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VALIDATION OF QUIKSCAT WIND RETRIEVALS IN TROPICAL CYCLONE ENVIRONMENTS

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1. INTRODUCTION

The violence of the hurricane limits its predictability by creating a hostile environment for in situ observation. The failure to obtain accurate and timely data of the hurricane wind and thermodynamic structure is a large limiting factor in forecast accuracy. Recent developments in the use of remotely sensed data in tropical cyclones have provided a more comprehensive picture of this structure. In particular, the use of Stepped Frequency Microwave Radiometers (SFMR, onboard National Oceanic and Atmospheric Administration aircraft) and QuikSCAT active scatterometry now provide surface wind information that was not routinely available just a few years ago.

SFMR wind speed retrievals in hurricanes are well correlated with in situ dropsonde measurements (Uhlhorn and Black 2003). However, QuikSCAT wind vectors experience a substantial loss of accuracy under the hurricane circulation. Although this is mainly due to the effects that heavy rain has on the backscatter signal, one must also consider the difficulty in retrieving wind speeds (35 – 75+ m/s) well outside of the QSCAT-1 geophysical model function (GMF) design limit (30 m/s).

Because of this condition, forecasters have been limited in how QuikSCAT data are used in hurricane analysis and forecasting. At present, data are employed to diagnose 34 and 50 kt. wind radii and, for less mature systems, the existence of (or lack of) a closed circulation. These are certainly important uses of QuikSCAT wind vectors; however, there exists a large potential benefit if more accurate retrievals of QuikSCAT winds can be obtained. For example, the magnitude and extent of the most destructive inner core winds could be more accurately diagnosed. This would allow for more highly refined forecasts.

The first step towards a better retrieval algorithm in hurricanes is a comprehensive validation of the current retrievals. In the past, this has been very difficult because there have not been enough measures of the "true" surface hurricane wind. With the increasing use of SFMR wind data and a recent increase in Atlantic Basin hurricane activity, more frequent coincident QuikSCAT passes have allowed for a comprehensive validation study.

The purpose of this study is to evaluate both operational and research QuikSCAT GMFs in hurricane environments in order to establish a baseline measure for enhanced algorithm performance.

2. DATA AND MODEL FUNCTIONS

The SeaWinds scatterometer on QuikSCAT measures the normalized radar backscatter (σ_o) from up to four azimuth angles. A 10-meter wind speed and direction are determined from σ_o through a GMF. Four GMF variations are tested here. The first two are 25 km and 12.5 km spatial resolution versions of the QSCAT-1 operational GMF (hereafter QLOW and QHI). These data are routinely used at operational forecast centers. The final two GMFs are experimental. Long (2001) developed a method based on the QSCAT-1 GMF to process σ_o data to yield ultra high resolution (2.5 km) wind vectors (hereafter UHR). Finally, Wentz et al. (2001) used objective smoothing and empirically tuned wind speeds in the Ku-2001 GMF. It is also post-processed to be a 2.5

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km high resolution product (denoted as UHR KU).

The retrievals are validated against individual SFMR wind speeds and H*Wind analyses. H*Wind (Powell et al. 1998) is a wind analysis system that assimilates all available wind data into a storm centered framework. These data are then used to create a 6 km gridded wind field of the hurricane. It should be noted that errors in H*Wind analyses are on the order of 10-20% (due to sampling and smoothing issues), while SFMR winds typically deviate 10-15% from in situ dropsonde measurements (Uhlhorn and Black 2003).

The nine hurricanes and one tropical storm cases used for this study are shown in Table 1. Note that the data sample is biased toward very mature tropical systems. It is expected that the results would be different if more tropical depressions and storms were included (since the surface signal would be weaker and thus affected differently by rain).

3. COINCIDENCE CRITERIA

H*Wind analyses were only chosen if they included at least SFMR and/or reconnaissance data and had coverage in all four quadrants of the hurricane. QuikSCAT data were not included in the H*Wind analyses. For SFMR validation, the QuikSCAT wind vector had to be measured within 2 km and 20 minutes of the SFMR wind observation. The QuikSCAT measurement had to be within 1 km of the H*Wind grid point to be considered.

4. RESULTS

H*Wind validation statistics for the core area (< 150 km of the storm center, typically with the most vigorous convection and rain) are shown in Table 2 – the statistics were similar for all methods outside of the core region. The negative biases are significant and indicate that attenuation of the signal by the intense storm convection is the dominating effect (for weaker systems with less vigorous convection, enhanced backscatter by rain will give a large positive bias). The root mean square error (RMSE) is approximately 30% lower for QLOW than UHR for the inner core. The QLOW is also less noisy than the other methods.

Name	Date	Time (UTC)	Max. Wind (NHC)
Humberto	09/24/2001	2304	33.4
Isidore	09/26/2002	2343	28.3
Lili	09/30/2002	2316	46.3
Lili	10/03/2002	0003	64.3
Fabian	09/02/2003	2149	59.2
Fabian	09/04/2003	0250	59.2
Isabel	09/12/2003	2230	69.5
Isabel	09/16/2003	1515	48.9
Ivan	09/12/2004	1045	69.5
Ivan	09/14/2004	2359	61.7

Table 1. QuikSCAT pass date/time and National Hurricane Center (NHC) maximum wind speed (m/s) of storms used for validation.

