Q-Winds satellite hurricane wind retrievals and H*Wind comparisons

Pet Laupattarakasem and W. Linwood Jones
Central Florida Remote Sensing Laboratory
University of Central Florida
Orlando, Florida 32816-2450

Christopher C. Hennon, John R. Allard, and Amy R. Harless
University of North Carolina-Asheville,
Asheville, North Carolina

Peter G. Black
SAIC Inc. /Naval Research Laboratory,
Monterey, California

ABSTRACT

This paper presents a new hurricane ocean vector wind (OVW) product known as Q-Winds produced from the SeaWinds scatterometer active/passive measurements on QuikSCAT using a unique OVW retrieval algorithm developed for tropical cyclones. SeaWinds OVW retrievals are presented for ten hurricane passes with near-simultaneous aircraft underflights with the Stepped Frequency Microwave Radiometer (SFMR) and GPS dropsondes surface wind measurements. Independent OVW analyses are provided by the NOAA Hurricane Research Division's H*Wind analysis; and these results are compared with Q-Winds and the standard SeaWinds Project L2B wind vector products.

Corresponding author address: Pet Laupattarakasem, Central Florida Remote Sensing Lab, University of Central Florida, SEECS Box-162450,
Orlando, FL 32816-2450.
E-mail: pe_lau@yahoo.com

1. Introduction

Unfortunately, after almost three decades of research, the promise of satellite scatterometer hurricane measurements remains an illusive goal; and there remains significant challenges for both Ku-band and C-band scatterometry to meet the ocean vector winds (OVW) requirements of scientific and operational communities [1].

For Ku-band scatterometry, the most pressing issue is associated with the measurement of ocean surface winds in tropical cyclones is the presence of precipitation, which can significantly degrade the wind vector retrieval. Also, at high wind speeds (> 32 m/s) Ku-band scatterometers suffer from radar backscatter saturation effects, which limit satellite observations to maximum wind speeds < 50 m/s. Furthermore, satellite scatterometer spatial resolutions and associated OVW retrieval algorithms have been specifically developed for global synoptic-scale wind measurements, and NOT specially tailored to extreme wind events. Because of this and precipitation effects, scatterometers have failed to estimate the peak winds in tropical cyclones; and unfortunately, reliable tropical cyclone wind vector measurements are not routinely available.

This paper presents new hurricane OVW retrievals using a novel active/passive scatterometer retrieval algorithm designed specifically for extreme wind events, hereafter identified as the Central Florida Remote Sensing Laboratory (CFRSL) QuikSCAT wind retrieval (Q-Winds) algorithm. Simultaneous passive ocean brightness temperatures (Tb), derived from the SeaWinds antenna noise measurements [2], are combined with multi-azimuth radar-look ocean backscatter measurements to yield improved ocean wind vectors in tropical cyclones. Q-Winds scatterometer wind retrievals are compared with independent National Oceanic and Atmospheric Administration (NOAA) Hurricane

Research Division (HRD) H*Wind surface wind analyses [3] derived from near-simultaneous in-situ and remote sensor measurements of the hurricane surface winds from NOAA and U.S. Air Force Weather Squadron aircraft flights.

Further, results are presented for the SeaWinds Project's standard L2B 12.5km ocean vector wind product (hereafter referred to as L2B-12.5km). Comparisons with H*Wind derived fields demonstrate that the higher spatial resolution of the L2B-12.5km results in improved retrievals compared to the standard L2B (25 km) product. Results also demonstrate that the new CFRSL Q-Winds algorithm has a significant advantage over L2B-12.5km for hurricane OVW retrievals at both low-moderate (5 - 20 m/s) and high (> 30 m/s) wind speeds. Details of the Q-Winds algorithm improvements are discussed and comparisons are presented for SeaWinds overpasses of ten hurricanes (2003 – 2005) where high-quality H*Wind analyses are available.

