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PHYSICAL ENVIRONMENT

METEOROLOGY IN VICTORIA

From earliest times man has been vitally interested in the weather because of its effect on his crops, his travel, and, in modern times, his industry and his leisure activities. All weather phenomena derive from the atmosphere which surrounds the earth, and the science of meteorology is the study of the atmosphere and its behaviour.

General factors

The atmosphere

The atmosphere consists of a mixture of gases, all of which, with one exception, remain in the gaseous phase under the natural conditions of temperature and pressure found on earth. The exception is water vapour, which undergoes constant changes of phase from gas to liquid to solid and vice versa. Although present only to a maximum of 2 to 3 per cent in the atmosphere, it is responsible for almost all weather phenomena, including cloud, rain, fog, hail, and snow. Carbon dioxide, which is present in the atmosphere only to the extent of about 0.03 per cent, is also important because it is transparent to solar radiation reaching the earth but opaque to radiation leaving the earth. An increase in the amount of carbon dioxide could lead to a new balance of radiation reaching and leaving the earth, and to higher temperatures at the earth's surface.

The atmosphere exerts a pressure which, at any one place, is due to the weight of the air above it. The pressure at mean sea level normally varies between about 900 mb and 1,040 mb. The extremes recorded are 877 mb in a typhoon off Guam and 1,079 mb at Barnaul in the Altai territory of Russia in winter. Pressure decreases with height; at 6,000 metres it is only half that at mean sea level, and at 17,000 metres it is only one tenth.

Motion in the atmosphere is caused by the heat energy received from the sun. Over the earth as a whole there is a balance between the radiation received from the sun and that emitted by the earth. However, the equatorial region absorbs more heat than it loses, while the polar zones give off more heat than they receive. The warm air of the equatorial region, being less dense, rises and flows towards the poles in the higher levels, while the colder air at the poles flows towards the equator at the surface. This simple circulation pattern is made very complicated by the rotation of the earth. In the lower levels of the atmosphere vortices are formed in the temperate zones of the earth, while in the higher levels of the atmosphere belts of strong,

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generally westerly, winds are formed. These upper westerlies have the effect of steering the lower vortices, i.e., the depressions and anticyclones, in a generally west to east direction. The atmospheric circulation is further complicated because the surface of the earth is not uniform. High mountain ranges, such as the Andes and Himalayas, disturb the atmospheric flow. Land surfaces become warmer in summer and colder in winter than the adjoining oceans. Over the great land masses of the northern hemisphere intense anticyclones develop in winter, to be replaced by large low pressure systems in summer. In the southern hemisphere, where four fifths of the surface is covered by ocean, this effect is less marked. However, over Australia there is still a tendency for anticyclones to be centred over the continent in winter, and low pressure systems to appear there in summer.

In the southern hemisphere air spirals outwards in an anticlockwise direction from an anticyclone or centre of high pressure. This outward moving air is replaced at the centre of the anticyclone by descending air. As air descends it becomes warmer and clouds evaporate, and so anticyclones are usually associated with dry and clear weather. The reverse occurs with a depression. Air spirals inward, in a clockwise direction in the southern hemisphere, towards the centre of low pressure. Air at the centre rises and becomes cooler, so that moisture in the atmosphere condenses as cloud and may fall as rain. Thus depressions are often associated with cloudy, wet weather. This is a generalised picture; many anticyclones have extensive clouds, many depressions bring little or no rain. It is the assessment of the nature of these depressions and anticyclones, and of their development, movement, and decay, which makes the prediction of the weather such a difficult, exacting, and, at times, frustrating task.

Prediction problem

From ancient times man has attempted to predict the weather. Usually local phenomena were used as guides to prediction and many rough rules have passed into our folklore. A scientific approach only became possible in the nineteenth century when the electric telegraph allowed meteorological observations from a large area to be gathered quickly at a central point for analysis. Anticyclones and depressions were found to maintain their identity for several days, and forecasts were based on the prediction of the movement of these features of the atmospheric circulation. By the end of the nineteenth century the mathematical treatment of fluid dynamics was well developed and it was possible to formulate the equations governing the motion of a mixture of gases (one continually changing phase) held by gravity to a rotating sphere and heated by external radiation. The difficulties lay in knowing the initial state of the atmosphere over the whole earth in sufficient detail, and in solving the equations in time to make a useful forecast for the next 24 hours. The first of these difficulties is now being tackled by means of satellites, drifting balloons, and buoys. The second is being overcome by the development of powerful electronic computers. The international programmes of the Global Atmospheric Research Programme and World Weather Watch are designed to improve the observation and prediction of global weather. The three World Meteorological Centres of the World Weather Watch are in Washington, Moscow, and Melbourne.

The advances in the scientific, mathematical treatment of the atmosphere have made it imperative that meteorologists should be professionally trained.

Meteorologists have at least a Bachelor of Science degree or its equivalent, with a sound knowledge of thermodynamics and mathematics. The Bureau of Meteorology provides postgraduate training in meteorology for meteorologists in its employment and also for graduates from south-east Asian countries under the Colombo Plan. There is also a School of Meteorology at the University of Melbourne. Not all meteorologists are employed in forecasting duties; many are occupied with the statistical treatment of data, the planning of instrumental and observational programmes, and with research. Meteorologists engaged in research are also employed in the C.S.I.R.O. Division of Atmospheric Physics at Aspendale, and in the Commonwealth Meteorological Research Centre, which is a joint agency of the Bureau of Meteorology and the C.S.I.R.O. Division of Atmospheric Physics.

History of meteorology in Victoria

Meteorological observations began in Melbourne in 1840, but as the exact type of instruments used and their exposure are not known, the results are not accepted as part of the official record. Following Separation in 1851 observations ceased, but were resumed in 1855 by the Lands Department. Stations were established at Melbourne and some twenty places in different districts of the Colony. In 1858 Professor G. Neumayer began 5 years of hourly observations in Melbourne, and in 1859 all meteorological stations in the Colony were placed under his control. In 1863 the elements were regularly observed at eight stations, namely, Melbourne, Ararat, Ballarat, Bendigo, Cape Otway, Gabo Island, Port Albert, and Portland, and there were 24 other stations where rainfall alone was measured. Following Professor Neumayer's return to Europe, control of meteorological observations passed to the Astronomical Observatory, which continued this work until 1907.

In 1875 the Melbourne Observatory began issuing a daily bulletin of telegraphic reports, from which the public could learn the existing weather over the State. The first Australian Meteorological Conference was held in Sydney in 1879, followed by a second in Melbourne in 1881. At the latter Conference the heads of the colonial weather departments of Victoria, New South Wales, South Australia, and New Zealand agreed upon the interchange of daily weather information. The other colonies joined the scheme, and from 1881 a weather chart was prepared by the Melbourne Observatory each day, Sunday excepted, and copies were posted at a number of public places in the city. Synopses of the weather over Australia and forecasts for Victoria accompanied the chart, while forecasts began to be published in the newspapers each day.

On 1 January 1908 the Australian Government took control of the meteorological services in the various States. The advent of wireless has enabled ships to be informed of the latest weather forecast, while the introduction of broadcasting to the general public has enabled forecasts and warnings to be communicated rapidly.

The number of observing stations has steadily increased, and in 1972 there were over 1,000 current rainfall stations in Victoria, of which over 100 measure temperature and humidity as well as other elements. There are more than 300 stations where rainfall records have been kept for more than 70 years. These records, for the most part, are the results of the gratuitous work of many hundreds of voluntary observers. These observers were government officials (e.g., postmasters, school teachers, policemen, lighthouse-keepers), or graziers, farmers, and other people in private employment.

Winds in the upper atmosphere can be measured by means of a free hydrogen balloon tracked by means of a theodolite. Balloon flights began in Melbourne in 1921, and at Mildura and East Sale during the Second World War. The measurement of temperatures in the upper air proved more difficult. In the 1930s an aeroplane flew daily from Point Cook, measuring the temperature and humidity each thousand feet as it climbed. But it was not until the development of the radiosonde, an electronic device which automatically transmits by radio its observations to a ground station, that satisfactory operational measurements could be made. Since 1935 more and more use has been made of radiosondes; observations up to heights of 20 to 30 km can be obtained. Throughout the world about 600 radiosonde stations record this data every 12 hours, while winds in the upper air are observed every 6 hours. The first regular radiosonde flights in Victoria began at Laverton in 1943. Radar enables balloons to be tracked in all conditions, whereas visual tracking by theodolites is limited by cloud. Radar has the additional facility of detecting rain. A wind finding radar was first installed at Laverton in 1949 and another was placed at Mildura in 1963, while a large radar, capable of measuring rainfall intensity, was installed in the Melbourne office in 1964, with dual control and display at the University of Melbourne.

Until 1939 forecasts in Australia were prepared on the basis of reports received at 9 a.m., with a very limited network of observations at 3 p.m. In April of that year reporting networks were established for 6 a.m. and mid-day. Further extension in the following years led to the present system of reports every 3 hours except midnight on every day of the year, while forecasts are prepared for the public four times a day and for shipping twice a day. Throughout the world, observations are made by 10,000 surface stations every 3 or 6 hours, and every 30 minutes at major airports.

The development of aviation led to a demand for detailed forecasts for aeroplane flights. A meteorological office was opened at Essendon Airport in 1937, and offices were established during the Second World War at Laverton, East Sale, and Mildura ; the two former at Royal Australian Air Force bases. The rapid increase in the use of light aircraft led to another office being opened at Moorabbin Airport in 1968. A meteorological office was opened at Melbourne Airport (Tullamarine) in 1970. Since 1973 forecasts for both aeronautical and general purposes in Victoria have been issued from the centralised Regional Forecasting Centre in Melbourne.

Throughout Australia the Bureau of Meteorology employs a full-time staff of about 2,000 persons of whom half are forecasters, observers, or briefing officers. These are assisted by a force of about 9,000 part-time or volunteer observers.

Climate of Victoria

Victoria is situated between latitudes 35°S and 39°S, on the south-eastern side of the Australian continent. The major topographical determinant of the climate is the Great Dividing Range, running east-west across the State and varying in elevation from about 500 metres to nearly 2,000 metres. This acts as a barrier to the moist south-east to south-west winds, causing the south of the State to receive more rain than the north. To the south of Victoria, except for Tasmania and its islands, there is no land for 3,000 km. This vast area of ocean has a moderating influence on Victoria's climate in winter. Snow, which is a common winter occurrence at similar latitudes on the edge of the great land masses of the northern hemisphere, e.g., Washington and Tientsin, is rare in Victoria below elevations of 600 metres. To the north of Victoria, the land mass of Australia becomes very hot in the summer, and on several days at this time of the year the temperature over the State may rise to between 35°C and 40°C, often with a strong northerly wind.

Victoria lies on the northern side of the belt of travelling depressions, which are at their farthest north in winter. Westerly winds prevail over the State at this season, and the rainfall in most districts is higher in winter and spring than in other seasons. This effect is most marked in the south-west quarter of the State. In summer, when the southern depressions are further south, Victoria is more dominated by anticyclones. Disturbances in the easterlies on the northern side of these anticyclones, often associated with moist air from the northern Tasman Sea, can bring considerable rain in summer, particularly to the eastern half of the State. However, these disturbances are not as regular as those in the westerlies, and summer rainfall is far more variable than that of winter. Depressions sometimes form off the New South Wales coast and move south. When centred off Gabo Island heavy rain can result in eastern Gippsland. There is no preferred time of year for this occurrence.

There can be large departures from the generalised picture presented above. Westerlies can reach Victoria in the summer months, and on some occasions cold south-westerly winds and showers can prevail in summer. Anticyclones frequently move over Victoria, or to the south of Victoria in winter, bringing spells of frost or fog. On rare occasions, disturbances in the easterlies can bring rain to Victoria in the cooler months of the year. This article describes the rarer weather events which cause extremes of rainfall, temperature, and wind in Victoria.

Meteorological phenomena

Rain

Rain is produced by the ascent and cooling of moist air. The amount of water vapour which can be present in the air depends on the air temperature; the warmer the air, the more water vapour it can hold. As moist air rises it becomes cooler, until eventually it becomes saturated. Further ascent and cooling causes the water vapour to condense out as tiny droplets, which become visible as clouds. As further ascent goes on, the clouds become thicker and the droplets coalesce, eventually falling to the ground as rain.

The causes and rates of ascent of moist air are varied. When air rises in the centre of a depression widespread cloud and rain may result. A cold front, which is a boundary of advancing cold air undercutting warm moist air and forcing it to rise, usually causes rain of a showery nature. A warm front, where advancing warm air rises over cold air, usually produces widespread cloud and prolonged rain. On warm days direct solar heating of the ground, and hence the lower layers of air, may be sufficient to cause the air to ascend, with resulting showers.

Water drops must acquire a diameter of well over 0.1 mm, even in humid air, if they are to resist evaporation and arrive at the ground. Raindrops have a diameter of more than 0.5 mm, but drizzle is made up of drops of smaller size. The size of raindrops depends on the rate of ascent of the air. If ascent is very rapid, as in a large cumulus cloud, the average diameter may exceed 1 mm before being able to fall to the ground against the rising air currents. If the diameter of a raindrop is greater than 5.5 mm the drop breaks into smaller ones as it falls through the air.

The intensity of the rainfall depends not only on the rate of ascent of the air, but also on the moisture content of the air. The highest moisture content is found in the warm air of the tropics and high rainfall intensities are observed in this region. Tropical cyclones cause very heavy rain, and where they affect a coast with a nearby mountain range which further forces the ascent of the onshore wind, extreme falls result. The highest rainfall ever recorded for a 24 hour period is 1,870 mm, which fell at Cilaos, Ile de Réunion (near Mauritius in the Indian Ocean), on 15-16 March 1952.

The most common causes of rain in Victoria are cold fronts. These are associated with the depressions that travel over the ocean to the south of Australia. The amount of rain which a cold front causes depends on its intensity and speed of movement, and also on the characteristics of the air ahead of, and behind, it. Most frequently cold fronts cause showers, particularly in the cold air behind them, but sometimes they cause a period of two to three hours of steady rain; occasionally they may pass with little more than a band of cloud. Warm fronts are very rare in Victoria; they are characterised by a prolonged period of rain followed by a rapid clearance and a rise in temperature.

Prolonged heavy rain in Victoria is most often caused by the development of a depression over the State. Not all depressions which affect Victoria have travelled from distant parts; it may happen that a depression actually forms over the State. If, before the development, the air over the State has been very warm and humid, thus holding a considerable amount of water vapour, the rain can be very heavy. As the depression develops, the pressure falls near its centre, and strong to gale force winds occur along with the rain.

Some examples of heavy rainstorms in Victoria since 1910 are described below.

Areas other than eastern Gippsland

March 1910 A depression formed in a trough extending from northern Australia to Victoria. On 5 March very heavy rain fell over a large area of the western Wimmera and Mallee; 200 mm fell in the Yanac area and 141 mm at Bleak House (both near Nhill), and 127 mm fell at Jeparit.

February 1911 Early in the month an extensive trough extended south to Victoria from northern Australia, bringing moist tropical air over the State. During the period 5 to 11 February thunderstorms with rain of a phenomenal character occurred daily in the Mallee and the Wimmera, and in the northern districts. Floods were caused at many places and considerable damage occurred to grain stacks and orchards. At Nyah 230 mm fell in 3 days and in the same period Glenorchy recorded 196 mm, Birchip 183 mm, and Ultima 177 mm. Further heavy rain with violent thunderstorms occurred in the first week of March, mainly in the central and Gippsland districts.

September 1916 For 8 days before 20 September a large anticyclone persisted over the Tasman Sea. Moist air from the Coral Sea was brought southwards over eastern Australia as far as Victoria. On 20 September a trough began to form over the Northern Territory, and by 22 September it extended south to Victoria. A depression then formed in this trough, and moved off the east coast of Australia, remaining in this area until 27 September. Rain fell throughout Victoria on most days from 21 to 27 September. Steady rain began in Melbourne at 9.30 p.m. on 21 September, and continued without a break for 63 hours, in which time 130 mm fell. The heaviest rain fell in the central and north central districts. In three days 210 mm fell at Mt Macedon, 165 mm at Kyneton, and 159 mm at Yea. Widespread flooding occurred, resulting in the loss of thirteen lives, and much damage to roads, railways, bridges, livestock, and other property.

June 1917 Two southern depressions moved in succession from the south of Western Australia to Tasmania during the period 5 to 7 June. The pressure gradient of the first depression became very weak over Victoria, and winds were very light during steady rain. The second depression moved close to Kangaroo Island early on 6 June, and rain continued falling in the northerly winds over Victoria, clearing after they changed to south-west. The heaviest rain fell on the ranges of the north-east, where in two days Mt Buffalo recorded 383 mm and Harrietville 230 mm. Severe flooding occurred on all north-eastern rivers with some loss of life. The remainder of 1917 was very wet, and heavy rain in October led to further severe flooding in the north-east.

May 1918 Another rainstorm of a similar type to that of June 1917 occurred from 11 to 13 May 1918. In two days 249 mm fell at Mt Buffalo, 194 mm at Harrietville, and 171 mm at Woods Point.

December 1930 After warm tropical air had been brought southward on the eastern side of an anticyclone in the Tasman Sea, a low pressure trough formed over Victoria from the north. Heavy rain began in the Mallee on 5 December and continued in many parts of the State through the weekend. In three days Beulah recorded 212 mm, Woodend 198 mm, and Boort 167 mm. There was considerable local flooding and damage.

November 1933 An extensive low pressure system over the Australian continent formed a trough south to Victoria after moist tropical air had been brought over the State. Rain began on 29 November and was mostly confined to the western halves of the northern, north central, and central districts. Among the heavier falls in two days were Creswick 206 mm, Talbot 187 mm, and Ballan 183 mm. Further rain with thunder and hail occurred in many parts of the State in the first week of December. Widespread flooding occurred along the Loddon and Avoca Rivers and also along the Moorabool.

November 1934 The spring in Victoria had been marked by a succession of heavy rainstorms, hailstorms, and severe windsqualls which had caused widespread damage as well as considerable inconvenience to the Melbourne centenary celebrations and the visit of H.R.H. the Duke of Gloucester. Sultry, thundery weather with northerly winds had prevailed for three days when a cold front arrived on 29 November. Some hours after the front, barometers fell rapidly as a depression developed in Bass Strait. (See fig. 1.) The south-west wind strengthened overnight and in Melbourne blew with gale force for most of Friday 30 November. Heavy rain also

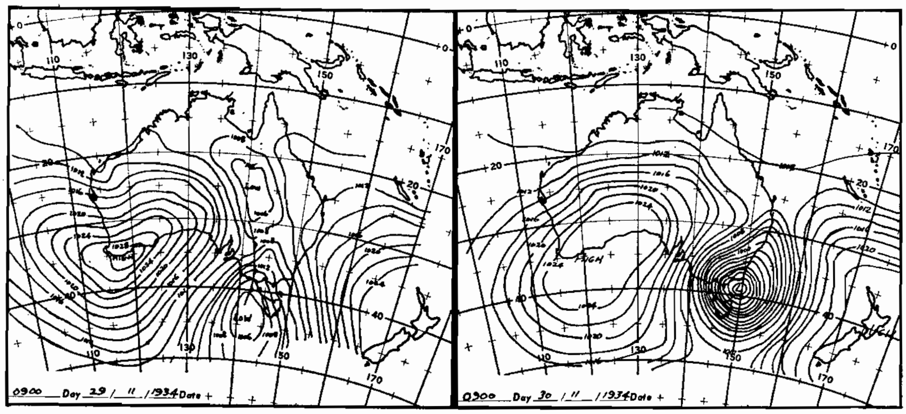
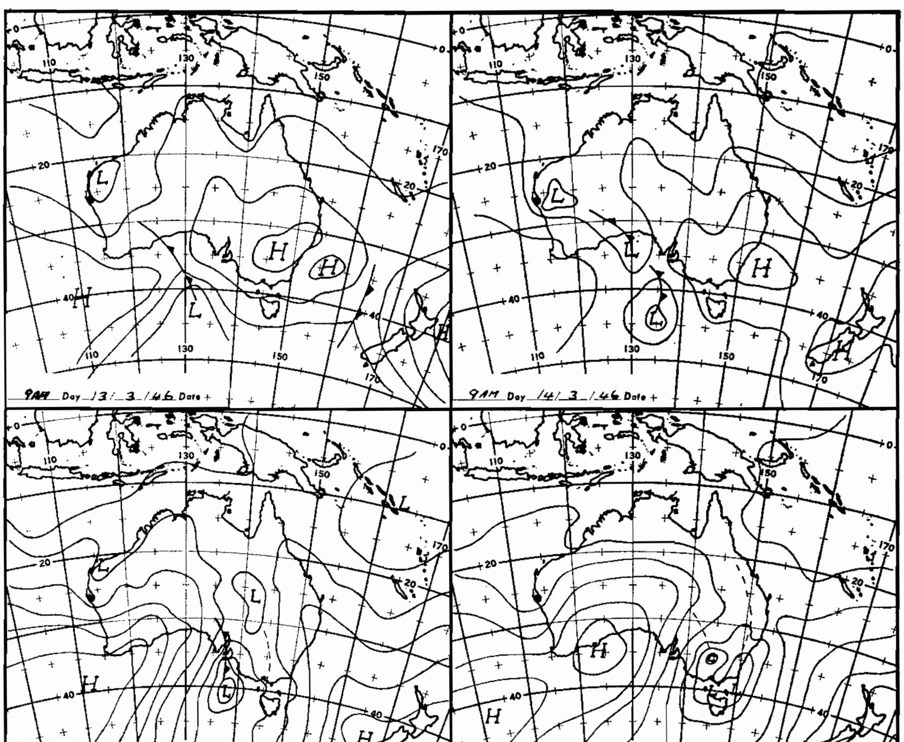


FIGURE 1. Development of a depression in eastern Bass Strait, 29 and 30 November 1934. Heavy rain and floods in central and Gippsland districts. See pages 7 and 9.

