Plans for Operational Hurricane Modeling in FY19

Avichal Mehra[1] and the EMC Hurricane Team

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

[1]***Environmental Modeling Center***
NOAA / NWS / NCEP

HFIP Annual Review Meeting, November 6, 2018

Outline

- FV3GFS implementation in FY19
- FV3GFS downstream testing for HWRF
- FY19 HWRF upgrades
- FV3GFS downstream testing for HMON
- FY19 HMON upgrades
- HWRF/HMON diversity
- Ongoing and future work

NGGPS FV3GFS-v1 Transition to Operations

FV3GFS is being configured to replace spectral model based GFS (NEMS GSM) in operations in Q2FY19

Configuration of GDAS/GFS V15.0.0:

- FV3GFS C768 (~13km deterministic)
- GFS Physics + GFDL Microphysics
- FV3GDAS C384 (~25km, 80 member ensemble)
- 64 layer, top at 0.2 hPa
- Uniform resolution for all 16 days of forecast

Evaluation Strategy:

- Retrospective experiments from May 2015 – May 2018
- Real-time parallel experiments from May 2018 – implementation date
- Independent EMC MEG Evaluation and Stakeholder Evaluation

Major Science Changes: GFDL FV3 Dynamic core and Microphysics

GSM

Spectral
Gaussian
Hydrostatic
64-bit precision

Finite-volume
Cubed-Sphere
non-hydrostatic
32-bit precision

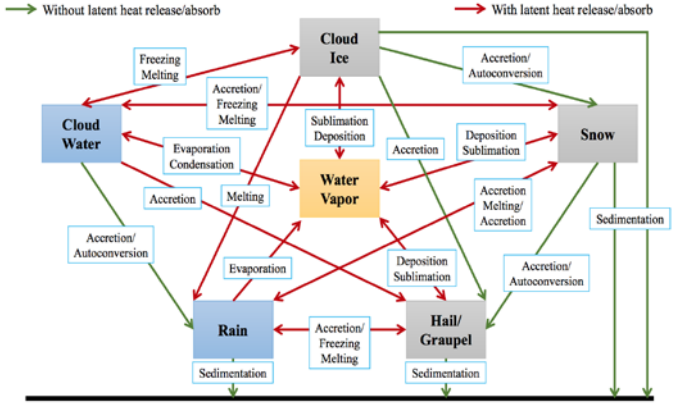
Physics runs at 64-bit precision

Zhao-Carr MP

Prognostic cloud species: one
total cloud water

GFDL MP

Prognostics cloud species : five
Liquid, ice, snow, graupel, rain;
more sophisticated cloud processes



Downstream testing with FV3GFS

HWRF v12.1.0 *

* Approved for implementation with FV3GFS in FY19Q2

HWRF Configurations

- H18I: Interpolated results for FY18 HWRF using 2017 GFS (operational GFS v14) results (2015-2017)

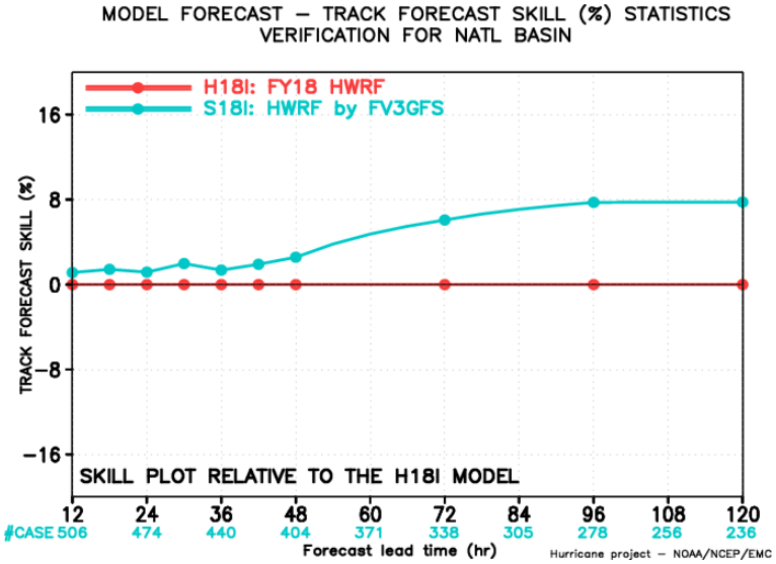
- S18I: Interpolated results for FY18 HWRF using FV3GFS (proposed GFS v15) retrospective results (2015-2017)

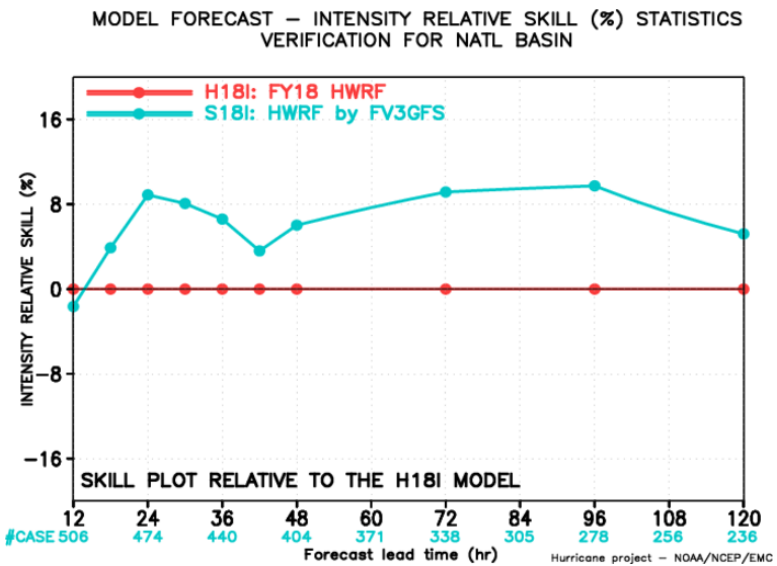
Changes Include:

- ✓ scripts and source code changes in HWRF initialization process to read in FV3GFS GRIB2;
- ✓ scripts and source code change HWRF/GSI for FV3GFS;
- ✓ bug fix for the case when storm moved too far north (> 60N).

