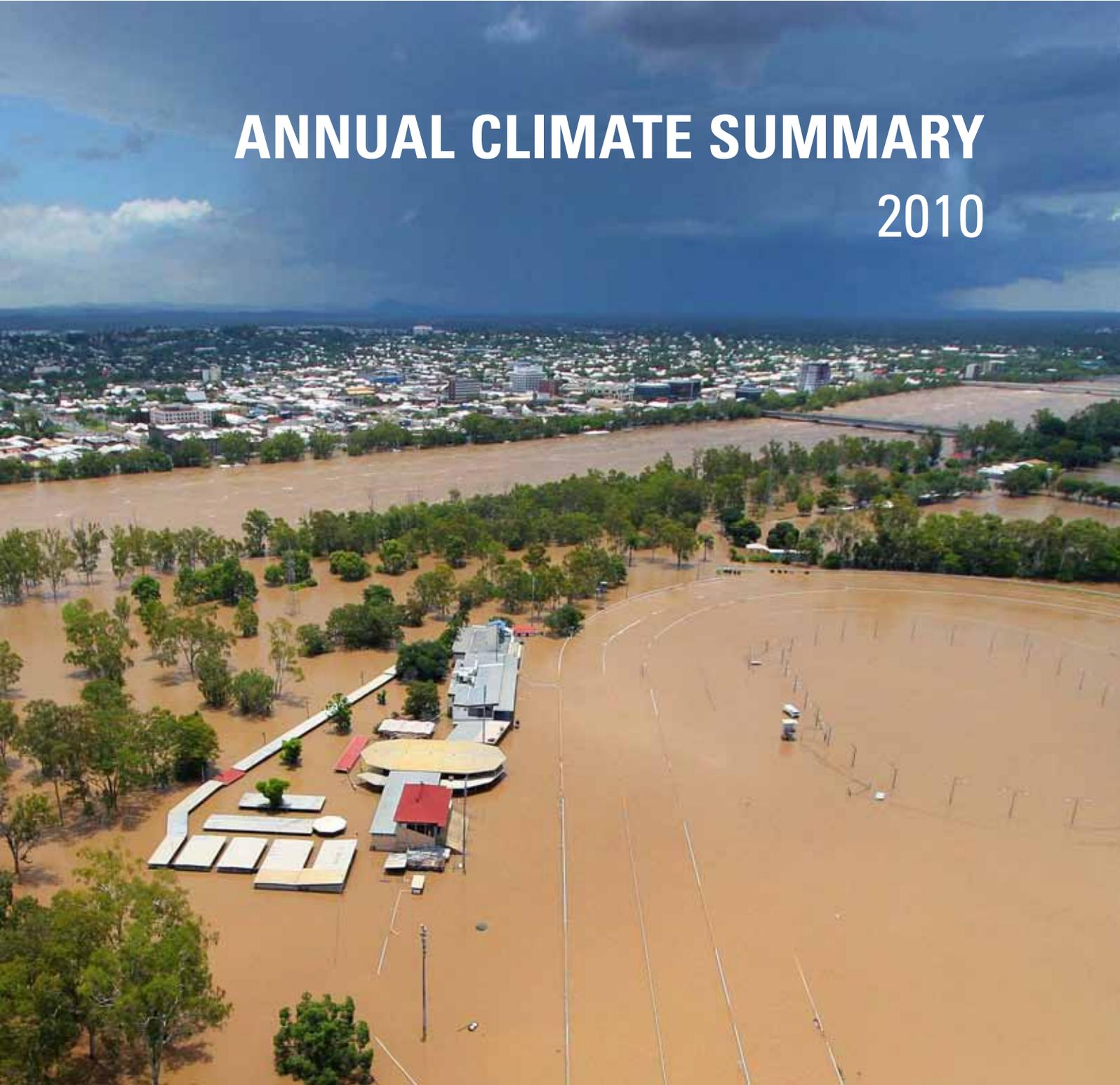




**Australian Government**  
**Bureau of Meteorology**

# ANNUAL CLIMATE SUMMARY

## 2010



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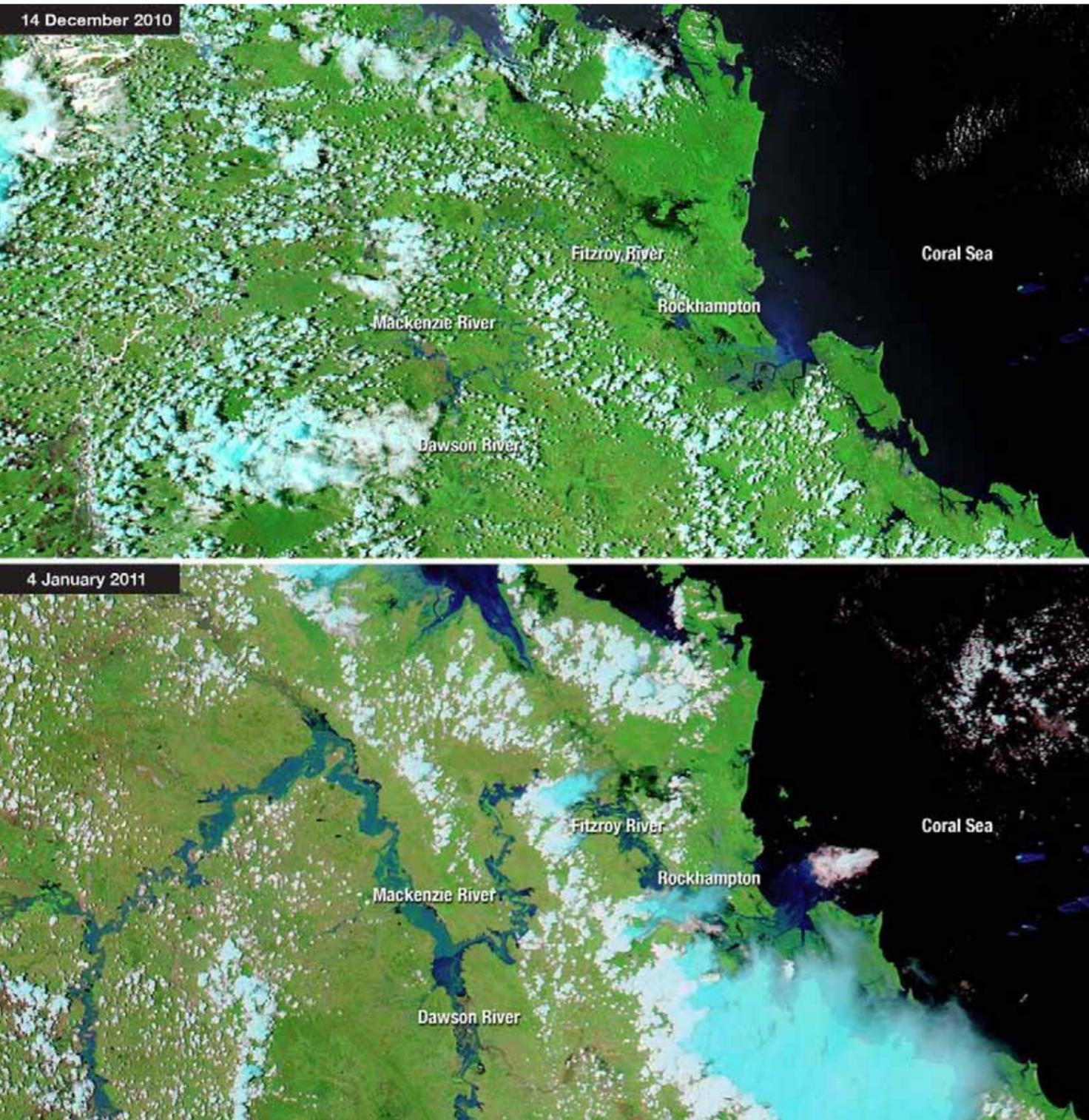
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This edition is based on data available as of 25 January 2011.

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**COVER PICTURE:** Floodwaters cover the Callighan Park Racecourse in the foreground, with the Fitzroy River and Rockhampton in the background, 3 January 2011. Heavy rainfalls occurred around Rockhampton between Christmas and New Year, and on Boxing Day in particular (see pages iv and 18). Photograph courtesy of Chris Ison, *The Morning Bulletin*.



The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite captured these images of flooding of the Mackenzie River, Dawson River and Fitzroy River in Queensland. Damaging floods hit the City of Rockhampton in late December 2010, and continued into early 2011. These floods were part of a much larger sequence of floods covering eastern Australia in summer 2010–2011.

# 1. Overview

## Coollest year since 2001, warmest decade on record

Widespread rainfall across the country was associated with Australia's coolest year since 2001. However 2010 was still warmer than the 1961 to 1990 average<sup>1</sup> and overnight minimum temperatures were the eighth-highest on record.

The Australian mean temperature in 2010 was 22.00 °C, which is 0.19 °C above the average of 21.81 °C. The last decade (2001-2010) was the warmest ten-year period on record (0.52 °C above average). Records indicate that Australia's climate has steadily warmed over the last 60 years, with very few cool years occurring in the last three decades. Temperatures were generally below average in the interior of the continent where rainfall was particularly high. In contrast, the north and west were much warmer than normal. Tasmania was also warm.

