

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

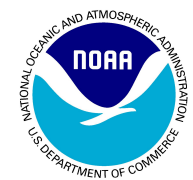
- Improve track and intensity forecasts with superior analyses of the large scale and vortex structure
- Improve the pre-formation and cyclogenesis in the regional framework

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

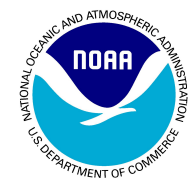
Basic HAFS-DA system

- ❑ 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 3DVar 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

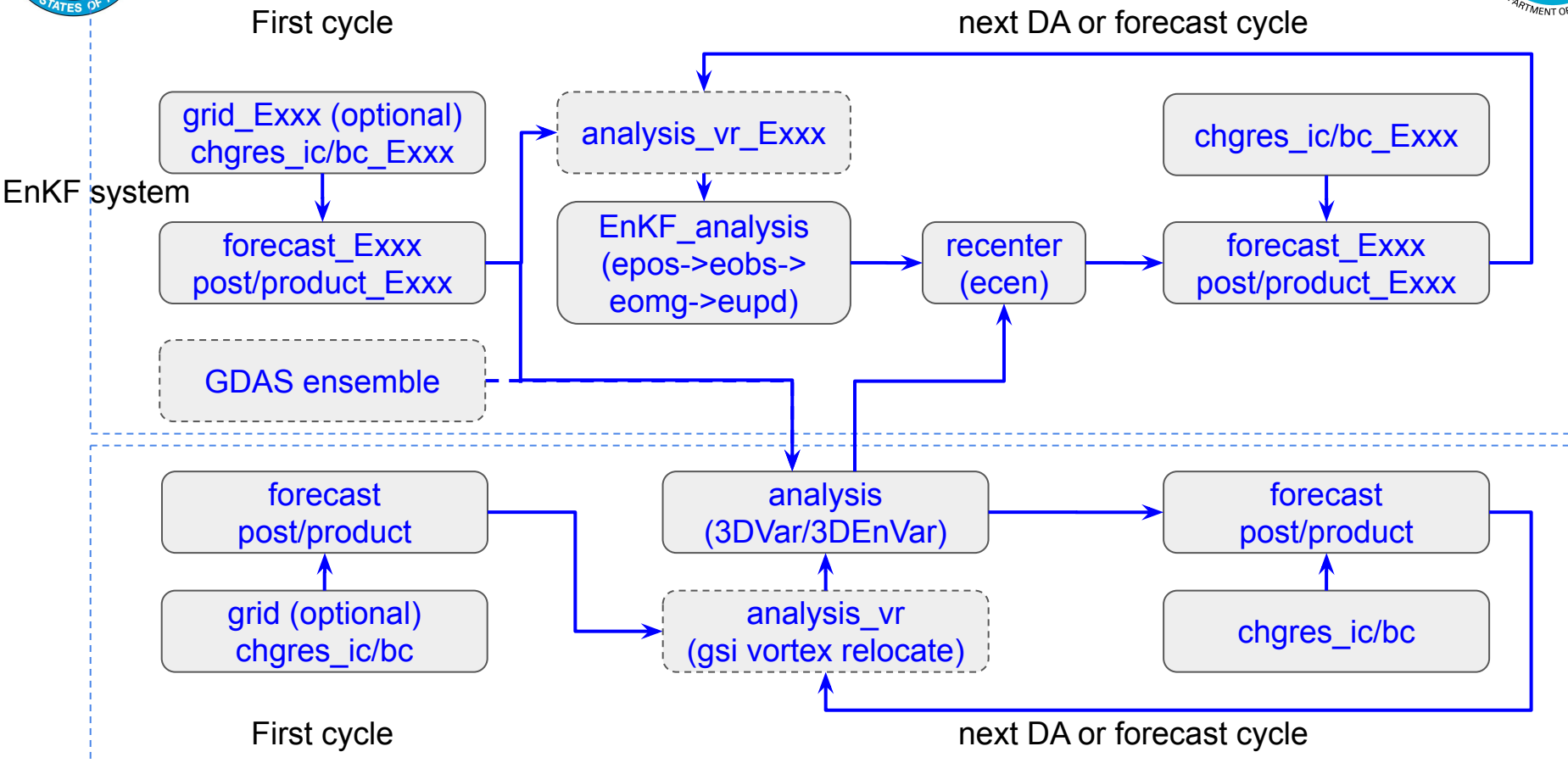
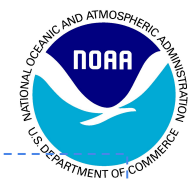
- ❑ IAU (incremental analysis updating) capability
- ❑ 6-hourly (configurable) 4DEnVar
- ❑ GOES-16 radiance DA capabilities (with online bias correction)

