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 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 2 on page 57. 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 north-east 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 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	1974	1975	1976	1977	1978
Under 300	18.4	—	1.4	49.6	62.4	3.3
300–400	36.5	—	29.7	32.7	27.8	15.4
400–500	27.5	18.5	25.1	21.3	20.3	45.8
500–600	34.9	23.5	22.1	31.4	33.9	21.6
600–800	52.3	81.7	64.2	51.9	45.7	43.7
800–1,000	29.0	38.1	35.8	29.6	28.4	38.3
Over 1,000	29.0	65.8	49.3	11.1	9.1	59.5

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

VICTORIA—RAINFALL IN DISTRICTS
(mm)

Year	District							
	Mallee	Wimmera	Northern	North Central	North-Eastern	Western	Central	Gippsland
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
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	488	587	839	1,041	827	969	1,194
Average *(a)*	335	467	473	719	872	728	743	863

(a) Average for 66 years 1913 to 1978.

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

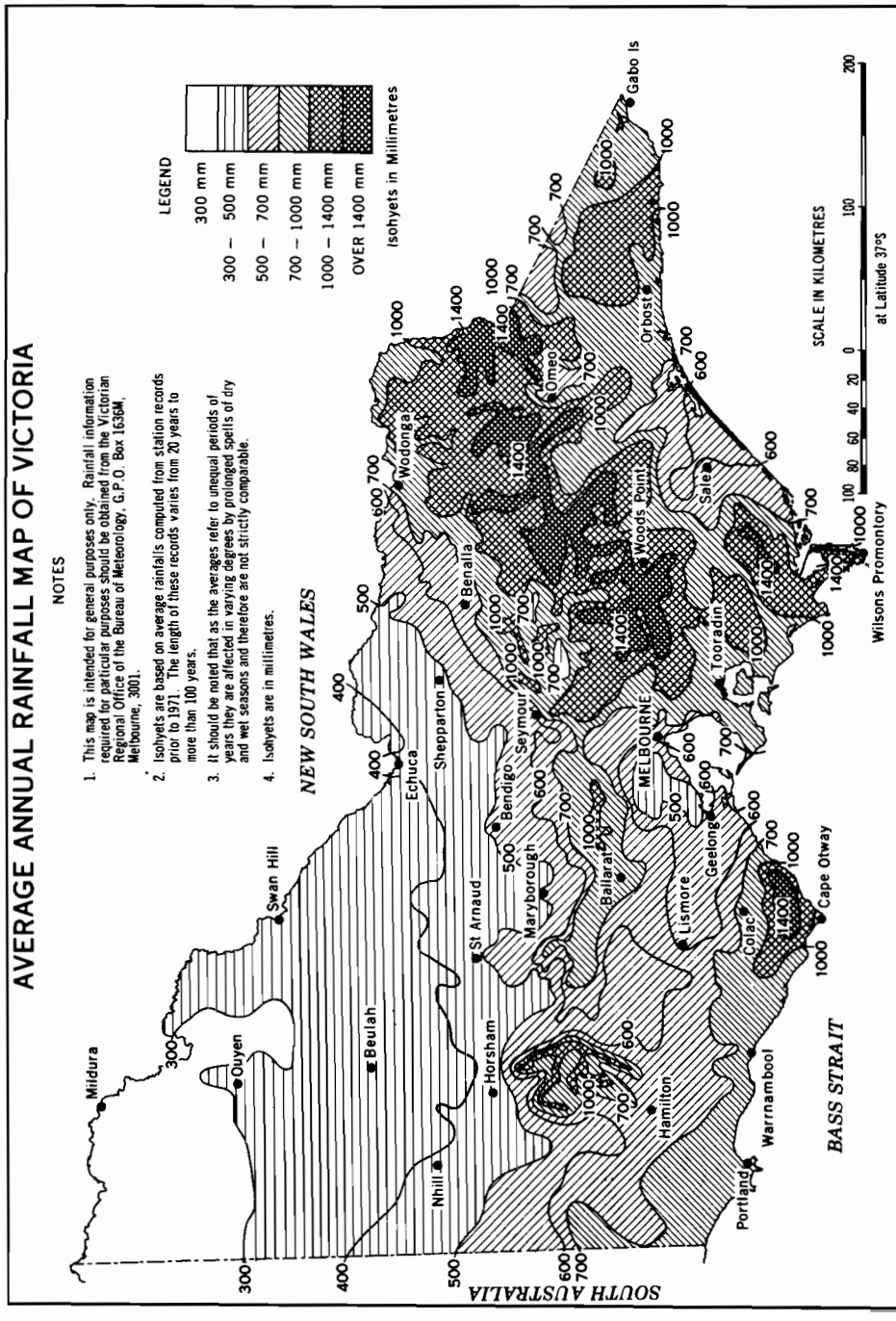

FIGURE 2. Average annual rainfall map of Victoria.

