3

CLIMATE

CLIMATE IN VICTORIA

General conditions

Victoria is situated between latitudes 35°S and 39°S in the south-east of the Australian continent. The major topographical determinant of the climate is the Great Dividing Range, running east-west across the State, and rising to nearly 2,000 metres in the eastern half. This acts as a barrier to the moist south-east to south-west winds and together with its proximity to the coast, causes 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 kilometres. 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 eastern seaboard of the great land masses of the northern hemisphere, 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.

Climatic divisions

Northern plains

The mean annual rainfall varies from below 300 mm in the northern Mallee to 500 mm on the northern slopes of the Great Dividing Range. Variability of rain from year to year is high and increases northwards. Average monthly rainfall totals range from 20 to 30 mm in the summer to between 30 and 50 mm during the colder six months—May to October.

Cold fronts bring rain to the Wimmera, particularly in winter, but have less effect in the Mallee and the Northern Country. Rain in these latter districts is usually brought by depressions moving inland from the region of the Great Australian Bight, or from depressions developing over New South Wales or northern Victoria itself.

Summers are hot with many days over 32°C, while winter nights can be very cold with widespread frost.

Highlands

The average annual rainfall depends on elevation, ranging from 500 mm in the foothills in the west to over 1,500 mm on the mountains in the east. The higher mountains are snow covered in the winter months. During the colder part of the year, essentially May to October, monthly rainfall is generally higher than for the remainder of the year. Pasture growth is limited by cold in winter and the main growth occurs in autumn and spring.

The lower valleys are subject to hot summer days but mean maximum temperature decreases by about 1°C per 200 metres elevation. Winter nights are very cold and the valleys are particularly prone to frost and fog.

Western districts

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.

Average annual rainfall ranges from less than 600 mm over the plains from Geelong to Lismore to over 1,400 mm on the higher parts of the Otways. Pasture growth is limited by dryness in summer and cold in winter; the main growth occurs in autumn and spring.

Sea breezes near the coast temper the heat on many summer days and on many occasions the sea breeze develops into a weak cold front which extends over most of the area. There are, however, a number of days when the temperature exceeds 32°C.

Gippsland

In West and South Gippsland most rain comes with the westerly winds and cold fronts that predominate in winter, but some rain also falls in summer from depressions over eastern New South Wales. The difference between winter and summer rainfall is not as marked as in the western districts.

Depressions off the east coast bring most rain to East Gippsland and such rainfall can be very heavy. The frequency of a three day rainfall over 75 mm is much greater in this district than elsewhere in Victoria. Rainfall in the east is fairly evenly distributed throughout the year.

Average annual rainfall is less than 600 mm in the Sale-Maffra area, which lies between the influence of western cold fronts and eastern depressions. Over the higher parts of the South Gippsland hills, the average annual rainfall exceeds 1,400 mm. Along the upper valleys of the Mitchell, Tambo, and Snowy Rivers, rainfall is much less than on the surrounding highlands.

Most of the closely settled areas are within reach of the sea breeze on summer days and the frequency of high temperatures is less than in other parts of Victoria of similar elevation.

On some winter days, however, the coastal areas of East Gippsland have the highest temperatures in the State, due to the Föhn effect of north-westerly winds descending from the mountains.

Weather patterns

The general weather of southern Australia is determined primarily by the behaviour of high pressure systems, which move from west to east on a more or less latitudinal track. The mean track is centred south of the continent from November to April, but is located between latitudes 30°S and 35°S from May to October. These anticyclones are separated by low pressure areas, which usually contain active frontal surfaces separating air masses of different characteristics. The low pressure areas are often rain bearing systems and their most northerly influence occurs in winter.

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, where the average rainfall in July is three times that of January. East Gippsland, however, receives little rain from cold fronts and depressions approaching from the west. The heaviest rain in that district is produced by intense depressions to the east of Bass Strait which have usually developed to the east of New South Wales or further north, and moved southwards along the coast. Rainfall in East Gippsland is fairly evenly distributed through the year.

On occasions, in late autumn, winter, or spring, an anticyclone develops a ridge of high pressure to southern waters and a depression intensifies east of Tasmania. This causes cold and relatively dry air to be brought rapidly across Victoria, bringing windy, showery weather with some hail and snow. On other occasions, when an anticyclone moves slowly over Victoria or Tasmania, a spell of fine weather with frost or fog results. These spells can last as long as a week.

In summer, the more southerly location of the anticyclone belt frequently brings a light easterly wind flow over Victoria with sea breezes near the coast. When anticyclones move into the Tasman Sea, where they sometimes stagnate for several days, winds tend north-east to northerly and sometimes increase in speed. This situation results in heat wave conditions, which persist until relieved by the west to south-west winds associated with the next oncoming depression. The fall in temperature associated with the wind change can be quite sharp.

The weather over south-eastern Australia in summer is occasionally influenced by the penetration of moist air of tropical origin. Although an infrequent event, this is responsible for some of the heaviest rainfalls over the State.

Rainfall

The distribution of average annual rainfall in Victoria is shown in Figure 9 on page 53. Average rainfall ranges from 250 mm for the driest parts of the Mallee to 2,600 mm at Falls Creek in the Alps. There would be other locations in the Alps with similar rainfall, but where the rain is not measured.

Except for East Gippsland, more rain falls in winter than in summer. Summer rainfall is more variable and the higher evaporation of this season greatly reduces the effectiveness of the rainfall.

All parts of Victoria are occasionally subject to heavy rain and monthly totals exceeding three times the average have been recorded. Monthly totals have exceeded 250 mm on several occasions in Gippsland and the Northeast and rarely along the West Coast. The highest monthly total recorded in the State is 891 mm at Tanybryn in the Otway district in June 1952.

Intense rainfall of short duration is usually the result of a thunderstorm. On 17 February 1972, 78 mm fell within one hour over an area of about 3.5 square kilometres in central Melbourne. Falls of similar intensity and duration occur from time to time in Victoria, but because such a small area is affected, not all are officially recorded.

