The impact of GPSRO observations on HWRF forecast accuracy for Hurricane Gonzalo

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Abstract

An initial capability to perform Observation System Experiments (OSE's) for tropical cyclones has been developed at The Aerospace Corporation. The use of the system will be focused on determining the impact of satellite data on tropical cyclone track and intensity forecasts with a particular emphasis on the use and impact of **"non-traditional"** satellite sources. This capability, which is heavily based on Version 3.7a of the Developmental Testbed Center's (DTC) community Hurricane Weather Research and Forecasting (HWRF) model system, will be described along with preliminary results from an initial Global Positioning System Radio-Occultation (GPSRO) OSE.

HWRF v3.7a Overview[1]

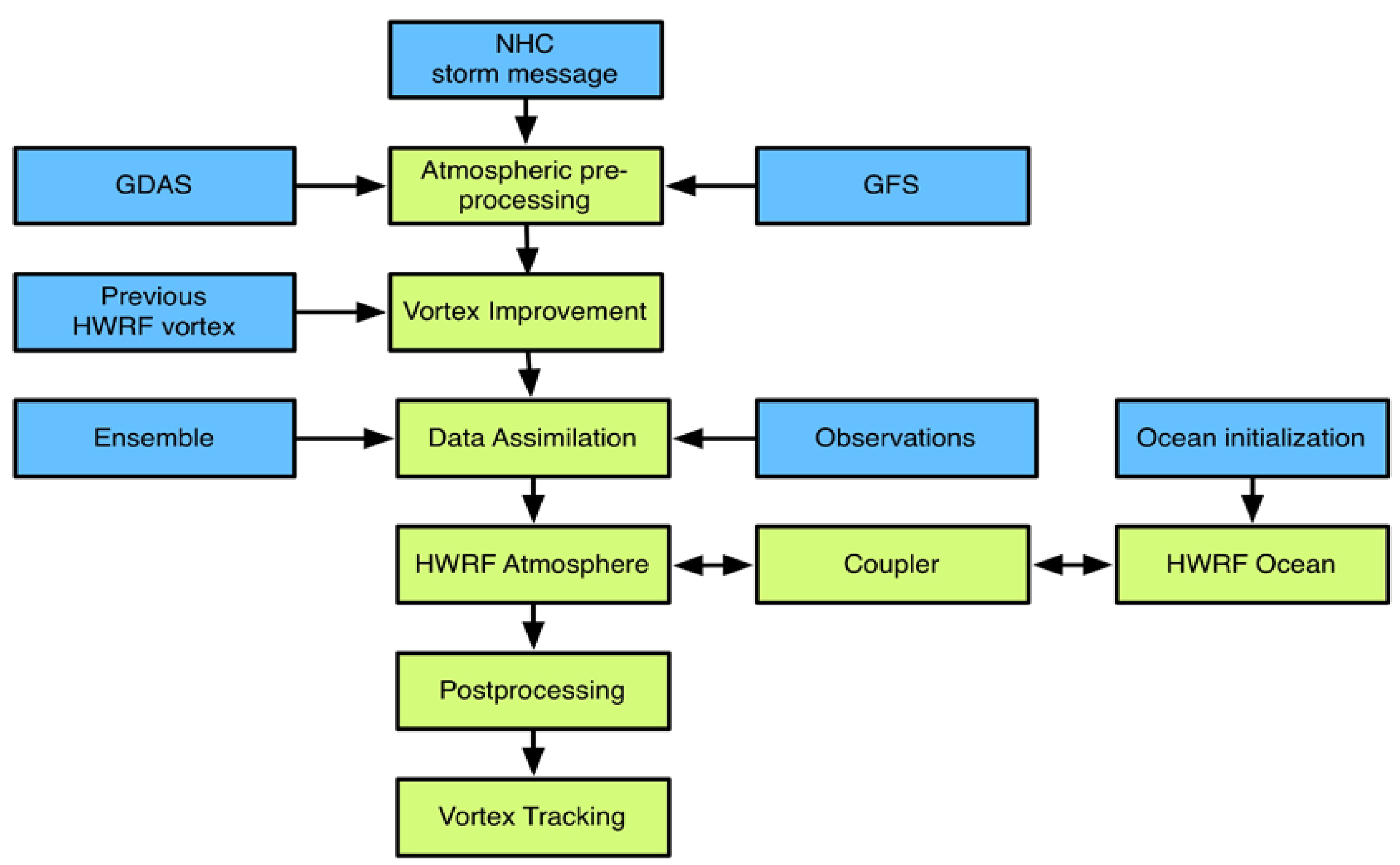

Figure 1. Simplified overview of the HWRF system as configured for operations in the Atlantic basin. Components include the atmospheric initialization (WPS and prep_hybrid), the vortex improvement, the GSI data assimilation, the HWRF atmospheric model, the atmosphere-ocean coupler, the ocean initialization, the MPIPOM-TC, the post processor, and the vortex tracker