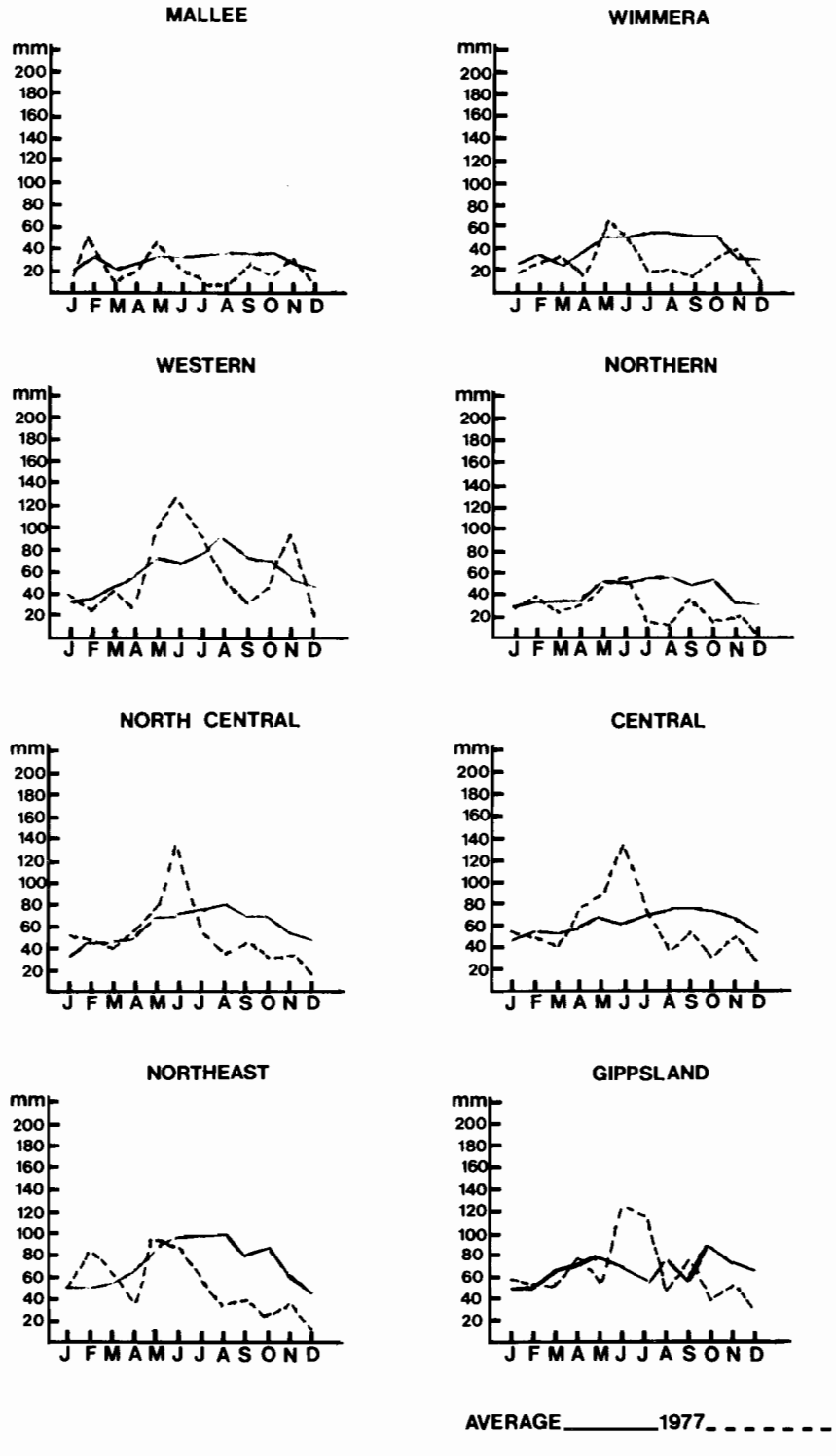

FIGURE 3. Victoria—district monthly rainfall: average and 1977.

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 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 coefficient has been calculated for the fifteen climatic districts of Victoria (see Figure 4) for the 66 years 1913 to 1978 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	778	124	15.9
2 West Gippsland	921	149	16.2
3 East Central	895	149	16.6
4 Western Plains	636	113	17.8
5 West Central	617	123	19.9
6 East Gippsland	784	157	20.0
7 South Wimmera	501	108	21.6
8 North Central	722	164	22.7
9 North Wimmera	415	98	23.6
10 Upper North-east	1,111	274	24.7
11 Lower North-east	779	210	27.0
12 South Mallee	354	98	27.7
13 Upper North	519	156	27.9
14 Lower North	436	133	30.5
15 North Mallee	309	95	30.7

(a) Average for 66 years 1913 to 1978.

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 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 rrom 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. Almost the whole of Victoria experienced serious to severe rainfall deficiencies during at least part of the latter 6 months of 1977.

Bushfires

An article on bushfires in Victoria can be found on pages 78-9 of the *Victorian Year Book* 1978.

