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# Measurements of meteorological conditions and ablation at Tyndall Glacier, southern Patagonia, in December 1990

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**Abstract**

Measurements of meteorological conditions and ablation of ice were made in the ablation area of Tyndall Glacier, southern Patagonia, from December 8 to 18, 1990. No systematic daily fluctuation of air temperature was obtained. A daily maximum air temperature was sometimes observed during night time. This may be caused by the effect of variation in winds. Wind speeds showed almost always high values, ranging from 1.4 m/s to 17.7 m/s, and the direction of winds was predominantly northerly, that is from the upglacier area to the downglacier area.

Based on the relationships between the amount of ablation and the cumulative air temperature, it was considered that ablation rates were strongly affected by different meteorological conditions such as wind speed and solar radiation.

## 1. Introduction

Tyndall Glacier flows southward from the Southern Patagonia Icefield, and its terminus position is located at 51°15'S and 73°15'W. The ablation area of the glacier forms a valley glacier about 20 km long and 3.5 to 10 km wide.

Naruse *et al.* (1987) made measurements of flow velocity and observations of surface structure on Tyndall Glacier during a short period in December 1985. However no meteorological observations and ablation measurements have ever been done in this area.

Extensive studies on meteorological conditions, ablation of ice and heat balance have been carried out at Soler and San Rafael glaciers in the Northern Patagonia Icefield in 1983-84 and 1985 (Kobayashi and Saito, 1985a ; Kobayashi and Saito, 1985b ; Fukami *et al.*, 1987 ; Fukami and Naruse, 1987 ; Ohata *et al.*, 1985 ; Inoue, 1987 ; Fujiyoshi *et al.*, 1987 ; Kondo and Inoue, 1988). Much information and knowledge on meteorological conditions in Patagonian glaciers were obtained, especially on the characteristics of strong winds such as glacier winds or Föhn, and the importance of the latent and the sensible heats to the total ablation in windy and cloudy conditions.

In order to obtain preliminary data for meteorological conditions and characteristics of ablation of Tyndall Glacier, measurements were made during a period from December 8 to 18, 1990. The main observation area was selected on almost flat bare-ice in the ablation area of Tyndall Glacier. This report presents the methods and the results of measurements.

## 2. Observation sites and systems

Two observation sites, M1 and M2, were established, as shown in Fig. 1. Station M1 was the main observation site, and was set up on bare ice about 1.5 km from the eastern margin of the glacier. Station M2 was the subsidiary observation site placed on the bare-rock about 0.5 km from the glacier margin. The following observations were made to investigate the ablation processes.

1) Meteorological measurements: From December 8 to 18, measurements were made at M1 and M2. A list of meteorological elements, observation sites and instruments used is shown in Table 1. Air temperature and wind speed were continuously measured at 1.0 m above the ice surface, and were recorded with a

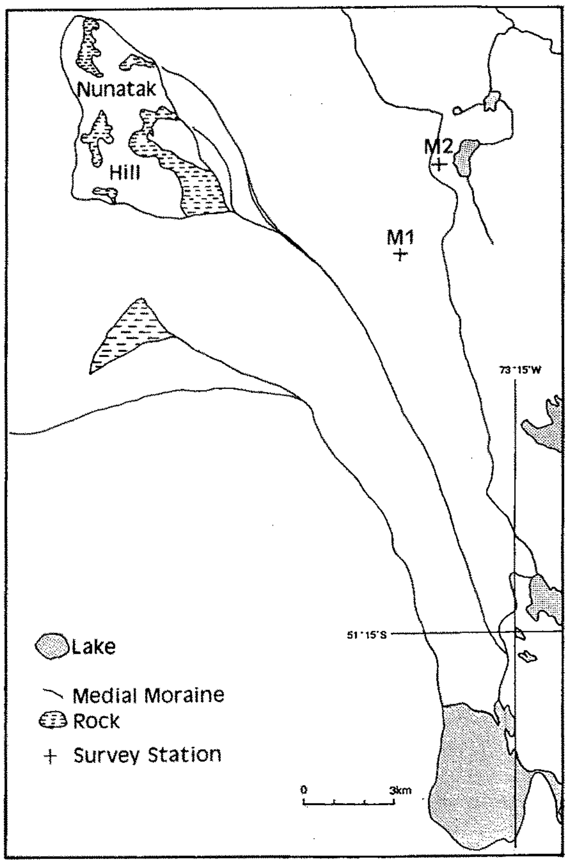


Fig. 1. Observation sites at Tyndall Glacier in southern Patagonia. Station M 1 is the main observation site on bare-ice of the glacier. Station M2 is the subsidiary observation site on the left (eastern) bank of the glacier.

portable data logger. A thermistor sensor was inserted in a double steel pipe to insulate solar radiation, and the inlet of the pipe was set toward the upglacier direction so as to coincide with the prevailing wind direction on the glacier. Temperature data were corrected using the data measured occasionally with an Assmann thermometer. An anemometer was set up on a tripod which was firmly fixed on the ice surface by lots of small rocks.

