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Glacier variations in the Northern Patagonia Icefield between 1990/91 and 1993/94

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Abstract

The snout variations of 18 outlet glaciers distributed in the Northern Patagonia Icefield between 1990/91 and 1993/1994 were elucidated by using oblique aerial photographs taken by hand-held 35 mm cameras. Although it was recognized that most glaciers showed retreats, the recession rates of most glaciers have generally declined when compared with the period from 1985/86 to 1990/91. For example, San Rafael Glacier had been retreating at a maximum rate of 300 m/a during the 1985/86–90/91 period, but between 1990/91 and 93/94, the left side (small part) of the snout has receded at a rate of only 20 m/a, while the right side (small part) has advanced at a rate of 17 m/a. On the other hand, Reicher Glacier showed the fastest recession rate of 1,183 m/a due to breaking up of the disintegrating snout in the proglacial lake. In general, the recession rates of the glaciers on the west side of the icefield were larger than those of the glaciers on the east side, a similar trend to the previous periods ; however, the differences were smaller than the previous periods.

1. Introduction

The Northern Patagonia Icefield (NPI), which lies in the southern part of Chile, is located around 47°S and 73° 30′W, and its length, width, and area are approximately 100 km, 40–45 km, and 4,200 km², respectively. The NPI has the highest mountain, Monte San Valentin (3,910 m) in Patagonia and the elevation of the icefield generally ranges from 1,000 to 1,500 m. There are many outlet glaciers which are distributed all around the icefield (Fig. 1). As part of the GRPP (Glacier Research Project in Patagonia) 1993, we flew over the NPI on December 26 and 27, 1993 for aerial survey. On the 26th, we could take photographs of only Exploradores Glacier because of the bad weather. The next day, we managed to take oblique aerial photographs of the snout areas of 18 out of 21 outlet glaciers, that were previously studied, with hand-held cameras despite the inclement weather conditions. However, it was difficult to exactly locate the snout positions of some glaciers from these photographs, because they were taken at low altitudes due to low cloud ceilings.

The purpose of this study is to elucidate glacier variations between 1990/91 and 1993/94, and to compare them with the results of the previous studies (Aniya and Enomoto, 1986 ; Aniya, 1988, 1992).

2. Method

The snout positions were drawn on the topographic maps which were published by Instituto Geográfico Militar of Chile in 1982. These topographic maps, at a scale of 1 : 50,000 with a contour interval of 50 m, were produced from vertical aerial photographs taken in 1974. Due to the difficulty of direct comparison between topographic maps and oblique aerial photographs taken with a hand-held camera, the oblique aerial photographs taken in 1990 and 93 were first compared with the vertical aerial photographs taken in 1974. Then by comparing the vertical aerial photographs with the topographic maps, it was possible to draw the snout positions onto the topographic maps.

