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Recent climate changes in southern Patagonia

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Abstract

Recent climate changes in the region east of the Southern Patagonia Icefield are shown by analyzing temperature and precipitation data at four stations in the Province of Santa Cruz (47°–52° S), southern Argentina. It became clear that trends of temperature change during the last half century were different from place to place, namely strong warming at Río Gallegos, and weak warming at San Julián on the Atlantic coast and at Lago Argentino near Patagonian glaciers, while nearly stable at Puerto Deseado on the coast. Annual precipitation shows a decreasing trend at Lago Argentino, whereas an increasing trend at San Julián and an almost stable trend at Puerto Deseado. It was also recognized at Lago Argentino that temperature in the warm season has been slightly rising and year-to-year variations in precipitation were remarkable in the cold season.

1. Introduction

A large ice-covered area, called Southern Patagonia Icefield (SPI), stretches longitudinally for 350 km from 48°20'S to 51°30'S (Fig. 1) with a surface area of 13,000 km². A number of outlet glaciers discharge from the accumulation areas in the icefield, and calve into fjords on the western side and into lakes on the eastern side of the SPI (Naruse and Aniya, 1995).

By analyzing satellite data and air photographs, variations in glacier fronts during the last half century were revealed at nine major outlet glaciers from the SPI (Aniya *et al.*, 1992 ; Aniya and Skvarca, 1992 ; Naruse *et al.*, 1995). Among the eastern outlet glaciers, O'Higgins and Upsala glaciers retreated considerably at mean rates of 330 m/a and 90 m/a, respectively, whereas Viedma and Moreno glaciers have been in near steady-states. When glacier variations in southern Patagonia are discussed from a climatic point of view, meteorological data at Punta Arenas (Endlicher and Santana, 1988) have often been cited (Aniya *et al.*, 1992 ; Warren and Sugden, 1993). Though the data set is a longest record (covering 100 years) available around the SPI, the station Punta Arenas is very far from the glaciers (Fig. 1), being 250 km south of the southern end of the SPI. For a study on recent climatic changes in Patagonia, Rosenblüth *et al.* (1995) analyzed temperature and precipitation data from Chilean and Argentine stations. However, no precipitation data from Argentine stations were utilized and, in the southern Patagonia region, only one Argentine station (Río Gallegos) was selected for the temperature analysis. Temperature and precipitation variations in the whole Argentina have been studied by Hoffmann (1988 ; 1990), focusing on the difference in decadal means between the 1940s and the 1980s. With respect to the temperature, the warming was as much as 1.2°C at Río Gallegos and 0.7°C at San Julián in southeastern Patagonia.

The present study aims to examine the local details of the positive trends, in the southern hemisphere, as to temperature since the late-1950s (Jones *et al.*, 1986) and precipitation since the 1940s (Diaz *et al.*, 1989). Moreover, it may help to solve the problem whether the Antarctic warming (Drewry, 1990) extends to southern Patagonia.

This report presents recent climatic changes in the region east of the Southern Patagonia Icefield, which should serve as basic knowledge for the further

