Supplementary information: Recent glacier and lake changes in High Mountain Asia and their relation to precipitation changes

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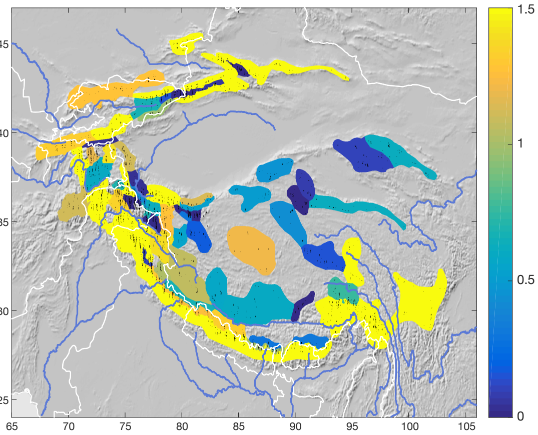
S1 Effect of December 2008 snow correction and off-glacier trends

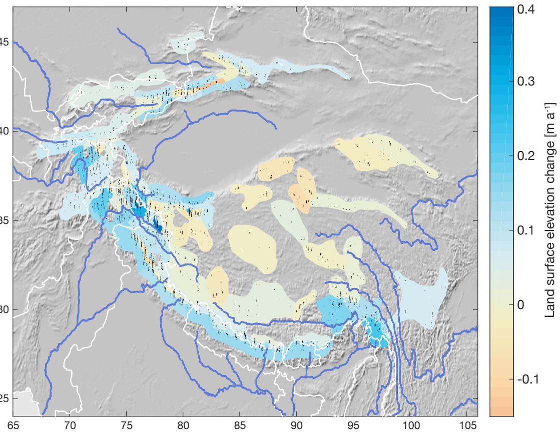
The surface elevation measurements of the December part of the split ICESat campaign in autumn 2008 are prone to be affected by snow cover in mountainous regions of the northern hemisphere. Samples in either end of the x-axis data range have a particularly strong influence of the slope of a linear fit.We therefore compute a correction for December 2008 snow cover using the method of Treichler and Kääb (2016).

Our estimate for snow accumulated between the October and December 2008 campaigns decreased December 2008 glacier dh in 80 of 100 units. In 11 cases, there are not enough off-glacier samples in either October or December 2008 to compute a correction, in 4 units there are no glacier samples in December 2008 to correct (i.e. all autumn 2008 samples are from the October campaign), and in 5 cases the linear relationship was negative, i.e. correction would have made December 2008 dh more positive (all shown in grey in Fig. S1c). The correction decreases December 2008 glacier dh on average by 0.9 m (Fig. S1a) and off-glacier dh by 0.6 m.

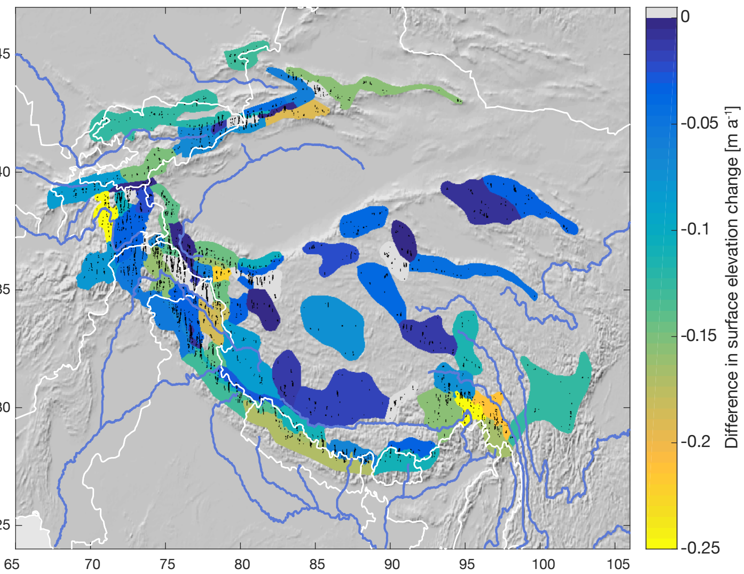
The effect of the December 2008 correction is considerable and its spatial pattern corresponds well to units where MERRA-2 data suggests snow has fallen in October–December 2008 (Fig. S1f) and where off-glacier samples suggest a positive surface change trend (Fig. S1b).The difference is the same for robust, t- and Theil-Sen fits, and also off-glacier trends are decreased by on average $0.038\,\mathrm{m\,a^{-1}}$. Correcting for December 2008 snow bias increases the number of units where off-glacier trends are not significantly different from zero (1σ) from 41 to 59 units. In many units with a persistent off-glacier trend also after December 2008 snow correction, the median dh of campaign 2003 is higher or lower than all other campaign medians.



