



Overview of Hurricane Analysis and Forecast System: Current Status and Future Priorities



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HAFS Development Goals

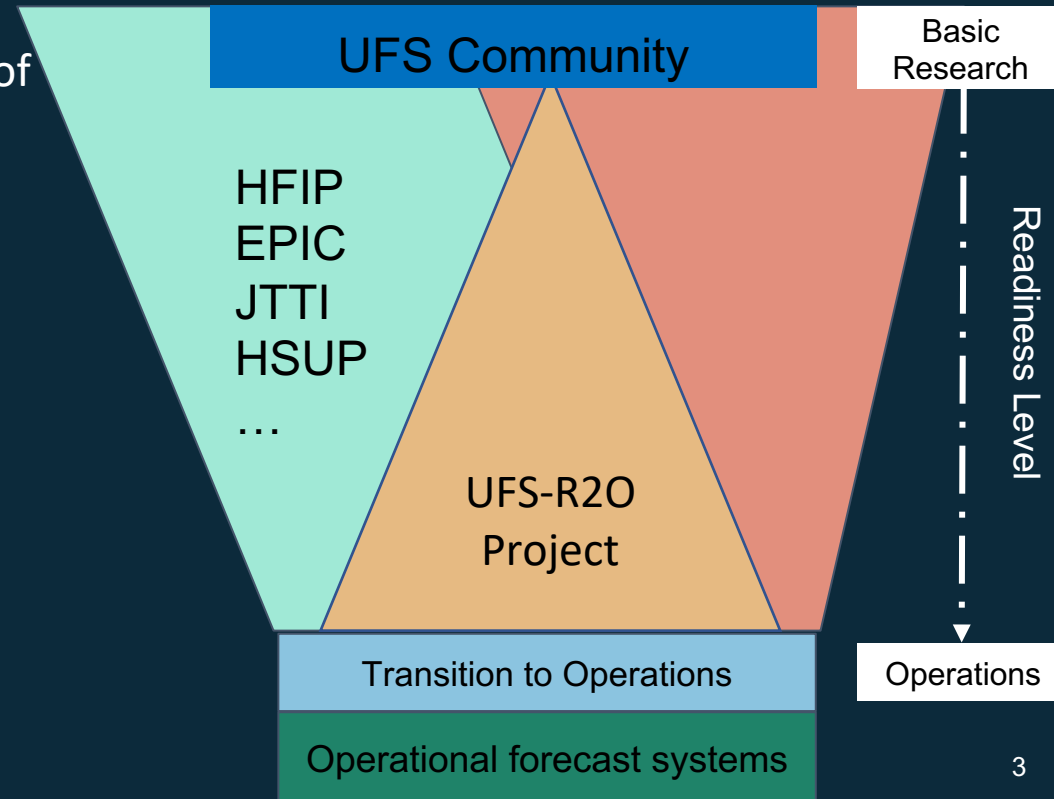
HAFS development is aligned with the latest HFIP strategic plan. Its development goals are to:

- Improve forecast accuracy
 - Hurricane impact areas (track): 50% in 5 years
 - Severity (intensity): 50% in 5 years
 - Special focus: Rapid intensity change
- Extend forecast reliability out to 7 days
- Quantify, bound and reduce forecast uncertainty
- Improve the downstream forecasts

