Temporal Resolution Enhancement for AMSR Polar Images

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Abstract

Current popular techniques which separate AMSR satellite data into ascending- and descending-only sets create images with diminished temporal resolution near the poles. This results from the averaging of data from multiple overlapping passes which are separated by several hours. Overlap can be reduced by instead grouping data according to local time of day. This new[1] method maximizes temporal resolution by decreasing both the number and the temporal variation of overlapping data sets at extreme latitudes.

1 Introduction

The Advanced Microwave Scanning Radiometer (AMSR) is a spaceborne radiometer in a near-polar sun-synchronous orbit. Because of its orbit geometry and wide swath, this instrument scans areas near the poles multiple times a day. This high sampling frequency is valuable in studies over regions of extreme latitudes, especially those envolving transient phenomena such as weather or ice.

Current satellite image-creating techniques combine data from several satellite passes by averaging the normalized radar cross section from each pass for pixels in which they overlap. Usual methods create daily or twice-daily (ascending/descending) images. Daily images include data from all passes for that day, maximizing spatial coverage. Although useful in some contexts, the number and extreme temporal variation of overlapping passes make this method less than ideal for use in studying transients.

Improving temporal resolution from the daily images, ascending/descending images only use half of the daily data. While this decreases spatial coverage, it decreases polar overlap

[1] This method has also been applied to QuickSCAT [1].

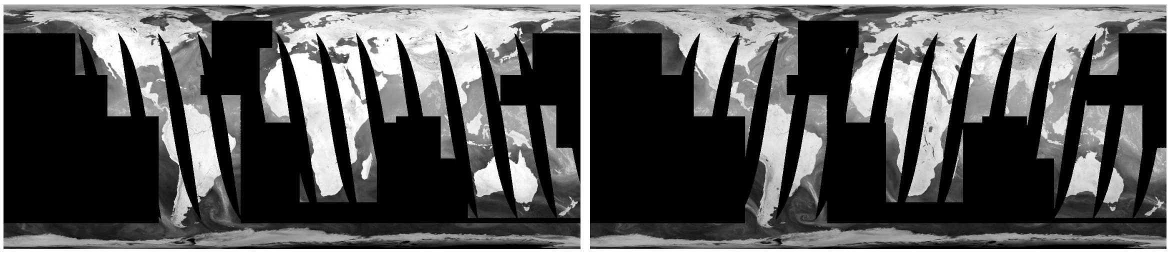

Figure 1: Continental images for ascending/descending swaths, respectively. The equatorial nodes are at 8:00 am/pm local time.

and eliminates equitorial overlap. However, due to the high sampling density near the poles characteristic of the AMSR's orbital geomtry, the ascending/descending method still produces images with diminished temporal resolution over the polar regions.

A new method improves upon this by separating data instead by local time of day. This method preserves all collected satellite data while minimizing the overlap and time gap between distinct swaths in an image.

Before evaluating this new method, we will first introduce the SIR **p** image as a useful evalutaion tool, after which we will further discuss the directional (ascending/descending) method and its drawbacks. Following this discussion, the local time of day (L-TOD) method will be presented.

2 The SIR p Image as a Useful Tool

The simplest method for creating AMSR satellite images plots the average of all corresponding normalized radar cross sections to each pixel. While the gridded images produced by this method have a high signal-to-noise ratio, their spatial resolution is limited by the footprint of the antenna pattern. Scatterometer Image Reconstruction (SIR) is an alternate technique which improves spatial resolution while introducing some noise [2] [3].

While our purpose here is not to explore techniques which increase spatial resolution, the SIR process creates many auxiliary images, one of which estimates the time at which the value for each pixel was measured. This image type, referred to as the **p** image, will be our primary tool in the analysis of temporal resolution processes.

3 Ascending/Descending Method

Ascending and descending images have been particularly useful in studying transient phenomena because of the decreased swath overlap compared to daily images. Because these images only account for half of the daily data, the most obvious drawback associated with these images when compared to the daily images is the decreased spatial coverage; however, near the poles (above 60 or below -60 degrees latitude) coverage is at least twice-daily.

The repeated coverage near the poles causes a decrease in temporal resolution relative to the sampling frequency. This results from the overlapping of swaths near the polar boundary and at the day boundary. Both overlap types and their effect on ascending/descending images will be addressed in this section. An image's temporal resolution will be evaluated by considering the maximum number of overlapping swaths and the time separation between them.

