Seasonal climate summary southern hemisphere (winter 2013): Australia’s third warmest winter on record.

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Southern hemisphere circulation patterns and associated anomalies for austral winter 2013 are reviewed, with an emphasis on Pacific Basin climate indicators and Australian rainfall and temperatures. El Niño–Southern Oscillation (ENSO) conditions remained neutral throughout winter 2013 though some ENSO indicators, such as the SOI, surpassed La Niña thresholds at times during the season. Sea surface temperature patterns across the equatorial Pacific Ocean displayed a weak La Niña-like signal, but did not reach La Niña thresholds. A negative Indian Ocean Dipole event contributed to above average rainfall across southern and northwestern Australia, before weakening in early August, whilst a strongly negative phase of the Southern Annular Mode (SAM) contributed to above-average rainfall across southern areas in August. Above average rainfall saw an easing of rainfall deficiencies in the southeast, but a lack of winter rainfall saw a worsening of deficiencies in inland Queensland and northern New South Wales. Averaged across Australia, winter maxima were second warmest on record, and minima were sixth warmest on record. Overall, Australia’s mean winter temperature was 1.29 °C above average: the third highest on record. An unusual period of warmth which started in the last week of winter also saw Australia record its warmest winter day on 31 August.

Introduction

This summary reviews the southern hemisphere and equatorial climate patterns for winter 2013, with particular attention given to the Australasian and Pacific regions. The main sources of information for this report are analyses prepared by the Bureau of Meteorology’s National Climate Centre and the Centre for Australian Weather and Climate Research (CAWCR).

Pacific Basin climate indices
Southern Oscillation Index
The Troup Southern Oscillation Index (SOI) is based on the mean sea-level pressure (MSLP) difference between Tahiti and Darwin. Sustained negative values below –8 generally indicate an El Niño event, while sustained positive values above +8 are associated with La Niña periods. Figure 1 shows monthly SOI values between January 2010 and August 2013, and a five-month weighted moving average.

Following the summer of 2011–12, monthly SOI values were mostly neutral, with the exception of June 2012 when the SOI dropped to −10.4 and March 2013 when the SOI reached +11.1 (Fig. 1). The SOI remained positive through spring 2013 and into winter, but rapidly moved toward neutral values during winter. Monthly values were +13.9 in June, +8.1 in July and −0.5 in August. The overall winter average was +7.17.

While SOI values approached, and exceeded, La Niña thresholds in some months of spring and winter 2013, highly positive values of the SOI were not sustained. Winter MSLP anomalies (not shown) were generally positive at Tahiti and negative at Darwin, which contributed to the positive SOI values seen in June and July. Monthly values for June, July and August were +0.4 hPa, +0.6 hPa and +0.3 hPa respectively at Tahiti, and −1.3 hPa, −0.6 hPa and +0.3 hPa respectively at Darwin. The negative phase of the Indian Ocean Dipole (IOD), discussed further in the Indian Ocean Dipole section, may have contributed to the negative MSLP anomalies seen at Darwin in June and July, which weakened in August 2013.

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Fig. 1. Southern Oscillation Index, January 2010–August 2013, together with a five-month binomially weighted moving average. Means and standard deviations used in the computation of the SOI are based on the period 1933–1992.

Fig. 2. 5VAR composite standardised monthly ENSO index from January 2010 to August 2013, together with a weighted three-month moving average. See text for details.
The Multivariate ENSO Index (MEI), produced by the US Physical Sciences Division (PSD) of the Earth System Research Laboratory (ESRL), is derived from a number of atmospheric and oceanic parameters calculated as a two-month mean. Significant negative (positive) anomalies are typically associated with La Niña (El Niño) events. The June–July (−0.47) and July–August (−0.61) MEI values (not shown) were consistent with weakly negative 5VAR values in winter 2013, and with negative SST anomalies in the eastern tropical Pacific Ocean.

