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Obtaining 3d models of surface snow and ice features (penitentes) with a Xbox Kinect

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Penitentes are snow or ice spikes that can reach several metres in height. They are a common feature of snow and ice surfaces in the semi-arid Andes as their formation is favoured by very low humidity, persistently low temperatures and sustained high solar radiation. While the conditions of their formation are relatively well constrained it is not yet clear how their presence influences the rate of mass loss and meltwater production from the mountain cryosphere and there is a need for accurate measurements of ablation within penitente fields through time in order to evaluate how well existing energy balance models perform for surfaces with penitentes.

The complex surface morphology poses a challenge to measuring the mass loss at snow or glacier surfaces as (i) the spatial distribution of surface lowering within a penitente field is very heterogeneous, and (ii) the steep walls and sharp edges of the penitentes limit the line of sight view for surveying from fixed positions. In this work we explored whether these problems can be solved by using the Xbox Kinect sensor to generate small scale digital terrain models (DTMs) of sample areas of snow and ice penitentes. The study site was Glaciar Tapado in Chile (30°08'S; 69°55'W) where three sample sites were monitored from November 2013 to January 2014.

The range of the Kinect sensor was found to be restricted to about 1 m over snow and ice, and scanning was only possible after dusk. Moving the sensor around the penitente field was challenging and often resulted in fragmented scans. However, despite these challenges, the scans obtained could be successfully combined in MeshLab software to produce good surface representations of the penitentes. GPS locations of target stakes in the sample plots allow the DTMs to be orientated correctly in space so the morphology of the penitente field and the volume loss through time can be fully described.

At the study site in snow penitentes the Kinect DTM was compared with the quality of DTMs obtained using (i) terrestrial laser scanning (TLS) from multiple fixed positions and (ii) photogrammetry processed with Visual Structure from Motion software (VSfM). At the study site on the glacier the Kinect DTM was also compared to manual measurements of multi-point surface lowering. We found that the Kinect method is capable of producing more complete DTMs than TLS or VSfM, and that the representativeness of manual measurements is strongly dependent on the measurement location.

In conclusion, we successfully produced the first detailed surface scans of penitentes and their changes through time, and determined that the Kinect sensor offers a useful tool for determining surface roughness parameters over snow and ice that are needed as inputs for surface energy balance modelling.