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Fluctuations of the glaciers from the 1970s to 1989 in the Khumbu, Shorong and Langtang regions, Nepal Himalayas

Tomomi YAMADA[1], Takayuki SHIRAIWA[1], Hajime IIDA[2], Tsutomu KADOTA[3], Teiji WATANABE[4], Birbal RANA[5], Yutaka AGETA[3] and Hiroji FUSHIMI[6]

1 Institute of Low Temperature Science, Hokkaido University, Sapporo 060 Japan
2 Yoshida Science Museum, Kurobe, Toyama 938 Japan
3 Water Research Institute, Nagoya University, Nagoya 464 Japan
4 Graduate School of Environmental Science, Hokkaido University, Sapporo 060 Japan
5 Department of Hydrology and Meteorology, Ministry of Water Resources, His Majesty's Government of Nepal, Kathmandu, Nepal
6 Lake Biwa Research Institute, Shiga 520 Japan

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Abstract

Fluctuations of glaciers were investigated by means of the ground survey in the Khumbu, Shorong and Langtang regions, Nepal Himalayas, which was carried out as a part of the Glaciological Expedition of Nepal in the post-monsoon season of 1989. The previous surveys were conducted from the 1970s to the beginning of the 1980s ; therefore, we obtained the trend of glacier fluctuation during the last decade. Almost all glaciers have greatly shrunk since the 1970s, although a possible advance was recorded for some glaciers during the first half of the 1980s. The retreating rate of some glaciers has been accelerated during the 1980s, compared to that recorded in the 1970s.

1. Introduction

Terminal fluctuations of glaciers provide important information for past as well as present climatic condition of study areas. Extensive investigation of the fluctuation of worldwide-glaciers was encouraged as one of the activities of the International Hydrological Decade (IHD : 1965–1974). It has been succeeded by the International Hydrological Programme (IHP), and the results have been periodically published as "Fluctuation of Glaciers" by IAHS, UNESCO (e.g., Müller, 1977).

As a part of both IHD and IHP, fluctuations of the glaciers in Nepal were investigated during the 1970s by the Glaciological Expedition of Nepal, the joint research project between Japan and Nepal (Higuchi, 1976, 1977, 1978, 1980). Higuchi *et al.* (1979) reported that the glaciers in the Khumbu region in east Nepal were retreated between 1960 and 1975 by comparing the terminal positions of the glaciers in the 1970s with those in 1960 reported in Müller's inventory (Müller, 1970). Fushimi and Ohata (1980), who investigated the terminal positions of 15 glaciers in the Khumbu region from 1970 to 1978, concluded that 8 glaciers were retreated, 3 stationary, 3 advancing and 1 irregular.

The investigation of the glacier termini was also started in the Langtang region, approximately 100 km west of the Khumbu region (Ageta *et al.*, 1984). The terminal position of the Yala Glacier was determined both by photogrametry (Yokoyama, 1984) and by ground survey.

In the post-monsoon season of 1989, the Glaciological Expedition of Nepal sent two teams to the Khumbu, Shorong, and Langtang regions in order to survey the terminal positions of the glaciers which were surveyed from the 1970s to the beginning of the 1980s (Yamada, 1991). This paper reports the terminal fluctuations of the glaciers in the Khumbu, Shorong, and Langtang regions between the 1970s and 1989.

2. Glaciers surveyed and method of observation

The terminal positions of the specified glaciers were surveyed in the Khumbu, Shorong, and Langtang

