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Monitoring of Icebergs in Antarctic Waters and A Note on the Secular Movement of Dakshin Gangotri Glacier

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Abstract

Iceberg monitoring in the Antarctic waters, during onward and return cruise of Ninth Indian Antarctic Expedition, has revealed concentration of icebergs in two well defined zones separated by an iceberg free zone, in between. Distribution pattern and the analyses of size-shape parameters of these icebergs have shown that the majority of large sized (> 500m), tabular icebergs are concentrated in the area close to the Antarctic coastline as compared to the pinnacled and/or disintegrating icebergs (of < 500 m class) which show relative abundance between the S 51 ° and S 60° latitudes. A marked similarity in the distribution patterns of the icebergs during successive voyages has been noticed.

Monitoring of the snout of Dakshin Gangotri glacier during austral summer of 1991 and its comparison with the results of earlier studies reveals minor oscillation of the frontal part of snout and the proglacial lake at the foot of this snout.

Introduction

Large blocks of ice, calved from the ice shelf or derived from the glacier tongues are termed as icebergs. As per an estimate, nearly 5000 icebergs of varying dimensions are produced annually in Antarctica. Those of the icebergs which are not grounded, float in the southern ocean waters, governed by the circumpolar currents and the strong Antarctic wind patterns, causing navigational hazards. Monitoring of the icebergs visually and by satellite imagery has become an integral part of glaciological studies as this provides an important input to the overall mass balanee studies of Antarctic icesheet.

Iceberg monitoring was carried out during the onward and return voyages of the Ninth Indian Antarctic Expedition as per the guidelines of Norsk Polar Institute (Norwegian Polar Research Institute). It included recording of location, dimensional aspects like size, shape, tilt etc. and the study of morphological characteristics of icebergs encountered along the cruise. First iceberg was sighted on 17th December 1989 at south latitude 51° 23' and east longitude 34° 14', which proved to be an early sighting when compared to the available data of last four expeditions.

Distribution Pattern

A total of 291 icebergs were observed between 17th December 1989 and 27th December 1989 when the ship was moored to the fast ice. Out of these, 268 icebergs were visually sighted while 23 could be picked up only on ship's radar due to poor visibility.

Majority of the icebergs (54%) were found to fall within a narrow zone bounded by south latitude 68° 30' and south latitude 69° 50'. Another zone of high concentration of icebergs was noticed between S 57° 10' and S 60° 0'. Between S 51° 23' and S 57° 10' there were sporadic occurrences of icebergs with gradual increase in number, southwards. However, after the first zone of high concentration, there was a conspicuous absence of any iceberg till south latitude 68° 30' (Fig. 1). Similar observation was made during the iceberg monitoring conducted, more or less, along the same cruise line during 7th Indian Antarctic Expedition (Ravindra *et al.,* 1988) when two zones of iceberg concentration were delineated between S 57° 0' & S 61° 0' and S 64° 0' & S 69° 0' separated by an iceberg free area between S61°0'andS64°0'(Fig.2).

