



Australian Government
Bureau of Meteorology

Annual Climate Report 2013



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This edition is based on data available as of 23 January 2014.

Cover picture: Helicopters take to the air in a water-bombing operation near Bell in the New South Wales Blue Mountains as bushfires threaten homes, 20 October. Photograph: Jeremy Piper, *Oculi*.

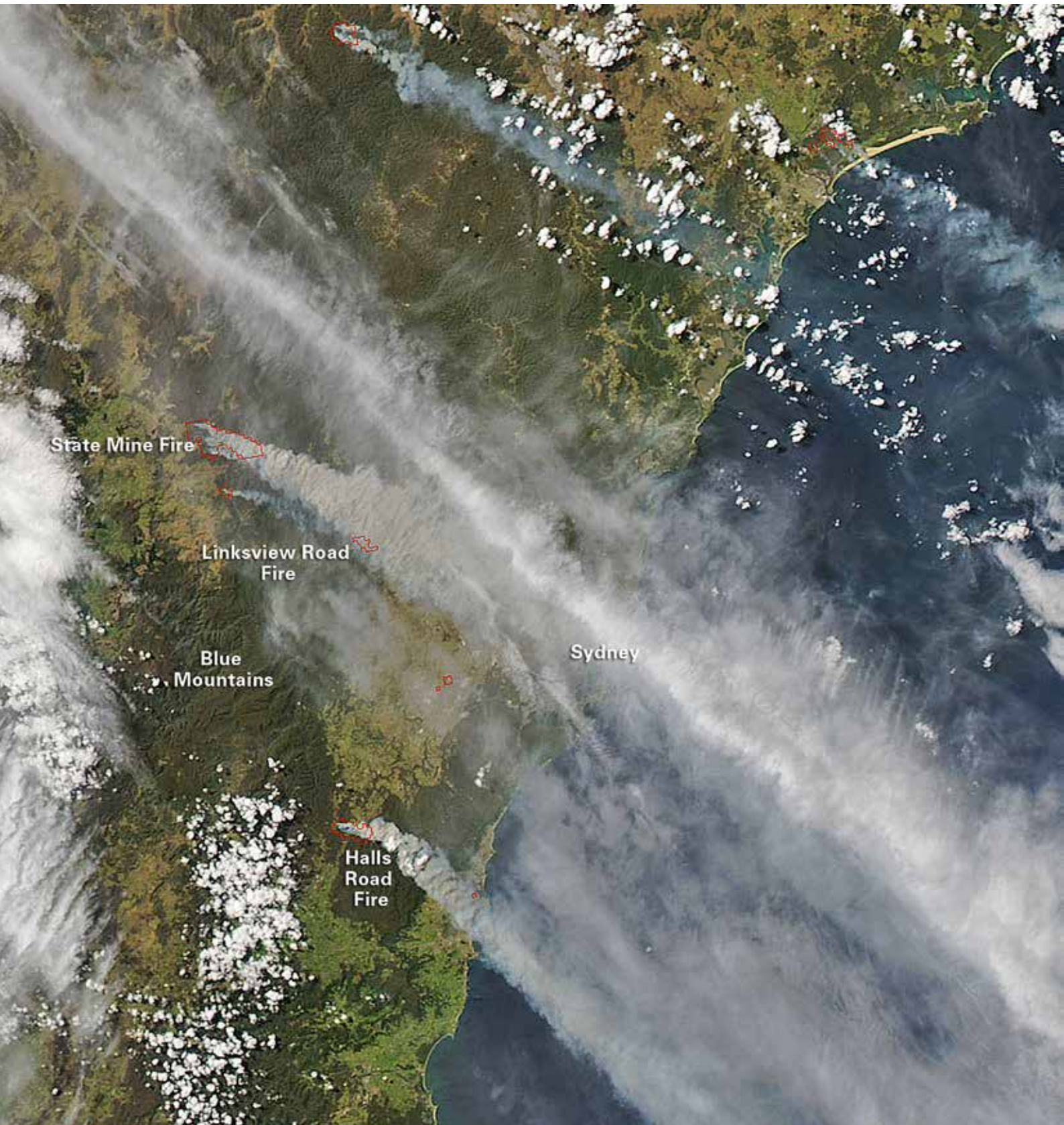
Picture on this page: Limestone Station near Broken Hill, where the temperature reached over 44 °C on 8 January. Photograph: Braden Fastier, News Limited.



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Numerous significant fires across the Blue Mountains are shown in these images captured by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite on 17 October. Prolonged dry conditions and high temperatures following a very warm early spring contributed to an early start to the fire season for New South Wales. Active fire boundaries are outlined in red.

1. Overview

2013 was Australia's warmest year since national records began in 1910. Persistent warmth throughout the year led to record-breaking temperatures and several severe bushfires. While national-averaged rainfall was slightly below average, areas of the inland eastern States and northern interior experienced below-average rainfall. Parts of the east coast, northern Tasmania and Western Australia had above-average rainfall.

Australia's hottest year on record

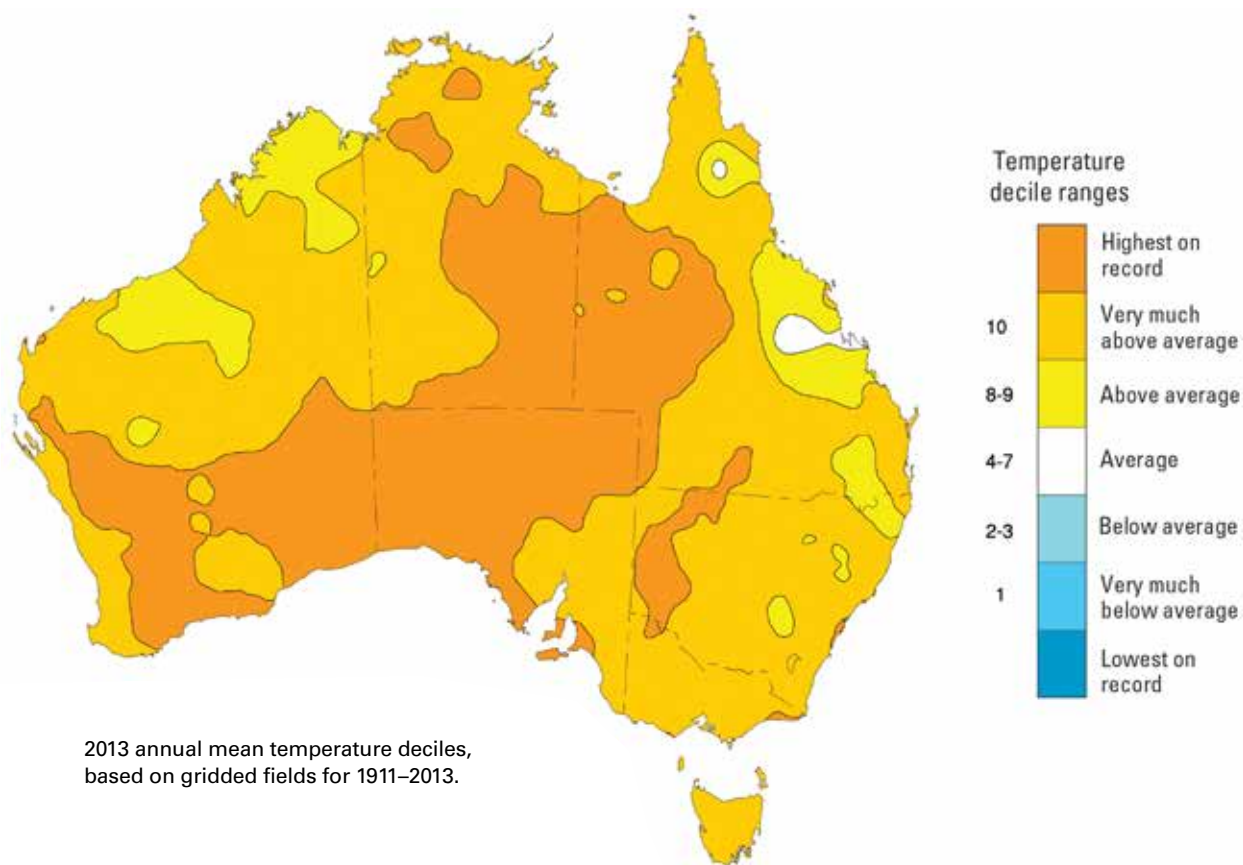
The Australian area-averaged mean temperature for 2013 was 1.20 °C above the 1961–1990 average* of 21.81 °C, making it the warmest year since records began in 1910. Annual mean temperatures for all States and the Northern Territory were also in the four warmest years on record.

Maximum temperatures were 1.45 °C above average nationally, the warmest on record. Minimum temperatures were 0.94 °C above average, second-warmest on record.

Mean and maximum temperatures were above average over nearly all of the country and were highest on record

over large areas of inland and southern Australia. Minimum temperatures were also the highest on record for parts of the southern mainland. Only small areas near the eastern and northern coastline recorded near- or below-average minimum temperatures.

Following a warm spring in 2012, mean temperatures generally remained well above average throughout 2013. Numerous heat records were set during summer and winter–spring (see page 17). Summer 2012–13 and spring 2013 were the warmest on record, with



* Unless otherwise stated, all climatological averages are calculated over the 30-year period 1961–1990, as defined by the World Meteorological Organization. Anomalies are the difference between an observed value and the corresponding average over the reference period. Unless otherwise noted, rankings of temperature records are for the period from 1910 and rainfall records for the period from 1900.

mean temperatures 1.11 °C and 1.57 °C above average, respectively. Winter was the third-warmest on record with a mean temperature 1.29 °C above average. Long stretches of warmer-than-average days were common during 2013, with a distinct lack of cold weather.

These warm temperatures occurred in a neutral phase of the El Niño–Southern Oscillation (ENSO). In Australia, warm years are more often associated with the El Niño phase.

January was Australia’s warmest month on record in absolute terms, with a mean temperature of 29.67 °C. Temperatures were above average over nearly all of the continent.

February–April was warmer than average, with record warmth in Tasmania during March, and the south of Western Australia during April. May and June were generally warm, with May warmth notable across the northern tropics and South Australia while northwest cloudbands suppressed daytime temperatures in the northwest and central Australia during June.

From July onwards temperatures again became more extreme. A negative phase of the Southern Annular Mode contributed to hot, dry weather across most of Australia except the southern mainland and Tasmania. Although the negative phase of the Southern Annular Mode ended in early August, the heat persisted with a record-warm September (mean temperature 2.75 °C above average) and spring. The September mean temperature anomaly was the highest on record for any month.

November and December were generally warmer than average, although large areas of eastern Australia

recorded below-average minimum temperatures during October–December.

In the past ten years (2004–2013), only 2011 has been cooler-than-average for Australia. Mean temperatures averaged over the past decade were 0.50 °C above average, the equal-warmest on record. Averages for every ten-year period between 1995–2004 and 2004–2013 have ranked within the ten warmest on record. Long-term temperature trends show that temperatures over Australia have warmed by about 1 °C since the start of last century, with most of the warming occurring since 1950.

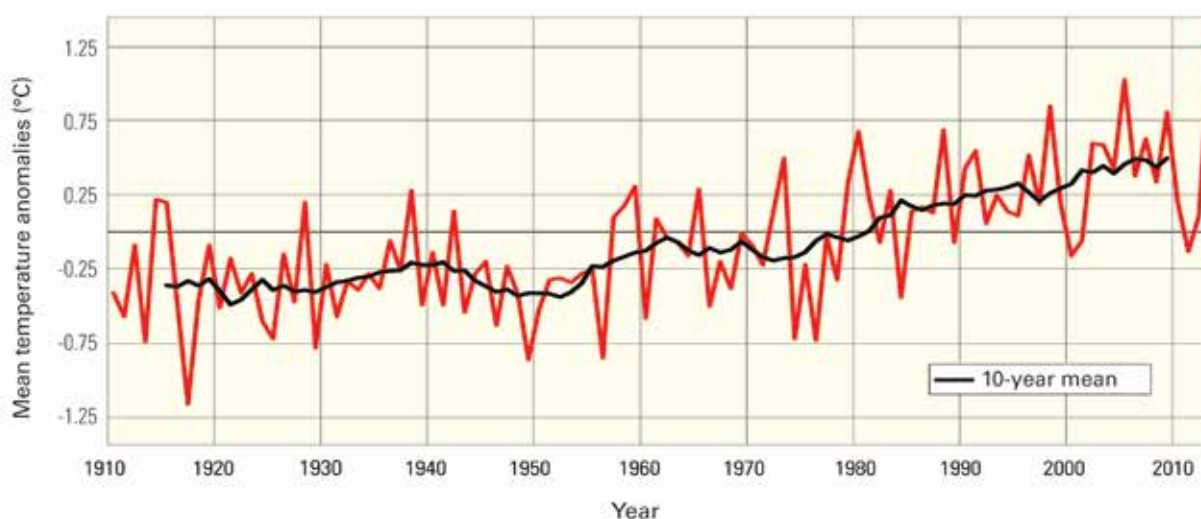
Globally, the sixth-warmest year on record

The World Meteorological Organization combines data from three datasets* to calculate global mean temperatures. Based on January–December data, the combined sea surface and land air temperature for 2013 was 0.50 °C ± 0.12 °C above the long-term average of 14.0 °C.

Global mean temperatures for 2013 ranked as the fourth-warmest year on record. 2013 was also warmer than 2011 and 2012 (0.41 °C and 0.45 °C above average, respectively), when La Niña conditions had a cooling influence on global temperature.

No year since 1985 has recorded a below-average global mean temperature and nine of the ten warmest years have occurred in the twelve years since 2002. The ten-year global average for 2004–2013 was 0.47 °C above average; the equal-second-warmest 10-year period since 1880.

* Those maintained by the UK Met Office Hadley Centre (HadCRU3v), the US National Climatic Data Centre (blended GHCNv3 and ERSST3b) and the US Goddard Institute of Space Studies (GISTEMP).



Annual mean temperature anomalies (1910–2013) for Australia. The black line shows the ten-year moving average.

Near-average rainfall, although dry in the inland east

Nationally-averaged rainfall was 430 mm, which is 35 mm below the long-term average of 465 mm. This places 2013 close to the median or mid-point of historical observations. Tasmania and Western Australia were the only States to record above-average annual totals.

Annual rainfall was below-average across a large region of the inland east centred on western Queensland and extending into northern South Australia, the Northern Territory, inland New South Wales and Victoria. Rainfall was above average over parts of the Pilbara, the south coast of Western Australia, and northern and east coast Tasmania.

January was generally drier than average, except for Western Australia and along the east coast of Queensland and New South Wales where ex-tropical cyclone *Oswald* brought very heavy rain.

February was also wet for the east coast while in the northwest tropical cyclone *Rusty* brought heavy falls. A late finish to the wet season saw above average March–April rainfall for the north. March rainfall was also generally above average for the southern half of the mainland and April was very dry for the southeast.

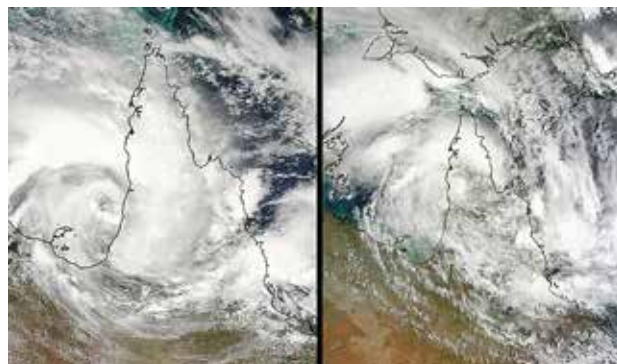
A negative phase of the Indian Ocean Dipole between late autumn and early August contributed to above-average rainfall over large parts of Australia between May and July—particularly that associated with northwest cloudbands extending from the northwest through to South Australia.

