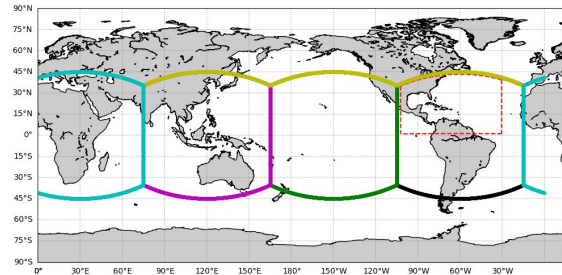


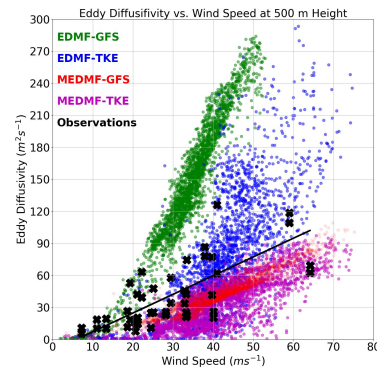
2020 Real-Time Configuration

Thanks to Collaborators: Xuejin Zhang (AOML), Morris Bender (GFDL), Tim Marchok (GFDL), Zhang Zhang (EMC), Bin Liu (EMC), Jili Dong (EMC), Chunxi Zhang (EMC), Lin Zhu (EMC), Weiguo Wang (EMC), Jongil Han (EMC)

- HREx real-time demo
- Global-nested HAFS (HAFSV0.1B)
- 3-km horizontal resolution
- L75 (2019 L64) with enhanced PBL resolution
- Slightly smaller Atlantic nest
- EDMF-TKE with modifications for hurricane PBL (MEDMF-TKE)
- Other physics options similar to the 2019 version
- Over 400 total cases in 2020

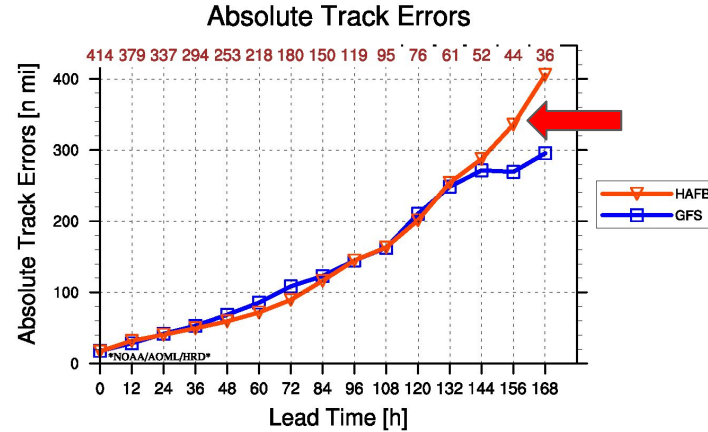
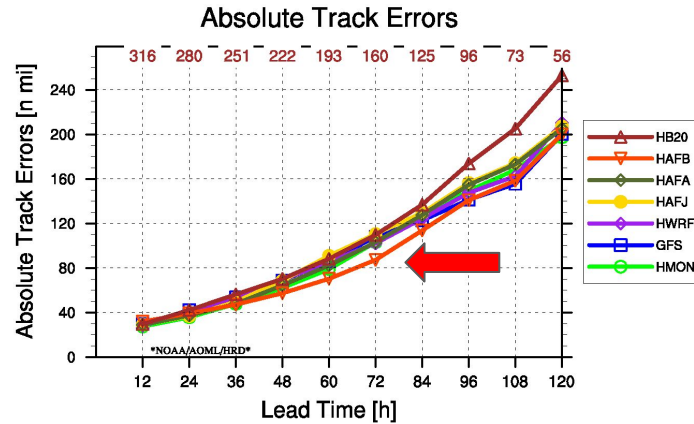


