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OPERATIONAL USE OF QUIKSCAT OVER TROPICAL CYCLONES

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1. INTRODUCTION

The active microwave scatterometer, Sea Winds, on the NASA QuikSCAT satellite has been available to tropical cyclone (TC) forecasters during the past 3-½ years (Edson and Hawkins, 2000). The "QuikSCAT" scatterometer's unique ability to provide both wind speed and direction on a nearly bi-daily basis has offered the operational forecaster the ability to significantly increase near real-time knowledge of TC genesis, development of inner core winds, outer wind structure, and a 'minimum estimate' for a TC's maximum sustained winds. Unfortunately, each pass over a TC or suspect area cannot always be directly used for reconnaissance grade interpretation. While wind speeds have been found to be extremely accurate away from the TC core (and outside heavy rain areas), wind speeds and directions in rain-contaminated areas and other 'low skill' areas are often found to be confusing and cannot be directly analyzed without the use of various (and sometimes difficult) interpretation procedures. A summary of some of the operational concerns regarding QuikSCAT data is shown in Table 1. This paper addresses some of these concerns and offers some solutions that will allow for the increased use and confidence of this unique and invaluable data source.

2. SATELLITE RECONNAISANCE ACCURACY

Precise knowledge of a TC's current position and character is an important step in the tropical cyclone warning process. Small errors in the analysis, especially in the early stages of development, can lead to much larger errors in the multi-day forecasts. Each conventional fix platform has a characteristic accuracy in navigation, measurement ability and meteorological interpretation (OFCM, 2001). This allows for a standard degree of confidence, accuracy and interpretation for all users. (See Table 2 for criteria established for satellite data.) The Position Code Number (PCN) is usually associated with the 90% radius of confidence circle for each fix category (defined as 1.52 X the Standard Vector Deviation, SVD). The results shown in Table 2, are compatible with current fixing techniques and can serve as a goal for any methodology developed for TC positioning with the scatterometer.

3. DIRECTIONS, SPEEDS AND POSITIONS

The greatest interpretation issue concerns the correct wind direction selection procedure. Rain-flagged wind vector cells (wvc's) greatly affect these results by expanding the (erroneous) cross track wind directions for a few wind cells into their neighbors though the median filter procedure (called 'rain contagion'). Upon further examination, correct wind directions often appeared in the alternative ambiguity solutions or could be interpreted from the Normalized Radar Cross-Section (NRCS) or Sigma0 images. The details for physically retrieving (up to 4) solutions and selecting one specific solution for each wind vector cell is nicely explained in Atlas (2001). QuikSCAT wind speeds have been shown to be accurate, outside of rain, at an rms of better than 2 m/s. Of course it is nearly impossible to evaluate winds near a TC without considering the effect of rain. Recently, Stiles and Yueh (2001) showed that while light to moderate winds (< 10m/s) in heavy rain were severely overestimated, this overestimation decreased in stronger winds as the wind signal became more dominant over the rain-related surface roughness signal. For winds in heavy rains in excess of 15 m/s, speeds were found to be underestimated primarily due to volume and path attenuation, depending upon polarization. This characteristic allows for a method that

Table 1. QuikScat Problem Areas
(Usually in low skill areas)

1) Edge of swath (~7 wind vector cells, wvc) and along sub-track (3-4 wvc).
    a) Regions with less than 4 independent solutions.
2) Sensitivity to heavy rain.
    a) Surface roughness (especially in low wind areas).
    b) Rain scattering of up and down signal (13.4 Ghz).
3) Sensitivity to errors in NWP model in low skill locations.
4) "Practical" wind regime between 5 and 30 m/s.
    a) Problems in both **Light** and very **Heavy** winds.
5) Resolution (25 km) of footprint will limit wind retrieval in tight gradient regions, especially in core region of TC.
6) Ambiguity selection process and how rain flags are treated (no direct measurement of rain on QuikSCAT).
    a) Watch out for rain blocks caused by 'rain contagion' due to median filter and 'buddy system checks'.
    b) Model weights cross-track solutions in isotropic(rain) conditions (winds are artificially perpendicular to swath).

Table 2. TC Position Code Number (PCN) Accuracy
(Adapted from 1 WWP 105-10)

PCN	CLASS	Mean Dev (nm)	SVD (nm) (63%)	1.52 SVD (nm) (90%)
1-2	Eye	15	16.5	25
3-4	Well-defined	20	26	40
5-6	Poorly-defined	30	36	55

**Corresponding author address:* Roger T. Edson *c/o* WERI, Univ. of Guam, Mangilao, Guam 96923*;* email: redson@uog.edu uses isotachs to find the center of most developing TCs (even if the highest gradient winds are not resolved in the TC core). A summary of the methodology used to position TCs is shown in Table 3.

