Glacier snowline survey 1998

T J Chinn

Institute of Geological & Nuclear Sciences science report 98/12

Institute of Geological & Nuclear Sciences Limited
Lower Hutt, New Zealand
1998

BIBLIOGRAPHIC REFERENCE

Chinn, T.J., 1998. Glacier snowline survey 1998. *Institute of Geological & Nuclear Sciences science report* 98/12. 28 p.

T J Chinn, Alpine & Polar Processes Consultancy, Dunedin

ISBN 1171-9184
ISSN 0-478-09622-4

CONTENTS

ABSTRACT

The 1997-98 end-of-summer snowline survey of some 49 "index" glaciers of the Southern Alps was undertaken in March 1998. The 1997-98 glacial year was dominated by an El Niño atmospheric circulation pattern which normally would be characterised by heavy snowfalls and low snowlines. An aberration within the El Niño system generated a persistent warm north westerly airstream throughout February, which induced exceptionally high melt rates over the glaciers. The responses of the glaciers were variable, ranging from near 'average' snowlines to very high snowlines.

KEYWORDS: Snowline, glacier fluctuations, climate change.

1. INTRODUCTION

The 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).

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 the dry 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 exponentially to about 1,000 mm in the eastern ranges. This situation creates steep eastward precipitation gradients and the mean altitudes of the glaciers closely follow these gradients (Chinn and Whitehouse, 1980).

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.

