Developing Hurricane Analysis and Forecast System: Initial Operational Capabilities and Future Priorities

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Background
Adopted from Bin Liu's workflow

High-resolution deterministic coupled HAFS

- ocn_prep
- wav_prep
- atm_prep
- atm_ic
- atm_lbc
- atm_init
- atm_vi
- atm_vi_fgathh
- analysis (FGAT, 3DEnVar, 4DEnVar, IAU)
- atm_merge
- coupled_forecast
- ocn_post
- wav_post
- atm_post
- graphics
- product
- launch
- input
- COMgfs (gfs, gdas, ens)
- WWIII, COMrtofs, DCOM
- obs_proc
- enkf_mean
- enkf_hx_mean
- enkf_hx_ens
- enkf_update
- enkf_recenter
- forecast_ens
- atm_post_ens
- product_ens
- archive

Prior cycle

Next analysis/forecast cycle
HAFS Current Status

Workflow
- Configurable moving nest capability
- Optional vortex initialization
- Configurable storm-region and/or entire domain data assimilation
- Post-process both parent and nest domain
- Research and forecast products

Moving nest
- Storm following nest
- Full physics nest motion
- Auto storm tracking
- Namelist option for moving nest
- Optimized running moving nest

Ocean/Wave coupling with moving nest
- HYCOM ocean coupling with HAFS parent
- Downsacle HAFS parent SST for nest domain
- One-way coupling with WW3: generate HAFS/wave IC/BC from GFS/wave
HAFS Current Status

Utilities for DA and VI
- Interpolating/remapping functions
- Merging domains
- Interface to Data Assimilation
- Vortex consistency
- First Guess at Appropriate Time (FGAT)

Data Assimilation
- Storm-region inner-core DA
- DA cycling for entire parent domain for the coarser res. (~6km)
- 3DEnVAR with GDAS (or HAFS ensemble)
- Additional obs. Assimilated
  - Tail Doppler Radar (TDR)
  - Next Generation Weather Radar (NEXRAD)
  - Drifting corrected Dropsondes
  - Metar observations
  - GOES-16 AMVs
  - Test CIMSS Rapid scan winds

Infrastructure
- WriteGrid component for multiple domains
- FMS support telescopic & multiple nests

[Map showing HAFS Storm-Focused Domain with labels for ATM Parent, ATM Nest, HYCOM Ocean, WWII Wave]
HAFS Development Priorities: before IOC

- Merge HAFS developments back to ufs-weather-model
  - Moving nest related developments
  - Static and moving nest coupling
  - WriteGrid component support for moving nest
  - Merge GSI FGAT capability back to GSI master

- Workflow
  - MET-TC based verification package into workflow
  - Optimized workflow

- Science Evaluation
  - T&E for each of new components and configurations

- Real-time HFIP demo
  - T&E for each of new components, configurations and other basins

- Physics optimization in current suite

- HAFS Pre-processing
  - Generate a regional ESG grids for moving nest configuration
  - Generate IC for regional ESG parent and nest
  - Optimize ICs for Ocean and Waves
HAFS Development Priorities: after IOC

- **Moving nest**
  - Multiple storms
  - Flexible nesting refinement

- **Data assimilation**
  - New data ingestion including all-sky radiance
  - 4DEnVar
  - Atmosphere/Ocean coupled DA
  - Multi-scale DA
  - JEDI infrastructure
  - JEDI transition

- **Physics evaluation, transition & development**
  - PBL for TC application
  - NOAH-MP evaluation
  - saSAS upgrade, transition, & evaluation
  - Microphysics parameterization upgrade

- **Ocean model transition**
  - Develop MOM6
  - Prepare HYCOM to MOM6 transition
HAFS Development Priorities: Future Coupling
HAFS Development Priorities: future challenges or innovation

- **Moving nest**
  - Global moving nest

- **Data assimilation**
  - Efficiency vs. accuracy
  - Computer technology advancement
  - Atmosphere/Ocean coupled DA: strongly vs. weakly
  - All-sky radiance: CRTM vs. RRTMG
  - New DA methodology: scale-aware, particle filter, etc.
  - DA and physics parameterizations

- **Observations**
  - New observations
  - Observation strategy

- **Products**
  - Ensemble products
  - Product fidelities

- **Physics**
  - AI and physics parameterizations
  - Sub-kilometer physics
  - Physics interactions

\[
R^2(y, \hat{y}) = 1 - \frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2}
\]

LM: Linear Model  RF: Random Forest Model
Summary

- HAFS is ready for 2022 hurricane season real-time HFIP demo
- HAFS is aiming to initial operational implementation in 2023 hurricane season
- HAFS development and operational implementation will prioritize the following aspects:
  - Moving nest refinement
  - Multiple moving nests
  - New DA methodologies and data
  - New physics for high-resolution
  - Synchronize development to NOAA’s Unified Forecast System (UFS)

Dare to rethink! Dare to be innovative! Dare to be wrong!