The Regional Ocean-Coupled HAFS with a Storm-Following Moving Nest and Inner-Core Vortex Initialization and Data Assimilation

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In collaboration with the UFS Hurricane Application Team

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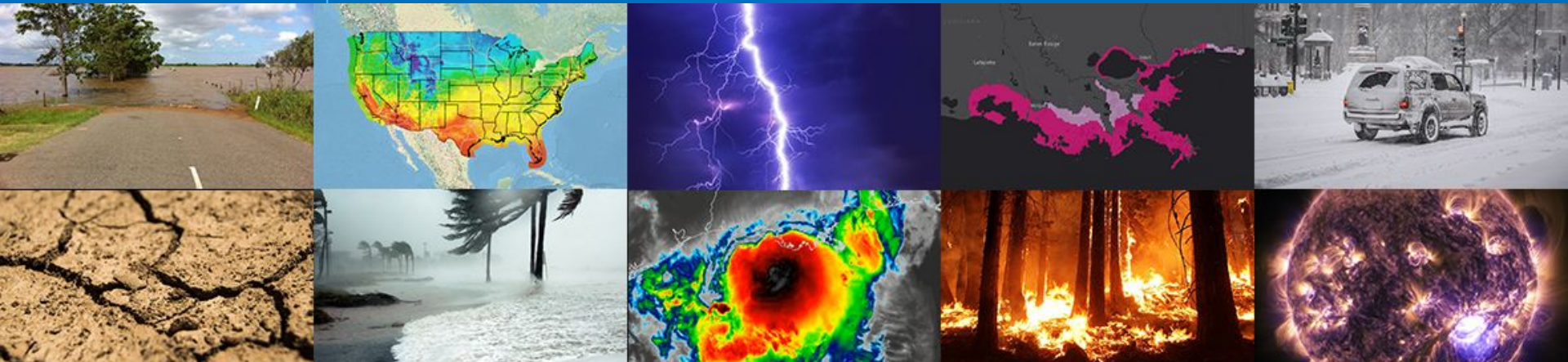
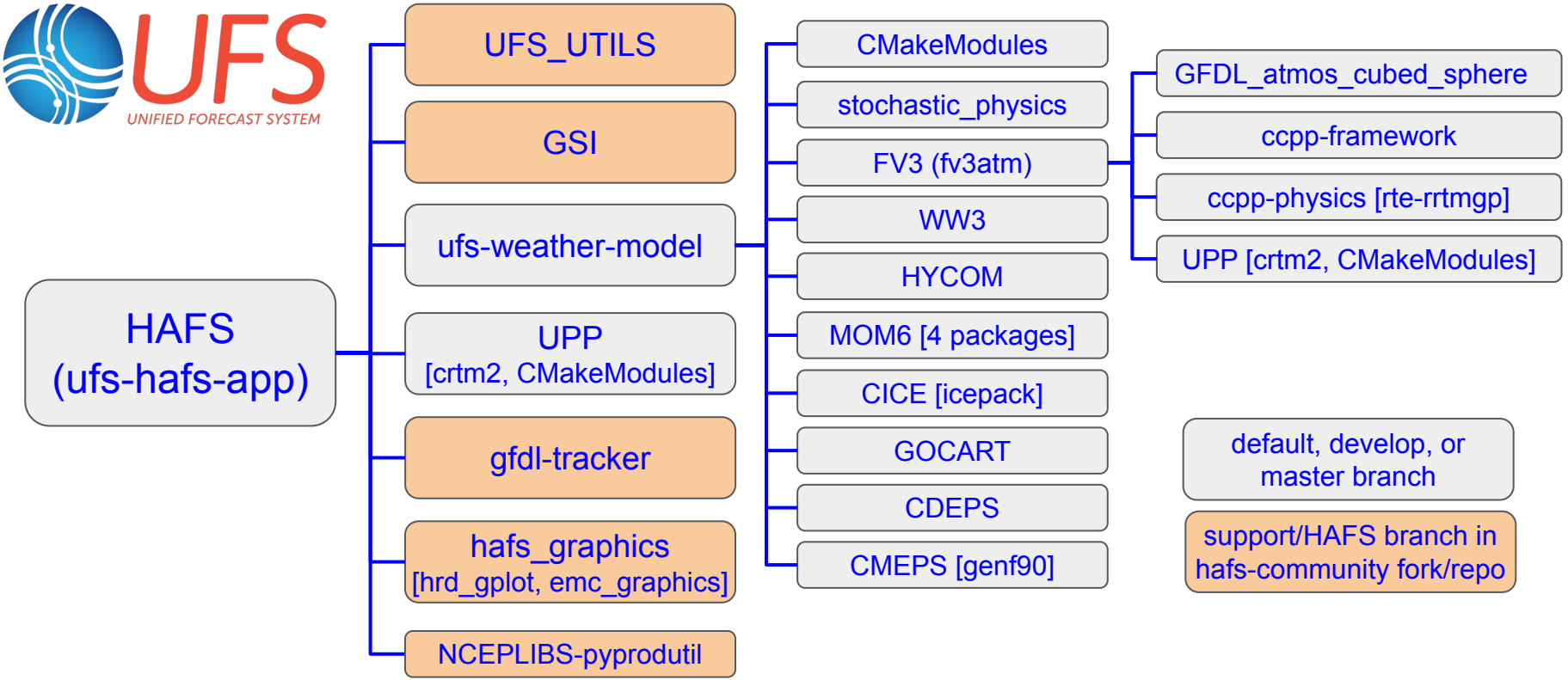
Unifying Innovations in Forecasting Capabilities Workshop, July 18-22, 2022



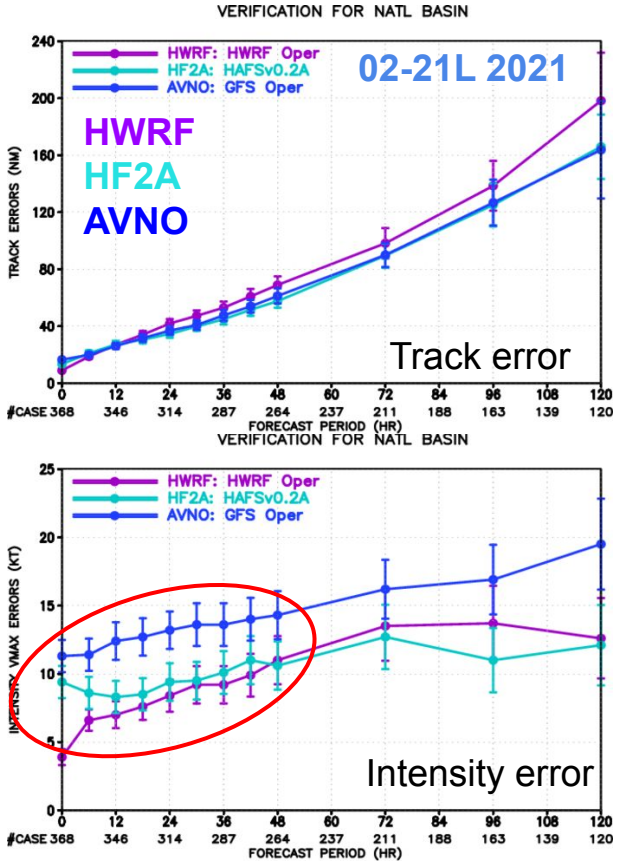
The UFS-HAFS Hurricane Application Subcomponents

