

## Supplementary Material:

## Ice cliff dynamics of debris-covered Trakarding Glacier

## in the Rolwaling region, Nepal Himalaya



Figure S1. (A) Camera positions on the helicopter (white circles) and (B) Fixed-wing UAV X-5.



Figure S2. GCP locations (blue points): (A) 2007, (B) 2018, and (C) 2019. The red polygon indicates the study area, and the black line is the outline of Trambau Glacier.



**Figure S3.** Accuracy of the SfM-DEMs. **(A)** Box plot and **(B)** kernel density estimation plot of the differences between the SfM-DEMs (2007, 2018, and 2019) and GPS-DEM. The symbols in panel **(A)** are as follows: the whiskers indicate the standard deviation, the boxes show the upper and lower quartiles, the thick lines indicate the median values, and the circles are the mean values of the vertical errors for each year.



Figure S4. Delineated ice cliffs: (A) SfM Ortho-image, (B) hill shade, (C) aspect image , and (D) slope gradient. These raster data have 0.2 m resolution. (E) Observed ice cliff during the 2018 field campaign.



Figure S5. Ice cliff delineation uncertainty (standard deviation) of (A) ice cliff edge length and (B) ice cliff map-view area of the slope.



**Figure S6.** Histograms of the surface elevation change rate (dh/dt) for the (A) 2007–2018 and (B) 2018–2019 periods.



Figure S7. Stacked histograms of ice cliff morphology: (A) edge length, (B) inclined area, (C) height, and (D) slope.



Figure S8. Aerial photographs that indicate ice cliff formation mechanisms of (A) collapse of englacial conduit and (B) crevassing. The upper conduit intake in (A) is shown in Figure 8c.

**Table S1.** Accuracy of the 2018 SfM-DEM. The presented assessment is based on a comparison between the reference GCP elevation (extracted from the 2018 SfM-DEM) and generated SfM-DEM GCP elevations (2007 and 2019).

GCP vertical error [m]								
Year	MEAN	SD	MEDIAN	RMSE				
2007	2.99	4.23	2.03	5.18				
2018	_	_	_	_				
2019	0.73	1.21	0.65	1.42				

**Table S2.** Estimated GCP errors from the SfM data processing workflow.

Estimated GCP errors from SfM									
Year	X error [m]	Y error [m]	Z error [m]	Total [m]	Total [pixels]				
2007	2.01	2.20	2.34	3.79	1.12				
2018	0.43	0.64	0.61	0.98	2.50				
2019	0.38	0.51	0.26	0.69	3.48				

	NE	SE	SE	NW
	(0-90°)	(90-180°)	(180-270°)	(270-360°)
Incl. area of survived-2018 (×10 <sup>-2</sup> m <sup>2</sup> )	577	119	394	753
Incl. area of survived-2019 (×10 <sup>-2</sup> m <sup>2</sup> )	735	146	462	1280
Relative area change from 2018 to 2019 (%)	127	123	117	170

 Table S3 Inclined area of survived ice cliff and its relative change.