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 events 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.

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, North-Eastern, West Central, and East Gippsland Districts.

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.

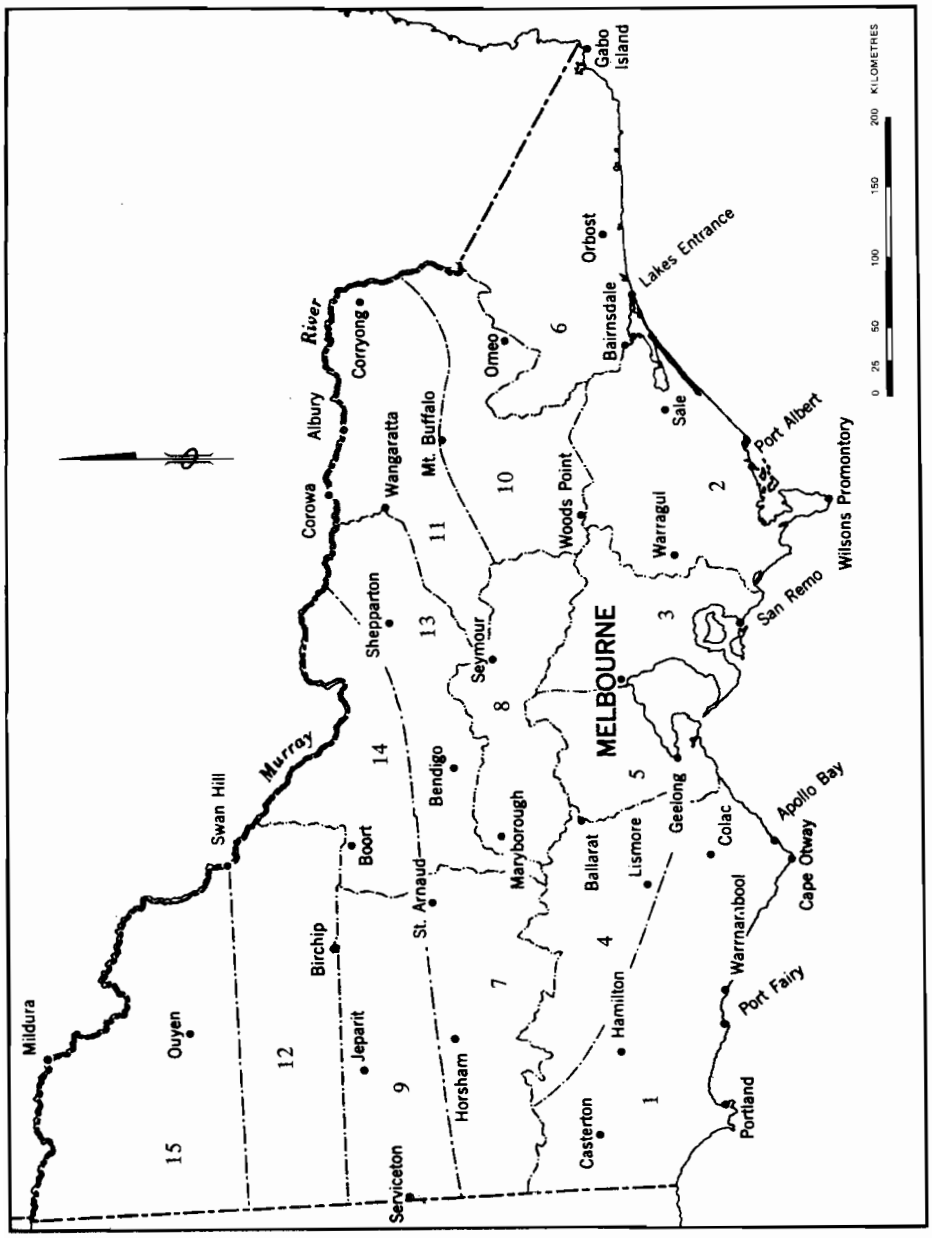

FIGURE 4. Relative rainfall variability by districts. Names of climatic districts are shown in the table on page 59.

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 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 north-east 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 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 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 67 at the end of 1977, 61 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 wide variations from this general description, however, and this is shown by the wind roses for selected towns, which are shown in Figures 5 and 6 on pages 66 and 67. 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.

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 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.

Further reference: Bushfires, *Victorian Year Book* 1978; pp. 78–9

URBAN METEOROLOGY

Historically speaking, cities have developed in areas where the greatest advantage could be gained from the natural environment, especially from the ready availability of water and thus food. As a result, Australia has become one of the most urbanised countries in the world.

