The Developmental Testbed Center

HWRF Sensitivity to Cumulus Schemes

Test Plan

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1. Introduction

The DTC will perform extensive testing and evaluation for the Hurricane WRF (see all acronyms in Appendix B), known as HWRF (Gopalakrishnan et al. 2011), in order to evaluate the sensitivity of the model to cumulus parameterizations. This test will be configured using the HWRF 2012 baseline codes as of February 16, 2012. The control run will use the default physics, while sensitivity studies will be conducted using alternate cumulus schemes and keeping the other parameterizations unchanged.

This HWRF configuration uses three domains, with grid spacing 27, 9, and 3 km and has the following components: WPS, vortex relocation and initialization, WRF model using a modified NMM dynamic core tuned for tropical forecasting, POM, features-based ocean initialization, UPP, GFDL vortex tracker and GrADS-based graphics. The GSI 3D-VAR code is not part of this test.

HWRF is currently operational in the North Atlantic and Eastern North Pacific basins. In this configuration, Atlantic forecasts are run in a coupled ocean-atmosphere mode, while Pacific forecasts use only the atmospheric model.

The goal of this test is to document HWRF's sensitivity to the cumulus parameterizations. Results will be used by EMC to configure the experimental HWRF ensemble they will run in the 2012 season. In order for results to be available in a timely fashion and be relevant for the 2012 experimental ensemble, DTC needs to start tests in March 2012. Therefore, the HWRF Baseline code as of February 16, 2012 , and not the final 2012 operational configuration was chosen. While results obtained with this tag will differ from those obtained with the finalized 2012 operational model, the overall conclusions about sensitivity to cumulus schemes are not expected to change.

2. Experiment Design

The end-to-end system is composed of WPS, vortex relocation and initialization, ocean initialization, POM, WRF, coupler, UPP, tracker, graphics generation, data archival, and dissemination of results.

a. Codes to be employed

The test will be conducted with the 2012 operational HWRF baseline as of February 26, 2012 (https://svn-dtc-hwrf.cgd.ucar.edu/tags/hwrf-baseline-20120216-2300) .

The scripts for running the model will be obtained from the DTC in-house repository at https://svn-dtc-hwrf.cgd.ucar.edu/tags/hwrf-tne.

b. Domain Configurations

The HWRF domain will be configured in the same way as the NCEP/EMC 2012 operational system. The atmospheric model employs a parent and two movable nested grids. The parent grid has 216 x 432 grid points and covers a 75x75° area with 0.18° (approximately 27 km) horizontal grid spacing. Domain Two has 88 x 170 grid points and covers a 5.4 x 5.4° area with 0.06° (approximately 9 km) grid spacing. There are 154 x 272 grid points in d03 with 0.02° (approximately 3 km) horizontal grid spacing. Both the parent and the nests use the WRF-NMM rotated latitude-longitude projection and the E-staggered grid. Indices in the E-staggered grid are such that a square domain has approximately twice as many points in the y-direction as the x-direction. The location of the parent and nest, as well as the pole of the projection, vary from run to run and are dictated by the location of the storm at the time of initialization. Forty-two vertical levels (43 sigma entries) will be employed, with a pressure top of 50 hPa.

In this configuration, HWRF is run coupled to the POM ocean model for Atlantic storms and in atmosphere-only mode for East Pacific storms. The POM domain for the Atlantic storms depends on the location of the storm at the initialization time and on the 72-h NHC forecast for the storm location. Those parameters define whether the East Atlantic or United domain of the POM will be used. Both POM domains cover an area from 10.0°N to 47.5°N in latitude, with 225 latitudinal grid points. The East Atlantic POM domain ranges from 60.0° W to 30.0° W longitude with 157 longitudinal grid points, while the United domain ranges from 98.5° W to 50.0° W with 254 longitudinal grid points. Both domains have horizontal grid spacing of approximately 18 km in both the latitudinal and longitudinal directions. The POM uses 23 vertical levels and employs the terrain-following sigma coordinate system.

