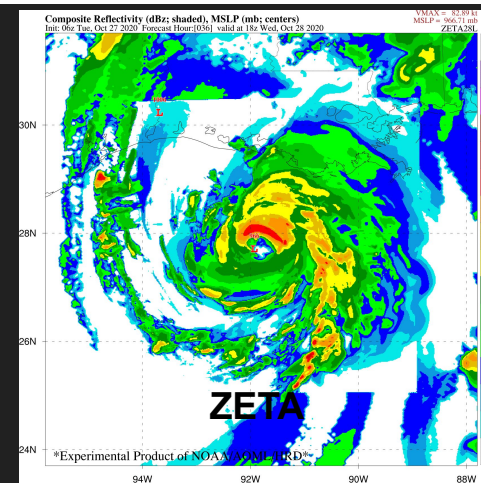
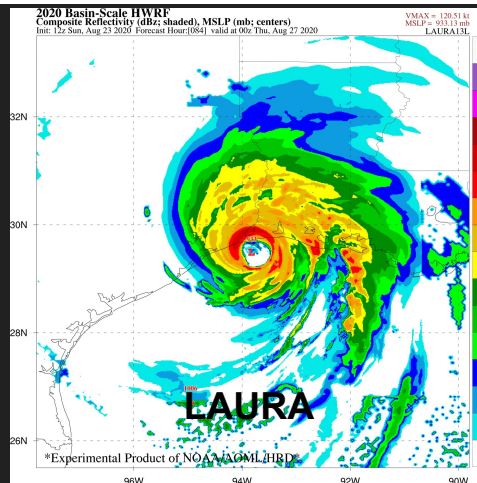
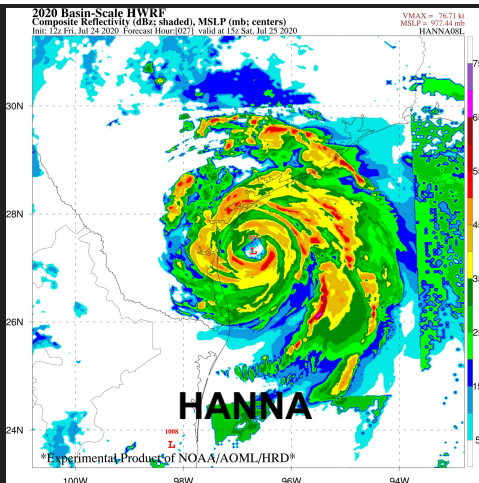


# 2020 Basin-scale HWRF (HWRF-B) HFIP Real-time Experiment (HREx)

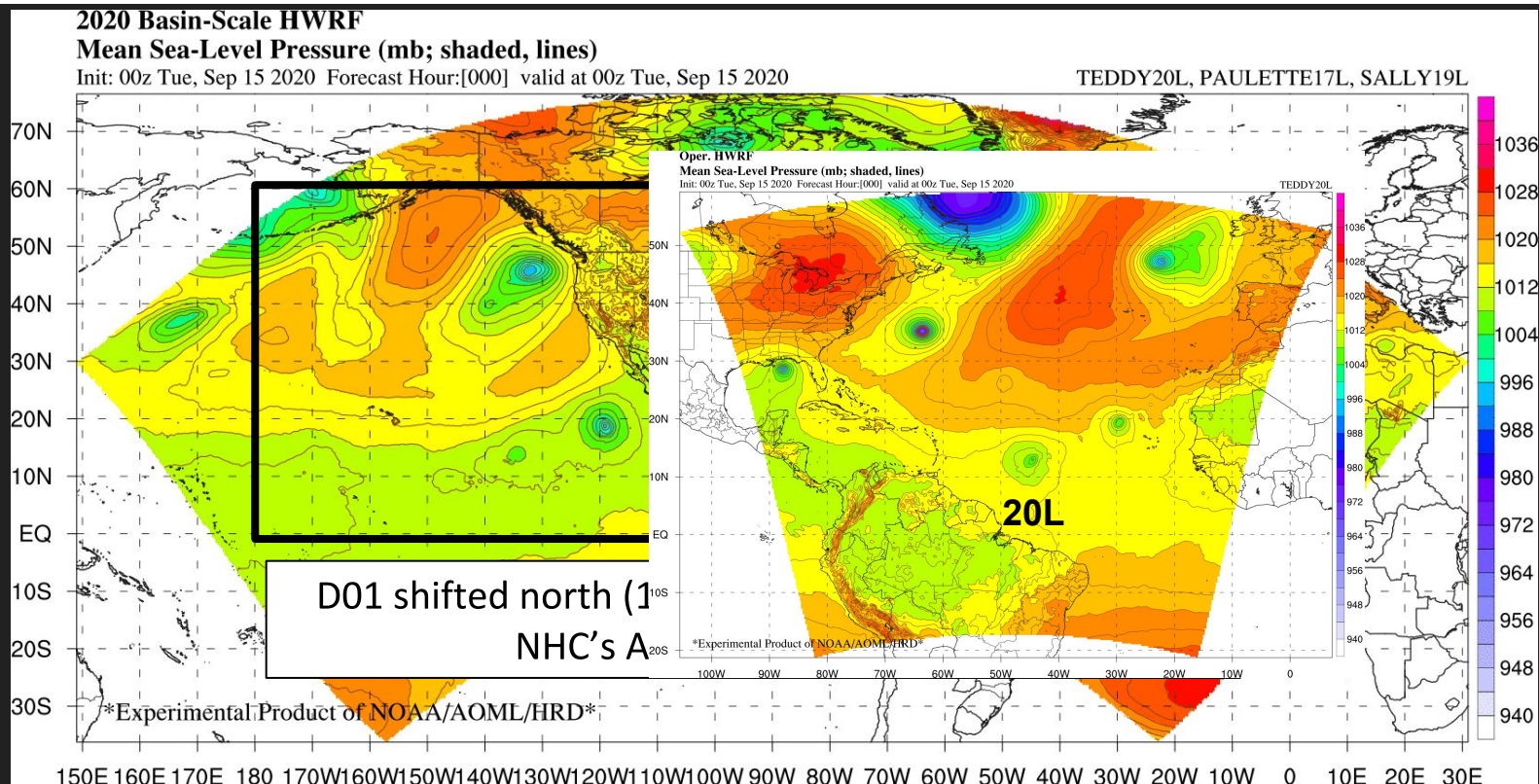


PIs: Ghassan Alaka<sup>1</sup>, Lew Gramer<sup>1,2</sup>  
Collaborators: HRD Modeling Team, EMC Hurricane Team, DTC

<sup>1</sup>NOAA Atlantic Oceanographic and Meteorological Laboratory

<sup>2</sup>UM Cooperative Institute for Marine and Atmospheric Studies

# What is Basin-scale HWRF (HWRF-B)?



A busy day in the tropics...

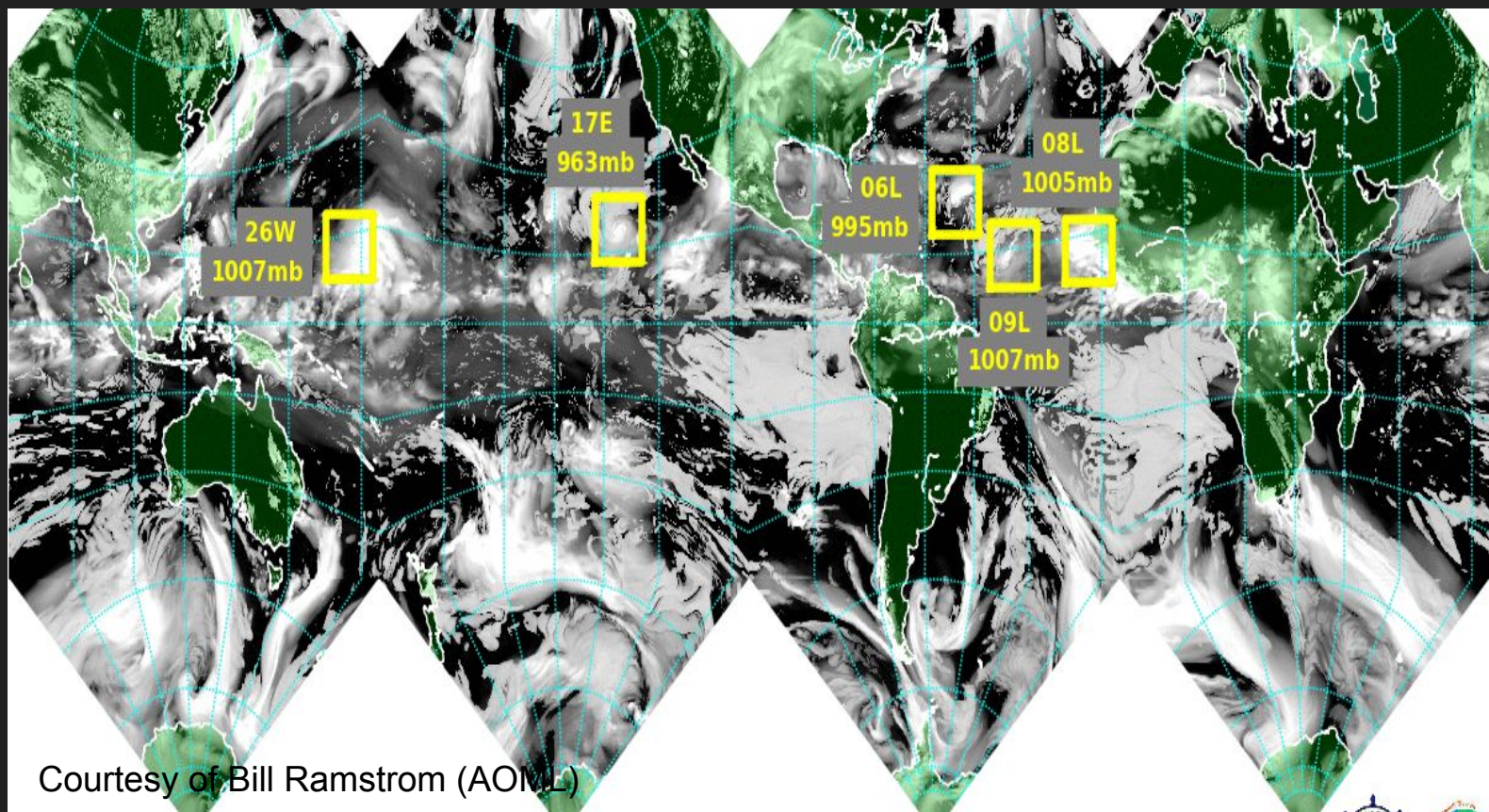
# HWRF-B Configuration

- HWRF and HWRF-B nearly identical:
  - Dynamical core
  - All physics
  - Vertical/horizontal resolution
  - Ocean model
- Key configuration differences
  - **Outermost domain size**  
*Covers NHC Area Of Responsibility*
  - **Multiple high-resolution nests**  
*Up to 3 this year*
  - **Ensemble data assimilation**  
*Developed for multiple storms (no RT)*
  - **Ocean coupling**  
*POM initialized from RTOFS w/ multi-storm coupling (Alaka et al. 2020)*

Configuration Options	HWRF-B	HWRF
Domain	13.5 km: 194.0° x 84.2° 4.5 km: 16.5° x 16.5° 1.5 km: 5.5° x 5.5°	13.5 km: 77.2° x 77.2° 4.5 km: 17.7° x 17.7° 1.5 km: 5.9° x 5.9°
Model Top	10 hPa	10 hPa
Vertical Levels	75	75
Vortex Init.	At 4.5/1.5 km	At 4.5/1.5 km
Data Assimilation	<b>Hybrid &amp; TDR-based EnKF (for multiple storms)</b>	<b>Hybrid &amp; TDR-based EnKF (for 1 storm)</b>
Ocean Coupling	13.5/4.5 km: YES (POM) 1.5 km: Downscaled	13.5/4.5 km: YES (POM) 1.5 km: Downscaled
Multi-Storm	<b>YES</b>	<b>NO</b>
<b>PHYSICS SCHEMES</b>		
Microphysics	Ferrier-Aligo	Ferrier-Aligo
Radiation (LW,SW)	RRTMG	RRTMG
Surface Layer	HWRF (GFDL-based)	HWRF (GFDL-based)
PBL	GFS Hybrid-EDMF	GFS Hybrid-EDMF
Convection	Scale-Aware SAS	Scale-Aware SAS
Land Surface	Noah LSM	Noah LSM



# HWRF-B: A Baseline for HAFS





# Important Milestones

- 884 forecasts from 2020 HWRF-B (**HB20**) for 37 NATL and EPAC storms (56+ w/ invests)
  - 25% of HB20 forecasts ran on Hera (fallback w/ no reservation)
  - 318 forecasts for **B220**: Parallel experiment (**HB20** w/ 5 storms & ensemble DA) on Hera
- Delivery of ATCF files for HWRF-B (and all HFIP models) to NHC in near real-time
  - Thanks to Stephanie Stevenson, Brian Zachry, and others @ NHC!
- Effectively communicated with the public via the AOML Hurricane Model Viewer:
  - Delivery of over 30M graphics for the 2020 hurricane season (5M for HWRF-B)
  - 2830 unique users, 23000 page views
- Successful implementation of HWRF's self-cycled DA system for multiple storms
  - Did not run in **HB20** due to CPU resource constraints
- Generalized coupling scheme implemented to simplify coupling for multiple nests
- HWRF-B tested for potential ops. implementation on WCOSS last winter (TRL8)
  - Came within 10% of the NCO forecast time limit for HWRF (~110 min)
- Six HWRF-B peer-reviewed publications published since 2017 on a wide variety of topics.

