Insights on rock mass disintegration at the Moosfluh slope, Switzerland

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1. Introduction

The Moosfluh slope, located in the vicinity of the current tongue of the Great Aletsch glacier, Switzerland, hosts one of the largest active instabilities of the European Alps. Despite at this location accelerated slope displacement has been detected over the past decades (Strozzi et al., 2010), the rapid evolution observed between September and November 2016, locally reaching tens of meters, was largely unexpected. During this “crisis phase”, the rock mass experienced substantial internal deformation mainly composed of toppling, formation of tensile scarps, and basal sliding (Glueer 2019). The large internal deformation caused also several local failure events in the form of single block falls and/or rock mass collapses of moderate size. Here we focus on the post-crisis phase, i.e. the period going between spring 2017 until today. The deformation occurring at the Moosfluh slope is still large and rock failure events are regularly going on. We show the first results obtained by jointly investigating terrestrial imagery, as well as the data recorded from a local seismic network. The dataset presented here is unique, and allows for a detailed interpretation of rapid spatial and temporal rock mass disintegration in an alpine slope. Our results are of interest to understand mutual influences between predisposing slope instability factors (i.e., mainly due to geological, structural, and geomorphological conditions), and external driving factors (i.e., seismicity and meteo-climatic effects) on the progressive evolution of rock mass, specifically at the Moosfluh slope but also in similar case scenarios.

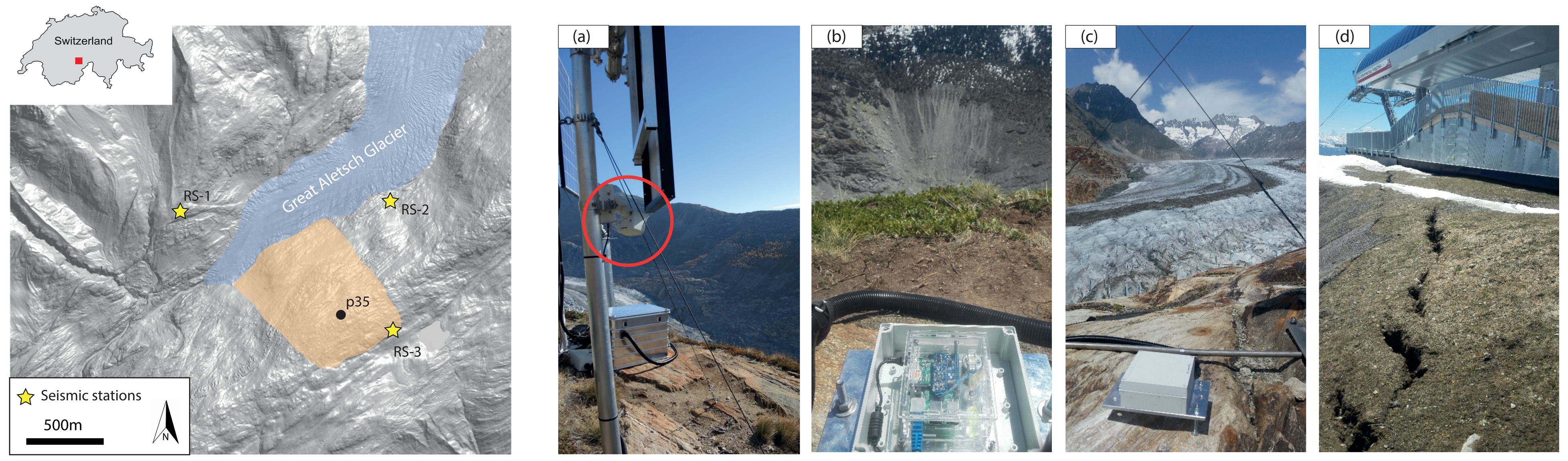

Fig. 1: Map of the area of investigation with indication of the location of the three seismic stations (RS stands for RaspberryShake) installed starting from May 2017 (RS-1 installed on 19 May 2017, RS-2 installed on 27 June 2017, RS-3 installed on 03 July 2017). (a) Mobotix M25 webcam (5Mpixel resolution) is installed at the RS-1 location and acquired pictures every 10 minutes. Data is transmitted in real-time to the ETH Zurich servers via GSM network. (b-d) Pictures of the seismometer installation at the three locations. Details about the seismic data acquisition and data quality are reported in Manconi et al. 2018a

