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SEVERE HAIL AND WIND DAMAGE IN WEST AUCKLAND NOVEMBER 1984

M. S. McGill

Abstract

Between 2 and 3 a.m. on the morning of 4 November 1984 a large active thunderstorm moved rapidly southward over the western edge of Auckland City. The strong winds and hail associated with the thunderstorm caused damage, estimated at about $4,000,000 to crops and buildings, mostly in the Waimauku, Haupai, Kumeu, Taupaki region.

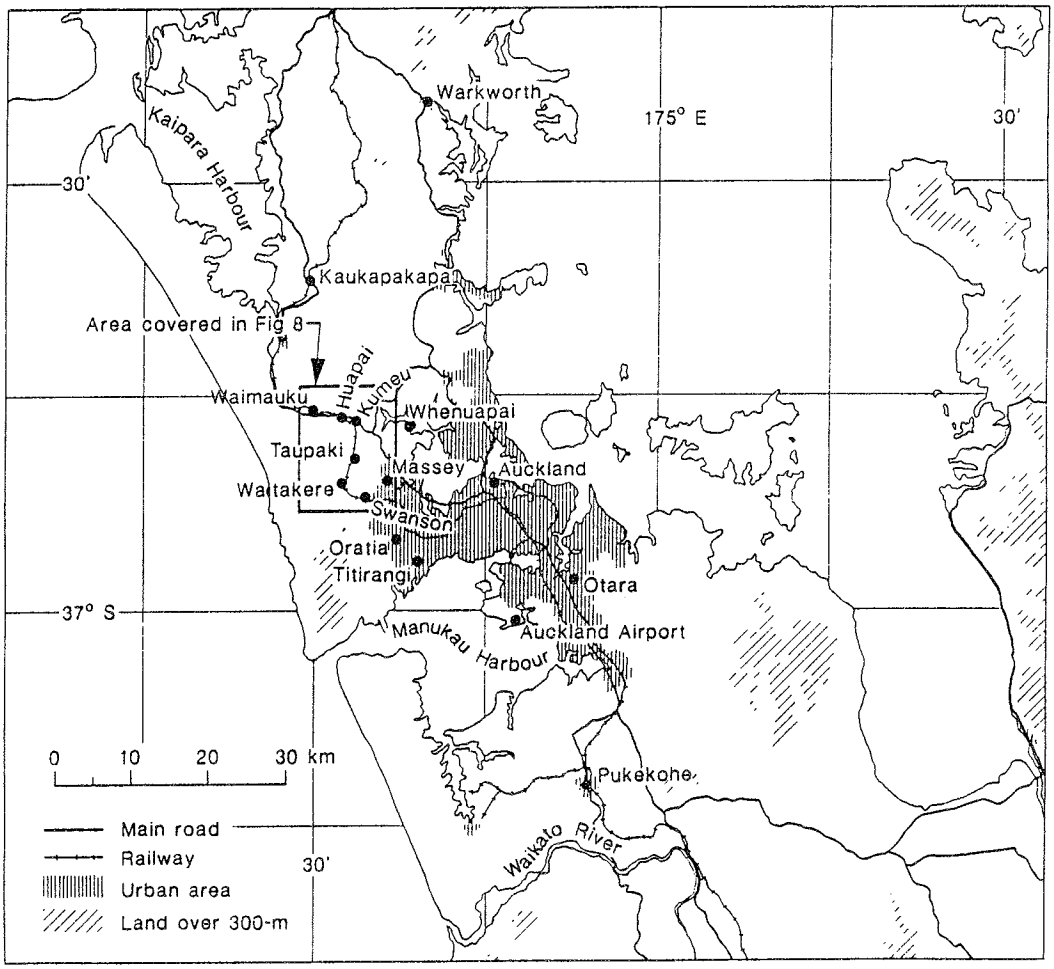


Fig. 1. Locations referred to in the text

1. INTRODUCTION

The growth of horticulture around Auckland City has resulted in an increased interest in the nature and frequency of severe crop damaging weather. The thunderstorm of the morning of the fourth was unusual in that it caused such severe damage over so wide an area. Over 300 hectares of crops were damaged between Waimauku and Taupaki.

Wind driven hail was reported as lasting between 30 seconds and 30 minutes, and severely damaging pip and stone fruits, the soft bark of fruit trees, grapes, kiwi fruit, strawberries, celery, and pepinos etc. A trail of severe damage to glass houses, sheds, fences and trees near Haupai gave rise to claims of tornadoes with the thunderstorm.

Long term residents of Kumeu, Huapai and Taupaki mentioned that damaging hail occurs in most years, but usually affects only a few farms and that it occurs most often in November or December. Neale (1977) found that severe damaging hail occurs most frequently between May and January to the west of the main ranges of the North and South Islands.

2. THE SYNOPTIC SITUATION

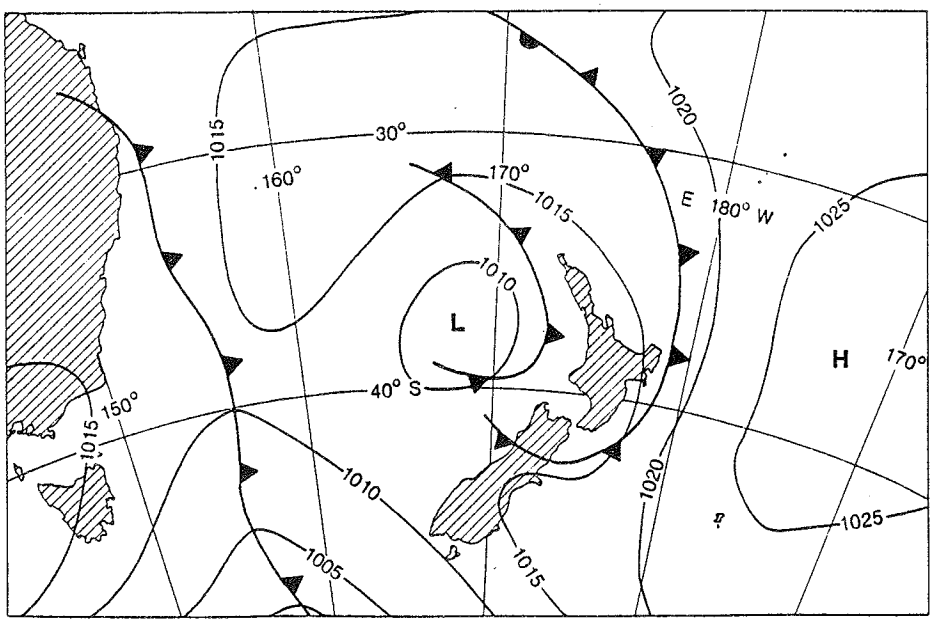


Fig. 2: MSL Analysis 1200 GMT 3 November 1984

The midnight mean sea level analysis of 3 November 1984 (Fig. 2) shows a north-west airstream covering the northern half of the North Island, ahead of a slow moving depression centred several hundred miles out in the Tasman Sea.

