3D Ocean Coupling for the North Western Pacific Typhoon Forecasts

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1. Introduction

Under the auspices of development of the next generation hurricane forecast model at U. S. NWS/NCEP/EMC, , 3D eddy-resolving HYbrid Coordinate Ocean Model (HYCOM) has been coupled to the Hurricane Weather Research Forecast (HWRF) model.. The atmospheric component of this new system (HYCOM-HWRF) is the same model that has been providing numerical guidance to the Joint Typhoon Warning Center (JTWC) in a non-coupled configuration since 2012. This new system has been extensively tested in real-time for the North Atlantic and Eastern Pacific hurricanes starting in 2009. The coupled system exhibits intensity improvements by reducing absolute mean errors and bias, but shows little impact on the track forecasts (Kim et al., 2014). With the availability of global Real-Time Ocean Forecast System (RTOFS) operational products from October 2011, application of this coupled system is now possible without any geographic limitations. For the first time in 2012, HYCOM-HWRF was employed to conduct Typhoon forecasts in the Western North Pacific. This report documents its performances for the 2012 and 2013 season in comparison to the non-coupled HWRF.

2. Experimental design

Coupled simulations were produced at 6-h cycles for the entire lifetime of the individual storms. Initial and boundary conditions for HYCOM are provided from daily operational products of global RTOFS by subregioning but at the same $1/12^{o}$ horizontal and 32-level vertical resolutions. Ocean initialization is obtained from a 24-h free run using RTOFS nowcasts forced by Global Data Assimilation System forcing. The atmospheric physics and air-sea parameters used are identical to the non-coupled HWRF system (ref. Tallapragada et al., 2014). Homogeneous verifications are prepared for both coupled and non-coupled runs using the National Hurricane Center verification tools for comparisons. Figure 1 shows tracks for all 31 TCs encompassing the 2012 (A) and 2013 (B) seasons.

3. Results

Comparisons of track forecasts between coupled (cpl) and non-coupled (ctl) runs (Fig. 2) show little difference in absolute mean error (Fig. 2A) and bias (Fig. 2B) for either season or for the two seasons combined together. Intensity differences, on the other hand, exhibit a seasonal variation where coupled runs retained smaller mean errors by < 5 kt (< 6 hPa) in 2013 than 2012, as compared to the non-coupled runs. The season intensity improvement is more notable at late lead times, with the error decreasing from ~17 kt (14 hPa) at 48 h to ~13 kt (10 hPa) at 120 h, whereas the error for non-coupled forecasts is relatively flat for the same lead hours (Fig. 2C and 2E). The intensity bias (Fig. 2D and 2F) suggests two significant differences: First, there is a distinct offset between the two runs, with largest bias at mid lead times, which then is reduced (for V_{max}) or kept at the same difference (for P_{min}). The pattern, however, is indistinguishable for the two seasons. Second, the coupled HYCOM-HWRF system under-predicts intensity. The intensity forecast by the non-coupled HWRF show little bias at early lead times (≤ 48 h), but then undergo a rapid change afterwards (negative for 2012 and positive for 2013), which results in an overall small bias by cancelling out for the two seasons put together. Meanwhile, coupled forecasts are biased to the negative (positive) for V_{max} (P_{min}), showing no apparent seasonal dependency.

4. Concluding remarks

HYCOM-HWRF coupling persistently reduces intensity forecast errors with seasonal variability, but shifts intensity bias with respect to the non-coupled runs regardless of season. It suggests that dynamic HYCOM coupling alters the gradient wind balance in the atmospheric model. One plausible explanation is that coupling realizes storm-driven sea surface temperature cooling, which in turn results in weakening thermodynamic instability in the atmospheric boundary layer. Efforts are underway to increase skill of the coupled system by identifying the responsible primary processes and determining an optimum air-sea interaction configuration.

