HAFS Configuration Strategies and Initial Operational Capability (IOC)

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HFIP Annual Review Meeting, November 18, 2021

Outlines

- HAFS IOC and goals
- Proposed HAFS IOC domain configurations
- Model DA plan
- Model physics strategy
- Computer Resource requirements
- HAFS IOC timeline
- Future plan

Hurricane Analysis and Forecast System (HAFS): A collaborative Project in UFS Framework

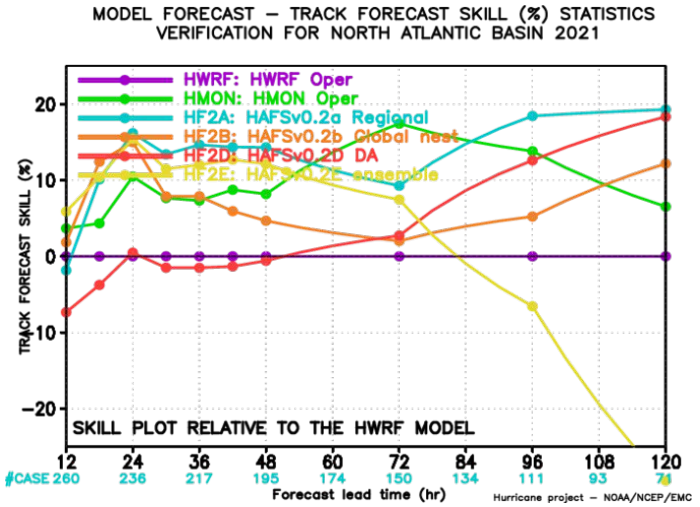
- Develop UFS based cloud-allowing Hurricane Analysis and Forecast System (HAFS) to replace current NOAA's operational hurricane forecast systems, HWRF and HMON
- HAFS Initial Operational Capability (IOC) is proposed for implementation for FY23 Hurricane season
- **All decisions on HAFS IOC based on EMC and NHC science evaluations**

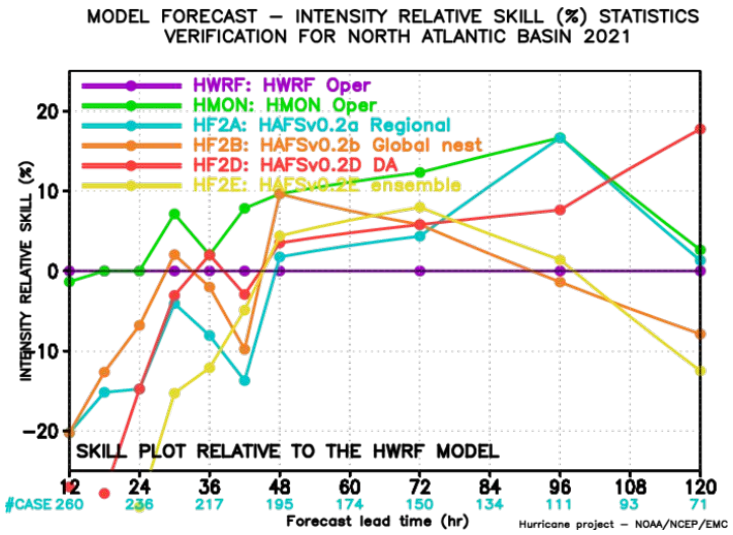
HAFS development is aligned with the objectives of UFS Strategic Implementation Plan (SIP). Active HAFS developments are ongoing with collaborative efforts among NCEP/EMC, AOML/HRD, GFDL, GSL, ESRL/NESII, OFCM/AOC, DTC, NCAR, as well as the broader research community.

- Maintain current CONOPS: max 5 storms in NHC AOR for HWRF & HMON; max 7 storms for HWRF in all global basins (NHC, CPHC and JTWC) i.e. total max 12 storms --- Two configurations for HAFS IOC
- Functionality before May 01, 2022 for all targets:
  - Moving nest capability in regional framework
  - GSI-based data assimilation capability
  - Formal vortex initialization (VR/VM) and/or GSI-based VR
  - Two physics suites in CCPP framework
  - Couple with ocean/wave (two-way with HYCOM, one-way with WW3
  - Workflow

