JP 4.9 RESULTS OF QUIKSCAT HIGH WIND DATA VALIDATION

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ABSTRACT

Traditional validation of satellite-derived winds includes comparison with *insitu* data collected by instruments located on buoy platforms or ship masts. These comparisons, though not perfect due to the spatial/temporal mismatch between the observations, are useful for most of the typical wind conditions found over the oceans. Validation of satellite high wind speeds is more difficult as buoy and ship data are frequently not available or are not always accurate under such intense weather conditions. The Ku-2001 geophysical model function used to derive 10-meter surface wind speeds and directions from the SeaWinds (on QuikSCAT) scatterometer observations delivers wind speeds between 0 and 70 m/s. Here, we present validation results from several case studies used to determine the accuracy of retrieved winds greater than 20 m/s. These studies show winds above 20 m/s are 5–10 m/s too high. We also introduce results from an improved model function, Ku-2003. The QuikSCAT data will be entirely reprocessed with this new model function and re-released later this year.

1. INTRODUCTION

For this analysis we define “high winds” as data with wind speeds greater than 20 m/s. Global measurements of such wind speeds over the ocean are limited and instrument capability is often questioned given the state of the sea under such conditions. An assessment of the rate of occurrence and the location of high winds is shown in Figures 1 and 2. We recently processed over 17500 orbits of QuikSCAT ocean vector rain-free winds and found that for over 70% of the orbits high winds made up less than 1% of the valid ocean data within the orbit (Figure 1). On rare occasions, the high wind percentage increased to as high as 14% of orbit data. The majority of these high winds occur in mid-latitude winter storms, tropical cyclones or specific gap flow events, such as the winds over the Gulf of Tehuantepec, Mexico. The earth locations with the most frequent high wind data exist in higher latitude open-oceans where little standard validation data exist.

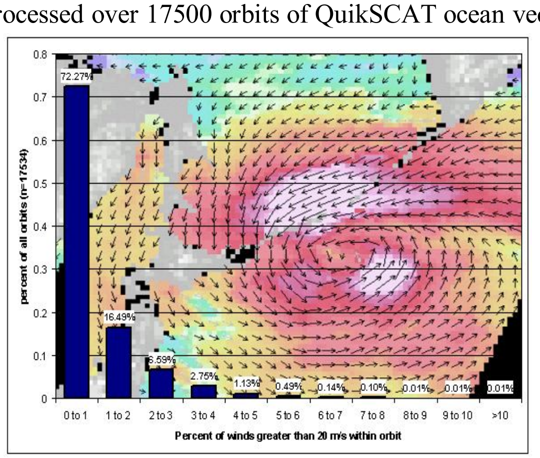

Figure 1. Summary of the percentage of winds greater than 20 m/s within a given QuikSCAT orbit.

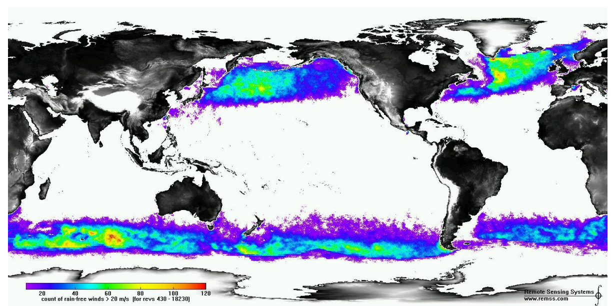

Figure 2. Count of winds greater than 20 m/s for each 0.25-degree grid cell calculated from 17500 orbits (approximately 3.5 years).

The Ku-2001 model function developed by Remote Sensing Systems (RSS) is capable of deriving winds up to 70 m/s (Wentz, 2001). Previous scatterometer model functions only provided winds between 0 and 37 m/s, as it was believed there was no signal at higher winds. We found, however, that the horizontally polarized signal returns continue to respond. Immediately these higher winds were found useful by meteorologists, especially those forecasting hurricane and typhoon intensity. However, validation of these new higher winds proved difficult as few buoy winds coincided, buoy winds failed to reach such high wind speed, and ships were steered from the danger. Air reconnaissance, a proven method of wind speed estimation is used only in Atlantic hurricanes limiting the amount of data available for validation.

The Ku-2001 model function relates wind speed to normalized radar cross-section and was derived using a limited number of high wind data. Validation studies of QuikSCAT winds below 20 m/s have been performed by many and are well-documented showing rms accuracies of less than 1.5 m/s and 18 degrees (Wentz et al., 2003; Bourassa et al., 2002, and others). Above

20 m/s however, too few reliable data exist for accurate comparison. For this reason, we turned to studying individual storm events using whatever supporting data could be found as a means of determining the quality of the QuikSCAT high winds. We have now studied over 1000 tropical cyclones and 20 mid-latitude storms. Several of these case studies are presented here along with recent buoy validation results.