2. Workflow

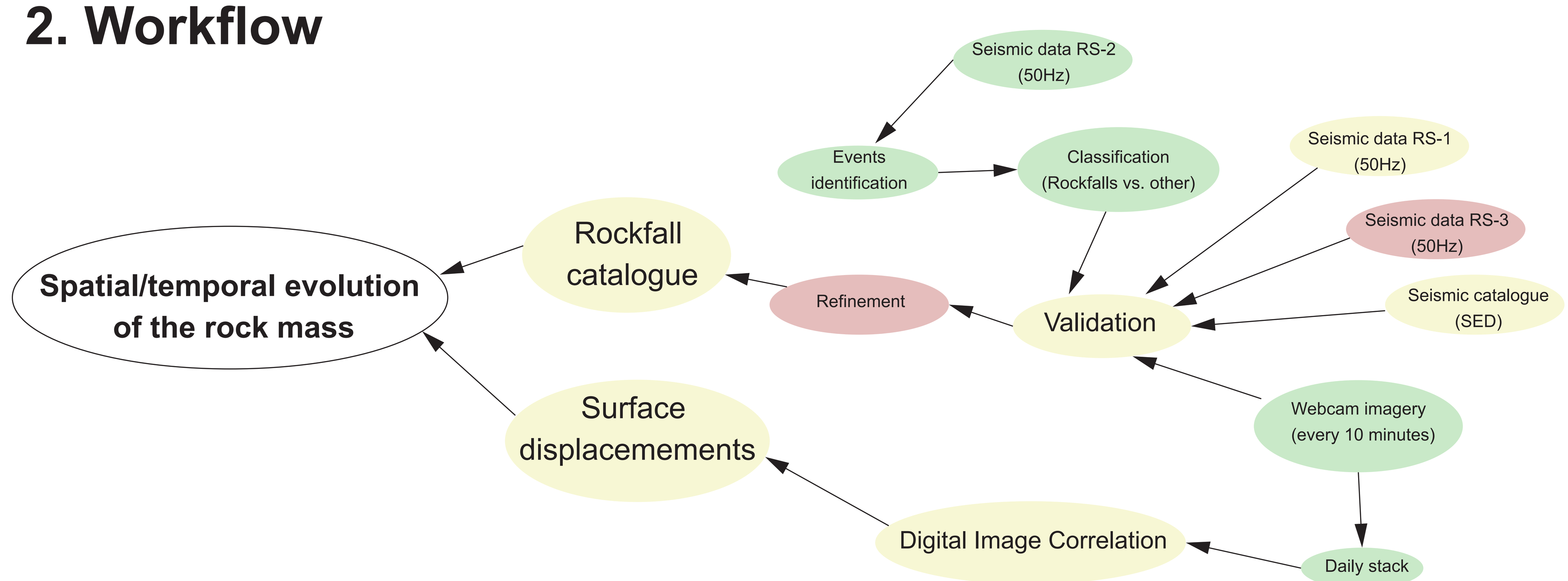

Fig. 2: Flow chart showing the step of the analysis designed to study the spatial and temporal evolution of the Moosfluh rock slope after the large acceleration reported in fall 2016. In green are shown the completed tasks, in yellow ongoing analyses, and in red the taks not yet started.

3. Results

3.1 Slope evolution from time lapse imagery

By using the images acquired every 10 minutes during ca. 2 years (~100,000 total pics), we have generated representative daily images by stacking good pics and excluding images with bad visibility. The images have been combined to produce a time lapse that is useful to follow the evolution of the rockmass during different temporal windows, and to identify and characterize different spatial domains (**scan the QR code on the right and watch the time lapse in youtube!**). In addition, we have also started to process the imagery using Digital Image Correlation (Manconi et al., 2018b; Bickel et al., 2018) to quantitatively measure surface displacement affecting the rock mass during several stages.

https://youtu.be/_SefC58kE-s

3.2 Rockfall catalogue

We have generated a preliminary rock fall catalogue by classifying events detected at the station RS-2 (see position in Fig.1). The automatic detection of events was performed using a standard STA/LTA approach and the classification performed with visual interpretation of both waveforms and spectrograms to distinguish between rockfalls, local and regional earthquakes, teleseisms, and unknown events. This initial catalogue is composed of ~3,500 events for the period 01-Jul-2017 and 15-Mar-2019.

