2020 HMON Implementation Science Briefing

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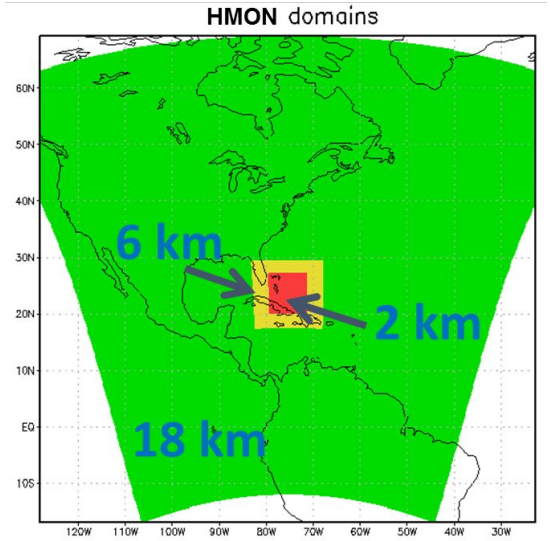
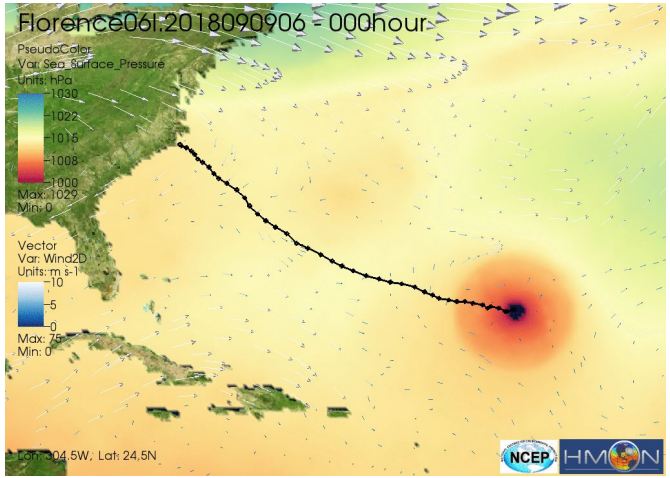
in collaboration with
HRD, DTC, NHC, GFDL, ESRL, CCU, OU and others.

HMON: Hurricanes in a Multi-scale Ocean coupled Non-hydrostatic model





Operational HMON :
First version implemented in 2017 (by replacing the legacy GFDL Hurricane Model)

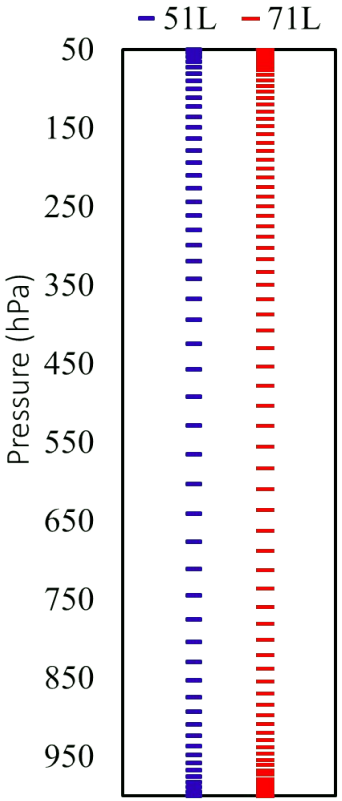
HMON: Implements a long-term strategy at NCEP/EMC for multiple static and moving nests globally, with one- and two-way interaction and coupled to other (ocean, wave, land, surge, inundation, etc.) models using NEMS-NUOPC infrastructure. Precursor to UFS-based **HAFS** (Hurricane Analysis and Forecast System

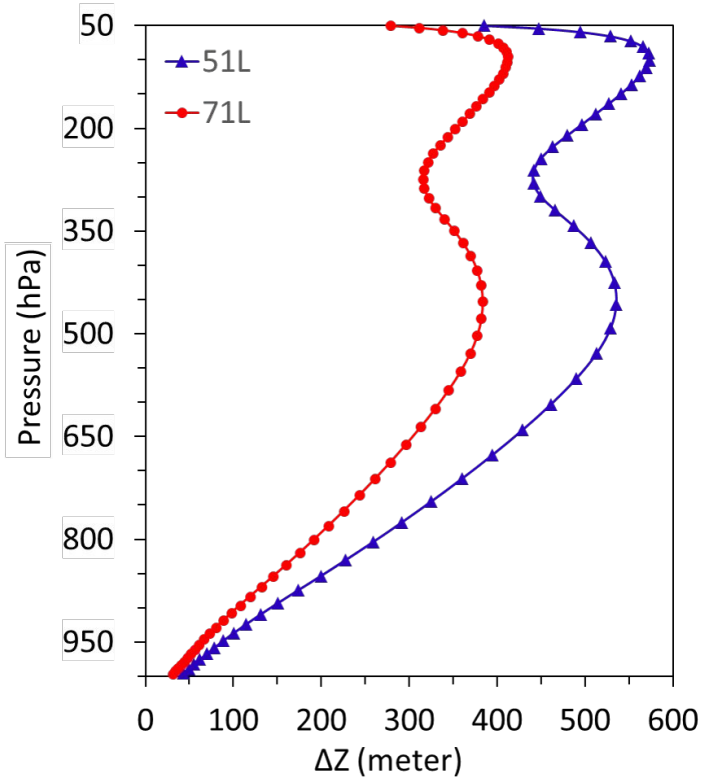
FY2020 HMON Implementation
(Infrastructure Enhancements)

- Upgrade/enhance dynamic core NMMB: capability to add random perturbations in the NMMB code, improve robustness of interpolation when domains move
- Increase number of vertical levels of the atmospheric model from 51 to 71
- ~~Increase size of nest domains~~

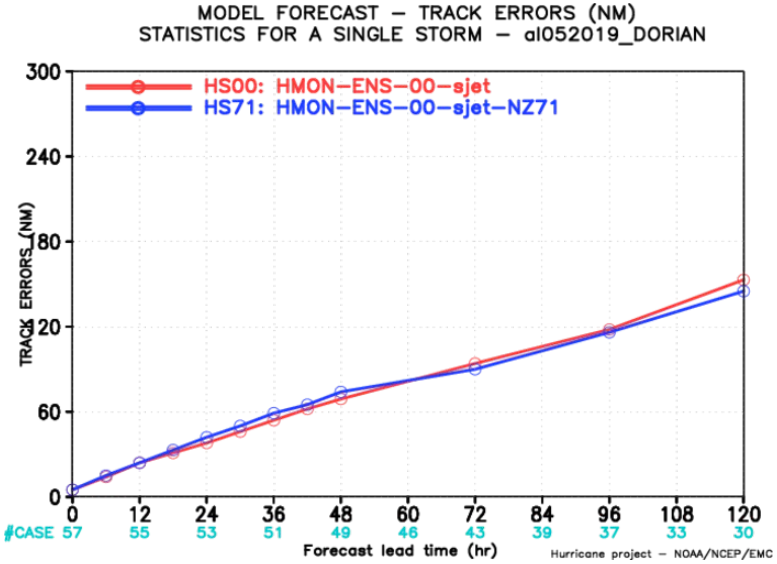
- Green indicates upgrades to be included in H220 baseline configuration
- Items in Red: first time in 2020
- Orange denotes experiments made for the final decision

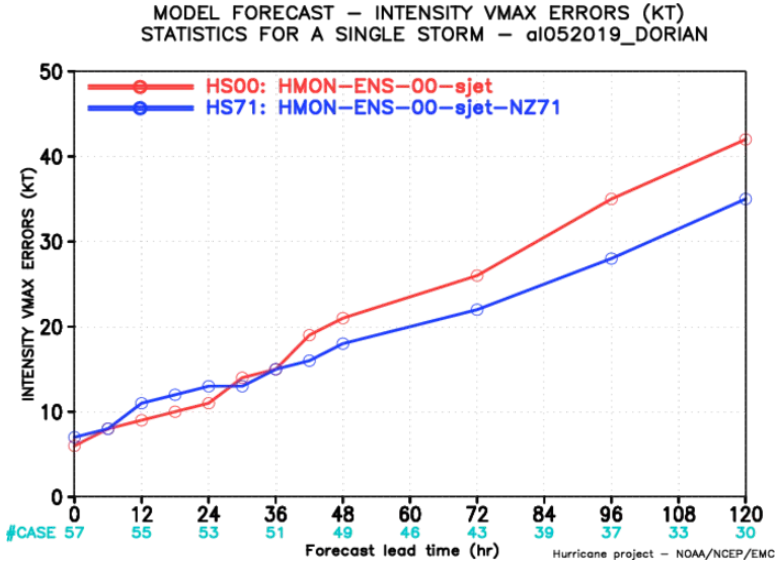
Vertical Level Distribution for the Proposed HMON Upgrade





Hurricane Dorian: Impact of increasing vertical levels (from 51 to 71)





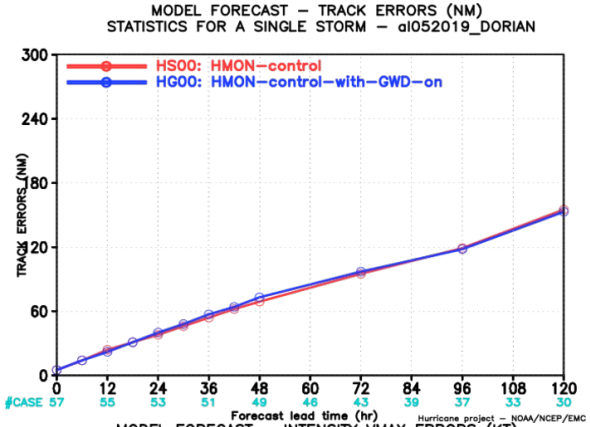
Simulations of Dorain (2019-05L) using HMON suggest that increasing nz from 51 to 71 can benefit intensity forecast.

