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Brief communication: Ad hoc estimation of glacier contributions to sea-level rise from the latest glaciological observations

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Table S1 Overview on regional data availability and complementary data series from neighbouring regions. The table shows the overall number of glaciers with glaciological (glac) and geodetic (geod) observations as available in the reference dataset by Zemp et al. (2019, based on the FoG database version 2018-11) as well as available updates of the glaciological sample (all) and corresponding WGMS *reference* glacier sub-samples (ref) for 2016/17 and 2017/18 (based on the FoG database version 2019-12). Complementary mass-balance series from neighbouring regions were used for regional mass-change estimations in *ad hoc* years without glaciological observations. For the present study, we excluded the glaciological data of Hamaguri Yuki, a perennial snow patch in Japan, region 10.

Region	Complementary mass-balance series	Zemp et al. (2019) glac / geod	2017 all glac	2017 ref glac	2018 all glac	2018 ref glac
01 Alaska	Place, Helm, Peyto, Columbia 2057, Rainbow, South Cascasde (all 02)	26 / 1,220	4	3	2	1
02 Western Canada & USA	Gulkana, Wolverine, Lemon Creek (all 01)	55 / 95	14	6	9	2
03 Arctic Canada North	Midtre Lovenbreen, Austre Broeggerbreen (all 07)	17 / 6	4	4	0	0
04 Arctic Canada South	White Glacier (03), Meighen Ice Cap (03), Devon Ice Cap NW (03), Melville South Ice Cap (03), Midtre Lovenbreen (07), Austre Broeggerbreen (07)	9 / 11	0	0	0	0
05 Greenland	Storglaciaeren (08), Storbreen (08), White (03)	13 / 1,206	3	0	1	0
06 Iceland	Storglaciaeren, Storbreen (08)	16 / 283	9	0	6	0
07 Svalbard & Jan Mayen	Storglaciaeren, Engabreen, Langfjordjoek. (all 08)	21 / 1,110	10	2	7	2
08 Scandinavia	none	57 / 1,047	18	8	11	8
09 Russian Arctic	Midtre Lovenbreen, Austre Broeggerbreen (all 07)	3 / 373	0	0	0	0
10 North Asia	Ts. Tuyuksu (13), Urumqi No. 1 (13)	19 / 11	0	0	0	0
11 Central Europe	none	77 / 1,451	51	11	36	9
12 Caucasus & Middle East	Argentiere, Saint Sorlin, Sarennes, Gries, Gietro, Allalin, Silvretta, Vernagt, Hintereis, Kesselwand, Careser (all 11)	12 / 362	2	1	2	1
13 Central Asia	Leviy Aktru (10), Maliy Aktru (10), Vodopadniy No. 125 (10), Chhota Shigri (14), Hamtah (14), Parlung No. 94 (15), Mera (15)	42 / 4,314	12	2	11	2
14 South Asia West	Ts. Tuyuksu, Urumqi No. 1 (all 13)	11 / 3,631	0	0	0	0
15 South Asia East	Ts. Tuyuksu, Urumqi No. 1 (all 13)	21 / 1,182	6	0	3	0
16 Low Latitudes	Echaurren Norte, Martial Este (all 17)	14 / 49	7	0	5	0
17 Southern Andes	Yanamarey, Artesonraju, Zongo, Charquini Sur, Antizana 15α, Conejeras (all 16)	14 / 2,331	9	1	7	0
18 New Zealand	Echaurren Norte, Martial Este (all 17)	5 / 439	2	0	2	0
19 Antarctic & Subantarctic	Echaurren Norte, Martial Este (all 17)	20 / 6	3	0	1	0
Global total		452 / 19,127	154	38	103	25

Table S2 *Ad hoc* estimates of regional mass changes for 2016/17 and 2017/18 according to different regression models. Specific mass changes (B_{adhoc}) are shown for *ad hoc* estimates (Eq. 4) with slope m equal to 1 (as used in Table 1) and with m as derived from linear regressions (as shown in Fig. S2), together with corresponding differences (ΔB) for both years. Large values for ΔB are found in regions with small slopes and low correlation coefficients (e.g. New Zealand).