2. METHODOLOGY

Traditional wind validation involves comparison with insitu observations; however, this process requires long periods of time to amass a statistically large high wind comparison data set. In 3.5 years of QuikSCAT operation we are now able to make such comparisons (see section on Buoy Validation). Our case studies often include whatever associated data can be located and include buoy, ship, and land-based station data. We also compare winds with mesoscale model output, data from air recon flights and dropsondes, and Dvorak method estimates. Buoys and ships represent the insitu observations most often used by researchers in validating ocean vector winds despite the differences in measurements made by satellites (instantaneous spatial averages) with buoys and ships (time averaged spot measurements). For better comparison, we correct all alternative wind data to a 10-meter neutral stability wind using a simple logarithmic algorithm if the instrumentation height is known. The differences that exist between the data sets due to spatial and temporal incongruities of wind measurement are handled by using a correction factor. Previous comparisons have shown satellite-derived winds to be comparable to 8 to 10 minute averages of winds; this is related to the speed of passing storm. A typical storm traveling at 30 m/s will move approximately 18 km in a 10 minute time period. The wind retrieval resolution of QuikScat is a grid cell of 25 km square, but individual sigma-0 antenna footprint ellipses are approximately 25 km by 37 km (QuikSCAT User's Manual, 2001). Tropical cyclone winds are often reported as 1-minute maximum sustained winds. The correction factors used by the U.S. Navy, 1-minute mean = 1.14* 10-minute mean, are used in this study.

All comparisons are performed under rain-free conditions as rain affects Ku-band microwaves (Mears, 2000). We use our scatterometer stand-alone rain flag and available collocated radiometer data to remove rain contaminated data from comparison. In the case studies shown at the far right, rain flagged data are marked with a gray circle at the wind barb or wind vector base. The stand-alone scatterometer rain flag is a goodness-of-fit tool that describes how well the data agree with the geophysical model. In addition, we flag data as rain when the derived wind direction is within +/- 15 degree of cross-track (or perpendicular to satellite motion) and at least 5 of 8 surrounding cells have sum-of-squares values greater than 1.9. This combination works to eliminate the most grossly affected winds, those below 12 m/s. For the higher wind speeds, it under-flags the data as the fit to the model function is better.

3. BUOY VALIDATION

Comparisons between Ku-2001 and buoy winds have been routinely performed since instrument launch. To do this, RSS maintains a consistently processed open ocean buoy database of NDBC (coastal US), TAO/TRITON (tropical Pacific), PIRATA (tropical Atlantic) and MEDS (coastal Canada) wind observations going back to 1989. Both tropical data sets are downloaded from NOAA Pacific Marine Environmental Lab, the NDBC data are obtained by ftp from NOAA National Buoy Data Center, and the MEDS data are obtained from the Marine Environmental Data Service, Dept. of Fisheries, Canada. In this 15-year database consisting of over 9 million observations, only 466 are greater than 25 m/s. High wind observations by buoys are few and mostly occur in tropical cyclones, the most typical high wind event to occur in tropical and sub-tropical locations where the majority of buoys are located. The recent addition of the MEDS data to the database has increased the number of high winds observed in northern Pacific and Atlantic mid-latitude cyclones. Scatter plots of buoy and QuikSCAT winds speeds, shown in Figure 3 contain these higher Canadian buoy winds and from them we can now conclude that the Ku-2001 data are too high relative to the buoys. The lower wind speeds derived with Ku-2003 are an improvement.

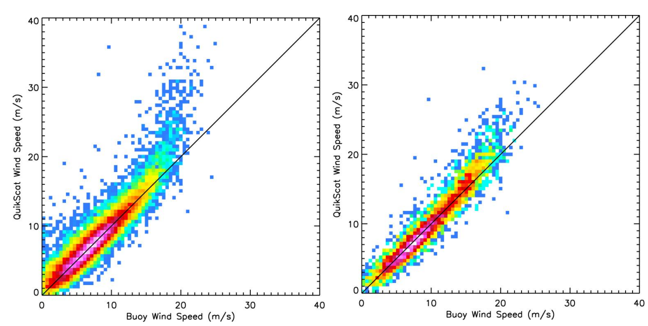

Figure 3. Comparison of buoy wind speeds with QuikSCAT Ku-2001 (left) and Ku-2003 (right) winds.

