New Zealand Glacier Monitoring: End of summer snowline survey 2019

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Prepared by:
A. Willsman
G. Macara

For any information regarding this report please contact:

Andrew Willsman
Team Leader
Dunedin Field Team
+64-3-471 7765

National Institute of Water & Atmospheric Research Ltd
PO Box 6414
Dunedin 9016

Phone +64 3 477 8615

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	Formatting checked by:	Rachel Wright
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Photograph: Barrier Peak Glacier, Fiordland, 20 March 2019 (A.Lorrey)

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Executive summary

New Zealand glaciers respond to a changing and variable climate. The NIWA End of Summer Snowline (EOSS) uses aerial oblique photographs from a light aircraft to document 50 index glaciers and snowline altitudes at the end of summer. The absolute and relative positions of the snowline over each index glacier are documented, and this provides a proxy for the equilibrium line altitude (ELA) that helps to control ice gain and loss. The long time series of glacier photos and these data let us examine glacier-climate interactions back to 1977, and they provide a surrogate for annual glacier mass-balance.

The EOSS mission has been completed in most years since 1977, but rarely do weather conditions during the flight permit all 50 of the index glaciers to be surveyed each year. For the 2019 mission, 46 of the 50 index glaciers were visited and 35 glaciers were used for snowline elevation calculations. Seven glaciers could not be used because the summer snowline elevation projected above the highest elevation of permanent ice and firn. Four of the smaller index glaciers have now lost such significant amounts of permanent ice and are so fragmented that they are no longer usable for the EOSS mission.

On average, the latest survey of index glaciers suggest a large negative glacier mass balance during the 2018/19 glacier hydrological year (March 2018/April 2019[AL1]). The 2018/19 estimate for negative glacier mass balance is the second largest estimated from the 43-year record of snowline survey, and is only slightly less than the largest negative glacier mass balance estimate for the previous 2017/18 glacier year. The snowlines (as a proxy for the ELAs) on all the index glaciers in March 2019 were located at either the highest elevations on the glaciers, or were completely above the maximum elevation of many smaller glaciers exposing ice or firn accumulation from previous winters.

The glacier hydrological year was warmer and drier than usual across the Southern Alps. The winter and spring period were very dry, and temperatures were warmer than usual from July to October. It is likely that snow accumulation in alpine areas was relatively reduced as a result of these seasonal climate conditions. December, January and March were very warm months, and December was very dry. It is likely that ablation would have been higher than normal during this period. Based on the climate summary information, the snowfall input for 2018/19 has been estimated as extremely low.

The large negative mass balance estimate for 2018/19 is part of a 14-year trend of predominantly negative mass balance years, with no intervening years characterised by a large positive gain in snow and ice. This year is the second largest mass balance loss in this 14-year period, and it is also the second largest single loss since the survey began in 1977. This 14-year negative trend is visible in aerial photographs as reductions in permanent ice areas around the entire margin of many index glaciers, and fragmentation of previously continuous ice into smaller discrete areas[AL2].

Over the 43-year monitoring period there have been 17 years with average snowline departures above the equilibrium altitude (implying negative mass balance). Conversely, there are 26 years of averaged snowline departures below the equilibrium altitude (implying positive mass balance). Even though the apparent number of years with lower snowlines are greater than higher snowlines, there has not been an overall gain in ice at the index glaciers. Instead we have observed loss of ice, corresponding to large negative mass balance years, which has not been replaced during the positive mass balance years. All 50 index glaciers have thinned and/or have lost permanent ice area over the period of observation.

1 Introduction

The results presented in this report continue an annual glacier/climate photographic monitoring programme, begun in 1977, of the position (altitude) of the end-of-summer snowline on 50 selected index glaciers, arranged in several transects across the Southern Alps (see Figure 1-1).

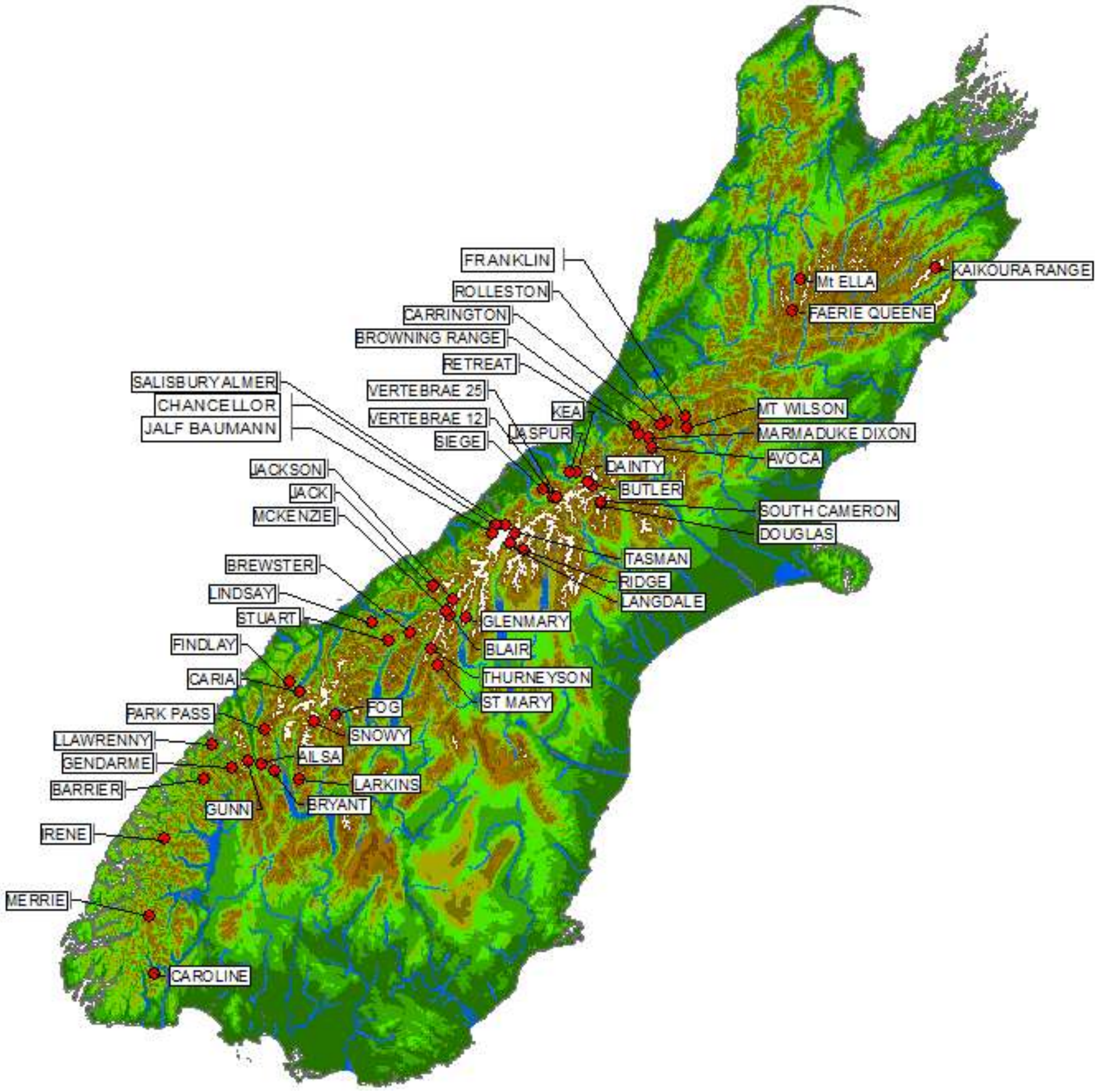

Figure 1-1: Location of the 50 index glaciers across the South Island of New Zealand.

Between 1977 and 1985, a New Zealand glacier inventory was undertaken from Mount Ruapehu in the North Island at 39° 15' S to southern Fiordland at 45° 57' S (Chinn, 2001). A total of 3144 glaciers were identified for the inventory, where a glacier was defined as a permanent area of snow greater than 0.01 km^2 (one hectare). In the South Island, average peak summits range from 1850 m in Fiordland to 3000 m in the central Southern Alps and descend to 2000 m in the north-central Southern Alps. To the north east, the Kaikoura ranges reach to over 2700 m, where active rock glaciers have developed under the relatively dry climate. Three North Island volcanic cones reach close to the permanent snowline, but only Mount Ruapehu, with a summit at 2752 m, supports glaciers. Logistics of the glacier flights do not currently allow the North Island region to be included in annual surveys because of the distances involved.

New Zealand has a humid maritime climate, with the Southern Alps lying across the path of the 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 to about 1000 mm in the eastern ranges over less than 30 km from the divide. This creates a steep west-east precipitation gradient across the Southern Alps, and the mean altitude of the glaciers closely follows this gradient (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 indicators of the Earth's surface energy balance. Glaciers register distinct signals of past climate change on scales from decades to millennia. Atmospheric changes are signalled by direct, immediate changes in annual mass balance, which are filtered, and smoothed before they become apparent at the glacier front. Glacier snowline altitudes provide a direct value for annual glacier health and balance. Changes indicated by glacier frontal positions are strongly modulated by glacier response times and dynamics related to climate variability, so determination of annual glacier change using frontal positions is problematic.

1.2 The Equilibrium Line Altitude (ELA)

The winter snowpack normally covers the entire glacier in a wedge-shaped profile, with the greatest snow depths near the highest altitudes, tapering to zero at the lower edge (Figure 1-2). This lower margin, or transient snowline, of the snowpack retreats up-glacier as summer melt progresses, until it reaches a maximum altitude for the year at the end of summer (March - April). Located somewhere near the mid-point of the glacier, the end-of-summer snowline indicates where snowfall exactly equals snow loss over the past glacial year (Figure 1-2). This line of demarcation aligns to the equilibrium line altitude (ELA; Meier and Post, 1962), and it is normally visible as a contrast on the glacier surface between discoloured dust on firn (below the equilibrium line) and the clean snow of the previous winter (above the equilibrium line). The ELA is approximated each year by the snowline survey. The higher the altitude of the estimated ELA, based on the end of summer snowline, the less the amount of winter snow remaining to contribute to long term glacial ice after summer melt, indicating a lower mass balance. Conversely, a lower altitude for the estimated annual ELA indicates a large amount of winter snow remained at the end of summer and a positive mass balance. It follows that there is a unique position for the ELA across the glacier where the volume of snow accumulated over the past year exactly balances the total volume of snow and ice lost during the year. If the ELA were to lie at (or maintain an average of) this altitude for many years, then there would be no change to the mass or size of the glacier (assuming no other processes are involved, e.g., ice-margin lake development and calving). This unique position of the snowline and ELA, which indicates that the glacier is in equilibrium with the climate, is defined as the steady-state Equilibrium Line Altitude (ELAo). A snowline aligned to this altitude will indicate zero change to the balance of the glacier. To avoid confusion between the annual and the long-term ELAs, some authors have also referred to the altitude of the annual glacier snowline as the end-of-summer snowline or EOSS.

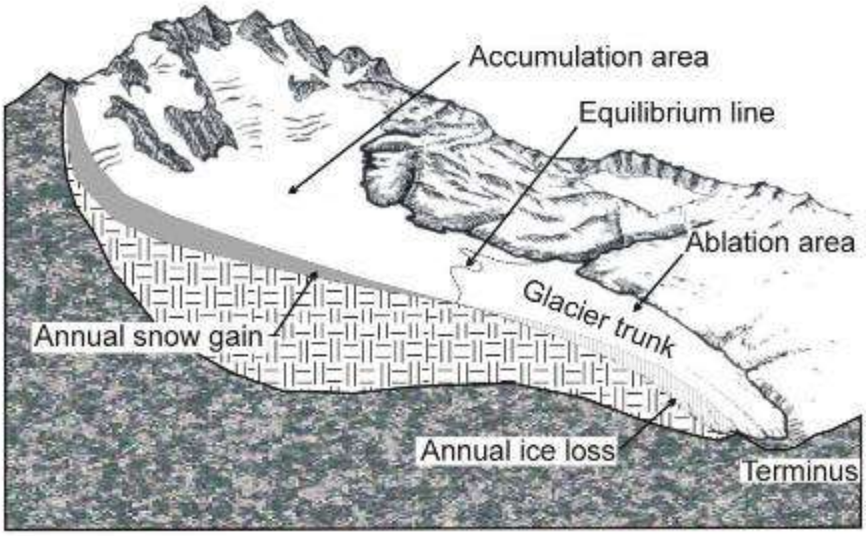

Figure 1-2: Basic parameters of a glacier.

A shift in climate can change the glacier mass balance and alter the altitude of the annual ELA. Thus the annual snowline position with respect to the long-term average or steady-state ELAo (see section 3) is used as a surrogate for annual mass balance changes at each glacier (Chinn 2005, Chinn 1995). It is the departure of the glacier snowline from the steady-state ELAo, ie., ELAo - ELA that is reported here. These ELA departure values provide a measure of mass balance changes.

Glacier studies worldwide (e.g., Haeberli et al. 2007) have demonstrated that, on average, the accumulation area is about twice that of the ablation area so that the ELAo lies at an altitude where the ratio of the accumulation area (AAR) to the total glacier area has an average value close to 0.66. For this programme, the steady-state ELAo was initially estimated using AAR values of 0.66 for each glacier, then, as more ELA data were obtained, these approximate values have been progressively adjusted for most index glaciers as outlined in Section 3 below.

2 Field methods

Collection of field data involves flying over the glaciers in a light aircraft to take oblique photographs of the position of the end-of-summer glacier snowlines. A GPS with waypoints has been used since 2007 and this has ensured that the oblique photographs have been taken from a similar position every time. It is worth noting here that the GPS waypoints are not of the glacier snow line itself, but the position in the air above the glacier, to achieve the same oblique photo. The snowlines visible on the photographs have historically been sketched on to a map of each glacier and the resulting accumulation or ablation areas are mapped and measured by digitisation. Since 2008 the area interpretation has been done for selected glaciers by digitally rectifying the oblique photos then mapping the accumulation or ablation areas. The 'snowline altitude' can then be accurately assessed from the glacier area-altitude curve or directly from a digital elevation model.

2.1 The survey flights

On the flights, the "navigator" seated beside the pilot, holds a folder of photographs of each glacier. These photographs are used to closely duplicate the position from where previous photographs were taken. Photographs are taken by small- and medium-format SLR cameras, and since the 2001 flight, by digital SLR cameras. Data on selected glacier termini, geomorphic features, such as moraines and supra-glacial lakes, are recorded in addition to the index glacier end of summer snowlines. The flights are generally flown between 9,000 ft. (2,700 m) and 10,000 ft. (3,000 m). The upper limit is determined by civil aviation regulations.

Significant snow melt continues throughout February and March, but by April there is a high probability that the first winter snowfall in the Southern Alps will have occurred. Experience has shown that although successful surveys have been made in April, there is about a 1 in 4 probability of a snowfall before this time. Every year the challenge of the survey is to measure the highest altitude reached by the rise of the glacier snowline as ablation losses precede, before the first "winter" snowfall. A light fall of fresh snow will conceal the position of the snowline as effectively as a coat of paint. The problem has been standardised by setting the earliest date for the flight at March 1. Appendix B lists the dates that the annual survey flights were conducted on from the start of the survey in 1977.

A successful survey cannot be guaranteed as there is also a 1 in 10 probability that there will be no suitable flying weather in the month of March before a fresh snowfall occurs because of the prevailing westerly circulation.

As well, 'suitable' weather to fly the entire Southern Alps demands particularly settled cloud free conditions.

2.2 March 2019 fieldwork details

Coordination of the field work was done by Andrew Lorrey, and Brian Anderson of Victoria University.

An additional continuing objective of this year's field work was to continue to collect more photographs of specific glaciers for a Victoria University study using the Structure from Motion technique to develop digital elevation models (Vargo, et. al., 2017). This project had started in 2015, and collecting large numbers of photographs of individual glaciers while circling above with a georeferenced camera. In addition, it was the second year the EOSS flight utilised a FLIR thermal image camera, and the first year with a modified multispectral image camera onboard.

Prior to the survey starting on 20 March, two cooler southerly frontal systems moved up the Southern Alps. The cold fronts on 7 and 13 March bought some precipitation and lower temperatures in the mountains with possibly a light dusting of snow at higher elevations. After 14 March there was a switch to warmer northerly conditions with a small amount of light northerly precipitation on 15 and 18 March.

An anticyclone moved over the South Island on 19 March bringing settled cloud free weather. The forecast was for a NW system to build from late on 22 March so the decision was made to complete the flight on 20 and 21 March.

On Wednesday 20 March the first leg of the two-day survey flight departed from Queenstown at 10:00 a.m. in a Milford Sound Flights Cessna 208B Caravan piloted by Aaron Duff and co-piloted by Andy Woods with Andrew Lorrey, Gregor Macara, Brian Anderson, Lauren Vargo, and Oliver Wigmore on board. The flight headed south with low valley cloud present below the level of the glaciers and clear cloud free conditions above. The route went south via Mt Larkins, Bryant Glacier, Ailsa Gunn, Genderme, and Llawrenny Peaks. Then the flight continued south past Barrier Peak then to Mt Irene in central Fiordland. From here the flight went north to the Park Pass and Findlay Glaciers then continued to Wanaka via the glaciers in the Arawhata and Matukituki area. Snowlines were clear and visible at the top of the neves on the larger index glaciers although it was apparent that the snowline was above the maximum elevation of some smaller index glaciers as only firn and ice was left exposed on these. A lunch break and refuel stop was had in Wanaka.

After the break at 2:00 p.m. the second leg of the day continued north to the Brewster, Stuart and Lindsay Glaciers in the Haast region, then on up the Landsborough Valley to the Jack Glacier on Mt Hooker then Jackson Glacier on the eastern side of the valley. The flight continued north on the western side of the Divide photographing the Fox, Franz, Jalf, and Salisbury Glaciers. From there it crossed into the Tasman valley photographing the Tasman, Langdale and Ridge Glaciers. The team then returned south to Queenstown down the eastern side of the Divide via the Ohau Glaciers, then Thurneyson Glacier.

On Thursday 21 March the same plane and crew left Queenstown at 9:00 a.m. and flew north to the Brewster Glacier where five circles were completed to capture photographs from all angles for the Structure from Motion project. Thermal images were also captured for Brewster and Rolleston. The flight continued north up the Landsborough Valley crossing to the east of the Divide into the upper Dobson Valley then across the Ben Ohau Range to the glacier on Nuns Veil in the lower Tasman Valley. A circle was completed around Nuns Veil then the flight stayed east of the Divide into the upper Godley Valley where a circle was completed around the FitzGerald Glacier on Mt D'Archiac. From here it went north across the Divide to the Seige and Vertebrae Glaciers in the upper Whataroa valley and then the Kea and Jaspur Glaciers on the Smyth Range. The flight continued north photographing the glaciers around Arthurs Pass and circling the Rolleston Glacier a number of times to get a complete perspective set for the Structure in Motion project. From there the flight went north of the Lewis Pass to the small glaciers on Faerie Queen in the Spencer Mountains, and on Mt Ella in the Ella Range. The flight then returned south via the glaciers on the Arrowsmith Range then back to the Glentanner airstrip at Mt Cook for a refuel and food stop.

After lunch the flight went back into the Tasman Valley and did two circuits of the valley photographing the Tasman and tributary glaciers. Thermal imagery of the Tasman Glacier was shot out of the pilot "storm window" on the left hand side of the plane over Tasman Glacier, unlike 2018 when one of the doors needed to be opened mid-flight. The flight then returned directly to Queenstown.

Mild conditions continued through the Alps during March with the first cold front bringing persistent snow on the glaciers arriving on 4 April 2019.

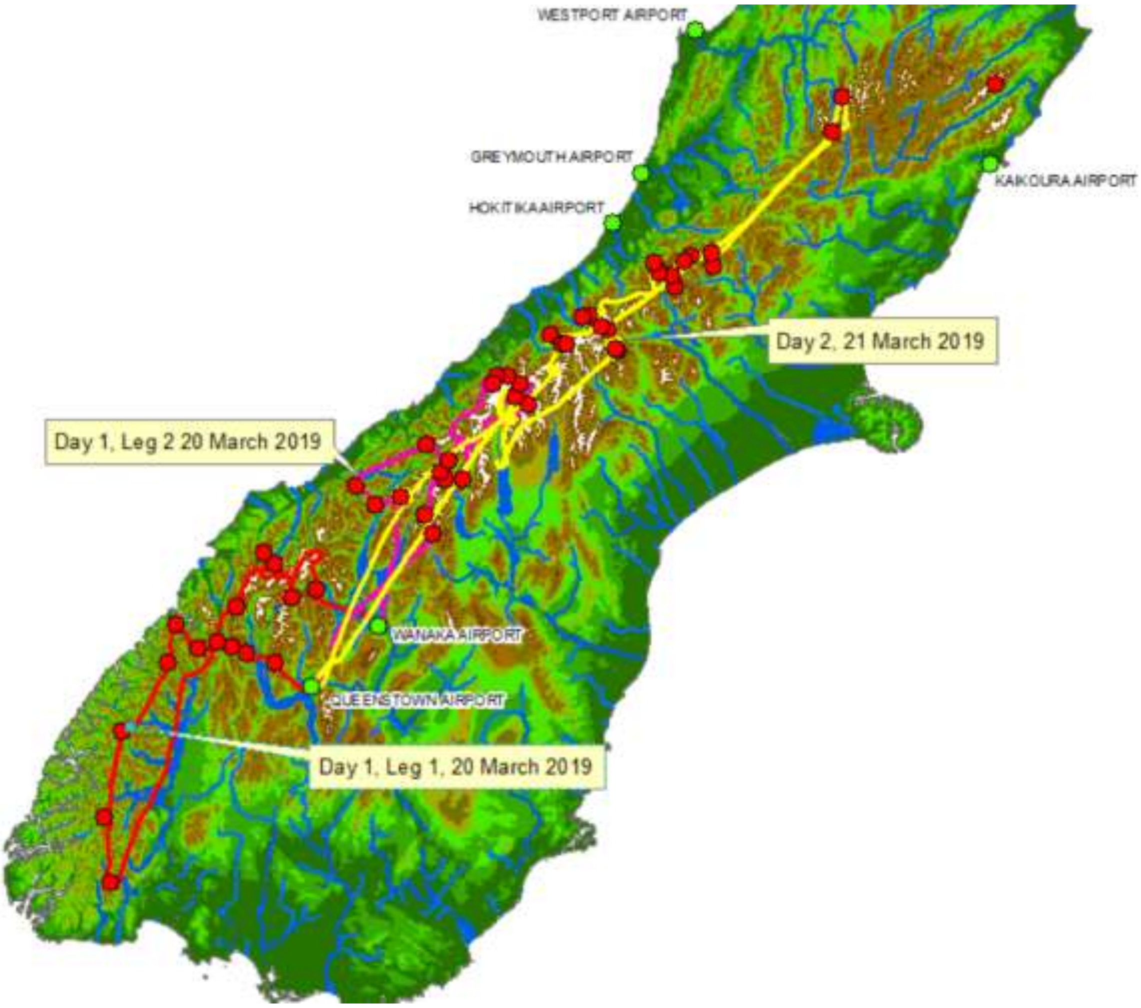

Figure 2-1: An overview of the glacier flight path for 2019.

3 Derivation of the glacier snowline

Data in this report are presented as "departures from the ELAo" which represents "departure of the climate of the year from the mean climate for glacier equilibrium". Thus an accurate estimate of the position of the ELAo is an important part of the programme. Associated glacier parameters used are accumulation area (Ac of Figure 3-1) and ablation area (Ab of Figure 3-1); total glacier area A, or Ab +Ac; and accumulation area ratio (AAR) the ratio of the accumulation area to the entire area of the glacier, Ac/(Ac+Ab).

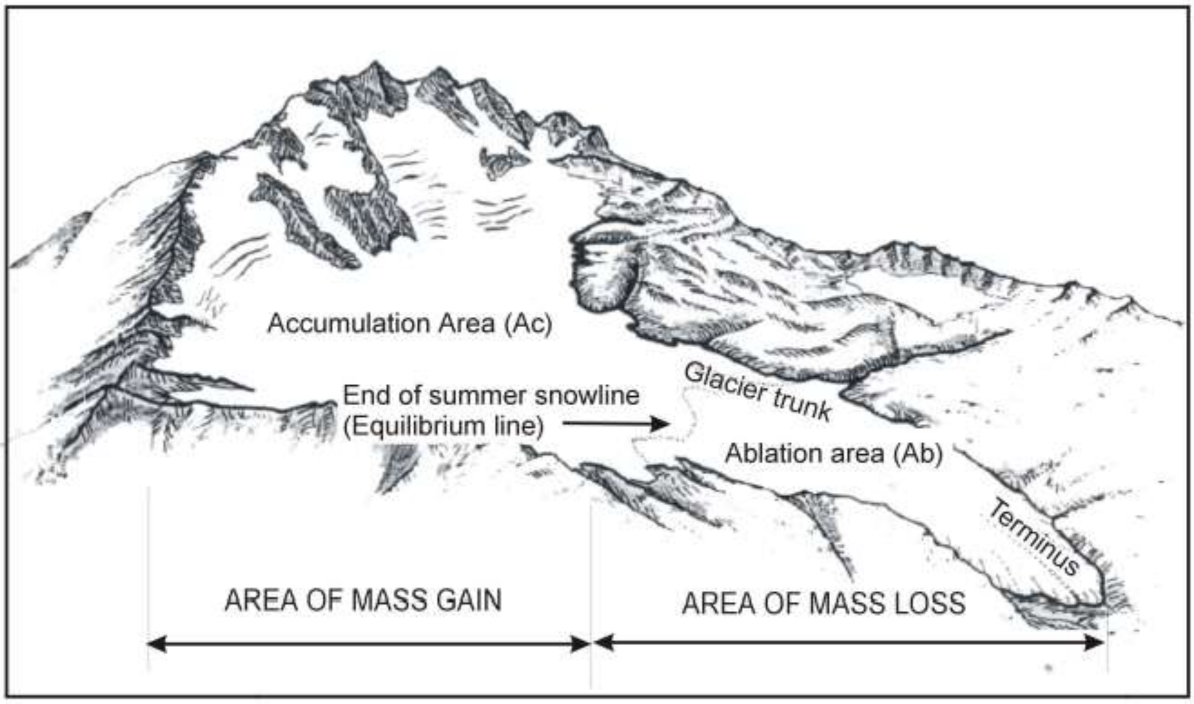

Figure 3-1: Basic parameters of a glacier.

At the commencement of this project, the value of the ELA was gained by plotting the observed snowline directly on to a topographic map:-

Map + snowline $\longrightarrow$ ELA

On the average glacier, the long term EOSS (ELAo) divides the accumulation and ablation areas by an approximate ratio of 2:1 (AAR value of 0.66). This position was estimated on small glaciers, and derived from the area-altitude curve on the larger glaciers. As the number of years of data increased, many of the ELAo values were subjectively adjusted (see section 3.5 for details of the adjustment methods):-

Est. AAR @ 0.6 $\longrightarrow$ ELAo, + adjustment $\longrightarrow$ refined ELAo.

Leading to small annual changes to:-

ELA – ELAo $\longrightarrow$ Departure value

The use of a GIS mapping system associated with digitised areas has added significant accuracy to the data by supplying measured glacier and accumulation or ablation areas:-

Digitised (Ac or Ab) + Area Curve $\longrightarrow$ accurate ELA

Digitised Ac + Glacier Area $\longrightarrow$ accurate AAR

In addition, with a longer time series of annual photographs it is frequently more efficient to directly interpolate ELA values between those of previous years which bracket the current year's snowline (described below), and more than half of the ELA values have been derived by this method:-

Interpolation $\longrightarrow$ direct ELA

Where ELA – ELAo $\longrightarrow$ Departure

and ELA + Area Curve $\longrightarrow$ AAR

The most significant problems in processing the results are recognising the position of the true end-of-summer snowline (Figure 3-1), especially when;

- There has been a recent summer snowfall, which effectively "paints out" the snowline.
- The snowline has been only partially recorded due to cloud cover, backlighting or other reasons.
- The current snowline is obscure or ambiguous due to limited discolouration of snowpacks of previous years.
- There is a wavy or patchy snowline.

Glacier snowline elevations are normally obtained from detailed mass balance studies where the snowline is mapped as the zero isohyet on the annual mass balance map. Results from glaciers around the world where this technique is used are published in the Glacier Mass Bulletin (WGMS 2011). In this study the snowlines are derived from oblique aerial photographs by one of "three" methods, depending on the snow cover conditions at the end of summer:

1. Digitalisation method: Digitising either the accumulation or ablation area to provide a definitive ELA.
2. Interpolation method: Interpolating between photographs of past years where a number of snowlines are close in altitude.
3. Snow patch method: Comparing the sizes of adjacent snow patches when fresh snow or cloud obscures the snowline of the index glacier.

These procedures are given in Chinn (1995) and in Chinn and Salinger (1999).

3.1 ELAs derived by digitising

This method gives the definitive ELA values upon which the interpolation and snow patch methods rely.

Here the end-of-summer snowline positions are carefully sketched from the oblique photographs onto detailed rectified digital aerial image base maps of each glacier. The mapped accumulation or ablation zones are then digitised using GIS techniques to accurately measure the areas. From 2009 on, however, some of the oblique digital images are now rectified using the Photogeoref software (Corripio 2004). This software utilised the camera position (GPS input), focal length, image size, NZ Digital Elevation Model, and ground control points (clearly observed features identifiable on the NZTM topographic map sheets) to rectify the image.

From the total ablation area for each glacier, the snowline elevation is then read off an area-altitude curve constructed for each glacier. Once the accumulation area is measured, the ablation area is found by subtracting the accumulation area from the total glacier area. If a glacier has aa significant change to its permanent ice area then a new area elevation curve is derived for the new outline area, so the ablation and accumulation areas are related to the new outline area.

This method provides a single figure for the glacier ELA for the year, regardless of the shape of the measured area, as it eliminates subjective estimation of the altitude of the snowline. The difference between this altitude and that of the long-term ELA_0 is a proxy for the annual mass balance of the glacier. Positive values or high snowline elevation signifies less snow and therefore a negative mass balance.

Most of the glaciers have lost formerly permanent ice since the survey began in 1977, and this requires outline area remapping and derivations of new area elevation curves. Many of the glacier outlines have been remapped since 2010 using orthorectified satellite imagery made available by the government agency KiwImage project. This imagery is accurate to within +/- 2.6 m and is now available for approximately 80 per cent of the index glaciers. Some KiwImage satellite images are not useable due to large amounts of recent snow obscuring the permanent ice areas.

The initial GIS work was completed in the NZMG projection. Since 2010 these original files have been converted to the NZTM projection as this more readily suits GPS based systems and the new satellite imagery.

3.2 ELAs derived by interpolation

With the many photos now available, for many glaciers it may be more accurate and efficient to obtain the ELA value by interpolation.

For each glacier, photos for all years are arranged in increasing area of snow cover (descending order of ELAs). The current year’s photograph is then carefully compared and inserted into its appropriate place in the sequence of photographs arranged from lowest to highest snowline elevation. It has been found that very small differences in snow cover can easily be recognised and that two photos separated by many years can have identical snow coverage. The ELA value is interpolated from the ELA values of the adjacent years.

Depending on the similarity of the ELAs, this method frequently places the value of the ELA within a few metres.

3.3 ELAs derived by snow-patch size when the snowline is obscured

Where the true end-of-summer snowlines are obscured by fresh snow, cloud or other reasons, the hidden snowline may be interpolated from the degree of snow cover surrounding the glacier, i.e., the size of the intermittent snow patches.

Fresh snow on rock has quite a different appearance from fresh snow on existing snow, and it is usually possible to discern the snow-patch outline beneath a light cover of new snow. As in the interpolation method, photographs of the glacier for all years are arranged in order of increasing snow cover on the glacier, which may also reflect the size of the snow-patches surrounding the glacier. The photograph from the latest survey is then slotted into its appropriate place in the snow-patch sequence. The ELA values for this glacier are interpolated from those of adjacent years as described above. Note, there is no consideration of uncertainty for the ELA estimate in this approach that has been formally vetted to test how the snow patch method compares to ELA evaluations keeping both the snow patches and the snowline over the glacier independent. This is work that needs to be done in the future.

3.4 Accuracy of values associated with ELA measurements

Accuracy of the data is dependent on the accuracy of the digitised accumulation (Ac) and/or ablation (Ab) areas, glacier area and its area elevation curve. Normally all of these values are measured with a high degree of accuracy, provided each glacier maintains a constant size. However many of the smaller glaciers have undergone large variations of size and both the area and associated area-altitude should be re-measured each year of change.

Associated with small glaciers and area changes are the problems of when the snowline (ELA) rises above the glacier or falls below the glacier terminus. When the ELA falls below the glacier, the ELA can be estimated, but the AAR becomes >1 which causes mathematical problems. When the ELA rises above the glacier, it is not possible to extrapolate its value and the AAR becomes negative.

3.5 Derivation of the Long-term or Steady-state ELAo value

Glacier studies worldwide have demonstrated that the ELAo lies at an altitude which divides the accumulation area from the ablation area in a ratio of near 2:1, and this ratio has been used extensively for the derivation of paleo-snowline altitudes (Maisch 1992). The accumulation area ratio (AAR) of accumulation area to the total glacier area has an average value close to 0.6 (Paterson, 1994). However, accumulation ratios can range from about 0.1 to 0.75 (Haeberli, Hoelzle and Zemp 2007) with the largest deviations occurring for abnormally shaped glaciers (Table 3-1), and can also be abnormally flow for debris covered glaciers (Lorrey, 2005).

The 2:1 ratio of the accumulation to ablation areas, or AARo of 0.66, was tested and found to apply to New Zealand glaciers without debris cover, terminal lakes, or an abnormal shape. The test uses the snowline data from the index glaciers as determined from 29 years of monitoring given in Hoelzle et al. (2007). Values of AARo for each index glacier in Appendix B are estimated from the accumulation and ablation areas on the area elevation curve at the ELAo elevation. They vary considerably with the type of glacier, from 0.09 to 0.84. Closer examination shows that the largest deviations are for glaciers with extensive debris cover, and for those with pro-glacial lakes. The results of Table 3-1 show what happens to the mean AARo for the index glaciers as the classification is changed. The nearer the selection to the morphology of a "normal" glacier, the closer the accumulation area ratio approaches the 0.66 mean. Initial observations of the index glacier AAR values suggest that the most significant of the topographic controls for raising the AAR value (lowering the ELA) appear to be the surface topographic gradients below the ELA and any divergence of ice flow. Conversely, any flattening of the glacier tongue lifts the ELA to drive a low AAR value. Surprisingly, parallel flow, as is common in ice aprons, does not appear to affect the AAR.

Table 3-1: Derived AARo values for New Zealand glaciers.

Sample	Number	Mean AARo	Std Dev
All index glaciers	50	0.57	0.18
Without (a) rock glaciers	46	0.59	0.16
Without (a) and (b) lakes	39	0.63	0.12
Without, (a), (b), and (c) abnormal shapes	26	0.65	0.10

Mass balance, the specific depths of mass gain or loss over a balance year, do not follow an even change along the glacier profile, and for simplification, mid-latitude glaciers are usually assumed to have a single linear gradient along the longitudinal profile of the glacier. However, for equilibrium, the volume of snow gained during the glacier year equals the volume of the ice lost (using water equivalents). Due to the 2:1 rule used here, the accumulation area is approximately twice the ablation area. Thus for the purposes of this work, it is assumed that the ablation mass balance gradient is twice the accumulation gradient.

Values for the long-term ELAo were initially derived by applying an AAR value of 0.66 (Gross et al. 1976) to the area-altitude curve for each glacier. The ELAo is read off the glacier area curves at 0.4 of the area up from the glacier terminus.

Initially, the ELAo values were approximate estimates only, as measured AARs on glaciers in equilibrium vary from 0.5 to 0.75, depending on glacier individuality, local topography and other idiosyncratic factors. The ELAo may then be adjusted using the record of annual ELAs and the annual mean ELA for all index glaciers. The method assumes that the ELAo indicates the snowline position for a zero mass balance, and that ELA changes each year on an individual glacier are linearly proportional to the average change over the entire Southern Alps.

The regression plots for each of the index glaciers are given in Appendix B, where the annual departures for each glacier are regressed against the annual mean for the Alps without the glacier in question. The correlation and representativeness indicated by these regressions is discussed below. At the zero intercept, which indicates a zero average mass balance for the Alps, the mass balance of the individual glacier should also be zero. The adjustment of the ELAo from its estimated value to a precise value indicated by the dataset is carried out using the constant of the regression equation.

The slope of the regression line indicates the character of the response of the glacier to the climate, within the constraints of the assumptions of linearity. The average climate response is given by the mean for the Southern Alps, so that any deviation from a 45° slope is an indicator of the individual characteristics of the glacier. Since each year’s climate is thought to be similar over all of the Southern Alps, with the noted exception of the Kaikoura Ranges, which lies in a distinctly different climate district (Mullan 1998, Mullan and Thompson 2006), the regression slope changes must represent an altitudinal signal in the ELA values. Similarly, the range of the highest and lowest ELA values is also influenced by the glacier topography and aspect. The significance of these properties has yet to be analysed and warrants further investigation.

4 The 2019 snowline results

4.1 The 2018/2019 glacial climate

A summary of key regional and local climate conditions taken from the National Climate Centre's monthly summaries (https://www.niwa.co.nz/climate/monthly) from April 2018-March 2019 is found below, broken down by season within the glacier mass balance year (April-March). Lower than normal air pressures over New Zealand occurred during the first three months of the glacial year (Figure 4-1). This air pressure pattern delivered cooler temperatures than usual to the Southern Alps during April to June 2018. Air pressures were higher than normal over much of New Zealand during the second half of the glacial year (Figure 4-2). This delivered more frequent airflows from the north, and generally more settled weather than usual than usual for the time of year. Overall, air temperatures were higher than average from July 2018 to March 2019. Sea surface temperatures (SSTs) in the Tasman Sea west of New Zealand were between 0.25-0.75°C higher than normal from April to September 2018 (Figure 4-1Figure 4-1: Southwest Pacific anomalies at the 1000hPa geopotential height (top row) April-June 2018 (left) and July-September 2018 (right). Geopotential height indicates areas of relatively high or low pressure (green/red shades indicating 'highs', blue/purple shades indicating 'lows'). The bottom row shows the corresponding sea surface temperature (SST) anomalies across the New Zealand sector for the same time period (green/red shades indicating warmth, blue/purple shades indicating cool).

). Positive SST anomalies increased over the course of the glacial year, such that SSTs were above normal for the time of year from October to December 2018, and well above normal from January to March 2019 (Figure 4-2Figure 4-2: Southwest Pacific anomalies at the 1000hPa geopotential height (top row) October-December 2018 (left) and January-March 2019 (right). The bottom row shows the corresponding sea surface temperature (SST) anomalies across the New Zealand sector for the same time.).

Temperature and rainfall anomalies observed at Arthur's Pass Village, Mount Cook Village and Milford Sound during the glacier mass balance year are presented in Table 4-1. These locations were selected due to their proximity to the Main Divide of the Southern Alps. Table 4-1 illustrates that temperatures were near or below average for the first three months of the glacial year, then higher than average from July 2018 to March 2019. Overall, precipitation was near or below normal for the first half of the glacial year, considerably below normal from October to December 2018, and near or above normal from January to March 2018. The monthly variability of temperature and precipitation are described below.

April-June 2018

- Mean sea level pressure (MSLP) during April and May was lower than usual over and southeast of New Zealand, bringing more frequent west and southwest winds. MSLP was much higher than usual over the South Island during June.
- Precipitation near to below normal for the season overall, although June was very dry with precipitation just 20-50% of usual about the Southern Alps.
- Air temperatures were near or below average about the Southern Alps for this 3-month period overall, although notably cooler than average in April.
- Regional sea surface temperatures (SSTs) surrounding New Zealand were above normal, particularly to the east of New Zealand.

- Five notable snowfall events[1] occurred in the South Island; 10 April, 21 May, 23-24 May, 6 June and 25-26 June.

July-September 2018

- Overall MSLP was below normal southwest of New Zealand, and higher to the east of the country. There were more frequent northwesterly airflows in July and August, and more frequent southeasterly airflows in September.
- Precipitation was below normal overall, however July was wetter than usual. Both August and September were drier than usual about the Southern Alps.
- Air temperatures were above average overall, especially in July. It was New Zealand's fifth-warmest July on record[2], temperatures about the Southern Alps were 1.2-2.0°C higher than average.
- SSTs east of New Zealand remained above normal, but were near or only slightly above normal in the Tasman Sea.
- There were four notable snowfall events across the South Island; 7-8 July, 3 September, 17 September and 26 September.

October-December 2018

- MSLP was higher than normal over and to the south of New Zealand, delivery more settled weather and fewer westerlies than usual to the Southern Alps.
- Precipitation was considerably below normal for the Southern Alps overall, although central and northern parts received above normal precipitation during November.
- Air temperatures were higher than average for the three-month period overall, especially during December with temperatures around 2°C higher than average.
- Regional SSTs became increasingly higher than normal surrounding and to the west of New Zealand.
- There were three notable snowfall events in the South Island during this period; 10 October, 9 November and 19-20 November.