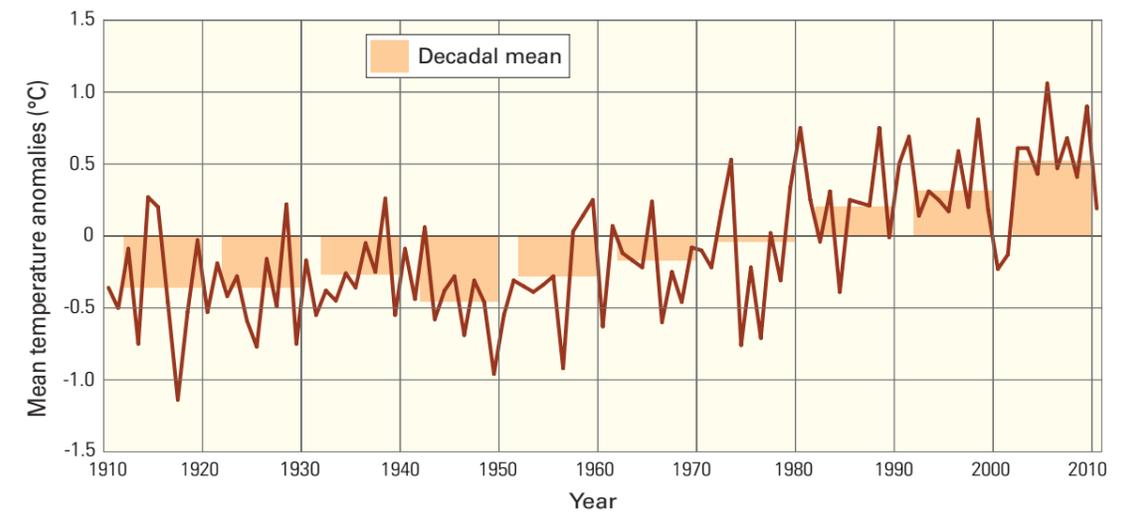
Australia's mean minimum temperature was 0.59 °C above normal, while maximum temperatures were 0.21 °C below normal. The tropics were particularly warm from July to October, with widespread areas observing record high mean temperatures. In marked contrast to 2009, record high maximum temperatures were scarce, but very high overnight minimum temperatures were common in the northern tropics, particularly during winter.

## Globally, 2010 equal warmest year on record

The World Meteorological Organization (WMO) has stated that 2010 ranked as the world's equal warmest year on record, together with 2005 and 1998. This was calculated through their use of three separate datasets. The global combined sea-surface and land-surface air temperature for 2010 was 0.53 °C above the annual average of 14 °C.

The global mean temperature has been above average every year for the last 25 years (1986-2010). The past ten years were the globe's hottest on record: 0.46 °C above the long-term normal. International data show that there are many current indicators of a warming globe. Warming has been recorded by thermometers over land, thermometers in the oceans and by satellite remote sensors. Warming is also indicated through evidence of global reductions in ice and snow cover, and through rises in global sea levels.

<sup>1</sup> Unless otherwise stated, all climatological averages are calculated over the 30-year period from 1961 to 1990, as recommended by the World Meteorological Organization. Anomalies are defined as the difference between the observed temperature and the corresponding average over the reference period 1961 to 1990.



Annual and decadal mean temperature anomalies (1910-2010) for Australia. Anomalies are calculated with respect to the 1961–1990 period.

## Australia's second-wettest year on record

2010 was Australia's second-wettest year on record since national rainfall records commenced in 1900. Australia's mean rainfall for 2010 was 701 mm, well above the long-term average of 465 mm. Only 1974 (760 mm), itself a La Niña year, was wetter. The only month with a national rainfall total below the long-term average was June. Above-average rainfall was recorded in eleven months of the year, an occurrence observed only once previously, in 1973.

2010 began with El Niño conditions in the Pacific, followed by a rapid transition towards La Niña during autumn. From January to May, rainfall was generally above average except in southern Tasmania and the western half of Western Australia. By July, La Niña conditions were well established and most of Australia experienced significantly higher than average rainfall. Australia had its wettest second half of the year (July

to December) on record. However, not all areas were unusually wet; southwest Western Australia had its driest year on record in 2010, and Tasmania received near-average rainfall.

## Wet through the north and east

2010 was the wettest year on record for Queensland; the third-wettest for the Northern Territory, New South Wales and South Australia; and the fifth-wettest for Victoria. Record rainfall occurred across much of the southern half of Queensland, and parts of central Australia, the Top End and the Gulf Country. Unusually heavy falls were experienced in Queensland, New South Wales, the Northern Territory and South Australia. As can occur during strong La Niña events, numerous significant floods occurred in Australia in 2010, especially in the eastern States (see page 15).

## Drought eases in the east but continues in the southwest

For parts of southeast Australia, 2010 was the first year since 1996 to see above-average rainfall. The heavy rainfall in 2010 marked a reversal of dry conditions across Queensland, New South Wales, Victoria and South Australia, which had dominated the first nine years of the decade. Few areas in the east missed out on significant rainfall. Areas along the coast east and south of the Great Dividing Range in New South Wales and Victoria experienced near-average rainfall, consistent with previous La Niña years.

The Murray-Darling Basin had its wettest year on record, ending the record sequence of years with below-average rainfall starting in 2001. This rainfall led to a dramatic recovery in water storages across

the Basin. Storages started the year at 26 per cent (6 500 193 ML) of capacity and reached 80 per cent (20 390 963 ML) at the start of 2011. This is based on data collected by the Bureau for 80 storages within the Murray-Darling Basin.

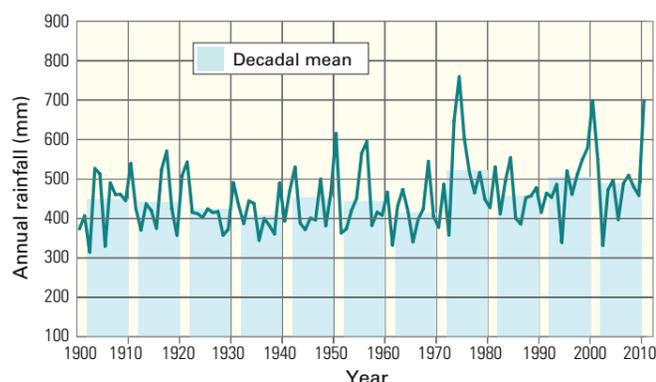
In terms of surface water, soil moisture and annual rainfall totals, 2010 effectively ended the 'long dry' that commenced in late 1996 in the far southeast of mainland Australia and in late 2001 across much of the Murray-Darling Basin.

In contrast to the rest of the continent, the southwest of Western Australia experienced a very dry year, continuing the long drying trend that has affected the southwest since the late 1960s. For the southwest region, 2010 rainfall was a record low 395 mm, well below the previous 1940 low of 439 mm.

## Capital cities

All capital cities (page 4) had warmer than average days, and all except Perth had warmer than average nights. Melbourne recorded the highest maximum temperature of any capital city for the year, with 43.6 °C on 11 January. Melbourne also equalled its record high overnight minimum (measured between 3 pm and 9 am) of 30.6 °C on 12 January. The lowest temperature recorded for the year at a capital city was -5.0 °C at Canberra on 28 June.

Although most of the country had above-average rain, Perth, Hobart and Sydney were drier than average. Melbourne reached its highest annual rainfall total since 1978, while Brisbane received its highest since 1974. Adelaide registered its highest observed daily December rainfall total on record with 66.2 mm on 8 December.

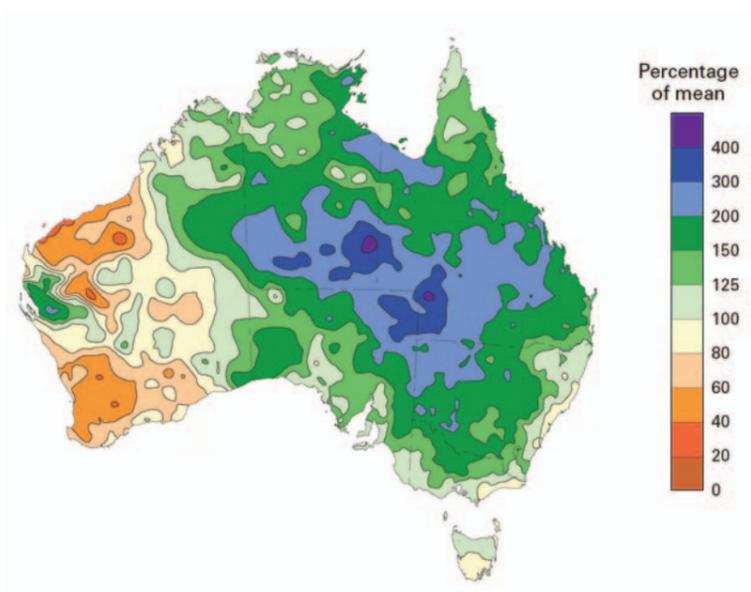


Australian annual and decadal mean rainfall (1900-2010).

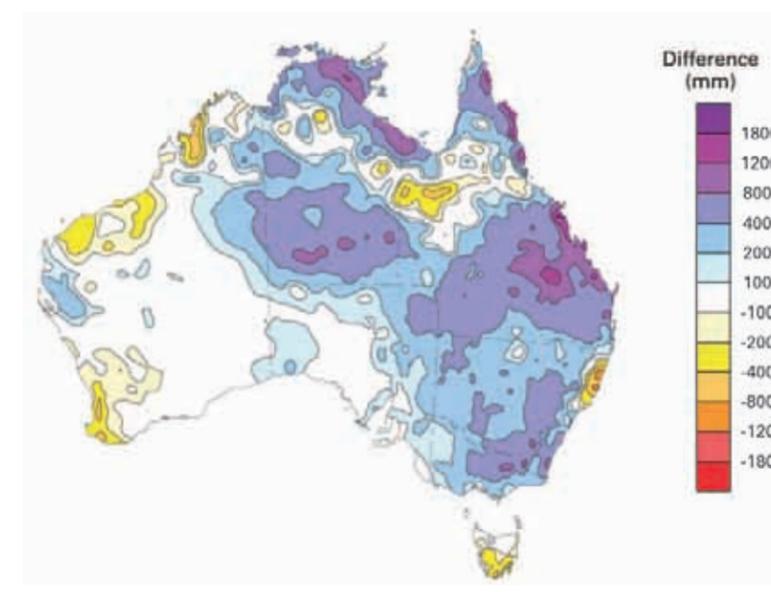
	Rainfall (mm)			Maximum temperature (°C)			Minimum temperature (°C)		
	2010 total	Normal 1961-90	Rank (of 111)	2010 anomaly	Normal 1961-90	Rank (of 101)	2010 anomaly	Normal 1961-90	Rank (of 101)
AUSTRALIA	701	465	2	-0.21	28.55	64	0.59	15.07	8
New South Wales/ACT	815	553	3	-0.47	23.91	80	0.60	10.75	11
Northern Territory	941	540	3	-0.99	31.88	92	0.23	18.45	33
Queensland	1133	623	1	-0.85	29.88	96	0.78	16.57	9
South Australia	367	225	3	-0.30	26.71	66	0.31	12.20	24
Tasmania	1390	1390	59	0.48	14.72	10	0.52	5.99	7
Victoria	864	660	5	0.30	19.85	28	0.67	8.34	5
Western Australia	338	341	55	0.70	29.27	9	0.74	15.66	3
Murray-Darling Basin	805	488	1	-0.58	24.45	85	0.58	10.87	11

Summary of 2010 mean rainfall and temperatures for Australia, the States and Territories and the Murray-Darling Basin. Normal values are calculated using 1961-1990 averages. Ranks are from highest to lowest and are calculated using all years since high-quality records began (1900 for rainfall, 1910 for temperature). Annual mean temperatures can be calculated from the average of the mean maximum and mean minimum temperatures. Area averages are calculated over continental Australia and the main island of Tasmania.