Urbanisation leads to changes in the local microclimate through a threefold process. The

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	30	19	26	24	21	28	22	25	27	27	35	25	21	300
		2	31	31.9	30.9	28.1	23.2	18.7	16.0	15.4	17.1	20.1	22.9	26.8	29.7	23.4
		3	31	16.6	16.4	13.9	10.2	7.4	5.2	4.3	5.4	7.3	9.8	12.1	14.6	9.9
	Swan Hill	1	93	21	24	23	25	34	35	31	35	32	36	26	25	347
		2	77	31.4	31.1	27.8	22.7	18.3	14.8	14.4	16.3	19.3	22.8	26.8	29.9	23.0
		3	71	15.3	15.4	12.9	9.6	6.8	4.7	4.0	4.9	6.5	8.9	11.5	13.8	9.6
WIMMERA	Horsham	1	103	22	27	25	34	47	50	45	48	45	44	34	28	440
		2	69	29.9	29.8	26.5	21.4	17.1	13.9	13.3	15.0	17.7	21.0	24.8	27.7	21.1
		3	70	13.3	13.6	11.4	8.6	6.3	4.5	3.7	4.5	5.6	7.6	9.7	11.9	8.4
	Nhill	1	91	22	25	23	31	41	47	45	47	43	41	30	28	423
		2	72	29.6	29.4	26.7	21.2	17.3	14.3	13.7	15.1	17.8	21.0	24.8	27.8	21.8
		3	3	12.9	13.3	11.0	8.3	6.0	4.2	3.4	4.1	5.4	7.2	9.3	11.4	8.0
WESTERN	Ballarat	1	69	37	49	47	55	70	64	69	77	74	70	56	51	719
		2	66	24.9	24.8	21.9	17.3	13.3	10.6	9.9	11.3	13.8	16.5	19.4	22.3	16.2
		3	65	10.8	11.8	10.1	7.7	5.9	4.2	3.4	3.9	5.0	6.4	7.8	9.6	7.2
	Hamilton	1	106	33	33	43	55	68	73	74	77	72	66	51	45	698
		2	90	25.7	25.6	23.0	18.8	15.2	12.7	12.0	13.2	15.3	17.7	20.5	23.3	18.6
		3	91	11.4	12.0	10.5	8.6	6.8	5.2	4.5	5.0	6.0	7.1	8.4	10.0	7.9
	Warrnambool	1	80	33	36	48	60	78	76	86	84	73	66	54	45	739
		2	74	22.1	22.1	21.0	18.5	16.0	13.8	13.2	14.0	15.6	17.3	18.9	20.6	17.8
		3	74	12.7	13.3	12.2	10.3	8.6	6.8	6.2	6.6	7.7	8.9	10.0	11.6	9.6
NORTHERN	Bendigo	1	116	33	35	37	41	54	60	55	56	54	53	38	32	548
		2	110	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	108	14.1	14.3	12.4	9.1	6.4	4.7	3.7	4.4	6.0	8.1	10.3	12.4	8.8
	Echuca	1	98	27	29	33	34	42	44	40	43	39	44	32	29	436
		2	94	30.8	30.4	27.1	22.1	17.4	14.1	13.3	15.1	18.2	22.0	26.0	29.0	22.1
		3	93	15.2	15.3	13.1	9.0	6.7	4.8	4.0	5.0	6.5	8.9	11.3	13.6	9.5

NORTH CENTRAL	Alexandra	1	96	41	39	51	53	65	73	71	74	67	70	57	48	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	105	39	42	46	55	74	88	82	84	76	71	53	50	760
		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	108	31	39	41	44	50	49	45	48	51	53	49	39	539
		2	66	25.1	25.0	23.2	19.9	16.6	14.0	13.6	14.6	16.8	19.1	21.2	23.4	19.4
		3	67	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	86	44	44	52	64	70	70	68	71	71	70	58	53	735
		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
NORTH-EASTERN	Omeo	1	97	52	54	54	47	54	57	52	56	62	72	63	61	684
		2	93	26.2	25.8	23.1	18.7	14.1	10.8	10.2	12.1	15.2	18.3	21.5	24.5	18.4
		3	94	9.4	9.6	7.8	4.8	2.2	0.8	-0.2	0.6	2.6	4.7	6.4	8.3	4.7
	Wangaratta	1	98	38	40	47	48	56	71	63	63	60	64	46	42	639
		2	74	30.9	30.6	27.3	22.0	17.3	13.5	12.7	14.5	17.5	21.0	26.2	28.9	22.4
		3	73	15.0	15.0	12.3	8.4	5.4	3.7	3.2	4.1	5.8	8.2	10.7	13.2	8.7
WEST GIPPSLAND	Yallourn	1	28	49	57	56	63	93	77	82	96	89	87	85	68	902
		2	28	24.7	24.4	21.1	18.1	14.7	12.5	11.9	13.0	15.2	17.6	19.5	22.1	18.1
		3	28	12.7	13.3	12.1	9.7	7.5	5.8	4.7	5.3	6.5	8.3	9.6	11.1	8.9
	Sale	1	34	45	45	53	47	55	47	41	56	51	66	65	58	629
		2	32	25.1	25.0	23.3	20.1	16.5	14.0	13.6	14.7	16.7	18.9	20.7	23.1	18.7
		3	32	12.5	13.5	11.4	8.6	6.1	4.2	3.2	4.2	5.4	7.6	9.2	11.1	8.1
EAST GIPPSLAND	Bairnsdale	1	82	60	51	64	52	54	58	49	51	58	70	66	69	702
		2	68	24.6	24.7	23.1	20.4	16.8	14.4	14.0	13.9	17.5	19.6	21.6	23.5	19.6
		3	67	12.4	12.8	11.2	8.6	6.1	4.3	3.5	4.2	5.9	7.8	9.5	7.9	8.1
	Orbost	1	94	69	61	67	71	71	84	66	61	70	79	71	76	846
		2	35	25.1	25.1	23.6	20.7	17.4	14.6	14.2	15.2	17.1	18.5	20.1	23.5	23.0
		3	35	12.8	13.4	11.9	9.2	6.8	5.0	4.0	4.7	6.0	8.2	9.9	11.6	8.7

