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SUPPLEMENTARY INFORMATION

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Global-scale hydrological response to future glacier mass loss

Matthias Huss [1,2*] and Regine Hock [3,4]

[1]Laboratory of Hydraulics, Hydrology and Glaciology (VAW), ETH Zurich, Zurich, Switzerland. [2]Department of Geosciences, University of Fribourg, Fribourg, Switzerland. [3]Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK, USA. [4]Department of Earth Sciences, Uppsala University, Uppsala, Sweden. *e-mail: huss@vaw.baug.ethz.ch

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1 SUPPLEMENTARY TEXT

1.1 The concept of "peak water"

The concept of peak water (Fig. 1, main text) refers to the variation of glacier runoff with time as the climate warms and glaciers retreat. Annual runoff will initially increase, but then peak, followed by a decline. Peak water refers to the timing of peak flow, which is a critical variable for water resources planning and management in catchments in which glacier runoff is a significant contributor to streamflow.

Initially (t_0-t_1), the glacier is in balance, i.e. averaged over the entire glacier and one year, seasonal glacier volume losses (mostly melt) are compensated by accumulation of snow, thus annual glacier mass change $\Delta M_\mathrm{a} = 0$. Assuming other water balance components to be negligible, the annual runoff is given by $Q_\mathrm{a} = P_\mathrm{a} - E_\mathrm{a}$, where P_a is annual precipitation and E_a evaporation.

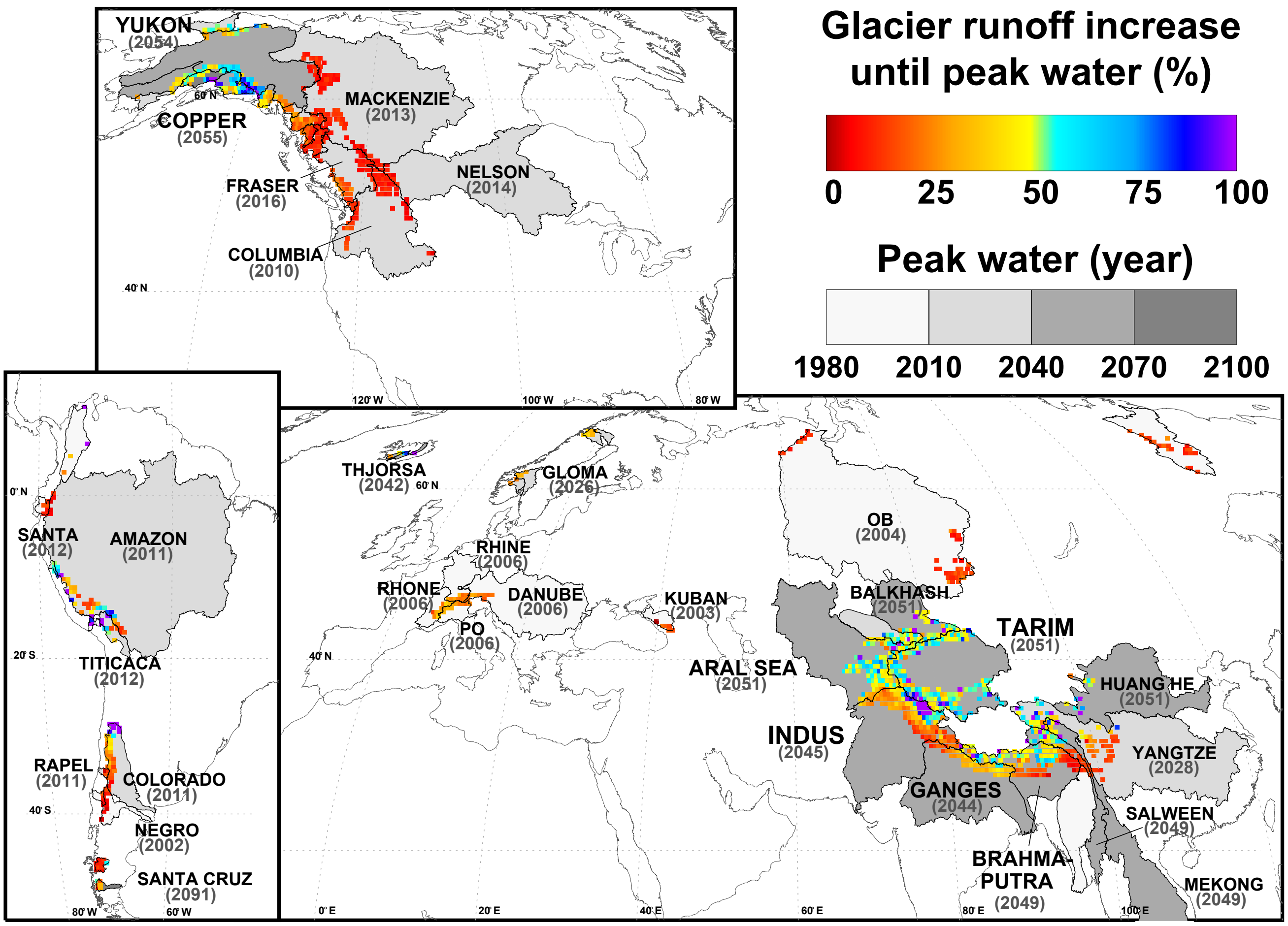
When ΔM turns negative in response to atmospheric warming (t_1), the annual runoff from the glacierized basin will first increase due to enhanced melt. A tipping point is reached beyond which the annual runoff will decrease, since the additional water provided by annual glacier storage change decreases as the glacier mass shrinks. During this phase (t_1-t_2), $Q_\mathrm{a} = P_\mathrm{a} - E_\mathrm{a} - \Delta M_\mathrm{a}$. Assuming that all components of the water balance over the glacierized basin (precipitation, evapotranspiration, groundwater storage, human water extraction, etc.), except for glacier storage change, ΔM_a, remain unaltered, the runoff will return to its initial value at t_1 once the glacier has disappeared or reached a new equilibrium (i.e. $\Delta M_\mathrm{a} = 0$, and $Q_\mathrm{a} = P_\mathrm{a} - E_\mathrm{a}$). Hence, the basin runoff is identical at t_1 and t_2, although glacier coverage is different. As long as $\Delta M_\mathrm{a} = 0$ (i.e. the glacier is not gaining or losing mass over the course of a year), there is no additional runoff component due to changes in glacier storage no matter glacier size, or whether or not the basin is glacierized at all. Note that the runoff volume derived from integrating annual runoff in excess of the initial value at t_1 is equal to the total glacier volume lost in period t_1-t_2, or equal to total initial glacier volume in case the glacier has melted entirely.

Here, summer runoff is defined as the runoff over each year's melt season which varies in length in different climates. It will experience similar changes as annual runoff, but will eventually drop below its initial value at t_1, since summer glacier mass balances are typically strongly negative (net mass losses), and therefore summer runoff $Q_\mathrm{s} = P_\mathrm{s} - E_\mathrm{s} - \Delta M_\mathrm{s}$. Hence, as long as the glacier exists, during summer, additional water is provided from glacier storage (even in years with balanced or positive mass budgets, i.e. when $\Delta M_\mathrm{a} \geq 0$). However, this excess water from the glacier will eventually drop below its initial value at t_1 as the glacier continues to shrink. The fraction of runoff in the remaining months of the year increases relative to annual runoff as more precipitation falls as rain and the glacier influence is diminished.

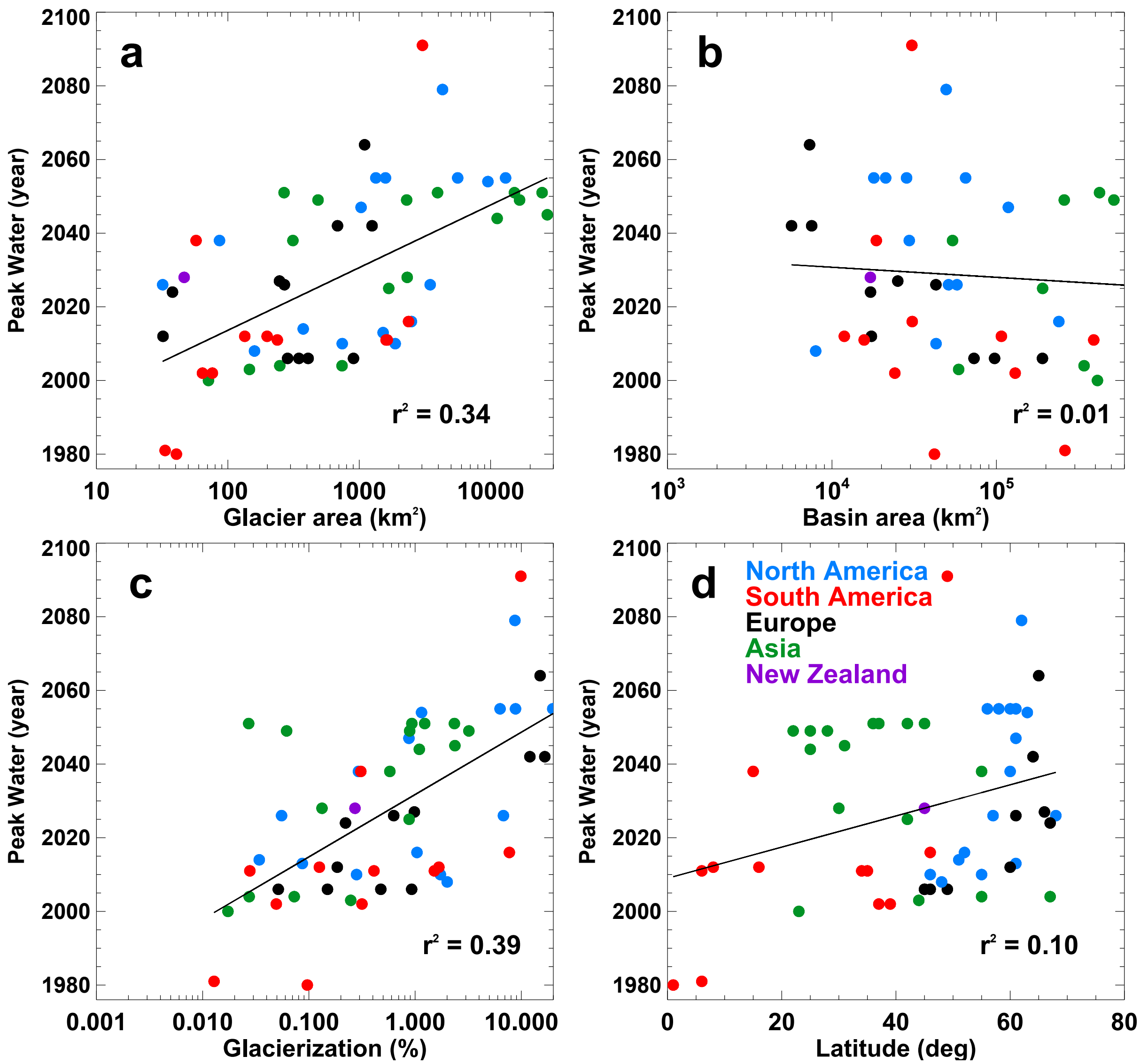
The changes in summer runoff illustrated in Figure 1 of the main text refer to glaciers in climates with a pronounced melt and accumulation season as typically found in mid- and high-latitudes, while glaciers in the tropics or monsoon-dominated regions may show different regimes. In reality, runoff evolution may substantially deviate from this schematic concept since other components of the water balance (e.g. precipitation, evapotranspiration) are expected to change in response to both the air temperature changes and land cover (e.g. vegetation) and morphological changes (e.g. proglacial lake formation) that may occur when glaciers retreat.

Similar illustrations have been reported in the literature[1–4]. In contrast to Figure 1 (main text), Milner et al.[2] and Baraer et al.[4] show a decrease in annual runoff below the initial value as the glacier disappears but refer to runoff from the continuously changing glacierized area. Here, we isolate the glacier impact on runoff from a highly glacierized basin, fixed in area, including glacierized and increasingly non-glacierized terrain.

