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

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Revised HFIP Goals aligned with the Weather Act

1. Reduce forecast guidance errors, including during RI, by 50% from 27

2. Produce 7-day forecast guidance as good as the 27 5-day forecast guidance

3. Improve guidance on pre-formation disturbances, including genesis timing, and track and intensity forecasts, by 20% from 27

4. 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
HAFS: Hurricane Analysis and Forecast System

Goals:

• Develop FV3 based multi-scale model and data assimilation package capable of providing analyses and forecasts of the inner core structure key to improving size and intensity predictions, as well as the large-scale environment that is known to influence the TC’s motion.

• Provide an advanced Hurricane Analysis and Forecast System for cutting-edge research within the outlined Next Generation Global Prediction System (FV3) plans for the Unified Forecast System.
# Ongoing Efforts at EMC Towards Simplified Production Suite

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

- R&D for HAFS to advance deterministic and ensemble prediction capabilities
- R&D for fusion of modeling, data assimilation and observations to produce an analysis of record
- R&D for ensemble post-processing to extract guidance and uncertainty information
HAFS: Guidance & Products

2. Improve probabilistic guidance
   - Calibrate guidance with HAFS
   - Incorporate dynamically-based uncertainty into hazard models and products
   - R&D for hazard-specific products from HAFS

Potential Storm Surge Flooding Map

Planned improvements to P-Surge to Improve the Potential Storm Surge Flooding Map

3. Enhance communication of risk and uncertainty
   - Evaluate TC products for the effective communication of risk
   - Modernize TC products as informed by social and behavioral science
HAFS Experimental Configurations

HAFS domains

Blue: Global with 3km static nest

Purple: 3km Stand-Alone Regional Model

HAFS 0.A:
The NATL basin focused standalone regional domain configuration
- C768 with a refinement ratio of 4
- the regional domain size: 2880x1920 (~85x56deg)

HAFS 0.B:
The NATL basin focused global-nesting domain configuration
- C768 with a refinement ratio of 4
- the nested domain size of 2880x1536 (~85x45deg)
Hurricane Moving Nest
Single 3km Nest on Global Parent
Hurricane Moving Nest
Two Static Nests on Two Tiles

- Stable runs to 96 hours
- Scalable performance
- 24 (12) cores global (nest)
- 1 nest:36 cores: 1:29
- 2 nests:48 cores: 1:32
- Validation underway
- Original single nest results identical
- Multiple nests alter forecast in expected ways

Maria, Jose (NATL) and Otis (EPAC)

- 10m wind speeds
- Init: 270918 00Z
- 4x refinement (~25km)
Incremental approach to nest development:
  - Two static nests (almost done)
Incremental approach to nest development:

- Two static nests (almost done)
- Telescoping static nests
Incremental approach to nest development:

- Two static nests (almost done)
- Telescoping static nests
- Nest moving within one tile
Incremental approach to nest development:

- Two static nests (almost done)
- Telescoping static nests
- Nest moving within one tile
- Nest moving across an edge (likely needed for recurving cases and long tracks)
Incremental approach to nest development:

- Two static nests (almost done)
- Telescoping static nests
- Nest moving within one tile
- Nest moving across an edge (likely needed for recurving cases and long tracks)
- Nest crossing a corner (hopefully less frequent but needs to be dealt with)
HAFS Sub-Projects

• Reproduce HWRF/HMON functionality with FV3 based HAFS
• Accelerate multiple, moving nest implementations in FV3
• FV3 nests coupling to ocean and waves using NEMS/CMEPS NUOPC
• Implement vortex initialization for FV3
• Implement inner-core Hybrid En-VAR DA
• Implement HWRF Physics in FV3 using CCPP
• Coupling advanced LSM, hydrology, inundation and surge models (future)
Major sub-tasks for HAFS in the first year

<table>
<thead>
<tr>
<th>Task ID</th>
<th>Subtasks</th>
<th>Start Date</th>
<th>Completion Date</th>
<th>Lead</th>
<th>Dependendees</th>
<th>Collaborators</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Implement HWRF physics in FV3 through CCEPP</td>
<td>July 2019</td>
<td>June 2020</td>
<td>EMC  (85K)</td>
<td>None</td>
<td>GMTB/GSD (90K)</td>
<td>3A.2</td>
</tr>
<tr>
<td>1.6</td>
<td>DA capability in the regional stand-alone FV3</td>
<td>June 2019</td>
<td>May 2020</td>
<td>EMC  (170K)</td>
<td>EMC’s ongoing regional DA project</td>
<td>AOML</td>
<td>3A.2</td>
</tr>
<tr>
<td>1.9</td>
<td>Vortex initialization and storm relocation for FV3</td>
<td>June 2019</td>
<td>May 2020</td>
<td>EMC  (170K)</td>
<td>None</td>
<td>AOML</td>
<td>3A.2</td>
</tr>
<tr>
<td>1.12</td>
<td>Develop hurricane specific model diagnostic products for HAFS v0.A and v0.B</td>
<td>July 2019</td>
<td>June 2020</td>
<td>AOML</td>
<td>None</td>
<td>GFDL, EMC</td>
<td>3A.1</td>
</tr>
<tr>
<td>1.18</td>
<td>Advance moving nest framework for existing idealized/semi-idealized vortex (without physics)</td>
<td>June 2019</td>
<td>May 2020</td>
<td>AOML</td>
<td>Task 1.7</td>
<td>GFDL, EMC</td>
<td>1A.4</td>
</tr>
<tr>
<td>1.20</td>
<td>Prepare and Run HAFSv0.A and HAFSv0.B experiments, document performance and the importance of global parent</td>
<td>June 2019</td>
<td>November 2019</td>
<td>EMC (170K)</td>
<td>Tasks 1.1, 1.2 and 1.9</td>
<td>AOML</td>
<td>3A.2</td>
</tr>
</tbody>
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HAFS Development Coordination

- Bi-weekly HAFS Development Meetings (HFIP)
- Published HAFS user/developer guide materials
  - **HAFS Developer Guide; Quick Start for HAFS Developers; Quick Start for HAFS Users**
- HSupp activities to gain momentum once funding in place and staff hired
- Need dedicated HPC resources (MSU, Cloud?? Others?)
Questions?