2021 Real Time Experiments

	HAFS-A	HAFS-B	HAFS-D	HAFS-E
Resolution/Model top	~3km (ESG), L91/10hPa	~13-3km global-nest, L75/2hPa	~3km (ESG)/L91, 10hPa	~6km, L64, 10hPa
Domain	~94°×65°, 3121×2161	Global ATM:(C768), Nest ATM:~79°×43° OCN: ~330°×89°	~94°×65°, 3121×2161	~86°×58°, 1441×1081
IC/BC	GFSv16/3hrly	GFSv16/3hrly	GFSv16/3hrly	GEFS/6hrly
Coupling Ocean IC	CMEPS-HYCOM RTOFSv2	CMEPS-HYCOM RTOFSv2	CMEPS-HYCOM RTOFSv2	No ocean model NSST
Data Assimilation	No	No	Yes (addl:TDR, METAR, meso GOES-R AMVs)	No
Radiation	RRTMG (30min)	RRTMG(30min)	RRTMG(30min)	RRTMG(60min)
PBL/Surf GWD	M-TKE-EDMF/M-GFS orographic/convective on/off	M-TKE-EDMF/M-GFS saGWD	M-TKE-EDMF/M-GFS orographic/convective on/off	M-TKE-EDMF/M-GFS orographic/convective on/off
CP/MP	saSAS/GFDL	saSAS/GFDL	saSAS/GFDL	saSAS/GFDL
LSM	NOAH	NOAH	NOAH	NOAH

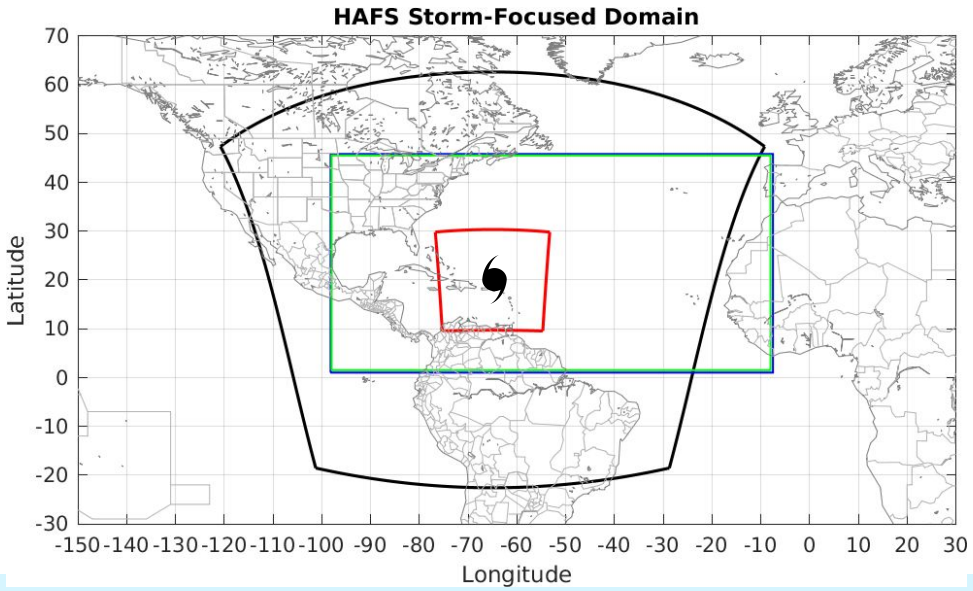




HAFSs have skillful track forecasts than HWRF
HAFSs mostly improved over HWRF after 36 h in intensity forecasts
HMON performed very well in 2021 hurricane season

Proposal HAFS IOC Primary Configuration -- Storm-centric with one moving nest

	Domain	Resolution	DA/VI	Ocean/Wave Coupling	Physics	Computer resource
HAFS	Storm-centric with one moving nest, parent: ~86x86 degree, nest: ~19x19 degree	Regional ESG, ~6/2 km, ~L91, ~10 hPa model top	Storm inner-core DA, cycling for NATL/EPAC TCs, VI	Two-way HYCOM, one-way WW3 coupling for NHC AOR	HAFSv0.3A/GFS like CCPP physics suite	~6,000 cores per storm x 7 storms = ~42,000 cores



FV3ATM parent and nested domains
HYCOM ocean domain
WW3 wave domain

This configuration will replace current operational HWRF, providing TC track/intensity forecast guidances in all global oceanic basins, 7 storms maximum.

