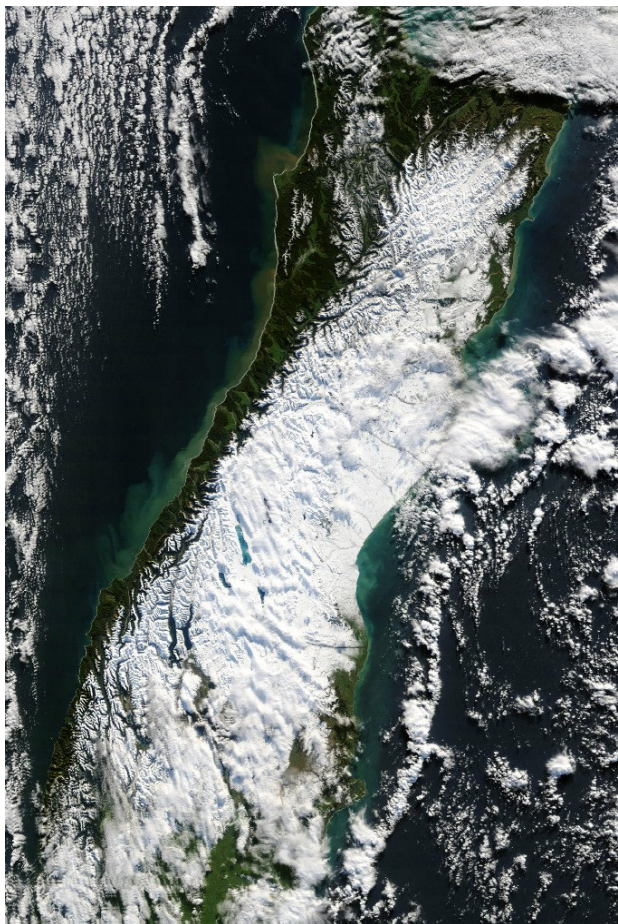


**Preliminary analysis of the 12 June
2006 Canterbury snow storm**



Satellite image of the South Island on Monday 12 June, 2006 (NASA, 2006)

**NIWA Client Report: CHC2006-088
June 2006**

NIWA Project: ORI06502

Preliminary Analysis of the 12 June 2006 Canterbury snow storm

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Prepared for

Orion New Zealand Ltd

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Executive Summary

Orion New Zealand Ltd has engaged NIWA to investigate the June 12, 2006 snow storm. This snow storm caused considerable damage to electricity distribution systems in Canterbury. There is a high level of public interest due to the duration of loss of supply to some areas, the cost of damage to the distribution system and consequential losses to businesses and householders.

This investigation uses point measurements from the manual rain gauge network and other sources of data where available to recreate snow depths across the Canterbury region. These measurements were then compared to published information on previous snow storms in Canterbury.

In areas north of the Rakaia River snow depths from the June 12 storm were not unprecedented. Snow depths in inland areas north of the Rakaia River were similar to the 1973 storm. The 2006 storm did produce pockets of significantly deeper snow west of Darfield and towards the foothills which experienced conditions more similar to the 1945 storm. In the coastal plains areas (north of the Rakaia) the snow was much deeper than the 1992, 1973 or 1967 snow storms, except in Christchurch where the 1992 snow storm was much more severe.

Snow depths were extreme in areas south of the Rakaia River. In the Canterbury plains and foothills the June 12, 2006 snow storm produced greater snow depths than the 1973 and 1967 snow storms. Snow depths throughout this area were similar to the 1945 snow storm and in some areas much deeper. Ashburton had the greatest maximum snow depth on record.

Inland areas around Fairlie and Burkes Pass had similar snow depths to the 1973 storm, while areas further west into the McKenzie Basin had significantly less snow than most previous notable snow storms with only 50cm being recorded at the Hermitage, opposed to over 100cm in 2002, 1973 and 1967.

Future work to map the return period and associated uncertainty of such an event, or to map the estimated 1 in 50 year event is strongly recommended to provide more quantitative results to support decision making processes and regional planning.

1. Background

The heavy snowstorm of Monday 12 June 2006 caused considerable damage to electricity distribution systems in Canterbury. The storm generated a high level of public interest due to the duration of loss of supply to some areas, the cost of damage to the distribution system and consequential losses to businesses and householders.

This report aims to place this snow storm in context with historical snow storms to provide an indication of the magnitude and severity of the storm in terms of snow depth. Information on snow density will also be presented as this is an important parameter in terms of damage, but this is comprised of only a few data points and is presented at a more qualitative level.

The area of this study extends throughout Canterbury and down to North Otago. While this is well beyond the boundaries of concern to Orion New Zealand Ltd this extent was required to obtain an overall understanding of the snowfall in Canterbury and to enable a reasonable basis of comparison to previous events.

2. Review of previous snow storms in Canterbury

A literature review has been undertaken to put the 12 June, 2006 event into the context of previous storms. This is a "semi-quantitative" exercise as many early records of severe weather events in New Zealand are sketchy, and it is difficult to rank these records of events in order of importance.

The significance of a snow storm depends on the location within Canterbury. Snowfall is very spatially variable and snow storms can severely affect one part of Canterbury, while producing little or no effect on other areas. Burrows (1992) in DTEC (2001) list the worst years for snow storms in the Canterbury – Mackenzie area as 1867, 1895, 1903, 1918, 1945 and 1992, when there were multiple snow storms compounded by heavy frosts. Other notable years include 1862, 1879, 1888 and 1967. Additional significant events not listed by Burrows but included by DTEC (2001) include 1894, 1938 and 1973. However, Tait et al., (2001) and Tait et al., (2005), consider the storms in 1945, 1967, 1973, 1992, 1996 and 2002 to be the most severe snow storms affecting the Timaru and Ashburton districts.