https://github.com/hafs-community/HAFS



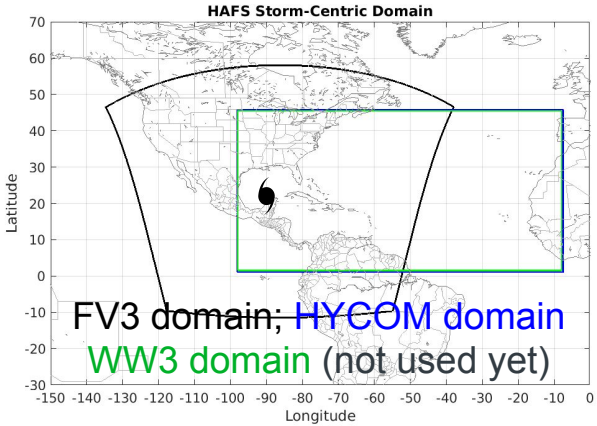
Objectives

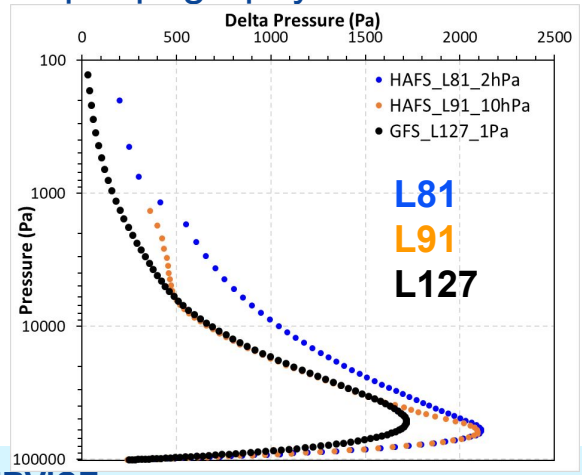
- HAFS is a community based and developed coupled hurricane modeling system, promoting cutting-edge research on TC dynamics and physics, advanced data assimilation techniques, and earth-system coupling and interaction processes.
- Developing and advancing HAFS is one of the key strategies of the HFIP (Hurricane Forecast Improvement Program) to address its science and R2O challenges.
- The HAFSv0.3 series developments focus on the regional storm-centric ocean-coupled configuration with
  - High-resolution storm-following moving nesting
  - Sophisticated vortex initialization
  - Advanced inner-core data assimilation
  - Optimized physics suites for hurricane forecasting

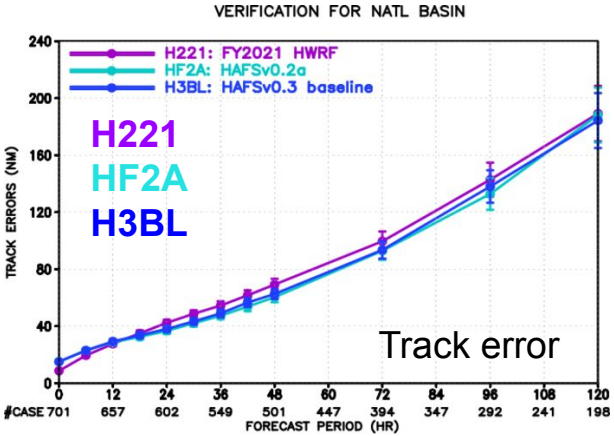


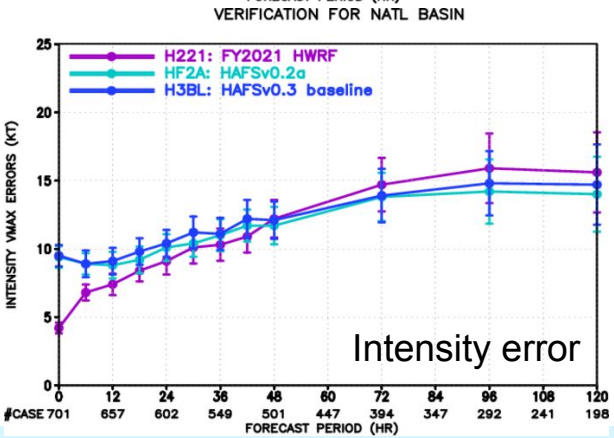
The HAFSv0.3 Baseline Configuration
(on top of the 2021 HAFSv0.2A configuration)

- Use the HAFS feature/hafsv0.3_baseline branch with its subcomponents being synced as of 03/02/2022
- Regional storm-centric 3-km resolution domain (~78x72 degree) using regular Gnomonic grid with L81 vertical levels (2-hPa top)
- Positive-definition tracer advection scheme
- Turn on topography smoothing so that the model is more stable when interacting with steep topography





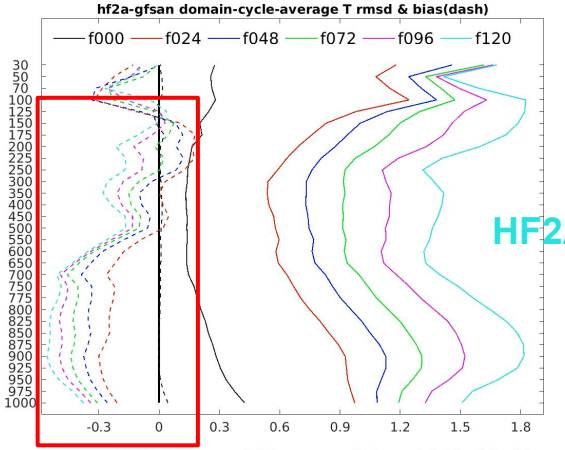




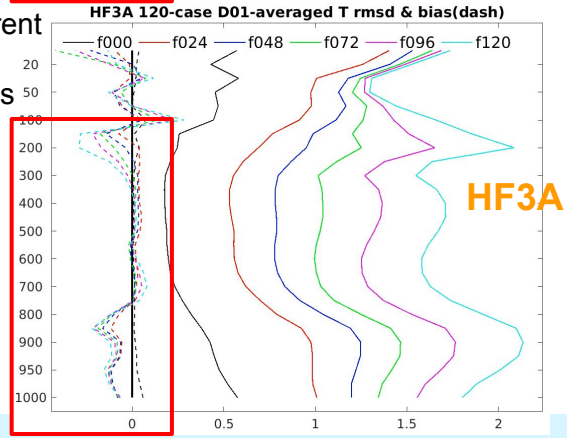
HAFSv0.3 Physics Development and Updates
With substantially improved model temperature bias

