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ANALYSIS OF QUIKSCAT RAIN-FLAGGED WINDS WITHIN THE TROPICAL CYCLONE ENVIRONMENT

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Meteorologists are using scatterometer winds in the detection and forecasting of tropical cyclones, especially in the data-sparse ocean regions. In particular, these high-density winds are being used for early identification of tropical depressions (Katsaros, 2001) and for determination of the 35 and 50-knot wind radii that are important to storm warnings. However, scatterometer winds are difficult to use because of rain effects on the microwave signals. More validation is needed of the retrieved winds within the tropical cyclone environment.

1. THE SEAWINDS (QUIKSCAT) INSTRUMENT

The SeaWinds scatterometer is an active microwave instrument that senses the roughness of the ocean surface by measuring the signal backscattered by the capillary waves generated by surface wind stress. By viewing the same ocean surface from several different azimuth angles, the ocean surface wind speed and direction can be obtained.

A detailed description of this conical-scanning dual-beam SeaWinds scatterometer, commonly known as QuikScat, is found in Wu et al. (1994). The scatterometer has two beams, a horizontally polarized inner beam with a 46-degree incidence angle and a vertically polarized outer beam making observations at a 54-degree incidence angle. Our Ku-2001, empirically derived geophysical model function (GMF) is used to relate the normalized radar cross-sections (signal returns) with wind speed and direction.

QuikScat has been in operation since July 1999 and has been shown during this time to perform well under typical weather conditions in which winds are below 15 m/s and no rain is present. Wind comparisons made with data from global analyses, satellites and buoys show speed rms errors within 1.4 m/s and direction rms errors within 18 degrees. However, statistics show that it is far more difficult to retrieve quality winds within the high wind, intense rain conditions of a tropical cyclone. Clearly a better understanding of these winds is needed.

In this study we make use of an extensive archive of over 2400 QuikScat storm overpasses available from our web page located at www.remss.com/hurricane/data_archive.html. These tropical storm images show QuikScat winds within an 8-degree box centered on tropical cyclone center positions. Approximately 30% of these images consist of high quality images containing storm centers located within the best part of the QuikScat swath. Wind vectors affected by rain can be identified in these images by non-geophysical winds or a dot placed at the base of the wind barbs. We have compared these rain-affected QuikScat data with available buoy data, H*Wind model analyses, NHC produced wind radii, and best-track intensity estimates to determine if the wind speeds are usable.

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2. RAIN EFFECT ON SCATTEROMETER DATA

It is well known that microwave signals are scattered and absorbed by raindrops located within the signal path. The amount of signal alteration is dependant on the frequency, polarization and angle of incidence of the microwave signal in addition to the amount of rain present in the path and the speed of the local wind field. The higher frequency of QuikScat's Ku-band pulse (~14 GHz) suffers greater rain contamination than that of the ERS-2 scatterometer, a lower frequency instrument. In addition, QuikScat data suffer greater rain contamination than those from the previous stick-beam scatterometer, NSCAT, due to the higher ratio of horizontally to vertically polarized signal returns and the two high incidence angle beams.

A study of rain in QuikScat data shows two main effects, 1) higher derived wind speeds in low wind fields and 2) the presence of wind vectors turned perpendicular to the satellite track in high wind and rain locations (referred to as cross-track winds). Figure 1 shows Tropical Storm Olga on March 17th, 2000. In this case, both cross-track vectors and higher winds are found in the very heavy rain cell to the west of the storm center. A time difference of approximately one hour exists between these scatterometer and radiometer measurements.

Further analysis shows that cross-track vectors are often obtained under very heavy rain conditions. When heavy rain occurs, the resulting large raindrops tend to flatten and become less spherical. The flatter shape scatters horizontally polarized (h-pol) microwave radiation more than vertically polarized (v-pol) signals. It is the variation of the h-pol to v-pol ratio with respect to the relative azimuth angle (the angle between the look direction and the wind direction) that allows us to retrieve wind direction from the backscattered signals. The greater h-pol

