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CHARACTERISTICS OF MASS BALANCE OF SUMMER-ACCUMULATION TYPE GLACIERS IN THE HIMALAYAS AND TIBETAN PLATEAU

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With 4 figures

ABSTRACT

Most of the annual accumulation and ablation occur simultaneously in summer on the Himalayan and Tibetan glaciers. The time of minimum mass in the annual variation cycle of mass balance for such "summer-accumulation type glacier" in the Nepal Himalaya changes sensitively depending on air temperature. On a glacier in Tanggula Mountains, Tibet, the time of the lowest surface level in the annual variation cycle is found at the end of August in every year. However, the time of minimum mass in the annual variation is not distinct due to contribution of superimposed ice formation to mass balance. Consequently, "fixed date system" has more generality in the definitions of mass balance terms than "stratigraphic system" which is based on distinct identification of "summer" and "winter". A monitoring method of accumulation and ablation variations for summer-accumulation type glaciers is mentioned.

MASSENBILANZ VON GLETSCHERN MIT SOMMERAKKUMULATION IM HIMALAYA UND IN TIBET

ZUSAMMENFASSUNG

Auf den Gletschern des Himalaya und in Tibet findet der Großteil der jährlichen Akkumulation und Ablation zur gleichen Zeit im Sommer statt. Die Zeit der geringsten Masse im Massenbilanzjahreszyklus eines solchen „Summer-accumulation type glacier" im nepalesischen Himalaya verändert sich mit der Lufttemperatur. Auf einem Gletscher im Tanggula-Gebirge (Tibet) kann jedes Jahr Ende August die geringste Oberfläche im Jahresverlauf gemessen werden. Aufgrund des Beitrages des aufgefrorenen Eises zur Massenbilanz kann die Zeit der geringsten Masse in der jährlichen Veränderung nicht genau festgelegt werden. Folglich ist das „fixed date system" ein allgemeiner Begriff bei der Definition der Massenbilanztermini als „stratigraphic system", das auf einer genauen Unterscheidung von Sommer und Winter basiert. In dem nachfolgenden Beitrag wird auch eine Methode zur Überprüfung der Veränderungen von Akkumulation und Ablation eines „Summer-accumulation type glaciers" vorgestellt.

1. INTRODUCTION

In the Himalayas and the Tibetan Plateau, glaciers of both maritime and continental types are distributed under humid and arid climates, respectively with much different annual water exchange. From a viewpoint of seasonal water cycle, a common characteristics of these glaciers is that the annual accumulation is provided mainly in summer. Ageta and Higuchi (1984) called such glaciers "summer-accumulation type", and compared them with glaciers of "winter-accumulation type" well known in Europe and North America.

Since most of the annual accumulation and ablation occur simultaneously in summer on such glaciers, annual variation of the balance generally has small amplitude in comparison with that of winter-accumulation type glaciers, as described by Ageta and Higuchi (1984). This paper will describe such characteristics of the mass balance focused on its annual variation.

2. ANNUAL VARIATION OF MASS BALANCE

On a small glacier in the Nepal Himalaya (Glacier AX010), experimental formulae to calculate accumulation and ablation from total precipitation and the mean air temperature at a specific point for each half-month were obtained (Ageta, 1983; Ageta and Kadota, 1992). Figure 1 shows the calculated cumulative value of annual variation of accumulation, ablation and balance in a "balance year" (UNESCO/IASH, 1970) under various annual pre-

