# Variations in Radar Backscatter Across the Great Ice Sheets

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## ABSTRACT

Radar backscatter over the great ice sheets is modulated by the near surface properties of polar firn. These properties (grain size, density, stratigraphy, wetness) change in time and from region to region. Information was compiled on the spatial variation in backscatter across selected parts of Antarctica and Greenland from ERS-1 SAR data. The SAR-derived $\sigma^{\circ}$ compared favorably with both in situ and the ERS-1 scatterometer data obtained from literature. These results will be used to refine processing schemes for the Radarsat Antarctic Mapping Project.

A difference plot of the azimuthal anisotropy of SAR-derived $\sigma^{\circ}$ was created to determine the magnitude of azimuthal anisotropy on a pixel by pixel basis. Azimuthal variability for a region of the Antarctic Peninsula was found to vary from 0 to 14dB.

## INTRODUCTION

Radar backscatter over the great ice sheets is related to the near surface properties of polar firn. These properties (grain size, density, stratigraphy, wetness) change in time and from region to region.

Histograms of SAR-derived $\sigma^{\circ}$ (Fig. 1, 2) across selected parts of Antarctica and Greenland (Fig. 3, 4) were created to determine the backscatter distribution for ESA ERS-1 SAR PRI (European Space Agency European Remote Sensing Synthetic Aperture Radar Precision Image) images. A difference plot (Fig. 5) was created from overlapping ascending and descending orbits of SAR-derived $\sigma^{\circ}$ over the Antarctica Peninsula area.

## PROCEDURE

Histograms:

Geographic locations (Fig 3, 4) were obtained from the GDMS home page [1]. Histograms (Fig. 1, 2) of the SAR-derived $\sigma^{\circ}$ were created from the 12.5m resolution PRI data and binned at 0.5dB intervals [3]. All images are representative of the winter season.
1

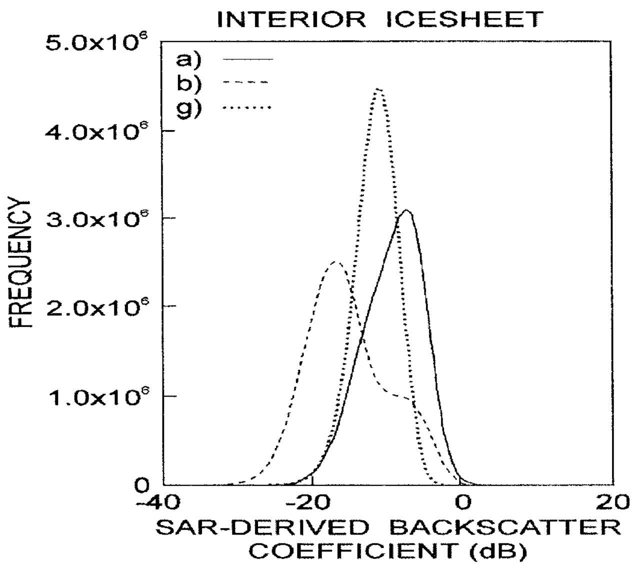


Fig. 1. Histogram of $\sigma^{\circ}$ for the interior ice sheet of Antarctica (a), (b) and Greenland (g). Letters correspond to geographic locations on Fig. 3, 4.

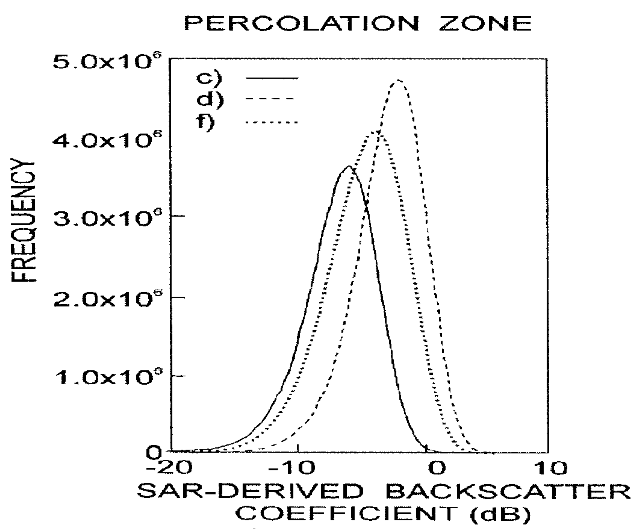


Fig. 2. Histogram of $\sigma^{\circ}$ for the percolation zone of Antarctica (c), (d) and Greenland (f). Letters correspond to geographic locations on Fig. 3, 4.