A negative phase of the Southern Annular Mode between mid-July and October meant the subtropical ridge was located further north than usual. This brought strong

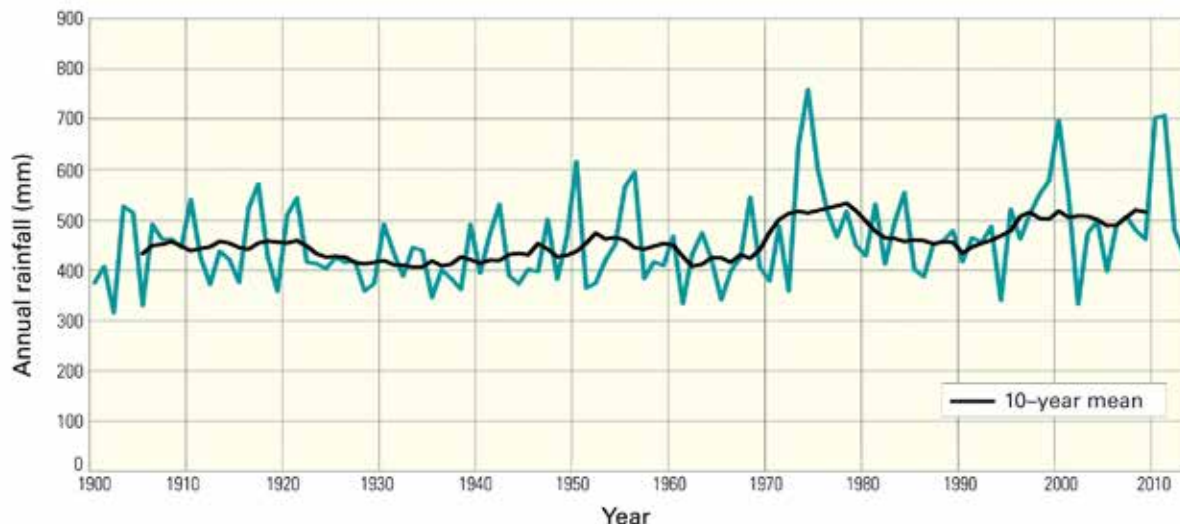
westerly flow across southern Australia and above-average rainfall to regions of the coast exposed to the westerlies. Further north, this pattern produced very dry conditions in New South Wales and Queensland. September rainfall was above average for the south of Western Australia and along the northwest coast during October.

November brought an early start to the wet season for northern Australia. It was also a wet month for the east coast and eastern Tasmania, while conditions turned dry for eastern Australia in December.

There were a number of flood and storm events during 2013. The most widespread was in late January as the remnants of tropical cyclone *Oswald* brought heavy rain to much of the east coast. Several other events occurred during the year, predominantly resulting from short-lived weather systems, while persistent rain in the northern half of Tasmania caused flooding during winter and spring (see page 19).



These two images of tropical cyclone *Oswald* show the storm's progression over the Cape York Peninsula, Queensland. The MODIS instrument aboard NASA's Aqua satellite captured these on 21 and 22 January.



Australian mean rainfall (1900–2013). The black line shows the ten-year moving average.

	Rainfall (mm)			Maximum temperature (°C)			Minimum temperature (°C)		
	Total 2013	Average 1961–1990	Rank (of 114)	Anomaly 2013	Average 1961–1990	Rank (of 104)	Anomaly 2013	Average 1961–1990	Rank (of 104)
AUSTRALIA	429.9	465.2	52	+1.45	28.55	104	+0.94	15.07	103
New South Wales/ACT	463.9	552.7	35	+1.76	23.91	104	+0.69	10.75	93
Northern Territory	461.1	540.3	42	+1.56	31.88	104	+1.11	18.45	102
Queensland	491.7	623.4	23	+1.51	29.88	104	+0.93	16.57	100
South Australia	196.4	225.2	48	+1.88	26.71	104	+1.24	12.20	104
Tasmania	1543.1	1390.4	85	+0.68	14.72	99	+0.58	5.99	100
Victoria	608.8	660.2	39	+1.30	19.85	102	+0.78	8.34	102
Western Australia	407.2	340.9	92	+1.11	29.27	104	+0.84	15.66	103
Murray–Darling Basin	370.8	488.4	20	+1.76	24.45	104	+0.75	10.87	97

Summary of 2013 mean rainfall and temperatures for Australia, the States, Northern Territory and Murray–Darling Basin. Ranks are for all years since national records began (1900 for rainfall, 1910 for temperature), with 1 indicating the driest/coolest year. 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.

Capital cities

All capital cities recorded warmer-than-average maximum temperatures (see page 5). Canberra was the only capital to record cooler-than-average nights. For all capitals except Brisbane, days were equal-third-warmest or warmer. For Sydney, they were warmest on record. Minimum temperatures were the second-warmest or equal-second-warmest for Hobart, Adelaide and Melbourne, and equal-third-warmest for Sydney.

At 45.8 °C on 18 January, Sydney's temperature was the highest daily maximum temperature for a capital city during 2013. It was also the highest temperature recorded at Sydney's Observatory Hill in 155 years of record. Hobart also broke its daily maximum temperature record on 4 January with 41.8 °C. The lowest temperature recorded at a capital city was –6.0 °C in Canberra on 25 July.

Darwin, Sydney and Hobart were the only capitals to exceed their long-term annual average rainfall, although Melbourne very nearly equalled its long-term average. Annual rainfall for the other capitals was somewhat below the long-term average. Canberra rainfall was 14 per cent below the long-term average. Hobart recorded the highest number of rain days (158), while Canberra recorded the fewest (94).



The heat rolled on in Melbourne during February. Photograph: Glenn Campbell, *The Age*, 25 February.

2. Capital city summary

Data for 2013 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.

City	Highest temperature	Lowest temperature	Average maximum	Average minimum	Rainfall (mm) & no. rain days
	Date (°C)	Date (°C)	Average Anomaly (°C)	Average Anomaly (°C)	Average (mm) Decile range
Perth	40.5	1.4	25.5	13.7	782.4 on 114 days
	21 February	18 July	24.5	12.6	819.4
			+1.0	+1.1	4
Darwin	36.6	15.8	32.7	23.5	1758.2 on 126 days
	10 October	8 August	32.0	23.3	1705.1
			+0.7	+0.2	7
Adelaide	45.0	3.6	23.5	13.2	508.0 on 121 days
	4 January	19 June	22.3	12.2	546.3
			+1.2	+1.0	5
Brisbane	35.5	5.7	26.6	16.5	1111.6 on 136 days
	5 December	24 June	25.6	16.4	1217.7
			+1.0	+0.1	6
Sydney	45.8	7.0	23.7	15.1	1344.4 on 119 days
	18 January	9 August	22.1	14.2	1302.2
			+1.6	+0.9	8
Canberra	42.0	-6.0	21.8	6.2	533.8 on 94 days
	18 January	25 July	19.6	6.5	623.2
			+2.2	-0.3	4
Melbourne	41.1	1.5	21.5	12.2	638.4 on 150 days
	4 January	23 June	20.0	11.0	638.8
			+1.5	+1.2	6
Hobart	41.8	-0.4	18.1	9.4	609.8 on 158 days
	4 January	21 August	17.1	8.7	586.4
			+1.0	+0.7	6

Long-term averages are based on the 1961–1990 period, with the exceptions of Adelaide (1981–2010), Brisbane (1961–1985, temperature only), and Perth (1994–2013, temperature only).

Decile ranges* are calculated from station data for stations with an available long-term record, supplemented with gridded monthly analyses based on all available data where suitable station observations are not available (particularly for Darwin and Canberra during 1900–1940). Some data have not yet been fully quality-controlled.

*Decile range 1 means the lowest 10 per cent of records, decile range 2 the next lowest 10 per cent of records, and so on, up to decile 10 which means the highest 10 per cent of records. Deciles are calculated with respect to the period 1900–2013.

3. Rainfall and temperature extremes by State and Territory

Temperatures are in degrees Celsius and rainfall totals are in millimetres. Daily minimum temperatures and daily rainfalls are for 24 hours ending 9.00 am on the date shown.

NEW SOUTH WALES

Highest daily maximum temperature	48.6 at Wanaaring Post Office on 12 January
Lowest daily minimum temperature	-11.6 at Perisher Valley AWS on 13 September
Highest average maximum temperature	30.0 at Mungindi Post Office
Lowest average minimum temperature	1.3 at Thredbo AWS
Highest daily rainfall	444.0 at Yarras (Mount Seaview)
Highest annual rainfall	3238.0 at Yarras (Mount Seaview)

NORTHERN TERRITORY

Highest daily maximum temperature	46.7 at Walungurru on 9 January and Rabbit Flat on 25 January
Lowest daily minimum temperature	-3.4 at Arltunga on 22 June
Highest average maximum temperature	36.4 at Bradshaw
Lowest average minimum temperature	14.0 at Alice Springs Airport
Highest daily rainfall	262.1 at Mataranka Airstrip on 29 March
Highest annual rainfall	1997.6 at Pirlangimpi

QUEENSLAND

Highest daily maximum temperature	49.0 at Birdsville Airport on 13 January
Lowest daily minimum temperature	-5.6 at Oakey Aero on 21 August and Stanthorpe (Leslie Parade) on 22 August
Highest average maximum temperature	36.3 at Century Mine
Lowest average minimum temperature	9.2 at Applethorpe and Stanthorpe (Leslie Parade)
Highest daily rainfall	653.0 at Numinbah on 28 January
Highest annual rainfall	7902.0 at Bellenden Ker Top Station

SOUTH AUSTRALIA

Highest daily maximum temperature	49.6 at Moomba Airport on 12 December
Lowest daily minimum temperature	-4.9 at Gluepot Reserve (Gluepot) on 10 July
Highest average maximum temperature	31.0 at Oodnadatta Airport
Lowest average minimum temperature	8.4 at Keith (Munkora)
Highest daily rainfall	150.8 at Murray Lagoon (Hawks Nest) on 12 June
Highest annual rainfall	1170.4 at Uraidla

TASMANIA

Highest daily maximum temperature	41.8 at Hobart (Ellerslie Road) on 4 January
Lowest daily minimum temperature	-12.2 at Liawenee on 9 July
Highest average maximum temperature	19.1 at Launceston (Ti Tree Bend)
Lowest average minimum temperature	1.9 at Mount Wellington
Highest daily rainfall	258.0 at Gray (Haven of Hope) on 13 November
Highest annual rainfall	4242.4 at Mount Read*

VICTORIA

Highest daily maximum temperature	45.7 at Yarrawonga on 5 January
Lowest daily minimum temperature	-8.1 at Mount Hotham on 13 September
Highest average maximum temperature	25.7 at Mildura Airport
Lowest average minimum temperature	2.0 at Mount Hotham
Highest daily rainfall	145.4 at Mount Baw Baw on 14 June
Highest annual rainfall	2530.8 at Falls Creek (Rocky Valley)

WESTERN AUSTRALIA

Highest daily maximum temperature	49.0 at Leonora on 9 January
Lowest daily minimum temperature	-5.0 at Eyre on 14 October
Highest average maximum temperature	36.8 at Fitzroy Crossing Aero
Lowest average minimum temperature	9.3 at Collie East and Wandering
Highest daily rainfall	261.6 at Hooley on 24 January
Highest annual rainfall	1768.5 at Cape Leveque

AUSTRALIA

Highest mean temperature [#]	36.8 at Fitzroy Crossing Aero, Western Australia
Lowest mean temperature [#]	1.3 at Thredbo AWS, New South Wales

*Mount Read's true total is unknown but likely higher, as the gauge was affected by snow several times through the year.

[#]The mean temperature is the average of all maximum and minimum temperatures.

AWS: automatic weather station

4. Monthly maximum and minimum temperatures

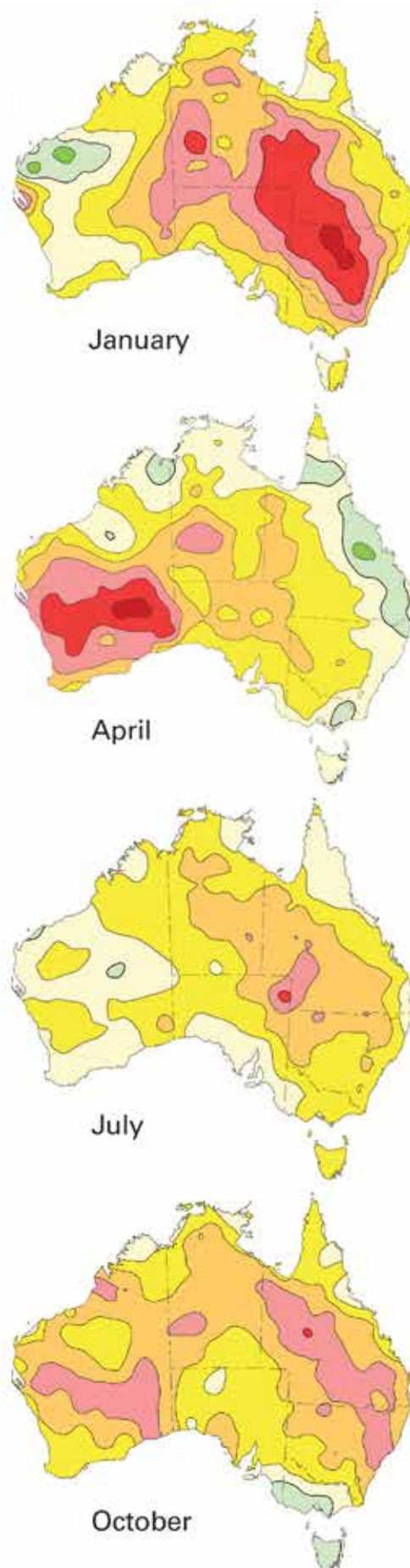
January was Australia’s hottest month on record (mean temperature 1.76 °C above average), and summer 2012–13 was Australia’s hottest summer on record (mean temperature 1.11 °C above average).

Both maximum and minimum temperatures were above average over the majority of the country during January, while being generally restricted to the north, southern coastline and Tasmania during February and March, with Tasmanian March maxima the highest on record. Temperatures were below average on the central east coast during February and March, and in southern Western Australia for maxima during March.

April was very warm for the southern half of Western Australia, with record-high monthly maxima and minima in the State’s southern third. Minima were also above average for South Australia and northern Victoria but below average in southern Queensland and northern New South Wales. Above-average maximum temperatures generally covered all but the eastern coast. Both maxima and minima were above average during May for most of the country except parts of the eastern States and for the west coast of Western Australia. For South Australia, May was the warmest on record for minima and fourth-warmest for maxima.

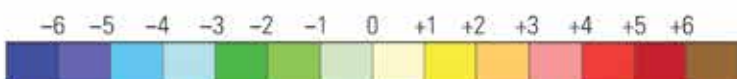
Below-average June maxima were associated with extensive rain in a band extending from northwest Western Australia to central South Australia. Maxima were also above average for the South West Land Division of Western Australia, the tropics and southeast Australia. Minima were below average for the South West Land Division and generally above average elsewhere, except for the southeast and eastern central Queensland where they were near average.

