Evaluating the Performance of High-Resolution Hurricane Prediction Modeling System

Rosimar Rios-Berrios[1] and T. Vukicevic[2], A. Aksoy[2,3] and K. Sellwood[2,3]

[1]*NOAA EPP Scholar / Department of Physics, University of Puerto Rico at Mayagüez*
[2]*NOAA's Atlantic Oceanographic and Meteorological Laboratory, Hurricane Research Division*
[3]*U. Miami/RSMAS Cooperative Institute for Marine & Atmospheric Studies*

Introduction

An experimental version of the Hurricane Weather Research and Forecasting System (designated HWRFx) is currently being used at NOAA's Hurricane Research Division (HRD) to evaluate possible improvements to the prediction of both track and intensity of tropical cyclones. Observations obtained from NOAA's aircraft missions are combined with the HWRFx output for a specific storm, using a technique called data assimilation. In what is known as cycling, HRD's Hurricane Ensemble Data Assimilation System (HEDAS) sequentially updates the dynamic and thermodynamic fields of the model in the vicinity of the storm. In each cycle the update is computed by an Ensemble Kalman Filter (EnKF) algorithm in which ensemble-based covariances between observations and model fields are utilized (**Figure 1**). The combined data in a form of gridded fields from the final update cycle, called analysis, are then used to initialize HWRFx to generate a forecast. In this study, the performance of different experiments that were carried out with HEDAS for a case of Hurricane Bill of 2009 is analyzed.

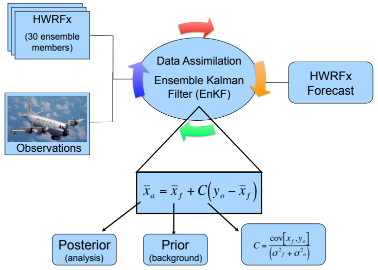

Figure 1. Diagram showing how the output data from the model are combined with the observations in HEDAS using an EnKF algorithm.

Study Approach

Case of study

- Hurricane Bill (**Figure 2**)
- 08/19/2009 (09Z – 13Z)

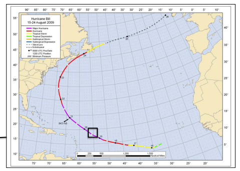

Figure 2. Hurricane Bill track retrieved from NHC Cyclone Report of Bill.

Methods

- Different experiments were carried out by HRD's data assimilation group (**Figure 3**).

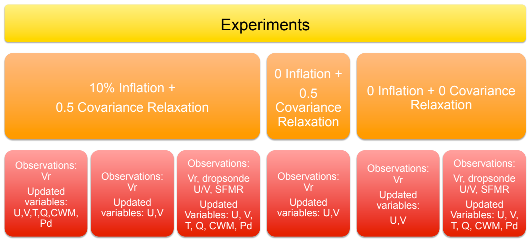

Figure 3. Experiments that were run by HRD's data assimilation group.

- Output files were provided to evaluate the performance of each experiment.
- Time cycles of different variables (T, Q, Theta-e, MSLP, CWM, Vr, Vt, W) were analyzed.
- Final analyses of each experiment were compared to observations when available.
- The ensemble covariance data were analyzed for the experiment that showed the best performance, to understand the behavior of the model when updating the physical variables within the cycles.

Results

FINAL ANALYSES
10-M Horizontal Wind

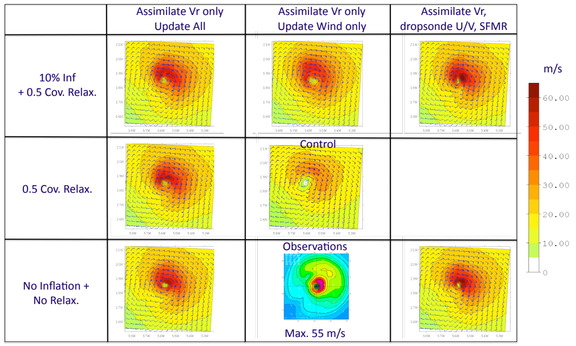

Figure 4

FINAL ANALYSES
Tangential Wind (Primary Circulation)

