Hurricane Analysis and Forecast System (HAFS): A UFS (Unified Forecast System) Application

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Outline

- HAFS -- Objectives
- HAFS – Accomplishments and Current Status
- HAFS – Lessons Learned from Year 1
- HAFS – Plans for year 2
- Long term Vision

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

07 NCAR/DTC

06 OFCM/AOC

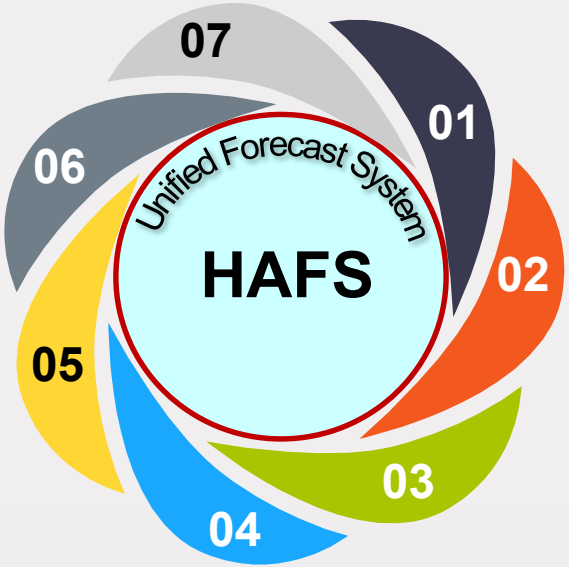
05 ESRL/NESII

04 ESRL/GSD

NCEP/EMC 01

AOML/HRD 02

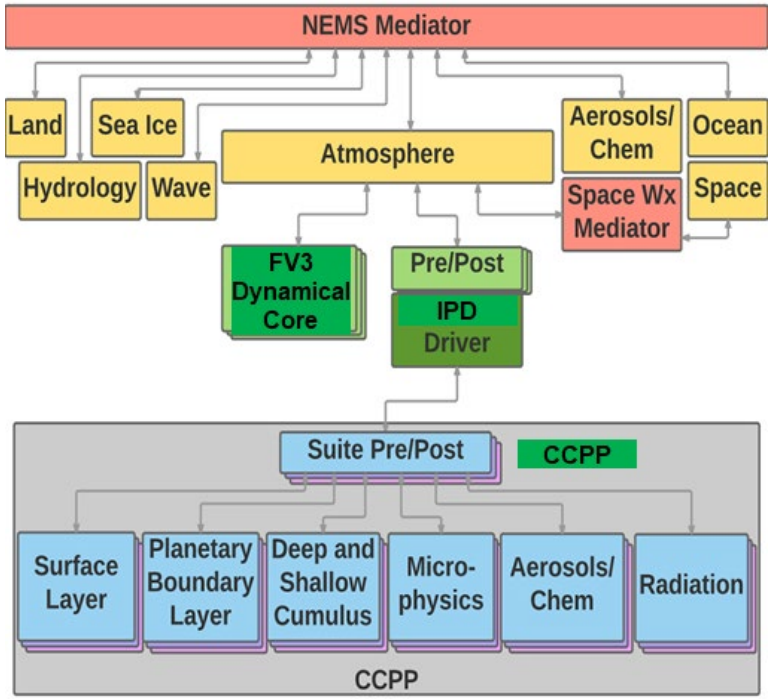
GFDL 03



FV3-based Unified Forecast System

- NWS UFS system consists of the following components (at the moment)
  - NEMS for infrastructure
  - FV3 dycore with Physics driver (IPD)
  - MOM6 ocean model (S2S scales)
  - HYCOM ocean model (weather scales)
  - WW3 wave model
  - CICE5 ice model
  - GOCART aerosol model
  - Noah MP land model

- Each component has its own authoritative repository. NEMS infrastructure allows flexibility to connect instantiations of the repositories together to create a coupled model.



Ongoing Efforts at EMC Towards Simplified Production Suite

Modeling System	Current Status	Proposed Plans in the UFS Context
Global Deterministic	FY19: Transition FV3GFS into operations	Advancement of NGGPS/FV3GFS (biennial upgrades)
Global DA	4D-Hybrid En-Var using GSI	Migrate to JEDI
Global Ensembles (Sub-seasonal)	FV3/NEMS based reanalysis/ reforecasts	FY20: Implement FV3 GEFS for sub-seasonal weather forecasts (35 days)
Global Seasonal Climate	Develop coupled UFS and coupled DA	Implement FV3 SFS for seasonal climate forecasts (MOM6, CICE5, Noah-MP, WWIII, GOCART,JEDI)
Global Aerosols	NGAC V2 (NEMS/GSM + GOCART)	FY20: Merge with FV3 GEFS
Hurricanes	HWRF & HNMMB	FV3 GFS with multiple moving nests (HAFS)
Waves	Waves Multi2 merged with HWRF	FY20: Merge wave ensembles models with FV3GEFS FY21: Merge deterministic Waves with GFSv16
Ocean	RTOFS/HYCOM	MOM6 + NCODA + Marine JEDI
Meso-Scale	NAM V4 & NMMB frozen	Transition to FV3 CAM, NAM/RAP Parent domains subsumed by FV3GFS?
Short-range ens.	SREF V7.1 frozen	FY20: Replace SREF with FV3GEFS???
HREF	V2: HiRes Window + NAM Nests (SSEO)	FV3 SAR to replace poor performing HREF members
RAP/HRRR	V2/V3	FY20: V3/V4 UFS CAM (RRFS)
Products, V&V	UPP, VSDB/MET, MEG, NAWIPS	UPP+, MET+, MEG+
Collaborative Infrastructure	Various	NEMS/ESMF/NUOPC+; EE2+; CROW; Shared infrastructure and distributed development

HAFS Overview and Objectives

- As a Unified Forecast System (UFS) application, HAFS is an FV3 (Finite Volume Cubed-Sphere Dynamical Core) based multi-scale model and data assimilation system capable of providing Tropical Cyclone (TC, including Hurricanes and Typhoons) analyses and forecasts of the inner core structure and the large-scale environment.