# AOML Hurricane Model Viewer

**AOML Hurricane Model Viewer**

Graphical products for experimental NOAA models and operational models

2020-11-09 12Z

Project: Real-time

Search Type:  
☐ Storm ☐ Date ☒ Model

**View Recent Events**

**View Recent Models**

**View Map**

**View Summary**

**View All Graphics**

**Links and Policies**

[NOAA/OAR/AOML](#)  
[AOML Hurricane Modeling Group](#)  
[HRD Hurricane Data](#)  
[Operational HWRF](#)  
[National Hurricane Center](#)  
[Disclaimer & Policies](#)

**More Related Links**

**ETA29L**

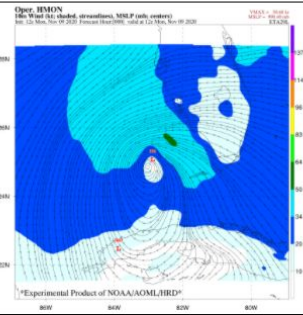

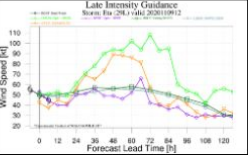
2020-11-09 12Z

Model: **HMON**

HMON

HWRF

HWRFB

**INVEST97L**

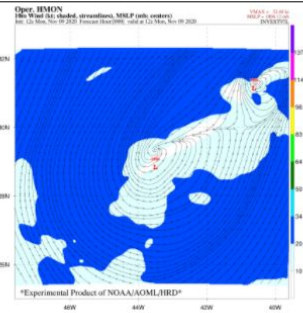
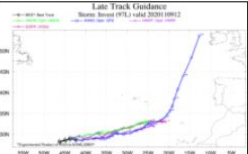
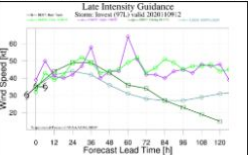
2020-11-09 12Z

Model: **HMON**

HMON

HWRF

HWRFB

<https://storm.aoml.noaa.gov/viewer>

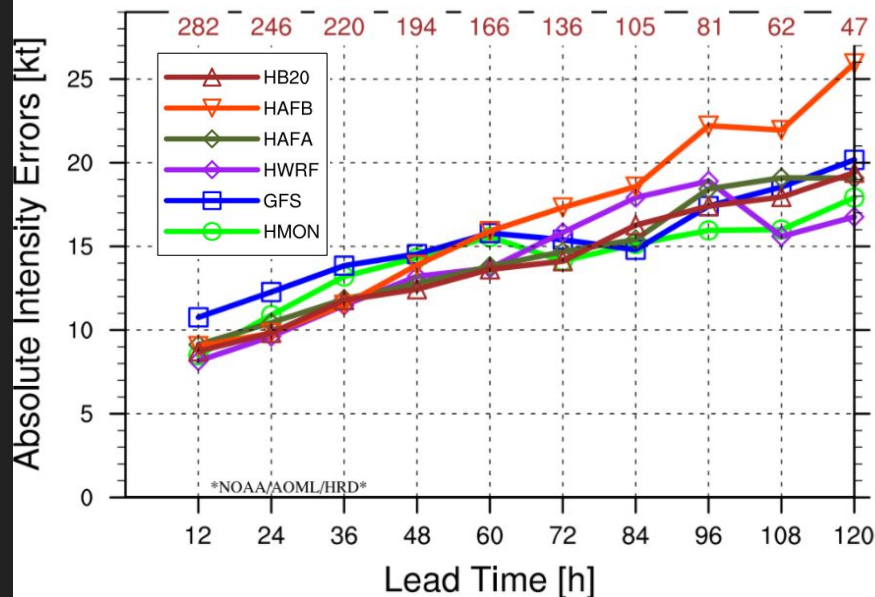
Supported these models in 2020:

- HWRF-B\*
- HAFS-A\*
- HAFS-B\*
- HAFS-E\*
- HAFS-J\*
- FV3-RRFS\*
- HWRF
- HMON
- GFS
- ECMWF

\*denotes HFIP model

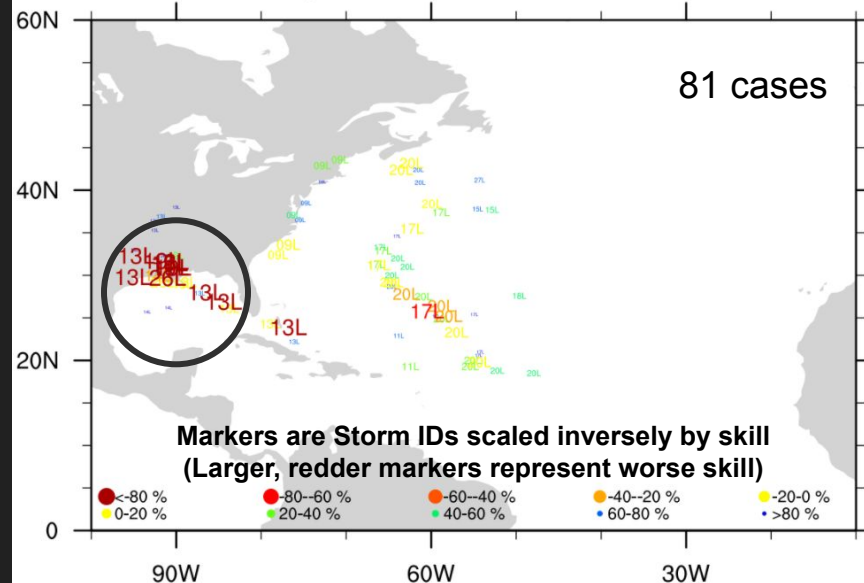
# Intensity Verification: North Atlantic

## Absolute Intensity Errors



HWRF-B (**HB20**) intensity errors were quite good (especially vs. **HWRF**) at most lead times. **HB20** had lowest intensity errors at 48/60/72 h.

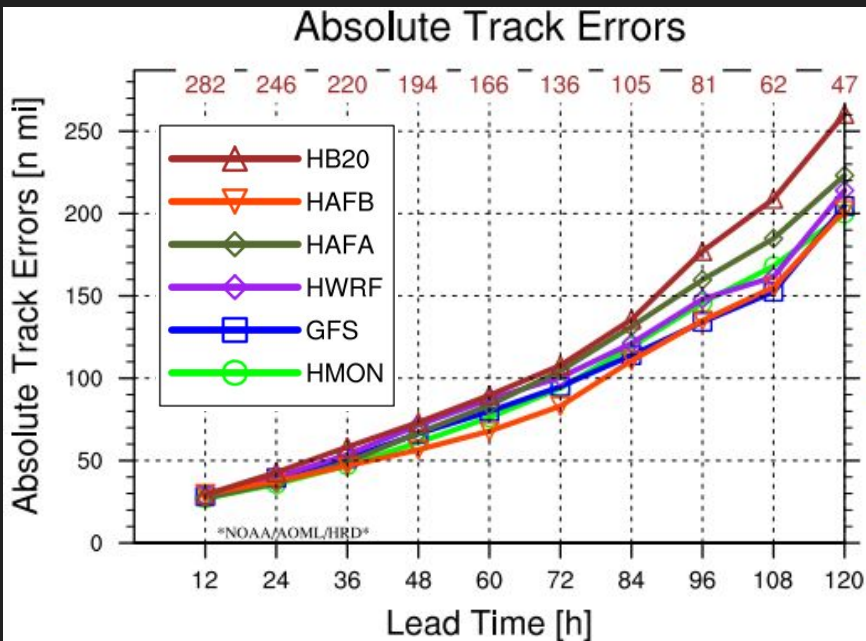
## Intensity Skill Vs. HWRF @ 96 hrs



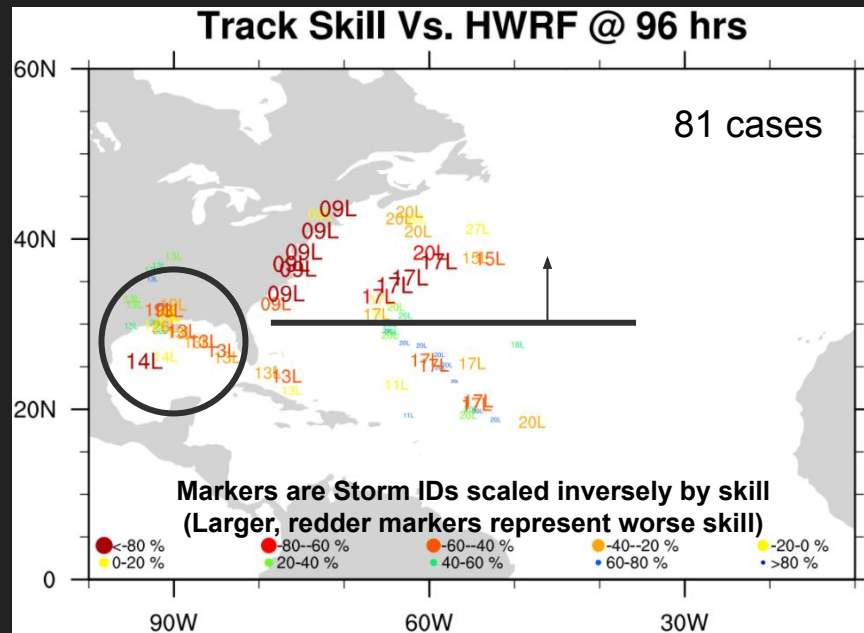
**HB20** intensity skill was generally positive in the open Atlantic. Lower track skill in the Gulf of Mexico.



# Track Verification: North Atlantic



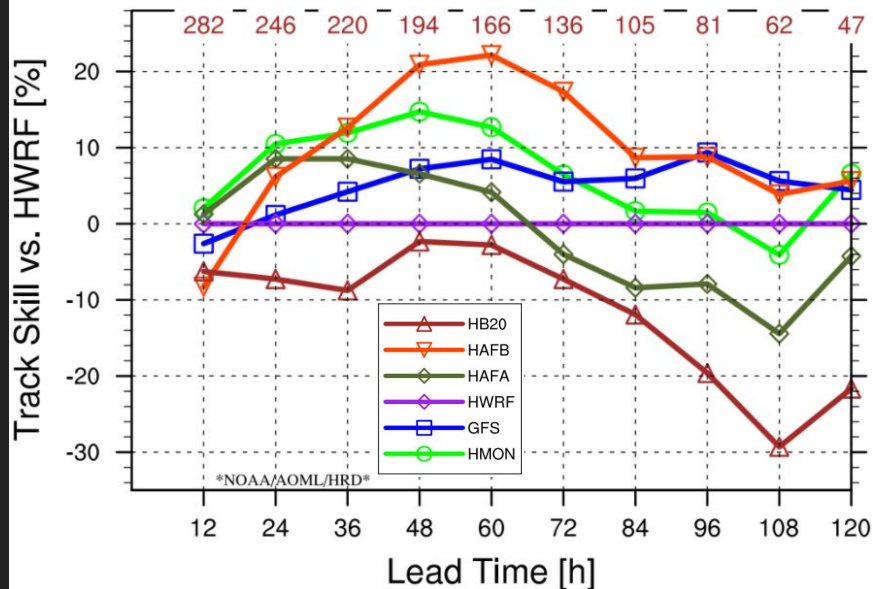
**HB20** track errors were quite large at 72+ hours (> 250 n mi at 120 h). We were surprised by differences with **HWRF**; not so in retro forecasts.



