Hurricane Analysis and Forecast System (HAFS) Data Assimilation Advancements

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Nov. 19, 2020
The Current HAFS DA Development Team

- EMC hurricane project team in collaboration with the CAM group
- OU collaborators
- UMD collaborators
- HRD/CIMAS collaborators
- University at Albany collaborators
- DTC collaborators
- HAFS DA related group meetings
  - EMC HAFS DA biweekly tag-up meeting
  - HAFS DA community bi-weekly telecon meeting
  - HAFS DA coding/working sessions (focusing on technical issues, based on needs)
Scientific and Technical Goals

Scientific
- Improve track and intensity forecasts with superior analyses of the large scale and vortex structure
- Improve the pre-formation and cyclogenesis in the regional framework

Technical
- Innovate upon global data assimilation system to provide improved HAFS initial large-scale environment (e.g., cycle whole state, use HAFS-specific bias correction)
- Leverage HWRF DA techniques to improve vortex structure
Requirements and Milestone for HAFS-DA

A Configurable HAFS Data Assimilation workflow that includes various DA components/options, and meets both operational and research requirements, easy transition R2O and O2R

Basic HAFS-DA system

- Cold start from GFS analysis (without DA)
- Warm start the current forecast cycle from its prior forecast cycle (must be bitwise reproducible without DA)
- GSI-based TC relocation capability (configurable, on/off)
- 3DVar DA to assimilate the observational data used by operational HWRF
- 6-hourly hybrid 3DEnVar by using GDAS ensemble
- HWRF-alike vortex initialization, including vortex relocation and modification (Configurable, on/off)
- Nest-parent domain merging techniques
- Wavenumber increment truncation to control how the DA increments are used in the model (especially for the inner-core area for strong storms)
- 3-hourly (configurable) FGAT capability

*Complete
Requirements and Milestone for HAFS-DA

Near-term

- 1-hourly (configurable) 3DVar
- 1-hourly (configurable) 3DEnVar with GDAS ensemble
- 6-hourly hybrid 3DEnVar by using self-cycled ensemble system with dual resolution capability
- 1-hourly (configurable) EnKF
- 1-hourly (configurable) hybrid 3DEnVAR by using self-cycled ensemble system with dual resolution capability
- Storm inner-core (and/or moving nest focused) high-resolution DA
- Online clear-air satellite bias correction

Mid-term wishlist

- IAU (incremental analysis updating) capability
- 6-hourly (configurable) 4DEnVar
- GOES-16 radiance DA capabilities (with online bias correction)

Longer-term innovations and advancements

- Effective Multiscale DA for TC
- Atmosphere-ocean (earth-system) coupled DA
- JEDI transition
Potential HAFS ENSDA Workflow Schematics

First cycle

- grid_Exxx (optional)
- chgres_ic/bc_Exxx
- forecast_Exxx
- post/product_Exxx
- GDAS ensemble

next DA or forecast cycle

- analysis_vr_Exxx
- EnKF_analysis (epos->eobs->eomg->eupd)
- recenter (ecen)

EnKF system

- chgres_ic/bc_Exxx
- forecast_Exxx
- post/product_Exxx

First cycle

- grid (optional)
- chgres_ic/bc

- analysis (3DVar/3DEnVar)
- analysis_vr (gsi vortex relocate)

- forecast
- post/product

next DA or forecast cycle

- chgres_ic/bc

Current Status of HAFS-DA Development

1. **Grid (optional)**
2. **CHGRES_IC/BC**
3. **Forecast Post/Product**
4. **Analysis (3DVar/3DEnVar)**
5. **Analysis VR (GSI vortex relocate)**
6. **GDAS Ensemble**
7. **Forecast Post/Product**

**First cycle**

**Next DA or forecast cycle**
Technical Testing for Hurricane Laura (13L2020)
Control (cold-start from GFS analysis) vs 3DEnVar with GDAS ensembles

Experiment CTRL:
- Same as the HAFSv0.1A configuration
- Regional and ocean coupled
- Running on Orion

Experiment 3DVar:
- Simple 3DVar

Experiment 3DEnVar:
- 3DEnVar with GDAS ensembles:
  - Initialized 2020082000, first cycle of Hurricane Laura, weaker initial Vmax
  - Initialized 2020082406, when Laura started developing

Experiment GSIVR+3DEnVar:
- GSI based vortex relocation
- 3DEnVar with GDAS ensembles

Experiment 3DEnVar with FGAT (OU):
- GSI based vortex relocation
  - 3DEnVar with HAFS ensembles
  - FGAT
The HAFS first-guess is used to create synthetic profile-type “observations.”
Ocean-relative observations are sampled at radial intervals with respect to the predicted TC location within specified radius (< 600Km).
- The positions for the observations is updated to reflect their respective locations relative to the observed TC-vitals position.
- Run GSI to move the TC to observed position.

Before VR

After VR

VR increments
Storm-Scale Comparison
Before and After 3DEnVAR

Before DA

After DA, Analysis

GSI Increments
Synoptic-Scale Comparison at F000

CTRL (top) VS 3DEnVAR (bottom)

850hPa wind and streamline

850hPa T, GHT, and wind

700-500hPa RH, 700hPa Geo. Height (x10m), and Wind (kt)

3DEnVar
Preliminary analysis comparison

From Xuguang, OU
Towards First Operational HAFS DA system

Target option 1  ---- storm-centric w/ one moving nest (4.5km/1.5km)

1. GSI based or/and possibly HWRF-alike vortex relocation, vortex modification
2. Self-cycled DA in inner-core regions
3. 3DEnVar, 3hrly FGAT DA
4. Large-scale from GFS analysis

Target option 2 ---- static domain; no moving nests (3km)

1. GSI based relocation or/and HWRF-alike intensity modification
2. Self-cycled DA for entire domain
3. 3DEnVar, 3hly FGAT or high frequency cycling DA
4. DA for entire domain

Risks/Mitigation:  Moving Nests; Computer resources; DA development delays; Unexpected/poor performance.

1. DA unable to represent vortex structure (Fallback: HWRF-like vortex correction)
2. No resources for self-cycled ensemble (Fallback: GDAS)
3. Large-scale analysis drift (Fallback: re-center to GFS)
HAFS Specific Observation Data

Besides assimilating all observations included in global DA, HAFS Specific observations

- Tail Doppler Radar (TDR)
- Next Generation Weather Radar (NEXRAD)
- Dropsondes with drift
- Mesonet data
- High resolution Atmospheric Motion Vector (AMV)
Future Work

- Leverage Options from global DA
  - All-sky radiance
  - IAU capability
  - All observation data assimilated in GFS/GDAS

- HAFS specific capabilities
  - All HWRF specific innovations for HAFS-DA
  - Cloudy-radiances
  - Ocean Atmosphere DA
  - Contributions from research (R2O). e.g. Effective multi-scale DA, non Gaussian application, etc.

- DA Workflow
  - Continue adding DA options/components to the workflow
  - Leverage JEDI capability