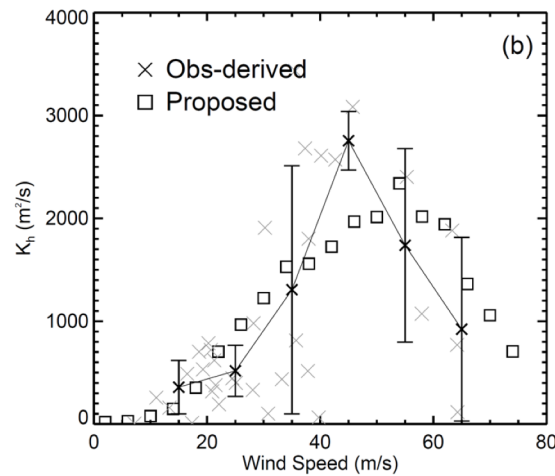
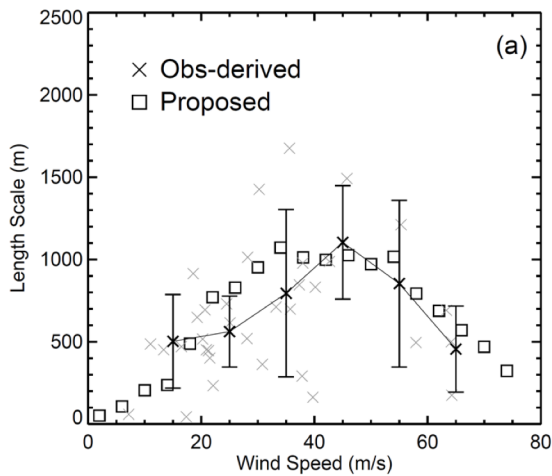
D_h -- horizontal deformation.

L_h used in current HWRF:

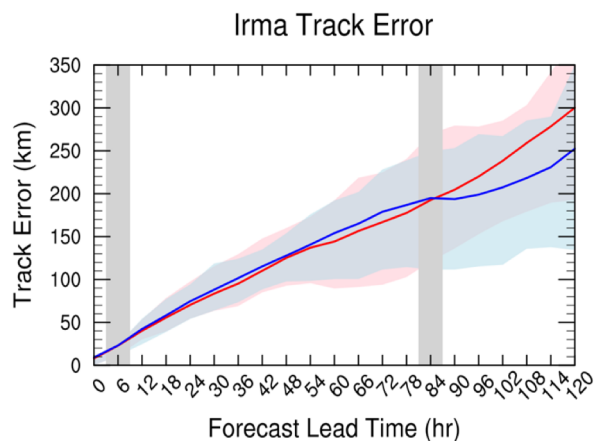
L_h -- $c\Delta$ (grid size) with c as a constant.

Proposed L_h :

L_h -- $F(L_{h1}, L_{h2})$, a function of length scales of shear and stretching.

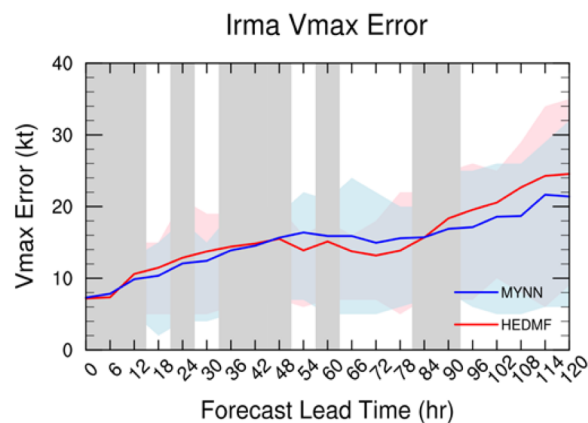


Hurricane Irma: Impact of MYNN PBL



In the MYNN, the Mass Flux (MF) part is activated when:

- at least one plume is activated;
- there must be a positive surface buoyancy flux (LH+HFX);
- the surface layer must be superadiabatic in the lowest 50 m (-0.4K/50m over ocean, -1.0K/50m over land).



