# GLACIOLOGICAL CHARACTERISTICS OF SPARTAN GLACIER, ALEXANDER ISLAND

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ABSTRACT. This paper summarizes the more important characteristics of Spartan Glacier in order to provide reference data for others working in the area and to allow comparison with results from other glaciers studied as part of the International Hydrological Decade.

SPARTAN GLACIER (Figs. 1, 2, 3 and 4a) has been studied since 1969 as a contribution to the International Hydrological Decade, 1965–74 (UNESCO/IASH, 1970, 1973). This paper summarizes the more important characteristics of this glacier in order to provide reference data for others working in the area and to allow comparison with results from other glaciers studied as part of the International Hydrological Decade.

Fig. 1. Spartan Glacier (centre foreground), November 1966. (U.S. Navy photograph for U.S. Geological Survey.)

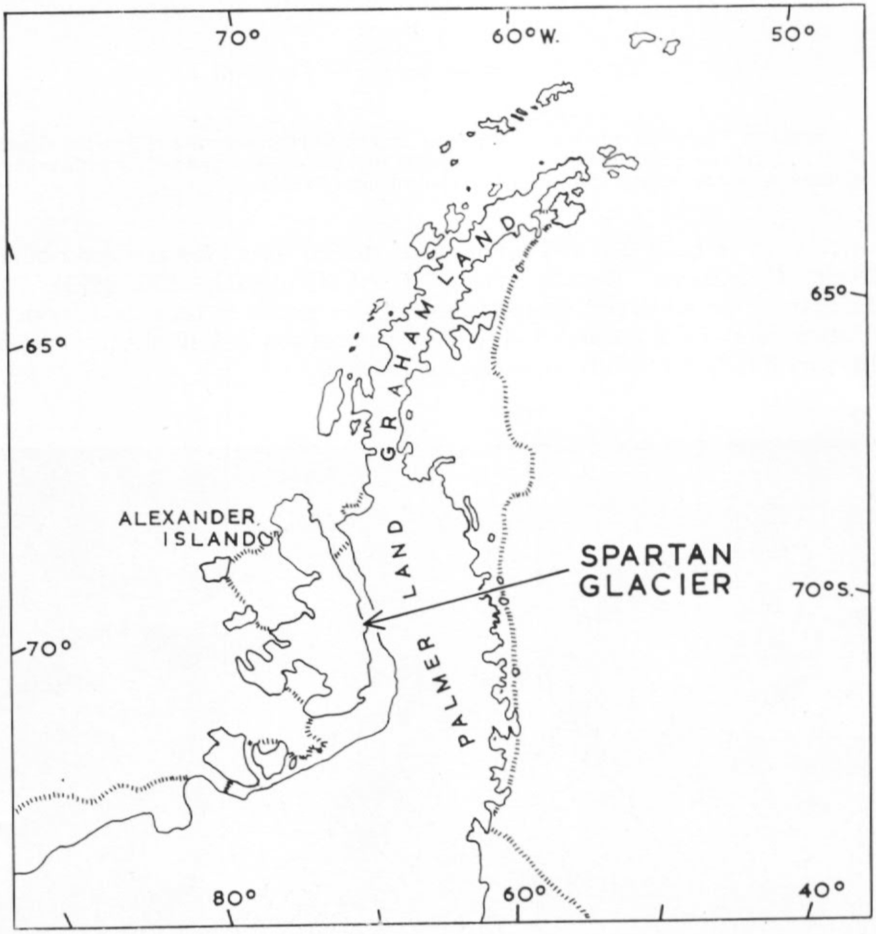


Fig. 2. Location of Spartan Glacier.

## Summary of Studies

| | |
|---|---|
| Mass-balance measurements: | 1969–74. |
| Surface-movement studies: | 1969–73. |
| Energy-balance study: | 1972–74. |
| Ice-depth survey: | 1972. |

Some results of this work have already been published (Jamieson and Wager, 1983; Wager, 1982; Wager and Jamieson, 1977). It is believed that these observations represent the most detailed study ever made of a local glacier in Antarctica.

## Physical Characteristics

Position: lat. 71°03′S., long. 68°20′W.
Mass: $720 \times 10^9$kg. $\pm$ 10 per cent.
Volume: $800 \times 10^6$m.$^3$ $\pm$ 10 per cent.
Surface area: 6·3 km.$^2$.
Altitude: Range 40–450 m.; mean 215 m.