The following section provides a brief overview of six selected snowfall events for the Canterbury region. These have been selected based on the availability of reliable information and extent of coverage across Canterbury. This selection also corresponds

to those used by Tait et al. (2005). These storms occurred in 1945, 1967, 1973, 1992, 1996, 2002.

2.1. The 12–14 July 1945 Storm

The July 1945 storm produced very heavy snowfall down to sea level. Christchurch, Ashburton, and Timaru are estimated to have had 30–45 cm of snow on the ground with inland areas such as Methven, Staveley, and Alford Forest reporting over 60 cm. Temuka had 25cm of snow, the largest on record, and there was 30cm of snow in the town of Geraldine (Timaru Herald 15 July, 1945). The July 12-14, 1945 storm was described as the heaviest fall in the Ashburton Borough in 40 years (Ashburton Guardian, July 14 1945).

The snow was followed by -1 to -7 °C frosts that froze the snow to power and telephone lines, resulting in several broken and bent poles (Tait et al., 2005). Power was cut off for about a week in many rural areas; however power was restored to Ashburton, Methven, Rakaia, and Hinds by the evening of 16 July (DTEC, 2001).

The heavy snowfall was the result of a cold southwesterly airstream combined with a deep depression which formed off the coast of Australia and moved across the South Island on 13th of July, 1945 (Tait et al., 2005).

2.2. The 16–19 November 1967 Storm

The November 1967 snowfall is regarded as the most severe spring snowfall on record and the worst in Canterbury since 1945. It hit inland South Canterbury and North Otago particularly hard. In the McKenzie snow was between 60 and 90cm deep. Snow depths of over a metre were recorded at The Hermitage, 50 cm at Fairlie, 25 cm at Methven, and around 11.5 cm at Geraldine (Hughes, 1967; Hughes, 1969). However, in coastal areas only sleet and rain fell and no snow settled on the ground. Figure 1 shows the estimated maximum snow depths (in inches) from the storm. Electric power and telephone lines were broken in many places (405 poles were damaged)

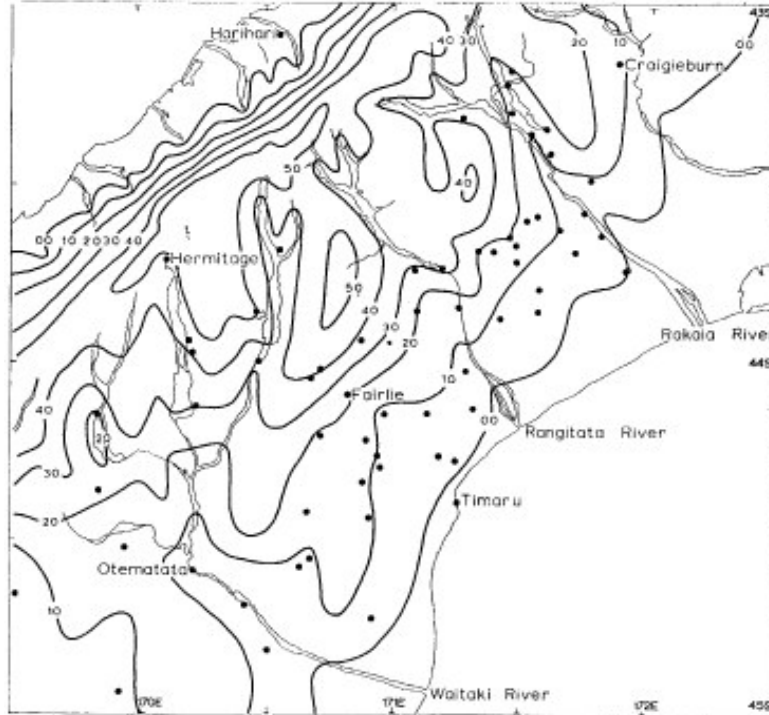


Figure 1: Maximum snow depths (inches) from the November 1967 snowfall. Dots represent measurement sites (Hughes, 1967).

The snow fall was the result of a slow moving low pressure system located in the Tasman Sea causing a cold southwesterly airflow over New Zealand. On the 16th a slow moving trough of low pressure moved up over the South Island lowering the surface air temperatures down to 2 °C in Ashburton (Figure 2). Precipitation began falling around midday on the 16th, peaking at around 6pm with a secondary peak around 9am on the 18th (Hughes, 1967; Hughes, 1969; Tait et al., 2005)