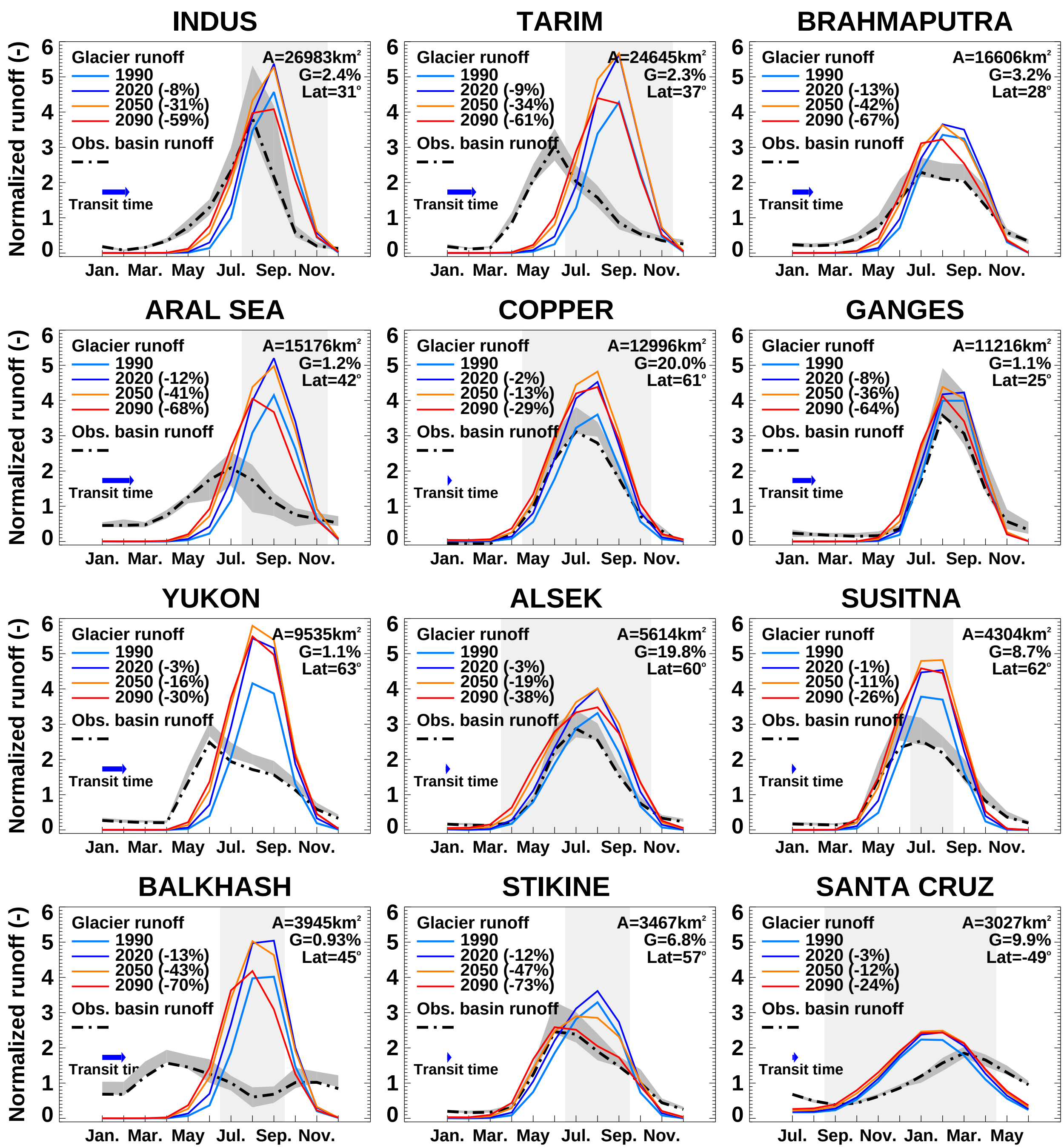
2 SUPPLEMENTARY FIGURES



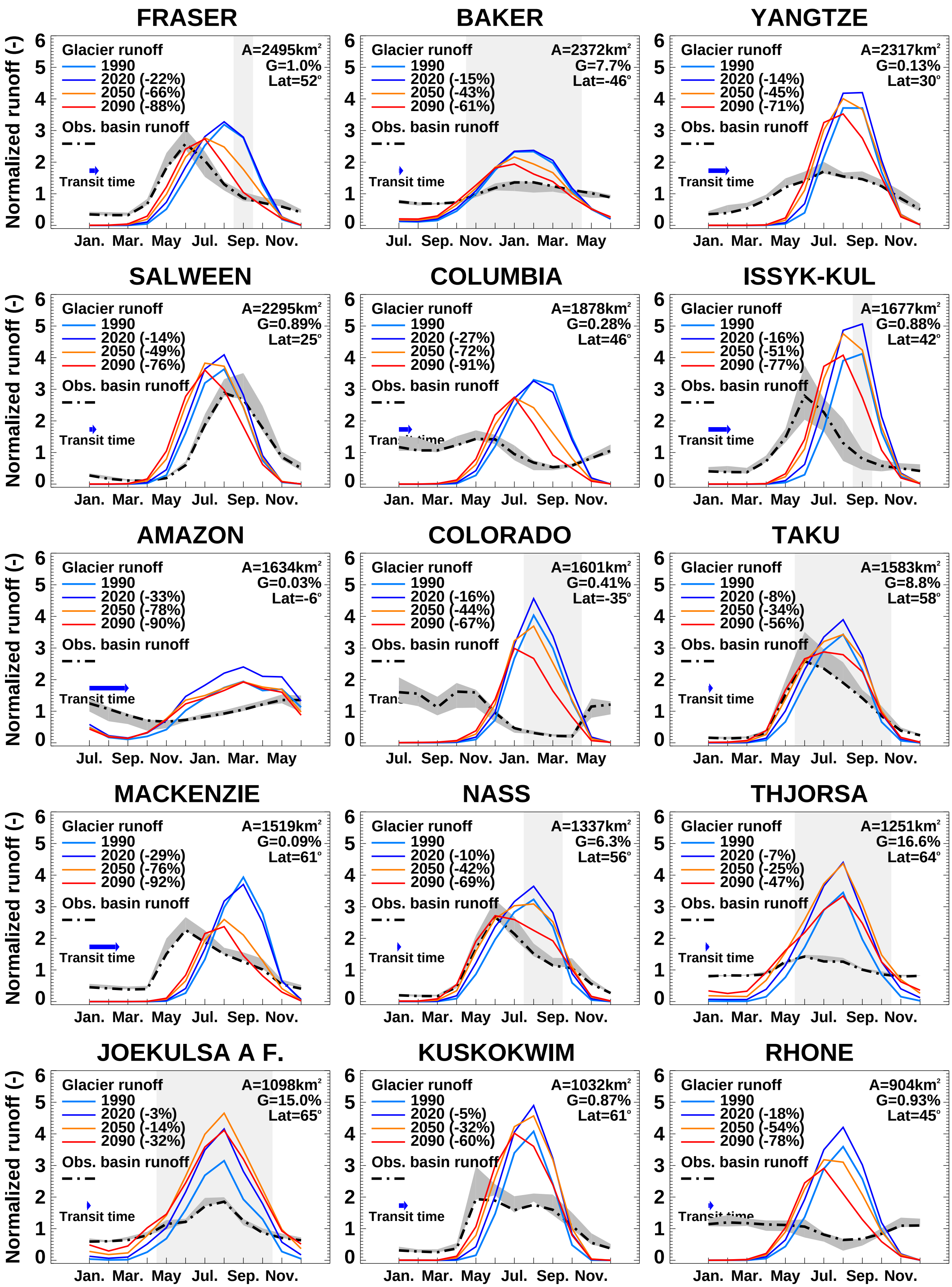
Supplementary Figure 1. Increase in annual glacier runoff until peak water relative to 1980-2000 (%). Colours show the runoff increase for all glaciers located in the 56 investigated drainage basins, aggregated in $0.5\times0.5^{\circ}$ grid cells. Grey scales refer the year of peak water for the macroscale basins in 30-year intervals. Peak water (in years) is also given in brackets below the basin names. Glacier runoff is defined as runoff from the initially glacierized area. Peak water is computed from 11-year moving averages of annual glacier runoff. Results refer to multi-GCM means and RCP4.5.

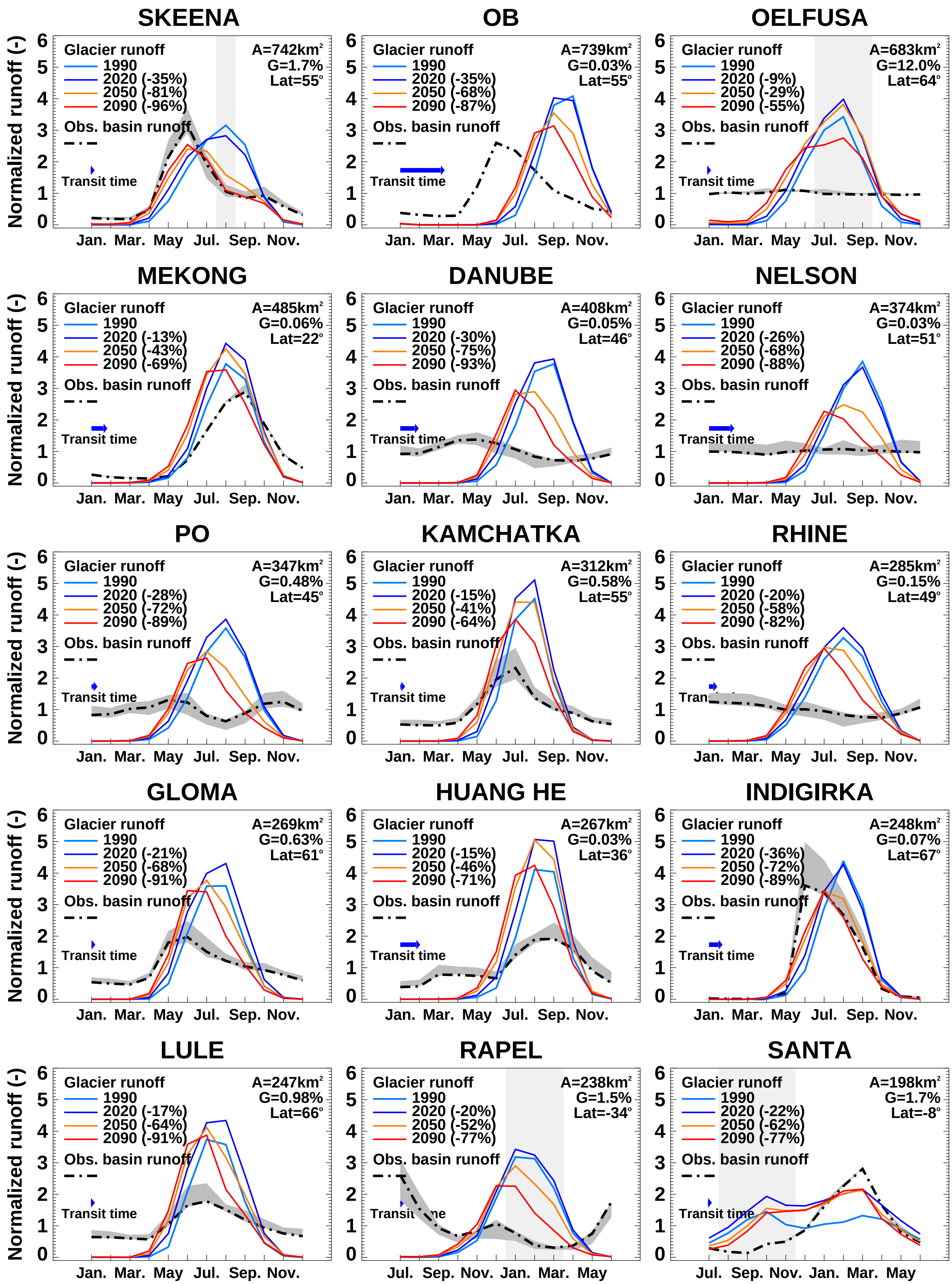


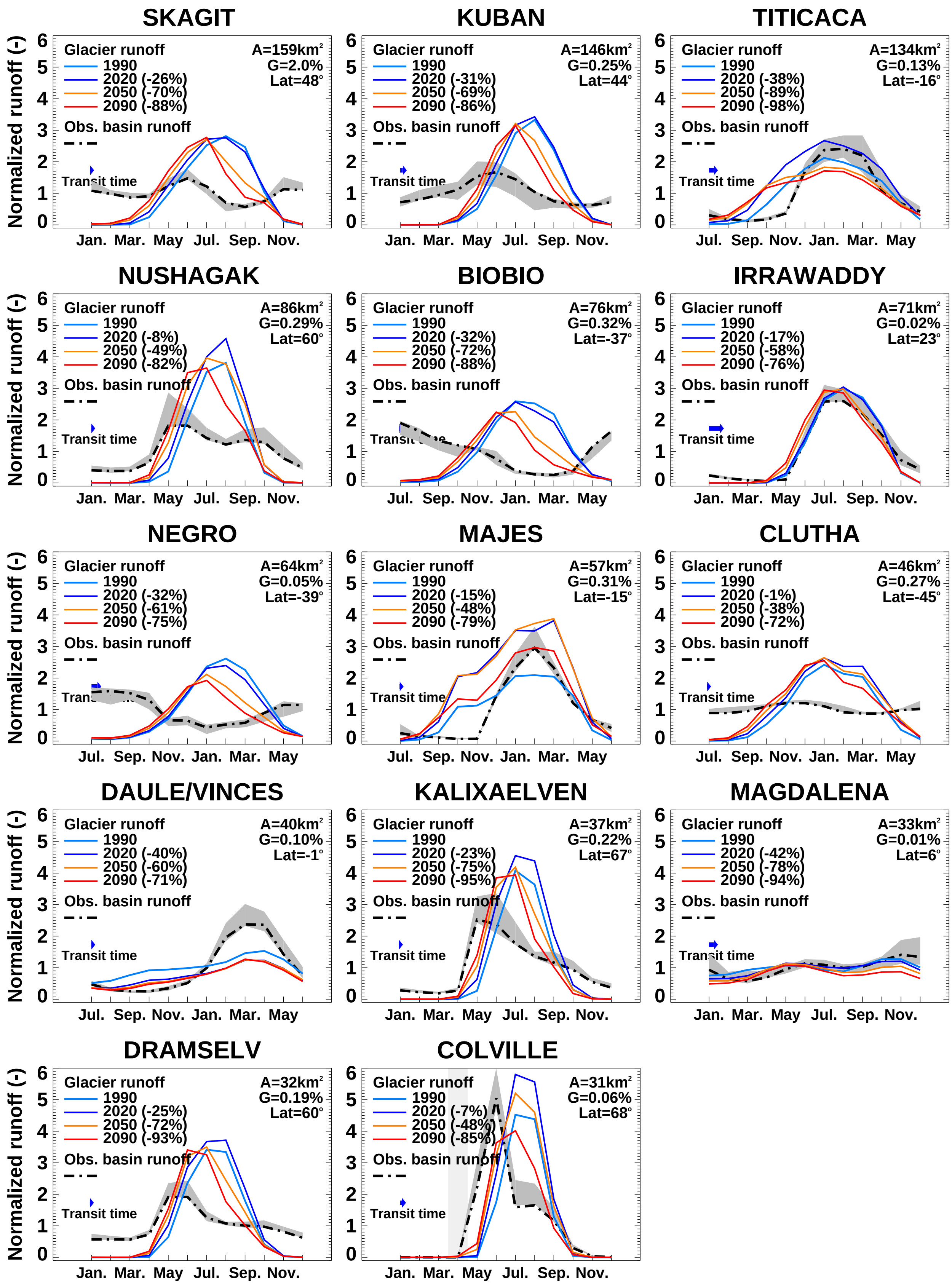
Supplementary Figure 2. Timing of peak water in all 56 investigated glacierized macroscale drainage basins in dependence of different variables. **a**, Total glacier area in the drainage basin, **b**, basin area, **c**, glacierization, and **d**, absolute geographic latitude of the basin's center. Symbols are colour-coded to continents and refer to multi-GCM means and emission scenario RCP4.5. Coefficients of determination (r^2) in **a-c** are given for a logarithmic representation of the dependent variable. All correlations, except for basin area (**b**) are significant at the p<0.01 level.