- The HAFS development targets an operational analysis and forecast system for Hurricane forecasters with reliable, robust and skillful guidance on TC track and intensity (including rapid intensification), storm size, genesis, storm surge, rainfall and tornadoes associated with TC's.

- HAFS will provide an advanced analysis and forecast system for cutting-edge research on modeling, physics, data assimilation, and coupling to earth system components for high-resolution TC predictions within the outlined Next Generation Global Prediction System (NGGPS)/Strategic Implementation Plan (SIP) objectives of the Unified Forecast System (UFS).

Major Sub-tasks for HAFS in the First Year

Task ID	Subtasks	Start Date	Completion Date	Lead	Dependencies	Collaborators	Project	Status
1.1	Implement HWRF physics in FV3 through CCPP	*July 2019*	June 2020	EMC	None	GMTB/GSD	3A.2	Ongoing
1.6	DA capability in the regional stand-alone FV3	*June 2019*	May 2020	EMC	EMC's ongoing regional DA project	AOML	3A.2	Ongoing
1.9	Vortex initialization and storm relocation for FV3	June 2019	May 2020	EMC	None	AOML	3A.2	Ongoing
1.12	Develop hurricane specific model diagnostic products for HAFS v0.A and v0.B	*July 2019*	June 2020	AOML	None	GFDL, EMC	3A.1	Ongoing
1.18	Advance moving nest framework for existing idealized/semi-idealized vortex (without physics)	*June 2019*	May 2020	AOML	Task 1.7	GFDL, EMC	1A.4	Ongoing
1.20	Prepare and Run HAFSv0.A and HAFSv0.B experiments, document performance and the importance of global parent	*June 2019*	November 2019	EMC	Tasks 1.1, 1.2 and 1.9	AOML	3A.2	**Completed**

HAFS Accomplishments in the 1st Year

- HAFS code repository and management
- HAFS workflow development
- HAFS Configurations
- HAFS multiple static nests – towards moving nests
- HAFS physics – HWRF physics in CCPP

HAFS Code Repository and Management

Incorporates the three-tier repository/fork structure

The authoritative HAFS repository:

- https://github.com/NOAA-EMC/HAFS
- Supports the main development activities and operational implementations.

Trusted community/organizational HAFS forks:

- e.g., https://github.com/hafs-community/HAFS
- Mainly provides community support and promotes organizational level collaborations.

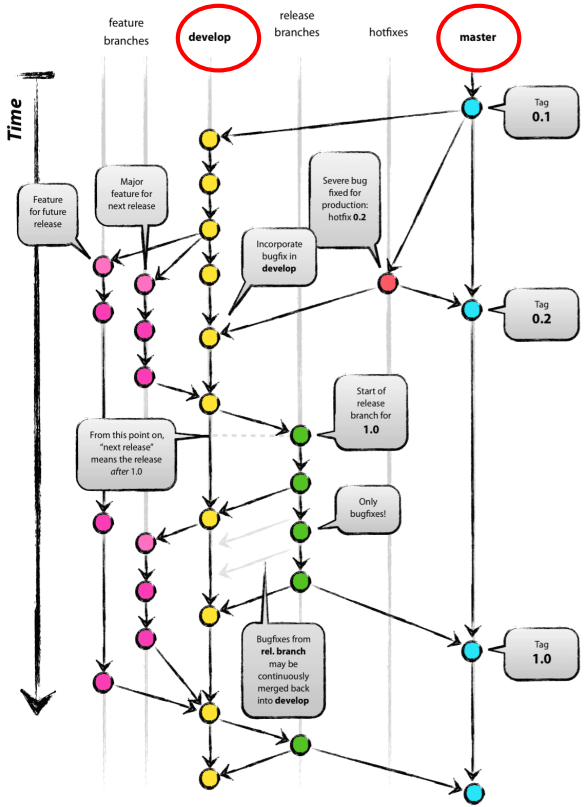
HAFS developer forks:

- Developer's forks for individual feature (or capability) development.