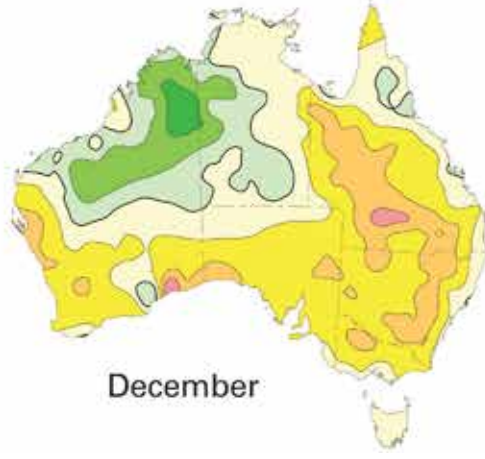
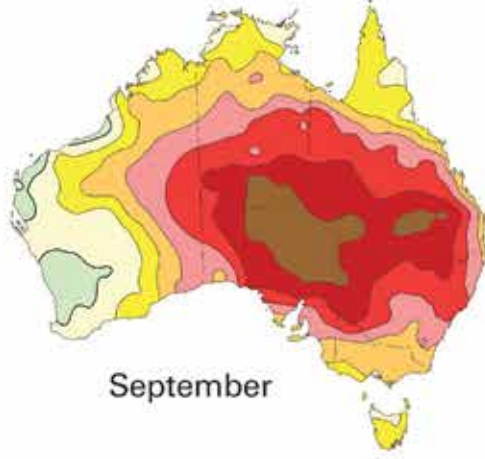
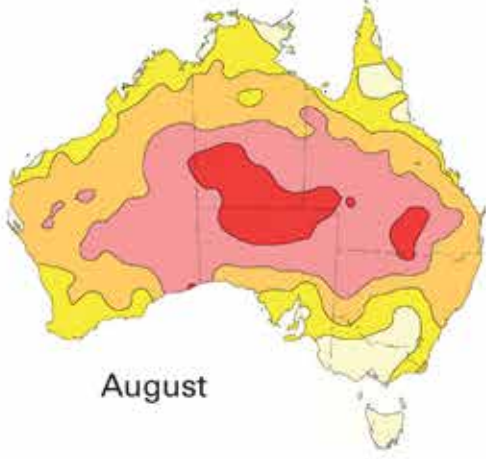
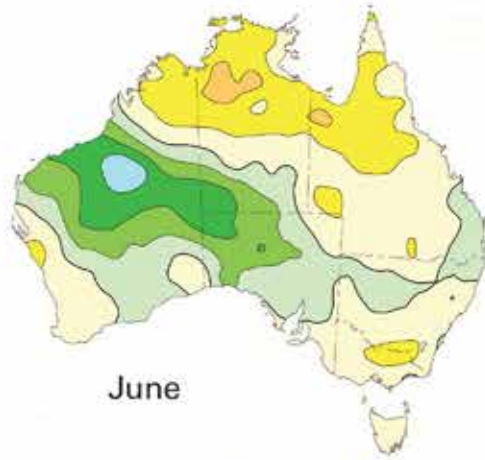
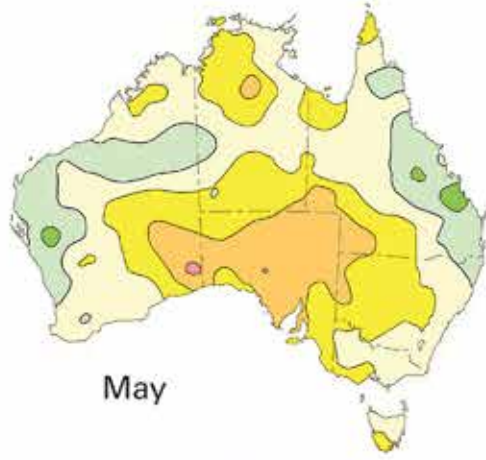
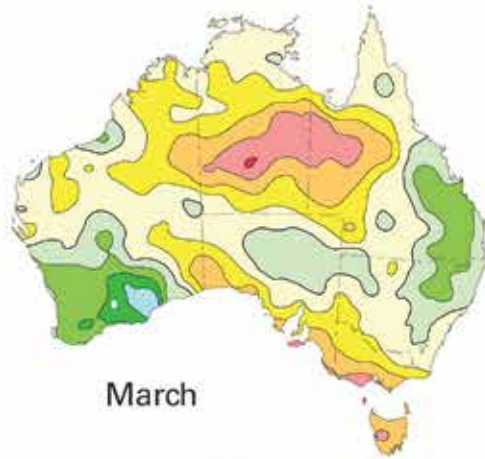
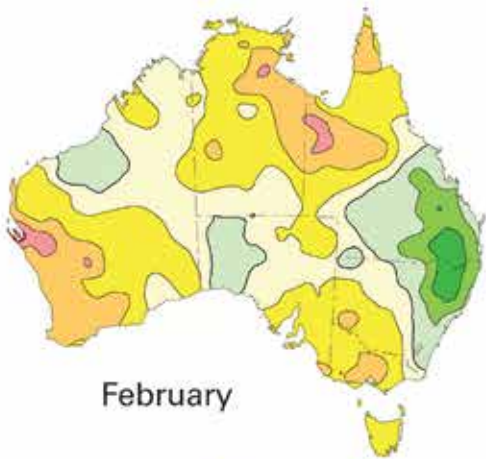
From July onwards, temperatures became more extreme as generally westerly airflow brought persistently dry and hot weather to inland regions. July was Australia’s third-warmest on record for both maximum and mean temperatures and August the second-warmest on record for both. July was warmer than average for most of Australia, especially so in the east, while near or below average for parts of the centre and west. During August maxima were in the warmest 10 per cent of records for most of Australia, except the southeast, and



Maximum temperature: departures from average (°C)

Based on 30-year mean calculated from 1961–1990



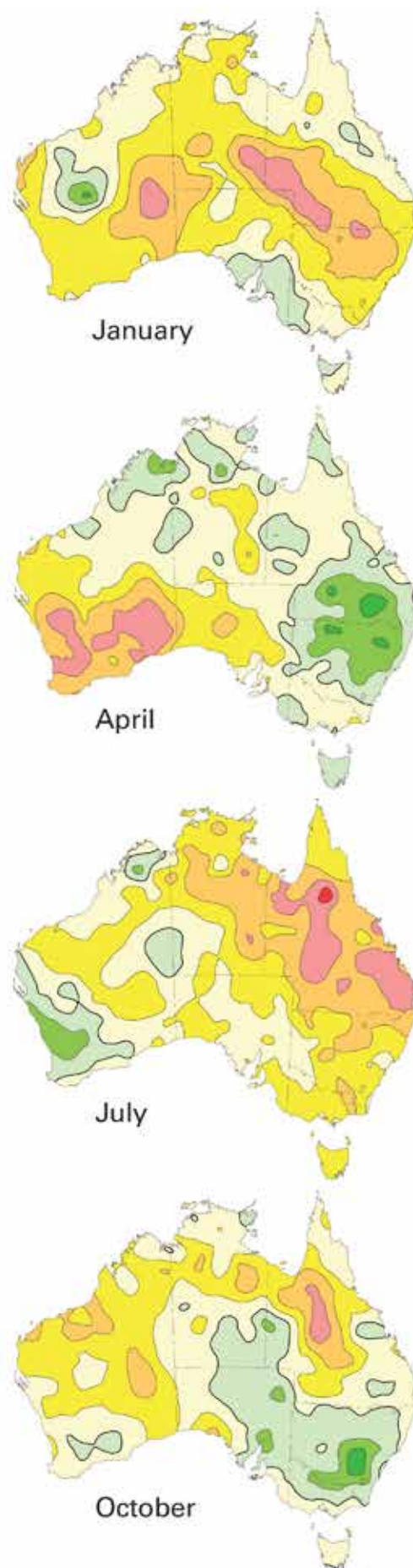


minima were very much above average for southern Australia while below average for areas of the north. Australia observed its warmest 12-month period for September 2012–August 2013 (mean temperature 1.11 °C above average). The following four months each saw the old record (1.08 °C above average for February 2005–January 2006) surpassed, culminating with December again seeing a record set for any 12-month period. Mean temperatures for each month from September 2012 to November 2013 were at least 0.50 °C above average.

September maxima were above average for all of Australia except the west of Western Australia. Maxima were the warmest on record for September for more than half of the country, with anomalies reaching six to seven degrees in central Australia and parts of southern inland Queensland. Minimum temperatures were also highest on record for much of South Australia, Victoria and parts of adjacent States and highest on record nationally, although near average for parts of the north. The mean temperature for September was not only the warmest on record by more than one degree, but had the largest positive anomaly on record for any month: +2.75 °C.

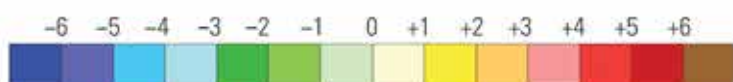
October maxima were less extreme but record-warm for parts of the north and above average for all but Victoria, Tasmania and eastern South Australia. Minima followed a similar pattern, although average to below-average minima were recorded in central Australia, New South Wales and Victoria away from the coast as low soil moisture in some parts of the southeast contributed to unusually large daily temperature ranges. Southern New South Wales and northeastern Victoria experienced a number of severe frosts during October, resulting in significant crop damage.

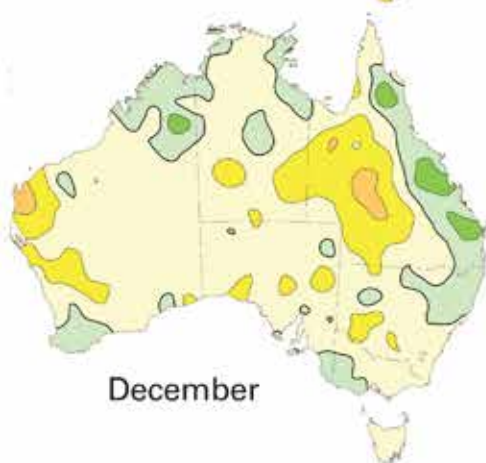
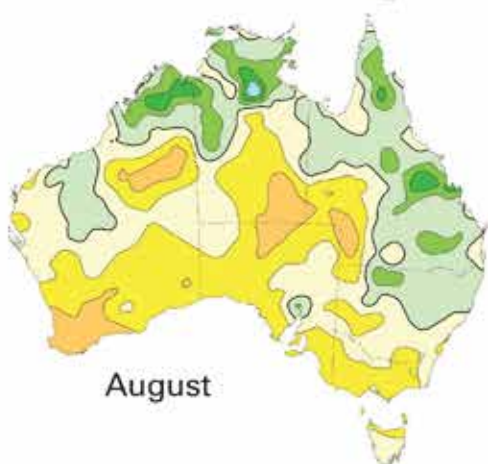
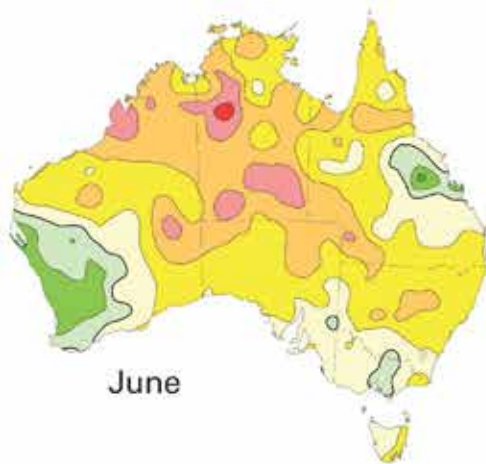
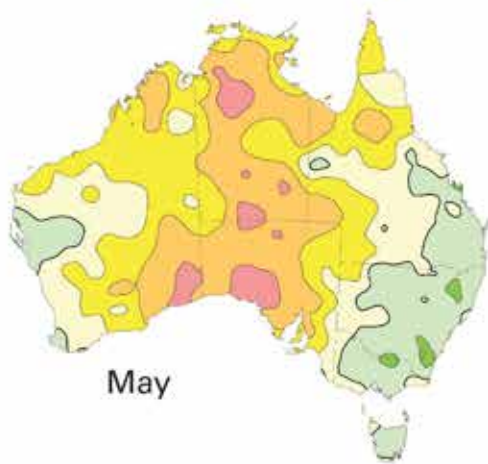
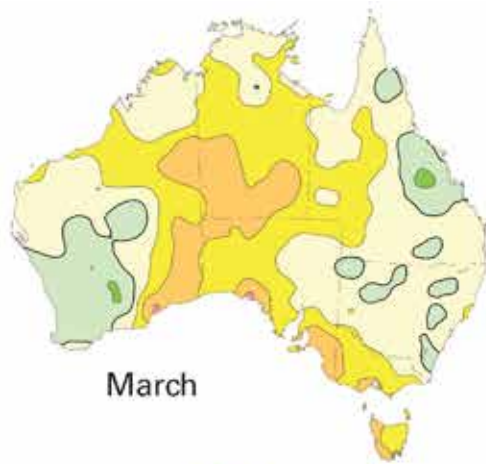
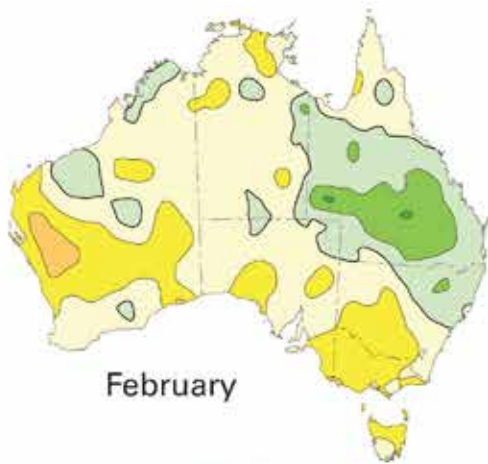
Easterly flow off the continent during November brought consistently hot conditions to western parts of Western Australia, where many locations had their hottest November on record, with patches of above-average temperatures also in the Northern Territory and Queensland. November was cool for the southeast, with minima below average for much of eastern South Australia, New South Wales and northern Victoria and maxima below average for eastern Tasmania and southern Victoria. December was a warm month across the southern mainland and east excluding coastal Queensland, with below-average maxima associated with high rainfall in the northwest and cooler-than-average minima on the Queensland coast and small areas of the tropical north.



Minimum temperatures: departures from average (°C)

Based on a 30-year mean calculated from 1961–1990





5. Monthly rainfall

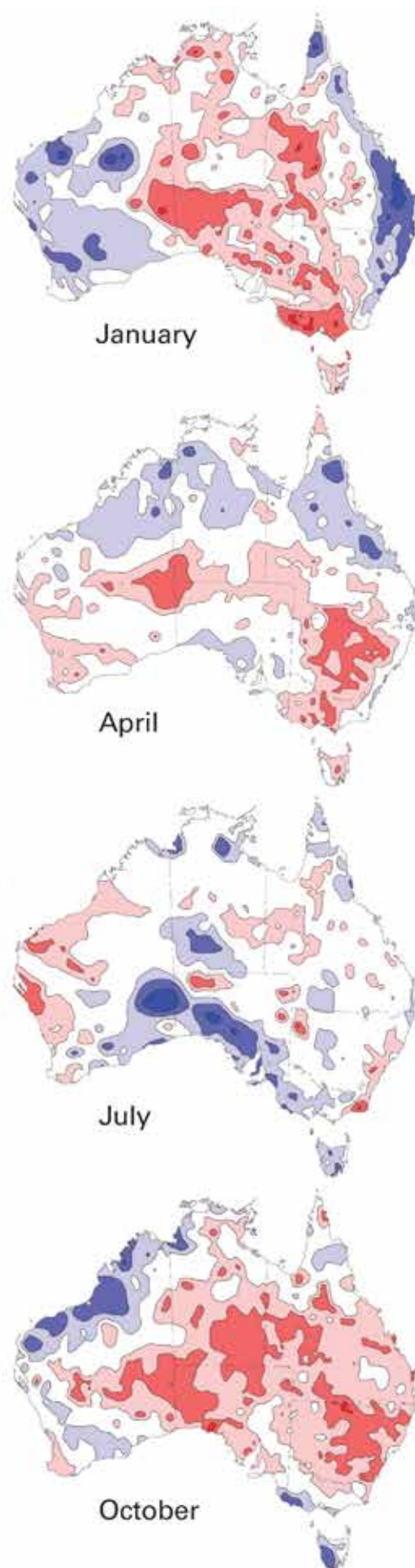
Australian rainfall has been near-average during the past two years, following very high rainfall during 2010 and 2011, associated with La Niña conditions in the tropical Pacific Ocean. With neither La Niña nor El Niño conditions during 2013, a negative Indian Ocean Dipole event between late autumn and early August and a negative phase of the Southern Annular Mode between mid-July and October were the dominant large-scale drivers of climate variability over Australia.

Rainfall over most of Queensland away from the eastern coast has been well below average since late 2012. Following a poor rainy season (December–April), significant rainfall deficiencies developed during 2013 and yearly totals were in the lowest 10 per cent of records for much of the west and inland south. Areas of below-average annual rainfall extended into neighbouring parts of northern inland New South Wales, the eastern Northern Territory and northeastern South Australia. Over the entire Murray–Darling Basin annual rainfall was 24 per cent below average.

West coast Western Australia between Learmonth and Morawa also recorded below-average annual rainfall. Rainfall was above average over much of the Pilbara and interior regions of Western Australia and an area extending inland from Esperance, along the east coast from central Queensland south to Sydney, northern Tasmania and small areas of the tropical north. Rainfall was generally above average along a narrow coastal margin between Sydney and the Eyre Peninsula in South Australia.

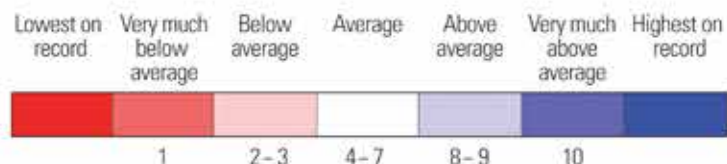
Rainfall during January was very much above average along the east coast of Queensland and New South Wales, corresponding to the track of ex-tropical cyclone *Oswald*. Rainfall was also generally above average for Western Australia but below average elsewhere. It was especially low for Victoria where January was the eighth driest on record. The east coast also received above-average rainfall during February while tropical cyclone *Rusty* contributed to very high February totals in a large area of northwest Western Australia.