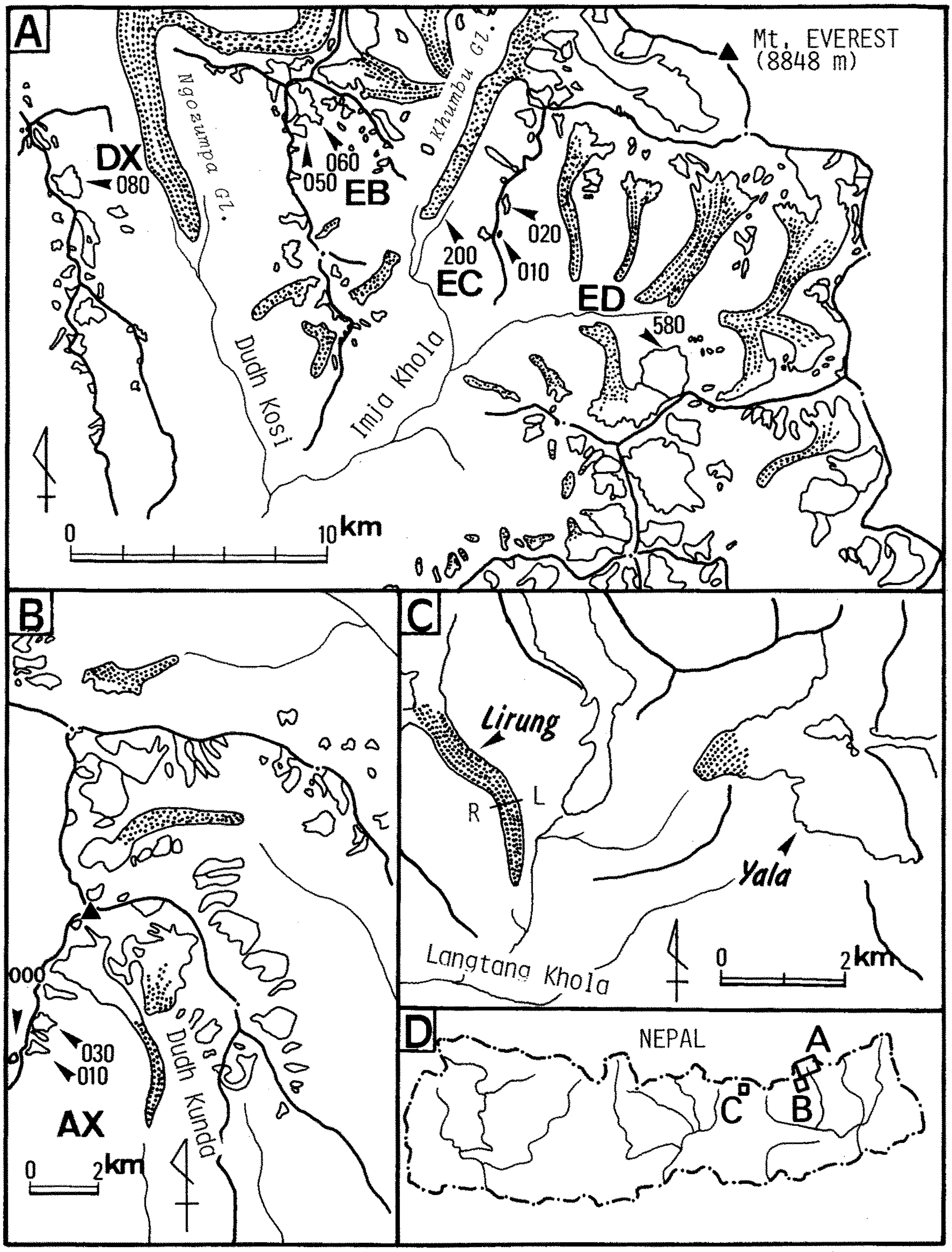

Fig. 1. The location maps of the glaciers surveyed. A : Dudh Kosi and Imja Khola basins in the Khumbu region ; B : Dudh Kunda basin in the Shorong region ; C : Langtang Khola basin in the Langtang region ; D : Maps A to C are located in the squares in the map of Nepal.

regions from the end of October to December, 1989 (Fig. 1 A-C). Debris-free glaciers, namely, clean type glaciers (Moribayashi and Higuchi, 1977) were especially selected for the measurement of the terminal positions because this type of a glacier is considered to be sensitive to climatic changes. The individual names of the glaciers are DX080 in the Dudh Kosi basin, EB050, EB060, ED010, ED020 and ED580 in the Imja Khola basin, Khumbu region (Fig. 1 A), AX000, AX010, AX030 in the Dudh Kunda basin, Shorong region (Fig. 1 B), according to the cord names given by Higuchi *et al.* (1978), and the Yala Glacier in the Langtang Khola basin, Langtang region (Fig. 1 C).

In addition to the measurement of the termini of clean-type glaciers, transverse profiles of valley glaciers were surveyed for debris-covered glaciers. The debris-covered glaciers develop extensively in the Nepal Himalayas ; therefore, we should know present mass balance regime of the glaciers. The glaciers surveyed were EC200 (Khumbu Glacier) in the Imja Khola basin and the Lirung Glacier in the Langtang Khola basin.