Analyses from Yonghui Weng

- Using the HAFS CCPP physics suite with
  - GFDL microphysic
  - RRTMG radiation
  - Scale-aware SAS convection
  - Noah LSM
  - GFS surface layer with HWRF exchange coefficients
  - Scale-aware TKE-EDMF PBL scheme with modified mixing length near surface
  - Turn on orographic GWD but keep convective GWD off
  - Turning off the NSST component
  - Use the latest MERRA2 aerosol (iaer=1011)
- Improved model physics leveraged from other UFS applications (e.g., MRW/S2S's Prototype-8 developments)
- Upgraded sa-SAS convection scheme to address the cold bias issue in HAFSv0.2A (with close collaboration among EMC hurricane and physic groups and HRD colleagues)

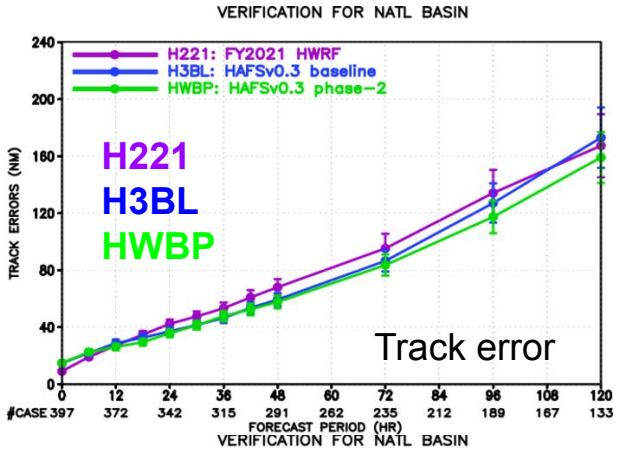


Note: different sample period/sizes

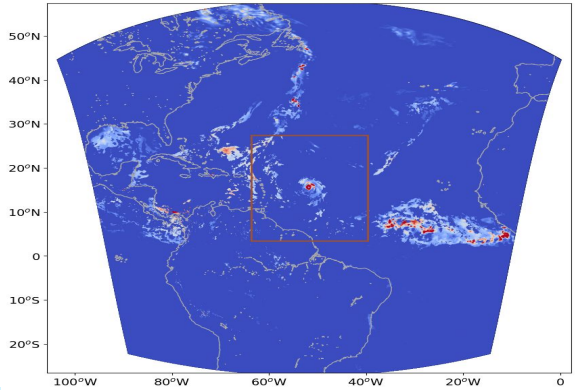


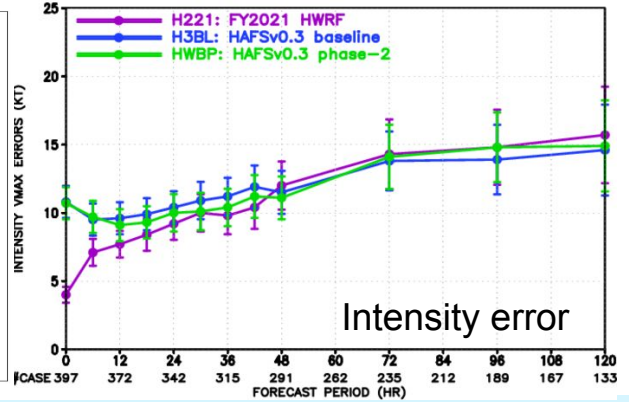
HAFSv0.3 Moving-Nesting and Ocean Coupling Capabilities

- The moving-nesting and ocean coupling capabilities were mainly developed with collaborations among AOML, EMC, GFDL, NCAR/ESMF
- The end-to-end application/workflow support for the regional moving-nesting and ocean coupling configuration is currently available in the UFS-HAFS application GitHub repository.
  - Regional 6-km resolution parent with a 2-km storm-following moving nest based on the regular Gnomonic grid
  - Ocean coupling with the FV3ATM parent domain while SST is downscaled from the parent domain into the moving nest



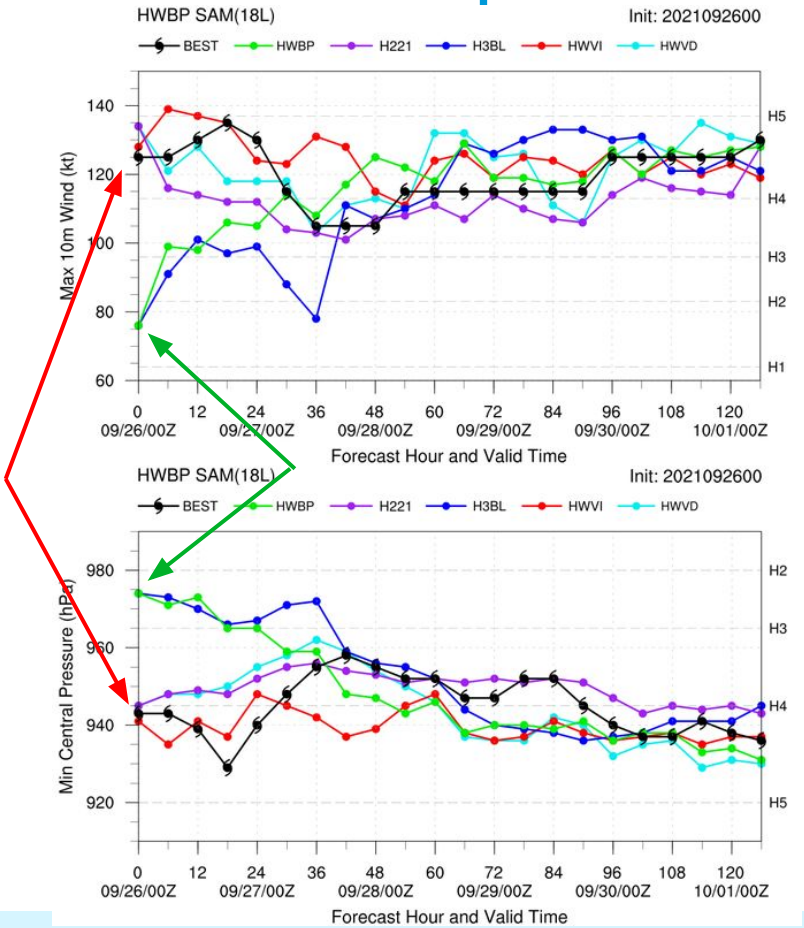
Simulated precip rate for Sam18L 2021092112Z from Biju Thomas