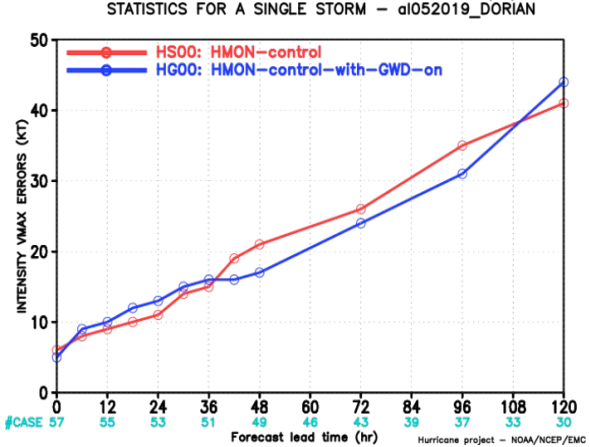
FY2020 HMON Implementation
(Physics Advancements)

- Bug fix for cloud water tendencies due to convection
- Bug fix eliminating possible negative ice/rain fractions (when domains move or ice/rain closes to zero)
- Use original IGBP (**International** Geosphere-Biosphere Programme) roughness length
- Turn on GWD over the outermost domain
- ~~Tested WRF Single-Moment 6-Class (WSM6) microphysics scheme~~
- ~~Tested a flow-dependent horizontal mixing length to improve the representation of horizontal diffusion.~~
- ~~Tested a modification of PBL K profile removing possible K discontinuity neat PBL top~~

- Green indicates upgrades to be included in H220 baseline configuration
- Items in Red: first time in 2020
- Orange denotes experiments made for the final decision

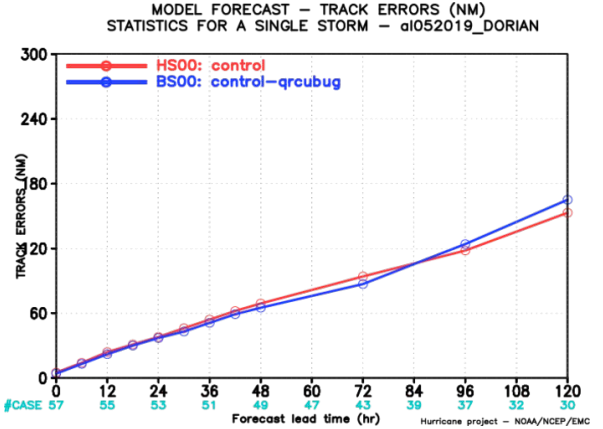
Hurricane Dorian: Impact of Physics Changes

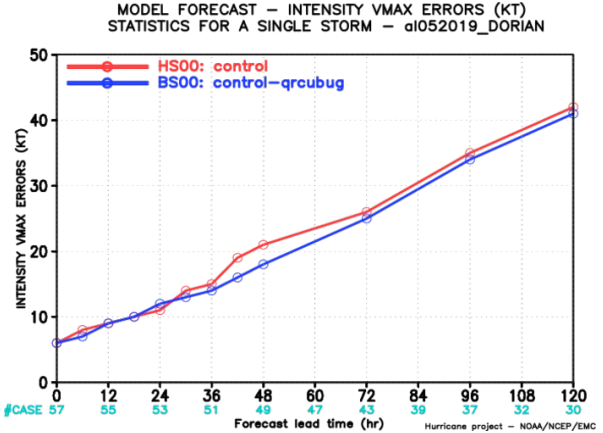




Left panels show track and intensity error comparisons between operational HMON (red line) and with GWD turned on for for the outermost domain (blue line). **Right panels** shows track and intensity error comparisons between operational HMON (red line) and with bug fixes in physics (blue line).

These changes give us reduced intensity errors (**bottom panels**) while track errors remained neutral.



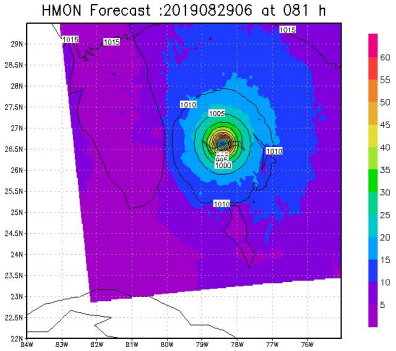


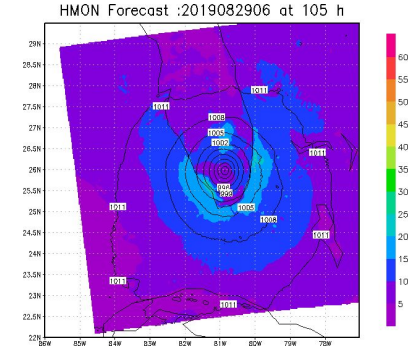
Landfalling Hurricane : Impact of Orginal IGBP Roughness Length

Before landfall

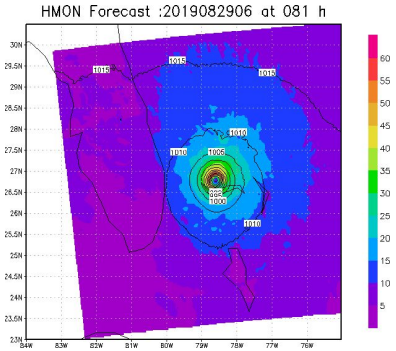
During Landfall

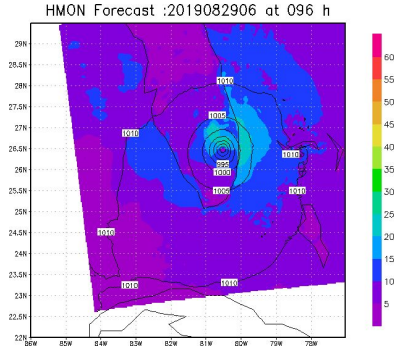
Current HMON



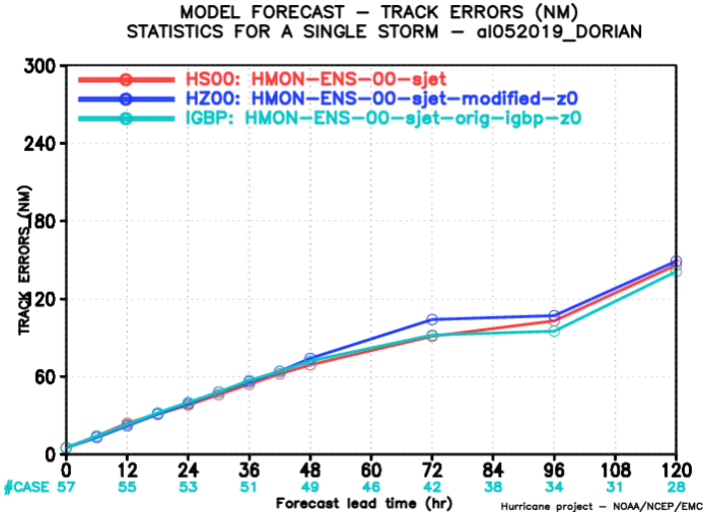


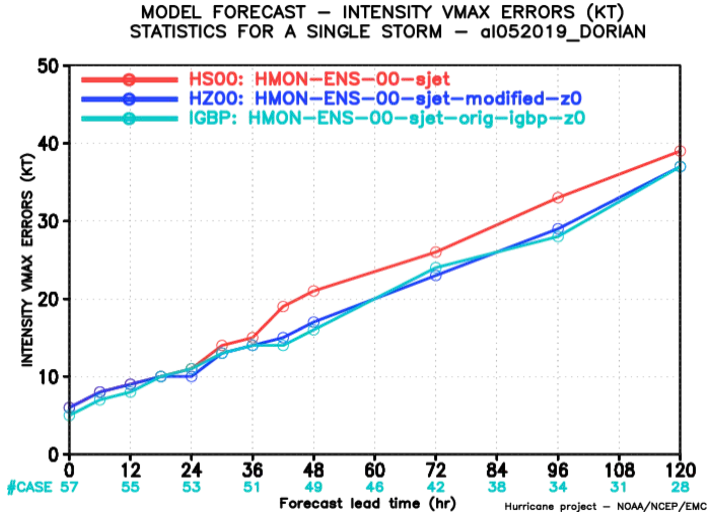
With Original IGBP





Hurricane Dorian: Impact of Orginal IGBP Roughness Length





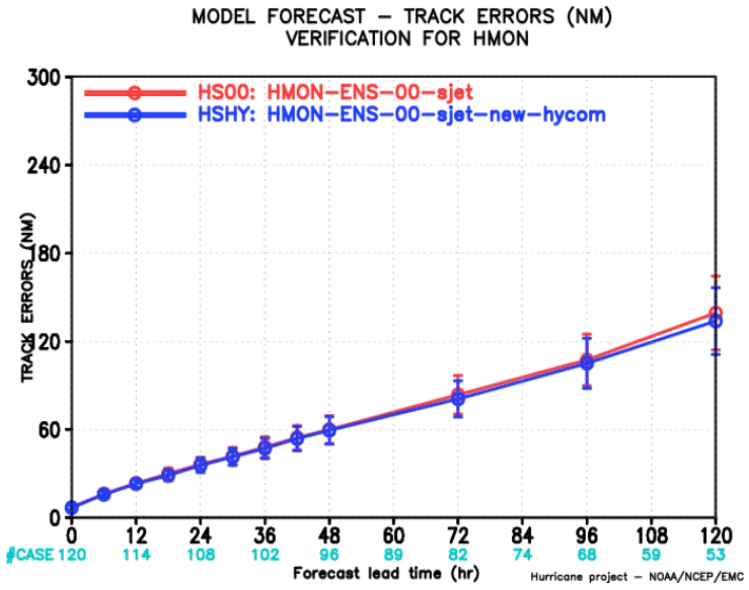
With IGBP (cyan line), HMON gives reduced track errors at longer lead times for Hurricane Dorian. Intensity errors are also considerable reduced at Day 2 and beyond as compared to the current operational configuration (red line).

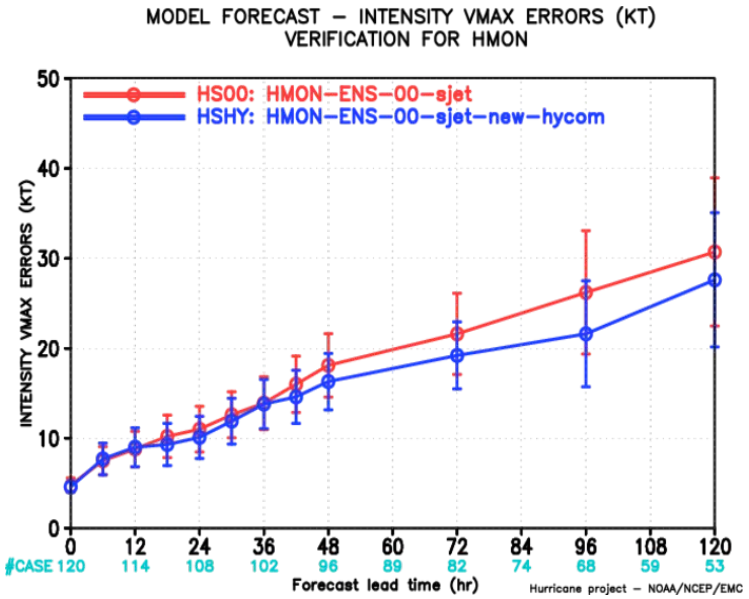
FY2020 HMON Implementation
(Coupling and Post-Processing Upgrades)

- Use the latest version of HYCOM, including computation of sigma-2 using 17 terms instead of 7 terms; use of chlorophyll as default for radiation attenuation
- Correct the momentum reduction from 0.7 to 1.0.
- New version of mixed layer routines include estimation of fraction of short wave radiation penetration
- Additional C_d formula based on CORE v3, where Vmax set to 34 m/s in momentum module.
- Newtonian relaxation employed in an implicit time step

- Green indicates upgrades to be included in H220 baseline configuration
- Items in Red: first time in 2020

Impact of HYCOM changes





Using latest HYCOM improved track and intensity.

