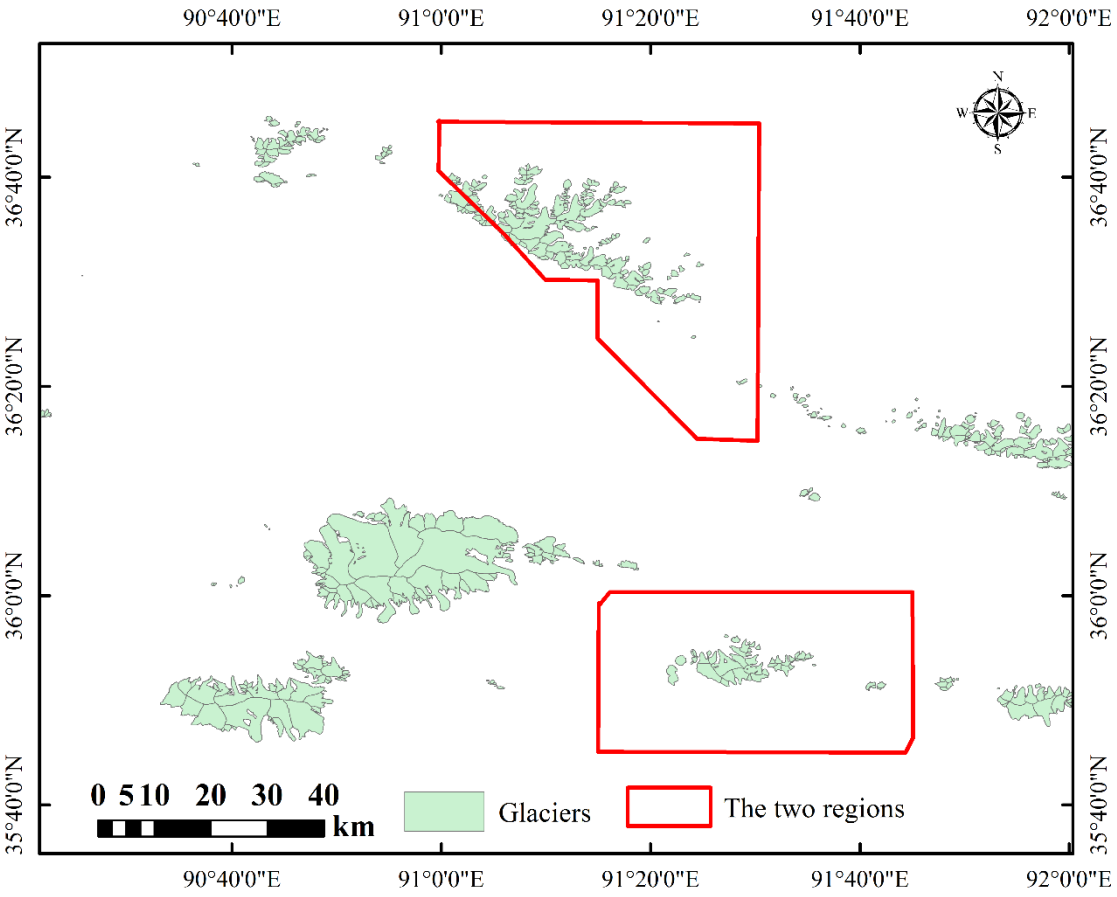
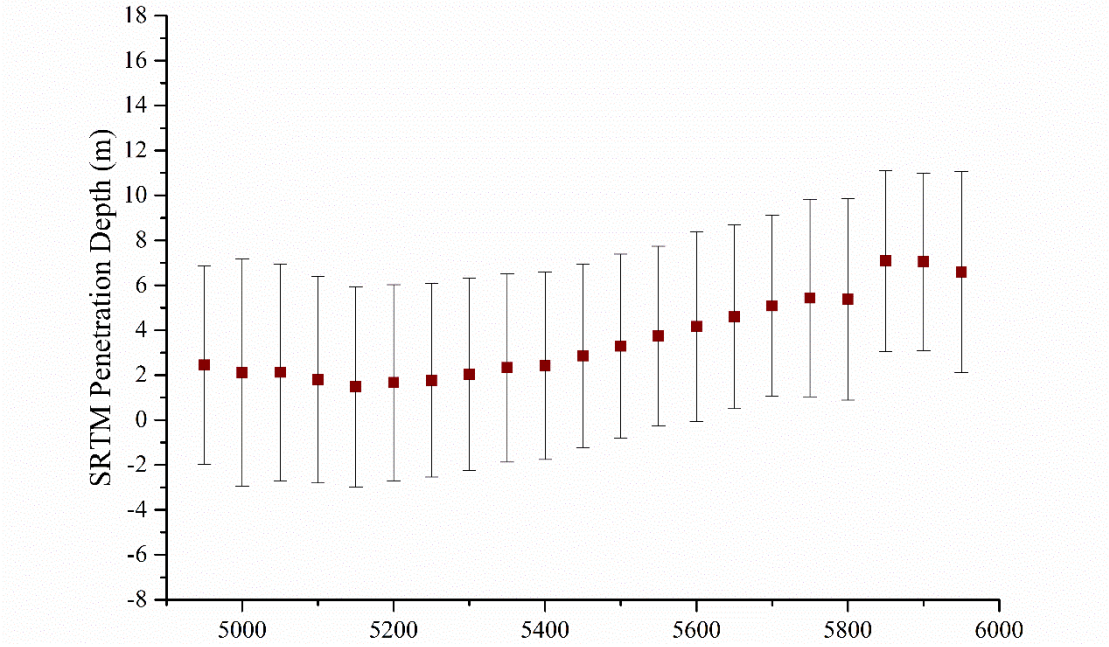
Glacier variations at Xinqingfeng and Malan Ice Caps in the inner Tibetan Plateau since 1970

