Coupling Strategy for Hurricane Analysis and Forecast (HAFS)

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HFIP Annual Review Meeting, November 19, 2020
Outline

❖ Coupled Operational Hurricane Systems

❖ Current Coupled HAFS configuration

❖ Future Coupled HAFS Configuration

❖ Future Coupled HAFS Data Assimilation
Coupled Operational Hurricane Models at NCEP

Configurations:

- **HWRF:**
  - MPIPOM (2-way) at 1/12° and WW3 (1-way) at 1/10° (NATL, EPAC and CPAC)
  - HYCOM (2-way) at 1/12° (WPAC, NIO and SH)

- **HMON:**
  - HYCOM (2-way) at 1/12° (NATL, EPAC and CPAC)
Current: Operational Hurricane Forecasting Models

- HWRF/HYCOM
  - North-West Pacific, North Indian Ocean, Southern Hemisphere Basins

- HMON/HYCOM
  - North Atlantic, North-East Pacific, Central Pacific Basins

- HWRF/MPIPOM
  - North Atlantic, North-East Pacific, Central Pacific Basins

Initial Conditions from Global RTOFS

Adapted from Maria Vargas (Rutgers Univ)
Current: Real Time Ocean Forecast System (RTOFS) at NWS/NCEP

- Eddy Resolving Ocean Modeling and Initialization
- Coupled Modeling for Hurricanes (Air-Sea-Wave flux interactions, mixing)
- Inputs to operational Global (GFS v16) and Coastal (NWPS) wave models to allow for wave-current interactions.
- Coupled Ecosystem Forecasting (Biogeochemical, NPZD, tracers)
- RTOFS presently based on HYCOM

Strong collaboration with US Navy, leveraging core HYCOM and ocean data assimilation developments at NRL.
## New: Q1FY21 RTOFS-DA Implementation Timeline

<table>
<thead>
<tr>
<th>Dates</th>
<th>Milestone</th>
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<tr>
<td>May 1, 2020</td>
<td>Retrospective T&amp;E at EMC</td>
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<tr>
<td>July 20, 2020</td>
<td>Real time T&amp;E at EMC</td>
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<td>July 23, 2020</td>
<td>External Evaluation</td>
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<td>July 24, 2020</td>
<td>Approval from EMC Director</td>
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<td>August 7, 2020</td>
<td>Approval from NCEP Director's Office</td>
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<td>August 31, 2020</td>
<td>Submission of Codes to NCO</td>
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<td>October-November 2020</td>
<td>NCO IT Testing completed</td>
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<td>December 3rd, 2020 (scheduled)</td>
<td>IT briefing to NCEP Director's Office</td>
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<tr>
<td>December 8th, 2020 (tentative)</td>
<td>Operational implementation by NCO</td>
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Hurricane Analysis and Forecast System (HAFS):
A collaborative Project in UFS Framework
HAFS v0.1A Baseline Configuration

- The HAFS.v0.1a baseline configurations on top of the 2019 HAFS.v0.0a real-time experiment
  - Modeling infrastructure, dynamics, and physics advancement (FV3dycore, CCPP, UFS_UTILS, etc.)
  - Slightly increased domain size in the 3-km resolution from ~85x55 deg to ~85x63 deg
  - Increased vertical levels from L64 to L75
  - Lateral boundary condition blending (nrows_blend=10)
  - Both convective and orographic GWD are turned off
  - Reduced radiation scheme time step from 3600s to 900s
- Same dynamics and physics options as HAFS v0.0A
  - Time step of 90s, advection scheme hord=6
  - GFDL microphysic; RRTMG radiation; No CP; Noah LSM
  - GFS surface layer with HWRF exchange coefficients
  - GFS EDMF PBL with HWRF modification
  - NSST on; Convective GWD off; orographic GWD on
The HAFS v0.1A Coupled Configuration

- The FV3 atmospheric model component
  - Further increased model domain (~85x72 deg)
  - Further increase the vertical levels from L75 to L91
  - Use the HAFS_v0_gfdlmplmp_nocpnsstugwd physics suite
    - GFDL microphysic; RRTMG radiation; No CP; Noah LSM; GFS surface layer with HWRF exchange coefficients; GFS EDMF PBL with HWRF modification; Both convective and orographic GWD are turned off; Turning off the NSST component
  - Radiation scheme time step 1800s
    - GFS NEMSIO file for IC; 3-hrly GFS grib2 files for LBC
- The HYCOM ocean model component
  - Cover NATL basin (1-45.78N, 261.8-352.5E) at a 1/12-degree resolution with 41 vertical layers
  - Ocean IC from RTOFS nowcast and/or forecasts
  - Use persistent oceanic LBC
  - Atmospheric forcing from 0.25-degree GFS grib2 files to cover non-overlapped area

Blue: FV3 domain
Red: HYCOM domain
ESMF/NUOPC Based HAFS-HYCOM Coupling

Direct coupling through the bilinear regridding method with the data merging for non-overlapped areas

From ATM to OCN:
- 10-m wind, air-sea momentum flux, 2-m temperature, 2-m humidity, net short-wave and long-wave radiation fluxes, precipitation, surface pressure

From OCN to ATM:
- sea surface temperature

Shapes
- Component
- Connector

Color Code
- Blue: Driver
- Yellow: Model
- Green: Connector
- Orange: Mediator
- Gray: Off
Performance of the HAFS V0.1A Coupling Configuration
(For selected 2019 NATL storms 05-13L)
Future Coupled HAFS: HWRF/HWRF-B provides Blueprints

