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Hydrological observations in Langtang Valley, Nepal Himalayas during 1987 monsoon－postmonsoon season

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Abstract

Glacio-hydrological observations were carried out at a glacier-fed watershed in Langtang Valley, Nepal Himalayas from August to October, 1987, from monsoon season to postmonsoon season. Air temperature, precipitation, streamflow and electrical conductivity of stream water from glacier(s) were observed at two sites, and the fluctuations of glacier surface level and melting rate were measured on Yala glacier. Discharge and specific electrical conductivity (S.E.C.) were inversely correlated. The diurnal relationship between discharge and S.E.C. showed clockwise hysteresis. The equilibrium line was 5200－5250 m a.s.l. during the observational period. Melting factor (degree hour factor) was obtained as 0.53 mm/°Ch on bare ice surface, Y1a (5096m a.s.l.) at the ablation area of Yala glacier and 0.8 mm/°Ch on the wet granular snow surface, DS87 (5304m a.s.l.) at the lower part of the accumulated area.

1.Introduction

Since 1981, glacio-hydrological observations were carried out as the cooperative project between Japan and Nepal at Langtang Valley which is glacier-fed watershed of Langtang Himal.

As a part of the project, contribution of glacier meltwater to runoff in glacialized watersheds of Langtang Valley have been represented by Yamada and Motoyama (1988). They showed that amount of glacier meltwater accounted for some 54% of annual runoff in Langtang Khola watershed (333km^2) and 76% in the Lirung Khola watershed (13.8km^2).

The next step of the hydrological study is, (1) to clarify the runoff process, how meltwater (or rainwater) moves from glacier surface to a stream through glacier body, (2) to improve the calculating method of mass input to watershed, for which such precise parameters should be obtained as the degree day factor for estimating the amount of snow/ice meltwater, the characteristics of areal distributions in air temperature and precipitation, altitudinal lapse rates of surface air temperature, etc. In this paper, we present the relation between discharge and electrical conductivity to discuss the runoff process of snow/ice meltwater, and degree hour factors on glacier to estimate meltwater. The characteristics of areal distribution of meteorological features were mainly reported by Ueno and Yamada (1989).

2. Area and method of observations

Observations were carried out in the glacialized watershed in Langtang Valley, which was located in Langtang Himal on the border of Nepal and China, some 60km northward from Kathmandu, and in the head area of the River Trisuli in the Narayani River System.

The observed watershed is covered by glaciers in the area of 127 km^2 or 38% of the total area of 333 km^2. The highest part of the watershed extends beyond 7200 m a.s.l. The lowermost altitude of the watershed is 3840 m a.s.l. where a hydrological station (S1) was established. Near the hydrological station, a meteorological station (BH) were set up at 3920 m a.s.l. as shown in Fig.1. The annual mean air temperature and the annual precipitation were reported as 2.7°C and 1224.5mm at BH by Takahashi *et al.* (1987). The annual runoff as 1357.5mm at S1 by Fukushima et.al. (1987) using the data obtained in the period during July 1985 to June 1986. Another hydrological and meteorological station were set up at glacier camp (GC) near the terminus of Yala (Dakpatsen) glacier, at the altitude of 5090 m a.s.l, within Langtang Khola watershed. The area of the watershed referred to GC is not defined in this stage because of no reliable map of the watershed. Air temperature, precipitation and stream discharge were continuously measured by self recording system using digital recorders, and stream temperature and electrical conductivity were manually measured at the stations above mentioned. On Yala glacier, change in the glacier surface were routinely observed at nine points (Y1–Y9) along the route of GC to Drilling site (DS87, 5304 m a.s.l.) by snow stakes. Ablation and evaporation of glacier surface were measured by using 16cm diameter pans at DS87.