Zhen Zhang, Shiyin Liu , Zongli Jiang, Donghui Shangguan, Junfeng Wei, Wanqin Guo, Junli Xu, Yong Zhang, Shasha Zhang and Danni Huang

Supplementary information.



(a)



(b)

Figure S1. (a) The two regions near our study region (northeast by 45 km and southeast by 25 km) where the C-band radar penetration was estimated by comparing the SRTM C-band with the X-band. (b) C-band Radar Penetration depth differences at each elevation bin.

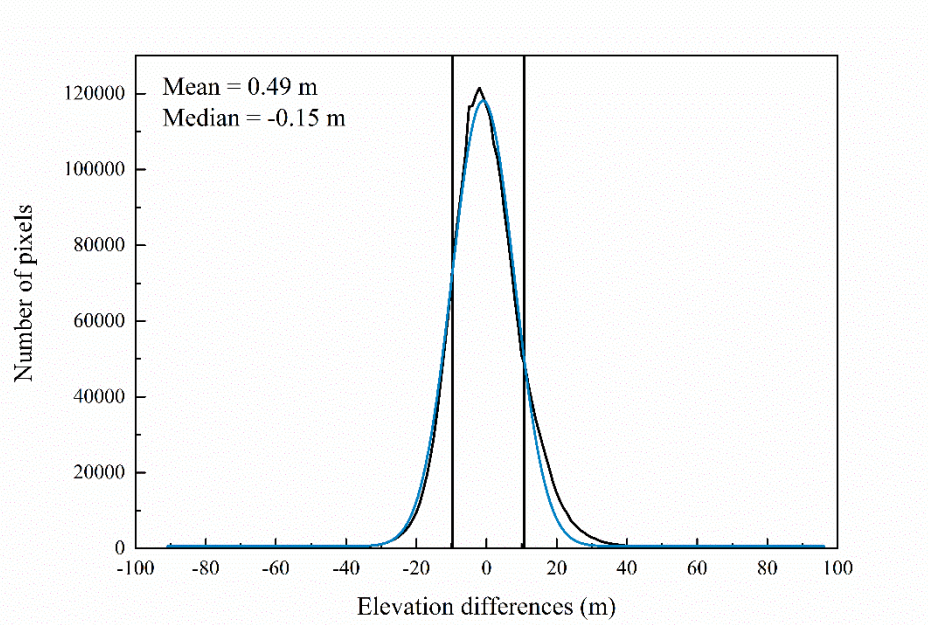


Figure S2. Distribution of elevation differences (black line) between TOPO and SRTM on the ice-free terrain after planimetric and vertical adjustment of the DEMs. The blue line represents the corresponding gaussian fit. The vertical lines represent the standard deviation of elevation differences.

