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**MASS BALANCE OF THE WARD HUNT ICE RISE
AND ICE SHELF: AN 18-YEAR RECORD**

H. V. Serson

November 1979

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ABSTRACT

The result of 18 years' record (1958-1976) of accumulation and ablation from the Ward Hunt ice rise and of 10 years record (1965-1976) from the Ward Hunt Ice Shelf are presented. The net mass balances on the ice rise for the years 1962-1965 and on both the ice rise and the ice shelf for 1972-1975 are positive. The net mass balances for all other years are negative. There is only fair correlation between the net ablation and the mean summer temperatures at Alert since the ablation rate is sensitive to several other factors, notably the surface albedo.

RESUME

On présente les résultats de 18 ans (1958-1976) d'observations sur l'accumulation et l'ablation de glace sur le dôme de glace de Ward Hunt et ceux de 10 ans d'observations des mêmes opérations sur la banquise de Ward Hunt. Le bilan annuel net de ces deux opérations sur le dôme de glace est positif pour les années 1962-1965 et 1972-1975, tandis que celui des autres années est négatif. En ce qui concerne le bilan pour la banquise, seul celui des années 1972-1975 est positif. Il n'y a qu'une corrélation médiocre entre l'ablation nette et la température moyenne d'été à Alert, puisque l'ablation dépend également d'autres éléments, surtout de l'albédo de la surface.

INTRODUCTION

Since the recognition in 1950 that ice shelves occur off the north coast of Ellesmere Island (Koenig et al., 1952), there has been speculation on whether they should be considered relic features or as essentially the product of present climatic conditions. Field work in 1953-1954 showed that the Ward Hunt Ice Shelf in its most recent history had undergone a long period of net ablation (Hattersley-Smith et al., 1955). This was evident from the heavy concentration of wind-blown dust at the surface and from the discovery of debris resting on the ice from one of R.E. Peary's overnight camps of 1906; since then there evidently had been no net accumulation until the years 1972-1973. Both the Ward Hunt Ice Shelf and ice rise showed considerable net surface ablation for the budget year 1953-1954; at one pole of the 1954 main survey line on the ice shelf this amounted to as much as 630 mm of water. In the four summers 1955 to 1958 the total net ablation on the ice shelf amounted to more than 1350 mm of water (Crary, 1959). Further work on the ice shelf and ice rise showed net surface ablation of from 70 mm to 200 mm of water in both the 1958-1959 and 1959-1960 budget years (Lotz, 1961; Lister, 1962; Sagar, 1962). In the winter of 1961-1962 massive calving reduced the area of the Ward Hunt Ice Shelf by about 600 km²; a strip of the ice shelf up to 8 km wide had moved to sea along a line back to the northern edge of the Ward Hunt ice rise (Hattersley-Smith, 1963). The part of the ice shelf where the 1959-1960 observations had been made was removed, but the 1959-1960 grid of poles on the Ward Hunt ice rise was unaffected (Figure 1).

From 1963 to 1976 continued observations of accumulations and ablation were carried out each spring at the original grid of poles on the ice rise. In 1964 four poles were set out to form a strain rate network on the ice shelf 3 km N.E. of the island (Konecny and Faig, 1966) and in 1966 a

1 km² grid of 100 poles was established just south of the strain network (Figure 1). In this paper, results of 18 years' records (1958-1976) on the ice rise and 10 years' records (1965-1975) on the ice shelf are analyzed.

FIELD DATA

The results of the measurements at the 45 poles on the ice rise, at the 100 poles on the ice shelf and at the 4 poles at the strain rate network are shown in Tables I, II and III. In each table the ranges and the means of the total annual accumulation and the net annual accumulation or ablation at the various poles are shown. For the years 1960-1962 there are figures only for the combined net ablation for 2 years, the 1966 accumulation data were not available, and it was not possible for a party to visit the area in 1970.

The ice shelf is characterized by a system of parallel surface ridges and troughs (Hattersley-Smith, 1957); the strain rate network poles are located on ridges and the poles in the 100 pole grid in the south are placed at equal 100 m spacing, some on ridges, slopes or in troughs (Figure 2).

