Supplementary Information

Arctic glacier snowline altitudes rise 150 meters over the last four decades

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Table S1. Glaciers with long-term measurements of ELA

ID	Region	Name	# of years with ELA measurements between 1984-2022
RGI60-05.11186	Greenland	Mittivakkat Glacier	24
RGI60-03.02435	Arctic Canada North	Devon Ice Cap NW	30
RGI60-03.04539	Arctic Canada North	White Glacier	35
RGI60-01.00570	Alaska	Gulkana Glacier	37
RGI60-01.09162	Alaska	Wolverine Glacier	37
RGI60-07.00504	Svalbard	Austre Broeggerbreen	37
RGI60-07.00240	Svalbard	Hansbreen	29
RGI60-07.00493	Svalbard	Midtre Lovenbreen	37
RGI60-07.01481	Svalbard	Kongsvegen	34
RGI60-08.00199	Scandinavia	Marmaglaciaeren	27
RGI60-08.00006	Scandinavia	Riukojietna	30
RGI60-08.00188	Scandinavia	Rabots Glaciaer	31
RGI60-08.00213	Scandinavia	Storglaciaeren	36

RGI60-08.02666	Scandinavia	Aalfotbreen	37
RGI60-08.01286	Scandinavia	Austdalsbreen	33
RGI60-08.01657	Scandinavia	Engabreen	37
RGI60-08.00987	Scandinavia	Graasubreen	37
RGI60-08.02650	Scandinavia	Hansebreen	34
RGI60-08.01779	Scandinavia	Rembesdalskaaka/Hardanger	37
RGI60-08.00449	Scandinavia	Hellstugubreen	37
RGI60-08.01258	Scandinavia	Langfjordjoekulen	30
RGI60-08.01126	Scandinavia	Nigardsbreen	37
RGI60-08.00312	Scandinavia	Storbreen	37
RGI60-06.00377	Iceland	Bruarjoekull	24
RGI60-06.00472	Iceland	Eyjabakkajoekull	26
RGI60-06.00238	Iceland	Hofsjoekull N	29
RGI60-06.00234	Iceland	Thjorsarjoekull (Hofsjoekull E)	31
RGI60-06.00236	Iceland	Blagnipujoekull (Hofsjoekull SW)	28
RGI60-06.00309	Iceland	Hagafellsjoekull East (Langjoekull S Dome)	21
RGI60-06.00443	Iceland	Tungnaarjoekull	24

Note: ELA data from Ohmura and Boettcher (2022).

Table S2. Zero–order correlations (*r*) between detrended normalized composite time series of late–summer snowline altitude, and annual and seasonal climate variables for grid cells in "wet" and "dry" settings

	Wet		**Dry**	
	Temperature	Snowfall	Temperature	Snowfall
Annual	0.21	–0.25	0.20	–0.21
Summer	**0.50**	**–0.54**	**0.42**	**–0.40**
Fall	0.14	–0.21	0.01	0.15
Winter	–0.04	–0.09	0.26	–0.13
Spring	0.04	–0.03	0.12	–0.03

Bold values are significant ($p<0.05$; $n=39$). Wet (Dry) grid cells are defined as those with mean annual precipitation totals of >785 (<785) mm w.e. per year.

