

CHAPTER 2

CLIMATE AND PHYSICAL GEOGRAPHY OF AUSTRALIA

General description of Australia

This chapter is mainly concerned with the climate of Australia, although some geographic comparisons and a summary of landform features influencing climate have been included together with a summary of atmospheric climate controls.

Position and area

Position. Australia comprises a land area of 7,682,300 square kilometres. The land lies between latitudes 10° 41 'S. (Cape York) and 43° 39 'S. (South Cape, Tasmania) and between longitudes 113° 09 'E. (Steep Point) and 153° 39 'E. (Cape Byron). The most southerly point on the mainland is South Point (Wilson's Promontory) 39° 08 'S. The latitudinal distance between Cape York and South Point, Wilson's Promontory (South East Cape, Tasmania) is about 3,180 kilometres (3,680 kilometres) respectively and the longitudinal distance between Steep Point and Cape Byron is about 4,000 kilometres.

Area of Australia compared with areas of other countries. The area of Australia is almost as great as that of the United States of America (excluding Alaska), about 50 per cent greater than Europe (excluding U.S.S.R.) and 32 times greater than the United Kingdom. The following table shows the area of Australia in relation to areas of other continents and selected countries.

AREAS OF CONTINENTS AND SELECTED COUNTRIES

('000 square kilometres)

Country	Area	Country	Area
Continental divisions—		Country—	
Europe (a)	4,936	Australia	7,682
Asia (a)	27,532	Brazil	8,512
U.S.S.R. (Europe and Asia)	22,402	Canada	9,976
Africa	30,319	China	9,590
North and Central America and West Indies	24,247	Germany, Federal Republic of	248
South America	17,834	India	3,288
Oceania	8,504	Indonesia	1,919
		Japan	372
		Papua New Guinea	462
		New Zealand	269
		United Kingdom	244
		United States of America (b)	9,363
Total, land mass excluding Arctic and Antarctic continents	135,771		

(a) Excludes U.S.S.R., shown below.

(b) Includes Hawaii and Alaska.

Land forms

The average altitude of the surface of the Australian land mass is only 300 metres. Approximately 87 per cent of that land mass is less than 500 metres and 99.5 per cent is less than 1,000 metres. The highest point is Mount Kosciuszko (2,228 metres) and the lowest point is Lake Eyre (—15 metres).

Australia has three major landform features: the western plateau, the interior lowlands and the eastern uplands. The western half of the continent consists of a great plateau of altitude 300 to 600 metres. The interior lowlands include the channel country of southwest Queensland (drainage to Lake Eyre) and the Murray-Darling drainage system to the south. The eastern uplands consist of a broad belt of varied width extending from north Queensland to Tasmania and consisting largely of tablelands, ranges and ridges with only limited mountain areas above 1,000 metres.

Rivers and lakes

The rivers of Australia may be divided into two major classes, those of the coastal plains with moderate rates of fall and those of the central plains with very slight fall. Of the rivers of the northern part of the east coast, the longest are the Burdekin and the Fitzroy in Queensland. The Hunter is the largest coastal river of New South Wales, and the Murray River, with its great tributary the Darling, drains part of Queensland, the major part of New South Wales, and a large part of Victoria, finally flowing into the arm of the sea known as Lake Alexandrina, on the eastern side of the South Australian coast. The total length of the Murray is about 2,520 kilometres, 650 kilometres in South Australia and 1,870 kilometres from South Australia to the source of the Murray. The Darling from its junction with the Murray to its junction with the Culgoa is 1,390 kilometres. The Upper Darling (1,140 kilometres) incorporates the Barwon which commences at the junction of the Culgoa to its junction with the Weir River and the Macintyre River from its junction with the Weir to its source near Maybole. The rivers of the north-west coast of Australia (Western Australia) e.g. the Murchison, Gascoyne, Ashburton, Fortescue, De Grey, Fitzroy, Drysdale, and Ord are of considerable size. So also are those rivers in the Northern Territory, e.g. the Victoria and Daly, and those on the Queensland side of the Gulf of Carpentaria, such as the Gregory, Leichhardt, Cloncurry, Gilbert, and Mitchell. The rivers of Tasmania have short and rapid courses, as might be expected from the configuration of the country.

The 'lakes' of Australia may be divided into three classes: true permanent lakes; lakes which being very shallow, become mere morasses in dry seasons or even dry up, and finally present a cracked surface of salt and dry mud; and lakes which are really inlets of the ocean, opening into a lake-like expanse. The second class, which are a characteristic of the interior lowlands are of considerable extent. The largest are Lake Eyre 9,500 square kilometres, Lake Torrens 5,900 square kilometres and Lake Gairdner 4,300 square kilometres.

For further information on the landforms and the geographical features of Australia earlier issues of the Year Book should be consulted. The list of special articles, etc., at the end of this volume indicates the nature of the information available and its position in the various issues.

Area, coastline, tropical and temperate zones, and standard times. The areas of the States and Territories and the length of the coastline were determined in 1973, by the Division of National Mapping, Department of National Resources, by manually digitising these features from the 1:250,000 map series of Australia. This means that only features of measurable size at this scale were considered. About 60,000 points were digitised at an approximate spacing of 0.5 kilometres. These points were joined by chords as the basis for calculation of areas and coastline lengths by computer.

The approximate high water mark coastline was digitised and included all bays, ports and estuaries which are open to the sea. In these cases, the shoreline was assumed to be where the seaward boundary of the title of ownership would be. In mangroves, the shoreline was assumed to be on the landward side. Rivers were considered in a similar manner but the decisions were rather more subjective, the line being across the river where it appeared to take its true form.

AREA, COASTLINE, TROPICAL AND TEMPERATE ZONES, AND STANDARD TIMES: AUSTRALIA

NOTE. See paragraphs above for methods of estimating area and coastline.

State or Territory	Estimated area		Length of coastline	Percentage of total area		Standard times	
	Total	Percentage of total area		Tropical zone	Temperate zone	Meridian selected	Ahead of G.M.T. (a)
	km ²		km				hours (b)
New South Wales	801,600	10.43	1,900	..	100	150°E	(b)10.0
Victoria	227,600	2.96	1,800	..	100	150°E	(b)10.0
Queensland	1,727,200	22.48	7,400	54	46	150°E	10.0
South Australia	984,000	12.81	3,700	..	100	142°30' E	(b)9.5
Western Australia	2,525,500	32.87	12,500	37	63	120°E	8.0
Tasmania	67,800	0.88	3,200	..	100	150°E	(b)10.0
Northern Territory	1,346,200	17.52	6,200	81	19	142°30' E	9.5
Australian Capital Territory	2,400	0.03	35	..	100	150°E	(b)10.0
Australia	7,682,300	100.00	36,735	39	61

(a) Greenwich Mean Time.

(b) For States with 'daylight saving' an hour should be added for this period.

Climate of Australia

General

The climate of Australia is predominantly continental but the insular nature of the land mass is significant in producing some modification of the continental pattern.

The island continent of Australia is relatively dry with 50 per cent of the area having a median* rainfall of less than 300 millimetres per year and 80 per cent less than 600 millimetres. Extreme minimum temperatures are not as low as those recorded in other continents because of the absence of extensive mountain masses and because of the expanse of ocean to the south. However, extreme maxima are comparatively high, reaching 50°C over the inland, mainly due to the great east-west extent of the continent in the vicinity of the Tropic of Capricorn.

Climatic discomfort, particularly heat discomfort, is significant over most of Australia. During summer, prolonged high temperatures and humidity around the northern coasts and high temperatures over the inland cause physical discomfort. In winter, low temperatures and strong cold winds over the interior and southern areas can be severe although for relatively short periods.

Climatic controls

The generally low relief of Australia causes little obstruction to the atmospheric systems which control the climate. A notable exception is the eastern uplands which modify the atmospheric flow.

In the winter half of the year (May–October) anticyclones, or high pressure systems, pass from west to east across the continent and often remain almost stationary over the interior for several days. These anticyclones may extend to 4,000 kilometres along their west-east axes. Northern Australia is then influenced by mild, dry south-east trade winds, and southern Australia experiences cool, moist westerly winds. The westerlies and the frontal systems associated with extensive depressions over the Southern Ocean exert a controlling influence on the climate of southern Australia, causing rainy periods during the winter season. Cold outbreaks, particularly in south-east Australia, occur when cold air of Southern Ocean origin is directed northwards by intense depressions having diameters up to 2,000 kilometres. Cold fronts associated with the southern depressions, or with secondary depressions over the Tasman Sea, may produce extreme day-to-day changes in temperature in southern areas, particularly in south-east coastal regions.