The Numerical Weather Prediction (NWP) 500 and 300 hPa analyses of 0000 and 1200 GMT (Fig. 3) show a deep north-west airflow covering the North Island and adjacent seas.

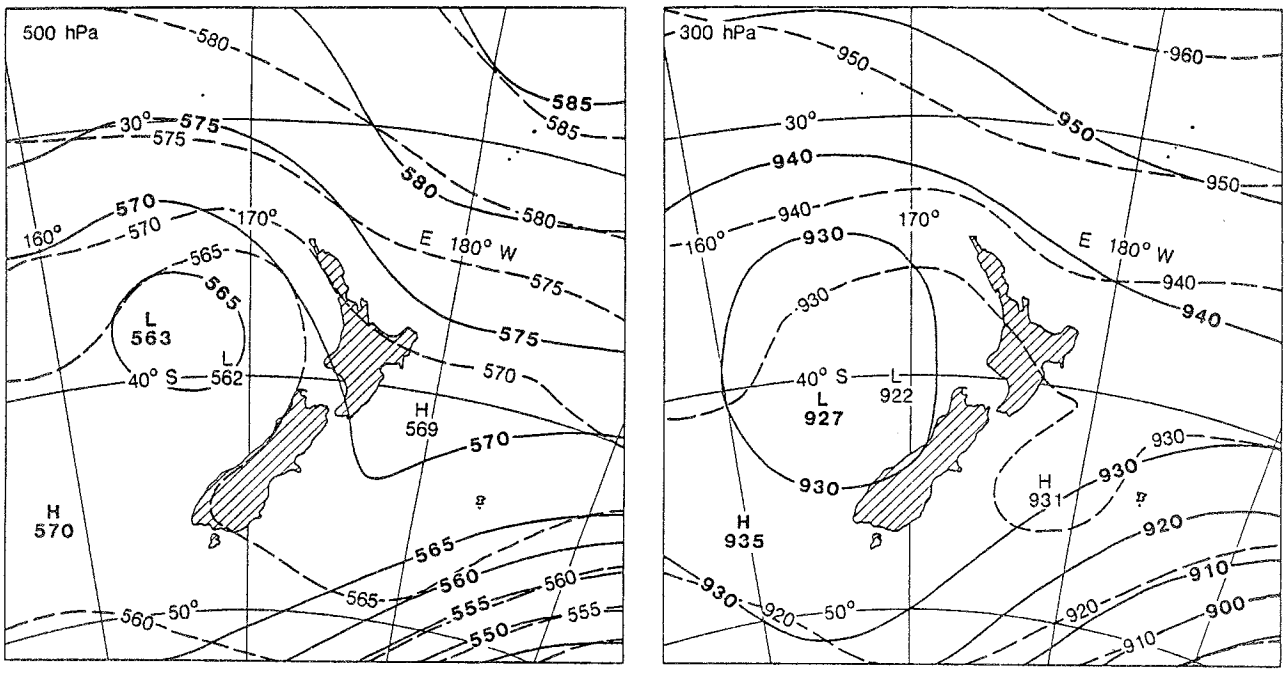


Fig. 3. NWP 500 and 300 hPa analyses for 3 November 1984
Bold lines indicate pressures at 0000 GMT and dashed lines indicate pressures at 1200 GMT

Three vertical temperature and moisture soundings (tephigrams) were available within the north-west airflow; Auckland Airport at 0000 and 1200 GMT (Fig. 4) and Norfolk Island at 0000 GMT. With the exception of shallow stable layers or inversions, all tephigrams show conditional instability to between 400 and 300 hPa and potentially unstable layers in the lower Troposphere (Table 1), where the potential pseudo wet bulb temperature ($\hat{a}_{SW}$) decreases with height. When lifted to saturation potentially unstable layers become unstable and ascent occurs.

Table 1. Tephigram readings

Auckland Airport 3.11.84				Norfolk Island 3.11.84	
0000 GMT Height	θ_{SW}	1200 GMT Height	θ_{SW}	0000 GMT Height	θ_{SW}
surface	17C	surface	14.5C	surface	21C
950 HPA	16.5	950	15	950	19.5
900	16	900	15	900	17.5
850	16.5	850	14.5	850	17.5
800	16.5	800	13.5	800	17
750	16	750	11.5	750	17
700	13	700	11.5	700	16
650	12	650	12	650	15
600	12.5	600	12.5	600	14
550	13.5	550	13	550	15

