Replacing Hurricane Ocean Wave Model in NCEP Operations

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Outline

• Current Operational Wave Models

• 2016 Hurricane Wave Model configuration and results

• 2017 plans

• Future configuration and initial test results
Current: Global Wave Model (Multi_1)

- Multi-grid modeling system
- 4 cycles a day; each cycle 9 hours hindcast + 180 hours forecast
- Winds from Global Data Assimilation System (GDAS) for hindcast/Global Forecast System (GFS) for forecast
- Domain resolution $1/2^\circ$ - $1/12^\circ$
Current: Hurricane Wave Model (Multi_2)

- Multi-grid modeling system
- 4 cycles a day; each cycle 6 hours hindcast+120 hours forecast
- Winds from GFS/HWRF blend interpolated/sub-sampled onto a 1/4° grid
- Domain resolution 1/2°-1/12°

Note the similar resolution and similar scales in resolution as multi_1, which are coarser than HWRF’s resolution and therefore require averaging of the forcing wind fields.
System & Resolution Enhancements
- T&E with new 2016 4D-Hybrid GDAS/GFS IC/BC
- Upgrade dynamic core from WRF3.6a to WRF3.7.1a (with bug fixes)
- Smaller time step (dt=30 s vs. 38 4/7 s)
- *Increase the size of nested domains (details on next slide)*
- More products: MAG and AWIPS2

Initialization/Data Assimilation Improvements
- GSI upgrades; *new data sets for GSI (CrIS, SSMI/S, METOP-B changes)*
- *Turn on Data Assimilation for all storms in East Pacific and use of ROTFS initialization*

Physics Advancements
- Implement *new GFS PBL* (2015 version)
- Upgrade to *new scale-aware SAS convection scheme* for all domains
- Update momentum and enthalpy exchange coefficients (Cd/Ch)
- Improved vertical wind profile in the surface and boundary layer

First time in 2016....
- Implementation on WCOSS Cray
- Ocean coupling for CPAC, WPAC and NIO (all NH basins)
- One-way coupling to wave model *(Hurricane Wave Model)*
- Use of dev-ecflow for accelerated T2O
Multiple separate domains
Runs with HWRF (4 cycles a day; each cycle 6 hours hindcast+120 hours forecast)
Winds from 6km/18km HWRF and GFS (outside of HWRF domains) interpolate/sub-sample to the 1/10° wave grid
Domain resolution 1/10°
Boundary conditions to be added FY2017
2016 HWRF Vs. Multi_1 Vs Multi_2
Hurricane Matthew: 20161005 12Z

Significant Wave Height (m)

Wind Speed (m/s)

Multi_1 Multipurpose 1
Multi_2 Multipurpose 2
HWRF Hurricane Weather Research Forecasting Model
Buoy Buoy Station
2016 HWRF Vs. Multi_1 Vs Multi_2
Hurricane Matthew: 20161005 12Z

Forecast Hr: 012

Forecast Hr: 015

Forecast Hr: 048
Plans for 2017

• Hurricane Wave Model fully subsumed in 2017 HWRF (one-way coupled)

• Multi_2 decommissioned!
Three way coupled atmosphere-wave-ocean (AWO) model, that accounts for sea-state dependent air-sea fluxes.

WAVEWATCH III modifies the wind stress, which is chosen so that the drag coefficient is reduced for wind speeds greater that 20 m/s as in FY2016 operational HWRF.

Compare results between the full three-way coupled model and one-way coupled model (atmosphere->wave only).

Results indicate that storm intensities are better predicted in the three-way coupled system.
Future: Three-way experiments
Control Set-up

Use NCEP Coupler with 360s time step

- **Atmosphere → Waves**
  - Wind field (lowest level wind, height)
  - Stability Richards number
- **Atmosphere → Ocean**
  - Surface fluxes
- **Ocean → Atmosphere**
  - Sea surface temperature
  - Sea surface currents

**HWRF**
NCEP's operational hurricane model
3 nested grids (18 / 6 /2 km)
inner most nest moves with hurricane

**POM**
Ocean circulation model
Single grid (1/12°)

**WAVEWATCH III**
3rd generation wave model
Single grid option (1/10°)
Future: Three-way experiments
Coupled (AWO) Set-up

Use NCEP Coupler with 360s time step

- Atmosphere $\rightarrow$ Waves
  - Wind field (lowest level wind, height)
  - Stability Richards number

- Waves $\rightarrow$ Atmosphere
  - Sea state dependent drag formulation (Reichl et al 2014)

- Waves $\rightarrow$ Ocean
  - Wave modified wind stress (Fan et al 2010)
  - Coriolis Stokes Drift Forcing / Stokes drift
  - Mean wave length (for current field)

- Ocean $\rightarrow$ Waves
  - Surface current (for relative wind speed)
  - Current at depth (for wave – current interaction)

- Atmosphere $\rightarrow$ Ocean
  - Surface fluxes

- Ocean $\rightarrow$ Atmosphere
  - Sea surface temperature
  - Sea surface currents

HWRF
- NCEP's operational hurricane model
- 3 nested grids (18 / 6 / 2 km)
- Inner most nest moves with hurricane

POM
- Ocean circulation model
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Future: Three-way experiments
Test Storms

Hurricane Arthur
July 1st – July 5th, 2014
Category 2 storm

Hurricane Edouard
Sept 11th – Sept 19th, 2014
Category 3 storm

Hurricane Matthew
Sept 28th – Oct 10th, 2016
Category 5 storm

Source: wikipedia
Future: Three-way experiments
Hurricane Edouard (2014)
Future: Three-way experiments
Hurricane Arthur (2014)

Operational
HWRF
Control
Coupled
Future: Three-way experiments
Hurricane Matthew (2016)

Operational HWRF
Control
Coupled
Future: Three-way experiments
Test Storms (all cases)

Operational
HWRF
Control
Coupled
Future: Three-way experiments
Hurricane Matthew 20161001 12Z
Three-way coupled atmosphere-wave-ocean model for hurricanes
  - Sea-state dependent air-sea fluxes

Storm intensities are better predicted by including
  - Reduced drag coefficients
  - Sea-state dependent coupling processes

Future work:
  - Full three year study
  - Investigate impact of different mixing schemes for ocean coupling