New Zealand Glacial Snowline Fluctuations

Report of the Survey of Autumn 1992

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BACKGROUND

The very obvious and easily measurable variations of glacier frontal positions have long been documented as indicators of climate fluctuation and change. However the more complex problem of the relationship between climatic parameters and glacier fluctuation has only been addressed at a few selected locations in New Zealand. Detailed mass, water and energy balance studies have been made on the Ivory Glacier, while snout fluctuation studies have in the main been restricted to the Franz Josef Glacier. This glacier is readily accessable as it reaches to an unusually low altitude and it reacts with spectacularly large fluctuations to small variations of climate. Latterly the Franz Josef Glacier has been the subject of a lively debate, carried out in literature, on the relative importance of temperature verses precipitation as the dominant cause of its fluctuations. Restricting studies to a single or only a few glaciers ignores the possibility of significant spatial variations of glacial climates over the Southern Alps.

A glacier inventory has been compiled for the 3153 glaciers of New Zealand, and from this total, some 36 index glaciers have been selected for annual monitoring of end-of-summer snowline elevations. To assist with the compiling of the inventory, a programme was initiated where oblique aerial photographs were taken of the glaciers on annual end-of-summer flights. These surveys provided data for both the inventory and monitored numerous annual changes in the glaciers. The first of these flights was made in 1977, and repeats have been attempted each year since that time, but these have not always been successful. Completion of the surveys has alwas been problematical because of weather and early snowfalls. Theoretically the surveys should be timed just before the first snowfall of winter and made in totally fine weather. The weather is rarely cooperates with these stringent conditions, and although the end of the glacial year occurs about mid April, the survey flights are normally programmed from early march. This year the flight was programmed for the first fine day after the end of February, but an unfortunate series of storms persisted throughout March, and by the time the flight was able to be made over April 6 and 7, new snow obscured most of the glacial snowlines.

THE GLACIAL SNOWLINE

The end-of-summer snowline on a glacier is the maximum elevation reached at the end of summer by the retreating snowpack of the previous winter.(about April). This line marks the location on the glacier where the net balnce is zero, ie where summer snowmelt exactly equals the winter snow gain, and is normally visible as a discoloured line of concentrated dust. The

Although the absolute elevation of any one snowline can be estimated to no better accuracy than about ±50m, the differences in snowline elevation from year to year can be interpolated to within ±5m. The large error in absolute elevation is of small consequence because this project has been designed to compare annual differences in snowlines and hence mass balances.

The mean altitudes of glaciers and their snowlines vary systematically with aspect, with north facing glaciers being some 200m higher than those of a southern aspect. Ideally the snowline elevations should be plotted as departures from the the elevation of the glacier equilibrium line, but this value is either unknown or difficult to obtain. In order to establish a datum from which to compare the results year by year, the unusually comprehensive 1978 dataset was chosen as the "standard equilibrium year". This particular year provided the best quality and coverage of any of the surveys, and the snowline elevations were very close to an "average" year. All results here are compared to the 1978 values.

The year to year range of altitudes recorded differ between different glaciers. These differences are in part a function of glacier morphology, where the larger, steeper glaciers tend to have a greater range of snowline altitudes than the smaller gentler glaciers.

RESULTS

To simpilify comparisons of the data, the figures are grouped into sets, one set for each of the transverse sections (Fig. 1). These sets are followed by annual trend surface maps constructed for each year.

INDIVIDUAL GLACIERS

The estimated snowline elevation departures from the 1978 values are plotted in the histograms of Figs. 2, 5, 6, 9, 10, 13 and 14. Values above 0 are of years where the snowlines have receded up-glacier to higher than average elevations, and are effectively years of negative balance which, if continued, will initiate a recession of the glacier front. Conversely, those years below the 0 line indicate a positive balance and a number of these will produce a glacial advance.

SECTION SNOWLINE ELEVATIONS

Snowline elevation values (uncorrected for aspect) are plotted for each transverse section of index glaciers in Figs 3, 7 and 11. These plots demonstrate the steep 400 m difference in the west - east glacial gradient which parallels the precipitation gradient.

SECTION DEPARTURE VALUES

Elevation departures from the 1978 values are plotted in Figs. 4, 8 and 12. These differentiate the years of high snow accumulation and positive balance (low elevations) and those years of little snow gain (high elevations). Crossed traces indicate deviations from the normal weather

1991. No flight, because of weather and logistics problems.

1992. From the limited number of useful results, indicate another year of massive positive balance, equal to or greater than 1983. Should the next one or two years remain positive balances, this event should send an advance pulse into all glaciers.

SUMMARY

A year by year summary of the means of all values for each year is given in Fig. 27. The histograms indicate the relative health of all observed glaciers at the end of each year. To this must be added the response time for the accumulated effects to appear at the glacier termini. Up until 1982 the glaciers were all generally in a state of recession when the period of positive balances from 1983 to 1985 reversed this trend. At the majority of glaciers, the readvance peaked about 5 years later in 1990. The mass loss to the strongly negative balance of 1991 was offset by the 1992 gain, and in the near future the glaciers may be predicted to maintain their present positions or even show a readvance.

CONCLUSION

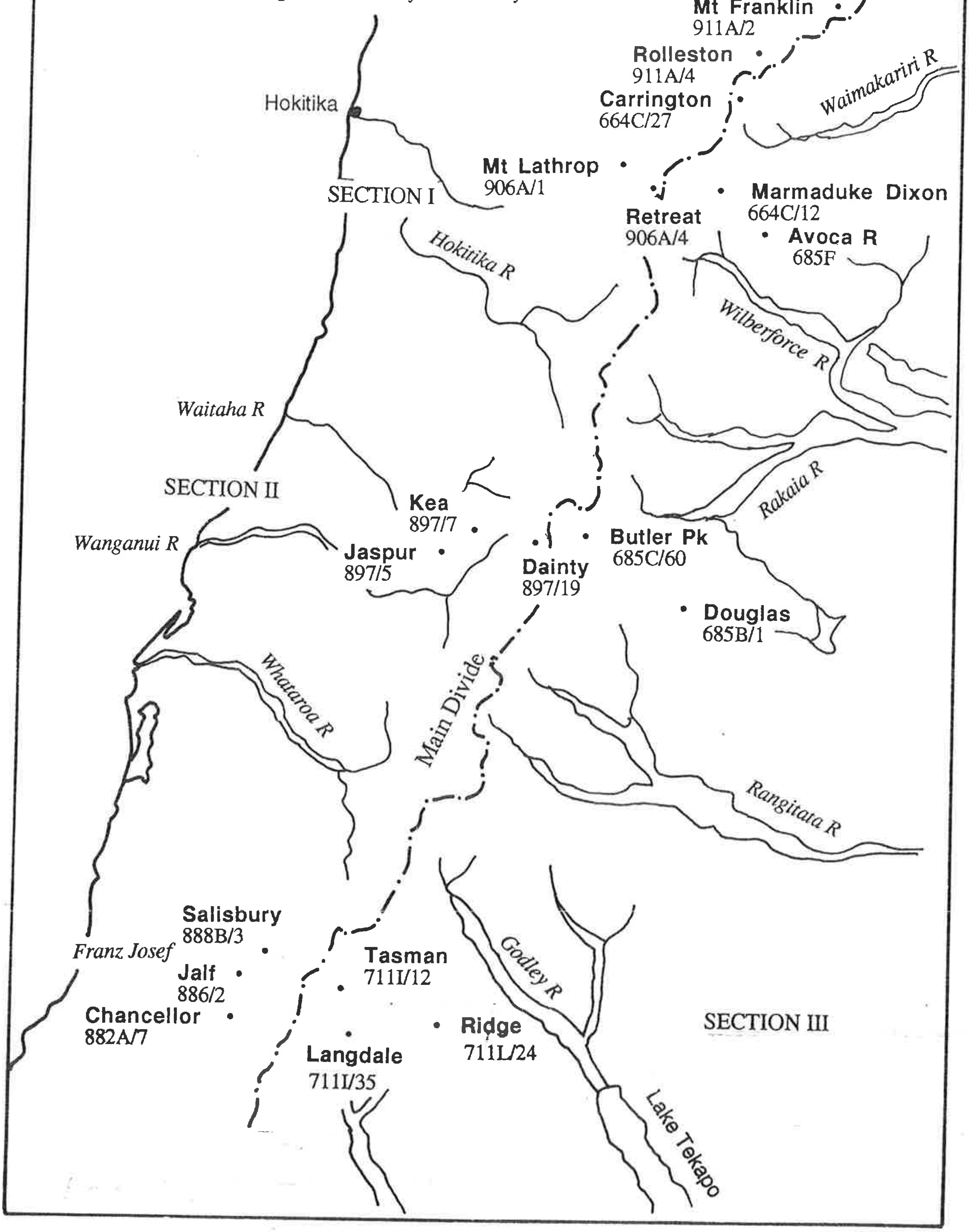
The results of the snowline surveys demonstrate that this programme is an effective method of monitoring climate change. The detailed data gained on alpine climate patterns combined with glacier fluctuation observations is fundamental to interpreting the climates associated with past glacial extents.