January-March 2019

- The end of the glacial year was characterised by high pressure anomalies east of New Zealand, which resulted in more frequent northerly airflows.
- Precipitation was near or above normal overall, but with considerable latitudinal variability about the Southern Alps during January and February. January was much drier than normal in Milford Sound, but rainfall was near normal farther north. In February, Arthur's Pass Village was much drier than normal, whereas Milford Sound was wetter than normal. March was wetter than normal throughout the Southern Alps.

[1] A notable snowfall event is defined here as widespread snowfall (i.e., more than one geopolitical region affected) to relatively low elevations in the South Island, which typically occur during a southerly outbreak. The Southern Alps frequently receive considerable additional snowfalls due to the prevailing westerly airflow in the austral mid-latitudes, however these are usually not reported on in the National Climate Centre's monthly climate summaries.
[2] Based on NIWA's seven-station temperature series, which begins in 1909.

- Air temperatures were above average in January and March, and near average in February. It was New Zealand's third-warmest January and equal second-warmest March on record.
- SSTs remained well above normal around the South Island and in the Tasman Sea, with marine heatwave conditions present.
- One notable snowfall event occurred during this period; 24 February.

Table 4-1: Climate summary for the glacial mass balance year. Temperature anomalies (a; difference from 1981 – 2010 average) and rainfall anomalies (b; percentage of 1981 – 2010 normal) over the glacier mass balance year at locations near the Southern Alps.

Location		Apr-Jun 2018	Jul-Sep 2018	Oct-Dec 2018	Jan-Mar 2019
Arthur's Pass Village	a	0.0	+1.6	+1.1	+1.2
	b	99%	81%	66%	115%
Mount Cook Village	a	-0.8	+1.5	+0.8	+1.6
	b	83%	78%	71%	138%
Milford Sound	a	-0.3	+0.7	+1.1	+1.0
	b	93%	112%	57%	101%

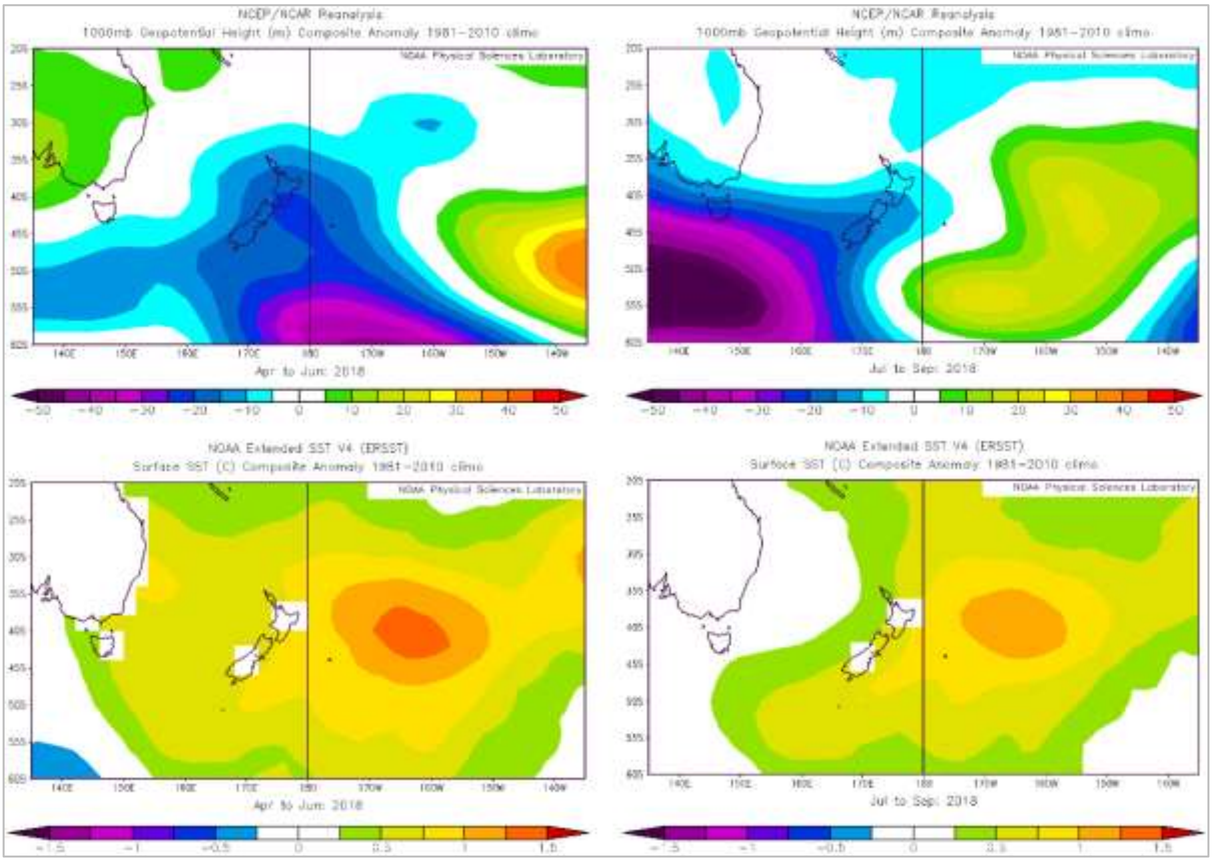

Figure 4-1: Southwest Pacific anomalies at the 1000hPa geopotential height (top row) April-June 2018 (left) and July-September 2018 (right). Geopotential height indicates areas of relatively high or low pressure (green/red shades indicating 'highs', blue/purple shades indicating 'lows'). The bottom row shows the

corresponding sea surface temperature (SST) anomalies across the New Zealand sector for the same time period (green/red shades indicating warmth, blue/purple shades indicating cool).

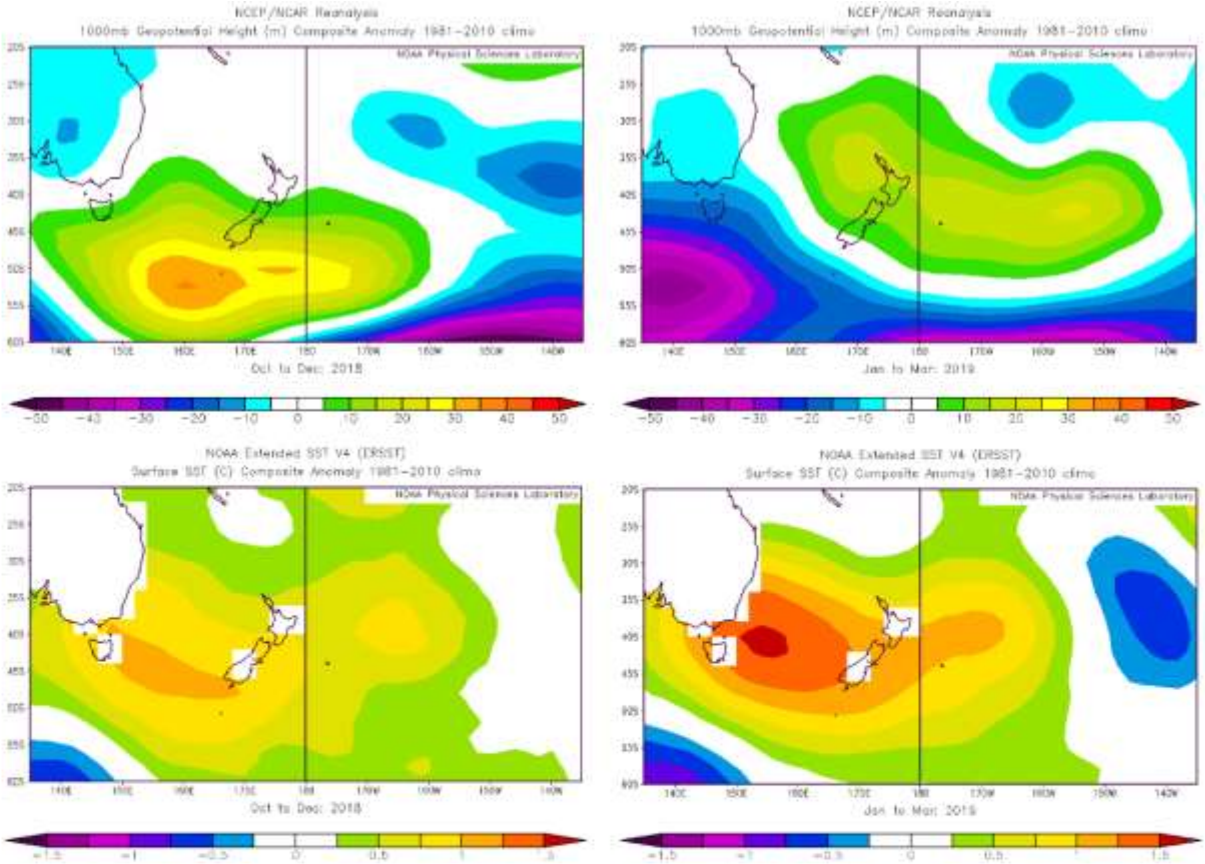

Figure 4-2: Southwest Pacific anomalies at the 1000hPa geopotential height (top row) October-December 2018 (left) and January-March 2019 (right). The bottom row shows the corresponding sea surface temperature (SST) anomalies across the New Zealand sector for the same time.

4.2 Photographic coverage of the index glaciers

Forty-six of the original 50 index glaciers were visited this year. Of the four not visited, two of these glaciers are in southern Fiordland and are very small fragments that are difficult to measure and require a much longer flight. Similarly, the rock glacier on Mt Alarm in the inland Kaikoura Range is a long way to the north and does not add much useful information due to it not having an obvious direct snowline. Mt Avoca at the eastern end of the Rakaia River catchment was missed but this was not important as this small glacier has fragmented into small remnants that do not have a snowline.

An extensive collection of digital photos from many angles was collected for some of the index glaciers by Brian Anderson and Lauren Vargo for use in constructing digital terrain models. The following glaciers had photographic circuits completed; Brewster, Snow White, Thurneyson, Nuns Veil, Kahutea, Rolleston, and Mt Wilson (which has reduced in size so much that it is nearly extinct).

All of the index glaciers photographed on the survey flight had pictures taken from their standard waypoint positions.

The survey photographs were taken with a Nikon D200 digital camera (sensor size = 23.6 x 15.8 mm, 3872 pixels x 2592 pixels, effective pixels = 10 megapixels) linked to a Garmin GPSmap 60Csx with an external aerial on the windscreen of the plane. Each digital image has the GPS location (latitude and longitude WGS84 datum) and camera focal length embedded in the EXIF information section of the digital photograph. The GPS used on the survey was used to navigate to the standard photograph waypoint positions. These photographs are available as compressed jpegs from the digital archive.

This year 32 of the 46 glaciers visited had clear snowlines visible in the photographs with no obstruction from any recent pre-flight snow falls. The snowlines present on these were in the upper regions of the neves, or at the very top of the glaciers.

For 10 of the 46 glaciers visited this year no snowline was present on the glacier as all seasonal snow had gone leaving only large areas of ice and firn. For 3 of these glaciers with no snowline (Chancellor, Jalf, and Jack) an estimate of the snowline elevation was derived from an adjacent higher elevation glacier which did have a visible snowline.

Historical snowline information has been reported in Appendix D for the rock glacier on Mt Alarm in the Kaikoura Range, Douglas Glacier, Mt Avoca, St Mary, and Mt Caria but these have not been used in the snowline calculation since 2015 (Appendix A). These glaciers have been excluded because of the large uncertainty in deriving a snowline elevation for the two rock glaciers (Mt Alarm in the Kaikoura Range, and Mt St Mary), and the difficulty in deriving area elevation curves and resulting snowline elevations for the three small fragmented and variable area glaciers (Douglas Glacier, Mt Avoca, and Mt Caria).

The Douglas glacier has been replaced in the annual EOSS calculations with observations from the adjacent and much larger South Cameron Glacier. This replacement glacier has proved to be more suitable for determining glacier area and snowline elevations.

An archive of historical photographs from the Snowball glaciers in the upper Arawhata valley is at the point where one of these glaciers could be used as a replacement for the adjacent Caria Glacier.

A low resolution image of each index glacier photograph is in Appendix D.

4.3 Snowline elevation departures - 2018/2019 glacier year

All the monitoring results for the 32 index glaciers used for snowline elevation departure calculation in the 2018/2019 glacial year are shown in Figure 4-3. Missing values are due to either the glacier not being visited (Kaikoura Range, Mt Ella, and Faerie Queen), or not being used due to their small size and area fragmentation (Avoca, Mt St Mary, and Caria), or for the remaining 12 glaciers with missing values having the snowline above the maximum elevation of the glacier so a value could not be determined. Three glaciers (Jalf, Chancellor, and Jack) with snowlines above the maximum glacier elevation do have a snowline value as these have been derived from an adjacent higher glacier with a clear snowline.

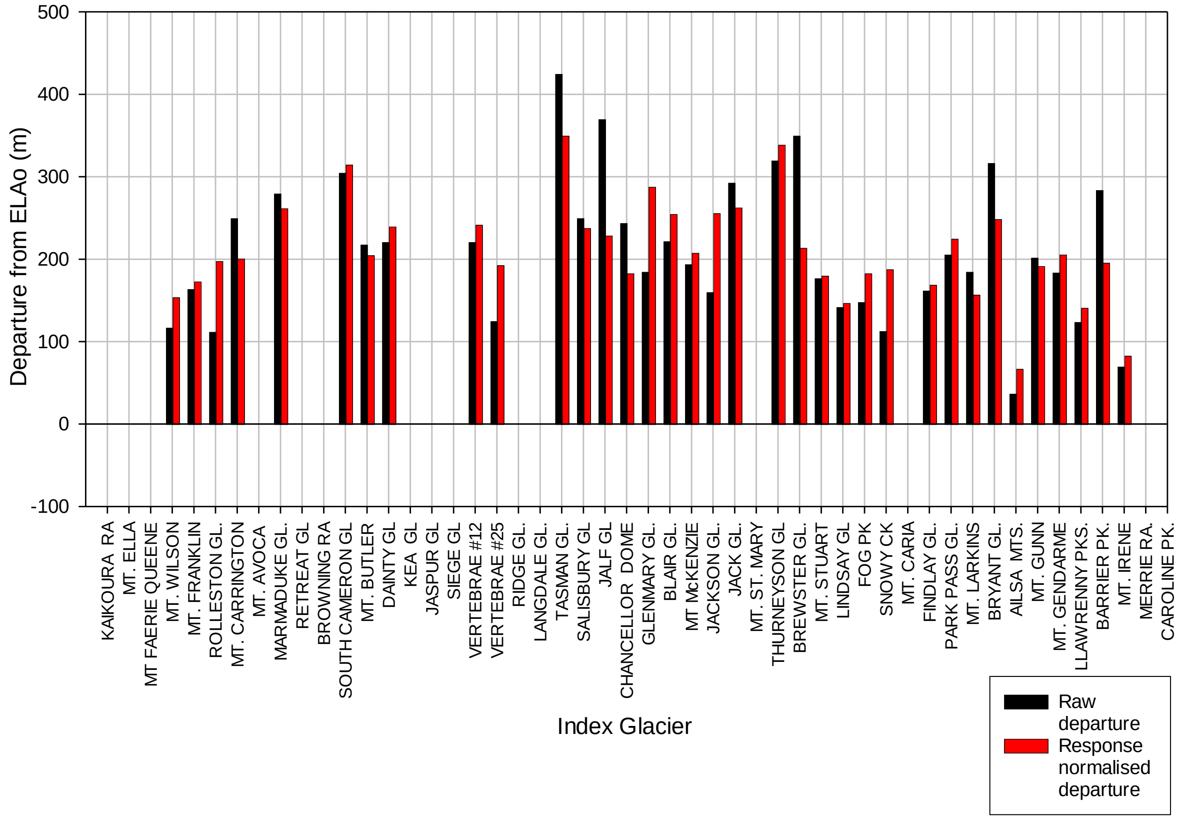

Figure 4-3: Histogram plot of the 2018/2019 snowline departures (raw and response normalised) for each index glacier from the long-term ELAo. Missing values are due to either the glacier not being visited, used, or the snowline was above the maximum elevation of the glacier.

The departures are shown for each glacier in both raw and normalised form. The normalised departures are considered to be more representative as each index glacier responds differently to the annual climate signal due in part to the topography of the respective glacier (discussed in section 3.5). This topographic departure elevation variation for each glacier has been normalised by applying the slope from the regression between the individual glacier's annual departure and the annual mean Alps value. The derived slope values are considered to be reasonably valid as there are now a considerable number of observations, with 35 index glaciers having 33 or more annual observations, and the least number of annual observations being 22 at one index glacier. The correlations for these regression relationships are listed in Table 4-2. At many glaciers the effect of normalising is minimal as most of the index glaciers have a near 1:1 ratio response to the Alps mean. Normalising does have the effect of reducing the magnitude of the offset for some of the glaciers with a large elevation range of ELA values. This year the largest reduction was at the Jalf Glacier (+370 m to +229 m), and this was due to derivation of the snowline for this glacier coming from a higher elevation glacier alongside the Jalf Glacier, as the snowline had risen well above the maximum elevation of the Jalf. The normalisation process for each glacier is especially important when aggregating the results for the full length of record for the whole of Southern Alps, as it accounts for the irregular sample size, and the impact of individual glaciers with high sensitivities in years with only a few observations.

Most of the glaciers have normalised ELA departures at record levels above the long-term mean ELAo position, with the smallest observation of 67m above the respective long term mean ELAo position at small Ailsa Glacier, and the largest departure at 350m above the respective long term mean ELAo position at the Tasman Glacier. Nineteen of the 33 observations are >200m above their respective long term mean ELAo positions. All 33 index glaciers with these large observed positive snowline departures had a large loss of snow and ice in this glacier year.

The seven glaciers with missing snowline elevation values due to the snowline height being above the top of the glacier were observed visually to have lost large amounts of snow, firn, and permanent ice compared to the photographs from previous years. Cursory observations from the snowline flight team noted that the lateral margins and upper perimeter of many smaller glaciers located near index glaciers appeared to be significantly reduced in areal coverage, and/or appeared to be undergoing enhanced calving and retreat relative to the eyewitness observations prior to 2018.

Some variability exists between index glaciers this year even after normalisation of the departures.

The variability in the departures are due to:

- Difficulty finding a clear visible snowline, in these cases it can be hard to distinguish if covered by fresh snow or differentiated from older firn layers. In the case of fresh snow then estimation of the snowline is done indirectly by comparing surrounding snow patches. This year the snowlines if present on the glacier (ie not above) were very clear so this source of error is expected to be smaller than years with lower elevation snowlines.

- Measurement uncertainty due to the difficulty determining a snowline elevation on some of the smaller fragmented glaciers. Mapping these small remaining ice areas is problematic due to the lack of accurate maps thus leading to difficulty determining the annual area elevation corrected ELA.

- Geographical variability. Some of the smallest departures occur in the north and the south although there is not a consistent trend from north to south or east west across the transects this year. The smallest normalised departures are at the smallest glaciers indicating that there may still be some topographic effect rather that geographic variability this year. Many of the smaller glaciers are at the northern and southern extremes.

- Topographic effects. Geographical variability cannot account for all the variation as in some cases neighbouring glaciers on the same transect have a different scale of response event with normalisation. The Langdale Glacier is one of these with both an unusual shape (hypsometry) and topography that appears to be effected by wind causing unusual accumulation and ablation in some years.

4.4 Snowline elevation departures 1977 to 2019

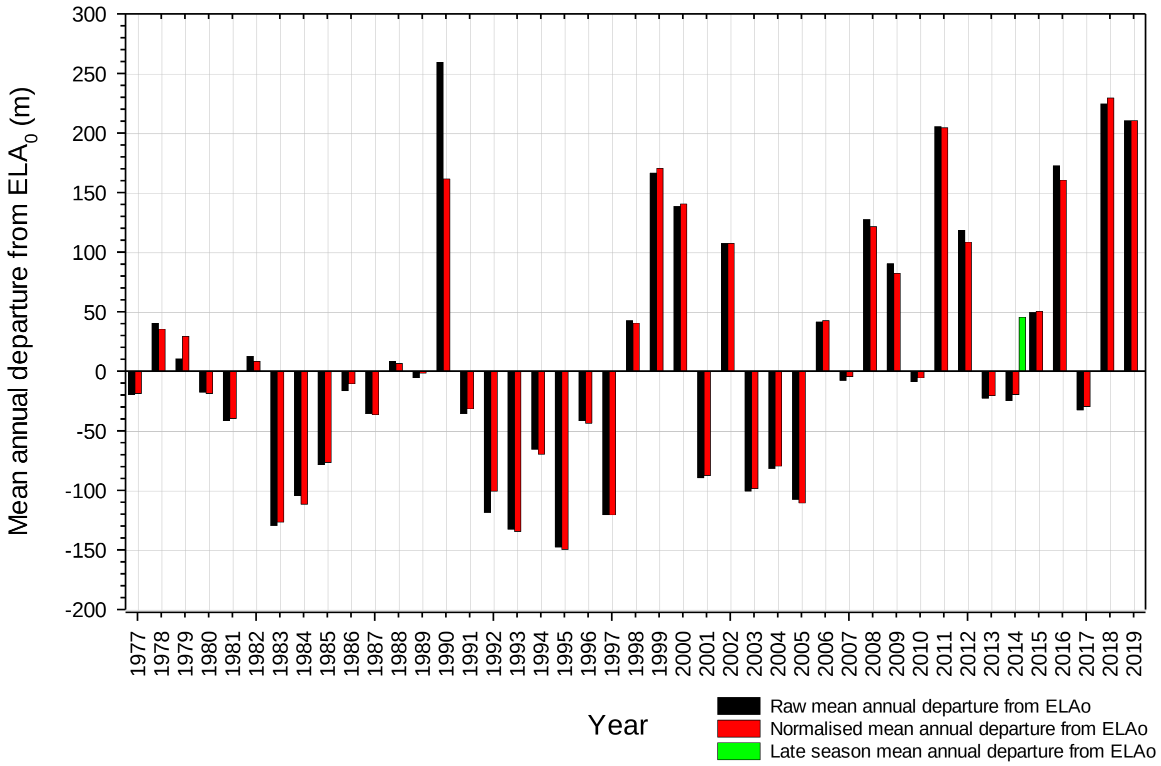

Figure 4-4: Mean annual departures (raw and normalised) from the ELAo for all measured glaciers for the entire period of the surveys.

The raw mean snowline departure for this year (2018/2019), that is the average of the 33 observations of ELA index glacier departures, was 211 m above the long-term mean ELAo position (Figure 4-4). This is the third largest raw mean departure after the 1989/1990 and 2017/2018 values, although the raw 1989/1990 value is based on only one observation from the Tasman glacier.

The average of the **normalised** 2018/2019 observations was 211 m above the long-term mean ELAo position. This normalised departure is the second largest recorded in the 43 years of observations and indicates a large loss of snow and ice over the 2018/2019 glacier year. The previous year 2017/2018 was the largest recorded normalised departure in the history of the survey with a value of 229m, and this year's result is of a very similar scale indicating two consecutive years of extremely high snowlines.

The **normalised** average is considered to be the most appropriate value as some of the individual glacier specific sensitivity factors are removed from the calculation. Interestingly, the raw and normalised results are similar for most years as the effect of the outliers is relatively small when nearly all glaciers are sampled. This year this was certainly the case as both values were the same. But for years with limited observations it can have a significant and important effect. The largest change due to normalisation occurred in 1989/1990 where the mean annual departure was reduced by 98 m, due to it being derived from a single relatively high elevation snowline observation from the high topographic range Tasman Glacier. The details on the two observations from the 1989/90 year are included in Appendix E, along with normalisation calculation process for these and expected uncertainty of these observations.

Snowline departures have tended to be largely above, or if negative within 30 m of the ELAo position, for the last 14 years (2006 to 2019) this indicates a trend of predominately negative mass balance with a corresponding loss of snow and ice.

The 14 year negative trend in the ELA departures, which is a loss of snow and ice, is visually apparent at the index glaciers as reductions in the permanent ice areas, and fragmentation of previously continuous ice into smaller discrete areas. These area reductions are particularly noticeable at some of the smaller index glaciers. Two small index glaciers (Avoca and Caria) are still photographed each year, but are not used in the departure calculation as they are too fragmented and small to be able to see a snowline or determine a permanent ice area. Alternative glaciers (Kahutea, Griffiths, Snowball, and Tyndall) with a history of photographs are being photographed and mapped as replacements although these are currently not being reported.

The raw snowline departures from the steady-state ELAo for each index glacier since 1977 are presented in Appendix A. Missing values in these tables are years of no data for the particular glacier.

The normalised snowline departures from the steady-state ELAo for each index glacier since 1977 are presented in Appendix B. Missing values in these tables are years of no data for the particular glacier.

Appendix D gives a data table of all measured snowline fluctuation histories as metres of departure from the steady-state ELAo for each index glacier. The data table provides essential glacier data, snowline data statistics and a table of all measurements and immediate derived values. Photographs of each glacier are available from the digital archive and are included in low resolution in Appendix D.

4.5 Glacier representativeness

The "representativeness" of each glacier as an indicator of the overall annual climate of the Southern Alps is indicated by how well the annual values for an individual glacier correlates with the mean value of the 50 index glaciers over the Southern Alps.

Correlation coefficients of individual snowline departures for each glacier correlated against the mean of all remaining values for each year are given in Table 4-2. The correlation plots for each glacier are given in Appendix B. The correlations give a surprising result where representativeness appears to be independent of size, gradient or topography. The high correlations coefficient values indicate that the ELA surface of individual glaciers have a strong relationship with the "mean ELA" over the whole alpine range. This follows the finding of Clare et al. (2004) where it was demonstrated that the entire Southern Alps behaves as a homogenous climatic unit. However, the consistently low correlation of the Kaikoura Range glacier suggests that the behaviour of this range is that of a separate climate zone, while it is assumed that accumulation on the low correlation Langdale glacier is dominated by wind redistribution. The low correlation of Faerie Queen, Snowy, Larkins, and Retreat are assumed to be due to difficulties in mapping these small area low elevation range glaciers.

Four of the high correlation glaciers (Vertebrae 25, Findlay, Barrier, and Marmaduke Dixon) all cover relatively large elevation ranges and are relatively easy to determine snowline elevations. The process of determining snowline elevations at these glaicers is helped by well-defined permanent ice areas, and relatively smooth ice and snow covered glacier surfaces.

Another high correlation (0.93) is from the Jalf Glacier and this is in part due to snowline elevations in being determined from a higher elevation adjoining ice covered ridge in years when the snowline has risen above the highest point on the glacier. This has had the effect of stretching the elevation range and so making the annual points fit better to a straight line.

Table 4-2: Correlation coefficients of individual snowline departures for each glacier correlated against the mean of all remaining values for the period 1977-2019.

Glacier	Correlation Coefficient
VERTEBRAE #25	0.93
JALF GL	0.93
FINDLAY GL.	0.92
MT. BUTLER	0.91
BARRIER PK.	0.90
MARMADUKE GL.	0.90
BRYANT GL.	0.90
MT. STUART	0.90
THURNEYSON GL	0.90
VERTEBRAE #12	0.89
MT McKENZIE	0.89
BREWSTER GL.	0.89
SIEGE GL	0.89
SALISBURY GL	0.89
DAINTY GL	0.89
CHANCELLOR DOME	0.88
KEA GL	0.88
JACKSON GL.	0.88
TASMAN GL.	0.87
MT. ST. MARY	0.87
CAROLINE PK.	0.87
MT. CARRINGTON	0.86
PARK PASS GL.	0.86
MT. GENDARME	0.86
BLAIR GL.	0.85
JACK GL.	0.85
MT. FRANKLIN	0.85
LINDSAY GL	0.85
LLAWRENNY PKS.	0.83
SOUTH CAMERON GL	0.83
MT. GUNN	0.83
MERRIE RA.	0.82
GLENMARY GL.	0.82
JASPUR GL	0.82
MT. ELLA	0.82
MT. AVOCA	0.81
RIDGE GL.	0.79
ROLLESTON GL.	0.78
FOG PK	0.78
AILSA MTS.	0.77
MT. WILSON	0.76
BROWNING RA	0.75
MT. LARKINS	0.75
MT. IRENE	0.74
RETREAT GL	0.73
LANGDALE GL.	0.73
MT FAERIE QUEENE	0.72
SNOWY CK	0.69
KAIKOURA RA	0.59

5 Discussion

5.1 Ice gain and loss

Glaciers accumulate the mass changes of net annual balance variations over years to decades. These effects of yearly climate variations are delayed and distorted before being delivered to the terminus after individual glacier response times have elapsed. The index glaciers records the annual climate related mass gains and losses with some degree of accuracy as the majority of these glaciers are small and steep with relatively fast response times, and have areas that are in equilibrium with the climate of recent decades. The large valley glaciers with long, near 100 year response times have large surface areas inherited in a previous climate, and all are in a state of on-going recession mainly by downwasting of their debris-covered trunks, but recently ice loss has accelerated by the formation of pro-glacial lakes. For these glaciers, the ELA changes measure only the mass balances of a smaller area that would be in equilibrium with the present climate. Ice mass changes in these glaciers are accounted for in Chinn et al. (2012).

To assess the mass changes in response to climate fluctuations a cumulative plot of the "mass balance indices" (MBI) is presented in Figure 5-1. The raw MBI is the inverse of the mean annual departure value and this represents the mean departure from steady state (ELAo). Snowline departure changes with negative ELA (i.e., lower snowline) result in positive MBI, and conversely positive ELA departures (i.e., higher snowline) result in negative MBI. The reliability of use of the ELA as an indicator of mass balance change has been investigated by Chinn et al. (2005), where the r (correlation) values between the ELA and measured mass balance had an average of 0.9 with a standard deviation of 0.07.

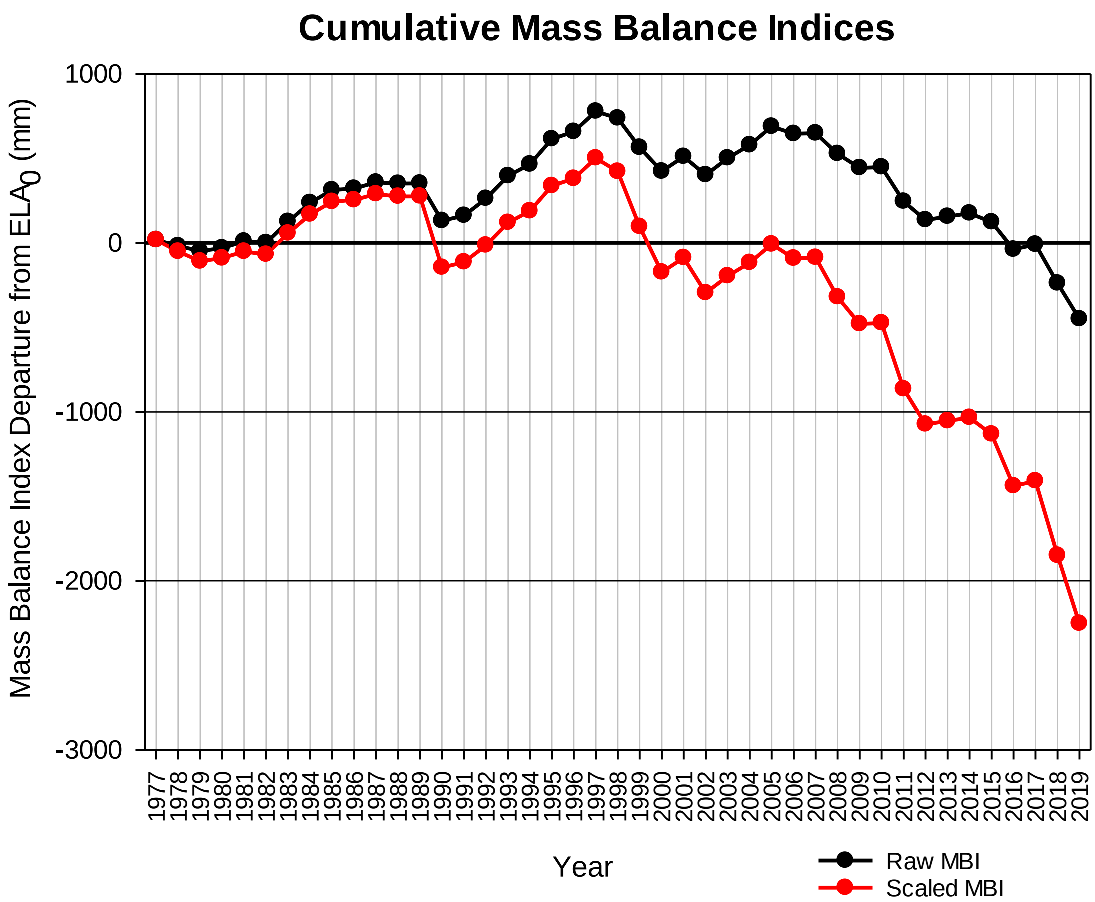

Figure 5-1: Raw and Scaled Cumulative Mass Balance Indices for the index Glaciers.

The annual trends in the raw MBI as shown in Figure 5-1 agree with the generalised climates given in Table 5-1. However, the cumulative total of the raw MBI (black line) on the plot does not agree with the obvious ice volume decrease at most of the index glaciers. Over the course of the 43-year monitoring period, there has been permanent ice loss during large negative mass balance years that has not been recovered after a cycle of positive mass balance years. A negative mass balance year has a greater impact on ice volume than a positive mass balance year for MBIs of the same magnitude. This is due to ablation rates typically being almost twice the accumulation rates on most glaciers.

To account for this difference a scaled mass balance index is also shown in Figure 5-1 where negative mass balance years have been scaled by 1.92 and a positive mass balance year departures scaled by 1 (i.e., left unchanged). The scale factors are averages of published mass balance gradient rates (Table 5-2) from studies on the Tasman (Anderton 1975) and Ivory Glaciers (Anderton and Chinn 1978) for the period 1966-1975. The assumption is that these averaged mass balance gradients apply to the average annual departure values for the index glaciers.

The trend in permanent ice area in many of the index glaciers agrees with the cumulative scaled (1.92) mass balance index rather than the cumulative raw mass balance index which does not account for the mass balance gradient. Further work needs to be done to determine what scaling is appropriate for the index glaciers.

This scaled cumulative mass balance index has cycled through negative and positive cycles from the start of the survey to 2005 when it returns to a position of zero. From 2006 to 2019 this index has a negative trend with short periods of one to two years of near zero change.

Table 5-1: Generalised climate for 2018/2019 year and previous 21 years in Southern Alps and inferred glacier snow input.

Glacier year	Generalised Climate	Inferred glacier snow input
1997/1998	Higher frequency of anticyclones and westerly winds over the south, southerlies further north. Temperatures 0.2°C below normal, but a very warm summer.	Average
1998/1999	Stronger westerly and northwesterly winds over New Zealand, temperatures 0.8°C above average, with above normal precipitation on the West Coast.	Low
1999/2000	Very anticyclonic, with weaker westerlies than normal. Temperatures 0.7°C above normal, and rainfall slightly below normal.	Low
2000/2001	More northwesterlies over the South Island, temperatures 0.2°C above normal. Rainfall close to average.	Average-High
2001/2002	Higher than normal pressures and more easterlies over the South Island, temperatures 0.3°C above normal, well below average rainfall.	Low
2002/2003	Persistent westerlies and southwesterlies over New Zealand. Cooler spring, rainfall slightly above average in the west and south.	Average-High
2003/2004	More cyclonic westerlies and south westerlies over the South Island from September.	Higher
2004/2005	Cool westerlies during autumn and early winter (temperatures 0.4°C below normal), then strong cold cyclonic southwesterlies through to December (temperatures 0.6°C below normal), precipitation overall close to average.	High
2005/2006	More anticyclones and mild westerlies and northwesterlies during autumn and winter (winter temperatures 0.7°C above normal), then more frequent southeasterlies during spring bringing low precipitation.	Low
2006/2007	More southwesterlies June – November bringing increased accumulation, but then anticyclones and south easterlies December – March with low precipitation and increased ablation. Temperatures near average overall, and precipitation above average.	Average

2007/2008	Variable circulation April – August with little accumulation. From September on, mainly easterly circulation, and especially warm (1.0°C above normal) from December with low precipitation and much increased ablation.	Very low
2008/2009	Northerly and easterly quadrant flow anomalies related to La Niña, with associated normal to above normal temperatures, except during Spring. Below normal precipitation during late Winter and Summer.	Low
2009/2010	Highly variable year with regard to temperature and precipitation swings within and between seasons, particularly for winter 2009 and summer 2010. More frequent southwesterly flow as a result of El Niño development from spring was opposed to record high temperatures in August 2009 and February 2010.	Average
2010/2011	One of the strongest La Niñas in the last 50 years induced more frequent anticyclones (settled conditions) than normal across New Zealand during summer and autumn. 'Highs' were prominent across the South Island during the ablation season, with warmer than normal temperatures as a whole, elevated sunshine hours, and reduced rainfall.	Very Low

Glacier year	Generalised Climate	Inferred glacier snow input
2011/2012	Residual La Niña conditions in the Southwest Pacific through winter, with redevelopment of a weak La Niña in spring. More prevalent northerly and easterly quadrant winds on a seasonal scale, except for July-September (more frequent southwesterlies). Month-to-month saw variable circulation patterns that produced both positive and negative temperature anomalies for the Southern Alps, and the warmest May on record. Precipitation was mostly below normal, particularly for the second half of the season, with intermittent snowfall events.	Low
2012/2013	Neutral ENSO conditions in the southwest Pacific across the glacial year. Anticyclones ('highs') dominant at the start of the season, and intense ridges of high pressure east of the Chatham Islands extending back over the South Island persisted in the late season. Late spring and early summer characterized by more southwesterly winds. 2 of 3 months in each glacier year season had below normal precipitation, and many sunshine hours and high temperature records were broken. Regional SSTs were near or above normal at the start and end of the year, and near normal at other times.	Average-Low
2013/2014	Continuation of ENSO-neutral conditions in the equatorial and southwest Pacific for the glacier hydrology year. Pressure patterns supported more southerly-quarter winds at the onset and end of the year, while northerly-quarter winds were more prevalent July-December. Warm SSTs around the South Island and central Tasman Sea persisted for much of the year, contributing to average-above average temperatures.	Average-Low
2014/2015	Higher pressure than normal to the east and southeast of New Zealand resulted in more frequent northeasterly winds in the early and latter parts of the glacial year. More frequent southerly-quarter winds from July-October 2014 were not coupled with lower than average temperatures – possibly a result of SSTs which remained above normal south and west of New Zealand throughout the year. Air temperatures were above average for most of the year, including the warmest June on record, which likely reduced accumulation. It was drier and warmer than normal during the ablation season, which likely enhanced ablation during this time.	Low
2015/2016	A strong El Niño developed over the glacier hydrology year, but began weakening in the Tropical Pacific from February 2016. Higher pressure than normal north of New Zealand resulted in more frequent westerly winds from April-June and October-December 2015. These periods were typified by above average temperatures and near-above normal precipitation, although December was very dry with many sunshine hours. Northerly winds were more frequent than normal during January-March 2016 that contributed to well above normal temperatures for summer, and it is likely that ablation was considerably enhanced during this time.	Average-Low
2016/2017	ENSO-neutral conditions prevailed during the glacier hydrology year. Highly variable year with periods of very warm/cool and wet/dry weather. April to July was typified by much warmer than normal temperatures and above normal rainfall. August was cool and dry, while September was warm and dry. It is likely that accumulation was relatively low as a result, although highest elevation areas may have seen considerable accumulation during a very wet July. Summer temperatures were lower than normal, and it is likely ablation would have been reduced compared to normal during this time. A warm and dry March likely resulted in relatively high ablation rates for that time of year.	Average
2017/2018	La Niña conditions developed and strengthened through to summer, before decaying towards March 2018. Temperatures were warmer than normal for the year overall. Summer was remarkably warm; New Zealand observed its hottest summer on record, and January was New Zealand's hottest ever month on record. The Tasman Sea experienced a marine heatwave. It was also New Zealand's equal second-warmest spring on record. Precipitation was variable, but lower than normal overall. April-June and October-December 2017 were considerably drier than normal.	Extremely low
2018/2019	ENSO-neutral conditions prevailed during the glacier hydrology year. A marine heatwave developed and strengthened in the Tasman Sea from December 2018 to March 2019. Except for July and November, the winter and spring period was very dry. In addition, temperatures were warmer than usual from July to October. It is likely that snow accumulation was relatively low as a result. December, January and March were very warm months, and December was very dry. This likely resulted in high ablation rates.	Extremely low

Table 5-2: Vertical gradients of mass balance as measured for Ivory and Tasman Glaciers (mm/m). * is an estimated value.

Zone year	Ivory Glacier Ablation	Ivory Glacier Accumulation	Tasman Glacier Ablation	Tasman Glacier Accumulation	Both Glaciers Ablation	Both Glaciers Accumulation
1966-67				6		
1967-68				8.6		
1968-69				7.5		
1969-70	26.3			5.4		
1970-71	35.5		11.7	5		
1971-72	20.8		13.7	7.4		
1972-73	28.9		12.4	10.1		
1973-74	28		14.3	7		
1974-75	15.4		10.4	6.6		
Mean	25.8	12.9*	12.5	7.1	19.2	10

6 Acknowledgements

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NIWA wishes to acknowledge the wonderful work of Trevor Chinn who had the vision and motivation to start the snowline survey in 1977. Trevor continued being the instigator for the annual flights until his last in March 2018. He was always passionate about the value of the annual survey and this passion carried it through some difficult years when funding for the flight was difficult to obtain. Trevor completed 38 annual flights and meticulously documented and archived the glacier and snowline photographs and turned these into a quantitative record of change. He has left New Zealand with a priceless photographic archive of its glaciers and mountains. Trevor sadly passed away in December 2018, and we will always be grateful for his vision, effort, stories, and clever observations.