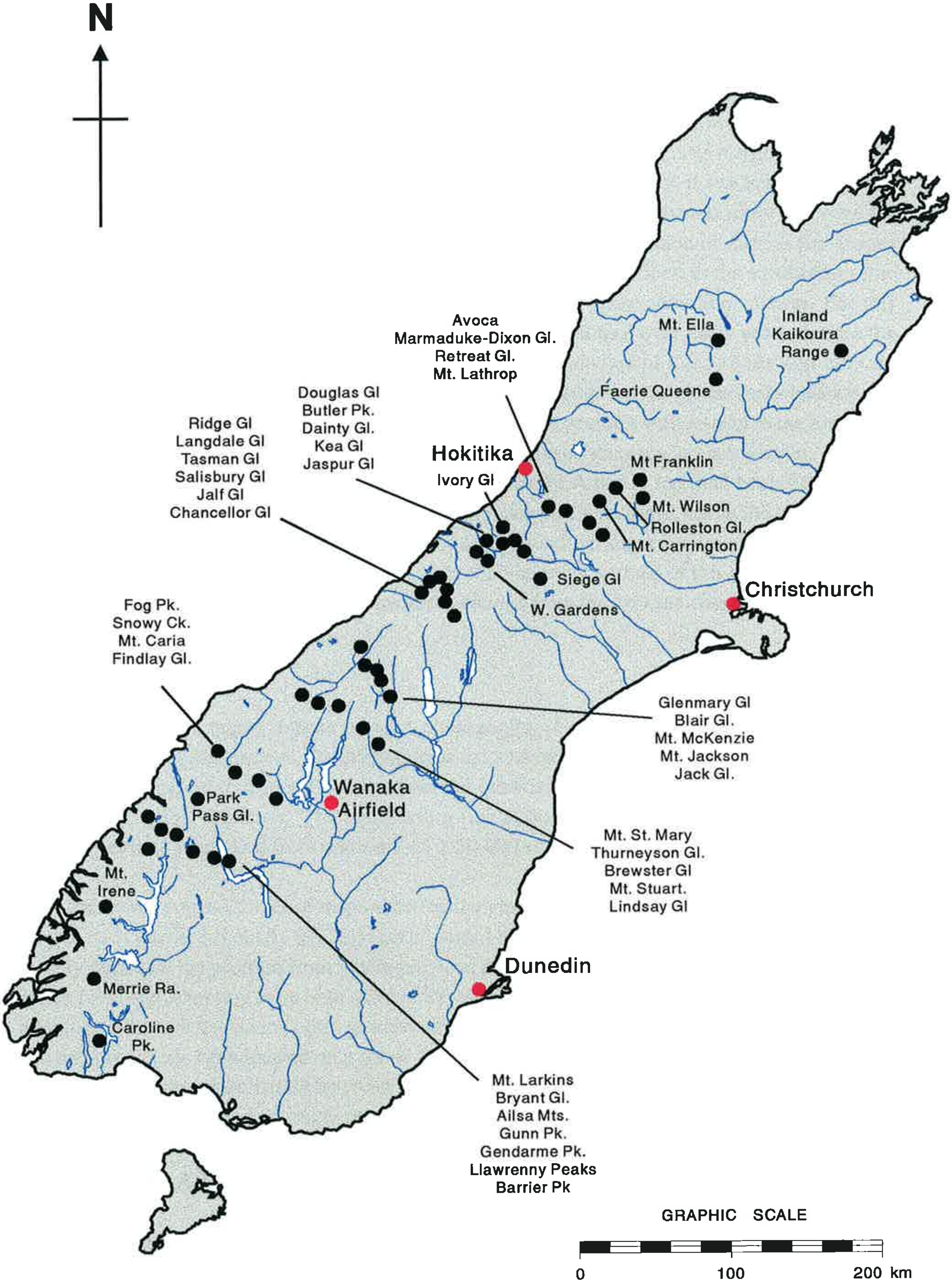


Figure 1. Location of the snowlines index glaciers

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 an equilibrium line where snowfall exactly equals snow loss over the past glacial year. 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 (defined as the equilibrium line altitude (ELA) by Meier and Post, 1962) 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 (steady-state 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 steady-state ELA that is reported here. For glaciers in balance the steady-state ELA would be the mean of many years' readings, but as the New Zealand glaciers have been dominated by positive balances since this programme 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. 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.

During the survey flight 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. As has been customary on these surveys, in addition to the index glaciers, other glaciers and selected glacier termini were also photographed. These had previously been located on a set of 1:63,360 scale glacier inventory maps carried on the flight. The flight was made mainly between 9,000 ft. and 10,000 ft. 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