In computing the water equivalents from these data certain assumptions have been made. First, a mean density of 0.31 Mg.m⁻³ had been assumed for the spring snow cover for the years 1958 to 1969. This was based on snow pit studies carried out in 1968 and 1969 and was applied to both shelf and rise data. In 1971 a snow density of 0.34 Mg.m⁻³ was obtained for the ice rise and 0.29 Mg.m⁻³ for the ice shelf; these factors were reconfirmed in 1975 and 1976 and have been applied to the data after 1970. It must be remembered, however, that the total accumulation in any year was not measured, since no record is available of snow that fell between the time the poles were scaled and the end of the ablation season. Hence, figures for

snow accumulation must be regarded as minima. The limited data cause an obvious discrepancy in the 1965 summer when the net accumulation for the ice rise exceeds the apparent total accumulation by 25 mm (Table I). Evidently, in this very cool summer there was appreciable snowfall after the middle of June. Secondly, in computing net accumulation which on the ice rise and the ridges of the ice shelf takes the form of superimposed ice or very icy firn, a mean density of 0.65 Mg.m^{-3} has been assumed for the material on the ice rise (Hattersley-Smith and Serson, 1970). On the ice shelf the melt water flows into the troughs (Figure 2) and accumulates in frozen lakes having a density of 0.92 Mg.m^{-3} . This lateral movement of the melt presents a problem compounded by the fact that occasionally the lakes drain through cracks in the ice shelf leaving hanging fringes of ice and ice rubble up to a metre in thickness. For the 4 poles on the strain rate network a density of 0.62 Mg.m^{-3} has been used while a density of 0.80 Mg.m^{-3} has been assumed as a mean for all the stakes in the 1 km^2 grid.

ANALYSIS

The data in Tables I, II and III have been plotted in Figure 3. Since there are no complete meteorological data for Ward Hunt Island for the summers in question, temperature data from Alert, the nearest weather station, have been used to provide an indication of the "warmth" or otherwise of the summers from 1959 to 1975. Plotted below the mass balance data on Figure 3 are the mean temperatures for the months of June, July and August and the mean temperature for July alone.

Considering first the 18 years' data from the Ward Hunt ice rise, we note:

- (1) the great range of snow depths measured in the spring varying from 5:1 to 1:1 about a mean,

- (2) similarly the great range in net ablation and accumulation including both ablation and accumulation at different poles in the same season.

Snow depths are dependent on wind action and on irregularities of the previous season's ablation surface which are comparatively large in relation to snow depths, of the order of 500 mm. At the same time, the topography of the ice rise, although subdued with an elevation nowhere exceeding 30 m, is such that poles are situated with aspects varying from northerly to southerly and leading to differences in amounts of ablation. The main point emerging from a comparison of summer ablation values on the ice rise with the corresponding mean monthly temperatures at Alert is that, neglecting the years when the ablation was not scaled, the correlation coefficient is calculated to be 0.5. However, from the data presented one might expect there to be a net gain to the ice rise during years when the Alert mean July temperature was below +3°C. Ward Hunt Island is 200 km northwest of Alert, so that local variations in the general weather pattern of north-eastern Ellesmere Island may well account for the lack of closer correlation.

There are two other factors that should be taken into consideration. The method of calculating mean daily temperatures at Alert (from which the mean monthly temperatures are derived) as $\frac{1}{2}$ (daily maximum plus daily minimum) may not provide the best assessment of an ablation season, as Arnold and MacKay (1964) have pointed out. Nor in the present case does the use of mean daily maximum temperatures at Alert give any better correlation. Furthermore, any assessment of the ablation season based on temperatures alone ignores the drastic reduction in melting caused by a new snow cover with its high albedo. In an area where the mean summer temperature does not exceed +3°C, the small temperature difference that determines whether preci-

precipitation falls as rain or snow is very much out of proportion to the effect of ablation at an ice surface (Hattersley-Smith, 1960). The high incidence of low cloud and fog near Ward Hunt Island in summer (Sagar, 1962) is probably a further factor leading to low ablation, as has been suggested by Paterson (1969) in the case of the Meighen Ice Cap, and to distortion of any comparison with the weather at Alert.

For the ice shelf grid in the 10 years 1965 to 1975 there is a range of snow accumulation both for ridges and troughs similar to that measured on the ice rise (Table II) with the mean snow depths in the troughs being 30 mm greater than on the ridges. At the same time net ablation in the troughs is greater than on the ridges with wide variations in both places. The current regime, from 10 years' observation, shows that less ablation takes place on the ridges than in the troughs due to the higher albedo of the unsaturated snow. The lakes occupying the troughs overflow through natural drainage channels (Figure 2) and occasionally drain through cracks in the ice shelf: this preserves the ridge-trough topography of the ice shelf and even allows for slight deepening of the troughs. The anomalous loss occurring on the ice shelf in the 1974 ablation season (Figure 3) can not be justified by the low winter accumulation for that year. However the reduced snow cover coupled with the lower albedo of the ice shelf relative to the ice rise may have provided a longer period of energy input.