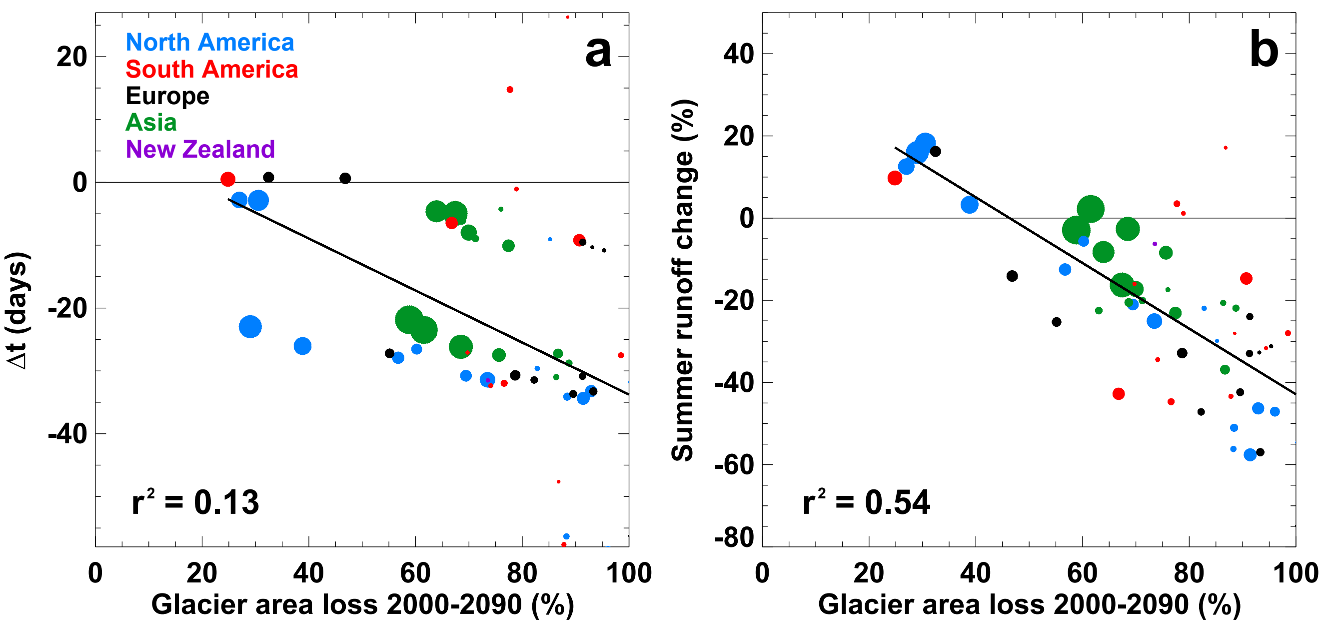
Supplementary Figure 3. 21st century changes in glacier runoff seasonality for individual glacier basins (continued on next three pages). Modelled monthly mean glacier runoff (shifted by water transit time) is averaged over four 20-year periods (1980-2000, 2010-2030, 2040-2060, 2080-2100) and normalized with respect to each basin's mean annual runoff in 1980-2000. Results refer to the multi-GCM mean and RCP4.5. Also shown is observed monthly mean basin runoff[5,6] normalized with mean annual runoff over basin-specific periods of available data (see Suppl. Table 6). The area in dark grey indicates the spread in basin runoff by the end of the 21st century when basin runoff is adjusted based on precipitation changes from 14 GCMs, as done in our sensitivity experiment (see Methods). Present glacier area, *A*, glacierization, *G*, and geographic latitude, Lat., of the basin's center are given. Numbers in brackets refer to the modelled change in glacier area for 2020, 2050 and 2090 relative to initial ice coverage (referring to the period between 2000 and 2010). Grey bars mark the months with shares of modelled glacier runoff (1980-2000) relative to observed basin runoff of >30%. The length of the blue arrows is linearly proportional to each basin's transit time (see Supp. Table 1). The basins are shown in the order of decreasing glacier area.


FRASER
Glacier runoff
1990
2020 (-22%)
2050 (-66%)
2090 (-88%)
Obs. basin runoff
Transit time
A=2495km²
G=1.0%
Lat=52°
BAKER
Glacier runoff
1990
2020 (-15%)
2050 (-43%)
2090 (-61%)
Obs. basin runoff
Transit time
A=2372km²
G=7.7%
Lat=-46°
YANGTZE
Glacier runoff
1990
2020 (-14%)
2050 (-45%)
2090 (-71%)
Obs. basin runoff
Transit time
A=2317km²
G=0.13%
Lat=30°
SALWEEN
Glacier runoff
1990
2020 (-14%)
2050 (-49%)
2090 (-76%)
Obs. basin runoff
Transit time
A=2295km²
G=0.89%
Lat=25°
COLUMBIA
Glacier runoff
1990
2020 (-27%)
2050 (-72%)
2090 (-91%)
Obs. basin runoff
A=1878km²
G=0.28%
Lat=46°
ISSYK-KUL
Glacier runoff
1990
2020 (-16%)
2050 (-51%)
2090 (-77%)
Obs. basin runoff
Transit time
A=1677km²
G=0.88%
Lat=42°
AMAZON
Glacier runoff
1990
2020 (-33%)
2050 (-78%)
2090 (-90%)
Obs. basin runoff
Transit time
A=1634km²
G=0.03%
Lat=-6°
COLORADO
Glacier runoff
1990
2020 (-16%)
2050 (-44%)
2090 (-67%)
Obs. basin runoff
A=1601km²
G=0.41%
Lat=-35°
TAKU
Glacier runoff
1990
2020 (-8%)
2050 (-34%)
2090 (-56%)
Obs. basin runoff
Transit time
A=1583km²
G=8.8%
Lat=58°
MACKENZIE
Glacier runoff
1990
2020 (-29%)
2050 (-76%)
2090 (-92%)
Obs. basin runoff
Transit time
A=1519km²
G=0.09%
Lat=61°
NASS
Glacier runoff
1990
2020 (-10%)
2050 (-42%)
2090 (-69%)
Obs. basin runoff
Transit time
A=1337km²
G=6.3%
Lat=56°
THJORSA
Glacier runoff
1990
2020 (-7%)
2050 (-25%)
2090 (-47%)
Obs. basin runoff
Transit time
A=1251km²
G=16.6%
Lat=64°
JOEKULSA A F.
Glacier runoff
1990
2020 (-3%)
2050 (-14%)
2090 (-32%)
Obs. basin runoff
Transit time
A=1098km²
G=15.0%
Lat=65°
KUSKOKWIM
Glacier runoff
1990
2020 (-5%)
2050 (-32%)
2090 (-60%)
Obs. basin runoff
Transit time
A=1032km²
G=0.87%
Lat=61°
RHONE
Glacier runoff
1990
2020 (-18%)
2050 (-54%)
2090 (-78%)
Obs. basin runoff
A=904km²
G=0.93%
Lat=45°
Normalized runoff (-)
Jan. Mar. May Jul. Sep. Nov.
Jul. Sep. Nov. Jan. Mar. May

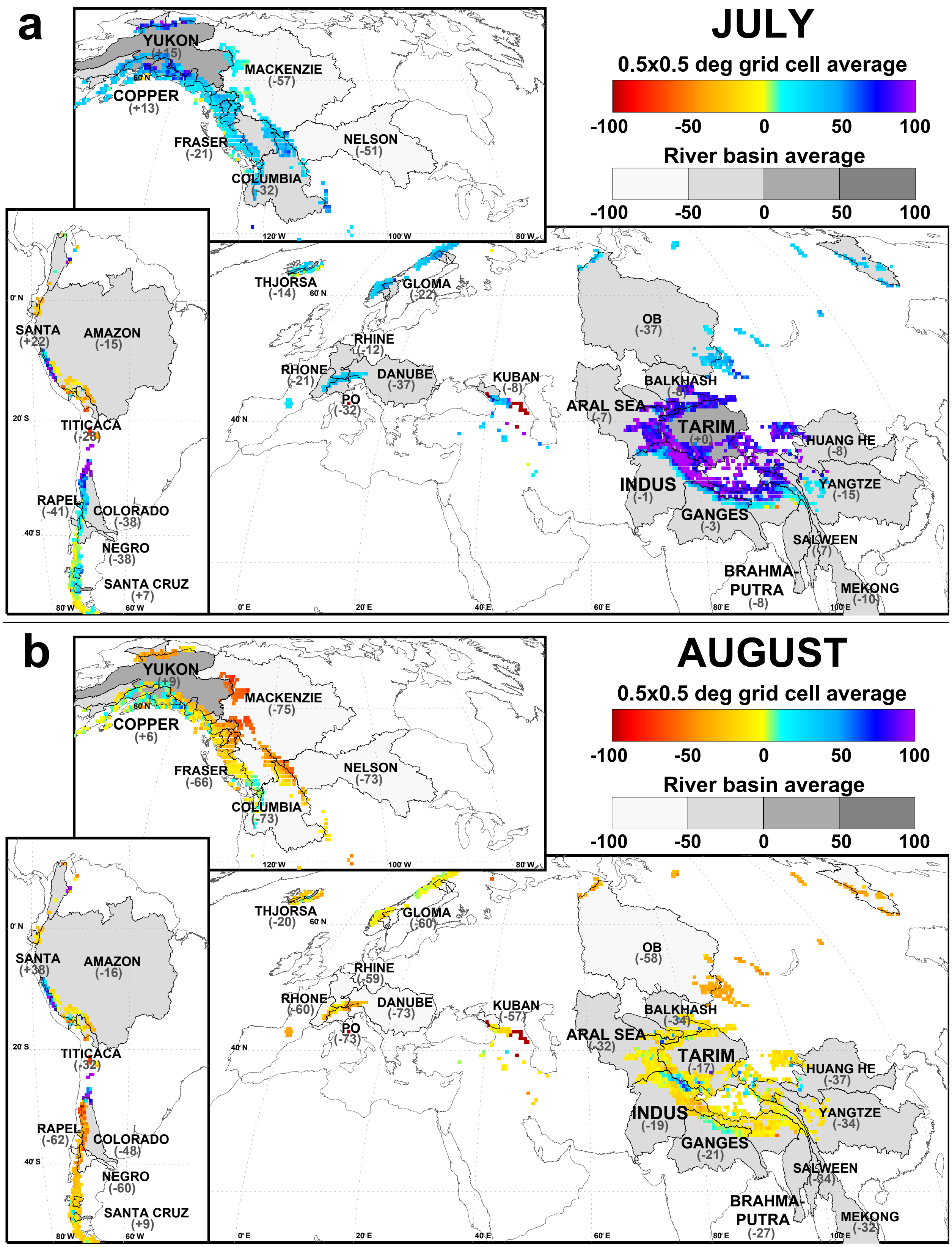

SKEENA
Glacier runoff
1990
2020 (-35%)
2050 (-81%)
2090 (-96%)
Obs. basin runoff
Transit time
A=742km²
G=1.7%
Lat=55°
OB
Glacier runoff
1990
2020 (-35%)
2050 (-68%)
2090 (-87%)
Obs. basin runoff
Transit time
A=739km²
G=0.03%
Lat=55°
OELFUSA
Glacier runoff
1990
2020 (-9%)
2050 (-29%)
2090 (-55%)
Obs. basin runoff
Transit time
A=683km²
G=12.0%
Lat=64°
MEKONG
Glacier runoff
1990
2020 (-13%)
2050 (-43%)
2090 (-69%)
Obs. basin runoff
Transit time
A=485km²
G=0.06%
Lat=22°
DANUBE
Glacier runoff
1990
2020 (-30%)
2050 (-75%)
2090 (-93%)
Obs. basin runoff
Transit time
A=408km²
G=0.05%
Lat=46°
NELSON
Glacier runoff
1990
2020 (-26%)
2050 (-68%)
2090 (-88%)
Obs. basin runoff
Transit time
A=374km²
G=0.03%
Lat=51°
PO
Glacier runoff
1990
2020 (-28%)
2050 (-72%)
2090 (-89%)
Obs. basin runoff
Transit time
A=347km²
G=0.48%
Lat=45°
KAMCHATKA
Glacier runoff
1990
2020 (-15%)
2050 (-41%)
2090 (-64%)
Obs. basin runoff
Transit time
A=312km²
G=0.58%
Lat=55°
RHINE
Glacier runoff
1990
2020 (-20%)
2050 (-58%)
2090 (-82%)
Obs. basin runoff
A=285km²
G=0.15%
Lat=49°
GLOMA
Glacier runoff
1990
2020 (-21%)
2050 (-68%)
2090 (-91%)
Obs. basin runoff
Transit time
A=269km²
G=0.63%
Lat=61°
HUANG HE
Glacier runoff
1990
2020 (-15%)
2050 (-46%)
2090 (-71%)
Obs. basin runoff
Transit time
A=267km²
G=0.03%
Lat=36°
INDIGIRKA
Glacier runoff
1990
2020 (-36%)
2050 (-72%)
2090 (-89%)
Obs. basin runoff
Transit time
A=248km²
G=0.07%
Lat=67°
LULE
Glacier runoff
1990
2020 (-17%)
2050 (-64%)
2090 (-91%)
Obs. basin runoff
Transit time
A=247km²
G=0.98%
Lat=66°
RAPEL
Glacier runoff
1990
2020 (-20%)
2050 (-52%)
2090 (-77%)
Obs. basin runoff
A=238km²
G=1.5%
Lat=-34°
SANTA
Glacier runoff
1990
2020 (-22%)
2050 (-62%)
2090 (-77%)
Obs. basin runoff
A=198km²
G=1.7%
Lat=-8°
Normalized runoff (-)
Jan. Mar. May Jul. Sep. Nov.
Jul. Sep. Nov. Jan. Mar. May