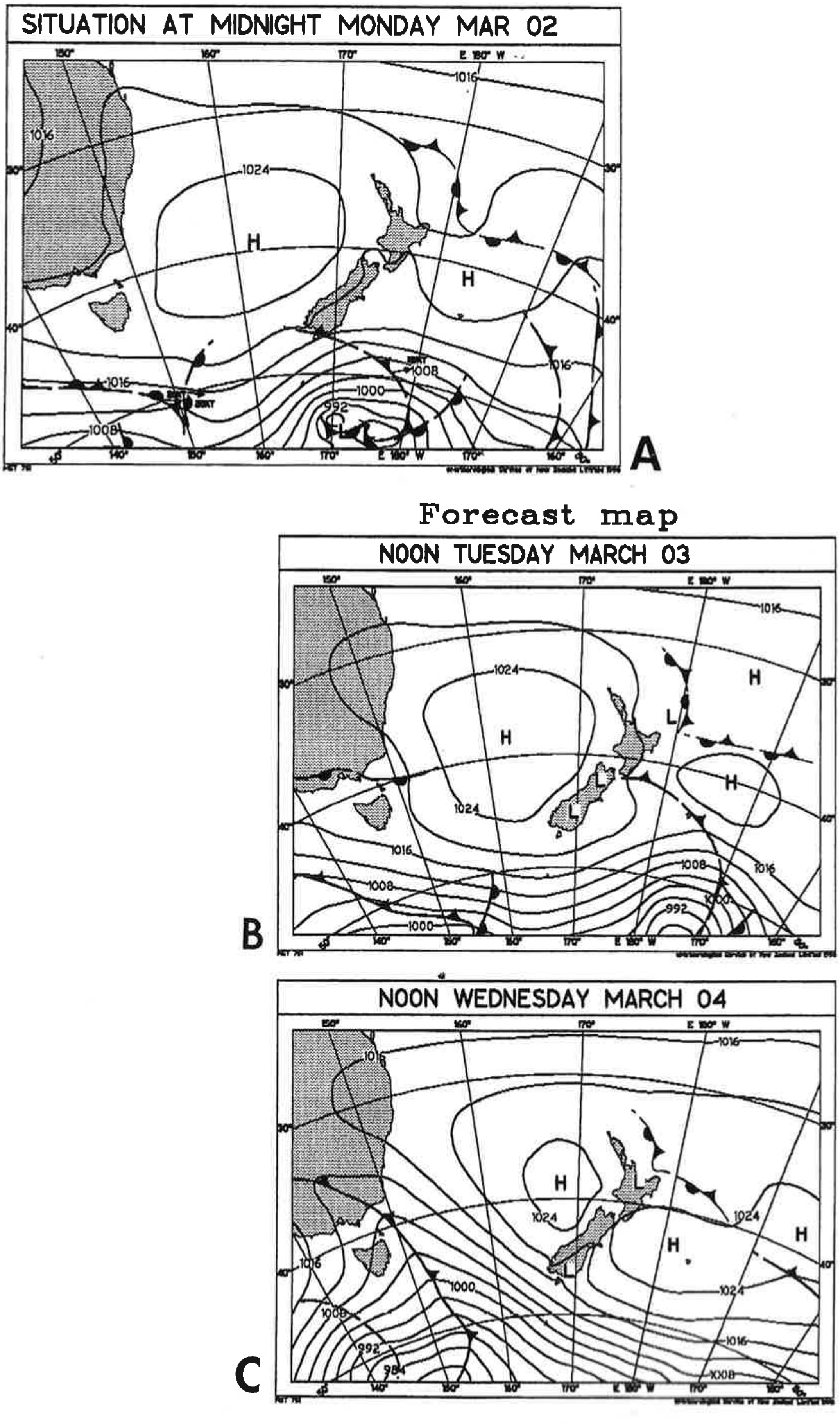


Figure 2. "Met fax" weather maps on which the first day of the 1998 snowline survey was planned;
[A] Midnight, Monday, 2 March, anticyclone approaching.
[B] Forecast for noon, Tuesday, 3 March.
[C] Forecast for Wednesday, March 4, the day on which the flight was made.

April there is a high probability 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 a snowfall 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. Recently a policy of making the flight on 'the first clear weather after March 1' has proved successful.

In early March 1998, warm north-westerly system was replaced by fine anticyclonic weather, and a forecast anticyclone commenced moving towards the South Island on Monday March 2 (Fig. 2). This year, newspaper forecasts were confirmed by 'Met fax' weather situations and predictions. The Monday 2 'Met fax' forecast 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 pilot permitted direct "front window" navigation without any flying time lost to searching for our positions on the maps.

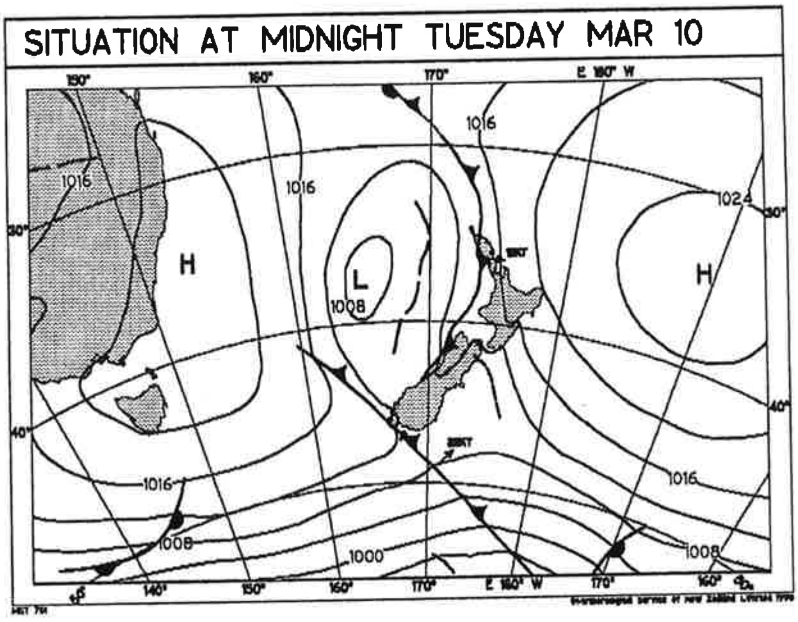
4. ITINERARY

As the anticyclone approached the country, the first leg of the snowlines flight was made by P. Glassey and T. Chinn on Wednesday 4th March (Fig. 2), in an Aspiring Air Cessna Cardinal flown by Andy Woods. As a westerly flow persisted over Fiordland, the first flight was made from Haast pass northwards (Fig.4) completing the West Coast in the morning before the daily cloud build-up, and after a refuelling stop at Greymouth, on to the Kaikouras. A second refuelling stop was made on the return at Hokitika (as this airport is much closer to the glaciers than the alternative at Rangiora). The Whitcombe Pass was negotiated in thick 'afternoon cloud' to complete the glaciers to the east of the Main Divide.