Longer-term innovations and advancements

- ❑ Effective Multiscale DA for TC
- ❑ Atmosphere-ocean (earth-system) coupled DA
- ❑ JEDI transition

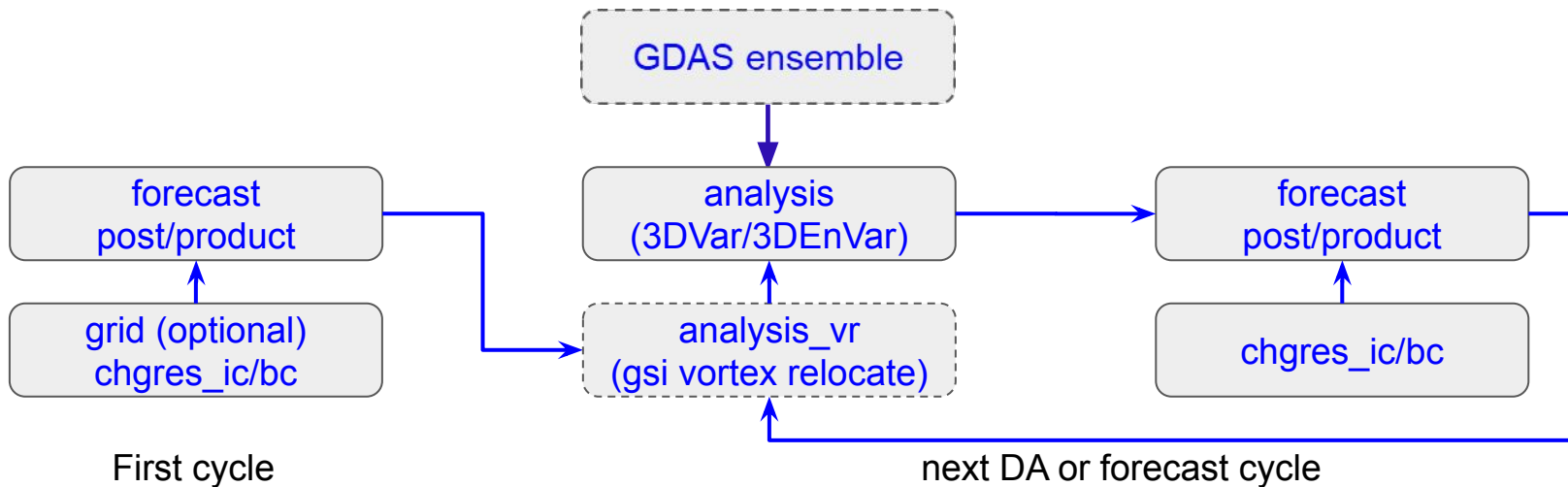
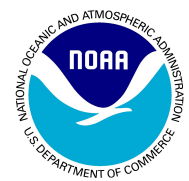


