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PERFORMANCE EVALUATION OF RAIN-CORRECTED SCATTEROMETER WINDS IN TROPICAL CYCLONES

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1. INTRODUCTION

For 6-months in 2003, the Japanese Midori-II spacecraft operated a microwave scatterometer (SeaWinds) and a microwave radiometer (AMSR). This unique instrument pairing provided the opportunity to use the radiometer observations to better understand the impact of various sources of uncertainty on SeaWinds measured radar cross-sections such as attenuation, volumetric backscatter and rain roughening of the sea surface. Using this limited data set, we have developed a method for improving rain-contaminated scatterometer winds (Hilburn et al., in print) and applied the technique to the SeaWinds data set. The Ku-2001 model function (Wentz, et al., 2001) was used in processing the scatterometer data so observed changes to the wind vectors are due entirely to the correction technique. In this paper, we present an example of the rain corrected wind vectors and discuss the differences between the rain-corrected and standard SeaWinds ocean wind vectors in the tropical cyclone environment.

2. DATA DESCRIPTION

An operational anomaly caused the premature end of the Midori-II mission resulting in a combined SeaWinds and AMSR dataset available from 10 April through 25 October 2003.

The SeaWinds scatterometer is a Ku-band (13.4 GHz) scatterometer with calibration and performance characteristics almost identical to SeaWinds on QuikScat. A brief description of the SeaWinds instrument and overall data quality is given in Wentz (2001). The Ku-2001 model function is different from the QSCAT-1 model funciton used to process the JPL science data and the NOAA real-time data shown at NRL and ORA/NOAA web sites. While these two model functions produce very similar results under most wind conditions (less than 0.5 m/s standard deviation for winds 3 – 20 m/s), the Ku-2001 model function has been adjusted to derive higher wind speeds. Unfortunately, the Ku-2001 wind vectors seem to be more likely to turn cross-swath in very heavy rain. We continue to refine and develop our model function to reduce the cross-track tendencies and produce more reliable, validated winds. SeaWinds on Midori-II data are available for browsing or downloading from Remote Sensing Systems (RSS) at http://www.remss.com.

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RSS routinely derives ocean surface wind speeds, columnar water vapor, cloud liquid water, rain rates and SSTs from radiometer observations. These ocean products are distributed freely via the RSS web site (www.remss.com) or the DISCOVER web site (www.discover-earth.org). We produce these geophysical products for AMSR and use the rain rate and brightness temperature measurements in our correction scheme.

While the time differences between AMSR and SeaWinds observations do not exceed 2.5 minutes, the different sampling geometries of the two instruments provide mismatch between the SeaWinds and AMSR observations that limit any potential correction especially when dealing with an inhomogeneous field such as rain. For example, SeaWinds collects data looking forwards and backwards while AMSR collects data looking forwards only, the SeaWinds horizontal polarization beam has a smaller incidence angle than AMSR, the SeaWinds and AMSR footprints are different sizes and the centers of the AMSR and SeaWinds footprints are not in exactly the same locations on the earth.

3. RAIN EFFECT ON SCATTEROMETER DATA

Rain affects scatterometer data in three ways: 1) rain reduces the transmission of the radar pulse through the atmosphere, 2) rain alters the roughness of the sea surface, and 3) the radar pulse is backscattered by the intervening raindrops. The basic equation for the effects of rain on scatterometer data (in linear units) is given by

$$\sigma_{0,meas} = \tau^2\left(\sigma_{0,wind} + \Delta\sigma_{0,rain}\right) + \sigma_{0,vbs}$$

where $\sigma_{0,meas}$ is the measured radar cross-section, $\sigma_{0,wind}$ is the cross-section resulting from the wind alone, $\Delta\sigma_{0,rain}$ is the change in surface roughness due to rain impact (may be positive or negative), τ^2 is the atmospheric transmission, and $\sigma_{0,vbs}$ is the volumetric backscatter by rain.

The nonlinear nature of the wind retrieval process makes the effects of rain on the retrieved wind speeds and directions quite complicated. Even small amounts of rain can have large effects on retrieved winds. Typically, the net effect of rain is to increase the retrieved wind speeds. However, in tropical cyclone cases where the rain is very heavy and the true wind speed is high, the attenuation effect can dominate and lead to lower retrieved wind speeds. The effect of rain on wind direction retrievals is very complicated and the exact nature of the effect depends upon how the spatial distribution of the rain causes a differential effect on the various σ_0 observations within a wind vector cell. In general, the presence of rain tends to decrease the azimuthal signal and increase the horizontal to vertical polarization ratio. Both effects cause the retrieved wind directions to be oriented perpendicular to the satellite movement (i.e., the winds blow “cross-track”).

