P1.97 Life after QuikSCAT...Tropical Cyclone Analysis using Microwave Imagery and Data

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1. INTRODUCTION

This paper provides a brief review of available microwave imagery and data that are currently being used for near real-time tropical cyclone (TC) analysis now that the QuikSCAT instrument is gone. Until this past November 2009, estimated winds (and imagery) from the QuikSCAT instrument have been one of the mainstays for tropical ocean surface analysis, especially for the TC forecaster. For the past 10 years, ocean surface vector winds from QuikSCAT have provided wind speed and direction over more than 90% of the tropical oceans in a 24 hour period. Since its loss, TC forecasters have had to rely more on the remaining scatterometer instruments such as ASCAT (ESA), WindSAT (US Navy) and the venerable ERS-2 (ESA) even though these data provide less near real-time coverage with more limited speed and directional capabilities. Of course, the passive microwave data remains, including the extremely valuable 85 and 37GHz imagery from the TRMM, AMSR-E, SSMIS and WindSAT (37 GHz only) sensors. As was shown in an earlier presentation (Edson, 2002), an integrated approach to evaluating these less frequent satellite-based microwave sensors was required, even with the QuikSCAT data, in order to maximize the inherently infrequent nature of these polar-orbiting sensors; especially with their vulnerability to heavy rain, tight TC gradients, and to both light and very high wind speeds. Now, with the loss of the QuikSCAT instrument, these techniques are even more necessary. A background of the data available and examples of some of these integrated techniques follows.

2. COMPARISON BETWEEN QUIKSCAT AND OTHER OCEAN SURFACE VECTOR WIND SENSORS.

Previous studies (Edson, 2002) have shown that the QuikSCAT data is most successfully used for evaluating TCs, by looking at the three types of QuikSCAT data shown in Fig 1: Winds, Ambiguities and the Normalized Radar Cross-Section (NRCS) products. Here, especially for the more difficult cases, QuikSCAT could be used to a higher degree of certainty to find a TC center position, an outer wind structure, a 'minimum' (at least) value of maximum intensity, and a degree of knowledge of how and when genesis is taking place. These methods, especially when used with the other microwave data, have all shown significant advantages over the use of the more conventional satellite-based (IR and VIS) data.

Characteristics of the data coverage and other important parameters are shown in Table 1 between QuikSCAT and the other ocean surface vector wind sensors. The

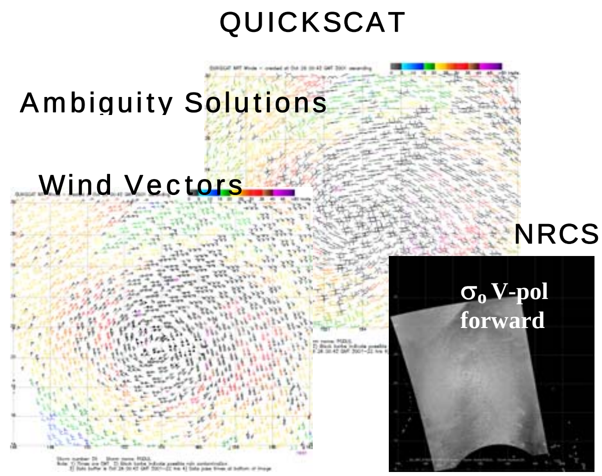

Fig 1. The three types of QuikSCAT scatterometer data used to evaluate tropical include wind vector data, ambiguities, and a normalized radar cross-section product.

