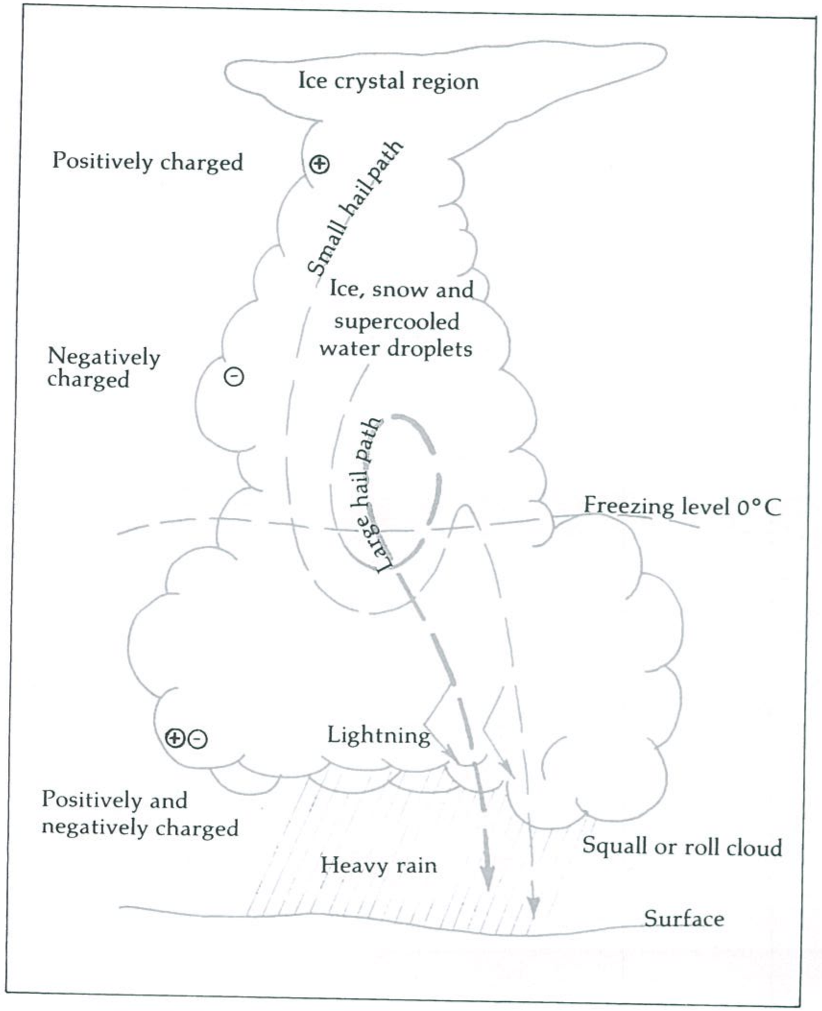
Water will fall from the cumulonimbus cloud in heavy raindrops, or even in frozen form as hailstones. New Zealand's western regions are more prone to thunder and hailstorms. Most places in Westland, Taranaki and Northland experience thunderstorms on 15 to 30 days a year, whereas most places east of the main ranges experience thunderstorms on only about three to five days a year. Severe hailstorms are more likely to occur in eastern districts on the afternoons of the warmer months of the year. The average number of severe hailstorms per year throughout New Zealand is nine, but this number can vary considerably from year to year.

Cumulonimbus cloud



NEW ZEALAND'S WEATHER PATTERNS

The great frontal systems sweeping towards us across the oceans are a major influence on our weather, but our rugged landscape also has a significant effect. At the coast, and over land, clouds are formed through mechanical turbulence, convection, and orographic ascent.

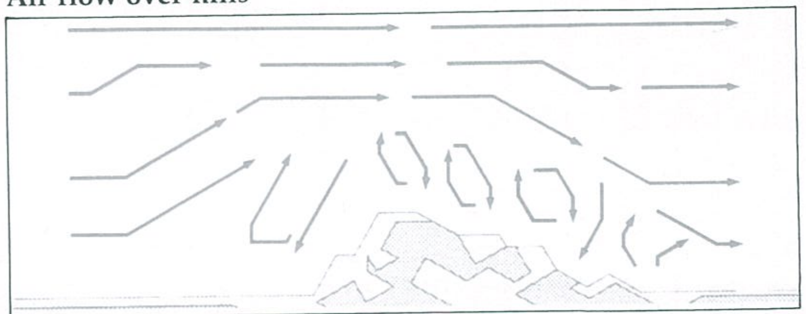
Mechanical turbulence occurs when air flows over the land and is disturbed by obstacles such as buildings, trees, and hills. At a specific point above the ground, water vapour from the turbulent air will condense to form a layer of stratocumulus cloud. Turbulence near Earth's surface can also produce ragged low clouds in the air beneath the main formation.

Convection is the term given to thermal turbulence, which occurs when air is heated by the land or sea. New Zealand's extensive coastal regions are obviously good breeding grounds for clouds formed by convection.

Orographic ascent occurs when moist air rises over a mountain range or barrier of hills. In general, orographic cloud forms continuously on the windward side of hills, but clears away on the lee side.

