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Understanding slow glacier flow under climate change: A case study on Vernagtferner, Austria

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Section S1 Data overview

dataset	date of acquisition	sensor/instruments	resolution [m]	processing	coverd area	source / access	dataprovider
stake measurement	yearly, end of september [1966-2023]	multiple forward intersections, tachymetric polar coordinate or GNSS	/	remove gross errors	entire glacier, mainly ablation area	https://doi.org/10.1594/PANGAEA.854595	
	2022-08-04, 2022-07-10, 2020-09-21, 2023-08-08	multi-frequency GNSS receiver	/	post-processing with fixed ambiguities	Parts of Taschach and Brochkogel	https://doi.org/10.1594/PANGAEA.854595	
glacier bed topographie	2006, & 2007	Radar transmitter with antenna	20	see Mayer et al 2013	entire glacier	https://doi.org/10.5281/zenodo.17590496	Mayer et al 2013
Orthofotos	2022-07-10 and 2022-09-21	UAV DJI with optical RGB camera	0,04	Georeferenzierung wih ground control points, orthophotogneierung in Agisoft Metashape	Parts of Taschach and Brochkogel	https://doi.org/10.5281/zenodo.17590496	
	2018-09-16	Optical airborne photogrammetry, UltraCam Eagle Mark 2	0,2	Aerotriangulation: Inpho(Match-AT) by Trimble, orthofoto generation: SURE (nFrames) see Iris Tirol	entire glacier	publication do to legal rights not possible tiris Tirol online	Geissler 2021
	2020-09-08	Optical airborne photogrammetry	0,2		entire glacier		
	2021-09-25	Optical airborne photogrammetry	0,2	information not available	entire glacier	publication do to legal rights not possible	
	2022-08-23	Optical airborne photogrammetry	0,2	information not available	entire glacier	publication do to legal rights not possible	
DSM	1969	aerial photogrammetry	20	information not available	entire glacier	https://doi.org/10.5281/zenodo.17590496	
	1982-09-14	aerial photogrammetry	20	information not available	entire glacier	https://doi.org/10.5281/zenodo.17590496	
	1990-08-24	aerial photogrammetry	20	information not available	entire glacier	https://doi.org/10.5281/zenodo.17590496	
	1999-09-09	aerial photogrammetry	20	information not available	entire glacier	https://doi.org/10.5281/zenodo.17590496	Weber 2013
	2009	Laserscaning	1	information not available	entire glacier	https://doi.org/10.5281/zenodo.17590496	
	2016-09-29	aerial photogrammetry, Canon EOS 5D Mark II	1	Photogrammetric analysis: PIX 4D 4.2.27	entire glacier	https://doi.org/10.5281/zenodo.17590496	
	2018	aerial photogrammetry, UltraCam Eagle Mark 2	2	Aerotriangulation: Inpho(Match-AT) by Trimble, DSM generation: SURE (nFrames)	entire glacier	publication do to legal rights not possible	Geissler 2021
glacier outline	1969,1979,1990,1999,2009,2016,2018		/	information not available	entire glacier	https://doi.org/10.5281/zenodo.17590496	
mass balance	yearly 1966-2024	glaziological mass balance	/		entire glacier	WGMS	
global dataset ice dynamic		ITS_LIVE	/	see Gardner et al 2022	entire glacier	Gardner et al 2022	
		FAU's glacierportal	/	see Friedl et al 2021	entire glacier	Friedl et al 2021	
		Millan's dataset	/	see Millan et al 2022	entire glacier	Millan et al 2022	
satellite SAR imagery	see Appendic C	Terra-SAR-X	2	GAMMA Remote sensing Software	entire glacier		

Fig. S1: Overview of all datasets used in this study.

Section S2 Stake network overview

Table S1: Stake overview (observation period and altitude range).

