PROJECT TITLE: Using synthetic satellite brightness temperatures to evaluate the ability of HWRF parameterization schemes to accurately simulate clouds and moisture in the tropical cyclone environment

INVESTIGATORS:

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PROJECT DURATION: 2 years (2014-2016)

TIME PERIOD ADDRESSED BY REPORT: February 2015 – April 2015

PROJECT OVERVIEW:

This project will use synthetic satellite observations to evaluate the ability of different cloud microphysical, planetary boundary layer, and cumulus parameterization schemes in the HWRF model to accurately forecast the spatial characteristics and temporal evolution of the cloud and moisture fields associated with tropical cyclones. Model output from high-resolution HWRF simulations will be converted into synthetic infrared and microwave brightness temperatures using the Community Radiative Transfer Model in the Unified Post Processor (UPP). The satellite simulator capabilities of the UPP will be enhanced by adding a subroutine that computes the effective particle diameters for each hydrometeor species predicted by a given microphysics parameterization scheme based on the assumptions made by that scheme, and by expanding the number of satellite sensors and bands that can be simulated.

We will rigorously evaluate the accuracy of the simulated cloud and moisture fields through comparison of observed and simulated infrared and microwave brightness temperatures. Bulk cloud characteristics such as the horizontal extent and temporal evolution of cloud cover will be examined using neighborhood verification approaches, probability distributions, brightness temperature differences, and traditional point statistics. In addition, the simulated satellite observations will be input to other satellite derived verification methods, such as the Advanced Dvorak Technique (ADT) and the Automated Rotational Center for Hurricane Eye Retrieval (ARCHER) method. Metrics output by these algorithms will be used to assess the accuracy of the satellite-inferred tropical cyclone intensity and the organization and location of deep convection in the eye wall and surrounding areas.

RECENT ACCOMPLISHMENTS:

During the past three months, we continued to develop the data processing infrastructure and analysis tools that will be used on the Jet supercomputer to evaluate the accuracy of HWRF model forecasts generated by our group for individual case studies and by the

HWRF model development team at the Environmental Modeling Center (EMC) for their 2015 operational HWRF model pre-implementation tests. This two-pronged analysis approach will facilitate operational model development by assisting in the identification of parameterization schemes and model configurations that produce realistic cloud and moisture distributions as observed by satellite sensors.

We are currently generating model forecasts from cycled data assimilation experiments for Hurricane Edouard (2014) in the Atlantic basin using two cloud microphysics schemes (Ferrier and Thompson), two convection schemes (SAS and Meso-SAS), and two radiation schemes (GFDL and RRTMG), thereby resulting in eight different parameterization scheme configurations to be evaluated. This case study was chosen because of the availability of numerous high quality dropsonde observations that provide valuable information about the moisture and thermodynamic fields within the tropical cyclone environment. For the pre-implementation analysis, we are currently assessing differences in the cloud and moisture fields for tropical storm Douglas (2014) in the eastern Pacific. This case was chosen after consultation with Zhan Zhang (EMC) to better understand why the tropical cyclone track forecast performance was low for this particular tropical cyclone.

A necessary first step toward a realistic assessment of the model accuracy is to remap the simulated satellite observations from the model grid to the appropriate satellite projection so that the simulated observations have the correct horizontal resolution at all satellite zenith angles. For simulated infrared brightness temperatures from GOES and SEVIRI, a model-to-satellite remapping tool previously developed by the PI was modified to ingest data files produced by the UPP. For simulated microwave observations from SSMI and SSMIS, the HWRF Satellite Verification (HWRF-SatV) system developed by Tomislava Vukicevic was used to accurately convolve the simulated observations to the correct microwave sensor footprint size. After thoroughly testing each tool, scripts were written to remap the simulated observations from our HWRF model simulations and from the EMC pre-implementation tests. All simulated satellite observations for the Edouard and Douglas case studies have been remapped to their appropriate projections and will be used during our subsequent analysis. In addition, real GOES, SEVIRI, SSMI, and SSMIS observations have been obtained for these two case studies.

To assess the accuracy of the simulated tropical cyclone intensity as observed by satellite imagery, we also implemented the UW-CIMSS Advanced Dvorak Technique (ADT) software package on Jet. The original version of the ADT system was modified to ingest remapped simulated HWRF infrared brightness temperatures stored in NETCDF format files. It was also necessary to write a tool to create a Hurricane Satellite (HURSAT) B1 compliant version of the remapped satellite observations. Scripts have subsequently been written to automate the file conversion process and ADT workflow.