All these landscape-related processes influence the local climate in New Zealand's distinct weather regions.

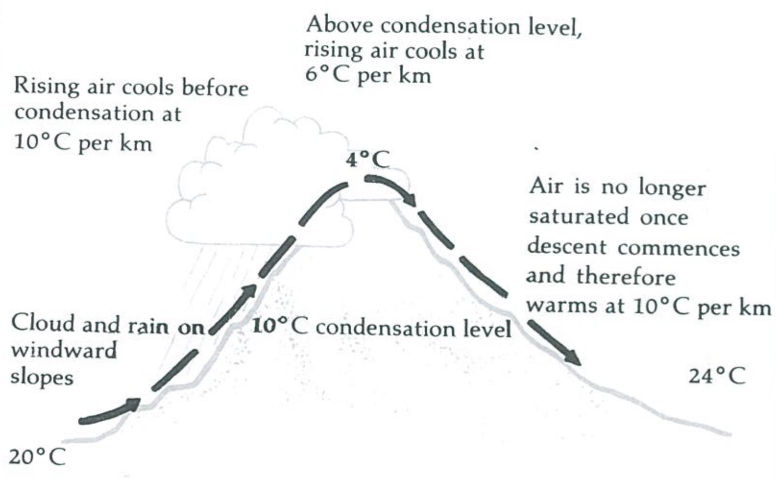
Air flow over hills



When it crosses hilly terrain the air flow becomes turbulent. The turbulence is caused by the presence of uneven terrain and the increased frictional drag

Air crossing a mountain range

Air is forced to rise as it crosses a mountain range such as the Southern Alps, then it cools and loses condensed moisture. Subsequently it is heated as it descends the slope



THE MOUNTAINS

The most striking feature of New Zealand's landscape is its mountainous character. Less than one-quarter of the country's land surface is below the 200-metre contour line.

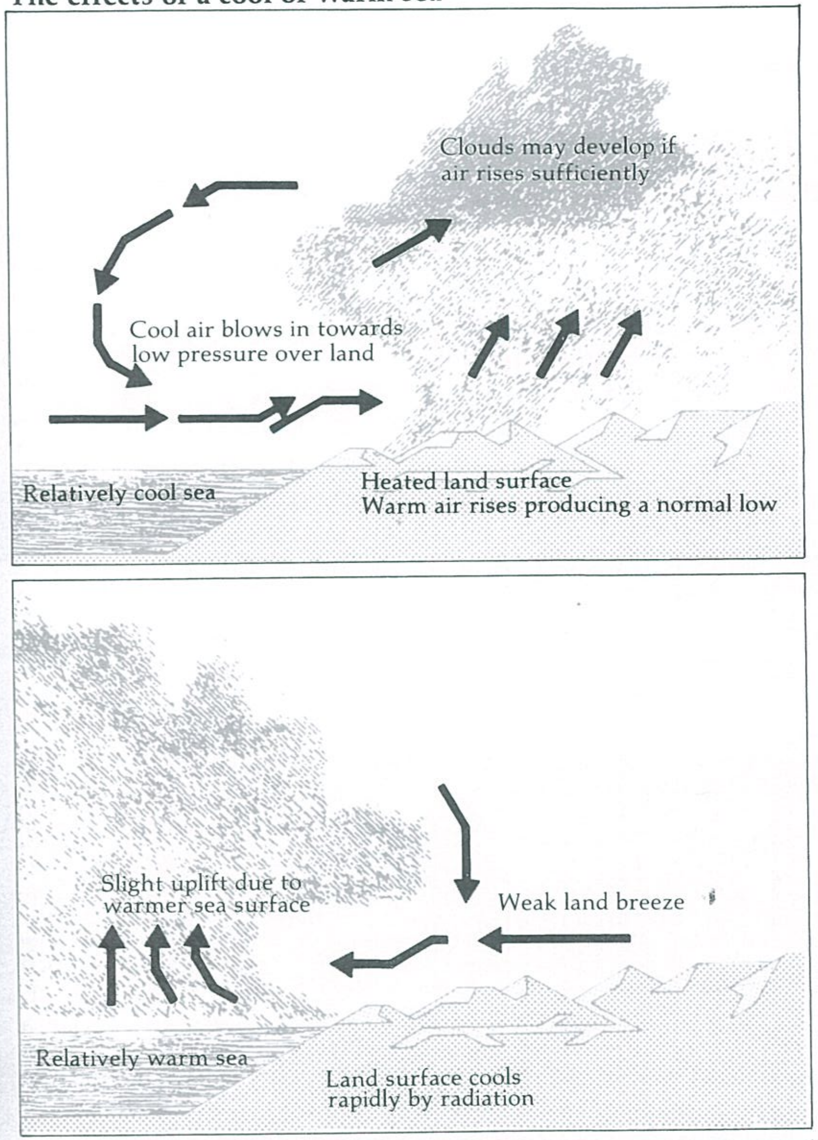
In the North Island, one-tenth of the land surface is occupied by mountains, most of which do not reach higher than 1800 metres, although the four volcanic peaks of Egmont, Ruapehu, Ngauruhoe, and Tongariro are considerably higher.

