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Some Aspects of Mass Balance of the Xiao Dongkemadi Glacier in the Tanggula Mountains on the Tibetan Plateau, 1989～1994

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ABSTRACT Mass balance observations on the Xiao Dongkemadi Glacier have been continued since 1989 as a part of a Sino–Japanese joint study on the role of glaciers in the water cycle on the Tibetan Plateau. The area of the glacier is 1.8 km^2 and the equilibrium line altitude was around 5 600 m a.s.l. The glacier develops under a semi–arid continental climate. Variation of surface level has been measured with automatic snow depth gauges and stakes, and the growth of superimposed ice has been also measured. Annual balance of the Xiao Dongkemadi Glacier for the measurement years (from autumn to the next autumn) had both positive (1989 / 90, 1991 / 92, 1992 / 93) and negative years (1990 / 91, 1993 / 94); the annual balance was mainly controlled by the balance in summer. Gradients of annual balance against altitudes were nearly linear, and around 3 mm / m in the positive balance years while about 6～7 mm / m in the negative years. When the annual balance was negative, amounts of mass loss were quite high in comparison with mass gain in the positive years. Negative balance in the last year, 1993 / 94, especially showed the highest mass loss. There is a possibility that ablation of the glacier is accelerating.

KEYWORDS mass balance, balance gradient against altitude, glacier shrinkage

1 INTRODUCTION

Glaciological observations on the Xiao Dongkemadi Glacier in the Tanggula Mountains have been continued since May, 1989 as a part of the project on the role of snow and ice in the water cycle on the Tibetan Plateau. This project is a cooperative study between the Lanzhou Institute of Glaciology and Geocryology, Chinese Academy of Sciences, and the study group in Japanese universities(Institute for Hydrospheric–Atmospheric Sciences, Nagoya University and others). The outline of this project was described by Yao *et al.* (1991, 1993) and Ageta *et al.* (1994).

The results of mass balance study on the Xiao Dongkemadi Glacier were reported by Ageta *et al.* (1991), Pu and Yao (1993, 1994), Seko *et al.* (1994), Ageta and Fujita (1996) and Fujita *et al.* (1996). Some aspects of mass balance of this glacier are described in the present paper on the basis of observational results during the period from 1989 to 1994.

2 OBSERVATIONAL RESULTS

Location of the Tanggula Mountains and a map of the Xiao Dongkemadi Glacier is shown in Fig. 1 and 2. This glacier has been observed as a representative glacier in the Tanggula Mountains developed in a semi–arid continental climate. The highest and the lowest altitudes, the length and the area of the glacier are 5 926 m, 5 380 m, 2.8 km and 1.8 km^2, respectively.

Observed sites of automatic snow depth gauges of two types, which record the glacier surface level using photo diode sensors or glass–fibre sensors, and stakes for mass balance measurement are shown in Fig. 2.

Variation of the glacier surface level for a long

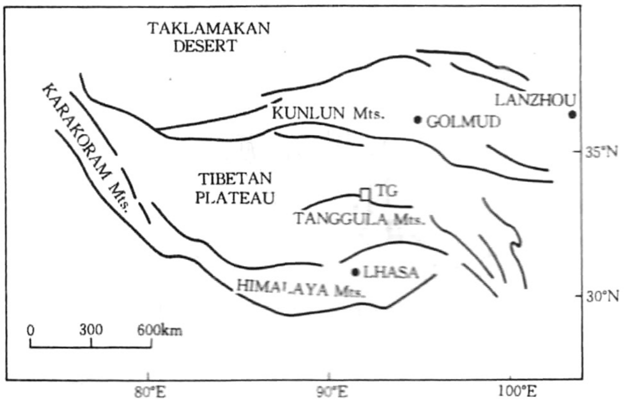

Fig. 1 Location map of the Tanggula Mountains on the Tibetan Plateau. The Xiao Dongkemadi Glacier is located in the open square denoted with TG

