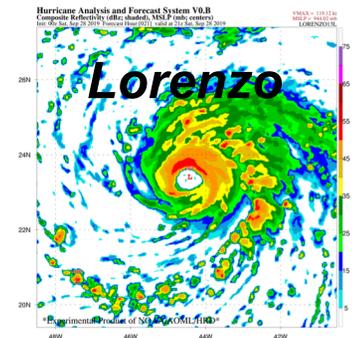
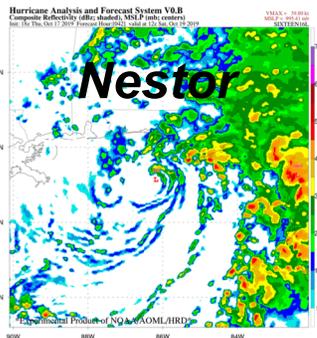
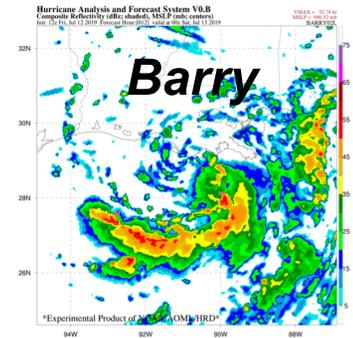
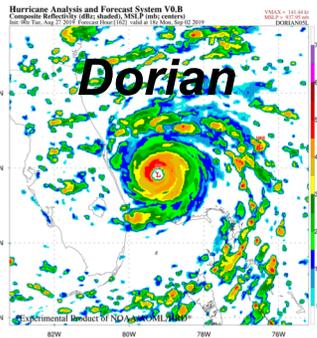




Global-Nested HAFS 2019 Real-time Demo Results

Andy Hazelton^{1,2} and Zhan Zhang^{3,4}



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- Thanks to HFIP and Jet management for the HPC reservation
- Thanks to JetHelp (specially Wei Yu and Shawn Needham) for technical help

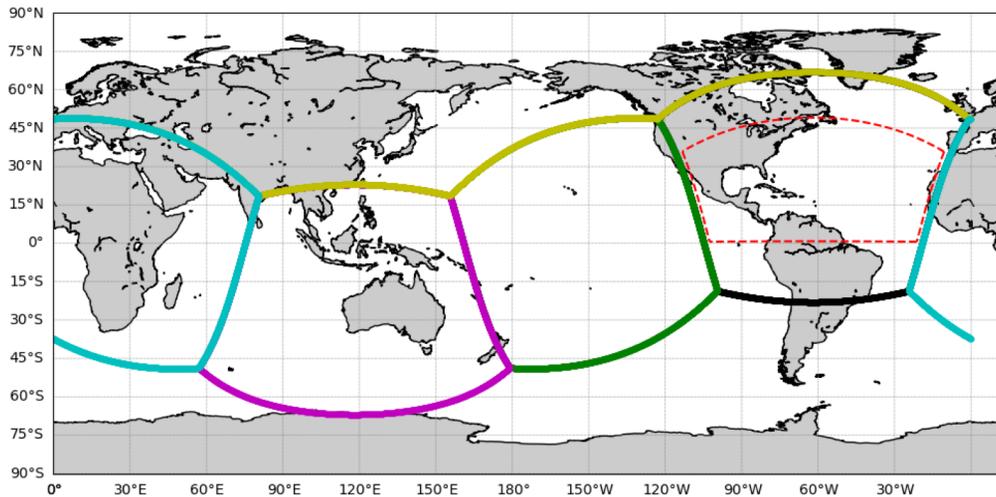




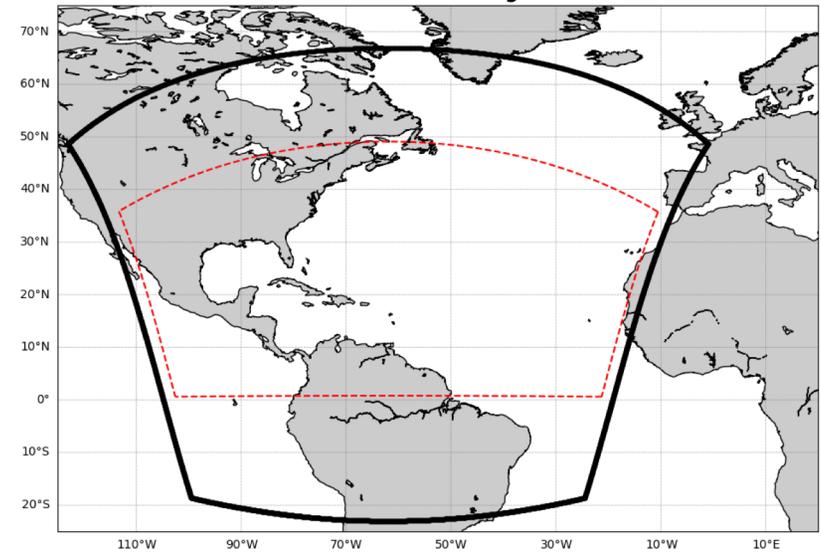
Global-Nested HAFS Configuration



Global Cubed-Sphere Layout



Tile 6 Layout



- Global-nested domain
- Tile 6 centered over the Atlantic
- Will be adjusted in the future for multiple basins
- Forecasts run out to 168h