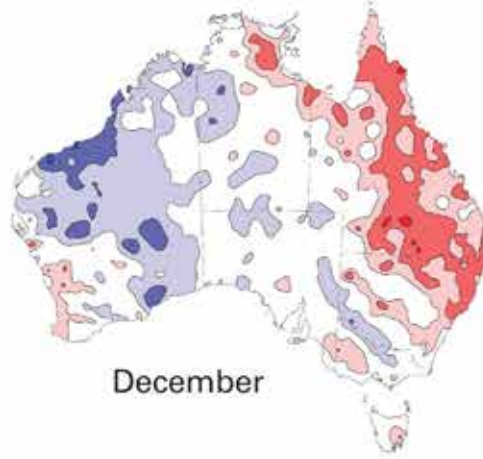
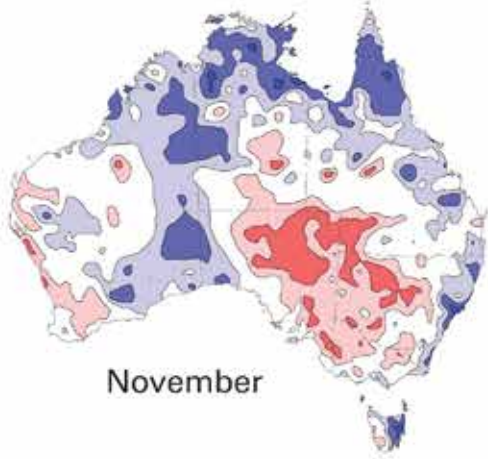
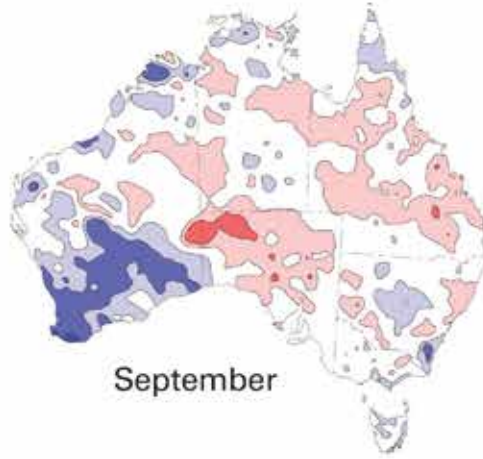
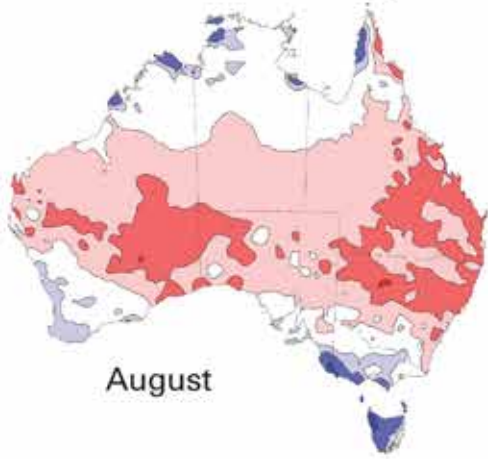
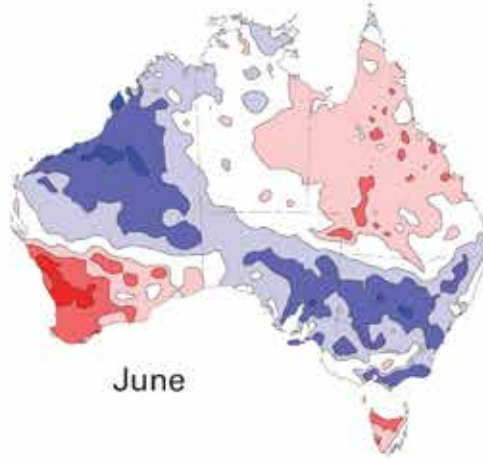
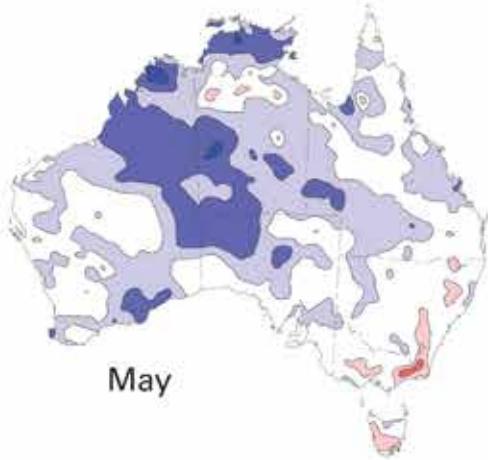
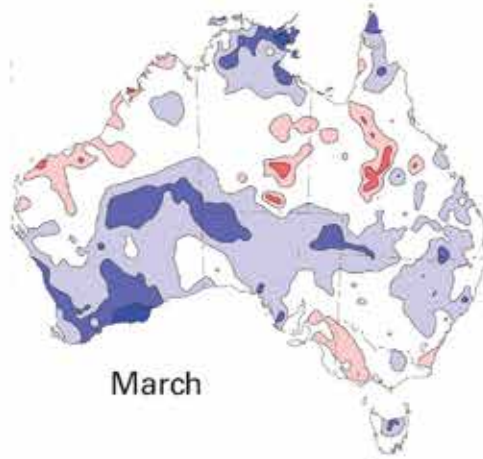
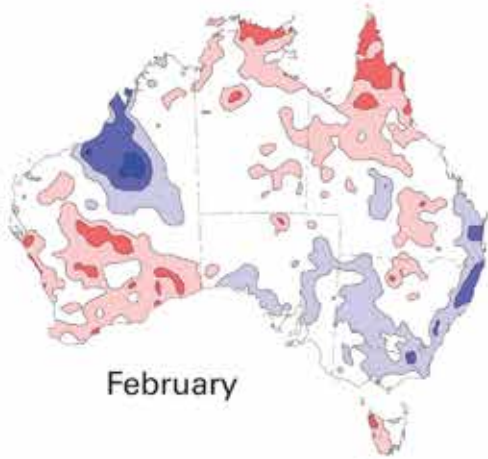
Rainfall was below average for the south of Western Australia during February and above average during March, especially in the region around Esperance. March rainfall was also above average through much of the subtropics, extending to the east coast, as well as across the far north.



Monthly distribution of rainfall deciles

Based on a 114-year climatology of gridded fields from 1900–2013





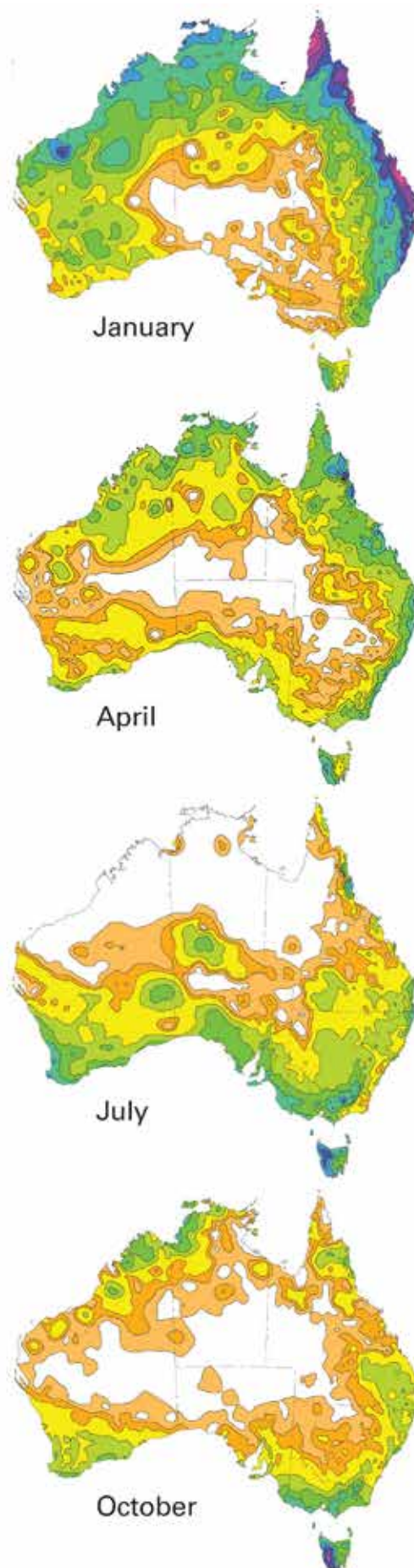
April saw a late finish to the northern wet season, with rainfall again above average across much of the north. For the southeast away from the coast, April was a dry month with monthly totals in the lowest 10 per cent of records for much of inland New South Wales and central Victoria.

Warm water to the northwest of Australia, associated with a negative phase of the Indian Ocean Dipole, enhanced northwest cloudband activity between May and early July. This contributed to above-average May rainfall across much of the mainland, particularly in the northwest, while showers late in the month were responsible for above-average monthly totals in the Top End. Northwest cloudbands also contributed to above-average June rainfall in the northern half of Western Australia, South Australia and the southeast mainland.

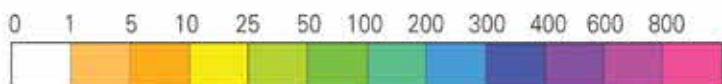
A lack of strong cold fronts resulted in a dry June for the southwestern half of Western Australia and Tasmania, while multiple fronts during July brought above-average rainfall to much of the south coast and Tasmania. The change in weather patterns was associated with a negative phase of the Southern Annular Mode, shifting the subtropical ridge further north and allowing westerly flow to dominate southern Australia. This brought rain to regions of the coast exposed to the westerlies: southwest Western Australia, southeast South Australia, southern Victoria west of Wilsons Promontory and western Tasmania.

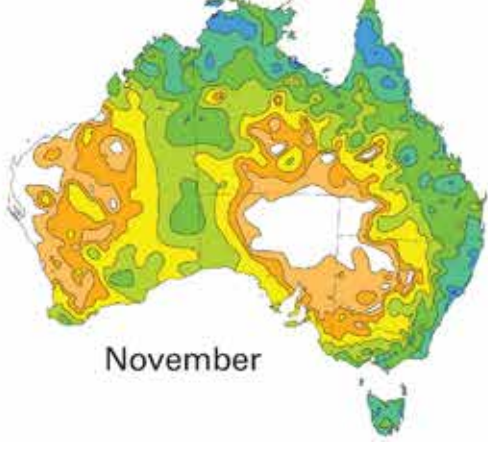
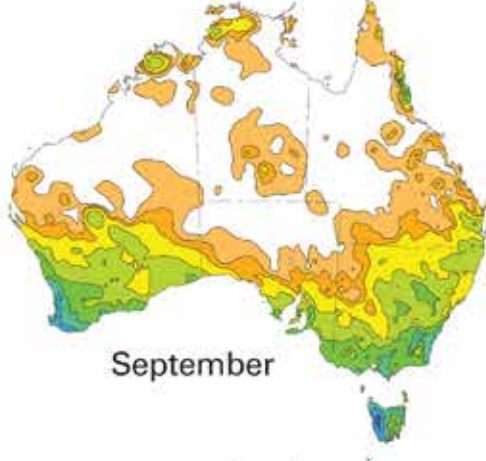
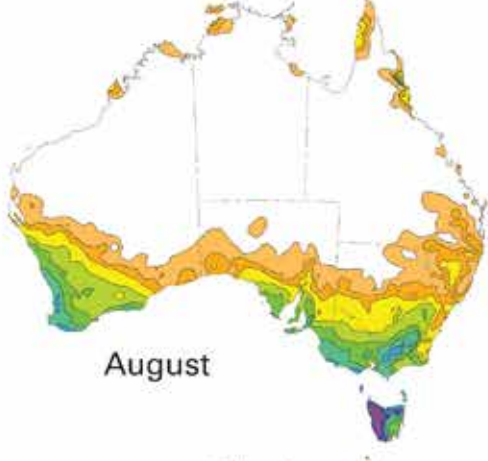
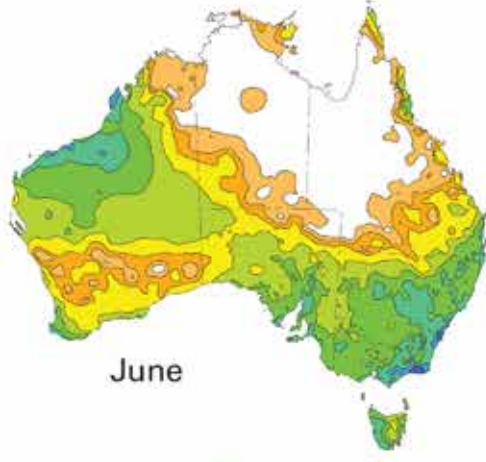
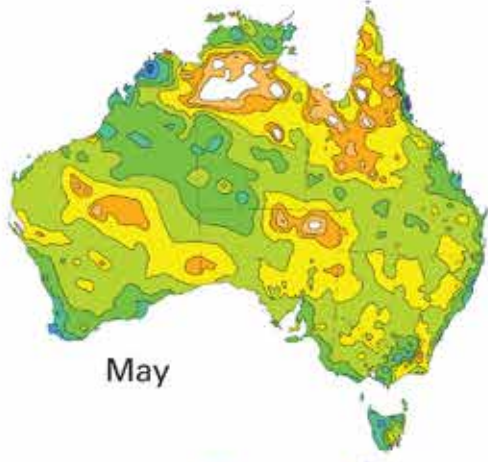
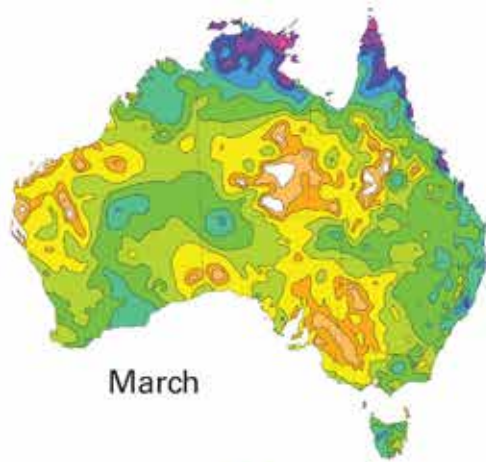
The negative phase of the Southern Annular Mode lasted until October. The August–October index value was the lowest since 1988 and Tasmania recorded its second-highest August–October rainfall. Conversely, this pattern brought dry conditions to Queensland and New South Wales, where August–October rainfall was the fifth- and ninth-lowest on record respectively. The southern half of Western Australia received above-average September rainfall due to several significant cold fronts while humid northeasterlies and showers brought above-average October totals to the coastal northwest.

Most of November was dominated by easterly flow with moist onshore flow bringing above-average rainfall and frequent severe thunderstorms to the eastern mainland coast and eastern Tasmania. The second half of November also saw an early start to the northern wet season, with unusual widespread heavy rain resulting in above-average monthly totals across much of the tropics. Weak monsoonal activity and a persistent ridging of high pressure along the east coast saw below-average December rainfall for much of the eastern States and Top End.

