Glacier snowline survey 1997

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CONTENTS

ABSTRACT

The end-of-summer snowline survey of some 49 "index" glaciers of the Southern Alps, undertaken in March 1997, showed that the 1996-97 glacial year continued the trend of positive glacier balances occurring over the past decade.

KEYWORDS: Snowline, glacier fluctuations, climate change.

1. INTRODUCTION

The aerial survey results presented here continue a glacier/climate monitoring programme, commenced in 1977 for the New Zealand Glacier Inventory, where the position (altitude) of the end-of-summer snowline is photographed annually on a set of some 49 selected glaciers arranged in transects across the Southern Alps (Fig. 1).

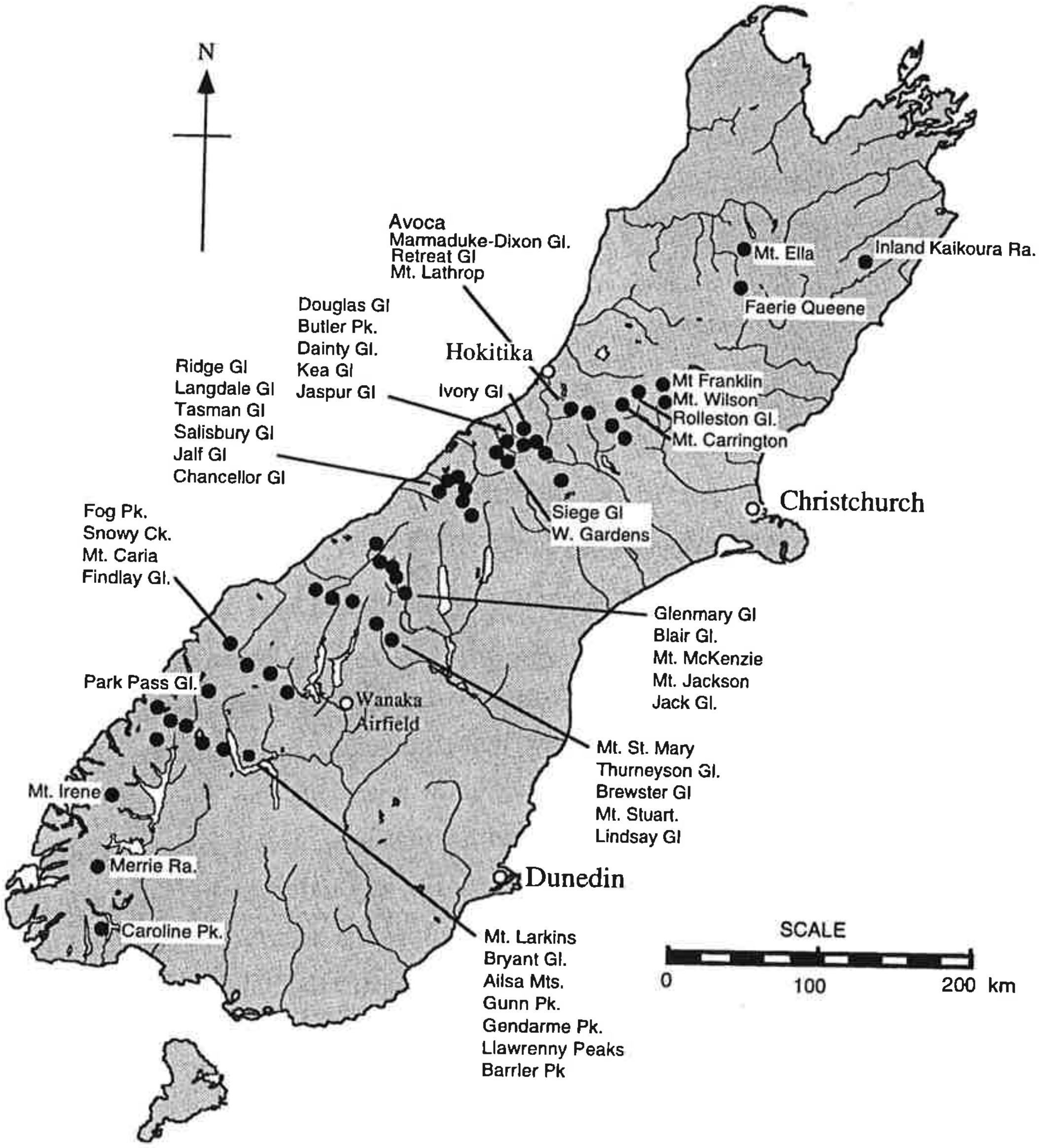


Figure 1. Location of the snowlines index glaciers

The 3149 glaciers of New Zealand extend from Mt. Ruapehu in the North Island at 39° 15' S. to southern Fiordland at 45° 57' S. Three North Island volcanic cones reach close to the permanent snowline, but only Mount Ruapehu with a summit at 2,752 m, supports glaciers. These glaciers are not included in this survey. In the South Island, average peak summits range from 1,850 m in Fiordland to 3,000 m in the central Southern Alps and descend to 2,000 m in the north-central Southern Alps. To the north-east, the Kaikoura Ranges reach to over 2,700 m, where active rock glaciers have developed under an arid climate.

New Zealand has a humid maritime climate, with the Southern Alps lying across the path of prevailing westerly winds. Mean annual precipitation rises rapidly from 3000 mm along the narrow western coastal plains to a maximum of 15,000 mm or more in the western part of the Alps close to the Main Divide. From this maximum, precipitation diminishes approximately exponentially to about 1,000 mm in the eastern ranges. This situation creates steep eastward precipitation gradients and the altitudes of the glaciers closely follow these gradients.

1.1 Glaciers and Climate Change

Glacier fluctuations are amongst the clearest signals of climate change, because glaciers are highly sensitive, large-scale indicators of the energy balance at the earth's surface. They give convincing signals of past climate change, from decades to millennia. Atmospheric changes are signalled by direct, undelayed changes in annual mass balance, which are filtered, smoothed and enhanced before they become apparent at the glacier front. Glacier snowline altitudes give a direct value for glacier health and balance, whereas glacier frontal positions are modified by response times and glacier dynamics.

1.2 The Equilibrium Line Altitude (ELA)

The winter snowpack normally covers the entire glacier in a wedge shape, with the greatest snow depths near the highest altitudes, tapering to zero at the lower edge. This lower margin, or transient snowline, of the snowpack melts and rises as summer progresses, until it reaches a maximum altitude for the year at the end of summer (in April). It follows that somewhere in the middle of the glacier there is an equilibrium line where snowfall exactly equals snow loss. This line, normally visible as a discoloured concentration of dust, is the glacier snowline for that year, and it is the altitude of this glacier snowline that is measured by these snowline surveys. For any individual glacier, the altitude of the annual glacier snowline, averaged over many years, defines the steady-state equilibrium line altitude (ELA). A snowline of this altitude will indicate zero change to the balance of the glacier. A climate change will change the glacier mass balance and shift the altitude of the annual ELA. Thus the annual snowline position with respect to the long term or steady state ELA is used as a surrogate for annual balance changes at each glacier. It is the difference between the glacier snowline and the ELA that is reported here. For glaciers in balance the ELA would be the mean of many years' readings, but as the glaciers have been dominated by positive balances since this progamme commenced, this altitude has been estimated from glacier morphology. Note that the trend surface of this difference IS NOT a measure of snowline altitude. It is a measure of the CHANGE FROM THE AVERAGE CLIMATE at each glacier.

2. METHOD

The method involves taking simple oblique photographs of the position of the end-of-summer glacier snowlines on the glaciers, which are later converted to an altitude value. The photographs are analysed by ranking all photographs of each glacier in ascending order of snowline elevation and inserting this year's snowline elevation photo in its position in this sequence. The equilibrium line altitude is then interpolated both from the values of previous years, and from contours on 1:50,000 scale topographic maps.

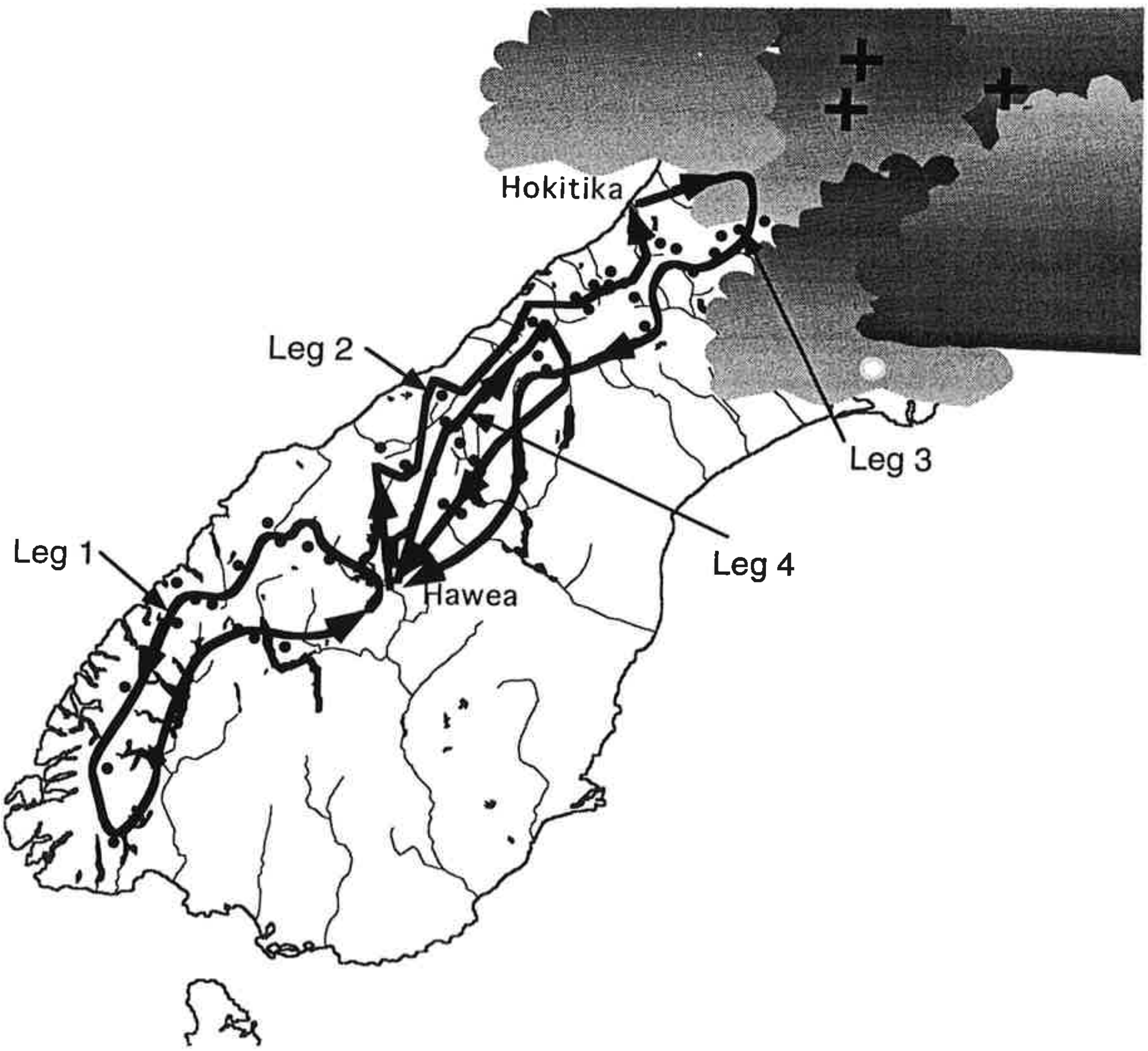


Figure 2. Flight paths for the 1997 glacier survey. Crosses indicate glaciers not visited because of cloud cover.

