Glaciological Studies on Yala Glacier in Langtang Himal

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Abstract

Some aspects of mass balance, the surface flow and the thickness of annual layers exposed at the ice cliffs of Yala Glacier in central Nepal are reported on the basis of the results observed from September to October in 1982. The amount of snow deposited in summer, balance and ablation in autumn, and the horizontal and the vertical flow velocity vary with the altitudes of 10 stations in the range of 5100 m–5500 m. Annual layers at the ice cliffs of Yala Glacier are compared with those of the glaciers in east Nepal, and the relations between the variations of the layer thickness and summer climate (mean air temperature and total precipitation from June to September) in Kathmandu and around Langtang Himal during the past 20 years are discussed.

1. Introduction

Some aspects of mass balance, surface flow and thickness of annual layers exposed at ice cliffs were observed on Yala Glacier (Dakpatsen Glacier) for understanding its glaciological conditions at the present and in recent years. Observations were made during the post-monsoon season in 1982 as a part of the boring project by the Glaciological Expedition of Nepal.

Yala Glacier faces southwest from the ridge of the right bank (north-side) of Langtang Valley in central Nepal. As shown in Fig. 1, the glacier has a small altitude span (5100 m–5700 m) and relatively large width. The uppermost 100 m–200 m of altitude consists of a steep ice wall with 'Himalayan fluting' and rock faces. Below this wall, many ice cliffs can be seen. There is no supraglacial debris on the glacier. The total area and the length of the central part of the glacier are 2.6 km^2 and 1.5 km, respectively.

2. Mass balance in the post-monsoon season

Stake measurements were made at 10 stations (S9–S0) along the route from the terminus to the upper ridge of the glacier (Fig. 1) during the period from September 18 to October 28. The altitude interval between stations from S8 to S1 is approximately 50 m. The surface level change obtained from these measurements is shown in Fig. 2 with precipitation and air temperature at the 'Glacier Camp' (GC: 5090 m a.s.l.) just below the terminus of the glacier. The larger amounts of surface level change can be seen at the higher stations in this figure, the gradient during this period of 40 days being about 10 cm per 100 m of altitude. Upward change of the surface level is remarkable around October 20 due to snowfall.

Profiles of mass balance of the glacier against the altitude were obtained and are shown in Fig. 3. Fig. 3a indicates the amount of snow deposited until the beginning of October above

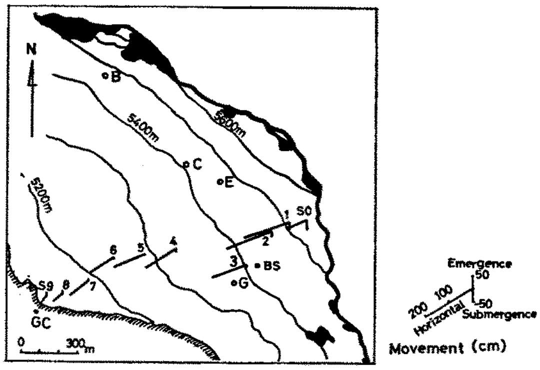

Fig. 1. Locations of stations on Yala Glacier and ice movement during the period from September 28 to October 27 (29 days).
GC: Glacier Camp, BS: Boring Site, S0–S9: stakes for the observations of mass balance and flow, B–G: survey points of ice cliffs

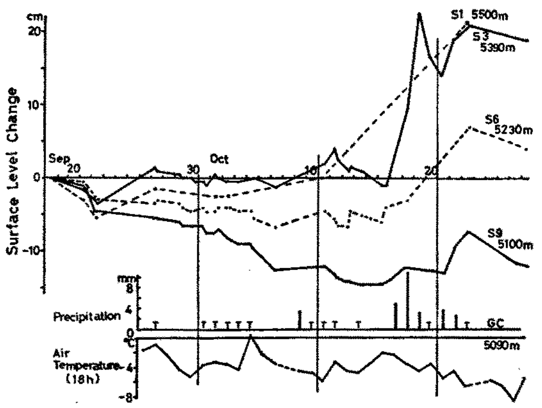

Fig. 2. The level change of the glacier surface, and daily precipitation and air temperature at 18h at the Glacier Camp (altitude 5090 m, the terminus of the glacier).
T: trace precipitation.