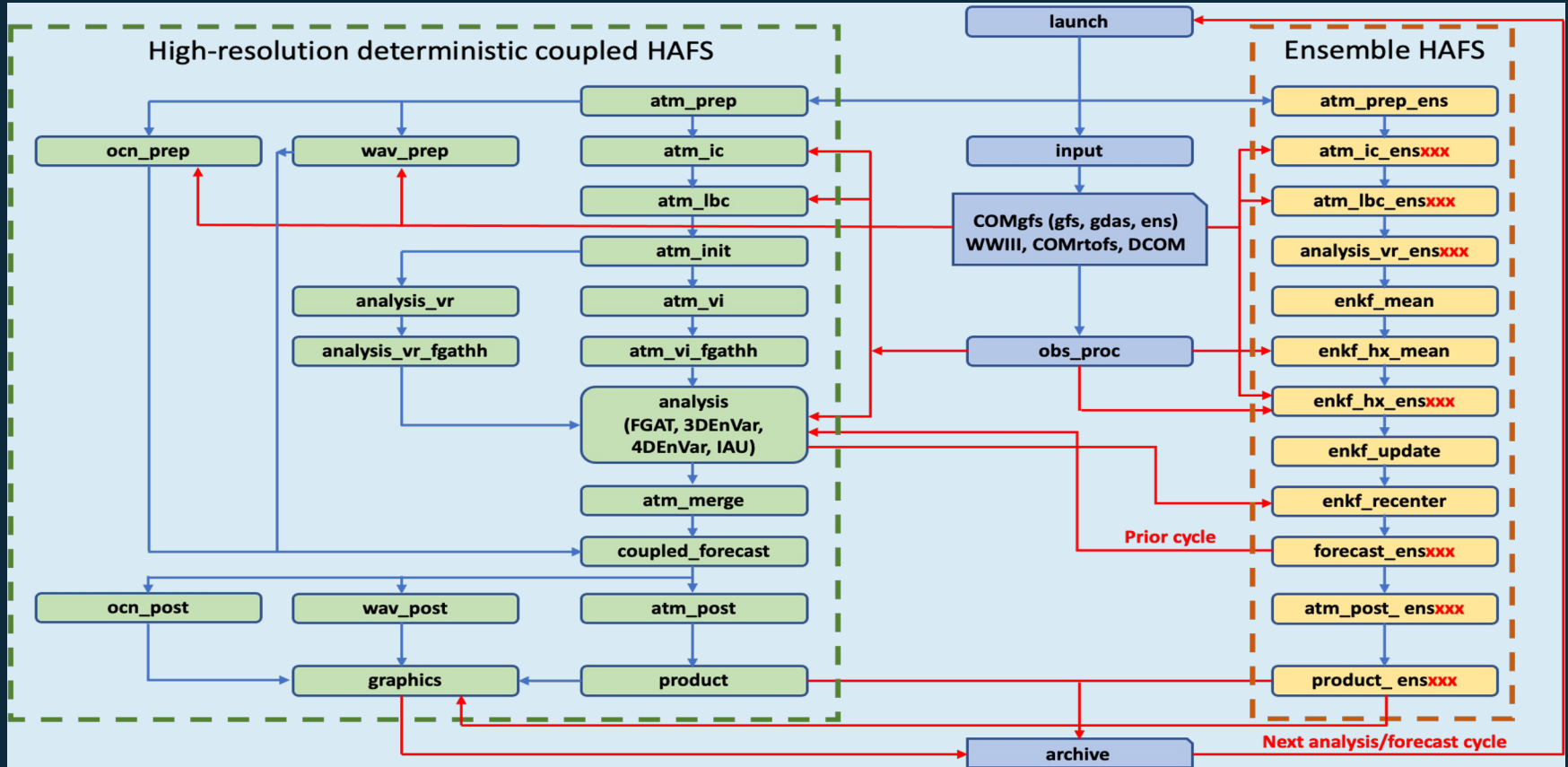
HAFS Development Approach

HAFS is a hurricane application, one of three applications in the UFS-R20 Project. Its development follows the same approach of the UFS-R20 project:

- Develop innovations into operations
- Ensure lower Readiness Level (RL) research in the R20 pipeline
- Leverage other research and development programs and projects
- Transfer high RL research into operations