2010 rainfall as a percentage of the 1961 to 1990 annual average.



Difference between the 2010 and 2009 annual rainfall totals. The areas shaded blue and purple were wetter in 2010, while those shaded in yellow and orange were drier.



## 2. Capital city summary

Long-term averages are based on the 1961 to 1990 period, with the exceptions of Adelaide (1981 to 2010), Brisbane (1961 to 1985) and Perth (1994 to 2010, temperature only).

Data were recorded at existing Bureau of Meteorology official city observation stations. Averaging periods are calculated based on the availability of historical data from these, or comparable, stations.

Decile ranges are calculated from gridded monthly analyses based on all available data from 1900 to 2010. Some data have not yet been fully quality-controlled.

City	Highest temperature	Lowest temperature	Average maximum	Average minimum	Rainfall (mm) & no. rain days
	Date	Date	Long-term average	Long-term average	
	(°C)	(°C)	Anomaly (°C)	Anomaly (°C)	Long-term average (mm) Decile range
Perth	42.9	-0.6	25.3	12.3	503.8 on 65 days
	17 January	26 June	24.5	12.7	819.4
			0.8	-0.4	1
Darwin	36.5	16.0	32.6	23.9	2257.2 on 151 days
	24 October	5 June	32.0	23.3	1705.1
			0.6	0.6	10
Adelaide	42.8	2.2	22.5	12.6	592.6 on 128 days
	11 January	14 June	22.3	12.2	549.1
			0.2	0.4	7
Brisbane	35.1	6.1	25.8	16.8	1658.6 on 156 days
	18 January	14 August	25.6	16.4	1217.7
			0.2	0.4	10
Sydney	41.3	4.3	22.6	15.0	1154.0 on 150 days
	23 January	30 June	22.1	14.2	1302.2
			0.5	0.8	7
Canberra	39.8	-5.0	20.3	7.3	959.6 on 105 days
	12 January	28 June	19.6	6.5	623.2
			0.7	0.8	10
Melbourne	43.6	3.2	21.0	12.1	780.6 on 148 days
	11 January	20 July	20.0	11.0	638.8
			1.0	1.1	9
Hobart	36.5	1.1	18.2	9.0	524.0 on 150 days
	11 January	23 May	17.1	8.7	586.4
			1.1	0.3	4

## 3. Rainfall and temperature extremes by State

Temperatures are in degrees Celsius, rainfalls are in millimetres. Daily minimum temperatures and daily rainfalls are for the 24 hours ending at 9 am on the date shown. Daily maximum temperatures are for the 24 hours beginning at 9 am on the date shown. The mean temperature is the average of all maximum and minimum temperatures.

### WESTERN AUSTRALIA

Highest daily maximum temperature	49.2 at Onslow on 1 January
Lowest daily minimum temperature	-6.8 at Eyre on 11 August
Highest average maximum temperature	36.2 at Fitzroy Crossing Aerodrome
Lowest average minimum temperature	7.9 at Jarrahwood
Highest daily rainfall	216 at Cape Leveque on 19 May
Highest annual rainfall	1621 at Theda

### NORTHERN TERRITORY

Highest daily maximum temperature	44.1 at Rabbit Flat on 8 December
Lowest daily minimum temperature	-2.7 at Alice Springs on 15 June and at Arltunga on 15 June
Highest average maximum temperature	35.5 at Bradshaw
Lowest average minimum temperature	12.8 at Alice Springs
Highest daily rainfall	443 at Bulman on 31 March
Highest annual rainfall	2467 at Leanyer

### SOUTH AUSTRALIA

Highest daily maximum temperature	45.8 at Murray Bridge (Pallamana) and Keith (Munkora) on 11 January
Lowest daily minimum temperature	-4.5 at Renmark on 6 July
Highest average maximum temperature	27.8 at Oodnadatta
Lowest average minimum temperature	7.4 at Yongala
Highest daily rainfall	147 at Waikerie on 8 December
Highest annual rainfall	1197 at Uraidla

### QUEENSLAND

Highest daily maximum temperature	45.4 at Birdsville on 24 January
Lowest daily minimum temperature	-6.0 at Oakey on 28 June
Highest average maximum temperature	33.5 at Kowanyama
Lowest average minimum temperature	9.6 at Applethorpe
Highest daily rainfall	364 at Mount Tamborine on 7 February
Highest annual rainfall	12438 at Bellenden Ker Top Station

### NEW SOUTH WALES

Highest daily maximum temperature	45.1 at Pooncarie on 10 January
Lowest daily minimum temperature	-19.6 at Charlotte Pass on 20 July
Highest average maximum temperature	26.8 at Mungindi Post Office
Lowest average minimum temperature	2.4 at Thredbo Village
Highest daily rainfall	332 at Tuross Head on 16 February
Highest annual rainfall	2914 at Yarras (Mount Seaview)

### VICTORIA

Highest daily maximum temperature	45.7 at Avalon Airport on 11 January
Lowest daily minimum temperature	-8.2 at Dinner Plain on 20 July
Highest average maximum temperature	23.6 at Mildura
Lowest average minimum temperature	2.0 at Mount Hotham
Highest daily rainfall	182 at Falls Creek (Rocky Valley) on 9 December
Highest annual rainfall	3027 at Falls Creek (Rocky Valley)

### TASMANIA

Highest daily maximum temperature	40.7 at Ouse on 11 January
Lowest daily minimum temperature	-10.2 at Liawenee on 22 May
Highest average maximum temperature	18.8 at Launceston
Lowest average minimum temperature	1.6 at Mount Wellington
Highest daily rainfall	203 at Gray on 29 May
Highest annual rainfall	3664 at Mount Read

### AUSTRALIA

Highest mean temperature	29.6 at Wyndham
Lowest mean temperature	4.3 at Thredbo

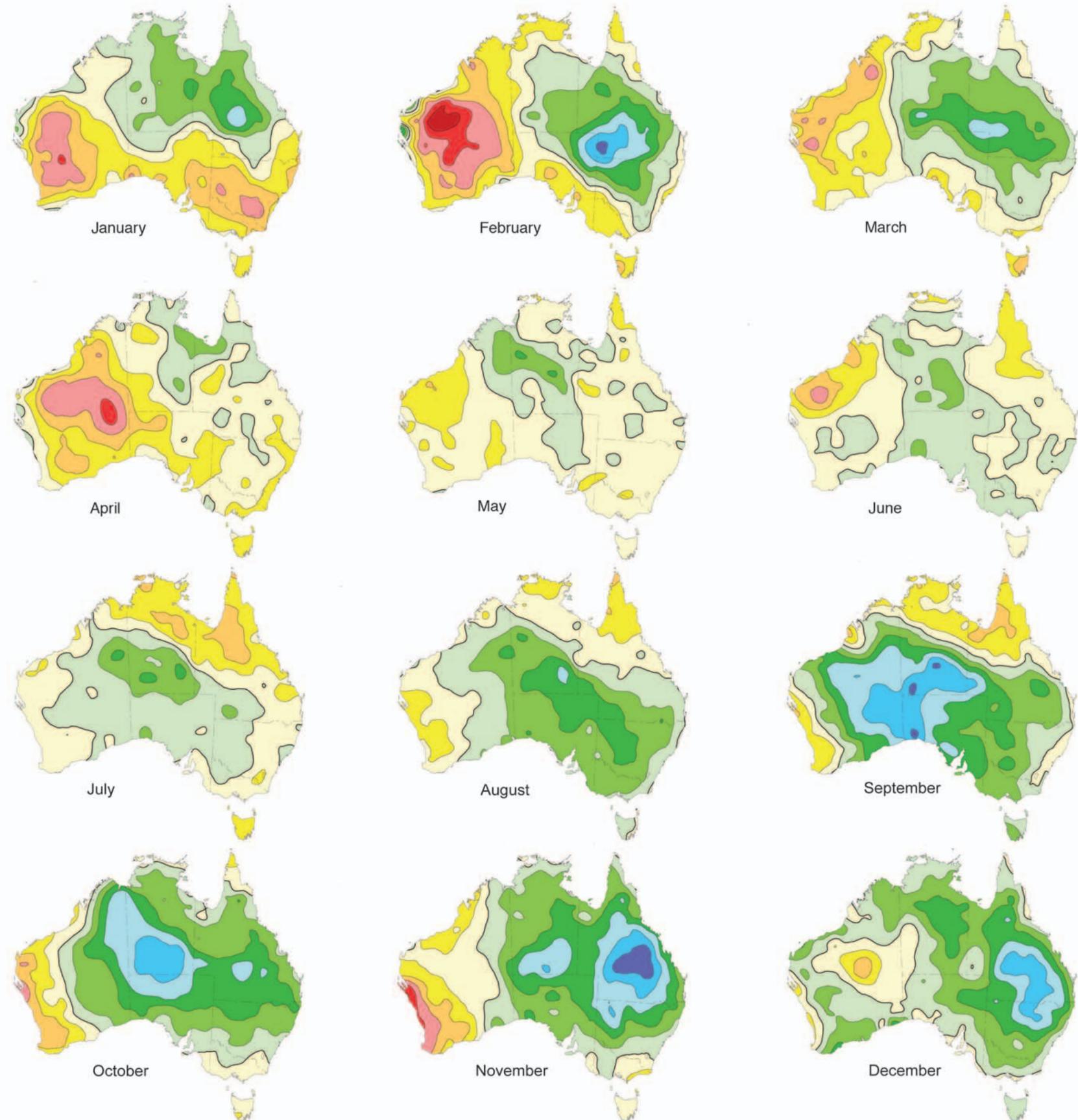
## 4. Monthly maximum temperatures

Temperatures during January were above normal across southern Australia but below normal in the north. In February and March, above-average conditions were experienced in the west, the south and the far north but below-average temperatures occurred in central and eastern areas. April was warmer than average across most areas, and in May and June much of the country had near-normal maximum temperatures.