Proposal HAFS IOC Secondary Configuration

- Secondary HAFS configuration will only be run for NHC AOR, NATL and EPAC
- Possible variants
  - Domain and resolutions
  - Model physics
  - Ocean coupling
  - Vortex initialization
  - Data assimilation

HAFS IOC Data Assimilation Analysis Configurations (FY23)

HAFS cycled inner-core DA configuration

- Storm-regional DA, cycling nest domain
- Use GFS analysis for parent domain
- Enable GSI-based VR if needed
- Use GDAS or HAFS ensemble for error background covariance
- Assimilate GFS/HWRF and additional high res. obs.

HAFS Model Physics Strategy and Plan

- Use the model physics schemes as close as possible to the those used in GFS, TC-calibrated physics schemes for TC application, need to be carefully and thoroughly evaluated
- Take advantage of CCPP/UFS infrastructure
- Modify and tune the physics specifically and uniquely for TC application
- Focus on improvement of PBL, Cumulus convection, and Microphysics schemes.
- Issues in current version of HAFS related to physics
  - Large cross-track bias and large storm size bias
  - Cycle to Cycle forecast variation, both track and intensity forecasts
  - Under-prediction of Rapid Intensification
- Challenges
  - Two configurations for HAFS IOC in CCPP framework, diverse and complementary to each other
  - Scale-awareness, physics for high-res. nests
  - Storm-scale structure forecast and verification
  - QPF improvement

HPC Resources for the Forecast job*

Current operational (WCOSS/Cray):

- HWRF: 5x2149+2x2038=14821 cores
- HMON: 5x1032=5160 cores
- Total: 19981 cores = 833 nodes (on WCOSS Cray)*

Proposed HAFS IOC (WCOSS-2):