HWRF/S18I Verification for Priority Storms

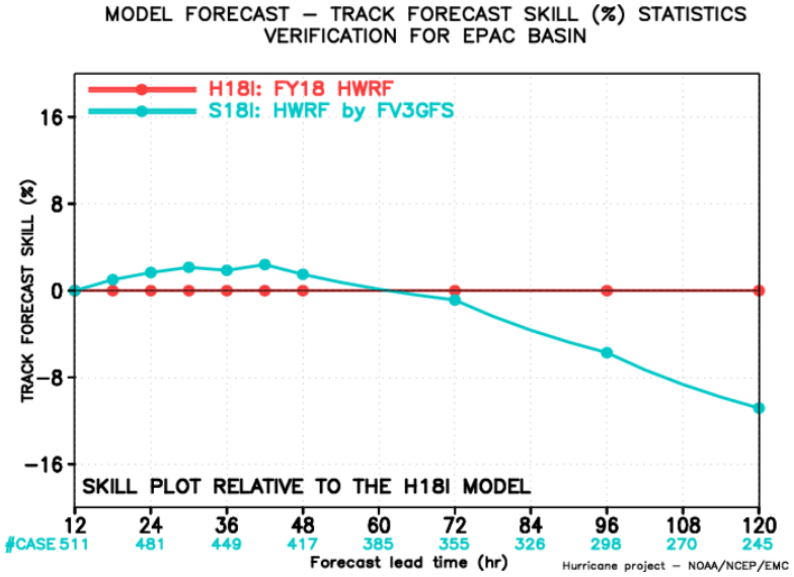
Track and Intensity skill for NATL basin (priority storms) (Early Model)

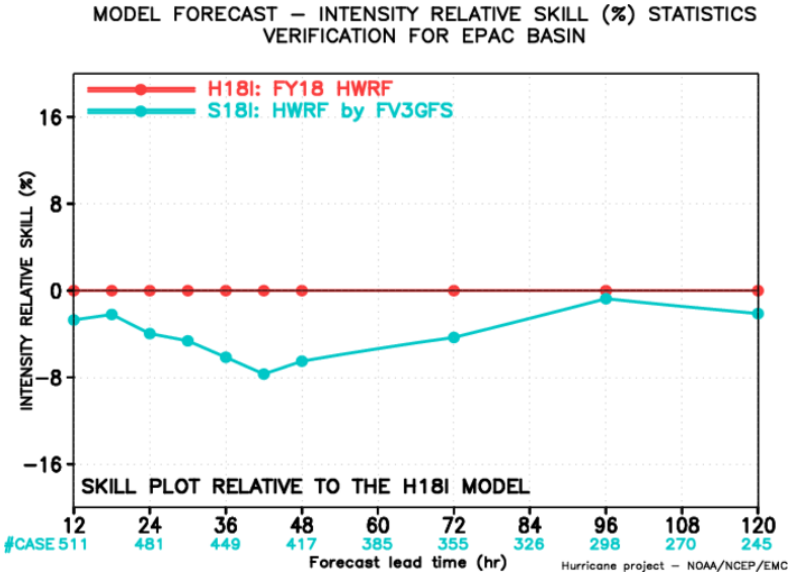




There is good improvement in track skill especially for longer lead times reaching 8% at Days 4 and 5. Intensity skill improvements are evident at all lead times with more than 8% improvements at Day 1 and again at Day 4.

Track and Intensity skill for EPAC basin (priority storms) (Early Model)





Track forecast skill is improved for the first 2 days and then neutral for Day 3, but behind for Days 4 and 5. Intensity skill, on the other hand, is behind for the first 3 days and then mostly neutral for longer lead times at Days 4 and 5.

FY19 HWRF v13.0.0
Potential Upgrades

Scope of FY19 HWRF Upgrades

➢ System & Resolution Enhancements

- Framework upgrade to WRFV4.0 with bug fixes
- T&E with 2019 FV3GFS IC/BC

- **High Resolution land-sea mask**
- Increase vertical resolution

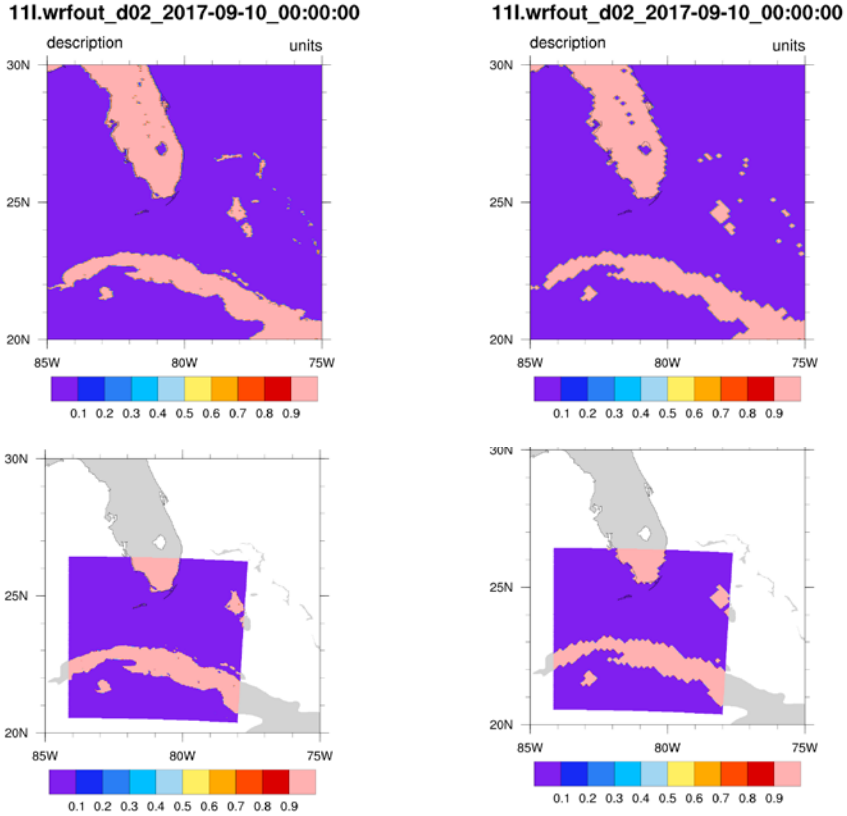
  or
- Increase domain size (d01, d02, d03)
- Test with GRIB2 inputs (vs. NEMSIO)

-- Green: **Included in Baseline/S218**
-- Orange: **Tested separately as an option**