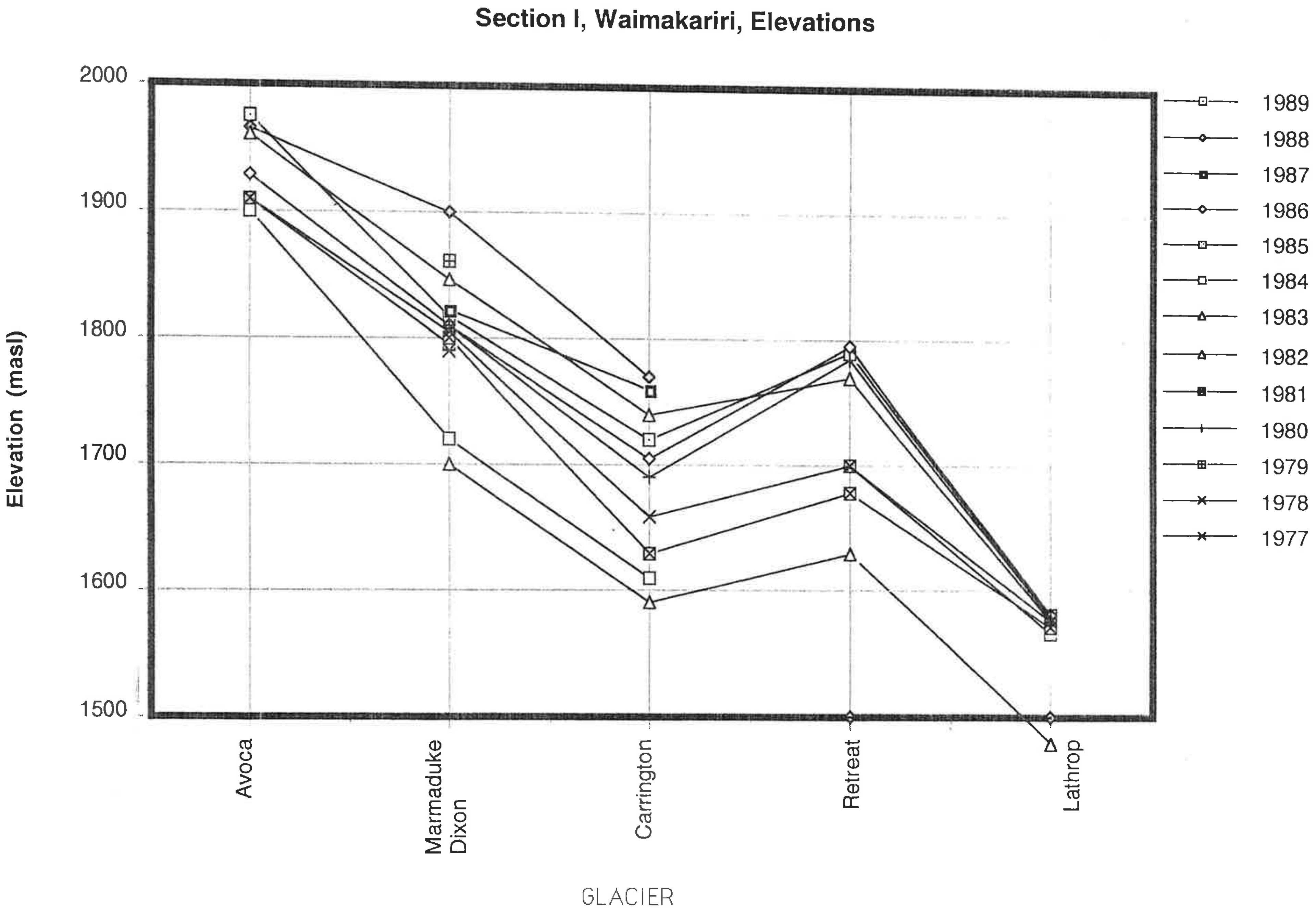
The snowline studies are of basic importance to climate change studies as they makes the connection between glacier snout fluctuations and the climate producing these changes through the glacier system. This connection is most effectively made by modelling selected glaciers and fine tuning the model between the annual budgets gained from the snowline data, and the glacier responses measured as fluctuations of the terminus.