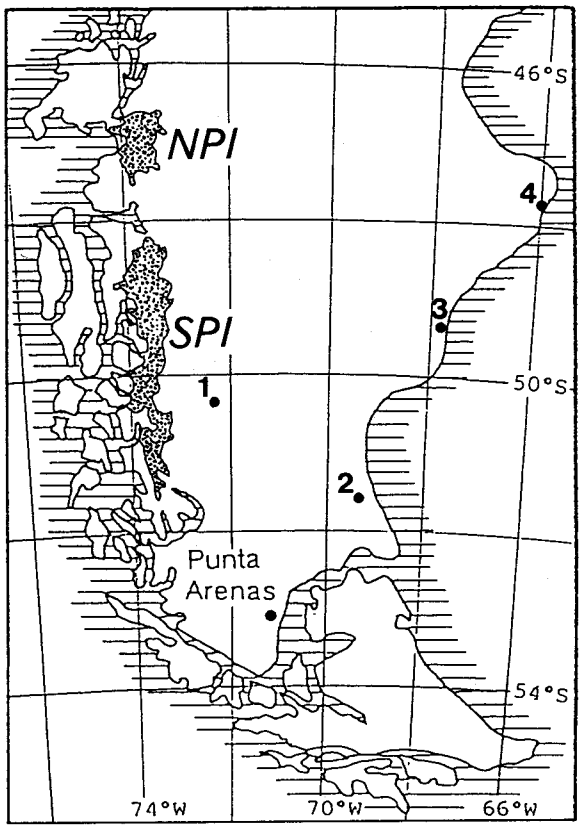

Fig. 1 Map of southern Patagonia.
SPI : Southern Patagonia Icefield, NPI : Northern Patagonia Icefield. Numbers 1 to 4 indicate locations of meteorological stations, for which results of analyses are shown in this report. 1 : Lago Argentino, 2 : Río Gallegos, 3 : San Julián, 4 : Puerto Deseado.

study on glacier responses to climatic changes. Simple statistical analyses were made for temperature and precipitation data from Argentine stations between 47°S and 52°S, including a nearest station (Lago Argentino) to glaciers of the SPI.

2. Methods

2.1. Meteorological stations and data

Climatic records at 29 meteorological stations in the region east of the southern Patagonian Andes (47°–52°S), the Argentine Province of Santa Cruz, are compiled in the archives of the Argentine Meteorological Service. In the present report, results of analyses are shown at selected four stations (Table 1, Fig. 1), which have long, continuous records of temperature and precipitation covering more than 50 years. The station Lago Argentino at Calafate is the nearest station to the eastern outlet glaciers of the SPI, 60 or 80 km from the fronts of Moreno and Upsala glaciers. The other three stations are located near the Atlantic coast and have been moved from towns to airports at the end of the 1940s or beginning of the 1950s. After examinations of the data around the period, no significant effect due to the station shift was recognized (Hoffmann, 1990).

Because the four stations are located in villages or towns of less industrialized and sparsely populated areas, and are subjected to strong Patagonian winds throughout the year (annual means : about 8 m/s), it is not necessary to consider the effects of urbanization on temperature changes.

Table 1. Selected meteorological stations in Argentina.

(A) Stations shown in Figs. 1~5

No.	Station	Latitude	Longitude	Altitude	Period of data
1	Lago Argentino (Aero)	50° 20′ S	72° 18′ W	220m	1937-1990
2	Río Gallegos (Aero)	51° 37′ S	69° 17′ W	19m	1927-1990
3	San Julián (Aero)	49° 19′ S	67° 47′ W	62m	1937-1991
4	Puerto Deseado (Aero)	47° 44′ S	65° 55′ W	80m	1937-1992

*(Aero) in Station name indicates the airport.

(B) Other reference stations

5	Base Orcadas (South Orkney island)	60° 45′ S	44° 53′ W	12m	1904-1990
6	Ventisquero Moreno	50° 26′ S	73° W	—	1955-1975
7	Puerto Santa Cruz	50° 01′ S	68° 34′ W	113m	1903-1960
8	Buenos Aires	34° 35′ S	58° 29′ W	25m	1903-1990
9	Córdoba	31° 14′ S	61° 11′ W	425m	1901-1990

2.2. Analyses

To smooth out the year-to-year fluctuations, moving averages of five years were employed to the annual mean air temperature and the annual amount of precipitation. This report aims chiefly to show the general trend of climatic changes in the last several decades. Then, a linear regression was applied to annual values during the whole period of data, and the linear line is called a tendency in this report. If the tendency increases with time it is positive, while it decreases it is negative. In order to evaluate the significance of variations, the following tests (WMO, 1966) have been applied to the meteorological parameters :

(a) A Mann Kendall rank test, in order to test randomness against trend, and
(b) Evaluation of the tendency significance.

The adopted confidence levels were 1% and 5% in both tests.

At Lago Argentino, changes in seasonal values were also examined, in which autumn is a season from March to May, winter is from June to August, spring is from September to November, and summer is from December to February.

3. Results and discussion

3.1. Temperature changes

Fluctuations in the annual mean air temperature, the moving average of five years and the tendency during the whole period at four stations are shown in Fig. 2.

We can first notice different tendencies from station to station : a strong positive tendency (with the 1% level of significance) at Río Gallegos (Fig. 2−2), a positive tendency at San Julián (Fig. 2−3), a weak positive tendency at Lago Argentino (Fig. 2−1), and almost stable conditions at Puerto Deseado (Fig. 2−4). Thus the warming decreases toward the north along the coast. In the region to the north of about 48°S, there is no significant temperature variation in Argentina in the present century, except local warming due to the urbanization in the metropoles Buenos Aires and Córdoba, +1.5 to +1.0°C during the last 70 years, respectively. On the other hand, at Base Orcadas in South Orkney Island to the southeast of Río Gallegos, the warning trend is evidently stronger than in Río Gallegos.

