GEORESEARCH

Neun Jahre Felswand-Monitoring
Kitzsteinhorn (2011-2020):

Gletscherrückgang verstärkt hochalpine Steinschlagaktivität

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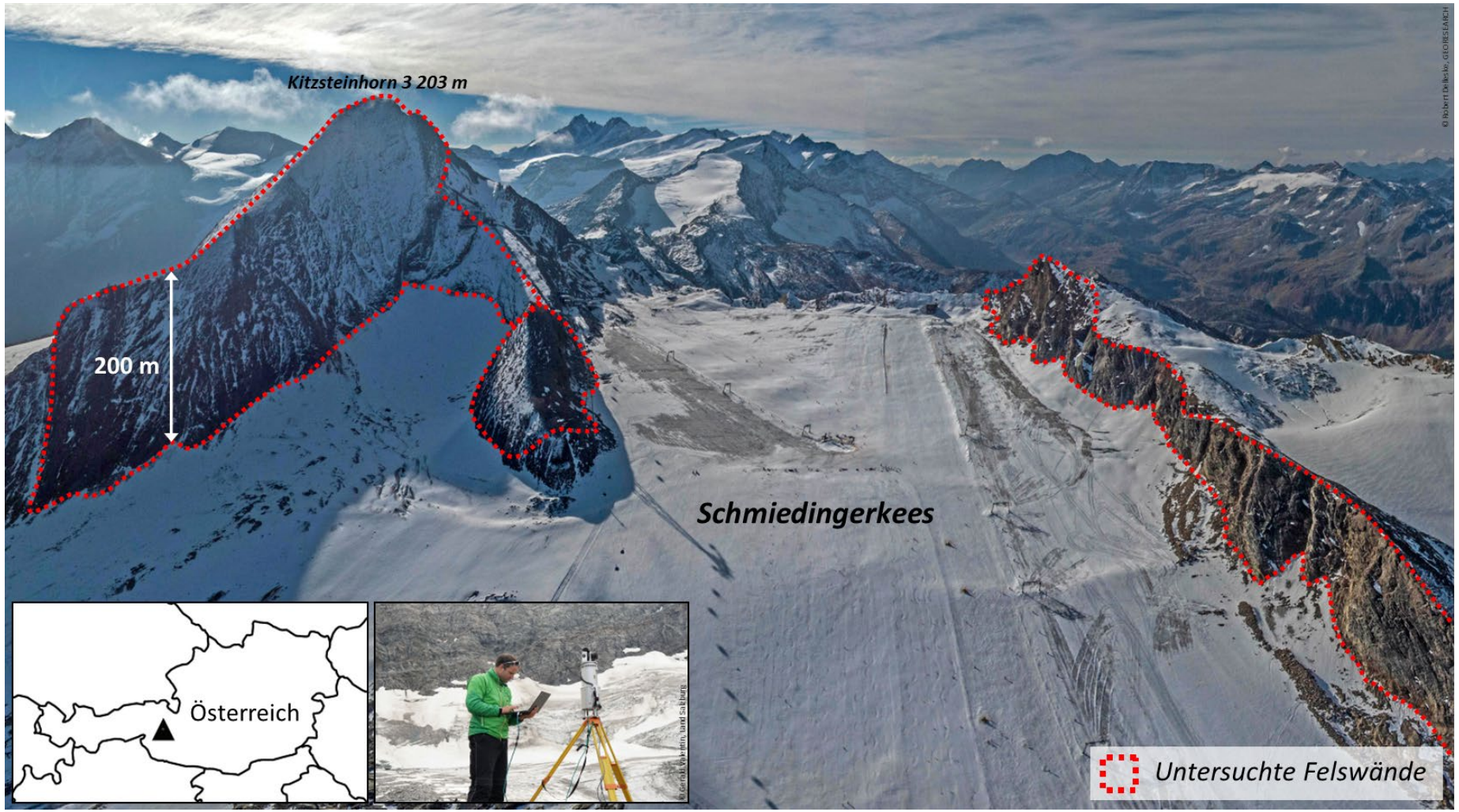
9 INDUSTRIE, INNOVATION UND INFRASTRUKTUR

