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Observation on the Snow Accumulation/Ablation over Shelf and Continental Ice in Parts of Central Dronning Maud Land, East Antarctica

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Abstract

Snow accumulation and ablation patterns over shelf and continental ice in parts of Central Dronning Maud Land, East Antarctica were studied during summer of 1989-90, austral winter of 1990 and summer of 1990-91. While there was negligible addition on the shelf ice near Dakshin Gangotri, between December 1989 and March 1990, the period between March 1990 and end of October 90, recorded a steep rise in accumulation of the order of 15.9 gm/cm^2. The summer that followed (1st November 90 to March 91) experienced ablation to the tune of 10.3 gm/cm^2. An year long profile of the snow surface between Maitri and Dakshin Gangotri has revealed a marked accumulation beyond the grounding line as compared to the area close to the Schirmacher oasis. The stake data collected over the continental ice between Maitri and Northern Humboldt (Nordvestoya) has shown heavy accumulation (average 32.5 gm/cm) during austral winter of 1990 and an ablation of 7.4 gm/cm in just one month of summer that followed it.

Introduction

Antarctic icesheet is in approximate state of equilibrium with respect to its height and lateral extent. Hollin (1962) has shown that the altitude of this icesheet is controlled mainly by the flow of ice rather than by accumulation and air temperature. However, in the coastal regions snow accumulation does take place due to deposition of drift snow and its transformation to ice because of melting, drop in temperature and weight of the overriding snow of subsequent periods. Cameron (1964) established that an approximate calculation of the mass balance of Antarctic icesheet can be done by monitoring systematically laid stakes over shelf and continental ice.

The snow accumulation and ablation studies over the shelf ice near Dakshin Gangotri in the Central Dronning Maud Land of East Antarctica, were initiated in 1983 during the Second Indian Expedition to Antarctica by Kaul *et at,* (1985). Regular stake readings, on a continuous basis, commenced during Fifth Expedition onwards (Singh *et al.,* 1988) on a 100 m X 100 m plot of shelf ice, which was essentially an obstacle free area about 1.25 km east of Dakshin Gangotri. A total of nine stakes, each at 50 m interval, were fixed in a rectangular pattern as shown in Fig. 1A. The stakes were 3 m high and had rubber shoes at their base. Tttese stakes have been measured for snow accumulation/ablation since 1985 at a fortnightly or monthly interval by the successive expedition teams.

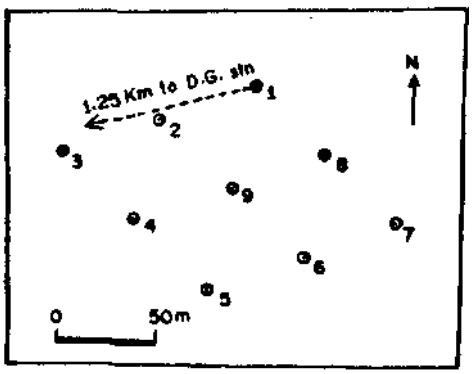

Fig. 1A. Location of Stakes near Dakshin Gangotri Station (after Singh et al, 1988).