(a) Legend: 1. Average monthly rainfall in mm (for all available years of record to 1977).
2. Average daily maximum temperature (°C) (for all years of record to 1977).
3. Average daily minimum temperature (°C) (for all years of record to 1977).

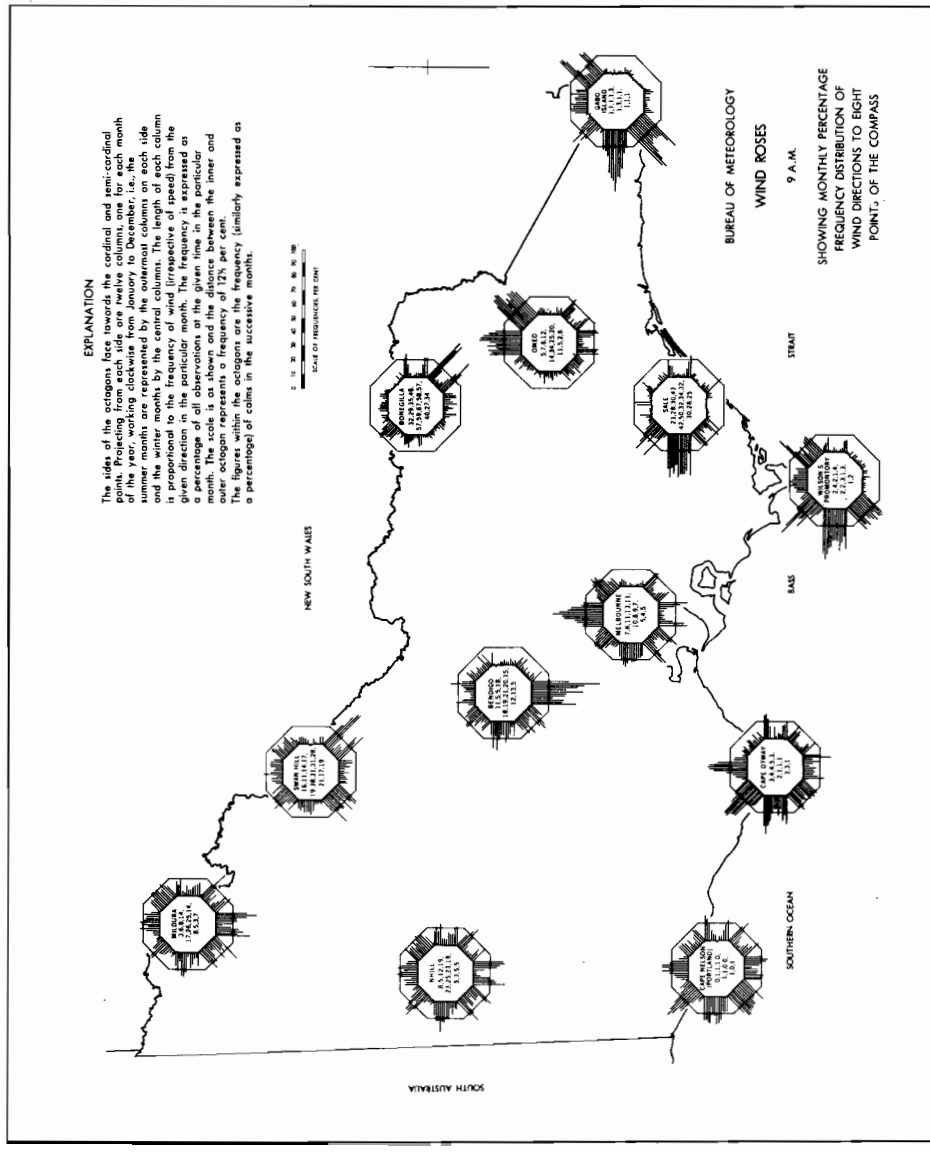

FIGURE 5. Victoria—wind roses for 9 a.m.