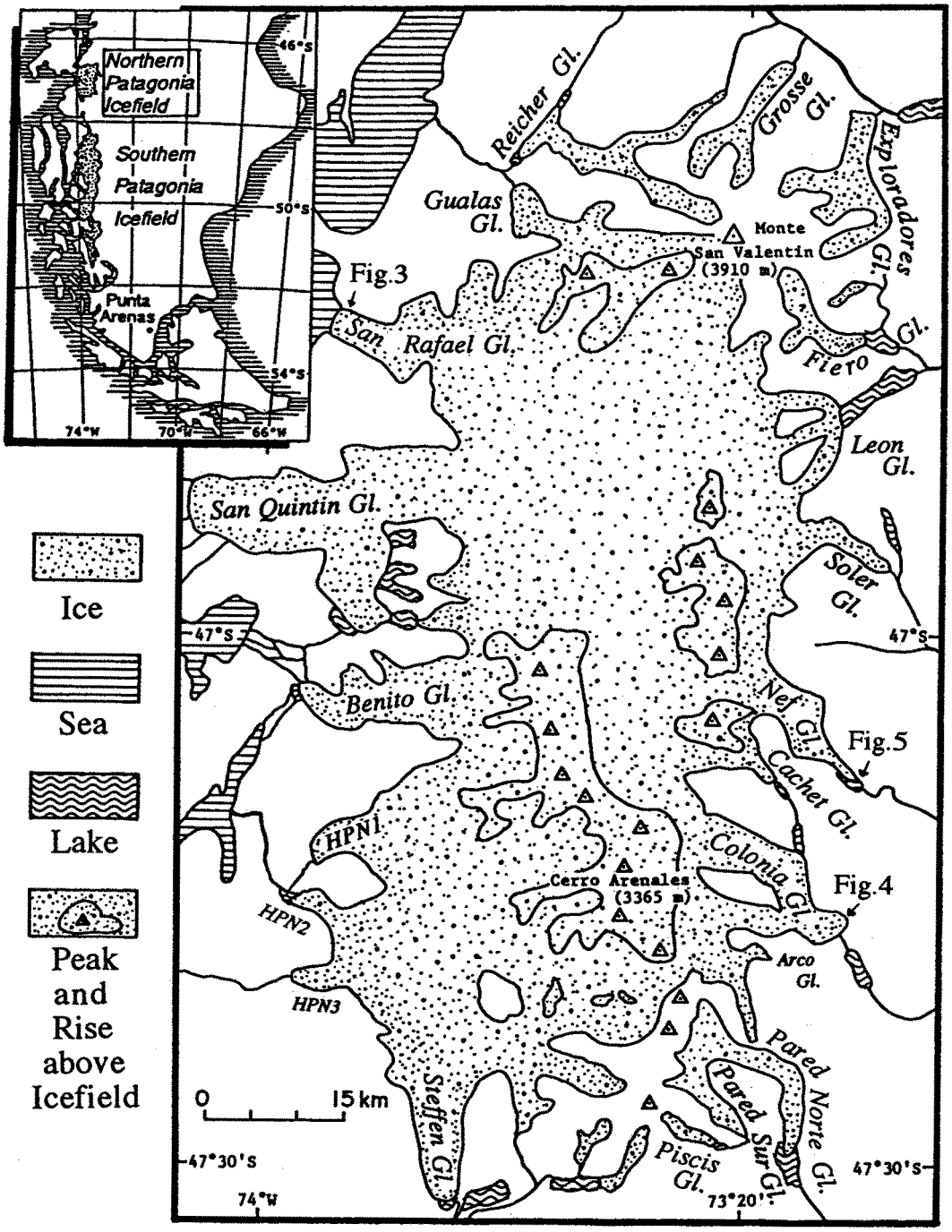

Fig. 1. The Northern Patagonia Icefield and outlet glaciers. Glaciers written with small letters (HPN2, HPN3, and Arco) are not included in this study. Locations of Figs. 3, 4, and 5 are indicated.

3. Results

Figure 2 illustrates variations of 18 outlet glaciers during the period of 1990/91−93/94 and Table 1 summarizes the variations of these glaciers between 1944/45 and 93/94, which is broken down into four periods. The data between 1944/45 and 90/91 were taken from Aniya and Enomoto (1986), and Aniya (1988, 1992). On the basis of the trend in the rate of recession, glaciers are grouped into three categories for description ; decreased, increased, and little change. The following paragraphs briefly describe characteristics of glaciers in each category.

3.1. Decreased rate

The following glaciers showed decreased recession rates between 1990/91 and 93/94 from those between 1985/86 and 90/91 ; the northeast tongue of Reicher, San Rafael, San Quintin, Benito, HPN1, eastern side of Steffen, Pared Norte, Colonia, Cachet, Leõn, and Fiero glaciers.

