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Chemical features of the precipitation in summer at Tyndall Glacier, Patagonia

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Abstract

Precipitation in summer at Tyndall Glacier, southern Patagonia, was analyzed for major soluble chemical compounds. The pH values were almost 6.0 and the concentrations of anions and cations, especially nitrate, were relatively low. The mean concentrations of Cl^-, NO_3^-, SO_4^{2-}, Na^+, $NH_4{}^+$, K^+, Ca^{2+} and Mg^{2+} are 20.9, 0.4, 8.0, 0.9, 10.6, 7.6, 2.3, 3.8 and 3.5 μeq/l, respectively. It is also noticed that the concentrations of non-sea-salt potassium and calcium were higher, compared with those of the other ions. They could be linked to either contribution by vegetation or local crustal source.

1. Introduction

The Southern Patagonia Icefield has an area of 13000 km² and stretches for 350 km from 48°30′S to 51° 30′S. In spite of its large extent and importance as physical and chemical parameters relevant to the environmental change, it has been poorly studied in the past.

Recently extensive data sets have been obtained for the Patagonia Icefield by the Glaciological Research Project in Patagonia (GRPP) during 1983 to 1990 (Nakajima, 1985, 1987 ; Naruse and Aniya, 1992). Nevertheless, little is known of chemical characteristics of snow and ice of the glaciers and precipitation around the icefield. The chemical composition of the local precipitation has not been determined yet. The relating investigations on chemical composition have been published on firn core studies (Yamada,1987 ; Aristarain and Delmas, 1993), and chemical features of river discharge from glaciers (Saito and Kobayashi, 1985 ; Fukami and Escobar, 1987).

Samples were obtained from the surface glacier ice, river water and the precipitation at the base camp of Tyndall Glacier at the southern edge of the Southern Patagonia Icefield (Fig. 1), in December 1993.

2. Methods and materials

The sampling of the precipitation was conducted at the base camp (about 360 m above sea level), not covered with snow and ice. Sites M1 and M2 in Fig. 1 are the meteorological observation stations set up on the glacier and on the lateral moraine close to the glacier margin, respectively. The samples of the glacier ice near site M1 were also obtained. River water, originating from the glacier, was sampled at site M2 and the base camp. These samples were kept in pre-cleaned air-tight polyethylene bottles, being kept frozen until the chemical analyses after sending back to Japan.

The pH values were measured by a pH meter (COM-11, DENKI KAGAKU KEIKI Co., Ltd.). The measurement of electrical conductivity was carried out with an electrical conductivity meter (DS-15, HORIBA Ltd.). Major ions were determined by the ion chromatographic method (using model HIC-6A and LC-10, SHIMADZU Ltd.).

The glacio-meteorological observations at sites M1, M2 and base camp were made in the same period (Takeuchi *et al.*, 1995a, 1995b).

3. Results and discussion

There were many rainy days during the observation period and it snowed on December 7 and 18, 1993. Figure 2 shows the daily precipitation at the base camp, with its pH and electric conductivity (EC) values. It is seen that pH values in precipitation are