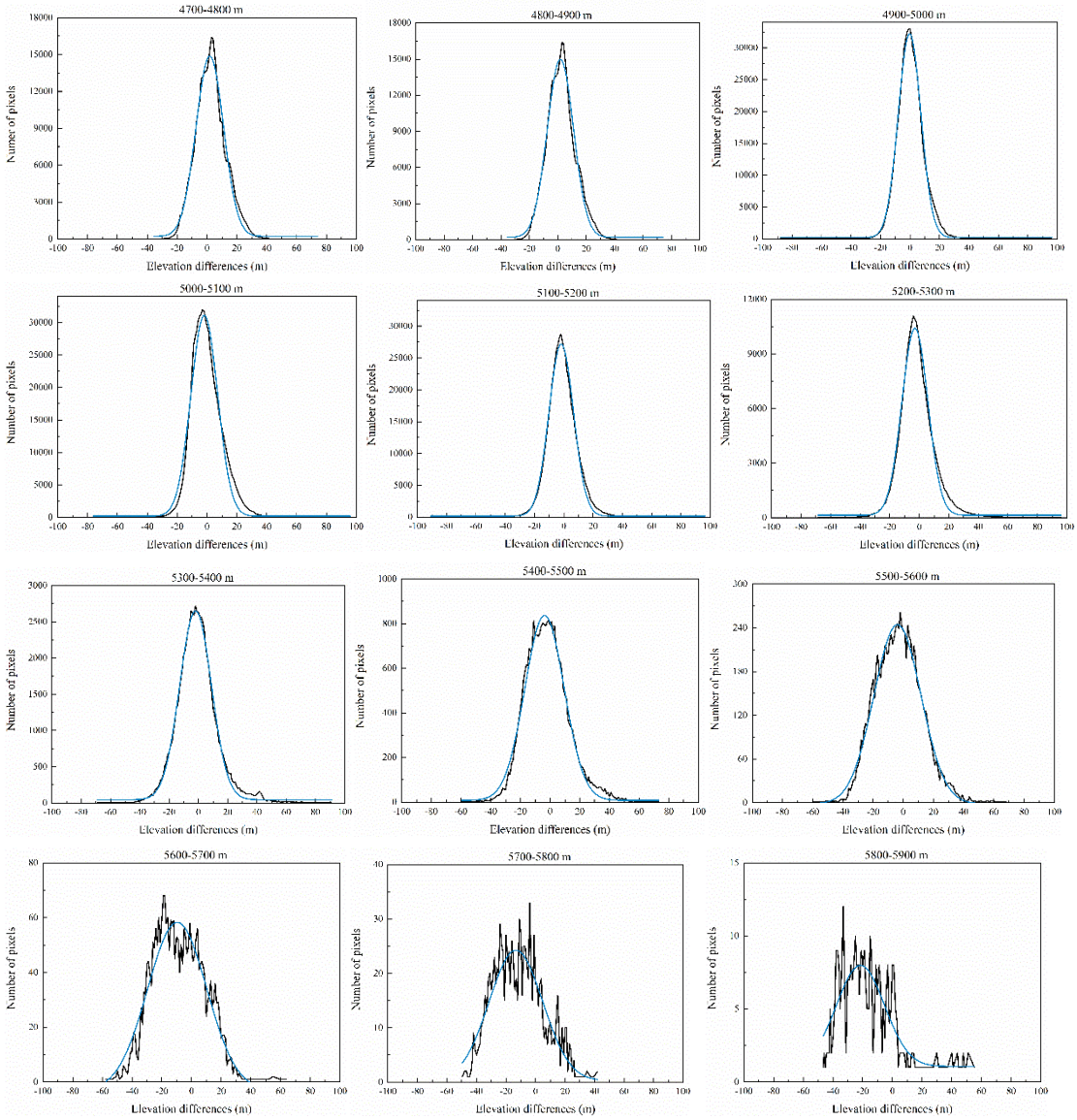


Figure S3. Distribution of elevation changes between TOPO and SRTM (black line) in each altitude interval. The blue line represents the corresponding gaussian fit.