A folder of maps showing the glacier locations, together with copies of past photos of each glacier is held by the "navigator" seated beside the pilot. These past photos are used to closely duplicate the position from where previous photos were taken. The photographer operates from the back seat, shooting from both sides of the aircraft. This year, additional to the index glaciers, a number of remaining minor glaciers not yet included in the glacier inventory archive were photographed, and a set of 1:63,360 scale glacier inventory maps was carried for this purpose. The flight was made mainly at 9,500 ft. with some descents to 8,500 ft to conform with Civil Aviation instructions. An altitude of 10,000 ft altitude has been found to give the best angle on the glacier snowlines.

3. PREPARATIONS

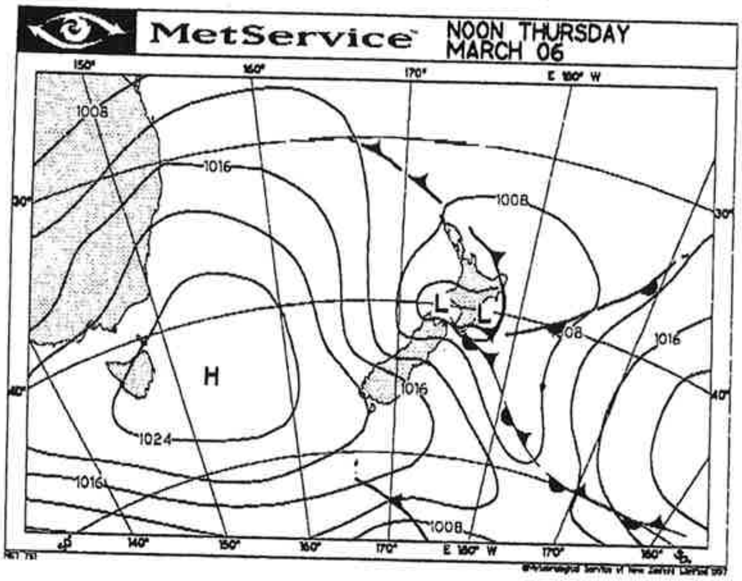
The flight should be made on the elusive "last perfect day before the first winter snowfall", after the last significant summer melt. Significant melt continues throughout February and March, but by April there is a high probability of that a snowfall will have occurred. Experience has shown that although the survey has been made in April, there is about a 1 in 4 probability of snow before this time. Consequently the surveys are planned to be done in March, but this cannot be guaranteed as there is also a 1 in 10 probability that there will be no suitable flying weather in March.

The flight was planned for the first clear weather after March 1, and took the opportunity of a forecast anticyclone moving towards the South Island on Wednesday March 5. This year the news-media weather forecast maps were supplemented by the use of 'Met fax' weather situation maps. The 'Met fax' of Thursday 6 (Fig. 3) gave a situation which promised suitable flying weather over the next few days.

The flights were made in a Cessna Cardinal 177 chartered from Aspiring Air at Wanaka airfield. This high wing aircraft is eminently suitable as it has no obstructing wing struts and a relatively high cruising speed. The detailed mountain knowledge of the party permitted direct "front window" navigation without any flying time lost to searching for our positions on the maps.

4. ITINERARY

The flights commenced on the morning of Friday 7 March, from Wanaka airfield, with the first leg southward to cover Fiordland while easterly conditions continued to blanket the northern half of the South Island with cloud (Fig. 3). The second leg, west of the Main Divide to Arthur's Pass, was made on Sat. 8, as a low over the North Island continued to bring an easterly cloud layer (Fig. 2). On Sunday 9, although the Main Divide cleared of cloud, the Nelson Lakes area to the north was blanketed with 8/8 cloud cover, so the flight deviated to do the eastern glaciers where at Arthur's Pass Mt. Franklin glacier remained unseen under cloud. As the survey continued southward, it encountered westerly winds, there being a very limited



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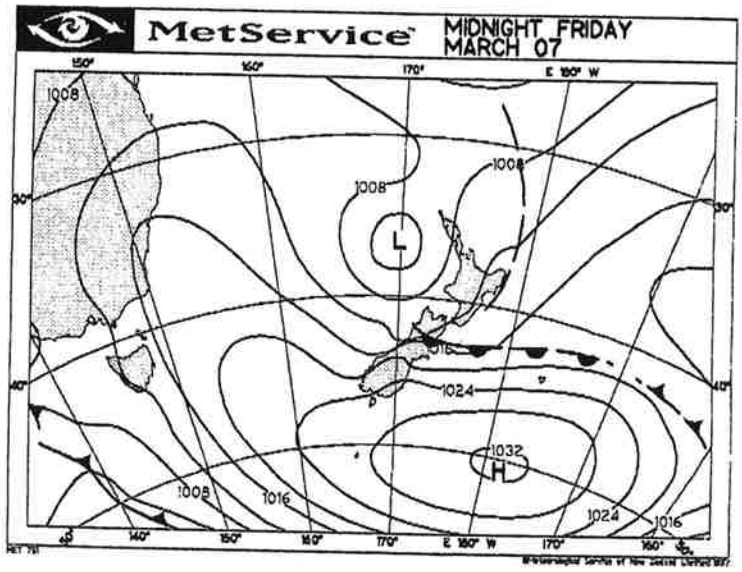

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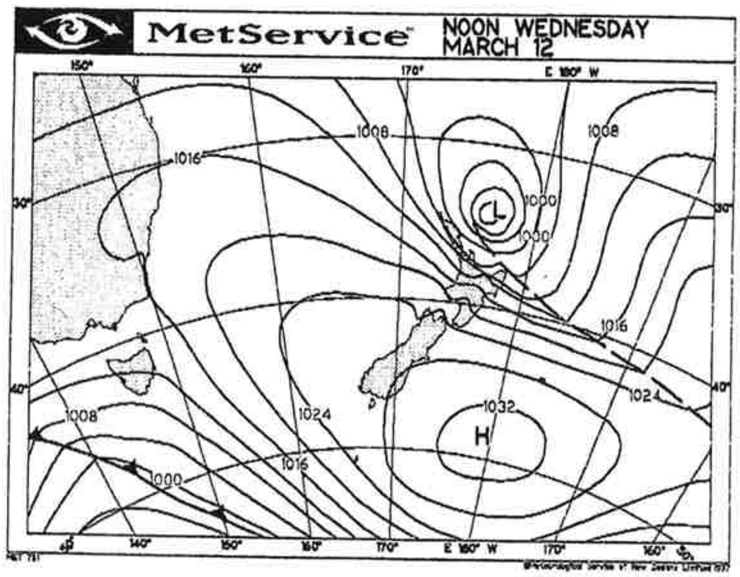


C

Figure 3. "Met fax" weather maps for the 1997 snowline survey.
[A] Noon, Thursday, 6 March.
[B] For the first two legs of the flight, midnight, Friday, 7 March.
[C] For leg 4, Wednesday March 12.

	1997 DATA			
GLACIER	INVENTORY NUMBER	ELA (m)	SNOWLINE DEPARTURES	NORMALISED VALUES
KAIKOURA RA	621/001	2530		
MT. ELLA	932B/012	2141		
MT FAERIE QUEENE	646/006	2012		
MT. WILSON	None	1850	-93	-0.50
MT. FRANKLIN	911A/002	1890		
ROLLESTON GL.	911A/004	1780	-65	-1.19
MT. CARRINGTON	646C/027	1720	-127	0.35
MT. AVOCA	685F/004	1992	-109	-0.10
MARMADUKE GL.	664C/012	1830	-120	0.18
RETREAT GL	906A/004	1740	-80	-0.82
BROWNING RA	906A/001	1600	-90	-0.57
DOUGLAS GL	685B/001	2120	-97	-0.40
MT. BUTLER	685C/060	1840	-130	0.42
DAINTY GL	897/019	1930	-65	-1.19
KEA GL	897/007	1810	-198	2.37
JASPUR GL	897/003	1785	-65	-1.19
SIEGE GL	893A/006	1722	-122	0.23
VERTEBRAE COL	893A/025	1880	-70	-1.07
RIDGE GL.	711L/024	2260	-152	0.97
LANGDALE GL.	711I/035	2260	-175	4.03
TASMAN GL.	711I/012	1790	-105	-0.20
SALISBURY GL	888B/003	1860	-124	0.27
JALF GL	886/002	1810	-130	0.42
CHANCELLOR DOME	882A/007	1835	-100	-0.32
GLENMARY GL.	711F/006	2134	-94	-0.47
BLAIR GL.	711D/038	2000		
MT McKENZIE	711D/021	1960	-160	1.17
JACKSON GL.	868B/094	2080	-135	0.55
JACK GL.	875/015	1940	-130	0.42
MT. ST. MARY	711B/039	2043	-68	-1.12
THURNEYSON GL	711B/012	1930	-70	-1.07
BREWSTER GL.	868C/020	1880	-120	0.18
MT. STUART	752I/104	1725	-145	0.80
LINDSAY GL	867/002	1753	-78	-0.87
FOG PK	752E/051	2000	-105	-0.20
SNOWY CK	752C/103	2160	-120	0.18
MT. CARIA	863B/001	1470	-75	-0.94
FINDLAY GL.	859/009	1700	-135	0.55
PARK PASS GL.	752B/048	1750	-75	-0.94
MT. LARKINS	752E/002	2060	-145	0.80
BRYANT GL.	752B/025	1750	-110	-0.07
AILSA MTS.	752B/013	1650	-55	-1.44
MT. GUNN	851B/057	1620	-120	0.18
MT. GENDARME	797G/033	1720	-130	0.42
LLAWRENNY PKS.	846/035	1450	-123	0.25
BARRIER PK.	797f/004	1595	-103	-0.25
MT. IRENE	797D/001	1638	-133	0.50
MERRIE RA.	797B/010	1646	-76	-0.92
CAROLINE PK.	803/001	1525	-138	0.62
	NUMBER	49	44	44
	MEAN	1861	-110	0.00
	STD. DEV.	217	32.3	1

Table 1 Results of the 1997 snowline survey. Departures from the ELA value in m, and normalised values for each glacier surveyed.