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

D2@4.5 KM

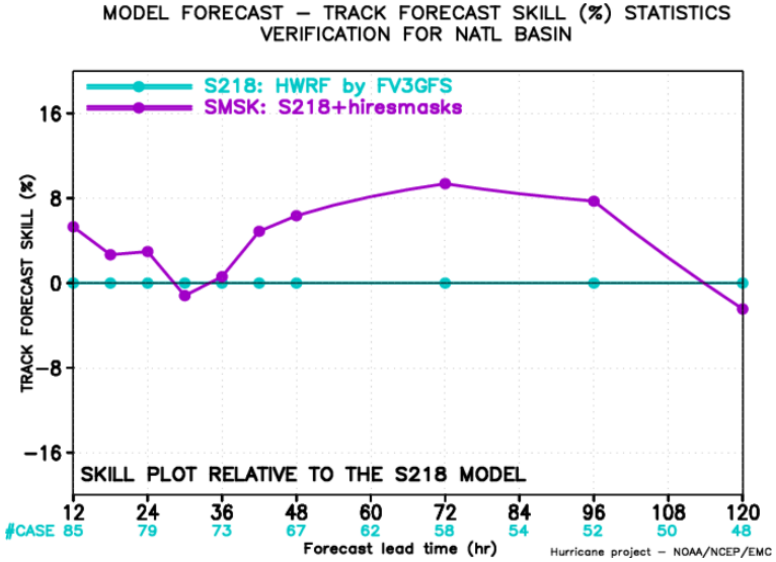
D3@1.5 KM

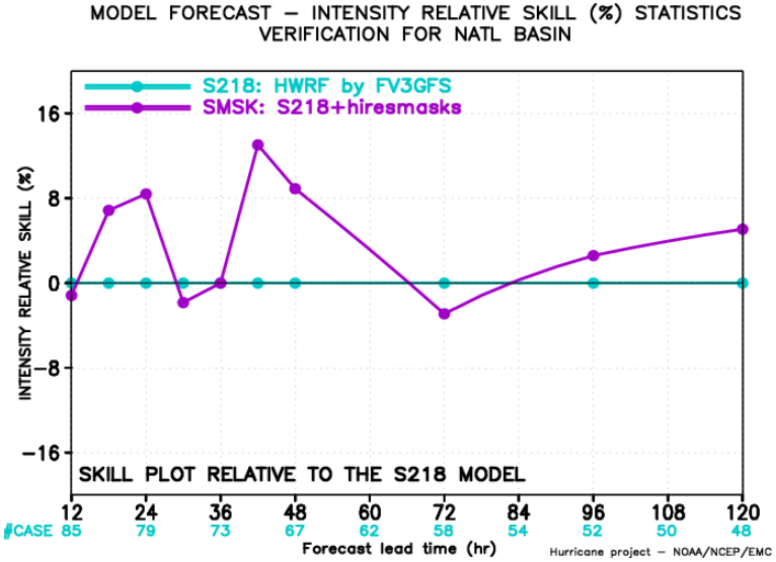


Using Hurricane Irma (2017) as an example, high-resolution land-sea masks are compared for outer nest domain (D2) (top left panel) with operational HWRF (top right panel) and for inner nest domain with high-resolution mask (bottom left) with operational HWRF (bottom right).

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 FY19 HWRF Upgrades

➢ Physics Advancements (Lin's talk)

- Updates/options for PBL schemes (MYNN; in-cloud mixing; YSU)
- G-F cumulus scheme (ESRL)
- Consider YSU surface layer scheme (with YSU PBL)
- Radiation, RRTMG- cloud overlap (AER/DTC)
- Adjust surface flux exchange coefficients

-- Green: **Included in Baseline/S218**
-- Orange: **Tested separately as an option**

Scope of FY19 HWRF Upgrades

➢ Initialization/Data Assimilation Improvements (Henry's talk)

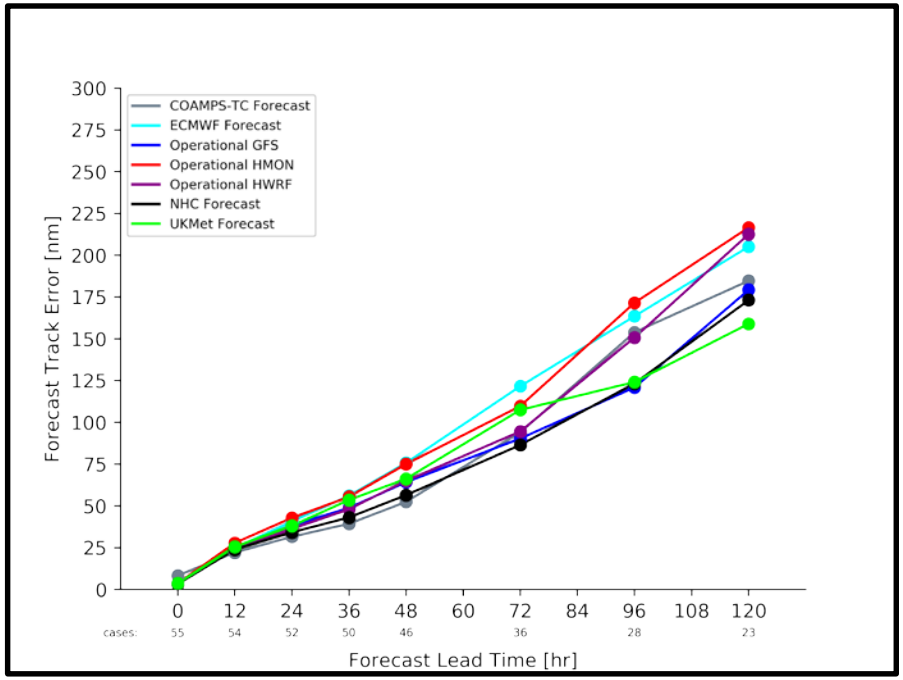
- Improve vortex initialization (for FV3GFS)
- GSI code upgrades (for FV3GFS); add new data sets

- SFMR observation errors tuning
- Tuning increments for storms > 135 kt
- Changes to front-end (Relocation, VI, VM), explore fully cycling D02/D03 instead of limited area around vortex
- **Extending self-cycled system to two concurrent storms**
- Satellite background covariance coefficients
- Extend DA to WPAC

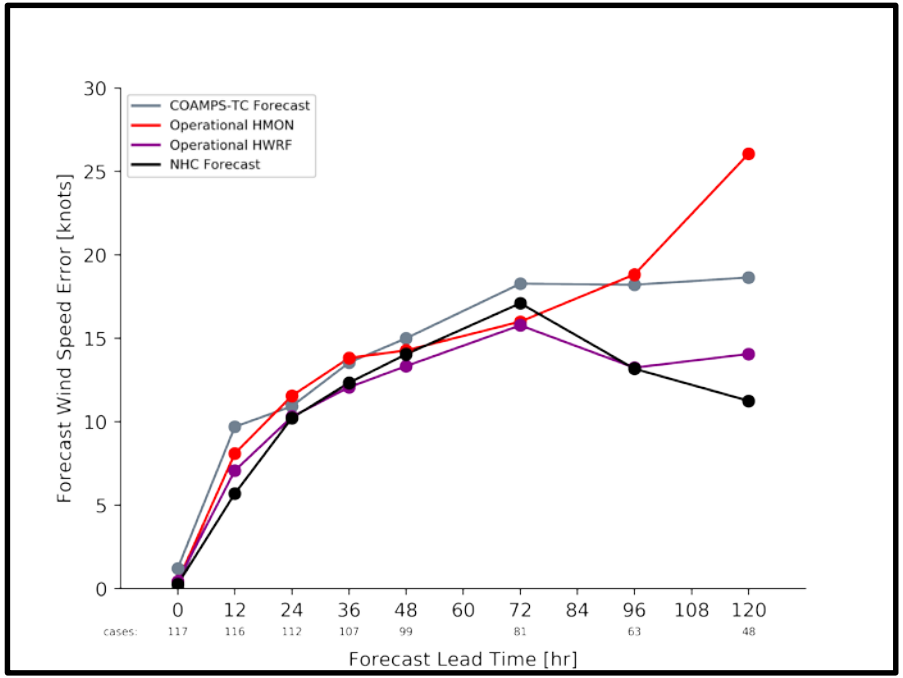
-- Green: **Included in Baseline/S218**
-- Orange: **Tested separately as an option**

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.