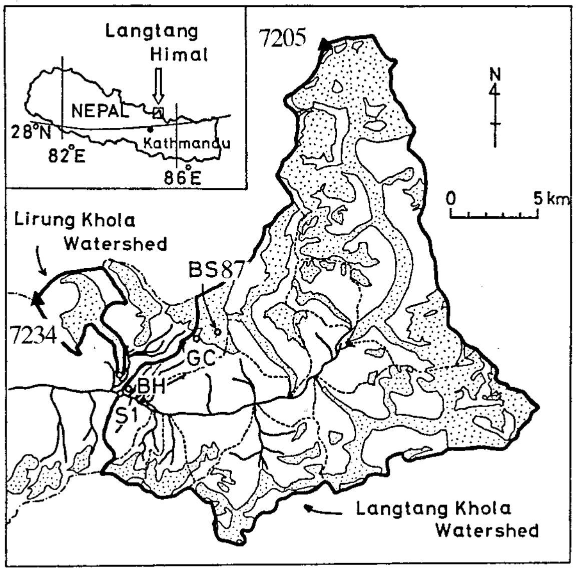

Fig. 1. A typographical map of Langtang Valley. Thick solid line indicates the boundary of the Langtang Khola watershed (333 km², observation site at S1, 3840m a.s.l.). BH: the station of meteorological observations (3920m a.s.l.), GC: the station of meteorological and hydrological observations (5090 m a.s.l.), DS: drilling site for glaciological observations (5304 m a.s.l.).

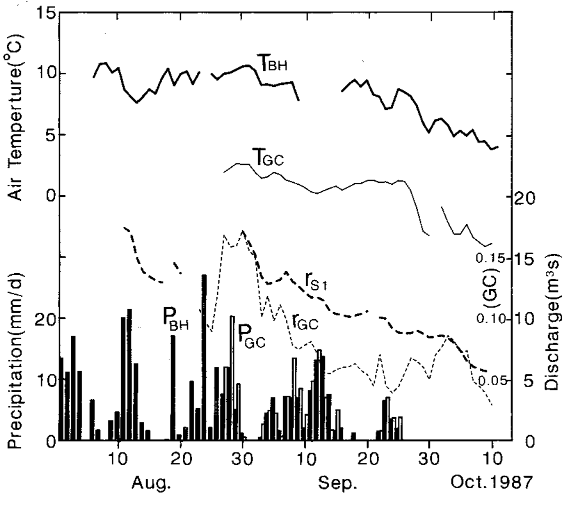

Fig. 2. Seasonal variation of daily mean air temperature, T, daily amount of precipitation, P, daily mean discharge, r; subscripts mean observational sites (Fig.1), in the period of August.1 to October.10, 1987.

Observational periods are mainly from August.1 to October.10, 1987 at BH and S1, from August.26 to October.10 at GC and DS87.

3.Results and discussions

3.1. *Air temperature, precipitation and streamflow*

a) Seasonal variation

The seasonal variation of daily mean air temperature, T, daily amount of precipitation, P, and daily mean discharge, r, are shown in Fig.2. Average difference of Ta between BH and GC was about 8°C. Precipitations of both sites were nearly equal in the amount, while snowfall often occurred at GC though it rained at BH. The discharge at S1 decreased monotonously with time; runoff at GC, which drainage area was assumed to be constant, also decreased with irregularity.

Since air temperature and precipitation at BH and discharge at S1 were previously observed in 1982, 1985 in the same seasons (Yamada et.al. 1984, Fukushima et.al. 1987), comparisons were made of the daily values with the data obtained in 1987 to the data in 1982 and 1985 as shown in Figs. 3a, b and c, respectively. Differences in temperature and discharge were limited within 20% in these three years. The range of daily precipitation was found to be 10–20 mm/d in 1987, which was the same value of usual precipitation in 1982 and 1985. Daily precipitation over 50mm/d observed at the late monsoon (or the early postmonsoon) season in 1985 was considered to be unusual in