Global-Nested HAFS Physics Description



Parameter	HAFS-globalnest (Nested Domain)	HAFS-globalnest (Global Domain)	GFSv15.1
Convective Scheme	None	Scale-aware SAS	Scale-aware SAS
Microphysics	GFDL	GFDL	GFDL
PBL	EDMF with modified K for Hurricane Conditions (as in HWRF)	EDMF with modified K for Hurricane Conditions (as in HWRF)	EDMF
Surface	GFDL (modified drag as in HWRF)	GFDL (modified drag as in HWRF)	GFS
Advection Scheme	hord_mt = 6 (more diffusive) hord_tr = 8	hord_mt = 5 (less diffusive) hord_tr = 8	hord_mt = 5 (less diffusive) hord_tr = 8
3-d Ocean Coupling	None	None	None

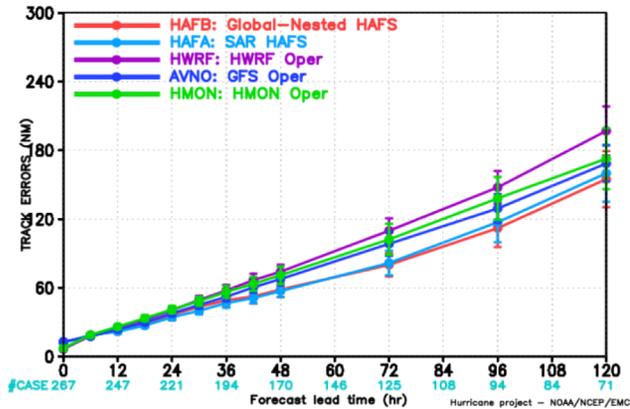




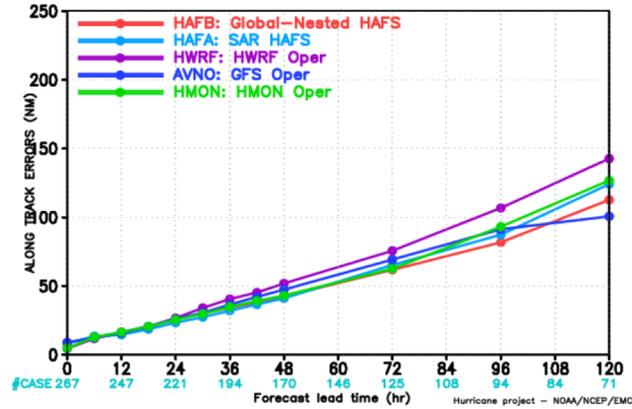
Global-Nested HAFS Track Statistics



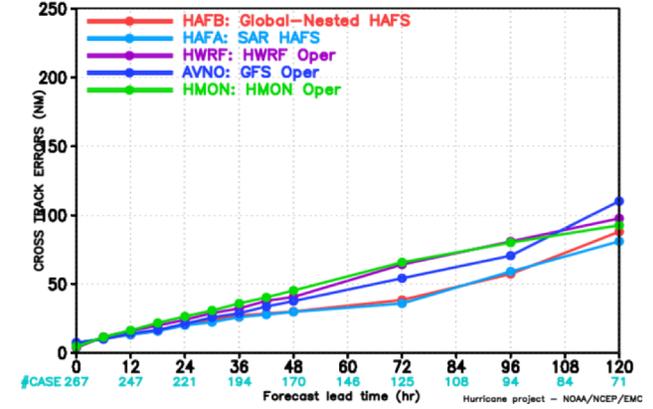
MODEL FORECAST – TRACK ERRORS (NM)
VERIFICATION FOR NORTH ATLANTIC BASIN 2019



MODEL FORECAST – ALONG TRACK ERRORS (NM)
VERIFICATION FOR NORTH ATLANTIC BASIN 2019



MODEL FORECAST – CROSS TRACK ERRORS (NM)
VERIFICATION FOR NORTH ATLANTIC BASIN 2019



- Global-nested HAFS had the best track forecasts at D4-5
- HAFS in general did very well compared to other GFS-based guidance
- Biggest difference was cross-track error