Reference

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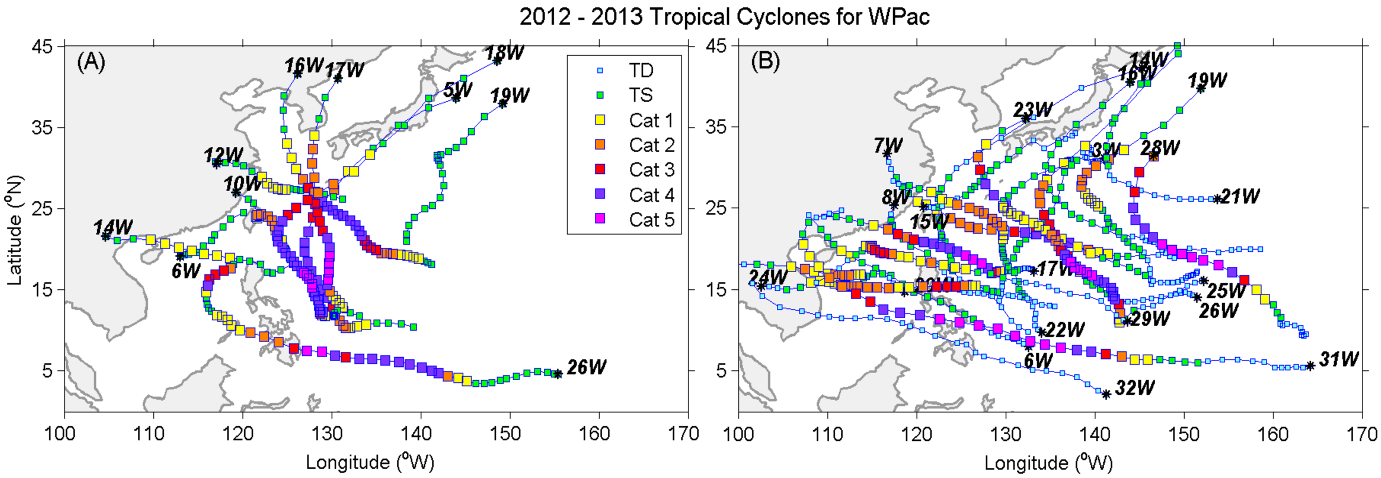

Figure 1. 2012 (A) and 2013 (B) Tropical Cyclones of study.

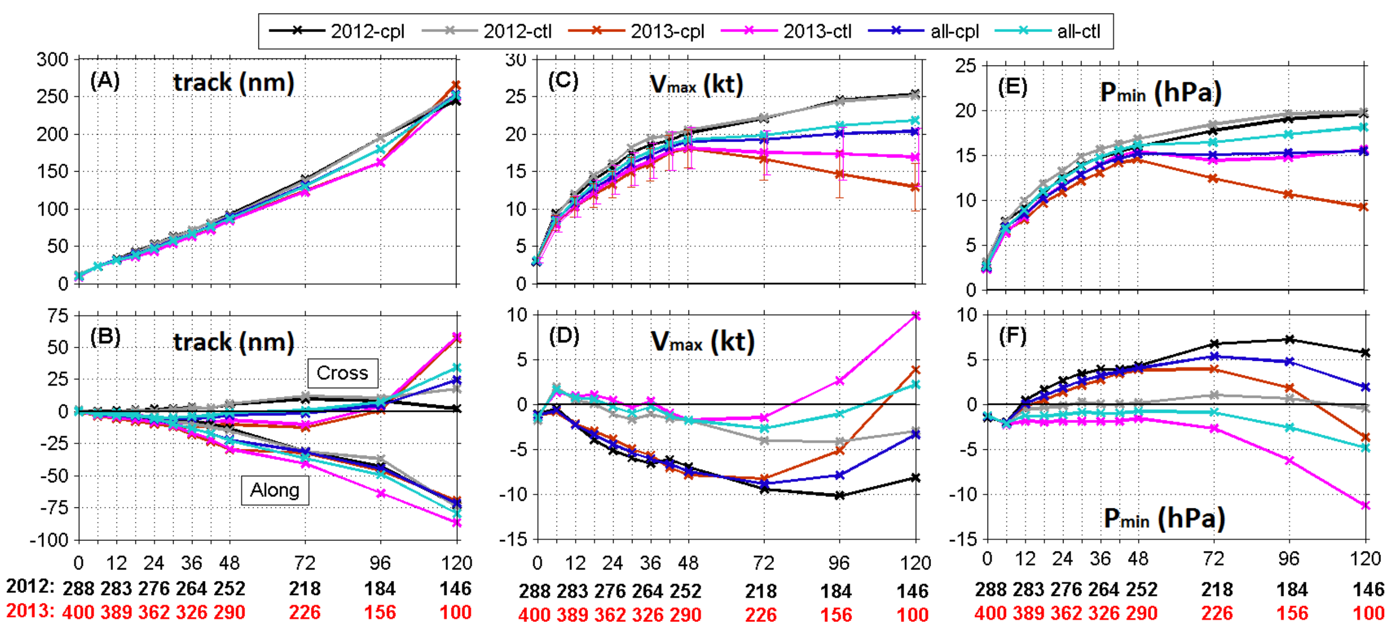

Figure 2. Comparisons of run verifications between coupled (cpl) and non-coupled HWRF (ctl): Absolute mean track error (A); along- and cross-track error (B); absolute mean error of maximum velocity (C) and its bias (D); and central pressure error (E) and its bias (F). Along the x-axis, top labels denote forecast hours, two lines below (middle and bottom) represent number of cases for 2012 (black) and 2013 (red), respectively. Vertical bars in panel (C) are intervals at the 95% confidence.