Comparisons of the observed and simulated GOES-15 infrared brightness temperatures from the 6.7 μm and 11 μm bands for three model configurations examined during the EMC pre-implementation tests are shown for Tropical Storm Douglas in Figs. 1 and 2, respectively. Figure 1 shows 24-hour forecast imagery from the 18-km outer domain and

Fig. 2 shows imagery from the 2-km inner domain. A brief description of each model configuration is provided in Table 1. Overall, the colder brightness temperatures in the simulated 6.7 μm imagery (Fig. 1) indicate that the HWRF model has a positive moisture bias in the upper troposphere throughout the tropics. It is also apparent that the spatial coverage of the upper level cloudiness associated with the tropical cyclone (Fig. 2) is far too extensive, especially with the H15F and H15W configurations. The most accurate cloud cover distribution was evident in the H15U configuration, which was chosen by the EMC developers to be the 2015 HWRF operational configuration. It is important to note, however, that the cloud cover in the 2015 operational HWRF version is still too extensive and higher in the troposphere than the observed imagery depicts.

In the next three months, we will perform a rigorous evaluation of the forecast accuracy for these cases through the use of grid point statistics (e.g. root mean square error, mean absolute error, bias) and cumulative frequency distributions for each satellite sensor and band. These statistics will be computed as a function of forecast time and region to more thoroughly assess the model performance for different cloud types and forecast lead times. Additionally, the newly available ADT tool will be used to obtain objective estimates of tropical cyclone intensity using both the observed and simulated imagery. Because the ADT is an objective tool that uses the tropical cyclone structure to estimate its intensity, it will provide a measure of how well the HWRF model reproduces the observed tropical cyclone structure in a way not possible with simple gridpoint statistical methods. Last, an analysis of dropsonde observations from Hurricane Edouard will be used to provide additional insight concerning potential biases or other errors identified using the simulated satellite observations.

Table 1. Brief description of the HWRF 2015 pre-implementation test configurations (via personal communication with Zhan Zhang).

Configuration	*Description*
H15U	Final FY2015 configuration
H15F	As H15U, but with FY2014 radiation
H15W	As H15U, but with new enthalpy exchange coefficient.