Adopts the GitFlow rational

Branch naming convention:

- **develop** for the develop branch
- **master** for the master branch
- **feature/**[name] for feature branches



A GitFlow branching strategy (from Vincent Driessen's blog)

From: Bin Liu & Jili Dong

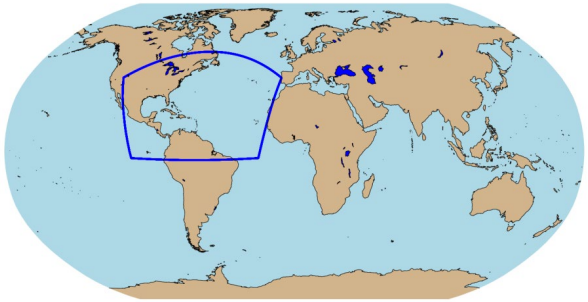
HAFS Prototype Workflow

- HAFS workflow is capable of supporting stand-alone regional FV3 as well as global-nest FV3
- Rocoto workflow management with python/shell scripts for individual task components
- Flexible domain setup (fixed domain or domain shift cycle by cycle based on TCs)
- Support NCEP WCOSS and NOAA RDHPCS (jet, hera, orion) clusters
- Continuous day to day run without storms or only launch with NHC storm message triggering

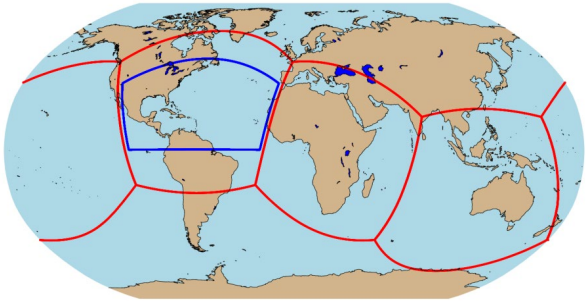
From: Bin Liu & Jili Dong

HAFS v0.A (SAR) and HAFS v0.B set ups: model grids

HAFS v0.A- SAR



HAFS v0.B- Global-nest



For FY19, both configurations ran in real time

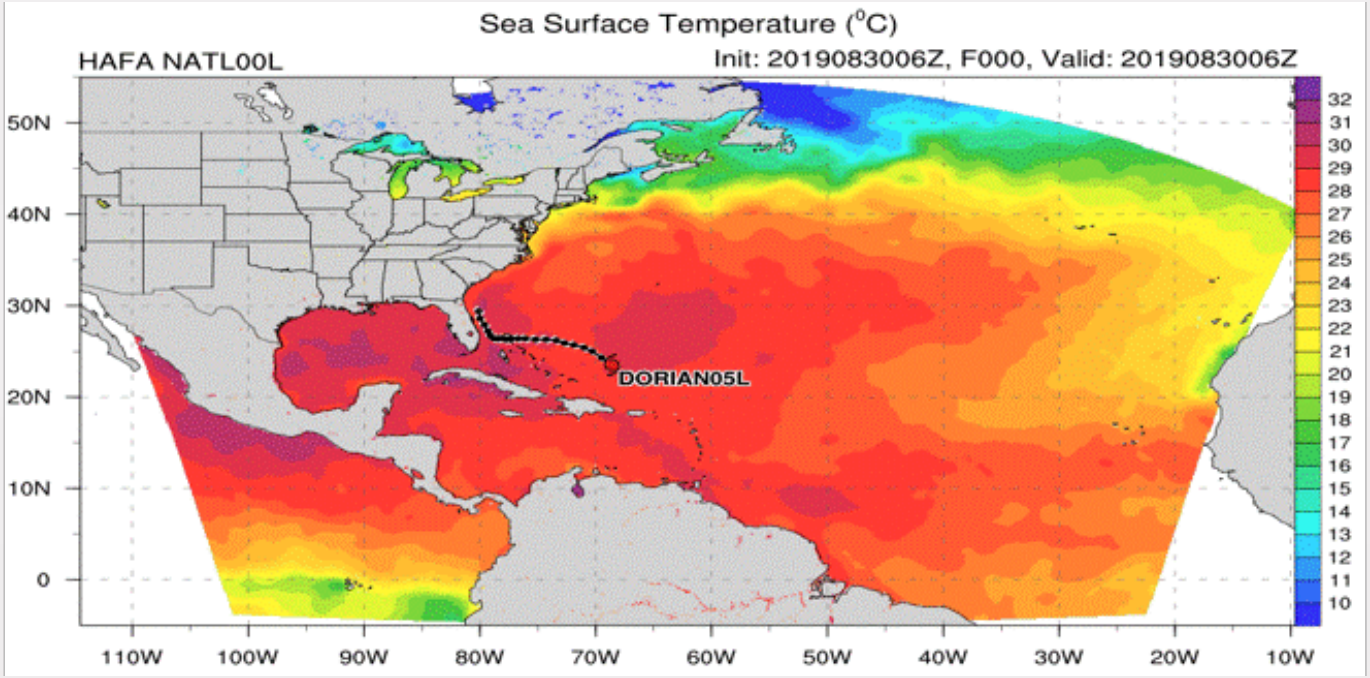
The NATL basin focused standalone regional (SAR) domain configuration (3km)

- C768 with a refinement ratio of 4
- the regional domain size: 2880x1920 (~85x56deg)

The NATL basin focused global-nesting domain configuration (3 km, global at 13 km)

- C768 with a refinement ratio of 4
- the nested domain size of 2880x1536 (~85x45deg)