'fine break' between the two weather systems! The glaciers were successfully photographed southward to Mt Cook, where turbulence became so severe that the survey was abandoned.

On Monday 10 another anticyclone was forecast to approach the country and the flight was continued in another anticyclone of Wed. 12 (Fig. 3) while a tropical cyclone was drifting on to the North Island (Fig. 3). Again there was considerable low easterly valley cloud, which, in the Huxley valley, rose to cover the lower half of the Blair and Mt. McKenzie glaciers, obscuring the critical snowlines. The remainder of the eastern glaciers were successfully photographed in calm, fine weather.

The first winter snow fell on April 8, when 15 to 30 cm of snow fell on the Central Otago skifields, emphasising the necessity to complete this survey by the end of March. However there then followed an "indian summer" of fine weather which continued into mid-June. It is not known whether the April snow was lost and the snowlines retreated further during this period.

5. RESULTS

Despite the occurrence of favourable anticyclonic conditions, this year the survey was unable to record the snowlines of 5 of the index glaciers due to cloud cover, mainly over the Nelson Lakes mountains. Mt. Franklin at Arthur's Pass was not seen because of cloud, and a partial cloud cover of Blair Glacier totally obscured the snowline.

Snowlines at some glaciers were among the lowest recorded, indicating a year of strong positive balance with none of the glaciers having a negative balance. Results for individual glaciers, both as departures from the ELA value and as normalised values for each glacier surveyed, are listed in Table I. Departure values are summarised in the histograms for each glacier in Appendices 4 to 8, where they are given as metres of departure from the ELA. Missing values are years of no survey.

These results are summarised in Figure 4, where the snowline depression below equilibrium is dominantly between -50 and -150 m. Values below the zero ELA datum indicate depressed snowlines and therefore positive mass balances.

6. COMPARISONS WITH PREVIOUS YEARS

The 1997 glacier year is compared with averages from very variable numbers of glaciers observed over the past 20 years in (Fig. 5). 1997 was among the four years of lowest snowlines, and continues a positive balance which has persisted uninterrupted since 1991. Figure 6 presents the percentage of all glaciers surveyed each year which showed a positive

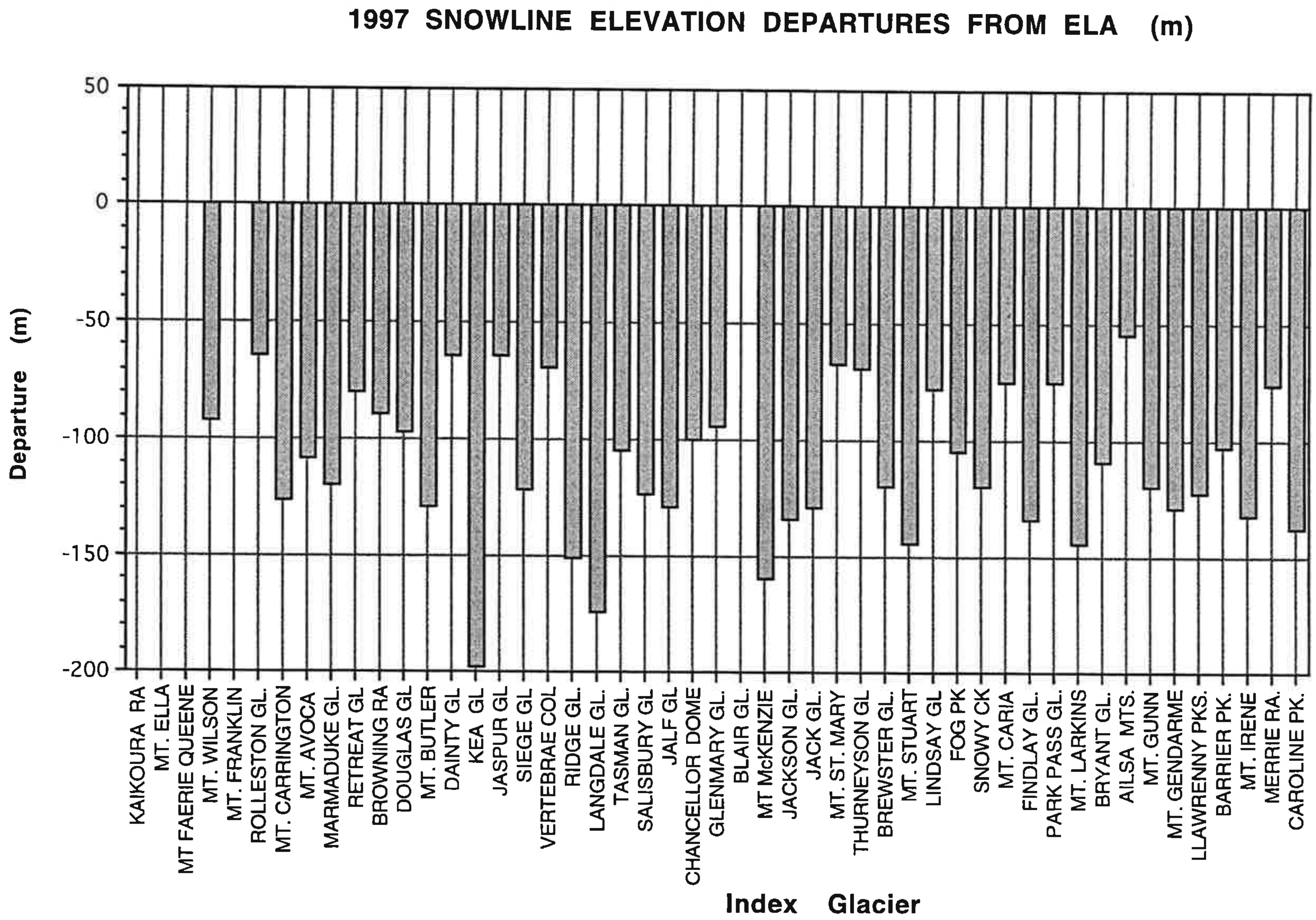


Figure 4 Summary of the 1997 snowline elevations.

balance. Here 1997 was one of the nine years measured where no single glacier showed a negative balance.

7. ANALYSES

Prior to this season's flight, the quality of the data from earlier years was improved by making enlargements of many past photographs where the glacier and snowlines were small or obscure. This work considerably improved the accuracy and ease of comparing photographs from different years. A small number of the steeper glaciers have shown consistently low values. These were examined, and where the ranges of snowline altitudes were excessive, the ranges of snowlines adjusted. In a few other cases the mean values of the snowlines have been anonymously low or high. For these glaciers the means were adjusted in line with the mean found for of all glaciers. These adjustments, which apply to all years of record, have considerably improved the internal consistency of the data set.

The pattern of snowline elevation departures throughout the Southern Alps is presented diagrammatically in Figure 7, where the contoured trend surface shows some quite complex undulations not readily attributable to a single circulation pattern that may have dominated the year.

To compare the 1997 trend surface variations with the mean for all of the 1997 reading, rather than with the more arbitrary ELA, the dataset was normalised, (v - m)/s.d., and the results plotted in the trend surface of Figure 8. Again it is difficult to interpret the surface undulations in terms of the dominance of any particular atmospheric circulation pattern.

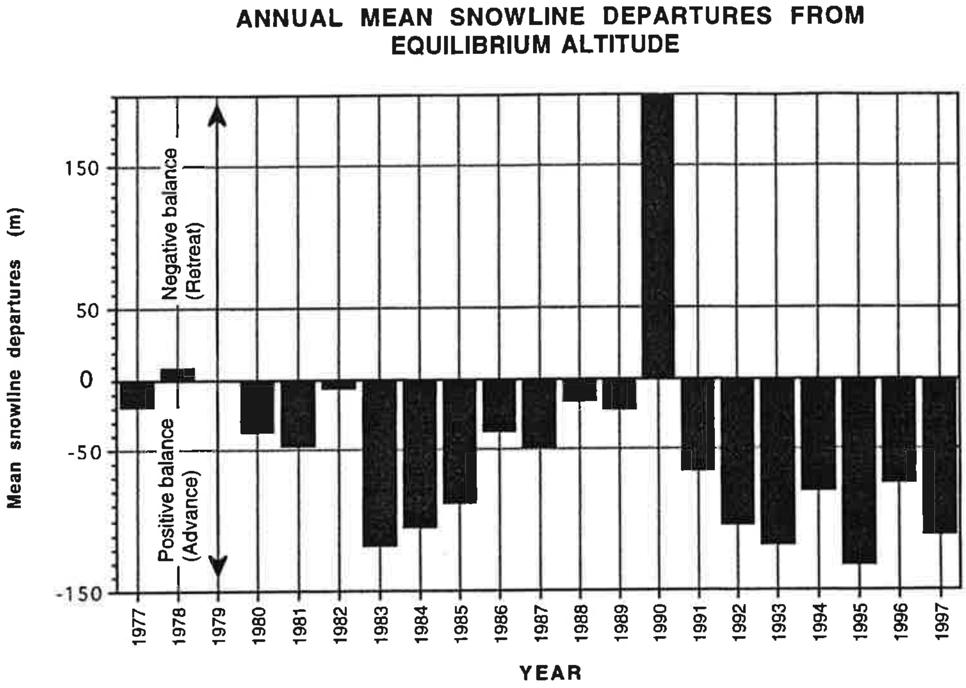


Figure 5. Mean annual snowline elevation departures from the steady-state ELA, for the 20 years, 1977 to 1997.

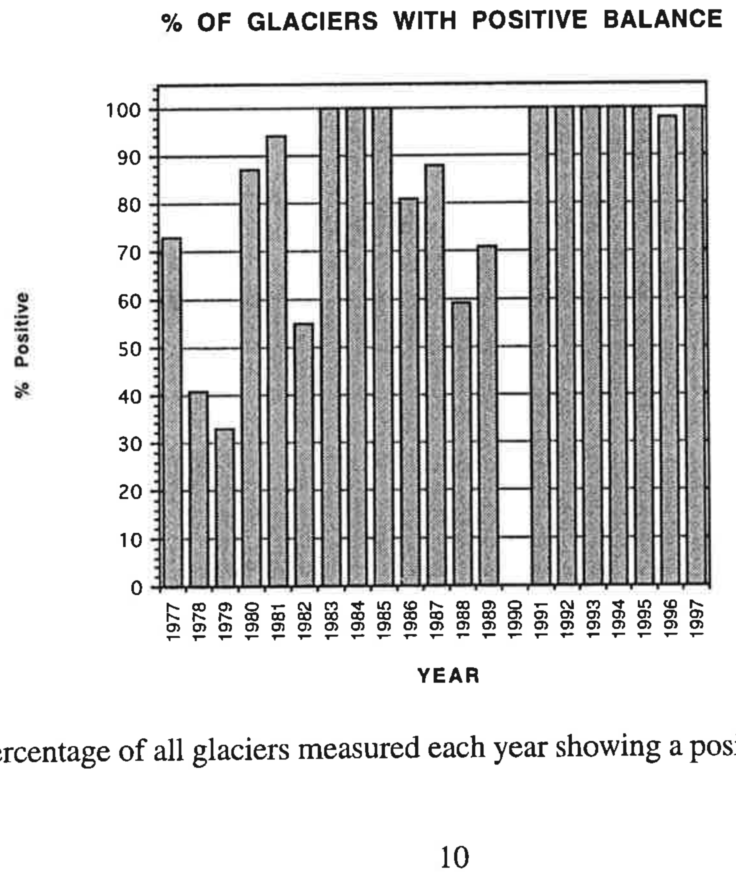


Figure 6 The percentage of all glaciers measured each year showing a positive balance.