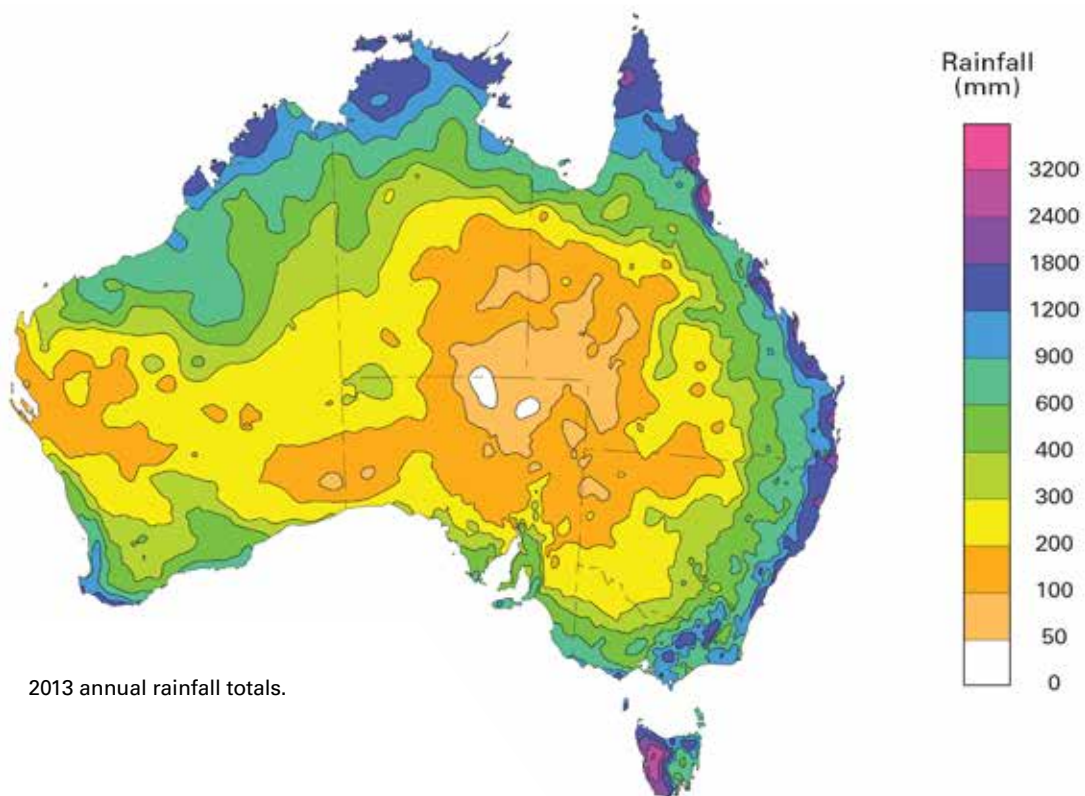
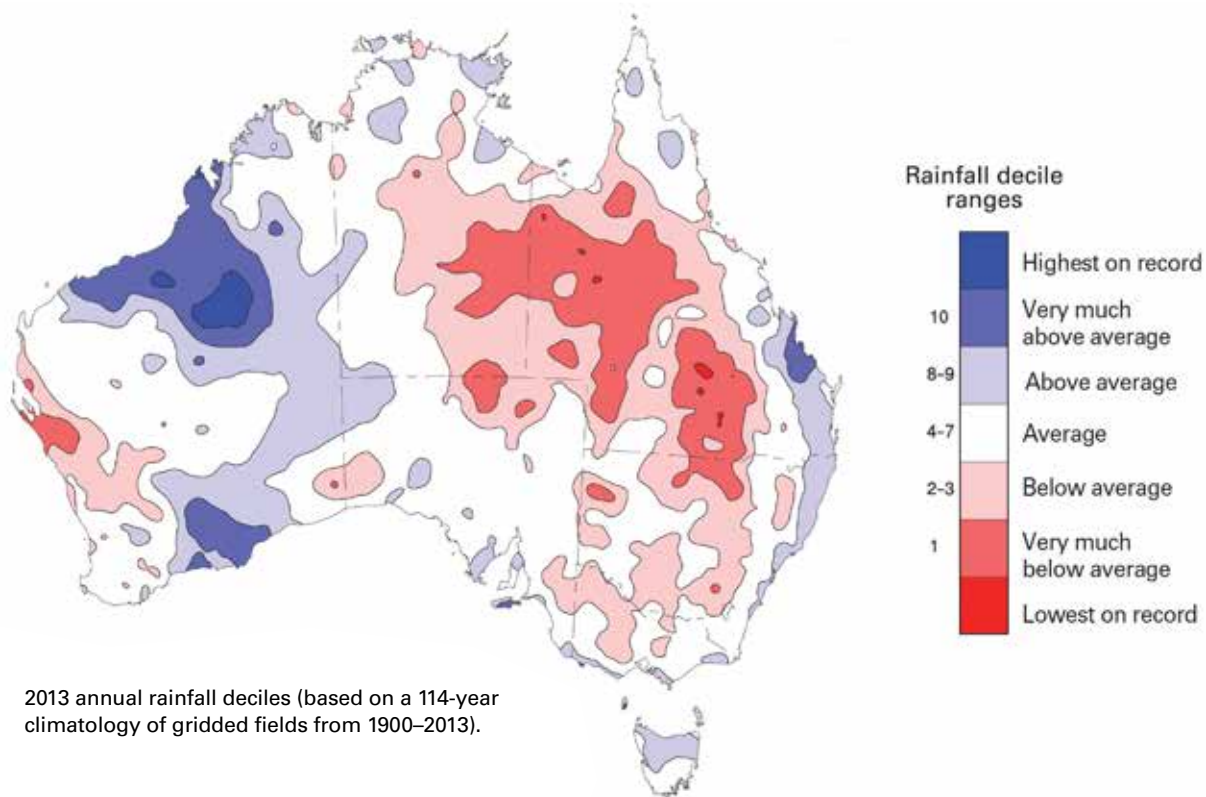


Monthly rainfall totals (mm)





6. Annual rainfall deciles and totals



7. Annual review and significant events

January and February: heat, fires and damaging storms

Numerous heatwaves were recorded during 2013, the first commenced in the last week of December 2012. Heat built over southwest Western Australia before spreading along the southern coastline and covering much of the southeast a few days later. Areas of southern and eastern Australia continued to experience temperatures more than ten degrees above average until 18 December.

A national-average maximum temperature* of 40.30 °C was recorded on 7 January, beating the previous record of 40.17 °C from 21 December 1972. Maxima exceeded 48 °C at many locations in northwest New South Wales, northeast South Australia and western Queensland. The heat was most extreme and persistent in the centre and southern interior of the continent, while records were set in every State and Territory.#

Dry weather, extreme heat and strong winds in early January led to the worst fire danger across the southeast since Black Saturday in 2009. Numerous significant bushfires burnt across southeast Australia during January

*The area-averaged daily maximum temperature, taken across all of Australia.

Special Climate Statement 43—extreme heat in January 2013, Bureau of Meteorology, 7 January 2013:
www.bom.gov.au/climate/current/statements

and February, some for many weeks. Tasmania's most destructive fire of the year was in southeast Tasmania on 4 January, when a fire that started near Forcett rapidly expanded. The Tasman Peninsula was isolated on 4 January. More than 2000 people were evacuated by boat while a further 2000 sheltered at Nubeena. Significant infrastructure, including 193 dwellings and 186 other buildings were destroyed or seriously damaged. There were heavy losses of stock, vehicles and farm machinery. The fire continued to burn for most of the month, eventually reaching over 25 000 ha. Other fires burnt 60 000 ha across the southwest wilderness area.

Victoria's most significant fire for the year started on 17 January near Aberfeldy, east of Lake Thomson, burning 48 000 ha by the following day and 75 000 ha by month's end. As the fire spread the towns of Licola, Heyfield and Newry were threatened, and at least 22 homes were destroyed around Seaton and Glenmaggie, resulting in one death. Other significant fires occurred at Kentbruk, northwest of Portland, when a fire began in a pine plantation on 4 January and moved into the Lower Glenelg National Park, burning more than 7000 ha; west of Ballarat on the night of the 8th, burning 1300 ha and nine properties in communities around Snake Valley; in the Alpine National Park when lightning started a fire near Harrietville on 21 January, eventually burning 35 000 ha; in the Grampians National Park from lightning on 14 February,



The Glenmaggie fire in bushland east of Thomson Dam in Victoria the day after ignition, 18 January. This fire went on to burn 75 000 ha and threatened several towns with the loss of 22 houses. Photograph: Wayne Taylor, *The Sydney Morning Herald*.

continuing to burn well into March and consuming 30 000 ha; and at Donnybrook north of Melbourne when a grassfire burnt more than 2000 ha on 19 February, destroying one house and several factories.

Lightning also started numerous fires in New South Wales, with around 140 significant fires burning by 9 January, mostly across the south of the State. Fortunately few homes were burnt but stock and fencing losses were extensive. Up to 10 000 stock animals were killed and around 500 000 ha burnt in the first half of the month. A fire starting on 13 January burnt more than 54 000 ha in the Warrumbungle National Park and surrounds. The fire was still burning on 20 January, having destroyed 51 homes, numerous farm outbuildings, and several buildings at the Siding Springs Space Observatory.

A tropical low formed in the Timor Sea on 5 January, reaching cyclone strength on the 8th. Severe tropical cyclone *Narelle* reached category 4 strength on the 11th, well offshore of the northwest coast. *Narelle* brought scattered strong thunderstorms along the Western Australian coast, including one on the 15th at Karlgarin in the southwest, which tore roofs from structures.



Wall-cloud and raised dust as severe tropical cyclone *Narelle* approaches Onslow, in Western Australia's Pilbara, 9 January. Photograph: Brett Martin, Perth Weather Live.

Tropical cyclone *Oswald* formed over the Gulf of Carpentaria on 17 January, reaching category 1 strength shortly before making landfall north of Kowanyama, on the western Cape York Peninsula, on 21 January. The ex-cyclone tracked southeastward inland from and parallel to the coast. Heavy rain was recorded in east coast Queensland and as far south as the Illawarra in New South Wales, causing flooding in many areas. Associated storms caused significant erosion on New South Wales and Queensland beaches, while a series of tornadoes damaged more than 150 homes near Bundaberg. Many

**Special Climate Statement 44—extreme rainfall and flooding in coastal Queensland and New South Wales*, Bureau of Meteorology, 5 February 2013: www.bom.gov.au/climate/current/statements/

rainfall records were set during the event.*

Two cyclones from the Arafura Sea affected Western Australia: *Peta*, which grew from a tropical low on 20 January, briefly reaching category 1 before making landfall near Karratha on the 23rd and *Rusty*, developing from a tropical low on 22 February, reaching cyclone strength on the 24th. *Peta* brought heavy rain to much of the western Pilbara and caused Port Hedland to close to shipping. *Rusty* reached category 4 strength before making landfall near Pardoo on 27 February. The large and slow-moving *Rusty* brought heavy rain and destructive winds to coastal regions, major flooding in Pilbara catchments and the far western Kimberley and significant rainfall from the interior to Esperance as the decaying storm travelled south.

An East Coast Low brought flooding rains from southeast Queensland to the Illawarra between 23 and 26 February, causing further major beach erosion on the New South Wales central coast and southeast Queensland. More than 200 homes were damaged on the evening of the 24th in Sydney and the Illawarra. Heavy rain continued into the first days of March in southeast Queensland and eastern New South Wales, causing further flooding in some areas.



Flooding around Dalby, 3 March, following heavy rain across southeast Queensland and eastern New South Wales. Photograph: Western Downs Regional Council.

March: record heatwave for the southeast and tornadoes in Victoria

Southeast Australia experienced a second notable heatwave between 2 and 13 March as a near-stationary high pressure system over the Tasman Sea brought northerlies to the region. Southeast South Australia, Tasmania and southern Victoria felt the brunt of the heat, with a number of notable records set.# The nine days from 4 to 12 March reached at least 32 °C in Melbourne,

#*Special Climate Statement 45—a prolonged autumn heatwave for southeast Australia*, Bureau of Meteorology, 15 March 2103: www.bom.gov.au/climate/current/statements/

setting a record for consecutive days of 30 °C or higher in any month.

A cold front passed through northern Victoria and southern New South Wales on 21 March, spawning super-cell thunderstorms which caused extensive damage and injuries. At least 20 people required hospital attention. Five tornadoes were confirmed along and south of the border between Kerang, Rutherglen and Benalla, with those at Violet Town and Cobram/Yarrawonga estimated to have reached at least F3 intensity (220–266 km/h winds).

April and May: flooding in Tasmania and an East Coast Low

Heavy showers associated with a slow-moving low pressure trough brought isolated but very high rainfall totals and local flash flooding to southeast Tasmania overnight on 8 April. The highest was 156.4 mm during the 24 hours to 9.00 am on 9 April at Eaglehawk Neck, its second-wettest day on record for any month. The State Emergency Service (SES) received call-outs for water in houses at Howden, Copping and Eaglehawk Neck with further flash flooding around Boomer Bay.

An East Coast Low tracked along the east coast between northern New South Wales and southeastern Queensland from 24 to 26 May. Strong winds and two-day rainfall totals in excess of 200 mm between 24 and 25 March were widespread across the Mid North Coast. Wave heights of over 4 m were recorded at Byron Bay and over 5 m at Coffs Harbour with severe erosion at a number of southeast Queensland beaches between 25 and 26 May due to an associated storm surge.

Winter: storms, wind and rain

Thunderstorms and heavy rain affected the mainland southeast between 31 May and 2 June. Record June daily rainfall in Melbourne caused flash flooding, while the Merri Creek and Yarra River reached minor flood levels. A low in the Tasman Sea brought widespread heavy rainfall to parts of southeast Australia in the days following 11 June, especially across Gippsland. Associated with the same system, supercell thunderstorms southwest of Brisbane on the night of the 12th damaged seven houses (destroying one), sheds and a silo in Pratten and Bony Mountain, northwest of Warwick. Trees were uprooted and powerlines downed along a narrow strip 60–100 m wide.

An East Coast Low brought heavy rain and strong winds to coastal southern New South Wales and East Gippsland between 23 and 25 June. Localised flooding, roof damage and downed trees were reported, with more than 700 calls to the SES. Parts of Goulburn were evacuated, as were low-lying areas around Richmond

when the Warragamba Dam spilled, causing minor to moderate flooding in parts of the Hawkesbury–Nepean.

A surface trough saw rare heavy dry season rain in parts of northwestern Western Australia in early June, with West Roebuck recording 202.0 mm in the 24 hours to 9.00 am 6 June. A tropical low brought heavy rainfall over the Pilbara between the 24th and 26th. Karratha tripled its previous record June daily rainfall total with 209.4 mm in the 24 hours to 9.00 am on the 25th, while Roebourne recorded 223.6 mm. Road closures resulted in both events, temporarily isolating some communities.

Strong cold fronts in early July caused roof damage and brought trees down across Tasmania. Power was cut to thousands of houses around Hobart and boats were torn from their moorings in Opossum Bay. Low-level snow, high tides and damaging winds were also recorded across southeast South Australia, Tasmania and Victoria between the 4th and the 6th. Damage was widespread in Melbourne, particularly in the eastern bayside suburbs, mostly related to falling trees.

Heavy rain across northwest Tasmania caused minor flooding, with daily totals to 9.00 am on 15 July approaching 90 mm at some sites and following falls of up to 40 mm on the 13th. Persistent rain over saturated catchments during August resulted in flooding in the north and west. One notable event was flash flooding around Railton, minor flooding on the Meander River and a rock fall near Penguin on the evening of the 5th. Another notable event was flash flooding inundating more than 20 homes around Launceston and Smithton overnight on the 13th, with moderate flooding on the North Esk, Lower South Esk and Lower Meander and closures of some roads and rail lines due to flooding or landslips.

A complex low pressure system and associated cold fronts crossed southern Australia in mid-July. They caused damage, flash flooding in the southwest of Western Australia, including Perth, between the 15th and 17th. The Department of Fire and Emergency Services received more than 138 calls. The South Australian SES received over 250 calls on the 18th as sustained winds of more than 70 km/h were recorded in the southern Mount Lofty Ranges. Power to more than 10 000 houses around Hobart and southeast Tasmania was cut and a handful of sites set July daily rainfall records as the system crossed the state between the 20th and the 22nd. Another strong cold front passed over the south of Western Australia between the 25th and 27th, with damage around Perth, Mandurah, Kalgoorlie, Moora, and York.

A suspected waterspout on 6 August injured six people, two seriously, in Port Coogee, southwest of Perth, when it was driven into a construction site.

Storms associated with a strong cold front swept through southeast South Australia on the afternoon of 3 August. High winds and at least two small tornados felled trees and damaged more than 30 buildings around Kingston, with the second reported at nearby Keilira. A tornado was reported on the 21st, damaging three properties and tipping over a 10-tonne truck near Waterloo Corner, in Adelaide's northern fringe.

Gale-force winds on 12 August felled trees, damaged a number of properties in Sydney, and cut power to more than 17 000 premises—mostly in the southwest and western suburbs. The SES received more than 635 calls in New South Wales and 670 in Victoria as squally showers passed through Melbourne on the same day, where over 9000 homes lost power across around 50 suburbs. Maximum wind gusts in the vicinity of 90 km/h were recorded across both cities.

A strong cold front brought strong to near gale-force winds to coastal South Australia on 16 August and heavy rain in southwest Victoria, causing road closures and minor flooding of some homes around Portland. A second cold front brought strong winds and rain to the coastal southeast, elevated regions and northern Tasmania on the 17th and 18th. The Victorian SES received 330 calls, about half from the metropolitan area. The Tasmanian SES received 150 calls between the 18th and 19th, including some for flash flooding. Snow fell to 400 m and more than 17 roads were closed in the north. Wind damage was also reported in South Australia across the Mount Lofty Ranges.

Spring: heat, storms and extensive bushfires in New South Wales

It was unusually warm across much of Australia in the last week of August and during September. The national-average maximum temperature of 29.92 °C on 31 August was a record for winter. Warm temperatures were widespread and prolonged, especially away from the coast. Numerous station records were set for monthly temperature and early-season records.

Heat and strong winds early in September were significant contributors to an early start to the New South Wales bushfire season. More than 50 bushfires were burning by the 10th, including damaging fires in the Blue Mountains. Further hot and windy conditions on 25 and 26 September fanned fires across the State, with the worst on the Mid North Coast, threatening homes around Taree, Forster, and Port Stephens. A significant fire on the 28th burnt more than 60 per cent of the Barranjoey headland, in Sydney's Northern Beaches.