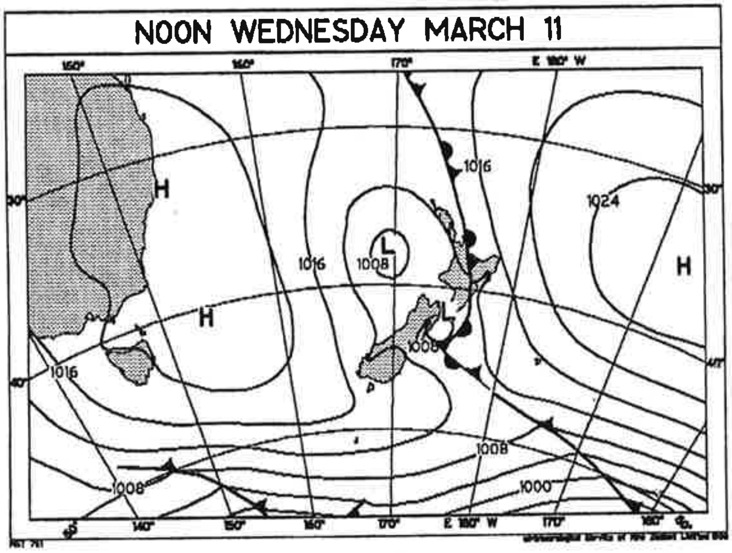
The next day was unsuitable for flying, and a second warm, tropical airstream formed over the country.

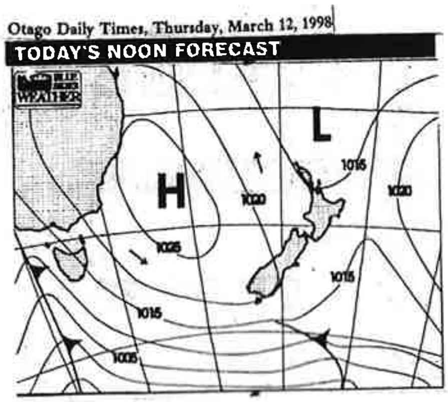
On the forecast of another anticyclone approaching the country, (Fig. 3) the second leg of the flight was made a week later on Thursday 12, by J. Forsyth and T. Chinn, with the same aircraft and pilot. With a minor westerly drift still persisting to the north of Fiordland, together with a heavy cover of low easterly cloud, the flight was made in a clockwise direction around Fiordland, completing the eastern glaciers first (Fig. 4) with a refuelling stop at Milford Sound. Time and cloud conditions allowed for three glaciers on the Haast Pass section to be photographed a second time.

It was gratifying to complete the survey of the entire set of index glaciers, particularly as the 'first snowfall of winter' fell only 3 days later on Sunday 15! Subsequently, further snowfalls down to 600m on the 29th and on 1 April blanketed the Otago skifields with up to 30 cm snow (Appendix 12). In some past years the snowline flight has been successfully made in mid to late April.



Forecast maps





Otago Daily Times, Thursday, March 12, 1998

Figure 3. Weather maps of the anticyclone conditions used for the second flight on March 12, to the Fiordland glaciers.

