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# Close range photogrammetry reveals recession pattern of Kilimanjaro ice cliffs

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Ice cliffs, up to 50 m high, have been a persistent feature at the plateau glaciers of Kibo (5895 m a.s.l.) - at least since the 1880s. Too steep for snow accumulation and too low to enable ice flow the cliffs continuously recede due to sublimation and melt. Consequently, the plateau glaciers shrink and areal glacier decline cannot be directly linked to climatic changes.

Our aim is to quantify the different drivers of the recession and to assess the ice cliff sensitivity. A process-based energy and mass balance model of the cliff surface is being developed and will help to increase our understanding of the micro-meteorological processes in the dry, high altitude boundary layer between the near-vertical ice cliffs and the flat, dark ash ground.

Model calibration and testing is only possible when the recession rate is known at sufficient temporal and spatial resolution. During four field campaigns (January and October 2009, March and October 2010) terrestrial photogrammetry was used to survey a ca. 60 m wide part of the cliffed margin of the Northern Ice Field on Kibo. Calibrated DSLR cameras (Nikon D2X and D200) and photogrammetric software (Photomodeler 2010) were used for automatic stereo matching, and point meshes of the cliff surface with typical minimal point distances of about 5 cm could be derived for all four survey dates. The "study cliff" on the whole turned out to be around 69° steep and facing towards south-southeast.

Gridded digital surface models at 10 cm resolution were calculated in order to compare the cliff location within a fixed reference system between the four different dates. This provides a laminar picture of the changes at the cliff between the consecutive surveys. Small scale variations in aspect and slope as well as alterations in the surface roughness can be quantified. Additionally, recession rates can be studied as a function of aspect, slope, height above ground, and insolation.

We expect the recession pattern to be bimodal during one year because of insolation modeling and point measurements. Preliminary results of the photogrammetric surveys support this expectation but also add more insight into the pattern of the changes: A slight steepening of the ice cliff during the period with high insolation seems to be detectable (high recession rates ($\sim$ 1 m) in the lower section of the cliff and low rates (a few cm) in the section high above the ash ground). The opposite tendency is seen during the "shaded phase". An error analysis of the applied methods is on the way and will help to support or necessitate the withdrawing of our findings.