Outgoing long-wave radiation
Outgoing long-wave radiation (OLR) over the equatorial Pacific Ocean is a good proxy of tropical convection, with decreases in OLR associated with increased convection and hence rainfall. During a La Niña event, OLR is often above average near the Date Line, indicating suppressed convection in that area. The opposite is true during an El Niño event.

Standardised monthly anomalies of OLR are computed by the Climate Prediction Center (CPC), Washington, for an equatorial region near the Date Line ranging from 5°S to 5°N and 160°E to 160°W. Standardised monthly values for winter 2013 were +0.4 W m\(^{-2}\), +0.7 W m\(^{-2}\) and +0.9 W m\(^{-2}\) for June, July and August, respectively.

**Composite monthly ENSO index 5VAR**

5VAR\(^2\) is a composite monthly ENSO index, calculated as the standardised amplitude of the first principal component of monthly Darwin and Tahiti MSLP\(^3\) and monthly NINO3, NINO3.4 and NINO4 sea-surface temperatures\(^4\) (SSTs). The sequence of monthly 5VAR values between January 2010 and August 2013 are shown in Fig. 2, along with the weighted three-month moving average.

5VAR values were negative between mid-2010 and early 2012, associated with the 2010–11 and 2011–12 La Niña events, before rising through autumn and winter 2012 (Reid et al. 2013). After peaking at +1.0 in August 2012, 5VAR values started to weaken in spring 2012 and continued to drop through to winter 2013, reaching a low of −0.57 in June 2013. A drop in the 5VAR index from winter 2012 indicates a cooling of the eastern equatorial Pacific Ocean, and is consistent with a rising trend in the SOI between winter 2012 and winter 2013 (Fig. 1). 5VAR values then moved back toward zero over July and August 2013.

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\(^2\) ENSO 5VAR was developed at the Bureau’s National Climate Centre and is described in Kuleshov et al. 2009. The principal component analysis and standardisation of this ENSO index is performed over the period 1950–1999.


et al. 1999), the difference in SST anomalies between the
western (50°E to 70°E and 10°S to 10°N) and eastern (90°E
to 110°E and 10°S to 0°S) equatorial Indian Ocean. Weekly
DMI values, shown in Fig. 4 between January 2010 and
September 2013, dropped below −0.4 °C (the threshold used
for a negative IOD phase) in mid-May 2013 and remained
below −0.4 °C through to the week ending 4 August 2013.
The lowest value was −0.67 °C for the week ending 14 July.
This negative phase of the IOD through June and July
2013 is consistent with negative OLR anomalies across the
eastern Indian Ocean and Maritime Continent in winter 2013
(Fig. 3), as well as above average rainfall across northwest
and southern Australia. Suppressed convection can also be
seen over the western Indian Ocean.

Indian Ocean Dipole
The IOD describes the pattern of sea surface temperatures
(SSTs) across the equatorial Indian Ocean. A negative phase
of the IOD is characterised by warmer than usual water near
Indonesia and cooler than usual water in the tropical western
Indian Ocean, and is associated with increased convection,
and hence rainfall in the eastern Indian Ocean and across
southern Australia during winter and spring. The opposite
is true for a positive IOD.

The pattern of SSTs across the equatorial Indian Ocean
can be represented by the Dipole Mode Index (DMI) (Saji
et al. 1999), the difference in SST anomalies between the
western (50°E to 70°E and 10°S to 10°N) and eastern (90°E
to 110°E and 10°S to 0°S) equatorial Indian Ocean. Weekly
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eastern Indian Ocean and Maritime Continent in winter 2013
(Fig. 3), as well as above average rainfall across northwest
and southern Australia. Suppressed convection can also be
seen over the western Indian Ocean.

