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Topographical survey of July 1st Glacier in Qilian Mountains, China

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Abstract

In order to evaluate recent glacier shrinkage in the arid region of China, surveys using a global positioning system (GPS) and digital theodolite with laser distance meter were carried out on the July 1st glacier in the Qilian Mountains from 2002 to 2005. Benchmarks and stakes on around the glacier were installed in 2002. A new 2002 map was carefully superposed on a map created in 1975 using a salient moraine ridge and boundary of the accumulation area, since no ground control point was available in the old 1975 map. A retreat of the glacier termini has been detectable since 1956 with a notable retreat occurring between 2002 and 2003. Surface flow velocities were obtained by repeated measurements of a stake network. The new map and benchmarks provide basic information for future survey studies.

1. Introduction

Water from glaciers is significant as water reservoirs, especially in the arid inland regions of China such as the Taklimakan and Gobi Deserts (Kang *et al.,* 1999). The Qilian Mountains are located on the northern fringe of the Tibetan Plateau (Fig. 1) and hold 2815 glaciers, occupying about 1930 km^2 (Tsvetkov *et al.,* 1998). Glacier meltwater and more abundant precipitation in the mountains supply a fair amount of water to oases scattered across the huge desert area, where the scant precipitation cannot support human inhabitants (Ding and Kang, 1985; Kang *et al.,* 1999; Wang and Chen, 1999). The river discharge into the desert region has been analyzed and estimated in the context of warming on the Tibetan Plateau (Kang *et al.,* 1992; 1999; Ye *et al.,* 1999; 2003; Liu and Chen, 2000; Liu *et al.,* 2003). They concluded that the glacier shrinkage derived from warming would increase water discharge briefly since the glaciers lost their ice body as redundant water. The amount of additional water and its persistent duration would depend on the scale, dynamics and change in mass balance of the glaciers.

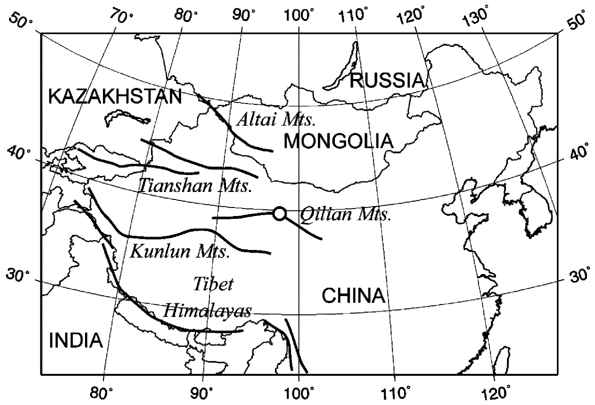

Fig. 1. Location of July 1st glacier in Qilian Mountains (open circle).

Determining fluctuations in a glacier is significant, therefore, in evaluating its historical and future discharge together with its contribution to human lives in a desert area.

The July 1st Glacier is located in the western region of the Qilian Mountains (39°15′N, 97°45′E, Fig. 2). A map of the glacier based on aerial photographs was made in 1975 (Xie *et al.,* 1985a; included in Shi, 1988). The length and area of the glacier in 1975 were 3.8 km and 2.98 km^2, respectively (Liu *et al.,* 1992). Based on that initial map, the thickness using the gravitational method (Su, 1985) and the glacier surface flow between 1976 and 1977 (Sun and Huang, 1985) have been measured. In 1985, various studies such as a resurvey around the ablation area (Liu *et al.,* 1992), glacier flow between 1984 and 1985 (Song *et al.,* 1992), and internal ice temperature (Xie *et al.,* 1985b) have been carried out. In order to determine the recent condition of the glacier, we started meteorological, hydrological and glaciological observations in 2002. Preliminary results on meteorology (Sakai *et al.,* 2006 a), glacial discharge (Sakai *et al.,* 2006b), and mass balance of the glacier (Matsuda *et al.,* 2004) were reported. Here summarize the preliminary results of a survey in this report.