**HB20** track skill versus **HWRF** was negative in two regions: (i) higher latitudes and (ii) the Gulf of Mexico

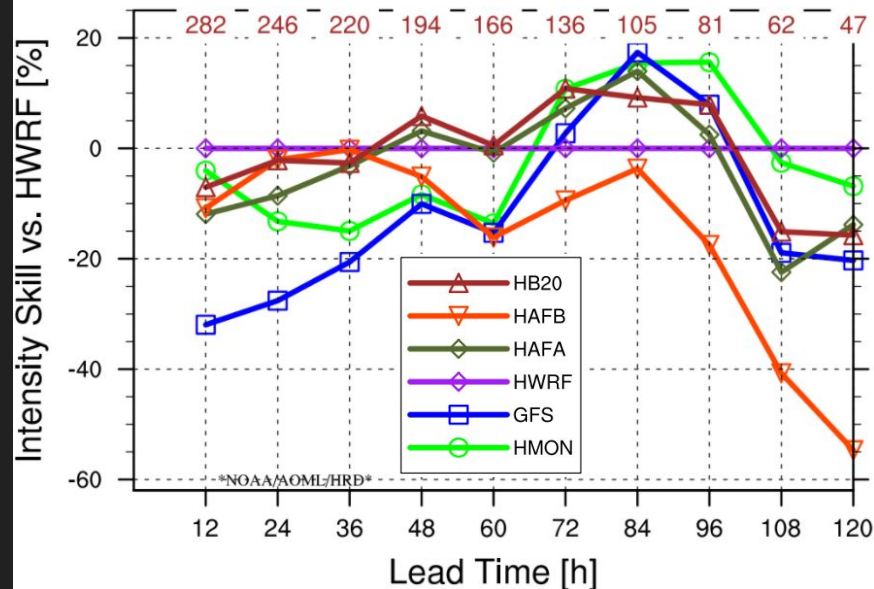
# Track & Intensity Verification: North Atlantic

## Track Skill vs. HWRP



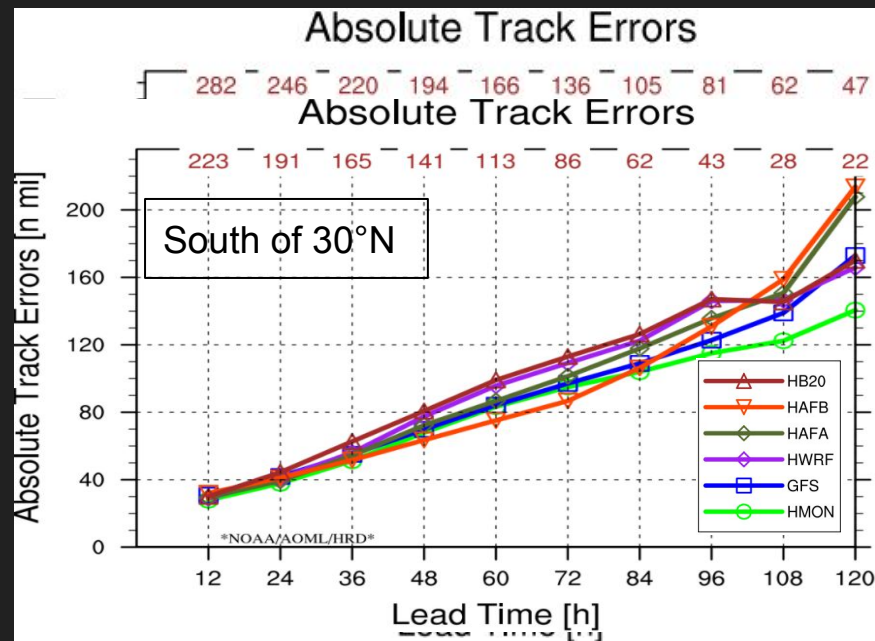
**HB20** track errors were quite large at 72+ hours (> 250 n mi at 120 h). We were surprised by differences with **HWRP**; not so in retro forecasts.

## Intensity Skill vs. HWRP

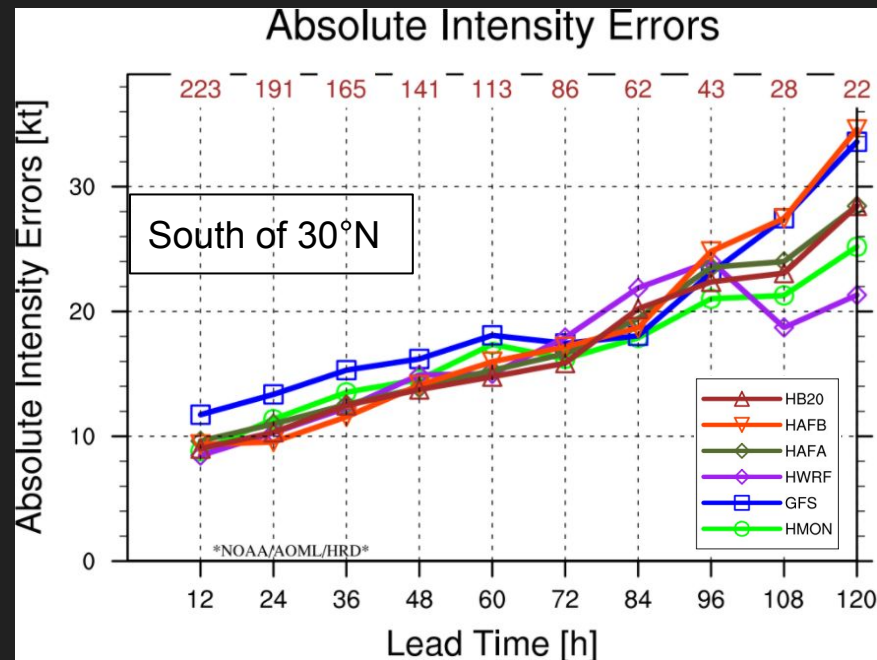


**HB20** intensity errors were quite good (especially vs. **HWRP**) at most lead times. **HB20** had lowest intensity errors at 48/60/72 h.

# Performance at Lower Latitudes



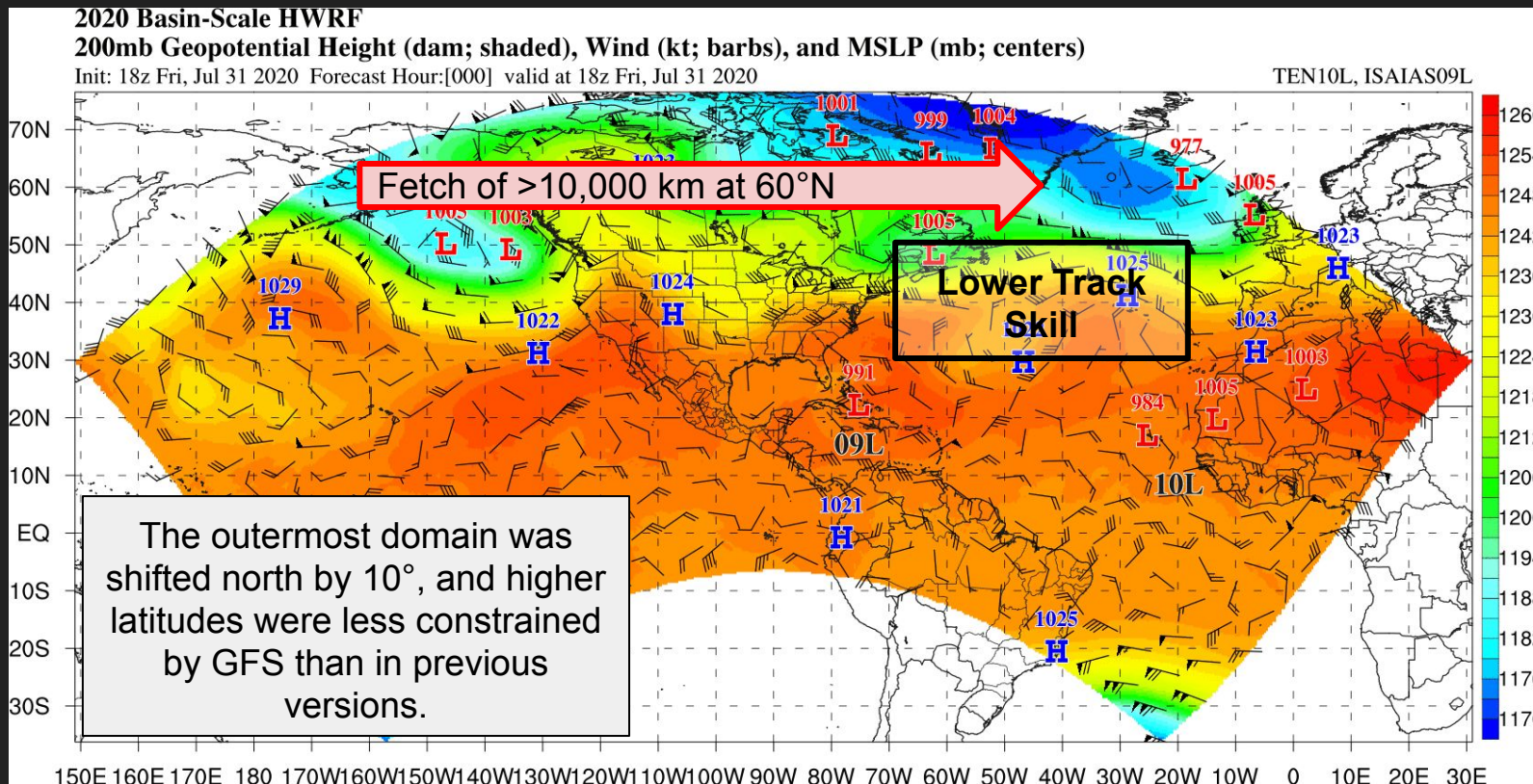
**HB20** track errors reduced considerably for points south of 30°N and were comparable with **HWRF** at most lead times.



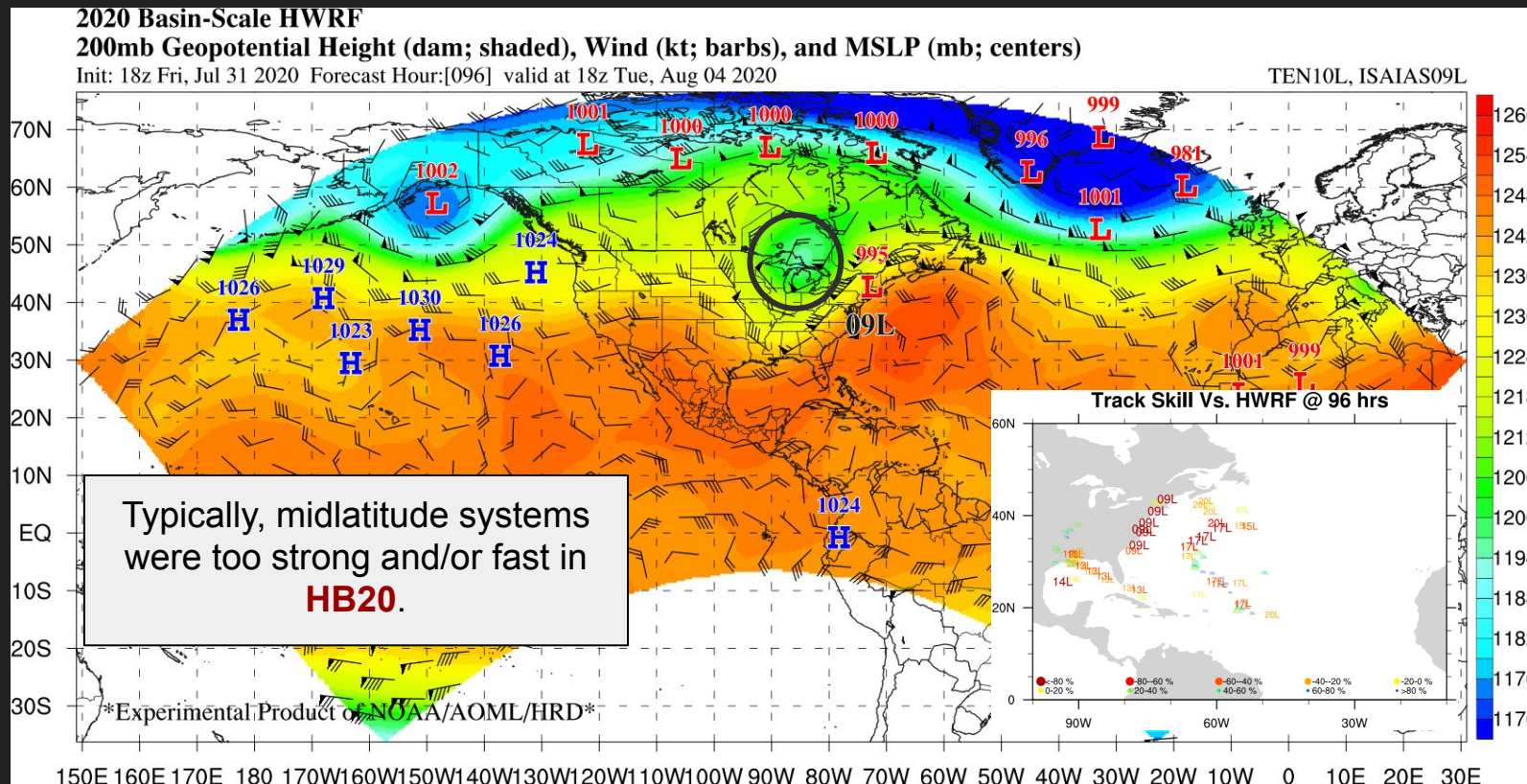
**HB20** intensity errors were still comparable or better than **HWRF** at most lead times.