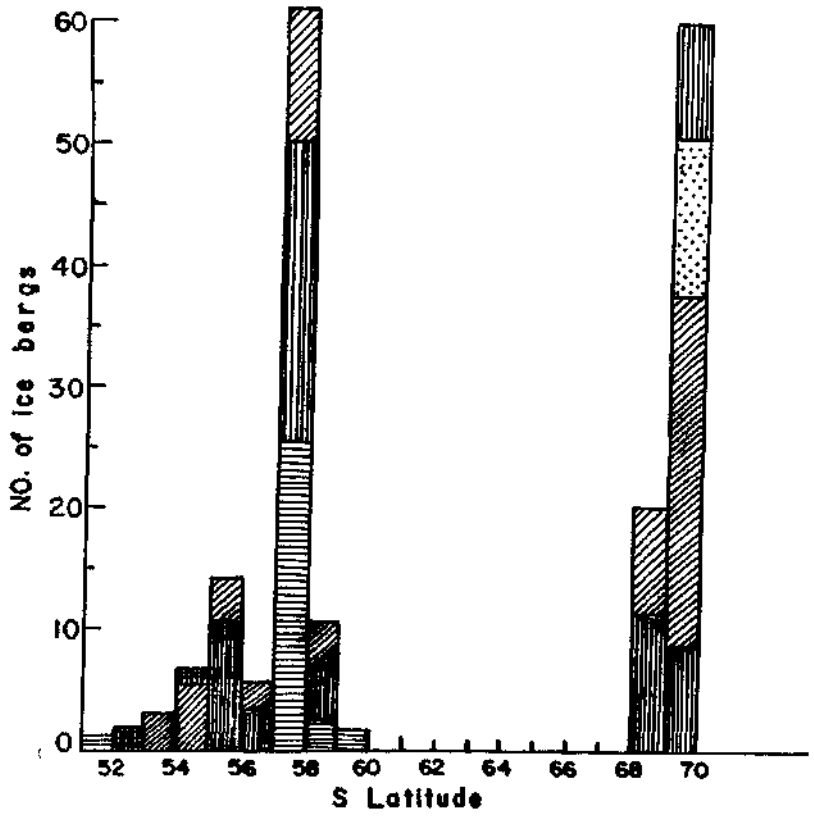

Fig.1. Distribution of icebergs in Antarctic waters during onward journey in Ninth Expedition.

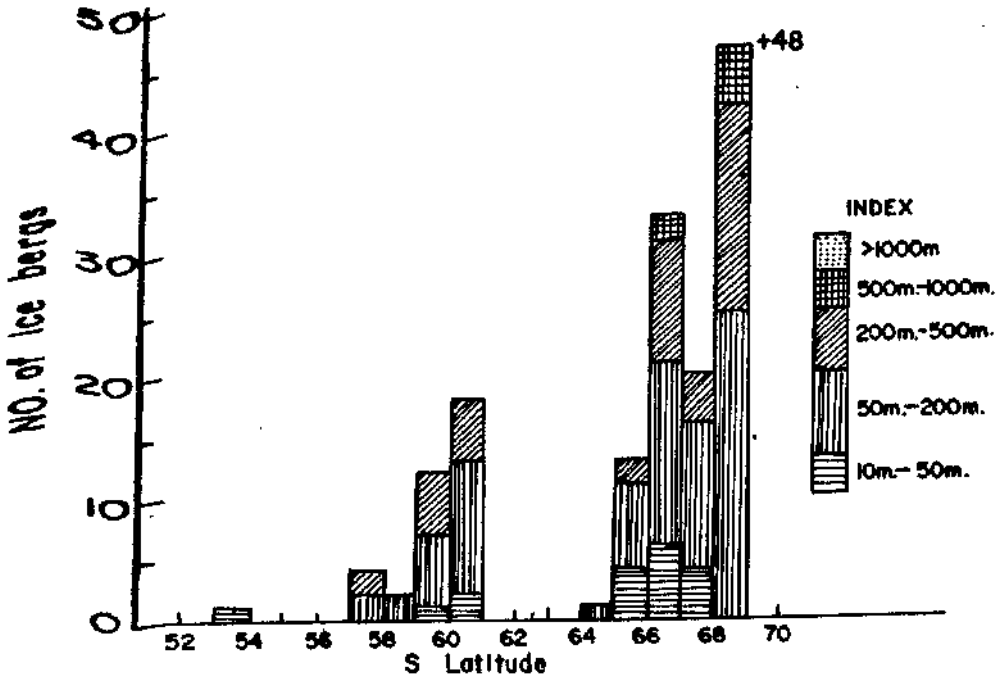

Fig.2. Iceberg distribution pattern during 1987-88.