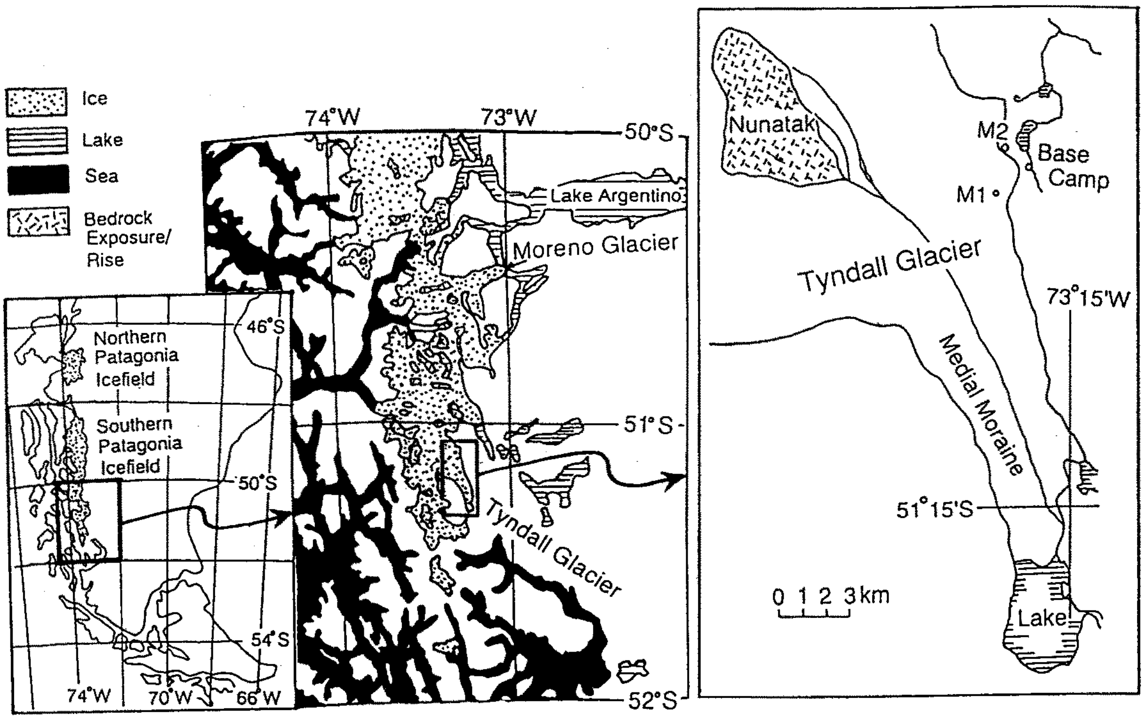

Fig. 1. Map of Tyndall Glacier in Southern Patagonia Icefield. M1 and M2 are meteorological observation sites.

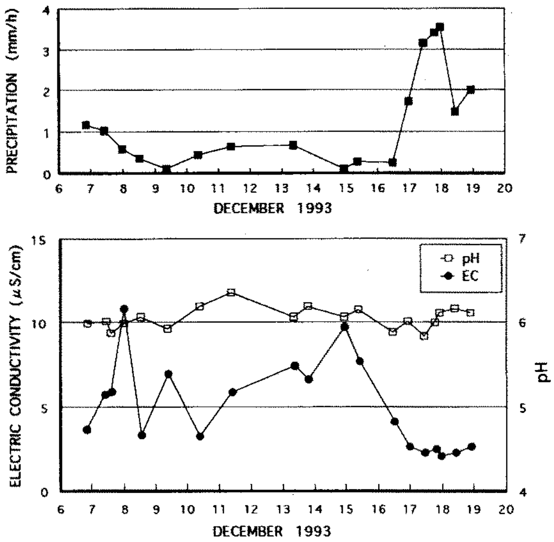

Fig. 2. Daily precipitation, pH and electric conductivity of its precipitation in December 1993 at the base camp, Tyndall Glacier.

almost uniform (cf. Fig.7 too) and the average of pH is 6.0, while the EC values are between 2.3 and 10.8 μS/cm.

In Fig. 3, the temporal variations of major ion concentrations in precipitation are shown during the observation period. Figures 4 and 5 show the mean concentrations of anions and cations in precipitation, and their compositions, respectively. These concentration levels are relatively low or nearly equal to those of firn on the Antarctic ice sheet (Kamiyama *et al.*, 1989). The major ions in precipitation at Tyndall Glacier are Cl^-, Na^+, SO_4^{2-} and NH_4^+ in this order. The H^+ concentration, however, is much lower, compared with those of firn on the Antarctic ice sheet (Kamiyama *et al.*, 1989).

Figure 6 shows the relationships between the concentration of Na^+, that is regarded to be mostly originated in sea salt, and the concentration of other ions. Some straight lines express the ratios of the concentration of Na^+ to that of the other ions of sea salt. As is evident in Fig. 6, the relations of Cl^- and Mg^{2+} to Na^+ are roughly similar to the sea salt-line.

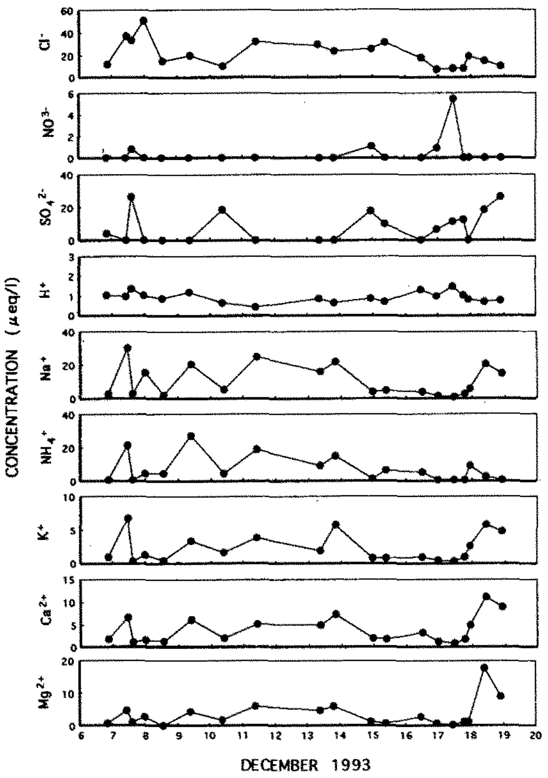

Fig. 3. Concentrations of the major ions in precipitation at Tyndall Glacier in December 1993.

