Quantifying high temporal and spatial forecast improvements attributable to GPSRO and IR imagery data in HWRF

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Abstract

New space-based microwave and temporal atmospheric profiling measurements are yielding high spatial and temporal sounding measurements for water vapor, temperature, and pressure. These techniques are expected to improve short and long-range operational weather forecasts. Improvements in data assimilation and forecast models to ingest these increased numbers and densities of observations have yet to be fully realized. Infrared radiometers have the temporal and spatial resolution to validate the improvements.

The Hurricane Weather Research and Forecasting model was run with the capability of assimilating radio occultation data for forecasting typhoon cyclogenesis. The potential for forecast skill improvements are characterized, along with improved validation observations.

Experimental Workflow and Summary

Experimental Workflow *was established for experiments investigating the effect of high temporal and spatial observations on numerical forecast skill. An initial investigation identified, acquired, wrote and installed tools using Katrina (2005) and Gonzalo (2014) as test cases. Gonzalo formed on October 12-19, 2014 in the W. Atlantic, reaching peak intensity on October 15 as a Category 4 Hurricane, decaying slightly and returning to Category 4 with a pressure of 940 mb and wind speed of 145 mph. Two runs for Gonzalo (2014) were completed: (1) A control run initialized with GPS Radio Occultation (GPSRO) data, and (2) An experimental run initialized without GPSRO data. Both cases were run for 61 pressure levels at three-hour time steps to create a 5-day forecast.*

Summary*: Although the observations have high temporal and spatial resolutions, our assimilation and core physics approach may not yet fully exploit these new sensor capabilities. Validation information provided by these sensors is better than previously available and offers the opportunity to tune the model approaches, including: Assimilation rate, Higher resolution time steps, and Model physics.*