Grid Layout for 2020 HAFSV0.1B



Eddy Diffusivity from Several HAFS PBL Schemes and Observations

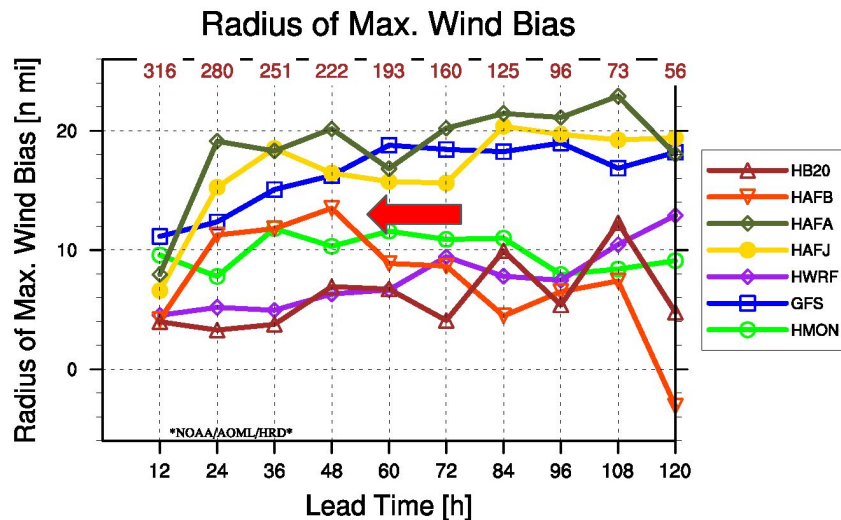
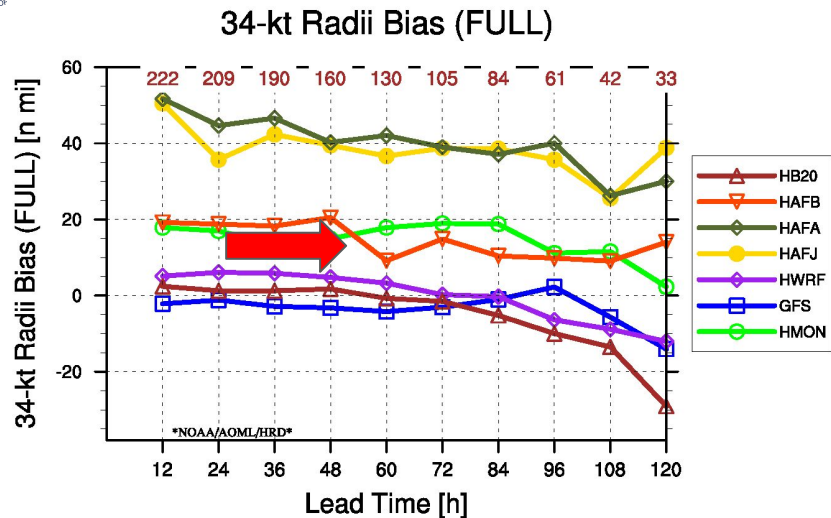
Summary Stats: Track



Left: 5-day Track Error; Right: 7-day Track Error

- HAFSV0.1B generally has lowest error out to D5
- Similar to GFS D5/6
- Slight degradation at D7 (small sample)

Summary Stats: Wind Radii

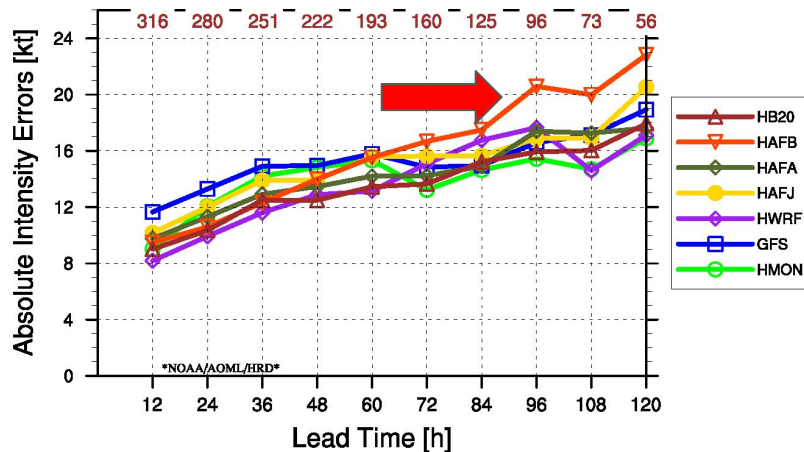


Left: Radius of 34-knot wind (R_{34}) bias, Right: Radius of Maximum Wind (RMW) bias

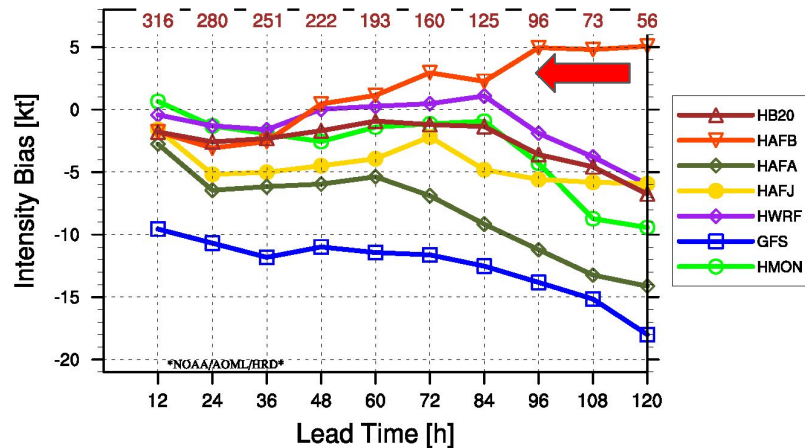
- R_{34} bias greatly reduced in HAFS-B
- Likely tied to PBL scheme (both HAFS-A, HAFS-B had more levels)
- HAFS-B RMW bias slightly higher than HWRF/HMON early (resolution & initialization)