# What is Happening at Higher Latitudes?



# What is Happening at Higher Latitudes?

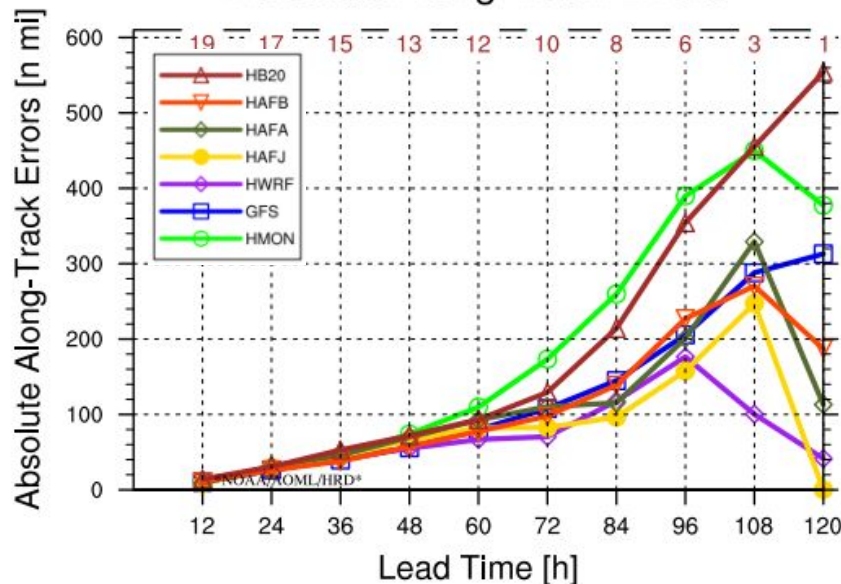




# What is Happening at Higher Latitudes?

Isaias (09L) had large along track errors (too fast) due to stronger synoptic-scale systems north of 40°N.

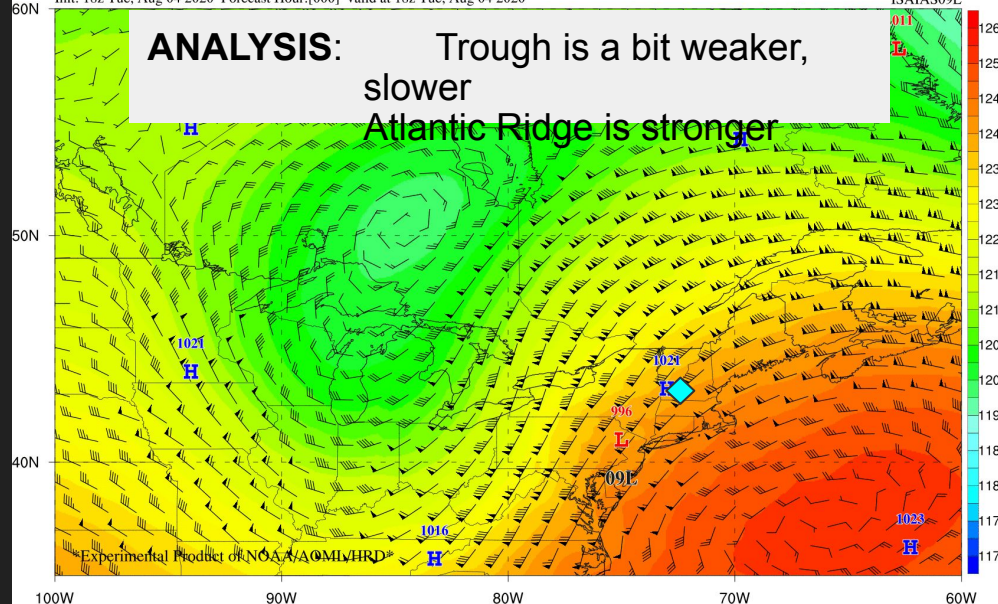
## Absolute Along-Track Errors



## 2020 Basin-Scale HWRP

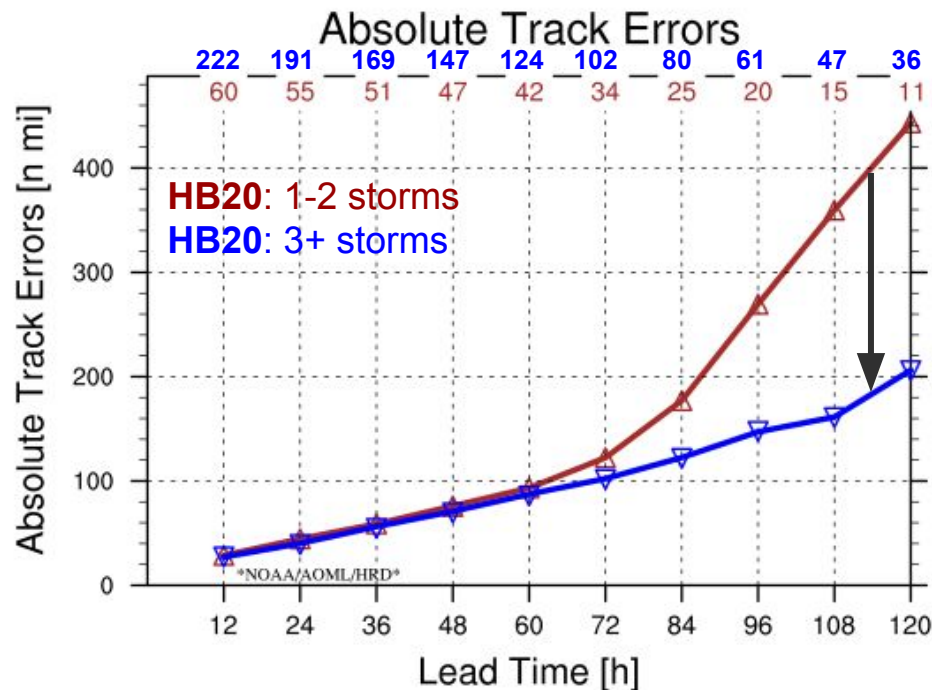
200mb Geopotential Height (dam; shaded), Wind (kt; barbs), and MSLP (mb; centers)

Init: 18z Tue, Aug 04 2020 Forecast Hour:[000] valid at 18z Tue, Aug 04 2020

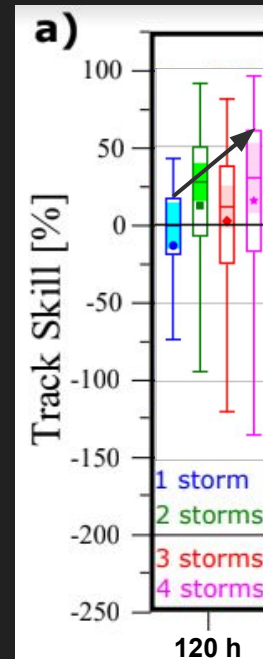




# Multi-Storm Evaluation



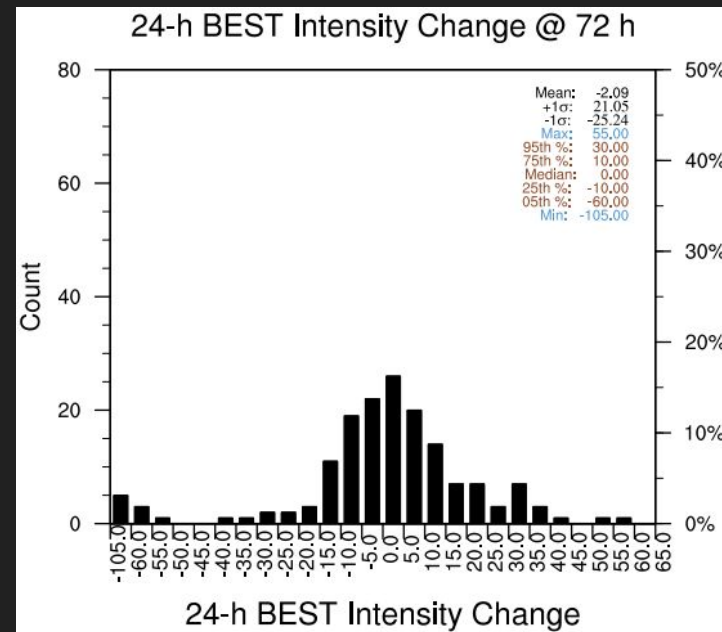
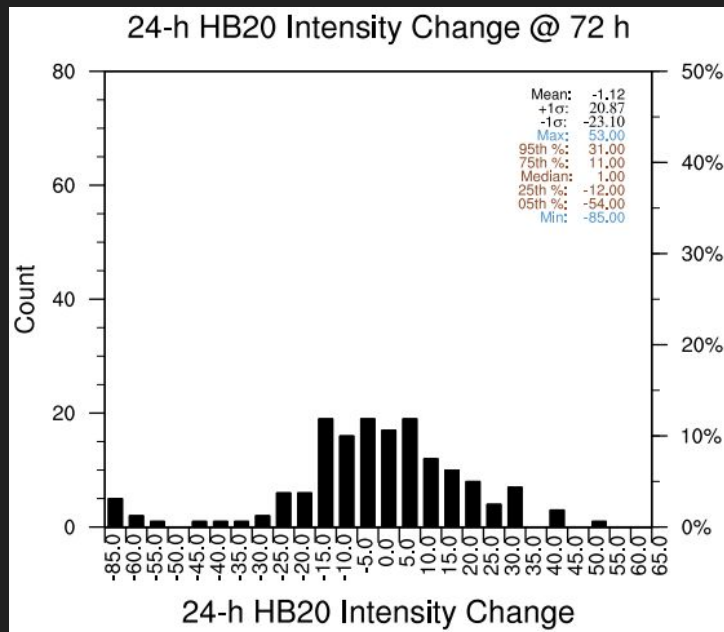
- (left) HB20 track errors were cut in half by day 5 when 3+ storms were active in NATL/EPAC
- (right) HB20 results are consistent with HWRF-B retrospective results that showed higher track skill score at later lead times when more storms were active.



Alaka et al. 2020,  
*Atmosphere*



# 24-h Intensity Change: HWRF-B vs. Best Track



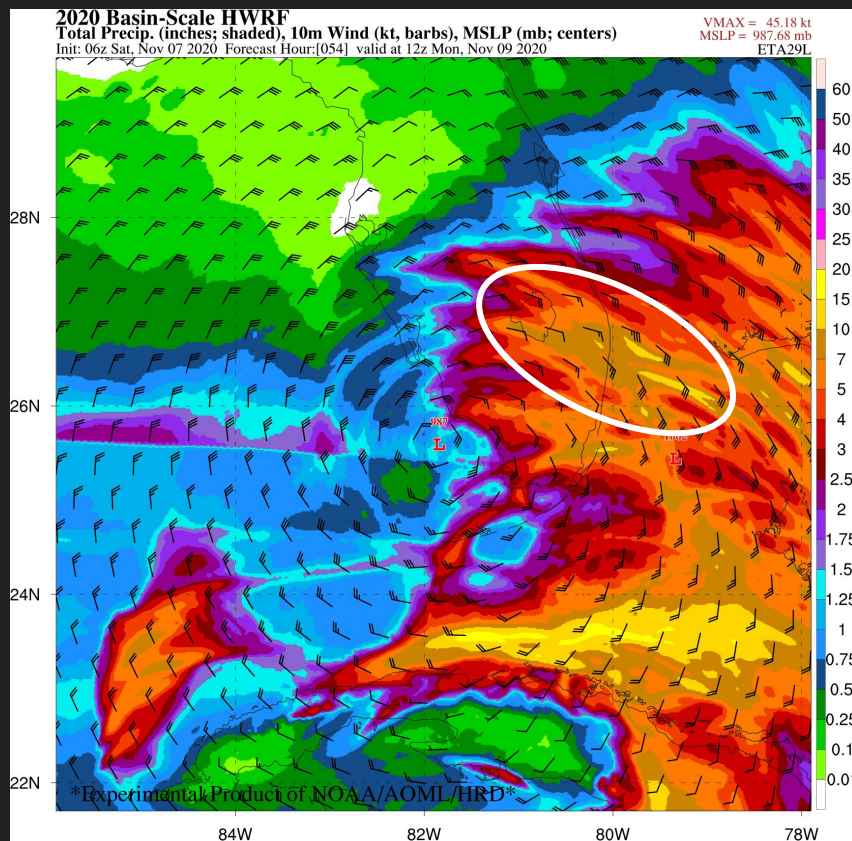
**HB20** RI was very well calibrated  
 95th percentile:  
 Interquartile range:

**HB20**  
 31 kt / 24 h  
 23 kt

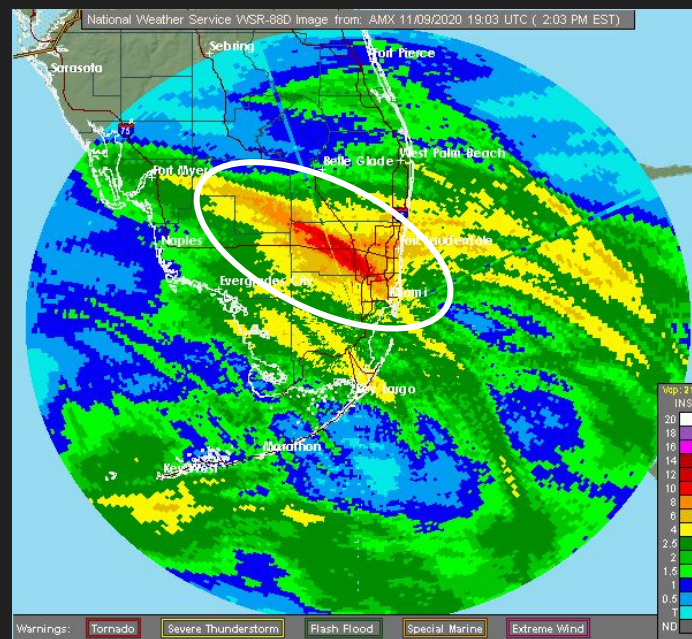
**Best Track**  
 30 kt / 24 h  
 20 kt



# Rainfall Evaluation: Eta (29L)



\*Note different colorbars



- **HB20** predicted a significant rainfall threat at least 2 days in advance (widespread 4"+).
- Strip of higher rainfall totals (7"+) was well predicted but displaced to the north.

# Summary & Conclusions

- For the first time, the HWRF-B system has caught up with the HWRF repository
  - However, ensemble DA wasn't run in real-time due to resources
- HWRF-B continues to show value for multiple high-resolution nests in the same outer domain
- HWRF-B performance was degraded at higher latitudes ( $> 30^{\circ}\text{N}$ )
  - Attention should be paid to the evolution of the midlatitude flow in large regional domains (or nests)
- The benefits of self-cycled ensemble DA alone are still unclear due to small sample sizes  $\rightarrow$  B220 experiment
  - Lower intensity errors at early lead times for B220 versus HB20
- Rainfall predictions for Eta were excellent. It will be a priority to continue to develop and evaluate rainfall products in HAFS...

# Recent HWRF-B Publications

- Wu, Shun-Nan, Brian J. Soden, and Ghassan J. Alaka, Jr., 2020: Ice Water Content as a Precursor to Tropical Cyclone Rapid Intensification. *Geophys. Res. Lett.*, **47**, e2020GL089669, <https://doi.org/10.1029/2020GL089669>.
- Alaka, Ghassan J., Jr., D. Sheinin, B. Thomas, L. Gramer, Z. Zhang, B. Liu, H.-S. Kim, and A. Mehra, 2020: A Hydrodynamical Atmosphere/Ocean Coupled Modeling System for Multiple Tropical Cyclones. *Atmosphere*, **11**, 869, <https://doi.org/10.3390/atmos11080869>.
- Ko, Mu-Chieh, Frank D. Marks, Ghassan J. Alaka, Jr., and Sundararaman G. Gopalakrishnan, 2020: Evaluation of Hurricane Harvey (2017) Rainfall in Deterministic and Probabilistic HWRF Forecasts. *Atmosphere*, **11**, 666, <https://doi.org/10.3390/atmos11060666>.
- Alaka, Ghassan J., Xuejin Zhang, Sundararaman Gopalakrishnan, Zhan Zhang, Frank D. Marks, and Robert Atlas, 2019: Track Uncertainty in High-Resolution HWRF Ensemble Forecasts of Hurricane Joaquin. *Wea. Forecasting*, **34**, 1889-1908, <https://doi.org/10.1175/WAF-D-19-0028.1>.
- Alaka, Ghassan J., Xuejin Zhang, Sundararaman Gopalakrishnan, Stanley B. Goldenberg, and Frank D. Marks, 2017: Performance of Basin-Scale HWRF Tropical Cyclone Track Forecasts. *Wea. Forecasting*, **32**, 1253-1271, <https://doi.org/10.1175/WAF-D-16-0150.1>.
- Zhang, X., S. Gopalakrishnan, S. Trahan, T. Quirino, Q. Liu, Z. Zhang, G. Alaka, and V. Tallapragada, 2016: Representing Multiple Scales in the Hurricane Weather Research and Forecasting Modeling System: Design of Multiple Sets of Movable Multilevel Nesting and the Basin-Scale HWRF Forecast Application. *Wea. Forecasting*, **31**, 2019–2034, <https://doi.org/10.1175/WAF-D-16-0087.1>.

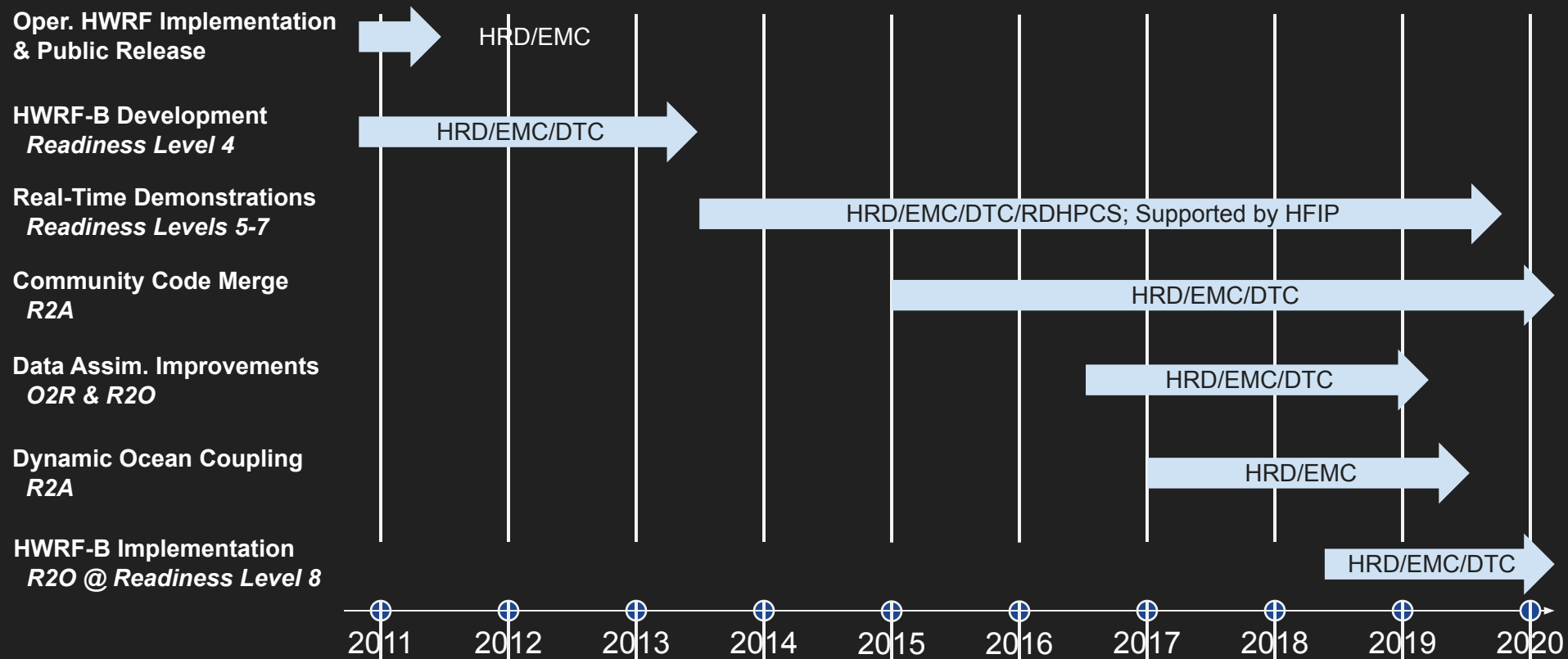


# EXTRA SLIDES

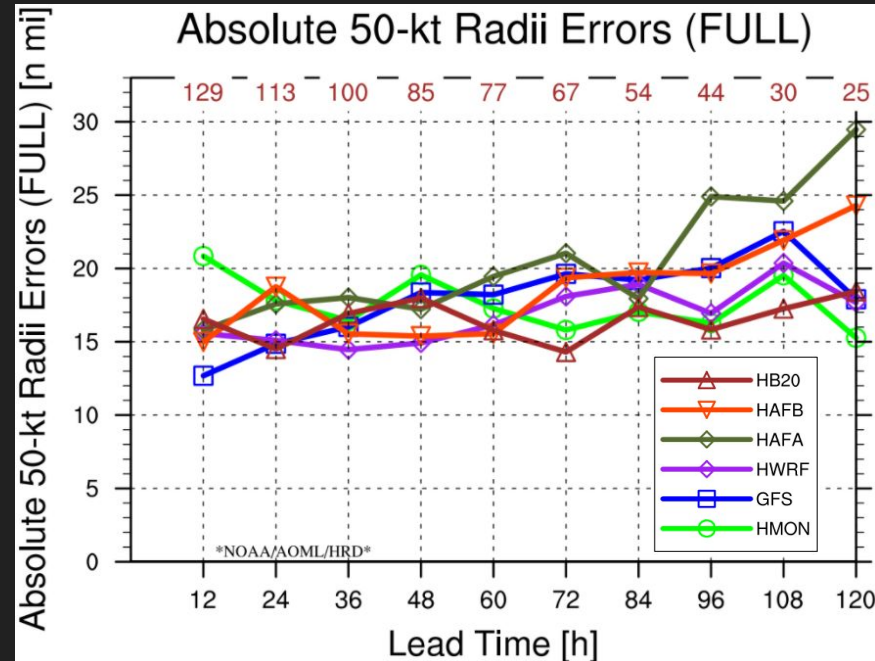
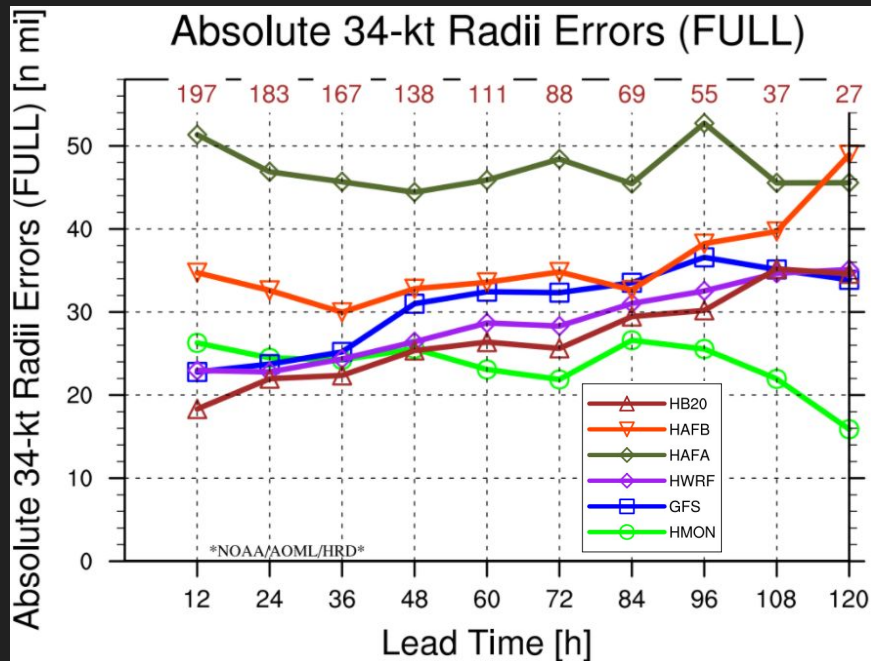


Please email questions or comments to:  
[Ghassan.Alaka@noaa.gov](mailto:Ghassan.Alaka@noaa.gov)

