CHARACTERIZATION OF GLACIER SUBSURFACE USING SAR POLARIMETRY AT L- AND P-BAND

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1. INTRODUCTION

Glaciers and ice sheets represent sensitive indicators of climate change being their properties strictly related to the environmental temperature and its fluctuations. Therefore, the interest in studying these components of the Cryosphere has strongly increased in recent years. The need of observations on a global scale has promoted airborne and satellite remote sensing techniques for glaciological applications. In particular, synthetic aperture radars (SARs) led to significant improvements in scale as well as temporal and spatial resolution of cryospheric observations. Long wavelengths SAR sensors have the capability to penetrate into the ice, interacting with surface as well as sub-surface (up to several tens of meters depth) structures. This makes the scattering scenario very complex; consequently SAR backscattering from glaciers and ice sheets remains not completely understood.

In this study we present first results of a polarimetric decomposition technique based on the scattering model introduced in [1]. Different scattering component are considered, according to the specific glacier facies where the test sites are located. Validation is performed using airborne Pol-SAR data at L- and P-band collected by the DLR's E-SAR system within the ICESAR campaign in Svalbard, Norway. Tomographic analysis and a set of ground measurements are also employed to support the decomposition results.

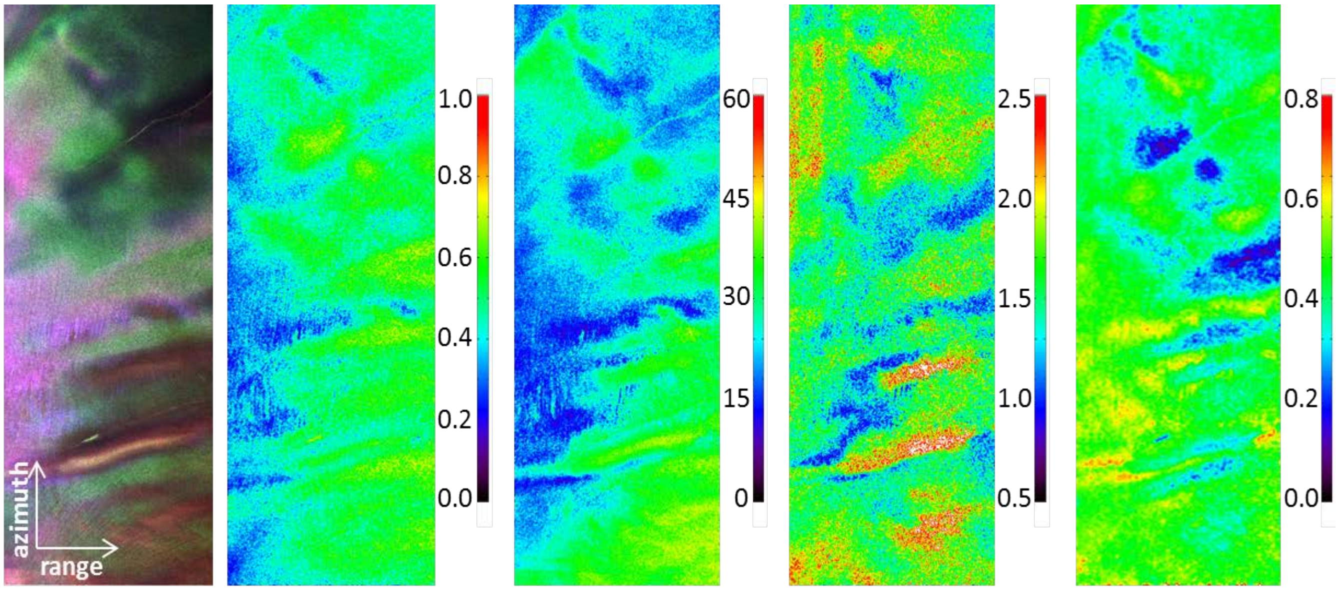
2. STATE OF THE ART

The potential of Synthetic Aperture Radar (SAR) for monitoring glaciers and ice sheets has been widely recognized in the last decades. Nevertheless, most of the studies conducted over land ice employing SAR focus on the analysis of polarimetric backscattering coefficients for glacier facies classification and monitoring. However, polarimetric SAR measurements potentially contain much more information about the targets, like their physical and geometrical properties.