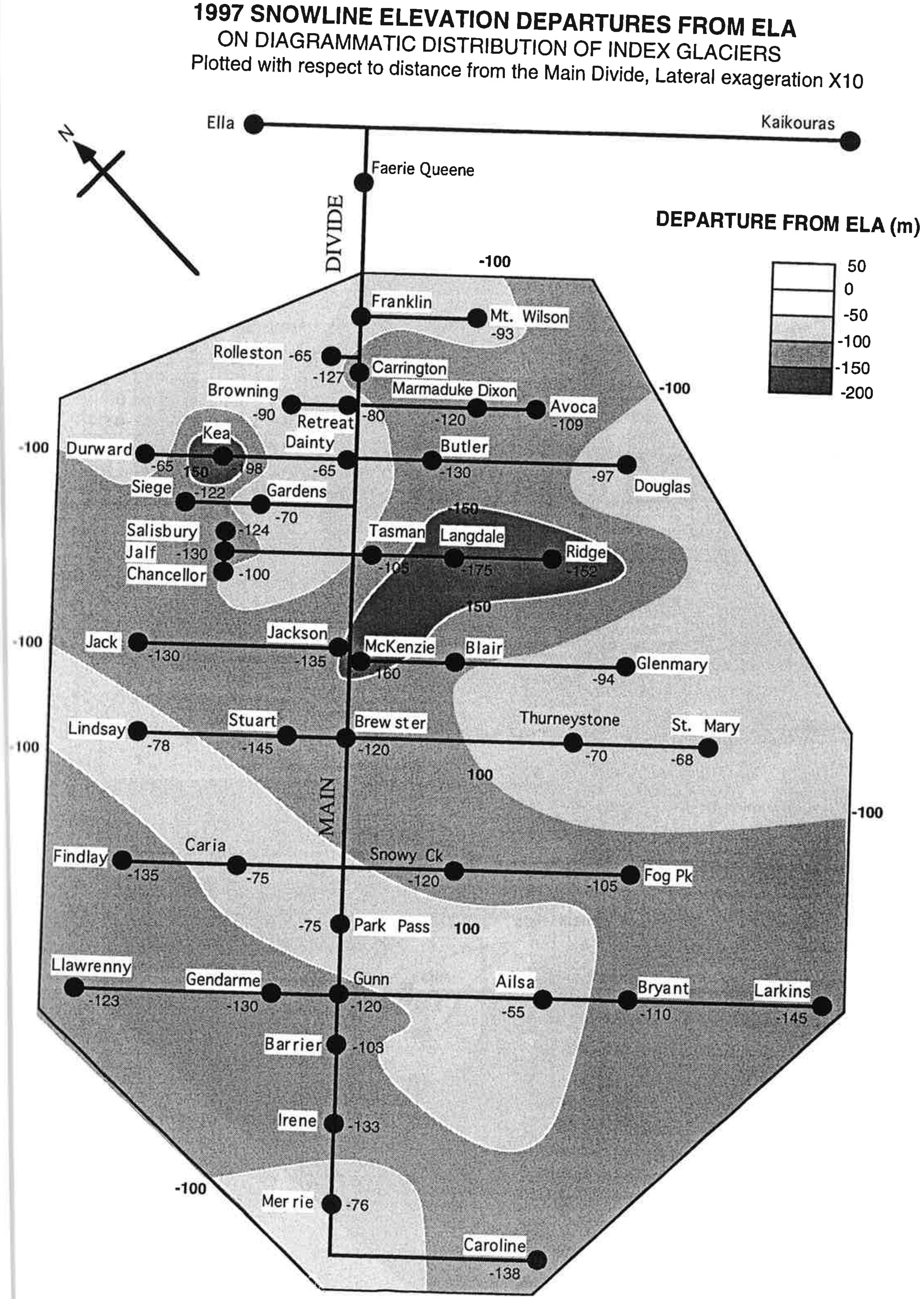


Figure 7. Diagrammatic trend surface for 1997 of departures from the ELA, measured in m.

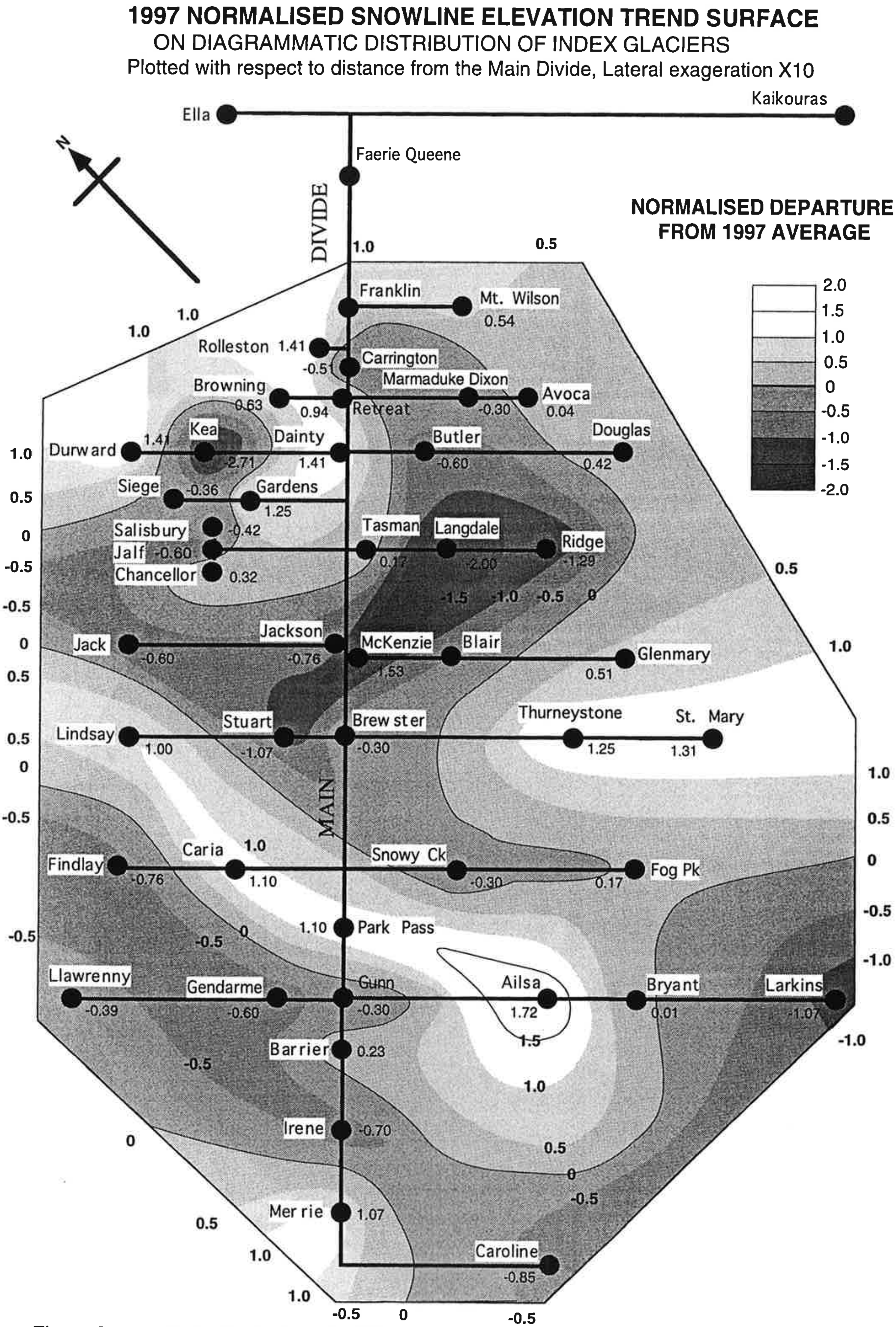
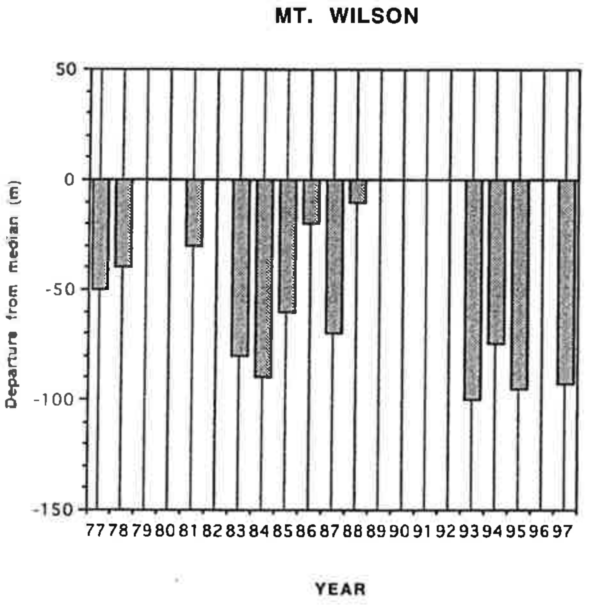


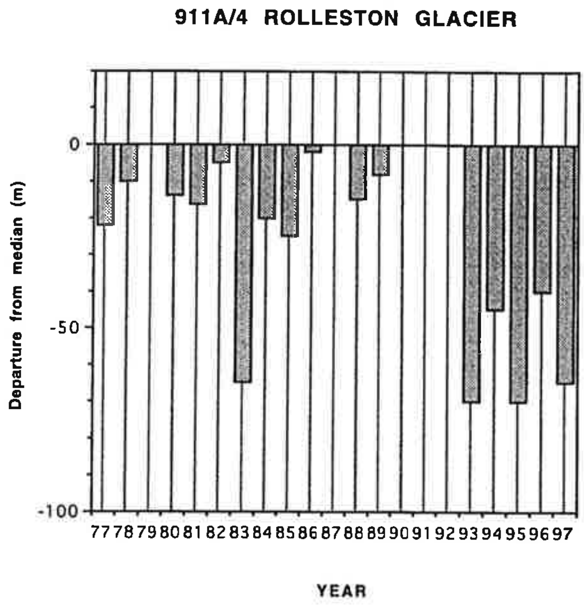
Figure 8. Normalised values for 1997, plotted as a trend surface which depicts departures from the 1997 average value.