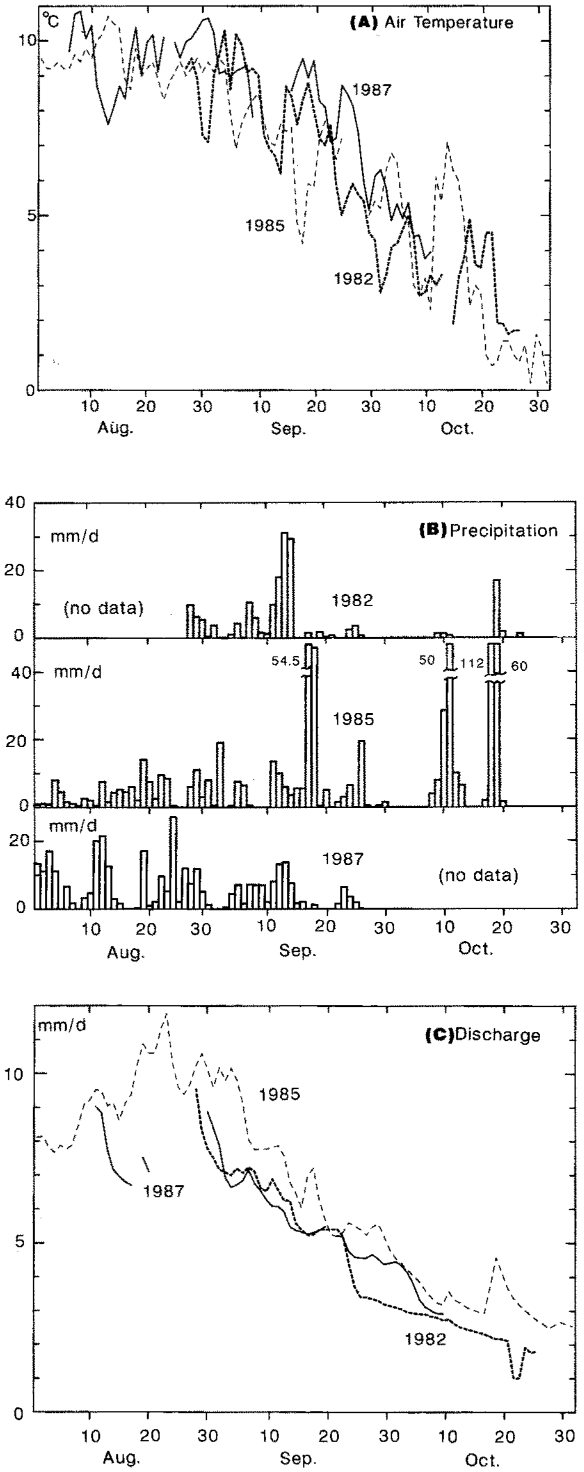

Fig. 3. Comparison with seasonal variations of (A) daily mean air temperature, (B) precipitation and (C) discharge in the same seasons of different years, 1982 (thick broken line), 1985 (thin broken line) and 1987 (thick solid line).

comparison with the data in other two years. The values of discharge show that the stable runoff is one of the most important hydrological characteristics in the glacialized watershed.

b) Diurnal variation

Diurnal variations of T and r in the monsoon season (8/31–9/4) and the postmonsoon season (10/5–10/9) were shown in Fig.4a and b, respectively. Diurnal amplitudes of T were 5–8°C at BH and only 5°C at GC in the monsoon season. In the fine day of postmonsoon season, diurnal amplitudes of T at BH and GC were larger than those in the monsoon season in the amplitude of 10°C. The maximum of discharge appeared 19–21h at S1 and 14–16h at GC in the monsoon season, and 1–2h earlier in the postmonsoon season at both the stations in decreasing diurnal amplitudes of runoff. As seen in the figures, diurnal

