Hurricane WRF: Testing activities and community support at the DTC

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1. Introduction

The Hurricane Weather Research and Forecast (HWRF) model, a coupled atmosphere-ocean system, is a National Oceanic and Atmospheric Administration (NOAA) operational model for predicting tropical storms. It is important for the HWRF model to benefit from research and development in hurricane numerical weather prediction (NWP) that is occurring in the scientific community in order to accelerate the rate of forecast improvement and meet the goals of the NOAA Hurricane Forecast Improvement Project (HFIP) of reducing track and intensity errors by 50% in first 5 days of forecast.

To facilitate the transition of research results onto operations, the Developmental Testbed Center (DTC) has been working with HWRF since 2009. The DTC (Bernardet et al. 2008) is a joint effort between the National Center for Atmospheric Research (NCAR) and the Global Systems Division (GSD) at the NOAA Earth System Research Laboratory. The main mission of the DTC is to accelerate the infusion of promising new NWP capabilities developed by the research community into operational applications.

The HWRF activities at the DTC are focused around three main goals: 1) create a code management system that facilitates the transfer of new developments to the operational system; 2) support HWRF to the general community so research and development can be done with the operational code; and 3) conduct testing and evaluation of HWRF to assure the integrity of the community code and to evaluate new developments for potential operational implementation. This abstract summarizes what the DTC has accomplished thus far towards these goals and describes the community version of HWRF system and its forecast skill.

2. HWRF description

The atmospheric component of HWRF is a configuration of the Weather Research and Forecasting (WRF) model that has been designed to predict tropical cyclones, and includes the Non-hydrostatic Mesoscale Model dynamic core with a vortex-following moving nest, the Simplified Arakawa-Schubert cumulus scheme, the Geophysical Fluid Dynamics Laboratory (GFDL) surface layer parameterization, the Global Forecasting System (GFS) planetary boundary layer parameterization, and the tropical Ferrier microphysics scheme. HWRF's oceanic component is a version of the Princeton Ocean Model adapted for tropical cyclones (POM-TC), which was developed at the University of Rhode Island (URI). The atmospheric and oceanic components communicate through a coupler developed at NOAA National Centers for Atmospheric Prediction (NCEP). In addition, HWRF uses a vortex cycling and relocation technique for atmospheric initialization and a features-based ocean initialization. HWRF post-processing includes a vortex tracker, which can extract the tropical cyclone's track, intensity and structure from the model output.

Figure 1 is a schematic flowchart of the community HWRF components. Storm messages issued by the National Hurricane Center, including storm location and intensity, are used to define the HWRF domain. The WRF preprocessor (WPS) is used to generate preliminary initial and boundary conditions, which are used in the vortex initialization process to improve the initial vortex representation. If a previous 6-h HWRF forecast is available, it is used in the vortex cycling process; otherwise, a bogus vortex based on HWRF climatology is used. The Gridpoint Statistical Interpolation (GSI) 3-D variational data assimilation system is used to ingest observational data into the initial fields. An ocean initialization process generates initial conditions for the oceanic component POM-TC. HWRF atmospheric and oceanic components then run in parallel and exchange information through a coupler: the atmospheric model calculates and sends the momentum and heat fluxes to the ocean, while the ocean model sends the sea surface temperature to the atmosphere. The Unified Post-Processor is used to de-stagger the forecast, to interpolate it to a regular latitude-longitude grid on pressure levels, and to compute derived quantities. Finally, the GFDL vortex tracker is used to obtain properties of the forecast tropical cyclone, such as location and intensity.

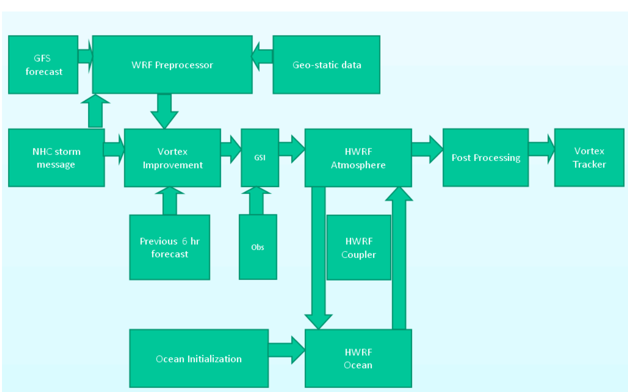

Figure 1: Schematic flowchart of the community HWRF system components.

3. Code Management

HWRF was developed at the NCEP Environmental Modeling Center (EMC) based upon WRF version 2.0 and became operational in the 2007 hurricane season. During its development, numerous features were implemented to improve performance. However, most of these advances were not available to the research community. Meanwhile, the general WRF model had evolved with contributions from the research community, but these contributions did not have a clear path to benefit operations at NCEP.

The DTC, in collaboration with the URI and NOAA NCEP/EMC, GFDL, and Atlantic Oceanographic and Meteorological Laboratory (AOML), ported the operational HWRF capabilities of WRF and WPS to the community code repositories, and established new community code repositories for the vortex initialization, vortex tracker, POM-TC and the coupler based on the operational code, effectively establishing a single code base for all HWRF components that can be shared between the operational and research communities.

An important part of transitioning HWRF codes to the community was the generalization of the components so they could be run in Linux platforms in addition to the operational platform, currently an IBM.

A community HWRF Beta version, utilizing WRF v3.1.1, was released in March 2010, containing the capability of the 2009 operational model. The next community HWRF release, based on WRF v3.3, is planned for July 2011 and will contain the capability of the 2011 operational model.