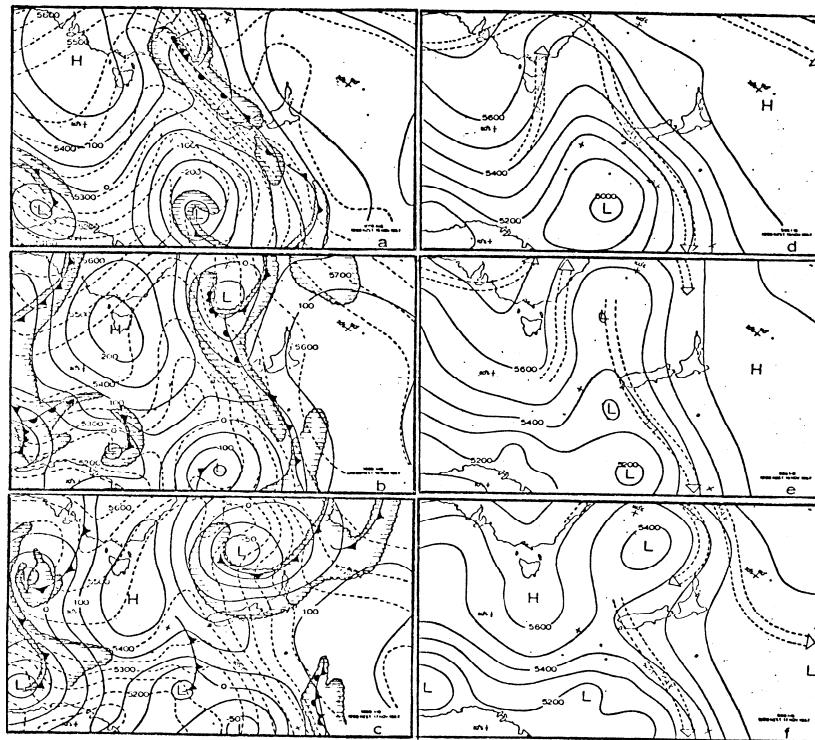


Figure 2: (a) – (c) 1000 mb height analyses (solid lines), 1000 – 500 mb thickness contours (dashed lines), surface fronts and multi-layered cloud systems (hatched) for the 15, 16, and 17 November, 1967. (d) – (f) 500 mb height analyses (solid lines) with approximate location of jet stream axes (arrows). Analyses valid at 1200NZST. (NZ Meteorological Service Ltd (Tait et al., 2005)).

2.3. The 5–6 August 1973 Storm

The August 1973 storm was described as the heaviest since July 1945 (Burrows, 1977). Snow depths resulting from the storm were 180 cm at Mount Hutt, 71 cm at Fairlie, 67 cm at Lake Tekapo, and 61 cm at Methven (Figure 3). The rain–snow boundary was between 10 and 15 km inland from the east coast (Hughes, 1974; Hughes, 1976). There was extensive disruption of communications, power supply and transport, with secondary roads blocked for several days (Neale and Thompson, 1977). Compared with 1967, when a thaw set in relatively quickly, gangs were unable to gain access to damaged sections of the power network for up to ten days after the snow fell (Hughes, 1974). The extensive damage to lines running east–west and comparatively minor damage to north–south lines was notable, and was due to the progression of the storm from south to north (Tait et al., 2005). Damage to farm buildings and power lines due to snow loading was also quite extensive, particularly in the high country.



Figure 3: Maximum snow depths (inches) from the August 1973 snowfall. Dots represent measurement sites (Hughes, 1974).

The snowfall was the result of a slow moving low pressure system which moved over North Otago and Canterbury from the south and west which was embedded in a very cold southwesterly airstream (Figure 4) (Hughes, 1974).

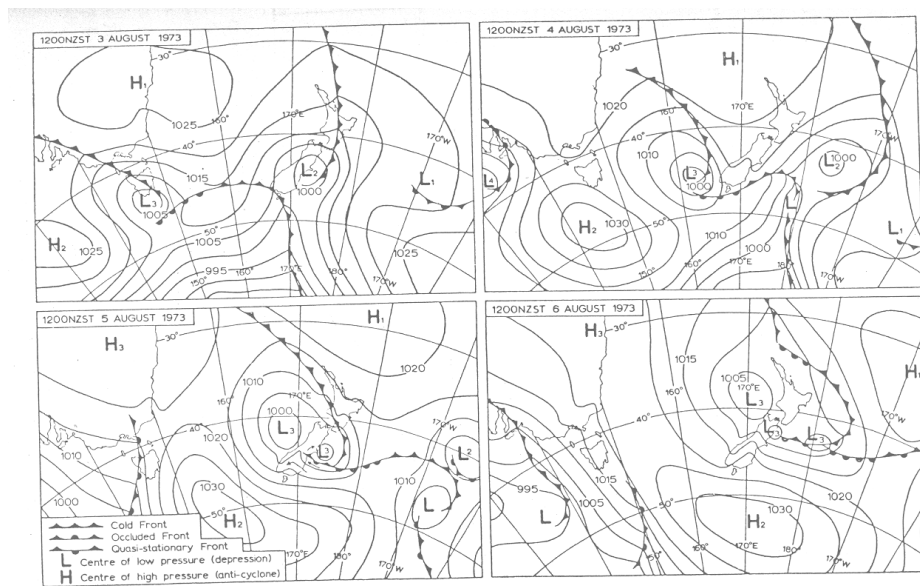


Figure 4: Surface pressure maps from the 5 to 6 August, 1973. (Hughes, 1974)

2.4. The 27–29 August 1992 Storm

The August 1992 snow storm brought very heavy snowfall to all of Canterbury, compounding the effects of a heavy snowfall only a month earlier (which was rated the worst in 20 years) (King, 1992; Tait et al., 2005). Snowfalls of 5–30 cm fell in Christchurch and over 100 cm of snow fell on the Port Hills on the 27th of August (Christchurch Engineering Lifelines Group, 1997). Across the plains approximately 40cm of snow fell, which in some locations fell on top of snowfall from the previous month. While this snow storm was particularly heavy in Christchurch, other areas of the Canterbury plains seem to have been less affected than in previous events.

The snowfall was the result of a rapidly deepening depression or ‘bomb’ which moved from the west coast of the North Island, over the north of the South Island and off to the east coast of the South Island (Figure 5). This low was very deep, with pressures reaching 979 hPa; it was accompanied by a supply of cold air from the southerly flow once positioned off the east coast of the South Island (King, 1992; Christchurch Engineering Lifelines Group, 1997).

2.5. The 9–13 June 1996 Storm

The June 1996 snow storm has been described as The Big Chill (Trevor McGavin, NZ Meteorological Service). The first significant snowfalls in Canterbury began during the night of 11/12 June. The heaviest falls occurred inland where about 40 cm of snow fell in some places. Ashburton recorded 10 cm of snow and there was 20 cm in Methven (Tait et al., 2005). In inland areas of Ashburton district, about 2000 homes lost power supplies and there were several reports of damage to infrastructure due to heavy snow loads. ECNZ said it believed that power consumption in the South Island hit an all-time record – 1901 MW at 6pm on the 11th (NZ Meteorological Service, 2006).

