Bulletin of Glacier Research 5 (1987) *111–114*

Characteristics of discharge from a glacier, observed in West Kunlun Mountains, China

Masayoshi Nakawo[1] and Okitsugu Watanabe[2]

1 Department of Applied Physics, Faculty of Engineering, Hokkaido University, Sapporo 060 Japan
2 National Institute of Polar Research, Itabashi, Tokyo 173 Japan

(Received Dcecmber 19, 1986 ; Revised manuscript received January 19, 1987)

Abstract

The discharge of a small stream from a glacier was observed on the south slope of the West Kunlun Mountains. It decreased from morning to afternoon, and finally the stream ended near the observation site, forming a water tongue. Its location retreated upstream toward the end of the day, corresponding with the subsequent decrease in discharge. The peak runoff was at night, and the time lag was very large for the short distance between the glacier and the observation site. The long time lag was considered mainly due to the relative importance of subsurface water flow for discharge of glacier melt water.

1. Introduction

Many glaciers are developed in the Kunlun Mountains (Zhang and Jiao, 1987), which, however, are surrounded by vast arid areas such as the Taklamakan Desert. The discharges from those glaciers irrigate, as a major water source, many oases distributed around the southern edge of the desert. The characteristics of the discharge from the mountain glaciers, hence, are of great importance for the lives of those people who live in the desert.

Reconnaissance investigations were carried out on glaciers of the West Kunlun Mountains by a Sino–Japanese joint party in July, 1985 (Watanabe and Zheng, 1987). The field study period was rather short, but information was obtained for a comprehensive joint future expedition.

This paper presents the results of a preliminary study of the discharge from one of the glaciers, and briefly describes its characteristics in the dry area.

2. Meteorological conditions

The reconnaissance party stayed in the mountains for about 10 days, from July 21 to 29, 1985. Two camp sites were chosen for the first and second halves of the observation period.

Every 1 to 2 hours, meteorological variables were observed during the daytime, such as temperature, humidity, wind speed, wind direction, solar radiation, and cloud condition. Observations were not made at night.

Figure 1 shows air temperature and humidity variations, as measured by a ventilated psychrometer. The measurements were made at an elevation of 5112 m a.s.l. before July 24, and at 5790 m a.s.l. starting 25 July. The general decreasing trend of air temperature is mainly attributed to the difference in observation site elevation. Simultaneous measurements of air temperature at different elevations indicated that the lapse rate was 1.05°C/100m, almost the dry adiabatic rate (Fig. 2). Taking into account the lapse rate and the elevation difference of the two sites, the air temperature was rather stable during the observation period : −3 to 15°C at 5112 m or −8 to 10°C at 5790 m.

Relative humidity was about 50 to60 % on the average during the daytime in the first period. This value is not surprising, but the shortage of water vapor is significant, taking into account the rather high air temperature. The humidity became larger

