

*Supplementary Material to:*

# Rock glacier kinematics in the Kaunertal, Ötztal Alps, Austria

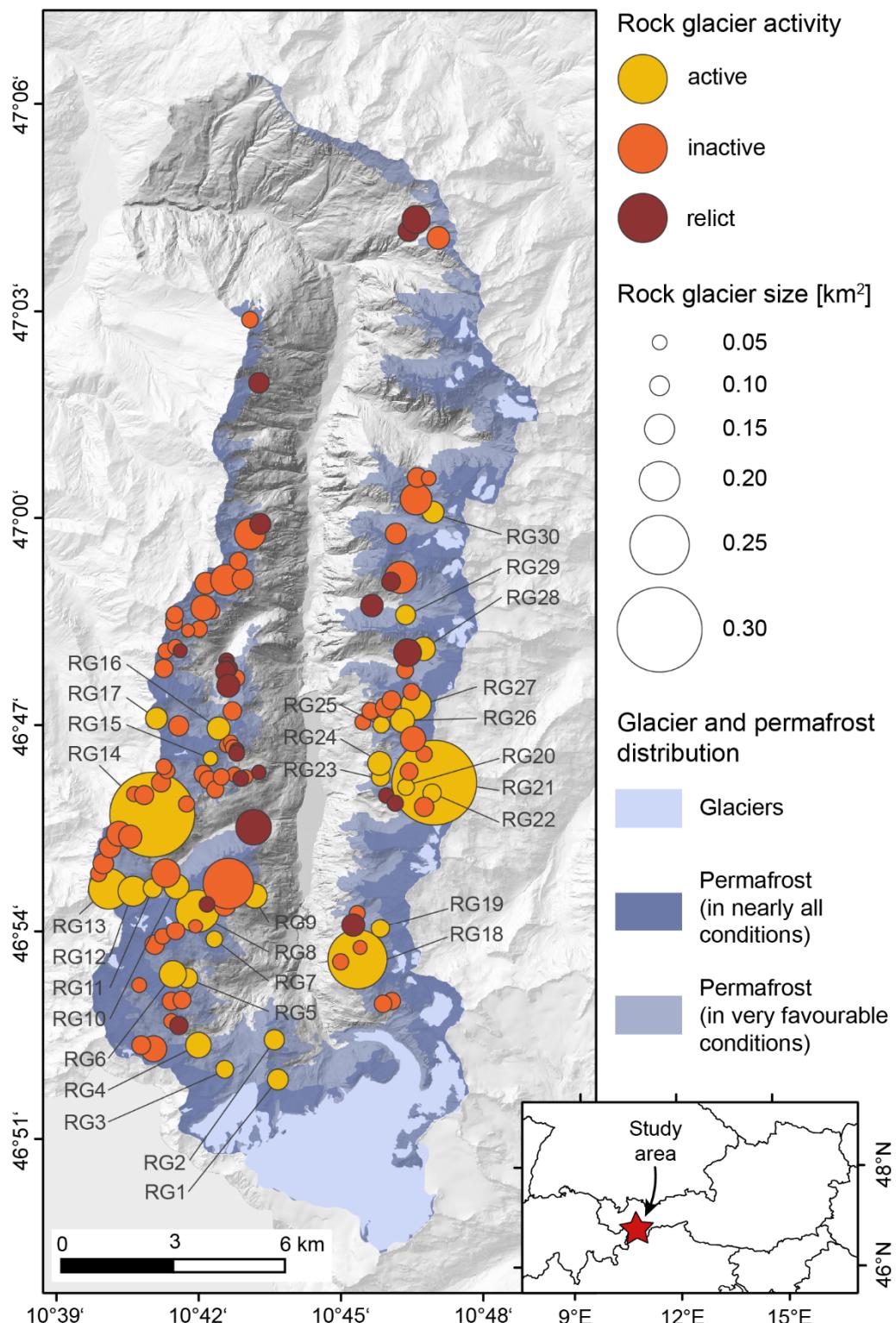
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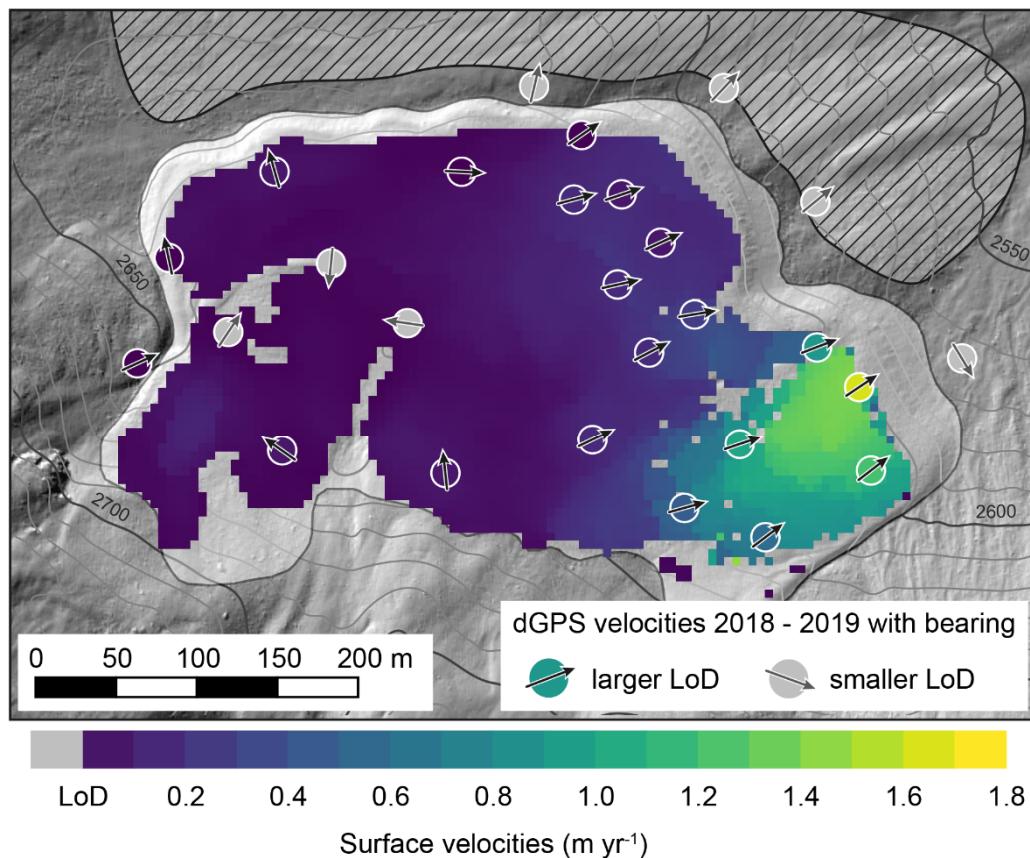
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**Table S1.** Level of detection and horizontal surface velocity for 30 rock glaciers classified as active based on feature-tracking analysis in aerial imagery. Average values in  $\text{m yr}^{-1}$  are given for entire length of observation period between 2001 resp. 2003 and 2015.

