Supplementary Figures and Tables

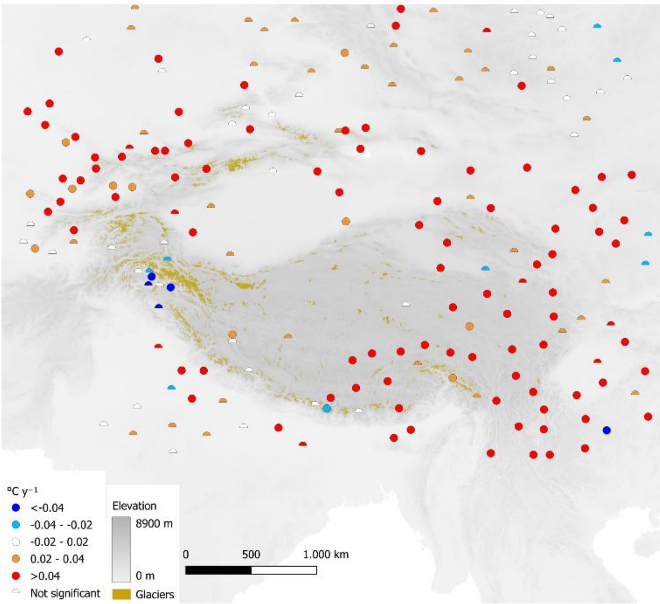

Figure S1 | Map of selected observational meteorological time-series in the HMA (216 stations; Suppl. Table 1). The map reports the $2m - JJA - Tmax$ *trend for the 1994–2023 period. Stations are associated with glacier surfaces within a 100 km radius (see Main Text Fig. 1 and Methods). Stations with glaciers present within a 100 km radius were used for the analysis in Fig. 1b.*

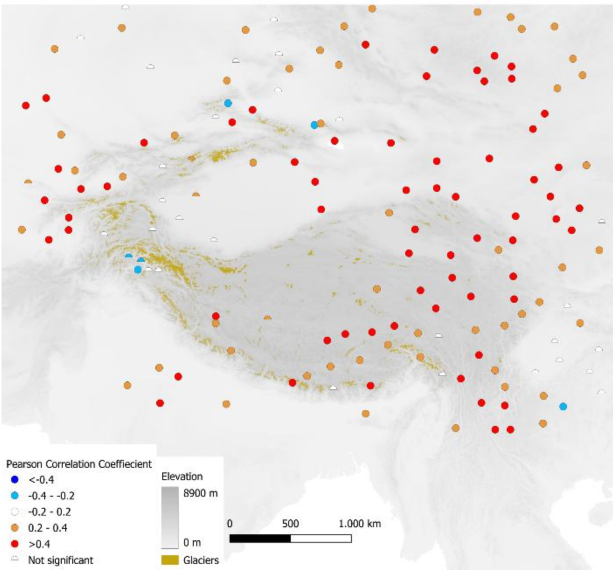

Figure S2 | Correlation between the Atlantic Multidecadal Oscillation (AMO) index and $2m - JJA - Tmax$ *changes (1960–2023). Correlations are calculated with respect to glacier cover within a 100 km radius of each station (see Main Text Fig. 1 and Methods for subset selection from figure S1).*

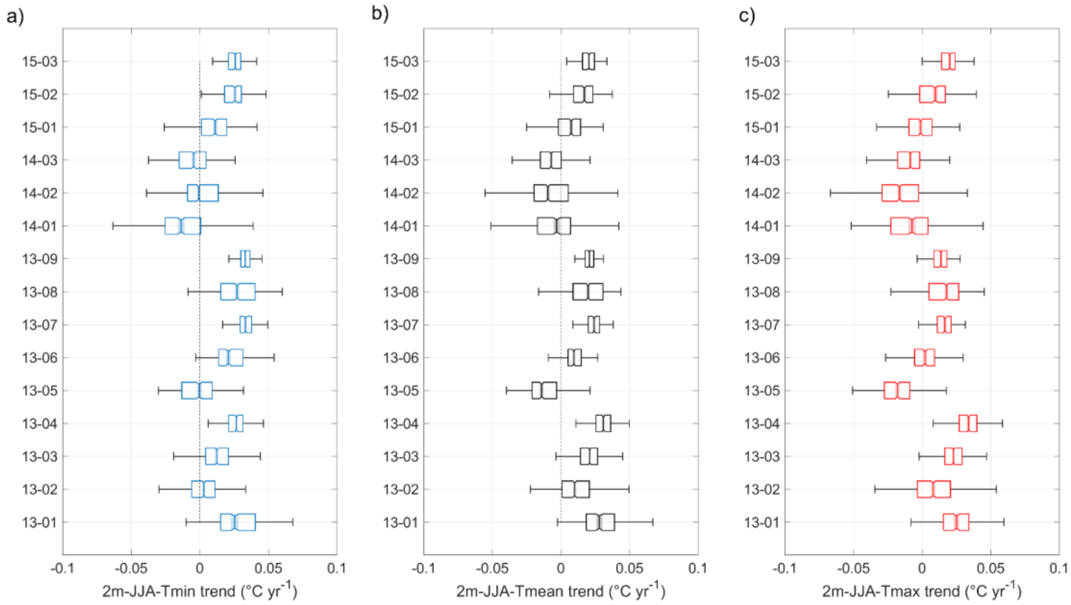

Figure S3 | Box-plots of ERA5-Land T_{max}, T_{min}, and T_{mean} trends for JJA (1994–2023). Trends are grouped by Randolph Glacier Inventory (RGI) sub-region and expressed as Sen's slopes derived from the two-tailed Mann–Kendall test. Figs. 1, S4, and S5 graphically represent these trends for T_{max}, T_{min}, and T_{mean}, respectively. Median values are reported in Table S2. ***Central Asia: 13.1*** *Hissar Alay,* ***13.2*** *Pamir,* ***13.3*** *West Tien Shan,* ***13.4*** *East Tien Shan,* ***13.5*** *West Kunlun,* ***13.6*** *East Kunlun,* ***13.7*** *Qilian Shan,* ***13.8*** *Inner Tibet,* ***13.9*** *South and East Tibet.* ***South Asia West: 14.1*** *Hindu Kush,* ***14.2*** *Karakoram,* ***14.3*** *West Himalaya.* ***South Asia East: 15.1*** *Central Himalaya,* ***15.2*** *East Himalaya,* ***15.3*** *Hengduan Shan.*

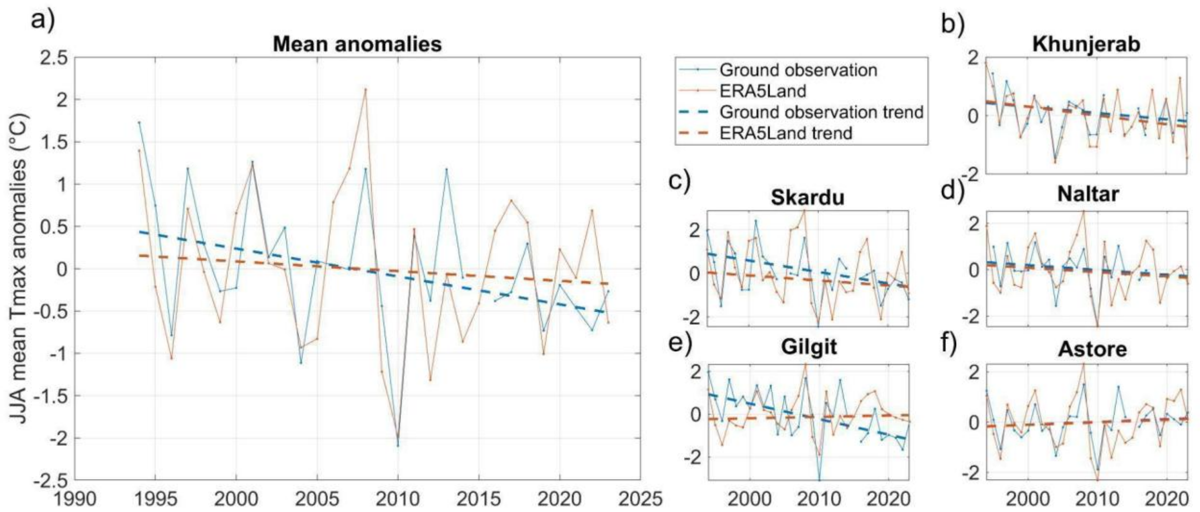

Figure S4 | Trend comparison between five high-elevation time series (>2500 m a.s.l.) in the Karakoram for $2m - JJA - Tmax$ *and the corresponding ERA5-Land reanalysis. a, Mean values of these stations (from panels b to f). All data are expressed as anomalies.*

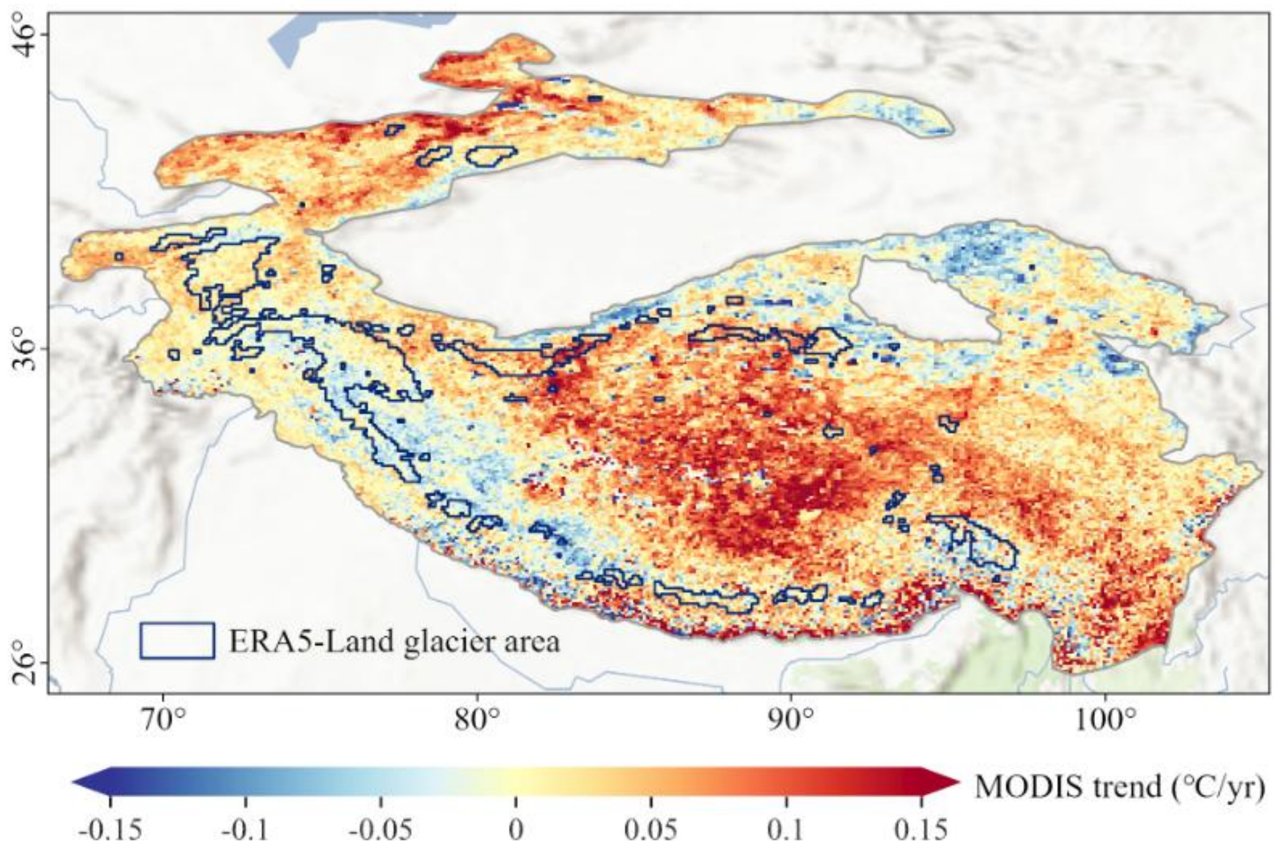

Figure S5 MODIS-derived summer surface temperature trends across High Mountain Asia (2000–2020).

Spatial distribution of daytime Land Surface Temperature (LST) trends (see Methods) during the summer season (JJA). The map displays the ERA5-Land glacier mask (see Methods)

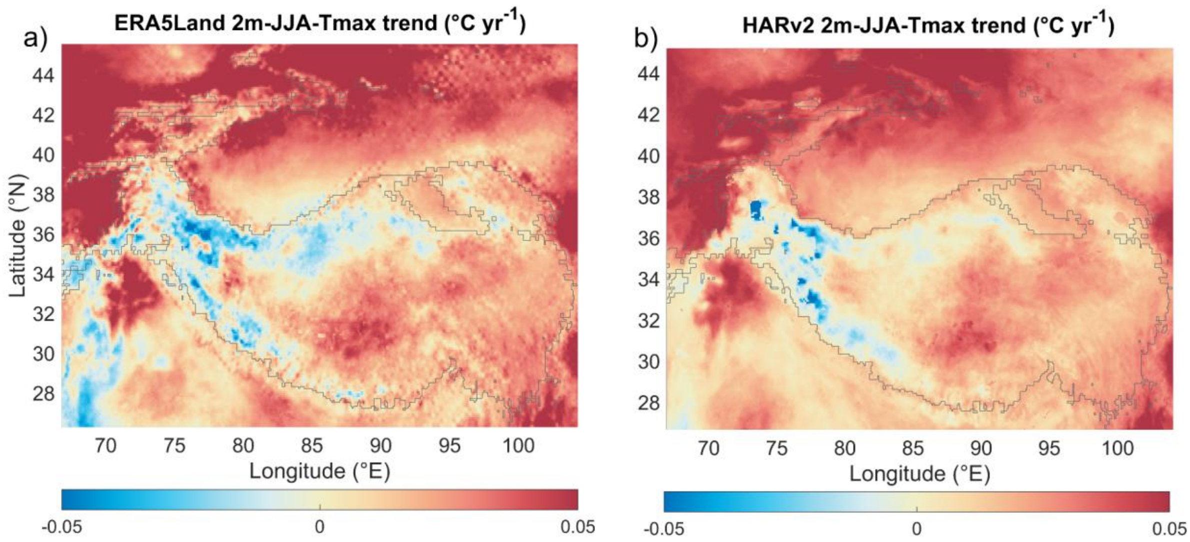

Figure S6 | $2m - JJA - Tmax$ trend simulated by ERA5-Land (a) and HAR-v2 reanalysis (b) for 1994–2023. Cold and warm colors represent decreasing and increasing trends, respectively.