On the other hand, SO_4^{2-} concentrations show wide scatters. Both K^+ and Ca^{2+} increase as Na^+ increases, but contain a large volume of non-sea-salt. Such excess K^+ and Ca^{2+} could be attributed to either local crustal source or contribution by vegetation. Aristarain and Delmas (1993) reported on the concentrations of major soluble ions by a firn core analysis at Moreno Glacier (see Fig. 1). Their results indicated that NO_3^- concentration was very low or equal to that of my work, but the concentration levels of the other major ions were one fourth to one tenth of my results. This may be due to the difference in the method in which the concentration values at Moreno Glacier were calculated by averaging six samples for one

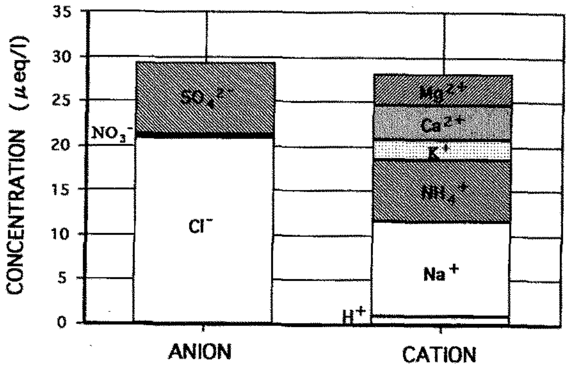

Fig. 4. Mean concentrations of anions and cations in the precipitation at Tyndall Glacier in December 1993.

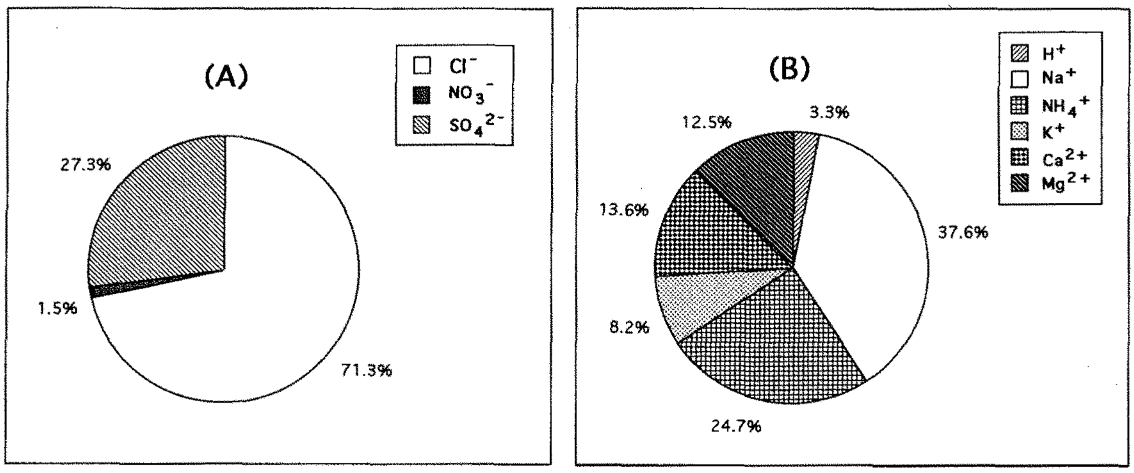

Fig. 5. Ratios of mean concentrations of anions (A) and cations (B) in the precipitation at Tyndall Glacier in December 1993.