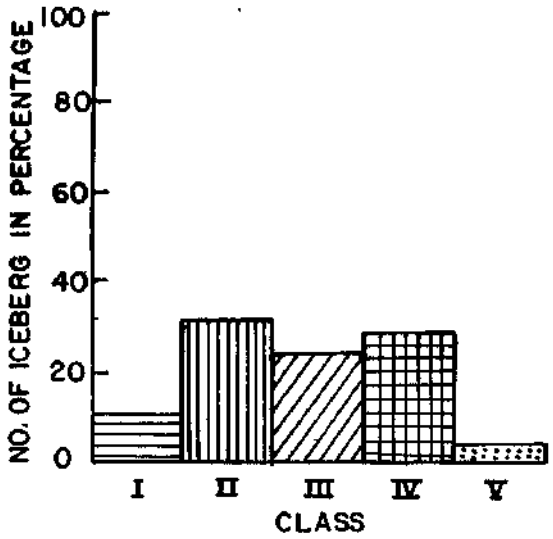

Fig.3. Relative abundance of different classes of icebergs.

The icebergs were divided into five classes depending upon their largest dimension, as given below:

Class	Largest dimension
I	10m-50m
II	50m-200m
III	200m-500m
IV	500m-1000m
V	> 1000m

Icebergs belonging to class I were found to be localised only in the first zone of concentration (Fig.1). This can be attributed to the gradual disintegration of icebergs away from their provenance in the shelf ice area of Antarctic coast. These constituted 11 % of the total number of icebergs. The class II icebergs were more frequent, especially between south lat. 55° 0' and South lat. 59° 0', accounting for 32% of the total visibly sighted icebergs. The icebergs belonging to class III, i.e. 200m-500m, were common between S 57° 0' and S 58° 0' and between lat. 69° 0' & 70° 0'. Together these constituted 24% of the total icebergs. The large sized icebergs (Class IV) which varied in its largest dimension from 500 m to 1000 m and the very large icebergs (> 1000 m) classified under class V, were found concentrated mostly in the higher latitudes, very close to the Antarctic shelf ice. These constituted 29%

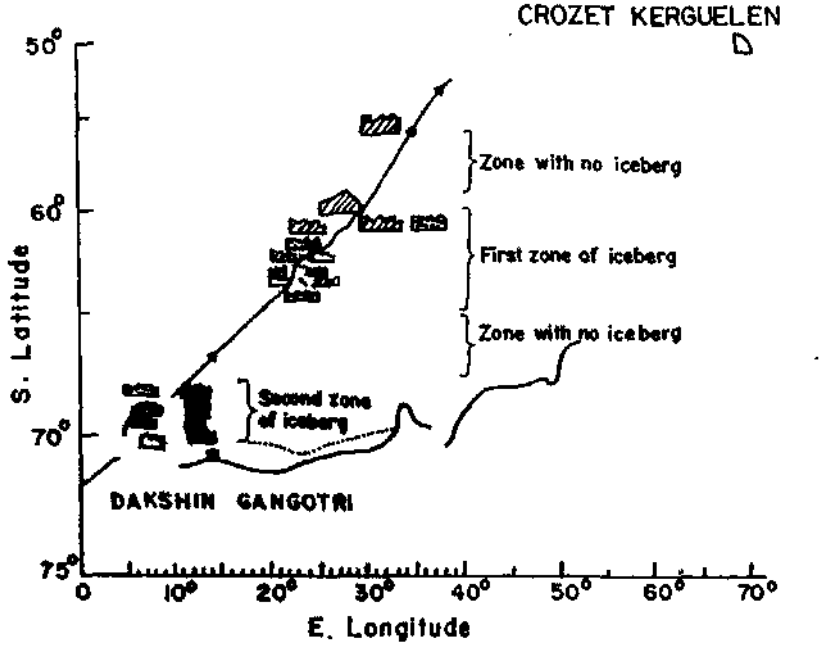

Fig.4. Distribution pattern of the icebergs during the return voyage in the Ninth Expedition.