Additional intermediate domains are used for the atmospheric model during the vortex relocation and initialization procedures (see Bao et al. 2011), and during postprocessing (see item 3.g below).

c. Initial and Boundary Conditions

Initial conditions will be obtained from the retrospective forecasts of the GFS model implemented operationally on ??date??. Input files contain the spectral coefficients in binary format and are read using a HWRF utility named prep hybrid. HWRF applies a vortex relocation procedure as described in Bao et al. 2011 and Gopalakrishnan et al. 2011. If a 6-h forecast from a previous HWRF run (initialized

6-h before a given cycle) is available, that forecast cycle is used in the initialization process. The vortex relocation procedure will remove the vortex from the GFS analysis and substitute it with the vortex from the previous HWRF forecast, after correcting it using the observed location and intensity. When a previous HWRF forecast is not present, the GFS vortex is removed and substituted by a synthetic vortex derived from a procedure that involves theoretical considerations and HWRF climatology. This procedure is referred to as *cold start*.

d. Forecast Periods

Forecasts will be initialized every 6 hours for selected storms of the 2011 season (see list in Appendix A) and will run out to 126 hours.

e. Physics Suite

The operational physics suite configuration (Gopalakrishnan et al. 2011) is described in Table 1. The convective parameterization is applied in both the parent and d02 domains. No cumulus parameterization is used in d03. Sensitivity studies will be conducted swapping the cumulus parameterization and including the new SAS scheme conded by Yonsei University (14), the Kain-Fritsch scheme with moisture advection trigger (1) and the Tiedtke scheme (6).

Table 1. Control Physics Suite for Cumulus test.

Microphysics	Ferrier for the tropics (85)
Radiation SW/LW	GFDL/GFDL (98/98)
Surface Layer	GFDL (88)
Land Surface Model	GFDL slab model (88)
Planetary Boundary Layer	GFS (3)
Convection	SAS (84)

f. Other aspects of code configuration

The HWRF system will be compiled with the environmental variables WRF_NMM_CORE, WRF_NMM_NEST, WRFIO_NCD_LARGE_FILE_SUPPORT and HWRF set to 1 in order for the executables to contain the HWRF-specific instructions.

As in the operational configuration, a time step of 54 s will be used for the parent grid, while a time step of 18 s will be used in d02 and 6 s for d03. Calls to the turbulence, cumulus parameterization and microphysics will be every 108 seconds for the parent domain and d02, and every 36 s on d03. Calls to the radiation will be every 54 minutes on every domain. Coupling to the ocean model and nest motion are restricted to a 9-minute interval.

The gravity wave drag parameterization will be applied in the parent-domain only, and the advection will be using the Lagrangian scheme.

g. Post-processing and Vortex Tracking

The unipost program within UPP will be used on the parent and nest domains to destagger the forecasts, generate derived meteorological variables (including MSLP), and vertically interpolate the fields to isobaric levels. The post-processed fields will include two- and three-dimensional fields on constant pressure levels and at shelter level, all of which are required by the plotting and verification programs.

Using the copygb program contained in UPP, the post-processed parent and nest domains will be horizontally interpolated and combined in a 20° x 20° grid with 0.03° grid spacing, centered on the forecast storm. This grid will be used for vortex tracking.Three-hourly forecasts on his grid will be used for vortex tracking.

h. Model Verification

The characteristics of the forecast storm (location, intensity, structure), as contained in the respective ATCF files produced by the tracker, will be compared against the Best Track using the NHCVx. The NHCVx will be run separately for each case, at 6-hourly forecast lead times, out to 126 h, in order to generate a distribution of errors. Due to the lack of a community package for hurricane forecast verification, the NHCVx was chosen since it is the system used operationally.

A R-statistical language script will be run separately to aggregate the errors and to create summary metrics including the mean and median of track error, along-and across track error, intensity error, absolute intensity error, and radii of 34, 50, and 64 kt wind in all four quadrants. All metrics will be accompanied of 95% confidence intervals to describe the uncertainty in the results due to sampling limitations. The largest outliers (worst forecasts) will be identified.

i. Graphics

Graphics will be generated using GrADS scripts originally developed at EMC. Graphics will include line plots of track, maximum winds and mean sea level pressure.