Although there appears to be twice as much ablation on the ice shelf as on the ice rise one cannot assume that there is necessarily an actual reduction in the mass of the floating shelf. It has been shown (Hattersley-Smith and Serson, 1967) that the fresh run off water with a freezing point of 0°C dammed by the floating shelf can only escape from Disraeli Fiord by flowing under the shelf over a layer of seawater at -1.8°C resulting in the up-

ward precipitation of ice platelets observed by Keys et al. (1969), Lyons et al. (1971) and Keys (1978). This low density, high freezing point water should fill in the thinner portions of the shelf and create a smooth lower surface. Whether this is actually taking place could be determined by re-surveying the strain net stakes, the vertical control having been established by Serson in 1969 (Dorrer, 1970). Assuming a standard error of ± 100 mm for the comparatively short distances involved and a history of net ablation of from 63 mm to 96 mm per year requiring a freeboard adjustment of 8 mm per year, a 25 year period combined with improved leveling techniques should show the trend.

CONCLUSIONS

On the ice shelf the years 1906 to 1962 were a period of net surface ablation of the order of several metres of water; they were followed by 3 years (1952 to 1965) of probable positive surface regime, then by 10 years having a total net ablation of 960 mm but showing a trend towards lower ablation rates (Table II). On the ice rise the years 1958 to 1976 were a period of net negative mass balance totalling 405 mm water with two periods 1962 to 1968 and 1972 to 1976 having mean temperature appear to determine whether the mass balance is positive or negative and for this reason neither the ice shelf or ice rise should be considered a relic glacial feature.