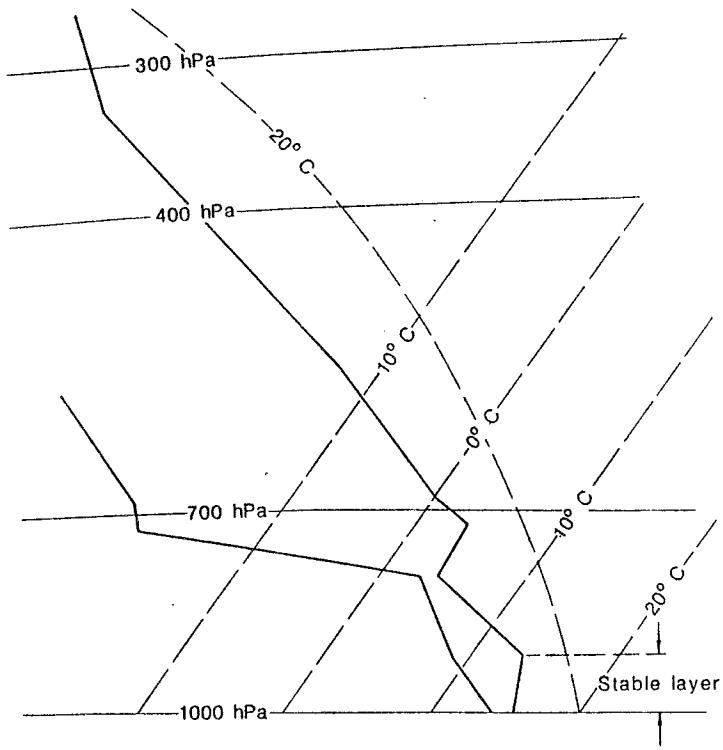


Fig. 4. Tephigram for Auckland airport 1200 GMT 3 November 1984

The NWP 600 hPa vertical motion analyses between 0000 and 1800 GMT (Fig. 5) moves an intensifying area of upward motion onto the North Island within the north-west airflow.

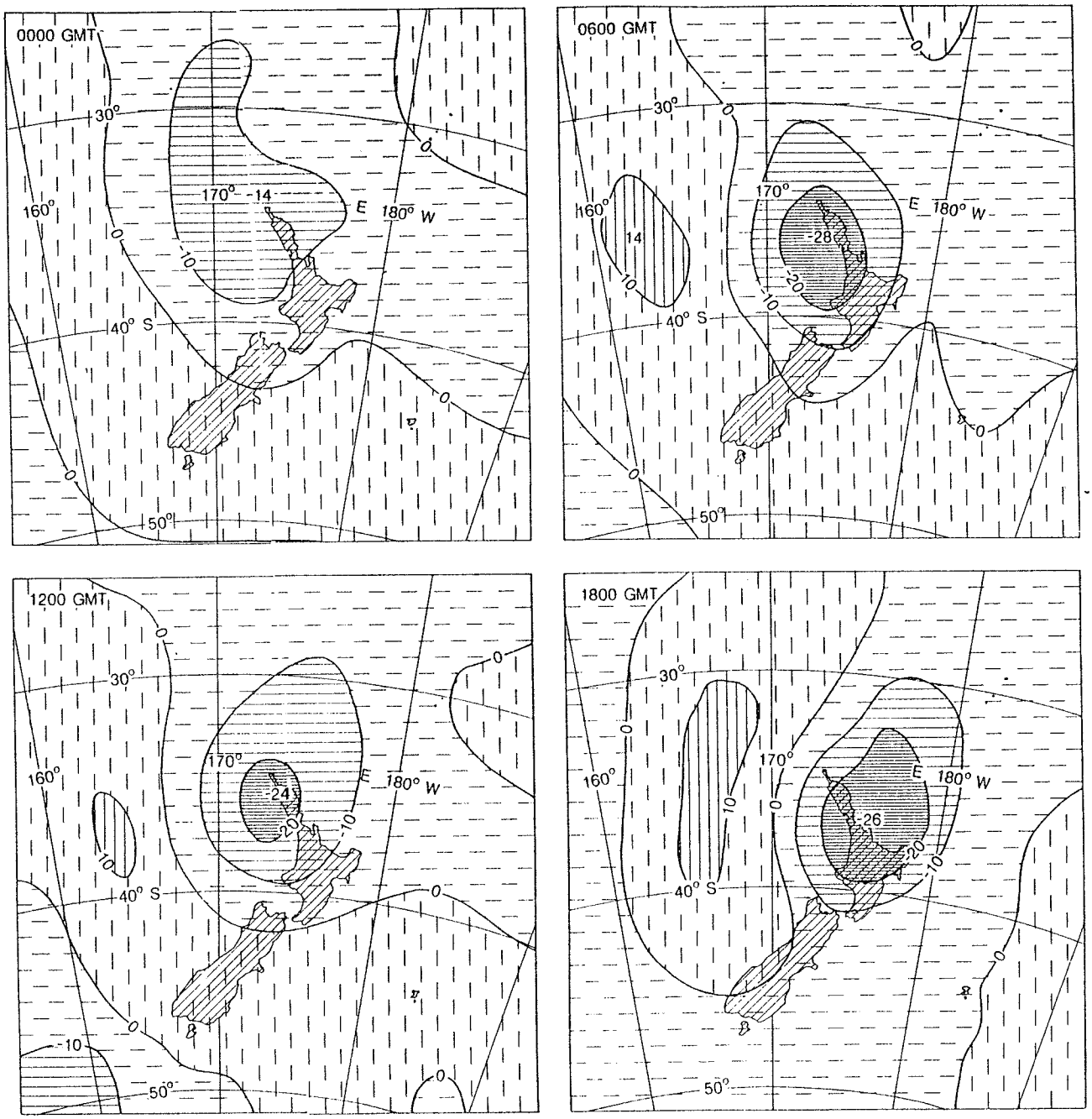


Fig. 5. Six hourly 600 hPa vertical motion 3 November 1984

The combination of large scale ascent and instability within the north-west airflow provides a favourable environment for deep convective outbreaks initiated by meso-scale effects, such as fluctuations in the vertical moisture distribution, topography, and surface heating.