HAFS Overarch Framework



HAFS Current Status

Workflow

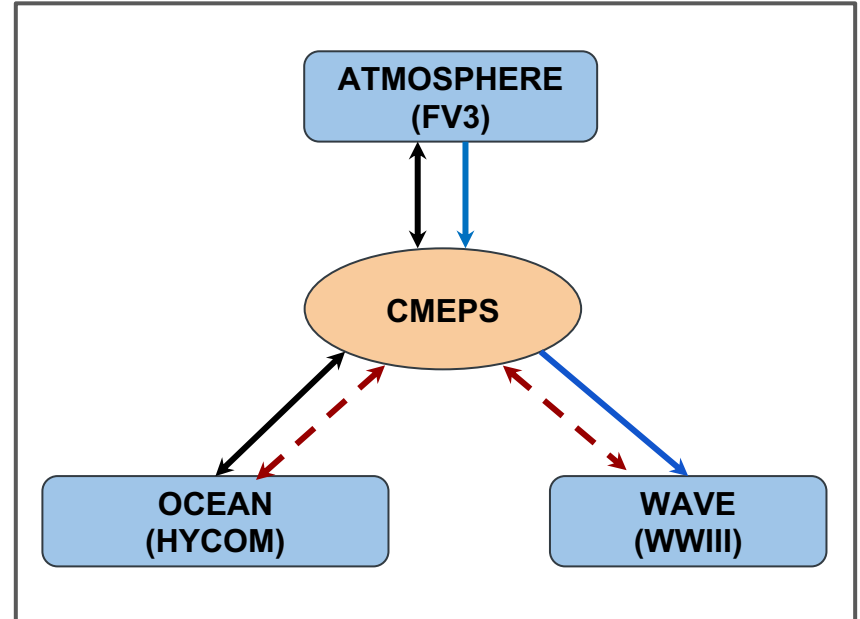
- Configurable moving nest capability
- Optional vortex initialization
- Configurable storm-region and/or entire domain data assimilation
- Post-process both parent and nest domain
- Research and forecast products
- ESG configuration

Moving nest

- Single-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
- Downscale 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

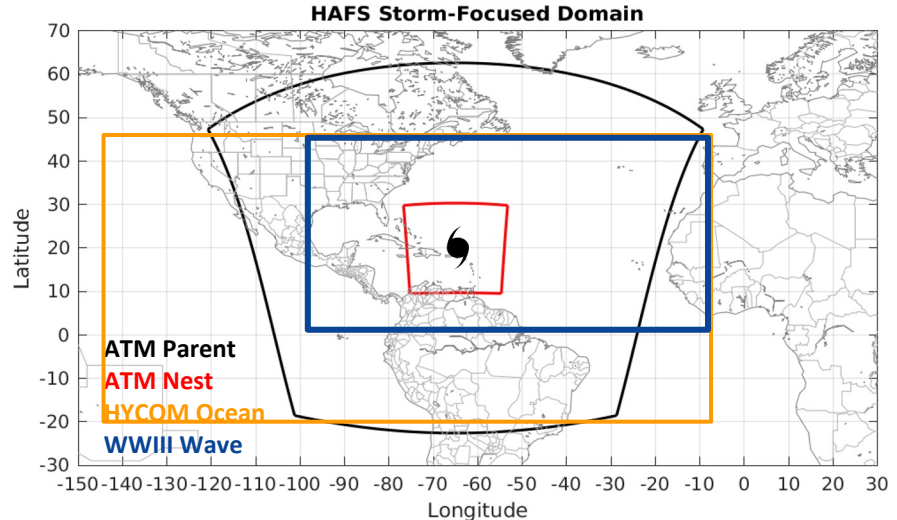
- Interpolating/remapping functions
- Merging domains
- Interface to Data Assimilation
- Vortex consistency
- First Guess at Appropriate Time (FGAT)