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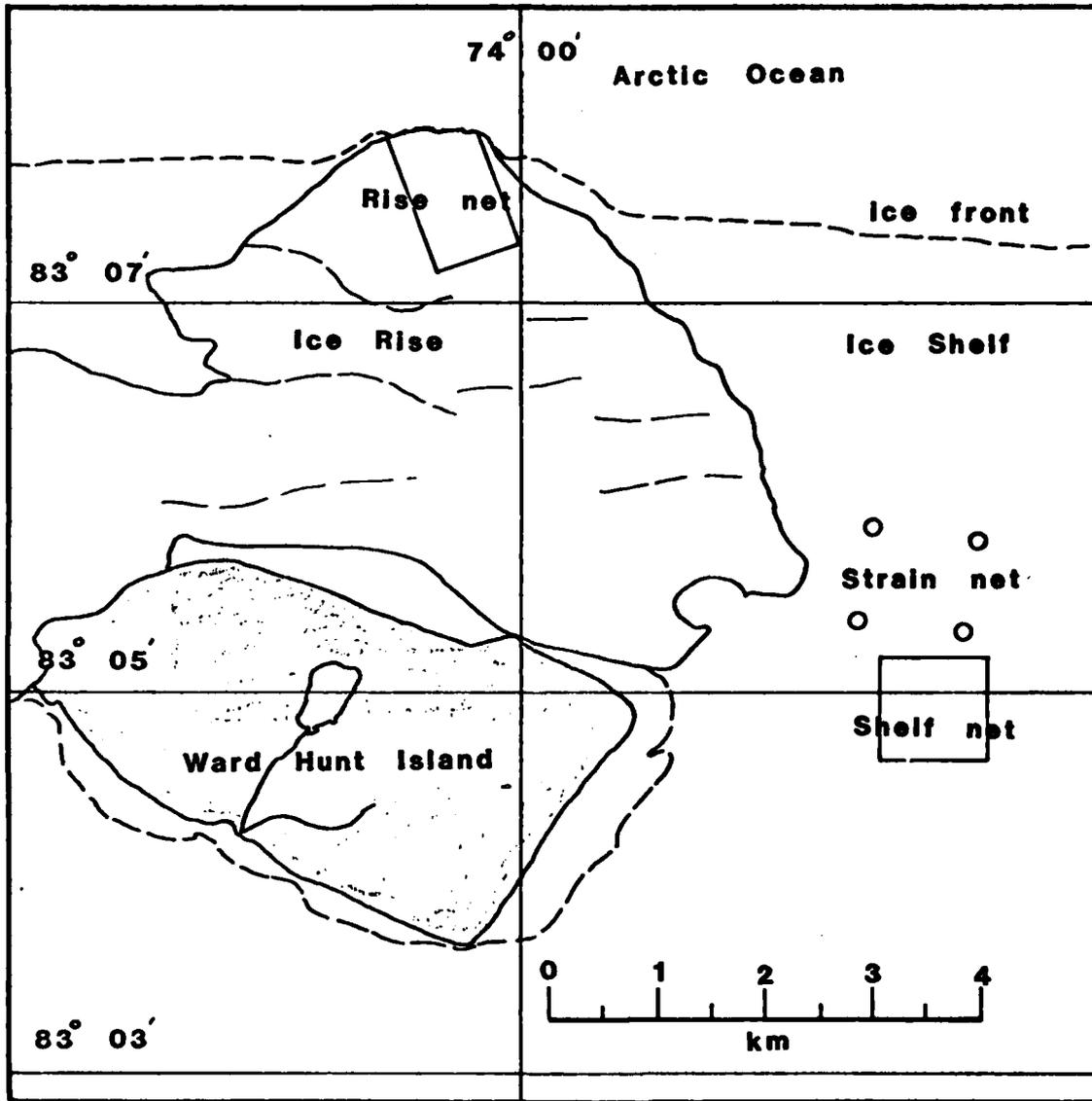
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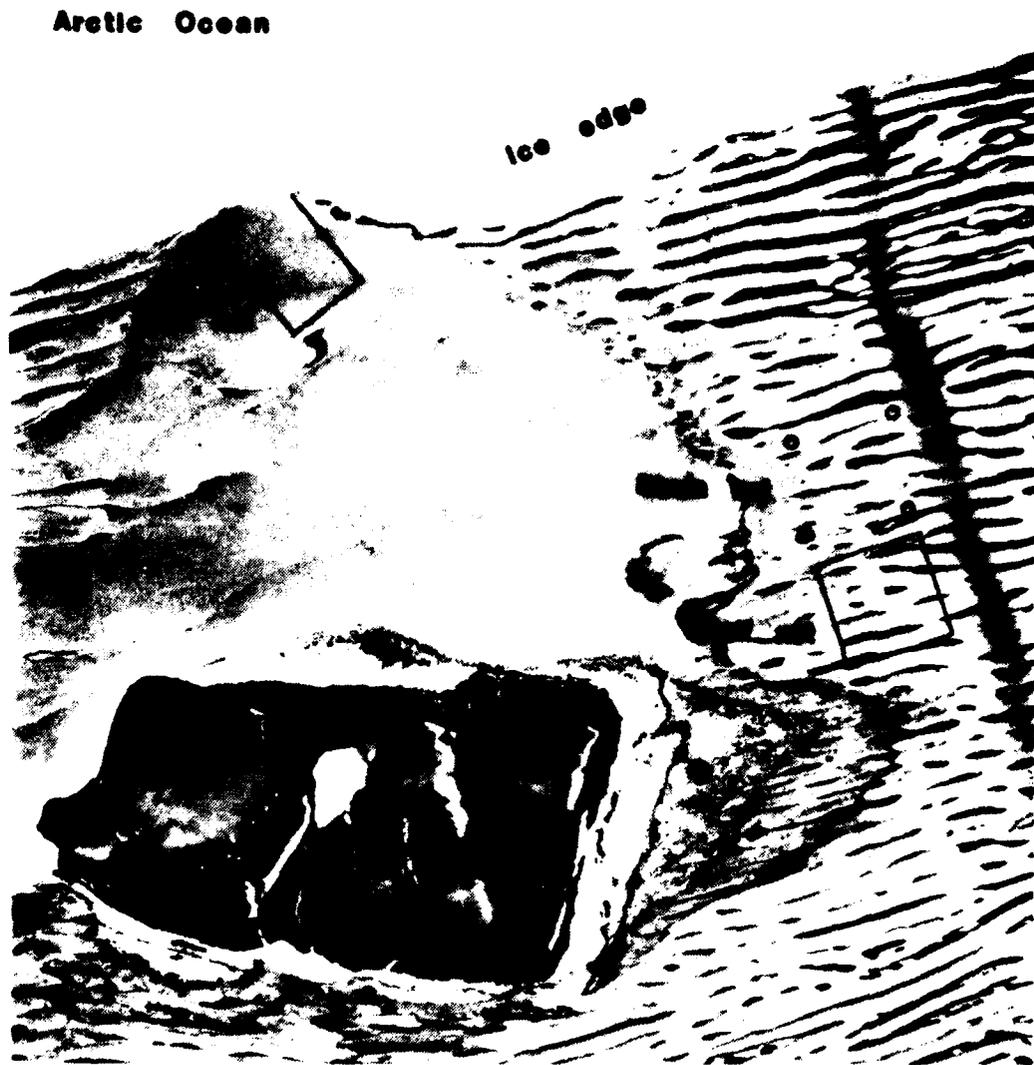