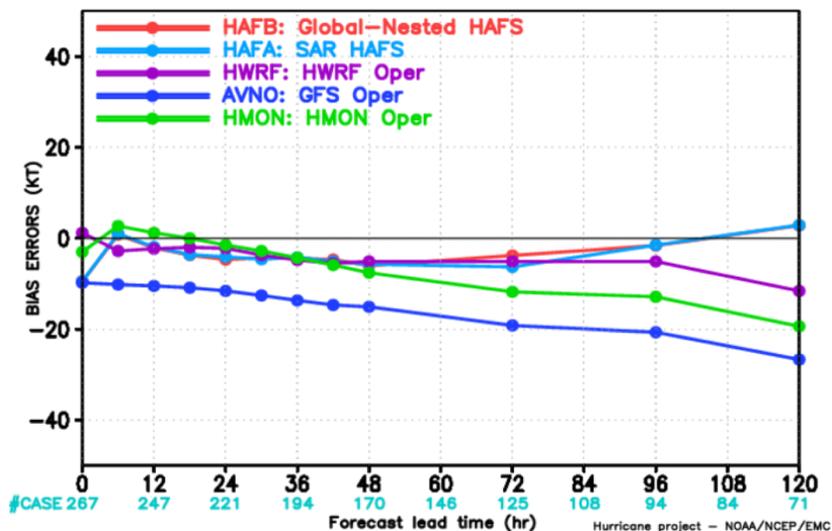




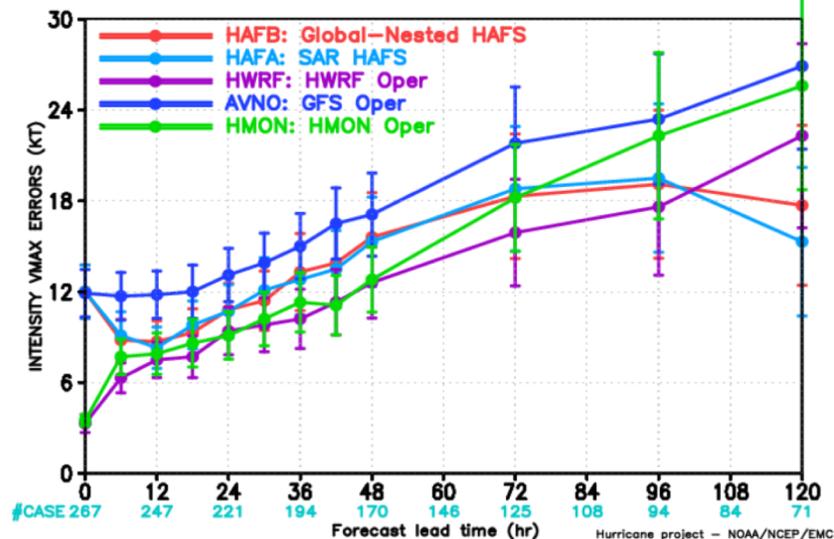
Global-Nested HAFS Intensity Statistics



MODEL FORECAST – BIAS ERRORS (KT)
VERIFICATION FOR NORTH ATLANTIC BASIN 2019



MODEL FORECAST – INTENSITY VMAX ERRORS (KT)
VERIFICATION FOR NORTH ATLANTIC BASIN 2019



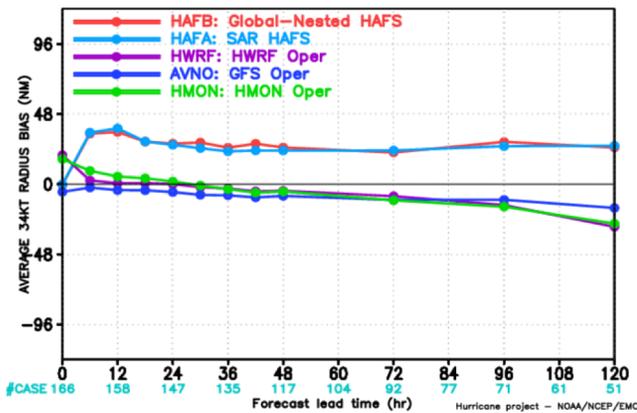
- HAFS has a low bias at initialization due to GFS init
- Catches up within about 6-12 hr
- Slightly worse than HWRF/HMON at days 1-2, but better 4-5
- Bias is low (offsetting high and low?)



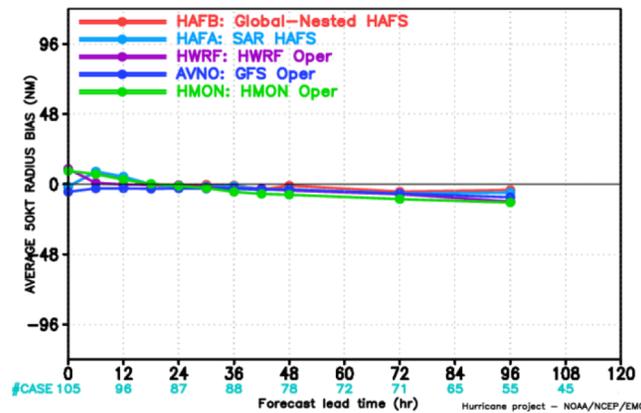


Global-Nested HAFS Wind Radii Statistics

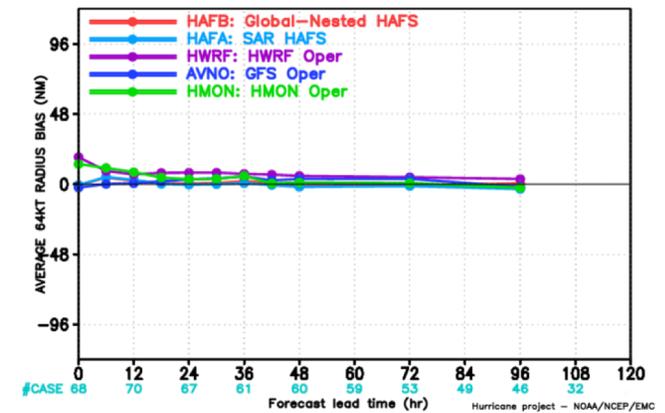
MODEL FORECAST – AVERAGE 34KT RADIUS BIAS (NM)
VERIFICATION FOR NORTH ATLANTIC BASIN 2019