The average annual number of days of rain (0.2 mm or more in 24 hours) is over 150 on the West Coast and in 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 160 kilometres 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 is given in the following tables:

VICTORIA—DISTRIBUTION OF AVERAGE AND ANNUAL RAINFALL

Rainfall (mm)	Area ('000 square kilometres) *(a)*					
	Average	1976	1977	1978	1979	1980
Under 300	18.4	49.6	62.4	3.3	0.1	24.4
300–400	36.5	32.7	27.8	15.4	39.7	40.1
400–500	27.5	21.3	20.3	45.8	63.3	26.4
500–600	34.9	31.4	33.9	21.6	48.6	37.5
600–800	52.3	51.9	45.7	43.7	44.1	49.8
800–1,000	29.0	29.6	28.4	38.3	29.5	25.6
Over 1,000	29.0	11.1	9.1	59.5	2.3	23.8

(a) Total area of Victoria is 227,600 square kilometres.

VICTORIA—RAINFALL IN DISTRICTS
(mm)

Year	District							
	Mallee	Wimmera	Northern	North Central	North-east	Western	Central	Gippsland
1971	384	568	529	891	888	905	849	872
1972	261	365	331	576	522	600	564	601
1973	634	764	905	1,144	1,307	856	933	908
1974	530	692	763	993	1,254	805	895	1,102
1975	406	531	618	885	1,081	818	787	920
1976	268	362	307	599	594	667	640	792
1977	263	336	322	621	596	667	709	762
1978	419	481	587	839	1,041	819	969	1,194
1979	402	510	469	717	750	678	616	627
1980	301	450	412	700	795	707	682	832
Average *(a)*	337	466	478	722	875	729	740	857

(a) Average for 68 years 1913 to 1980.

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

Aura Vale Lake is a popular resort for boating enthusiasts.
Melbourne and Metropolitan Board of Works

The Clover power station located in north-east Victoria. It forms part of the Kiewa hydro-electric scheme.
State Electricity Commission

A popular Victorian pastime: fly fishing in the Kiewa River.

Ministry for Conservation

Groundwater exploration being carried out by a drilling rig at Wattle Point.

Department of Minerals and Energy

Macquarie Perch, a rare native fish found in some Victorian streams.

Ministry for Conservation

Filamentous algae found in Lake Learmonth. This natural lake is situated 18 kilometres north-west of Ballarat and covers an area of approximately 485 hectares.

Ministry for Conservation

Damage to water pipe by electrolysis.

Melbourne and Metropolitan Board of Works

Straw-necked ibis in a northern Victorian swamp.

Ministry for Conservation

Lake Bullen Merri, a natural lake covering approximately 540 hectares. It is located 3 kilometres south-west of Camperdown.

Ministry for Conservation

Vegetation and debris obstructing flow in a stream.

State Rivers and Water Supply Commission

Leaf scorch on pear trees in the Ardmona area due to saline water.

Department of Agriculture

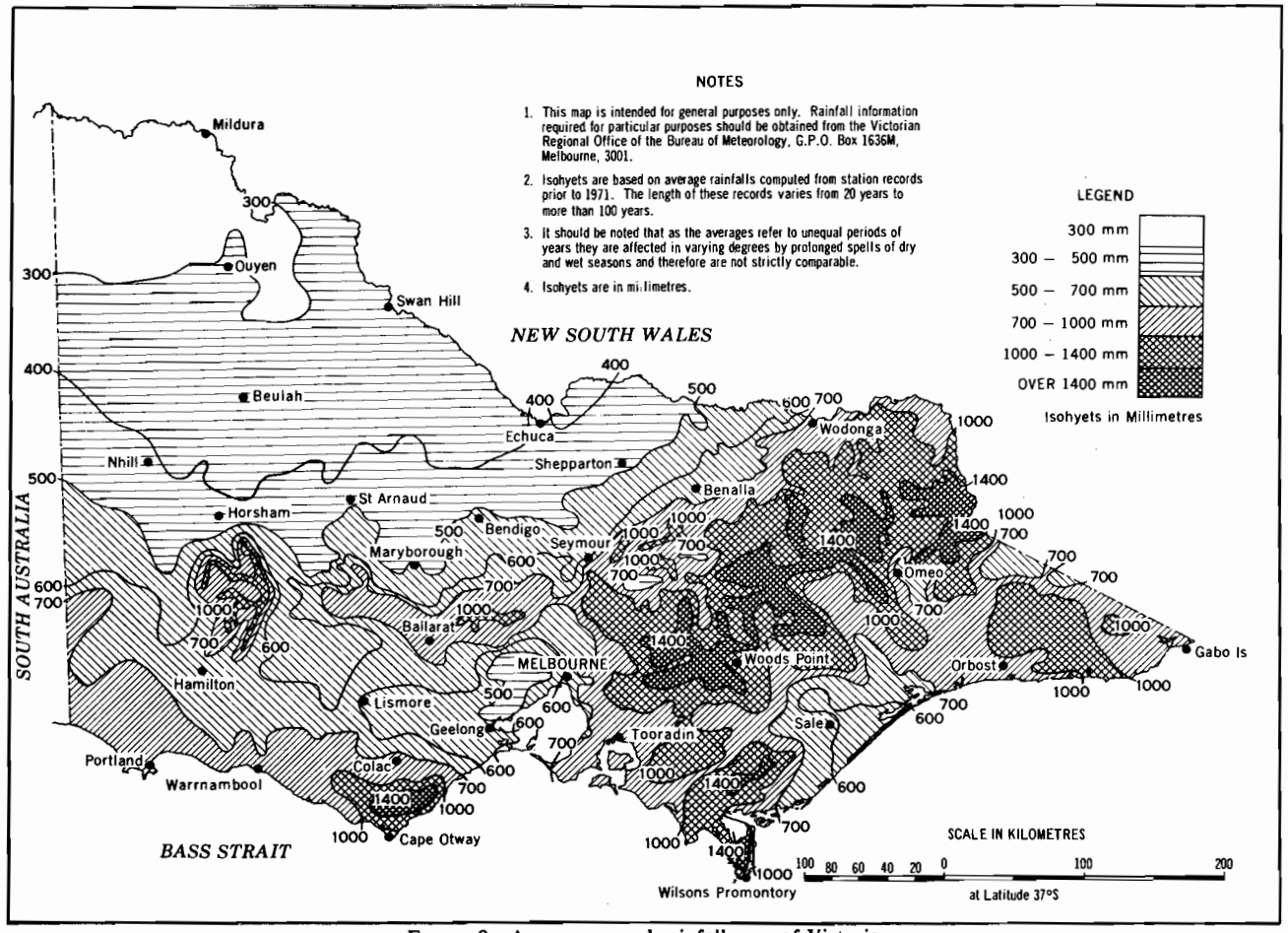

FIGURE 9. Average annual rainfall map of Victoria.