San Rafael Glacier (Fig. 3), a tidewater glacier and one of the largest in the NPI with the similar size to the neighboring San Quintin Glacier, seems to have stopped its retreat since 1990. It is very interesting to note that the glacier showed only a 20 m/a recession rate at a small part of the left side while a 17 m/a advance was observed at a spot on the right side. The glacier had shown the fastest recession rates of 200 m/a between 1974/75 and 85/86, and 190−300 m/a between 1985 and 90 in the NPI, although during the period of 1944/45−74/75, it retreated at a rate of only 13−30 m/a.

Another example, Colonia Glacier (Fig. 4) showed a recession rate of 53 m/a during this study period. This rate is nearly a half of the previous rate of 100 m/a during the 1985/86−90/91 period. Due to the rapid recession during 1985/86−90/91, many moraines were formed around the snout, and a new line of shear moraines has appeared due to the recession during 1990/91−93/94.

3.2. Increased rate

The following glaciers showed increased recession rates between 1990/91 and 93/94 from those between 1985/86 and 90/91 ; Grosse, southwest tongue of Reicher, northern and southern fronts of Gualas, front of Steffen, and Piscis glaciers.

At Reicher Glacier, the southwest tongue had retreated at a rate of 1,183 m/a, the most in the NPI for the period of 1990/91−93/94 and many huge icebergs have calved in a proglacial lake, leaving high ice cliffs at the snout. Apparently, the snout had been disintegrating in the proglacial lake, and this unusually large recession was caused by breaking up of the snout. The northern front of Gualas Glacier showed a recession rate of 67 m/a between 1990/91 and 93/94, which was effected by breaking away of a large piece of ice at the front in a proglacial lake. Steffen Glacier showed a large recession rate of 333 m/a at its front between 1990/91 and 93/94, due to disintegration and breaking away of a large piece of ice in a proglacial lake.

Grosse, the southern front of Gualas, and Piscis glaciers retreated 23m/a, 30m/a, and 13m/a, respectivly during the period of 1990/91−93/94. Although these rates are small, these glaciers showed no substantial changes between 1985/86 and 90/91. Grosse Glacier have been leaving some ponds near the snout.

3.3. Similar rates

The recession rates of Pared Sur, Nef, Soler, and Exploradores glaciers between 1990/91 and 93/94 were generally similar to those of the previous period of 1985/86−90/91.

Nef Glacier, which extended its slender snout into a proglacial lake, retreated at a rate of 10 m/a at its front and narrowed by rates of 13−117 m/a between 1990/91 and 93/94. The glacier snout had been progressively becoming more pointed since 1944. A SAR image taken by JERS (Japanese Earth Resources Satellite)−1 on May 10, 1994 shows that the pointed snout in the proglacial lake had been broken up, causing a sudden large retreat (Fig. 5) similar to that observed at Reicher Glacier.

Exploradores and Pared Sur glaciers are known as debris-covered glaciers, and therefore it was hard to distinguish their real snouts from the appearent snouts. These glaciers have probably showed no substantial changes. The surface topography near the snout of these glaciers is pitted due to differential melting of the stagnant ice under the debris cover. The snout position of Exploradores Glacier probably did not change between 1990 and 93 ; however, some ponds became larger, indicating that gradual wasting is taking an effect. Pared Sur Glacier did not show significant recession during this study period. It had showed a recession rate of 30 m/a between 1944 and 85, and no substantial changes were found after 1985.