When we look at the moving average curves, a warming trend in the last two decades is remarkable at San Julián. At Puerto Santa Cruz, located between San Julián and Río Gallegos, temperature data are available from 1903 to 1960, and do not show a tendency during that period. Rosenblüth *et al.* (1995) stated as follows : "Between 43° and 45°S the surface data show no significant trend during the last 100 years. South of 46°S a definite warming trend appears both on the Pacific and the Atlantic coast. A warming of 1.4°C from 1938 to 1988 is observed at Río Gallegos. Curiously, the weakest warming (0.3°C from 1900 to 1988) occurs at Punta Dúngenes, only 100 km southeast from Río Gallegos." The behavior of Punta Dúngenes might be due to the data quality and maritime conditions. Considering temperature trends at these stations, the southern hemispheric warming during the last half century (Jones *et al.*, 1986) has not appeared uniformly over the Patagonia region.

3.2. Precipitation changes

Fluctuations in the annual precipitation at four stations are shown in Fig. 3, with the 5-years moving average and the tendency during the whole period.

We can see a negative tendency at Lago Argentino (Fig. 3−1). Results of the significance tests indicate no significant trend at Río Gallegos (Fig. 3−2) and a weak positive trend at San Julián (Fig. 3−3). Puerto Deseado (Fig. 3−4) shows almost stable conditions.

Large inter-annual variations are noticed at all stations. Extreme values (a maximum and a minimum in the period analyzed) of annual precipitation are 364 mm in 1963 and 60 mm in 1988 at Lago Argentino, and 366 mm in 1976 and 127 mm in 1968 at Río Gallegos. It should be pointed out that, in the decade of the 1980s, annual precipitation at Lago Argentino was considerably small, especially 97 mm in 1984, 82 mm in 1986 and 60 mm in 1988.

At the station Ventisquero Perito Moreno, near the front of Moreno Glacier, precipitation had been measured during a short period from 1955 to 1975. The year-to-year fluctuation pattern is similar to that of Lago Argentino, coinciding with the maximum in 1963 and the minima in 1960 and 1964.

3.3. Changes in seasonal values

When one intends to discuss a climatic effect on the mass-balance change of a glacier, seasonal values, such as precipitation in an accumulation period and mean temperature in an ablation period, may some-