4. SELECTED CASE STUDIES

Specific examples of mid-latitude storms, tropical cyclones and high wind events are used for better understanding the QuikSCAT performance. We find any available supporting data such as buoy, ship, land station data or mesoscale model output for use in our analysis. In each case, the Ku-2001 winds are always shown on the top, with the new Ku-2003 model function winds on the bottom.

4a. Overturned Buoy (Figure 4)

On Feb 8th 2001, a strong winter storm in the Bering Sea produced wave heights greater than 14 meters causing a 12-meter Discus NDBC buoy to capsize (Gilhousen, 2002). The buoy at 56.9 N and 177.8 W measured winds exceeding 20 m/s for 22 hours prior to the last report at 18Z. The highest 10 meter / 10-minute average wind, 27.2 m/s, was reported at 11Z. Comparison with QuikSCAT overflights at 0730 and 1720 Z show Ku-2001 winds to be approximately 10 to 12 m/s higher than the time interpolated buoy winds. The large wave heights suggest the buoy may indeed measure lower than the actual 10 m winds due to sheltering in wave troughs. The Ku-2003 winds show better agreement with the buoy observations.

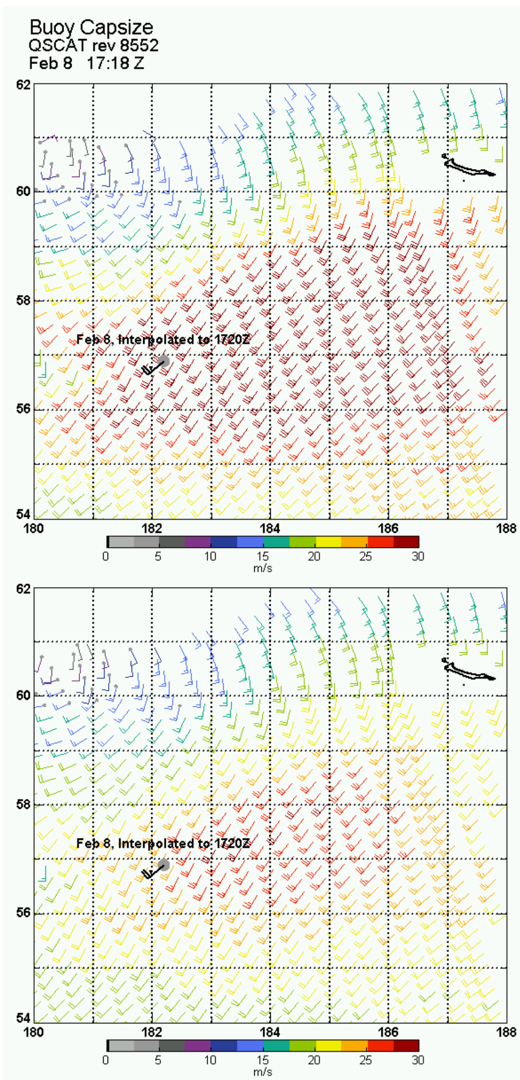

Figure 4. Ku-2001 and Ku-2003 winds for winter storm in Bering Sea.

4b. Bavi

Typhoon Bavi (2002) became extratropical prior to the QuikSCAT overpass on October 14th 18Z. This very large tropical cyclone had winds exceeding 30 kts over a region greater than 350 km in diameter. A cable-laying vessel, the Tyco Responder, was unable to move swiftly out of harms way and was passed by the storm to the North from 10/14/02 18Z to 10/15/02 06Z. QuikSCAT captured the storm at 18Z and 06 Z. At 04Z on Oct 15th, the captain of the vessel was contacted and reported 76 kt winds in 15 m seas. The method of measurement is unknown. The storm-relative positions of the vessel during the storm are shown in both figures. In this example, Ku-2001 is approximately 15 m/s overestimated. A thorough inspection of the tropical cyclone archive maintained at RSS shows the Ku-2001 model function to overestimate most extratropical storms in the Atlantic and Pacific, especially storms of larger size such as Podul (2001) and Michelle (2001). This seems to be a problem with

