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P5.7 MERGING AMSR-E HYDROMETEOR DATA WITH COASTAL RADAR DATA FOR SHORT TERM HIGH-RESOLUTION FORECASTS OF HURRICANE IVAN

Keith A. Brewster*
Center for Analysis and Prediction of Storms
University of Oklahoma, Norman, Oklahoma

1. INTRODUCTION

In addition to the prediction of the path* and intensity of the hurricane eye, the prediction of the detailed evolution of hurricane rainbands can be quite important for warnings, preparedness activities and protection of off-shore assets. High-resolution numerical modeling offers the promise of making such forecasts, and recently success has been shown in using 3-dimensional volumetric radar data to initialize non-hydrostatic models and provide detailed high resolution forecasts of thunderstorms in the Great Plains (e.g., Hu et al. 2005a,b and others as summarized in Brewster et al. 2005).

In the United States, the operational radar network can provide data at the lowest tilt out to 460 kilometers from the coastal radar sites, barring any difficulties with attenuation. However, the 3-dimensional depiction of the structure is limited to a range of 230 km. Fig 1 shows the coverage at that range for the coastline of the Southeastern United States. A large portion of the Gulf of Mexico is not sampled with 3-d volumetric radar data.

One way to extend the range of information further from coast is to use remotely sensed rainfall data and to combine this information with radar information on the vertical structure. Figure 2 demonstrates the type of coverage one can obtain by mosaicking radar-derived rainfall rates with rainfall rate data from the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E).

The AMSR-E is a microwave radiometer on the Aqua polar-orbiting satellite, which provides two passes per day over most locations. Precipitation rate is retrieved from the observed radiances using the GPROF algorithm (Wilheit et al., 1999, Kummerov et al. 2001), and data are produced with about a 5-km x 5-km horizontal resolution at nadir.

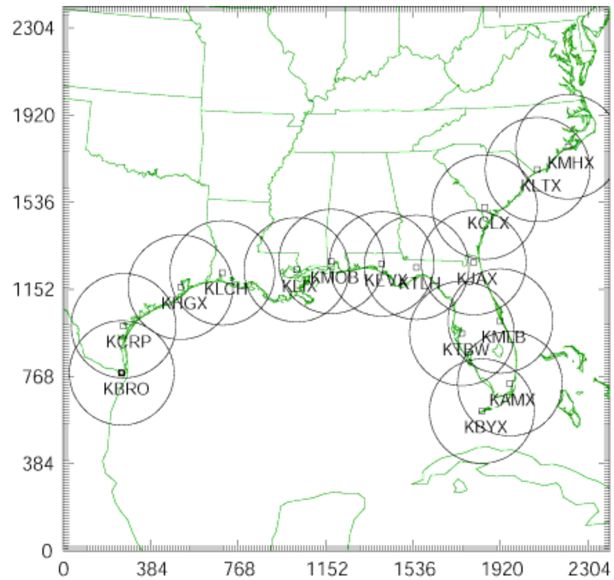

Fig. 1. Location of United States WSR-88D radars along the coast of the Southeastern United States, with 230 km range rings indicated.

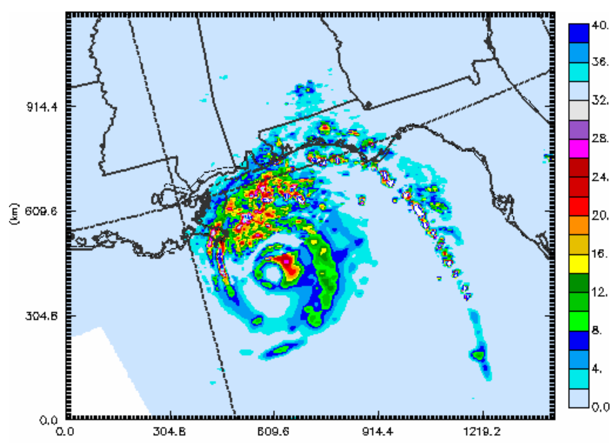

Fig. 2. Mosaicked rainfall rate (mm/h) from six US operational NEXRAD radars combined with AMSR-E rainfall data for 18:50 UTC 15 Sep 2004. Light blue shaded area includes zero to indicate the domain of valid data.

* Corresponding author address:
Keith Brewster, CAPS/Univ of Oklahoma,
Norman, OK 73019
kbrewster@ou.edu

In this work oceanic rainfall algorithm are combined with WSR-88D radar data and other cloud data sources into an analysis suitable for use in non-hydrostatic numerical weather prediction.

2. MERGING RADAR AND SATELLITE DATA

Here the satellite rainfall data are employed after first combining the other cloud and rainfall datasets. Volumetric radar data, surface data, and geostationary visible and 10-μm infrared data are analyzed in the ADAS complex cloud analysis, which has been adapted from the LAPS cloud analysis (Albers et al. 1996), with a number of enhancements and modifications (Zhang et al. 1998, Brewster 2002 and Hu et al. 2005a). The cloud data are then used to apply latent heat adjustments in the initial conditions.