Potential HAFS ENSDA Workflow Schematics



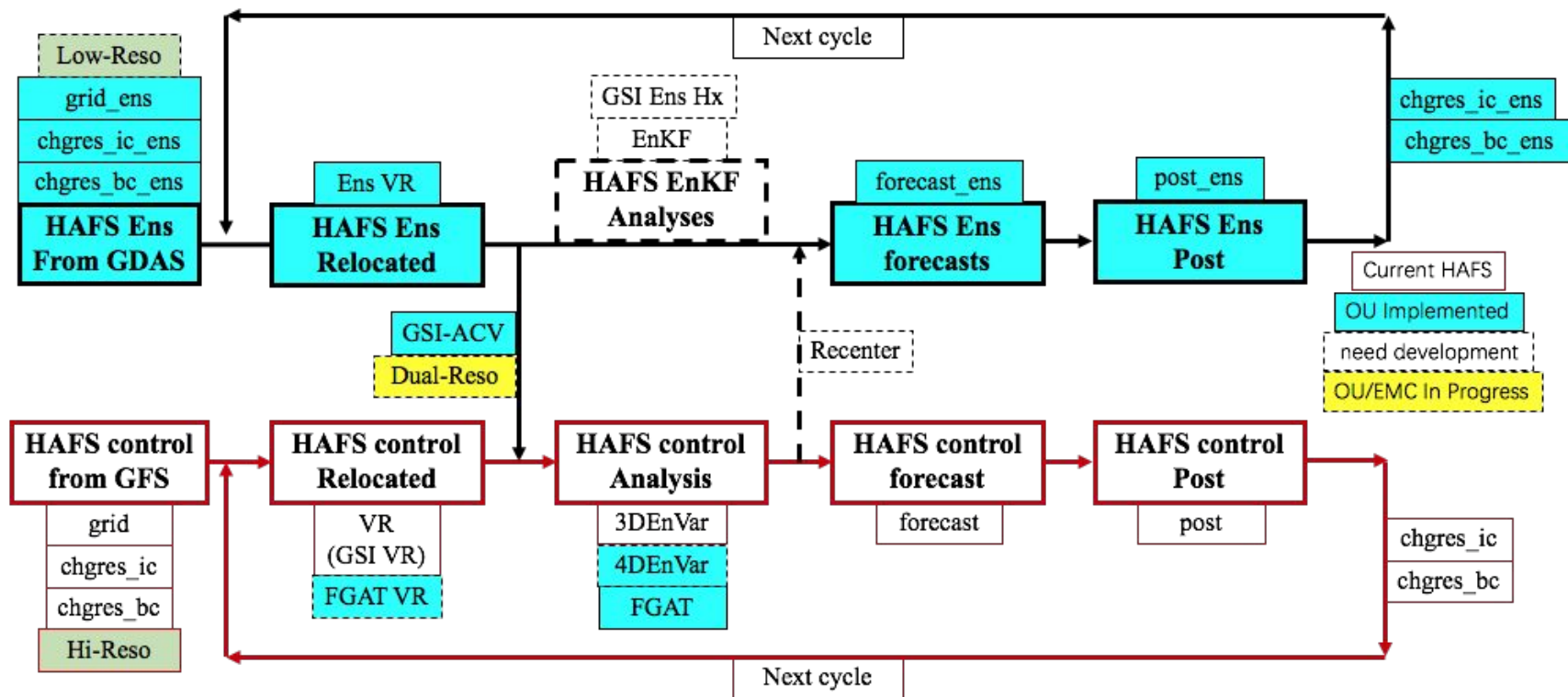


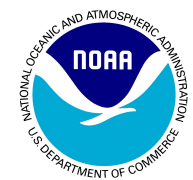
Current Status of HAFS-DA Development





HAFS Workflow plan and updates





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:

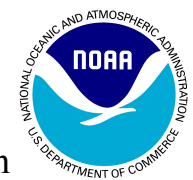
- GSI based vortex relocation
- 3DEnVar with GDAS ensembles

Experiment 3DEnVar with FGAT (OU):