Proposed Strategy for Testing and Evaluation of Hurricane Retrospectives for planned FY20 Upgrades of HMON & HWRF

1. Use available **consistent** GFS forcings for 2018 (starting on 25th August) and complete 2019 Hurricane season (current operational version of FV3GFS)

2. Use **all available storms** for retrospective cases in the NATL and EPAC basins from the above time period.

Total cycles in this sample size

- HMON in NATL: 679 forecast cycles total (including 623 non-invest cycles)
- HMON in EPAC: 620 forecast cycles total (including 542 non-invest cycles)

HMON Upgrade Plan for 2020 Implementation

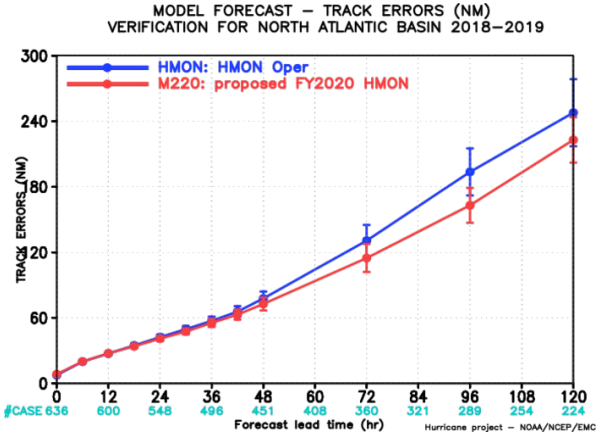
Multi-season Pre-Implementation T&E

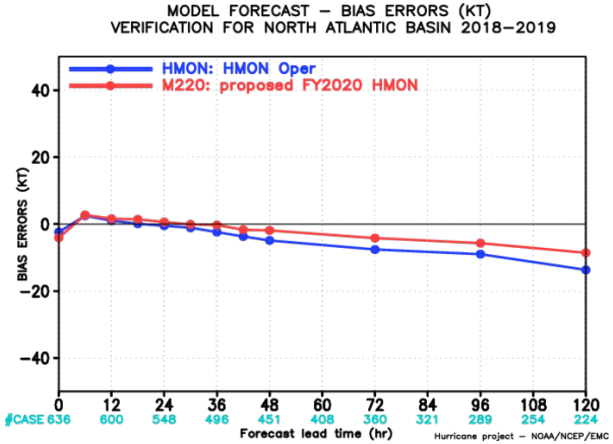
Experiment	Model upgrades	High resolution	Physics and Coupling upgrades		Combined
	Baseline (M20B)	**M20R**	**Physics (M20P)**	**Coupling (M20C)**	**M220**
Description	1. Upgrade to the latest NMMB core; 2. Bug fixes.	Baseline + higher vertical resolution	Baseline + physics changes	Baseline + coupling changes	Baseline + all resolution changes + all physics changes + all coupling changes
Platform	WCOSS-Cray, Jet and Hera	WCOSS Cray, Jet and Hera	WCOSS-Cray, Jet and Hera	WCOSS-Cray, Jet and Hera	**WCOSS Cray**

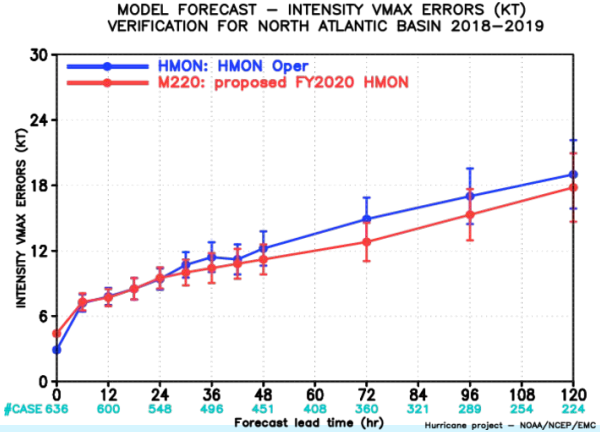
HMON Verification for North Atlantic Storms (2018-2019)

- HMON: Current operational HMON (2019) + 2018 with operFV3GFS
- **M220: Proposed FY20 HMON configuration with operFV3GFS**

Track and Intensity errors for NATL basin (2018-2019) (Late Model)

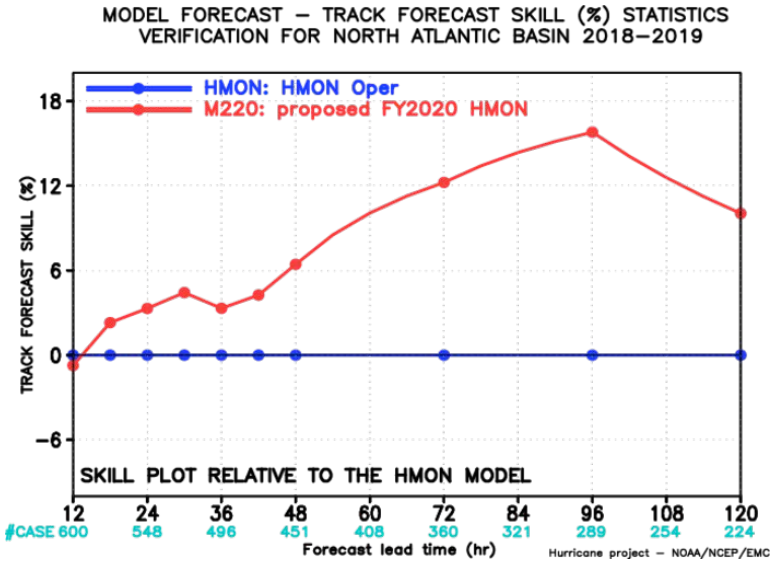


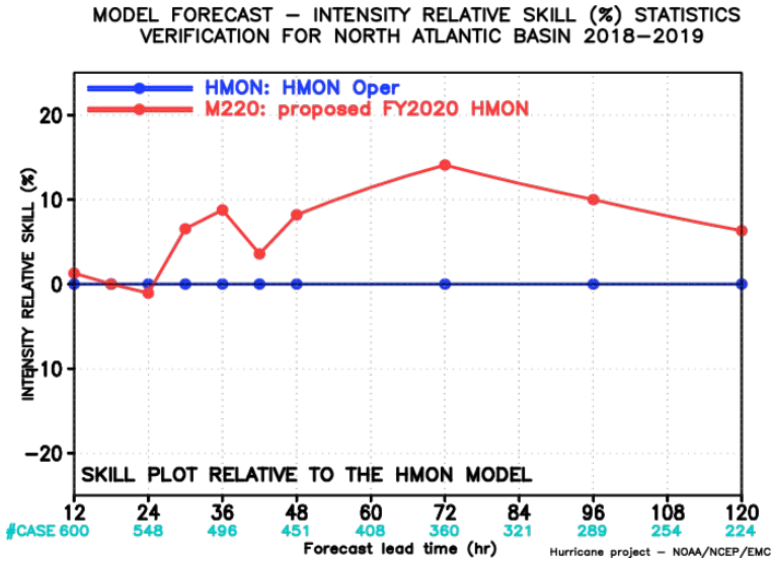




There are significant improvements in track, intensity and bias errors for the NATL basin with M220. These improvements are noteworthy for the extended lead times beyond Day 2.

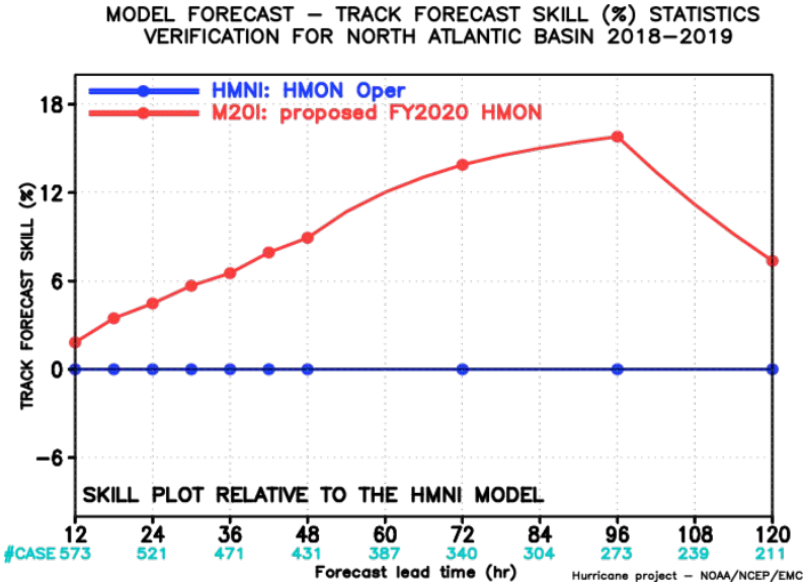
Track and Intensity skill for NATL basin (2018-2019) (Late Model)

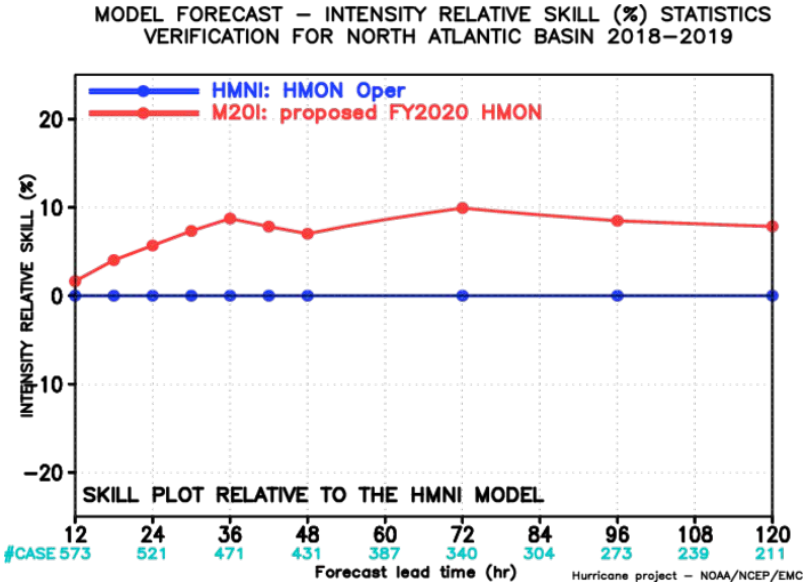




Improvement in track skill are > 10% for Days 3, 4 and 5 while improvements in intensity skill are close to 10% for most lead times beyond Day 2.