From July to September, far northern Australia and much of the west coast was warmer than usual. Anomalies below  $-1\text{ }^{\circ}\text{C}$  expanded in central regions and by September covered most of Australia, with some areas more than  $5\text{ }^{\circ}\text{C}$  below average. Low daytime temperatures in central Australia during September and October were associated with record high rainfall.

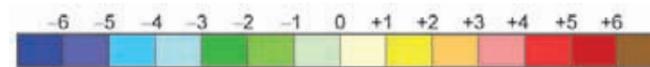
In November, the west of Western Australia remained generally warmer than usual with negative anomalies elsewhere (except for the far southeast), most significantly over Queensland. December was generally cooler than normal, especially over southern Queensland and northern New South Wales, but slightly warmer than normal over central and west coast Western Australia.

The largest positive anomalies for the year occurred in February, with areas of the Pilbara and Gascoyne districts of Western Australia recording temperatures more than  $5\text{ }^{\circ}\text{C}$  above normal for the month. Below-average maximum temperatures were most widely recorded in November; with temperatures more than  $5\text{ }^{\circ}\text{C}$  below average across a large area of inland Queensland. Smaller areas also saw anomalies of  $-5\text{ }^{\circ}\text{C}$  in central Australia and southwest South Australia during September, and in southwest Queensland during February. Averaged over the country, maximum temperature anomalies ranged from  $-1.27\text{ }^{\circ}\text{C}$  for October to  $+0.89\text{ }^{\circ}\text{C}$  for April.



### Maximum temperature: departures from average ( $^{\circ}\text{C}$ )

Based on a 30-year mean calculated from 1961 to 1990.



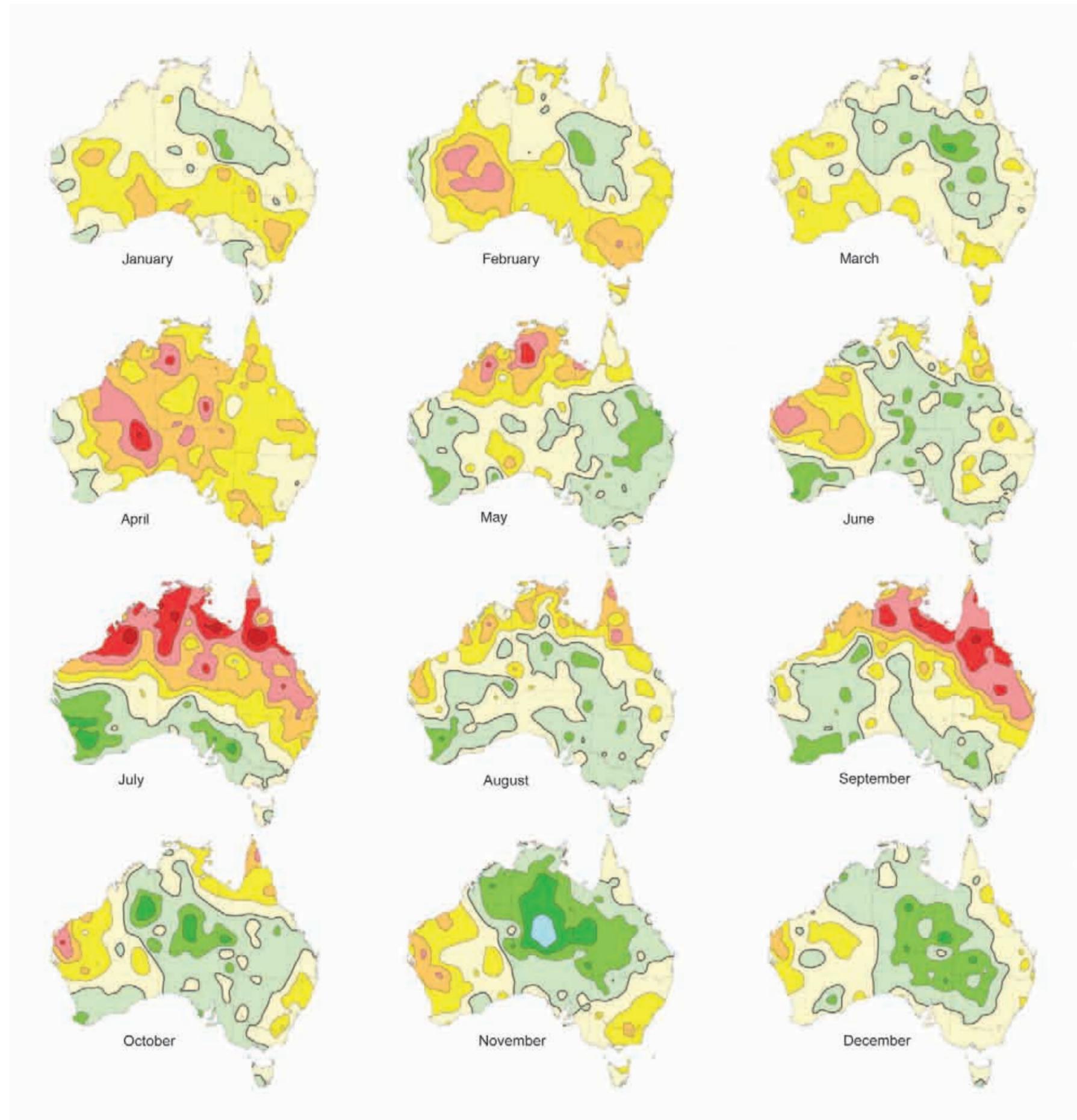
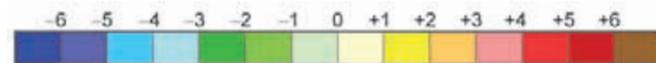
## 5. Monthly minimum temperatures

Minimum temperatures during January to March were generally above average across southern Australia and near normal across much of the remainder of the country. A small region in southwest Queensland was cooler than normal. Warmer than average conditions were pronounced in February, especially in Western Australia. Above-average overnight temperatures covered most of the country during April and were again strongest in Western Australia. Northern Australia was unusually warm during May, and Western Australia during June. July to September was very warm over northern Australia, particularly in July when record highs were widespread. Later in the year, the east and north coasts and much of Western Australia experienced above-average minimum temperatures while the inland regions were mostly cooler than average, most notably in central Australia in November.

The largest positive anomalies were recorded in July, when mean daily minimum temperatures were 4 to 6 °C higher than usual across large parts of northern Australia. Mean November minimum temperatures more than 3 °C lower than usual were recorded in a large area around Alice Springs in the south of the Northern Territory. Australia-wide, area-averaged anomalies ranged from -0.32 °C for November to +1.68 °C for April (the second-highest April anomaly on record). Overall, positive Australia-wide anomalies were experienced in nine out of twelve months.

### Minimum temperature: departures from average (°C)

Based on a 30-year mean calculated from 1961 to 1990.



## 6. Monthly distribution of rainfall deciles

January brought heavy rainfall to much of northern Queensland and the Northern Territory. In contrast, parts of Tasmania and southern Western Australia had very much below-average rainfall. Rain was below average in parts of Western Australia during February and near the northwest coast of Australia during March. February and March were wet across much of the interior and east, with small areas of record falls.

April and May brought above-average rain to large areas of the country (except for the east coast and the west of Western Australia), including record falls around the Gulf of Carpentaria and central South Australia in April, and in the northwest in May. June rainfall was generally below average and Australia-wide was the fourth-lowest on record.