The Madden-Julian Oscillation
The Madden-Julian Oscillation (MJO) is a tropical atmos-
pheric anomaly which develops in the Indian Ocean
and propagates eastwards into the Pacific Ocean (Zhang
2005). The MJO has a period of around 30–60 days, with
a frequency of 6–12 events per year (Donald et al. 2004). An
active phase of the MJO is associated with increased tropical
rainfall and can be detected by negative OLR anomalies

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Fig. 4. Weekly Dipole Mode Index (DMI), a measure of the Indian Ocean Dipole, from weeks ending 10 January 2010–September
2013, together with a five-week weighted moving average. See text for details.
which travel the equator from west to east; however these signals in convection are typically only visible in the Indian and western Pacific oceans (Zhang 2005). A time-longitude plot of OLR anomalies between March and August 2013 is shown in Fig. 5. The MJO was weak for much of winter 2013, with the exception of June and the end of August. The clearest signal of the MJO in Fig. 5 can be seen between 80°E and 140°E in mid-June, dissipating as it reaches the West Pacific around 20 June. Other negative OLR signals evident between 80°E and 140°E throughout winter were largely associated with the negative phase of the IOD which saw enhanced convection in the eastern Indian Ocean, as well as enhanced convection in the Maritime Continent area.

The real-time Multivariate MJO (RMM) index developed by Wheeler and Hendon (2004) combines OLR data with 850 hPa and 200 hPa zonal winds to monitor the MJO each day. This index can be plotted in a phase-space diagram, as shown in Fig. 6 for winter 2013. The MJO was weak (the amplitude\(^7\) remained within the unit circle) over the first 10

\(^7\) The amplitude of the MJO is measured by \((\text{RMM1}^2 + \text{RMM2}^2)^{1/2}\) where \(\text{RMM1}\) and \(\text{RMM2}\) are described by Wheeler and Hendon (2004). Records began in June 1974.
SSTs were cooler than average across the eastern equatorial Pacific Ocean and along the Peruvian coast during winter 2013, with anomalies dropping below −1 °C east of 120°W. Warm SST anomalies were evident in the South Pacific Convergence Zone (SPCZ) area and down toward the east of New Zealand, the Maritime Continent area, along the south coast of Australia, and across the North Pacific Ocean.

Across the equatorial Pacific, all three standard monthly NINO indices were relatively steady through winter. In the east, the NINO3 index had monthly values of −0.6 °C, −0.7 °C and −0.5 °C in June, July and August respectively. Warm SST anomalies were evident in the South Pacific Convergence Zone (SPCZ) area and down toward the east of New Zealand, the Maritime Continent area, along the south coast of Australia, and across the North Pacific Ocean.

Oceanic patterns

Sea-surface temperatures

Global SST anomalies for winter 2013, obtained from the US National Oceanic and Atmospheric Administration (NOAA) Optimum Interpolation analyses (Reynolds et al. 2002), are shown in Fig. 7. The base period is 1981–2010. SSTs were cooler than average across the eastern equatorial Pacific Ocean and along the Peruvian coast during winter 2013, with anomalies dropping below −1 °C east of 120°W. Warm SST anomalies were evident in the South Pacific Convergence Zone (SPCZ) area and down toward the east of New Zealand, the Maritime Continent area, along the south coast of Australia, and across the North Pacific Ocean.

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Fig. 7. Anomalies of SST for winter 2013 (°C).

Niña thresholds.
In the Indian Ocean, winter SST anomalies were as cool as −2 °C in the Arabian Sea (Fig. 7), coinciding with the western sector of the IOD, and positive off the coast of Java and Sumatra in the eastern sector of the IOD. This led to a negative phase of the IOD, as discussed in the Indian Ocean Dipole section.

Subsurface patterns
The equatorial thermocline is a region of the subsurface where the temperature gradient between warm near-surface water and cold deep-ocean waters is greatest. The 20 °C isotherm depth corresponds well with the depth of the equatorial thermocline and is typically used as a proxy; positive anomalies corresponding to a deeper-than-average thermocline and vice versa. Shifts in the depth of the 20 °C isotherm provide an indication of subsequent temperature changes in SSTs; a shallow thermocline indicates the presence of, or potential for, upwelling, and therefore a cooling of surface temperatures. A Hovmöller diagram for the 20 °C isotherm depth anomaly along the equator from January 2010 to August 2013, obtained from NOAA’s TAO/TRITON data, is shown in Fig. 8.