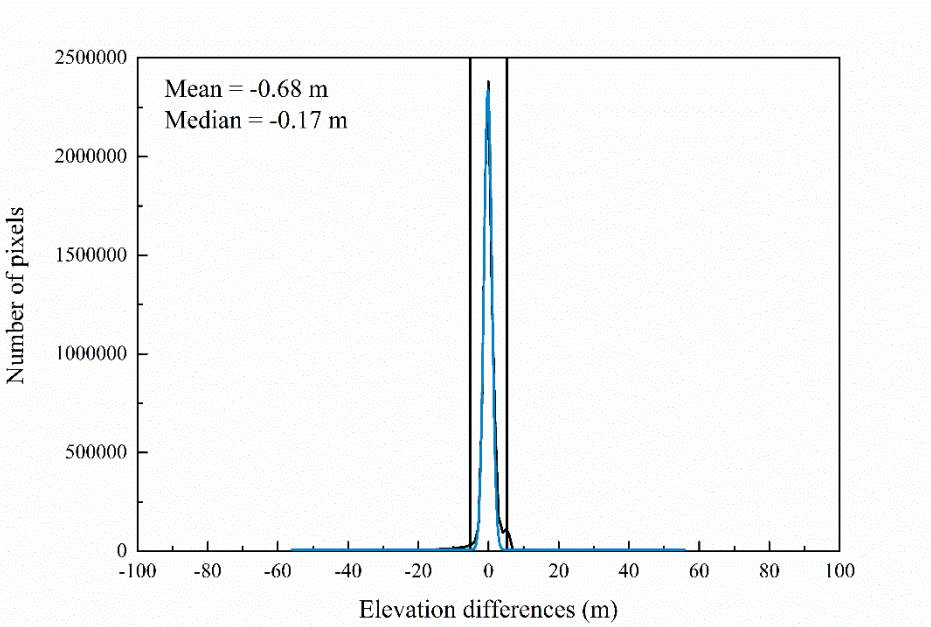
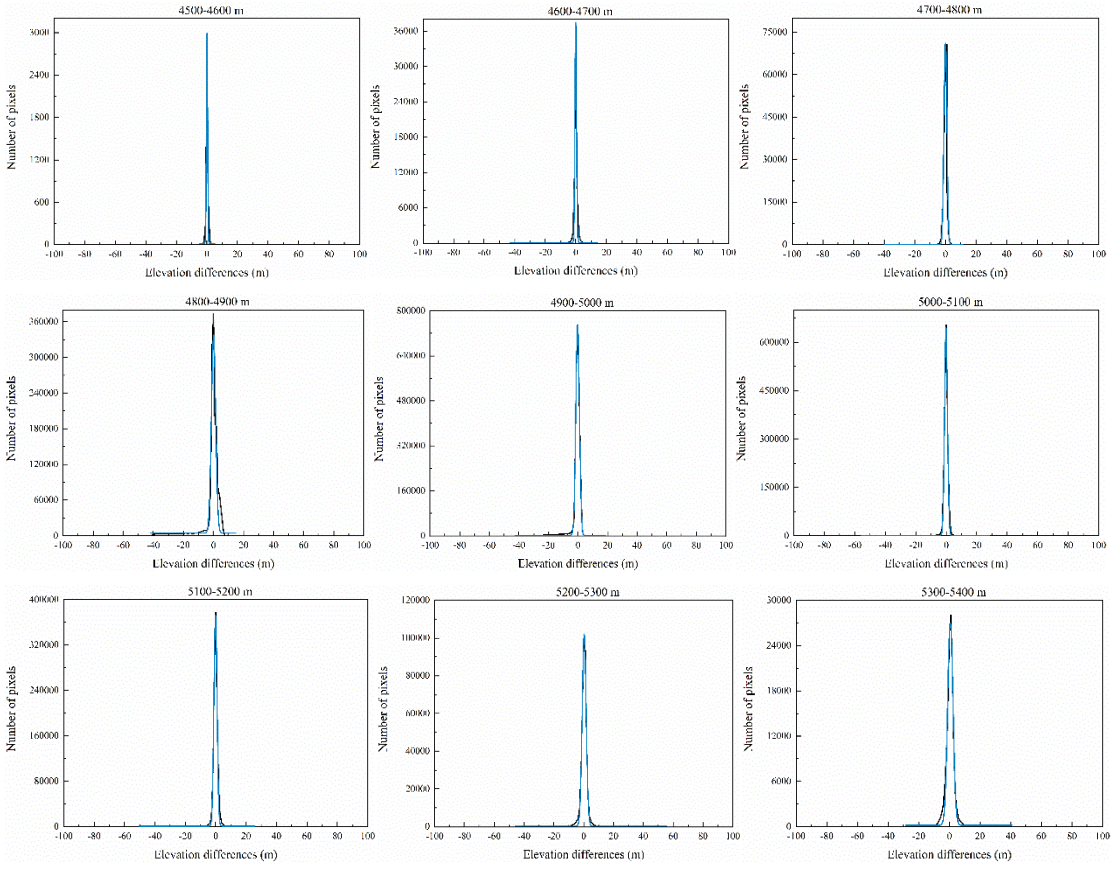


Figure S4. Distribution of elevation differences (black line) between TSX/TDX-X and SRTM on the ice-free terrain after planimetric and vertical adjustment of the DEMs. The blue line represents the corresponding gaussian fit. The vertical lines represent the standard deviation of elevation differences.