The South Island is much more mountainous. The massive chain of the Southern Alps runs almost the entire length of the island. There are at least 223 named peaks that reach over 2300 metres in altitude.

The chain of mountains extending from the southwest to northeast in the South Island is a great hurdle in the face of the prevailing westerly winds. This chain produces sharp contrasts in the weather on the west and east of New Zealand.

The blocking effect of the mountains blunts the westerlies as they encounter their uphill face. The main ranges of the South Island turn the great westerly winds towards the northeast, producing a southwesterly wind along the West Coast and regions west of the main ranges. North of

The effects of a cool or warm sea



The effects of cool or warm seas and the development of sea breezes are frequently experienced in New Zealand because of the country's extensive coastal regions. During the day, air heated over the warm land surface rises and is replaced by air from the sea. On a clear night the land becomes cooler than the sea. Air over the sea rises and is replaced by cooler air off the land

Taranaki, however, the general air flow is more southwesterly and there is a noticeable reduction in wind speed during summer.

The winds speed through the funnels of the mountain passes, and through Cook and Foveaux Straits between New Zealand's main islands.

Crossing the ranges of the Southern Alps, or speeding through Cook Strait (often at gale force in late spring and early summer), the wind swings again towards the southeast giving mainly northwesterly winds in the Cook Strait area and inland districts of the South Island.

In the lee of the mountain chain, a low pressure trough develops over the plains of the South Island. This draws in easterly sea breezes during the days of summer, augmented by the deflected flow southeastwards from Cook Strait. As a result, easterlies and northeasterlies are almost as common here as the prevailing southwesterlies slipping round the south of the South Island's mountain chain.

Our Southern Alps also produce another interesting weather effect: föhn wind. This is a warm dry wind flowing down the eastern slopes of the mountain ranges and out onto the foothills and plains. The process starts on the western side of the mountains as the air flows uphill, releasing latent heat during the process of cloud formation. The rain begins to fall, mainly in the west, so that the air descending in the east is drier. It then undergoes 'adiabatic' compression which warms it. The result: the air flow down the eastern slopes is warmer than it was travelling uphill on the western side of the alps.

TYPICAL WEATHER PATTERN IN NEW ZEALAND

A typical weather pattern in New Zealand will start with a low pressure trough approaching from the west. First, we feel the clockwise flow of air around the trough as a freshening northwesterly wind. The wind may reach gale force and rain may fall.

The passage of the trough across New Zealand is signalled by a change in the direction of the wind. A cold southwesterly or southerly wind indicates that the trailing edge of the clockwise circulation of air around the depression is now passing across the country. These winds will usually be accompanied by showery weather and, occasionally, hail and thunder.

The barometer will then begin to rise, signalling the arrival of the next anticyclone. The tropical anticyclone will stretch for some 1000 kilometres, east to west. As the anticyclone

prevails, winds will moderate and there will be fair weather for a few days, but sometimes this will be a period of low cloud and drizzle. Anticyclones generally pass over New Zealand at intervals of between three and seven days.

Most often the centres of the anticyclones will pass over the North Island, but some centres pass to the north or south of the country. Anticyclones will generally track north of New Zealand in spring and to the south in autumn and winter. Occasionally, anticyclones will appear well to the south of New Zealand when they are often associated with a slowly changing weather pattern.

Sometimes, vigorous tropical depressions will develop north of New Zealand. Some of our worst storms originate as tropical cyclones over the seas between Fiji and New Guinea from December to April. The effects of these tropical depressions range from several days of heavy rain to very heavy downpours and destructive gales over wide areas of the country.

THE RAIN PATTERN

Much of New Zealand has a rainfall of between 800 and 1600 millimetres per year. Areas which reach 1600 millimetres a year — mostly in the northern half of the North Island — are our most productive farmlands.

Our heaviest rainfalls occur in the mountain ranges and in the west of the South Island. The Hokitika Catchment on the West Coast is one of our rainiest areas in any given year. One recording station in this area has reported an average annual fall of 8180 millimetres of rain.

Most areas of New Zealand have periods without any significant rainfall. These dry periods occur in most summers in Gisborne, Hawke's Bay, Wairarapa, Nelson, and Marlborough, over a large part of the Canterbury Plains, and over most of lowland Otago (except for the far west and south). A small part of Central Otago receives the least annual rainfall, only 350 millimetres a year.

The southwest of New Zealand has the least variable rainfall pattern, while the most variable pattern is found in the east and the north. Over most of northern and central New Zealand, more rain falls in winter than in summer with winter rainfall in the north being almost double the summer level. In much of the southern half of the South Island, however, winter is the season of least rainfall. Afternoon or evening 'summer showers' are the major factor in this seasonal rainfall pattern.

New Zealand's rainfall distribution

There are more than 200 rain days (days with at least 1 millimetre of rain) in the southwest of the South Island and Stewart Island. Other western and southwestern regions record an average of 175 rain days a year. There are 150 rain days in much of the North Island, but in some places east of the ranges the annual average drops to 125 rain days a year.