Sensor/Sat	QuikSCAT	ASCAT	WindSAT	ERS2
TYPE	Active	Active	Passive	Active
AGENCY	JPL	ESA	US Navy	ESA
LAUNCH/END	Jun 99/Nov09	Jun-06	Jan -03	Apr-95
SWATH (KM)	1800	2 X 550	~1100	500
GAP (KM)	0	600	N/A	N/A
RESOLUTION (KM)	25 (12.5)	50 (25)	25	50 (25)
SPEED (KT)	4-80	5-60	10-40	6-50
FREQ (GHz)	13.4 (Ku-Band)	5.6(C-Band)	6.8	5.3(C-Band)
COVERAGE (90%)	1 Day	~2 Days	~2 Days	~4 Days
ASND NODE (LST)	0600	2200	1800	2200

Table1. Ocean surface wind sensors in orbit.

loss of the extensive daily coverage over the tropics is noted as is the range and resolution of the data. On the other hand, it has been shown that the use of C-Band frequencies (for the **active** sensor) provides a less

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sensitive signal through the atmosphere in moderate to heavy rain situations. This is NOT the case for the **passive** microwave sensor (e.g. WindSAT and SSMI) which is extremely vulnerable to signal interference in even light rain situations (Fig 2).

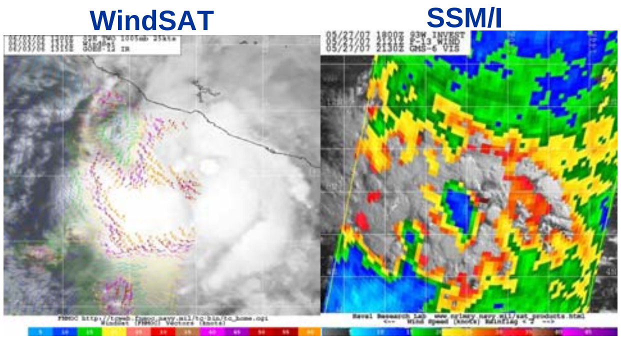

Fig. 2. Coverage of passive microwave data over a tropical cyclone is extremely sensitive to rain. Note even where the data are plotted, artificially high wind speeds are often noted and most be recognized.

One way of increasing the coverage of the wind data is shown in Fig. 3 where the double swath of the ASCAT data follows 4 hours after and slightly west of the most recent WindSAT pass.

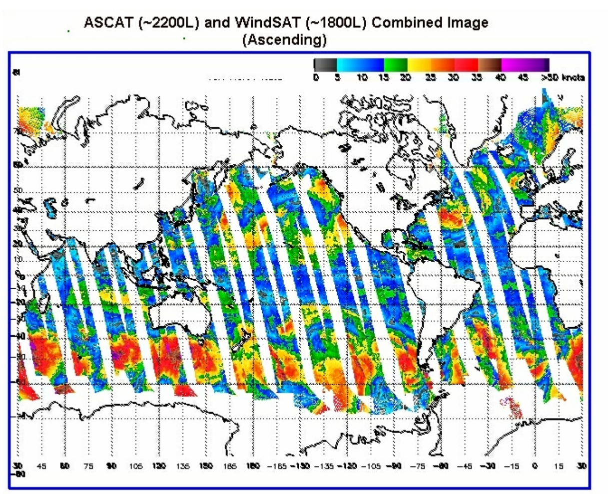

Fig. 3. Coverage of the combined microwave ASCAT and WindSAT sensor provides at least a preliminary view of the large scale wind field. Once an area is noted for further investigation, the data should be analyzed separately, where they overlap, due to their large difference in rain sensitivity.

As noted above, the range of wind speeds is more limited with the remaining sensors. Where there is a systematic bias, this can be somewhat corrected. See Fig. 4 for a comparison between ASCAT and QuikSCAT and Fig. 5 between WindSAT and QuikSCAT (both cases are for a rain-free environment).