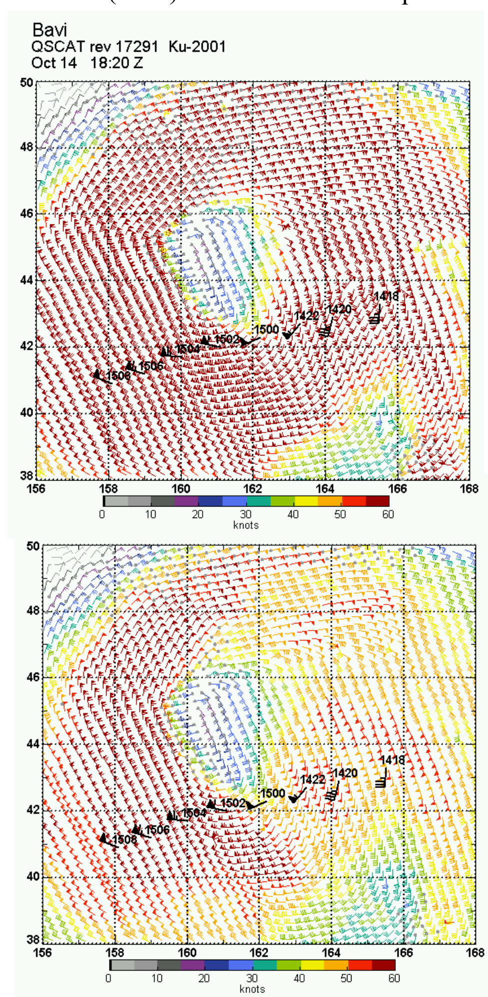

Figure 5. Ku-2001 and Ku-2003 winds for Typhoon Bavi in the Northwest Pacific. Storm-relative ship positions and times are shown.

the Ku-2001 model function, as the new Ku-2003 does not show the same behavior.

4c. French Storm

In December 1999 a series of fierce winter storms blew into the Bay of Biscay on December 27th, 1999. Damage occurred throughout many European countries but was worst in France within the vicinity of Paris. No moored buoy or ship data were available for comparison, however, coastal automated land station data were obtained from Meteo France. The Ku-2001 QuikScat winds from orbit 2724 are plotted in Figure 6 with the location and maximum gust (corrected to 10-min) recorded at each of the land stations. Direct comparison of these data are complicated as the stations are over 25 km from the nearest QuikScat wind vector cell, the frictional forces increase on land, wind heights vary by station with some anemometers as high as 60 meters (actual values for instrumentation at each station is unknown, only altitude of the station is available), these winds are gust measurements (max wind observed for the day with associated time of observation) corrected to a 10-min average, and the time difference between the station data and QuikScat overpass are between 15 minutes and 4 hours as some stations failed prior to the 1900 Z QuikScat overpass. What is apparent in Figure 1 is a North-South wind speed gradient visible in both the QuikScat and station data. Collocated radiometer (SSM/I) data show little rain present at the time of QuikScat observation.

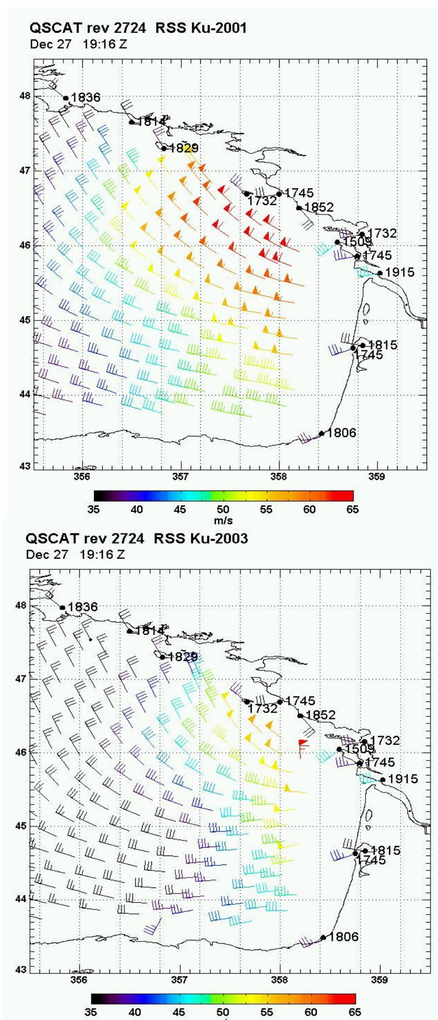

Figure 6. Ku-2001 and Ku-2003 winds for winter storm in Bay of Biscay, December 1999.

4d. Gulf of Tehuantepec

A 40 km wide gap in the Sierra Madre range enhance air flow from the Gulf of Mexico into the Gulf of Tehuantepec in the cool season (October thru April) when a high pressure center is located over the Eastern US and the Gulf of Mexico. A single event can last for days and has been documented to produce winds exceeding 40 knots (Cobb et al, Poster JP4.1 this meeting, Schultz et al. 1997 and references therein). Due to limited and inaccessible verification data for these events it is difficult to validate the QuikSCAT winds. This image of gap flow from Oct 29th, 2002 shows the wind speeds of this high wind feature. A buoy located at 12N, 95W is on the edge of the gap flow and agrees with the lower winds found there (Figure 7).