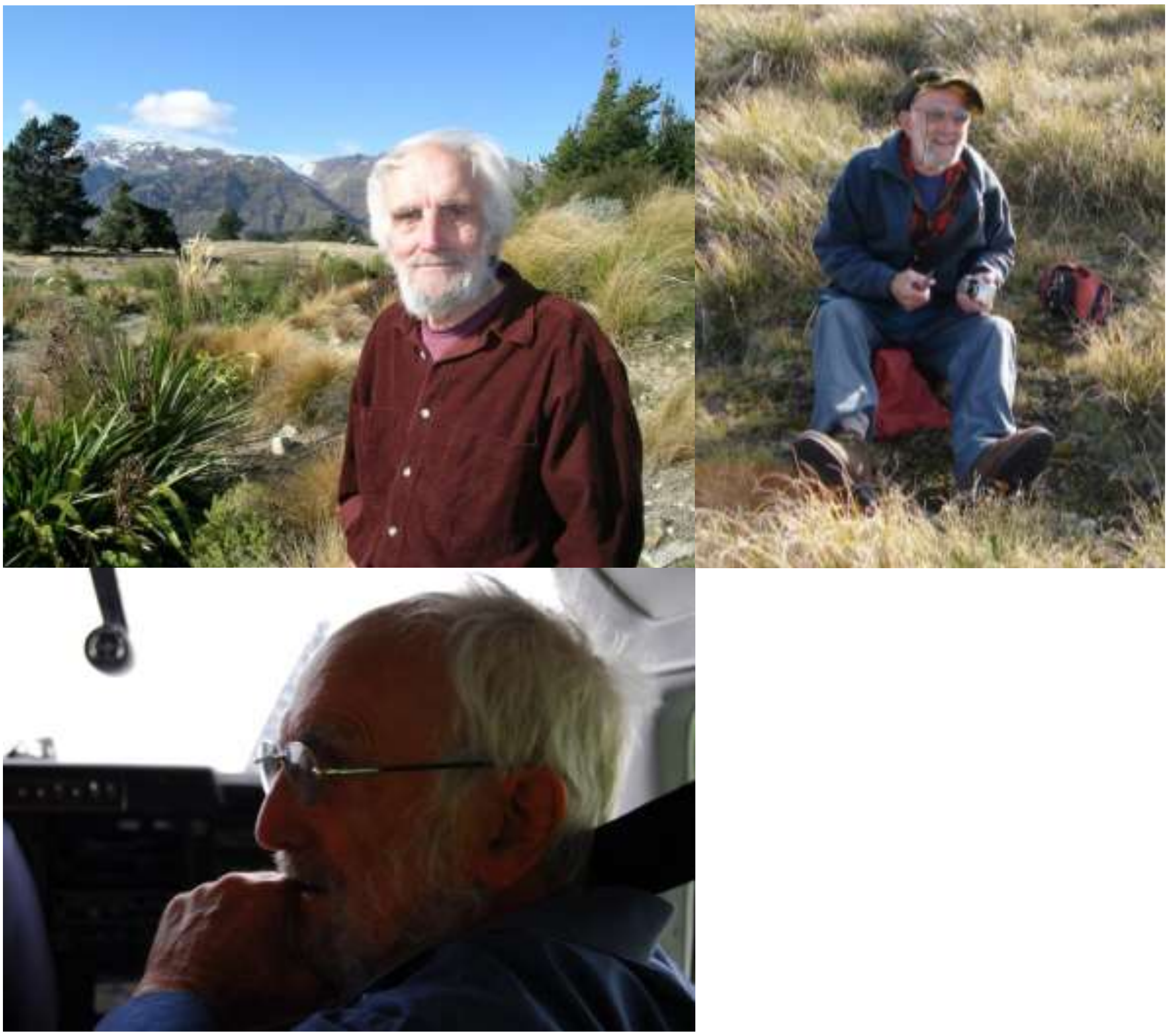

Figure 6-1: Trevor Chinn. At home in Hawea (top left), fixing a camera with pocketknife during a Godley Glacier survey April 2007 (top right), during a snowline flight (bottom left).

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7 Glossary of abbreviations and terms

Ablation	All processes by which snow and ice are lost from a glacier
Accumulation	All processes by which snow and ice are added to a glacier
Accumulation Area Ratio (AAR)	The ratio of the accumulation area above the equilibrium line, to the entire area of the glacier
Departure of the ELA	The elevation difference between the long-term ELAo and the annual snowline altitude. Positive departures mean a higher snowline and therefore a negative mass balance
ELA	The mean altitude of the snowline or equilibrium line across a glacier at the end of summer
ELAo	The long-term or steady-state altitude of the ELA which will maintain the glacier in equilibrium with the climate
Mass balance index	The negative of the ELA departure value. This gives values for annual changes with the same sign as the mass balance changes
Shaded cells	Areas which have been measured by digitising
Snowline elevation	The snowline elevation is synonymous with ELA when measured at the end of summer. All other snowline elevations apply to a transient seasonal snowline
Total Area	The entire area of the glacier. This may change from year to year, especially on the smaller glaciers

Appendix A Raw Index Glacier ELAs (1977-2019)

GLACIER	GL.IN. No	ELAo	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
KAIKOURA RA	621/001	2490						5		-30				-5
MT. ELLA	932B/012	2142						12						
MT FAERIE QUEENE	646/006	2030						-45						5
MT. WILSON	None	1912	-37	-11			15		-115	-141	-63	41	-89	68
MT. FRANKLIN	911A/002	1814		-12	122	-41	-74		-148			-18	-54	35
ROLLESTON GL.	911A/004	1763	-8	7	-8	6	-3	10	-123	-8	-8	13	15	-1
MT. CARRINGTON	646C/027	1715		-45		-22	-87	25	-150	-115		-10	45	55
MT. AVOCA	685F/004	1965		-55				-15		-95	-55	-5		10
MARMADUKE GL.	664C/012	1830	-43	-35	78	2	-28	30	-136	-122	-50	9	-5	65
RETREAT GL	906A/004	1742		-4		38	-50	14	-252		-4	20		
BROWNING RA	906A/001	1598		7		10	-34	7	-113		-2	17		
SOUTH CAMERON GL	685B/003	2250				0		40	-100	-120	-100	0		25
MT. BUTLER	685C/060	1840	-55	112	55	-34	-40	28	-200	-65	-70	10	-9	42
DAINTY GL	897/019	1954	-32	36		-7	-77	93	-99		-81	-73	-84	-12
KEA GL	897/007	1820		65		44	-85	134	-230		-120	-82	-83	-58
JASPUR GL	897/003	1725		43		63		-15	-155		-105	-42		-42
SIEGE GL	893A/006	1736	-64	-24		-76	-70	-46	-268		-94	35		-70
VERTEBRAE #12	893A/012	1864		7		36	-51	-14	-64		-56	-44		7
VERTEBRAE #25	893A/025	1840		30		25	-39	0	-62		-50	-27		3
RIDGE GL.	711L/024	2226		79			2	10	-15	-141	-32	-9		59
LANGDALE GL.	711I/035	2186	34	89			79	119	-1	-226	-221	14	-1	4
TASMAN GL.	711I/012	1790	-10	85	-90	20	-35	-30	-80	-95	-90	-10	-29	50
SALISBURY GL	888B/003	1810	17	17		32	-58	17	-92	-51	-76	-1	-35	-81
JALF GL	886/002	1790	-15	-10		-32	-65	5	-230	-78	-146	-20	-51	-32
CHANCELLOR DOME	882A/007	1756	96	95		77	-93	92	-211		-147	-78	-28	52
GLENMARY GL.	711F/006	2175		57		-95	-45	6	-40	-155	-67			5
BLAIR GL.	711D/038	1938		74		-75	-13	-51	-126	-80	-85		-68	17
MT McKENZIE	711D/021	1904		46		6	-16	-2	-184	-62	-124	13	-14	
JACKSON GL.	868B/094	2070		28		-20		5	-38	-80	-56		-9	
JACK GL.	875/015	1907		31		23	-22	44	-157	-79	-32	28	-2	-32
MT. ST. MARY	711B/039	1926												
THURNEYSON GL	711B/012	1970	-40			-44	-27		-105	-88	-65	-32	-52	-20
BREWSTER GL.	868C/020	1935		25		-89	-80	36	-141	-135	-139	-93	-107	
MT. STUART	752I/104	1673	-86	57		-23	-67	3	-135		-53	-13	5	
LINDSAY GL	867/002	1730		8		-78	-49	51	-170		-64	38	-115	42
FOG PK	752E/051	1987				-71		35		-96		-57	-85	35
SNOWY CK	752C/103	2092		64		-68	66	-54	-59	-68	-72	-56	-67	-55
MT. CARIA	863B/001	1472		-30			-59	-48	-100		-49	53	-50	28
FINDLAY GL.	859/009	1693					-89	42	-111		-64	32	-71	-8
PARK PASS GL.	752B/048	1824		79		-16	-46	34	-62	-59	-122	39	19	
MT. LARKINS	752E/002	2050								-180		-180		0
BRYANT GL.	752B/025	1783	-43	101			-20	-3	-163	-163	-173	-13	-20	
AILSA MTS.	752B/013	1648		-5					-88	-53	-53	1	-23	
MT. GUNN	851B/057	1593	22	45		-64	-62	17	-115		-53		-38	
MT. GENDARME	797G/033	1616					-46	-43	-136		-94	59	34	
LLAWRENNY PKS.	846/035	1476		4			-68	-4	-132		-36		-22	
BARRIER PK.	797F/004	1596		116		-51	-73	-31	-218		-72		-41	
MT. IRENE	797D/001	1563		137					-156		-37		-37	
MERRIE RA.	797B/010	1515		140										
CAROLINE PK.	803/001	1380												
NUMBER		50	15	39	5	32	36	41	41	26	40	37	33	32
MEAN		1842	-18	37	31	-16	-42	13	-129	-99	-77	-12	-35	6
STD. DEV.		223	46	50	83	47	39	43	63	49	46	48	40	40
No. below ELA (+ve balance)			9	6	1	19	29	17	40	25	32	19	22	15
% with +ve M.B.			60	15	20	59	81	41	98	96	80	51	67	47

GLACIER	GL.IN. No	ELAo	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
KAIKOURA RA	621/001	2490	50				-57	-30	-60			30	15	10
MT. ELLA	932B/012	2142	28				-87	-72	-142	-15		17	108	60
MT FAERIE QUEENE	646/006	2030	5				-62	-57	-65	-57		-50	145	160
MT. WILSON	None	1912	93				-167	-102	-154		-149	41	113	108
MT. FRANKLIN	911A/002	1814	52				-164	-109	-156	-82		122	164	136
ROLLESTON GL.	911A/004	1763	7				-143	-18	-143	-13	-123	40	87	105
MT. CARRINGTON	646C/027	1715	5				-170	-128	-158	-125	-137	-39	190	237
MT. AVOCA	685F/004	1965	6				-115	-25	-45	12	-75	70	115	65
MARMADUKE GL.	664C/012	1830	-13				-175	-75	-155	-82	-129	143	164	153
RETREAT GL	906A/004	1742	36				-73	-120	-277	16	-97	47	146	133
BROWNING RA	906A/001	1598	14				-116	-71	-118	-28	-108	30		
SOUTH CAMERON GL	685B/003	2250	90				-100	0	-120	0	-115	90	150	115
MT. BUTLER	685C/060	1840	-34			-95	-136	-28	-190	-60	-176	68	98	148
DAINTY GL	897/019	1954	-32			-103	-176	-73	-111	-12	-92	98	176	74
KEA GL	897/007	1820	-36				-230	-92	-250	80	-152	78	200	190
JASPUR GL	897/003	1725	-29				-150	-120	-145	-90	-100	43		
SIEGE GL	893A/006	1736	-64			-323	-386	-116	-396	-72	-203	214	414	279
VERTEBRAE #12	893A/012	1864	-39			-96	-86	-57	-86	-57	-73	-9	221	121
VERTEBRAE #25	893A/025	1840	-20			-94	-84	-54	-84	-54	-71	-5	125	70
RIDGE GL.	711L/024	2226	51				-126	-56	-94	-88	-136	9	109	79
LANGDALE GL.	711I/035	2186	69			-226	-231	14	-226	-1	-226	142	134	129
TASMAN GL.	711I/012	1790	-30	260	-35	-100	-108	-20	-124	-35	-102	63	186	110
SALISBURY GL	888B/003	1810	-66			-129	-100	-38	-165	-58	-84	42	220	172
JALF GL	886/002	1790	-31			-210	-220	-38	-240	-8	-191	-3	260	265
CHANCELLOR DOME	882A/007	1756	-78				-206	-147	-211	-36	-176	92	209	204
GLENMARY GL.	711F/006	2175	5			-15	-68	-30	-35	-45	-130	20	115	70
BLAIR GL.	711D/038	1938	-62				15	-73	-85	2		34	152	147
MT McKENZIE	711D/021	1904	8				-122	8	-99	6	-189	31	174	148
JACKSON GL.	868B/094	2070	5				-78	-25	-52	2	-54	5	95	45
JACK GL.	875/015	1907	-9			-90	-142	-27	-152	51	-102	33	101	85
MT. ST. MARY	711B/039	1926												
THURNEYSON GL	711B/012	1970	0			-40	-60	-66	-102	-32	-70	-5	142	162
BREWSTER GL.	868C/020	1935	-17			-84	-185	-145	-158	27	-156	47	345	220
MT. STUART	752I/104	1673	-10				-138	-33	-158	39	-106	-17	132	177
LINDSAY GL	867/002	1730	34				-175	-120	-180	45	-85	70	145	140
FOG PK	752E/051	1987	45				-93	-87	-99	-93	-97	111	148	138
SNOWY CK	752C/103	2092	11				-34	-58	-62	-35	-72	66	148	68
MT. CARIA	863B/001	1472	-43				-97	-72	-106	-82	-77	-55	178	188
FINDLAY GL.	859/009	1693	-51				-118	-59	-132	-61	-113	87	197	152
PARK PASS GL.	752B/048	1824	-30					-41	-189	-16	-79	56	131	111
MT. LARKINS	752E/002	2050	-25				-180	-180	-180	-180	-180	155	150	135
BRYANT GL.	752B/025	1783	-30				-108	-55	-153	-103	-113	-5	247	182
AILSA MTS.	752B/013	1648	-36				-84	-52	-93	-64	-55	-27	182	137
MT. GUNN	851B/057	1593	-59				-108	-64	-122	-86	-73	-34	209	217
MT. GENDARME	797G/033	1616	-36				-114	-64	-198	-100	-126	32	188	159
LLAWRENNY PKS.	846/035	1476	-47				-116	-68	-176	-15	-155	2	194	181
BARRIER PK.	797F/004	1596	-71				-168	-118	-236	-126	-132	86	304	207
MT. IRENE	797D/001	1563	-26				-156	-51	-163	-65	-103	49	95	100
MERRIE RA.	797B/010	1515	30				-135	-95	-165	-90	-130	-70	173	
CAROLINE PK.	803/001	1380					-160	1	-150	-78	-130	2	182	
NUMBER		50	48	1	1	13	48	49	49	47	44	49	47	45
MEAN		1842	-8	260	-35	-123	-131	-65	-146	-42	-119	42	168	140
STD. DEV.		223	42			83	63	43	66	52	42	58	68	58
No. below ELA (+ve balance)			19	0	1	14	46	44	48	34	44	11	0	0
% with +ve M.B.			40	0	100	108	96	90	98	72	100	22	0	0

GLACIER	GL.IN. No	ELAo	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
KAIKOURA RA	621/001	2490	-15	25			-25		14	50	5	13	30	
MT. ELLA	932B/012	2142	-22	46	-64		-77	17	27	38	30	38		38
MT FAERIE QUEENE	646/006	2030	-55	55	-54		-60	-48	-33	55	45	-47		45
MT. WILSON	None	1912	13	93	-121	-92	-82	93	40	93	88	11	98	88
MT. FRANKLIN	911A/002	1814	-104	121	-70		-106	126	-23	126	124	11	166	124
ROLLESTON GL.	911A/004	1763	-8	97	-94	-1	-23	37	32	52	51	5	102	50
MT. CARRINGTON	646C/027	1715	-135	210	-84	-120	-137	135	-45	155	155	-90	245	155
MT. AVOCA	685F/004	1965	-52	88	-52	-20	-53	35	3	85	10	5	105	65
MARMADUKE GL.	664C/012	1830	-57	140	-117	-27	-130	145	13	160	140	-20	164	150
RETREAT GL	906A/004	1742	-60	93	-78	18	-132	48	-22	68	63	18		58
BROWNING RA	906A/001	1598	-30	62	-77	-28	-110	12	21	27	22	2		22
SOUTH CAMERON GL	685B/003	2250	-30	50		25	-30	90	10	150	40	115	300	50
MT. BUTLER	685C/060	1840	-95	90	-147	-80	-176	75	22	120	85	-33	215	120
DAINTY GL	897/019	1954	-58	126	-67	-44	-94	-9	-12	116	41	-34	216	116
KEA GL	897/007	1820	-150	195	-159	-90	-155	78	-36	150	200	-83		140
JASPUR GL	897/003	1725	-95	195	-74	-95	-125	35	-41		195	40		135
SIEGE GL	893A/006	1736	-126	239	-160	-116	-203	-72	-18	394	224	-72	444	394
VERTEBRAE #12	893A/012	1864	-59	131	-48	-57	-74	-34	-8	166	60	-24	226	156
VERTEBRAE #25	893A/025	1840	-33	80	-51	-45	-75	-6	-16	110	19	-6	155	100
RIDGE GL.	711L/024	2226	-116	74	-63	2	-61	84	30	99	79	54		99
LANGDALE GL.	711I/035	2186	-226	99	-226	-1	-221	109	74	394	129	76		214
TASMAN GL.	711I/012	1790	-80	105	-80	-40	-40	60	6	235	175	-20	320	210
SALISBURY GL	888B/003	1810	-95	50	-95	-78	-95	40	0	140	140	-30	285	170
JALF GL	886/002	1790	-85		-190	-170	-190	-5	2	260	250	-35	370	260
CHANCELLOR DOME	882A/007	1756	-186	104	-186	-151	-181	94	43	109	109	-6	244	109
GLENMARY GL.	711F/006	2175	-37	35	-60	-30	-65	30	15	105	35	5	130	70
BLAIR GL.	711D/038	1938	-96	67	-93	-88	-88	22	34	132	34	15	222	122
MT McKENZIE	711D/021	1904	-99	56	-134	-122	-132	6	15	111	31	-2	181	46
JACKSON GL.	868B/094	2070	-54	33	-55	-54	-56	15	14	75	12	2	160	70
JACK GL.	875/015	1907	-109	78	-147		-112	28	16	83	73	-9	293	73
MT. ST. MARY	711B/039	1926												
THURNEYSON GL	711B/012	1970	-92	135	-97	-35	-70	10	-7	140	130	5	180	140
BREWSTER GL.	868C/020	1935	-165	115	-141	-155	-155	-65	-120	335	55	-5	350	335
MT. STUART	752I/104	1673	-83	142	-103	-108	-108	52	-66	127	117	4	185	175
LINDSAY GL	867/002	1730	-90	142	-123	-122	-118	50	-30	130	80	-20	148	120
FOG PK	752E/051	1987	-92	133	68	-95	-97	45	13	118	45	45	148	143
SNOWY CK	752C/103	2092	-88	28	-51	-58	-72	68	-2	66	64	64		66
MT. CARIA	863B/001	1472	-52	153	-50	-92	-98	43	-17	48	48	-74		48
FINDLAY GL.	859/009	1693	-73	132	-81	-115	-113	-3	-32	139	112	-61	177	97
PARK PASS GL.	752B/048	1824	-76	86	-163	-159	-154	76	26	86	86	56	181	116
MT. LARKINS	752E/002	2050	-180	115	-115	-180	-180	110	115	120	120	110	150	120
BRYANT GL.	752B/025	1783	-118	87	-117	-108	-118	17	-8	167	-8	-28	307	182
AILSA MTS.	752B/013	1648	-55	37	-65	-58	-68	-3	-35	22	27	-33	132	-33
MT. GUNN	851B/057	1593	-78	42	-68	-108	-108	17	-43	52	197	-78	227	192
MT. GENDARME	797G/033	1616	-131	34	-96	-133	-129	32	-40	33	34	-46	184	34
LLAWRENNY PKS.	846/035	1476	-71	137	-100	-96	-76	9	-37	104	124	-68	124	-4
BARRIER PK.	797F/004	1596	-108	194	-148	-131	-131	104	-17	119	194	-41	259	119
MT. IRENE	797D/001	1563	-162	170	-146	-130	-160	70	-85	50	68	-90	170	65
MERRIE RA.	797B/010	1515	-103	175	-100	-110	-105	150	-56	155	160	-75		154
CAROLINE PK.	803/001	1380	-105	195	-89	-110	-125	30	-44	50	40	0	170	45
NUMBER		50	49	48	47	44	49	48	49	48	49	49	38	48
MEAN		1842	-87	106	-99	-82	-108	43	-6	123	89	-9	204	116
STD. DEV.		223	48	54	49	52	47	51	39	82	64	48	84	79
No. below ELA (+ve balance)			46	0	47	41	49	9	26	0	1	27	0	2
% with +ve M.B.			94	0	100	93	100	19	53	0	2	55	0	4

GLACIER	GL.IN. No	ELAo	2013	2014	2015	2016	2017	2018	2019
KAIKOURA RA	621/001	2490			14				
MT. ELLA	932B/012	2142			43				
MT FAERIE QUEENE	646/006	2030			45				
MT. WILSON	None	1912	11	11	93	113	13	113	117
MT. FRANKLIN	911A/002	1814	36	-9	46	131	41	164	164
ROLLESTON GL.	911A/004	1763	2	37	2	102	2	105	112
MT. CARRINGTON	646C/027	1715	-120	-90	135	155	-87	230	250
MT. AVOCA	685F/004	1965	-17	-17	10				
MARMADUKE GL.	664C/012	1830	-20	-27	9	165	-20	275	280
RETREAT GL	906A/004	1742	18	18	18	183	18		
BROWNING RA	906A/001	1598	12	2	22	62	2		
SOUTH CAMERON GL	685B/003	2250	20	0	30	200	0	300	305
MT. BUTLER	685C/060	1840	-33	-60	-33	210	-33	215	218
DAINTY GL	897/019	1954	-34	-34	-32	126	-58	216	221
KEA GL	897/007	1820	-83	-84	65	200	-84		
JASPUR GL	897/003	1725	-95	-75	35		-95		
SIEGE GL	893A/006	1736	-72	-74	-72	394	-74		
VERTEBRAE #12	893A/012	1864	-24	-34	6	166	-34	226	221
VERTEBRAE #25	893A/025	1840	-6	-6	20	110	-6	155	125
RIDGE GL.	711L/024	2226	9	4	9		4	254	
LANGDALE GL.	711I/035	2186	76	-1	-1	394	76		
TASMAN GL.	711I/012	1790	-35	-35	50	235	-35	330	425
SALISBURY GL	888B/003	1810	-30	-30	-30	170	-30	172	250
JALF GL	886/002	1790	-35	-35	-5	265	-35	265	370
CHANCELLOR DOME	882A/007	1756	-147	-21	-6	209	-21	244	244
GLENMARY GL.	711F/006	2175	-5	-25	35	130	-5	145	185
BLAIR GL.	711D/038	1938	12	12	34	132	12	222	222
MT McKENZIE	711D/021	1904	-14	-14	31	174	-14	191	194
JACKSON GL.	868B/094	2070	2	0	5	150	0	220	160
JACK GL.	875/015	1907	-9	-27	33	273	-92	393	293
MT. ST. MARY	711B/039	1926	-46	-126	74				
THURNEYSON GL	711B/012	1970	-32	-55	110	150	-32	220	320
BREWSTER GL.	868C/020	1935	-17	15	75	350	-17	415	350
MT. STUART	752I/104	1673	-67	4	92	175	-67	186	177
LINDSAY GL	867/002	1730	-64	-20	85	85	-64		142
FOG PK	752E/051	1987	28	28	103		28	171	148
SNOWY CK	752C/103	2092	-32		64		-32		113
MT. CARIA	863B/001	1472							
FINDLAY GL.	859/009	1693		-8	112	139	-13	202	162
PARK PASS GL.	752B/048	1824	26	19	86	119	19	216	206
MT. LARKINS	752E/002	2050	100	-180	120	175	-30	185	185
BRYANT GL.	752B/025	1783	-8	-113	-8	167	-113	307	317
AILSA MTS.	752B/013	1648	-33	-33	27	37	-33	152	37
MT. GUNN	851B/057	1593	-53	-63	192	197	-63	227	202
MT. GENDARME	797G/033	1616	-56	-46	32	34	-56	188	184
LLAWRENNY PKS.	846/035	1476	-68	-6	124	124	-6		124
BARRIER PK.	797F/004	1596		84	222	254	-72	304	284
MT. IRENE	797D/001	1563		68	40	20	-90		70
MERRIE RA.	797B/010	1515			160	160	-103		
CAROLINE PK.	803/001	1380			50		-78		
NUMBER		50	41	43	49	39	44	32	35
MEAN		1842	-22	-24	48	170	-31	225	211
STD. DEV.		223	47	49	58	85	42	72	87
No. below ELA (+ve balance)			28	29	8	0	32	0	0
% with +ve M.B.			68	67	16	0	73	0	0

Figure A-1: Raw Index Glacier ELAs (1977-2019). Shaded columns indicate years of ELA departures below the long term ELAo.

Appendix B Normalised Index Glacier ELAs (1977-2019)

GLACIER	GL.IN. No	ELAo	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
KAIKOURA RA	621/001	2490						22		-130				-22
MT. ELLA	932B/012	2142						21						
MT FAERIE QUEENE	646/006	2030						-73						8
MT. WILSON	None	1912	-47	-14			19		-147	-180	-80	52	-113	87
MT. FRANKLIN	911A/002	1814		-12	126	-42	-76		-152			-19	-56	36
ROLLESTON GL.	911A/004	1763	-14	12	-14	10	-5	17	-215	-14	-14	23	26	-2
MT. CARRINGTON	646C/027	1715		-36		-18	-70	20	-120	-92		-8	36	44
MT. AVOCA	685F/004	1965		-97				-26		-168	-97	-9		18
MARMADUKE GL.	664C/012	1830	-41	-33	74	2	-26	29	-130	-116	-48	9	-5	62
RETREAT GL	906A/004	1742		-4		41	-54	15	-270		-4	21		
BROWNING RA	906A/001	1598		13		18	-61	13	-202		-4	30		
SOUTH CAMERON GL	685B/003	2250				0		43	-108	-130	-108	0		27
MT. BUTLER	685C/060	1840	-52	105	52	-32	-38	26	-188	-61	-66	9	-8	39
DAINTY GL	897/019	1954	-35	40		-8	-85	103	-109		-90	-81	-93	-13
KEA GL	897/007	1820		44		30	-58	92	-157		-82	-56	-57	-40
JASPUR GL	897/003	1725		35		52		-12	-127		-86	-34		-34
SIEGE GL	893A/006	1736	-28	-11		-34	-31	-20	-119		-42	16		-31
VERTEBRAE #12	893A/012	1864		8		40	-57	-16	-71		-62	-49		8
VERTEBRAE #25	893A/025	1840		46		38	-59	0	-95		-77	-41		4
RIDGE GL.	711L/024	2226		98			2	12	-19	-176	-40	-11		73
LANGDALE GL.	711I/035	2186	21	56			50	75	-1	-143	-139	9	-1	3
TASMAN GL.	711I/012	1790	-9	74	-79	18	-31	-26	-70	-83	-79	-9	-25	44
SALISBURY GL	888B/003	1810	16	16		31	-56	16	-89	-49	-74	-1	-34	-79
JALF GL	886/002	1790	-9	-6		-20	-41	3	-144	-49	-91	-13	-32	-20
CHANCELLOR DOME	882A/007	1756	71	71		57	-69	68	-157		-109	-58	-21	39
GLENMARY GL.	711F/006	2175		93		-154	-73	10	-65	-252	-109			8
BLAIR GL.	711D/038	1938		87		-88	-15	-60	-148	-94	-100		-80	20
MT McKENZIE	711D/021	1904		49		6	-17	-2	-198	-67	-133	14	-15	
JACKSON GL.	868B/094	2070		46		-33		8	-62	-131	-92		-15	
JACK GL.	875/015	1907		29		21	-20	41	-145	-73	-30	26	-2	-30
MT. ST. MARY	711B/039	1926												
THURNEYSON GL	711B/012	1970	-45			-50	-31		-119	-100	-74	-36	-59	-23
BREWSTER GL.	868C/020	1935		15		-54	-49	22	-86	-82	-85	-57	-65	
MT. STUART	752I/104	1673	-86	57		-23	-67	3	-135		-53	-13	5	
LINDSAY GL	867/002	1730		8		-78	-49	51	-169		-64	38	-114	42
FOG PK	752E/051	1987				-86		42		-116		-69	-102	42
SNOWY CK	752C/103	2092		104		-111	108	-88	-96	-111	-117	-91	-109	-90
MT. CARIA	863B/001	1472		-37			-73	-59	-124		-61	66	-62	35
FINDLAY GL.	859/009	1693					-91	43	-113		-65	33	-72	-8
PARK PASS GL.	752B/048	1824		86		-18	-50	37	-68	-65	-134	43	21	
MT. LARKINS	752E/002	2050								-150		-150		0
BRYANT GL.	752B/025	1783	-35	81			-16	-2	-131	-131	-139	-10	-16	
AILSA MTS.	752B/013	1648		-8					-149	-90	-90	2	-39	
MT. GUNN	851B/057	1593	21	42		-60	-58	16	-108		-50		-36	
MT. GENDARME	797G/033	1616					-52	-49	-154		-106	67	38	
LLAWRENNY PKS.	846/035	1476		4			-74	-4	-144		-39		-24	
BARRIER PK.	797F/004	1596		79		-35	-50	-21	-149		-49		-28	
MT. IRENE	797D/001	1563		151					-172		-41		-41	
MERRIE RA.	797B/010	1515		115										
CAROLINE PK.	803/001	1380												
NUMBER		50	15	39	5	32	36	41	41	26	40	37	33	32
MEAN		1842	-18	36	32	-18	-40	9	-127	-110	-76	-10	-36	8
STD. DEV.		223	39	51	80	50	39	41	51	51	35	46	42	40
No. below ELA (+ve balance)			9	6	1	19	29	17	40	25	32	19	22	15
% with +ve M.B.			60	15	20	59	81	41	98	96	80	51	67	47

GLACIER	GL.IN. No	ELAo	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
KAIKOURA RA	621/001	2490	217				-248	-130	-261			130	65	43
MT. ELLA	932B/012	2142	49				-151	-125	-247	-26		30	188	104
MT FAERIE QUEENE	646/006	2030	8				-100	-92	-105	-92		-81	234	258
MT. WILSON	None	1912	119				-213	-130	-196		-190	52	144	138
MT. FRANKLIN	911A/002	1814	54				-169	-112	-161	-84		126	169	140
ROLLESTON GL.	911A/004	1763	12				-250	-31	-250	-23	-215	70	152	184
MT. CARRINGTON	646C/027	1715	4				-136	-102	-126	-100	-110	-31	152	190
MT. AVOCA	685F/004	1965	11				-203	-44	-97	21	-132	123	203	115
MARMADUKE GL.	664C/012	1830	-12				-167	-72	-148	-78	-123	137	157	146
RETREAT GL	906A/004	1742	39				-78	-129	-297	17	-104	50	156	142
BROWNING RA	906A/001	1598	25				-207	-127	-211	-50	-193	54		
SOUTH CAMERON GL	685B/003	2250	97				-108	0	-130	0	-124	97	162	124
MT. BUTLER	685C/060	1840	-32			-89	-128	-26	-179	-56	-165	64	92	139
DAINTY GL	897/019	1954	-35			-114	-195	-81	-123	-13	-102	108	195	82
KEA GL	897/007	1820	-25				-157	-63	-171	55	-104	53	137	130
JASPUR GL	897/003	1725	-24				-123	-99	-119	-74	-82	35		
SIEGE GL	893A/006	1736	-28			-143	-171	-51	-176	-32	-90	95	184	124
VERTEBRAE #12	893A/012	1864	-43			-107	-96	-63	-96	-63	-81	-10	246	135
VERTEBRAE #25	893A/025	1840	-31			-144	-129	-82	-129	-82	-108	-8	192	107
RIDGE GL.	711L/024	2226	63				-157	-70	-117	-110	-169	11	136	98
LANGDALE GL.	711I/035	2186	44			-143	-146	9	-143	-1	-143	90	85	81
TASMAN GL.	711I/012	1790	-26	162	-31	-88	-95	-18	-109	-31	-89	55	163	96
SALISBURY GL	888B/003	1810	-64			-125	-97	-36	-159	-56	-81	41	212	166
JALF GL	886/002	1790	-19			-131	-138	-24	-150	-5	-120	-2	163	166
CHANCELLOR DOME	882A/007	1756	-58				-153	-109	-157	-27	-131	68	155	152
GLENMARY GL.	711F/006	2175	8			-24	-111	-49	-57	-73	-211	33	187	114
BLAIR GL.	711D/038	1938	-73				18	-86	-100	2		40	178	172
MT McKENZIE	711D/021	1904	9				-131	9	-106	6	-203	33	187	159
JACKSON GL.	868B/094	2070	8				-128	-41	-85	3	-88	8	155	74
JACK GL.	875/015	1907	-8			-83	-131	-25	-140	47	-94	30	93	78
MT. ST. MARY	711B/039	1926												
THURNEYSON GL	711B/012	1970	0			-45	-68	-75	-116	-36	-79	-6	161	184
BREWSTER GL.	868C/020	1935	-10			-51	-113	-88	-96	16	-95	29	210	134
MT. STUART	752I/104	1673	-10				-138	-33	-158	39	-106	-17	132	177
LINDSAY GL	867/002	1730	34				-174	-119	-179	45	-84	70	144	139
FOG PK	752E/051	1987	54				-112	-105	-119	-112	-117	134	178	166
SNOWY CK	752C/103	2092	18				-55	-95	-101	-57	-117	108	241	111
MT. CARIA	863B/001	1472	-53				-120	-89	-131	-101	-95	-68	220	233
FINDLAY GL.	859/009	1693	-52				-120	-60	-135	-62	-115	89	201	155
PARK PASS GL.	752B/048	1824	-33					-45	-207	-18	-86	61	143	121
MT. LARKINS	752E/002	2050	-21				-150	-150	-150	-150	-150	129	125	112
BRYANT GL.	752B/025	1783	-24				-87	-44	-123	-83	-91	-4	199	147
AILSA MTS.	752B/013	1648	-61				-142	-88	-157	-108	-93	-46	308	232
MT. GUNN	851B/057	1593	-56				-102	-60	-115	-81	-69	-32	197	204
MT. GENDARME	797G/033	1616	-41				-129	-72	-224	-113	-143	36	213	180
LLAWRENNY PKS.	846/035	1476	-51				-126	-74	-192	-16	-169	2	211	197
BARRIER PK.	797F/004	1596	-49				-115	-81	-161	-86	-90	59	208	142
MT. IRENE	797D/001	1563	-29				-172	-56	-180	-72	-114	54	105	111
MERRIE RA.	797B/010	1515	25				-111	-78	-136	-74	-107	-58	142	
CAROLINE PK.	803/001	1380					-167	1	-157	-82	-136	2	190	
NUMBER		50	48	1	1	13	48	49	49	47	44	49	47	45
MEAN		1842	-1	162	-31	-99	-135	-70	-151	-44	-121	42	172	142
STD. DEV.		223	53			40	47	39	49	50	38	55	46	44
No. below ELA (+ve balance)			19	0	1	14	46	44	48	34	44	11	0	0
% with +ve M.B.			40	0	100	108	96	90	98	72	100	22	0	0

GLACIER	GL.IN. No	ELAo	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
KAIKOURA RA	621/001	2490	-65	109			-109		61	217	22	56	130	
MT. ELLA	932B/012	2142	-38	80	-111		-134	30	47	66	52	66		66
MT FAERIE QUEENE	646/006	2030	-89	89	-87		-97	-77	-53	89	73	-76		73
MT. WILSON	None	1912	17	119	-154	-117	-105	119	51	119	112	14	125	112
MT. FRANKLIN	911A/002	1814	-107	125	-72		-109	130	-24	130	128	11	171	128
ROLLESTON GL.	911A/004	1763	-14	170	-164	-2	-40	65	56	91	89	9	178	87
MT. CARRINGTON	646C/027	1715	-108	168	-67	-96	-110	108	-36	124	124	-72	196	124
MT. AVOCA	685F/004	1965	-92	155	-92	-35	-93	62	5	150	18	9	185	115
MARMADUKE GL.	664C/012	1830	-54	134	-112	-26	-124	138	12	153	134	-19	157	143
RETREAT GL	906A/004	1742	-64	100	-84	19	-141	51	-24	73	67	19		62
BROWNING RA	906A/001	1598	-54	111	-138	-50	-197	21	38	48	39	4		39
SOUTH CAMERON GL	685B/003	2250	-32	54		27	-32	97	11	162	43	124	324	54
MT. BUTLER	685C/060	1840	-89	85	-138	-75	-165	71	21	113	80	-31	202	113
DAINTY GL	897/019	1954	-64	139	-74	-49	-104	-10	-13	128	45	-38	239	128
KEA GL	897/007	1820	-103	133	-109	-62	-106	53	-25	103	137	-57		96
JASPUR GL	897/003	1725	-78	160	-61	-78	-103	29	-34		160	33		111
SIEGE GL	893A/006	1736	-56	106	-71	-51	-90	-32	-8	175	99	-32	197	175
VERTEBRAE #12	893A/012	1864	-66	146	-53	-63	-82	-38	-9	185	67	-27	251	173
VERTEBRAE #25	893A/025	1840	-51	123	-78	-69	-115	-9	-25	169	29	-9	237	153
RIDGE GL.	711L/024	2226	-144	92	-78	2	-76	105	37	123	98	67		123
LANGDALE GL.	711I/035	2186	-143	62	-143	-1	-139	69	47	249	81	48		135
TASMAN GL.	711I/012	1790	-70	92	-70	-35	-35	53	5	206	153	-18	280	184
SALISBURY GL	888B/003	1810	-92	48	-92	-75	-92	39	0	135	135	-29	275	164
JALF GL	886/002	1790	-53		-119	-106	-119	-3	1	163	157	-22	232	163
CHANCELLOR DOME	882A/007	1756	-138	77	-138	-112	-134	70	32	81	81	-4	181	81
GLENMARY GL.	711F/006	2175	-60	57	-98	-49	-106	49	24	171	57	8	211	114
BLAIR GL.	711D/038	1938	-113	79	-109	-103	-103	26	40	155	40	18	260	143
MT McKENZIE	711D/021	1904	-106	60	-144	-131	-142	6	16	119	33	-2	195	49
JACKSON GL.	868B/094	2070	-88	54	-90	-88	-92	25	23	123	20	3	262	115
JACK GL.	875/015	1907	-101	72	-136		-103	26	15	77	67	-8	270	67
MT. ST. MARY	711B/039	1926												
THURNEYSON GL	711B/012	1970	-104	153	-110	-40	-79	11	-8	159	147	6	204	159
BREWSTER GL.	868C/020	1935	-101	70	-86	-95	-95	-40	-73	204	34	-3	214	204
MT. STUART	752I/104	1673	-83	142	-103	-108	-108	52	-66	127	117	4	185	175
LINDSAY GL	867/002	1730	-89	141	-122	-121	-117	50	-30	129	79	-20	147	119
FOG PK	752E/051	1987	-111	160	82	-114	-117	54	16	142	54	54	178	172
SNOWY CK	752C/103	2092	-143	46	-83	-95	-117	111	-3	108	104	104		108
MT. CARIA	863B/001	1472	-64	189	-62	-114	-121	53	-21	59	59	-92		59
FINDLAY GL.	859/009	1693	-74	135	-83	-117	-115	-3	-33	142	114	-62	180	99
PARK PASS GL.	752B/048	1824	-83	94	-178	-174	-169	83	28	94	94	61	198	127
MT. LARKINS	752E/002	2050	-150	96	-96	-150	-150	92	96	100	100	92	125	100
BRYANT GL.	752B/025	1783	-95	70	-94	-87	-95	14	-6	135	-6	-23	247	147
AILSA MTS.	752B/013	1648	-93	63	-110	-98	-115	-5	-59	37	46	-56	223	-56
MT. GUNN	851B/057	1593	-73	40	-64	-102	-102	16	-40	49	185	-73	214	181
MT. GENDARME	797G/033	1616	-148	38	-109	-150	-146	36	-45	37	38	-52	208	38
LLAWRENNY PKS.	846/035	1476	-77	149	-109	-104	-83	10	-40	113	135	-74	135	-4
BARRIER PK.	797F/004	1596	-74	133	-101	-90	-90	71	-12	81	133	-28	177	81
MT. IRENE	797D/001	1563	-179	188	-161	-144	-177	77	-94	55	75	-99	188	72
MERRIE RA.	797B/010	1515	-85	144	-82	-91	-86	124	-46	128	132	-62		127
CAROLINE PK.	803/001	1380	-110	204	-93	-115	-131	31	-46	52	42	0	178	47
NUMBER		50	49	48	47	44	49	48	49	48	49	49	38	48
MEAN		1842	-87	109	-99	-80	-110	44	-4	122	84	-6	204	109
STD. DEV.		223	36	44	40	46	32	48	39	49	45	50	46	52
No. below ELA (+ve balance)			46	0	47	41	49	9	26	0	1	27	0	2
% with +ve M.B.			94	0	100	93	100	19	53	0	2	55	0	4

GLACIER	GL.IN. No	ELAo	2013	2014	2015	2016	2017	2018	2019
KAIKOURA RA	621/001	2490							
MT. ELLA	932B/012	2142			75				
MT FAERIE QUEENE	646/006	2030			73				
MT. WILSON	None	1912	14	14	119	144	17	149	154
MT. FRANKLIN	911A/002	1814	37	-9	47	135	42	173	173
ROLLESTON GL.	911A/004	1763	3	65	3	178	3	186	198
MT. CARRINGTON	646C/027	1715	-96	-72	108	124	-70	185	201
MT. AVOCA	685F/004	1965	-30	-30	18				
MARMADUKE GL.	664C/012	1830	-19	-26	9	158	-19	257	262
RETREAT GL	906A/004	1742	19	19	19	196	19		
BROWNING RA	906A/001	1598	21	4	39	111	4		
SOUTH CAMERON GL	685B/003	2250	22	0	32	216	0	310	315
MT. BUTLER	685C/060	1840	-31	-56	-31	197	-31	202	205
DAINTY GL	897/019	1954	-38	-38	-35	139	-64	234	240
KEA GL	897/007	1820	-57	-57	44	137	-57		
JASPUR GL	897/003	1725	-78	-62	29		-78		
SIEGE GL	893A/006	1736	-32	-33	-32	175	-33		
VERTEBRAE #12	893A/012	1864	-27	-38	7	185	-38	248	242
VERTEBRAE #25	893A/025	1840	-9	-9	31	169	-9	240	193
RIDGE GL.	711L/024	2226	11	5	11		5	316	
LANGDALE GL.	711I/035	2186	48	-1	-1	249	48		
TASMAN GL.	711I/012	1790	-31	-31	44	206	-31	272	350
SALISBURY GL	888B/003	1810	-29	-29	-29	227	-29	164	238
JALF GL	886/002	1790	-22	-22	-3	166	-22	164	229
CHANCELLOR DOME	882A/007	1756	-109	-4	-4	155	-16	183	183
GLENMARY GL.	711F/006	2175	-8	-57	57	211	-8	226	288
BLAIR GL.	711D/038	1938	14	14	40	155	14	255	255
MT McKENZIE	711D/021	1904	-15	-15	33	187	-15	205	208
JACKSON GL.	868B/094	2070	3	0	8	245	0	353	256
JACK GL.	875/015	1907	-8	-25	30	252	-85	353	263
MT. ST. MARY	711B/039	1926					-38		
THURNEYSON GL	711B/012	1970	-36	-19	125	170	-36	233	339
BREWSTER GL.	868C/020	1935	-10	9	46	214	-10	254	214
MT. STUART	752I/104	1673	-67	4	92	175	-67	189	180
LINDSAY GL	867/002	1730	-64	-20	119	84	-64		147
FOG PK	752E/051	1987	34	34	124		34	212	183
SNOWY CK	752C/103	2092	-52		104		-52		188
MT. CARIA	863B/001	1472	-52	-52					
FINDLAY GL.	859/009	1693		-8	114	142	-13	211	169
PARK PASS GL.	752B/048	1824	28	21	94	130	21	235	225
MT. LARKINS	752E/002	2050	83	-150	100	146	-25	157	157
BRYANT GL.	752B/025	1783	-6	-91	-6	135	-91	241	249
AILSA MTS.	752B/013	1648	-56	-56	46	63	-56	275	67
MT. GUNN	851B/057	1593	-50	-59	181	185	-59	216	192
MT. GENDARME	797G/033	1616	-63	-52	36	38	-63	210	206
LLAWRENNY PKS.	846/035	1476	-74	-7	135	135	-7		141
BARRIER PK.	797F/004	1596		57	152	174	-49	210	196
MT. IRENE	797D/001	1563		75	44	22	-99		83
MERRIE RA.	797B/010	1515			132	132	-85		
CAROLINE PK.	803/001	1380			52		-82		
NUMBER		50	41	43	47	39	45	32	35
MEAN		1842	-20	-19	52	161	-29	229	211
STD. DEV.		223	41	41	53	52	37	52	61
No. below ELA (+ve balance)			28	29	8	0	33	0	0
% with +ve M.B.			68	67	17	0	73	0	0

Figure B-1: Normalised Index Glacier ELAs (1977-2019). Shaded columns indicate years of ELA departures below the long term ELAo.