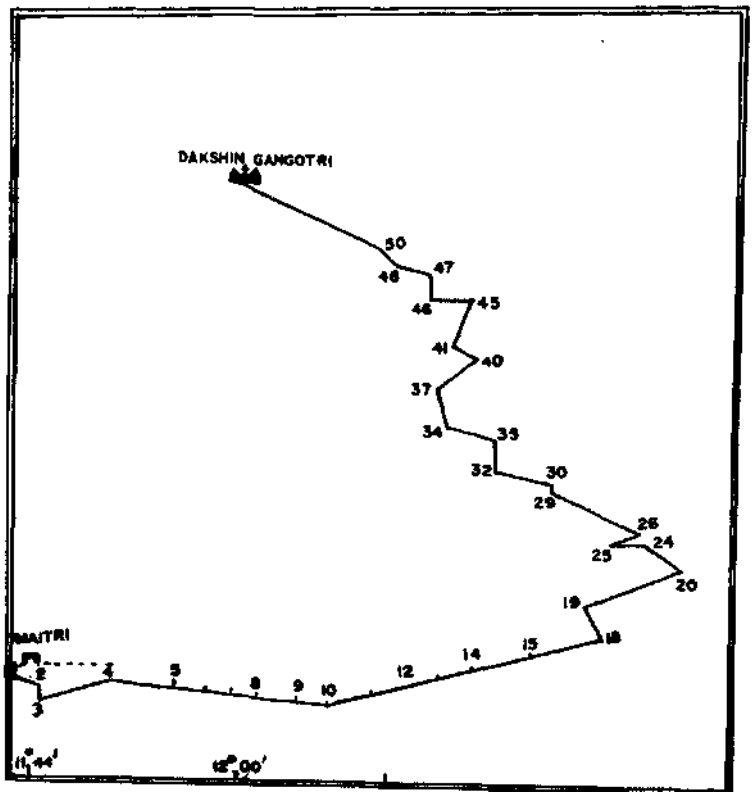

Fig. 1B. Location of Glaciological Stakes along DG-Maitri route.

During Ninth Indian Expedition to Antarctica (1989-91), apart from the observations on the above mentioned stakes, the observations spread over a year, were made on an additional set of 50 stakes, which were fixed on the shelf ice between Dakshin Gangotri (D.G.) and Maitri, along the winter convoy route. These stakes were fixed by drilling one metre deep holes at an approximate spacing of one km. The location of each stake was fixed on the map by vehicle mounted SATNAV equipment (Fig. 1B).

A third set of 80 stakes was fixed on the continental ice between Maitri and Nordvestoya (Fig. 2). Observations on the former set of stakes are available for austral winter of 1990 and summer of 1990-91, while the data on the latter set of stakes was recorded thrice between April 1990 and October 1990. The observations thus pertain to three glacial domains — shelf ice close to sea, shelf ice between sea and the continental ice and the continental ice.

Accumulation/Ablation Pattern over Shelf Ice near DG

The set of nine glaciological stakes near DG station (Fig. 1A) were monitored for accumulation/ablation studies on monthly basis. However, since DG station was decommissioned in the beginning of 1990, the recording of the data could be done only during the time of convoys to DG from Maitri. Thus the observation over stakes are available for the months of December 1989, January, February, March, May, August, September, November 1990 and February and March 1991. The snow accumulation and/or ablation figures, in terms of water equivalents, are given in Table 1.

A scrutiny of this table would reveal that most of the stakes recorded accumulation of snow during the winter months i.e. March to October, except the stake Nos 7 and 8 which recorded no change in terms of accumulation or ablation during the months of August and September. An overall average accumulation of the order of 19.1 gm/cm^2 took place on the

Table 1: Snow Accumulation/ablation Data for 1990-91 from shelf Ice, DG. (in water equivalent, gm/cm^2)

Stake No.	March	May.	Aug.	Sept.	Total	Nov.	March	Total	G. total
			(Winter)			(Summer)			
1.	9.25	3.33	4.07	0.74	8.14	5.18	-5.92	-0.74	16.65
2.	4.81	9.62	2.59	1.11	13.32	-1.85	-11.10	-12.95	5.18
3.	4.44	5.92	2.59	0.74	9.25	6.29	-12.21	-5.92	7.77
4.	2.96	10.73	4.44	1.11	16.28	1.85	-10.36	-8.51	10.73
5.	2.22	14.06	4.07	0.74	18.87	0.37	-5.18	-4.81	16.28
6.	5.18	4.81	12.58	0.74	18.13	1.11	-8.88	-7.77	15.54
7.	1.85	15.17	0.00	0.74	15.91	0.00	-11.84	-11.84	5.92
8.	7.03	4.07	9.25	0.00	13.32	-0.37	-10.73	-11.10	9.25
9.	2.22	8.14	10.73	0.37	19,24	-1.11	-5.18	-6.29	15.17
Average:	4.44	8.43	5.59	0.70	0.70	1.27	-9.04	-7.77	11.39

