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Spatial and temporal variability of snowpack depth on Svalbard glaciers from GPR and POLSAR measurements

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The behaviour of snow depth (SD) with several polarimetric parameters at the L-band is studied. Fully polarimetric SAR data from ALOS-2/PALSAR-2 was used to generate the polarimetric coherence and 6SD decomposition powers. These parameters are studied with the help of the ground-truth GPR measurements that were carried out in near real-time. The resolution of GPR measurements are reduced to match the resolution of the SAR products. After relating the SD with the polarimetric parameters, the following results are obtained.

The firn areas demonstrate variations in scattering powers, especially in the compound scattering powers, which is indicative of the heterogeneity of the medium and the associated anisotropy effect. Four different polarimetric parameters have been introduced to show their relationship with snow depth. Among them, the co-polarization coherence (between HH and VV) and the ratio of volume to double-bounce scattering powers show a good correlation with the snow depth.

A negative correlation is found with the double-bounce scattering power. This relationship is tested with two sets of GPR points, i.e., the ones used for testing as well as the set used for validation. The study is taken further by introducing a snow depth inversion algorithm using the combination of these polarimetric parameters. Among the univariate models for SD inversion, inputs with polarimetric coherence performed the best while the combination of coherence with normalized volume and double-bounce scattering powers demonstrated the power of the multivariate SD inversion process. An R^2 of 0.84 and RMSE of 0.18 are obtained with these inversions. The inverted SD using POLSAR data are also validated with the ground-based GPR measurements, showing a fairly good agreement. The error map generated between the POLSAR inverted SD and GPR measurements indicated positive errors near the terminus and negative errors to the south-west part of the Austre Grønfjordbreen.

While shallow depth snow accumulation explains the positive error difference, uncertainty in the extrapolation of the field points could provide a plausible explanation for the negative errors. We have even extended the analysis to demonstrate the spatial and temporal variability in snowpack depth estimated over the entire Western Nordenskiöld Land region. This is performed using multi-temporal POLSAR data that span over three different dates with varied snow precipitation conditions. Between 13 April 2015 and 15 May 2015, four to five significant snowfalls were recorded. Due to this, the SD on 15 May 2015 is greater than on 13 April. The increase in snow depth due to some heavy snow precipitation events is well captured by the proposed inversion equation using the POLSAR data. The proposed methodology is useful in continuous monitoring of the spatial and temporal variability of snow cover depth. However, it is noticed that when the snow thickness is less than 0.75 m near the terminus, the discrepancy between POLSAR and RES interpolated snow thickness (depth) is more than 1.2 m, covering 8.7% of total glacier area. This issue with the proposed method related to shallow snow depth retrieval can be addressed in the near future.

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