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Short note
Mapping ice front changes of Müller Ice Shelf, Antarctic Peninsula

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Introduction

Müller Ice Shelf (67°15'S, 66°52'W) is situated at the southern end of Lallemand Fjord. It is a small ice shelf (~ 80 km^2) fed by Brückner and Antevs glaciers, which both flow northward off the central peaks of Arrowsmith Peninsula; the ice shelf contains an ice rise (Humphreys Ice Rise). Data sources have indicated that not only has the ice front retreated since 1947 but also that there have been two advances. This paper describes how these changes were recorded using simple photogrammetric techniques.

Methodology

Data sources

Seven sources of data were used (Table I), spanning the period 1947–1993. These included both oblique and vertical aerial photographs, and visible satellite imagery. The quality of the images used varied greatly.

Techniques

A variety of techniques were used to compile the map of Müller Ice Shelf, depending upon the format of the data. The ice fronts identified on the oblique aerial photographs were sketched in by hand, those from satellite images digitized directly from the photographic product or digital data on screen, and vertical aerial photographs were interpreted using a radial-line plotter. Once the ice fronts had been drawn onto an existing base map, the cartographic data were edited using a Laser-Scan software package for editing geographic information and map data. The initial base map had been compiled by conventional cartographic methods, at 1:250 000 scale, for a BAS geological project (Moyes *et al.* 1994) and digitized subsequently. The details of the base map were improved by overlaying it on the 1986 digital Landsat image and, with the help of the IfAG photographs, the coastline and grounding line were digitized at a larger scale.

Oblique aerial photographs. By far the most approximate ice fronts mapped were those sketched from the oblique aerial photographs. These were estimated by noting significant features on the photographs (e.g. the position of the ice front at the mainland coast and at Humphreys Ice Rise) and extrapolating a line from these points.

Satellite images. The satellite images, available as photographic products at 1:250 000 scale and as digital data, are of a resolution that clearly depicts the ice front. Using known control points from the BAS triangulation network, the images could be positioned accurately with respect to the base map. Ice fronts were digitized directly using a graphics package, which allowed accurate mapping to better than 100 m.

Vertical aerial photographs. Radial distortion from the principle point of the image is enhanced by the change in elevation of the ground surface, although on an ice shelf this change is negligible. Because large-scale photographs, such as the 1956 FIDASE series, would have produced a noticeable radial error in the ice front data, tracing was regarded as too inaccurate for this project. A Watts Radial-line plotter, which is designed to transfer planimetric detail directly from vertical stereoscopic photographs on to a base map, was used instead. By using the radial-line triangulation, the displacement produced by relief and radial-lens distortion is compensated for by the intersection of images from an overlapping pair. The plotter was used to create a larger-scale base map of the coast, grounding line and rock outcrop polygons of the area around Müller Ice Shelf; these details were subsequently digitized and merged with the existing map data to enhance the earlier map. After transferring the digital data into a GIS package (ARC/INFO software) the

Table I. Details of data sources used.

Source	Format	Date	Scale of data
RARE	Oblique aerial photography	1947	-
FIDASE	Vertical aerial photography	1956	1:27 000
TMA	Oblique aerial photography	1963	-
LANDSAT	Satellite image (photographic product)	1974	1:250 000
LANDSAT	Satellite image (digital)	1986	1:250 000
IfAG	Vertical aerial photography	1989	1:70 000
BAS	Vertical aerial photography	1993	1:25 000 1:20 000
BAS (Moyes *et al.*)	Digital topographic base map	1994	1:250 000

RARE = Ronne Antarctic Research Expedition, FIDASE = Falkland Islands Dependencies Aerial Survey, TMA = Trimetrogon aerial photographs, IfAG = Institut für Angewandte Geodäsie, BAS = British Antarctic Survey.

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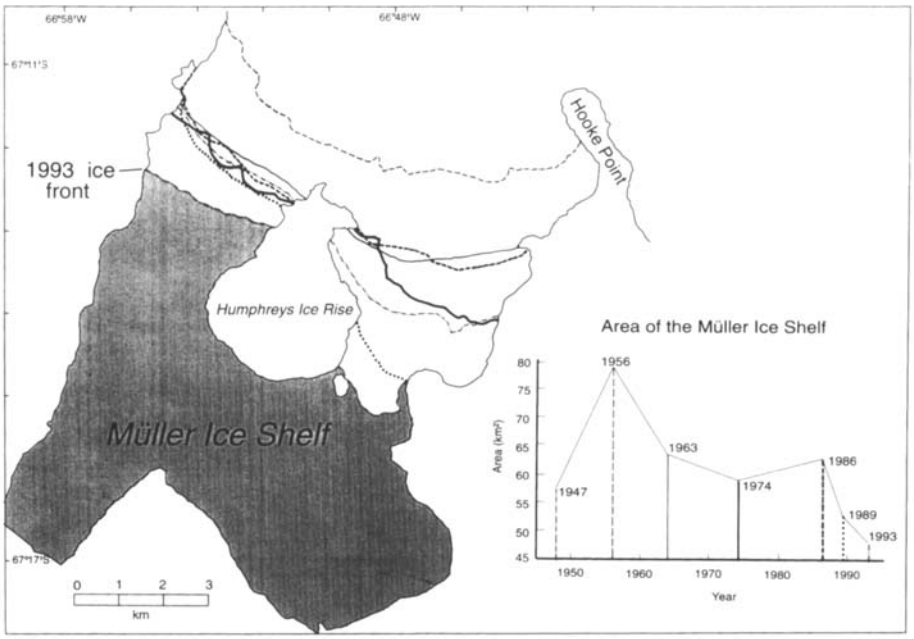


Fig. 1. Map showing the retreat and advance of the Müller Ice Front between 1947 and 1993. The graph indicates changes in the area of Müller Ice Shelf with time; patterned lines (with dates) correspond to ice-front ornaments on the map.

area of the ice shelf could be calculated for each year mapped and the variations with time assessed (Fig. 1).

Results

The map of the Müller Ice Shelf (Fig. 1) with seven ice fronts indicates that the ice shelf has decreased in size over the 46-year period. However, the regression pattern is not simple since a rapid advance of the ice front occured between 1947 and 1956, increasing the ice shelf area from approximately 51 km² to *c.* 78 km². A second period of ice front advance, 1974–1986, represents an area increase of *c.* 4 km². These results do not agree with those documented by Domack *et al.* 1995, who found no noticeable change during the period 1947–1974 and from 1974 to the present day. Despite the range in quality of the source data, the variations in the position of the ice front with time, as recorded by this study, are considered to be real. The ice shelf does appear to be undergoing some form of change reaching a minimum extent in 1993. Over the past 46 years it has experienced a variation of *c.* 31 km², 40% of its maximum extent in 1956. Similar changes in ice shelf areas have been recorded elsewhere in the Antarctic Peninsula (Doake & Vaughan 1991, Skvarca 1993), possibly reflecting recent climate variability in the region (Morrison 1990, King 1994).

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