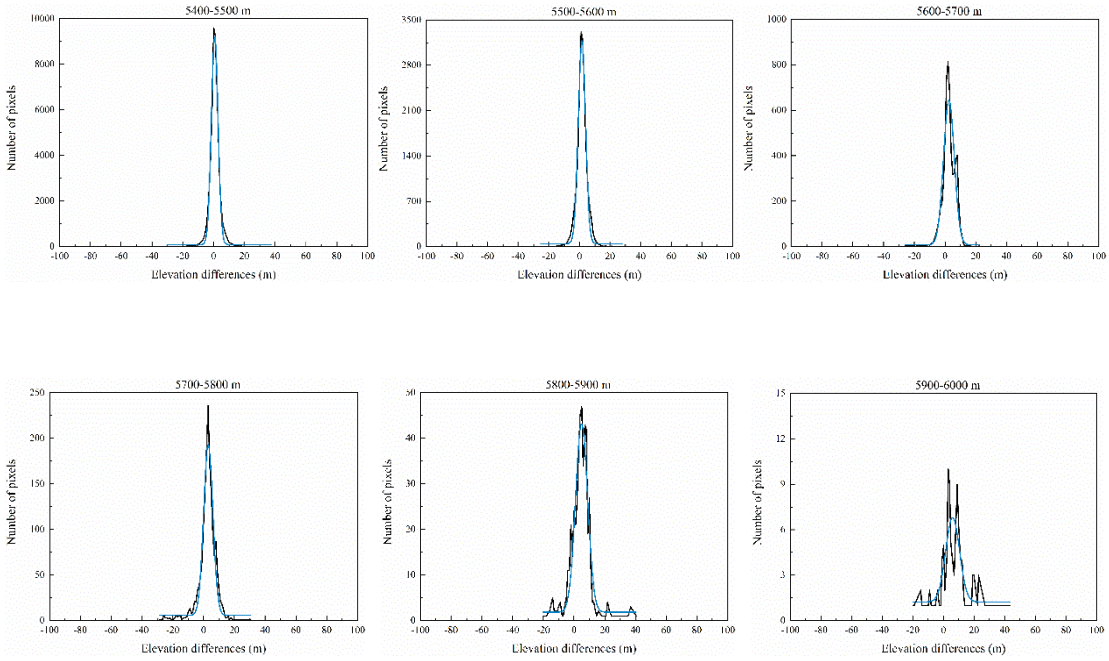


Figure S5. Distribution of elevation changes between TSX/TDX-X and SRTM (black line) in each altitude interval. The blue line represents the corresponding gaussian fit.

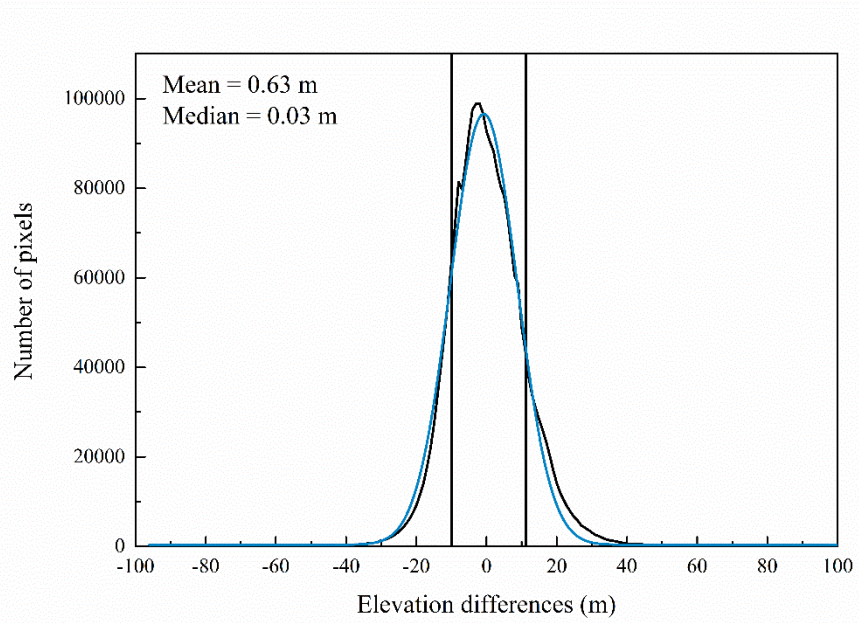


Figure S6. Distribution of elevation differences (black line) between TSX/TDX-X and TOPO on the ice-free terrain after planimetric and vertical adjustment of the DEMs. The blue line represents the corresponding gaussian fit. The vertical lines represent the standard deviation of elevation differences.

