Report 9

Hydrological observations at Soler Glacier

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Abstract. Hydrological characteristics at Soler Glacier were studied by measuring the amount of runoff, water temperature, the concentrations of dissolved substances and of suspended substance in Cacho River, Patagonia Northern Icefield, CHILE during the period from December 17, 1983 to January 2, 1984.

The whole observation period can be divided into two periods, that is, a large runoff period after rainfall and a rainless period during which diurnal variation in runoff was observed.

The water temperature tends to be high in the former period and low in the latter period, and seems to show daily variation corresponding to the variation of the runoff. Among the dissolved substances, the concentration of soluble-SiO_2 was low in the former period and high in the latter period. These variations of runoff, water temperature and dissolved substances can be considered to be caused from the change of mixing ratio between the amount of direct runoff of melt-water from the glacier and the amount of ground-water or direct runoff of rain-water.

It is indicated that the runoff of the ground-water or the direct runoff of rain-water has a large role in the hydrological characteristics in this glaciated region.

1. Introduction

It is important to know hydrological characteristics in temperate glaciers such as Patagonian glaciers which have much accumulation and ablation. However there are few studies and reports from the viewpoint of hydrology (NARUSE and ENDO, 1967; YAMADA et al., 1984). Hydrological observations were carried out in Cacho River running from Soler Glacier in the period from December 17, 1983 to January 2, 1984.

In this report, we discuss the hydrological characteristics in this glaciated region based on the hydrological data and dissolved substances obtained in Cacho River.

2. Observation sites and methods

Soler Glacier is located at 46°54'S, 73°10'W in the east side of the Patagonia Northern Icefield and from its terminus Cacho River runs out. We set up a watergauge and observed the change of water level of the river at the observation site H1 (in Fig. 1) about 2 km below the terminus of Soler Glacier. A cross-section of the river was measured by observing the height of a horse over the water when crossing the river. The surface velocities were measured by the float method at five points across the river in three times with different water levels. The results were calibrated with surface velocity obtained by currentmeter (electric generator type) at the left side of the river.

At observation site H2, about 500 m below the terminus of Soler Glacier along the river,

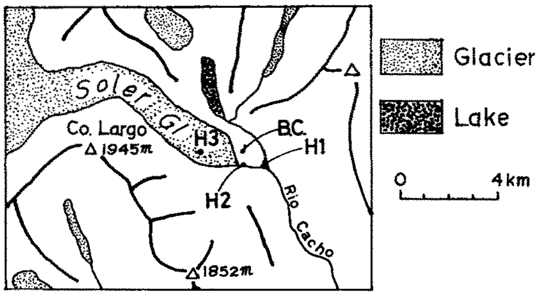

Fig. 1. Observation sites in Soler Glacier and Cacho River.

water samplings were carried out, and water temperature was measured at the same time by a thermometer.

3. Results

3.1. Hydrological observation

The obtained cross-section of the river is shown in Figure 2. To obtain a Q-H curve, we used cross-section and the values of mean velocity which is the surface velocity multipled by the value of 0.6 to adjust the vertical profile of flow velocity (Fig. 3). The amount of discharge is calculated by the change of water level at site H1 on the basis of the Q-H curve.

The variations in the river discharge at site H1, the precipitation at site BC, and water temperature at site H2 in the period from December 17, 1983 to January 2, 1984 are shown in Figure 4. The precipitation at site BC is the three hours average value, and all the precipitation was in liquid phase during the observation period.

In Figure 4, we can see two types of variations: one is in the period after precipitation (approximately from December 21 to 26) and the other is in the period of rainless days (from December 28 to January 1). In the period of rainless days, the highest values of discharge in a day occurred at approximately 18 h, and the lowest values at approximately 6 h LT; the variation of discharge has a clear periodical variation. The water temperature of Cacho River was relatively high in the period after rainfall and low during the rainless days. In addition, although the number of measured samples is small, the variation of water temperature showed an inverse behavior to the variation of discharge on the rainless days. The water temperatures at 09 and 12 h were higher than those at 18 and 21 h.

The water samples were kept in pre-cleaned air-tight polyethylene bottles and brought to Kyoto University in Japan for analyses. The dissolved anions Cl^-, SO_4^{2-}, HCO_3^-, cations, Na^+, K^+, Ca^{2+}, Mg^{2+} and soluble-SiO_2 were measured by the methods as shown in Table 1.