Glacier termini were depicted by measuring the termini from one to nine fixed-base-point (s) towards the given direction, using a plain compass and a tape with the errors within 5 minutes in angle and 5 cm in length. Transverse profiles of the glaciers were surveyed by triangulation from the fixed points established at lateral moraines of the glaciers, using a theodolite (WILD T-2) and Geodimeter (DISTMAT WILD DIOR−3002).

3. Results

The characteristics of the glaciers are listed on Table 1, partly according to Fushimi and Ohata (1980). Table 2 shows the terminal fluctuation of ten glaciers in a given period. The terminal changes of glaciers AX000, AX010, DX080, EB050 and the Yala Glaciers are illustrated in Fig. 2. The surface levels recorded in the Lirung Glacier both in 1987 and 1989 are shown in Fig. 7. The characteristics of the fluctuations of the glaciers are, hereafter, described in detail.

3.1. Khumbu region

Seven glaciers were chosen in this area, namely glacier DX080 in the Dudh Kosi basin, glaciers EB050, EB060, EC200, ED010, ED020 and ED580 in the Imja Khola basin. All glaciers are clean type glaciers lacking supraglacial moraines in the ablation area, except for glacier EC200 (Khumbu Glacier).

Glacier DX080 is located in the west of the Gokyo summer village located at the right bank of the Ngozumpa Glacier. The glacier develops at the eastern side of the N-S stretching ridge. A base point for surveying was installed on a large boulder in front of the terminus in 1976. Four parts of the glacier terminus were surveyed from a new base point established between the 1976 base point and present terminus. The retreat of the terminus amounted approximately to 60 m from 20 September, 1976 to 16 November, 1989 (Fig. 2). The annual retreating rate for the period is calculated as 4.6 m/a.

Glacier EB050 develops in the north-west of the

Table 1. The characteristics of the glaciers surveyed. Glacier number, glacier name, longitude, latitude, orientation, length, surface area, highest glacier elevation, lowest glacier elevation, average inclination and classification are listed. The glacier type C stands for a debris-free glacier, and D for a debris-covered glacier.

Gl. No.	Gl. Name	Longitude E	Latitude N	Orientation	Length km	Surface area km²	Highest elevation (m)	Lowest elevation (m)	Average incline.	Classification	Gl. type
DX 080		86°34'0"	27°57'0"	N	1.3	0.97	5480	5140	14	646110	C
EB 050		86°45'9"	27°57'6"	SE	1.5	0.42	5555	5215	13	606410	C
EB 060	Dzonglha	86°46'2"	27°57'9"	SE	1.8	1.10	5920	5150	23	636110	C
ED 010	Kongma Tikpe	86°50'5"	27°55'7"	N	0.2	0.02	5500	5440	17	706110	C
ED 020	Kongma	86°50'6"	27°56'0"	S	0.8	0.19	5790	5450	16	606110	C
ED 580	Chukhung	86°53'7"	27°53'1"	NW	2.3	2.99	6040	4970	23	686013	C
EC 200	Khumbu	86°48'8"	27°56'0"	SW	17.0	17.50	7980	4920	10	516410	D
AX 010		86°34'0"	27°42'8"	E	1.7	0.57	5360	4952	13	63611 X	C
AX 030		86°34'0"	27°43'5"	E	1.0	0.53	5600	5050	28	63621 X	C
	Yala	85°37'	28°15'	SW	1.2	2.57	5733	5090	15	681 XXX	C
	Lirung	85°33'	28°15'	S	6.5	6.24	6100	3962	−	521 XXX	D

Table 2. The fluctuations of the glaciers in the Khumbu, Shorong and Langtang regions. A negative value (m) of the fluctuations shows a terminal retreat.