- GSI based vortex relocation
 - 3DEnVar with HAFS ensembles
 - FGAT



GSI based TC Relocation

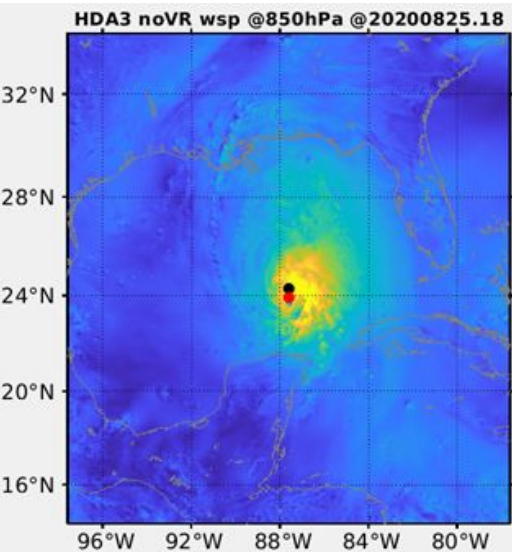


The HAFS first-guess is used to create synthetic profile-type “*observations*”

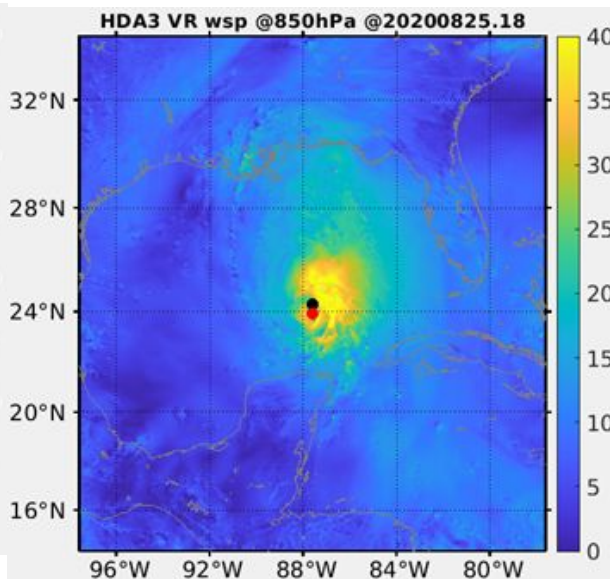
Ocean-relative observations are sampled at radial intervals with respect to the predicted TC location within specified radius ($< 600\text{Km}$)