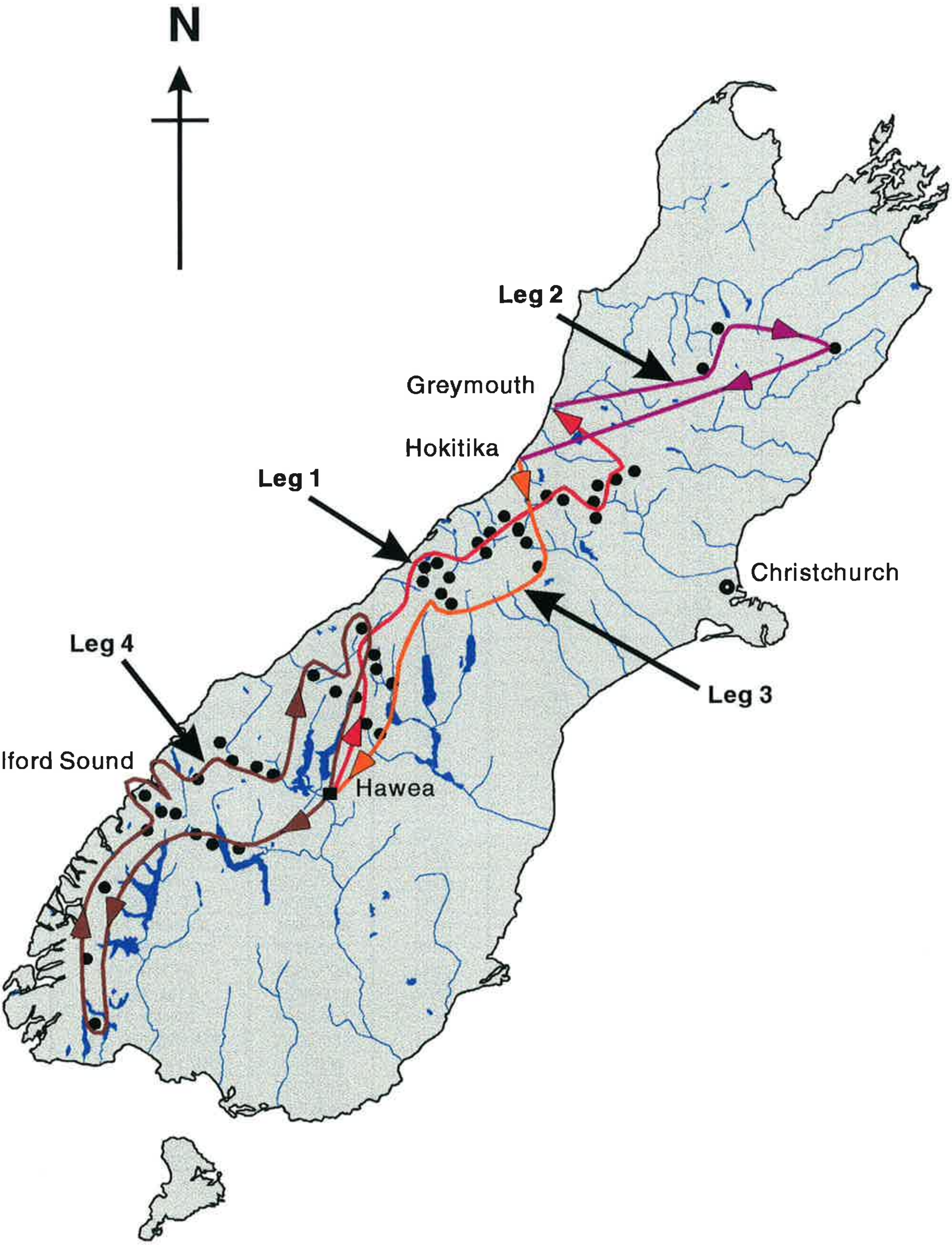


Figure 4. Flight paths for the 1998 glacier surveys

			1998 DATA		
GLACIER	INVENTORY NUMBER	LONG TERM ELA (m)	SNOWLINE DEPARTURES 1998 (m)	NORMALISED 1998 VALUES	No. OF READINGS TO DATE
KAIKOURA RA	621/001	2530	0	0.91	8
MT. ELLA	932B/012	2141	-30	0.47	6
MT FAERIE QUEENE	646/006	2012	-94	-0.17	8
MT. WILSON	None	1850	-20	1.05	15
MT. FRANKLIN	911A/002	1890	30	1.36	13
ROLLESTON GL.	911A/004	1780	30	1.99	18
MT. CARRINGTON	646C/027	1720	80	1.79	16
MT. AVOCA	685F/004	1992	68	1.93	13
MARMADUKE GL.	664C/012	1830	70	1.47	20
RETREAT GL	906A/004	1740	55	1.20	14
BROWNING RA	906A/001	1600	20	1.59	14
DOUGLAS GL	685B/001	2120	0	1.28	16
MT. BUTLER	685C/060	1840	55	1.48	20
DAINTY GL	897/019	1930	105	2.26	18
KEA GL	897/007	1820	25	1.63	16
JASPUR GL	897/003	1785	-25	0.76	14
SIEGE GL	893A/006	1722	78	1.28	17
VERTEBRAE COL	893A/025	1880	-25	1.05	16
RIDGE GL.	711L/024	2260	45	1.56	15
LANGDALE GL.	711I/035	2260	40	1.82	18
TASMAN GL.	711I/012	1790	85	1.15	22
SALISBURY GL	888B/003	1860	44	1.46	19
JALF GL	886/002	1810	20	1.30	19
CHANCELLOR DOME	882A/007	1835	-35	0.81	17
GLENMARY GL.	711F/006	2134	-34	0.33	16