- Expected resources: ~3.5x than currently used for hurricane models#

* Operational forecast jobs needs to be completed in ~96min

\# Resources yet to be confirmed

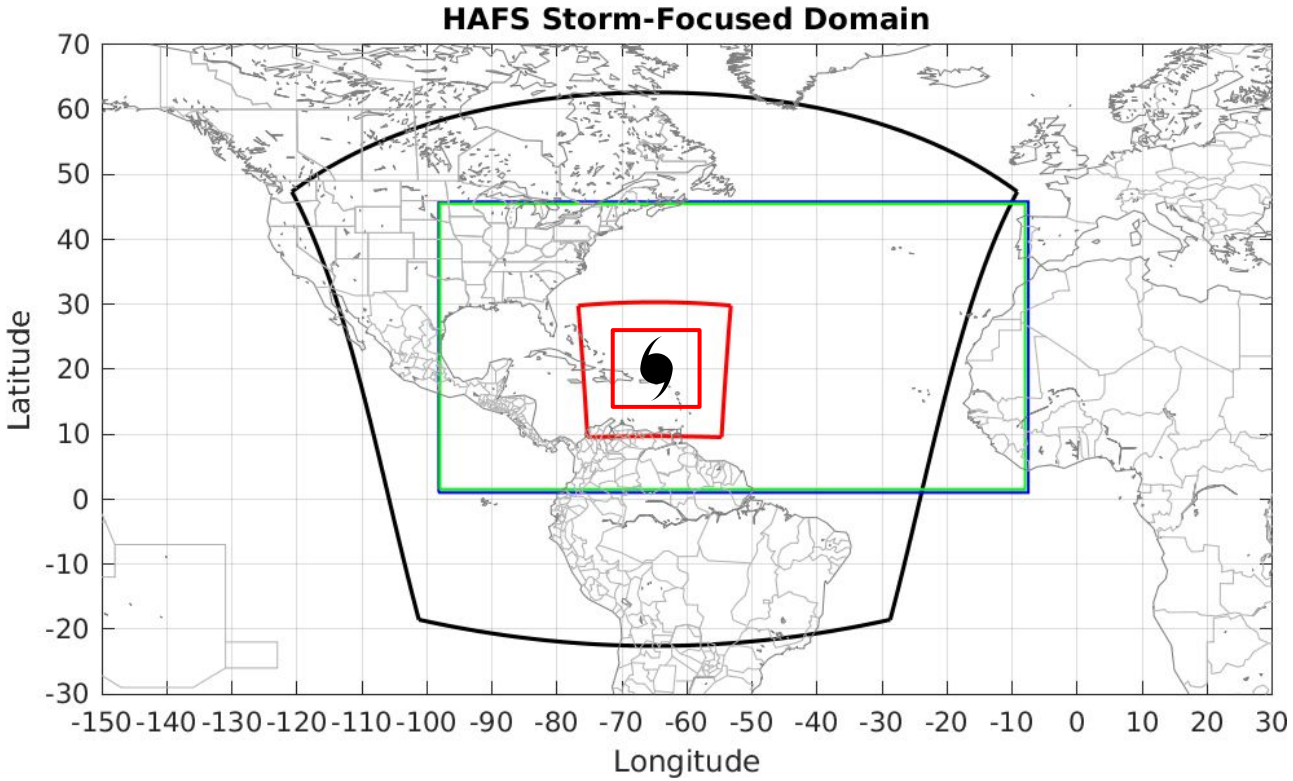
Detailed HAFS FY23 IOC timelines

Tasks	11/01/21-02/28/21	03/01/22-04/30/22	05/01/22-07/31/22	08/01/22-10/30/22	11/01/22-01/14/23	01/15/23-02/28/23	03/01/23-05/31/23	**06/01/23**
HAFSv0.3, 2 configurations								
source code development								
Configuration/framework development								
Retrospective T&E								
Code freeze/Real time experiment								
HAFSv1.0, 2 configurations								
Realtime results evaluation								
T&E (infrastructure, dynamics, physics, coupling, pre-processing, initialization/DA, post-processing and products)								
final configurations EMC code freeze								
final configurations three-season (2020-2022) retrospective tests and technical testing (Primary/secondary)								
NCO code delivery/IT tests								
Targeted HAFSv1.0 implementation								

Potential HAFS v2/v3 Storm-Focused Configuration (FY24-25)

HAFSv2/v3 Storm-Focused Configuration:

- Regional parent with telescopic storm-following moving nests (e.g., 9-3-1 km nesting)
- Using regular gnomonic grid or ESG grid
- Vortex Initialization (VR/VM)
- Storm-region DA and cycling
- HAFSv0.2/GFS-like CCPP physics suite
- MOM6 to replace HYCOM
- 3-way coupling (FV3-OCN-WW3)

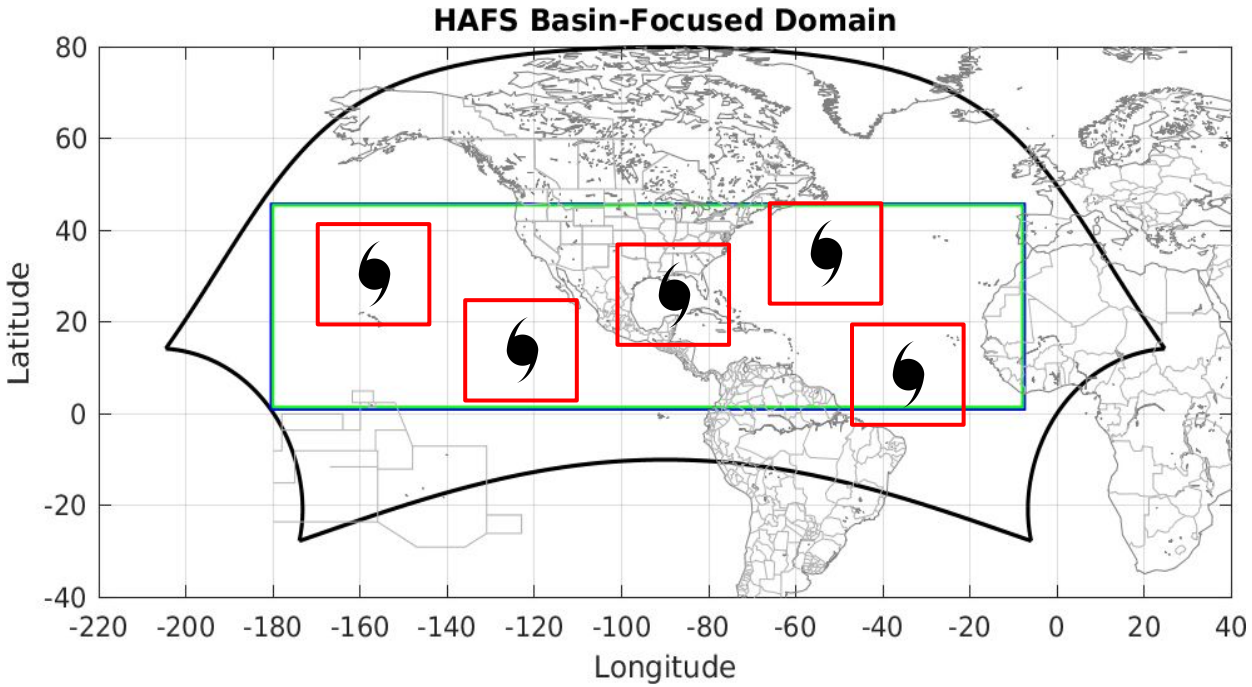


FV3ATM parent and nested domains
HYCOM/MOM6 ocean domain
WW3 wave domain

Potential HAFS v2/v3 Basin-Focused Configuration (FY24-25)

