MOUNT EVEREST FOUNDATION

Patron: HRH The Duke of Edinburgh KG KT

BRITISH MOUNTAINEERING COUNCIL

1 - Name of Expedition: Catchment wide topographic survey of Glacier 24K, Tibet

2 - Expedition Leader/Organiser: Rebecca Stewart

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3 - MEF reference: 19-36 BMC reference: N/A

4 - Country/Region: Bomi, Nyingchi Province, Tibet

5 - Names of all expedition members, indicating leader, climbing members, and support:

Rebecca Stewart (leader)

6 - Original objective(s) of expedition – mountaineering / scientific / medical, include location of objective (or study area) with indication of special points of interest (e.g. 'first ascent of NW Ridge') and heights of peaks:

The original objective of this expedition was scientific and aimed to create a catchment wide topographic survey of Glacier 24K with aim to assess the sediment cascade through the system.

7 - Overall dates of expedition (e.g. 'March-June 2015'), showing time spent on approach, climbing, and return:

October 4th – October 23rd.

Schedule: Rebecca Stewart was making use of logistics from PhD supervisor Dr Francesca Pellicciotti, via a Royal Society grant. This grant paid for accommodation and living costs whilst in China and Tibet. Thus, Rebecca was involved in various other field tasks whilst at Glacier 24K, please see below for a detailed itinerary. This trip was also preceded by a field campaign in June 2019, where initial scans were obtained of the catchment.

Trek days	Dates	Summary	Overnight	Done	
	4-oct.	Depart Switzerland / Northumbria		MK, SF & MT: Departure 13:30	
	5-oct.	Arr Chengdu & transfer to hotel.	Hotel	MK, SF & MT: Arrival 12:40 – Meeting with Prof. Liu Qiao to borrow TLS	
	6-oct.	Hailuogou visit with Liu Qiao	Hotel	Drive to Mo Xi, visit of IMHE station	
	7-oct.	Hailuogou visit with Liu Qiao	Hotel	Visit of Hailuogou glacier, drive back to Chengdu	
	8-oct.	Flight to Lhasa	Hotel	Shopping for field equipment (power adaptors)	
	9-oct.	Day in Lhasa	Hotel	Visit of Potala palace & acclimatization in Lhasa	
	10-oct.	Drive to Nyingchi	Hotel	N/A	
	11-oct.	Drive to Bomi	Hotel	Shopping for field equipment (solar panel, spray paint)	
1	12-oct.	Research tasks	Hotel Bomi	Fluorometer installation dye-tracing of proglacial stream eBee flight (Yang Wei) TLS terminus cliff	checked AWS checked time-lapse network (orientation, bearing etc on phone) Thermal camera to terminus Spray-painting GCPs (esp. cliff zone)
2	13-oct.			GPR for ice thickness on the upper part of the glacier HOBO checking	Checked logger station Measured stage/depth 1 Mavic thermal flight Dye tracing moulin
3	14-oct.			Dilution gauging (no records) dGPS of all on-glacier GCPs	Installing stakes in upper and central zone
4	15-oct.			Move thermal camera to hunting camera location TLS headwall Phantom RTK flights (Zhao)	Stake transect in ice cliff area GPR for ice thickness in cliff area
5	16-oct.			Dilution gauging (records) dGPS moraine GCPs Drill Stake transect cliff zone Uninstalled thermistor string from AWS	Restarted DSLR timelapse cameras Collected all WSL/NU GCPs GPR transect for ice thickness next to the AWS

6	17-oct.			TLS terminus cliff Checked thermal camera Dye tracing of pond area Installed 2 hunting cameras at the DSLR location dGPS remaining stakes	Brought down thermal camera Mavic repeat thermal flights Exploration of the new moulin: Dye tracing & water chemistry
7	18-oct.			TLS headwall	Uninstalled fluorometer
	19-oct.	Drive to Nyingchi or research station	Hotel	Repacked – drive to Nyingchi	
	20-oct.	Flight to Chengdu	Hotel	Field campaign wrap-up	
	21-oct.	Day in Chengdu	Hotel	Planning buffer day	
	22-oct.	Flight to Newcastle	Hotel	Flight to Newcastle (16:50, 22nd, arrive 08.30, 23rd)	

Table 1. Summary of itinerary of Glacier 24K team. Tasks in orange Rebecca participated in, tasks in red were carried out by Rebecca in direct relation to the Mount Everest funded work. Background filled in yellow represents travel/ permit acquisition/ altitude adjustment days, background filled in blue represents field days at Glacier 24K.