Scope of FY19 HWRF Upgrades

➢ **Other upgrades in 2019….**

- POM SST initialization from RTOFS in NATL basin (similar to EPAC and CPAC basins),
- Use updated coupler, test HYCOM coupling
- Adjust damping coefficients
- Updated tracker
- Graphics included in operational workflow

-- Green: **Included in Baseline/S218**
-- Orange: **Tested separately as an option**

HMON Configurations

- M18I: Interpolated results for FY18 HMON using 2017 GFS (operational GFS v14) results (2015-2017)

- MFVI: Interpolated results for FY18 HMON using FV3GFS (proposed GFS v15) retrospective results (2015-2017)

Changes include:

  - ✓ source and scripts changes in HMON initialization process to read in FV3GFS GRIB2;
  - ✓ bug fix for rain swath product

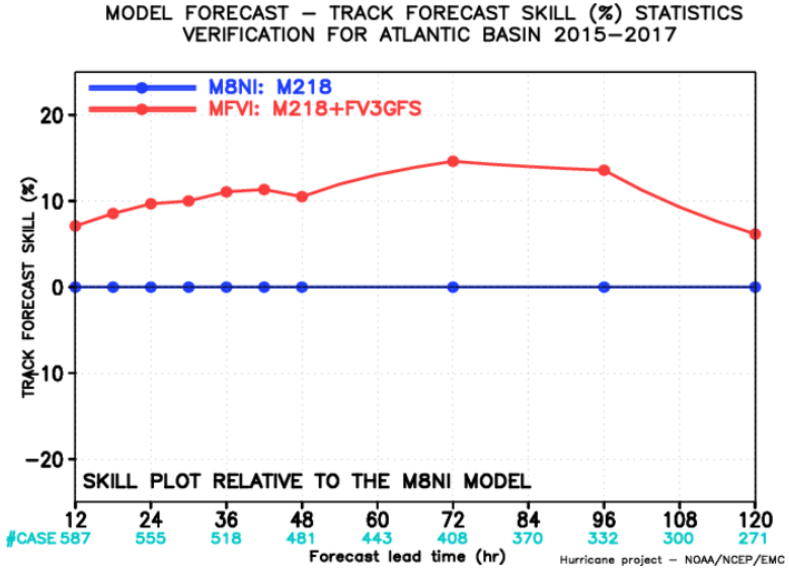
Downstream testing with FV3GFS

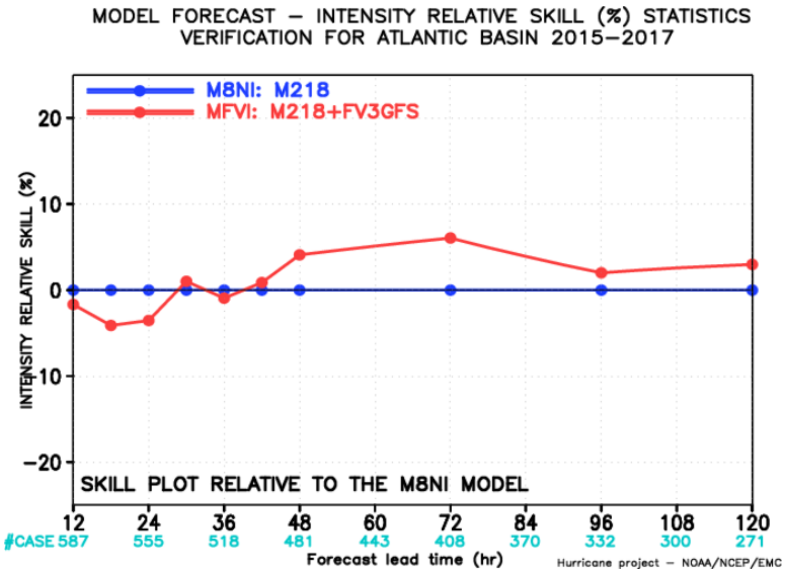
HMON v2.1.0 *

* Approved for implementation with FV3GFS in FY19Q2

HMON/MFVI Verification for Priority Storms

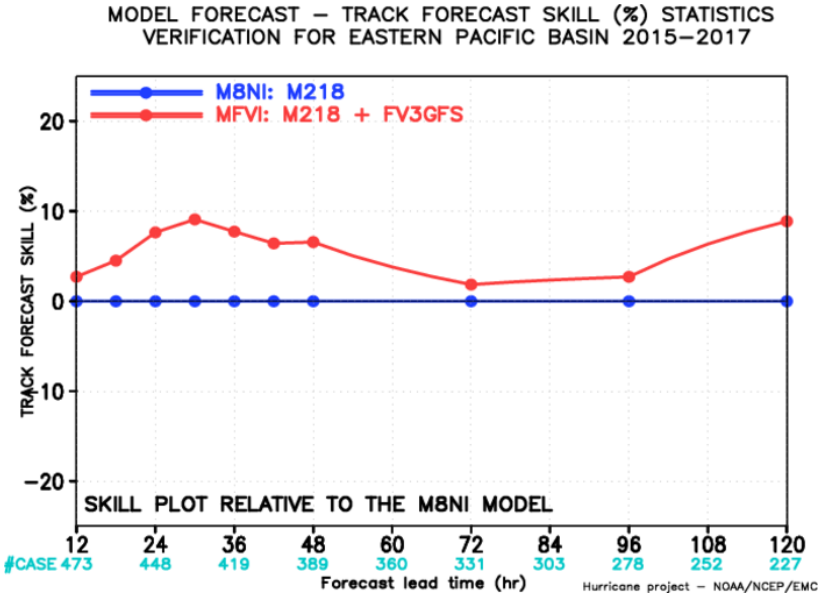
Track and Intensity skill for NATL basin (priority storms) (Early Model)

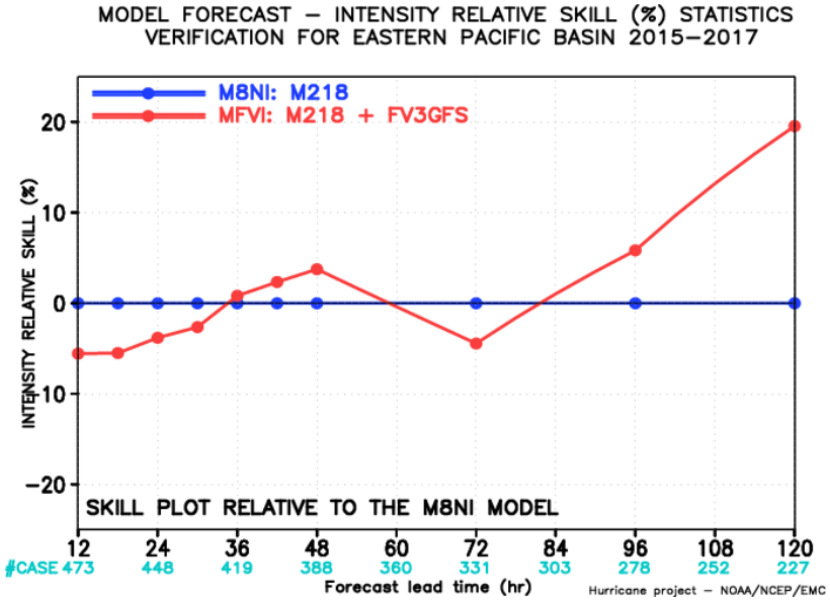




There is good improvement in track skill for all lead times peaking at around 14 % (at Day 3) while giving an average improvement of 10%. Intensity skill improvements start after Day 2 with 4-6% improvements at Day 2 and 3. There is some degradation at Day 1 but overall its positive.

