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Major Calving of Petermann Gletscher, Greenland

Kurzfassung

Studien, die auf Fernbeobachtungen von Meereseis beruhen, haben zufällig ein Kalben des Petermann-Gletschers im Nordwesten von Grönland enthüllt, das im Zeitraum August–September 1991 stattfand. Die Studien beruhen auf Daten des Spezialradars SAR auf dem ERS-1 Satelliten, der im Juni 1991 in den Weltraum geschossen wurde. Dieses Phänomen wird beschrieben und mit anderen, früheren und späteren Beobachtungen des Gletschers in Verbindung gebracht.

Abstract

Remote sensing studies of sea ice have – by chance – revealed a calving of Petermann Gletscher, Northwest Greenland, which took place in the period August–September 1991. The studies are based on data from the synthetic aperture radar (SAR) on the ERS-1 satellite, which was launched in July 1991. The phenomenon is described and related to other earlier and later observations of the glacier.

Résumé

Des recherches par télédétection satellitaire ont révélé – par hasard – que le Petermann Gletscher, dans le nord-ouest du Groenland, a révélé pendant la période août/septembre 1991. Ces recherches s'appuient sur des données fournies par le radar à synthèse d'ouverture installé sur le satellite ERS-1 qui a été mis en orbite en juillet 1991. Le phénomène est décrit et comparé avec des observations du glacier faites à d'autres époques.

Keywords

Tabular Icebergs, Petermann Gletscher, Northwest Greenland, Nares Strait, Calving of Icebergs

1. Introduction

In a correspondence to Journal of Glaciology Dunbar (1978) reported a discharge of a large tabular iceberg from Petermann Gletscher, Northwest Greenland. The correspondence included a photograph taken from an aircraft in May 1975 of a 3.5-km^2 iceberg positioned in Hall Basin about 15 km from the glacier terminal. On the basis of this and other observations she suggested that the iceberg calved in September 1974.

HIGGINS (1989 and 1991) carried out detailed studies of the glaciers in Northwest Greenland including Petermann Gletscher based on aerial photos acquired in 1978 and determined by photogrammetric means the surface velocities over the glacier. RIGNOT (1996 and 1998) studied the region of the grounding line of the glacier exploiting interferometry based on repeat-pass SAR data from ERS-1 and 2. From these studies it appears, that the outer about 70 km of the glacier is floating on the narrow fjord subject to a basal melting so that the thickness decreases from about 900 m at the grounding line to about 40 m at the front of the glacier. The resulting freeboard at the front is 3 to 4 m. Velocities at the centre of the glacier near its terminal are determined to about 950 m/a.

2. Research Area

Fig. 1 is a map of Nares Strait that stretches about 600 km from Lincoln Sea to Baffin Bay. Petermann Gletscher extends from the Greenland inland ice to Hall Basin in a narrow fjord in an almost northerly direction. The position of the front of the glacier is shown according to the official map of the Geodetic Institute, Copenhagen (now National Survey and Cadastre) where the width of the valley is about 15 km. The five squares drawn in the map represent the area of SAR scenes of 100 km x 100 km exploited in the studies reported here with the relevant frame numbers attached: 1935 in Hall Basin to 2007 in southern Smith Sound.

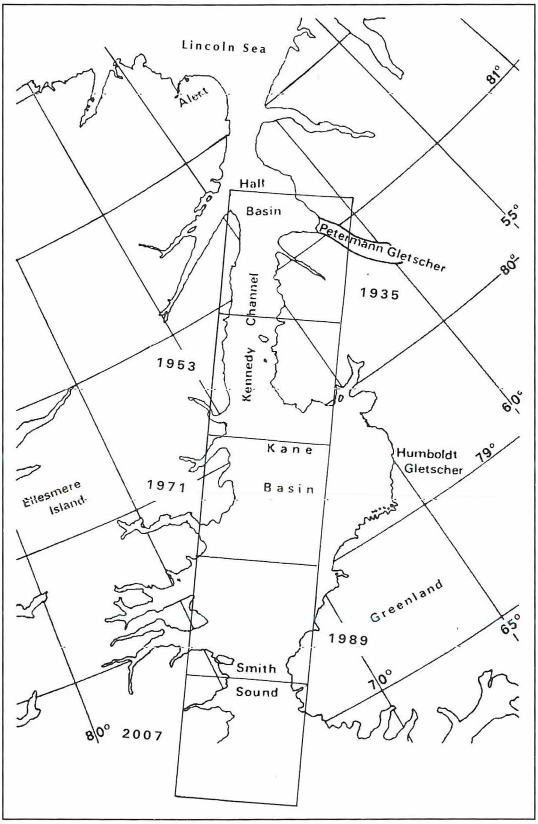

Fig. 1: Map of Nares Strait (adapted from DUNBAR, 1978). The track and frames of the ERS SAR scenes exploited are shown.