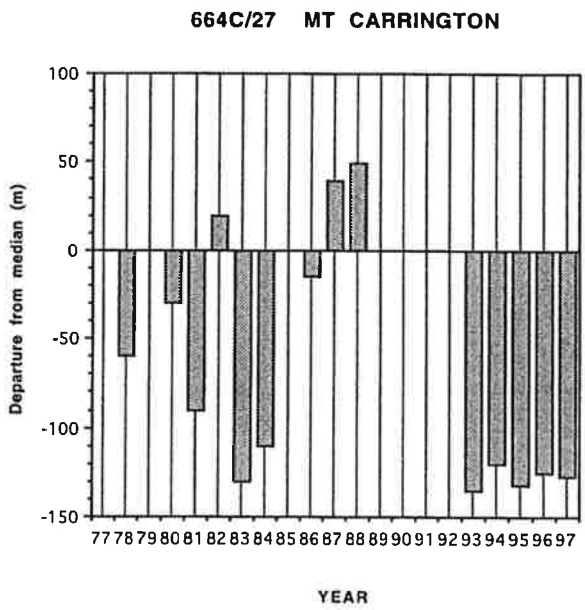
APPENDIX; DATA PLOTS FOR INDIVIDUAL GLACIERS

NORTHERN GLACIERS

Appendix 1 Snowline elevation departures from the estimated steady-state ELA values for 3 of the 7 northern glaciers.

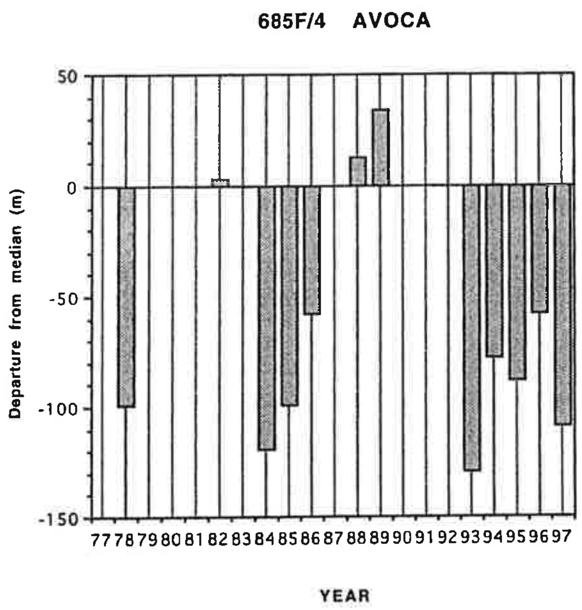


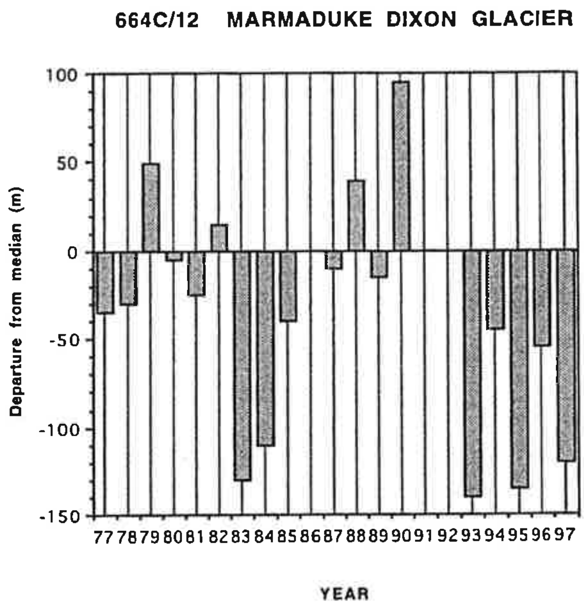


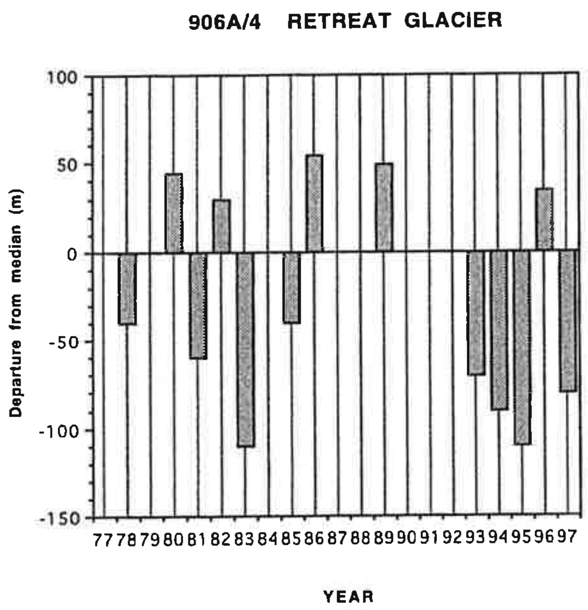


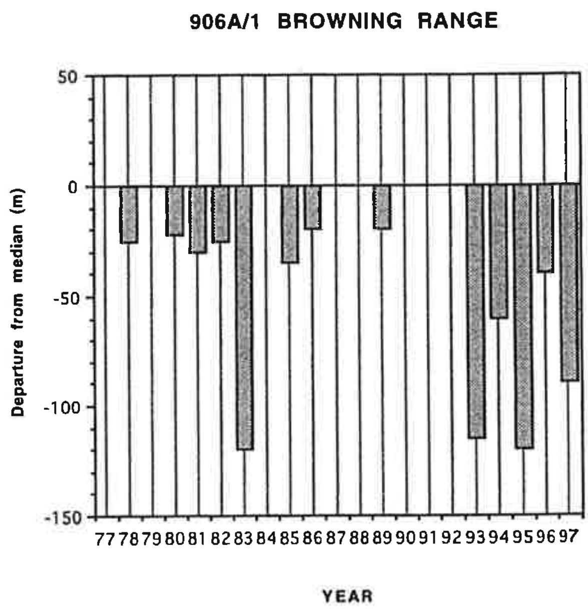
SECTION I AVOCA - KOKATAHI

Appendix 2. Snowline elevation departures from the estimated steady-state ELA values for each of the glaciers of Section I, Avoca - Kokatahi.



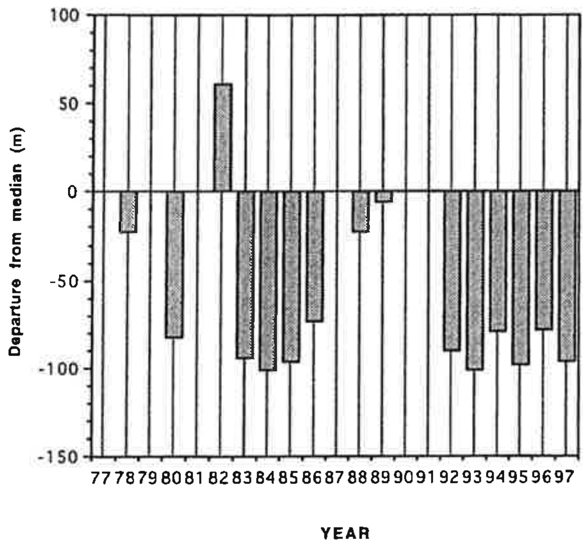




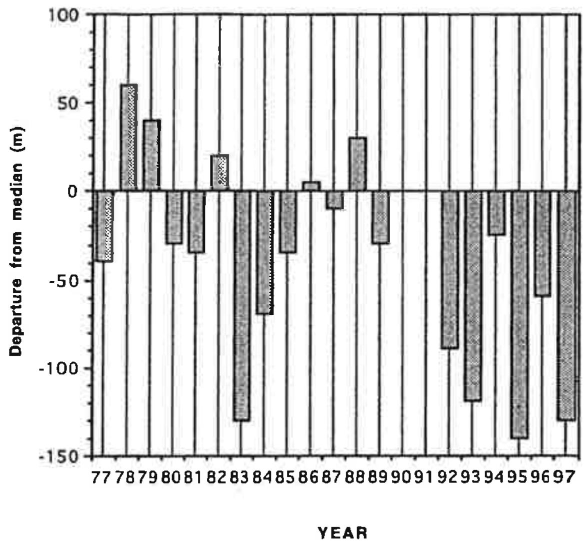


Appendix 3. Snowline elevation departures from the estimated steady-state ELA values for each of the glaciers of Section II, Arrowsmith - Wanganui.