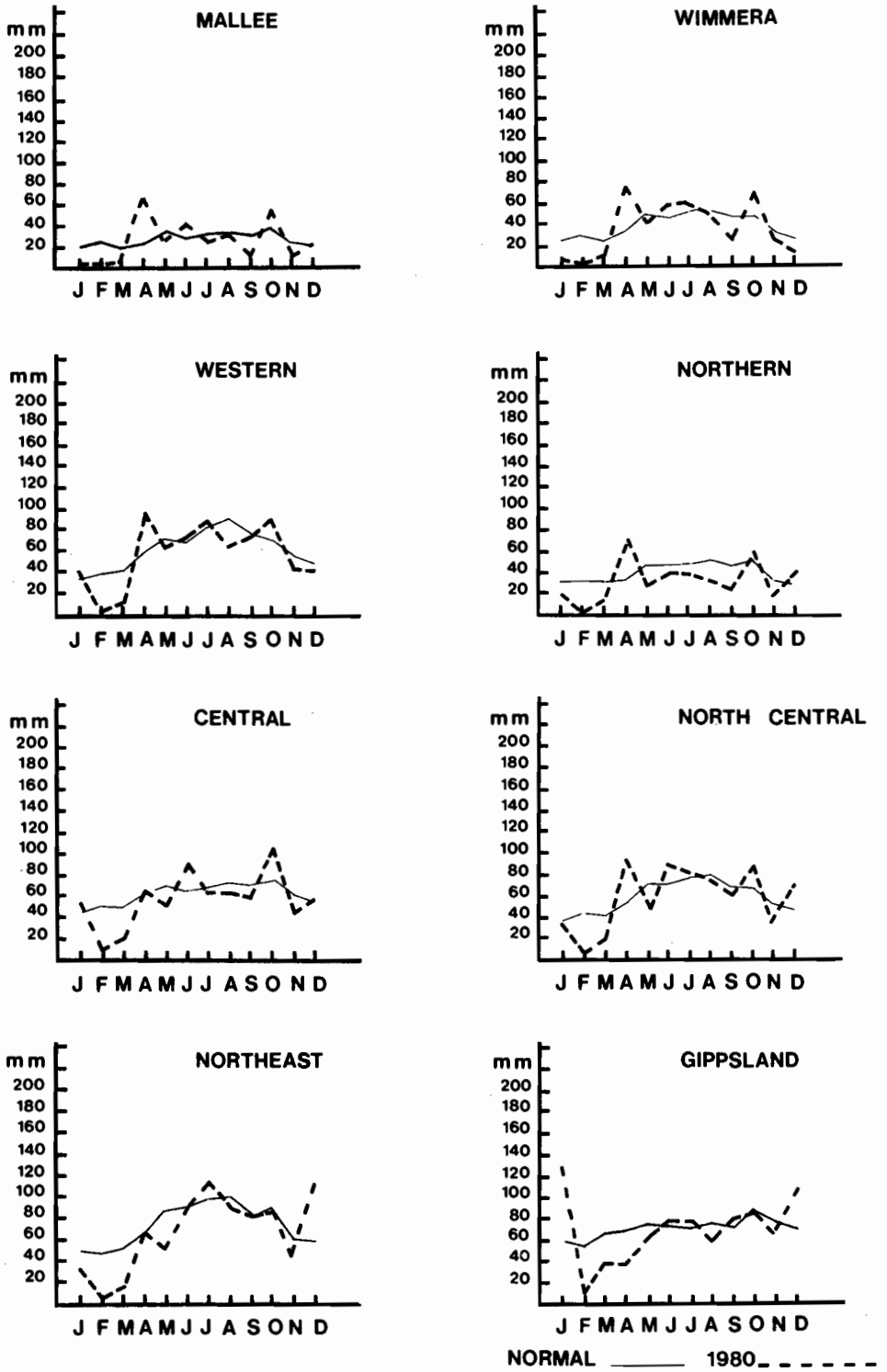

FIGURE 10. Victoria—district monthly rainfall: normal and 1980.

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 likely 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.

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 the variability at one station with that at another, the percentage coefficient of variation $\left(\frac{\text{standard deviation}}{\text{the average}} \times 100\right)$ has been used. This percentage coefficient has been calculated for the fifteen climatic districts of Victoria (see Figure 11) for the 68 years 1913 to 1980 and the results are tabulated in the following table 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 Coast	776	122	15.7
2 West Gippsland	916	148	16.2
3 East Central	893	148	16.6
4 Western Plains	634	112	17.7
5 West Central	612	122	19.9
6 East Gippsland	777	160	20.6
7 South Wimmera	502	107	21.3
8 North Central	722	162	22.4
9 North Wimmera	416	97	23.3
10 Upper Northeast	1,107	271	24.5
11 Lower Northeast	776	207	26.7
12 South Mallee	355	96	27.0
13 Upper North	518	143	27.6
14 Lower North	436	131	30.0
15 North Mallee	310	94	30.4

(a) Average for 68 years 1913 to 1980.

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

Droughts

The exact definition of drought is not specific in nature. A general term is "severe water shortage", but a severe shortage of water to a large consumer, such as a market gardener may not be of undue concern to a pastoralist.