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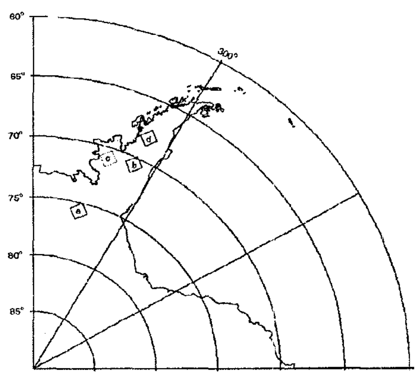


Fig 3. Geographic location of images where (a) (b) correspond to interior ice sheet on Fig. 1 and (c) (d) to percolation zone on Fig. 2.

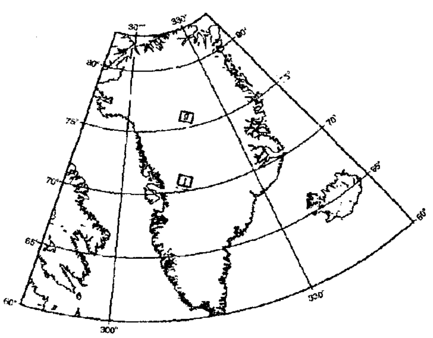


Fig. 4. Geographic location of images where (g) corresponds to interior ice sheet on Fig.1 and (f) to percolation zone on Fig. 2.

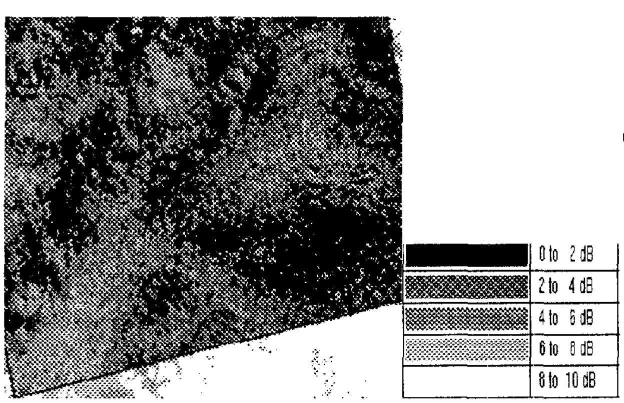


Fig. 5. Difference plot of the absolute value of SAR-derived $\sigma^{\circ}$ from overlapping ascending and descending orbits depicting azimuthal anisotropy variations (Antarctica).

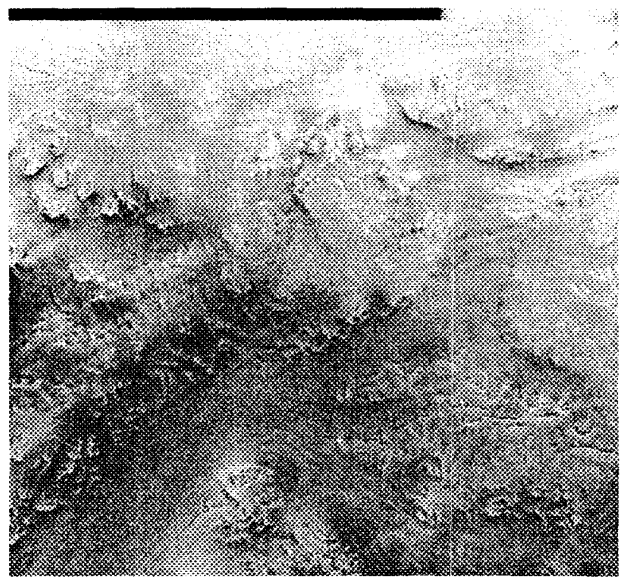

Fig. 6. The full image of the descending orbit used to create the difference plot.