- 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

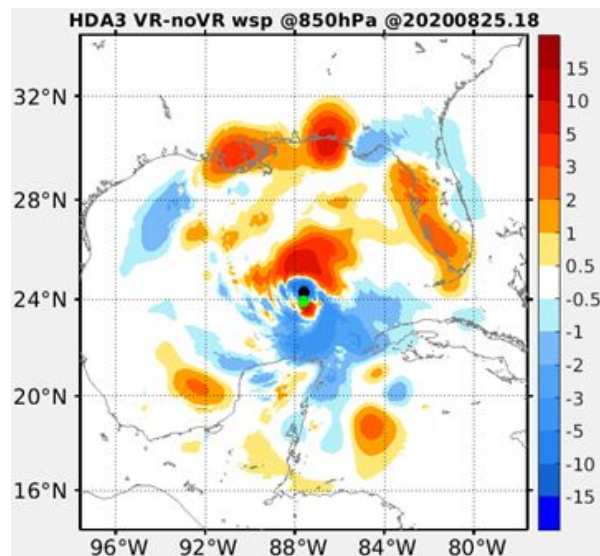
Before VR



After VR



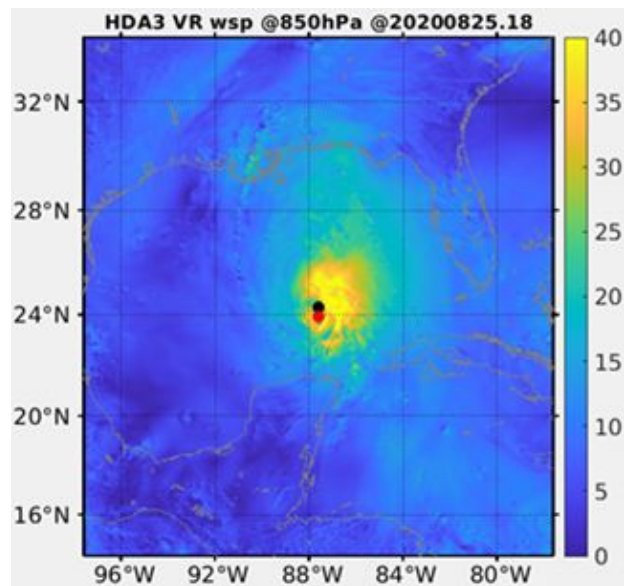
VR increments



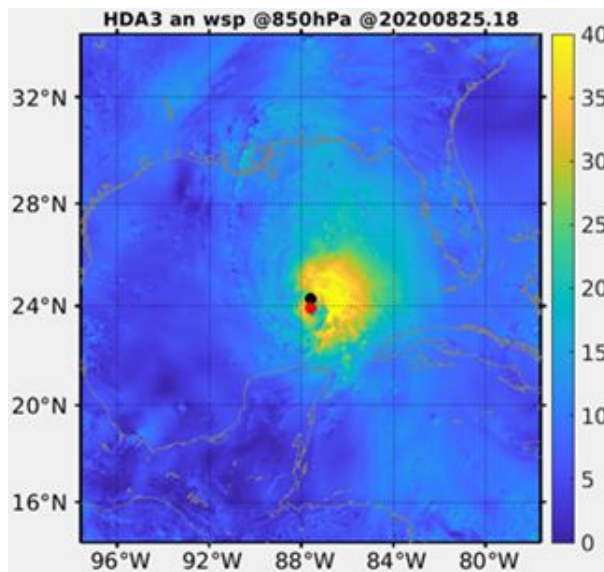
Storm-Scale Comparison

Before and After 3DEnVAR

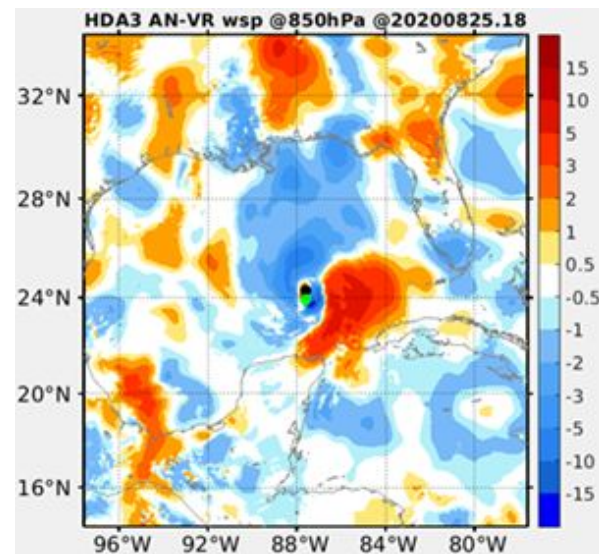
Before DA



After DA, Analysis