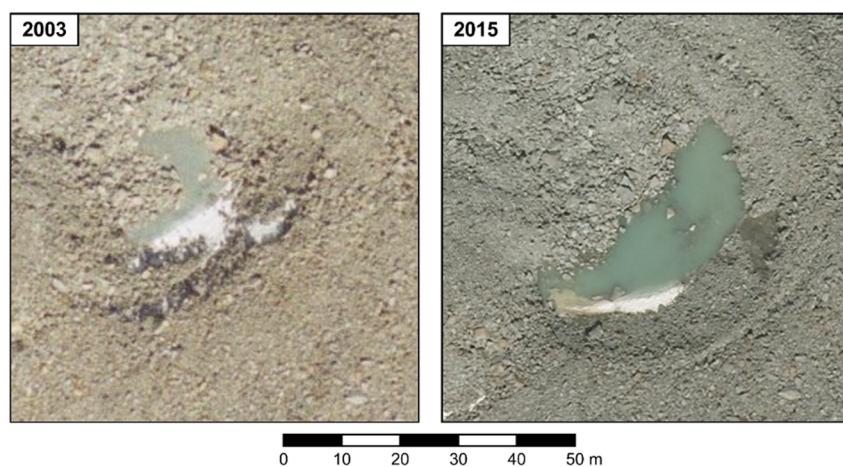
Name	Level of detection (LoD)			Horizontal surface velocity ( $\text{m yr}^{-1}$ )					Mean
	(px)	(m)	( $\text{m yr}^{-1}$ )	25 <sup>th</sup>	50 <sup>th</sup>	75 <sup>th</sup>	95 <sup>th</sup>	Max.	
RG01	1.66	0.33	0.03	0.04	0.05	0.07	0.17	0.27	0.07
RG02	0.76	0.15	0.01	0.04	0.14	0.38	0.64	0.82	0.22
RG03	1.77	0.35	0.03	0.07	0.28	0.34	0.43	0.46	0.23
RG04	0.89	0.18	0.01	0.10	0.18	0.27	0.53	0.80	0.20
RG05	0.73	0.15	0.01	0.29	0.34	0.39	0.49	0.77	0.34
RG06	0.97	0.19	0.02	0.03	0.05	0.08	0.15	0.25	0.06
RG07	0.39	0.08	0.01	0.06	0.09	0.50	0.61	0.74	0.22
RG08	1.98	0.40	0.03	0.07	0.11	0.18	0.40	0.56	0.15
RG09	0.70	0.14	0.01	0.07	0.10	0.12	0.14	0.17	0.09
RG10	1.00	0.20	0.02	0.11	0.19	0.32	0.57	0.74	0.23
RG11	0.54	0.11	0.01	0.02	0.05	0.12	0.16	0.22	0.07
RG12	0.62	0.12	0.01	0.05	0.11	0.25	1.19	1.52	0.26
RG13	0.69	0.14	0.01	0.02	0.04	0.09	0.26	0.41	0.07
RG14	1.05	0.21	0.02	0.04	0.05	0.19	0.47	0.75	0.13
RG15	1.33	0.27	0.02	0.35	0.38	0.44	0.52	0.56	0.40
RG16	0.46	0.09	0.01	0.02	0.03	0.06	0.14	0.20	0.05
RG17	0.65	0.13	0.01	0.04	0.07	0.23	0.63	0.77	0.18
RG18	0.71	0.14	0.01	0.19	0.43	0.73	1.32	1.77	0.51
RG19	5.54	1.11	0.09	0.22	0.28	0.35	0.61	0.81	0.31
RG20	1.23	0.25	0.02	0.03	0.05	0.09	0.26	0.30	0.08
RG21	1.33	0.27	0.02	0.09	0.14	0.19	0.25	0.42	0.14
RG22	0.27	0.05	0.00	0.09	0.13	0.16	0.25	0.34	0.14
RG23	1.66	0.33	0.03	0.37	0.68	0.82	0.91	0.98	0.57
RG24	1.37	0.27	0.02	0.05	0.08	0.10	0.13	0.18	0.08
RG25	0.58	0.12	0.01	0.06	0.08	0.09	0.10	0.12	0.07
RG26	0.70	0.14	0.01	0.18	0.35	0.45	0.50	1.05	0.31
RG27	0.89	0.18	0.01	0.20	0.41	0.61	0.78	0.98	0.41
RG28	0.96	0.19	0.02	0.04	0.05	0.11	0.34	0.56	0.09
RG29	1.52	0.30	0.03	0.29	0.33	0.40	0.54	0.83	0.35
RG30	2.13	0.43	0.04	0.20	0.34	0.52	0.81	1.02	0.38



