FACULTY OF SCIENCES

DEPARTMENT OF GEOGRAPHY
RESEARCH GROUP PHYSICAL GEOGRAPHY

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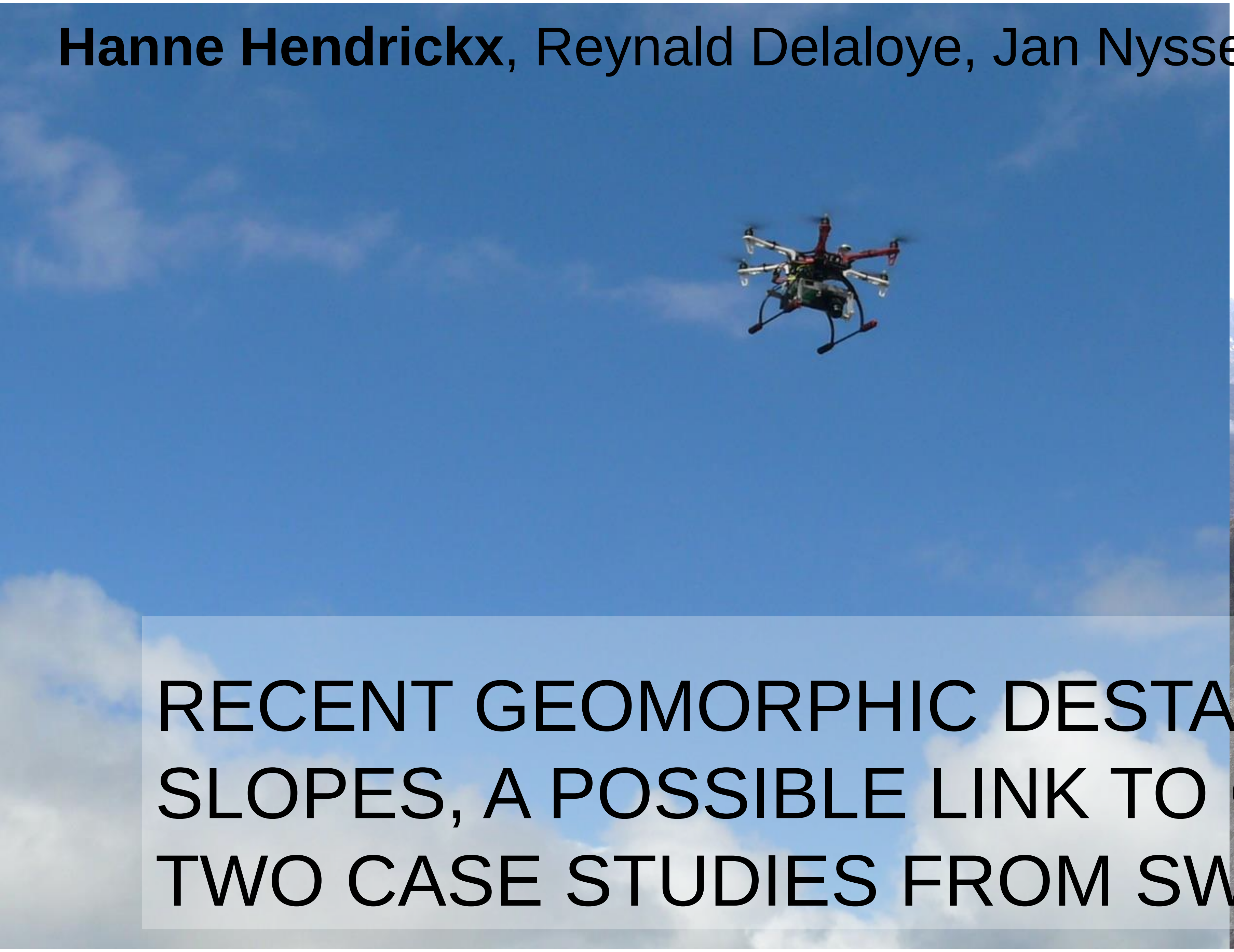

RECENT GEOMORPHIC DESTABILIZATION OF MOUNTAIN SLOPES, A POSSIBLE LINK TO CLIMATE CHANGE? TWO CASE STUDIES FROM SWITZERLAND

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geography department Ghent University

Fribourg Alpine Cryosphere and Geomorphology

EGU General Assembly 2020

FRAMEWORK OF THIS STUDY

– Geomorphic destabilisations in high mountain areas are often linked to permafrost degradation and changing precipitation intensities, induced by climate change.

– Keeping in mind the complex interaction between meteorological and geological conditions, two alpine mass movements were investigated with regard to their possible causes (2017 – 2019).

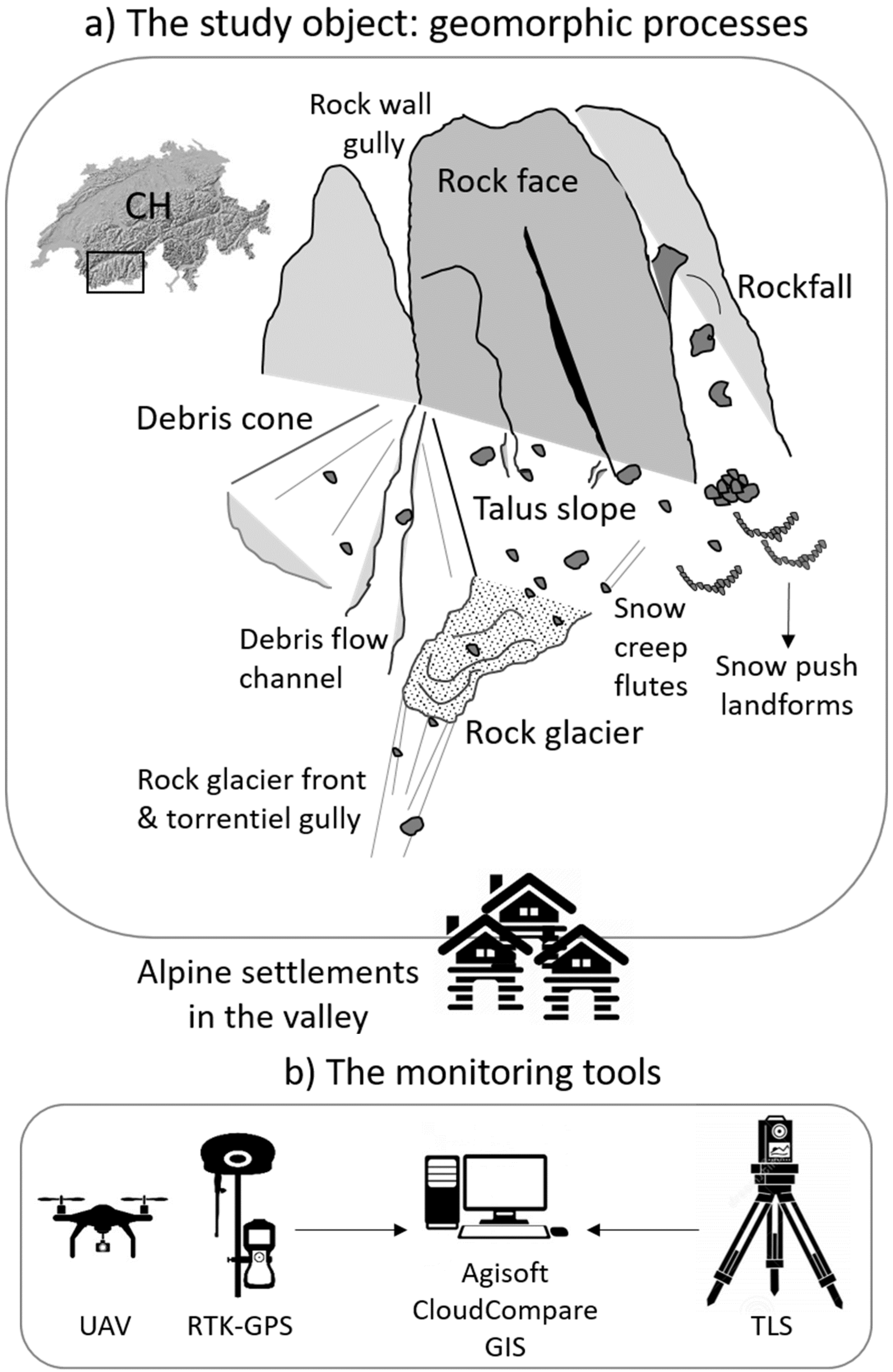

Figure 1. a) the studied high alpine environment with the different geomorphic processes observed, b) the used methods for monitoring these landscapes (technical specs at the end of the slides).