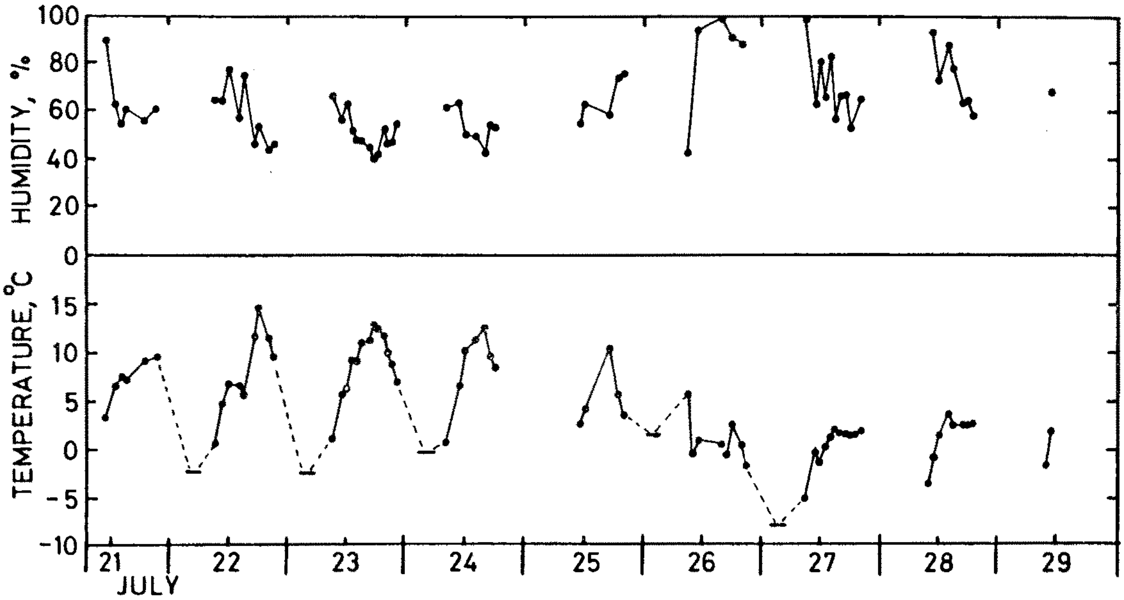

Fig. 1. Air temperature and relative humidity during the observation period. Horizontal dashes show the minimum temperature each night. The observation site elevations were 5122 m for July 21 to 24, and 5790 m for 25 to 29, 1985.

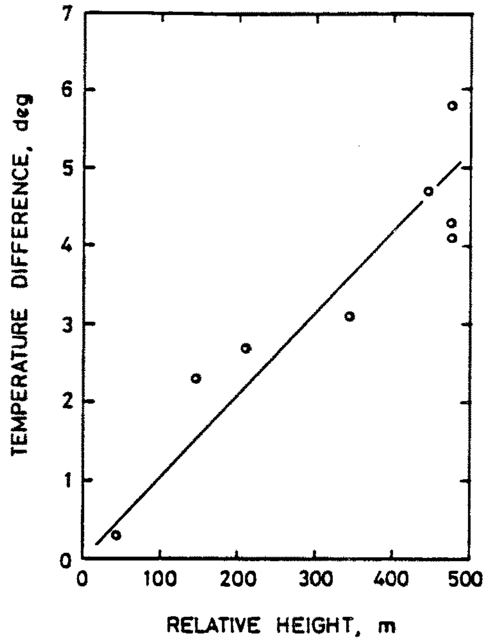

Fig. 2. Temperatures at different elevations. The linear least square fit gave the lapse rate 1.05°C/100 m.

at the second camp site, where a glacier tongue was very close.

Solar radiation was very strong in the area. It reached 1 kW/m^2, with no clouds, at around noon Local Mean Time, which lagged behind Chinese Standard Time by about 2.5 hours.

It snowed twice during the 10 days, with total precipitation of more than 10 mm. This amount is large in comparison with the precipitation recorded at meteorological stations near the mountains (Zhang and Jiao, 1987).

3. Discharge

Discharge observations were carried out on July 23 to 24 on a small stream running by the first camp-

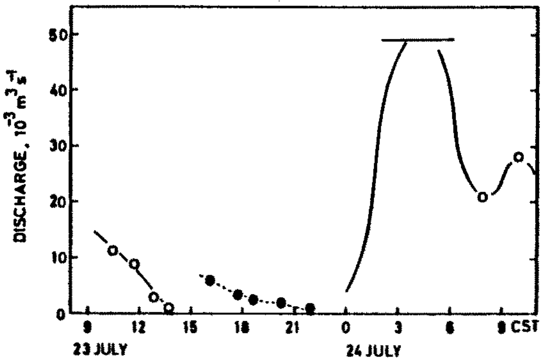

Fig. 3. Time variation of discharge. Open and solid circles show the discharges at site A and B respectively. Horizontal bar indicates the discharge during the night estimated from the level of surface ice found the following morning.

site. The stream, with a slope of about 0.67 degree (1.17 %, was from a glacier located 4 km upstream fom the observation site (site A).