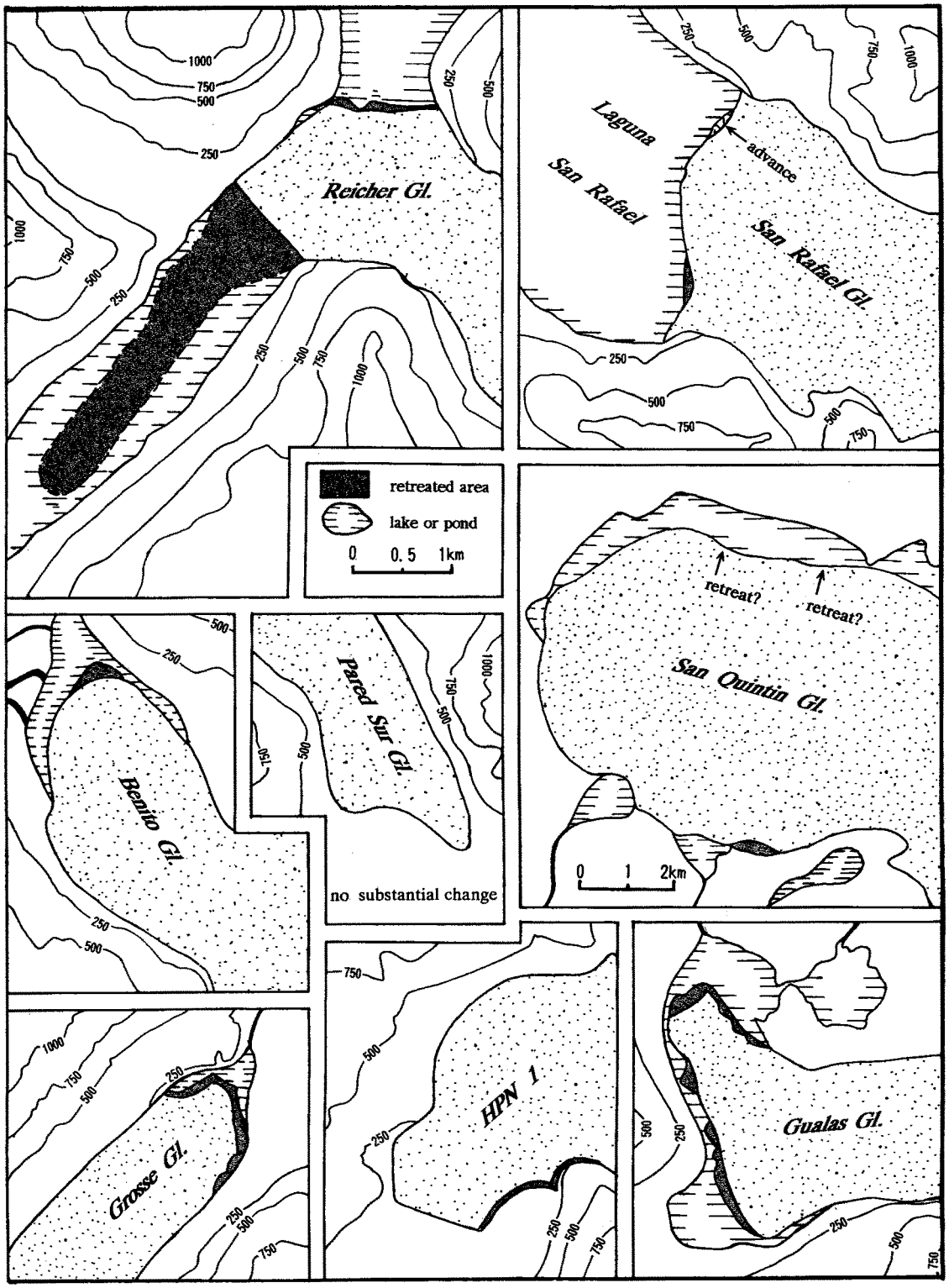

Fig. 2. Glacier variations between 1990/91 and 1993/94 (from summer to summer, three year period).