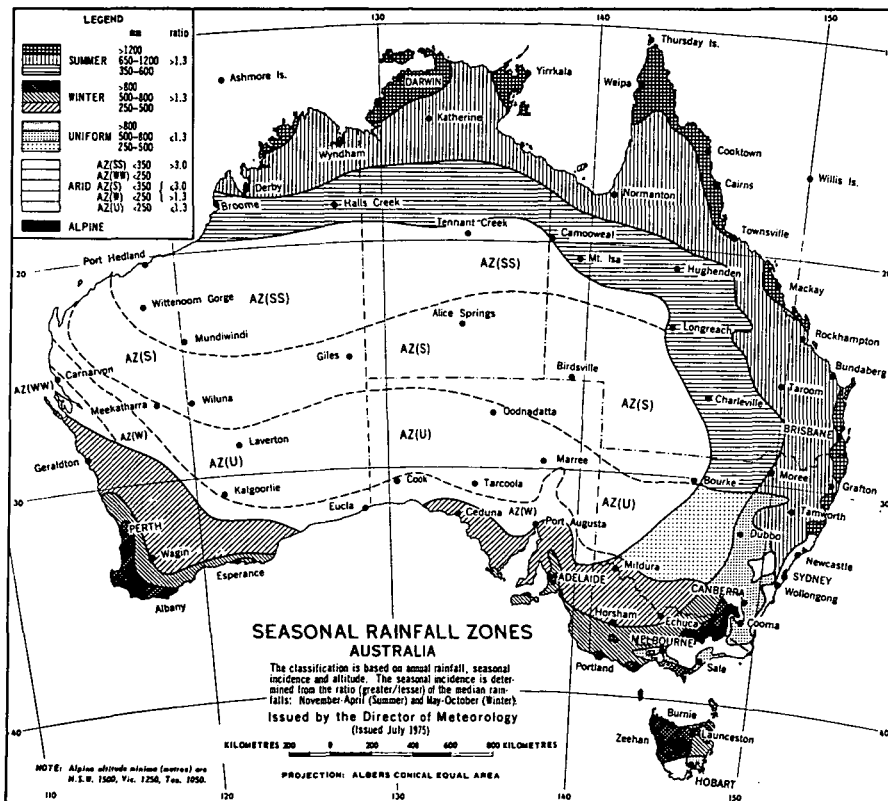
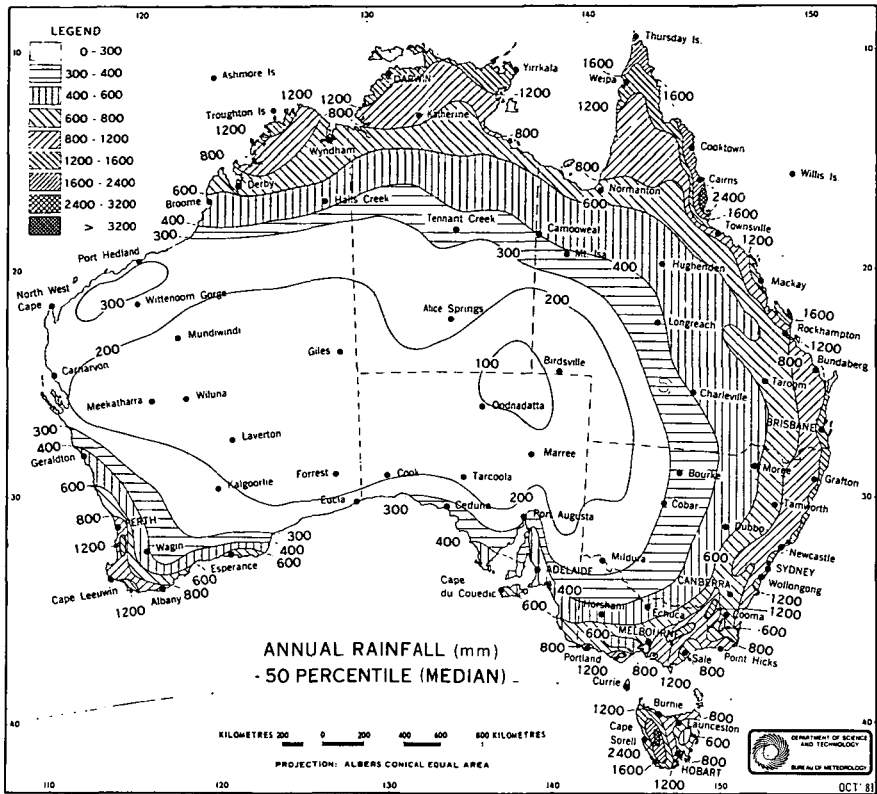
In the summer half of the year (November–April) the anticyclones travel from west to east on a southerly track across the southern fringes of Australia directing easterly winds generally over the continent. Fine, warmer weather predominates in southern Australia with the passage of each anticyclone. Heat waves occur when there is an interruption to the eastward progression of the anticyclone (blocking) and winds back northerly and later north-westerly. Northern Australia comes under the influence of summer disturbances associated with the southward intrusion of warm moist monsoonal air from north of the inter-tropical convergence zone resulting in a hot rainy season.

Tropical cyclones develop over the seas to the north-west and the north-east of Australia in summer between November and April. Their frequency of occurrence and the tracks they follow vary greatly from season to season. On the average, about three cyclones per season directly affect the Queensland coast, and about three affect the north and north-west coasts. Tropical cyclones approaching the coast usually produce very heavy rain in coastal areas. Some cyclones move inland, losing intensity but still producing widespread heavy rainfall. Individual cyclonic systems may control the weather over northern Australia for periods extending up to three weeks.

Rainfall

Annual. The annual 50 percentile (medium) rainfall map is shown on Plate 3. The area of lowest rainfall is east of Lake Eyre in South Australia, where the median rainfall is only about 100 millimetres. Another very low rainfall area is in Western Australia in the Giles-Warburton Range region, which has a median annual rainfall of about 150 millimetres. A vast region extending from the west coast near Shark Bay across the interior of Western Australia and South Australia to south-west Queensland and north-west New South Wales has a median annual rainfall of less than 200 millimetres. This region is not normally exposed to moist air masses for extended periods and rainfall is irregular, averaging only one or two days per month. However, in favourable synoptic situations, which occur infrequently over extensive parts of the region, up to 400 millimetres of rain may fall within a few days and result in widespread flooding.

* The amount that is exceeded by 50 per cent of all recordings is the 50 percentile or the fifth decile. The 50 percentile is usually called the median.



PLATES 3 and 4

The region with the highest median annual rainfall is the east coast of Queensland between Cairns and Cardwell, where Tully has a median of 4,203 millimetres (56 years to 1980 inclusive). The mountainous region of western Tasmania also has a high annual rainfall, with Lake Margaret having a median of 3,575 millimetres (68 years to 1980 inclusive). In the mountainous areas of north-east Victoria and some parts of the east coastal slopes there are small pockets with median annual rainfall greater than 2,500 millimetres, but the map scale is too small for these to be shown.

The Snowy Mountains area in New South Wales also has a particularly high rainfall. The highest median annual rainfall isohyet drawn for this region is 3,200 millimetres, and it is likely that small areas have a median annual rainfall approaching 4,000 millimetres on the western slopes above 2,000 metres elevation.

The following table shows the area l distribution of the median annual rainfall.