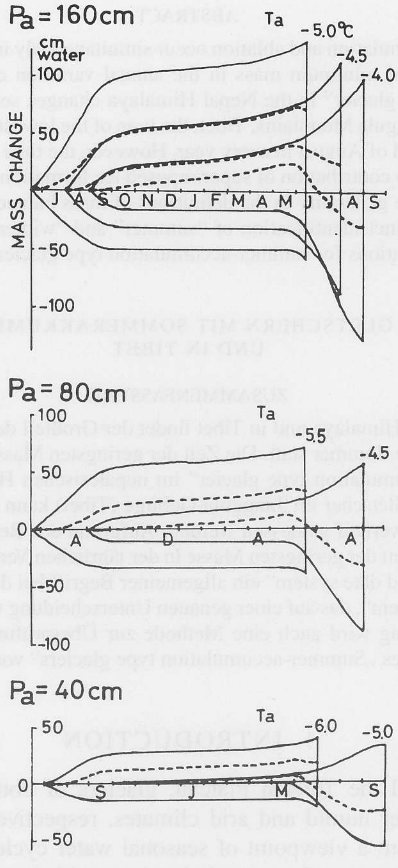

Fig. 1: Calculated variation of mass balance elements at a point in "balance year" under various annual precipitation (Pa) and annual mean air temperature (Ta) for a small glacier in the Nepal Himalaya
Solid line: positive value – accumulation, negative value – ablation; dashed line: balance

cipitation and annual mean air temperature by Ageta (1983). It can be seen in this figure that the end of the balance year, namely the time of minimum mass in an annual cycle changes 2 or 3 months sensitively with 1 °C difference of annual mean air temperature.

On the Tibetan Plateau, variation of surface level around the equilibrium line on Xiao Dongkemadi Glacier in the Tanggula Mountains has been recorded with an automatic gauge for more than 4 years as shown in Figure 2 (Seko et al., 1994). The time of the lowest surface level in a cycle of the annual variation can be found at the end of August in every year, as indicated with dashed lines in this figure.

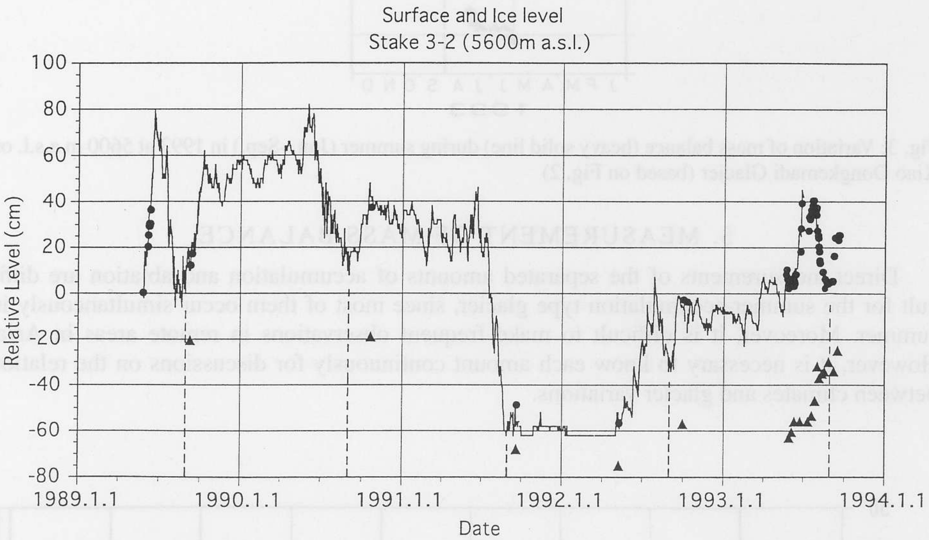

Fig. 2: Variation of surface level at 5600 m a.s.l. on Xiao Dongkemadi Glacier in Tibet from May 1989 to August 1993. The levels of the interface of snow and superimposed ice are shown with solid triangles. (solid circle: surface level measured by manual observation, dashed line: the end of August) (Seko et al., 1994)

However, the time of the lowest surface level does not always coincide with the time of the minimum mass, namely the end of the balance year, since superimposed ice formation due to refreeze of infiltrated water is important for mass balance of Tibetan glaciers. For example, Figure 3 shows the variation of mass balance during summer in 1993 which is calculated from the changes of the surface level and the level of the interface of snow and superimposed ice shown in Figure 2, with a snow density of 350 kg · m^{-3} and a superimposed ice density of 850 kg · m^{-3}. It can be seen in Figure 3 that the end of the balance year of this glacier is not well defined.

As described in the cases of glaciers in the Himalayas and Tibetan Plateau, the period of "winter", "summer" and "balance year" which are defined by UNESCO/IASH (1970) is changeable and not clear for the summer-accumulation type glaciers. Consequently, "fixed date system" has more generality than "stratigraphic system" in the definitions of mass balance terms by UNESCO/IASH (1970).