Figure 3 shows the time variation of discharge, which decreased gradually from 10 a.m. to 2 p.m. At about 3 p.m., the stream was dried up, forming a water tongue several meters upstream from observation site A. The discharge was measured, therefore, at another site (site B) 100 m upstream from the previous site.

The discharge at site B also decreased from 4 p.m. to 10 p.m. Consequently, the location of the water tongue (the terminus of the stream) retreated gradually as shown in Fig. 4, although a slight advance was observed at about 20 minutes to 6 p.m.

On the morning of July 24, the stream was frozen at its surface, under which a discharge of about $20 \times 10^{-3} m^3 s^{-1}$ was observed. It was not certain whether the upper ice surface was the maximum water level of the stream during the night. It is considered, however, the water must have been at least at the level indicated by the surface ice found the following morning. It was estimated, hence, that the maximum discharge took place during the night, and was at least $50 \times 10^{-3} m^3 s^{-1}$.

With increasing temperature and solar radiation, the surface ice melted progressively, and the discharge increased to $28 \times 10^{-3} m^3 s^{-1}$ at 10 a.m., when most of the surface ice disappeared. The time variation of discharge, therefore, exhibited two peaks in one day : one during the night and the other in the morning. The former represents the peak discharge, since the latter is mainly due to the effect of ice formation/deterioration.

The rate of melting at the source glacier was not measured. The meteorological data during July 23 indicated, however, that the melting would have been most pronounced at around noon LMT, *i.e.* 2 to 3 p.m. CST. This implies that the time lag in peak discharge was 10 to 15 hours. This value is much larger than the normal time lag of discharge (*e.g.* Nakawo *et al.*, 1976 ; Kobayashi, 1981) for the short distance between the glacier and the observation site (*ca.* 4 km).

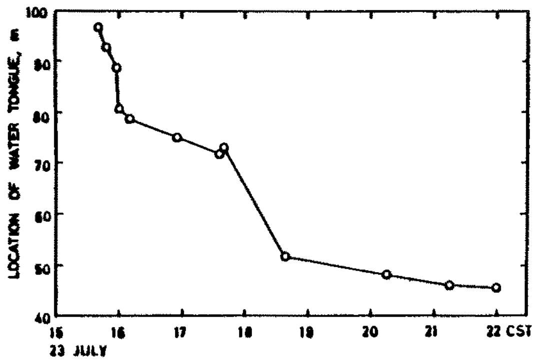

Fig. 4. Retreat of the water tongue in July 23.

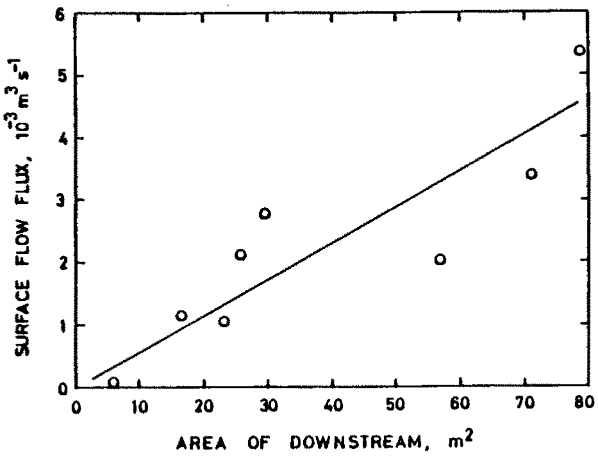

Fig. 5. Surface flow flux versus the area of the stream between the observation site and the stream terminus. The linear least square fit to the data gave a vertical water flow flux of 58×10^{-6} m s^{-1}.