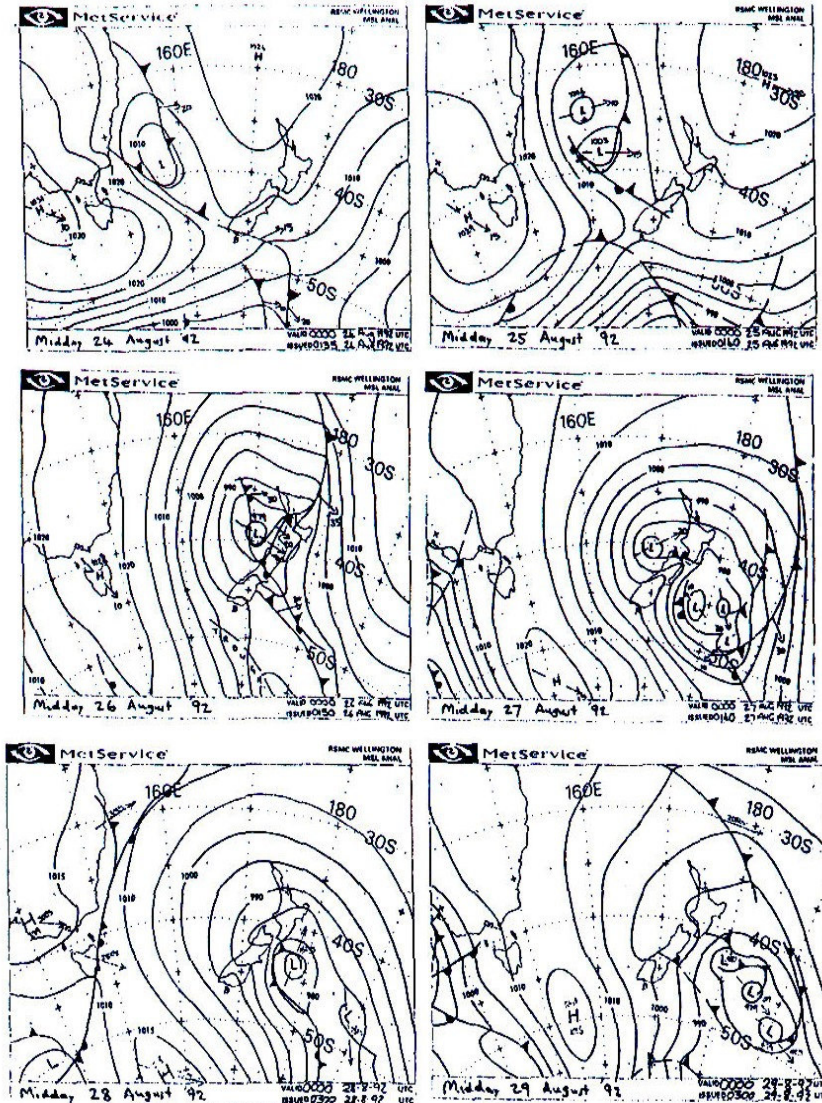


Figure 5: Surface pressure maps from the 24 to 29 August, 1992. (NZ Meteorological Service Ltd (Tait et al., 2005))

The snowfall was the result of the development of a complex area of low pressure to the east of New Zealand during the 11th of June. This caused a sequence of disturbances rotating around this low bringing snow onto the east coast from the south to southeast (NZ Meteorological Service, 2006) (Figure 6).