THE SUNSHINE PATTERN

In New Zealand's summer, there is very little difference in the amount of solar radiation reaching the various districts of the country. For instance, in January Invercargill receives only 5 percent less solar radiation than that being absorbed in Auckland.

In winter, however, there are major differences. Invercargill will record about only half as much solar radiation as Auckland — about a sixth of its January level.

The sunniest parts of New Zealand are Nelson and Marlborough, averaging around 2400 hours of sunshine a year. Districts that could be rated as 'sunny' (averaging over 2200 hours of sunshine a year) are the Bay of Plenty, Hawke's Bay, a few inland areas of South Canterbury, and Central Otago. In view of its reputation for rain it is worth noting that the West Coast of the South Island records 1900 hours of sunshine a year on average — much more than Southland's typical total of 1600 hours.

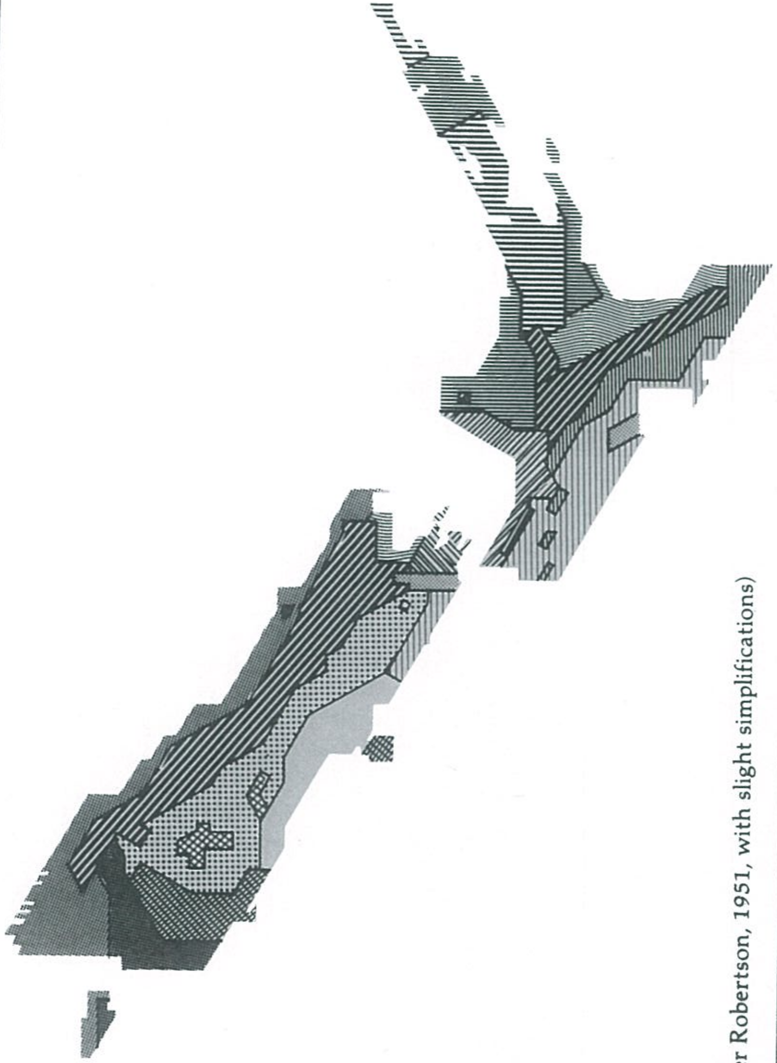
THE TEMPERATURE PATTERN

New Zealand's mean annual temperature at sea level ranges from more than 15°C in Northland to less than 10°C in Southland.

Winter and summer produce quite small temperature variations in the west and southwestern coastal districts (7°C to 9°C) but inland and east of the ranges the summer/winter variation is much greater (11°C to 14°C).

Our coldest month is usually July. The warmest temperatures occur in January and February.

Major climate types in New Zealand



(after Robertson, 1951, with slight simplifications)

Key

A. Warm humid summers, mild winters. Annual rainfall 1100-1500 mm, with maximum in winter. Prevailing wind SW, but occasional strong gales and heavy rains from E or NE from Auckland northwards and about Coromandel

A2. Similar to type A but much wetter. Rainfall 1500-2500 mm

B. Sunny rather sheltered areas which receive rains of very high intensity at times from NE and N. Very warm summers and mild winters. Annual rainfall 1000-1500 mm with winter maximum

C. Very warm summers; day temperatures occasionally rise above 32°C with dry föhn NW wind blowing. Rainfall 1000-1500 mm per annum; marked decrease in amount and reliability of rain in spring and summer, moderate winter temperatures with maximum rainfall in this season

C0. Drier than type C; rainfall 650-900 mm. Very sunny

C2. Cooler and wetter hill climates. Very heavy rains at times from S or SE; annual rainfall mainly 1500-2000 mm