Track and Intensity skill for EPAC basin (priority storms) (Early Model)





There is good improvement in track skill for early lead times peaking at around 10 % (at hr 30) and once again at Day 5 while giving improvement at all lead times. Intensity relative skills are neutral till Day 3 and significantly positive at Day 4 (6%) and Day 5 (20%).

Scope of FY19 HMON Upgrades

➢System & Resolution Enhancements

- Upgrade to the latest NMMB dynamic core
- Add vertical levels, revise nest domain sizes

➢Initialization Improvements

- Updated composite vortex

➢Physics Advancements

- Update momentum and enthalpy exchange coefficients(Cd/Ch)
- Deep convection (with FV3)
- Use scale aware TKE EDMF PBL scheme
- Use MYNN-EDMF scheme

➢ Coupling Upgrades

- Use updated coupler
- 3-way coupling

-- Green: Included in Baseline/MFVI
-- Orange: Tested separately as an option

FY2018 HWRF/HMON Configuration (maintain diversity for FY19)

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, NOAH LSM, Modified RRTM, Ferrier	Surface (GFDL), GFS-EDMF PBL, Scale-aware SAS, NOAH 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

Ongoing and Future Tasks

- Further improvements to hurricane physics
- Further improvements to vortex initialization and data assimilation
- Increase/change resolution, domain sizes
- Three-way Atmosphere-Ocean-Wave coupling
- 5-10 Member Ensembles for HWRF & HMON
- **HAFS**

Thank You !

Additional Slides

2015-2017 NATL/EPAC Priority Storms*

NATL priority storms	EPAC priority storms
2017 17L Ophelia*	2017 17E Norma
2017 16L Nate*	2017 15E Otis
2017 15L Maria*	2017 13E Kenneth
2017 14L Lee	2017 10E Irwin
2017 12L Jose*	2017 09E Hilary
2017 11L Irma*	
2017 09L Harvey*	2016 15E Newton
	2016 13E Lester
2016 15L Nicole	2016 11E Javier*
2016 14L Matthew*	2016 07E Frank
2016 12L Karl*	2016 05E Darby
2016 09L Hermine*	2016 04E Celia
2016 07L Gaston	
2016 06L Fiona	2015 20E Patricia*
2016 05L Earl*	2015 19E Olaf
	2015 13E Jimena
2015 11L Joaquin*	2015 12E Ignacio
2015 07L Grace	2015 06E Enrique
2015 06L Fred	
2015 05L Erica*	
2015 04L Danny*	

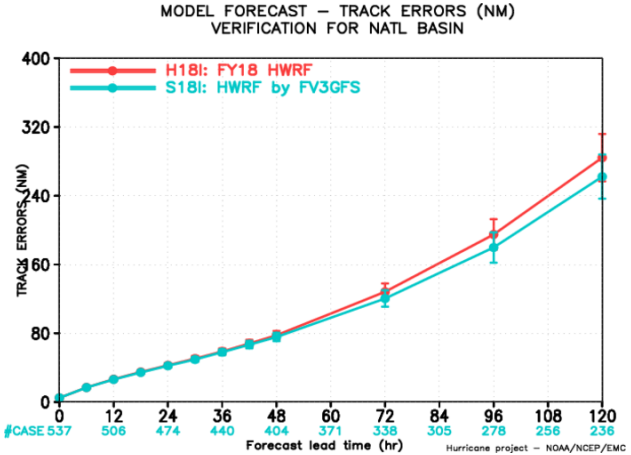
* This list was jointly devised by NHC and EMC based on criterion related to best representation of basins

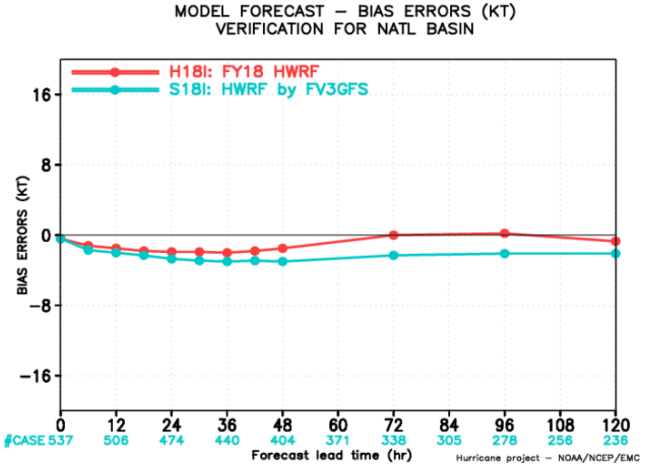
Total cycles in this sample size

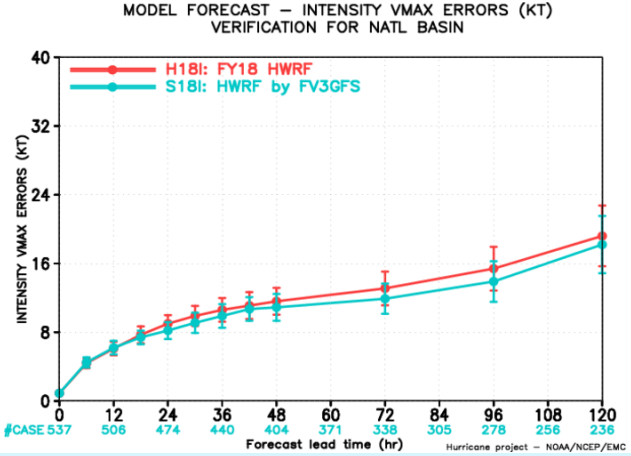
- HWRF in NATL: 787 forecast cycles total (including 734 non-invest cycles)
- HWRF in EPAC: 611 forecast cycles total (including 574 non-invest cycles)
- HMON in NATL: 723 forecast cycles total (including 721 non-invest cycles)
- HMON in EPAC: 553 forecast cycles total (including 551 non-invest cycles)