The AMSR-E ocean rainfall data were obtained from the NOAA/Snow and Ice Data Center (Adler et al. 2004) in the original observed distribution as geo-referenced measurements of rainfall rate. These data are remapped to the 4-km Lambert Conformal model grid using an objective analysis with Cressman weighting and a 6-km radius of influence.

An algorithm has been developed to seek nearby grid cells with radar rainfall rates that match those observed by the satellite. Low-level reflectivities are used to assign a 2-D field of rainfall rates to the remapped and mosaicked volumetric radar data. The assignment to rainfall uses the tropical Z-R relationship of Rosenfeld et al. (1993),

$$R = 250\,Z^{1.2} \qquad (1)$$

where R is rainfall in mm h^{-1} and Z is the reflectivity factor. Radar data from Lake Charles, New Orleans, Mobile and Tallahassee WSR-88D radars are combined in the radar mosaicking and subsequent rainfall rate estimation for this demonstration domain.

For each grid cell that has a non-zero satellite observation of rainfall and lies outside the 230-km range of radars, the algorithm searches the domain for the best radar rainfall rate match. After the global minimum difference in rainfall rate is identified, the search is repeated to find a radar rainfall rate that at the nearest location to the satellite observation grid cell and within a threshold from the global minimum. The threshold is set to 10 percent of the satellite-observed rainfall rate or 1 mm/h, whichever is smallest. Where the satellite observation is zero, any precipitating hydrometeors outside the radar coverage area (originating from the background forecast field) are removed.

3. RESULT OF ANALYSIS

Hurricane Ivan made landfall as a Category 3 hurricane on the early morning of 16 September 2004, 0650 UTC, near Mobile, Alabama. The time chosen to test the analysis algorithm is 19:00 UTC on 15 September. At this time the center of the hurricane is beyond the 230 km range of volumetric radar, lying about 250 km south-southeast of New Orleans. Although the New Orleans radar can depict echoes beyond 230 km, beyond the eye, out to 460 km at the 0.5 elevation, there is evidence of attenuation in the low-level scan of radar reflectivity at this time (not shown), so such data are not very useful in this case.

The vertically integrated water field based on the ADAS cloud analysis is shown in Fig 3. Note that the analyzed hydrometeors are almost entirely located north of the storm center due to the lack of radar data distant from the coast. The infrared satellite data does create a relatively thin layer of cirrus ice that is not represented in Fig. 3, but does extend for the entire breadth of the storm as shown in Fig 4.

Figure 5 shows the vertically integrated water after the application of the hydrometeor algorithm utilizing the satellite rainfall data. Qualitatively it seems the hurricane is well depicted in these fields.

Sample vertical cross-sections of the total water fields through the middle of the storm in the *x-z* (west-to-east) and *y-z* (south-to-north) planes are shown in Figures 6 and 7, respectively.

As in the horizontal view, the fields produced by the algorithm appear realistic in depicting the areas of hydrometeors with the texture that matches the texture we see in the infrared satellite image (reflected also in Fig. 4), with taller towers on the western side of the storm in Fig. 6, weaker convection to the south of the eye and more dense areas of precipitating hydrometeors in the bands on the north side of the eye, in Fig. 7.

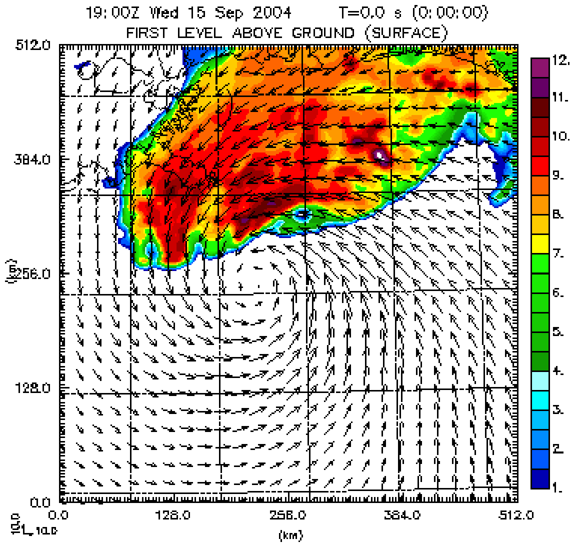

Fig 3. Vertically integrated water (mm) for Hurricane Hugo at 1900 UTC using only WSR-88D data from coastal radars. With wind vectors every 20 km and lat-lon grid lines every degree.

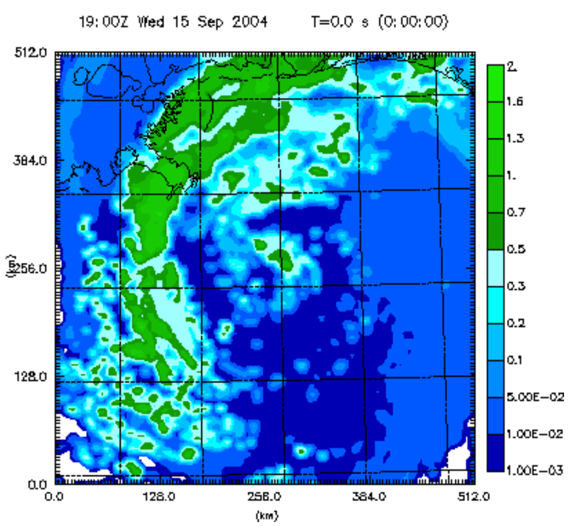

Fig 4. Vertically integrated cloud ice (mm) for 1900 UTC 15 September 2004.