CASE STUDY 1

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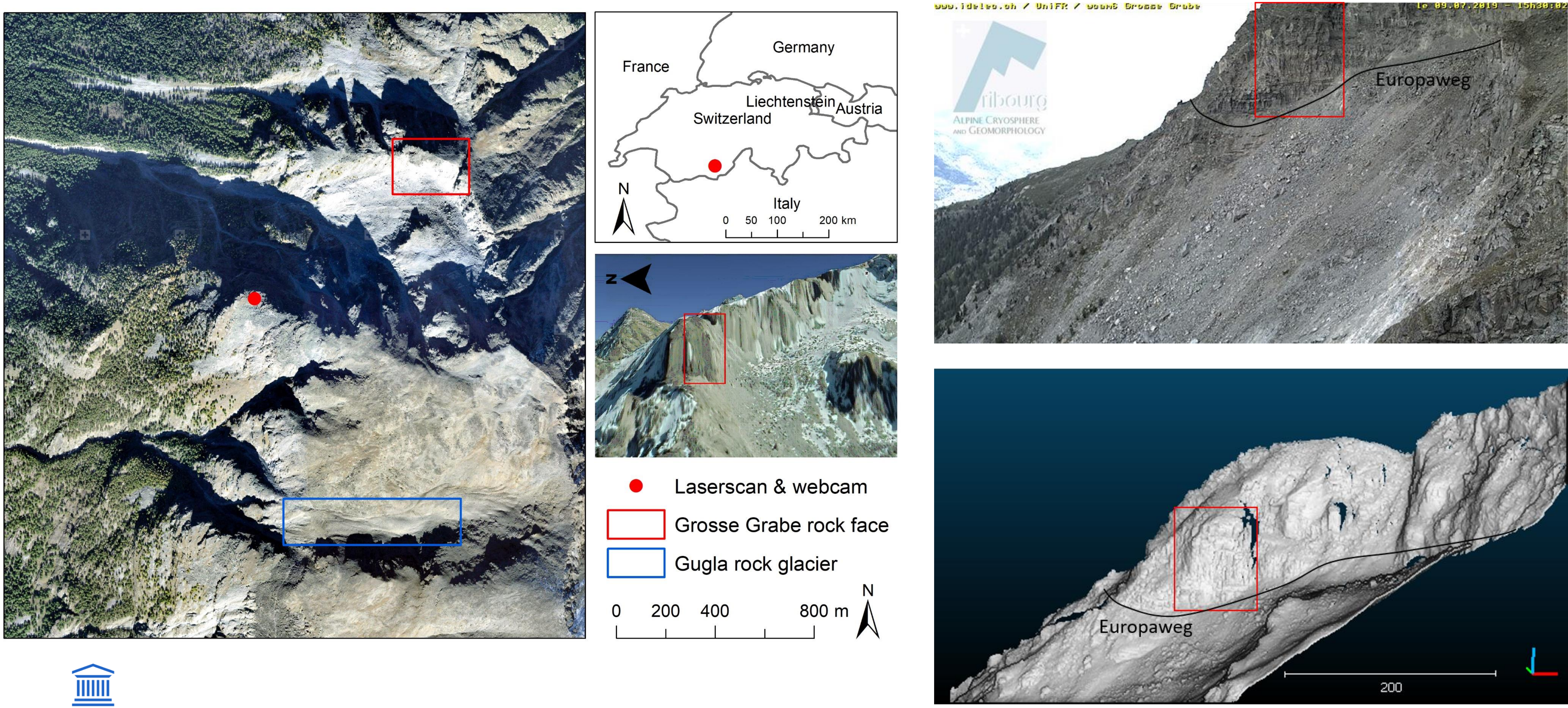
CASE STUDY 1: GROSSE GRABE ROCK FACE



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CASE STUDY 1: GROSSE GRABE ROCK FACE

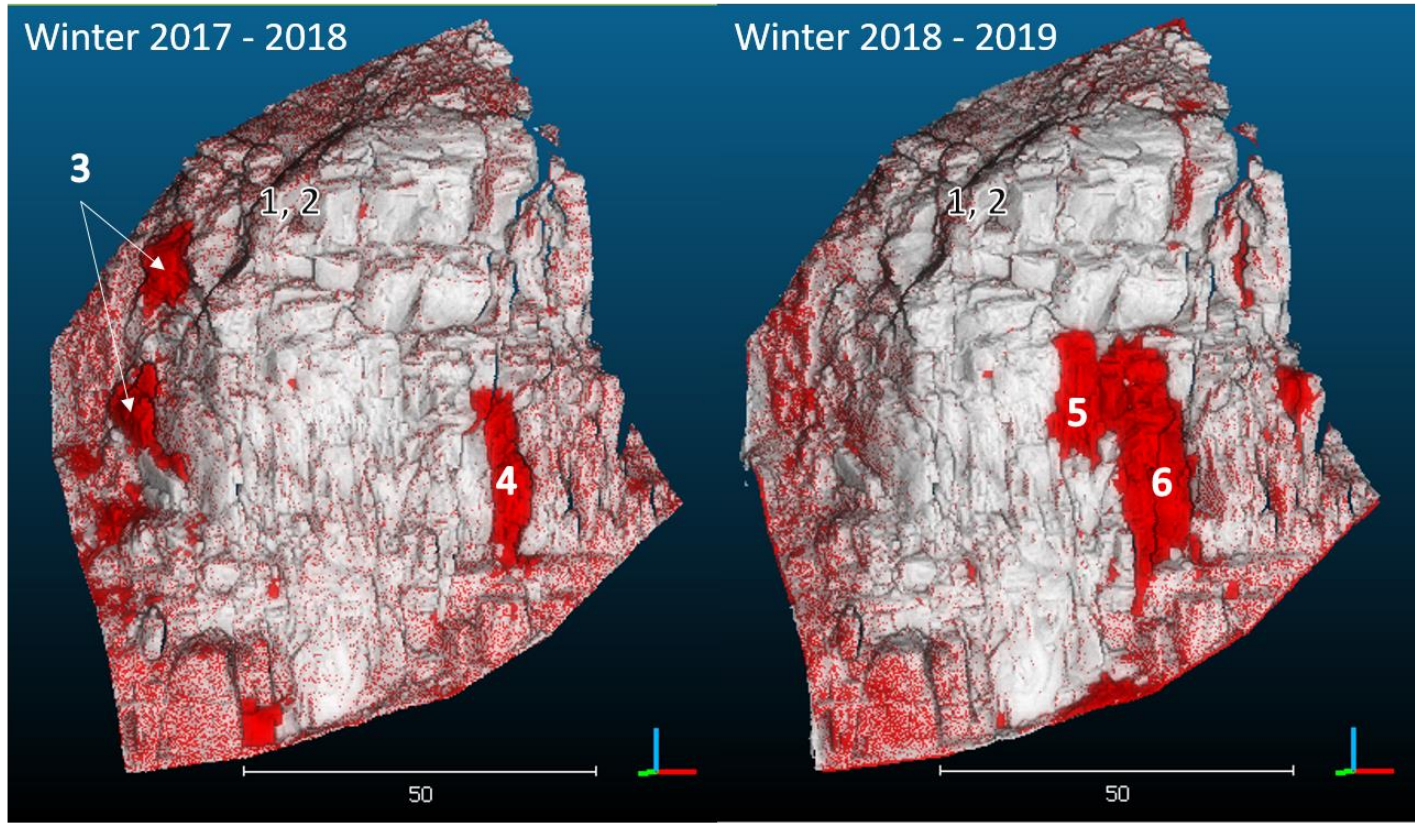
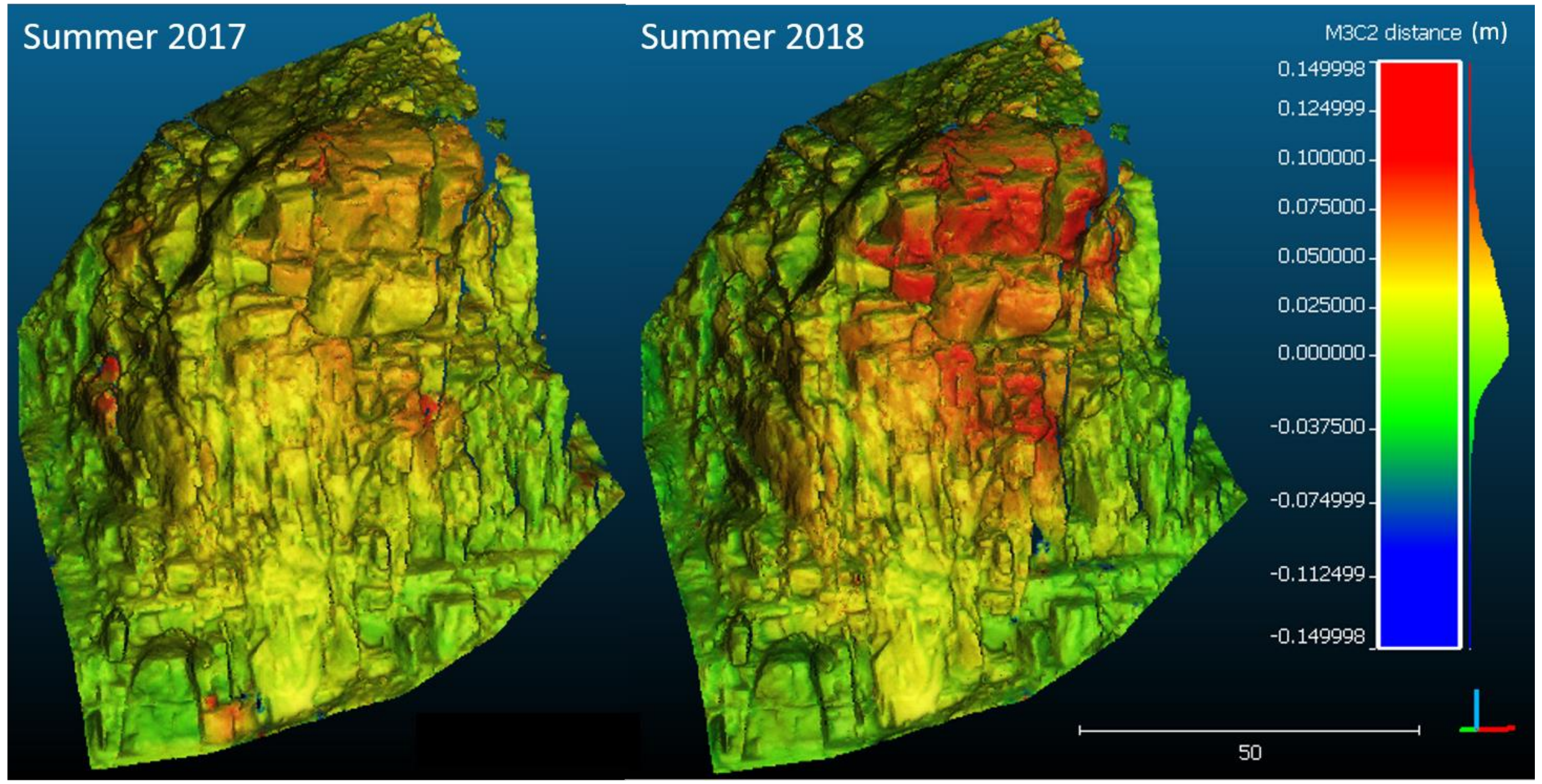