3. Observations

Fig. 2 is the first SAR scene of the outer part of the fjord of Petermann Gletscher and eastern part of Hall Basin (Frame 1935) acquired on 19 August 1991. It shows an irregular front extending more than 15 km from the 'official' front of the glacier (Fig. 1). The next scene of the same area acquired on 12 September shows that the glacier calved three tabular icebergs leaving the front at a position close to the 'official' one. The scene, Fig. 2, shows that the eastern part of Hall Basin was ice-free and that a katabatic wind was blowing down the glacier into the basin.

The three bergs were first detected in a scene (Frame 1953) acquired on 12 September after having moved more than 130 km and later again on 24 September (Frame 1971). Fig. 3 shows that very scene with the three bergs lined up as they drift southwards in western Kane Basin. It appears that the shape of the bergs has largely be maintained so that their original position may easily be determined. Thus, the wide apostrophe-shaped crevasse seen at the edge of the most southern berg shows that it originates from the north-eastern part of the glacier, for instance, broken off along a central crevasse. The most northern one originates from the opposite side of the glacier whereas the middle berg comes from the outer, central part of the front. We name them E, W, and C, respectively. The white areas represent strong radar echoes from the edge of crevasses and in the case of berg E from a rough area of the glacier comprising ice from smaller glaciers (like Porsild Gletscher) that merges with the main stream on the eastern side of the glacier.

Data for these icebergs are given in Tab. 1. The volumes are calculated assuming the mean thickness' determined by HIGGINS (1991) who labels the three parts of the glacier as we do. The total area of the three bergs is measured to 135.7 km^2 (Tab. 1). This is close to the area lost by the glacier, measured at 139.5 km^2. This 3% deviation may represent the measurement accuracy but may equally well be due to small break-off's. It may also be due to the difficulty in detecting the boundaries of bergs with a low freeboard in a sea ice environment considering the angle of incidence of the radar of 20° to 26°.

Iceberg name	Iceberg shape	Largest dimensions km	Area km^2	Thickness m (HIGGINS, 1978)	Volume km^3	Movement km 12-24 Sept.	Velocity km/day	Velocity cm/sec.
E	Trapezoid	8.1x13.5	73.5	72	5.29	90.2	7.5	8.7
C	Irregular round	8.4x10.0	47.1	40	1.88	95.1	7.9	9.2
W	Trapezoid	2.7x6.5	15.1	32	0.48	97.8	8.2	9.4
Sea ice	–	–	–	–	–	–	9.5	11.0

Tab. 1: The three icebergs calving by Petermann Gletscher (Greenland) in 1991

In the period 12 to 24 September the icebergs moved about 100 km from Kennedy Channel into Kane Basin at mean velocities included in Tab. 1. The table also includes the average velocity of eleven floes in the neighbourhood of the three bergs observed in the two scenes (FRAMES 1953 and 1971). The differences in velocity may reflect different displacement and/or different bottom profiles but may also reflect a profile of current velocities across the channel.

Acquisitions are missing or failed in the subsequent 21-day period so that the course of the three bergs is unknown until 15 October. At that date, berg C was identified in eastern Smith Sound at the entrance to Northwater and Baffin Bay (Frame 2007). The shape had changed very little on its long voyage (about 270 km) since the last observation on 24 September. The average (great circle) velocity is determined at 12.9 km/day or 14.9 cm/sec. A smaller berg is observed in the same scene which is likely to be a disintegrated part of berg W. If so, it has travelled about 257 km at a velocity of about 12.3 km/day or 14.1 cm/sec. Apparently, berg E already passed into Baffin Bay by that time.

4. Discussion

After the calving the three bergs moved into Hall Basin and Kennedy Channel. They travelled a distance of about 130 km and assuming a velocity equal to the mean velocity determined in the subsequent 12 days (Tab. 1) we find that the calving took place on 28 August. However, the migration in Hall Basin may initially have been slow before they were caught by the south-going current in Kennedy Channel so the calving might have occurred shortly after 19 August under the influence of the katabatic wind observed.

Comparing the ERS scene from 12 September 1991 with that acquired eight years later on 14 September 1999 it is found that the eastern flank of the glacier front has