AREA DISTRIBUTION OF MEDIAN ANNUAL RAINFALL: AUSTRALIA

(Per cent)

Median annual rainfall	N.S.W.(a)	Vic.	Qld	S.A.	W.A.	Tas.	N.T.	Aust.
Under 200 mm . . .	8.0	..	10.2	74.2	43.5	..	15.5	29.6
200 to 300 " . . .	20.3	6.3	13.0	13.5	29.6	..	35.6	22.9
300 " 400 " . . .	19.0	19.2	12.3	6.8	10.5	..	9.0	11.2
400 " 500 " . . .	12.4	11.8	13.5	3.2	4.3	..	6.6	7.6
500 " 600 " . . .	11.3	14.1	11.6	1.8	3.1	12.2	5.8	6.6
600 " 800 " . . .	15.1	24.5	20.5	0.5	4.6	18.2	11.6	10.7
800 " 1,200 " . .	11.3	17.7	12.6	..	3.7	25.0	9.6	7.7
Above 1,200 " . .	2.6	6.4	6.3	..	0.7	44.6	6.3	3.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

(a) Includes Australian Capital Territory.

For further information on annual rainfall, see Year Book No. 68.

Seasonality. As outlined under the heading of Climatic controls, the rainfall pattern is strongly seasonal in character with a winter rainfall regime in the south and a summer regime in the north.

The dominance of rainfall over other climatic elements in determining the growth of specific plants in Australia has led to the development of a climatic classification based on two main parameters. The parameters are, median annual rainfall and seasonal rainfall incidence. Plate 4, is a reduced version of the seasonal rainfall zones arising from this classification (see Bureau of Meteorology publication *Climatic Atlas of Australia, Map Set 5, Rainfall, 1977*).

Evaporation and the concept of rainfall effectiveness are taken into account to some extent in this classification by assigning higher median annual rainfall limits to the summer zones than the corresponding uniform and winter zones. The main features of the seasonal rainfall are:

- marked wet summer and dry winter of northern Australia;
- wet summer and relatively dry winter of south eastern Queensland and north-eastern New South Wales;
- uniform rainfall in south-eastern Australia—much of New South Wales, parts of eastern Victoria and in southern Tasmania;
- marked wet winter and dry summer of south-west Western Australia and (to a lesser extent) of much of the remainder of southern Australia directly influenced by westerly circulation;
- arid area comprising about half of the continent extending from the north-west coast of Western Australia across the interior and reaching the south coast at the head of the Great Australian Bight.

Variability. The adequate presentation of rainfall variability over an extensive geographical area is difficult.

One index for assessing the variability of annual rainfall is given by the ratio of the 90–10 percentile range to the 50 percentile (median value) i.e. Variability Index = $\frac{90 - 10}{50}$ percentiles.

Variability based on this relationship is shown in Plate 5. The region of high to extreme variability shown in Plate 5, lies mostly in the arid zone with summer rainfall incidence, AZ(S), defined on Plate 4. In the winter rainfall zones the variability is generally low to moderate as exemplified by the south-west of Western Australia. In the tropics, random cyclone visitations cause extreme variations in rainfall from year to year: at Onslow (Western Australia), annual totals varied from 15 millimetres in 1912 to 1,085 millimetres in 1961 and, in the four consecutive years 1921 to 1924, the annual totals

were 566, 69, 682 and 55 millimetres respectively. At Whim Creek (Western Australia), where 747 millimetres have been recorded in a single day, only 4 millimetres were received in the whole of 1924. Great variability can also occur in the heavy rainfall areas: at Tully (Queensland), the annual rainfalls have varied from 7,898 millimetres in 1950 to 2,486 millimetres in 1961.

For more information on variability, see Year Book No. 68.

Rainday frequency. The average number of days per year with rainfall of 0.2 millimetres or more is shown in Plate 6.

The frequency of rain-days exceed 150 per year in Tasmania (with a maximum of over 200 in western Tasmania), southern Victoria, parts of the north Queensland coast and in the extreme south west of Western Australia. Over most of the continent the frequency is less than 50 rain-days per year. The area of low rainfall with high variability, extending from the north-west coast of Western Australia through the interior of the continent, has less than 25 rain-days per year. In the high rainfall areas of northern Australia rain-days number are about 80 per year, but falls heavier in this region than in southern regions.

Intensity. The highest rainfall intensities for some localities are shown in the following table. These figures represent intensities over only small areas around the recording points because turbulence and exposure characteristics of the measuring gauge may vary over a distance of a few metres. The highest rainfall measured for one hour is 330 millimetres at Deeral, Queensland, 13 March 1936. The highest 24-hour (9 a.m. to 9 a.m.) falls are also listed by States in the accompanying table. Most of the very high 24-hour falls (above 700 millimetres) have occurred in the coastal strip of Queensland, where a tropical cyclone moving close to mountainous terrain provides ideal conditions for spectacular falls. The highest 24-hour fall (1,140 millimetres) occurred at Bellenden Ker (Top Station) on 4 January 1979. Bellenden Ker (Top Station) has also recorded the highest monthly and annual rainfall in Australia (5,387 millimetres in January 1979 and 11,251 millimetres in 1979, respectively).

The highest annual rainfalls are listed by States in the following table.

HIGHEST ANNUAL RAINFALLS (All years to 1980 inclusive)

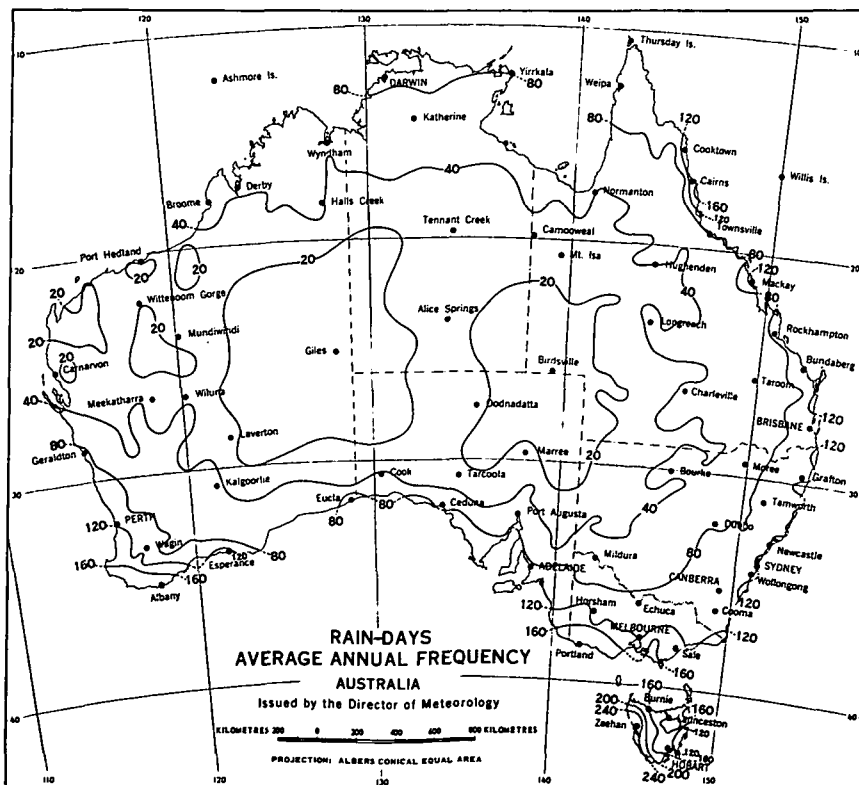
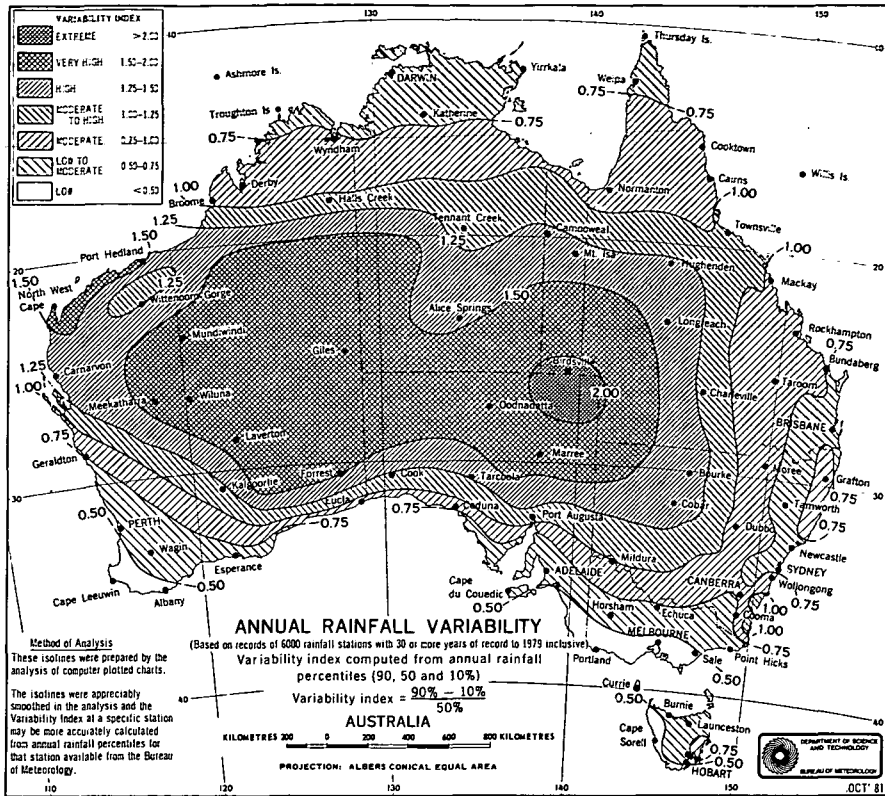
State	Station	Year	Amount
			mm
New South Wales	Tallowood Point	1950	4,540
Victoria	Mt Buffalo Chalet	1917	3,342
Queensland	Bellenden Ker (Top Station)	1979	11,251
South Australia	Aldgate State School	1917	1,851
Western Australia	Karnet	1964	2,601
Tasmania	Lake Margaret	1948	4,504
Northern Territory	Elizabeth Downs	1973	2,966