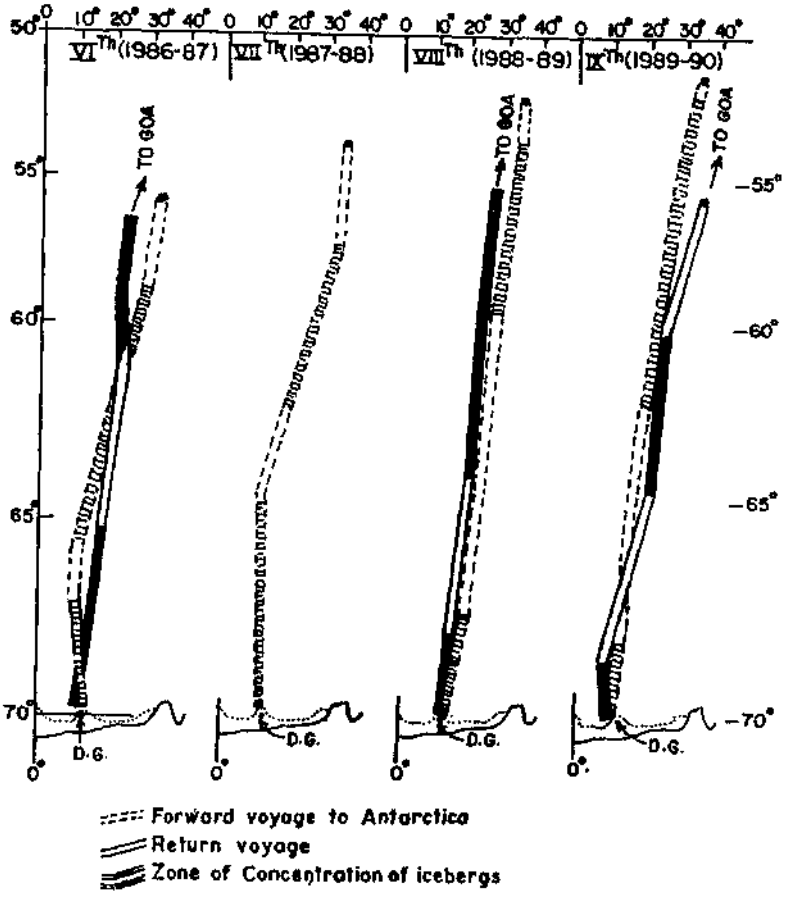

Fig.5. Relative distribution of icebergs during last four expeditions (1986-87 to 1989-90).

and 4% of the total number of icebergs respectively. The relative abundance of different classes of icebergs encountered is summarised in Fig. 3.

The distribution pattern of the icebergs during the return voyage (Fig.4) was not much different from the one observed previously during onward cruise, except that the number of iceberg sighting was greatly reduced, perhaps due to movement of some of these away from the cruise line of Indian Expedition. A comparison of the relative distribution pattern of icebergs monitored from 1986-87 to 1989-90 (Fig.5) shows successive early sightings of icebergs. It is interesting to note that during second Antarctic Expedition (1982-83), Kaul *et al.* (1985) recorded first appearance of iceberg at south latitude 59°, while the Seventh (1987-88) and Ninth Indian Expeditions (1989-90) recorded their first icebergs at south latitudes 53° 42' and 51° 23', respectively. In each of the four expeditions the distribution pattern has a marked similarity though there is a systematic northward shift in the iceberg zones.

Shape Analyses

Icebergs exhibit different shapes and forms. The morphological features widely depend upon the distance travelled, antiquity and the degree of disintegration caused by strong winds and wave action. Based on these parameters, the icebergs encountered during voyage, have been classified as tabular, pinnacled or pyramidal, tilted, weathered or disintegrating and grounded icebergs.