2. Survey of July 1st Glacier

Surveys by the differential Global Positioning System (GPS, CMC Co., Ltd. All Star) and a digital theodolite with laser distance meter (SOKIA SET2100) have been carried out on/around the July 1st glacier since June 2002, as summarized in Table 1. Data processing of GPS measurements was performed using

Fig. 2. Photograph of July 1st glacier from the north (2 September 2003).

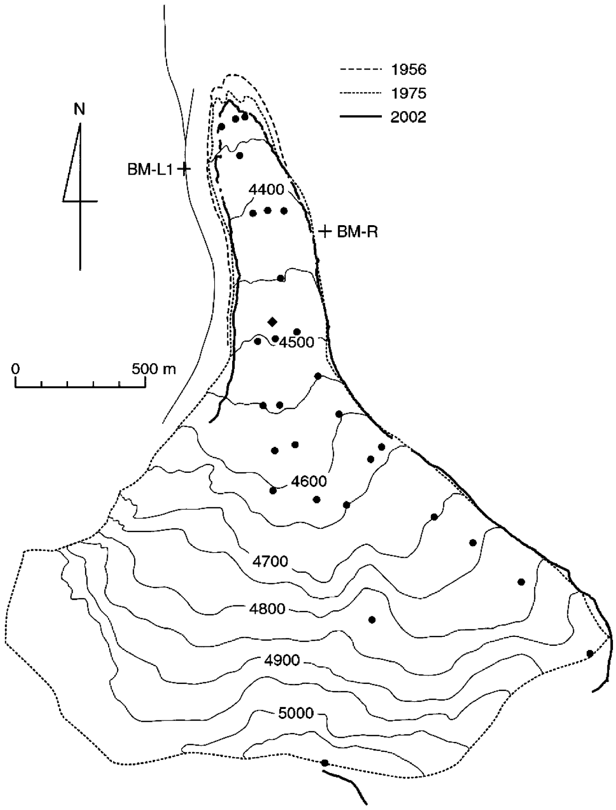

Fig. 3. Map of July 1st glacier. Crosses denote the benchmarks installed in 2002 (BM-L1 and BM-R). Glacier boundaries in 1956 and 1975, contour lines and moraine ridge of left bank are traced from a original map surveyed in 1975 (Xie *et al.,* 1985a). Boundary of 2002 is drawn from GPS data. Dots denote stakes installed in 2002 for mass balance and surface flow measurements. Rhombus denotes a rock on the glacier.

Table 1. Surveys on/around the July 1st glacier since 2002. TS in method denotes a digital theodolite with laser distance survey.

Season	Method	Observers	Markers
June 15–20, 2002	GPS	KF	Boundaries, stakes, side moraines
Aug. 31–Sep. 7, 2002	GPS	YM	Stakes
Aug. 15–Sep. 13, 2003	TS	AS, WX, NN	Stakes, terminus
June 14–16, 2004	TS	AS, WX	Stakes, terminus
July 27–29, 2004	GPS	KF	Glacier, end moraine
Aug. 31–Sep. 2, 2004	TS	AS, WX, CN	Stakes, terminus
Sep. 5, 2004	GPS	CN	End moraine
June 26–July 5, 2005	GPS	KH	Terminus, end moraine
June 27, 2005	TS	SY, KH	Stakes

Abbreviations for observers: KF, Koji Fujita; YM, Yoshihiro Matsuda; AS, Akiko Sakai; WX, Wang Xinming; NN, Nozomu Naito; CN, Chiyuki Narama; KH, Kuniharu Hiyama; SY, Satoru Yamaguchi.

Table 2. Locations of benchmarks and a rock on the glacier in the Universal Transverse Mercator (UTM) coordinate and the geodetic coordinate with WGS84 (last line for BM-L1).

Object	Northing	Easting	Altitude	Date
BM-L1	4345382.20	392107.74	4348.00	—
BM-R	4345926.03	391867.07	4388.75	—
Rock	4345722.78	391516.92	4443.84	2 Sep. 2004
BM-L1	39°15′4.157″	97°44′57.922″	4348.00	—

Units of UTM coordinate and altitude are in meters.