Fig. 3. The snout of Spartan Glacier viewed from the north-west. The area of the snout is approximately 0·5 km.[2] (one-thirteenth of the glacier area). About half the ablation takes place in this area.

| | |
|---|---|
| Average surface slope: | 5·1°. |
| Average surface velocity: | 6·3 m. yr. $^{-1}$ (17 mm. day$^{-1}$). |
| Average bottom slope: | 8·4°. |
| Average ice depth: | 135 m. |
| Temperature 10 m. below surface: | —8°±0·3°C (mean of three measurements at different altitudes and different places). |

## Mass Balance

The process of melting at the glacier surface was difficult to study. The regime of high isolation, low air temperatures and fresh snow of high albedo meant that much melting took place in the dirty ice layers below the surface. Honeycombing occurred, the density near the surface became difficult to measure and the layers in which melting took place could not be identified. These uncertainties meant that the water equivalent of the observed ablation may have been in error by as much as 30 per cent on some occasions.

Accumulation measurements could not be made near the snout because crevasses made access too dangerous. Therefore, measurements on the rest of the glacier were supplemented by ice-depth (Fig. 4b) and velocity measurements (Fig. 5a and b) near the snout to obtain the mass flow out of the study area. The masses lost in each of 4 years of study are summarized in Table I.

The general pattern of accumulation (Fig. 6) shows a number of accumulation areas rather than an equilibrium line. The mass changes at the surface of the glacier (Fig. 7), combined with flow into the snout of $10^9$ kg. yr.$^{-1}$, indicate an average mass decrease of $1·6 \times 10^9$ kg. yr.$^{-1}$. This corresponds to one five-hundredth of the total mass.

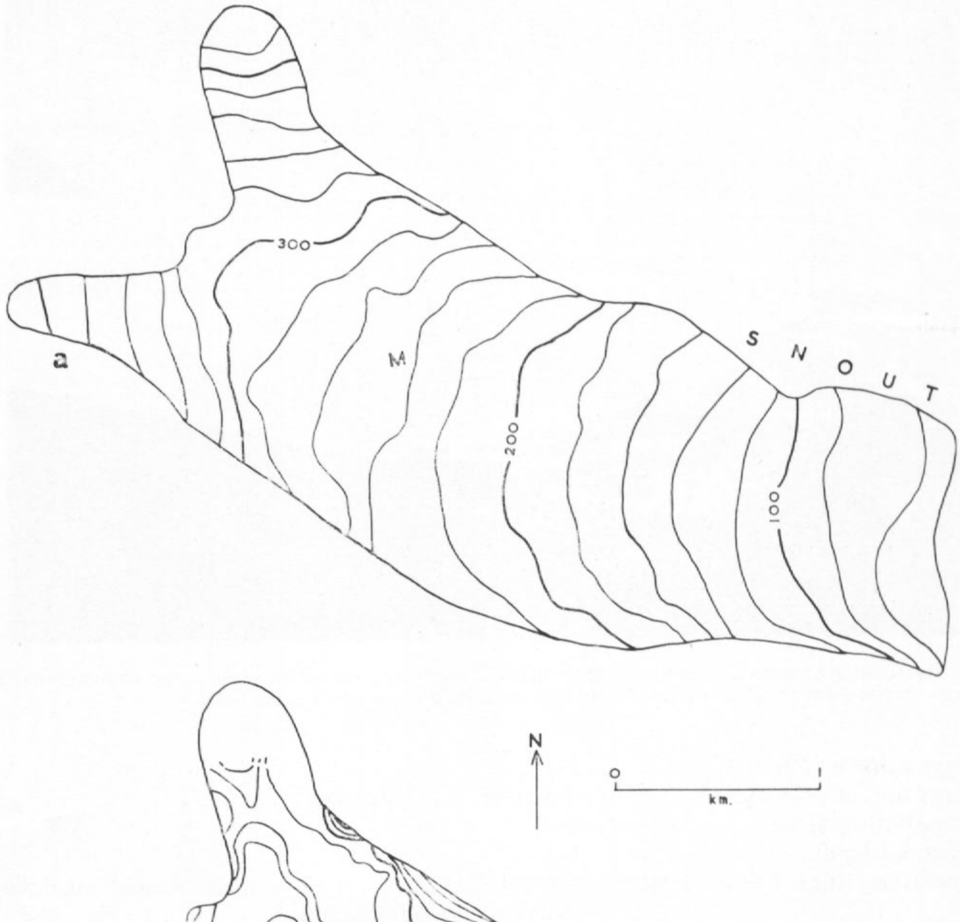


Fig. 4. a. Surface elevation of Spartan Glacier. M indicates the site at which meteorological measurements were made in 1972–74.
b. Ice-thickness measured by radio-echo sounding. Contour interval is 20 m. on both maps.