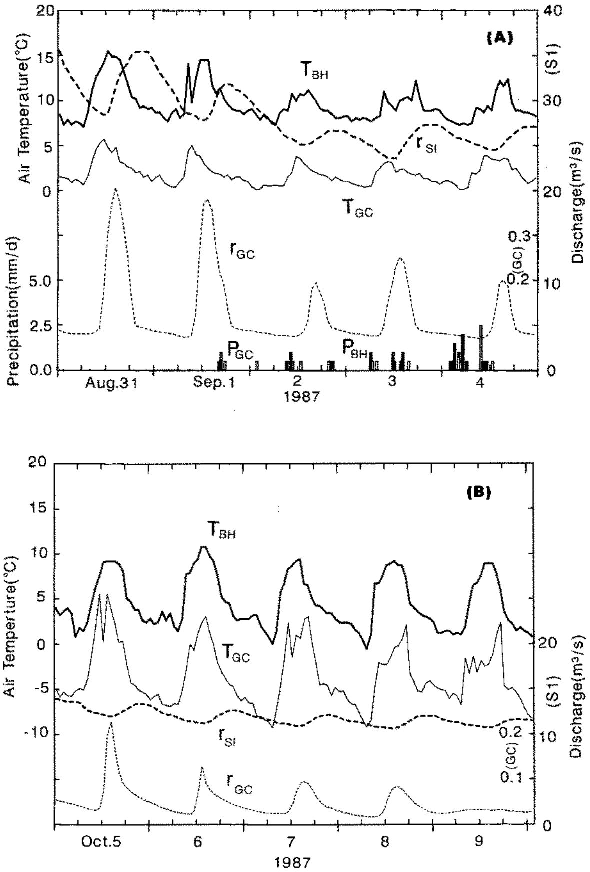

Fig. 4. Seasonal variation of hourly mean air temperature, T, hourly precipitation, P and hourly discharge, r; subscripts mean observational sites (Fig.1), in the periods of (A) August. 31–September.4 and (B) October. 5–October. 9

change of runoff is regarded as depending rarely on precipitation.

3.2 Relationship between streamflow and electrical conductivity

a) Seasonal characteristics

Specific electrical conductivity (S.E.C.) means the value of electrical conductivity at the temperature of 25°C. Figure 5 shows the relationship between discharge and S.E.C. at S1, which were observed at 14–16h every day. Figure 6 shows the same relation at GC at 18h every day. As seen in Figs.5 and 6, S.E.C. increased with decreasing discharge. In general, meltwater of snow or ice (fresh water) has lower value of S.E.C. than en-glacial water and/or groundwater (old water) as mentioned latter section. The large contribution of fresh water results in high discharge and in the decrease of S.E.C. of stream flows. The dependency of discharge to S.E.C. were shifted at GC in the monsoon season (marks x, in Fig.6) to the postmonsoon season (marks o), though no shift appeared at S1.

b) Diurnal characteristics

Diurnal variations of discharge and S.E.C. in the stream drained out from glacier terminus at GC and in the supra-glacial stream near GC are respectively shown in Figs.7 and 8. Water level, WL, and S.E.C. at EC−3 in Fig.8 were values measured in supra-glacial stream and S.E.C. at EC−2 was that of en-glacial water in the bore hole near the supra-glacial stream. The peak of discharge was appeared in about 1 hour earlier than the minimum of S.E.C at GC. The value of S.E.C. in drained water from glacier terminus were larger than that in supra-glacial water. When water level increased, S.E.C. of the en-glacial water EC−2 suddenly decreased and continued almost the constant value of around 0.3 μS/cm; when WL decreased less than 0 cm, S.E.C. quickly recovered to near 0.8 μS/cm. Otherwise, S.E.C. at EC−3 showed the almost constant in low values around 0.15 μS/cm. The low values of S.E.C. means that water in the supra-glacial stream considered to consist of meltwater of ice or snow only.

Figure 9 shows the relationship between discharge and S.E.C. at GC in daytime. They had good correlation and clockwise hysteresis. Same hysterises were reported by Kobayashi (1986) in seasonal snow-covered watershed in Japan and Collins (1979) in Alpine glacier. Figure 10 shows the same relation on the en-glacial water at EC−2 and the supra-glacial

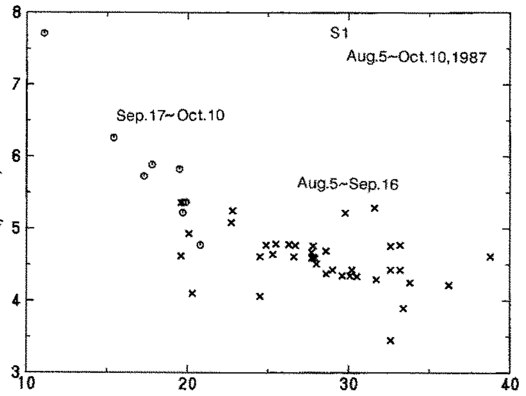

Fig. 5. Relation between discharge and specific electrical conductivity at S1; cross: August. 5−September. 16, circle: September. 17−October. 10