Figure 2. Observed winter rock fall.



- Isolated rock fall started in January 2017 (webcam observations) → launching the TLS campaign (Fig. 2).

- The next two summers the rock face had been tilting at an increasing rate:1 - 3,3 cm/month (Fig. 3).

Figure 3. Observed summer deformation.

CASE STUDY 1: GROSSE GRABE ROCK FACE

– Summer 2019, consecutive large rock fall events (> 10,000 m3) lead to the complete collapse of the rock face with a total volume of more than 60,000 m3 (Fig. 4, Fig. 5, Fig. 6).

– The wet rock fall scar probably indicates permafrost thawing (Fig. 6). Besides the geological characteristics, which are favouring the rock wall instability, multi-decennial warming of the permafrost is presumably an implicated factor.

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See figures on the next slide

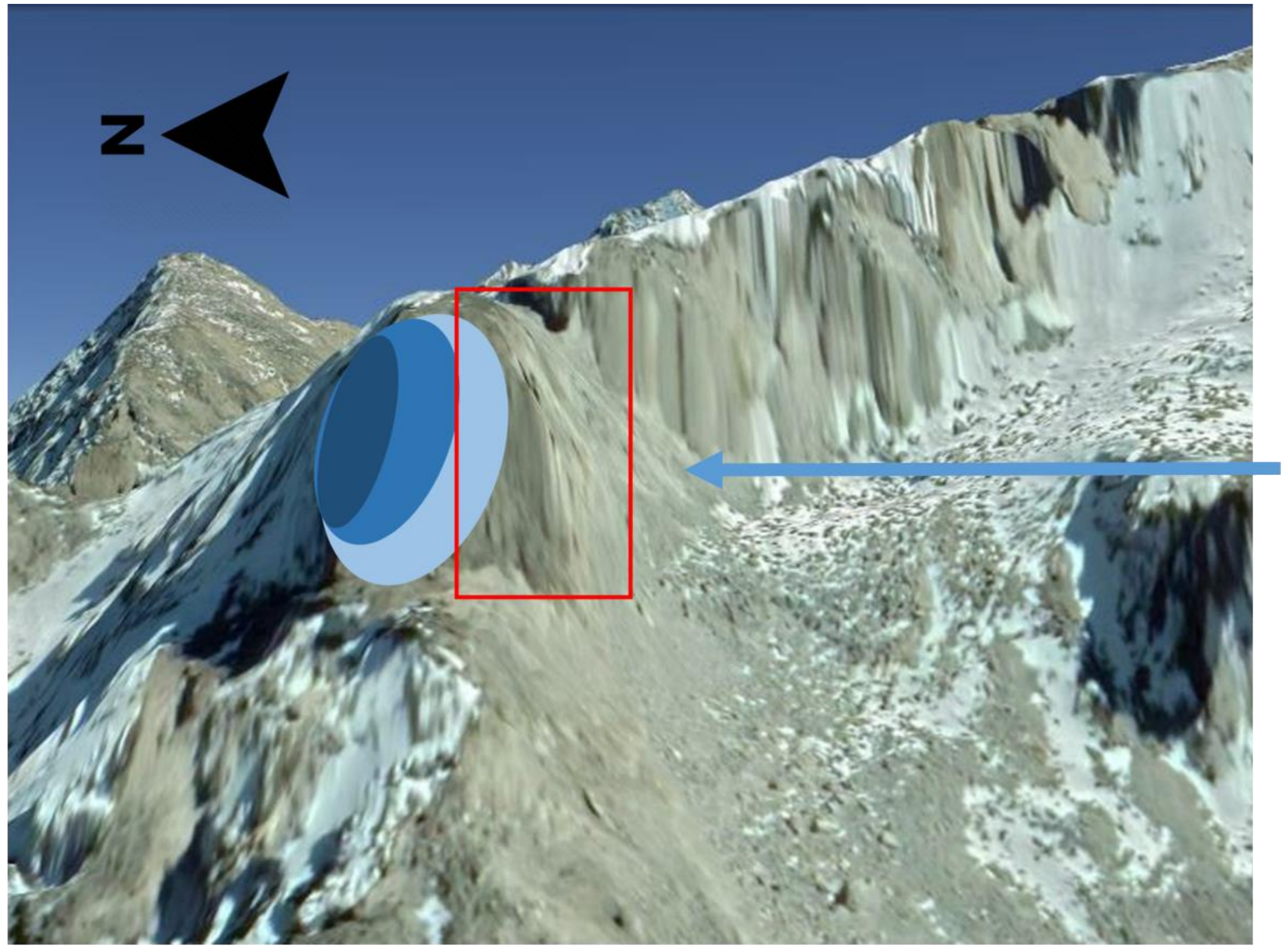
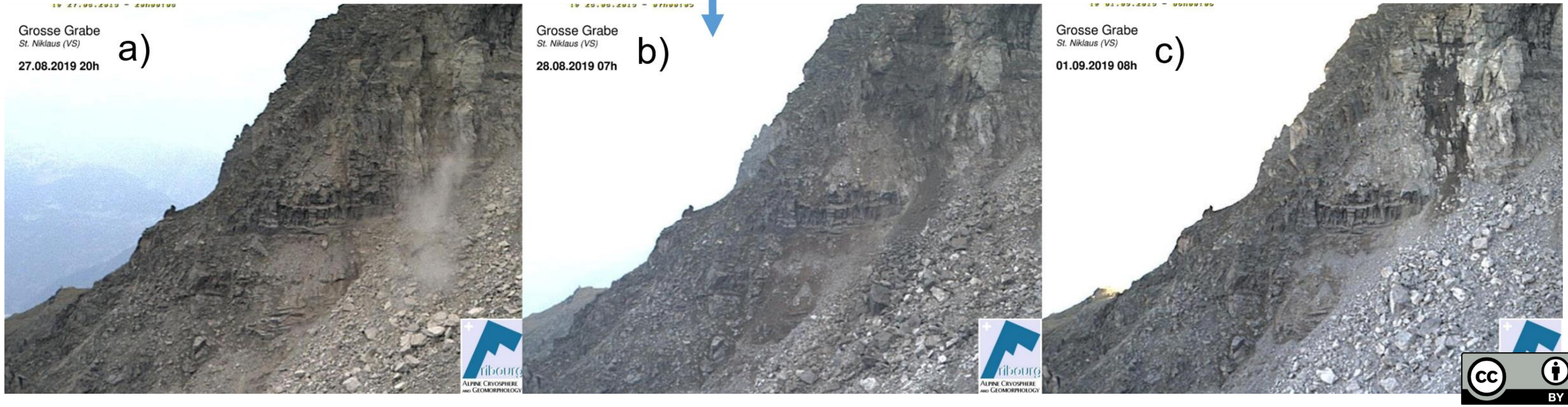


Figure 4. Assumed permafrost setting of the collapsed rock face.