Appendix C Survey flight dates 1977-2019

Table C-1: Survey flight dates 1977-2019.

Year	Survey flight date	Staff	Glaciers surveyed
1977	April 18	Trevor Chinn, Maurice McSaveney, Graeme Horrell, R.Christian Aircraft Piper Warrior from Queenstown	15
1978	April 11	Trevor Chinn, Maurice McSaveney, Ian Whitehouse, Graeme Horrell. Aircraft Cessna 206 Air Safaris Tekapo	40
1979	No flight, other information	*Other sources: Marmaduke Dixon and Mt Butler Glacier photographs, and Tasman Glacier snowline information only*	3
1980	March 14 and April 16	Trevor Chinn, Maurice McSaveney, Graeme Horrell, Gavin Craig (pilot) Aircraft Cessna 185 Air Safaris Tekapo	32
1981	March 20	Trevor Chinn, Maurice McSaveney, Graeme Horrell, Les Basher, Rob? (pilot) Aircraft Cessna 206 Air Safaris Tekapo	36
1982	March 4, 5 and 16	Maurice McSaveney, Ian Whitehouse, pilot?	41
1983	March 22	Trevor Chinn, Maurice McSaveney, Ian Whitehouse, Eric Colhoun, Gavin Craig (pilot) Aircraft Cessna 206 Air Safaris Tekapo	41
1984	March 20	Trevor Chinn, Ian Whitehouse, Llyod Smith, Ian Halstead, Gavin Craig (pilot) Aircraft Cessna 206 Air Safaris Tekapo	27
1985	March 12 and 15	Trevor Chinn, Ian Whitehouse, Maurice McSaveney, Les Basher, Philip Tonkin, pilot? Aircraft Cessna 206 Air Safaris Tekapo	40
1986	April 10 and 11	Trevor Chinn, Warren Chinn, J.Laramme, pilot? Aircraft Cessna 206 Air Safaris Tekapo	38
1987	March 6	Trevor Chinn, Ian Whitehouse, Les Basher, James Barringer, pilot? Aircraft Cessna 206 Air Safaris Tekapo	33
1988	March 23 and 25	Trevor Chinn, Les Basher (Flt 1), James Barringer (Flt 2), Alan Smith (pilot Flt 1), Bruce Drake (pilot Flt 2) Aircraft Cessna 182 Drake Aviation	33
1989	April 1, 2 and 3	Trevor Chinn, Lloyd Homer, D.Russel, P.Teawata (pilot) Cessna 208 Nelson Aviation	49
1990	No flight, other information	*Tasman Glacier snowline from photo taken by Andrew Ruddell on 22 March 1990. Long distance photo from the ground of Mt Harper. No funding for snowline flight.*	1

Year	Survey flight date	Staff	Glaciers surveyed
1991	No flight, other information	*Tasman and Murchison Glacier snowlines. Andrew Ruddell observations on the ground during Feb and March and his photo on 9 Feb 1991. No funding for the snowline flight.*	2
1992	April 6 and 7	Trevor Chinn, Lloyd Homer, Stuart, Miles, pilot? Cessna 208 Nelson Aviation	15
1993	February 15 and 16	Trevor Chinn, Ian Turnbull, pilot? Cessna 177, Aspiring Air	49
1994	March 10 and 11	Trevor Chinn, P.Jane Forsyth, pilot? Cessna 177, Aspiring Air	50
1995	March 4 and 5	Trevor Chinn, P.Jane Forsyth, Davida Mead (pilot) Cessna 177, Aspiring Air	50
1996	March 5 and 6	Trevor Chinn, P.Jane Forsyth, Simon Cox, Andy Woods (pilot) Cessna 177, Aspiring Air	48
1997	March 7, 8, 9 and 12	Trevor Chinn, P.Jane Forsyth, Davida Mead (pilot Flt1), Andy Woods (pilot Flt 2) Cessna 177, Aspiring Air	45
1998	March 4-12	Trevor Chinn, P.Jane Forsyth, Phil Glassey, Andy Woods (pilot) Cessna 177, Aspiring Air	50
1999	March 15,16, 21 and 25	Trevor Chinn, Gareth Clare (Flt 1,2,3), Jim Salinger (Flt 4), Andy Woods (pilot) Cessna 177, Aspiring Air	48
2000	March 7, 8 and 9	Trevor Chinn, Gareth Clare, Andy Woods (pilot) Cessna 177, Wanaka Flightseeing	46
2001	March 2, 5 and 6	Trevor Chinn, Clive Hyendrych, Andy Woods (pilot) Cessna 177, Wanaka Flightseeing	50
2002	March 11 and 12	Trevor Chinn, Clive Hyendrych, Andy Woods (pilot) Cessna 177, Wanaka Flightseeing	49
2003	March 7, 8 and April 25	Trevor Chinn, Clive Hyendrych (Flt 1,2), Andy Woods (pilot) Cessna 177, Wanaka Flightseeing	49
2004	March 17 and 18	Trevor Chinn, Jim Salinger, Katrin Rohl, Andy Woods (pilot) Cessna 206, Wanaka Flightseeing	45
2005	March 14 and 15	Trevor Chinn, Andrew Willsman, Miles Wislang, Andy Woods (pilot) Cessna 206, Wanaka Flightseeing	50
2006	March 4 and 5	Trevor Chinn, Andrew Willsman, Dorothea Stumm, Graeme Lloyd (pilot) Cessna 206, Wanaka Flightseeing	49
2007	March 8, 9 and 10	Trevor Chinn, Andrew Willsman, Jordy Hendrikx, Wendy Lawson, Andy Woods (pilot) Cessna 206, Wanaka Flightseeing	50

Year	Survey flight date	Staff	Glaciers surveyed
2008	March 13 and 14	Trevor Chinn, Andrew Willsman, Jim Salinger, Andy Woods (pilot) Cessna 206, Wanaka Flightseeing	50
2009	March 3 and 4	Trevor Chinn, Jordy Hendrikx, Jim Salinger, Mette Riger-Kusk (Flt1), Andy Woods (pilot) Cessna 206, Wanaka Flightseeing	50
2010	March 5 and 6	Trevor Chinn, Andrew Willsman, Jordy Hendrikx. Graeme Lloyd (pilot) Cessna 206, Wanaka Flightseeing	50
2011	March 12,13 and 30	Andy Woods (pilot), Trevor Chinn, Andrew Willsman (Flt 1,2), Blair Fitzharris (Flt 1,2), Tim Kerr (Flt 1,2), Andrew Lorrey (Flt 3), Andy Woods (pilot) Cessna 206, Wanaka Flightseeing	49
2012	March 4, 20 and 21	Andy Woods (pilot), Trevor Chinn, Andrew Willsman, Brian Anderson (Flt 1), Royden Thompson (Flt 2,3), Andy Woods (pilot) Cessna 206, Wanaka Flightseeing	50
2013	March 12	Trevor Chinn, Andrew Willsman, Heather Purdie, Andy Woods (pilot) Cessna 207 Milford Sound Flights	41
2014	March 11	Andy Woods (pilot), Trevor Chinn, Andrew Lorrey	43
2015	March 14 and 15	Trevor Chinn, Brian Anderson, Huw Horgan, Andy Woods (pilot) Cessna 206 Milford Sound Flights	49
2016	March 11 (Flight 1)	Trevor Chinn, Brian Anderson, Royden Thompson, Andy Woods (pilot) GippsAero Airvan, Milford Sound Flights	44
	March 30 (Flight 2)	Andy Woods (pilot), Trevor Chinn, Brian Anderson, Andrew Mackintosh, Sabine Bauman, Lauren Vargo	
2017	March 9 (Flight 1)	Trevor Chinn, Andrew Lorrey, Brian Anderson, Huw Horgan, Lauren Vargo, Andy Woods (pilot) GippsAero Airvan, Milford Sound Flights	47
	March 10 (Flight 2)	Trevor Chinn, Andrew Lorrey, Brian Anderson, Huw Horgan, Lauren Vargo, Andy Woods (pilot) GippsAero Airvan, Milford Sound Flights	
2018	March 10 (Flight 1)	T. Chinn, Andrew Lorrey, Dave Allen, Brian Anderson, Huw Horgan, Lauren Vargo, Andy Woods (pilot) GippsAero Airvan, Milford Sound Flights	47
	March 11 (Flight 2)	T. Chinn, Andrew Lorrey, Brian Anderson, Huw Horgan, Lauren Vargo, Andy Woods (pilot) GippsAero Airvan, Milford Sound Flights. Also, a second chase plane	

Year	Survey flight date	Staff	Glaciers surveyed
		with photographers and the press. Dave Allen (NIWA), TVNZ.	
2019	March 20 (Flight 1)	Andrew Lorrey, Gregor Macara, Brian Anderson, Lauren Vargo, Olliver Wigmore, Aaron Duff (chief pilot), Andy Woods (co-pilot). Cessna 208 Caravan, Milford Sound Flights	46
	March 21 (Flight 2)	Andrew Lorrey, Gregor Macara, Brian Anderson, Lauren Vargo, Olliver Wigmore, Aaron Duff (chief pilot), Andy Woods (co-pilot). Cessna 208 Caravan, Milford Sound Flights	

Appendix D Index Glacier details

No. 621/1 **KAIKOURA RANGE** NZMS 260 sheet O 30

Rock Glacier

GLACIER DATA		
AREA	45.42	ha
Debris area	41.66	ha
Max Elev	2640	m
Min Elev	2200	m
Mean Elev	2420	m
Length	1.4	km
Elev Range	440	m
Gradient	0.31	

SNOWLINE DATA		
Aspect	S	
ELAo	**2490**	m
Max SL	2540	m, 1989
Min SL	2430	m, 1995
Mean SL	2491	m
SL Range	110	m
No. surveys	18	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	AREAS ACCUM. ha	AREAS DEBRIS ha	AREAS TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**2490**	**0**	**3.88**	**41.66**	**45.54**	**0.09**	**0**
1977							
1978							
1979							
1980							
1981							
1982	2495	5	3.90	41.64	45.54	0.09	-5
1983							
1984	2460	-30	6.74	38.80	45.54	0.15	30
1985							
1986							
1987							
1988	2485	-5	5.14	40.40	45.54	0.11	5
1989	2540	50	0.90	44.64	45.54	0.02	-50
1990							
1991							
1992							
1993	2433	-57	12.84	32.70	45.54	0.28	57
1994	2460	-30	6.74	38.80	45.54	0.15	30
1995	2430	-60	13.29	32.25	45.54	0.29	60
1996					no visit		
1997					cloud		
1998	2520	30	2.29	43.25	45.54	0.05	-30
1999	2505	15	2.74	42.80	45.54	0.06	-15
2000	2500	10	3.44	42.10	45.54	0.08	-10
2001	2475	-15	6.52	38.90	45.42	0.14	15
2002	2515	25	2.32	43.10	45.42	0.05	-25
2003					No visit	cloud	
2004					No visit	cloud	
2005	2465	-25	6.74	38.80	45.54	0.15	25
2006					no visit		
2007	2504	14	2.84	42.70	45.54	0.06	-14
2008	2540	50	0.90	44.64	45.54	0.02	-50
2009	2495	5	3.90	41.64	45.54	0.09	-5
2010	2503	13	3.34	42.20	45.54	0.07	**-13**
2011	2520	30	2.29	43.25	45.54	0.05	**-30**
2012					no visit		
2013					no visit		
2014					no visit		
2015	2504	14	3.35	42.19	45.54	0.07	**-14**
2016					no visit		
2017					no visit		
2018					no visit		
2019					no visit		
MEAN	**2491**	**1.4**	**4.8**	**40.7**	**45.5**	**0.11**	**-1**

Mt Alarm – no photograph, as this glacier was not visited.

No. 932B/12

Mt ELLA

Glacierette

NZMS 260 sheet M30

GLACIER DATA		
Aspect	E	
AREA	5.32	ha
Max Elev	2250	m
Min Elev	2080	m
Mean Elev	2165	m
Length	0.34	km
Elev Range	170	m
Gradient	0.5	

SNOWLINE DATA		
ELAo	**2142**	m
Max SL	>2250	m, 2011
Min SL	2000	m, 1995
Mean SL	2143	m
SL Range	250	m
No. surveys	20	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**2142**	**0**	**3.19**	**1.45**	**5.32**	**0.60**	**0**
1977							
1978							
1979							
1980							
1981							
1982	2154	12	5.32	0.00	5.32	1.00	-12
1983							
1984							
1985							
1986							
1987							
1988							
1989	2170	28	2.17	3.15	5.32	0.41	-28
1990							
1991							
1992							
1993	2055	-87	5.91	0.00	5.91	1.11	87
1994	2070	-72	5.74	0.00	5.74	1.08	72
1995	2000	-142	15.10	0.00	15.10	2.84	142
1996	2127	-15	4.42	0.90	5.32	0.83	15
1997					In cloud		
1998	2159	17	2.92	2.40	5.32	0.55	-17
1999	2250	108	0	5.17	5.17	0.00	-108
2000	2202	60	0.1	2.46	2.56	0.04	-60
2001	2120	-22	4.57	0.75	5.32	0.86	22
2002	2188	46	0.33	1.61	1.94	0.17	-46
2003	2078	-64	5.32	0.00	5.32	1.00	64
2004					No visit	cloud	
2005	2065	-77	5.80	0.00	5.80	1.00	77
2006	2159	17	2.92	2.40	5.32	0.55	-17
2007	2169	27	2.20	3.10	5.30	0.42	-27
2008	2180	38	0.50	2.44	2.94	0.17	-38
2009	2172	30	0.89	2.05	2.94	0.30	-30
2010	2180	38	0.50	2.44	2.94	0.17	-38
2011	>2250		0.00	1.20	1.20	0.00	0
2012	2180	38	0.00	1.20	1.20	0.00	-38
2013					No visit		
2014					No visit		
2015	2185	43	0.49	2.45	2.94	0.17	-23
2016					No visit		
2017					No visit		
2018					No visit		
2019	>2250			~0.1	~0.1	0.00	
MEAN	**2143**	**1**	**3.10**	**1.61**		**0.60**	**0**

Figure D-1: Mt Ella on 21 March 2019.

No. 646/6 **FAERIE QUEENE** NZMS 260 sheet M 31

Glacierette

GLACIER DATA		
Aspect	SE	
AREA	5.74	ha
Max Elev	2200	m
Min Elev	1940	m
Mean Elev	2070	m
Length	0.36	km
Elev Range	260	m
Gradient	0.72	

SNOWLINE DATA		
ELAo	**2030**	m
Max SL	>2200	m, 2011
Min SL	1920	m, 1995
Mean SL	1979	m
SL Range	280	m
No. Surveys	21	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELA	**2030**	**45**	**3.44**	**2.30**	**5.74**	**0.60**	**0**
1977							
1978							
1979							
1980							
1981							
1982	1940	-45	5.74	0.00	5.74	1.00	45
1983							
1984							
1985							
1986							
1987							
1988	1990	5	4.55	1.19	5.74	0.79	-5
1989	1990	5	4.55	1.19	5.74	0.79	-5
1990							
1991							
1992							
1993	1923	-62	6.09	0.00	6.09	1.00	62
1994	1928	-57	5.99	0.00	5.99	1.00	57
1995	1920	-65	8.04	0.00	8.04	1.00	65
1996	1928	-57	5.99	0.00	5.99	1.00	57
1997							
1998	1935	-50	5.84	0.00	5.84	1.00	50
1999	2130	145	0.00	5.74	3.80	0.00	-145
2000	2145	160	0.00	2.90	2.90	0.00	-160
2001	1930	-55	4.57	0.00	4.57	1.00	55
2002	2040	55	3.09	2.65	5.74	0.54	-55
2003	1931	-54	4.57	0.00	4.57	1.00	54
2004					no visit	cloud	
2005	1925	-60	6.09	0.00	6.09	1.00	60
2006	1937	-48	5.74	0.00	5.74	1.00	48
2007	1952	-33	5.44	0.30	5.74	0.95	33
2008	2040	55	0.60	2.80	3.40	0.18	-55
2009	2030	45	1.10	2.30	3.40	0.32	-45
2010	1938	-47	3.46	0.00	3.46	1.00	47
2011	>2200		0.00	2.72	2.72	0.00	0
2012	2030	45	1.10	2.30	3.40	0.32	-45
2013					no visit		
2014					no visit		
2015	2030	45	1.10	2.30	3.40	0.32	-45
2016					no visit		
2017					no visit		
2018					no visit		
2019	>2200				<0.5		
MEAN	**1979**	**-6**	**3.93**	**1.15**		**0.71**	**6**

Figure D-2: Faerie Queen, remnants of the glacier on the face on the left of frame, 21 March 2019.

Not numbered

Mt WILSON

Snow patch

NZMS 260 sheet K33

GLACIER DATA		
Aspect	S	
AREA	17.58 to 0.68	ha
Max Elev	2030	m
Min Elev	1740	m
Mean Elev	1885	m
Length	N/A	
Elev Range	290	m
Gradient		

SNOWLINE DATA		
ELAo	**1912**	@ 7.03 ha
Max SL	2025	m, 1999
Min SL	1745	m, 1993
Mean SL	1919	m
SL Range	280	m
No. Surveys	30	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	AREAS ACCUM. ha	AREAS ABL. N/A	AREAS TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELA	**1912**		**10.55**	N/A	**7.03**	N/A	
1977	1875	-37	6.28		6.28		37
1978	1901	-11	4.68		4.68		11
1979							
1980							
1981	1927	15	3.28		3.28		-15
1982							
1983	1797	-115	4.88		4.88		115
1984	1771	-141	14.78		14.78		141
1985	1849	-63	8.38		8.38		63
1986	1953	41	2.28		2.28		-41
1987	1823	-89	10.48		10.48		89
1988	1980	68	1.48		1.48		-68
1989	2005	93	0.70		0.70		-93
1990							
1991							
1992							
1993	1745	-167	17.13		17.13		167
1994	1810	-102	11.38		11.38		102
1995	1758	-154	15.98		15.98		154
1996							
1997	1763	-149	15.48		15.48		149
1998	1953	41	2.28		2.28		-41
1999	2025	113	0.13		0.13		-113
2000	2020	108	0.68		0.68		-108
2001	1925	13	3.56		3.56		-13
2002	2005	93	0.63		0.63		-93
2003	1791	-121	4.40		4.40		121
2004	1820	-92	10.55		10.55		92
2005	1830	-82	10.48		10.48		82
2006	2005	93	0.65		0.65		-93
2007	1952	40	2.25		2.25		-40
2008	2005	93	0.65		0.65		-93
2009	2000	88	0.88		0.88		-88
2010	1923	11	3.45		3.45		-11
2011	2010	98	0.63		0.63		-98
2012	2000	88	0.88		0.88		-88
2013	1923	11	3.45		3.45		-11
2014	1923	11	3.45		3.45		-11
2015	2005	93	0.65		0.65		-93
2016	2025	113	0.31		0.13		-113
2017	1925	13	3.56		3.56		-13
2018	2025	113	0.31		0.13		-113
2019	2029	117	0.05		0.05		-117
Mean	**1919**	**4**	**4.75**		**4.74**		**-7**

Figure D-3: Mt Wilson 21 March 2019.

No. 911A/2

Mt. FRANKLIN

Cirque

NZMS 260 sheet K33

GLACIER DATA		
Aspect	E	
AREA	8.85	ha
Max Elev	2010	m
Min Elev	1680	m
Mean Elev	1845	m
Length	0.5	km
Elev Range	330	m
Gradient	0.66	

SNOWLINE DATA		
ELAo	**1814**	m
Max SL	1980	m, 2011
Min SL	1650	m, 1993
Mean SL	1839	m
SL Range	330	m
No. Surveys	31	

MEASUREMENTS

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	AREAS ACCUM. ha	AREAS ABL. ha	AREAS TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**1814**	**0**	**7.45**	**1.40**	**8.85**	**0.84**	**0**
1977							
1978	1802	-12	7.74	1.11	8.85	0.87	12
1979	1936	122	0.84	8.01	8.85	0.09	-122
1980	1773	-41	8.30	0.55	8.85	0.94	41
1981	1740	-74	8.60	0.25	8.85	0.97	74
1982							
1983	1666	-148	?	0.00			148
1984							
1985							
1986	1796	-18	8.00	0.85	8.85	0.90	18
1987	1760	-54	8.40	0.45	8.85	0.95	54
1988	1849	35	5.30	3.55	8.85	0.60	-35
1989	1866	52	4.62	4.23	8.85	0.52	-52
1990							
1991							
1992							
1993	1650	-164	13.04	0.00	13.04	1.47	164
1994	1705	-109	8.80	0.05	8.85	0.99	109
1995	1658	-156	12.00	0.00	12.00	1.38	156
1996	1732	-82	8.65	0.20	8.85	0.98	82
1997					cloud		
1998	1936	122	0.84	8.01	8.85	0.09	-122
1999	1978	164	0.26	8.59	8.20	0.03	-164
2000	1950	136	0.57	8.28	7.90	0.07	-136
2001	1710	-104	8.85	0.00	7.90	1.12	104
2002	1935	121	0.87	6.88	7.75	0.11	-121
2003	1744	-70	7.50	0.25	7.75	0.97	70
2004					cloud		
2005	1708	-106	7.75	0.00	7.75	1.00	106
2006	1940	126	0.85	6.90	7.75	0.11	-126
2007	1791	-23	7.75	0.00	7.75	1.00	23
2008	1940	126	0.85	6.90	7.75	0.11	-126
2009	1938	124	0.80	6.95	7.75	0.10	-124
2010	1825	11	5.65	1.22	6.87	0.82	-11
2011	1980	166	0.10	6.77	6.87	0.01	-166
2012	1938	124	0.80	6.07	6.87	0.12	-124
2013	1850	36	4.37	2.50	6.87	0.64	-36
2014	1805	-9	6.47	0.40	6.87	0.94	9
2015	1860	46	3.87	3.00	6.87	0.56	-46
2016	1945	131	0.70	6.17	6.87	0.10	-131
2017	1855	41	5.10	1.77	6.87	0.74	-41
2018	1978	164	0.26	6.61	6.87	0.04	-164
2019	1978	164	0.26	6.61	6.87	0.04	-164
Mean	**1839**	**25**	**4.81**	**3.33**		**0.59**	

Figure D-4: Mt Franklin 21 March 2019.

No. 911A /4

ROLLESTON GL.

NZMS 260 sheet K33

Cirque glacier

GLACIER DATA		
Aspect	SE	
AREA	11.1	ha
Max Elev	1900	m
Min Elev	1710	m
Mean Elev	1805	m
Length	0.36	km
Elev Range	190	m
Gradient	0.53	

SNOWLINE DATA		
ELAo	**1763**	m
Max SL	1868	m, 1993, 95
Min SL	1620	m, 2000
Mean SL	1772	m
SL Range	248	m
No. Surveys	38	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
1955	1800	29					
1960	1800	29					-29
ELAo	**1763**	**0**	**8.45**	**2.65**	**11.1**	**0.76**	**0**
1977	1755	-8	9.46	1.64	11.1	0.85	8
1978	1770	7	8.55	2.55	11.1	0.77	-7
1979	1755	-8	9.46	1.64	11.1		8
1980	1769	6	8.55	2.55	11.1	0.77	-6
1981	1760	-3	8.96	2.14	11.1	0.81	3
1982	1773	10	8.45	2.65	11.1	0.76	-10
1983	1640	-123	10.74	0.00	11.1	0.97	123
1984	1755	-8	9.46	1.64	11.1	0.85	8
1985	1755	-8	9.46	1.64	11.1	0.85	8
1986	1776	13	8.30	2.80	11.1	0.75	-13
1987	1778	15	8.20	2.90	11.1	0.74	-15
1988	1762	-1	8.90	2.20	11.1	0.80	1
1989	1770	7	8.55	2.55	11.1	0.77	-7
1990							
1991							
1992							
1993	1620	-143	10.74	0.00	11.1	0.97	143
1994	1745	-18	10.26	0.84	11.1	0.92	18
1995	1620	-143	10.8	0.00	11.1	0.97	143
1996	1750	-13	9.85	1.25	11.1	0.89	13
1997	1640	-123	10.74	0.00	11.1	0.97	123
1998	1803	40	4.98	6.12	11.1	0.45	-40
1999	1850	87	1.3	9.80	11.1	0.12	-87
2000	1868	105	0.41	10.69	11.1	0.04	-105
2001	1755	-8	9.46	1.64	11.1	0.85	8
2002	1860	97	0.61	10.49	11.1	0.05	-97
2003	1669	-94	10.74	0.00	11.1	0.97	94
2004	1762	-1	8.90	2.20	11.1	0.80	1
2005	1740	-23	10.50	0.60	11.1	0.95	23
2006	1800	37	6.36	4.74	11.1	0.57	-37
2007	1795	32	6.31	4.79	11.1	0.57	-32
2008	1815	52	4.32	6.78	11.1	0.39	-52
2009	1814	51	4.75	6.35	11.1	0.43	-51
2010	1768	5	8.60	2.50	11.1	0.77	-5
2011	1865	102	0.50	10.60	11.1	0.05	-102
2012	1813	50	4.40	6.20	10.6	0.42	-50
2013	1765	2	8.30	2.30	10.6	0.78	-2
2014*	1800	37	5.75	4.85	10.6	0.54	-37
2015	1765	2	8.30	2.30	10.6	0.78	-2
2016	1865	102	0.50	10.10	10.6	0.05	-102
2017	1765	2	8.30	2.30	10.6	0.78	-2
2018	1868	105	0.41	9.19	9.6	0.04	-105
2019	1875	112	0.14	9.46	9.6	0.01	-112
MEAN	**1772**	**9**	**7.08**	**3.82**		**0.64**	**-9**

Figure D-5: Rolleston Glacier 21 March 2019.

No. 664C/21 **Mt CARRINGTON** NZMS sheet K33

Cirque glacier

GLACIER DATA		
Aspect	S	
AREA	9.7	ha
Max Elev	1970	m
Min Elev	1595	m
Mean Elev	1783	m
Length	0.71	km
Elev Range	375	m
Gradient	0.53	

SL DATA		
ELAo	**1715**	m
Max SL	1960	m, 2011
Min SL	1545	m, 1993
Mean SL	1723	m
SL Range	415	m
No. Surveys	37	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	AREAS ACCUM. ha	ABL. ha	TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**1715**	**0**	**7.0**	**8.5**	**15.5**	**0.45**	**0**
1977							
1978	1670	-45	8.9	6.6	15.5	0.57	45
1979							
1980	1693	-22	7.7	7.8	15.5	0.50	22
1981	1628	-87	11.6	3.9	15.5	0.75	87
1982	1740	25	6.5	9.0	15.5	0.42	-25
1983	1565	-150	18.5	0.0	15.5	1.00	150
1984	1600	-115	14.5	1.0	15.5	0.94	115
1985							
1986	1705	-10	7.2	8.3	15.5	0.46	10
1987	1760	45	6.0	9.5	15.5	0.39	-45
1988	1770	55	5.8	9.7	15.5	0.37	-55
1989	1720	5	6.9	8.6	15.5	0.45	-5
1990							
1991							
1992							
1993	1545	-170	20.6	0.0	15.5	1.33	170
1994	1587	-128	15.7	0.0	15.5	1.01	128
1995	1557	-158	16.6	0.0	15.5	1.07	158
1996	1590	-125	14.9	0.6	15.5	0.96	125
1997	1578	-137	17.4	0.0	15.5	1.00	137
1998	1676	-39	8.7	6.8	15.5	0.56	39
1999	1900	185	2.9	10.1	13.0	0.23	-185
2000	1952	237	0.5	11.0	11.5	0.04	-237
2001	1580	-135	11.5	0.0	11.5	1.00	135
2002	1945	230	1.3	8.4	9.7	0.13	-230
2003	1631	-84	8.7	1.0	9.7	0.90	84
2004	1595	-120	9.6	0.1	9.7	0.99	120
2005	1578	-137	9.7	0.0	9.7	1.00	137
2006	1850	135	4.5	5.2	9.7	0.46	-135
2007	1670	-45	7.6	2.1	9.7	0.78	45
2008	1870	155	4.2	5.5	9.7	0.43	-155
2009	1870	155	4.2	5.5	9.7	0.43	-155
2010	1625	-90	8.9	0.8	9.7	0.92	90
2011	1960	245	0.5	9.2	9.7	0.05	-245
2012	1870	155	4.2	5.5	9.7	0.43	-155
2013	1595	-120	9.6	0.1	9.7	0.99	120
2014	1625	-90	8.9	0.8	9.7	0.92	90
2015	1850	135	4.5	5.2	9.7	0.46	-135
2016	1870	155	4.2	5.5	9.7	0.43	-155
2017	1628	-87	6.2	3.5	9.7	0.64	87
2018	1945	230	1.3	4.3	5.6	0.23	-230
2019	1965	250	0.2	4.4	4.6	0.04	-250
MEAN	**1723**	**8**	**8.9**	**4.3**		**0.63**	**-8**

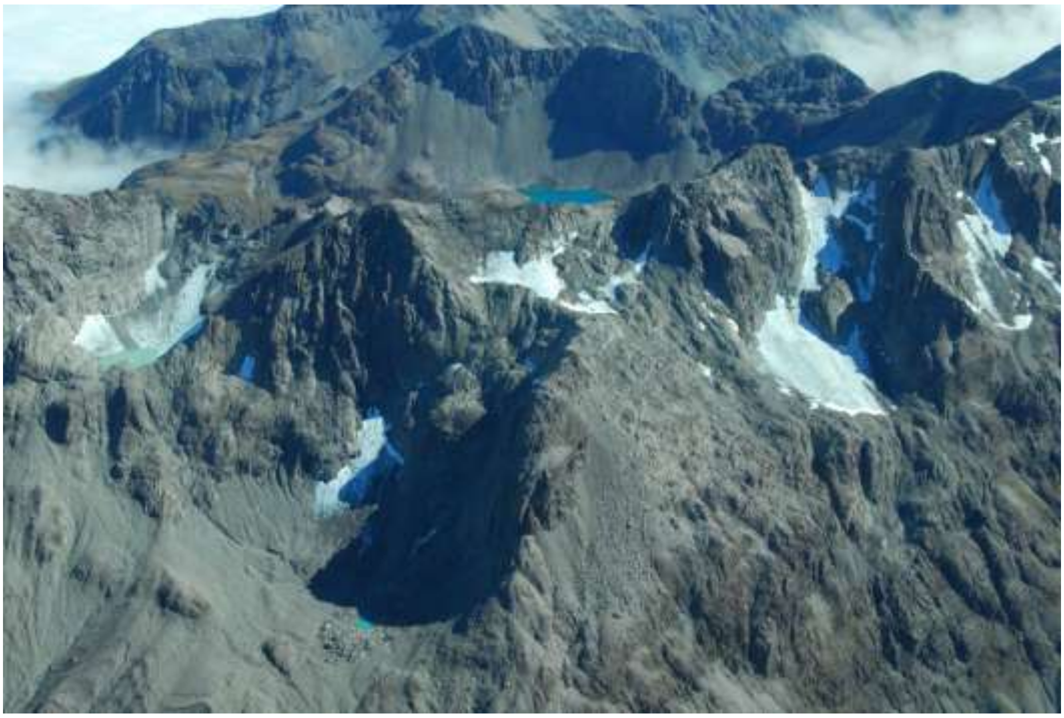

Figure D-6: Mt Carrington 21 March 2019.

No. 685F/4

Mt AVOCA

Glacierette

NZMS sheet K34

GLACIER DATA		
Aspect	E	
AREA	9.803	m
Max Elev	2080	m
Min Elev	1890	m
Mean Elev	1985	m
Length	0.36	km
Elev Range	190	m
Gradient	0.53	

SNOWLINE DATA		
ELAo	**1965**	m
Max SL	2080	m, 1999
Min SL	1850	m, 1993
Mean SL	1966	m
SL Range	230	m
No. Surveys	34	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL (ha)	AREA RATIO	BALANCE
	m	m	ha	ha	Persistent Ice	(AAR)	INDEX
ELA	**1965**	**0**	**4.4**	**5.4**	**9.8**	**0.45**	**0**
1977							
1978	1910	-55	9.2	0.6	9.8	0.94	55
1979							
1980							
1981							
1982	1950	-15	5.9	3.9	9.8	0.60	15
1983							
1984	1870	-95	10.5	0.0	9.8	1.00	95
1985	1910	-55	9.2	0.6	9.8	0.94	55
1986	1960	-5	4.9	5.0	9.8	0.49	5
1987							
1988	1975	10					-10
1989	1971	6	4.0	5.8	9.8	0.40	-6
1990							
1991							
1992							
1993	1850	-115	11.4	0.0	11.4	1.16	115
1994	1940	-25	7.2	2.6	9.8	0.73	25
1995	1910	-55	9.8	1.0	9.8	1.00	55
1996	1977	12	3.6	6.2	9.8	0.36	-12
1997	1890	-75	9.8	0.0	9.8	1.00	75
1998	2035	70	1.0	5.3	6.3	0.16	-70
1999	2080	115	0.0	3.2	3.2	0.00	-115
2000	2030	65	1.1	2.5	3.6	0.31	-65
2001	1913	-52	7.1	0.0	7.1	0.00	52
2002	2053	88	0.4	3.1	3.6	0.12	-88
2003	1913	-52	7.1	0.0	7.1	1.00	52
2004	1945	-20	6.5	3.3	9.8	0.66	20
2005	1912	-53	7.1	0.0	7.1	1.00	53
2006	2000	35	1.8	1.8	3.6	0.50	-35.00
2007	1968	3	2.4	1.2	3.6	0.66	-3.00
2008	2050	85	0.5	3.1	3.6	0.13	-85.00
2009	1975	10	2.3	1.3	3.6	0.64	-10.00
2010	1970	5	2.3	1.3	3.6	0.65	-5.00
2011	2070	105	0.1	1.0	1.1	0.09	-105.00
2012	2030	65	0.3	0.8	1.1	0.28	-65.00
2013	1948	-17	3.5	0.0	1.1	1.00	17.00
2014	1948	-17	3.5	0.0	1.1	1.00	17.00
2015	1975	10			1.1	1.00	-10.00
2016	2030	65	too fragmented to determine areas			1.00	-65.00
2017	1948	-17	too fragmented to determine areas, well above				
2018	>2080		too fragmented to determine areas, SL well above				
2019	not visited						
MEAN	**1966**	**1**	**4.7**	**1.9**		**0.63**	**-1**

Mt Avoca - no photograph, as this glacier was not visited.

No. 664C/12 **MARMADUKE DIXON GL** NZMS 260 sheet K33

Mountain glacier

GLACIER DATA		
Aspect	E	
AREA	93	m
Max Elev	2160	m
Min Elev	1615	m
Mean Elev	1888	m
Length	1.7	km
Elev Range	545	m
Gradient	0.285	

SNOWLINE DATA		
ELAo	1830	m
Max SL	2105	m, 2018
Min SL	1655	m, 1993
Mean SL	1854	m
SL Range	450	m
No. Surveys	41	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	AREAS ACCUM. ha	AREAS ABL. ha	AREAS TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**1830**	**0**	**63.7**	**28.8**	**92.5**	**0.69**	**0**
1977	1788	-43	73.0	19.5	92.5	0.79	43
1978	1795	-35	71.5	21.0	92.5	0.77	35
1979	1908	78	44.5	48.0	92.5	0.48	-78
1980	1832	2	63.5	29.0	92.5	0.69	-2
1981	1803	-28	69.7	22.8	92.5	0.75	28
1982	1860	30	49.7	42.9	92.5	0.54	-30
1983	1694	-136	86.7	5.8	92.5	0.94	136
1984	1708	-122	85.5	7.0	92.5	0.92	122
1985	1780	-50	74.0	18.6	92.5	0.80	50
1986	1839	9	61.7	30.8	92.5	0.67	-9
1987	1825	-5	64.8	27.8	92.5	0.70	5
1988	1895	65	48.0	44.5	92.5	0.52	-65
1989	1818	-13	67.0	25.5	92.5	0.72	13
1990	1998	168	22.5	70.0	92.5	0.24	-168
1991							
1992							
1993	1655	-175	90.3	2.2	92.5	0.98	175
1994	1755	-75	78.5	14.0	92.5	0.85	75
1995	1675	-155	92.1	0.4	92.5	1.00	155
1996	1748	-82	82.2	10.3	92.5	0.89	82
1997	1701	-129	91.9	0.7	92.5	0.99	129
1998	1973	143	26.8	65.7	92.5	0.29	-143
1999	1994	164	21.5	71.0	92.5	0.23	-164
2000	1983	153	23.8	68.8	92.5	0.26	-153
2001	1773	-57	75.3	17.2	92.5	0.81	57
2002	1970	140	28.4	53.4	81.8	0.35	-140
2003	1713	-117	74.5	7.3	81.8	0.91	117
2004	1803	-27	66.5	19.4	85.9	0.77	27
2005	1700	-130	91.9	0.7	92.5	0.99	130
2006	1975	145	27.8	54.0	81.8	0.34	-145
2007	1843	13	54.0	27.8	81.8	0.66	-13
2008	1990	160	26.8	55.0	81.8	0.33	-160
2009	1970	140	28.4	53.4	81.8	0.35	-140
2010	1810	-20	61.0	20.8	81.8	0.75	20
2011	1994	164	21.5	57.1	78.6	0.27	-164
2012	1980	150	24.0	54.6	78.6	0.31	-150
2013	1810	-20	61.0	17.6	78.6	0.78	20
2014	1803	-27	59.3	19.3	78.6	0.75	27
2015	1839	9	61.7	16.9	78.6	0.78	-9
2016	1995	165	17.0	61.6	78.6	0.22	-165
2017	1810	-20	61.0	17.6	78.6	0.78	20
2018	2105	275	3.7	74.9	78.6	0.05	-275
2019	2110	280	3.6	75.0	78.6	0.05	-280
MEAN	**1854**	**24**	**55.8**	**31.9**		**0.62**	**-24**

Figure D-7: Marmaduke Dixon Glacier 21 March 2019.