FIGURE 2. Formation of a complex depression over Victoria, 13 to 16 March 1946. Heavy rain and floods in south-western Victoria. See page 9.



began overnight and continued through the day. Considerable damage was done to the shores of Port Phillip Bay and the steamer *Coramba* was sunk off Phillip Island. Record rain fell over the catchments of the Yarra and La Trobe Rivers and in many parts of southern Gippsland. Some of the heavier rainfall totals for two days were 316 mm at Jindivick, 311 mm at Hazel Park, 292 mm at Korumburra, and 261 mm at Warragul. Disastrous flooding occurred in the central district and in southern and central Gippsland with some loss of life.

February 1939 A trough extended southwards to Victoria from northern Australia, and warm, moist, tropical air was brought over the State. A surface depression developed in this trough over south-eastern New South Wales and moved south-west to south-western Victoria. Rain began in western Victoria early on 25 February and extended east and north-east. More than 100 mm fell over almost all of eastern Victoria. The heaviest falls were in the north-east where in two days Yackandandah recorded 269 mm, Wangaratta 192 mm, and Beechworth 184 mm. This rainstorm followed an extremely dry six months, so that run-off and flooding were not severe.

March 1946 The first three months of 1946 had seen a succession of heavy rainstorms in Victoria : in western Victoria in mid-January and mid-February and in central Victoria at the end of February. On 14 March a depression was approaching Victoria from the south-west and by 16 March this had combined with another depression which had arrived from the north-west of Australia to form a complex depression over Victoria (see fig. 2). Rain began in the south-west of the State on the night of 15 March and continued through the weekend. In two days 250 mm fell at Branxholme, 247 mm at Koroit, and 217 mm at Warrnambool. The resulting floods caused loss of life as well as heavy losses of stock and damage to property. Gales blew about the south-west coast and also in South Australia throughout the period of the storm.

March 1950 The development of the circulation pattern on this occasion was most unusual, in that a tropical depression near the Gulf of Carpentaria moved steadily southwards over the continent from 15 to 18 March (see fig. 3). It reached northern Victoria on 18 March, and very heavy rain fell over the lower Goulburn valley. In two days Murchison recorded 275 mm, Strathbogie 252 mm, and Rushworth 215 mm, and flooding of the Goulburn River caused considerable damage.

February 1951 A similar occurrence to that of November 1934, with the development of a depression in Bass Strait, occurred in February 1951. Hot weather prevailed on 15 and 16 February, and the depression developed near Wilsons Promontory following the passage of a cold front on 17 February. In Melbourne, rain began during the afternoon of 17 February. The wind strengthened overnight and blew with gale force from the south to south-east until 2 p.m. on 18 February when it suddenly dropped. A gust of 119 km/h is the highest ever recorded in Melbourne. The ship *Nairana* was driven aground in Port Phillip Bay and much damage was caused to foreshores, homes, and trees. The heaviest rain fell in southern Gippsland, where two-day rainfalls included 436 mm at Balook and 246 mm at Budgeree, but the area of very heavy rain was far smaller than in 1934. This storm occurred after a long dry spell so that run-off and flooding were not so

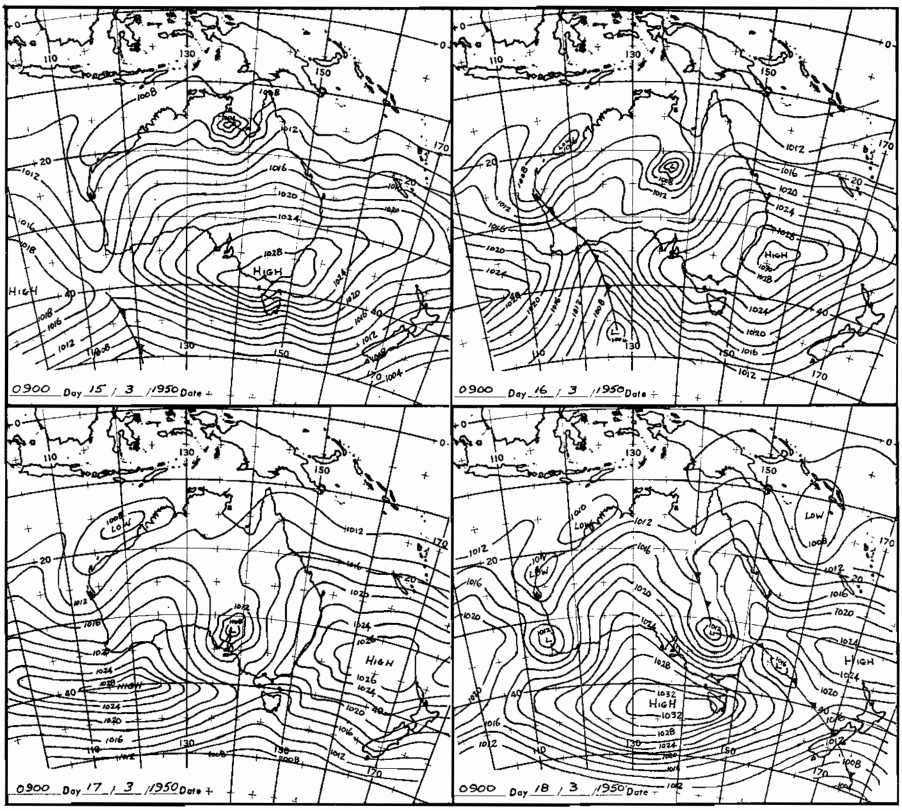


FIGURE 3. Movement of a depression from the Gulf of Carpentaria to Victoria, 15 to 18 March 1950. Heavy rain and floods in the Goulburn valley. See page 9.

great as in 1934. The depression weakened and moved slowly to the north-west on 19 and 20 February, bringing widespread rain and thunder to inland Victoria, particularly to the Campaspe River basin.

February 1973 Early in February a tropical cyclone moved inland from the Gulf of Carpentaria, and another cyclone off the north-west coast contributed further moisture. The very moist air mass moved southwards towards Victoria. On 5 February colder air of southerly origin arrived and the interaction with the moist tropical air caused very heavy rain over the central and north-western parts of the State. The heaviest falls occurred between Ballarat and Geelong and over the Mornington Peninsula. In two days 212 mm fell at Elaine, 208 mm at Red Hill, and 203 mm at Portarlington. Considerable flooding occurred near Lara and Inverleigh. On the night of 20 February exceptionally heavy rain fell over a small area near Seymour. Rapid and severe flooding occurred in Whiteheads Creek, which flows through the town, with the loss of one life.

Eastern Gippsland

Heavy rainfalls, which are fairly rare in other parts of Victoria, are much more common in eastern Gippsland. A fall of 125 mm in three days has only occurred three or four times in 80 years at most places in northern and western Victoria, and at Melbourne ten times in this period. Even as far east as Sale there have been only half a dozen occurrences. But at Bairnsdale the number of such falls rises to over twenty, and at Orbost, Cann River, and Bonang such falls have occurred more than thirty times in 80 years. This is because of the proximity of east Gippsland to the warmer waters of the Tasman Sea and the prevalence of depressions off the east coast, which cause lifting of the moist air, as well as a strong southerly airflow that is forced to rise over the ranges near the coast.

One particularly heavy rainstorm to affect coastal areas of eastern Gippsland occurred at Christmas 1935. In three days 356 mm fell at Orbost, 290 mm at Lakes Entrance, and 237 mm at Bairnsdale. These rainstorms caused rapid and severe flooding of the short coastal streams such as the Bemm and the Cann. The catchment of the Snowy River extends north into New South Wales, and major floods on the Snowy result when heavy rain falls over most of the catchment. This is usually the result of an extensive depression over south-eastern Australia that is also present in the higher levels of the atmosphere. There have been four major floods recorded on the Snowy when great damage was done along the river flats near Orbost with considerable loss of stock and crops.

December 1893 Rain began on 27 December and in three days Butchers Ridge recorded 472 mm and Bonang 295 mm.

January 1934 Heavy rain had fallen in the north-east of Victoria on 5–6 January, and on 7 January heavy rain fell over the catchment of the Snowy. Three-day falls included 185 mm at Delegete River and 166 mm at Bonang. Heavier falls were recorded in the Bombala area of New South Wales. Great damage was caused along the valley of the Snowy and the bridges over the river at Orbost and McKillops were both washed away.

June 1952 The previous month had been very wet, and there had already been some minor flooding on 9 June, when on 13 June the circulation over south-eastern Australia became more typical of summer. A trough extended southwards to Victoria and on 14 June a depression developed, bringing heavy rain to most parts of Victoria, with south to south-east gales. The Snowy reached an extremely high level on 16 June (see fig. 4).

February 1971 Early in the month a large area of low pressure covered the continent of Australia, causing north-east winds over eastern Victoria, but there was little development at the surface. In the upper atmosphere, however, a depression that had been over New South Wales moved over the Snowy Mountains area on 5 February. That night very heavy rain fell over the mountains but the heaviest falls were in New South Wales on the eastern side of the mountains, in the headwaters of the Bega River. More than 400 mm were recorded in this area in a day. Only a small part of the Snowy catchment received more than 150 mm in this period, but this was sufficient for the Snowy to reach near record level at Orbost with widespread damage to crops, stock, roads, and bridges.

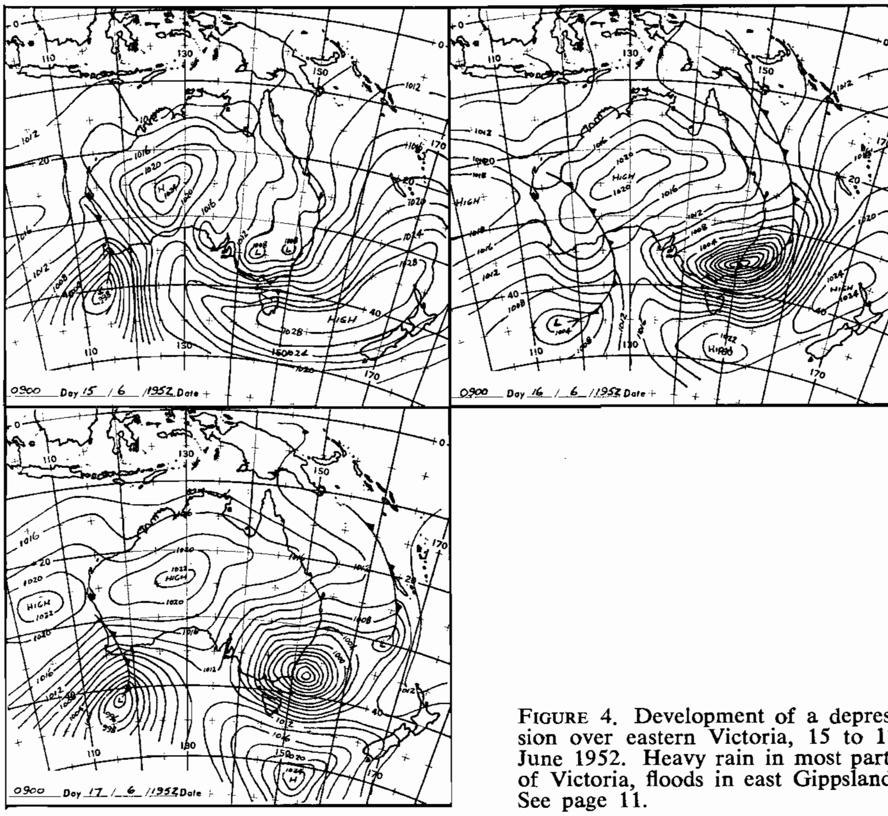


FIGURE 4. Development of a depression over eastern Victoria, 15 to 17 June 1952. Heavy rain in most parts of Victoria, floods in east Gippsland. See page 11.

Wettest places

The highest recorded annual average rainfall in Victoria is at Falls Creek in the Alps where the annual average is 2,615 mm. A considerable amount of this falls as snow in the winter. There will be other locations in the Alps with similar rainfall, but where the rain is not measured. Other high annual averages are 1,908 mm at Mt Buffalo and 1,933 mm at Weeaproinah on the main ridge of the Otway Ranges. These rainfalls are low compared to some of those measured elsewhere. Tully in northern Queensland has an annual average of 4,500 mm, while the world record is held by Mt Waialeale in the Hawaiian Islands where the average rainfall for a year is 11,980 mm. The highest rainfall recorded in any one calendar year in Victoria is 3,700 mm at Falls Creek in 1955. The highest yearly rainfall recorded in the world is almost 23,000 mm at Cherrapunji in Assam, India, where the local topography provides additional uplift to the monsoon airflow. The highest monthly rainfall recorded in Victoria is 891 mm at Tanybryn in the Otway Ranges in June 1952.

Driest places

The extreme north-west corner of the State has an annual average rainfall of just under 250 mm. The lowest yearly total recorded is 76 mm at Kindalyn near Robinvale in the Mallee in 1967. The driest place on earth is believed to be the Atacama desert in northern Chile, which may not experience any rain for years at a time.

Thunderstorms

A summer day may be clear early in the morning, but before midday cumulus clouds begin to appear as a result of the sun heating the ground, which in turn warms the air near the surface ; the air becomes less dense and begins to rise. If the air mass is unstable, that is, if it is one in which temperature falls rapidly with increasing height, the rising air continues to be warmer and less dense than the surrounding air, so it continues to rise. As it does so, it cools until moisture begins to condense as a cloud. The greater the moisture content of the atmosphere the lower the level at which this will happen. The air continues to rise and the cumulus cloud becomes taller and taller, while the airflow inside the cloud becomes increasingly turbulent. If the air mass is sufficiently unstable, the cloud will grow to heights of up to 10 km, and a mature thunderstorm develops. The top of the cloud is now composed of ice crystals because of the cold at these heights and is usually blown by the strong winds at this level to form a characteristic anvil shape. Electric charges which have built up are discharged by lightning strikes causing explosions that can be heard more than 16 km away. The cloud droplets coalesce into raindrops, which, because of the violent updraughts in the cloud, may attain considerable size before falling to the ground. Some rain drops are carried so high in the cloud that they freeze into pellets of ice, which then fall as hail. In particularly violent thunderstorms, the ice pellet may go up and down several times, growing in size each time, until it eventually falls to the ground as a lump of ice 3 cm or more in diameter. This large hail can cause much damage.

Downdraughts also develop in the mature stage of the thunderstorm and continue through the base of the cloud to reach the ground below. This descending air is quite cool, and on reaching the surface spreads out across the surrounding area, often accompanied by strong wind gusts and squalls. Destructive winds sometimes result, and these will be discussed below. Eventually downdraughts predominate throughout the cloud, the rain and hail cease, and the cloud dissipates. The duration of the mature stage of a single thunderstorm is usually less than an hour; however, more thunderstorm cells may develop before the first one dissipates, and it is possible for thunder activity to persist in a locality for many hours.

The basic factor required for thunderstorms is the presence of a moist unstable air mass. In the above description, surface heating by the summer sun was sufficient to release the potential energy of the unstable air mass. Another trigger may be the passage of a cold front, when the advancing cold air forces the warmer, unstable air upwards. A line of thunderstorms may develop along the cold front, and advance with it. The arrival of very cold air in the high levels of the atmosphere may be sufficient to set off thunderstorms, and this is often a cause of thunderstorms that occur in the middle of the night.

Thunderstorms are most frequent in the tropics, where they may be almost a daily occurrence. They are fairly rare in the polar regions. In Victoria they are most frequent over the ranges, which give added uplift to warm air forced over them, and where the sloping ground gives added impetus to the rising air currents on hot summer days. Thunder is heard on an average of more than 40 days a year over the north-east ranges, but only on an average of about 10 days a year in the west of the State. Thunderstorms are far more frequent in summer than in winter.

Because of the rapid ascent of moist air in a thunderstorm, intense rainfall can result. Thunderstorms are usually responsible for the greatest short period rainfall intensities on record. Some thunderstorms move at speeds of over 30 kilometres per hour (km/h), distributing their rain over a considerable area. Others become almost stationary for some time and cause high rainfall over a small area. One such storm occurred over Melbourne on 17 February 1972, when 78 mm fell within one hour (see fig. 5). This amount of rainfall fell over an area of about 3.5 sq km, while an addi-

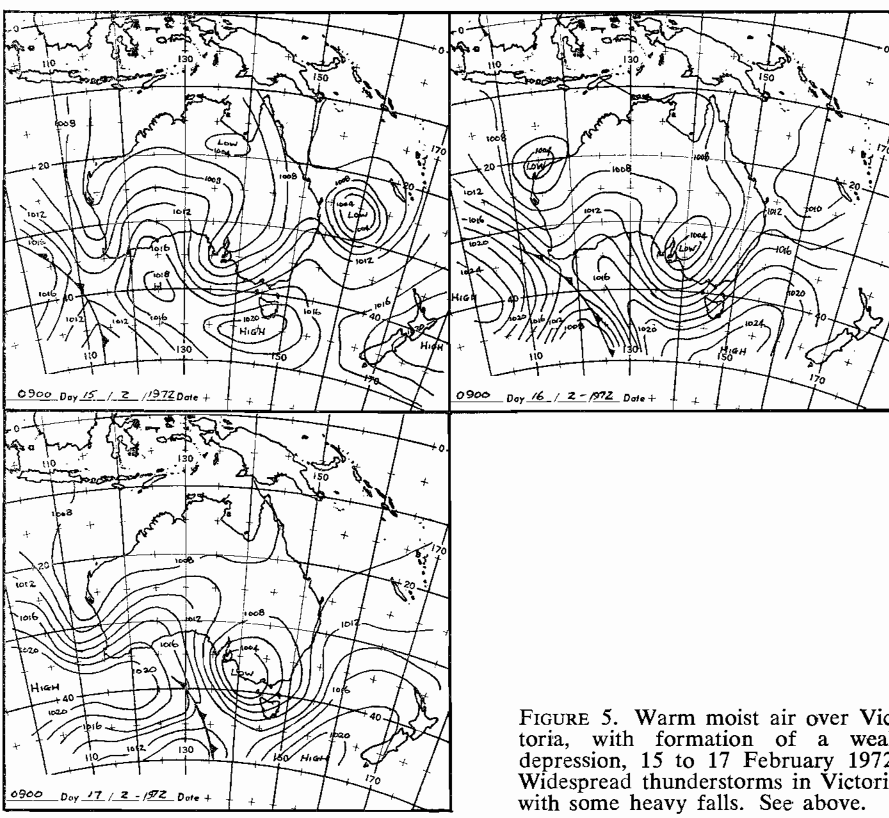


FIGURE 5. Warm moist air over Victoria, with formation of a weak depression, 15 to 17 February 1972. Widespread thunderstorms in Victoria with some heavy falls. See above.

tional 8.5 sq km received more than 50 mm. The total mass of water which fell from this thunderstorm can be calculated to be about 825,000 tonnes. Considerable flooding of streets, shops, and basements occurred and transport services were disrupted for some hours.

Thunderstorms that produce more than 75 mm of rain in an hour are not uncommon in Victoria, but because they affect such a small area, it is not very often that they are measured by a rain gauge. Some of the most intense falls recorded are given in the following table. One of the most intense falls in the world for a period less than an hour was recorded at Holt, Missouri, U.S.A. on 22 June 1947 when 305 mm fell in 42 minutes.

VICTORIA—SOME EXAMPLES OF INTENSE RAINFALL

Location	Date	Amount of fall	Period of fall
		mm	minutes
Stawell	26 March 1878	41	20
Prahran	5 November 1911	58	30
Bendigo	27 March 1914	51	20
Blackburn	21 February 1922	39	15
Flemington	25 December 1933	72	45
Balmoral	20 March 1941	48	25
Tiree	21 October 1955	39	15
Deer Park	30 March 1961	102	60
Walhalla	9 November 1970	51	40
Wedderburn (near)	5 November 1971	76	60
Kinglake	13 November 1971	89	45
Cranbourne	6 February 1972	54	25
Melbourne	17 February 1972	78	60

Tornadoes and severe storms

When a thunderstorm is produced in an extremely unstable air mass, the turbulence is very great and tornadoes may form. A tornado first appears as a funnel-shaped cloud somewhat resembling an elephant's trunk dipping down from a thunder cloud. The funnel elongates downwards, sometimes reaching the ground, and it has winds up to several hundred km/h revolving tightly around the core. The tornado is also known as a " twister " because of its roaring, whirling fury and its approach is often heralded by a roar likened to that of an express train. The funnel causes great destruction over a strip usually less than 1.5 km wide and sometimes as little as 100 metres. It may continue along its path for a few hundred metres or for many kilometres and it may lift from the ground for a distance and then descend again. After the funnel strikes the ground, it is blackened by soil and debris which is being drawn into it and whirled upward. Over water surfaces, dense spray is drawn upwards as a waterspout. The centre of the tornado has extremely low pressure, and as it passes over buildings, it has an explosive effect. The sudden outside pressure reduction leaves higher pressure inside a closed building and this causes the roof or walls to explode outwards. The violent suction effect has been known to lift cows, motor cars, and other heavy objects high into the air and dump them several hundred yards away. Sometimes a thunderstorm becomes a terrifyingly turbulent storm, which wreaks a path of destruction some kilometres wide for distances of hundreds of kilometres, spawning tornadoes to its right or left, and accompanied by intense rain and giant hailstones. One of these is reputed to have crossed France for nearly 800 km on 13 July 1788, ruining the harvest and contributing to the shortage of food in the following year.

Severe storms and tornadoes are reasonably frequent in Australia, particularly in the parts more northerly than Victoria, but many occur in uninhabited areas. In a forest, a swathe of twisted trunks, uprooted trees, and torn branches is often the only indication that a tornado has passed that way. In Victoria, they are mostly confined to the spring and summer months and there have been some noteworthy occasions when they have caused considerable damage to property.