# Evolution of HWRF-B: A Team Effort

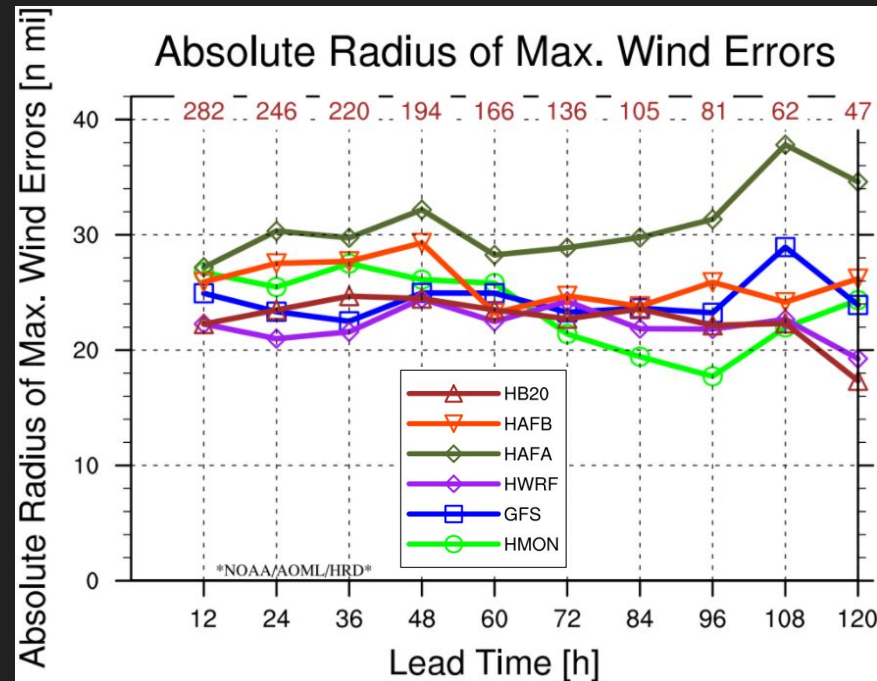
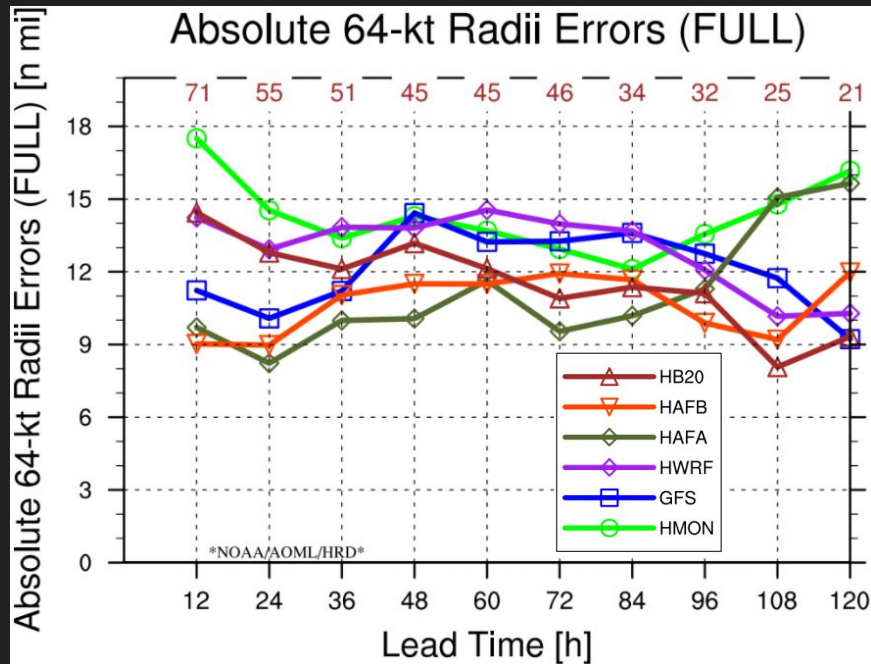


# Storm Size Verification: North Atlantic



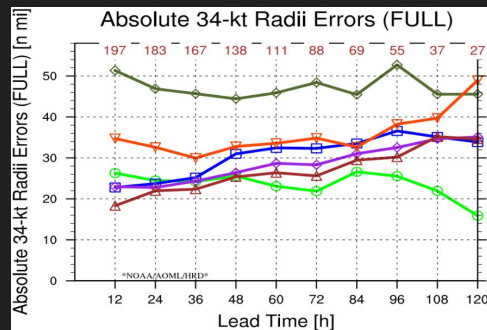


# Storm Size Verification: North Atlantic

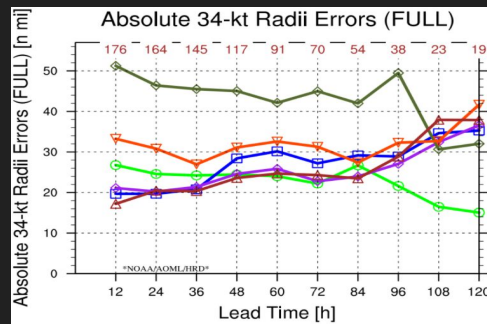


# Storm Size Verification: North Atlantic

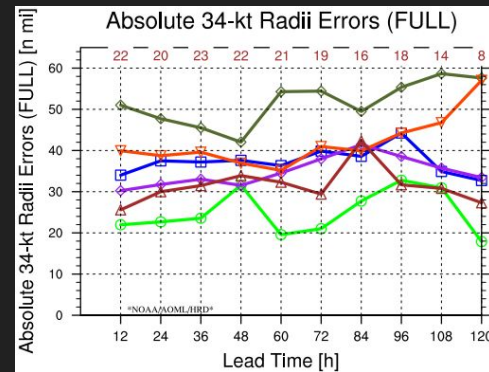
Absolute  
Errors



Full Sample

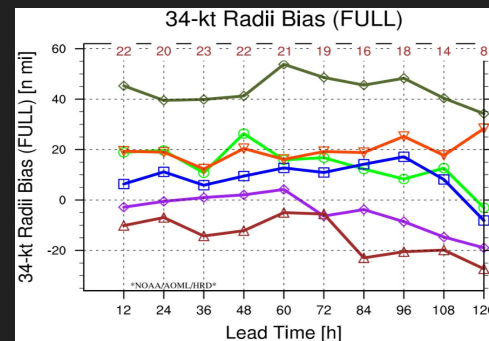
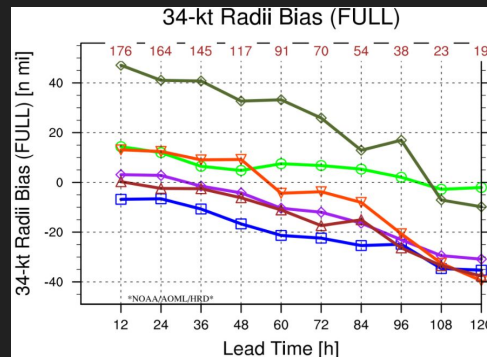
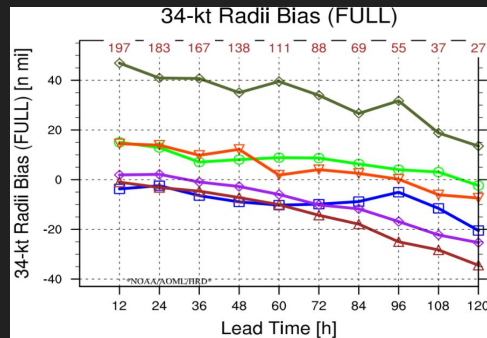


$\leq 30N$



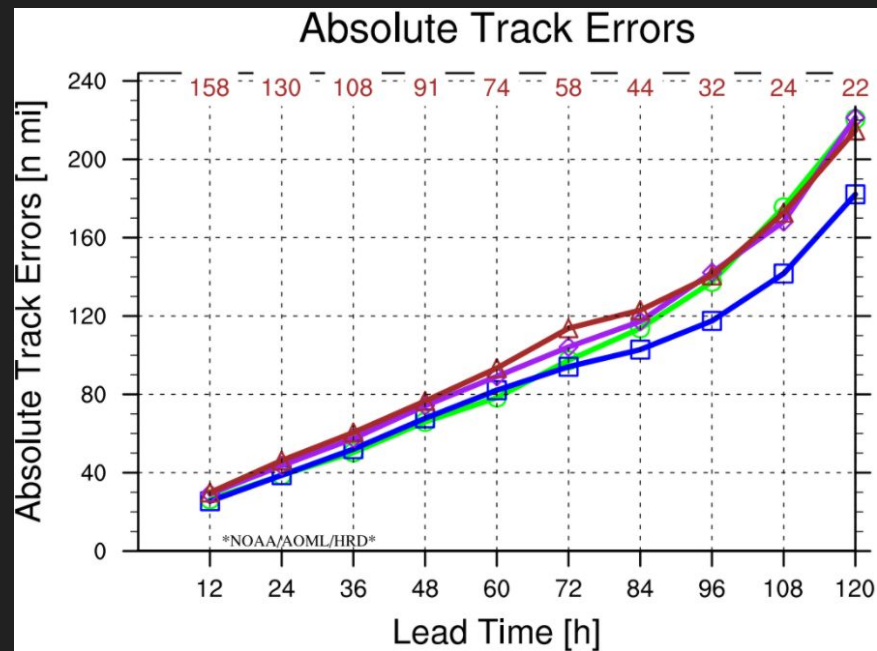
$> 30N$

BIAS

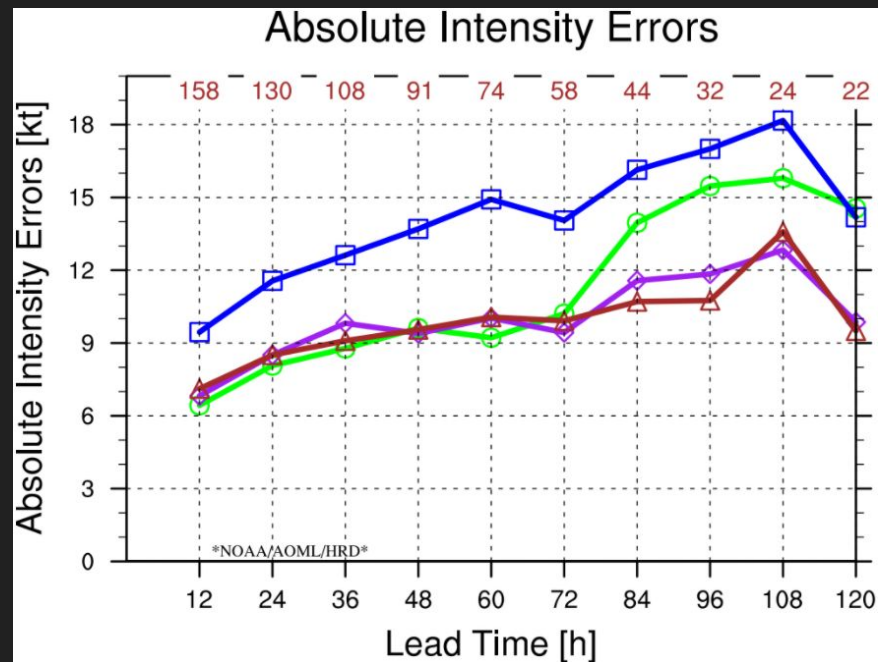


**HB20**  
R34 errors  
are worse for  
storms north  
of 30N at  
12-72 h

# Track/Intensity Verification: Eastern North Pacific



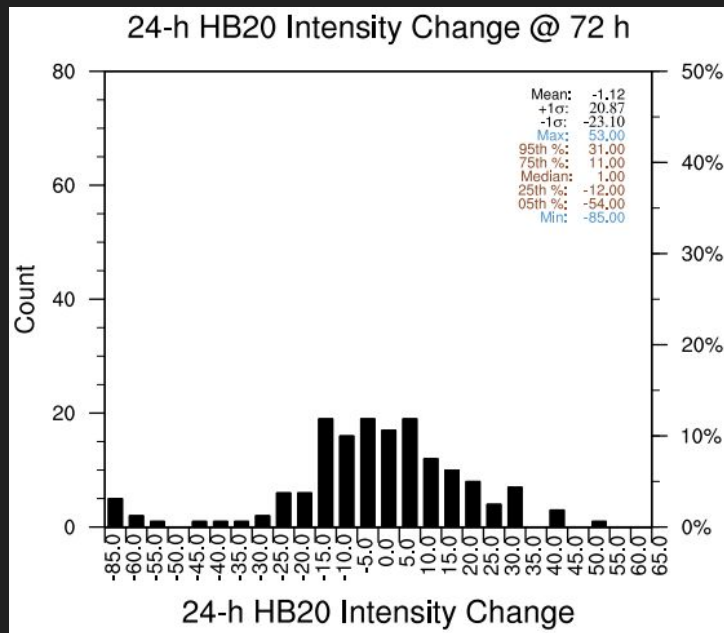
HWRF-B (**HB20**) track errors were comparable with **HWRF**.