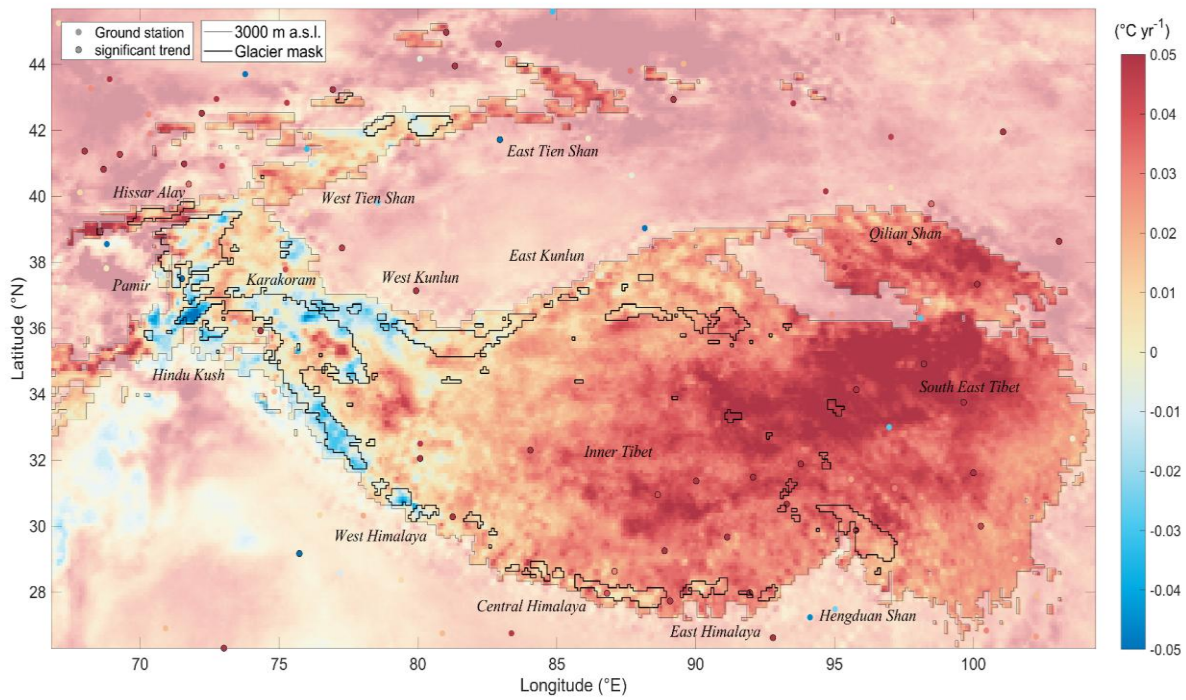

Figure S7 | HMA trend of ERA5-Land minimum temperature during the warm season (JJA, 1994–2023). The map displays the ERA5-Land glacier mask (see Methods). Cold and warm colors represent decreasing and increasing trends, respectively.

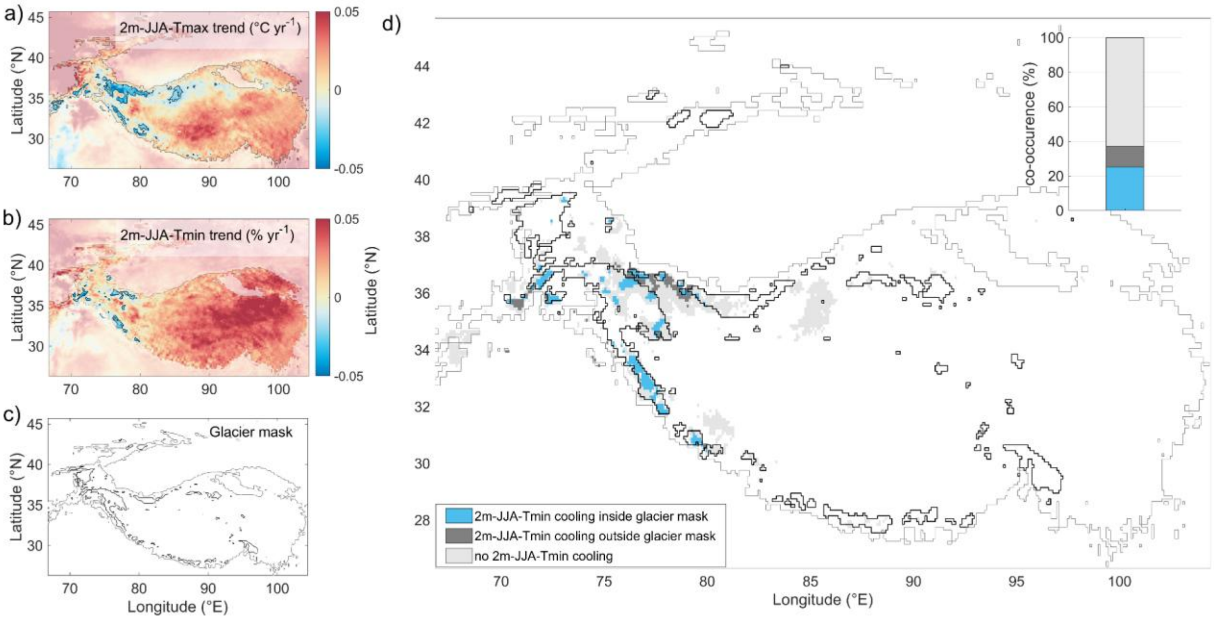

Figure S8 | Relationship between negative $2m-JJA-Tmax$ trends (a), negative $2m-JJA-Tmin$ trends (b), and the glacier mask (c). Panel d displays the spatial intersection (co-occurrence) of b with respect to a. The color code and histogram quantifies co-occurrence relative to the glacier mask.

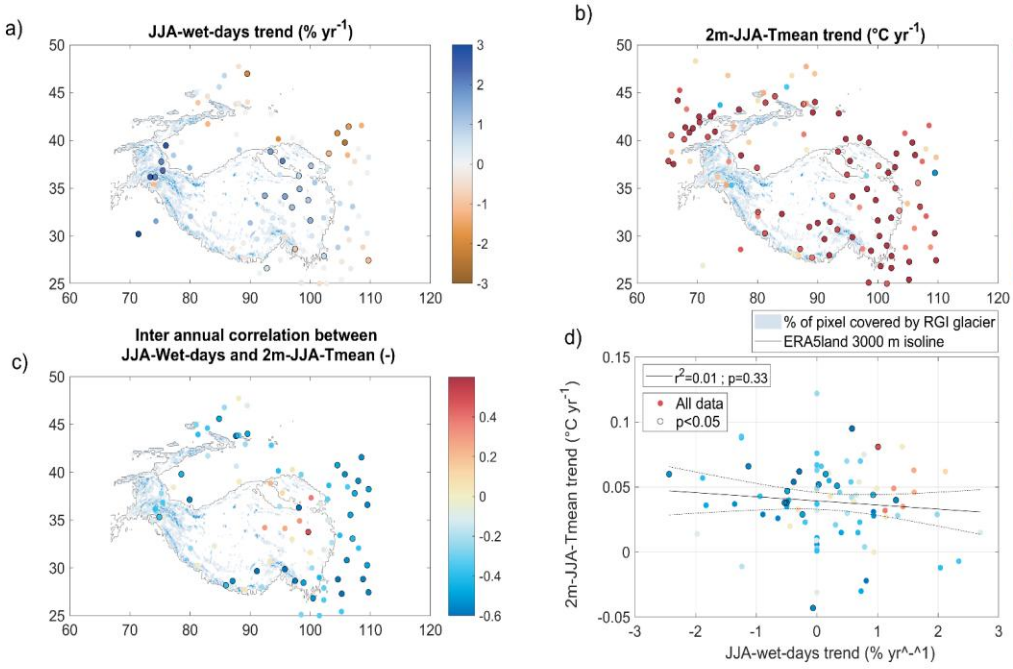

Figure S9 | Comparison between mean summer temperature ($2m-JJA-Tmean$) and corresponding rainy days (JJA, 1994–2023) for the overall HMA. a, Trends in wet days expressed in % of the corresponding mean value. b, Mean temperature trends. c, Inter annual correlation between the two time series. d, Regression between $2m-JJA-Tmean$ trends and wet-day trends. Panels c and d share the same color scale.

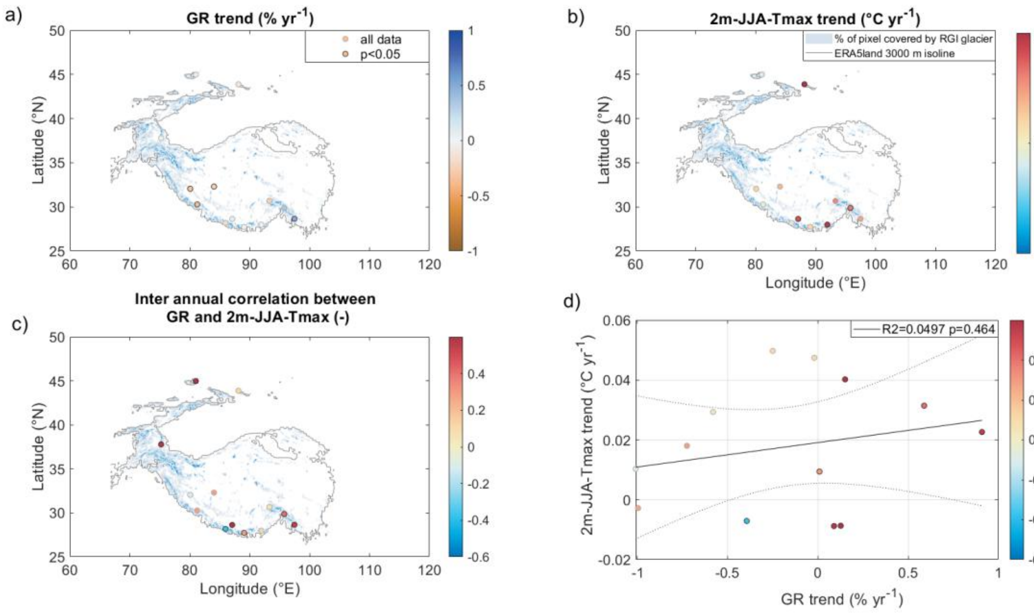

Figure S10 | Comparison between $2m-JJA-Tmax$ and sunshine-derived shortwave radiation for 13 Chinese high-elevation stations. a, Trends in sunshine-derived shortwave radiation expressed in % of the corresponding mean value. b, Daily maximum temperature trends. c, Inter annual correlation between the two time series. d, Regression between $2m-JJA-Tmax$ trends and sunshine-derived shortwave radiation. Panels c and d share the same color scale.

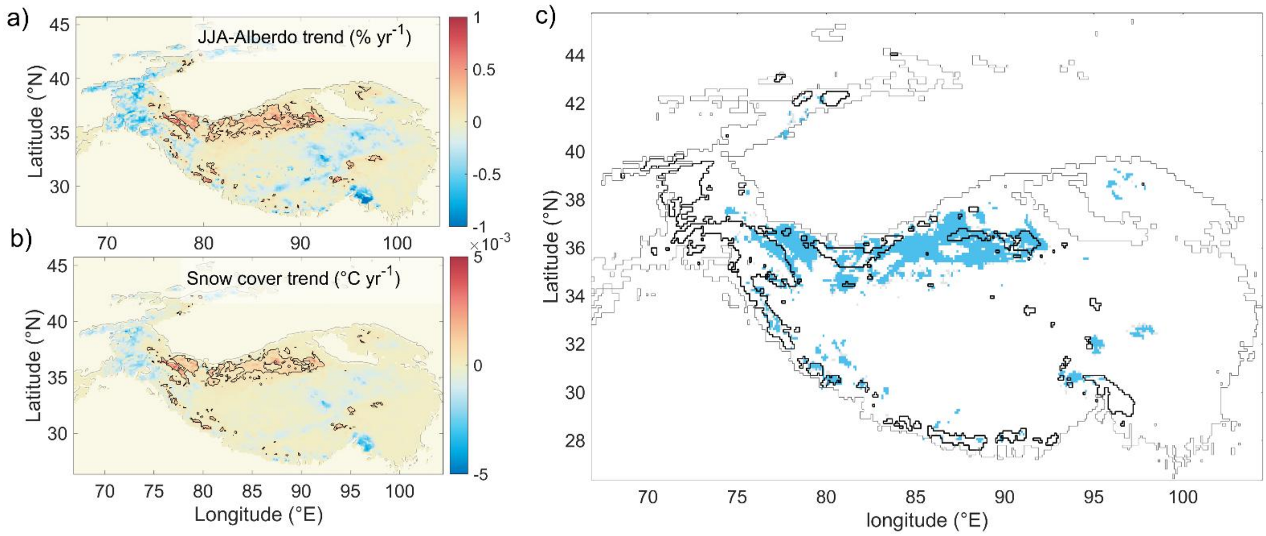

Figure S11 | Relationship between positive albedo trends (a) and positive snow cover JJA trends (b). Panel c displays the spatial intersection (co-occurrence) of b with respect to a. The glacier mask is reported with a black line

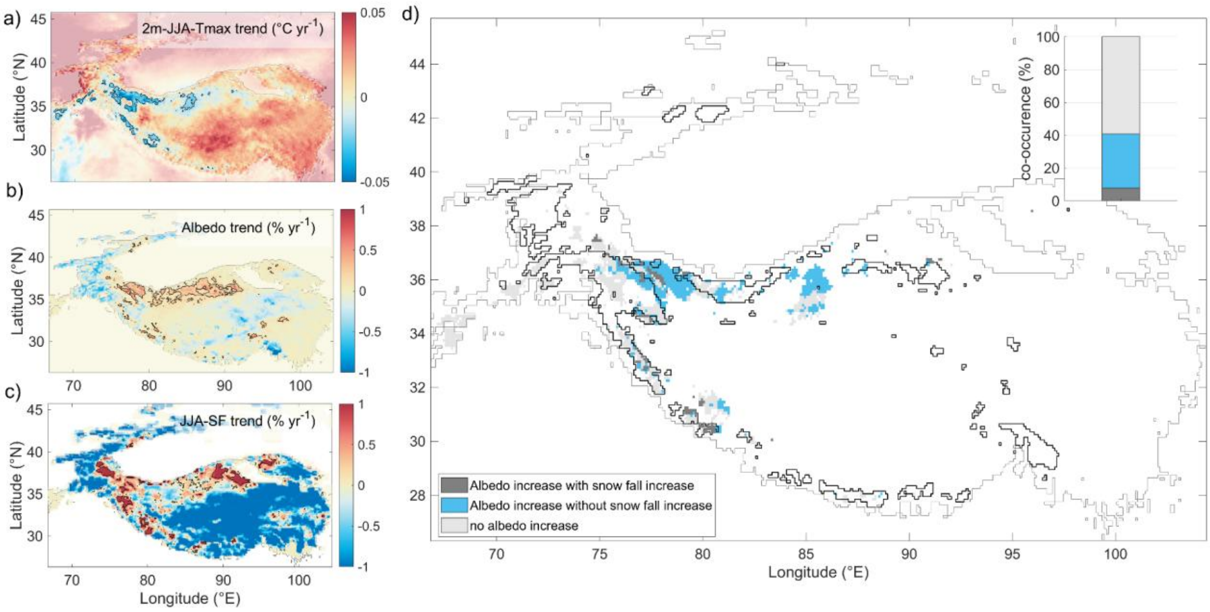

Figure S12 | Relationship between negative $2m-JJA-Tmax$ trends (a), positive albedo trends (b), and positive snowfall trends (c). Panel d displays the spatial intersection (co-occurrence) of c and b with respect to a. The glacier mask is reported with a black line