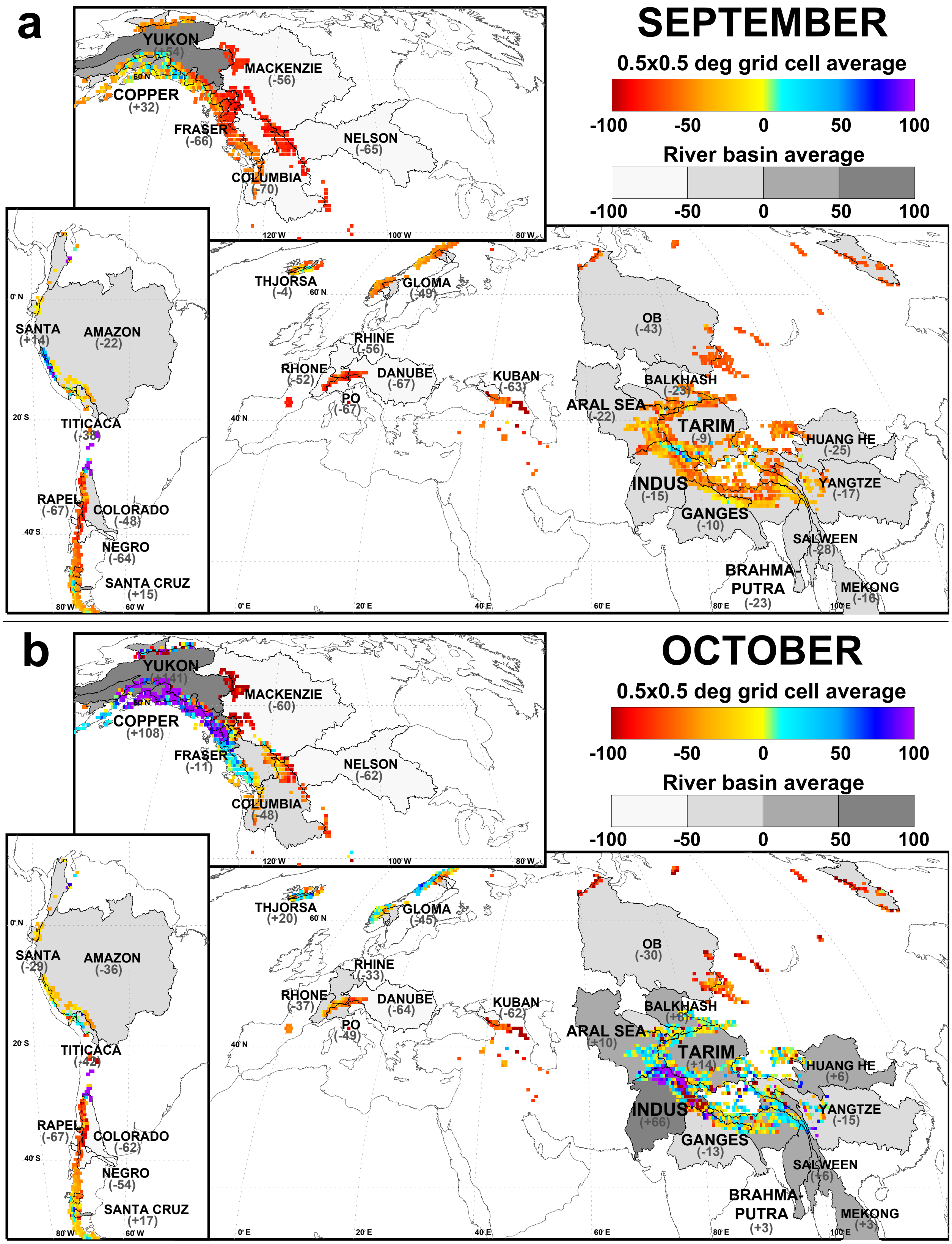
SKAGIT
Glacier runoff
1990
2020 (-26%)
2050 (-70%)
2090 (-88%)
Obs. basin runoff
Transit time
A=159km²
G=2.0%
Lat=48°
KUBAN
Glacier runoff
1990
2020 (-31%)
2050 (-69%)
2090 (-86%)
Obs. basin runoff
Transit time
A=146km²
G=0.25%
Lat=44°
TITICACA
Glacier runoff
1990
2020 (-38%)
2050 (-89%)
2090 (-98%)
Obs. basin runoff
Transit time
A=134km²
G=0.13%
Lat=-16°
NUSHAGAK
Glacier runoff
1990
2020 (-8%)
2050 (-49%)
2090 (-82%)
Obs. basin runoff
Transit time
A=86km²
G=0.29%
Lat=60°
BIOBIO
Glacier runoff
1990
2020 (-32%)
2050 (-72%)
2090 (-88%)
Obs. basin runoff
A=76km²
G=0.32%
Lat=-37°
IRRAWADDY
Glacier runoff
1990
2020 (-17%)
2050 (-58%)
2090 (-76%)
Obs. basin runoff
Transit time
A=71km²
G=0.02%
Lat=23°
NEGRO
Glacier runoff
1990
2020 (-32%)
2050 (-61%)
2090 (-75%)
Obs. basin runoff
A=64km²
G=0.05%
Lat=-39°
MAJES
Glacier runoff
1990
2020 (-15%)
2050 (-48%)
2090 (-79%)
Obs. basin runoff
Transit time
A=57km²
G=0.31%
Lat=-15°
CLUTHA
Glacier runoff
1990
2020 (-1%)
2050 (-38%)
2090 (-72%)
Obs. basin runoff
Transit time
A=46km²
G=0.27%
Lat=-45°
DAULE/VINCES
Glacier runoff
1990
2020 (-40%)
2050 (-60%)
2090 (-71%)
Obs. basin runoff
Transit time
A=40km²
G=0.10%
Lat=-1°
KALIXAELVEN
Glacier runoff
1990
2020 (-23%)
2050 (-75%)
2090 (-95%)
Obs. basin runoff
Transit time
A=37km²
G=0.22%
Lat=67°
MAGDALENA
Glacier runoff
1990
2020 (-42%)
2050 (-78%)
2090 (-94%)
Obs. basin runoff
Transit time
A=33km²
G=0.01%
Lat=6°
DRAMSELV
Glacier runoff
1990
2020 (-25%)
2050 (-72%)
2090 (-93%)
Obs. basin runoff
Transit time
A=32km²
G=0.19%
Lat=60°
COLVILLE
Glacier runoff
1990
2020 (-7%)
2050 (-48%)
2090 (-85%)
Obs. basin runoff
Transit time
A=31km²
G=0.06%
Lat=68°
Normalized runoff (-)
0 1 2 3 4 5 6
Jan. Mar. May Jul. Sep. Nov.
Jul. Sep. Nov. Jan. Mar. May



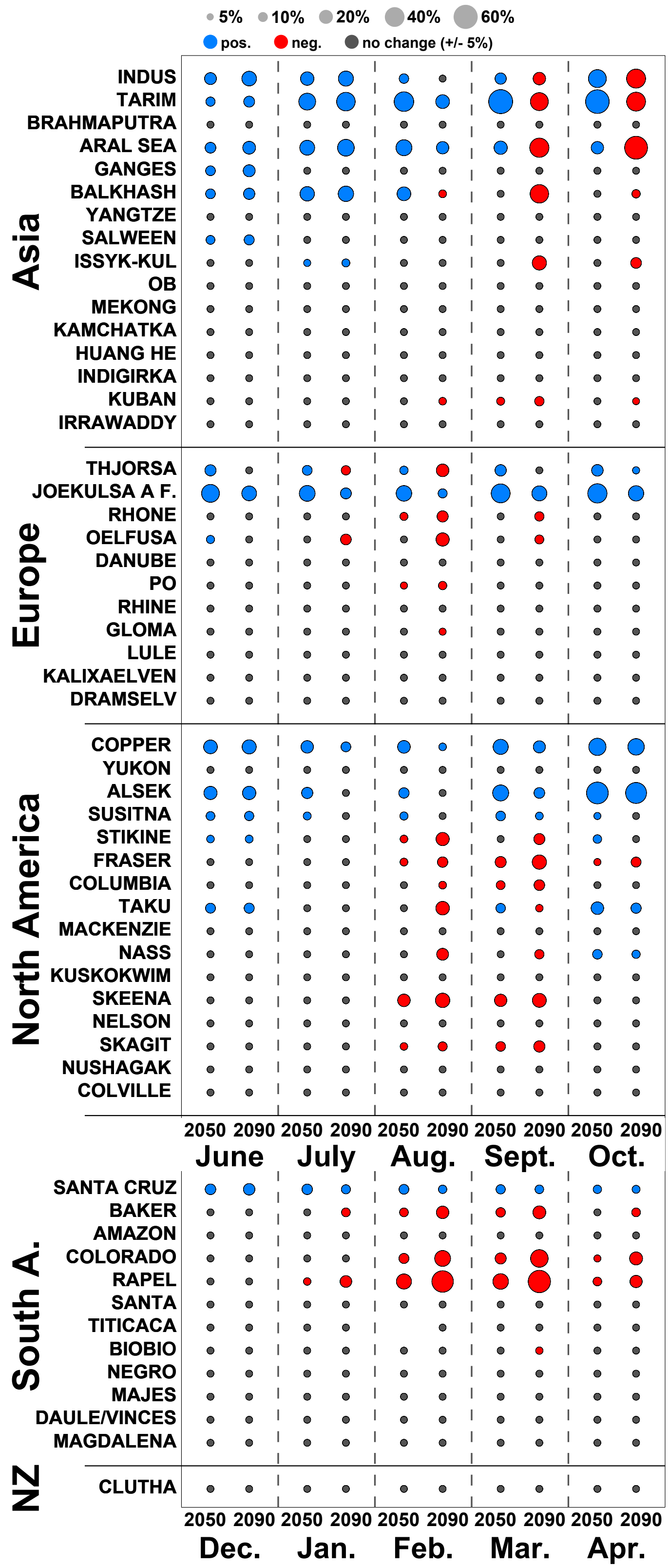
Supplementary Figure 4. Dependence of future changes in glacier runoff of all 56 investigated basins with glacier area loss over the period 2000 to 2090. Changes are computed from 20-year averages centered around these years. **a**, Change in the timing when the modelled seasonal maximum glacier runoff occurs in a year, Δt, versus glacier area loss. Negative values of Δt indicate that the runoff maximum occurs earlier in the season. To achieve finer than monthly resolution, Δt was computed from the shift of the center of gravity of the three months with the highest runoff volumes. The grouping of the basins into two distinct clusters separated by about 20 days results from the monthly model resolution. **b**, Change in summer glacier runoff versus glacier area loss over the same 90-year period. The runoff change is computed from the runoff volume of each year's two consecutive months with maximum runoff. Results refer to multi-GCM means and RCP4.5. Circle area scales linearly with the basin's glacier area, and colours indicate basin location. With decreasing glacier area, the seasonal discharge maximum occurs earlier in the year (0.4 days per percent glacier area loss), and summer runoff decreases (0.8% per percent glacier area loss). Note that for glacier area changes of less than about –40%, higher summer runoff is projected. r^2 is the coefficient of determination. The correlations are statistically significant at the $p < 0.01$ level according to the F-test.