The 20 °C isotherm was deeper than average in both the eastern and western equatorial Pacific Ocean at the start of June 2013, and shallower in the central equatorial Pacific.

* Hovmöller plot obtained from www.pmel.noaa.gov/tao/jsdisplay/
August as SAM switched to being mostly negative and westerly winds eased (Reid et al. 2014). SAM is described further in the Southern Annular Mode section. Transient cyclonic activity in the Ross Sea also provided conditions suitable for wind driven sea ice expansion in that area (the region where positive sea ice extent anomalies were most prominent), augmented by thermal expansion due to the cooler-than-normal SSTs evident to the north of the ice edge (Reid et al. 2014).

Atmospheric patterns

Surface analyses

The MSLP for winter 2013, computed using data from the 0000 UTC daily analyses of the Bureau of Meteorology’s Australian Community Climate and Earth System Simulator (ACCESS) model, is shown in Fig. 10. The corresponding MSLP anomalies are shown in Fig. 11. Anomalies are the difference from a 1979–2000 climatology obtained from the National Centers for Environmental Prediction (NCEP) II Reanalysis data (Kanamitsu et al. 2002). The MSLP anomaly field is not shown over areas of elevated topography (grey shading).

The winter 2013 MSLP pattern shows the subtropical ridge circling the southern hemisphere centred on 30°S. Centres of high pressure were located in the southern Atlantic (greater than 1025 hPa), near 90°W (1024.8 hPa) and over Australia (1022.9 hPa). The subtropical ridge was generally close to its climatological position and strength, but slightly stronger than usual to the west of Chile (Fig. 11). An area of anomalous high pressure can also be seen to the east of New Zealand near 160°W. The circumpolar trough is evident off the Antarctic coast, with a peak low pressure centre of 979.7 hPa near 90°W. The circumpolar trough was slightly weaker than usual around 0°E, 90°E and 180°E, but stronger than usual near 90°W (Fig. 11).

Mid-tropospheric analyses

The 500 hPa geopotential height (an indicator of the steering of surface synoptic systems across the southern hemisphere), is shown in Fig. 12 for winter 2013, with corresponding anomalies in Fig. 13. The winter 500 hPa geopotential height field was zonal over high latitudes, with four weak troughs near 130°W, 50°W, 15°E and 105°E. Geopotential height anomalies largely reflect MSLP anomalies shown in Fig. 11; a peak low of −110 gpm can be seen over the Amundsen Sea, and was bounded on either side by positive anomalies off the west coast of South America (reaching +95 gpm near 90°W) and over the Antarctic continent (reaching +128 gpm).

Sea ice

One measure of sea ice is sea ice extent, which is the area of sea ice with a concentration of 15% or more. Southern hemisphere sea ice extent was above average through winter 2013, and record high for the month of August (records begin in 1979). Monthly averages through winter were 14.62 km$^2\times10^6$ in June, 17.10 km$^2\times10^6$ in July and 18.88 km$^2\times10^6$ in August. Southern Hemisphere sea ice area extent then reached an all-time monthly averaged high in September 2013 at 19.72 km$^2\times10^6$.

Such high values of southern hemisphere sea ice extent were the result of wind-driven sea ice expansion during the sea ice advance period between April and early August, associated with a positive phase of the Southern Annular Mode (SAM), followed by thermal processes from mid-

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9 Values of southern hemisphere sea ice extent obtained from www.cawcr.gov.au/staff/preid/ice/
Fig. 10. Winter 2013 MSLP (hPa). The contour interval is 5 hPa.

Fig. 11. Winter 2013 MSLP anomalies (hPa), from a 1979–2000 climatology.
Fig. 12. Winter 2013 500 hPa mean geopotential height (gpm).