Summary Stats: Intensity

Absolute Intensity Errors



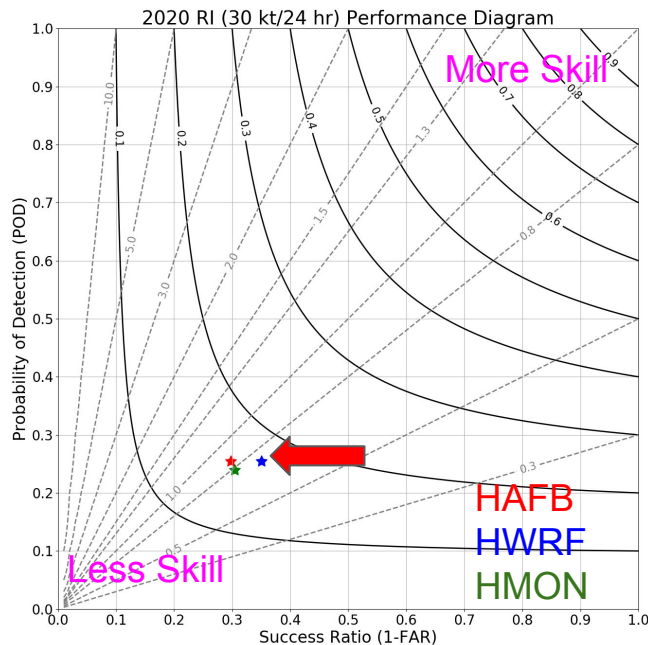
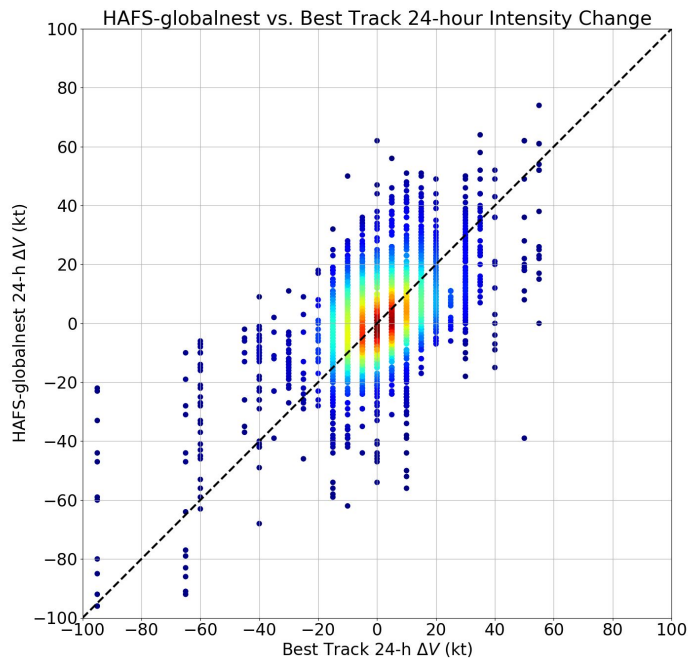
Intensity Bias



Left: Mean intensity bias (kt), Right: Mean absolute intensity error (kt)

- HAFSV0.1B had a high bias at longer leads
- Some of this may be due to the lack of ocean coupling
- PBL physics may need to be slightly adjusted

Summary Stats: Rapid Intensification

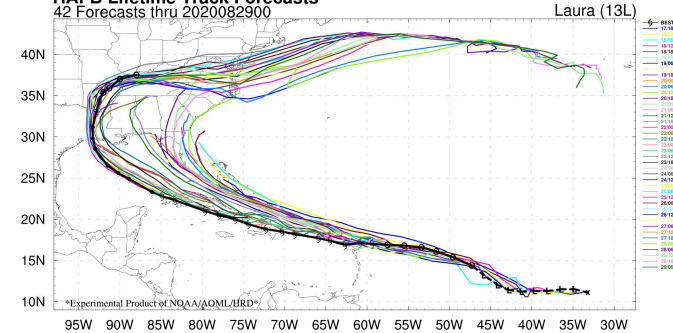


Left: Modeled 24-hr dV vs. Observed, Right: Skill Score Diagram for Rapid Intensification

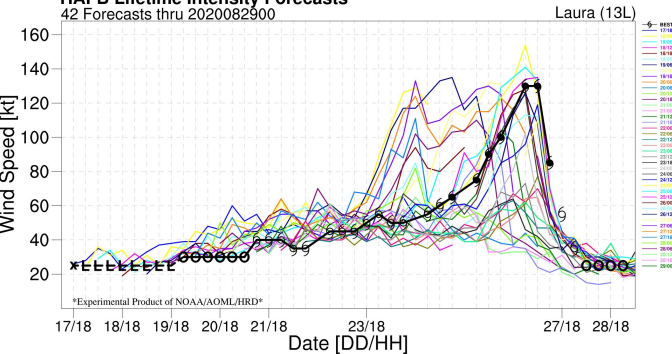
- 24-hour intensity change vs. observed is fairly well-calibrated
- Overall RI skill is similar to HWRF/HMON
- This should improve with vortex DA