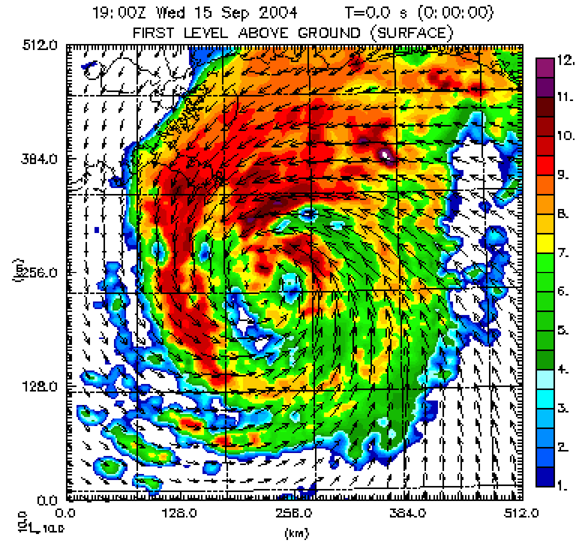

Fig 5. As in Fig 3, but after the addition of AMSR-E rainfall data using the present technique.

4. DISCUSSION AND ONGOING WORK

In ongoing work, the author is developing enhancements to the rainfall matching algorithm to include 1) latent heat adjustment step similar to that already done with the cloud water from the ADAS cloud analysis 2) a calibration step where grid-cells with overlapping satellite and radar measurements are to be used to calibrate the satellite rainfall, and finally 3) more sophisticated replication of data from a radar grid column to a satellite-observed grid column can be designed to account for any possible differences in the lifting condensation level between the two grid cells. The latter is anticipated to be a minor adjustment.

Additional data from the AMSR-E instrument may also be employed. Lower resolution cloud liquid measurements are derived from the radiances and produced by Remote Sensing Systems, Inc (RSS) using the Wentz algorithm (Wentz et al. 2003). The author has obtained 0.25 x 0.25 degree resolution data from RSS and the present algorithm can be modified to adjust the columns to match this cloud liquid water.

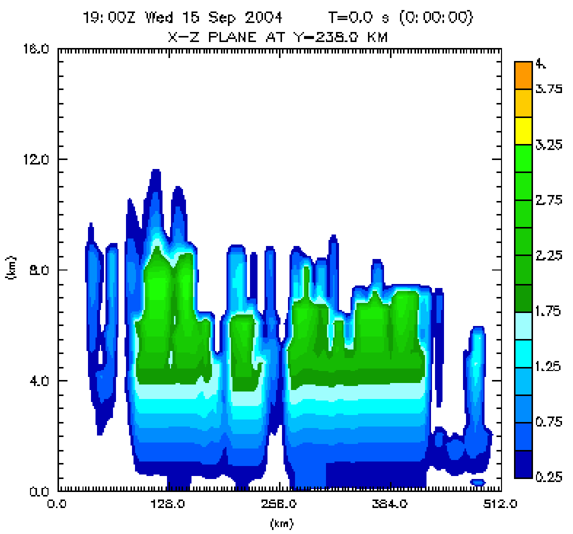

Fig 6. X-Z cross section of total water (g/kg) taken near the hurricane center after employing the AMSR-E rainfall data.

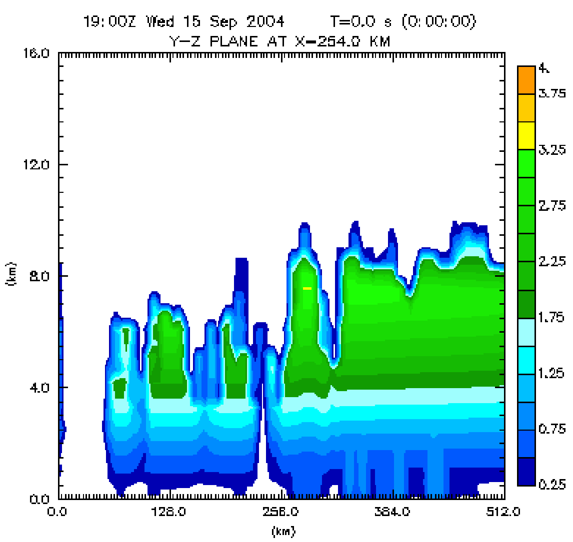

Fig 7. X-Y cross section of total water (g/kg) near the hurricane center

Forecasts will be performed with the analyzed data and verified for retention of cloud features. The model results will be scored against radar reflectivities and rainfall rates along the coast. These forecasts will be presented at the conference.

5. ACKNOWLEGMENTS

The author has benefited from discussions about the AMSR-E and other satellite data with scientists at the Marshall Space Flight Center, including Gary Jedlovec and Bill Lapenta of the SPoRT Program, Roy Spencer and Elena Lobl.

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