Area	Gl. No.	Gl. Name	Base No.	Fluctuation of glacier termini (m)
Khumbu	D X 080			(20 Sep.,'76) ··········· (16 Nov.,'89) −60
	E B 050			(22 Sep.,'76) ··········· (22 Nov.,'89) −30
	E B 060	Dzonglha		(29 Jun.,'78) ··········· (22 Nov.,'89) All base points were not found. New base points and a photo point were established for future survey.
	E D 010	Kongma Tikpe		(25 Aug.,'78) ··········· (1 Nov.,'89) −27
	E D 020	Kongma		(24 Aug.,'78) ··········· (1 Nov.,'89) at least −32
	E D 580	Chukhung		(22 Aug.,'78) ··········· (28 Oct.,'89) All base points were not found. The terminal shape of the central part was mapped in 1989. Photographical interpretation suggests the terminal retreat of approximately 100 m.
Shorong	A X 000			(19 Sep.,'78) ··········· (5 Nov.,'89) One of the two tongues disappeared, which resulted in retreat of 160 m.
	A X 010			(8 Sep.,'78) ··········· (2 Nov.,'89) −30
	A X 030			(13 Aug.,'78) ··········· (3 Nov.,'89) stationary
Langtang		Yala	1	(15 Oct.,'82) ········ (27 Sep.,'87) ········ (4 Dec.,'89) − 8.4 − 0.3
			2	(15 Oct.,'82) ········ (27 Sep.,'87) ········ (4 Dec.,'89) − 3.4 − 6.9
			3	(15 Oct.,'82) ········ (27 Sep.,'87) ········ (4 Dec.,'89) + 2.4 − 6.7
			4	(16 Oct.,'82) ········ (28 Sep.,'87) ········ (4 Dec.,'89) + 0.4 − 5.0
			5	(16 Oct.,'82) ········ (28 Sep.,'87) ········ (4 Dec.,'89) +10.1 − 3.6
			6	(16 Oct.,'82) ········ (28 Sep.,'87) ········ (5 Dec.,'89) + 2.6 + 0.2
			7	(16 Oct.,'82) ········ (28 Sep.,'87) ········ (5 Dec.,'89) +10.2 − 5.3
			8	(16 Oct.,'82) ········ (28 Sep.,'87) ········ (5 Dec.,'89) + 6.7 − 4.1
			9	(8 Oct.,'87) ········ (5 Dec.,'89) − 5.4