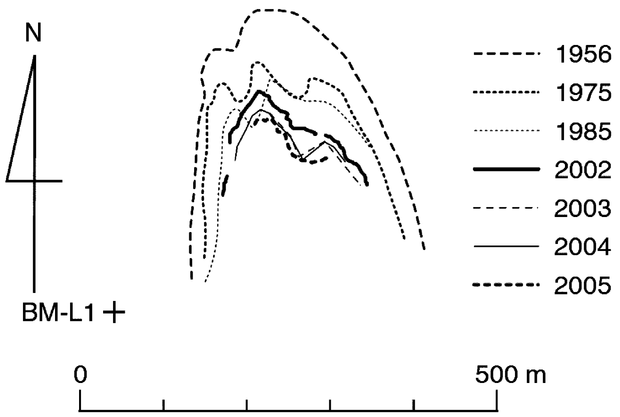

Fig. 4. Change in the terminus of July 1st glacier since 1956. Cross denotes the benchmark (BM-L1).

GrafNav and GrafNet software (Waypoint). Relative positions of all points were calculated on a system of coordinates with their origin at the benchmark on the left bank moraine (BM-L1). Benchmarks, stakes, and glacier boundaries are shown in Fig. 3. Locations of benchmarks and a rock on the glacier are shown in Table 2 on the Universal Transverse Mercator coordinate with WGS84. The position of BM-L1 was obtained as an average of a measurements repeated several times, since absolute positions cannot be reliably measured by the GPS system. A rock located in the mid-ablation area (solid rhombus in Figs. 3 and 5) serves as a significant marker on the glacier, and its location will provide useful information for future surveys.

Measurement errors in the survey were evaluated by comparing the positions of the 5 benchmarks (considered to be immovable) installed around the glacier. Standard deviations of differences (32 measurements) from the averages were obtained as measurement errors. Horizontal and vertical errors were within 0.07 and 0.12 m, respectively.

Figure 3 also shows the boundaries of the glacier in 1956, 1975, and 1985 (Xie *et al.,* 1985a; Liu *et al.,* 1992). Contour lines are those of 1975 (Xie *et al.,* 1985a). Surveyed data were carefully superposed on the previous maps by matching the glacier boundaries of the accumulation area and moraine ridge, since no ground control point was available from the previous maps. A retreat history of the terminus since 1956 is shown in Fig. 4. Retreat distances and rates of the terminus are summarized in Table 3. Dividing the ablated area by the width around the terminus gives the retreat distance. Both the area and width are obtained from a detailed map (Fig. 4). A remarkable retreat between 2002 and 2003 was considered to be due to drastic melting in the summer of 2002. This phenomenon was suggested by Sakai *et al.* (2006a) based on the meteorological data.