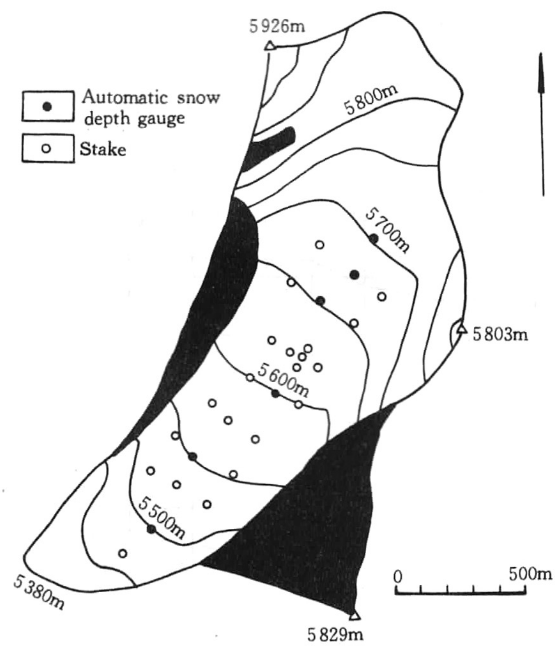

Fig. 2 Map of the Xiao Dongkemadi Glacier and observed sites on the glacier

period has been recorded automatically at Site 3–2, 5 600 m a.s.l.(near the usual equilibrium line altitude as mentioned later) since the end of May, 1989 as shown in Fig. 3. The surface level changed in a range of ± 80 cm from the beginning of the measurement with a distinct minimum level at the end of August, every year. The measurement year of mass balance for this glacier is defined from the beginning of autumn to the end of next summer, since the glacier surface level reaches its minimum usually at the end of August in each annual cycle (Seko *et al.*, 1994). Due to high ablation since the summer in 1994, the gauge had fallen down when visited in June, 1995. The remarkable level down of 154 cm during the period from June 8 (the end of record in Fig. 3) to October 22, 1994 was measured from the change of stake height.

Stake height and snow cover thickness above ice surface at each site on the glacier was measured in September or October for every year and May or June for some years. From these observations, the variations of snow surface level and ice surface level beneath snow cover at main sites are shown in Fig. 4 for the five measurement years. Snow surface positions in September, 1989 in Fig. 4 correspond to the altitude at each site along the left vertical axis, and amounts of level up and down for each succeeding observation period are shown according the scale of level which is indicated in the figure. Vertical solid lines in the figure which indicate the measurement dates in autumn correspond roughly to the beginning / end of the measurement years.

The following matters can be seen from Fig. 4. The upward change of ice surface level is caused by growth of superimposed ice; that is distinct at higher altitudes and in summer (excluding 1994). The important role of superimposed ice in mass balance of this glacier is described in detail by Fujita *et al.* (1996). The level variations of snow and ice surfaces at different altitudes are nearly parallel but show an altitudinal difference of mass balance. Although Fig. 4 does not directly show mass balance, it can be seen from this figure that annual balance for the whole glacier was clearly negative in the measurement years of 1990 / 91 and 1993 / 94, and was positive in the other three years; the annual balance is mainly controlled by the balance in summer. The altitude of 5 600 m at Site 3–2 corresponds to the equilibrium line altitude on an average for the four years excluding the measurement year of 1993 / 94.

Annual balance at each site for the four measurement years from 1990 / 91 to 1993 / 94 was calculated from the change of snow surface and ice surface levels with densities of snow and ice, 350 and 850 kg / m^3, respectively. And their altitudinal distribution is shown in Fig. 5. The period of each measurement year started and ended roughly at the beginning of

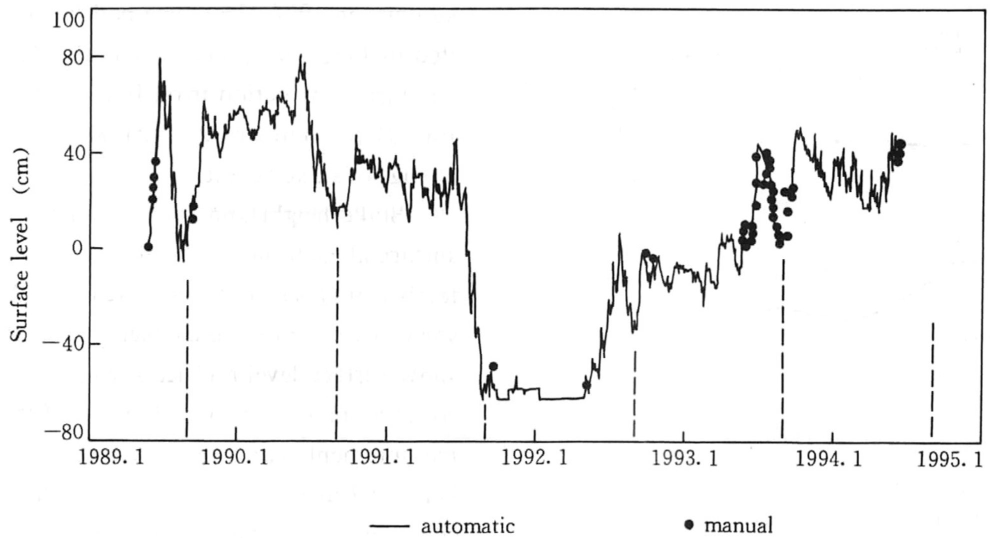

Fig. 3 Variation of surface level at 5 600 m a.s.l. on the Xiao Dongkemadi Glacier from May, 1989 to June, 1994 measured with an automatic snow depth gauge (solid circle: stake data, dashed line: the end of August)