the uppermost dirt layer. Since such dirt is considered to be deposited during the previous winter (the dry period from the post-monsoon season to the pre-monsoon season), snow in Fig. 3a is considered to have been deposited mainly during the present summer due to the monsoon precipitation. As reported by Ageta and Satow (1978), ablation of old snow or ice below the dirt layer occurs during summer on the glaciers in the Nepal Himalaya when the current summer snow above the dirt layer happens to disappear temporarily. Therefore, the balance during this summer must be less than the amount of snow above the dirt layer, especially at the lower part, if the amount of refreezing of melt water can be neglected.

Fig. 3b shows the accumulation, ablation and balance during the 1 month period starting at the end of September. Accumulation was estimated from rough data of precipitation at the Glacier Camp and the boring site, and the stake data on the glacier, assuming from the results on small glaciers in the Nepal Himalaya (Higuchi et al., 1982) that precipitation had the same amount at all stations because of the small distance between them. The balance was obtained directly from the results of the stake measurements and the stratigraphic observations. Then ablation was calculated as the residual of the balance and the accumulation. Since

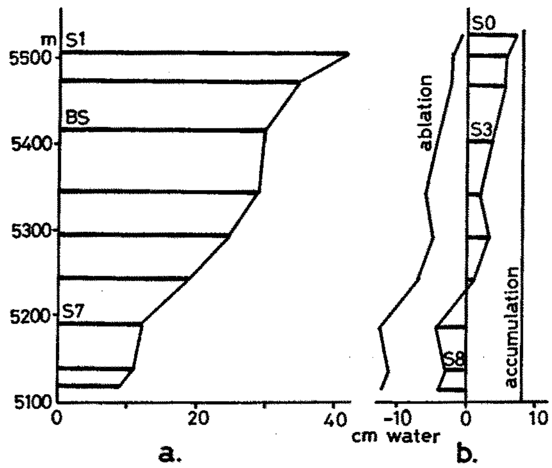

Fig. 3. Profiles of mass balance against altitude.
a. Amount of snow on October 2 or 3 above the uppermost dirt layer.
b. Mass balance during the period from September 27 to October 28.

all precipitation during the observed period was snow over the whole area of the glacier, the difference of the albedo at the glacier surface between the upper part and the lower part was small. Therefore, the relation between the ablation and the altitude in Fig. 3b is not expressed as the power function such as that obtained by Ageta et al. (1980) from the results including more rainfall on the lower part of a glacier in east Nepal during the summer monsoon season.

3. Surface flow of the glacier

Surface movements at stakes S0–S9 on Yala Glacier were surveyed by triangulation from the base line (length: 284.63 m, direction: S22.5°E) which was set up on the moraines about 400 m west from the Glacier Camp. Stake positions were measured with a Wild T2 theodolite on September 28 and October 27. Ice movements during this period (29 days) are shown in Fig. 1 and Table 1 with the relative data.

The flow lines around the stations S4–S9 are not connected from those at the stations S0–

Table 1. The surface flow of Yala Glacier.