HAFSv0.3 Vortex Initialization and Data Assimilation Capabilities

- Sophisticated Vortex Initialization technique (inherited/modernized from operational HWRF and HMON) including Vortex Relocation and Vortex Modification
- Newly developed HAFS DA tool for VI and DA pre and post-processing (from Yonghui Weng)
- High-resolution inner-core DA for the regional moving-nesting configuration
  - 3DEnVar for domain 2 with GDAS ensembles
  - 3-hourly FGAT
  - Cycling storm region only with large scale environment from GFS analysis
  - Assimilate all the observation types ingested by HWRF and GFS/GDAS



The HAFSv0.3A Final Configuration
(Based on the HAFSv0.3 baseline configuration)

- Use the HAFS feature/hafsv0.3_final branch with its subcomponents being synced as of 05/26/2022
- Regional storm-centric 6-km parent with a 2-km storm-following moving nest
- L81 vertical levels with a 2-hPa model top
- Model physics time step of 90s and radiation time step of 900s
- Positive-definition tracer advection scheme
- Turn on topography smoothing
- Use the HAFS CCPP physics suite with GFDL MP
- Inner-core VI and DA for model initialization and warm-cycling
- CMEPS-based ocean coupling with an extended HYCOM ocean domain
- Upgraded GFDL vortex tracker from Tim Marchok (GFDL) on 06/02/2022
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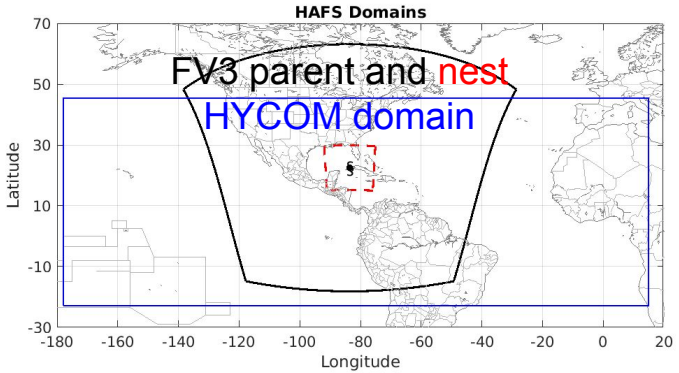
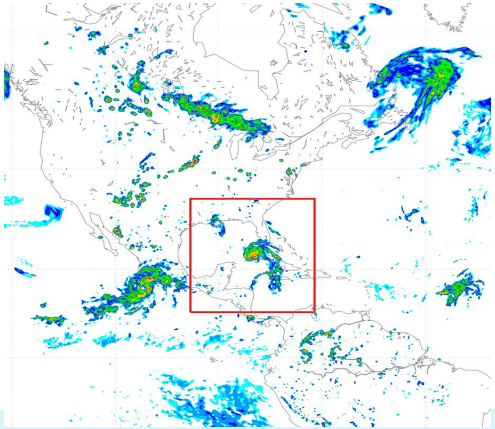
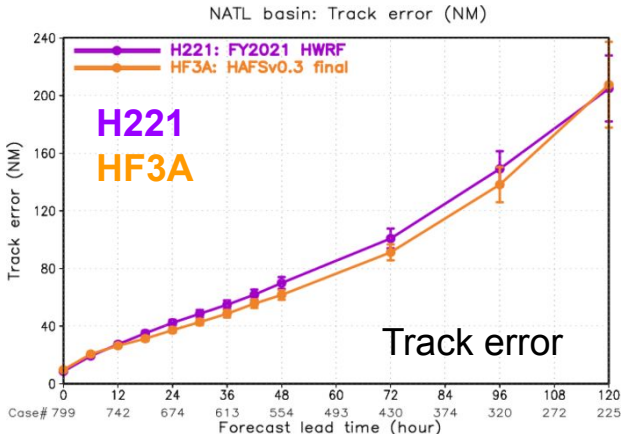
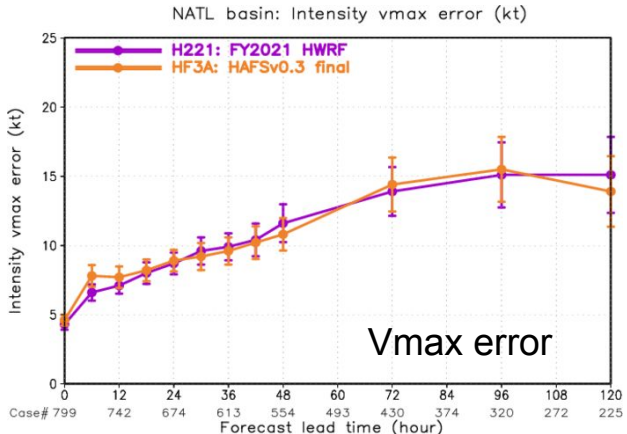


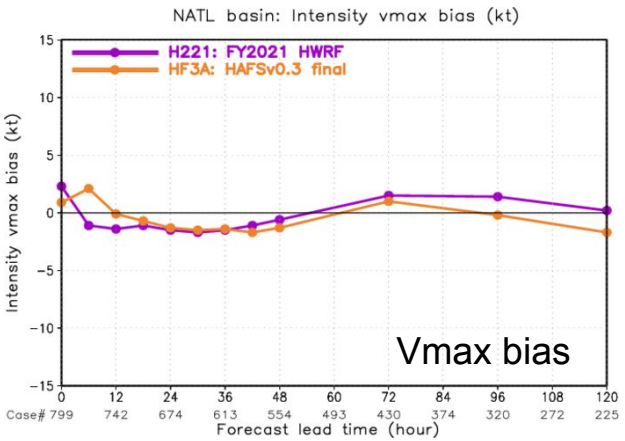
Composite reflectivity for Ida 2021082800Z from Yonghui Weng