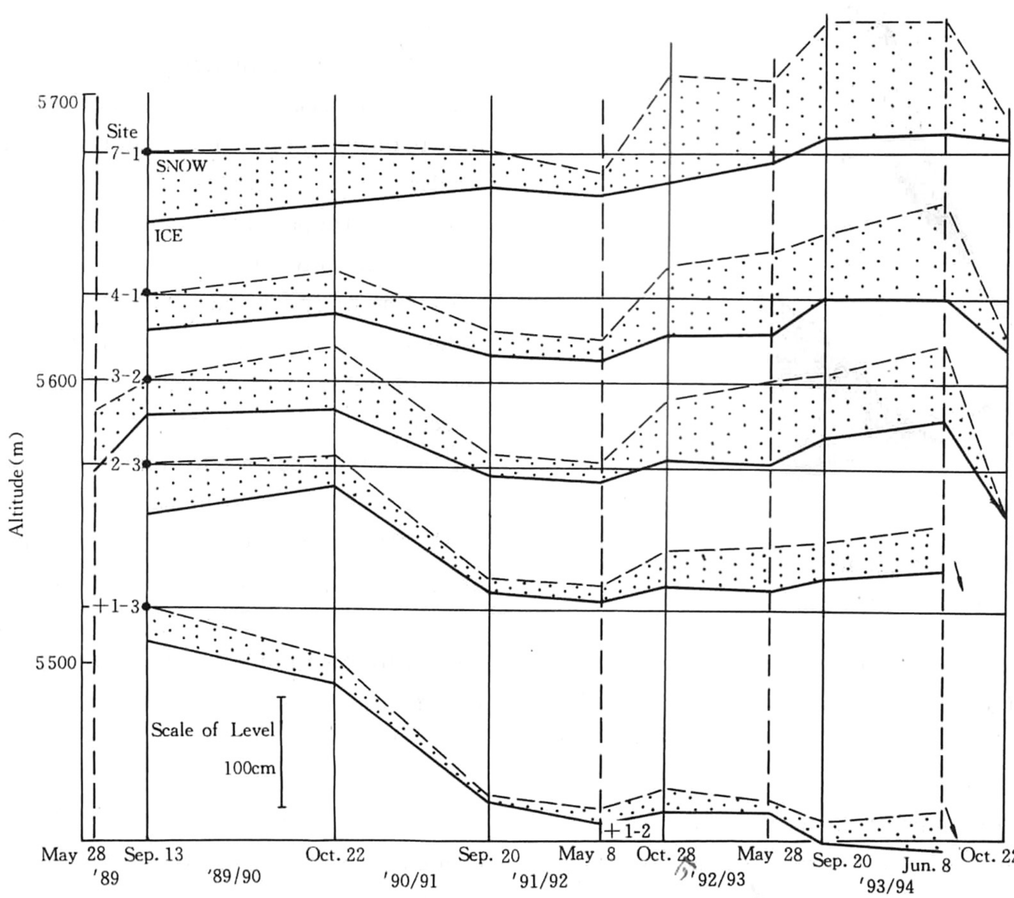

Fig. 4 Variations of snow suface level (dashed line) and ice surface level(solid line) of the Xiao Dongkemadi Glacier for five meaurement years (Vertical width of dotted parts show snow thickness with the scale of level)

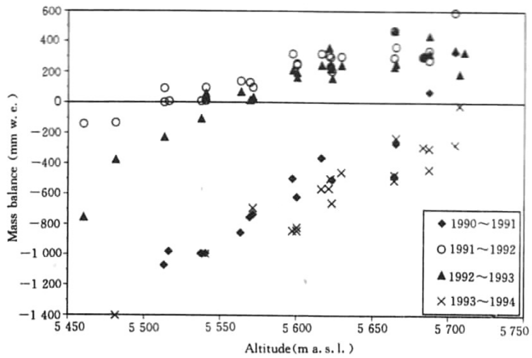

Fig. 5 Altitudinal distribution of annual balance (water equivalent) of the Xiao Dongkemadi Glacier for four measurement years from 1990 / 91 to 1993 / 94

every autumn as indicated in Fig. 4. It can be seen from Fig. 5 that annual balance for the whole glacier in the measurement years of 1991 / 92 and 1992 / 93 was positive, and that of 1990 / 91 and 1993 / 94 was distinctly negative as mentioned in Fig. 4.