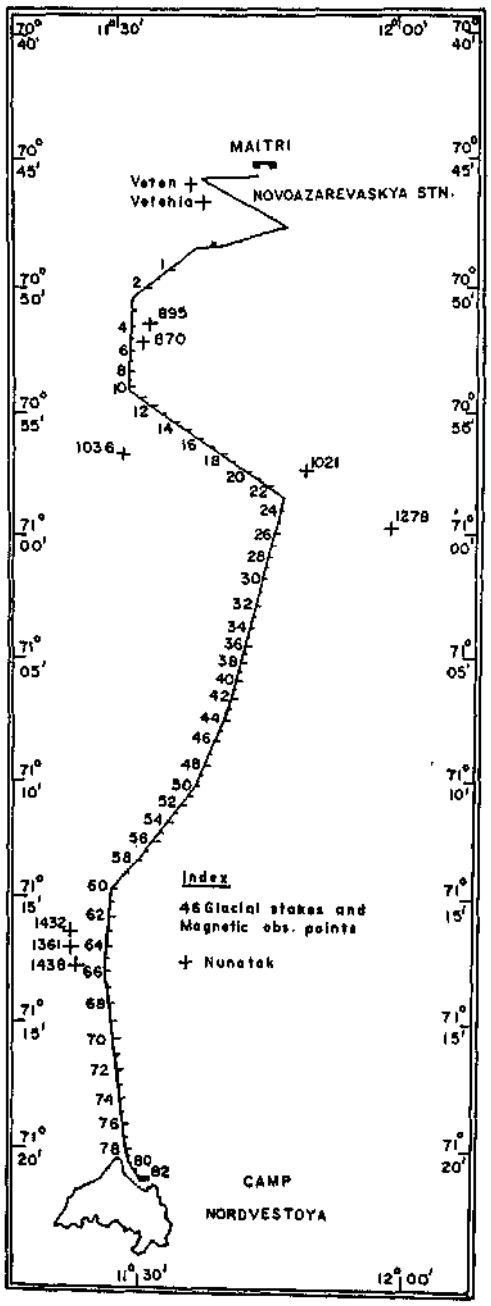

Fig. 2. Route Map between Maitri and Nordvestoya showing location of glaciological stakes.

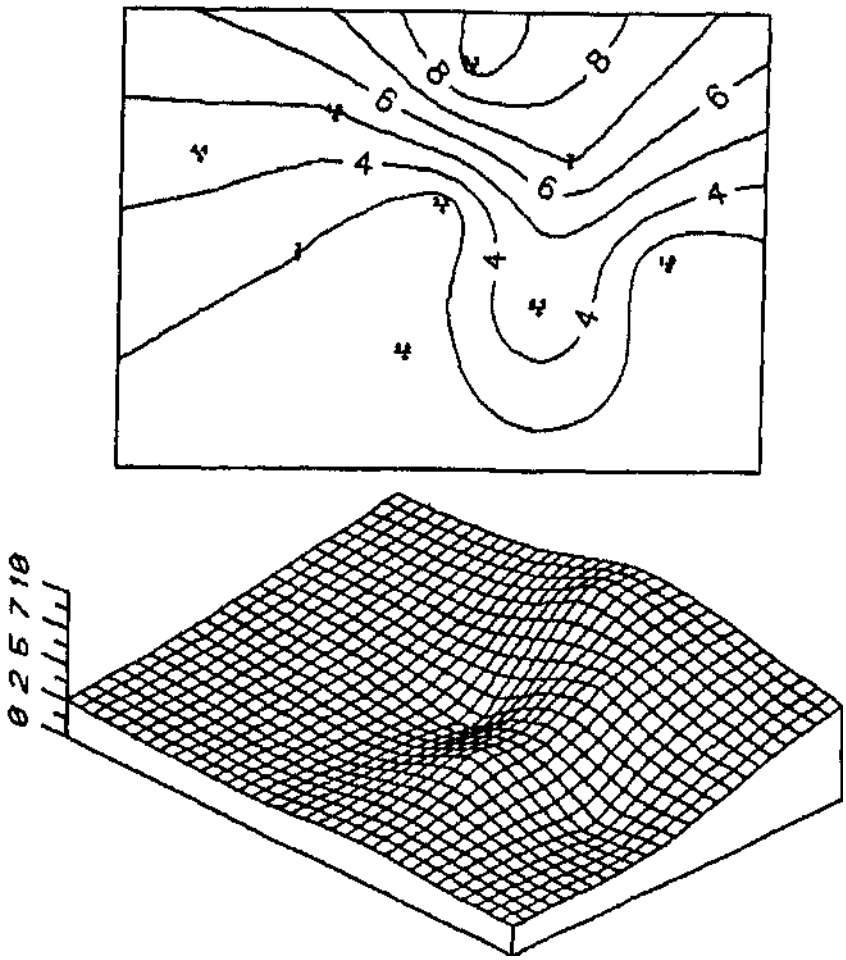

Fig. 3. Contour and trend surface of the area covered by stakes shown in Fig.1A, during March 1990.