HAFSv2/v3 Basin-Focused Configuration:

- Regional static basin-focused parent domain covering NHC basins (NATL, EPAC, CPAC), with up to 5 storm-following 2-km moving nests
- Using ESG grid or regular gnomonic grid
- GSI-based VR or VR/VM if needed
- Whole domain or storm-region only DA cycling
- HAFSv0.2/GFS like CCPP physics suite (or RRFS-like CCPP physics suite)
- MOM6 to replace HYCOM
- Explore Marine DA (via JEDI)
- 3-way coupling (FV3-OCN-WW3)



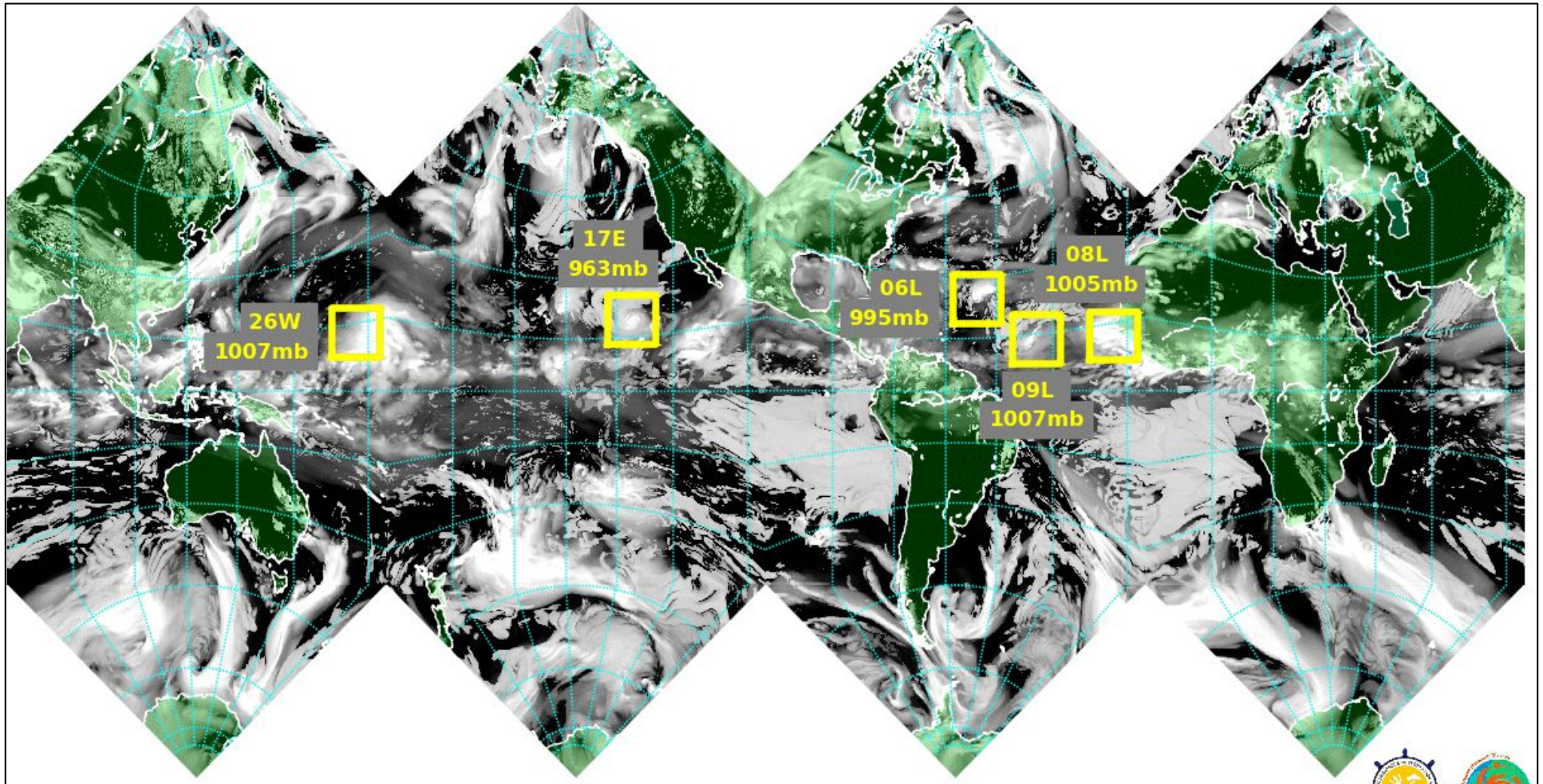
FV3ATM parent and multiple storm-following moving nests nests

HYCOM/MOM6 ocean domain

WW3 wave domain

This configuration will eventually transform into global GFS/GDAS with storm-following moving nests.