On 27 September 1911 a tornado swept through the Marong and Lockwood districts near Bendigo. Several houses were completely demolished and a mining battery was completely wrecked, much of its machinery being badly twisted. Windmills and tanks were ripped to pieces and the sheets of corrugated iron carried for miles. On 2 February 1918 a violent tornado sweeping across Port Phillip Bay crossed the shoreline at Brighton and devastated houses from Brighton to Bentleigh. The tornado was accompanied by thunder, lightning, and jagged hail. Many houses were unroofed, chimneys and walls collapsed, and two lives were lost. A severe storm on 22 July 1926 affected areas from Geelong to Lismore and one life was lost, and on 19 June 1927 considerable damage was caused at Bungaree, near Ballarat, by a tornado.

A number of severe storms occurred on 7 November 1934 in the western half of the State, with torrential downpours of rain. At Ouyen a grandstand was unroofed and trees uprooted. At Horsham three men were killed by lightning. Near Sea Lake a house was wrecked, killing a man ; pieces of three-ply wall were found six miles away. Houses were unroofed and windows broken at Jeparit, and at Culgoa trees and fences were blown down. The greatest damage occurred at Heywood where few homes were left standing. A windstorm with torrential rain and deafening thunder struck Gisborne on 29 December 1936, leaving a trail of ruin extending for a mile. On 7 November 1954 houses were badly damaged at Mildura by wind, while huge hailstones battered grape vines and citrus crops. Severe damage occurred in the Tallangatta district on 1 January 1960 ; roofs were blown away and a boat on the Hume Reservoir was upset by waves, drowning three persons. Visibility on land was reduced by red dust.

On 24 September 1960 a tornado unroofed more than fifty buildings at Numurkah ; sheets of roofing iron were blown for distances of up to three miles. Numurkah again suffered a tornado which unroofed buildings and uprooted trees on 10 August 1964, and six weeks later, on 27 September, a tornado cut a swathe through forest and demolished two houses at Murphys Creek near Dunolly. A severe storm travelled for some 100 km from Finley in New South Wales to Devenish in north-eastern Victoria on 28 January 1967. In one hour over 1,000 square kilometres of country was littered with uprooted trees and broken branches, fallen power lines and telephone wires, unroofed buildings, and stripped fruit trees. Torrential rain and giant hail fell at some places in the path of the storm. On 11 December 1969 a severe storm moved across the southern suburbs of Melbourne, particularly St Kilda, Moorabbin, and Glen Waverley. Trees were uprooted, houses and blocks of flats were unroofed, and large hailstones fell. Other storms, causing a smaller amount of damage, but lifting roofs and causing balconies to collapse, have occurred on many other occasions in Victoria.

Hail

Hail is formed by the freezing of droplets of water. Much of the hail which falls in Victoria is of small size and occurs in winter and early spring during outbreaks of cold southerly air. At these times the freezing level is only one kilometre or so above sea level and water droplets do not have to be carried very high in a cumulus cloud to freeze. Soft hail is really a form of snow, consisting of pellets of closely packed ice crystals. It breaks with a splash upon striking a hard surface, whereas true hail neither rebounds as much nor disintegrates as easily. The small pellets of hail, usually less than 5 mm in diameter, generally do little damage, even when they fall in such quantities as to pile up on the ground.

In more violent weather when thunderstorms occur hailstones can grow to considerable size, as previously described. Larger hail is most likely to occur in the warmer months of the year, but can occur in winter if a particularly violent outbreak of cold air occurs. Large hail can cause great damage, stripping fruit from trees, ruining crops, breaking windows, and denting corrugated iron roofs. Although many severe hailstorms have occurred in Victoria, they are a rare occurrence at any one spot because a given hailstorm usually covers only a small area. Many of the severe storms described above were accompanied by large hail. Hail diameters of over 2.5 cm have been measured on many occasions, and the size has often been likened to that of the eggs of pigeons, swallows, and other birds, or to marbles or almonds. One hailstorm which occurred over Melbourne on 14 November 1901 had stones almost 4 cm in diameter, and an egg-shaped mass of ice picked up in Victoria Parade had dimensions 7 cm x 4.5 cm x 4 cm.

Other large hailstones reported in Victoria include the following:

VICTORIA—SOME EXAMPLES OF LARGE HAILSTONES

Location	Date	Size
Daylesford	17 August 1874	4.5 cm
Berwick	25 October 1874	2.6 cm x 2.5 cm
Warrandyte	4 April 1876	6.5 cm
Murrungowar	20 January 1900	4 cm
Charlton	27 March 1914	170 gm (weight)
Silvan	30 April 1942	2.5—5 cm
Warrion	29 March 1950	2.5 cm
Poowong	9 April 1966	2.5 cm

Snow

Snow flakes are an agglomeration of ice crystals which have formed in clouds where the temperature is below freezing point. If the temperature is high enough between the cloud level and the ground, the snow will melt as it falls and turn to rain. At temperatures only a little above freezing point, partial melting takes place. Snow can reach ground level with temperatures up to about 4°C, and at these temperatures the snow consists of large flakes because the partial melting allows the smaller flakes to stick together. If the temperature is well below freezing, the snowflakes are small, dry, and powdery.

In Victoria in winter the freezing level in the atmosphere is often about 1,500 metres, and precipitation falls as snow on mountains higher than this. On the Alps, the first snow lies on the ground in May or June and the last significant falls occur in September, or occasionally in October. The amount of snow can vary considerably from year to year: in dry winters there may not be any snow until July and it may not accumulate to any great depth through the winter ; in wet winters snow may accumulate to a depth of several metres. Snow can fall on the higher mountains such as Hotham and Bogong in summer, but it does not last for long. On the colder wet days in winter, snow falls at lower levels. Snow falls on Mt Donna Buang (elevation 1,250 metres), on many days, but there is no permanent cover through the winter months. At Ballarat (elevation 435 metres) snow falls on about three days each year ; on the Dandenong Ranges (elevation 600 metres) it is usually cold enough for snow once or twice each year.

On rare occasions in Victoria, when outbreaks of particularly cold air from the south occur, snow can fall at lower levels, almost down to sea level. Often only a few flakes are reported, which melt as soon as they reach the ground, but sometimes a blanket of snow which may last for some hours is laid down. Some of the more notable occasions are listed below.

Streets and housetops in Melbourne were covered with several inches of snow on 31 August 1849. One report of the event states that the terrified state of the Aboriginals suggested that they had never seen snow before. On 28 July 1901 snow fell over much of the western and west central districts. The You Yangs were mantled in snow and Hamilton, Casterton, Cobden, and Mortlake reported snow inches deep. On 4 August 1943 snow fell over an area extending from the Western District well into New South Wales. At Portarlington snow had not been seen before, while at Sale it was the first time in twenty years. On 31 August 1945 snow fell on the coast at Hastings and at Port Campbell, and over most of central and western Gippsland on 9 August 1951, when two inches also fell in some Melbourne suburbs and falls extended to sea level over the Mornington Peninsula and Gippsland (see fig. 6). On 15 July 1966 a large area of the lower country of north-eastern Victoria was covered in snow, including Wodonga and Wangaratta. Snow also fell in the La Trobe valley.

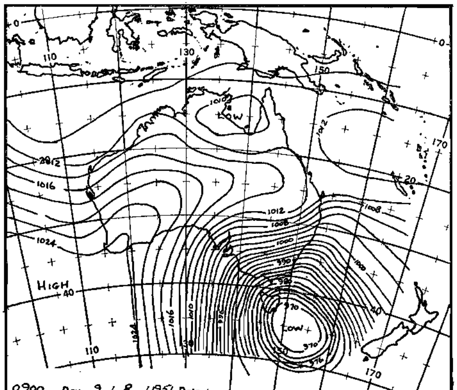


FIGURE 6. Outbreak of very cold southerly air over Victoria, 9 August 1951. Snow at sea level in central and west Gippsland districts. See above.

Cloud

Water vapour present in the atmosphere can condense into tiny droplets, which appear as clouds. Clouds can form at various levels in the atmosphere, and the motion of the air near them can give them a variety of shapes. There are ten basic varieties of cloud:

Cumulus This type is formed in rising air currents when the rising air has cooled sufficiently for water vapour to condense. In fair weather they remain small and detached, but when the atmosphere is unstable they grow taller, in the form of rising mounds, domes, or turrets, of which the bulging upper part often resembles a cauliflower. If there is sufficient vertical development showers can fall from a cumulus cloud.

Cumulonimbus If the atmosphere is particularly unstable, the cumulus cloud can grow to a considerable vertical extent until its top is composed of ice crystals. Thunderstorms develop from cumulonimbus clouds.

Stratus This is a layer cloud formed under stable atmospheric conditions. When fog is raised off the ground it is classed as stratus cloud. Stratus sometimes appears as ragged patches, scudding below other clouds.

Nimbostratus A layer of stratus cloud can become so thick, under circumstances of an approaching warm front, or a depression, that it becomes dark grey and continuous rain or snow falls out of it. It is then classed as nimbostratus.

Stratocumulus This is a layer of cloud in which there are sufficient vertical air currents to form rounded masses or rolls. It often forms under a temperature inversion, which inhibits the growth of cumulus elements. In Victoria the eastern side of an anticyclone is often associated with stratocumulus cloud, which may disperse in the afternoon, to reform overnight, or may maintain dull conditions all day. Light drizzle may fall from stratocumulus cloud.

Altostratus This is a layer of cloud formed at heights of about 3,000 metres. It has a grey uniform appearance, and, when the layer is thin, the sun may appear through it as if through ground glass. Altostratus may thicken and lower to produce continuous rain.

Altocumulus This type is formed at similar levels to altostratus, but there is some vertical air movement. It is composed of rounded masses which may or may not be merged. The sun shining through altocumulus may produce a coloured corona, of much smaller extent than a halo.

Cirrus Cirrus clouds are so high, where the air is so cold, that they are composed of ice crystals. When they are in an area of strong winds they form long narrow bands of filaments, popularly described as " mares' tails ".

Cirrostratus This type forms a thin veil covering the whole or part of the sky; it causes haloes to appear around the sun or the moon.

Cirrocumulus These appear as small elements, giving a rippled wave-like pattern popularly called a " mackerel sky ".

Wind

The heat energy received from the sun produces temperature differentials in the atmosphere, which cause differences of pressure, as a result of which air is put in motion. This motion is felt as wind. The speed of the wind depends on the difference in pressure, the temperature of the air, and because of the rotation of the earth, the latitude. At the surface of the earth the wind is rarely steady, particularly over land where there are obstructions to the flow. In the central areas of large cities, where there are tall buildings, there are many gusts and eddies. The mean wind speed for meteorological purposes is taken as the average over a period of ten minutes. In this time the actual speed can vary considerably, reaching much higher values in gusts which last for only a few seconds. The wind is usually stronger during the day than during the night.

In the evening, particularly when the sky is clear, the temperature of the air near the surface falls, and may become lower than that of the air above it. As this is the reverse of the usual state of affairs, it is said that a temperature inversion has formed. In the cooler air below the inversion the wind may drop completely, but above the inversion at 1,000 metres or so, it may still be blowing quite strongly. In the morning, some hours after sunrise, the lower layer of air becomes warm again, the inversion disappears and the wind blows again at the surface.

In the warmer months of the year, near the coast, a sea breeze springs up during the day due to the temperature contrast between land and water, and dies down again in the evening. In hilly areas, on sunny days, air in the valleys is warmed and moves upslope as a light wind. On cold nights, cold air on the higher slopes may move downwards and these downslope winds can reach considerable speeds at times. When an intense depression is located near Victoria very strong winds blow for several hours, and sometimes for days. These winds cause considerable damage by bringing down trees, power and telephone lines, and unroofing buildings, while waves generated erode foreshores and smash jetties and boats. In earlier days ships would be lost off the Victorian coast. Some storms which caused considerable damage have already been described in the section on rain.

Gales in Victoria usually blow from the north-west to the south-west quarter, but many of the strongest winds have been easterlies when a depression has been centred over the north of the State. On other occasions southerly gales blow following an outbreak of cold air from the south. In general, gales are most frequent in the winter and spring, but the worst storms have occurred at all times of the year. An example of easterly gales occurred on 18 January 1946 when a depression moved southward from the Northern Territory to South Australia. Barges and yachts were damaged, small craft were washed ashore, and the pier at Apollo Bay was badly battered. A Harbor Trust motor launch sank off the end of the Queenscliff pier. Miles of fencing were blown down in the Ararat district. On 18 February 1951 the highest gust ever recorded in the City of Melbourne of 119 km/h was from the south-east. A further description of this storm is given on pages 9–10.

Outbreaks of cold southerly air occur on a few occasions each year, and can sometimes be violent. In the early hours of 13 July 1963 a violent storm raged over Melbourne with incessant thunder, lightning, and hail, and there were many gusts over 80 km/h. On another occasion, 22 February 1964, considerable damage was caused over much of southern Victoria by gale force southerly winds following a cold front. North-west to south-west gales are caused when intense depressions pass to the south of the State. On 6 September

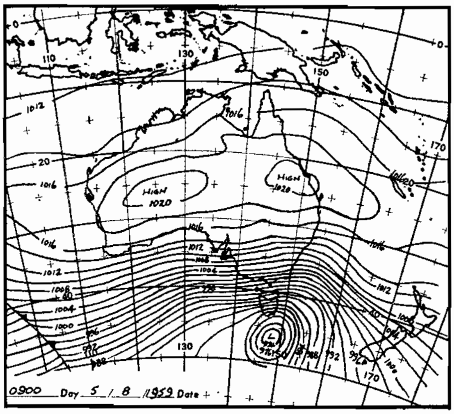


FIGURE 7. Gales in Victoria with widespread damage, 5 August 1959. See below.

1948 a trail of damage was left by a gale which raged for fourteen hours. At Essendon Airport the highest gust was a record 143 km/h. Two men were killed and twelve others injured by collapsing walls and flying debris as the storm shattered plate glass windows, wrecked houses, and blew down trees. On 5 August 1959 a violent gale caused widespread damage over the State. At Sale, a record gust of 114 km/h was recorded. Trees were uprooted in many areas, killing one woman and injuring another. Many parked cars were crushed and road, rail, and tram services were disrupted. Power and telephone lines were brought down and it took more than 24 hours to restore services to some places (see fig. 7).

High wind gusts are often experienced with thunderstorms, tornadoes, and severe storms. Although the wind persists for only a short time, great damage can be done, as described above in the section on severe storms. The highest wind gust recorded in Victoria is 164 km/h at Point Henry, near Geelong, although here the anemometer is 23 metres above ground level compared to the standard 10 metres of meteorological anemometers.

Duststorms

In dry years, when there is considerable loose soil in north-western Victoria and adjacent parts of South Australia and New South Wales, strong winds can raise large quantities of dust. Most places in the Mallee and Wimmera have experienced severe duststorms, which are at their worst in times of drought. On some occasions dust can be carried high into the atmosphere and transported hundreds of kilometres, to be brought down by rain in distant parts. Melbourne and other areas of southern Victoria have experienced this " red rain " from time to time.

Humidity

There is a limit to the amount of water vapour which a given volume of air can hold and when the air holds this limiting amount it is said to be saturated. Warm air can hold more water vapour than cold air. At sea level, at 0°C, the maximum amount of water vapour is 3.8 gm per kg of air, but at 25°C the maximum amount is 20 gm per kg of air. For most of the time, air is not saturated and the amount of water vapour in the air, expressed as a percentage of the maximum amount which can be held at that temperature, is the relative humidity. Relative humidity is not a good guide to discomfort due to humid weather. In a fog at 5°C, the relative humidity is 100 per cent, but on a noticeably humid day, when the temperature is 30°C, the relative humidity may be only 50 per cent. A better measure of humidity is the dew point, which is related to the actual water vapour content of the air. It is the temperature to which the air would have to be cooled for dew to form, i.e., for the relative humidity to become 100 per cent.

The most humid weather in Victoria occurs when light north-easterly winds persist for several days in summer, bringing moist air from the Tasman Sea or from further north. On these occasions the dew point can rise to 20°C, which is average for the coast of southern Queensland in summer. In the tropics the dew point is usually about 25°C. When north-westerly winds blow over Victoria in summer and dry air arrives from central Australia, the dew point can fall to 0°C and lower. When combined with high temperatures, the relative humidity can fall below 10 per cent. The cold air which arrives over the State from the far south from time to time in winter can also be very dry, with a dew point of about 0°C. The mean dew point in eastern Gippsland in summer is higher than elsewhere in Victoria, due to its proximity to the Tasman Sea.

Fog

Fog is really cloud resting on the ground and is caused by cooling and condensation in moist air. Fog is said to occur when the visibility is reduced below 1 km. Most fogs over land in Victoria occur in autumn and winter when the sky is clear and the wind is light. Typically, an anticyclone is centred over Tasmania, and very light south-easterly winds prevail over Victoria. Because of the clear sky, the ground cools rapidly after sunset, cooling the air in contact with it until the moisture condenses out as fog. Because cold air is dense, it tends to accumulate in hollows and valleys, which are more prone to fog than the hilltops. The fog is usually dispersed by the sun in the morning, but occasionally, when it is very thick or when cloud has formed above the fog, it may remain throughout the day. When an anticyclone remains stationary near Tasmania for some time, fog may occur

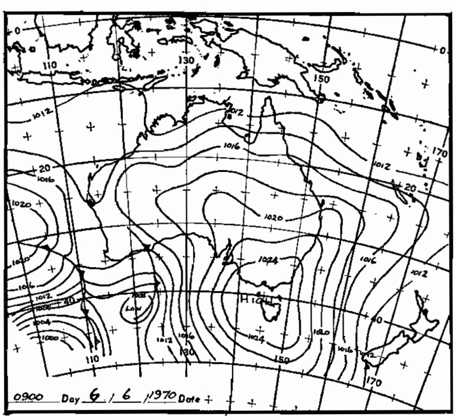


FIGURE 8. Anticyclone over Tasmania in winter, 6 June 1970. Widespread fog in Victoria.

night after night for as long as a week, barely lifting in the afternoon. The worst month on record for fog in Melbourne is June 1937 when fog occurred on 20 days during the month. Fog can also be formed at sea when warm moist air flows over colder water. This frequently happens in eastern Bass Strait in the summer, and fog is most frequent in that season over the water. During periods of east to north-east winds over Victoria in summer, when the State is having its most humid weather, this sea fog occurs. The fog also affects the coastline, and during prolonged easterlies can form as far west as Warrnambool and Portland. It can happen that the seaward slopes of the Otway Ranges are in fog, while the northern side is experiencing a warm sunny day.

Temperature

Meteorologists, in measuring the temperature of the air, ensure that their thermometers are shielded from direct radiation from the sun or reflected radiation from walls or the ground. The thermometer is placed in a specially louvred white box so that it is 1.2 metres above ground covered with short grass. For this reason official temperatures on hot days are frequently lower than those measured by thermometers not correctly exposed.

Victoria is subject to very high temperatures on some days in summer when an anticyclone is centred over the Tasman Sea. The temperature exceeds 38°C on an average of four days a year in Melbourne and of twelve days a year at Mildura. There is considerable variation from year to year; there have been summers in Melbourne when the temperature has not reached 38°C at all, while in 1897–98 this temperature was reached on fifteen days. A temperature of 44°C is very rarely reached in southern Victoria, but occasionally occurs in the north-west. It has happened at Mildura on six days in twenty years. Mildura holds the record for the State's highest temperature of 50.8°C on 6 January 1906. The highest air temperature officially recorded in the world is 57.8°C near Tripoli, Libya, on 13 September 1922.

Occasionally an anticyclone remains stationary over the Tasman Sea for several days and Victoria experiences a heat-wave. From 15 to 20 January 1908 the temperature exceeded 40°C in Melbourne on each of the six days. The temperature did not fall below 20°C during this period. One of the longest and hottest periods on record in Victoria occurred in the first fortnight of January 1939. Northern Victoria experienced hot weather throughout this period, and at Mildura the temperature exceeded 38°C on each of twelve consecutive days, reaching 47°C on 10 January. Weak cool changes affected southern Victoria, but temperatures on the hot days were extreme. In Melbourne the temperature reached 43°C on Sunday 8 January, 44.7°C on Tuesday 10 January, and a record 45.6°C on Friday 13 January. During that week disastrous fires burnt some millions of acres of Victoria's forests and some 700 houses ; 71 lives were lost.

The extremely hot days in Victoria are usually accompanied by a strong northerly wind, which can have a mean speed of about 50 km/h. The phenomenon of hot wind was remarked upon by the early settlers and the dates of its occurrence were specially listed in early weather records. The conditions of high temperature, low relative humidity, and strong wind lead to the extremely rapid spread of any outbreak of fire. When the summer has been preceded by several months of drought as in 1926, 1939, and 1944, fires can be very severe, causing much damage and considerable loss of life.

