



Supplement of

Seasonality in terminus ablation rates for the glaciers in Greenland (Kalaallit Nunaat)

Aman KC et al.

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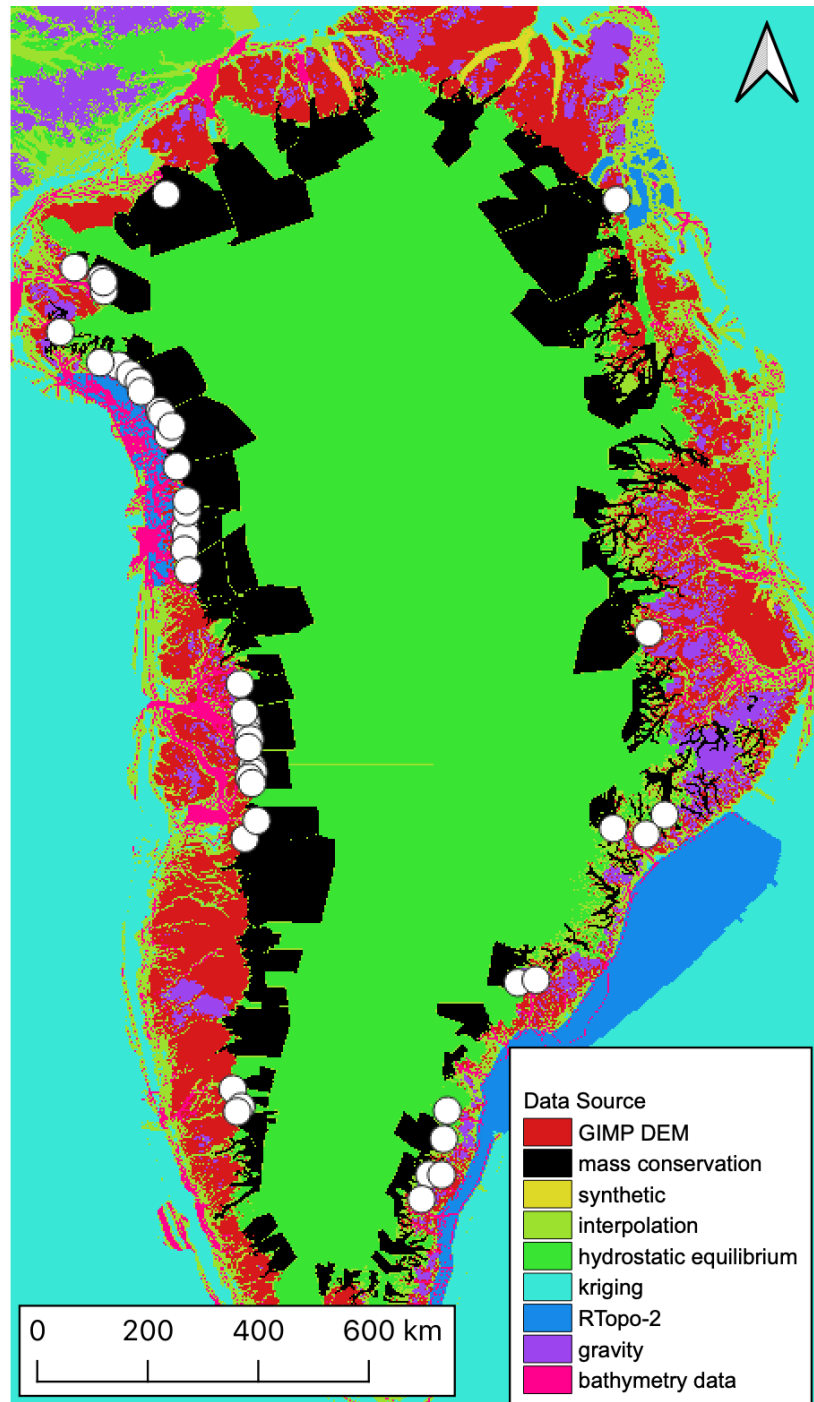


Figure S1. Map showing the data sources used to calculate ice thickness in BedMachine 5 (Morlighem et al., 2022). Different colors indicate regions where each method or dataset was applied. White circles represent the glaciers included in the study.

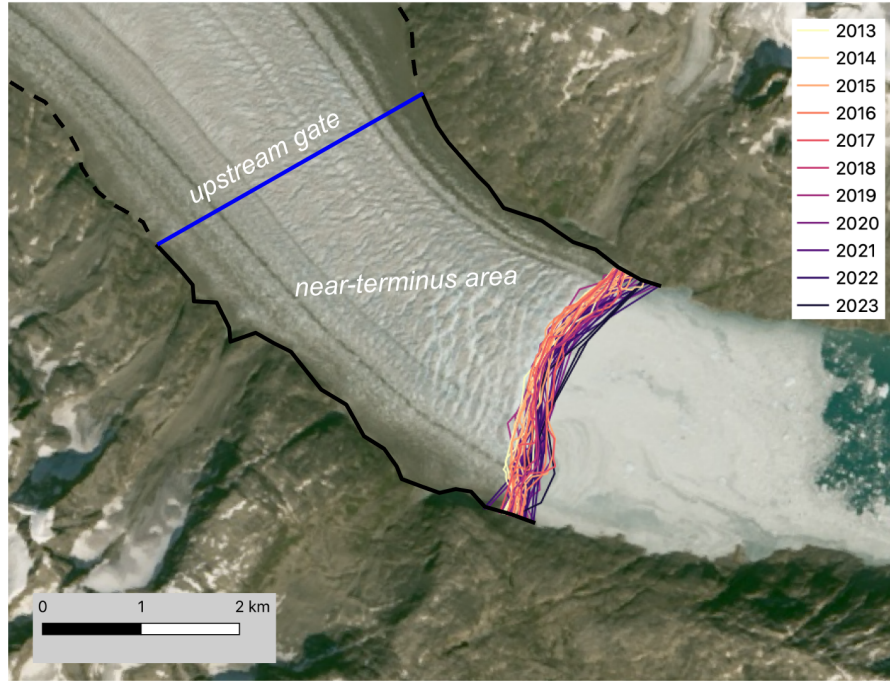


Figure S2. Figure showing the use of Sentinel-2 image for tracing fjord walls (denoted by black lines), arbitrary upstream boundary (denoted by blue line), and terminus positions from 2013–2023 at Sermeq Kujalleq N2.