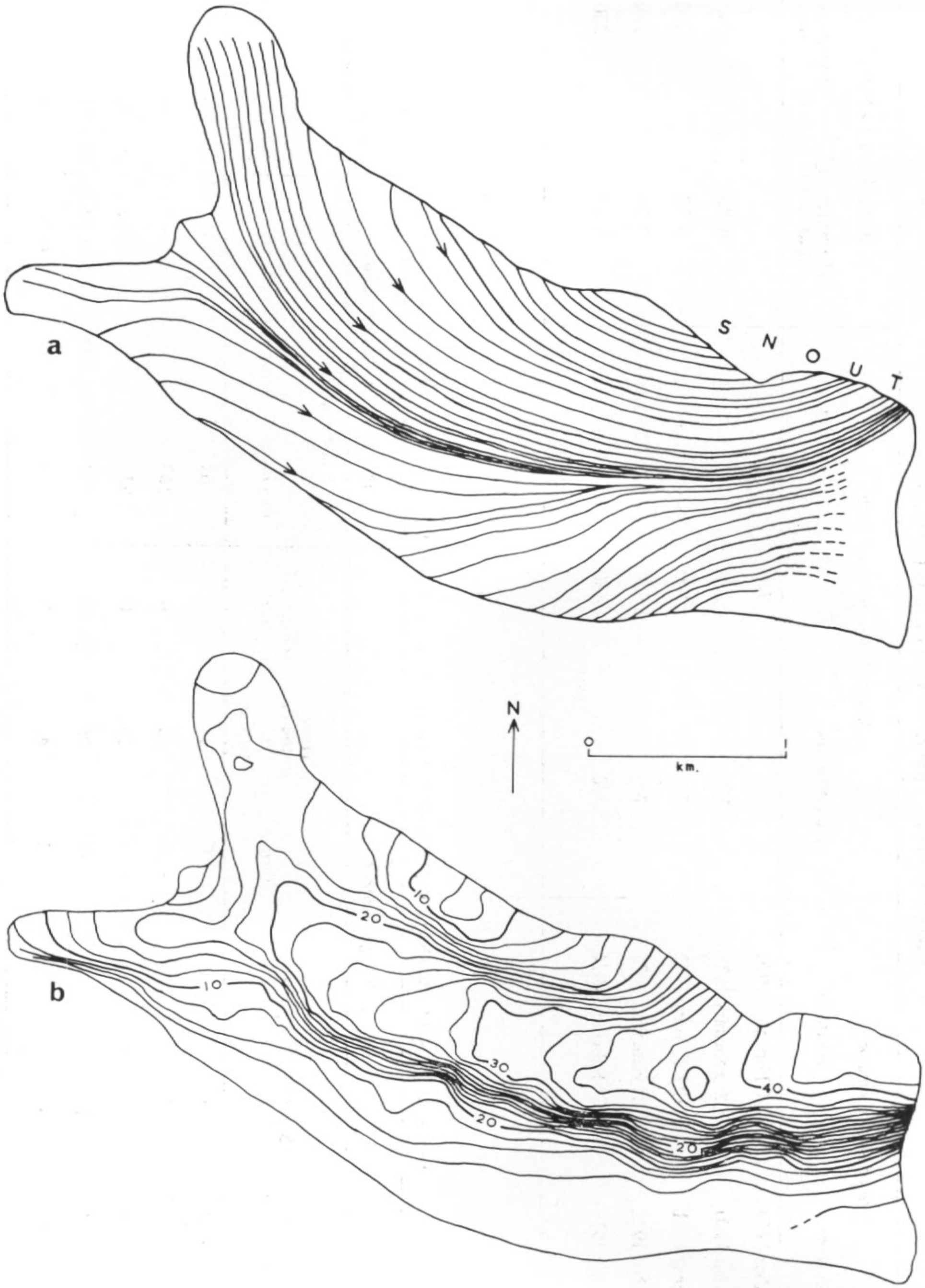


Fig. 5. Surface movements determined by measurements of positions on Spartan Glacier of over 100 stakes in 1972 and 1973.
a. Flow lines.
b. Lines of equal velocity. Interval is 2 mm. day$^{-1}$.