	QLOW	QHI	UHR	UHR KU
Bias	-3.94	-4.04	-6.86	-4.28
Std. Dev	6.70	8.65	8.57	8.56
RMSE	7.73	9.46	10.97	9.57
R	0.80	0.73	0.69	0.67
N	59	43	8757	8713

Table 2. Validation statistics with H*Wind for the hurricane core. Values are in m/s.

The coarse resolution of the QLOW and QHI retrievals resulted in a small number of collocations (< 35) with the SFMR observations. However, there were an acceptable number of collocations with the high resolution products. Figure 1 shows scatterplots of the UHR and UHR KU inner-core retrievals vs. SFMR. The correlation coefficient for the UHR (UHR KU) data was 0.63 (0.60). The UHR retrievals rarely exceed 30 m/s and some inner core retrievals underestimate the surface wind by as much as 15-20 m/s. The effect of the high wind tuning is seen in the UHR KU retrievals as there is a larger number of values > 30 m/s. However, there also exists a larger spread in the UHR KU retrievals – RMSE for UHR KU are 1 m/s more than UHR. Clearly there is room for improvement in both algorithms.

Finally, retrievals of QLOW, UHR, and UHR KU vs. H*Wind are shown for the 2149 UTC Hurricane Fabian pass in Figure 2. A pattern emerges from all three retrievals. Up to surface winds of 15 m/s, QuikSCAT winds have a relatively low variance (with a clear but small negative bias). Once the 15 m/s threshold is crossed, the skill in QuikSCAT retrievals diminishes dramatically. This is not unexpected, given that 1) the model functions were not designed to retrieve in these wind regimes, and

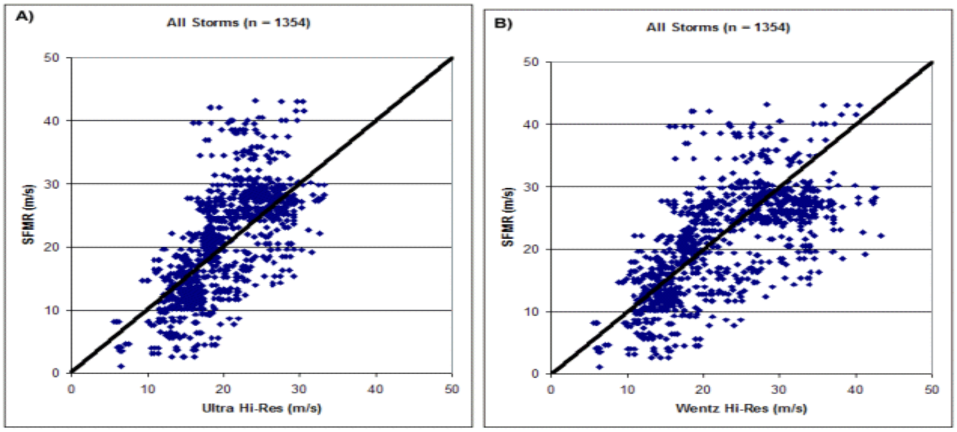

Figure 1. QuikSCAT retrievals vs. SFMR (m/s) for a) UHR, and b) UHR KU.

2) Intense convection probably attenuated much of the signal anyway.

5. CONCLUSION

QuikSCAT wind retrievals from two operational and two experimental methods were validated against SFMR and H*Wind winds. QuikSCAT retrievals are very accurate outside of the intense convection of the hurricane inner core, but are of little use inside the core region. A new technique has been developed to simultaneously retrieve wind *and* rain from SeaWinds (Draper and Long 2004). We are hopeful that this will lead to better retrievals in the hurricane core, and hence become a more useful product for tropical cyclone forecasting and research.

6. REFERENCES

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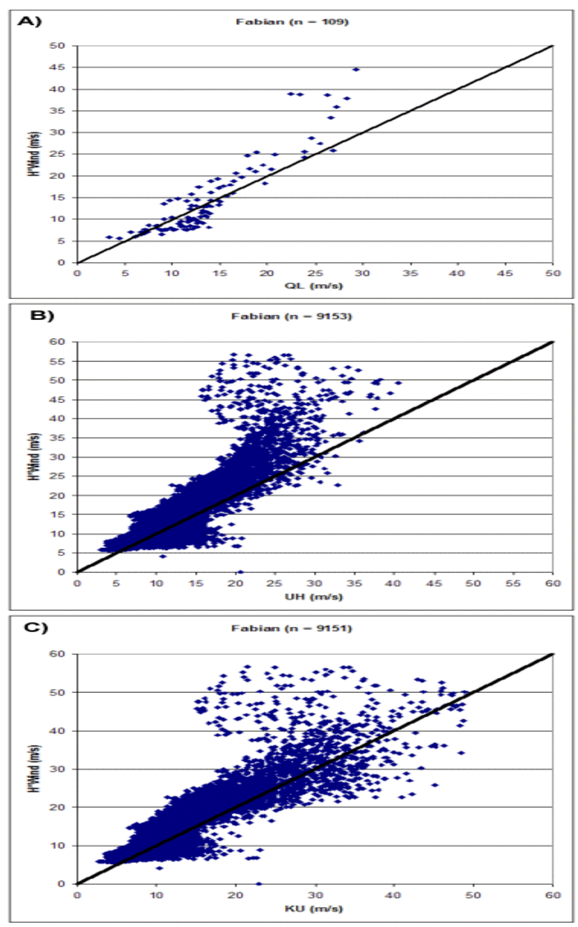

Figure 2. Fabian (2149 UTC) H*Wind vs. QuikSCAT retrievals (m/s) for a) QLOW, b) UHR, and c) UHRKU.