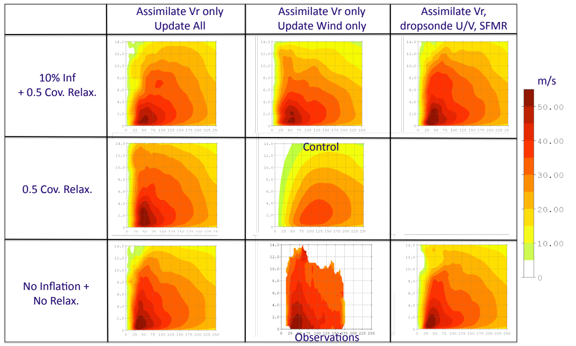

Figure 5

FINAL ANALYSES
Radial Wind + W (Secondary Circulation)

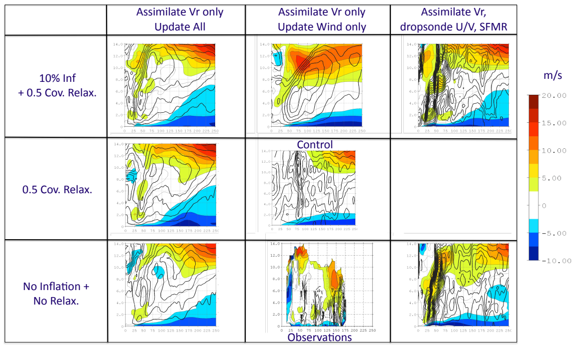

Figure 6

Results (cont.)

- **Figures 4-6** show a sample of the results obtained from the last analysis of each of the experiments that were carried out for the case of Hurricane Bill.

- **Figure 4** shows the results for 10-M horizontal wind. The experiments are being compared to the H*wind analysis. It is noticeable that, in terms of structure, the experiments with no inflation and no relaxation showed the most similar structure in comparison to the observations. In terms of intensity the same experiments produced a stronger storm that it was observed. In the experiment which only updated U and V the structure is not as similar as it was in the other cases and the storm is much more weaker than it was observed.

- **Figure 5** shows vertical cross sections of the tangential wind, which is also known as the primary circulation. The values of the wind were calculated by taking the azimuthal average around the center of the storm. The same was done to the doppler wind measured during a NOAA's aircraft mission to be used as the observations at that moment. In this case, the best two results, in terms of structure and intensity, were again those with no inflation and no relaxation.

- **Figure 6** shows vertical cross sections of radial wind in colored contours and vertical wind (W) in black contours, representing the secondary circulation. The results did not show realistic structures as in figs. 4 and 5, but at least in the experiments with more observations being assimilated there is a strong updraft possibly defining the eyewall of the storm.

COVARIANCE ANALYSIS
Experiment: No inflation + No relaxation, Assimilate Vr, dropsonde U/V and SFMR
Cycles 3 & 5
Equivalent Potential Temperature & Radial Wind

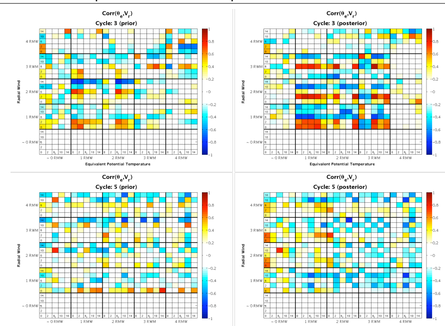

Figure 7

A 4-D plot was designed to include the normalized covariance (also known as correlation) between dynamic and thermodynamic variables at different distance from the center of the storm, as well at different heights. **Figure 7** shows an example of this plot, which can provide a great amount of information of the vortex dynamics of the storm.

Conclusions

- Results showed HEDAS had a good performance for the study case of Bill, but it could be improved.
- The experiment with no inflation and no covariance relaxation showed the best skill among the experiments that were run with HEDAS.
- The thermodynamic field should always be updated even when only the winds are the observations being assimilated.
- The covariance calculation showed realistic patterns of vortex dynamics, but further research is required for a better interpretation.

Acknowledgements

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Related Work

Results from other experiments done with HEDAS will be presented at the 15th Conference on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS, talks J11.3, J11.4, and J11.5, AMS Annual Meeting, 2011)