BLAIR GL.	711D/038	2000	-35	0.91	15
MT McKENZIE	711D/021	1960	-5	1.11	16
JACKSON GL.	868B/094	2080	-15	1.33	14
JACK GL.	875/015	1940	38	1.84	18
MT. ST. MARY	711B/039	2043	-35	0.76	11
THURNEYSON GL	711B/012	1930	30	1.90	17
BREWSTER GL.	868C/020	1880	70	2.09	17
MT. STUART	752I/104	1725	-25	1.05	16
LINDSAY GL	867/002	1753	47	1.72	16
FOG PK	752E/051	2000	120	2.01	13
SNOWY CK	752C/103	2160	40	1.89	17
MT. CARIA	863B/001	1470	-55	0.18	15
FINDLAY GL.	859/009	1700	-40	1.10	14
PARK PASS GL.	752B/048	1750	110	1.59	15
MT. LARKINS	752E/002	2060	80	2.15	10
BRYANT GL.	752B/025	1750	-5	1.23	16
AILSA MTS.	752B/013	1650	-5	1.04	13
MT. GUNN	851B/057	1620	60	1.28	15
MT. GENDARME	797G/033	1720	-60	0.93	13
LLAWRENNY PKS.	846/035	1450	15	1.54	13
BARRIER PK.	797F/004	1595	50	1.46	14
MT. IRENE	797D/001	1638	-88	0.65	11
MERRIE RA.	797B/010	1646	-36	0.28	8
CAROLINE PK.	803/001	1525	-120	1.35	6
	NUMBER	49	49	49	721
	MEAN	1861	15	1.29	14.71
	STD. DEV.	217	55	0.54	3.50
	No. +ve		28		
	% with +ve M.B.		43		

Table 1 Results of the 1998 snowline survey. Departures from the steady-state ELA value in m, and normalised values for each glacier surveyed.

