Multi-Temporal Investigation of Greenland Ice Sheet Snow Facies using TanDEM-X Mission Data

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Abstract

The Greenland ice sheet is a vast ice-covered plateau extending for about 1,700,000 km$^2$ over 80% of the whole Greenland surface. It represents the second largest ice body of the planet after the Antarctica ice sheet and its characteristics are significantly affected by temperature changes. The knowledge of its properties can substantially contribute to better understand the arctic ecosystem and its responses to climatic changes. Melt phenomena have strongly increased in the last years, leading to modifications in the characteristics of the snow pack. Previous studies of the Greenland ice sheet led to the definition of different snow facies, depending on the amount of snow melt and on the properties of the snow coverage itself. C. S. Benson divided the ice sheet into four zones [1]: melt does not occur in the dry snow zone, which is situated at the highest altitudes at the center of the Greenland plateau. It is surrounded by the percolation zone, where a limited amount of melting occurs, leading to the generation of larger snow grains and to the formation of small ice structures, such as lenses and pipes, within the snow pack. The wet snow zone is located further down slope towards Greenland’s coasts, where previous year accumulation saturates with water during summer melt. Outer coastal regions are classified as ablation zone, where the previous year accumulation completely melts during summer, resulting in a surface of bare ice and surface moraine. Up to now, such facies have been located using microwaves radar sensors by estimating the backscatter levels of the reflected signal. An incident radar wave is able to penetrate the snow-pack, depending on the sensor parameters and on the characteristics of the ground. Interferometric synthetic aperture radar (SAR) acquisitions over Greenland ice-sheet are therefore subjected to volume decorrelation. The intensity of such phenomena can be associated to different dominant scattering mechanisms on ground and can therefore help to classify the type of snow coverage. In this paper we present an approach for classifying the different snow facies of the Greenland ice sheet by exploiting X-band TanDEM-X interferometric SAR acquisitions. TanDEM-X data is particularly suitable for this analysis due to the single-pass bistatic acquisition mode which does not suffer from temporal decorrelation. As far as spaceborne SAR sensors is concerned, this data set is unique. Large-scale mosaics of radar backscatter and volume decorrelation, derived from the interferometric coherence, represent the starting point for applying an unsupervised classification method based on the c-means fuzzy clustering algorithm. The detected snow facies can then be related to the well-known Benson’s facies. Results show a good agreement with external snow melt data and independent multi-temporal TanDEM-X data. Moreover, given the proper location of the different facies, we estimate the X-band penetration depth into the whole ice sheet and finally, we analyze TanDEM-X interferometric time series, acquired over dedicated test sites located within the different snow facies, in order to monitor their evolution in time.

Index Terms


REFERENCES