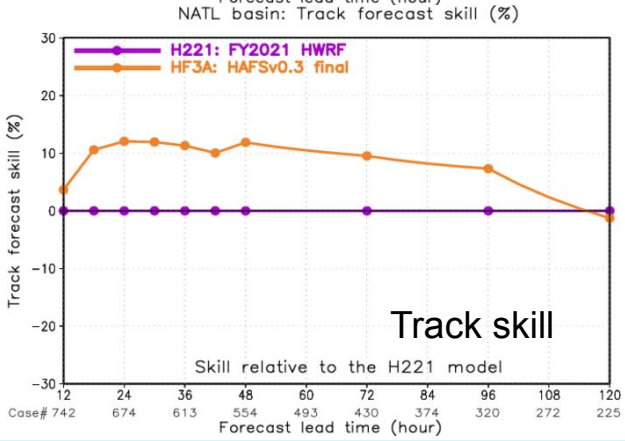


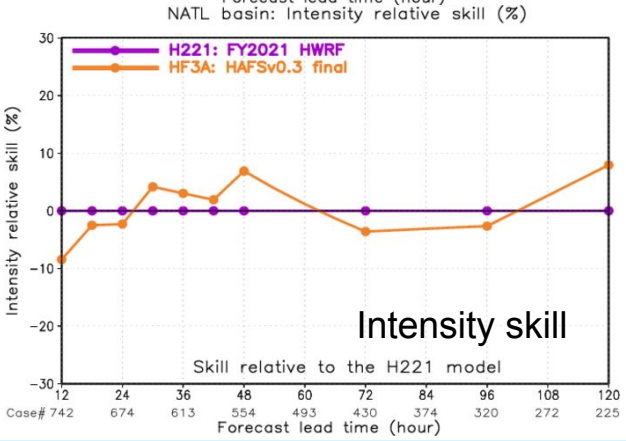
HAFSv0.3A Configuration Performance
For 2020/2021 NATL Storms

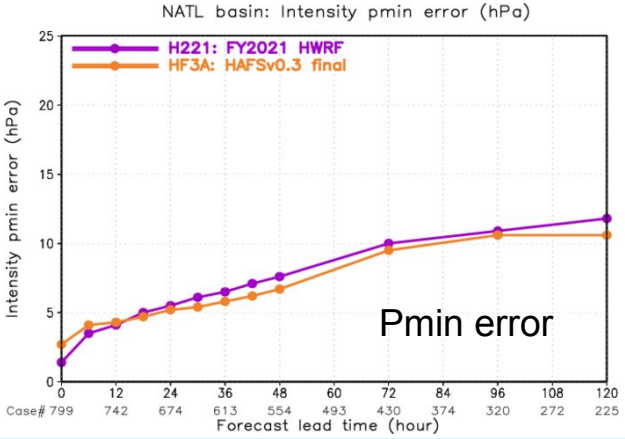






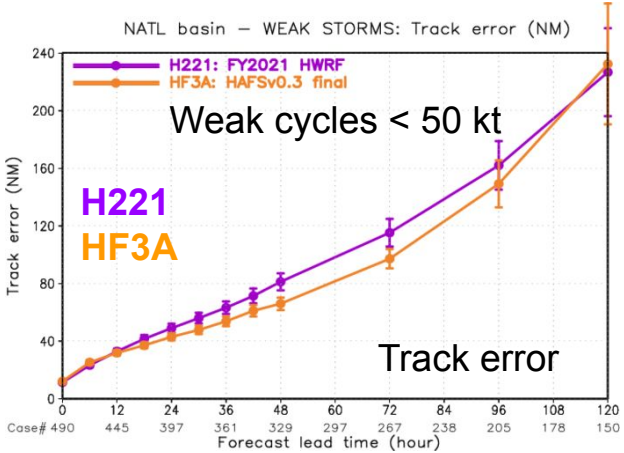


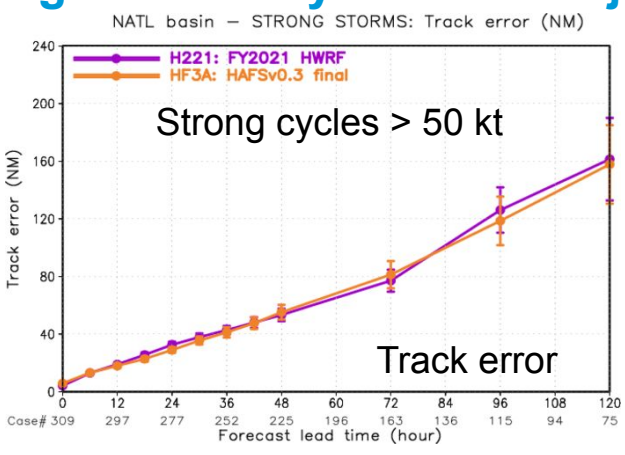


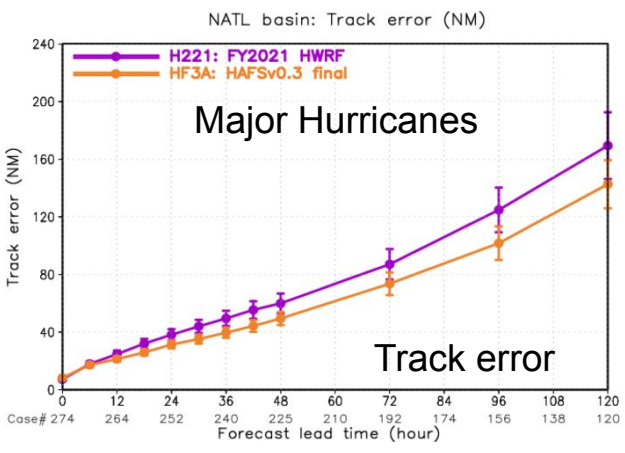


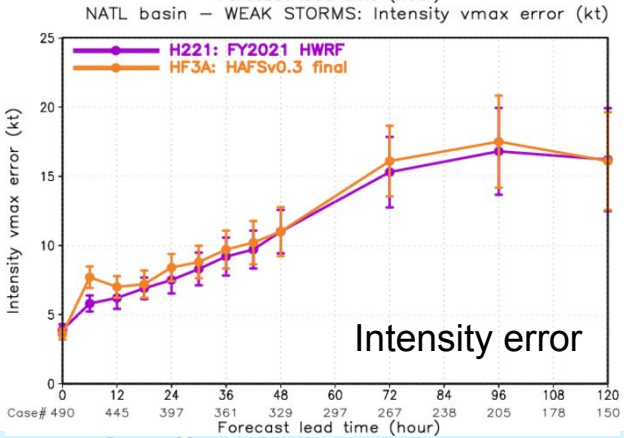
HAFSv0.3A Configuration Performance

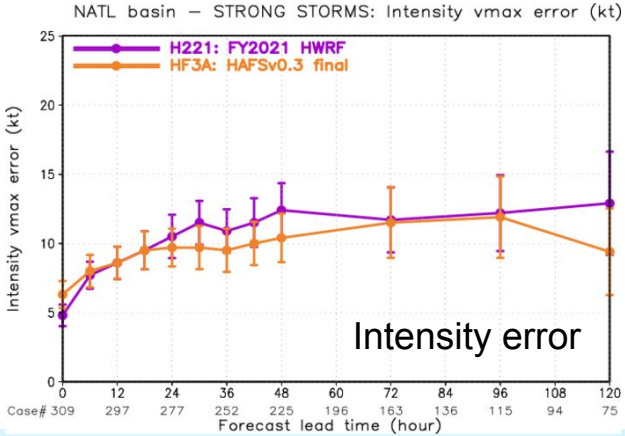
For weak/strong forecast cycles and major hurricanes

