HAFS Configuration Strategies and Initial Operational Capability (IOC)

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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

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

<table>
<thead>
<tr>
<th>Domain</th>
<th>Resolution</th>
<th>DA/VI</th>
<th>Ocean/Wave Coupling</th>
<th>Physics</th>
<th>Computer resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAFS</td>
<td>Storm-centric with one moving nest, parent: ~86x86 degree, nest: ~19x19 degree</td>
<td>Regional ESG, ~6/2 km, ~L91, ~10 hPa model top</td>
<td>Storm inner-core DA, cycling for NATL/EPAC TCs, VI</td>
<td>Two-way HYCOM, one-way WW3 coupling for NHC AOR</td>
<td>~6,000 cores per storm x 7 storms = ~42,000 cores</td>
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</table>

**HAFSv0.3A/GFS like CCPP physics suite**

**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.
• 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

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<tr>
<th>Tasks</th>
<th>11/01/21-02/28/21</th>
<th>03/01/22-04/30/22</th>
<th>05/01/22-07/31/22</th>
<th>08/01/22-10/30/22</th>
<th>11/01/22-01/14/23</th>
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<th>03/01/23-05/31/23</th>
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<td>HAFSv0.3, 2 configurations</td>
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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)

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
  o The hafs.v0.2.0 version was used with all HAFS subcomponents synced with their authoritative branches as of 05/12/2021
  o Regional ESG C3089 grid (~3-km) with L91 (10 hPa top) levels
  o GFSv16 netcdf files for IC; 3-hrly GFSv16 grib2 files for LBC
  o dt_atmos=90s; k_split=3; n_split=5; radiation time step: 1800s; LBC blending with nrows_blend=10
  o 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
  o Utilize inline post to generate grib2 products within the forecast model
  o Fix the boundary-crawler issue and turn off two thickness parameters in the GFDL tracker (from Tim Marchok, GFDL)

● The HYCOM component
  o CMEPS based ocean coupling with updated exchange flux variables
  o Updated 1/12-degree NATL domain (1-45.78N, 261.8-352.5E) L41
  o Ocean IC from RTOFSv2 with persistent oceanic LBC
  o Atmospheric forcing from GFSv16 grib2 files for non-overlapping area
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
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

- Launch
- ATM_prep
- ATM IC
- OCN_prep
- ATM_LBC
- FGAT
- 3DEnVar
- Forecast
- Post
HAFS vo.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