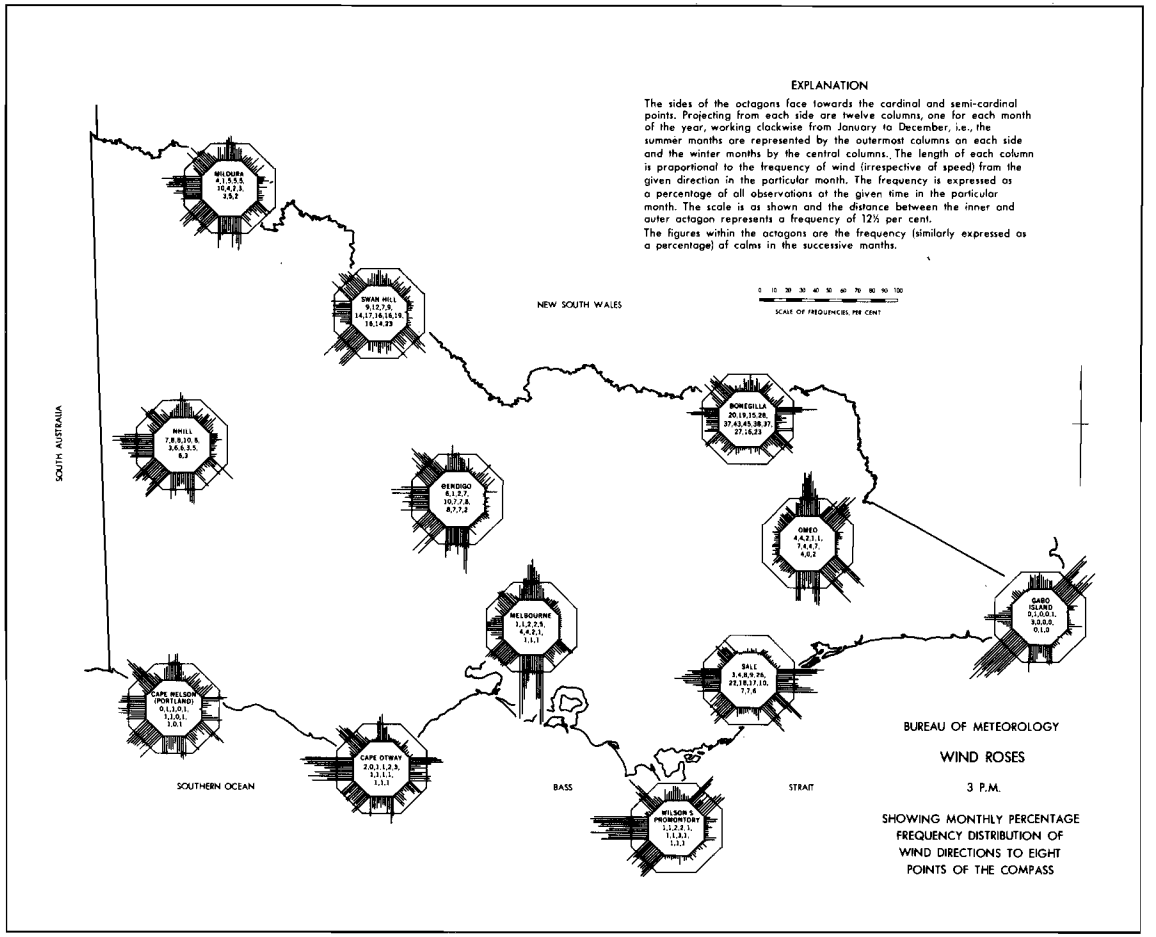

FIGURE 6. Victoria—wind roses for 3 p.m.

first and most obvious is the change from natural vegetative surfaces to impervious and heat-retentive surfaces of brick, concrete, steel, and asphalt. Thus the budget of heat in the area, and the aerodynamic roughness of the surface, have been altered significantly.

Second, towns and cities may generate very large amounts of heat artificially from industrial, transport, or domestic sources. Production of heat in some cities in certain seasons may approximate to that derived from the sun.

Third, the micro climate may be changed by the large quantities of gaseous and solid pollutants propelled into the air. These may also alter the amount of solar radiation which reaches the ground.

Of all the urban-rural meteorological differences, those of air temperature are probably the best documented. The centre of the city is warmer than its surroundings, forming a "heat island". During summer, city building materials retain larger amounts of solar radiation than does the natural vegetation, and at night the concrete and steel structures radiate this additional stored heat, raising the urban temperature. During winter, artificial heating may warm the urban air. These effects can be amplified by airborne pollutants acting as a "blanket" which decreases the rate of radiative heat loss.

The flow of wind over a city differs in several aspects from that of the surrounding countryside. Modification of wind strength occurs because of convergence effects of low-level winds and from changes in the roughness of ground surfaces. Light winds may be strengthened and become more gusty, whilst strong winds may be decreased.