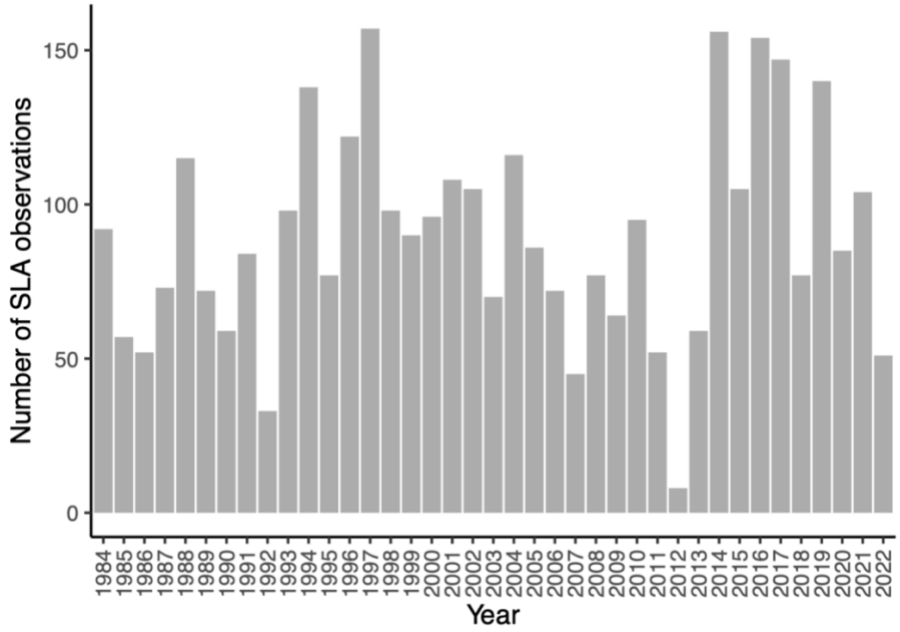

Figure S1. Number of snowline altitude observations per year between 1984 and 2022. The total number of snowlines delineated over the 39-year observational period is *n=3489*. The least number of snowlines were delineated in 2012 (*n=8*). The greatest number of snowlines were delineated in 1997 (*n=157*). There is no significant trend in the number of snowlines delineated over time.