Rainfall is the best single index of drought, although evaporation losses and storages in reservoirs must also be taken into account when determining the severity of a drought.

One advantage of assessing droughts on the basis of rainfall statistics is that records are available dating back for over 100 years at some locations, thus providing an objective basis for assessing drought severity. Studies based on drought effects on plants and animals, however, would be of a more subjective nature, due to technological advances in drought resistance.

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 from 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.

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

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 ending after heavy rain in February 1973.

Northern Victoria experienced drought conditions for about 10 months until September 1975, while in 1976 the failure of summer and early autumn rains in the south led to severe rainfall deficiencies, particularly in South Gippsland. The drought had extended to most of Victoria before ending with good rains in September and October. Large sections of Victoria experienced serious to severe deficiencies during the latter half of 1977 and the first 5 months of 1978. Drought conditions prevailed in north-east Victoria in the latter half of 1979. However, good rainfall in January 1980 provided some relief from these rainfall deficiencies. Rain in the latter half of April was sufficient to break the five month drought in most of Victoria, but not in Gippsland. It was not until good rain was received in October that the eight month drought was broken in East Gippsland.

Floods

Lands bordering rivers, lakes, and coastal regions have historically attracted settlement and development. These areas, known as "flood-plains", are susceptible to occasional inundation, and depending on their extent of development, extensive damage to property and even loss of life may result. The realisation of this danger has led man to attempt to reduce the effect of flood damage by means such as the construction of dams and discouragement of development in certain areas. However, it should be recognised that as floods are a natural phenomenon, they have major beneficial as well as detrimental effects. The very existence of fertile flood plains depends on the occurrence of floods.

Flooding occurs in all districts but is most frequent in the north-east and in Gippsland. The occurrence of flooding in place and time is highly variable since it depends on the location and intensity of rainfall. In general, in Victoria, flooding is most likely in late winter or early spring, since this is the time of maximum rainfall and maximum catchment wetness, but floods can occur at any time of the year. On many streams, particularly in East Gippsland, some of the most severe floods have been in January or February.

The extent and effect of flooding is dependent not only on rainfall but also on topography, land-use, water control structures, and the location of towns.

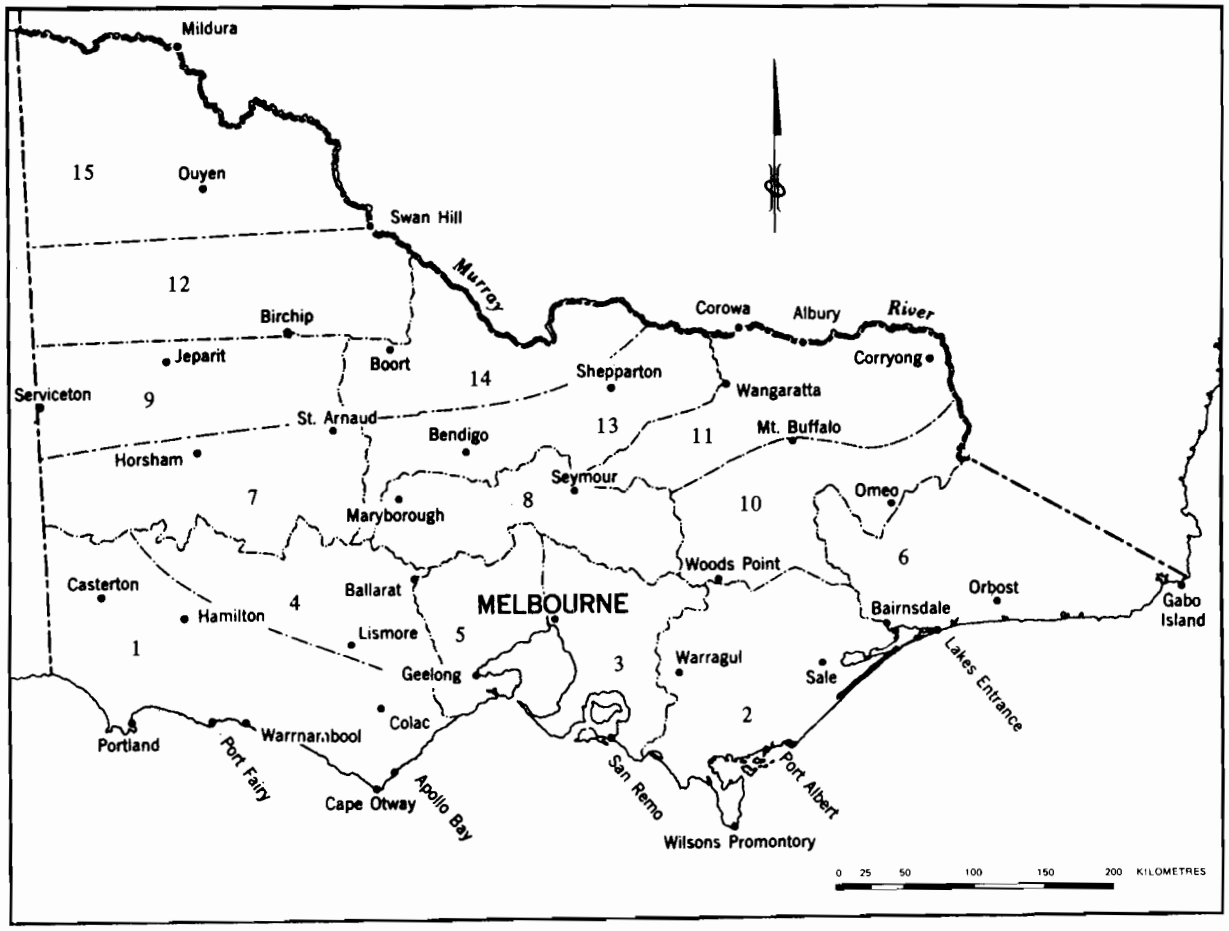

FIGURE 11. Relative rainfall variability by districts. Names of climatic districts are shown in the table on page 55.

