QuikSCAT Wind Retrievals for Tropical Cyclones

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Abstract—**The use of QuikSCAT data for wind retrievals of tropical cyclones is described. The evidence of QuikSCAT σ_0 dependence on wind direction for >30 m/s wind speeds is presented. The QuikSCAT σ_0s show a peak-to-peak wind direction modulation of ~1 dB at 35 m/s wind speed, and the amplitude of modulation decreases with increasing wind speed. A correction of the QSCAT1 model function for above 23 m/s wind speed is proposed. We explored two microwave radiative transfer models to correct the effects of rain for wind retrievals. Both radiative transfer models have been used to retrieve the ocean wind vectors from the collocated QuikSCAT and SSM/I rain rate data for several tropical cyclones. The resulting wind speed estimates of these tropical cyclones show improved agreement with the wind fields derived from the best track analysis for up to about 15 mm/h SSM/I rain rate. A comparative analysis of maximum wind speed estimates suggests that other rain parameters likely have to be considered for further improvements.**

Keywords: Scatterometer,tropical cyclone

I. INTRODUCTION

Skillful forecasts of tropical cyclone (TC) track and intensity depend on an accurate depiction of the initial conditions of air and sea states in TC forecast models. A primary source of difficulty in past efforts for TC forecasts has been the inability to make direct observations of the surface wind field.

QuikSCAT, which is the SeaWinds scatterometer on the QuikSCAT satellite, is a spaceborne Ku-band (13.402 GHz) scatterometer designed to measure the normalized radar cross section (σ_0) of sea surfaces. The QuikSCAT scatterometer has been operating since August 1999 to provide global mapping of ocean winds. It was shown to be accurate for wind speed of up to at least 20 m/s. The performance of QuikSCAT is uncertain for above 20 m/s wind speeds.

This paper presents the results from the analysis of QuiksCAT data from 1999-2000 hurricane seasons for the wind direction modeling of ocean σ_0s for extreme high winds. A simple functional correction of the QSCAT1 geophysical model function (GMF), presently used by the JPL and National Oceanic and Atmospheric Administration (NOAA) data processing systems for QuikSCAT, is proposed for rain-free conditions (Section II). We applied two radiative transfer (RT) models for the effects of rain., together with the modified QuikSCAT GMF, to the processing of QuikSCAT data to indicate how accurate the effects of rain can be corrected (Section IV).

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II. QUIKSCAT σ_0 OBSERVATIONS

The azimuth diversity of QuikSCAT fore- and aft-look geometry allows a direct examination of the wind direction dependence of TC σ_0s. Fig. 1 illustrates the fore- and aft-look σ_0s acquired by the inner antenna beam for hurricane Alberto in 2000 from five QuikSCAT passes with the maximum wind speeds in the range of 44 to 56 m/s based on the best track analysis from the National Hurricane Center.

The σ_0 images in the first two rows of Fig. 1 indicate the evolution and location of Alberto. The spatial patterns of σ_0 appeared asymmetric with respect to the center of the cyclone, marked by black crosses. The images in the third row of Fig. 1 illustrate the σ_0 asymmetry (fore-look σ_0 divided by aft-look σ_0) in dB. The σ_0 asymmetries suggest the influence of wind direction on σ_0s for hurricane winds. Examination of several other revs of QuikSCAT data indicates similar characteristics.

The wind direction dependence of σ_0s can be expressed in terms of a cosine series with coefficient A_i denoting the amplitude of the ith harmonics. Using the ratios of fore- and aft-look σ_0 observations, we estimated the ratio A_2/A_0 from the ratio of each pair of fore- and aft-look σ_0s. The estimates were binned and averaged as a function of wind speed and rain rate using data from the QuikSCAT passes of hurricanes in 1999 and 2000. From the estimates, we propose the following modifications to the QSCAT1 GMF for wind speeds (w) above w_C=23 m/s:

$$\frac{A_i}{A_0} = \frac{1-\exp[-(25/w)^2]}{1-\exp[-(25/w_C)^2]} \frac{A_i}{A_0}_{QSCAT1, w=w_C} \tag{1}$$

for $i \geq 1$, and

$$A_0 = A_{0,QSCAT1}(w_C) + \beta(w - w_C) \tag{2}$$

Here 'w' is the wind speed in m/s. The value of β is 0.0025 for inner beam and 0.0018 for outer beam [2]. The modified GMF is called 'QSTC02'.