HIGHEST RAINFALL INTENSITIES IN SPECIFIED PERIODS

(millimetres)

(Source: Pluviograph records in Bureau of Meteorology archives.)

Station	Period of record	Years of complete records	Period in hours				
			1	3	6	12	24
			mm	mm	mm	mm	mm
Adelaide	1897-1980	80	69	133	141	141	141
Alice Springs	1951-1980	28	75	77	87	108	150
Brisbane	1911-1980	67	88	144	182	265	327
Broome	1948-1979	32	112	157	185	313	351
Canberra	1932-1979	44	51	68	71	89	139
Carnarvon	1956-1979	24	32	63	83	95	108
Charleville	1953-1980	28	42	66	75	111	142
Cloncurry	1953-1975	20	59	118	164	173	204
Darwin (Airport)	1953-1980	25	88	138	214	260	277
Esperance	1963-1979	15	23	45	62	68	79
Hobart	1911-1980	67	28	56	87	117	168
Meekatharra	1953-1979	25	33	67	81	99	112
Melbourne	1878-1980	90	79	83	86	97	130
Mildura	1953-1977	23	49	60	65	65	91
Perth	1946-1980	33	32	38	47	64	93
Sydney	1913-1979	63	97	135	166	190	282
Townsville	1953-1980	26	88	158	235	296	319



PLATES 5 and 6

HIGHEST DAILY RAINFALLS

(All years to July 1981)

State	Station	Date	Amount
			mm
New South Wales	Dorrigo	21.2.1954	809
	Cordeaux River	14.2.1898	574
Victoria	Balook	18.2.1951	275
	Hazel Park	1.12.1934	267
Queensland	Bellenden Ker (Top Station)	4.1.1979	1,140
	Crohamhurst	3.2.1893	907
	Finch Hatton	18.2.1958	878
	Mount Dangar	20.1.1970	869
South Australia	Stansbury	18.2.1946	222
	Stirling	17.4.1889	208
Western Australia	Whim Creek	3.4.1898	747
	Kilto	4.12.1970	635
	Fortescue	3.5.1890	593
Tasmania	Cullenswood	22.3.1974	352
	Mathinna	5.4.1929	337
Northern Territory	Roper Valley	15.4.1963	545
	Groote Eylandt	28.3.1953	513

Thunderstorms and hail. A thunder-day at a given location is a calendar day on which thunder is heard at least once. The average annual number of thunder-days varies from 80 per year near Darwin to less than 10 per year over parts of the southern regions. Convectonal processes during the summer wet season cause high thunderstorm incidence in northern Australia. The generally high incidence (40–60 annually) over the eastern upland areas is produced mainly by orographic uplift of moist air streams.

For further information on thunderstorms, see Year Book No. 68.

Hail, mostly of small size (less than 10 millimetres diameter), occurs with winter/spring cold frontal activity in southern Australia. Summer thunderstorms, particularly over the uplands of eastern Australia, sometimes produce large hail (greater than 10 millimetres diameter). Hail capable of piercing light gauge galvanised iron occurs at irregular intervals and can cause widespread damage.

Snow. Generally, snow covers much of the Australian Alps above 1,500 metres for varying periods from late autumn to early spring. Similarly, in Tasmania the mountains are covered frequently above 1,000 metres during these seasons. The area, depth and duration of falls are highly variable and in the lower altitude range, 500–1,000 metres, no falls occur some years. Snowfalls at levels below 500 metres are occasionally experienced in southern Australia, particularly in the foothill areas of Tasmania and Victoria, but falls are usually light and short lived. In some seasons parts of the eastern uplands above 1,000 metres from Victoria to south-eastern Queensland are covered with snow for several weeks. In ravines around Mt Kosciuszko (2,228 metres) small areas of snow may persist through summer but no permanent snowfields remain.

Temperature

Average temperatures. Average annual air temperatures as shown in Plate 7 range from 28° C along the Kimberley coast in the extreme north of Western Australia to 4° C in the alpine areas of south-eastern Australia. Although annual temperature may be used for broad comparisons, monthly temperatures are required for detailed analyses.

July is the month with the lowest average temperature in all parts of the continent. The months with the highest average temperature are January or February in the south and December in the north (except in the extreme north and north-west where it is November). The slightly lower temperatures of mid-summer in the north are due to the increase in cloud during the wet season.

Average monthly maxima. Maps of average maximum and minimum temperature for January and July respectively are shown in Plates 8 and 9.

In January, average maximum temperatures exceed 35° C over a vast area of the interior and exceed 40° C over appreciable areas of the north-west. The consistently hottest part of Australia in terms of summer maxima is around Marble Bar, Western Australia (150 kilometres south-east of Port Hedland) where the average is 41° C and daily maxima during summer may exceed 40° C consecutively for several weeks at a time.

The marked gradients of isotherms of maximum temperature in summer in coastal areas, particularly along the south and west coasts, are due to the penetration inland of fresh sea breezes initiated by the sharp temperature discontinuities between the land and sea surfaces. There are also gradients of a complex nature in south east coastal areas caused primarily by the uplands.

In July a more regular latitudinal distribution of average maxima is evident. Maxima range from 30°C near the north coast to 5° C in the alpine areas of the south-east.

Average monthly minima. In January average minima range from 27° C on the north west coast to 5° C in the alpine areas of the south east. In July average minima fall below 5° C in areas south of the tropics (away from the coasts). Alpine areas record the lowest temperatures; the July average is as low as -5° C.

For further information on average monthly maxima and minima, see Year Book No. 68.



PLATE 7

Extreme maxima. Temperatures have exceeded 45°C at nearly all inland stations more than 150 kilometres from the coast and at many places on the north west and south coasts. Temperatures have exceeded 50°C at some inland stations and at a few near the coast. It is noteworthy that Eucla on the south coast has recorded 50.7°C, the highest temperature in Western Australia. This is due to the long trajectory over land of hot north-west winds from the Marble Bar area. Although the highest temperature recorded in Australia was 53.1°C at Cloncurry (Queensland), more stations have exceeded 50°C in western New South Wales than in other areas due to the long land trajectory of hot winds from the north west interior of the continent.

Extreme maximum temperatures recorded at selected stations, including the highest recorded in each State, are shown in the following table.

