Supplement of The Cryosphere, 16, 2083–2101, 2022
https://doi.org/10.5194/tc-16-2083-2022-supplement

The Cryosphere Open Access EGU

Supplement of

Glacier–permafrost relations in a high-mountain environment: 5 decades of kinematic monitoring at the Gruben site, Swiss Alps

Isabelle Gärtner-Roer et al.

Correspondence to: Isabelle Gärtner-Roer (isabelle.roer@geo.uzh.ch)

Figure S1:

Sketch map and position of seismic refraction soundings/BTS measurements at the Gruben site. Note the viscous creep-features D and E in the frozen talus below “Rothorn” and permafrost-free terrain in the glacier forefield with its tographic depression and in places fine material. Reproduced from Haeberli et al. (1979)

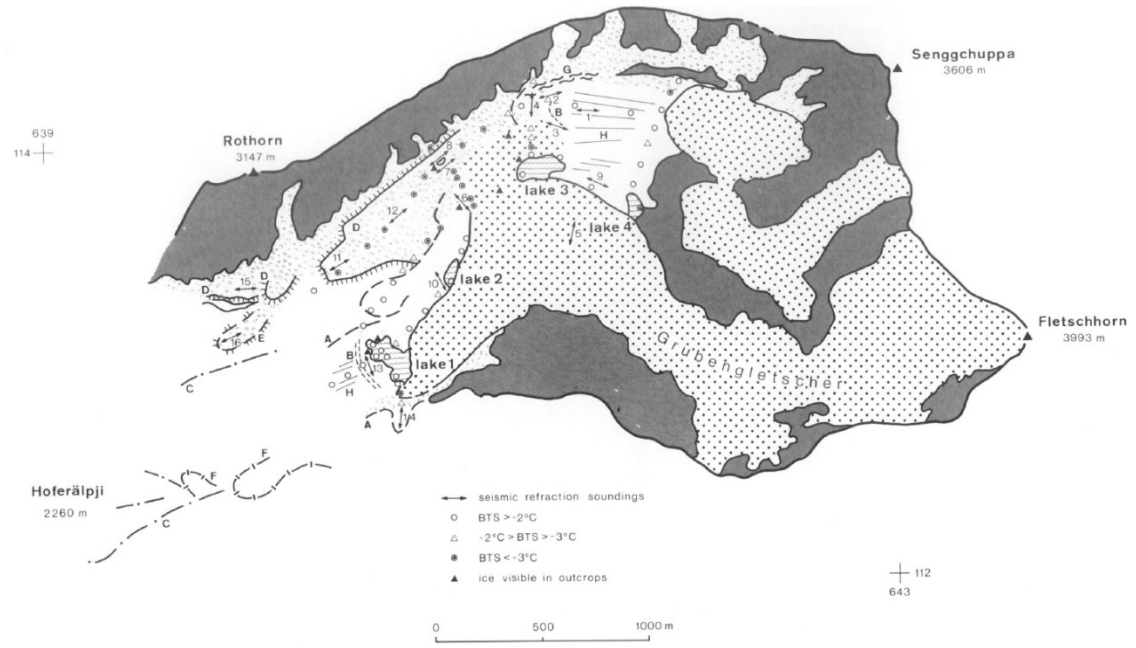

FIGURE 1. Situation at the Grubengletscher. Bedrock is indicated by a dark screen, glacier ice by dots and frozen debris by irregular circles. A—moraines from the maximum glacier extent during Neoglaciation (“1850”); B—small moraines from 1890/1920; C—late glacial moraines; D—active rock glaciers; E—inactive rock glacier; F—fossil rock glaciers; G—Holocene push moraine; H—fluted moraines; BTS—bottom temperature of the winter snow cover; 1, 2, 3 . . . —number of seismic profiles.

Figure S2:

Site of shallow core drilling (Barsch et al., 1979) and center positions of electromagnetic and resistivity soundings on Gruben rock glacier. Reproduced from King et al. (1987).

