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Special Climate Statement 59—humidity, heavy rain and heat in central and southern Australia

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1 Introduction

A low pressure system which originated over the Top End of the Northern Territory brought tropical conditions over a wide area of Australia in the final days of December 2016. These conditions included high temperatures, heavy rainfall at both short and longer durations, and exceptionally high levels of atmospheric moisture (humidity).

Heavy rain affected a region extending from the Kimberley in northern Western Australia, and progressively south through the eastern interior of Western Australia, the southern Northern Territory, and most of South Australia. High-intensity short-duration rainfalls affected many areas further east as severe thunderstorms developed in very humid air in northerly flow to the east of the low, particularly in Victoria. The rains resulted in substantial flooding in central Australia and in parts of the Kimberley. There was also flash flooding in parts of South Australia and Victoria, with metropolitan Melbourne amongst the most-affected areas.

Temperatures were well above average in the northerly flow to the east of the system. Overnight minimum temperatures were particularly high. December records were set at a number of locations in coastal New South Wales and around Melbourne. At a statewide level, records for persistent overnight warmth were set in Victoria and Tasmania.

The penetration of such a tropical air mass into the southeastern part of the continent has few recorded precedents. The nature of the air mass was indicated both by its precipitable water content (an indication of the total moisture content of the air mass) and by the surface dewpoint[1] (an indication of the amount of moisture in the air mass at the surface). Records were set for both of these indicators at numerous locations, with dewpoints in southern Victoria reaching levels more characteristic of Darwin at the peak of the wet season than of southern Australia.

[1] The dewpoint is the temperature which a given parcel of air would need to be cooled to in order for dew to start to form. Since the amount of moisture air can hold increases with increased temperature, a higher dewpoint indicates a higher total moisture content of the air.

2 Event details

2.1 The evolution of the system

A tropical low formed over the Top End of the Northern Territory on 20 December. The low moved west and was over the Kimberley by the 21st, then remained slow-moving over the northern interior of Western Australia for several days.

On the 25th, the low absorbed the remnants of Tropical Cyclone *Yvette*, which had weakened below cyclone intensity offshore before crossing the coast near Broome, and then began to move south. It was centred near the Northern Territory border on the 26th, before crossing western South Australia and deepening below 990 hPa on the 27th and 28th.

The low passed near Adelaide early on the 28th and was centred near Mount Gambier later in the day, before being absorbed by another low-pressure system approaching from the west from south of Western Australia. This system consolidated in the Great Australian Bight and then moved southeast, passing to the west of Tasmania before moving out into the south Tasman Sea on the 31st. To the north of the low, a trough extended northwards across much of the continent and moved slowly east, crossing Victoria on the 29th and then reaching central New South Wales on the 31st. This sequence allowed for the southward penetration of unusually humid tropical air into southern Australia.

2.2 Significant rainfalls during the event

The first significant rainfalls developed on the 20th, when totals locally exceeded 50 millimetres over the east Kimberley. Heavy rain became more extensive over the next two days, with numerous totals above 100 millimetres on the 21st in the north Kimberley, extending to the west on the 22nd and 23rd.

Heavy rains then shifted to the southern Northern Territory from the 25th. Totals locally exceeded 200 millimetres on the 26th, with further daily totals above 100 millimetres on the 27th in southwestern parts of the Territory, extending to the far northwest of South Australia.

Major rainfalls shifted south into South Australia on the 28th, with 25 to 50 millimetres in a broad band extending across the State from northwest to southeast. There were locally higher falls in places, especially in the Adelaide region, where some Adelaide Hills sites exceeded 100 millimetres.

From the 29th onwards, widespread rains became less significant but locally heavy falls occurred in thunderstorms near and to the east of a trough crossing southeastern Australia. Very high rainfall intensities, and storm totals above 50 millimetres, occurred on the 30th in many parts of metropolitan Melbourne (see section 2.2.2). Daily totals

also exceeded 50 millimetres in parts of northern Victoria, locally exceeding 100 millimetres in the Alpine region. There were also local thunderstorm-related rainfalls above 100 millimetres on the 29th in parts of South Australia. By the 31st, severe thunderstorms became largely confined to the ranges and tablelands of southeastern New South Wales and the Australian Capital Territory.