No. 906A/4 **RETREAT GL.** NZMS 260 sheet K33

Mountain glacier

GLACIER DATA		
Aspect	SW	
AREA	28.7	ha
Max Elev	1930	m
Min Elev	1570	m
Mean Elev	1750	m
Length	1.05	km
Elev Range	360	m
Gradient	0.343	

SNOWLINE DATA		
ELAo	**1742**	m
Max SL	1925	m, 1999
Min SL	1465	m, 1995
Mean SL	1739	m
SL Range	460	m
No. Surveys	35	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1742**	**0**	**13.9**	**14.8**	**28.7**	**0.48**	**0**
1977							
1978	1738	-4	14.7	14.0	28.7	0.51	4
1979							
1980	1780	38	8.3	20.4	28.7	0.29	-38
1981	1692	-50	20.3	8.4	28.7	0.71	50
1982	1756	14	13.3	15.4	28.7	0.46	-14
1983	1490	-252	31.6	-2.9	28.7	1.10	252
1984							
1985	1738	-4	14.8	13.9	28.7	0.52	4
1986	1762	20	10.8	17.9	28.7	0.38	-20
1987							
1988							
1989	1778	36	8.9	19.8	28.7	0.31	-36
1990							
1991							
1992							
1993	1669	-73	22.8	5.9	28.7	0.80	73
1994	1622	-120	27.2	1.5	28.7	0.95	120
1995	1465	-277	32.4	-3.7	28.7	1.13	277
1996	1758	16	11.7	17.1	28.7	0.41	-16
1997	1645	-97	25.2	3.5	28.7	0.88	97
1998	1789	47	7.3	21.4	28.7	0.25	-47
1999	1888	146	1.9	26.8	12.3	0.16	-146
2000	1875	133	2.4	5.6	8.0	0.30	-133
2001	1682	-60	0.7	7.3	8.0	0.09	60
2002	1835	93	2.9	5.1	8.0	0.36	-93
2003	1664	-78	7.2	0.8	8.0	0.90	78
2004	1760	18	2.2	5.8	8.0	0.27	-18
2005	1610	-132	6.5	1.5	8.0	0.81	132
2006	1790	48	0.4	7.6	8.0	0.05	-48
2007	1720	-22	5.1	2.9	8.0	0.64	22
2008	1810	68	0.6	7.3	8.0	0.08	-68
2009	1805	63	0.9	6.6	7.5	0.12	-63
2010	1760	18	1.7	5.8	7.5	0.23	-18
2011	>1888		0.0	5.3	5.3	0.00	0
2012	1800	58	1.2	4.1	5.3	0.22	-58
2013	1760	18	3.6	1.7	5.3	0.68	-18
2014	1760	18	3.6	1.7	5.3	0.68	-18
2015	1760	18	3.6	1.7	5.3	0.68	-18
2016	1925	183	0.1	5.2	5.3	0.02	-183
2017	1760	18	3.6	1.7	5.3	0.68	-18
2018	>1888		0.0	5.3	5.2	0.00	0
2019	>1888		0.0	4.0	4.0	0.00	0
MEAN	**1739**	**-3**	**8.5**	**7.6**		**0.45**	**3**

Figure D-8: Retreat Glacier 21 March 2019.

906A/1 **BROWNING RA.** NZMS 260 sheet J33

Small cirque

GLACIER DATA		
Aspect	S	
AREA	4.08	ha
Max Elev	1700	m
Min Elev	1530	m
Mean Elev	1615	m
Length		km
Elev Range	170	m
Gradient		

SNOWLINE DATA		
ELAo	1598	m
Max SL	>1790	m, 2000
Min SL	1480	m, 1995
Mean SL	1582	m
SL Range	220	m
No. Surveys	35	

MEASUREMENTS Digitised values in bold type

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1598**	**0**	**1.01**	**3.07**	**4.08**	**0.25**	**0**
1977							
1978	1605	7	0.78	3.3	4.08	0.19	-7
1979							
1980	1608	10	0.74	3.34	4.08	0.18	-10
1981	1564	-34	2.45	1.63	4.08	0.60	34
1982	1605	7	0.78	3.3	4.08	0.19	-7
1983	1485	-113	7.48	0	7.48	1.00	113
1984							
1985	1596	-2	1.01	3.07	4.08	0.25	2
1986	1615	17	0.68	3.4	4.08	0.17	-17
1987							
1988							
1989	1612	14	2.01	2.07	4.08	0.49	-14
1990							
1991							
1992							
1993	1482	-116	2.03	2.05	4.08	0.50	116
1994	1527	-71	4.33	0	4.33	1.06	71
1995	1480	-118	20.38	0	20.38	5.00	118
1996	1570	-28	1.38	2.7	4.08	0.34	28
1997	1490	-108	12.81	0	12.81	1.00	108
1998	1628	30	0.55	3.53	4.08	0.13	-30
1999	>>1790		0	above gl	2.27	0.00	
2000	>>1790		0	above gl	1.38	0.00	
2001	1568	-30	2.18	1.9	3.58	0.61	30
2002	1660	62	0	1.14	1.14	0.00	-62
2003	1521	-77	4.08	0	4.08	1.00	77
2004	1570	-28	3.58	0	3.58	1.00	28
2005	1488	-110	12.81	0	12.81	1.00	110
2006	1610	12	0.33	3.25	3.58	0.09	-12.00
2007	1619	21	0.08	3.5	3.58	0.02	-21.00
2008	1625	27	0.05	2.55	2.60	0.02	-27.00
2009	1620	22	0.05	2.45	2.50	0.02	-22.00
2010	1600	2	0.10	1.49	1.59	0.06	-2.00
2011	>1790		0.00	0.88	0.88	0.00	
2012	1620	22	0.05	2.45	2.5	0.02	-22.00
2013	1610	12	3.58	0	3.58	1.00	-12.00
2014	1600	2	0.1	1.49	1.59	0.06	-2.00
2015	1620	22	0.05	2.45	2.5	0.02	-22.00
2016	1660	62	0	1.14	1.14	0.00	-62.00
2017	1600	2	0.10	1.49	1.59	0.06	-2.00
2018	>1790			0.14	0.14	0.00	
2019	>1790			0.14	0.14	0.00	
MEAN	**1582**	**-16**	**2.56**	**1.66**		**0.46**	**16**

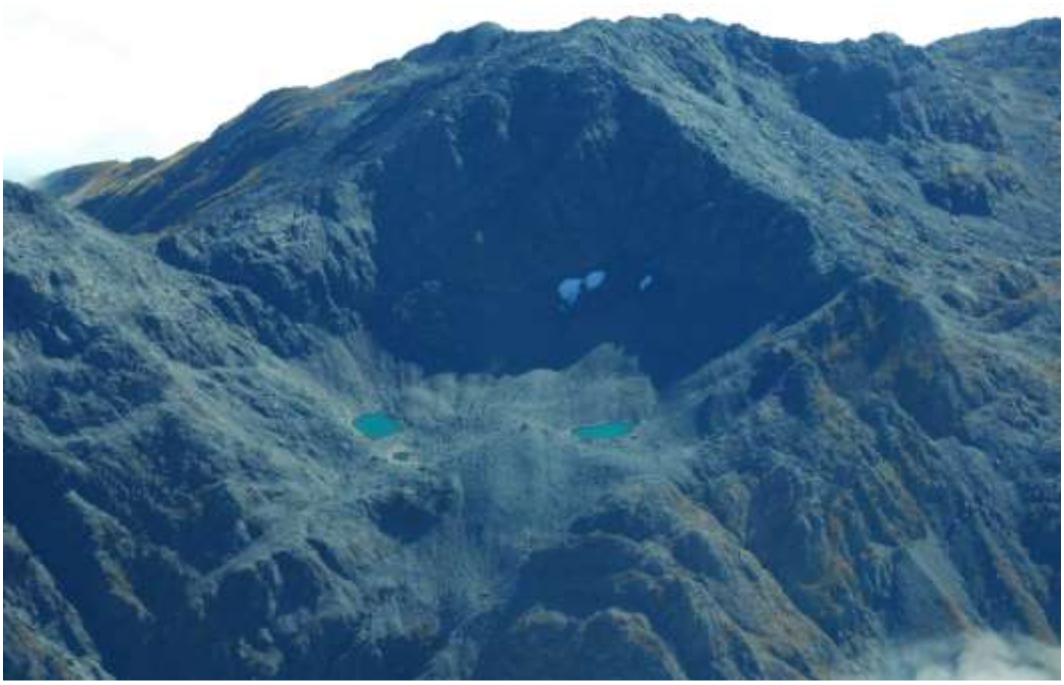

Figure D-9: Browning Range 21 March 2019.

No. 685B/1

DOUGLAS GL

NZMS 260 sheet J35

Small mountain glacier

GLACIER DATA		
Aspect	SE	
AREA	33.93	ha
Max Elev	2440	m
Min Elev	1820	m
Mean Elev	2130	m
Length	1.18	km
Elev Range	620	m
Gradient	0.508	

SNOWLINE DATA		
ELAo	2040	m
Max SL	2380	m, 2008
Min SL	1780	m,1993
Mean SL	2062	m
SL Range	600	m
No. Surveys	37	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
1974	2450				14.04		
ELAo	**2040**	**0**	**24.73**	**9.20**	**33.93**	**0.73**	**0**
1977							
1978	2131	91	19.93	14.00	33.93	0.59	-91
1979							
1980	1877	-163	32.03	1.90	33.93	0.94	163
1981							
1982	2022	-18	25.80	8.13	33.93	0.76	18
1983	1826	-214	33.73	0.20	33.93	0.99	214
1984	1800	-240	35.73	-1.80	33.93	1.05	240
1985	1817	-223	34.23	-0.30	33.93	1.01	223
1986	1912	-128	30.13	3.80	33.93	0.89	128
1987							
1988	2131	91	19.93	14.00	33.93	0.59	-91
1989	2212	172	15.74	18.19	33.93	0.46	-172
1990							
1991							
1992	1843	-197	33.13	0.80	33.93	0.98	197
1993	1780	-260	42.42	-8.49	33.93	1.25	260
1994	1886	-154	31.23	2.70	33.93	0.92	154
1995	1809	-231	35.43	-1.50	33.93	1.04	231
1996	1890	-150	31.43	2.50	33.93	0.93	150
1997	1817	-223	34.23	-0.30	33.93	1.01	223
1998	2260	220	10.71	23.22	33.93	0.32	-220
1999	2280	240	8.91	25.02	33.93	0.26	-240
2000	2290	250	7.96	25.97	33.93	0.23	-250
2001	2000	-40	22.21	6.60	28.81	0.77	40
2002	2285	245	3.31	25.50	28.81	0.11	-245
2003	1906	-134	25.61	3.20	28.81	0.89	134
2004	2010	-30	23.41	5.40	28.81	0.81	30
2005	1877	-163	28.80	0.00	28.80	1.00	163
2006	2280	240	8.91	19.90	28.81	0.31	-240
2007	1996	-44	22.41	6.40	28.81	0.78	44
2008	2380	340	0.90	21.20	22.10	0.04	-340
2009	2283	243	3.30	18.80	22.10	0.15	-243
2010	2340	300	3.97	18.09	22.06	0.18	-300
2011	2370	330	2.40	18.60	21.00	0.11	-330
2012	2350	310	2.60	18.40	21.00	0.12	-310
2013	2005	-35	15.80	5.20	21.00	0.75	35
2014	1998	-42	16.00	5.00	21.00	0.76	42
2015	2131	91	7.00	14.00	21.00	0.33	-91
2016	2380	340	0.90	15.10	16.00	0.06	-340
2017	2005	-35	10.80	5.20	16.00	0.68	35
2018	>2440		14.70		14.70	1.00	0
2019	>2440		14.70		14.70	1.00	0
Mean	**2062**	**22**	**19.20**	**9.56**		**0.65**	**-21**

Figure D-10: Douglas Glacier 21 March 2019.

No. 685B/003

South Cameron Glacier

Mountain glacier

NZTM Sheet BW18
NZTM East 1436911
NZTM North 5197733

GLACIER DATA		
Aspect	NE	
AREA	71.8	ha
Max Elev	2620	m
Min Elev	2030	m
Mean Elev	2285	m
Length	1.2	km
Elev Range	590	m
Gradient	0.49	

SNOWLINE DATA		
ELAo	2250	m
Max SL	2555	m,
Min SL	2130	m,
Mean SL	2294	m
SL Range	425	m
No. Surveys	34	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**2250**	**0**	**42.8**	**29.0**	**71.8**	**0.60**	
1977							
1978							
1979							
1980	2250	0	42.8	29.0	71.8	0.60	0
1981							
1982	2290	40	37.3	34.5	71.8	0.52	-40
1983	2150	-100	59.9	11.9	71.8	0.83	100
1984	2130	-120	63.3	8.5	71.8	0.88	120
1985	2150	-100	59.9	11.9	71.8	0.83	100
1986	2250	0	42.8	29.0	71.8	0.60	0
1987							
1988	2275	25	39.8	32.0	71.8	0.55	-25
1989	2340	90	28.8	43.0	71.8	0.40	-90
1990							
1991							
1992							
1993	2150	-100	59.9	11.9	71.8	0.83	100
1994	2250	0	42.8	29.0	71.8	0.60	0
1995	2130	-120	63.3	8.5	71.8	0.88	120
1996	2250	0	42.8	29.0	71.8	0.60	0
1997	2135	-115	62.6	9.2	71.8	0.87	115
1998	2340	90	28.8	43.0	71.8	0.40	-90
1999	2400	150	18.3	53.5	71.8	0.25	-150
2000	2365	115	24.3	47.5	71.8	0.34	-115
2001	2220	-30	50.6	21.2	71.8	0.70	30
2002	2300	50	35.8	36.0	71.8	0.50	-50
2003					71.8	0.00	0
2004	2275	25	39.8	32.0	71.8	0.55	-25
2005	2220	-30	50.6	21.2	71.8	0.70	30
2006	2340	90	28.4	41.1	69.5	0.41	-90
2007	2260	10	42.0	27.5	69.5	0.60	-10
2008	2400	150	18.5	51.0	69.5	0.27	-150
2009	2290	40	37.5	32.0	69.5	0.54	-40
2010	2365	115	24.3	43.2	67.5	0.36	-115
2011	2550	300	2.6	64.9	67.5	0.04	-300
2012	2300	50	35.5	32.0	67.5	0.53	-50
2013	2270	20	39.8	27.7	67.5	0.59	-20
2014	2250	0	44.0	23.5	67.5	0.65	0
2015	2280	30	34.8	32.7	67.5	0.52	-30
2016	2450	200	11.5	52.9	64.4	0.18	-200
2017	2250	0	43.5	20.9	64.4	0.68	0
2018	2550	300	2.6	51.0	53.6	0.05	-300
2019	2555	305	2.5	51.1	53.6	0.05	-305
Mean	**2294**	**44**	**37.1**	**31.6**		**0.5**	**-42**

Figure D-11: South Cameron 21 March 2019.

No. 685C/60

Mt BUTLER

NZMZ 260 sheet J34

Shelf glacier

GLACIER DATA		
Aspect	E	
AREA	75	ha
Max Elev	2060	m
Min Elev	1680	m
Mean Elev	1860	m
Length	1	km
Elev Range	360	m
Gradient	0	

SL DATA		
ELAo	1840	m
Max SL	2058	
Min SL	1640	m, 1995
Mean SL	1841	m
SL Range	418	m
No. surveys	41	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	ACCUM. ha	AREAS ABL. ha	TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**1840**	**0**	**42.8**	**31.8**	**74.6**	**0.57**	**0**
1977	1785	-55	60.7	13.9	74.6	0.81	55
1978	1952	112	6.4	68.2	74.6	0.09	-112
1979	1895	55	21.5	53.1	74.6	0.29	-55
1980	1806	-34	55.8	18.8	74.6	0.75	34
1981	1800	-40	57.4	17.1	74.6	0.77	40
1982	1868	28	32.1	42.5	74.6	0.43	-28
1983	1640	-200	89.6	0.0	89.6	1.00	200
1984	1775	-65	62.7	11.9	74.6	0.84	65
1985	1770	-70	63.6	11.0	74.6	0.85	70
1986	1850	10	39.4	35.2	74.6	0.53	-10
1987	1831	-9	46.8	27.8	74.6	0.63	9
1988	1882	42	26.6	48.0	74.6	0.36	-42
1989	1806	-34	55.8	18.8	74.6	0.75	34
1990							
1991							
1992	1745	-95	67.4	7.2	74.6	0.90	95
1993	1704	-136	72.1	2.5	74.6	0.97	136
1994	1812	-28	53.6	21.0	74.6	0.72	28
1995	1650	-190	94.1	0.0	74.6	1.26	190
1996	1780	-60	62.1	12.5	74.6	0.83	60
1997	1664	-176	76.6	0.0	76.6	1.00	176
1998	1908	68	16.1	58.5	74.6	0.22	-68
1999	1938	98	8.0	53.7	61.7	0.13	-98
2000	1988	148	3.6	58.1	61.7	0.06	-148
2001	1745	-95	54.4	7.3	61.7	0.88	95
2002	1930	90	8.7	53.0	61.7	0.14	-90
2003	1693	-147	60.5	1.2	61.7	0.98	147
2004	1760	-80	53.6	8.1	61.7	0.87	80
2005	1664	-176	61.7	0.0	61.7	1.00	176
2006	1915	75	14.7	47.0	61.7	0.24	-75
2007	1862	22	34.4	16.4	50.9	0.68	-22
2008	1960	120	13.9	37.0	50.9	0.27	-120
2009	1925	85	10.4	40.5	50.9	0.20	-85
2010	1807	-33	45.2	5.7	50.9	0.89	33
2011	2055	215	0.3	39.6	39.9	0.01	-215
2012	1960	120	2.9	37.0	39.9	0.07	-120
2013	1807	-33	36.9	3.0	39.9	0.92	33
2014	1780	-60	38.6	1.3	39.9	0.97	60
2015	1807	-33	36.9	3.0	39.9	0.92	33
2016	2050	210	0.4	28.8	29.2	0.01	-210
2017	1807	-33	36.9	3.0	39.9	0.92	33
2018	2055	215	0.3	27.7	28.0	0.01	-215
2019	2058	218	0.2	27.8	28.0	0.01	-218
Mean	**1841**	**1**	**38.6**	**23.6**	**61.7**	**0.59**	**-1**

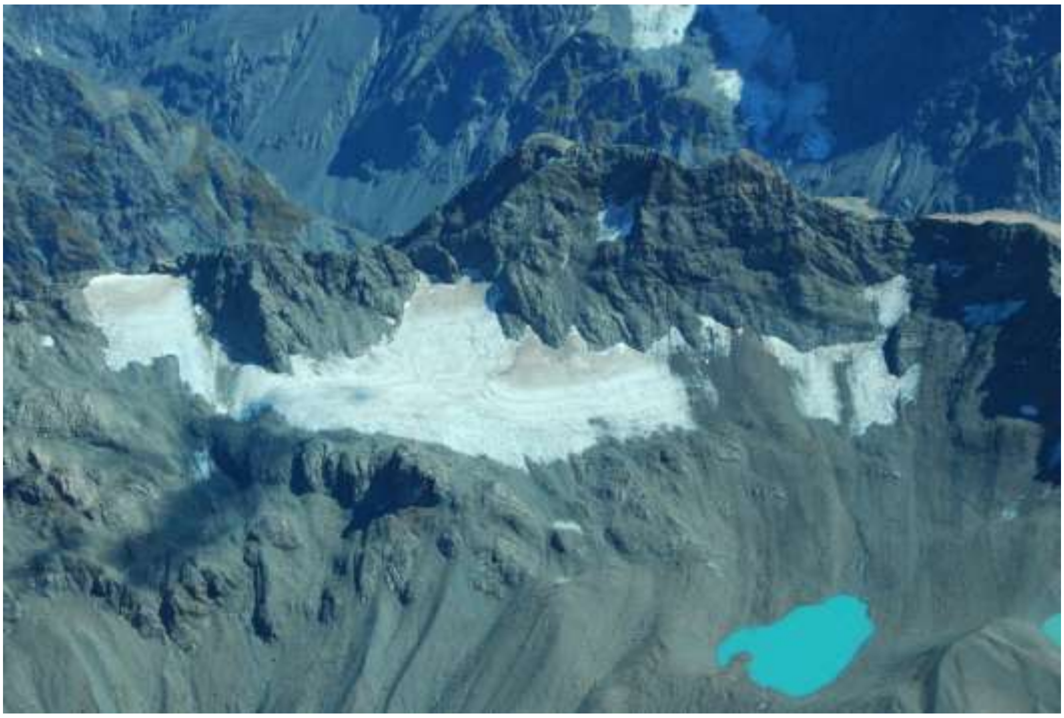

Figure D-12: Mt Butler 21 March 2019.

No. 897-19 | **DAINTY GL.** | NZMS sheet J34

Mountain gl, reliability A

GL DATA		
Aspect	W	
AREA	45.3	ha
Max Elev	2330	m
Min Elev	1750	m
Mean Elev	2040	m
Length	1.45	km
Elev Range	580	m
Gradient	0.4	

SL DATA		
ELA	1954	m
Max SL	2175	m, 2011
Min SL	1778	m, 1993
Mean SL	1957	m
SL Range	397	m
No. Surveys	39	

MEASUREMENTS Digitised values in bold type

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELA m	ACCUM. ha	AREAS ABL. ha	TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
1955	2100						
ELAo	**1954**	**0**	**18.3**	**27.0**	**45.3**	**0.40**	**0**
1977	1922	-32	25.8	19.5	45.3	0.57	32
1978	1990	36	14.8	30.5	45.3	0.33	-57
1979							
1980	1947	-7	20.2	25.1	45.3	0.45	7
1981	1877	-77	37.6	7.7	45.3	0.83	77
1982	2047	93	10.5	34.8	45.3	0.23	-93
1983	1855	-99	40.9	4.4	45.3	0.90	99
1984							
1985	1873	-81	38.3	7.0	45.3	0.85	81
1986	1881	-73	36.9	8.4	45.3	0.82	73
1987	1870	-84	39.1	6.2	45.3	0.86	84
1988	1942	-12	21.0	24.3	45.3	0.46	12
1989	1922	-32	25.8	19.5	45.3	0.57	32
1990							
1991							
1992	1851	-103	41.4	3.9	45.3	0.91	103
1993	1778	-176	43.7	1.6	45.3	0.97	176
1994	1881	-73	36.9	8.4	45.3	0.82	73
1995	1843	-111	41.9	3.4	45.3	0.93	111
1996	1942	-12	21.0	24.3	45.3	0.46	12
1997	1862	-92	40.3	5.0	45.3	0.89	92
1998	2052	98	10.2	35.1	45.3	0.23	-98
1999	2130	176	4.2	41.1	45.3	0.09	-176
2000	2028	74	11.8	33.5	45.3	0.26	-74
2001	1896	-58	33.0	12.3	45.3	0.73	58
2002	2080	126	8.3	37.0	45.3	0.18	-126
2003	1887	-67	36.1	9.2	45.3	0.80	67
2004	1910	-44	29.1	16.2	45.3	0.64	44
2005	1860	-94	40.9	4.4	45.3	0.90	94
2006	1945	-9	20.2	25.1	45.3	0.45	9
2007	1942	-12	21.0	24.3	45.3	0.46	12
2008	2070	116	9.0	36.3	45.3	0.20	-116
2009	1995	41	13.6	31.7	45.3	0.30	-41
2010	1920	-34	26.3	19.0	45.3	0.58	34
2011	2170	216	2.7	42.0	44.7	0.06	-216
2012	2070	116	9.0	36.3	44.7	0.20	-116
2013	1920	-34	25.7	19.0	44.7	0.57	34
2014	1920	-34	25.7	19.0	44.7	0.57	34
2015	1922	-32	25.8	18.9	44.7	0.58	32
2016	2080	126	8.4	36.3	44.7	0.19	-126
2017	1896	-58	34.2	10.5	44.7	0.77	58
2018	2170	216	2.7	42.0	44.7	0.06	-216
2019	2175	221	2.6	42.1	44.7	0.06	-221
MEAN	**1957**	**3**	**24.0**	**21.2**	**45.2**	**0.53**	**-3**

Figure D-13: Dainty Glacier 21 March 2019.

No. 897/7 **KEA GL** NZMS 260 sheet J34

Cirque

GL DATA		
Aspect	S	
AREA	76.94	ha
Max Elev	2030	m
Min Elev	1650	m
Mean Elev	1840	m
Length	0.95	km
Elev Range	380	m
Gradient	0.453	

SL DATA		
ELAo	1820	m
Max SL	2020	m, 1999
Min SL	1570	m, 1995
Mean SL	1805	m
SL RANGE	450	m
No. Surveys	37	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	ACCUM. ha	AREAS ABL. ha	TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**1820**	**0**	**43.6**	**23.5**	**67.1**	**0.65**	**0**
1977							
1978	1885	65	34.3	42.7	76.9	0.45	-65
1979					no flight		
1980	1864	44	39.3	37.6	76.9	0.51	-44
1981	1735	-85	66.6	10.3	76.9	0.87	85
1982	1954	134	16.5	60.4	76.9	0.21	-134
1983	1590	-230	96.4	19.5	115.9	0.83	230
1984							
1985	1700	-120	73.1	3.8	76.9	0.95	120
1986	1738	-82	66.5	10.4	76.9	0.86	82
1987	1737	-83	66.6	10.4	76.9	0.87	83
1988	1762	-58	60.9	16.0	76.9	0.79	58
1989	1784	-36	56.4	20.5	76.9	0.73	36
1990							
1991							
1992							
1993	1590	-230	94.8	17.9	112.7	0.84	230
1994	1728	-92	68.1	8.8	76.9	0.89	92
1995	1570	-250	100.8	23.8	124.6	0.81	250
1996	1900	80	31.3	45.7	76.9	0.41	-80
1997	1668	-152	80.8	3.9	84.6	0.95	152
1998	1898	78	31.7	45.2	76.9	0.41	-78
1999	2020	200	1.5	75.5	76.9	0.02	-200
2000	2010	190	2.3	74.6	76.9	0.03	-190
2001	1670	-150	76.9	0.0	76.9	1.00	150
2002	2015	195	0.9	66.2	67.1	0.01	-195
2003	1661	-159	67.1	0.0	67.1	1.00	159
2004	1730	-90	58.3	8.8	67.1	0.87	90
2005	1665	-155	67.1	0.0	67.1	1.00	155
2006	1898	78	31.7	35.4	67.1	0.47	-78
2007	1784	-36	46.6	20.5	67.1	0.69	36
2008	1970	150	5.6	61.5	67.1	0.08	-150
2009	2020	200	1.5	65.7	67.1	0.02	-200
2010	1737	-83	59.1	8.0	67.1	0.88	83
2011	>2030		0.0	67.1	67.1	0.00	0
2012	1960	140	12.1	55.0	67.1	0.18	-140
2013	1737	-83	59.1	8.0	67.1	0.88	83
2014	1736	-84	59.0	8.1	67.1	0.88	84
2015	1885	65	34.0	33.1	67.1	0.51	-65
2016	2020	200	1.5	58.1	59.6	0.03	-200
2017	1736	-84	51.5	8.1	59.6	0.86	84
2018	>2030		0.0	50.2	50.2	0.00	0
2019	>2030		0.0	48.2	48.2	0.00	0
MEAN	**1805**	**-15**	**43.8**	**30.5**		**0.56**	**15**

Figure D-14: Kea Glacier 21 March 2019.

No. 897/1 to 5 **JASPUR GL.** NZMS sheet I34

Glacierette group

GLACIER DATA		
Aspect	SW	
AREA	14.09	ha
Max Elev	1920	m
Min Elev	1600	m
Mean Elev	1760	m
Length		km
Elev Range	320	m
Gradient		

SNOWLINE DATA		
ELAo	1725	m
Max SL	>1950	m, 2011
Min SL	1570	m, 1983
Mean SL	1674	m
SL Range	350	m
No. Surveys	35	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1725**	**0**	**9.4**	**4.7**	**14.1**	**0.67**	**0**
1977							
1978	1768	43	6.5	7.6	14.1	0.46	-43
1979					no flight		0
1980	1788	63	4.3	9.8	14.1	0.30	-63
1981							0
1982	1710	-15	10.3	3.8	14.1	0.73	15
1983	1570	-155	14.1	0.0	14.1	1.00	155
1984							0
1985	1620	-105	14.1	0.0	14.1	1.00	105
1986	1683	-42	11.8	2.3	14.1	0.84	42
1987							0
1988	1683	-42	11.8	2.3	14.1	0.84	42
1989	1696	-29	11.2	2.9	14.1	0.80	29
1990					no flight		0
1991					no flight		0
1992							0
1993	1575	-150	25.6	0.0	25.6	1.00	150
1994	1605	-120	17.4	0.0	17.4	1.00	120
1995	1580	-145	19.2	0.0	19.2	1.00	145
1996	1635	-90	13.6	0.0	13.6	1.00	90
1997	1625	-100	16.6	0.0	16.6	1.00	100
1998	1768	43	5.8	8.3	14.1	0.41	-43
1999	>1950			14.1	14.1	0.00	0
2000	>1950			7.8	10.3	0.00	0
2001	1630	-95	10.1	0.2	10.3	0.98	95
2002	1920	195	0.0	7.8	7.8	0.00	-195
2003	1651	-74	7.8	0.0	7.8	1.00	74
2004	1630	-95	7.6	0.2	7.8	0.97	95
2005	1600	-125	7.8	0.0	7.8	1.00	125
2006	1760	35	5.0	2.8	7.8	0.64	-35
2007	1684	-41	5.5	2.3	7.8	0.71	41
2008	> 1950		0.0	7.8	7.8	0.00	0
2009	1920	195	0.0	7.8	7.8	0.00	-195
2010	1765	40	6.5	1.3	7.8	0.83	-40
2011	> 1950		0.0	14.1	6.8	0.00	
2012	1860	135	0.5	6.3	6.8	0.07	-135
2013	1630	-95	6.8	0.0	6.8	1.00	95
2014	1650	-75	6.8	0.0	6.8	1.00	75
2015	1760	35	6.4	0.4	6.8	0.94	-35
2016	> 1950		0.0	5.5	5.5	0.00	0
2017	1630	-95	5.5	0.0	5.5	1.00	95
2018	>1950		0.0	2.8	2.8	0.00	0
2019	>1950		0.0	2.4	2.4	0.00	0
MEANS	**1693**	**-32**	**7.8**	**3.4**	**10.9**	**0.63**	**23**

Figure D-15: Jaspur Glacier group 21 March 2019.

No. 893A-6 **SIEGE GL.** NZMS 260 sheet I35

Valley glacier

GLACIER DATA		
Aspect	SE	
AREA	151.9	ha
Max Elev	2130	m
Min Elev	1370	m
Mean Elev	1750	m
Length	3.186	km
Elev Range	760	m
Gradient	0.239	

SNOW LINE DATA		
ELAo	1736	m
Max SL	2180	m, 2011
Min SL	1340	m, 1995
Mean SL	1675	m
SL Range	810	m
No. Surveys	38	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	ACCUM. ha	AREAS ABL. ha	TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**1736**	**0**	**61.4**	**90.5**	**151.9**	**0.40**	**0**
1977	1672	-64	78.9	73.0	151.9	0.52	64
1978	1712	-24	67.7	84.2	151.9	0.45	24
1979					no flight		
1980	1660	-76	82.2	69.7	151.9	0.54	76
1981	1666	-70	80.4	71.5	151.9	0.53	70
1982	1690	-46	80.4	71.5	151.9	0.53	46
1983	1468	-268	130.6	21.3	151.9	0.86	268
1984							
1985	1642	-94	88.0	63.9	151.9	0.58	94
1986	1771	35	48.3	103.6	151.9	0.32	-35
1987							
1988	1666	-70	80.4	71.5	151.9	0.53	70
1989	1672	-64	78.8	73.1	151.9	0.52	64
1990					no flight		
1991					no flight		
1992	1413	-323	141.9	10.0	151.9	0.93	323
1993	1350	-386	153.9	0.0	153.9	1.00	386
1994	1620	-116	78.4	73.5	151.9	0.52	116
1995	1340	-396	155.4	0.0	155.4	1.00	396
1996	1664	-72	80.5	71.4	151.9	0.53	72
1997	1533	-203	116.4	35.5	151.9	0.77	203
1998	1950	214	30.8	121.1	151.9	0.20	-214
1999	2150	414	4.4	147.5	151.9	0.03	-414
2000	2015	279	24.3	127.6	151.9	0.16	-279
2001	1610	-126	97.6	54.3	151.9	0.64	126
2002	1975	239	28.9	123.0	151.9	0.19	-239
2003	1576	-160	107.4	44.5	151.9	0.71	160
2004	1620	-116	94.9	57.0	151.9	0.62	116
2005	1533	-203	116.4	35.5	151.9	0.77	203
2006	1664	-72	80.5	71.4	151.9	0.53	72
2007	1718	-18	66.2	85.7	151.9	0.44	18
2008	2130	394	5.8	146.1	151.9	0.04	-394
2009	1960	224	30.1	121.8	151.9	0.20	-224
2010	1664	-72	80.5	71.4	151.9	0.53	72
2011	2180	444	1.7	150.3	151.9	0.01	-444
2012	2130	394	7.9	144.0	151.9	0.05	-394
2013	1664	-72	80.5	71.4	151.9	0.53	72
2014	1662	-74	81.9	70.0	151.9	0.54	74
2015	1664	-72	80.5	71.4	151.9	0.53	72
2016	2130	394	5.8	146.1	151.9	0.04	-394
2017	1662	-74	81.9	70.0	151.9	0.54	74
2018	>2180		0.0	151.9	151.9	0.00	0
2019	>2180		0.0	151.9	151.9	0.00	0
MEANS	**1728**	**-8**	**71.5**	**80.5**		**0.47**	**8**

Figure D-16: Siege Glacier 21 March 2019.

893A-12

VERTEBRAE COL No 12

NZMS 260 sheet I35

Cirque glacier

GLACIER DATA		
Aspect	SW	
AREA	20.6	ha
Max Elev	2100	m
Min Elev	1730	m
Mean Elev	1915	m
Length	0.63	km
Elev Range	370	m
Gradient	0.592	

SNOWLINE DATA		
ELAo	1864	m
Max SL	2090	m, 1999
Min SL	1768	m, 1992
Mean SL	1881	m
SL Range	322	m
No. surveys	37	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	AREAS ACCUM. ha	AREAS ABL. ha	TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**1864**	**0**	**15.04**	**5.60**	**20.64**	**0.73**	**0**
1977							
1978	1871	7	14.7	5.9	20.6	0.71	-7
1979					no flight		
1980	1900	36	12.9	7.7	20.6	0.63	-36
1981	1813	-51	17.5	3.1	20.6	0.85	51
1982	1850	-14	15.8	4.8	20.6	0.77	14
1983	1800	-64	18.3	2.4	20.6	0.89	64
1984							
1985	1808	-56	18.0	2.6	20.6	0.87	56
1986	1820	-44	17.3	3.3	20.6	0.84	44
1987					no visit		
1988	1871	7	14.7	5.9	20.6	0.71	-7
1989	1825	-39	27.0	3.5	20.6	1.31	39
1990					no flight		
1991					no flight		
1992	1768	-96	19.5	1.1	20.6	0.95	96
1993	1778	-86	19.1	1.5	20.6	0.93	86
1994	1807	-57	18.0	2.6	20.6	0.87	57
1995	1778	-86	19.1	1.5	20.6	0.93	86
1996	1807	-57	18.0	2.6	20.6	0.87	57
1997	1791	-73	18.6	2.0	20.6	0.90	73
1998	1855	-9	15.7	5.0	20.6	0.76	9
1999	2085	221	0.7	19.9	20.6	0.04	-221
2000	1985	121	5.5	15.1	20.6	0.27	-121
2001	1805	-59	18.1	2.6	20.6	0.88	59
2002	1995	131	4.9	15.7	20.6	0.24	-131
2003	1816	-48	17.5	3.2	20.6	0.85	48
2004	1807	-57	18.0	2.6	20.6	0.87	57
2005	1790	-74	18.7	2.0	20.6	0.90	74
2006	1830	-34	16.7	3.9	20.6	0.81	34
2007	1856	-8	15.5	5.1	20.6	0.75	8
2008	2030	166	3.1	17.5	20.6	0.15	-166
2009	1924	60	8.4	12.3	20.6	0.41	-60
2010	1840	-24	16.4	4.2	20.6	0.80	24
2011	2090	226	0.5	20.1	20.6	0.03	-226
2012	2020	156	3.5	17.1	20.6	0.17	-156
2013	1840	-24	16.4	4.2	20.6	0.80	24
2014	1830	-34	16.7	3.9	20.6	0.81	34
2015	1870	6	15.0	5.9	20.6	0.73	-6
2016	2030	166	3.1	17.5	20.6	0.15	-166
2017	1830	-34	16.7	3.9	20.6	0.81	34
2018	2090	226	0.5	16.7	17.2	0.03	-226
2019	2085	221	0.7	16.5	17.2	0.04	-221
MEAN	**1881**	**17**	**13.6**	**7.2**	**20.5**	**0.66**	**-17**

Figure D-17: Vertebrae 12 Glacier (left) on 21 March 2019.

893A/ 25		VERTEBRAE COL No. 25			NZMS 260 sheet I35	
			Mountain glacier			

GLACIER DATA		
Aspect	SW	
Area	75.6	ha
Max Elev	2040	m
Min Elev	1700	m
Mean Elev	1850	m
Length	1.15 Km	km
Elev Range	360 m	m
Gradient	0.313	

SNOWLINE DATA		
ELAo	1840	m
Max SL	1995	m, 1999
Min SL	1746	m, 1992
Mean SL	1846	m
SL Range	249	m
No. surveys	37	

No 25

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	AREAS ACCUM. ha	ABL. ha	TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**1840**	**0**	**45.3**	**30.2**	**75.6**	**0.60**	**0**
1977							
1978	1870	30	49.5	26.1	75.6	0.66	-30
1979							
1980	1865	25	52.1	23.4	75.6	0.69	-25
1981	1802	-39	70.4	5.1	75.6	0.93	39
1982	1840	0	65.5	10.0	75.6	0.87	0
1983	1778	-62	71.6	4.0	75.6	0.95	62
1984							
1985	1790	-50	70.6	5.0	75.6	0.93	50
1986	1813	-27	67.1	8.5	75.6	0.89	27
1987							
1988	1843	3	60.4	15.2	75.6	0.80	-3
1989	1820	-20	65.6	10.0	75.6	0.87	20
1990							
1991							
1992	1746	-94	73.7	1.9	75.6	0.97	94
1993	1756	-84	73.1	2.5	75.6	0.97	84
1994	1786	-54	71.1	4.5	75.6	0.94	54
1995	1756	-84	73.1	2.5	75.6	0.97	84
1996	1786	-54	71.1	4.5	75.6	0.94	54
1997	1770	-71	72.3	3.3	75.6	0.96	71
1998	1835	-5	62.0	13.6	75.6	0.82	5
1999	1965	125	2.6	72.9	75.6	0.03	-125
2000	1910	70	18.1	57.5	75.6	0.24	-70
2001	1807	-33	68.0	7.5	75.6	0.90	33
2002	1920	80	12.6	63.0	75.6	0.17	-80
2003	1789	-51	70.8	4.8	75.6	0.94	51
2004	1795	-45	70.6	5.0	75.6	0.93	45
2005	1765	-75	72.3	3.3	75.6	0.96	75
2006	1834	-6	62.0	13.6	75.6	0.82	6
2007	1824	-16	64.9	10.7	75.6	0.86	16
2008	1950	110	4.8	70.8	75.6	0.06	-110
2009	1859	19	36.7	38.8	75.6	0.49	-19
2010	1834	-6	62.0	13.6	75.6	0.82	6
2011	1995	155	0.6	69.2	69.8	0.01	-155
2012	1940	100	12.0	57.8	69.8	0.16	-100
2013	1834	-6	62.0	13.6	69.8	0.82	6
2014	1834	-6	62.0	13.6	69.8	0.82	6
2015	1860	20	50.1	19.7	69.8	0.66	-20
2016	1950	110	4.8	65.0	69.8	0.06	-110
2017	1834	-6	62.0	13.6	69.8	0.82	6
2018	1995	155	0.6	62.5	63.1	0.01	-155
2019	1965	125	2.6	60.5	63.1	0.03	-125
MEAN	**1846**	**6**	**50.6**	**22.7**		**0.67**	**-6**

Figure D-18: Vertebrae Glacier 25 (right) on 21 March 2019.