EXTREME MAXIMUM TEMPERATURES

(All years to July 1982)

Station	°C	Date	Station	°C	Date
New South Wales—			Western Australia—		
Bourke	52.8	17.1.1877	Eucla	50.7	22.1.1906
Walgett	50.1	2.1.1903	Mundrabilla	49.8	3.1.1979
Wilcannia	50.0	11.1.1939	Forrest	49.8	13.1.1979
Victoria—			Madura	49.4	7.1.1971
Mildura	50.8	6.1.1906	Tasmania—		
Swan Hill	49.4	18.1.1906	Bushy Park	40.8	26.12.1945
Queensland—			Hobart	40.8	4.1.1976
Cloncurry	53.1	16.1.1889	Northern Territory—		
Winton	50.7	14.12.1888	Finke	48.3	2.1.1960
Birdsville	50.0	24.12.1972	Jervois	47.5	3.1.1978
South Australia—			Australian Capital Territory—		
Oodnadatta	50.7	2.1.1960	Canberra (Acton)	42.8	11.1.1939
Kyancutta	49.3	9.1.1939	Canberra Airport	42.2	1.2.1968

Extreme minima. The lowest temperatures in Australia have been recorded in the Snowy Mountains, where Charlotte Pass (elevation 1,760 metres) has recorded -22.2°C on 14 July 1945 and 22 August 1947. Temperatures have fallen below -5°C at most inland places south of the tropics and at some places within a few kilometres of southern coasts. At Eyre, on the south coast of Western Australia, a minimum of -3.9°C has been recorded, and at Swansea, on the east coast of Tasmania, the temperature has fallen as low as -4.4°C .

In the tropics, extreme minima below 0°C have been recorded at many places away from the coasts as far north as Herberton, Queensland (-3.3°C). Even very close to the tropical coastline temperatures have fallen to 0°C , a low recording being -0.8°C for Mackay.

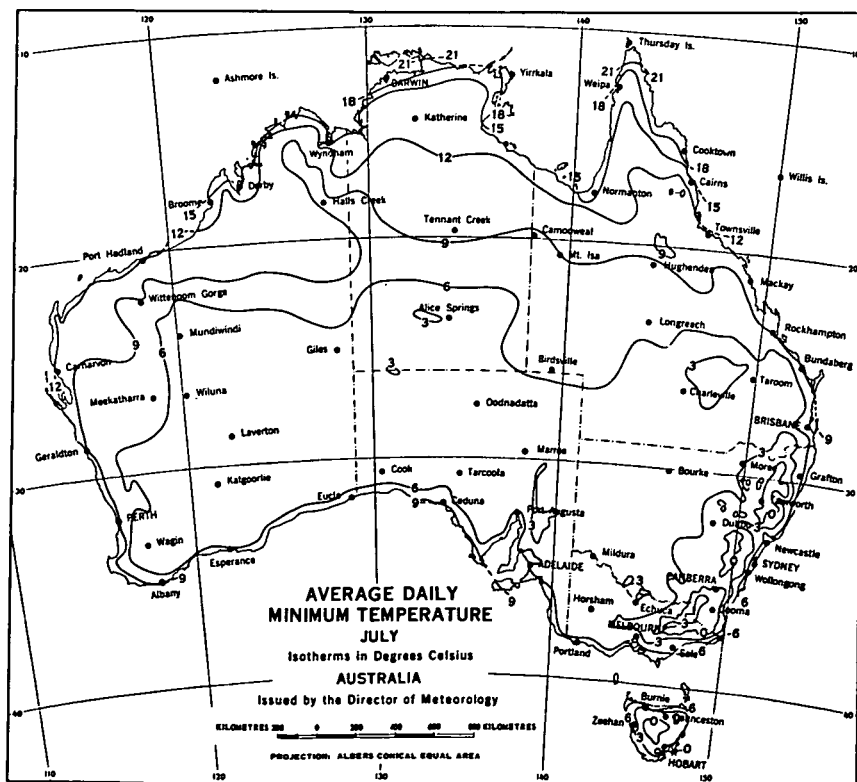
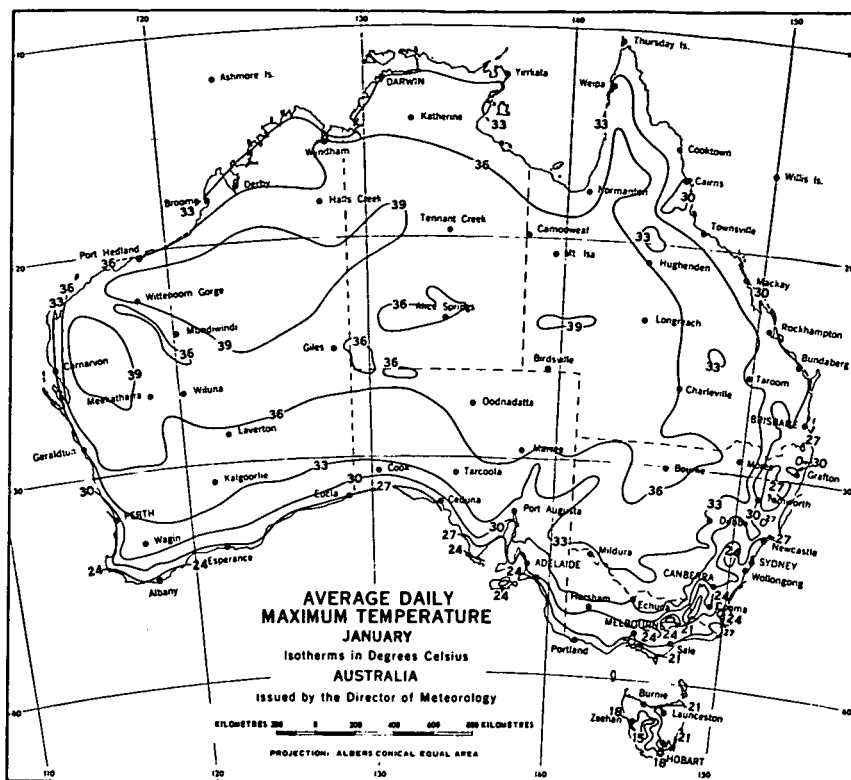
The next table shows extreme minimum temperatures recorded at specified stations, including the lowest recorded in each State.

EXTREME MINIMUM TEMPERATURES

(All years to July 1982)

Station	°C	Date	Station	°C	Date
New South Wales—			Western Australia—		
Charlotte Pass	-22.2	14.7.1945	Booylgoo	-6.7	12.7.1969
		22.8.1947	Wandering	-5.7	1.6.1964
Kiandra	-20.6	2.8.1929	Tasmania—		
Kosciusko Hotel	-14.4	3.7.1929	Shannon	-13.0	30.6.1983
		6.7.1939	Butlers Gorge	-13.0	30.6.1983
Cooma	-11.2	13.7.1898	Tarraleah	-13.0	30.6.1983
Victoria—			Northern Territory—		
Mount Hotham	-12.8	13.8.1947	Alice Springs	-7.5	12.7.1976
Omeo	-11.7	15.6.1965	Tempe Downs	-6.9	24.7.1971
Bairnsdale	-7.2	16.8.1896	Australian Capital Territory—		
Queensland—			Canberra	-10.0	19.7.1924
Stanthorpe	-11.0	4.7.1895			11.7.1971
Mitchell	-9.4	15.8.1979			
Nanango	-9.3	16.7.1918			
South Australia—					
Yongala	-8.2	20.7.1976			
Yunta	-7.7	19.7.1976			

Heat waves. Periods with a number of successive days having a temperature higher than 40°C are relatively common in summer over parts of Australia. With the exception of the north west coast of Western Australia, however, most coastal areas rarely experience more than three successive days of such conditions. The frequency increases inland, and periods of up to ten successive days have been recorded at many inland stations. This figure increases in western Queensland and north western Western Australia to more than twenty days in places. The central part of the Northern Territory and the Marble Bar-Nullagine area of Western Australia have recorded the most prolonged heat waves. Marble Bar is the only station in the world where temperatures of more than 37.8°C (100°F) have been recorded on as many as 161 consecutive days (30 October 1923–7 April 1924).



Heat waves are experienced in the coastal areas from time to time. During 11–14 January 1939, for example, a severe heat wave affected south eastern Australia: Adelaide had a record of 47.6°C on the 12th, Melbourne a record of 45.6°C on the 13th and Sydney a record of 45.3°C on the 14th.

The Kimberley district of Western Australia is the consistently hottest part of Australia in terms of annual average maximum temperature. Wyndham, for example, has an annual average maximum of 35.5°C.

Frost

For details see Year Book No. 63, pages 23 to 25.