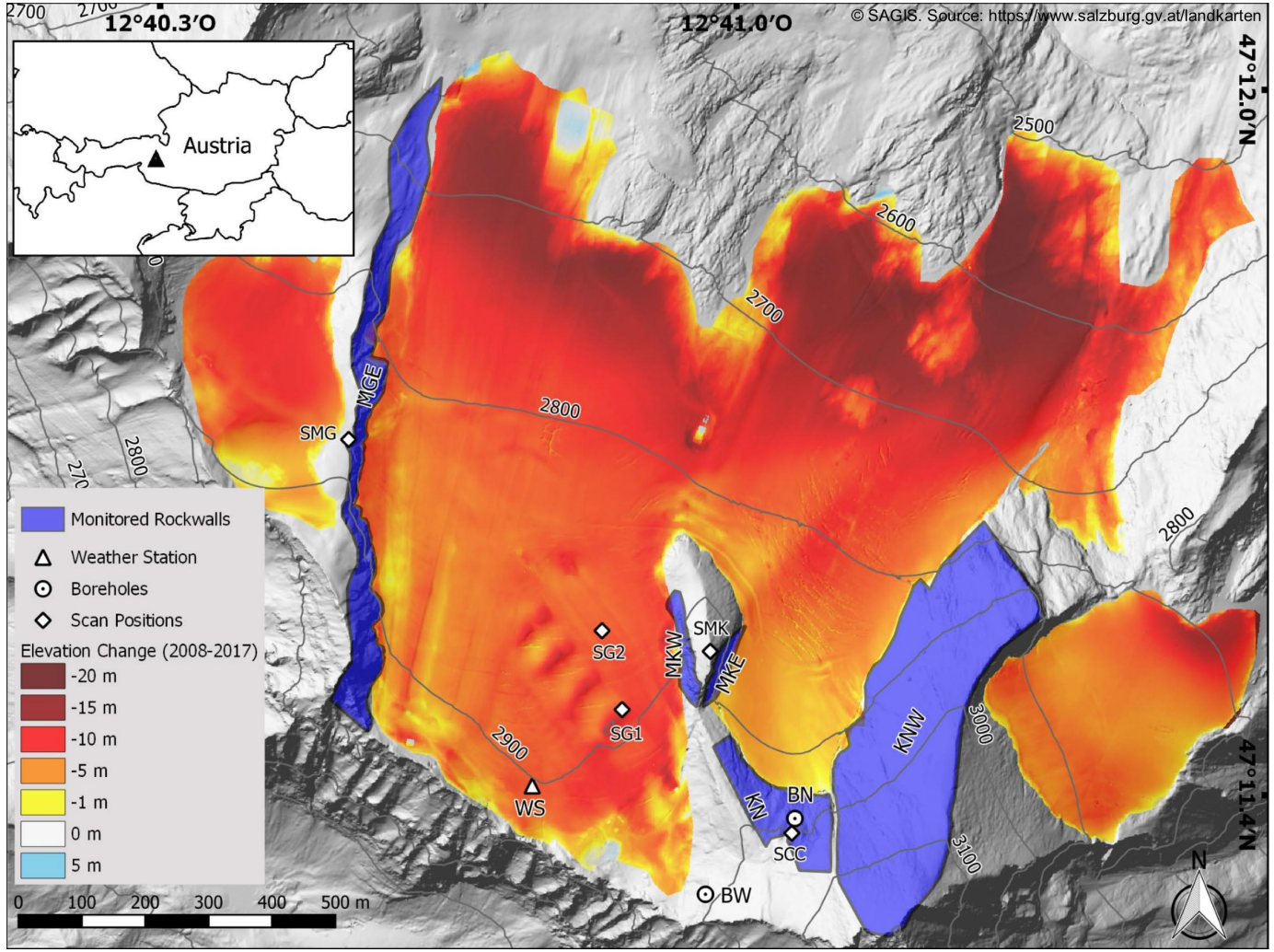
13 KLIMASCHUTZ UND ANPASSUNG

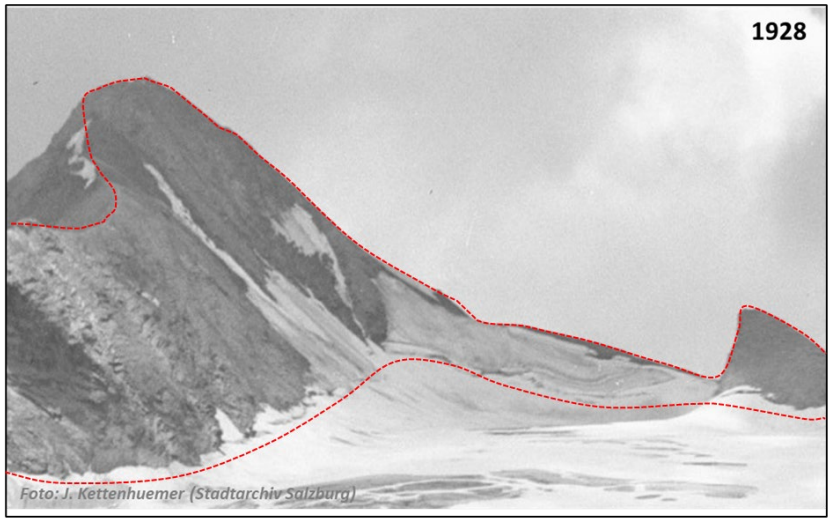
Untersuchungsgebiet Kitzsteinhorn



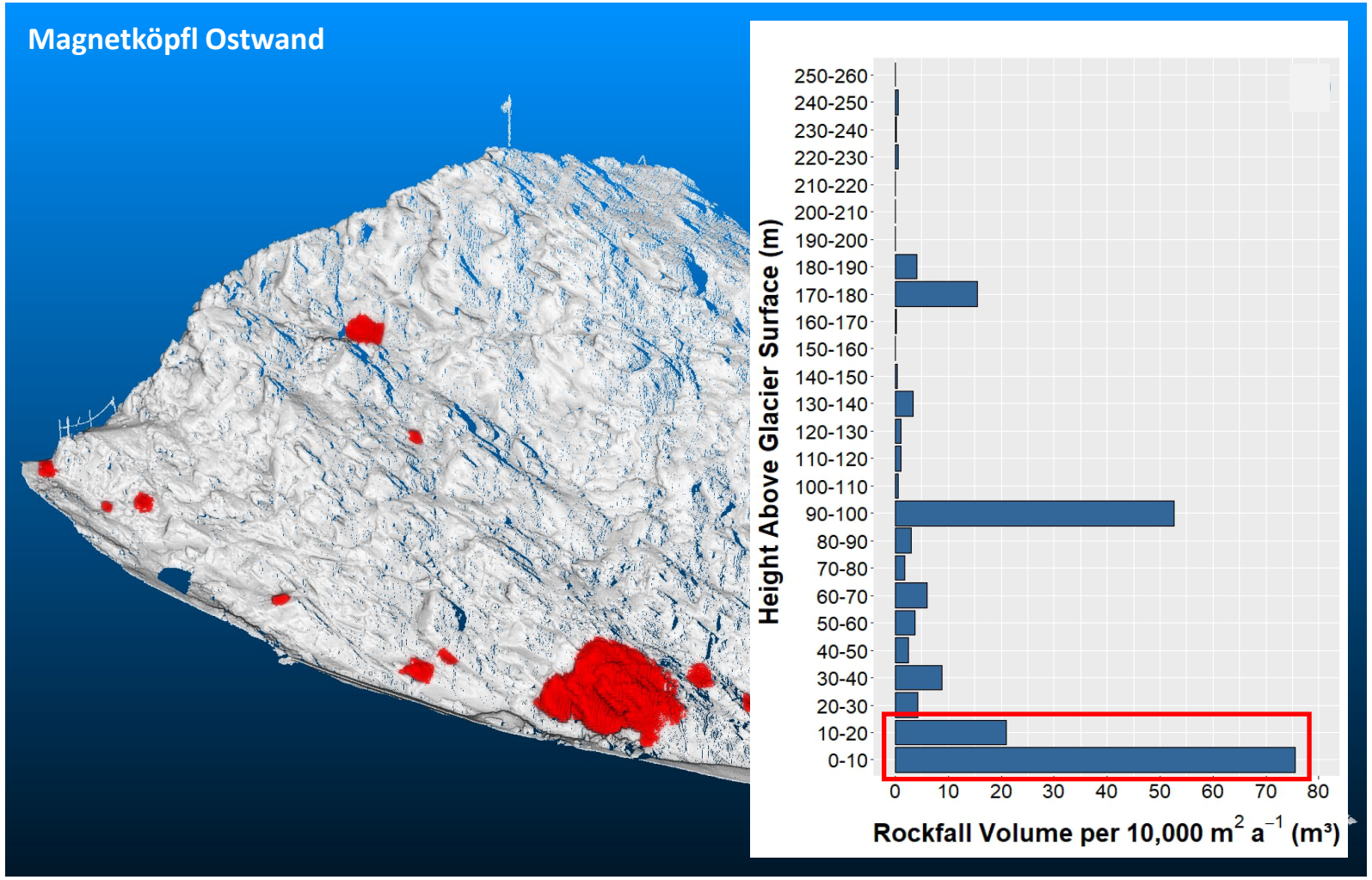
- Überwachung der Rück- und Seitenwände des Schmiedingerkees mittels **terrestrischem Laserscanning** (2011-2020)
- Alle untersuchten Felswände grenzen direkt an den Gletscher
- Untersuchte Felsfläche: **235 000 m²**
- Geologie: **Kalkglimmerschiefer**
- Höhenlage: **2700-3200 m (Permafrost)**
- Hangausrichtung: **N, NW, O**