3.1 Polar Boundary

The asymmetry of the polar boundary for ascending and descending image generation is one cause of decreased temporal resolution. To understand how this affects temporal resolution, we will first discuss the satellite's orbital geometry and instrumental orientation.

Having a near-polar sun-synchronous orbit, the AMSR maintains a constant angle relative to the sun and therefore crosses the equator on its descending pass (at approximately 8:00 pm local time of day) twelve hours after crossing the equator on its ascending pass, and visa versa. The sets of raw data for the AMSR satellite use the polar node (the time at which the satellite reaches its extreme latitude) as the separation boundary between ascending and descending passes. The ascending/descending imaging method uses this same boundary for minimum processing. This method, used as a simple estimator of local time of day, assumes constant local time of day for each pass.

The AMSR instrument uses a forward-scanning reflector dish system with constant incidince angle relative to the Earth's surface and a 4 second period. The curvature of the scan required to maintain constant incidence creates an asymmetry in the polar boundary between ascending and descending swaths. The center part of the last few scans in the ascending passes cover regions beyond the point of highest latitude. Conversely, the outer parts of the the first few scans in the descending passes cover regions previous the point of highest latitude. This increases the amount of swath overlap and thus decreases the temporal resolution of the image. Furthermore, due to dense time-zone boundaries near the poles, the otherwise small discrepancy between the time boundaries and the data-separation boundaries is magnified in its effects on temporal resolution.

The polar boundary as defined for ascending/descending images creates a convex boundary for the pre-boundary swaths and a concave boundary for the post-boundary swaths. Although twice-daily images are usually categorized by time—being **n** (noon) or **m** (midnight) images—or by direction, for the ascending/descending method we will instead use the descriptors *convex* and *concave* for convenience both in describing their images and differentiating between these and the **n** and **m** images of the new method. We will present Arctic images in each case. The **m** swaths are concave and descending while **n** swaths are convex and ascending for the Arctic boundary.

3.1.1 Concave Overlap

The concavity of the post-boundary swaths can be observed in Fig. 2. Between consecutive passes, the Earth rotates underneath the satellite, which allows daily coverage of the polar regions. As passes are added to the image, they overlap and the associated data is averaged. In the seven-pass image, we can see that some regions contain information contributed by all seven passes, which introduces a temporal variation of 12 hours.

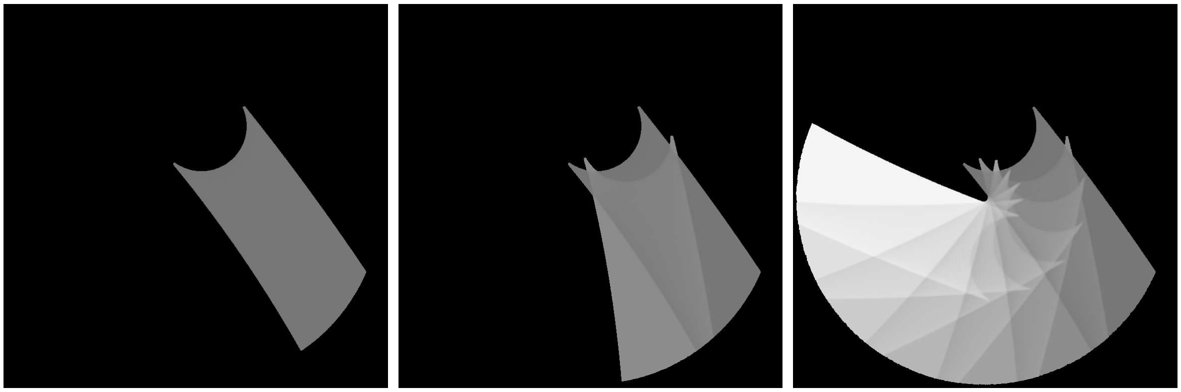

Figure 2: SIR **p** images with various swaths showing polar boundary overlap for the concave boundary.