Humidity

Australia is a dry continent in terms of the water vapour content or humidity of the air. Humidity is measured at Bureau of Meteorology observational stations by a pair of dry and wet bulb thermometers mounted in a standard instrument screen. These measurements enable moisture content to be expressed by a number of parameters, two of which are vapour pressure and relative humidity.

Vapour pressure is an actual quantitative measure whereas relative humidity is a ratio (expressed as a percentage). Both of these are included here showing their respective applications but more detailed treatment is given to relative humidity because of its wider usage.

Vapour pressure. Vapour pressure is defined as the pressure exerted by the water vapour in the air; and it is a measure of the actual amount of water vapour present. The amount of water vapour does not normally vary greatly during the day, although afternoon sea breezes at coastal stations may bring in moisture to increase the vapour pressure temporarily by amounts up to 5 millibars. The 9 a.m. vapour pressure may be taken to approximate the mean value for the day.

The annual averages range from 9.5 millibars at Hobart to 27.9 millibars at Thursday Island. At the high level station Kiandra (1,400 metres) the annual average is 7.9 millibars. Excluding Kiandra, monthly averages range from 6.7 millibars at inland stations in winter months to 30.9 millibars at Broome in February.

Vapour pressure together with corresponding air temperature have been used to measure climatic discomfort affecting human beings. Comfortable conditions are generally accepted as being within the vapour pressure range 7–17 millibars with respective air temperatures in the range 15–30°C. Above these limits heat discomfort increases and below them cold discomfort increases. The wet bulb temperature may also be used as a simple measure of heat discomfort when this temperature rises above 20°C.

Relative humidity. Relative humidity at a given temperature is the ratio (expressed as a percentage) of actual vapour pressure to the saturated vapour pressure at that temperature. As a single measure of human discomfort relative humidity is of limited value because it must be related to the temperature at the time.

Since the temperature at 9 a.m. approximates the mean temperature for the day (24 hours), the relative humidity at 9 a.m. may be taken as an estimate of the mean relative humidity for the day. Relative humidity at 3 p.m. occurs around the warmest part of the day on the average and is representative of the lowest daily values. Relative humidity on the average is at a maximum in the early morning when air temperature is minimal.

The table on page 21 contains average relative humidity at 9 a.m. for the year and for each month. Average annual figures on the table range from 34 per cent at Mundiwindi and Marble Bar to 79 per cent at Thursday Island illustrating the range of average relative humidity over Australia. Adelaide has the lowest value for a capital city with an annual average of 60 per cent, compared with Melbourne 69 per cent and Darwin 73 per cent.

Monthly averages shown in the table range from 23 per cent at Mundiwindi in November to 89 per cent at Katanning in June and July. At Alice Springs monthly averages vary from 30 per cent in November to 66 per cent in the winter month of June when low temperatures have the effect of raising relative humidity over the interior. Broome varies from 46 per cent in August to 73 per cent in February, which is a marked seasonal change for a coastal station.

The pattern of variation of relative humidity differs from that of vapour pressure particularly in southern Australia. This is due to the difference in variation of the two parameters with temperature. If the amount of moisture in the air remains constant, vapour pressure decreases slightly with falling temperatures, whereas relative humidity increases. Perth for example has an average 9 a.m. vapour pressure of 14.7 millibars in January and 11.0 in August; and the respective average relative humidity figures (51 and 74 per cent respectively) show a reverse change.

AVERAGE RELATIVE HUMIDITY AT 9 A.M.
(per cent)

Station	Period of record													Year
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Adelaide	1955-78	49	51	54	59	69	73	75	71	63	56	53	51	60
Alice Springs	1940-78	36	41	42	46	57	66	61	50	36	33	30	31	44
Armidale	1957-78	67	71	72	73	78	80	75	72	64	59	58	59	69
Brisbane	1951-78	67	68	70	69	68	69	66	62	60	59	58	60	64
Broome	1939-78	70	73	69	55	51	50	49	46	48	54	58	64	57
Canberra	1939-78	60	65	68	74	81	84	84	78	72	65	60	56	70
Carnarvon	1945-78	60	60	58	57	60	70	70	63	54	52	55	58	59
Ceduna	1939-78	55	59	62	68	77	82	81	77	66	56	54	54	65
Charleville	1942-78	49	54	54	54	63	71	66	56	45	41	37	41	52
Cloncurry	1939-75	53	61	53	45	47	50	45	37	31	30	32	41	43
Darwin	1941-78	82	84	83	76	67	63	64	68	71	70	73	77	73
Esperance	1957-69	62	67	66	71	76	81	82	76	71	65	62	62	70
Halls Creek	1944-78	51	55	44	33	36	35	31	25	22	25	30	40	35
Hobart	1944-78	58	62	65	69	75	78	78	73	65	62	60	55	67
Kalgoorlie	1939-78	48	54	56	62	70	76	75	68	56	50	46	45	58
Katanning	1957-78	59	65	69	77	85	89	89	87	82	70	60	57	74
Kiandra	1957-74	67	68	73	75	83	86	86	85	72	67	63	65	74
Marble Bar	1957-78	47	48	41	33	35	41	37	30	24	24	24	34	34
Melbourne	1955-78	61	65	67	71	77	81	80	75	69	64	62	61	69
Mildura	1946-78	50	56	61	70	82	88	86	79	68	59	53	49	66
Mundibindi	1957-78	32	37	35	37	41	50	47	39	28	25	23	25	34
Perth	1942-78	51	53	57	65	72	78	78	74	68	50	54	51	63
Sydney	1955-78	68	71	72	70	70	73	68	66	63	61	62	65	67
Thursday Island	1950-78	83	85	85	82	81	80	79	78	75	73	73	77	79
Townsville	1939-78	73	76	74	69	67	66	66	63	60	61	64	66	67

For further details on humidity, *see* Year Book No. 68.

Global radiation

For details *see* Year Book No. 63, pages 25 and 26.

Sunshine, cloud and fog

Sunshine. Sunshine as treated here refers to bright or direct sunshine. Australia receives relatively large amounts of sunshine although seasonal cloud formations have a notable effect on its spatial and temporal distribution. Cloud cover reduces both incoming and outgoing radiation and thus affects sunshine, air temperature and other climatic elements at the earth's surface.

Most of the continent receives more than 3,000 hours of sunshine a year, or nearly 70 per cent of the total possible. In central Australia and the mid-west coast of Western Australia totals slightly in excess of 3,500 hours occur. Totals of less than 1,750 hours occur on the west coast and highlands of Tasmania; this amount is only 40 per cent of the total possible per year (about 4,380 hours).

In southern Australia generally the duration of sunshine is greatest about December when the sun is at its highest elevation and lowest in June when the sun is lowest. In northern Australia sunshine is generally greatest about August-October prior to the wet season and least about January-March during the wet season.

For further information on sunshine *see* Year Book No. 68.

Cloud. Seasonal changes in cloudiness vary with the distribution of rainfall. In the southern parts of the continent, particularly in the coastal and low lying areas, the winter months are generally more cloudy than the summer months. This is due to the formation of extensive areas of stratiform cloud and fog during the colder months, when the structure of the lower layers of the atmosphere favours the physical processes resulting in this type of cloud. Particularly strong seasonal variability of cloud cover exists in northern Australia where skies are clouded during the summer wet season and mainly cloudless during the winter dry season. Cloud coverage is greater near coasts and on the windward slopes of the eastern uplands of Australia and less over the dry interior.

Darwin has the least average daily coverage of 3.2 eighths and Hobart the highest daily average of 5.0 eighths. The highest daily average for any month occurs at Darwin (5.9 eighths for January) and the lowest daily average is also at Darwin (1.1 eighths for August).

Fog. The formation of fog depends on the occurrence of favourable meteorological elements—mainly temperature, humidity, wind and cloud cover. The nature of the local terrain is important for the development of fog and there is a tendency for this phenomenon to persist in valleys and hollows. The incidence of fog may vary significantly over distances as short as one kilometre.

Fog in Australia tends to be greater in the south than the north, parts of the east coastal areas are relatively fog prone even in the tropics. Incidence is much greater in the colder months, particularly in the eastern uplands. Fog may persist during the day but rarely until the afternoon over the interior. The highest fog incidence at a capital city is at Canberra which has an average of 46 days per year on which fog occurs, 28 of which are in the period May to August. Brisbane averages 22 days of fog per year, 17 of which occur between April and September. Darwin averages only 3 days per year, June to September.

