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QuikScat/Seawinds Sigma-0 Radiometric and Location Accuracy Requirements for Land/Ice Applications

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Summary

This report provides requirements on the radiometric and location accuracy of σ^o measurements made by QuikScat and Seawinds for application in land and ice studies. The requirements are summarized here.

Two classes of measurements are defined: primary (high accuracy center slices) and secondary (lower accuracy slices). Slices which do not meet either primary or secondary accuracy requirements are considered unusable.

In the following, the absolute requirements apply over mission life while relative apply over a 3 day period.

Primary requirements:

- σ^o radiometric accuracy (1 σ rms): better than 0.5 dB absolute and 0.4 dB relative.
- σ^o knowledge location accuracy (3 σ rms): better than 4 km absolute (goal of 2 km) and 2 km relative.

Secondary requirements:

- σ^o accuracy (1 σ rms): better than 1 dB relative, bias relative to primary measurements less than 0.25 dB
- location accuracy: same as primary

1 Introduction

Spaceborne wind scatterometers are important in remote sensing because of their proven ability to make all-weather measurements of vector winds over the ocean, a capability first demonstrated by the Ku-band (14.6 GHz) Seasat scatterometer (SASS) in 1978. The success of SASS lead to the development of the NASA Scatterometer (NSCAT) which was launched in August 1996 [20]. Like SASS, NSCAT was originally designed to measure the near-surface wind field over the ocean by inferring the wind from measurements of the surface radar backscatter. However, the scatterometers also measure the normalized radar backscatter coefficient (σ^o) over land and ice and such measurements have proven useful in a variety of scientific studies. We want to continue to collect highly accuracy Ku-band scatterometer observations to extend the existing SASS and NSCAT data sets with the QuikScat and Seawinds missions.

Some of the applications of scatterometer data over land and ice include: mapping and studying sea ice in the polar regions [4, 3, 5, 6, 12, 14, 21, 26, 30], mapping ice facies in major land ice bodies [15, 27], fisheries [29], wind measurement over ice [22], tropical vegetation mapping [10, 11, 13, 17, 28], studies of boreal forests [1, 19, 23, 24, 25], desert studies [9], and change studies [2, 7]. Additional applications for scatterometer data over land and ice can be expected; for example, I am currently combining scatterometer data and TRMM precipitation radar for vegetation and rain studies.

Because the scatterometer provides frequent, wide-area coverage at a variety of incidence angles, it can supplement higher resolution instruments (such as synthetic aperture radar) which often have narrow swaths with limited coverage and incidence angle diversity. For example, scatterometer data enables th high resolution data to be placed with in a global context [1, 4, 3]. As an active instrument scatterometer data can be a useful adjunct to passive sensors such as the SSM/I. Scatterometer data has also been used with AVHRR data [10, 11].

2 Radiometric σ^o Accuracy Requirements

Scatterometer data offers several advantages over radar sensors: 1) frequent global coverage, 2) multiple incidence angles, and 3) high radiometric accuracy. Dual pol observation is also an advantage. The low resolution of scatterometer data is a disadvantage but is offset by the high radiometric accuracy and can be ameliorated to some degree by resolution enhancement [17]. It is sensible to preserve these advantages as much as possible in future sensors.

From the perspective of the land and ice studies I have been involved with NSCAT was an almost ideal sensor: it offered all of the advantages noted plus was well-suited for resolution enhancement. The accommodation issues which resulted in the pencil-beam design used for QuikScat and Seawinds designs sacrificed the incidence angle and polarization diversity available with the NSCAT design but has resulted in a denser sampling of the surface. (The latter improves the imaging time-period/resolution enhancement tradeoff to enable more frequent enhanced resolution imaging for the new sensors.) The QuikScat/Seawinds design also offers a wider swath which improves the coverage.

The two most demanding applications for accurate measurements are in change studies (e.g., [2, 7]) and inverse scattering (e.g., [15]). For the former, measurements with a relative accuracy *between sensors* is required to better than $\sim$0.5 dB to enable detection of subtle changes in vegetation and ice. Note that a calibration error between sensors could be confused with a change (or lack thereof) in the target, resulting in erroneous conclusions.