8 - Give the following details for each route climbed or attempted:

Name of mountain/crag, altitude, estimated route length, dates, grade, style (eg alpine, fixed rope), whether first ascent, successful or not, high point reached, reason for retreat (if applicable), weather conditions, and names of climbers:

N/A as our objectives were scientific. Below is a full scientific expedition report:

Travelling and fieldwork schedule:

Due to permitting restrictions, we fly from Chengdu, into Lhasa, Tibet. On the return leg we are able to fly from Nyingchi (Linzi Airport in Chinese), this saves a day of travelling by car allowing time for an extra field day. The drive from Lhasa to Nyingchi took a total of 6 hours with a small break at a service station, allowing us to hike a small hill to ~4500 m gaining some extra acclimatization. Gaining permission from Nyingchi province authorities was quick and simple the following morning. The drive from Nyingchi to Bome again took about 6 hours. We were once again able to hike a small hill on the high pass (~4600 m). Once we arrived in Bome, we stayed at Hotel Shan Xia, where we received a 60% discount in prices due to the friendly relationship between our drivers and the hotel owner. See Table 1 for a full summary of our activities in the field.

Glacier access:

After a short drive up a mountain road (35-45 minutes, ~ 24 km), parking was possible at Galong

Temple (Figure 1). Access to the glacier terminus is possible by navigating through the hummocky moraine system that lies in front of Glacier 24K (see Figure 4 for examples of the terrain). From here it is possible to walk up side of the terminal ice cliff to the Automatic Weather Station (AWS) located on-glacier. Alternatively, a valley trail exists beyond the true right moraine. This allowed us to bypass the hummocky moraine system and walk up and over the lateral moraine and onto the glacier directly next to the AWS. This valley trail can be followed all the way up glacier and there is further access to the upper ablation zone this way. Caution is advised when accessing the glacier over the moraines as access is quite steep and can be tricky when wet.