Urban complexes have been known to increase the amount of precipitation in their vicinity. The urban atmosphere contains greater concentrations of particles on which condensation of water droplets can take place. Higher urban temperatures and increased wind turbulence also lead to increased growth to vertical air currents and more rapid formation of convective clouds. However, due to rapid run-off from impervious surfaces, much more useable water is lost.

A prime concern of urban planners must be to assess the vulnerability of cities and surroundings to extreme events such as floods, and to plan steps to mitigate the possible effects. Among other matters of concern must be the effects of vertical temperature structures and light wind drifts on industrial and residential areas. Attempts to control air pollution by concentrating solely on the source of emission have not been entirely successful and the probability of a slow build-up of pollutants (and possibly photochemical smog) over a number of suitable days must be assessed.

In summary, planners of new settlements must learn not only to work in with the environment in its most common states, but they should also be aware of the likely impact of new industries, suburbs, and transport systems, as well as of the likely extremes of meteorological conditions.

CLIMATE IN MELBOURNE

General conditions

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. 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)	14.3	19.4	15.3	10.1
Mean daily range of temperature of air in shade (°C)	10.3	11.6	9.5	7.7
Mean relative humidity at 9 a.m. (saturation = 100)	64	62	72	80
Mean rainfall (mm)	187	156	170	148
Mean number of days of rain	40	25	34	44
Mean amount of evaporation (mm) *(a)*	261	441	208	97
Mean daily amount of cloudiness (scale 0 to 8) *(b)*	4.8	4.2	4.7	5.1
Mean daily hours of sunshine *(c)*	6.0	7.7	5.2	3.9
Mean number of days of fog	1.4	0.6	6.0	11.0

(a) Measured by Australian Sunken Tank (prior to 1967).
(b) Scale: 0 = clear, 8 = overcast.
(c) Measured at Melbourne (prior to 1968)

In the following table the yearly means of the climatic elements in Melbourne for each of the years 1974 to 1978 are shown. The extreme values of temperature in each year are also included.

MELBOURNE—YEARLY MEANS AND EXTREMES OF CLIMATIC ELEMENTS

Meteorological element	1974	1975	1976	1977	1978
Mean atmospheric pressure (millibar)	1,015.7	1,015.8	1,016.9	1,017.2	1,016.3
Temperature of air in shade (°C)—					
Mean	15.6	15.6	15.5	15.2	15.1
Mean daily maximum	19.7	19.8	19.6	19.5	19.2
Mean daily minimum	11.4	11.4	11.1	10.8	11.0
Absolute maximum	36.5	39.6	40.6	40.3	38.1
Absolute minimum	0.6	0.9	0.9	1.7	2.6
Mean terrestrial minimum temperature (°C)	9.7	9.7	9.2	9.1	9.1
Number of days maximum 35°C and over	3	7	7	4	5
Number of days minimum 2°C and under	5	3	3	4	0
Rainfall (mm)	804	710	504	605	867
Number of days of rain	165	169	143	137	148
Total amount of evaporation (mm) *(a)*	1,421	1,393	1,390	1,388	1,254
Mean relative humidity at 9 a.m. (saturation = 100)	r73	71	r69	69	72
Mean daily amount of cloudiness (scale 0 to 8) *(b)*	5.1	4.9	4.7	4.9	5.2
Mean daily hours of sunshine *(c)*	6.2	6.1	6.4	6.3	5.8
Mean daily wind speed (km/h)	9.4	10.3	10.9	8.7	8.1
Number of days of wind gusts 63 km/h and over	59	43	51	54	32
Number of days of fog	5	13	6	3	7
Number of days of thunder	11	10	10	7	15

(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 661 mm over 143 days. The average monthly rainfall varies from 48 mm in January to 68 mm in October. Rainfall is relatively steady during the winter months, and observed totals have ranged from 7 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 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-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 36.7 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 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 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 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 1977

The main feature of the weather in Victoria during 1977 was the lack of significant rainfall in the second half of the year. As 1977 drew to a close, most of the State was very dry and experiencing serious to severe rainfall deficiencies.

January was a dry month in north-western Victoria, but elsewhere rainfall totals were near the long-term average. Maximum temperatures were near normal, while minima were near or slightly above normal. A cold front accompanied by severe thunderstorm activity entered western Victoria during the afternoon of 14 January and progressed steadily across the State. A violent thunderstorm with hail and very strong winds caused structural damage to many houses and demolished a church at Milawa in north-eastern Victoria. A number of grape and tobacco crops in the district were destroyed. Many houses in the Melbourne metropolitan area were unroofed and flash flooding was reported from some suburbs.

Temperatures were above normal throughout Victoria during February. The State's highest temperature for the year of 43°C was recorded during this month at Swan Hill on 11 February and at Sale on 17 February. On the morning of 12 February an anticyclone was located over the Tasman Sea and a cold front was approaching the western border areas. Between these two systems fresh to strong and hot northerly winds blew across the State. These winds fanned eleven major fires which affected large areas of the Western District, claiming five lives and injuring seventeen people, as well as destroying 81 homes and causing considerable stock losses. Low pressure systems embedded in the easterly troughs caused particularly heavy rain in northern and north-eastern Victoria towards the end of the month. The maximum temperature of 17.1°C in Melbourne on 28 February was the lowest February maximum since 1964.

