FIRST RESULTS OF A LOW-FREQUENCY 3D-SAR APPROACH FOR MAPPING GLACIERS

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1. INTRODUCTION

In this paper we demonstrate first results of a three dimensional SAR processing method to generate height profiles of glaciers with the CARABAS UWB sensor. Several algorithms exist to extract height information in SAR data, ranging from interferometric approaches (for CARABAS e.g. [1]) and cross correlation in circular tracks [2] to tomographic processing of dual-pol data [3, 4].

The 3D SAR application of the CARABAS sensor is especially interesting for glacier height profiles since the low-frequency radar waves penetrate into ice and thus approximate the profile of the glacier bed up to a certain depth. In a CARABAS campaign conducted in 2003 the Aletsch Glacier, Switzerland, was recorded in several flight tracks. Due to the large antenna necessary for UWB SAR only HH polarization can be recorded in monostatic mode. Unfortunately, caused by air space restrictions, the flown tracks are suboptimal for generating a 3D profile of the Aletsch Glacier bed. Nevertheless, some promising results could be generated by an extended global backprojection processor which is capable to extract 3D information from only few, arbitrary flight tracks illuminating the area of interest.

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2. METHOD

To generate a 3D profile, first a three dimensional reconstruction grid matrix is initialized with the digital elevation model values at the top layer in z-direction. Then for each flight track the 3D backprojection algorithm calculates for each voxel an intensity value as the 2D standard backprojection algorithm does it for each pixel. Since for a coherent summing of the resulting 3D-matrices too few flight tracks are available and additionally the flight configuration is suboptimal for coherent summing, we use instead the absolute values (incoherent) and multiply them for each flight track as a reasonable approximation to merge the single track results to one voxel image. Height information up to a certain depth of the glacier bed can be approximated by finding the position in z-direction with the maximum value. Hence, the position with the most intensive backscattering response is assumed to be the height of the surface (which means in the case of glaciers and low-frequency radar the rocks of the glacier bed). Finally, we apply a low-pass filter to suppress noise effects and get a smooth, more realistic estimate of the surface.

3. RESULTS

We applied the method described in section 2 to a test site in the Swiss Alps (Konkordiaplatz, Aletsch Galcier). The result for the 3D grid matrix after the merging step is illustrated in Fig. 1. While for the snow and ice free surface (e.g. mountain tops) the highest backscattering response can be found in the top layers, in the glacier ice the low-frequency radar waves penetrate into the ice. At the point where the glacier ice starts, a line is observable that seems to indicate the shape of the glacier bed; this line then becomes unsharp and fades to some kind of undefined volume scattering. The height information can be derived by maximum value assignment as mentioned in section 2. The results are illustrated in Fig. 2. The results are only a first step towards mapping glacier beds with low-frequency UWB SAR and their accuracy is not to be seen as a perfect mapping of glaciers, but to illustrate the potential of this technology for future projects with additional, more suitable flight tracks for the problem of glacier mapping.