The correction technique is described in detail in Hilburn (2006, in print).

4. FABIAN EXAMPLE

In September 2003, Hurricane Fabian approached Bermuda. We have applied the correction to the SeaWinds data and provide both the uncorrected and corrected wind vectors in Figure 1. In this example, the correction actually increased the wind speeds from 44 m/s (uncorrected) to 51 m/s (corrected) at 1500 Z. The NHC 1-minute sustained maximum wind based on a dropsonde at 1730 Z was reported as 57 m/s. This one-minute mean is converted to the scatterometer ten-minute mean using the US NAVY reduction factor of 0.88 yielding a wind speed of 50 m/s. Tropical storm examples are very sensitive to the attenuation correction, and the fact that our correction increases the wind speed to a reasonable value is evidence that our attenuation correction is working properly. It is interesting to note that the rain correction makes the hurricane structure of Fabian more asymmetric and more similar to the Hurricane Research Division H-wind analysis field at http://www.aoml.noaa.gov/hrd/data_sub/wind.html as shown in Figure 2. The H-wind analysis in this case did not assimilate scatterometer data.

Although the corrected winds in this example show improvement, we find that not all winds are improved. Further examples of tropical cyclones will be shown in the presentation. All tropical cyclones within the 6-month SeaWinds data period are available for viewing within the Tropical Cyclone Archive (described in Smith,2004) and available at http://www.remss.com/hurricane/data_archive.html. This archive contains data from July 1999 through the present in a simple, focused environment specifically designed to aid in user understanding of microwave data sets. Figure 3 shows the interface for Fabian on September 9, 2003. The AMSR rain rate information is provided in the bottom right image. The SeaWinds ambiguities (all possible wind directions derived from the model function before wind vector selection is performed) are plotted for the standard SeaWinds data.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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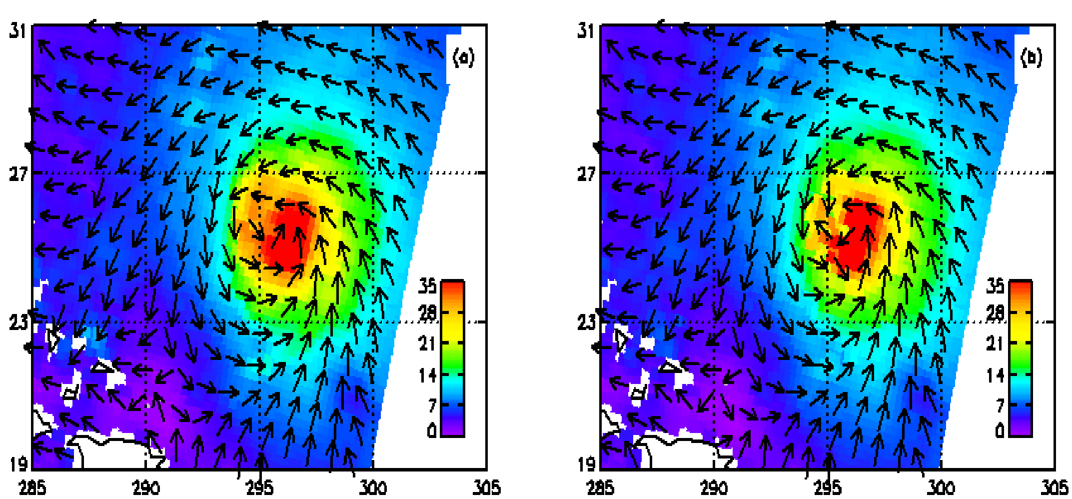

Figure 1. SeaWinds wind speeds (color, in m/s) and wind direction vectors (every 5th vector is plotted) for Hurricane Fabian, September 4th, 2003, 1515Z. Uncorrected winds on the left (a) and corrected winds on the right (b).