1. HWRF Component

The community Hurricane Weather Research and Forecasting (HWRF) model is a sophisticated and complete end-to-end system designed to support both tropical cyclone research and operational forecasting. *"The HWRF system is composed of the WRF (Weather Research and Forecasting) model software infrastructure, the Non-Hydrostatic Mesoscale Model (NMM) dynamic core, the MPIPOM-TC, and the NCEP coupler. HWRF employs a suite of advanced physical parameterizations developed for tropical cyclone applications. These include the GFDL surface-layer parameterization to account for air-sea interaction over warm water and under high-wind conditions, the Noah Land Surface Model (LSM), the GFDL radiation scheme, the Ferrier-Aligo microphysical parameterization, the GFS PBL scheme, and the GFS SAS deep and shallow convection schemes. **Fig. I** illustrates all components of HWRF supported by the DTC, which also include the WRF Preprocessing System (WPS), prep_hybrid (used to process spectral coefficients of GDAS and GFS in their native vertical coordinates), a sophisticated vortex initialization package designed for HWRF, the regional hybrid Ensemble Kalman Filter (EnKF) - three-dimensional variational data assimilation system (3D-VAR) GSI, the NCEP Unified Post-Processor (UPP), and the GFDL vortex tracker."* [1]

2. Quantitative Verification Component

The DTC's Model Evaluation Tools (MET, v. 6.0) – Tropical Cyclone (MET-TC) package was employed as the primary quantitative verification tool.

3. Visualization component

The need to display and interact simultaneously with model output, satellite data, and "conventional" observations led to the selection of Unidata's Integrated Data Viewer (IDV) as the primary visualization tool.

Figure 2. GOES ch 2 (3.8 – 4.0 µm) forecast brightness temperatures (°K) time sequence rendered using IDV from inner nest Control run output

4. High-Performance Computing System

This OSE capability was instantiated on one of the Aerospace Corporation's high-performance computing clusters using 2820 processing cores under the CentOS operating system. Message Passing Interface (MPI) and Open Multi-Processing (OpenMP) software libraries were used to enable parallel computing.

Table 1: Observation types, platform code, and number of observations used by domain	# used d2	# used d3
Surface Pressure (total)	**908**	**407**
120-Rawinsonde	8	3
180-Surface marine	430	255
181-Surface land (SYNOPIC)	83	17
182-Splash-level dropsonde	2	2
187-Surface land (METAR)	385	131
Wind (total)	**1,678**	**437**
220- Rawinsonde	417	161
224- NEXRAD vertical azimuth display	21	21
232-Flight-level reconnaissance and profile dropsonde	34	38
243-METEOSAT IR and visible cloud drift at levels below 850 mb	62	0
245-GOES IR cloud drift	363	0
246-GOES water vapor cloud drift	234	0
253-METEOSAT IR and visible cloud drift at levels above 850 mb	57	0
254- METEOSAT water vapor (all levels) –cloud top & deep layer	52	0
280-Surface marine	292	217
290-Non-superobed scatterometer winds over ocean (ASCAT)	146	0
Temperature (total)	**852**	**450**
120-Rawinsonde	534	209
132-Flight-level reconnaissance and profile dropsonde	36	34
180-Surface marine	279	204
182-Splash-level dropsonde	3	3
Humidity (total)	**395**	**164**
120-Rawinsonde	278	100
132-Flight-level reconnaissance and profile dropsonde	33	31
180-Surface marine	81	30
182-Splash-level dropsonde	3	3
GPS-Integrated Precipitable Water	**33**	**13**
AMSUA (n15 & n18)	**19,732**	**0**
Goes Sounder Radiances (g13, 4-Detectors, channels 1-15)	**20,108**	**0**
GPSRO Bending Angle	**3,246**	**0**
Pseudo mean sea-level pressure at TC center (112)	**1**	**1**

