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Meteorological observation in Langtang Valley, Nepal Himalayas, 1996

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Abstract

Meteorological observations were carried out in Langtang Valley, Nepal Himalayas, from May to October in 1996. Meteorological stations were installed at four sites where the surface conditions and altitudes were different. Daily or seven days running mean values of meteorological parameters are summarized in this report. The monthly averaged parameters are compared with the data obtained since 1985. Meteorological conditions of the observation period, the monsoon season of 1996, are summarized as follows ; warmer, more humid, weaker wind, more precipitation and slightly less short wave radiation than those of the other years.

1. Introduction

Many glaciological, meteorological and hydrological observations have been performed in Langtang Valley since 1981 (*e.g.* Higuchi, 1984 ; Watanabe and Higuchi, 1987 ; Yamada, 1989). Although Fukushima *et al.* (1991) and Braun *et al.* (1993) made the runoff models to evaluate the discharge from the glacierized basin of Langtang Valley, the estimated discharge has some disagreements with the observed one. They pointed out the necessity to estimate the melting under debris cover accurately. Rana *et al.* (1997) evaluated the discharge from the Lirung Glacier in Langtang including the estimation of melting under the large debris cover on the lower part using the distribution of the surface temperature. Although their model represented the discharge from the Lirung Glacier well, there are many problems which should be improved to estimate the response of the discharge to the future climate change.

The fluctuations of glaciers in Langtang Valley were reported by Yamada *et al.* (1992) and Kappenberger *et al.* (1993). Some studies related to mass balance of glaciers in the valley were also evaluated by Ageta *et al.* (1984) and Steinegger *et al.* (1993). Seko (1987), Seko and Takahashi (1991), Shiraiwa *et al.* (1992) and Ueno *et al.* (1993) evaluated the distribution of precipitation in the valley. Although the altitudinal dependence of precipitation in the valley was evaluated largely by their analysis, it is still not enough to clarify how the local climate would change around debris free glaciers as well as debris covered ones when the global climate has changed. Meteorological observation was performed from May to October, 1996 to evaluate the spatial distribution and temporal variation of the meteorological parameters related to glacier mass balance and discharge. The preliminary results of the observation will be presented in this report.

2. Locations and observations

The Langtang region, where the observations were carried out, is located 60 km north of Kathmandu, the capital city of Nepal (Fig. 1). The main river, called Langtang Khola, has its source at Mt. Langtang Ri (7232 m a.s.l.), comes down to southwest. It is pointed out that the annual precipitation of this district is rather small than that of the southern slope of the Himalayas (Yasunari and Inoue, 1978).

Five meteorological stations were established as shown in Fig. 1. The main meteorological station was installed on the grass land at Kyangjin Base House (BH, 3920 m a.s.l.). The meteorological obser-

