ASSIMILATION OF GOES RAPID-SCAN WINDS INTO AN EXPERIMENTAL ETA MODEL DURING ATLANTIC HURRICANES

Howard I. Berger

University of Wisconsin-Cooperative Institute for Meteorological Satellite Studies
1225 West Dayton Street, Madison, WI 53706, USA

ABSTRACT

Experiments designed to optimize the assimilation of winds derived from GOES rapid-scan data into the National Centers for Environmental Prediction's Eta model are being performed. These experiments have been performed on various Atlantic hurricanes in the 2000 and 2001 storm season. The wind data are being assimilated into parallel runs of the Eta model through the Eta Data Assimilation System. Although the assimilation experiments showed impact in the wind and height field aloft, continued experiments and optimizations will be needed to improve the surface features of the hurricanes.

1. Introduction

The lack of in-situ data in the tropics makes it difficult to properly initialize tropical cyclones in Numerical Weather Prediction (NWP) models. To account for this data void, synthetic data has traditionally been used to initialize hurricanes within NWP models. An alternative solution to this initialization problem involves using remotely sensed data from satellites in addition to synthetic data.

To examine this solution, experiments have been performed that are designed to optimize the assimilation of winds derived from GOES rapid-scan data into the National Centers for Environmental Prediction's (NCEP) Eta model. The wind data are assimilated into the Eta model through the Eta Data Assimilation System (EDAS). The preliminary case study evaluated is Atlantic Hurricane Keith, (Sept/Oct 2000) although additional cases, such as hurricane Humberto (Sept 2001), will be presented. The satellite-derived winds will more accurately describe the initial upper-level environment over these storms. This paper presents various assimilation strategies designed to optimize the influence of these wind data on the model initialization and resulting analyses.

2. Methodology, Data and Case Study

2.1 Eta Model

The Eta model version used in the preliminary study has 48 km resolution and 45 vertical levels. The model is being run on a Silicon Graphics Origin workstation at the University of Wisconsin-CIMSS. For the subsequent cases, the 22 km, 50 vertical level Eta will be used. This model version will be run remotely on NCEP's IBM machine. The Eta was chosen for these experiments because it is one of NCEP's primary operational regional models and it has a well-established assimilation system.