INDEX GLACIER SNOWLINE ELEVATIONS, NORTHERN SECTION

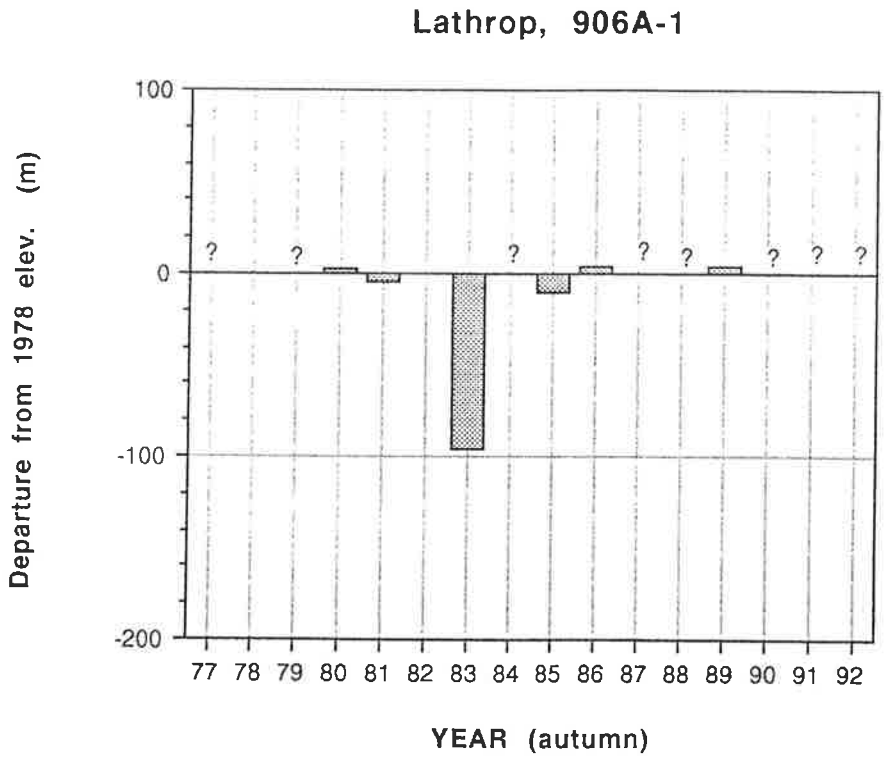
INDEX GLACIER LOCATION MAP

Numbers are from the glacier inventory reference system

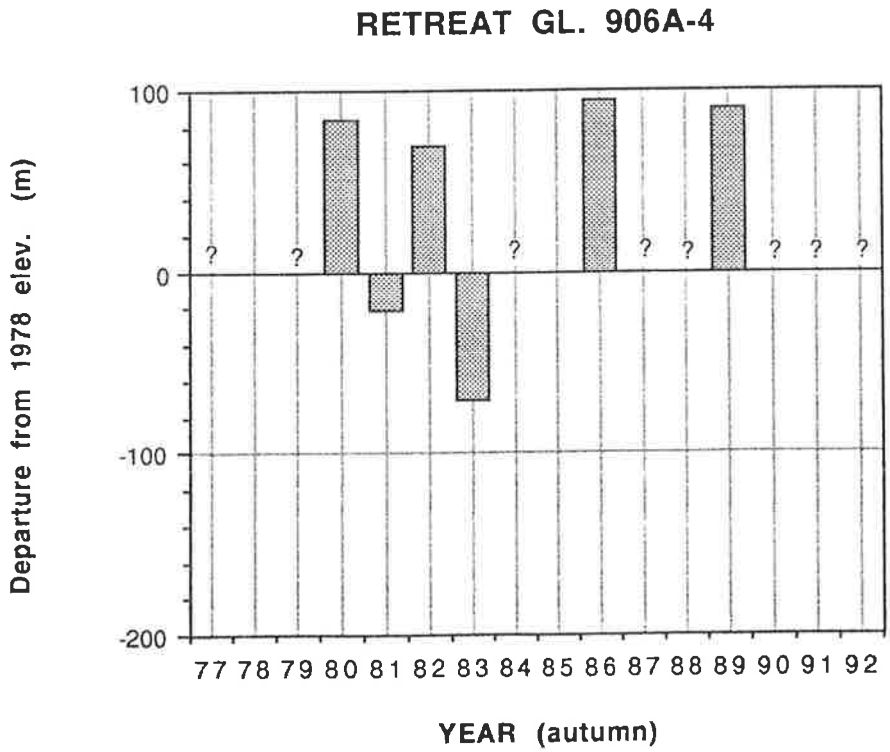




Section I, Waimakariri, Elevations
Elevation (masl)
2000
1900
1800
1700
1600
1500
Avoca
Marmaduke Dixon
Carrington
Retreat
Lathrop
GLACIER
1989
1988
1987
1986
1985
1984
1983
1982
1981
1980
1979
1978
1977



Lathrop, 906A-1
100
0
-100
-200
Departure from 1978 elev. (m)
?
77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92
YEAR (autumn)



RETREAT GL. 906A-4
100
0
-100
-200
Departure from 1978 elev. (m)
?
77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92
YEAR (autumn)

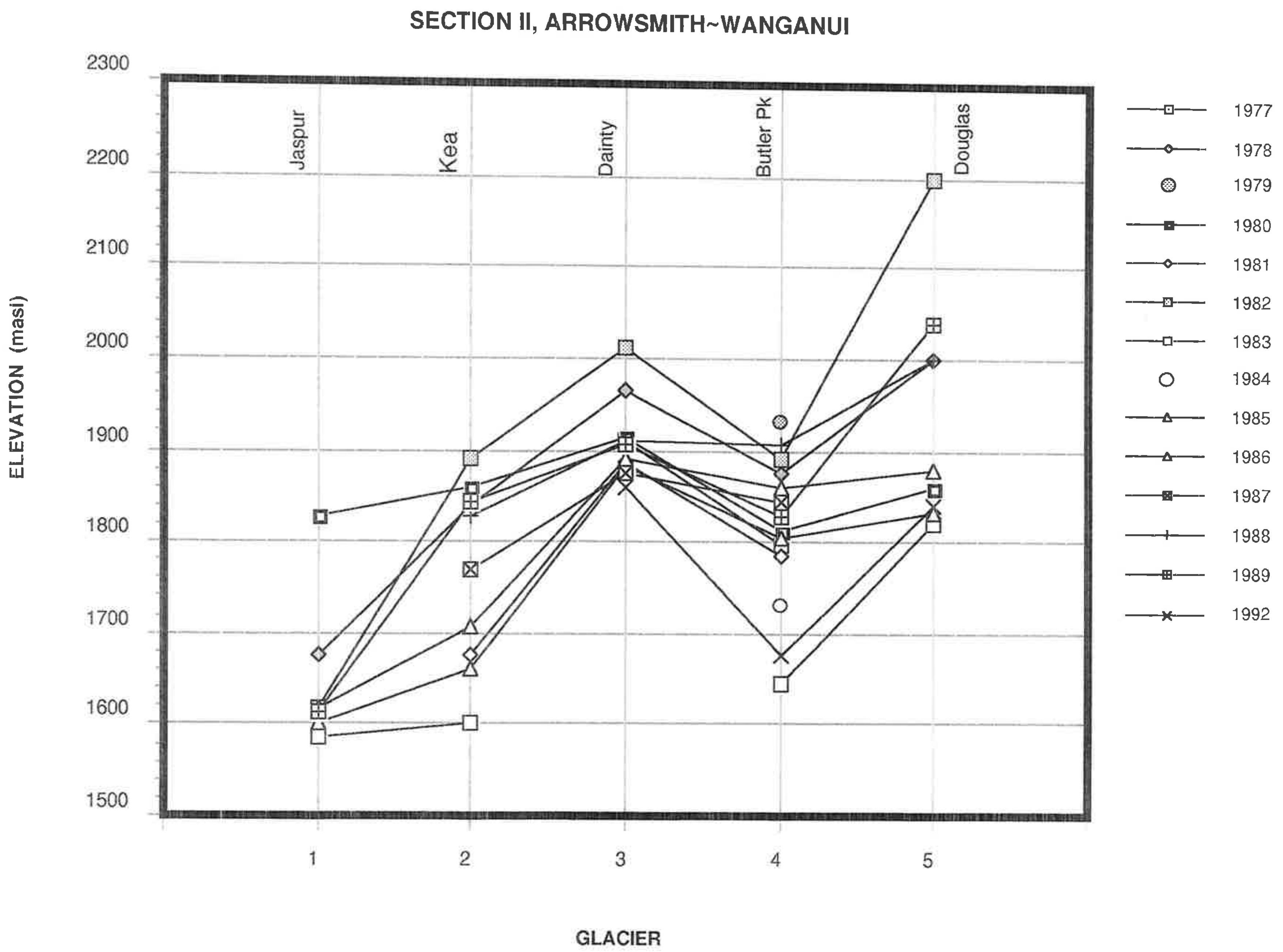


Figure 7. Snowline elevations, Section II, Arrowsmith~Wanganui.