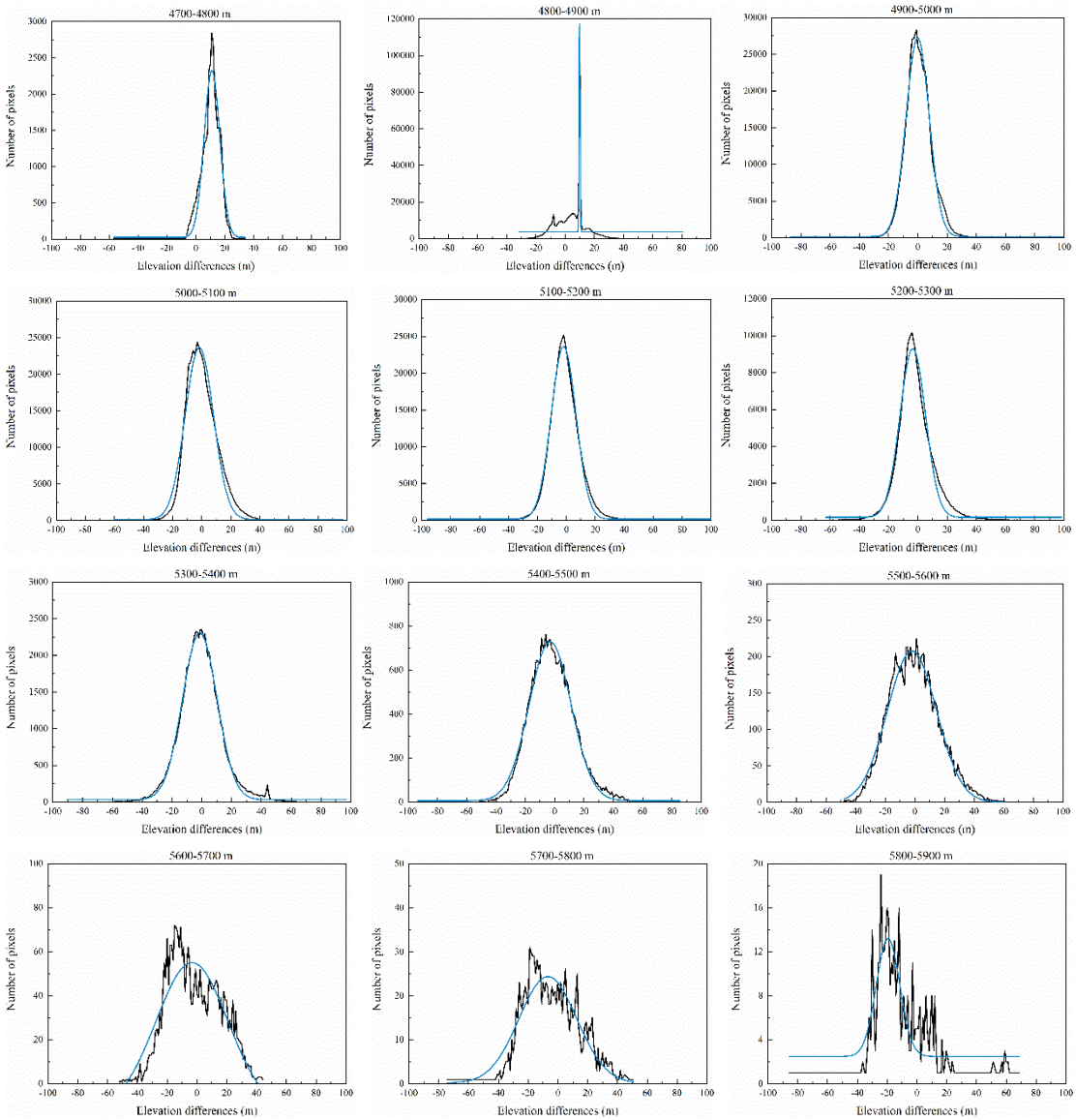


Figure S7. Distribution of elevation changes between TSX/TDX-X and TOPO (black line) in each altitude interval. The blue line represents the corresponding gaussian fit.

Table 1S. Glacier area (A) and changes (ΔA) from 1970−2018 for selected glaciers that have mass−balance estimates and for all glaciers of the study area.

Region	ID	GLIMS ID	A_{1970}	1970−2000			2000−2013			1970−2013			2013−2018			1970−2018		
			(km^2)	ΔA (km^2)	ΔA (%)	Rate (% a^{-1})	ΔA (km^2)	ΔA (%)	Rate (% a^{-1})	ΔA (km^2)	ΔA (%)	Rate (% a^{-1})	ΔA (km^2)	ΔA (%)	Rate (% a^{-1})	ΔA (km^2)	ΔA (%)	Rate (% a^{-1})
Xinqingfeng	1	G090837E36060N	26.7	1.9	7.2	0.23	−0.4	−1.4	−0.11	1.5	5.5	0.13	−0.2	−0.6	−0.11	1.4	4.9	0.11
	2	G090884E36076N	66.6	2.4	3.6	0.12	−0.4	−0.6	−0.05	2.0	2.9	0.07	−0.0	−0.0	−0.00	2.0	2.9	0.06
	3	G091076E36106N	27.2	−1.0	−3.5	−0.12	−0.5	−1.9	−0.15	−1.5	−5.6	−0.13	−0.0	−0.2	−0.03	−1.5	−5.8	−0.12
	4	G091032E36060N	94.8	−10.8	−11.4	−0.40	3.6	4.3	0.33	−7.2	−8.2	−0.18	1.5	1.7	0.34	−5.7	−6.4	−0.13
	5	G090983E36018N	22.2	−0.6	−2.6	−0.09	−0.2	−1.1	−0.09	−0.8	−3.9	−0.09	−0.2	−0.8	−0.17	−1.0	−4.7	−0.10
	6	G090901E36002N	23.3	−0.4	−1.5	−0.05	−0.3	−1.2	−0.09	−0.6	−2.8	−0.06	0.1	0.3	0.06	−0.5	−2.1	−0.04
	7	G090868E35998N	8.5	−0.2	−2.4	−0.08	0.1	1.1	0.08	−0.1	−1.4	−0.03	−0.1	−1.0	−0.19	−0.2	−2.4	−0.05
	8	G090846E36001N	5.7	0.0	0.7	0.02	0.0	0.6	0.05	0.1	1.3	0.03	−0.0	−0.6	−0.12	0.0	0.7	0.02
subtotal			443.0	−16.9	−3.8	−0.13	−0.2	−0.0	−0.00	−17.1	−3.9	−0.09	0.5	0.1	0.02	−16.6	−3.7	−0.08
Malan	9	G090796E35893N	5.3	−0.0	−0.8	−0.03	−0.0	−0.7	−0.06	−0.1	−1.5	−0.04	−0.1	−1.2	−0.25	−0.1	−2.8	−0.06
	10	G090781E35848N	10.5	−0.4	−3.9	−0.13	−0.0	−0.0	−0.00	−0.4	−4.0	−0.09	−0.0	−0.3	−0.07	−0.4	−4.4	−0.09
	11	G090668E35840N	10.9	−0.3	−2.9	−0.10	−0.1	−1.2	−0.09	−0.4	−4.3	−0.10	−0.0	−0.2	−0.03	−0.5	−4.4	−0.09
	12	G090621E35846N	12.1	−0.4	−3.3	−0.11	−0.1	−0.7	−0.06	−0.5	−4.2	−0.09	−0.0	−0.4	−0.07	−0.5	−4.5	−0.09
	13	G090782E35805N	23.0	−0.4	−1.8	−0.06	−0.3	−1.1	−0.09	−0.7	−3.0	−0.07	−0.2	−0.9	−0.17	−0.9	−3.8	−0.08
	14	G090693E35807N	32.2	−1.7	−5.1	−0.18	0.2	0.6	0.05	−1.5	−4.8	−0.11	0.0	0.0	0.00	−1.5	−4.8	−0.10
	15	G090633E35808N	14.5	−0.2	−1.3	−0.04	−0.1	−0.5	−0.04	−0.3	−1.8	−0.04	−0.0	−0.2	−0.03	−0.3	−2.0	−0.04
	16	G090575E35839N	9.2	−0.2	−2.2	−0.07	−0.0	−0.5	−0.04	−0.3	−2.8	−0.06	−0.0	−0.1	−0.02	−0.3	−2.9	−0.06
subtotal			198.2	−7.9	−4.0	−0.14	−2.2	−1.2	−0.09	−10.1	−5.1	−0.12	−0.7	−0.4	−0.07	−10.8	−5.4	−0.11
total			641.2	−24.8	−3.9	−0.13	−2.3	−0.4	−0.03	−27.2	−4.2	−0.10	−0.2	−0.0	−0.01	−27.4	−4.3	−0.09