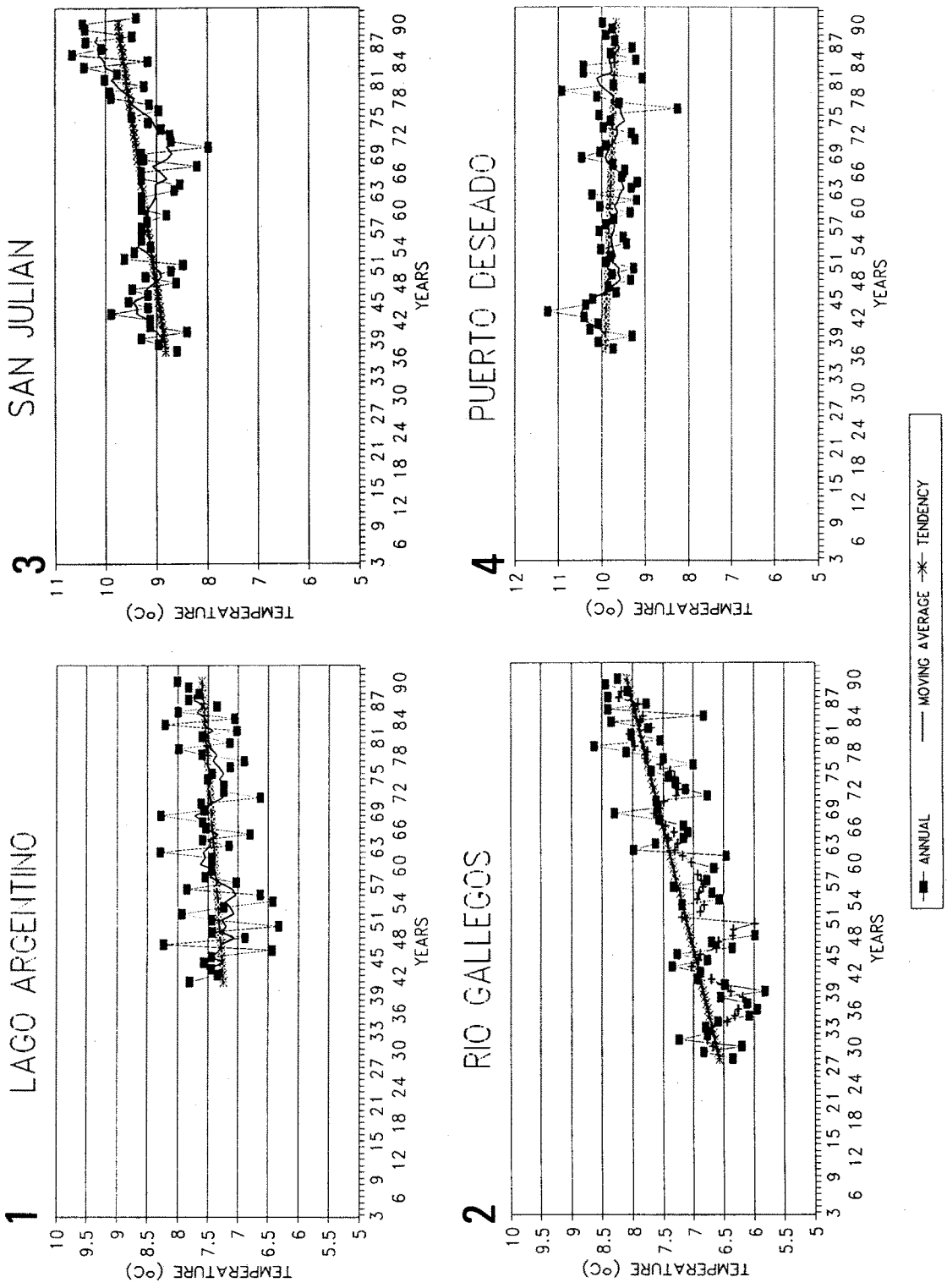

Fig. 2 Fluctuations in air temperatures at four stations.