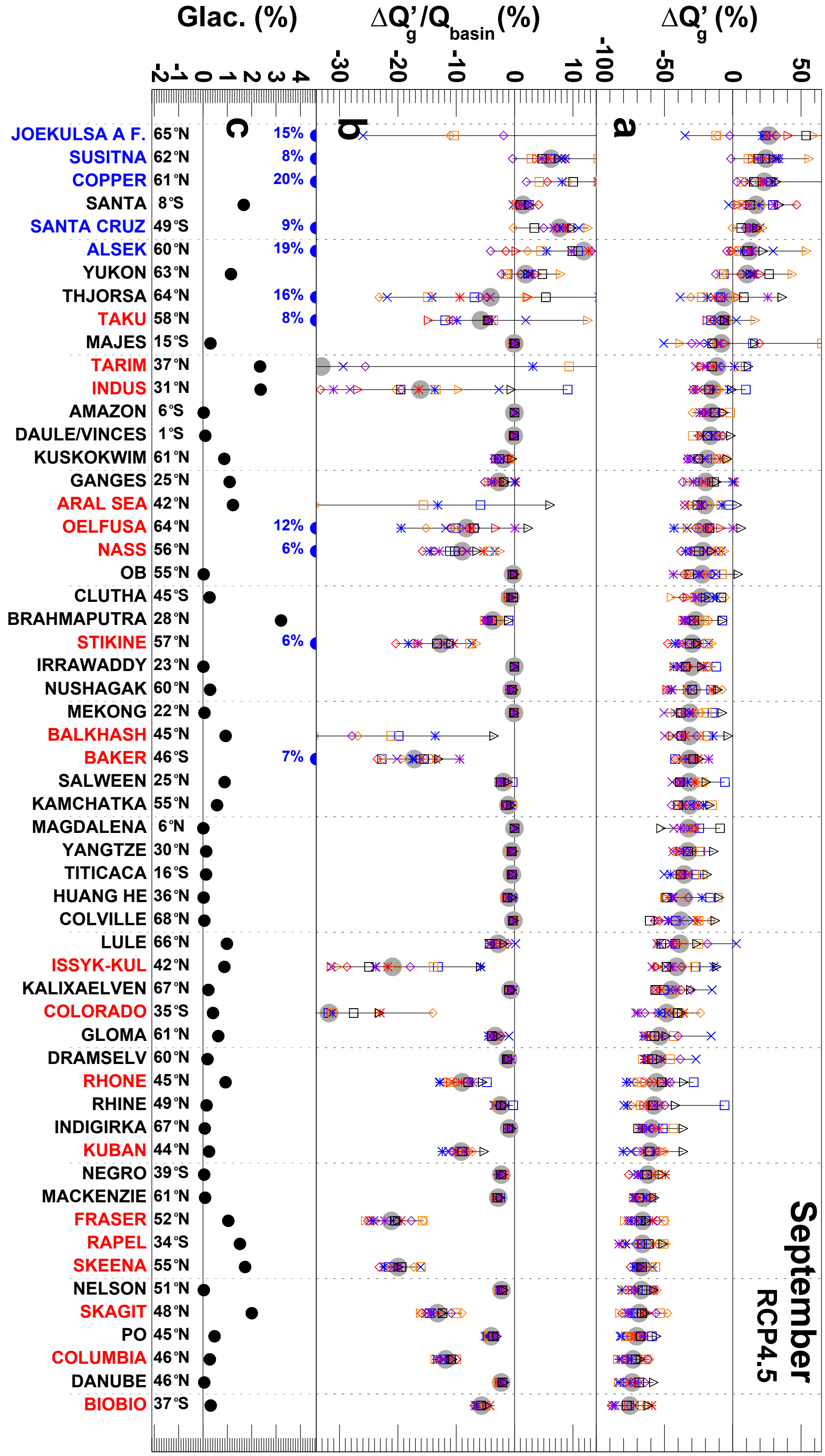
Supplementary Figure 5. Glacier runoff changes in (a) July and (b) August between 2000 and 2090. (January/February for southern hemisphere) Changes are computed from 20-year averages centered around these years and based on the glacier runoff volume from all glaciers for (i) each glacierized 0.5×0.5° grid cell (colour scale, including cells outside the investigated basins), and (ii) each investigated river basin (grey-scale). Glacier runoff is defined as runoff from the initially glacierized area. Results refer to multi-GCM means and RCP4.5.



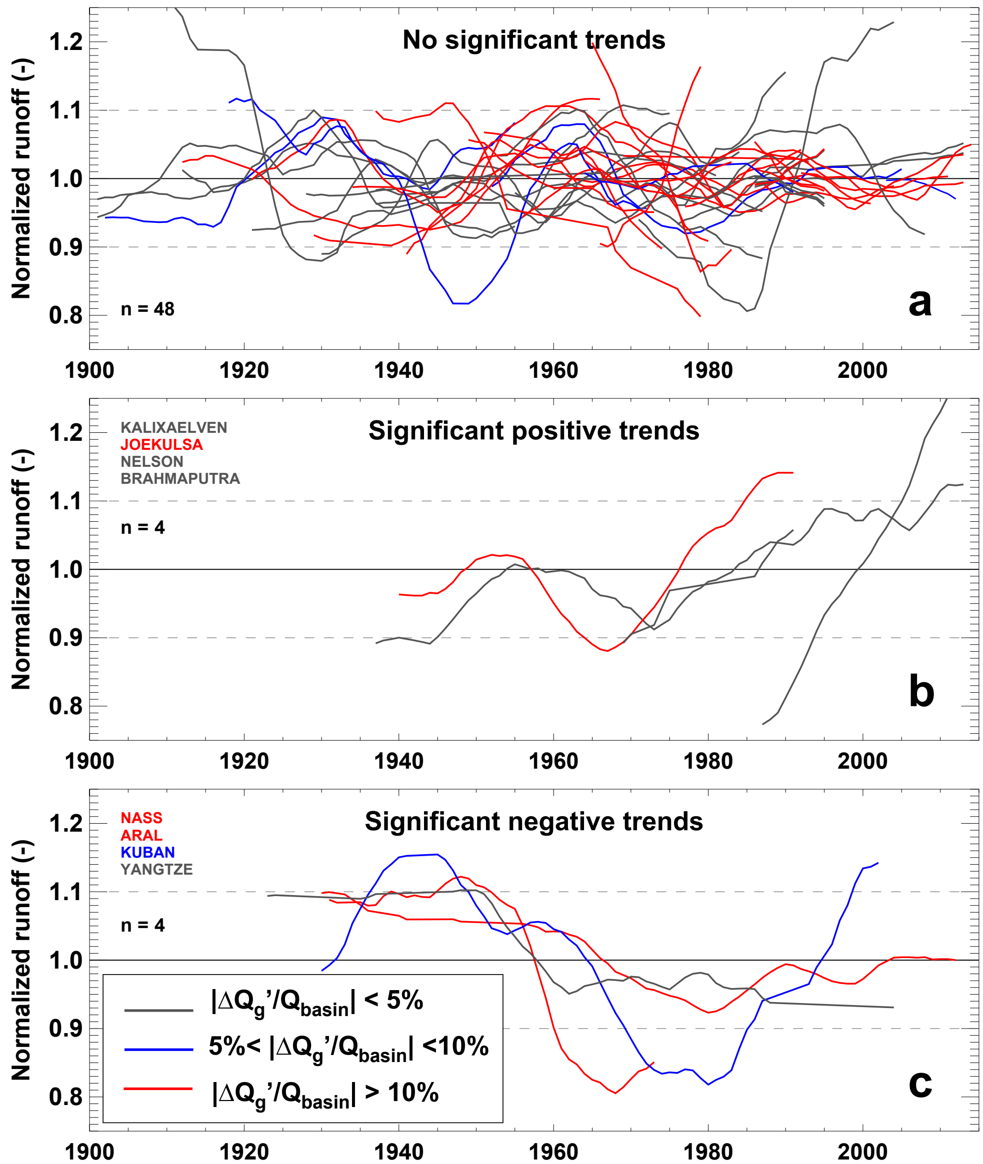
Supplementary Figure 6. Glacier runoff changes in (a) September and (b) October between 2000 and 2090 (March/April for southern hemisphere). Changes are computed from 20-year averages centered around these years and based on the glacier runoff volume from all glaciers for (i) each glacierized 0.5×0.5° grid cell (colour scale, including cells outside the investigated basins), and (ii) each investigated river basin (grey-scale). Glacier runoff is defined as runoff from the initially glacierized area. Results refer to multi-GCM means and RCP4.5.



Supplementary Figure 7. Projected glacier runoff changes relative to basin runoff, $\Delta Q'_{\mathrm{g}}/Q_{\mathrm{basin}}$. Monthly glacier runoff changes, $\Delta Q'_{\mathrm{g}}$, refer to the periods 2000 to 2050, and 2000 to 2090, and are computed from 20-year averages centered around these years. Glacier runoff is defined as runoff from the initially glacierized area and is shifted to account for water transit times to the drainage basin's mouth (see Methods). $\Delta Q'_{\mathrm{g}}/Q_{\mathrm{basin}}$ is evaluated for the months June to October (December to April for southern hemisphere). The area of the dots scales linearly with the absolute values of $\Delta Q'_{\mathrm{g}}/Q_{\mathrm{basin}}$ using the same scale as in Figure 3 of the main text. Results refer to multi-GCM means and RCP4.5. Basins are listed for each continent in the order of decreasing glacier area.



Supplementary Figure 8. Overview of results for all 56 investigated basins for September (March in the southern hemisphere). Results are based on projected glacier runoff changes over the period between 1990-2010 and 2080-2100. Individual GCMs (for RCP4.5) are indicated with symbols and the multi-GCM mean with a grey dot. **a**, Glacier runoff change $\Delta Q'_g$ (shifted with water transit time), **b**, glacier runoff change relative to mean basin runoff, $\Delta Q'_g/Q_{basin}$, and **c**, basin glacierization. Blue dots indicate values beyond the plotted range. Catchments are ordered according to $\Delta Q'_g$. Blue basin names indicate cases where glacier runoff is projected to increase by >5% of basin runoff ($\Delta Q'_g/Q_{basin}$ >0.05), while names in red mark basins where $\Delta Q'_g/Q_{basin} < -0.05$.



Supplementary Figure 9. Time series of annual runoff observations for all 56 investigated river basins[5,6]. 11-year running means normalized to their period means are plotted for all basins that show, **a**, no temporal trend, **b**, a significant positive, and **c**, a significant negative trend. Trends were calculated using the Mann-Kendall test and significance was evaluated at the $p < 0.05$ level. Colours refer to three ranges of $|\Delta Q'_g / Q_{basin}|$ distinguishing basins with negligible, moderate and large fractions of glacier runoff changes relative to total basin runoff. 92% of the basins with $|\Delta Q'_g / Q_{basin}| > 10\%$ show no significant trend in annual runoff. The smoothed runoff series rarely exceed $\pm 10\%$ of their period average (dashed lines). River basin names are listed for **b** and **c**.

3 SUPPLEMENTARY TABLES

Supplementary Table 1. **Characteristics of all 56 investigated glacierized macroscale drainage basins**. We analyze all basins >5,000 km^2 with >30 km^2 of ice and >0.01% ice cover based on GRDC[7]. Ice-covered area ($A_{glacier}$) according to the Randolph Glacier Inventory version 4.0[8], total basin area (A_{basin}), glacierization (Glac.), basin center-point latitude (lat.) and longitude (lon.) and population density (ρ_{pop}) in 2000[9] are given. Transit times (t_w) of the glacier runoff from the initially glacierized area through the basin were estimated using the empirical approximation by Nieuwenhuyse[10]. Basins are ordered according to decreasing glacier area.

Basin	$A_{glacier}$ (km^2)	A_{basin} (km^2)	Glac. (%)	lat. (deg)	lon. (deg)	ρ_{pop} (p. km^{-2})	t_w (d)	Continent
INDUS	26,983.8	1,139,075	2.37	31	74	186.5	39	Asia
TARIM	24,645.4	1,051,731	2.34	37	81	9.0	41	Asia
BRAHMAPUTRA	16,606.7	518,011	3.21	28	90	128.2	30	Asia
ARAL SEA	15,176.7	1,233,148	1.23	42	67	33.5	45	Asia
COPPER	12,996.0	64,959	20.01	61	–143	0.1	7	North America
GANGES	11,216.0	1,024,462	1.09	25	82	434.6	33	Asia
YUKON	9,535.4	829,632	1.15	63	–144	0.1	35	North America
ALSEK	5,614.8	28,422	19.76	60	–137	0.0	4	North America
SUSITNA	4,304.0	49,470	8.70	62	-149	0.1	6	North America
BALKHASH	3,945.4	423,657	0.93	45	78	11.9	34	Asia
STIKINE	3,467.6	51,147	6.78	57	–129	0.0	6	North America
SANTA CRUZ	3,027.8	30,599	9.89	–49	–71	0.3	8	South America
FRASER	2,495.1	239,678	1.04	52	–122	3.0	15	North America
BAKER	2,372.3	30,760	7.71	–46	–72	0.4	7	South America
YANGTZE	2,317.4	1,745,094	0.13	30	106	217.4	33	Asia
SALWEEN	2,295.9	258,475	0.89	25	96	24.7	11	Asia
COLUMBIA	1,878.4	668,561	0.28	46	–116	9.9	21	North America
ISSYK-KUL	1,677.3	191,032	0.88	42	73	16.9	36	Asia
AMAZON	1,634.1	5,880,854	0.03	–6	–64	4.3	63	South America
COLORADO	1,601.2	390,631	0.41	–35	–67	6.9	24	South America
TAKU	1,583.6	17,967	8.81	58	–132	0.0	7	North America
MACKENZIE	1,519.2	1,752,001	0.09	61	–120	0.2	48	North America
NASS	1,337.3	21,211	6.30	56	–129	0.1	4	North America
THJORSA	1,251.8	7,527	16.63	64	–19	0.3	2	Europe
JOEKULSA A F.	1,098.6	7,311	15.03	65	–16	0.1	2	Europe
KUSKOKWIM	1,032.8	118,114	0.87	61	–156	0.1	14	North America
RHONE	904.2	97,485	0.93	45	5	101.6	8	Europe
SKEENA	742.3	42,944	1.73	55	–127	1.0	5	North America
OB	739.5	2,701,040	0.03	55	75	10.3	71	Asia
OELFUSA	683.4	5,678	12.04	64	–20	2.4	3	Europe
MEKONG	485.7	787,256	0.06	22	101	72.4	25	Asia
DANUBE	408.4	793,704	0.05	46	18	102.4	30	Europe
NELSON	374.7	1,099,380	0.03	51	–101	5.1	40	North America
PO	347.3	73,066	0.48	45	9	231.6	10	Europe
KAMCHATKA	312.7	54,103	0.58	55	159	0.5	8	Asia
RHINE	285.0	190,522	0.15	49	7	317.5	13	Europe
GLOMA	269.4	42,862	0.63	61	10	13.6	6	Europe
HUANG HE	267.9	988,062	0.03	36	107	163.6	32	Asia
INDIGIRKA	248.4	341,227	0.07	67	144	0.1	22	Asia
LULE	247.2	25,127	0.98	66	18	1.0	6	Europe
RAPEL	238.1	15,689	1.52	–34	–70	49.7	6	South America
SANTA	198.9	11,882	1.67	–8	–77	45.8	5	South America
SKAGIT	159.5	7,961	2.00	48	–121	3.1	4	North America
KUBAN	146.0	58,935	0.25	44	40	57.4	10	Asia
TITICACA	134.5	107,215	0.13	–16	–68	24.5	14	South America
NUSHAGAK	86.4	29,513	0.29	60	–156	0.1	6	North America
BIOBIO	76.2	24,108	0.32	–37	–71	20.9	5	South America
IRRAWADDY	71.2	411,516	0.02	23	96	86.2	24	Asia
NEGRO	64.1	130,062	0.05	–39	–68	5.6	16	South America
MAJES	57.3	18,612	0.31	–15	–72	5.4	5	South America
CLUTHA	46.5	17,118	0.27	–45	169	1.8	3	New Zealand
DAULE/VINCES	40.6	41,993	0.10	–1	–79	93.1	6	South America
KALIXAELVEN	37.9	17,157	0.22	67	20	1.5	4	Europe
MAGDALENA	33.3	261,204	0.01	6	–74	104.7	14	South America
DRAMSELV	32.1	17,364	0.19	60	9	8.8	4	Europe
COLVILLE	31.9	57,544	0.06	68	–154	0.0	9	North America

Supplementary Table 2. Global Circulation Models from the CMIP5 project[11] used in this study. Grid cell resolution and the responsible institutions and countries are listed.