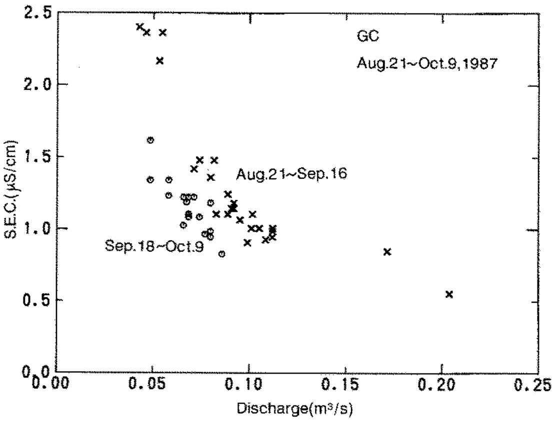

Fig. 6. Relation between discharge and specific electrical conductivity at GC; cross: August. 21−September. 16, circle: September. 18−October. 9

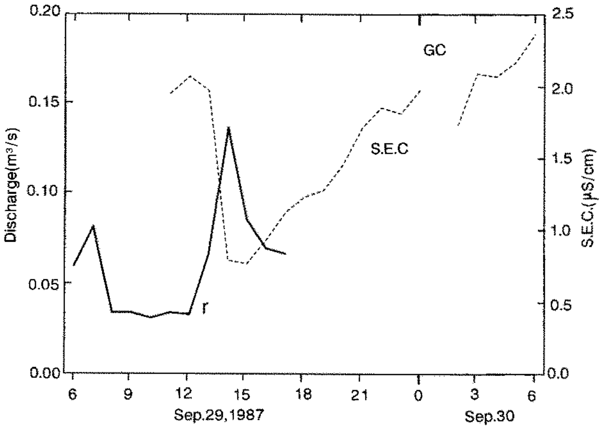

Fig. 7. Hourly variation of discharge, r, and specific electrical conductivity, S.E.C., at GC.

stream at EC−3.. Hysteresis of the en-glacial water was larger than the stream at GC. But S.E.C. of supra-glacial stream was kept almost constant value in spite of the change of discharge. Assumed that E.S.C. of fresh meltwater was 0.15μS/cm (Fig.10) and en−glacial old water or ground water was 2.5 μS/cm (Fig. 9), contribution of fresh water to runoff at GC was 80% at peak discharge when S.E.C. was 0.6 μS/cm (Fig.9).

3.3 Change of glacier surface

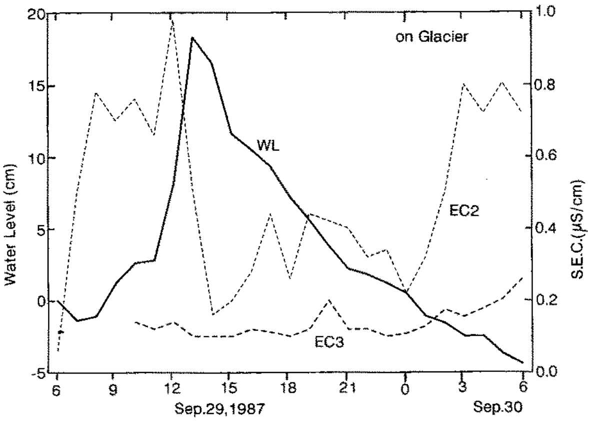

Fig. 8. Hourly variation of water level, WL, and specific electrical conductivity at EC2 and EC3 at the terminus of the Yala glacier near GC. WL and EC3 are the values of supra-glacial stream. EC2 is the value of en-glacial water in a bore hole.

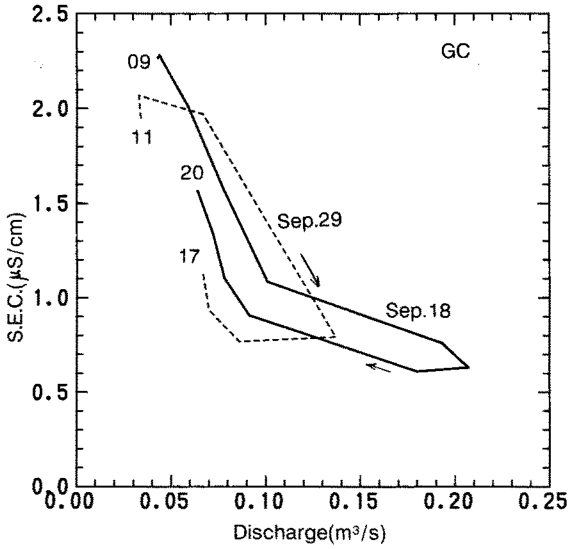

Fig. 9. Relation between hourly discharge and specific electrical conductivity at GC; solid line: Sep. 18, broken line: Sep. 29.