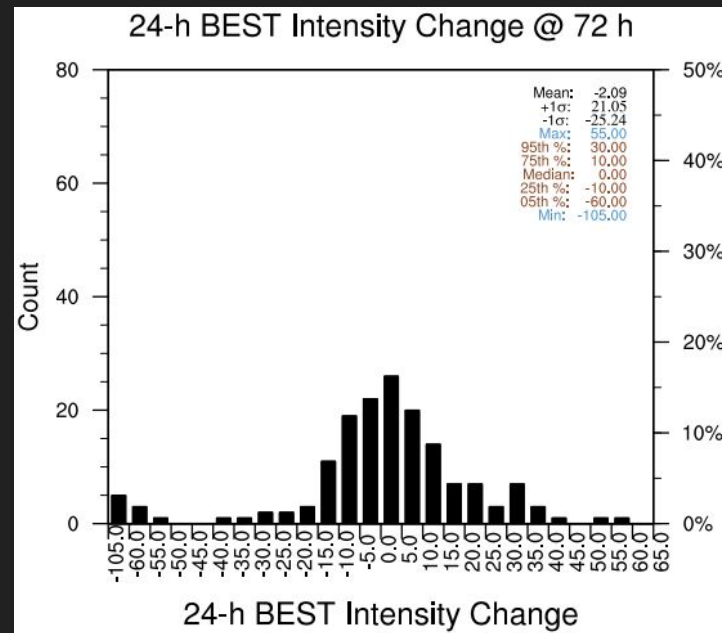
HWRF-B (**HB20**) intensity errors were comparable with **HWRF**.



# 24-h Intensity Change: HWRF-B vs. Best Track



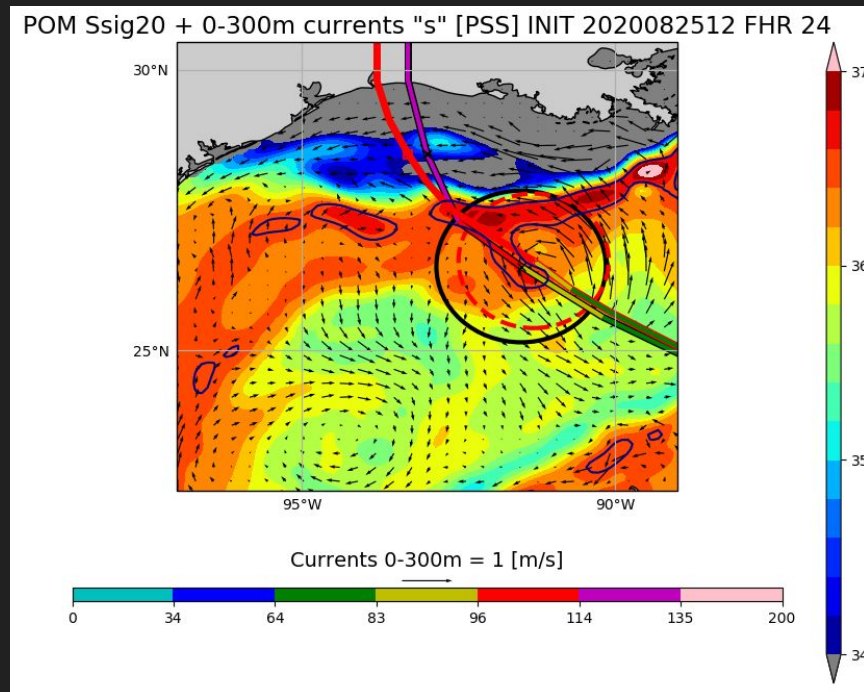
HWRF-B (**HB20**) track errors were comparable with **HWRF**.



HWRF-B (**HB20**) intensity errors were comparable with **HWRF**.

# Coastal Ocean Impacts: HWRF-B Studies

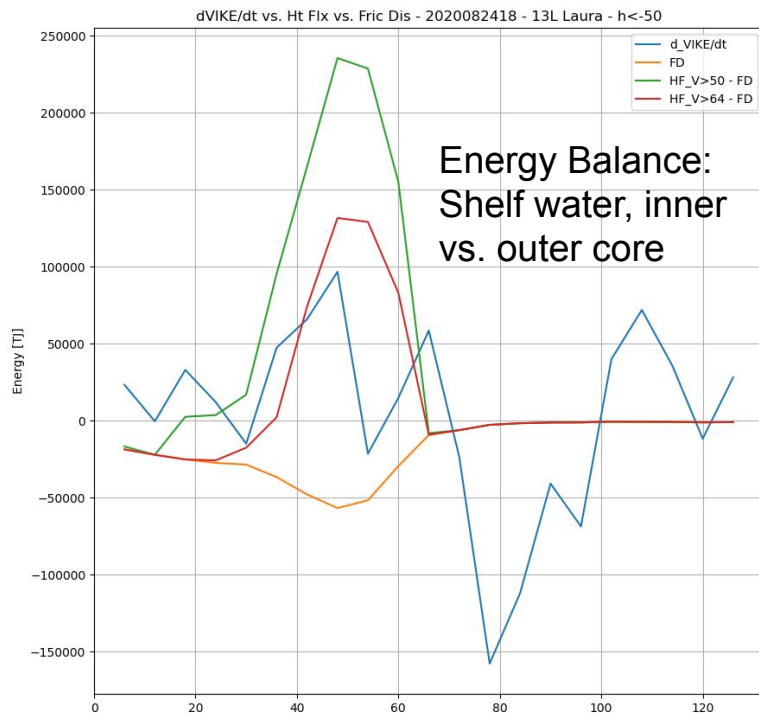
- Shelf heat fluxes impacted by coastal processes:
  - Coastal Ekman upwelling and downwelling
  - Barrier layers: river outflow
  - Coastal trapped as well as ocean internal waves
- Poorly resolved at 9 km?
  - Model bathymetry critical
- Impact “slow-moving” storms:  
<10 mph in tropics, to 15+ mph



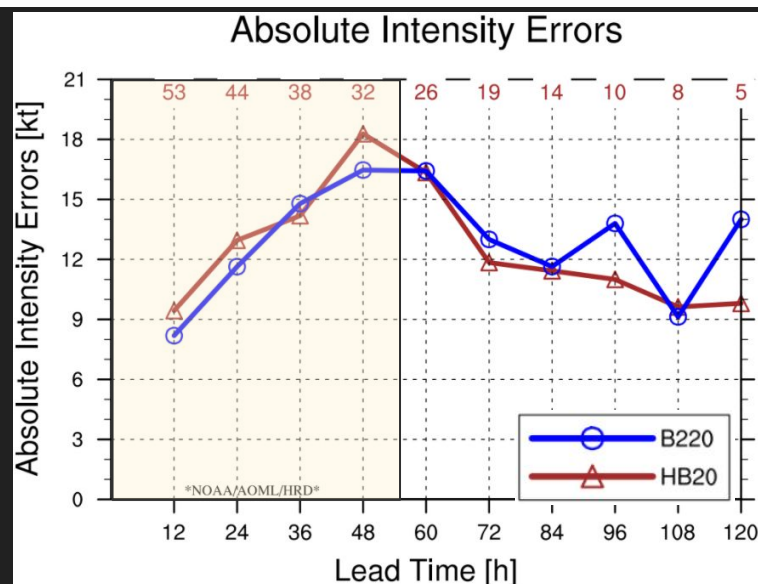
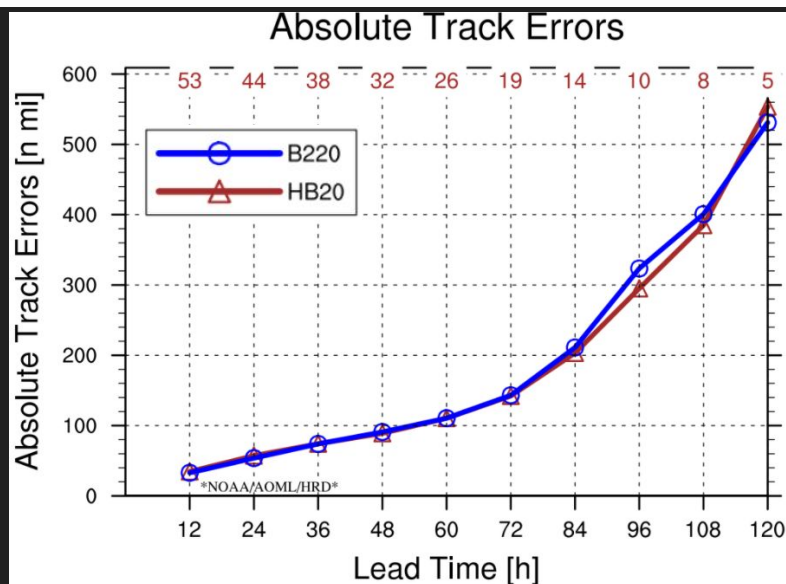
Mississippi Boundary Layer (~50 m depth, from RTOFS init)

# Coastal Ocean Impacts: HWRF-B Studies

- Shelf heat fluxes impacted by coastal processes:
  - Coastal Ekman upwelling and downwelling
  - Barrier layers: river outflow
  - Coastal trapped as well as ocean internal waves
- Poorly resolved at 9 km?
  - Model bathymetry critical
- Impact “slow-moving” storms: <10 mph in tropics, to 15+ mph



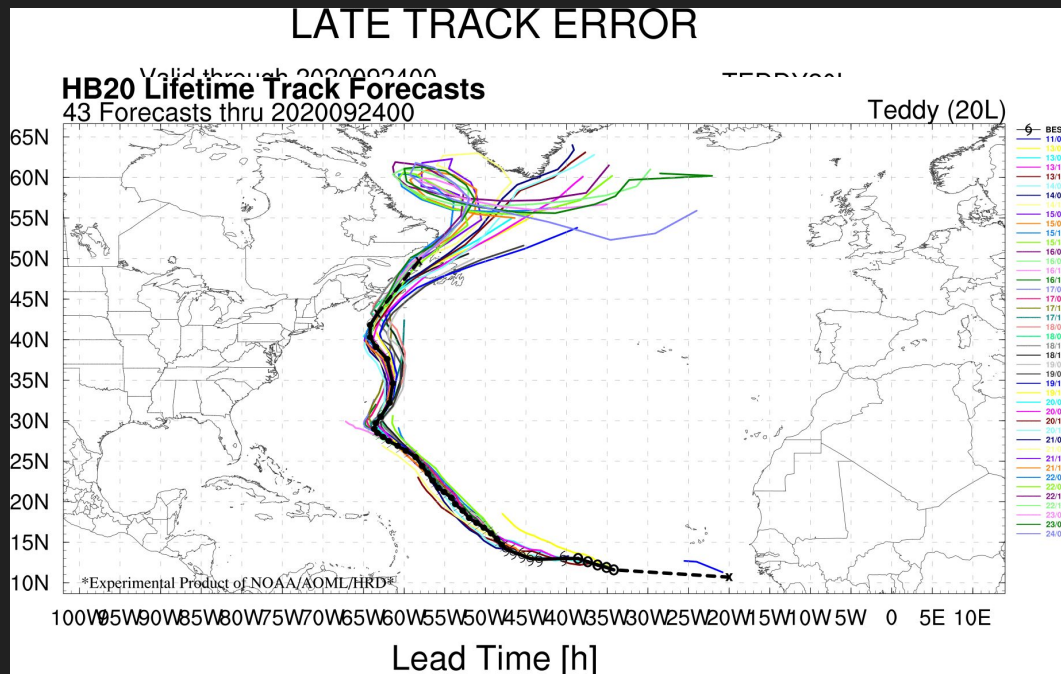
# Self-Cycled Ensemble DA (B220)



- Parallel version of **HB20** ran with up to 5 storms and ensemble DA (**B220**)
- **B220** intensity errors were 1-2 kt lower than **HB20** in the first 48 h. Track errors are a wash.
- Hanna was the only Gulf of Mexico storm from this sample. OperHWRF has shown great skill in the GoM with the impact of ensemble DA (which may not be reflected in the **B220** sample so far...)