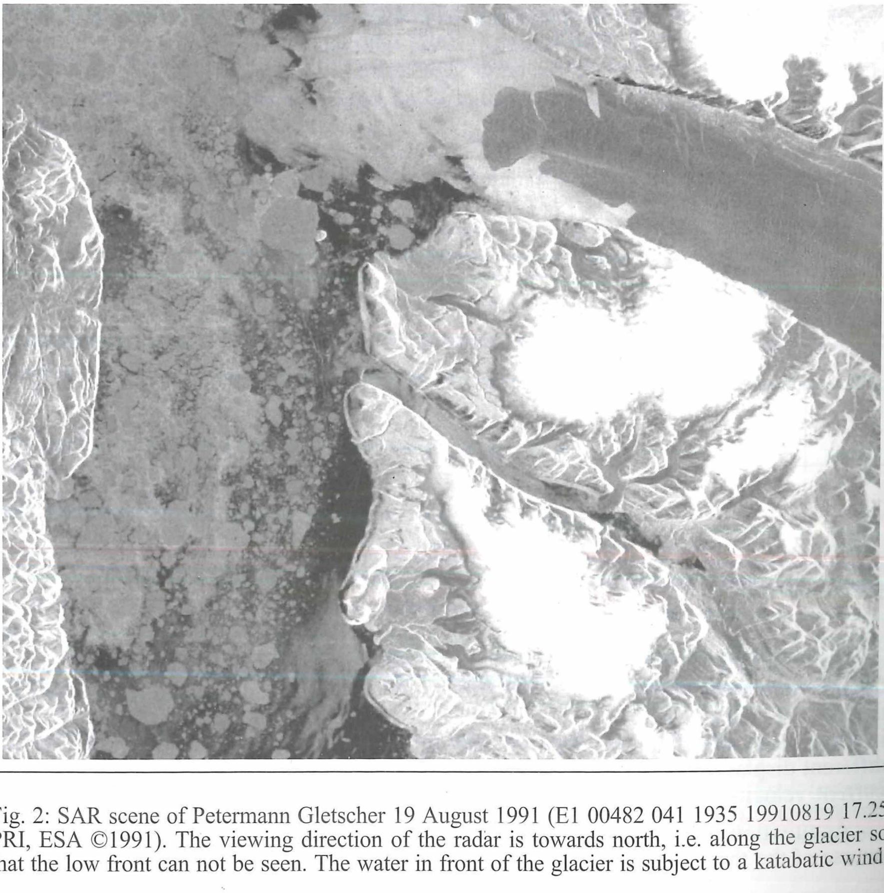

Fig. 2: SAR scene of Petermann Gletscher 19 August 1991 (E1 00482 041 1935 19910819 17.25 PRI, ESA ©1991). The viewing direction of the radar is towards north, i.e. along the glacier so that the low front can not be seen. The water in front of the glacier is subject to a katabatic wind.

advanced by 7.7 km. This corresponds to an average velocity of 0.96 km/a, which is close to the velocity determined by HIGGINS (1991) for the same part of the glacier. If calving takes place when the glacier front has reached the same position(s) as observed in August 1991, we may expect the next calving by 2006/07.

HIGGINS (1991) suggested that a major calving took place between 1959 and 1961. This proposition is supported by observations of the glacier in 1962 and 1963 based on data made available under the recently Declassified Intelligence Photography Project (G. Zhou, Personal Communication, 2000). They show advancements of the front from a position identical to that of 12 September 1991 and we would suggest that the calving occurred in 1961 rather than in 1959. Furthermore, aerial photography of the glacier in July 1978 shows a front reaching about 12 km from the position in 1961 and that it has a shape similar to that of September 1991. It might be a coincidence, but the 1978-photograph shows a crevasse that looks like the apostrophe-shaped crevasse observed in 1991 so it may be concluded that the majority of the ice present in 1978 is likely to be part of the 1991-calving. The irregular shape of the glacier tongue in August 1991 (Fig. 2) indicates, however, that calving of bergs of the size observed by DUNBAR (1978) takes place in the course of the period between major calvings. It is therefore interesting that a great part of the eastern side of the glacier referred to above calved unnoticed in 2000 and was indirectly observed by a tabular iceberg that was spotted from a Canadian

Fig. 3: SAR scene of western Kane Basin on 24 September 1991 (E1 00998 041 1971 19910924 17.25 PRI, ESA ©1991) with the three tabular icebergs, E, C and W from south to north.

reconnaissance aircraft in southern Kane Basin on 21 September 2000 (Ray Walker, personal communication, 2001). The shape of the berg is closely that of the part of the glacier lost and the distance travelled indicates that the calving took place by mid-August 2000. A Radarsat scene of 18 September 2001 confirms the calving. It shows that the front of the other parts of the glaciers have not changed in shape since the observation in 1999.

From measurements of surface velocities and the ice thickness' HIGGINS (1991) arrived at an annual calf-ice production of 0.59 km³. The volume estimated for the three bergs is 7.7 km³ which represents an ice production of about 13 years – assuming a constant ice production.

The span of years of observation is short on a glacial scale, but the observations indicate that major calving may take place at intervals of 13–16 years interspersed by smaller cases, like the year-2000-case. The individual cases will be dependent on a number of external parameters such as the occurrence of katabatic winds and of open water in front of the glacier in Hall Basin. Thus, we may expect that calving normally will take place in an August-September period. There is a rather large diurnal tidal component in Hall Basin of the order of 80 cm – observed by Hall at Thank God Harbour in 1871 (only 10 km from the glacier fjord) and estimated by RIGNOT (1996). Calving may therefore be conditioned by the joint effect of these parameters.

5. Acknowledgement

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