The Impact of Ocean Conditions on the Hurricane Blanca (2015) Forecasts with a Coupled Model

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1. Introduction

The 2015 North Eastern Pacific hurricane season was affected by the strongest El Niño-Southern Oscillation (ENSO) ever recorded, setting a record long season and an all-time large number of hurricanes (http://www.nhc.noaa.gov/text/MIATWSEP.shtml). By May, the SST anomaly already exceeded 2°C (http://www.cpc.ncep.noaa.gov/products/Epac_hurr/Epac_hurricane.html) in the Nino index areas 1 and 2. Consequently, the Main Development Region (MDR) was set for favorable conditions even before the official season started. The season's second Tropical Cyclone (TC) Blanca formed on 12Z May 31, centered (102.2°W, 12.0°N) in the MDR. Over the next 78 hours, the storm intensified to a cat 4 hurricane (125 kts), and strengthened by 60 kts during a 24 hour period (18Z June 2–18Z June 3). Of specific interest, however, was its quasi-stationary translation speed of 0.5-1.5 ms^{-1} during this rapid intensification period. Models used for numerical guidance by the NHC (National Hurricane Center) estimated a SST cooling of *O*(18°C), while predicting maximum winds that were weaker by 40 kt than the NHC's observed values. This is a baroclinic response of the thermodynamic coupling between SST, deep convection and surface wind. This feedback can further accelerate if a storm moves more slowly. Here we present evidence of the impact of oceanic conditions on intensity forecasts, using a Hurricane Weather Research Forecast (HWRF) model coupled to the Princeton Ocean Model (POM) (which is NHC's operational guidance), and coupled to the HYbrid Coordinate Ocean Model (HYCOM) system. The ocean models solve the same 3D governing, free-surface, primitive equations on a similar 1/12° resolution. The major differences between the POM and HYCOM are, respectively: a) initialization from climatology vs. the Navy Coupled Ocean Data Assimilation (NCODA)-HYCOM analysis; b) climatology vs. NCEP RTOFS forecasts for boundary conditions; c) Mellor-Yamada 2.5 closure vs. KPP mixing physics; and d) 24 sigma vs. 36 hybrid level-isopycnal vertical layers.

2. Simulation Results

Comparisons of track and intensity forecasts for the 00Z cycle on June 3, between HWRF-HYCOM (henceforth H5Y5), HWRF-POM (henceforth HCTL) and the "best track" (BT) are shown in Fig. 1. The H5Y5 and HCTL tracks both have an eastward bias with respect to BT, with very little difference between them (Fig. 1A). However, each model under-predicted the maximum wind intensity (Vmax) (Fig. 1B) though H5Y5 exhibits better skill than HCTL, with error reductions up to 30 kt. The Vmax at 24 h (vertical line in Fig. 1B), for instance, is 93 kt vs. 63 kt for H5Y5 and HCTL, respectively. Sea Surface Temperature (SST) cooling at that forecast hour is 7.7°C for H5Y5, and is 1.1°C higher than that predicted by HCTL (not shown). This somewhat contradicts a typical thermodynamic coupling relationship.

Comparisons of the 24-h upper ocean structure in near field show that HCTL simulates shallower mixed layer (~40 m) for HCTL than the H5Y5 depth (> 80 m). Also, the mixed layer temperature for HCTL is cooler by <1°C and <3°C for 40 m and 80 m, respectively, than the H5Y5 estimates. An outstanding difference, however, is the presence of warm eddies at depths (< 95 m) for H5Y5 runs.

The pre-storm ocean conditions are drastically different. Fig. 3 shows ocean heat content (OHC) for an initial time of 18Z May 31, which indicates the structure of the upper layer. The OHC differences are not only in spatial variability, including warm eddies and filaments, but also the magnitude. The overall OHC difference between HCTL and H5Y5 is more than 50 $kJcm^{-2}$, and the largest difference exists in the area surrounding Blanca. The maximum available OHC is ~94 $kJcm^{-2}$ at (105°W, 12°N) for HCTL vs. ~145 $kJcm^{-2}$ for H5Y5, and it locates in the surrounding area of Blanca in the form of meso-scale eddy. Comparisons against the Argo observations (Table 1) support the difference. Specifically, HCTL under-estimates OHC at low latitudes by ≤54.4 $kJcm^{-2}$ and over-estimates it by 8.9 $kJcm^{-2}$ at higher latitudes. For comparison, the H5Y5 OHC exhibits similar magnitudes to those observed, with mean and RMS differences of 4.1 and 2.7 $kJcm^{-2}$, respectively. H5Y5 provides significantly larger and more accurate initial OHC estimates than HCTL. The representation of realistic pre-storm upper oceanic conditions with H5Y5 leads to compelling improvements in its hurricane intensity forecasts (Fig. 1B).