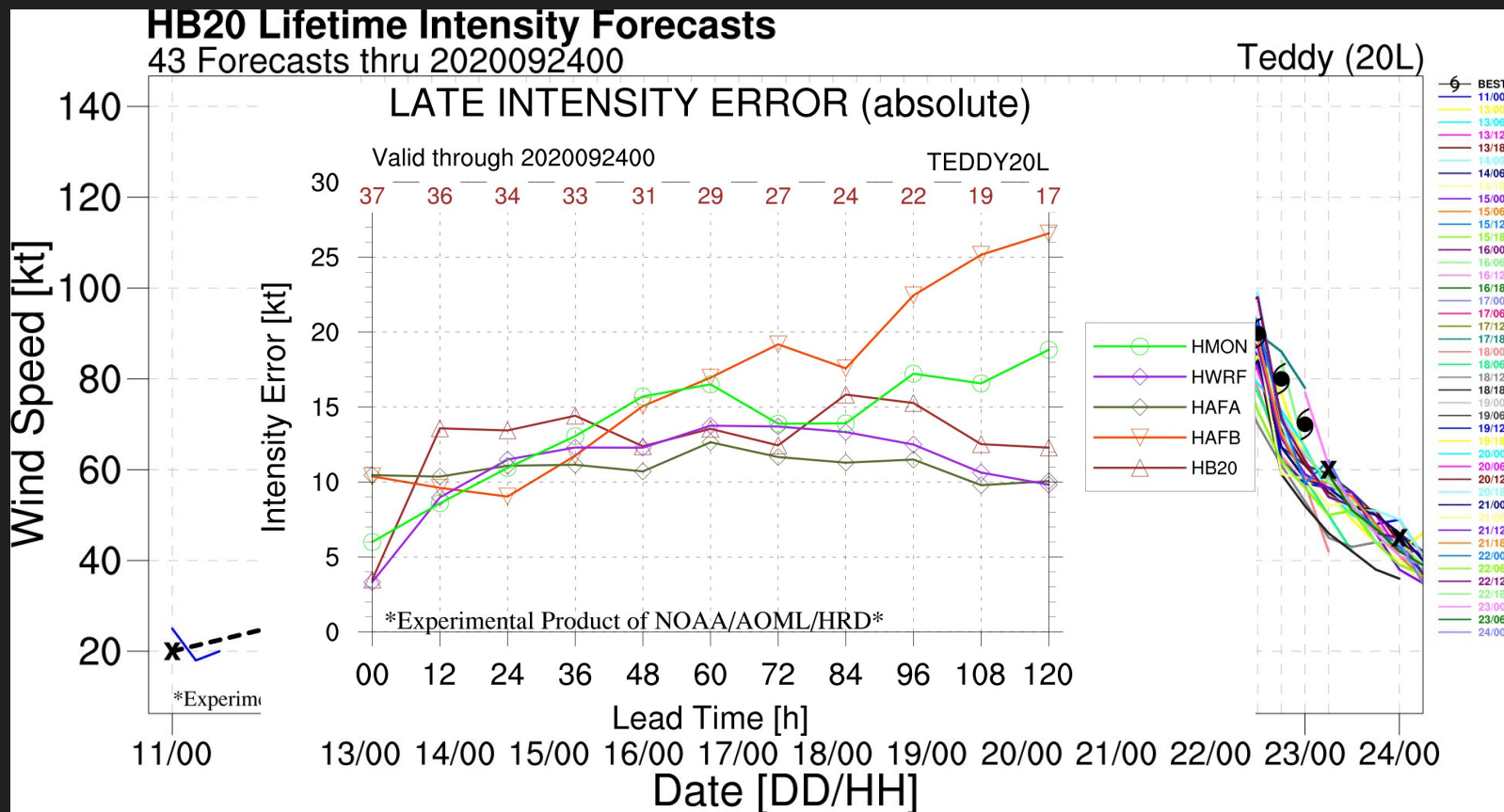


# Track Forecast Evaluation: Teddy (20L)



- **HB20** had lower track errors for Hurricane Teddy compared with **HWRF** at later lead times.
- Teddy was often concurrent with at least 2 other storms (e.g., **HB20** had 3 high-res moving nests).
- **HB20** performed well at lower latitudes, consistent with season-long results.

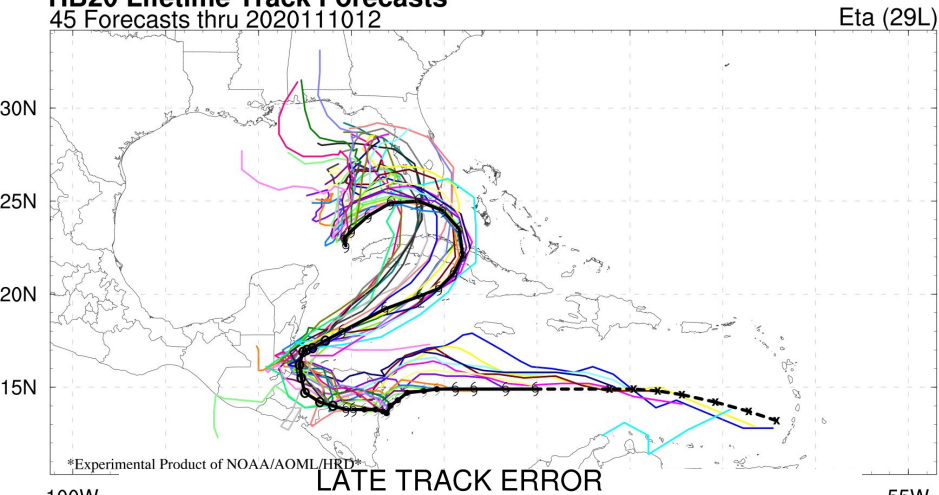
# Individual Storm Highlight: Teddy (20L)



# Individual Storm Highlights: Eta (29L)

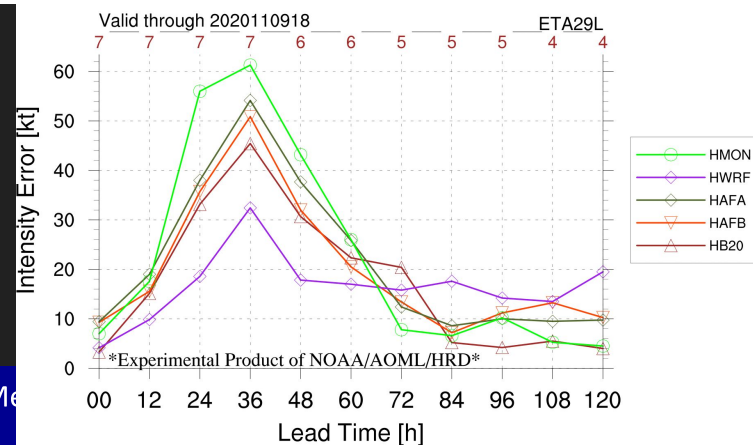
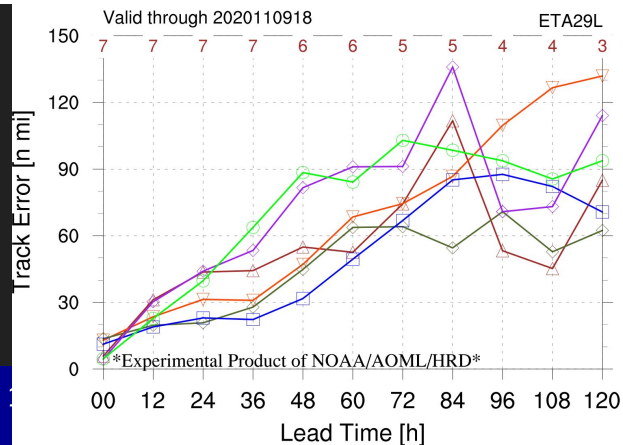
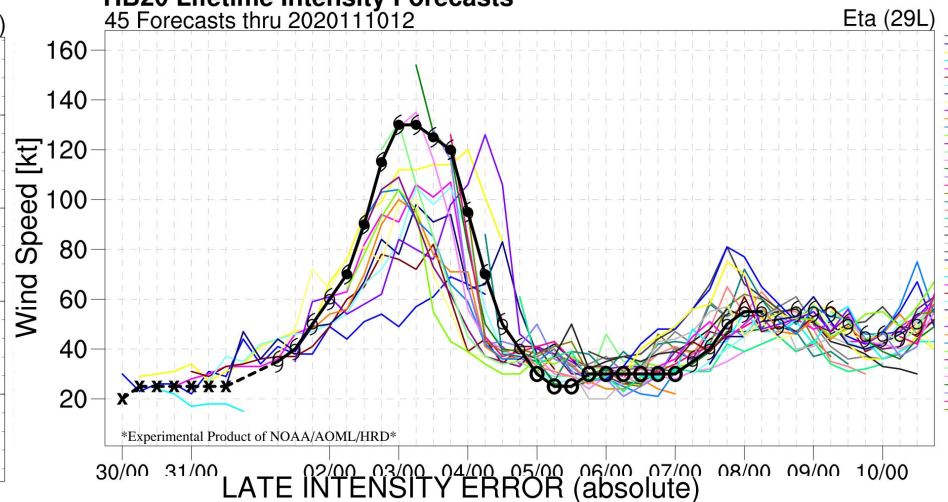
## HB20 Lifetime Track Forecasts

45 Forecasts thru 2020111012



## HB20 Lifetime Intensity Forecasts

45 Forecasts thru 2020111012

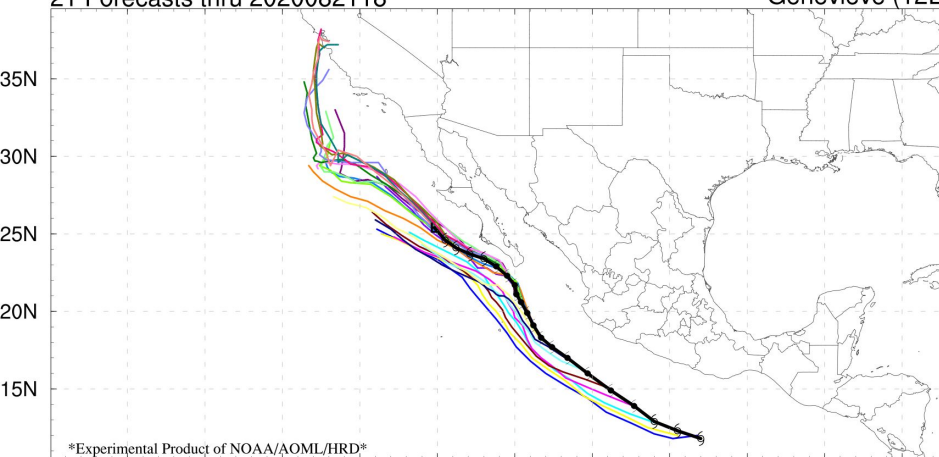


# Individual Storm Highlights: Genevieve (12E)

## HB20 Lifetime Track Forecasts

21 Forecasts thru 2020082118

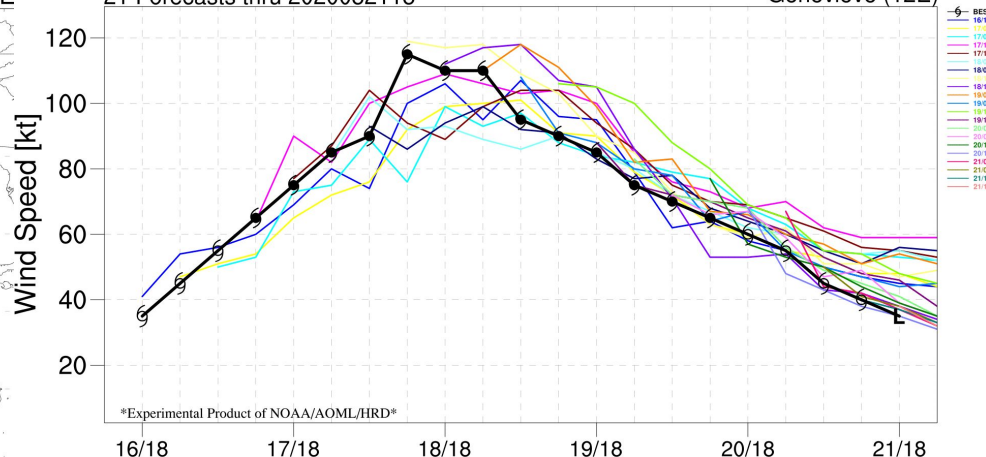
Genevieve (12E)



## HB20 Lifetime Intensity Forecasts

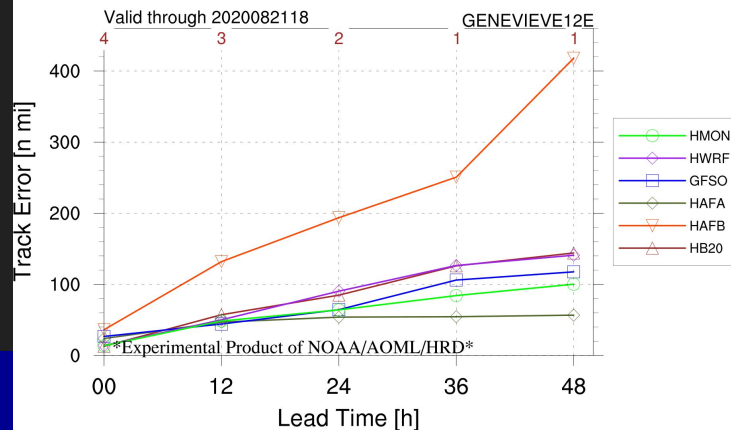
21 Forecasts thru 2020082118

Genevieve (12E)



## LATE TRACK ERROR

90W 85W



## LATE INTENSITY ERROR (absolute)