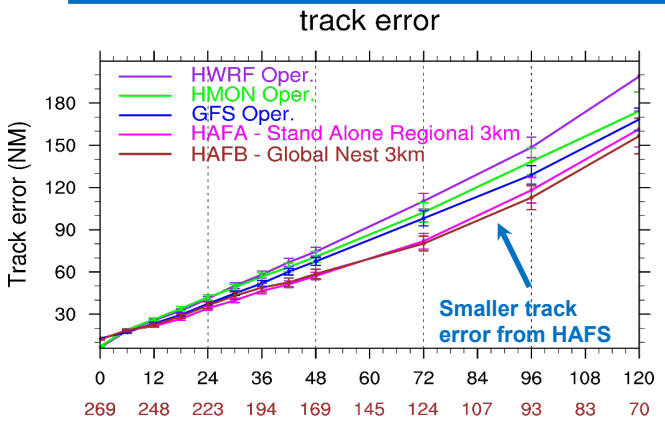
HAFS Experimental Configurations

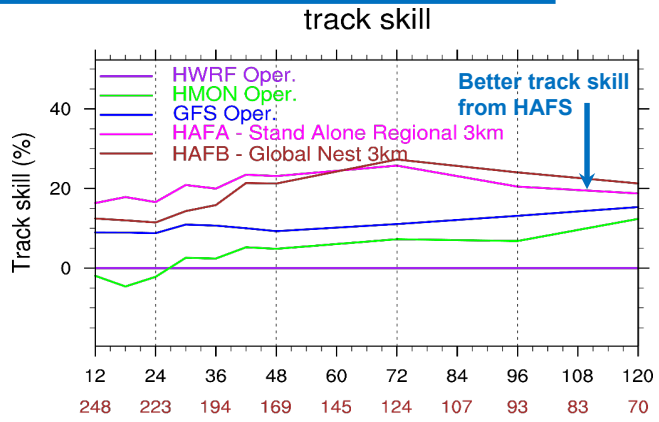


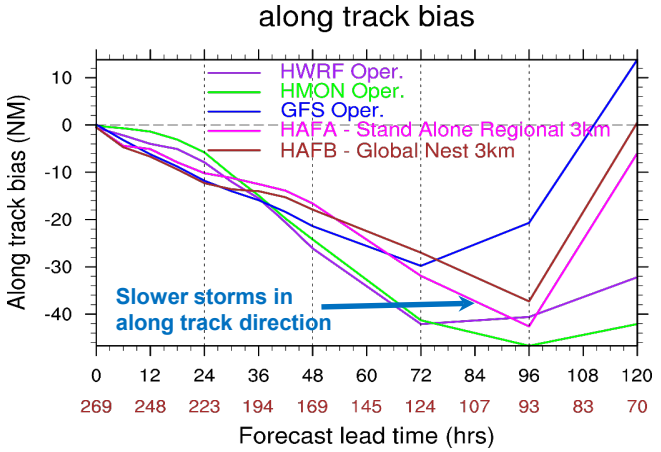
Hurricane Dorian forecasts using the HAFSv0.A configuration from HFIP real-time experiments.

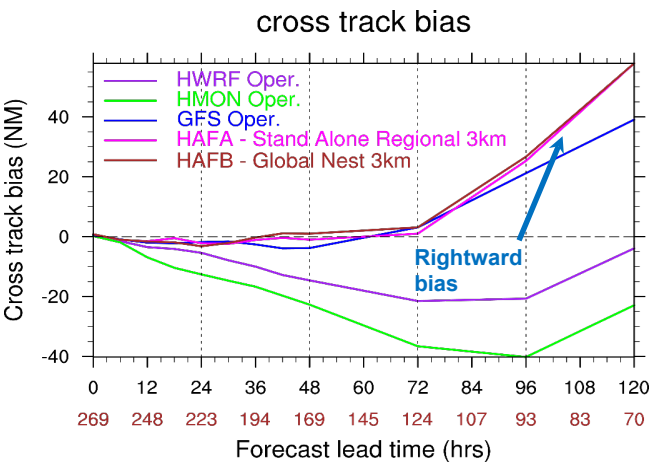
Dorian track forecasts from HAFS picked up on the right turn before the operational models.