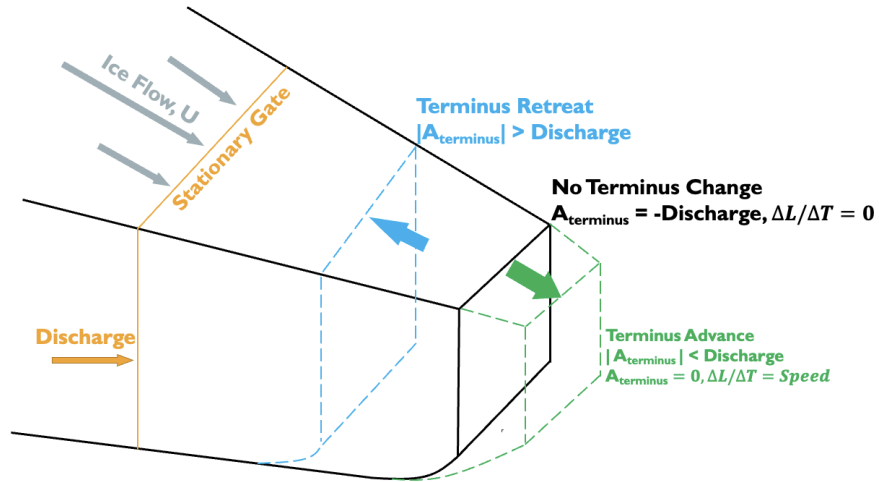


Figure S3. Schematic sketch showing glacier terminus ablation. The green terminus position shows glacier advance, blue shows glacier retreat and solid black shows no change in terminus. Solid orange line shows a stationary gate used to calculate ice discharge. Here, $\Delta M/\Delta t$ is change in terminus over time, A_{terminus} is terminus ablation and U is the velocity.

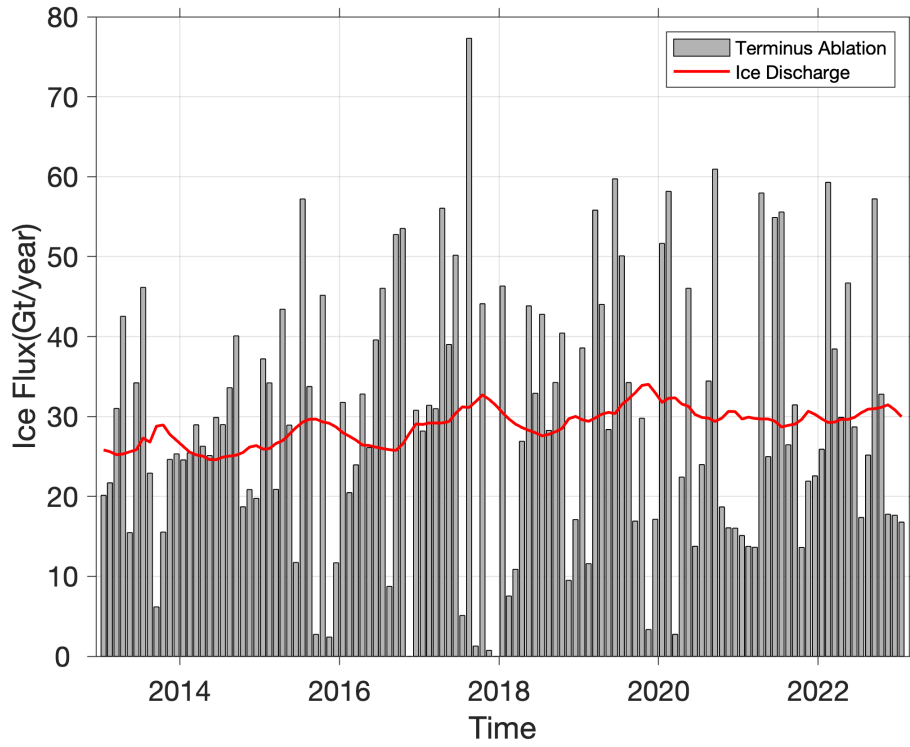


Figure S4. Time series for terminus ablation and discharge in gigatons per year for Helheim Gletsjer (SE) during 2013–2023.

The periodogram $P(f_k)$ at frequency f_k for a time series $x(t)$ with N data points is:

$$P(f_k) = \frac{1}{N} |X(f_k)|^2, \quad (1)$$

where $|X(f_k)|^2$ denotes the squared magnitude of the Discrete Fourier Transform (DFT) at frequency f_k ;

$$X(f_k) = \sum_{t=0}^{N-1} x(t) e^{-i2\pi f_k t}, \quad (2)$$

5 where $f_k = \frac{k}{N}$, $k = 0, 1, \dots, N-1$.