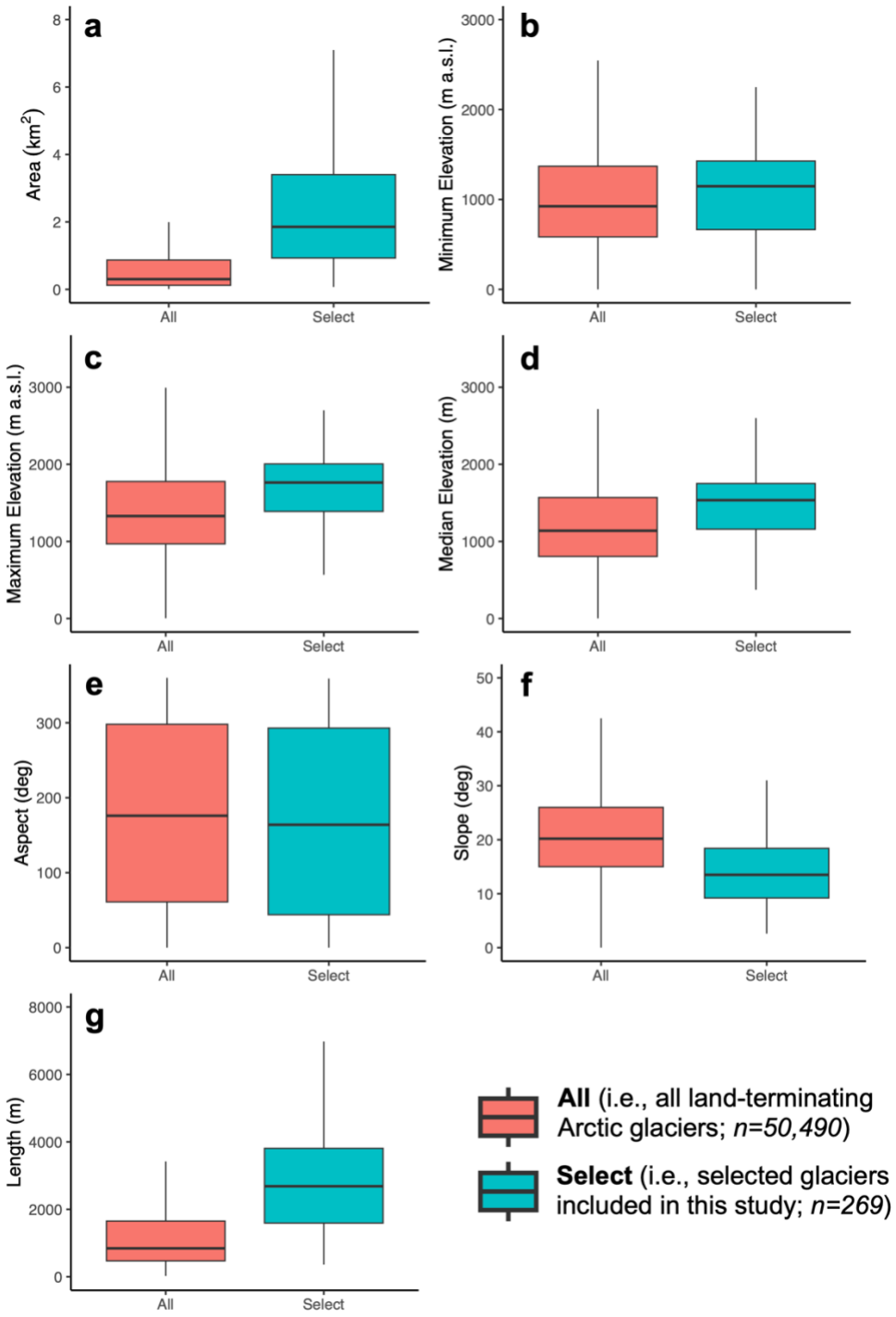

Figure S2. Comparison of morpho-topographic variables for study glaciers versus the entire Arctic glacier population. Glacier **(a)** area, **(b)** minimum elevation, **(c)** maximum elevation, **(d)** median elevation, **(e)** aspect, **(f)** slope, and **(g)** length are shown for two groups: All land-terminating glaciers (i.e., Form=0; TermType=0) across the Arctic located above 60°N (red; n=50,490) and glaciers studied here (blue; n=269). Morpho-topographic variables are from the Randolph Glacier Inventory (RGI) Version 6. In each box plot the center line represents the median, the edges of the box represent the first and third quartiles, and the whiskers extend to span a 1.5 interquartile range from the edges. Outliers are not shown.

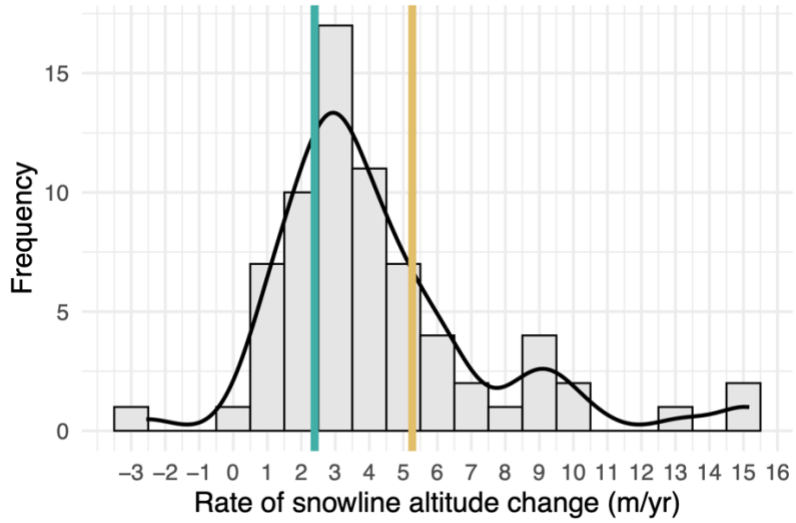

Figure S3. Distribution of the rate of snowline altitude change. Green line and yellow lines mark the boundaries of the lower and upper 25% of the distribution, respectively. Black curve is the kernel density estimate, a smoothed approximation of the histogram. Rates are gridded mean values.

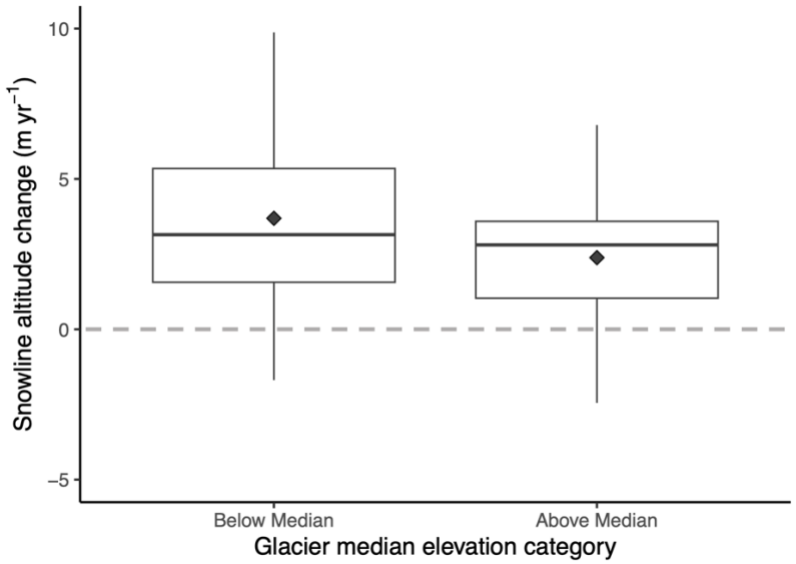

Figure S4. Relationship between glacier snowline altitude change and glacier topographic setting. Rate of snowline altitude change for two categories: Glaciers situated at relatively low elevations (where the median elevation is *<1535 m*) and glaciers situated at relatively high elevations (where the median elevation is *>1535 m*). The categories were defined based on the median of the median elevation across all study glaciers. The box plot center lines represent the median, the edges of the box represent the first and third quartiles, and the whiskers extend to span a 1.5 interquartile range from the edges. The means are denoted by the gray diamonds. Outliers are not shown.