HAFS track forecasts for the NATL 2019 season

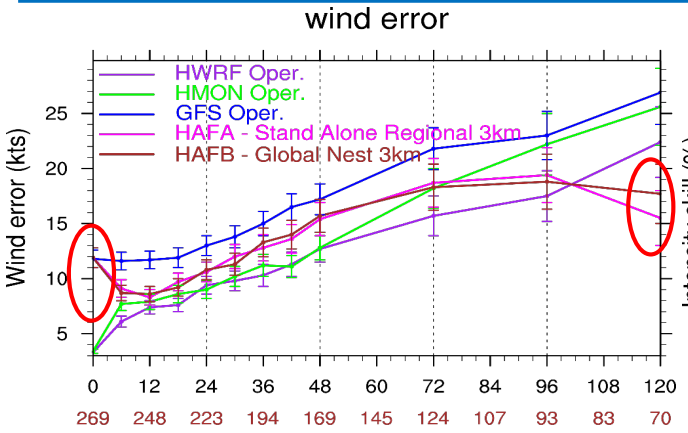


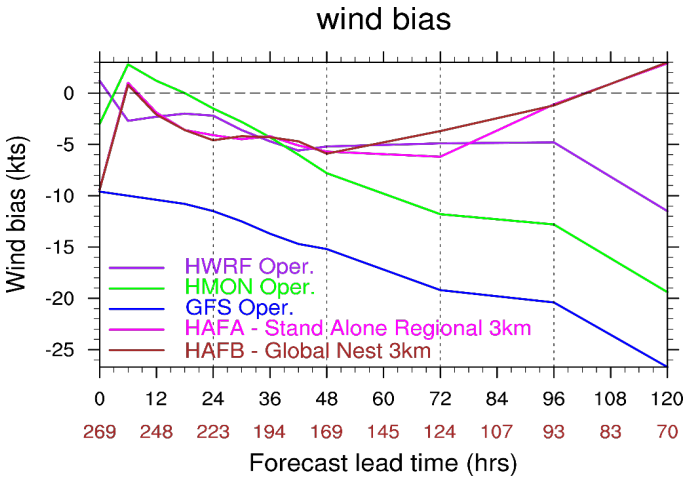


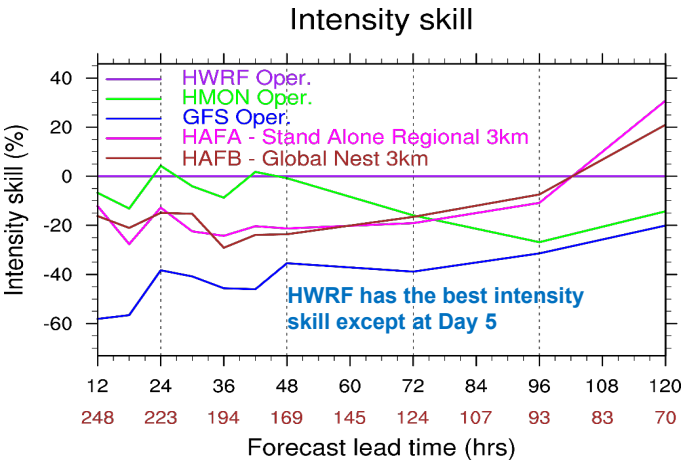




HAFS intensity forecasts (wind) for the 2019 NATL season







- Large initial intensity errors in both HAFS models (spin down)
- Error reduced at 6 hours and increases afterwards till Day 3
- Relatively small errors at 120 hours
- Both HAFS models under-predict intensity in terms of maximum wind before Day 5
- HAFS v0.A and v0.B are comparable in intensity forecasts

Lessons Learned: HAFS FY19 Real-time Experiments

- Results from real-time HAFS configurations are very similar until 5 days
- HAFS v0.B (global-with-nests) remains our long term goal; impact of feedback from nests on the global model remains an open science question
- HAFS v0.A configuration is computationally cheaper; provides for ease of use and close collaborations with FV3-SAR developments (Physics; DA; utilities etc.); but do these configurations fit for T2O?
- Need to consider low-resolution configurations with moving nests for T2O

Hurricane Moving Nest : Multiple Static Nests

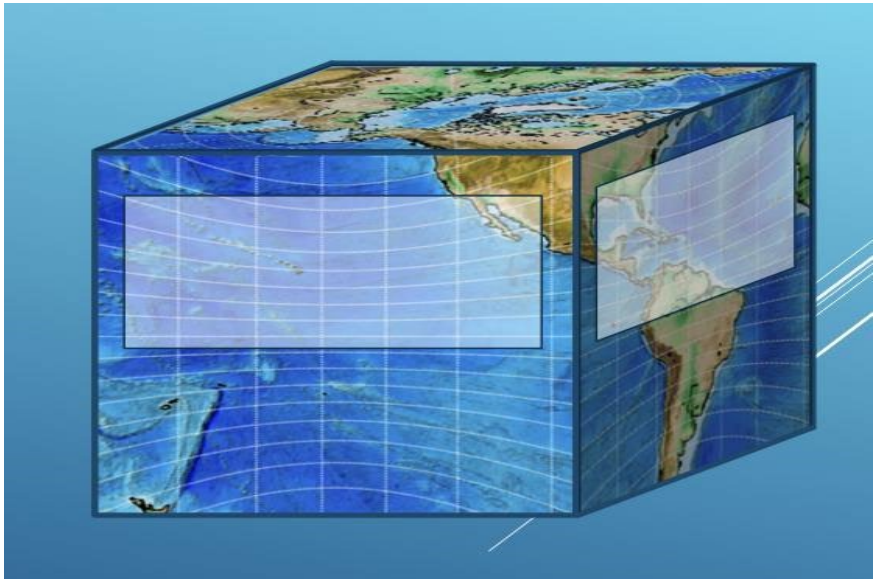
Extend from One to Many Nests (non-overlapping, one per tile):

- Understand nesting code
- 1st stage toward multiple moving nests

Code Modifications:

- Grid and terrain generation step
- Interpolation of GFS initial conditions (chgres)
- FV3 dynamic core