Figure 6 shows a recent ASCAT pass over a tropical cyclone just off the northwest coast of Australia. Here the cyclonic wind field and structure is well depicted in the ASCAT data. However, the lower resolution and the character of the two-way, 180 degree opposite ambiguity solutions limit the precision of determining a center position. Once the winds intensify, ASCAT winds begin to

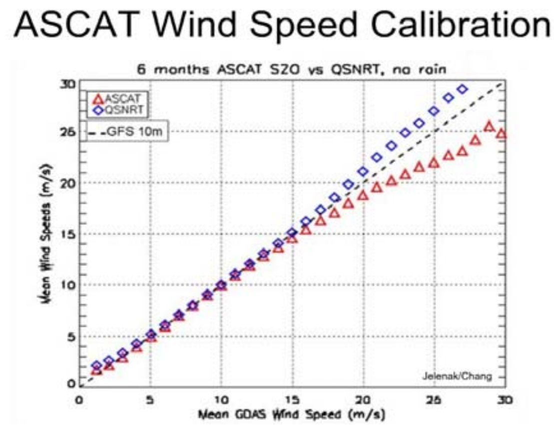

Fig. 4 Comparison between winds speeds for ASCAT and QuikSCAT shows the low bias of the ASCAT winds above 12 m/s. Other studies (not shown) indicate the both sensors show a low bias in winds much above 25 m/s, especially in moderate to heavy rain.

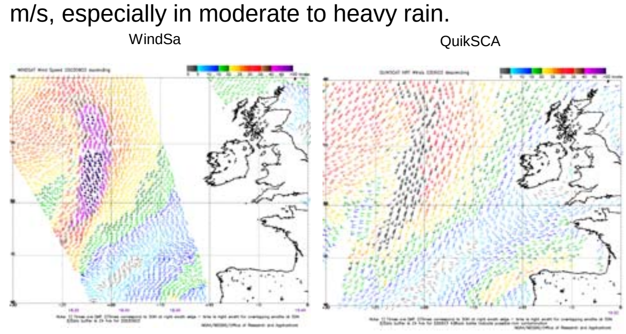

Fig 5. Comparison between WindSAT and QuikSCAT winds in light to moderate rain, demonstrates the sensitivity of the passive sensor to rain (from Briefing Slides by Peter Geiser, 2004, NRL)

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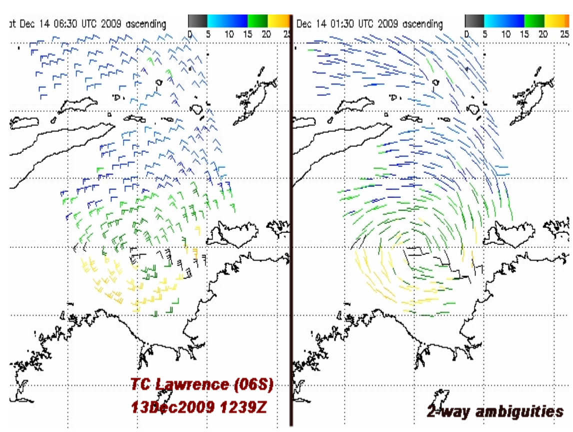
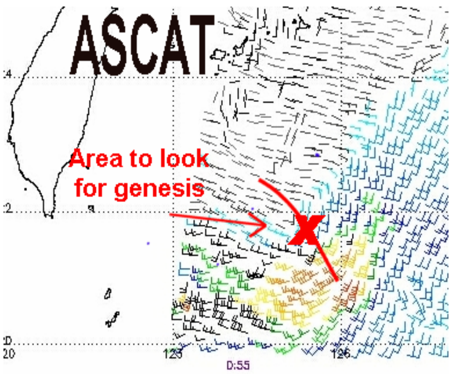


Fig 6. ASCAT winds and ambiguities in the vicinity of TC Lawrence, 13 December 2009.

saturate even quicker than they do for QuikSCAT (this is partially due to the character of the wind retrieval model, but also due to the character of the higher frequency data (Ku- versus C-band) for QuikSCAT.