Station	Horizontal flow (m) 29 days'* movement	Annual** movement	Flow direction*	Vertical flow (m)*** 29 days'* movement	Annual** movement	Surface slope*
S0	0.84	10.6	S68°W	−0.41	−5.1	10°
S1	1.77	22.3	S70°W	−0.28	−3.5	15°
S2	1.80	22.7	S67°W	−0.21	−2.7	15°
S3	1.42	17.9	S69°W	−0.10	−1.3	16.5°
S4	1.33	16.8	S58°W	−0.15	−1.8	10°
S5	1.26	15.9	S67°W	−0.01	−0.2	14.5°
S6	1.07	13.4	S57°W	−0.03	−0.4	16°
S7	0.91	11.4	S52°W	+0.10	+1.2	15°
S8	0.49	6.2	S50°W	+0.13	+1.7	14°
S9	0.38	4.7	S42°W	+0.15	+1.8	10°

*Sep. 28–Oct. 27
**calculated assuming the flow speed in October to be the same as the annual mean speed
***−: submergence flow; +: emergence flow

S3. However, the vertical flow shows the typical distribution of the velocity which changes gradually from a submergence flow in the upper part to an emergence flow in the lower part.

Borings to the bottom of the glacier were done near the station S3 in the accumulation area (BS in 1982, 5405 m a.s.l.) and near the station S7 in the ablation area (in 1981, 5180 m a.s.l.). The thickness of the glacier at the upper and the lower boring sites was known to be 59 m and 31 m, respectively. The obtained core samples at the upper site consist of snow and ice which flowed from the upper part around the stations S0–S2 to S3. Averages of the horizontal speed and the vertical speed at the surface of these stations S0–S3 are 18 m/year and −3.2 m/year (submergence), respectively.

4. Thickness of annual layers exposed at ice cliffs

4.1. Results on Yala Glacier

Many ice cliffs, which expose the many layers of snow and ice on their vertical surface, are seen on Yala Glacier. Dirt layers on such cliffs can be seen distinctly from far away. As mentioned in Chapter 2, a snow and ice layer which is sandwiched between two dirt layers can be assumed to be an annual layer. Therefore, the thickness of each layer between the two neighbouring dirt layers is measured for the study on inter-annual variations of the glacier mass balance.

Ice cliffs at 8 places (A-H) selected in the whole area of the upper part of Yala Glacier, as shown in Fig. 1. The largest ice cliffs named 'G', just below the boring site, are shown in Fig. 4. Heights of these ice cliffs were surveyed by triangulation from the base line which was used for the surface flow measurements. The intervals between dirt layers on each cliff were calculated from those on a telephoto and the real scale obtained by the triangulation survey.

Variations of such intervals at various cliffs are shown in Fig. 5a. The result at S3–4 in this figure was observed directly at the actual spot between the stations S3 and S4 in November, 1981. The thickness of each layer in Fig. 5 is not water equivalent. According to the analysis of the bored cores by Watanabe et al. (1984), snow densities near the surface are around 0.4

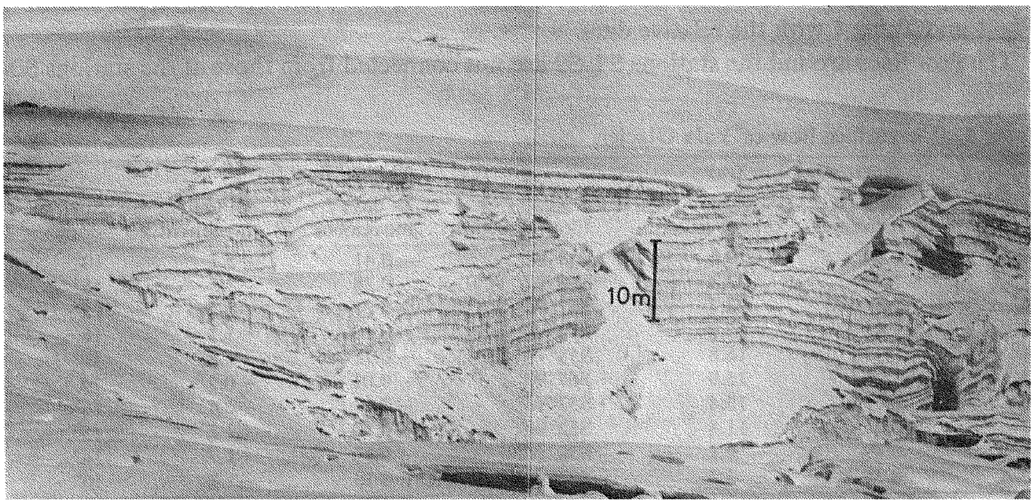

Fig. 4. Ice cliffs (G) below the boring site (BS: altitude 5405 m, upper-left in the picture).

