HAFS-HYCOM Coupling Progress Update

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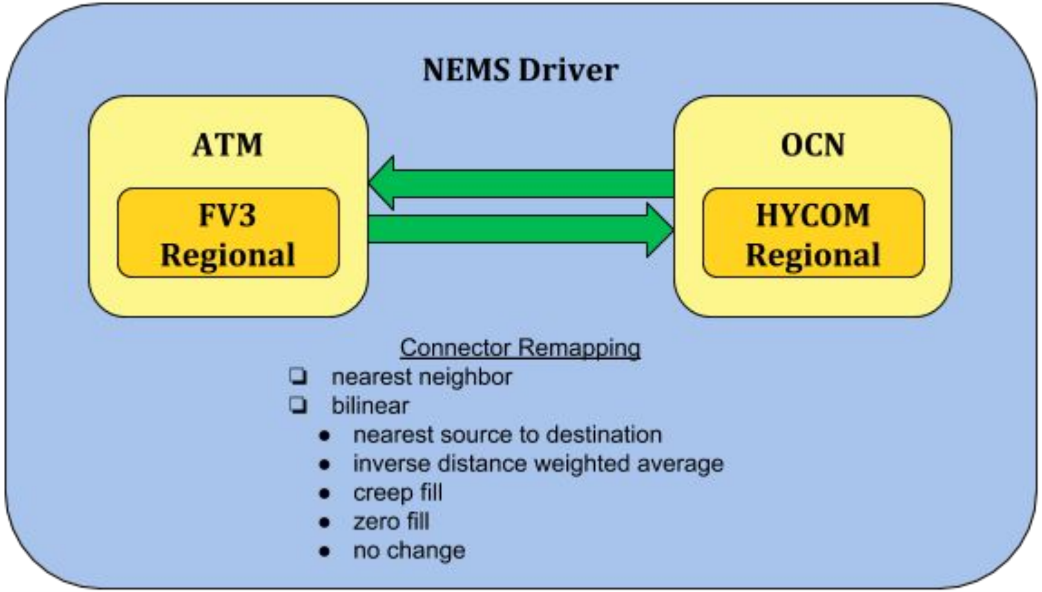
Outline

- Development Updates
- Sensitivity Experiments

Development Update

HAFS-HYCOM NUOPC Architecture



Connector Remapping

- ☐ nearest neighbor
- ☐ bilinear
  - nearest source to destination
  - inverse distance weighted average
  - creep fill
  - zero fill
  - no change

Shapes	
▭	Component
⇨	Connector

Color Code		
🟦	Blue	Driver
🟨	Yellow	Model
🟩	Green	Connector
🟧	Orange	Mediator
▨	Gray	Off

Available

https://github.com/hafs-community/HAFS/tree/feature/hafs_couplehycom

HAFS-HYCOM NUOPC Architecture

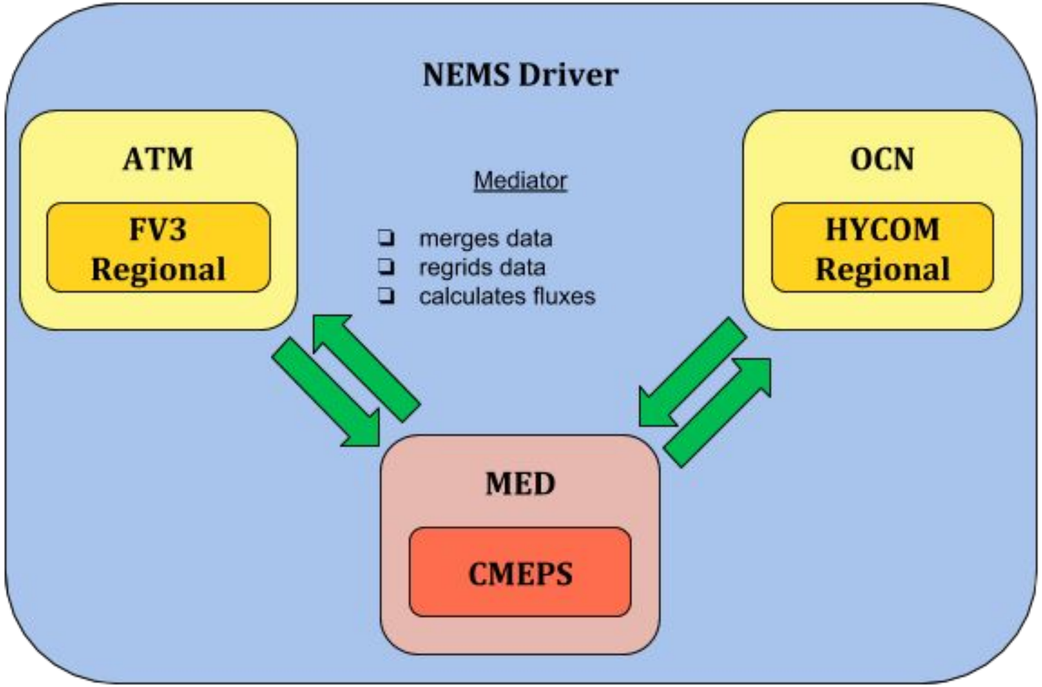
Development is ready for pre-release v0.1.0