The highest rainfall totals for the period from 20 to 31 December (Figure 1) were in the north Kimberley and the western Top End of the Northern Territory, with totals above 400 millimetres in places. Falls above 200 millimetres covered most of the Kimberley, and a band extending from west to east across the southern Northern Territory, with most remaining areas of the Territory receiving at least 100 millimetres. General totals of 50 to 100 millimetres, with locally much higher falls associated with thunderstorms, occurred across many parts of South Australia, central and northeast Victoria, and northern and western Tasmania. The extensive nature of the rains in South Australia, combined with earlier falls, resulted in the wettest December on record for the State.

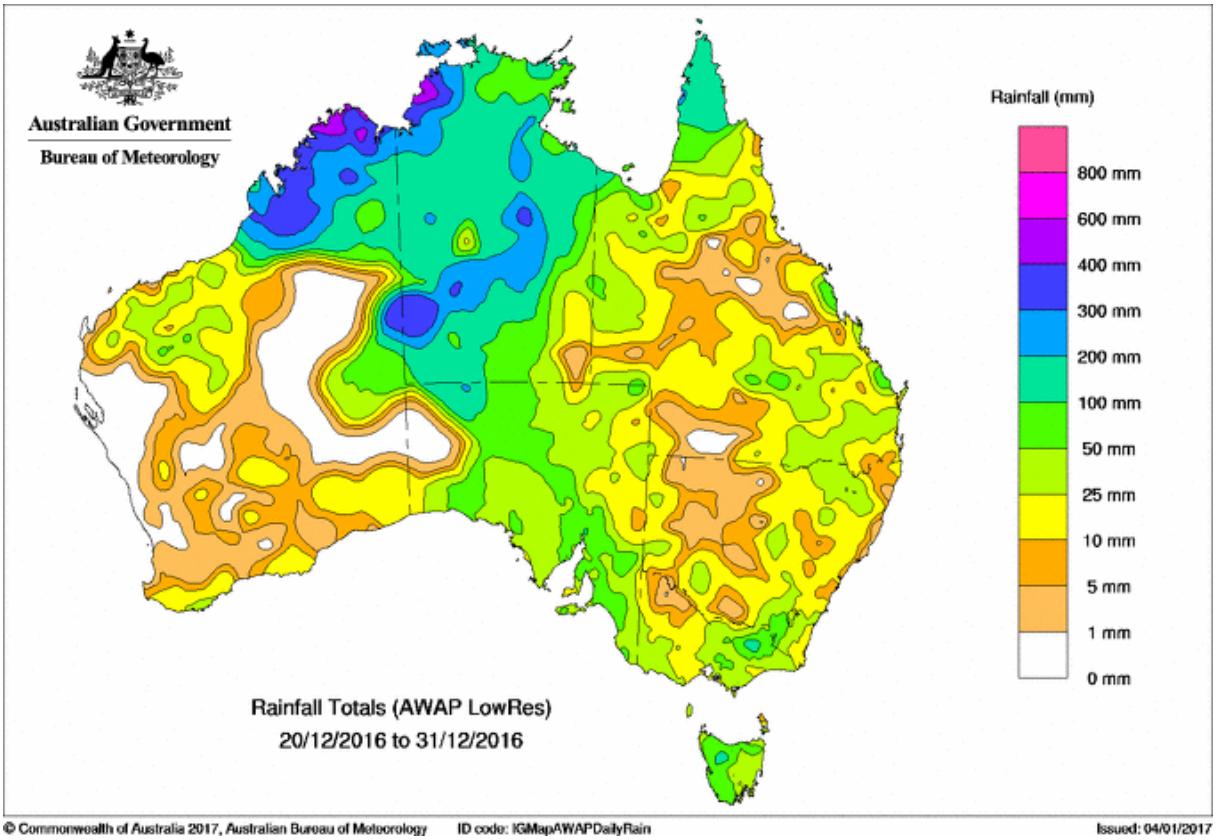

Figure 1. Rainfall totals for the period from 20 to 31 December 2016.