3. Concluding remarks

The study of temperature and OHC simulations from operational and experimental coupled HWRF systems suggests that the ocean component of the operational model (POM) provides less accurate upper ocean conditions for Hurricane Blanca. The reason is that POM is initialized from a climatological temperature and salinity structure, and daily GFS SST assimilation is insufficient in correcting the upper structure to a realistic representation. This is implied in the OHC comparisons against observations, showing that POM underestimates OHC by as much as 54.5 $kJcm^{-2}$. In contrast, RMS differences for OHC in HYCOM are small (2.7 $kJcm^{-2}$), and the model correctly captures most subsurface features. This study demonstrates the importance of ocean initial conditions to hurricane forecasting, and that the climatology-based initial conditions are ill-equipped to represent the correct heat potential source in an intensifying tropical cyclone.

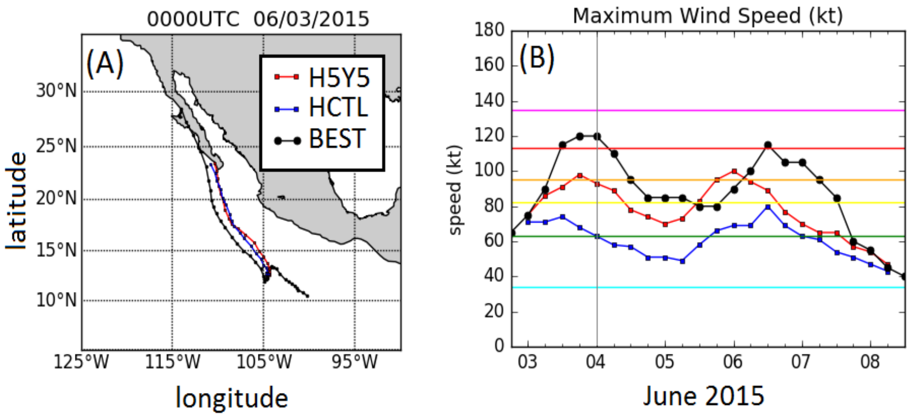

Figure 1. Comparisons of forecast track (A) and the maximum wind (Vmax) intensity (B) for Blanca (IC=0000 UTC June 3, 2015) between HYCOM (H5Y5) and POM coupling (HCTL), against best track. Horizontal color lines represent the Saffir-Simpson Hurricane wind scale.

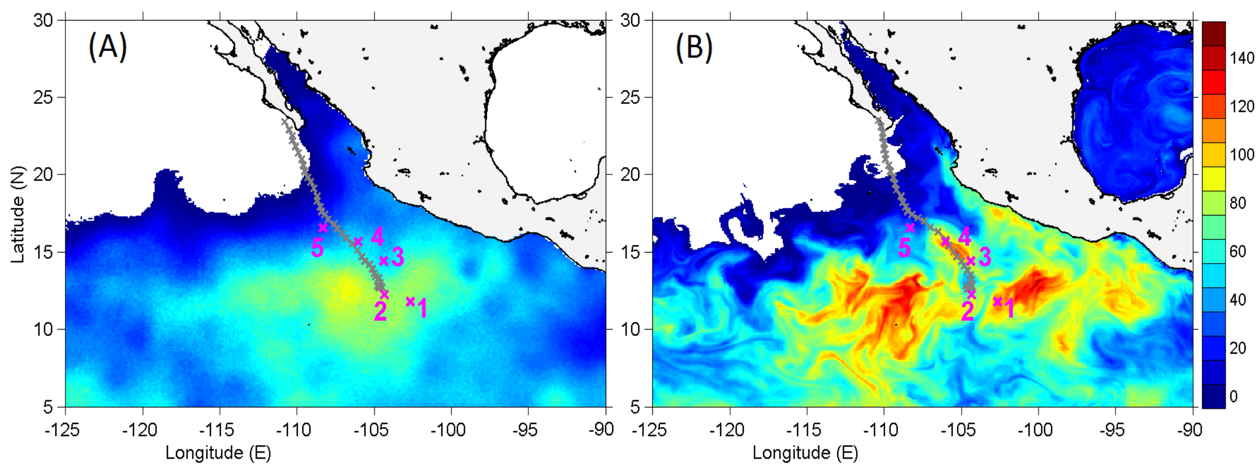

Figure 2. Ocean heat content at initial time (18Z May 31) for HCTL (A) and H5Y5 (B), with superimposed forecast track (IC=00Z June 3). Numbers on/around the track represent Argo positions (see Table 1).

Table 1. Comparisons of ocean heat content (OHC) for a pre-storm period against Argo estimates. The uncertainty of the Argo OHC is 1.5 $kJcm^{-2}$. Units are $kJcm^{-2}$.

	Argo					HCTL			H5Y5		
#	ID	Julian day	Lon. (°W)	Lat. (°N)	OHC	Lon. (°W)	Lat. (°N)	Δ OHC	Lon. (°W)	Lat. (°N)	Δ OHC
1	4901510	23891.45	102.66	11.79	123.0	102.70	11.86	-54.5	102.64	11.91	5.6
2	4901509	23890.34	104.33	12.23	118.2	104.33	12.20	-38.3	104.32	12.23	0.0
3	4901511	23889.79	104.38	14.41	105.1	104.33	14.38	-58.9	104.40	14.41	8.2
4	4900842	23885.86	106.03	15.67	84.7	106.06	15.63	-35.9	106.00	15.64	4.0
	4901638	23893.26	108.30	16.56	29.2	108.26	16.55	8.9	108.32	16.56	2.8