Validation of SeaWinds on QuikSCAT Cell Location

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***Abstract*- Increased interest in high resolution ocean wind measurements, as well as excellent past performance, has led to the development of enhanced resolution applications of SeaWinds on QuikSCAT scatterometer data. An essential requirement of this development is the validation of the cell location accuracy - the latitude and longitude of each measurement. This paper discusses two methods of validating measurement location accuracy. One method entails analysis of normalized backscatter coefficients over specific land / ocean boundaries. This method has proven accurate for nominal resolution; it is refined for increasing resolution. Another technique employs the QuikSCAT Calibration Ground Station (CGS). Telemetry-reported cell location is compared to the known location of the CGS. Calibration of measurement location using these techniques reveals the limits of SeaWinds pointing accuracy and precision.**

I. Introduction

SINCE its launch in June of 1999, SeaWinds on QuikSCAT has successfully and accurately measured marine winds. Since that time enhanced resolution imaging and other applications have sought to take advantage of its favorable geometry and resolution. Though SeaWinds' performance has met, and in most cases exceeded, its design specifications, the reliability of the advanced applications are heavily dependent upon improved validation of the data's accuracy beyond specification. For this reason, it becomes increasingly necessary to define the performance of SeaWinds in increasingly accurate terms.

As intuition would suggest, in order to obtain accurate measurements from a satellite, the location of the observation must be accurately known. If the ground location of a measurement is in error, the observed value can not be properly related to ground topography or other measurements. For nominal QuikSCAT egg resolutions of 25 km by 25 km, satellite calculation errors have to be severe in order to significantly mislocate measurements: a 25 km error corresponds to a 1.15° attitude error or a 3.5 second time error.

The majority of QuikSCAT applications use colocated σ° measurements, underscoring the necessity of having accurate calculations of ground location. Current advanced data applications, such as enhanced resolution imaging, are attempting to improve the resolution of QuikSCAT, requiring the evaluation of location variance. To accomplish this goal the accuracy of the location of each measurement must be calibrated to levels that exceed the design specification value.

This paper focuses on two methods of evaluating the accuracy of cell location. The first method entails the use of normalized backscatter coefficients, (σ°), over specific land / ocean boundaries. The second method incorporates data recorded by the QuikSCAT Calibration Ground Station (CGS) to better determine the accuracy of the measurements. After presenting the findings of these two methods, we summarize the results and conclude.

II. Land / Ocean Boundaries

Boundaries between land and ocean provide an effective method for determining the accuracy of cell location because of their large contrast in σ° value, ranging up to 30 dB or more. Large location errors would give rise to spurious islands and lakes in σ° images.

One method of determining cell location is to compare enhanced resolution σ° images derived from the SeaWinds data to a map and analyze the coast line. This method is appropriate for large scale location misalignment, though this method is limited to errors of more than of a few kilometers. Another approach recognizes that QuikSCAT obtains four independent measurements for a given ground location, using both outer and inner beam, as they approach and as they recede. Utilizing this geometry, comparisons between approaching and receding measurements can be made to evaluate geometry-based location errors. Additionally, and typically more profitably, comparisons between measurement combinations of individual beams, azimuth angles, and orbit types can be made. Employment of this method is beneficial because it enables evaluation over the changing orbit geometry.

These types of analyses are performed over several selected sites. For this paper an area covering southern Florida, the Bahamas and a section of Cuba is selected to illustrate the results. Images are generated using a combination of 28 days of QuikSCAT L1B data from JD 001-028, 2000, and have been enhanced using the Scatterometer Image Reconstruction (SIR) algorithm. The use of multiple days of data emphasizes the long term stability of the instrument. Images using only 2 or 3 days of data typically show similar, albeit noisier, results.

Fig. 1 shows a SIR enhanced image of the area of interest. The coastline has been superimposed on the image for reference. Overall the image is consistent with the coastline. However, some discrepancies are noted such as Andros Island, the largest island in the Bahamas, where the image seems to be blurred, especially on the west side. This blurring is primarily due to the along scan spatial response function. Each pixel in the images is approximately 2.25 km x 2.25 km, yet the slice resolution of SeaWinds is 6 km x 25 km. However, the blurring on the island is expected to be uniform around the island. This asymmetrical blurring suggests a small azimuthal location error in the SeaWinds mea-

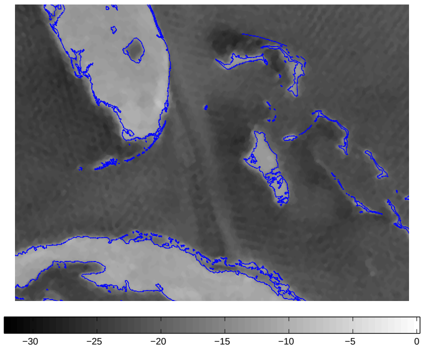

Fig. 1. SIR-enhanced σ° image of southern Florida, the Bahamas and Cuba, ascending orbits only, V-pol. Superimposed coast line added.