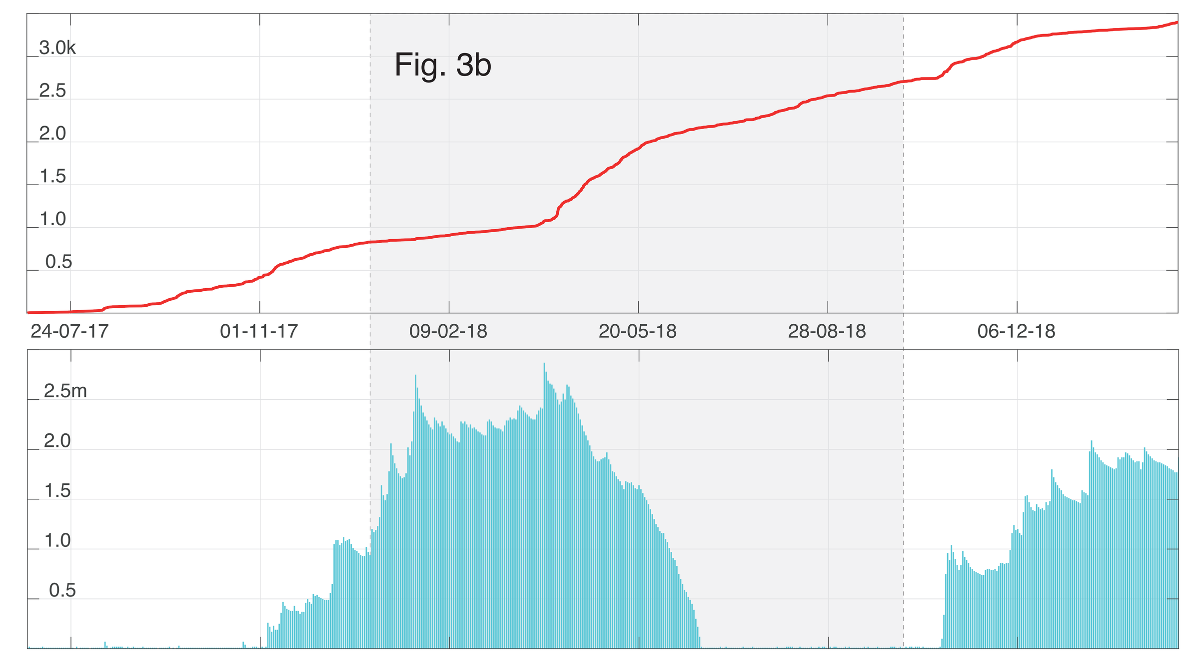

Fig. 3a: (top) cumulative number of rockfall events recorded at the RS-2 seismic station. (bottom) Snow height at the station Heggishorn, representative for the the area of investigation. Sharp increase in the number of the rockfalls coincides with the snowmelt period (April-June 2018), while during winter periods the number of rockfall events decreases substantially. Some increase on rockfall activity is also observed during rainfall events.