711L-24			RIDGE GL.		NZMS sheet L24
			Mountain glacier		

GLACIER DATA		
Aspect	SE	
AREA	68.0	ha
Max Elev	2490	m
Min Elev	2110	m
Mean Elev	2300	m
Length	1.04	km
Elev Range	380	m
Gradient	0.365	

SNOWLINE DATA		
ELAo	**2226**	m
Max SL	>2490	m,2011
Min SL	2085	m,1984
Mean SL	2234	m
SL Range	405	m
No. surveys	36	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	AREAS ACCUM. ha	AREAS ABL. ha	AREAS TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**2226**	**0**	**51.7**	**21.8**	**73.5**	**0.70**	**0**
1977							
1978	2305	79	22.2	51.3	73.5	0.30	-79
1979					no flight		
1980							
1981	2228	2	49.4	24.1	73.5	0.67	-2
1982	2236	10	48.0	25.5	73.5	0.65	-10
1983	2211	-15	56.3	17.2	73.5	0.77	15
1984	2085	-141	73.5	0.0	73.5	1.00	141
1985	2194	-32	60.4	13.1	73.5	0.82	32
1986	2217	-9	55.0	18.5	73.5	0.75	9.1
1987							
1988	2285	59	27.8	45.7	73.5	0.38	-59
1989	2277	51	30.0	43.5	73.5	0.41	-51
1990					no flight		
1991					no flight		
1992							
1993	2100	-126	73.5	0.0	73.5	1.00	126
1994	2170	-56	66.3	7.2	73.5	0.90	56
1995	2132	-94	70.8	2.7	73.5	0.96	94
1996	2138	-88	70.0	3.5	73.5	0.95	88
1997	2090	-136	73.5	0.0	73.5	1.00	136
1998	2235	9	47.0	25.5	72.5	0.65	-9
1999	2335	109	19.9	52.0	71.9	0.28	-109
2000	2305	79	25.9	44.9	70.7	0.37	-79
2001	2110	-116	70.1	0.0	70.1	1.00	116
2002	2300	74	22.5	47.0	69.5	0.32	-74
2003	2163	-63	62.4	6.5	68.9	0.91	63
2004	2228	2	50.0	18.5	68.5	0.73	-2
2005	2165	-61	61.7	6.3	68.0	0.91	61
2006	2310	84	20.0	48.0	68.0	0.29	-84
2007	2256	30	38.3	29.7	68.0	0.56	-30
2008	2325	99	17.5	50.5	68.0	0.26	-99
2009	2305	79	34.1	44.9	68.0	0.50	-79
2010	2280	54	27.2	40.8	68.0	0.40	-54
2011	>2490		0.0	61.4	61.4	0.00	
2012	2325	99	16.9	44.5	61.4	0.28	-99
2013	2235	9	44.4	17.0	61.4	0.72	-9
2014	2230	4	45.4	16.0	61.4	0.74	-4
2015	2235	9	44.4	17.0	61.4	0.72	-9
2016	>2490		0.0	61.4	61.4	0.00	0
2017	2230	4	45.4	16.0	61.4	0.74	-4
2018	2480	254	1.5	59.9	61.4	0.02	-254
2019	>2490		0.0	54.9	54.9	0.00	0
MEAN	**2234**	**8**	**42.0**	**27.4**		**0.58**	**-8**

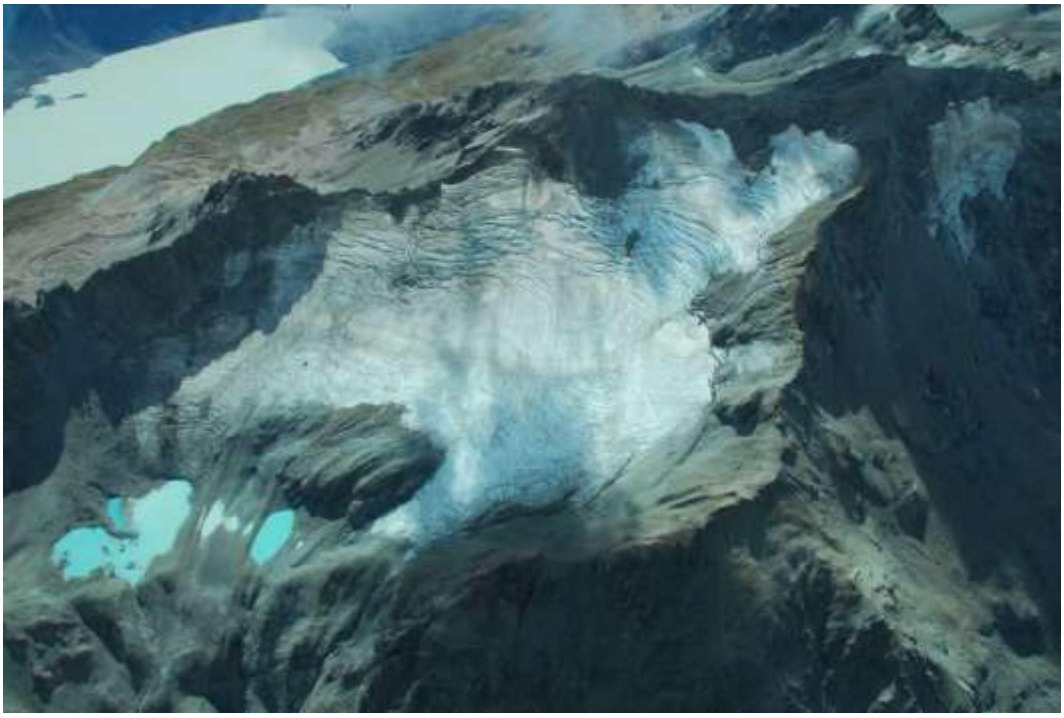

Figure D-19: Ridge Glacier on 20 March 2019.

No. 711 I/35			LANGDALE GL.		NZMS 260 sheet H36
			Cirque glacier		

GLACIER DATA		
Aspect	NW	
AREA	34.10	ha
Max Elev	2580	m
Min Elev	2090	m
Mean Elev	2335	m
Length	1.03	km
Elev Range	490	m
Gradient	0.478	

SNOWLINE DATA		
ELA	2186	m
Max SL	>2580	m,2011
Min SL	1955	m,1984
Mean SL	2198	m
SL Range	625	m
No. surveys	33	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELA m	AREAS ACCUM. ha	ABL. ha	TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**2186**	**0**	**29.4**	**11.0**	**40.4**	**0.73**	**0**
1977	2220	34	32.6	7.8	40.4	0.81	-34
1978	2275	89	19.1	21.0	40.1	0.48	-89
1979					no flight		
1980							
1981	2265	79	15.1	24.3	39.4	0.38	-79
1982	2305	119	23.3	16.2	39.4	0.59	-119
1983	2185	-1	32.7	6.7	39.4	0.83	1
1984	1960	-226	39.4	0.0	39.4	1.00	226
1985	1965	-221	37.7	1.7	39.4	0.96	221
1986	2200	14	35.2	4.2	39.4	0.89	-14
1987	2185	-1	36.5	2.9	39.4	0.93	1
1988	2190	4	26.6	12.5	39.1	0.68	-4
1989	2255	69	18.4	20.7	39.1	0.47	-69
1990					no flight		
1991					no flight		
1992	1960	-226	38.1	0.0	38.1	1.00	226
1993	1955	-231	38.1	0.0	38.1	1.00	231
1994	2200	14	13.9	24.3	38.1	0.36	-14
1995	1960	-226	38.1	0.0	38.1	1.00	226
1996	2185	-1	32.1	6.0	38.1	0.84	1
1997	1960	-226	38.1	0.0	38.1	1.00	226
1998	2328	142	5.4	32.3	37.7	0.14	-142
1999	2320	134	6.7	30.0	36.7	0.18	-134
2000	2315	129	6.4	29.3	35.7	0.18	-129
2001	1960	-226	35.7	0.0	35.7	1.00	226
2002	2285	99	8.8	26.0	34.8	0.25	-99
2003	1960	-226	34.8	0.0	34.8	1.00	226
2004	2185	-1	26.0	8.8	34.8	0.75	1
2005	1965	-221	34.8	0.0	34.8	1.00	221
2006	2295	109	6.8	27.7	34.5	0.20	-109
2007	2260	74	14.5	20.0	34.5	0.42	-74
2008	2580	394	0.0	34.1	34.1	0.00	-394
2009	2315	129	6.4	27.7	34.1	0.19	-129
2010	2262	76	13.2	20.9	34.1	0.39	-76
2011	>2580		0.0	34.1	34.1	0.00	
2012	2400	214	1.6	32.5	34.1	0.05	-214
2013	2262	76	13.2	20.9	34.1	0.39	-76
2014	2185	-1	28.1	6.0	34.1	0.82	1
2015	2185	-1	28.1	6.0	34.1	0.82	1
2016	2580	394	0.0	29.8	29.8	0.00	-394
2017	2262	76	13.2	16.6	29.8	0.44	-76
2018	>2580		0.0	29.8	29.8	0.00	0
2019	>2580		0.0	29.8	29.8	0.00	0
MEAN	**2198**	**12**	**21.0**	**15.3**		**0.56**	**-12**

Figure D-20: Langdale Glacier on 201 March 2019.

Figure D-21: Langdale Glacier on 20 March 2019.

No. 711I/12			TASMAN GL.			NZMS 260 sheet	
			Valley glacier				

GLACIER DATA			SNOWLINE DATA		
Aspect	SW				
Max Elev			**ELAo**	**1790**	1955 to '01
Min Elev			ELA	1826	1977 to '01
Mean Elev			Max SL	2215	m, 2011
Elev Range			Min SL	1666	m, 1995
Length			Mean SL	1826	m
Gradient			SL Range	549	m
Gradient @ S	0.096		No. surveys	43	

MEASUREMENTS Values from contour counts shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELA m	AREAS ACCUM. ha	ABL. ha	TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**1790**	Too large to measure					
1977	1780	-10					10
1978	1875	85					-85
1979	1700	-90					90
1980	1810	20					-20
1981	1755	-35					35
1982	1760	-30					30
1983	1710	-80					80
1984	1695	-95					95
1985	1700	-90					90
1986	1780	-10					10
1987	1761	-29					29
1988	1840	50					-50
1989	1760	-30					30
1990	2050	260					-260
1991	1755	-35					35
1992	1690	-100					100
1993	1682	-108					108
1994	1770	-20					20
1995	1666	-124					124
1996	1755	-35					35
1997	1688	-102					102
1998	1853	63					-63
1999	1976	186					-186
2000	1900	110					-110
2001	1710	-80					80
2002	1895	105					-105
2003	1710	-80					80
2004	1750	-40					40
2005	1750	-40					40
2006	1850	60					-60
2007	1796	6					-6
2008	2025	235					-235
2009	1965	175					-175
2010	1770	-20					20
2011	2110	320					-320
2012	2000	210					-210
2013	1755	-35					35
2014	1755	-35					35
2015	1840	50					-50
2016	2025	235					-235
2017	1755	-35					35
2018	2120	330					-330
2019	2215	425					-425
MEAN	**1826**	**36**					**-36**

Figure D-22: Tasman Glacier on 20 March 2019.

No. 888B/3

SALISBURY SNOWIELD

NZMS 260 sheet H35

Mountain glacier

GLACIER DATA		
Aspect	SW	
AREA	311.90	ha
Max Elev	2390	m
Min Elev	1340	m
Mean Elev	1865	m
Length	2.98	km
Elev Range	1050	m
Gradient	0.352	

SNOWLINE DATA		
ELAo	1810	m
Max SL	2095	m, 1999
Min SL	1645	m, 1995
Mean SL	1820	m
SL Range	450	m
No. surveys	40	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1810**	**0**	**246.9**	**65.0**	**311.9**	**0.79**	**0**
1977	1827	17	239.9	72.0	311.9	0.77	-17
1978	1827	17	239.9	72.0	311.9	0.77	-17
1979					No flight		
1980	1842	32	228.5	83.4	311.9	0.73	-32
1981	1752	-58	268.9	43.0	311.9	0.86	58
1982	1827	17	239.9	72.0	311.9	0.77	-17
1983	1718	-92	279.6	32.3	311.9	0.90	92
1984	1760	-51	266.9	45.0	311.9	0.86	51
1985	1734	-76	275.9	36.0	311.9	0.88	76
1986	1809	-1	250.9	61.0	311.9	0.80	1
1987	1775	-35	261.9	50.0	311.9	0.84	35
1988	1729	-81	268.9	43.0	311.9	0.86	81
1989	1744	-66	271.9	40.0	311.9	0.87	66
1990					No flight		
1991					No flight		
1992	1681	-129	289.9	22.0	311.9	0.93	129
1993	1710	-100	279.9	32.0	311.9	0.90	100
1994	1772	-38	229.0	82.9	311.9	0.73	38
1995	1645	-165	296.7	15.2	311.9	0.95	165
1996	1752	-58	267.9	44.0	311.9	0.86	58
1997	1726	-84	276.9	35.0	311.9	0.89	84
1998	1852	42	223.2	88.7	311.9	0.72	-42
1999	2030	220	116.7	195.2	311.9	0.37	-220
2000	1982	172	132.5	179.4	311.9	0.42	-172
2001	1715	-95	281.7	30.2	311.9	0.90	95
2002	1860	50	219.0	92.0	311.0	0.70	-50
2003	1715	-95	279.9	32.0	311.9	0.90	95
2004	1732	-78	275.9	36.0	311.9	0.88	78
2005	1715	-95	281.7	30.2	311.9	0.90	95
2006	1850	40	223.2	88.7	311.9	0.72	-40
2007	1810	0	248.9	63.0	311.9	0.80	0
2008	1950	140	156.9	155.0	311.9	0.50	-140
2009	1950	140	156.9	155.0	311.9	0.50	-140
2010	1780	-30	259.9	52.0	311.9	0.83	30
2011	2095	285	61.8	250.1	311.9	0.20	-285
2012	1980	170	133.9	178.0	311.9	0.43	-170
2013	1780	-30	251.6	52.0	303.6	0.81	30
2014	1780	-30	259.9	52.0	311.9	0.83	30
2015	1780	-30	259.9	52.0	311.9	0.83	30
2016	1980	170	133.9	178.0	311.9	0.43	-170
2017	1780	-30	259.9	52.0	311.9	0.83	30
2018	1982	172	132.0	159.0	291.0	0.42	-172
2019	2060	250	82.0	209.0	291.0	0.26	-250
Mean	**1820**	**10**	**229.1**	**81.5**		**0.75**	**-10**

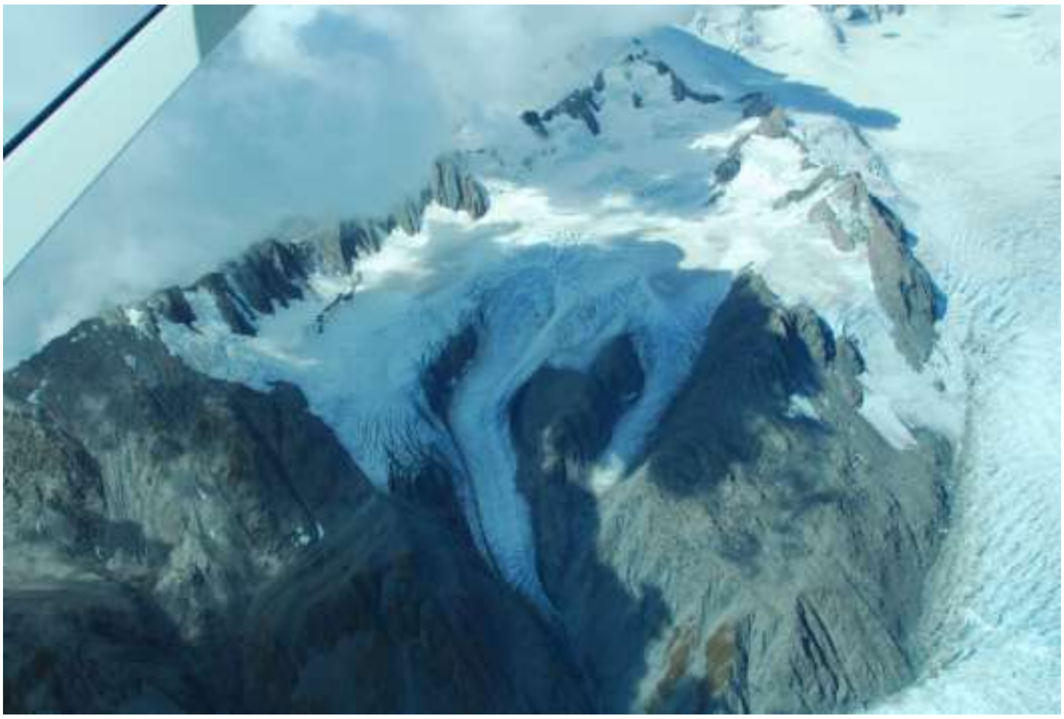

Figure D-23: Salisbury Glacier on 20 March 2019.

No. 886/2 & 888B/7

JALF GL. and Baumann Gl.

Small saddle glacier

GLACIER DATA (2008)		
Aspects	N &S, E & W	
AREA	41.50	ha
Max Elev	1880	m
Min Elev	1600	m
Mean Elev	1740	m
Length	na	
Elev Range	280	m
Gradient	na	

SNOWLINE DAT
ELAo
Max SL
Min SL
Mean SL
SL Range
No. surveys

Glacier area has reduced since the first map in 1977

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS	
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL
	m	m	ha	ha	ha
ELAo	**1790**	**0**	**14.1**	**88.0**	**102.1**
1977	1775	-15	21.3	80.8	102.1
1978	1780	-10	19.1	83.0	98.6
1979					*95.1*
1980	1758	-32	36.4	58.7	95.1
1981	1725	-65	55.6	36.0	91.6
1982	1795	5	2.6	89.0	91.6
1983	1560	-230	91.6	0.0	91.6
1984	1712	-78	73.0	18.7	91.6
1985	1644	-146	91.6	0.0	91.6
1986	1770	-20	13.9	77.7	91.6
1987	1739	-51	45.6	46.0	91.6
1988	1758	-32	22.1	66.0	88.1
1989	1759	-31	21.7	66.5	88.1
1990					no visit
1991					no visit
1992	1580	-210	77.7	0.0	77.7
1993	1570	-220	77.7	0.0	77.7
1994	1752	-38	17.0	60.6	77.7
1995	1550	-240	77.7	0.0	77.7
1996	1782	-8	17.3	60.4	77.7
1997	1599	-191	75.1	2.6	77.7
1998	1787	-3	15.8	57.2	73.0
1999	2050	260	0.0	102.1	62.6
2000	2055	265	0.0	102.1	52.1
2001	1705	-85	26.0	26.0	52.1
2002					43.0
2003	1600	-190	43.0	3.0	43.0
2004	1620	-170	42.8	0.2	43.0
2005	1600	-190	40.0	3.0	43.0
2006	1785	-5	5.6	37.2	42.8
2007	1792	2	0.0	42.8	42.8
2008	2050	260	0.0	41.5	41.5
2009	2040	250	0.0	37.0	37.0
2010	1755	-35	3.5	33.5	37.0
2011	2160	370	0.0	31.0	31.0
2012	2050	260	0.0	29.4	22.2
2013	1755	-35	3.5	18.7	22.2
2014	1755	-35	3.5	18.7	22.2
2015	1785	-5	4.2	18.0	22.2
2016	2055	265	0.0	21.8	21.8
2017	1755	-35	3.5	14.1	17.6
2018	2055	265	0.0	5.7	5.7
2019	2160	370	0.0	5.7	5.7
MEAN	**1794**	**4**	**26.4**	**35.8**	

Figure D-24: Jalf Glacier on 20 March 2019.

No. 882A/7			CHANCELLOR DOME		NZMS 260 sheet H35 & H36		
				Cirque glacier			

GLACIER DATA		
Aspect	SW	
AREA	17.51	ha
Max Elev	1960	m
Min Elev	1660	m
Mean Elev	1810	m
Length	0.55	km
Elev Range	300	m
Gradient	0.436	

SNOWLINE DATA		
ELAo	1756	m
Max SL	2000	m, 2011
Min SL	1545	m, 1995
Mean SL	1757	m
SL Range	455	m
No. surveys	38	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	AREAS ACCUM. ha	AREAS ABL. ha	AREAS TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**1756**	**0**	**18.8**	**5.3**	**24.1**	**0.78**	**0**
1977	1852	96	9.5	14.6	24.1	0.39	-96
1978	1851	95	9.6	14.5	24.1	0.40	-95
1979							
1980	1833	77	13.9	10.2	24.1	0.58	-77
1981	1663	-93	21.1	3.0	24.1	0.87	93
1982	1848	92	10.7	13.4	24.1	0.44	-92
1983	1545	-211	28.9	0.0	28.9	1.20	211
1984							
1985	1609	-147	23.0	1.1	24.1	0.95	147
1986	1678	-78	20.7	3.4	24.1	0.86	78
1987	1728	-28	19.3	4.8	24.1	0.80	28
1988	1808	52	17.3	6.8	24.1	0.72	-52
1989	1678	-78	20.6	3.5	24.1	0.86	78
1990							
1991							
1992							
1993	1550	-206	24.1	0.0	24.1	1.00	206
1994	1609	-147	23.0	1.1	24.1	0.95	147
1995	1545	-211	28.9	0.0	28.9	1.00	211
1996	1720	-36	7.4	16.7	24.1	0.31	36
1997	1580	-176	24.1	0.0	24.1	1.00	176
1998	1848	92	10.7	13.4	24.1	0.44	-92
1999	1965	209	0.0	17.5	17.5	0.00	-209
2000	1960	204	0.0	17.5	17.5	0.00	-204
2001	1570	-186	17.5	0.0	17.5	1.00	186
2002	1860	104	1.5	16.0	17.5	0.09	-104
2003	1570	-186	17.5	0.0	17.5	1.00	186
2004	1605	-151	17.5	0.0	17.5	1.00	151
2005	1575	-181	17.5	0.0	17.5	1.00	181
2006	1850	94	10.0	16.1	17.5	0.57	-94
2007	1735	-21	12.9	4.6	17.5	0.74	21
2008	1865	109	1.3	16.2	17.5	0.07	-109
2009	1865	109	1.3	16.2	17.5	0.07	-109
2010	1735	-21	12.9	4.6	17.5	0.74	21
2011	2000	244	0.0	15.6	15.6	0.00	-244
2012	1865	109	1.3	14.3	15.6	0.08	-109
2013	1609	-147	14.5	1.1	15.6	0.93	147
2014	1735	-21	11.1	4.5	15.6	0.71	21
2015	1750	-6	8.6	7.0	15.6	0.55	6
2016	1965	209	0.0	15.6	15.6	0.00	-209
2017	1735	-21	11.1	4.5	15.6	0.71	21
2018	2000	244	0.0	15.6	11.8	0.00	-244
2019	2000	244	0.0	15.6	11.8	0.00	-244
MEAN	**1757**	**1**	**12.3**	**8.1**		**0.58**	**-1**

Figure D-25: Chancellor Glacier on 20 March 2019.

No. 711F/6 **GLENMARY GL.** NZMS 260 sheet H37

Cirque glacier

GLACIER DATA		
Aspect	S	
AREA	58.51	ha
Max Elev	2380	m
Min Elev	2040	m
Mean Elev	2210	m
Length	1.19	km
Elev Range	340	m
Gradient	0.277	

SNOWLINE DATA		
ELAo	**2164**	m
Max SL	2360	m, 2018
Min SL	2020	m, 1984
Mean SL	2182	m
SL Range	340	m
No. Surveys	37	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**2175**	**0**	**35.4**	**19.0**	**54.4**	**0.65**	**0**
1977							
1978	2232	57	22.9	31.5	54.4	0.42	-57
1979							
1980	2080	-95	48.5	5.6	54.1	0.90	95
1981	2130	-45	42.2	11.5	53.7	0.79	45
1982	2181	6	36.0	17.7	53.7	0.67	-6
1983	2135	-40	41.8	12.0	53.7	0.78	40
1984	2020	-155	53.7	0.0	53.7	1.00	155
1985	2108	-67	49.3	4.4	53.7	0.92	67
1986					53.7		
1987					53.7		
1988	2180	5	36.0	17.4	53.4	0.67	-5
1989	2180	5	36.0	17.4	53.4	0.67	-5
1990					52.4		
1991					52.4		
1992	2160	-15	37.8	14.6	52.4	0.72	15
1993	2107	-68	45.5	6.9	52.4	0.87	68
1994	2145	-30	40.0	12.4	52.4	0.76	30
1995	2140	-35	40.7	11.7	52.4	0.78	35
1996	2130	-45	42.3	10.1	52.4	0.81	45
1997	2045	-130	50.5	1.9	52.4	0.96	130
1998	2195	20	32.3	19.7	52.1	0.62	-20
1999	2290	115	7.7	43.9	51.6	0.15	-115
2000	2245	70	20.2	31.0	51.2	0.39	-70
2001	2138	-37	41.1	10.1	51.2	0.80	37
2002	2210	35	30.0	20.8	50.9	0.59	-35
2003	2115	-60	44.5	6.3	50.8	0.88	60
2004	2145	-30	40.0	10.8	50.8	0.79	30
2005	2110	-65	39.7	11.1	50.8	0.78	65
2006	2205	30	31.1	19.7	50.8	0.61	-30
2007	2190	15	32.4	18.4	50.8	0.64	-15
2008	2280	105	9.7	41.1	50.8	0.19	-105
2009	2210	35	30.0	20.8	50.8	0.59	-35
2010	2180	5	34.3	14.8	49.1	0.70	-5
2011	2305	130	5.3	43.8	49.1	0.11	-130
2012	2245	70	20.1	29.0	49.1	0.41	-70
2013	2170	-5	36.0	13.1	49.1	0.73	5
2014	2150	-25	38.0	11.1	49.1	0.77	25
2015	2210	35	28.0	21.1	49.1	0.57	-35
2016	2305	130	5.3	38.7	44.0	0.12	-130
2017	2170	-5	36.0	8.0	44.0	0.82	5
2018	2320	145	4.0	38.7	42.7	0.09	-145
2019	2360	185	1.1	41.6	42.7	0.03	-185
Mean	**2182**	**7**	**32.2**	**18.6**		**0.62**	**-7**

Figure D-26: Glenmary Glacier on 20 March 2019.

No. 711-D/38

BLAIR GL.

NZMS 260 sheet H37 & G37

Mountain glacier

GLACIER DATA		
Aspect	SE	
AREA	24.62	ha
Max Elev	2240	m
Min Elev	1790	m
Mean Elev	2015	m
Length	0.63	km
Elev Range	450	m
Gradient	0.71	

SNOWLINE DATA		
ELAo	**1938**	m
Max SL	2160	m, 2011
Min SL	1812	m, 1983
Mean SL	1956	m
SL Range	348	m
No. Surveys	36	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	AREAS ACCUM. ha	AREAS ABL. ha	AREAS TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**1938**	**0**	**18.5**	**7.9**	**26.4**	**0.70**	**0**
1977							
1978	2012	74	13.4	13.0	26.4	0.51	-74
1979							
1980	1863	-75	22.8	3.6	26.4	0.86	75
1981	1925	-13	19.2	7.2	26.4	0.73	13
1982	1887	-51	21.5	4.9	26.4	0.81	51
1983	1812	-126	25.3	1.1	26.4	0.96	126
1984	1858	-80	23.1	3.3	26.4	0.88	80
1985	1853	-85	23.3	3.1	26.4	0.88	85
1986							
1987	1870	-68	22.4	4.0	26.4	0.85	68
1988	1955	17	17.8	8.6	26.4	0.67	-17
1989	1876	-62	22.1	4.3	26.4	0.84	62
1990							
1991							
1992							
1993	1953	15	17.7	8.7	26.4	0.67	-15
1994	1865	-73	22.7	3.7	26.4	0.86	73
1995	1853	-85	23.3	3.1	26.4	0.88	85
1996	1940	2	18.4	8.0	26.4	0.70	-2
1997							
1998	1972	34	16.4	10.1	26.4	0.62	-34
1999	2090	152	6.0	20.4	26.4	0.23	-152
2000	2085	147	6.2	20.3	26.4	0.23	-147
2001	1842	-96	23.8	2.7	26.4	0.90	96
2002	2005	67	14.0	12.4	26.4	0.53	-67
2003	1845	-93	23.6	2.8	26.4	0.89	93
2004	1850	-88	23.3	3.1	26.4	0.88	88
2005	1850	-88	23.3	3.1	26.4	0.88	88
2006	1960	22	17.6	8.8	26.4	0.67	-22
2007	1972	34	16.4	10.1	26.4	0.62	-34
2008	2070	132	7.9	18.5	26.4	0.30	-132
2009	1972	34	16.4	10.1	26.4	0.62	-34
2010	1953	15	17.7	8.7	26.4	0.67	-15
2011	2160	222	2.5	21.9	24.4	0.10	-222
2012	2060	122	8.9	15.5	24.4	0.34	-122
2013	1950	12	17.8	6.6	24.4	0.67	-12
2014	1950	12	17.8	8.6	24.4	0.67	-12
2015	1972	34	16.4	10.1	24.4	0.62	-34
2016	2070	132	7.9	16.5	24.4	0.30	-132
2017	1950	12	17.8	6.6	24.4	0.67	-12
2018	2160	222	2.5	21.9	24.4	0.09	-222
2019	2160	222	2.5	21.9	24.4	0.09	-222
MEAN	**1956**	**18**	**16.7**	**9.4**		**0.63**	**-18**

Figure D-27: Blair Glacier on 20 March 2019.

No. 711D/21

Mt. McKENZIE

NZMS 260 sheet G37

Mountain glacier

GLACIER DATA		
Aspect	S	
AREA	48.67	ha
Max Elev	2100	m
Min Elev	1760	m
Mean Elev	1930	m
Length	0.69	km
Elev Range	340	m
Gradient	0.49	

SNOWLINE DATA		
ELAo	**1904**	m
Max SL	2098	m, 2018
Min SL	1715	m, 1983
Mean SL	1908	m
SL Range	383	m
No. Surveys	37	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1904**	**0**	**30.9**	**17.8**	**48.7**	**0.63**	**0**
1977							
1978	1950	46	22.8	25.9	48.7	0.47	-46
1979							
1980	1910	6	29.9	18.8	48.7	0.61	-6
1981	1888	-16	33.5	15.2	48.7	0.69	16
1982	1902	-2	31.4	17.3	48.7	0.64	2
1983	1720	-184	60.6	-12.0	48.7	1.25	184
1984	1842	-62	39.6	9.0	48.7	0.81	62
1985	1780	-124	48.7	0.0	48.7	1.00	124
1986	1917	13	28.9	19.8	48.7	0.59	-13
1987	1890	-14	33.2	15.4	48.7	0.68	14
1988							
1989	1912	8	29.7	19.0	48.7	0.61	-8
1990							
1991							
1992							
1993	1782	-122	46.4	2.3	48.7	0.95	122
1994	1912	8	29.7	19.0	48.7	0.61	-8
1995	1805	-99	43.9	4.8	48.7	0.90	99
1996	1910	6	29.9	18.8	48.7	0.61	-6
1997	1715	-189	60.6	-12.0	48.7	1.25	189
1998	1935	31	25.5	23.1	48.7	0.52	-31
1999	2078	174	2.8	45.9	48.7	0.06	-174
2000	2052	148	5.8	42.8	48.7	0.12	-148
2001	1805	-99	43.9	4.8	48.7	0.90	99
2002	1960	56	20.7	28.0	48.7	0.42	-56
2003	1770	-134	47.7	1.0	48.7	0.98	134
2004	1782	-122	46.4	2.3	48.7	0.95	122
2005	1772	-132	47.7	1.0	48.7	0.98	132
2006	1910	6	29.9	18.8	48.7	0.61	-6
2007	1919	15	28.7	20.0	48.7	0.59	-15
2008	2015	111	11.1	37.6	48.7	0.23	-111
2009	1935	31	25.5	23.1	48.7	0.52	-31
2010	1902	-2	31.4	17.3	48.7	0.64	2
2011	2085	181	1.6	40.1	41.7	0.03	-181
2012	1950	46	18.3	23.4	41.7	0.38	-46
2013	1890	-14	27.8	13.9	41.7	0.57	14
2014	1890	-14	27.8	13.9	41.7	0.57	14
2015	1935	31	20.5	21.2	41.7	0.42	-31
2016	2078	174	2.4	39.3	41.7	0.05	-174
2017	1890	-14	27.8	13.9	41.7	0.57	14
2018	2095	191	0.7	38.1	38.8	0.01	-191
2019	2098	194	0.3	38.5	38.8	0.01	-194
MEAN	**1908**	**4**	**28.7**	**18.1**		**0.59**	**-4**

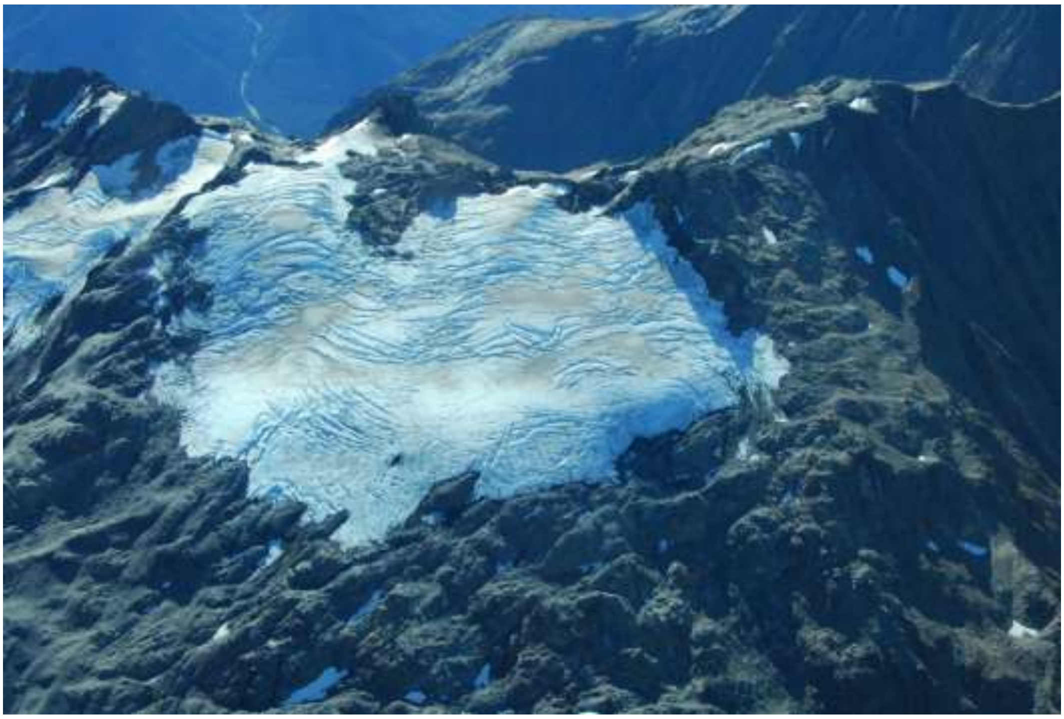

Figure D-28: McKenzie Glacier on 20 March 2020.

No. 868B/94

JACKSON GL

NZMS 260 sheet H37

Mountain glacier

GLACIER DATA		
Aspect	NW	
AREA	52.15	ha
Max Elev	2300	m
Min Elev	1920	m
Mean Elev	2110	m
Length	0.5	km
Elev Range	380	m
Gradient	0.76	

SNOWLINE DATA		
ELAo	2070	m
Max SL	2290	m, 2011
Min SL	1990	m, 1984
Mean SL	2083	m
SL Range	300	m
No. Surveys	35	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
55	2100						
ELAo	**2070**	**0**	**30.2**	**22.0**	**52.2**	**0.58**	**0**
1977							
1978	2098	28	23.4	28.8	52.2	0.40	-28
1979							
1980	2050	-20	35.7	16.5	52.2	0.62	20
1981							
1982	2075	5	29.2	23.0	52.2	0.50	-5
1983	2032	-38	41.9	10.3	52.2	0.72	38
1984	1990	-80	49.1	3.1	52.2	0.85	80
1985	2014	-56	45.3	6.8	52.2	0.78	56
1986							
1987	2061	-9	32.7	19.4	52.2	0.56	9
1988							
1989	2075	5	29.2	23.0	52.2	0.50	-5
1990							
1991							
1992							
1993	1992	-78	49.0	3.2	52.2	0.85	78
1994	2045	-25	37.1	15.0	52.2	0.64	25
1995	2018	-52	44.3	7.8	52.2	0.77	52
1996	2072	2	30.0	22.2	52.2	0.52	-2
1997	2016	-54	44.9	7.3	52.2	0.77	54
1998	2075	5	27.1	18.5	45.5	0.47	-5
1999	2165	95	8.6	31.9	40.5	0.15	-95
2000	2115	45	15.5	23.0	38.5	0.27	-45
2001	2016	-54	32.4	6.1	38.5	0.56	54
2002	2103	33	22.8	15.3	38.1	0.39	-33
2003	2015	-55	36.6	1.5	38.1	0.63	55
2004	2016	-54	36.6	1.5	38.1	0.63	54
2005	2014	-56	36.6	1.5	38.1	0.63	56
2006	2085	15	22.6	15.5	38.1	0.39	-15
2007	2084	14	22.6	15.5	38.1	0.39	-14
2008	2145	75	9.1	28.5	37.6	0.24	-75
2009	2082	12	23.1	14.5	37.6	0.61	-12
2010	2072	2	26.3	11.3	37.6	0.70	-2
2011	2230	160	2.5	33.9	36.5	0.07	-160
2012	2140	70	11.4	25.1	36.5	0.31	-70
2013	2072	2	25.2	11.3	36.5	0.69	-2
2014	2070	0	25.3	11.2	36.5	0.69	0
2015	2075	5	26.1	10.0	36.1	0.72	-5
2016	2220	150	2.6	33.5	36.1	0.07	-150
2017	2070	0	24.9	11.2	36.1	0.69	0
2018	2290	220	0.4	35.7	36.1	0.01	-220
2019	2230	160	2.5	33.6	36.1	0.07	-160
MEAN	**2083**	**13**	**26.6**	**16.5**		**0.51**	**-13**

Figure D-29: Jackson Glacier on 20 March 2019.

No. 875/15

JACK GL.

NZMS 260 sheet G37

Small cirque glacier

GLACIER DATA		
Aspect	W	
AREA	21.48	ha
Max Elev	2280	m
Min Elev	1800	m
Mean Elev	2040	m
Length	0.337	km
Elev Range	480	m
Gradient	1.42	

SNOWLINE DATA		
ELAo	**1907**	m
Max SL	2300	m, 2018
Min SL	1750	m, 1983
Mean SL	1925	m
SL Range	550	m
No. Surveys	38	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1907**	**0**	**15.7**	**5.8**	**21.5**	**0.73**	**0**
1977							
1978	1938	31	11.5	10.0	21.5	0.53	-31
1979							
1980	1930	23	12.9	8.6	21.5	0.60	-23
1981	1885	-22	17.4	4.1	21.5	0.81	22
1982	1951	44	9.0	12.5	21.5	0.42	-44
1983	1750	-157	29.8	-8.3	21.5	1.39	157
1984	1828	-79	19.7	1.8	21.5	0.92	79
1985	1875	-32	17.9	3.6	21.5	0.83	32
1986	1935	28	12.0	9.5	21.5	0.56	-28
1987	1905	-2	15.9	5.6	21.5	0.74	2
1988	1875	-32	17.9	3.6	21.5	0.83	32
1989	1898	-9	16.6	4.9	21.5	0.77	9
1990					no visit		
1991					no visit		
1992	1817	-90	19.9	1.6	21.5	0.93	90
1993	1765	-142	21.1	0.4	21.5	0.98	142
1994	1880	-27	17.7	3.8	21.5	0.82	27
1995	1755	-152	27.0	0.5	21.5	1.00	152
1996	1958	51	7.6	13.9	21.5	0.36	-51
1997	1805	-102	20.2	1.3	21.5	0.94	102
1998	1940	33	11.2	10.3	21.5	0.52	-33
1999	2008	101	2.0	15.5	17.5	0.11	-101
2000	1992	85	2.9	12.1	15.0	0.19	-85
2001	1798	-109	13.9	1.1	15.0	0.93	109
2002	1985	78	3.2	11.8	15.0	0.21	-78
2003	1760	-147	15.0	0.0	15.0	1.00	147
2004					cloud		
2005	1795	-112	15.0	0.0	15.0	1.00	112
2006	1935	28	9.2	5.8	15.0	0.61	-28
2007	1923	16	10.8	4.2	15.0	0.72	-16
2008	1990	83	2.8	12.2	15.0	0.19	-83
2009	1980	73	3.8	11.2	15.0	0.25	-73
2010	1898	-9	13.2	1.8	15.0	0.88	9
2011	2200	293	0.0	15.0	15.0	0.00	-293
2012	1980	73	3.8	11.2	15.0	0.25	-73
2013	1898	-9	13.2	1.8	15.0	0.88	9
2014	1880	-27	13.9	1.1	15.0	0.93	27
2015	1940	33	8.6	6.4	15.0	0.57	-33
2016	2180	273	0.0	15.0	15.0	0.00	-273
2017	1815	-92	15.0	0.1	15.0	1.00	92
2018	2300	393	0.0	15.0	15.0	0.00	-393
2019	2200	293	0.0	15.0	15.0	0.00	-293
MEAN	**1925**	**18**	**11.9**	**6.4**		**0.62**	**-18**

Figure D-30: Jack Glacier on 20 March 2019.