Scope of FY20 HWRF Upgrades

➤ Initialization/Data Assimilation Improvements (Jason's talk)

- Improve vortex initialization
- **GSI code upgrades; update merging and tempdrop processing**
- **Un-flag and use a different thinning method for the ASCAT data**
- **Changes for the DA/GSI increment blending**

- Test the possibility of including the land-based radar observations (88D Vr data) in the inner-core DA
- Explore the new DA initialization method developed at DTC combined with the GSI relocation method
- Extending self-cycled system to two concurrent storms
- Adjust satellite background covariance coefficients

-- Green:

Included in Baseline/H220

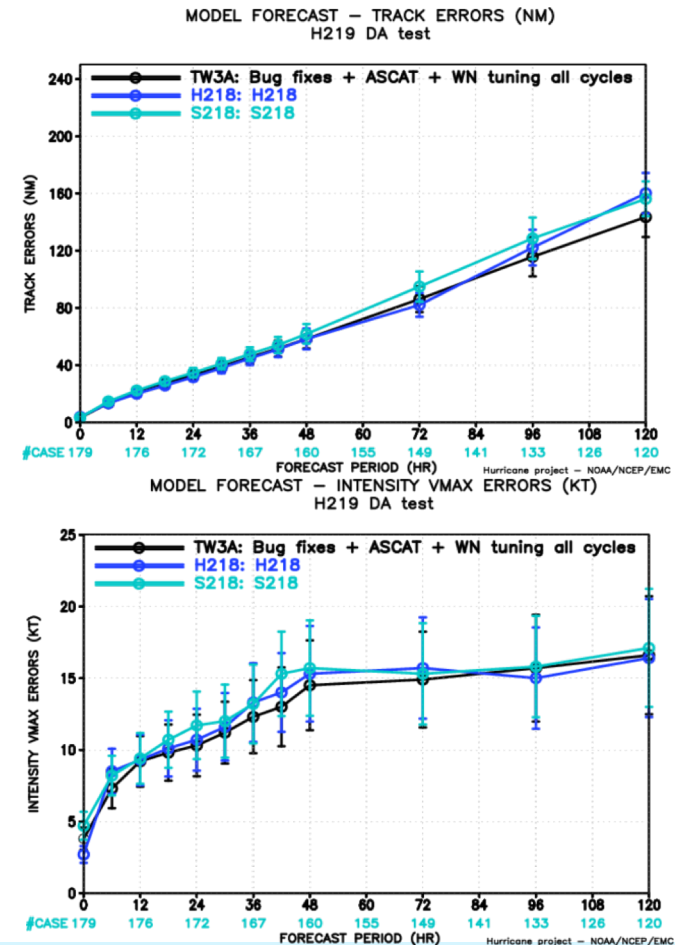
-- Orange:

Tested separately as an option



DA related Upgrades and Impacts

- ❖ Unflag and use a different thinning method for the ASCAT data
- ❖ Bug fixes for the domain merging method and the tempdrop data preprocessing
- ❖ Changes for the DA/GSI increment blending
 - Lower the GSI increment blending wind threshold from 64kt to 50kt
 - For vmax in the range of 50-64kt, using wave-number 0+1 for DA/GSI increment blending
 - For vmax stronger than 64kt, using the wave-number 0 (instead of 0+1) for DA/GSI increment blending
 - For the new merging method, increase the environment transition/relaxation radius from 250 to 300 km



Scope of FY20 HWRF Upgrades

➤ Other upgrades in 2020....