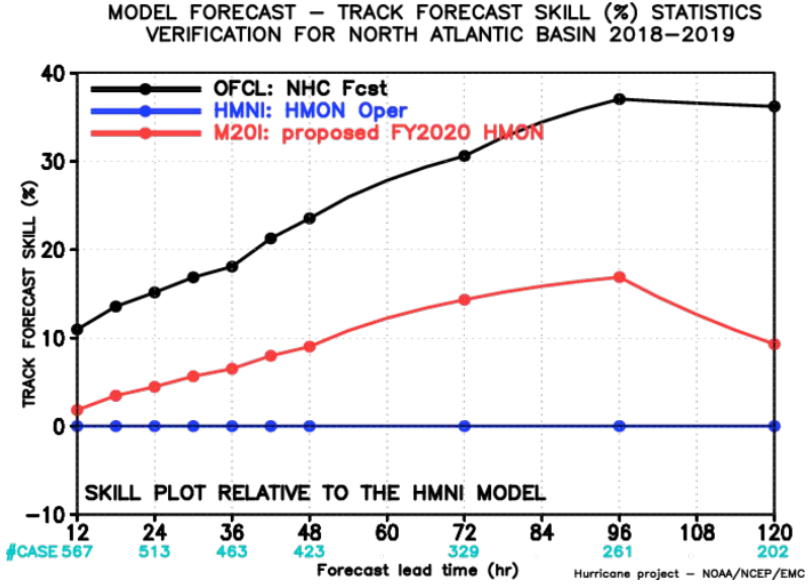
Track and Intensity skill for NATL basin (2018-2019) (Early Model)

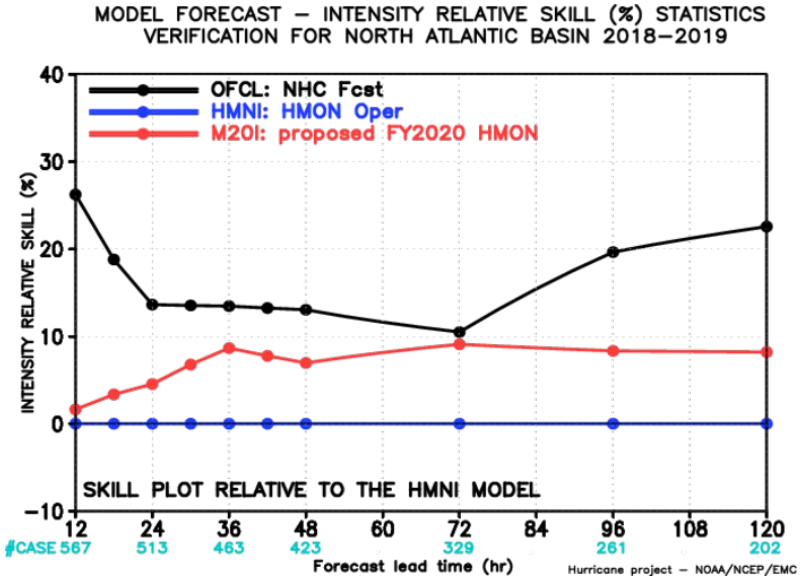




Early model results also show similar significant improvements in skill in both track and intensity from M20I. While these improvements are impressive for track skill beyond Day 1, the improvements in intensity can be seen at all lead times.

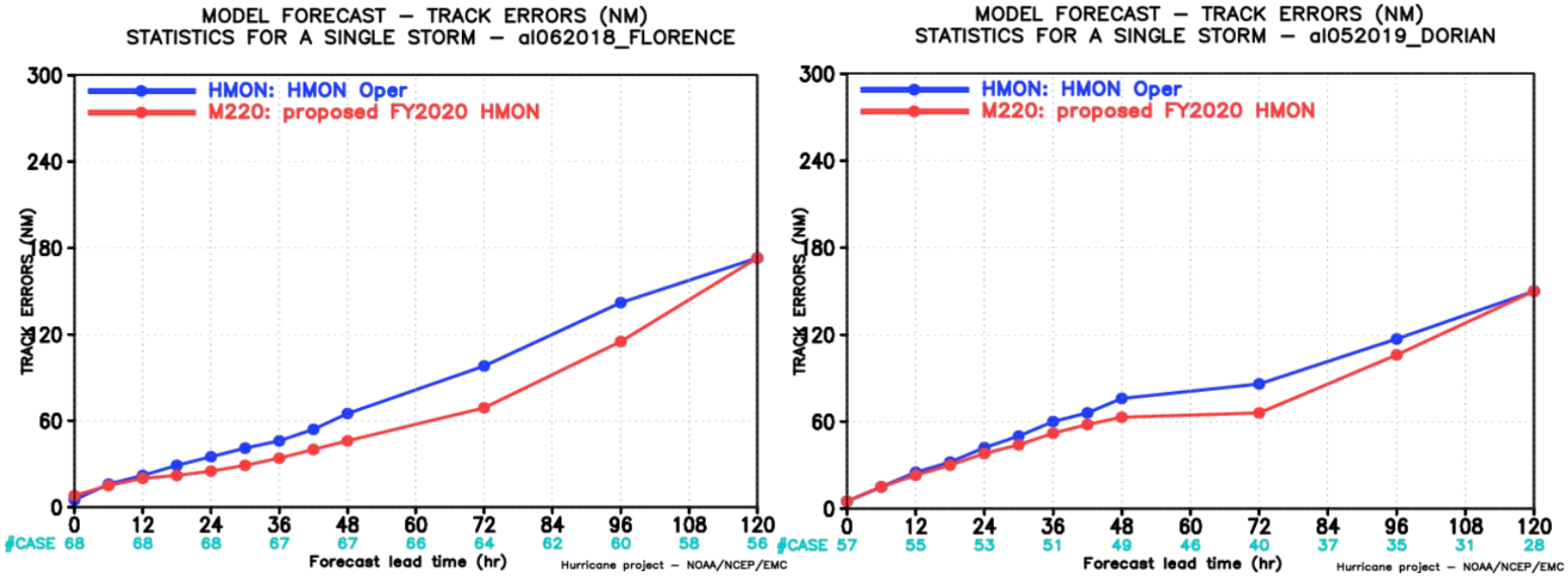
Track and Intensity skill for NATL basin (2018-2019) (Early Model)





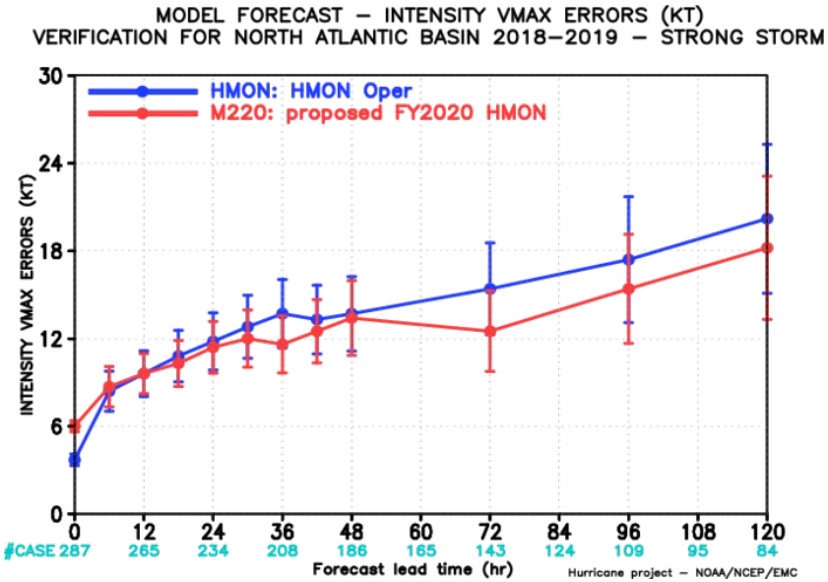
Improvements in track and intensity skill for the proposed HMON (M20I, red line) over operational HMON (HMNI, blue line) when compared with the official skill.

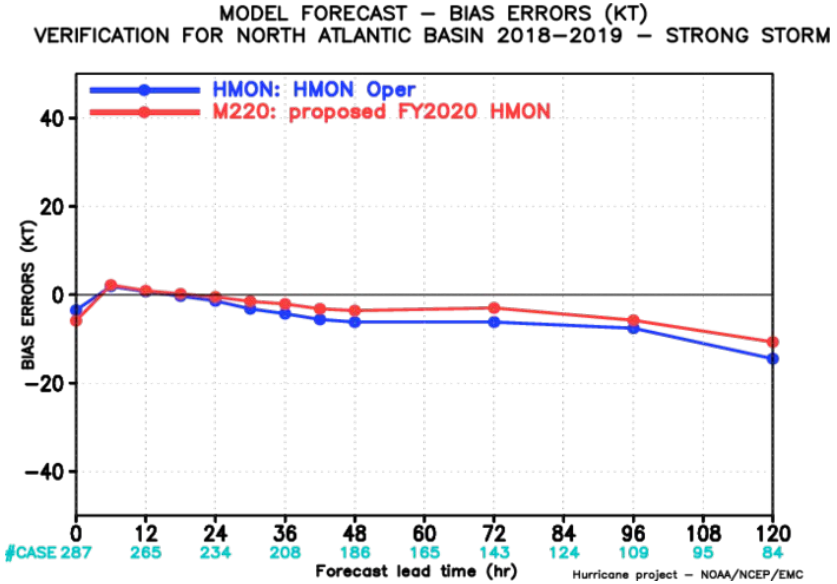
Track error improvements for Priority NATL storms (2018-2019)



Large reductions in track error were seen for some of the NATL priority storms in 2018 (Florence, left panel) and 2019 (Dorian, right panel). Improvements were maximum for Days 2, 3 and 4.

