Replacing Hurricane Ocean Wave Model in NCEP Operations

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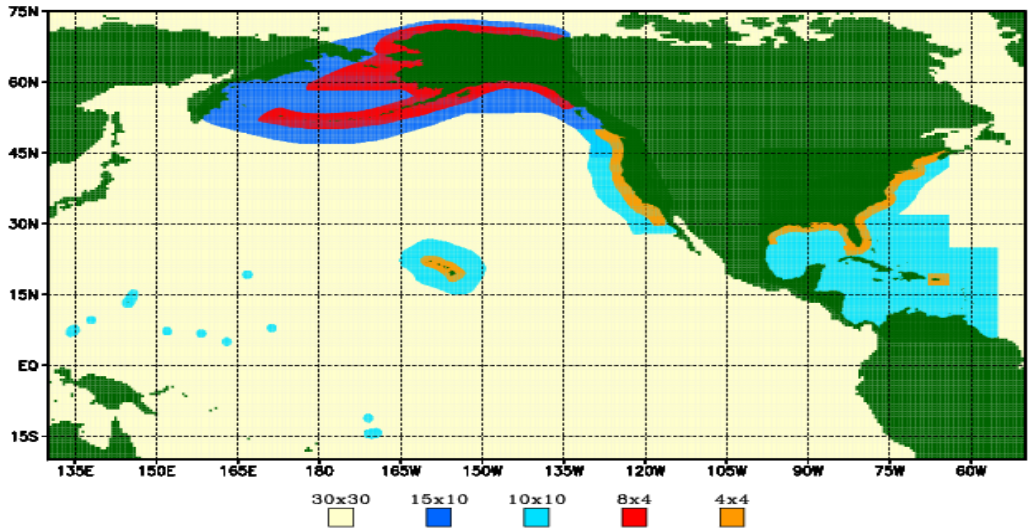
Outline

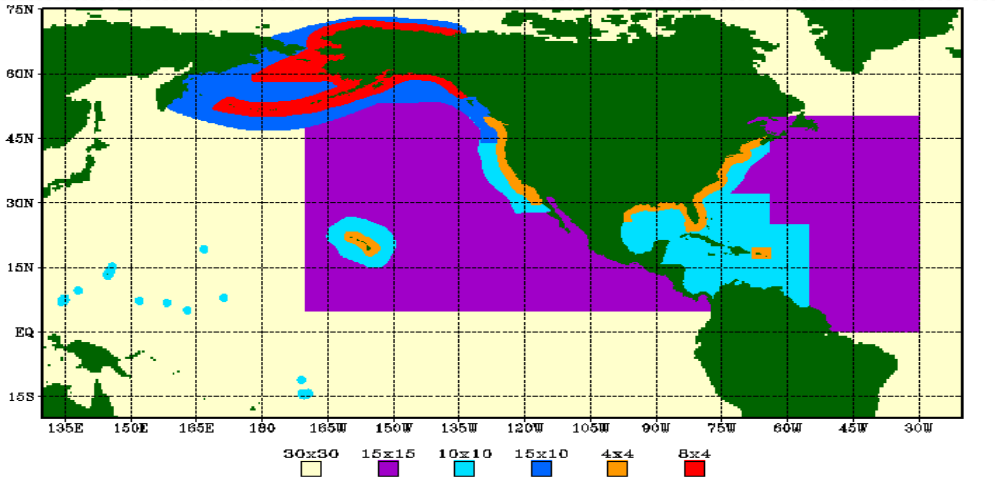
- Current Operational Wave Models
- 2016 Hurricane Wave Model configuration and results
- 2017 plans
- Future configuration and initial test results

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°-1/12°

Current: Hurricane Wave Model (Multi_2)



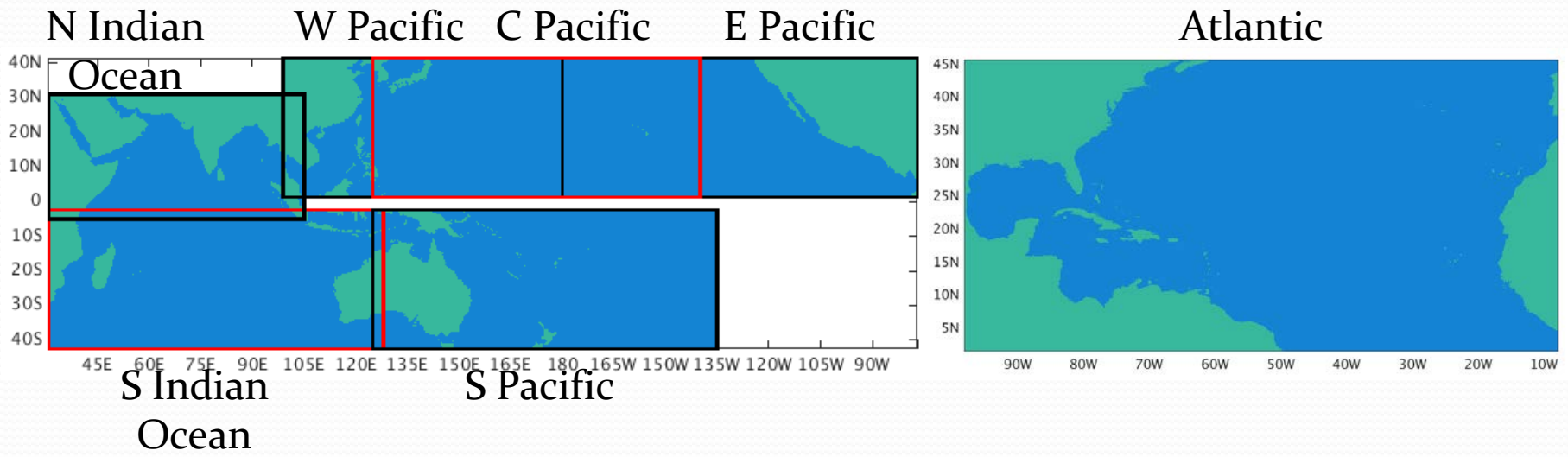
Note the similar resolution and similar scales in resolution as multi_1, which are coarser than HWRF's resolution and therefore require averaging of the forcing wind fields.