- Directly connects FV3-HYCOM through NUOPC connectors
- Each model internally merges data for non-overlapped areas
- Physics scheme tuning (in progress)
- Documentation (in progress)
  https://github.com/hafs-community/HAFS/wiki/HAFS-Coupled-HYCOM-Report-v0_1_0

Computational cost

- 169 xjet nodes (FV3: 160 compute nodes + 4 IO nodes; HYCOM: 5 nodes)
- ~305 min
- Output tuning (in progress)

HAFS-HYCOM NUOPC Architecture with CMEPS



NEMS Driver

ATM

FV3 Regional

Mediator

- merges data
- regrids data
- calculates fluxes

OCN

HYCOM Regional

MED

CMEPS

Shapes	
▭	Component
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In Progress

HAFS-HYCOM NUOPC Architecture with CMEPS

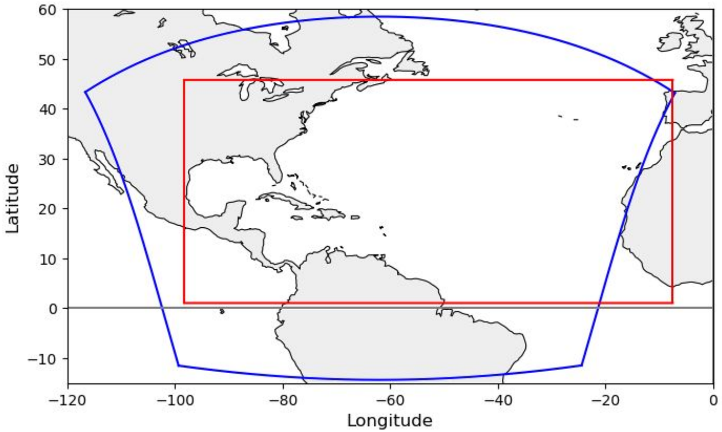
Development is in progress

- CMEPS revision UFS compatibility
- Build passes
- Regression testing: Disabled CMEPS (in progress)
  - System configuration changes are needed for CMEPS build version
- Regression testing: CMEPS pass-through (in progress)
  - Replicate results of the directly coupled system