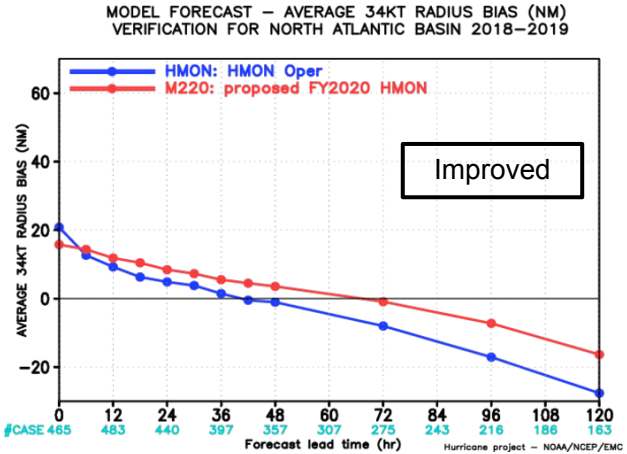
Intensity skill improvements for NATL basin (2018-2019) (Strong Storms > 50 kt)

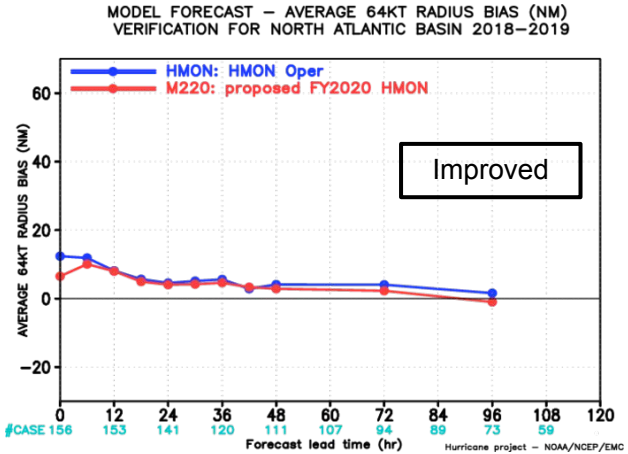


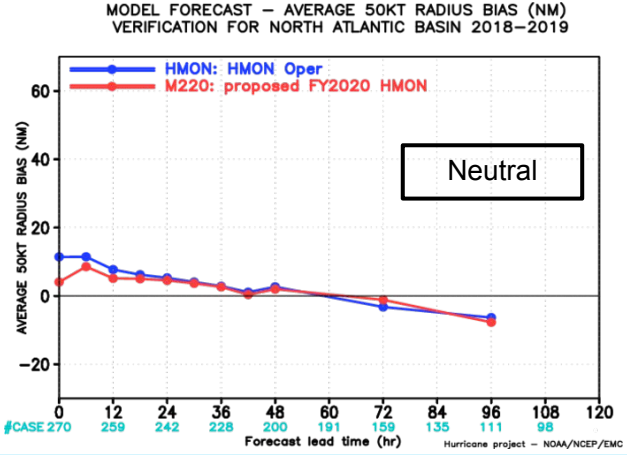


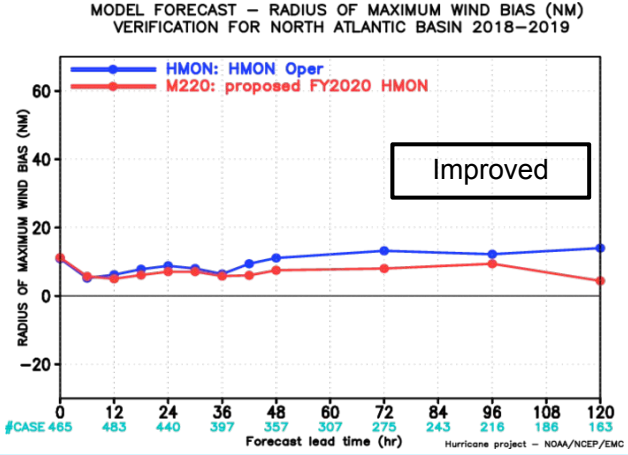
Both intensity errors and bias errors are significantly reduced for M220 for strong storms at all lead times as compared to current HMON for the NATL basin.

Storm Size Errors for NATL basin (2018-2019)

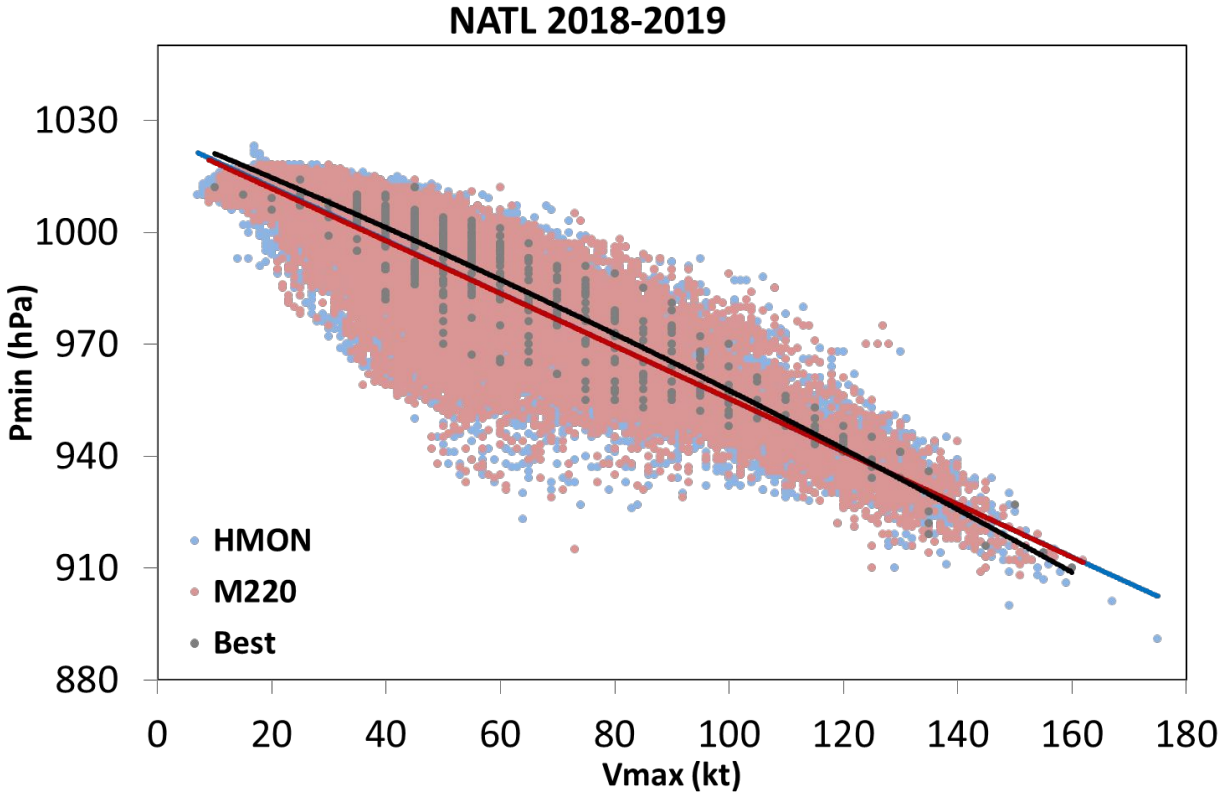








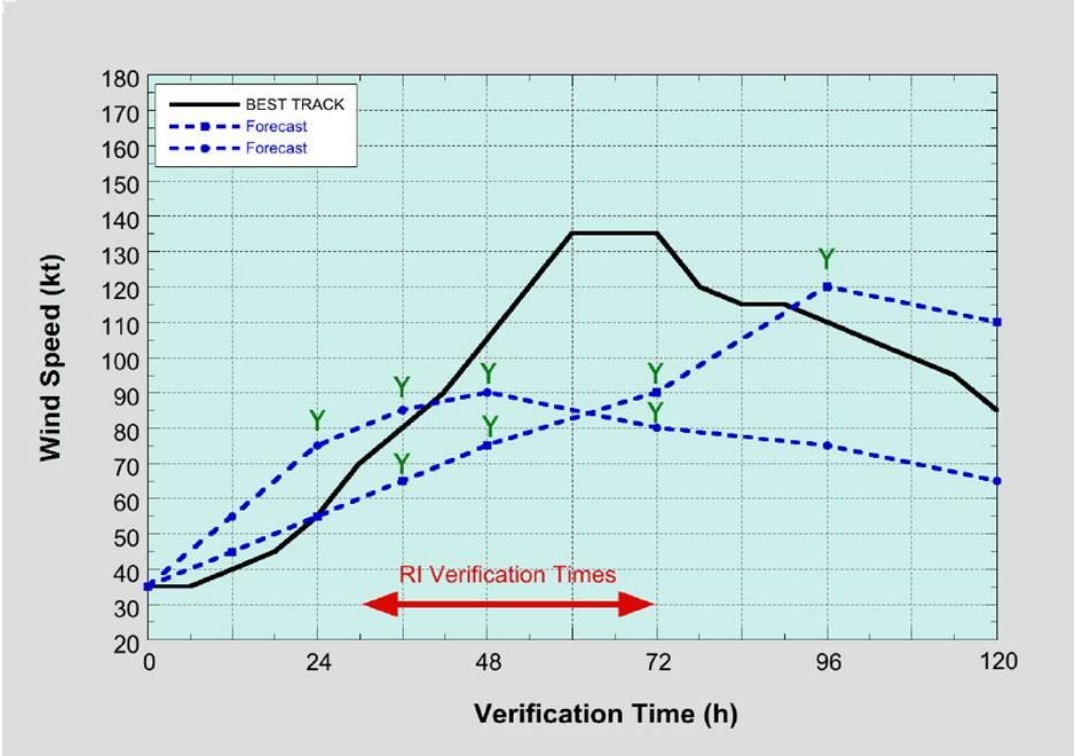
Pressure/Wind relationship for the NATL basin (2018-2019)



New Rapid Intensification Metric

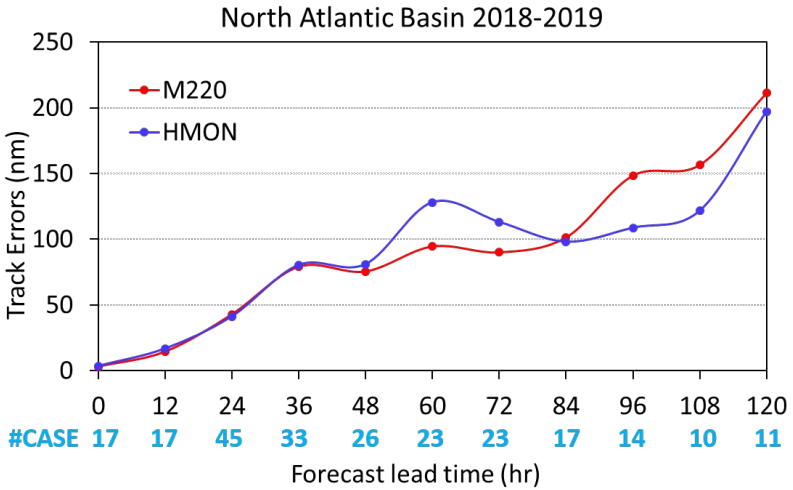
Definition* :

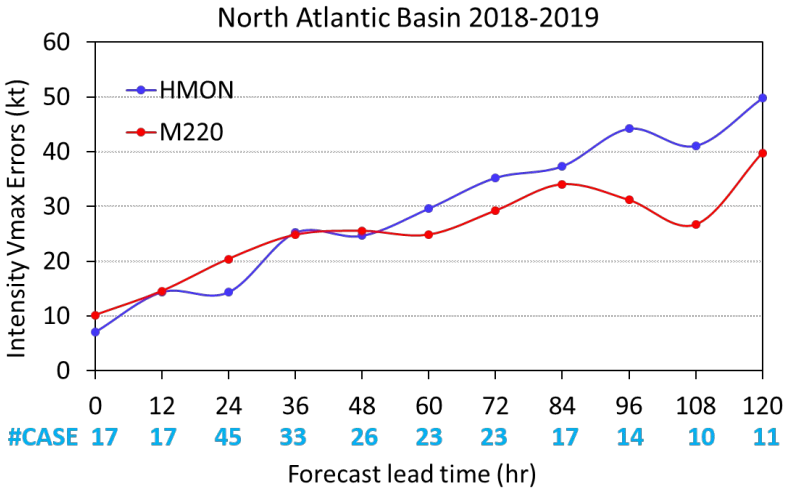
Mean intensity error evaluated for those subset of cycles when at verification times, RI is either ongoing or was forecasted to occur.