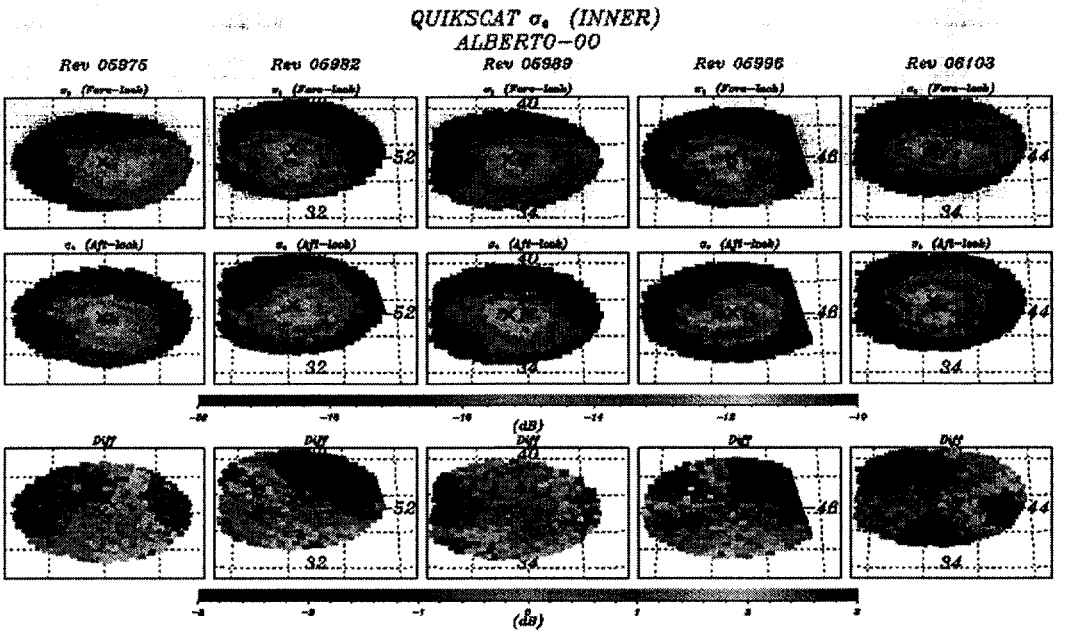

Figure 1. Images of QuikSCAT inner beam σ_0s for hurricane Alberto in August 2000 with the first row for the fore-look observations, the second row for aft-look observations, and the third row for the ratio of fore- and aft-look data. Five revs of data are organized in five columns.

III. WIND RETRIEVALS FOR TROPICAL CYCLONES

Two radiative transfer models, together with the revised rain-free QSTC02 GMF, have been applied to the wind retrievals for hurricanes in 1999 and 2000. One was based on the rain scattering and attenuation coefficients published by Haddad et al. [2] and Bliven et al. [3] (HB model), and the other was suggested by Stiles and Yueh [4] (SY model.) The methodology for wind retrieval is described in [1] and is based on the maximum likelihood measure to minimize the difference between QuikSCAT σ_0 measurements and model estimates.

A quantitative comparison is shown in Figure 2 for the wind speed retrievals along two cuts near the eye of Alberto: One is along track and the other is across track. The wind speed retrievals from the QSTC02/SY and QSTC02/HB models reach above 50 m/s, significantly higher than the maximum wind speed estimate of about 35 m/s from the QS1 product. The wind speeds from the regions with >15mm/h rain rate were significant underestimates for the SY model and overestimates for the HB model and were not included in the figure. As a reference, Fig. 2 includes the Holland model field wind averaged over the locations of QuikSCAT σ_0 samples within a WVC. The wind speed retrievals from the SY model seem to have a better agreement with the Holland model field. However, the HB model agrees better with the Holland model for some other hurricanes.

An indicator of the intensity of tropical cyclones is the maximum sustained wind speed. For most hurricanes, the NHC best track analysis performs the maximum wind speed estimates using the Dvorak technique [8], which is based on a pattern matching analysis. We performed wind retrievals for several cyclones and searched for the maximum wind speed in the region with less than 15 mm/h rain rate. Because the regions with >15 mm/h are excluded, the "maximum" wind speed estimates from QuikSCAT will in general be lower than the maximum wind speed of the storm under consideration. Figure 3 compares the QuikSCAT estimates with the NHC best track analysis versus time for hurricanes Alberto and Isaac in 2000 and Gert and Dora in 1999. The estimates from QS1 products poorly indicate the strengthening and weakening of cyclones. In contrast, the estimates from the QSTC02 model function with the SY or HB rain model corrections track the intensity changes of Alberto and Gert reasonably well. The intensity tracking using the QuikSCAT estimates for Isaac and Dora is not as good, but still indicates the intensification and weakening of cyclones during certain periods of time.