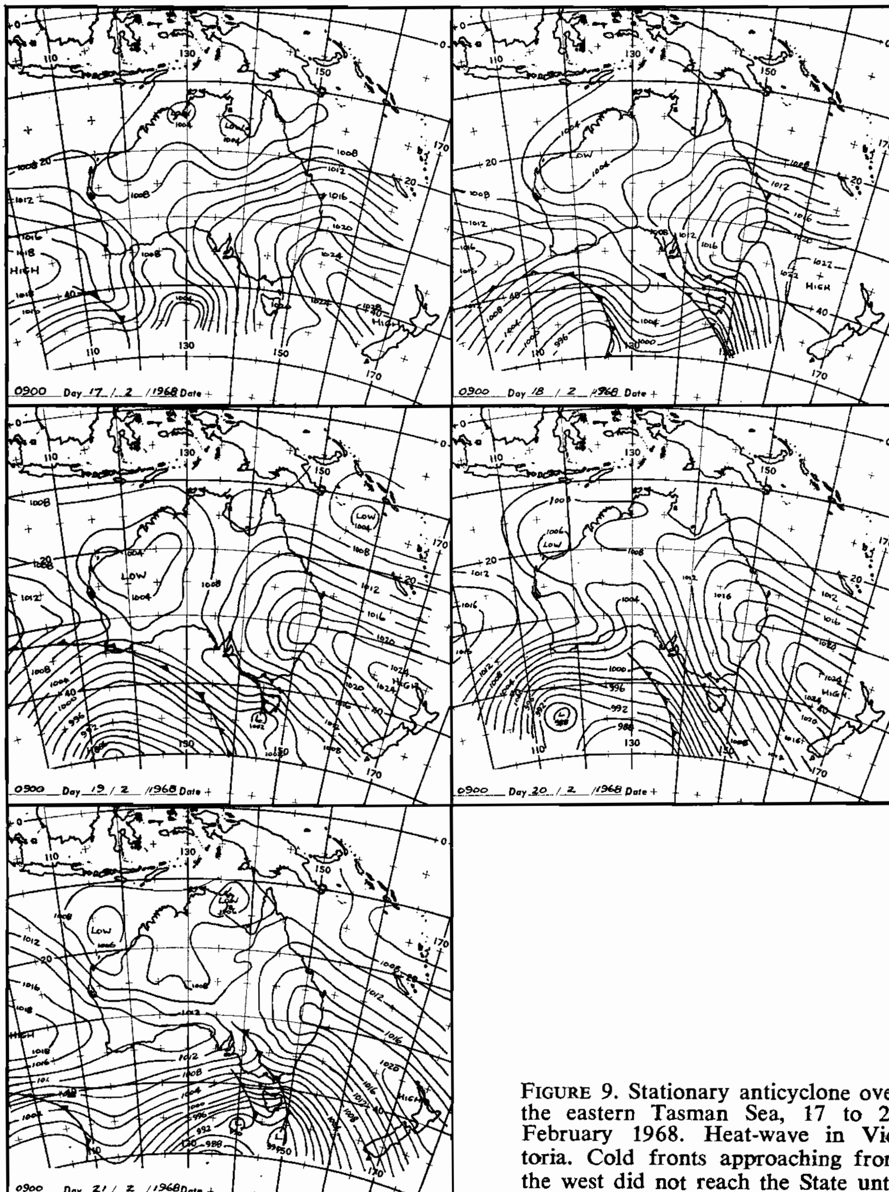


FIGURE 9. Stationary anticyclone over the eastern Tasman Sea, 17 to 20 February 1968. Heat-wave in Victoria. Cold fronts approaching from the west did not reach the State until 21 February.

On 8 January 1969, although the preceding weeks had not been dry, the winds were so extreme that, combined with high temperature and low humidity, an area of about 2,500 sq km of grassland was burnt in a number of fires on the one day. At Avalon, between Geelong and Melbourne, the wind averaged 75 km/h with gusts of over 120 km/h.

Hot weather in Victoria often ends abruptly with the arrival of a cold front. The wind changes from north-west to south-west and the temperature falls rapidly. A change of 10°C in 20 minutes is not uncommon. Some days of cool weather may then follow, with the temperature remaining below 20°C in the south of the State and below 30°C in the north. Some cold fronts are weak and do not move over the Great Dividing Range, so that the north of the State continues to be hot. Not infrequently the front penetrates to all but the north-east of the State.

The lowest temperatures in Victoria occur on calm, clear winter nights when the moisture content of the air is low. After sunset the ground rapidly loses heat by radiation, cooling the air, which is too dry for fog to form. A day or two after an outbreak of cold dry air from the far south has occurred, an anticyclone may become centred over the State. Under these conditions frosts are widespread and severe. The temperature falls below freezing point at most places in the State on a few nights each winter, the main exceptions being those places close to the sea. The lowest temperature recorded in Victoria is –12.8°C at Hotham Heights ; equally low or lower temperatures have probably occurred in other parts of the Victorian Alps. The lowest temperature recorded in Australia is –22.2°C at Charlotte Pass near Mt Kosciusko, the lowest in the world being –88.3°C at Vostok in Antarctica. In Melbourne the lowest temperature on record is –2.8°C, which occurred on 21 July 1869. This was recorded at the Melbourne Observatory site. The lowest temperature recorded since 1908 is –1.6°C on 31 July 1929. In common with large cities throughout the world, it is found that the mean minimum temperature in winter measured near the centre of the city is higher than in the suburbs due to the heat generated by the city.

Day time temperatures in winter are fairly uniform over the State, averaging about 13°C. On a very cold day over the lower parts of the State the temperature may not reach 10°C, while in June and July the temperature seldom exceeds 16°C, except in eastern Gippsland where the Föhn effect is experienced. This occurs when north-westerly winds are blowing over eastern Victoria, particularly if they are bringing rain to the north-east highlands. The air loses much of its moisture on the windward side of the ranges, and on descending from the mountains becomes quite warm. The effect is well known in the European Alps and in the Rocky Mountains in North America. Although not so pronounced in eastern Gippsland, as the mountains are not so high, the Föhn effect does cause the temperature to rise to over 20°C. On these occasions this area has the highest temperatures in the State.

Frost

When the temperature falls below 0°C on surfaces cooled by radiation, thin ice crystals are deposited, which are called hoar-frost. The deposit is frequently composed in part of drops of dew frozen after deposition and in part of ice formed directly from water vapour. Occasionally the air is so dry that no deposit of hoar-frost is formed when the temperature falls well below

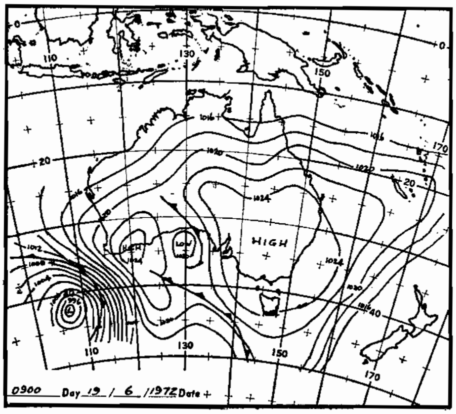


FIGURE 10. Anticyclone over Victoria in winter, 19 June 1972. Widespread frost in Victoria.

freezing point. This is termed a black frost, and damage is still caused to the tissues of growing plants by freezing of the water in their cells. On cold, clear nights, when the air close to the ground becomes much colder than air even a metre above the ground, the difference in temperature can be several degrees. When the air temperature at one metre falls only to 2°C, it is likely that light ground frosts will occur in the vicinity. When the air temperature falls to 0°C, heavy ground frosts are likely.

Frost can be a very localised phenomenon, dependent on local topography. Cold air drains into low lying areas, so that hollows experience frost while the surrounding area is free of frost. Hedges across the slope of a hill impede the downward flow of cold air and frosts occur on their upslope side. Away from the highlands and the sea, the first frosts of the season usually occur in May and the last in September. Spring frosts are very hazardous for the fruit growing industry owing to the susceptibility of fruit blossoms to frost. Occasionally frosts occur in these areas as late as October. On 22 October 1929 severe frost caused much damage to crops in the Wangaratta, Bendigo, Stawell, and Hamilton areas. Over the ranges below an elevation of 1,000 metres frosts have been known to occur in summer. Ballarat has recorded frost at Christmas, and Kyneton in January. Over the higher ranges frost can occur at any time of the year.

Drought

There are occasions when the normal circulation pattern is interrupted for lengthy periods. It may be that depressions bring a succession of rainstorms over Victoria for a period of some months. It may also be that rain-bearing systems avoid the State for a considerable time. Anticyclones may become stationary over the western Tasman Sea and eastern Australia, forcing cold fronts approaching from the west to move to the south-east and not affect Victoria. Alternatively, a belt of high pressure may extend across the Bass Strait area; cold fronts penetrating it may be too weak to bring much rain, and no troughs extending from Victoria to the north may exist. There may be a complete absence of those depressions off the east coast that bring much rain to the south coast of New South Wales and to eastern Gippsland. There can be periods of several weeks, usually in summer, when little or no rain falls. In Melbourne the longest spell without rain is 40 days from 19 December 1954 to 27 January 1955, while in the 64 days from 18 January to 22 March 1967 only 5 mm of rain fell. Long rainless periods are more common in north-western Victoria, and two consecutive rainless months have been recorded on several occasions. The longest rainless period at Mildura is 109 days, from 12 December 1892 to 30 March 1893.

Dry weather in summer is often to be expected in Victoria, but when the autumn or spring rains fail, little pasture growth occurs, with bad effects on primary production. The winter and early spring rains are all important for the wheat crop. The first drought in Victoria of which much is recorded occurred in 1865, particularly in the central and Wimmera districts, and there was another dry spell in 1868. In the next 27 years there were several dry periods, namely in 1877–78, 1881–82, and 1888, but major drought did not occur until the period 1895 to 1902. The worst effects were in northern Victoria, although 1898 is the second driest year on record in Melbourne. The worst year was 1902, when drought affected the greater part of eastern Australia, and the average wheat yield in Victoria was only 1.3 bushels per acre. The Murray River became so low that river traffic stopped, having deleterious effects on transport at Mildura, which was not connected by railway at that time. In the central district, however, the drought was relieved by heavy rainstorms in March and December 1902.

The year 1908 was very dry in many parts of Gippsland, but the next State-wide drought did not occur until 1912–1915. Exceptionally heavy rain fell throughout the State early in 1911, but the first half of 1912 was very dry, as was the winter of 1913. The worst year was 1914, when rainfall was very low. The period from August to October was almost rainless in the north, and the average wheat yield was reduced to 1.4 bushels per acre. The Murray River was at its lowest level ever known at Echuca, and ceased to flow at Swan Hill in December 1914. Rain fell in November, too late to be of much value. The drought finally broke in May 1915, except in eastern Gippsland, which had a dry year. In the next 22 years there were several dry periods, but without the disastrous effects of major drought. The winter and spring of 1919 were dry except in Gippsland, and the summer and autumn of 1923 were very dry, causing an acute water shortage in many parts of Victoria. The thirteen months from March 1925 to March 1926 were very dry except in eastern Gippsland where there were floods. Heavy rain fell in the autumn of 1926, but dry conditions again prevailed in the summer and autumn of 1927.

The period from 1937 to 1945 was marked by three major droughts. The first commenced in February 1937 and continued, with a break in the spring and summer, until February 1939. The six months from August 1938 to January 1939 were very dry, culminating in disastrous bushfires. The drought broke with very heavy rain at the end of February 1939. Following a wet year, drought again prevailed through 1940. The third drought of this period began in 1943 and lasted until 1945, except for heavy rain in Gippsland in May 1944. The winter and spring of 1944 were very dry, leading to failure of the wheat crop, the average yield being 1.6 bushels per acre.

The next 22 years were free of widespread drought, but the Western District was very dry for much of 1950. The first half of 1957 was generally dry, as was the spring and summer of 1961–62. Eastern Gippsland suffered a drought for much of 1965. The next major drought occurred in 1967, which, for two thirds of the State, is the driest year on record. The drought began in the west of the State in January and extended to the east in the summer of 1967–68, finally breaking in the autumn of 1968. Following floods early in 1971, the winter of that year was very dry in eastern Gippsland. In 1972 this drought extended westwards, affecting most parts of the State by the end of the year. The drought broke when widespread heavy rain fell in February 1973.

Conclusion

Compared to most other parts of Australia, and indeed, the world, the climate of Victoria is rather equable. Weather extremes experienced over the State have not been as bad as in most of Australia. Heat-waves are not prolonged, although temperatures may reach a very high level, while periods of frost longer than three or four days are most unusual. Flooding is more sporadic than in Queensland, where a single river catchment could equal the whole area of Victoria. Rainfall does not reach the phenomenal proportions, nor do winds reach the speeds, of the tropical cyclones which have on occasions caused havoc in coastal towns of northern Australia. The populated parts of the State never experience the disorganisation of heavy snow, with the attendant hazards of rime and black ice, which are common to many countries in the northern hemisphere.

Victoria experiences rapid changes in the wind regime and day-to-day temperature levels, with relatively frequent changes in the general weather. Marked short-period variations from the more usual pressure distribution occasionally result in unusual weather events such as heat-waves, cold spells, floods, and severe storms. Occasionally a change in the pressure pattern may be more extended, resulting in exceptionally wet or dry years, possibly leading to slow strangulation by drought of normally productive country. However, no regular cycle in the occurrence of prolonged wet or dry periods has been determined.

No long-term trend in the climate of Victoria has been found, but weather records have been kept for only a little over 100 years. This is far shorter than the time scale of climatic change. The best application of climatic data can be based on the expectation that history, as far as weather is concerned, will be repeated.

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PROTECTION OF THE ENVIRONMENT

Towards the end of the 1960s the pressures being put on the world's environment became increasingly obvious, and many people were becoming concerned at the lack of organisational machinery available to solve the problem. In Victoria, pollution control responsibilities were spread among numerous State and local government agencies. This resulted in considerable problems of co-ordination and confusion, partly because some agencies had insufficient jurisdiction ; the need for a central body to control all waste entering the environment and to supervise air, water, and land pollution and excessive noise and litter, became evident. The earlier draft legislation for this control dealt solely with water pollution, but the final draft legislation covered all wastes, noise, and litter.

The *Environment Protection Act* 1970 established the Environment Protection Authority, the advisory seventeen member Environment Protection Council, the policy-making procedures, and the administrative powers of the Authority. In May 1972 the Act was amended to provide for appeals by the general public against licensing decisions of the Authority and its agencies, and to empower it to settle disputes over the responsibilities for controlling pollution situations.

A responsibility of the Authority is the formulation of broad policies for environmental quality throughout the State. Draft policies issued to date cover water quality in Port Phillip Bay, in the Yarra River and its tributaries, in the streams of the Dandenong valley, and in the Maribyrnong River and its tributaries. Each policy sets out the usages of water which are to be protected from the effects of pollution and waste discharge. Different usages such as drinking water supply, fishing, or boating, require different water qualities. Each policy is placed on public review for at least two months. After all comments have been considered and amendments made where necessary, then, subject to the approval of the Governor in Council, the policy becomes State environment protection policy. All licensing decisions must be in accordance with declared policies.

Broadly speaking, the Authority's main powers can be divided into two areas—waste licensing and pollution control. The licensing system provides for waste discharged directly into the air, into water, or onto land to be licensed by the Authority or one of its agencies, while the general pollution control powers cover emergency problems such as oil and chemical spills, together with other types of pollution not caused by regular waste discharges.

Under the Act anyone who is discharging waste directly into the air, into water, or onto land, must hold a waste discharge licence, unless the discharge has been specifically exempted. Initially, no one is required to obtain a noise licence; regulations to control noise are to be introduced progressively.

From the date of full operation of the Environment Protection Act (1

March 1973) existing dischargers were allowed three months in which to apply for a waste discharge licence, and the Authority had four months from receipt of each application in which to deal with it. For new discharges, a licence must be obtained before the discharge begins. A licence can be refused if the Authority considers that granting it will have too harmful an effect on the receiving environment; or a licence can be granted with conditions specifying discharge standards. People may be prosecuted and incur a heavy fine for either breaching their licence conditions, or for making a waste discharge without a licence. Exemption from the need to hold a licence does not mean exemption from possible prosecution (with a fine of up to $5,000) for a pollution offence.

The Authority's regulation-making powers will be used to control certain types of emission which are not suitable for licensing, e.g., noise emissions and gaseous emissions from motor vehicles.

Two types of appeal are allowed under the Act—one from licence applicants who are dissatisfied with the decisions of the Authority or its agencies, and the other from third parties who feel they will be adversely affected by a licensed discharge. Licences and licence applications are available for public review and third parties who disagree with licensing decisions have two lines of appeal—first, to the Authority itself, sitting as an appeal tribunal, and second, to the Appeal Board. Licence applicants who are dissatisfied with Authority or agency decisions can appeal directly to the Environment Protection Appeal Board, a three member tribunal comprising one who is a barrister and solicitor and two who are experienced in environmental control or management.

The Authority has delegated tasks to five other government agencies, which carry out licensing and enforcement functions according to the policies of the Authority. The responsibilities of these agencies are as follows : the Latrobe Valley Water and Sewerage Board has control of licences in the field of water, air, and land waste for the La Trobe valley and for eastern Gippsland as far as the New South Wales border. Licences for discharges to water within the Melbourne metropolitan area are controlled by the Melbourne and Metropolitan Board of Works. The Dandenong Valley Authority licenses discharges to water within its area. The State Rivers and Water Supply Commission controls licences for discharges to inland water for the rest of the State. The Commission of Public Health has control of licences for discharges to land for the whole of Victoria except the area covered by the Latrobe Valley Water and Sewerage Board. The Authority directly controls air licences for all of the State except the Latrobe Valley Water and Sewerage Board area, water licences for coastal waters including Port Phillip and Western Port, and all of the noise control programme. No delegated protection agency can license its own discharge ; all such discharges are licensed by the Authority.

GEOGRAPHICAL FEATURES

Area and boundaries

Victoria is situated at the south-eastern extremity of the Australian continent, of which it occupies about a thirty fourth part and covers about 87,884 square miles or 56,245,760 acres.

The following table shows the area of Victoria in relation to that of Australia :

AUSTRALIA—AREA OF STATES AND TERRITORIES

State or Territory	Area	Percentage of total area
	sq miles	
Western Australia	975,920	32.88
Queensland	667,000	22.47
Northern Territory	520,280	17.53
South Australia	380,070	12.81
New South Wales	309,433	10.43
Victoria	**87,884**	**2.96**
Tasmania	26,383	0.89
Australian Capital Territory	939	0.03
Australia	2,967,909	100.00

Victoria is bounded on the north and north-east by New South Wales, from which it is separated by the Murray River and a boundary about 110 miles long running north-westerly from Cape Howe to the nearest source of the Murray River, being a point known as The Springs, on Forest Hill. All the waters of the Murray River are in New South Wales, the State boundary being the left bank of the stream. The total length of the New South Wales boundary is about 1,175 miles.

On the west the State is bounded by South Australia and on the south by the Indian Ocean and Bass Strait. Its greatest length from east to west is about 493 miles, its greatest breadth about 290 miles, and its extent of coastline 980 miles, including the length around Port Phillip Bay 164 miles, Western Port 90 miles, and Corner Inlet 50 miles. Great Britain, inclusive of the Isle of Man and the Channel Islands, contains 88,119 square miles, and is therefore slightly larger than Victoria.

The most southerly point of Wilsons Promontory, in latitude 39 deg 8 min S., longitude 146 deg 22½ min E., is the southernmost point of Victoria and likewise of the Australian continent; the northernmost point is where the western boundary of the State meets the Murray, latitude 33 deg 59 min S., longitude 140 deg 58 min E.; the point furthest east is Cape Howe, situated in latitude 37 deg 31 min S., longitude 149 deg 58 min E. The westerly boundary lies upon the meridian 140 deg 58 min E., and extends from latitude 33 deg 59 min S. to latitude 38 deg 4 min S.—a distance of 280 miles.

Physiographic divisions

This article should be read in conjunction with the articles on physical environment and land use, area, and climate.

The chief physiographic divisions of Victoria are shown on the map (see fig. 11). Each of these divisions has certain physical features which distinguish it from the others as a result of the influence of elevation, geological structure, climate, and soils. The following divisions are recognised:

1. *Murray Basin Plains:*
    (*a*) The Mallee
    (*b*) The Murray Valley
    (*c*) The Wimmera
    (*d*) The Northern District Plains

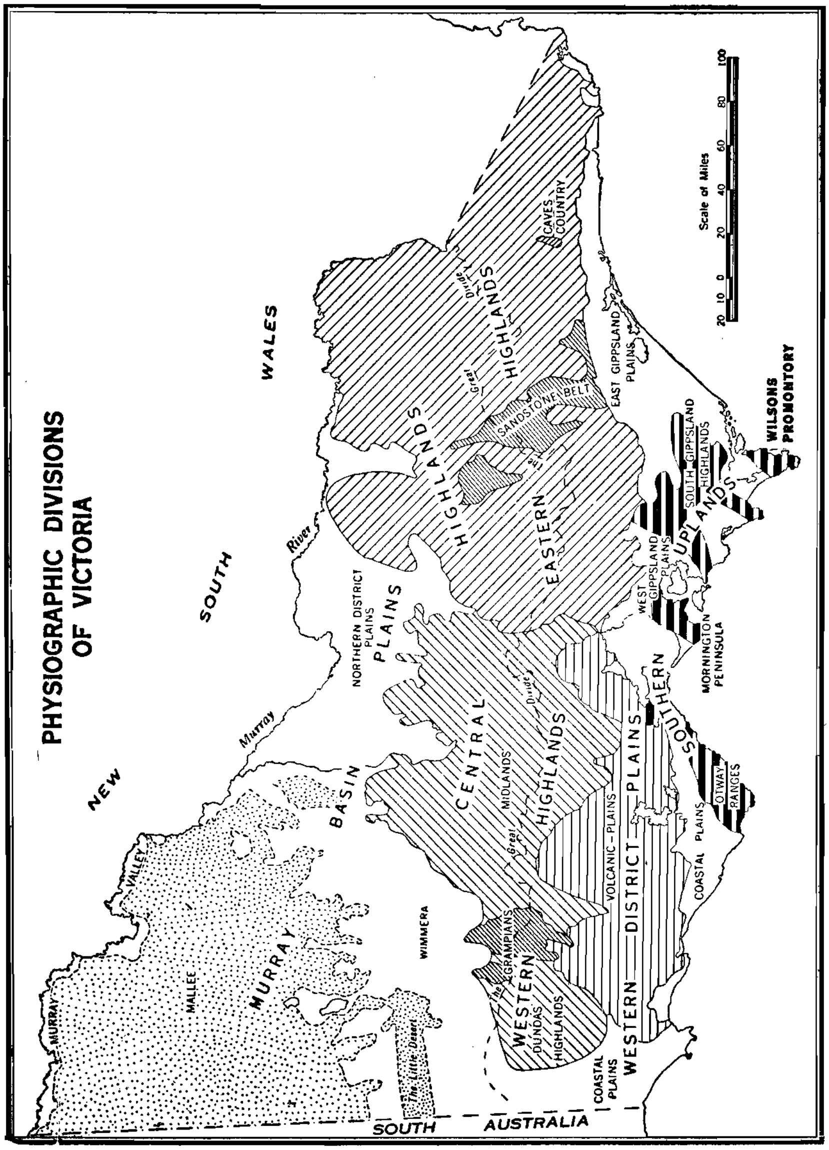


FIGURE 11.