- 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°

Scope of FY16 HWRF Upgrades

- **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

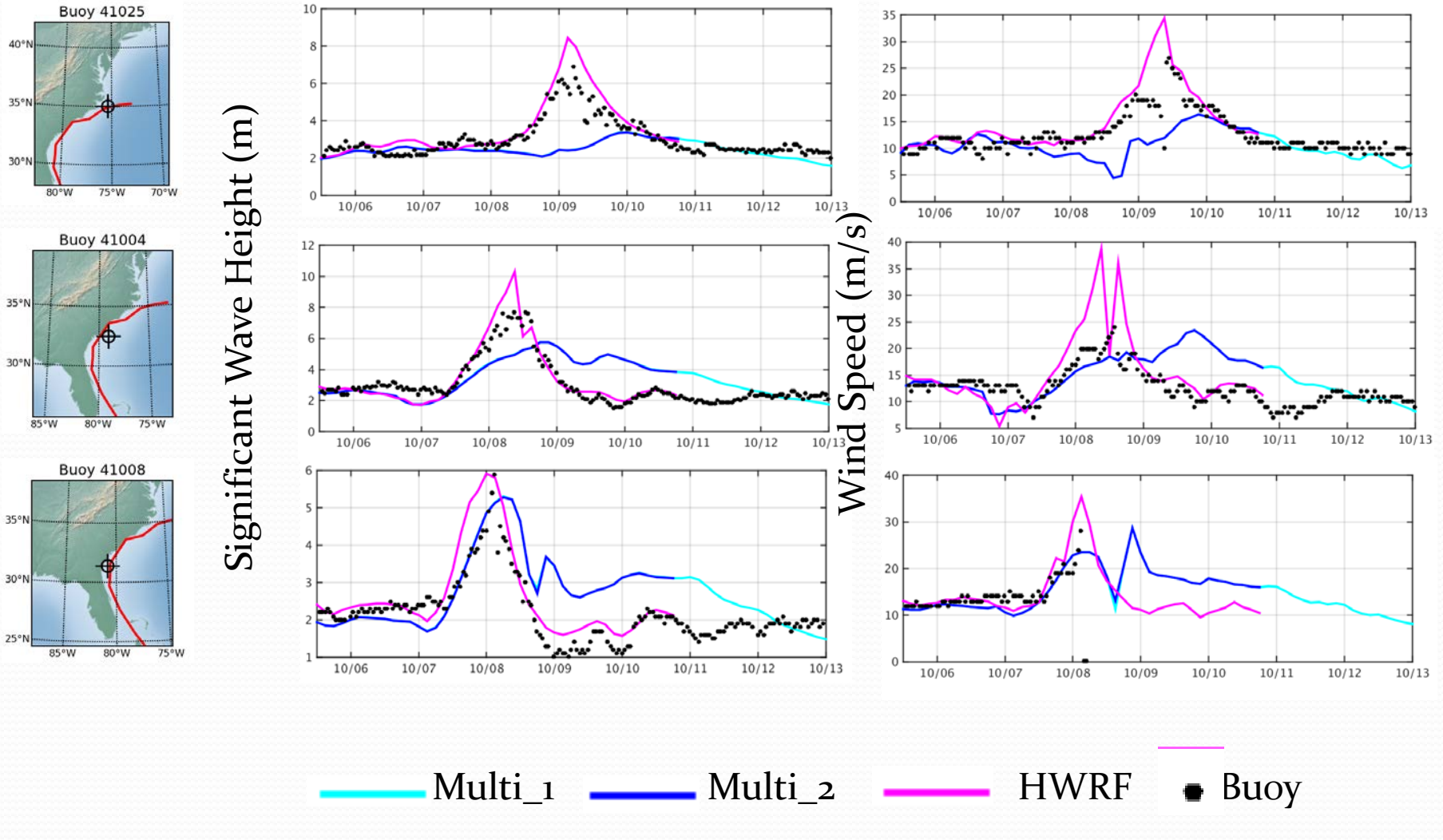
2016 HWRF: Hurricane Wave Domains



- 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

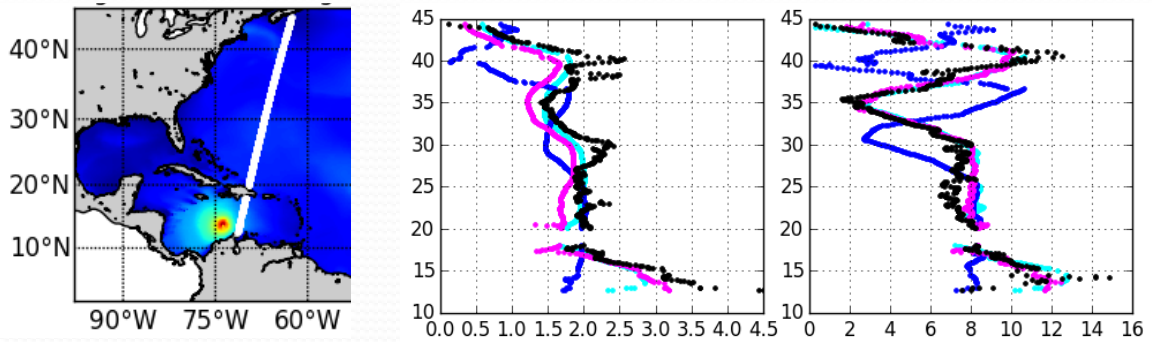


2016 HWRF Vs. Multi_1 Vs Multi_2

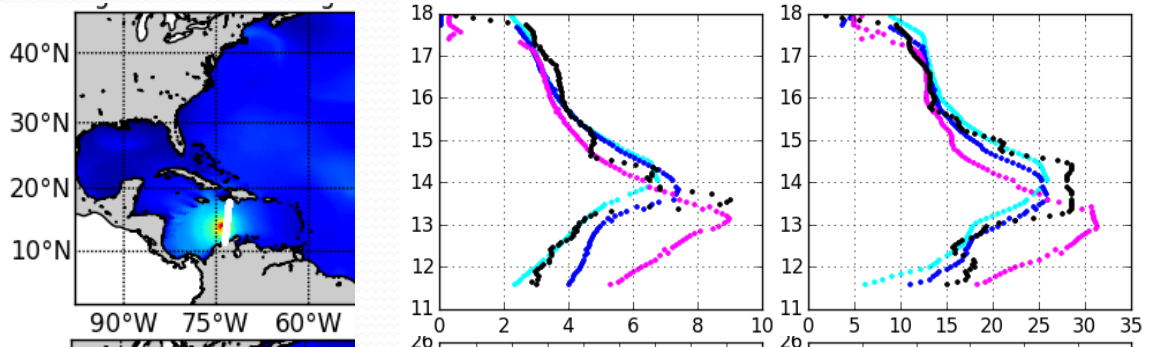
Hurricane Matthew: 20161005 12Z

Sig. Wave Height (m) Wind Speed

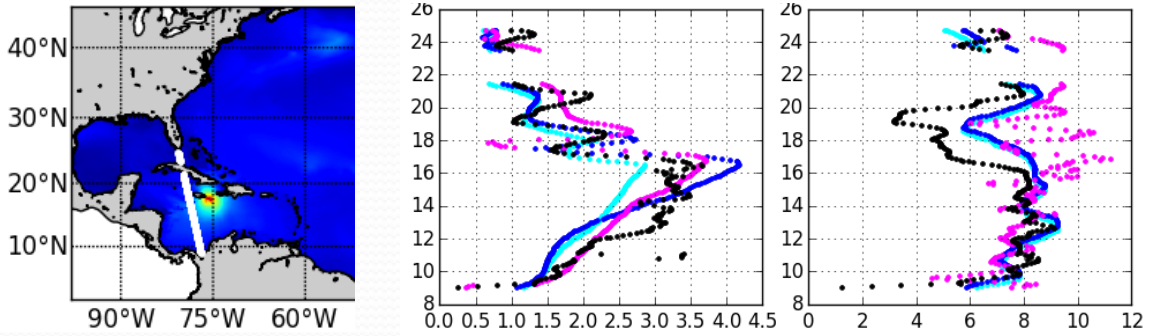
Forecast Hr: 012



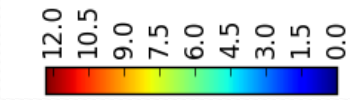