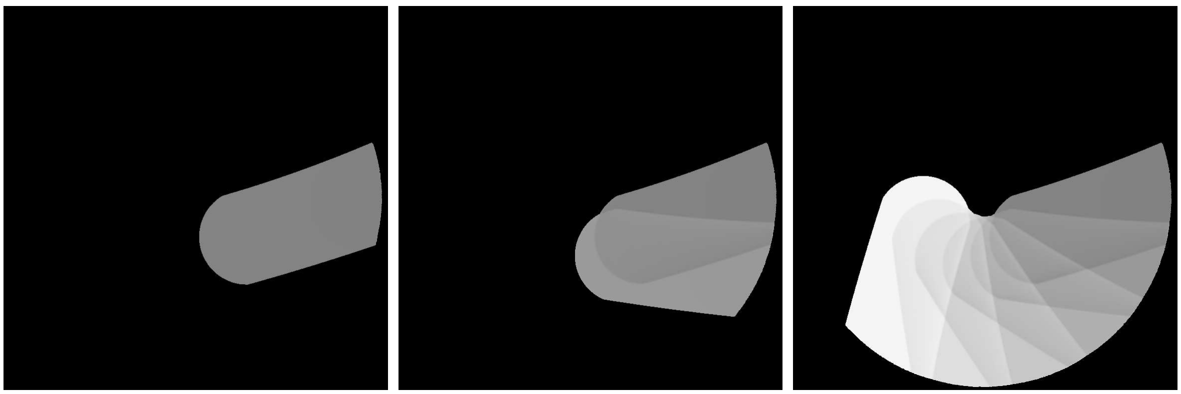

Figure 3: SIR **p** images with various swaths showing polar boundary overlap for the convex boundary.

While averaging multiple passes of satellite data generally decreases noise and measurement anomalies, it also suppresses transients. Therefore, the value of these images in studies requiring high temporal resolution is compromised.

3.1.2 Convex Overlap

The convexity of the pre-boundary swaths can be observed in Fig. 3. The overlap is observed as passes are added; however, the maximum number of passes contributing to any given area is only four. This presents a temporal variation of less than 7 hours which is much better than the concave case, which had seven overlapping swaths with a temporal variation of 12 hours.

One interesting characteristic of this image is the larger no-data aperture surrounding the pole. It is apparent that the information corresponding to much of this region is included in the post-boundary data set. While this image type has less overlap than the concave type, it has lower spatial coverage.

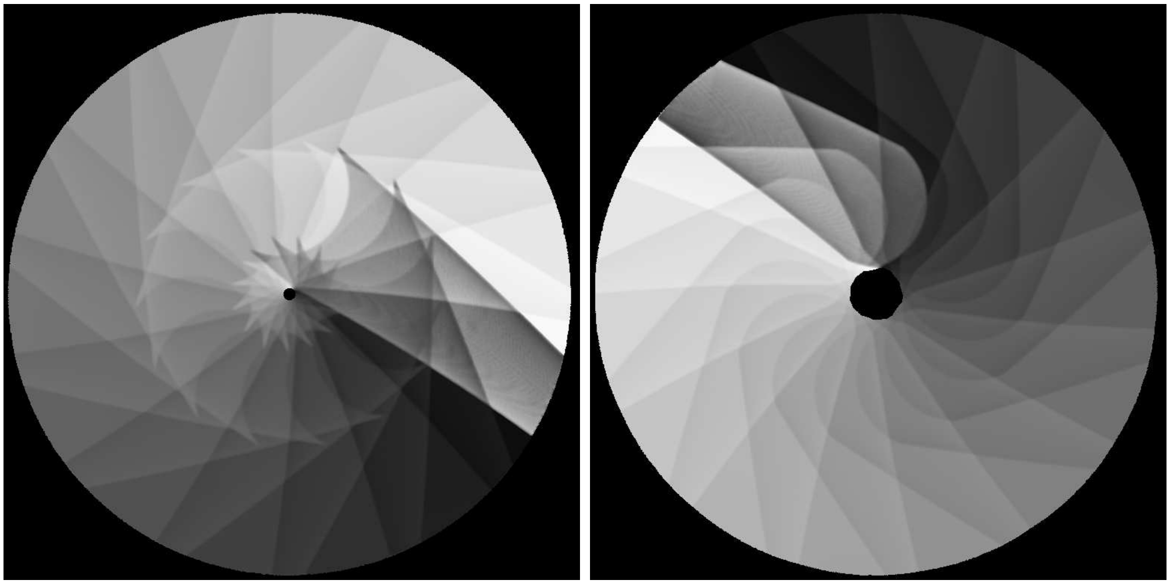

Figure 4: Complete SIR **p** images for descending and ascending Arctic swaths, respectively, showing the day boundary overlap for each.