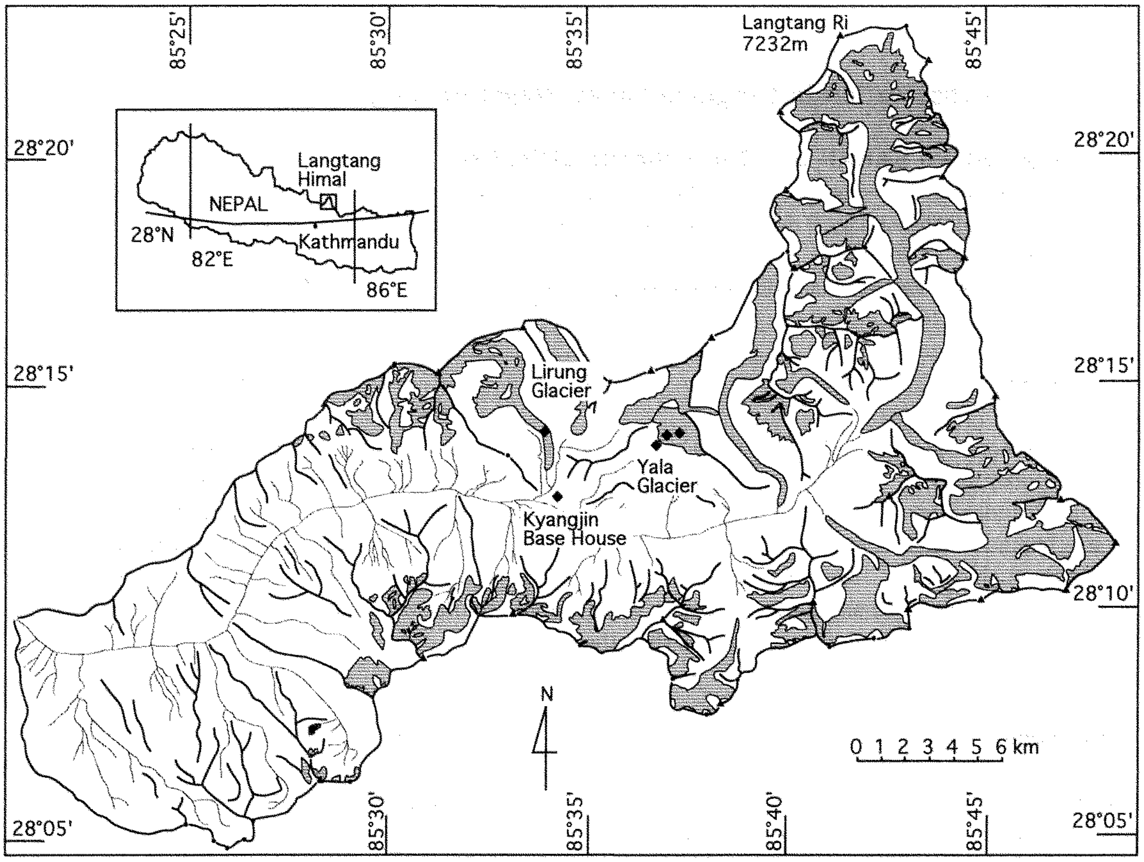

Fig. 1. Map of Langtang Valley based on Shiraiwa and Yamada (1991). Gray parts denote glaciers. The squares denote the meteorological stations installed in this study.

vation was carried out at BH from July 1985 to July 1986 (Takahashi *et al.*, 1987a ; 1987b). Further, the continuous meteorological observation has started since July 1987 at BH (Department of Hydrology and Meteorology, 1993 ; 1995).

The meteorological station to evaluate glacier ablation under debris cover was installed on the debris covered area of Lirung Glacier (LR, 4180 m a.s.l.). The LR station is surrounded by the complicated surface morphology, which is the tangled distribution of melt hollows, ice cliffs, ponds and streams. The LR station was installed at one of the peaks of complicated relief, of which the height difference is a few tens of meters.

Two meteorological stations were installed on the Yala Glacier. One was near the equilibrium line altitude (YE, 5390 m a.s.l.) and another was in the ablation area (YA, 5260 m a.s.l.). The precipitation and long wave radiation were measured at Glacier Camp located on the terminus moraine of the Yala Glacier (GC, 5150 m a.s.l.).

The altitudes of these stations were determined by a laser range-finder and a theodolite (Wild T1600 and Sokkia 2000). The accuracy of measured elevational difference among the stations is less than $\pm$ 0.1 m. The meteorological components measured and the sensor heights at each station are summarized in Table 1. The measured parameters were recorded automatically at an interval of five minutes with some exceptions. Manned conventional weather observation was carried out at an interval of 3 hours in daytime at BH. The measured parameters by manual observation are also summarized in Table 1.

Table 1. Altitudes and measured parameters at each meteorological station. Almost all parameters were recorded automatically at an interval of 5 minutes. Note that the measurement height can not be specified on Yala Glacier because its surface varied with accumulation and ablation.