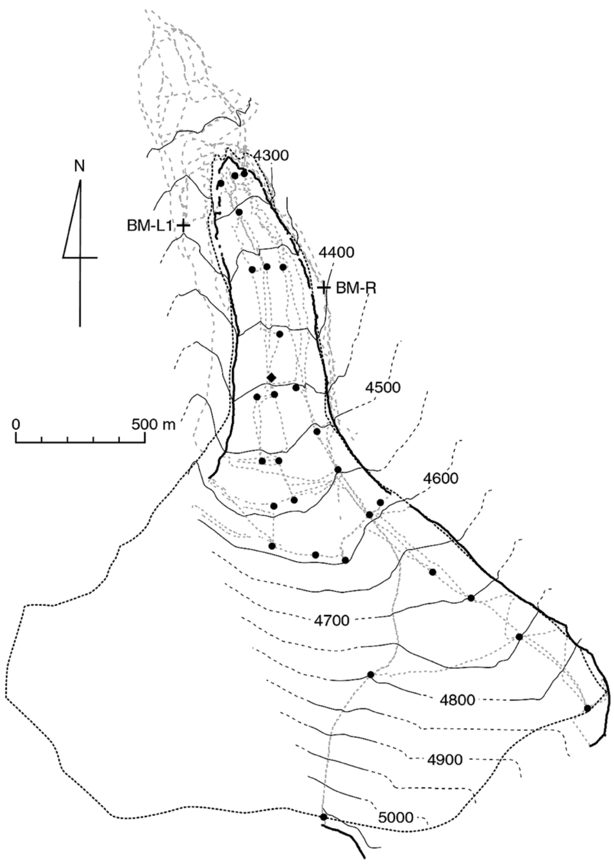

Fig. 5. New map of July 1st Glacier. All GPS traces on the glacier (gray dotted lines) and the end/side moraines (gray broken lines) are used for drawing contour lines (thin lines). Thick solid and dotted lines denote the boundary of the glacier in 2002 and 1975, respectively.

A new map of the glacier was drawn based on all the measurement data (Fig. 5). Elevation of the glacier

Table 3. Retreat distance and rate of the termini of July 1st Glacier since 1956.

Year	Duration (yr)	Retreat distance (m)	Retreat rate ($m\ yr^{-1}$)
1956			
	19	68.3	3.6
1975			
	10	26.4	2.6
1985			
	17	25.9	1.5
2002			
	1	20.1	20.1
2003			
	1	0.0	0.0
2004			
	1	5.9	5.9
2005			

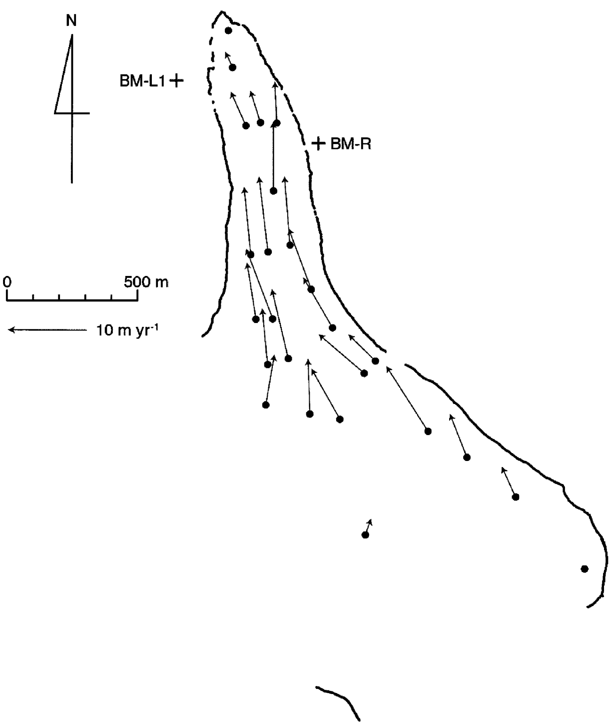

Fig. 6. Surface flow velocities of July 1st glacier between 2004 and 2005. Circles denote original positions of stakes installed in 2002.

surface in the 2000s was lower by about 50 m than that in 1975, a difference apparently due to an elevation of the benchmark that was determined by only a single GPS measurement (Table 2). We cannot naively compare altitudinal changes between the new and previous maps since no ground control point was available from the older maps (Xie *et al.,* 1985a; Liu *et al.,* 1992). Sakai *et al.* (2006c) analyzed the surface lowering of the glacier by comparing the end and side moraines, and concluded that the surface thinning was about 30 m in the ablation area and had changed little in the accumulation area since 1975. Although the location determined by a single GPS survey will vary widely with each measurement, the relative elevation from the benchmarks shown in Table 2 should be comparable in future surveys. This map and the benchmark locations, therefore, will provide basic information for future studies of fluctuations in the glacier. A detailed map of the area around the end moraine will be analyzed elsewhere in order to evaluate the shrinkage of the glacier since the Little Ice Age.

Surface flow velocities were obtained by comparing the locations of stakes (Fig. 6). Decreasing surface speeds since the 1970s are explainable by thinning of the glacier ice (Sakai *et al.,* 2006c). Seasonal changes in the surface flow speed, ice temperature, and thickness of the glacier will be analyzed elsewhere.

Acknowledgments

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