2. *Central Highlands :*
   - A. The Eastern Highlands, within which
     - (*a*) the Sandstone Belt and
     - (*b*) the Caves Country may be distinguished from the remainder
   - B. The Western Highlands :
     - (*a*) The Midlands
     - (*b*) The Grampians
     - (*c*) The Dundas Highlands

Melbourne's skyline reflected in a sunshine recorder.
Bureau of Meteorology

School children enjoy throwing snowballs after a rare snowfall in the Dandenongs.
The Herald and Weekly Times Ltd

An example of the damage caused by flooding in East Gippsland during February 1971. This is a washed out section of the Princes Highway at Orbost.
The Herald and Weekly Times Ltd

Elizabeth Street, Melbourne, became a raging torrent during the city's heaviest recorded downpour on 17 February 1972.

The Age

The severity of flooding in the Melbourne suburb of Hawthorn after the storm of 29 November 1934 found policemen wading waist-deep to rescue trapped families.

The Herald and Weekly Times Ltd

Cirrus cloud showing " mares' tails ".

Cirrostratus with halo round the sun.

Altostratus.

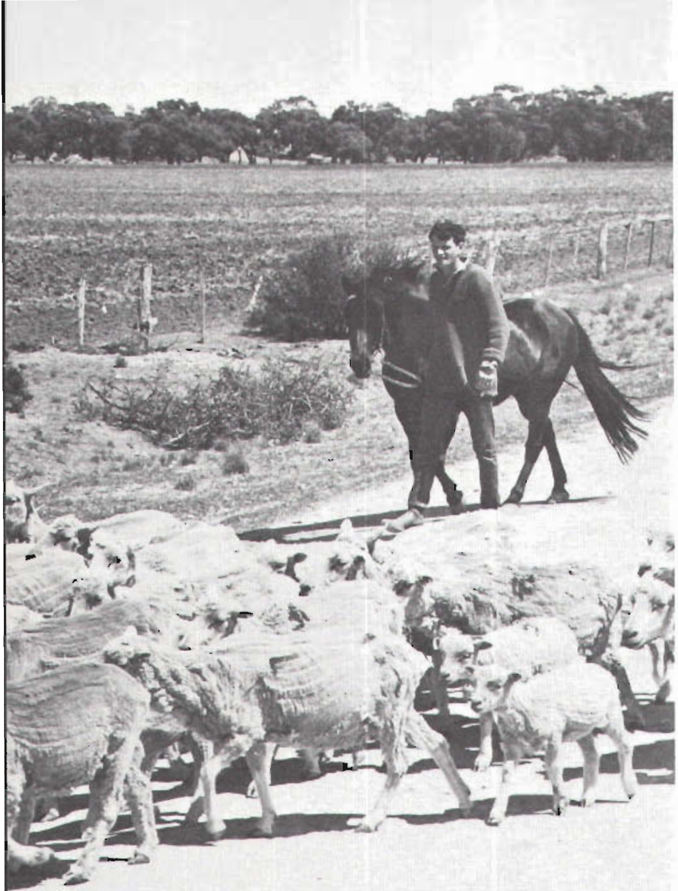
Altocumulus.

Cumulus.

Stratus (fog cloud).

Stratocumulus.

Cumulonimbus (thunder cloud).



A mob of sheep being grazed on the Victoria Valley Road near Hamilton. Lack of pasture in the paddocks made this a common practice in the Western District during the drought period of 1967–68.
The Herald and Weekly Times Ltd

A great dust storm gathers on its approach to Mildura during January 1968.
Sunraysia Daily

Bushfires burn along the Lorne road about a mile from the Lorne township.

The Herald and Weekly Times Ltd

Bushfires rage out of control in the Moorabool River gorge.

The Herald and Weekly Times Ltd

Radar equipment being used to detect areas of rain.
Bureau of Meteorology

Launching a radio-sonde balloon from the Laverton weather station.
Bureau of Meteorology

3. *Western District Plains :*
    (*a*) The Volcanic Plains
    (*b*) The Coastal Plains
4. *Gippsland Plains :*
    (*a*) The East Gippsland Plains
    (*b*) The West Gippsland Plains
5. *Southern Uplands :*
    (*a*) The Otway Ranges
    (*b*) The Barrabool Hills
    (*c*) The Mornington Peninsula
    (*d*) The South Gippsland Highlands
    (*e*) Wilsons Promontory

Murray Basin Plains

These plains include the Mallee, the Wimmera, the Northern District Plains, and the Murray valley itself. The most noticeable distinguishing features of the Mallee are the soils, vegetation, and topography. It is not a perfect plain, but exhibits broad low ridges and depressions which appear to be due to folding and faulting of the rocks. Sand ridges trending due east and west are an indication of a former more arid climate, but they are now fixed by vegetation. When cleared, the sand distributes itself irregularly without forming new ridges. There is evidence of a succession of former wet and dry periods in the Mallee, but at the present time all the streams entering it lose so much water by evaporation and percolation that they fail to reach the Murray and terminate in shallow lakes, many of which are salt. The Murray valley itself is cut into the higher Mallee land and is subject to periodic flooding by the river.

The Northern District Plains are formed from the combined flood plains of rivers flowing to the Murray, with an average gradient of between 3 and 5 ft to the mile, the surface being almost perfectly flat except where small residual hills of granite rise above the alluvium as at Pyramid Hill.

The Wimmera lies between the Western Highlands and the Mallee and is also composed mainly of river plains, except to the north of the Glenelg where old abandoned river channels contain a succession of small lakes. Most of the lakes of the Murray Basin Plains have crescentic loam ridges (lunettes) on their eastern shores.

Central Highlands

The Central Highlands form the backbone of Victoria, tapering from a broad and high mountainous belt in the east until they disappear beyond the Dundas Highlands near the South Australian border. They were formed by up-warping and faulting. The Eastern Highlands differ from the Western in their greater average elevation, with peaks such as Bogong, Feathertop, and Hotham rising above 6,000 ft, while the Western Highlands are generally lower, the peaks reaching above 3,000 ft, and the valleys being broader. Also, in the Eastern Highlands patches of Older Volcanic rocks occur, whereas in the Western the volcanic rocks belong mainly to the Newer Volcanic Series. Several well known volcanic mountains are still preserved, Mounts Buninyong and Warrenheip near Ballarat being examples.

Because of the great variety of geological formations in the Central Highlands and the effects of elevation and deep dissection by streams, the features of the country are very varied and there are many striking mountains and gorges. The severe winter climate, with heavy snow on the higher land, is also a special feature of the Eastern Highlands. Included in the area are several high plains such as those near Bogong and the Snowy Plains. Caves are well known in the limestone around Buchan.

In the Western Highlands the Grampians, with their striking serrate ridges of sandstone, may be compared with the belt of sandstone stretching from Mansfield to Briagolong in the east.

The Dundas Highlands are a dome that has been dissected by the Glenelg and its tributaries, the rocks being capped by ancient laterite soils which form tablelands with scarps at their edges.

Western District Plains

Many of the surface features of the Western District Plains are a result of volcanic activity, very large areas being covered with basalt flows of the Newer Volcanic Series above which prominent mountains rise, many of them with a central crater lake. Some of the youngest flows preserve original surface irregularities practically unmodified by erosion, thus forming the regions known as " stony rises ".

The coastal plains of the Western District are for the most part sandy, the soils being derived from Tertiary and Pleistocene sedimentary deposits, which in places attain a thickness of some 5,000 ft and yield considerable quantities of artesian water.

Gippsland Plains

Continuing the east-west belt of plains on the eastern side of the drowned area represented by Port Phillip Bay and Western Port are the Gippsland Plains. These are underlain by marine and non-marine Tertiary and Pleistocene sedimentary deposits, including the thick seams of brown coal of the La Trobe valley. A notable feature is the Ninety Mile Beach and the lakes and swamps on its landward side. This beach is an offshore bar on which aeolian sand ridges have accumulated.

Southern Uplands

Lying to the south of the plains above mentioned is a group of uplifted blocks for which faulting is mainly responsible, these constituting the Southern Uplands. The Otway Ranges and the South Gippsland Highlands are composed of fresh water Mesozoic and Tertiary sediments with Older Volcanic basalts in south Gippsland, and the Mornington Peninsula is an upraised fault block of complex geology, including granites. The Sorrento Peninsula is entirely composed of Pleistocene calcareous dune ridges which have been responsible for almost blocking the entrance to Port Phillip Bay.

Physical environment and land use

The Central Highland Zone (see fig. 11) is the dominant physiographic region of Victoria. The greatest importance of these Highlands is their influence on the drainage pattern of the State. They act as a drainage division and catchment areas between the long north and north-west flowing rivers that are part of the Murray system and the shorter south flowing rivers.

The Highlands are divided into two parts by the 1,200 ft Kilmore Gap, a natural gateway for transport routes leading north from Melbourne.

Eastern Highlands

To the east, the Eastern Highlands form a broad, rugged region of deeply dissected high plateaux with elevations of up to 6,000 ft. They form a barrier to east-moving air masses, giving rise to heavy orographic rainfall of over 1,250 mm a year in the higher parts. This is the wettest part of the State, and is the coldest region in winter with substantial snowfalls at higher elevations, a factor enabling the development of skiing resorts at locations such as Mt Buffalo, Mt Buller, Mt Hotham, and Falls Creek. Because of the elevation, this is also the coolest part of the State in summer. The rugged topography and dense forest cover of the Eastern Highlands makes them rather inaccessible and of little agricultural potential, so that they are the only large area of Victoria that is very sparsely settled and almost devoid of transport routes. However, the foothill zone adjoining the East Gippsland Plains is an important forestry area, while the lower slopes and valleys are used for grazing, particularly of cattle. High alpine grassland areas in the north-east, such as the Bogong High Plains, are used for summer grazing, this area being one of the rare cases of a transhumance farming economy in Australia. The high run-off and steep stream gradients have made the Eastern Highlands important for water storage and hydro-electricity generation at Kiewa, Eildon, and Rubicon.

Western Highlands

West of the Kilmore Gap, the Western Highlands are much lower than those to the east. These Highlands culminate in the west in a series of block mountains, of which the Grampians and the Dundas Highlands form the final western outlines of the Highland Zone. Stream gradients are more gentle than in the Eastern Highlands, so that hydro-electricity potential is low. However, the Rocklands Dam and the Eppalock and Cairn Curran Reservoirs are important storages for water supply to farms of the northern plains of Victoria.

The Western Highlands, because of their lower elevation, have a lower rainfall than the Eastern Highlands, and they do not act as a barrier to settlement and transport. The reasonably reliable rainfall of 500 mm to 750 mm a year, cool winters, warm summers, rolling topography, open dry sclerophyll forest and grasslands, and moderately fertile, although thin, volcanic soils offer an environment suitable for sheep grazing for wool and fat lambs, fodder cropping, dairying, and potato growing. Early settlement of the area was stimulated by the gold discoveries of the 1850s and 1860s in the Ballarat and Bendigo districts, and these two cities have developed as important regional centres. Castlemaine, Maryborough, and Clunes are additional service centres.

Murray Basin Plains

North of the Central Highland Zone are the flat Murray Basin Plains (see fig. 11). The western section is comprised of the Mallee–Wimmera Plain, characterised by areas of east-west running sand ridges, grey-brown and solonised Mallee soils, and some areas of sandy wastelands. Rainfall is around 500 mm a year in the southern Wimmera, but it decreases to under

250 mm a year in the north-western Mallee, which is the driest area of the State. As well as being low, rainfall is erratic and unreliable in the Mallee–Wimmera area, but the warm winters and hot summers ensure a year round growing season where water is available. Early farms were too small, and over-cropping led to widespread crop failures and soil erosion. Since the 1930s farming here has become more stable as a result of the provision of adequate and assured water supplies from the Wimmera–Mallee Domestic and Stock Water Supply System, larger farms of over 1,000 acres, crop rotations, the development of a crop-livestock farming pattern, the use of superphosphate and growing of legumes to maintain soil fertility, and soil conservation practices. The winter rainfall maximum and dry summer harvesting period, the good rail and road network and bulk handling facilities, and scientific farming techniques have enabled the Wimmera to become a region of high-yielding wheat and mixed farms. The drier areas of the Mallee are characterised more by larger sheep properties.

Of great significance in the Mallee are the irrigation areas of the Mildura–Merbein–Red Cliffs and Swan Hill districts, with close settlement farming growing vines and fruits. Mildura, Ouyen, Swan Hill, Horsham, Warracknabeal, and St Arnaud are the main regional centres of the Mallee–Wimmera Plains.

The Northern District Plains form the narrower eastern section of the Murray Basin Plains. Here rainfall increases from 400 mm a year in the western part to over 750 mm a year in the eastern part of the plain adjoining the Eastern Highlands. Rainfall is more reliable than in the Mallee–Wimmera District. However, there is generally a summer water deficiency which restricts pasture growth, so that the Northern District Plains are characterised by extensive grazing and mixed wheat-sheep farms. Recently there has been increasing emphasis on " ley " farming (i.e., rotation of crops and pastures) in order to increase carrying capacities and productivity. The higher, eastern section of the Northern District Plains with more reliable rainfall is one of the best sheep and cattle grazing areas in the State.

There is a marked contrast in the Northern District Plains between the " dry " farming areas and those closely settled irrigation areas of the Murray and its tributaries, especially in the Kerang, Echuca–Rochester, Kyabram–Shepparton, and Cobram–Yarrawonga areas, using water from the Loddon, Campaspe, Goulburn, and Murray Rivers, respectively. Fruits, vegetables, hops, and tobacco growing with local specialisations, and dairying based on improved pastures are the main activities in the irrigated districts. Shepparton has become an important centre for canned and frozen fruits and vegetables. These areas are also important as suppliers for the metropolitan fresh fruit and vegetable market.

In the Northern District Plains Shepparton, Wangaratta, and Benalla are large and expanding regional centres with manufacturing industries, while Echuca, Rochester, Kyabram, and Wodonga are smaller service centres with a small range of urban functions.

Coastal Region

South of the Central Highland Zone, coastal Victoria is readily divided into three regions.

The first of these is Port Phillip Bay and environs, bounded by the You Yang Range and Keilor Plain in the west, the Central Highlands in the north, the Dandenong Ranges and West Gippsland Plain in the east, and the Mornington Peninsula in the south-east. Melbourne, Geelong, and the developing Western Port area provide port facilities in this region. This region is dominated by the urban areas of Melbourne, which is the hub of the State's transport system, and Geelong. The urban areas are surrounded by intensively farmed rural landscapes in which market gardening is important in addition to cattle and sheep fattening, dairying, and fodder cropping. The bayside beach resorts and the seaside resorts of the Mornington Peninsula are the centre of an important tourist industry.

The second region of coastal Victoria is the extensive volcanic plain stretching westwards from the Port Phillip region. This is possibly the best agricultural region in Victoria. The rolling surface is characterised by volcanic plains and cones, lakes, and stony rises, with rich but shallow volcanic soils. Rainfall is above 500 mm a year in all areas, with a slight winter-spring maximum, and temperatures are warm in summer and mild in winter so that year round pasture growth and cropping are possible. Western District farms produce cattle, sheep for wool and fat lambs, fodder crops, and potatoes. This is also an important dairying district. Rural population densities, as well as those of the west Gippsland dairying country, are second highest in the State after the northern irrigation districts. Colac, Warrnambool, Portland, Hamilton, and Camperdown are the main regional centres. Portland has modern port facilities.

South of the Western District Plains lie the Otway Ranges, a sparsely populated region of rugged scenery and very high rainfall. The coastline between Anglesea and Apollo Bay has a number of popular tourist resorts.

The third region of coastal Victoria is Gippsland. East of Port Phillip Bay are the West Gippsland Plains, which are sandy in their western section where large areas of swamp have been drained for market gardening. The South Gippsland Highlands, a sparsely populated area of little agricultural potential, is bounded by the West Gippsland Plain and to the east by a fault trough stretching from Warragul to the La Trobe valley (included in East Gippsland Plains in fig. 11). The fault trough with its rolling hills, 750 mm rainfall, and year round pasture, is among the best dairying country on the Australian mainland, supplying the metropolitan wholemilk market. The La Trobe valley towns have experienced rapid post-war development as a result of the brown coal mining operations in the Yallourn–Morwell area.

East of the La Trobe valley, rainfall decreases to below 750 mm a year between Traralgon and the Gippsland lakes. Here the coastline is characterised by sand dunes and lagoons, backed by the riverine plains of the La Trobe, Macalister, Avon, and Mitchell Rivers. The relatively low rainfall necessitates irrigation for cropping. Irrigated farming in the Sale–Maffra, Bairnsdale, and (further east) Orbost districts is based on maize, bean, potato, and fodder growing. Elsewhere the main land use is cattle and sheep grazing.

The plains narrow east of Lakes Entrance when the coastline becomes one of alternating river valleys and hilly headlands where the Eastern Highlands protrude south to the sea. Forestry is the main activity here, with some grazing and fodder cropping in the valleys and foothills. Tourism is important in the area around Lakes Entrance, which is also a fishing port. Gippsland is linked with Melbourne by the Princes Highway and by rail as far east as Orbost.

Mountain regions

The mountainous regions of Victoria comprise the Central Highlands and a belt known as the Southern Uplands lying to the south and separated from the Central Highlands by plains.

The Central Highlands form the backbone of Victoria, tapering from a broad and high mountainous belt in the east until they disappear near the South Australian border. In the eastern sector patches of Older Volcanic rocks occur and peaks rise over 6,000 ft, while in the western sector the volcanic rocks belong mainly to the Newer Volcanic Series and the peaks reach 3,000 ft.

The Highlands descend to plains on their southern and northern flanks. On the south are the Western District Plains and the Gippsland Plains, and beyond these again rises a group of uplifted blocks constituting the Southern Uplands. The Otway Ranges and the hills of south Gippsland are composed of fresh water Mesozoic sediments and Tertiary sands and clays with Older Volcanic rocks in south Gippsland, and the Mornington Peninsula is an upraised fault block of complex geology, including granites.

By 1875 the mountainous areas of the State were embraced by a geodetic survey which had been started in 1856. This was the first major survey, although isolated surveys had been carried out as early as 1844. Further surveys were carried out by the Australian Survey Corps during the Second World War, and by the Department of Lands and Survey in the post-war years. Most recent values for some of the highest mountains in Victoria are Mt Bogong, 6,516 ft ; Mt Feathertop, 6,307 ft ; Mt Nelse, 6,181 ft ; Mt Fainter, 6,157 ft ; Mt Loch, 6,152 ft ; Mt Hotham, 6,108 ft ; Mt Niggerhead, 6,048 ft ; Mt McKay, 6,045 ft ; Mt Cobberas, 6,030 ft ; Mt Cope, 6,026 ft ; Mt Spion Kopje, 6,025 ft ; and Mt Buller, 5,919 ft.

Rivers

Stream discharges

Water is a limited resource and a major factor in the development of the State, hence a knowledge of its water resources is essential to their optimum use. Tabular data giving the mean, maximum, and minimum discharges at selected gauging stations are published by the State Rivers and Water Supply Commission in *Victorian River Gaugings to 1969,* containing records of 299 gauging stations.

An average value such as the mean annual discharge is a useful relative single measure of magnitude, but variability is equally important. A crude measure of variability is given by the tabulated values of the maximum and minimum annual discharges ; however, the difference between these extremes, termed the " range ", will increase with increasing length of record.

Drainage areas and lengths

Other characteristics relating to streams are the size of the catchment and the lengths of the rivers. Drainage areas of gauged catchments are given in *Victorian River Gaugings to 1969,* and the lengths of 230 rivers are tabulated on pages 31 to 35 of the *Victorian Year Book* 1963.

Drainage areas may be regarded as the hydrologically effective part of a " basin ", or the area from which there is " run-off " to the stream. Thus, the whole of any area may be subdivided into basins, but parts of some basins may be regarded as non-effective, being either too flat or the rainfall too small to contribute to normal stream flows. There is little or no contribution in the north-west of the State where the annual rainfall is less than 457 mm to 508 mm. Above this amount, roughly half the rainfall appears as stream flow.

Total flow

The current estimate of mean annual flow is 17 million acre ft each year, about half of which flows into the Murray, the other half flowing south-

VICTORIA—MAIN STREAM FLOWS

Div.	Basin	Stream	Site of gauging station	Drainage area (square miles)	Year gauged from	No. of water years	Annual flows in '000 acre ft		
							Mean	Max.	Min.
IV. Murray-Darling	1	Murray	Jingellic, N.S.W.	2,520	1890	80	1,925	4,978	549
	1	Mitta Mitta	Tallandoon	1,821	1935	34	1,032	2,613	222
			Tallangatta	1,953	1886	49	1,147	3,460	203
	2	Kiewa	Kiewa	442	1886	84	514	1,684	135
	3	Ovens	Wangaratta	2,250	1941	29	1,278	3,368	180
	4	Broken	Goorambat	743	1887	84	201	887	15.5
	5	Goulburn	Murchison	4,159	1882	88	1,739	5,991	118
	6	Campaspe	Elmore	1,240	1886	78	192	667	0.6
	7	Loddon	Laanecoorie Reservoir	1,613	1891	78	188	602	7.5
	8	Avoca	Coonooer	1,020	1890	80	62	321	2.6
	15	Wimmera	Horsham	1,570	1889	77	104	479	..
II. South East Coast	22	Snowy	Jarrahmond	5,182	1922(*a*)	33	1,475	3,254	315
	23	Tambo	Swifts Creek	364	1965	5	47	98	17
	24	Mitchell	Glenaladale	1,507	1938	32	749	1,779	157
	25	Thomson	Cowwarr	420	1901	50	325	553	142
	25	Macalister	Lake Glenmaggie	730	1919	51	403	1,246	37
	26	La Trobe	Rosedale	1,600	1901(*b*)	55	764	2,634	220
	28	Bunyip	Bunyip	255	1908(*c*)	47	124	246	56
	29	Yarra	Warrandyte	899	1892(*d*)	52	654	1,215	143
	30	Maribyrnong	Keilor	503	1908(*e*)	39	87	266	3
	31	Werribee	Melton Reservoir	446	1917	53	64	255	5.4
	32	Moorabool	Batesford	430	1908(*f*)	24	57	180	1.2
	33	Barwon	Inverleigh	490	1966	4	47	83	5.5
	35	Carlisle	Carlisle River	30	1930(*g*)	33	31	71	5.2
	36	Hopkins	Wickliffe	520	1921(*h*)	38	26	103	0.7
	38	Glenelg	Balmoral	606	1889(*i*)	60	117	439	2.5

Source: *Victorian River Gaugings to 1969,* State Rivers and Water Supply Commission.