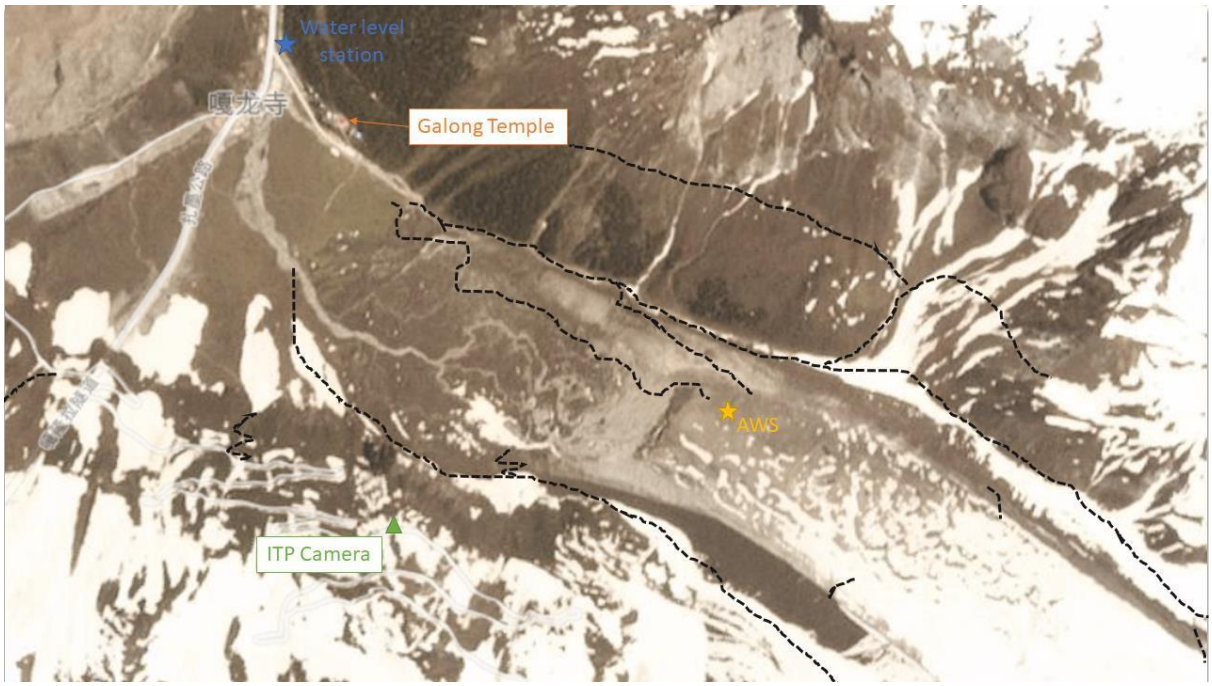

Figure 1. General Galong Temple-24K study area. Black dashed lines denote access trails to the glacier and surrounding slopes.

Visible changes since June 2019:

The terminal ice cliff remains very similar between June 2019 and October 2019 (Figure 2). Obvious changes include the cleaning of the ice surface, (almost) daily rainfall and snowfall in October 2019, plus the occurrence of the monsoon rains earlier in the summer mean that the ice cliff has become less 'dirty', with the thin layer of surface debris being washed away from most of the surface. The ice cliff is also gradually steepening as the glacier flows, resulting in several 'calving' events onto the proglacial area (Figure 3).