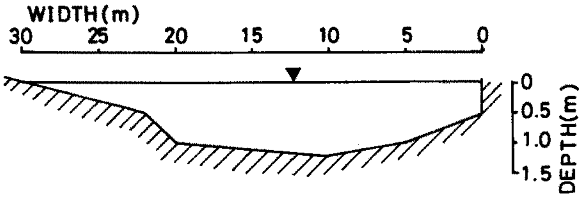

Fig. 2. Cross-section of Cacho River at site H1.

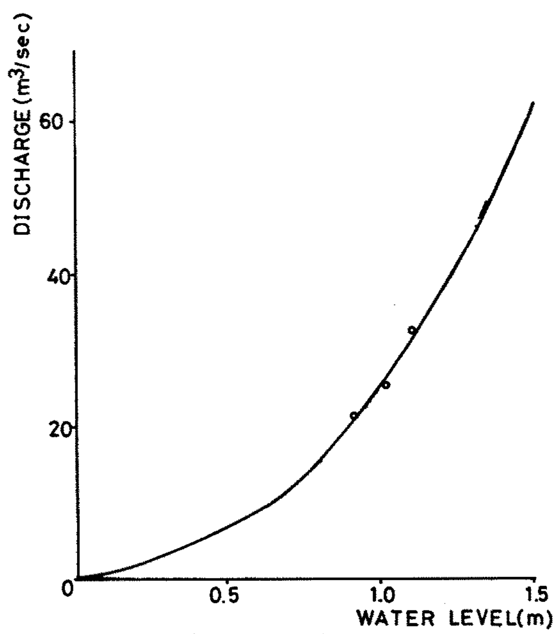

Fig. 3. Q-H curve obtained by a cross-section area method.

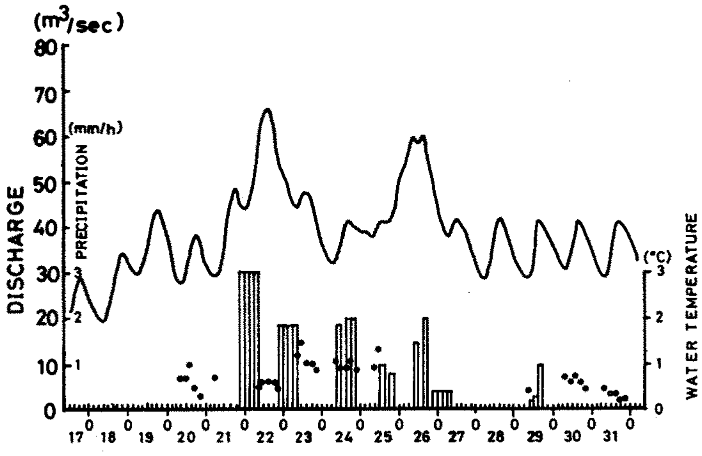

Fig. 4. Hydrograph of Cacho River. The heavy solid curve shows discharge, open circles show the water temperature and the bar graph shows the averaged precipitation.

Table 1. The chemical substances and the methods of analyses.

Substance	Method
Na^+, K^+	Flame spectrophotometry
Ca^{2+}, Mg^{2+}	Atomic absorption method
Cl^-	Colorimetric analysis by mercury thiocyanate
HCO_3^-	Bromocresol purple alkalimetry
SO_4^{2-}	Barium chromate method
Soluble-SiO_2	Colorimetric analysis by molybdenum yellow

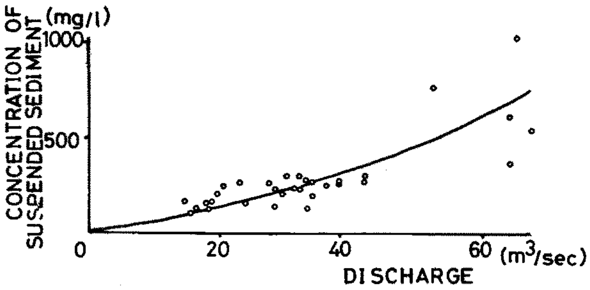

Fig. 5. The relation between discharge and the concentration of suspended sediment.

Concentrations of suspended sediments in the Cacho River were measured by following methods. Water samples were filtered with milipore filters (pore size of 0.45 μm), then the dry weight was measured.