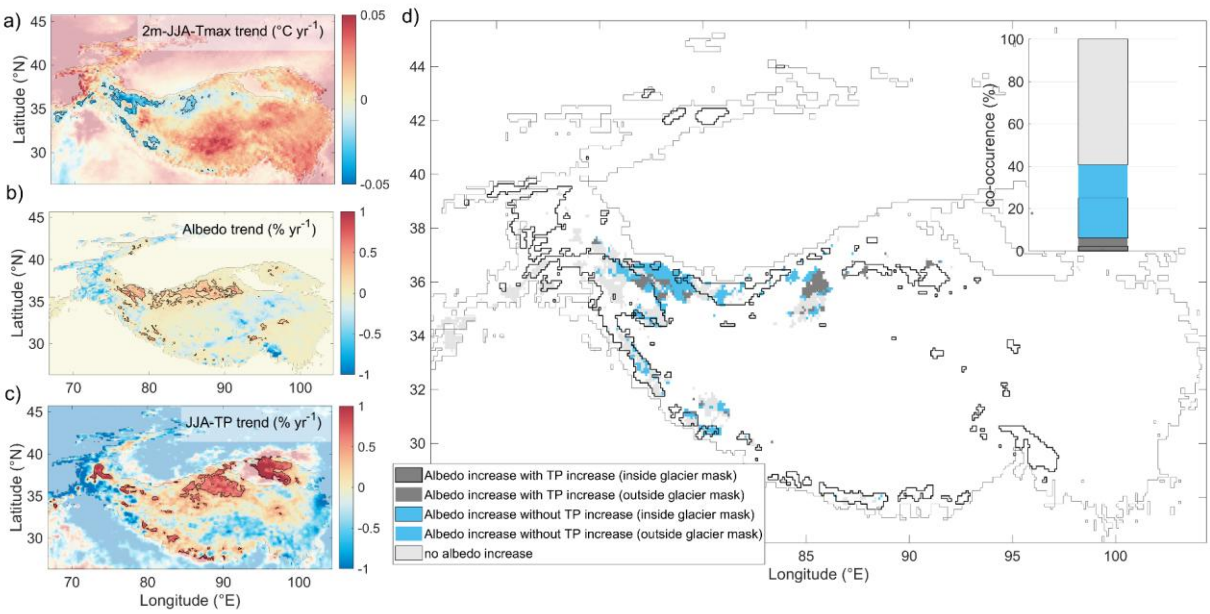

Figure S13 | Relationship between negative $2m-JJA-Tmax$ trends (a), positive albedo trends (b), and Total Precipitation (TP) trends (c). Panel d displays the spatial intersection (co-occurrence) of c and b with respect to a. The glacier mask is reported with a black line

Ground based evidence of wind regime at high elevation

In the western part of the Central Himalaya region (Figs. S14a, f), data are available from two distinct sub-regions: the Lirung, Yala, and Morimoto glaciers to the west (Fig. S14b), and the Mera Glacier to the east (Fig. S14g). Focusing first on the westernmost glaciers, the Lirung and Morimoto stations exhibit a simpler, clearer, and more emblematic pattern: characteristic up-valley winds during the day (Figs. S14c1, e1) driven by the monsoon, with peak intensities occurring in the afternoon (Figs. S14c2, e2). For these stations, downslope winds are rare, although they also display their highest intensities during the afternoon hours (Figs. S14c2, e2). Conversely, the Yala station presents a mixed pattern, where diurnal up-valley winds alternate with down-valley winds (Fig. S14d1), though the latter exhibit lower intensities (Fig. S14d2). The Mera Glacier is included here for the sake of completeness; however, we hypothesize that because these stations are situated on a high-altitude plateau, they are less influenced by typical valley circulation patterns (i.e., adiabatic and katabatic winds) and are instead dominated by synoptic scale circulation (Figs. S14h1 to j2).

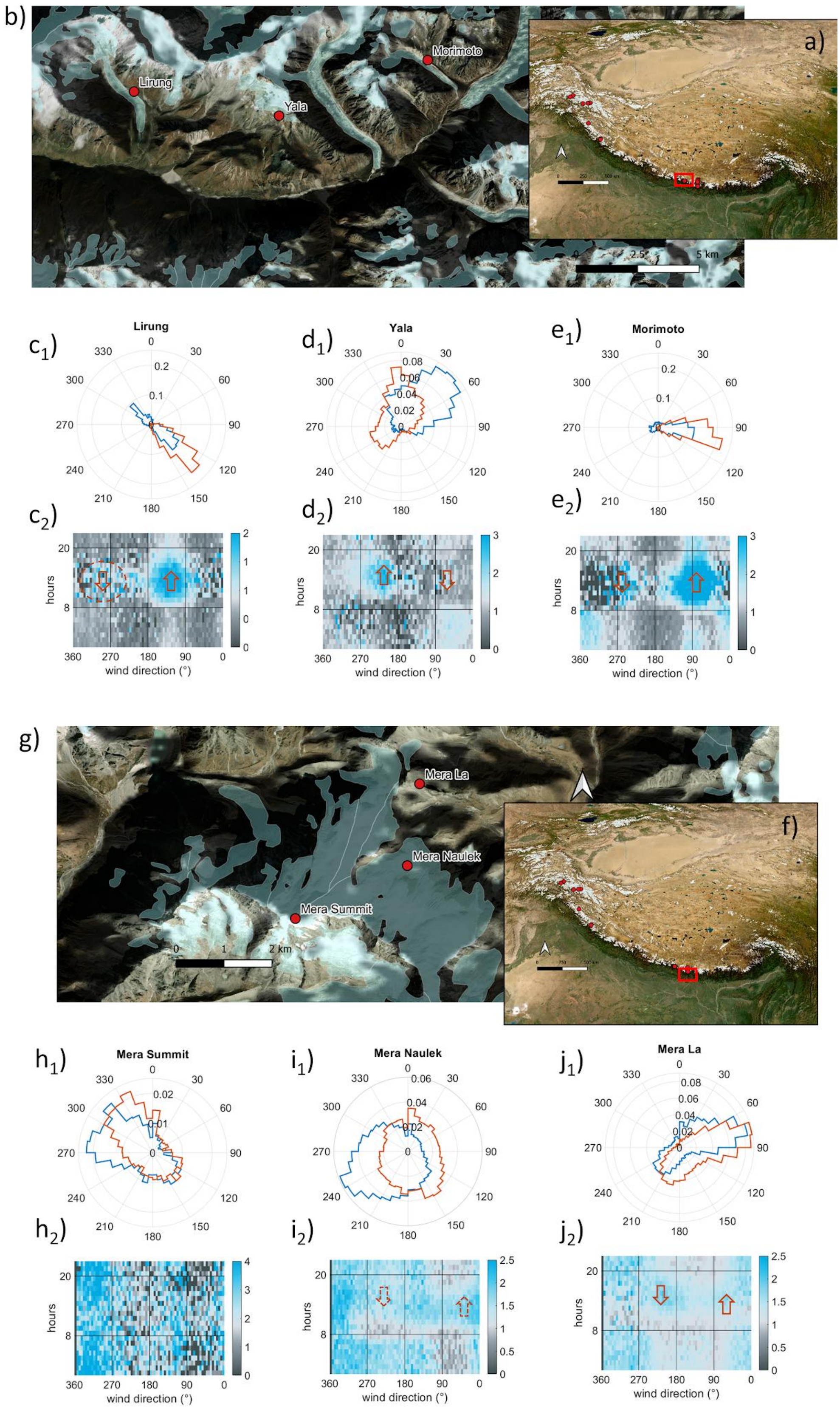

Figure S14 | ***Central Himalaya (West).*** *a, Map showing the Lirung, Yala, and Morimoto glaciers. f, Map showing the Mera glacier. For each station, plots show the frequency of diurnal (orange) and nocturnal (blue) winds by direction. Below, wind intensity ($m\ s^{-1}$) is displayed (grey to blue color scale) as a function of wind direction and local time. Orange arrows indicate upslope winds (upward) and downslope winds (downward).*

In the Central Himalayas (Mt. Everest region), on-glacier data are available from six weather stations (Fig. S15a, b). Five of these stations are located on the southern slopes of Mt. Everest. Specifically, the prevailing orientation is south for the Pyramid, Bishop Glacier, and Changri Glacier stations (Fig. S15d1, d2; Fig. S15h1, h2; and Fig. S15c1, c2, respectively), whereas it is predominantly west for the remaining two southern stations: South Col (Fig. S15g1, g2) and Camp 2 (Fig. S15f1, f2). The only station located on the northern slopes of Mt. Everest is the QMOS Camp (Fig. S15e1, e2). Considering these variations in orientation and location, we observe that the Pyramid station exhibits dominant up-valley winds (Fig. S15d1) interspersed with sparse but intense downslope events during diurnal hours (Fig. S15d2)—a wind pattern typical of valleys influenced by the monsoon. At higher elevations, the Changri Nup station presents an intense diurnal activity of both downslope winds that alternate with up-valley winds (Fig. S15c1, S15c2). A similar situation is observed at Camp 2, with less frequent downslope winds occurring earlier in the day (Fig. S15f1, f2). Closer to the Mt. Everest summit, the South Col (Fig. S15g1, g2) and Bishop station (Fig. S15g2, h2) do not present a clear daytime patter. Finally, on the northern slopes of Mt. Everest, we observe that the QOMS Camp station presents a dominant diurnal downslope wind pattern (Fig. S15e1, S15e2).

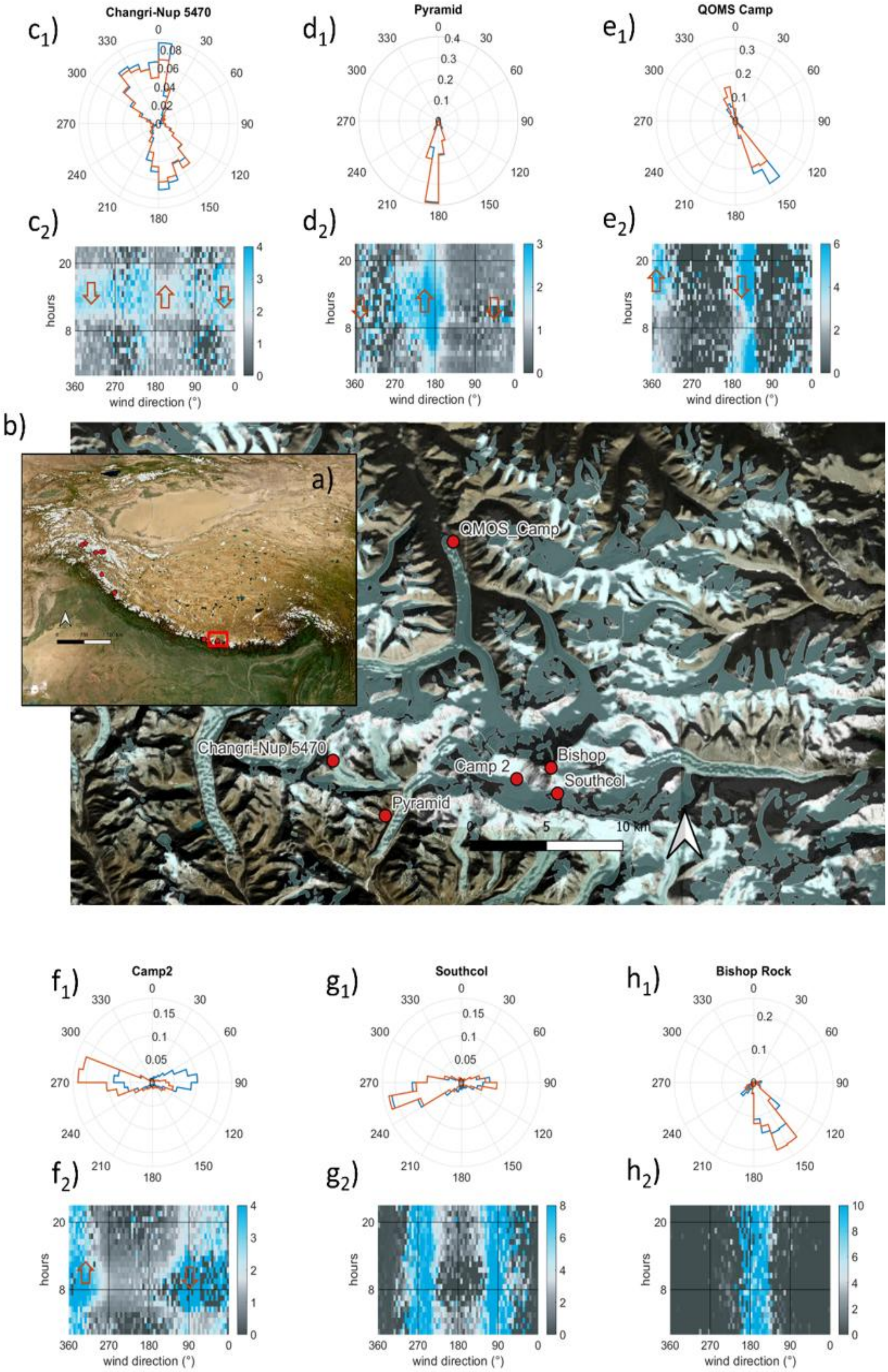

Figure S15 | ***Central Himalaya (Everest region).*** *a, Map showing the study site and the glaciers of the Everest region. b, For each station, plots show the frequency of diurnal (orange) and nocturnal (blue) winds by direction. Below, wind intensity* ($m\ s^{-1}$) *is displayed (grey to blue color scale) as a function of wind direction and local time. Orange arrows indicate upslope winds (upward) and downslope winds (downward).*

In the Western Himalaya region (Fig. S16a), data are available from two distinct sub-regions: the Drang-Drung glacier to the west (Fig. S16b) and the Chhota-Shigri glacier to the east (Fig. S16e). Both glaciers are northward-oriented, resulting in a lower influence of monsoonal up-valley winds. The on-glacier stations at both locations exhibit dominant downslope winds throughout the day (Figs. S16c1 and S16e1). Furthermore, an elevated downward wind intensity is observed on both glaciers during the afternoon (Figs. S16c2 and S16e2), while up-valley winds are consistently absent (Figs. S16c1, c2, and S16e1, e2). In contrast, the off-glacier station located near the down valley of the Chhota-Shigri Glacier presents a more complex pattern, characterized by well-defined up-valley winds (Fig. S16f1) and higher diurnal wind intensities (Fig. S16f2).

