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Results from the High-Resolution Hurricane Test Using the Advanced Hurricane-research WRF

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There is little doubt that the prediction of hurricane intensity, as measured by the maximum sustained 10-m wind, remains a daunting challenge even after four decades of research. The emphasis of NOAA's Hurricane Forecast Improvement Project (HFIP) is to coordinate research and operational efforts to improve the prediction of hurricane intensity out to at least 5 days lead time. During the past year, several groups have participated in a test of the importance of increased horizontal resolution in the prediction of tropical cyclone intensity. This project was known as the High-Resolution Hurricane (HRH) test. Specifically, groups were instructed to use model configurations of their choosing, with the constraint that the coarse and fine-scale configurations had to be identical apart from the addition of finer resolution. Typically this enhanced resolution is achieved through nesting. With the hurricane, moving nests are critical to obtain enhanced horizontal resolution for a manageable increase in computational cost.

The model that is the focus of this paper is the Advanced Hurricane-research WRF (AHW), derived from the Advanced Research WRF (ARW). Many of the upgrades in the AHW have become part of ARW. For the present test this year, the major upgrades were (a) use of ensemble data assimilation to initialize the storm and (b) improved representation of the spatial variation of the upper-ocean mixed layer with the simple 1-D ocean model.

The basic configuration of the AHW is summarized in Table 1 and is an extension of that reported in Davis et al. (2008). Two grid spacings were tested, 12-km and 1.33 km (the latter actually containing concentric 4-km and 1.33-km moving nests centered on the storm). Hurricane intensity is sensitive to the ratio of exchange coefficients of drag and enthalpy. The wind-speed dependence

	12-km	4-km	1.33-km
size	469x424	202x202	241x241
levels	36	36	36
dt	60 s	20 s	6.7 s
Cumulus	K-F	none	none
Microphys	WSM5	WSM5	WSM5
PBL	YSU	YSU	YSU

Table 1. AHW configuration. The model top is at 20 hPa.

of these coefficients appears in Fig. 1.

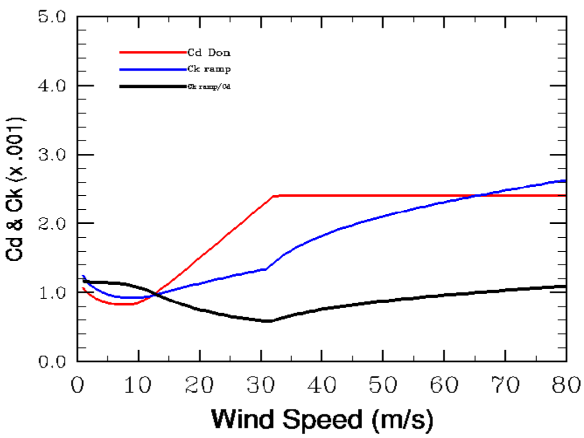

Figure 1. drag coefficient (C_d, red), enthalpy exchange coefficient (C_k, blue) and ratio of C_k/C_d (black) as a function of wind speed.

For the HRH test, we performed 69 pairs of simulations for a total of 10 Atlantic tropical cyclones. The model was initialized using an ensemble Kalman filter consisting of 96 members at 36-km grid spacing (Torn and Hakim 2008). Assimilated observations included surface pressure, rawinsonde (including G-IV dropsondes), ACARS, cloud motion vectors and tropical cyclone best track data. The update cycle for the ensemble assimilation was 6 h. The ensemble was initialized roughly two days

Storm	# Forecasts
Emily (2005)	10
Katrina (2005)	6
Philippe (2005)	6
Rita (2005)	7
Ophelia (2005)	11
Wilma (2005)	11
Felix (2007)	8
Humberto (2007)	2
Ingrid (2007)	4
Karen (2007)	4

Table 2. Storms and # forecasts for each resolution for each storm.