Forecast Hr: 015



Forecast Hr: 048



HS



Multi_1 Multi_2

HWRF ALtiKa/CryoSAT

Plans for 2017

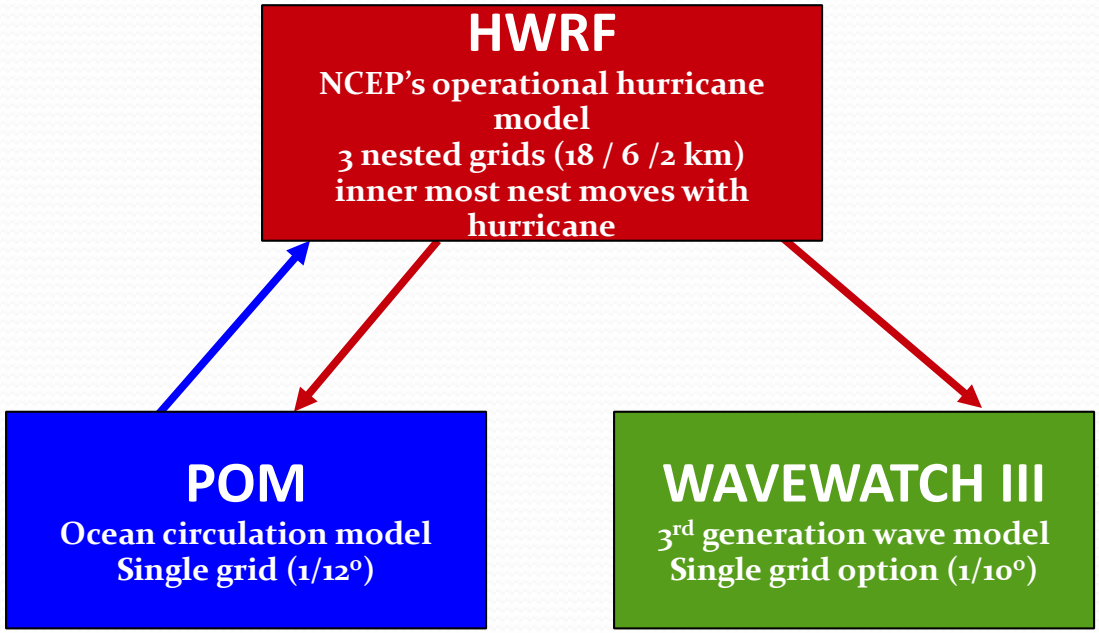
- Hurricane Wave Model fully subsumed in 2017 HWRF (one-way coupled)
- Multi_2 decommissioned!

Future: Three-way coupling setup

- 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

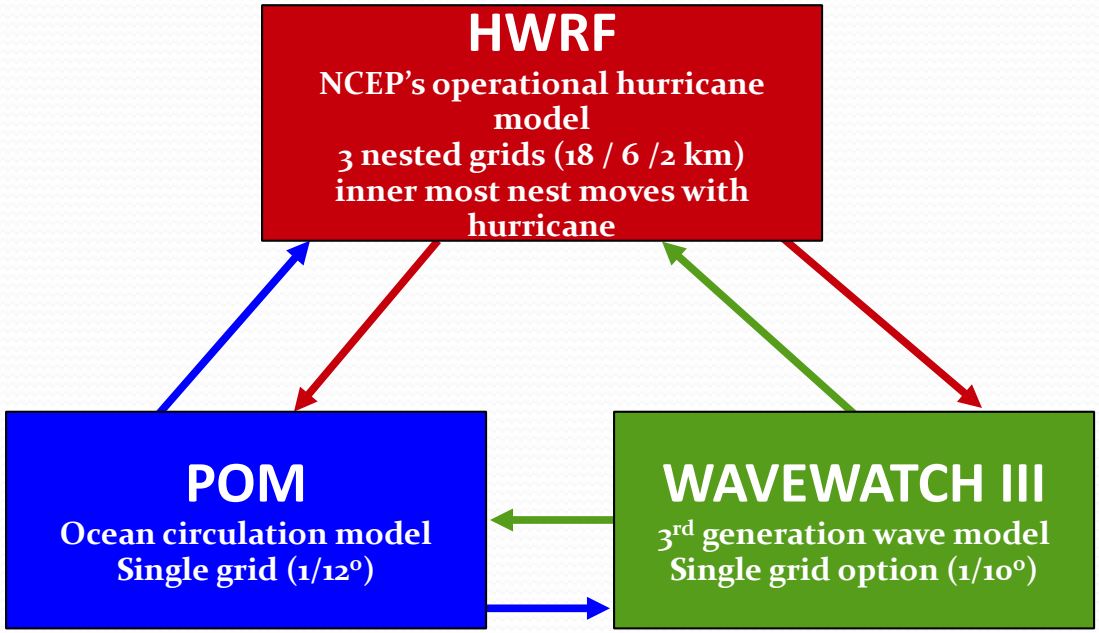
Use NCEP Coupler with 360s time step



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

Future: Three-way experiments Coupled (AWO) Set-up

Use NCEP Coupler with 360s time step



- Atmosphere → Waves
  - Wind field (lowest level wind, height)
  - Stability Richards number
- Waves → Atmosphere
  - Sea state dependent drag formulation (Reichl et al 2014)
- Waves → Ocean
  - Wave modified wind stress (Fan et al 2010)
  - Coriolis Stokes Drift Forcing / Stokes drift
  - Mean wave length (for current field)
- Ocean → Waves
  - Surface current (for relative wind speed)
  - Current at depth (for wave – current interaction)
- Atmosphere → Ocean
  - Surface fluxes
- Ocean → Atmosphere
  - Sea surface temperature
  - Sea surface currents