Sensitivity Experiments

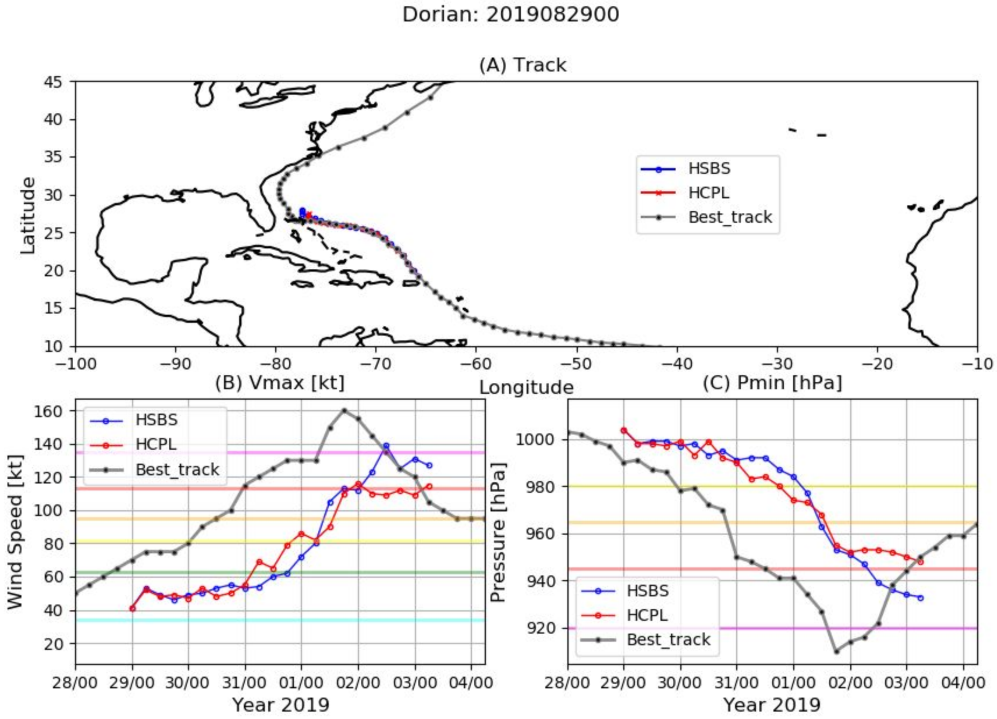
HAFS-HYCOM Model Settings

- The atmospheric FV3atm model component
  - 2880x2400 (~85x72 deg) L91
  - 90s dt_atmos with k_split of 4 and n_split of 5
  - GFS NEMSIO file for IC; 3-hrly GFS grib2 files for LBC
  - Use the HAFS_V0_gfdlmp_nocpnsst CCPP physics suite
    - GFDL microphysics; GFS EDMF PBL with HWRF modification; No convection; Noah LSM; RRTMG radiation; GFS surface layer with HWRF sea surface exchange coefficients; with orographic GWD but no convective GWD; Turning off the NSST component
- The HYCOM ocean model component
  - Same NATL ocean domain as in HWRF & HMON: 1-45.78N, 261.8-352.5E at 1/12-degree and 41-layer resolution
  - Ocean IC from RTOFS without spinup
  - Use persistent ocean LBC
  - Atmospheric forcing from 0.25 degree GFS grib2 files



Blue: FV3atm domain
Red: HYCOM domain

1. Track and Intensity Forecasts

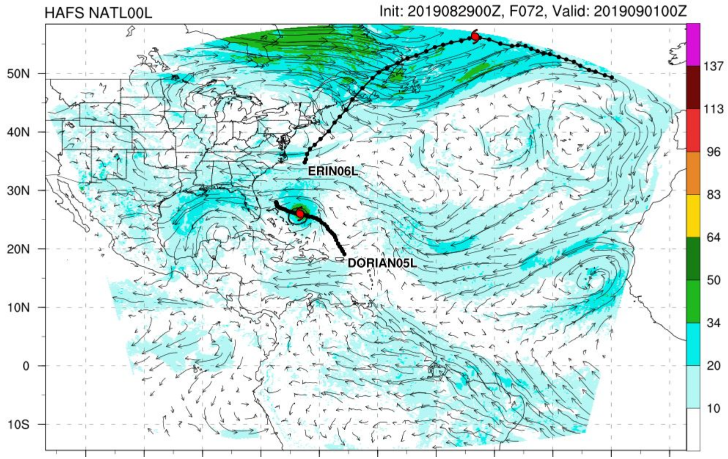


1. Vmax and Pmin at T=0 are already under-estimated. Vortex initialization and/or data assimilation needed.
2. Ocean coupling impact became significant from day 2.
3. The HCPL intensity is under-estimated by an average of 30 kt/21 hPa at later lead time, compared to the HSBS.

