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The 1983 Recession of Columbia Glacier

by M. F. Meier[1], Austin Post[2], R. M. Krimmel[3], and C. L. Driedger[4]

The iceberg-calving terminus of Columbia Glacier was relatively stable from the time of the first scientific studies in 1899 up to 1979. During this period the glacier terminated partly on Heather Island and partly on a submerged moraine shoal (fig. 1). Post (1975) pointed out that if it were to retreat from the stabilizing moraine shoal, a period of drastic retreat would ensue. Detailed studies of this glacier were made during 1977-78 and monitoring has continued through 1983. In June, 1980, a prediction of drastic retreat was issued (Meier and others 1980).

In December, 1978, the glacier terminus broke back from Heather Island, and retreat has accelerated each year since then, except during a period of anomalously low calving in 1980. Although the glacier has not terminated on Heather Island since 1978, a portion of the terminus has remained on or near the crest of the moraine shoal. By November 8, 1983, the part of the glacier on the shoal had been reduced to a narrow point (fig. 2). By December 8, 1983, that point had receded more than 300 m (1,000 ft) from the crest of the shoal (fig. 1, 3).

Recession of the glacier from the shoal has placed the terminus in deeper water, although at no place does the glacier float. The active calving face of Columbia Glacier now terminates against water ranging in depth from about 50 m (160 ft) to more than 250 m (820 ft). Rapid calving speeds appear to be associated with deep water at the terminus (Post, 1975; Brown and others, 1982) or with a more complex function involving water depth, ice cliff height, and subglacial runoff (Sikonia, 1982), so calving speed is expected to be high.

During the summer of 1983, high rates of calving were observed. Post, using the Research Vessel *Growler*, observed iceberg calving at Columbia Glacier from June 7 to November 12, 1983. The calving events occurred almost randomly in time, but appeared to increase during or following periods of heavy rain. Very large iceberg calving events were observed on August 14 and 18. During these events, a section of glacier perhaps as much as 300 m (1,000 ft) wide and 100 m (300 ft) deep distintegrated in a few minutes, releasing on the order of 10 million tons of ice to the sea. Calving was extremely heavy during the day and night of August 25, perhaps releasing even more ice, but this event could not be observed due to fog. Observations of the very large calving events suggest the possibility, not yet confirmed, that they are triggered by a pulse of high ice velocity, perhaps due to a local decoupling of the glacier from its bed.

Oceanographic methods were used to measure the water outflow from under the glacier (Walters, Driedger, and Josberger, 1983). The discharge of a river on land that drains the eastern part of Columbia Glacier was measured continuously, and the results suggest a rough correlation between water discharge and calving

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speed (Driedger, Walters, and Josberger, 1983). A time-lapse camera was used to measure ice velocity and terminus changes, and therefore calving speed, on a daily basis. Ice velocity near the terminus was relatively high during August to September, averaging about 7.5 m/day (25 ft/day) and occassionally reaching 10 m/day (33 ft/day). As the water depth increased due to recession in late summer, calving speed and ice velocity increased; average speeds greater than 12 m/day (40 ft/day) were measured during the period November 8 to December 8. These are the highest values of ice velocity yet observed at Columbia Glacier.

In spite of the heavy calving during the summer of 1983, ice caused few problems in the shipping lanes of Valdez Arm. This was partly due to the fact that ice tended to drift west, away from the shipping lanes, (A. Klingel, oral communication, Sept. 1983) more often than usual. Also, water temperature was higher than normal (R. Walters, oral communication, Sept. 1983), presumably an effect of El Niño, and the icebergs may have melted and broken up more rapidly than usual.

Two major earthquakes shook the terminus of Columbia Glacier during the summer of 1983; the effects of both were observed from the R. V. Growler. During the earthquake of July 12, rapid calving was observed along the ice face and an immense iceberg, 500 m (1,600 ft) long, appeared from below sea level 20 minutes after the earthquake. No water discharge could be observed at the time. Radar images of the ice face before and after the earthquake showed only the disappearance of a minor point along the eastern cliff. After 3 days the ice cliff appeared to be completely normal. The earthquake only speeded up the calving that would normally have occurred in the next 1-3 days.