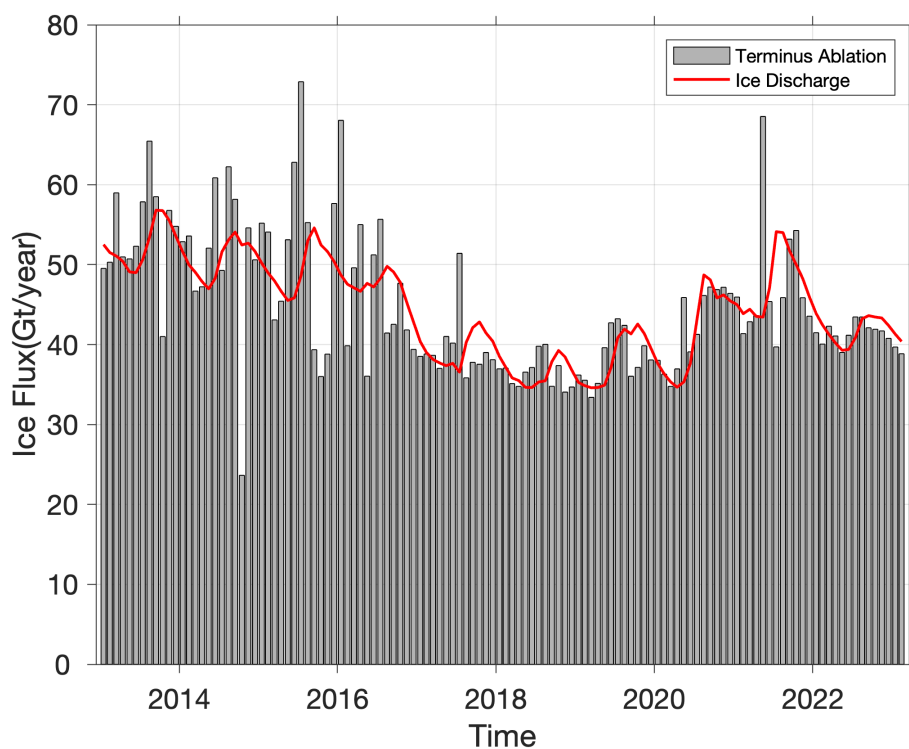


Figure S5. Time series for terminus ablation and discharge in gigatons per year for Sermeq Kujalleq (CW) during 2013–2023.

Table S1. Comparison of average glacier discharge (Gt/yr) across regions between this study and Mankoff et al. (2021)

Region	This Study	Mankoff et al. (2021)
NW	57.63 (22)	109.70 (71)
CW	73.47 (12)	86.25 (16)
SW	8.01 (3)	19.05 (13)
SE	46.88 (7)	145.03 (88)
CE	40.99 (4)	77.28 (52)
NE	15.18 (1)	29.04 (8)

Values are averaged over the decade. Numbers in parentheses indicate the number of glaciers included in each region for the respective study.

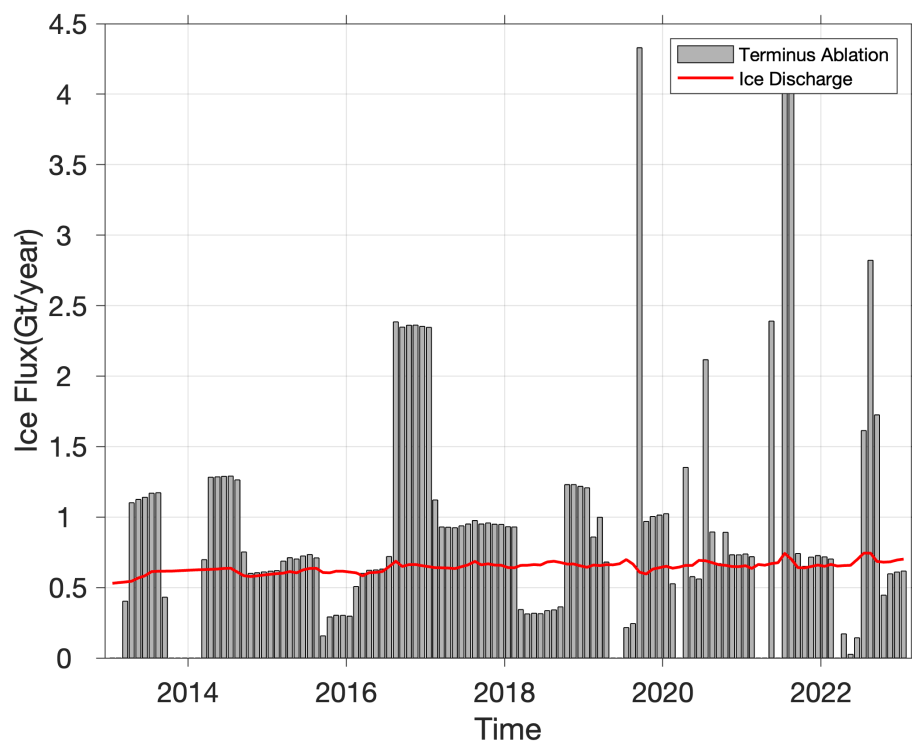


Figure S6. Time series for terminus ablation and discharge in gigatons per year for Yngvar Nielsen Gletsjer (NW) during 2013–2023.

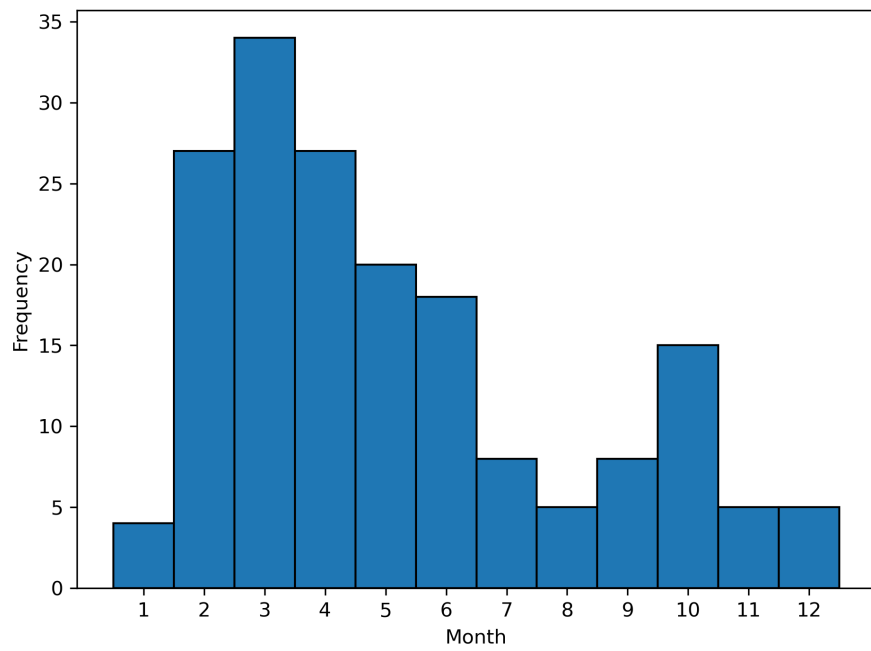


Figure S7. Histogram for the months having negative ablation values.