Data Assimilation

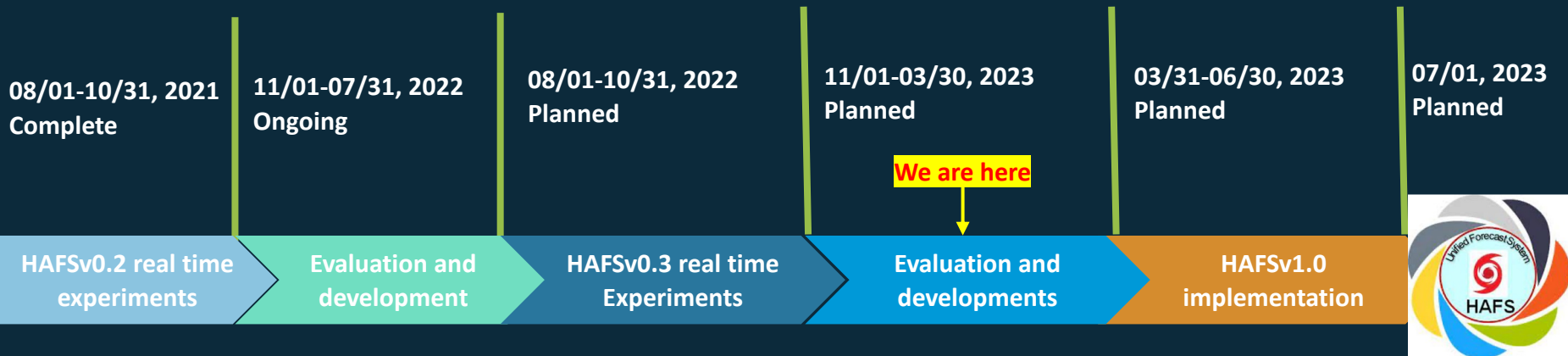
- 6-hourly DA cycling in nested domain region
- +/- 3-hour FGAT window
- 4DEnVar with GDAS ensembles
- Leverage observation used in GFS
- Additional observations assimilated
 - Tail Doppler Radar (TDR)
 - Next Generation Weather Radar (NEXRAD)
 - Drifting corrected Dropsondes
 - Metar observations
 - High resolution GOES-16 AMVs

Infrastructure

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



Timelines for HAFS T20



Prepare New configurations (HAFSv0.3):

- High resolution moving nest
- Updated model physics
- Vortex initialization and Inner-core data assimilation
- T&E to select optimal configurations

Finalize HAFSv1.0

- New GFSv16.3 input
- ESG grid with Dynamic core diffusion tuning
- Vortex initialization threshold
- 4DENVAR using GDAS ensemble
- Enhanced GOES-R AMVs and GOES-18
- NOAA MP LSM with VIIRS Veg Type
- Ocean coupling bug fix
- Unified Gravity Wave Drag, uGWP
- Code modernization and optimization
- Model instability
- JTWC basins T&E

NCO implementation

HAFS Development Priorities: after IOC

- **Moving nest**
 - Multiple storms
 - Flexible nesting refinement
 - Mass adjustment for fine topography consistency in blending zones
 - Code optimization
- **Data assimilation**
 - New data ingestion
 - 4DEnVar
 - Atmosphere/Ocean coupled DA
 - JEDI infrastructure
 - JEDI transition
- **Physics**
 - PBL for TC application
 - NOAA-MP evaluation
 - saSAS upgrade, transition, & evaluation
 - Microphysics parameterization upgrade
- **Ocean and wave model transition**
 - HYCOM to MOM6 transition
 - Atmosphere-MOM6-Wave three-way coupling
 - Coupling scheme

HAFS Development Priorities: future innovation

- **Moving nest**

- Global moving nest
- Telescopic moving nest for LES capability

- **Data assimilation**

- AI/ML technology for DA
- 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 interaction