On September 7, a second major earthquake shook the area, at a time when the R.V. Growler was on station in front of the glacier. No appreciable calving discharge occurred in spite of considerable shaking. Thus, the relatively minor effect of earthquakes on glaciers is again confirmed. (Post, 1967).

Calving speed appears to increase with increasing water discharge (Sikonia and Post, 1980; Sikonia, 1982). Thus calving varies seasonally, and this produces a seasonal change in glacier advance and retreat. Columbia Glacier normally retreats during the heavy-calving months of summer and fall, and then advances during the ensuing period. This seasonal fluctuation is superimpossed on a long-term recession trend, and can be displayed by plotting the length of glacier as a function of time. Superimposing all years of record onto one graph shows that the seasonal fluctuation is remarkably consistent from year to year (fig. 4), with retreat changing to advance in about mid-November. However, retreat was continuing on December 8, 1983.

The glacier variation observations can be compared with those predicted earlier using numerical models. The 1980 prediction was based on a model using a simple approach based on the equation of continuity, and was subsequently refined and subjected to a sensitivity analysis (Rasmussen and Meier, 1982). It was based on data obtained during 1977-78 together with terminus retreat data through May 12, 1980. When compared with observation (fig. 5) it can be seen that the model predicted accelerating retreat to begin more than one year before observed. This may be due in part to the unpredicted, anomalously low amount of calving retreat in late 1980. The inherent error in the model is approximately plus or minus one year. Alternatively, the glacier might be considered as beginning drastic retreat less abruptly than predicted.

A finite-element dynamic model (Sikonia, 1982) also produced a prediction that can be compared with the observed points, and it includes the effect of seasonal calving. These results used data through July 22, 1980. The fit of predicted retreat to observed values in late 1983 is excellent (fig. 5).

What do these results suggest about the immediate future? The answer is not entirely clear. The model predictions might be interpreted as indicating that retreat will now continue. The continuity-equation model does not incorporate seasonal fluctuations and therefore cannot assess whether a seasonal advance will occur in early 1984. The finite-element model suggests that little if any future advance will occur. These conclusions must be considered in the light of the great sensitivity of the model predictions to slight changes in the calving law constant, which is a reflection of accurately locating the point of balance between glacier ice discharge and calving discharge. Also, the models were based on the dynamics of a glacier which formed an annual embayment at the terminus; Columbia Glacier did not form an embayment in 1983. The data shown in figure 4 also afford no clear indication of what will happen in early 1984, although it is clear that recession is accelerating each year and a period of very rapid retreat is beginning. Another mid-winter advance is not impossible, but if it occurs, it is likely to be followed next summer by even more rapid retreat with an even larger increase in iceberg discharge.

Figure Captions

Figure 1. Vertical aerial photograph, looking down on the terminus of Columbia Glacier as it appeared on December 8, 1983. Also indicated is the position of the terminus at the end of the 1977-78 period of intense measurement, the October 15, 1982 position, and the position of the moraine shoal (dotted line).

Figure 2. Oblique aerial photograph of the lower Columbia Glacier taken November 8, 1983. View is looking north, Heather Island is in the foreground. The terminus ice cliff is about 30 to 70 m (100 to 230 ft) high and stretches 5 km (3 mi) across the fiord. The position of a terminal moraine shoal, connecting Heather Island with both sides of the fiord, can be inferred from the lines of stranded icebergs that block the movement of other pieces of ice, causing much of the water surface near the terminus to be covered with ice. The sharp point near the left (west) margin and the short point near the center of the picture disappeared in the next month (compare with figure 1). USGS photograph by Austin Post.

Figure 3. Map showing the configuration of the terminus of Columbia Glacier after summer retreat, for the years 1976-83. Large crosses (labled 65.0, 66.0,...) indicate a coordinate system in kilometers along the length of the glacier. Small crosses represent the Universal Transverse Mercator coordinates in meters.

Figure 4. Seasonal advance and retreat of Columbia Glacier for the years 1976-83, superimposed onto one year for comparison. The curves are repeated too either side in the gray areas to help visualize trends. Solid dots are data points obtained by photogrammetry (error is about 10 m), open circles are observations by less-accurate methods (ship-borne radar, ground surveys), and the lines are smooth curves drawn through data points. Values are averaged over the width of the active terminus.