3.2 Day Boundary Effects

The day boundary overlap of ascending/descending images causes greater deterioration in temporal resolution than the polar boundary overlap which we discussed in the section 3.1. While polar boundary overlap occurs between nearly-consecutive swaths separated by approximately 1.5-12.5 hours, the overlap at the day boundary occurs between swaths which are nearly 24 hours apart.

The AMSR completes just over 14 orbital cycles in a 24 hour period. One can see from Fig. 4 that the last 3–5 swaths overlap with the first. This may destroy the transient utility of the effected region completely. Considering the day boundary overlap in addition to the polar boundary overlap gives ample motivation to improve upon the ascending/descending method.

4 Separation by Local Time of Day

The L-TOD method separates data according to local time of day instead of by satellite time and direction. We will first discuss the process, then the subsequent implications for temporal resolution.

4.1 Process

A discussion of terminology is in order before introducing the process. The *location* of a data sample refers to the location on Earth's surface to which it corresponds. The *longitude* of a data sample we will define as measured westernly from the International Date Line. The *Universal Time* is the time of the first time zone west of the International Date Line.

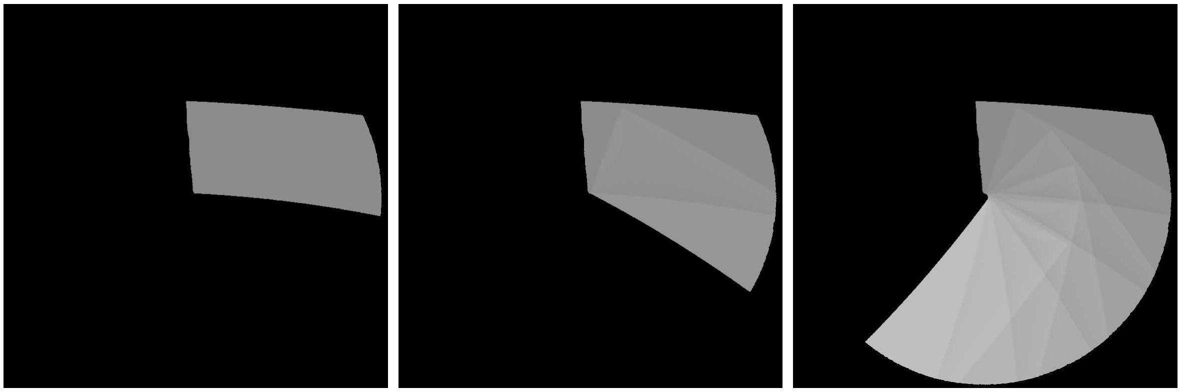

Figure 5: L-TOD **p** midnight images for various numbers of swaths.

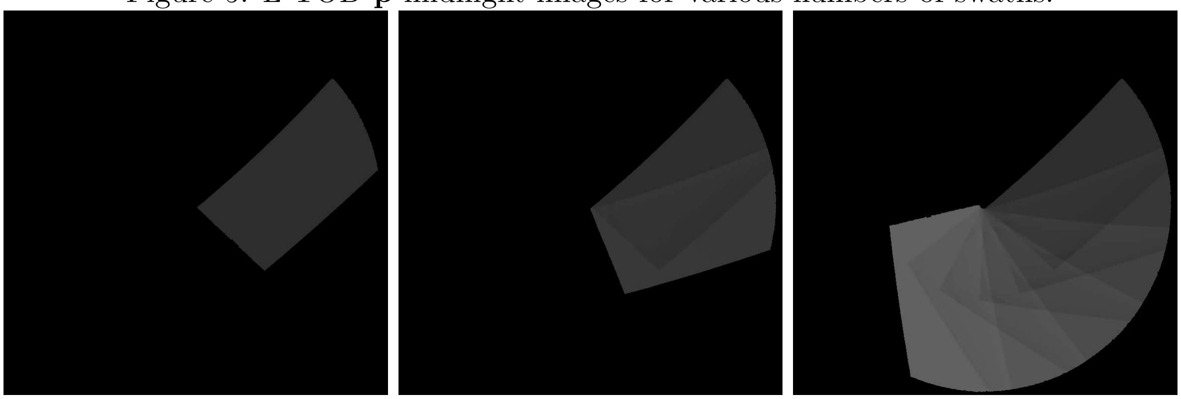

Figure 6: L-TOD **p** noon images for various numbers of swaths.