All districts of Victoria have experienced disastrous flooding, although it is relatively unusual for major floods to occur on several catchments at once. East Gippsland suffered major flooding in 1971. In 1973, 1974, and 1975 widespread flooding, varying from moderate to major, occurred throughout Victoria, particularly in the Northern, Northeast, West Central, and East Gippsland Districts. In 1978, major flooding again occurred on most rivers in East Gippsland.

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. 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.

Temperatures

January and February are the hottest months of the year. Average maximum temperatures are under 20°C on the higher mountains and under 24°C along the coast, but exceed 32°C in parts of the Mallee.

Average maximum temperatures are lowest in July, when they are below 10°C over most of the Great Dividing Range, and less than 3°C on the higher mountains. Over the lower country there is little variation across the State, ranging from 13°C near the coast to 16°C in the northern Mallee.

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 January and February. They are below 9°C over the higher mountains, but otherwise the range is chiefly 13°C to 15°C. The highest night temperatures are recorded along the Murray River and on the East Gippsland coast. Average July minima exceed 6°C along parts of the coast, but are below 0°C in the Alps. Although three or four stations have been set up at different times in the mountains, none has a very long or satisfactory record. The lowest temperature on record to date 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 Northeast while it exceeds 200 days within 80 kilometres 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 Northeast.

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 Northeast,

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 over 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. 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.

When northerly winds blow over Victoria in summer and dry air arrives from central Australia, the dew point can fall to 0°C or 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 3°C.

Evaporation

Since 1967, the Class A Pan has been the standard evaporimeter used by the Bureau of Meteorology. This type is now used exclusively at evaporation recording stations in Victoria; there were 78 at the end of 1980, 53 of which were owned by the Bureau of Meteorology.

Measurements of evaporation have been made in the past with the Australian tank at about 30 stations, about half of which were 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 mm 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 direction, although it may arrive over the State from the north-west or south-west. Easterly winds are least frequent over Victoria, but are often associated with widespread rain in Gippsland. There are, however, wide variations from this general description. For example, Melbourne has a predominance of northerlies and southerlies, while Sale has an easterly sea breeze on most summer afternoons.

The wind is usually strongest during the day, when the air in the lower atmosphere is well mixed. As the ground cools after sunset, stratification of the air above it takes place, and the wind near the surface dies down. In valleys, however, the cooler air near the ground begins to flow down the slope, and the valley or katabatic breeze may blow through the night, to die down after sunrise.

At the surface of the earth the wind is rarely steady, particularly over land where there are obstructions to its 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 levels in gusts which last for only a few seconds.

The sensitive equipment required to measure extreme wind gusts has been installed at only a few places in Victoria and the highest gust recorded to date is 164 km/h at Point Henry near Geelong in 1962, although here the anemometer is 23 metres above ground level compared to the standard 10 metres for meteorological anemometers. It is considered that any place in Victoria could feasibly experience at some time a local gust of 160 km/h or more. Two diagrams of wind roses for Victoria at 9 a.m. and 3 p.m., respectively, are shown on pages 78 and 79 of the *Victorian Year Book* 1980.

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 storms occur each year

VICTORIA—MEANS OF CLIMATIC ELEMENTS: SELECTED VICTORIAN TOWNS

	Locality	Legend (a)	Years of record	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
MALLEE	Mildura	1	33	18	24	22	23	29	24	25	27	28	34	26	20	300
		2	34	31.9	31.0	28.1	23.2	18.7	15.9	15.3	17.1	20.1	23.5	27.0	29.9	23.5
		3	34	16.6	16.4	13.9	10.2	7.5	5.2	4.4	5.3	7.3	9.8	12.1	14.6	10.3
	Swan Hill	1	96	21	23	23	26	34	35	32	35	32	35	26	24	346
		2	80	31.5	31.2	27.8	22.8	18.3	14.9	14.5	16.3	19.3	22.8	26.8	29.9	23.0
		3	78	15.3	15.4	12.9	9.6	6.8	4.7	4.0	4.9	6.6	8.9	11.5	13.8	9.5
WIMMERA	Horsham	1	106	23	27	25	34	48	50	45	48	46	44	34	28	452
		2	75	29.8	29.7	26.5	21.4	17.1	13.9	13.3	15.0	17.7	20.9	24.8	27.8	21.5
		3	73	13.3	13.6	11.5	8.6	6.3	4.5	3.7	4.5	5.7	7.5	9.7	11.9	8.4
	Nhill	1	94	22	23	22	32	41	47	45	47	44	41	31	27	422
		2	76	29.6	29.4	26.3	21.5	17.3	14.3	13.7	15.1	17.8	21.0	24.8	27.8	21.6
		3	77	12.9	13.2	11.0	8.4	6.1	4.2	3.4	4.1	5.4	7.2	9.3	11.6	8.1
WESTERN	Ballarat	1	72	38	48	45	55	70	63	68	77	74	71	56	51	716
		2	71	24.9	24.8	22.0	17.3	13.2	10.6	9.9	11.3	13.8	16.5	19.4	22.4	17.2
		3	72	10.8	11.7	10.1	7.7	5.9	4.2	3.4	3.9	5.0	6.5	7.8	9.6	7.2
	Hamilton	1	108	32	32	42	55	69	72	74	77	73	66	52	45	689
		2	92	25.7	25.6	23.0	18.8	15.3	12.7	12.0	13.2	15.4	17.7	20.6	23.3	18.6
		3	93	11.4	11.9	10.6	8.6	6.8	5.2	4.5	5.0	6.0	7.1	8.4	10.0	8.0
	Warrnambool	1	83	32	37	47	60	78	77	89	85	75	67	56	45	744
		2	80	22.1	22.2	21.0	18.6	16.0	13.9	13.3	14.1	15.6	17.4	18.9	20.7	17.8
		3	80	12.8	13.3	12.2	10.4	8.6	6.9	6.2	6.7	7.7	9.0	10.1	11.6	9.6
NORTHERN	Bendigo	1	119	33	33	37	42	54	60	55	57	55	53	38	32	549
		2	116	29.4	29.0	25.9	20.9	16.1	12.9	12.1	13.8	16.7	20.3	24.1	27.3	20.7
		3	113	14.1	14.4	12.3	9.1	6.5	4.8	3.7	4.4	6.0	8.1	10.3	12.5	8.9
	Echuca	1	101	27	27	33	35	41	44	40	43	40	44	32	28	434
		2	98	30.8	30.5	27.2	22.1	17.4	14.1	13.4	15.2	18.3	22.0	26.0	29.0	22.2
		3	98	15.2	15.3	13.1	9.6	6.7	4.8	4.0	5.0	6.5	8.9	11.3	13.6	9.5