NOTE. Years excluded in estimating mean :

(*a*) 1949–50 to 1963–64
(*b*) 1919–20 to 1928–29 and 1934–35 to 1936–37
(*c*) 1951–52
(*d*) 1933–34 to 1958–59
(*e*) 1933–34 to 1955–56
(*f*) 1921–22 to 1958–59
(*g*) 1943–44 to 1946–47
(*h*) 1933–34 to 1943–44
(*i*) 1933–34 to 1938–39

ward to the Victorian coast. The geographic distribution of flow is heavily weighted towards the eastern half where the total flow is about 14 million acre ft (with about 8 million acre ft in the north-east and 6 million acre ft in the south-east), hence leaving 3 million acre ft in the western half.

Location of streams

The location of about 2,500 streams in Victoria may be obtained by referring to the *Alphabetical Index of Victorian Streams* compiled by the State Rivers and Water Supply Commission in 1960. Owing to the replication of names for some streams, there are over 2,900 names; these have been obtained by examining Department of Crown Lands and Survey and Royal Australian Survey Corps maps, so as to include names which

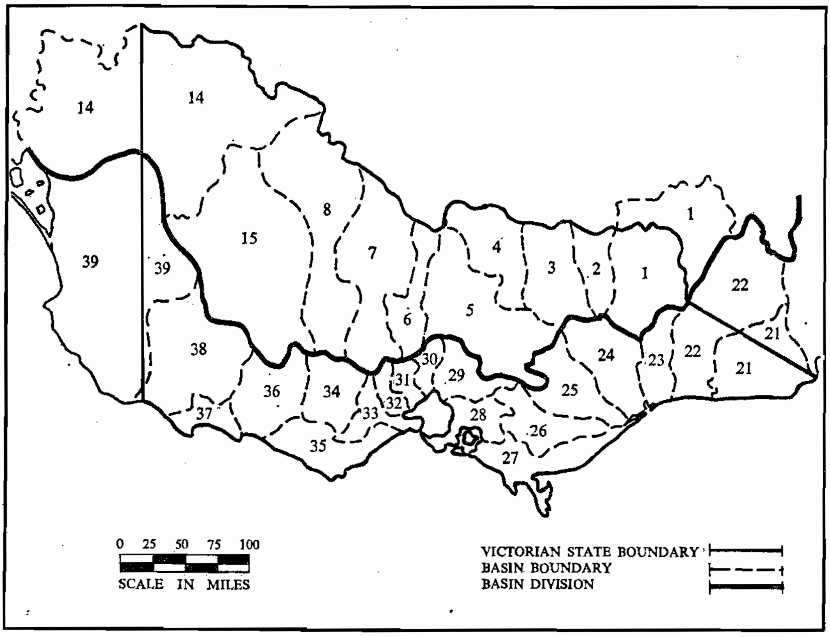


FIGURE 12. Relevant basins of the two Divisions (South East Coast Division and Murray–Darling Division) which include Victoria and some adjacent areas. The basins are numbered as shown on Map 3 (Sheet 2) in *Review of Australia's Water Resources,* published by the Department of National Development, 1965.

SOUTH EAST COAST DIVISION

21. East Gippsland
22. Snowy River
23. Tambo River
24. Mitchell River
25. Thomson River
26. La Trobe River
27. South Gippsland
28. Bunyip River
29. Yarra River
30. Maribyrnong River
31. Werribee River
32. Moorabool River
33. Barwon River
34. Lake Corangamite
35. Otway
36. Hopkins River
37. Portland
38. Glenelg River
39. Millicent Coast

MURRAY–DARLING DIVISION

1. Upper Murray River
2. Kiewa River
3. Ovens River
4. Broken River
5. Goulburn River
6. Campaspe River
7. Loddon River
8. Avoca River
14. Mallee
15. Wimmera–Avon River

have appeared on them. There are, in addition, many unnamed streams, those with locally known names, and those named on other maps or plans. No attempt was made in the *Index* to suggest a preferred name ; this is a function of the committee appointed under the *Survey Co-ordination Place Names Act* 1965.

Stream reserves

In 1881, under the then current Land Act, an Order in Council created permanent reserves along the banks of streams where they passed through Crown land. These are scheduled in the *Township and Parish Guide* reprinted by the Lands Department in 1955. This schedule indicates the location and width of reservations for 280 streams which (except for the Murray) are 1, 1½, or 2 chains wide on *each* bank of the stream. The areas thus reserved were not fully delineated until subsequently surveyed prior to alienation.

Further reference, 1963 ; Droughts, 1964

Floods

The natural history of unregulated rivers is largely the history of their floods and droughts. Rainfall intensity increases with decrease in latitude and consequently Victoria is less subject to floods than the northern States. The practical importance of floods is, however, largely related to the damage they do in occupied areas.

Flood damage usually occurs because of the occupation of flood plains, and once occupied there is a demand for protection which is commonly provided by levees. Such levees have been constructed along the major streams including the Murray, Snowy, and Goulburn, and also in urban areas occupying the flood plain of the Dandenong Creek. The objection to levees is that by restricting the flood plain, the flood level for a given discharge is increased, and if overtopping does occur, damage is more serious. Other flood mitigation measures used in Victoria, such as straightening the stream to increase the gradient and flow rate, have also been used on such streams as the Bunyip and the Yarra. Provision to prevent excessive scour may be necessary in some cases.

Lake level changes

Another form of flood damage that has occurred in the Western District is due to the increase in level of closed lakes flooding marginal land. This has been caused by a series of wet years since 1950 upsetting the normal balance between evaporation and inflow. In the decade from 1950 the winter rainfalls in the region of Lake Corangamite were 15 per cent above average, and the lake level rose 11 ft above its normal level of 380 ft to 391 ft to inundate about 20 square miles of adjacent land.

To reduce the inflow to this lake and hence the area flooded, a 28 mile channel, completed in 1959, diverts water to the Barwon River from the Cundare Pool. This pool, which was formed by building a low barrage across a shallow area at the head of the lake, acts as a temporary storage for the relatively fresh waters of the Woady Yaloak River which normally enter the lake.

The rate of diversion is governed by the level of the Cundare Pool and by the relative salinities of water in the pool and in the Barwon River.

If the 60,000 acre ft diverted in 1960 had entered Lake Corangamite, the lake level would have been 9 inches above the maximum observed level. The level would have been almost as high again in late 1964—another very wet year—but for the diversion in the preceding five years of about 180,000 acre ft. These wet years have maintained the relatively high lake level.

Legislation has been passed to permit the Government to pay compensation on a special scale to landowners who may elect to surrender land up to 388 ft above sea level around Lake Corangamite, plus any higher land rendered inaccessible to the landowner by the initial surrender. The legislation also makes similar provision for the neighbouring Lakes Gnarpurt and Murdeduke.

Other floods

Owing to the tendency for major floods to overflow the banks and, in flat country, to pass down other channels which may not rejoin the main stream, it is often difficult to determine even the relative magnitude of major floods. The difficulty is magnified by the necessity for maintaining records of the level of the gauge in relation to a permanent datum, if a true comparison is to be made.

The year 1870 is regarded as the wettest Victoria has experienced for over a century. As there were only thirteen rainfall stations whose records are available, the estimated average of 950 mm over the State is crude, but is 80 mm more than the next highest figure of 870 mm for 1956. River gauges in 1870 were practically restricted to the Murray, and consequently flood estimates on other streams are crude and can only be inferred from dubious evidence. Furthermore, subsequent to the 1870 floods, levees were constructed along the Goulburn and other streams and consequently heights of subsequent floods were augmented by the restrictions imposed.

In the north-east, floods occurred in the years 1906, 1916, 1917, and 1956. Although records of flood flows at gauging stations on the main streams have been published, such estimates are open to correction in the light of more recent evidence. Owing in part to under-estimation of earlier floods, the protection at the S.E.C. works at Yallourn was inadequate and the 1934 flood overflowed the banks of the La Trobe into the open cut at Yallourn. This flood was caused by a storm which is, on the basis of rainfall over large areas, the most severe to have been recorded within Victoria. An earlier storm of December 1893 which occurred over east Gippsland was heavier, but this also covered part of New South Wales.

Lakes

Lakes may be classified into two major groups : those without natural outlets which are called closed lakes and those with a natural overflow-channel which may be termed open lakes. For closed lakes to form, annual evaporation must exceed the rainfall : this is the case over most of Victoria.

Closed lakes occur mainly in the flat western part of the State. They fluctuate in capacity much more than open lakes and frequently become dry if the aridity is too high. Lake Tyrrell in the north-west is usually dry throughout the summer and can consequently be used for salt harvesting.

The level of water in an open lake is more stable because as the lake rises the outflow increases, thus governing the upper lake level and partially regulating streams emanating from it. This regulation enhances the economic value of the water resources of open lakes but Victoria does not possess any natural large lake-regulated streams. However, there are small streams of this type in the Western District, such as Darlots Creek partly regulated by Lake Condah and Fiery Creek by Lake Bolac.

Salinity is often a factor which limits the use of lake water ; even the use of freshwater lakes is not extensive in Victoria due to the cost of pumping. The average salinity of closed lakes covers a wide range depending upon the geological conditions of the catchments and the water level.

Lake Corangamite is Victoria's largest lake. It can be regarded as a closed lake although during the wet period in the late 1950s it rose to within 4 ft of overflowing. The total salt content is about 16 million tons, giving the lake a salinity somewhat higher than seawater under average water level conditions.

The Gippsland lakes are a group of shallow coastal lagoons in eastern Victoria, separated from the sea by broad sandy barriers bearing dune topography, and bordered on the ocean shore by the Ninety Mile Beach. A gap through the coastal dune barrier near Red Bluff, which was opened in 1889, provides an artificial entrance to the lakes from the sea. However, sea water entering this gap has increased the salinity of some lakes, which in turn has killed some of the bordering reed swamp and led to erosion. The Gippsland lakes have been of value for commercial fishing and private angling and also attract many tourists. Coastal lagoons of this type rarely persist for more than a few thousand years and as deposition of sediment proceeds and bordering swamps encroach, the lakes will gradually be transformed into a coastal plain.

A number of Victorian lakes and swamps have been converted to reservoirs. Waranga Reservoir is an example of this, as are Lake Fyans, Batyo Catyo, and Lake Whitton in the Wimmera. A good example of lake utilisation is the Torrumbarry irrigation system on the riverine Murray Plains near Kerang in north-west Victoria.

Further reference, 1965 ; Natural Resources Conservation League, 1965

Survey and mapping

The Survey and Mapping Division of the Department of Crown Lands and Survey is responsible for the development of the National Geodetic Survey within Victoria; the preparation of topographic maps in standard map areas; the survey of Crown lands under the provisions of the *Land Act* 1958; the co-ordination of surveys throughout the State under provisions of the *Survey and Co-ordination Act* 1958 ; surveys for the Housing Commission, the Rural Finance and Settlement Commission, and other departments and authorities; and the documentation of these surveys.

An Australia-wide primary geodetic survey was completed in 1966, and in Victoria this is continuously being extended to provide a framework of accurately fixed points for the control of other surveys and for mapping. A State-wide network of levels was completed in 1971. The datum, based on mean sea level values around the whole coast of Australia, is known as the Australia Height Datum (AHD), and its adoption obviates the multitude of local datums formerly in use throughout the State. Issued lists of level values on the AHD are in metres.

An official map of Victoria showing highways, roads, railways, watercourses, towns, and mountains, together with other natural and physical features, has been published in four sheets at a scale of 1 : 500,000. A less detailed map of Victoria is also available in one sheet at a scale of 1 : 1,000,000. Topographic maps at a scale of 1 : 250,000 providing a complete map coverage of the whole State have been published by the Division of National Mapping of the Department of National Development and the Royal Australian Survey Corps. A joint State–Australian Government mapping project, commenced in 1966, is proceeding with the production of topographic maps at a scale of 1 : 100,000 with a 20 metre contour interval. A number of these maps have been published, and it is expected complete map coverage of the State in this series will be available by the end of 1976. The Mines Department and the Forests Commission also contribute to State mapping by publishing maps for geological and forestry purposes.

A series of 22 maps at a scale of 1 : 25,000 showing streets, rivers, creeks, and municipal boundaries in Melbourne and its suburban area has been produced. A long-term programme for production of general purpose standard topographic maps, at 1 : 25,000 scale with a 10 metre contour interval, has been planned to extend this map coverage over the greater metropolitan area, and to embrace many of the larger provincial centres. Other maps of urban and suburban areas at 1 : 10,000 scale showing full subdivisional information, are being prepared of the Mornington Peninsula area; similar maps of various rural centres are on programme in conjunction with Australian Government maps at the same scale required for census purposes.

Large scale base maps have been prepared for rapidly developing areas throughout the State, including the outer metropolitan area, Mornington Peninsula, Ballarat, Geelong, Bendigo, Phillip Island, and a number of other rural areas. These maps were originally compiled at a scale of 1: 4,800 (400 feet to 1 inch) with a 5 foot contour interval. However, with the introduction of the metric system, all new maps will be prepared at a scale of 1 : 5,000, generally with a 2 metre contour interval. The publication *Official Map and Plan Systems Victoria* has been issued setting out the standard format size and numbering systems which have been adopted for the production of maps and plans at the standard scales of 1 : 5,000, 1 : 2,500, 1 : 1,000, 1 : 500, and 1 : 250. The systems are based on the Australian Map Grid (AMG), which fulfils the basic principles necessary for the complete integration of surveys.

The Division carries out cadastral surveys of Crown lands for the purpose of defining boundaries and for determining dimensions and areas of reservations and of allotments for the subsequent issue of Crown grants. This information forms the basis for the compilation of county, parish, and township plans, which are published at various scales and show details of the original subdivision of Crown lands. Recently further investigations have been made with the object of introducing a fully integrated topographic-cadastral map and plan system. Although cadastral requirements may result in the publication of plans using an additional range of scales, it will be a fundamental principle that the Australian Map Grid will be the basic framework of their compilation.

As part of its mapping activity the Department provides an aerial photography service, and maintains an aerial photography library of approximately 300,000 photographs from which prints and enlargements may be obtained. Maps, plans, and aerial photographs are available for purchase from the Central Plan Office of the Department.

Further references, 1962; Hydrography, Coastline, 1966; Coastal physiography, 1967; Plant ecology of the coast, 1968; Marine animal ecology, 1969; Marine algae of the Victorian coast, 1970; Erosion and sedimentation on the coastline, 1971; Conservation on the Victorian coast, 1972

CLIMATE

Victoria

Victoria experiences a wide range of climatic conditions ranging from the hot summer of the Mallee to the winter blizzards of the snow covered Alps, and from the relatively dry wheat belt to the wet eastern elevated areas where many of Victoria's permanent streams spring.

Circulation patterns affecting Victoria

The predominating pattern which affects Victoria is an irregular succession of depressions and anticyclones. Although these systems generally move from west to east, this is not always the case. Systems can develop or degenerate *in situ*. Their speed of movement can vary considerably. They can remain quasi-stationary for even a week or more at a time.

The mean tracks of the depressions and anticyclones show a marked annual variation across the Australian region. In winter, due to the cold continent, anticyclones are centred over inland Australia, and a series of depressions over southern waters provide a persistent zonal flow across southern parts of the continent. However, on occasions when an anticyclone develops a ridge to southern waters and a depression intensifies east of Tasmania, a " cold outbreak " occurs. This brings cold and relatively dry air from southern waters rapidly across Victoria, giving windy, showery weather with some hail and snow. On other occasions, when an anticyclone moves slowly over Victoria, a prolonged spell of fine weather with frost and fog results.

During the spring the average track of depressions and anticyclones shifts further south until in summer the average position for anticyclones is south of the continent. At this time of the year the troposphere is warmer, and therefore can hold more moisture. For this reason, rainfall during the summer months tends to be heavier. However, lifting agents in the form of cold fronts are weaker and are not as frequent as the succession of fronts that pass in winter and spring, and so rain days are less frequent in summer.

Heat-wave conditions, which usually last between two and three days, and occasionally longer, are not infrequent in summer when a large anticyclone remains quasi-stationary over the Tasman Sea. Dry air from the hot interior of the continent is brought over south-eastern Australia, and hot gusty northerly winds strengthen with the approach of a southerly change. These changes vary in intensity and while some are dry, others may produce rain and thunderstorms.

During the autumn, the mean track of the anticyclones moves northwards and extremes of temperature become less frequent as the season progresses.

The circulation pattern at the surface does not always bear the same relation to the weather pattern. Rainfall may be produced by a depression in the upper atmosphere without any indication at the surface. One of the greatest State-wide rain producing systems is a weak surface depression, centred over the State and extending upwards in the atmosphere to 6,000 metres and more. On occasions, the surface depression is not a closed system, but a trough extending south from northern Australia. This situation is more common in the summer months and when preceded by an extensive flow of moist humid air over Victoria from the Tasman Sea, very heavy rainfall can result.

The heaviest rainfall in east Gippsland is produced by intense depressions to the east of Bass Strait. These may have come from the west and intensified in this area, or alternatively may have developed to the east of New South Wales or further north, and moved southwards along the coast.

The distribution of the average annual rainfall in Victoria is shown in the map on page 49.

Rainfall

Rainfall exhibits a wide variation across the State and although not markedly seasonal, most parts receive a slight maximum in the winter or spring months. The relatively dry summer season is a period of evaporation, which greatly reduces the effectiveness of the rainfall. Average annual totals range between 250 mm for the driest parts of the Mallee to over 1,500 mm for parts of the North-Eastern Highlands. An annual total exceeding 3,500 mm has been reported from Falls Creek in the north-east ; however, with the sparse population and inaccessibility of the highland localities, it is not practicable to obtain a representative set of observations from this area. Most areas south of the Divide receive an annual rainfall above 600 mm, with over 1,000 mm on the Central Highlands, Otway Ranges, and southern Gippsland. The wheat belt receives chiefly between 300 and 500 mm. With the exception of Gippsland, 60 to 65 per cent of the rain falls during the period May to October. This proportion decreases towards the east, until over Gippsland the distribution is fairly uniform with a warm season maximum in the far east. All parts of the State have on rare occasions been subjected to intense falls, and monthly totals exceeding three times the average have been recorded. Monthly totals exceeding 250 mm have been recorded rarely at most places on and south of the Divide, the chief exception being over the lowlands extending from Melbourne to the central Western District. Occurrences are more frequent, but still unusual, over the north-east and east Gippsland and isolated parts such as the Otways. This event has rarely been recorded over the north-west of the State. The highest monthly total ever recorded in the State was a fall of 891 mm at Tanybryn in the Otway district in June 1952.

The average annual number of wet days (0.2 mm or more in 24 hours) is over 150 on the west coast and west Gippsland, and exceeds 200 over the Otway Ranges. The average number of wet days a year is reduced to 100 at a distance of approximately one hundred miles inland from the coast.

An estimate of the area, distribution of average annual rainfall, and the actual distribution of rainfall in Victoria as shown by area for the years 1968 to 1972 are shown in the following table :

VICTORIA—DISTRIBUTION OF AVERAGE AND ANNUAL RAINFALL

Rainfall (mm)	Area ('000 sq km) (a)					
	Average	1968	1969	1970	1971	1972
Under 300	18.4	13.7	..	8.8	9.6	55.2
300–400	36.5	22.0	45.2	36.7	23.6	38.5
400–500	27.5	38.1	42.4	29.6	30.0	35.0
500–600	34.9	33.4	34.8	18.2	24.6	40.7
600–800	52.3	56.2	37.8	35.8	50.0	40.9
800–1,000	29.0	25.6	37.2	38.2	47.1	12.9
Over 1,000	29.0	38.6	30.2	60.3	42.7	4.4

(a) Total area of the State is 227,619 sq km.

District rainfall

Mallee and Northern Country

These districts receive very little rain from western cold fronts, and rain is usually brought by depressions moving inland, " upper lows ", and thunderstorms. The amount received is highly variable from year to year. The average rainfall is fairly even through the year, except near the northern edge of the ranges where more rain falls in winter than in summer.

Wimmera

Rainfall in this district is more reliable than further to the north, as cold fronts bring showers, particularly in winter. The average rainfall shows a slight maximum in the winter months. This district includes part of the Grampians, which receive much higher rainfall than the plains.

Western and Central Districts

Rain may fall in these districts in a variety of situations and they have the most reliable rainfall in the State. Most rain comes with the westerly winds and cold fronts that predominate in winter and the average rainfall shows a winter maximum which is most marked along the west coast. The heaviest rain falls on the Otways, the Dandenongs, and the upper Yarra valley, while the plain to the west and south-west of Melbourne has relatively low rainfall due to the " rain shadow " of the Otway Ranges.

North Central

Most of this district consists of elevated country surrounding the Dividing Range and rainfall is heaviest on the higher parts, particularly towards the east. There is a well marked winter maximum in the yearly rainfall distribution.

North-Eastern

The greater part of this district consists of ranges, some mountains being 1,800 metres in elevation, and rainfall on this higher country is generally heavy. The higher peaks lie under snow cover for most of the winter. A marked " rain shadow " area is evident near Omeo, which receives only half as much rain as the highlands to the north-west or north-east.