- Coupler can exchange data with multiple moving concurrent nests and the static parent domain.
- Efficient and accurate treatment of moving grid interpolations.
- Use of real*8 for grid-to-grid interpolation while allowing real*4 execution of component models.
- 3-way coupled.
- Scalable.
Unified Forecast System

- NWS UFS system consists of the following community components
  - NEMS for infrastructure
  - CMEPS mediator
  - FV3 dycore with CCPP Physics driver
  - MOM6 ocean model (S2S scales)
  - HYCOM ocean model (weather scales)
  - WW3 wave model
  - CICE ice model
  - GOCART aerosol model
  - Land model*

- Each component has its own authoritative repository. NEMS infrastructure allows flexibility to connect instantiations of the repositories together to create a coupled model.

- https://ufscommunity.org
Current UFS Coupled Model Developments

Each of these is a working coupled application which is actively being tested and developed

- **UFS - weather**
  Atmosphere and one-way wave coupling.

- **UFS – CHEM**
  Atmosphere, aerosols interaction (prototype with GSDCHEM, moving to GOCART)

- **UFS - marine DA**
  Ocean-Ice coupled model with a Data Atmosphere, used for ocean and sea ice DA

- **ADCIRC – WW3**
  Wave and surge coupling (COASTAL ACT)

- **UFS - S2S**
  Fully coupled atmosphere - ocean - ice - wave model (25 km atm, ¼ deg ocean and ice, ½ deg waves)

- **UFS - HAFS**
  Hurricane Analysis and Forecast System
Future Coupled Developments at NCEP/EMC

➢ NCEP/EMC developments transitioning to Community Mediator for Earth Prediction Systems (CMEPS) which also uses NUOPC layer

➢ Advantages of CMEPS over NEMS

❖ Community development in close collaboration with NCAR
❖ Modular design; ease of use
❖ Advanced “Geometric Structure” which can handle both structured and unstructured grids
❖ Multiple options for handling flux computations
❖ Remap and Merge defined in a single file for field exchanges
❖ Use of YAML external file for NUOPC field dictionary
Future Coupled HAFS Configuration

- Atm/Ocn fluxes are computed by atm model
- Atm/Ocn land/sea masks do not match
- SST is interpolated from ocean→atm using conservative interpolation followed by nearest neighbor fill
Future Coupled HAFS Configuration

- Wave model sends $z_0$ roughness length to atm
- Ocean sends surface currents to Waves
- Wave sends Stokes Drift $(u,v)$ to ocean for sea-state dependent Langmuir mixing
Title: Advance ocean data assimilation and coupling of air-sea models in the NOAA UFS in support of improved flood and inundation forecasting through coordination with NWS and NOS

Objectives:
- Coupled model development within the UFS framework with regional FV3
- Transition NWS and NOS ocean data assimilation efforts toward a common infrastructure (JEDI) and incorporate currently unused high-resolution ocean observations
- Enable comparison of ocean models and DA methods, and future leveraging of research activities for improved coupled Hurricane forecasts
- Establish capabilities of air-sea interface modeling and gaps that must be addressed for future coupled DA and explore strongly coupled DA for Hurricane applications
Regional ODA Implementation

- Established regional ODA capability in the UFS-GODAS/JEDI-SOCA system
  - Implemented global-to-regional state converter and linked to DA workflow

Goal:
provide best estimate ocean IC & BC for coupled Hurricane forecast system

Current Experiment configuration: 1/12-degree resolution
Forcing: CORE/JRA55
IC & BC: Climatology from SODA3, Rutgers-developed OBC options
Thank You!
New: Data Flow through RTOFS-DA*

Ocean Data QC:
- Fully automated, executed in real-time

2DVAR:
- Univariate analyses of SST, SSS, ICE

3DVAR:
- Multivariate analysis of temperature, salinity, velocity, sea ice coverage
- Hourly FGAT for ICE, SST, SSS

HYCOM:
- Coupled to CICE model
- 3-hr incremental analysis update (IAU)

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SST:
- METOP, NPP, JPSS, GOES, HIMAWARI, Ship, Buoy

SSS:
- SMAP, SMOS, Buoy

Profile Temp/Salt:
- XBT, CTD, Argo Floats, Buoy, Gliders, ALAMO, Animal-borne sensors, Saildrone

Altimeter SSH:
- Jason, CryoSat, Altika, Sentinel

Sea Ice:
- SSMI/S, AMSR

Velocity:
- ADCP, Drifters, Gliders

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Sensors

Adaptive Sampling
Data Impacts (off-line)

Forecast Fields
Prediction Errors

Assimilation

First Guess

Foram Model

* Based on NCODA
Coupled Experimental Hurricane Models at NCEP

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Verification Statistics for Michael (14L) 2018

H218 – 2018 operational HWRF; H321 – 3-way coupled (H219 + WW3)

Track

Vmax

Vmax - Bias

Pmin - Bias

Courtesy: H-S Kim
Verification Statistics for Michael (14L) 2018

H218 – 2018 operational HWRF; H321 – 3-way coupled (H219 + WW3)

Courtesy: H-S Kim
Ongoing Developments:

- Include sea-spray impacts
- Data assimilation for Ocean & Wave components
- Improve mixing physics, especially shear instability and entrainment
- Improve representation of Stokes Drift forcing
- Conduct a large sample size experiment with the 3-way coupled system

Courtesy: H-S Kim