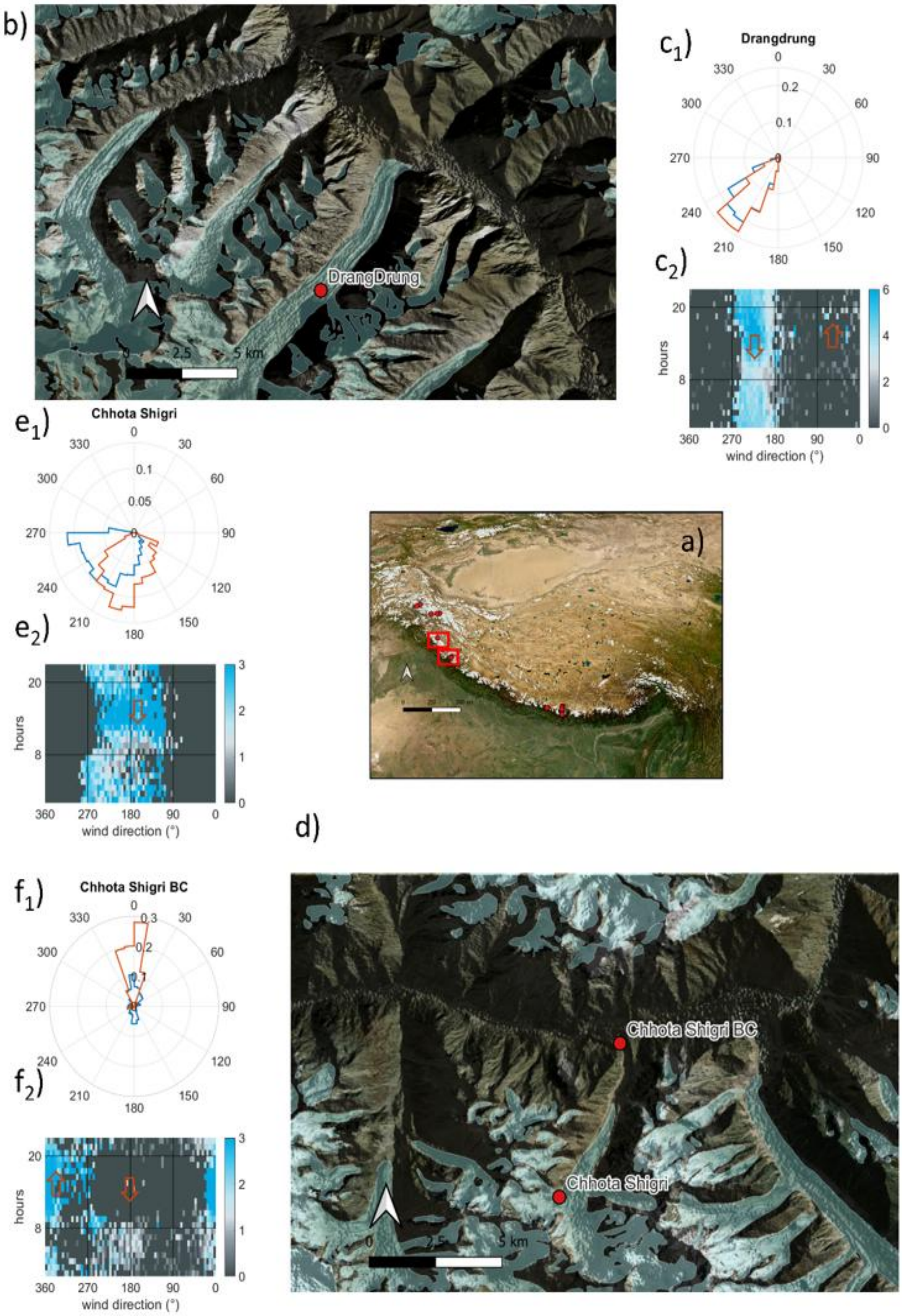

Figure S16 ***West Himalaya****. a, Map showing the study sites. b, Drang-Drung glacier station. d, Chhota-Shigri glacier stations. For each station, plots show the frequency of diurnal (orange) and nocturnal (blue) winds by direction. Below, wind intensity ($m\ s^{-1}$) is displayed (grey to blue color scale) as a function of wind direction and local time. Orange arrows indicate upslope winds (upward) and downslope winds (downward).*

In the Karakoram region (Fig. S17a), data are available from two distinct sub-regions: The Shisparé Sar glaciers (Shispar and Passu stations) to the northwest (Fig. S17b), and the Baltoro glacier to the center Karakoram region (Fig. S17e). Regarding the western glaciers, we observe dominant downslope winds during both day and night (Fig. S17c1 and d1), punctuated by a few intermittent events of diurnal up-valley winds (Fig. S17c2 and d2). Further east, on the Baltoro glacier, the on-glacier station of Urdukas (Fig. S17g1) and the off-glacier valley station of Askole (Fig. S17f1) exhibit dominant downslope winds at night, and a combination of daytime up-valley and down-valley winds. Moreover, we note that the diurnal downslope winds show elevated intensities in the late morning on the glacier tongue (Fig. S17g2), and during the late afternoon at the down-valley station (Fig. S17f2). Conversely, the station located in the accumulation zone (Concordia) presents a lower frequency of diurnal downslope winds (Fig. S17h1), along with a slight daytime shift in downslope wind direction (Fig. S17h2) that aligns with the main glacier tongue (approximately 120°).

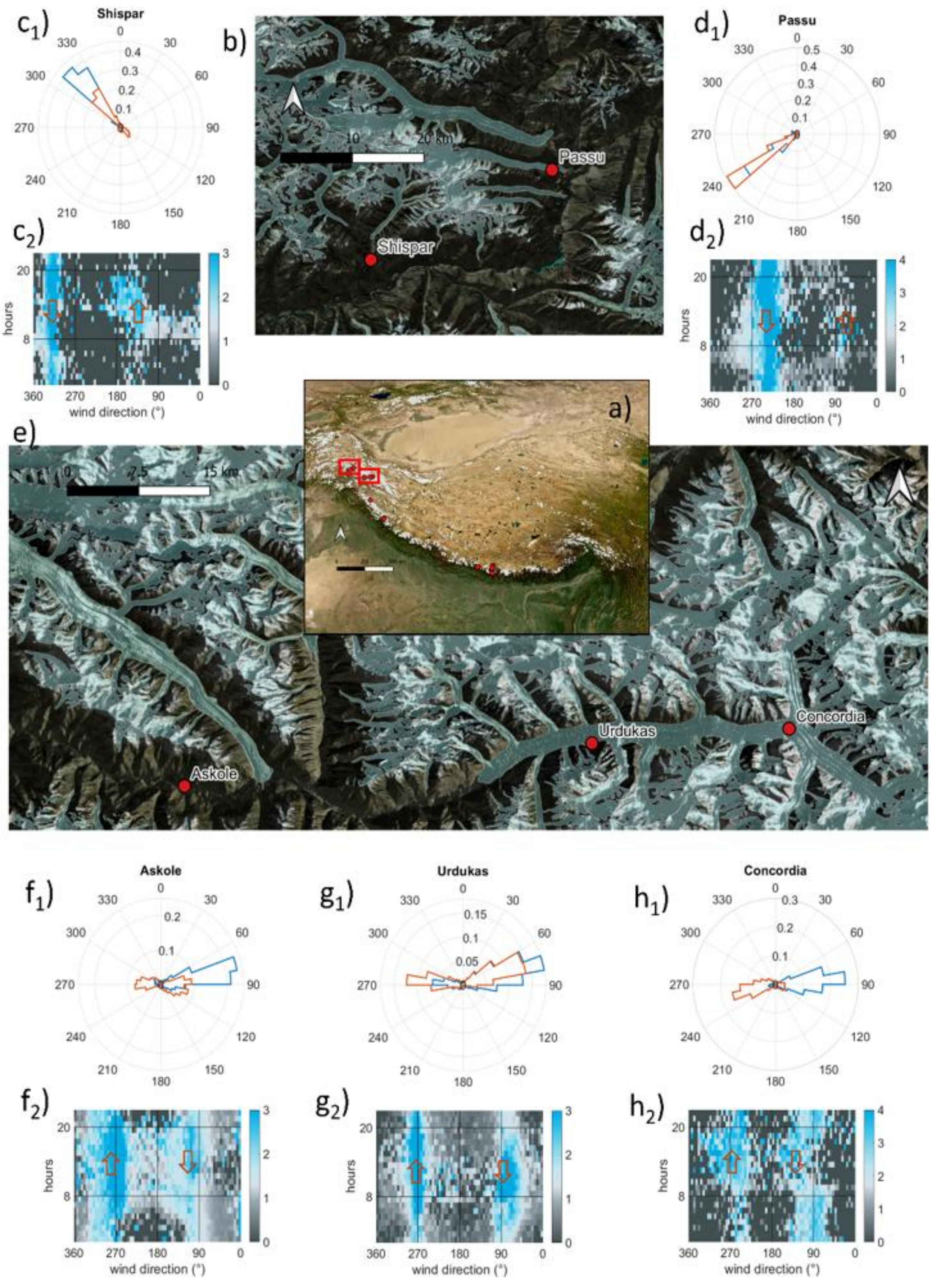

Figure S17 ***Karakoram.*** *a, Map showing study sites. b, Shispar and Passu stations. e, Baltoro glacier stations. For each station, plots show the frequency of diurnal (orange) and nocturnal (blue) winds by direction. Below, wind intensity ($m\ s^{-1}$) is displayed (grey to blue color scale) as a function of wind direction and local time. Orange arrows indicate upslope winds (upward) and downslope winds (downward).*

Interaction between local and synoptic winds

We investigated whether large-scale synoptic wind circulation influences near-surface wind trends. To address this, we conducted an analysis using ERA5 data (see methods), evaluating the relationship as a function of proximity to glacier surfaces. Although this assessment remains preliminary—with further detailed mechanisms being beyond the scope of the present study—we observed a weak but significant relationship (R2 = 0.19, $p < 0.05$) between increasing synoptic wind intensity and a decreasing UWI trend over glaciated areas (Fig. S18 b3), indicating that stronger synoptic winds may reinforce diurnal downslope activity specifically where glaciers are present. This correlation progressively weakens near glacier margins (Fig. Sx18b2) and entirely dissipates far from glaciers (Fig. S18 b1). Notably, considering ERA5 JJA-UWII trends at 350 hPa (i.e. component of the synoptic wind intensity trend aligned with the underlying flowline, see methods), this relationship cannot be attributed to geometric alignment between synoptic and local wind over glaciated areas (Fig. S18 a3, a2). In contrast, a relationship (R2 = 0.20, $p<0.05$) for geometric alignment emerges exclusively far from glaciers (Fig. S18 a1), albeit remaining weak .

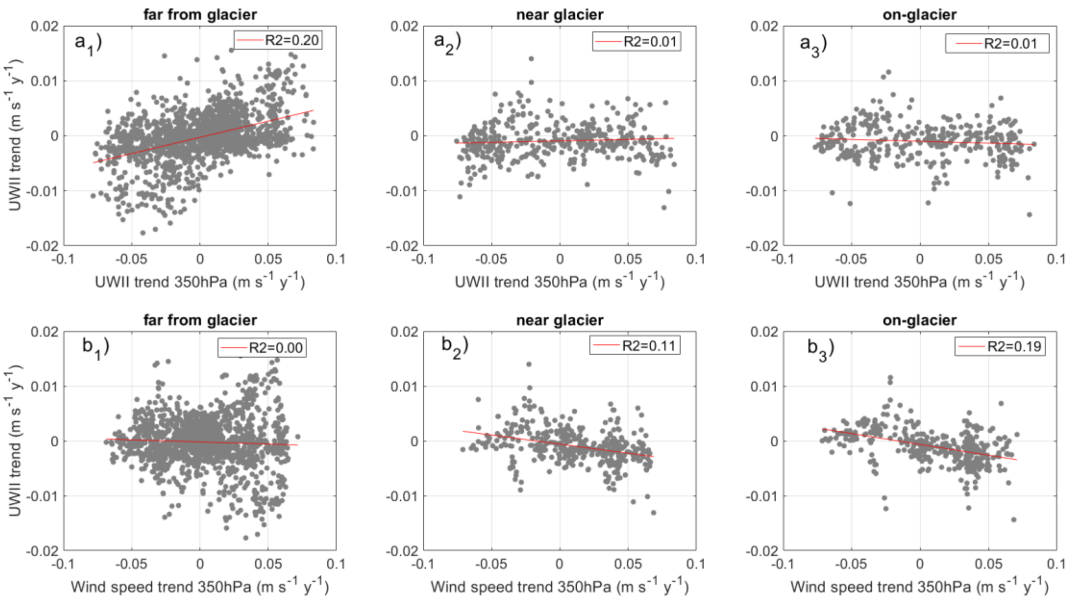

Figure S18 | Relationship between ***synoptic and local up-valley wind trends*** *as a function of distance to glaciers. Analysis restricted to grid cells with ERA5 terrain slope > 0.05 (see Fig. 3a). a1–a3, Relationship between ERA5 JJA-UWII trends at 350 hPa and at 2 m for far-from-glacier (>30 km), near-glacier (<30 km), and on-glacier nodes. UWII trend at 350 hPa represents the component of the synoptic wind intensity trend aligned with the underlying flowline. b1–b3, Relationship between ERA5 wind speed trends at 300 hPa and ERA5 JJA-UWII trends at 2 m for the same distance categories. 300 hPa wind speed trends represent the synoptic wind intensity trend independent of direction.*

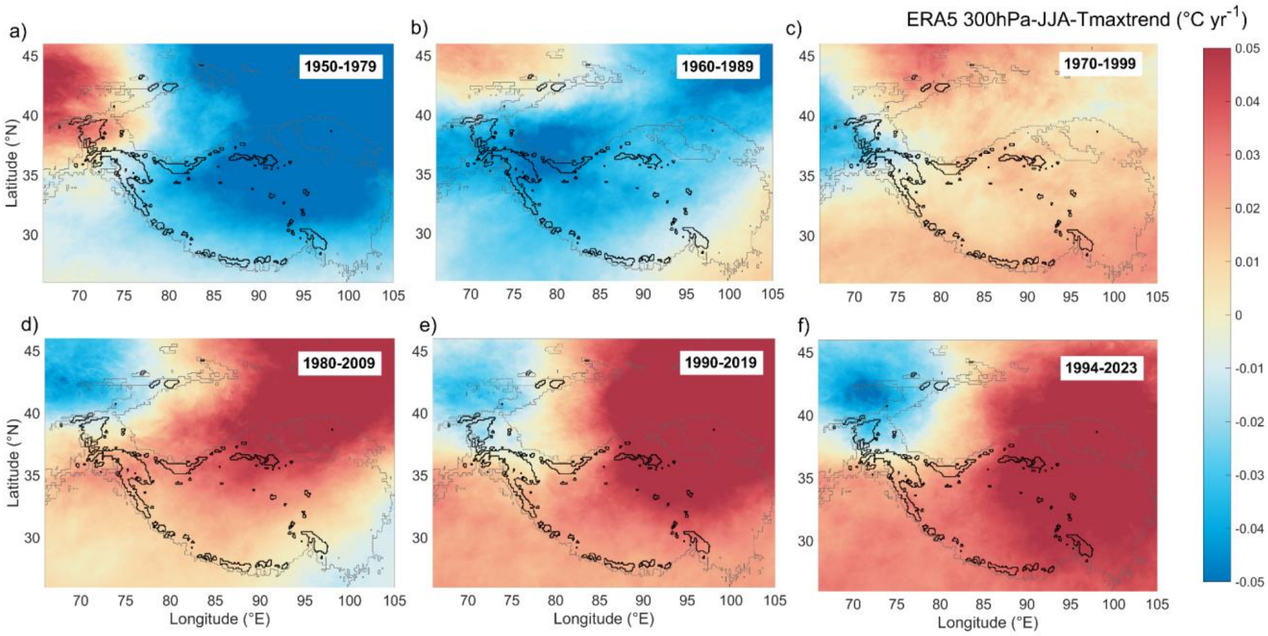

Figure S19 30 years baselines $300hPa - JJA - Tmax$ *trends (ERA5) for every decade from 1950-1979 (a) to 1990-2019 (e). The 1994-2023 baseline is reported in panel f.*