Region	$m = 1$		m from regression		Δ	
	B_{adhoc} 2017 (m w.e.)	B_{adhoc} 2018 (m w.e.)	B_{adhoc} 2017 (m w.e.)	B_{adhoc} 2018 (m w.e.)	ΔB 2017 (m w.e.)	ΔB 2018 (m w.e.)
01 Alaska	–1.37	–2.29	–1.24	–1.92	–0.13	–0.37
02 Western Canada & USA	–0.68	–0.85	–0.78	–0.84	0.10	–0.01
03 Arctic Canada North	0.07	–0.90	–0.07	–0.82	0.14	–0.08
04 Arctic Canada South	–0.22	–0.90	–0.28	–0.84	0.06	–0.06
05 Greenland	–0.27	–0.44	–0.49	–0.55	0.22	0.11
06 Iceland	–0.11	0.14	–0.17	0.03	0.06	0.11
07 Svalbard & Jan Mayen	–0.57	–0.69	–0.58	–0.71	0.01	0.02
08 Scandinavia	–0.09	–1.48	–0.09	–1.46	0.00	–0.02
09 Russian Arctic	–0.69	–0.80	–0.65	–0.74	–0.04	–0.06
10 North Asia	–0.67	–0.17	–0.52	–0.30	–0.15	0.13
11 Central Europe	–1.60	–1.43	–1.59	–1.42	–0.01	–0.01
12 Caucasus & Middle East	–0.89	–0.28	–0.90	–0.45	0.01	0.17
13 Central Asia	–0.39	–0.11	–0.25	–0.13	–0.14	0.02
14 South Asia West	–0.34	0.17	–0.12	0.00	–0.22	0.17
15 South Asia East	–0.77	–1.10	–0.49	–0.59	–0.28	–0.51
16 Low Latitudes	–1.13	–0.29	–1.07	–0.71	–0.06	0.42
17 Southern Andes	–0.13	–1.11	–0.26	–1.11	0.13	0.00
18 New Zealand	0.13	–2.62	–0.59	–0.89	0.72	–1.73
19 Antarctic & Subantarctic	–0.52	–0.16	–0.20	–0.12	–0.32	–0.04

