Toward Initial Operational Capability: Progresses, Challenges, and Issues in Developing and Improving HAFS

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Background

- HAFS is one of the UFS-R2O projects under UFS (Unified Forecast System), focusing on transitioning tropical cyclone modeling research to operation.

- HAFS has been running in real time for three years (2019-2021), Initial Operational Capability (IOC) is planned in 2023, replacing HWRF/HMON.
HAFS Development Status

- Reproduced 2021 real-time experiment (HAFSv0.2A) results with latest GFS dynamic/physics code base
- Developed moving nest capability
- Implemented CMEPS based HYCOM coupling for moving nest
- Developed DA_tool for grids interpolation
- Implemented vortex initialization capability
- Implemented 6-hrly cycle DA system for storm-region or entire domain
- Post-process: output both parent/nest domain, all HWRF/HMON products including model satellite imagery
- Added all above components to HAFS workflow
Development of HAFS (6/2 km with moving nest, VI/DA)

- FSP > 50%, Performed better than HWRF
- HDVD intensity forecast outperformed HWRF at most of the forecast lead times
- Intensity forecast skills are improved by adding moving nest, VI, and DA. (HDVD vs H3BL)

H3BL: Baseline, 3 km single domain
HDVD: Latest version of HAFS, 6/2 km moving nest, VI, and DA
Latest Track/Intensity forecast errors/skills (HAFS vs HWRF)

- Track-Error
- Vmax-Error
- Vmax-Bias
- Track-Skill
- Vmax-Skills
## HAFS IOC Primary/Secondary Configuration

<table>
<thead>
<tr>
<th>HAFSv1.0</th>
<th>Domain*</th>
<th>Resolution*</th>
<th>DA/VI</th>
<th>Ocean/Wave Coupling</th>
<th>Physics</th>
<th>Basins</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Config.</strong></td>
<td>Storm-centric with one moving nest, parent: ~81x81 degree, nest: ~12x12 degree</td>
<td>Regional (regular Gnomonic), ~6/2 km, ~L81, ~2 hPa model top</td>
<td>VI and DA</td>
<td>Two-way HYCOM, one-way WW3 coupling for NHC AOR</td>
<td>Physics suite-1</td>
<td>All global Basins NHC/CPHC/JTWC Max 7 Storms Replace HWRF</td>
</tr>
<tr>
<td><strong>Secondary Config.</strong></td>
<td>Storm-centric with one moving nest, parent: ~81x81 degree, nest: ~12x12 degree</td>
<td>Regional (ESG), ~6/2 km, ~L81, ~2 hPa model top</td>
<td>VI and/or DA (TBD)</td>
<td>Two-way HYCOM No Wave</td>
<td>Physics suite-2</td>
<td>NHC/CPHC Max 5 Storms Replace HMON</td>
</tr>
</tbody>
</table>

*Subject to change based on T&E and available computer resource*
## HAFS Model Physics

<table>
<thead>
<tr>
<th></th>
<th>Suite 1</th>
<th>Suite 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulus Convection (Shallow &amp; Deep)</td>
<td>sa-SAS: Positive definite mass flux; Stochastic convective organization; Optimization for CAPE</td>
<td>sa-SAS: Positive definite mass flux; Stochastic convective organization; Optimization for CAPE, TC-specific tuning</td>
</tr>
<tr>
<td>Surface Layer</td>
<td>GFS: Sea spray, optimization</td>
<td>GFS: Sea spray; optimization, TC-specific tuning</td>
</tr>
<tr>
<td>PBL</td>
<td>Modified sa-TKE-EDMF: Positive definite tracer advection; optimization</td>
<td>Modified TKE-EDMF: Positive definite tracer advection; optimization, TC-Specific tuning</td>
</tr>
<tr>
<td>Gravity Wave Drag</td>
<td>Orographic/Convective: On/Off</td>
<td>uGWP.v1 (TBD)</td>
</tr>
<tr>
<td>Land Surface Model</td>
<td>Noah LSM</td>
<td>NOAH MP and VIIRS veg type</td>
</tr>
<tr>
<td>Microphysics</td>
<td>GFDL MP</td>
<td>Thompson MP (requires ~10% more resources)</td>
</tr>
<tr>
<td>Radiation (LW &amp; SW)</td>
<td>RRTMG (30 min)</td>
<td>RRTMG (30 min)</td>
</tr>
</tbody>
</table>
Improving intensity and RI forecasts

- HWRF over-predicted intensities for some cycles of Hurricane Grace, HDVD (6/2km with VI/DA) provided better intensity forecasts for these cycles, but failed to predict RI for the later cycles.

- HWRF under-predicted some RI cycles for Hurricane Ida, HDVD did better jobs for these cycles.

- Still working on HAFS to further improve intensity forecast.
Verification for RI Cycles

Adding VI and DA components help improving RI forecasts in HAFS
More physics tuning, especially, air-sea interaction, PBL, Convection schemes are required to further improve RI forecasts

Courtesy of Lin Zhu
Spatial Intensity Forecasts Variability

Samples are based on Hurricanes Grace 07L, Henri 08L, Ida 09L, Larry 12L, Peter 16L, Sam 18L
Will re-evaluate when more samples are available.

Courtesy of George Alvey
Comparison of High Frequency Vmax

Operational HWRF
Hurricane IDA 09L, 00 UTC August 28, 2021

HAFS baseline with VI and DA
Hurricane IDA 09L, 00 UTC August 28, 2021

~15kt Vmax fluctuation
Isolated convective cells are identified as R34

Courtesy of Weiguo Wang
Challenges ahead

- Code speed-up to fit operation time window
- Physics improvement
- HAFS T&E for other basins (non-NHC)
- Code NCO compliance
- Transition HYCOM to MOM6, 3-way coupling
- Flexible parent-nest ratio for moving nest
- Multiple moving nests in basin-centric domain
- Advanced DA system
- GSI to JEDI transition
Thank you!