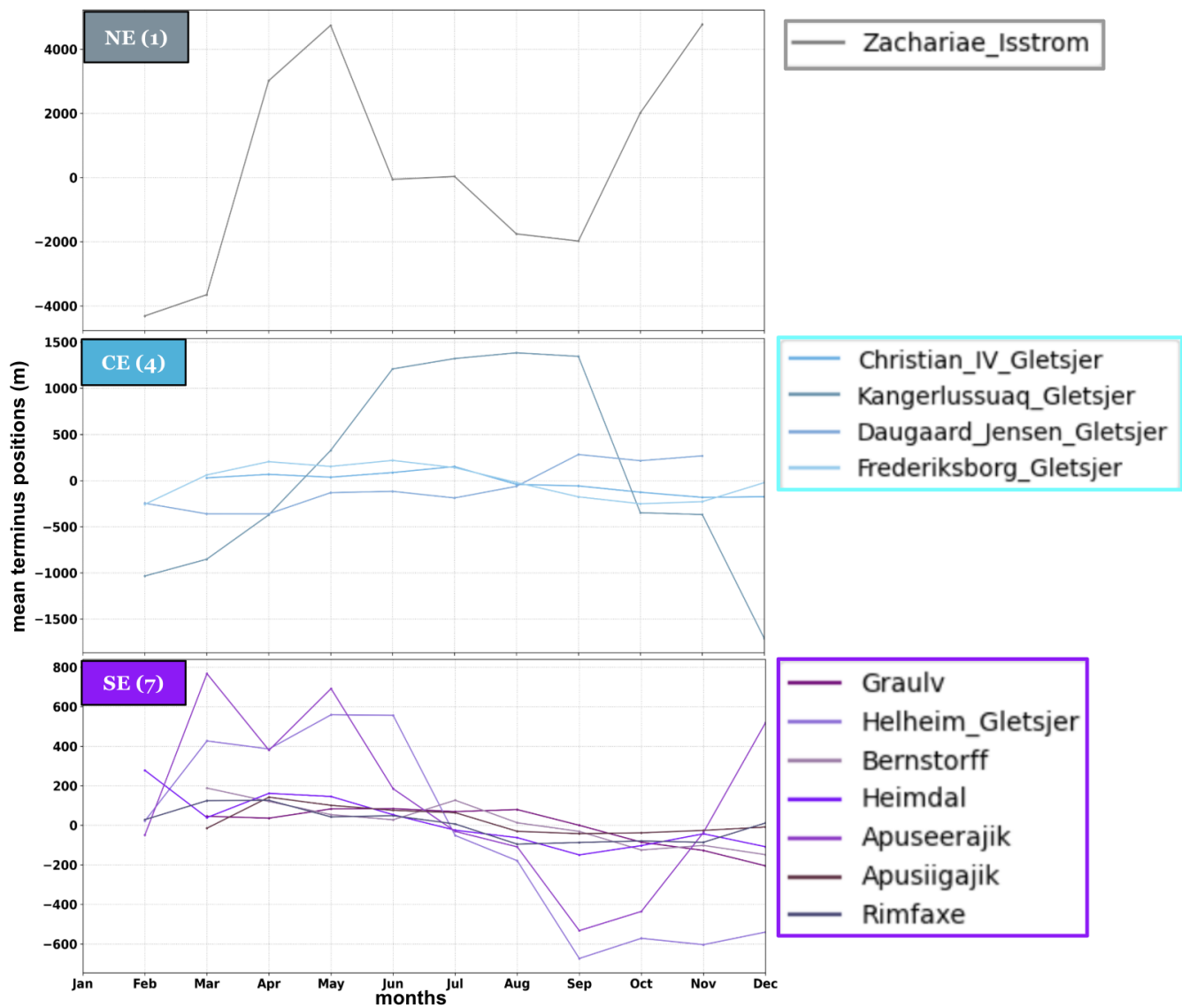


Figure S8. Seasonality of terminus position time series for east Greenland, with colors corresponding to the regions in Fig. 1. Each line indicates an individual glacier, corresponding to the names in the side panel — which groups glaciers by region. The numbers in parentheses indicate the number of study glaciers in the region.