2.2.1 Record and other significant daily rainfalls

The only location with 50 or more years of rainfall data which had its wettest day on record (for all months) during this event was Curtin Springs in the Northern Territory, where 128 millimetres fell on the 27th.

December daily rainfall records (Table 1) were set in a number of regions (Figure 2). The major areas where records occurred were the Kimberley from the 21st to the 23rd, the southern Northern Territory on the 26th and 27th, around and to the east of Adelaide on the 28th, and in Alpine regions of Victoria on the 30th.

The heaviest daily total was 231.6 millimetres on the 26th at Walungurru[2], near the Northern Territory/Western Australia border, with a two-day total for 25–26 December of 287.0 millimetres. This is the highest daily December rainfall on record for any location in the southern Northern Territory[3], surpassing the previous December record of 196.6 millimetres at Horseshoe Bend on 15 December 1975.

Broome received 225.6 millimetres on the 23rd, a December record, whilst Bidyadanga, south of Broome, had 130 millimetres on the 23rd and a further 210 millimetres on the 24th. Other daily totals above 200 millimetres in the Kimberley were at Theda (203.0 millimetres on the 21st) and Siddins Creek (218.0 millimetres on the 22nd).

Several sites in the Adelaide Hills exceeded 100 millimetres on the 28th, with the highest 110.0 millimetres at Uraidla. Whilst the maximum regional totals fell short of those observed on 8 December 2010, some records were set at individual sites. Adelaide (61.2 millimetres) had its third-wettest December day on record, falling 5 millimetres short of the record set on 8 December 2010. There were further heavy falls in South Australia in localised severe thunderstorms the next day, with the highest observed total 104.4 millimetres at Mount Mary, between Burra and Morgan.

On the 30th, a number of sites in the Victorian Alpine region had daily totals exceeding 100 millimetres. The highest total was 158.6 millimetres at Mount Hotham. In metropolitan Melbourne, the highest total was 108.0 millimetres at Bundoora, with falls between 70 and 100 millimetres at numerous other locations.

[2] Also known as Kintore.
[3] Defined as the Bureau's Alice Springs rainfall district. The record for any month is 325.0 millimetres at Glen Helen on 31 March 1988.

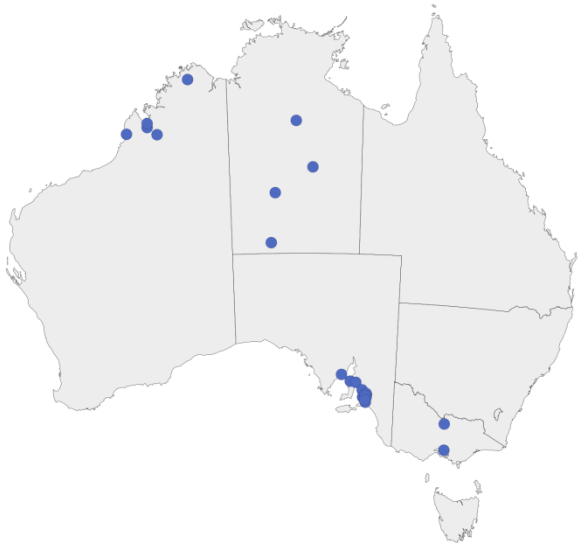

Figure 2. Locations with 50 or more years of data which set December daily rainfall records between 20 and 31 December 2016.