The collapse of the rock face: 63,138 m^3 of total volume

	Rock fall dates	Volume in m^3
1	21/01/2017 17h – 22/01/2017 10h (UTC+1)	Est. 500
2	21/05/2017 20-21h (UTC+2)	Est. 500
3	20/05/2018 18h – 21/05/2018 07h (UTC+2)	513
4	30/05/2018 20h – 31/05/2018 07h (UTC+2)	318
5	13/01/2019 13h - 14/01/2019 11h (UTC+1)	346
6	16/04/2019 17h – 17/04/2019 08h (UTC+2)	756
7	15/07/2019 16-17h (UTC+2)	Est. 1000
8	27/08/2019 18h46 (UTC+2)	Est. 15 000
9	28/08/2019 00h10 (UTC+2)	Est. 30 000
10a	02/09/2019 04h53 (UTC+2)	Est. 10 000
10b	02/09/2019 12h49 (UTC+2)	
11a	05/09/2019 06h33 (UTC+2)	Est. 5000
11b	05/09/2019 12h50 (UTC+2)	
12	22/10/2019 13h19 (UTC+2)	Est. 1000 – 2000 ??
13	23/10/2019 13-14h (UTC+2)	Est. 100-500
14	23/10/2019 17h – 24/10/2019 12h (UTC+2) (various)	Est. 50-200
15	27/10/2019 17h – 28/10/2019 10h (UTC+1)	<25
16	30/10/2019 10h – 12h (UTC+1)	<25

Figure 5. Rock fall dates from webcam imagery and volumes from TLS.



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CASE STUDY 2*

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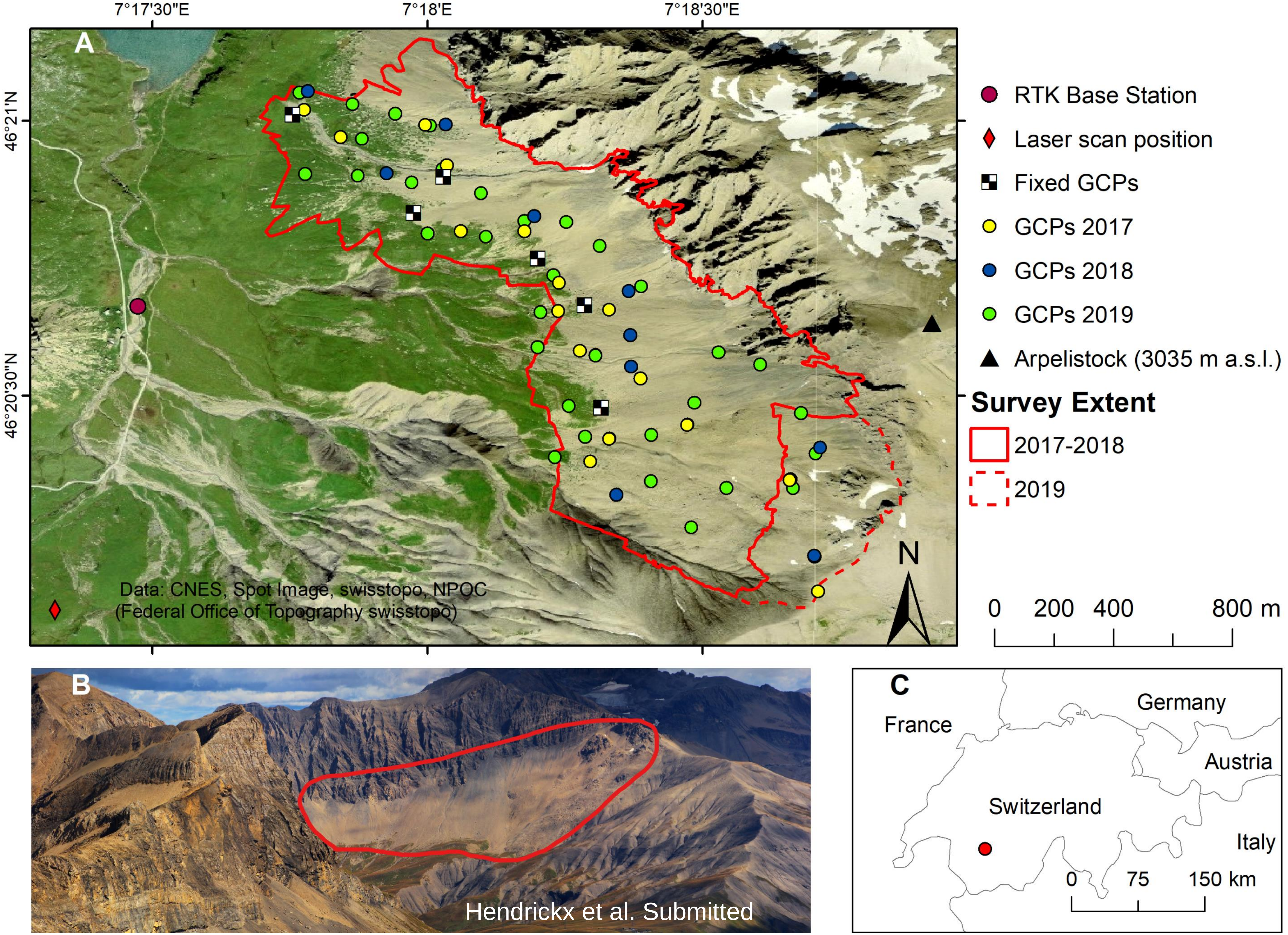
*Hendrickx et al. “Exploring sequential high resolution topographic surveys on active alpine talus slope geomorphology.” Submitted to Earth Surface Processes and Landforms

CASE STUDY 2: COL DU SANETSCH TALUS SLOPE



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CASE STUDY 2: COL DU SANETSCH TALUS SLOPE

– General geomorphic processes on the studied talus slope are dominated by debris flow scour and deposits, snow push phenomena (ridges and flutes) and occasional rill erosion (Fig. 8).