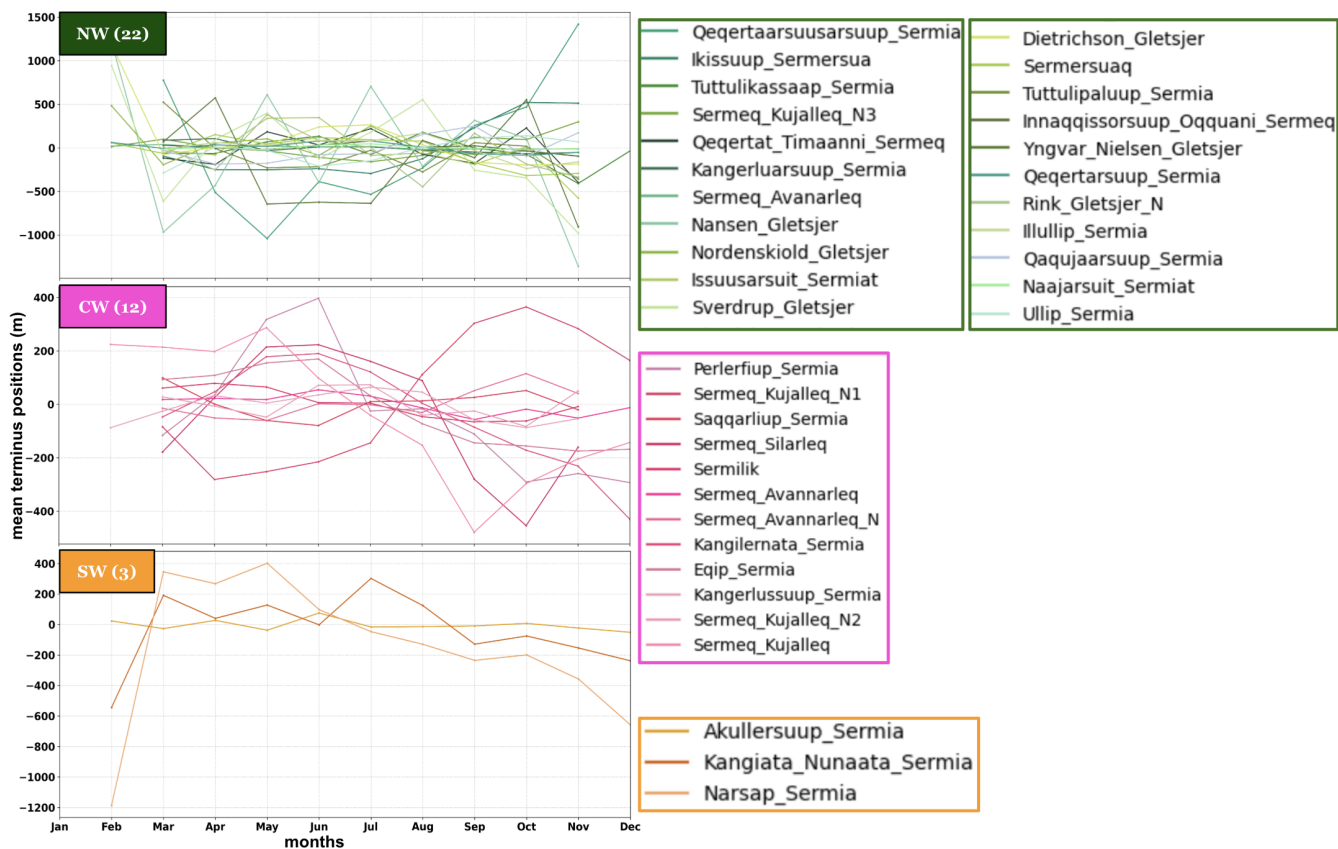


Figure S9. Seasonality of terminus position time series for west Greenland, with colors corresponding to the regions in Fig. 1. Each line indicates an individual glacier, corresponding to the names in the side panel — which groups glaciers by region. The numbers in parentheses indicate the number of study glaciers in the region.