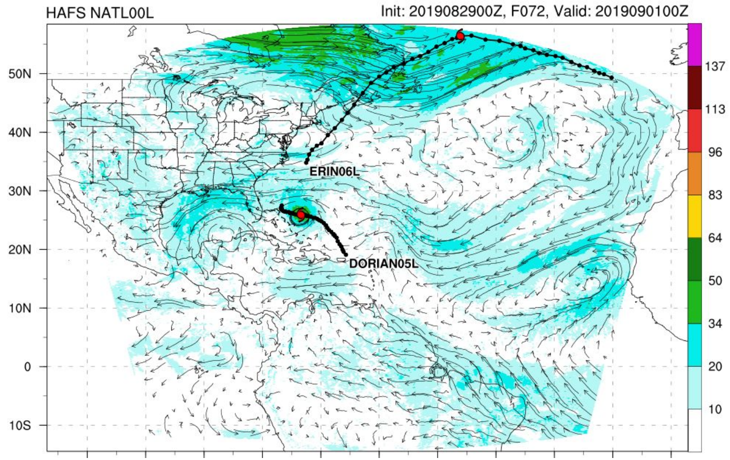
Synoptic-Scale Comparison

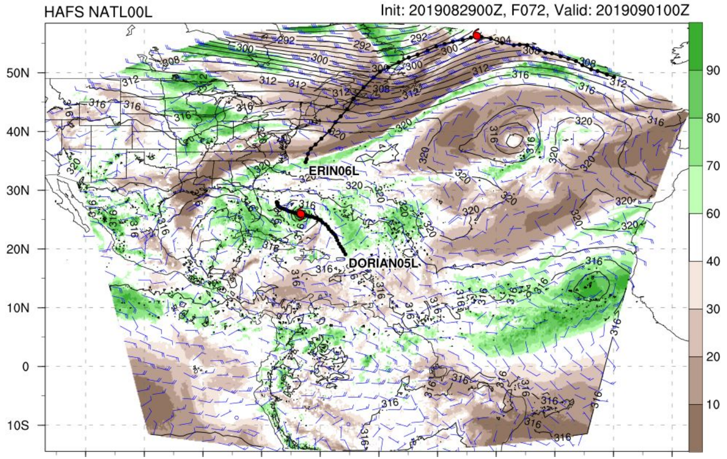
HSBS

HCPL

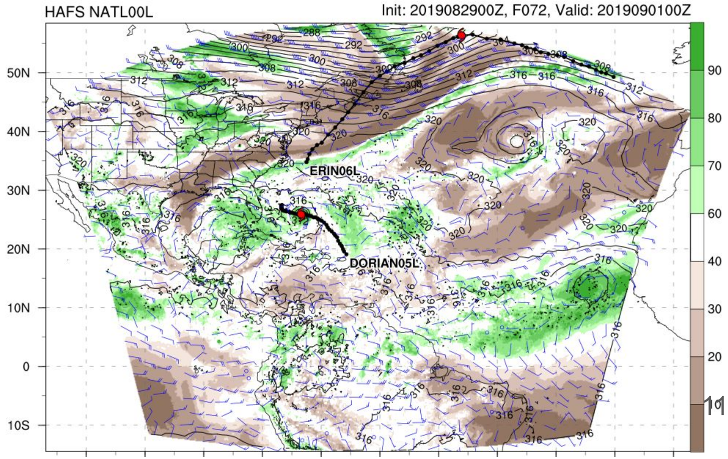


850 hPa wind and streamline