Fig. 13. Winter 2013 500 hPa mean geopotential height anomalies (gpm), from a 1979–2000 climatology.
After being positive for the first five months of 2013, the monthly SAM index dropped below zero in June (−0.27) before rising in July (+0.95), and then falling sharply in August (−1.56). Rainfall patterns across southeast Australia in August correlate with the strongly negative phase of the SAM that month, with wetter-than-average conditions across most of Tasmania, southern Victoria and areas of southwest Western Australia, and drier-than-average conditions across most of New South Wales (not shown). The SAM index remained strongly negative into spring, with the August–October mean SAM index (−1.23) being the lowest for that period since 1988 (see Annual Climate Statement 2013, Bureau of Meteorology 2014).

Winds
Low-level (850 hPa) and upper-level (200 hPa) wind anomalies (from the 22-year NCEP II climatology) for winter 2013 are shown in Fig. 14 and Fig. 15 respectively. Isotach contours are at 5 m s\(^{-1}\) intervals. At 850 hPa, easterly winds were slightly stronger than usual in the Northwest Pacific Ocean to the east of the Philippines, and across the Pacific.

Southern Annular Mode
The Southern Annular Mode (also known as SAM or the Antarctic Oscillation or AAO) describes a north/south shift in the belt of strong westerly winds in the middle to high latitudes of the southern hemisphere. A positive phase of the SAM is associated with higher pressure over the mid-latitudes and lower pressure over the Antarctic region as the belt of westerly winds (and hence cold fronts) shifts southwards. A negative SAM is associated with lower pressure over the mid-latitudes and higher pressure over the Antarctic region, as westerly winds shift northwards. In winter, a negative SAM tends to increase rainfall across southwest Victoria, northern Tasmania and southwest Western Australia, and decrease rainfall in inland New South Wales (Hendon et al. 2007).

The CPC produces a standardised monthly SAM index (Climate Prediction Center 2010).\(^{11}\) After being positive for the first five months of 2013, the monthly SAM index dropped below zero in June (−0.27) before rising in July (+0.95), and then falling sharply in August (−1.56). Rainfall patterns across southeast Australia in August correlate with the strongly negative phase of the SAM that month, with wetter-than-average conditions across most of Tasmania, southern Victoria and areas of southwest Western Australia, and drier-than-average conditions across most of New South Wales (not shown). The SAM index remained strongly negative into spring, with the August–October mean SAM index (−1.23) being the lowest for that period since 1988 (see Annual Climate Statement 2013, Bureau of Meteorology 2014).

\(^{11}\)For more information on the SAM index from the Climate Prediction Center (NOAA), see www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/aoa/aoa.shtml.
Ocean between 10°S and 40°S as a result of anomalous high pressure in the South Pacific to the east of New Zealand and near 90°W.

Westerly wind anomalies are evident in an area off the coast of equatorial South America, and in the Southeast Pacific as a result of anomalous low pressure in the Amundsen Sea near 90°W and a stronger-than-usual subtropical ridge to the north. Weak east-to-southeast wind anomalies can be seen in the Australian region, with the exception of Tasmania where wind anomalies are westerly, associated with a negative phase of the SAM, which was strongest in August.

At 200 hPa, anticlockwise gyres are evident in the southeast Pacific Ocean, northeast of New Zealand and in the Indian Ocean to the west of Australia. A clockwise gyre sits to the south of Australia, producing westerly wind anomalies across southern Australia, consistent with a negative phase of the SAM. Westerly wind anomalies over the equator northeast of Australia indicate an enhanced Walker circulation. Weak easterly wind anomalies can be seen across northern Australia.

**Australian region**

**Rainfall**

Australian winter rainfall totals are shown in Fig. 16, and corresponding deciles in Fig. 17. The rainfall deciles are calculated with respect to gridded rainfall data for all winters.

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**Fig. 16.** Winter 2013 rainfall totals (mm) for Australia.