Kyangjin Base House (BH, 3920 m a.s.l.)	
Air temperature	Height : 123 cm, 23 cm
Relative humidity	Height : 123 cm, 23 cm
Wind speed	Height : 144 cm, 47 cm
Wind direction	Height : 150 cm
Surface temperature	Depth : 0.5 cm
Precipitation	on the ground
Net radiation	Height : 136 cm
Downward short wave radiation	Height : 153 cm
Upward short wave radiation	Height : 130 cm
Downward long wave radiation	Height : 153 cm
Upward long wave radiation	Height : 130 cm
Heat flux in the ground	Depth : 0.5 cm
Manual observation at BH with an interval of 3 hours	
Weather & surface condition	
Visibility	
Wind direction & speed	
Ground & sky temperature by infrared thermometer	
Cloud type & amount	
Dry & wet air temperature	
Debris covered area of Lirung Glacier (LR, 4190 m a.s.l.)	
Air temperature	Height : 120 cm, 20 cm
Relative humidity	Height : 120 cm, 20 cm
Wind speed	Height : 155 cm
Infrared surface temperature	remote
Surface temperature	Depth : 0.5 cm
Precipitation	on the ground
Net radiation	Height : 113 cm
Downward short wave radiation	Height : 150 cm
Upward short wave radiation	Height : 138 cm
Equilibrium line on Yala Glacier (YE, 5390 m a.s.l.)	
Air temperature	
Relative humidity	
Wind speed	
Wind direction	
Infrared surface temperature	remote
Net radiation	
Downward short wave radiation	
Upward short wave radiation	
Ablation area of Yala Glacier (YA, 5260 m a.s.l.)	
Air temperature	
Downward short wave radiation	
Upward short wave radiation	
Glacier Camp of Yala Glacier (GC, 5150 m a.s.l.)	
Precipitation	on the ground
Downward long wave radiation	on the ground

3. Results

3.1 Temperatures

Fig. 2a shows the daily mean air temperature at BH, LR, YE and YA. Takahashi *et al.* (1987a) concluded that the temperature constancy during monsoon season is due to the persistent thick clouds. The similar trends of air temperature variation are also found at all stations from the end of June to the middle of September. This period corresponds to the period of rainfall at BH.

Fig. 2b shows the daily lapse rates with altitude at LR/BH, YE/BH and YA/BH. Takahashi *et al.* (1987a) reported the lapse rate between BH and GC to be 6.0 °C/km using the altitudinal difference of 1170 m. In this study, however, the altitudinal difference between BH and GC was determined to be 1230 m by a laser range-finder. Thus the lapse rate of Takahashi *et al.* (1987a) is corrected to be 5.7 °C/km. Although the calculated period is not the same each other, the lapse rate with altitude at LR/BH, YE/BH and YA/BH are 5.1 °C/km, 5.5 °C/km and 5.5 °C/km, respectively. The values at YE and YA, which are smaller than that of Takahashi *et al.* (1987a), should be due to the surface condition surrounding the stations, which is the moraine at GC (Takahashi *et al.*, 1987a) and the snow or ice at YE and YA in this study. Temperature sensor set above snow or ice might be heated due to reflected solar radiation by high albedo surface. The lapse rate at LR is rather small with large amplitude. It would be due to the environment of LR located at bottom of deep valley, whereas YE and YA were located on the open slope of the Yala Glacier. It is unclear, however, whether the surrounding topography (deep valley) or the surface condition around LR (complicated surface morphology) would determine the air temperature. It should be discussed further including the diurnal variation of other parameters around LR in detail because the air temperature would be determined by the interaction of a several parameters.

The surface temperatures at BH, LR and YE are shown in Fig. 2c. The difference of the surface temperatures between the stations is larger than that of air temperatures. It would be caused from the different surface conditions, which is grass land at BH, rocks at LR and snow at YE.

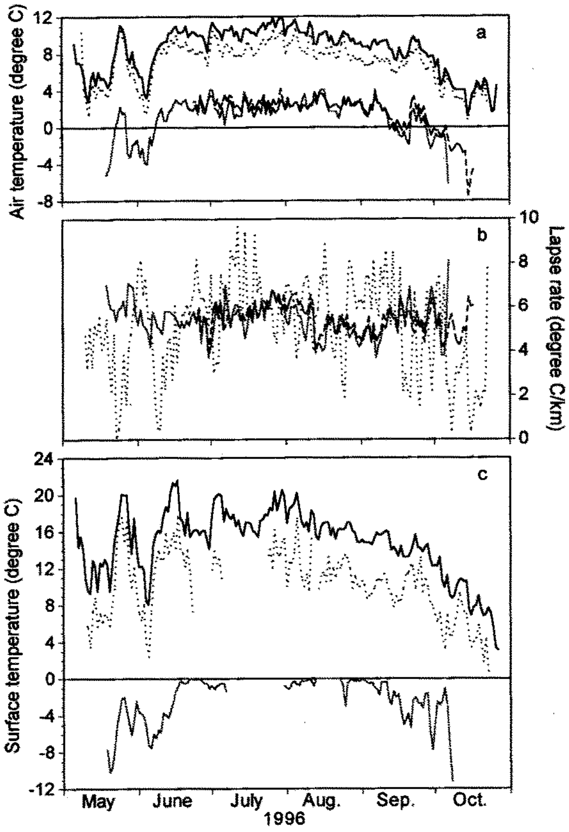

Fig. 2. a) Daily mean air temperature at BH, LR, YE and YA. b) Daily mean lapse rate with altitude at LR/BH, YE/BH and YA/BH. c) Daily mean surface temperature BH, LR and YE. The solid, dotted, gray and broken lines denote the parameters at BH, LR, YE and YA, respectively in all figures.