700-500 hPa humidity and 700 hPa height and wind

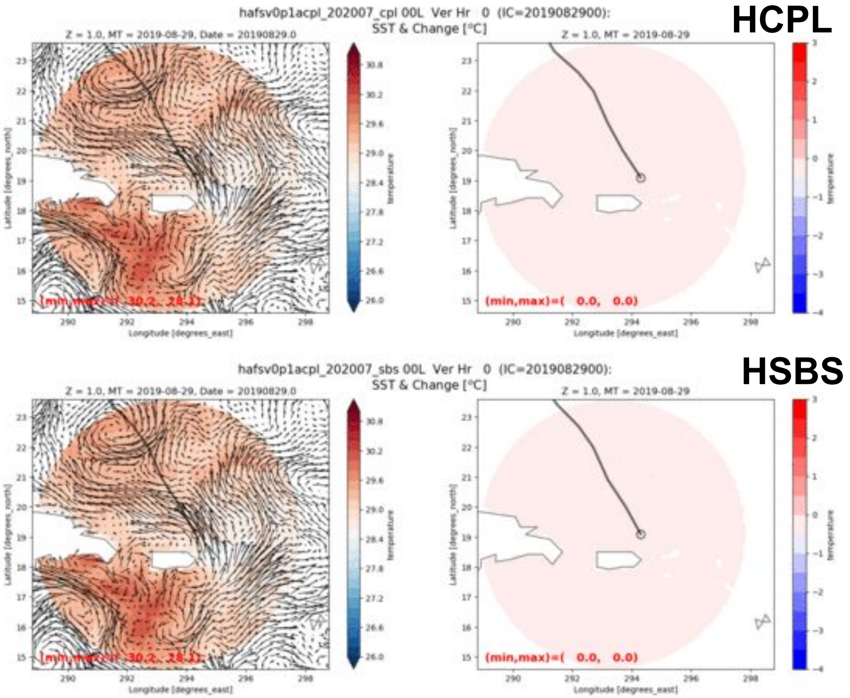


Comparisons of ocean variables between HSBS and HCPL

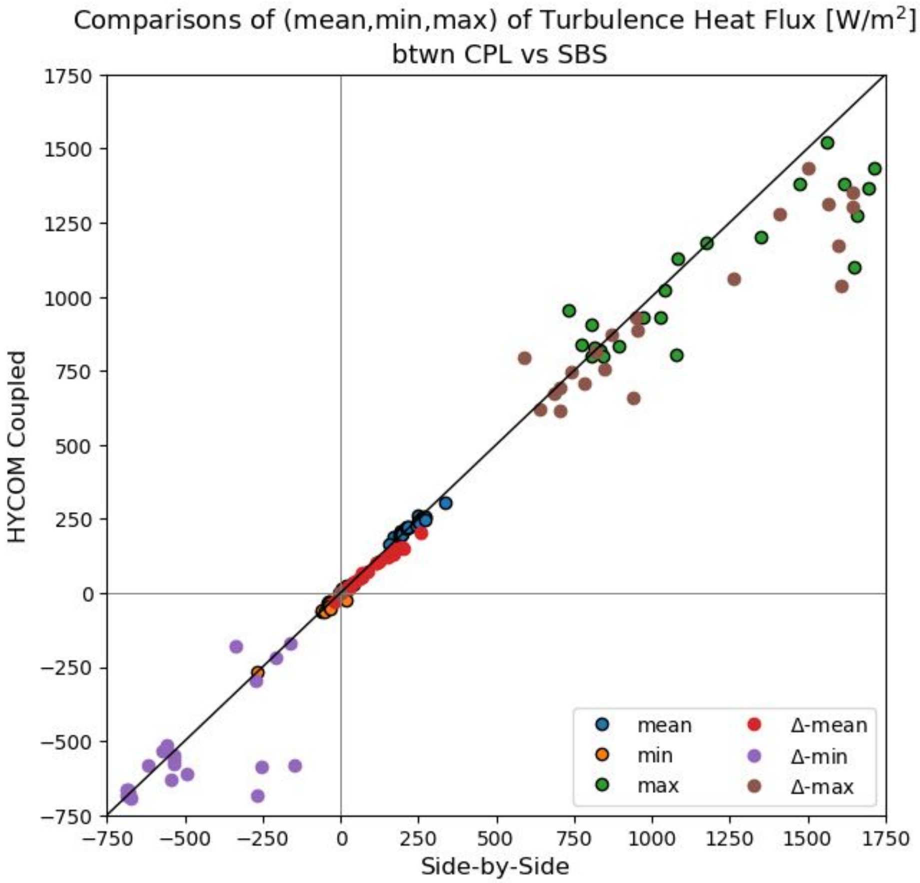
TC-scale analysis (radius <= 500 km):