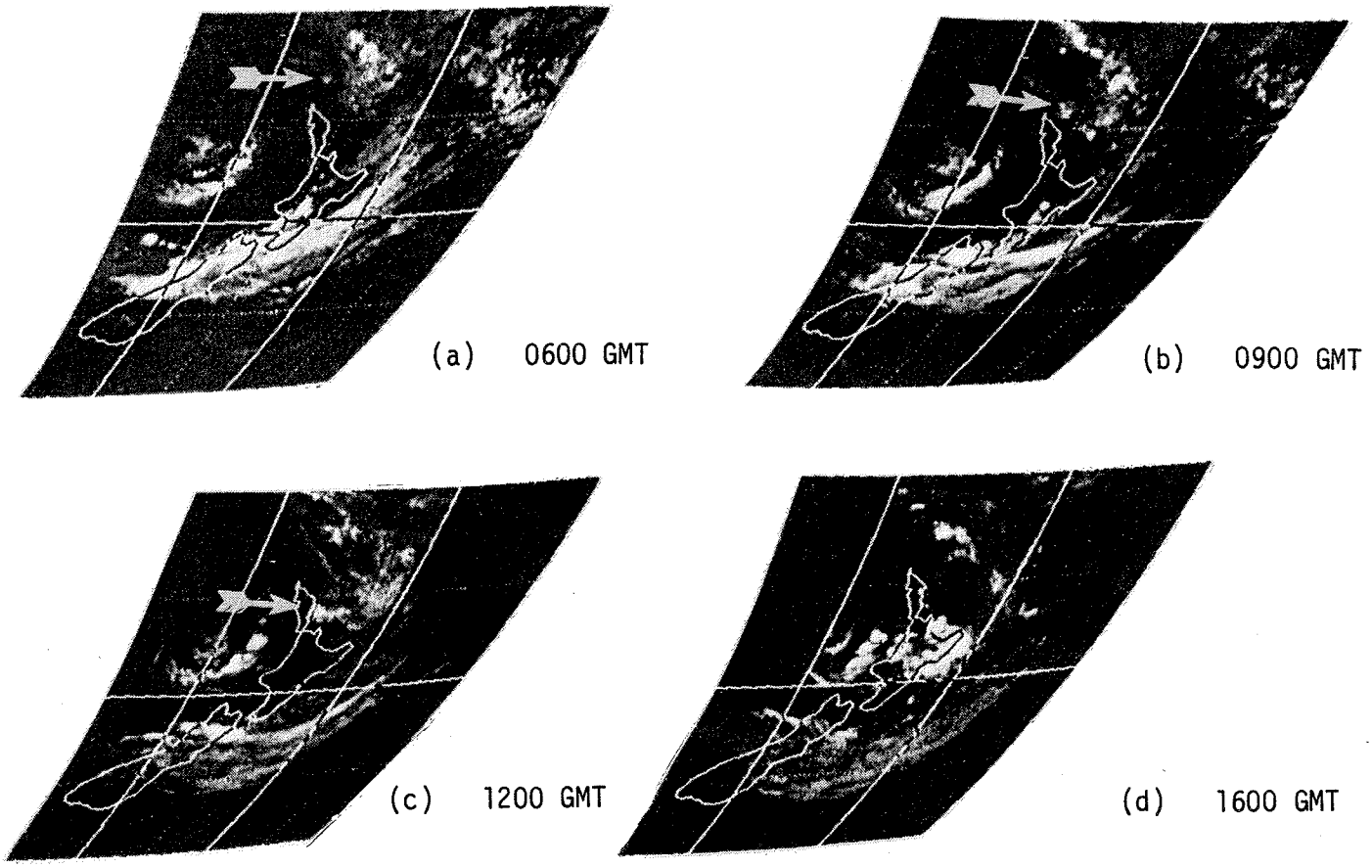


Fig. 6. GMS, IR imagery 3 November 1984

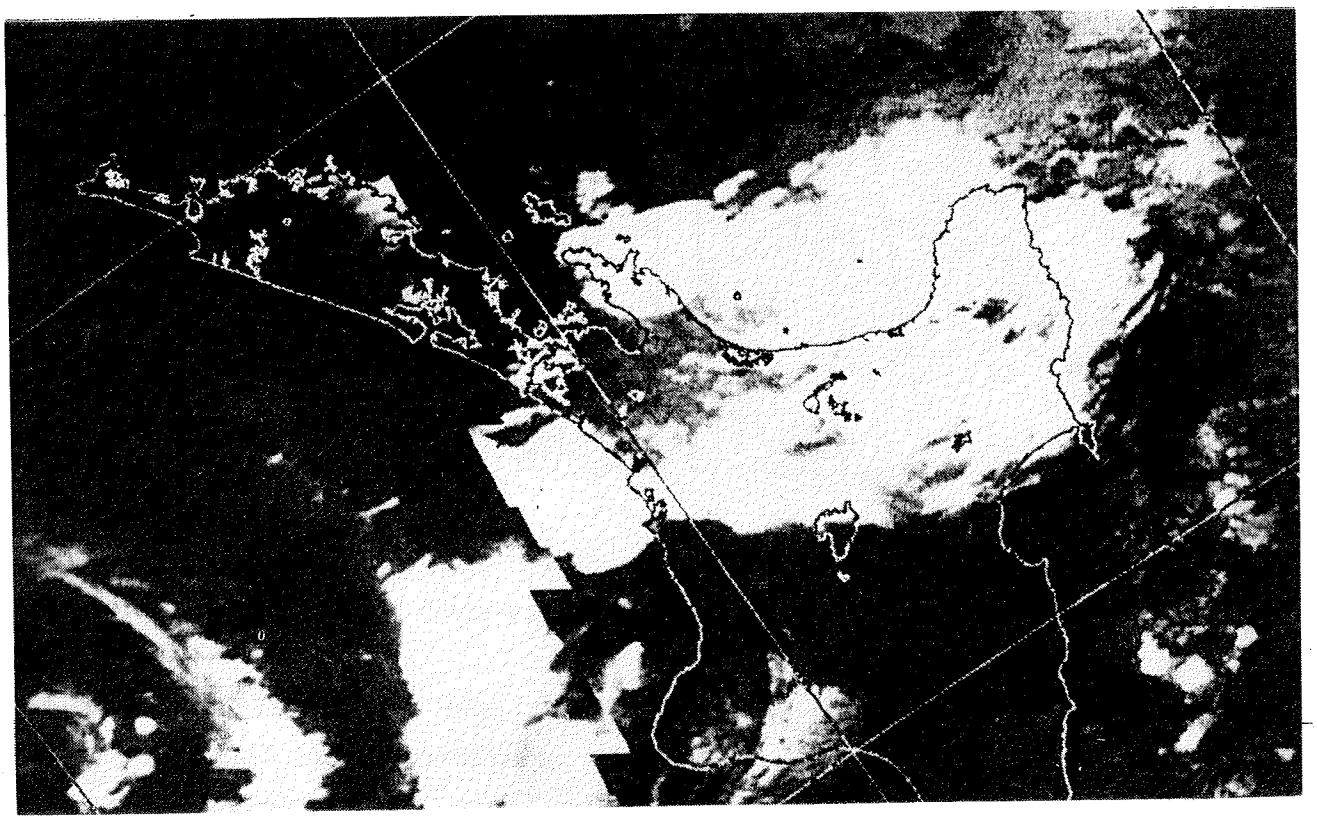


Fig. 7. NOAA 7 Orbit 17355 IR imagery 3 November 1984

A sequency of images from the GMS 3 satellite (Fig. 6 (a), (b), (c), and (d)) reveals high topped convective cloud moving onto the North Island in the north-west airflow, expanding considerably in area as it does so.