Albedo of surface ice and all-wave radiation balance were measured several times a day, though only in the daytime, by holding manually the instruments at about 0.5 m above the ice surface near station M1. Solar radiation (global shortwave radiation) was measured at M2 about 2 km from M1, so the values obtained by a pyranometer do not directly indicate those at M1.

2) Ablation measurements: To obtain the surface melting of ice, ablation measurements were carried out using wooden stakes. Four stakes were set in drilled holes about 0.5 m deep around M1. The measurements were made once to four times a day from December 10 to 18. Ice density is assumed to be 900 kg/m$^3$.

## 3. Results

### *3.1. Meteorological conditions*

The hourly mean values of meteorological elements are shown in Fig. 2. During the observation period, the air temperature increased gradually. However, no systematic daily fluctuation can be seen,

Table 1. List of meteorological elements observed at M1 and M2.

| Elements | Sites | Continuous measurement Yes | Continuous measurement No | Instruments |
|---|---|---|---|---|
| Air temperature at 1.0m | M1 | 0 | 0 | Thermistor/Assmann |
| Wind speed at 1.0m | M1 | 0 | | Three-cup anemometer |
| Solar radiation | M2 | 0 | | Pyranometer |
| All-wave net radiation | M1 | | 0 | Net radiometer |
| Albedo | M1 | | 0 | Albedo meter |

namely a daily maximum air temperature was sometimes observed during night time. It seems that this was due to the effect of winds. Wind speeds showed almost always high values and the direction was predominantly northerly, that is from the upglacier area to the downglacier area. The hourly mean wind speed ranged from 1.4 m/s to 17.7 m/s. This range was comparable with the values at Soler Glacier, namely between 1.6 m/s and 16.7 m/s (Kobayashi and Saito, 1985a), and between 0.4 m/s and 14.0 m/s (Fukami *et al.*, 1987).

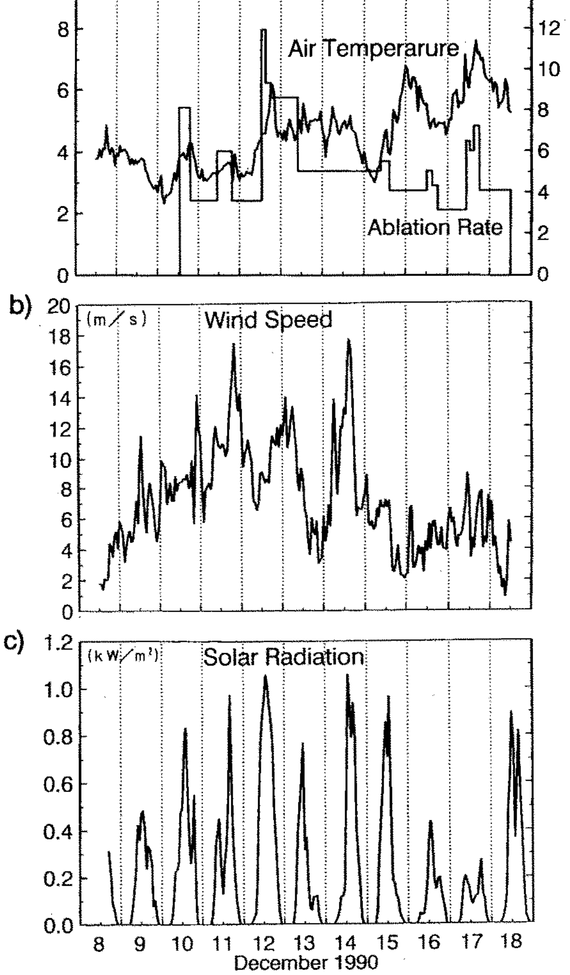


Fig. 2. Hourly mean values of meteorological elements observed at stations M1 and M2 in December 1990. (a) Air temperature and ablation rate. (b) Wind speed. (c) Solar radiation.

The values of surface albedo of bare ice around M1 ranged from 0.28 to 0.35. No remarkable variations in albedo with time were observed.