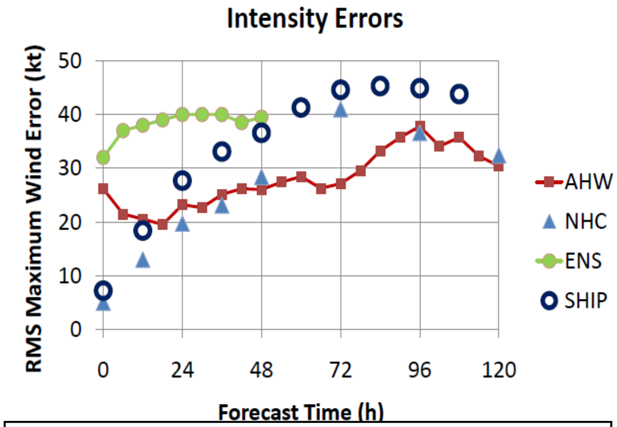

Figure 2. RMS intensity errors (kt). ENS=ensemble.

prior to being classified as a depression by adding balanced perturbations from the WRF-Var system to the GFS 36-h forecast valid at the appropriate time. Using an old forecast with high amplitude perturbations helped the ensemble develop a flow-dependent ensemble quicker than starting from short-term forecasts.

Computational constraints forced the selection of a single member for the deterministic forecast. This member was chosen as the one closest to the observed intensity at initialization time. Pairs of forecasts, one with a single 12-km grid, the other with storm-centered, moving nests of

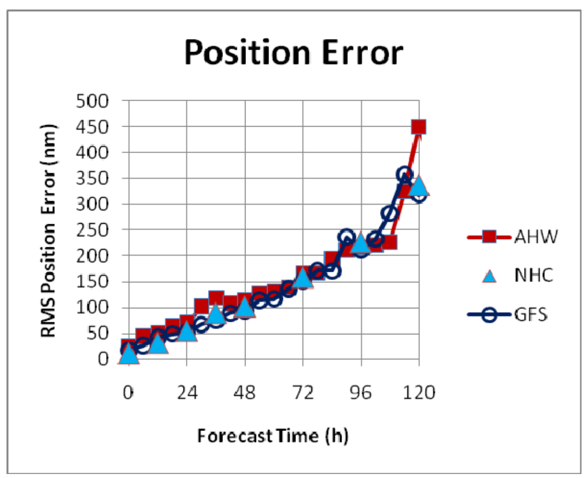

Figure 3. Position Errors (nm).

4-km and 1.33-km grid spacing, were integrated to 126 h or until the time the observed storm dissipated. Table 2 summarizes the storms and number of forecasts for each.

From Fig. 2, the root-mean-square (RMS) intensity error from the deterministic forecasts is comparable to or smaller than the official forecast and the forecasts from the SHIPS statistical model. At short lead times of 24 h or less, the model intensity is adjusting to the initial condition which tends to underestimate the intensity of intense storms due to the coarse resolution of the ensemble. However, no large imbalances were noted as had occurred with cold starts using other models. The adjustment from the 36-km initial data tends to be rather smooth in time. The bias in the initial intensity in the ensemble is about 20 kts and in the best ensemble member it is about 14 kts. These are clearly major contributors to the RMS error at t=0.

Position errors were slightly larger for the AHW around 36 h than both the errors in the GFS and in the NHC official forecasts, but otherwise, all errors are comparable. The rapid rise of AHW errors around 120 h is mainly contributed by a few forecasts of Ophelia which moved out of the model domain.

One of the primary shortcomings of intensity forecasts is the prediction of rapid intensity change. Here we adopt the definition of an increase of maximum sustained wind of 25 knots in 24 h (the operational definition is 30 knots, but this does not notably affect results). To define skill, we compute the equitable threat score where a hit is defined as a correct forecast of a 25-knot intensity increase or greater, and a correct negative is the correct forecast of the absence of such an event. For the full sample, the ETS values were: AHW=0.17, NHC=0.03, SHIPS=0.00 and GFS=0.00. Thus, while not a high degree of skill perhaps, the AHW is showing some skill where the operational forecasts have essentially none.

At the time of this writing, the results of the 12-km simulation are being analyzed and will be reported at the workshop.

In summary, the AHW appears to offer useful guidance about hurricane intensity. The use of a coarse-resolution ensemble for initialization appears to reduce imbalances in the initial condition, but also imprints a low bias of intensity into the initial condition. It takes at least 12 h to remove the effects of this bias, and from 24 h and beyond, the AHW intensity forecasts were as good as, or better than, the NHC official forecast. Furthermore, some skill of rapid intensity change was noted. Work in the near future will involve reducing the bias in the ensemble-derived initial condition for quasi-operational forecasts with AHW planned for 2009 as part of the HFIP real-time demonstration project.

References

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