March was a relatively dry month in most districts except for slightly above average rainfall occurring in the north-east and along the western border regions. The last particularly hot weather of the season was experienced on 11 March with temperatures well into the 30s at most places.

April was cool throughout Victoria. On 6 April a low pressure system developed to the west of Bass Strait and moved eastward to be positioned over eastern Victoria on 7 April. This system intensified and produced extremely heavy rainfalls in the Central and Gippsland Districts. Severe local flooding occurred in the Melbourne metropolitan area on 7 April, resulting in temporary closure of most main roads leading from the city. Major flooding occurred on the Merri Creek necessitating the evacuation of 50 houses. A severe local storm badly damaged a number of houses at Altona. Laverton recorded 188 mm of rain in the 24 hours to 9 a.m. on 8 April. This figure is 2 mm higher than the previous highest monthly rainfall total on record for Laverton. Snow fell on the higher peaks of the eastern ranges on 7 and 8 April.

Rainfall in May was above normal in most districts and temperatures were generally near average. However, following the passage of an intense cold front on 31 May, unseasonably cold weather occurred throughout Victoria. Snowfalls were reported from

stations at low elevations in all districts except the Mallee. The maximum temperature of 8.3°C in Melbourne on 31 May equalled the lowest May maximum on record.

June was a wet month in most districts with several stations in the Western, Central, and West Gippsland Districts experiencing their wettest June on record. Tanjil Bren reported 530 mm of rain for the month. Melbourne, with a rainfall total of 109 mm experienced its second wettest June.

Rainfall for July was generally well below normal north of the Great Dividing Range, but close to or above normal in the south. Gippsland received more than one and a half times its average and heavy rain during the last week of the month resulted in serious flooding along the La Trobe River. Frosts were widespread from 3 to 13 May and from 19 to 27 May.

For the first time since 1901 the temperature in Melbourne did not reach 16°C in either June or July.

August saw the commencement of an exceptionally dry period over almost the entire State. The month's rainfall was nearly all produced by cold frontal activity. Most of the fronts were weak and fairly rapid, resulting in only light precipitation. This month was unusually warm and in the north-west of the State maximum temperatures were up to 10°C above normal on 19 August and 11°C above on 26 August. In Melbourne only 24 mm of rain fell, the lowest August total since 1944. Melbourne's mean maximum temperature of 16.5°C was the highest on record and 20.9°C recorded on 11 August was the highest maximum for the first half of August since 1937.

September rainfall was below normal in most parts with much of western and north-eastern Victoria registering less than half of their average. Only east Gippsland and parts of central Victoria reported significantly above average rainfall. The only major rain producing systems were two depressions, the first of which moved across Bass Strait between 9 and 10 September and the second which moved across Victoria between 12 and 13 September. The associated rain caused minor flooding of the Merri Creek and east Gippsland rivers. Temperatures were generally below average with conditions becoming somewhat warmer in the second half of the month due to a higher frequency of occurrence of northerly winds.

It was dry throughout almost the entire State during October and many places received less than half of their normal rainfall. Severe thunderstorm activity was reported in the Mallee on 4 October, when severe local storms with hail caused major damage to property and crops in the Red Cliffs area. Other features of the month's weather were two exceptionally warm spells, the first between 8 and 13 October, and the second from 25 to 28 October. In both spells maximum temperatures were up to 15°C above normal. Robinvale reached 40°C on 13 October. The night of 12–13 October in Melbourne was the warmest October night on record with a minimum of 24.1°C being recorded. The maximum of 34.5°C on 28 October was the highest October temperature since 1940 and it was the first time since records began in 1855 in Melbourne that the temperature exceeded 30°C on six days of this month.

Most of Victoria experienced another dry month in November. However, on 26 November rain and thunderstorms developed near a quasi-stationary cold front lying just west of the State. Lightning associated with one of these storms killed a boy swimming off Williamstown. Rain continued for several days as a surface depression developed along the front near Adelaide and then moved south-east. The rapid movement of an anticyclone over Victoria during the night of 5–6 November following a day of cold south-westerly winds caused widespread frosts, some of which were severe, on the morning of 6 November. Ararat recorded a minimum temperature of -5°C and several other places reported minima below 0°C. During the evening of 9 November a dust storm accompanied by wind gusts of up to 135 km/h caused considerable damage to buildings and crops in the Mildura area.

December rainfall was well below normal throughout Victoria. However, on 19 and between 27 and 28 December the passage of strong cold fronts was followed by unseasonable snowfalls on the higher north-eastern ranges. The temperature fell to -5°C at Mt Hotham on 19 December. In Melbourne no rain fell during the first 24 days of the month.

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