Gonzalo Peak Intensity 15 Oct 2014: 949 mb Pressure and 135 mph Wind

HWRF Gonzalo 5-Day Forecast | HWRF Model Gonzalo Initialization

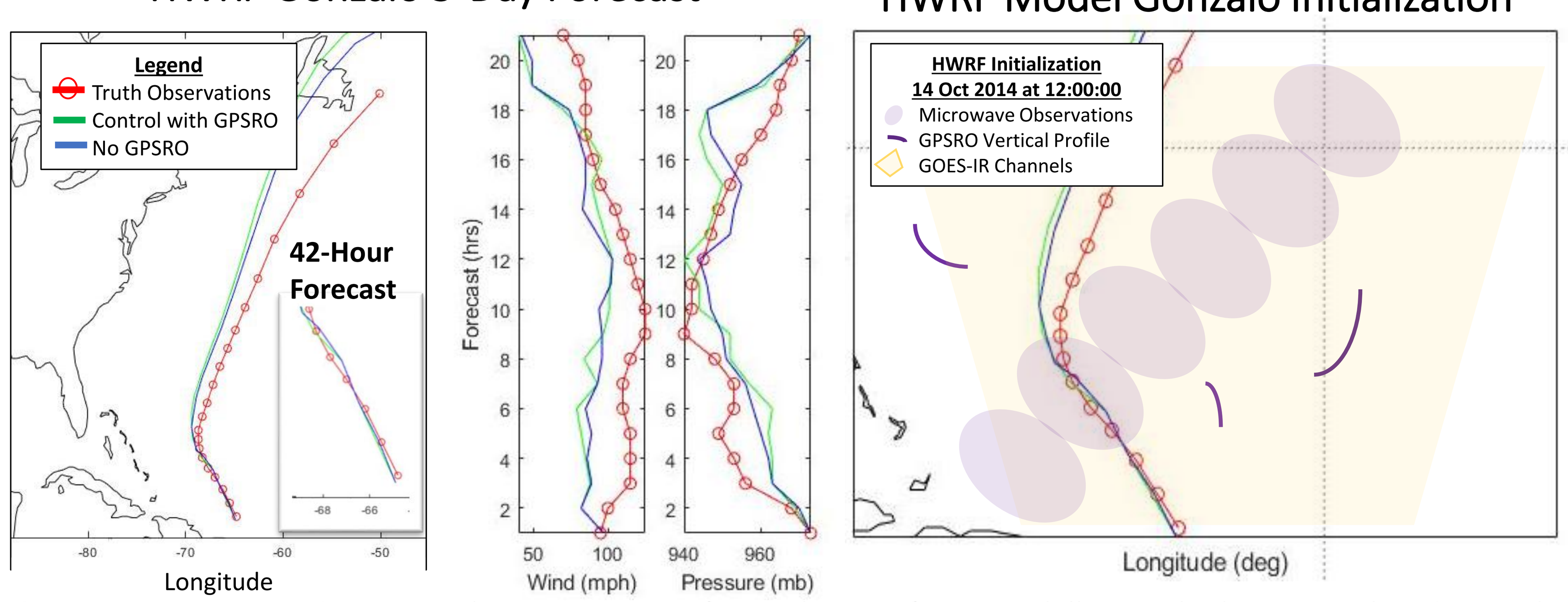

Figure 1. HWRF provides research opportunities for evaluating forecast skill using high temporal and spatial resolution observations. HWRF coupled with the Princeton Ocean Model 5-day and 48-hour forecast (left). Notional illustration of GPSRO, Microwave, and IR data assimilated with HWRF preprocessor (right).

High Resolution Numerical Forecasts of Wind and Pressure

1. Numerical Forecast Runs (HWRF, v. 3.7)

NOAA's Hurricane Weather Research and Forecast (HWRF), 3.7 was installed and run using the Non-Hydrostatic Mesoscale Model (NMM) core, coupled with the Princeton Ocean Model. The forecast was initialized at 1200Z with observational data prepared using WRF Preprocessing System running triply nested for five days.

2. Forecast Evaluation (MET, v. 6.0)

Using the MET package, wind speed/direction and pressure data for both model runs were compared against NRL truth observations (**Fig 1**). Cumulative precipitation comparisons and rapid intensification were identified (**Fig 2**).

Gonzalo Peak Intensity 15 Oct 2014: Precipitation

Forecasted Precipitation (with GPSRO) | **Observed Microwave Precipitation**

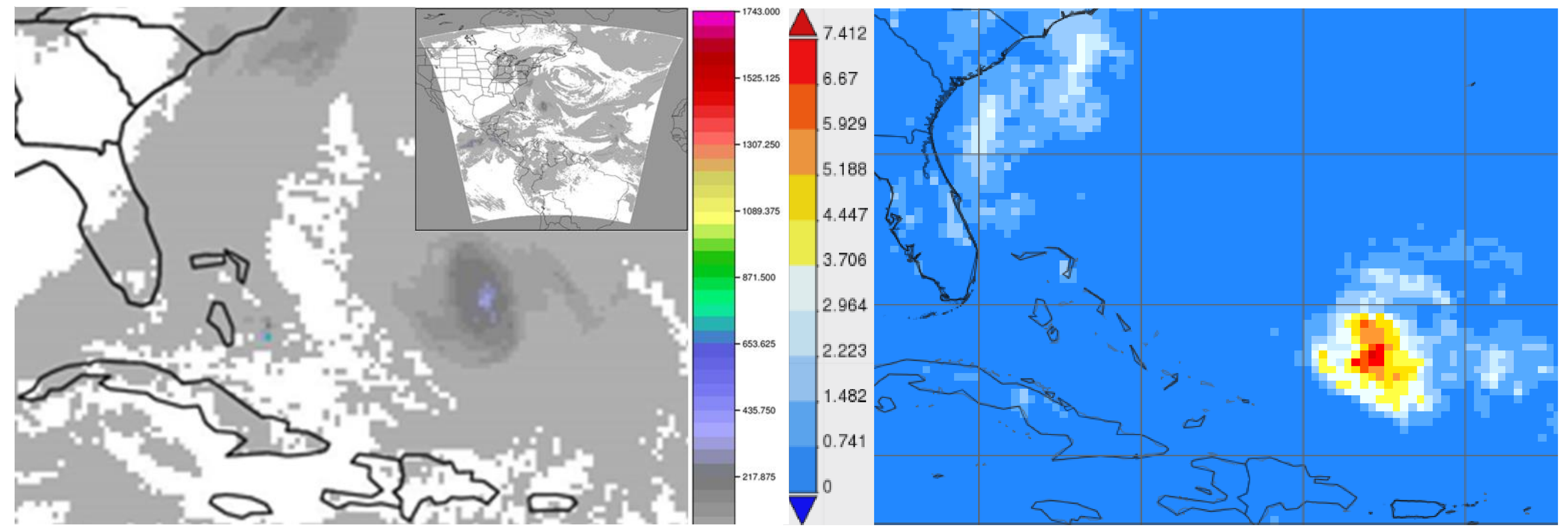

Figure 2. HWRF Forecasted precipitation rendered by NcView (left). TRMM Observed Time Averaged Precipitation Map, 3-hourly, 0.25 deg visualization (right) produced by Giovanni data system, NASA GES DISC.

