Earth Surf. Dynam. Discuss.,
https://doi.org/10.5194/esurf-2020-55-AC1, 2020

Interactive comment on "Disaggregating surface change mechanisms of a rock glacier using terrestrial laser scanning point clouds acquired at different time scales" *by* Veit Ulrich et al.

Veit Ulrich et al.

v.ulrich@stud.uni-heidelberg.de

Received and published: 3 August 2020

Dear Reviewer 1,

Thank you for your constructive and thorough review, which we highly appreciate particularly during the fieldwork period and the pandemic situation. In the following, we would like to give a first response concerning your general comments. Please do not hesitate to reply and keep the discussion ongoing, and to contact us directly via email if you wish. We will address all of your specific comments and straightforward corrections in the full revision.

Printer-friendly version

Discussion paper

We learnt from your response and agree with your main assessment that our objective and argument with respect to drivers behind the observed change and the "causal" disaggregation of processes can be misunderstood. Our objective is to develop and explore a method for multidirectional 3D change analysis over different (overlapping) periods, which can be used for any 3D point clouds - not only LiDAR. The findings in our paper will help in developing future observation networks, where our approach centres on analysing the 3D surface change signal over time. We cannot and we do not aim in this paper to identify the underlying drivers and triggers that cause the observed, indeed potentially superimposed, surface change. We aim to separate and identify the different multidirectional change but have to leave the explanation open due to lack of long-term dense monitoring data of surface, subsurface and environment conditions. We will reformulate our paper in the full revision to clarify this element.

Bernhard Höfle and Veit Ulrich on behalf of all authors

Time-lapse imagery/photogrammetry/higher temporal resolution within three-week period

In an ideal setting we would have multiple sensors to acquire point clouds of the rock glacier that complement each other in terms of platform (i.e. diversity in viewing angle), spatial and temporal resolution, spatial coverage, direct vs. indirect georeferencing, and of course having a dense sensor network for surface, subsurface and environmental conditions (such grant proposal should be funded in the future!). The issue of how to measure surface change and how to analyse it is a crucial step that warrants deeper investigation. Surface change values are usually quickly computed with standard methods, with a meaningful understanding of the types of change they actually represent (and the drivers they could be correlated with) more difficult to gain. We therefore consider our method to be of value in creating the basis for future observation systems of rock glaciers, by covering the part of multidirectional 3D surface change analysis over different (overlapping) epochs. We would like to provide differentiated surface change data to be able to link them properly to models and other observational data in the future. For this, it would also be interesting to achieve a higher temporal resolution and we could certainly gain additional information from time-lapse imagery/photogrammetry. With higher frequency, however, the problem of how to quantify change (over varying timescales) and how to interpret it without mixing change components remains the same. We contribute exactly to this gap. Our findings support that three weeks are a suitable monitoring interval for separating these surface changes with the proposed method (lines 225 ff.) and we do not expect a gain in information from higher frequency due to the low change rates in relation to the measurement accuracy (for LiDAR as well as photogrammetry).

Linking spatial patterns of change to drivers (precipitation etc.) and/or subsurface information

See comments above. The focus of our manuscript lies in the benefit of deriving 3D surface changes at different timescales and considering change in different directions (as opposed to only local normal direction, as is done by M3C2), which we see as a fundamental step to derive useful surface change values that can be used as input in such comprehensive and interdisciplinary rock glacier studies.

Inconsistency of boulder movement interpretation

We examine two main areas exhibiting two different types of boulder movement. At the rock glacier front (active zone 1), there is both gravitative movement of single boulders and boulder movement in flow direction, reflecting rock glacier creep. On the rock glacier surface (active zone 2), there is only boulder movement in flow direction reflecting rock glacier creep, which is why we can use boulder movements in this zone as an indicator for change in the flow direction. We agree that the distinction between these two areas, the different types of boulder movement in these areas, and the way we used the boulders as indicators for rock glacier flow is not clear and will revise these parts of the manuscript.

Overplaying of interpretation of annual data

As already outlined above, our aim is to develop a method for disaggregating surface changes (and not disaggregating and explaining the underlying drivers) using data acquired at shorter timescales. For comprehensive rock glacier monitoring, we would propose repeat measurements at the beginning and end of snow-free periods and in between (e.g. every three weeks). This would allow us to link observed changes to physical processes and their drivers.

Independent checks of data registration accuracy

Checks of data registration accuracy were carried out by measuring robust cloud-to-cloud distances between the point clouds in stable test areas (e.g. rock faces) outside the rock glacier tongue. We will include information about this in the revision.

Interactive comment on Earth Surf. Dynam. Discuss., https://doi.org/10.5194/esurf-2020-55, 2020.