West Gippsland

The western part of this district has a very similar rainfall régime to the Western and Central Districts. The heaviest rain falls on the ranges of the Divide and the south Gippsland hills. Towards the east, however, a " rain shadow " is evident in the Sale–Maffra area. This eastern section receives some of its rain from east coast depressions.

East Gippsland

Depressions off the east coast bring most rain to this district, and such rainfall can be very heavy. The average rainfall shows a summer maximum. Fronts moving in a westerly stream bring very little rain, and with north-westerly winds in winter, the coastal section has the mildest weather in the State. " Rain shadows " are evident along the valleys of the Mitchell, Tambo, and Snowy Rivers while the heaviest rain falls on the surrounding highlands.

VICTORIA—RAINFALL IN DISTRICTS
(mm)

Year	District							
	Mallee	Wimmera	Northern	North Central	North-Eastern	Western	Central	Gippsland
1963	410	471	525	774	901	657	720	905
1964	410	636	532	874	1,023	983	899	965
1965	299	387	390	656	655	627	637	668
1966	317	418	515	812	1,048	746	815	990
1967	130	221	240	408	448	417	434	593
1968	348	500	532	880	1,004	852	733	865
1969	408	443	481	690	878	679	664	915
1970	367	474	515	843	993	857	937	1,122
1971	384	568	529	891	888	905	849	872
1972	261	365	331	576	522	600	564	601
Average (*a*)	327	459	466	709	864	724	738	856

(*a*) Average for 60 years 1913 to 1972.

Rainfall reliability

It is not possible to give a complete description of rainfall at a place or in a district by using a single measurement. The common practice of quoting the annual average rainfall alone is quite inadequate in that it does not convey any idea of the extent of the variability likely to be encountered. Examination of rainfall figures over a period of years for any particular place indicates a wide variation from the average ; in fact, it is rare for any station to record the average rainfall in any particular year. Thus for a more complete picture of annual rainfall the variability or deviation from the average should be considered in conjunction with the average.

Rainfall variability assumes major importance in some agricultural areas. Even though the average rainfall may suggest a reasonable margin of safety for the growing of certain crops, this figure may be based on a few years of heavy rainfall combined with a larger number of years having rainfall below minimum requirements. Variability of rainfall is also important for water storage design, as a large number of relatively dry years would not be completely compensated by a few exceptionally wet years when surplus water could not be stored.

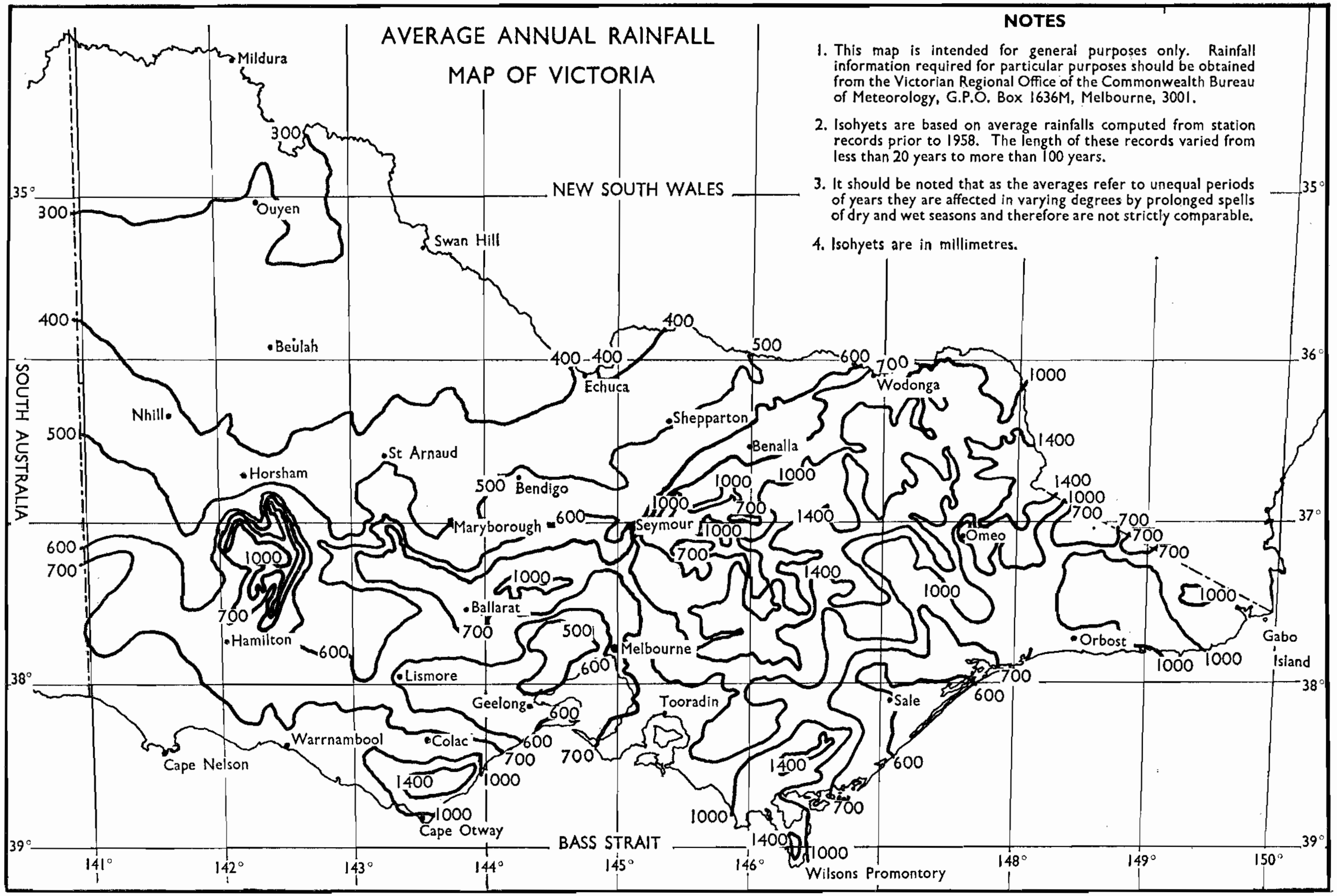

AVERAGE ANNUAL RAINFALL
MAP OF VICTORIA
NOTES
1. This map is intended for general purposes only. Rainfall information required for particular purposes should be obtained from the Victorian Regional Office of the Commonwealth Bureau of Meteorology, G.P.O. Box 1636M, Melbourne, 3001.
2. Isohyets are based on average rainfalls computed from station records prior to 1958. The length of these records varied from less than 20 years to more than 100 years.
3. It should be noted that as the averages refer to unequal periods of years they are affected in varying degrees by prolonged spells of dry and wet seasons and therefore are not strictly comparable.
4. Isohyets are in millimetres.
NEW SOUTH WALES
SOUTH AUSTRALIA
BASS STRAIT
Mildura
Ouyen
Swan Hill
Beulah
Echuca
Nhill
Shepparton
Benalla
Wodonga
St Arnaud
Horsham
Bendigo
Maryborough
Seymour
Omeo
Ballarat
Hamilton
Melbourne
Orbost
Gabo Island
Lismore
Geelong
Tooradin
Sale
Warrnambool
Colac
Cape Nelson
Cape Otway
Wilsons Promontory
35°
36°
37°
38°
39°
141°
142°
143°
144°
145°
146°
148°
149°
150°

FIGURE 13.

VICTORIA—DISTRICT MONTHLY RAINFALL: AVERAGE AND 1972

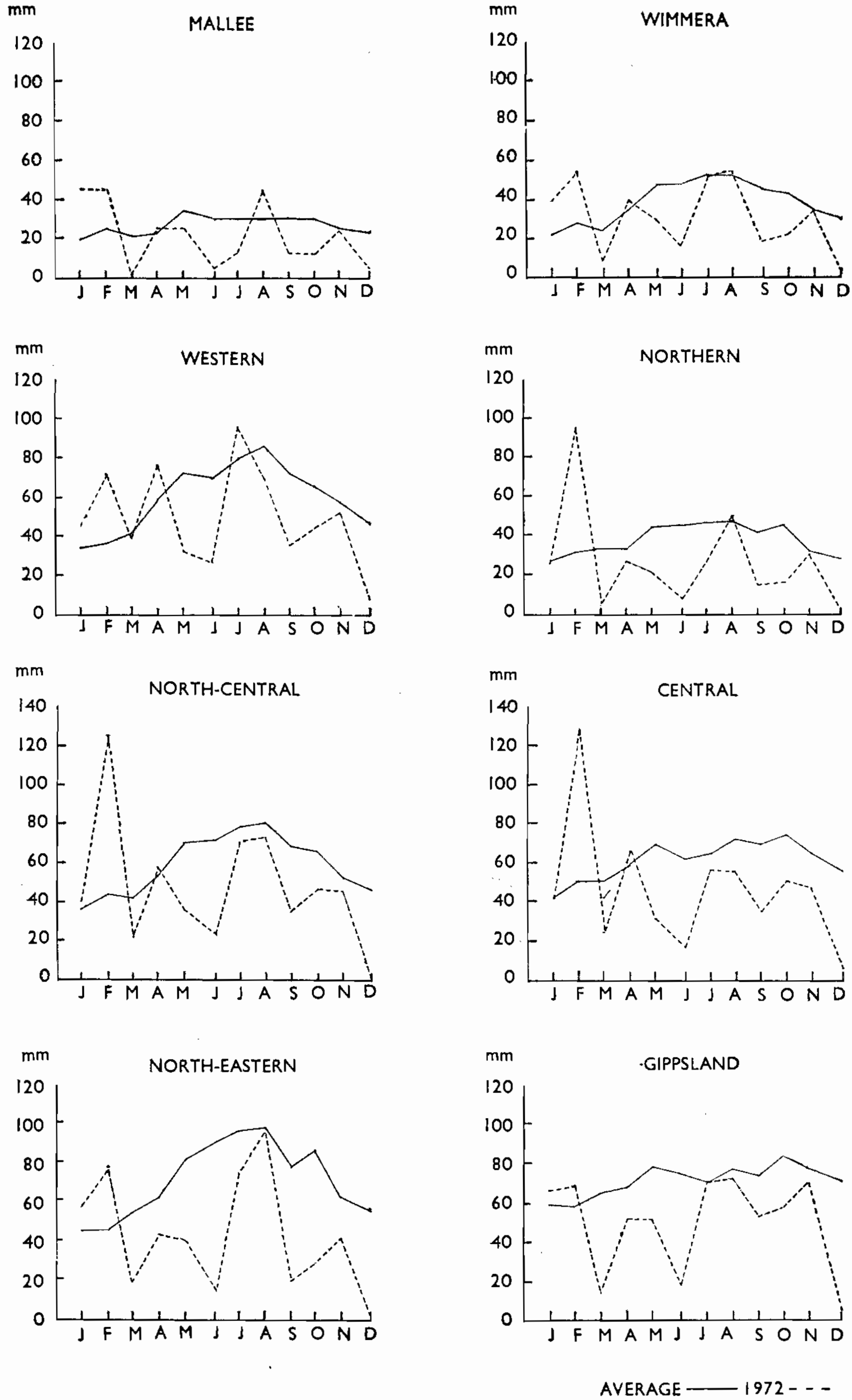


FIGURE 14.

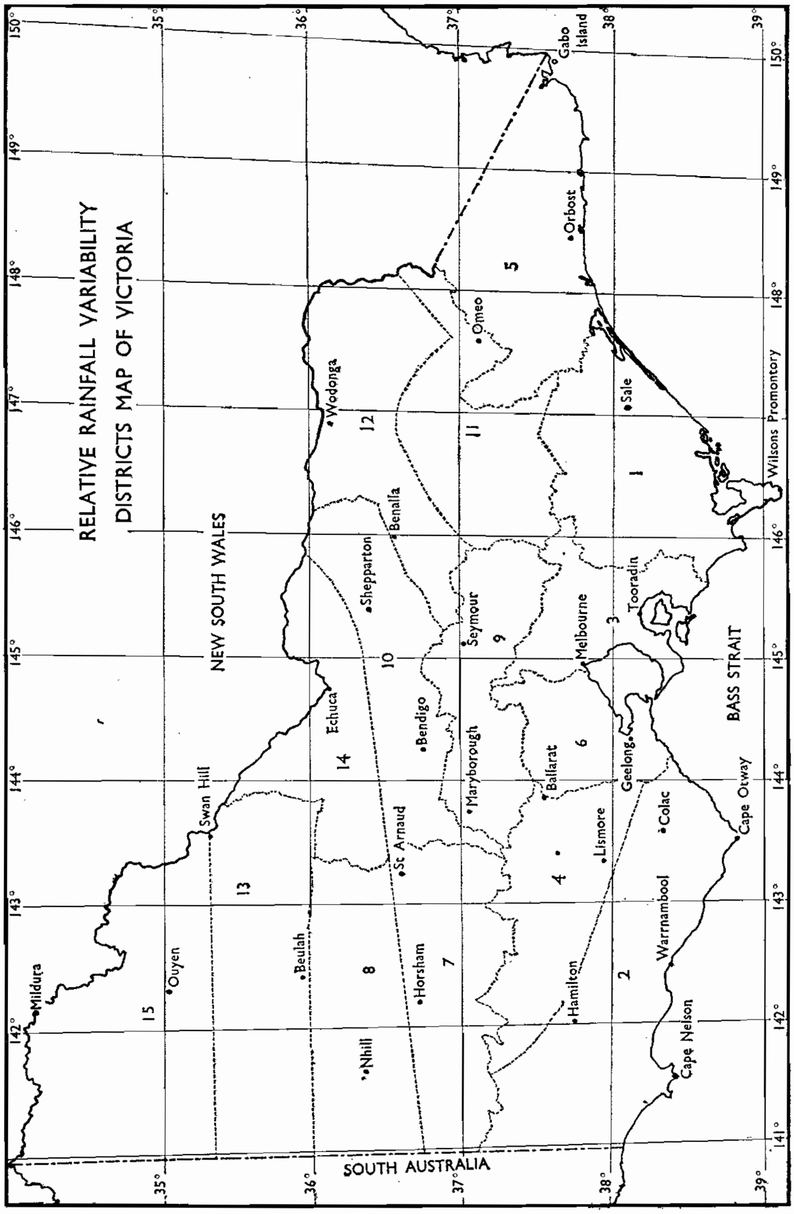


FIGURE 15. Relative rainfall variability regions. Names of climatic regions are shown in the table on page 52.

Although variability would give some indication of expected departures from normal over a number of years, variability cannot be presented as simply as average rainfall.

Several expressions may be used to measure variability, each of which may have a different magnitude. The simplest measure of variability is the range, i.e., the difference between the highest and lowest annual amounts recorded in a series of years. Annual rainfall in Victoria is assumed to have a " normal " statistical distribution. These distributions can be described fully by the average and the standard deviation. To compare one distribution with the other, the coefficient of variation $\left(\frac{\text{standard deviation}}{\text{the average}} \times 100\right)$ has been used. The coefficient of variation has been calculated for the fifteen climatic regions of Victoria (see Figure 15) for the 60 years 1913 to 1972 and the results are tabulated below in order of rainfall reliability :

VICTORIA—ANNUAL RAINFALL VARIATION

District	Average annual rainfall (a)	Standard deviation	Coefficient of variation
	mm	mm	per cent
1 West Gippsland	915	144	15.7
2 West Coast	773	127	16.4
3 East Central	885	150	16.9
4 Western Plains	630	113	17.9
5 East Gippsland	767	144	18.8
6 West Central	607	119	19.6
7 Wimmera South	493	99	20.1
8 Wimmera North	407	88	21.6
9 North Central	709	157	22.1
10 Upper North	508	119	23.4
11 Upper North-east	1,106	268	24.2
12 Lower North-east	766	187	24.4
13 Mallee South	348	89	25.6
14 Lower North	423	116	27.4
15 Mallee North	299	85	28.4

(a) Average for 60 years 1913 to 1972.

The higher the value of the coefficient of variation of the rainfall of a district, the greater the departure from the average and hence the more unreliable the rainfall.

Droughts

The variability of annual rainfall is closely associated with the incidence of drought. Droughts are rare over areas of low rainfall variability and more common in areas where this index is high.

Since records have been taken, there have been numerous dry spells in various parts of Victoria, most of them of little consequence but some widespread and long enough to be classified as droughts. The severity of major droughts or dry spells is much lower in Gippsland and the Western District than in northern Victoria.

The earliest references to drought in Victoria appear to date from 1865 when a major drought occurred in northern Victoria, and predominantly dry conditions prevailed in the Central District. Another dry spell of lesser intensity occurred in 1868.

The most severe and widespread drought recorded since European settlement in Australia occurred in the period 1897 to 1902. Victoria was most affected in the south in 1897–98 and in the north in 1902.

The next major drought commenced about June 1913 and continued until April 1915 in the north and west and until August 1916 in Gippsland. The worst period was from May to October 1914.

The period from 1937 to 1945 was marked by three major droughts. The first commenced in February 1937 and continued with a break in the succeeding spring and summer until January 1939, the effects being felt much more severely in northern districts than elsewhere. Good rains in 1939 were followed by another dry period from December 1939 to December 1940. The third drought of the period extended from 1943 to 1945 in which the worst period was from June to October 1944. The drought from 1967 to 1968 is described on pages 53 and 67 of the *Victorian Year Book* 1969 and other effects noted on pages 309–12 of the *Victorian Year Book* 1970.

Drought prevailed in east Gippsland in 1971. In 1972 this drought extended westwards to affect most parts of the State by the end of the year, before breaking with heavy rain in February 1973.

Droughts of shorter duration and lower intensity occurred in 1877, 1888, in 1907–08 in Gippsland, and in the 1920s, particularly 1925, 1927, and 1929.

Readers are referred to the publication *Droughts in Australia,* Bulletin No. 43 of the Commonwealth Bureau of Meteorology, published in 1957, for a definitive treatment of the subject of droughts in Victoria.

1967–68 drought, 1969

Floods

Floods have occurred in all districts, but they are more frequent in the wetter parts of the State such as the north-east and Gippsland. However, although a rarer event over the north-west lowlands, they may result from less intense rainfall and continue longer because of the poor drainage in this section of the State. In many instances the frequency of flooding is increased by valley contours and damage is often greater because of the higher density of adjacent property and crops.

Snow

Snow in Victoria is confined usually to the Great Dividing Range and the alpine massif, which at intervals during the winter and early spring months may be covered to a considerable extent, especially over the more elevated eastern section. Falls elsewhere are usually light and infrequent. Snow has been recorded in all districts except the Mallee, Wimmera, and northern country. The heaviest falls in Victoria are confined to sparsely populated areas and hence general community disorganisation is kept to a minimum. Snow has been recorded in all months on the higher Alps, but the main falls occur during the winter. The average duration of the snow season in the alpine area is from three to five months.