GCM	resolution	Institution	Country
BCC-CSM1-1	2.81°×2.81°	Beijing Climate Center China Meteorological Administration	China
CanESM2	2.81°×2.81°	Canadian Centre for Climate Modeling and Analysis	Canada
CCSM4	0.90°×1.25°	National Center for Atmospheric Research	United States
CNRM-CM5	1.41°×1.41°	Centre National de Recherches Meteorologiques/Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique	France
CSIRO-Mk3-6-0	1.88°×1.88°	Commonwealth Scientific and Industrial Research Organization in collaboration with Queensland Climate Change Centre of Excellence	Australia
GFDL-CM3	2.00°×2.50°	NASA Geophysical Fluid Dynamics Laboratory	Unites States
GISS-E2-R	2.00°×2.50°	NASA Goddard Institute for Space Studies	Unites States
HadGEM2-ES	1.24°×1.88°	Met Office Hadley Centre	United Kingdom
INMCM4	1.50°×2.00°	Met Office Hadley Centre	Russia
IPSL-CM5A-LR	1.90°×3.75°	Institut Pierre-Simon Laplace	France
MIROC-ESM	2.81°×2.81°	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (University of Tokyo) and National Institute for Environmental Studies	Japan
MPI-ESM-LR	1.88°×1.88°	Max Planck Institute for Meteorology	Germany
MRI-CGCM3	1.13°×1.13°	Meteorological Research Institute	Japan
NorESM1-M	1.88°×1.88°	Norwegian Climate Centre	Norway

Supplementary Table 3. **Modelled timing of peak water and corresponding uncertainties for all 56 investigated macroscale drainage basins.** Peak water, P_W, refers to the year when modelled annual glacier runoff has reached a maximum as determined from an 11-year moving average. Results refer to multi-GCM means derived from three emission scenarios (RCP2.6, RCP4.5, RCP8.5). The total uncertainty, σ_{tot}, is obtained by combing individual error components based on error propagation assuming the terms to be independent of each other. σ_1 refers to the standard deviation of the results from 14 GCMs. σ_2 refers to the uncertainty in peak water due to errors in initial ice volume, while σ_3 is uncertainty resulting from two sets of experiments varying parameterizations in the model (energy-balance instead of degree-day model; volume-area scaling instead of retreat parameterization, see Methods). Values are given in the unit year. ΔQ_{ann} is the change in annual glacier runoff (in %) between the period 1980-2000 and the year of peak water.

Basin	**RCP2.6**					**RCP4.5**					**RCP8.5**				
	$P_W \pm \sigma_{tot}$	σ_1	σ_2	σ_3	ΔQ_{ann}	$P_W \pm \sigma_{tot}$	σ_1	σ_2	σ_3	ΔQ_{ann}	$P_W \pm \sigma_{tot}$	σ_1	σ_2	σ_3	ΔQ_{ann}
		(years)			(%)		(years)			(%)		(years)			(%)
INDUS	2029±10	10	1	1	+26	2045±17	17	1	4	+32	2064±19	18	6	1	+48
TARIM	2030±8	6	2	5	+43	2051±13	11	6	5	+53	2058±15	14	4	5	+67
BRAHMAPUTRA	2030±18	7	14	9	+15	2049±18	16	9	2	+16	2049±30	19	17	16	+22
ARAL SEA	2030±5	5	2	1	+37	2051±14	14	3	0	+42	2044±15	15	5	0	+53
COPPER	2033±28	24	0	15	+40	2055±19	19	0	0	+51	2087±7	7	0	0	+88
GANGES	2028±19	19	0	5	+15	2044±21	21	3	0	+19	2053±32	28	12	10	+25
YUKON	2033±25	25	0	0	+47	2054±19	19	0	0	+56	2094±11	11	0	0	+112
ALSEK	2033±21	21	0	0	+36	2055±22	22	0	0	+44	2087±10	10	0	0	+71
SUSITNA	2033±19	19	6	0	+36	2079±18	18	0	0	+46	2094±9	9	0	2	+85
BALKHASH	2030±7	7	2	2	+37	2051±12	11	0	5	+42	2049±20	18	1	10	+53
STIKINE	2025±17	16	7	0	+20	2026±15	14	6	2	+18	2048±22	18	14	0	+21
SANTA CRUZ	2050±18	18	1	0	+14	2091±24	20	14	0	+21	2096±9	8	3	3	+48
FRASER	2017±3	3	0	0	+12	2016±14	11	10	0	+11	2010±13	11	7	5	+11
BAKER	2015±18	8	15	6	+5	2016±13	8	9	7	+5	2020±16	15	4	5	+5
YANGTZE	2028±15	6	8	12	+20	2028±13	12	1	5	+21	2044±19	19	2	2	+28
SALWEEN	2028±11	6	7	7	+20	2049±19	18	1	7	+20	2043±19	19	6	0	+26
COLUMBIA	2010±10	7	8	0	+7	2010±14	8	12	0	+6	2010±6	6	0	0	+7
ISSYK-KUL	2028±9	9	3	0	+35	2025±10	10	0	0	+35	2042±17	17	3	0	+44
AMAZON	2010±3	2	2	2	+34	2011±7	4	3	6	+35	2012±24	3	1	24	+35
COLORADO	2010±13	4	9	9	+17	2011±10	9	1	5	+17	2011±15	13	4	7	+17
TAKU	2027±5	4	3	0	+25	2055±12	12	0	0	+25	2077±13	13	3	0	+40
MACKENZIE	2011±18	7	9	15	+7	2013±10	8	6	0	+8	2011±8	8	1	0	+8
NASS	2025±19	19	0	0	+22	2055±16	16	1	0	+22	2069±13	10	8	4	+32
THJORSA	2046±21	20	9	0	+50	2042±20	20	0	0	+62	2071±21	18	6	11	+78
JOEKULSA A F.	2047±21	19	0	11	+64	2064±22	22	0	0	+79	2080±20	14	12	8	+124
KUSKOKWIM	2030±21	21	0	0	+37	2047±20	20	0	0	+39	2057±11	9	6	2	+48
RHONE	2006±14	9	11	0	+28	2006±7	7	2	0	+27	2006±24	18	16	0	+28
SKEENA	2009±6	6	0	0	+9	2010±7	7	0	0	+9	2010±6	6	1	0	+9
OB	2004±10	10	0	0	+14	2004±14	12	4	7	+12	2006±27	27	1	2	+16
OELFUSA	2045±23	18	12	8	+32	2042±20	20	6	2	+38	2048±25	19	11	12	+45
MEKONG	2029±17	6	13	10	+25	2049±20	20	0	0	+26	2043±23	23	6	0	+33
DANUBE	2006±7	4	6	0	+24	2006±4	4	1	0	+23	2006±2	1	2	1	+23
NELSON	2013±11	8	8	0	+7	2014±17	10	13	5	+6	2010±10	9	6	0	+7
PO	2006±7	5	6	0	+26	2006±3	3	0	0	+25	2006±6	2	6	0	+26
KAMCHATKA	2025±6	6	0	0	+26	2038±17	13	12	0	+24	2030±18	18	1	5	+32
RHINE	2006±18	17	7	3	+21	2006±15	15	2	2	+20	2005±21	17	13	0	+20
GLOMA	2010±9	5	8	0	+26	2026±16	10	10	9	+23	2016±18	17	6	0	+26
HUANG HE	2029±6	5	4	2	+36	2051±17	17	1	1	+40	2043±20	20	1	0	+48
INDIGIRKA	2004±8	8	1	0	+15	2004±12	11	6	3	+12	2006±15	15	1	1	+16
LULE	2022±22	22	4	0	+29	2027±12	11	5	4	+30	2029±26	25	10	0	+29
RAPEL	2010±13	4	6	11	+12	2011±11	10	4	4	+12	2010±16	10	9	9	+12
SANTA	2011±21	5	21	3	+50	2012±25	7	18	17	+53	2016±29	29	1	2	+53
SKAGIT	2008±6	6	2	0	+12	2008±13	12	5	0	+11	2007±7	7	0	0	+11
KUBAN	2002±7	7	0	0	+16	2003±6	4	4	4	+17	2013±8	8	2	0	+17
TITICACA	2011±5	4	2	3	+42	2012±9	4	1	8	+43	2012±7	4	0	6	+43
NUSHAGAK	2027±14	14	1	0	+34	2038±12	12	2	0	+31	2032±15	15	3	0	+34
BIOBIO	2002±3	3	2	1	+9	2002±4	3	3	1	+8	2003±6	3	5	2	+9
IRRAWADDY	2000±17	17	0	0	+7	2000±35	35	0	0	+8	2095±45	45	0	0	+10
NEGRO	2002±12	11	4	4	+5	2002±11	10	3	5	+4	2003±11	11	4	2	+5
MAJES	2026±7	4	3	6	+79	2038±5	4	1	3	+97	2046±21	21	3	4	+119
CLUTHA	2038±17	17	0	0	+22	2028±12	12	0	0	+21	2040±21	21	0	0	+26
DAULE/VINCES	1980±0	0	0	0	+14	1980±0	0	0	0	+15	1980±0	0	0	0	+15
KALIXAELVEN	2019±10	6	4	8	+25	2024±23	9	14	16	+23	2014±27	25	11	6	+26
MAGDALENA	1981±6	0	0	6	+22	1981±14	0	0	14	+22	1981±14	0	0	14	+22
DRAMSELV	2010±8	4	8	0	+20	2012±14	10	10	0	+17	2013±16	16	1	1	+19
COLVILLE	2026±13	13	0	0	+40	2026±20	18	10	0	+42	2040±27	16	21	8	+42

Supplementary Table 4. **Projected monthly glacier runoff changes (%), ΔQ_g, including uncertainties.** ΔQ_g refers to the change in monthly glacier runoff between the periods 1990-2010 and 2080-2100, and is listed for the months June to September (December to March for the southern hemisphere, marked with *). Results refer to multi-GCM means and are given for three emission scenarios (RCP2.6, RCP4.5 and RCP8.5). Numbers in bold indicate cases with $|\Delta Q_\mathrm{g}|$ exceeding the uncertainty indicating that the sign of modelled runoff change is robust. Basins are ordered according to decreasing glacier area.