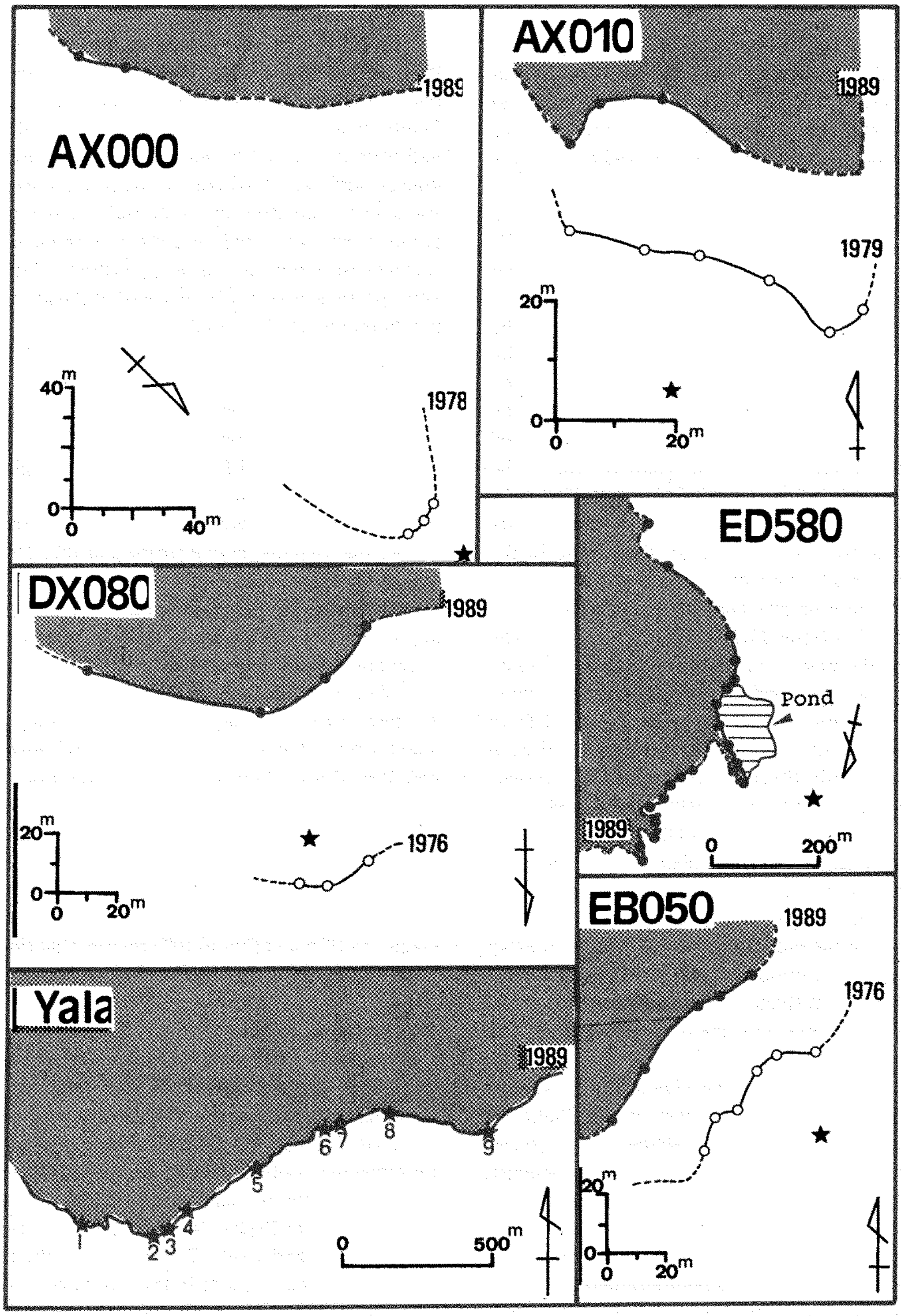

Fig. 2. Terminal fluctuations of the glaciers surveyed. Note that scales are different in each map.

Tukhla summer village of the Imja drainage basin. Measurement of the five parts of the terminal position shows that the glacier has retreated about 30 m from 22 September, 1976 to 22 November, 1989 (Figs. 2 and 3). The annual retreating rate of 2.28 m/a is larger than the value previously reported as 0.93 to 1.79 m/a from 1976 to 1978 (Fushimi and Ohata, 1980).

Glacier EB060 is located just north of glacier EB050. Since we failed to find the base point for the survey, no data were available. We only established new base points for the future survey.

Glacier ED010 is a glacieret developed on the northern slope of Peak 5749 m in the Imja Khola basin. The terminal fluctuation of this glacier had been monitored every year from 1974 to 1978, and the annual retreating rate of 0.6 to 1.2 m/a was observed (Fushimi and Ohata, 1980). The total retreat of the glacier attained 26.9 m from 25 August, 1978 to 1 November, 1989 (Fig. 4). The annual retreating rate of 2.4 m/a in this period is larger than those in the period between 1974 and 1978.

ED020, the Kongma Glacier, is located on the southern flank of the Mehra Peak (5817 m). The terminus of the glacier in 1976 stretched as an elongated ice tongue beyond the precipitous rock wall, whereas it became a dead ice mass detached from main ice body in 1981 (Fig. 5, Yokoyama, 1982 cited in Yasunari and Fujii, 1983). The terminus has retreated approximately 30 m from 1970 to 1976, and 7.8 m from 1976 to 1978 (Fushimi and Ohata, 1980). When we visited this glacier in November 1989, the dead ice was melted away (Fig. 5). The terminal retreat has amounted at least to 32 m since August 1978. Interestingly, one of the base points which was 22 m away from the glacier terminus in 1978 was buried by a glacial till of 30 cm thick. This may suggest a possible advance of the glacier some time between 1981 and 1989.

Glacier ED580 (Chukhung Glacier) is a widely-extended glacier at the south-east of the Chukhung summer village. The terminal shape of the glacier was observed from 19 September, 1976 to 22 August, 1978 (Fushimi and Ohata, 1980). They reported that the glacier advanced at the rate of 3.52 to 6.78 m/a in its central part, and of 2.56 m/a in its left part during this period. The terminus is photogrametrically considered to have been retreated approximately 100 m between 1978 and 1989, although the exact value was not available due to the missing of the previous base points. The terminal shape was surveyed in 1989 for the future measurement (Fig. 2).

Glacier EC200, the Khumbu Glacier, flows down from Mt. Everest (Sagarmatha in Nepal) and terminates at the altitude of 4900 m. Because of the difficulty in surveying the terminal position, this glacier had been monitored by means of the leveling of the glacier surface. Two transverse profiles were measured in the ablation areas in 1978. Since the base points were not found in 1989, the changes of the surfaces were not able to be quantified. Two transverse profiles were newly surveyed at the almost same points previously surveyed.