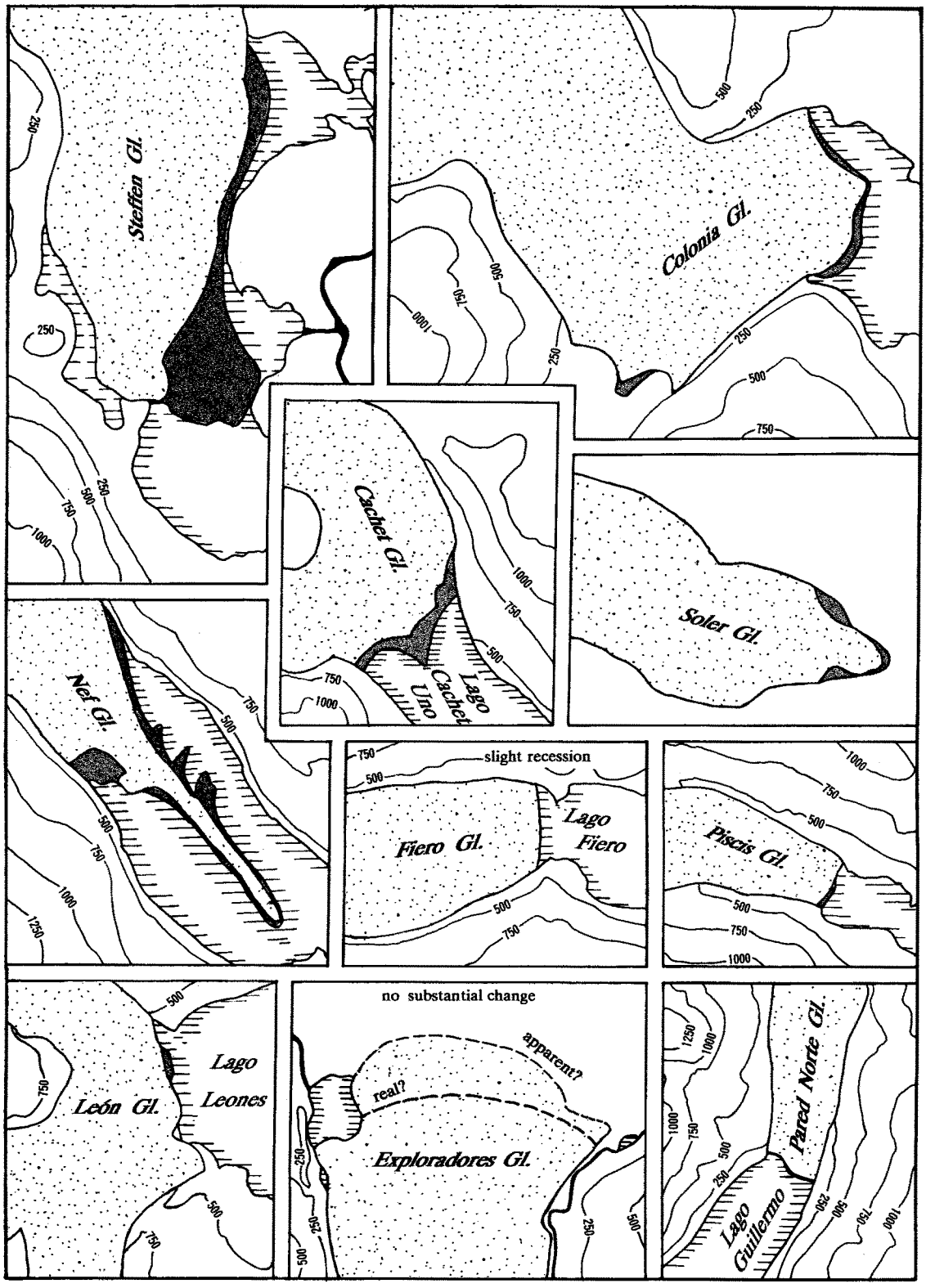
Steffen Gl.
Colonia Gl.
Cachet Gl.
Lago Cachet Uno
Soler Gl.
Nef Gl.
slight recession
Fiero Gl.
Lago Fiero
Piscis Gl.
León Gl.
Lago Leones
no substantial change
apparent?
real?
Exploradores Gl.
Pared Norte Gl.
Lago Guillermo

Table 1. Glacier variations in the Northern Patagonia Icefield between 1944/45 and 93/94.