MODEL FORECAST – AVERAGE 50KT RADIUS BIAS (NM)
VERIFICATION FOR NORTH ATLANTIC BASIN 2019



MODEL FORECAST – AVERAGE 64KT RADIUS BIAS (NM)
VERIFICATION FOR NORTH ATLANTIC BASIN 2019



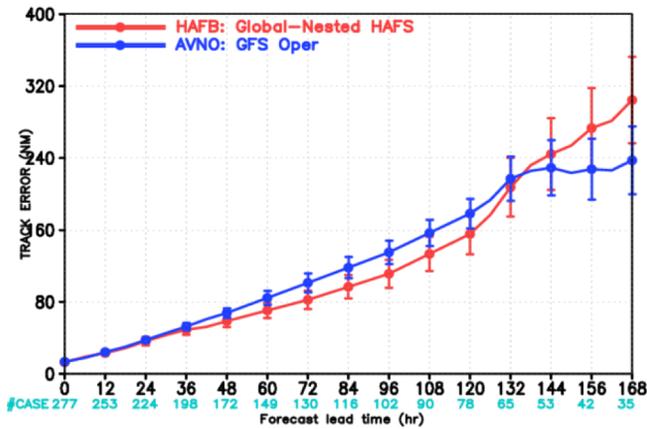
- HAFS had a high bias in R34 consistently through the season
- Doesn't seem to be from GFS init - shows up after spinup
- R50 and R64 are more consistent with other guidance
- Physical and/or dynamical reasons for the structure issue will be explored



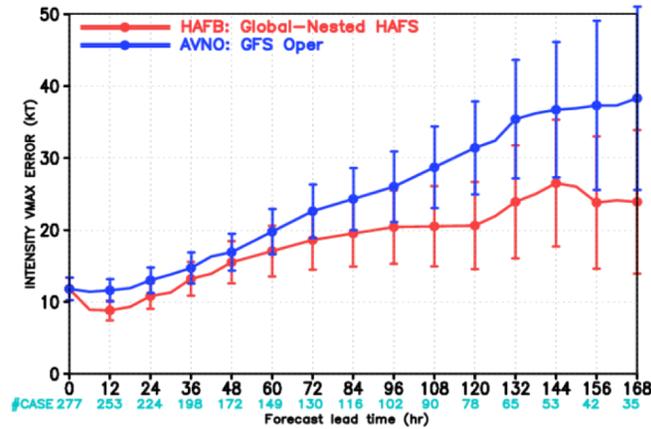


7-day Statistics

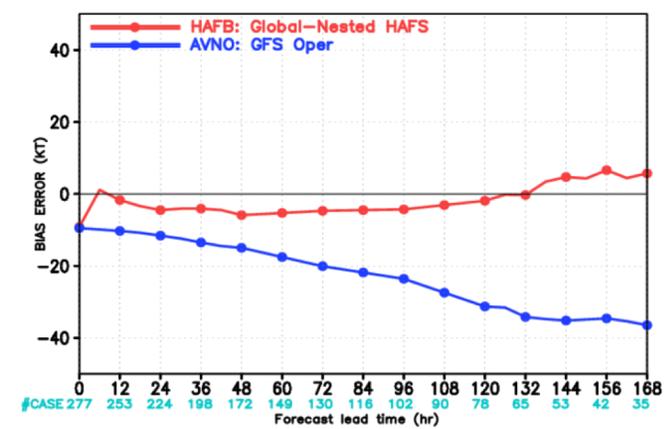
MODEL FORECAST – TRACK ERROR (NM) STATISTICS
VERIFICATION FOR NORTH ATLANTIC BASIN 2019