VICTORIA—MEANS OF CLIMATIC ELEMENTS: SELECTED VICTORIAN TOWNS—*continued*

	Locality	Legend *(a)*	Years of record	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
NORTH CENTRAL	Alexandra	1	99	41	38	51	54	65	72	70	75	66	71	57	49	709
		2	48	29.3	29.3	26.0	20.5	15.8	12.0	11.7	13.8	17.0	20.3	23.8	27.3	20.6
		3	48	11.2	11.7	9.4	6.3	4.3	2.9	2.5	2.9	4.4	6.0	8.0	9.9	6.6
	Kyneton	1	94	37	39	47	54	75	90	82	84	74	69	52	50	753
		2	78	27.0	26.6	23.5	18.2	13.8	10.7	9.9	11.6	14.7	17.9	21.4	24.9	18.2
		3	71	9.9	10.3	8.5	5.7	3.6	2.3	1.6	2.0	3.4	4.9	6.6	8.6	5.6
CENTRAL	Geelong	1	99	31	37	41	45	50	49	46	48	51	52	48	40	538
		2	74	25.1	25.0	23.2	19.9	16.6	14.1	13.6	14.9	16.9	19.1	21.3	23.4	19.4
		3	75	13.2	13.8	12.5	10.2	8.0	6.0	5.2	5.7	6.9	8.4	10.1	11.9	9.3
	Mornington	1	89	45	43	52	64	71	70	68	71	70	72	58	53	737
		2	43	25.0	25.0	23.3	19.4	16.2	13.5	12.8	13.8	15.9	18.1	20.3	23.1	18.9
		3	40	13.4	13.9	12.9	10.9	9.1	7.1	6.5	6.8	8.1	9.5	10.7	12.1	10.1
NORTHEAST	Omeo	1	100	52	52	55	46	54	56	52	55	62	73	63	61	681
		2	99	26.2	25.8	23.1	18.6	14.1	10.8	10.1	12.1	15.2	18.5	21.7	24.5	18.4
		3	99	9.4	9.6	7.8	4.8	2.2	0.8	-0.2	0.6	2.7	4.7	6.4	8.3	4.8
	Wangaratta	1	101	38	38	46	48	56	70	63	64	61	64	46	43	637
		2	78	31.0	30.6	27.3	22.0	17.3	13.7	12.7	14.5	17.5	21.0	25.3	28.9	21.8
		3	78	15.0	15.0	12.2	8.3	5.5	3.8	3.3	4.1	5.8	8.2	10.7	13.3	8.8
WEST GIPPSLAND	Yallourn	1	31	50	55	57	63	92	77	81	95	90	87	84	69	900
		2	31	24.7	24.5	22.5	18.7	14.8	12.5	11.9	13.0	15.2	17.7	19.6	22.2	18.1
		3	30	12.7	13.3	12.1	9.7	7.5	5.8	4.7	5.4	6.6	8.3	9.6	11.2	8.9
	Sale	1	37	47	43	54	46	58	49	39	54	51	65	64	58	628
		2	35	25.2	25.0	23.3	20.1	16.5	14.1	13.6	14.7	16.8	19.0	20.9	23.2	19.4
		3	35	12.5	13.2	11.5	8.6	6.1	4.3	3.2	4.1	5.5	7.6	9.3	11.1	8.1
EAST GIPPSLAND	Bairnsdale	1	65	60	50	67	50	54	58	50	49	57	70	64	68	697
		2	65	24.6	24.7	23.0	20.3	17.0	14.3	13.8	15.3	17.4	19.6	21.7	23.4	19.6
		3	64	12.3	12.6	11.2	8.5	6.0	4.2	3.4	4.1	5.9	7.7	9.4	11.2	8.0
	Orbost	1	97	70	59	69	73	72	86	65	60	70	78	69	77	848
		2	41	25.2	25.2	23.7	20.7	17.5	15.0	14.6	15.7	17.7	19.6	21.3	23.6	20.0
		3	41	12.9	13.4	12.0	9.3	6.9	5.1	4.0	4.7	6.1	8.2	10.0	11.7	8.7

(a) Legend: 1. Average monthly rainfall in mm (for all available years of record to 1980).
2. Average daily maximum temperature (°C) (for all years of record to 1980).
3. Average daily minimum temperature (°C) (for all years of record to 1980).

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.

NATIONAL METEOROLOGICAL ANALYSIS CENTRE (NMAC)

The major Australian meteorological analysis centre is located in the Bureau of Meteorology's Head Office in Melbourne. It is one of three World Meteorological Centres (the other two are in Washington and Moscow) in the World Weather Watch system operated by the World Meteorological Organization.

The NMAC, and a tropical centre located in Darwin, produce analyses and prognoses of large-scale weather systems that support the forecasting and warning activities of the Bureau's Regional Forecasting Centres and the briefing services provided at all major airports. The products are also supplied to the defence services, private industry, and a number of educational institutions. Radiofacsimile broadcasts service ships at sea and a number of overseas meteorological services. The centres also provide forecasts over the Australian area for high level domestic and international aviation and for special Antarctic and southern ocean flights. Archived data in the form of microfilm and magnetic tape are supplied for various national and international needs.