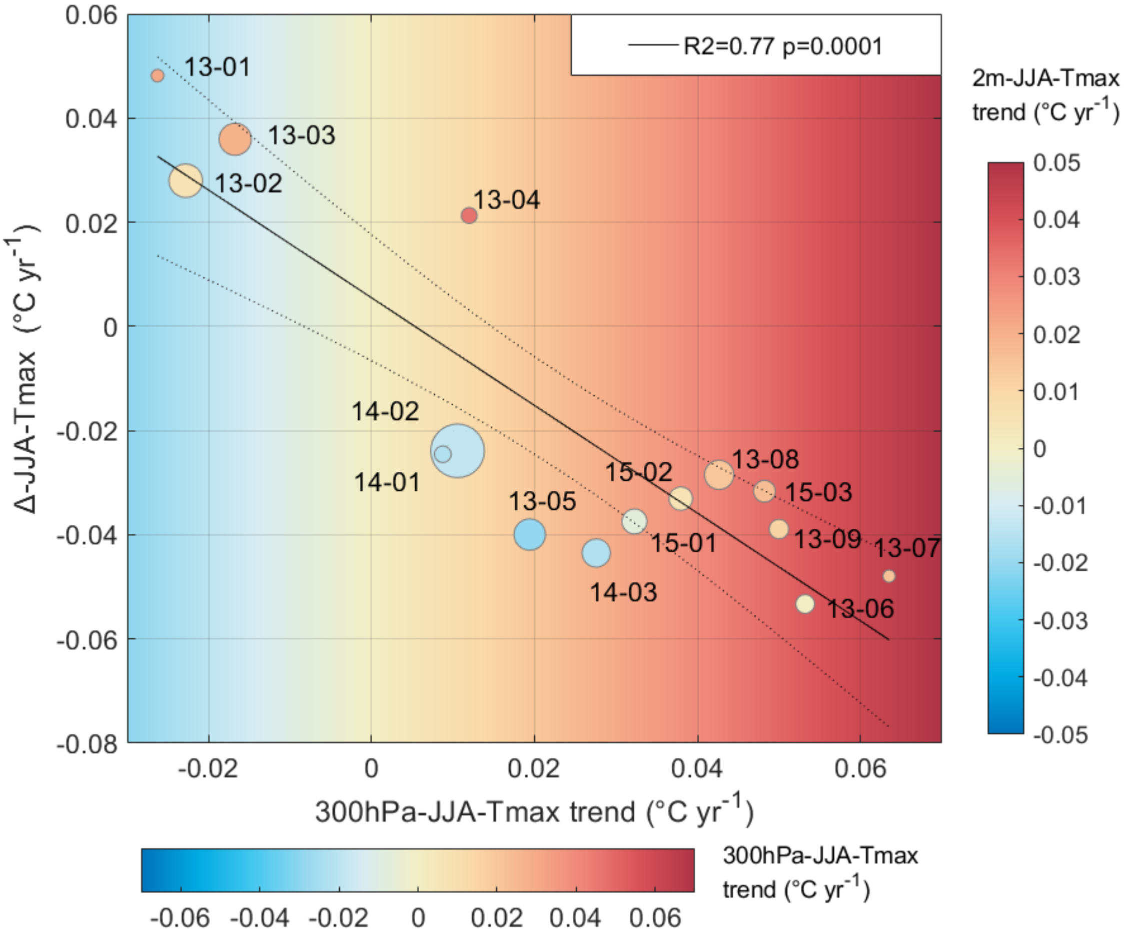

Figure S20 | Relationship between $\Delta - JJA - Tmax$ (difference between $300hPa - JJA - Tmax$ and $2m - JJA - Tmax$ trends) and $300hPa - JJA - Tmax$ trend (1994–2023). Bubble colour (right scale) refers to the $2m - JJA - Tmax$ trend; background colour (bottom scale) refers to the $300hPa - JJA - Tmax$ trend. Bubble size is proportional to the glacier surface area of each RGI sub-region (see Methods).

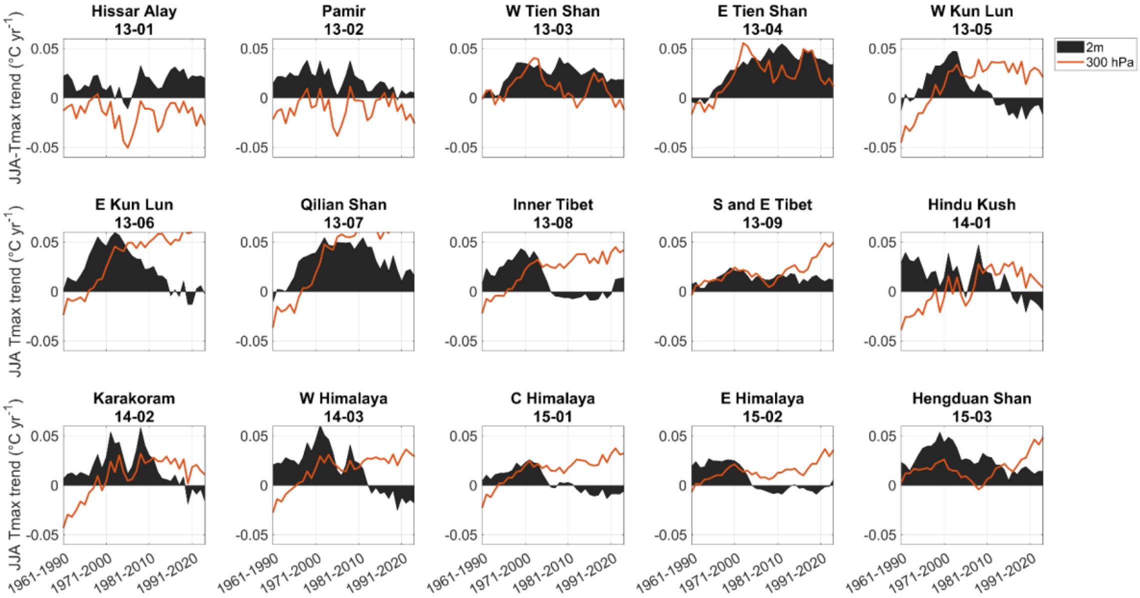

Figure S21 Temporal evolution of surface ($2m - JJA - Tmax$, black area) and upper-atmospheric ($300hPa - JJA - Tmax$, red line) temperature trends. Trends are calculated for each RGI sub-region (see Methods) using a 30-year rolling window.

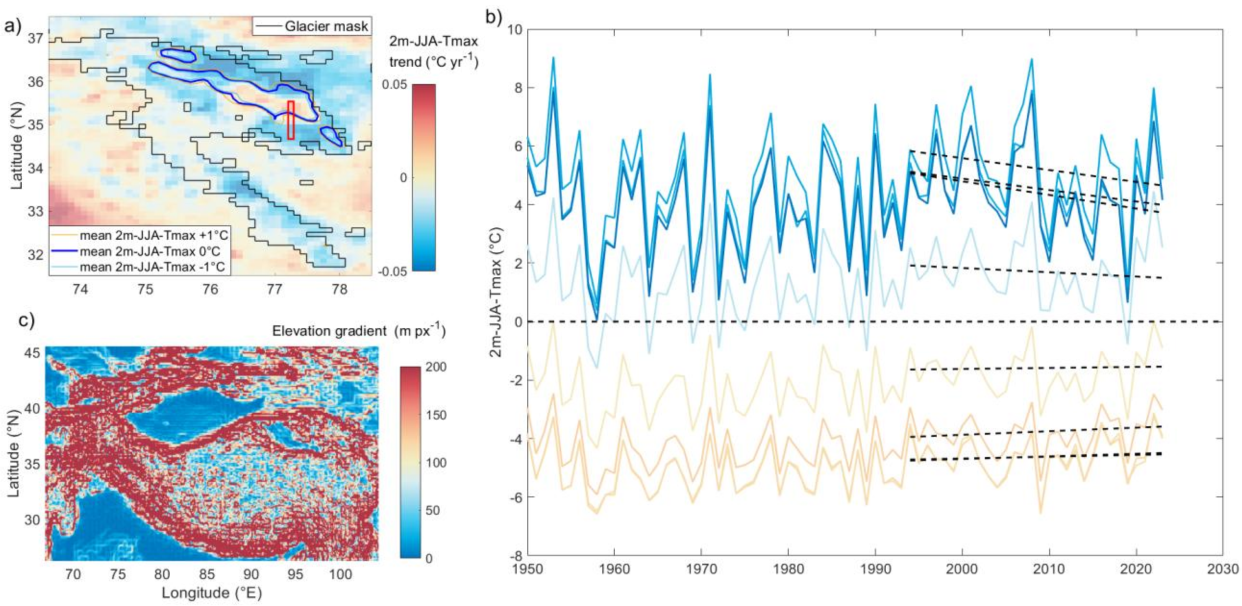

Figure S22 | Karakoram $2m - JJA - Tmax$ analysis. a, $2m - JJA - Tmax$ trend for the Karakoram region. b, $2m - JJA - Tmax$ time series for each pixel along the red transect shown in a. The color code of each line is the $2m - JJA - Tmax$ trend in a (the trends refer to the 1994-2023 bassline indicates with black dash lines).

Mean $2m-JJA-Tmax$ below the 0°C show positive trend while temperatures above show negative ones. c, Elevation gradient of ERA5-Land ($m\ px^{-1}$). An elevation gradient > 200 $m\ px^{-1}$ (in red) roughly indicates that the ERA5-Land spatial resolution did not able to appreciate a spatial variation in the temperature isolines associated with a typical temperature trend range of [-0.04 +0.04]°C yr^{-1} considering a mean lapse rate of 6.5 °$C\ km^{-1}$ (i.e. a variation of [-185 185] m in 30 years; see also the overlapping of -1, 0 and +1°C mean $2m-JJA-Tmax$ isolines in panel a). This prevent from a more direct and systematic spatial analyses of the $2m-JJA-Tmax$ 0°C isoline variation in HMA glacierised area over the past decades.

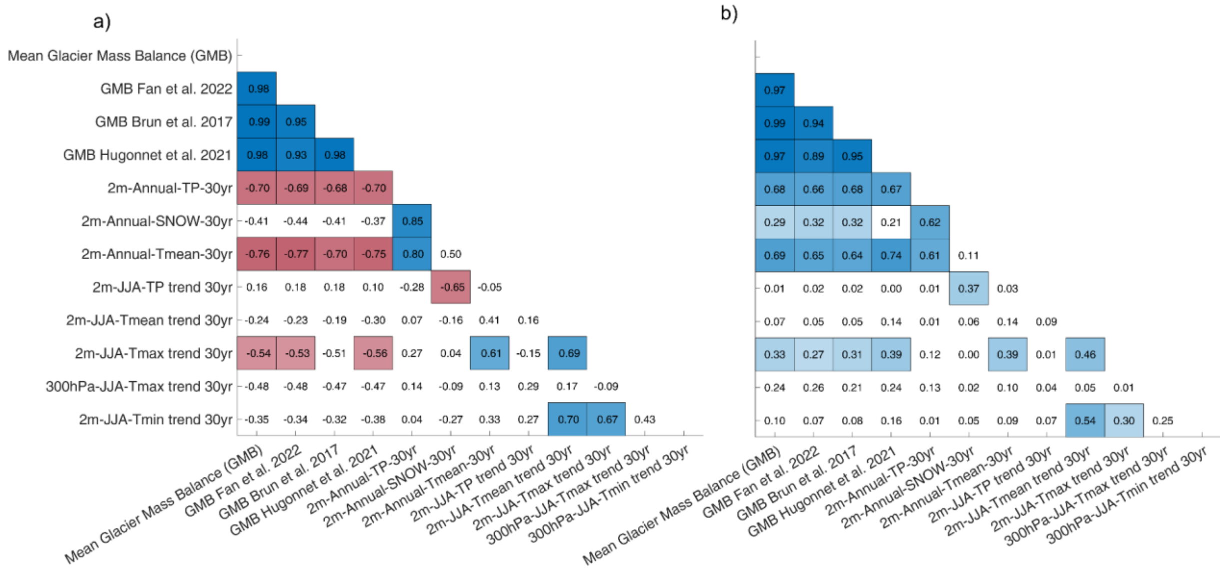

Figure S23 | Predictors tested for the multi-regression model. Correlations (a) and R^2 values (b) for glacier MB predictors. Colour coding indicates significance ($p < 0.05$).

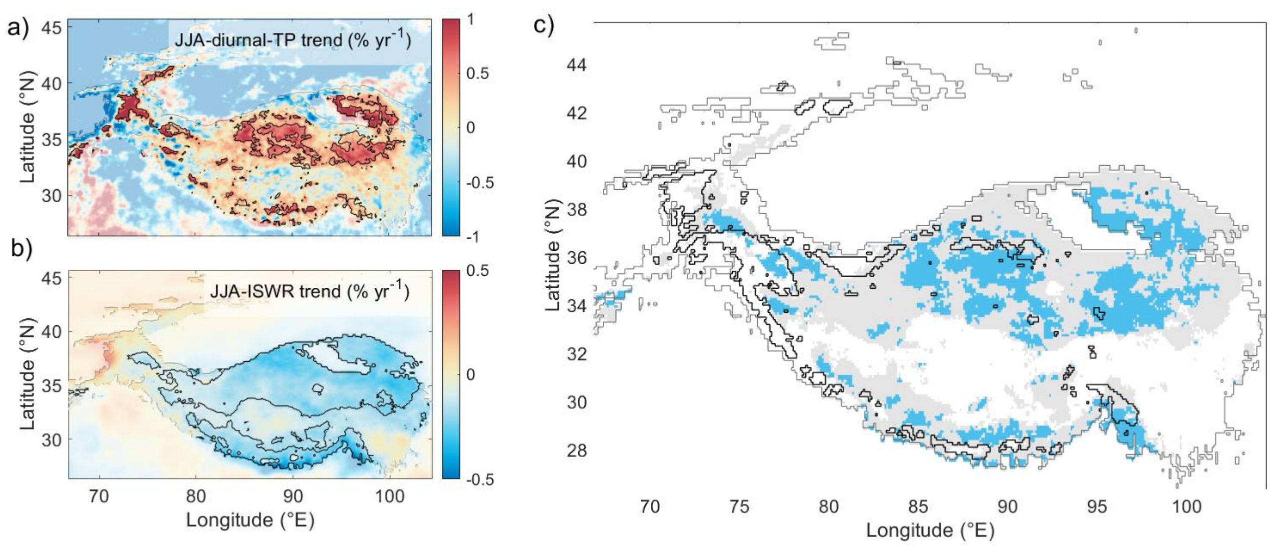

Figure S24 | Relationship between positive Total Precipitation trends (a) and negative ISWR (increasing cloud cover) trends (b). Panel c displays the spatial intersection (co-occurrence) of b with respect to a. The glacier mask is reported with a black line.

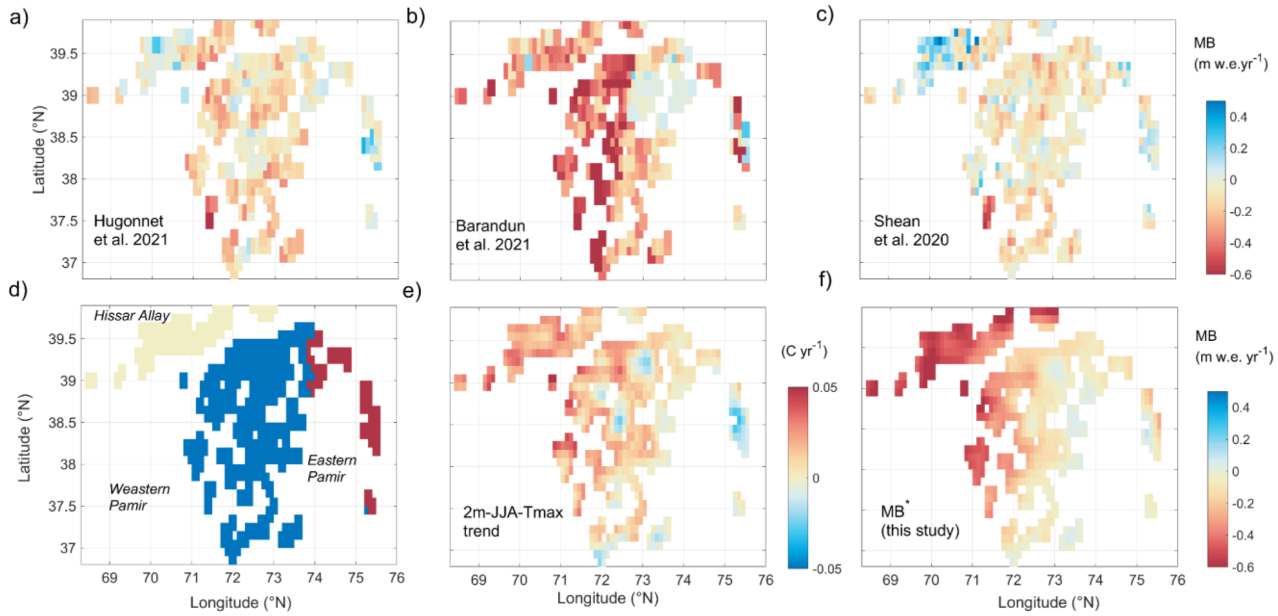

Figure S25 | Spatial MBs. a–c, MB estimates from Hugonnet et al. (2021) (a), Barandun et al. (2021) (b), and Shean et al. (2020) (c) for the 2000–2018 period. d, sub regions. e, $2m - JJA - Tmax$ trend (1990–2020). f, Predicted values from the multi-regression model developed in this study (this study).