MODEL FORECAST – INTENSITY VMAX ERROR (KT) STATISTICS
VERIFICATION FOR NORTH ATLANTIC BASIN 2019



MODEL FORECAST – BIAS ERROR (KT) STATISTICS
VERIFICATION FOR NORTH ATLANTIC BASIN 2019

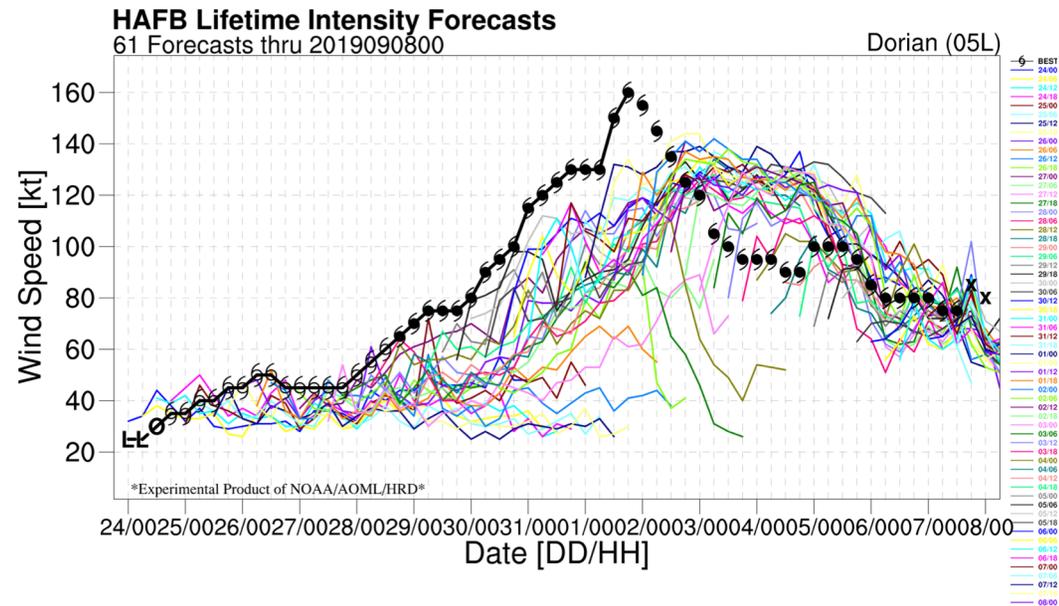
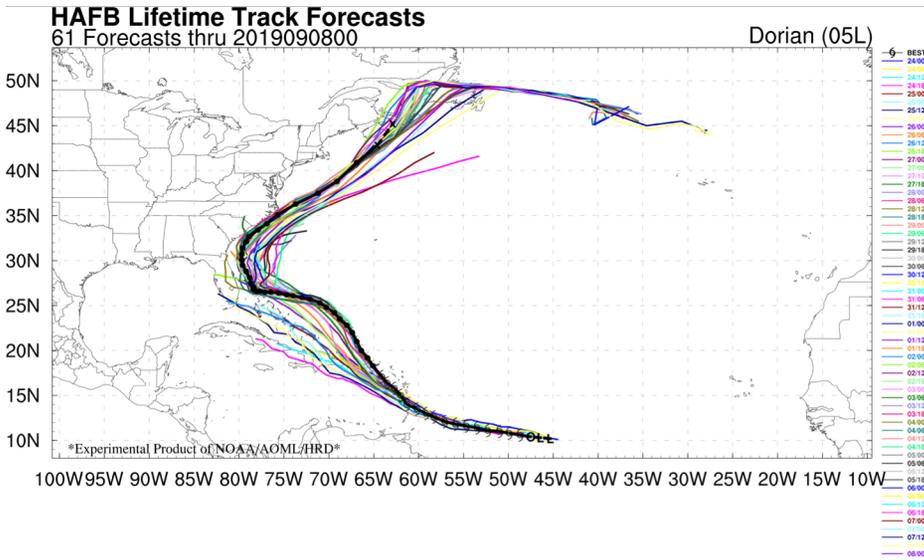


- Global-nested HAFS was run out to 7 days
- Chance to see nest impact at longer range
- Track was better through 132h, degraded D7 (tough cases looked at later!)
- Very large negative bias in GFS increasing with time
- Shows value of high-resolution nest for structure/intensity





Hurricane Dorian Results



- Early tracks were generally too far west (like most models)
- HAFS mostly showed the turn/stall in the Bahamas, before Florida
- After a few early cases, intensification was generally predicted (rate a bit off)
- Slight high bias after peak (ocean coupling?)



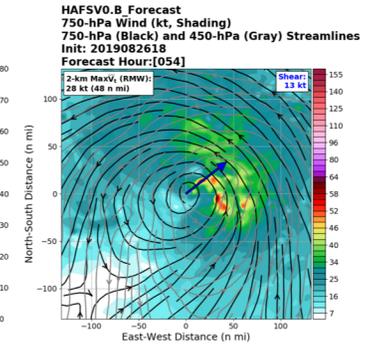
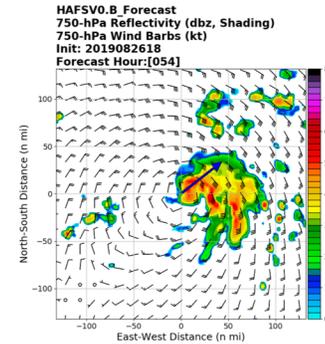


Structure Compared With Observations

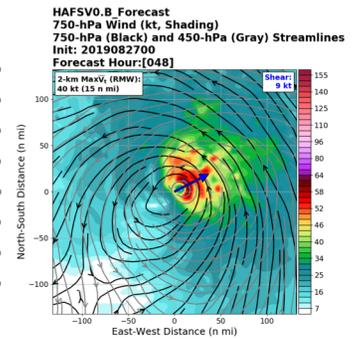
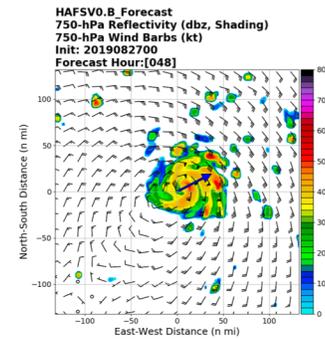


- Two forecasts initialized 6 hours apart
- Near the time of center relocation
- Very different wind structures
- Second one correctly predicted the small wind core that developed
- Track/intensity very different

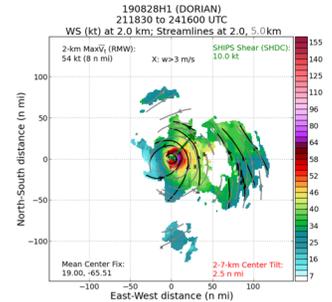
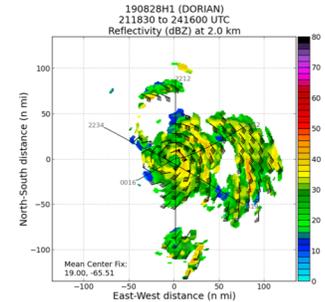
54-h Fcst