Gletscherrückgang



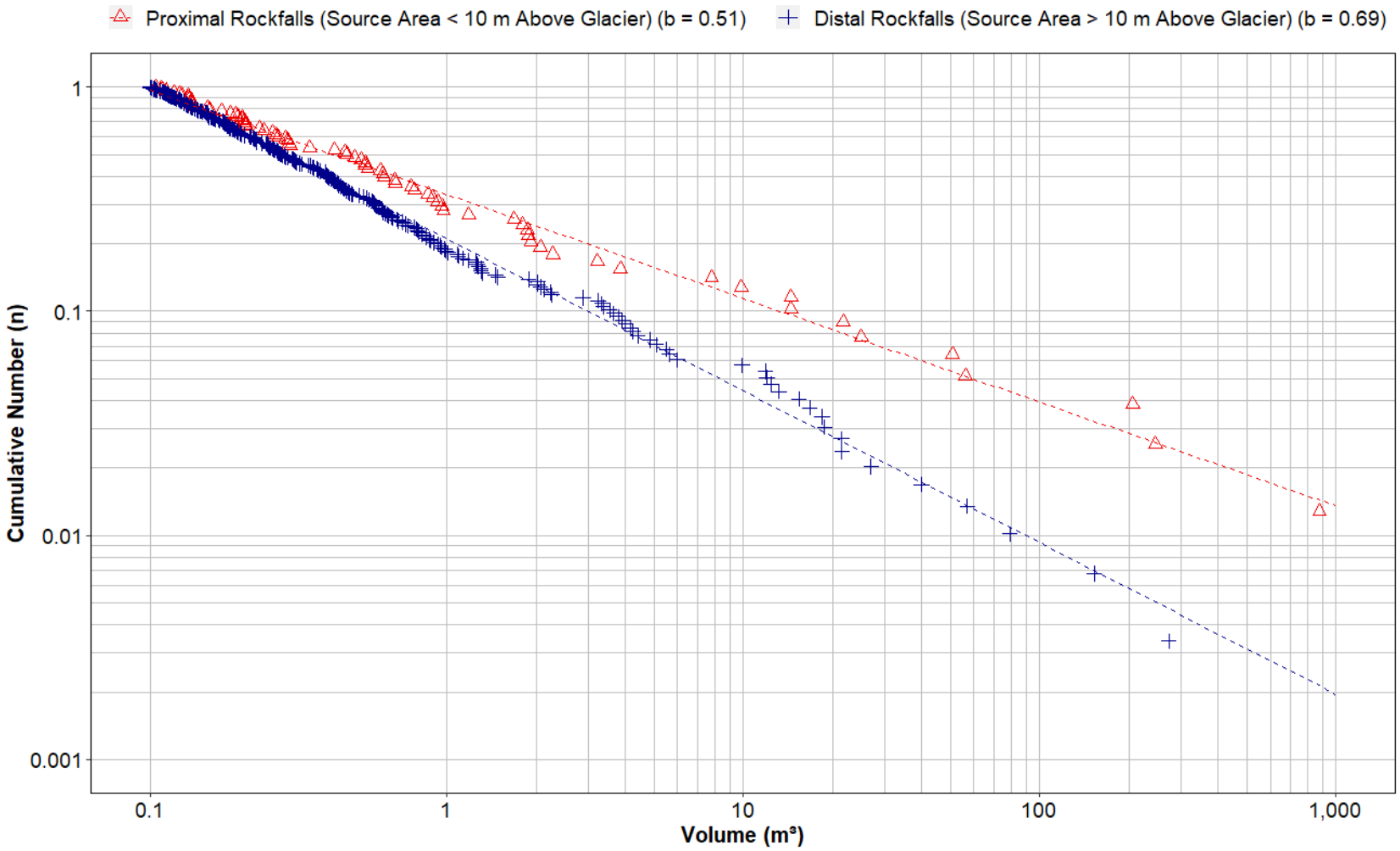


Steinschläge & Felsstürze



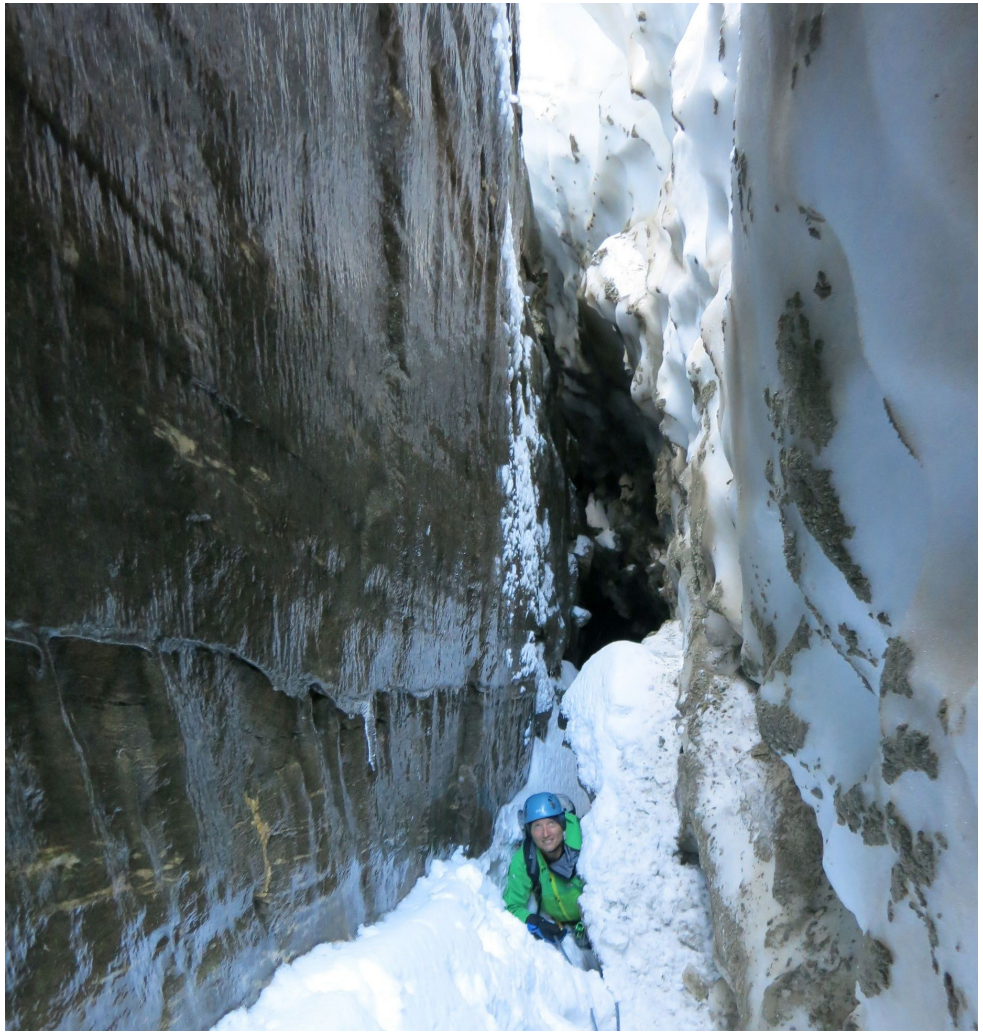
- Erstmals wurde die Reaktion eines ganzen Gletscherkares auf den Eisrückgang mit **hochauflösenden Fernerkundungs-methoden** (Laserscanning) flächendeckend erfasst.
- Das resultierende Inventar beinhaltet **756 Steinschlagereignisse (2011-2019)** mit einem Gesamtvolumen von rund 3100 m³ und ist damit die umfangreichste Dokumentation von hochalpinem Steinschlag weltweit.
- Die Daten zeigen einen klaren Zusammenhang zwischen Gletscherrückgang und Steinschlagaktivität:
  An die aktuelle Gletscheroberfläche angrenzende Felsflächen weisen ein **8x höheres Steinschlagvolumen** auf als die vom Gletscherrückgang unbeeinflussten, höher gelegenen Wandbereiche.