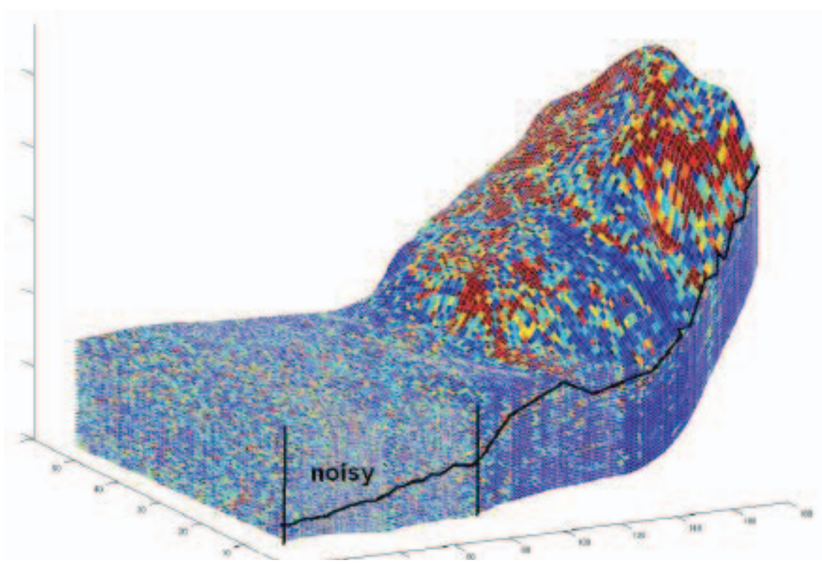

Fig. 1: Three dimensional backscattering response for an area in the Aletsch glacier test region, (voxel image after merging).

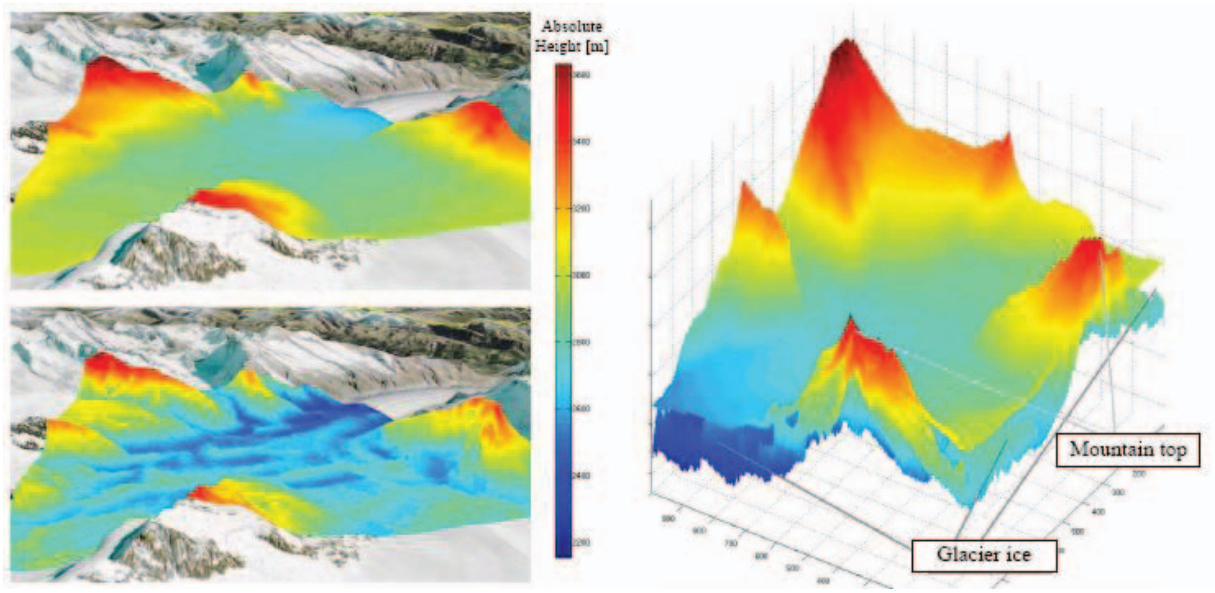

Fig. 2: Surface maps.
Left, top: Glacier surface generated using conventional surface mapping techniques (optical, X-band InSAR).
Left, bottom: Height derived from CARABAS 3D processing.
Right: Combined 3D-plot of both surface maps. The influence of the glacier volume can clearly be seen.

4. CONCLUSION

The methods and results introduced in this paper indicate the capability of low-frequency UWB SAR sensors to generate glacier height profiles and thus give a rough estimate of glacier volume. Further campaigns with an unrestricted flight track selection for the problem of 3D glacier mapping and more research including ground truth validation has to be done to verify the results. Furthermore, aspects like refraction of the radiation caused by glacier ice or the maximum penetration depth are not taken into account for the calculations in this paper and have to be investigated to improve results of future campaigns.

5. REFERENCES

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