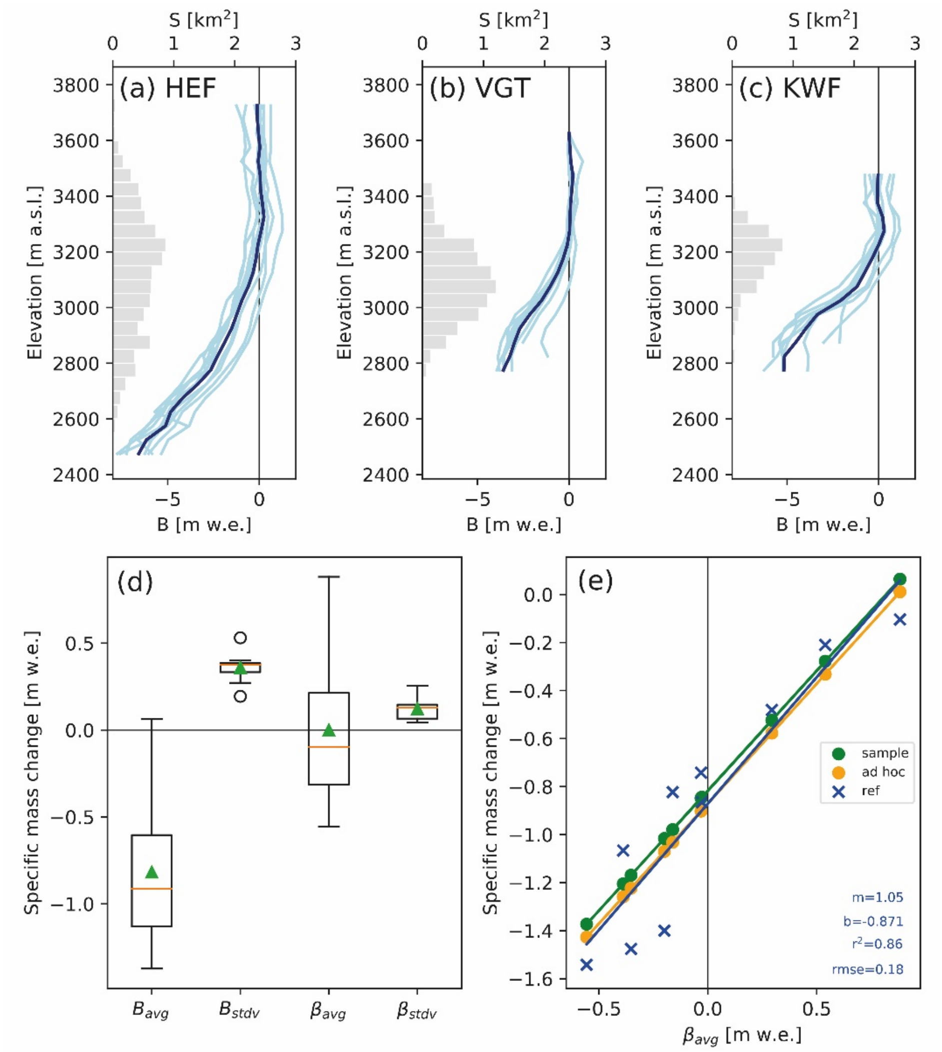

Figure S1 *Ad hoc* estimation of regional mass changes exemplified with glaciological data from Hintereisferner (HEF), Vernagtferner (VGT), and Kesselwandferner (KWF) located in the Ötztal, Austria. **(a–c)** Vertical mass-balance profiles (B, lower horizontal axis) for the reference period from 2006/07 to 2015/16 (light blue) are plotted together with the corresponding arithmetic average (dark blue) for the three glaciers. Glacier hypsometries are shown as horizontal grey bars (S, upper horizontal axis). **(d)** Boxplots showing mean (green triangle), median (orange line), and distribution of annual means (avg) and annual standard deviations (stdv) of both mass balance (B) and mass-balance anomaly (β, cf. Eq. 3) of the glaciological sample (i.e., HEF, VGT, KWF) over the observation period (i.e., from 2006/07 to 2015/16). On average, the annual mass balance of the three glaciers was –0.82 m w.e. and β – by definition – is zero over the reference period. Note that the mean annual standard deviation of the mass-balance anomalies (β_{stdv}) is typically smaller than the one of the mass balance (B_{stdv}; here by about three times). For this reason, we expect the anomaly approach to perform better than a simple bias correction. **(e)** Plots of glacier mass balance versus mass-balance anomaly (β_{avg}) for the glaciological sample (green circles), the reference data by Zemp et al. (2019, blue squares), and the *ad hoc* estimate (orange circles). The latter (orange, cf. Eq. 4) is basically obtained by vertically shifting the regression of the glaciological sample (green line with slope *m* = 1 and intercept b = –0.82 m w.e.) to fit the intercept (b = –0.87 m w.e.) of the reference data regression (blue line with statistics given at the bottom of plot).