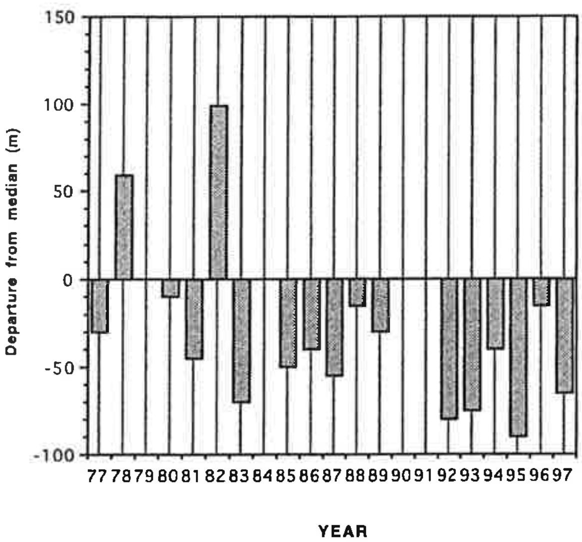
685B/1 DOUGLAS GLACIER



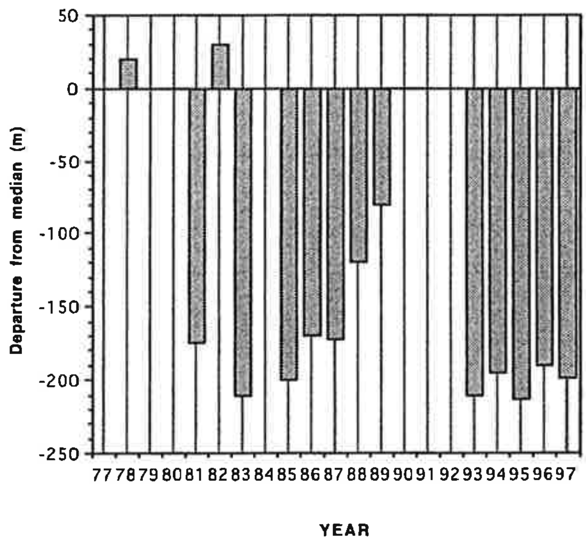
685B/60 MT. BUTLER



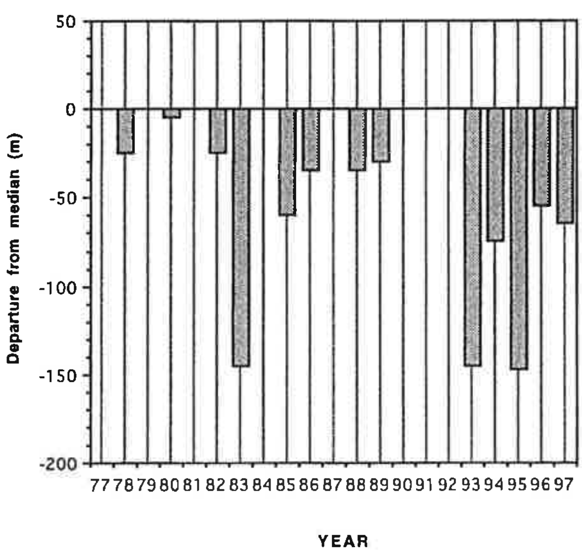
897/19 DAINTY GLACIER



897/7 KEA GLACIER

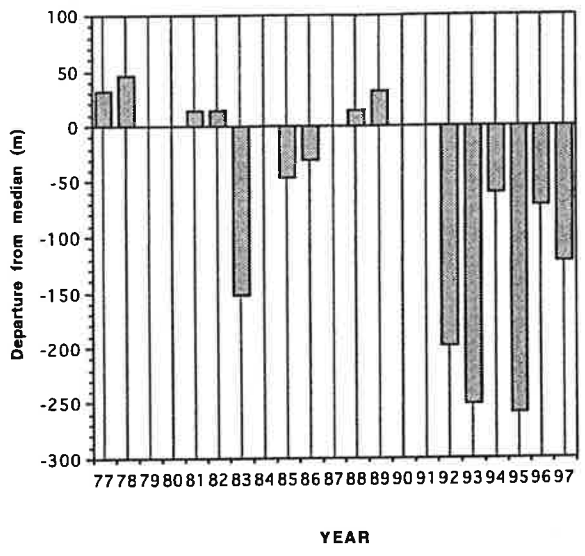


897/1 to 5 JASPUR GLACIER

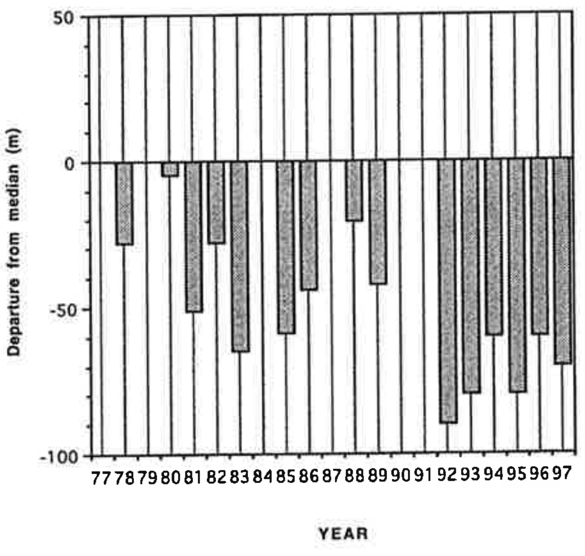


Appendix 4. Snowline elevation departures from the estimated steady-state ELA values for the two glaciers intermediate between Sections 2 and 3.

893A/6 SIEGE GLACIER



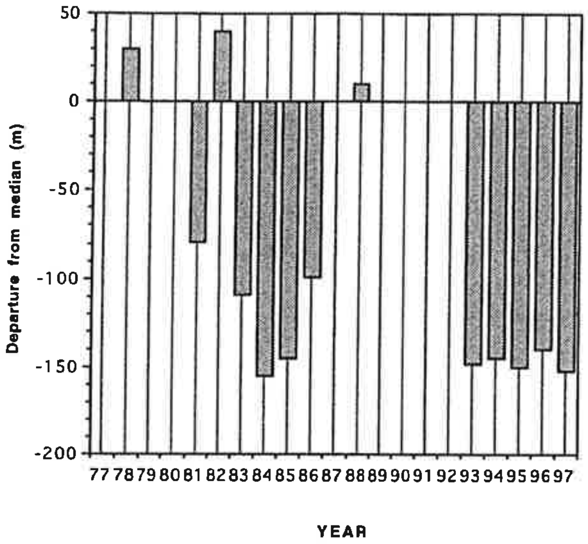
893A/12 & 25 VERTEBRAE COL



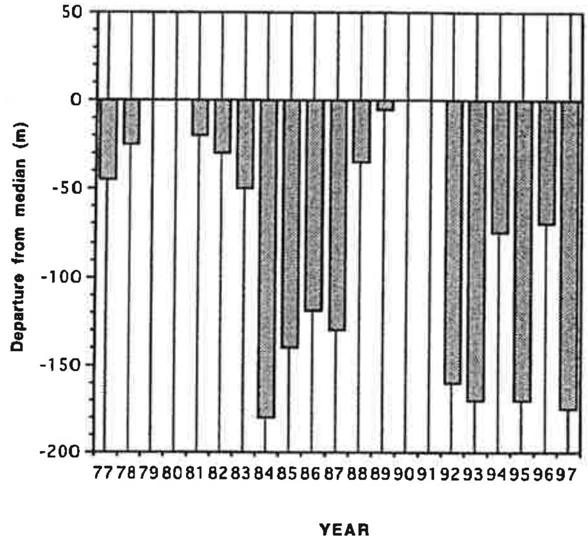
SECTION III JOLLIE - FOX

Appendix 5. Snowline elevation departures from the estimated steady-state ELA values for each of the glaciers of Section III, Jollie - Fox.