Hurricane Laura

HAFB Lifetime Track Forecasts
42 Forecasts thru 2020082900

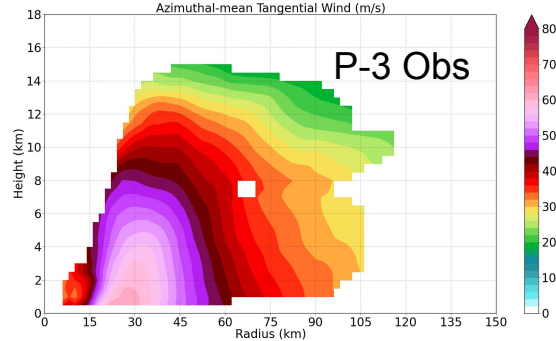
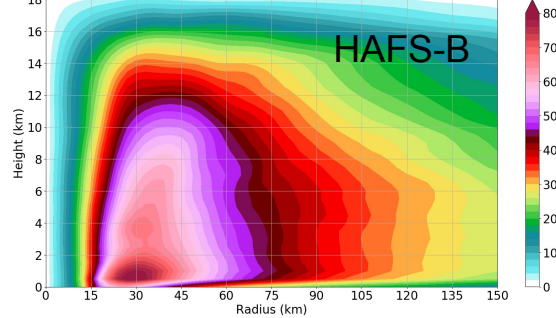


HAFB Lifetime Intensity Forecasts
42 Forecasts thru 2020082900



Top: All Laura Tracks, Bottom: All Laura Intensity Forecasts

HAFSV0.1B_2020_RT
Azimuthal Mean Tangential Wind ($m s^{-1}$, Shading)
Init: 2020082500 Forecast Hour:[048]



Top: Model Vt (r-z mean)
Bottom: P-3 observed Vt (r-z mean)

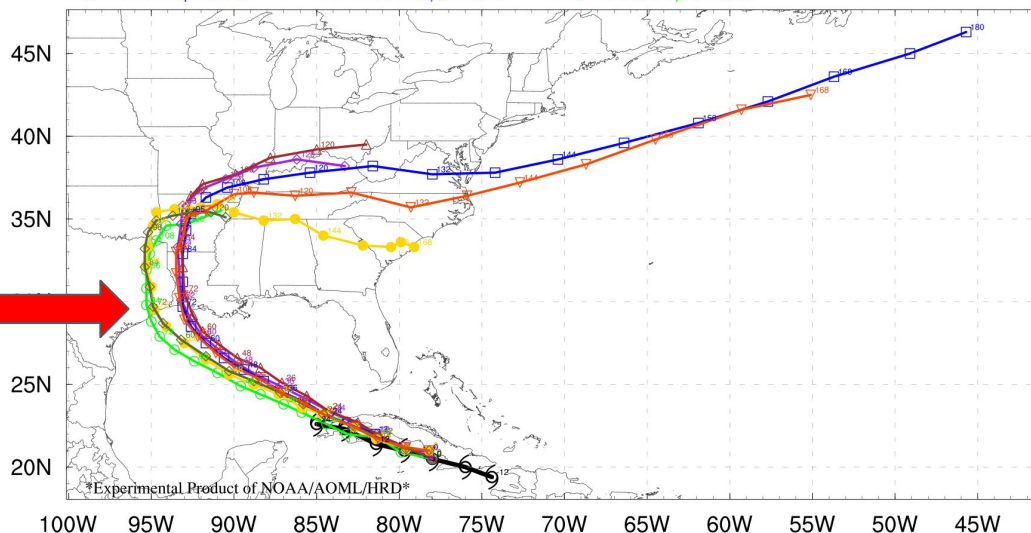
- Tracks right of observed initially
- High bias from these runs due to missing Hispaniola
- Runs in the Gulf of Mexico got TC structure better

Texas or Louisiana?

Late Track Guidance

Storm: Laura (13L) valid 2020082406

—●— BEST: Best Track
 —▽— HAFB: HAFS V0.1.B
 —◇— AVNO: Oper. GFS
 —◇— HAFJ: HAFS ESQ V0.1J
 —◇— HWRf: Oper. HWRf
 —◇— HMON: Oper. HMON
 —△— HB20: 2020 HWRf-Basin