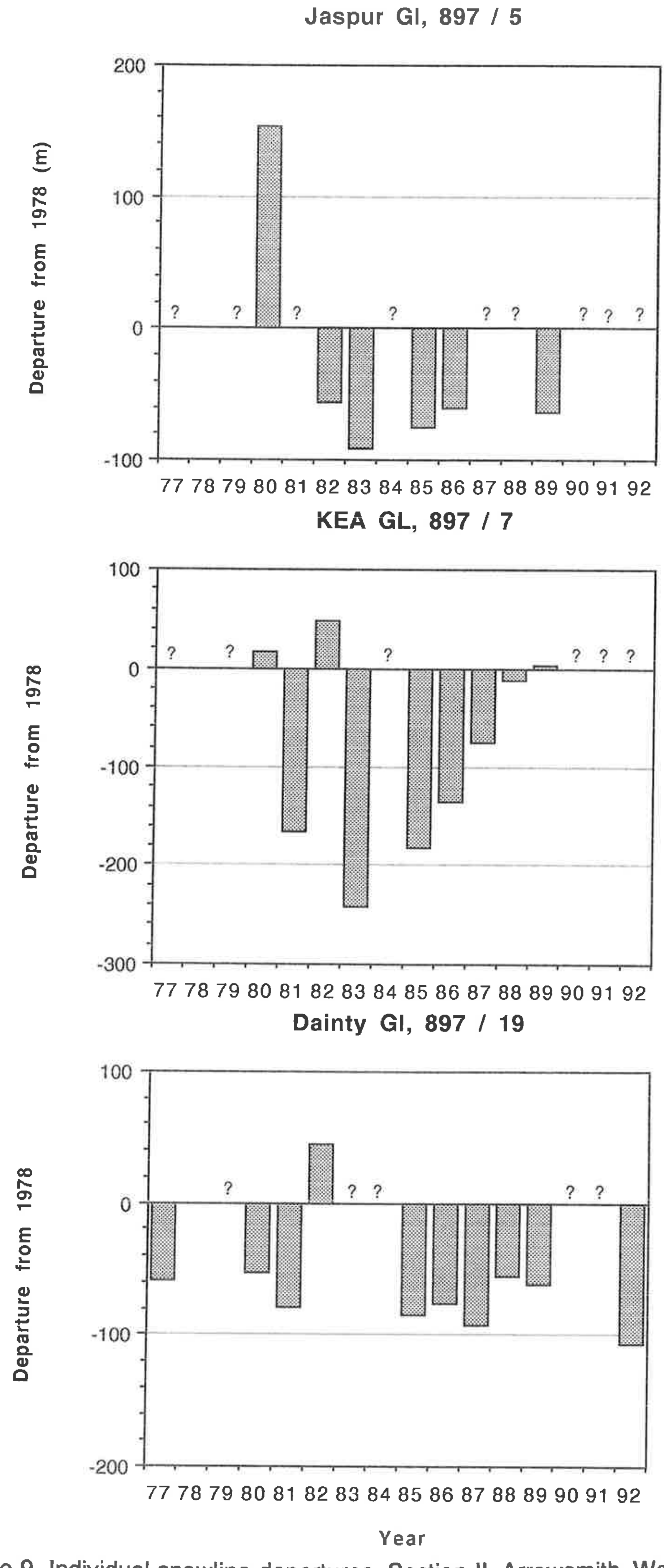


Figure 9. Individual snowline departures, Section II, Arrowsmith~Wanganui.

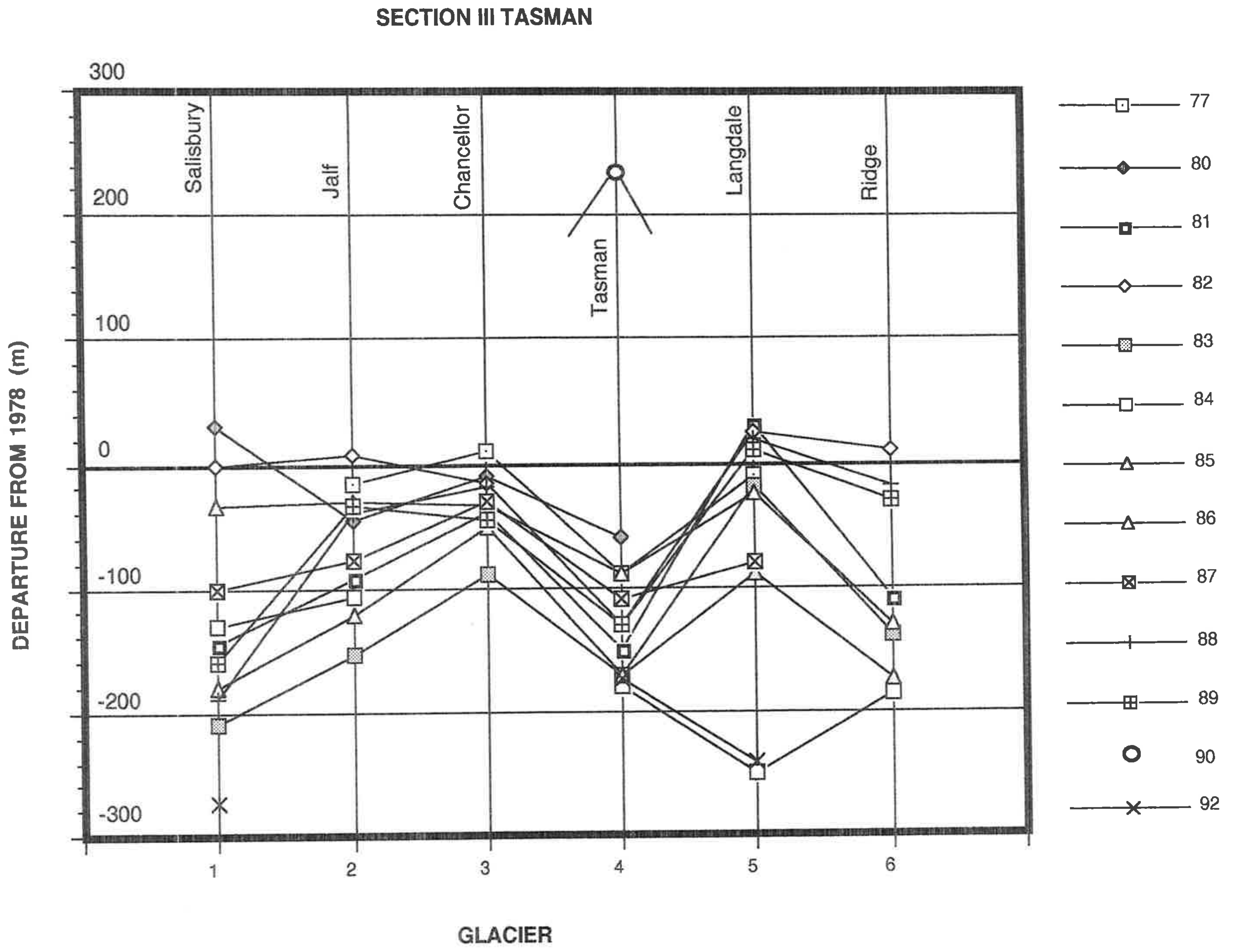
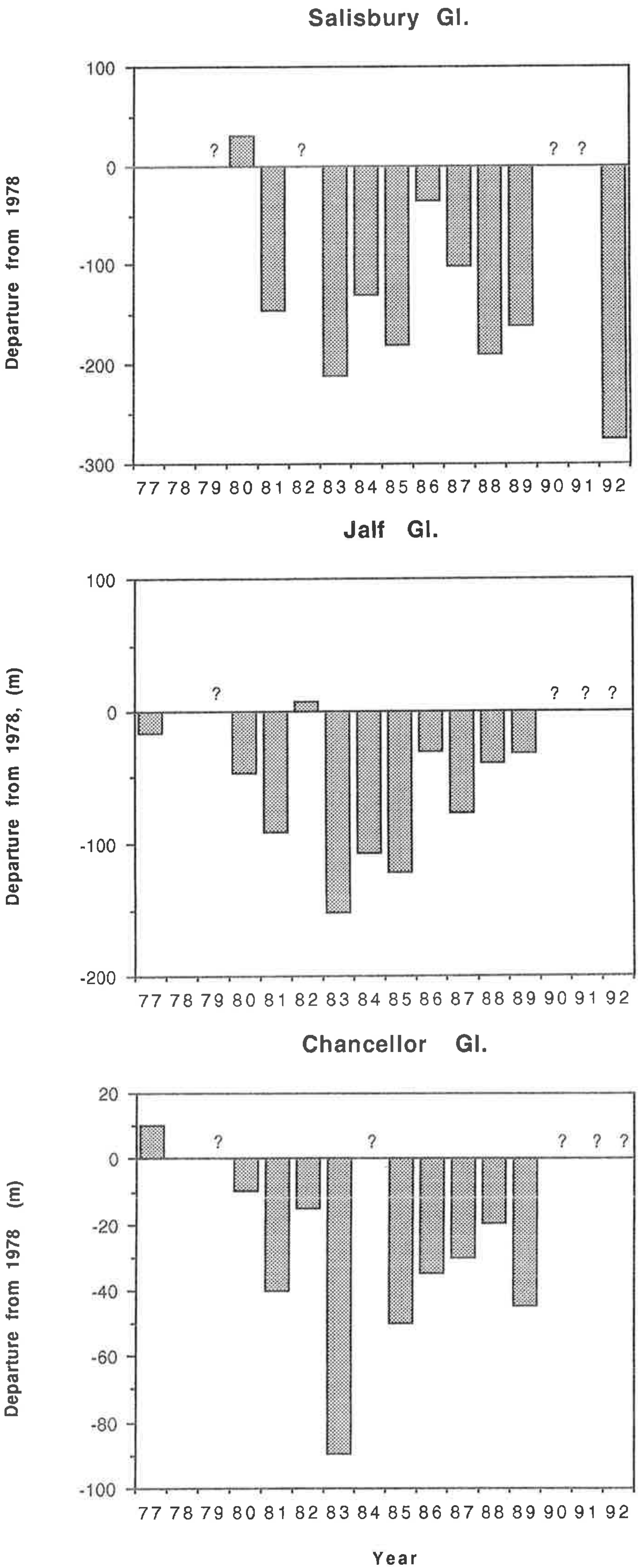