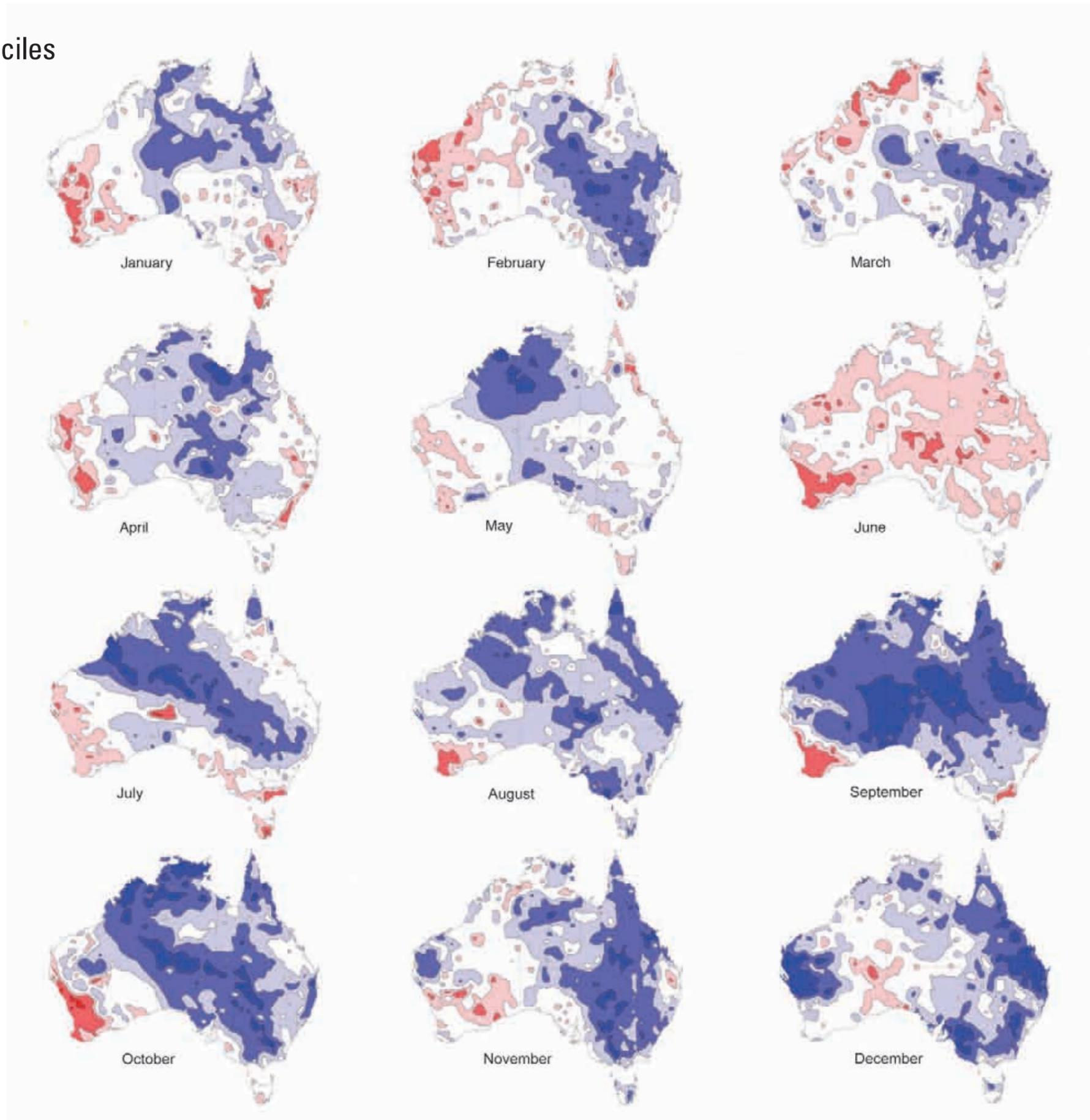
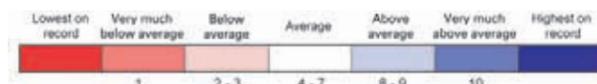
From July onwards, the La Niña event consolidated, and exceptionally high rainfall was common. Record July rain fell in a number of locations along a band between Broome and central New South Wales. Records were also broken at locations in northern, central and eastern Australia in August, and throughout northern and central Australia and western New South Wales in October. Record-breaking rain was exceptionally widespread in September. Averaged over Australia, the spring was the wettest on record.

November and December saw very much above-average rainfall in most of Queensland, New South Wales and Victoria, and parts of eastern South Australia. Record-breaking rain fell in a large area of Western Australia around Carnarvon in December. Southeast Queensland also set new records with high rainfall in December.

The southwest of Western Australia remained very dry over winter and spring. 2010 rainfall was lowest on record for winter, the growing season (April to October), and annually in this region.

### Monthly distribution of rainfall deciles

Based on a 111-year climatology of gridded fields from 1900 to 2010. Decile range 1 means the lowest 10 per cent of records, decile range 2 the next lowest 10 per cent of records, ..., decile 10 the highest 10 per cent of records.



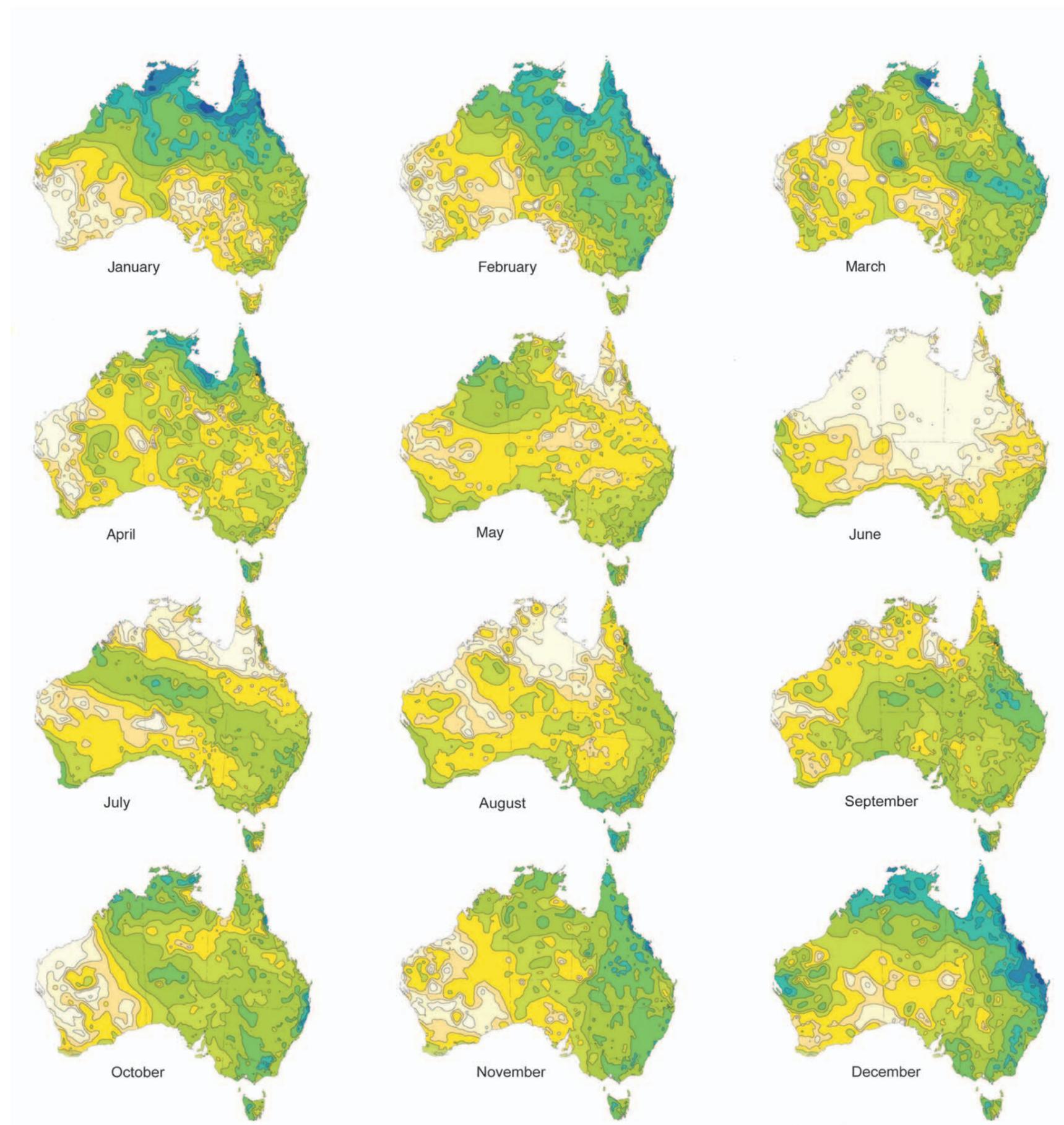
## 7. Monthly rainfall totals

Above-average rainfall was received in all months except June, and for northern Australia the dry season (May to October) was the wettest on record. Averaged over the country as a whole, it was the second-wettest year on record. Australia-wide, average rainfall ranged from 11.7 mm for June to 104.1 mm for January.

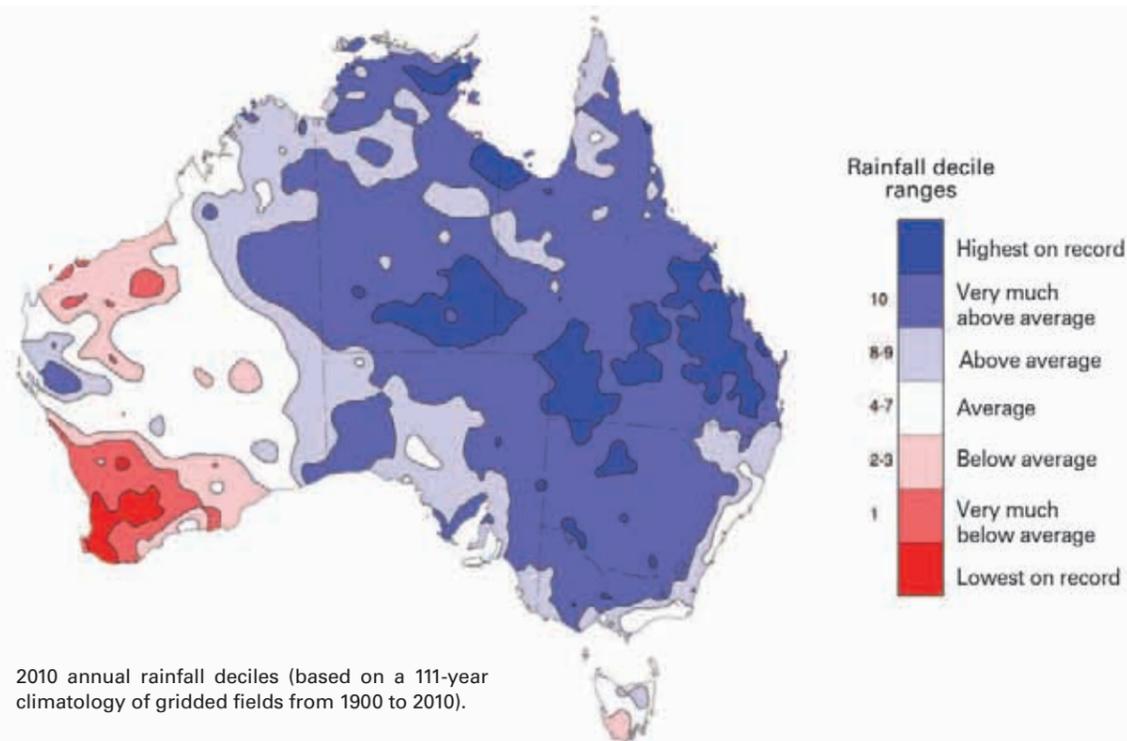
The highest monthly rainfalls occurred in January along the northern coast of Australia; totals of 400 to 600 mm were widespread in the far north, exceeding 800 mm near Cairns. Heavy falls were widespread during February; exceeding 400 mm in the Gulf Country and along much of the east coast of Queensland, exceeding 800 mm on the central coast, and exceeding 600 mm in the south coast area of New South Wales. March falls exceeded 600 mm in the eastern coastal area of Queensland and the Northern Territory Arnhem district, where tropical cyclone *Paul* brought heavy rain. April rainfalls exceeded 400 mm in the Arnhem district, the Gulf Country and the central Queensland coast.