This assimilation system, the EDAS, uses a regional 3-d variational analysis (Rogers 1996a). The EDAS creates its analysis by minimizing a cost function at observation locations. It is designed to use high-resolution mesoscale data types, making it an ideal system to test assimilating rapid scan winds (Rogers 1996a). For the Keith runs, experiments were performed on the 00Z Oct 02, 2000 Eta. NCEP's parallel development run (48 km) was used as the control run. For Hurricane Humberto, the 22km Eta was used.
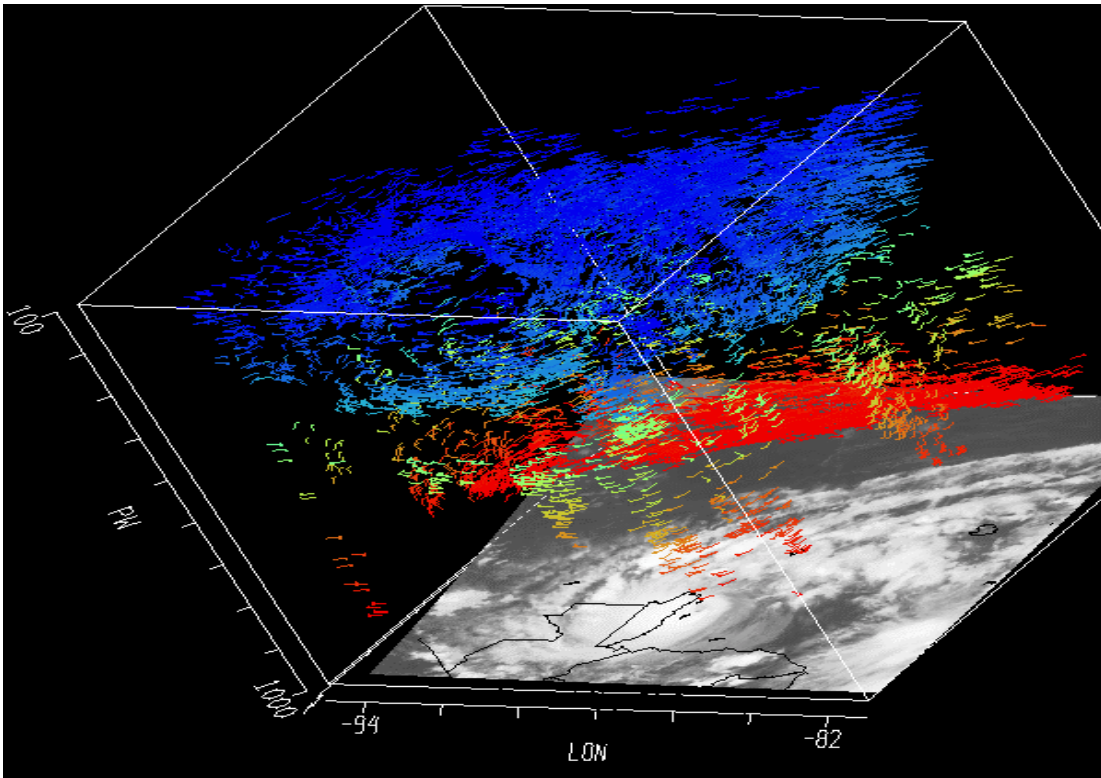
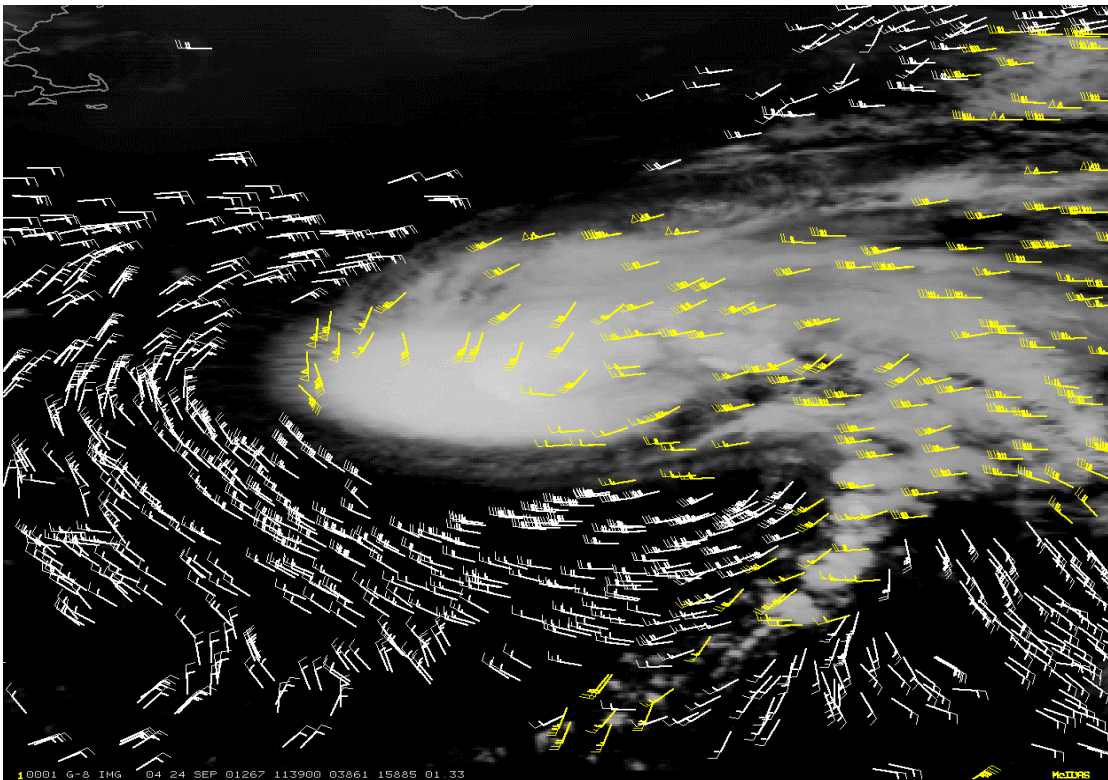Figure 1a. 3-Minute GOES Rapid Scan winds over Hurricane Keith.