Inflow/Outflow and Precipitation Visualization

3. Precipitation Comparisons (NcView, 2012)

Precipitation within the HWRF innermost nest, accumulated over a 24-hour period is compared with observed Microwave TRMM results (**Fig 2**).

4. Wind Visualization (VAPOR, 2.5)

VAPOR renders WRF-ARW output to illustrate high resolution phenomenology, with the ability to animate selected fields. Three functions useful for inflow/outflow visualization are displayed for Katrina (2005) (**Fig 3**):

- **Direct Volume rendering (DVR)**: WRF-ARW variables water vapor and clouds may be viewed as a density, varying transparency, color, in time series animation.
- **Flow**: Streamlines illustrate inflow and outflow regions, showing wind motion and direction over time.
- **Isosurfaces**: Isosurfaces are selectable to illustrate pressure and temperature surfaces, as well as variability of secondary variables along the isosurface.

Katrina Inflow/Outflow Separated by Isothermal Pressure Variability

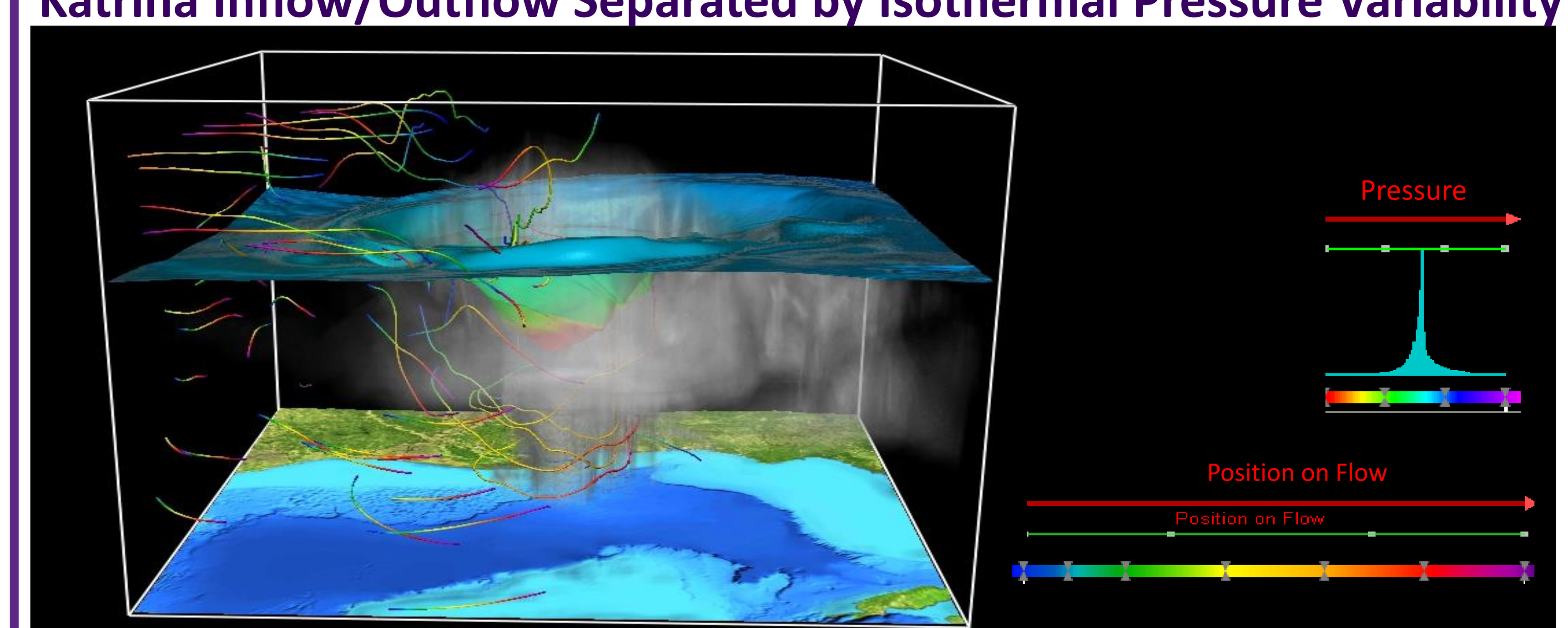

Figure 3. Katrina Inflow and Outflow (lower left quadrant only) and Pressure Variability separated by Isotherm using WRF-ARW model output. HWRF provides research opportunities for improving forecast accuracy, at improved spatial resolutions (5 m) by utilizing high cadence observations from RO, MW, and IR data. (Image rendered using Katrina WRF-ARW output in NCAR's VAPOR Tool.)