Station number	Station name	State	Value (mm)	Date	Previous record
1010	Theda	WA	203.0	21st	176.0 (16/12/2009)
3003/3002	Broome	WA	225.6	23rd	210.1 (5/12/1970)
3018	Myroodah	WA	171.6	23rd	132.1 (9/12/1952)
3026	Yeeda	WA	139.4	22nd	125.0 (19/12/2009)
3032/3007	Derby	WA	147.4	22nd	139.7 (20/12/1926)
15511	**Curtin Springs**	**NT**	**128.0**	**27th**	**85.4 (5/12/1988) (Dec) 104.6 (26/3/1982) (all)**
15537	Kurundi	NT	121.2	26th	105.0 (11/12/2000)
15607	Mount Denison	NT	116.6	27th	90.0 (12/12/2000)
18022	Cowell	SA	60.2	28th	44.0 (6/12/1990)
21133/21046	Snowtown	SA	80.0	28th	72.2 (8/12/2010)
22011	Moonta	SA	60.4	28th	48.8 (25/12/1946)
22022	Port Clinton	SA	69.6	28th	59.9 (27/12/1929)
23013	Parafield	SA	61.2	28th	51.2 (8/12/2010)
23028	Two Wells	SA	71.4	28th	59.4 (31/12/1995)
23707	Bridgewater	SA	105.0	28th	84.6 (8/12/1986)
23720	Hahndorf	SA	77.4	28th	49.4 (22/12/2007)
23721	Happy Valley Reservoir	SA	58.0	28th	56.4 (4/12/1966)
23731	Millbrook Reservoir	SA	92.0	28th	65.5 (28/12/1929)
23733	Mount Barker	SA	76.0	28th	63.0 (7/12/1986)
23734	Mount Bold Reservoir	SA	66.2	28th	61.0 (14/12/1993)
23750	Uraidla	SA	110.0	28th	84.6 (8/12/1986)
23799	Prospect Hill	SA	62.6	28th	45.8 (8/12/2010)
24586	Mount Mary	SA	104.4	29th	99.3 (27/12/1929)
81046	Stanhope	VIC	88.8	30th	69.3 (4/12/1954)
86210	Bonbeach	VIC	60.0	30th	56.4 (23/12/2000)

Table 1. Locations with 50 or more years of data which had their wettest December day on record. Stations shown in bold set a record for any month.

2.2.2 High-intensity short-duration rainfalls

Extremely high rainfall intensities occurred at a number of locations during the event. One significant example was in Melbourne on the afternoon of 29 December, when heavy rain fell in many northern, eastern and southeastern suburbs. Numerous gauges in metropolitan Melbourne had rainfall rates during storms which were well in excess of 1 millimetre per minute, with some exceeding 2 millimetres per minute.

The highest short-duration rainfalls during this storm were at Viewbank, in the northeastern suburbs of Melbourne, where 40.2 millimetres fell in 15 minutes between 3.07 and 3.22 p.m. This is amongst the heaviest known rainfalls for such a duration in Victoria (Table 2) This rainfall rate surpassed the 1% annual exceedance probability rainfall (AEP)[4] at all durations from 6 minutes to 6 hours, highlighting the very extreme nature of the rainfall (Figure 3).

Location	Rainfall (mm)	Date
Blackburn	39 in 15 minutes	21/2/1922
Mont Albert	30 in 10 minutes	3/3/1928
Swanpool	39 in 15 minutes	20/10/1955
Sunbury	24 in 6 minutes 37 in 12 minutes 40 in 18 minutes	24/12/1959
Bright	32 in 6 minutes 38 in 12 minutes 44 in 18 minutes	28/12/1980
Viewbank	40 in 15 minutes	29/12/2016

Table 2. Selected notable short-duration rainfalls in Victoria. This list is not necessarily exhaustive.

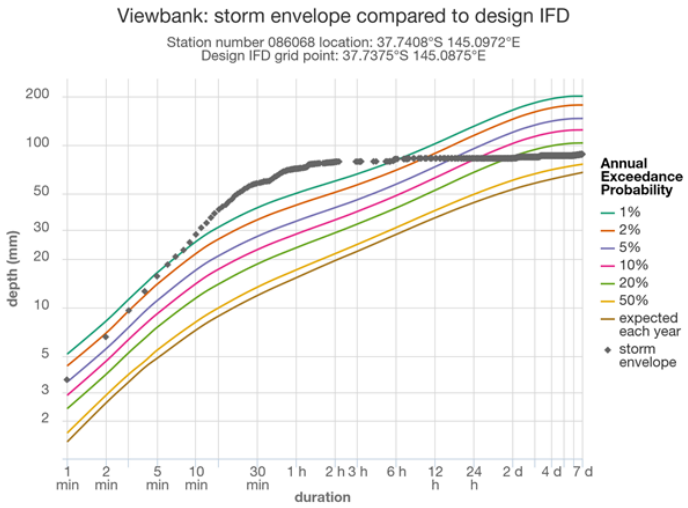

Figure 3. Rainfall on 29 December 2016 at Viewbank, compared with annual exceedance probabilities.

