P5.1

SATELLITE PRODUCTS AND IMAGERY WITH HURRICANE ISABEL

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1. INTRODUCTION

Satellite data and products for monitoring and analyzing hurricanes have improved in recent years. Geostationary satellite images remain as the primary tool for tracking and intensity analysis. However, other complimentary remotely sensed data sets are now available from other instruments such as scatterometers, microwave sounders and imagers.

Hurricane Isabel traversed the Atlantic during 3-18 September 2003. Hurricane Isabel persisted at or near Category 5 intensity for three full days, as it tracked about 500 km north of Puerto Rico. Fortunately it weakened to Category 2 intensity by the time it went ashore in North Carolina on 18 September.

2. GOES SRSO (SUPER RAPID SCAN OPERATIONS)

With Hurricane Isabel, one-minute interval image scanning with GOES-12 provided unique views of mesovortices inside the hurricane eye (Fig.1) (Kossin and Schubert, 2004). With SRSO, a small area (approx. 15 x 15 deg. lat) centered on the hurricane is scanned with eight one-minute interval images each half hour. The SRSO period for Hurricane Isabel was approximately 12-18 UTC, on seven consecutive days. SRSO transmits 22 images per hour except during full disk scanning once every 3 h. The rapid interval images provide more accurate tracking of rapidly evolving small-scale features and better coverage of cloud motion derived wind vectors.

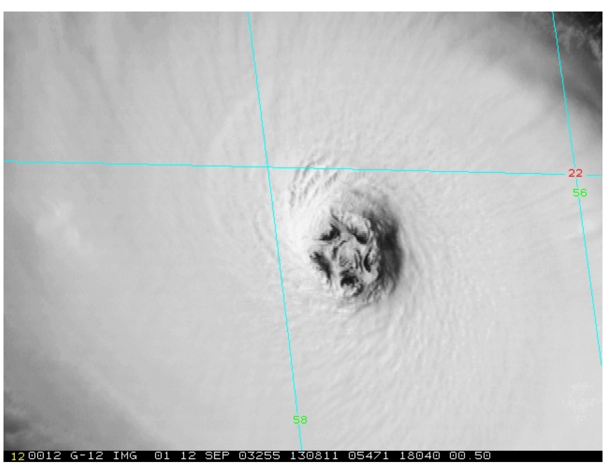

Figure 1. Hurricane Isabel's eye in GOES SRSO visible image, 1308 UTC 12 September 2003.

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3. 1-KM RESOLUTION IR IMAGES

NASA's two EOS (Earth Observing System) satellites' MODIS (Moderate Resolution Imaging Spectroradiometer) and NOAA's AVHRR (Advanced High Resolution Radiometer) are polar orbiting sensors with 1 km resolution IR images that reveal features not well depicted by the lower resolution geostationary images. Fig. 2 is the GOES IR image near the time of the AVHRR image in Fig.3 that shows distinct thin cyclonically curved cloud lines that are difficult to discern with GOES IR images. A composite data set of 1 km IR images using both AVHRR and MODIS reveals interesting changes in the appearance of the inner core cloud pattern features. Transverse bands aligned radially outward are observed in addition to the previously described thin cloud lines and the extent to which each of these cloud types predominate shows a lot of variability from image to image (Fig. 4). The AVHRR enhanced IR image in Fig.5 shows extensive transverse banding over the inner core and with the outflowing cirrus clouds.

The causes, implications, and role that such features play in tropical cyclone evolution have not been well documented. More investigations are needed to understand why they exist and what they mean.

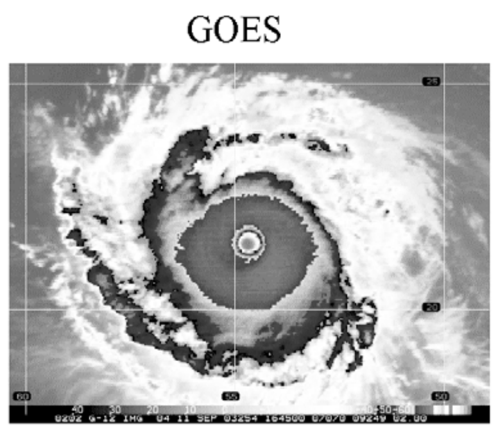

Figure 2. 1715 UTC, 11 September 2003 GOES enhanced IR channel 4 image, 2.7x 4 km subpoint resolution remapped to 2 km Mercator projection.