A straightforward and exhaustive link between SAR observables and geophysical parameters of the scattering scenario can be provided by model-based polarimetric decomposition techniques specifically developed for a certain environment or application. Furthermore, in the case of glaciological applications, the availability of multi-temporal SAR acquisitions allows a physical interpretation of glaciers dynamics. Nevertheless, SAR backscatter modeling and interpretation is still in an early stage for this kind of scenario because of the complexity of the involved scattering mechanisms. A first model-based decomposition for glacier scenarios has been proposed in [2] as adaptation of conventional 3-component polarimetric decomposition models. The total scattering is considered as the sum of a surface contribution attributed to a shallow snow-ice interface, a volume component due to the underlying ice volume (populated by possibly oriented dipoles), and a scattering contribution related to the eventual presence of an oriented sastrugi field on the glacier surface. However this approach showed its main limitation in interpreting the polarization phase differences observed in the SAR data. Moreover, same scattering mechanisms were considered for test sites located in different facies, therefore characterized by different subsurface structures. In this paper we introduce a novel polarimetric decomposition approach, which is strictly related to the specific structure of the considered glacier facies and is based on the electromagnetic model presented in [1].

3. POLARIMETRIC DECOMPOSITION

The approach proposed in this work addresses the interpretation of PolSAR backscatter of a sub-polar ice-cap through the development of a dedicated model-based polarimetric decomposition technique. In particular, the cases of wet-snow and superimposed ice facies are presented. The total backscattering is considered as the sum of volume and (eventually) surface contributions. In the wet snow zone, most of the scattering is postulated to come from the icy inclusions present in the shallow layer of firn [3], while a possible contribution from the dry winter snow cover is considered negligible at L- and P-band. For such scenario, polarimetric decomposition can help to quantify the amount of scattering from the different types of inclusions, like ice lenses and pipes, and to extract information about the microstructure of polar firn [4]. The typical subsurface structure of the superimposed ice zone suggests the presence of two different scattering mechanisms: a surface contribution generated at a shallow snow/ice interface and a volume mechanisms due to the presence of small air bubbles in the ice layers [3]. As for the wet-snow case, possible scattering from the winter snow cover is assumed negligible. The main output of the polarimetric decomposition over the superimposed ice zone is the surface-to-volume ratio (StoV), indicating the



(a) Pauli (b) entropy (c) mean alpha [°] (d) co-pol ratio (e) surf-to-vol ratio

Figure 1: a) Pauli representation of the SAR scene of the superimposed ice zone ($R=|HH-VV|^2$, $G=|2*HV|^2$, $B=|HH+VV|^2$); b) polarimetric entropy; c) mean alpha angle, d) co-polarization ratio ($|HH|^2/|VV|^2$); e) estimated surface-to-volume ratio.

relative intensity of the surface and volume scattering contributions. For both, wet-snow and superimposed ice zone, the volume scattering model in [1] is adopted, whereas surface scattering is considered to conform to the X-Bragg model [5]. The estimation of parameters is performed by minimizing a cost function which accounts for the relative errors between a set of Pol-SAR signatures extracted from the data and their simulated counterparts.

4. PRELIMINARY RESULTS

First results of the developed polarimetric decomposition are reported in this section. For the sake of brevity, only the case of superimposed ice at L-band is presented (see Figure 1). In order to provide a first validation of the estimated StoV ratio (Figure 1.e) also some polarimetric signatures of the data are depicted (Figure 1.a-d). Generally, the inverted StoV map fits well the polarimetric properties of the SAR scene. Regions which exhibit a higher surface contribution correspond to mauvish areas of the Pauli image (Figure 1.a) and are characterized by relatively low values of entropy (Figure 1.b) and alpha angle (Figure 1.c). Similarly, a good correspondence is found with areas of co-polar ratio lower than 1 (Figure 1.d), which conforms to scattering from a slightly rough surface [5]. Conversely, estimated low StoV values are supported by their spatial correspondence to the green areas of the Pauli image and high values of entropy and alpha angle, which all indicate dominant volume scattering. Moreover, co-pol ratio values much higher than 1 suggest a preferred horizontal orientation of the scatterers. Further details about the developed decomposition technique, together with a more complete set of results and their validation will be presented in the full paper.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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