Study of Iceberg B10A using Scatterometer Data

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Abstract— The Antarctic continent continually releases glacial ice into the ocean in the form of icebergs calving from glaciers and ice shelves. Microwave scatterometers can provide useful information about the spatial and temporal behavior of large icebergs. In this paper, results from the observation of B10A during 1992-2000, using ERS-1/2 AMI Scatterometer (ESCAT), NASA Scatterometer (NSCAT) and SeaWinds on QuikScat (QSCAT) data are presented. Multi-sensor analysis shows a general consistency of C-band σ^o measurements from ESCAT and Ku-band σ^o measurements from NSCAT and SeaWinds. Certain subtle differences are observed which reflect the frequency dependence of iceberg σ^o measurements.

INTRODUCTION

The Antarctic ice sheet plays a very important role in the regulation of global climate. Glacial ice is continually released into the ocean in the form of icebergs calving from glaciers and ice shelves. Iceberg B10A, which has been floating in the sea ice for several years, originated as the Thwaites ice tongue and began drifting in 1992. B10A started with an approximate surface area of 38 by 77 kilometers extending 90 meters above the water with an estimated 300 meters of free-board under the ocean's surface. It broke up north west of South Georgia Island in January 2000. As a large glacial ice mass, it can be distinctively identified in resolution enhanced scatterometer images as an object of high backscatter against the generally lower backscatter of sea ice or wind roughened ocean.

Iceberg B10A was regularly tracked by National Ice Center but was lost for several months in the summer of 1999. It was relocated, floating in the Drake Passage in June 1999, with the help of data from SeaWinds aboard QuikScat (QSCAT). SeaWinds is a low (25 km) resolution radar designed to measure near-surface ocean wind fields, but as illustrated here, it can also be useful for monitoring land and ice. Coupled with day/night and all weather data acquisition, its high temporal resolution makes it a unique choice for large scale monitoring of Antarctic sea ice. In this paper, results from the observation of B10A, from its initial motion to breakup, are presented based on ERS-1/2 AMI Scatterometer (ESCAT), NASA Scatterometer (NSCAT) and QSCAT data.

The limitations imposed by the intrinsically low resolution (25-50 km) of the scatterometer data is ameliorated by using the Scatterometer Image Reconstruction (SIR) resolution enhancement algorithm [1]. The SIR algorithm generates A and B images where A is the normalized radar backscatter at 40° incidence angle in (dB) and B is the incidence angle dependence of backscatter in terms of slope (dB/°). The two quantities are related to the normalized radar backscatter (σ^o) at angle θ by the following linear model.

$$\sigma^o(dB) = A + B(\theta - 40^\circ)$$

ESCAT operates at C-band with vertical polarization and has a continuous data set from 1992 to the present. Using the SIR algorithm with data acquired over six day period, it is possible to construct enhanced resolution images with an effective resolution of 25 km. These images are used to study the backscatter variation and track the overall path of the iceberg from 1992 to the present. Both NSCAT and QSCAT operate at Ku-band in horizontal and vertical polarization. NSCAT collected data for 1996-1997 while QSCAT data began in June 1999. SIR applied to these data yield images with an effective pixel resolution of 10 km or better. These images are used to compare the response of the iceberg to different microwave frequencies.

ICEBERG TRACKING

B10A has been drifting at variable speed through the sea ice for several years and has previously been tracked with unenhanced ESCAT data [2, 3]. The ERS enhanced resolution image time series indicate that the B10A iceberg remained stationary at the location of its initial break off from the ice shelf in Amundsen sea until the end of 1994, when it began drifting in the sea ice, forced by the prevailing ocean currents. The iceberg has a very high radar backscatter response and shows as a very bright spot in the images. A semi-automated tracking algorithm was developed to locate the iceberg in the enhanced resolution time series of scatterometer images. A training sample of the iceberg from the first image is located and entered as input to the algorithm. This training sample is used to locate the iceberg in the next image by calculating the cross-correlations in the proximity of the previous coordinates. The point with highest correlation and proximity is most likely to be the iceberg, and hence is chosen to be the location of the iceberg. A window extracted around the selected point along with the coordinates serves as the

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training sample for locating iceberg in the next image in the sequence. The criteria for choosing iceberg location (t_1, s_1) in $(i+1)th$ image is given by

$$R_{X_iW_{i+1}}(t_1, s_1) = Max\{R_{X_iW_{i+1}}(t, s))\}$$
$$(|t_1|, |s_1|) = Min\{|t|, |s|\}$$

where

$R_{X_iW_{i+1}}(t, s)) = Correlation\ function\ between\ the\ training\ sample\ and\ the\ image$

$X_i = training\ sample\ from\ ith\ image$

$W_{i+1} = window\ from\ (i+1)th\ image.$

This algorithm performs well for most of the year, except during the summer when, due to surface melting, the iceberg merges with the generally low backscatter background. Figure 1 presents the track of the iceberg from the 1992 to the time of its breakup. Comparing with the measurements made by National Ice Center, shown as rhombic symbols, clearly indicates that microwave satellite imagery can be very useful for monitoring dynamic objects like iceberg at high temporal resolution.