Thus the *local time* for a data sample is approximated by adding to the Universal Time four minutes times its longitude. This results from the Earth's rotation of 360 longitudenal degrees occurs every 1440 minutes per day or 1 degree every 4 minutes.

After calculating the local time of day for a data sample, the process uses polar nodes of 2:00 am and pm to separate the data into noon/morning **n** images and midnight/evening **m** images. In contrast to the ascending/descending method, all **n** and **m** images for L-TOD use data from both ascending and descending swaths during the corresponding time period. While this increases the amount of processing required, the results are justifying.

The improvement results from the algorithm's change in both the polar boundary and day boundary from those of the ascending/descending method. These differences will be discussed and improvements shown for each.

4.2 Polar Boundary

By using local time of day, we can see from Fig. 5 and 6 that the polar boundaries for the **n** and **m** images are symmetrical. The maximum overlap for either is four swaths. Although it is apparent that the convex-swath and L-TOD images both have four overlapping swaths and that their swath-overlap area is comparable, the L-TOD image improves in both spatial and temporal coverage.

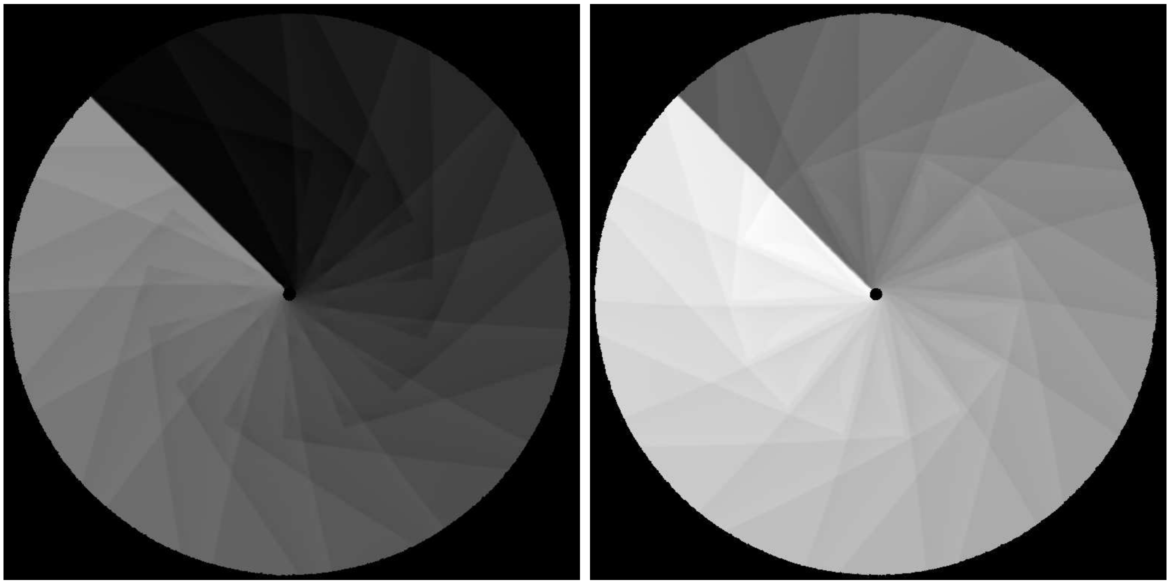

Figure 7: Complete L-TOD **p** images for noon and midnight images, respectively.

While the increased spatial coverage for the L-TOD image is easily observed in the smaller aperture around the pole, the increased temporal coverage is more difficult to identify. Hypothetically, consider eliminating swath overlap completely by only allowing data contribution from the first swath to cover any pixel. This would increase temporal resolution for the individual pixels, but some transients captured only in the discarded passes would be lost. Similarly, the convex image appears to have higher temporal resolution because of the decreased overlap, but it instead has decreased temporal coverage. On the other hand, L-TOD images preserve all data while maintaining high temporal resolution.