Figure S5. Distribution of snowline observations per month between 1984 and 2022. The colored bar indicates the number of observations made per day in the months of July, August, and September.

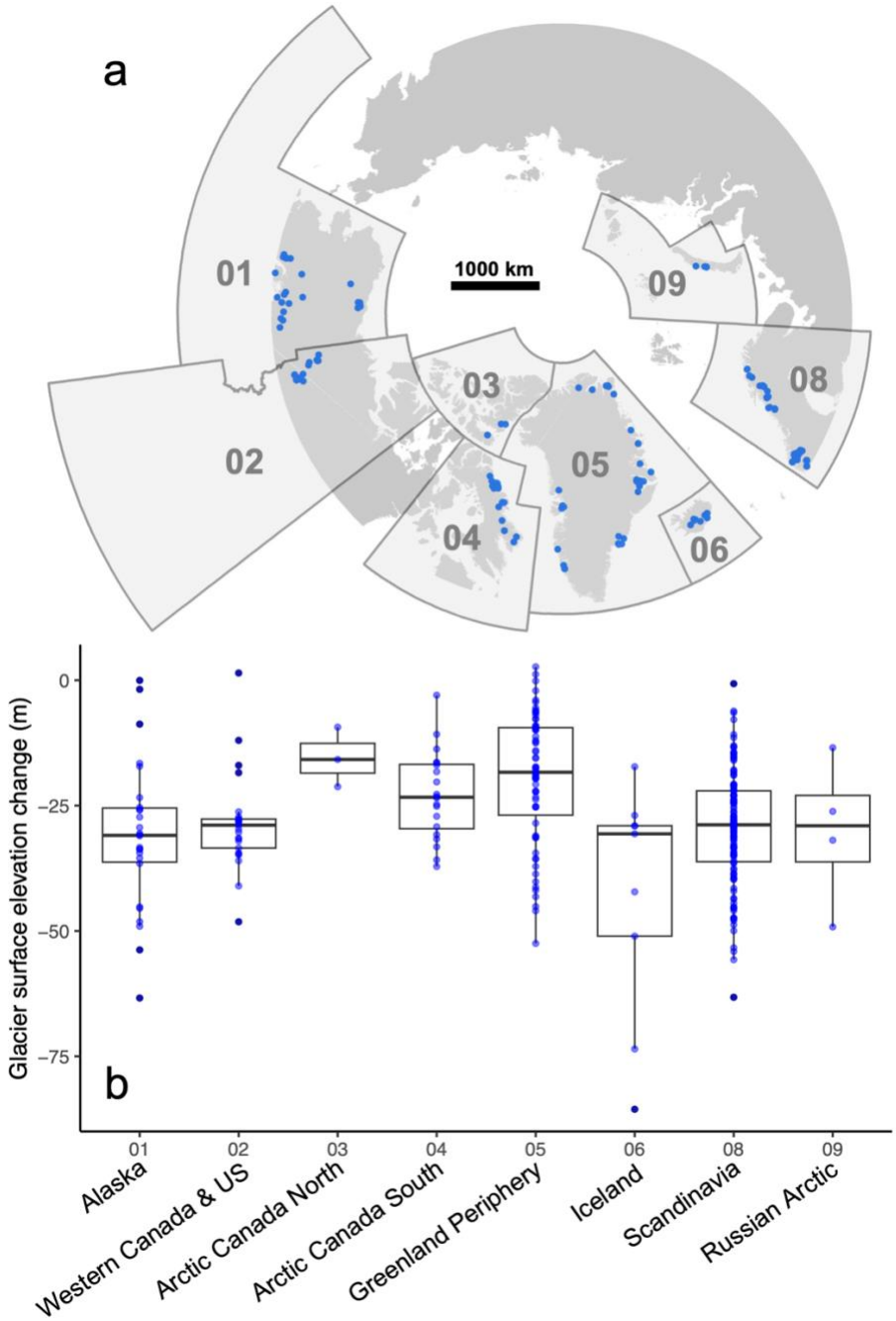

Figure S6. Estimated cumulative glacier surface elevation change between 1984 and 2022. **(a)** Map of eight first order regions defined by the Randolph Glacier Inventory (RGI Consortium, 2017) Version 6 in which our study glaciers fall (blue dots). **(b)** Glacier surface elevation change in meters (m) at each of our 269 study glaciers (blue dots) was estimated using the elevation change rate in meters per year (dhdt) for 2000-2020 as reported by Hugonnet et al. (2021) multiplied by the number of years in our observational period (i.e., 39 years). We suggest this represents a maximum constraint on glacier surface lowering as changes were very likely larger in the 21st century than prior. From west to east, Arctic regions are as follows: 01 Alaska; 02 Western Canada and US; 03 Arctic Canada North; 04 Arctic Canada South; 05 Greenland Periphery; 06 Iceland; 08 Scandinavia; and 09 Russian Arctic. In each box plot the center line represents the median, the edges of the box represent the first and third quartiles, and the whiskers extend to span a 1.5 interquartile range from the edges.