4. Discussion

The presence of a water tongue implies that water is lost from the stream, moving vertically, *i.e.* evaporation from the top surface and/or infiltration into the ground soil through the bottom of the stream. The water tongue is formed where the incoming surface flow flux equals vertical losses toward the atmosphere /ground. The total surface flow at a given place of the stream should be lost, therefore, over the area of the stream from the observation site to its terminus.

In Fig. 5, the surface flow flux, measured at different locations and different times, is plotted against the area of the stream between the observation site and the terminus at corresponding times. They seem to show a positive correlation with each other. The straight line in the figure is the linear least square fit to the data. If the rate of evaporation and infiltration is independent of time and place, the slope of the line gives the rate of vertical move-

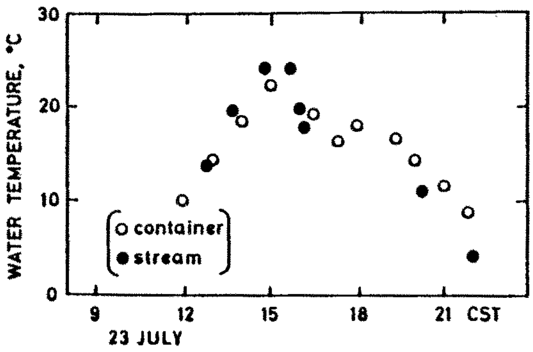

Fig. 6. Comparison of water temperatures in the container and of river water.

ment of water. The vertical flux was thus estimated to be 58×10^{-6}m s^{-1}.

A water–filled container was placed (half buried) on the ground, and the change of its water level was measured. The rate of evaporation thus estimated was about 0.4×10^{-6}m s^{-1} in average between 11 a.m. and 10 p.m., or about 15 mm/day. Since the water temperature in the container was almost equal to the river water temperature during the period (Fig. 6), the evaporation rate from the stream also would be similar to these values. Shrestha *et al*. (1976) observed an evaporation rate of about 3.5 mm/day in Hidden Valley, a dry area on the northern side of the Himalaya. In comparison, the evaporation rate in the Kunlun Mountains is surprisingly large.

The contribution of evaporation is about two orders of magnitude less than the total water loss from the stream. It is considered, hence, that most of the surface water flow went into the soil underneath. The ground water level is in the influent state, *i.e*. the water level is higher at the surface stream than the ground water level in the adjacent soil. The potential gradient would exist not only along the stream transversally but also at the water tongue toward downstream.

Unfortunatelly, the ground water level was not measured around the stream. No quantitative discussion, hence, will be given further, but the observation indicated that the subsurface flow was essential and significant for the mass balance of the river water. It is considered, therefore, the extraordinarily long time lag found in peak discharge is caused by divergence of the water through the river bed.

Acknowledgments

The authors are grateful to all the members of the reconnaissance party for their kind support in the field. This study was aided by a Grant–in–Aid for Scientific Research from Ministry of Education, Science and Culture, Japanese Government.

References

Kobayshi, D. (1981) : Time lag between the centroid of snowmelt and the peak runoff rate I. Low Temperature Sience, Ser. A, **40**, 61–66.

Nakawo, M., Fujii, Y. and Shrestha, M. L. (1976) : Water discharge of Rikha Samba Khola in Hidden Valley, Mukut Himal. Seppyo, Spec. Issue, **38**, 27–30.

Shrestha, M. L., Fujii, Y. and Nakawo, M. (1986) : Climate of Hidden Valley, Mukut Himal during monsoon in 1974. Seppyo, Spec. Issue, **38**, 105–108.

Watanabe, O. and Zheng Benxing (1987) : First glaciologicel expedition to West Kunlun Mountains 1985. Bulletin of Glacier Research, **5**, 77–84.

Zhang Zhenshuan and Jiao Keqin (1987) : Modern glaciers on the south slope of the West Kunlun Mountains (in Aksaiqin Lake and Guozha Co Lake drainage areas). Bulletin of Glacier Research, **5**, 85–91.