The change of the surface level on the glacier was observed by snow stakes along the route from GC to BS87(Fig. 11). Bare ice were exposed from Y1 to Y3. Upper other points consisted of snow surface. Despite of the heavy snow fall in mid-September, the equilibrium line, which divide ablation and accumulation zone, is seemed to be situated at the altitude near Y6 during our observational period. The altitude between Y6 and Y7 is critical for the change of the surface level as seen in the figure, in spite of only 24m in the difference of altitude between them.

3.4 Glacier melting

The rate of ablation and evaporation at glacier surface were measured by the small pans in a diameter of 16cm at DS87 from Sep.3 to Oct.7. The bottom of a pan employed for ablation measurement was netted and another was closed. Pans were filled in snow and were buried in snow as the snow surface of the pans coinciding with glacier surface. The rate of ablation and evaporation were obtained by measuring the weights of pans every 3−24 hours intervals. The glacier melting rate was calculated by the difference of ablation and evaporation. This method has no influence of sporadic snowfalls.

The relation between accumulated hourly melting index, ΣTh^+ (°Ch) and accumulated amount of snowmelt, Σm (mm) is shown in Fig.12. Hourly melting

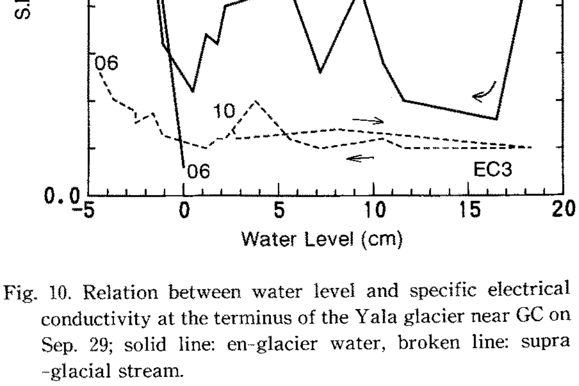

Fig. 10. Relation between water level and specific electrical conductivity at the terminus of the Yala glacier near GC on Sep. 29; solid line: en-glacier water, broken line: supra-glacial stream.

index is useful in our observation. Usual degree-day method for estimating snowmelt is not applicable at DS87 because of the meteorological condition in low temperature and frequent snowfall.

The accumulated amount of snowmelt Σm is proposed to ΣTh^+, which expressed as $\Sigma m = 0.8\Sigma Th^+$ (mm). Kojima et.al.(1983) reported the melting factor as 0.2−0.3 mm/°Ch for seasonal snow in Japan. That was third times smaller than our values. Low air temperature and high solar radiation may result in the large proportional constant called hourly melting factor.

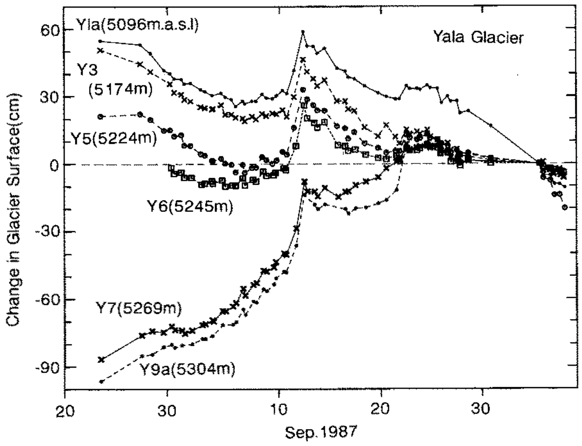

Fig. 11. Changes in the glacier surface referring to the surface levels on Oct. 5 measured by snow stakes along the route from GC to DS.