Figure 11. Snowline elevations, Section III, Tasman.

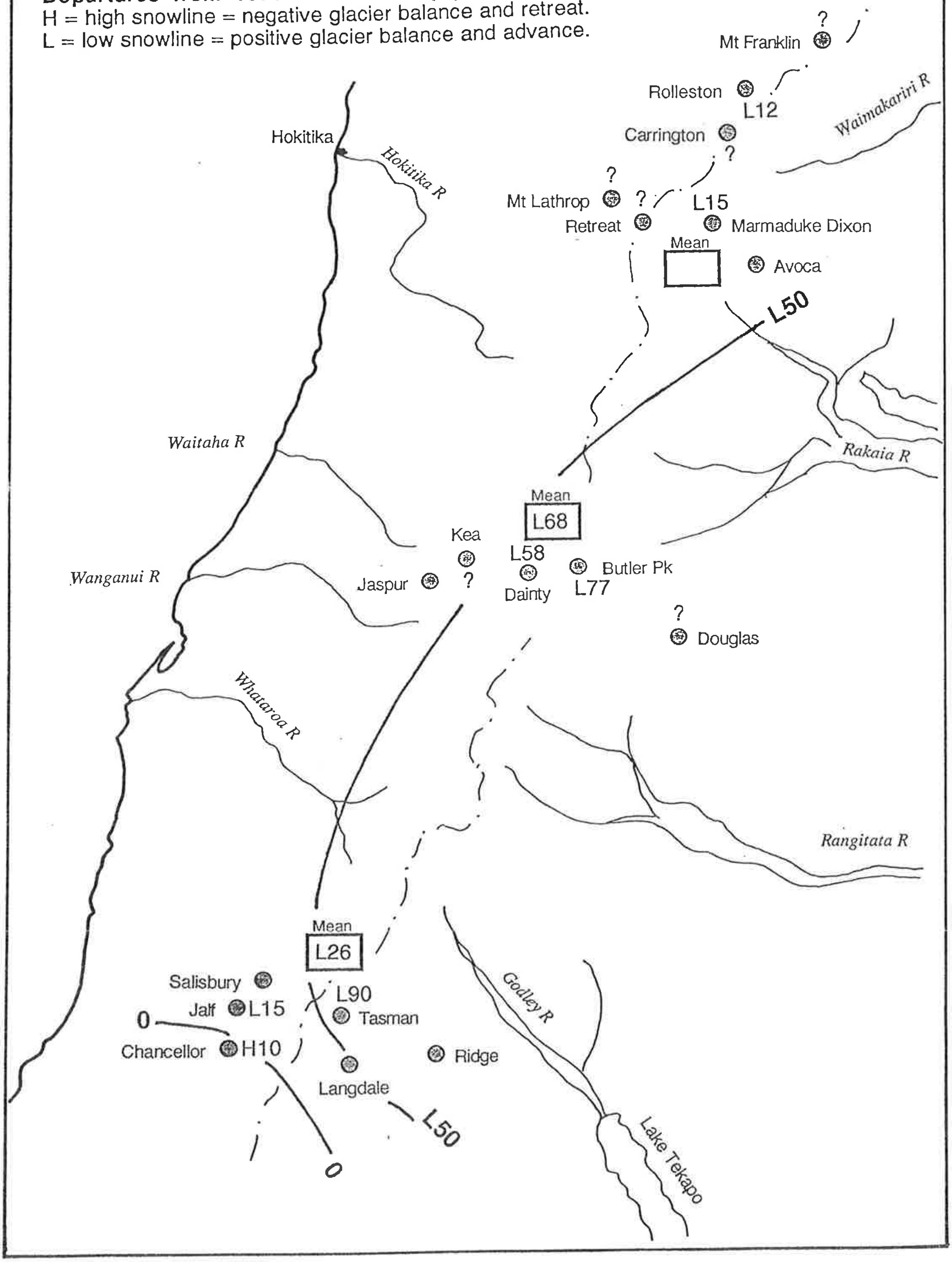


Salisbury Gl.
Departure from 1978
100
0
-100
-200
-300
?
?
? ?
77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92
Jalf Gl.
Departure from 1978, (m)
100
0
-100
-200
?
? ? ?
77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92
Chancellor Gl.
Departure from 1978 (m)
20
0
-20
-40
-60
-80
-100
?
?
? ? ?
77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92
Year

Figure 13.