Dry, hot and windy conditions during October saw more than 100 significant fires burning across the State at

times during the month. A large grassfire at the Olympic Park Aquatic Centre in Homebush destroyed 43 vehicles on the 13th and damaged another 30, while 1500 people were evacuated. Three large fires at Port Stephens destroyed four houses and at least 17 other structures. The situation worsened on the 17th with large fires in the Blue Mountains, the north of the Wollemi National Park and at Port Stephens. The State Mine fire near Lithgow burnt more than 50 000 ha by the end of the month, merging with the smaller fire at Mount Victoria, north of Katoomba. The Springwood fire, northeast of Penrith, was the most damaging. It destroyed 193 homes in Springwood and Winmalee, while damaging a further 122. Fifteen other houses were also lost at Victoria, Lithgow, Wyong, and Balmoral.



Firefighters battle a blaze at Fingal Bay, near Port Stephens, New South Wales, 13 October. Photograph: Jonathan Carroll, *The Sydney Morning Herald*.

Between 21 and 22 September fast-moving cold fronts crossed Western Australia, with major storm surges recorded from Geraldton in the north, to Geographe Bay in the south. Surge peaks up to 110 cm above the Highest Astronomical Tide were recorded at Fremantle, Bunbury and Busselton on both nights. Gusts of 100 km/h to 150 km/h were recorded at coastal sites from Ocean Reef, north of Perth, to Cape Leeuwin. The SES received at least 170 calls and power cuts were widespread. At least 15 houses in Maddington, southeast of Perth, were badly damaged by a tornado.

Fast-moving cold fronts crossed southeastern Australia between the afternoon of 25 September and the 26th, and again between the evening of 29 September and 1 October. Strong to gale-force winds, thundery showers and gusts around or exceeding 100 km/h were widespread in South Australia, Victoria, Tasmania and southeastern New South Wales on both occasions. Damage was reported in Tasmania with fallen trees and power outages, especially in the northwest. Over the two events the SES received about 580 calls across

Adelaide, the Hills and greater southeast; 135 calls in Canberra; 1342 calls in New South Wales, from as far west as Broken Hill although the worst damage was on the Central Coast; and more than 3300 calls in Victoria, mostly in Melbourne and the eastern suburbs where power was cut to 150 000 premises during the second event. Further high winds were observed across Victoria in the first week of October with the eastern suburbs of Melbourne again worst hit; although winds were not as strong as those on the 1st, the SES received another 2000 calls.

A number of early-season heat records were set in the three days to 10 October around the top of the Great Australian Bight, in central Australia, northwestern New South Wales and in the inland north. The exceptional warmth had repercussions for grain farmers across South Australia, with substantial yield losses reported.

Largely as a result of dry conditions, southern New South Wales and northeastern Victoria experienced a number of severe frosts during October, resulting in significant damage to crops, predominantly grains, but wine grapes, stone fruit and strawberries were also affected. Many producers lost at least 50 per cent of their crop. The extensive damage was in part driven by unusual spring warmth, causing plants to develop earlier and faster than normal, exposing them to risks of greater damage from frost.

A deep low and cold fronts brought strong to gale-force winds and isolated thundery showers across southeastern South Australia and northern Tasmania on 1 and 2 October. Sustained gales were reported at several coastal sites with gusts in excess of 90 km/h in South Australia and up to 143 km/h in eastern Tasmania. Reports of storm damage were most common in the Lower South East and the western parts of the Murraylands District while in Tasmania there were more than 30 SES callouts, delays to shipping and air transport and several road closures. Tasmania experienced further high winds on the 15th and 16th.

On 22 October an intense complex low pressure system produced gale-force winds and damaging gusts over southeastern South Australia and Victoria. There were numerous reports of trees down and some property damage in the Lower Eyre Peninsula, southern Yorke Peninsula and across Adelaide and the Mount Lofty Ranges. Later that evening a small tornado passed across Ararat in western Victoria, damaging several homes, sheds and a hardware store. The SES received ten calls in Ararat with around another 100 calls across Victoria for wind and rain damage, 38 from Melbourne.

Thunderstorms over Sydney early on 28 October caused heavy rainfall and flash flooding in the eastern

suburbs while on the 29th an afternoon southerly change produced a more widespread outbreak, with severe thunderstorms along the eastern seaboard from Sydney to southeast Queensland. The New South Wales SES received more than 600 calls for roof damage and downed trees, mostly around and north of Sydney, and six people were injured.

Severe thunderstorms and very large hail continued to be a feature across southeast Queensland and Capricornia during the first half of November. Storms on the 14th caused property damage and extensive agricultural losses. Further storms on the 16th included hail as large as tennis balls in Maroochydore. On the 18th, storms in southeast Queensland and coastal New South Wales spawned a tornado at Hornsby in northern Sydney. Fifteen people were injured at a shopping centre, mostly by falling glass, with roof damage, other minor injuries and numerous felled trees reported. A suspected tornado lifted roofs at Coomera, on the Gold Coast. There were also storms and hail north of Perth on 16 November, causing significant losses for grain farmers in the region.



Damage from the tornado at Hornsby, New South Wales, 18 November. Photograph: News Limited.

Frequent heavy rain in northern and eastern Tasmania brought flash flooding during spring. The most notable falls were across the north and northeast between 16 and 18 September, when Gray (Haven of Hope) reported 119 mm in the 24 hours to 9.00 am on 18 September with over 50 mm at several other sites, and again in the east during November, with very heavy rain between 11.00 pm and 5.00 am on the 12–13th when Gray (Haven of Hope) received 258 mm in the 24 hours to 9.00 am.

November 8 was unseasonably cold in northern Tasmania with several sites setting new records including 9.7 °C at Launceston Airport, the first November day below 10 °C at either the present or previous site.

The northern wet season started unusually early, with widespread heavy rain in the second half of November and an early tropical cyclone. A tropical low reached cyclone strength off the northwest coast on 22 November, *Alessia* then tracked close to the northern Kimberley coast before making landfall south of Darwin as a category 1 storm at 6.30 pm on the 24th. The cyclone subsequently reformed over the Gulf of Carpentaria, making a second landfall east of Borroloola on the 28th. Storm-force winds were reported across the north of the Territory and heavy rain, breaking November daily records in some locations around the Gulf. Records were also set at six sites in the Top End earlier in the month associated with a thunderstorm on the night of the 5th, including Darwin Airport where 105 mm of rain was recorded, the most in its 73 years of record.

December: a warm finish

The year ended with further widespread and persistent warmth. High temperatures developed over southwest Western Australia from 15 December, migrating eastward with maximum temperatures more than 12 degrees above average along large areas of the southern coastline over following days before contracting into inland New South Wales and dissipating by the 22nd. A few sites set daily maximum temperature records for December during the event, the most numerous in southern South Australia on the 19th.

Heat built again during the last week of December, initially over southern Australia but spreading through central Australia into the eastern mainland by the start of 2014. The most extreme temperatures were recorded in the eastern interior where a number of locations in Queensland had their hottest day on record on 29 or 30 December, and several other records were set during the event.

A tropical low formed northwest of Darwin on 22 December then passed over the northern Kimberley before reaching cyclone strength north of Broome on the 28th. *Christine* crossed the Pilbara coast near Roebourne overnight on the night of 30 December as a category 3 storm. Ports in the region were closed to shipping for three days but the cyclone only caused localised coastal flooding and generally minor wind damage between Port Hedland and Karratha. The system weakened as it passed across the Pilbara then became caught in westerly flow over southern Western Australia and turned east, passing across southern South Australia, with the remnants finally dissipating over southwestern New South Wales on 3 January 2014.

SEVERE WEATHER

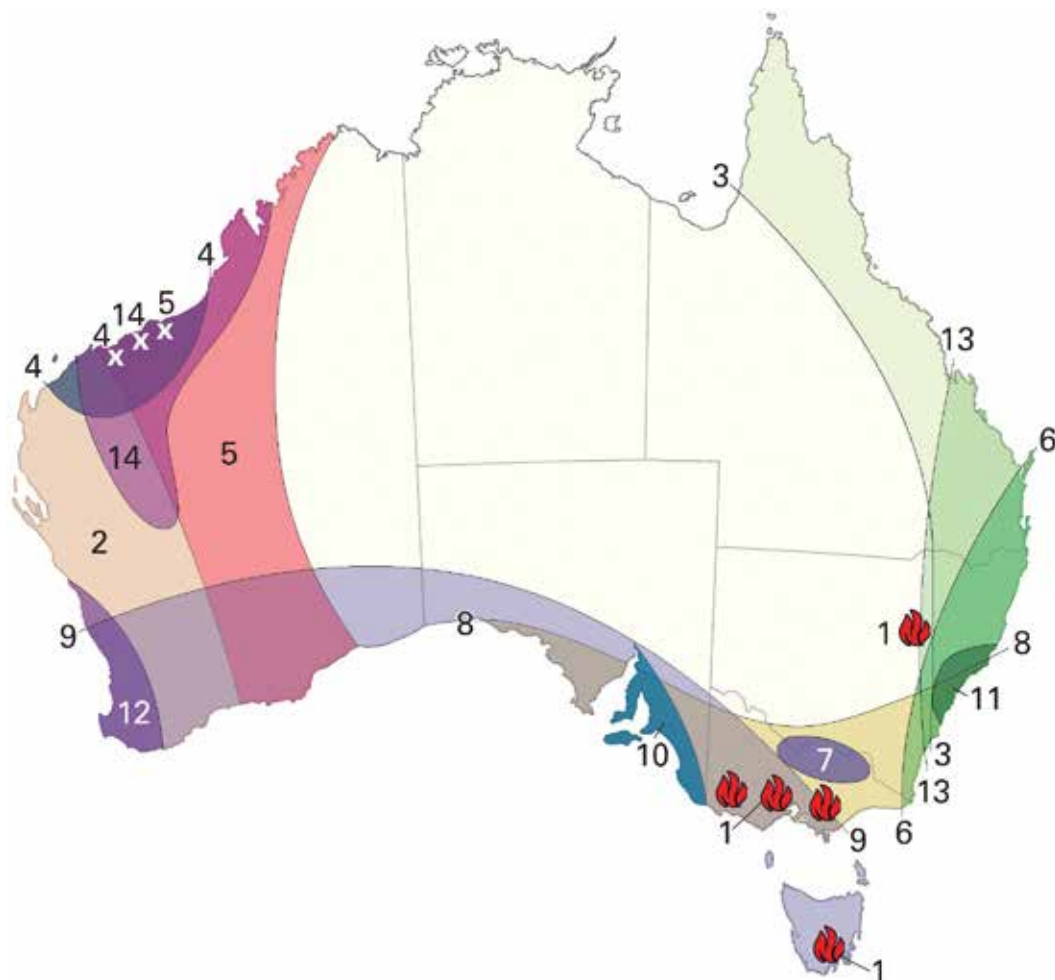
1. Numerous bushfires in southeastern Australia during January and February. Significant fires included the Dunalley fire in Tasmania; fires in Victoria at Glenmaggie, in the north of West Gippsland, at Snake Valley, west of Ballarat, at Mount Hotham, at the Grampians National Park, and at Donnybrook, north of Melbourne; and the Warrumbungle National Park fire in New South Wales.
2. Severe tropical cyclone *Narelle* disrupted shipping and brought scattered storms to parts of Western Australia, but remained offshore as it tracked southwards during the first half of January.
3. Tropical cyclone *Oswald* made landfall north of Kowanyama on 21 January. The ex-cyclone later caused heavy rain, flooding and tornadoes in areas of east coast Queensland and as far south as the Illawarra.
4. Tropical cyclone *Peta* made landfall near Karratha on 23 January, brought heavy rain to much of the western Pilbara and caused Port Hedland to close to shipping.
5. Severe tropical cyclone *Rusty* made landfall near Pardoo on 27 February, caused flooding in the Pilbara and western Kimberley and significant rainfall from the interior to Esperance over the following days.
6. Flooding from southeast Queensland to the Illawarra associated with an East Coast Low between 23 and 26 February, with further heavy rain and flooding in some areas in early March. This East Coast Low and another between 24 and 26 May caused significant erosion at multiple beaches.
7. Severe storms with the passage of a cold front through northern Victoria and adjacent southern New South Wales on 21 March. At least five tornadoes were reported along and south of the border.
8. There were numerous episodes of damaging winds in southern Australia in winter and spring, most associated with the passage of strong frontal systems.
9. Storm damage and flash flooding in Perth and southwest Western Australia between 15 and 17 July, followed by damage and sustained high winds in South Australia on the 18th and southeast Tasmania between the 20th and the 22nd as a cold front crossed southern Australia. Another front caused damage in the south of Western Australia between the 25th and 27th.

- 10. Storm damage in southeast South Australia on 3 August, with tornadoes reported near Kingston and Keilira.
- 11. Significant bushfires in New South Wales during September and October, including severe fires in the Blue Mountains and Wollemi National Park, on the Mid North Coast, at Port Stephens and the Barranjoey headland and at the Olympic Park Aquatic Centre in Homebush.
- 12. Major storm surges in coastal Western Australia from Geraldton to Geographe Bay associated with the passage of fast-moving cold fronts between 21 and 22 September, accompanied by storm damage.
- 13. Thunderstorms, heavy rain and localised flash flooding in Sydney on 28 October and more broadly from Sydney to southeast Queensland on the 29th. Severe thunderstorms and hail up to the size of tennis-balls were also reported across greater southeastern Queensland and coastal New South Wales during the first half of November.

- 14. Severe tropical cyclone *Christine* made landfall near Roebourne, in the Pilbara, overnight on 30–31 December, causing local coastal flooding and generally minor wind damage between Port Hedland and Karratha.



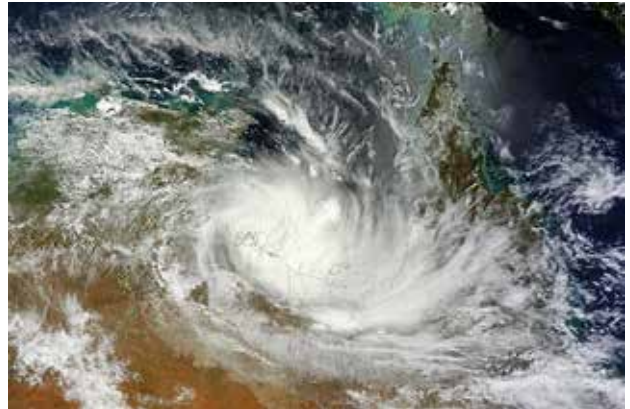
Floodwaters flowing down the Burnett River at Bundaberg, Queensland, following heavy rain associated with ex-tropical cyclone *Oswald*, 29 January. Photograph: Chris Hadfield, taken aboard the International Space Station.



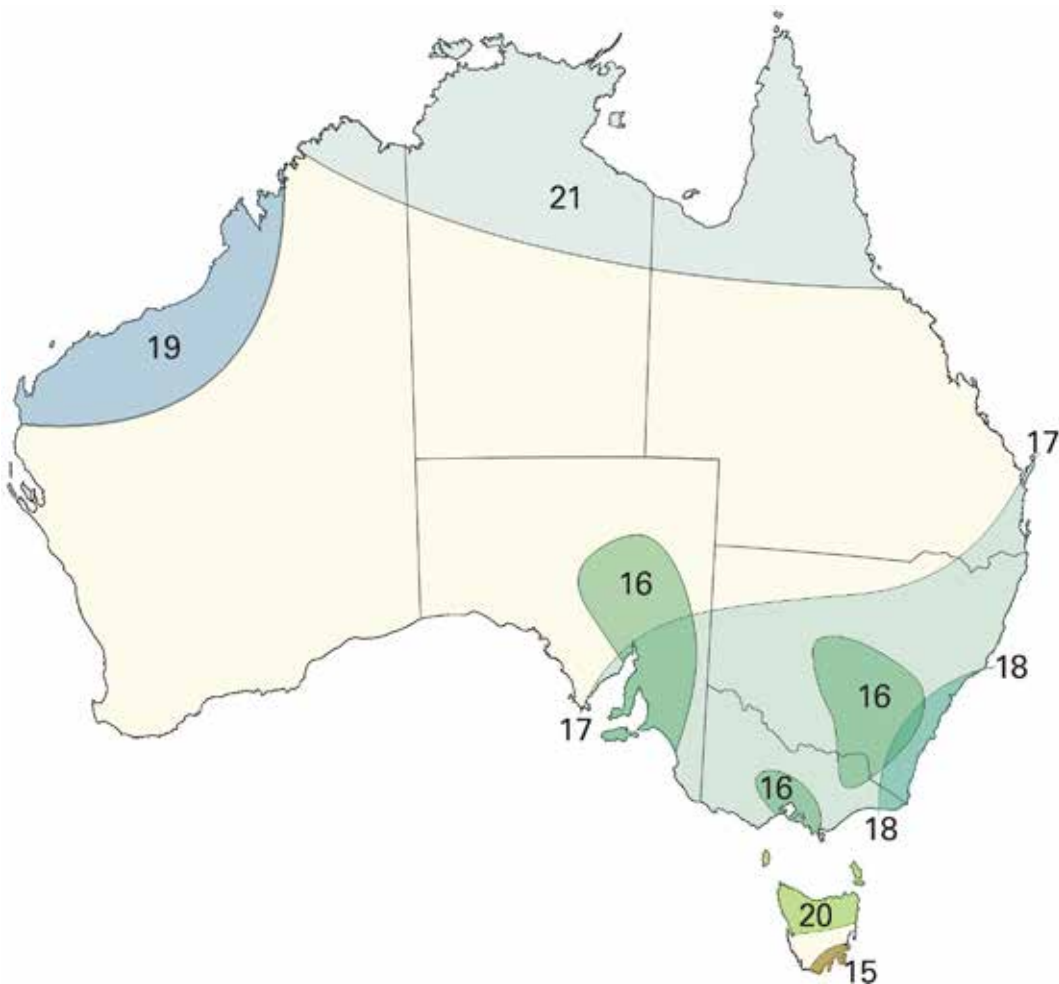
RAINFALL / FLOODS

15. Flash flooding in parts of southeast Tasmania following heavy overnight showers on 9 April.
16. Thunderstorms and heavy rain in parts of the mainland southeast between 31 May and 2 June caused localised flash flooding in parts of South Australia and in Melbourne.
17. Heavy rain in parts of southeastern Australia between 11 and 14 June, with some flooding in Gippsland. Damaging thunderstorms southwest of Brisbane on the night of the 12th were associated with the same system.
18. Localised flooding and wind damage between 23 and 25 June in coastal southern New South Wales and East Gippsland due to an East Coast Low.
19. Significant rainfall in northwestern Western Australia in early June, and again between the 24th and 26th, resulting in minor flooding and road closures.
20. Several occurrences of flooding in northern Tasmania during winter and spring owing to persistent, frequently heavy rain over saturated catchments.