Figure 5. Comparison of observed advance and retreat of Columbia Glacier since 1976 (dots) with that predicted by a continuity-equation model (Rasmussen and Meier, 1982) and by a finite-element dynamic model (Sikonia, 1982).

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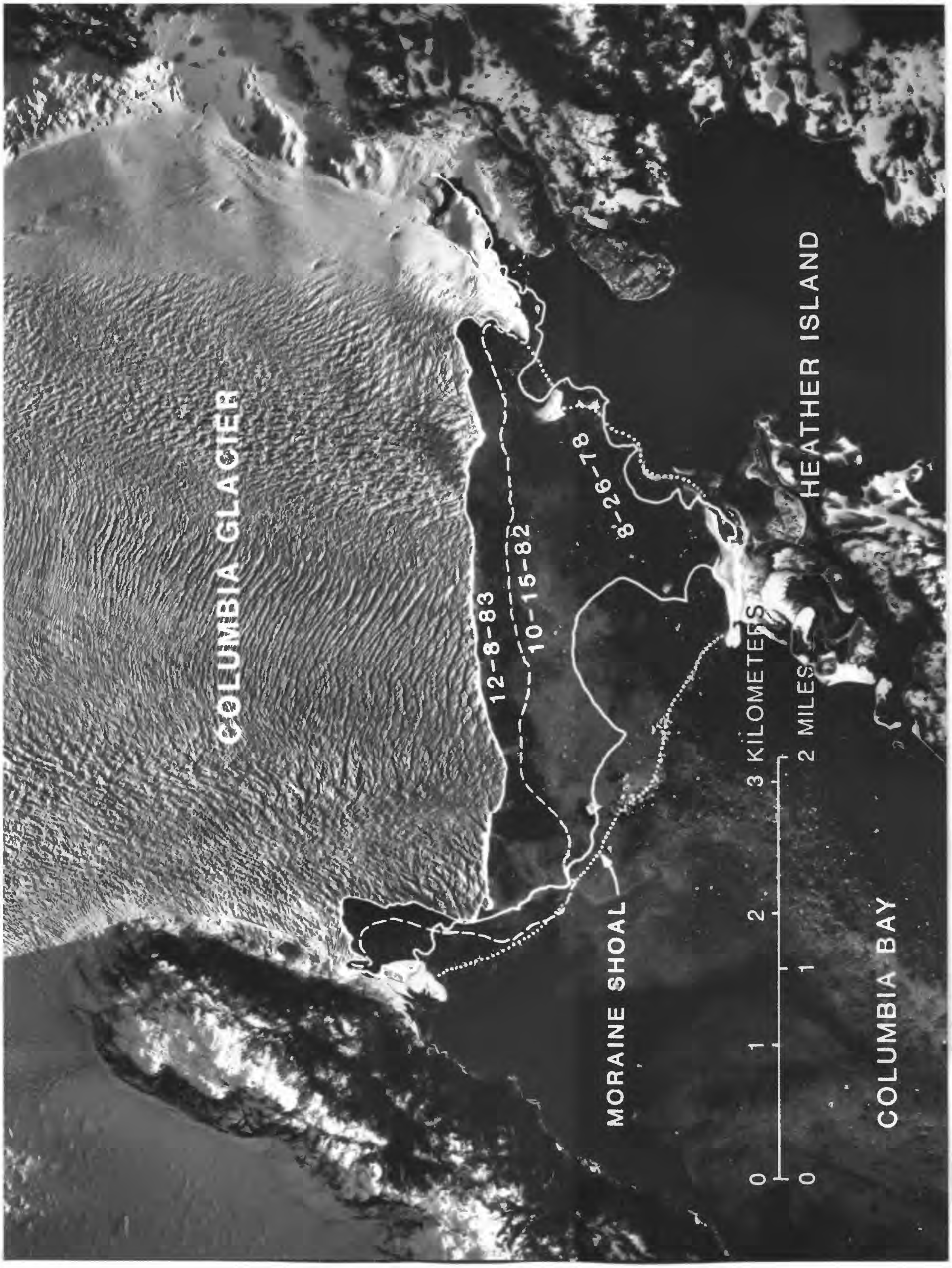
COLUMBIA GLACIER
HEATHER ISLAND
12-8-83
10-15-82
8-26-78
MORAINE SHOAL
COLUMBIA BAY
0 1 2 3 KILOMETERS
0 1 2 MILES