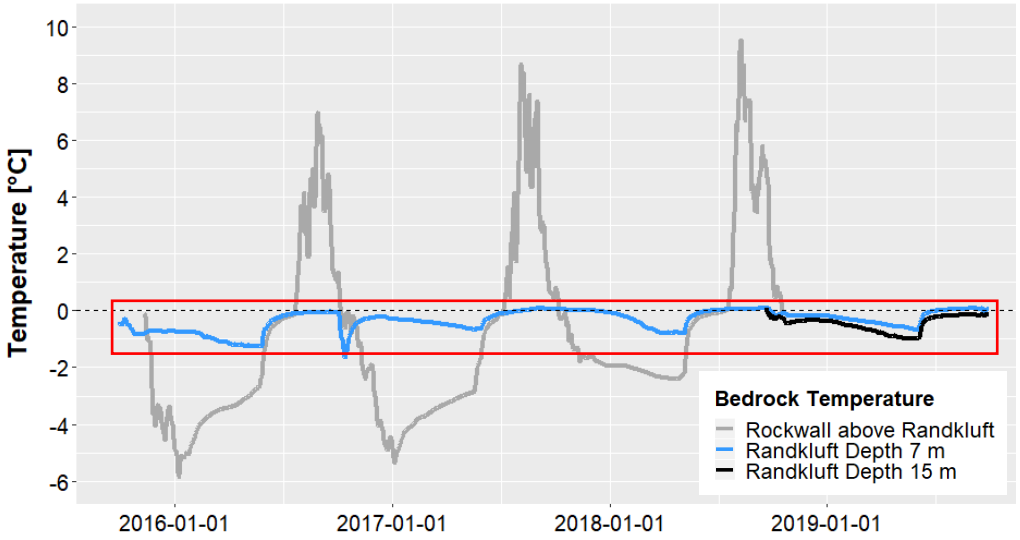
Steinschläge & Felsstürze



- Frequenz-Magnitude-Beziehung der erfassten Steinschläge folgt einem **Potenzgesetz über vier Größenordnungen.**
- Gletschernahe (proximale) und gletscherferne (distale) Steinschläge zeigen **deutlich abweichende raumzeitliche Verteilungen**. In Gletschernähe ist hierbei v.a. eine drastische Zunahme der Ereignisgrößen zu beobachten.
- …d.h. in vom aktuellen Gletscher-rückgang beeinflussten Felswänden verlieren **historische Aufzeichnungen und Inventare ihre Gültigkeit.**