[4] The rainfall level for a given duration at a given point which has a 1% chance of being exceeded in any individual year.

2.3 Atmospheric moisture

2.3.1 Precipitable water

An indicator of the total quantity of water in the atmosphere is the amount of precipitable water[5]. This is a measure of the water content of the atmosphere integrated from ground level to the upper atmosphere, and can be calculated at locations where weather balloon flights are made.[6]

Precipitable water amounts were exceptionally high through most of the region affected by this event, reflecting the depth of moisture through the atmosphere. Nine locations set new December records for precipitable water (Figure 4, Table 3), including all five of the locations in South Australia, Victoria and Tasmania where it is currently measured (Woomera, Adelaide Airport, Mount Gambier and Melbourne Airport).

At Giles, Woomera and Mount Gambier, the precipitable water amount was the highest on record for any month, indicating that the overall water content of the atmosphere was without precedent in the available records over large parts of South Australia. The most directly comparable event is that of 19−20 January 2007, which was the previous record-holder at Woomera and Mount Gambier (and slightly surpassed the December 2016 event at Adelaide Airport).

In Victoria and Tasmania, the December 2016 event has seen precipitable water amounts set December records, but substantially higher amounts occurred during January 2011. Both the January 2007 and January 2011 events were associated with substantial flooding in the affected regions, highlighting the relationship which often exists between very high humidity values and heavy rainfall.

[5] Precipitable water is the total water vapour contained in an atmospheric column from the surface to the upper atmosphere, expressed in terms of the depth of an equivalent mass of liquid water of the same cross-section.

[6] At most listed locations, approximately 25 years of data are available for precipitable water, except at Melbourne Airport (18 years).

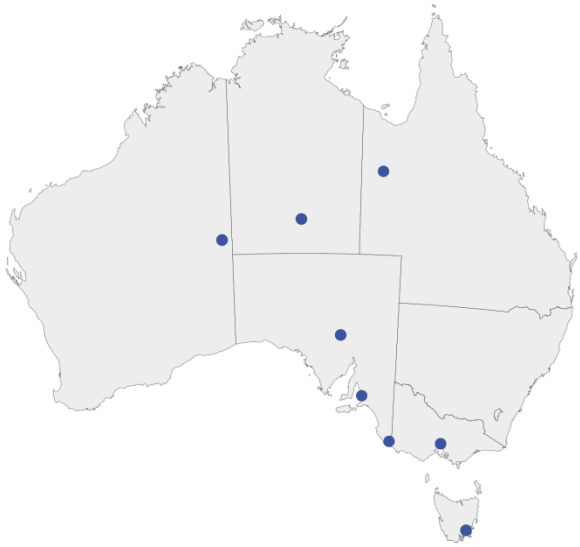

Figure 4. Locations which experienced their highest December precipitable water content on record during the event.

Station number	Station name	State	Value (mm)	Date	Previous record
13017	**Giles**	**WA**	**63.6**	**25th**	**53.8 (18/12/1998) (Dec) 57.4 (1/3/2011) (all)**
15590	Alice Springs	NT	54.5	26th	49.3 (21/12/2015)
16001	**Woomera**	**SA**	**64.2**	**27th**	**49.7 (29/12/2003) (Dec) 63.6 (19/1/2007) (all)**
23034	Adelaide Airport	SA	58.7	27th	55.2 (31/12/2005)
26021	**Mount Gambier**	**SA**	**52.0**	**28th**	**47.3 (2/12/1999) (Dec) 50.2 (19/1/2007) (all)**
29127	Mount Isa	QLD	61.3	28th	59.8 (30/12/1998)
86282	Melbourne Airport	VIC	48.2	29th	44.4 (21/12/2000)
94008	Hobart Airport	TAS	46.7	28th	42.3 (7/12/2010)

Table 3. Locations which set December records for precipitable water content during the event. Locations where a record was set for any month are shown in bold.