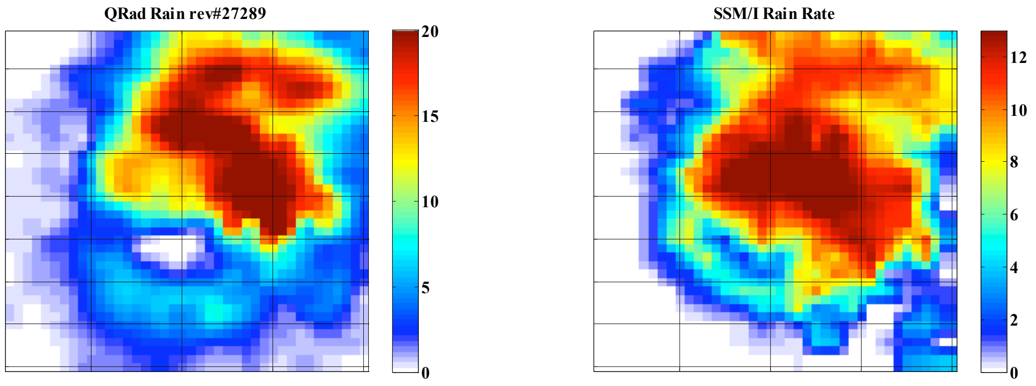
2. SeaWinds Ocean Wind Vector Products

SeaWinds on QuikSCAT retrieves global ocean vector surface winds (OVW) from the ocean radar reflectivity in 25 km resolution elements – called wind vector cell's (WVC's) over a swath of ~ 1400 km. This oceanic OVW product known as Level 2B (L2B) has been validated against buoys and numerical weather models and achieves an accuracy of ~ 1.5 m/s for wind speed and within ±15° for wind direction for the vast majority of rain-free conditions. Also, in the summer of 2006, an improved spatial resolution data product called L2B-12.5km became available. Nevertheless, these OVW products are not well-suited for hurricane conditions as both fail to capture high peak wind speeds and often miss-locate the storm eye.

Recently, the Central Florida Remote Sensing Laboratory (CFRSL) developed a special wind vector retrieval algorithm optimized for hurricane conditions, known as QuikSCAT hurricane wind vector retrieval (Q-Winds). Unlike SeaWinds L2B and L2B-12.5km, which ignore the effects of rain, Q-Winds uses the QuikSCAT radiometer (QRad) brightness temperature [3] to estimate the rain attenuation and volume backscatter. By correcting light rain corrupted ocean surface backscatter, the Q-Winds retrieves wind speeds up to ~50 m/s. Furthermore, for quality assurance purposes, QRad derived rain rate is used to flag unreliable rain contaminated pixels.

3. QuikSCAT Hurricane Results

Previously, QRad rain rates have been shown to yield useful estimates of oceanic rain in the tropics [3], but these rain estimates have not been previously validated in tropical cyclone conditions. Results presented herein address QRad rain retrievals in extreme wind conditions, and the comparisons are made with near-simultaneous rain rates from SSM/I in hurricane. An example displayed in the Fig. 1 occurred during Hurricane Ivan in 2004, where QRad (Fig. 1a) and SSM/I (Fig. 1b) overpass times are at 23:59 UTC and 23:44 UTC, respectively. QRad rain estimates are in good agreement with SSM/I rain in both rain intensity and spatial distribution, and the QRad 12.5 km pixel classification agreement for rain is 78.0%, miss-rain percentage is 9.1%, and false-rain percentage is 0.7%.

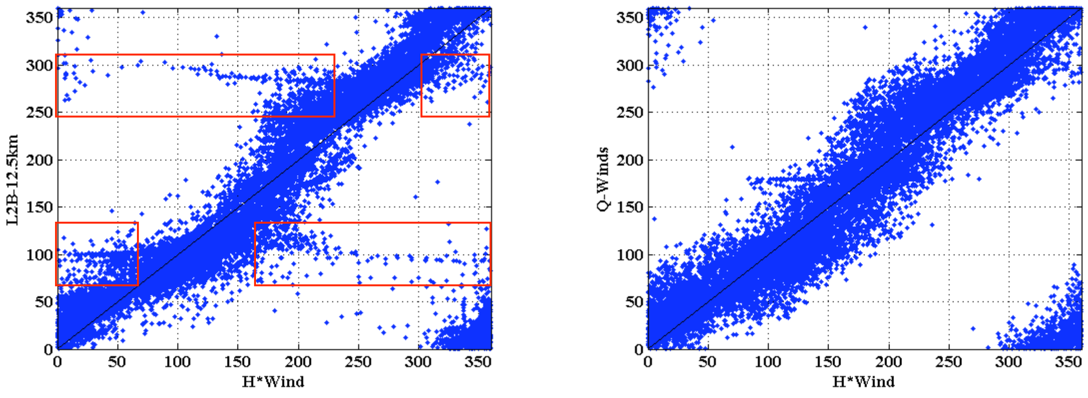


a) b)

Fig. 1. Collocated rain comparisons for hurricane Ivan in 2004. a) QRad rain rate (rev#27289 at 23:59 UTC), b) SSM/I rain rate (at 23:44 UTC). Rain image x- and y-axis are relative longitude and latitude scales, with 12.5 km grid spacing.