In inverse scattering the observed backscatter response (including both polarization and incidence angle) is used to infer the scattering mechanism and physical characteristics of the surface. For example, Long and Drinkwater [15] use a simple electromagnetic (EM) scattering model to relate σ^o to surface parameters such as surface roughness, layer thickness, firn grain size, and firn density. Using Seasat scatterometer (SASS) data they were able to infer these parameter quite accurately as demonstrated by comparison the inferred parameters with *in situ* measurements. They used the incidence angle dependence of the observations to aid in fitting the model to the observed data. By comparing SASS and NSCAT observations they were able to identify long-term (multi-decadel) changes in locations of key ice facies Greenland consistent with global warming [2].Their technique requires a measurement accuracy of about 0.5 dB in order to extract the facies extent. The spread of incidence angles simplified the model parameter extraction and reduced the need for absolute calibration at any particular incidence angle. With only σ^o measurements at one or two incidence angle measurements for QuikScat and Seawinds, the accuracy requirement should ideally be more stringent.

Noting the difficulty of improving the relative calibration accuracy, I suggest a relative accuracy of 0.4 dB, including stability (variations) over a 3 day period. This is the typical period used for making land/ice images. Following historical precedent, this should be treated as a 1 σ rms value. The inter-sensor calibration accuracy requirement should be 0.5 dB with a goal of 0.4 dB or better. However, this should hold over the life of the mission. Note that if the sensor is stable, cross calibration using measurements the Dry Snow zone of Greenland and other target sites should make it possible to remove residual absolute calibration bias.

3 Location Accuracy Requirements

Scatterometer measurements can be used directly or can be first processed with imaging/resolution enhancement algorithms. Work done by K. McDonald [19] represents the former approach, while I have typically used resolution enhancement. For an applications similar to McDonald's, the slice measurement location accuracy should probably be commensurate with the smallest dimension of the slice, e.g., ∼8 km. A tighter requirement arises when resolution enhancement is used.

The coarse resolution of scatterometer measurements, while suitable for ocean wind measurement, can be a significant limitation in the application of scatterometer data to land and ice studies. Until recently the principle application of land σ^o measurements has been in the calibration of the scatterometer using tropical forests as homogeneous targets [13]. However, by combining data from multiple passes with the Scatterometer Image Reconstruction with Filtering (SIRF) algorithm, enhanced resolution images of the surface backscatter. For SASS and NSCAT the effective resolution which can be attained is better than 8 km (as fine as 4.5 km [17]). An initial assessment for QuikScat/Seawinds suggests that this design can do at least as well as NSCAT but with a shorter imaging time interval. The ERS-1 scatterometer resolution enhancement is limited by the resampling and filter done during ground processing and the uncertainty in the actual measurement locations (since they are not reported in the final data product).

In order to effectively apply SIRF, the locations of the measurements must be known within about 1/2 a pixel in the final product. This suggests a knowledge location accuracy requirement of better than about 2 km to produce the images. This is the relative accuracy requirement. This relative accuracy requirement should apply for any two measurements within a 1000 km radius over a three day period (corresponding to the maximum land imaging period).

In application, the SIRF-generated images are compared to maps and data from other sensors. Associated with each pixel is a lat/lon position which should be within one pixel of the true value. Thus, the absolute location requirement should be better than about 4 km with a goal of 1/2 pixel or 2 km. For convenience, the location accuracy requirements can be treated as 3 σ rms. Because the imaging application uses the variations in measurement location to enhance the image resolution, no location control requirements are given.

4 Requirement Levels

It is recognized that because some of the slices occur off the center of the gain pattern in the roll off of the antenna gain, that σ^o measurements by different slices will have different accuracies. Since some applications can tolerate somewhat lower accuracies, two classes of measurements are defined: primary and secondary. The *primary* measurements are high accuracy measurements (typically the center slices) which can be used in all studies while *secondary* measurements have some what lower accuracies and will have more limited application. Slices which do not meet either primary or secondary accuracy requirements are unusable.

The requirements previously discussed are the *primary* requirements. The location accuracy requirements are kept for both primary and secondary measurements. For the radiometric accuracy requirements for secondary measurements, the requirements can be relaxed to 1 dB relative with less than 0.25 dB bias relative to the primary measurements.

For effective application in land imaging, at least one half (6 of 12) of the slices should be primary measurements. The remaining slices which meet at least the secondary accuracy requirements should be retained. Unusable slices can be discarded. Measurements should be flagged according to their estimated quality class: primary, secondary, unusable.

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