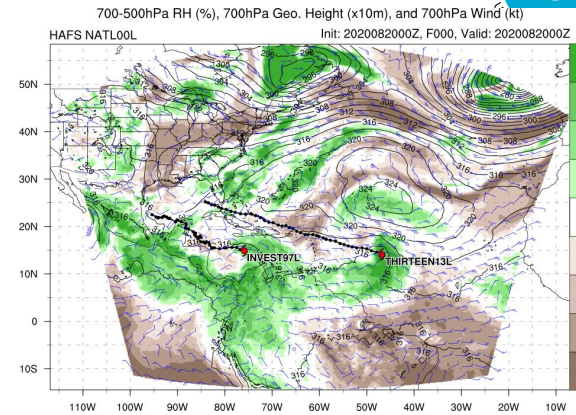
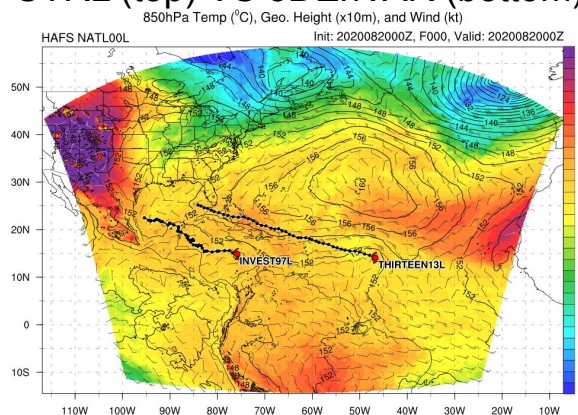
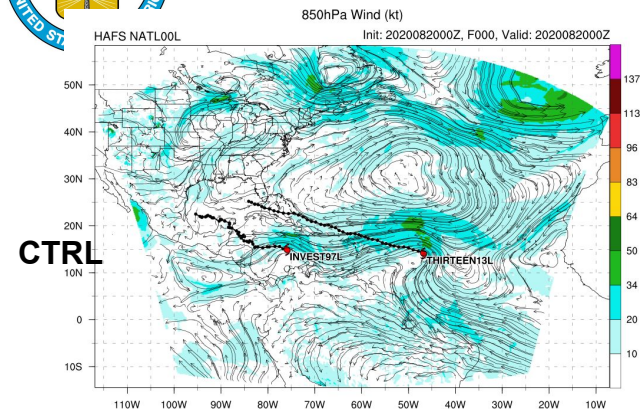


GSI Increments



Synoptic-Scale Comparison at F000

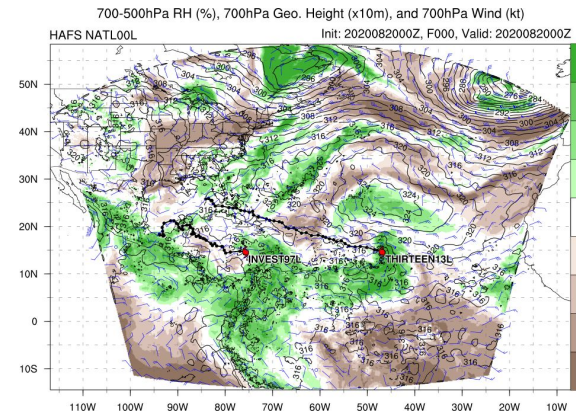
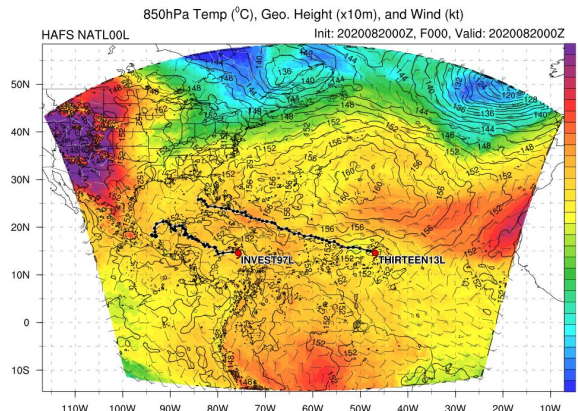
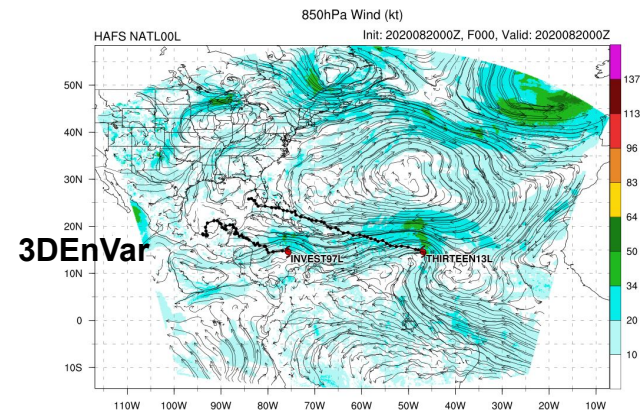
CTRL (top) VS 3DEnVar (bottom)