Winds

The mid-latitude anticyclones are the chief determinants of Australia's two main prevailing wind streams. In relation to the west-east axes of the anticyclones these streams are easterly to the north and westerly to the south. The cycles of development, motion and decay of low pressure systems to the north and south of the anticyclones result in diversity of wind flow patterns. Wind variations are greatest around the coasts where diurnal land and sea breeze effects are important.

Wind roses for the months of January and July at 9 a.m. and 3 p.m. at selected stations are shown in Plates 10–13 inclusive, extracted from *Climatic Atlas of Australia, Map Set 8*, 1979. The wind roses show the percentage frequency of direction (eight points of compass) and speed ranges of winds.

Orography affects the prevailing wind pattern in various ways such as the channelling of winds through valleys, deflection by mountains and cold air drainage from highland areas. An example of this channelling is the high frequency of northwest winds at Hobart caused by the northwest south-east orientation of the Derwent River Valley.

Perth is the windiest capital with an average wind speed of 15.6 kilometres per hour; Canberra is the least windy with an average speed of 5.8 kilometres per hour.

The highest wind speeds and wind gusts recorded in Australia have been associated with tropical cyclones. The highest recorded gust was 246 kilometres per hour during a cyclone at Onslow, Western Australia on 19 February 1975 and gusts reaching 200 kilometres per hour have been recorded on several occasions in northern Australia with cyclone visitations. The highest gusts recorded at Australian capitals were 217 kilometres per hour at Darwin and 156 kilometres per hour at Perth.

Evaporation

For details see Year Book No. 62.

Floods

Widespread flood rainfall may occur anywhere in Australia but it has a higher incidence in the north and in the eastern coastal areas. It is most economically damaging along the shorter streams flowing from the eastern uplands eastward to the seaboard of Queensland and New South Wales. These flood rains are notably destructive in the more densely populated coastal river valleys of New South Wales; the Tweed, Richmond, Clarence, Macleay, Hunter and Nepean-Hawkesbury; all of which experience relatively frequent flooding. Although chiefly summer rains, they may occur in any season.

The great Fitzroy and Burdekin river basins of Queensland receive flood rains during the summer wet season. Much of the run-off due to heavy rain in north Queensland west of the eastern uplands flows southward through the normally dry channels of the network of rivers draining the interior lowlands into Lake Eyre. This widespread rain may cause floods over an extensive area, but it soon seeps away or evaporates, occasionally reaching the lake in quantity. The Condamine and other northern tributaries of the Darling also carry large volumes of water from flood rains south through western New South Wales to the Murray and flooding occurs along their courses at times.

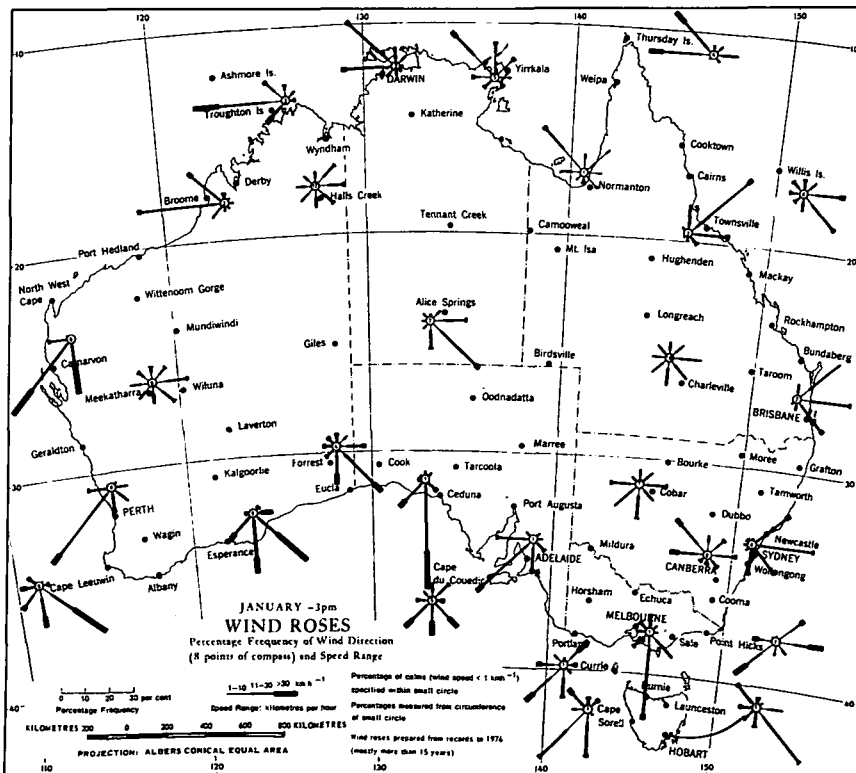
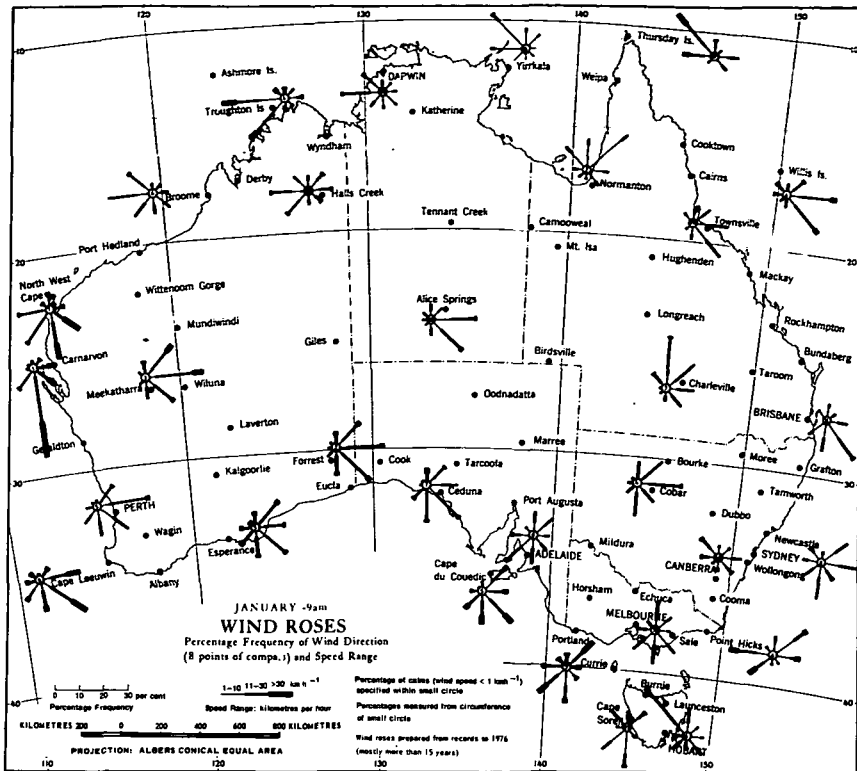
Flood rains occur at irregular intervals in the Murray-Murrumbidgee system of New South Wales and Victoria, the coastal streams of southern Victoria and the north coast streams of Tasmania.