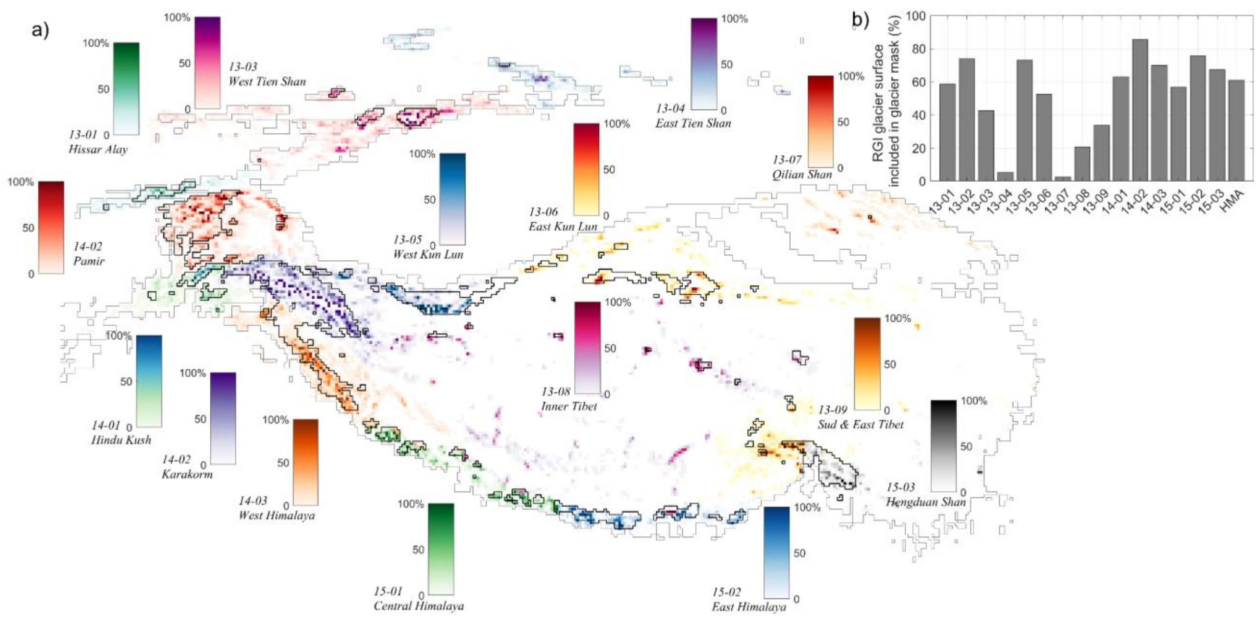

Figure S26 | Glacier mask comparison. a, Comparison between the glacier mask developed in this study and the glacier coverage of each RGI sub-region. Colors represent the percentage of glacier surface within each ERA5-Land pixel. b, Percentage of RGI glacier surfaces represented by the study mask for each sub-region.

Table S1 | Climatic time-series used in this study The table lists each station ID, location, manager, and elevation. Additionally, it reports the $2m - JJA - Tmax$ trend, glacier coverage (percentage within a 100 km radius), and the correlation between the AMO and the $2m - JJA - Tmax$ trend. Significant values are reported in bold.

Station name or code	Country	Manager	Lat (°)	Long (°)	Elevation (m a.s.l.)	Glacier coverage (%) (radius 100 km)	JJA Tmax trend (1994-2023) (°C yr^{-1})	Correlation AMO vs JJA-Tmax (1960-2023)
51330	China	CMA	44.97	81.02	1351	1.5%	-0.01	0.106
51470	China	CMA	43.88	88.12	2102	0.6%	**0.05**	0.201
51804	China	CMA	37.78	75.23	3085	7.0%	-0.01	**0.354**
55228	China	CMA	32.05	80.08	4289	0.9%	0.01	**0.472**
55248	China	CMA	32.30	84.05	4424	0.8%	0.02	**0.401**
55437	China	CMA	30.28	81.25	4913	5.2%	0.00	-0.3
55655	China	CMA	28.18	85.97	4340	8.9%	-0.01	-0.156
55664	China	CMA	28.63	87.08	4441	6.5%	**0.04**	**0.249**
55690	China	CMA	27.98	91.95	4483	4.7%	**0.05**	0.213
55773	China	CMA	27.73	89.08	4326	5.2%	0.01	**0.317**
56202	China	CMA	30.67	93.28	5239	6.2%	0.03	0.128
56227	China	CMA	29.87	95.77	2922	11.2%	**0.03**	-0.02
56434	China	CMA	28.65	97.47	3165	4.8%	0.02	0.095
ASTORE	Pakistan	PMD	35.37	74.90	3617	14.0%	0.01	
CHILAS	Pakistan	PMD	35.42	74.10	1240	6.2%	-0.06	
GILGIT	Pakistan	PMD	35.92	74.33	1464	18.0%	**-0.073**	-0.034
GUPIS	Pakistan	PMD	36.17	73.40	4653	13.5%	0.011	-0.163
khunjerab	Pakistan	PMD	36.85	75.46	4581	0%	-0.021	
naltar	Pakistan	PMD	36.16	74.18	2941	0%	-0.021	
SKARDU	Pakistan	PMD	35.30	75.68	2211	18.8%	**-0.052**	
pyramid	Nepal	EVK2CNR	27.96	86.81	5105	0%	**-0.026**	

CHM00051076	*China*	*NOAA GHCNd*	*47.73*	*88.08*	*721*	*0.1%*	***0.04***	***0.395***
CHM00051087	*China*	*NOAA GHCNd*	*46.98*	*89.52*	*807*	*0.1%*	*0.017*	
CHM00051156	*China*	*NOAA GHCNd*	*46.78*	*85.72*	*1280*	*0%*	*0.032*	***0.315***
CHM00051243	*China*	*NOAA GHCNd*	*45.60*	*84.85*	*426*	*0%*	*-0.011*	*-0.083*
CHM00051334	*China*	*NOAA GHCNd*	*44.62*	*82.90*	*307*	*0.9%*	*0.015*	***0.618***
CHM00051379	*China*	*NOAA GHCNd*	*44.02*	*89.57*	*763*	*0.4%*	***0.044***	*0.246*
CHM00051431	*China*	*NOAA GHCNd*	*43.95*	*81.33*	*676*	*0.3%*	***0.047***	***0.326***
CHM00051463	*China*	*NOAA GHCNd*	*43.80*	*87.65*	*868*	*1.8%*	*0.032*	***0.299***
CHM00051573	*China*	*NOAA GHCNd*	*42.93*	*89.20*	*8*	*0.3%*	***0.103***	***0.589***
CHM00051644	*China*	*NOAA GHCNd*	*41.72*	*82.95*	*1063*	*0.7%*	*0.014*	***0.467***
CHM00051656	*China*	*NOAA GHCNd*	*41.75*	*86.13*	*933*	*0.1%*	***0.048***	***0.416***
CHM00051709	*China*	*NOAA GHCNd*	*39.47*	*75.98*	*1299*	*0.5%*	*0.043*	
CHM00051716	*China*	*NOAA GHCNd*	*39.80*	*78.57*	*1117*	*0%*	*0.023*	*0.209*
CHM00051765	*China*	*NOAA GHCNd*	*40.63*	*87.70*	*852*	*0%*	***0.062***	***0.592***
CHM00051777	*China*	*NOAA GHCNd*	*39.03*	*88.17*	*883*	*0%*	***0.035***	***0.551***
CHM00051811	*China*	*NOAA GHCNd*	*38.43*	*77.27*	*1219*	*0%*	*0.041*	*0.05*
CHM00051828	*China*	*NOAA GHCNd*	*37.13*	*79.93*	*1351*	*0.1%*	*0.024*	*0.266*
CHM00052203	*China*	*NOAA GHCNd*	*42.82*	*93.52*	*756*	*0.5%*	***0.092***	
CHM00052267	*China*	*NOAA GHCNd*	*41.95*	*10.11*	*940*	*0%*	***0.055***	***0.523***
CHM00052323	*China*	*NOAA GHCNd*	*41.80*	*97.03*	*1773*	*0%*	***0.086***	***0.612***
CHM00052418	*China*	*NOAA GHCNd*	*40.15*	*94.68*	*1139*	*0%*	***0.057***	***0.557***
CHM00052436	*China*	*NOAA GHCNd*	*40.27*	*97.03*	*1528*	*0.7%*	*0.032*	***0.618***
CHM00052495	*China*	*NOAA GHCNd*	*40.75*	*10.45*	*1337*	*0%*	***0.051***	***0.499***
CHM00052533	*China*	*NOAA GHCNd*	*39.77*	*98.48*	*1479*	*0.8%*	***0.063***	
CHM00052602	*China*	*NOAA GHCNd*	*38.83*	*93.38*	*2759*	*0.3%*	***0.042***	
CHM00052681	*China*	*NOAA GHCNd*	*38.63*	*10.31*	*1369*	*0%*	***0.093***	***0.413***
CHM00052713	*China*	*NOAA GHCNd*	*37.85*	*95.37*	*3194*	*1.3%*	*0.041*	***0.247***
CHM00052754	*China*	*NOAA GHCNd*	*37.33*	*10.01*	*3308*	*0.1%*	*0.033*	***0.596***
CHM00052787	*China*	*NOAA GHCNd*	*37.20*	*10.29*	*3034*	*0.1%*	***0.055***	***0.396***
CHM00052818	*China*	*NOAA GHCNd*	*36.42*	*94.90*	*2808*	*0.7%*	***0.046***	***0.267***

CHM00052836	*China*	*NOAA GHCNd*	*36.30*	*98.10*	*3187*	*0%*	*-0.018*	***0.405***
CHM00052866	*China*	*NOAA GHCNd*	*36.62*	*10.18*	*2258*	*0.2%*	***0.062***	*0.25*
CHM00052955	*China*	*NOAA GHCNd*	*35.58*	*10.08*	*3115*	*0%*	*0.058*	
CHM00053231	*China*	*NOAA GHCNd*	*41.45*	*10.64*	*1445*	*0%*	***0.053***	***0.415***
CHM00053336	*China*	*NOAA GHCNd*	*41.57*	*10.85*	*1283*	*0%*	***0.066***	***0.353***
CHM00053502	*China*	*NOAA GHCNd*	*39.78*	*10.58*	*1031*	*0%*	***0.062***	***0.407***
CHM00053529	*China*	*NOAA GHCNd*	*39.10*	*10.80*	*1371*	*0%*	***0.061***	***0.41***
CHM00053614	*China*	*NOAA GHCNd*	*38.47*	*10.62*	*1111*	*0%*	***0.121***	***0.58***
CHM00053646	*China*	*NOAA GHCNd*	*38.23*	*10.97*	*1136*	*0%*	*-0.020*	*0.176*
CHM00053723	*China*	*NOAA GHCNd*	*37.80*	*10.74*	*1357*	*0%*	***0.063***	***0.421***
CHM00053845	*China*	*NOAA GHCNd*	*36.60*	*10.95*	*972*	*0%*	*-0.019*	***0.261***
CHM00053915	*China*	*NOAA GHCNd*	*35.55*	*10.67*	*1368*	*0%*	*0.031*	***0.316***
CHM00055228	*China*	*NOAA GHCNd*	*32.50*	*80.08*	*4314*	*1.3%*	*0.035*	*0.03*
CHM00055279	*China*	*NOAA GHCNd*	*31.37*	*90.02*	*4730*	*0%*	***0.055***	***0.416***
CHM00055299	*China*	*NOAA GHCNd*	*31.48*	*92.07*	*4522*	*0.6%*	***0.062***	***0.584***
CHM00055472	*China*	*NOAA GHCNd*	*30.95*	*88.63*	*4655*	*0.6%*	***0.057***	***0.324***
CHM00055578	*China*	*NOAA GHCNd*	*29.25*	*88.88*	*3850*	*0.4%*	***0.087***	***0.351***
CHM00055591	*China*	*NOAA GHCNd*	*29.67*	*91.13*	*3655*	*1.4%*	***0.095***	***0.421***
CHM00056004	*China*	*NOAA GHCNd*	*34.22*	*92.43*	*4536*	*0.1%*	*-0.008*	***0.438***
CHM00056021	*China*	*NOAA GHCNd*	*34.13*	*95.78*	*4178*	*0.4%*	***0.056***	***0.599***
CHM00056029	*China*	*NOAA GHCNd*	*33.00*	*96.97*	*3718*	*0.1%*	*0.035*	***0.292***
CHM00056033	*China*	*NOAA GHCNd*	*34.92*	*98.22*	*4271*	*0%*	***0.041***	***0.414***
CHM00056046	*China*	*NOAA GHCNd*	*33.75*	*99.65*	*3981*	*0.2%*	***0.079***	
CHM00056079	*China*	*NOAA GHCNd*	*33.58*	*10.30*	*3456*	*0%*	***0.072***	***0.518***
CHM00056080	*China*	*NOAA GHCNd*	*35.00*	*10.29*	*2943*	*0%*	*0.050*	***0.433***
CHM00056096	*China*	*NOAA GHCNd*	*33.40*	*10.49*	*1011*	*0%*	*0.033*	***0.339***
CHM00056106	*China*	*NOAA GHCNd*	*31.88*	*93.78*	*4059*	*1.5%*	***0.077***	*-0.322*
CHM00056116	*China*	*NOAA GHCNd*	*31.42*	*95.60*	*3931*	*2.9%*	***0.083***	***0.479***
CHM00056137	*China*	*NOAA GHCNd*	*31.15*	*97.17*	*3360*	*0.1%*	***0.086***	***0.54***
CHM00056146	*China*	*NOAA GHCNd*	*31.62*	*10.00*	*3377*	*0.4%*	***0.085***	***0.263***
CHM00056172	*China*	*NOAA GHCNd*	*31.90*	*10.22*	*2816*	*0.2%*	***0.099***	*0.2*