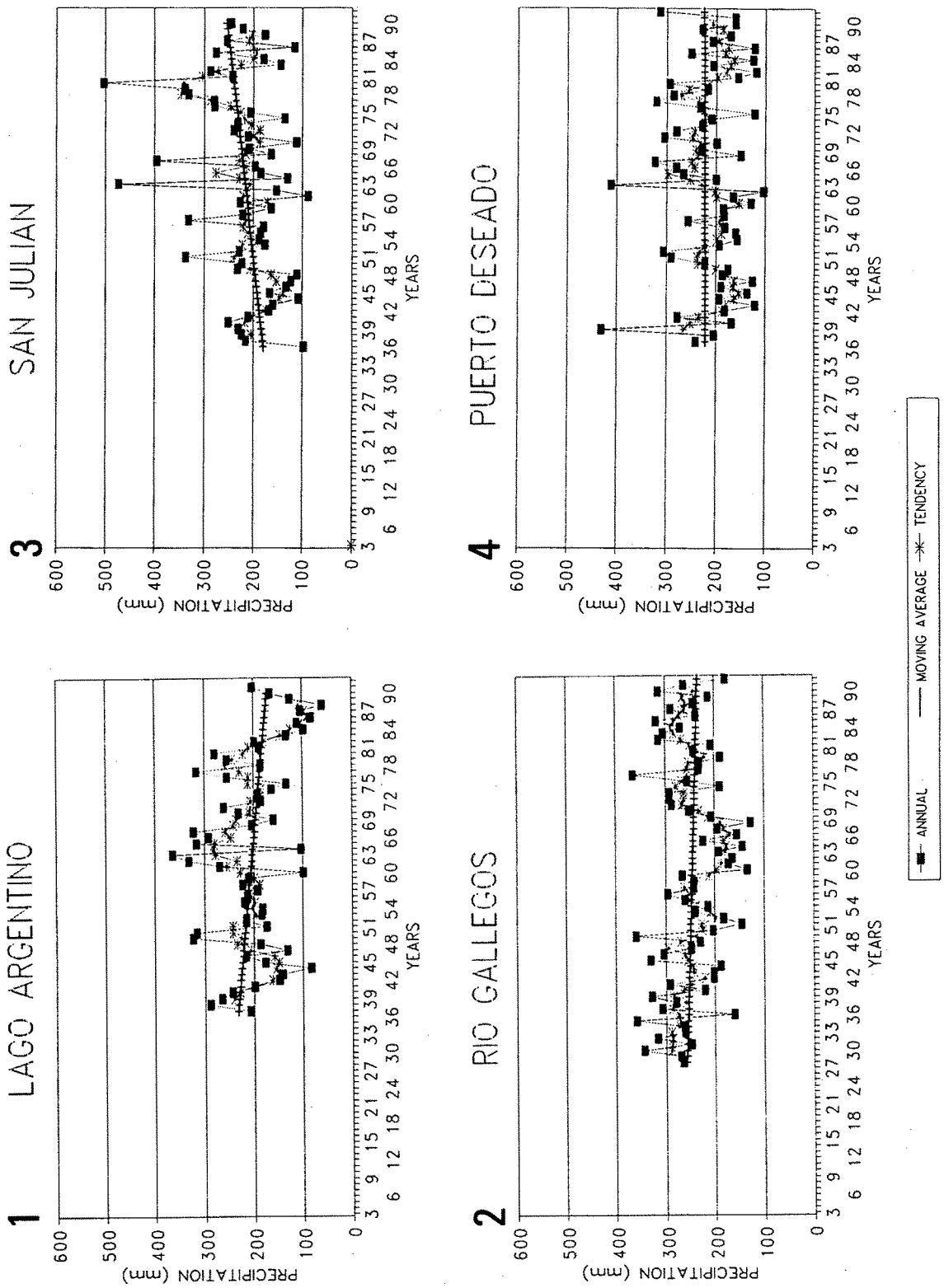

Fig. 3 Fluctuations in precipitations at four stations.