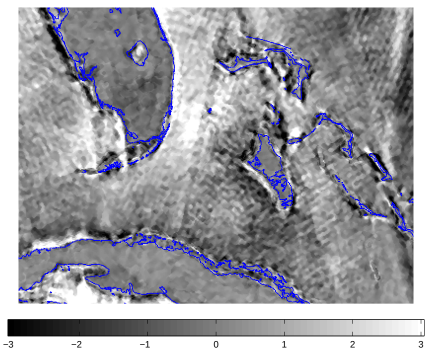

Fig. 2. SIR enhanced image of an descending pass subtracted from an ascending pass; H-pol.

surements, though it may be an unexpected artifact of the image processing.

To further evaluate the features of the data, a more detailed analysis entails examination of the difference between an ascending pass and a descending pass. Fig. 2 shows a σ° image of the difference between the two passes, again with the coast line superimposed on the image. This image does not contain the blurring of Andros Island. However, a close look at the Florida peninsula shows a black stripe on the west side, and a white stripe on the east side, suggesting a slight azimuth misalignment of 7 km from east to west.

Another type of analysis possible is to break the passes down even further, using only fore or aft looking azimuth angles. Fig. 3 shows the same region, only subtracting a descending pass, aft looking measurements from an ascending pass, fore looking measurements. This image appears a bit smoother, and is lacking the black stripe on the west side of the Florida peninsula. However, the white stripe on the East side of the peninsula is present, though it is only 10 km in width, corresponding to a 5 km azimuth offset.

Fig. 3 can be compared to Fig. 4, which is an ascending, aft looking and descending fore looking difference image. This image contains the dark strip on the west side of the Florida peninsula, but is missing the white stripe on the East side of the peninsula.

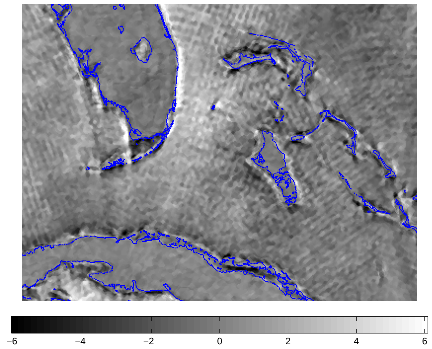

Fig. 3. SIR enhanced image of an aft looking descending pass subtracted from a fore looking ascending pass; H-pol

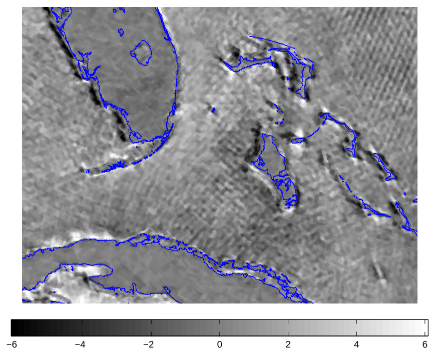

Fig. 4. SIR enhanced image of a fore looking descending pass subtracted from an aft looking ascending pass; H-pol.

Overall, the images show that QuikSCAT measurements are well located within the 10 km design requirement. However, the minor differences in the beam based images pose some interesting questions. The data suggests that location measurements are slightly biased in an east to west direction. This might be related to an azimuth angle bias. Though a possibility such as attitude error exists, the location errors may also be due to the inherent limitations of the along scan resolution enhancement. Conclusions of measurement accuracy from this data are difficult to determine beyond the resolution presented. Further analysis is in progress.

III. CGS Comparison

While land / ocean boundary images allow location accuracy to be validated within 5 - 10 kilometers, it is desired to improved upon this level of accuracy. Another method of determining the location of QuikSCAT measurements is to employ the use of the QuikSCAT Calibration Ground Station (CGS). The CGS passively receives and records the microwave transmissions of QuikSCAT. Fig. 5 shows a typical segment of data from the CGS.