CHM00056182	*China*	*NOAA GHCNd*	*32.65*	*10.36*	*3283*	*0%*	*0.032*	***0.333***
CHM00056257	*China*	*NOAA GHCNd*	*30.00*	*10.03*	*3963*	*0.4%*	***0.075***	***0.606***
CHM00056444	*China*	*NOAA GHCNd*	*28.45*	*98.88*	*3436*	*0.8%*	***0.087***	***0.345***
CHM00056462	*China*	*NOAA GHCNd*	*29.00*	*10.15*	*3175*	*1.1%*	***0.052***	***0.534***
CHM00056492	*China*	*NOAA GHCNd*	*28.80*	*10.46*	*328*	*0%*	***0.059***	*0.158*
CHM00056571	*China*	*NOAA GHCNd*	*27.90*	*10.23*	*1582*	*0%*	***0.105***	***0.391***
CHM00056651	*China*	*NOAA GHCNd*	*26.83*	*10.05*	*2467*	*0.1%*	***0.072***	***0.323***
CHM00056671	*China*	*NOAA GHCNd*	*26.65*	*10.23*	*1784*	*0%*	***0.100***	***0.461***
CHM00056739	*China*	*NOAA GHCNd*	*25.12*	*98.48*	*1997*	*0%*	***0.067***	***0.029***
CHM00056768	*China*	*NOAA GHCNd*	*25.02*	*10.15*	*1839*	*0%*	***0.049***	***0.512***
CHM00056778	*China*	*NOAA GHCNd*	*25.02*	*10.27*	*1890*	*0%*	***0.091***	***0.646***
CHM00057127	*China*	*NOAA GHCNd*	*33.07*	*10.70*	*509*	*0%*	*0.043*	***0.173***
CHM00057237	*China*	*NOAA GHCNd*	*32.07*	*10.80*	*645*	*0%*	***0.052***	*0.239*
CHM00057411	*China*	*NOAA GHCNd*	*30.80*	*10.61*	*279*	*0%*	*0.041*	*0.047*
CHM00057447	*China*	*NOAA GHCNd*	*30.28*	*10.95*	*454*	*0%*	*0.044*	*0.121*
CHM00057516	*China*	*NOAA GHCNd*	*29.58*	*10.65*	*254*	*0%*	***0.083***	*0.049*
CHM00057633	*China*	*NOAA GHCNd*	*28.83*	*10.88*	*660*	*0%*	*0.021*	*0.059*
CHM00057707	*China*	*NOAA GHCNd*	*27.30*	*10.52*	*1753*	*0%*	***0.084***	***0.301***
CHM00057745	*China*	*NOAA GHCNd*	*27.45*	*10.97*	*260*	*0%*	***0.093***	*0.177*
CHM00057816	*China*	*NOAA GHCNd*	*26.58*	*10.67*	*1223*	*0%*	***-0.073***	***-0.277***
CHM00057902	*China*	*NOAA GHCNd*	*25.43*	*10.52*	*1360*	*0%*	***0.091***	***0.393***
IN003020100	*India*	*NOAA GHCNd*	*26.62*	*92.78*	*69*	*0%*	***0.059***	
IN003041800	*India*	*NOAA GHCNd*	*26.10*	*91.58*	*51*	*3.5%*	***0.080***	*0.13*
IN004102500	*India*	*NOAA GHCNd*	*25.60*	*85.10*	*64*	*0%*	*0.046*	
IN006031000	*India*	*NOAA GHCNd*	*29.17*	*75.73*	*215*	*0%*	*-0.022*	***0.364***
IN008010200	*India*	*NOAA GHCNd*	*34.08*	*74.83*	*1584*	*0%*	*-0.058*	
IN011150300	*India*	*NOAA GHCNd*	*26.23*	*78.25*	*205*	*0%*	*0.020*	
IN018103100	*India*	*NOAA GHCNd*	*30.33*	*76.47*	*255*	*0%*	***0.071***	
IN019040100	*India*	*NOAA GHCNd*	*25.75*	*71.38*	*253*	*0%*	***0.000***	
IN019070100	*India*	*NOAA GHCNd*	*28.00*	*73.30*	*219*	*0%*	*-0.005*	***0.395***

IN019120700	*India*	*NOAA GHCNd*	*29.92*	*73.92*	*178*	*0%*	***0.000***	
IN019131301	*India*	*NOAA GHCNd*	*26.82*	*75.80*	*382*	*0%*	*0.025*	***0.529***
IN019140400	*India*	*NOAA GHCNd*	*26.90*	*70.92*	*227*	*0%*	*0.015*	
IN019180500	*India*	*NOAA GHCNd*	*26.30*	*73.02*	*281*	*0%*	*0.039*	
IN019191200	*India*	*NOAA GHCNd*	*25.15*	*75.85*	*281*	*0%*	*-0.004*	
IN022021900	*India*	*NOAA GHCNd*	*28.58*	*77.20*	*220*	*0.9%*	***0.072***	***0.398***
IN023101700	*India*	*NOAA GHCNd*	*28.37*	*79.40*	*173*	*0%*	*0.016*	
IN023160900	*India*	*NOAA GHCNd*	*30.32*	*78.03*	*653*	*0%*	***0.088***	
IN023261300	*India*	*NOAA GHCNd*	*26.75*	*83.37*	*85*	*0%*	***0.057***	
IN023351400	*India*	*NOAA GHCNd*	*26.75*	*80.88*	*126*	*0%*	*0.007*	***0.334***
INM00042071	*India*	*NOAA GHCNd*	*31.71*	*74.80*	*226*	*0%*	*0.042*	
KG000036911	*kirghizistan*	*NOAA GHCNd*	*42.83*	*75.28*	*813*	*0%*	***0.067***	
KG000036974	*kirghizistan*	*NOAA GHCNd*	*41.43*	*76.00*	*2050*	*1.5%*	***0.058***	*0.317*
KG000036982	*kirghizistan*	*NOAA GHCNd*	*41.88*	*78.23*	*4341*	*7.4%*	***0.045***	***0.415***
KG000038345	*kirghizistan*	*NOAA GHCNd*	*42.52*	*72.22*	*1224*	*0%*	***0.067***	
KG000038353	*kirghizistan*	*NOAA GHCNd*	*42.83*	*74.58*	*856*	*1.2%*	***0.078***	***0.567***
KG000038613	*kirghizistan*	*NOAA GHCNd*	*40.92*	*72.95*	*740*	*0.2%*	*0.035*	***0.452***
KZ000035394	*Kazakistan*	*NOAA GHCNd*	*49.80*	*73.15*	*540*	*0%*	*0.026*	***0.171***
KZ000035497	*Kazakistan*	*NOAA GHCNd*	*48.85*	*72.87*	*704*	*0%*	*0.027*	***0.248***
KZ000035563	*Kazakistan*	*NOAA GHCNd*	*48.65*	*67.00*	*638*	*0%*	***0.000***	
KZ000035576	*Kazakistan*	*NOAA GHCNd*	*48.30*	*69.70*	*363*	*0%*	*0.013*	*0.182*
KZ000035671	*Kazakistan*	*NOAA GHCNd*	*47.80*	*67.72*	*375*	*0%*	***0.071***	***0.364***
KZ000035699	*Kazakistan*	*NOAA GHCNd*	*47.45*	*74.82*	*657*	*0%*	***0.112***	
KZ000035796	*Kazakistan*	*NOAA GHCNd*	*46.80*	*75.08*	*338*	*0%*	*0.011*	*0.184*
KZ000035969	*Kazakistan*	*NOAA GHCNd*	*45.25*	*67.07*	*131*	*0%*	***0.065***	***0.497***
KZ000036394	*Kazakistan*	*NOAA GHCNd*	*49.58*	*81.05*	*339*	*0%*	***0.000***	
KZ000036397	*Kazakistan*	*NOAA GHCNd*	*49.22*	*81.22*	*451*	*0%*	*0.024*	
KZ000036421	*Kazakistan*	*NOAA GHCNd*	*49.72*	*84.28*	*454*	*0%*	***0.000***	
KZ000036428	*Kazakistan*	*NOAA GHCNd*	*49.20*	*84.52*	*393*	*0%*	*0.024*	*0.123*
KZ000036439	*Kazakistan*	*NOAA GHCNd*	*49.18*	*85.62*	*1040*	*0%*	***0.000***	

KZ000036498	*Kazakistan*	*NOAA GHCNd*	*48.17*	*78.42*	*680*	*0%*	***0.000***		
KZ000036535	*Kazakistan*	*NOAA GHCNd*	*48.75*	*82.37*	*533*	*0%*	*0.035*		***0.322***
KZ000036639	*Kazakistan*	*NOAA GHCNd*	*47.12*	*81.62*	*497*	*0%*	*0.025*		*0.082*
KZ000036665	*Kazakistan*	*NOAA GHCNd*	*47.47*	*84.92*	*567*	*0%*	***0.000***		*0.141*
KZ000036729	*Kazakistan*	*NOAA GHCNd*	*46.17*	*80.93*	*393*	*0.3%*	***0.041***		***0.524***
KZ000036821	*Kazakistan*	*NOAA GHCNd*	*44.83*	*76.27*	*393*	*0%*	***0.080***		
KZ000036859	*Kazakistan*	*NOAA GHCNd*	*44.35*	*77.97*	*648*	*2.5%*	*0.003*		*-0.14*
KZ000036870	*Kazakistan*	*NOAA GHCNd*	*43.23*	*76.93*	*867*	*3.8%*	***0.054***		*-0.085*
KZ000038062	*Kazakistan*	*NOAA GHCNd*	*44.85*	*65.50*	*127*	*0%*	***0.105***		***0.673***
KZ000038069	*Kazakistan*	*NOAA GHCNd*	*44.17*	*66.75*	*151*	*0%*	***0.101***		
KZ000038191	*Kazakistan*	*NOAA GHCNd*	*43.72*	*67.42*	*174*	*0%*	***0.000***		
KZ000038196	*Kazakistan*	*NOAA GHCNd*	*43.55*	*68.90*	*797*	*0%*	***0.065***		
KZ000038198	*Kazakistan*	*NOAA GHCNd*	*43.27*	*68.22*	*207*	*0%*	***0.029***		***0.322***
KZ000038222	*Kazakistan*	*NOAA GHCNd*	*43.70*	*73.78*	*455*	*0%*	*0.017*		
KZ000038334	*Kazakistan*	*NOAA GHCNd*	*42.48*	*70.30*	*842*	*0%*	***0.129***		
KZ000038343	*Kazakistan*	*NOAA GHCNd*	*42.95*	*72.75*	*680*	*0%*	***0.063***		
KZ000038439	*Kazakistan*	*NOAA GHCNd*	*41.37*	*68.00*	*232*	*0%*	***0.047***		***0.499***
MG000044212	*Mongolia*	*NOAA GHCNd*	*49.80*	*92.08*	*1143*	*0%*	*0.041*		***0.394***
MG000044218	*Mongolia*	*NOAA GHCNd*	*48.02*	*91.57*	*1485*	*0%*	*0.040*		***0.453***
MG000044231	*Mongolia*	*NOAA GHCNd*	*49.63*	*10.02*	*1282*	*0%*	*-0.002*		***0.274***
MG000044239	*Mongolia*	*NOAA GHCNd*	*48.80*	*10.36*	*1175*	*0%*	*0.002*		***0.345***
MG000044272	*Mongolia*	*NOAA GHCNd*	*47.75*	*96.85*	*1785*	*0%*	*0.029*		***0.411***
MG000044288	*Mongolia*	*NOAA GHCNd*	*46.27*	*10.28*	*1831*	*0%*	*0.015*		***0.415***
MG000044341	*Mongolia*	*NOAA GHCNd*	*45.77*	*10.63*	*1428*	*0%*	*0.011*		***0.386***
MG000044373	*Mongolia*	*NOAA GHCNd*	*43.58*	*10.44*	*1455*	*0%*	*0.011*		***0.419***
MGM00044213	*Mongolia*	*NOAA GHCNd*	*49.65*	*94.40*	*1273*	*0%*	*0.021*		
MGM00044214	*Mongolia*	*NOAA GHCNd*	*48.93*	*89.93*	*1977*	*0%*	*0.012*		***0.396***
MGM00044215	*Mongolia*	*NOAA GHCNd*	*49.02*	*91.72*	*1740*	*0%*	*0.042*		
MGM00044225	*Mongolia*	*NOAA GHCNd*	*48.73*	*98.20*	*1714*	*0%*	*0.043*		
MGM00044230	*Mongolia*	*NOAA GHCNd*	*49.57*	*10.20*	*1164*	*0%*	*-0.010*		

MGM00044232	*Mongolia*	*NOAA GHCNd*	*49.38*	*10.27*	*922*	*0%*	*-0.014*	***0.359***
MGM00044237	*Mongolia*	*NOAA GHCNd*	*48.53*	*10.14*	*1501*	*0%*	*0.004*	
MGM00044241	*Mongolia*	*NOAA GHCNd*	*48.92*	*10.61*	*816*	*0%*	*-0.034*	***0.324***
MGM00044265	*Mongolia*	*NOAA GHCNd*	*46.12*	*91.47*	*1268*	*0%*	*0.030*	
MGM00044275	*Mongolia*	*NOAA GHCNd*	*46.83*	*98.08*	*2362*	*0%*	*0.018*	
MGM00044277	*Mongolia*	*NOAA GHCNd*	*46.40*	*96.25*	*2158*	*0%*	*0.030*	***0.459***
MGM00044282	*Mongolia*	*NOAA GHCNd*	*47.45*	*10.15*	*1784*	*0%*	*-0.013*	***0.457***
MGM00044284	*Mongolia*	*NOAA GHCNd*	*46.70*	*10.01*	*2109*	*0%*	*0.014*	***0.443***
MGM00044285	*Mongolia*	*NOAA GHCNd*	*46.90*	*10.28*	*1649*	*0%*	*0.017*	***0.474***
MGM00044287	*Mongolia*	*NOAA GHCNd*	*46.13*	*10.07*	*1827*	*0%*	*0.048*	***0.52***
MGM00044292	*Mongolia*	*NOAA GHCNd*	*47.84*	*10.68*	*1292*	*0%*	***0.000***	
MGM00044294	*Mongolia*	*NOAA GHCNd*	*47.30*	*10.75*	*1425*	*0%*	*-0.029*	***0.347***
MGM00044298	*Mongolia*	*NOAA GHCNd*	*46.45*	*10.82*	*1285*	*0%*	*0.003*	***0.345***
MGM00044336	*Mongolia*	*NOAA GHCNd*	*45.45*	*10.39*	*1309*	*0%*	*-0.006*	
MGM00044347	*Mongolia*	*NOAA GHCNd*	*44.42*	*10.53*	*1286*	*0%*	*0.019*	***0.45***
PK000041620	*Pakistan*	*NOAA GHCNd*	*31.35*	*69.47*	*1435*	*0%*	***0.000***	
PKM00041624	*Pakistan*	*NOAA GHCNd*	*31.91*	*70.90*	*180*	*0%*	***0.000***	
PKM00041660	*Pakistan*	*NOAA GHCNd*	*30.25*	*66.94*	*0*	*0%*	***0.000***	
PKM00041675	*Pakistan*	*NOAA GHCNd*	*30.20*	*71.42*	*119*	*0%*	***0.000***	
PKM00041685	*Pakistan*	*NOAA GHCNd*	*29.88*	*69.72*	*1226*	*0%*	***0.000***	
PKM00041696	*Pakistan*	*NOAA GHCNd*	*29.03*	*66.58*	*0*	*0%*	***0.000***	
PKM00041715	*Pakistan*	*NOAA GHCNd*	*28.28*	*68.45*	*55*	*0%*	***0.000***	
PKM00041718	*Pakistan*	*NOAA GHCNd*	*28.65*	*70.68*	*90*	*0%*	***0.000***	
PKM00041744	*Pakistan*	*NOAA GHCNd*	*27.83*	*66.63*	*1293*	*0%*	***0.000***	
PKM00041749	*Pakistan*	*NOAA GHCNd*	*26.22*	*68.39*	*30*	*0%*	***0.000***	
PKM00041764	*Pakistan*	*NOAA GHCNd*	*25.38*	*68.42*	*22*	*0%*	***0.000***	
PKM00041768	*Pakistan*	*NOAA GHCNd*	*25.52*	*69.78*	*5*	*0%*	***0.000***	
TI000038836	*Tagikistan*	*NOAA GHCNd*	*38.55*	*68.80*	*800*	*1.2%*	***0.089***	*0.18*
TI000038933	*Tagikistan*	*NOAA GHCNd*	*37.82*	*68.78*	*421*	*0%*	*0.016*	***0.432***
TI000038954	*Tagikistan*	*NOAA GHCNd*	*37.50*	*71.50*	*2178*	*5.7%*	*0.013*	*-0.07*