nine stakes after the winter of 1990. During the winter months, the least accumulation (0.7 gm/cm^2) took place in September, while the maximum accumulation was observed in May (8.4 gm/cm^2). With the onset of summer, accumulation gradually shows a decreasing trend (1.3 gm/cm^2 in November) till it is replaced by ablation in subsequent months. Ablation during the summer of 1990-91, as measured on individual stakes, ranged between 5.18 gm/cm^2 and 12.21 gm/cm^2 with a net ablation figure of 9.0 gm/cm^2. The net result of accumulation and ablation (average) for the period March 90-March 91 amounts to an accumulation of 11.4 gm/cm^2 (Fig.7).

The contour and the trend surface diagrams for summer (beginning of November to end of March) and the winter months (beginning of April to end of October) as compared to the

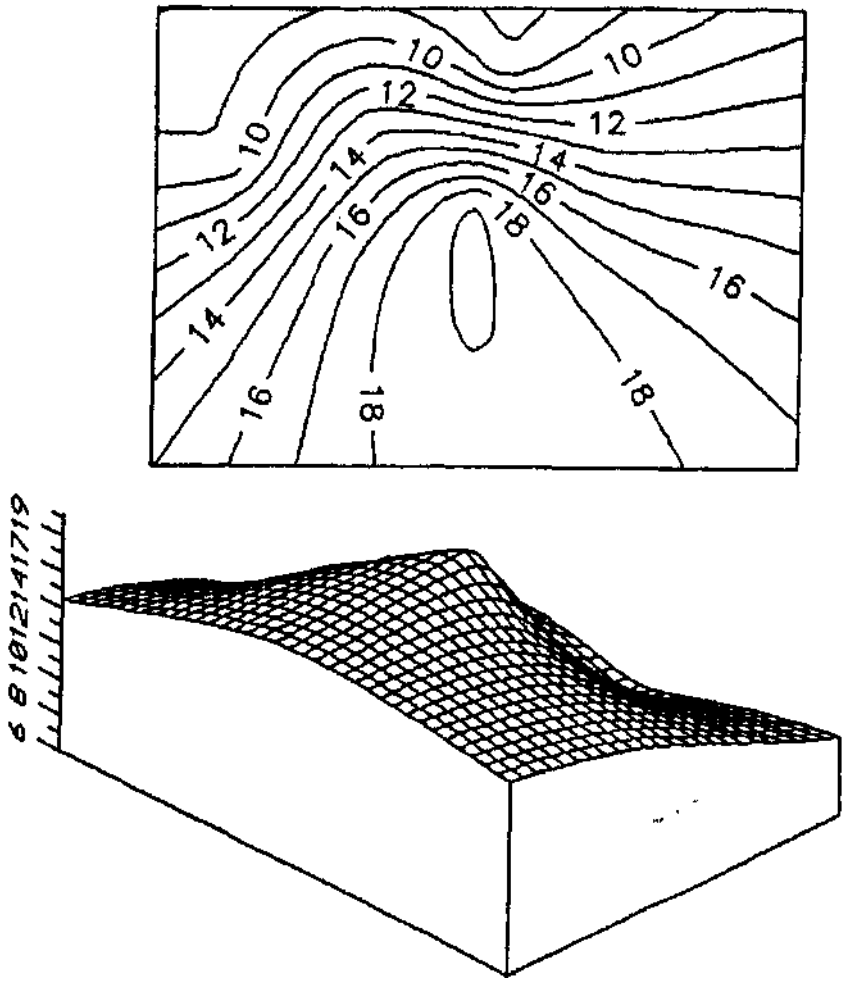

Fig. 4. Contour and trend surface of accumulation during winter of 1990.

overall period (March 90 - March 91), shown in Figs 3 to 6, depict a gradual change in the morphology of snow surface. When superimposed on each other, these surfaces (Fig.7) clearly bring out the accumulation trend of the winter period as compared to the ablation that took place during the summer.