TABLE I. SEASONAL CHANGE IN MASS OF SPARTAN GLACIER

| Year | Date of end of season: Accumulation | Date of end of season: Ablation | Mass change in study area (× $10^6$ kg.): Accumulation | Ablation | Annual | Mass lost by whole glacier: Percentage of total mass | Water equivalent (mm.) |
|---|---|---|---|---|---|---|---|
| 1969 | 20 November 1969 | 20 February 1970 | | 740 | | | |
| 1970 | 7 November 1970 | 20 February 1971 | 720 | 1,260 | − 540 | 0·20 | 240 |
| 1971 | 13 November 1971 | 19 February 1972 | 620 | 1,100 | − 680 | 0·22 | 270 |
| 1972 | 12 November 1972 | 24 February 1973 | 760 | 1,950 | −1,190 | 0·29 | 350 |
| 1973 | 14 November 1973 | 20 February 1974 | 790 | 1,180 | − 390 | 0·18 | 220 |

TABLE II. MONTHLY MEANS OF COMPONENTS OF THE ENERGY EXCHANGE (IN W $m.^{-2}$) OF SPARTAN GLACIER

| | Energy balance | | | | | | Short-wave radiation balance | | | Radiation summary | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Solar radiation | | | | |
| | Net radiation | Sensible heat | Latent heat | Storage | Heat available for melting | Observed melt | Incoming | Outgoing | Albedo | Net short wave | Net long wave |
| September 1973 | −18 | 52 | −10 | 0 | 24 | 0 | 63 | — | — | — | — |
| October 1973 | −12 | 64 | −18 | − 2 | 32 | 6 | 153 | — | — | — | — |
| November 1973 | − 4 | 41 | − 1 | − 7 | 29 | 0 | 259 | 219 | 0·85 | 40 | −44 |
| December 1973 | 16 | 27 | − 3 | −14 | 26 | 11 | 313 | 242 | 0·77 | 71 | −55 |
| January 1974 | 11 | 37 | − 2 | − 5 | 41 | 0 | 284 | 211 | 0·74 | 73 | −62 |

Outgoing solar radiation was not measured in September and October 1973.

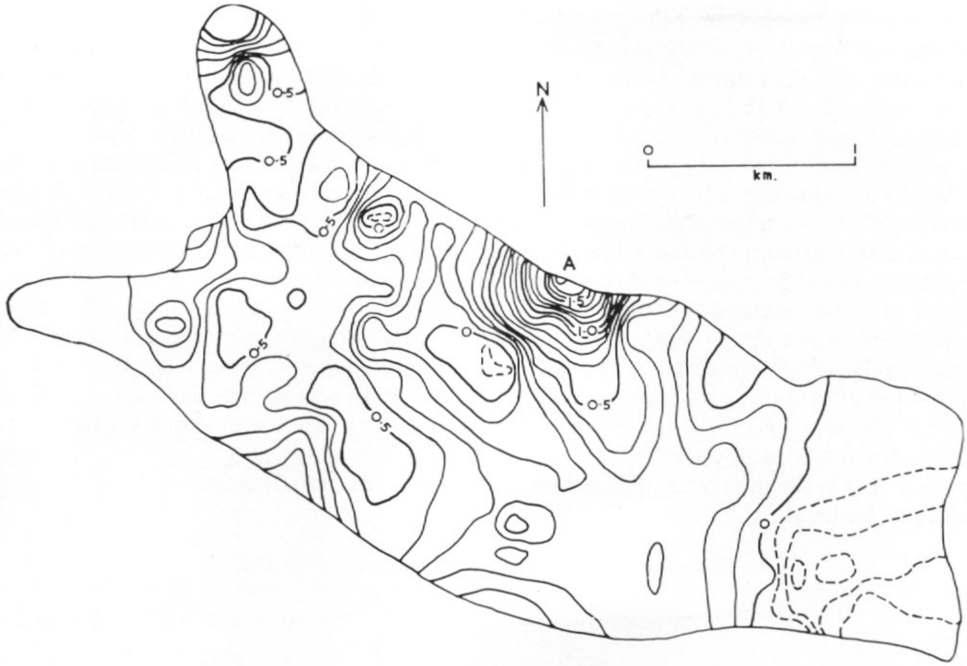


Fig. 6. Change in height of the surface of Spartan Glacier from stake measurements between 5 February 1972 and 13 January 1974. The pattern of ablation in summer is determined mainly by the position of the sun. The north side of the glacier is shaded by the valley wall. The pattern of accumulation in winter is determined by the effect of the topography on the prevailing wind (north-west). The large amount of accumulation at A probably corresponds to low wind speed caused by a standing wave.