Majority of the icebergs were of tabular type with flat tops (Fig.6). While perfect rectangular icebergs of this type with 30- 50m height and largest dimension varying between 200m to 1000m were common in Polynya; the tabular icebergs northwards were found to have a convex top surface dissected by deep crevasses. Formation of caves in some of these icebergs (Fig.7) was noticed. In one of such ice caves, stratified ice in the vertical face was studied. The individual units of stratification varied from a few cm to 30cm and were marked by difference in colour (blue, dirty white, white, etc) and granularity. The walls were free of caught-up boulders and deep scourings were observed on the icebergs at sea level.

Pinnacled or pyramidal icebergs (Fig.8), as the term denotes, refer to the icebergs with broader base and narrow conical top. Such bergs were recorded throughout the cruise from south latitude 54° 30' onwards till Polynya but they were more common in the 'fifties'. Many pinnacled icebergs appeared to be disintegrating (Fig.9) with large crevasses running from one corner to the other. A few grounded icebergs were also noticed in the fast ice area where giant sized icebergs are berthed more or less permanently. The lower levels of these icebergs displayed horizontal stratification indicating their genesis from ice shelf. Some

Fig.6. Tabular iceberg displaying flat top and crevasses.

Fig. 7. *Close-up view of a tabular iceberg showing development of caves. Note the horizontal stratification at upper section of the iceberg.*

tabular icebergs (monitored in the open sea between S 68° 0' and 70° 0'), were tilted at one of their sides (Fig. 10) owing to the uneven disintegration at its base.

Monitoring of Glacier Snout

The continental ice of Antarctica is in a dynamic state, showing a wide variation in rate of flow. A part of the margin of this icesheet is exposed south of Schirmacher oasis, where several of its tongues, protrude outwards, overriding the bedrock. Two of such sites were examined. The first is located on the eastern extremity of Schirmacher. This tongue is present within narrow passage constrained on either side by hills. It exposes a vertical face of about 80m at the foot of which a large collection of morainal debris exists. The meltwater from the glacier drains into a large epishelf lake. A lobate structure formed on one of the margins of this tongue reveals successive morainal deposits of terminal type. A line of poles existing across this tongue, connecting the two hills on either side (to warn the snow vehicles) shows 2 to 5m shift of the poles towards WNW, with central poles showing greater shift as compared to the marginal poles.

Fig.8. Pinnacled iceberg.

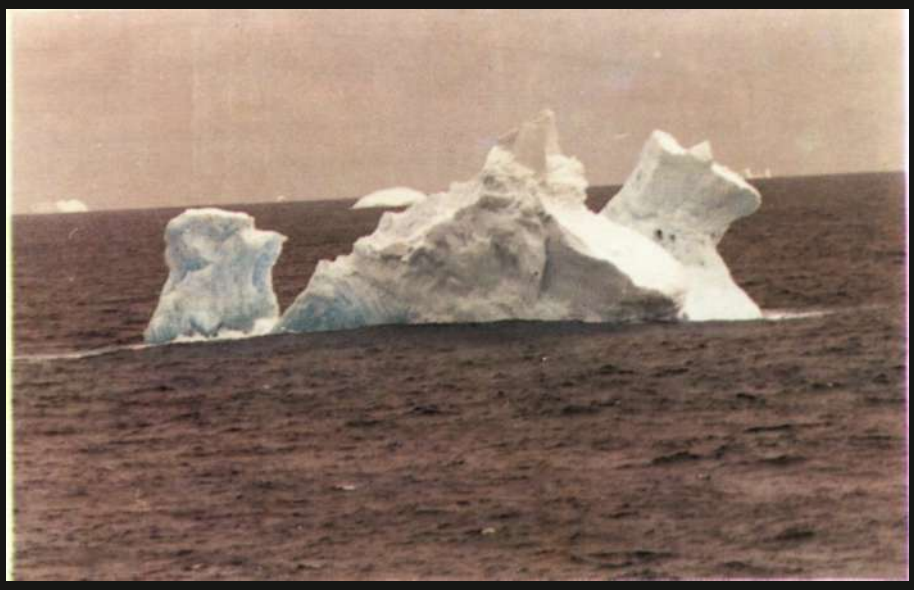

Fig.9. A disintegrating iceberg.