HAFS-B/GFS/HWRf
near Lake Charles

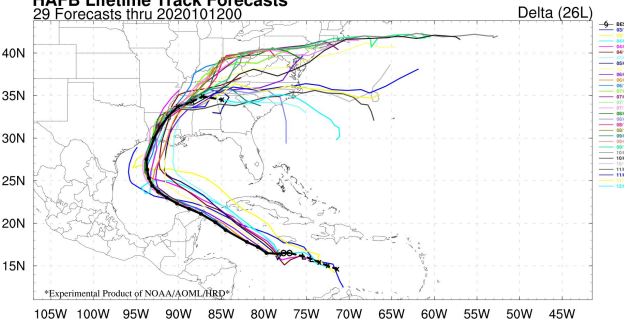
HAFS-A/J and
HMON near Houston

All Tracks from the 2020082406 Cycle for Hurricane Laura

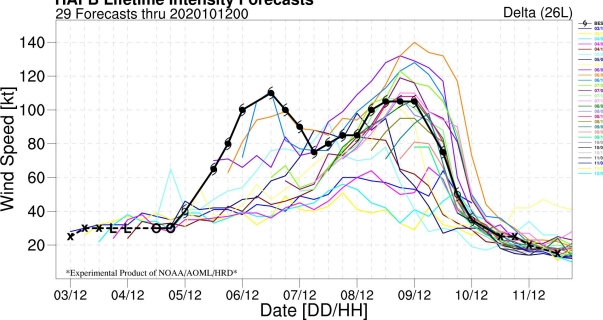
- A few cycles where HAFS-B, HWRf were showing SW Louisiana, HAFS-A, HAFS-J Texas
- Large-scale fields similar. Possible western boundary/2-way feedback differences

Hurricane Delta

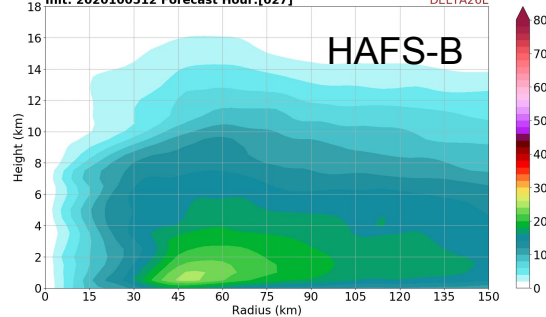
HAFB Lifetime Track Forecasts
29 Forecasts thru 2020101200



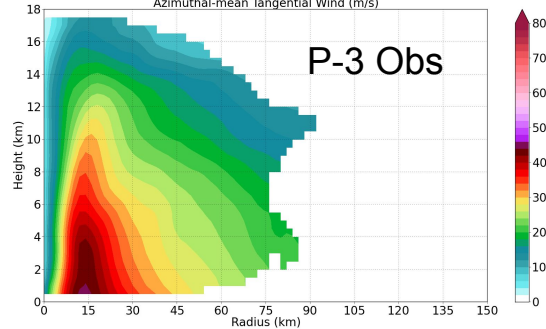
HAFB Lifetime Intensity Forecasts
29 Forecasts thru 2020101200



HAFSV0.1B_2020_RT
Azimuthal Mean Tangential Wind ($m s^{-1}$, Shading)
Init: 2020100512 Forecast Hour:[027]



201006H1 (DELTA)
111838 to 165633 UTC
Azimuthal-mean Tangential Wind (m/s)



- Slight right bias early
- Landfall location generally well-predicted
- Caribbean RI/RW missed
- TC structure too broad
- Secondary intensification in the Gulf well predicted

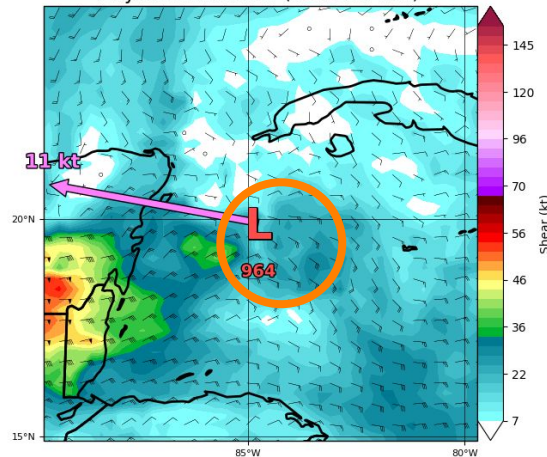
Top: Model Vt (r-z mean)
Bottom: P-3 observed Vt (r-z mean)

Hurricane Delta: Asymmetric Shear

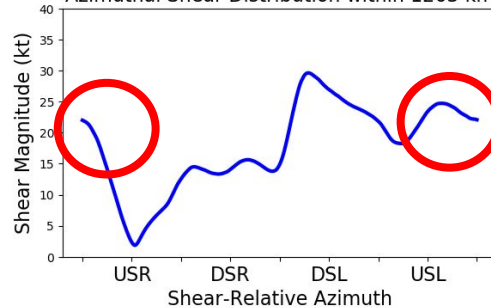
- TC located farther south within shear band in reality
- Shear band stronger than forecast (orange circles), especially in upshear quadrants (red circles)
- This may have resulted in greater vortex tilt and/or ventilation that caused a weaker TC

18-hour Forecast

Asymmetric Shear (850-200 hPa)