D. W to NW winds prevail with relatively frequent gales. Mean annual rainfall 900-1250 mm. Rainfall reliable and evenly distributed throughout the year. Warm summers, mild winters

D2. Wetter than type D; rainfall 1250-2000 mm

E. Mild temperatures, high rainfall increasing rapidly inland with height; minimum rainfall in winter, especially in the south. Prevailing winds SW but gales not frequent at low levels in spite of exposed coastline

F. Low rainfall — 600-750 mm; in the south slightly more in summer than in other seasons. Warm summers with occasional hot föhn northwesterlies giving temperatures above 32°C. Cool winters with frequent frosts and occasional light snowfalls. Prevailing winds NE near the coast, NW inland

F2. Cooler and wetter hill climates; rainfall 750-1500 mm. NW winds prevail with occasional very strong gales, especially along river courses. Snow may lie for weeks in winter

F0. Semi-arid areas; rainfall 330-500 mm. Very warm dry summers; cold winters

G. Warm summers, cool winters. Rainfall 650-900 mm, evenly distributed except for slight falling off in winter

G2. Wetter and slightly cooler than G climate; rainfall 900-1250 mm; in coastal districts cloudy, windy conditions and frequent showers

H. High rainfall; mountain climate

6 Weather forecasts

The forecast map—prognosis

In Chapter 3, reference was made to the forecast weather map, or prognosis. This map shows the expected appearance of weather systems at certain times in the future; for instance in 24 or 48 hours. They are a vital step in the preparation of weather forecasts presented on radio, television and in newspapers. A description is given in Chapter 7 of the role that computers and the numerical weather prediction process play in the preparation of both forecast maps and weather forecasts.

Once the prognosis shows the expected type, intensity and location of weather systems, it is possible to make forecasts of the wind, cloud cover, precipitation and temperature.

Influence of topography on weather systems

The larger weather systems, e.g. anticyclones, ridges, lows, and troughs, change little as they cross the mountains. However, the weather (surface wind, cloud, precipitation, and temperature) associated with them is affected, especially when the wind blows across the range of mountains or hills. These effects are shown in Figs 12 and 17.

Fronts are affected, particularly immediately after they have crossed a mountain range. In simple terms, the front is carried across the range by the wind, and the effect on the cloud, precipitation, and temperature is similar to that shown in Fig. 17. For example, the cloud and precipitation in the front increase as it arrives at the range; once the front has crossed the range, both cloud and precipitation decrease again, becoming less than they were originally, and the temperature rises.

Many of the fronts which cross New Zealand come from the west. Consequently, eastern districts of both islands receive much less cloud and precipitation from these fronts, than do districts west of the mountains. Often the conditions experienced in the east depend on the direction of the surface wind after a front has passed by. Two typical situations are shown in Fig. 32/33. The top map and cross-section show what happens when the wind following the front reaches eastern districts after crossing the mountains: skies there tend to contain little cloud, and showers are confined to western districts. In the east, all that remains of the frontal cloud band is the part above the altitude of the mountain tops, and precipitation from this cloud does not always reach the ground. The föhn effect means that, even after the front has passed, conditions continue mild or even warm in eastern regions.

Conditions are different when the surface wind following the front reaches eastern districts without having first crossed the mountains, as shown in the bottom map and cross-section. However, this difference is confined to the lower troposphere. Winds aloft behind the front continue to cross the mountains before reaching the east coast, as they did in the previous situation, and conditions there are similar to those in that example. But, near the surface the air has not been dried out and warmed by passage over the mountains, and is moist and cool enough for some low