* Differences between HWRF/HMON due to availability of RTOFS data

HWRF Performance (NATL Basin): Early Model



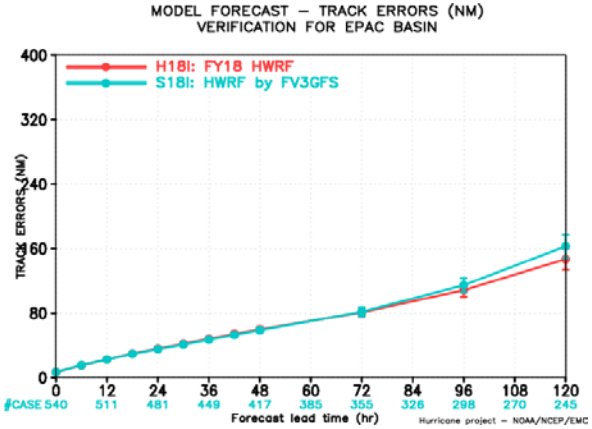


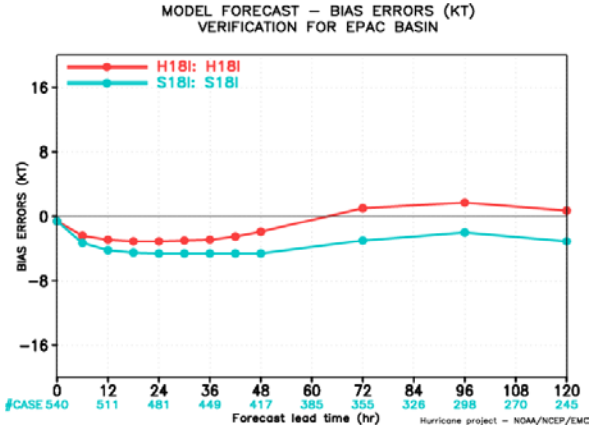


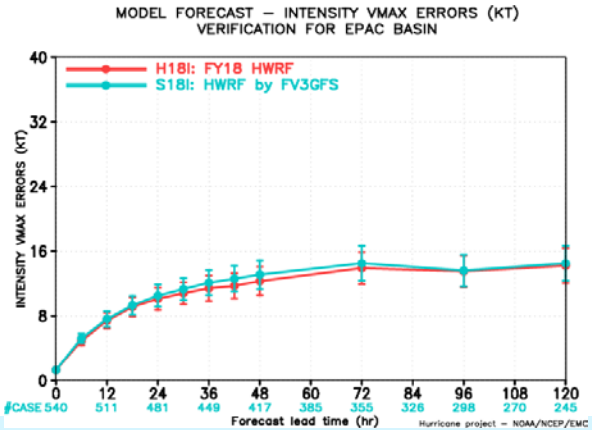
S18I has reduced track errors as compared to H18I (the operational version of HWRF) especially for longer lead times (> 3 days0.

The intensity errors are also smaller for all lead times for S18I but the bias errors are on the negative side.

HWRF Performance (EPAC Basin): Early Model



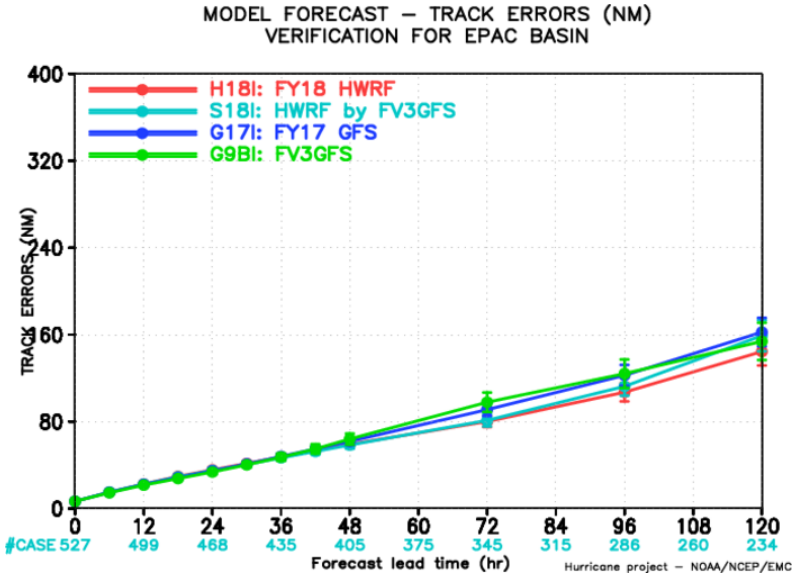


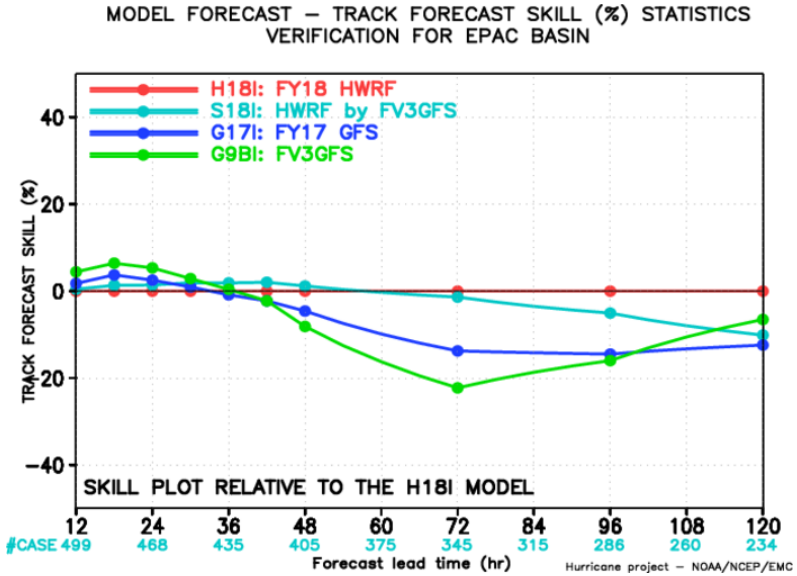


S18I has similar track errors for early lead times up to Day 3 but larger errors for Days 4 and 5 as compared to H18I.

The intensity errors are larger for early lead times but similar for Days 4 and 5. Intensity biases are also larger and negative when compared with H18I.

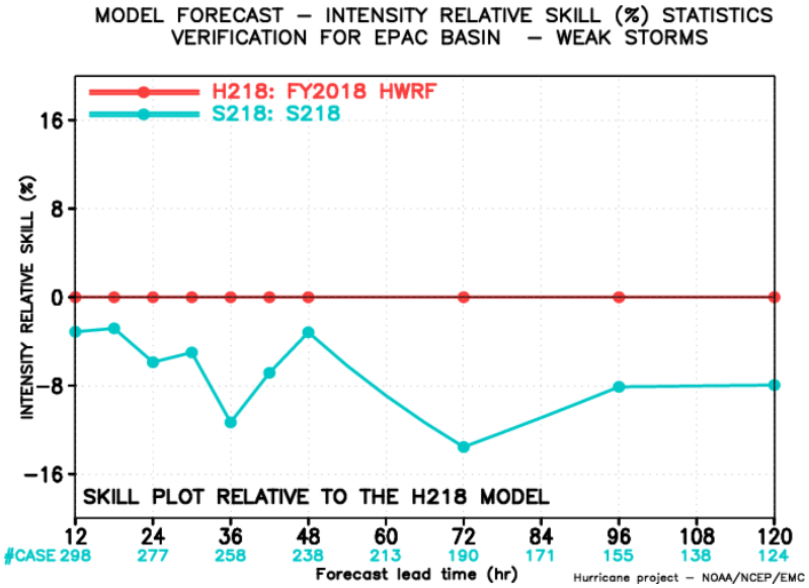
Track Error Comparisons for the EPAC basin (priority storms)

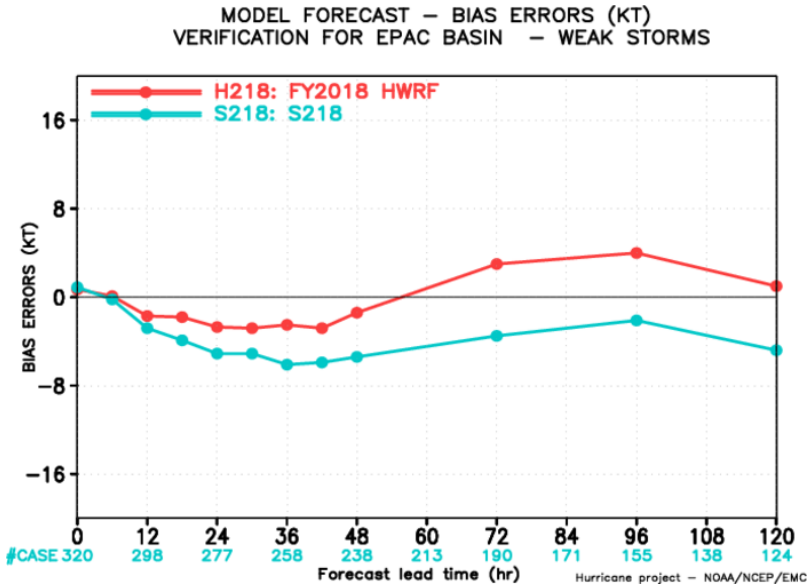




Track errors for FV3GFS (for this sample size in EPAC) are larger than GFS for Days 2, 3 and 4 but better performance than GFS at Days 1 and 5.