Table 2S. Glacier length (L) and changes (ΔL) at Xinqingfeng and Malan for selected glaciers.

Region	ID	GLIMS ID	$L_{1970/71}$ (km)	$\Delta L_{1970/71\text{-}2000}$ (m)	$\Delta L_{2000\text{-}2013}$ (m)	$\Delta L_{2013\text{-}2018}$ (m)	$\Delta L_{1970/71\text{-}2018}$ (m)
Xinqingfeng	1	G090837E36060N	12.05 ± 0.01	329.3 ± 20.2	0.0 ± 16.8	−83.2 ± 10.6	246.1 ± 15.4
	2	G090884E36076N	15.36 ± 0.01	584.8 ± 20.2	0.0 ± 16.8	0.0 ±10.6	584.8 ± 15.4
	3	G091076E36106N	9.67 ± 0.01	−52.9 ± 20.2	0.0 ± 16.8	0.0 ± 10.6	−52.9 ± 15.4
	4	G091032E36060N	20.98 ± 0.01	−2546.8 ± 20.2	650.5 ± 16.8	513.5 ± 10.6	−1382.8 ± 15.4
	5	G090983E36018N	9.50 ± 0.01	−169.1 ± 20.2	−55.0 ± 16.8	−216.4 ± 10.6	−440.5 ± 15.4
	6	G090901E36002N	10.80 ± 0.01	−45.0 ± 20.2	−46.8 ± 16.8	46.0 ± 10.6	−45.8 ± 15.4
	7	G090868E35998N	6.90 ± 0.01	40.8 ± 20.2	107.8 ± 16.8	−43.4 ± 10.6	105.2 ± 15.4
	8	G090846E36001N	5.78 ± 0.01	432.0 ± 20.2	−19.7 ± 16.8	−75.7 ± 10.6	336.6 ± 15.4
	Selected glaciers (mean)			−178.4 ± 20.2	79.6 ± 16.8	17.6 ± 10.6	−81.2 ± 15.4
	Selected glaciers (mean annual)			−5.9 ± 0.7	6.1 ± 1.3	3.5 ± 2.1	−1.7 ± 0.3
Malan	9	G090796E35893N	3.87 ± 0.01	0 ± 20.2	−44.5 ± 16.8	−37.8 ± 10.6	−82.3 ± 15.4
	10	G090781E35848N	5.20 ± 0.01	−89.3 ± 20.2	−17.6 ± 16.8	−9.7 ± 10.6	−116.6 ± 15.4
	11	G090668E35840N	5.13 ± 0.01	−121.6 ± 20.2	−306.2 ± 16.8	−78.1 ± 10.6	−505.9 ± 15.4
	12	G090621E35846N	6.01 ± 0.01	−220.5 ± 20.2	−75.4 ± 16.8	−51.6 ± 10.6	−347.5 ± 15.4
	13	G090782E35805N	8.61 ± 0.01	−55.5 ± 20.2	−82.8 ± 16.8	−26.1 ± 10.6	−164.4 ± 15.4
	14	G090693E35807N	9.18 ± 0.01	−873.9 ± 20.2	183.4 ± 16.8	0.0 ± 10.6	−690.5 ± 15.4
	15	G090633E35808N	5.81 ± 0.01	−60.0 ± 20.2	−72.7 ± 16.8	−54.9 ± 10.6	−187.6 ± 15.4
	16	G090575E35839N	4.28 ± 0.01	−10.9 ± 20.2	−35.6 ± 16.8	−14.8 ± 10.6	−61.3 ± 15.4
	Selected glaciers (mean)			−179.0 ± 20.2	−56.4 ± 16.8	−56.4 ± 10.6	−269.5 ± 15.4
	Selected glaciers (mean annual)			−6.0 ± 0.7	−4.3 ± 1.3	−11.3 ± 2.1	−5.6 ± 0.3
Total	Selected glaciers (mean)			−178.7 ± 20.2	11.6 ± 16.8	−8.3 ± 10.6	−175.3 ± 15.4
	Selected glaciers (mean annual)			−6.0 ± 0.7	0.9 ± 1.3	−1.7 ± 2.1	−3.7 ± 0.3