VICTORIA—MEANS OF CLIMATIC ELEMENTS: SELECTED VICTORIAN TOWNS

	Locality	Legend (a)	Years of record	January	February	March	April	May	June	July	August	Sept.	October	Nov.	Dec.	Annual
MALLEE	Mildura	1	25	17	23	24	15	30	23	26	27	28	29	25	20	287
		2	25	32.1	30.9	28.2	23.3	18.6	16.0	15.2	16.9	20.1	23.7	26.9	29.6	23.4
		3	25	16.6	16.2	13.9	10.2	7.3	5.3	4.3	5.2	7.2	9.8	12.1	14.5	10.2
	Swan Hill	1	85	20	23	23	25	34	37	31	33	31	33	26	24	340
		2	71	31.4	31.1	27.8	22.8	18.2	14.8	14.3	16.2	19.3	22.9	26.8	29.8	22.9
		3	65	15.3	15.4	12.9	9.6	6.8	4.8	4.1	4.8	6.6	8.9	11.6	13.9	9.6
WIMMERA	Horsham	1	98	21	26	25	34	47	51	45	48	45	43	34	29	448
		2	63	29.8	29.9	26.6	21.4	17.1	13.9	13.3	14.9	17.7	21.0	24.9	27.8	21.5
		3	64	13.3	13.6	11.4	8.6	6.3	4.7	3.9	4.6	5.7	6.9	9.9	11.9	8.4
	Nhill	1	85	20	23	22	31	41	48	45	47	43	40	30	28	418
		2	66	29.6	29.3	26.4	21.4	17.2	14.2	13.6	15.1	17.9	21.1	24.9	27.8	21.5
		3	65	12.8	13.0	11.0	8.3	6.1	4.4	3.4	4.1	5.3	7.1	9.3	11.6	8.0
WESTERN	Ballarat	1	61	36	47	47	57	68	63	70	76	73	68	57	53	715
		2	61	24.9	24.7	21.9	17.3	13.3	10.6	9.9	11.3	13.9	16.6	19.6	22.3	17.2
		3	60	10.6	11.6	9.9	7.6	5.8	4.2	3.4	3.9	5.0	6.4	7.7	9.5	7.1
	Hamilton	1	101	33	32	42	55	68	74	74	77	72	65	51	46	689
		2	84	25.6	25.5	22.9	18.7	15.1	12.7	11.9	13.1	15.3	17.6	20.6	23.2	18.6
		3	84	11.3	11.9	10.5	8.5	6.8	5.2	4.5	4.9	6.0	7.1	8.4	10.0	7.9
	Warrnambool	1	74	32	35	47	59	77	75	84	83	71	63	53	45	724
		2	67	21.9	22.1	20.9	18.4	15.8	13.8	13.2	13.9	15.4	17.2	18.8	20.4	17.7
		3	67	12.7	13.2	12.1	10.3	8.6	6.8	6.1	6.6	7.6	8.8	10.0	11.5	9.5
NORTHERN	Bendigo	1	110	32	33	37	40	53	61	55	56	53	51	38	33	542
		2	105	29.4	29.1	25.9	20.9	16.2	12.9	12.1	13.8	16.7	20.3	24.2	27.3	20.7
		3	101	14.1	14.1	12.4	9.2	6.5	4.8	3.8	4.5	6.1	8.1	10.4	12.5	8.9
	Echuca	1	93	25	27	33	33	41	45	40	42	39	42	32	29	428
		2	89	30.8	30.4	27.2	22.1	17.3	14.1	13.3	15.1	18.2	22.0	25.9	28.9	22.1
		3	86	15.3	15.3	13.1	9.6	6.7	4.9	4.1	4.9	6.5	8.9	11.3	13.7	9.6

NORTH CENTRAL	Alexandra	1	93	41	37	51	52	64	73	72	74	66	70	57	49	706
		2	48	29.3	29.3	26.0	20.5	15.9	12.1	11.7	13.8	17.1	20.3	23.8	27.3	20.6
		3	48	11.2	11.7	9.4	6.3	4.3	2.8	2.5	2.9	4.3	6.1	8.0	9.9	6.6
	Kyneton	1	96	39	41	47	56	76	91	83	84	75	70	53	51	766
		2	73	27.2	26.8	23.7	18.3	13.9	10.7	9.9	11.6	14.8	18.1	21.8	24.9	18.5
		3	67	9.8	10.2	8.5	5.7	3.6	2.3	1.6	1.9	3.3	4.8	6.7	8.6	5.6
CENTRAL	Geelong	1	99	30	37	41	45	50	49	45	48	51	52	47	40	535
		2	61	25.0	24.9	23.2	19.8	16.6	14.1	13.6	14.8	16.8	19.3	21.4	23.2	19.4
		3	62	13.1	13.8	12.5	10.3	8.1	5.7	5.3	5.8	6.9	8.4	10.1	11.9	9.4
	Mornington	1	82	44	41	48	63	70	70	70	70	70	70	59	52	727
		2	39	24.8	24.8	23.2	19.3	16.1	13.4	12.7	13.7	15.8	18.0	20.3	22.9	18.7
		3	37	13.2	13.7	12.8	10.8	9.8	7.2	6.3	6.7	7.9	9.4	10.7	12.1	10.0
NORTH-EASTERN	Omeo	1	92	51	53	54	47	53	57	52	55	62	71	62	63	680
		2	87	26.2	25.8	23.1	18.7	14.2	10.8	10.1	12.1	15.3	18.5	21.8	24.5	18.4
		3	87	9.4	9.6	7.8	4.8	2.2	0.9	-0.2	0.6	2.6	4.6	6.4	8.3	4.8
	Wangaratta	1	93	36	38	47	48	56	73	64	64	59	62	47	42	636
		2	68	30.9	30.6	27.3	22.1	17.3	13.6	12.7	14.4	17.6	21.0	25.4	28.8	21.8
		3	67	14.9	14.8	12.1	8.3	5.4	3.9	3.3	4.1	5.8	8.2	10.8	13.3	8.7
WEST GIPPSLAND	Yallourn	1	22	49	58	59	63	101	81	80	95	88	88	85	71	918
		2	22	24.8	24.1	22.6	18.8	14.5	12.5	11.8	12.9	15.2	17.6	19.6	22.0	18.0
		3	22	12.6	13.3	12.1	9.6	7.5	6.0	4.7	5.3	6.5	8.2	9.4	11.2	8.9
	Sale	1	27	45	45	58	42	62	48	41	53	51	68	67	62	642
		2	26	25.1	24.7	23.1	20.1	16.2	13.9	13.4	14.6	16.6	18.8	20.7	22.8	19.2
		3	24	12.4	13.1	11.4	8.6	6.1	4.4	3.4	4.2	5.4	7.6	9.2	11.1	8.1
EAST GIPPSLAND	Bairnsdale	1	65	61	50	64	51	53	55	49	48	56	69	65	66	687
		2	65	24.6	24.7	23.1	20.3	17.0	14.3	13.9	15.2	17.4	19.6	21.6	23.4	19.6
		3	64	12.2	12.7	11.2	8.5	6.0	4.3	3.5	4.2	5.9	7.8	9.4	11.2	8.1
	Orbost	1	88	69	60	69	71	72	82	66	59	69	78	68	77	840
		2	30	25.1	25.0	23.7	20.6	17.3	14.9	14.4	15.6	17.5	19.5	21.2	23.4	19.8
		3	28	12.7	13.3	11.8	9.2	6.7	5.1	4.0	4.6	5.8	8.1	9.8	11.5	8.6

(*a*) Legend : 1. Average monthly rainfall in mm (for all years of record to 1971).
2. Average daily maximum temperature (°C) (for all years of record to 1971).
3. Average daily minimum temperature (°C) (for all years of record to 1971).

Temperatures

February is the hottest month of the year while January is only slightly cooler. Average maximum temperatures are under 25°C along the coast and over elevated areas forming the Central Divide and North-Eastern Highlands. Apart from these latter areas, there is a steady increase towards the north, until, in the extreme north, an average of 32°C is reached. Values decrease steadily with height, being under 20°C in alpine areas above 1,000 metres and as low as 15°C in the very highest localities.

Temperatures fall rapidly during the autumn months and then more slowly with the onset of winter. Average maximum temperatures are lowest in July; the distribution during this month again shows lowest values over elevated areas, but otherwise there is practically no variation across the State. Day temperatures along the coast average about 13°C in July; much the same value is recorded over the wheat belt, and only a degree or two higher in the far north-west under conditions of few clouds and relatively high winter sunshine. The Alps experience blizzard conditions every year with minimum temperatures 5 to 10°C ltss than at lowland stations.

In summer high temperatures may be experienced throughout the State except over the alpine area. Most inland places have recorded maxima over 43°C with an all time extreme for the State of 50.8°C at Mildura on 6 January 1906. Usually such days are the culmination of a period during which temperatures gradually rise, and relief comes sharply in the form of a cool change when the temperature may fall as much as 17°C in an hour. However, such relief does not always arrive so soon and periods of two or three days or even longer have been experienced when the maximum temperature has exceeded 38°C. On rare occasions extreme heat may continue for as long as a week with little relief.

Night temperatures, as gauged by the average minimum temperature, are, like the maximum, highest in February. Values are below 10°C over the elevated areas, but otherwise the range is chiefly 13 to 15°C. The highest night temperatures are recorded in the far north and along the coast. In mid-winter average July minima exceed 5°C along the coast and at two or three places in the far north. The coldest point of the State is the north-east alpine section, where temperatures frequently fall below freezing point. Although three or four stations have been set up at different times in this area, none has a very long or satisfactory record. The lowest temperature on record so far is – 12.8°C at Hotham Heights (station height 1,760 metres) at an exposed location near a mountain. However, a minimum of —22.2°C has been recorded at Charlotte Pass (station height 1,840 metres)—a high valley near Mt Kosciusko in New South Wales—and it is reasonable to expect that similar locations in Victoria would experience similar temperatures, although none has been recorded due to lack of observing stations.

Frosts

Frosts may occur at any time of the year over the ranges of Victoria, whereas along the exposed coasts frosts are rare and severe frosts (air temperature 0°C or less) do not occur. Frost, however, can be a very localised phenomenon, dependent on local topography. Hollows may experience frost while the surrounding area is free of frost.

The average frost-free period is less than 50 days over the higher ranges of the north-east while it exceeds 200 days within 50 miles of the coast and north of the Divide. The average number of severe frosts (air temperature 0°C or less) exceeds 20 per year over the ranges. The average number of light frosts (air temperature between 0°C and 2°C) varies from less than 10 per year near the coast to 50 per year in the highlands of the north-east.

The first frosts of the season may be expected in April in most of the Mallee and northern country and in March in the Wimmera. Over the highlands of the north-east frosts may be severe from March to November. Severe frosts on the northern side of the Divide are twice as frequent as on the southern side at the same elevation.

Humidity

Generally, humidity in the lower atmosphere is much less over Victoria than in other eastern States. This is because the extreme south-east of the continent is mostly beyond the reach of tropical and sub-tropical air masses. For several periods in the summer, however, air from the Tasman Sea has a trajectory over Bass Strait and parts of the State, and it is then that the moisture content rises to show wet bulb temperatures above 18°C. The incidence of high humidity is important to the vine and fruit industry, tobacco growers, and wheat farmers.

Evaporation

Since 1967 the Class A Pan has been the standard evaporimeter used by the Bureau of Meteorology. This type is being progressively installed at evaporation recording stations in Victoria ; there were fifty-seven in mid-1973, forty-six of which were owned by the Bureau of Meteorology.

Measurements of evaporation have been made with the Australian tank at about thirty stations, about half of which are owned by the Bureau of Meteorology. Results from these stations show that evaporation exceeds the average annual rainfall in inland areas, especially in the north and north-west, by about 1,000 mm. In all the highland areas and the Western District the discrepancy is much less marked, and in the Central District and the lowlands of east Gippsland annual evaporation exceeds annual rainfall by 200 to 400 mm. Evaporation is greatest in the summer months in all districts. In the three winter months rainfall exceeds evaporation in many parts of Victoria, but not in the north and north-west.

Winds

The predominant wind stream over Victoria is of a general westerly origin, although it may arrive over the State from the north-west or south-west. There are wide variations from this general description, however, and many northerlies and southerlies occur. The latter is the prevailing direction from November to February with a moderate percentage of northerlies often associated with high temperatures. Easterly winds are least frequent over Victoria, but under special conditions can be associated with some of the worst weather experienced over the State. Wind varies from day to night, from season to season, and from place to place. Examples of the diurnal variation are the sea breeze, which brings relief on many hot days along the coastline, and the valley or katabatic breeze, which brings cold air down valleys during the night. The latter is well developed in many hilly areas of Victoria, being the result of differential cooling after sunset. It springs up during the night, often suddenly, and continues after sunrise until the land surfaces are sufficiently heated again. The sensitive equipment required to measure extreme wind gusts has been installed at only about five or six places in the State and to date the highest value recorded is 164 kilometres per hour (km/h) at Point Henry near Geelong in 1962. There is no doubt, however, that similar gusts have been experienced in other parts of the State, although not in the vicinity of a recording anemometer. It is considered that any place in Victoria could feasibly experience at some time a local gust of 160 km/h or more.

Thunderstorms

Thunderstorms occur far less frequently in Victoria and Tasmania than in the other two eastern States. They occur mainly in the summer months when there is adequate surface heating to provide energy for convection. Between ten and twenty a year occur in most of Victoria, but the annual average is about thirty in the north-eastern ranges. Isolated severe wind squalls and tornadoes sometimes occur in conjunction with thunderstorm conditions, but these destructive phenomena are comparatively rare. Hailstorms affect small areas in the summer months ; and showers of small hail are not uncommon during cold outbreaks in the winter and spring.

Melbourne

Temperature

The proximity of Port Phillip Bay bears a direct influence on the local climate of the metropolis. The hottest months in Melbourne are normally January and February, when the average maximum temperature is 26°C. Inland, Watsonia has an average of 27°C, while along the Bay, Aspendale and Black Rock, subject to any sea breeze, have an average of 25°C. This difference does not persist throughout the year, however, and in July average maxima at most stations are within 1°C of one another at approximately 13°C. The hottest day on record in Melbourne was 13 January 1939, when the temperature reached 45.6°C, which is the second highest temperature ever recorded in an Australian capital city. In Melbourne, the average number of days per year with maxima over 38°C is about four, but there were fifteen in the summer of 1897–98 and there have been a few years with no occurrences. The average annual number of days over 32°C is approximately nineteen.

Nights are coldest at places a considerable distance from the sea, and away from the City where buildings may maintain the air at a slightly higher temperature. The lowest temperature ever recorded in the City was —2.8°C on 21 July 1869, and likewise, the highest minimum ever recorded was 30.6°C on 1 February 1902.

In Melbourne the overnight temperature remains above 20°C on only about two nights a year and this frequency is the same for nights on which the air temperature falls below 0°C. Minima below —1°C have been experienced during the months of May to August, while even as late as October extremes have been down to 0°C. During the summer minima have never been below 4°C.

Wide variations in the frequencies of occurrences of low air temperatures are noted across the metropolitan area. For example, there are approximately ten annual occurrences of 2°C or under around the bayside, but frequencies increase to over twenty in the outer suburbs and probably to over thirty a year in the more frost susceptible areas. The average frost free period is about 200 days in the outer northern and eastern suburbs, gradually increasing to over 250 days towards the City, and approaching 300 days along parts of the bayside.

The means of the climatic elements for the seasons in Melbourne computed from all available official records are given in the following table :

MELBOURNE—MEANS OF CLIMATIC ELEMENTS

Meteorological elements	Spring	Summer	Autumn	Winter
Mean atmospheric pressure (millibar)	1014.9	1013.2	1018.3	1018.4
Mean temperature of air in shade (°C)	14.3	19.3	15.3	10.1
Mean daily range of temperature of air in shade (°C)	10.3	11.6	9.6	7.8
Mean relative humidity at 9 a.m. (saturation=100)	64	61	72	80
Mean rainfall (mm)	185	155	169	148
Mean number of days of rain	40	25	34	44
Mean amount of evaporation (mm)	261	441	208	97
Mean daily amount of cloudiness (scale 0 to 8) (*a*)	4.8	4.2	4.7	5.1
Mean daily hours of sunshine	6.0	7.7	5.2	3.9
Mean number of days of fog	1.5	0.6	6.2	11.2

(*a*) Scale: 0 = clear, 8 = overcast.

In the following table are shown the yearly means of the climatic elements in Melbourne for each year 1968 to 1972. The extreme values of temperature in each year are also included.

MELBOURNE—YEARLY MEANS AND EXTREMES OF CLIMATIC ELEMENTS

Meteorological elements	1968	1969	1970	1971	1972
Mean atmospheric pressure (millibars)	1014.5	1017.5	1015.8	1014.2	1018.2
Temperature of air in shade (°C)—					
Mean	15.6	15.2	15.1	15.5	15.5
Mean daily maximum	20.1	19.7	19.4	19.8	20.3
Mean daily minimum	11.2	10.8	10.7	11.0	10.8
Absolute maximum	43.7	38.7	37.3	38.7	39.9
Absolute minimum	1.8	-0.8	0.6	-0.1	0.0
Mean terrestrial minimum temperature (°C)	9.8	9.8	9.2	9.4	8.9
Number of days maximum 38°C and over	8	3	..	1	2
Number of days minimum 2°C and under	2	3	3	4	7
Rainfall (mm)	532	625	803	779	566
Number of wet days	141	137	153	154	120
Total amount of evaporation (mm) (*a*)	1,513	1,438	1,465	1,503	1,587
Mean relative humidity at 9 am (saturation=100)	66	70	71	70	69
Mean daily amount of cloudiness (scale 0 to 8) (*b*)	4.8	4.7	4.5	4.9	4.3
Mean daily hours of sunshine (*c*)	6.4	5.8	6.3	5.9	6.7
Mean daily wind speed km/h	10.0	11.6	11.4	12.2	12.7
Number of days of wind gusts 63 km/h and over	79	41	61	69	58
Number of days of fog	3	7	9	7	9
Number of days of thunder	12	8	12	13	11

(*a*) Evaporation measured by Class A Pan.
(*b*) Scale: 0 = clear, 8 = overcast.
(*c*) Sunshine measured at Laverton.

Rainfall

The average annual rainfall in the City is 657 mm over 143 days. The average monthly rainfall varies from 47 mm in February to 67 mm in October. Rainfall is relatively steady during the winter months, when the extreme range is from 7 mm to 180 mm, but variability increases towards the warmer months. In the latter period totals range between practically zero and over 230 mm.

Over 75 mm of rain have been recorded in 24 hours on several occasions, but these have been restricted to the warmer months, September to April. Only twice has a fall above 50 mm during 24 hours been recorded in the cooler months.

The average rainfall varies considerably over the Melbourne metropolitan area. The western suburbs are relatively dry and Deer Park has an average annual rainfall of 485 mm. Rainfall increases towards the east, and at Mitcham averages 901 mm a year. The rainfall is greater still on the Dandenong Ranges and at Sassafras the annual average is 1,370 mm.

The number of wet days, defined as days on which 0.2 mm or more of rain falls, exhibits marked seasonal variation ranging between a minimum of eight in January and a maximum of fifteen each in July and August. This is in spite of approximately the same total rainfall during each month and indicates the higher intensity of the summer rains. The relatively high number of wet days in winter gives a superficial impression of a wet winter in Melbourne which is not borne out by an examination of total rainfall.

The highest number of wet days ever recorded in any one month in the City is twenty-seven, in August 1939. On the other hand, there has been only one rainless month in the history of the Melbourne records—April 1923. On occasions, each month from January to May has recorded three wet days or less. The longest wet spell ever recorded was eighteen days and the longest dry spell forty days.

Fogs

Fogs occur on an average of four or five mornings each month in May, June, and July, and average twenty days for the year. The highest number ever recorded in a month was twenty in June 1937.

Cloud and sunshine

Cloudiness varies between a minimum in the summer months and a maximum in the winter, but the range, like the rainfall, is not great compared with many other parts of Australia. The number of clear days or nearly clear days averages two to three each month from May to August, but increases to a maximum of six to seven in January and February. The total number for the year averages forty-seven. The high winter cloudiness and shorter days have a depressing effect on sunshine in winter and average daily totals of three to four hours during this period are the lowest of all capital cities. There is a steady rise towards the warmer months as the days become longer and cloudiness decreases. An average of over eight hours a day is received in January ; however, the decreasing length of the day is again apparent in February, since the sunshine is then less in spite of a fractional decrease in cloudiness. The total possible monthly sunshine hours at Melbourne range between 465 hours in December and 289 in June under cloudless conditions. The average monthly hours, expressed as a percentage of the possible, range between 55 per cent for January and February to 34 per cent in June.

Wind

Wind exhibits a wide degree of variation, both diurnally, such as results from a sea breeze, and as a result of the incidence of storms. The speed is usually lowest during the night and early hours of the morning just prior to sunrise, but increases during the day, especially when strong surface heating induces turbulence into the wind stream, and usually reaches a maximum during the afternoon. The greatest mean wind speed at Melbourne for a 24 hour period was 36.7 km/h, while means exceeding 30 km/h are on record for each winter month. These are mean values; the wind is never steady. Continual oscillations take place ranging from lulls, during which the speed may drop to or near zero, to strong surges which may contain an extreme gust, lasting for a period of a few seconds only, up to or even over 95 km/h. At Melbourne, gusts exceeding 95 km/h have been registered during every month with a few near or over 110 km/h, and an extreme of 119 km/h on 18 February 1951. At Essendon a wind gust of 143 km/h has been measured.

Thunder, hail, and snow

Thunder is heard in Melbourne on an average of 14 days per year, the greatest frequency being in the summer months. On rare occasions thunderstorms are severe, with damaging wind squalls. Hail can fall at any time of the year, but the most probable time of occurrence is from August to November. Most hail is small and accompanies cold squally weather in winter and spring, but large hailstones may fall during thunderstorms in summer.

Snow has occasionally fallen in the City and suburbs; the heaviest snow storm on record occurred on 31 August 1849. Streets and housetops were covered with several centimetres of snow, reported to be 30 cm deep at places. When thawing set in, floods in Elizabeth and Swanston Streets stopped traffic, causing accidents, some of which were fatal. One report of the event indicates that the terrified state of the Aboriginals suggested they had never seen snow before.

Victorian weather summary 1972

The generally humid weather of December 1971, with widespread rain and frequent thunderstorms, continued through the first two months of 1972. Rain fell somewhere in Victoria on almost every day in the first half of January. Rain and thunder were particularly widespread from 11 to 20 February. On Tuesday 15 February, a thunderstorm moved southwards over the City of Melbourne and bayside suburbs, with some damaging wind squalls. In the City 21 mm fell in 15 minutes. Two days later another thunderstorm remained stationary over the central city area for an hour, when 78 mm fell. Water up to a metre deep flowed down some streets, flooding shops and basements, and rail services were disrupted for some hours. This storm caused Melbourne to have its wettest month ever recorded, a total of 238 mm.

The summer was cool and there were no major bushfires. In January the temperature only exceeded 38°C in the north and west in the last two days of the month. In Melbourne it was only the second time on record that the temperature did not reach 33°C in January.

After some further rain on the first two days in March, the weather in Victoria became very dry. In Melbourne, May was the driest for 25 years. A remarkable warm spell occurred at the beginning of May. For nine days, from 30 April to 8 May, calm sunny weather prevailed and the temperature in Melbourne reached 27.7°C, the highest for May since 1905.

Dry weather continued in June and some places in south Gippsland had their driest January to June period on record. On 8 June the temperature in Melbourne reached 19.6°C, the highest for June since 1961, but in the middle of the month there was a series of very cold nights.

Westerly weather prevailed for a good deal of July and the first half of August, bringing substantial rain to the south-west and west Gippsland, but east Gippsland and the north-east remained dry. In the Sale–Orbost area July rainfall was the lowest ever recorded.

Spring opened with a warm spell. Four consecutive days in Melbourne over 22°C was the warmest period in the first half of September since 1869, while a temperature of 27°C had never been known before as early as 5 September. In the middle of September about 40 bush and grass fires broke out in east Gippsland. The largest covered about 5,000 acres and caused temporary closure of the Princes Highway near Orbost.

Dry weather continued through spring, but on 11 October cold showery weather prevailed. Light snow fell at Ballarat and on the Dandenong Ranges.

At the end of November, east Gippsland had some of the best rain of the year, but very dry weather prevailed in December. For much of southern Victoria, including Melbourne, it was the driest December on record. The temperature reached 44°C in the Mallee on 21 and 22 December, while in Melbourne 39.9°C was the highest in December for 19 years. In the second half of December, 31,000 acres of forest were destroyed by fire in the Mt Buffalo area.

The ten month period, March to December, was the driest on record in the East Gippsland, East Central, and Upper North-east Districts.

Agricultural meteorology, 1964; Maritime meteorology, 1966; Aeronautical meteorology, 1967; Meteorology in fire prevention, 1968; Meteorological services for commerce and industry, 1969; Meteorological observations, 1970; Computers in meteorology, 1971; Hydrometeorology, 1972