Basin	**RCP2.6**				**RCP4.5**				**RCP8.5**			
	ΔQ_Jun	ΔQ_Jul (%)	ΔQ_Aug	ΔQ_Sep	ΔQ_Jun	ΔQ_Jul (%)	ΔQ_Aug	ΔQ_Sep	ΔQ_Jun	ΔQ_Jul (%)	ΔQ_Aug	ΔQ_Sep
INDUS	**+37±24**	–4±7	**–20±10**	**–21±15**	**+87±25**	–2±9	**–20±11**	–15±16	**+128±33**	–9±19	**–25±18**	+7±28
TARIM	**+35±15**	–1±5	**–21±11**	**–22±10**	**+79±13**	+1±10	**–18±13**	–9±13	**+95±26**	–13±17	**–24±17**	+19±29
BRAHMAPUTRA	+13±13	–4±4	**–21±10**	**–21±10**	**+23±9**	**–9±6**	**–27±9**	**–24±8**	+27±34	**–21±16**	**–35±13**	**–25±16**
ARAL SEA	**+35±14**	–4±4	**–28±11**	**–29±11**	**+74±13**	–7±9	**–33±12**	**–23±12**	**+82±23**	**–27±15**	**–42±13**	–10±20
COPPER	**+27±19**	+6±9	–1±8	+12±12	**+42±14**	**+13±10**	+7±14	**+33±24**	**+69±23**	**+27±13**	**+24±16**	**+71±26**
GANGES	+12±21	**–8±7**	**–19±12**	–17±18	**+35±16**	–4±10	**–21±9**	–11±11	**+52±36**	–8±25	–23±24	–3±20
YUKON	**+31±20**	+5±7	–4±10	**+19±14**	**+51±16**	**+16±7**	+10±12	**+55±25**	**+95±15**	**+42±8**	**+43±12**	**+161±16**
ALSEK	+19±25	–0±11	**–11±8**	+6±13	**+28±20**	+4±11	–7±9	+17±18	**+41±34**	+9±14	+0±18	**+35±27**
SUSITNA	**+27±12**	+2±5	–1±9	+11±11	**+42±10**	**+8±6**	+6±9	**+36±17**	**+69±12**	**+23±10**	**+25±13**	**+92±16**
BALKHASH	**+31±13**	–4±4	**–29±11**	**–29±12**	**+65±13**	–9±10	**–34±12**	**–23±14**	**+66±23**	**–30±17**	**–43±11**	–10±21
STIKINE	**+15±13**	**–13±8**	**–38±14**	**–23±13**	**+23±6**	**–19±8**	**–44±10**	**–24±13**	+9±21	**–39±18**	**–52±12**	**–26±14**
SANTA CRUZ*	+0±6	+0±6	+3±4	+3±5	**+10±6**	**+8±5**	**+10±7**	**+16±8**	**+26±7**	**+19±7**	**+18±10**	**+31±11**
FRASER	**+14±10**	**–15±6**	**–55±15**	**–59±16**	**+30±9**	**–22±11**	**–66±9**	**–66±7**	**+24±12**	**–48±17**	**–80±7**	**–73±6**
BAKER*	+0±5	**–12±6**	**–24±8**	**–28±10**	+3±6	**–18±6**	**–32±7**	**–31±8**	**–14±11**	**–38±9**	**–47±8**	**–40±9**
YANGTZE	+14±19	**–11±10**	**–31±10**	**–24±10**	**+34±5**	**–16±6**	**–35±7**	**–17±9**	+32±52	**–31±11**	**–43±9**	–14±19
SALWEEN	**+19±12**	–3±4	**–27±10**	**–28±11**	**+41±8**	**–7±6**	**–34±9**	**–29±9**	**+37±27**	**–30±14**	**–46±10**	**–29±13**
COLUMBIA	**+17±10**	**–22±10**	**–64±19**	**–68±18**	**+33±14**	**–33±21**	**–74±9**	**–70±8**	**+26±12**	**–57±17**	**–83±6**	**–75±5**
ISSYK-KUL	**+38±15**	**–6±5**	**–38±14**	**–43±13**	**+76±16**	**–14±11**	**–47±14**	**–39±13**	**+68±27**	**–42±16**	**–59±12**	**–33±15**
AMAZON*	**–22±11**	**–19±12**	**–20±10**	**–25±10**	**–22±10**	**–16±14**	**–17±14**	**–23±15**	**–22±19**	–12±24	–12±28	**–21±19**
COLORADO*	**+14±10**	**–28±9**	**–36±17**	**–46±16**	**+26±13**	**–38±13**	**–48±15**	**–49±17**	+15±24	**–55±14**	**–58±14**	**–50±15**
TAKU	**+12±11**	–12±13	**–27±18**	–6±14	**+19±9**	–12±13	**–26±12**	+3±13	+18±25	–12±25	**–19±13**	**+21±12**
MACKENZIE	+4±8	**–49±14**	**–73±19**	**–63±18**	**+12±9**	**–58±10**	**–76±4**	**–56±8**	+0±18	**–67±6**	**–79±4**	**–43±12**
NASS	**+19±13**	**–8±5**	**–29±12**	**–16±14**	**+25±7**	**–15±6**	**–36±13**	**–19±18**	+10±9	**–33±14**	**–46±18**	**–23±22**
THJORSA	+9±16	**–18±13**	**–26±13**	–14±17	+10±19	**–14±14**	**–20±11**	–5±18	+14±19	–4±19	–10±19	+11±22
JOEKULSA A F.	+15±21	+3±12	–2±13	+11±21	**+33±30**	+15±21	+9±15	+29±32	**+56±41**	**+35±31**	+25±31	**+52±40**
KUSKOKWIM	**+28±17**	**–12±4**	**–28±10**	–11±12	**+43±10**	**–12±7**	**–30±11**	+13±19	**+55±12**	**–18±17**	**–31±19**	**+45±23**
RHONE	+9±15	**–18±12**	**–52±15**	**–47±16**	**+30±9**	**–22±11**	**–61±12**	**–52±14**	**+31±17**	**–56±19**	**–76±11**	**–62±15**
SKEENA	**+13±10**	**–20±11**	**–63±20**	**–61±17**	**+22±6**	**–34±12**	**–74±9**	**–65±5**	–3±32	**–63±23**	**–84±6**	**–67±3**
OB	**+24±8**	**–30±12**	**–55±17**	**–53±17**	**+41±9**	**–38±13**	**–59±10**	**–44±11**	**+36±19**	**–54±15**	**–65±10**	**–23±18**
OELFUSA	+13±15	**–20±12**	**–32±14**	**–21±16**	+9±12	**–27±13**	**–31±13**	**–19±13**	–9±22	**–30±16**	**–30±16**	–15±18
MEKONG	**+20±15**	**–5±5**	**–27±10**	**–20±18**	**+45±9**	**–10±8**	**–33±8**	**–16±9**	**+44±29**	**–29±18**	**–44±17**	–15±16
DANUBE	**+16±12**	**–23±14**	**–63±18**	**–63±18**	**+29±10**	**–38±7**	**–74±8**	**–67±7**	+10±27	**–67±13**	**–81±5**	**–70±9**
NELSON	**+15±10**	**–39±15**	**–67±19**	**–66±18**	**+27±24**	**–51±22**	**–73±7**	**–65±9**	+11±25	**–67±16**	**–80±8**	**–67±7**
PO	**+14±13**	**–20±12**	**–64±17**	**–61±18**	**+31±9**	**–33±10**	**–74±8**	**–67±9**	+18±21	**–67±14**	**–83±5**	**–72±9**
KAMCHATKA	**+53±20**	**–21±10**	**–42±16**	**–35±14**	**+92±26**	**–22±12**	**–41±14**	–18±18	**+118±32**	**–38±17**	**–45±18**	+29±48
RHINE	+10±15	–8±9	**–47±16**	**–49±16**	**+30±9**	**–13±7**	**–59±11**	**–56±12**	**+36±14**	**–51±20**	**–78±10**	**–70±13**
GLOMA	**+31±15**	**–15±10**	**–59±21**	**–57±18**	**+47±17**	**–23±14**	**–60±14**	**–50±12**	**+61±23**	**–39±26**	**–70±12**	**–45±11**
HUANG HE	**+36±14**	–4±5	**–34±13**	**–37±13**	**+73±13**	–8±12	**–37±14**	**–25±15**	**+75±24**	**–31±15**	**–46±9**	–8±14
INDIGIRKA	**+28±9**	**–31±13**	**–58±18**	**–56±18**	**+45±11**	**–37±13**	**–61±8**	**–45±13**	**+41±21**	**–56±13**	**–67±8**	**–23±21**
LULE	**+25±11**	–2±10	**–45±21**	**–34±16**	**+45±13**	–11±13	**–55±14**	**–31±20**	**+58±32**	**–35±21**	**–68±8**	**–31±19**
RAPEL*	+2±7	**–28±9**	**–47±16**	**–60±19**	+10±11	**–41±12**	**–62±14**	**–67±17**	–6±23	**–65±13**	**–78±10**	**–77±14**
SANTA*	+12±20	+12±15	+20±23	+6±13	+16±17	**+23±22**	**+38±34**	+14±15	+34±50	+39±75	+55±86	+28±44
SKAGIT	+8±9	–5±5	**–43±13**	**–61±18**	**+23±11**	–3±5	**–56±12**	**–71±8**	+13±13	**–39±26**	**–80±12**	**–83±5**
KUBAN	**+31±16**	–2±9	**–45±16**	**–55±20**	**+38±10**	–8±11	**–57±10**	**–64±7**	**+53±16**	**–44±12**	**–77±10**	**–73±12**
TITICACA*	**–34±14**	**–28±13**	**–32±13**	**–40±14**	**–38±9**	**–28±9**	**–33±9**	**–38±11**	**–43±11**	**–27±16**	**–30±13**	**–40±13**
NUSHAGAK	**+32±21**	–9±9	**–44±16**	**–28±14**	**+48±16**	–12±12	**–49±14**	–19±19	**+55±25**	**–34±24**	**–59±12**	**–13±12**
BIOBIO*	+8±12	**–12±9**	**–44±14**	**–61±18**	**+12±8**	**–33±13**	**–66±12**	**–78±10**	**–25±21**	**–75±11**	**–89±5**	**–89±4**
IRRAWADDY	+4±5	–2±5	**–22±7**	**–30±9**	**+14±7**	–5±5	**–29±9**	**–33±9**	+12±13	**–20±10**	**–39±10**	**–34±10**
NEGRO*	+2±9	**–22±9**	**–46±14**	**–56±16**	+4±9	**–38±11**	**–60±11**	**–65±10**	**–25±16**	**–69±13**	**–78±10**	**–75±11**
MAJES*	–8±15	–10±20	–12±17	**–15±14**	–6±22	+3±16	+1±11	–10±15	–8±41	+0±49	+0±50	–15±42
CLUTHA*	**+9±8**	+4±5	**–9±7**	**–15±7**	**+13±4**	+1±7	**–19±7**	**–24±8**	+6±16	–22±23	**–43±9**	**–45±8**
DAULE/VINCES*	**–33±11**	**–24±12**	**–18±9**	**–24±9**	**–32±7**	**–20±7**	**–12±8**	**–17±9**	**–23±10**	**–15±12**	–8±18	–15±14
KALIXAELVEN	**+25±11**	–7±12	**–56±21**	**–49±16**	**+48±18**	**–16±14**	**–62±11**	**–38±20**	**+64±38**	**–37±21**	**–70±8**	**–26±23**
MAGDALENA	**–18±13**	**–26±18**	**–31±14**	**–31±12**	–12±13	–18±22	**–30±10**	**–34±8**	–1±22	–16±17	**–30±12**	**–38±7**
DRAMSELV	**+24±11**	–10±13	**–56±20**	**–57±17**	**+37±15**	**–17±14**	**–59±14**	**–54±11**	**+47±23**	**–37±25**	**–70±12**	**–52±9**
COLVILLE	**+44±12**	**–36±4**	**–42±10**	**–36±12**	**+60±7**	**–41±9**	**–43±12**	–7±19	**+77±23**	**–49±19**	**–41±14**	**+82±16**

Supplementary Table 5. **Projected glacier runoff changes relative to basin runoff (%), $R = \Delta Q'_{\mathrm{g}}/Q_{\mathrm{basin}}$, including uncertainties.** Monthly glacier runoff changes, $\Delta Q'_{\mathrm{g}}$, refer to the periods 2000 to 2090, and are computed from 20-year averages centered around these years. Glacier runoff is defined as runoff from the initially glacierized area and has been shifted in time to account for water transit times to the drainage basin's mouth (see Methods). $Q'_{\mathrm{g}}/Q_{\mathrm{basin}}$ is shown for the months July to October (January to April for southern hemisphere, marked with *). Results refer to multi-GCM means and are given for three emission scenarios (RCP2.6, RCP4.5, RCP8.5). Uncertainties account for the combined effect of uncertainties in the (1) climate projections, (2) initial ice thickness data, (3) melt model parameterization, (4) estimated water transit time t_{w} to the basin's mouth, and (5) overall basin runoff (see Methods). Numbers in bold indicate cases with $|R|$ exceeding 5%. Basins are ordered according to decreasing glacier area. Note that for the Santa basin (inner tropics) values of R (–11 to –55%) are found between July and October.