**Figure S1.** Distribution of active, inactive and relict rock glaciers in the Kaunertal valley, as classified by feature tracking analysis in aerial imagery and Wagner et al. (in review) [1], respectively. Rock glaciers are shown as colour-coded dots scaled to the planimetric size of individual landforms. Numbers indicate specific rock glaciers referred to in text and figures. Light blue, blue and dark blue areas show mapped distribution of glaciers [2] and modelled coverage of permafrost occurrence in very favourable conditions and nearly all conditions [3], respectively.



**Figure S2.** Average horizontal surface velocity of the Kaiserberg rock glacier (RG12) as derived by feature tracking in orthoimagery between 2003 and 2015 (coloured raster cells) and from repeated dGPS measurements of 27 ground control points between July 2018 and July 2019 (coloured circles), respectively. Note that dGPS survey and feature tracking approach have different LoDs averaged over the observation period, with  $0.05 \text{ m yr}^{-1}$  and  $0.01 \text{ m yr}^{-1}$ , respectively. Hatched polygon in the north of the rock glacier indicates stable ground area used for calculating affine transformation parameters between consecutive imagery..



**Figure S3.** The development and advance of a thermokarst lake on RG08 shows signs of permafrost degradation and subsidence effects. The lake's surface area increased from  $110 \text{ m}^2$  to  $470 \text{ m}^2$  between September 2003 and August 2015, while the steep lake front advanced 15 m in the direction of surface movement. For location of rock glacier see Figure S1.

## References

1. Wagner, T.; Pleschberger, R.; Kainz, S.; Ribis, M.; Kellerer-Pirklbauer, A.; Krainer, K.; Philippitsch, R.; Winkler, G. The first consistent inventory of rock glaciers and their hydrological catchments of the Austrian Alps. *Austrian J. Earth Sci.* In press.
2. Buckel, J.; Otto, J.-C. *The Austrian Glacier Inventory GI 4 (2015) in ArcGis (Shapefile) Format*; PANGAEA—Data Publisher for Earth & Environmental Science: 2018. Available online: <https://doi.org/10.1594/PANGAEA.887415>(accessed on 28 June 2019)
3. Boeckli, L.; Brenning, A.; Gruber, A.; Noetzli, J. *Alpine Permafrost Index Map. Supplement to: Boeckli, L.; Brenning, A.; Gruber, A.; Noetzli, J. (2012): Permafrost Distribution in the European Alps: Calculation and Evaluation of An Index Map and Summary Statistics. The Cryosphere*, 6, 807–820; PANGAEA—Data Publisher for Earth & Environmental Science: 2012.



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