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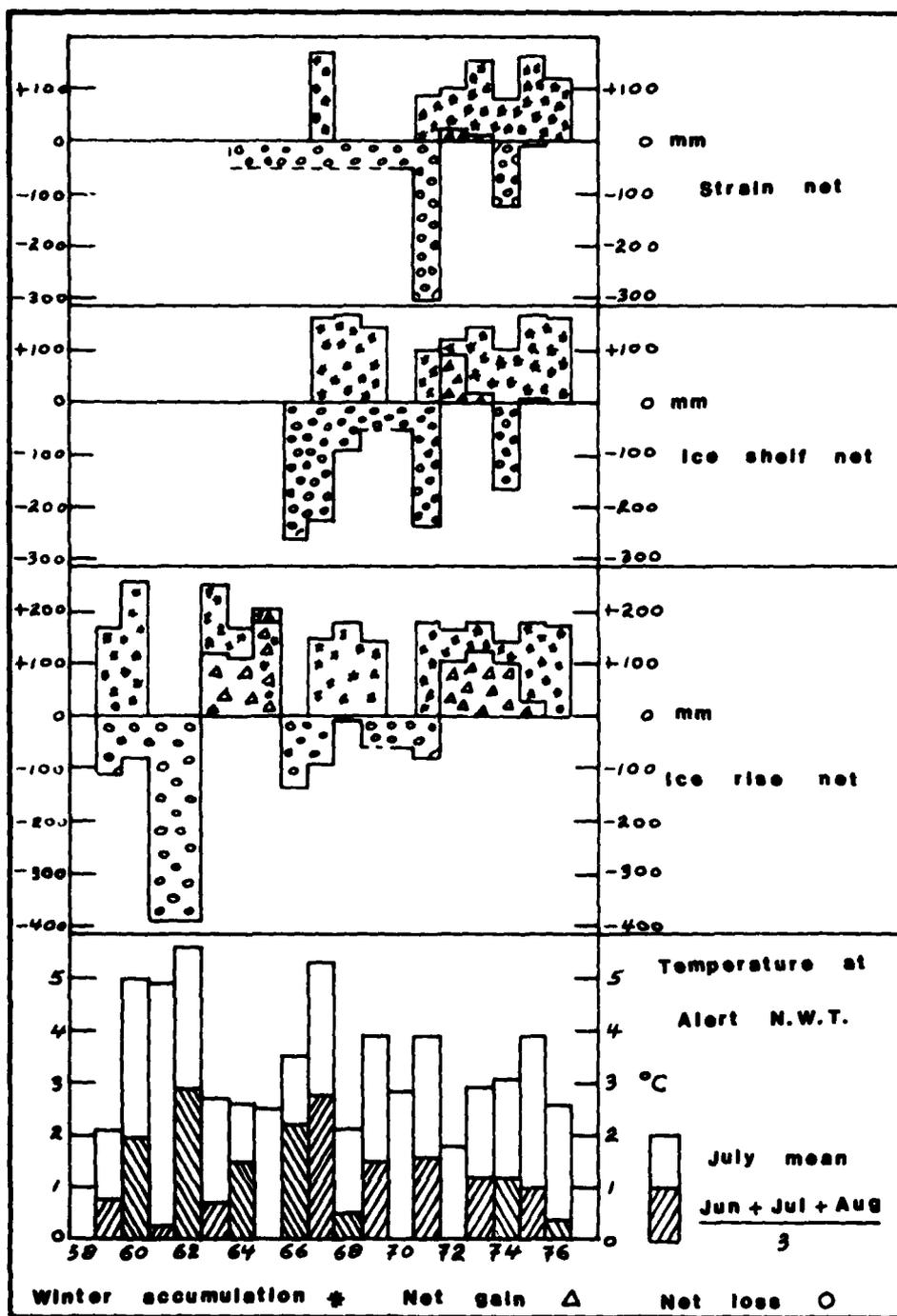
Ward Hunt Island and adjacent ice rise and ice shelf