1. Turbulence Heat Flux = Sensible and Latent heat flux
2. Ocean Heat Content
3. Oceanic Upper Layer Conditions

SST (left) and SST cooling (right)



2. Storm Turbulence Heat Flux



1. Large turbulence heat flux exchange exists at 126 lead hour at a maximum of ~1025 W/m^2 (HCPL) and ~1600 W/m^2 (HSBS): Ocean coupling under-estimates the flux by ~375 W/m^2.
2. Maximum heat flux for HCPL is underestimated, compared to the HSBS, especially from 80-h lead time, with an average of 260 W/m^2. This is in part contributed by dynamic air-sea dynamic interaction during a slow storm-moving period.

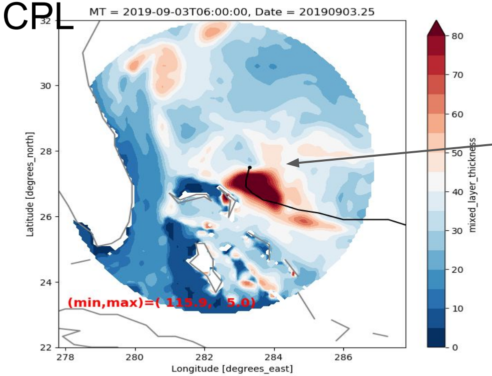
⇒ suggesting less heat flux feeds to a TC.

Mixed layer depth (MLD) and Ocean heat content (OHC)

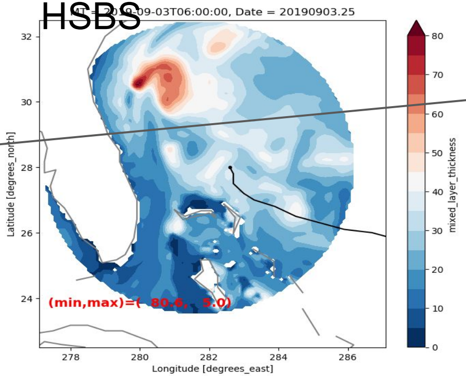
at 126 hr

MLD

HCPL



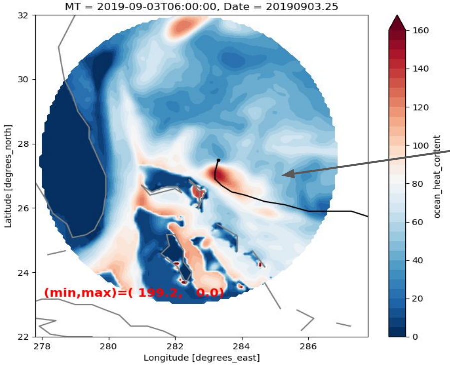
HSBS



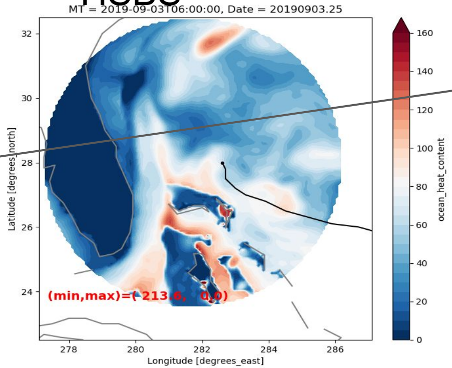
HCPL: deepening MLD by ~70 m, compared to HSBS.