Long-term Target for HAFS/GFS



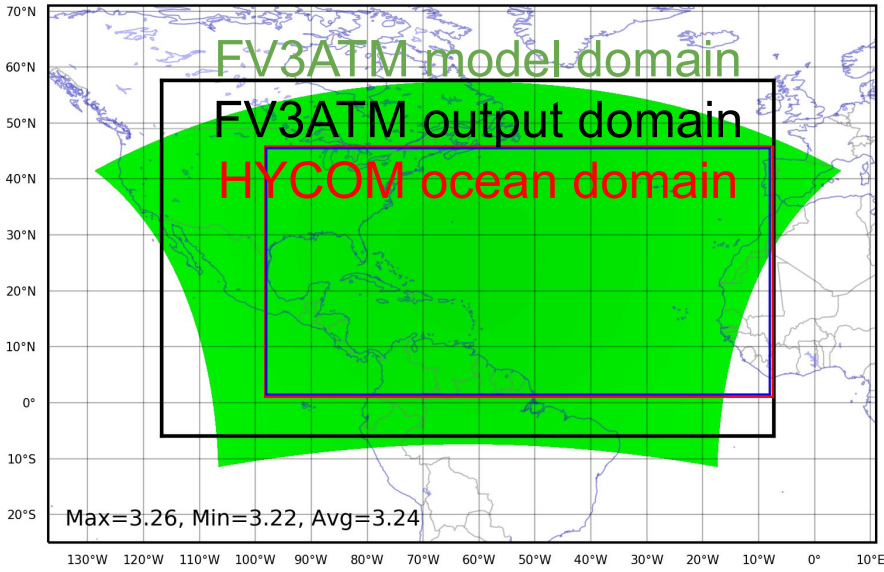
06L: Florence; 08L: Helene; 09L: Isaac; 17E: Olivia; 26W: Mangkhut

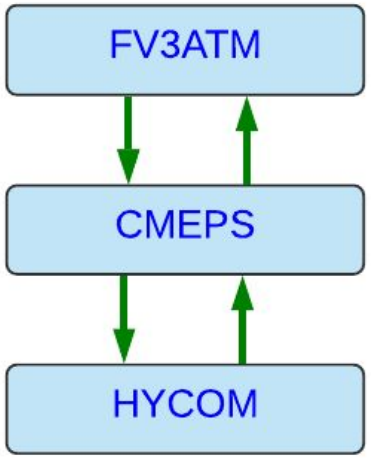
Thank You !

The HAFSv0.2A Configuration

(Baseline, phase-2, final configuration changes on top of HAFSv0.1A)

- The FV3ATM component
  - The hafs.v0.2.0 version was used with all HAFS subcomponents synced with their authoritative branches as of 05/12/2021
  - 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
  - CMEPS based ocean coupling with updated exchange flux variables
  - 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