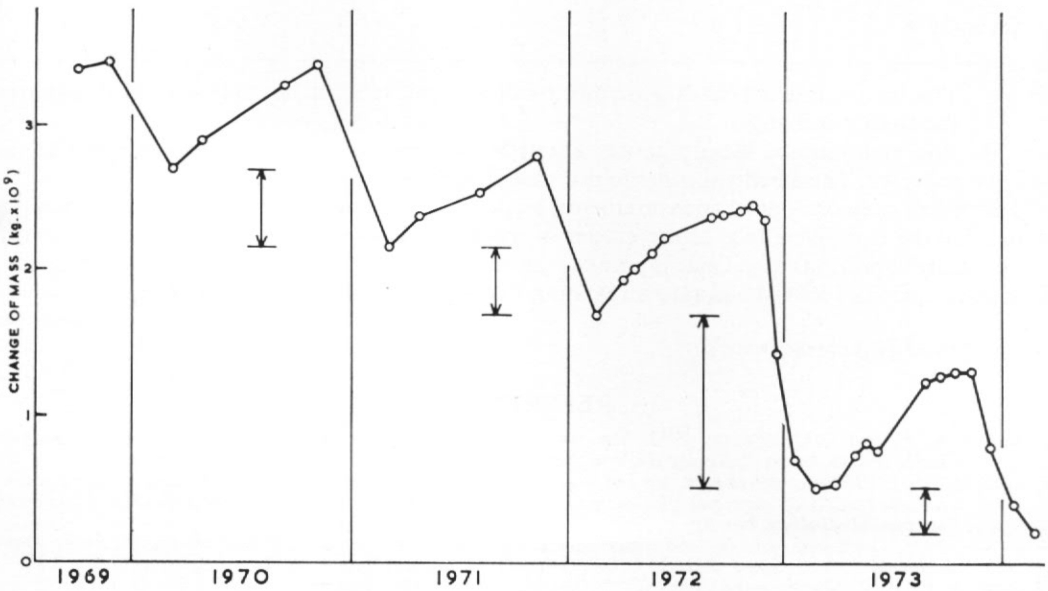


Fig. 7. Change in mass of Spartan Glacier from stake measurements. Densities of 250 kg. m.$^{-3}$ and 550 kg. m.$^{-3}$ were used for accumulation and ablation.

### METEOROLOGICAL MEASUREMENTS AND THE ENERGY BALANCE

Air temperature 2 m. above the snow surface was measured using a platinum resistance thermometer and differences in air temperature to three other heights were measured with thermocouples. Ice-bulb hygrometers have been found unsatisfactory in polar conditions and commercial hygrometers (Dewcels) using the hygroscopic properties of lithium chloride were used at three levels. Incoming and outgoing short-wave radiation was measured with Moll-Gorczynski solarimeters and net all-wave radiation was measured with a Funk radiometer. Sensitive cup anemometers measured wind speed at five levels up to 5 m. Ice temperatures were measured with platinum resistance thermometers and thermocouples. Output from each sensor was sampled every 72 sec. and records were made on 24 channel chart recorders.

An aerodynamic method was used to calculate sensible- and latent-heat fluxes. The amount of heat stored in the glacier was calculated by numerical integration of the temperature/heat-capacity profile at 5 day intervals. The problems encountered in operating micro-meteorological equipment in an Antarctic environment meant that the most reliable records were made during the summer season of 1973–74, following improvements to equipment based on the previous year's experience. Monthly total of the components of energy exchange (in W m.$^{-2}$) are given in Table II. Table III gives other meteorological factors. The main features of the regime shown in these two tables are:

TABLE III. MONTHLY MEAN METEOROLOGICAL VALUES

| | *Air temperature at 2·2 m.* (°C) | | | *Wind speed at 2·6 m.* (m. sec.$^{-1}$) | | *Humidity at 2·1 m.* (g. kg.$^{-1}$) |
|---|---|---|---|---|---|---|
| | *Mean* | *Maximum* | *Minimum* | *Mean* | *Maximum* | *Mean* |
| September 1973 | −13·0 | 1·5 | −23·7 | 2·4 | 16·9 | 1·51 |
| October 1973 | − 7·0 | 2·8 | −18·4 | 3·7 | 21·3 | 2·30 |
| November 1973 | − 2·9 | 7·9 | −12·3 | 2·3 | 11·8 | 2·10 |
| December 1973 | − 1·2 | 7·3 | − 7·8 | 1·5 | 7·8 | 2·58 |
| January 1974 | − 1·6 | 8·1 | − 7·1 | 1·4 | 7·8 | 2·39 |

i. The flux of latent heat is generally small and the sensible heat apparently dominates the energy exchange.
ii. The high surface albedo causes about 80 per cent of the incoming radiation to be reflected. The albedo appears to decrease slightly as the season advances.

The micro-meteorological measurements could not be made with sufficient accuracy to determine the energy balance of the glacier over a long period. However, by assuming steady temperature conditions in the glacier, the energy balance can be deduced from the mass balance. During the period 1969–74 annual energy input to the glacier was $5 \times 10^{14}$ J (3 W m.$^{-2}$).

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