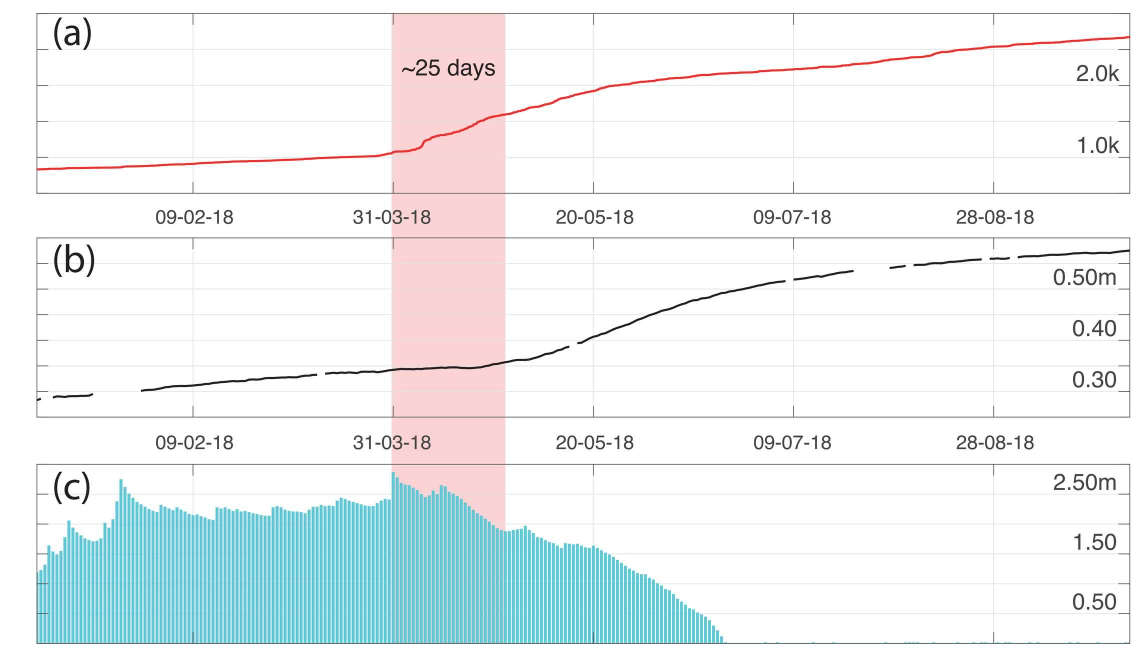

Fig. 3b: (a) Cumulative number of rockfalls (b) 3D surface displacement measured with a robotized total station (Leica MS50, Glueer, 2019) at the point 35 (see location of the target in Fig.1). (c) Snow height. The two signals in (a) and (b) are very similar, however, there is a temporal lag of about 25 days between the increase of rockfall events and the acceleration of surface displacements. The reason of such a delay is under investigation, and might be associated to heterogeneities affecting the slope at different depths influencing the hydraulic response of the rock mass.

3.3 Analysis of Seismic Energy Release (SER) vs. Surface Displacements

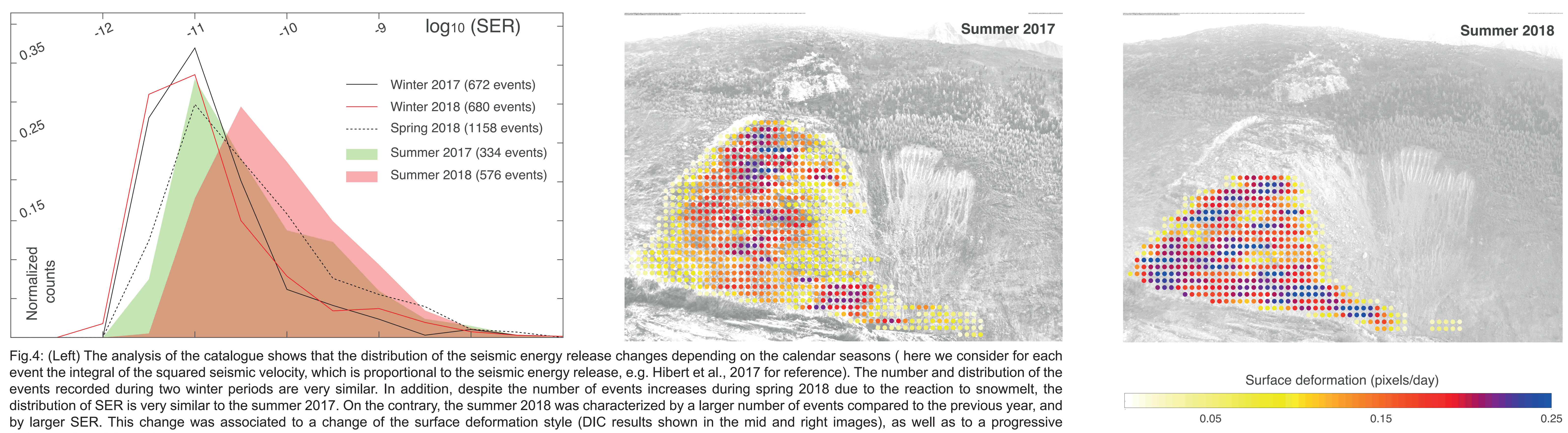

Fig.4: (Left) The analysis of the catalogue shows that the distribution of the seismic energy release changes depending on the calendar seasons (here we consider for each event the integral of the squared seismic velocity, which is proportional to the seismic energy release, e.g. Hibert et al., 2017 for reference). The number and distribution of the events recorded during two winter periods are very similar. In addition, despite the number of events increases during spring 2018 due to the reaction to snowmelt, the distribution of SER is very similar to the summer 2017. On the contrary, the summer 2018 was characterized by a larger number of events compared to the previous year, and by larger SER. This change was associated to a change of the surface deformation style (DIC results shown in the mid and right images), as well as to a progressive disintegration of the rock mass.

4. Outlook

We presented here the initial results of the analysis of a large dataset recorded during ~2 years on the Moosfluh slope instability. Despite preliminary, the information obtained combining data recorded by multitemporal terrestial imagery and local seismic stations already provides interesting insights on the evolution of the rock mass in the period 2017-2019. Further work is aimed at a progressive validation and integration of the two datasets in order to consolidate our understanding on progressive spatial and temporal evolution of the rock mass disintegration over several years.

References:

Bickel et al., 2018: Remote Sens., 10, 865; Glueer 2019, PhD Dissertation, ETH Zurich; Hibert et al, 2017: Earth Surf. Dynam., 5, 283-292; Manconi et al., 2018b: Earth Surf. Dynam., 6, 1219-1227; Manconi et al., 2018a:,Remote Sens., 10, 672; Strozzi et al., 2010: J. Geophys. Res. 2010, 115