Basin	**RCP2.6**				**RCP4.5**				**RCP8.5**			
	R_{Jul}	R_{Aug}	R_{Sep}	R_{Oct}	R_{Jul}	R_{Aug}	R_{Sep}	R_{Oct}	R_{Jul}	R_{Aug}	R_{Sep}	R_{Oct}
	(%)				(%)				(%)			
INDUS	**+10±6**	+0±4	**–17±10**	**–43±36**	**+23±10**	+4±6	**–16±11**	**–37±38**	**+38±13**	+3±10	**–23±20**	**–22±56**
TARIM	**+16±7**	**+7±9**	**–43±40**	**–54±45**	**+36±10**	**+20±17**	**–33±43**	**–37±40**	**+52±16**	**+10±31**	**–57±59**	**–22±60**
BRAHMAPUTRA	+1±0	–1±0	–3±2	–3±2	+2±0	–1±1	–4±1	–3±1	+2±1	–3±2	–5±3	–3±3
ARAL SEA	**+14±6**	**+7±8**	**–32±24**	**–52±34**	**+29±8**	**+16±15**	**–38±28**	**–54±36**	**+43±13**	**+5±26**	**–64±39**	**–60±46**
COPPER	**+5±7**	+0±7	+5±9	**+11±17**	**+10±9**	**+6±8**	**+15±14**	**+28±28**	**+19±15**	**+18±14**	**+35±20**	**+60±54**
GANGES	+2±1	–1±1	–3±2	–2±2	+4±2	–0±1	–3±1	–2±1	**+6±7**	–1±1	–3±3	–1±2
YUKON	+3±1	+1±1	–1±2	+1±2	+4±1	+3±2	+2±3	+3±3	**+8±2**	**+8±7**	**+8±9**	**+10±5**
ALSEK	+1±8	**–8±10**	+3±8	**+23±21**	+4±11	–5±13	**+12±11**	**+45±32**	**+8±22**	+1±30	**+27±23**	**+86±39**
SUSITNA	+1±4	–0±14	+2±15	+2±16	+4±5	+2±16	**+6±22**	+5±31	**+9±13**	**+9±27**	**+17±28**	**+12±44**
BALKHASH	**+12±5**	–3±7	**–30±13**	**–8±4**	**+25±6**	**–6±14**	**–35±15**	**–7±5**	**+27±10**	**–30±24**	**–46±14**	**–5±7**
STIKINE	–3±1	**–15±5**	**–11±5**	+0±2	–4±2	**–18±5**	**–13±4**	+3±3	**–10±5**	**–23±8**	**–14±6**	**+11±6**
SANTA CRUZ*	+0±5	+2±3	+2±2	–0±2	**+9±6**	**+7±4**	**+8±4**	**+7±3**	**+21±7**	**+15±7**	**+15±6**	**+15±5**
FRASER	–0±0	**–9±3**	**–18±5**	**–10±3**	–0±1	**–11±2**	**–21±3**	**–10±2**	–2±1	**–16±3**	**–25±3**	**–10±2**
BAKER*	**–5±2**	**–12±4**	**–15±5**	**–8±3**	**–8±3**	**–16±4**	**–17±4**	**–8±2**	**–19±5**	**–25±5**	**–23±5**	**–8±2**
YANGTZE	+0±0	–0±0	–1±0	–0±0	+0±0	–0±0	–1±0	–0±0	+0±0	–0±0	–1±0	–0±0
SALWEEN	+0±0	–2±0	–2±1	–1±0	+1±0	–2±0	–2±0	–1±0	–1±1	–3±1	–2±1	–0±0
COLUMBIA	+0±0	–5±1	**–11±3**	–5±1	+0±1	**–6±2**	**–12±1**	–5±1	–1±1	**–9±2**	**–13±1**	–5±1
ISSYK-KUL	+3±1	–1±1	**–17±8**	**–12±5**	**+7±1**	–2±3	**–21±9**	**–12±5**	**+7±2**	**–9±6**	**–29±9**	**–12±7**
AMAZON*	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0
COLORADO*	–0±2	**–19±8**	**–24±14**	**–16±7**	+1±4	**–26±10**	**–32±15**	**–17±10**	–3±6	**–36±12**	**–37±14**	**–18±9**
TAKU	–5±3	**–20±8**	**–10±5**	+2±7	–4±2	**–19±5**	**–6±12**	**+11±15**	–4±11	**–14±11**	+5±27	**+36±37**
MACKENZIE	+0±0	–1±0	–3±0	–3±1	+1±0	–1±0	–3±0	–3±1	+1±0	–1±0	–3±0	–3±1
NASS	–2±2	**–12±9**	**–8±10**	+4±8	–3±5	**–15±9**	**–9±13**	**+7±14**	**–8±10**	**–19±15**	**–11±22**	**+15±30**
THJORSA	**–11±9**	**–21±11**	**–10±10**	–2±6	**–9±9**	**–16±9**	–4±11	**+5±7**	–2±12	**–8±15**	**+6±14**	**+18±11**
JOEKULSA A F.	+3±10	–2±11	**+8±17**	**+8±17**	**+12±17**	**+9±13**	**+23±26**	**+24±25**	**+29±24**	**+23±27**	**+43±34**	**+50±37**
KUSKOKWIM	+0±2	–3±2	–3±3	–0±3	+1±2	–3±3	–2±4	+1±5	+1±4	–4±6	–1±6	+2±11
RHONE	–2±1	**–11±3**	**–8±2**	–2±1	–2±1	**–13±3**	**–9±2**	–2±0	**–6±2**	**–18±3**	**–11±2**	–2±0
SKEENA	–2±1	**–18±6**	**–18±5**	–4±1	–4±1	**–21±4**	**–20±2**	–2±2	**–8±3**	**–25±4**	**–21±2**	+1±2
OB	+0±0	+0±0	–0±0	–1±0	+0±0	+0±0	–0±0	–1±0	+0±0	+0±0	–0±0	–1±0
OELFUSA	**–9±5**	**–18±8**	**–9±5**	–1±2	**–12±6**	**–18±8**	**–8±5**	+2±2	**–14±8**	**–18±10**	**–7±7**	**+6±3**
MEKONG	+0±0	–0±0	–0±0	–0±0	+0±0	–0±0	–0±0	–0±0	+0±0	–0±0	–0±0	–0±0
DANUBE	+0±0	–1±0	–2±0	–1±0	+0±0	–1±0	–2±0	–1±0	+0±0	–2±0	–3±0	–1±0
NELSON	+0±0	–1±0	–2±0	–2±0	+1±0	–1±0	–2±0	–2±0	+1±0	–1±0	–3±0	–2±0
PO	–1±0	**–6±1**	–4±1	–1±0	–1±0	**–7±1**	–4±0	–1±0	–3±1	**–9±1**	–5±0	–1±0
KAMCHATKA	–0±0	–2±0	–1±0	–0±0	–0±0	–2±1	–1±0	–0±0	–1±0	–3±1	–1±1	+0±0
RHINE	–0±0	–2±0	–2±0	–1±0	–0±0	–2±0	–2±0	–1±0	–1±0	–3±0	–3±0	–1±0
GLOMA	–1±0	–5±1	–4±1	–1±0	–1±0	**–5±1**	–3±0	–1±0	–2±1	**–6±1**	–3±0	–0±0
HUANG HE	+1±0	–0±0	–1±0	–0±0	+1±0	–0±0	–1±0	–0±0	+1±0	–1±0	–1±0	–0±0
INDIGIRKA	–0±0	–1±0	–1±0	–1±0	+0±0	–1±0	–1±0	–1±0	–0±0	–1±0	–1±0	–0±0
LULE	+0±0	–4±1	–3±1	–1±0	–0±1	–5±1	–3±1	–0±0	–2±1	**–7±1**	–3±1	+1±1
RAPEL*	**–10±3**	**–35±13**	**–44±16**	**–14±6**	**–14±5**	**–48±14**	**–52±17**	**–16±6**	**–24±7**	**–62±13**	**–60±15**	**–17±6**
SANTA*	+1±2	+2±3	+1±1	–3±3	+2±4	+3±5	+1±2	–3±2	+4±12	+5±13	+3±7	–2±3
SKAGIT	–0±0	**–7±2**	**–11±3**	–3±1	–0±0	**–9±2**	**–13±1**	–3±0	–3±2	**–13±2**	**–16±2**	–2±0
KUBAN	+1±0	–4±2	**–8±3**	–5±1	+0±0	**–6±1**	**–9±1**	**–5±0**	–2±1	**–9±1**	**–11±2**	–5±1
TITICACA*	–0±0	–0±0	–1±0	–1±0	–0±0	–0±0	–1±0	–1±0	–1±0	–0±0	–1±0	–1±0
NUSHAGAK	–0±0	–1±0	–1±0	–0±0	–0±0	–1±0	–1±0	–0±0	–1±0	–2±1	–1±0	–0±0
BIOBIO*	–1±0	–3±1	–4±1	–1±0	–2±0	–5±1	**–6±0**	–2±0	–4±0	**–7±1**	**–7±0**	–2±0
IRRAWADDY	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0
NEGRO*	–1±0	–2±0	–2±0	–1±0	–1±0	–2±0	–2±0	–1±0	–3±0	–3±0	–3±0	–1±0
MAJES*	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0
CLUTHA*	+0±0	–0±0	–1±0	–0±0	+0±0	–1±0	–1±0	–0±0	–1±0	–1±0	–1±0	–0±0
DAULE/VINCES*	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0
KALIXAELVEN	–0±0	–1±0	–1±0	–0±0	–0±0	–2±0	–1±0	–0±0	–1±0	–2±0	–1±0	+0±0
MAGDALENA	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0	–0±0
DRAMSELV	–0±0	–2±0	–1±0	–0±0	–0±0	–2±0	–1±0	–0±0	–1±0	–2±0	–1±0	+0±0
COLVILLE	–0±1	–1±5	–0±7	–0±10	–0±1	–1±7	–0±10	–0±7	–0±6	–1±12	–0±13	+0±5

Supplementary Table 6. **Observed long-term average monthly runoff[5,6] for June to September for the 56 investigated basins.** For each basin the name of the gauging station, the country (two-letter code) and the time period for which data were available is listed. For basins lacking a station name, direct measurements were not available (13% of the basins), and we used the global-scale data set by Fekete et al.[5], which is based on grid-based macroscopic hydrological modelling. Note that for drainage basins in the Southern hemisphere (marked with *, 21% of the basins) runoff refers to the months December, January, February and March. Basins are ordered according to decreasing glacier area.

Basin	Station	Nat.	Period	Q_{June} ($m^3 s^{-1}$)	Q_{July} ($m^3 s^{-1}$)	Q_{Aug} ($m^3 s^{-1}$)	Q_{Sept} ($m^3 s^{-1}$)
INDUS	KOTRI	PK	1936-1979	3,623	6,552	10,724	6,073
TARIM			1986-1995	6,154	4,102	3,184	1,732
BRAHMAPUTRA	BAHADURABAD	BD	1969-1992	32,398	49,111	45,017	43,805
ARAL SEA	CHATLY	UZ	1936-1973	2,978	3,548	2,958	1,911
COPPER	CORDOVA	US	1988-2014	4,028	5,378	4,824	3,082
GANGES	FARAKKA	IN	1949-1973	4,314	20,793	43,030	36,899
YUKON	PILOT	US	1975-2014	16,161	12,609	11,133	10,146
ALSEK	YAKUTAT	US	1991-2012	1,995	2,528	2,241	1,357
SUSITNA	SUSITNA	US	1974-2014	3,378	3,653	3,164	2,170
BALKHASH	USH-TOBE	KZ	1965-1985	1,553	1,246	742	842
STIKINE	WRANGELL	US	1976-2014	3,875	3,766	3,000	2,327
SANTA CRUZ*	CHARLES FUHR	AR	1955-1994	599	839	1,099	1,291
FRASER	HOPE	CA	1912-2012	7,000	5,544	3,516	2,342
BAKER*	COLONIA	CL	1963-1984	1,029	1,181	1,184	1,077
YANGTZE	DATONG	CN	1922-1988	40,170	48,818	44,315	41,806
SALWEEN			1986-1995	1,706	5,355	8,252	7,645
COLUMBIA	QUINCY	US	1968-2014	9,521	6,371	4,566	3,573
ISSYK-KUL	UST.DJUMGOL	KG	1933-1980	2,677	2,180	1,246	767
AMAZON*	OBIDOS	BR	1928-1996	122,148	138,439	156,123	177,162
COLORADO*			1986-1995	1,589	778	518	367
TAKU	JUNEAU	US	1987-2014	999	909	735	546
MACKENZIE	RED RIVER	CA	1972-2013	20,774	17,245	13,772	11,558
NASS	SHUMAL CREEK	CA	1929-2012	2,079	1,665	1,175	887
THJORSA	THJORSARTUN	IS	1947-2014	498	444	442	353
JOEKULSA A F.	FERJUBAKKI	IS	1940-1991	230	323	352	238
KUSKOKWIM	CROOKED CREEK	US	1951-2014	2,253	1,896	2,096	1,907
RHONE	BEAUCAIRE	FR	1920-1999	1,818	1,384	1,097	1,155
SKEENA	USK	CA	1928-2011	2,841	1,734	951	767
OB	SALEKHARD	RU	1930-1994	32,994	29,759	21,964	13,753
OELFUSA	SELFOSS	IS	1950-2014	410	373	369	365
MEKONG	PHNOM PENH	KH	1960-1973	9,509	21,657	33,391	37,676
DANUBE	CEATAL IZMAIL	RO	1931-2010	8,158	6,897	5,399	4,679
NELSON	SPRUCE	CA	1987-2011	3,478	3,593	3,649	3,507
PO	PONTELAGOSCURO	IT	1918-1998	1,855	1,205	949	1,339
KAMCHATKA	SCHEKI	RU	1937-1987	1,804	2,139	1,265	938
RHINE	LOBITH	NL	1901-2013	2,240	2,114	1,841	1,689
GLOMA	LANGNES	NO	1988-2014	1,345	1,026	828	709
HUANG HE	SANMENXIA	CN	1953-1988	834	1,773	2,388	2,412
INDIGIRKA	VORONTSOVO	RU	1950-1996	5,705	5,356	4,235	2,604
LULE	BODENS	SE	1900-2012	828	891	759	597
RAPEL*	CORNECHE	CL	1966-1979	178	129	62	51
SANTA*			1986-1995	84	158	221	275
SKAGIT	MOUNT VERNON	US	1940-2014	694	574	330	265
KUBAN	TIKHOVSKY	RU	1936-2002	618	534	385	276
TITICACA*			1986-1995	1,220	1,706	1,734	1,579
NUSHAGAK	EKWOK	US	1977-1993	1,214	949	813	912
BIOBIO*	DESEMBOCADURA	CL	1963-1992	745	377	262	248
IRRAWADDY			1986-1995	17,302	34,147	34,324	29,044
NEGRO*	PALMAR	UY	1910-1979	466	312	380	416
MAJES*			1986-1995	228	371	470	370
CLUTHA*	BALCLUTHA	NZ	1954-2009	683	627	517	497
DAULE/VINCES*	LACAPILLA	EC	1970-2005	265	512	1,014	1,230
KALIXAELVEN	RAEKTFORS	SE	1937-2013	684	504	390	334
MAGDALENA	CALAMAR	CO	1971-1990	8,306	7,966	7,241	7,532
DRAMSELV	DOVIKFOSS	NO	1912-2005	579	381	324	304
COLVILLE	UMIAT	US	2002-2014	1,463	460	478	337

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