ID	Period	Alt. range [m]
10	1973–1977	3015–3027
80	1980–2007	3154–3175
100	1985–1992	2782–2816
110	1969–1982	2836–2851
113	1966–1998	2796–2880
114	1969–1980	2858–2876
116	1966–1981	2881–2952
117	1966–1986	2852–2959
118	1966–1999	2827–2938
123	1966–1999	2846–2962
141	2011–2014	2881–2893
142	2014–2016	2876–2883
150	1985–1994	2797–2839
151	1985–1998	2876–2925
152	1973–2004	2882–2997
153	1985–2004	2917–2967
154	1970–1999	2902–2975
156	2013–2022	2891–2909
157	1991–2021	2900–2961
158	1996–2023	2911–2974
159	1997–2021	2922–2962
160	1996–2023	3008–3062
161	2012–2023	3069–3087
163	2012–2021	3157–3170
164	2010–2023	2951–2985
165	2010–2021	3120–3137
167	2012–2021	3034–3047
168	2012–2021	3234–3259
169	2015–2022	2951–2970
170	2015–2021	2995–3007
181	2020–2021	3062–3064
203	1976–2006	2929–3002
204	2010–2015	2901–2918
210	1966–2022	2911–2955
211	1967–1978	2912–2933
212	1966–1979	2954–2967
213	1966–1987	2940–2958
214	1968–1982	2947–2981
215	1968–1982	2933–2981
217	1966–1981	2936–2981
218	1968–1982	2936–2963
220	1966–1990	2890–2969
223	1968–2002	2937–3031
225	1973–2004	2971–3005
227	1969–2006	2897–3006
231	1985–2005	2911–2983
250	1983–2002	2937–2973
251	1985–2020	2920–3007
252	1980–2023	2903–3014
254	1984–2019	2917–3001
255	1985–2002	2971–3015
256	1985–2001	2990–3030
257	2011–2019	2914–2939
258	1985–2021	2937–2992
265	1988–2021	2949–3031
266	1990–2022	2944–3028
267	1985–2004	2936–2996
270	1968–2005	2879–2939
272	1991–2021	2959–3021
273	1997–2022	3055–3092
274	1997–2021	3023–3084
275	2000–2019	3001–3047
278	2010–2021	3063–3083
280	2010–2016	3134–3141
281	2011–2021	3150–3162
282	2011–2016	2965–2980
283	2011–2023	3085–3110
285	2012–2021	3025–3040
288	2012–2023	3112–3127

Note that the stakes may have gaps in their measured period due to melting and reinstallation.

Dates and orbit information

Table S2: Dates and orbit information of the employed acquisitions.

date	orbit dir. (ascending/descending)	rel. orbit number	strip number
2011-07-03	D	78	6
2011-07-14	D	78	6
2011-08-08	A	131	10
2013-07-01	A	131	10
2014-06-07	A	131	10
2017-07-11	D	78	6
2017-08-13	D	78	6
2017-08-24	D	78	6
2018-07-31	D	78	6
2018-08-22	D	78	6
2019-07-29	D	78	6
2019-08-31	D	78	6
2020-01-02	A	131	7
2020-01-30	A	55	1
2020-02-21	A	55	1
2020-02-26	A	131	7
2020-05-02	A	131	7
2020-05-08	A	55	1
2020-07-04	D	78	6
2020-07-26	D	78	6
2020-09-11	A	131	7
2020-09-17	A	55	1
2020-11-11	A	55	1
2020-12-25	A	55	1
2021-01-27	A	55	1
2021-02-01	A	131	7
2021-02-07	A	55	1
2021-02-23	A	131	7
2021-03-25	D	78	5
2021-03-28	A	131	7
2021-04-08	A	131	7
2021-04-30	A	131	7
2021-05-11	A	131	7
2021-06-13	A	131	7
2021-06-24	A	131	7
2021-07-05	A	131	7
2021-08-18	A	131	7
2021-08-26	D	78	6
2021-09-09	A	131	7
2021-09-17	D	78	6
2021-10-12	A	131	7
2021-11-14	A	131	7
2021-11-25	A	131	7
2022-03-04	A	131	7
2022-03-26	A	131	7
2022-04-06	A	131	7
2022-05-09	A	131	7
2022-05-20	A	131	7
2022-05-31	A	131	7
2022-06-11	A	131	7
2022-07-03	A	131	7
2022-07-25	A	131	7
2022-08-02	D	78	6
2022-09-18	A	131	7
2022-09-29	A	131	7
2022-10-21	A	131	7