The high resolution NOAA 7 1457 GMT imagery (Fig. 7) shows two large cumulonimbus plumes over Northland, and cold high topped cloud over and south of Auckland. The 1530 GMT (4.30 a.m.) Auckland Airport radar scan confirmed the deep convective nature of the cloud, about and south of Auckland by detecting scattered moderate to strong precipitation echoes with tops to 14,000 ft to the south.

3. THE STORM

During the early hours of the morning of Sunday 4 November a small area of frequent lightning was seen by staff at the Auckland Weather Centre to move rapidly southward over west Auckland. At 2 a.m. lightning was observed far to the north-west, and at 3 a.m. well to the south. Between 2 and 3 a.m. two telephone calls were received from west Auckland suburbs reporting wind and hail damage.

The unusually large area in west Auckland affected by the thunderstorm's strong winds and hail was revealed on Monday morning through reports published in the New Zealand Herald.

The Herald published a photograph of wind damage (Appendix 2), interviews with farmers whose crops suffered hail and wind damage, and a hail damage track extending from Waimauku to Taupaki.

A visit to the Waimauku, Kumeu, and Taupaki areas yielded reports of early morning hail from Kaukapakapa in the north to Titirangi in the south, a distance of about 40 km. The width of the hail band is unknown but with hail reports extending from Kumeu township to Waimauku it would have been at least 6 km in this area. Strong winds were often reported with the hail, particularly at its onset. The severity of the wind damage in the Waimauku, and Huapai areas caused a number of people to suggest that there were tornadoes within the storm.

The observation at 1.30 a.m of active lightning to the west, by staff of the Post Office satellite receiving station at Warkworth, indicates that the storm was mature and active well north of Kaukapakapa. However, a search through provincial newspapers failed to find any reports of hail or wind damage associated with a thunderstorm either north of Kaukapakapa, south of Titirangi, in South Auckland or the Waikato.

Large individual moving thunderstorms, which last for hours and produce violent surface weather in the form of large hail, strong gusty winds and intense lightning over a band hundreds of kilometres long and kilometres wide, are known as intense travelling cumulonimbus. These large cumulonimbus clouds form when there is considerable vertical wind shear throughout the troposphere. The shear allows the continually evolving individual cloud cells of the non-severe smaller cumulonimbus cloud to be replaced by a much larger "supercell" in which one intense updraught and downdraught pair exist in an almost steady state for up to several hours (Browning 1968).

The 1200 GMT 3 November radar measured winds from Auckland Airport show considerable vertical velocity shear throughout the troposphere (Table 2). Between 1 and 9 km the velocity shear was 37 m sec^{-1}. This shear is considerably in excess of the several m sec^{-1} km^{-1} considered necessary for the development of large, intense, persistent travelling cumulonimbus clouds. (Ludlam 1980[1]).

Table 2. Auckland Airport Radar Winds 1200 GMT 3 November

Level	Direction (Degrees)	Speed (m sec^{-1})
Surface	070	02
900 hPa (1 km)	341	09
850	346	11
800	337	12
700 (3 km)	337	16
650	333	15
500 (6 km)	325	19
400	314	29
300 (9 km)	306	44
250	305	44
200	300	28

Movement

Non supercell cumulonimbus clouds have been found to move approximately with the mean wind in the mid-troposphere between 3 and 6 km. Large severe supercell cumulonimbus clouds exhibit more varied behaviour. Some move more slowly and to the left of the mid-tropospheric mean wind (southern hemisphere) while others move more rapidly and to the right. Vector differences between the mean wind velocity and the storm velocity can be as great as 30 degrees and 20 m sec^{-1} (Ludlam 1980[2]).

The parent cloud of the severe thunderstorm is marked by white arrows in Fig. 6 (a), (b), and (c) where it is seen to grow in area and move south-south-east at about 17 m sec^{-1}. This is close to the Auckland Airport 1200 GMT measured mean wind between 3 and 6 km of 16.5 m sec^{-1}.

Unfortunately, no visual or radar fixes were obtained of the storm as it moved southward over Auckland. However, using reports of wind and hail in west Auckland an estimate can be made of the direction, and speed of movement of the storm.

In Fig. 8 the hail and wind damage reports lie along a broad track close to the mean wind direction of 330 degrees between 3 and 6 km measured at Auckland Airport at 1200 GMT.

Two approximate times of hail onset allow a crude estimate to be made of the speed of movement of the storm. Just after 2 a.m. the storm gave a brief period of wind driven hail to the DSIR Research Centre in Waitakere Road, about 1 km south of Kumeu, and at 2.15 a.m. a caller to the Auckland Weather Centre reported severe hail at Titirangi. (Appendix 1. 15, 23).

The distance between the two hail reports is 20 $\pm$ 2 km (Titirangi is a suburb). Assuming a travel time of 10 $\pm$ 3 minutes an average speed of 33 m sec^{-1} is obtained for the storm with extremes of 23 and 52 m sec^{-1}.

The estimated lower limit of 23 m sec^{-1} of the storm speed is well above the measured mean mid-tropospheric wind speed of 17 m sec^{-1} between 3 and 6 km.