Future: Three-way experiments
Test Storms

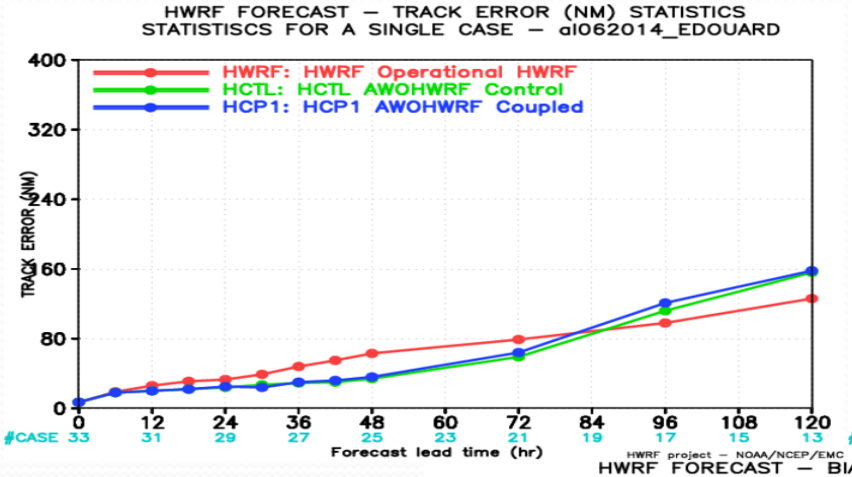
Hurricane Arthur
July 1st – July 5th , 2014
Category 2 storm

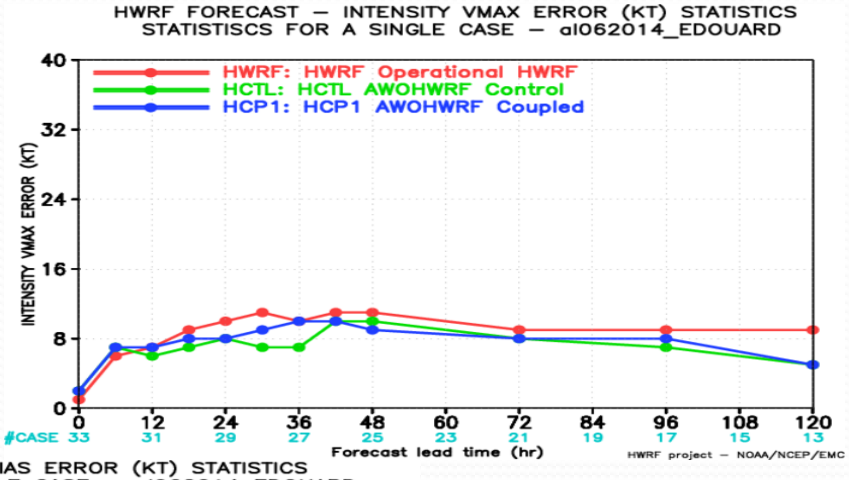
Hurricane Edouard
Sept 11th – Sept 19th , 2014
Category 3 storm

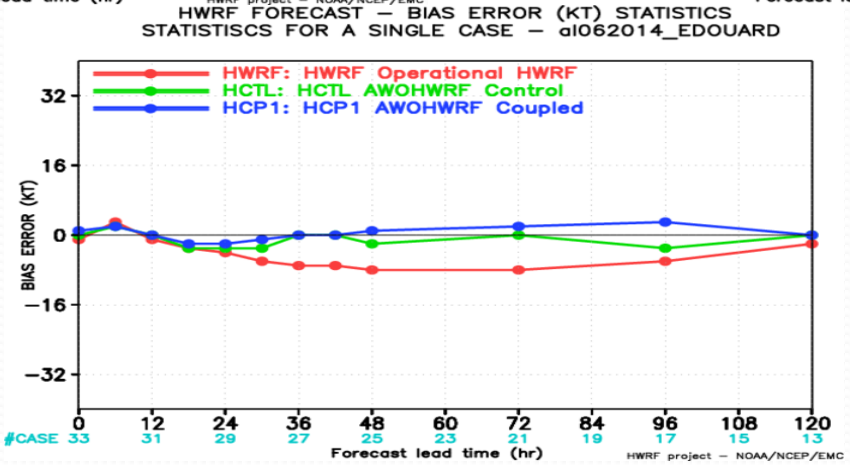
Hurricane Matthew
Sept 28th – Oct 10th , 2016
Category 5 storm

Source: wikipedia

Future: Three-way experiments
Hurricane Edouard (2014)