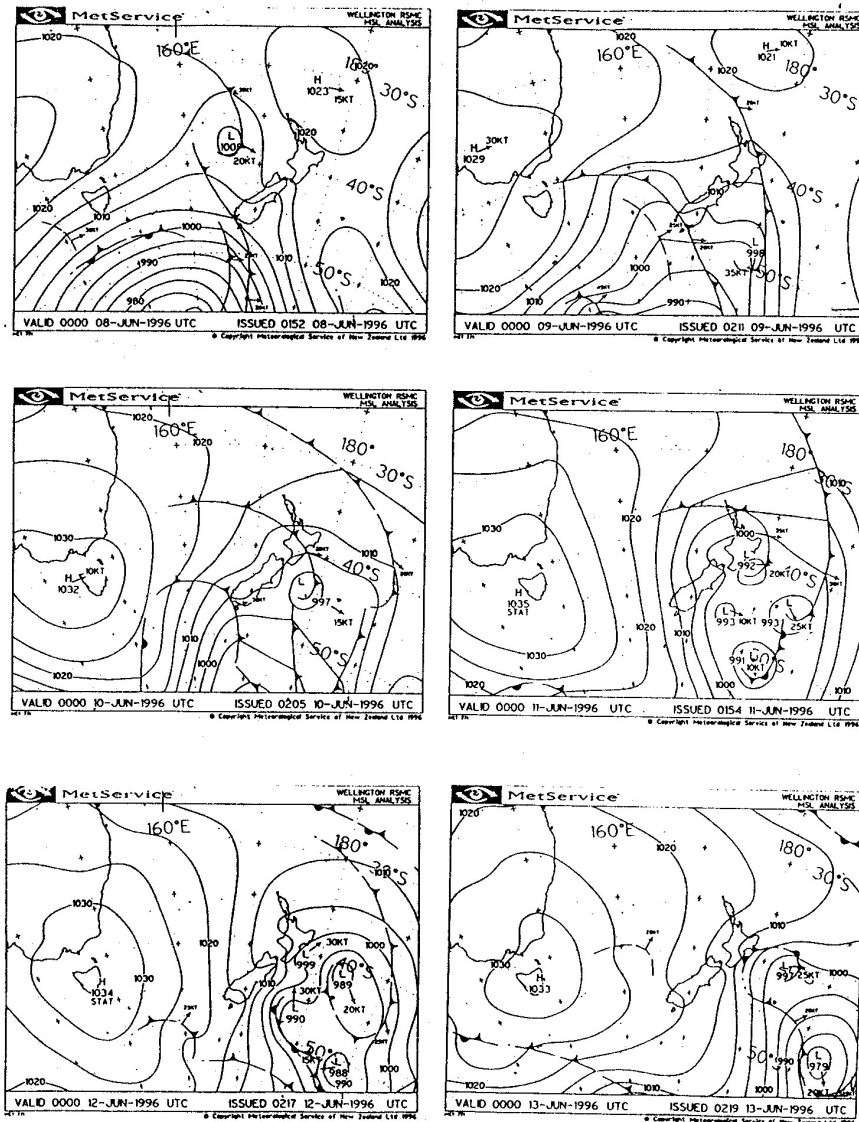


Figure 6: Surface pressure maps from the 8 to 13 June, 1996. (NZ Meteorological Service, 2006).

2.6. The 17–19 June 2002 Storm

The June 2002 snow storm brought significant snow to mid Canterbury and Otago, with snow to sea level and 10-40 cm deep in many other areas. Christchurch airport was closed. SH1 was closed from Dunsandel to Temuka and hundreds of travellers were stranded. Power lines failed due to the weight of snowfall in and near Ashburton, and snowfall was 1m deep at Mt Cook Village (NZ Meteorological Service, 2006).

The snowfall was the result of a complex depression with a number of centres which moved east–southeast over the South Island during the 48 hours from midday on the 17 June to midday on 19 June (Figure 7). The resulted in a flow of relatively mild, moisture-laden air aloft, coming in from the Tasman Sea which overran much colder air trapped at lower levels on the eastern side of the South Island. This combination of warm moist air over-running cold air in winter is a classic snow-producing situation (NZ Meteorological Service, 2006).

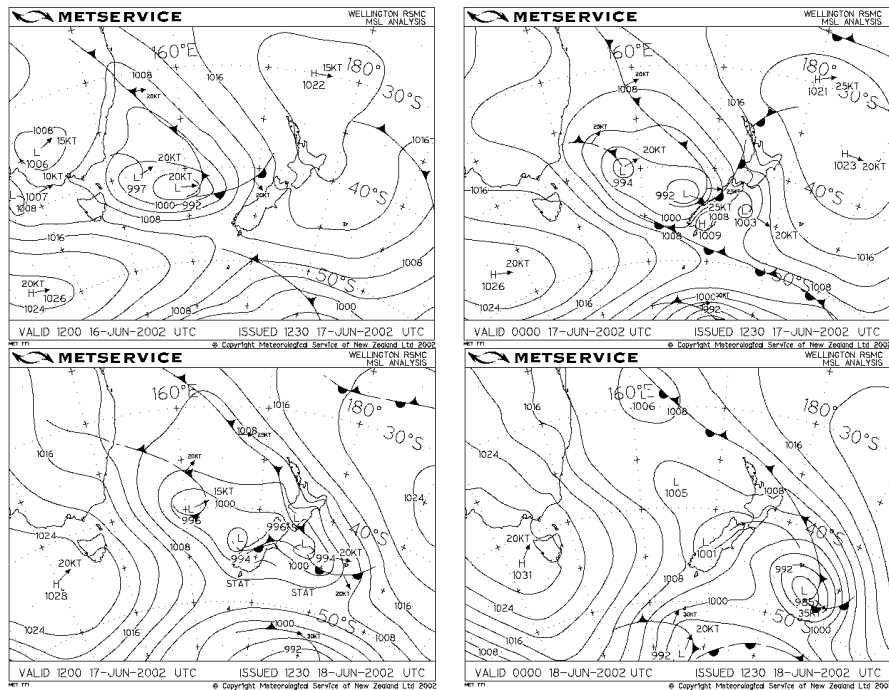


Figure 7: Surface pressure maps from the 17 to 19 June, 2002. (NZ Meteorological Service, 2006).

3. Synoptic overview of the 12 June 2006 storm

In general, large snow storms such as those shown in section two are the result of a rapidly deepening depression moving from the Tasman Sea southeastward across New Zealand, with a strong moist northwesterly airstream ahead and a very cold southerly flow behind. When the pressure at the centre of these depressions falls by more than 24 hPa in 24 hours as it approaches New Zealand it is often referred to as a “bomb” depression. Deepening rates of this magnitude can lead to very large precipitation rates and consequently heavy rain or snowfall totals, especially if the storm stalls over an area for more than 24 hours.

The snow storm of 12 June started as a mid-Tasman depression which deepened on 11 June. The centre of this depression tracked over the north of the South Island on 12 June. Heavy snowfall started in Canterbury on the night of 11/12 June, with heavy snow reported in Twizel at 10pm on 11 June (Figure 8a-d).