Data along Maitri-DG Route

Three metre high stakes were fixed on the shelf ice, starting from Maitri upto DG, along the route followed by the winter convoys. These stakes, numbering fifty, and spaced 1 to 1.5

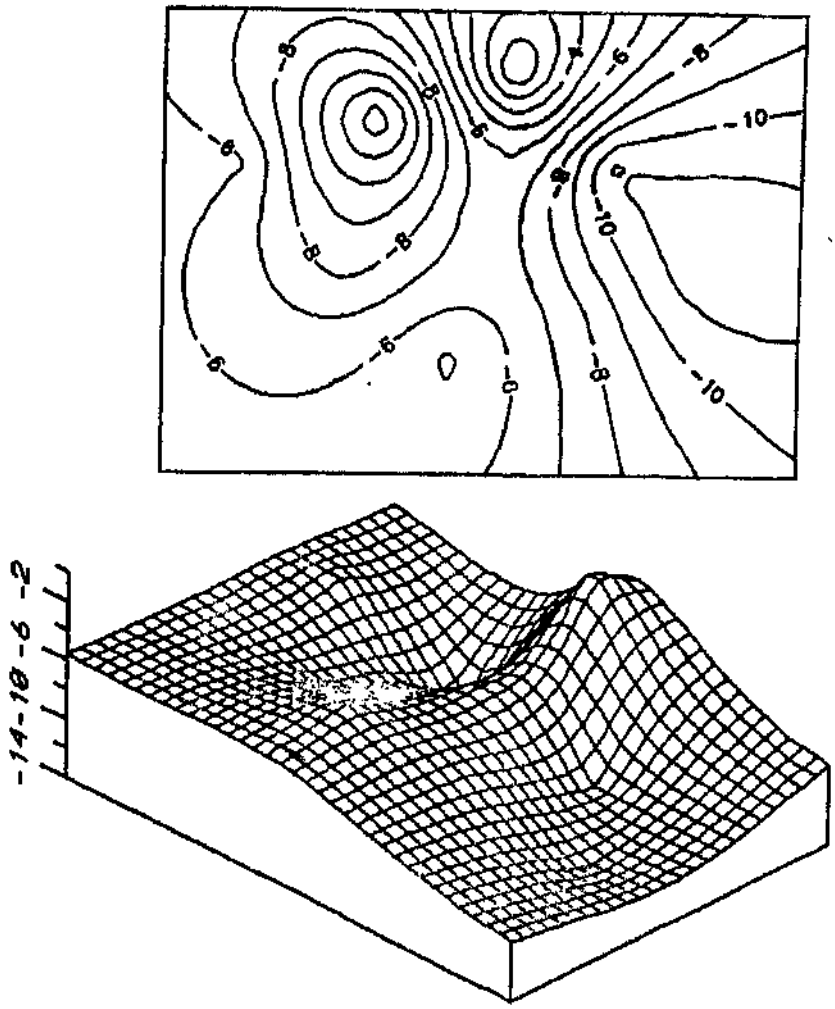

fig. *5. Contour and trend surface diagram depicting data of summer of 1990-91.*

km apart, traversed an undulating snow/ice surface with a gradual decrease in the altitude from 100 metre above msl to about 30 m above msl. The 80 km long trail intersects the grounding line, north of Maitri.

These stakes were monitored for snow accumulation and/or ablation during the months of May, July-August, September and November 1990. While there was considerable variation in the accumulation trend for the months of May and July-August, the observations taken in September 90 recorded only marginal variation when compared to the previous month's observations. The stake data of November 90, however, recorded ablation because of the onset of summer. Fig.8 shows a comparison between the May to September profile