3.2 Relative humidity

Fig. 3 shows the seven days running mean of

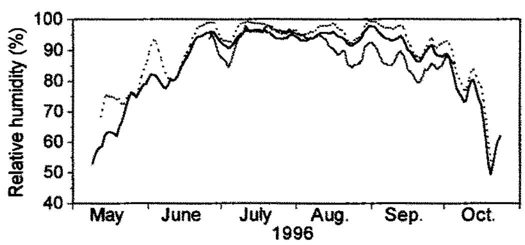

Fig. 3. The seven days running mean of relative humidity at BH (solid), LR (dotted) and YE (gray).

relative humidity at BH, LR and YE. The relative humidity at all station remained at high value, more than 90 %, during the monsoon season from the end of June to the middle of September in 1996. The variation of the relative humidity at the start and the end of monsoon season is similar to that observed by Takahashi *et al.* (1987). It increased gradually from May to June and decreased rapidly in October. The relative humidity at LR is higher than that at YE even though YE was on the wet snow surface.

3.3 *Wind speed and direction*

The seven days running mean variations of the daily mean wind speed at BH, LR and YE are shown in Fig. 4a. Wind speeds at all stations during the monsoon season were relatively stable. Takahashi *et al.* (1987a) concluded that the wind speed in Langtang Valley is relatively smaller than that at Khumbu Himal obtained by Inoue (1976). The wind speed at BH is almost always larger than that at LR and YE. Wind direction at BH was westerly as mentioned later although the valley direction of the debris covered area of the Lirung Glacier are from south to north. Weak wind at LR is thus due to the topographical environment. It would be due to the difference that the valley wind prevails at BH whereas the ascending wind is dominant at YE.

The seven days running mean variation of the daily mean wind direction at BH and YE are shown in Fig. 4b. The wind direction at BH was constant around west-southwest during the monsoon season. It was around north before the monsoon and it fluctuate largely in October. The wind direction at YE was around north during the whole observation period. The wind components are important to evaluate the environment associated with water and energy circulation in the valley.

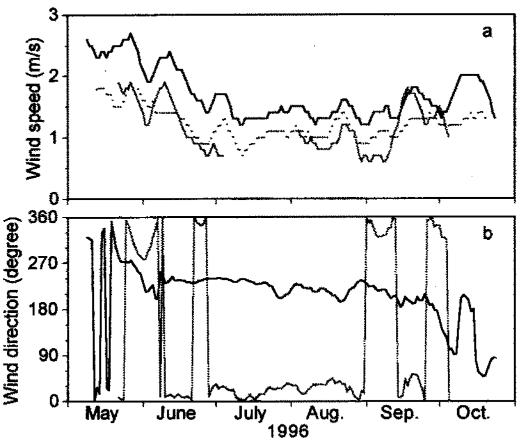

Fig. 4. a) The seven days running mean of wind speed at BH (solid), LR (dotted) and YE (gray). b) The seven days running mean of wind direction at BH (solid) and YE (gray). 0° (360°), 90°, 180° and 270° denote the direction of north, east, south and west.

3.4 *Precipitation*

Fig. 5 shows the daily precipitation at BH, LR and YE observed by tipping bucket with a few cases of the manual weighing observation. The daily amount denotes the amount summed from 18h NST of the previous day to 18h NST because the manual weighing observation was performed at 6h and 18h NST. Although a heavy rainfall was observed at the middle