From the concave image the improvement is obvious; by using the L-TOD separation method, the number and maximum time separation of the overlapping swaths is decreased dramatically, thus the temporal resolution is increased.

4.3 Day Boundary

As seen in Fig. 7, the L-TOD separation algorithm creates a well-defined day boundary at the International Date Line. Due to the nature of the algorithm, data that is collected to the east of the Date Line is thrown out for the first few swaths of the day, and data that is collected to its west is thrown out for the last few swaths. This boundary causes virtually no overlap which is synonymous to no degradation of the temporal resolution at the day boundary. This is a vast improvement over the 3–5 overlapping swaths from the convex and concave cases, whose maximum time separation is nearly 24 hours.

There are some drawbacks associated with the day boundary as defined by L-TOD. First, it becomes necessary to include data contributed by 2-3 swaths from both the preceding and following days in order to complete the image. This slightly increases processing time, but is acceptable due to the exclusion of that data from the previous and following days' images. Secondly, it creates a visible discontinuity in the image along the boundary, as seen in Fig. 8.

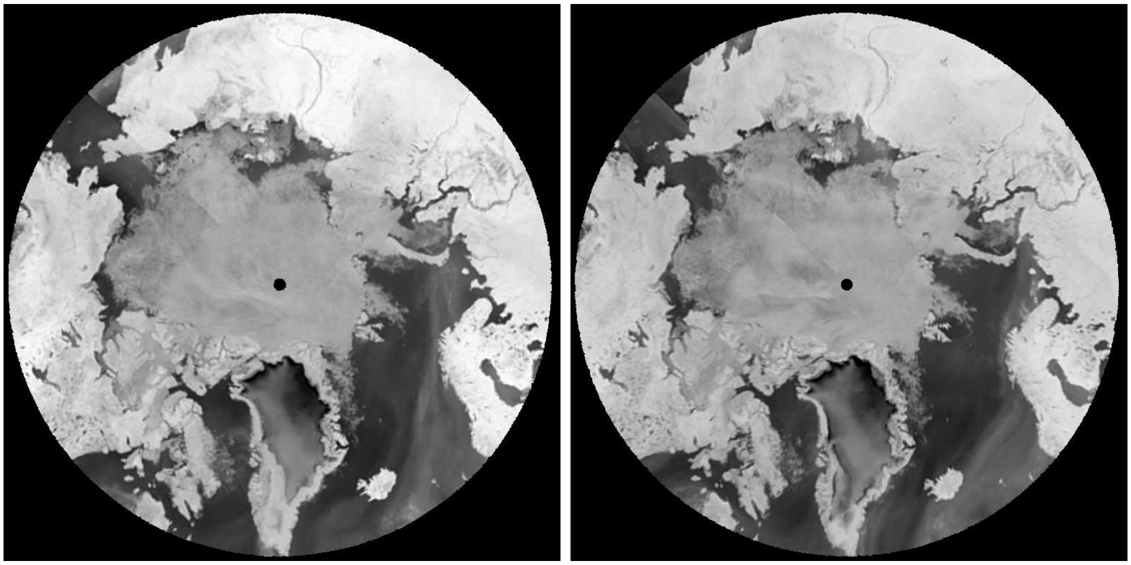

Figure 8: Complete L-TOD images for noon and midnight images, respectively. The day boundary is visible in the upper-left quadrant of each image.

While this may decrease the aesthetic value of the image, the inherent detriment is justified by its increased temporal resolution.

5 Conclusion

While the ascending/descending method of data separation in the creation of AMSR polar images is simple to implement and requires minimal processing, the resulting images suffer from decreased temporal resolution due to the asymetrical polar boundary and the loosely-defined day boundary. Separation by local time of day, while requiring some additional processing, returns images with maximized temporal resolution. These L-TOD images are especially valuable in studies treating transient phenomena, where temporal resolution is critical.

References

[1] Hicks, Brandon R., Long, David G., *Improving Temporal Resolution of SIR Images for QuickSCAT in the Polar Regions*, Brigham Young University MERS Lab, 25 March 2005.

[2] W. B. Davis, *Enhanced resolution from remotely sensed microwave data*, Master's thesis, Brigham Young University, Provo, Ut, 1993.

[3] P. Whiting and D. Long, *Resolution enhancement of seasat scatterometer data*, BYU MERS, 1992.