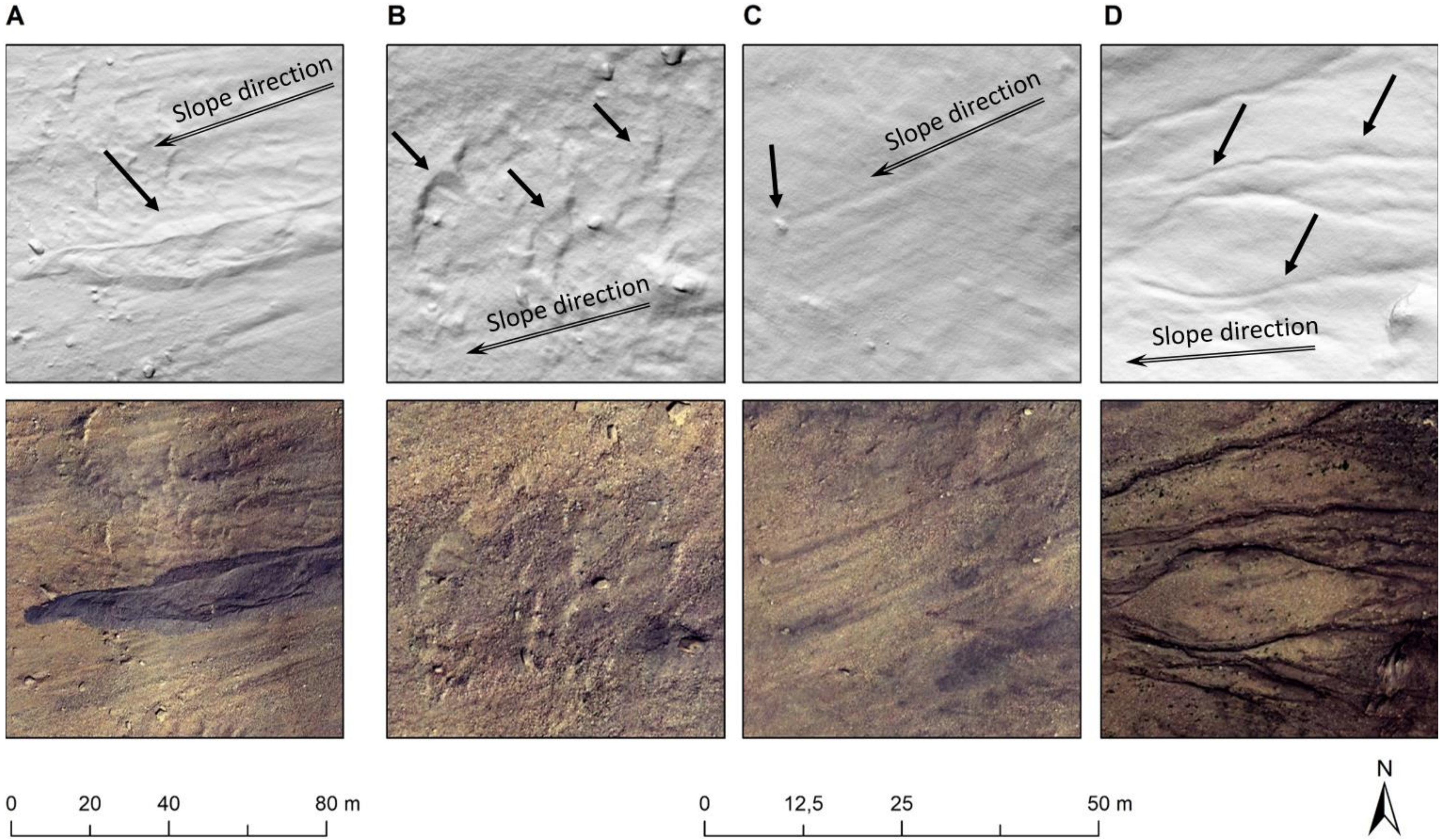

Figure 8. Talus slope geomorphology shown by the 10 cm resolution hill-shade and orthophoto derived from the UAV data of 2019, a) debris flow deposit, b) arched snow creep ridges, c) boulder pushed by slide/creep of the snow pack, here named as snow creep flutes, d) rill erosion in the more fine grained parts of the talus slope.

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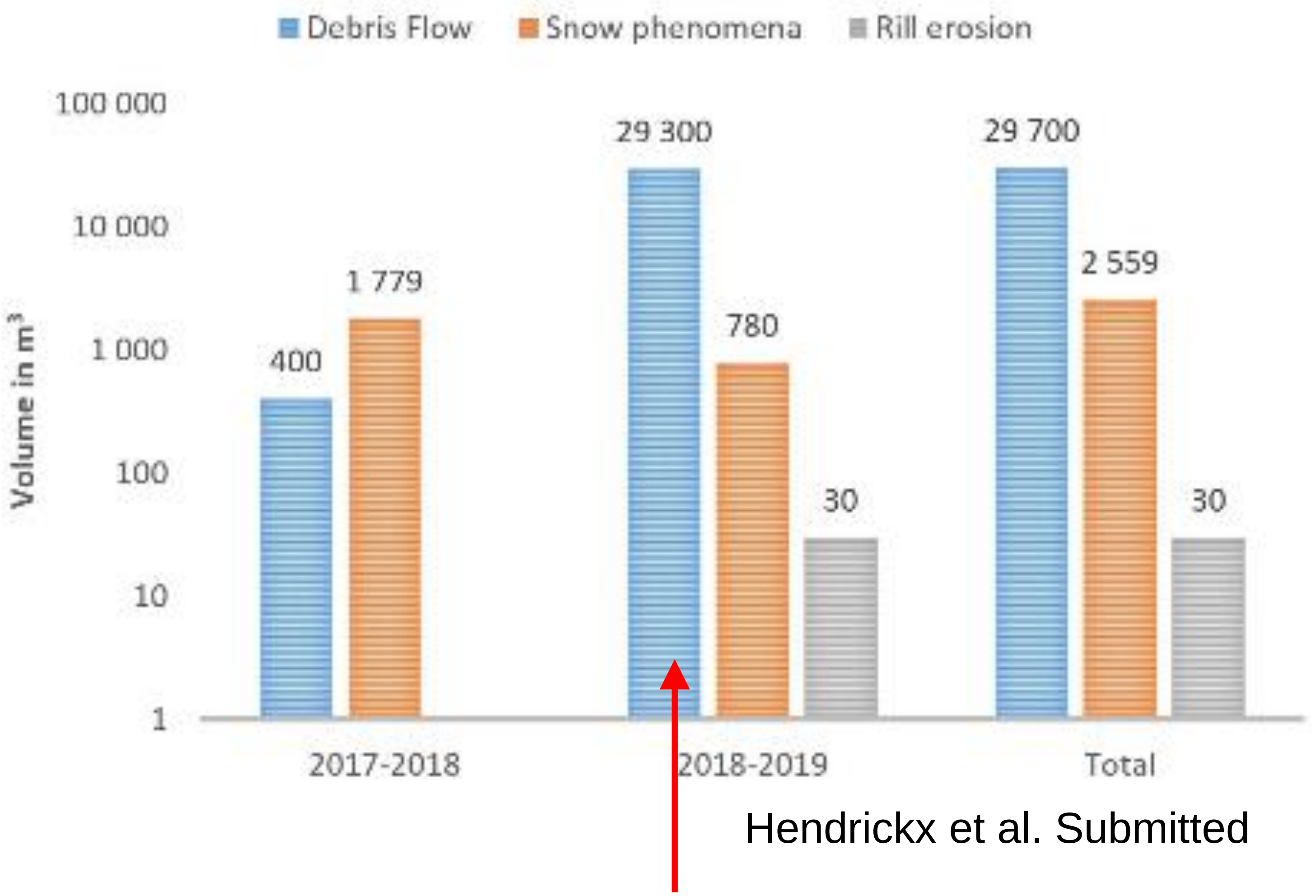
Figure 9. Volumes per main geomorphic reworking process per year on a logarithmic scale.



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Very large debris flow event in 2019

– Annual sediment rates consist of debris flow channel erosion and fill (~10 – 100 m3 per channel) and material displaced by snow creep/push (~1,000 – 2,000 m3) (Fig. 9) and are the most important sediment redistribution actor on the talus slope in years when no debris flow activity is observed

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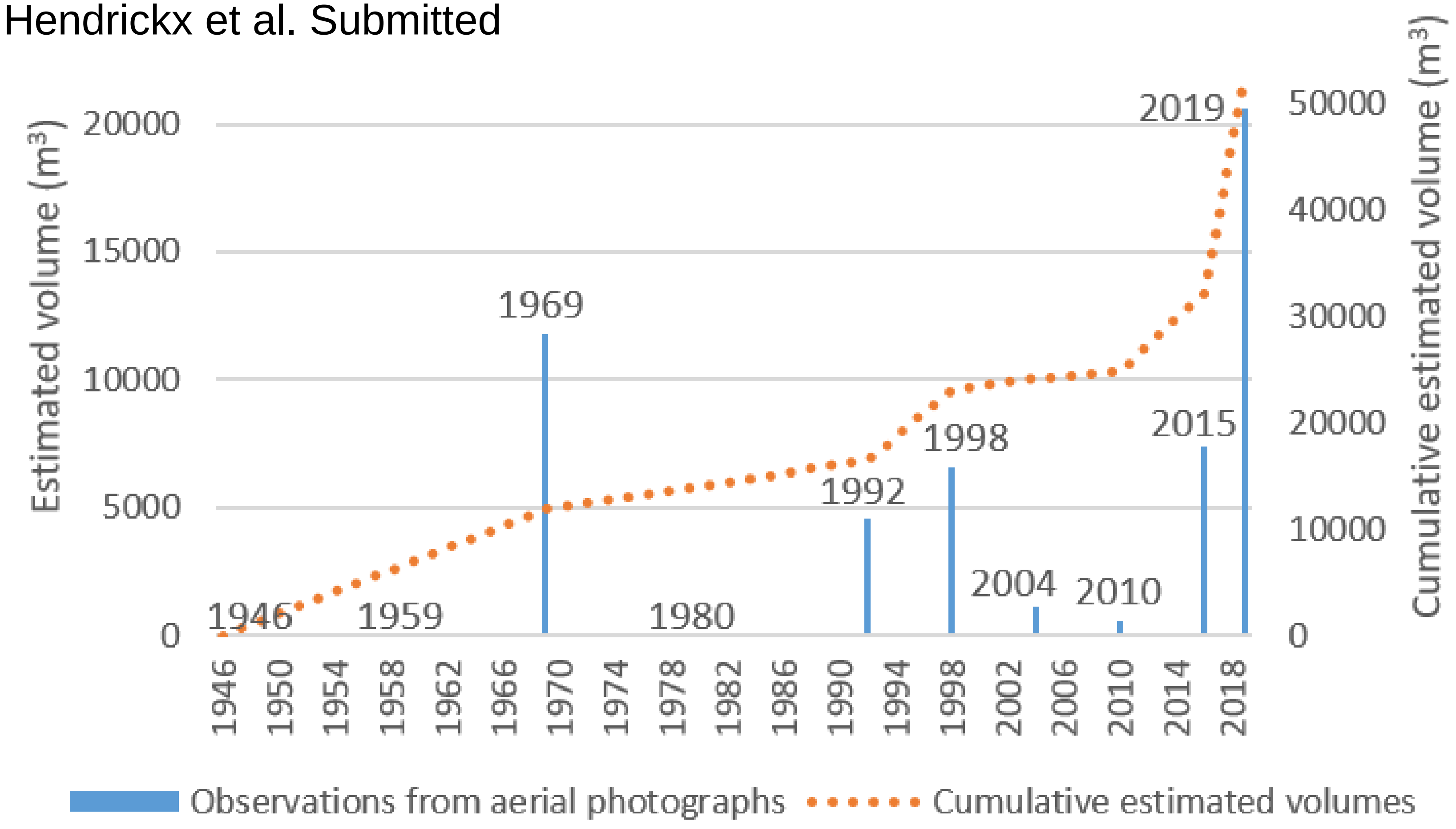

Figure 9. The estimated debris flow volume for the different time periods, based on historical aerial photographs dating back until 1946 (see examples at the end of the slides)

- In 2019, the largest debris flow event in the last 70 years was observed (Fig. 9), with a displaced volume > 20,000 m3.
- Most of the mobilized sediments originated from incision of the talus apex area, while only a small part came from intermediate debris storage within rock wall couloirs.