These observations and calculations indicate that the storm was of the Severe

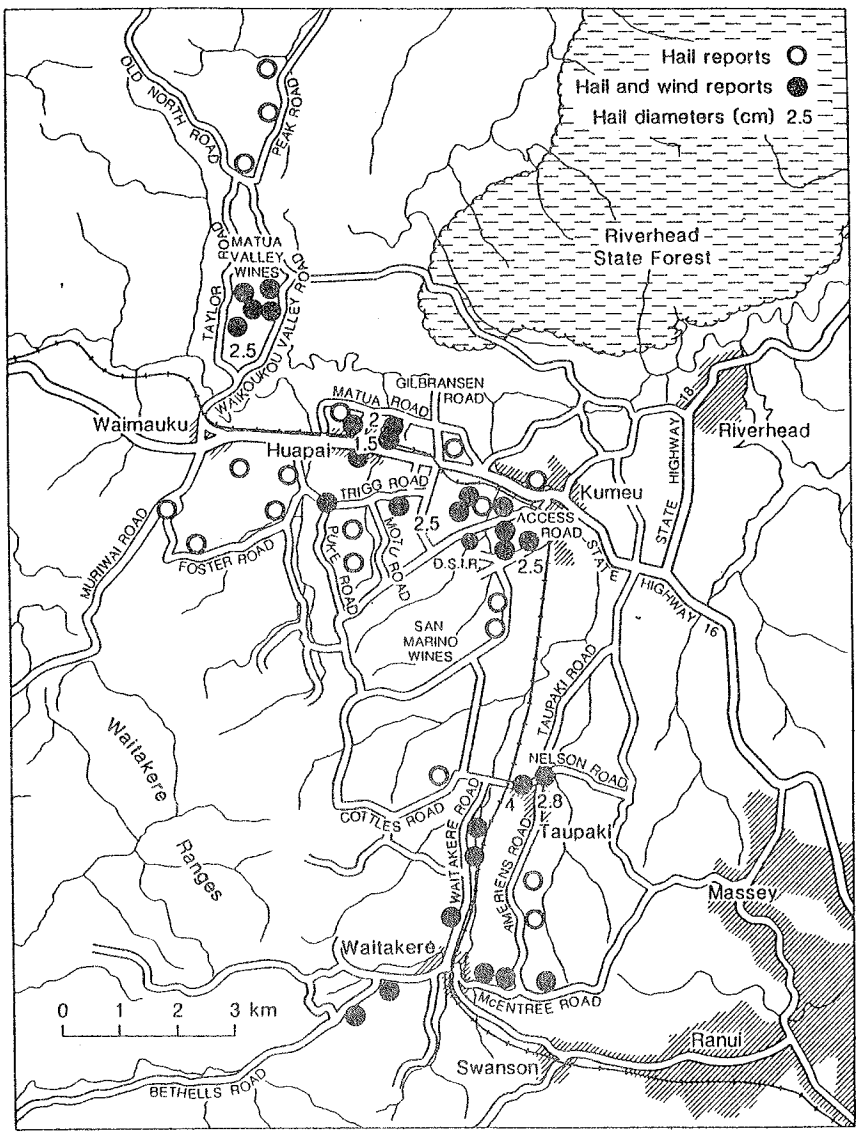


Fig. 8. Hail and wind reports

Right or SR type which in the southern hemisphere moves at a velocity greater than and to the right of the mid-tropospheric wind velocity between 3 and 6 km.

Hail, wind, and rain

Most of the reported storm damage was to crops and to the glass in glass houses from wind and hail, often acting together. Reports of damaging hail extended over a band about 40 km long from Kaukapakapa in the north to Titirangi in the south. in the Kumeu and Waimauku areas the width of the damaging hail band was at least 6 km.

Table 3. Hail and wind reports

Position		Hail duration (minutes)	Hail diameter (maximum)	Wind with rain/hail
4 B.	Waikoukou Valley Rd	-	2.5 cm	strong
6 B.	Highway 16 near Gilbransen Rd.	10	1.5 cm	strong
8 B.	Trigg Rd.	intermittent 5	2.5 cm	strong
11 A/B.	Corner Matua & Gilbransen Rd.	10	2.2 cm	strong
15 A/B.	DSIR	1/2	2.5 cm	strong
17 B/C.	Taupaki Rd, 100m north Nelson Rd.	30	light melting	little
18 B/C.	Nelson Rd.	30	4 cm	strong
19 B/C.	200 m north of site 18 B/C	3	2.8 cm	strong
23 C.	Titirangi	-	2 cm	-

Table 3 contains a selection of hail and wind reports from Appendix 1.

Estimates of hail size were the usual mixture of the numerical and descriptive, for example, about half an inch, as big as 10 or 20 cent coins, as large as golf balls. Conversion to numerical metric measurements gives a range of hail diameters within the storm of 1 to 4 cm. Hail preserved by Mr Way (Appendix 1, 11 A/B) was composed of mainly spherical stones of about 0.8 cm in diameter with a few larger irregular stones of up to 2.2 cm in diameter.

Estimated duration times for the hail of more than a few minutes are suspect. The damaging wind hail combination would have been moved very quickly over any position by the high storm velocity of about 30 m sec^{-1}. Northern hemisphere investigations of travelling supercell thunderstorms suggest that the hail producing region of the storm is usually up to 10 km in length (Chisholm 1973). Mr H. Skelton at his property in Trigg Road, well within the hail band, experienced wind and hail in waves for 5 minutes, fitting well a storm moving at about 30 m sec^{-1} and containing a damaging hail producing region about 10 km long. Hail reports of greater than 5 minutes are probably estimates of both the rain and hail from the storm and its parent cloud.

Little is known of the rainfall intensities and amounts produced by the storm. Only one recording rain gauge lay along the storm track on the morning of the 4 November. This gauge, at the DSIR site near Kumeu, records hourly rainfalls and measured only 3.2 mm during the passage of the storm between 2 and 3 a.m. Four functional recording rain gauges of the Meteorological Service were sited within 5 to 12 km of the storm path. The storm passed to the west of the gauges between 2 and 3 a.m. and the rainfalls for this period are listed in Table 4.

