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Snowpack properties in Dronning Maud Land, Antarctica, compared to Envisat ASAR and scatterometer measurements

Introduction

The knowledge of snow pack properties and it's temporal and spatial variability are of importance for the interpretation of backscattered signals in the microwave region. Spaceborne scatterometers provide valuable information on backscattering characteristics at low spatial but high temporal resolution. In addition, the surface is illuminated at different viewing angles during a single overflight.

This investigation focuses on the area of Dronning Maud Land (DML), Antarctica. VV-polarized backscattering properties from the two satellite borne scatterometers Ku band NSCAT (14.3 GHz) and C band Escat (5.3 GHz) as well as SAR (Synthetic Aperture Radar) images with high spatial resolution are compared to snow pack properties, in the first place accumulation rates derived by stake readings. This is done along a traverse route connecting the German bases Neumayer (70°39'S, 08°15'W) at the ice shelf Ekströmisen to Kottas base camp (74°12'S, 9°44'W).

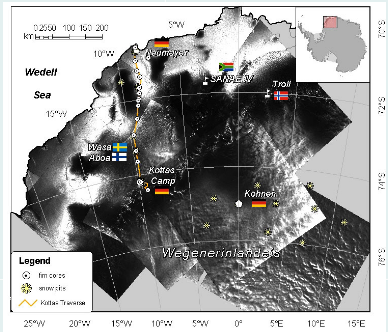


Fig.1. Envisat ASAR mosaic of Dronning Maud Land study region, showing the Kottas Traverse route connecting the German bases Neumayer and Kottas camp as well as snow pit and firn core sampling sides.

Differences in the backscattering signatures reflect the variable pattern in the snow morphology, although the relation is not straightforward. The signature study provides additional information for a better understanding of signals like radar altimeter and high resolution SAR.

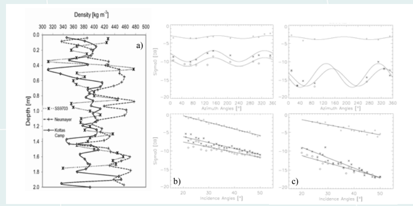


Fig. 2. Depth-density profiles for 3 snow pits, located along Kottas Traverse route (a) and corresponding Escat (b) and Nscat (c) scatterometer signatures Factor of Anisotropy (FA) on top, and Gradient over incidence angle (IG) on bottom.

Maximum Likelihood Classifcation

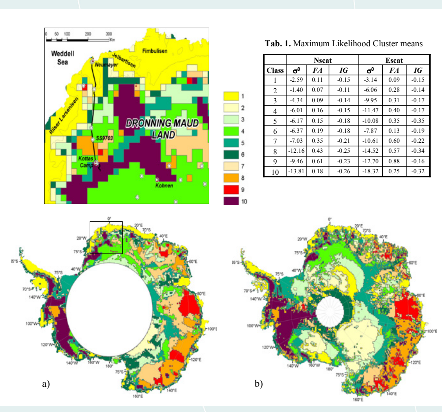
Three parameters have been used to characterize and classify spatial variations in the backscattering coefficient σ^0 and the degree of it's azimuthal modulation. Furthermore the gradient of σ^0 versus incidence angle (*IG*) was described by applying a linear fit over all measurements within the incidence angle range of 20°-50°. The factor of anisotropy was (*FA*) was calculated according to:

$$FA = \frac{\sum_{j=1}^{18} \left| \sigma^0_{j,mean} - \sigma^0_{mean} \right|}{\sigma^0_{mean}}$$

j = 1,18 azimuth angle bins in 20° steps

$$30^\circ \le \theta \le 40^\circ$$

The results yield a similar general pattern of surface classes for both Escat C-band and Nscat Ku-band data. Thus we consider this simple method as robust for mapping differing snow facies of a polar region. The higher resolution Nscat data enables a more detailed discrimination of the single classes shape and extent.



Tab. 1. Maximum Likelihood Cluster means

	Nscat			Escat		
Class	σ^0	*FA*	*IG*	σ^0	*FA*	*IG*
1	-2.59	0.11	-0.15	-3.14	0.09	-0.15
2	-1.40	0.07	-0.11	-6.06	0.28	-0.14
3	-4.34	0.09	-0.14	-9.95	0.31	-0.17
4	-6.01	0.16	-0.15	-11.47	0.40	-0.17
5	-6.17	0.15	-0.18	-10.08	0.35	-0.35
6	-6.37	0.19	-0.18	-7.87	0.13	-0.19
7	-7.03	0.35	-0.21	-10.61	0.60	-0.22
8	-12.16	0.43	-0.25	-14.52	0.57	-0.34
9	-9.46	0.61	-0.23	-12.70	0.88	-0.16
10	-13.81	0.18	-0.26	-18.32	0.25	-0.32

Fig.4. Maximum Likelihood classification results: a) Escat (DML magnification above), b) Nscat

Net Accumulation vs. ASAR σ^0

Accumulation data was gathered by repeated stake readings in the years 1997 till 2001 along a line of 675 stakes at 500-m interval, set up by the AWI for the Neumayer – Kottas Camp traverse route (Fig.1), The measured snow fall in meters was transformed into accumulation rates (kg m^{-2} a^{-1}) by using density profiles of the snow pack's upper 2 m (see also Fig.2).

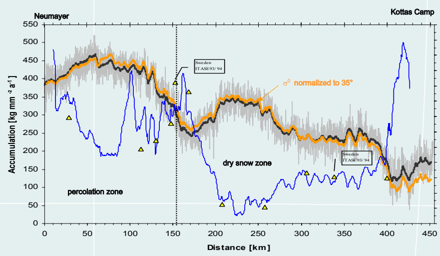


Fig. 3. Envisat ASAR wide swath data from March 2004, plotted against accumulation rates along Kottas Traverse (see Fig. 1). Yellow Triangles present accumulation data, received by firn core analyses.

A varying snow accumulation can be related to changes is snow pack properties, especially the annual layer thickness and grain size-depth profile. Such changes are mirrored by the corresponding surface backscattering coefficient σ^0 which shows a clear inverse correlation with snow accumulation. However no exclusive connection between absolute values of σ^0 can be made out over the entire spectrum of crossed snow pack conditions. It is obvious, that the relationships between accumulation rate and σ^0 must be described for each individual snow facies, respectively.

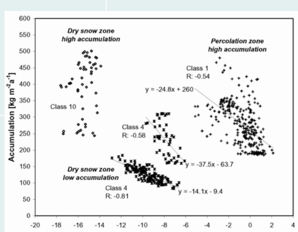


Fig. 5. Scatterplot ASAR wideswath σ^0 vs. stake line net accumulation rates. Clusters form according to the snow pack's physical properties and represent the Escat Maximum Likelihood classification results.

Summary

Scatterometer provide valuable information about incidence and azimuth angle dependence of the snow surfaces backscatter coefficient σ^0, which shows strong variations across the ice sheet of Antarctica. This can serve for normalization of high resolution Envisat ASAR data. SAR in turn can be used to study the relation between the snow's morphology and its backscattering properties in more detail. The backscatter coefficient σ^0 shows a clear inverse correlation to insitu accumulation data. With the gained experience some of the initial classes for the MLC algorithm can be redefined to approximate the classification pattern around well known snow classes.

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