### *3.2. Ablation of ice*

Ablation rate (mean of four stakes) around M1 indicates daily fluctuations with short time intervals (see Fig. 2-a). However daily mean ablation rates did not largely vary during this period, although the daily mean air temperature increased gradually.

Figure 3 shows the relation between the total amount of ablation in water equivalent, $\Sigma M$ (cm-water), and the cumulative daily mean air temperature, $\Sigma T$ (°C·day), during the period from December 10 to 18. If we fit the plots with a linear relation, namely

$$\Sigma M = k \, \Sigma T, \tag{1}$$

the parameter $k$ is called the degree-day factor (cm/°C·day). Three different values of $k$ were obtained as 1.45, 1.15 and 0.72 (cm/°C·day), respectively, as shown in Fig. 3.

It is considered that the parameter $k$ is strongly affected by meteorological conditions, such as the wind speed, the amount of solar radiation, and the surface features of ice. The meteorological condition during December 10 to 13 is characterized by the relatively strong wind (5.8 m/s – 17.5 m/s), large amount of solar radiation, and low air temperature (see Fig. 2). By the contribution of the wind and the solar radiation, the ablation rate was accelerated. Relatively low temperature results in the small value of cumulative air temperature. So the slope $k$ becomes steep (1.45). The second period from December 13 to 15 is also characterized by the relatively strong wind and large solar radiation ; however, the air temperature was higher than in the first period, and the slope becomes gentler (1.15). On the other hand, the condition in the third period from December 15 to 18 is considerably different from the previous two periods. That is relatively week wind, small solar radiation and high air temperature. Consequently the slope becomes much gentler (0.72).

The value of $k$ for the entire period is obtained to be 1.18 (cm/°C·day). This value is much greater than 0.54 (cm/°C·day) obtained at the bare ice (surface albedo : 0.28) of Soler Glacier (Fukami and Naruse, 1987).

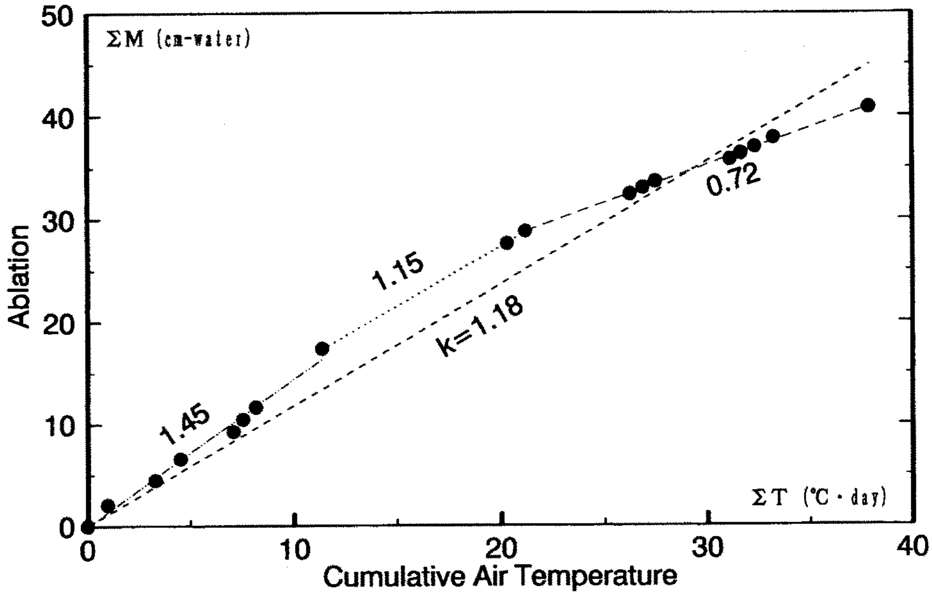


Fig. 3. The relation between the amount of ablation and the cumulative daily mean air temperature during the period from December 10 to 18, 1990. The degree-day factors *k* were obtained as 1.45, 1.15 and 0.72 (cm/°C·day) for each sub-period, and 1.18 (cm/°C·day) for the entire period, as shown in this figure.

## 4. Concluding remarks

Meteorological observations were made in the ablation area of Tyndall Glacier, for ten days in December 1990. Daily mean ablation rates did not change remarkably during this period. However, the degree of contribution of meteorological elements to the ablation was different day by day. A degree-day factor *k* was obtained from a linear relation between the ablation amount and the cumulative air temperature, which was large compared with that at Soler Glacier.

To discuss glacier variation and characteristics of mass balance of glaciers, more precise and long-term meteorological observations and heat balance studies are needed.

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