A code management plan for HWRF has been drafted by DTC and EMC. According to this plan, the community code repository will be used for the development and support of the HWRF system. HWRF will be fully integrated with the community codes, and its atmospheric component will be one of the many possible configurations of the WRF model.

4. HWRF user support

The DTC maintains a WRF for Hurricanes website where users can obtain code downloads, datasets and documentation. There are currently more than 170 registered HWRF users. DTC has published HWRF scientific (Gopalakrishnan et al. 2011) and technical documentations (Bao et al. 2011). Two WRF for Hurricanes tutorials were held jointly by DTC, NCEP and NCAR/MMM in February 2010 and April 2011.

The HWRF help desk, as a component of the WRF help desk, can be assessed by sending a message to wrfhelp@ucar.edu.

5. HWRF testing

DTC conducts various types of tests on HWRF. One class of tests aims at assuring the integrity of the community code. Since the atmospheric component of HWRF is one of many possible configurations of the WRF model, it is important to ascertain that the HWRF answer remains unchanged when WRF is updated in areas non-related to the HWRF configuration (e.g., chemistry). DTC also tests HWRF to make sure that any new developments done in the academic community, research laboratories or at EMC have been properly transitioned to the supported community code. Another class of tests is aimed at benchmarking the community code to create DTC Reference Configurations (RCs, Wolff et al. 2010). Finally, DTC tests HWRF to evaluate new developments for potential operational implementation.

The latest hurricane testing activity in the DTC was aimed at making sure that the capabilities of the 2011 HWRF Operational Baseline had been correctly transitioned to the community code prior to the planned July 2011 release and to benchmark that community code to create a DTC RC. The 2011 HWRF Operational Baseline is a HWRF configuration that uses WRF v3.2 with additional bug fixes and developments used for initial testing towards the 2011 operational model. It should be noted that the 2011 operational HWRF contains additional developments beyond those contained in the 2011 operational baseline, and will be benchmarked by the DTC at a later date.

The community HWRF runs of the 2011 operational baseline done by the DTC were dubbed HNR2 and they were compared against a similar configuration run at EMC dubbed HR20. A comprehensive description of the test configuration and results can be found at http://verif.rap.ucar.edu/eval/hwrf_hnr2_hr20. A total of 1190 cases from 53 storms were used, covering 3 seasons for both the North Atlantic and Eastern North Pacific basins.

It is important to understand that an exact match between HNR2 and HR20 is not expected due to small differences between the two configurations. In particular, HNR2 was run in the HFIP Linux cluster using NetCDF I/O format, while HR20 was run in the NCEP IBM using binary I/O format. Therefore, only a match of the bulk statistical results is sought.

Figures 2 and 3 show the track and absolute intensity mean error, respectively, with 95% confidence intervals, for the North Atlantic basin for the aggregations of all cases. The track errors increase linearly with forecast lead time and the HNR2 and HR20 forecasts are statistically indistinguishable. The absolute intensity errors grow quickly in the first 6-h of forecast, followed by a period of linear growth over 48 h. In the last three days of forecast the errors remain relatively constant. No statistically significant differences were found between the HNR2 and HR20 mean absolute intensities beyond the initial time, in which the maximum wind speeds differ by 2 kt. The reason for this initialization discrepancy is being investigated.

This test showed that the DTC functionally-similar testing and evaluation suite has been established and that the 2011 Operational Baseline was successfully ported to the community code. The HNR2 run will be used to designate a DTC RC.

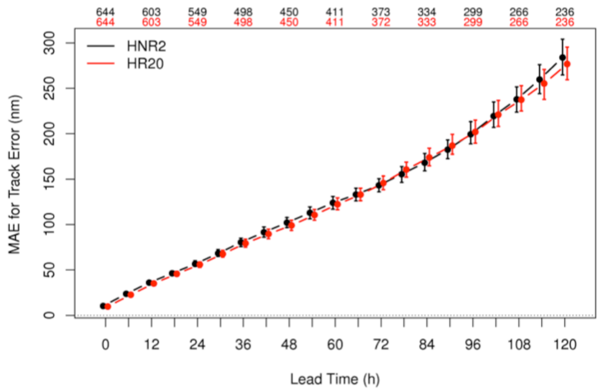

Figure 2. Mean and 95% confidence intervals for track errors (nm) as a function of forecast lead time (h) in the Atlantic basin of the HNR2 (black) and HR20 (red) HWRF configurations.

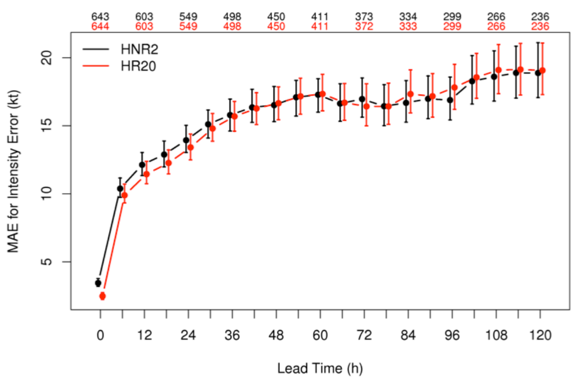

Figure 3. Same as Fig. 2, except for absolute intensity (kt).

6. Concluding remarks

Several important steps have been taken by DTC and collaborators to make HWRF a code that can be used for research and operations. This investment of time and efforts is expected to pay dividends in making it possible to have newly developed code readily available for testing and consideration for possible operational implementation. The support to the community of all HWRF components makes it possible for researchers in academic institutions and government laboratories to develop in the same code used by operations, and the functionally-similar suite developed and maintained at the DTC supports the integrity of the code and allows efficient test of new capabilities.

7. Acknowledgments

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