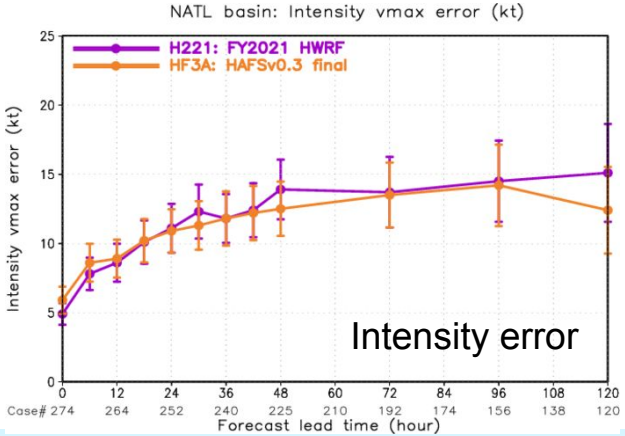






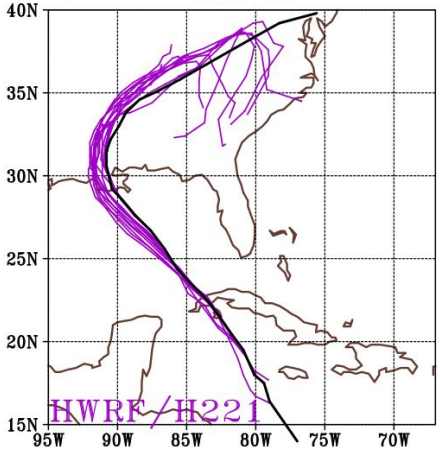


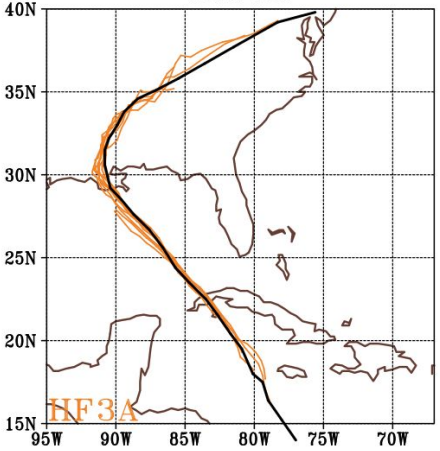


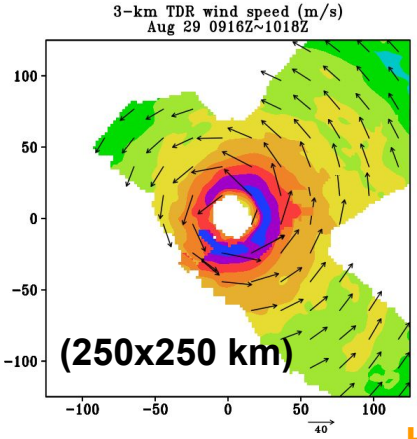


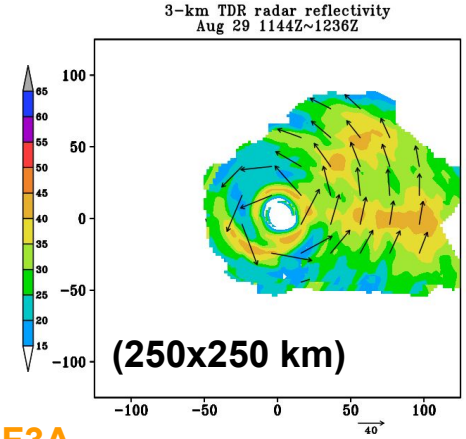
HAFSv0.3A Forecast for Hurricane Ida (09L2021)

Figures and analyses from JungHoon Shin

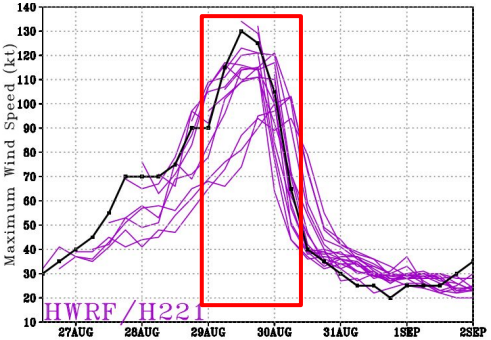


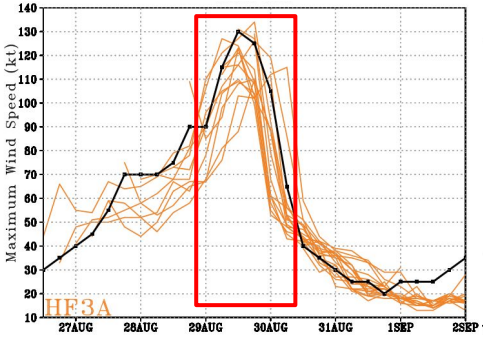


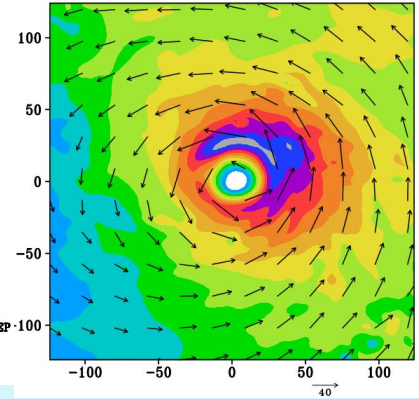


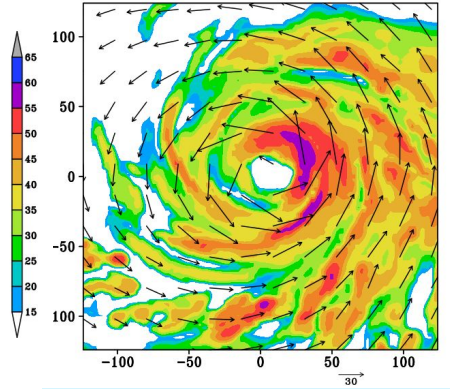


HF3A







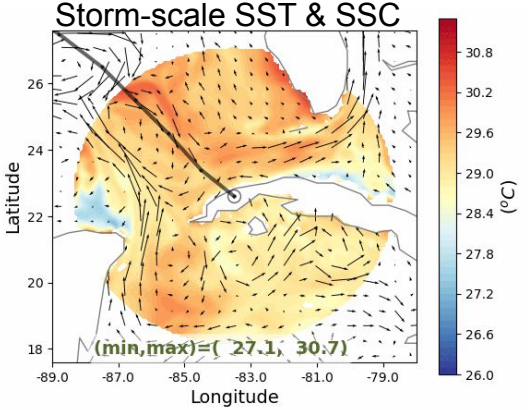


HAFSv0.3 Forecast for Hurricane Ida (09L)