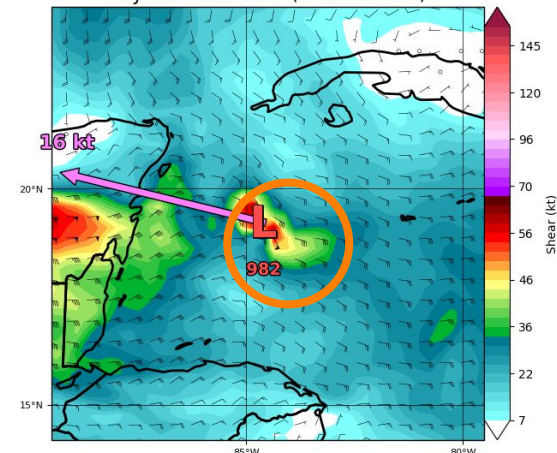


Azimuthal Shear Distribution within 1263 km

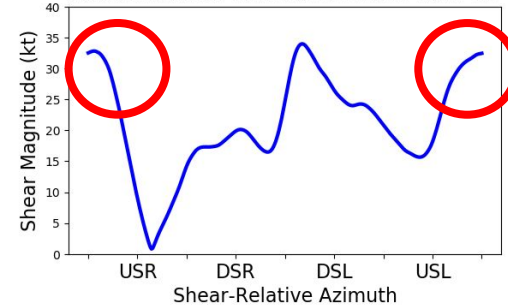


Analysis

Asymmetric Shear (850-200 hPa)



Azimuthal Shear Distribution within 1281 km



Left: Asymmetric Shear from 18h forecast; Right: Asymmetric Shear from Analysis

2020 Summary

- Large set of cases from a very busy season
- Track skill of HAFSV0.1B was very good compared to other models
- Some issues with long-range intensity (high bias)
- RI skill was reasonably well-calibrated
- Hurricane Laura had a right bias; Gulf RI well-predicted
- Initial RI/RW of Hurricane Delta missed (asymmetric shear?)
- All 2020 graphics at: <https://storm.aoml.noaa.gov/basin/?projectName=BASIN>

Planned Upgrades

- Multiple static nests (prototype already working)
- Forecasts in other basins
- Moving nest addition
- Improvements to resolution (horizontal and vertical)
- Ocean coupling is needed to help with high bias
- Continuing model physics development and evaluation
- Use of observations to evaluate upgrades

Questions?

-Hazelton, A. T., Alaka, G., S. Gopalakrishnan, and L. Cowan, 2020: Analysis of the Early Intensification of Hurricane Dorian Using an Ensemble of the Hurricane Analysis and Forecast System (HAFS), *Atmosphere*, in review.

-Hazelton, A. T., and coauthors, 2020: Atlantic Hurricane Forecasts From the Global-Nested Hurricane Analysis and Forecast System (HAFS): Composite statistics and key events, *Wea. Forecasting*, in revision.

-Gopalakrishnan, S., **Hazelton, A. T.,** and J. A. Zhang, 2020: A generalized framework for hurricane boundary layer parameterization scheme based on observations, *Earth and Space Science.*, in revision.

-Hazelton, A. T., Zhang, X., Ramstrom, W., Gopalakrishnan, S., Marks, F. D., and J. A. Zhang, 2020: High-resolution ensemble HFV3 forecasts of Hurricane Michael (2018): rapid intensification in shear, *Mon. Wea. Rev.*, **148**, 2009-2032.

Texas or Louisiana?

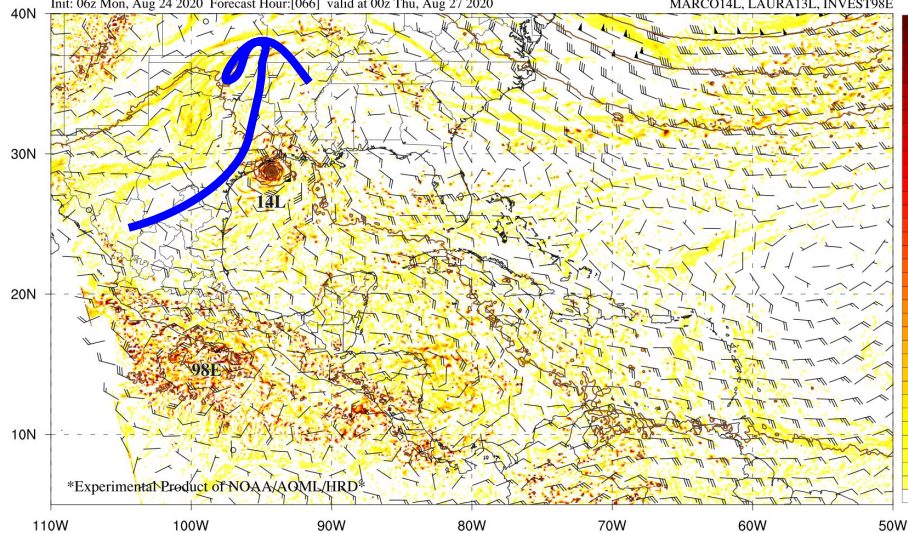
HAFSV0.1A

Hurricane Analysis and Forecast System V0.1A

500mb Rel. Vorticity (10^{-5} s^{-1} , shaded), GPH (dam; lines), and Wind (kt; barbs)