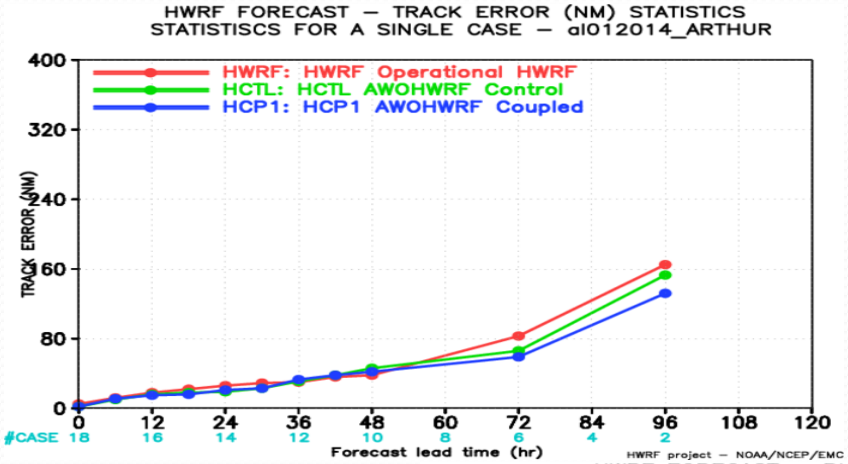


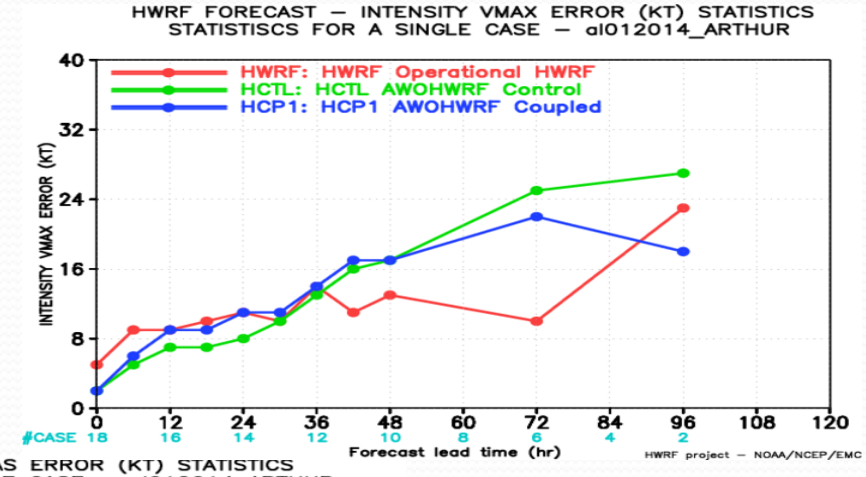
Operational HWRF

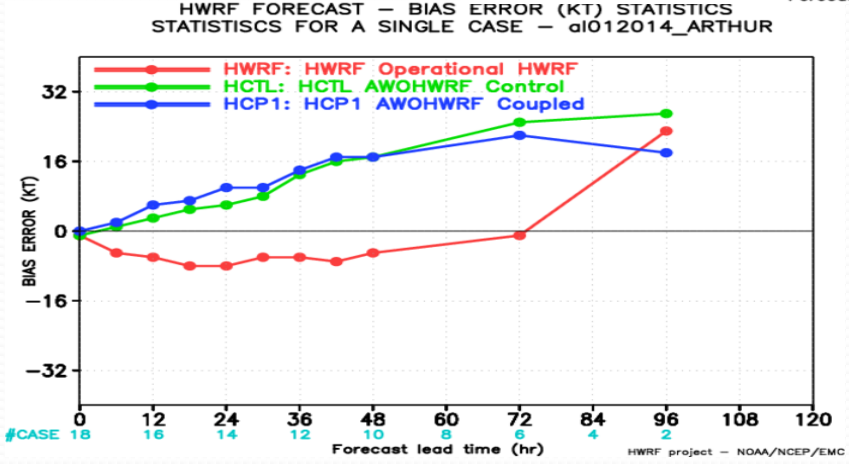
Control

Coupled

Future: Three-way experiments
Hurricane Arthur (2014)