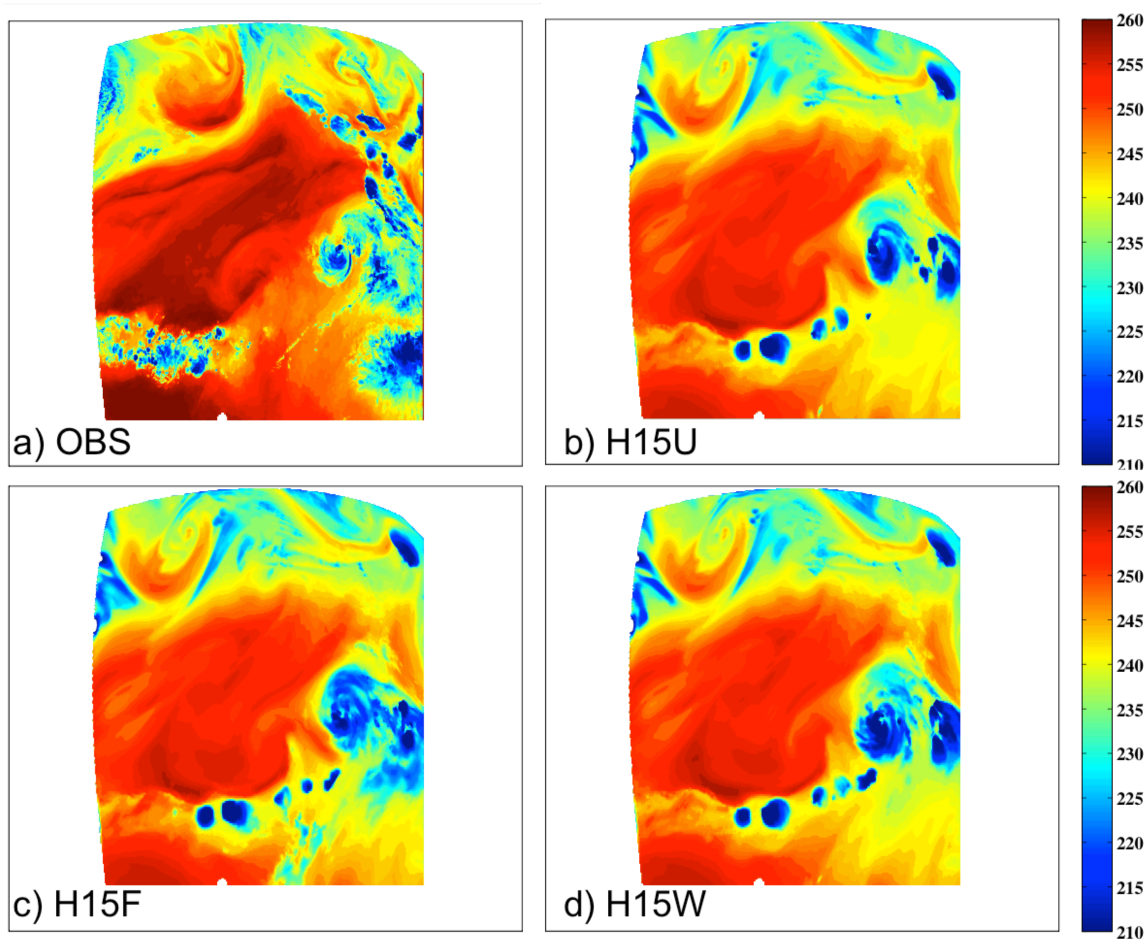

Figure 1. (a) Observed and (b-d) simulated GOES-15 6.7 μm brightness temperatures on the outer domain (18-km horizontal resolution) valid at 00 UTC on 01 July 2014 for tropical cyclone Douglas in the eastern Pacific. The simulated brightness temperatures are from a 24-hour forecast initialized at 00 UTC on 30 June 2014 for the three HWRF pre-implementation configurations listed in Table 1.

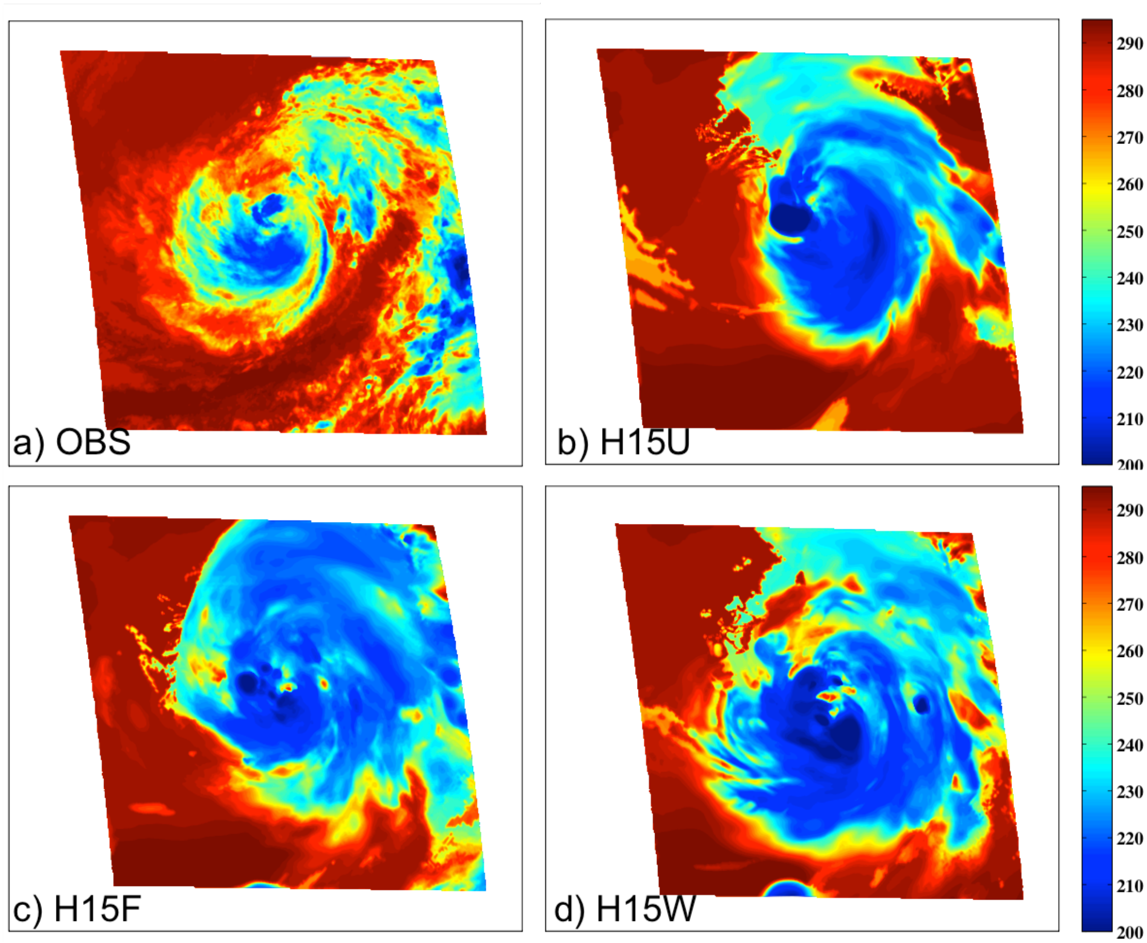

Figure 2. (a) Observed and (b-d) simulated GOES-15 11 μm brightness temperatures on the inner domain (2-km horizontal resolution) valid at 00 UTC on 01 July 2014 for tropical cyclone Douglas in the eastern Pacific. The simulated brightness temperatures are from a 24-hour forecast initialized at 00 UTC on 30 June 2014 for the three HWRF pre-implementation configurations listed in Table 1.