PolInSAR Signatures of Alpine Snow

Keith Morrison, DAPS , Cranfield University, Shrivenham, Swindon SN6 8LA, UK
Helmut Rott, ENVEO, Technikerstraße 21a, A-6020 Innsbruck, Austria.
Thomas Nagler, ENVEO, Technikerstraße 21a, A-6020 Innsbruck, Austria.
Pau Prats, Microwave and Radar Institute, DLR, PO Box 1116, D-82234, Wessling, Germany.
Helge Rebhan, ESA-ESTEC, Noordwijk, Netherlands.
Patrick Wursteisen, ESA-ESTEC, Noordwijk, Netherlands.

Abstract

Snow cover appears as a key indicator in climate change, and the ability to remotely measure the physical properties of snow is of vital importance. Current model-based approaches used to interpret satellite and airborne data need much stronger experimental confirmation. PolInSAR is a promising emerging technique for the measurement of snow depth. It exploits the polarisation dependence of scattering mechanisms to estimate scattering phase centre heights, which can be extrapolated to retrieve snow depth. Both modelling work and previous experimental campaigns indicate that the X and Ku-bands are particularly suited for retrieving the physical properties of a snow pack as they are sensitive to both the surface and volume characteristics. However, no comprehensive assessment of the operational potential and limitations of PolInSAR are yet available for snow. This work investigates the conditions under which PolInSAR produces accurate results with respect to snow parameters such as structural features and metamorphic state, as well as technical sensor specifications. A field study of the PolInSAR X- and Ku-band response of alpine snow was carried out with the UK's Ground-Based SAR (GB-SAR) system in a measurement campaign in the Austrian Alps during early 2007. Complementary detailed snow state and structural parameters were also recorded, as well as environmental meteorological data. A brief outline of the experimental technique is presented, and an example of an interferometric product.

1 Introduction

Over the last 30 years, Arctic warming has been almost twice the rate of the rest of the world [1]. As such, snow cover appears as a key indicator in such processes, and its dynamics need to be fully understood. Seasonally, it covers up to 50 million km^2, affecting atmospheric circulation and climate from regional to global scales [2].

Presently the representation of snow processes in global climate models remains rudimentary, and available data for modelling and forecasting snowmelt runoff is insufficient. Snow extent, water equivalent, wetness and metamorphic state are key input parameters for these models. Theory shows that the combination of X-and Ku-band is particularly promising for retrieving these physical properties. This work is aimed at understanding the PolInSAR signatures of different snow states and structures, and how the technique might be most usefully applied to this task.

2 Measurements

1.1 GB-SAR System

The GB-SAR System is a ground-based, stepped-frequency CW radar system which provides high-resolution imagery of a ~30m x 30m scene [3]. The discrete frequency response of the scene over a bandwidth of up to 4GHz is recorded. Complimentary cross-range resolution is provided by translation of the antenna across an aperture of up to 3.7m. The system is capable of continuous operation between heights of 2m to 9m, but for this campaign was operated at fixed heights of either 4m or 9m. A picture of its deployment at full height is shown in **Figure 1**. Polarimetric calibration of the system was carried out against a series of reference targets. The imaging geometry of the GB-SAR system is such that it always provides both horizontal and vertical components to the baseline (at about 30° to the horizontal). A variety of interferometric baselines sizes were used. The exact displacement of the antenna between the two interferometric images is controlled by a precision-made metal collar which sits over one of the hydraulic pistons. This allows the hoist to be displaced in exact and repeatable increments.

1.2 Test Sites

PolInSAR measurements were carried out on four different days over a 70-day period beginning in mid-January 2007. They were made at Kűhtai at 1800m elevation, and Leutasch at 1100m elevation. A wide range of different snow conditions were encountered, including dry snow with different metamorphic conditions, melting snow with refrozen crusts, and completely wet snow. Detailed snow parameters were recorded, as well as meteorological data, throughout the measurement campaign. Application of the PolInSAR technique relies upon a significant volume contribution. Because of the unusually warm winter of 2006/7, dry snow conditions were very limited. Thus, we also examine the PolInSAR signatures of other snow states, and the effects of environmental forcings on the polarimetric signatures such as diurnal variations of surface melt / freeze. Ultimately, this work will provide us with the capability to evaluate the sensitivity of PolInSAR backscattering in respect to various snow parameters, and critical performance of PolInSAR decomposition techniques of snow water equivalent and snow depth retrieval algorithms.

Figure 1 The GB-SAR system during night-time interferometric refreezing measurements at Kűhtai.

2 Results

High interferometric coherences were usually obtained, typically around 0.9. Regions of low coherence are associated with low signal-to-noise, which is primarily controlled by the antenna illumination pattern. Low coherence was also indicative of changes in the snow state during melting/refreezing experiments. Data can be processed in the usual slant-range projection, or in a ground-based projection. As height is included in the latter processing scheme, it preprocesses the flat-earth phase component out of the data.

Figure 2 shows a VV X-Band example from 15th March; the image is ±18m in cross-range by 27m in range. The dominating bright region is essentially the antenna main-lobe. The rectangular feature is a pit dug into the snow. The bright linear feature at the bottom right is a stream bank sloping towards the antenna.

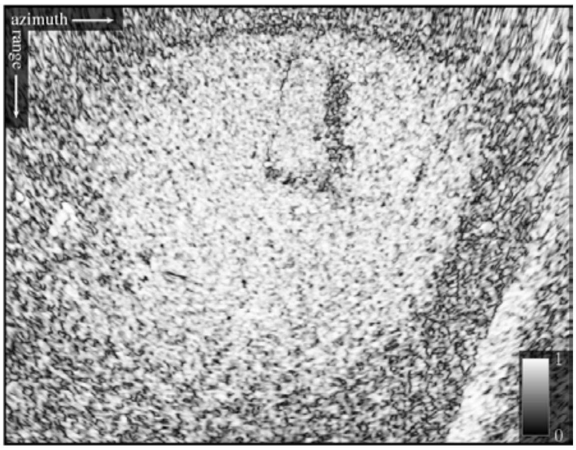

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Figure 2 Coherence map across a VV X-Band image.

Figure 3 shows the interferogram for the flatenned phase for the scene in **Figure 2**. A phase step is clearly visible in the pit, which is 60cm deep down to the bare ground. A consistent height change is also apparent in the L-shaped footpath which connects with the pit. The retrieved height profile is in agreement with the surveyed profile, and shows the step across the pit. Further work will examine the HH and VH result to provide a full PolInSAR analysis.

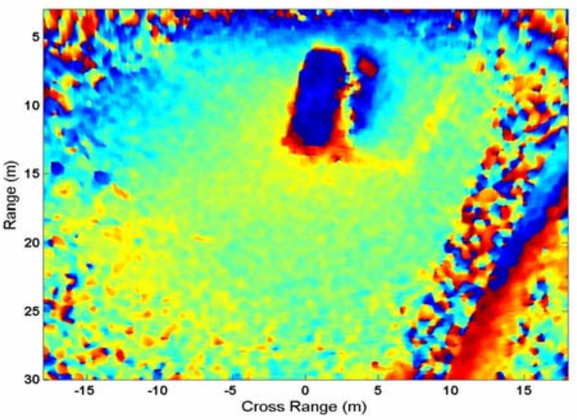

Figure 3 The phase interferogram**.**

References

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