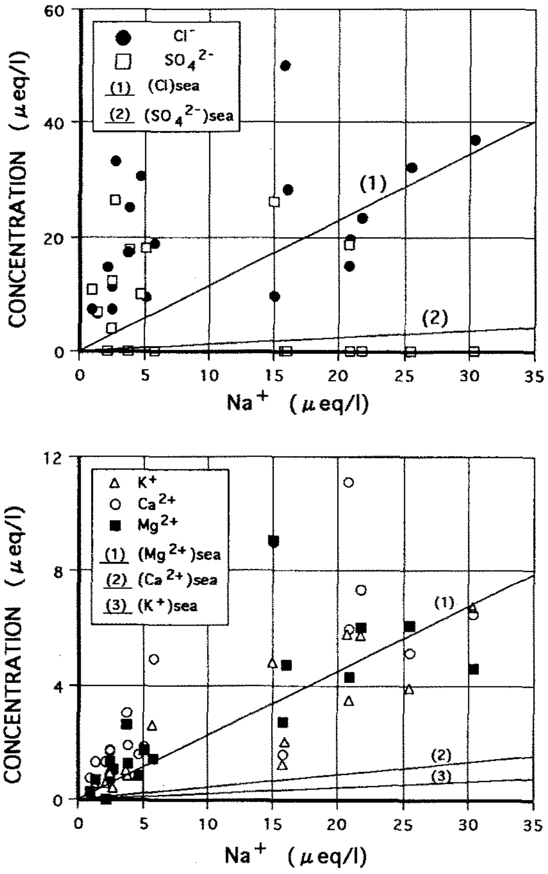

Fig. 6. Relationships between the concentrations of Na$^+$ and other major ions in precipitation at Tyndall Glacier. Straight lines show the ratios of Na$^+$ to each ion of sea salt.

year. On the other hand, the present work resulted from the precipitation analyses only in summer. Another reason is the fact that chemical species in the firn at Moreno Glacier may have been significantly disturbed by melt water percolation in summer and some ions may be preferentially eluted.

Table 1 gives the mean values (M), the standard deviations (σ) and the coefficients of variations (σ/M) of pH, electric conductivities (E) and the concentrations of major ions in precipitation in December 1993 at Tyndall Glacier. Judging from σ/M values, it is recognized that the variations of NO$_3^-$, SO$_4^{2-}$, Mg^{2+} and NH$_4^+$ concentrations are relatively large.

Figure 7 shows the relationships between pH and

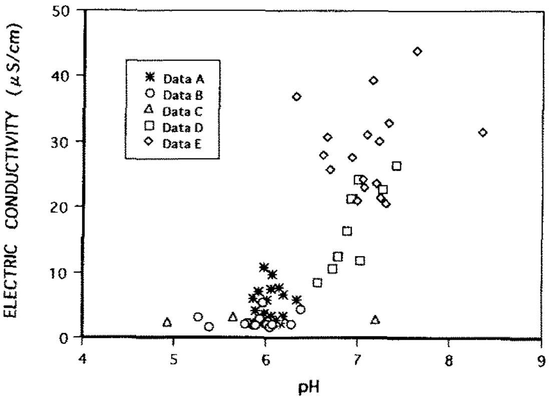

Fig. 7. Relationships between pH and electric conductivity of all samples at Tyndall Glacier.
Data A : precipitation. B : surface glacier ice. C : river water on the glacier. D : river water just below the side margin of the glacier. E : river water at the base camp.

Table 1. Mean values(M), standard deviations(σ) and coefficients of variations(σ/M) of pH, electric conductivities(EC) and concentrations of anions and cations in precipitation at Tyndall Glacier in December 1993. Units (EC : μS/cm, anions and cations : μeq/l).

	pH	EC	Cl$^-$	NO$_3^-$	SO$_4^{2-}$	H$^+$	Sa$^+$	NH$_4^+$	K$^+$	Ca^{2+}	Mg^{2+}
Mean value(M)	6.04	5.04	20.86	0.44	7.98	0.94	10.58	6.96	2.31	3.82	3.53
Standard deviation(σ)	0.12	2.59	11.62	1.24	9.22	0.26	9.30	7.76	2.04	2.95	4.11
Coefficiest of variation(σ/M)	0.02	0.51	0.56	2.84	1.16	0.28	0.88	1.11	0.88	0.77	1.16

EC of all the data in the neighborhood of Tyndall Glacier. Compared with the data of precipitation, EC values in river water outside the glacier (Data D and E in Fig.7) are much higher than those in precipitation. A tendency can be also found that the EC value of river water at the base camp is higher than that of river water at site M2. While both rivers originate from the glacier, the base camp is farther from the glacier than site M2. The difference of EC values between in precipitation (Data A in Fig. 7) and in river water (Data D and E in Fig. 7) indicates that the composition of dissolved substances in precipitation has been altered by the subglacial systems or the influence of crust and vegetation in this area.

4. Concluding remarks

Chemical analysis of the precipitation in summer at Tyndall Glacier was carried out. The pH values were almost 6.0 and the concentrations of soluble major ions (especially nitrate) were relatively low. It is recognized that the concentrations of non-sea-salt K^+ and Ca^{2+} were higher, compared with those of the other ions. These non-sea-salt ions may be attributed to either local crustal source or vegetation origin.

In this paper, the author did not discuss about the characteristics of other samples such as glacier ice and river water near the glacier. These will be presented in another paper. Firn core analyses, to be drilled on the accumulation area of this icefield in future, will give us more useful information of environmental history at mid-southern latitudes of the Southern Hemisphere.

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