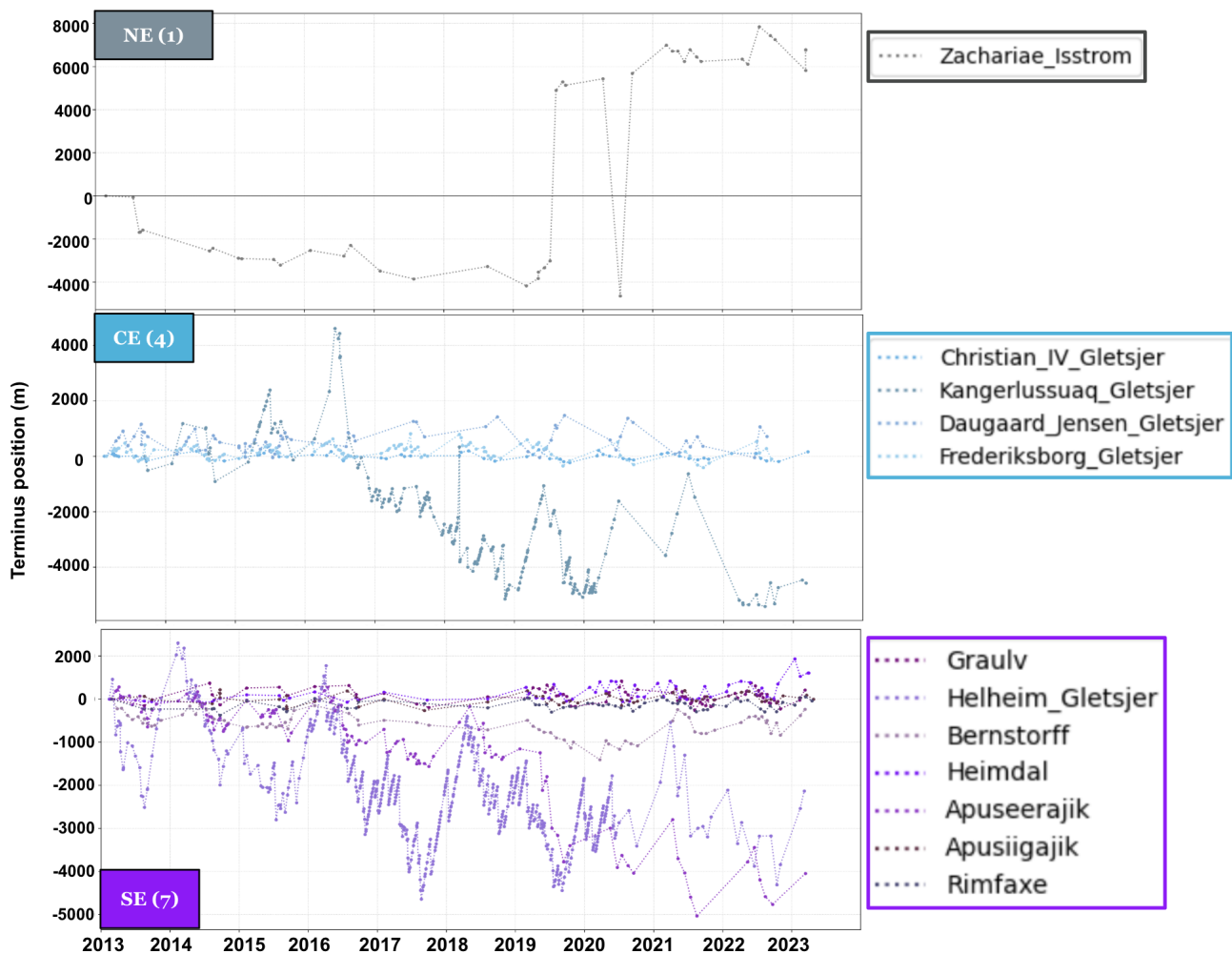


Figure S10. Terminus position time series for east Greenland, with colors corresponding to the regions in Fig. 1. Each line indicates an individual glacier, corresponding to the names in the side panel — which groups glaciers by region. The numbers in parentheses indicate the number of study glaciers in the region.

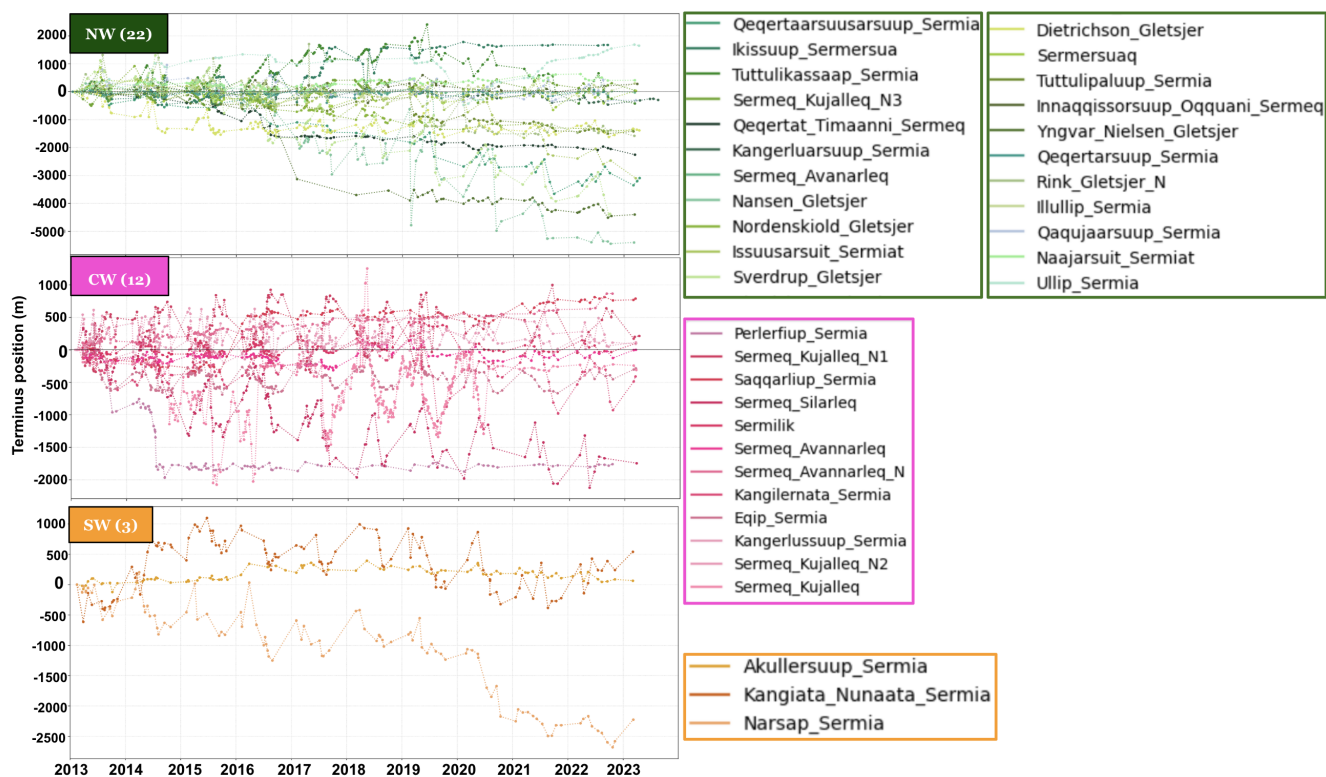


Figure S11. Terminus position time series for west Greenland, with colors corresponding to the regions in Fig. 1. Each line indicates an individual glacier, corresponding to the names in the side panel — which groups glaciers by region. The numbers in parentheses indicate the number of study glaciers in the region.