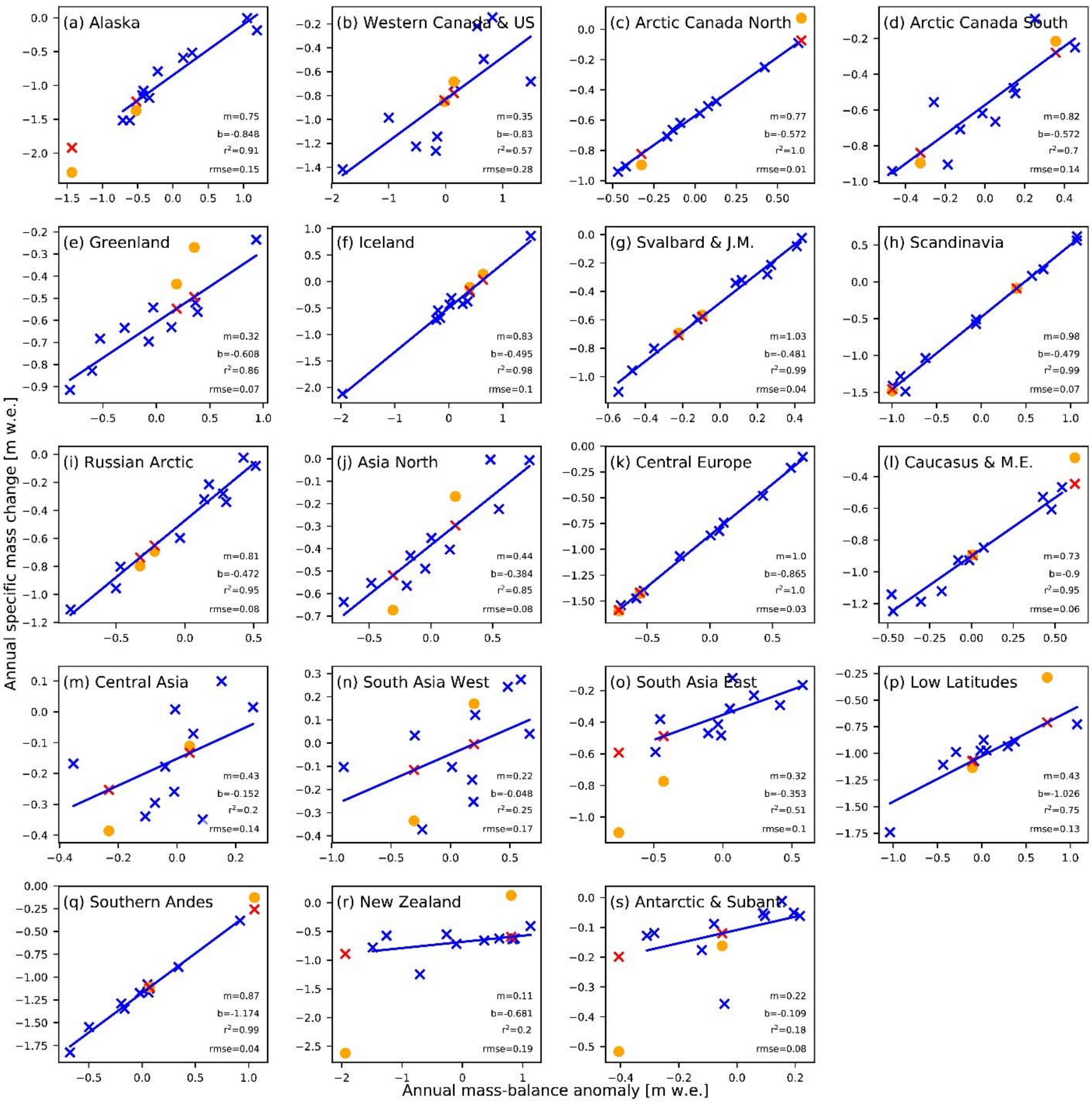

Figure S2 Relationship between annual specific mass changes of the reference data and glaciological mass-balance anomalies over the reference period from 2006/07 to 2015/16. For all regions **(a–s)**, linear regressions (blue line) are plotted with corresponding statistics (slope *m*, intercept *b*, coefficient of determination r^2, and root mean square error *rmse*) at the right bottom of the plots. *Ad hoc* estimates for 2016/17 and 2017/18 are shown for $m = 1$ (orange dots) – as used in Fig. 1 and Table 1 – and for *m* as derived from the regression (red crosses); corresponding values are compared in Table S2. Plots are ordered from top left to bottom right according to the region numbers in RGI 6.0 (see Table 1).