The CGS easily and accurately captures the power and time of arrival of each transmitted pulse. From Fig. 5 the gain of the SeaWinds antenna pattern is apparent, which is the cause of the variation in received power. This cut through the antenna pattern is the key to determining the location of

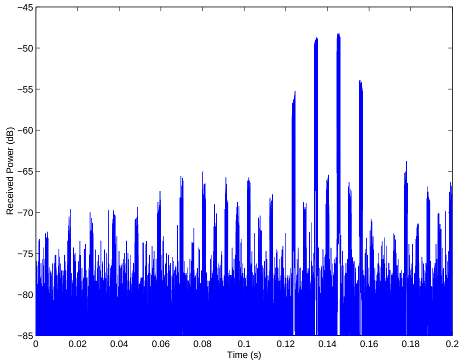

Fig. 5. A typical CGS data set, power versus time. The figure shows the pulses as they were observed at the CGS.

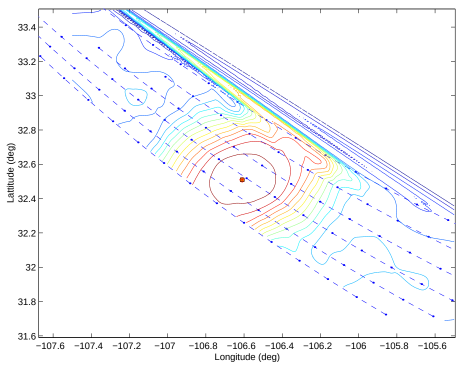

Fig. 6. Contour plot of reconstructed antenna pattern. This plot shows the location of the CGS to be directly in the center of the illuminated area.

the measurements. First, a number of CGS captures from the same QuikSCAT pass are assembled, along with the time of arrival and received power of each pulse. Secondly, timing information from QuikSCAT telemetry data is used to compare pulses recorded at the CGS with recorded telemetry data. From the telemetry data, the calculated locations are extracted. Using the location for each pulse from telemetry data along with the received power from CGS data, a plot of the antenna pattern of the instrument, as seen from the ground, is constructed, see Fig. 6. This reconstructed antenna pattern can be directly compared to the known antenna pattern of the SeaWinds instrument, shown in Fig. 7. Since the location of each pulse is calculated using the bore site of the antenna, the center of the reconstructed of the antenna pattern, should be located exactly at the CGS. Any discrepancies constitute a mislocation by the instrument.

This experiment was repeated for several QuikSCAT passes. For each pass the center of the antenna pattern was recorded. Fig. 8 shows the recorded center of the antenna pattern for each data set. The figure shows that the majority

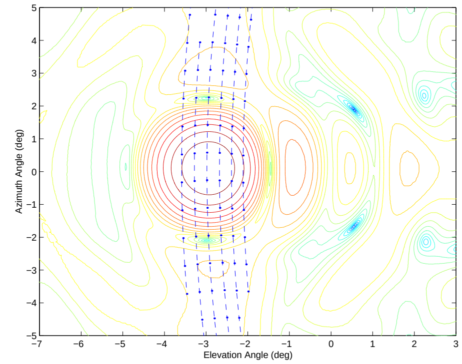

Fig. 7. Actual transmit antenna pattern for SeaWinds. The dashed curves are included for reference to Fig. 6.

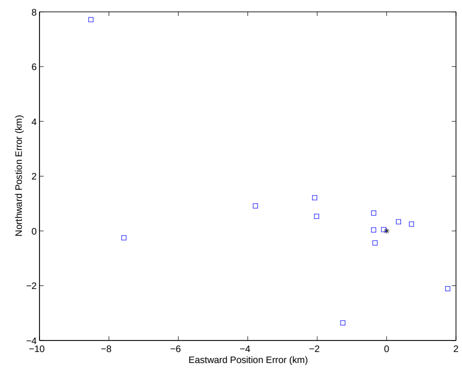

Fig. 8. Determined location error of QuikSCAT for several passes. Each point symbolizes the mean location error for a given pass. The CGS is located at the point (0,0).

of the measurements are within a few kilometers, though a few erroneous passes did occur. These errors could be due to a myriad of factors, too numerous to mention. However, they are attributed to computational errors. Using these measurements, the mean distance error is found to be 1.86 km. Discarding the two significantly deviant points, the mean location error is 0.70 km, which is considered negligible.

IV. Summary

Through the use of two independent sources, accurate cell location is confirmed. Using land / ocean boundary images, cell locations are shown to be accurate to within a few kilometers, limited by the resolution of the images. Using the QuikSCAT CGS and antenna pattern reconstruction techniques, the cell location is found to be accurate, on average, to within 1.8 km. These findings open the door for advanced data applications which require the improved location accuracy of the measurements. Continued analysis of this data to monitor long term stability is planned.