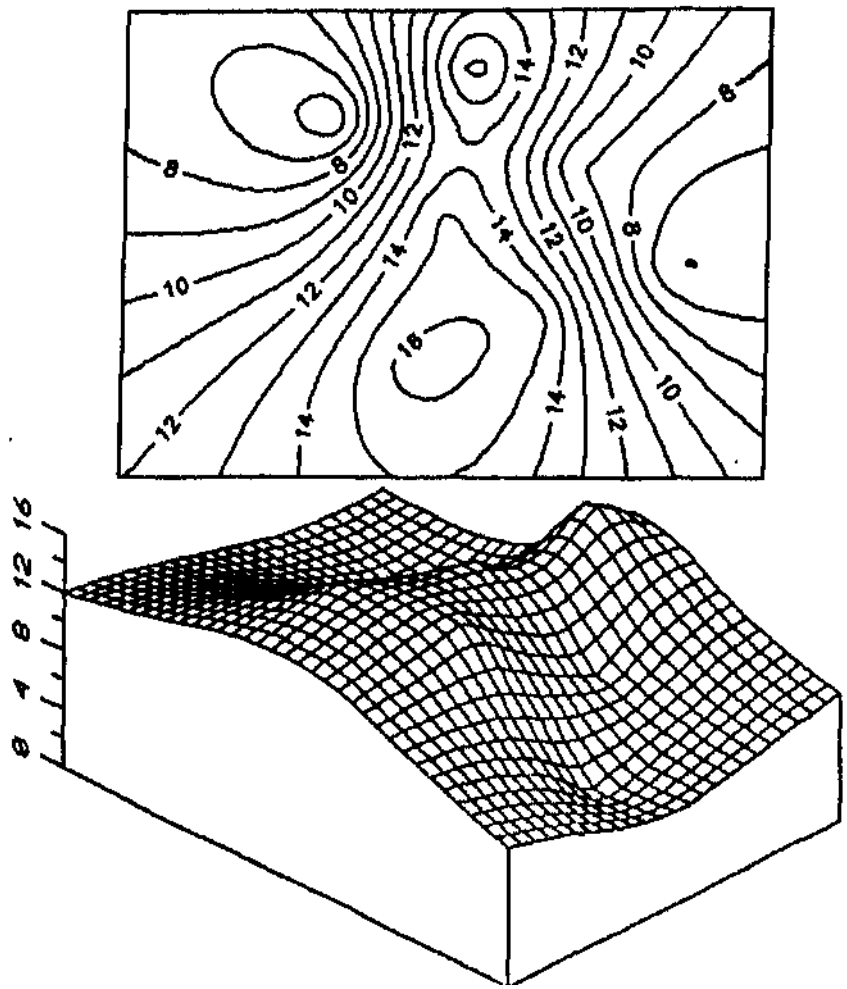

Fig. 6. Contour and trend surface diagram depicting cumulative picture of one year (March 1990-March 1991).

and that of May to November profile. Both the profiles show nearly parallel trends. Since these stakes could not be monitored after November owing to the opening up of the crevasses and formation of meltwater channels on the shelf ice, it may be noted that the summer profile does not encompass the ablation data for December to February months and hence the low ablation figures. The two anomalous behaviour in otherwise a normal profile are seen at the site of stake Nos 5 to 8 and again between stake Nos 29 and 33. The former is due to the proximity of nunataks while the latter can be explained because of the change in snow surface morphology. There is a general increase in the snow accumulation in the area beyond stake No. 29, which is close to the coast. This area is also marked by a zone of closely spaced crevasses.