3.2. Shorong region

Glacier AX000 (temporarily named), a north-facing small cirque glacier, is located at the south-west of glacier AX010 and feeds the Tsum Drangka basin (Fig. 1 B). The terminal position was initially measured in 1978 and was re-surveyed in 1989. The glacier had two distinctive tongues in 1978 ; however, one of them has completely disappeared by November, 1989 (Fig. 2). This gives the terminal retreat of approximately 160 m, while another tongue did not show any remarkable change.

Glacier AX010, which is one of the best studied glaciers in the Himalayas, is a small valley glacier. The terminus has retreated about 30 m between 1979 and 1989 (Figs. 2 and 6). Photogrametrical estimation revealed that the glacier surface decreased about 10 m in its terminal part.

Glacier AX030 is located in the Yuligolcha valley, north of glacier AX010. Although we failed to access the glacier, photographical comparison between the glacier in 1978 and that in 1989 reveals that there is no visible terminal fluctuation in this period.

3.3. Langtang region

The Yala Glacier has a trapezoidal shape and is located at the right bank of the Langtang Khola. Nine base points were established to measure the terminal fluctuations in 1982 (Fig. 2). The glacier terminus generally advanced between 1982 and 1987 (Table 2) by the amount of 0.4 to 10.2 m. This advancing trend in 1982−1987 turned to retreating trend between 1987 and 1989. The retreat of the terminus amounted to 0.2 to 6.9 m in the two years.

The Lirung Glacier is a debris-covered glacier developing at the right bank of the Langtang Khola (Fig. 1 C). The transverse profile in the ablation area was measured by triangulation in 1987 in its middle

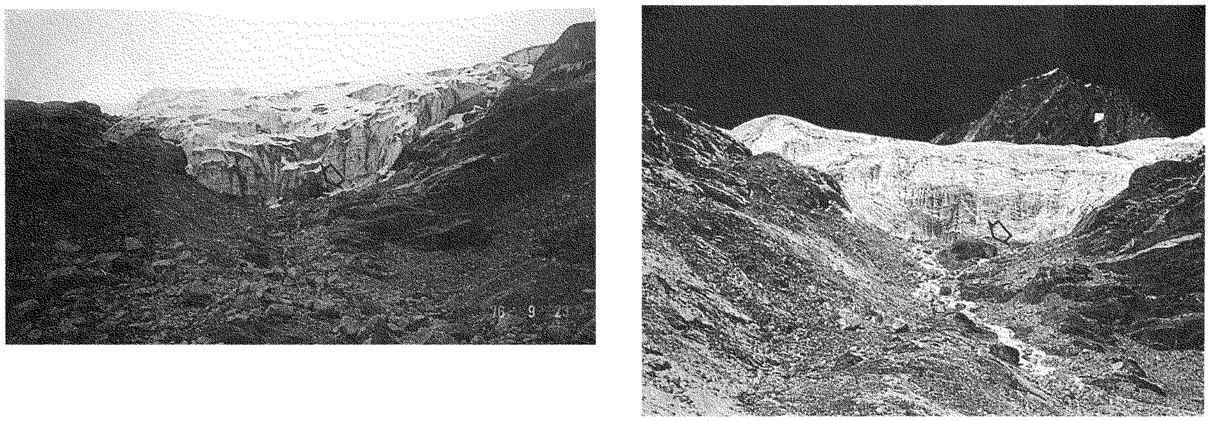

Fig. 3. The glacier terminus of EB050 in 1976 (left) and in 1989 (right). Note that the basement bump indicated by an arrow at the center of the terminus in 1976 was completely free from the ice in 1989.