48-h Fcst

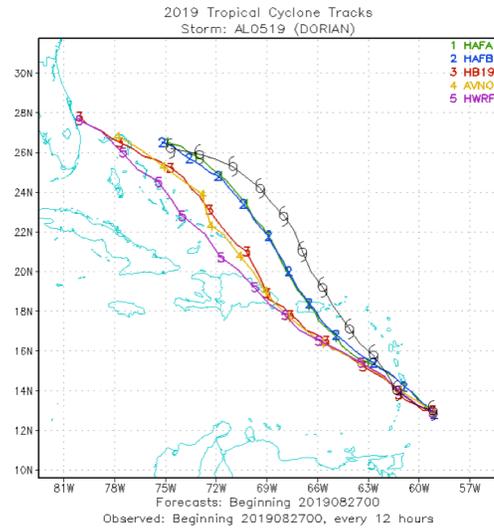
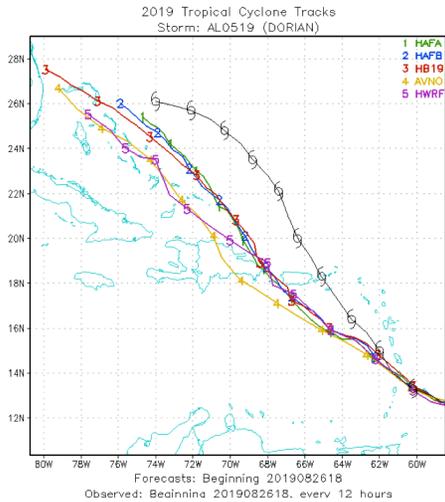


Observations

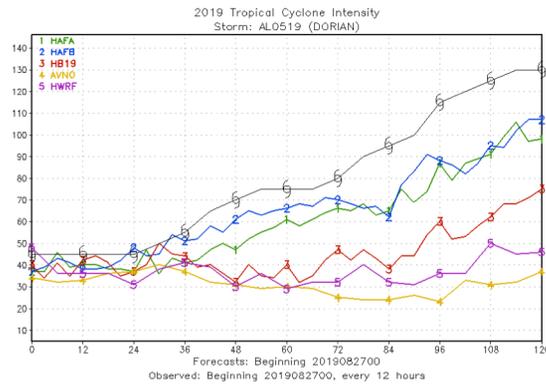
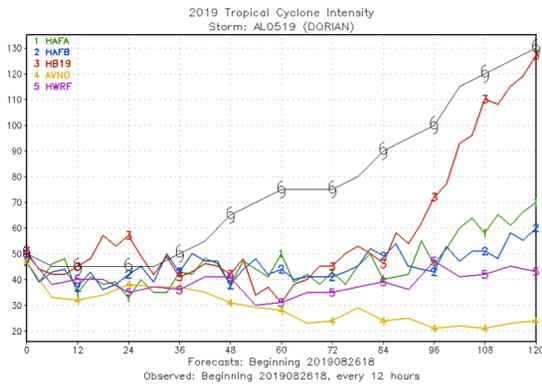




Structure Compared With Observations

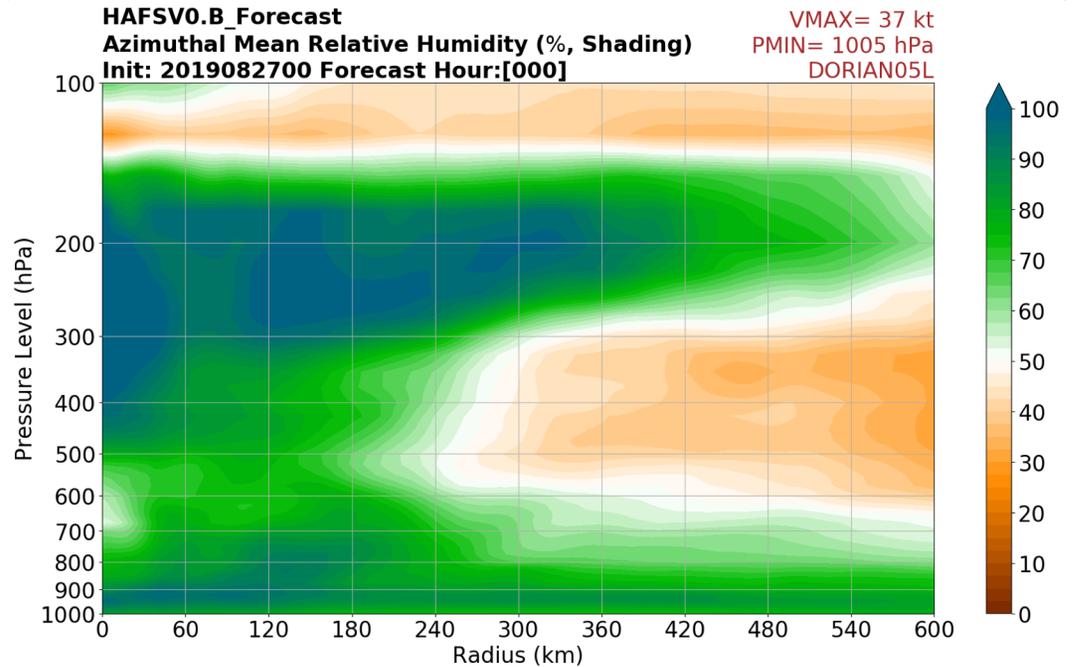
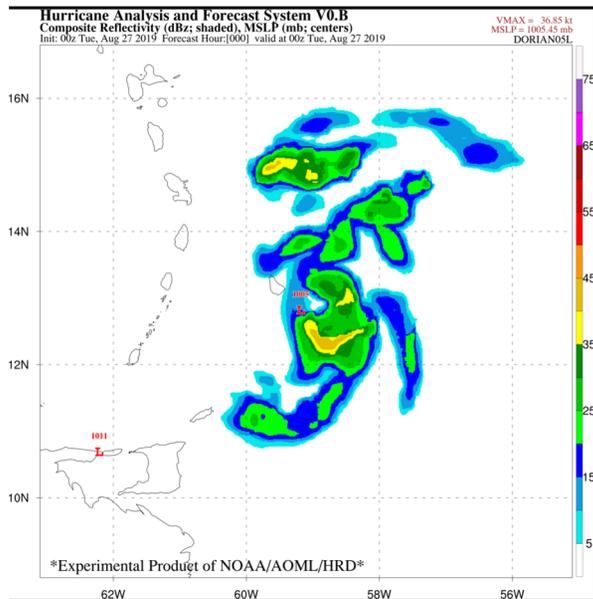