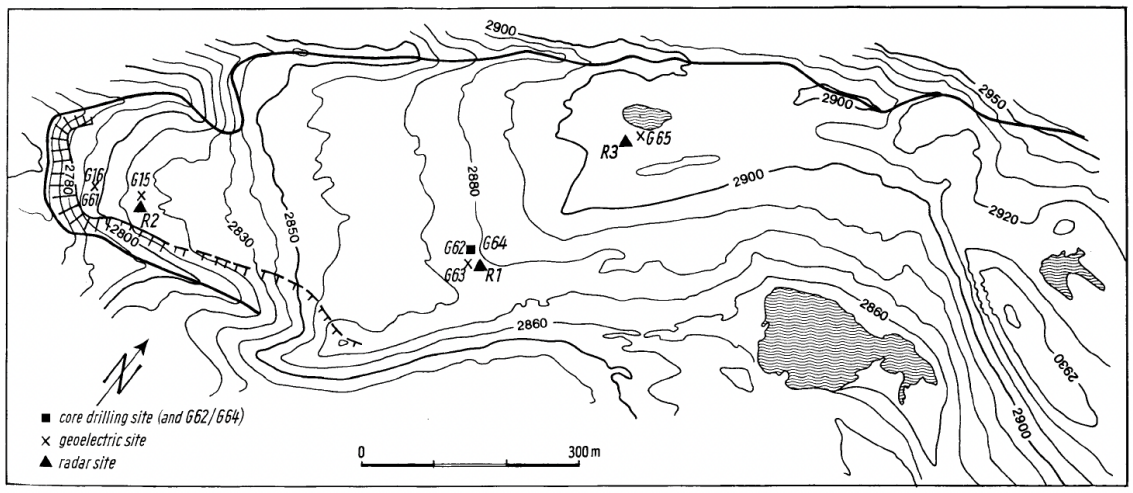

Fig. 2: Contour map of Gruben rock glacier with geoelectrical and radar sounding sites (after Haeberli, 1985)

Figure S3:

Aerophotogrammetrically determined flow trajectories on Gruben rock glacier. Note that the flowlines leading to the continuously advancing rock glacier front initiate in the talus at the foot of the Inner Rothorn. This general flow pattern already observed for the time interval 1970 - 1975 has remained unchanged since then. Reproduced from Haeberli et al. (1979).

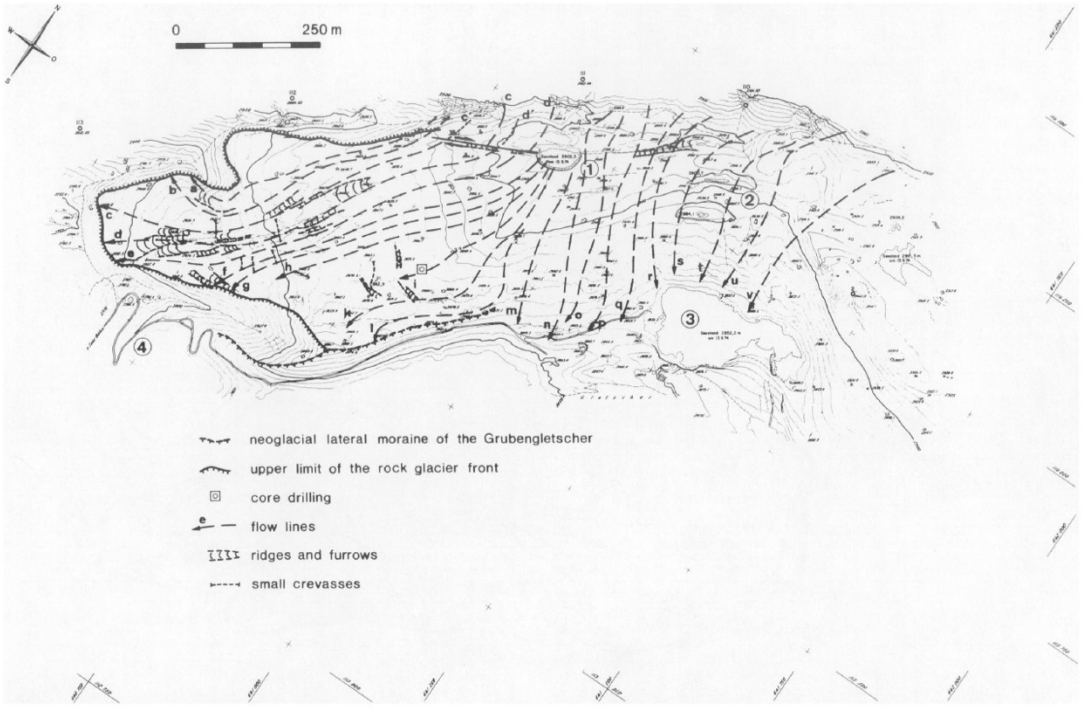

FIGURE 14. Flow lines and surface structure of the rock glacier. See Figure 13 for explanation.