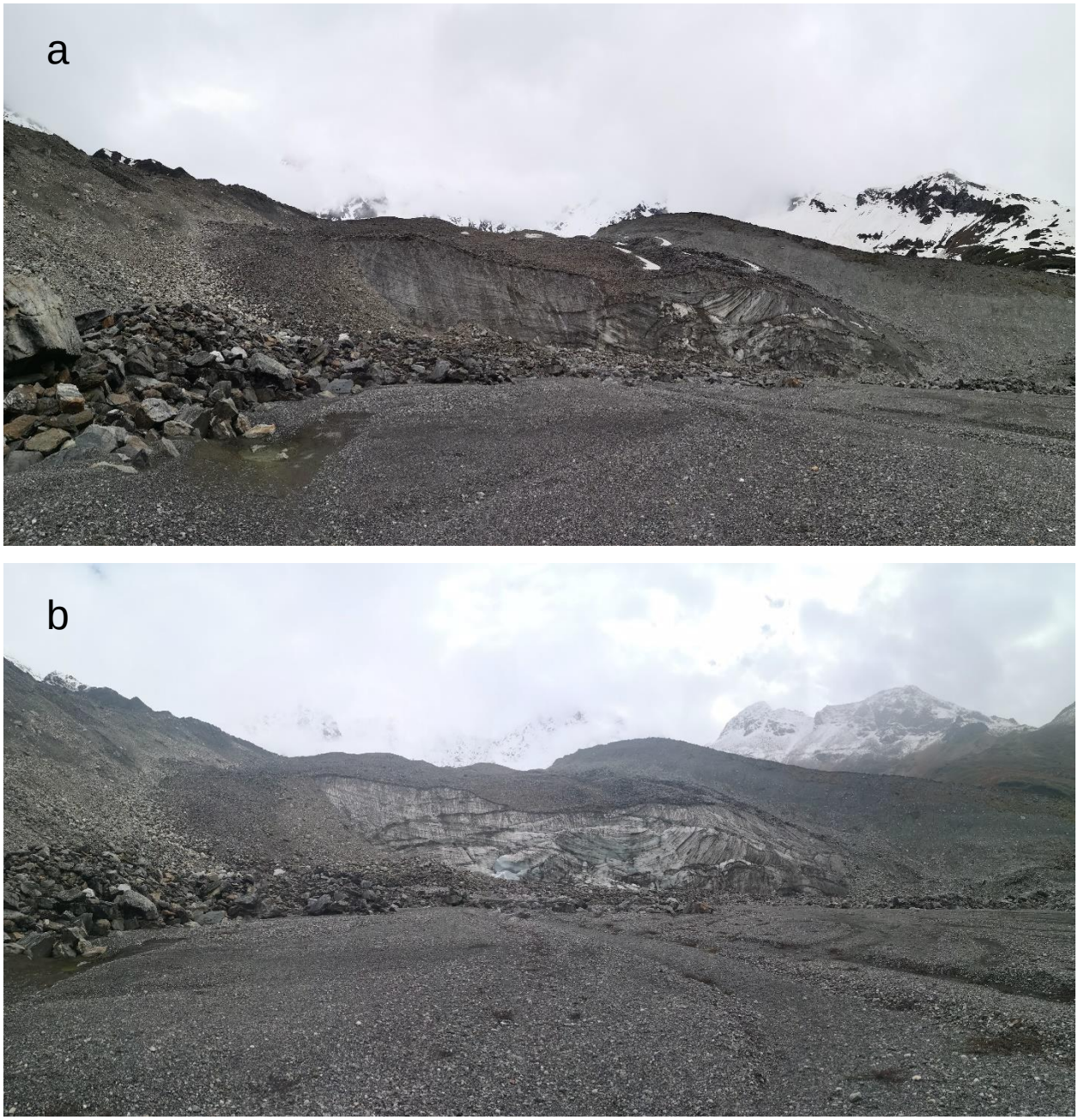

Figure 2. Glacier terminus changes between June 2019 and October 2019.

The proglacial zone has changed significantly since June, with the drainage of the two large ponds found being a key change (Figure 4). The stream has migrated somewhat, for example, the second scan position for the terminus TLS had to be changed due to the river undercutting the previous scan location.

Figure 3. a & b) Blocks of ice that have calved from the ice cliff at the terminus of Glacier 24K. c) Steepening/flaking of the terminus.