FIGURE 1



Ward Hunt Ice Shelf and ice rise showing ridge and trough structure relative to the location of the ablation nets

FIGURE 2



Mass balance of the Ward Hunt Ice Shelf and ice rise and mean summer temperature at Alert N.W.T.

FIGURE 3

TABLE I
ACCUMULATION AND ABLATION ON THE WARD HUNT ICE RISE
MET. CAMP ABLATION NETWORK

DATE SCALED	WINTER ACCUMULATION			NET ABLATION		
	Number of Poles	Range mm of snow	Mean mm of water	Range mm of snow	Mean mm of water	Mean mm of water
Late June 1959	45	-	173	-	-	-110
Late June 1960	45	-	255	-	-	- 68
Not Scaled 1961	42	-	-	-	-	- (-288)
Not Scaled 1962	42	-	-	- 90 to 1010	-	-576 (-288)
20 June 1963	42	410 to 1260	251	-140 to 570	-	+117
25 June 1964	41	250 to 1420	171	-270 to +360	-	+104
12 June 1965	42	230 to 900	177	+ 40 to +750	-	+202
24 June 1966	42	-	-	-420 to + 10	-	-137
17 June 1967	42	330 to 660	152	-470 to + 30	-	- 91
05 May 1968	40	240 to 1120	174	-470 to +170	-	- 7
15 May 1969	38	260 to 720	146	-	-	- (- 59)*
Not Scaled 1970	36	-	-	-850 to +730	-	-1118 (- 59)*
16 June 1971	36	100 to 1100	180	-1000 to -760	-	- 76
02 June 1972	36	110 to 680	164	-900 to +1270	-	+105
08 May 1973	36	300 to 750	179	-910 to +1140	-	+121
29 April 1974	36	150 to 890	144	-440 to + 690	-	+101
27 May 1975	36	320 to 1060	176	-440 to + 300	-	+ 28
17 June 1976	32	300 to 1100	173	-	-	-

* PER YEAR.

TABLE II
 ACCUMULATION AND ABLATION ON THE WARD HUNT ICE SHELF
 1 KM² ABLATION NETWORK

DATE SCALED	WINTER ACCUMULATION			NET ABLATION		
	Number of Poles	Range mm of snow	Mean mm of water	Range mm of snow	Mean mm of water	Mean mm of water
27 June 1966	21	Installed		-640 to -180	-256	
23 June 1967	21	420 to 740	167	-750 to -40	-224	
13 May 1968	95	270 to 1240	170	-460 to +250	-88	
18 May 1969	94	210 to 910	143	-	- (-56)*	
Not Scaled 1970	90	-	-	-1230 to -40	-111 (-55)*	
16 June 1971	90	80 to 1100	102	-1000 to -40	-233	
02 June 1972	90	80 to 680	116	-900 to +650	-95	
08 May 1973	90	320 to 710	144	-1040 to +810	+18	
29 April 1974	88	130 to 890	106	-380 to +690	-164	
27 May 1975	98	320 to 1060	169	-440 to +300	+1	
17 June 1976	94	300 to 1420	167	-	-	

* PER YEAR.

TABLE III
 ACCUMULATION AND ABLATION ON THE WARD HUNT ICE SHELF
 1 KM² STRAIN NETWORK

DATE SCALED	WINTER ACCUMULATION			NET ABLATION		
	Number of Poles	Range mm of snow	Mean mm of water	Range mm of snow	Mean mm of water	Mean mm of water
25 June 1964	4	Installed	-	-	-	(- 52)*
Not Scaled 1965	4	-	-	-	-	(- 52)*
Not Scaled 1966	4	-	-	-360 to - 70	-156	(- 52)*
23 June 1967	4	470 to 600	168	-	-	(- 52)*
Not Scaled 1968	4	-	-	-	-	(- 52)*
Not Scaled 1969	4	-	-	-	-	(- 52)*
Not Scaled 1970	4	-	-	-460 to - 90	-208	(- 52)*
16 June 1971	4	140 to 450	88	-530 to -330	-302	
22 June 1972	4	300 to 340	100	- 80 to +130	+ 22	
28 May 1973	4	460 to 520	151	- 80 to + 80	+ 13	
31 May 1974	4	220 to 280	80	-210 to -190	-122	
27 May 1975	4	490 to 550	161	- 50 to 0	- 7	
17 May 1976	2	350 to 490	117	-	-	

* PER YEAR.

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* PER YEAR.