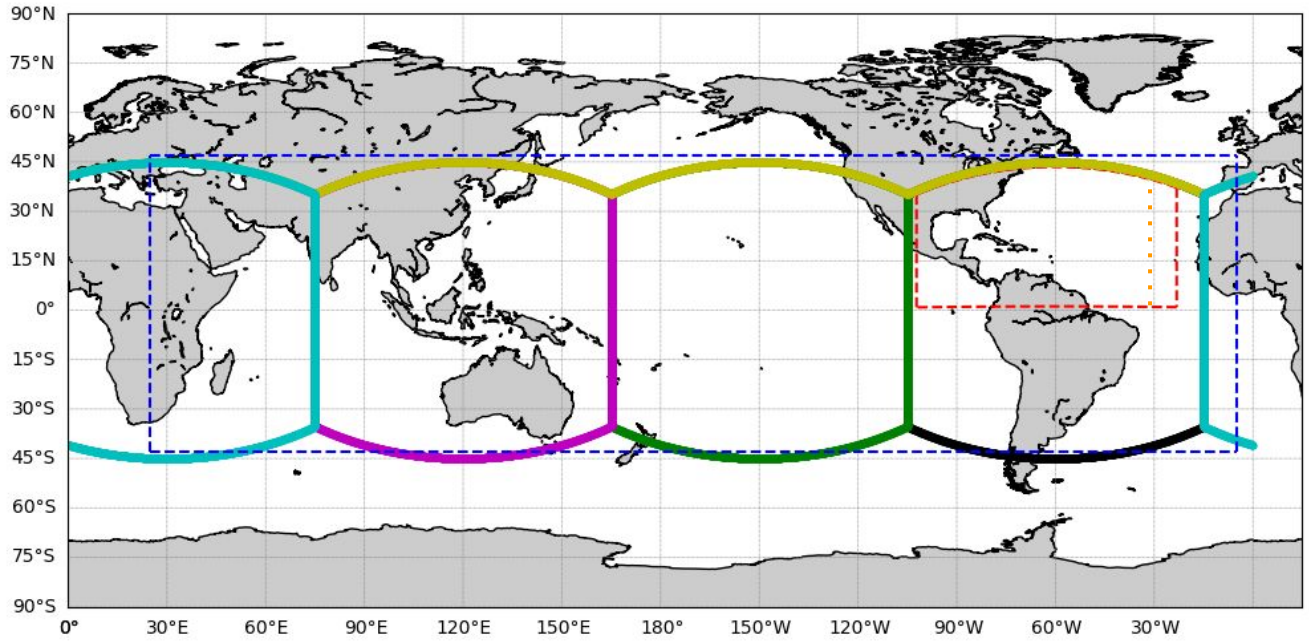




ATM to OCN:
air-sea momentum, sensible and latent heat fluxes, net shortwave and longwave radiation fluxes, surface pressure, and precipitation
OCN to ATM:
SST

2021 Grid Configuration and Model Setup

- Keep the 2020 “global tropical channel” FV3 layout, with 13-km global resolution (C768)
- Static 3-km nest covering most of the tropical Atlantic
- Requested resources to extend Atlantic nest from 2020 by ~6 degrees
- Nest was coupled to HYCOM for 2021
- 168h forecasts 4x daily
- 4560 cores in ~5 hours



