NCEP HWRF-based Hurricane Ensemble Prediction System

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1. Introduction

The Hurricane Weather and Research Forecasting (HWRF) is one of the operational hurricane modeling systems at NCEP. It has undergone yearly upgrades and consistent improvements since its operational implementation in 2007. The HWRF-based Ensemble Prediction System (HWRF-EPS) has been improved along with its deterministic version and has been running in a real time parallel for storms in the North Atlantic basin since 2014, funded by Hurricane Forecast Improvement Project (HFIP). Over the past 5-year HFIP real time demonstration, HWRF-EPS has proven its value in many respects. The ensemble mean of HWRF-EPS outperforms its deterministic system in terms of both tropical cyclone track and intensity forecasts. HWRF-EPS also provides probabilistic forecasts, including Rapid Intensification (RI) forecasts, by representing model uncertainties in both model initial conditions and model physics.

2. HWRF-based Ensemble Prediction System

HWRF is the flagship operational numerical modeling system at NCEP/EMC and provides tropical cyclone (TC) forecasts in all oceanic basins. The system consists of multiple movable two-way interactive nested grids that follow the projected path of a storm. The model resolution is 13.5/4.5/1.5km in the horizontal and 75 levels in the vertical. HWRF is an atmosphere-ocean coupled system, to provide an accurate representation of air-sea interactions. An advanced vortex initialization scheme and NCEP GSI-based HWRF Data Assimilation System (HDAS) provide the means to represent the initial location, intensity, size and structure of the inner core of a hurricane and its large-scale environment.

The HWRF-EPS is configured the same as its deterministic version except for 1) the use of coarser horizontal 18/6/2km and vertical L61 resolutions; 2) Data Assimilation is turned off; 3) the use of the NCEP Global Ensemble Forecast System (GEFS) (0.5x0.5 degree) as the host model to provide model initial and lateral boundary conditions; 4) the initial TC position and intensity are perturbed to account for uncertainties in TCVitals; 5) the initial sea surface temperature (SST) field is perturbed based on a 5-year climatological GFS SST analysis and; 6) stochastic perturbations are introduced in the convection, PBL, and surface layer schemes to account for the uncertainties in model physics.

3. Results and Discussion

HWRF-EPS was run in real time during the hurricane season in 2018. Due to limited computing resources, not all cycles of all storms were simulated. In total, we had 159 verifiable cycles for six storms (Florence, Gordon, Isaac, Kirk, Leslie, and Michael) in the North Atlantic basin and 85 verifiable cycles for two storms (Hector and Lane) in the East Pacific basin. The ensemble averaged track and intensity from HWRF-EPS outperformed its deterministic version of HW00 (Fig. 1) by about 5% in track and 13% in intensity forecasts, respectively. Similar results have been shown in the past 5-years from earlier real-time HWRF-EPS experiments.

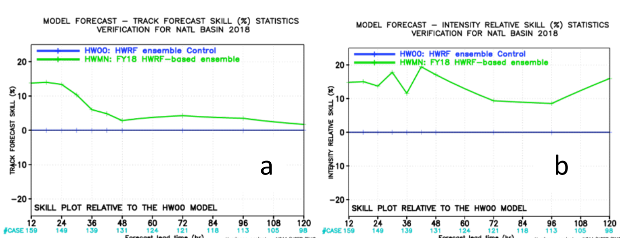

FIG. 1 Comparison of (a) track and (b) intensity forecast skill between HWRF-EPS (HWMN, green) and its deterministic version (blue).

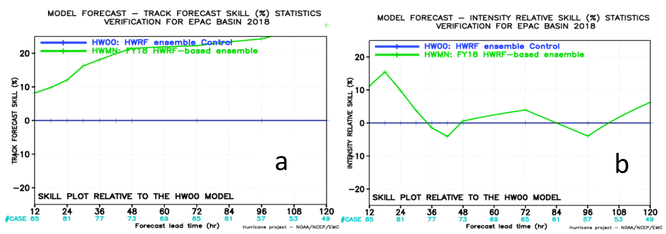

FIG. 2 As in Fig.1 except for East Pacific Basin.

For the Eastern Pacific basin, HWRF-EPS track forecasts are about 20% more skillful than its deterministic model, while having neutral impacts compared to the intensity forecasts from the deterministic version (Fig. 2). It should be noted that the sample size is too small to draw any firm conclusions.

Accurately predicting a Rapid Intensity (RI) event is one of the most difficult and challenging problems in TC intensity forecasting. Compared with the deterministic HWRF, HWRF-EPS has the advantage in forecasting RI of TCs in the form of probabilistic forecasts. Fig.3 shows an example of RI probabilistic forecasts from HWRF-EPS for Hurricane Michael. It lists all the cycles for which Hurricane Michael underwent RI compared to the RI probabilistic forecasts from the HWRF-EPS. It can be clearly seen that HWRF-EPS predicted all RI events well with high probability.

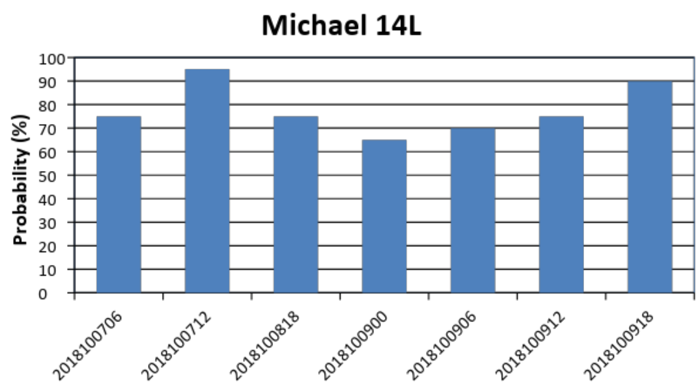

FIG. 3. Probabilistic prediction of an RI event for Hurricane Michael, 2018. The horizontal axis is the cycles where the hurricane went through RI, the vertical is the probability predicted by HWRF-EPS.

4. Conclusions

HWRF-EPS has been running in real time for the last 5 years, and has demonstrated that it has always outperformed its deterministic model in terms of track and intensity forecast skill. HWRF-EPS also provides statistical information and forecast uncertainties through ensemble spread. It also demonstrated its capability to predict RI events. Further work will focus on improving the uncertainty representations in model initial conditions and model physics.

References:

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