Little rain fell during June, with only moderate falls along the southern coast. Extensive cloudbands in July brought falls of 50 to 100 mm to a broad area from Broome to areas of New South Wales and Victoria. August and September were wet for western Tasmania with falls above 300 mm each month. Many areas of Western Australia received less than 10 mm in October and November. November was very wet across the eastern States with large areas receiving falls of over 100 mm. December was also very wet for the northern tropics, the Pilbara and Gascoyne districts of Western Australia and the eastern seaboard — exceeding 400 mm along much of Queensland's east coast.

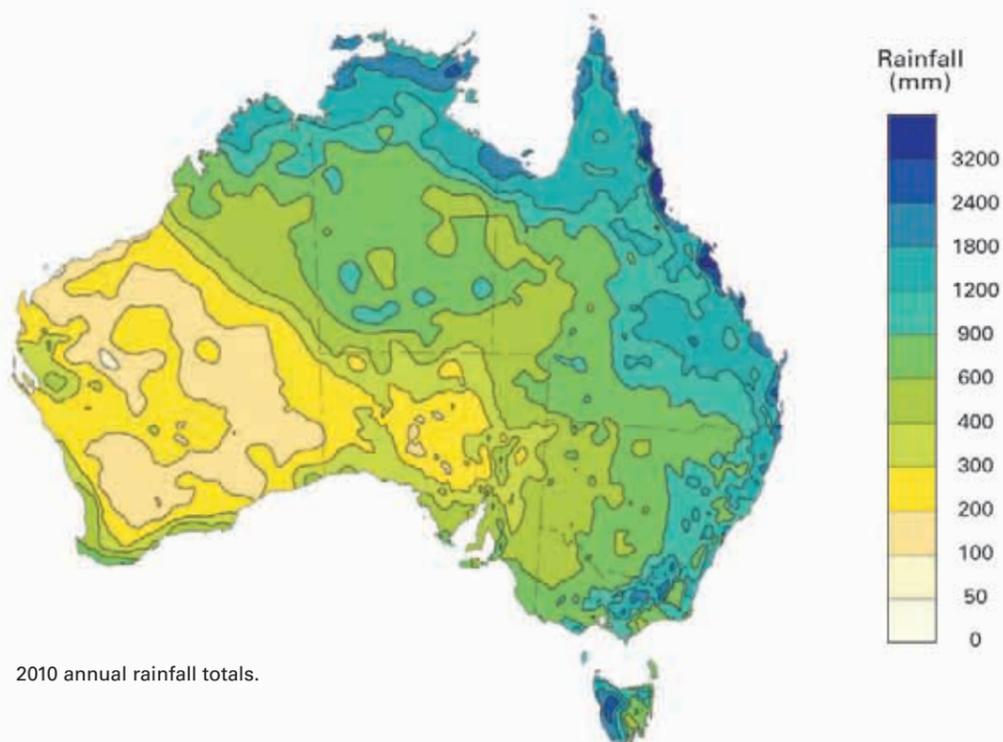
Monthly rainfall totals (mm)



## 8. Annual rainfall deciles and totals



2010 annual rainfall deciles (based on a 111-year climatology of gridded fields from 1900 to 2010).



2010 annual rainfall totals.

## 9. Annual review and significant events

**January to March:** *Generally wetter than normal in the mainland States, except Western Australia, and warmer in Tasmania.*

January to March was generally wetter than normal in the mainland States, except Western Australia. The year commenced with a few very wet days in parts of the eastern States, but the remainder of January was fairly dry in the southeast. Northern Queensland and the Northern Territory had a wet month. Tasmania recorded its sixth-driest January and most of Western Australia was also drier than normal.

Most of February was unusually dry in the tropical north. The Top End of the Northern Territory was particularly dry, where Point Fawcett on Bathurst Island received only 7 mm from 1 to 23 February during what is normally the wet season. Other parts of eastern and central Australia were unusually wet with New South Wales, Victoria and South Australia receiving more than double their average rainfall, while Tasmanian rainfall was near normal. Most of Western Australia remained dry.

Widespread heavy rainfall occurred across central and eastern Australia during late February and early March, the result of a monsoon low. This system produced widespread and, in some places, record-breaking flooding. The heavy rainfall during the late summer period is typical of many past El Niño breakdowns. January 2007, February 2003, April 1998, January 1995, March 1983 and February 1973 all produced significant falls over parts of northern and eastern Australia during the decline of an El Niño event. Remnants of the monsoon low drifted southward and interacted with an approaching cold front, triggering severe thunderstorm activity over Melbourne on 6 March. The heaviest rainfall occurred in less than 30 minutes, causing flash flooding in the inner city. Large hail, up to 5 cm in diameter, caused widespread damage to cars and houses across Melbourne. A 10 cm diameter hailstone was measured in Ferntree Gully in Melbourne's east, the largest on record for Melbourne.

Another severe thunderstorm occurred in Perth on 22 March breaking a dry spell of 122 days at Perth Airport. The thunderstorm produced heavy rain, severe winds and the largest hail on record for Perth, with a 6 cm hailstone reported in the suburb of Wembley.

January to March was very warm in Tasmania (warmest maximum on record at 2.27 °C above average) and most of Western Australia (third-warmest maximum on record, at 1.48 °C above average). Conditions were also warm in the southeast mainland

of Australia; however it was generally persistent warmth, rather than days of extreme heat. Melbourne, for example, had a spell of 123 consecutive days above 20 °C from 9 December (2009) to 10 April inclusive, breaking the previous longest run of 78 days set in 2000–01. Further north it was cooler during the daytime, with maximum temperatures 1 to 3 °C below normal across much of inland Queensland and the Northern Territory, largely the result of flooding rains in the region.

**April to May:** *Generally warm and wet. A transition period from El Niño to La Niña.*

April and May saw the decline of the El Niño which began in 2009, with Pacific conditions steadily moving towards a La Niña event. Rainfall and temperatures were near or above normal for most of Australia. April was wet through the Northern Territory and western Queensland, partly due to tropical cyclone *Paul*, and also in outback South Australia. Most of the country experienced a warm month, particularly at night. Australia had its second-highest April minimum temperature on record, +1.68 °C above normal.

Notable rain fell in northwest Australia during May, normally the start of the dry season. Heavy rain occurred in the Kimberley and western Northern Territory in the week 15 to 21 May, when falls exceeded 50 mm in many areas. Cape Leveque received 216 mm on 19 May, and Kuri Bay 274 mm from 15 to 20 May. This was the first of several highly unseasonable rain events in the tropics during the dry season. Overnight minimum temperatures were 2 to 4 °C above normal across the Kimberley and the Northern Territory Top End, setting records in several places. Temperatures and rainfall in the rest of the country were mostly unexceptional, although South Australia was again wet but Tasmania and southwest Western Australia were unusually dry.

**June:** *The only nationally dry month for 2010.*

In a year of widespread above-average rainfall, June was the only below-average month. Australia as a whole was dry, receiving 11.7 mm, the fourth-driest June on record (record 8.0 mm, in 1940). The national total was the result of general overall dryness.

Temperatures were mostly close to normal. Notable warm temperatures were experienced at the tip of Cape York Peninsula and in a region between Port Hedland and Carnarvon in Western Australia, which had their warmest June on record. The unusually high sea-surface temperatures (SSTs) in the Coral Sea contributed to the record warm air temperatures at

Cape York Peninsula. SSTs in the Coral Sea in June were a record 0.78 °C above average.

**July: Transition to a wet second half of the year. Warm in the northern tropics. La Niña strengthens.**

July 2010 was Australia's wettest July since 1998, with exceptional rainfall across northern and central Australia during what is usually a dry month. Falls above 100 mm were common. High rainfall records were set, particularly in the northern half of Western Australia.

Rainfall was below average across much of southern Australia, particularly in southwest Australia and southern Tasmania, where January to July rainfall was the lowest on record in some places around Hobart. Record high positive monthly values of the Southern Annular Mode were observed in June and July, with the August value the second highest on record. A positive index usually results in lower than average rainfall in southern Australia and is likely to have contributed to dry conditions in southwest Western Australia during winter. Southeast Australia was likely spared similar dry conditions to the southwest due to the influence of La Niña.

Temperatures in the northern tropics, particularly overnight, were exceptionally high. Monthly minima were 3 to 6 °C above normal, and set records in most

areas north of a line from Broome to Townsville. Cape Don (Northern Territory) set a new Australian record high minimum temperature for July, registering 26.9 °C on the 26th, with Darwin (26.6 °C) also breaking the previous record. Timber Creek and Bradshaw (both 37.5 °C on the 30th) set a new Northern Territory record, falling just 0.1 °C short of the Australian record high July maximum temperature. Richmond set a Queensland record July maximum with 36.1 °C on the same day.

Minimum temperatures across southern Australia were mostly near, or slightly below normal, with anomalies of -1 to -2 °C across much of southern Western Australia. Maximum temperatures were generally close to normal on the mainland, except for the northern tropics. Tasmania, however, had its warmest July on record, with mean maximum temperatures 1.90 °C above average.

**August to December: Wet and unusually cool for most places outside the west.**

By August, La Niña conditions were established and dominated for the rest of the year. The 2010 La Niña was exceptionally strong, as measured by the Southern Oscillation Index.