Table 4. Rainfall measurements from recording rain gauges in the Auckland area

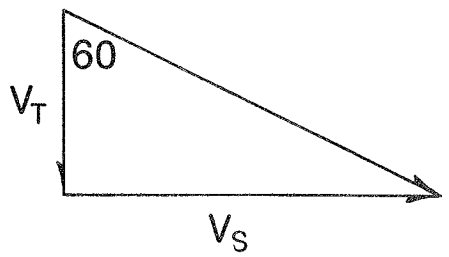
Station	2 to 3 a.m. rainfall	Distance from storm
Whenuapai airforce base	1.1 mm	about 5 km
Auckland City	0.2	" 12
Albert Park	0.3	" 12
Auckland Airport	0.3	" 7

Wind squalls in severe travelling thunderstorms are usually more than 15 m sec^{-1} and reach 50 m sec^{-1} (Ludlam 1980[3]).

No useful measurements are available of wind or gust speeds within the hail's path or close to the storm track. The storm moved so quickly over the DSIR site near Kumeu that the 2 to 3 a.m. integrated hourly wind speed remained below 1 m sec^{-1}. Of the three Meteorological Service wind recording instruments about Auckland City, the Auckland Weather Centre in the City recorded the strongest wind gust between 2 and 3 a.m of 27 knots or 13.5 m sec^{-1}.

Using the relationship established by Fawbush and Miller between the drop in temperature during thunderstorm rain and the strength of the peak gust at the surface, a range of likely wind gust speeds for the storm can be estimated (Pettersen 1956). A downrush temperature of 10.5°C, obtained from the 1200 GMT Auckland Airport tephigram, and a surface air temperature of 17°C gives a thunderstorm rain temperature drop of 6.5°C and a peak gust range of 36 to 53 knots or 18 to 26.5 m sec^{-1}.

A second cruder estimate of the range of wind speeds in the squall front can be made using hail terminal velocities and a report of hail driven almost horizontally by strong winds (Appendix 1, 11). Relating roof over-hang to the height of hail impact damage on window frames indicated that the hail was blown at about 30 degrees to the horizontal rather than horizontally. Simple vector calculations (Fig. 10) using hail moving at 30 degrees to the horizontal and several hail terminal velocities, then give a range of possible horizontal wind velocities in the squall front (Table 5).



V_T = hail terminal velocity
V_S = squall velocity
$V_S = V_T \text{ Tan } 60$

Fig. 10. Vector calculations

Table 5. Possible horizontal wind velocities in the squall front

Hail size	Terminal velocity	Squall front speeds
1 cm	15 m sec^{-1}	26 m sec^{-1}
2 cm	25 m sec^{-1}	43 m sec^{-1}

The reported and observed wind damage caused by the storm (Appendices, 1 and 2) included large trees blown over, large branches torn from trees, sheds and fences blown away, and a large glass house flung 3 metres. The Beaufort Wind Scale attributes such damage to storm force winds with speeds of 48 to 55 knots or 24 to 27.5 m sec^{-1}.

The upper end of the estimated wind gust speed range given by the method of Fawbush and Miller is almost identical with squall and gust speeds necessary to produce the observed wind damage. However, the simple vector calculations seem to have overestimated the gusts and squalls in the storm. By restricting the vector calculation to the small hail of about 1 cm in

diameter, on the grounds that this made up most of the hai in the area under consideration, close agreement is obtained.

Severe travelling thunderstorms often contain tornadoes. In this case no conclusive evidence, such as pronounced twisting of tree trunks could be found for the existence of tornadoes at ground level. All reported and observed damage could be explained by strong gusts and squalls.

4. DISCUSSION

Hail in the Auckland area is an occasional phenomenon more common to the north and west of the city than in the south, Table 6.

Table 6. Average hail days per year

North and west of City		Auckland City	South of City	
Warkworth	7.6	4.0	Auckland Airport	4.2
Riverhead forest	2.7		Otara	3.9
Whenuapai	11.4		Pukekohe	2.3
Oratia	6.8			

Falls of severe damaging hail are much less frequent than the figures of Table 6. Neale, 1977, using mostly newspaper reports, lists 23 occurrences of severe hail about Auckland city over 50 years between 1924 and 1973 inclusive, but mentions that an unknown number of falls will have escaped detection. Severe hailstorms are defined as those that either contain hailstones with long-axis diameters of at least 0.5 cm, or cause damage to crops or other property.

A search through the NZ Herald 'Hail and rain damage file', for the period 1974 to 1984 revealed eight occurrences of severe hail about Auckland in the eleven year period. This is 1.5 times the frequency recorded by Neale. Four of the eight hail reports were from west Auckland and involved damage to crops.

Growers in west Auckland agree that crop damaging hail occurs in most years but is usually confined to a relatively small area affecting only a few farms. Mr H. R. Skelton, who has farmed in the Huapai area since the late 1930's, was unable to recall another hail incident producing damage comparable to the severity and extent of that produced by the storm of 4 November 1984.

On the 4 November cumulonimbus clouds, heavy showers and some thunderstorms were reported over much of the North Island. However, only one other large thunderstorm of the size and severity of the west Auckland storm was reported. This second large severe thunderstorm moved south-east over Ohakea airforce base and Palmerston North, in the Manawatu, during the early afternoon producing hail of up to golf ball size (about 4 cm in diameter) over a band about 5 km wide and over 20 km long. Within the hail band wind gusts to 33 knots were measured during the thunderstorm at the Ohakea airforce base where at 2.30 p.m the weather radar recorded strong precipitation echoes up to 29,000 ft or 8.8 km. A market gardener affected by the storm claimed it was the worst of its type he had seen in 35 years of working in the Manawatu.

5. CONCLUSION

The large severe travelling thunderstorm, which moved rapidly southward over west Auckland on the morning of the 4 November 1984, caused enormous damage to crops, particularly in the Waimauku, Huapai, Kumeu, and Taupaki region. The damage was caused by wind and hail, usually together, over a path over 40 km long and at least 6 km wide in the Waimauku and Kumeu areas.

The thunderstorm belonged to that group of travelling thunderstorms known as the Severe Right or SR type which in the southern hemisphere move at a velocity, greater than and to the right of the mid-tropospheric wind velocity between 3 and 6 km.