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CASE STUDY 2: COL DU SANETSCH TALUS SLOPE

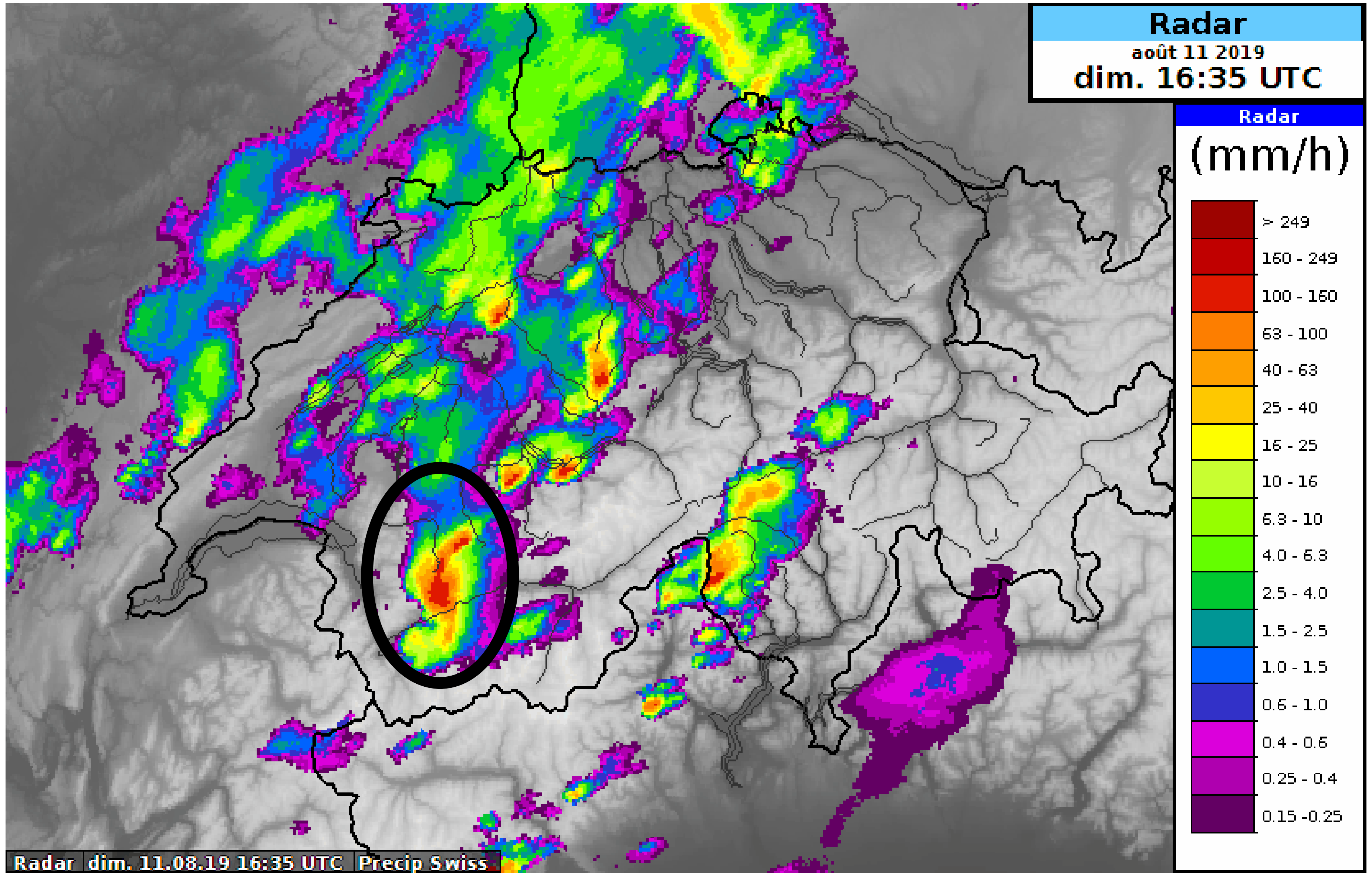

Figure 10. Radar data on August 11, 2019

- This debris flow event is linked to an intense prefrontal thunderstorm, causing a rainfall intensity of almost 10 mm/10 min for the study area (Fig. 10) (MeteoSwiss station VSTSN, 3 km from the study area).
- Future climate predictions show an increase in these events in the region, potentially altering the debris flow frequency and the dominant geomorphic process active on such slopes.

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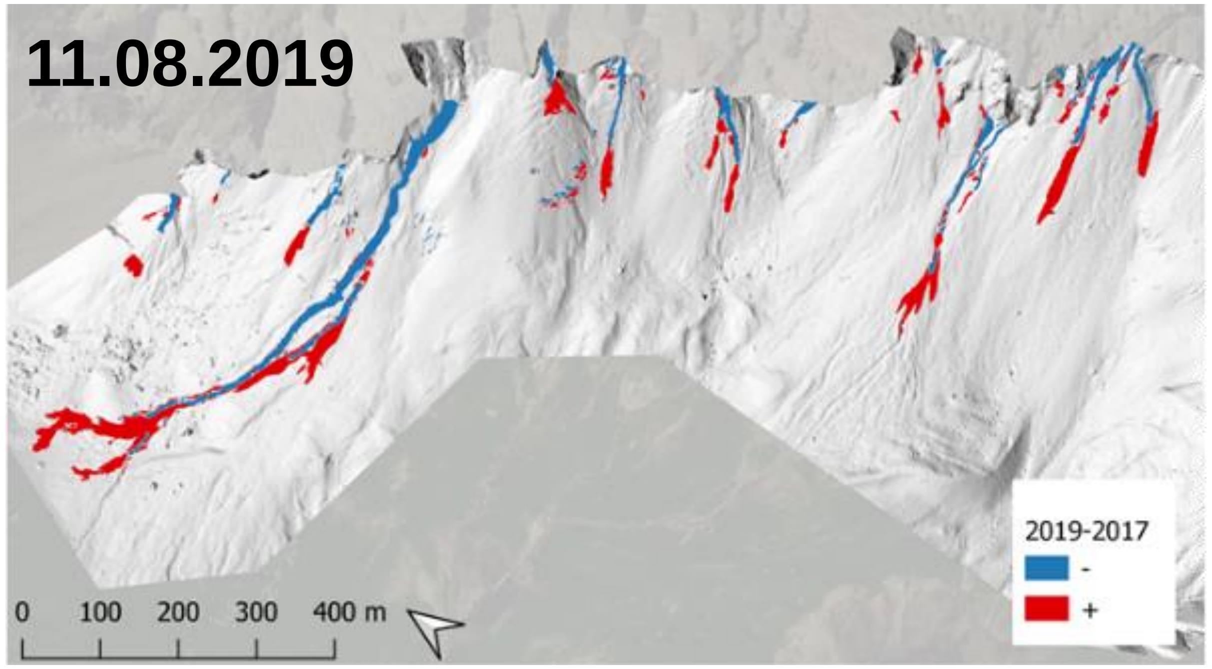
CONCLUSION

PRELIMINARY CONCLUSIONS

In a time-span of 3 yrs we observed the destabilization and the failure of an entire rock face. Permafrost was present, but it remains unclear if its degradation is an explanatory factor, rather than a geological predisposition.



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Intense rain fall events have the potential to mobilise a lot of sediment in an otherwise relatively stable talus slope environment, dominated by snow push phenomena.