OHC

HCPL



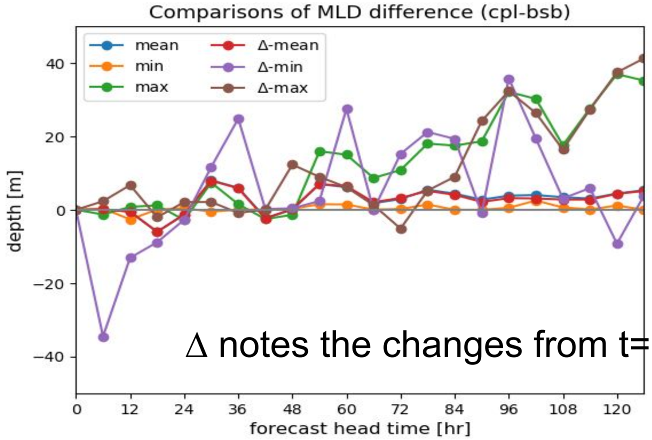
HSBS



HCPL: increase in OHC, with difference of 140 kJ/cm^2.

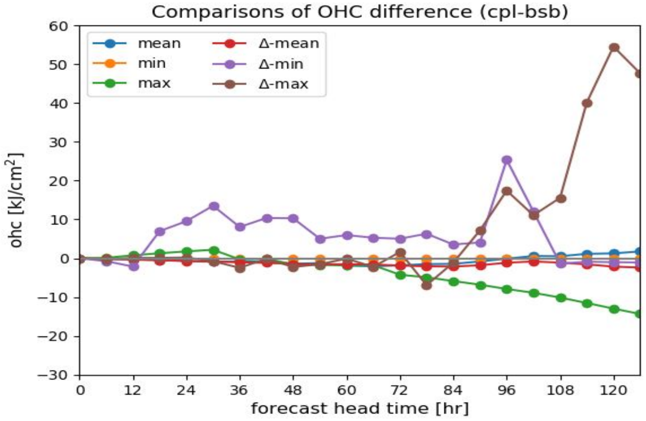
Mixed layer depth (MLD) and Ocean heat content (OHC)

MLD


Comparisons of MLD difference (cpl-bsb)

Δ notes the changes from t=0.

OHC


Comparisons of OHC difference (cpl-bsb)

Time series of MLD (top) and OHC differences from HCPL

A set of minimum, maximum and average are estimated an area of 500 km radius from a TC center at the 6 hour intervals.

HCPL predicts deepening MLD and increasing OHC, implying changes in the oceanic upper layer in response to a storm.

Summary

1. Initial TC intensity is already ~70 kt/15 hPa weaker than the Best Track, implying the needs of vortex initialization, warm start, and/or data assimilation, to close the gap.
2. Without adjustment of atmospheric parameters, ocean coupling simulations result in under-predicting intensity by 30 kt/13 hPa.
3. The ocean coupling impact appears in intensity forecasts from lead time day 2.
4. The largest turbulence heat flux difference is ~375 W/m^2 (at 126 h), where HSBS estimates ~1600 W/m^2 from persistent SST, and HCPL predicts less due to the dynamical interactions between 3D-ocean and a storm.
5. Despite of ~50 kJ/cm^2 OHC more available, HCPL provides less heat flux.

Summary: Continued

6. The storm local impact is observed at least in the upper 300-m depth, where Z20 deepens from 240 to 290 m.
7. A storm changes mixed-layer depth change by O(70 m) (for Vmax=115kt).
8. Storm-induced SST cooling is at an order of 2^{o}C and cold wake is estimated at ~4^{o}C.
9. HCPL exhibits altering the upper condition through the interactions between the ocean steering currents and topography, resulting in an anticyclonic circulation that leads to deepening MLD (by 100 m), warming T (by 3.7^{o}C @70 m) , and downwelling (by 171 m/day @70 m).

Conclusions:

Coupling 3D ocean modeling alters the oceanic upper layer, by deepening mixed layer depth and cooling water temperature directly and indirectly.

It enhance interactions of ocean currents and topography.

Ongoing and Future HAFS-HYCOM Coupling Developments

- Conduct small-scale HAFS-HYCOM coupling retrospective tests based on the HAFS.V0.1A baseline configuration
- Enable using the atmospheric surface pressure in HYCOM coupling
- Slightly increase HYCOM ocean domain and get the HAFS-HYCOM coupling ready for the HAFS.V0.1A real-time experiment (08/01/2020)
- Use the CMEPS mediator for coupling
- Establish the three-way atmosphere-wave-ocean coupled HAFS-WW3-HYCOM system

Thanks!