To examine the condition of water percolation of surface ice on Soler Glacier, a pumping test was carried out at site H3 shown in Figure 1, by three boring holes 180 cm in depth and 18 cm in diameter.

3.2. Concentration of suspended sediments and dissolved substances

The relation of concentration of suspended sediments with discharge shown in Figure 5 can be expressed by equation (1):

$$C_S = 0.13Q^{2.01} \qquad (1)$$

where Cs is the concentration of suspended sediment (mg/l) and Q is the discharge (m^3/sec). The number of samples used to derive this relation was 34. The maximum value of concentration of suspended sediment was 1044. 6 mg/l at 15:00 LT on December 22, and at that time the discharge was 64.5 m^3/sec.

Among the dissolved substances, the variation in soluble-SiO_2, originated by the water-rock interaction, shows a distinctive behavior, the relative low values occurred before December 25, and high values occurred after December 25. The variation of other dissolved substances in Figure 6 do not show such distinctive behavior as soluble-SiO_2.

3.3. Pumping test on the glacier

After boring on the glacier, liquid water percolated through the glacier body and the water oozed out from the wall of the bored hole. Water level in the hole (18 cm in diameter) was measured. The variations in the water head in the bored holes on Soler Glacier are shown in Figure 7. Figure 7 (a) and (b) show the variation in water head after boring to 180 cm deep and removing the ice column.

In case (a), water level increased gradually from 180 to 102 cm in depth in 11 hours, and in case (b), though the depth of the hole was 180 cm, the water in the ice body rushed into the hole to a depth of 110 cm, and water level increased to 23 cm in 6 hours and then went down to the initial level after 11 hours. Figure 7 (c) shows the variation in water head after pumping out the water from a depth of 12 cm to 113 cm below the glacier surface within 6 minutes. These data also will be used to determine the value of the coefficient of the permeability of the glacier ice later.

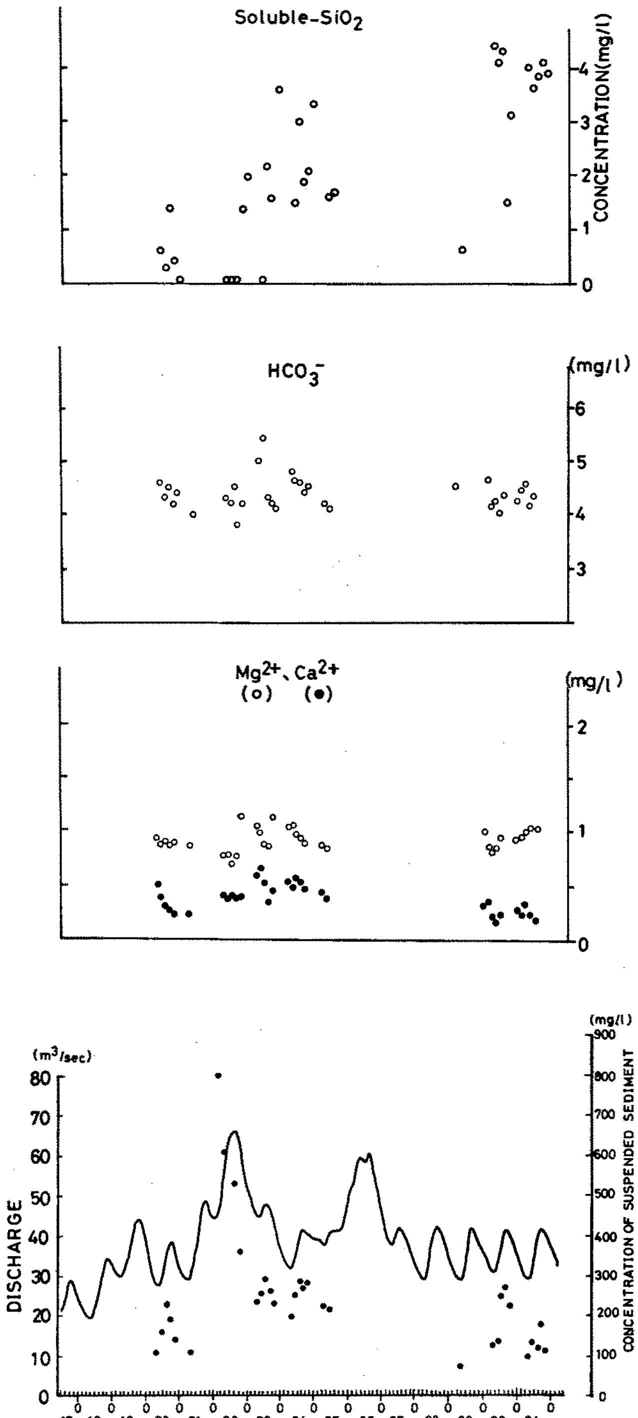

Fig. 6. The variation in chemical substances and the hydrograph of Cacho River. Solid circles in the figure of hydrograph show the concentration of suspended sediment.