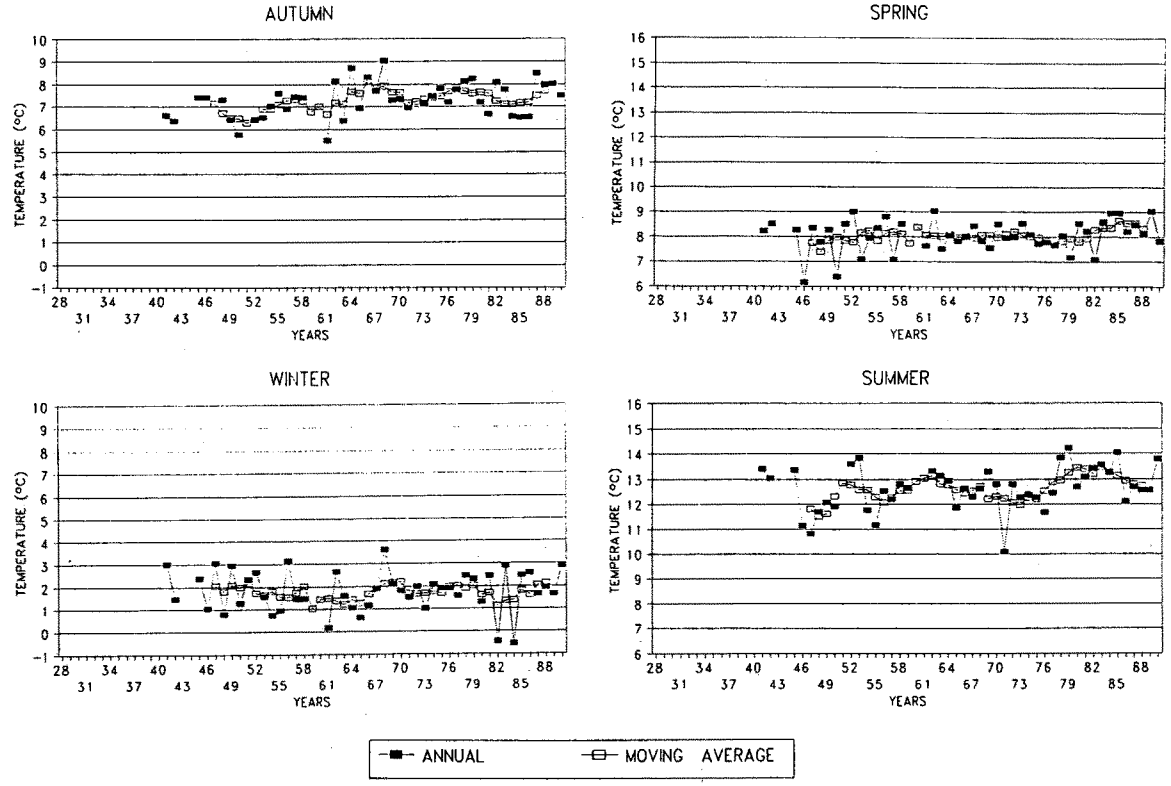

Fig. 4 Fluctuations in seasonal temperatures at the station Lago Argentino.

times become more important than annual values.

Variations in the seasonal mean temperature at Lago Argentino are shown in Fig. 4. When we look at the moving averages, it may be seen that temperatures in winter and spring are stable, while those in summer and autumn show slightly rising trends. These trends may have caused to increase the ablation of ice.

Variations in the seasonal amount of precipitation at Lago Argentino are shown in Fig. 5. It is clear that precipitation is relatively higher in autumn and winter, and lower in spring and summer. The inter-annual variations are large in autumn and winter.

4. Concluding remarks

The recent warming trend was found to be stronger in the coastal zone of southern Patagonia, and to become weaker to the north. The slight rising trend in temperature and the slight decreasing trend in precipitation at Lago Argentino, the nearest station from glaciers in the southern Patagonia, seem to help to interpret recent retreats of most glaciers in the SPI. Discussions on the thinning behavior of Patagonian glaciers with the use of climate data are presented elsewhere (Takeuchi *et al.*, 1995 ; Naruse *et al.*, submitted). Because the meteorological stations in Argentine Patagonia are located in a semi-arid climate which contrasts strikingly with a humid and stormy climate in glacier areas, more detailed and quantitative consideration on interaction between climate and glaciers can be made after having collected mass-balance and meteorological data from glaciers.