Steinschläge & Felsstürze



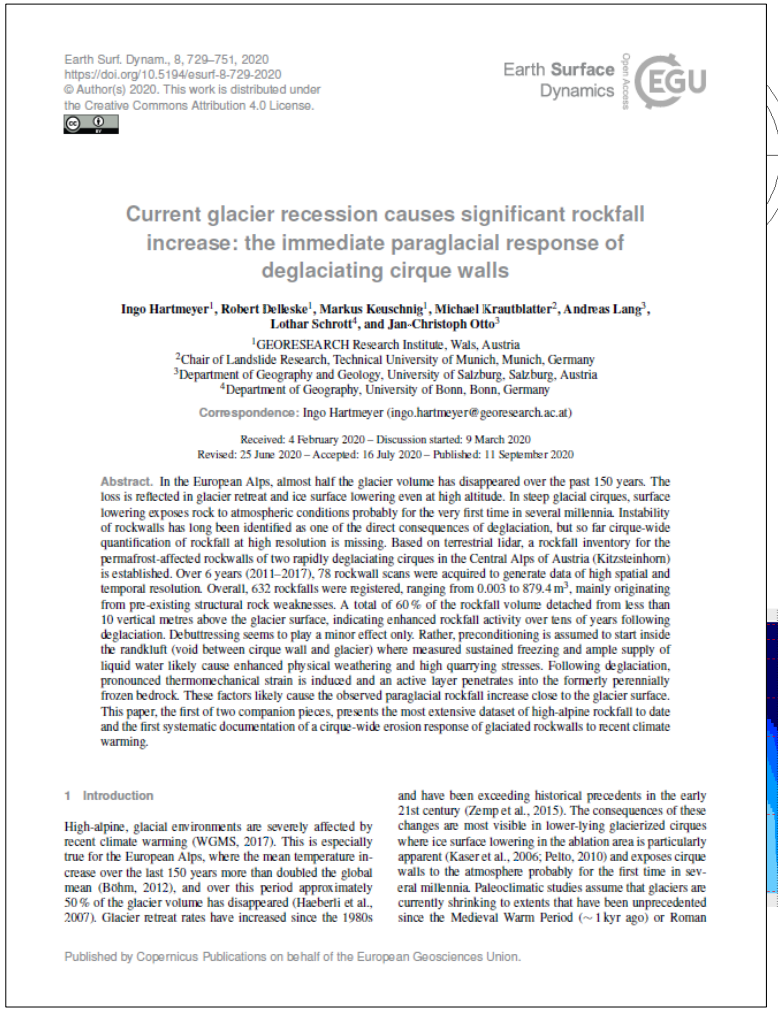


- **Kein glazialer Stützmauereffekt**: Randkluft trennt Felswand und Gletscher.
- Potenziell starke **physikalische Verwitterung innerhalb der Randkluft** (hohe Wasserverfügbarkeit, Dauerfrostbedingungen).
- Starke **thermische Spannungen** und Bildung einer **Auftauschicht** in ‘auftauchenden‘ Felsbereichen.

Zusammenfassung & Referenz

- 9-jähriges Felswandmonitoring (2011-2020) im Rahmen des Open-Air-Lab Kitzsteinhorn.
- > 750 Steinschläge & Felsstürze detektiert (weltweit größter hochalpiner Datensatz).
- 8-fach erhöhte Steinschlag-aktivität in kürzlich entgletscherten Felswand-bereichen.

Mehr Details und Analysen zum Thema finden Sie in unserer aktuellen Tandem-Publikation (September 2020) im Fachjournal **'Earth Surface Dynamics'**



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Earth Surface Dynamics

Current glacier recession causes significant rockfall increase: the immediate paraglacial response of deglaciating cirque walls

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Abstract. In the European Alps, almost half the glacier volume has disappeared over the past 150 years. The loss is reflected in glacier retreat and ice surface lowering even at high altitude. In steep glacial cirques, surface lowering exposes rock to atmospheric conditions probably for the very first time in several millennia. Instability of rockwalls has long been identified as one of the direct consequences of deglaciation, but so far cirque-wide quantification of rockfall at high resolution is missing. Based on terrestrial lidar, a rockfall inventory for the permafrost-affected rockwalls of two rapidly deglaciating cirques in the Central Alps of Austria (Kitzsteinhorn) is established. Over 6 years (2011–2017), 78 rockwall scans were acquired to generate data of high spatial and temporal resolution. Overall, 632 rockfalls were registered, ranging from 0.003 to 879.4 m^3, mainly originating from pre-existing structural rock weaknesses. A total of 60 % of the rockfall volume detached from less than 10 vertical metres above the glacier surface, indicating enhanced rockfall activity over tens of years following deglaciation. Debuttressing seems to play a minor effect only. Rather, preconditioning is assumed to start inside the randkluft (void between cirque wall and glacier) where measured sustained freezing and ample supply of liquid water likely cause enhanced physical weathering and high quarrying stresses. Following deglaciation, pronounced thermomechanical strain is induced and an active layer penetrates into the formerly perennially frozen bedrock. These factors likely cause the observed paraglacial rockfall increase close to the glacier surface. This paper, the first of two companion pieces, presents the most extensive dataset of high-alpine rockfall to date and the first systematic documentation of a cirque-wide erosion response of glaciated rockwalls to recent climate warming.

