Dual-Pol X-Band Pol-InSAR Time Series of a Greenland Outlet Glacier

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Abstract

The Helheim glacier in south-east Greenland faces a retreat and thinning like many other Greenland outlet glaciers, but showed two particular huge and fast retreats between 2000 and 2005, coinciding with an acceleration of glacier flow [1]. The estimation of glacier retreat and thinning are established procedures based on a variety of remote sensing techniques, e.g. SAR interferometry (InSAR) [1]. However, due to densification processes, e.g. refreezing of meltwater, changes in the mass balance cannot be calculated solely from changes in the volume of a glacier derived from interferometric elevation models [2]. A near surface densification related to refreezing of meltwater leads to a reduction in surface elevation, but does not contribute to a mass loss and thus cannot be attributed to a potential sea level rise. Likewise, the measurement of snow accumulation and its spatial distribution is error prone due to the penetration bias of InSAR measurements. While local data of accumulation or densification give precise information [2], satellite based polarimetric and interferometric SAR (Pol-InSAR) data has the potential to assess these changes in the near surface snow and firn layers with a better spatial and temporal coverage. This study investigates X-band (TanDEM-X) Pol-InSAR data in order to retrieve information about the temporal and spatial variations of surface and near- surface parameters of the Helheim glacier.

Although the retrieval of ice scattering extinction with Pol-InSAR at different frequencies (L- and P-band) is possible [3], the modelling of Pol-InSAR signatures of snow and ice is not yet fully understood [4]. Indeed examples exist where the typical Pol-InSAR models (RVuG, OVuG) cannot completely explain the SAR measurements. The expected scattering scenarios are on the one hand surface scattering for wet glacier surfaces in case of melting conditions, which prevents any penetration of the signal and therefore the retrieval of volume parameters. On the other hand, at freezing conditions, snow crystals are not contributing to scattering even at X-band, but introduce differential co-polar phase delays related to the anisotropy of the snow volume, which was successfully modelled for snow depth retrieval in [5]. The scattering in the latter scenario is assumed to originate from ice inclusions or layers with a density transition leading to a change in permittivity.

The Helheim super test site is comprised of the longest and most complete time series of dual-pol (HH and VV) TanDEM-X acquisitions over a glacier. Data takes are available almost every 11 days from April 2011 until July 2013 with perpendicular baselines in the order of 200 m. Polarimetric phase differences and Pol-InSAR signatures are used to investigate the temporal evolution of backscattering characteristics, with the goal to find observables which could be related to accumulation or densification processes. In a first assessment, the TanDEM-X measurements show surface scattering in summer during the melt period (May – September), which is confirmed by weather stations in south-east Greenland. Additionally, the interferometric combinations suffer partly from severe decorrelation due to low signal to

noise ratio. Over the winter, a build-up of polarimetric HH-VV phase difference is observable, which could be related to snow accumulation. Interestingly, the parts of the glacier which show this evolution of polarimetric co-pol differential phase, exhibit a rather stable behavior of Pol-InSAR signatures, e.g. the height difference of HH+VV and HH-VV channel combinations. If this is interpreted as a negligible elevation spread of different scattering mechanisms, with a simultaneous presence of co-polar differential phase, one could assume a surface like scattering below a certain height of snow, acting as an anisotropic medium. The high accumulation regime in south-east Greenland [6], combined with the typical glacier facies at the ice sheet margin, support this first assessment, which indicates the potential for estimating accumulation patterns. Unfortunately, the sparse availability of in-situ data hampers the interpretation of SAR signatures. Future work will focus on investigating these first hypotheses and the identification of suitable observables of dual-pol TanDEM-X measurements in relation with accumulation or changes in snow structure, which could support a better characterization of glacier mass balance.

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