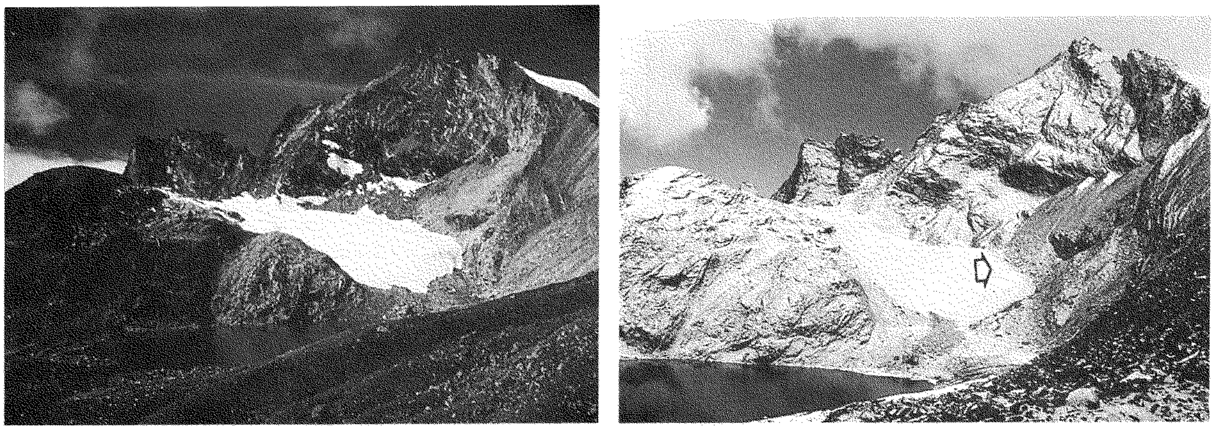

Fig. 4. Glacier ED010, Kongma Tikpe, in 1974 (left) and in 1989 (right). The left part of the glacier shrunk considerably from 1974 to 1989. The surface lowering resulted in the emergence of the bedrock or moraine topography in the right side (arrow).

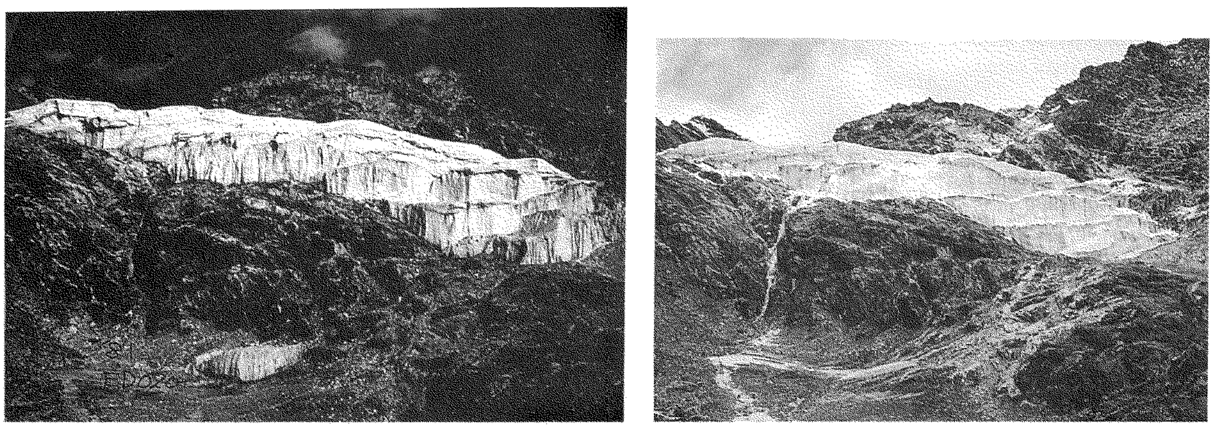

Fig. 5. Glacier ED020, Kongma, one of the best monitored glaciers in this region. The terminal retreat from 1981 (left) to 1989 (right) is quite obvious by these photos.