1 Introduction

High-alpine, glacial environments are severely affected by recent climate warming (WGMS, 2017). This is especially true for the European Alps, where the mean temperature increase over the last 150 years more than doubled the global mean (Böhm, 2012), and over this period approximately 50 % of the glacier volume has disappeared (Haeberli et al., 2007). Glacier retreat rates have increased since the 1980s and have been exceeding historical precedents in the early 21st century (Zemp et al., 2015). The consequences of these changes are most visible in lower-lying glacierized cirques where ice surface lowering in the ablation area is particularly apparent (Kaser et al., 2006; Pelto, 2010) and exposes cirque walls to the atmosphere probably for the first time in several millennia. Paleoclimatic studies assume that glaciers are currently shrinking to extents that have been unprecedented since the Medieval Warm Period (~ 1 kyr ago) or Roman

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Earth Surface Dynamics

A 6-year lidar survey reveals enhanced rockwall retreat and modified rockfall magnitudes/frequencies in deglaciating cirques

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Abstract. Cirque erosion contributes significantly to mountain denudation and is a key element of glaciated mountain topography. Despite long-standing efforts, rates of rockwall retreat and the proportional contributions of low-, mid- and high-magnitude rockfalls have remained poorly constrained. Here, a unique, terrestrial-lidar-derived rockfall inventory (2011–2017) of two glaciated cirques in the Hohe Tauern range, Central Alps, Austria, is analysed. The mean cirque wall retreat rate of 1.9 mm a^{-1} ranks in the top range of reported values and is mainly driven by enhanced rockfall from the lowermost, freshly deglaciated rockwall sections. Retreat rates are significantly elevated over decades subsequent to glacier downwasting. Elongated cirque morphology and recorded cirque wall retreat rates indicate headward erosion is clearly outpacing lateral erosion, most likely due to the cataclinal backwalls, which are prone to large dip-slope failures. The rockfall magnitude–frequency distribution – the first such distribution derived for deglaciating cirques – follows a distinct negative power law over 4 orders of magnitude. Magnitude–frequency distributions in glacier-proximal and glacier-distal rockwall sections differ significantly due to an increased occurrence of large rockfalls in recently deglaciated areas. In this paper, the second of two companion pieces, we show how recent climate warming shapes glacial landforms, controls spatiotemporal rockfall variation in glacial environments and indicates a transient signal with decadal-scale exhaustion of rockfall activity immediately following deglaciation crucial for future hazard assessments.

1 Introduction

Cirque erosion contributes significantly to the morphological appearance of glaciated mountain ranges. It controls rockwall retreat and creates emblematic high-alpine landform features such as horn-type peaks and sharp-edged ridges. Erosional processes operating in glacial cirques are widely recognized as important agents of high-alpine landscape evolution (Benn and Evans, 2010; Sanders et al., 2012; Scherler, 2014). Rockfall from cirque walls represents a primary source of debris for glacial systems and thus supplies tools for effective glacial erosion (Hallet, 1981). The disposal of sediment from cirque walls also represents a prominent entry point to the high-alpine sediment cascade and is therefore key to understanding of high-alpine sediment flux (Hales and Roering, 2005; Krautblatter et al., 2012; Bennett et al. 2014).

Cirque wall retreat is governed by rock slope failure, which can be statistically characterized by their magnitude–frequency distribution (Dussauge et al., 2003; Bennett et al., 2012). Magnitude–frequency distributions are widely used to derive probabilistic recurrence rates of an event of a given size (Dussauge-Peisser et al., 2002) and are key

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