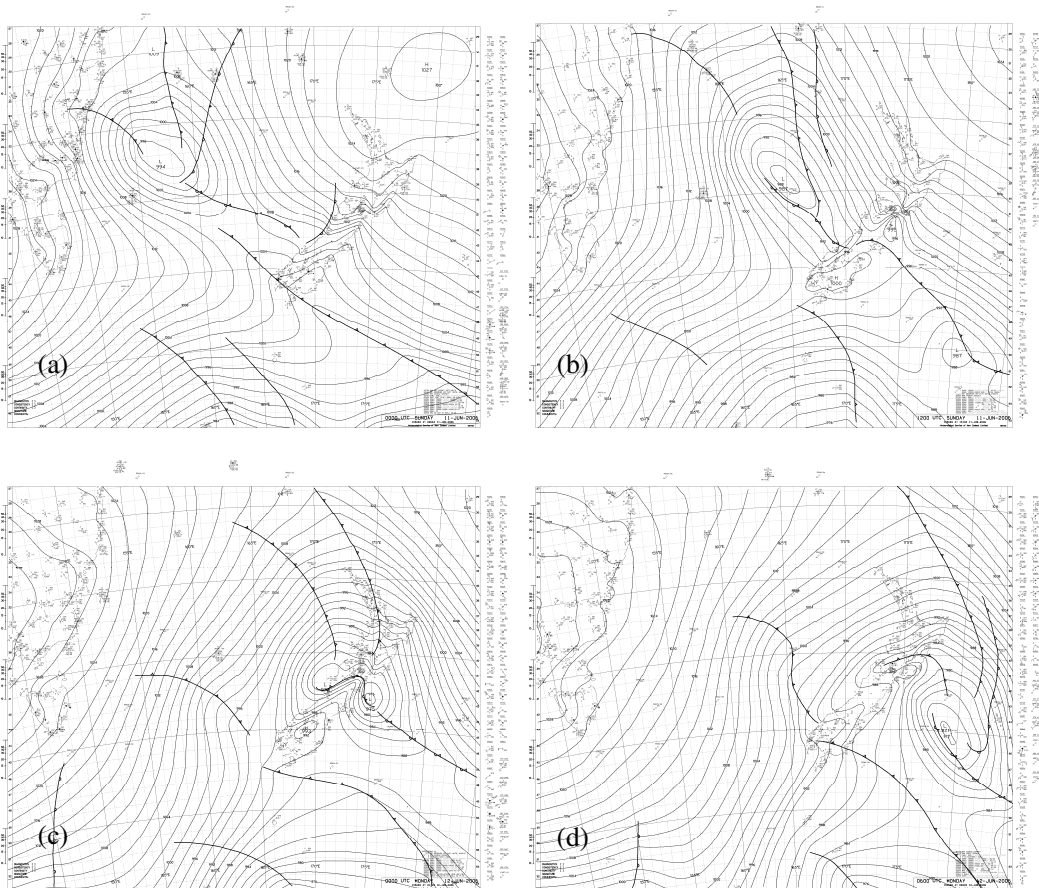


Figure 8: Surface pressure maps for (a) 1200 NZST 11 June, (b) 0000 NZST 12 June, (c) 1200 NZST 11 June and (d) 1800 NZST 12 June, 2006. Contour intervals are 2hPa (NZ Meteorological Service, 2006).

Strong vorticity advection at upper levels in the atmosphere (above 500hPa or about 5km) was the key factor behind the rapid deepening of the storm’s centre on 10-11 June. The depression’s central pressure fell by 20hPa between midnight on 10 June and midnight on 11 June. The resulting intense vertical motion in the northwest flow ahead of the front associated with the depression (commonly referred to as a moisture conveyor belt), lead to the heavy precipitation rates over the surface low and the very cold air undercutting the front from the southwest enabled the precipitation to fall to the ground as snow not rain. A rough rule of thumb in New Zealand latitudes is 1cm of rain will produce about 10cm of snow.

The topography of the Southern Alps added to the difficulty in forecasting the extent and location of the June 12 snow. This is because as the depression moved across the Southern Alps, centres reformed off the east coast as the original centres weakened on the western side of the Southern Alps (Figure 8c). South of where these centres reformed was the location of the most intense storm activity and greatest snow depth. On June 12, 2006 these centres reformed over Canterbury, and southern Canterbury bore the brunt of the resulting precipitation.

This type of storm has been classified by Neale and Thompson (1977) as a vorticity advection type storm and was responsible for 6 out of 10 snow storms described in the decade 1966 to 1975. The storms that occurred in 1945 and 1996 as reviewed in section two can also be classified as vorticity advection type storms.

4. Snowfall depth and extent in Canterbury for the June 12, 2006 storm

To enable a semi quantitative study of the June 12, 2006 snow storm the snow extent and depth must be documented throughout Canterbury.

To achieve this, observers in the national network of manual rain gauges were contacted throughout the Canterbury region. These observers usually report on a monthly basis at the end of each calendar month, with data becoming available by the middle or end of the following month. To hasten the documentation of this snow storm, more than 50 observers were contacted over the period 14-19 June, and questioned about the June 12 snow storm.

Each observer was asked for a measurement of maximum snow depth at their gauge for Monday 12 June and Tuesday 13 June. They were also asked about how representative they felt this measurement was for the area they were in.

A further 12 data points were obtained from Andrew Hare, GIS Administrator at Waimate District Council which he collected on the morning of the storm from concerned people calling in across the Waimate district.

Additional data points were added using data obtained from Stuart Burgess (NIWA Wellington), newspaper reports, internet snow reports (e.g. ski field data) and other inferred information.

This has resulted in a total of 53 data points across Canterbury and North Otago.

These data points have then been used to interpolate a maximum observed snow depth surface across the region. The result of this interpolation is presented in Figure 9. This is an approximate map, as only 53 data points ranging in quality have been used. Furthermore, the interpolation only considers the data points and does not attempt to account for the effects of topography. Despite this, the map is sufficient to provide an overall initial coarse scale understanding of the snow depth across the Canterbury region.

Figure 9 shows that the area from about Temuka to Rakaia had up to 30cm down to sea level with increasing amounts towards the northwest and into the lower foothills. Deeper pockets of snow were experienced around Methven and Lyndhurst Station. Further south, most coastal areas (e.g. Timaru, Oamaru) had 20-30cm of snow, while areas such as Glenavy and Studholme had less snow with maximums of 5-10cm recorded.