- Switch to RTOFS data (instead of GDEM climatology) to initialize ocean for the NATL basin (same as EPAC)
 - Improve re-gridding of initial data from RTOFS to POM grids especially over shallow layer to eliminate cold SST spots
 - Use updated coupler
 - Adjust damping coefficients and reduce model integration time step to avoid numerical instability
 - Upgrade to sync with the latest EMC Post (UPP) master/develop version
 - Update to the latest version of the GFDL tracker (from Tim Marchok, GFDL)
-
- Explore switching to HYCOM ocean coupling for NHC/CPHC basins
 - Test and tune three-way atmosphere-wave-ocean coupling
 - Graphics included in operational workflow

-- Green:

Included in Baseline/H220

-- Orange:

Tested separately as an option



Scope of FY20 HMON Upgrades

➤ System & Resolution Enhancements

- Upgrade/enhance dynamic core NMMB: add capability for random perturbations in the NMMB code, improve robustness of interpolation for moving domains
- **Add vertical levels**, revise nest domain sizes
- **Test different advection schemes**

➤ Coupling and Post Upgrades

- **Use the latest version of HYCOM**

➤ Product Upgrades

- Upgrade to sync with the latest EMC_Post (UPP) master/develop version
- Update to the latest version of the GFDL tracker (from Tim Marchok, GFDL)

➤ Physics Advancements

- Use original IGBP (International Geosphere-Biosphere Program) roughness length
- Turn on GWD over the outermost domain.
- Test WRF Single-Moment 6-Class ([WSM6](#)) microphysics scheme
- Upgrade to use the latest version of the scale-aware SAS convection scheme used in GFS
- Test flow-dependent horizontal mixing length to improve the representation of horizontal diffusion.

➤ Initialization Improvements

- Vortex initialization modifications including:
 - turn off smoothing in vortex relocation
 - turn off intensity correction if Pmin is shallower than OBS and Vmax is stronger than OBS