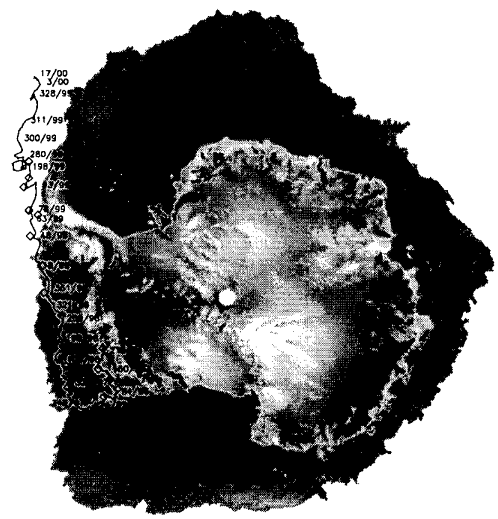

Figure 1: Track of Iceberg B10A, since 1992 from ESCAT data (line) and National Ice Center (symbols with dates), superimposed on an NSCAT A image for JD270 1996. The white spot near the data point 24/97 in the lower left is B10A.

TEMPORAL VARIATIONS OF B10A

Figure 2 shows the temporal signature of the backscatter observed by ESCAT. A measurements show that B10A has been going through a cyclic behavior until 1997 after which changes in the periodicity can be observed. Before 1997 a backscatter dip during the month of December can be observed every odd year with backscatter reaching as low as -24 dB relative to it nominal value of 4 dB during the remaining of the year. Beside this large dip, a small amount of lowering of backscatter during December of the even years can also be observed. Consistent behavior is found in the variations of dB/deg slope data, which decreases from its initial value of -0.18 dB/deg to -0.33 dB/°. The reason for the less defined periodicity of the backscatter behavior after 1997 is due to the northward drift of the iceberg where the temperature is relatively high during the summer causing more frequent variations of the B10A surface properties due to surface melt.

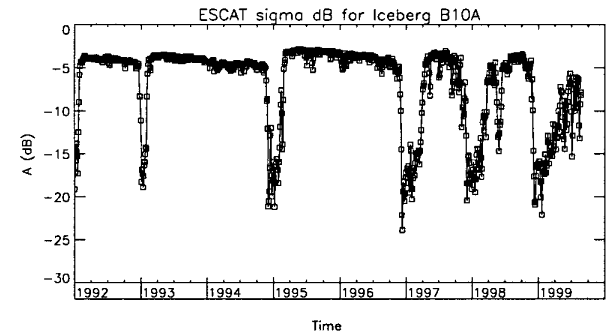

Figure 2: C-band time series of backscatter measurements of Iceberg B10A.

MULTI-SPECTRAL DATA ANALYSIS

Since C-band and Ku-band microwave frequencies are sensitive to different surface and volume interactions, they provide an opportunity to explore the multi-spectral signatures of the iceberg. The Ku-band scatterometer data from NSCAT for the period during 1996-1997 is utilized for this purpose. Figure 3 compares the time series of the radar backscatter measurements from ESCAT and NSCAT for the period of data overlap of the two sensors. It is evident that the two different sensors are generally consistent. However, in the winter, the iceberg merges into the background due to a reduction in C-band backscatter

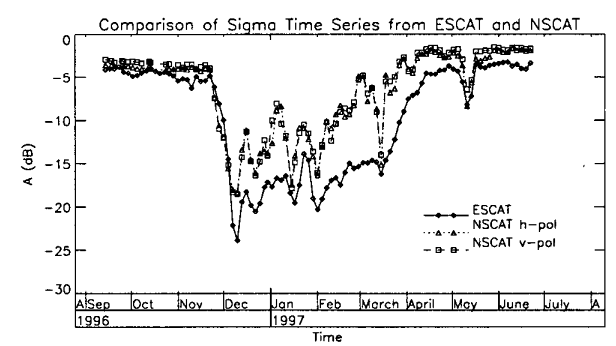

Figure 3: Comparison of Iceberg B10A backscatter at 40° (dB) time series from C-band ESCAT and Ku-band NSCAT data.