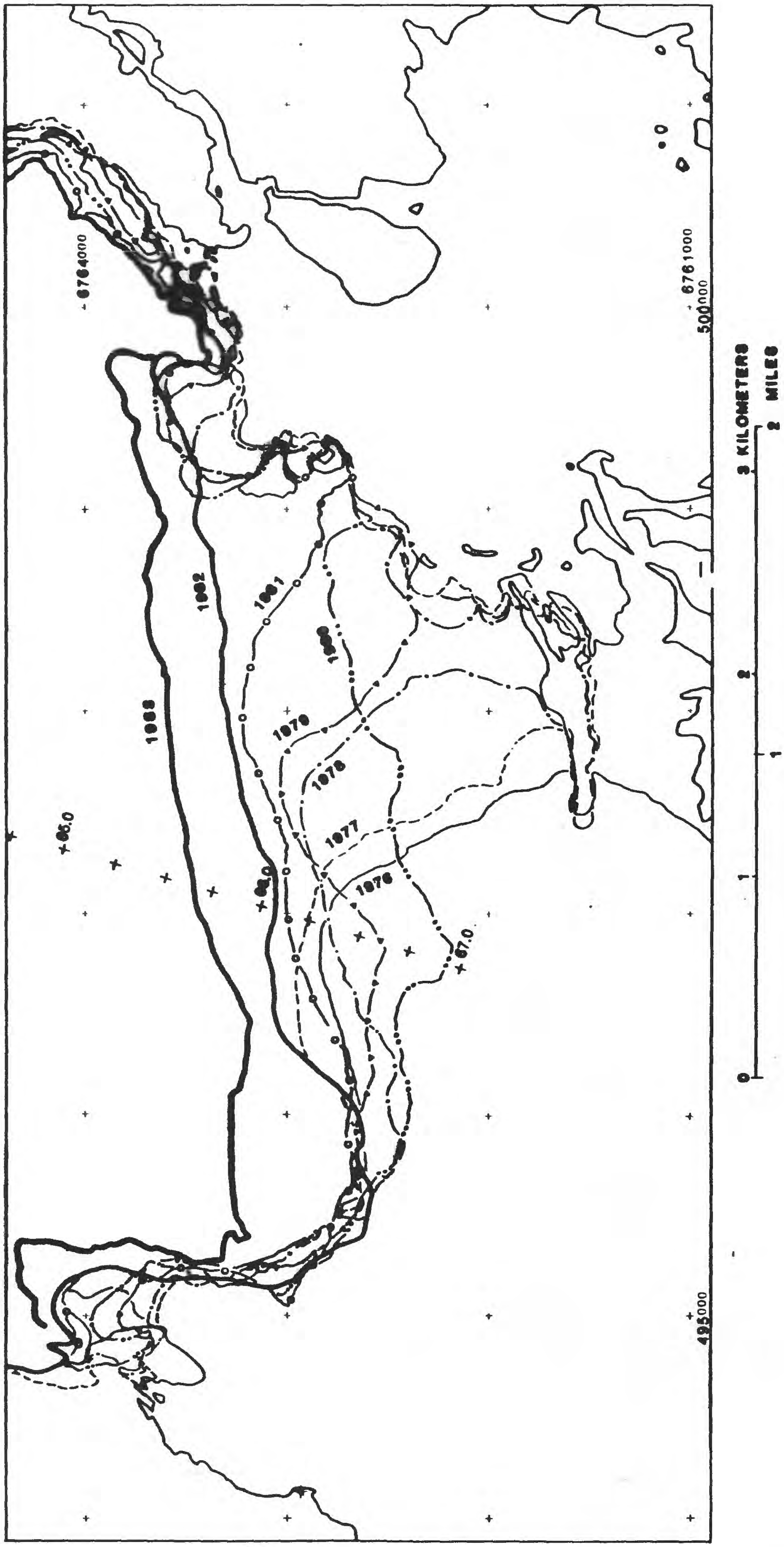
3 KILOMETERS
2 MILES
6761000
500000
495000
1982
1981
1979
1978
1977
1976
+67.0