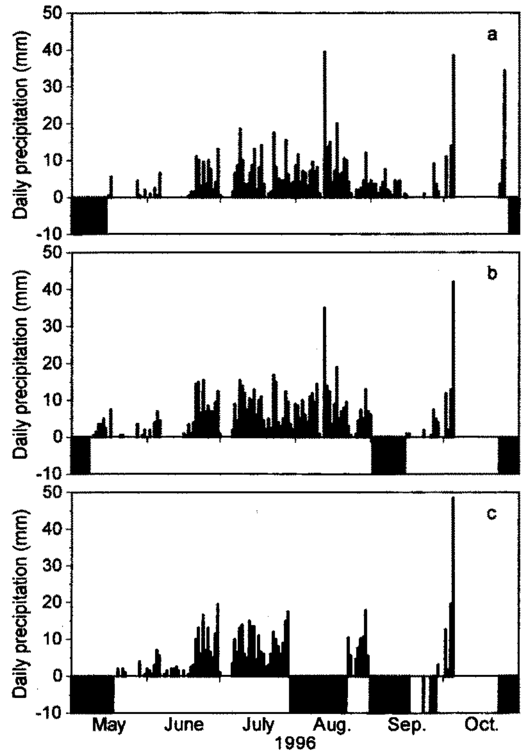

Fig. 5. Daily precipitation at YE (a), LR (b) and BH (c). The negative value denotes the data not available.

of August, the amount of daily precipitation was about 10 mm during the monsoon season. The no precipitation days can be seen in the figure at an interval of 15–20 days, corresponding to the variation of short wave radiation mentioned later. The snowfall at BH were observed a few times from the middle of May to early June and one time at the end of October. It is deduced that the precipitation at the Yala Glacier since the middle of August was snowfall from the variation of albedo as mentioned later.

The precipitation amount at LR and YE are compared with that at BH when the amounts were obtained at the both stations. Although the compared days and duration are different, the amount ratio to BH are 1.18 at LR (147 days) and 1.46 at GC (113 days). Seko (1987) reported that the precipitation amount at GC was 1.3 times that at BH during July to September 1985. He concluded that the increase of the amount with altitude was due to convective precipitation associated with meso-scale thermal circulation in the valley. The diurnal cloud convection related to the local circulation was also observed along the slope of the valley in this study.

It is pointed out that the precipitation in winter season is more important in Langtang Himal than in Khumbu Himal by Seko and Takahashi (1991) and by Shiraiwa (1993). Winter snow cover will prevent glacier ablation in coming melting season due to high albedo of snow in ablation area of glaciers. The high snowfall events were observed in October on the Yala Glacier. Although snowfalls were also observed since the middle of August, the precipitation in October will largely contribute to the accumulation of the glacier due to its large amount. The yearly fluctuation of the precipitation in October, however, which has been observed at BH since 1985, was larger than that in other months as mentioned later.

3.5 Radiation

The seven days running mean short wave radiation at BH, LR and YE and the calculated solar radiation at the top of atmosphere are shown in Fig. 6a. The radiation at BH is almost always larger than that at LR and YE. The short wave radiation would be inversely correlated with the cloud amount above the stations. It is important to analyze its diurnal variation considering the variations of other parameters for understanding the local circulation in the valley. The variation of short wave radiation at all stations shows a periodic variation with a period of about 15 days, corresponding to the precipitation variation described above. This period of the variation agree with one for Indian monsoon fluctuations pointed out by Murakami (1976).

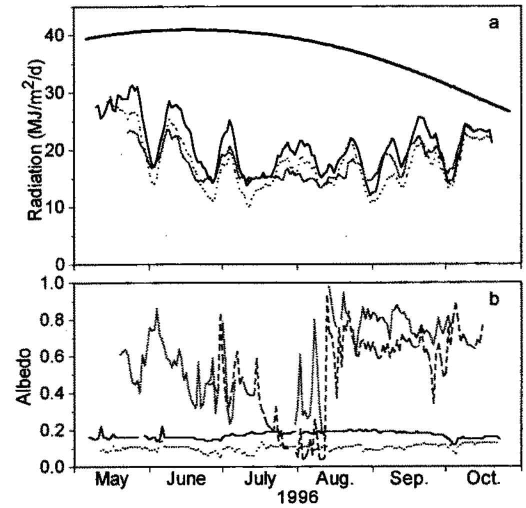

Fig. 6. a) The seven days running mean of daily mean short wave radiation at BH (solid), LR (dotted) and YE (gray) and at the top of atmosphere (thick solid). b) Daily mean albedo at BH (solid), LR (dotted), YE (gray) and YA (broken).