Figure 1b. 7.5-Minute GOES Rapid Scan winds over Hurricane Humberto.

2.2 Rapid-scan (RS) Winds from GOES

During selected hurricane events in 2000 and 2001, the GOES-8 satellite was operated in a special scanning mode that allowed multi-spectral images of the storm at 1-minute intervals over several hour periods. Winds are derived from successive images using automated feature (cloud) tracking techniques developed at CIMSS (Velden et al. 1998). It has been shown that the quantity and quality of cloud-motion winds can be greatly enhanced by more frequent sampling strategies. The normal operational sampling interval for generating GOES wind fields is 15-30 minutes.

In this study, the GOES RS data set was sub-sampled so that the winds were derived from successive 3-minute scans (to minimize the effects of image-to-image registration errors). Winds were produced from both visible and IR imagery. An example of the wind coverage during Hurricane Keith is shown in Figure 1a. Figure 1b shows the wind coverage of 7.5 minute scans for Hurricane Humberto.

2.3 Hurricane Keith

Keith was an intense tropical cyclone in the Northwest Caribbean Sea and the Gulf of Mexico during the fall of 2000. It was a Category 3 hurricane when it made landfall over Belize with maximum winds near 120 kts (Beven 2001).

The official National Hurricane Center (NHC) forecasts for Keith as a whole were worse than CLIPER (Climate-Persistence model) at the 12 and 24 hour forecast periods, and worse than the 10-year average at longer forecast intervals (Beven 2001). The NCEP Aviation (AVN) model in particular had a difficult job of predicting Keith's westward motion as well as being biased too far to the north. For the 12 UTC forecast on Oct. 02, the actual track was outside of the entire envelope of numerical guidance. Thus, the models had significant problems forecasting the track of this storm.

Forecasting Keith's intensity was also difficult, being significantly worse than the ten-year average. This intensity error was tied both to the uncertainty in forecasting the track (the storm remained over water when it was predicted to go over land), and to a lack of understanding of the storm's structural changes as it passed over changing surface types (Beven 2001).

3. Model Initialization Impact

Initially, operational values for visible and infrared cloud-drift winds were used for observation errors. The winds were assimilated into the 00 UTC initialization of the Eta model on 02 Oct., which was close to the time of the rapid scan wind set.