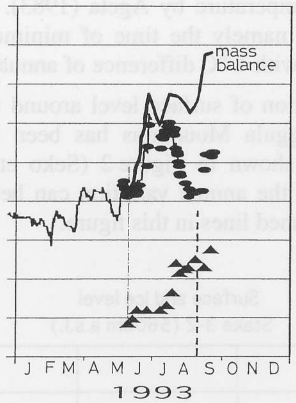

Fig. 3: Variation of mass balance (heavy solid line) during summer (Jun.–Sep.) in 1993 at 5600 m a.s.l. on Xiao Dongkemadi Glacier (based on Fig. 2)

3. MEASUREMENT OF MASS BALANCE

Direct measurements of the separated amounts of accumulation and ablation are difficult for the summer-accumulation type glacier, since most of them occur simultaneously in summer. Moreover, it is difficult to make frequent observations in remote areas in Asia. However, it is necessary to know each amount continuously for discussions on the relation between climates and glacier variations.

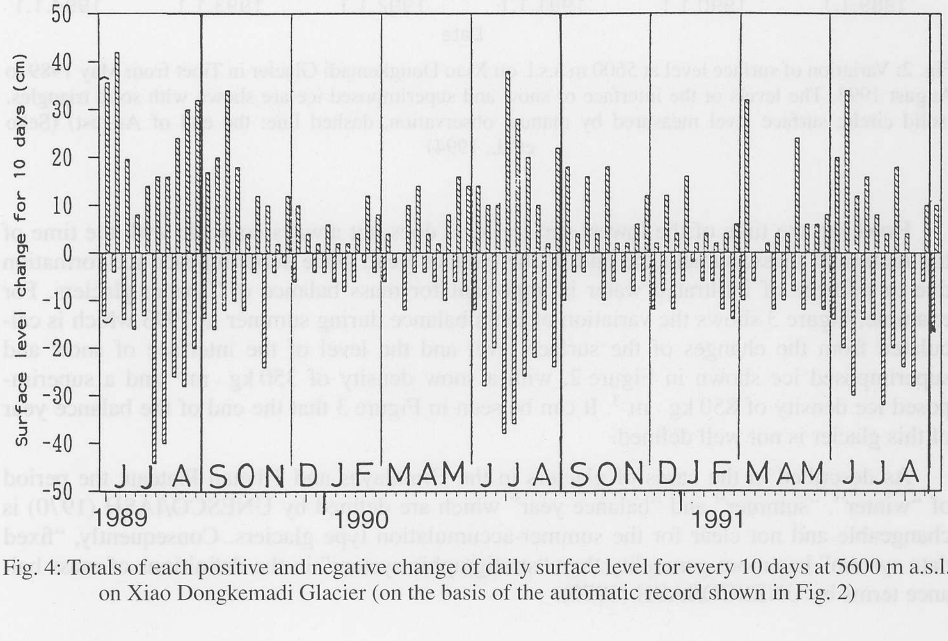

Fig. 4: Totals of each positive and negative change of daily surface level for every 10 days at 5600 m a.s.l. on Xiao Dongkemadi Glacier (on the basis of the automatic record shown in Fig. 2)

Figure 4 shows totals of each positive and negative change of daily surface level for every 10 days on the basis of the automatic record shown in Figure 2. Although Figure 4 cannot show the real amounts of accumulation and ablation, the characteristic tendency of the annual variation can be seen that both accumulation and ablation have extreme values in summer. In this way, we can observe the relative tendency of inter-annual variations of accumulation and ablation at the glacier surface.

In order to specify accumulation and ablation at the surface in terms of water equivalent, we would need to know more about the density of surface snow and its seasonal densification. Besides, it is important to evaluate the amount of superimposed ice formation from data of ice temperature and amount of melt water.

4. CONCLUDING REMARKS

In the Nepal Himalaya, shrinkage of some glaciers is accelerated in recent years (Yamada et al., 1992; Kadota et al., 1993). Monitoring of glacier variations and climate changes in high mountainous areas in Asia is very important to understand a role of the summer-accumulation type glaciers in the water cycle under the effect of Asian monsoon change related to the global climate change.

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