FMS changes have been made for moving nests and telescopic nests

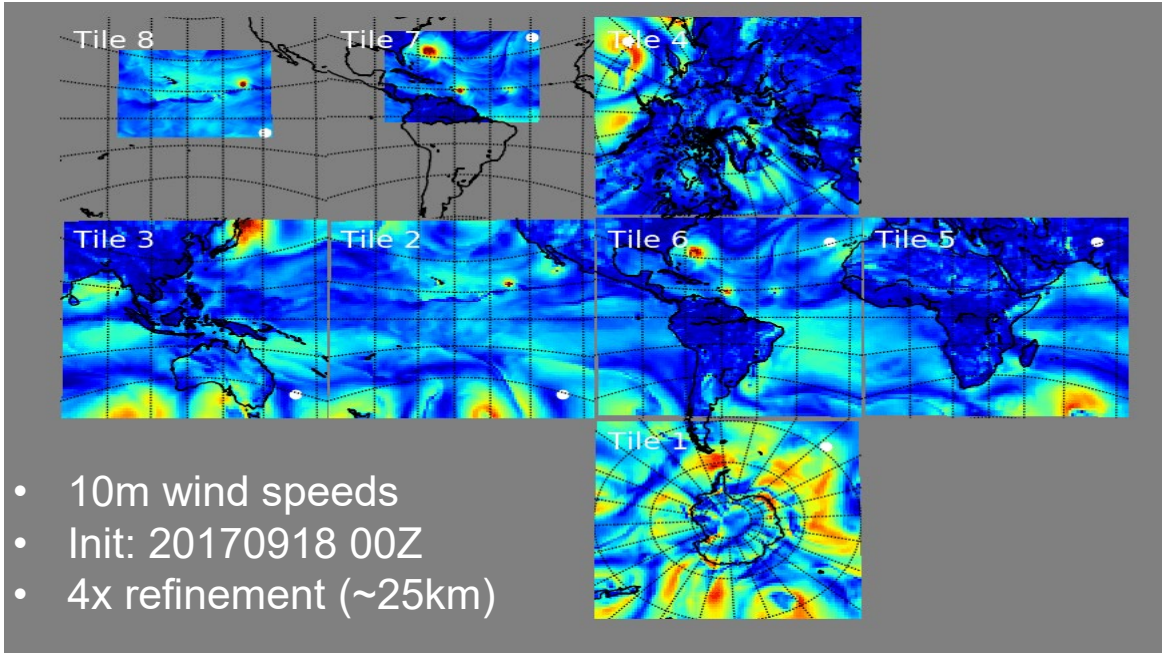


From: Xuejin Zhang

Hurricane Moving Nest : Two Static Nests on Two Tiles

Maria, Jose (NATL) and Otis (EPAC)

- Implementation of two static nests in FV3GFS completed
- Bitwise identical results with baseline FV3GFS code
- Successful 168 hour forecast run
- Second nest results also validated

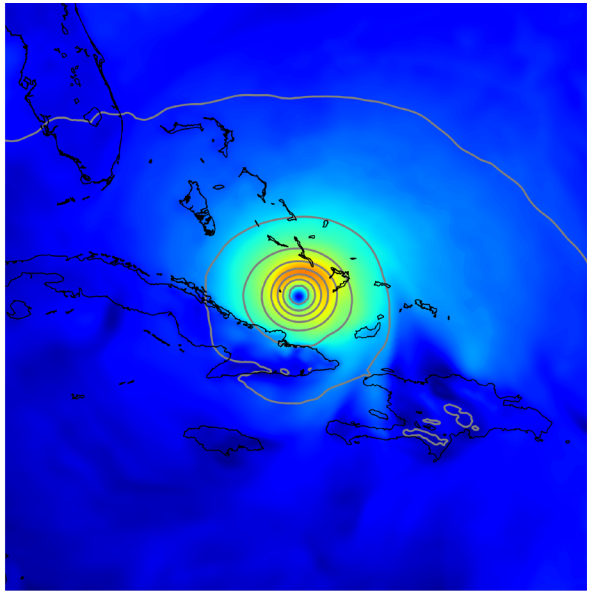


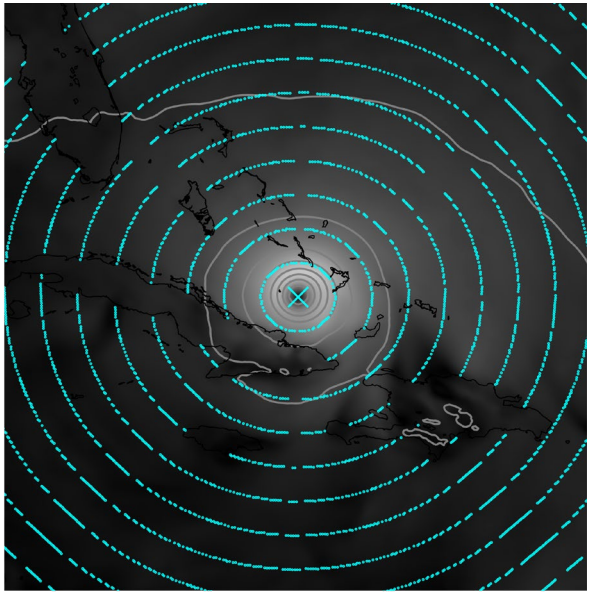
From: Xuejin Zhang

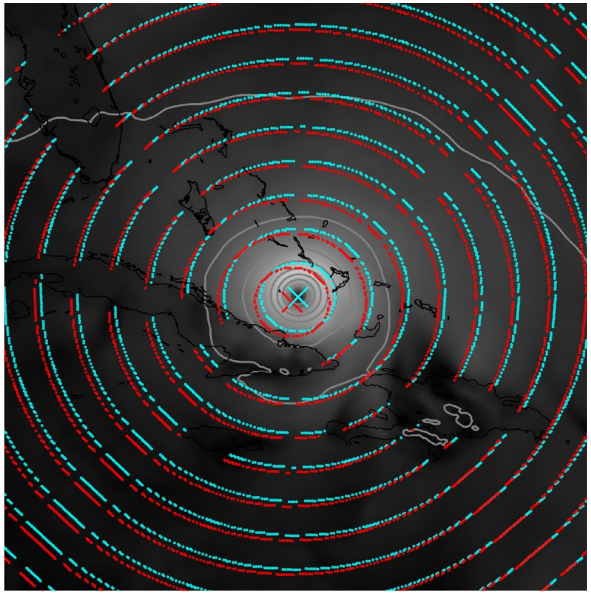
HAFS 2nd year Plans

- Accelerate multiple, telescopic, moving nest implementations in FV3
- FV3 nests coupled to ocean using CMEPS/NUOPC
- Test HWRF Physics and other available suites in FV3 using CCPP
- Implement vortex initialization and inner-core Hybrid En-VAR DA
- Explore coupled DA (Atmosphere-Ocean) within the JEDI framework (HSUP-2)