- - - - - - 2021 nested grid

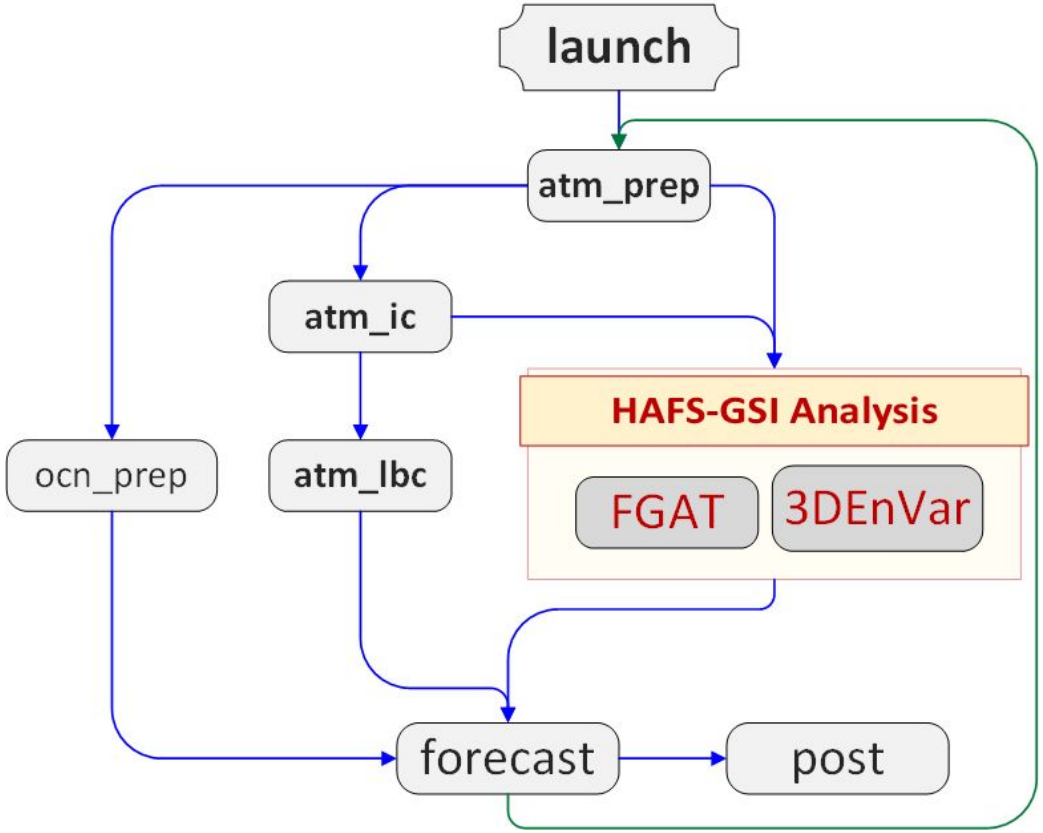
- - - - - - 2020 nested grid

- - - - - - 2021 HYCOM grid

HAFSv0.2D Real-Time System Configuration

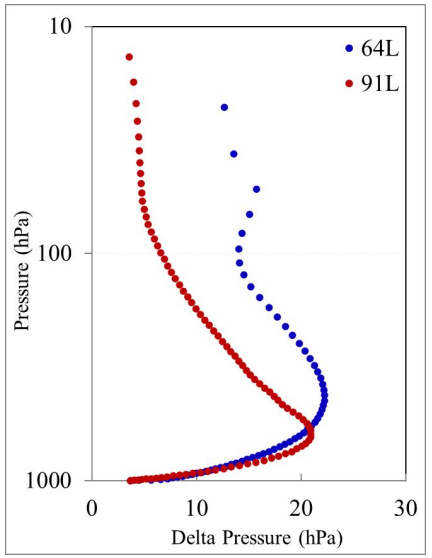
- FV3ATM
  - 3-km 91L FV3 regional ESG-grids;
  - 3-hrly operational GFS grib2 files for LBC
  - HAFS_V0_gfdlmp_nonsst physics suite
- HYCOM
  - CMEPS based ocean coupling;
  - 1/12-degree resolution NATL domain with L41
  - Ocean IC from RTOFSv2 and persistent oceanic LBC
  - Atmospheric forcing from GFS grib2 files for non-overlap area
- DA
  - 6-hourly hybrid 3DEnVar by using GDAS 6-h ensemble forecasts
  - 3-hourly FGAT

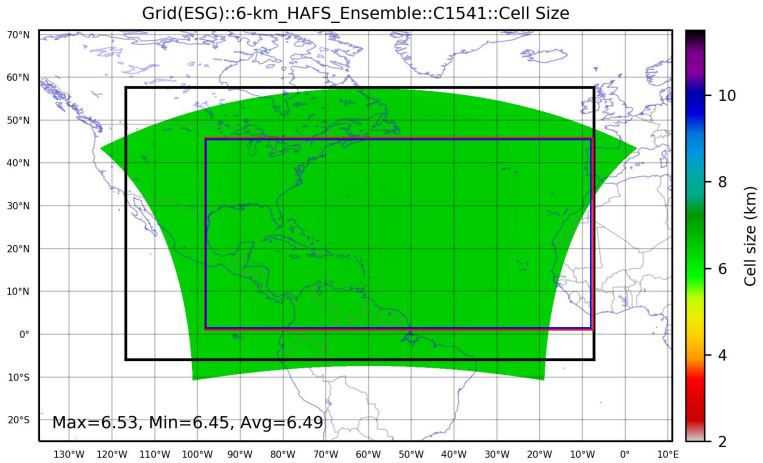
HAFSv0.2D Workflow



HAFS v0.2E Ensemble Configuration for 2021 HFIP Real-time

- Basic configuration, based on HAFSv0.2A
  - Lower horizontal resolution: refine ratio=2, ~6km vs. 3km, Lower vertical resolution: L64 vs. L91, with smaller domain
  - Ocean: NSST, No Ocean coupling
  - dt_atmos: 120s vs. 90s, k_/n_split= 3/4
  - Radiation time step: 3600s vs. 900s
  - One control member plus 20 perturbed ensemble members (11 on jet and 10 on orion)
  - Runs four cycles a day (00Z,06Z, 12Z and 18Z), Atlantic basin only
  - Computer resources: 14 nodes or 336 cores per forecast jobs.
- IC/BC Perturbation:
  - IC/BC: GEFS grib2 (0.5x0.5) vs. GFS
- Model Physics:
  - Stochastically perturbed physics tendencies (SPPT)
  - Stochastic kinetic energy backscatter (SKEB)
  - Stochastically perturbed PBL humidity (SHUM)





Domain size: 1441x1081