* From Mark DeMaria and James Franklin

New Rapid Intensification Metric



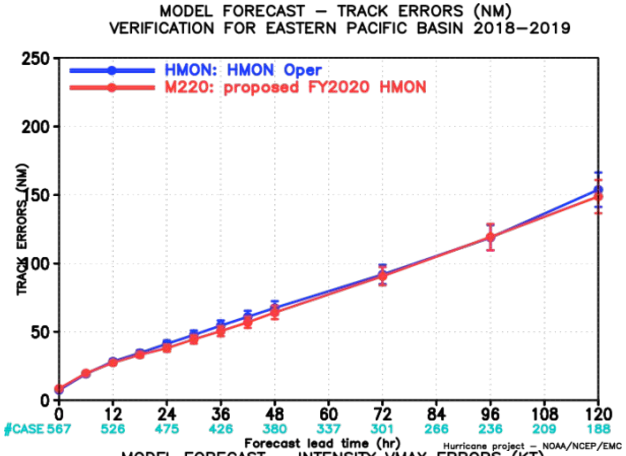


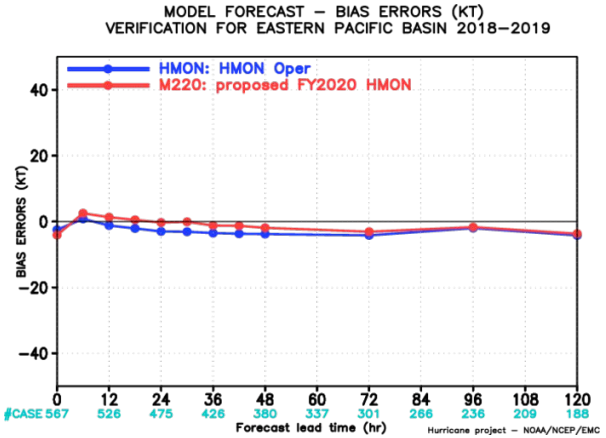
While the track errors for these selected cycles are neutral, M220 gives us lower intensity errors for longer lead times at Days 3-5 when compared to current HMON.

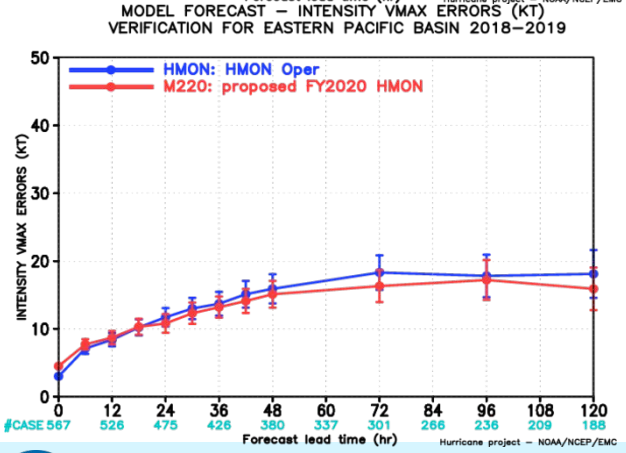
HMON Verification for East Pacific Storms (2018-2019)

- HMON: Current operational HMON (2019) + 2018 with operFV3GFS
- **M220: Proposed FY20 HMON configuration with operFV3GFS**

Track and Intensity errors for EPAC basin (2018-2019) (Late Model)



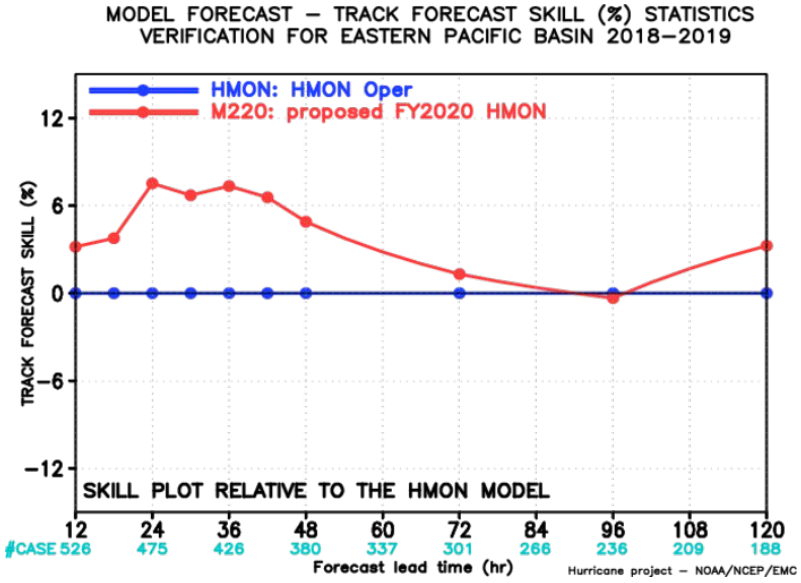


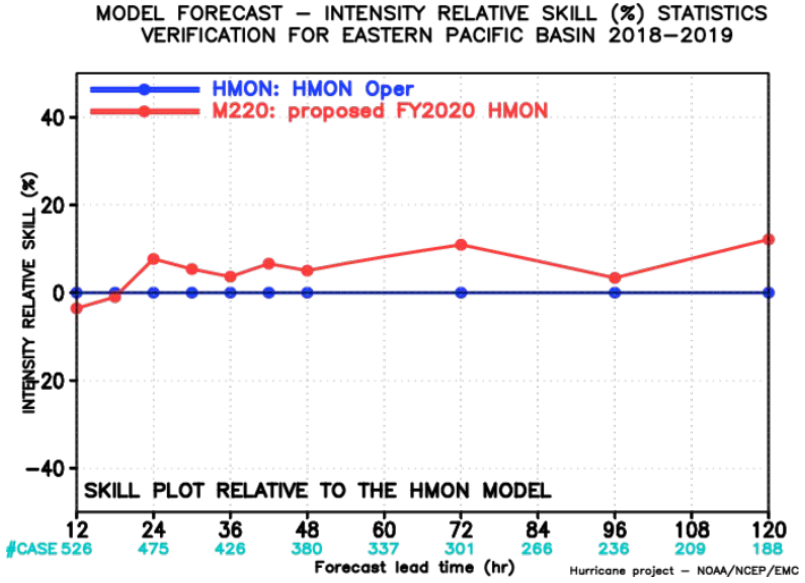


Both track and intensity errors are reduced at most lead times as compared to the current HMON.

Intensity bias is also reduced for early lead times as compared to the current model.

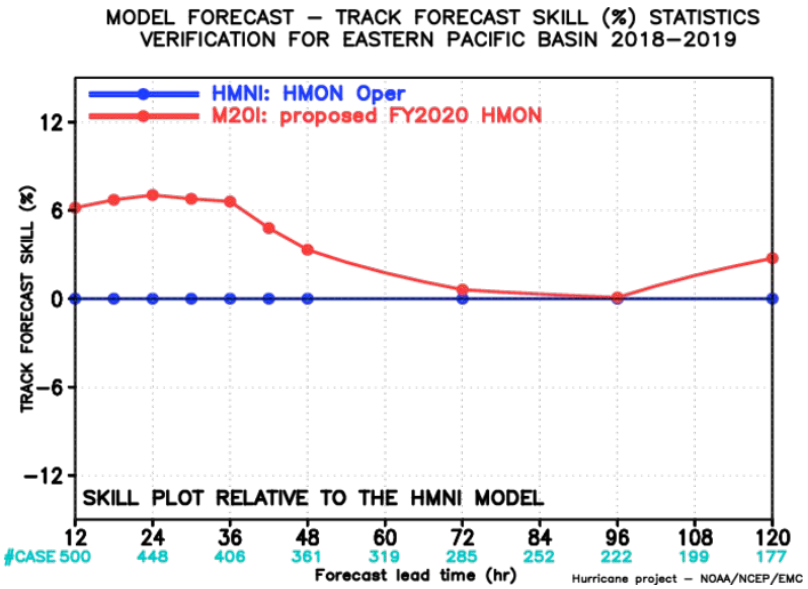
Track and Intensity skill for EPAC basin (2018-2019) (Late Model)

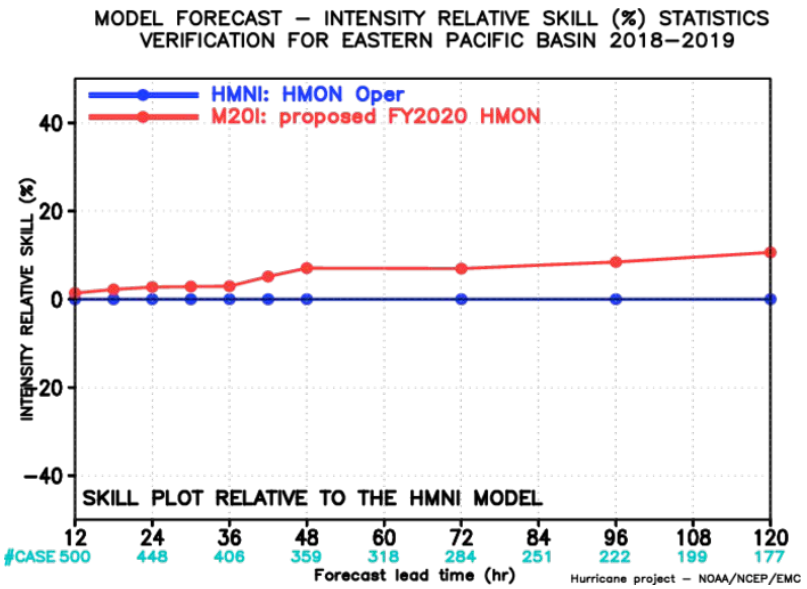




There is a good improvement in track skill for early lead times (first 48 hrs) and again for Day 5. Intensity skill is also ahead at all lead times.