- The run that correctly got the core development was much stronger and further NE
- Chicken/egg question: was earlier development a cause or result of track difference?
- Good case for ensembles





Dorian Structure/Environment Evolution



- One of the biggest obstacles for Dorian initially was low mid-level RH
- This animation shows the precip symmetrized and expanded as environmental RH increased

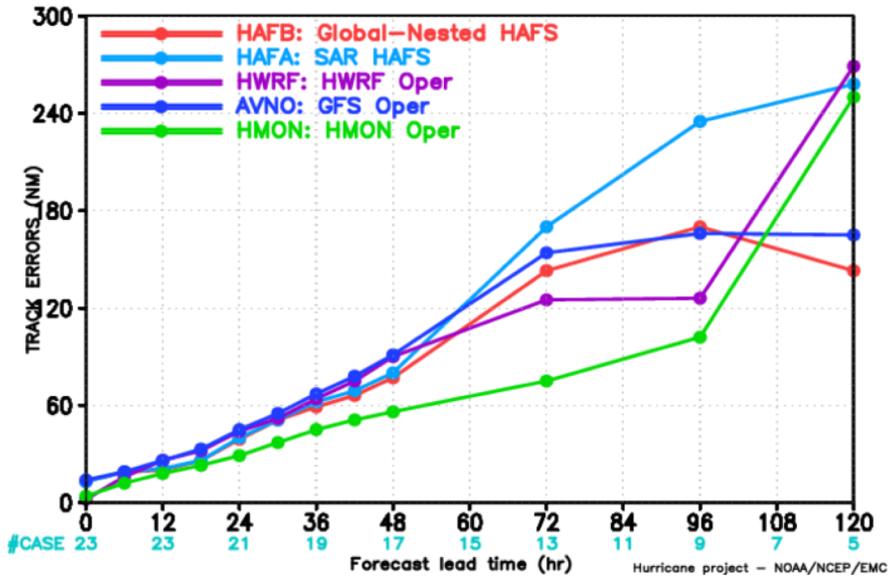




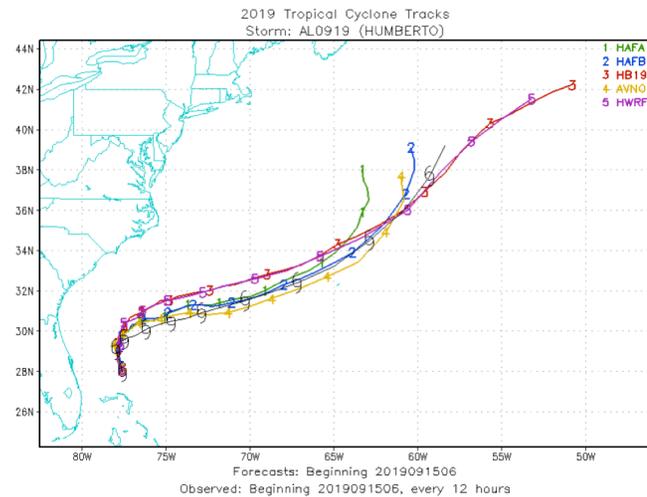
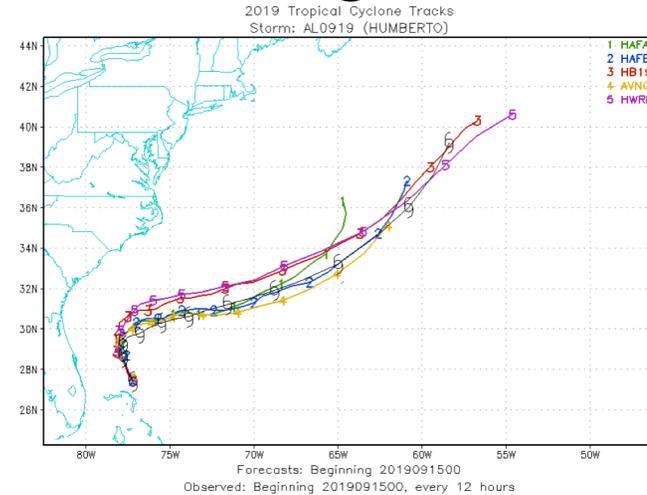
Humberto: HAFS-SAR vs. HAFS-globalnest