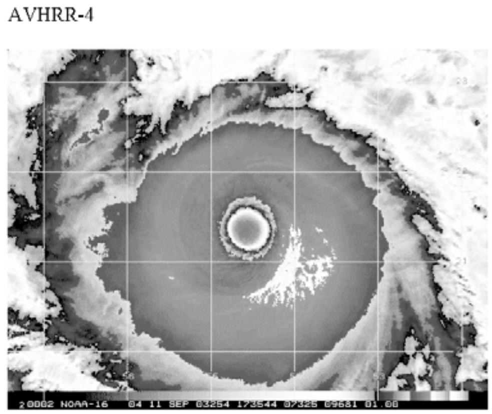

Figure 3. 1735 UTC, 11 September 2003 NOAA-16 AVHRR enhanced IR channel 4 image, 1 km subpoint resolution remapped to 1 km Mercator.

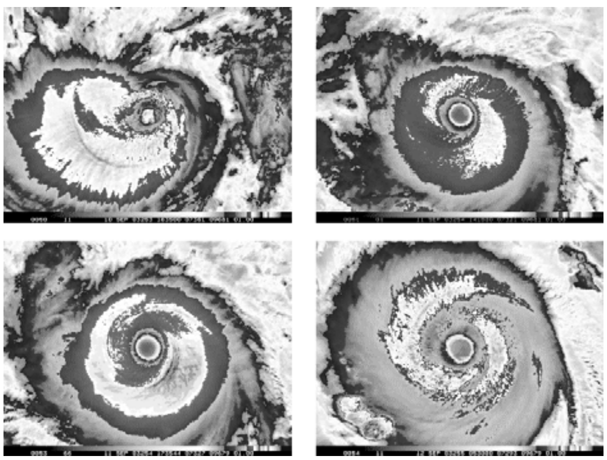

Figure 4. Sequence of 1-km resolution enhanced IR images. Upper left: 1635 UTC, 10 Sep 03. Upper right: 0350 UTC, 11 Sep 03. Lower left: 1735 UTC, 11 Sep 03. Lower right: 0325 UTC, 12 Sep 03.

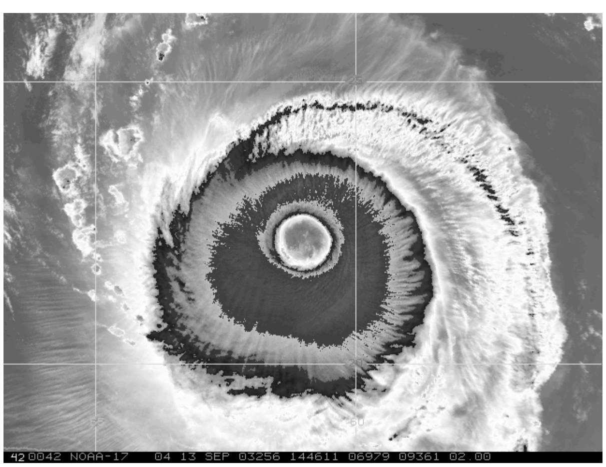

Figure 5. NOAA-17 AVHRR enhanced IR, 1446 UTC, 13 Sep 03.

4. MODIS TRUECOLOR AND 250-M VISIBLE

MODIS transmits 38 spectral bands of imagery at 1-km resolution with 8 bands at 500-m and 2 bands at 250-m resolution. The truecolor and 250-m resolution images of Hurricane Isabel's eye are quite spectacular. (Fig.6).

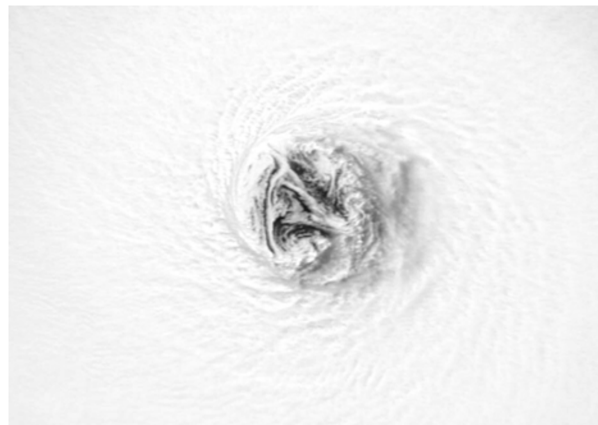

Figure 6. 250-m resolution MODIS image of Hurricane Isabel's eye, 1500 UTC 12 Sep 03. Image courtesy of NASA's MODIS Rapid Response System website, http://rapidfire.sci.gsfc.nasa.gov/