Fig. 6b shows the daily albedo calculated at BH, LR, YE and YA. The albedo values at BH and LR were stable due to the constant surface conditions. On the Yala Glacier, however, the albedo gradually decreased until the end of July. At the end of July, the ice with thick black dirt was exposed at YA, whereas the dirt snow remained at YE. The drastic albedo increase was observed at both YE and YA in August. It implies that the precipitation occurred as snow. Although daily mean air temperature was above 0 °C in the middle of August, the precipitation should have occured as snow in cold condition (below 0 °C) and change the surface albedo.

4. Meteorological condition of 1996

The meteorological observations have been continued since 1985 with some interruption (1985–1986 ; 1987–1993). The monthly averaged or summed value of measured parameters are compared with those of this study in Fig. 7. Air temperature shows the sinusoidal variation with small yearly fluctuations. Air temperature obtained in this study was

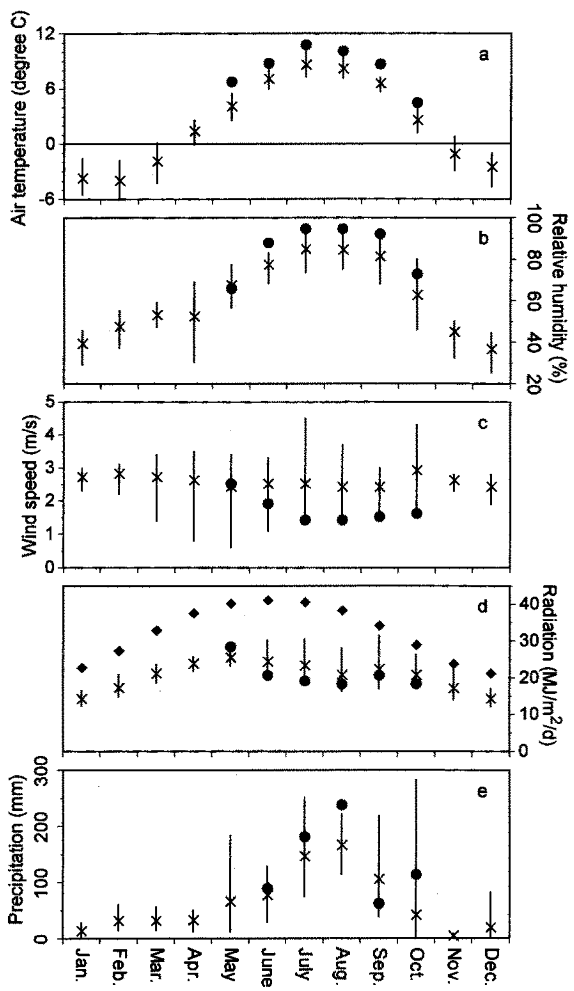

Fig. 7. Monthly averaged daily mean values of air temperature (a), relative humidity (b), wind speed (c) and daily mean short wave radiation (d) at BH. Precipitation shows the monthly summed amount (e). Crosses and circles denote the averaged values in 1985–1986 ; 1987–1992 and this study, respectively in all figures. Solid lines denote the range between the maximum and the minimum of the parameters in all figures. Squares in (d) denote the monthly averaged daily short wave radiation calculated for the top of atmosphere.

higher than the averaged one (Fig. 7a). Relative humidity has also the sinusoidal variation with a few cases of large yearly fluctuations. Relative humidity of this study also shows higher value than the averaged one (Fig. 7b). Although averaged wind speed is almost constant regardless of the season, it fluctuate largely year by year. Wind speed of this study was smaller than the averaged one (Fig. 7c).

Fig. 7d shows the monthly averaged daily short wave radiation and the calculated one at the top of atmosphere. The short wave radiation during monsoon season is restrained comparing with the top radiation due to the persistent thick cloud. The larger yearly fluctuations during monsoon season than that in winter season imply the fluctuations of the monsoon intensity year by year. This fluctuations might be emphasized in that of precipitation as mentioned later. Monthly averaged daily short wave radiation obtained in this study are slightly smaller than the seven years average. The yearly fluctuations of the precipitation from June to September would reflect the intensity of the monsoon (Fig. 7e). The fluctuation in October is remarkably high. It might be caused by the westerly disturbances, not by the monsoon. The fluctuations of winter precipitation would largely effect on the glacier mass balance as mentioned above. It is important and interest to analyze comprehensively the water and energy circulation in the valley further.

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