Glacier Name	Retreat(m) 1944/45–74/75	Retreat(m) 1974/75–85/86	Retreat(m) 1985/86–90/91	Retreat(m) 1990/91–93/94
Northern Side				
Grosse	500 (17)	250 (23)	No substantial frontal change, but thining	70 (23)
Western Side				
Reicher :NE	0	2150 (195)	300–500 (60–100)	90 (30)
:SW	−400 (−13); but narrowed by 200 (7)	280 (25)	850 (170) Tongue narrowed by 300 (60)	3550 (1183)
Gualas :N	100 (3)	250 (23)	100–150 (20–30)	200 (67)
:S	250 (8)	350 (32)	No substantial change	100 (33)
San Rafael	400–900 (13–30)	2200 (200)	900–1500 (190–300)	60 (20), left (small part); −50 (−17), right (small part)
San Quintin :front	200 (7); considerable thining	very slight, but considerable thining	200–400 (40–80) and considerable thining	No substantial change
:side	1000 (33)	0	300 (60)	side (N), Retreat? side (S), 190 (63) (small part)
Benito	550 (17) left; 0 right	0, left; 200 (18), right	450 (90)	160 (53) (tip of the snout)
HPN1	1400 (47)	300 (27)	600–1200 (120–240)	50 (17), left; The surface on the right side has been slightly lowered
Southern Side				
Steffen :front	900 (30)	250 (23)	350 (70)	1000 (333)
:side (E)	500 (17)	300 (27)	400 (80)	210 (70)
Eastern Side				
Pared Sur	1000 (33)	250 (23)	No substantial change	No substantial change
Pared Norte	1300 (43)	slight	400 (80)	20 (7)
Piscis	760 (25)	100 (9)	No substantial change	40 (13)
Colonia	500 (17)	200 (18)	500 (100)	160 (53)
Cachet	2000 (67)	250–750 (27–83)	400–950 (80–190)	90–350 (30–117)
Nef	0, front narrowed by 400–700 (13–23)	350 (32), front narrowed by 300–600 (27–55)	Probably no substantial frontal retreat, but calving front is breaking away. Narrowed by about 600 (120).	30 (10) Narrowed by 40–350 (13–117)
Soler	80–300 (3–10)	60–160 (5–15)	130–240 (26–48)	20–180 (7–60)
León	100 (3)	200 (18)	120–200 (24–40)	70 (23) (small part)
Fiero	300 (10)	0	200 (40)	Slight recession
Exploradores	200 (7), apparent: 0, real ?	350 (32), apparent: 150 (14), real ?	No substantial frontal change, but considerable thining	No substantial change

The number in parentheses indicates an average annual rate.

The data from 1944/45 to 90/91 were taken from Aniya and Enomoto (1986), and Aniya (1988, 1992).