5. MICROWAVE IMAGES

The SSMI (Special Sensor Microwave Imager) aboard the DMSP (Defense Meteorological Satellite Program) satellites have been transmitting microwave data for many years. In late 1997, the TRMM (Tropical Rainfall Measuring Mission) satellite began providing data from the same sensor but with improved resolution due to its lower orbit. The NOAA satellites' AMSU (Advanced Microwave Sounder Unit) also provide microwave data, but the field-of-view is considerably larger near the limb. Recently, data from a microwave imager, the Advanced Microwave Scanning Radiometer (AMSR-E), became available from NASA's EOS. Hawkins, et al (2004) discuss microwave image applications for tropical cyclone monitoring and future potential satellite data.

Microwave images are important for observing tropical cyclones because they depict some ice and water distributions that cannot be seen in visible images and the infrared spectrum. The extensive thick cirrus cloud shields near the tropopause with tropical cyclones may obscure the lower level cloud features. This is particularly true with developing tropical cyclones prior to the appearance of well-defined eye.

A TRMM 37 GhZ microwave image on 17 September shows the detailed structure of Hurricane Isabel's inner core and spiral bands (Fig. 7).

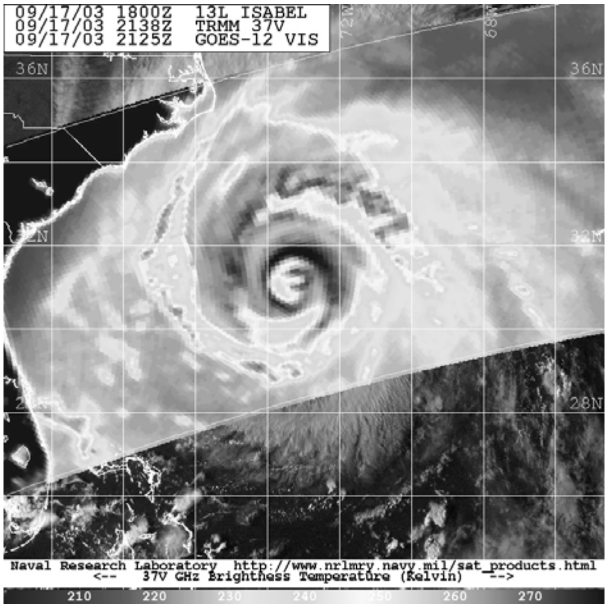

Figure 7. 37V TRMM microwave image, at 2138 UTC 17 September 2003. Image courtesy of Naval Research Laboratory website, www.nrlmry.navy.mil/tc_pages/tc_home.html

6. AMSU

The AMSU directly measures the upper layer hurricane warm core for which algorithms have been devised to estimate hurricane intensity and size (Demuth et al, 2004). Retrieved temperature profiles using AMSU can be used with an analysis technique to depict vertical profiles of mean azimuthal wind and surface pressure patterns (Kidder, et al 2000). New and improved AMSU wind analysis techniques are being developed (Bessho, et al, 2004).

7. SCATTEROMETER WINDS AND DATA

Scatterometers provide estimates of satellite winds over the oceans that can be used to estimate the intensity of weak tropical cyclones and also depict the outer wind patterns with hurricanes. Currently, the QuikScat instrument is the primary provider of real-time scatterometer observations with tropical cyclones. QuikScat uses backscattered power to retrieve surface wind direction and speed with a spatial resolution of about 25 km. QuikScat also provides high spatial resolution (3 km) images called Normalized Radar Cross-section (NRCS) to aid in tropical cyclone center fixing. Edson (2004) discusses tropical cyclone applications of QuikScat winds and NRCS images in combination with microwave images.

8. SUMMARY

The poster accompanying this paper shows color images and data plots for each of the data types with Hurricane Isabel. The purpose is to illustrate the diversity of remotely sensed hurricane data and the need for an integrated analysis approach (Zehr, 2001; Velden, et al, 2004; Edson, 2004)

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