No. 711B/39

Mt. St. MARY

NZMS 260 sheet G38

Rock glacier

GLACIER DATA		
Aspect	SE	
AREA	28.32	ha
Max Elev	2200	m
Min Elev	1760	m
Mean Elev	1980	m
Length	0.7	km
Elev Range	440	m
Gradient	0.629	

SNOWLINE DATA		
ELAo	**1926**	m
Max SL	2190	m, 2011
Min SL	1755	m, 1984
Mean SL	1932	m
SL Range	435	m
No. Surveys	32	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1926**	**0**	**6.5**	**21.8**	**28.3**	**0.23**	**0**
1977							
1978							
1979							
1980							
1981							
1982							
1983							
1984	1755	-171	20.3	8.0	28.3	0.72	171
1985							
1986	1835	-91	12.3	16.0	28.3	0.44	91
1987							
1988	1907	-19	7.9	20.4	28.3	0.28	19
1989	1972	46	4.4	23.9	28.3	0.16	-46
1990							
1991							
1992	1850	-76	11.3	17.0	28.3	0.40	76
1993	1785	-141	16.7	11.6	28.3	0.59	141
1994	1850	-76	11.3	17.0	28.3	0.40	76
1995	1770	-156	18.4	9.9	28.3	0.65	156
1996	1855	-71	11.1	17.2	28.3	0.39	71
1997	1842	-84	11.8	16.6	28.3	0.41	84
1998	1889	-37	8.9	19.4	28.3	0.32	37
1999	2125	199	0.4	27.9	28.3	0.01	-199
2000	2130	204	0.4	28.0	28.3	0.01	-204
2001	1780	-146	17.2	11.1	28.3	0.61	146
2002	2115	189	0.5	27.8	28.3	0.02	-189
2003	1795	-131	15.7	12.6	28.3	0.56	131
2004	1855	-71	11.1	17.2	28.3	0.39	71
2005	1800	-126	15.7	12.6	28.3	0.56	126
2006	1895	-31	8.5	19.8	28.3	0.30	31
2007	1910	-16	7.6	20.7	28.3	0.27	16
2008	2120	194	0.4	27.9	28.3	0.01	-194
2009	2000	74	3.2	25.1	28.3	0.11	-74
2010	1885	-41	9.1	19.2	28.3	0.32	41
2011	2180	254	0.0	28.3	28.3	0.00	-254
2012	2120	194	0.4	27.9	28.3	0.01	-194
2013	1880	-46	9.4	18.9	28.3	0.33	46
2014	1800	-126	15.7	12.6	28.3	0.56	126
2015	2000	74	3.2	25.1	28.3	0.11	-74
2016	2130	204	0.4	28.0	28.3	0.01	-204
2017	1880	-46			28.3	0.00	46
2018	>2280		0.0	28.3	28.3	0.00	0
2019	2190				no area assessment		
MEAN	**1932**	**-2**	**8.5**	**19.9**		**0.29**	**2**

Figure D-31: Mt St Mary on 20 March 2019.

No. 711B/12			THURNEYSTON GL.		NZMS 260 sheet G38
			Mountain gl, reliability C		

GLACIER DATA		
Aspect	S	
AREA	117.8	ha
Max Elev	2450	m
Min Elev	1720	m
Mean Elev	2085	m
Length	1.23	km
Elev Range	730	m
Gradient	0.59	

SNOWLINE DATA		
ELA	1970	m
Max SL	2190	m, 2018
Min SL	1865	m, 1983
Mean SL	1985	m
SL Range	325	m
No. Surveys	38	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELA	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1970**	**0**	**84.6**	**33.2**	**117.8**	**0.72**	**0**
1977	1930	-40	95.3	22.5	117.8	0.81	40
1978							
1979							
1980	1926	-44	98.0	19.8	117.8	0.83	44
1981	1943	-27	92.8	25.0	117.8	0.79	27
1982							
1983	1865	-105	109.8	8.0	117.8	0.93	105
1984	1882	-88	107.0	10.8	117.8	0.91	88
1985	1905	-65	103.4	14.4	117.8	0.88	65
1986	1938	-32	94.1	23.7	117.8	0.80	32
1987	1918	-52	100.3	17.5	117.8	0.85	52
1988	1950	-20	90.8	27.0	117.8	0.77	20
1989	1970	0	84.6	33.2	117.8	0.72	0
1990							
1991							
1992	1930	-40	95.3	22.5	117.8	0.81	40
1993	1910	-60	101.9	15.9	117.8	0.87	60
1994	1904	-66	103.4	14.4	117.8	0.88	66
1995	1868	-102	109.4	8.4	117.8	0.93	102
1996	1938	-32	94.1	23.7	117.8	0.80	32
1997	1900	-70	103.9	14.0	117.8	0.88	70
1998	1965	-5	85.3	32.5	117.8	0.72	5
1999	2112	142	38.7	79.1	117.8	0.33	-142
2000	2132	162	31.7	86.1	117.8	0.27	-162
2001	1878	-92	107.8	10.0	117.8	0.92	92
2002	2105	135	40.8	77.0	117.8	0.35	-135
2003	1873	-97	108.6	9.2	117.8	0.92	97
2004	1935	-35	95.3	22.5	117.8	0.81	35
2005	1900	-70	103.9	14.0	117.8	0.88	70
2006	1980	10	81.8	36.0	117.8	0.69	-10
2007	1963	-7	85.7	32.1	117.8	0.73	7
2008	2110	140	39.8	78.0	117.8	0.34	-140
2009	2100	130	42.8	75.0	117.8	0.36	-130
2010	1975	5	82.8	35.0	117.8	0.70	-5
2011	2150	180	24.8	93.0	117.8	0.21	-180
2012	2110	140	39.8	78.0	117.8	0.34	-140
2013	1938	-32	94.1	23.7	117.8	0.80	32
2014	1915	-55	100.8	17.0	117.8	0.86	55
2015	2080	110	49.8	68.0	117.8	0.42	-110
2016	2120	150	32.8	85.0	117.8	0.28	-150
2017	1938	-32	94.1	23.7	117.8	0.80	32
2018	2190	220	7.4	110.4	117.8	0.06	-220
2019	2290	320	7.4	110.4	117.8	0.06	-320
MEAN	**1985**	**15**	**78.4**	**39.4**		**0.67**	**-15**

Figure D-32: Thurneyson Glacier on 20 March 2019.

No. 868C-20

BREWSTER GL.

NZMS 260 sheet G38

Mountain glacier

GLACIER DATA		
Aspect	S	
AREA	249.5	ha
Max Elev	2390	m
Min Elev	1655	m
Mean Elev	2023	m
Length	2.69	km
Elev Range	735	m
Gradient	0.27	

SNOWLINE DATA		
ELAo	**1935**	m
Max SL	2360	m, 2018
Min SL	1750	m, 1993
Mean SL	1951	m
SL Range	610	m
No. Surveys	38	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	AREAS ACCUM. ha	AREAS ABL. ha	AREAS TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**1935**	**0**	**125.6**	128.0	**253.6**	**0.50**	**0**
1977							
1978	1960	25	98.7	154.9	253.6	0.39	-25
1979							
1980	1846	-89	193.5	60.1	253.6	0.76	89
1981	1855	-80	188.5	65.1	253.6	0.74	80
1982	1971	36	80.2	173.4	253.6	0.32	-36
1983	1794	-141	221.3	32.3	253.6	0.87	141
1984	1800	-135	218.4	35.2	253.6	0.86	135
1985	1796	-139	220.5	33.1	253.6	0.87	139
1986	1842	-93	195.5	58.1	253.6	0.77	93
1987	1828	-107	205.6	48.0	253.6	0.81	107
1988							
1989	1918	-17	140.4	113.2	253.6	0.55	17
1990							
1991							
1992	1851	-84	190.5	63.1	253.6	0.75	84
1993	1750	-185	234.7	18.9	253.6	0.93	185
1994	1790	-145	222.5	31.1	253.6	0.88	145
1995	1777	-158	227.6	26.0	253.6	0.90	158
1996	1962	27	89.9	163.7	253.6	0.35	-27
1997	1779	-156	226.3	25.7	252.0	0.90	156
1998	1982	47	67.0	183.4	250.4	0.27	-47
1999	2280	345	8.2	240.6	248.8	0.03	-345
2000	2155	220	29.2	218.0	247.2	0.12	-220
2001	1770	-165	228.7	20.8	245.6	0.93	165
2002	2050	115	203.0	40.9	243.9	0.83	-115
2003	1794	-141	213.3	29.0	242.3	0.88	141
2004	1780	-155	227.4	13.3	240.7	0.94	155
2005	1780	-155	227.4	11.7	239.1	0.95	155
2006	1870	-65	165.7	71.8	237.5	0.70	65
2007	1815	-120	211.0	24.9	235.9	0.89	120
2008	2270	335	-5.2	241.1	235.9	-0.02	-335
2009	1990	55	62.8	173.1	235.9	0.27	-55
2010	1930	-5	130.1	105.8	235.9	0.55	5
2011	2285	350	3.5	207.4	210.9	0.02	-350
2012	2140	205	28.3	181.1	209.4	0.14	-205
2013	1918	-17	96.4	113.0	209.4	0.46	17
2014*	1950	15	105.0	104.4	209.4	0.50	-15
2015	2010	75	54.5	147.7	202.2	0.27	-75
2016	2285	350	3.5	190.8	194.3	0.02	-350
2017	1918	-17	80.9	113.0	193.9	0.42	17
2018	2360	425	2.0	174.9	176.9	0.01	-425
2019	2285	350	3.5	173.4	176.9	0.02	-350
MEAN	**1951**	**16**	**134**	**102**		**0.55**	**-16**

Figure D-33: Brewster Glacier on 20 March 2019.

No. 752 I-104

Mt. STUART

Mountain glacier

NZMS 260 sheet G38

GLACIER DATA		
Aspect	SE	
AREA	31.55	ha
Max Elev	1860	m
Min Elev	1570	m
Mean Elev	1715	m
Length	0.54	km
Elev Range	290	m
Gradient	0.54	

SNOWLINE DATA		
ELAo	**1673**	m
Max SL	1859	m, 2018
Min SL	1515	m, 1995
Mean SL	1684	m
SL Range	344	m
No. Surveys	37	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	Glacier Ice Area	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1673**	**0**	**21.1**	**5.0**	**26.1**	**0.81**	**0**
1977	1587	-86	30.9	0.7	31.6	0.98	86
1978	1730	57	18.5	13.0	31.6	0.59	-57
1979							
1980	1650	-23	27.3	4.3	31.6	0.86	23
1981	1606	-67	29.9	1.7	31.6	0.95	67
1982	1676	3	25.3	6.2	31.6	0.80	-3
1983	1538	-135	31.6	0.0	31.6	1.00	135
1984							
1985	1620	-53	29.1	2.5	31.6	0.92	53
1986	1660	-13	26.6	5.0	31.6	0.84	13
1987	1678	5	25.1	6.5	31.6	0.79	-5
1988							
1989	1663	-10	26.3	5.2	31.6	0.83	10
1990							
1991							
1992							
1993	1535	-138	31.6	0.0	31.6	1.00	138
1994	1640	-33	28.0	3.6	31.6	0.89	33
1995	1515	-158	31.6	0.0	31.6	1.00	158
1996	1712	39	21.2	10.4	31.6	0.67	-39
1997	1567	-106	31.6	0.0	31.6	1.00	106
1998	1656	-17	26.9	4.7	31.6	0.85	17
1999	1805	132	5.5	26.1	31.3	0.17	-132
2000	1850	177	0.5	27.7	28.2	0.02	-177
2001	1590	-83	27.2	1.0	28.2	0.97	83
2002	1815	142	4.6	23.6	28.2	0.16	-142
2003	1570	-103	31.1	0.0	28.2	1.00	103
2004	1565	-108	31.5	0.0	28.2	1.00	108
2005	1565	-108	31.5	0.0	28.2	1.00	108
2006	1725	52	19.6	8.6	28.2	0.70	-52
2007	1607	-66	27.9	0.3	28.2	1.00	66.00
2008	1800	127	6.7	21.5	28.2	0.24	-127.00
2009	1790	117	8.3	19.9	28.2	0.29	-117.00
2010	1677	4	24.4	3.8	28.2	0.87	-4.00
2011	1858	185	0.3	25.5	25.8	0.01	-185.00
2012	1848	175	0.5	20.8	21.3	0.02	-175.00
2013	1606	-67	29.7	0.2	21.3	1.00	67.00
2014	1677	4	17.5	3.8	21.3	0.82	-4.00
2015	1765	92	10.7	10.6	21.3	0.50	-92.00
2016	1848	175	0.5	20.8	21.3	0.02	-175.00
2017	1606	-67	21.3	0.0	21.3	1.00	67.00
2018	1859	186	0.03	21.3	21.3	0.00	-186.00
2019	1850	177	0.5	20.80	21.3	0.02	-177.00
MEAN	**1684**	**11**	**20.0**	**8.6**		**0.67**	**-1**

Figure D-34: Stuart Glacier on 20 March 2019.

No. 867/2

LINDSAY GL.

NZMS 260 sheet F37

Mountain shelf glacier

GLACIER DATA		
Aspect	S	
AREA	52.53	ha
Max Elev	1880	m
Min Elev	1610	m
Mean Elev	1745	m
Length	0.57	km
Elev Range	270	m
Gradient	0.47	

SNOWLINE DATA		
ELAo	**1730**	m
Max SL	1878	m, 2011
Min SL	1550	m, 1995
Mean SL	1725	m
SL Range	328	m
No. Surveys	37	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1730**	**0**	**39.2**	**13.3**	**52.5**	**0.75**	**0**
1977							
1978	1738	8	37.1	15.4	52.5	0.71	-8
1979							
1980	1652	-78	50.5	2.0	52.5	0.96	78
1981	1681	-49	48.6	3.9	52.5	0.93	49
1982	1781	51	22.4	30.1	52.5	0.43	-51
1983	1560	-170	65.7	0.0	65.7	1.25	170
1984							
1985	1666	-64	49.6	2.9	52.5	0.94	64
1986	1768	38	27.5	25.0	52.5	0.52	-38
1987	1615	-115	52.3	0.2	52.5	1.00	115
1988	1772	42	24.6	27.9	52.5	0.47	-42
1989	1764	34	28.5	24.0	52.5	0.54	-34
1990							
1991							
1992							
1993	1555	-175	69.9	0.0	69.9	1.33	175
1994	1610	-120	52.5	0.0	52.5	1.00	120
1995	1550	-180	73.5	0.0	73.5	1.40	180
1996	1775	45	24.5	28.1	52.5	0.47	-45
1997	1645	-85	69.0	1.7	70.7	1.31	85
1998	1800	70	14.5	38.1	52.5	0.28	-70
1999	1875	145	0.9	51.6	52.5	0.02	-145
2000	1870	140	1.5	51.1	52.5	0.03	-140
2001	1640	-90	51.1	1.4	52.5	0.97	90
2002	1872	142	1.1	51.5	52.5	0.02	-142
2003	1607	-123	52.5	0.0	52.5	1.00	123
2004	1608	-122	52.5	0.0	52.5	1.00	122
2005	1612	-118	51.5	1.0	52.5	0.98	118
2006	1780	50	22.4	30.1	52.5	0.43	-50
2007	1700	-30	46.4	6.1	52.5	0.88	30
2008	1860	130	0.5	38.5	39.0	0.01	-130
2009	1810	80	9.0	30.0	39.0	0.17	-80
2010	1710	-20	37.6	1.4	39.0	0.72	20
2011	1878	148	0.5	25.5	26.0	0.01	-148
2012	1815	85	7.1	15.7	22.8	0.14	-85
2013	1666	-64	22.8	0.0	22.8	0.43	64
2014	1710	-20	22.7	0.1	22.8	0.43	20
2015	1815	85	7.1	15.7	22.8	0.14	-85
2016	1815	85	7.1	14.4	21.5	0.13	-85
2017	1666	-64	22.8	0.0	21.5	0.43	64
2018	>1880		0.0	22.8	14.0	0.00	
2019	1872	142	1.1	11.4	12.5	0.02	-142
MEAN	**1725**	**-5**	**30.5**	**15.3**		**0.58**	**5**

Figure D-35: Lindsay Glacier on 20 March 2019.

No. 752 E/51

FOG PK.

NZMS 260 sheet F39

Cirque glacier

GLACIER DATA		
Aspect	SE	
AREA	18.22	ha
Max Elev	2160	m
Min Elev	1840	m
Mean Elev	2000	m
Length	0.4	km
Elev Range	320	m
Gradient	0.8	

SNOWLINE DATA		
ELAo	**1987**	m
Max SL	2158	m, 2018
Min SL	1888	m, 1995
Mean SL	2009	m
SL Range	270	m
No. Surveys	34	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1987**	**0**	**12.0**	**6.2**	**18.2**	**0.66**	**0**
1977							
1978							
1979							
1980	1916	-71	34.4	0.0	18.2	>1	71
1981							
1982	2022	35	14.8	3.5	18.2	0.81	-35
1983							
1984	1891	-96	42.8	0.0	18.2	>1	96
1985							
1986	1930	-57	30.4	0.0	18.2	>1	57
1987	1902	-85	39.0	0.0	18.2	>1	85
1988	2022	35	14.8	3.5	18.2	0.81	-35
1989	2032	45	6.6	11.6	18.2	0.36	-45
1990							
1991							
1992							
1993	1894	-93	37.8	0.0	18.2	>1	93
1994	1900	-87	17.6	0.6	18.2	0.96	87
1995	1888	-99	44.4	0.0	18.2	>1	99
1996	1894	-93	41.7	0.0	18.2	>1	93
1997	1890	-97	43.3	0.0	18.2	>1	97
1998	2098	111	1.8	16.5	18.2	0.10	-111
1999	2135	148	0.7	11.6	12.3	0.06	-148
2000	2125	138	1.3	9.2	10.5	0.12	-138
2001	1895	-92	17.3	0.0	10.5	>1	92
2002	2120	133	1.1	8.4	9.5	0.12	-133
2003	2055	68	6.7	2.8	9.5	0.70	-68
2004	1892	-95	17.4	0.0	9.5	>1	95
2005	1890	-97	17.5	0.0	9.5	>1	97
2006	2032	45	8.0	1.6	9.5	0.84	-45
2007	2000	13	9.2	0.4	9.5	0.96	-13
2008	2105	118	1.9	7.6	9.5	0.20	-118
2009	2032	45	8.0	1.6	9.5	0.84	-45
2010	2032	45	8.0	1.6	9.5	0.84	-45
2011	2135	148	0.8	7.1	7.9	0.10	-148
2012	2130	143	1.0	6.9	7.9	0.13	-143
2013	2015	28	7.4	0.5	7.9	0.94	-28
2014*	2015	28	7.4	0.5	7.9	0.94	-28
2015	2090	103	3.2	4.7	7.9	0.40	-103
2016	>2160		0.0	7.9	7.9		
2017	2015	28	7.4	0.5	7.9	0.94	-28
2018	2158	171	0.1	7.8	7.9	0.02	-171
2019	2135	148	0.8	7.1	7.9	0.10	-148
MEAN	**2009**	**22**	**14.5**	**3.6**		**0.51**	**-22**

Figure D-36: Fog Peak on 20 March 2019.

No. 752C/103

SNOWY CK

Small mountain glacier

NZMS 260 sheet E40

GLACIER DATA		
Aspect	W	
AREA	53.13	ha
Max Elev	2210	m
Min Elev	2000	m
Mean Elev	2105	m
Length	0.73	km
Elev Range	210	m
Gradient	0.29	

SNOWLINE DATA		
ELAo	**2092**	m
Max SL	>2240	m, 2011
Min SL	2004	m, 1997
Mean SL	2084	m
SL Range	206	m
No. Surveys	37	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	AREAS ACCUM. ha	AREAS ABL. ha	AREAS TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**2092**	**0**	**31.9**	**21.3**	**53.1**	**0.60**	**0**
1977							
1978	2156	64	6.9	46.3	53.1	0.13	-64
1979							
1980	2024	-68	48.4	4.8	53.1	0.91	68
1981	2158	66	6.4	46.7	53.1	0.12	-66
1982	2038	-54	45.4	7.7	53.1	0.86	54
1983	2033	-59	53.1	0.0	53.1	1.00	59
1984	2024	-68	48.3	4.8	53.1	0.91	68
1985	2020	-72	49.1	4.0	53.1	0.92	72
1986	2036	-56	45.9	7.2	53.1	0.86	56
1987	2025	-67	48.2	4.9	53.1	0.91	67
1988	2037	-55	45.9	7.2	53.1	0.86	55
1989	2103	11	28.2	25.0	53.1	0.53	-11
1990							
1991							
1992							
1993	2058	-34	40.7	12.4	53.1	0.77	34
1994	2034	-58	46.1	7.0	53.1	0.87	58
1995	2030	-62	47.1	6.0	53.1	0.89	62
1996	2057	-35	41.0	12.1	53.1	0.77	35
1997	2020	-72	64.3	-11.2	53.1	1.21	72
1998	2158	66	6.4	46.7	53.1	0.12	-66
1999	2240	148	53.1	0.0	53.1	1.00	-148
2000	2160	68	6.1	47.0	53.1	0.12	-68
2001	2004	-88	52.7	0.4	53.1	0.99	88
2002	2120	28	21.8	31.3	53.1	0.41	-28
2003	2041	-51	44.7	8.4	53.1	0.84	51
2004	2034	-58	53.1	0.0	53.1	1.00	58
2005	2020	-72	50.1	3.0	53.1	0.94	72
2006	2160	68			40.5	0.00	-68
2007	2090	-2	*fragmented - areas not assessed*				2
2008	2158	66	*fragmented - areas not assessed*				-66
2009	2156	64	*fragmented - areas not assessed*				-64
2010	2156	64	*fragmented - areas not assessed*				-64
2011	>2210		*fragmented - areas not assessed*				0
2012	2158	66	*fragmented - areas not assessed*				-66
2013	2060	-32	*fragmented - areas not assessed*				32
2014			*fragmented - areas not assessed*				
2015	2156	64	*fragmented - areas not assessed*				-64
2016	>2210		*fragmented - areas not assessed*				0
2017	2060	-32	*fragmented - areas not assessed*				32
2018	>2210		*fragmented - areas not assesse*		12.1		
2019	2205	113	*fragmented - areas not assesse*		12.1		
MEAN	**2084**	**-7**	**39.7**	**13.4**		**0.72**	**6**

Figure D-37: Snowy on 20 March 2019.

No. 863B/1

Mt. CARIA

NZMS 260 sheet E39

Small cirque

GLACIER DATA		
Aspect	SE	
AREA	17.13	ha
Max Elev	1600	m
Min Elev	1400	m
Mean Elev	1500	m
Length	0.3	km
Elev Range	200	m
Gradient	0.67	

SNOWLINE DATA		
ELAo	**1472**	m
Max SL	>1660	m, 2011
Min SL	1366	m, 1995
Mean SL	1454	m
SL Range	234	m
No. Surveys	35	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION	DEPARTURE FROM ELAo	AREAS ACCUM.	ABL.	TOTAL	ACCUM. AREA RATIO	MASS BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1472**	**0**	**2.8**	**14.3**	**17.1**	**0.17**	**0**
1977							
1978	1442	-30	7.1	10.1	17.1	0.41	30
1979							
1980							
1981	1413	-59	13.7	3.5	17.1	0.80	59
1982	1424	-48	10.7	6.4	17.1	0.63	48
1983	1372	-100	42.8	0.0	42.8	2.50	100
1984							
1985	1423	-49	10.8	6.3	17.1	0.63	49
1986	1525	53	9.8	7.3	17.1	0.57	-53
1987	1422	-50	11.1	6.1	17.1	0.65	50
1988	1500	28	6.4	10.7	17.1	0.38	-28
1989	1429	-43	9.8	7.3	17.1	0.57	43
1990							
1991							
1992							
1993	1375	-97	36.0	0.0	36.0	2.10	97
1994	1400	-72	17.1	0.0	17.1	1.00	72
1995	1366	-106	54.5	0.0	54.5	3.18	106
1996	1390	-82	22.0	0.0	22.0	1.28	82
1997	1395	-77	19.5	0.0	19.5	1.14	77
1998	1417	-55	12.5	4.7	17.1	0.73	55
1999	1650	178	0.0	17.1	17.1	0.00	-178
2000	1660	188	0.0	8.7	8.7	0.00	-188
2001	1420	-52	9.2	3.5	12.7	0.72	52
2002	1625	153	0.0	8.7	8.7	0.00	-153
2003	1422	-50	8.1	0.6	8.7	0.93	50
2004	1380	-92	8.7	0.0	8.7	1.00	92
2005	1374	-98	36.0	0.0	36.0	1.00	98
2006	1515	43	0.7	8.0	8.7	0.08	-43
2007	1455	-17	3.7	5.0	8.7	0.43	17
2008	1520	48	0.4	6.8	7.3	0.06	-48
2009	1520	48	0.4	6.8	7.3	0.06	-48
2010	1398	-74	7.3	0.0	7.3	1.00	74
2011	>1660		0.0	4.5	4.5	0.00	0
2012	1520	48	0.4	4.0	4.5	0.10	-48
2013	1430	-42	3.0	1.5	4.5	0.67	42
2014	1430	-42	3.0	1.5	4.5	0.67	42
2015							
2016	1520	fragmented, and unusable			4.5		
2017	1398	fragmented, and unusable					
2018	>1660	fragmented, and unusable					
2019	1640	fragmented, and unusable			1.5		
MEAN	**1454**	**-18**	**11.8**	**4.5**		**0.75**	**18**

Figure D-38: Mt Caria on 20 March 2019.

No. 859/9

FINDLAY GL.

NZMS 260 sheet E39

Cirque glacier

GLACIER DATA		
Aspect	SW	
AREA	67.15	ha
Max Elev	1900	m
Min Elev	1550	m
Mean Elev	1725	m
Length	0.875	km
Elev Range	350	m
Gradient	0.4	

SNOWLINE DATA		
ELAo	**1693**	m
Max SL	1895	m, 1999
Min SL	1561	m, 1995
Mean SL	1705	m
SL Range	334	m
No. Surve	34	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	AREAS ACCUM. ha	ABL. ha	TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**1693**	**0**	**36.0**	**31.2**	**67.2**	**0.54**	**0**
1977							
1978							
1979							
1980							
1981	1604	-89	57.5	9.6	67.2	0.86	89
1982	1735	42	25.9	41.3	67.2	0.38	-42
1983	1582	-111	61.5	5.6	67.2	0.92	111
1984							
1985	1629	-64	48.9	18.3	67.2	0.73	64
1986	1725	32	28.0	39.2	67.2	0.42	-32
1987	1622	-71	51.1	16.1	67.2	0.76	71
1988	1685	-8	35.2	32.0	67.2	0.52	8
1989	1642	-51	44.2	23.0	67.2	0.66	51
1990							
1991							
1992							
1993	1575	-118	62.9	4.3	67.2	0.94	118
1994	1634	-59	46.9	20.3	67.2	0.70	59
1995	1561	-132	65.2	2.0	67.2	0.97	132
1996	1632	-61	47.5	19.6	67.2	0.71	61
1997	1580	-113	62.0	5.2	67.2	0.92	113
1998	1780	87	22.9	35.5	58.4	0.39	-87
1999	1890	197	2.1	51.4	53.6	0.04	-197
2000	1845	152	7.3	44.3	51.6	0.14	-152
2001	1620	-73	45.4	8.8	54.2	0.84	73
2002	1825	132	10.8	46.6	51.6	0.21	-132
2003	1612	-81	39.8	11.8	51.6	0.77	81
2004	1578	-115	47.2	4.4	51.6	0.91	115
2005	1580	-113	47.2	4.4	51.6	0.91	113
2006	1690	-3	32.0	19.7	51.6	0.62	3
2007	1661	-32	32.5	19.1	51.6	0.63	32
2008	1832	139	8.5	40.0	48.5	0.18	-139
2009	1805	112	15.0	33.5	48.5	0.31	-112
2010	1632	-61	35.3	13.2	48.5	0.73	61
2011	1855	162	4.0	40.5	44.5	0.09	-162
2012	1790	97	14.5	30.0	44.5	0.33	-97
2013							
2014	1685	-8	19.0	25.5	44.5	0.43	8
2015	1805	112	11.0	32.0	43.0	0.26	-112
2016	1832	139	6.6	36.0	42.6	0.15	-139
2017	1680	-13	26.4	16.2	42.6	0.62	13
2018	1895	202	0.5	42.1	42.6	0.01	-202
2019	1855	162	4.0	38.6	42.6	0.09	-162
Mean	**1705**	**12**	**34.4**	**23.2**		**0.58**	**3**

Figure D-39: Findlay Glacier on 20 March 2019.

No. 752 B/48

PARK PASS GL.

NZMS 260 sheet E 40

Valley glacier

GLACIER DATA		
Aspect	S	
AREA	191.2	ha
Max Elev	2200	m
Min Elev	1500	m
Mean Elev	1850	m
Length	2.63	km
Elev Range	700	m
Gradient	0.267	

SNOWLINE DATA		
ELAo	1824	m
Max SL	2040	m, 2011
Min SL	1635	m, 1995
Mean SL	1843	m
SL Range	405	m
No. Surveys	36	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1824**	**0**	**127.9**	**85.7**	**213.6**	**0.60**	**0**
1977							
1978	1903	79	91.3	122.3	213.6	0.43	-79
1979							
1980	1808	-16	131.6	82.0	213.6	0.62	16
1981	1778	-46	139.2	74.4	213.6	0.65	46
1982	1858	34	112.4	101.2	213.6	0.53	-34
1983	1762	-62	142.7	70.9	213.6	0.67	62
1984	1765	-59	141.6	72.0	213.6	0.66	59
1985	1702	-122	156.6	57.0	213.6	0.73	122
1986	1863	39	110.1	103.5	213.6	0.52	-39
1987	1843	19	117.6	96.0	213.6	0.55	-19
1988							
1989	1794	-30	134.6	79.0	213.6	0.63	30
1990							
1991							
1992							
1993							
1994	1783	-41	151.4	55.0	206.4	0.73	41
1995	1635	-189	187.6	18.3	205.9	0.91	189
1996	1808	-16	147.2	58.3	205.5	0.72	16
1997	1745	-79	160.2	44.8	205.0	0.78	79
1998	1880	56	105.8	98.7	204.5	0.52	-56
1999	1955	131	62.1	141.5	203.6	0.30	-131
2000	1943	119	71.3	131.3	202.6	0.35	-119
2001	1748	-76	156.3	45.4	201.6	0.78	76
2002	1910	86	82.8	117.8	200.6	0.41	-86
2003	1661	-163	173.1	26.5	199.6	0.87	163
2004	1665	-159	168.7	30.0	198.7	0.85	159
2005	1670	-154	166.7	31.0	197.7	0.84	154
2006	1900	76	91.7	105.0	196.7	0.47	-76
2007	1850	26	115.3	80.4	195.7	0.59	-26
2008	1910	86	87.4	107.3	194.7	0.45	-86
2009	1910	86	85.2	107.3	192.5	0.44	-86
2010	1880	56	95.2	93.6	188.8	0.50	-56
2011	2005	181	35.9	145.4	181.3	0.20	-181
2012	1940	116	64.2	117.1	181.3	0.35	-116
2013	1850	26	109.5	71.8	181.3	0.60	-26
2014	1843	19	113.0	68.3	181.3	0.62	-19
2015	1910	86	85.2	86.3	171.5	0.50	-86
2016	1943	119	55.0	116.5	171.5	0.32	-119
2017	1843	19	113.0	58.5	171.5	0.66	-19
2018	2040	216	31.3	125.2	156.5	0.20	-216
2019	2030	206	36	120.5	156.5	0.23	-206
Mean	**1843**	**19**	**116.6**	**83.5**		**1**	**-19**

Figure D-40: Park Pass Glacier on 20 March 2019.

No. 752 E/2

MT. LARKINS

NZMS sheet E 41

Glacierette

GLACIER DATA		
Aspect	SE	
AREA	19.6	ha (1984)
Max Elev	2260	m (1984)
Min Elev	1870	m (1984)
Mean Elev	2065	m
Length	0.5	km
Elev Range	390	m
Gradient	0.78	

SNOWLINE DATA		
ELAo	**2050**	m
Max. SL	2200	m, 1999, 2011
Min. SL	1870	m, 1995
Mean SL	2044	m
SL Range	330	m
No. surveys	27	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL (ha)	AREA RATIO	BALANCE
	m	m	annual (ha)	ha	Permanent Ice	(AAR)	INDEX
ELAo	**2050**	**0**	**11.7**	**7.9**	**19.6**	**0.60**	**0**
1977							
1978							
1979							
1980							
1981							
1982							
1983							
1984	1870	-180	19.60	0.00	19.6	1.00	180
1985							
1986	1870	-180	33.8	0.0	19.6	1.00	180
1987							
1988	2050	0	11.6	8.0	19.6	0.59	0
1989	2025	-25	11.5	6.5	18.0	0.64	25
1990							
1991							
1992							
1993	1870	-180	39.5	0.0	18.0	1.00	180
1994	1870	-180	23.4	0.0	18.0	0.85	180
1995	1870	-180	43.6	0.0	18.0	1.00	180
1996	1870	-180	27.5	0.0	18.0	1.00	180
1997	1870	-180	36.8	0.0	18.0	1.00	180
1998	2205	155	0.9	17.1	18.0	0.05	-155
1999	2200	150	1.0	13.9	14.8	0.06	-150
2000	2185	135	1.5	13.3	14.8	0.10	-135
2001	1870	-180	27.5	0.0	14.8	1.00	180
2002	2165	115	2.2	12.6	14.8	0.15	-115
2003	1935	-115	1.4	13.4	14.8	0.09	115
2004	1870	-180	27.5	0.0	14.8	1.00	180
2005	1870	-180	27.5	0.0	14.8	1.00	180
2006	2160	110	6.4	8.4	14.8	0.43	-110
2007	2165	115	2.2	12.6	14.8	0.15	-115
2008	2170	120	1.5	13.3	14.8	0.10	-120
2009	2170	120	1.6	11.7	13.3	0.12	-120
2010	2160	110	2.2	11.1	13.3	0.17	-110
2011	2200	150	0.4	9.5	9.9	0.04	-150
2012	2170	120	1.4	8.5	9.9	0.14	-120
2013	2150	100	2.1	7.8	9.9	0.21	-100
2014	1870	-180	27.0	0.0	9.9	1.00	180
2015	2170	120	0.4	9.5	9.9	0.04	-120
2016	2225	175	0.1	9.8	9.9	0.01	-175
2017	2020	-30	9.2	0.7	9.9	0.93	30
2018	2235	185	0.1	5.7	5.8	0.02	-185
2019	2235	185	0.1	4.8	4.9	0.02	
MEAN	**2044**	**-6**	**13.6**	**6.7**		**0.5**	**5.7**

Figure D-41: Mt Larkins on 20 March 2019.

No. 752B/25

BRYANT GL.

Mountain glacier

NZMS sheet E41

GLACIER DATA		
Aspect	SE	
AREA	29.7	ha
Max Elev	2180	m
Min Elev	1660	m
Mean Elev	1920	m
Length	0.94	km
Elev Range	520	m
Gradient	0.55	

SNOWLINE DATA		
ELAo	**1783**	m
Max. SL	2100	m, 2011
Min. SL	1610	m, 1995
Mean SL	1788	m
SL Range	490	m
No. surveys	37	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1783**	**0**	**12.2**	**17.5**	**29.7**	**0.41**	**0**
1977	1740	-43	20.9	8.8	29.7	0.70	43
1978	1884	101	4.9	24.8	29.7	0.16	-101
1979							
1980							
1981	1763	-20	15.7	14.0	29.7	0.53	20
1982	1780	-3	12.7	17.0	29.7	0.43	3
1983	1620	-163	34.5	0.0	29.7	1.00	163
1984	1620	-163	31.8	0.0	29.7	1.00	163
1985	1610	-173	37.3	0.0	29.7	1.00	173
1986	1770	-13	14.1	15.6	29.7	0.47	13
1987	1763	-20	15.7	14.0	29.7	0.53	20
1988							
1989	1753	-30	17.4	12.3	29.7	0.59	30
1990							
1991							
1992							
1993	1675	-108	17.2	12.5	29.7	0.58	108
1994	1728	-55	23.4	6.3	29.7	0.79	55
1995	1630	-153	40.2	0.0	29.7	1.35	153
1996	1680	-103	29.1	0.6	29.7	0.98	103
1997	1670	-113	29.0	0.7	29.7	0.98	113
1998	1778	-5	13.2	16.5	29.7	0.44	5
1999	2030	247	1.0	27.8	28.8	0.03	-247
2000	1965	182	1.9	26.9	28.7	0.06	-182
2001	1665	-118	0.1	28.6	28.7	0.00	118
2002	1870	87	6.5	22.2	28.7	0.23	-87
2003	1666	-117	28.6	0.1	28.7	1.00	117
2004	1675	-108	28.3	0.4	28.7	0.99	108
2005	1665	-118	28.6	0.1	28.7	1.00	118
2006	1800	17	12.1	16.6	28.7	0.42	-17
2007	1775	-8	15.3	13.4	28.7	0.53	8
2008	1950	167	3.4	25.3	28.7	0.12	-167
2009	1775	-8	15.3	13.4	28.7	0.53	8
2010	1755	-28	19.2	9.5	28.7	0.67	28
2011	2090	307	0.7	24.9	25.6	0.03	-307
2012	1965	182	5.2	20.4	25.6	0.20	-182
2013	1775	-8	15.8	9.8	25.6	0.62	8
2014	1670	-113	25.6	0.0	25.6	1.00	113
2015	1775	-8	15.8	9.8	25.6	1.00	8
2016	1950	167	2.3	23.3	25.6	1.00	-167
2017	1670	-113	29.0	0.0	25.6	1.00	113
2018	2090	307	0.3	20.9	21.2	0.02	-307
2019	2100	317	0.6	20.6	21.2	0.03	-317
MEAN	**1788**	**5**	**16.6**	**12.4**		**0.6**	**-5**

Figure D-42: Bryant Glacier on 20 March 2019.

No. 752B-13 | **AILSA MTS** | NZMS 260 sheet D40

Cirque glacier

GL DATA		
Aspect	S	
AREA	22.91	ha
Max Elev	1830	m
Min Elev	1530	m
Mean Elev	1680	m
Length	0.75	km
Elev Range	300	m
Gradient	0.4	

SNOWLINE DATA		
ELAo	1648	m
Max SL	1820	m, 1999
Min SL	1555	m, 1995
Mean SL	1639	m
SL Range	265	m
No. surveys	34	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1648**	**0**	**7.72**	**10.50**	**18.22**	**0.42**	**0**
1977							
1978	1643	-5	9.32	13.59	22.91	0.41	5
1979							
1980							
1981							
1982							
1983	1560	-88	17.65	3.70	21.35	0.77	88
1984	1595	-53	13.20	8.00	21.2	0.58	53
1985	1595	-53	13.10	8.00	21.1	0.57	53
1986	1649	1	8.57	12.23	20.8	0.37	-1
1987	1625	-23	11.48	8.72	20.2	0.50	23
1988							
1989	1612	-36	9.97	10.13	20.1	0.44	36
1990							
1991							
1992							
1993	1564	-84	15.43	4.10	19.53	0.67	84
1994	1596	-52	11.06	8.20	19.26	0.48	52
1995	1555	-93	15.87	3.12	18.99	0.69	93
1996	1584	-64	12.06	6.64	18.7	0.53	64
1997	1593	-55	12.16	6.28	18.44	0.53	55
1998	1621	-27	11.91	4.99	16.9	0.52	27
1999	1820	172	0.00	22.91	15.3	0.00	-172
2000	1785	137	0.77	22.14	14.79	0.05	-137
2001	1593	-55	9.51	5.28	14.79	0.64	55
2002	1685	37	4.35	13.87	14.5	0.30	-37
2003	1583	-65	12.20	2.00	14.2	0.86	65
2004	1590	-58	11.74	2.31	14.05	0.84	58
2005	1580	-68	11.99	1.96	13.95	0.86	68
2006	1645	-3	6.90	7.00	13.9	0.50	3
2007	1613	-35	9.80	4.10	13.9	0.71	35
2008	1670	22	3.70	10.20	13.9	0.27	-22
2009	1675	27	3.30	10.60	13.9	0.24	-27
2010	1615	-33	9.90	4.00	13.9	0.71	33
2011	1780	132	0.89	12.41	13.3	0.07	-132
2012	1615	-33	9.90	3.40	13.3	0.74	33
2013	1615	-33	9.90	3.80	13.3	0.74	33
2014	1615	-33	9.90	3.80	13.3	0.74	33
2015	1675	27	3.30	10.00	13.3	0.25	-27
2016	1685	37	1.50	11.80	13.3	0.11	-37
2017	1615	-33	9.90	3.80	13.3	0.74	33
2018	1800	152	0.2	9.31	9.5	0.02	-152
2019	1685	37	1.5	8.00	9.5	0.16	-37
MEAN	**1639**	**-9**	**8.6**	**8.0**		**0.49**	**9**

Figure D-43: Ailsa Glacier on 20 March 2019.