2.3.2 Extreme surface dewpoints

A further indication of the exceptionally humid nature of the air mass was the presence of very high dewpoints at the surface across many areas. In South Australia, a dewpoint of 27.6 °C occurred at Marree at 0830 on both 28 and 29 December, whilst in Victoria, a dewpoint of 26.0 °C occurred at Geelong at 1200 on 30 December.[7] These would be very high values even for tropical locations.[8]

Station dewpoint records were set at numerous locations (Table 4). As for precipitable water, the most significant extremes occurred in South Australia. Nine of the thirteen South Australian sites with long-term dewpoint data had their highest December dewpoint on record, with three of these (Woomera, Marree and Mount Gambier) having their highest on record for any month.

Elsewhere, Melbourne equalled its highest dewpoint on record for any month, and December dewpoint records were set over many parts of Victoria, northern Tasmania, southern and western border areas of New South Wales, and the southern Northern Territory. In total, 21 long-term stations set December dewpoint records, with five of these setting records for any month.

In Melbourne, the most immediately comparable events to the December 2016 event were those of January and February 2011. The December 2016 event had a slightly higher peak dewpoint (24.0 °C) than those recorded on 13 January 2011 (23.9 °C) or 4 February 2011 (23.2 °C), although the very high dewpoints were sustained over a longer period in the two 2011 events.

[7] In this section, hourly and half-hourly dewpoint data are used. Many sites have data at higher time resolution for the 2016 event, but these high-resolution data are not used for record assessment because of a lack of comparable historical data—most sites do not have high-resolution data until the last few years.

[8] By way of comparison, the dewpoint at Darwin has exceeded 27.6 °C only once in the last 25 years.

Station number	Station name	State	Value (°C)	Date/time	Previous record
15590	Alice Springs	NT	24.7	2230 29/12	24.0 (27/12/1987)
16001	**Woomera**	**SA**	**25.9**	**2030 27/12**	**24.0 (12/12/1975, 25/12/1988) (Dec) 25.0 (4 times, most recent 2/3/1979) (all)**
16098/16044	Tarcoola	SA	24.6	1530 27/12	24.0 (3 times, most recent 20/12/2007)
17126/17031	**Marree**	**SA**	**27.6**	**0830 29/12**	**25.6 (21/12/2007) (Dec) 27.1 (3/3/2009) (all)**
17043	Oodnadatta	SA	25.8	1430 27/12	25.2 (20/12/2007)
18012	Ceduna	SA	24.9	1730 27/12	24.0 (31/12/1990)
18044	Kyancutta	SA	22.4	1500 27/12	22.0 (5 times, most recent 5/12/1990)
23090/23000	Adelaide	SA	23.3	0330 28/12	23.0 (2/12/1986, 22/12/1989)
23373/23321	Nuriootpa	SA	22.8	1330 28/12	21.0 (3/12/1988)
26021	**Mount Gambier**	**SA**	**26.0**	**1500 28/12**	**20.6 (21/12/2003, 4/12/2016) (Dec) 24.0 (30/1/1973) (all)**
46126/46037	**Tibooburra**	**NSW**	**27.1**	**0000 30/12**	**25.9 (7/12/1951) (Dec) 26.8 (27/2/1951) (all)**
46012/46043	Wilcannia	NSW	24.1	2100 29/12	24.0 (4 times, most recent 29/12/1981)
72161/72091	Cabramurra	NSW	18.4	1400 30/12	17.5 (24/12/2014)
78015/78031	Nhill	VIC	22.4	1100 28/12	22.0 (3 times, most recent 11/12/1993)
82039	Rutherglen	VIC	24.8	0900 30/12	22.0 (21/12/2007)
86338/86071	**Melbourne**	**VIC**	**24.0**	**0100 30/12**	**23.0 (26/12/1961) (Dec) 24.0 (24/1/1982) (all)**
87031	Laverton	VIC	23.3	1500 29/12	22.0 (25/12/1988)
90015	Cape Otway	VIC	22.9	1400 28/12	22.0 (3 times, most recent 2/12/1975)
91293/91057	Low Head	TAS	20.1	0900 29/12	18.8 (26/12/1998)
91311/91104	Launceston Airport	TAS	19.4	1700 28/12	19.0 (3 times, most recent 8/12/2010)
92045	Larapuna (Eddystone Point)	TAS	20.0	1100 30/12	20.0 (29/12/1961)

Table 4. Locations with long-term data which set December records for highest dewpoint. Records for any month are shown in bold.