Table 3S. Glacier mean elevation (△H) and geodetic glacier mass balance rates measured from DEM differencing.

Region	ID	GLIMS ID	1970/71−1999		1999−2011/12		1970/71−2011/12		2000−2016*
			Mean ΔH (m)	Annual mass balance (m w.e. a^{-1})	Mean ΔH (m)	Annual mass balance (m w.e. a^{-1})	Mean ΔH (m)	Annual mass balance (m w.e. a^{-1})	Annual mass balance (m w.e. a^{-1})
Xinqingfeng	1	G090837E36060N			−4.41 ± 2.26	−0.29 ± 0.18			−0.22
	2	G090884E36076N			−5.97 ± 2.32	−0.39 ± 0.18			−0.33
	3	G091076E36106N	−4.44 ± 2.75	−0.13 ± 0.09	−4.41 ± 2.00	−0.31 ± 0.15	−8.65 ± 0.91	−0.17 ± 0.02	−0.40
	4	G091032E36060N			−4.77 ± 2.16	−0.35 ± 0.17			−0.02
	5	G090983E36018N			1.43 ± 2.11	0.10 ± 0.16			0.04
	6	G090901E36002N			1.02 ± 2.12	0.07 ± 0.16			0.05
	7	G090868E35998N			0.15 ± 2.09	0.01 ± 0.16			0.02
	8	G090846E36001N			−0.35 ± 2.00	−0.02 ± 0.15			0.04
subtotal					−3.50 ± 2.17	−0.22 ± 0.17			−0.14
Malan	9	G090796E35893N	−3.21 ± 3.71	−0.09 ± 0.13	−4.41 ± 2.15	−0.29 ± 0.17	−7.85 ± 0.84	−0.16 ± 0.02	−0.20
	10	G090781E35848N	−7.17 ± 3.48	−0.21 ± 0.12	−3.96 ± 2.11	−0.26 ± 0.17	−10.40 ± 0.85	−0.21 ± 0.02	−0.25
	11	G090668E35840N	−8.00 ± 3.90	−0.23 ± 0.13	−2.79 ± 2.25	−0.18 ± 0.18	−10.85 ± 0.81	−0.22 ± 0.02	−0.08
	12	G090621E35846N	−12.37 ± 4.28	−0.36 ± 0.15	−4.72 ± 2.24	−0.31 ± 0.18	−18.65 ± 0.81	−0.38 ± 0.02	−0.27
	13	G090782E35805N	−16.41 ± 3.89	−0.48 ± 0.13	−5.22 ± 2.23	−0.34 ± 0.18	−20.99 ± 0.83	−0.42 ± 0.02	−0.39
	14	G090693E35807N	0.84 ± 3.96	0.02 ± 0.14	−4.36 ± 2.25	−0.29 ± 0.18	−3.35 ± 0.81	−0.07 ± 0.02	−0.17
	15	G090633E35808N	0.04 ± 4.49	0.00 ± 0.15	−5.26 ± 2.33	−0.34 ± 0.18	−5.71 ± 0.80	−0.12± 0.02	−0.14
	16	G090575E35839N	−9.46 ± 3.86	−0.28 ± 0.13	−5.92 ± 2.12	−0.39 ± 0.17	−13.47 ± 0.84	−0.27± 0.02	−0.39
subtotal			−6.53 ± 3.95	−0.19 ± 0.14	−4.42 ± 2.21	−0.29 ± 0.17	−10.72 ± 0.91	−0.22 ± 0.02	−0.23
total					−3.78 ± 2.18	−0.24 ± 0.17			−0.17

*These results were derived from Brun et al. (2017).