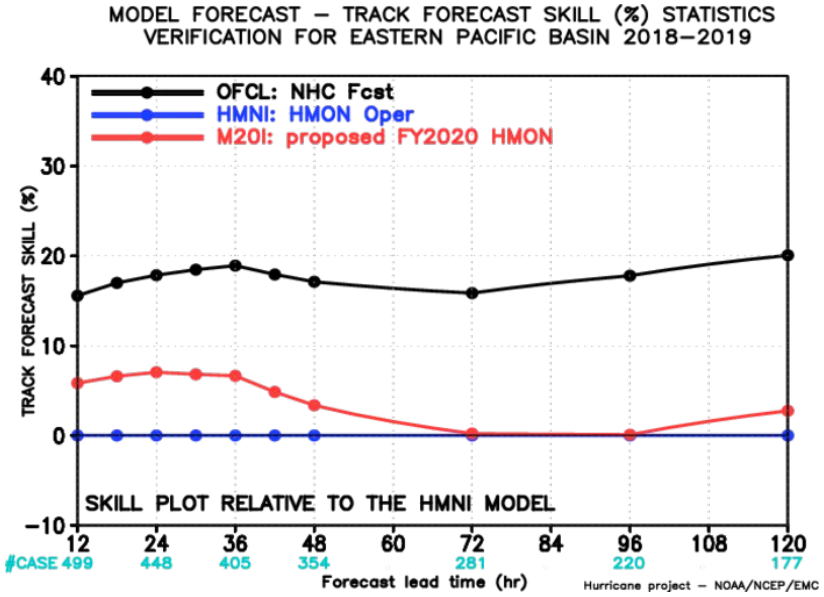
Track and Intensity skill for EPAC basin (2018-2019) (Early Model)

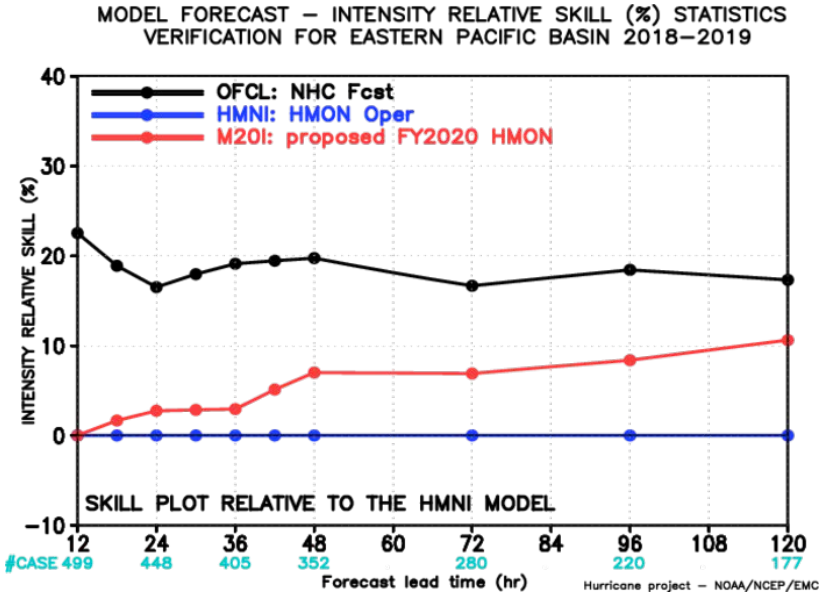




Very similar to the late model results, there is improvement in track skill for early lead times (> 6%) and intensity skill at all lead times. Overall, improvements are less than the NATL basin.

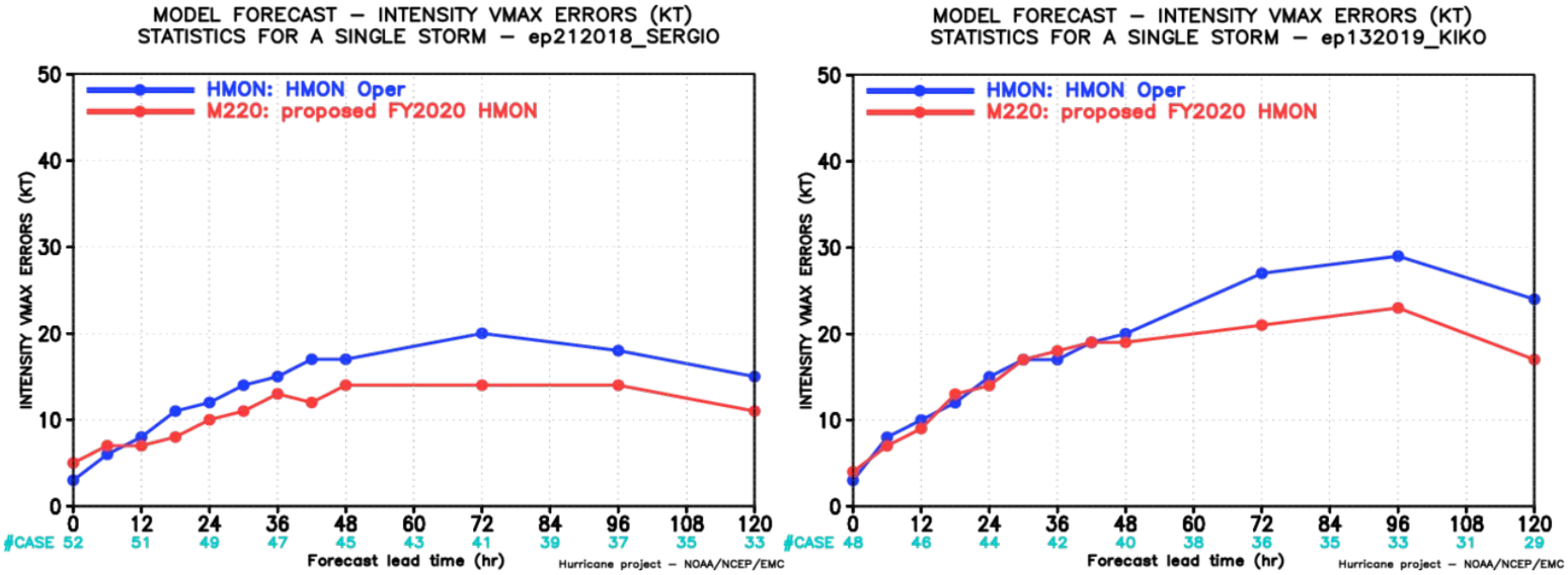
Track and Intensity skill for EPAC basin (2018-2019) (Early Model)





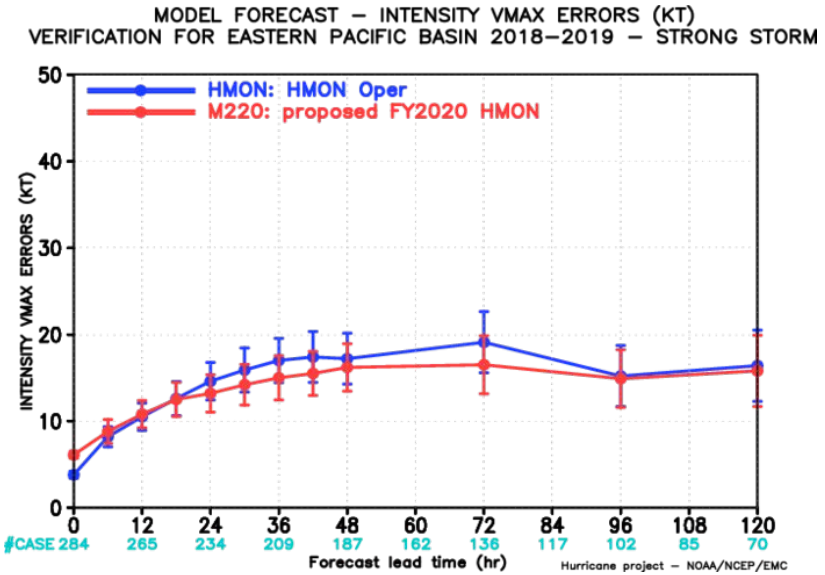
Improvements in track and intensity skill for the proposed HMON M20I, red line) over current HMON (HMNI, blue line) when compared with the official skill.

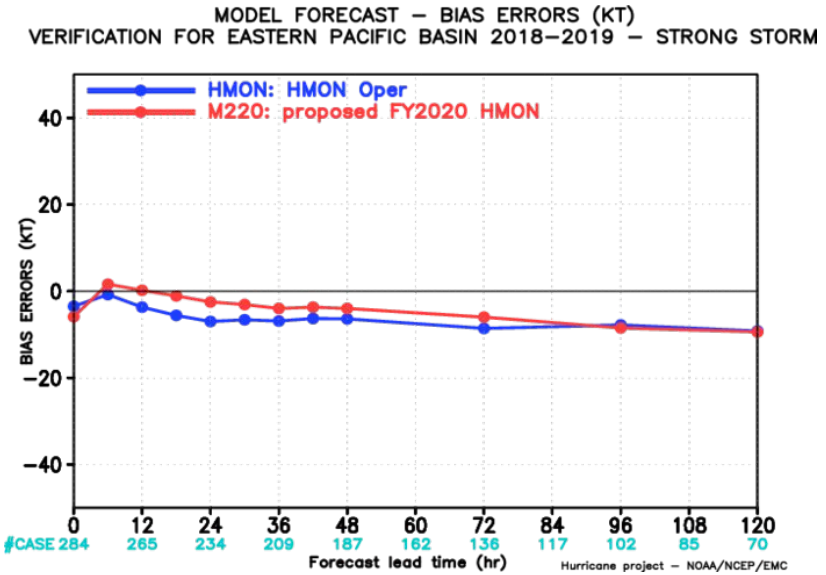
Intensity error improvements for Priority EPAC storms (2018-2019)



Large reductions in intensity error were seen for some of the long-lasting EPAC priority storms in 2018 (Sergio, left panel) and 2019 (Kiko, right panel). Improvements were maximum for Days 3, 4 and 5.