- **Observations**

- New observations
- Observation strategy

- **Products**

- Ensemble products
- Product fidelities
- 7-day forecast products

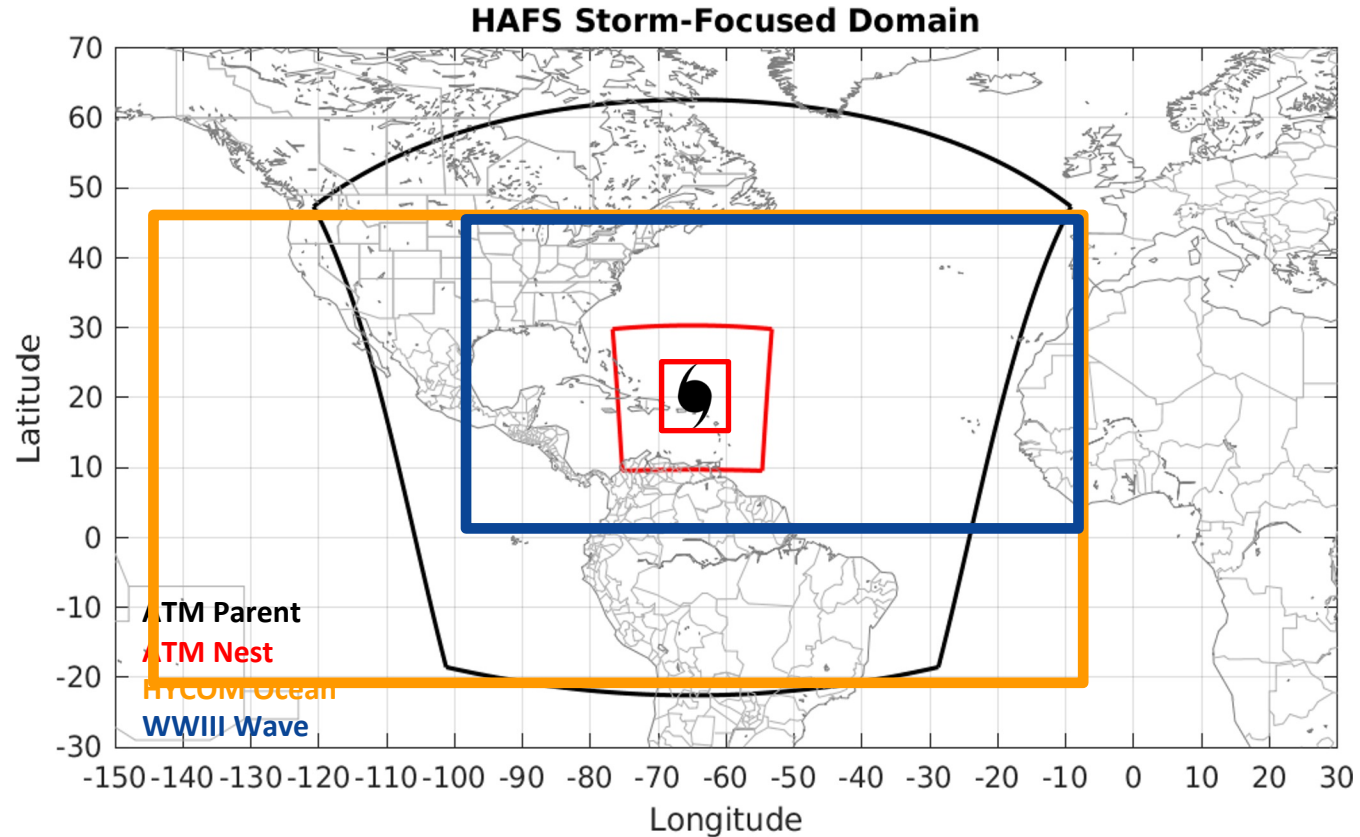
- **Physics**

- AI/ML for physics parameterizations
- Sub-kilometer physics
- Physics interactions