Init: 06z Mon, Aug 24 2020 Forecast Hour: [066] valid at 00z Thu, Aug 27 2020

MARCO14L, LAURA13L, INVEST98E



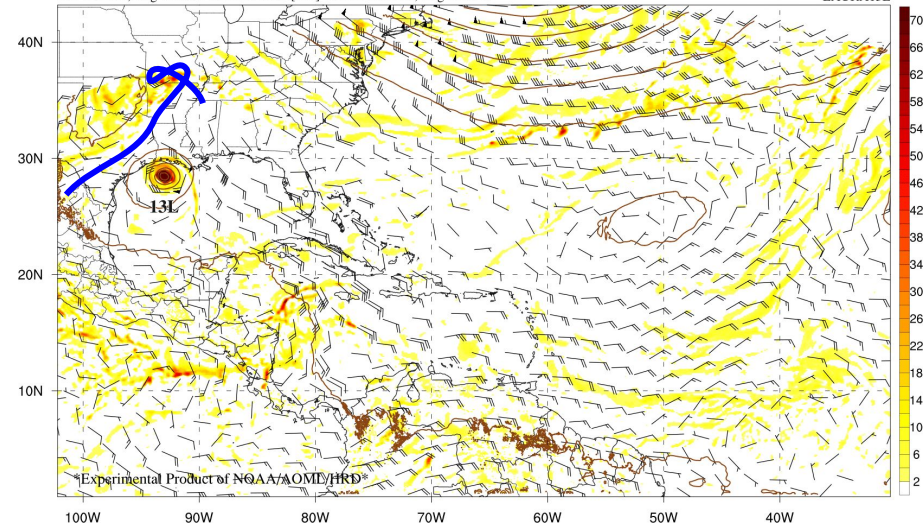
Analysis

2020 HAFS-globalnest (HAFSV0.1B)

500mb Rel. Vorticity (10^{-5} s^{-1} , shaded), GPH (dam; lines), and Wind (kt; barbs)

Init: 00z Thu, Aug 27 2020 Forecast Hour: [000] valid at 00z Thu, Aug 27 2020

LAURA13L



➤ HAFS-A shortwave was too negatively tilted

Texas or Louisiana?

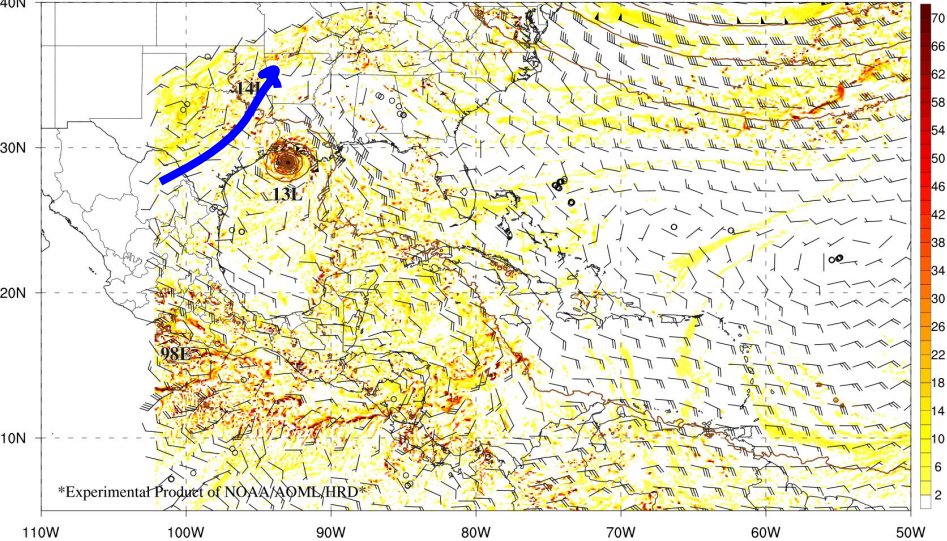
HAFSV0.1B

2020 HAFS-globalnest (HAFSV0.1B)

500mb Rel. Vorticity (10^{-5} s^{-1} , shaded), GPH (dam; lines), and Wind (kt; barbs)