2.4 High temperatures during the event

High temperatures occurred during much of the period in areas to the south and east of the low-pressure system. Temperatures were well above average from 25 December in southern South Australia, most of Victoria and Tasmania, and southern New South Wales, with some locations having their hottest Christmas Day for many years (for example, 41.3 °C at Adelaide was the highest Christmas Day temperature there since 1941). Maximum temperatures cooled in South Australia from the 26th as conditions became more cloudy and humid, but above-average temperatures persisted in Victoria until the 29th. From the 29th to the 31st, the focus of high temperatures shifted to coastal New South Wales, before gradually cooling as a trough moved northwards along the coast on the 31st.

The daytime warmth was significant but not exceptional by historical standards. No significant December records were set (many locations had higher temperatures in December 2015, for example). The highest temperatures observed during the period[9] were 44.0 °C at Mungindi (New South Wales) on the 31st, and 43.8 °C at Port Augusta (South Australia) on the 25th.

The most significant warmth occurred overnight. With the combination of the very warm air mass, high humidity and (in some cases) cloud cover, minimum temperatures were well above average throughout the period. The overnight warmth was most extreme in eastern New South Wales, where a number of locations had their highest December minimum temperature on record (Table 5). December-high minimum temperature records were also set in and around Melbourne, including at Melbourne itself, on the 30th.

At the regional level, in Tasmania, the statewide average minimum temperature on the 29th and 30th was 15.24 °C and 15.20 °C respectively. These values are the 8th and 9th highest on record for Tasmania and are only the second instance (after 30−31 December 2002) of consecutive December nights with statewide average minimum temperatures of 15 °C or above. In Victoria, the statewide average minimum temperature exceeded 20 °C on the 26th (20.19 °C), 28th (20.19 °C) and 29th (20.63 °C). Three such warm nights in four days is an unprecedented sequence for December, whilst two consecutive nights above 20 °C, and five consecutive nights (26−30 December) above 17 °C are both equal records for December. Five consecutive nights above 18 °C and three above 20 °C both equalled December records at Melbourne.

The combination of high day and night-time temperatures resulted in significant heatwave conditions in many parts of Australia (Figure 5). Extreme heatwave conditions occurred along the northern and southern parts of the New South Wales

[9] Excluding values in Western Australia not associated with the event.

coast, whilst severe heatwave conditions affected much of New South Wales, southern Queensland, central and eastern Victoria, and northern Tasmania.

Station number	Station name	State	Value (°C)	Date	Previous record
60085	Mount Seaview	NSW	24.2	31st	24.0 (31/12/2005)
61250	Tocal	NSW	25.6	31st	24.9 (1/12/2004)
68151/68034	Point Perpendicular	NSW	24.6	30th	23.9 (21/12/1953)
68241/68053	Wollongong Airport	NSW	22.4	31st	22.2 (26/12/1957)
69132/69010	Braidwood	NSW	20.3	29th	19.8 (23/12/2006)
69139/69002	Bega	NSW	22.4	30th	21.2 (12/12/1981)
69147/69093	Merimbula	NSW	22.7	30th	20.5 (30/12/1983)
86038	Essendon (=)	VIC	26.2	26th	26.2 (20/12/2015)
86338/86071	Melbourne	VIC	27.0	29th	26.6 (12/12/1998)
86351	Bundoora	VIC	26.5	29th	26.0 (7/12/1994)
88023	Lake Eildon	VIC	22.7	28th	22.3 (3/12/1999)
91284/91132/91007	Bridport (=)	TAS	20.0	26th	20.0 (20/12/2015)

Table 5. Locations which recorded their highest December minimum temperature during the event.