Rain contaminations caused errors in OVW (magnitudes and directions) measurements. Concerning wind speeds, the rain attenuation reduces the ocean backscatter and results in underestimating the true wind speeds. Furthermore, the scatterometer OVW retrievals are cross-swath wind directions in rain-contaminated pixels. This phenomenon is illustrated by comparing wind directions of ten hurricane passes (combined) to H*Wind analyzed wind directions in Fig. 2, where the left panel is L2B-12.5km wind directions and Q-Winds wind directions are on the right. Note that for the L2B-12.5km product, rain contaminated pixels are grouped within the red boxes of panel-(a); however, no such artifacts are observed in the Q-Winds OVW retrievals.

Hence, rain flags are crucial to eliminate the contaminated pixels; and the rain flag used in this paper is empirically derived from this QRad rain rate, which optimizes the agreement with H*Wind. Unfortunately, due to the QRad rain measurement limitations, the rain threshold is reliable up to only 7 mm/hr.

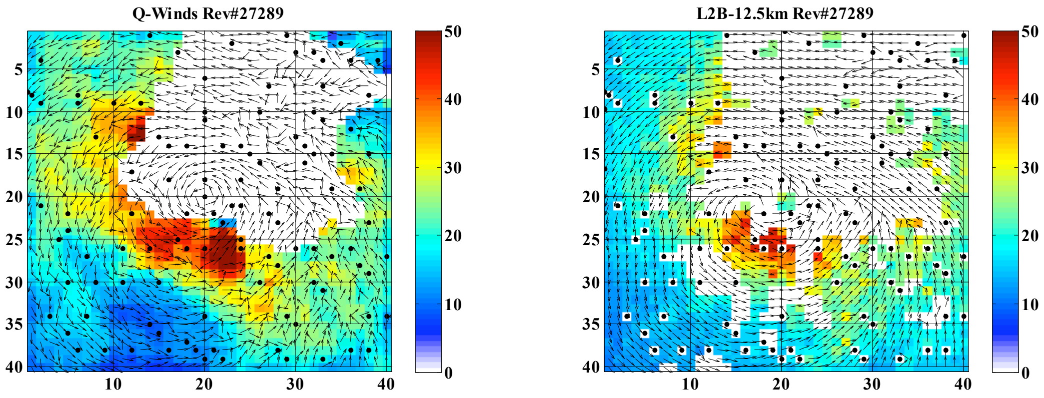


a) b)

FIG. 2. Wind direction scatter plots in rain condition. a) L2B-12.5km, b) Q-Winds

Based upon H*Wind comparisons, the L2B-12.5km RMS wind direction errors are 30.5° before applying the rain flags and 25.5° after flagging. The corresponding Q-Winds RMS wind direction errors are 29.0° and 27.3° (before and after apply rain flags). Although these statistics do not change significantly, rain flagging does generally eliminate unreliable pixels (wind vectors) in the intense rain bands (eye wall region) where wind speeds are high.

An example in Fig. 3 displays a typical hurricane pass obtained from Q-Winds (left) and L2B-12.5km (right) with their respective rain flags applied (shown in white area). Overall Q-Winds is able to correct for low-to-moderate rain rates and therefore flags less wind vector cells.



a) b)