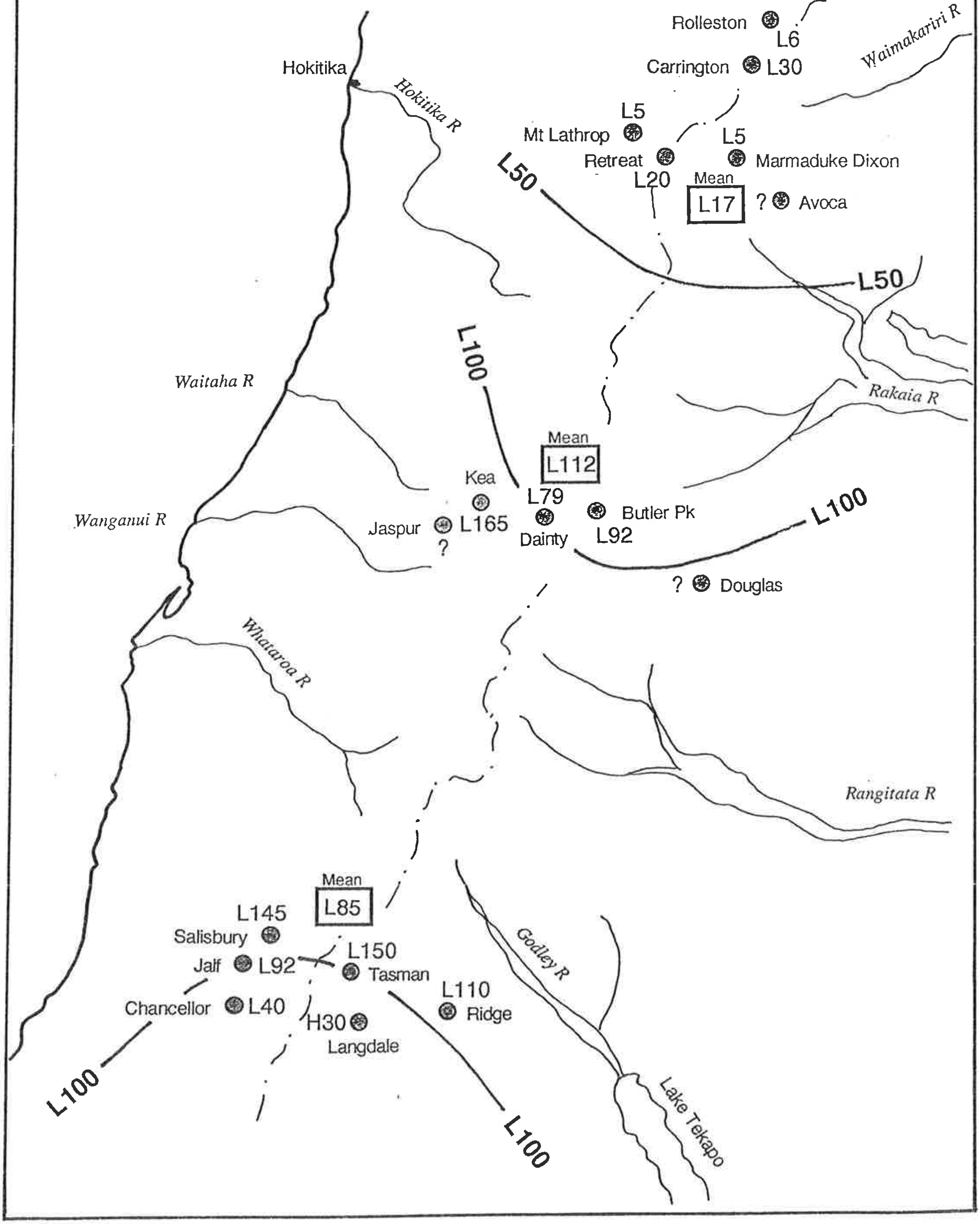
INDEX GLACIER SNOWLINE ELEVATIONS, 1977
NORTHERN SECTION

Departures from 1978 elevations (m)
H = high snowline = negative glacier balance and retreat.
L = low snowline = positive glacier balance and advance.



INDEX GLACIER SNOWLINE ELEVATIONS, 1981
NORTHERN SECTION

Departures from 1978 elevations (m)
H = high snowline = negative glacier balance and retreat.
L = low snowline = positive glacier balance and advance.