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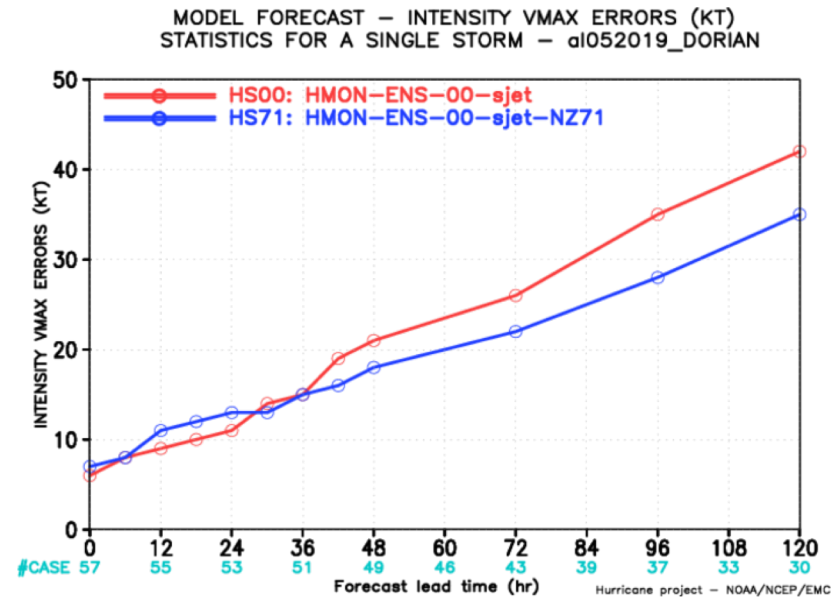
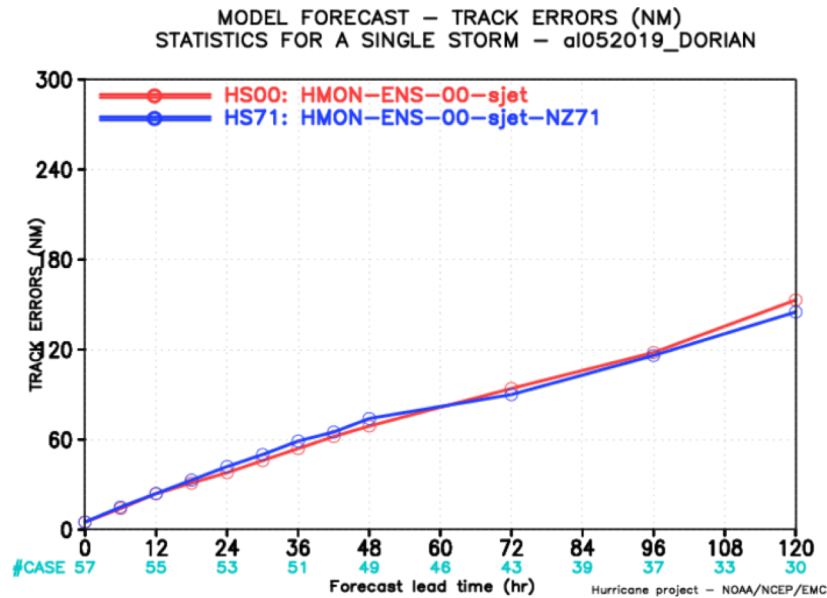
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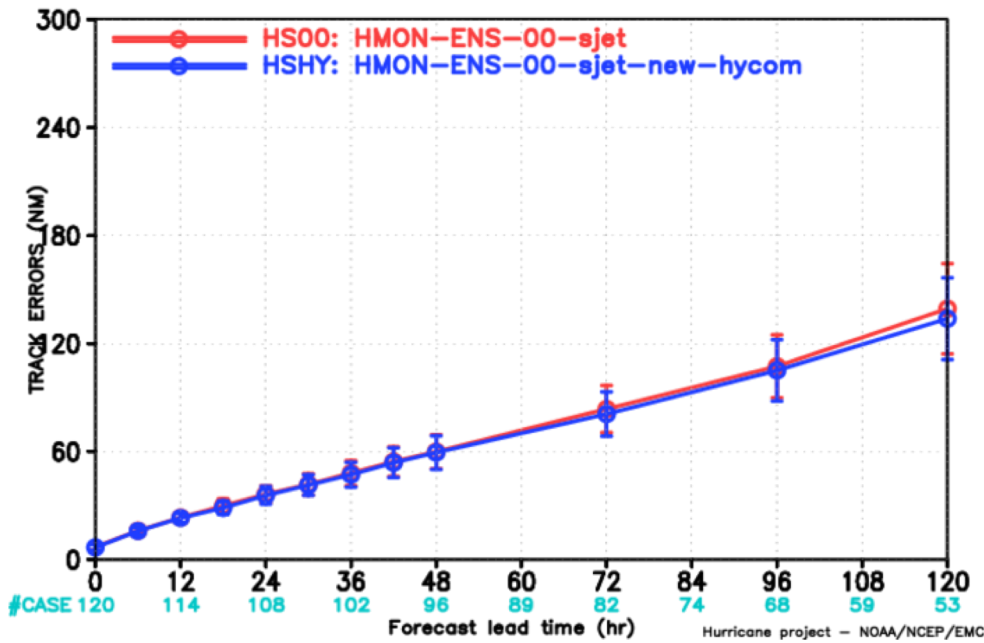
Hurricane Dorian: Increase vertical levels from 51 to 71