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Project: Talus slope dynamics in a permafrost environment

Sketchfab/hannehendrickx

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APPENDIX

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MEASURING EQUIPMENT GROSSE GRABE

- Long range Riegl-V6000
- Scanning from a distance of ~ 1 km
- Accuracy: 3 cm (after coarse and fine (MSA) co-registration in RiScanPro based on stable areas)
- Resolution: downscaled to 10 cm using an octree filter

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MEASURING EQUIPMENT COL DU SANETSCH

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	Hexacopter DJI F550	DJI Phantom 4 pro
Camera :	Panasonic Lumix DMX-GM5	Integrated
	Zoom lens	Prime lens
Sensor size (pixels)	4592 x 3448	5472 x 3648
Sensor size (mm)	17.3 x 13	13.2 x 8.8
Aperture	Varied	F/5.6 – 6.3
Shutter speed (s)	> 1/500	1/200 – 1/800
Shutter type	Global	Global
ISO	400	100
Focal length (mm)	12-20	8.8

Table A1. Characteristics of Uncrewed Aerial Vehicle (UAVs) cameras used in this study

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	2017	2018	2019
Used UAV	Hexacopter DJI F550	Hexacopter DJI F550	DJI Phantom 4 Pro
Flight planning software	Mission Planner	Mission Planner	UgCS
Number of flights	18	25	15
Survey days	4	3	3
Covered area in km²	1.2	1.3	2.0
GSD in cm/pixel	3.5 – 5.3	3.5 – 5.3	2.0
Used dGNNS system	Trimble RTK v4	Leica RTK GPS	Leica RTK GPS
Number of GCPs (& CPs)	10(4)	20(6)	24(15)

Table A2. Characteristics of the survey data for the three years

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DATA PROCESSING COL DU SANETSCH

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	Registration error (RMSE on 25 CPs)	$LoD_{95\%}$	$LoD_{80\%}$
UAV $\sigma_{seperate\ alignment}$	0.120	0.273	0.178
UAV $\sigma_{co\text{-}alignment}$	0.071	0.196	0.128
TLS σ	0.023	0.065	0.042

Table A3. Registration error (RMSE) per 3D model and the calculated level of detections in m.
UAV = Uncrewed Aerial Vehicle, TLS = Terrestrial Laser Scanner, LoD = Level Of Dectection

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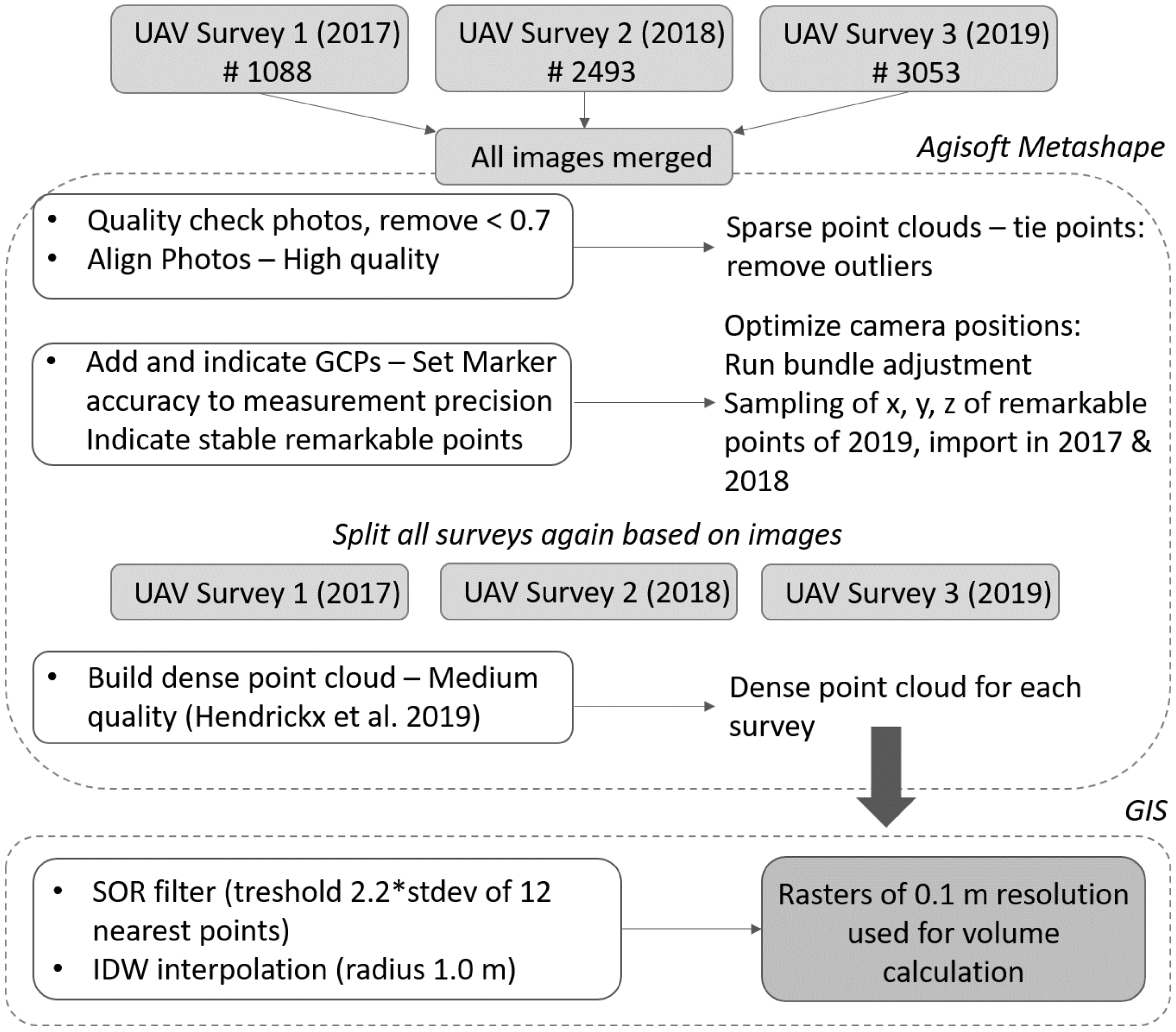

Fig A1. Workflow in Metashape and GIS environment, adopting co-alignment methodology (Cook & Dietze, 2019).

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DATA PROCESSING COL DU SANETSCH

UAV data is prone to deformations, especially if the ground control points (GCPs) are not evenly distributed. We confirm that the co-alignment approach (Cook & Dietze, 2019)* is useful to improve the comparative accuracy when GCPs do not have an optimal spatial distribution.

*Also view EGU abstract EGU2020-11735 from the same authors in the session GI1.3 and GM2.3

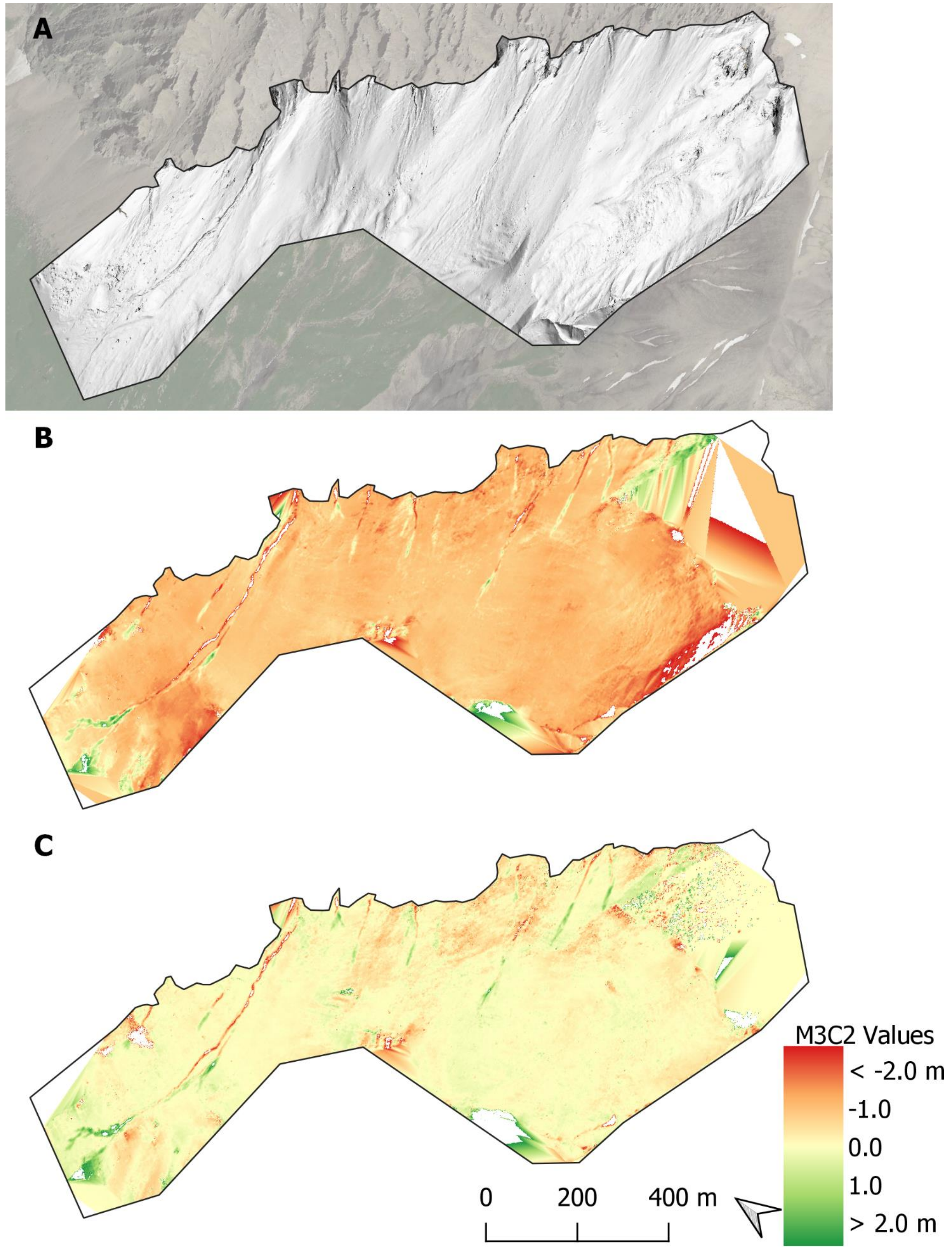

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Fig A2. a) hillshade of the study area, b) deformations adopting standard Methashape workflow, c) deformations adopting the co-alignment approach