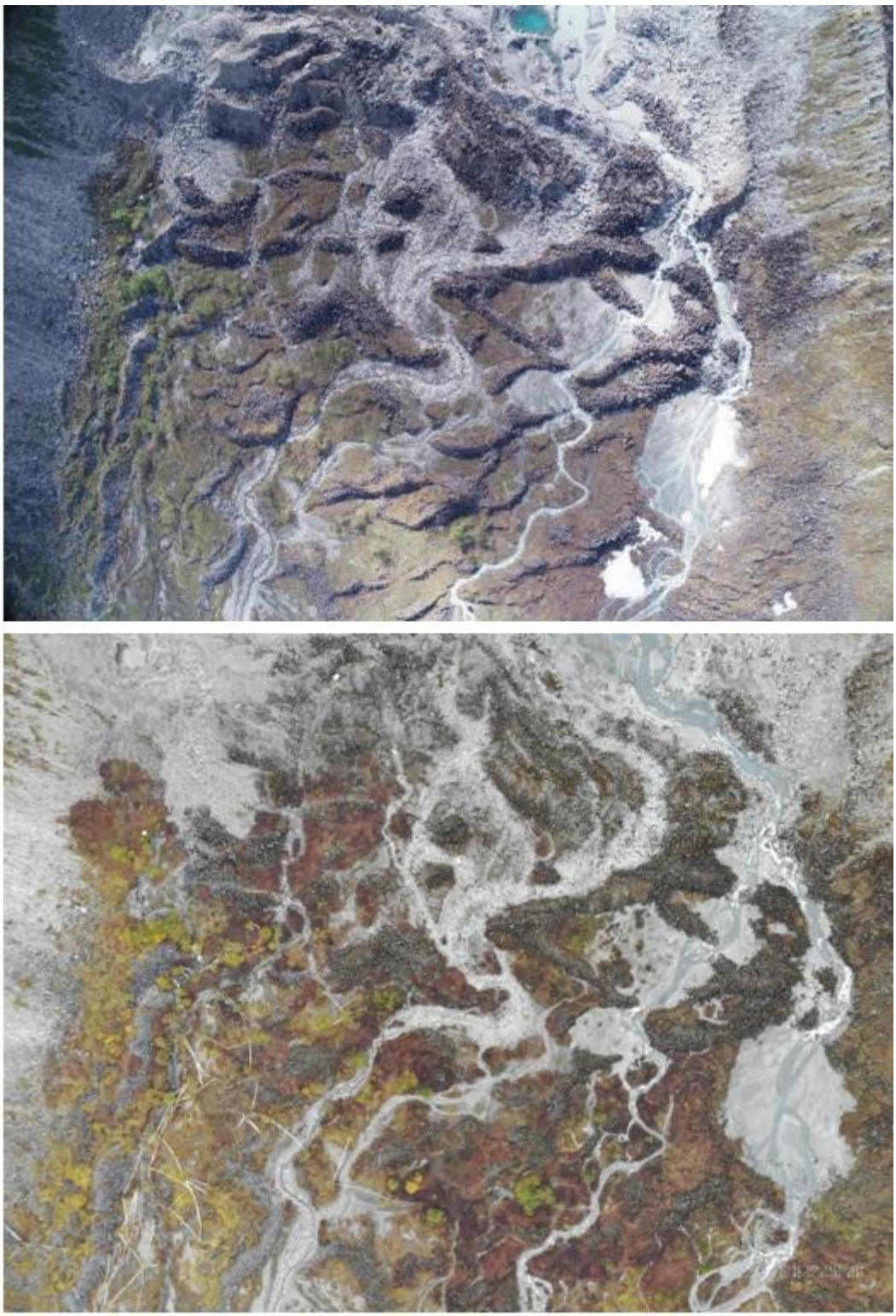

Figure 4. Changes in the proglacial area. NB. The absence of ponds in the top right of the second image.

Terrestrial Laser Scanning:

Glacier terminus:

Two repeat Terrestrial Laser Scan (TLS) surveys using a Riegl LMSZ620 were conducted at the terminal ice cliff of Glacier 24k between 12/10/19 and 18/10/19 (see Figure 5). The repeat surveys of the terminal ice cliff in conjunction with time lapse imagery from a FLIR t530 will enable comparison of temperature and surface changes at the terminal ice cliff.

The two repeat scans were obtained from three positions in the proglacial area, as multiple scan positions limit the occurrence of occlusions within the scan data (occlusions occur when features are not within line of sight of the laser scanner).

Figure 5. View from the central scan position of the terminal ice cliff and the subsequent point cloud.

Glacier Headwall:

The Riegl LMSZ620 TLS was additionally used to obtain an initial scan of the glacier headwall in June 2019. A second scan of the headwall during the October campaign will enable the application of a fully 3D change detection algorithm to be applied, where erosion and rockfall events will be quantified and a short-term headwall erosion rate obtained for the 2019 ablation season. Weather limitations meant that the initial attempt on 15th October was unsuccessful (Figure 6), however a second attempt on 18th October was successful (Figure 7). Conditions overall were not ideal due to recent unexpected snowfall covering the glacier headwall.

Figure 6. Onset of snow for initial headwall attempt (first image). Ideal conditions for headwall scanning on the second attempt (second image).

Figure 7. Headwall scan point cloud (18th October). Point distances range from 1 m (reds), to 2,000 m (blues).

This headwall scan will be cleaned (removing some snow and any vegetation on moraines) and aligned with the June 2019 scan in Riegl RiScan Pro. We plan to use CloudCompare and a 3D

change detection algorithm – M3C2, to difference the two scans. This will provide us with the first short-term, catchment-wide assessment of debris supply to a Himalayan glacier.

Figure 8. Headwall of Glacier 24K, with Terrestrial Laser Scanner in the foreground.


Figure 9. Aerial view of Glacier 24K, with lower headwall visible in the distance. Upper headwall is blanketed in cloud, it remained like this for most of the field campaign, providing difficult scanning conditions.

9 - Any other relevant comments (permits, liaison officer, etc):

Scientific work in Tibet is difficult due to strict permitting from the Chinese government. In order to enter Lhasa, the necessary permissions were organised by Chinese colleagues from the Institute of the Tibetan Plataeu (ITP) (Dr Yang Wei, and Chuan Xi Zhao). Further to this, in order to leave Lhasa, permissions were gained from the local authority (by Chuan Xi Zhao), and in every town/ province we stayed permissions from the local police had to be obtained. There were no issues with this process.