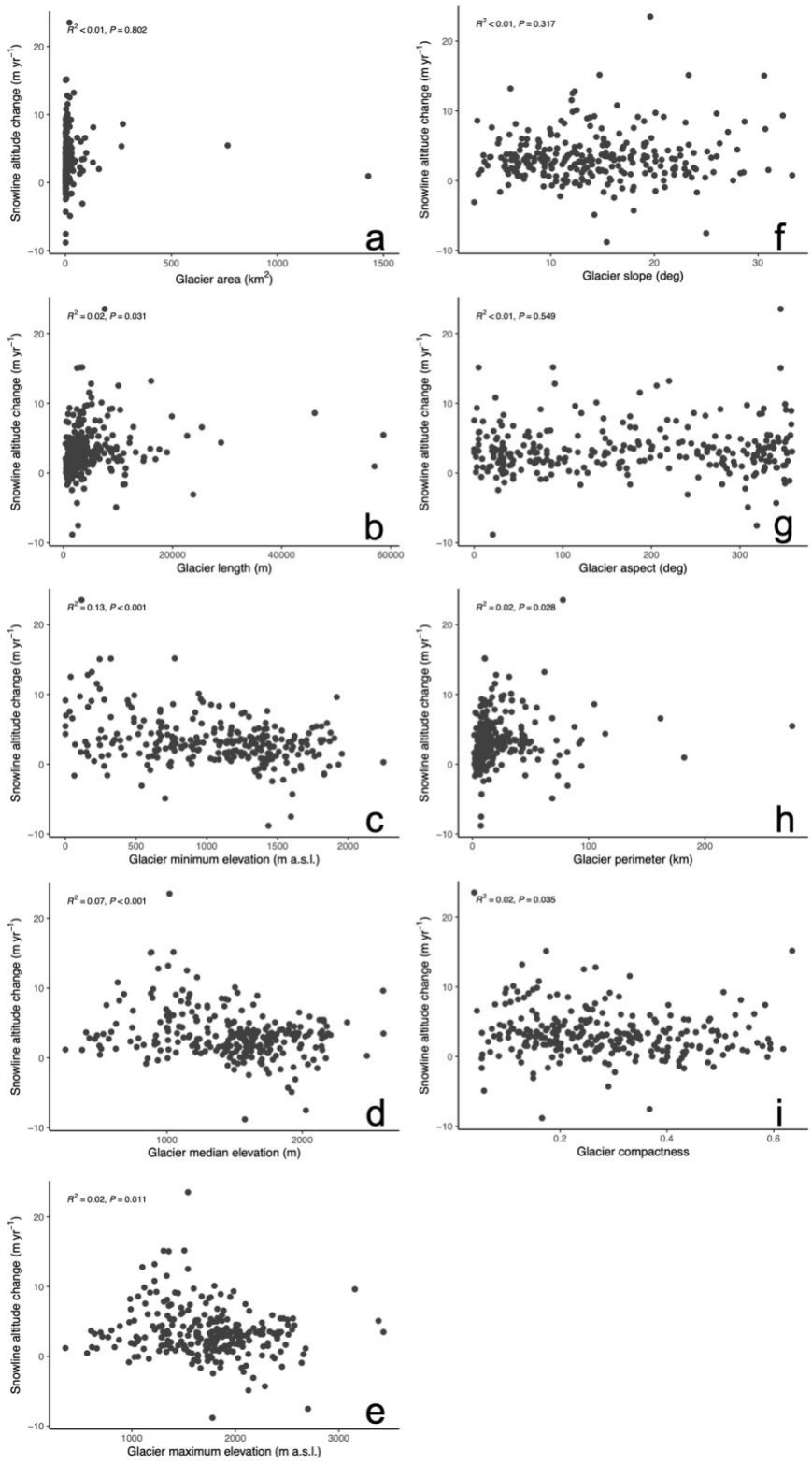

Figure S7. Relationships between rate of snowline altitude change and glacier morpho-topographic variables. Glacier (a) area; (b) length; (c) minimum elevation; (d) median elevation; (e) maximum elevation; (f) slope; (g) aspect; (h) perimeter; and (i) compactness.

References

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