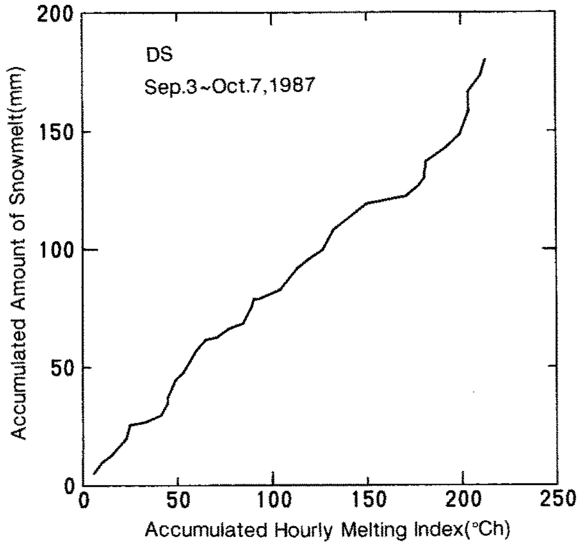

Fig. 12. Relation between accumulated hourly melting index and accumulated amount of snowmelt at DS (5304 m a.s.l.).

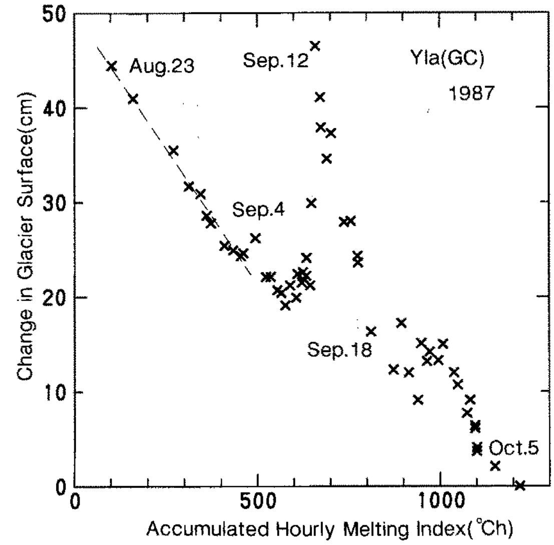

Fig. 13. Relation between accumulated hourly melting index and change in glacier surface at Yla (5096 m a.s.l.).

Same analysis were made by surface level observation at Y1, the terminus or Yala glacier. The upper sites was accumulation area, then it could not get the melting amount from the data of change of glacier surface (Fig. 11). The relation between accumulated hourly melting index ΣTh^+ and change in glacier surface d(HS) were shown in Fig.13. Since the level at the late period was varied up and down due to snowfall and densification, the data of the early period (Aug.23−Sep.3) were examined. Change in glacier surface is also proportional to ΣTh^+: $d(HS) = 0.58\,\Sigma Th^+$. Assumed that ice density of glacier was 920 kg/m^3, accumulated amount of melting amount Σm is expressed that, $\Sigma m = 0.53\Sigma Th^+$. The hourly melting factor at Y1 was smaller than that at DS87. In melting season, the energy sources of glacier melt consist mainly of net radiation, R, sensible and latent heat flux H, E. The melting factor K is,

$$K = \frac{\Sigma m}{\Sigma T} = \frac{R+H+E}{L\Sigma T}$$

where L is quantity of heat for melting ice. In our observations, the melting rate was higher at DS87 site than Y1 under same condition. This means that melting due to radiation was principle at DS87 and melting due to turbulent heat flux was principle at Y1. The details were remained in future investigation.

4. Concluding remarks

Hydrological observations of glacialized watershed were carried out in Langtang Valley, Nepal Himalayas during 1987 from the late monsoon to the postmonsoon season. The following results were obtained.

1. Discharge and specific electrical conductivity (S.E.C.) were inversely correlated both in outlet of glacialized watershed (333 km^2) and stream drained from glacier terminus.
2. The diurnal relation between discharge and S.E.C. had clockwise hysteresis.
3. Contribution of fresh water to discharge at stream drained from glacier was 80 % at peak discharge
4. The equilibrium line was 5200–5250 m a.s.l. during observational period from Aug.23 to Oct.7, 1987.
5. Melting factor (degree hour factor) was 0.53 mm/°Ch at bare ice of ablation area (5096 m a.s.l.) and 0.8 mm/°Ch at snow surface of accumulation area (5304 m a.s.l.).

Acknowledgments

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