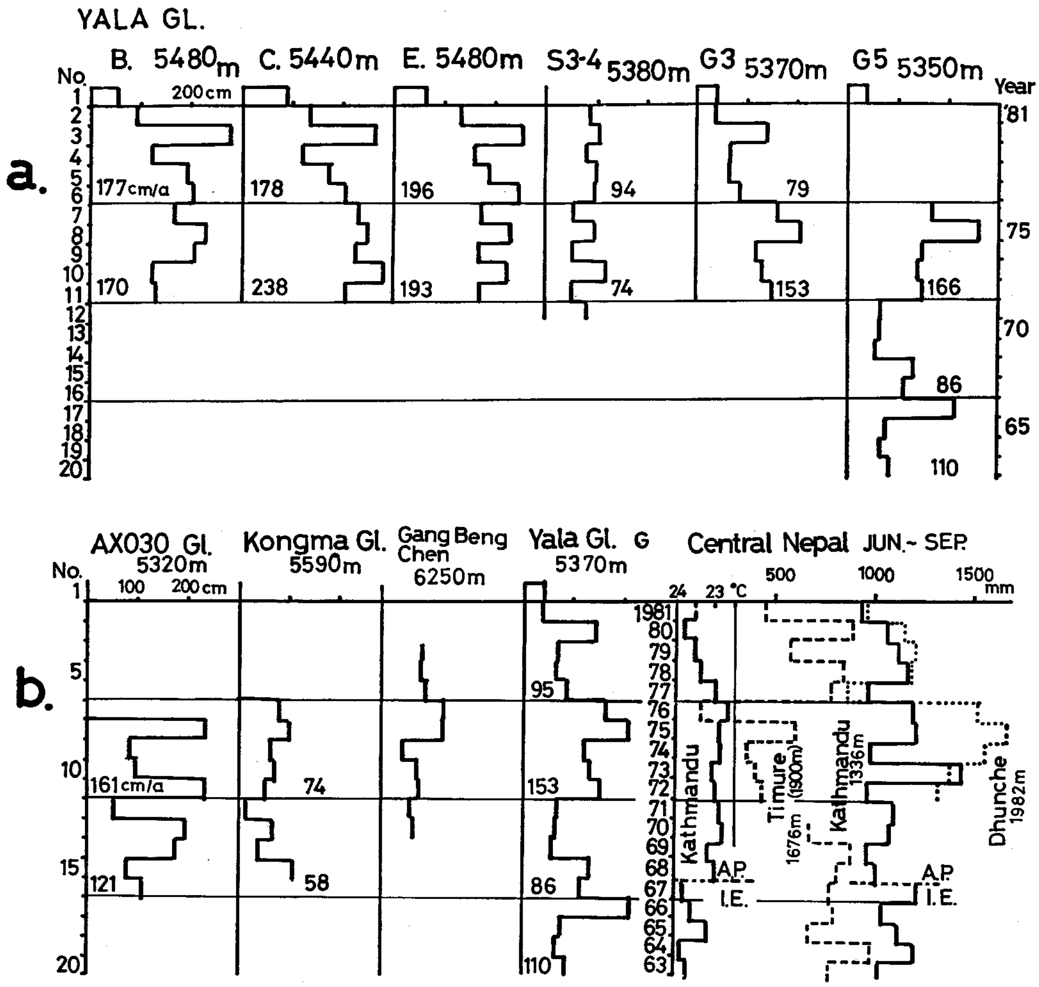

Fig. 5. Variations of thickness of a layer between the two neighbouring dirt layers exposed at ice cliffs, with mean thickness of 5 years.
a. Results at various places on Yala Glacier.
b. Results in east Nepal, Tibet and Langtang Himal with mean air temperature and total precipitation during summer (June to September) at the meteorological stations in central Nepal. (A.P./I.E.: Airport/Indian Embassy in Kathmandu)

g/cm^3 and gradually increase to 0.8 g/cm^3 at the depth of 17 m where the top of the continuous ice body is situated.