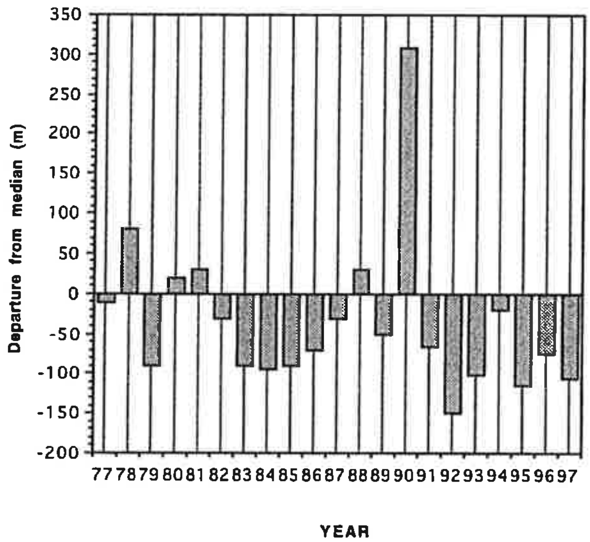
711L/24 RIDGE GLACIER



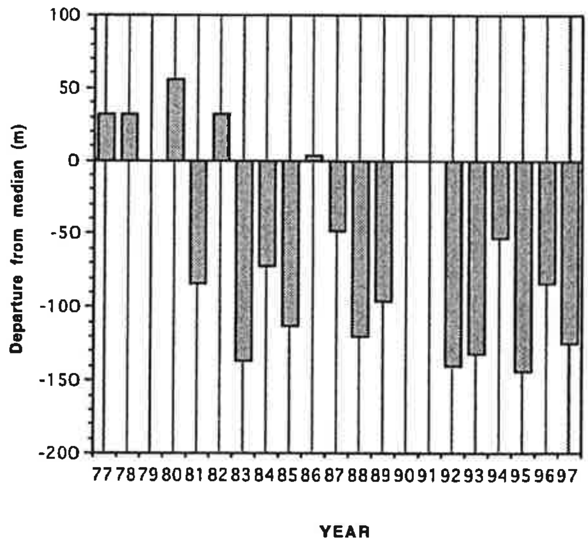
LANGDALE 97



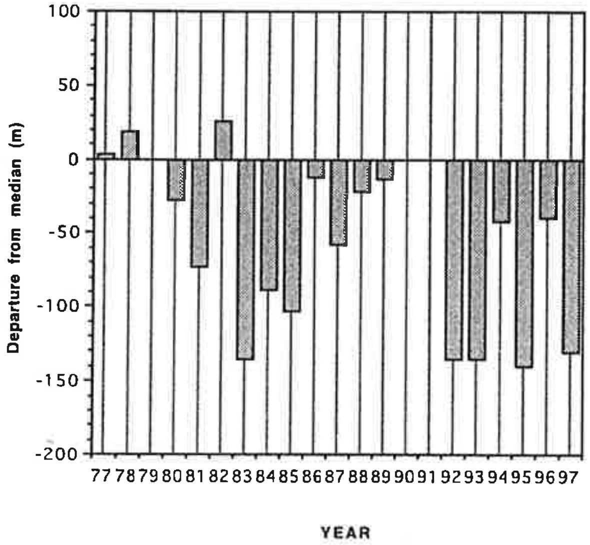
711I/12 TASMAN GLACIER



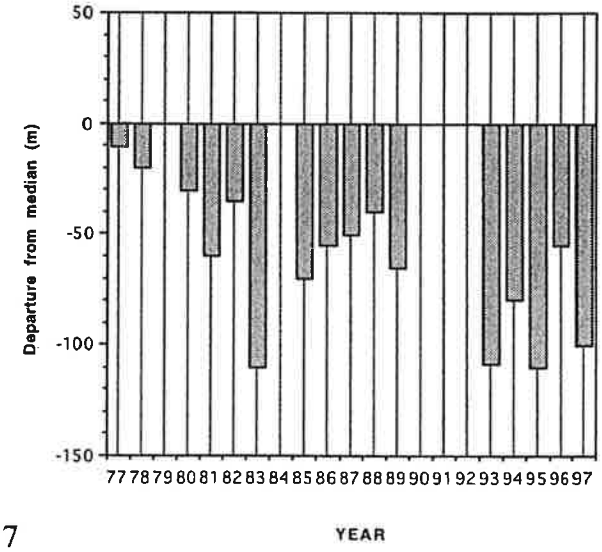
888B/3 SALISBURY GLACIER



886/2 & 888B/7 JALF GLACIER

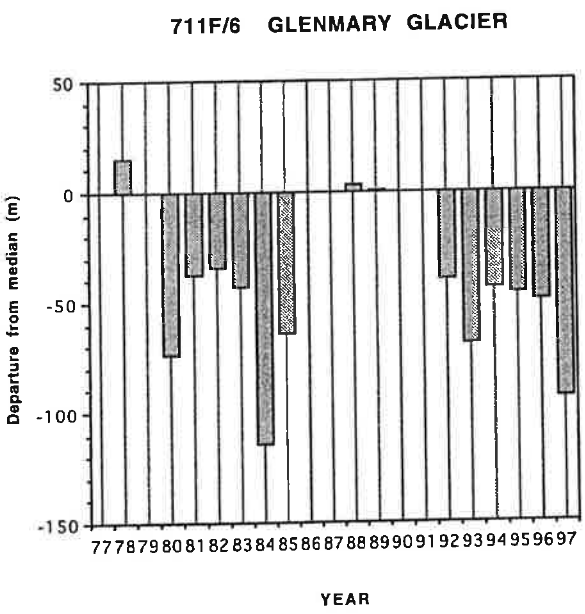


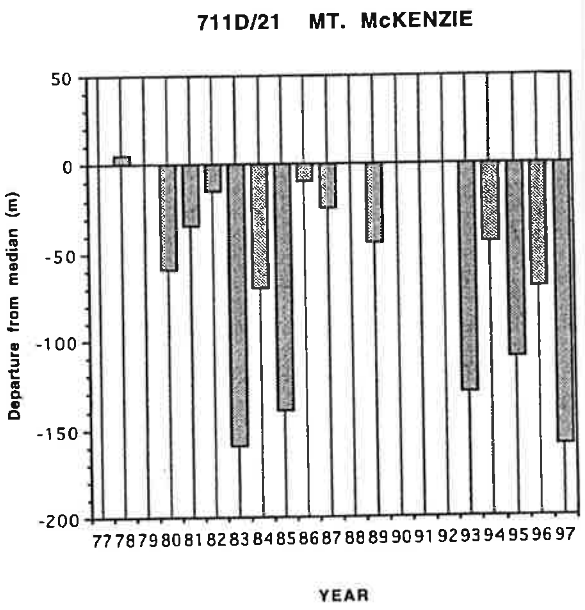
882A/7 CHANCELLOR GLACIER

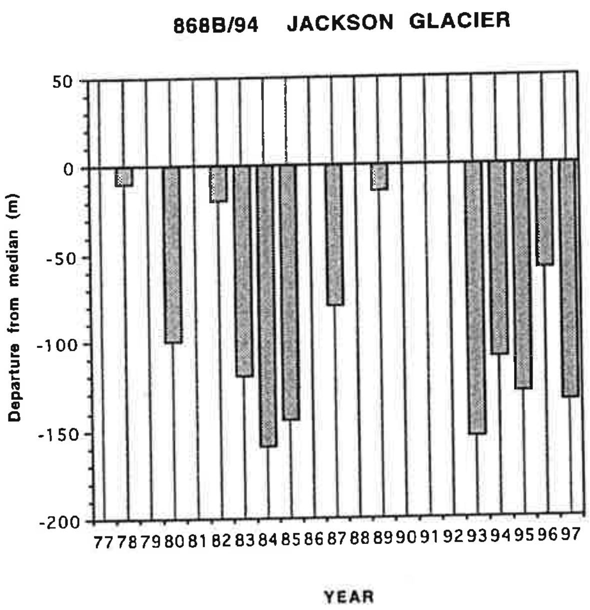


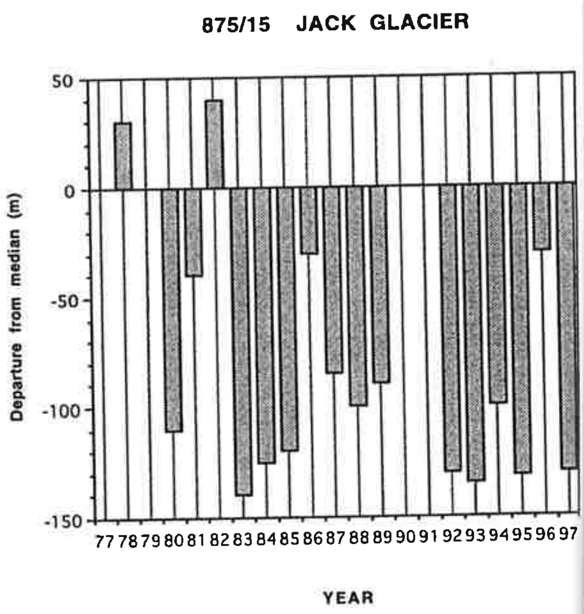
SECTION IV DOBSON - PARINGA

Appendix 6. Snowline elevation departures from the estimated steady-state ELA values for each of the glaciers of Section IV, Dobson - Paringa.





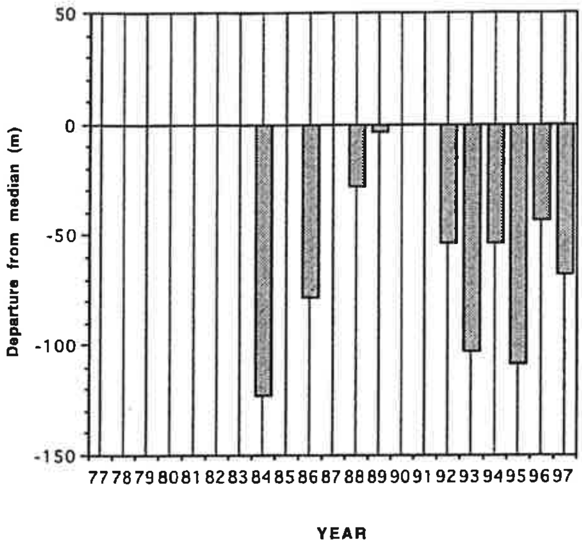




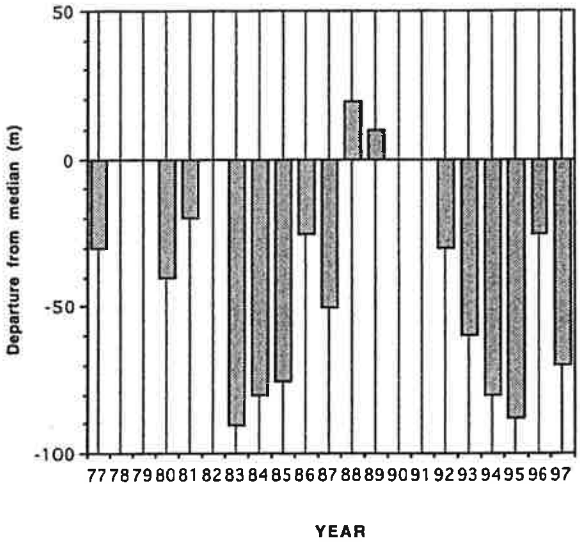
SECTION V AHURIRI - HAAST

Appendix 7. Snowline elevation departures from the estimated steady-state ELA values for each of the glaciers of Section V, Ahuriri - Haast.

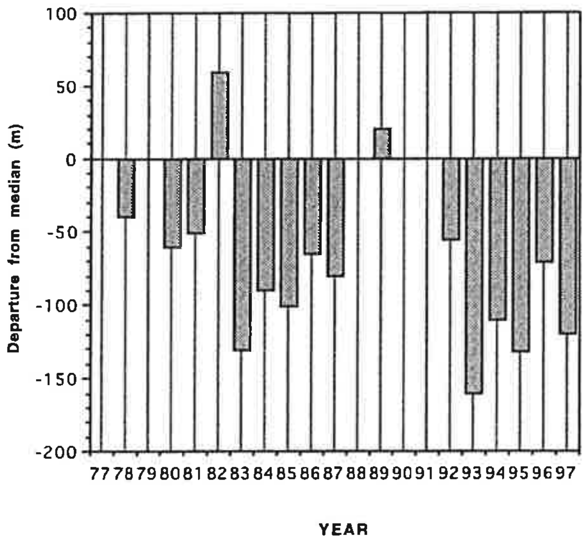
711B/39 MT. ST. MARY



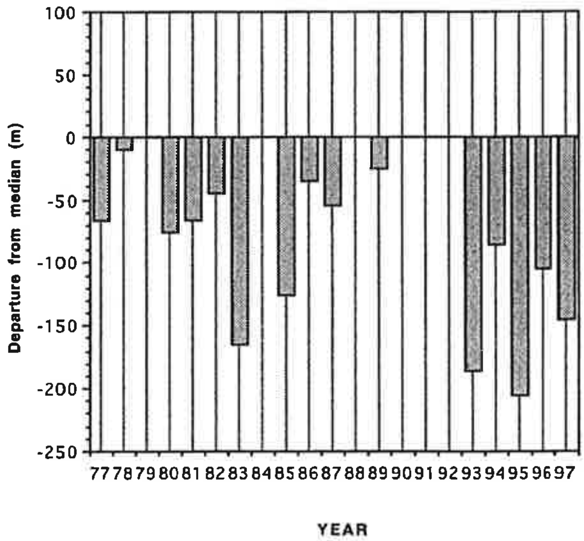
711B/12 THURNEYSTON GLACIER



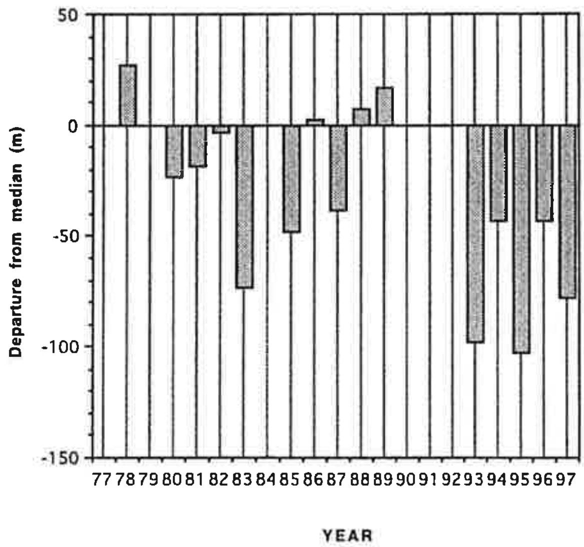
868C/20 BREWSTER GLACIER



752I/104 MT. STUART



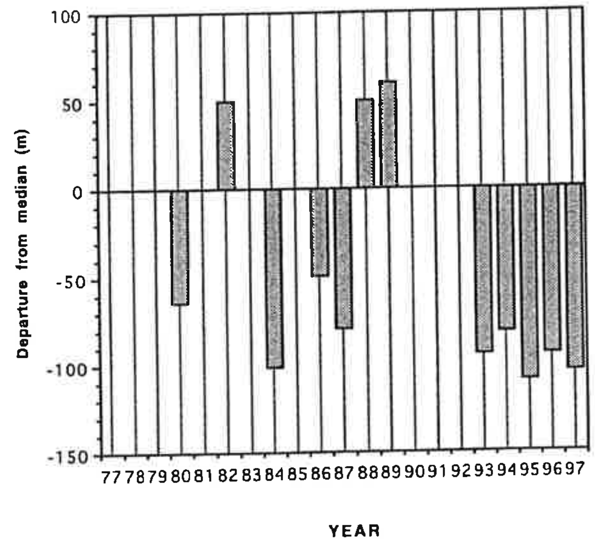
867/2 LINDSAY GLACIER



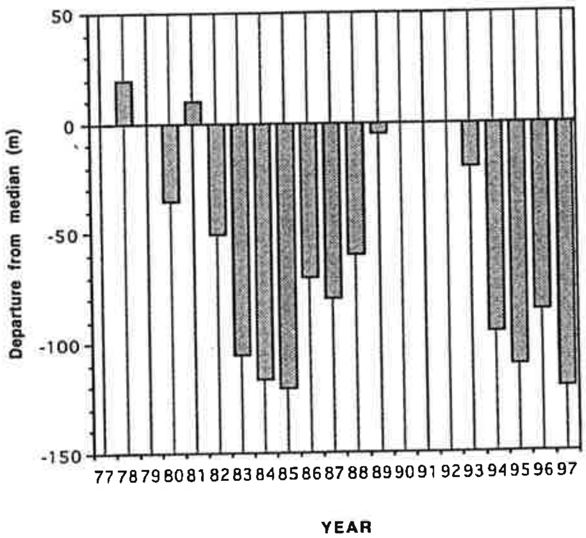
SECTION VI SHOTOVER - ARAWATA

Appendix 8. Snowline elevation departures from the estimated steady-state ELA values for each of the glaciers of Section 6. Missing values indicate years when the glacier was not surveyed.