TX000038911	*Turkmenistan*	*NOAA GHCNd*	*37.83*	*65.20*	*241*	*0%*	*0.009*	***0.318***
TX000038915	*Turkmenistan*	*NOAA GHCNd*	*37.52*	*66.02*	*266*	*0%*	***0.038***	
UZM00038457	*Uzbekistan*	*NOAA GHCNd*	*41.27*	*69.27*	*422*	*0%*	***0.067***	***0.289***
UZM00038462	*Uzbekistan*	*NOAA GHCNd*	*41.90*	*70.37*	*1126*	*0%*	***0.046***	
UZM00038565	*Uzbekistan*	*NOAA GHCNd*	*40.55*	*65.68*	*549*	*0%*	***0.022***	*0.206*
UZM00038579	*Uzbekistan*	*NOAA GHCNd*	*40.12*	*67.83*	*380*	*0%*	***0.053***	
UZM00038583	*Uzbekistan*	*NOAA GHCNd*	*40.82*	*68.68*	*265*	*0%*	***0.034***	
UZM00038611	*Uzbekistan*	*NOAA GHCNd*	*40.98*	*71.58*	*468*	*0%*	***0.035***	
UZM00038618	*Uzbekistan*	*NOAA GHCNd*	*40.37*	*71.75*	*597*	*1.8%*	***0.041***	***0.421***
UZM00038696	*Uzbekistan*	*NOAA GHCNd*	*39.57*	*66.95*	*787*	*0.1%*	***0.072***	***0.523***
UZM00038812	*Uzbekistan*	*NOAA GHCNd*	*38.80*	*65.72*	*359*	*0%*	*0.013*	
UZM00038927	*Uzbekistan*	*NOAA GHCNd*	*37.23*	*67.27*	*305*	*0%*	*-0.001*	***0.402***

Table S2 | Trends of ERA5-Land T_{max}, T_{min}, and T_{mean} for JJA (1994–2023) in °C yr^{-1}. Trends are expressed as Sen's slopes derived from the two-tailed Mann–Kendall test. When the 25th and 75th percentiles are both negative, the trends are indicated in bolds. The relevant box-plots are reported in Figure S3.

		Tmax			**Tmin**			**Tmean**		
RGI sub-region	**ID**	median	*25th*	*75th*	median	*25th*	*75th*	median	*25th*	*75th*
Hissar Alay	13-01	0.020	*0.014*	*0.025*	0.019	*0.010*	*0.032*	0.022	*0.014*	*0.033*
Pamir	13-02	0.005	*-0.006*	*0.016*	-0.002	*-0.012*	*0.008*	0.007	*-0.005*	*0.016*
W Tien Shan	13-03	0.019	*0.011*	*0.026*	0.006	*-0.002*	*0.012*	0.016	*0.008*	*0.022*
E Tien Shan	13-04	0.034	*0.026*	*0.041*	0.027	*0.020*	*0.034*	0.031	*0.026*	*0.038*
W Kun Lun	**13-05**	**-0.018**	***-0.027***	***-0.012***	0.005	*-0.010*	*0.013*	-0.010	*-0.020*	*-0.004*
E Kun Lun	13-06	-0.003	*-0.010*	*0.007*	0.032	*0.022*	*0.036*	0.012	*0.008*	*0.019*
Qilian Shan	13-07	0.016	*0.012*	*0.017*	0.034	*0.031*	*0.037*	0.024	*0.020*	*0.027*
Inner Tibet	13-08	0.014	*-0.003*	*0.024*	0.025	*0.011*	*0.041*	0.015	*0.004*	*0.028*
S and E Tibet	13-09	0.012	*0.005*	*0.016*	0.034	*0.031*	*0.037*	0.020	*0.016*	*0.024*
Hindu Kush	**14-01**	**-0.020**	***-0.032***	***-0.001***	-0.023	*-0.043*	*-0.010*	-0.018	*-0.035*	*-0.001*
Karakoram	**14-02**	**-0.017**	***-0.028***	***-0.001***	-0.001	*-0.009*	*0.014*	-0.009	*-0.019*	*0.005*
W Himalaya	**14-03**	**-0.018**	***-0.028***	***-0.009***	-0.013	*-0.022*	*-0.004*	-0.016	*-0.026*	*-0.005*
C Himalaya	15-01	-0.006	*-0.016*	*0.005*	0.006	*-0.005*	*0.016*	0.002	*-0.010*	*0.013*
E Himalaya	15-02	0.006	*-0.007*	*0.014*	0.021	*0.013*	*0.029*	0.014	*0.005*	*0.020*
Hengduan Shan	15-03	0.014	*0.007*	*0.021*	0.025	*0.017*	*0.029*	0.016	*0.012*	*0.021*
Median		0.006	-0.006	0.016	0.019	0.010	0.029	0.014	0.005	0.020

Table S3 High-elevation meteorological stations located on-glacier or adjacent to glacier snouts. The data sources are:
1 https://essd.copernicus.org/preprints/essd-2026-183/;
2 https://essd.copernicus.org/articles/17/4293/2025/essd-17-4293-2025.html;
3 https://journals.ametsoc.org/view/journals/bams/104/3/BAMS-D-22-0084.1.xml
4 https://geoportal.mountaingenius.org/portal/
5 https://egusphere.copernicus.org/preprints/2025/egusphere-2025-3756/
6 https://glacioclim.osug.fr/Donnees-du-Nepal-region-du-Khumbu

Station	**Lat (°N)**	**Lon (°E)**	**Elev (m)**	**Region**	**Period**	**Source**
Askole	35.68	75.82	3000	Baltistan, Pakistan	2005-10-08 / 2012-12-31	4
Concordia	35.74	76.51	4700	Baltistan, Pakistan	2012-01-01 / 2012-12-31	4
Urdukas	35.73	76.29	3926	Baltistan, Pakistan	2004-06-17 / 2012-12-31	4
Passu	36.45	74.86	2945	Baltistan, Pakistan	2022-08-31 / 2023-08-05	4
Shispar	36.32	74.57	2205	Baltistan, Pakistan	2022-08-29 / 2023-08-09	4
Bishop	27.99	86.93	8810	Everest, Nepal	2022-06-01 / 2022-07-29	1
Camp 2	27.98	86.90	6485	Everest, Nepal	2019-06-01 / 2023-07-01	1
Changri 5470	27.99	86.78	5470	Everest, Nepal	2014-11-30 / 2017-11-21	6
Pyramid	27.96	86.81	5050	Everest, Nepal	2009-06-01 / 2012-09-29	2
Southcol	27.97	86.93	7905	Everest, Nepal	2019-06-01 / 2023-07-04	1
Mera La	27.73	86.90	5352	Everest, Nepal	2013-11-15 / 2024-11-28	6
Mera Summit	27.71	86.87	6352	Everest, Nepal	2013-11-20 / 2016-08-02	6
Mera Naulek	27.72	86.90	5360	Everest, Nepal	2012-11-27 / 2024-11-26	6
QMOS_Camp	28.13	86.86	5200	Everest, Nepal	2021-09-15 / 2024-08-30	3
ChottaShigri	32.29	77.53	3844	Himachal Pradesh, India	2022-08-16 / 2022-09-29	5
ChottaShigri BC	32.23	77.51	4871	Himachal Pradesh, India	2022-06-07 / 2022-09-29	5
DrangDrung	33.79	76.33	4601	Ladakh, India	2023-06-01 / 2023-09-23	5

Lirung	28.24	85.56	4276	Langtang, Nepal	2018-06-01 / 2019-08-10	5
Morimoto	28.25	85.68	4925	Langtang, Nepal	2017-06-01 / 2019-09-30	5
Yala	28.23	85.62	5214	Langtang, Nepal	2016-06-01 / 2019-09-30	5

Table S4 Predictors tested for the multi-regression model. Predictors developed to explain glacier mass balances across HMA over the last two decades (~2010–2020). Significant regression are in bold.

		MB mean		MB Fan et al. 2022		MB Brun et al. 2017		MB Hugonnet et al. 2021	
		R^2	*p*	R^2	*p*	R^2	*p*	R^2	*p*
Summer temperature trend	JJA Tmean 30yr trend	0.07	*0.33*	0.05	*0.44*	0.05	*0.44*	0.14	*0.16*
	JJA Tmean 25yr trend	0.02	*0.65*	0.01	*0.74*	0.00	*0.83*	0.05	*0.41*
	JJA Tmean 20yr trend	0.06	*0.40*	0.03	*0.57*	0.04	*0.48*	0.13	*0.19*
	JJA Tmax 30yr trend	**0.33**	***0.03***	**0.27**	***0.05***	**0.31**	***0.03***	**0.39**	***0.01***
	JJA Tmax 25yr trend	**0.29**	***0.04***	0.22	*0.08*	0.25	*0.06*	**0.39**	***0.01***
	JJA Tmax 20yr trend	0.06	*0.38*	0.03	*0.54*	0.04	*0.47*	0.14	*0.18*
	JJA Tmax 300hPa 30yr trend	0.24	*0.06*	0.26	*0.05*	0.21	*0.09*	0.24	*0.06*
	JJA Tmin 30yr trend	0.10	*0.25*	0.07	*0.33*	0.08	*0.30*	0.16	*0.14*
	JJA Tmin 25yr trend	0.19	*0.11*	0.13	*0.18*	0.15	*0.16*	0.29	*0.04*
	JJA Tmin 20yr trend	0.12	*0.21*	0.08	*0.31*	0.09	*0.29*	0.21	*0.09*
	MJJASO Tmax trend	0.21	*0.09*	0.17	*0.12*	0.19	*0.10*	0.25	*0.06*
	MJJASO Tmin trend	0.14	*0.17*	0.12	*0.21*	0.12	*0.21*	0.19	*0.10*
precipitation trend	TP 30yr trend	0.01	*0.74*	0.02	*0.65*	0.02	*0.62*	0.00	*0.98*
	TP 25yr trend	0.03	*0.55*	0.03	*0.57*	0.04	*0.49*	0.02	*0.62*
	TP 20yr trend	0.23	*0.07*	**0.28**	***0.04***	0.24	*0.07*	0.15	*0.15*
	Snow 30yr trend	0.23	*0.07*	**0.27**	***0.05***	0.25	*0.06*	0.16	*0.14*
Mean climatology	TP 30yr	**0.68**	***0.00***	**0.66**	***0.00***	**0.68**	***0.00***	**0.67**	***0.00***
	TP 25yr	**0.68**	***0.00***	**0.66**	***0.00***	**0.67**	***0.00***	**0.67**	***0.00***
	TP 20yr	**0.68**	***0.00***	**0.65**	***0.00***	**0.67**	***0.00***	**0.67**	***0.00***
	Snow 30yr	**0.30**	***0.04***	**0.32**	***0.03***	**0.32**	***0.03***	**0.21**	***0.08***
	Tmean 30yr	**0.69**	***0.00***	**0.65**	***0.00***	**0.64**	***0.00***	**0.74**	***0.00***
	Tmean 25yr	**0.69**	***0.00***	**0.65**	***0.00***	**0.64**	***0.00***	**0.74**	***0.00***
	Tmean 20yr	**0.69**	***0.00***	**0.65**	***0.00***	**0.64**	***0.00***	**0.74**	***0.00***

Table S5 | Data used for developing the multi-regression model. Data includes TP, $2m - JJA - Tmax$ trends, MB estimated by selected studies (Brun et al., 2017; Hugonnet et al., 2021; Fan et al., 2022), and predicted MB (this study).

RGI sub-region	ID	Total glacier surface (km2)	Annual TP (mm)	2m-JJA-Tmax trend (°C yr-1)	Fan et al. 2022 (m w.e. yr-1)	Brun et al. 2017 (m w.e. yr-1)	Hugonnet et al. 2021 (m w.e. yr-1)	MB (mean of three studies) (m w.e. yr-1)	Predicted MB (this study) (m w.e. yr-1)
Hissar Alay	13-01	1147	1295	0.017	-0.18	-0.04	-0.09	-0.10	-0.44
Pamir	13-02	7946	643	0.001	-0.07	-0.06	-0.08	-0.07	-0.12
W Tien Shan	13-03	7325	813	0.014	-0.15	-0.20	-0.24	-0.20	-0.25
E Tien Shan	13-04	1787	800	0.035	-0.47	-0.40	-0.45	-0.44	-0.34
W Kun Lun	13-05	6965	422	-0.018	0.23	0.16	0.08	0.16	0.05
E Kun Lun	13-06	2521	468	-0.008	-0.09	-0.01	-0.07	-0.06	-0.01
Qilian Shan	13-07	1097	524	0.015	-0.38	-0.29	-0.26	-0.31	-0.14
Inner Tibet	13-08	6085	581	0.003	-0.25	-0.19	-0.29	-0.24	-0.11
S and E Tibet	13-09	2705	1270	0.016	-0.47	-0.55	-0.56	-0.53	-0.43
Hindu Kush	14-01	1965	752	-0.017	-0.18	-0.13	-0.14	-0.15	-0.08
Karakoram	14-02	20213	622	-0.012	-0.03	-0.03	-0.05	-0.04	-0.05
W Himalaya	14-03	5663	1021	-0.014	-0.42	-0.38	-0.29	-0.36	-0.20
C Himalaya	15-01	4403	1389	-0.012	-0.41	-0.28	-0.33	-0.34	-0.34
E Himalaya	15-02	3917	1490	-0.007	-0.35	-0.38	-0.42	-0.38	-0.40
Hengduan Shan	15-03	3377	1801	0.022	-0.62	-0.56	-0.58	-0.59	-0.65

Table S6 Mass balances for the last two decades and predicted values by the multi-regression model according to the Himap glacier inventory for Pamir and Hissar Alay.

HIMAP sub-region	Total glacier surface (km2)	Annual TP (mm)	2m-JJA-Tmax trend (°C yr-1)	300hPa-JJA-Tmax trend (°C yr-1)	Hugonnet et al. 2021 (m w.e. yr-1)	Barandum et al. 2021 (m w.e. yr-1)	Shean et al. 2020 (m w.e. yr-1)	MB mean to the three studies (m w.e. yr-1)	Predicted MB (m w.e. yr-1)
Eastern Pamir	1618	540	-0.012	-0.028	-0.03	-0.11	0.00	-0.05	-0.03
Western Pamir	6564	663	0.004	-0.027	-0.12	-0.27	-0.09	-0.16	-0.15
Parmir Alay	1136	1294	0.017	-0.031	-0.10	-0.30	-0.03	-0.14	-0.44