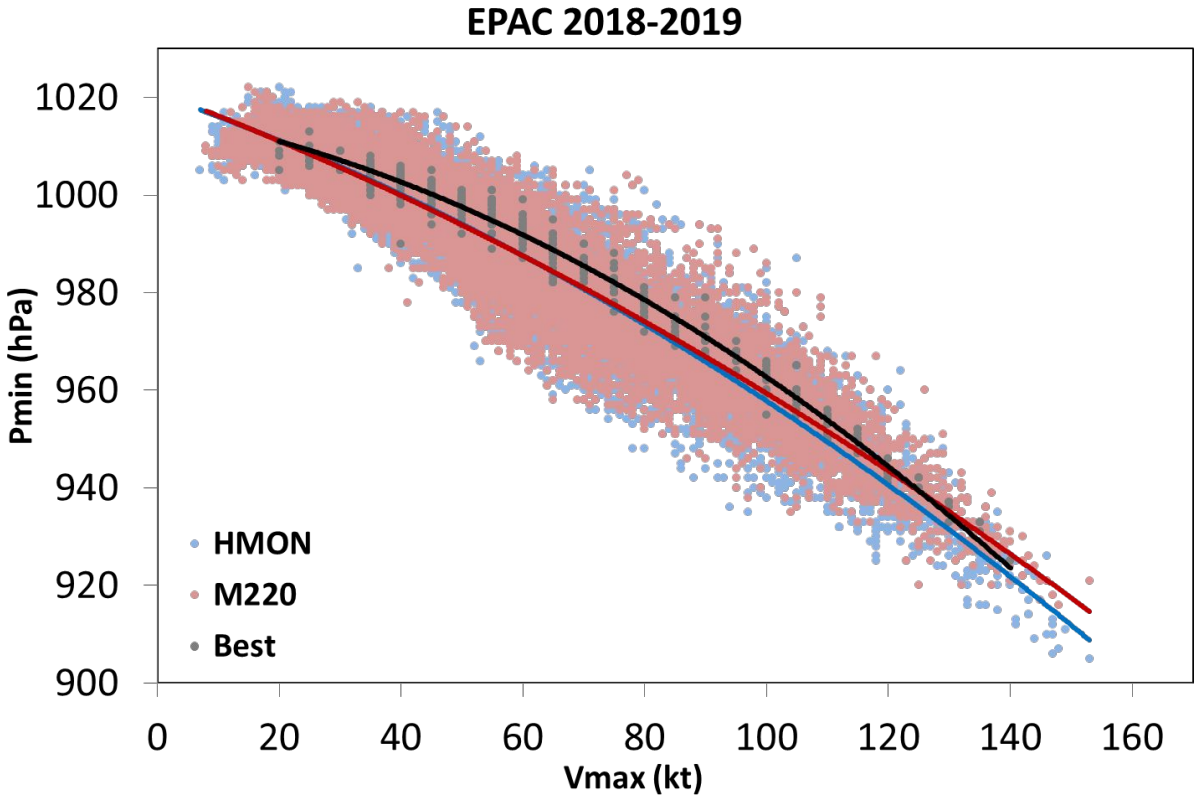
Intensity skill improvements for EPAC basin (2018-2019) (Strong Storms > 50 kt)



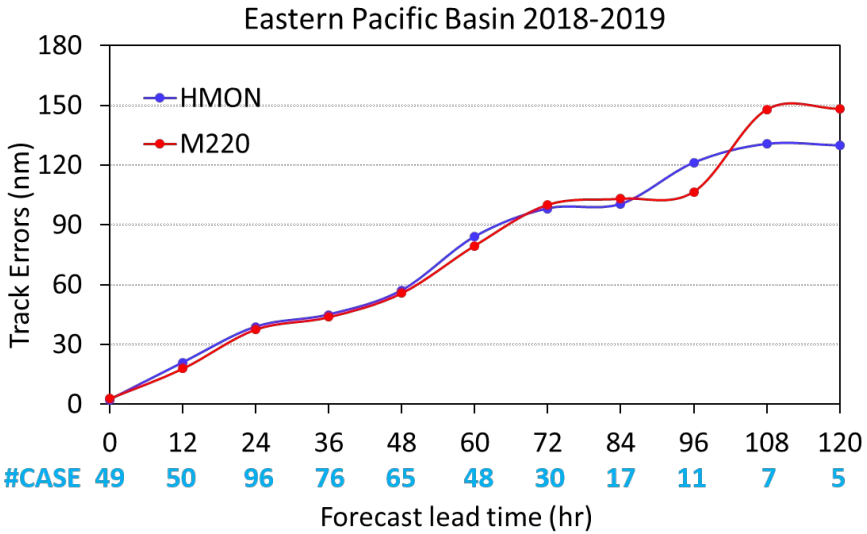


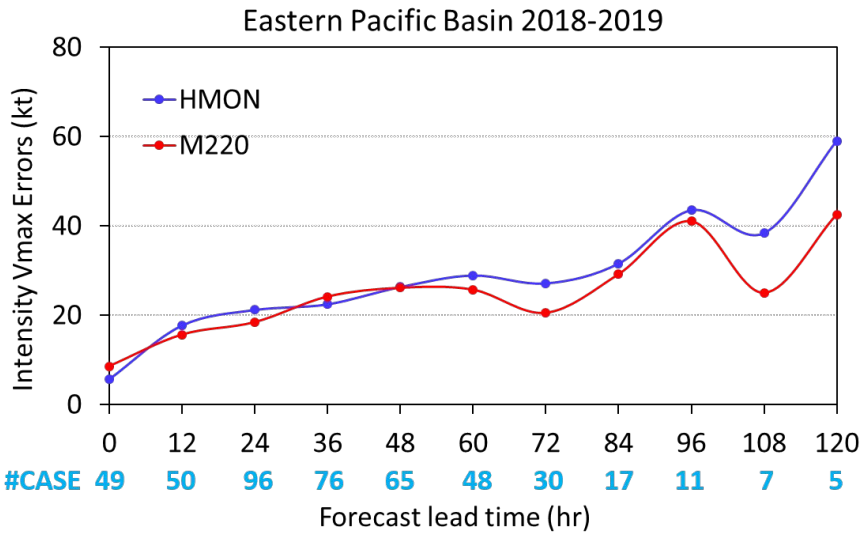
Both intensity errors and bias errors are reduced for M220 for strong storms up to Day 4 as compared to the current HMON for the EPAC basin.

Pressure/Wind relationship for the EPAC basin (2018-2019)



New Rapid Intensification Metric





While the track errors for these selected cycles are neutral, M220 gives us lower intensity errors at all lead times compared to current HMON other than at forecast hr 36. There are good improvements in intensity skill at Days 3 and 5.

Summary (HMON 2020)

- M220 retrospective evaluation of 2018-2019 hurricane seasons (total 623 verifiable cycles in NATL, 542 in EPAC) demonstrated much improved forecasts when compared with the current operational configuration;
- Results from M220 for the North Atlantic basin suggested significant improvements compared to current HMON for track and intensity (> 10%);
- Results in the NATL basin suggest reduction in intensity errors and bias for strong storms (initial intensity > 50 kts);
- Results from M220 for the North East Pacific suggested good improvement compared to current HMON for track and intensity (> 6%);
- Results in the EPAC basin also suggest reduction in intensity errors and bias for strong storms (initial intensity > 50 kts);
- Pressure-wind relationships are neutral for the NATL basin but improved for EPAC when compared to those from best track;
- The new RI metric shows reduced intensity errors but is overall neutral for track errors.

NHC's Verification for 2020 HMON

FY2020 HWRF/HMON Configuration (maintain diversity)

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°; 71 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, WaveWatch-III	HYCOM, RTOFS, 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	43 nodes in 100 mins*

What it takes in operations to run HMON in 2020

- Resource requirements:
  - FY20 HMON M218: 1032 cores or 43 nodes on Cray (increase form 26 nodes currently; pending HPCRAC approval)
  - Run maximum five storms for 3 basins (NATL, EPAC and CPAC) simultaneously
  - Delivery times same as HWRF (before t+6)

IT Testing (ongoing)

Test Objective	Comment
Missing ICs from GFS data	HMON fails with proper error message
Missing BCs from GFS data	HMON fails with proper error message
Missing previous cycle's 6-hr forecast output	HMON runs to completion in cold start mode
Failed HYCOM initialization	HMON runs in uncoupled mode
Tracker fails to identify initial storm location	HMON fails with proper error message
Test at least one storm in AL and EP basins	HMON runs to completion
Cross dateline and Greenwich test	Make sure HMON model and scripts properly handle the specially situations.

HMON Version 3.0
Status as of 03/05/20

Project Information & Highlights

Leads: Avichal Mehra & Lin Zhu, EMC and Steven Earle, NCO

Scope: TBD

Implement with: HWRF

Expected benefits: Improved track & intensity forecast guidance to NHC to fulfill their mission.

Dependencies: N/A.

Schedule

Milestones & Deliverables	Date	Status
Freeze system code;	02/01/20	Completed
Complete full retrospective/real time runs and evaluation	02/14/20	Completed
Deliver final system to NCO and conduct CCB/ODB	03/15/20	Planned
Issue Technical Information Notice	0316/20	Planned
Start the 30-day evaluation and IT testing & OD brief	3/16/20	Planned
Operational Implementation	6/15/20	Planned

EMC NCO Red text indicates change from previous quarter

Issues/Risks

Issue. Timely availability of HPC resources; **Resolution**: May delay implementation

Risk: Upgrades degrade forecast skill; **Mitigation**: Revert back to baseline.

Resources

Staff: 0.66 Fed FTEs + 3.5 contractor FTEs; including Dev (Vortex Initialization, Coupler and Physics)

Funding Source: STI

Compute: parallels: 100 nodes for 4 months (devonprod);; **EMC Dev**: 100 nodes for 4 months (devhigh); **Ops**: Delta = 40%

Archive: (Delta = TBD)

R Management Attention Required Y Potential Management Attention Needed G On Target

Next Steps

1. Retrospective T&E at EMC: **Feb 14, 2020 --- Completed**
2. Results shared with NHC: **Feb 21, 2020 ----- Completed**
3. NHC Evaluation: **March 5, 2020 -- Completed**
4. Briefing to EMC Director: **March 6, 2020 --- Now Completed**
5. Briefing to NCEP Director's Office: **March 13, 2020 (scheduled)**
6. Submission of Codes to NCO: ***March 16, 2020--- Code hand-off, submission of RFC forms, release notes and flow diagram***
7. SCN for 2020 HMON : ***May 15, 2020***
8. NCO IT Testing completed: ***May-June, 2020***
9. IT briefing to NCEP Director's Office: ***June 11, 2020 (tentative)***
10. Implementation by NCO: ***June 16, 2020 (tentative)***

Additional Slides

2018-2019 NATL/EPAC Priority Storms

NATL storms	EPAC storms
2019 20L Sebastien	2019 15E Lorena
2019 13L Lorenzo*	2019 14E Mario
2019 12L Karen*	2019 13E Kiko
2019 10L Jerry*	2019 11E Juliette
2019 09L Humberto*	2019 07E Flossie
2019 08L Gabrielle	2019 06E Erick
2019 05L Dorian*	2019 02E Barbara
2019 02L Barry*	
	2018 24E Willa
2018 14L Michael*	2018 21E Sergio
2018 13L Leslie	2018 20E Rosa
2018 09L Isaac	2018 17E Olivia
2018 08L Helene	2018 16E Norman
2018 07L Gordon*	2018 15E Miriam
2018 06L Florence*	

* Storms with recon data