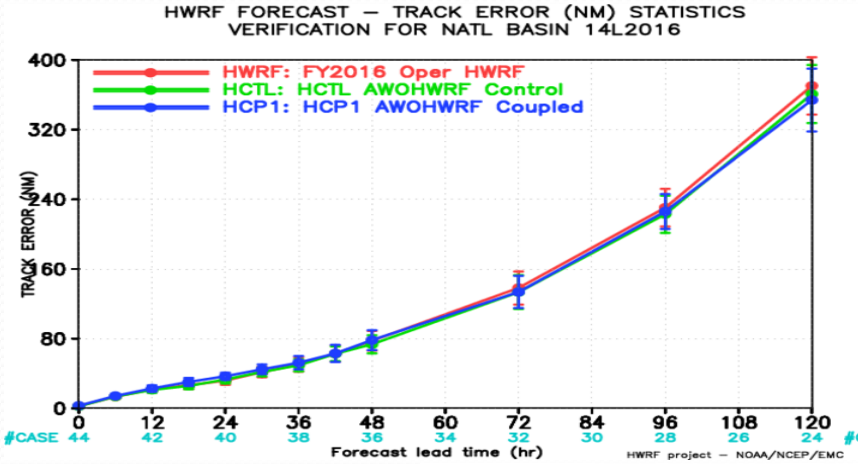


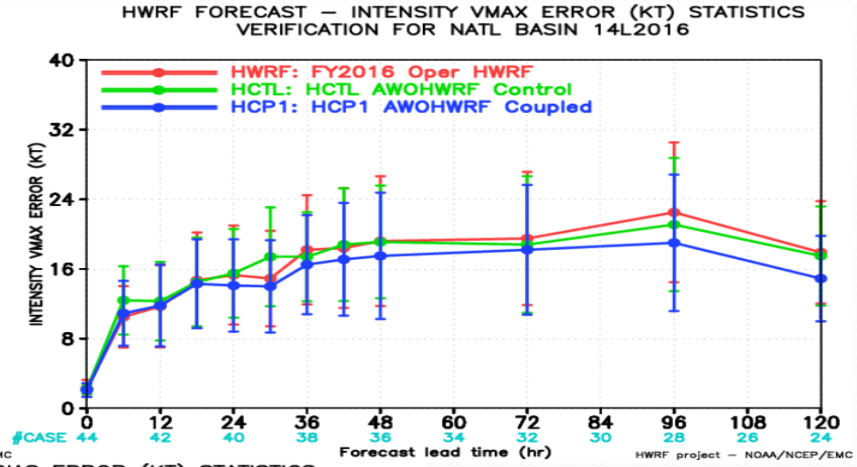
Operational HWRF

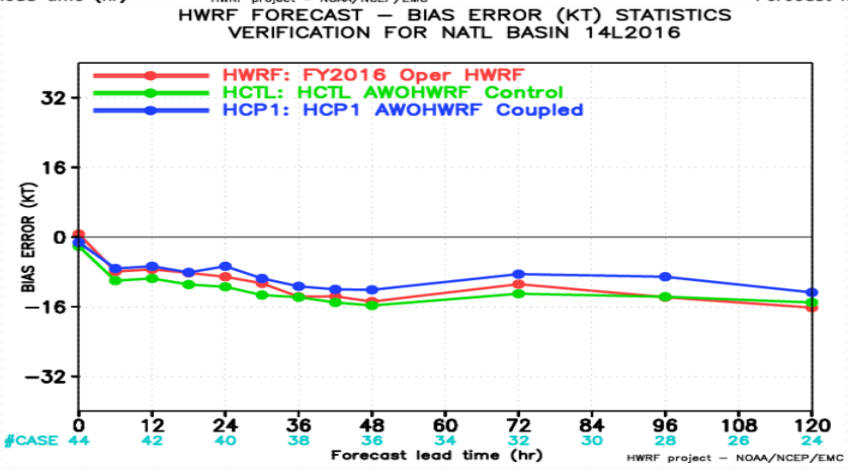
Control

Coupled

Future: Three-way experiments
Hurricane Matthew (2016)