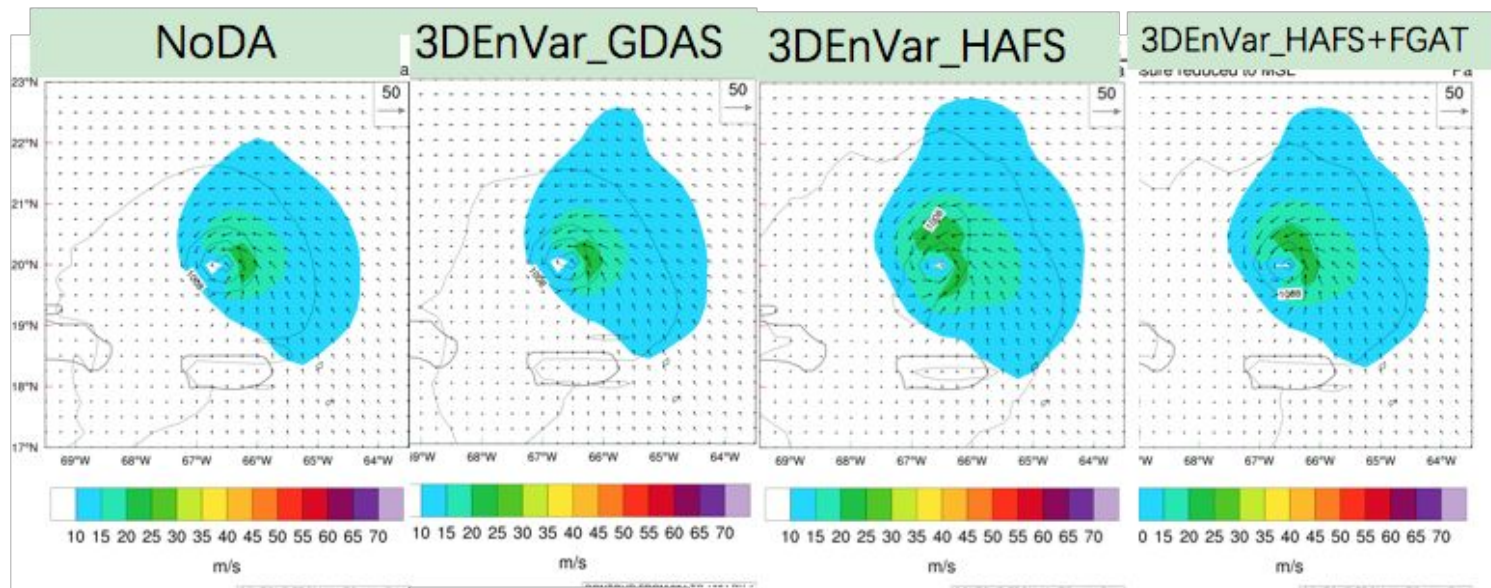


850hPa wind and streamline

850hPa T, GHT, and wind

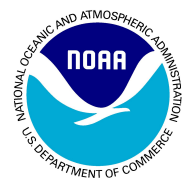
700-500hPa RH, 700hPa GHT, wind







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)

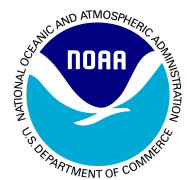
1. GSI based relocation or/and HWRF-alike intensity modification
2. Self-cycled DA for entire domain
3. 3DEnVar, 3hly FGAT or high frequency cycling DA
4. DA for entire domain

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

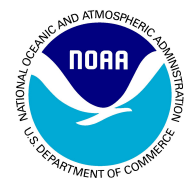


Besides assimilating all observations included in global DA, HAFS Specific observations

- ❑ 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