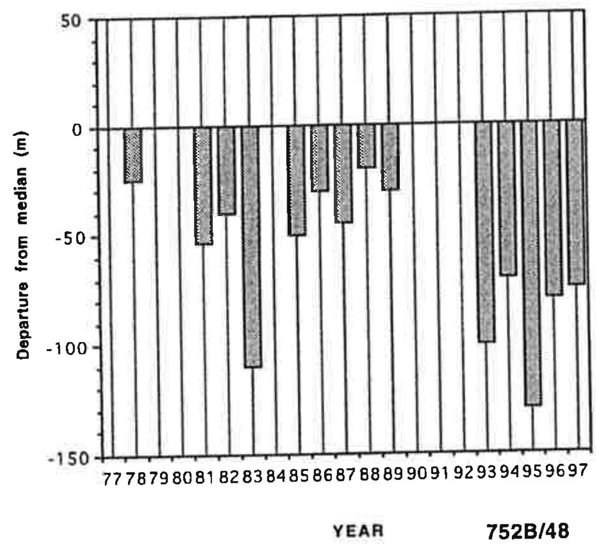
752E/51 FOG PK.



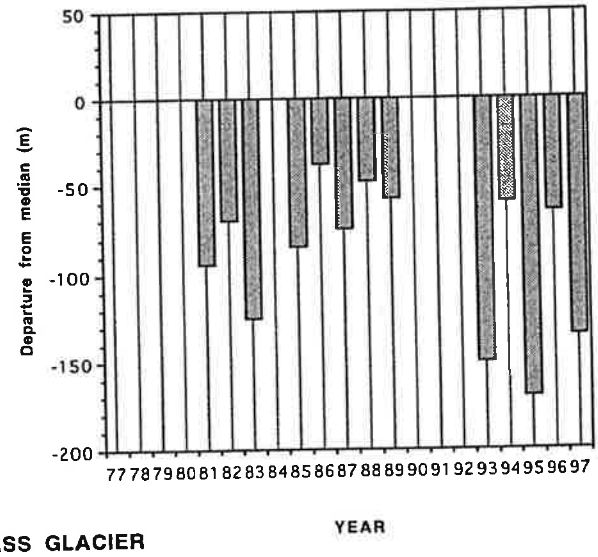
752C/103 SNOWY CK



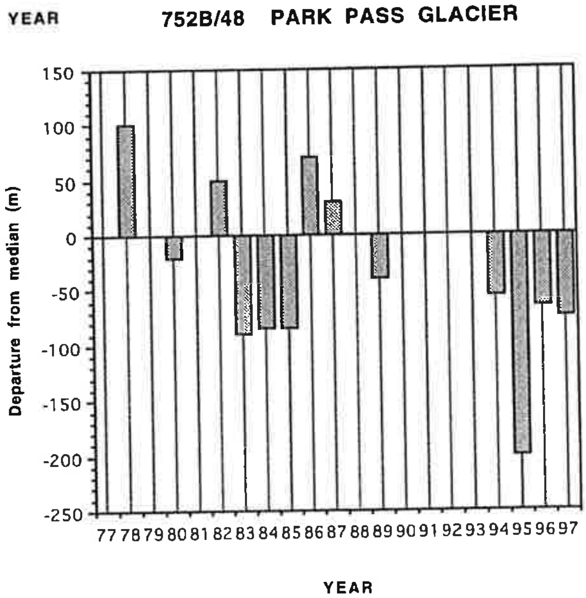
863b/1 MT. CARIA



859/9 FINDLAY GLACIER



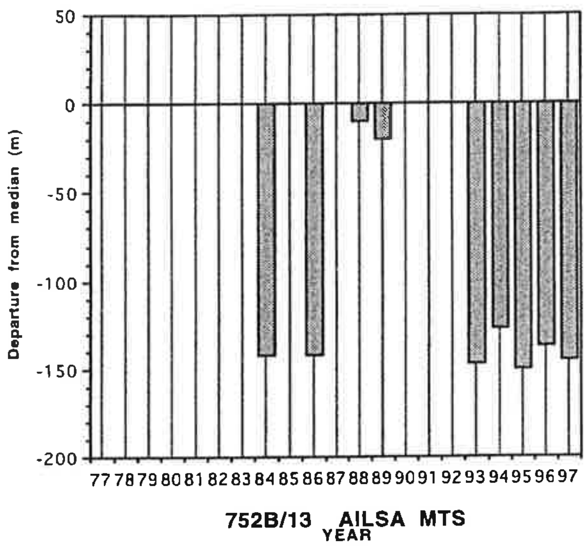
752B/48 PARK PASS GLACIER



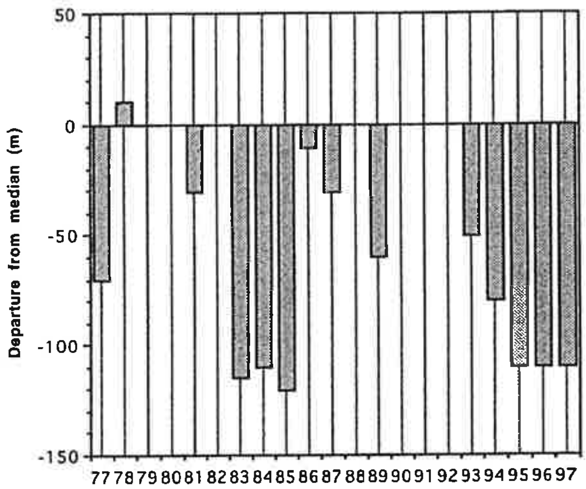
SECTION VII WAKATIPU - MILFORD

Appendix 9. Snowline elevation departures from the estimated steady-state ELA values for each of the glaciers of Section VII, Shotover - Arawata.

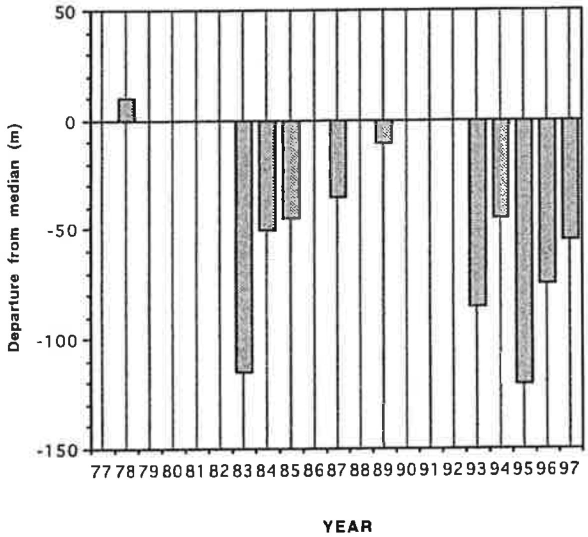
752E/2 MT. LARKINS



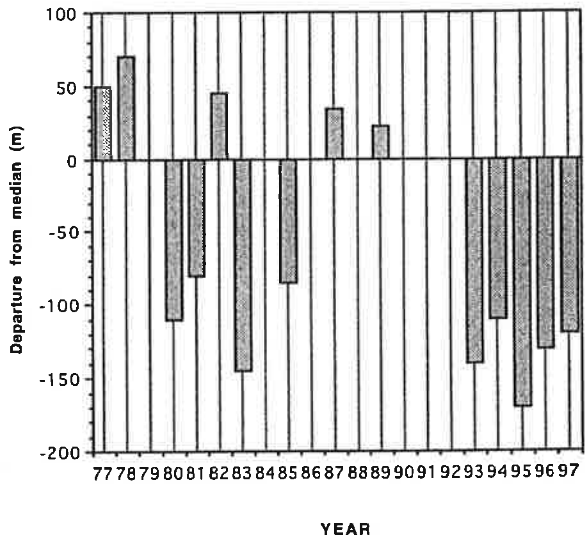
BRYANT GLACIER



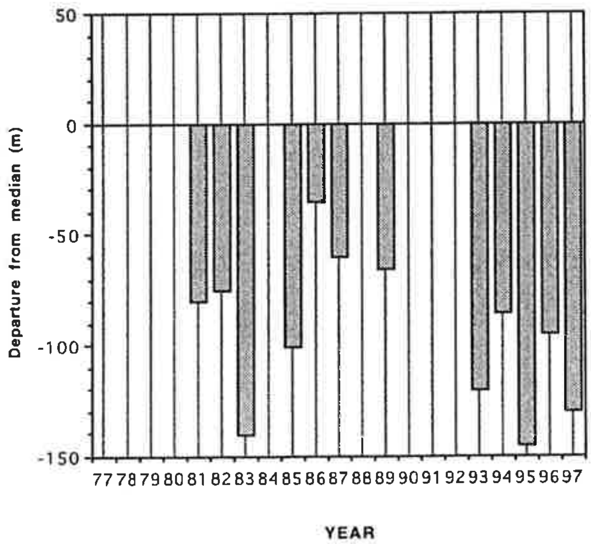
752B/13 AILSA MTS



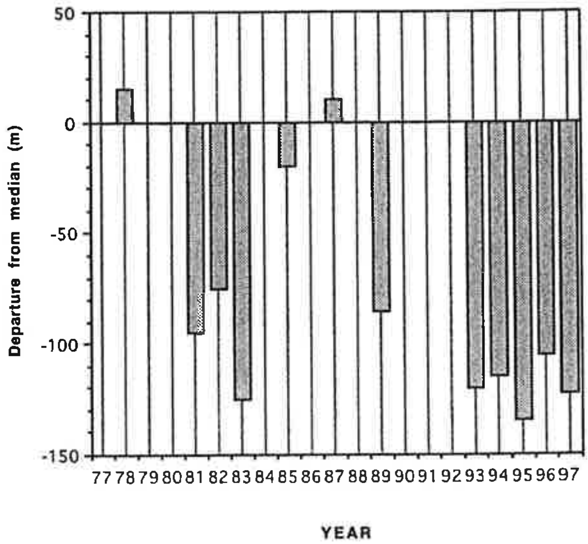
851B/57 MT. GUNN



797G/33 MT. GENDARME



846/35 LLAWRENNY PKS



FIORDLAND GLACIERS

Appendix 10. Snowline elevation departures from the estimated steady-state ELA values for each of the mid-south Fiordland glaciers.