For many years analysts had to rely on island, Antarctic, and ship reports to build up their picture of weather systems over ocean areas. The southern hemisphere network is still only 10 per cent of that in the northern hemisphere. The launching of weather satellites and, more recently, the relay by satellite of automated observations from drifting buoys and aircraft are improving the coverage. The Bureau relies to a great extent on satellite derived data for its southern hemisphere, Australian region, and tropical analyses. A basic requirement to produce an accurate forecast is an accurate analysis, and the accuracy of both has improved in recent years. The Japanese geostationary satellite and the U.S. polar orbiting satellites provide essential data for the Bureau's operational services.

The Melbourne based National Meteorological Analysis Centre (NMAC) uses a large computer for its southern hemisphere and Australian region analyses and prognoses. This computer checks obervational data for error, and builds up the analysis layer by layer, taking into account changes of temperature, moisture and wind at levels up to approximately 20 kilometres. Essential information on the locations and intensities of weather systems is produced by monitoring meteorologists using surface based observations and satellite pictures, and these are used to refine the computer based analysis system.

Prognoses for up to 36 hours are undertaken, based on the objective analyses, using complex computer "models". These are derived from the mathematical equations governing atmospheric motion. The models were developed by researchers at the Australian Numerical Meteorology Research Centre in Melbourne, each involving up to ten man years of scientific and programming effort, and are able to forecast the behaviour of large-scale weather systems better than meteorologists using traditional subjective methods. The models, however, do not perform well in the tropics and are unable to predict adequately small-scale disturbances like thunderstorms or sea breezes.

Analyses and prognoses from the Melbourne and Darwin Centres are transmitted by landline and radiofacsimile and are used as basic guidance material by users in preparing forecasts.

CLIMATE IN MELBOURNE

General conditions

Temperature

The proximity of Port Phillip Bay bears a direct influence on the climate of the metropolitan area. 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. This 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 heat retention by buildings, roads, and pavements 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 the highest minimum ever recorded was 30.6°C on 1 February 1902.

In Melbourne the overnight temperature remains above 20°C on about four nights per year. During the early years of record, temperatures below 0°C were recorded during most winters. However, over more recent years, the urban "heat island" effect has resulted in such low temperatures occurring only once in two years on average. 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 Melbourne metropolitan area. For example, there are approximately ten annual occurrences of 2°C or less around the Bay, 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 element	Spring	Summer	Autumn	Winter
Mean atmospheric pressure (millibar)	1,014.9	1,013.2	1,018.3	1,018.4
Mean temperature of air in shade (°C)	14.4	19.4	15.4	10.1
Mean daily range of temperature of air in shade (°C)	10.2	11.5	9.5	7.7
Mean relative humidity at 9 a.m. (saturation = 100)	64	62	72	79
Mean rainfall (mm)	186	155	170	148
Mean number of days of rain	40	25	34	44
Mean amount of evaporation (mm) *(a)*	375	599	301	147
Mean daily amount of cloudiness (scale 0 to 8) *(b)*	4.9	4.2	4.8	5.2
Mean daily hours of sunshine *(c)*	6.4	8.4	5.8	4.5
Mean number of days of fog	1.4	0.6	5.9	10.8

(a) Measured by Class A pan (records commenced 1967).
(b) Scale: 0 = clear, 8 = overcast.
(c) Measured at Laverton (records commenced 1968).

In the following table the yearly means of the climatic elements in Melbourne for each of the years 1976 to 1980 are shown. The extreme values of temperature in each year are also included.

MELBOURNE—YEARLY MEANS AND EXTREMES OF CLIMATIC ELEMENTS

Meteorological element	1976	1977	1978	1979	1980
Mean atmospheric pressure (millibar)	1,016.7	1,017.2	1,016.4	1,016.9	1,016.4
Temperature of air in shade (°C)—					
Mean	15.5	15.1	15.0	15.8	15.9
Mean daily maximum	19.6	19.5	19.2	20.3	20.4
Mean daily minimum	11.1	10.8	11.0	11.3	11.3
Absolute maximum	40.6	40.3	38.1	41.3	41.4
Absolute minimum	0.9	1.7	2.6	1.2	1.5
Mean terrestrial minimum temperature (°C)	9.2	9.1	9.1	9.4	9.4
Number of days maximum 35°C and over	7	4	5	10	14
Number of days minimum 2°C and under	3	4	0	2	1
Rainfall (mm)	504	605	867	543	644
Number of days of rain	143	137	148	151	149
Total amount of evaporation (mm) *(a)*	1,390	1,388	1,254	1,320	1,352

MELBOURNE—YEARLY MEANS AND EXTREMES OF CLIMATIC ELEMENTS—*continued*

Meteorological element	1976	1977	1978	1979	1980
Mean relative humidity at 9 a.m. (saturation = 100)	69	69	72	69	67
Mean daily amount of cloudiness (scale 0 to 8) *(b)*	4.7	4.9	5.2	5.1	4.8
Mean daily hours of sunshine *(c)*	6.4	6.3	5.8	6.0	6.5
Mean daily wind speed (km/h)	10.9	8.7	8.1	7.8	*(d)*
Number of days of wind gusts 63 km/h and over	51	54	32	42	*(d)* 59
Number of days of fog	6	3	7	8	10
Number of days of thunder	10	11	15	10	6

(a) Evaporation measured by Class A Pan.
(b) Scale: 0 = clear, 8 = overcast.
(c) Sunshine measured at Laverton.
(d) Incomplete, records for June not available.

Rainfall

The average annual rainfall in the city is 660 mm over 143 days. The average monthly rainfall varies from 48 mm in January and July to 68 mm in October. Rainfall is relatively steady during the winter months, and observed totals have ranged from 8 mm to 180 mm, but variability increases towards the warmer months. In the latter period, monthly totals have ranged between practically zero and over 230 mm.

Over 75 mm of rain has been recorded in 24 hours on several occasions, but these have been restricted to the warmer months — September to April. Only twice has over 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 only 500 mm. Rainfall increases towards the east, and at Mitcham averages 900 mm a year. The rainfall is greater still on the Dandenong Ranges, and at Sassafras the annual average is over 1,300 mm.