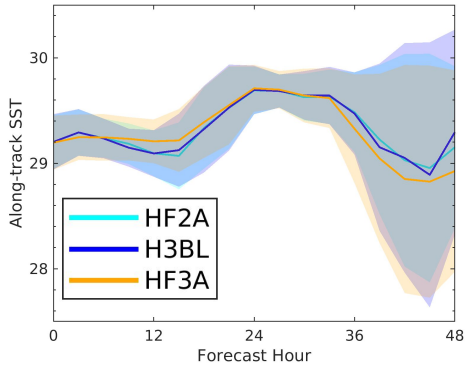
Ocean coupling and response from the 20210828Z forecast cycle

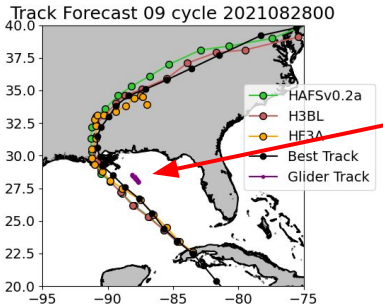
Animation from John Steffen

Storm-scale SST & SSC



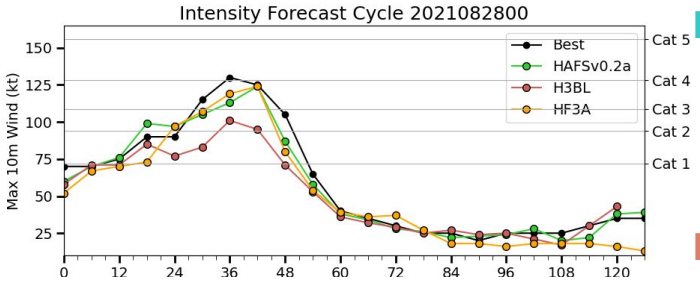
SST variability within 100km radius





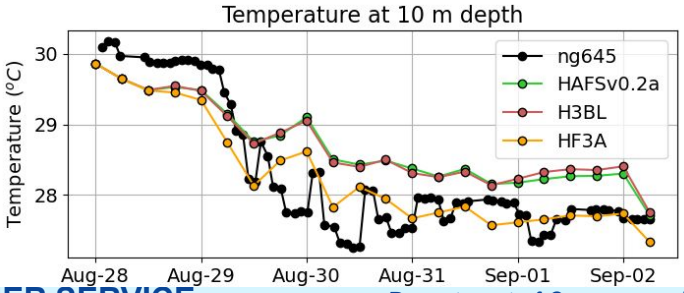
OBS

Analyses from
Maria Aristizabal

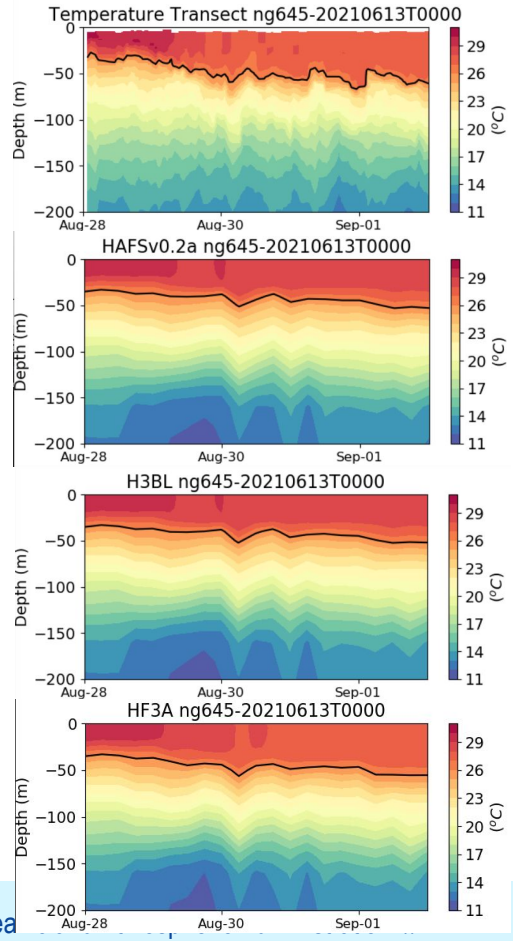


HF2A

H3BL



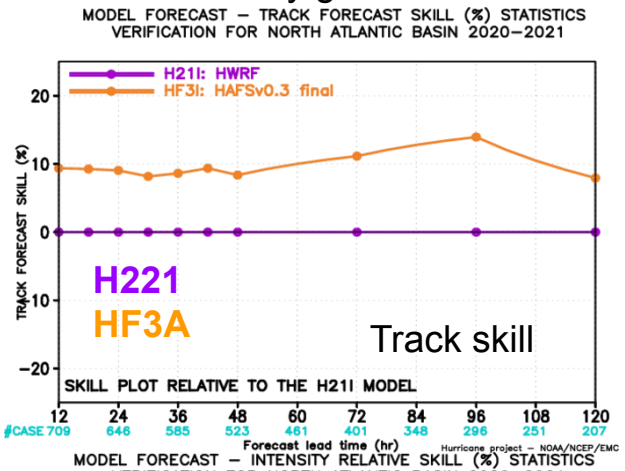
HF3A

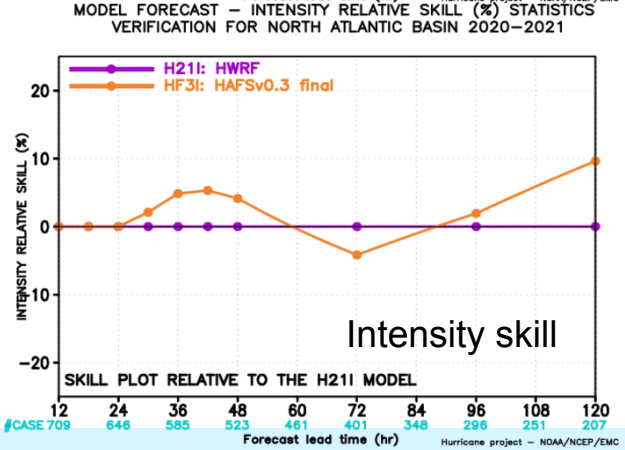


Summary and Future Work

- HAFSv0.3A regional storm-centric ocean-coupled moving-nesting configuration:
  - High-resolution moving-nesting configuration
  - Ocean coupling with HYCOM
  - Sophisticated vortex initialization
  - Advanced inner-core data assimilation
- Conduct the HAFSv0.3A real-time parallel experiment during the 2022 hurricane season as part of the HFIP real-time demo project
- Optimize model dynamics, physics, coupling, and data assimilation to further improve storm track, intensity, RI, size and structure forecasting
- The HAFSv1 operational implementation targeting the 2023 hurricane season to replace the NCEP operational regional hurricane forecast systems (HWRF/HMON)

Early guidance





Thank you!