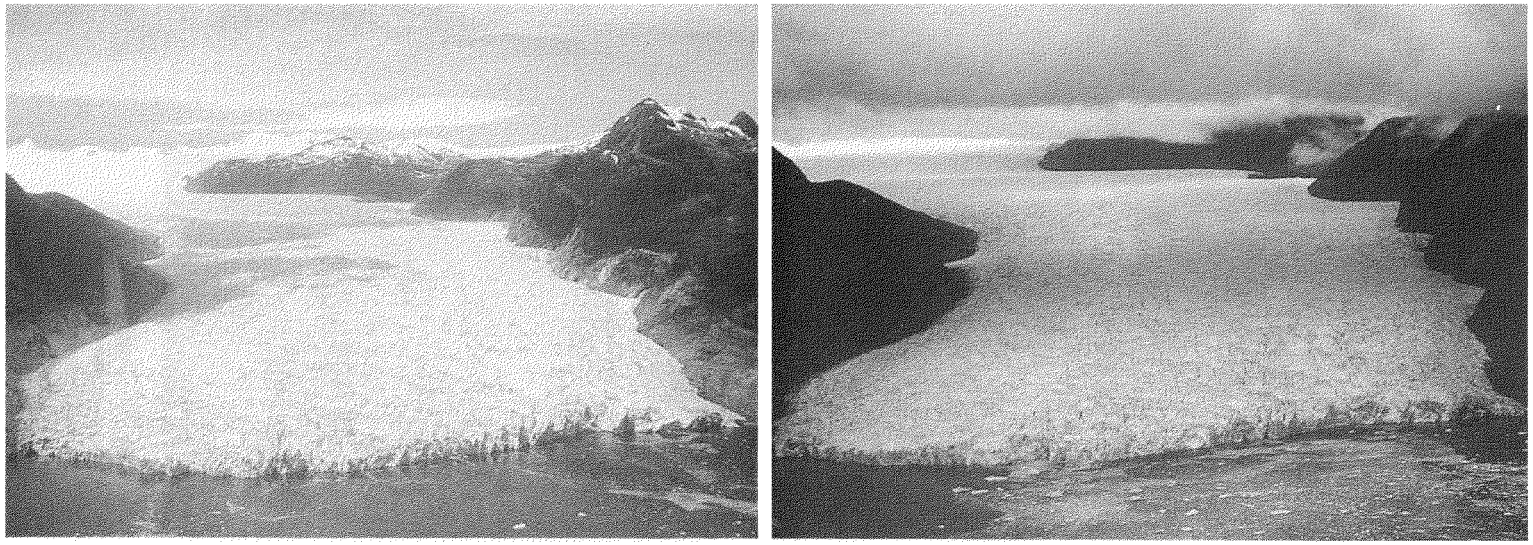

Fig. 3. Photographs showing slight changes at San Rafael Glacier. Left : December 23, 1990 ; right : December 27, 1993. Note : recession at left side and advance at right side.

Fig. 4. Photographs showing the tongue of Colonia Glacier and shear moraines. Left : December 23, 1990 ; right : December 27, 1993. Note : a line of new shear moraines appeared due to the recent recession.