MODEL FORECAST – TRACK ERRORS (NM)
STATISTICS FOR A SINGLE STORM – aI092019_HUMBERTO



- Humberto was a case with some differences between two HAFS versions
- Mostly from 1-2 cycles where HAFS-SAR turned back NW too quickly



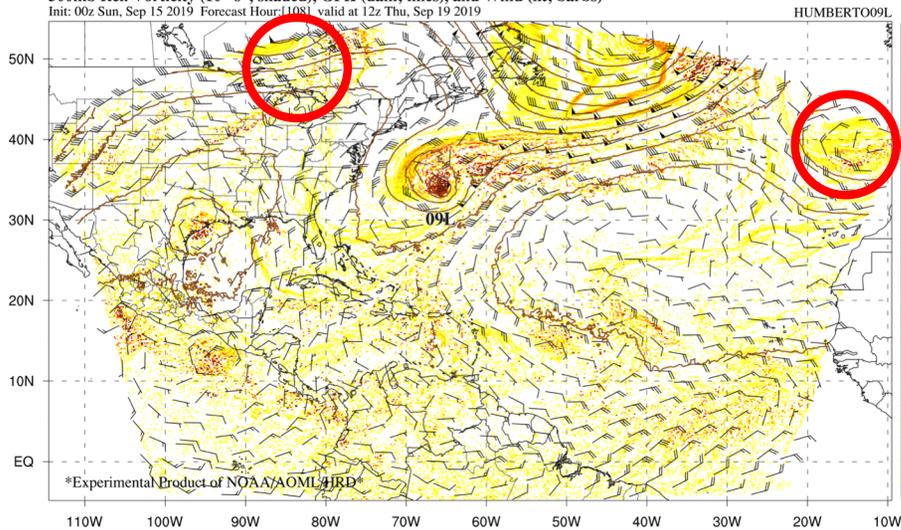


Humberto: HAFS-SAR vs. HAFS-globalnest



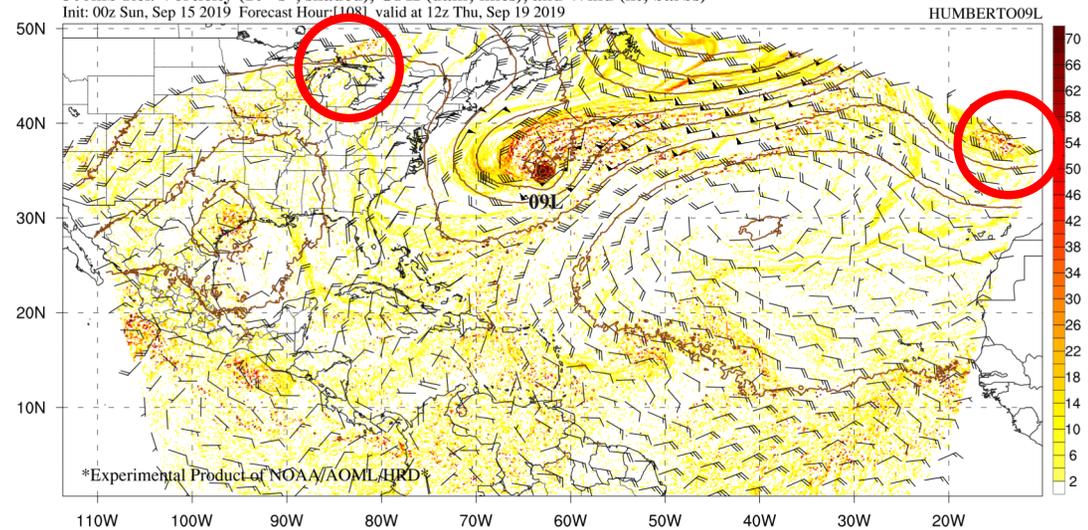
Hurricane Analysis and Forecast System V0.A

500mb Rel. Vorticity ($10^{-5} s^{-1}$, shaded), GPH (dam; lines), and Wind (kt; barbs)
Init: 00z Sun, Sep 15 2019 Forecast Hour:1081 valid at 12z Thu, Sep 19 2019



Hurricane Analysis and Forecast System V0.B

500mb Rel. Vorticity ($10^{-5} s^{-1}$, shaded), GPH (dam; lines), and Wind (kt; barbs)
Init: 00z Sun, Sep 15 2019 Forecast Hour:1081 valid at 12z Thu, Sep 19 2019



- More amplified storm track in HAFS-SAR than HAFS-globalnest
- Leads to a slightly more pronounced interaction with the trough?
- Feedback between the TC and large-scale (more testing needed)?





Summary

➤ HAFS-globalnest 2019 takeaways:

- Skillful track forecasts at all leads, especially 3-5 day (compared to other GFS-based guidance)
- Intensity evolution catches up well after spin-up (~12h)
- HAFS shows the ability to capture some aspects of small-scale TC structure
- 3-km nest demonstrates value for improving TC intensity and structure

➤ Lessons Learned For Further Improvement:

- Data assimilation (both large-scale and vortex scale) important for initial structure/vmax
- Full 3-dimensional ocean coupling will potentially help with high bias in some cases
- Less diffusive dynamics and improved PBL physics might help with the R34 bias as well as rapid intensification prediction