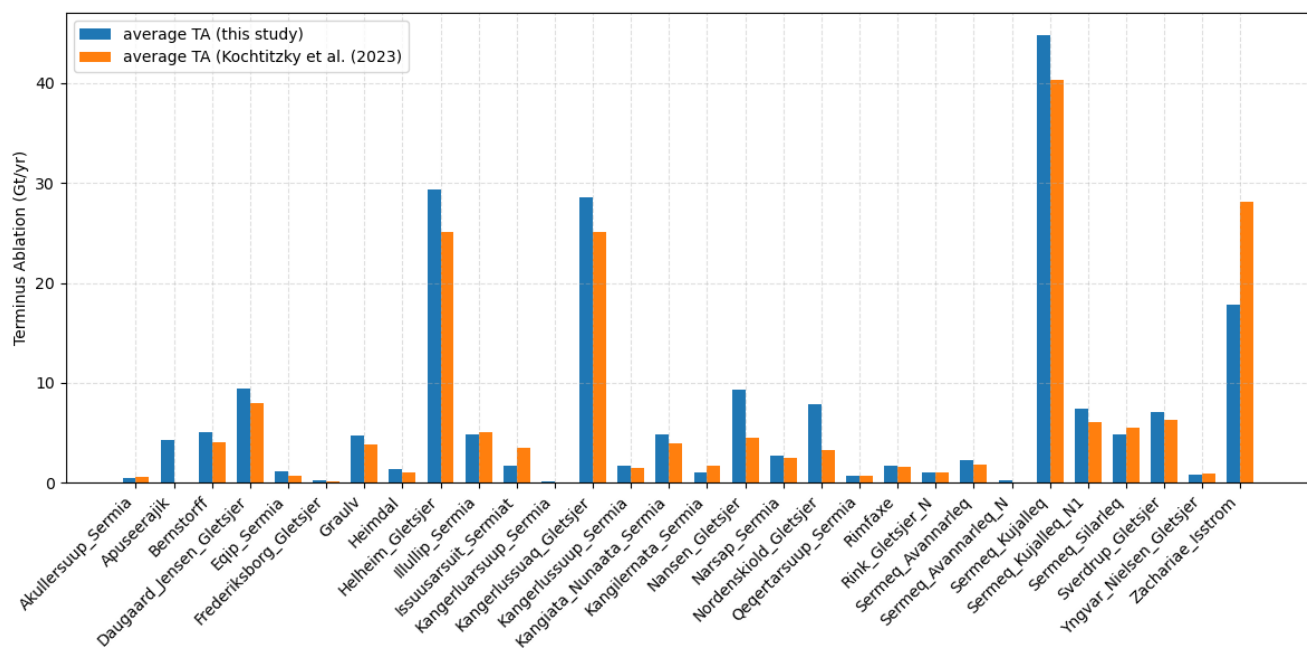


Figure S12. Comparison of terminus ablation rates for glaciers included in this study [2013–2023] and Kochtitzky et al. (2023) [2000–2020]. Bars represent decadal average values in gigatonnes per year (Gt/yr).

Table S2. Uncertainties for discharge and terminus ablation in Gt/yr

Glacier	Avg Dis	Avg Term Abl	Avg Dis Err	Avg NMC Err	Avg TA Err	region
Akullersuup Sermia	0.5194	0.5173	0.0014	0.0234	0.0235	SW
Apuseerajik	3.4889	4.2570	0.0095	0.0242	0.0260	SE
Apusiigajik	1.6161	1.6127	0.0044	0.0235	0.0239	SE
Bernstorff	5.0581	5.0792	0.0109	0.0233	0.0257	SE
Christian IV Gletsjer	3.8438	3.8324	0.0104	0.0239	0.0261	CE
Daugaard-Jensen Gletsjer	9.3719	9.4063	0.0257	0.0237	0.0349	CE
Dietrichson Gletsjer	1.1081	1.1788	0.0030	0.0240	0.0242	NW
Eqip Sermia	1.1478	1.1595	0.0031	0.0236	0.0238	CW
Frederiksborg Gletsjer	0.2306	0.2310	0.0006	0.0228	0.0228	CE
Graulv	4.7313	4.7220	0.0120	0.0230	0.0259	SE
Heimdal	1.4329	1.4324	0.0039	0.0229	0.0232	SE
Helheim Gletsjer	28.8648	29.3312	0.0791	0.0267	0.0835	SE
Ikissuup Sermersua	0.7277	0.8495	0.0014	0.0230	0.0230	NW
Illullip Sermia	4.9344	4.9035	0.0135	0.0224	0.0261	NW
Innaqqissorsuup Oqquani Sermeq	2.4643	2.5771	0.0068	0.0215	0.0225	NW
Issuusarsuit Sermiat	1.4272	1.7714	0.0039	0.0214	0.0218	NW
Kangerluarsuup Sermia	0.1342	0.1497	0.0004	0.0202	0.0202	NW
Kangerlussuaq Gletsjer	27.5417	28.5761	0.0751	0.0212	0.0780	CE
Kangerlussuup Sermia	1.7731	1.7593	0.0049	0.0212	0.0217	CW
Kangiata Nunaata Sermia	4.8169	4.8136	0.0132	0.0183	0.0226	SW
Kangilemata Sermia	1.0399	1.0783	0.0028	0.0182	0.0184	CW
Naajarsuit Sermiat	1.0912	1.0879	0.0030	0.0181	0.0184	NW
Nansen Gletsjer	7.7480	9.3539	0.0213	0.0238	0.0319	NW
Narsap Sermia	2.6690	2.7616	0.0073	0.0175	0.0189	SW
Nordenskiold Gletsjer	7.7480	7.9078	0.0213	0.0198	0.0291	NW
Perlerfiup Sermia	0.7185	0.9040	0.0020	0.0176	0.0178	CW
Qaqujaarsuup Sermia	1.6702	1.7042	0.0046	0.0173	0.0179	NW
Qeqertaarsuusarsuup Sermia	3.5742	4.2393	0.0098	0.0176	0.0202	NW
Qeqertarsuup Sermia	0.7080	0.7099	0.0019	0.0178	0.0179	NW
Qeqertat Timaanni Sermeq	1.4773	1.6649	0.0041	0.0181	0.0185	NW
Rimfaxe	1.6919	1.6895	0.0046	0.0171	0.0178	SE
Rink Gletsjer N	1.0324	1.0985	0.0028	0.0182	0.0184	NW
Saqqarliup Sermia	0.2482	0.3216	0.0007	0.0178	0.0178	CW
Sermeq Avannarleq	1.8760	1.8853	0.0037	0.0190	0.0194	NW
Sermeq Avannarleq	2.2239	2.2355	0.0061	0.0189	0.0198	CW
Sermeq Avannarleq N	0.1681	0.2193	0.0005	0.0168	0.0168	CW
Sermeq Kujalleq	44.4774	44.7986	0.1225	0.0383	0.1284	CW
Sermeq Kujalleq N1	7.4821	7.4678	0.0205	0.0277	0.0345	CW
Sermeq Kujalleq N2	9.0449	9.0461	0.0248	0.0257	0.0357	CW
Sermeq Kujalleq N3	1.9616	1.9619	0.0050	0.0257	0.0261	NW
Sermeq Silarleq	4.5756	4.8751	0.0125	0.0258	0.0287	CW
Sermersuaq	3.1741	5.0638	0.0087	0.0279	0.0292	NW
Sermilik	0.5730	0.5734	0.0016	0.0235	0.0235	CW
Sverdrup Gletsjer	5.1312	7.0744	0.0141	0.0264	0.0300	NW
Tuttulikassaap Sermia	7.6236	7.7135	0.0210	0.0260	0.0334	NW
Tuttulipaluup Sermia	0.4525	0.5076	0.0012	0.0244	0.0244	NW
Ullip Sermia	0.9268	1.0405	0.0026	0.0240	0.0242	NW
Yngvar Nielsen Gletsjer	0.6420	0.8780	0.0018	0.0240	0.0241	NW
Zachariae Isstrom	15.1848	17.7933	0.0419	0.0262	0.0494	NE