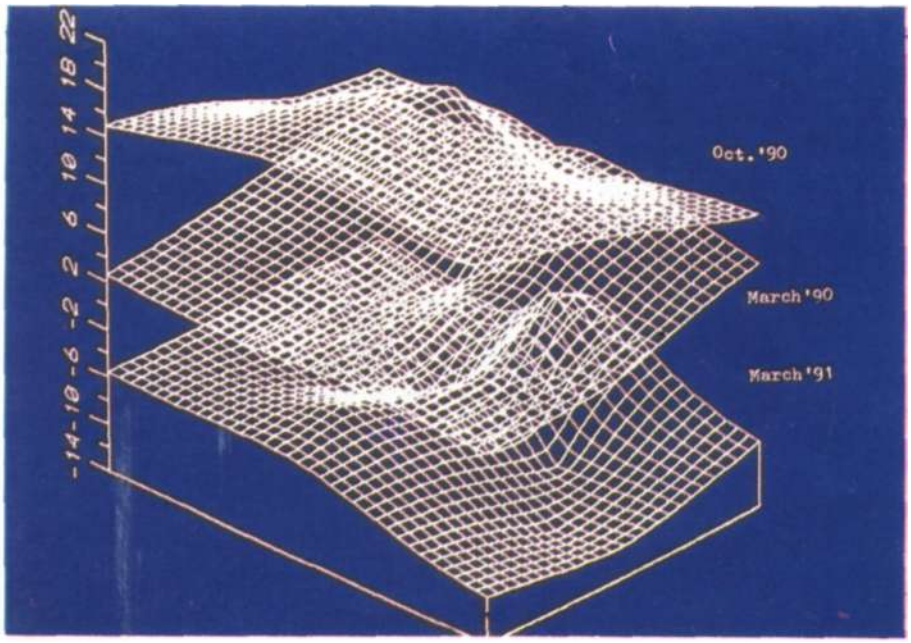

Fig. 7. Successive, superposed trend surfaces of summer-1990, winter-1990 and summer-1991.

Data from the Continental Ice

The continental ice depicts a contrasting morphological unit in its being constituted of denser ice. The sporadic occurrence of nunataks in between results in an uneven topography and local undulations.

Initially 62 stakes were fixed along the Maitri-Humboldt route, during April 1990. This network of stakes was extended upto Nordvestoya by adding another 20 stakes in October, covering thereby a total distance of about 100 km. These stakes were monitored during April 90, beginning of October and again at the end of October 90. Comparison of the data collected during beginning of October with that of the base data of April, gave the accumulation pattern on the continental ice during the winter months. The profile at Fig.9 displays the accumulation/ablation trend in this area. It will be observed from the perusal of this profile that winter months show an accumulation varying from 15 gm/cm^2 , near Maitri, to about 50 gm/cm^2 near the Per & Pal nunataks. There is a gradual increase in the accumulation trend southwards which coincides with the increase in altitude. The nunataks, whenever present close to the stakes, result in local anomalies. Thus the nunataks Tallak-senvarden (895), Stenersenknatten (870) around stake Nos 4 to 7; Andersensata (1036), Pevikhornet (1021) and Starheimtind (1278) located between stake Nos 16 and 26 have resulted in uneven accumulation. Since the nunataks present an obstacle in the path of wind carrying drift snow, there is a natural increased accumulation in their vicinity. Accumulation pattern can be judged from Fig. 10 where the accumulation of snow on the leeward side and a 'wind scoop' on windward side has resulted on the two sides of a temporary obstacle.

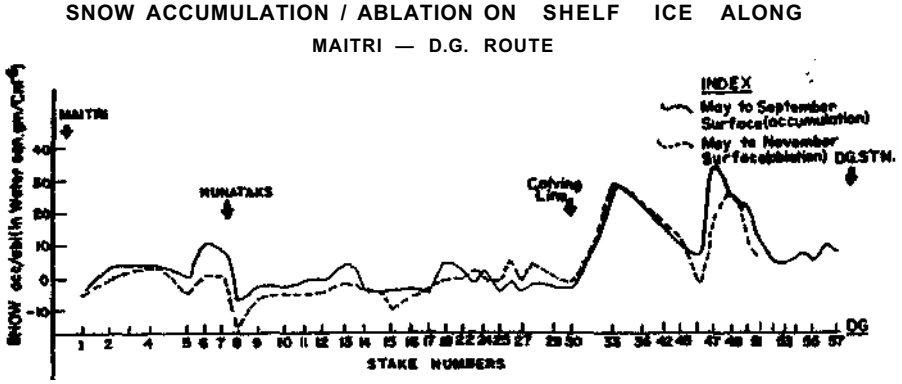

Fig. 8. Snow accumulation/ablation (in water equivalents gm/cm^2) along Maitri-DG route.