3. EXAMPLES OF TC ANALYSIS USING MICROWAVE DATA (WITHOUT QUIKSCAT).

Although the precision of determining a circulation center in the ASCAT data is not as easy as with QuikSCAT, some of the same principles developed with QuikSCAT can be used with ASCAT, as well. One scenario that often occurred with QuikSCAT (and occurs quite often with ASCAT) is the lack of finding a closed circulation in the wind solution during the early stages of TC development…when it is believed one exists. With QuikSCAT an analysis of either the ambiguity field or by looking at the NRCS product might reveal the answer. However if not, surface circulation centers were often found in the **light winds** along the trough axis but up against the **strongest wind gradient and curvature (vorticity)**.This is also possible to do with ASCAT(Fig. 7).



. **Fig. 7** Location of a potential surface center during TC development as seen in the ASCAT wind field.

The figure below, Fig 8, demonstrates the integration of the ASCAT wind field with the MI 85 and 37 GHz imagery to help determine a more precise center position and an outer wind structure. Knowledge of the location of the rain field also helps with this interpretation in order to determine where possibly the winds may be interpreted too low (or too high in some cases).

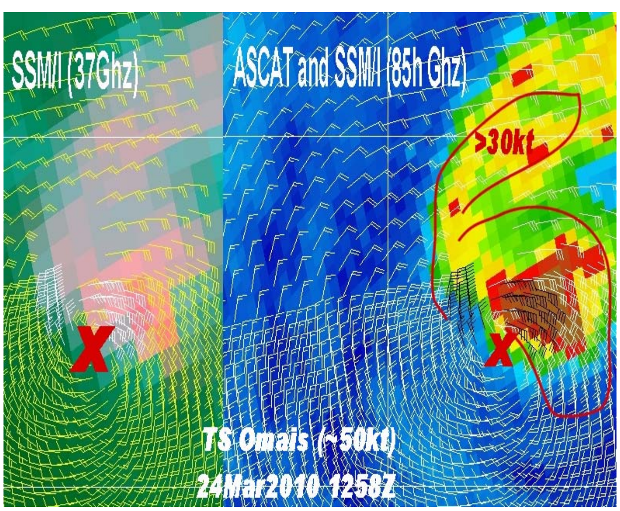


Fig 8. Analysis of TS Omais through an integration of the SSMI imagery with the ASCAT wind data.

4. FUTURE SCATTEROMETERS AND CAPABILITIES

The ESA ASCAT scatterometer will hopefully not be left alone for too long as future instruments, with new capabilities, are still being planned. In the near future, the Chinese Scatterometer and the OceanSAT scatterometer from India are almost ready for near real-time use. These data, with slightly different designs from the current group, will have to be examined for a period of time before being incorporated into some of the integrated schemes shown in this paper. The ESA is also planning future versions of the ASCAT instrument. Later, newer technology, based on the lessons-learned from QuikSCAT, should be (finance permitting) available under such joint NASA and JAXA programs as the Dual Frequency Scatterometer (DFS) and the Extended Ocean Vector Wind Mission (XOVWM) scatterometer.

An Operational Satellite Ocean Surface Vector Wind Team made up of NOAA, DOD and University users of scatterometer data have put together a list (Jelenak and Chang, 2008) of needs and capabilities of any new operational scatterometer instrument that is contemplated (guided by the needs of the TC forecaster). This list includes:

- The Ability to detect Higher Wind Speeds
- To have Higher Resolution with less 'gaps'
- To be Less Sensitive to Rain (or be able to detect when rainfall is affecting the measurements)
- To have shorter 'refresh' time (minimum 4X/Day)
- To have an Automated Capability to determine the correct Ambiguity Solutions (especially in regards To developing TC circulation centers in the tropics)

5. CONCLUSIONS.

Although the QuikSCAT scatterometer is gone, the use of the combined, existing ocean surface vector wind sensors, ASCAT, WindSAT, and the ERS2 integrated with the 85 and 37GHz microwave imagery (plus conventional data), remains the most effective way to take advantage of all satellite-based technology while still maintaining the necessary vigilance required of the Tropical Cyclone Forecaster**.**

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6. REFERENCES

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