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

Koji FUJITA, Akiko SAKAI, Yoshihiro MATSUDA, Chiyuki NARAMA, Nozomu NAITO, Satoru YAMAGUCHI, Kuniharu HIYAMA, Jiancheng PU, Tandong YAO and Masayoshi NAKAWO

1 Graduate School of Environmental Studies, Nagoya University, Nagoya 464-8601, Japan
2 Department of Environmental Information, Hiroshima Institute of Technology, Hiroshima 731-5193, Japan
3 Nagaoka Institute of Snow and Ice Studies, National Research Institute for Earth Science and Disaster Prevention, Nagaoka 940-0821, Japan
4 Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Science, Lanzhou 730000, China
5 Institute of Tibetan Plateau Research, Chinese Academy of Sciences, P.O. Box 2871, Beijing 100085, China
6 Research Institute for Humanity and Nature, Kyoto 602-0878, Japan

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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 km² (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.

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,
The length and area of the glacier in 1975 were 3.8 km and 2.98 km², 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., 1995b) 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 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

![Photograph of July 1st glacier from the north (2 September 2003).](image)

![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 an 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.](image)

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

Abbreviations for observers: KF, Koji Fujita; YM, Yoshihiro Matsuda; AS, Akiko Sakai; WX, Wang Xunming; NN, Nozomu Naito; CN, Chiyuki Narama; KH, Kuniharu Hiyama; SY, Satoru Yamaguchi.
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-L+). Benchmarks, stakes, and glacier boundaries are shown in Fig. 2. Locations of benchmarks and a rock on the glacier are shown in Table 2 on the Universal Transverse Mercator coordinate with WGS2. The position of BM-L+ was obtained as an average of 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. 2 and 3) 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.

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

### 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).

<table>
<thead>
<tr>
<th>Object</th>
<th>Northing</th>
<th>Easting</th>
<th>Altitude</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM-L1</td>
<td>4345382.20</td>
<td>392107.74</td>
<td>4348.00</td>
<td></td>
</tr>
<tr>
<td>BM-R</td>
<td>4345926.03</td>
<td>391867.07</td>
<td>4388.75</td>
<td></td>
</tr>
<tr>
<td>Rock</td>
<td>4345722.78</td>
<td>391516.92</td>
<td>4443.84</td>
<td>2 Sep. 2004</td>
</tr>
<tr>
<td>BM-L1</td>
<td>39°15’4.157”</td>
<td>97°44’57.922”</td>
<td>4348.00</td>
<td></td>
</tr>
</tbody>
</table>

Units of UTM coordinate and altitude are in meters.
accumulation area since m in the ablation area and had changed little in the
Sakai et al. and concluded that the surface thinning was about the glacier by comparing the end and side moraines, surface in the pare altitudinal changes between the new and previ-
ous watersheds of inland river basins in the arid area of northwest China to climatic changes. Science in China, Series D, 42, 52–63.
Matsuda, Y., Sakai, A., Fujita, K., Nakawo, M., Duan, K., Pu J. and Yao, T. (2004): Glaciological observations on July 1st glacier in Qilian Mountains of west China during sum-
Sakai A., Fujita, K., Duan, K., Pu, J., Nakawo, M. and Yao, T. (2006c): Five decades of shrinkage of the July 1st Glacier,
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 ana-
yzed 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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