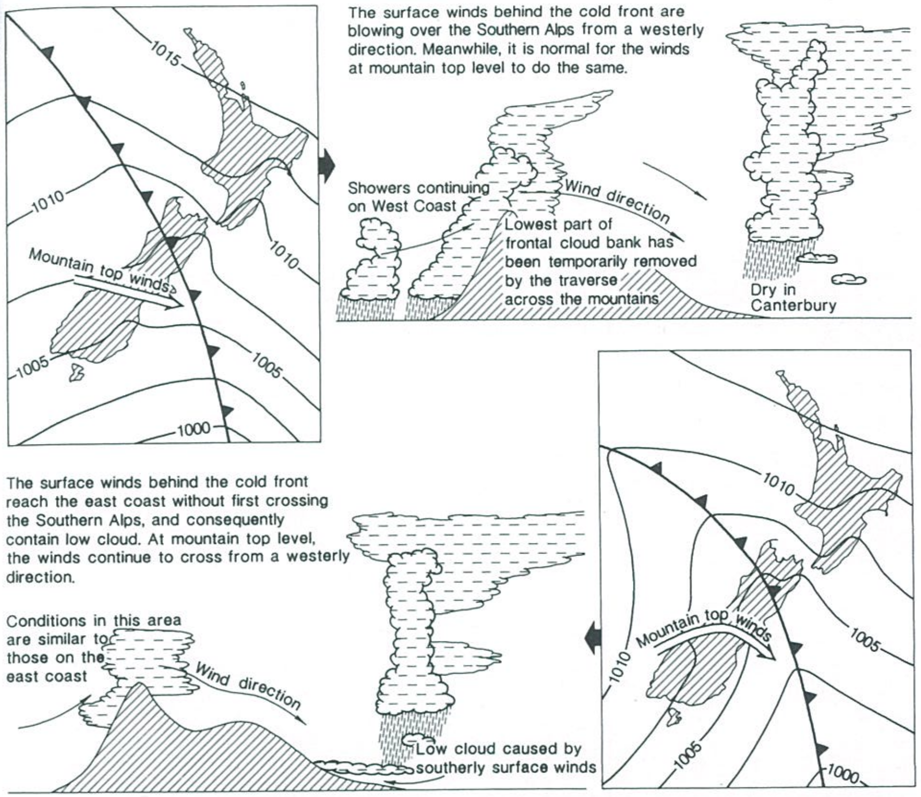


Fig. 32/33. The effect of a mountain range—the Southern Alps—on weather conditions. Cross-sections show what happens when the surface wind behind a cold front reaches the east coast from across the ranges (top 32), and from across the sea (bottom 33).

cloud. Typically the leading edge of the cloud forms a horizontal line at the wind change, similar to that shown in Fig. 34, and is called a *roll cloud*. Sometimes it is accompanied by a violent squall—a major hazard to small boats caught at sea. In both situations, after the front moves offshore and away from the influence of the mountains, the missing lower part re-forms and the front again develops the characteristic pattern shown in Fig. 20.

Features such as major thunderstorms, that cross the mountains, are affected in a similar manner to fronts; their upper parts travel on beyond the ranges, while their lower parts tend to be dissipated. Smaller systems, such as showers of more modest size, do not get beyond the mountains, although they may survive a passage across lower hills.

Another sort of topographical effect takes place when the air is stable, is forced to cross over a mountain range, and produces bands of 'lee-wave' clouds, as shown in Fig. 19. In favourable conditions, extensive regions of lee-wave clouds develop downwind from mountain ranges, as shown in the satellite picture in Fig. 35.

However it must be remembered that the descriptions given here deal with only a single range of mountains or line of hills. In reality New Zealand's topography is much more complex: in places there is a succession of ranges and hills, in others there are spur ranges that radiate out at a variety of angles from the main mountain chain. These result in very complex patterns of weather modification due to topography.

Predictability of weather systems

There is a rough relationship between the lifetime of a weather system and its size. In general, the smaller the system, the shorter its lifetime from formation to disappearance. This is shown schematically in Fig. 36. A large system, like a depression 1000 km or so across, lives about a week. During this time it continually evolves, going through a process of birth, growth, maturity, decay and death. A

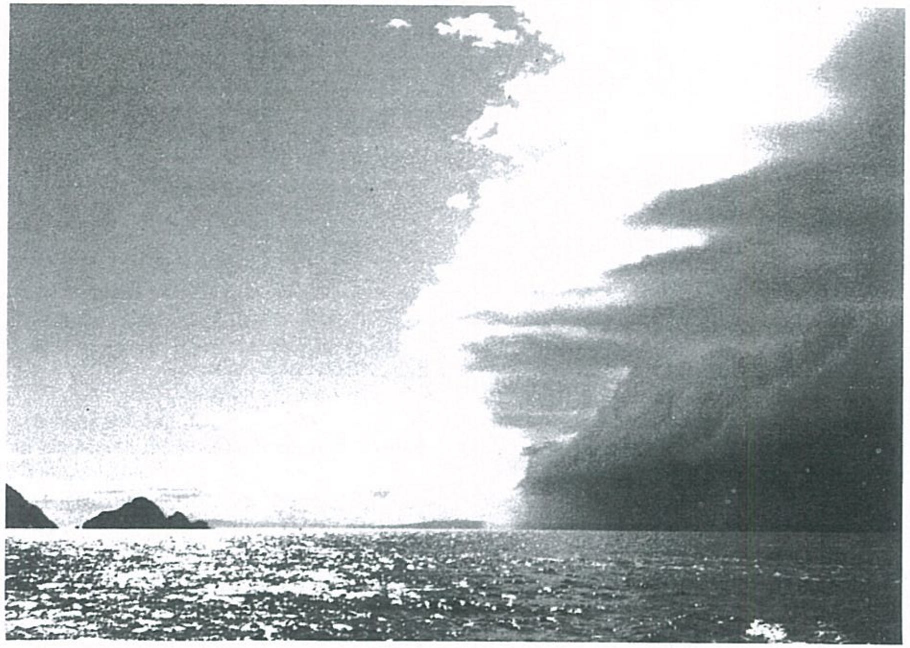


Fig. 34. A roll cloud beneath a more exensive layer of stratiform cloud. Destructive squalls sometimes accompany a roll cloud, which marks the onset of advancing colder air.

Fig. 35. Photograph taken by the NOAA 7 orbiting satellite on 29 March 1983, showing bands of lee wave clouds generated by a north-westerly flow over the North Island.

major thunderstorm—one that gives localised damaging hailstorms—is about 100 km across, and has a lifespan of five to ten hours. A much smaller shower, 5 km across, exists for only a few hours; while a tornado, 200 metres in diameter, lives ten to thirty minutes from formation to dissipation.