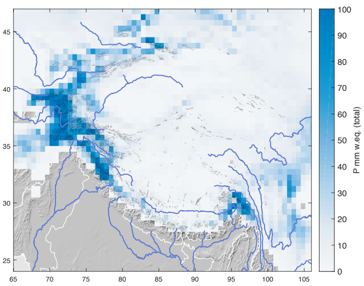
(a) December 2008 correction: difference in campaign median before–after correction



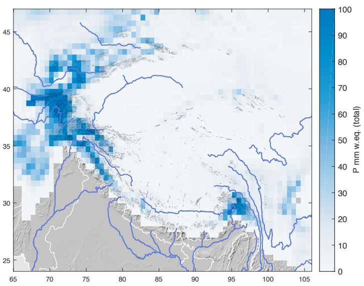
(b) Off-glacier trend



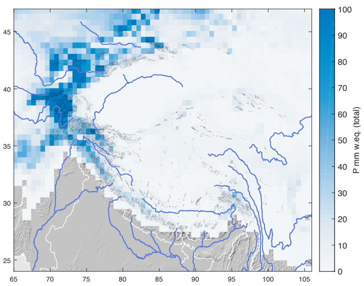
(c) Difference in glacier surface elevation change rates if December 2008 correction is applied. Spatial units where the correction could not be computed are shown in grey.



(d) Snowfall in October 2008



(e) Snowfall in November 2008



(f) Snowfall in December 2008

Figure S1: Correction for the effect of snow cover on the ICESat autumn 2008 campaign (a and c), off-glacier surface elevation trends (b) and total snowfall at the surface in October–December 2008 from MERRA-2 reanalysis data (d–f).

S2 Volume/mass changes

Glacier surface elevation change rates for 2003–2008 are converted to volume/mass changes in Gt assuming a density of $850\,\mathrm{kg\,m^{-3}}$ (Huss 2013, see Kääb et al. 2012 for the effect of different density scenarios) and glacier areas from the Randolph Glacier Inventory (RGI version 6, RGI Consortium, 2017). A shapefile with the spatial zonation and corresponding glacier changes is available as a data supplementary to this publication.

Total 2003–2008 glacier mass change for entire HMA sums up to $-23 + 2.3/-7.9\ \mathrm{Gt\,a^{-1}}$. When applying December 2008 snow correction, the estimate becomes considerably more negative: $-28.8+7.8/-2.2\ \mathrm{Gt\,a^{-1}}$, using the uncorrected estimate for units where December 2008 correction could not be computed. We assume the uncertainty from the contribution of December 2008 snow correction is one-directional (it should only make the estimate more negative), thus we assume full correlation of this part of the negative error budget, and positive error budget for the estimate corrected for December 2008 snow, respectively. Note that not the entire HMA glacier mass change contributes to sea level rise as some of HMA's river basins are endorheic.

Table S1 provides a volume/mass conversion of the water volume values in table 1 in the main text. Corresponding areal extents of the TP regions are given in the table.

Table S1: Lake water mass changes between decadal averages of the 1990s and the 2000s.

Region	SRTM $\mathrm{Gt\,a^{-1}}$	error	ICESat $\mathrm{Gt\,a^{-1}}$	error	area $\mathrm{km^2}$
Southwest TP	9.61	2.71	14.49	3.83	245 240
East TP	46.05	6.03	50.16	6.67	182 660
Central TP	10.77	1.49	11.00	1.74	154 260
Northwest TP	5.28	1.19	5.99	1.29	85 650
Northeast TP	6.73	1.35	6.05	1.03	111 460
Qaidam / Qilian	0.46	1.94	0.28	1.38	391 720

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