Especially for the year of 1993 / 94, almost the whole area of the glacier became the ablation area.

As seen in Fig. 5, gradients of annual balance against altitudes were nearly linear every year, excluding the lowest part in the year of 1992 / 93. Those in the two years with positive balance were similar and those in the other two years with negative balance were also similar, but were different between the positive years and the negative years. The former were around 3 mm / m, while the latter were around 6~7 mm / m, about two times of those in the positive years.

3 CONCLUDING REMARKS

During the period from 1989 to 1994, it was observed that annual balance of the Xiao Dongkemadi Glacier had both positive and negative years. Gradients of annual balance against altitudes were high in the negative balance years. When the annual balance was negative, amounts of mass loss were quite high in comparison with those of mass gain in the positive years. Negative balance in the last year, 1993 / 94, especially showed the highest mass loss and the balance during the succeeding winter in 1994 / 95, which was observed in June 1995, was negative even at the upper part of the glacier. Therefore, there is a possibility that ablation of the glacier is accelerating.

The above tendency of glacier shrinkage was reported on small glaciers in the Nepal Himalayas by Yamada *et al.*(1992) and Kadota *et al.*(1993). At present, monitoring of the variation of glacier mass balance is continuing as a joint study between China, Nepal and Japan along the north–south line from the East Kunlun Mts. and the Tanggula Mts. on the Tibetan Plateau to the Nepal Himalayas. Comparative study of the monitoring results on these glaciers is important.

REFERENCES

Ageta, Y., Yao Tandong, Jiao Keqin, Pu Jianchen, Shao Wenzhang, S. Iwata, H. Ohno and T. Furukawa. 1991. Glaciological studies on Qingzang Plateau, 1989, Part 2: Glaciology and geomorphology. *Bulletin of Glacier Research*, 9: 27~32.

Ageta, Y., Yao Tandong and T. Ohata. 1994. Outline of the study project on the role of snow and ice in the water cycle on Qingzang Plateau, 1990~ 1993. *Bulletin of Glacier Research*, 12: 87~94.

Ageta, Y. and K. Fujita. 1996. Characteristics of mass balance of summer–accumulation type glaciers in the Himalayas and Tibetan Plateau. *Zeitschrift fur Gletscherkunde und Glazialgeologie*, 32: 61~65.

Fujita, K., K. Seko, Y. Ageta, Pu Jianchen, Yao Tandong. 1996. Superimposed ice in glacier mass balance on the Tibetan Plateau. *Journal of Glaciology*, **42**(142): 454~460.

Kadota, T., K. Seko and Y. Ageta. 1993. Shrinkage of Glacier AX010 since 1978, Shorong Himal, East Nepal. *Snow and Glacier Hydrology* (*proceedings of the Kathmandu Symposium*, November 1992), IAHS Publ., No. 218: 145~154.

Pu Jianchen and Yao Tandong. 1993. Study on mass balance of Small Dongkemadi Glacier . In: *Glaciological Climate and Environment on Qing–Zang Plateau* (*The China–Japan Joint Glaciological Expedition to Qing–Zang Plateau, 1989*). Beijing, Science Press, 60~68. (In Chinese with English abstract)

Pu Jianchen and Yao Tandong. 1994. Mass balance of glaciers in the East Kunlun and Tanggula Mountains, Tibetan Plateau. *Bulletin of Glacier Research*, 12: 105~107.

Seko, K., Pu Jianchen, K. Fujita, Y. Ageta, T. Ohata and Yao Tandong. 1994. Glaciological observations in the Tanggula Mts., Tibetan Plateau. *Bulletin of Glacier Research*, 12: 57~67.

Yamada, T., T. Shiraiwa, H. Iida, T. Kadota, T. Watanabe, B. Rana, Y. Ageta and H. Fushimi. 1992. Fluctuations of the glaciers from the 1970s to 1989 in the Khumbu, Shorong and Langtang regions, Nepal Himalayas. *Bulletin of Glacier Research*, 10: 11~19.

Yao Tandong, Y. Ageta and T. Ohata. 1991. Glaciological studies on Qingzang Plateau, 1989, Part 1: Outline of the project. *Bull* *etin of Glacier Research*, 9: 23～26.

Yao T., Y. Ageta, T. Ohata, Jiao Keqin, Shao Wenzhang, Ding Liangfu and Pu Jianchen. 1993. Preliminary results from China–Japan Glaciological Expedition in Qing–Zang (Tibet) Plateau, 1989. In: *Glaciological climate and environment on Qing–Zang Plateau* (*The China–Japan Joint Glaciological Expedition to Qing–Zang Plateau, 1989*). Beijing, Science Press, 1～7. (In Chinese with English abstract)

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