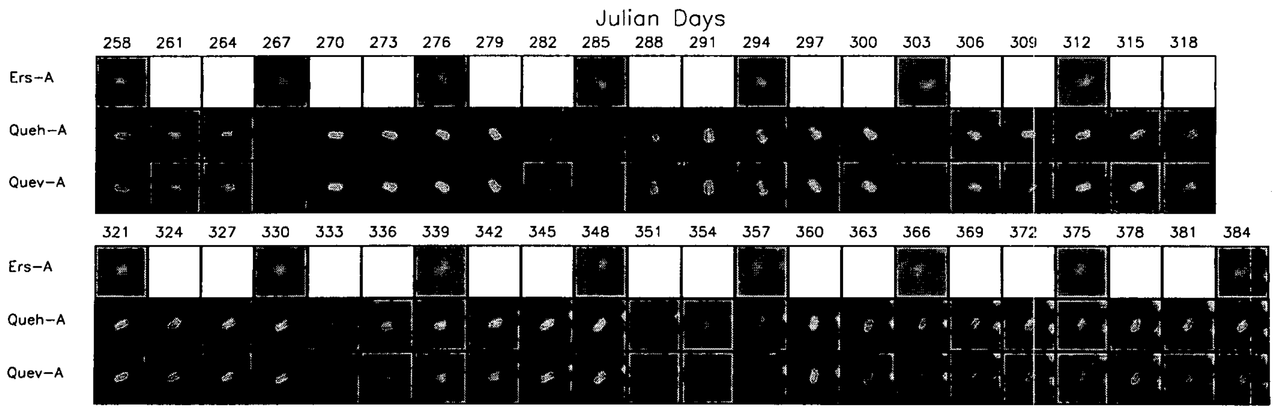

Figure 4: Comparison of B10A time series from C-band ESCAT and dual-pol Ku-band QSCAT data.

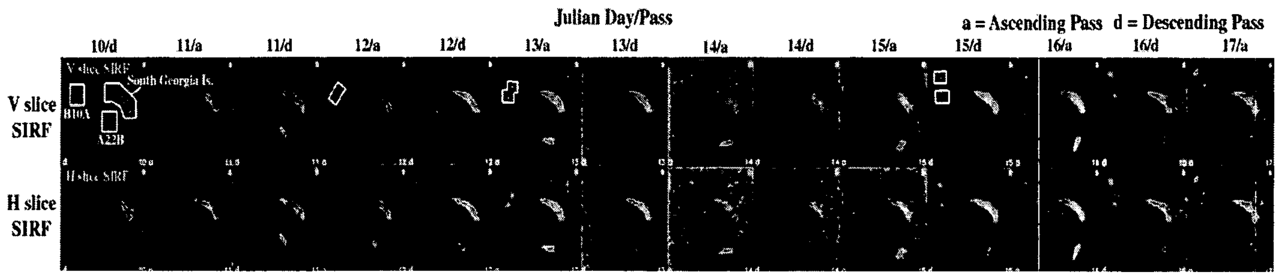

Figure 5: End of B10A as seen by SeaWinds scatterometer. A22B is also visible.

whereas the Ku-band backscatter measurements remain high, helping distinguish the iceberg from the background.

Comparison of ESCAT and QSCAT images from part of 1999 is shown in Figures 4 and 6. The overall consistency between the two sensors is also clear, except that the QSCAT has better temporal and spatial resolutions, which yields a more detailed picture of the fluctuations in the backscatter. During January 2000, B10A broke up, calving smaller bergs and could no longer be monitored.

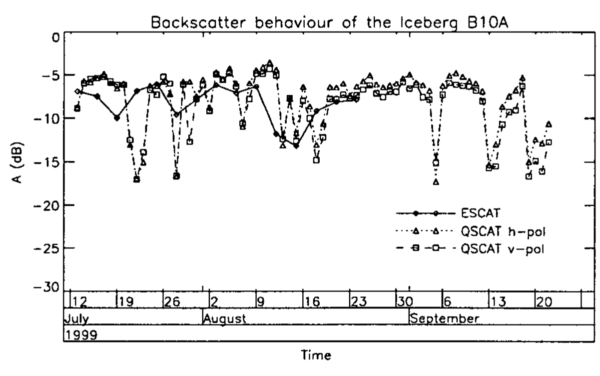

Figure 6: Comparison of Iceberg B10A backscatter time series from C-band ESCAT and Ku-band QSCAT data.

Figure 5 depicts the breakup of B10A from QSCAT data.

CONCLUSION

Various sea ice and atmospheric factors determine the track and ultimate destination of large icebergs. Scatterometers, operating at different frequencies, are found to provide useful information about the spatial and temporal behavior of these icebergs. The variations in the backscatter of the iceberg correlate with the location and the time of the year.

REFERENCES

[1] D. Long, P. Hardin, and P. Whiting, "Resolution Enhancement of Spaceborne Scatterometer Data," *IEEE Trans. on Geosci. and Rem. Sens.*, vol. 31, pp. 700–715, May 1993.

[2] R. Ezraty, C. Maroni and S. Pouliquen "Sea ice extent and types as seen by AMI-Wind on ERS and NSCAT on ADEOS. Tracking an iceberg in the southern Pacific for seven years," *Proc. of the 4th Pac. Ocea. Rem. Sens. Conf.*, pp650-654, 1998

[3] N.W. Young, "Antarctic Iceberg Drift and ocean Currents derived from Scatterometer image series" *Proc. of Joint ESA-Emusat Work. ESTEC, Noordwijk*, pp. 125–132, Nov. 1998.