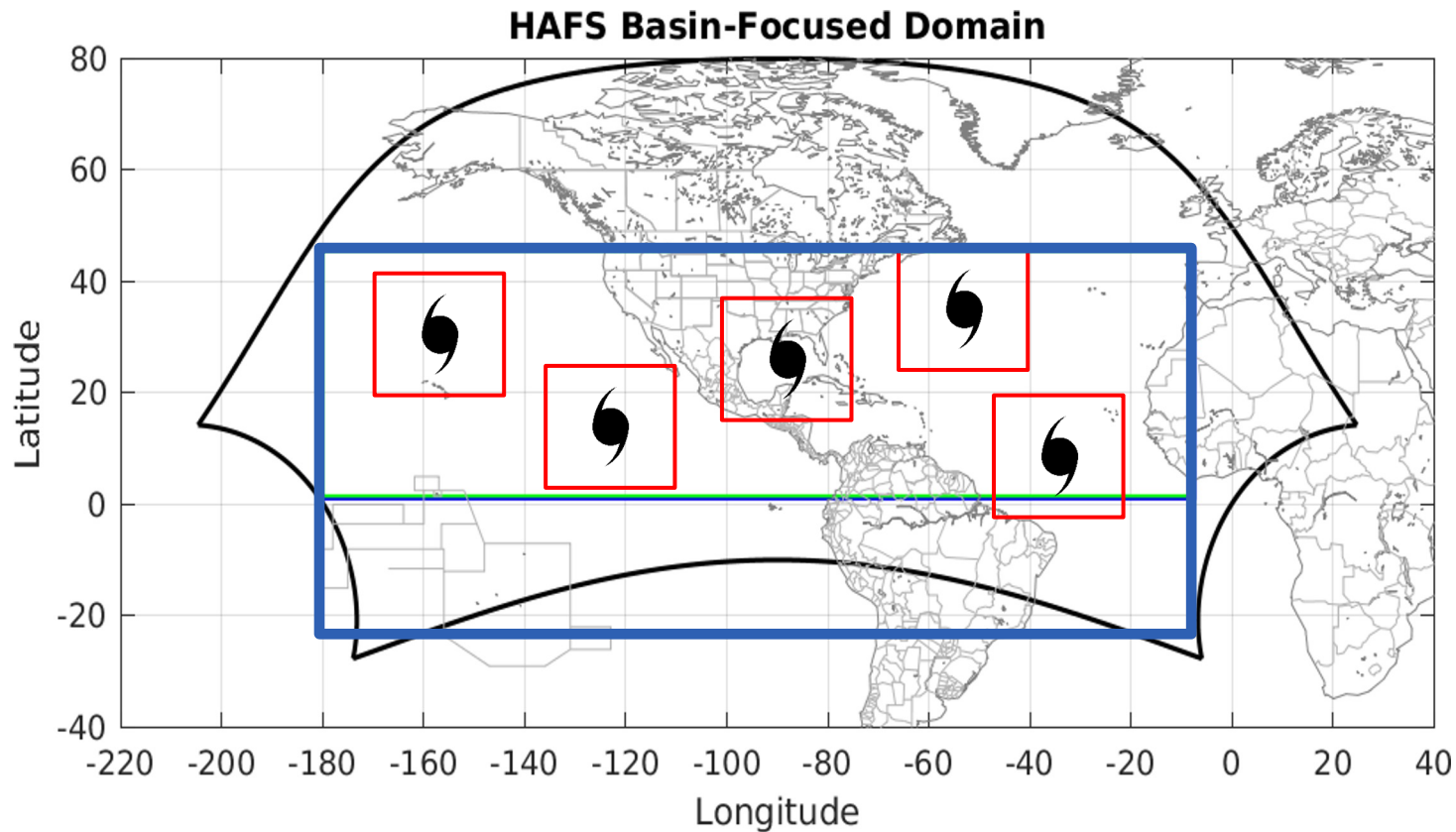
- **Ocean-Wave-Atmosphere coupling**

- Three-way coupling
- Coupling strategy
- Ocean and wave model physics
- Ocean and wave model initialization (DA)

Telescopic Nest Capability



Multiple Moving Nest Capability



Summary

- HAFS completed for 2022 hurricane season real-time HFIP demo
- HAFS is planned to initial operational implementation in 2023 hurricane season
- HAFS development and operational implementation will prioritize the following aspects:
 - Moving nest capabilities
 - New DA capabilities, methodologies and data
 - New physics ready for high-resolution
 - Synchronize development to NOAA's Unified Forecast System (UFS)
- Some statistics (incomplete)
 - Participating six conferences
 - 35+ presentations related HAFS
 - involving 50+ participants from public sectors, academia, and private sectors

List of HAFS-related Presentation (35 presentations)

13th Conference on Transition of Research to Operations

- 1B.2 - Progress Report on The Unified Forecast System Research to Operations (UFS R2O) Project: A Collaborative and Coordinated Development of MRW/S2S, CAM/SRW and Hurricane Applications
- 1B.3 - Development of UFS-based Coupled Global and Regional Operational Forecast Systems at NWS/NCEP
- 1B.5 - Advancing NOAA's Hurricane Modeling Systems: Operational Implementation of UFS-Based HAFS for 2023 and Beyond
- 2B.2 - Impacts of Different Physics Suites on the Hurricane Analysis and Forecast System Performances
- 7A.1 - The Hurricane Analysis and Forecast System: From Plan to Reality!
- 7A.2 - Development of the Regional Moving-Nesting and Ocean-Coupled HAFS Configuration for Tropical Cyclone Forecasting
- 7A.3 - Real-Time and Retrospective Evaluation of the Hurricane Analysis and Forecast System (HAFS-S Version)
- 7A.4 - Diagnosing the Relationship Between Biases in the Hurricane Analysis and Forecast System Using Innovation Statistics
- 7A.5 - Modeling Ocean Mechanisms That Improve Hurricane Forecasts
- 7A.6 - Case Studies Demonstrating the Potential Benefits of the NOAA Next-Generation Enterprise Ocean Heat Content Algorithm for Tropical Cyclone Intensification Forecasting in the Gulf of Mexico