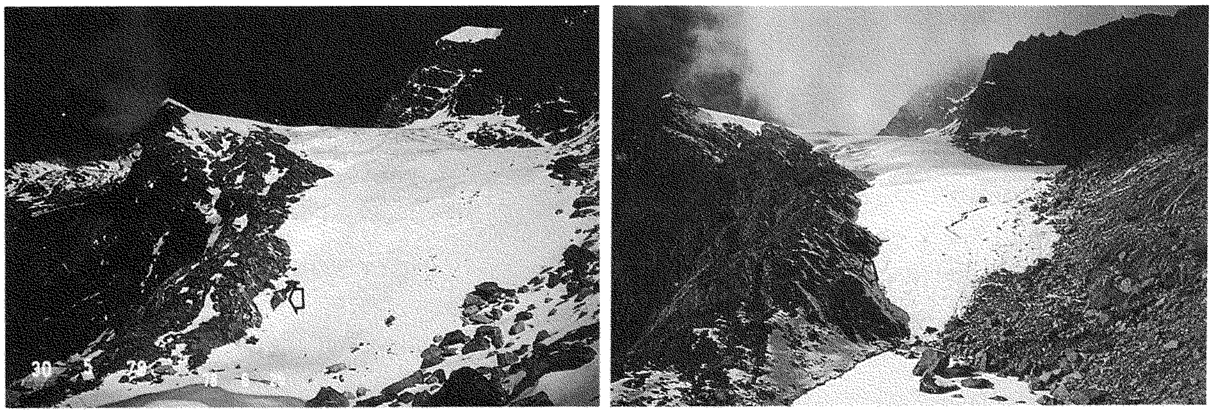

Fig. 6. The terminus of glacier AX010. The terminus retreated from 1978 (left) to 1989 (right). The surface lowering resulted in the emergence of the bedrock (arrow).

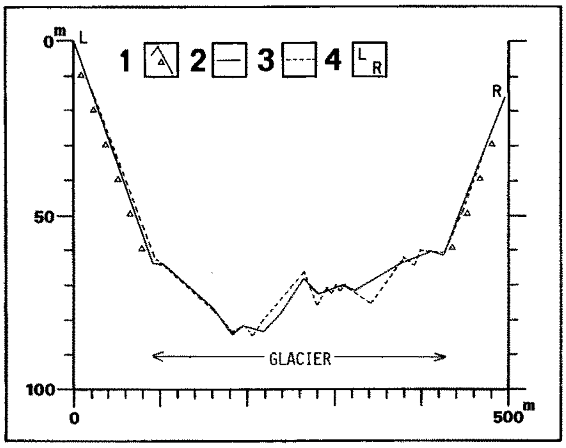

Fig. 7. Transverse profiles of the middle part of the Lirung Glacier in the Langtang Himal. The position of the profiles is shown in Figure 1-C by a solid line. Legends : 1. lateral moraine ; 2. surface profile in 1987 ; 3. surface profile in 1989 ; 4. letters L and R indicate the left and right banks.

part (Shiraiwa, 1989). The same part was surveyed from the base points established on the both sides of the glacier. The result indicates that the glacier surface did not show remarkable change (Fig. 7) ; some parts were slightly lowered and the others rose. Further monitoring is required.

4. Concluding remarks

The ground surveys and the photographical comparison have clarified the terminal fluctuations of the glaciers in the Khumbu, Shorong and Langtang regions. Among the fourteen glaciers in these areas, we obtained the terminal fluctuations of the nine glaciers: DX080, EB050, ED010, ED020, ED580, AX000, AX010, AX030 and the Yala. The surface change of debris-covered glaciers was illustrated only in one glacier ; the Lirung Glacier in the Langtang Valley.

The termini of almost all glaciers surveyed have retreated since the end of the 1970s, although the magnitude of the retreat varies from one glacier to another. The maximum retreat was recorded in glacier DX080 which has receded approximately 60 m from 1976 to 1989 ; the annual retreating rate amounted to about 4.6 m/a. Glacier AX030 is an exception, which does not show remarkable change in its terminus.

The retreating rate is considered to have been accelerated during the last decade if we compare our data with those in the 1970s reported by Fushimi and Ohata (1980). The retreating rate increased from 0.93 – 1.79 m/a to 2.28 m/a for EB050, and from 0.6 – 1.2 m/a to 2.4 m/a for ED010, although the rate of ED020 slightly decreased from 5 – 3.6 m/a to 2.9 m/a.

There is little observation on the glacier termini in the middle of the 1980s; therefore, the results obtained in this study indicate an overall mean of the terminal change during the last decade. In fact, the Yala Glacier advanced from 1982 to 1987. This strongly suggests that the terminal fluctuations of the glaciers in this period were not dominated by a simple retreating trend. The till-covered base point in the forefield of glacier ED020 may suggest that ED020 experienced a rapid advance during the 1980s followed by a rapid retreating.

The surface level fluctuation of a debris-covered glacier has been monitored in the middle reaches of the Lirung Glacier. The result, however, does not show a distinctive trend between 1987 and 1989. A further monitoring is needed for this kind of glaciers in the Himalayas.

In this study, the survey methods were mainly limited to the measurement of the distance between the termini both in 1970s and 1989. Uncertainty arises from this method; a glacier culmination or shrinkage does not necessarily influence its terminus in a short period. Volumes of glaciers must be quantified as well as obtaining the terminal fluctuations of glaciers, which will provide a further information of the glacier mass balance regime in the Himalayas.

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