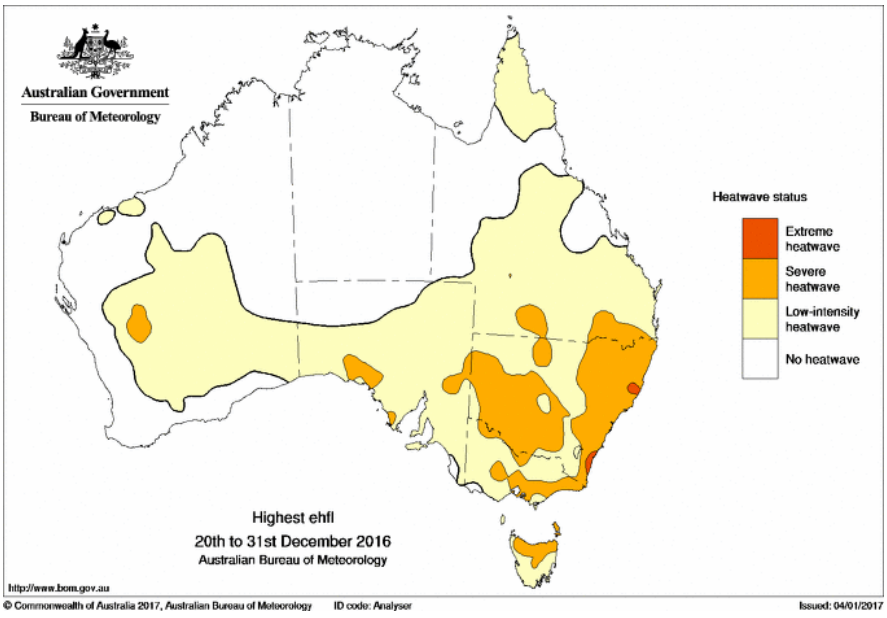

Figure 5. Regions which experienced a heatwave at some point during the period from 20 to 31 December 2016.

2.5 Air pressure

The intensity of the low-pressure system resulted in numerous records being set for low mean sea level pressure at locations in South Australia. Some outback locations, including Woomera, Tarcoola and Marree (which were too far north to experience the full intensity of the September 2016 storm), had their lowest mean sea level pressure on record for any month (Table 6).

Further south, pressure did not fall as low as that experienced in the September 2016 storm. However, December records were set at numerous locations, including Adelaide.

Station number	Station name	State	Value (hPa)	Date	Previous record
16001	**Woomera**	**SA**	**988.3**	**27th**	**993.8 (6/12/1953) (Dec) 988.6 (30/11/1987) (all)**
16098/16044	**Tarcoola**	**SA**	**985.7**	**27th**	**993.3 (7/12/2010) (Dec) 991.0 (30/11/1987) (all)**
17043	Oodnadatta	SA	992.6	27th	993.3 (7/12/2010)
17110	Leigh Creek	SA	993.6	27th	994.6 (10/12/1984)
18115	Neptune Island	SA	989.3	28th	993.6 (2/12/2002)
18192/18070	Port Lincoln	SA	990.1	28th	991.2 (23/12/1922)
21133/21046	Snowtown	SA	988.8	28th	992.1 (1/12/1996)
22823/22801	Cape Borda	SA	989.7	28th	992.7 (2/12/1978)
23034	Adelaide Airport	SA	985.9	28th	991.1 (1/12/1987)
23090/23000	Adelaide	SA	987.7	28th	988.7 (1/12/1987)
23373/23321	Nuriootpa	SA	990.0	28th	992.4 (1/12/1996)

Table 6. Locations which had their lowest December mean sea level pressure on record during the event. Records for any month are shown in bold.

Notes

This statement is based on data available as of 4 January 2017. There may be some changes as a result of late-arriving data or the Bureau's standard quality control processes.

Dewpoints reported in this statement generally cover the post-1957 period only, as the density of the available data is insufficient to allow most pre-1957 values to be verified.