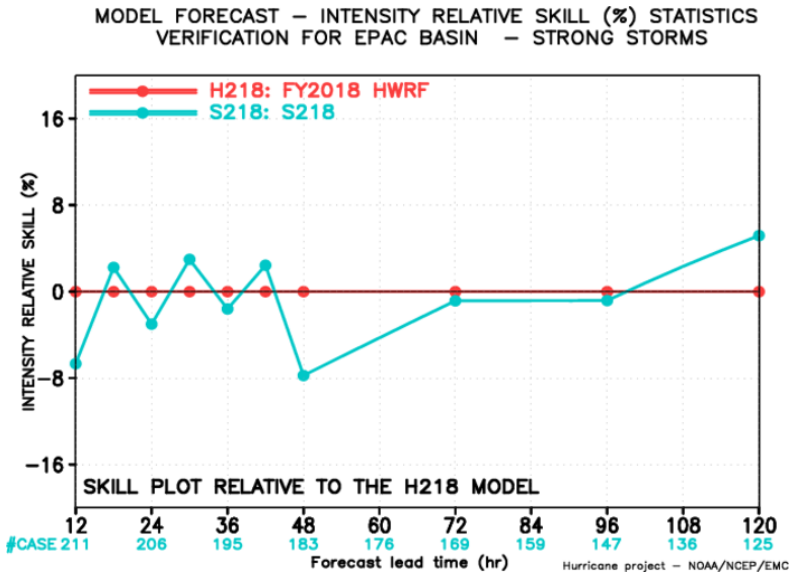
Intensity error comparisons for EPAC basin (weak storms < 64 Kts)

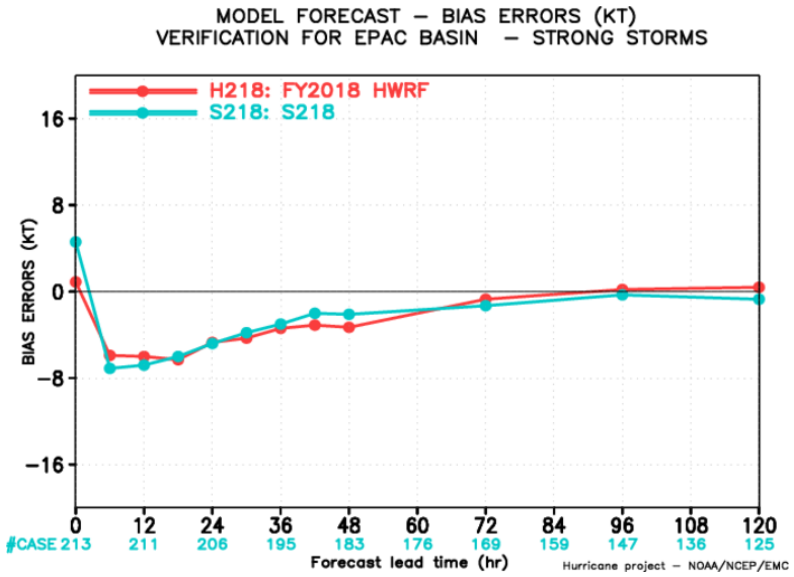




There are large intensity and bias (negative) errors when compared to 2018 operational HWRF for weak storms in the EPAC basin.

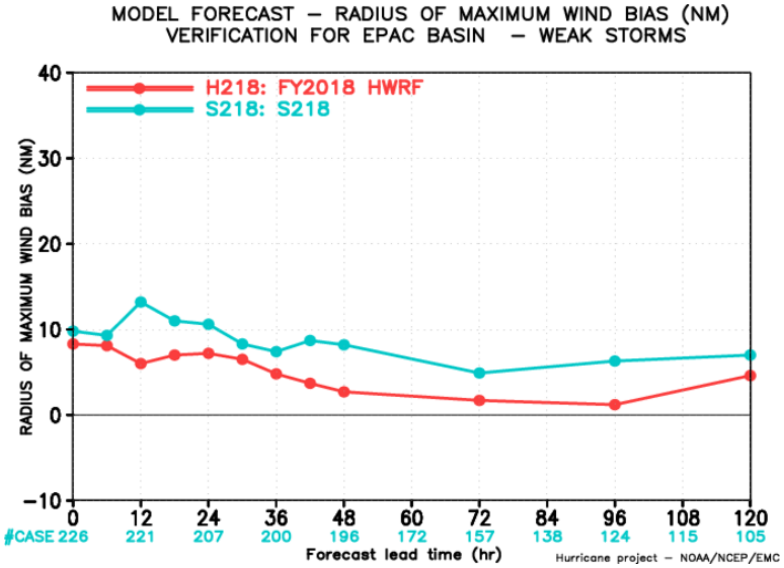
Intensity error comparisons for EPAC basin (strong storms > 64 Kts)

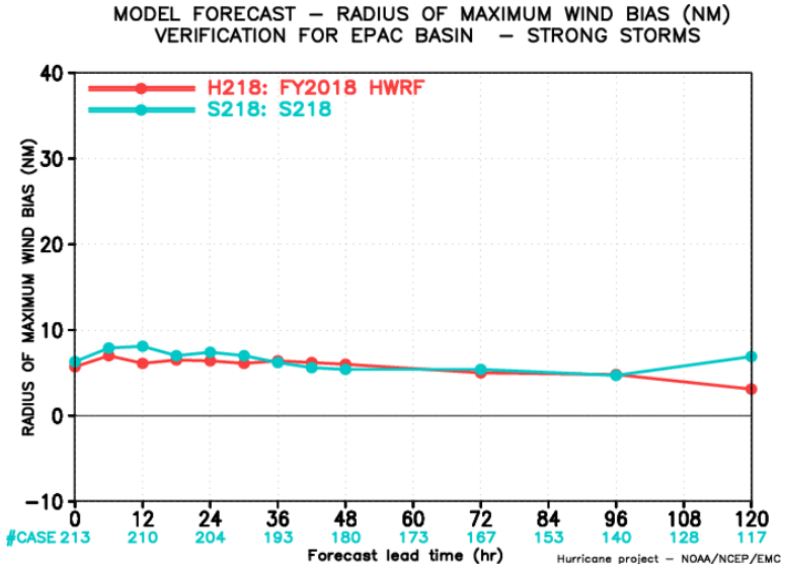




The intensity errors and bias are very similar to the 2018 operational HWRF for strong storms in the EPAC basin.