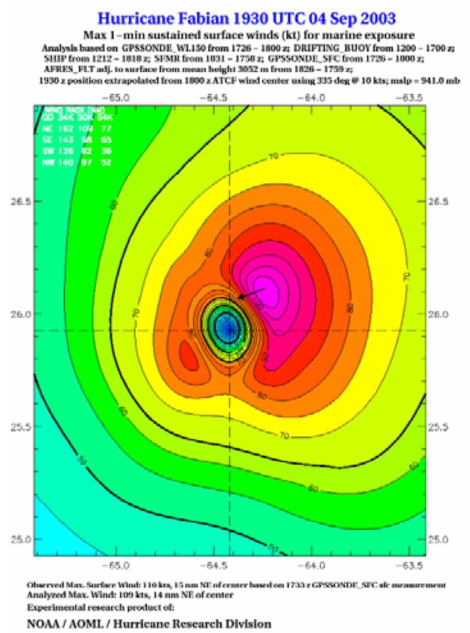

Figure 2. Results of the HRD H*wind analysis run without scatterometer data included for 1930 Z Sept 4th, 2003.

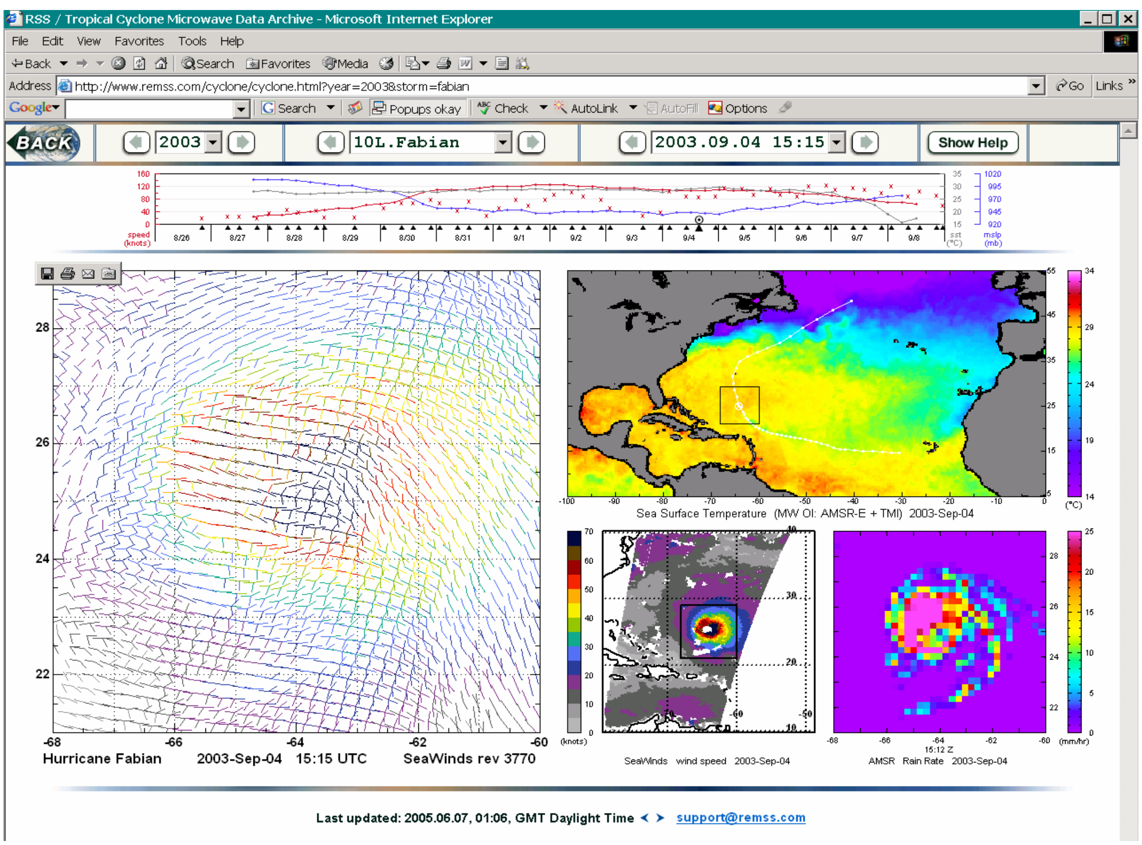

Figure 3. Example of microwave tropical cyclone archive interface available at www.remss.com. In this example, Hurricane Fabian approaches Bermuda. The AMSR rain rate data is shown in the lower right box. SeaWinds ambiguities are plotted in the left panel.