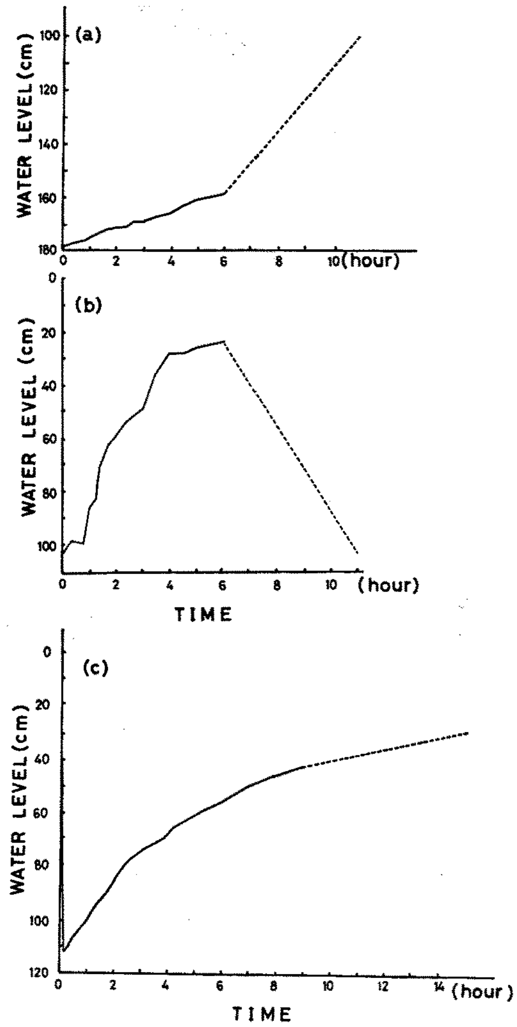

Fig. 7. (a), (b): The variation of water head in the bored hole on the glacier.
(c): The variation of water head after pumping.

4. Concluding remarks

The variations in water temperature and the concentration of dissolved substances can be considered to be caused by the change of the mixing ratio between the amount of the direct runoff of melt-water from the glacier and the amount of the ground-water or direct rain-water runoff (Dinçer et al., 1970). It is indicated that the runoff of ground-water and the direct rain-water runoff have large contribution to the hydrological characteristics in this glaciated region.

The estimation of the change of mixing ratio using the data of discharge, water temperature and concentration of dissolved substances will be discussed in a separate paper.

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Resumen. Observaciones hidrológicas en el Glaciar Soler

Se estrudió las características hidrológicas en un área glaciada por medio de la medición del escurrimiento, las concentraciones de sustancias disueltas y en suspensión en el Río Cacho, que desagüa desde el frente del Glaciar Soler, en el período comprendido entre Diciembre 17 de 1983 y Enero 2 de 1984.

El hidrograma pudo ser separado aproximadamente en dos períodos; uno es un período de gran escurrimiento después de una lluvia y el otro es un período que muestra variaciones diarias en días sin lluvia. La variación de la temperatura del agua mostró una tendencia a valores altos en el primer período y valores bajos en el segundo período, correspondiendo la variación diaria a la variación de escurrimiento.

Entre las sustancias disueltas, la concentración de SiO_2 soluble fue menor en el primer período y alta en el segundo período. Estas variaciones de escurrimiento, temperatura del agua y concentración de sustancias disueltas puede ser considerada como producida por el cambio en la razón de combinación entre el escurrimiento directo de agua de fusión glacial y el escurrimiento de agua subterránea o escurrimiento directo de agua de lluvia.

En esta zona glaciada el escurrimiento subterráneo y el escurrimiento directo de lluvia contribuyen en una buena medida en las características hidrológicas.