Avg Dis = average discharge, Avg Term Abl = average terminus ablation, Avg Dis Err = average discharge error, Avg NMC Err = average near terminus mass error, Avg TA Err = average terminus ablation error. All of the values are in Gt/yr with values averaged across the entire decade.

Table S3. Glacier properties including frequency, location, and seasonality classification

Glacier	Region	Frequency	Latitude	Longitude	Seasonality	Long-term Interannual
Sermeq_Avannerleq	CW	12.10	70.0853	-50.2468	C	N
Innaqsisoqssup_Oqquani_Sermeq	NW	4.52	76.3833	-62.7665	E	E
Sermeq_Avannarleq	NW	12.10	73.9410	-55.7679	C	N
Helheim_Gletsjer	SE	12.10	66.3735	-38.3067	C	N
Tuttulipaluuup_Sermia	NW	12.10	77.7000	-66.2330	C	N
Kangerdluusuaq_Sermia	CW	12.10	71.4588	-51.3101	C	N
Kangerdluusuaq_Gletsjer	CE	12.20	68.6746	-33.0760	C	N
Qaqujaarsuup_Sermia	NW	5.76	77.5167	-65.6664	C	N
Apuseerajik	SE	12.10	66.3820	-37.5439	C	N
Nordenskiold_Gletsjer	NW	60.50	75.8248	-59.0399	C	Y
Zachariae_Isstrom	NE	11.00	78.9333	-21.0000	C	N
Sermeq_Kujalleq_N1	CW	12.20	69.9960	-50.1596	C	N
Sermeq_Silarleq	CW	12.20	70.8268	-50.7627	C	N
Sermersuaq	NW	3.27	79.4462	-63.3957	E	N
Tuttuliksasap_Sermia	NW	12.10	74.9618	-57.0355	C	N
Nansen_Gletsjer	NW	6.05	75.7759	-58.8283	E	Y
Sermeq_Kujalleq_N3	NW	12.10	73.8317	-55.5825	C	N
Sermilik	CW	12.10	70.6333	-50.6167	C	N
Ikissuup_Sermersua	NW	12.78	74.2307	-55.8275	C	N
Christian_IV_Gletsjer	CE	12.20	68.7000	-30.6167	C	N
Qeqqertasuusaq_Sermia	NW	12.20	77.6564	-65.9679	C	N
Sermeq_Avannarleq_N2	CW	4.46	70.5454	-50.4896	E	N
Kangilernata_Sermia	CW	12.10	69.9000	-50.3420	C	N
Qeqqertasuup_Sermia	NW	6.05	73.5932	-55.5306	C	N
Rimfaxe	SE	12.20	63.3050	-42.3669	C	N
Kangerdluarsup_Sermia	NW	12.60	77.6934	-68.5829	C	N
Narsap_Sermia	SW	12.10	64.6672	-49.8576	C	N
Perlerfiup_Sermia	CW	12.89	70.9090	-50.9227	C	N
Bernstorff	SE	12.10	63.8846	-41.7654	C	N
Saqqarliup_Sermia	CW	11.00	68.8667	-50.2833	C	N
Akullersuup_Sermia	SW	12.20	64.3833	-49.4779	C	N
Apusiigajik	SE	12.20	63.2926	-41.9168	C	N
Qeqertat_Timaanni_Sermeq	NW	8.64	76.3000	-61.7666	C	N
Yngvar_Nielsen_Gletsjer	NW	11.00	76.3334	-64.0831	E	N
Ullip_Sermia	NW	12.20	76.5797	-67.6260	C	N
Sermeq_Kujalleq	CW	5.81	69.1833	-49.8000	E	Y
Naajarsuit_Sermiat	NW	12.10	73.2500	-55.0833	C	N
Heimdall	SE	12.20	62.9052	-42.6851	C	N
Graulv	SE	12.10	64.3500	-41.5667	C	N
Frederiksborg_Gletsjer	CE	11.60	68.4557	-31.6620	C	N
Illullip_Sermia	NW	12.10	74.4167	-55.9666	C	N
Rink_Gletsier_N	NW	5.76	76.2167	-60.9999	C	N
Issuusarsuit_Sermiat	NW	12.20	76.0667	-60.6333	C	Y
Daugaard_Jensen_Gletsjer	CE	11.50	71.7500	-29.0000	C	N
Sermeq_Kujalleq_N2	CW	2.52	70.4054	-50.5364	E	N
Dietrichson_Gletsjer	NW	12.30	75.4582	-58.0637	C	N
Kangiata_Nunaata_Sermia	SW	4.01	64.2966	-49.6102	E	N
Sverdrup_Gletsjer	NW	11.60	75.6195	-57.9704	C	N
Equip_Sermia	CW	12.20	69.8080	-50.1851	C	N

C = Consistent seasonal variability; E = Erratic; N = No long-term variability; Y = Present long-term variability. Frequency is given in cycles per year, rounded to two decimal places.