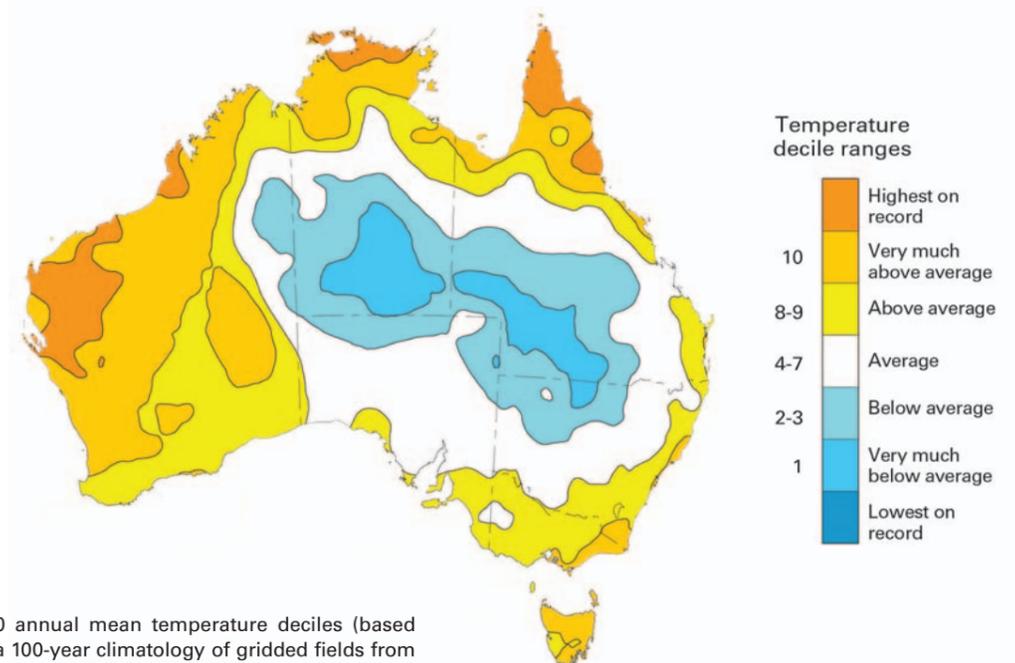
This period was very wet for Australia, with the heavy rains of earlier months extending south to include

most of Victoria and Tasmania. Virtually all of Australia had above-average rainfall for this period and many areas had record-breaking rainfall. In stark contrast to the rest of the country, southwest Western Australia had its lowest recorded rainfall for this period.

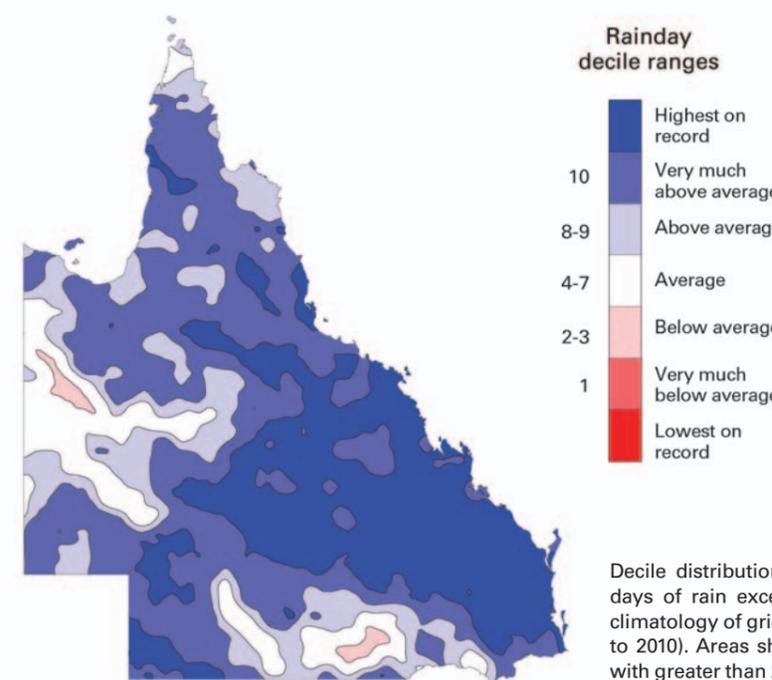
Rainfall for August to December was highest on record across vast areas of eastern Australia, particularly in Queensland, as well as the Top End of the Northern Territory and the Gascoyne region of Western Australia. Numerous monthly rainfall records were set, particularly in the central and eastern regions. Flooding was a regular occurrence and there was substantial recharge in many depleted water storages. The most widespread and damaging floods of the year occurred across Queensland in the final week of 2010 (continuing into early 2011). Floodwaters were fed by heavy rain over the Christmas period, falling over areas already saturated by persistent above-average rain during preceding months. The most severe impacts were in central and southern inland Queensland. Numerous rivers throughout the region reached record levels. Significant flooding occurred across inland New South Wales in December, particularly in the Murrumbidgee and Lachlan catchments. Major floods also occurred in northern Victoria and the New South Wales Riverina in early September, and in the Gascoyne River around and upstream of Carnarvon, Western Australia, in mid-December.

As is typical for a wet period with extensive cloud cover, maximum temperatures were below normal in most areas, excluding the west and far north. Most of central Australia, stretching into Queensland and New South Wales, had its coolest August to December on record (records commenced in 1911). Maximum temperatures were 3 to 4 °C below normal across the central and eastern interior, and there was a notable lack of warm days. In contrast, the west coast of Western Australia, south of Carnarvon, experienced maximum temperatures generally 1 to 2 °C above normal.

Minimum temperatures averaged across Australia for August to December were close to normal, with warm conditions in the northern tropics stretching down along the west and east coasts, and cool conditions in central Australia. The most significant anomalies in these months were in the far north with record high minima at Cape York Peninsula and parts of the Northern Territory Top End, as well as in the Pilbara and Gascoyne regions of Western Australia. Conditions were even more exceptional on offshore islands, most dramatically in Queensland when the August record high minimum temperature of 25.4 °C was surpassed at Horn Island and Coconut Island in the Torres Strait on 24 separate occasions (peaking at 26.8 °C at Horn Island on 19 August). These minimum air temperatures were mostly a result of record high SSTs in the region from June to December. SSTs can moderate minimum air temperatures over coastal and island regions.

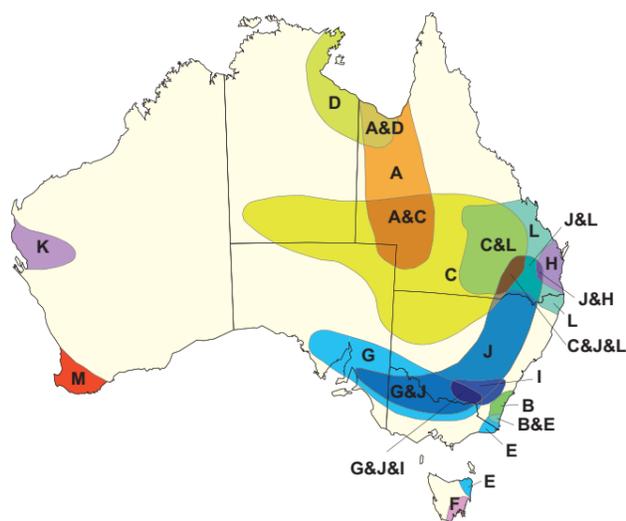


2010 annual mean temperature deciles (based on a 100-year climatology of gridded fields from 1911 to 2010).



Decile distribution of August to December 2010 total days of rain exceeding 25 mm (based on a 111-year climatology of gridded daily rainfall analyses from 1900 to 2010). Areas shaded dark blue recorded more days with greater than 25 mm of rainfall between August and December 2010 than in any other August to December period between 1900 and 2009.

### Rainfall/floods/drought



**A.** Floods in western Queensland associated with tropical cyclone *Olga* in late January and early February.

**B.** Severe local flooding on New South Wales south coast from 14 to 16 February.

**C.** Widespread major flooding in central and eastern Australia in late February and early March. Record flood heights on several Queensland rivers.

**D.** Floods in Gulf region associated with tropical cyclone *Paul* in late March and early April.

**E.** A trough causes floods in northeast Tasmania from 28 to 30 May. Wind damage is also reported in eastern Victoria and southeast New South Wales.

**F.** Floods and land slips in southeast Tasmania from 10 to 11 August.

**G.** Major flooding in early September on many rivers in northern Victoria. Also damaging storms in South Australia.

**H.** Floods in southeast Queensland from 10 to 12 October. Wivenhoe Dam spills for the first time since 2001.

**I.** Floods in the Riverina and southwest slopes of New South Wales from 13 to 16 October.

**J.** Widespread flooding on inland rivers during early December, especially in New South Wales. Floods also in the Adelaide region.

**K.** Severe floods in Gascoyne region of Western Australia associated with a tropical depression from 16 to 18 December.

**L.** Severe floods in much of southern and central Queensland from mid-December onwards. Moisture associated with tropical cyclone *Tasha* contributed to this rainfall.

**M.** Severe drought in southwest Western Australia—driest year on record.

**N.** Extreme heat was recorded in Western Australia in early January. Onslow (N1) recorded 49.2 °C on 1 January. Records were also broken at Learmonth (N2, 48.9 °C) and Esperance (N3, 46.9 °C).

**O.** Melbourne equalled its record high overnight minimum (measured from 3 pm to 9 am) on 12 January (30.6 °C).

**P.** Persistent low minimum temperatures during late June and early July. Norseman Aerodrome (P1) equalled the Western Australian record for June (-6.0 °C).

**Q.** Very warm minimum temperatures in the northern tropics through winter. The Australian July record high minimum was broken at Cape Don (Q1, 26.9 °C on 26 July) and the Queensland August record high minimum was broken at Horn Island (Q2, 26.8 °C on 19 August).

**R.** Snow to unusually low levels for summer in the Monaro district on 18 January.

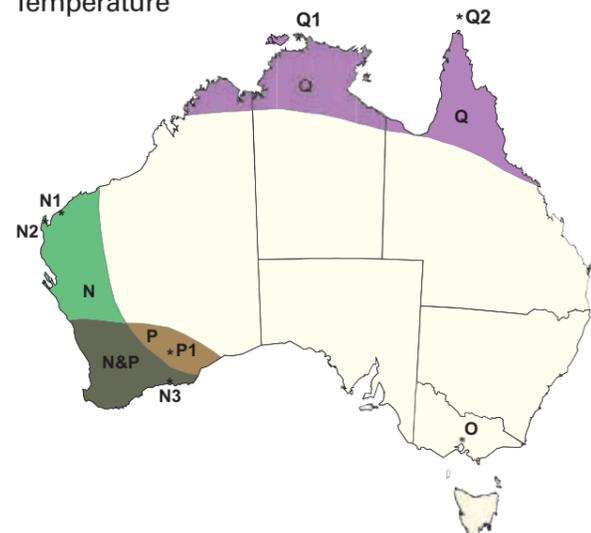
**S.** Widespread severe thunderstorms between 5 and 7 March, including a damaging hailstorm in Melbourne (S1). Damage from the hailstorm was estimated at more than \$1 billion.