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NORTHERN SECTION

Departures from 1978 elevations (m)
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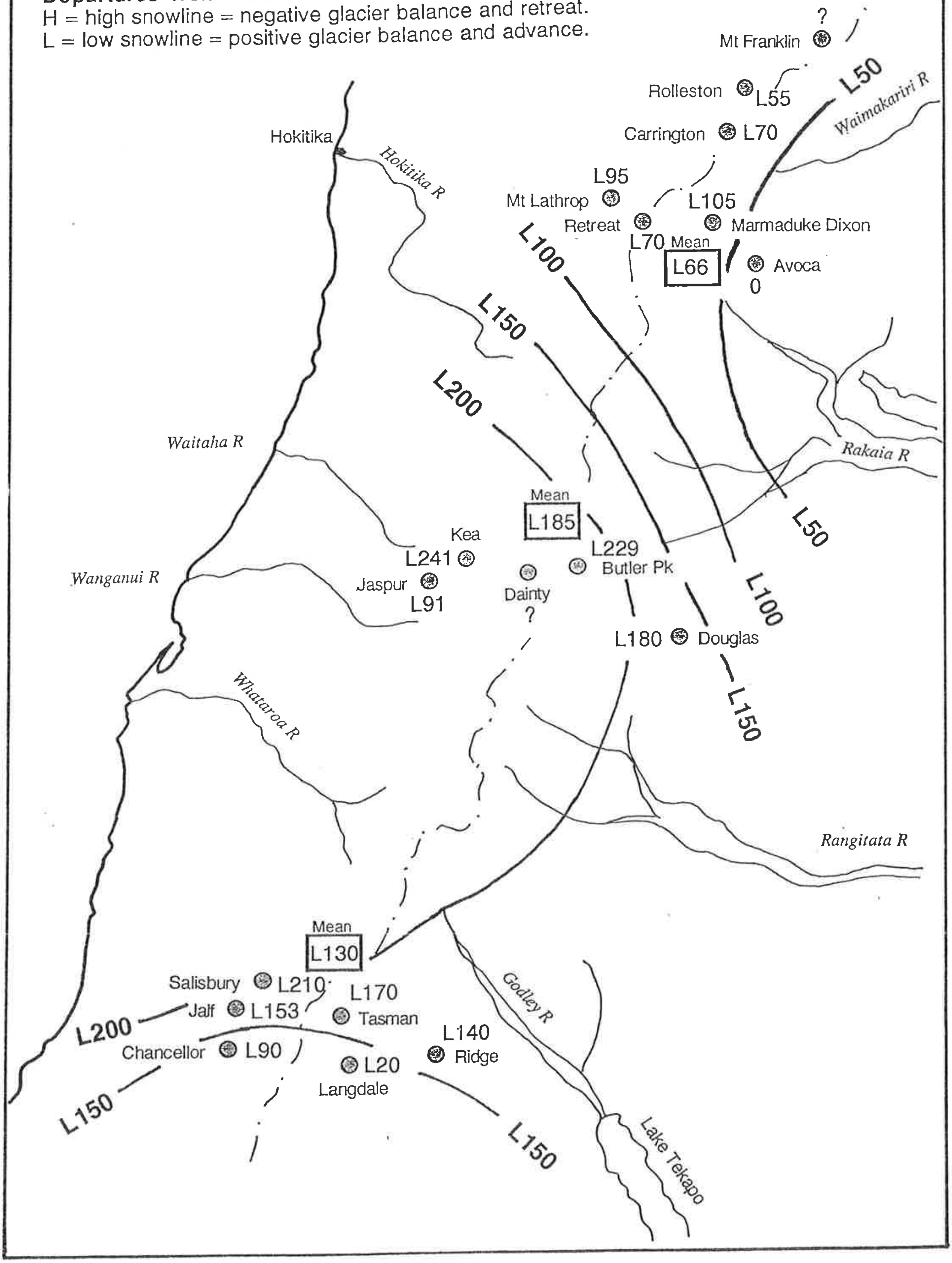
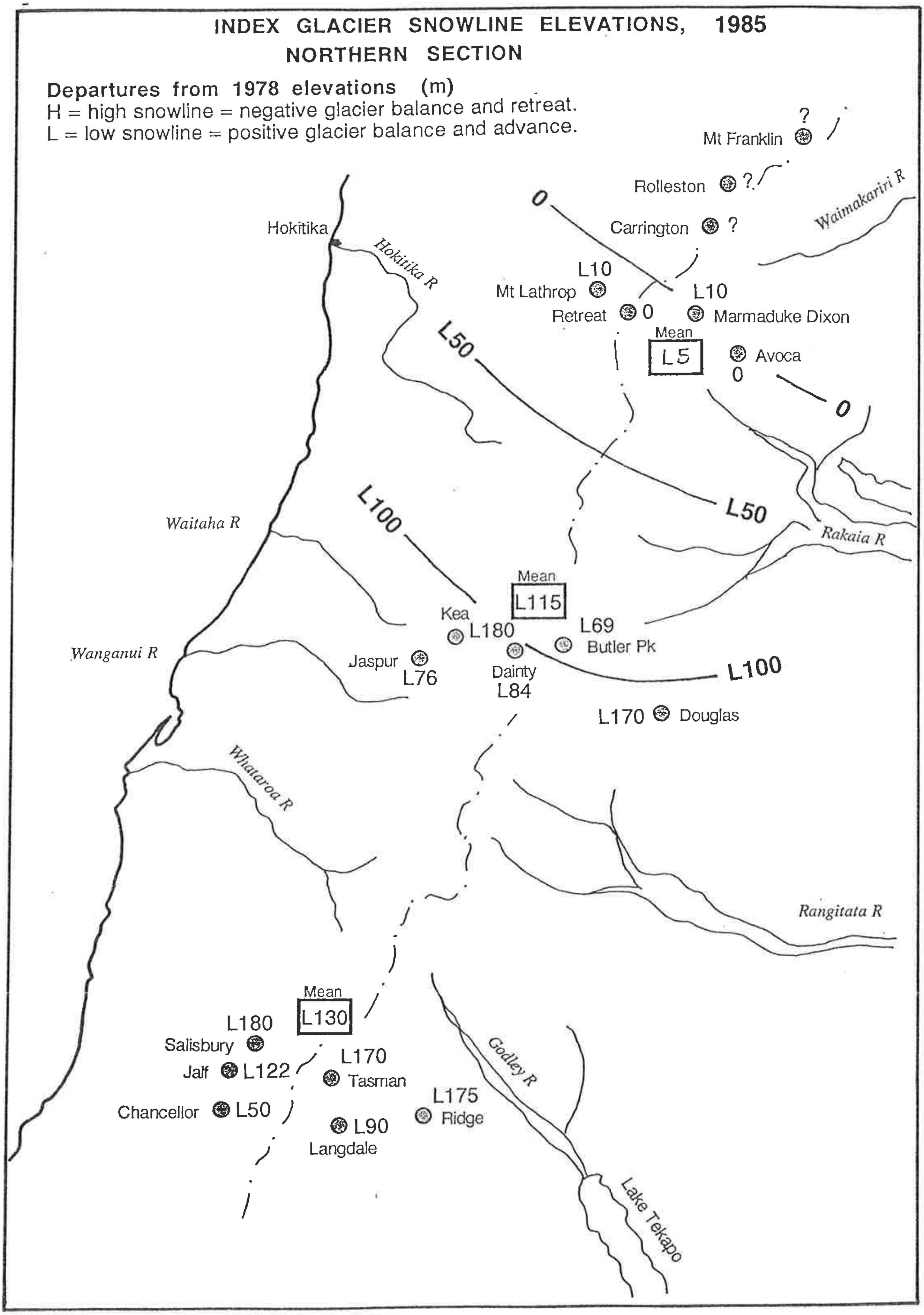
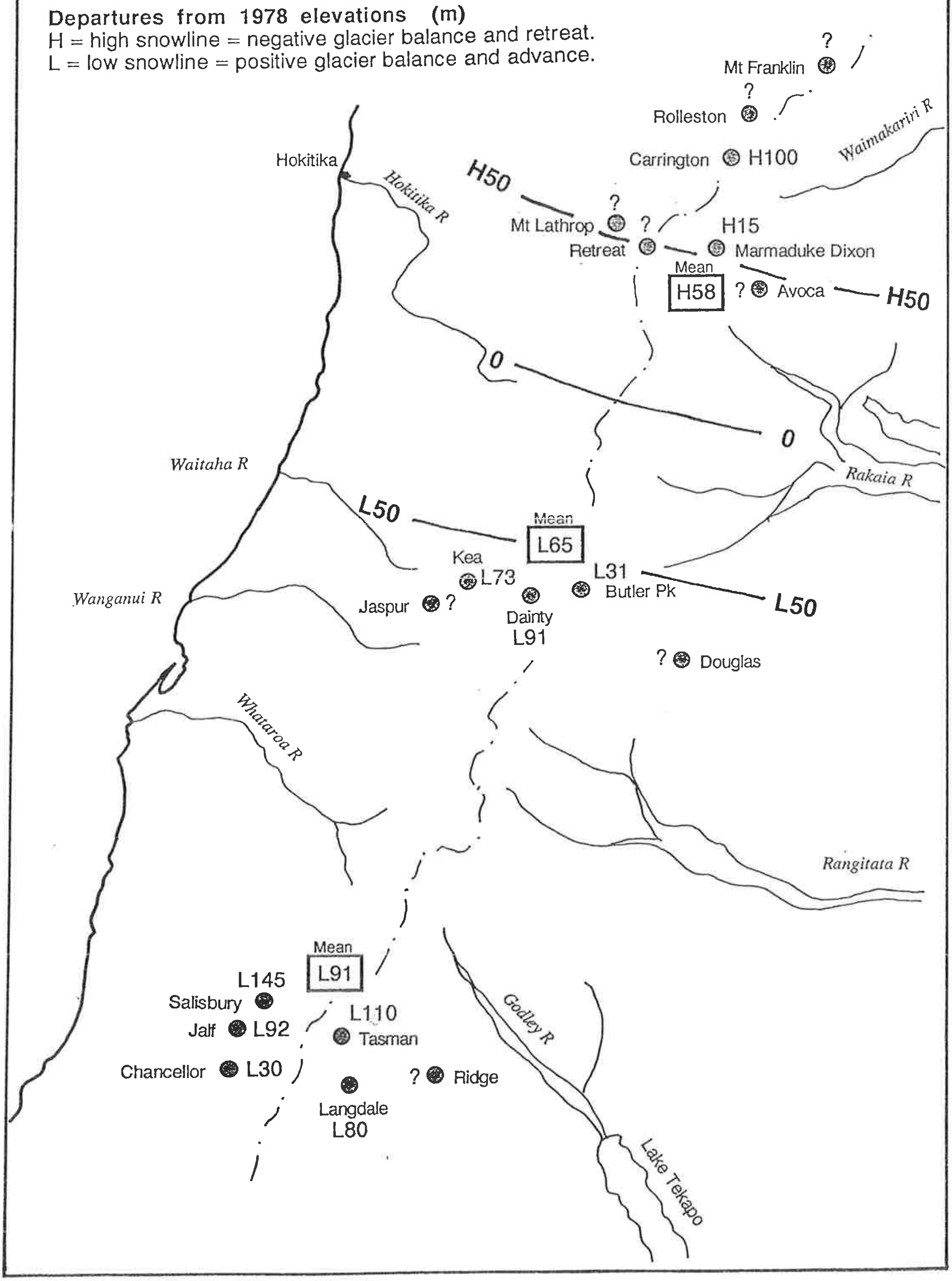
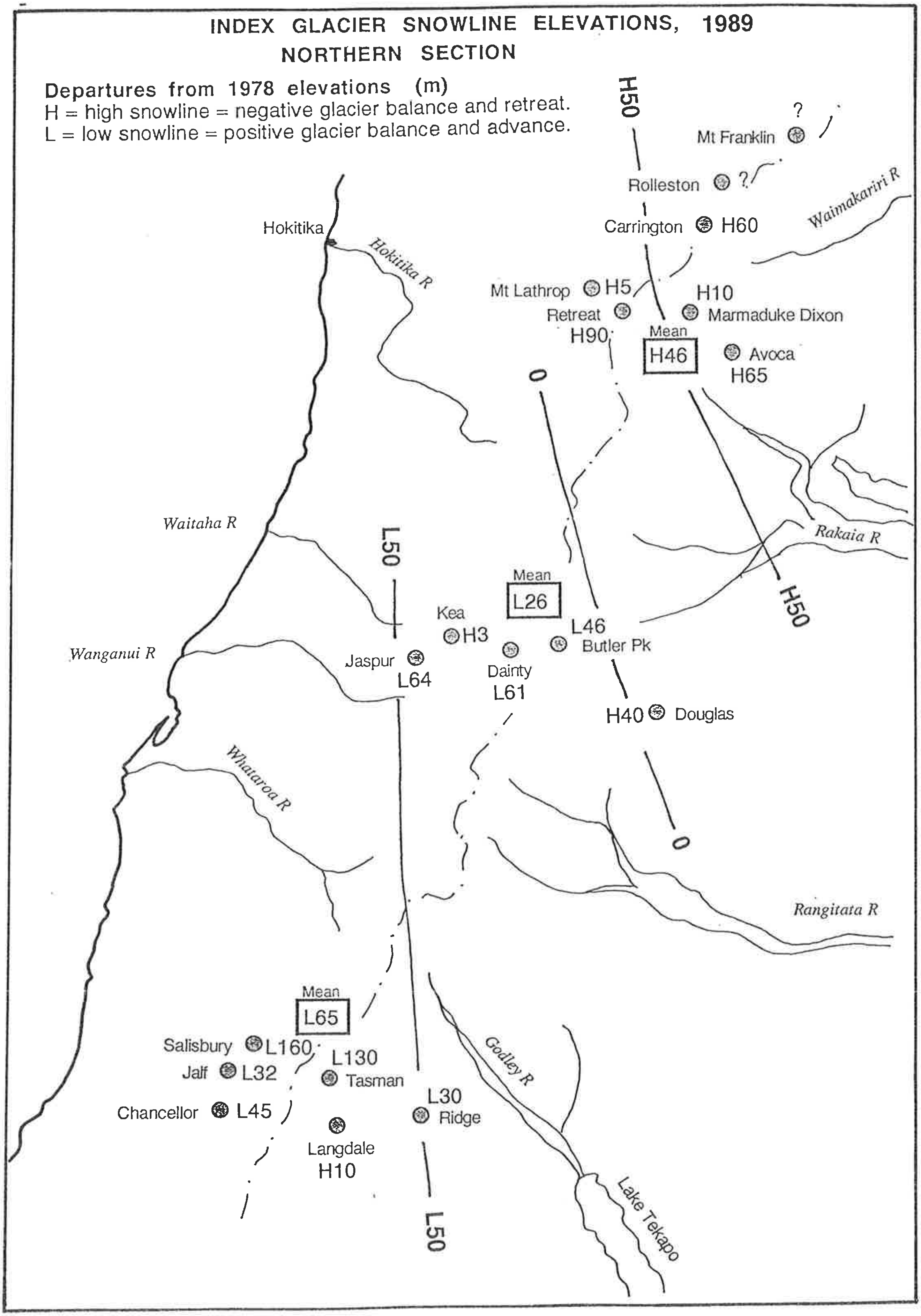
L = low snowline = positive glacier balance and advance.