This relationship is very important when it comes to making weather forecasts. It is much more difficult to predict exactly when and where a new weather system, e.g. a depression, a thunderstorm, or a tornado will develop, than it is to forecast what it will do once it has developed and its location has been detected by weather observations.

The size of a large system means that its existence is soon detected, except in regions devoid of observations. However, the formation of a small system can

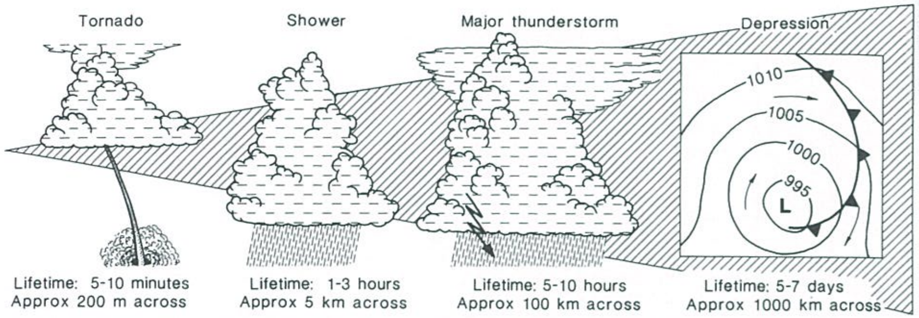


Fig. 36. In general, the smaller a weather system, the shorter its lifetime. This is illustrated by the four examples given in this figure.

remain undetected for much, if not all, its lifetime. For instance, even large thunderstorm systems are often detected too late in their lifetime for useful forecasts to be made of their dying stages. The prediction of New Zealand's rare tornadoes is just not feasible—they are too small, and last for too short a time.

It is unfortunate that these very difficult (or impossible) to predict systems bring some of the most violent weather phenomena—tornadoes, severe thunderstorms, damaging hail, cloudbursts—which leave a lasting impression on the public.

Interaction between systems

While it is difficult, or even impossible, to predict individual smaller weather systems, such as a particular shower, it is feasible to forecast showery weather, i.e. the smaller systems are predictable en masse, but not as individuals. This is because weather systems are not independent; they react with one another. In particular, larger systems provide the environment within which smaller ones can, or can not, develop. Occasionally the smaller ones manage to greatly influence the larger ones.

The pattern of wind, temperature and humidity within a large system creates areas with different environmental conditions, each of which favours the development of certain types of smaller systems, while inhibiting others. For example, in the depression shown in Fig. 29 (a), the pattern favours the development of large cumulonimbus clouds behind the cold front, while in the depression shown in Fig. 29 (c), the pattern inhibits their formation behind the front.

Since the larger systems are (reasonably) predictable, as are the environments they create, the smaller systems can be forecast as a group.

During the longer lifetime of the larger system, many smaller ones have time to complete their life cycles. Also, at any particular time, a number of smaller systems coexist, though at different stages of development. Fig. 28 provides an example in which the larger system is the cold front, and the smaller systems are the 'blobs' (or cells) of precipitation (some merging into one another), each evolving from birth to decay within the front.

Occasionally, particular favourable environmental conditions allow a smaller system to intensify and grow so much, that it alters the environmental conditions and greatly affects the evolution of the larger system within which it formed.

Forecast accuracy

Forecasts are sometimes incorrect; despite the very great advances that have recently been made in meteorology—namely, the use of computers, and the operation of meteorological satellites. There are many reasons why this is so. Major obstacles to accurate forecasts include fundamental things such as too few detailed weather observations, and lack of full understanding of the physical processes that occur in weather systems, particularly when active cumuliform clouds are involved.

There are two reasons in particular why a forecast may be incorrect: one is incorrect timing of events; the other is difficulty of forecasting exactly where a new weather system will form. As regards the former, while the sequence of weather changes is often forecast correctly, it sometimes happens either slower or faster than forecast. This error is magnified when an extended range forecast is being prepared. In Fig. 37 the forecast map (dashed) for the fifth day of such a forecast shows a trough crossing to the east of New Zealand. If this trough moves only 8 km/hr (5 knots) slower than forecast, the actual map on the fifth day will be as shown by the continuous lines. Therefore there will be mild north-westerly winds, instead of the forecast of cold south-westerlies.