Inland areas around Farlie, Kimbell and Burkes Pass had much deeper snow than the Canterbury Plains, with depths commonly exceeding 70cm. Further west into the McKenzie Basin, snow depths decreased with 40-50cm being more common across most parts.

North of Rakaia, the snow depth decreased northwards and eastwards with 20-30cm on the plains near Lincoln, decreasing to 5-6cm on Brighton Beach in Christchurch and 10-15cm in Amberly. Deeper pockets of snow were experienced west of Darfield with 75cm recorded at Homebush Station. Towards the foothills snow depth also increased with 50cm in Springfield and 80cm at Ryton Station.

Additional data will become available around the middle to end of July 2006 which on request could enable a more detailed map to be constructed which could take account of topography and other associated affects.

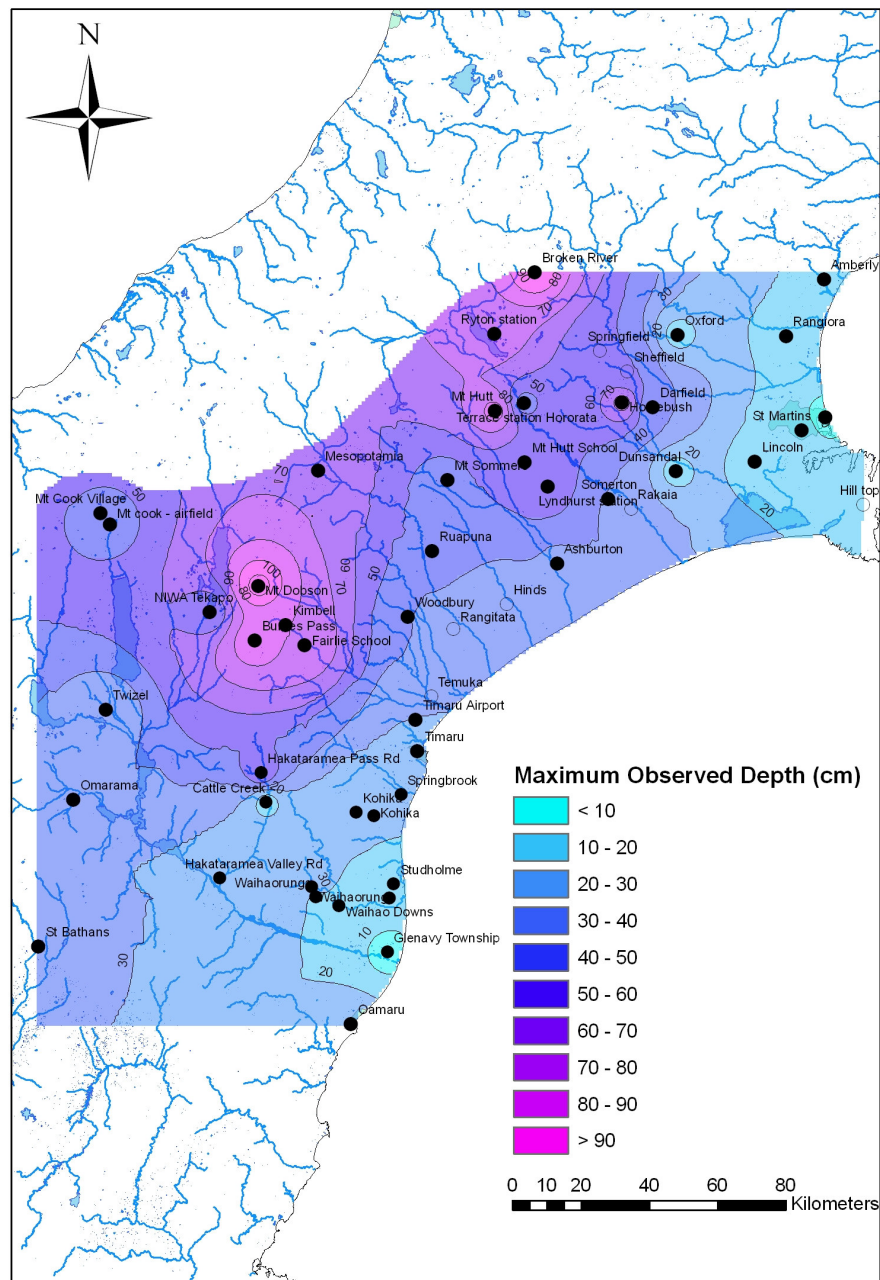


Figure 9: Maximum observed snow depths (cm) from the June 12, 2006 snow storm across the Canterbury region. The snow depth interpolation surface only considers the data points and does not attempt to account for the effects of topography.

5. How does the 12 June 2006 storm compare to previous storms?

It is very difficult to directly compare one storm to another due the sparse spatial information available from historical records. Furthermore, historical data on previous snow storms are incomplete and occasionally unclear. Therefore, the following section provides quantitative information where available, followed by a more qualitative comparison to previous events. No attempt is made to express this event in terms of a return period as data is too sparse to achieve this with any reasonable level of accuracy or with a realistic error band.

5.1. Snow depth

Table 1 presents snow depth information in centimetres for a selection of localities throughout Canterbury. Sparse point data of snow depth is available for the storms in 1945, 1992, 1996 and 2002. The 1967 and 1973 storms however have maps of snow depth and many points are able to be inferred from these figures.

Table 1: Table of observed maximum snow depth (cm) at selected location in Canterbury. Shaded figures indicate the storm with greatest recorded depth at each location.