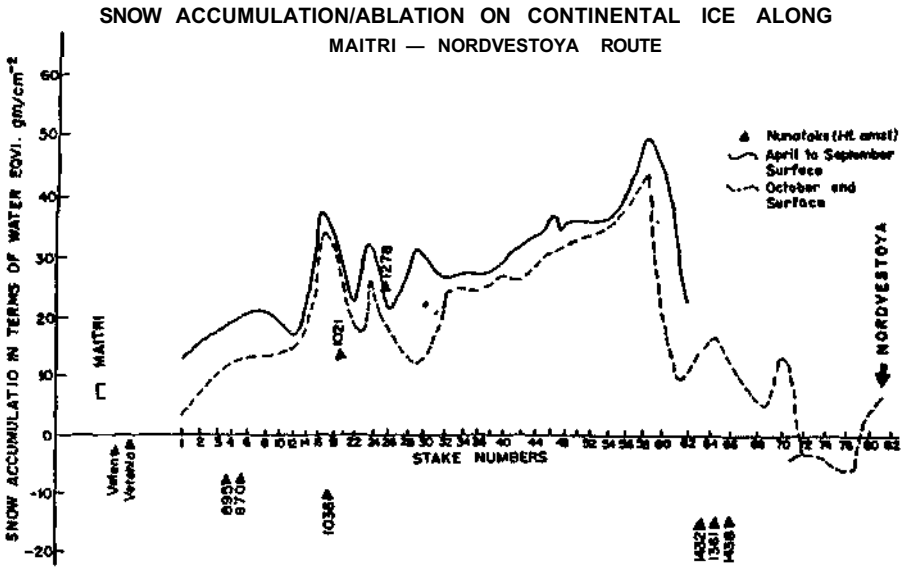

Fig. 9. Snow accumulation/ablation (in water equivalents gm/cm^2) on continental ice along Maitri-Nordvestoya route.

Similar effect can again be noticed near stakes 63 to **66** which pass close to Per (1432), Pal (1361) and Oskeladden (1438). The observations on these stakes at the end of October gave a general ablation varying between nil and 20 gm/cm in terms of water equivalents (Fig.9).

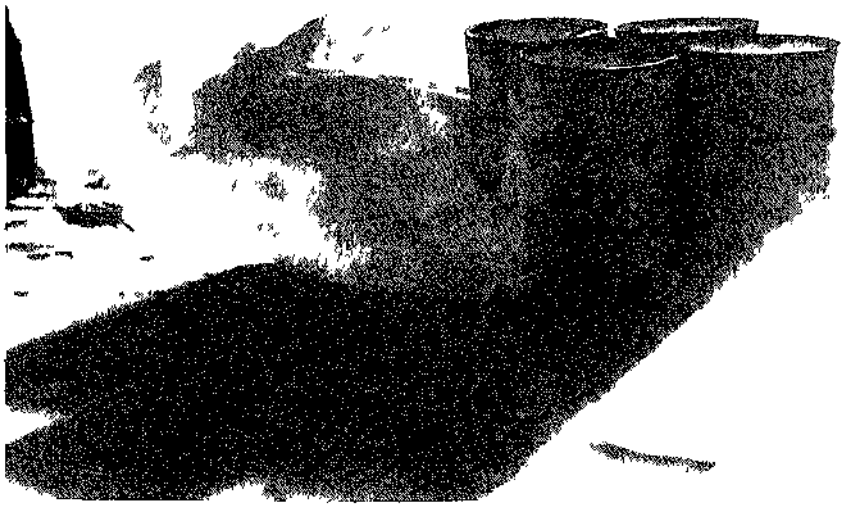

Fig. 10. Accumulation pattern caused by an obstacle

Discussion

Though there are several variables like wind speed, wind direction, elevation above mean sea level etc which have a direct bearing upon the snow accumulation/ablation pattern, it has been found that there is an overall consistency in the pattern of snow accumulation/ablation over different parts of Antarctica The accumulation/ablation figures from similar but widely separated area are comparable Cameron (1964) from his studies in Wilkes Station has also observed that snow accumulation generally takes place between March and September months while the period between October and March marks an overall ablation In Wilkes Station area, the snow accumulation between March 1958 and September 1958 was recorded to be 10 to 15 gm/cm^2 while the ablation during the period between October and March 1958 was 5 gm/cm^2 The corresponding figures from the shelf ice near Indian Station, DG, for 1990-91 are 19 1 gm/cm^2 and 9 gm/cm^2 respectively.

Acknowledgement

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