Table 3. Scatterometer Positioning Procedures (Developed for forecasters at JTWC---abbreviated---)

1) Examine SAT imagery and synoptic data for first guess position (include TC history).
2) Determine synoptic conditions (e.g., wave, monsoon trough, shear, TUTT, subtropical).
3) Examine scatterometer winds.
    a) Use highest resolution (currently FNMOC).
    b) Draw first guess streamlines.
        i) Identify problem areas (see Table 1).
        ii) Is center affected by problem areas?
4) Perform isotach examination.
    a) Center is often on axis of lightest winds.
    b) Center position with respect to highest winds depending upon known characteristics and development stage (early, mature, shear, etc.).
    c) Center located near min value within max wind isotach (especially for eye case).
5) Examine ambiguity solutions.
    a) Draw streamlines to meet ambiguities (Figure 1).
        i) Work inward from TC environment towards vortex center
        ii) Give priority to wvc's with 2 or 3-way ambiguities.
    b) Adjust center in order to avoid drawing streamlines that are not possible solutions.
6) Compare adjusted position with trough axis and isotach analysis from Step 4 and SAT imagery from Step 1.
7) Examine NRCS for wind signature (Figure 2).
    a) Use only after initial guess to focus search.
    b) Very precise when good signature exists.

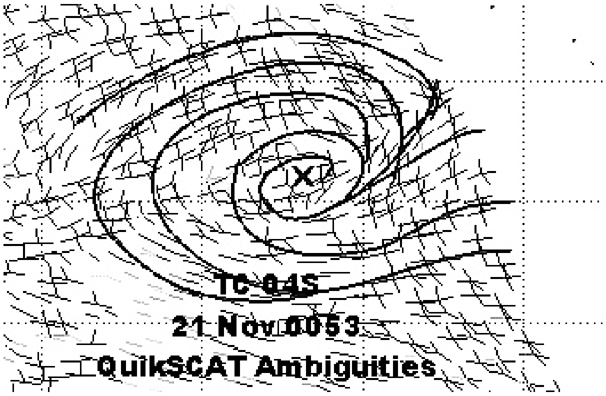

Fig 1. Ambiguity analysis. Streamlines must not violate available solutions (on rare cases 2-way ambiguities exist, perpendicular to swath indicating no solution).

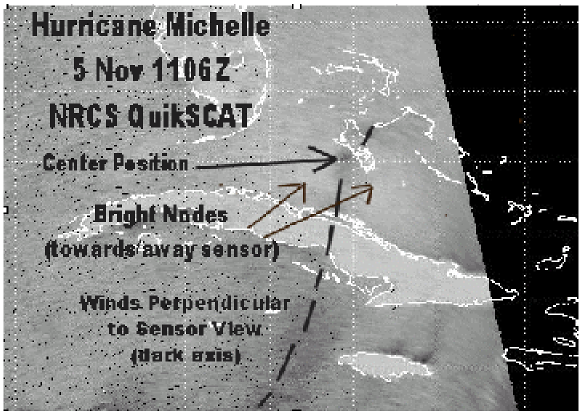

Fig 2. NRCS (Sigma-0) Solutions (7km resolution)

4. TEST OF METHODOLOGY

Using the methods described in this paper, Edson performed scatterometer fixes for all passes in the Atlantic 2001 season that fell within 12 hours of an aircraft fix. The results for the sample of 40 indicate scatterometer fix errors matching the well-defined PCN 3 and 4 (Fig 3 and Table 2). These fixes were prepared in post analysis without prior knowledge of best track data. We believe that these methods will allow the TC forecaster to use the scatterometer to its fullest capabilities.

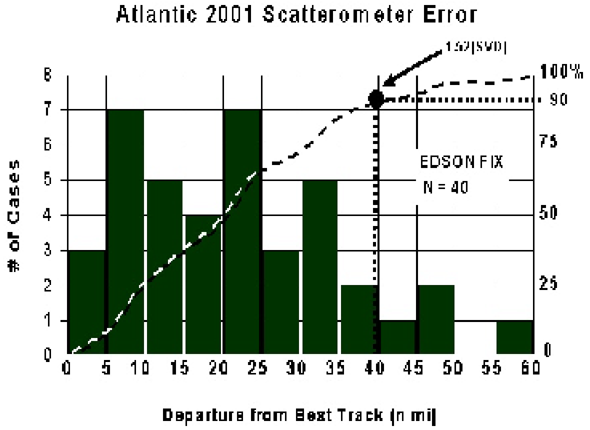

Fig 3. Scatterometer fix error distribution for sample of 40. Cumulative count shown by dashed line. PCN defined by error radius within which 90% of fixes fall.

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