IV. SUMMARY

This paper describes QuikSCAT wind retrievals for tropical cyclones. A direct examination of the QuikSCAT σ_0 data from several intense storms indicates a directional asymmetry of about 0.5-1 dB for wind speeds in the range of 30-50 m/s. The fore- and aft-look differences of σ_0s are used to estimate the amplitude of upwind and crosswind asymmetry. The corrections to the QSCAT1 GMF are expressed in a simple analytic form. The evidence on the directional behavior of σ_0 data suggests a potential for wind direction retrievals from spaceborne scatterometers in extreme high wind events, although an instrument with a better σ_0 detection sensitivity than the QuikSCAT is required.

To compensate for the effects of rain on wind retrieval, two radiative transfer models are examined. The predictions of scattering from raindrops and rain-roughened surfaces agree reasonably well between these two models, but there is a

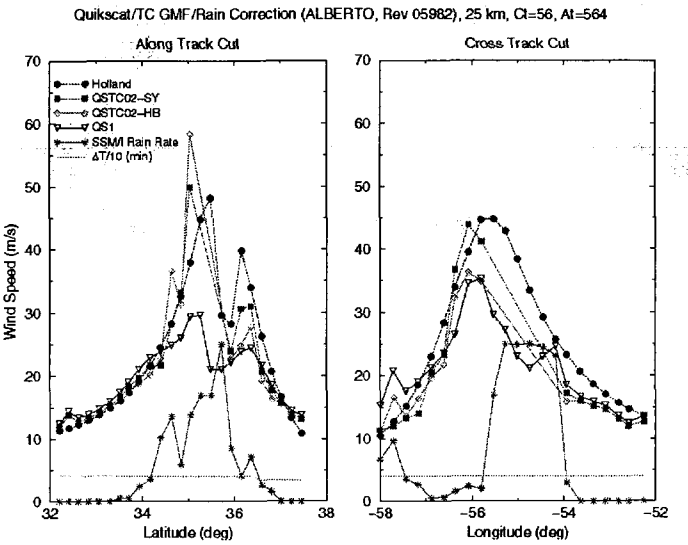

Figure 2. The wind speed profiles of Hurricane Alberto (QuikSCAT rev 5982) along and across track through near the center of the cyclone. The JPL ground data processing system output fields are labeled by QS1, wind retrievals using the SY-model by QSTC02-SY, wind retrievals using the HB-model by QSTC02-HB. The SSM/I rain rate is in mm/h. The time difference between the SSM/I and QuikSCAT observations is divided by 10 for illustration.

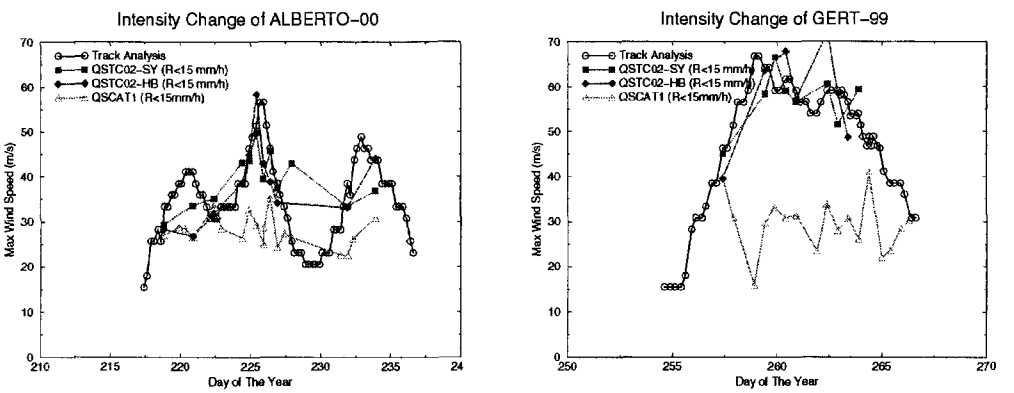

Figure 3. Best track and QuikSCAT estimates of maximum wind speed versus time. Upper left panel for hurricane Alberto, upper right for hurricane Gert, lower left for hurricane ISAAC, and lower right for hurricane DORA.

significant difference in the predictions of rain attenuation. Both models are applied to the processing of the QuikSCAT winds and improve the estimates of wind speed for areas with relatively light rain. The results are corroborated with a comparative analysis with the best track intensity estimates of maximum wind speeds for several hurricanes.

However, the results are unsatisfactory for areas of high rain rate (>15 mm/h). More detailed studies are recommended to improve the radiative transfer model and rain correction algorithm for wind retrievals.

ACKNOWLEDGMENT

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