Eyewall Organization and Imagery

5. Channel Simulation for Time Series Imagery (IDV, 3.1)

IDV Demonstrates movable, triply-nested grids capable of outputting fields to animated viewers. Simulated SSMIS Microwave Brightness Temperatures (3.8-4.0 μm) for the inner most movable nest with 1.7 km grid-spacing (**Fig 4**).

6. EOIR Imagery Channel Validation (Matlab, 2017b)

Brightness temperatures (TB) for VIIRS 3.74 um channel were compared against simulated imagery using the Dvorak technique using high spatial and temporal resolution imagery to identify intensification potential (**Fig 4**).

Gonzalo Peak Intensity 15 Oct 2014: Brightness Temperature

Forecasted Microwave T_B (3.8–4.0 μm) | **Observed Infrared T_B (3.74 μm)**

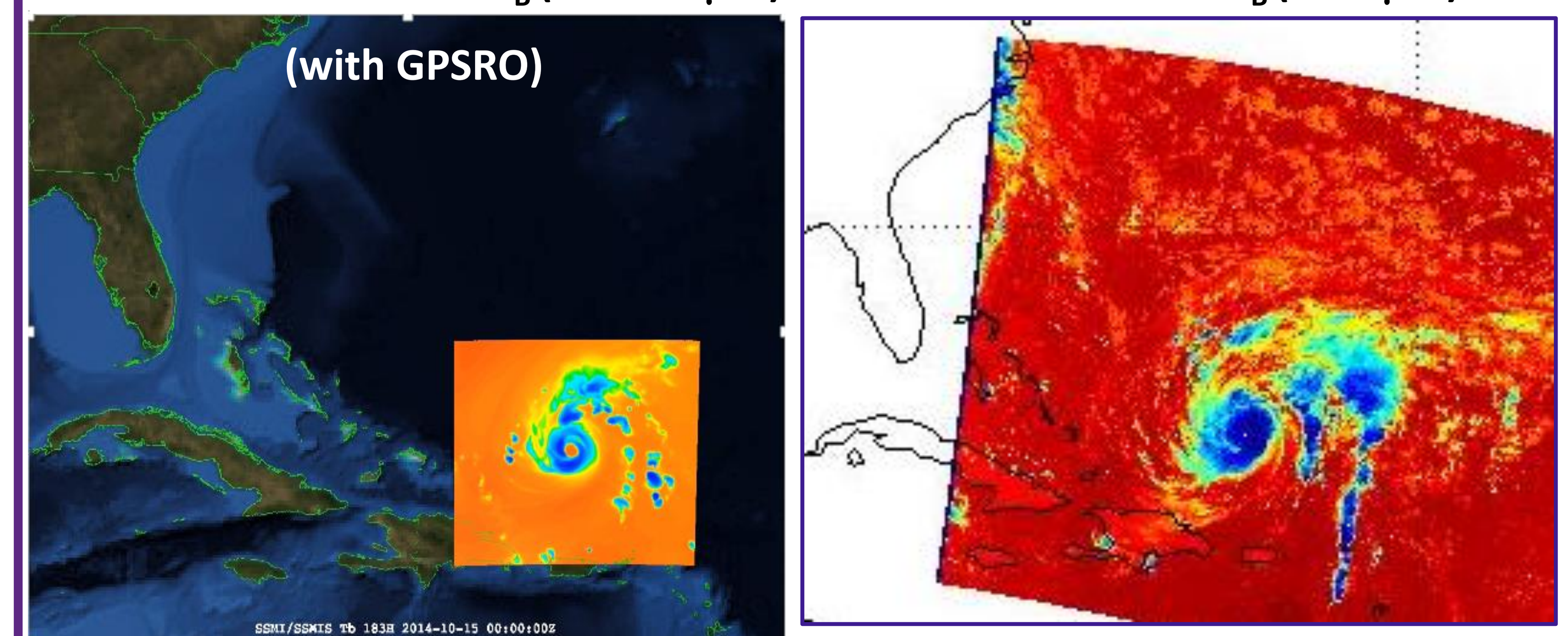

Figure 4. Comparison of forecasted simulated SSMIS Microwave (3.8-4.0μm) Brightness Temperatures for the inner most movable nest (1.66 km grid-spacing (left) with VIIRS Brightness Temperature for Imagery Channel 4 (3.74 μm) at 371 km² nadir resolution (right).

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Models and Tools

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