21. Early start to the northern wet season, with heavy rain in the second half of November and an early tropical cyclone, *Alessia*, which made landfall south of Darwin on the 24th and south of the Gulf of Carpentaria on the 28th.



Tropical cyclone *Alessia*, shown here over the Gulf of Carpentaria on 27 November, was one of only four cyclones recorded in November in the Australian region. Image captured by the MODIS instrument on NASA's Terra satellite.



TEMPERATURE

22. One of the most significant heatwaves on record, with temperatures well above average over much of southern and eastern Australia from late December until 18 January. The national-average maximum temperature on 7 January (40.30 °C) was unprecedented.

23. A second heatwave in southeast Australia between 2 and 13 March, with the worst of the heat felt in southeast South Australia, Tasmania and southern Victoria.

24. Exceptionally warm conditions across much of Australia from late August through September, including a winter-record national-average maximum temperature on 31 August (29.92 °C).

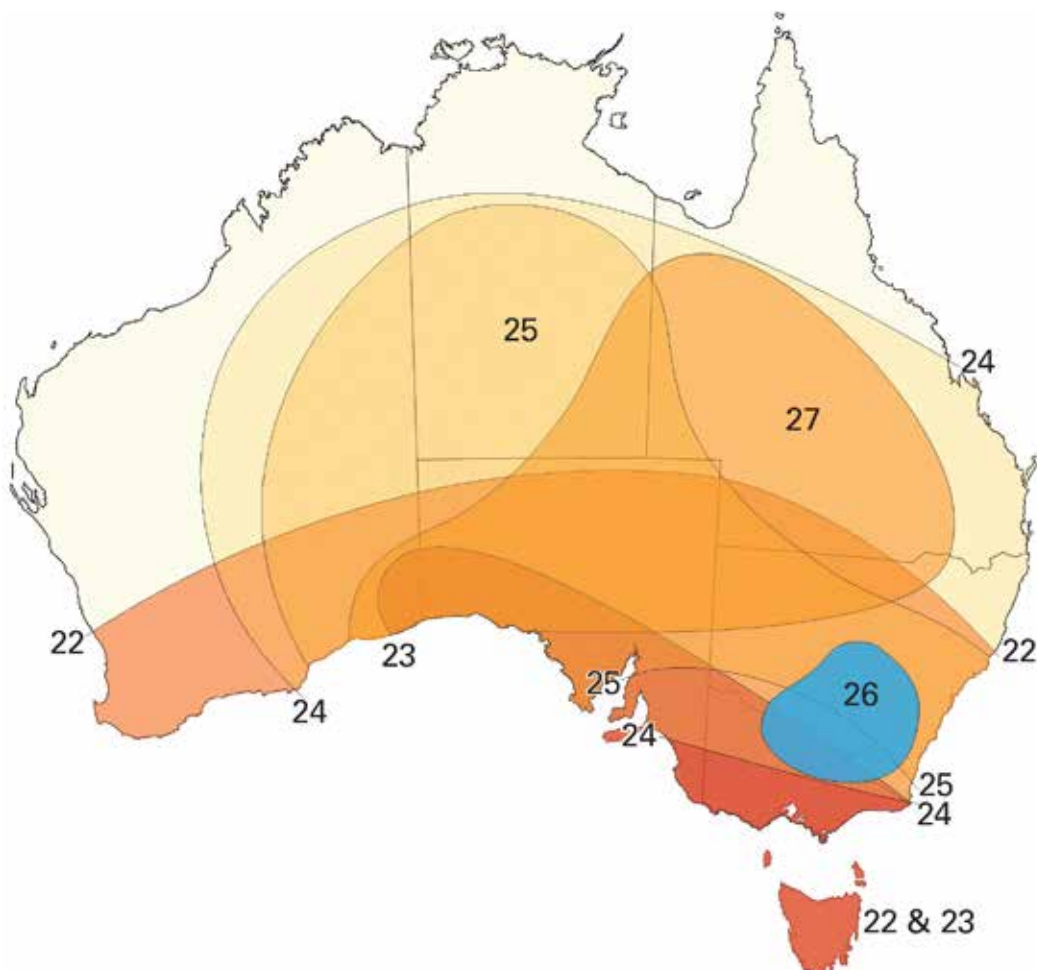
25. Widespread warmth between 8 and 10 October, with early-season heat records set around the top of the Bight, central Australia, northwestern New South Wales and the inland north.

26. Significant crop damage from a number of severe frosts in southern New South Wales and northeastern Victoria during October.

27. Extreme heat developed over southern, central and eastern Australia during the last week of December with particularly high temperatures continuing into the first days of 2014 in the eastern interior.



Frost-damaged Chardonnay vines near Griffith, in the New South Wales Riverina, 31 October. Photograph: Kristy Bartrop, Wine Grapes Marketing Board, Department of Primary Industries, New South Wales.



NEW SITE RECORDS

New site records set in 2013, for selected stations with more than 40 years of record, are shown below.

Record-high daily rainfall

Station name	State	Highest daily rainfall (mm)	Previous record (mm)	Years of record
Mundagai	Qld	210.0 on 20 Jan	143.5 on 7 Dec 1970	45
Beau Maison	Qld	154.2 on 20 Jan	136.1 on 5 Nov 1938	99
Weipa (Eastern Ave)	Qld	352.2 on 23 Jan	279.2 on 31 Jan 1982	100
Moonmera	Qld	538.2 on 25 Jan	381.0 on 21 Feb 1929	113
Duaringa Post Office	Qld	256.8 on 26 Jan	219.2 on 20 Dec 1973	127
Theebine	Qld	350.0 on 27 Jan	283.2 on 8 Jan 2011	114
Mundubbera	Qld	314.9 on 27 Jan	178.6 on 20 Jan 1929	103
Biggenden Post Office	Qld	295.8 on 27 Jan	246.4 on 13 Jul 1954	116
Gayndah	Qld	282.8 on 27 Jan	185.4 on 20 Jan 1929	114
Kingaroy	Qld	234.0 on 27 Jan	169.0 on 8 Feb 1981	109
Blackbutt Post Office	Qld	194.8 on 27 Jan	181.0 on 9 Feb 1999	104
Cooyar Post Office	Qld	180.0 on 27 Jan	179.6 on 12 Jan 1910	109
Tarome	Qld	297.6 on 28 Jan	247.0 on 27 Jan 1974	103
Old Koreelah (McPherson)	NSW	205.0 on 28 Jan	176.8 on 19 Feb 1961	102
Pine Ridge (Billabong)	NSW	131.0 on 29 Jan	114.8 on 24 Feb 1955	90
Dellicknora (Tellicura)	Vic.	136.0 on 29 Jan	127.0 on 28 Jan 1920	97
Yarras (Mount Seaview)	NSW	415.2 on 23 Feb	234.6 on 20 Mar 1978	52
Leigh (Rolling Acres)	NSW	386.0 on 23 Feb	325.0 on 9 Mar 2001	40
Ebor (Maplewood)	NSW	290.0 on 23 Feb	257.0 on 9 Mar 2001	40
Birdwood	NSW	257.0 on 23 Feb	217.4 on 20 Mar 1978	45
Tia (Highrent)	NSW	114.8 on 23 Feb	105.8 on 22 Feb 1977	53
Cocos Island Airport		416.0 on 25 Feb	322.6 on 6 Oct 1910	106
Glen-Ayle	WA	177.5 on 1 Mar	169.0 on 2 Feb 1997	64
Orange Agricultural Institute	NSW	103.4 on 1 Mar	98.6 on 24 Jan 1992	48
Bowen Downs	Qld	188.8 on 5 Mar	151.0 on 23 Mar 1976	124
Murray Lagoon (Hawks Nest)	SA	150.8 on 12 Jun	101.6 on 21 Feb 1930	96
Flinders Chase (Rocky River)	SA	82.2 on 12 Jun	76.8 on 29 Nov 1977	54
Biala (Alvison)	NSW	124.0 on 25 Jun	99.0 on 27 Jun 1997	76
Paterson Post Office	NSW	214.6 on 18 Nov	200.7 on 10 Dec 1920	113

There were many extreme rainfall totals at the end of January in Queensland and New South Wales. The list above shows only a small sample from sites with long records. More details are contained in *Special Climate Statement 44—extreme rainfall and flooding in coastal Queensland and New South Wales*.

Record-high daily maximum temperature (°C)

Station name	State	Highest temperature (°C)	Previous record (mm)	Years of record
Adelaide Airport	SA	44.1 on 4 Jan	44.0 on 28 Jan 2009	58
Hobart (Ellerslie Road)	Tas.	41.8 on 4 Jan	40.8 on 4 Jan 1976	118
Grove	Tas.	40.9 on 4 Jan	40.4 on 19 Jan 1959	54
Hobart Airport	Tas.	40.3 on 4 Jan	40.1 on 3 Jan 1991	55
Bushy Park (Bushy Park Estates)	Tas.	40.3 on 4 Jan	39.5 on 20 Jan 1973	52
Larapuna (Eddystone Point)	Tas.	36.5 on 4 Jan	36.1 on 16 Jan 1960	55
Hay (Miller Street)	NSW	47.7 on 5 Jan	47.2 on 1 Feb 1968	55
Wiluna	WA	48.0 on 8 Jan	46.9 on 25 Dec 1990	55
Meekatharra Airport	WA	47.1 on 8 Jan	45.7 on 5 Jan 2008	62
Leonora	WA	49.0 on 9 Jan	47.8 on 17 Jan 1958	57
Tibooburra Post Office	NSW	47.9 on 12 Jan	47.6 on 3 Jan 1973	98
Nyngan Airport	NSW	47.0 on 12 Jan	46.8 on 15 Jan 2001	53
Walgett	NSW	48.5 on 13 Jan	46.5 on 4 Jan 1973	134
Cunnamulla Post Office	Qld	47.0 on 13 Jan	46.9 on 4 Jan 1973	55
Thargomindah	Qld	18.8 on 13 Jan	47.5 on 3 Jan 1994	57
Giles Meteorological Office	WA	45.7 on 16 Jan	44.8 on 28 Jan 2011	57
Sydney Airport AMO	NSW	46.4 on 18 Jan	45.2 on 1 Jan 2006	73
Richmond	NSW	46.4 on 18 Jan	44.9 on 15 Jan 2001	78
Sydney (Observatory Hill)	NSW	45.8 on 18 Jan	45.3 on 14 Jan 1939	154
Nowra	NSW	45.4 on 18 Jan	45.1 on 30 Jan 2003	59
Williamstown RAAF	NSW	44.8 on 18 Jan	44.4 on 1 Jan 2006	63
Moruya Heads Pilot Station	NSW	43.8 on 18 Jan	43.3 on 1 Feb 1968	57
Newcastle Nobbys Signal Station AWS	NSW	42.5 on 18 Jan	42.0 on 23 Dec 1990	55

Extremely high daytime and warm overnight temperatures occurred several times through the year. The table above shows only those sites with at least 50 (maximum) or 30 (minimum) years of record that set new annual temperature records. More details can be found in *Special Climate Statement 43—extreme heat in January 2013*, *Special Climate Statement 45—a prolonged autumn heatwave for southeast Australia*, and *Special Climate Statement 46—Australia's warmest September on record*.

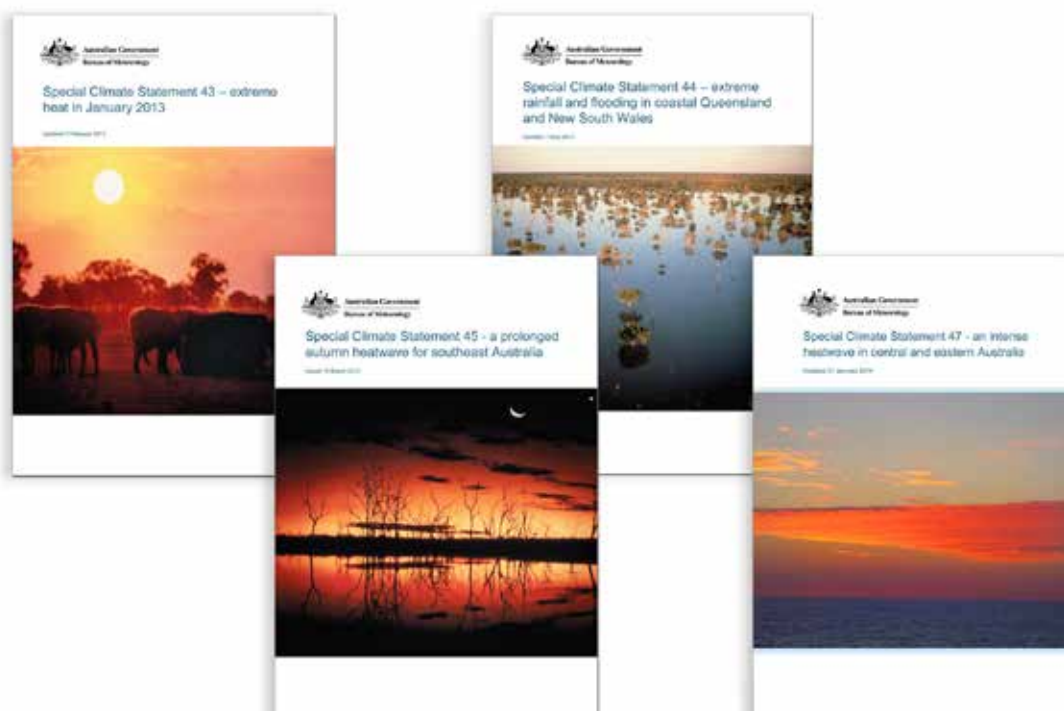
Record-low daily minimum temperature (°C)

Station name	State	Highest minimum (°C)	Previous record (°C)	Years of record
Beverley	WA	-3.8 on 8 Jul	-3.6 on 16 Jun 2006	45

Record-high daily minimum temperature (°C)

Station name	State	Highest minimum (°C)	Previous record (°C)	Years of record
Merredin	WA	29.7 on 8 Jan	29.4 on 27 Feb 1997	48
Jarrahwod	WA	26.0 on 8 Jan	24.4 on 6 Mar 1990	30
Bridgetown	WA	24.5 on 8 Jan	24.0 on 28 Dec 2000	104
Thredbo Village	NSW	21.0 on 8 Jan	20.2 on 8 Feb 2009	42
Scone SCS	NSW	29.9 on 9 Jan	29.7 on 28 Nov 1980	35
Lostock Dam	NSW	28.5 on 9 Jan	27.1 on 28 Nov 1980	41
Trangie Research Station AWS	NSW	31.3 on 18 Jan	29.3 on 12 Feb 2004	44
Mango Farm	NT	28.0 on 26 Jan	27.4 on 6 Jan 1998	33
Longreach Aero	Qld	30.7 on 30 Dec	30.6 on 4 Feb 1968	48

Warm overnight temperatures occurred several times through the year. The table above shows only those sites with at least 30 years of record that set new annual temperature records. More details can be found in *Special Climate Statement 43—extreme heat in January 2013*, *Special Climate Statement 45—a prolonged autumn heatwave for southeast Australia*, and *Special Climate Statement 46—Australia's warmest September on record*.