**T.** Tropical cyclone *Ului* makes landfall near Airlie Beach on 21 March, resulting in widespread tree and crop damage, and many boats damaged in harbours.

**U.** Severe hailstorm on 22 March in Perth. Hailstones of more than 6 mm in diameter (a new record) were reported and damage was estimated at more than \$1 billion.

**V.** Tornadoes caused severe damage at Lennox Head (V1) on 3 June and Penola (V2) on 31 July.

### Temperature



### Severe weather



## 10. Oceans: sea level and sea-surface temperatures

### Sea level

In 2010, a new reanalysis of sea-level data back to 1880 was undertaken. Based on this analysis, globally averaged mean sea level reached a new record high in 2010. Observations indicate that global mean sea level for January to September 2010 was  $213 \pm 25$  mm above the 1880 level (quality global records commenced in 1880).

Since 1993, high-quality global sea-level measurements have been made from satellites, in addition to traditional tide gauges. These satellite data indicate that sea level has risen over the period from January 1993 to September 2010 at an average annual rate of around 3.2 mm/year. This is slightly larger than, but not significantly different from, estimates of global sea-level rise from the coastal and island tide gauges over the same period.

The rate of sea-level rise is strongly influenced by fluctuations in climate, such as El Niño and La Niña. For this reason, the rate of sea-level rise is not uniform around the globe and varies from year to year. Local and regional trends can be above or below the global mean.

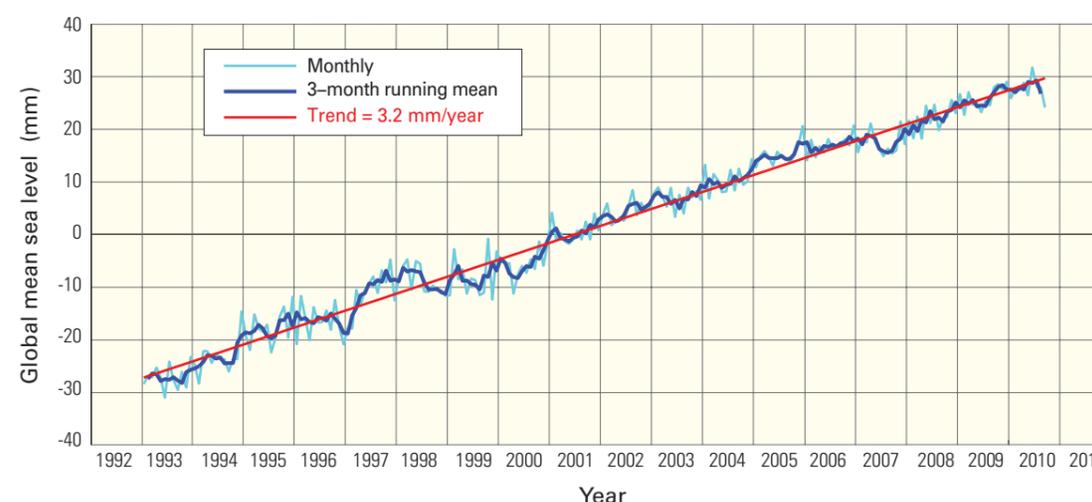
In the Australian region, the rate of sea-level rise (from the early 1990s to September 2010) has generally been above the global rate, with the exception of the central east coast and areas to the south of the

continent. The rate of sea-level rise to the north and northwest of Australia is two to three times the global average over this period. This is at least partly the result of the sequence of El Niño and La Niña events over this time with the early 1990s dominated by El Niño events that tend to suppress sea level in the region. Note that these local-scale variations remain superimposed on the underlying long-term trend of rising global sea levels. Short-term trends, especially at individual sites, should be viewed with caution.

### Sea-surface temperatures

Sea-surface temperatures (SSTs) in the Australian region were the highest on record during 2010, 0.54 °C above average. SSTs were particularly high from autumn onwards with individual monthly SST records set during March, April, June, September, October, November and December. The most recent decade (2001-2010) was also the warmest decade on record with an anomaly (departure from average) of +0.33 °C. Each of the last ten decades has been warmer than the preceding decade.

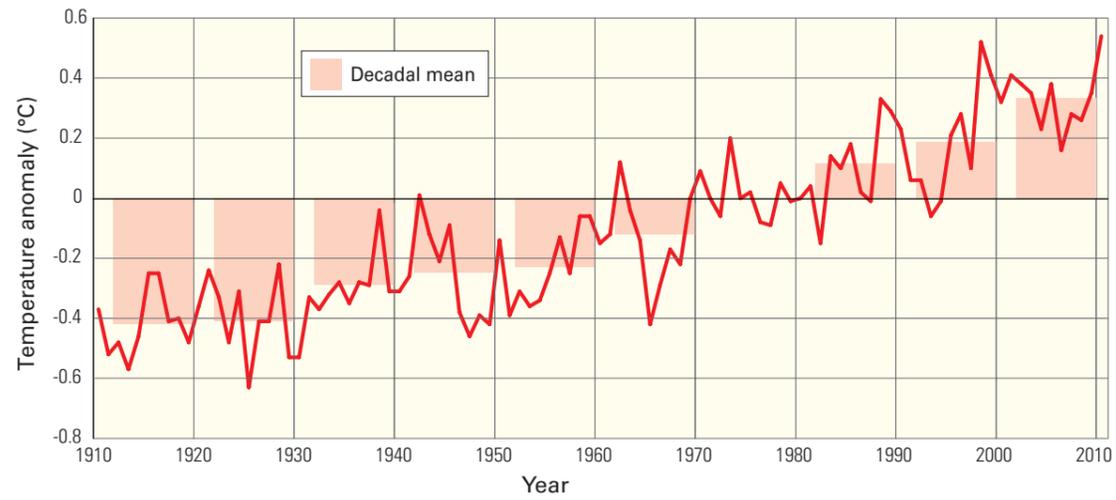
Early in the year, positive SST anomalies were generally located in southern Australian waters, however by March positive anomalies were becoming established in northern waters. Above-average SSTs were a feature of northern Australian waters for much of the year.



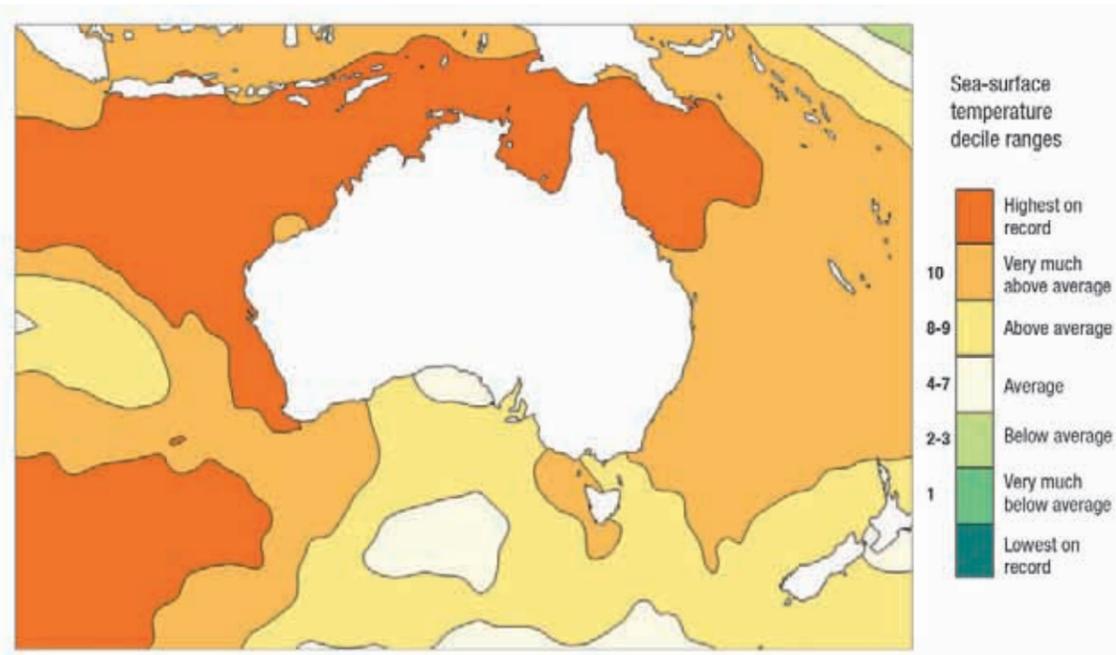
Measurements of global mean sea level from satellites for January 1993 to September 2010. The seasonal signal has been removed from the data and corrections applied for changes in atmospheric pressure and land motion. The light blue line shows the monthly data and the dark blue line the three-month moving average, while the red line shows the linear trend. October to December 2010 data not available at time of publication.

Along with a favourable hemispheric circulation associated with the 2010 La Niña, very high SSTs contributed to the record rainfall and very high humidity across eastern Australia during the second half of the year. For the months of October, November and December tropical SSTs broke previous

records by large margins and occurred in regions that, historically, have a strong association with Australian rainfall. Waters off the northwest coast of Western Australia during November had an anomaly of +1.08 °C, which was 0.30 °C above the previous record set in 1998.



Annual and decadal mean sea-surface temperature anomalies (1910 to 2010) for the Australian region (averaged over the area described by a box from 0° to 50°S and from 94°E to 174°E). Anomalies are calculated with respect to the 1961-1990 average. Values are calculated from the NOAA Extended Reconstructed Sea-Surface Temperature (NOAA\_ERSST\_V3) data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA.



September to December 2010 sea-surface temperature deciles calculated with respect to the 1900-2010 period from the NOAA Extended Reconstructed Sea-Surface Temperature (NOAA\_ERSST\_V3) data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA.

# Climate Service Centres

## New South Wales Climate Service Centre

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## Victorian Climate Service Centre

Bureau of Meteorology  
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