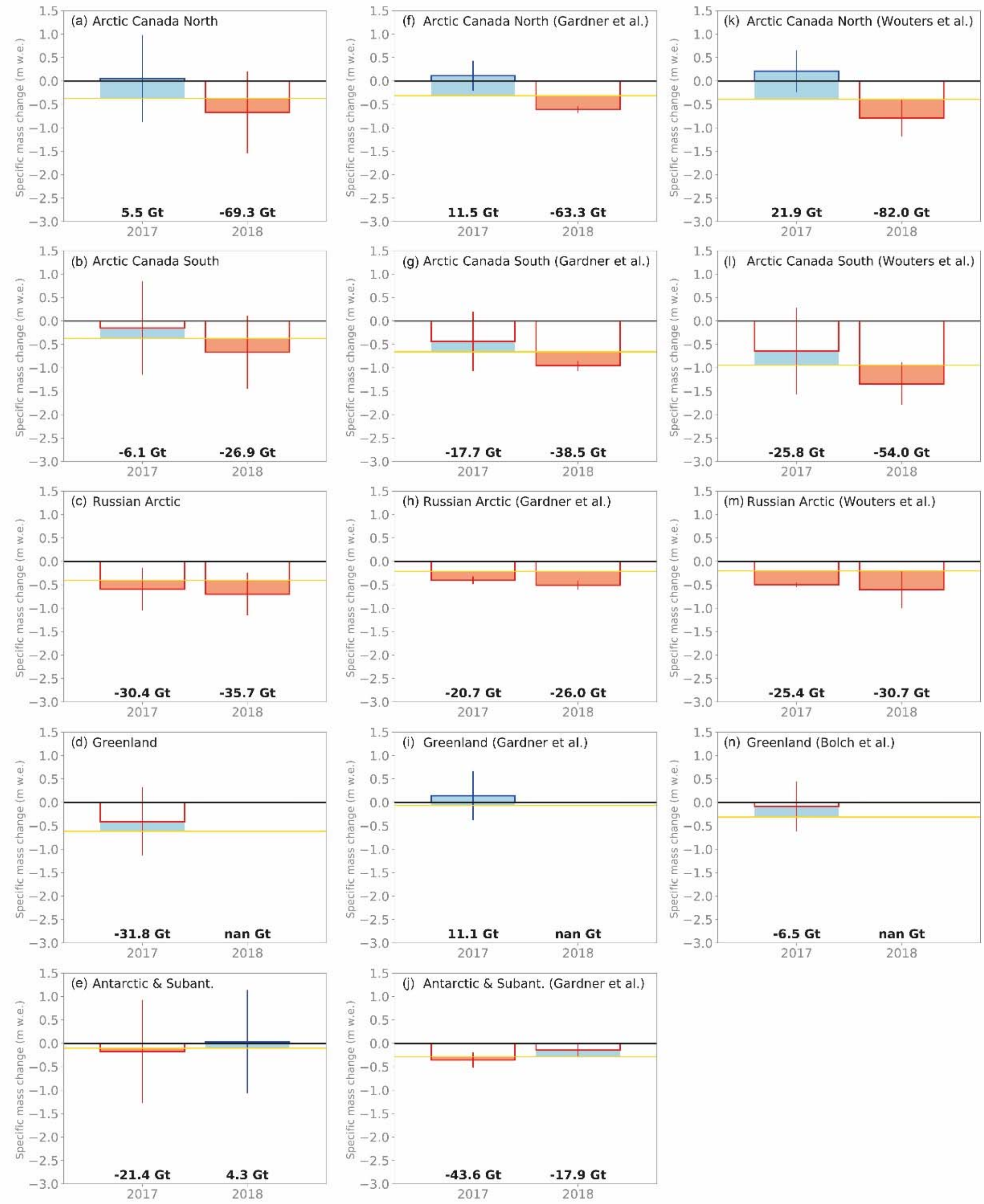

Figure S3 *Ad hoc* estimates of selected regional mass changes in 2016/17 and 2017/18 based on different reference datasets. The plots (**a–e**) in the left column correspond to plots in Fig. 1 using Zemp et al. (2019) as reference dataset but for the reference period 2003/04–2008/09. The plots in the middle column (**f–j**) use Gardner et al. (2013, 2003/04–2008/09) as reference dataset. The plots in the right column (**k–n**) are using Wouters et al. (2019, 2005/06–2014/15) or Bolch et al. (2013, 2003/04–2007/08) as reference dataset. Note that within a region, the annual anomalies (pale blue and pale red) are similar but absolute mass changes (in Gt) vary strongly in case of different mass-change rates in the reference datasets. For Greenland (**d, i, n**), no *ad hoc* estimate were calculated for 2017/18 because the glaciological observations are from a glacier without data in the reference periods.

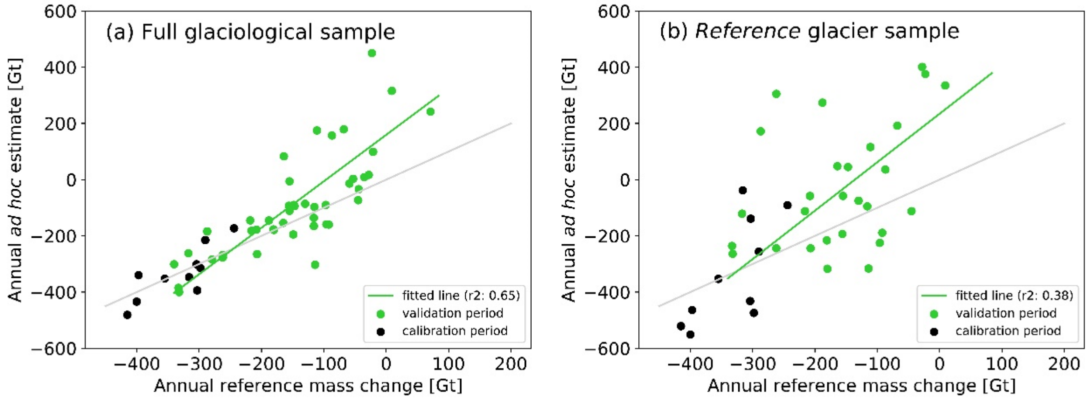

Figure S4 Annual global mass changes in comparison between the *ad hoc* estimates of this study and the reference dataset by Zemp et al. (2019). The comparison is shown for the *ad hoc* estimates as based on the full glaciological sample of corresponding years (**a**) and for the WGMS *reference* glaciers only (**b**). The linear regression refers to the fit between the values (green) over the validation period (2006/07−2015/16, cf. Fig. 2).