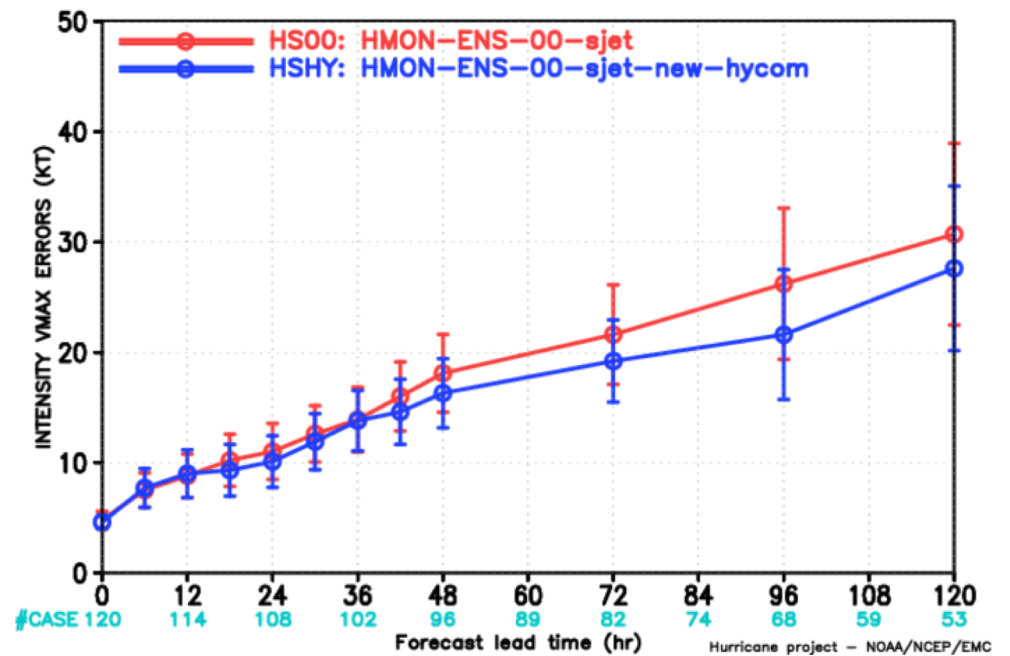
Simulations of Dorian (2019-05L) using HMON suggest that increasing nz from 51 to 71 can benefit intensity forecast.

Impact of using latest HYCOM source code

MODEL FORECAST – TRACK ERRORS (NM)
VERIFICATION FOR HMON



MODEL FORECAST – INTENSITY VMAX ERRORS (KT)
VERIFICATION FOR HMON



Using latest hycom improved track and intensity. Red– control; Blue– new hycom
Sample: 2019, 02L, 05L, 09L, 13L



FY2019 HWRF/HMON Configuration (maintain diversity for FY20)

Note: Items in Red are different

	HWRF	HMON
Dynamic core	Non-hydrostatic, NMM-E	Non-hydrostatic, NMM-B
Nesting	13.5/4.5/1.5 km; 77°/18°/6°; 75 vertical levels; Full two-way moving	18/6/2 km; 75°/12°/8°; 51 vertical levels; Full two-way moving
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), GFS-EDMF PBL, Updated Scale-aware SAS, NOAA LSM, Modified RRTM, Ferrier	Surface (GFDL), GFS-EDMF PBL, Scale-aware SAS, NOAA LSM, RRTM, Ferrier
Coupling	MPIPOM/HYCOM, RTOFS/GDEM, WaveWatch-III	HYCOM, RTOFS/NCODA, No waves
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