	1945	1967	1973	1992	1996	2002	2006
Christchurch	30-40	0*	0*	5-30	5-10	10	5-15
Port Hills		0*	0*	<100			10-15
Darfield	40	10*	25*	30-40			40
Sheffield		30*	60*				50
Amberly		0*	0*				10-15
Oxford		0-5*	0-5*				15
Lincoln		0*	0*				10-15
Rakaia		0*	0*				30
Ashburton	30	0*	0*	9	10	15-30	38
Methven	60+	25	61		20	40-50	55
Mt Hutt		>100*	180				85
Geraldine	30	11.5	45*				40-50
Mt peel		27.5	25*				45
Arundel		40*	25*	30-40			40
Mesopotamia		90	75*				70
Plains	< 45	0-60*	0-30*		<40 [#]	10-40	30-60
Temuka	25						30
Farlie		50	71				80
Lake Tekapo		75*	67				50
Hermitage		100	120			100	50
Timaru	30-40	0*	0*	5			30

*Derived from maps of snow depth (Figures 1 and 3)

[#]Inferred from source information (e.g. publications and newspaper clippings).

Due to the large number of missing point observation for each storm it is extremely difficult to accurately compare this data, and doing so is not a reliable method of assessment in itself.

Therefore a more qualitative analysis is undertaken. This analysis considers all available data for each snow storm, including anecdotal evidence contained in the text of the reports and inferences about the extent of the snow and snow depth. This analysis is supported by point measurements were available.

This qualitative analysis suggests that the snow storm of June 12, 2006 is similar in terms of snow depth to the 1973 snow storm in areas inland and north of the Rakaia River. Pockets of significantly deeper snow were experienced west of Darfield and towards the foothills which experienced conditions more similar to the 1945 storm. In the coastal plains areas (north of the Rakaia) the snow was much deeper than the 1992, 1973 or 1967 snow storms, except in Christchurch where the 1992 snow storm was much more severe.

In areas south of the Rakaia River but limited to the Canterbury plains and foothills this analysis suggests that in terms of snow depth the June 12, 2006 snow storm was more extreme and produced greater snow depths than the 1973 and 1967 snow storm. Snow depths throughout this area were more like the 1945 snow storm and in some areas much worse. Ashburton had the greatest maximum snow depth (38cm) on record (Figure 10).

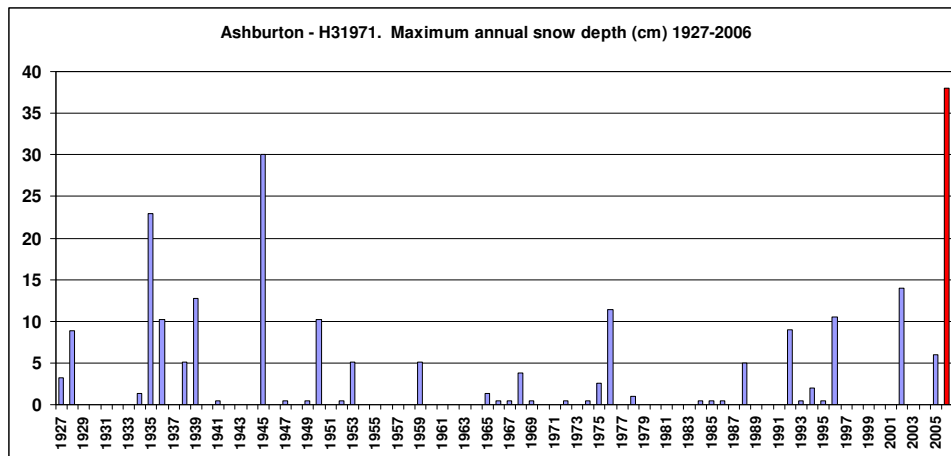


Figure 10: Maximum observed annual snow depths for station H31971 in Ashburton.

Inland areas around Fairlie and Burkes Pass had similar snow depths to the 1973 storm, while areas further west into the McKenzie Basin, had significantly less snow

than most previous notable snow storms with only 50cm being recorded at the Hermitage opposed to over 100cm in 2002, 1973 and 1967.

5.2. Snow density

While snow depth and extent is one measure of the effect of a snow storm, the density is also an important variable in determining the amount of damage that a snow storm can cause. Density provides information on snow loading; the weight of the snow can be computed by multiplying the snow depth and snow density.

Very sparse information is available regarding density of snow for previous storms. For the 1973 storm Hughes (1974; 1976) note the high density of snow (300-400 kg/m³) at low elevations and attribute this, combined with the low temperatures as the main reason for the extensive damage to the electricity network.

Anecdotal evidence such as the limited tree damage in certain parts of south Canterbury suggests that the 1992 snow storm was much less dense than the 2006 storm, however no quantitative evidence could be obtained to validate this.

Currently, only four observations of snow density have been obtained for the June 12, 2006 snow storm. These were 190 kg/m³ (Hororata), 170 kg/m³ (Lyndhurst Station), 160 kg/m³ (Methven) and 180 kg/m³ (Tekapo). These observations are of unknown reliability as density is not a parameter usually recorded, and the snow storm was preceded by a rain event, which some observers may have included in their density calculation.

Nevertheless, the measurements suggest that the snow density for the June 12, 2006 snow storm was lower than the 1973 storm, which causes reduced snow loading on buildings and power lines for the same depth of snow.

6. Conclusions

This investigation has documented six previous snow storms in the Canterbury region to enable a comparison to be made to the June 12, 2006 snow storm. Snow depth has been mapped across the greater Canterbury region and observations of density have been provided.

The spatial analysis of the snow storm suggests that the June 12, 2006 storm was a large event for parts of Canterbury north of the Rakaia River. In areas south of the

Rakaia but limited to the Canterbury Plains the snow storm was an exceptional and significant storm, with snow depths in some locations that were the greatest on record.

Future work to map the return period and associated uncertainty of such an event, or to map the estimated 1 in 50 year event is strongly recommended to provide more quantitative results to support decision making processes and regional planning.

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