HAFSv0.3A Wind-Pressure Relationship

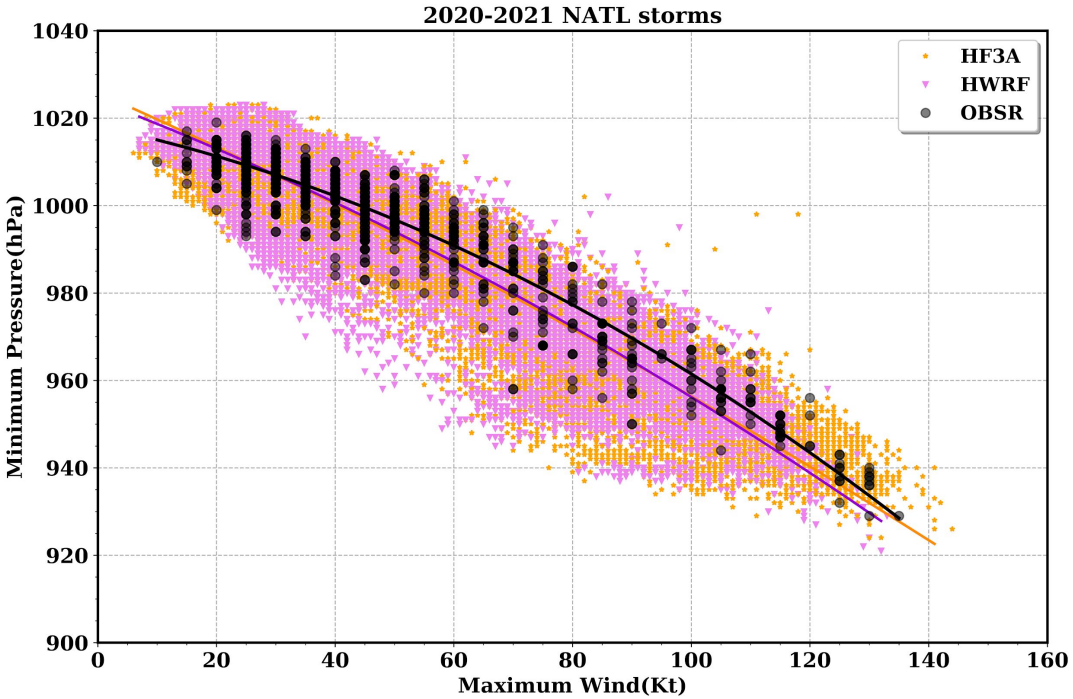
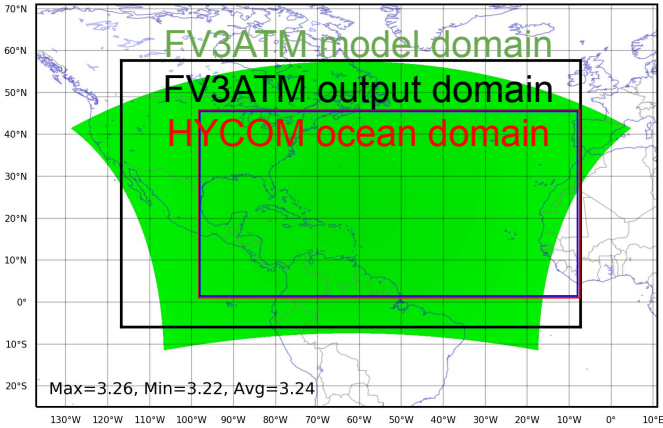
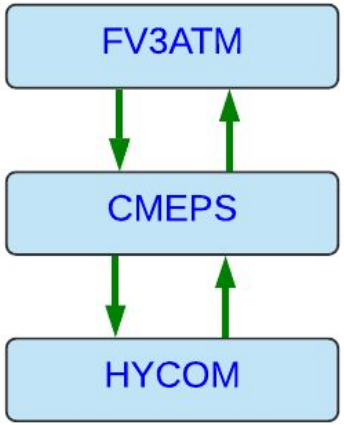


Figure from Biju Thomas

The HAFSv0.2A Configuration

- The hafs.v0.2.0 version (finalized 05/12/2021) was used
  - Available from https://github.com/hafs-community/HAFS
- The FV3ATM component
  - Regional ESG C3089 grid (~3-km) with L91 (10 hPa top) levels
  - GFSv16 netcdf files for IC; 3-hrly GFSv16 grib2 files for LBC
  - dt_atmos=90s; k_split=3; n_split=5; radiation time step: 1800s; LBC blending with nrows_blend=10
  - The HAFS_v0_gfdlmp_tedmf_nonsst physics suite was used
    - GFDL microphysic; RRTMG radiation; Scale-aware SAS convection; Noah LSM; GFS surface layer with HWRF exchange coefficients; Modified GFSv16 scale-aware TKE-EDMF PBL scheme (with modified surface layer mixing length scale, sfc_rlm=1); Turn on orographic GWD but keep convective GWD off; Turning off the NSST component
  - Utilize inline post to generate grib2 products within the forecast model
  - Fix the boundary-crawler issue and turn off two thickness parameters in the GFDL tracker (from Tim Marchok, GFDL)
- The HYCOM component
  - Updated CMEPS/NUOPC based atmosphere-ocean coupling
  - Updated 1/12-degree NATL domain (1-45.78N, 261.8-352.5E) L41
  - Ocean IC from RTOFSv2 with persistent oceanic LBC
  - Atmospheric forcing from GFSv16 grib2 files for non-overlapping area





ATM to OCN: air-sea momentum, sensible and latent heat fluxes, net shortwave and longwave radiation fluxes, surface pressure, and precipitation

OCN to ATM: SST

A Quick Start to Run HAFS

A. Clone and checkout

git clone --recursive https://github.com/hafs-community/HAFS.git ./

B. Build and install

cd sorc

./install_hafs.sh

Check/edit ../parm/system.conf afterwards if needed

C. Configure and run HAFS

cd ../rocoto

vi cronjob_hafs.sh

./cronjob_hafs.sh

Repeat running this driver periodically or add it as a cron task to advance the workflow.

Notes:

Standard application/workflow regression tests for various HAFS configurations:

cronjob_hafs_rt.sh