Future Implementations/Plans

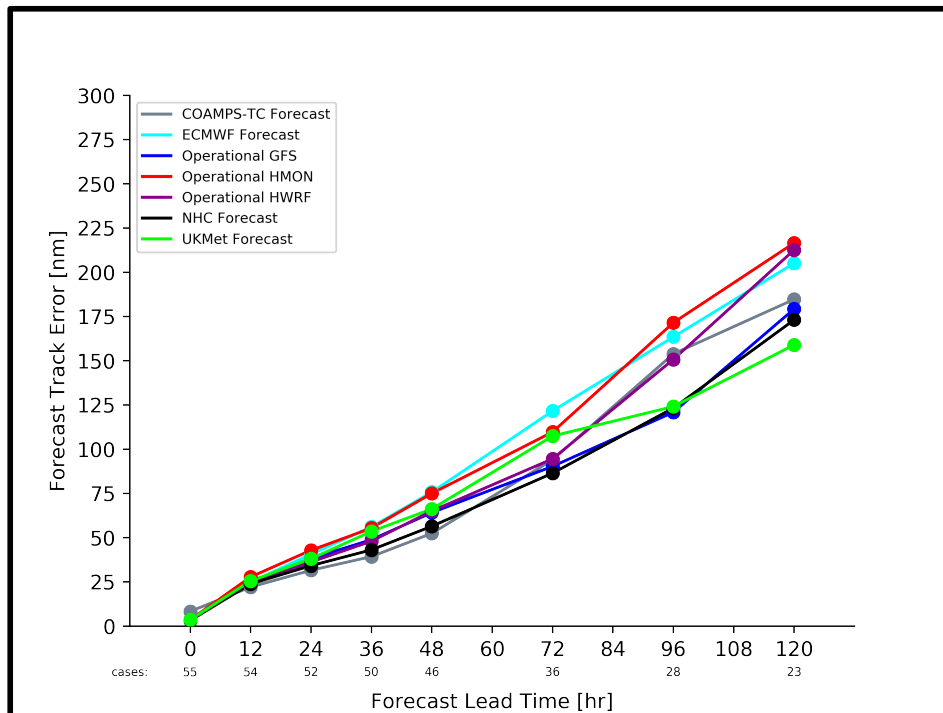
- ❖ FY20 – Full upgrades for HWRF and HMON targeted for Q3
- ❖ FY 21 – Adjustment/Evaluation for GFS v16 (127 levels, others)
- ❖ FY21 – **Second Moratorium** (new WCOSS available in FY22)
- ❖ FY 22 – HWRF/HMON/HAFS? (Wednesday afternoon)

Thank You !

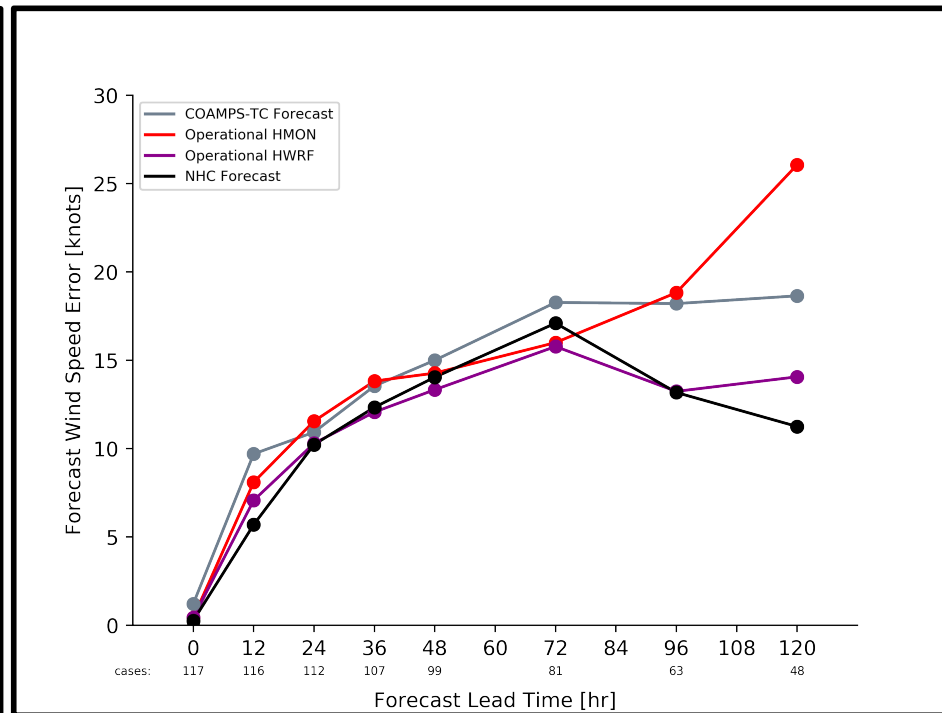


2018 North Atlantic Ocean Forecast Model Performance*:

Cases selected based on the assimilation of reconnaissance observations by the Operational HWRf



Track Forecast Error



Regional Model Maximum Wind Speed Intensity Error

* Does not contain TC Isaac (AL09) cases.