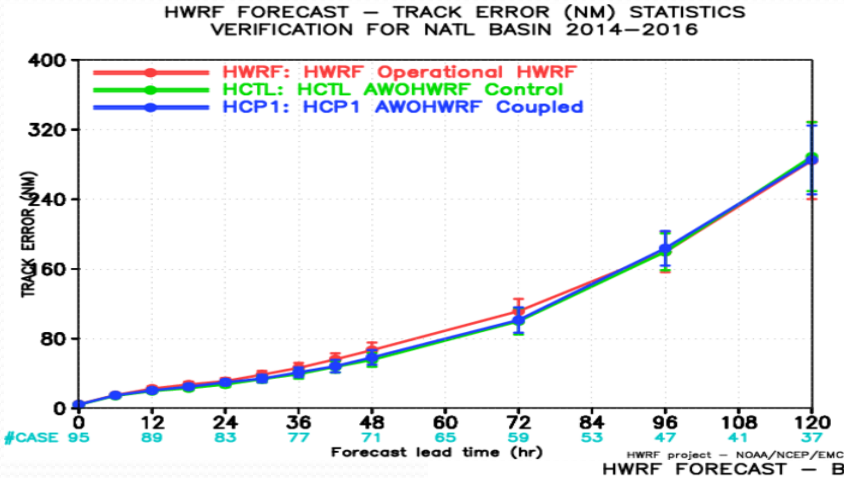


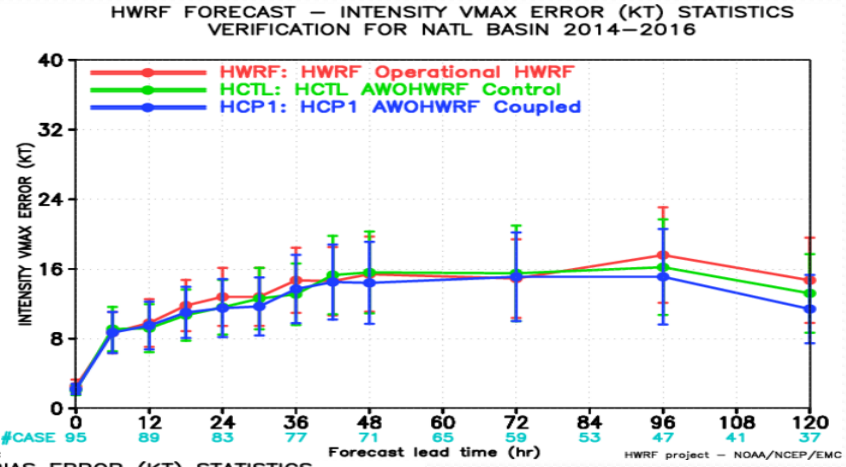
Operational HWRF

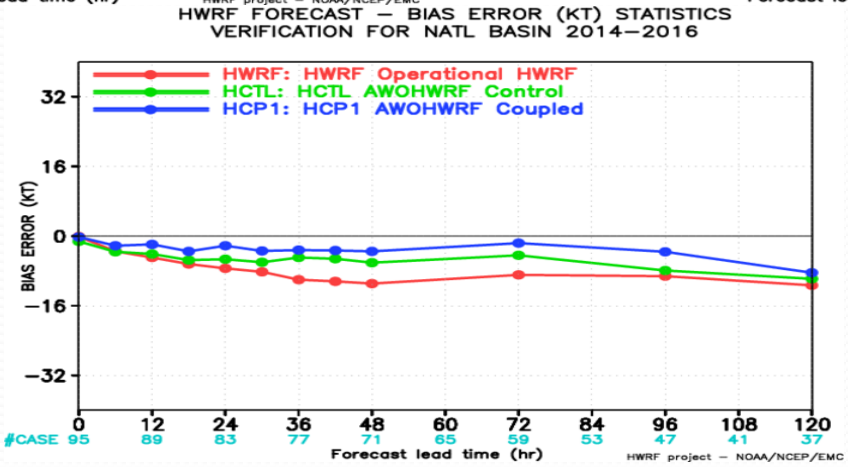
Control

Coupled

Future: Three-way experiments
Test Storms (all cases)





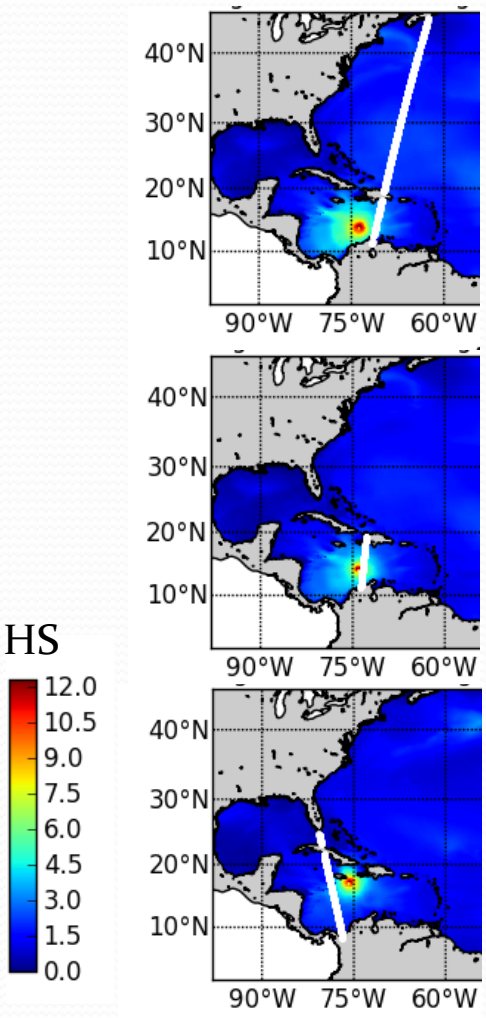


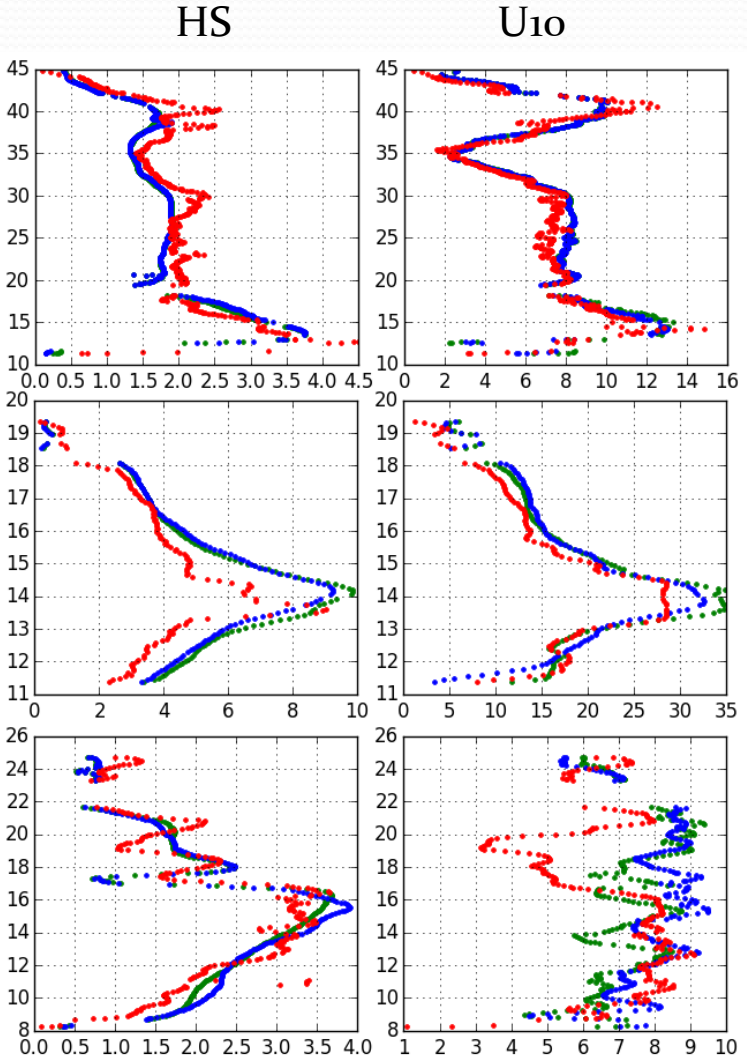
Operational HWRF

Control

Coupled

Future: Three-way experiments
Hurricane Matthew 20161001 12Z





Future: Three-way experiments
Conclusions

- 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