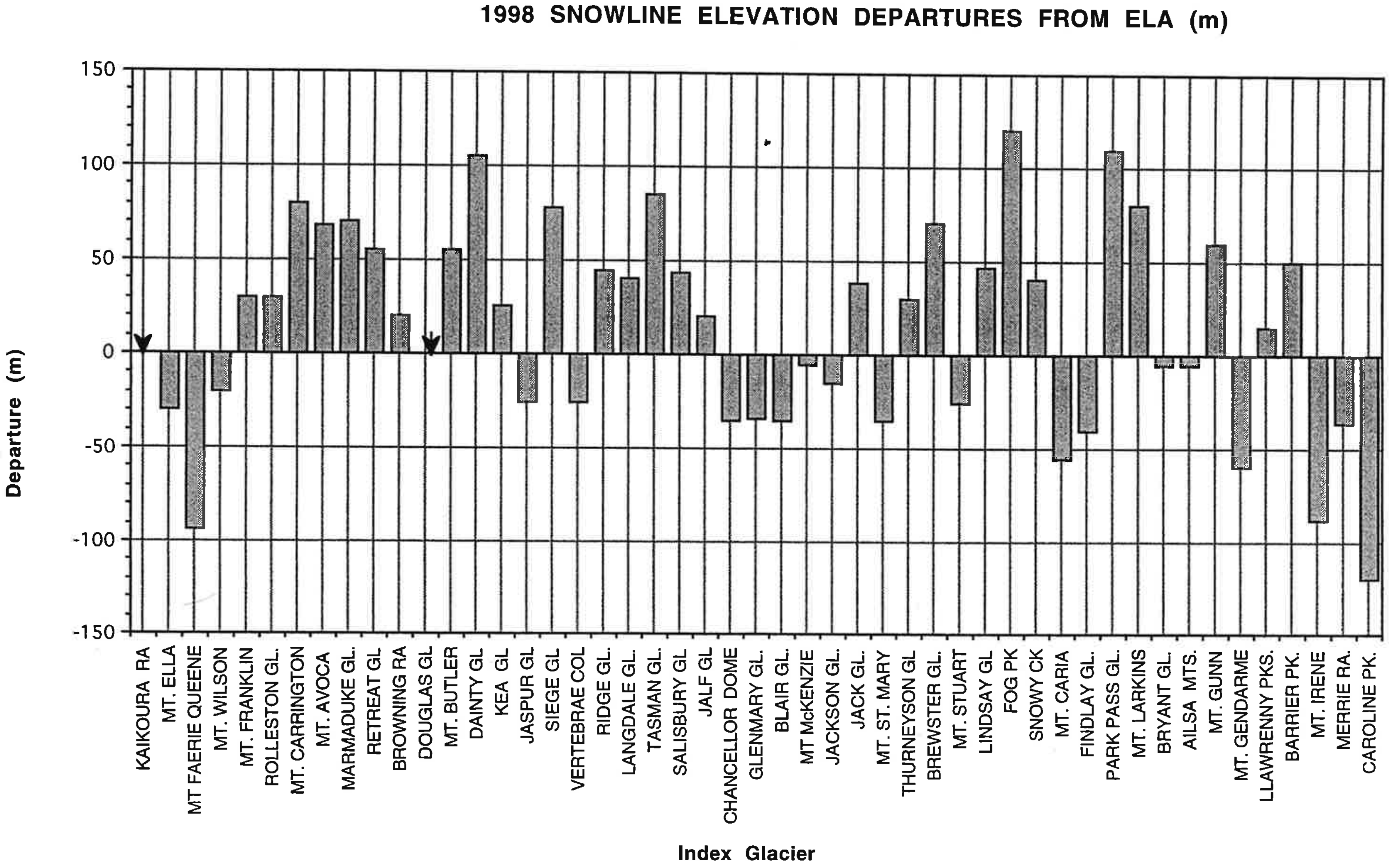


Figure 5. Summary of the 1998 snowline elevations. Arrows indicate zero values.

5. RESULTS

Despite favourable anticyclonic conditions, this year the survey was again troubled by afternoon cloud at some of the West Coast glaciers. However, for the third time only, all the index glaciers were photographed, with three re-photographed a week later. This double survey will permit an assessment of the amount of ablation during the intervening 8 days of warm north-westerlies.

Snowlines at some glaciers were among the highest recorded, indicating a year of strong negative balance, but still with most of the glaciers retaining positive balances. Results for individual glaciers, are listed as departures from the steady-state ELA value in Table 1 and plotted in Figure 5. Snowline fluctuation histories for each individual glacier are given in the histograms of Appendices 4 to 10, where values are given as metres of departure from the steady-state ELA. Missing values are years of no survey, and arrows indicate measured zero values.

The 1998 results are summarised in Figure 5, where the snowline departures from equilibrium vary strongly, but lie between -100m and +100m. Values below the zero ELA datum indicate depressed snowlines and therefore positive mass balances.

6. COMPARISONS WITH PREVIOUS YEARS

The 1998 glacier year is compared with averages from very variable numbers of glaciers observed over the past 20 years in Figure 6. 1998 was one of three years of high snowlines and recorded a slightly negative balance. Figure 7 presents the percentage of all glaciers surveyed each year which showed a positive balance. Here 1998 was one of the many years showing both positive and negative balances.

7. ANALYSES

Snowline elevations were subjectively derived from the photographs by the methods used in previous years (Chinn, 1995) where theoretically the visible snowline is transferred to the contour map of the glacier, and the altitude read. In practice, the results were more accurately derived by placing the 1998 photograph in its place in the sequence of all past photographs, arranged in ascending order of snowline elevations, and interpolating the altitude between past assessments. This gives a comparative elevation precision of a few metres compared with other years, but a large error remains in the absolute value of the altitude.

On many of the glaciers the high summer melt has revealed the firn layers of four or more past years, and frequently it was difficult to decide on which of the number of 'snowlines' on the glacier was the highest and represented the edge of the 1997 winter snowpack (Fig. 8). The youngest of the exposed layers of firn exhibit only subtle differences in discolouration, making the possibility of the edge of a late snowfall being mistaken for the true snowline. At least one glacier (752C/103, Snowy Ck.) had lost its entire winter snowpack with the snowline lying above the glacier.