INDEX GLACIER SNOWLINE ELEVATIONS, 1985
NORTHERN SECTION
Departures from 1978 elevations (m)
H = high snowline = negative glacier balance and retreat.
L = low snowline = positive glacier balance and advance.
Mt Franklin ?
Rolleston ?
Carrington ?
Waimakariri R
Hokitika
Hokitika R
0
L10
Mt Lathrop
Retreat 0
L10
Marmaduke Dixon
Mean
L5
Avoca
0
0
L50
L50
L100
Waitaha R
Rakaia R
Mean
L115
Kea
L180
L69
Butler Pk
Jaspur
L76
Dainty
L84
L100
L170
Douglas
Wanganui R
Whataroa R
Rangitata R
Mean
L130
L180
Salisbury
Jalf L122
L170
Tasman
Chancellor L50
L90
Langdale
L175
Ridge
Godley R
Lake Tekapo

INDEX GLACIER SNOWLINE ELEVATIONS, 1987
NORTHERN SECTION




INDEX GLACIER SNOWLINE ELEVATIONS, 1989
NORTHERN SECTION
Departures from 1978 elevations (m)
H = high snowline = negative glacier balance and retreat.
L = low snowline = positive glacier balance and advance.
H50
?
Mt Franklin
Rolleston
?
Waimakariri R
Hokitika
Hokitika R
Carrington
H60
Mt Lathrop
H5
H10
Retreat
Marmaduke Dixon
H90
Mean
H46
Avoca
H65
0
Waitaha R
L50
Rakaia R
Mean
L26
H50
Kea
H3
L46
Butler Pk
Wanganui R
Jaspur
L64
Dainty
L61
H40
Douglas
Whataroa R
0
Rangitata R
Mean
L65
Salisbury
L160
L130
Jalf
L32
Tasman
Godley R
L30
Chancellor
L45
Ridge
Langdale
H10
Lake Tekapo
L50

25

Annual mean variations