Figure 2 is a plot of wind differences between the experimental and control run at 300 hPa. Although the wind impact is not dramatic, one can see that the experimental winds are adding a counterclockwise rotation around the center of the storm. The vectors also show increased outflow in the experimental case. The rapid scan winds are capturing an upper level cyclonic circulation that the operational model analyses did not resolve and showing stronger outflow than the model.
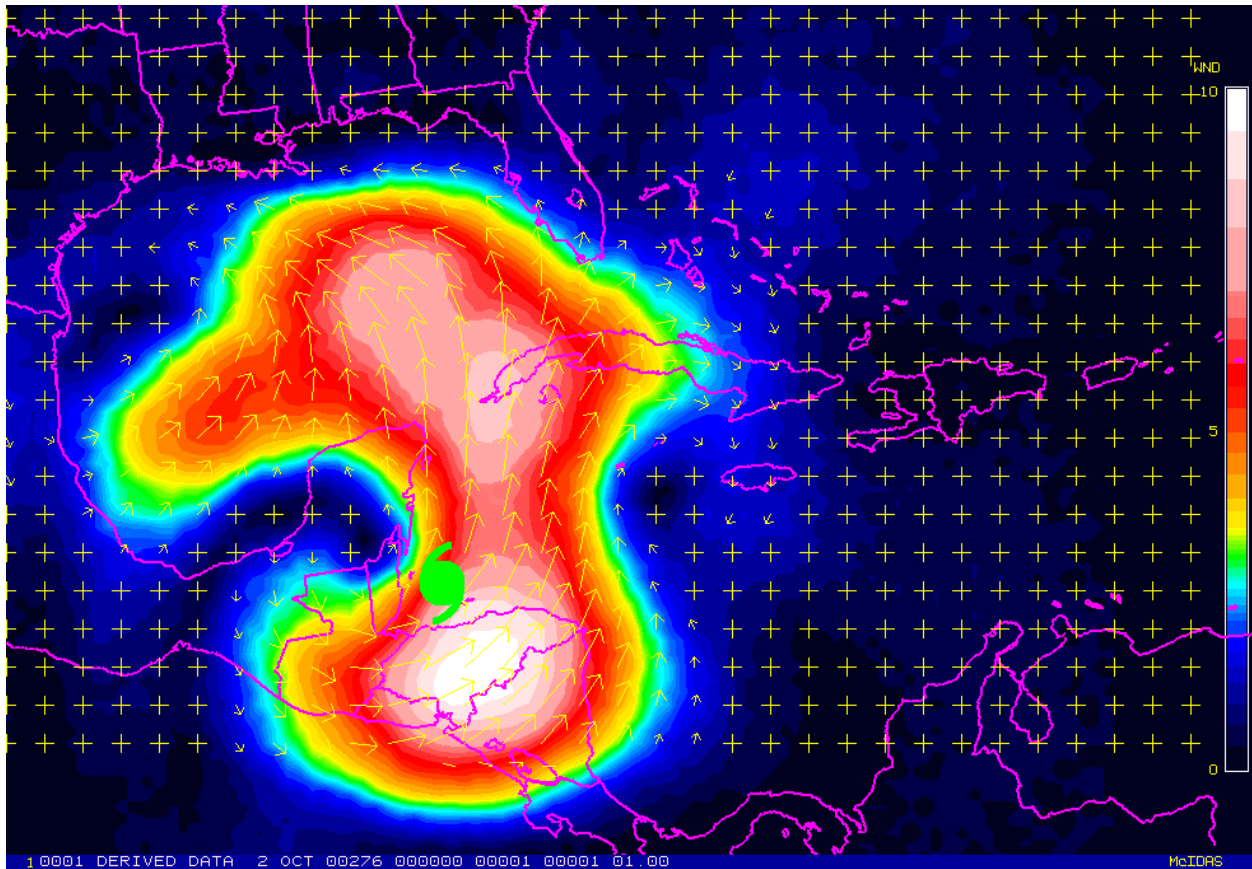
Fig. 2: 300 hPa wind differences between the experimental and control Eta analyses. The barbs show direction, while the isotachs show wind speed differences in ms^{-1}

4. Future Work

This project will continue to explore ways to optimally assimilate the GOES RS wind observations in hurricane events to improve the initialization of the storm structure that should improve forecasts.

Several directions for future study are envisioned. The first involves the implementation of a vortex relocation algorithm within the Eta model. A similar relocation algorithm showed improvement during some tests in NCEP's Aviation model during the 1999 hurricane season (Liu et al.,2000). The algorithm, similar to that used in the GFDL hurricane model, involves relocating the model's initial vortex to the location determined by the NHC. It is hoped that by improving the initial vortex position, adding the satellite winds will be even more effective because the winds will be assimilated to a properly initialized storm center.

The second direction involves modifying the observation weights and correlation lengths in the assimilation system. Using the operational weights showed only minor impact. It is hoped that an optimal configuration will have a greater impact on the initial analyses and result in an improved forecast track and intensity. The results from these experiments will be presented.
Finally, future storms are being tested, including the Eta model 22-km run on Hurricane Humberto. The improved EDAS system in this newer version of the Eta, along with the model's higher resolution should improve the effects of our assimilation. Additionally, wind data will be assimilated at multiple assimilation cycles, allowing for the winds to have more impact on the final analysis.

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