Fig. 3

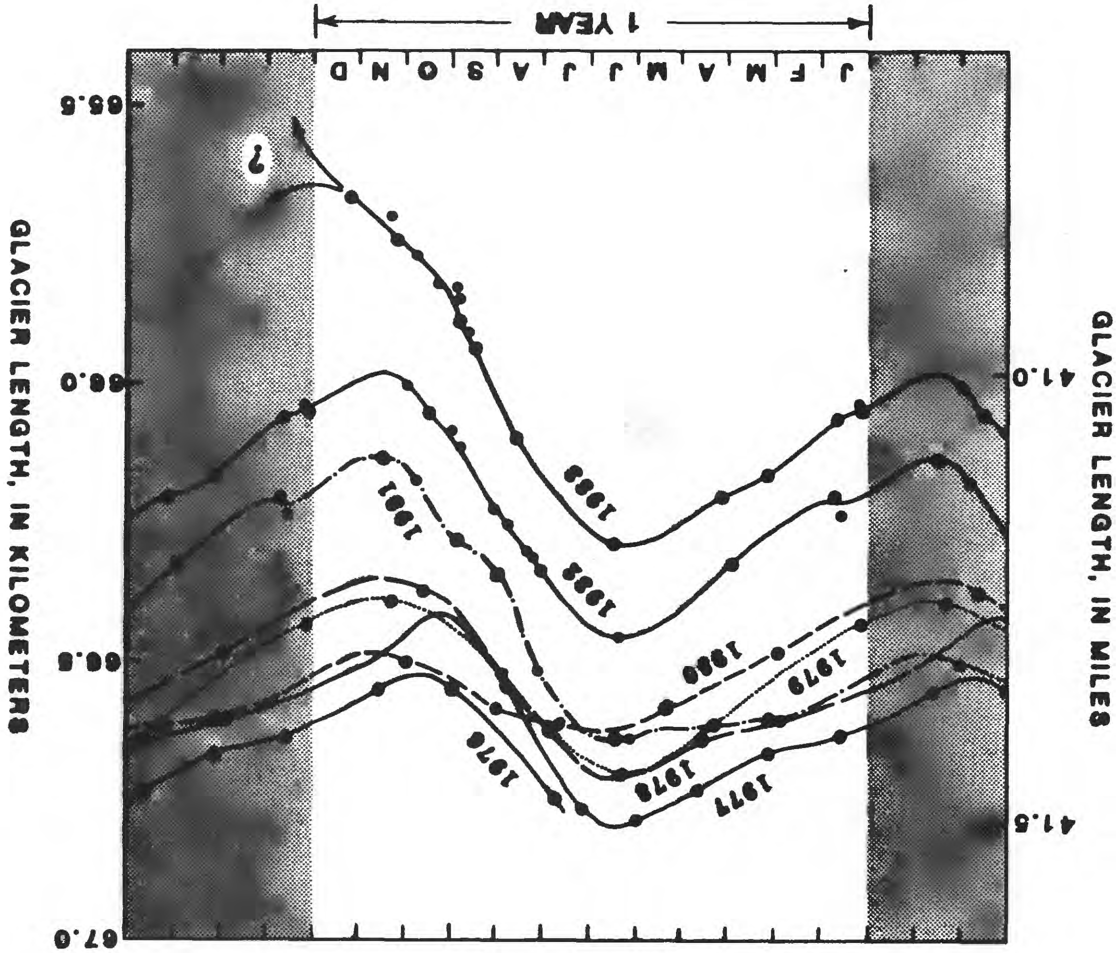
1 YEAR
J F M A M J J A S O N D
GLACIER LENGTH, IN KILOMETERS
GLACIER LENGTH, IN MILES
65.5
66.0
66.5
67.0
41.0
41.5
?
1983
1982
1981
1980
1979
1978
1977
1976