The second difficulty is forecasting exactly where a new weather system will form. This is illustrated in Fig. 38, where the forecaster is quite confident that a depression will form in a trough as it crosses New Zealand, but is much less certain of exactly where—any of the three situations shown in the figure could occur. In many parts of New Zealand, the weather will vary considerably depending on which situation

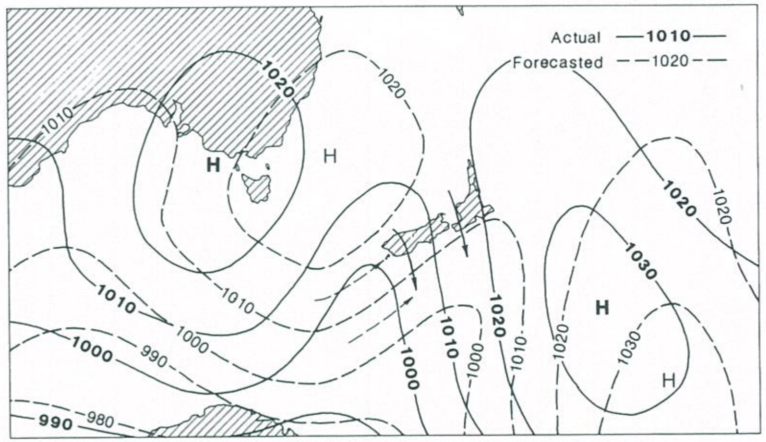


Fig. 37. A weather map showing how, by overestimating the eastward speed of a trough by 8 km/hr, there are mild north-westerlies (actual) over New Zealand in five day's time instead of cold south-westerlies (forecasted).

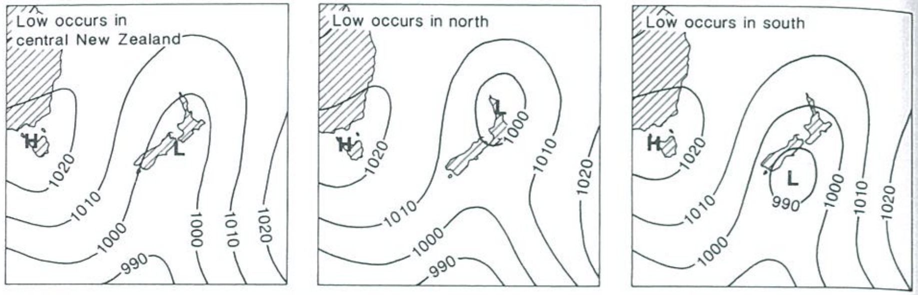


Fig. 38. Weather maps showing three different isobar patterns when a depression forms somewhere within a trough over New Zealand.

actually occurs. For instance, in the Wairarapa, the first situation (left hand map) would give light winds and showery weather; the second (centre) cool easterlies and persistent rain; and the third (right), warm north-westerlies and dry weather.

Most forecasts for the public contain predictions of wind, cloudiness, precipitation, and temperature. Over the past decade forecasts of wind and temperature have increased in accuracy more rapidly than have forecasts of precipitation. The slower rate of improvement is unfortunate because, for many people, rainfall prediction has top priority.

It is difficult to measure the accuracy of some forecasts. However, when the forecast gives the value of a weather element at a specified place and time, it can be checked precisely against the observed value. An example of this is 'today's maximum temperature in Napier is expected to be 24°C.' With all the uncertainties in current forecasting methods, it is unrealistic to expect the forecast to be exactly correct to within a degree. A tolerance of 2°C is more reasonable, i.e. an actual maximum of between 22 and 26°C is counted as correct. On this basis, a recent evaluation of the accuracy of maximum temperature forecasts for 'today' shows that 84 per cent are correct, and that 77 per cent of forecasts of tomorrow's maximum are correct.

Most public forecasts are not this precise, and use descriptive terms such as *fine, occasional rain, fresh westerlies* etc. Also many forecasts refer to a district, and times of occurrence are in general terms, e.g. in the afternoon. All this makes estimating the accuracy of the forecasts difficult, and moreover it is not easy to specify how much tolerance is allowable before the forecast is counted as incorrect.

Nevertheless, within broad guidelines, some of these forecasts have been marked by weather observers throughout New Zealand. Results show that 70 to 80 per cent of forecasts are reasonably accurate—a percentage similar to that found in overseas countries whose geographic situation and technological development are akin to those of New Zealand.

While considering the accuracy of forecasts, it is worth commenting on the effect caused by the smaller number of stations in New Zealand which make weather observations at night. It means that the first forecasts issued each day are based on

less detailed knowledge of the weather systems involved, than is the case after about 7 a.m. and may be less accurate.

Weather forecasts prepared by the Meteorological Service are issued from three offices. Forecasts for domestic aviation are issued by the Aviation Forecast Unit at Wellington Airport, and those for military activities by the Defence Forecast Unit at Whenuapai. Kelburn, Wellington which is the largest of the three, issues forecasts and warnings for the general public, international aviation, and marine activities in the south-western Pacific.

During the last five years there has been a change in the way weather forecasting has been financed in New Zealand. Prior to that time all weather forecasts were provided free of charge. However a change in Government policy towards 'user pays' has meant that users pay for most forecasts. Now the Government funds only the preparation and issue of warnings of weather which might affect human life and property, a basic forecast service, and marine forecasts. Among those who must pay for their forecasts are pilots, radio stations and newspapers.

The growth of commercialisation of weather forecasting has seen the establishment of a number of competitors for the Meteorological Service. Among these is the Christchurch company Blue Skies which provides forecasts to most newspapers, skifields and the farming community.