Special Climate Statements provide a detailed summary of significant weather and climate events. They are produced on an occasional basis for weather/climate events which are unusual in the context of the climatology of the affected region. They provide a historical record, inform the public on the broader historical and climatological context for events, and give easy access to data and information. www.bom.gov.au/climate/current/statements/

8. Oceans: sea level and sea surface temperatures

The El Niño–Southern Oscillation (ENSO) is a significant influence on sea level and sea surface temperature in the tropical Pacific Ocean, and throughout 2013 ENSO was in its neutral state. Temperatures were generally slightly below normal in the eastern equatorial Pacific, but remained within neutral thresholds for the entire 12 months. In the central equatorial Pacific temperatures were very close to average. Some of the monthly anomalies patterns, while having some characteristics of a La Niña event, remained within the neutral range.

Sea level

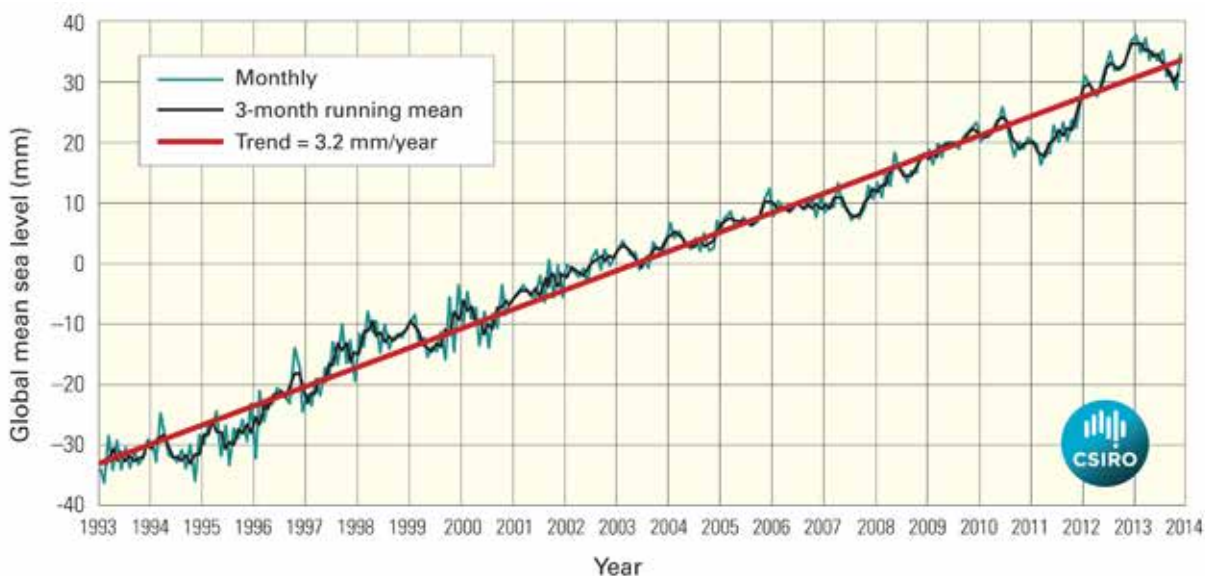
Using high-quality global sea-level measurements from satellite altimetry over the period 1993–2013, globally-averaged sea level has increased at a rate of 3.2 mm/year. This corresponds to an increase of approximately 7 cm in global mean sea levels over the same period. The variations in sea level over months to a few years can be dominated by natural climate variability.

Global average sea-level rise is the result of the expansion of the oceans as they warm and the addition of mass to the ocean from glaciers, small ice caps, and the ice sheets of Greenland and Antarctica.

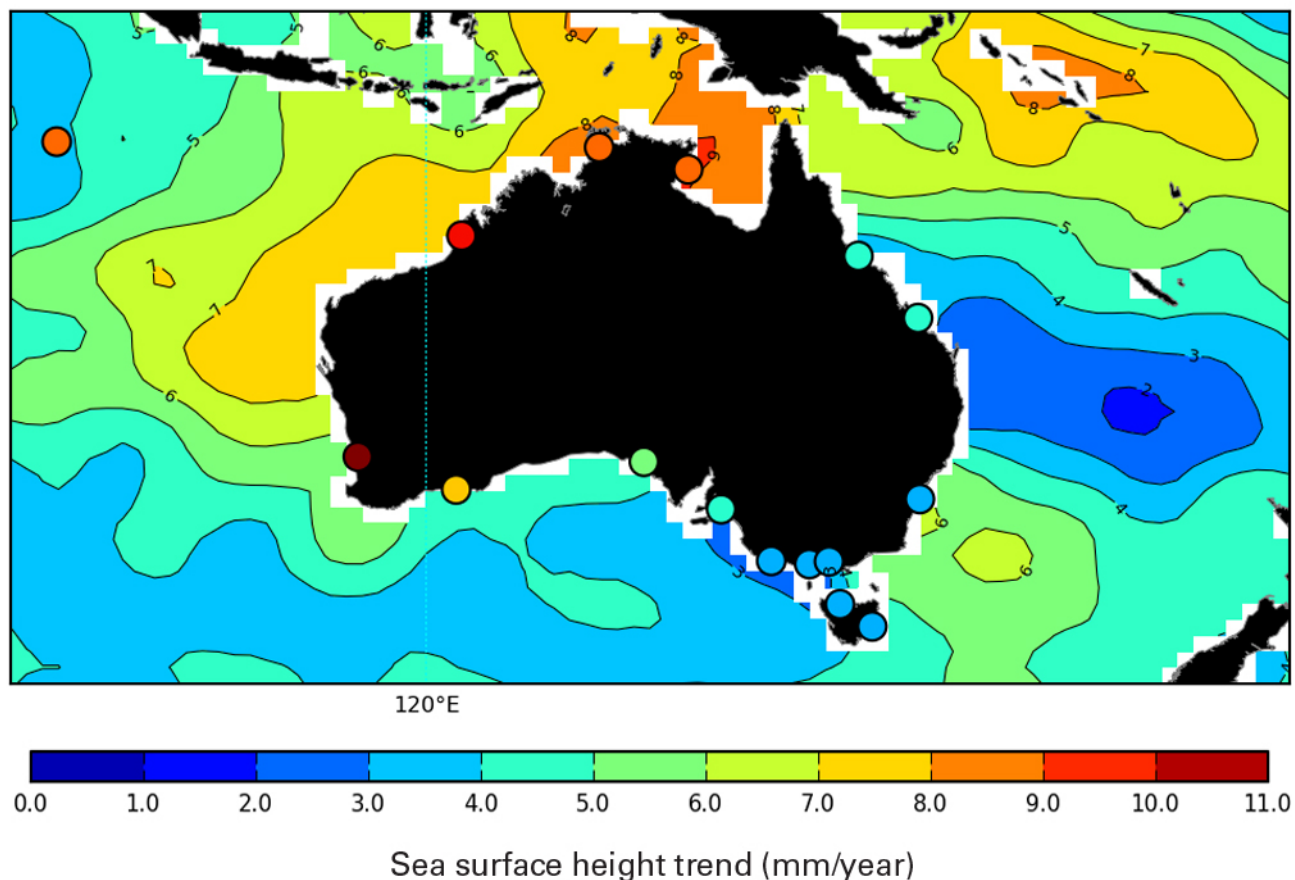
Sea level, and changes in sea level, are not uniform around the globe and are influenced by events such as

the El Niño–Southern Oscillation and changes in winds and currents on a range of timescales. This means that local and regional sea-level rise can be above or below the global mean rate. Rates of sea-level rise to the north and northwest of Australia over the measurement period have been two-to-three times the global average—that is, 8–10 mm/year. This is at least partly the result of the early 1990s being dominated by El Niño events, which lowered sea level in this region, contrasting with recent years which were affected by La Niña events. Care must be taken in interpreting individual tide gauges. For example: the greater apparent sea-level rise at Hillarys tide gauge near Perth is thought to be associated with sediment compaction and sinking of the coastal tide gauge, possibly due to ground water extraction. While the local sea-level rise relative to the coast observed at Hillarys is real, it cannot be compared directly with the absolute sea-level rise.

Oceans play a major role in the global climate system by absorbing heat energy, including upwards of 90 per cent of recent global warming. Over the past 40 years, heat has been accumulating primarily in the upper ocean, acting to reduce the rate of atmospheric warming. The oceans surrounding Australia continued to absorb heat during 2013, increasing the sea level through thermal expansion.



Global mean sea level from satellites from January 1993 to November 2013. The seasonal signal has been removed and small corrections applied for changes in atmospheric pressure. The light blue line shows the monthly data, the black line the three-month moving average, and the red line the linear trend. Source: CSIRO.



The rate of sea surface height rise measured by coastal tide gauges (coloured dots) and satellite observations from 1993–2013. Note: satellite observations have had the seasonal signal removed and small corrections applied for changes in atmospheric pressure. Source: Australian Baseline Sea Level Monitoring Project and CSIRO.

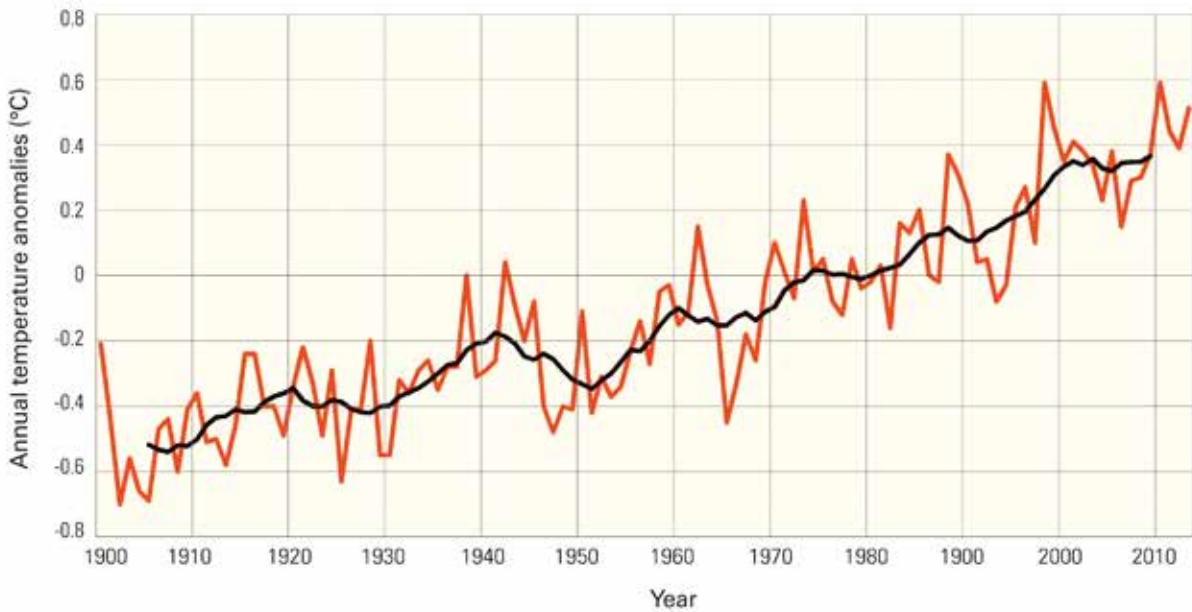
Sea surface temperatures

2013 saw higher-than-average sea surface temperatures (SST) in the oceans surrounding Australia. SSTs in the Australian region were 0.52 °C above the 1961–1990 average. This year ranked third-highest since 1910, beaten only by the record-setting La Niña years of 2010 and 1998. This ocean warmth continued the long pattern of years with significantly above-average temperatures; the Australian region has not experienced below-average SSTs since 1994.

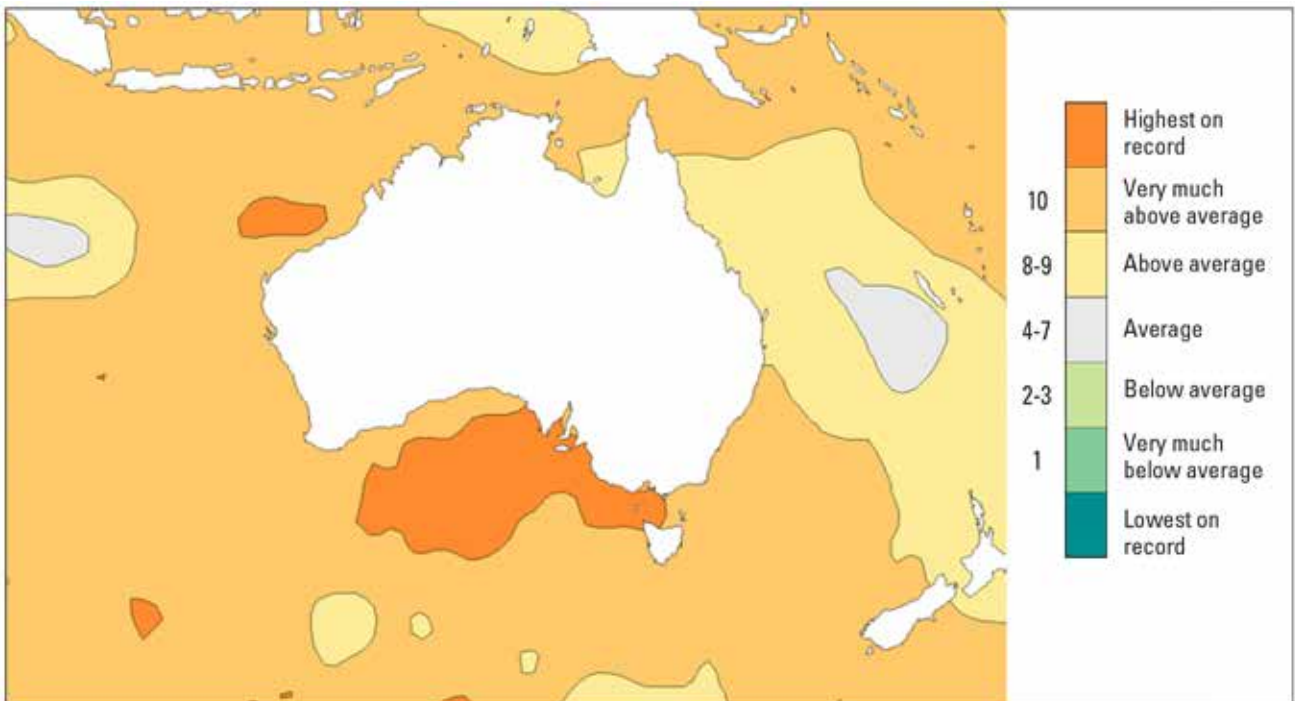
Over the past ten years the Australian region recorded SSTs that were 0.37 °C higher than average. This value is the warmest decade since the start of records in 1900, and is 0.01 °C above the record ten-year value held by 1998–2007. There has been a total rise in SST of approximately 0.9 °C since 1910, which is very similar to the observed warming of the near-surface atmosphere as measured over land.

All of the monthly SST anomalies (January, February, etc.) for the Australian region in 2013 ranked in the top 12 observed for that month; only June and July ranked outside the top five values. January, February and summer SST anomalies were the highest on record. The annual SSTs in the southern region were 0.59 °C above average, surpassing the annual record (+0.56 °C in 1999) by 0.03 °C.

Monthly SSTs in the Indian Ocean and off the coast of Western Australia persisted at higher-than-average values, a pattern which has continued since 2010. During 2013 a negative phase of the Indian Ocean Dipole developed rapidly during late autumn, and remained in place through to the end of July before breaking down in early August. The negative Indian Ocean Dipole phase contributed to above-average rainfall over large parts of Australia in the May–July period.



Annual mean sea surface temperature anomalies (1910–2013) for the Australian region (averaged over the area defined by a box from 0° to 50°S and from 94° to 174°E). The black line shows the ten-year moving average. Values are from the National Oceanographic and Atmospheric Association Extended Reconstructed Sea-Surface Temperature (NOAA_ERSST_V2) data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA.



January–December 2013 sea surface temperature deciles calculated with respect to the 1900–2013 period from the NOAA_ERSST_V3 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA.

For further information

National Climate Centre

Bureau of Meteorology

PO Box 1289, Melbourne Vic 3001

Contact hours: 10.00 am – 12.00 pm and 2.00–4.00 pm

Email: helpdesk.climate@bom.gov.au

www.bom.gov.au/climate