5. GPSRO OSE Setup

All model runs: used the HWRF system components listed in **Section 1** initialized at 2014101412

Control Run: assimilated all observations (see **Table 1**) using a triple nested domain (d) configuration (d1: 15 km, d2: 5 km, d3: 1.66 km grid-spacing; see **Fig. 3**) with the inner nests (d2, d3) moving with forecast storm position. Data assimilation was not performed on the parent nest (d1). A 5-day forecast was created with hourly output through nine hours and three-hourly output there after.

Experimental Run: no GPS RO data assimilated otherwise the same as the Control Run.

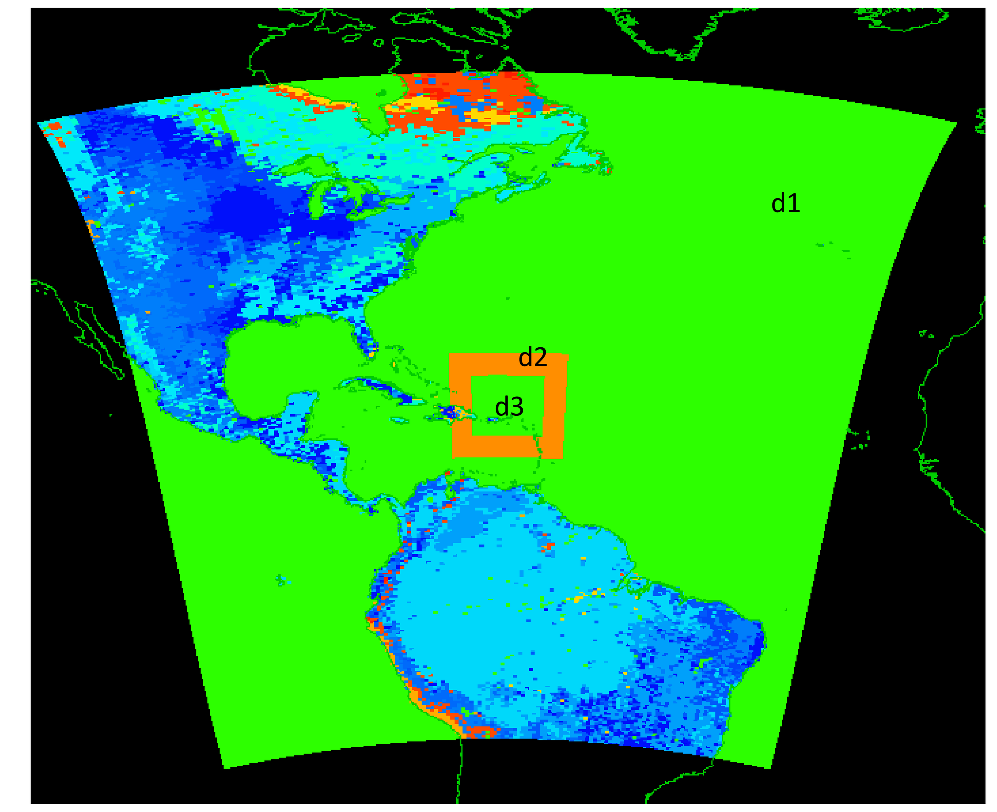

Figure 3. IDV rendered plot of land-use types for all three domains. Used to illustrate the domain coverage and nesting configuration of the HWRF system.

6. GPSRO OSE Preliminary Results

The MET-TC verification package was applied to both the Control and No-RO runs. Track and intensity measures (maximum sustained wind and storm central pressure) for both runs along with best track information obtained from the Navy Research Laboratory are shown in **Fig. 4**. The best track information is available every 6 hours. The track errors (**Fig. 4a**) through the first 42 hours of the forecast (see inset) are small for both runs with no significant differences between them. Larger track-errors begin to occur after 42 hours with the No-RO run appearing to slightly outperform the Control. The intensity errors (**Fig. 4b**) are large for both runs after the first 6 hours of the forecast again with little difference between the Control and No-RO runs.