HAFS: GSI-based TC Relocation Methodology

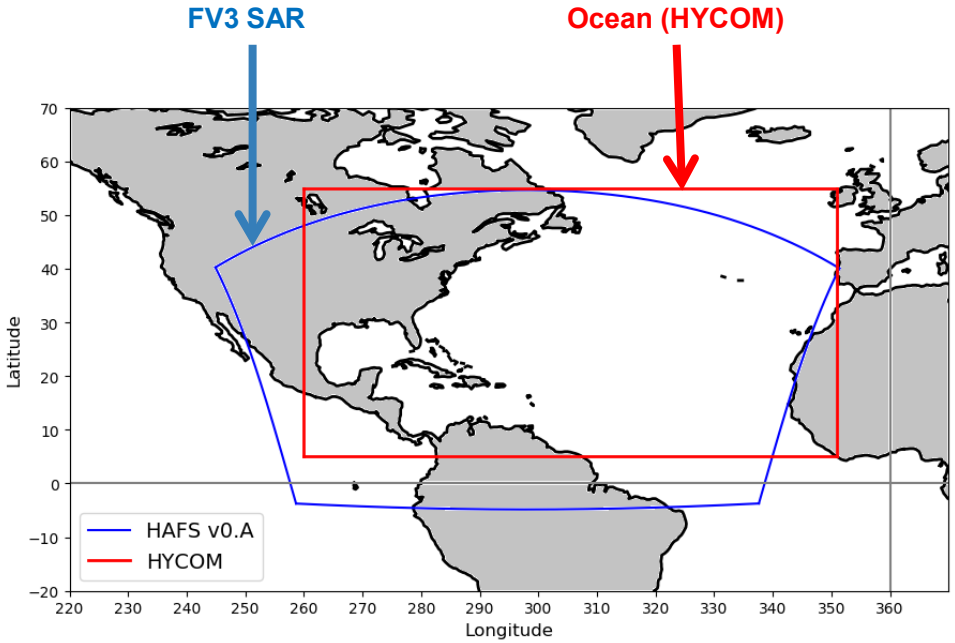






- The FV3 first-guess is used to create synthetic profile-type *observations*
- Ocean-relative observations are collected at radial intervals with respect to the forecast-time TC location (cyan points)
- The positions for the observations is updated to reflect their respective locations relative to the observed TC-vitals position (red points)
- The GSI assimilates these *observations* in order to relocate the TC

Progress on HAFS-HYCOM coupling



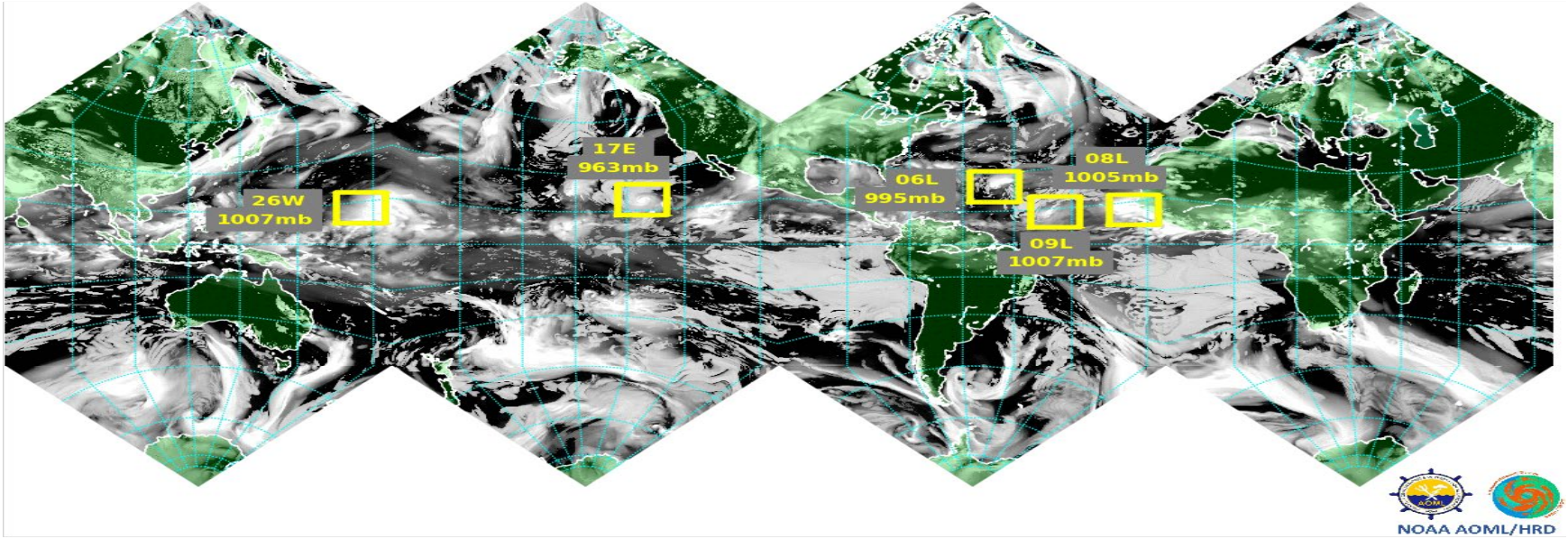
Tasks Completed:

- CMEPS coupler has been added to FV3 and HYCOM
- A side-by-side HAFS-HYCOM coupled forecast gives b4b reproducibility
- One single executable, both HAFS and HYCOM can be run simultaneously

Tasks Ongoing:

- One-way HAFS-HYCOM data exchange and validation
- New workflow developments in support of HAFS-HYCOM coupling

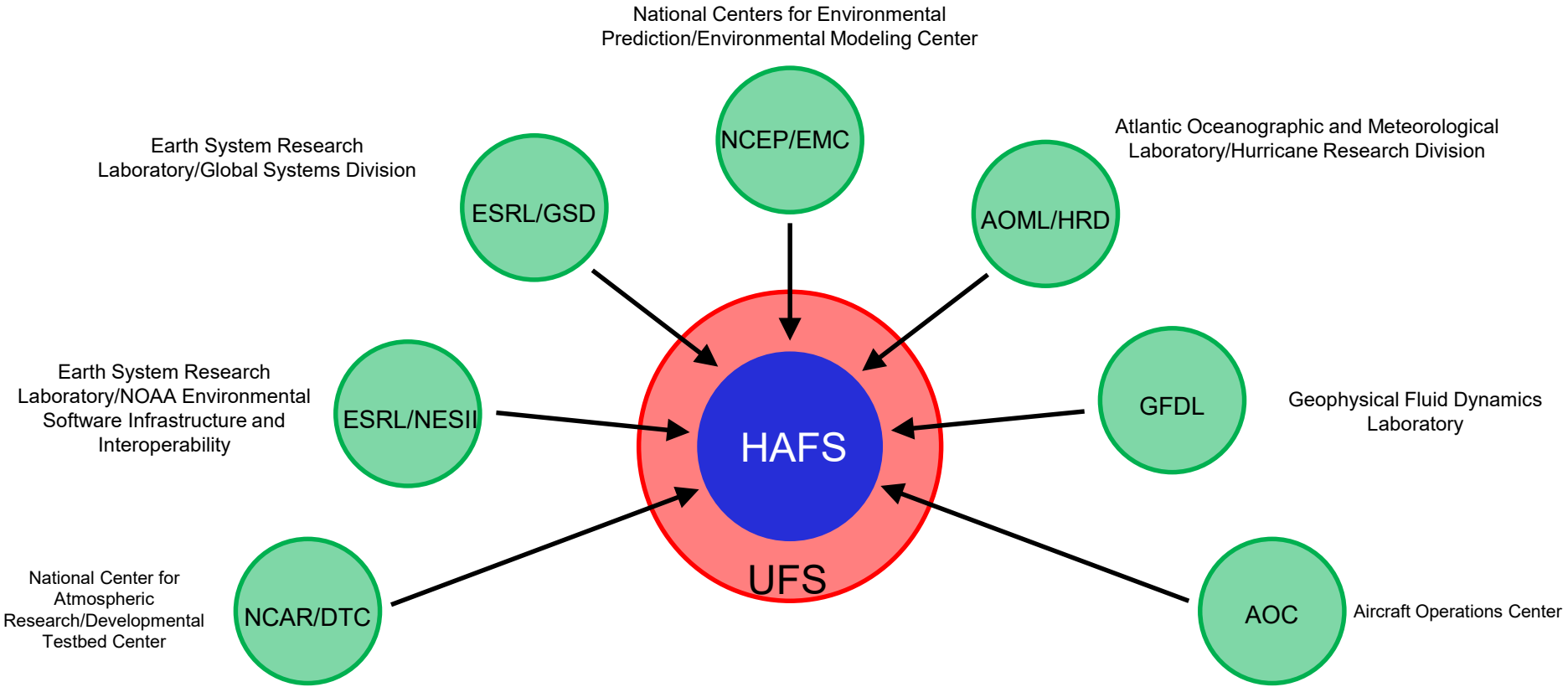
Long-term Target for HAFS/GFS



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

Thanks!

Hurricane Analysis and Forecast System (HAFS)



- A collaborative effort within the Unified Forecast System (UFS) Framework.

HAFS Overview and Objectives

- In order to address the Section 104 of *Weather Research and Forecasting Innovation Act of 2017*, the next generation of HFIP will build upon the original goals of the project through the following specific goals and metrics:
  - Reduce forecast guidance errors, including during RI, by 50% from 2017.
  - Produce 7-day forecast guidance as good as the 2017 5-day forecast guidance;
  - Improve guidance on pre-formation disturbances, including genesis timing, and track and intensity forecasts, by 20% from 2017;
  - Improve hazard guidance and risk communication, based on social and behavioral science, to modernize the TC product suite (products, information, and services) for actionable lead-times for storm surge and all other threats.
- Developing and advancing the Hurricane Analysis and Forecast System is one of the key strategies to address the next generation HFIP's science and R2O challenges.