No. 851B/57

Mt. GUNN

NZMS 260 sheet D40

Cirque glacier

GLACIER DATA		
Aspect	SE	
AREA	53.72	ha
Max Elev	1860	m
Min Elev	1470	m
Mean Elev	1665	m
Length	0.75	km
Elev Range	390	m
Gradient	0.52	

SNOWLINE DATA		
ELAo	**1593**	m
Max SL	1820	m, 2011
Min SL	1471	m, 1995
Mean SL	1607	m
SL Range	349	m
No. surveys	36	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
1977	1615	22	14.7	39.0	53.7	0.27	-22
1978	1638	45	12.1	41.6	53.7	0.23	-45
1979							
1980	1529	-64	33.4	20.3	53.7	0.62	64
1981	1531	-62	32.4	21.3	53.7	0.60	62
1982	1610	17	15.5	38.2	53.7	0.29	-17
1983	1478	-115	51.3	2.4	53.7	0.96	115
1984							
1985	1540	-53	30.2	23.5	53.7	0.56	53
1986							
1987	1555	-38	26.3	27.4	53.7	0.49	38
1988							
1989	1534	-59	31.8	20.6	52.4	0.59	59
1990							
1991							
1992							
1993	1485	-108	48.1	2.7	50.8	0.90	108
1994	1529	-64	33.4	16.6	50.0	0.62	64
1995	1471	-122	54.0	0.0	49.0	1.01	122
1996	1507	-86	40.1	7.6	47.7	0.75	86
1997	1520	-73	36.2	10.0	46.2	0.67	73
1998	1559	-34	25.4	19.3	44.7	0.47	34
1999	1802	209	0.8	41.7	42.5	0.01	-209
2000	1810	217	0.5	40.5	41.0	0.01	-217
2001	1515	-78	33.9	6.8	40.7	0.83	78
2002	1635	42	8.8	31.7	40.5	0.22	-42
2003	1525	-68	32.6	7.6	40.2	0.81	68
2004	1485	-108	37.9	2.1	40.0	0.95	108
2005	1485	-108	37.6	2.1	39.7	0.95	108
2006	1610	17	22.2	17.3	39.5	0.56	-17
2007	1550	-43	28.6	9.5	38.1	0.75	43
2008	1645	52	19.0	18.0	37.0	0.51	-52
2009	1790	197	7.1	28.6	35.7	0.20	-197
2010	1515	-78	33.3	0.7	34.0	0.98	78
2011	1810	217	1.1	23.6	24.7	0.04	-217
2012	1785	192	2.2	22.5	24.7	0.09	-192
2013	1540	-53	21.2	3.5	24.7	0.86	53
2014	1530	-63	21.8	2.9	24.7	0.88	63
2015	1785	192	2.2	13.9	24.7	0.09	-192
2016	1790	197	2.1	13.9	24.7	0.09	-197
2017	1530	-63	21.8	2.9	24.7	0.88	63
2018	1820	227	0.4	11.1	11.4	0.03	-227
2019	1795	202	2.0	9.4	11.4	0.18	-202
MEAN	**1607**	**14**	**23.4**	**16.9**		**0.54**	**-14**

Figure D-44: Gunn Glacier on 20 March 2019.

No. 797G/33

Mt. GENDARME

NZMS she

Mountain gl, reliability B

GLACIER DATA		
Aspect	S	
Area	49.35	ha
Max Elev	1900	m
Min Elev	1440	m
Mean Elev	1670	m
Length	0.525	km
Elev Range	460	m
Gradient	0.88	

SNOWLINE DATA	
ELA	**1616**
Max SL	1804
Min SL	1418
Mean SL	1603
SL range	386
No. surveys	34

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELA m	AREAS ACCUM. ha	ABL. ha	TOTAL ha	ACCUM. AREA RATIO (AAR)
ELAo	**1616**	**0**	**31.9**	**17.5**	**49.4**	**0.65**
1977						
1978						
1979						
1980						
1981	1570	-46	38.4	11.0	49.4	0.78
1982	1573	-43	37.9	11.5	49.4	0.77
1983	1480	-136	56.0	0.0	56.0	1.13
1984						
1985	1522	-94	44.5	4.8	49.4	0.90
1986	1675	59	22.0	27.4	49.4	0.44
1987	1650	34	25.9	23.5	49.4	0.52
1988						
1989	1580	-36	35.5	13.9	49.4	0.72
1990						
1991						
1992						
1993	1502	-114	46.4	2.9	49.4	0.94
1994	1552	-64	40.6	8.8	49.4	0.82
1995	1418	-198	58.7	0.0	49.4	1.19
1996	1516	-100	45.2	4.2	49.4	0.92
1997	1490	-126	47.3	2.1	49.4	0.96
1998	1648	32	26.5	22.9	49.4	0.54
1999	1804	188	2.3	32.3	34.6	0.07
2000	1775	159	4.8	28.7	33.5	0.14
2001	1485	-131	33.6	0.0	33.5	1.00
2002	1650	34	25.5	8.0	33.5	0.76
2003	1520	-96	32.1	1.4	33.5	0.96
2004	1483	-133	33.5	0.0	33.5	1.00
2005	1487	-129	33.5	0.0	33.5	1.00
2006	1648	32	25.4	8.1	33.5	0.76
2007	1576	-40	31.7	1.8	33.5	0.95
2008	1649	33	25.5	8.1	33.5	0.76
2009	1650	34	23.5	8.0	31.5	0.75
2010	1570	-46	30.0	1.5	31.5	0.95
2011	1800	184	2.5	28.2	30.7	0.08
2012	1650	34	25.1	5.8	30.9	0.81
2013	1560	-56	30.2	0.7	30.9	0.98
2014	1570	-46	30.0	0.9	30.9	0.97
2015	1648	32	20.8	10.1	30.9	0.67
2016	1650	34	25.1	5.8	30.9	0.81
2017	1560	-56	30.2	0.7	30.9	0.98
2018	1804	188	2.3	26.9	29.2	0.08
2019	1800	184	2.5	26.7	29.2	0.09
MEAN	**1603**	**-13**	**29.3**	**9.9**		**0.7**

Figure D-45: Mt Gendarme on 20 March 2019.

No. 846/35

LlAWRENNY PKS.

NZMS 260 sheet D40

Cirque glacier

GLACIER DATA		
Aspect	SW	
AREA	18.06	ha
Max Elev	1680	m
Min Elev	1310	m
Mean Elev	1495	m
Length	0.75	km
Elev Range	370	m
Gradient	0.49	

SNOWLINE DATA		
ELAo	**1476**	m
Max SL	1670	m, 1999
Min SL	1300	m, 1995
Mean SL	1472	m
SL Range	370	m
No. surveys	34	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1476**	**0**	**9.3**	**8.8**	**18.1**	**0.51**	**0**
1977							
1978	1480	4	9.0	9.1	18.1	0.50	-4
1979							
1980							
1981	1408	-68	15.6	2.5	18.1	0.86	68
1982	1472	-4	9.4	8.7	18.1	0.52	4
1983	1344	-132	17.5	0.6	18.1	0.97	132
1984							
1985	1440	-36	12.8	5.3	18.1	0.71	36
1986							
1987	1454	-22	11.4	6.7	18.1	0.63	22
1988							
1989	1429	-47	14.0	4.1	18.1	0.77	47
1990							
1991							
1992							
1993	1360	-116	17.1	0.9	18.1	0.95	116
1994	1408	-68	15.6	2.5	18.1	0.86	68
1995	1300	-176	27.8	0.0	27.8	1.00	176
1996	1461	-15	10.5	7.5	18.1	0.58	15
1997	1321	-155	17.7	0.4	18.1	0.98	155
1998	1478	2	9.2	8.9	18.1	0.51	-2
1999	1670	194	0.3	17.8	18.1	0.02	-194
2000	1657	181	0.6	17.4	15.7	0.04	-181
2001	1405	-71	13.4	2.3	15.7	0.85	71
2002	1613	137	2.1	12.5	14.6	0.14	-137
2003	1376	-100	13.8	0.8	14.6	0.95	100
2004	1380	-96	13.8	0.8	14.6	0.95	96
2005	1400	-76	13.1	1.5	14.6	0.90	76
2006	1485	9	6.3	8.3	14.6	0.43	-9
2007	1439	-37	10.1	4.5	14.6	0.69	37
2008	1580	104	1.8	11.6	13.4	0.14	-104
2009	1600	124	1.4	10.9	12.3	0.11	-124
2010	1408	-68	11.2	1.1	12.3	0.91	68
2011	1600	124	1.9	9.9	11.8	0.16	-124
2012	1472	-4	5.9	4.4	10.3	0.57	4
2013	1408	-68	8.9	1.4	10.3	0.86	68
2014	1470	-6	6.0	4.4	10.3	0.58	6
2015	1600	124	1.5	8.8	10.3	0.15	-124
2016	1600	124	1.5	8.8	10.3	0.15	-124
2017	1470	-6	6.0	4.4	10.3	0.58	6
2018	>1680		0.0	7.8	7.8	0.00	0
2019	1600	124	1.5	6.3	7.8	0.00	-124
MEAN	**1472**	**-4**	**9.1**	**6.0**		**0.56**	**4**

Figure D-46: Llawrenny Peaks on 20 March 2019.

No. 797F/4

BARRIER Pk.

NZMS 260 sheet D41

Mountain glacier

GLACIER DATA		
Aspect	S	
AREA	57.56	ha
Max Elev	1900	m
Min Elev	1420	m
Mean Elev	1660	m
Elev Range	480	m
Length	0.75	km
Gradient	0.64	

SNOWLINE DATA		
ELAo	**1596**	m
Max SL	1900	m, 1999
Min SL	1360	m, 1995
Mean SL	1622	m
SL Range	540	m
No. Surveys	34	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1596**	**0**	**40.4**	**17.2**	**57.6**	**0.70**	0
1977							
1978	1712	116	20.1	37.5	57.6	0.35	-116
1979							
1980	1545	-51	48.6	9.0	57.6	0.84	51
1981	1523	-73	51.2	6.3	57.6	0.89	73
1982	1565	-31	45.4	12.2	57.6	0.79	31
1983	1378	-218	63.9	0.0	57.6	1.11	218
1984							
1985	1524	-72	51.2	6.4	57.6	0.89	72
1986							
1987	1555	-41	46.9	10.7	57.6	0.81	41
1988							
1989	1525	-71	51.0	6.6	57.6	0.89	71
1990							
1991							
1992							
1993	1428	-168	60.7	0.0	57.6	1.05	168
1994	1478	-118	55.2	2.3	57.6	0.96	118
1995	1360	-236	65.0	0.0	57.6	1.13	236
1996	1470	-126	55.5	2.1	57.6	0.96	126
1997	1464	-132	56.8	0.8	57.6	0.99	132
1998	1682	86	25.1	32.4	57.6	0.44	-86
1999	1900	304	0.0	57.6	57.6	0.00	-304
2000	1803	207	3.3	31.5	34.8	0.09	-207
2001	1488	-108	31.8	3.0	34.8	0.91	108
2002	1790	194	5.4	29.4	34.8	0.15	-194
2003	1448	-148	34.8	0.0	34.8	1.00	148
2004	1465	-131	34.8	0.0	34.8	1.00	131
2005	1465	-131	34.8	0.0	34.8	1.00	131
2006	1700	104	20.0	14.8	34.8	0.57	-104
2007	1579	-17	20.6	14.2	34.8	0.59	17
2008	1715	119	15.0	19.8	34.8	0.43	-119
2009	1818	222	1.8	33.0	34.8	0.05	-222
2010	1555	-41	34.0	0.8	34.8	0.98	41
2011	1855	259	1.1	28.9	30.0	0.04	-259
2012	1715	119	13.9	16.1	30.0	0.46	-119
2013							
2014*	1680	84	18.7	11.3	30.0	0.62	-84
2015	1818	222	1.8	28.2	30.0	0.06	-222
2016	1850	254	2.1	27.9	30.0	0.07	-254
2017	1524	-72	29.8	0.2	30.0	0.99	72
2018	1900	304	0.1	23.7	23.8	0.00	-304
2019	1880	284	0.2	23.6	23.8	0.01	-284
MEAN	**1622**	**26**	**29.4**	**14.4**	**43.3**	**0.62**	**-26**

Figure D-47: Barrier Peak on 20 March 2019.

No. 797D/1

Mt. IRENE

Glacierette

NZMS 260 sheet C42

GLACIER DATA			
	1977 to 1999	**2002 on**	
Aspect	E		
Permanent Ice Are	17.95	7.75	**ha**
Max Elev	1800	1770	**m**
Min Elev	1450	1510	**m**
Mean Elev	1625	1640	**m**
Elev Range	350	260	**m**
Length	0.5	0.43	**km**
Gradient	0.7	0.6	

SNOWLINE DATA		
ELAo	**1563**	m
Max SL	1770	m, 2011
Min SL	1400	m, 1995
Mean SL	1570	m
SL Range	370	m
No. Surveys	31	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	ACCUM. ha	AREAS ABL. ha	Permanent ice Outline Total ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo 1977 to 1999	**1563**	**0**	**7.6**	**10.4**	**18.0**	**0.42**	**0**
ELAo 1999 on	**1600**	**0**	**3.3**	**4.5**	**7.8**	**0.42**	**0**
1977							
1978	1700	137	0.8	17.1	18.0	0.05	-137
1979							
1980							
1981							
1982							
1983	1407	-156	18.0	0.0	18.0	1.00	156
1984							
1985	1526	-37	10.1	7.9	18.0	0.56	37
1986							
1987	1526	-37	10.1	7.9	18.0	0.56	37
1988							
1989	1537	-26	9.3	8.7	18.0	0.52	26
1990							
1991							
1992							
1993	1407	-156	31.3	0.0	18.0	1.00	156
1994	1512	-51	11.1	6.9	18.0	0.62	51
1995	1400	-163	32.7	0.0	18.0	1.00	163
1996	1498	-65	12.1	5.8	18.0	0.68	65
1997	1460	-103	18.0	0.0	18.0	1.00	103
1998	1612	49	4.7	13.2	18.0	0.26	-49
1999	1695	95	0.8	7.8	8.6	0.05	-95
2000	1700	100	0.8	7.3	8.1	0.10	-100
2001	1438	-162	17.6	0.4	8.1	1.00	162
2002	1770	170	0.3	7.8	8.1	0.04	-170
2003	1454	-146	15.9	0.0	8.1	1.00	146
2004	1470	-130	14.8	0.0	8.1	1.00	130
2005	1440	-160	17.6	0.0	8.1	1.00	160
2006	1670	70	1.8	6.3	8.1	0.22	-70
2007	1515	-85	11.1	0.0	8.1	1.00	85
2008	1650	50	2.6	5.5	8.1	0.32	-50
2009	1668	68	1.9	6.3	8.1	0.23	-68
2010	1510	-90	7.8	0.0	8.1	0.96	90
2011	1770	170	0.3	7.7	8.0	0.04	-170
2012	1665	65	0.8	7.2	8.0	0.10	-65
2013							
2014*	1668	68	0.7	6.3	7.0	0.10	-68
2015	1640	40	1.5	5.5	7.0	0.21	-40
2016	1620	20	3.5	3.5	7.0	0.50	-20
2017	1510	-90	7.0	0.0	7.0	1.00	90
2018	>1800		0.0	4.6	4.6	0.00	
2019	1670	70	0.5	4.1	4.6	0.11	-70
MEAN	**1570**	**-16**	**8.6**	**4.8**		**0.52**	**16**

Figure D-48: Mt Irene on 20 March 2019.

No. 797 B/10

MERRIE RA

Patchy glacierette

NZMS 260 sheet C44

GLACIER DATA		
Aspect	E	
AREA	12.78	ha
Max Elev	1700	m
Min Elev	1400	m
Mean Elev	1550	m
Elev Range	300	m
Length	0.5	km
Gradient	0.6	

SNOWLINE DATA		
ELAo	1515	m
Max SL	>1700	m, 2011
Min SL	1350	m, 1995
Mean SL	1520	m
SL Range	350	m
No. Surveys	27	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE ELEVATION m	DEPARTURE FROM ELAo m	ACCUM. ha	AREAS ABL. ha	TOTAL ha	ACCUM. AREA RATIO (AAR)	MASS BALANCE INDEX
ELAo	**1515**	**0**	**7.1**	**5.7**	**12.8**	**0.56**	**0**
1977							
1978	1655	140	1.3	2.2	3.5	0.10	-140
1979					No visit		
1980					No visit		
1981					No visit		
1982					No visit		
1983					No visit		
1984					No visit		
1985					No visit		
1986					No visit		
1987					No visit		
1988					No visit		
1989	1545	30	5.8	7.0	12.8	0.46	-30
1990					No visit		
1991					No visit		
1992					No visit		
1993	1380	-135	16.2	0.0	16.2	1.27	135
1994	1420	-95	11.7	1.1	12.8	0.92	95
1995	1350	-165	19.3	0.0	19.3	1.51	165
1996	1425	-90	11.5	1.3	12.8	0.90	90
1997	1385	-130	15.7	0.0	15.7	1.22	130
1998	1445	-70	10.7	2.1	12.8	0.83	70
1999	1688	173	0.5	1.9	2.4	0.20	-173
2000					In cloud		
2001	1412	-103	12.4	0.4	12.8	0.97	103
2002	1690	175	0.4	1.8	2.2	0.19	-175
2003	1415	-100	11.9	0.9	12.8	0.93	100
2004	1405	-110	14.2	0.0	14.2	1.00	110
2005	1410	-105	12.4	0.4	12.7	0.97	105
2006	1665	150	1.3	1.7	3.0	0.43	-150
2007	1459	-56	8.3	2.7	11.0	0.65	56
2008	1670	155	1.1	1.4	2.5	0.45	-155
2009	1675	160	1.1	1.4	2.5	0.44	-160
2010	1440	-75	10.9	1.9	12.8	0.86	75
2011	>1700		0.0	2.5	2.5	0.00	0
2012	1669	154	1.1	1.4	2.5	0.44	-154
2013							
2014							
2015	1675	160	1.1	1.4	2.5	0.44	-160
2016	1675	160	1.1	1.4	2.5	0.44	-160
2017	1412	-103	2.5	0.0	2.5	1.00	103
2018	>1700		0.0	0.5	0.5	0.00	
2019					No visit		
MEAN	**1520**	**5.2**	**6.9**	**1.4**		**0.66**	**-5**

Merrie Glacier – no photo as not visited this year

No. 803/1

CAROLINE Pk.

NZMS 260 sheet C45

Patchy glacierette

GLACIER DATA		
Aspect	SE	
AREA	9.99	ha
Max Elev	1600	m
Min Elev	1260	m
Mean Elev	1430	m
Elev Range	340	m
Length	0.5	km
Gradient	0.68	

SNOWLINE DATA		
ELAo	**1380**	m
Max SL	1575	m, 2002
Min SL	1220	m, 1993
Mean SL	1366	m
SL Range	355	m
No. Surveys	19	

MEASUREMENTS Digitised values shaded

YEAR	SNOWLINE	DEPARTURE		AREAS		ACCUM.	MASS
	ELEVATION	FROM ELAo	ACCUM.	ABL.	TOTAL	AREA RATIO	BALANCE
	m	m	ha	ha	ha	(AAR)	INDEX
ELAo	**1380**	**0**	**7.50**	**2.50**	**10**	**0.75**	**0**
1977					No visit		
1978					No visit		
1979					No visit		
1980					No visit		
1981					No visit		
1982					No visit		
1983					No visit		
1984					No visit		
1985					No visit		
1986					No visit		
1987					No visit		
1988					No visit		
1989					No visit		
1990					No visit		
1991					No visit		
1992					No visit		
1993	1220	-160	15.79	0.00	15.79	1.00	160
1994	1381	1	8.95	1.04	7.60	1.18	-1
1995	1230	-150	14.90	0.00	14.90	1.00	150
1996	1302	-78	8.92	1.07	10.00	0.89	78
1997	1250	-130	13.30	0.00	13.30	1.00	130
1998	1382	2	7.43	2.56	9.99	0.74	-2
1999	1562	182	0.69	2.76	3.45	0.20	-182
2000					In cloud		
2001	1275	-105	9.40	3.60	13.00	0.72	105
2002	1575	195	0.46	2.27	2.73	0.17	-195
2003	1291	-89	9.10	3.00	12.10	0.75	89
2004	1270	-110	9.70	3.40	13.10	0.74	110
2005	1255	-125	9.75	3.55	13.30	0.73	125
2006	1410	30	6.60	0.60	7.20	0.92	-30
2007	1336	-44	8.30	1.90	10.20	0.81	44
2008	1430	50	5.80	1.00	6.80	0.85	-50
2009	1420	40	6.33	0.66	6.99	0.91	-40
2010	1380	0	12.46	0.34	12.80	0.97	0
2011	1550	170	0.90	2.60	3.50	0.26	-170
2012	1425	45	6.40	0.50	6.90	0.93	-45
2013					No visit		
2014					No visit		
2015	1430	50	5.80	1.00	6.80	0.85	-50
2016					No visit		
2017	1302	-78	8.92	1.07	10.00	0.89	78
2018	>1600		0.00	0.86	0.86	0.00	
2019					No visit		
MEAN	**1366**	**-14**	**8.09**	**1.57**		**0.79**	**15**

Caroline Peak Glacier – no photo as not visited this year

Appendix E 1989/1990 glacier observations

There was no funding available for Trevor Chinn to complete a snowline flight this year due to changes within the Geological Survey, although Trevor did manage to source snowline information from the Tasman glacier, and the Mt Harper glacier which was used as a surrogate for the Marmaduke Dixon Glacier.

This year is significant in the time series of departures because a relatively high ELA has been reported in previous reports implying large mass balance loss, and its reliance on limited information which implies a large degree of uncertainty. There has been no detailed evidence on the derivation of this ELA in previous reports. Future work will scrutinise this year and this evidence in more detail to determine whether or not these data need to be partitioned in years ahead, and what contribution (if any) they can make to our understanding of long-term changes and inter-annual variability.

Tasman Glacier

Andrew Ruddell of the University of Melbourne took photos of the Tasman snowline (slides 90-284, 90-286, 90-288 supplied as scans by Andrew Ruddell in Feb 2020) while on a flights over the neve on the 21 and 22 March 1990. Andrew was measuring net accumulation and ice velocities on the Tasman and Murchison neves as part of his PhD field studies (Ruddell, 1995) during the late summers of 1989 and 1991 so he was very familiar with the Tasman neve. Andrew Ruddell transposed this snowline to a topographic map in 1990 and this is included in Figure D-1. Andrew also lists the ELA at an elevation of 2100m in Table 4.1c of this thesis. Given Andrew's familiarity with the neve and his time spent mapping on the ground over the summers before and after this year some confidence can be had with his transposing of the photograph to the map.

This observed 1990 snowline was remapped and an elevation interpreted in September 2019 in comparison with other high snowline years (Figure D-2). A snowline elevation of 2050 m was determined which is 50 m lower than the original value of 2100 m that had been in use prior to this report. The lower value is due to the use of a standard method for this report of averaging the contours within the bounds of the main Tasman neve. This new snowline elevation corresponds to a raw ELA departure for the Tasman Glacier of +260 m above the long term ELAo elevation (1790 m).

This value was then normalised as the Tasman Glacier has a large snowline elevation range relative to the rest of the index glaciers. Without normalising this single observation for this year would be biased high relative to other years with large number of index glacier observations.

The normalisation was completed by deriving the regression relationship between the time series of all 39 (excluding 1990) years of Tasman snowline departures and the respective annual mean alps departures (Figure D-3, left). And, a second regression using the 5 highest years observations where the snowline elevation of the Tasman >2000 m, and >30 index glaciers were observed across the Alps (Figure D-3, right). Using the regression for all observations results in the Tasman raw ELA being scaled back to +184 m, and using the 5 highest years regression results in the raw ELA being scaled back to +162 m.

Given the relative position of the raw 1990 departure relative to the sequence for the Tasman snowlines (Figure D-4) with 2011 above and the 2008/2016 years below the normalised departure of +162 m is closer to the relative position.

The Tasman normalised ELA value of +162 m has been used in the time series of mean annual index glacier departures as the value for the 1989/1990 glacier year.

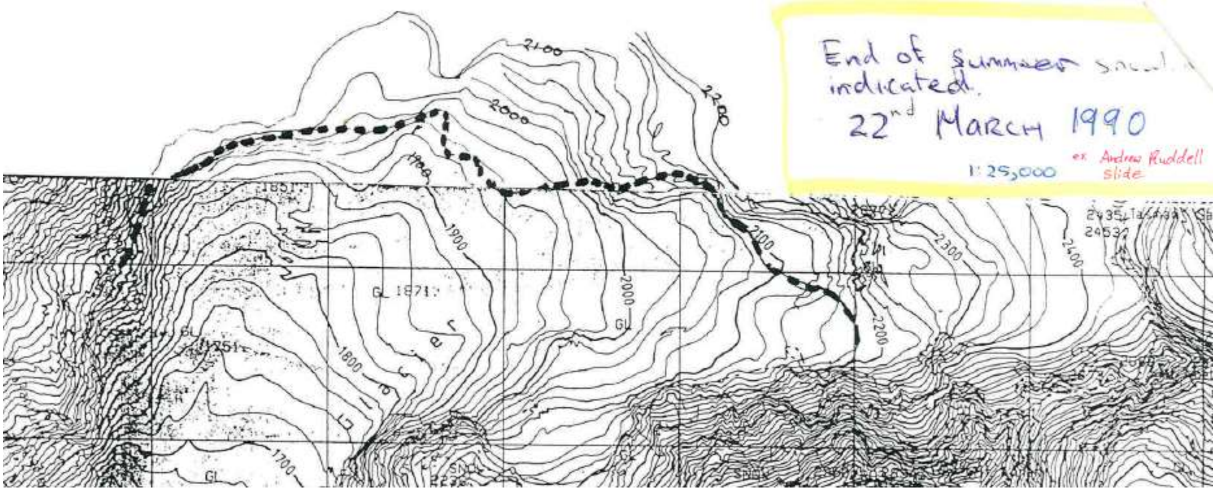

Figure E-1: **Tasman snowline on 22 March 1990 as observed and drawn by Andrew Ruddell.**

Figure E-2: **Tasman neve snowline photograph (90-262) taken by Andrew Ruddell on 21 March 1990.**

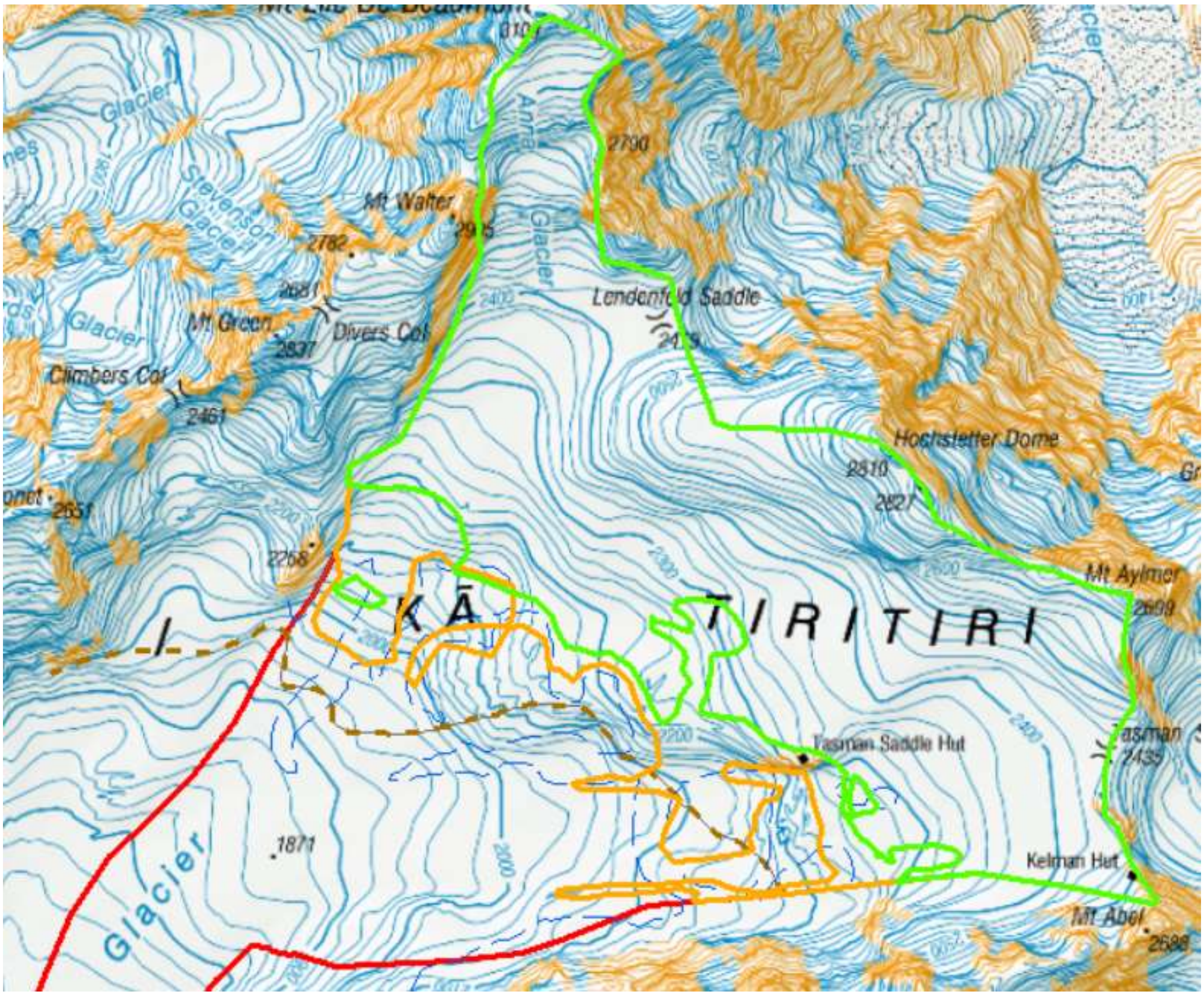

Figure E-3: Mapped Tasman snowline elevations for 1990 (brown dashed), 2018 (orange solid), and 2019 (green solid).

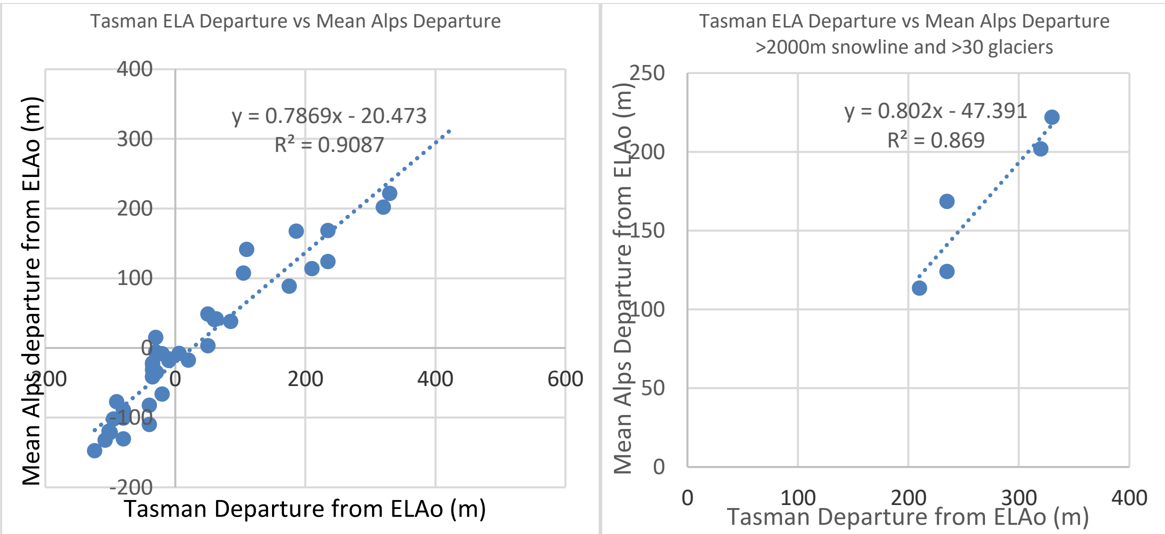

Figure E-4: Regression between all Tasman ELA departures and the mean Alps departures (left), and Tasman ELAs vs mean Alps departures where >30 observations in the year and Tasman snowline >2000m (right).

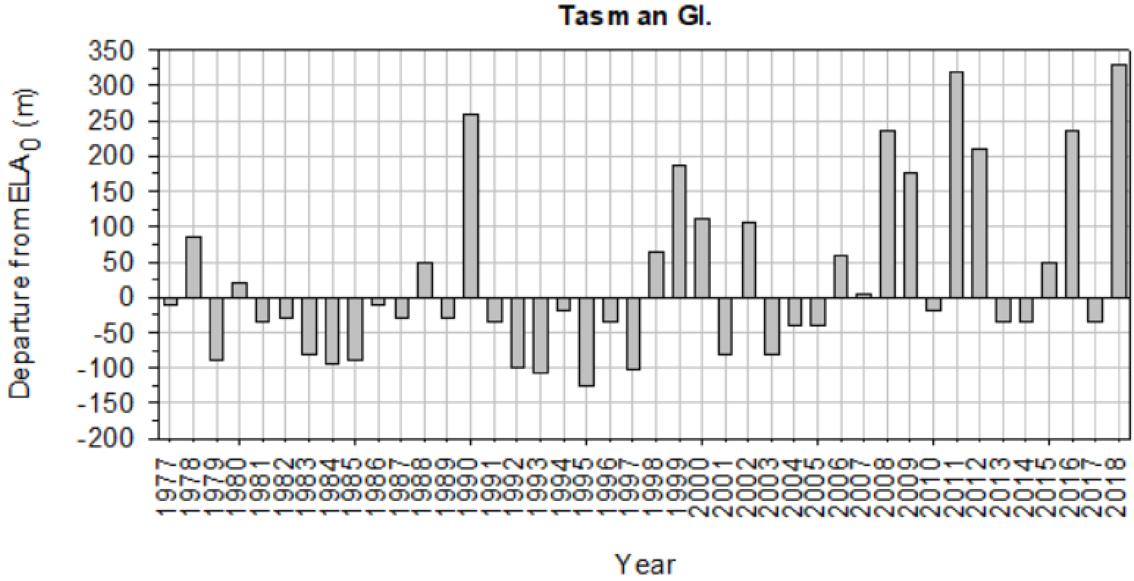

Figure E-5: Time series from 1977 to 2018 of raw ELA departures at the Tasman Glacier.

Mt Harper Glacier

The second observation was completed by Trevor Chinn on 24 March 1990 when he took a photograph (Figure D-5) of the glacier on the eastern face of Mt Harper from the ground at Klondyke Corner a point 13 km to the east of this glacier (Figure D-6). The Marmaduke Dixon glacier lies on the range 3 km directly behind and to the west of Mt Harper. The Mt Harper glacier has a similar east facing aspect but is approximately half the area of Marmaduke Dixon so Trevor thought it appropriate to use it as a surrogate to derive a snowline on Marmaduke Dixon.

This photo was enlarged to determine the snowline position and mean elevation from this very distant observation. Trevor then developed a regression between the Mt Harper snowline elevations and Marmaduke Dixon glacier snowline elevations for 7 previous years observations (1977, 1978, 1982, 1983, 1984, 1985, 1987) (Figure D-7). This regression equation (r^2=0.88) was then applied to the 1990 Mt Harper observation to derive the Marmaduke Dixon snowline elevation of 1998 m which is an ELA raw value of +168 m above ELA_0 for this glacier.

On 26 September 2019 this raw ELA observation of +168 m was normalised by applying the regression equation between the 39 Marmaduke Dixon ELA observations from 1977 to 1989 and 1993 to 2018, and their respective mean alps annual ELAs (Figure D-8). This regression has an r^2 of 0.88 but is very poor with a large scatter in the high range where this observation is situated.

The normalised ELA reduces to +139 m but is not considered to be accurate due to the lack of definition on the glacier in the long-range photograph, and the indirect nature of the Marmaduke Dixon derived ELA value with its reliance on a regression with an adjacent glacier. For these reasons the derived raw and normalised ELAs for the Marmaduke Dixon glacier for the 1989/1990 year have not been used for the mean annual departure index time series but remains documented here and reported in the individual glacier details in Appendix C.

Figure E-6: The glacier on the eastern face of Mt Harper (left of centre) as photographed by Trevor Chinn on 24 March 1990 (slide A22.56).

Figure E-7 Photograph location (blue X) of Mt Harper (blue outline), with the Marmaduke Dixon Glacier (red outline) on the range hidden behind.

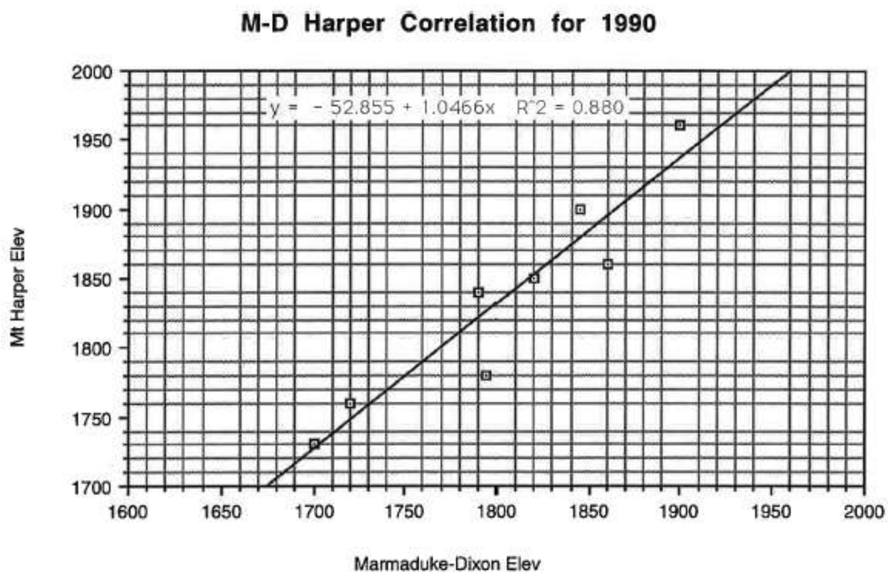

Figure E-8: The original regression document completed by Trevor in 1990 between the Marmaduke Dixon glacier snowlines and the Mt Harper glacier snowlines for 7 snowline years.

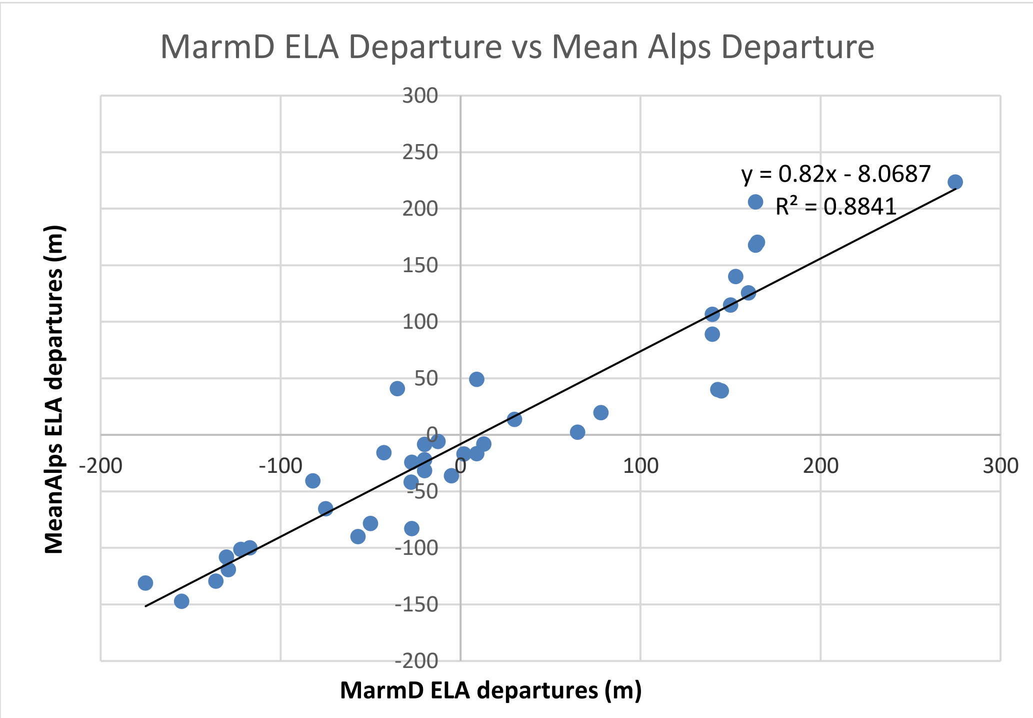

Figure E-9: Regression between the Marmaduke Dixon glacier observations and the Mean Alps ELA for the years 1977 to 1989, and 1993 to 2018.