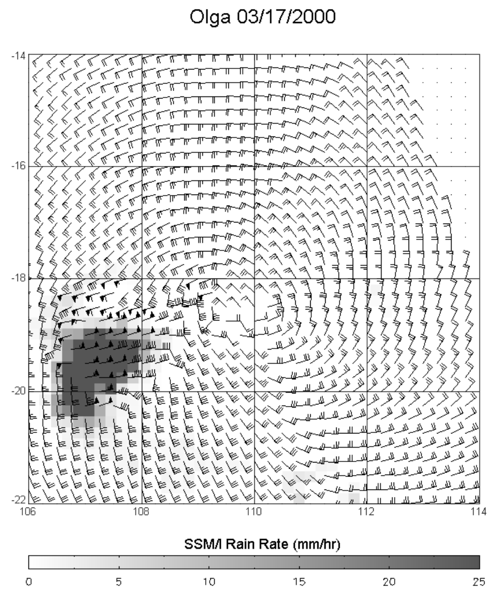

Figure 1. QuikScat wind vectors, shown as wind barbs in knots, are drawn over collocated F14 SSM/I rain rates for tropical cyclone Olga. Higher wind speeds and cross-track directions occur in and near the highest rain rates. The edge of the swath in the upper right corner can be used to determine the satellite sub-track direction and therefore identify cross-track erroneous wind vectors.

scattering increases this ratio causing the retrieved wind direction to be rotated towards the cross-track direction, where the ratio is at a maximum.

3. RAIN FLAGGED WINDS

A stand-alone rain flag was developed for QuikScat primarily to remove the greatly overestimated winds located throughout low-wind tropical regions. The rain flag available in the Ku-2001 data set from RSS is highly effective at these low winds, but flags far fewer rain cells in the high wind environment. A goodness-of-fit tool is used as the rain flag. It identifies when there is a sizeable difference between the observed and GMF predicted backscatter in both the cell in question and the surrounding cells. A cell is flagged as rain-affected if the wind speed is greater than 5 m/s, the goodness-of-fit value is above the threshold, the wind direction is within 15 degrees of being perpendicular to the satellite track and at least 5 of 8 adjacent cells are flagged.

In Figure 2, the scatterometer rain flag did not identify the cells located within the large rain band to the north of the storm. These winds have speeds close to those of surrounding cells and therefore look like good data. The few cross-track winds northwest of the storm were not flagged as rain as these did not satisfy all the flag requirements listed above. Comparison with buoy data collected at the each of the black circles show excellent agreement in all but the buoy located within the rain band (see Table 1).

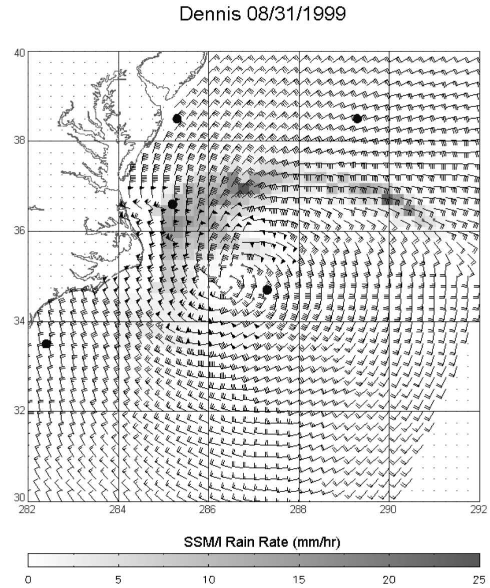

Figure 2. QuikScat wind vectors, drawn as wind barbs in knots, are positioned over F13 SSMI rain rates for Hurricane Dennis. Winds flagged as rain are noted by a dot at the base of the wind barb. In this example, there are no data flagged within the rain band region. Winds here are similar to those outside of the rain band and only a few wind directions northwest of the storm center are turned perpendicular to the swath.

In this case, the QuikScat wind is higher than the buoy wind. Despite this example, we will present in our talk comparisons of QuikScat with H*Wind model data that demonstrate the wind speeds of cross-track vectors are in fact often similar or slightly higher than those of nearby cells not affected by rain and can be used to derive reasonable 35 and 50 knot wind radii.

Table 1. Buoy and QuikScat wind speeds (knots) for Hurricane Dennis shown in Figure 2.

Buoy #	Latitude	Longitude	B speed	Q speed
41001	34.7	284.3	30.2	30.0
44004	38.5	289.3	30.6	31.9
44009	38.5	285.3	33.3	38.2
44014	36.6	285.2	40.8	58.5
FPSN7	33.5	282.4	23.1	21.3

4. ACKNOWLEDGEMENT

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5. REFERENCES

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