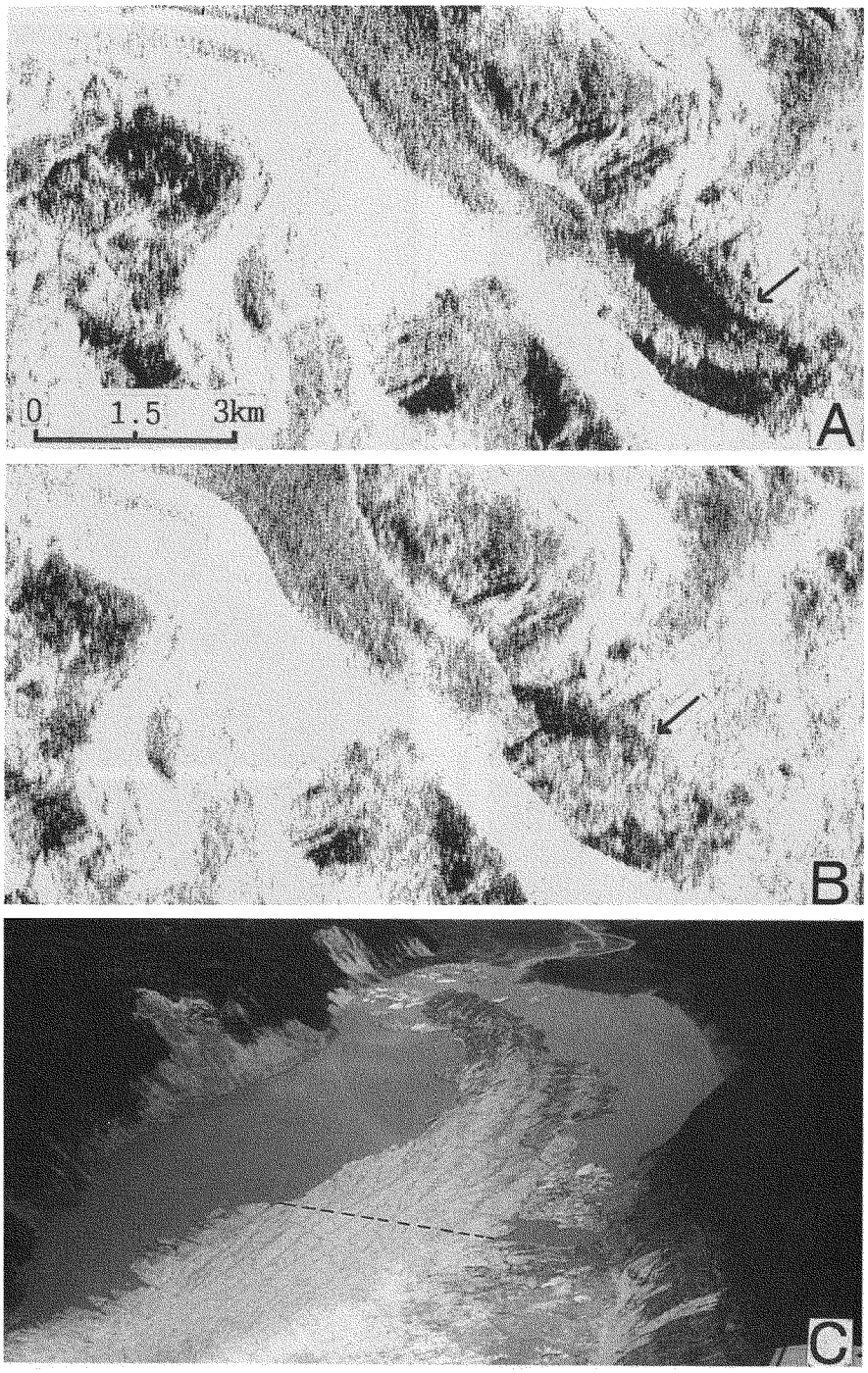

Fig. 5. SAR images of Nef Glacier snout taken with JERS-1 (A : December 29, 1993. B : May 10, 1994). C : oblique aerial photograph of the snout taken on December 27, 1993. Arrows in A and B indicate the snout which was broken up during the period December 1993 — May 1994. A broken line in C indicates the snout position after breaking up.

4. Discussion and concluding remarks

Although in general the gradual increase in the rate of the recession during the period of 1944–90 was observed, the trend of 18 major glaciers in the NPI during the 1990–93 period is found to be a decreasing rate of the recession, with a few exceptions of debris-covered glaciers. However, the southwest tongue of Reicher Glacier and the front of Steffen Glacier showed considerably faster recessions compared to the previous period of 1985–90. Since these snouts are terminating in proglacial lakes, large recessions were effected by breaking up of the snout in the water. As dramatically illustrated in the case of Nef Glacier (see Fig. 5), breaking away of a large piece of the front in a proglacial lake is probably sudden, causing an apparant large retreat not directly related to the climatic changes. However, unless we have frequent remotely-sensed data such as the case with Nef Glacier, we cannot detect such a change at the snout in the proglacial lake. Therefore, caution must be taken when interpreting the average annual rate of recession of calving glaciers. Where a large piece of ice broke away, a roughly-straight ice front with cliffs can generally be seen, suggesting that the ice broke away at some large, more or less continuous crevasses at which rough water attacked.

According to the previous studies (Aniya, 1988, 1992), the glaciers located on the west showed higher rates of the recession than those located on the east. Results obtained in this study show that the recession of glaciers located on the west side have slowed by about one-third of their previous rates ; yet they are still higher than the recession rates of the eastern glaciers. Reicher Glacier on the west side, where the recession increased dramatically due to a break up of the southwest snout, is the exception, though. It should be pointed out that glaciers with only slight changes usually have debris-covered snouts, and do not have proglacial lakes. Slight changes are probably due to the insulating effect of the debris, and no wasting by calving in proglacial lakes.

Acknowledgments

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