List of HAFS-related Presentation (cont')

13th Conference on Transition of Research to Operations

- 8A.1 - Hurricane Forecast Improvement Program (HFIP): Transition to Operational Improvement of Tropical Cyclone Forecasting
- 8A.2 - Moving Nest Implementation for the Hurricane Analysis and Forecast System (HAFS)
- 8A.3 - An Improved PBL Scheme in Hurricane Conditions using Large-Eddy Simulations and Its Impact on Hurricane Forecasts from Hurricane Analysis and Forecast System
- 8A.4 Developing a Multi-Storm Configuration of the Hurricane Analysis and Forecast System
- 8A.5 - Developing the Hurricane Analysis and Forecast System: Future Priorities
- 8B.4 - Transitioning Research Innovations into the Unified Forecast System Hurricane Application
- 9B.1 - Toward the Development of Coherent Modeling Requirements that Systematically Address the Effects of Upstream Systems on Downstream Systems for NWS Analysis and Forecast Systems
- V7 - An Overview of HAFS Physics Parameterizations and Their Performance
- V102 - Using MODE to Calculate the WPC, NBM, and HAFS QPF Displacement Error for Landfalling Tropical Cyclones During the 2021 Hurricane Season
- V142 - The Use of Composite GOES-R Satellite Images to Evaluate TC Forecast By an Operational Hurricane Forecast Model

List of HAFS-related Presentation (cont')

Second Symposium on Community Modeling and Innovation

- JointJ13A.1 - The Common Community Physics Package: Supporting Research and Operational Needs of the Unified Forecast System

Fifth Special Symposium on Tropical Meteorology and Tropical Cyclones

- 5.5 - Parameterization of Environmental Wind Shear Effect in the NCEP GFS Planetary Boundary Layer and Convection Schemes and its Impact on Hurricane Intensity and Track Forecasts
- 6.3 - Improvements in the Assimilation of Tropical Cyclone Inner-core Observations in NOAA's Next-Generation Hurricane Analysis and Forecast System (HAFS)
- 6.4 - Evaluation of the Coupled Ocean Response in the Hurricane Analysis and Forecast System (HAFS) during the 2022 Hurricane Season
- 10.4 - Evaluating and Post-processing HAFS version A QPF over the Tropical Atlantic for the 2020 and 2021 hurricane seasons
- 667 - Case Studies of Hurricane Landfalls in the Hurricane Analysis and Forecast System Moving-nest Configuration
- 670 - Improving Hurricane Forecasting Through Supplemental Program Projects
- 664 - Evaluating the Skillfulness of High Resolution Model Forecasts of Tropical Cyclone Precipitation using an Object-Based Methodology

List of HAFS-related Presentation (cont')

27th Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS)

- 6B.2 - Impacts of CyGNSS v3.1 L2 Winds on Analyses and Forecasts of Tropical Cyclones in Regional OSEs
- 8B.2 - Assimilation of TROPICS Pathfinder Radiance Observations from Ida (2021) in HAFS
- 11th AMS Symposium on the Joint Center for Satellite Data Assimilation (JCSDA)
- 8ii.2 - A JEDI-Based Regional Ocean Data Assimilation System for HAFS
- 8ii.3 - Current Capabilities and Future Plans for SOCA: The JEDI Based Marine Data Assimilation System
- 11B.2 - Tropical Cyclone Hazards Evaluated using Recent Advancements in Ensemble Data Assimilation

22nd Conference on Artificial Intelligence for Environmental Science

- 904 - The Development of a Tropical Cyclogenesis Index with a Consensus Machine Learning Model using the HAFS Dataset

22nd Annual Student Conference

- S244 - Applying the Method for Object-based Diagnostic Evaluation (MODE) to Precipitation Associated with Tropical Cyclones