Init: 06z Mon, Aug 24 2020 Forecast Hour:[066] valid at 00z Thu, Aug 27 2020

LAURA13L, INVEST98E, MARCO14L



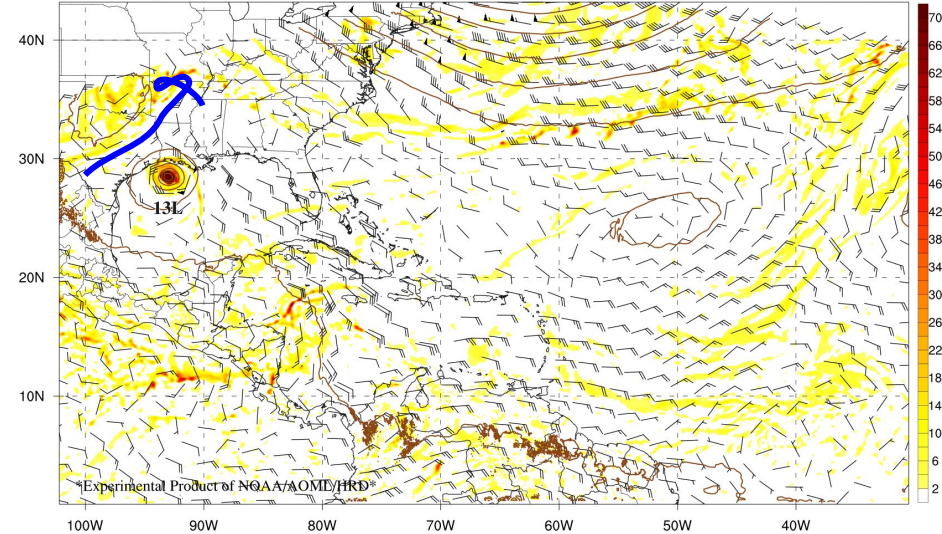
Analysis

2020 HAFS-globalnest (HAFSV0.1B)

500mb Rel. Vorticity (10^{-5} s^{-1} , shaded), GPH (dam; lines), and Wind (kt; barbs)

Init: 00z Thu, Aug 27 2020 Forecast Hour:[000] valid at 00z Thu, Aug 27 2020

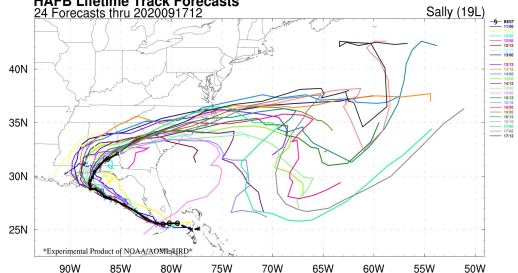
LAURA13L



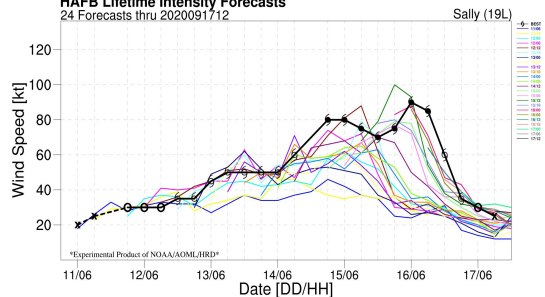
➤ HAFS-B had a more realistic positively-tilted shortwave

Hurricane Sally

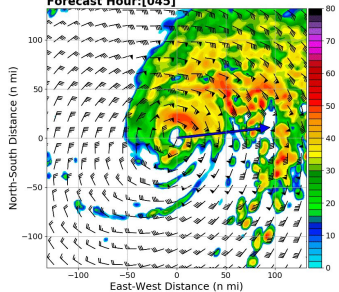
HAFB Lifetime Track Forecasts
24 Forecasts thru 2020091712



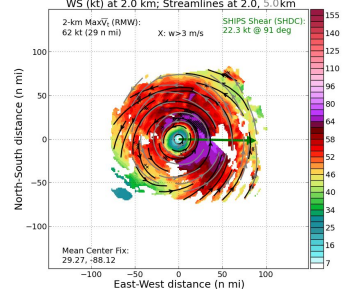
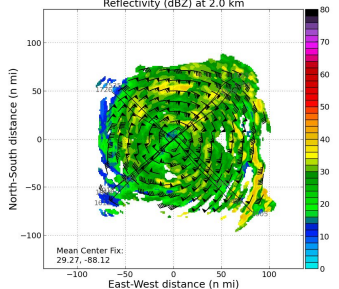
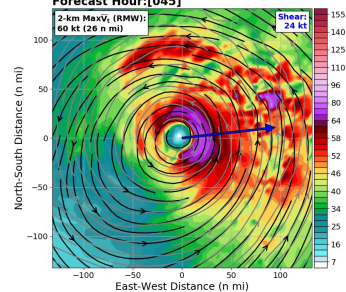
HAFB Lifetime Intensity Forecasts
24 Forecasts thru 2020091712



HAFSV0.1B_2020_RT
2-km Reflectivity (dbz, Shading)
2-km Wind Barbs (kt)
Init: 2020091400
Forecast Hour:[045]



HAFSV0.1B_2020_RT
2-km Wind (kt, Shading)
2-km (Black) and 5-km (Gray) Streamlines
Init: 2020091400
Forecast Hour:[045]



- Moderate shear and asymmetry
- well-predicted
- Slight left bias in some cases, but track generally good
- Intensity “double peak” mostly missed