Droughts

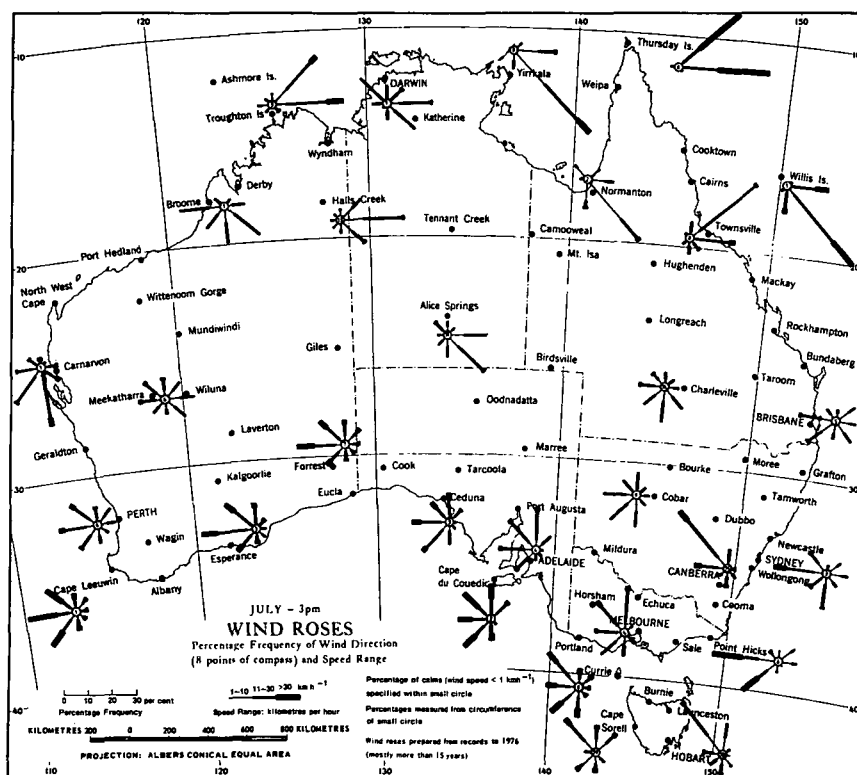
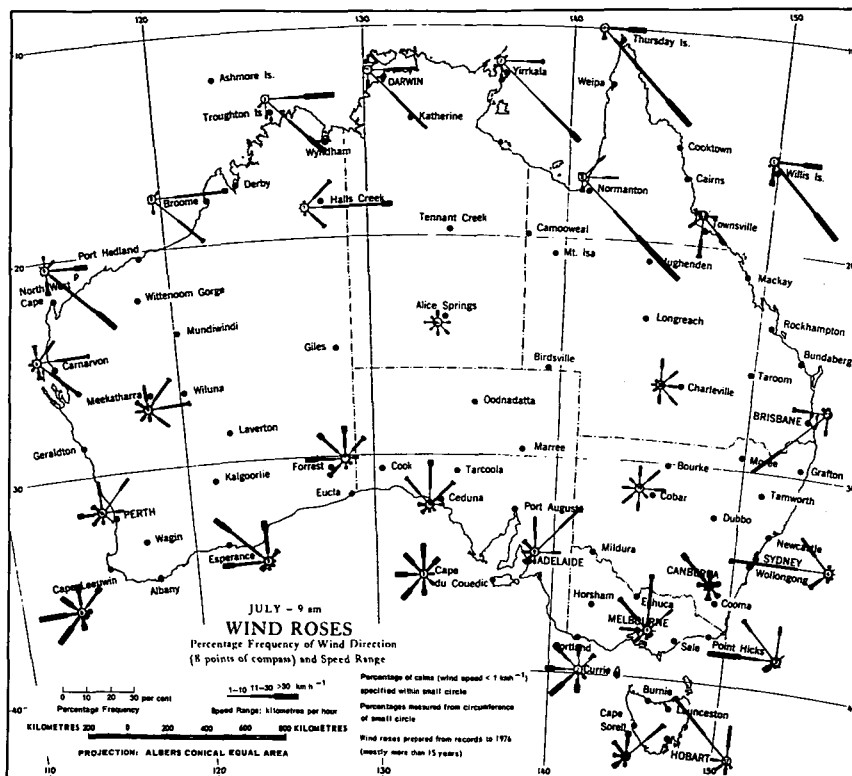
Drought, in general terms, refers to an acute water shortage. This is normally due to rainfall deficiency but with other parameters contributing to the actual water availability. The best single measure of water availability in Australia is rainfall; although parameters such as evaporation and soil moisture are significant or even dominant in some situations.

The Bureau of Meteorology publication *Droughts in Australia*, Bulletin No. 43 lists seven major widespread droughts which occurred in the period 1830 to 1955. These covered the following periods; 1864–68, 1880–86, 1888, 1895–1903, 1911–16, 1918–20 and 1939–45. The publication also lists five other droughts of lesser intensity but affecting wide areas, in this period.

A review of droughts in Australia to 1968 is included in Year Book Australia No. 54, 1968. That review contained a description of the severe drought of 1958–68 making use of the analysis of rainfall deciles.



PLATES 10 and 11



PLATES 12 and 13

Since 1968, there have been a number of severe droughts defined by rainfall deficiencies based on decile analyses (see the Bureau's *Drought Review Australia* series, 1968 to date). The most notable of these were the 1970-73 drought over the northeastern goldfields and adjacent areas of Western Australia, the 1975-76 drought over a large part of southeastern Australia and the 1982 drought over eastern Australia.

Climatic discomfort

In Australia climatic discomfort is significant in most areas. During the summer half of the year (November–April) prolonged high temperatures and humidity around the northern coasts and high temperatures over the inland cause physical stress. In winter, low temperatures and strong cold winds over the interior and southern areas can be severe for relatively short periods. However, cold stress does not cause prolonged physical hardship in Australia at altitudes lower than 1,000 metres, that is, over more than 99 per cent of the continent.

The climatic variables determining physical discomfort are primarily air temperature, vapour pressure and wind. The complete assessment of physical discomfort also requires analyses of such parameters as thermal conductivity of clothing, vapour pressure at the skin and the metabolic heat rate arising from activity of the human body. The cooling system of the human body depends on evaporation of moisture to keep body temperature from rising to lethal levels as air temperature rises. Defining criteria of discomfort is difficult because personal reactions to the weather differ greatly according to a number of variables including health, age, clothing, occupation and acclimatisation. However, climatic strain has been measured experimentally and discomfort indexes based on the average response of subjects under specified conditions have been derived.

Effective Temperature. The effective temperature with respect to any environmental combination of temperature, humidity and wind is defined as the temperature of still, saturated air in which a normally clothed sedentary worker would feel the same level of comfort or discomfort.

Environment studies carried out at the research laboratories of the American Society of Heating, Refrigerating and Air Conditioning Engineers established values of effective temperature corresponding to various combinations of temperature, humidity and air movement. The results were published as a series of research reports commencing in 1923, and have been widely used to measure climatic discomfort (see 1960 report of the Society).

Normally clothed sedentary workers are most comfortable within a range of effective temperatures between 15°C and 27°C. At effective temperatures greater than 27°C, the majority of people feel heat discomfort and when less than 15°C they feel cold discomfort.

The table below contains the annual average frequency of effective temperature at 3 p.m. within specified limits at selected stations. The figures provide comparisons of daily occurrence of afternoon discomfort for the given environmental conditions.

CLIMATIC DISCOMFORT: EFFECTIVE TEMPERATURE

Station	Period of record	Average days per year where effective temperature is:		
		Less than 15°C	15–27°C	Greater than 27°C
Adelaide	1955–72	128	234	3
Albury	1962–71	141	220	4
Alice Springs	1955–67	39	300	26
Brisbane	1951–70	6	356	3
Broome	1941–71	0	225	140
Canberra	1940–72	172	192	1
Carnarvon	1945–72	1	345	19
Ceduna	1955–71	77	279	9
Charleville	1942–72	28	316	21
Cloncurry	1940–72	1	268	96
Darwin	1955–69	0	225	140
Hobart	1944–67	239	126	0
Kalgoorlie	1940–72	66	281	18
Marble Bar	1957–71	0	220	145
Melbourne	1955–71	155	207	3
Mildura	1946–72	95	258	12
Perth	1944–71	57	302	6
Rockhampton	1940–72	2	337	26
Sydney	1955–72	69	295	1
Townsville	1941–69	0	333	32
Woomera	1954–72	73	279	13

Heat discomfort, on this index, is greatest in the north-west, where Marble Bar averages 145 days of high heat discomfort annually, and least in the south-east, where Hobart has only one day every five years. Cold discomfort is least in the north, where Townsville has one day of cold discomfort in ten years, and the greatest in the south-east, where Hobart has 239 days annually when the effective temperature is sufficiently low to cause discomfort. By the suitable choice of clothing discomfort can be decreased significantly on cold days. On cold days also, workers tend to take opportunities to move around, thus increasing metabolic heat rates.

Effective temperature is a useful index but its application is limited because available criteria relate only to normally clothed indoor workers in sedentary occupations. Furthermore, at lower air temperatures the effective temperature gives excessive weight to humidity.

For further details on climatic discomfort see Year Book No. 68.

Climatic data for capital cities

See Year Book No. 67 pages 58 to 65.

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