An unstable north-west airstream, containing large scale upward motion in the middle troposphere, brought widespread heavy showers, and some thunderstorms to the North Island on the 4 November 1984. The presence of strong vertical wind velocity shear provided a favourable environment for the

development of large severe travelling cumulonimbus and two were reported, one to west of Auckland and the other around Palmerston North.

Thunderstorms of this type could occur at any time of the year, but are more likely in the cooler months when the necessary vertical velocity shear is most often present throughout the troposphere.

Almost nothing is known in New Zealand of the frequency and preferred paths, if any, of large severe travelling thunderstorms. The comments of growers in west Auckland and Palmerston North suggest that these storms are uncommon, with return periods measured in decades.

ACKNOWLEDGEMENTS

The author wishes to thank the many members of the public of west Auckland who freely answered questions about the hail and wind damage caused by the storm. Thanks also to Mr N. R. Robinson and Mr G. Reeve of the Auckland Weather Centre for the preparation of diagrams, Mr D. McKellar for information about the Manawatu hail and Mr C. G. Revell of the research section for his advice.

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APPENDIX 1

Extensive information of the damage, caused by wind and hail, associated with the thunderstorm was obtained by observation, interviews, and from newspapers. This information was divided into three categories and is listed below.

Category	Source	Damage site	Remarks or Observations
1 C	W. Robinson	Kaukapakapa	Some hail not severe as Huapai/Kemeu area
2 C	Staff, Matua Valley Wines	Kaukapakapa & Peak Rd	Orchards wind/hail damage
3 C	"	Intersection Old North & Taylors Rds	Market Garden lost Pepinos, few panes glass
4 B	"	Waikoukou Valley Rd	Vineyard 1-2 km wide hail/wind. Hail 2.5 cm
5 B	Staff, Chemist Shop Kumeu	Access Rd	Hail/strong wind. Hail lasted up 10 min
6 B	W. Skelton Chemist Kumeu	Main Rd close to Gilbransen Rd	Orchard hail/strong winds Hail 1.5 cm lasted 10 min 40 year old tree blown over
7 B	ditto	Kumeu town	Less hail than further west
8 B	H. R. Skelton	Trigg Rd	Wind/hail in waves 5 min 12 pines broken off at 6 m Hail 2.5 cm

APPENDIX 1

Category	Source	Damage site	Remarks or Observations
9 C	ditto	Peak Rd	Orchards severe hail damage
C	ditto	Fosters Rd	50 percent damage to crops
C	ditto	South Fosters between Motu and Puke Rds	Severe hail damage, crops
10 A/B	Ross Ardern	Gilbransen Rd	Severe wind damage, glass huse blown 3 m. Two nearby glass houses only few broken panes. Hail lasted about 2 min
11 A/B	J. Way	Corner Matua and Gilbransen Rds	Severe wind/hail damage. Hail mostly spherical 0.8 cm, but up to 2.2 cm, lasted 10 min. 100 panes glass broken and iron fence lifted blown 50 m into trees. Small shed blown apart and branches blown off Macrocarpa trees. Initially hail blown almost horizontally against north side house where window frames pitted, 1.5 marks/cm^2
12 B/C	Orchardist	Matua Rd 200m west	On edge severe hail, experienced mostly wind driven rain 30 min. Severe hail damage Trigg Rd. Very heavy hail damage Trigg Rd
13 B	Staff, IGA	Just west Huapai town	Very heavy hail 10 min. but little wind. Thunder before hail
14 B	M. S. McGill	Main Rd about 1 km west Haupai	Line Macrocarpa trees parallel road (E/W) with four gaps where large trees blown over. Adjacent concrete power poles noticeable lean to south
15 A/B	Staff DSIR	Waitakere Rd, Kumeu	About 2 a.m. hail/wind 30 sec. Roaring sound before hail. Hail 2.5 cm and damage track about 1 km wide 0.3 marks/cm^2 on soft bark

APPENDIX 1

Category	Source	Damage site	Remarks or Observations
15 A/B continued			shelter trees. marks on north side only. Few of shelter trees broken off 4m above ground. Hail three times in 8 years, this worst
16 B	Staff San Marino Wines	Vineyeard between Waitakere Rd & Dysert lane	Severe hail damage Waitakere Rd side. hail lasted 1 min
17 B/C	Taupaki Flower Gardens	Taupaki Rd, 100 m north Nelson Rd	Light melting hail & little wind. Roaring sound. 500 panes glass replaced in Waitakere Rd and much damage in McEntree & Ameriens Rds
18 B/C	Western Stock Food Staff	Nelson Rd	Hail big as Golf Balls (4 cm) lasting 30 min. Window broken NW side shop
19 B/C	Grower	200 m north Western Stock Food	Hail for 3 minutes up to 20c size (2.8 cm). Strong wind gust with onset of hail. Severe hail damage Taupaki School in Cottles Rd
20 A	M. S. McGill	Waitakere Rd between Nelson & McEntree Rds	Line Macrocarpa trees parallel road with gaps where several large trees uprooted and blown over
21 C	Member of Public	Massey	No severe hail damage
22 B	E. Le Huquet Auckland Weather Centre		Frequent blue lightning to northwest in clump 2 a.m, 3 a.m moving away to south. Most vigorous concentrated display seen in 16 years in Auckland
23 C	ditto	Swanson	Fire Brigade rang about trees blown over and electric power failure
C	ditto	Titrangi	Call at 2.15 a.m about hail half size of golf balls, 2 cm

APPENDIX 1

Category	Source	Damage site	Remarks or Observations
24 C	NZ Herald newspaper 5 November	Waimauku Huapai, Kumeu Taupaki region	Nobilo Wines Station Rd., Huapai lost all grapes to hail
25 C	Auckland Star newspaper 6 November	Ditto	Quoting Mr B. Gunning MAF: Up to 100 growers on more 300 hectares suffered hail/wind damage. About $4,000,000 worth produce lost. Losses evenly divided between export and local markets

APPENDIX 2

New Zealand Herald photograph of Mr Ardern and remains of his glass house in Gilbransen Road on the morning of 4 November 1984.