Figure S4:

The earliest reliable topographic map from 1889 of the Gruben site shows the glacier shortly after its maximum LIA extent. Note that the glacier is essentially debris-free (debris-covered ice for the tongue of the “Grosser Triftgl.” is depicted at the bottom of the map) and that the southwestern glacier terminus near P. 2773 has only shrunk back a short distance from the LIA moraine. Gruben rock glacier is evidently but somewhat schematically represented as an ice-free debris (?) body with convex geometry and somewhat diffuse indications of longitudinal structures as indication of long-term flow direction. Other features of viscous permafrost creep in this region had not been recognized at that time.

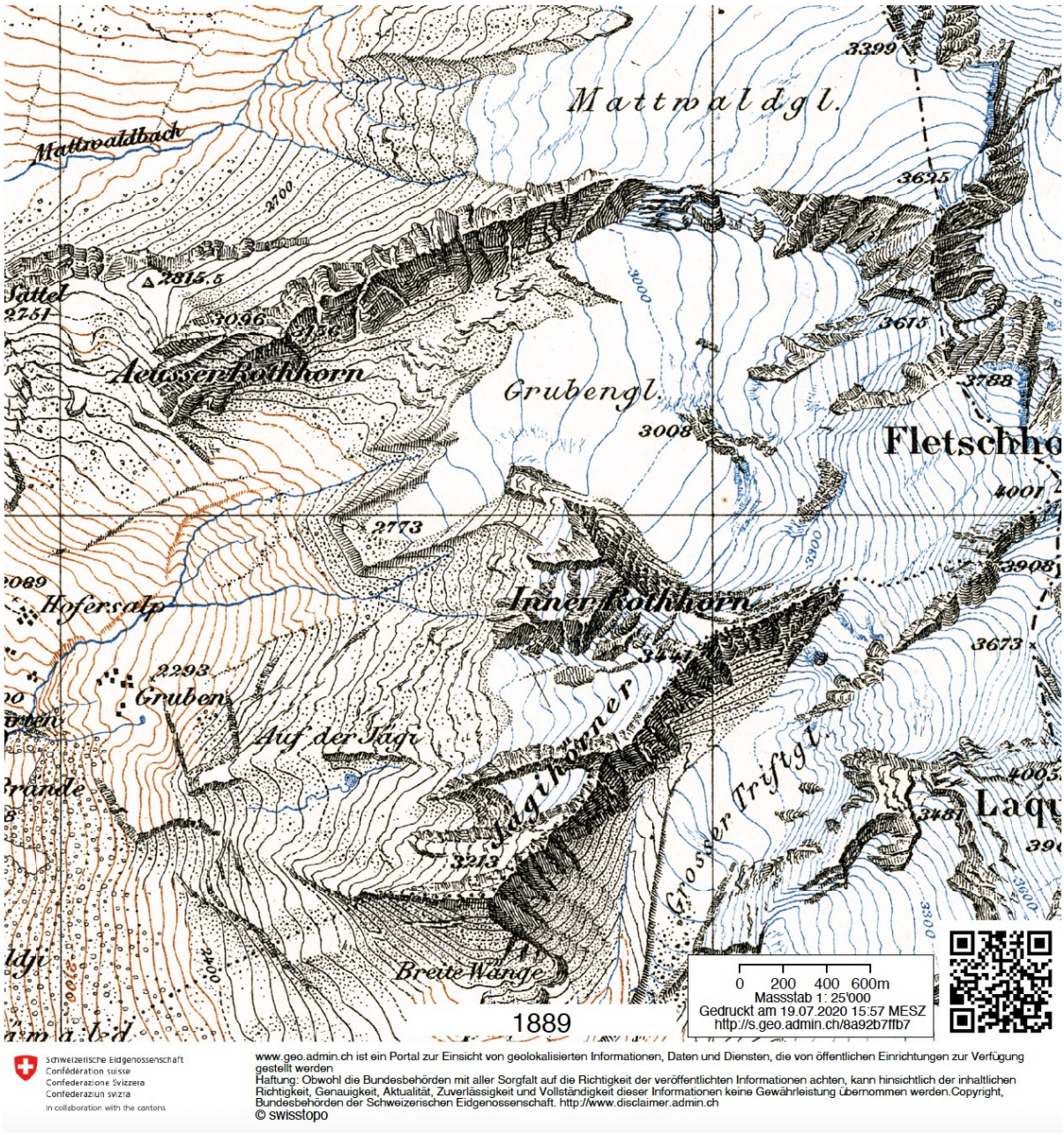

Figure S5:

The first modern, high-precision map from 1971 documents the existence of the lakes 1, 2, 3 and 4 and an obviously newly-formed heavy debris cover on the orographic left part of the glacier as obviously produced by the rock walls to the south of it. Gruben rock glacier as well as other permafrost creep features in the region are represented in fascinating detail, especially with respect to their steep fronts and their surface structures as indications of long-term cumulative deformation. The striking break in slope at the former contact of the glacier with the rock glacier permafrost may perhaps relate to the maximum extent of warm-based ice during the LIA. The later thermokarst lake on the glacier-affected part of Gruben rock glacier does not yet exist.

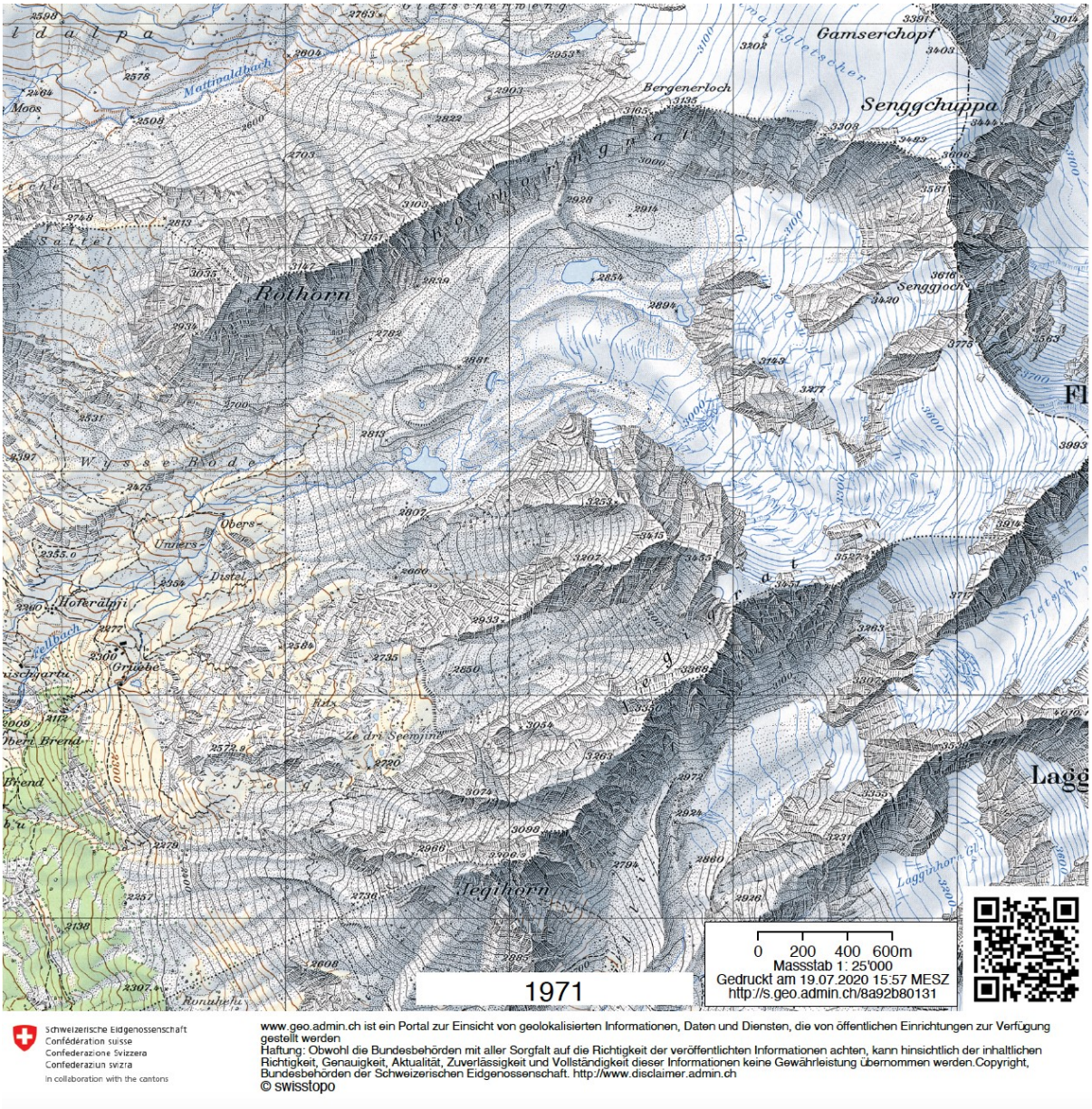

Figure S6:

High-resolution orthophoto 2017 of the Gruben site (source: SWISSIMAGE, geodata@swisstopo). Note the distinct longitudinal flow structures on the periglacial part of the Gruben rock glacier and the more complex deformation patterns in the former contact zone with the LIA glacier. The down-wasting debris-covered tongue of Gruben glacier has a strikingly different geometry/structure. Lakes 1, 7 and 3 (from left to right) are visible

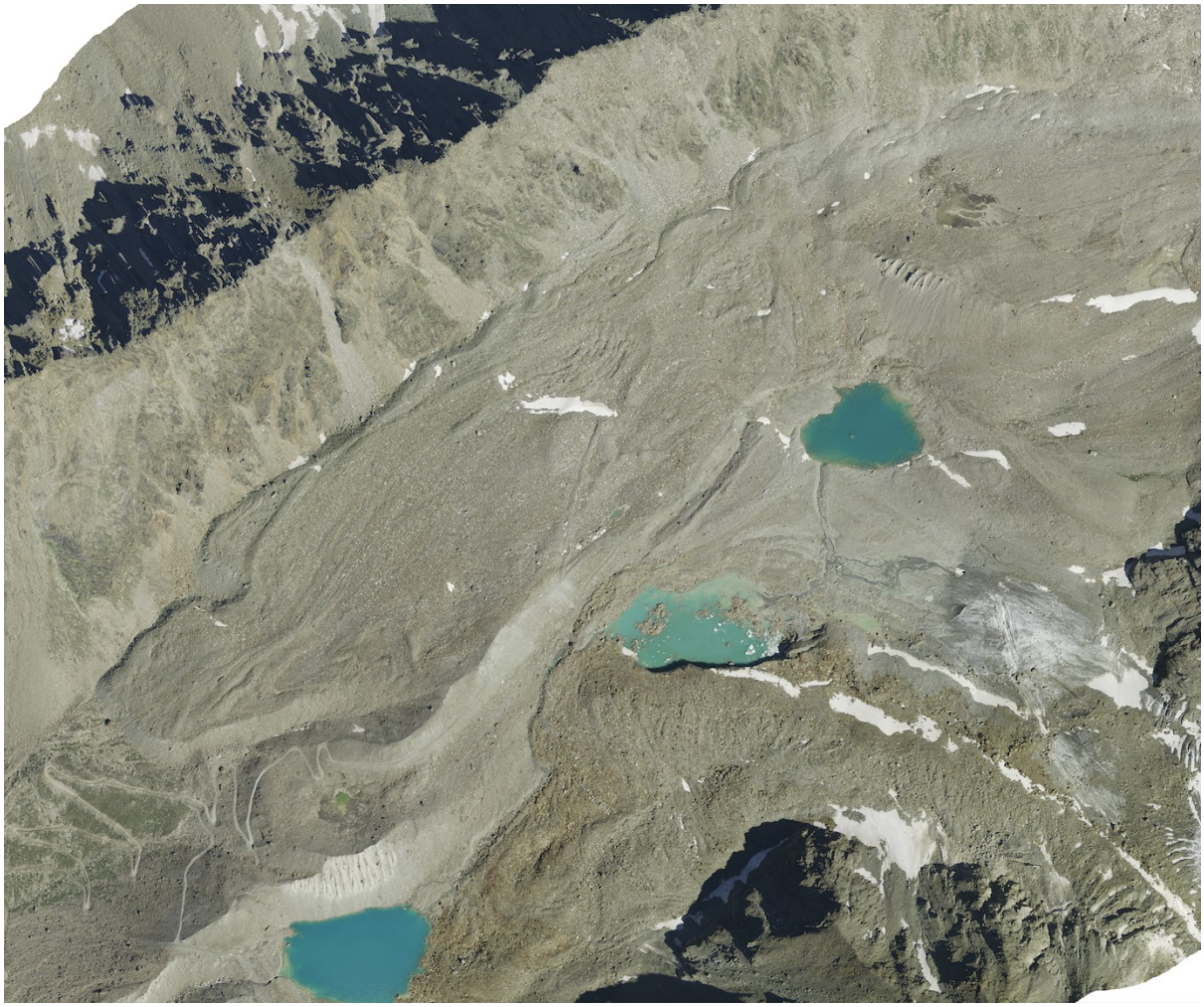

Figure S7:

Spatial permafrost simulation for the Gruben site as extracted from the first spatial permafrost map for the Swiss Alps (2005), published by the Federal Office of the Environment and available from PERMOS. Note that the simulation is well in accordance with the geophysically determined general permafrost pattern at the site and with viscous flow features in the region (cf. S1)

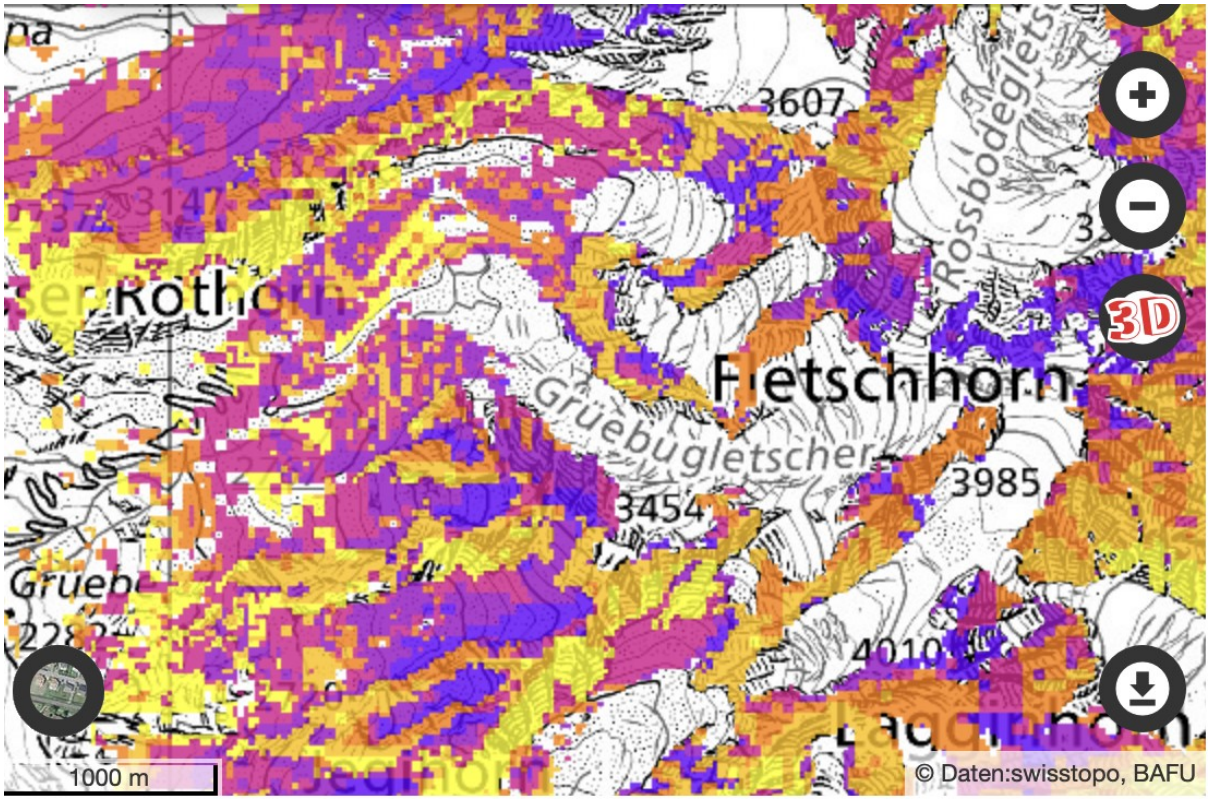

Figure S8:

Spatial permafrost simulation for the Gruben site as published by Kenner et al. (2019) with special consideration of ice-rich materials. Note that the simulation fits observed permafrost conditions well for various features in the region of viscous flow in ice-rich permafrost, including Gruben rock glacier, but produces too high temperatures for the debris-covered tongue of Gruben glacier.