It can be seen in Fig. 5a that the annual layers of the cliffs B, C and E are thicker than those of the cliffs S3–4, G3 and G5 where the altitudes are around 100 m lower. Considering the difference of snow densities with depth as described above, the mean thickness of the most recent 5 layers in water equivalent are less than those of the older 5 layers below them in almost all cliffs. Maximal thickness at layers No. 3 (1980) and No. 8 (1975) can be seen in common at all cliffs.

4.2. Comparison with the climatic conditions

In Fig. 5b, the results for Yala Glacier are compared with those in east Nepal (Glacier AX030 in Shorong Himal—bored cores, Kongma Glacier in Khumbu Himal) and Tibet (a glacier on the northeast slope of Mt. Gang Beng Chen, 35 km north from Yala Glacier). The results in east Nepal were obtained in 1976, and that of Gang Beng Chen was obtained without a scale from photographs taken in 1982 by the expedition of the Academic Alpine Club of Kyoto University. The results from Yala Glacier are represented by the connected results at G3 (layer Nos. 1–11) and G5 (layer Nos. 12–20) in Fig. 5a.

It can be seen in Fig. 5b that the mean thickness of the 5 layers Nos. 7–11 is more than those of the lower 5 layers in all 3 regions. Though the maximal thickness at layer No. 8 is common in all regions, the inter-annual variation is large at Glacier AX030.

Variations of mean air temperature and total precipitation during the period from June to September in central Nepal are shown for reference in Fig. 5b, since summer temperature and precipitation during the monsoon season are considered to be representative indicator of glacier mass balance in the Nepal Himalaya (Ageta, 1983). Distances and directions from Yala Glacier to Kathmandu, Dhunche and Timure are 70 km south, 35 km southwest and 23 km west, respectively.

Inter-annual variations of climatic records in Kathmandu do not correlate well with the variations of the layer thickness of Yala Glacier. However, the period of 5 summers in 1972–1976 with the lowest temperature and the highest precipitation among the most recent 20 years in Kathmandu corresponds to the period of the layers Nos. 7–11 which are the thickest. On the summer precipitation at Dhunche, the tendencies of lower precipitation in the most recent 5 years than in the previous 5 years and the maximum value in 1975 correspond to the variation of layer thickness of Yala Glacier. On the other hand, at Timure, the pattern of inter-annual variation of summer precipitation from 1972 to 1975 and the maximal value in 1980 correlate well with the tendency of the layer thickness of Yala Glacier. However, the correlation between other results at Timure and Yala Glacier is not well.

As described above, the correspondence between the stratification of the glacier and air temperature and precipitation in summer is limited. This discrepancy may be caused if a distinct dirt layer happened not to be formed or multiple dirt layers happened to remain in an annual layer, although the coincidence of the maximal value between the thickness of layer No. 8 and summer precipitation in 1975 at all places in Fig. 5 suggests the preservation of one dirt layer per year from 1975 to the present. Also, the difference of meteorological conditions between the glacier on the mountain and the weather stations at the foot of mountains can cause such a discrepancy.

5. Concluding remarks

The core samples bored to the bottom of Yala Glacier offer records of variations of mass balance influenced by climatic conditions. For better reading of such records, the annual cycle of mass balance and the stratigraphy should be studied. Also, a discussin of the particle path from the surface to the deep layer on the basis of the surface flow data is necessary. It is very important to understand the relations between glacier mass balance and climatic conditions. Especially, in order to deduce the past climate from the bored cores of the glacier, it is necessary to study further which factors among climatic conditions control the thickness of annual layers of the glacier.

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