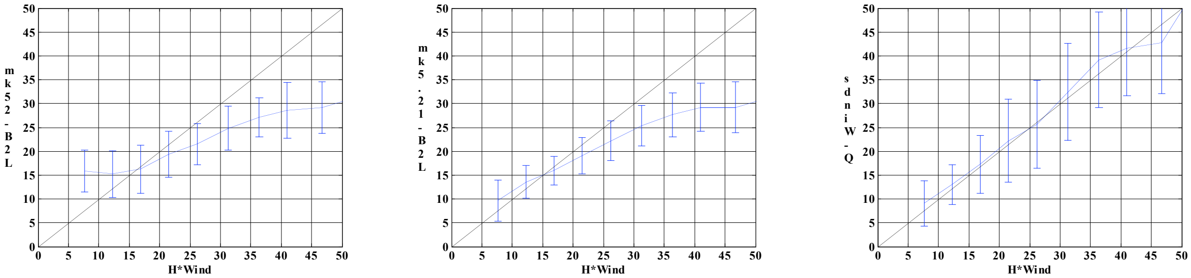
FIG. 3. Wind vectors retrieval for Hurricane Fabian on September 2nd 2003. a) Q-Winds with QRad rain flags, b) JPL L2B-12.5km wind product with MUDH flags.

To evaluate the OVW algorithm performance, Q-Winds and the standard SeaWinds data products (L2B and L2B-12.5km) are compared with the independent H*Wind wind speeds in Fig. 4. In this comparison for ten hurricane passes, bogus OVW retrievals have been eliminated by applying rain flags for L2B (far left), L2B-12.5km (middle), and Q-Winds (far right) respectively. In general, Q-Winds is in excellent agreement with H*Wind for all wind speeds up to the max retrieval limit of 50 m/s. On the other hand, both L2B and L2B-12.5km retrieve significantly lower wind speeds than H*Wind beyond wind speed 20 m/s.

Table 1 summarizes the comparison statistics for all wind vector cells without applying the rain flags. Unfortunately, as a consequence of quality control flagging rain contaminated pixels, most of the desirable high wind speeds are also eliminated; but this is the nature of scatterometer OVW retrievals in the presence of strong rain.

TABLE 1. Wind speeds statistics without rain flags

	L2B		L2B-12km		Q-Winds	
Wind speed (m s^{-1})	Mean (m s^{-1})	STD (m s^{-1})	Mean (m s^{-1})	STD (m s^{-1})	Mean (m s^{-1})	STD (m s^{-1})
< 20 m/s	0.17	5.34	0.57	3.61	0.47	5.75
> 20 m/s	6.23	7.63	5.67	7.44	2.47	12.01



a) b) c)

FIG. 4. Wind speed comparisons with H*Wind surface wind speeds (rain flags applied): Panel a) L2B (25km), Panel b) L2B-12.5km, and panel c) Q-Winds.

4. Conclusion

This paper presents comparisons of Q-Winds hurricane ocean vector wind (OVW) retrievals and the SeaWinds Scatterometer Project's L2B-12.5km OVW product to HRD H*Wind surface analysis for ten hurricane overpasses during 2003-2005. As for hurricane wind vector "surface truth", H*Wind is the best that is currently available. Results show that Q-Winds is superior to the JPL L2B-12.5km wind vector product as compared to H*Wind under hurricane conditions. The L2B-12.5km does not produce wind speeds > 30 m/s, while Q-Winds compares well with H*Wind for wind speed up to ~ 45 m/s (equivalent to hurricane category two) after a quality control excessive rain flag is applied. Concerning wind directions, Q-Winds also compares better to H*Wind than does the L2B-12.5km OVW product, especially in the presence of rain.

6. Acknowledgments

This research was sponsored under a grant with NASA Headquarters for ROSES earth sciences investigations for the Ocean Vector Winds science team.

References

[1] NOAA Operational Satellite Surface Vector Winds Requirements Workshop, Tropical Prediction Center, Miami, 2006, http//manati.orbit.nesdis.noaa.gov/SVW_nextgen/SVW_workshop_report_final.pdf.

[2] A. K. Ahmad, W. L. Jones, T. Kasparis, S. Vergara, I. S. Adams, and J. D. Park, "Oceanic rain rate estimates from the QuikSCAT Radiometer: A global precipitation mission pathfinder," *J. Geophys. Res.*, vol. 110, 2005.

[3] M. D. Powell, S. H. Houston, L. R. Amat, and N. Morisseau-Leroy, "The HRD real-time hurricane wind analysis system," *J. Wind Eng. Indust. Aerodynam.*, vol. 77 & 78, pp. 53-64, 1998.