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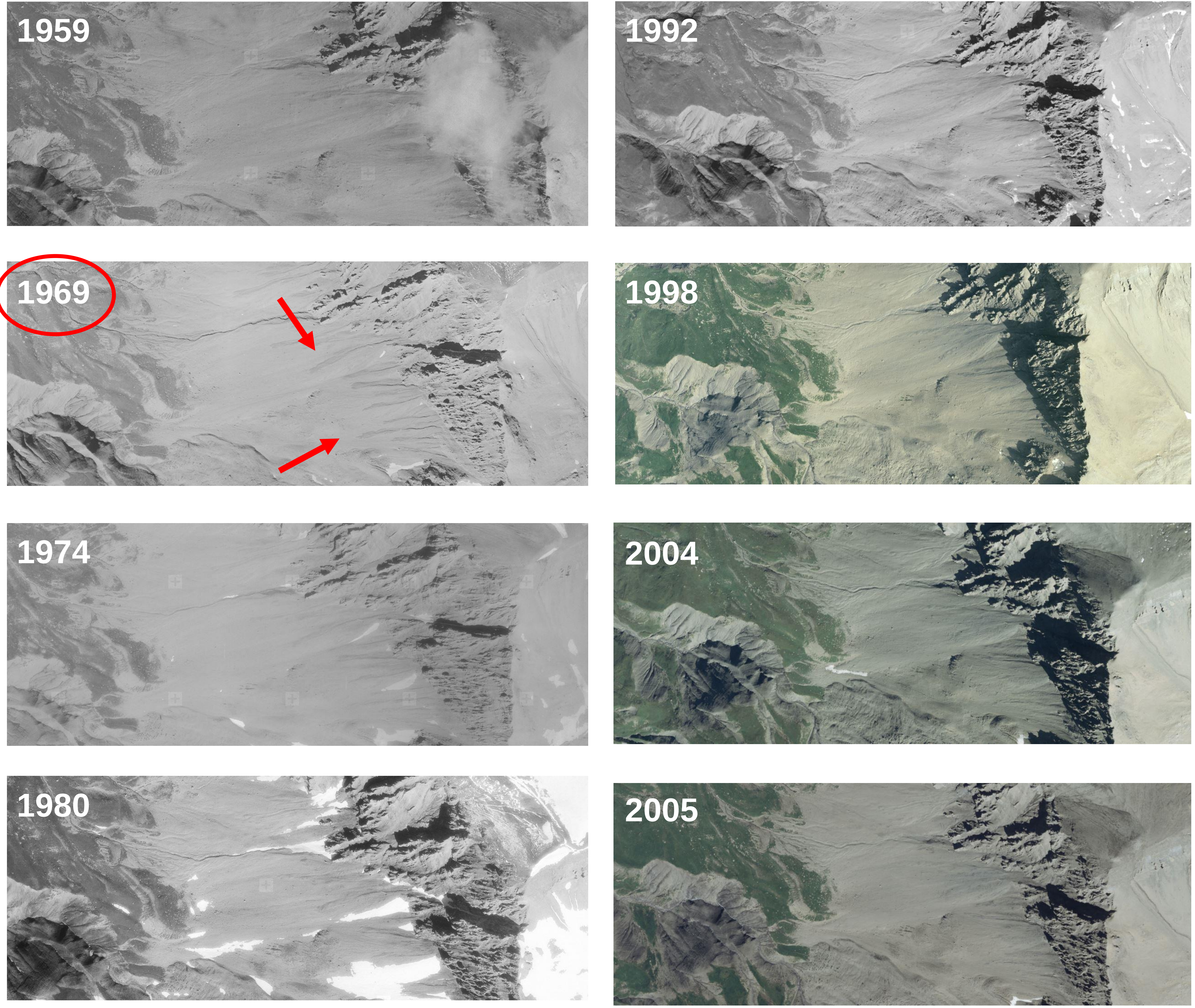

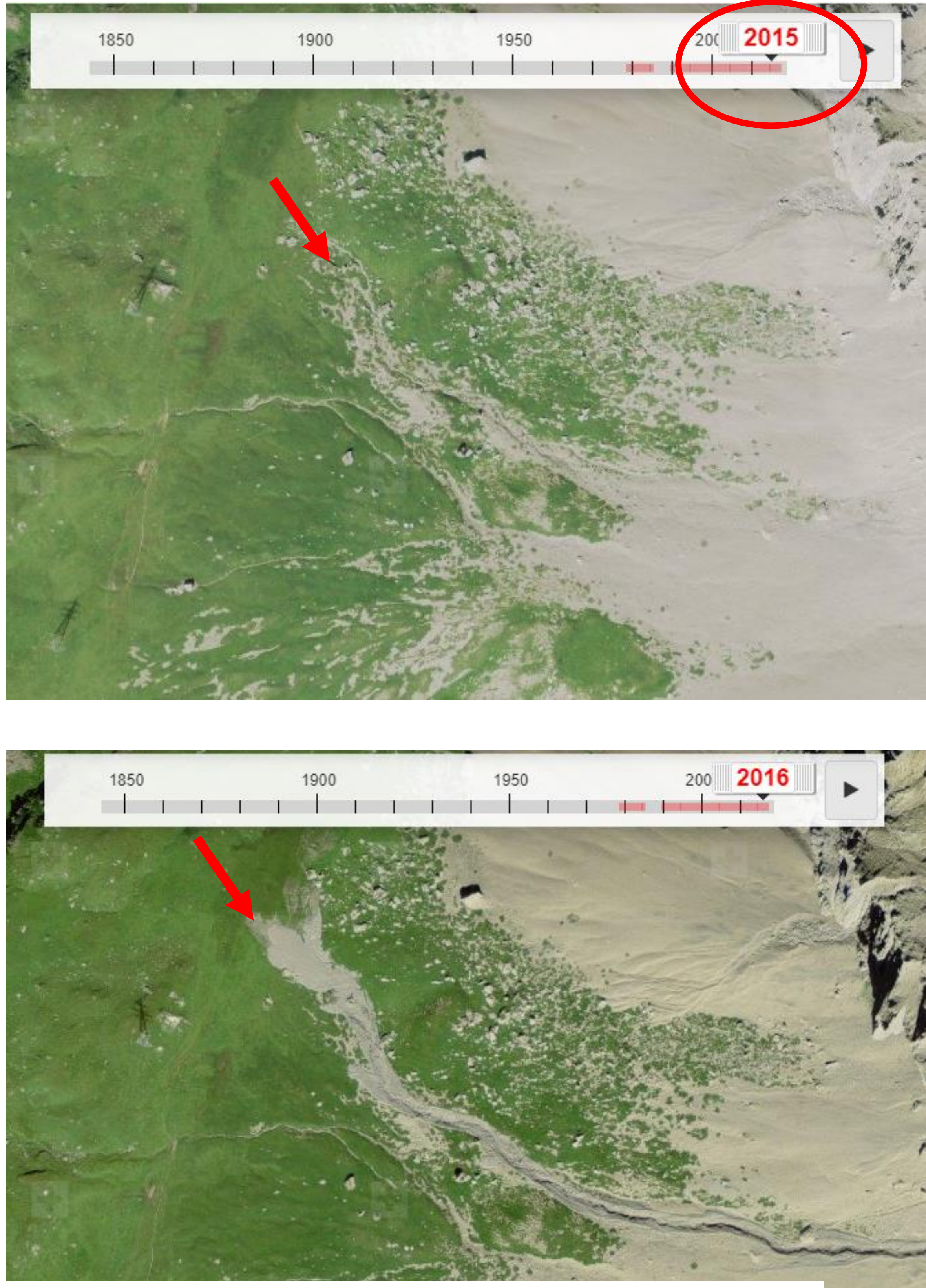

Fig A3. Historical aerial imagery used in this study © Swisstopo