The **Final Report** should include all the information from the **Summary Report,** plus the following information:

A. A sketch map of the area, and a photography showing the line of your route(s)

See figures above for details of the area and figure 10 below.

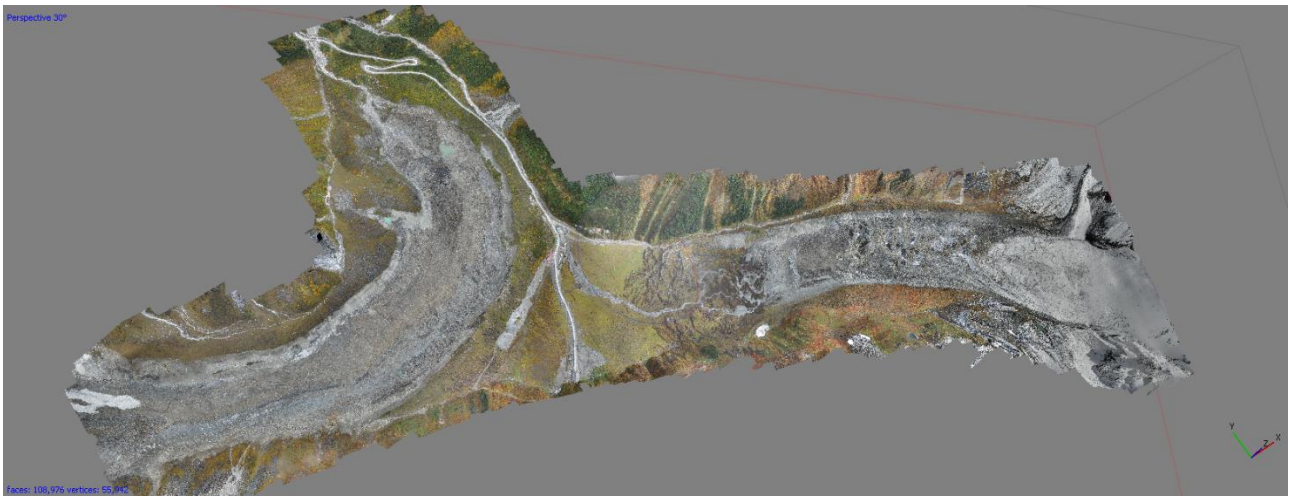

Figure 10. Orthophoto produced from drone-based structure from motion.

B. Photographs of glaciers for comparison with past and future pictures

See section ‘Visible changes since June 2019’ and the orthophoto of Glacier 24K.

C. Observations on the accuracy, or otherwise, of Google Earth images

There are no problems with the accuracy of Google Earth images.

D. Suggestions for new routes or new subjects for study in the area

As this was not a climbing expedition no new routes were observed. Future scientific study of glacier headwall erosion should be a focus as this is a self-contained catchment where different sediment sources can be identified, quantified and monitored. We also recommend further study of Glacier 24K for understanding debris-covered glacier processes.

E. Notes on access, porters, or other issues of interest to future visitors

See section 9 above for permitting comments. Access to the glacier is possible via several routes either directly onto the terminus or traversing and descending the lateral moraine. This is easily possible with care, especially in wet weather.

F. Details of any injury or illness to expedition members and/or porters

There were no injuries or illness during the fieldwork.

G. Details of waste disposal

We stayed at Hotel Shan Xia where they have their own waste disposal system which we used during the trip. Any waste produced in the field was carried out and disposed of at the hotel. All equipment was removed from the glacier, including GCP cloth targets for the drone flights. Any equipment left on glacier was with the permission of the local monk and our Chinese colleagues (i.e. timelapse cameras).

H. A summary of expedition accounts, including income and expenditure

Expense	**Cost (£)**	**Income (£)**
Return flights to Chengdu	465.30	
Return flights to Tibet	380.43	
Excess Air China baggage	108.22	
Mt Everest Foundation		825.00
Total	**953.95**	**825.00**

Table 1. Expenses for expedition. Costs which exceeded income provided by the Mount Everest Foundation were covered by funds awarded to PhD co-supervisor F. Pellicciotti via a Royal Society Newton Advanced Fellowship.