Fig. 10. An iceberg showing tilting at one of its sides.

Fig. 11. Snout of the Dakshin Gangotri glacier along with the proglacial lake at its foot.

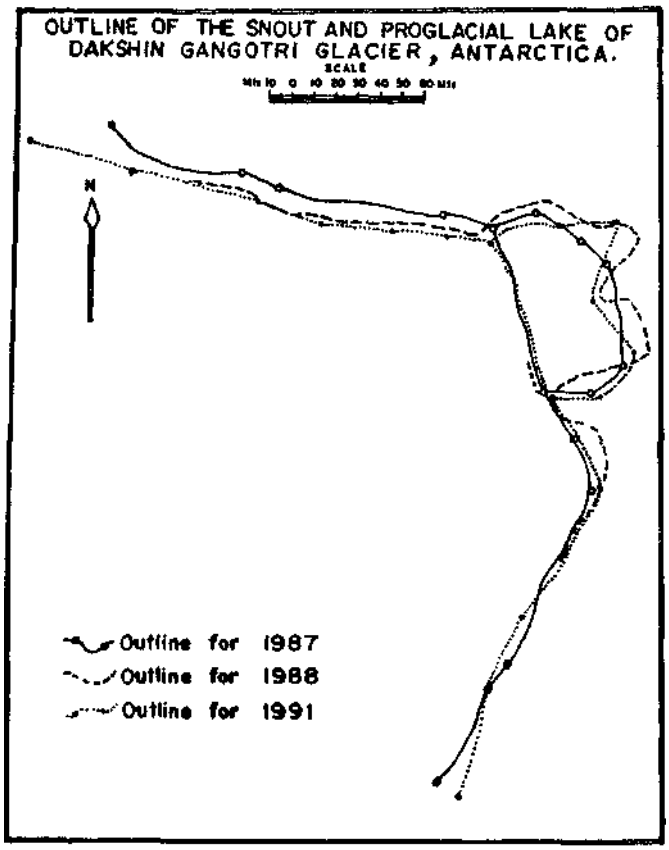

Fig. 12. Map showing the secular movement of snout of Dakshin Gangotri glacier between 1988 and 1991.

A more prominent tongue of the continental ice, present in the central part of Schirmacher has been called as Dakshin Gangotri glacier (Kaul *et al.,* 1985). The snout of this glacier is being regularly monitored since January 1983 for delineating its spatial configuration. The glacier snout exposes a vertical face with a number of deep crevasses running from top surface to the bottom of snout. The top surface which is about 70m above the ground level, shows cuspate structure (Fig.11) and development of a number of meltwater channels. A proglacia! lake occurring at the foot of snout is also seen in Fig. 11. The lake overflows during peak summer when water escapes to another lake lying at a lower altitude. Huge chunks of ice, broken from the vertical face were seen lying at the junction of snout and proglacial lake.

Both the glacier snout and the proglacial lake were mapped from the permanent ground station marked 'G' on the rock outcrop using an electronic distance measuring device. The

results of successive studies conducted during 1987, 1988 and 1991 are given in Fig. 12. A comparison of these maps reveals that the position of snout has advanced between 3 to 5m in different parts of the northern segment since 1988 though between 1987 and 1988 (Ravindra *et al*, 1988) shrinkage of the order of 8 metres was recorded in this sector. In the south eastern part, where an advance of 4m was noticed between 1987 and 1988 positions, a recession of 1 5m is recorded in 1991 (February) with respect to the position of the 1988 These results when further compared to the data collected during 1983 and 1986 (Kaul *et al*, 1988) show an oscillatory trend of the snout and the proglacial lake.

Conclusion

The monitoring of icebergs and Dakshin Gangotri glacier is a long-term programme aimed at understanding the dynamics of shelf and continental ice. The data collected over last few expeditions has helped in understanding the distribution pattern of icebergs and the nature of movement of snout of DG glacier.

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