Additionally, the following 4 graphics will be produced for six-hourly lead times

- 850-hPa streamlines and isotachs on the combined domain
- 850-hPa streamlines and isotachs on the nest
- MSLP and 10-m winds on the nest
- Zonal cross sections of zonal and meridional wind on the nest
- Meridional cross section of zonal wind on the nest

All graphics will be displayed on the DTC testing and evaluation website.

j. Data Archival and Dissemination of Results

Input and output data files from several stages of the end-to-end system will be archived in the NOAA ESRL/GSD MSS and the results will be summarized in a report.

3. Computer resources

- Processing resources

  All forecasts will be computed on the HFIP Linux cluster *tjet* located at NOAA GSD. The Intel compiler will be used. For the coupled run, 91 processors will be used for the atmospheric model, 1 for the coupler, and 1 for POM. All other programs will be run in a single processor.

- Storage resources

  All archival will be on the NOAA GSD MSS.

- Web resources

  Model forecast and verification graphics will be accessed through a web interface available on the DTC website.

4. Deliverables

The NOAA GSD MSS will be used to archive the files input and output by the forecast system. Additionally, all code compilation logs, input files and fixed files used in the runs will be archived. These files will be made available to the community for further studies.

The DTC website will be used to display the forecast and objective verification graphics.

Finally, a report will be written summarizing the results and conclusions from this test.

5. References

Bao, S., R. Yablonsky, D. Stark, and L. Bernardet, 2011. HWRF Users' Guide V3.3a. Developmental Testbed Center, 88pp.

Gopalakrishnan, S., Q. Liu, T. Marchok, D. Sheinin, N. Surgi, R. Tuleya, R. Yablonsky, and X. Zhang, 2011: Hurricane Weather and Research and Forecasting (HWRF) Model: 2011 scientific documentation. L. Bernardet, Ed., 75 pp.

Acknowledgements

This design document was written with input from the hurricane teams at DTC and EMC.

Appendix A: Case List

Columns on the table refer to the storm name, storm number, beginning and ending case (month, day and time UTC in format mmddhh). Typically the first case of a storm is initialized as a cold start and subsequent cases are cycled.

2011 Atlantic	**ID**	**Cases**	**Begin**	**End**
Harvey	08L	14	081900	082206
Irene	09L	32	082100	082818
Katia	12L	48	082906	091012
Maria	14L	40	090618	091612
Ophelia	16L	50	092100	100306
Rina	18L	20	102318	102812
Total 2011 Atlantic		**204**		

2011 Pacific	**ID**	**Cases**	**Begin**	**End**
Dora	04E	26	071812	072418
Eugene	05E	24	073112	080606
Fernanda	06E	20	081600	082000
Total 2011 Pacific		**70**		

Appendix C: List of Acronyms

3D-Var – Three dimensional Variational Analysis

ATCF – Automated Tropical Cyclone Forecasting

BC – Boundary Conditions

d02 – Domain Two

d03 – Domain Three

DTC – developmental Testbed Center

EMC – Environmental Modeling Center

GFDL – Geophysical Fluid Dynamics Laboratory

GFS – Global Forecasting System

GSD – Global Systems Division (of NOAA Earth System Research Laboratory)

GSI – Global Statistical Interpolator

GRIB – Gridded binary data format

HWRF – Hurricane Weather Research and Forecasting

IC – Initial Conditions

MSLP – Mean Sea Level Pressure

MSS – Mass Storage System

NCEP – National Centers for Environmental Prediction

NHC – National Hurricane Center

NHCVx – National Hurricane Center verification system

NMM – Non-hydrostatic Mesoscale Model

NOAA – National Oceanic and Atmospheric Administration

POM – Princeton Ocean Model

SAS – Simplified Arakawa-Schubert cumulus parameterization

UPP – Unified Post-Processor

WPS – WRF Preprocessing System

WRF – Weather Research and Forecasting