The number of days of rain, defined as days on which 0.2 mm or more of rain falls, exhibits marked seasonal variation ranging between a minimum of seven in February 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 days of rain 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 Melbourne's records — April 1923. On occasions, each month from November 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 mornings each month in May, June, and July, and average nineteen 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-eight. 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 more than 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 despite 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 possible hours, range between 55 per cent for January and February and 35 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 36.9 km/h, while means exceeding 30 km/h are on record for each month except March. 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 only a few seconds up to or even over 95 km/h. At the Melbourne observing site, 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 13 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 snowstorm on record occurred on 31 August 1849. Streets and house-tops were covered with several centimetres of snow, reported to be 30 centimetres deep at some places. When thawing set in, floods in Elizabeth and Swanston Streets stopped traffic and caused accidents, some of which were fatal.

VICTORIAN WEATHER SUMMARY 1980

Victoria's weather during 1980 was characterised by fluctuating rainfall, with falls varying from well below to well above normal from month to month. Widespread falls during April ended a five month drought that had affected most districts.

January rainfall was well below normal along and north of the Great Dividing Range and well above normal south of the Range. In the Mallee, the North Wimmera, and the Lower North, it was the driest January for more than a decade, while in East Gippsland, it was the wettest January since 1941. This was only the fourth January since records commenced in 1856, that the temperature in Melbourne did not exceed 34.0°C.

February rainfalls were very much below average in most of Victoria. It was the second driest February on record in the North Wimmera and the driest since 1933 in the Lower North. On 20 February, there were 50 outbreaks of fire at various places. Seven houses were destroyed in the Plenty area and 300 hectares of land burned out. About 1,100 hectares were burned out in the Castlemaine district.

March rainfall was below normal throughout Victoria. It was the driest March since 1953 in the Western District and the driest since 1967 in the South Wimmera, West Central, and North Central.

In contrast to the previous two months when rainfall was well below normal throughout Victoria, rainfall during April was above normal in all districts except Gippsland and the East Central. East Gippsland received only one-quarter of the normal and there have been only three drier Aprils in that district. In the north and west of Victoria it was the wettest April since 1974 and in the Mallee and Wimmera, it was one of the wettest Aprils on record. The rains were sufficient to break the five month drought in most of the State. During 8–22 April, temperatures in Melbourne exceeded 20°C on the fifteen consecutive days. This was the greatest number of consecutive days over 20°C in Melbourne during April since observations commenced in 1856. The previous record was 13 days in 1941 and 1970.

May rainfall was below normal throughout Victoria and it was the driest May since 1976 in all districts except East Gippsland where May 1977 was drier, and the West Coast

where May 1979 was drier. Melbourne's mean maximum temperature (18.5°C) was the highest for May since 1947 (19.5°C).

June rainfall was above normal in all districts except the Upper Northeast and East Gippsland. It was the wettest June since 1973 in the South Mallee and North Wimmera and one of the wettest June months on record in the East Central. Heavy rainfalls and blizzards were reported in the Victorian Alps. On 28 and 29 June, a deep depression brought strong winds to almost the whole of the State and gale to storm force winds in coastal areas. Several areas of the State reported heavy stock losses due to the combined effect of rain and strong winds on 28 and 29 June. In Melbourne, the mean 3 p.m. cloud amount was the highest in June since 1952.

Rainfall in July was close to normal in most districts. The most significant departures from normal were in East Gippsland and the West Central where about three-quarters of normal rainfall was received, and West Gippsland where July rainfall exceeded normal by 25 per cent. Severe wind squalls unroofed buildings, uprooted trees, and caused power blackouts in Melbourne on 3 July.

August rainfall was below normal throughout Victoria and in most districts it was the driest August since 1977. The greatest deficit occurred in East Gippsland where only 60 per cent of the normal was received. The unusually dry conditions led to the outbreak of several fires in that region. Gales on 30–31 August caused property damage in Gippsland; Melbourne Airport was closed briefly; and a cargo ship sank in the Yarra River. Winter rainfall was close to normal in most districts. However, East Gippsland received only 65 per cent of normal, while in the East Central, winter rainfall was about 20 per cent above normal. In Melbourne, the mean minimum temperature for the winter was the highest on record.

Rainfall in September was below normal in all districts except the Upper Northeast, West Gippsland, and the West Coast. In the North Mallee, there have been only two drier Septembers, namely, 1938 and 1914. The cumulative rainfall in East Gippsland for the eight months February to September was the lowest on record. In Melbourne, the mean minimum temperature (10.3°C) was the highest ever for September, and the lowest overnight temperature on 29–30 September (19.8°C) was the warmest September night on record. On 30 September, temperatures reached the mid-30s at several stations in Gippsland, making the warmest September day on record at many centres. It was the windiest September in Melbourne since 1952.

Rainfall during October was above normal in all districts except the Lower Northeast and West Gippsland where it was slightly below normal. The Mallee, Wimmera, West Central, and Western Plains received about one and a half times the normal and it was one of the wettest Octobers on record in the Western Plains. Major bushfires broke out in East Gippsland in the first week of the month, and 77 fires were burning on 4 October between Orbost and Maffra. Ninety thousand hectares of forest were burnt.

November rainfall was below normal throughout Victoria and it was the driest November since 1967 in the North Mallee, Upper and Lower North, and North Central. Severe wind squalls caused building damage and power blackouts in north-eastern Victoria on 18 November. Melbourne's minimum temperature on 4 November was the lowest November minimum since 1950 (3.7°C), and the maximum of 37.9°C on 13 November was the highest November maximum since 1966 (38.9°C). Several bushfires occurred in the Wimmera, Mallee, and East Gippsland.

The month of December was the wettest since 1970 in East Gippsland and the wettest since 1975 in the Mallee, Northern Country, Northeast, and North Central. Thunderstorms on 28 December caused widespread power blackouts, fires, flash floods, and property damage in Melbourne. Temperatures in the capital exceeded 40°C on two days, the first time since 1941. Several bushfires occurred throughout Victoria, causing property damage and substantial stock losses.

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