Gonzalo (2014) 5-Day Forecast

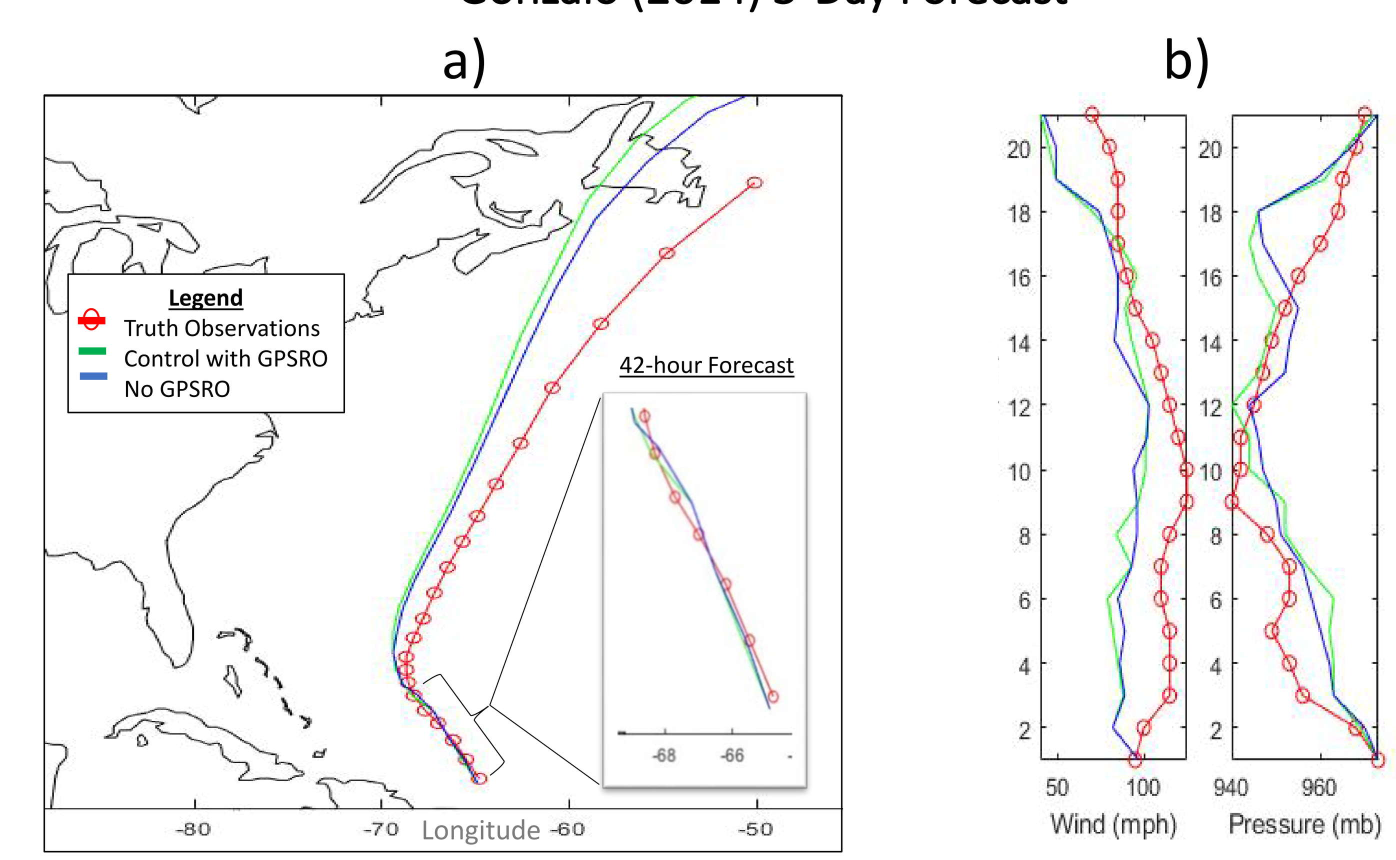

Figure 4. Gonzalo 6-hourly track (a) and intensity (b) for Control, No-RO, and Best Track. Initialized at 2014101412 (point 0) with forecasts through 120 hours (point 21)

7. Summary and Future Work

A complete OSE system has been implemented at The Aerospace Corporation and an initial "check-out" GPSRO OSE performed. More analysis of the Gonzalo case is needed before proceeding to additional experiments. Future OSE's will focus on the Western Pacific and the use of **"non-traditional"** satellite data for verification.

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