Fig. 4

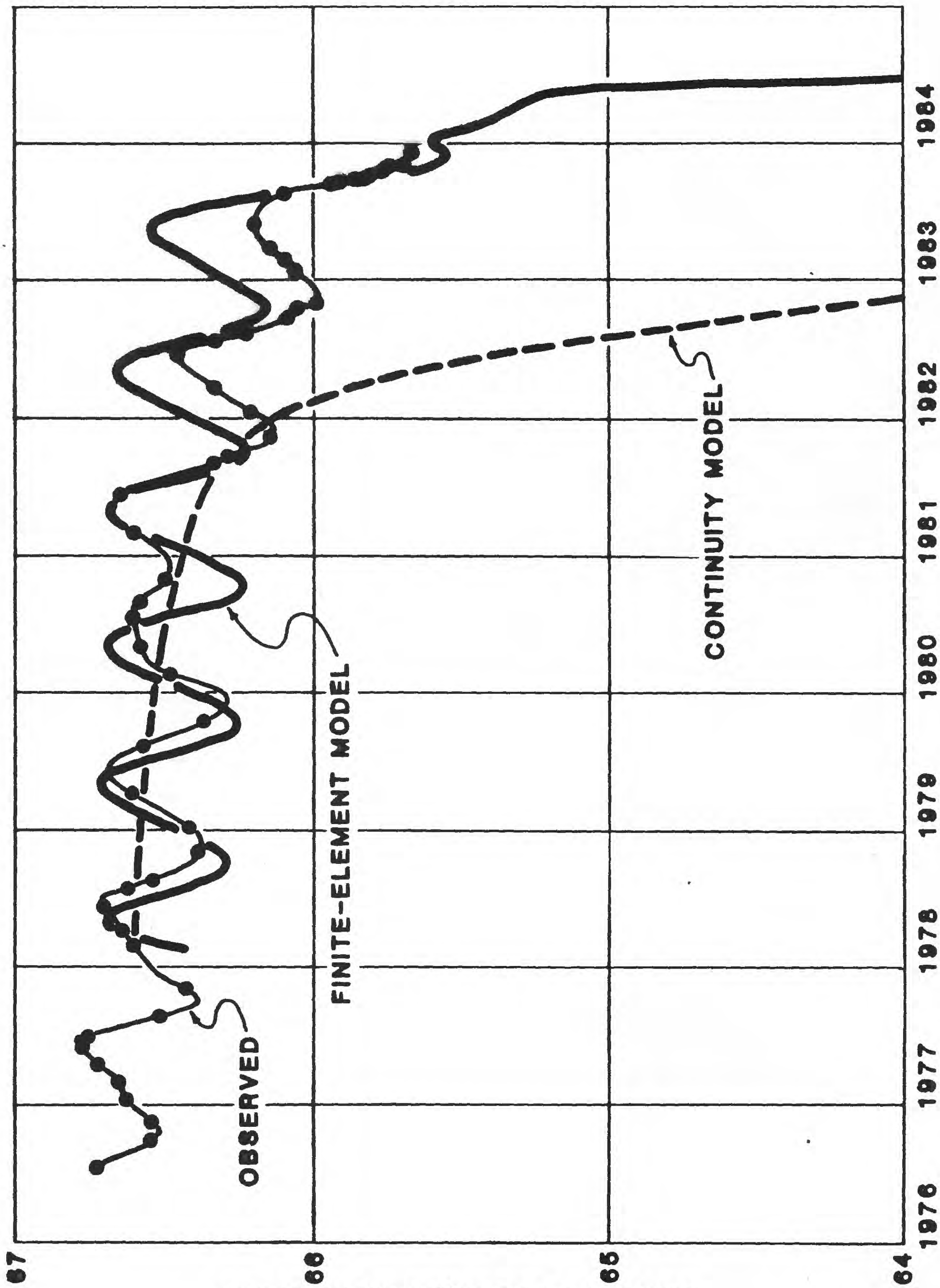
GLACIER LENGTH, IN KILOMETERS
67
66
65
64
1976
1977
1978
1979
1980
1981
1982
1983
1984
OBSERVED
FINITE-ELEMENT MODEL
CONTINUITY MODEL

Fig. 5