Azimuthal Anisotropy:

A difference plot of the $\sigma^{\circ}$ from overlapping ascending and descending orbits over the Antarctic Peninsula is created from 12.5m resolution PRI data and binned at 2dB intervals (Fig. 5). The azimuthal separation between the ascending and descending orbit is 93.75°. The images are geocoded and rectified (Fig. 6). To reduce inherent speckle a 9x9-pixel mean-filter is applied to the resultant image. The difference plot is created by level slicing using a 2dB intervals to determine the magnitude of azimuthal anisotropy on a pixel by pixel basis.

## DISCUSSION

Histograms:

*Interior Ice Sheet:* SAR-derived $\sigma^{\circ}$ for Antarctica have an approximate mean of -7dB and -16dB, where SAR-derived $\sigma^{\circ}$ for the Greenland interior ice sheet correspond to an approximate mean of -10dB. These low values of $\sigma^{\circ}$ occur over the interior ice sheet where volume scattering from individual snow grains dominates.

Rack [4] reports a range of $\sigma^{\circ}$ calculated from the ERS-1 scatterometer data over Antarctica (incidence angle 30°) of -5dB to -13dB during the austral winter. In 1992, Jezek and others [2] performed surface-based microwave radar measurements at 5.3 GHz with VV polarization on the western flank of the Greenland Ice Sheet. At incidence angle of 25° the glacier surface has a $\sigma^{\circ}$ of -12dB. The variation between VV and HH polarization at low incidence angles is negligible [6].

*Percolation Zone*: Mean $\sigma^{\circ}$ for Antarctica are about -3dB and -6dB. Mean $\sigma^{\circ}$ for Greenland are about -4dB. These higher values of $\sigma^{\circ}$ are caused by extensive near surface ice lenses formed during summer melt events.

Rack [4] report ERS-1 scatterometer measurements of $\sigma^{\circ}$ that range from -4dB to -7dB during the Antarctic austral winter. Jezek and others [2] report a total surface $\sigma^{\circ}$ from the western flank of the Greenland Ice Sheet of -2dB.

Table I. Summary of SAR-derived $\sigma^{\circ}$(dB) and data obtained from literature. AP=Antarctic Peninsula, GL=Greenland.

| | INTERIOR | | PERCOLATION | |
|---|---|---|---|---|
| REFERENCE | AP | GL | AP | GL |
| SAR-derived | -16 and -7 | -10 | -6 and -3 | -4 |
| Scatterometer [4] | -13 to -5 | - | -7 to -4 | - |
| Surface-based [2] | - | -12 | - | -2 |

The SAR-derived $\sigma^{\circ}$ compare favorable with both the in situ and the ERS-1 Scattterometer data obtained from literature.

Azimuthal Anisotropy:

A difference plot of SAR-derived $\sigma^{\circ}$ from overlapping ascending and descending orbits was created to determine the magnitude of azimuthal anisotropy on a pixel by pixel basis. Fig. 6 is one of the images used to create the difference plot. It shows a glacier surrounded by rugged mountains exposed through the ice sheet. Surface features of high relief are illuminated on the side facing the sensor while the side away from the sensor will be in shadow. The areas most illuminated by one direction and least illuminated by the other direction will have a range of relatively high azimuthal anisotropy. Low relief areas will be illuminated uniformly from both directions, giving a low azimuthal anisotropy, unless there is a change in the physical characteristics of the surface.

High azimuthal anisotropy in Fig. 5 correspond with two main features in Fig. 6. The mountains show up as isolated areas of high azimuthal anisotropy (> 8 dB) surrounded by relatively low azimuthal anisotropy (2-4dB). Examples of these areas are clearly evident in the upper right and middle far left of Fig. 5. Sections of the glacier also show high azimuthal anisotropy as evident in the lower left and lower middle of Fig. 5. Rott and Rack [5] report high azimuthal anisotropy (5.75dB) in areas of strong winds recorded by ERS-1 scatterometer measurements. Hence, drainage wind channeled by the glacial valley may explain our results.

## CONCLUSION

The SAR-derived backscatter distributions, discussed earlier, compare favorably with both the in situ and the ERS-1 scatterometer data obtained from literature. Azimuthal anisotropy calculated from ascending and descending SAR-derived $\sigma^{\circ}$ ranges from 0 to 14dB.

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