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Geomorphic change detection using repetitive topographic surveys and DEMs of Differences: Implementation for short-term transformation of the ice-cored moraines in the Petuniabukta, Svalbard

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The exposed glacial forelands are supposed to be intensively transformed by geomorphological processes due to the paraglacial adjustment of the topography. To recognize how high is the activity of such processes, we monitored the transformation rates of ice-cored moraines on the forelands of two glaciers, Ebbabreen and Ragnarbreen, both of which are located near the Petuniabukta at the northern end of the Billefjorden. The main objectives were to: (1) analyse the spatial and temporal aspects of debris flow activity in cm-scale, (2) quantify the short-term (seasonal and intra-seasonal) rate of volume changes, (3) compare transformations of the ice-cored moraine surfaces due to active geomorphic processes (including dead-ice backwasting and debris mass movements) with transformations caused by dead-ice downwasting only.

The short-term (yearly and weekly) dynamics of mass-wasting processes were studied in a cm-scale using repetitive topographic scanning. In total, four different locations were scanned, containing seven active debris flows or other mass wasting processes, and including non-active surfaces. Sites were chosen to ensure representation from different parts of the end moraine, different types of dominant processes (debris flows, debris falls, etc.) as well as different types of morphology (exposed ice cliffs, steep debris slope, gentle debris flows lobes, etc.). Altogether, the total scanned area was about 14,200 m^2, of which 5,500 m^2 were transformed by the active mass movement processes. Ten measurement sessions were carried out: three in summer of 2012, three in summer of 2013, and four in summer of 2014, which allowed for assessing the seasonal (annual) and intra-seasonal (weekly) variations. The results of the surveys in the form of cloud points were used to generate digital elevation models (DEMs) with cell size 0.05 m. Subtracting DEMs from subsequent time periods created DEMs of Differences – DoDs, which enabled us to investigate the volume of and spatial patterns of transformations.

The surveys indicate high dynamic rates of landforms' transformations. The mean annual volume loss of sediments and dead-ice for the most active parts of the moraines was up to 1.8 m a^{-1}. However, most of the transformation occurred during summer, with the short-term values of mean elevation changes as high as -104 mm/day. In comparison, the dynamics of the other (i.e. non-active) parts of the ice-cored moraines were much lower, namely, the mean annual lowering (attributed mainly to dead-ice downwasting) was up to 0.3 m a^{-1}, whereas lowering during summer was up to 8 mm/day. Our results indicate that in the case of the studied glaciers, backwasting was much more effective than downwasting in terms of landscape transformation in the glacier forelands. However, despite the high activity of localised mass movement processes, the overall short-term dynamic of ice-cored moraines for the studied glaciers was relatively low. We suggest that as long as debris cover is sufficiently thick (thicker than the permafrost's active layer depths), the mass movement activity would occur only under specific topographic conditions and/or due to occurrence of external meltwater sources and slope undercutting. In the other areas, ice-cored moraines remain a stable landsystem component in a yearly to decadal time-scale. Our results support the hypothesis of a spatio-temporal switching between stable and active conditions within an ice-marginal environment.

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