Size error bias comparisons for EPAC basin (weak and strong storms)





RMW size bias errors in EPAC are much larger for the weaker storms for S218 while they are very similar when compared to 2018 operational HWRF for stronger storms.

S18I Testing Summary

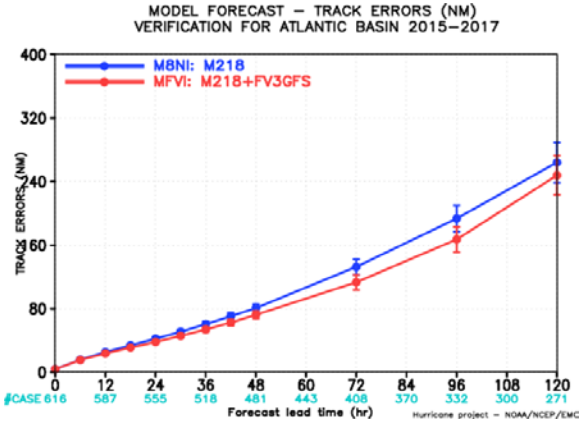
- Based on select priority storms, NATL Basin shows healthy improvements in intensity performance for all lead times and for track skill after Day 2. Intensity bias is more negative especially for longer lead times when compared with operational HWRF results

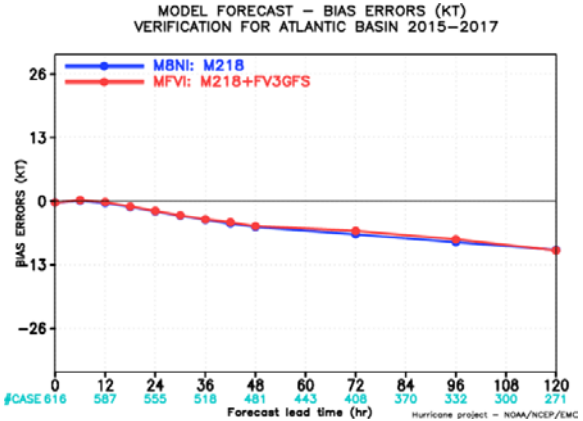
- Based on select priority storms, EPAC basin shows larger track errors for Days 4 and 5 but some improvements for the first 2 days. Intensity skill is behind for the earlier lead times up to Day 3 and neutral for longer lead times.

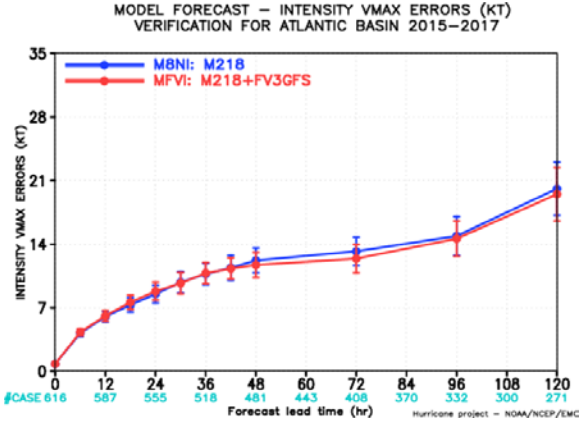
- Differences in NATL & EPAC performance:

  - ✓ Track degradation for this sample size is also evident in FV3GFS results for EPAC (supplemental slides) which is not the case for the NATL basin
  - ✓ Most of the degradation in EPAC results is from weak storms (< 64 kts, supplemental slides), which indicates larger impact of relocation differences for weaker smaller storms in EPAC. It seems presence of additional recon data for NATL storms mitigates this impact where the intensity performance is similar between weak and strong storms. Nevertheless, this issue needs to be explored further.

HMON Performance (NATL Basin): Early Model



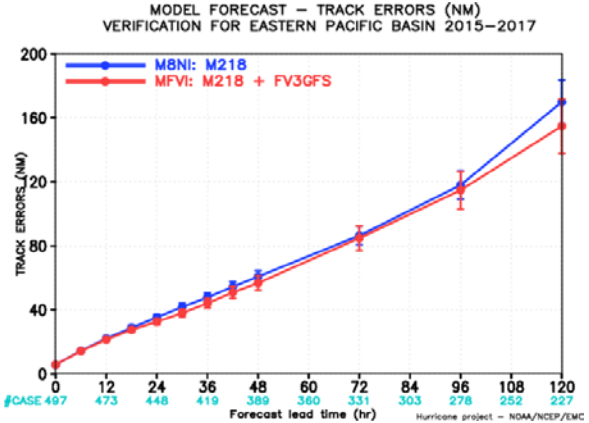


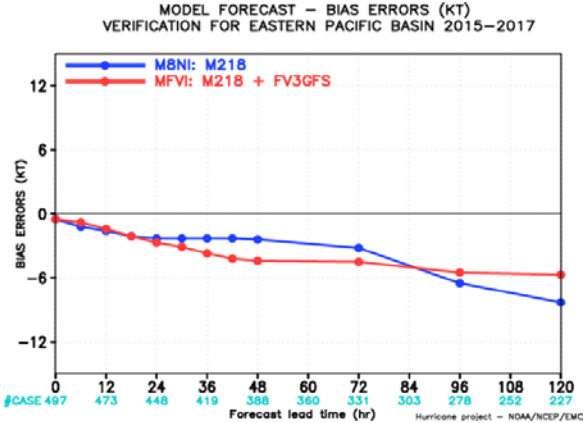


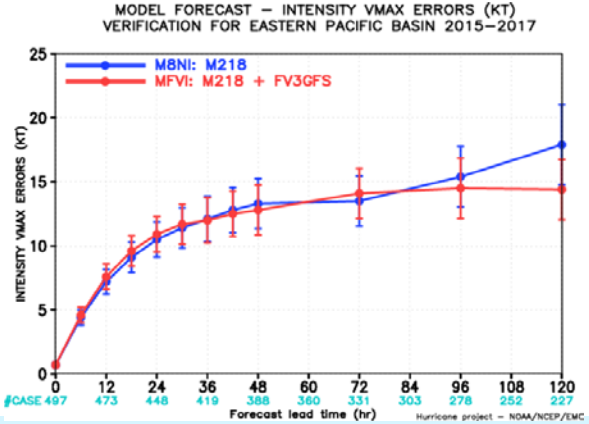
MFVI has much reduced track errors as compared to M18I (the operational version of HMON) especially for later lead times.

The intensity errors are also smaller for all lead times. The bias errors are very similar.

HMON Performance (EPAC Basin): Early Model







MFVI has reduced track errors at Days 2, 4 and 5 as compared to M18I (the operational version of HMON).

The intensity errors are also smaller for Day 2 and especially for Days 4 and 5. Biases are neutral as compared to the operational version.

MFVI Testing Summary

- Based on select priority storms, NATL Basin shows healthy improvements in track performance for all lead times and for intensity skill after Day 2. Intensity bias is very similar to operational HMON results

- Based on select priority storms, EPAC basin also shows healthy improvements for track at all lead times. Intensity performance is significantly improved for longer lead times (after Day 4). Intensity bias is neutral when compared with priority storm results with 2018 operational HMON.