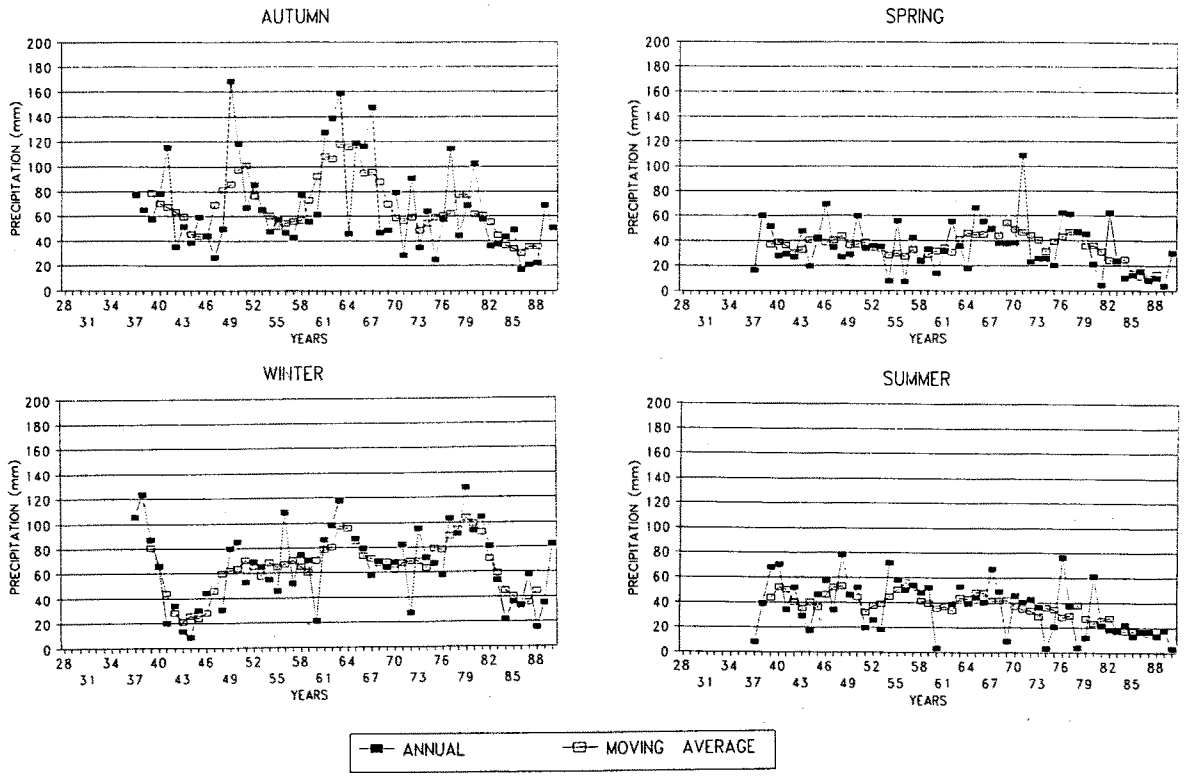

Fig. 5 Fluctuations in seasonal precipitations at the station Lago Argentino.

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References

1. Aniya, M., Naruse, R., Shizukuishi, M., Skvarca, P. and Casassa, G. (1992) : Monitoring recent glacier variations in the Southern Patagonia Icefield, utilizing remote sensing data. International Archives of Photogrammetry and Remote Sensing, Vol. **XXIX**, Part B7, (Proc. of XVIIth Congress of Inter. Soc. for Photogrammetry and Remote Sensing), 87–94.
2. Aniya, M. and Skvarca, P. (1992) : Characteristics and variations of Upsala and Moreno glaciers, southern Patagonia. Bull. Glacier Res., **10**, 39–53.
3. Diaz, H. F., Bradley, R. S. and Eischeid, J. K. (1989) : Precipitation fluctuations over global land areas since the late 1800's. J. Geophys. Res., **94**, No. D1, 1195–1210.
4. Drewry, D. J. (1990) : The role of ice sheets in a warming world. Primera Conferencia Latino-Americana sobre Geoffsica, Geodesia e Investigación Espacial Antárticas. Programa y Resúmenes. Buenos Aires.
5. Endlicher, W. and Santana, A. (1988) : El clima del sur de la Patagonia y sus aspectos ecológicos. Un siglo de mediciones climatológicas en Punta Arenas. Anales Instituto de la

Patagonia, **18**, 57–86.
6. Hoffmann, J. A. J. (1988) : Las variaciones climáticas ocurridas en Argentina desde fines del siglo pasado hasta el presente, el Deterioro del Ambiente en la Argentina. Fundación para la Educación, la Ciencia y la Cultura, Buenos Aires, 275–290.
7. Hoffmann, J. A. J. (1990) : De las variaciones de la temperatura del aire en la Argentina y estaciones en la zona subantártica adyacente, desde 1903 hasta 1989 inclusive. Actas de la Primera Conferencia Latino-Americana sobre Geofísica, Geodesia e Investigación Espacial Antárticas. Actas, Buenos Aires, 160–168.
8. Jones, P. D., Wigley, T. M. L. and Wright, P. B. (1986) : Global temperature variations between 1861 and 1984. Nature, **322**, 430–434.
9. Naruse, R. and Aniya, M. (1995) : Synopsis of glacier researches in Patagonia, 1993. Bull. Glacier Res., **13**, 1–10.
10. Naruse, R., Aniya, M., Skvarca, P. and Casassa, G. (1995) : Recent variations of calving glaciers in Patagonia, South America, revealed by ground surveys, satellite-data analyses and numerical experiments. Ann. Glaciol., **21**, 297–303.
11. Naruse, R., Skvarca, P. and Takeuchi, Y. (submitted) : Thinning and retreating of Glaciar Upsala, and an estimate of annual ablation changes in southern Patagonia.
12. Rosenblüth, B., Casassa, G. and Fuenzalida, H. (1995) : Recent climatic changes in western Patagonia. Bull. Glacier Res., **13**, 127–132.
13. Takeuchi, Y., Naruse, R. and Skvarca, P. (1996) : Annual air-temperature measurement and ablation estimate at Moreno Glacier, Patagonia. Bull. Glacier Res., **14**, 23–28.
14. Warren, C. and Sugden, D. (1993) : The Patagonian Icefields: A Glaciological Review. Arctic and Alpine Research, Vol. **25**, No. 4, 316–331.
15. WMO (1966) : Climate Change WMO. No. 195, 100pp.