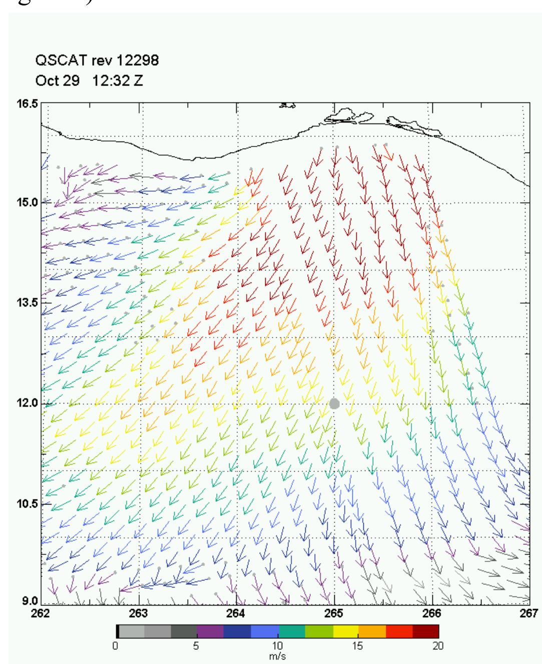

Figure 7. Gap flow in the Gulf of Tehuantepec, Mexico. The nearest buoy is located at 12N, 95W outside of the zone of maximum winds.

5. VALIDATION FINDINGS

From over 1000 tropical cyclones and comparison of buoy and ship observations in over 20 mid-latitude storms we have determined that Ku-2001 winds (greater than 20 m/s) are too high under rain-free conditions by approximately 5-10 m/s. In addition, Ku-2001 wind directions show a greater tendency of cross-track vectors in high-rain regions than the previous model function (Ku-2000) discontinued in August 2001.

6. KU-2003 MODEL FUNCTION

We are in the final stages of development of a refined model function that produces lower wind speeds within the high wind range and fewer cross-track vectors in heavy rain. The QuikSCAT to buoy wind speed comparison, shown in Figure 3 for both the Ku-2001 and Ku-2003 model functions, shows the comparison at speeds greater than 17 m/s has improved. In a specific example, a storm in the northern Atlantic is shown in Figure 8. In addition, each of the case studies presented above have better agreement with supporting data for the Ku-2003 model function. This does not mean, however, that all case studies have improved.

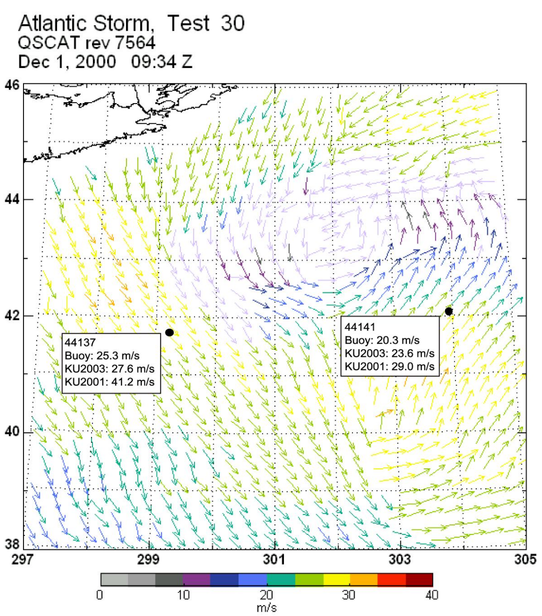

Figure 8. Winter storm in northern Atlantic Ocean.

We are also investigating new methods of ambiguity selection, including a simulated annealing process in the vicinity of tropical cyclones where ambiguity selection is often complicated by mislocation of the storm center. Simulated annealing is a statistical method used for searching for a global optimum in the presence of many local optima. We employ a cost function that depends on the ambiguity's sum-of-squares value, it's agreement with its neighbors and with the background field. Unfortunately, not all cases are improved and the current processing time is still too great for implementation on a global scale.

When modifications to Ku-2003 are complete and validation efforts show we have an improved product, we will reprocess the entire QuikSCAT and NSCAT data set. These winds will be available by Summer 2003 on the RSS web site (www.remss.com).

4. ACKNOWLEDGEMENT

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