![Winter 2013 rainfall totals (mm) for Australia.](image1)

**Fig. 17.** Winter 2013 rainfall deciles for Australia: decile ranges based on grid-point values over the winters 1900–2013.

![Winter 2013 rainfall deciles for Australia: decile ranges based on grid-point values over the winters 1900–2013.](image2)
Table 1: Summary of the seasonal rainfall ranks and extremes on a national and State basis for winter 2013. The ranking in the last column goes from 1 (lowest) to 114 (highest) and is calculated over the years 1900–2013. Percentages above/below mean are calculated with respect to the base period 1961–1990.

<table>
<thead>
<tr>
<th>Region</th>
<th>Highest seasonal total (mm)</th>
<th>Lowest seasonal total (mm)</th>
<th>Highest daily total (mm)</th>
<th>Area-averaged rainfall (mm)</th>
<th>Rank of area-averaged rainfall</th>
<th>% difference from mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>1351.8* at Mount Read (TAS)</td>
<td>0.0 at several locations</td>
<td>223.6 at Roebourne (WA), 25/06</td>
<td>61.8</td>
<td>51</td>
<td>−3</td>
</tr>
<tr>
<td>Queensland</td>
<td>926.0 at Bellenden Ker Top Station</td>
<td>0.0 at several locations</td>
<td>167.0 at Daradgee, 19/07</td>
<td>17.6</td>
<td>13</td>
<td>−65</td>
</tr>
<tr>
<td>New South Wales</td>
<td>860.0 at Perisher Valley</td>
<td>13.2 at Tibbooburra Airport</td>
<td>185.0 at Mongarlowe (Leweston), 25/06</td>
<td>118.1</td>
<td>60.5</td>
<td>2</td>
</tr>
<tr>
<td>Victoria</td>
<td>820.6 at Wyelangta</td>
<td>59.8 at Murray Lock Number 9</td>
<td>184.2 at Balook, 14/06</td>
<td>260.6</td>
<td>101</td>
<td>28</td>
</tr>
<tr>
<td>Tasmania</td>
<td>1351.8* at Mount Read</td>
<td>99.6 at Tunbridge (Austin-Vale)</td>
<td>100.4 at Mount Wellington, 22/07</td>
<td>581.1</td>
<td>100</td>
<td>33</td>
</tr>
<tr>
<td>South Australia</td>
<td>688.4 at Uraidla</td>
<td>2.0 at Moomba</td>
<td>150.8 at Murray Lagoon (Hawks Nest), 12/06</td>
<td>71.9</td>
<td>90</td>
<td>29</td>
</tr>
<tr>
<td>Western Australia</td>
<td>672.2 at Margaret River</td>
<td>0.0 at a few locations</td>
<td>223.6 at Roebourne, 25/06</td>
<td>66.4</td>
<td>71</td>
<td>9</td>
</tr>
<tr>
<td>Northern Territory</td>
<td>56.5 at Palm Valley</td>
<td>0.0 at several locations</td>
<td>41.0 at The Derwent, 9/07</td>
<td>8.7</td>
<td>47</td>
<td>−52</td>
</tr>
</tbody>
</table>

*The true total is higher as snow was lost on several days

Table 2: Percentage areas in different categories for winter 2013 rainfall. ‘Severe deficiency’ denotes rainfall at or below the 5th percentile. Areas in ‘decile 1’ include those in ‘severe deficiency’, which in turn include those which are ‘lowest on record’. Areas in ‘decile 10’ include those which are ‘highest on record’. Percentage areas of highest and lowest on record are given to two decimal places because of the small quantities involved; other percentage areas to one decimal place.

<table>
<thead>
<tr>
<th>Region</th>
<th>Lowest on record</th>
<th>Severe deficiency</th>
<th>Decile 1</th>
<th>Decile 10</th>
<th>Highest on record</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>0.00</td>
<td>3.8</td>
<td>12.7</td>
<td>9.9</td>
<td>0.36</td>
</tr>
<tr>
<td>Queensland</td>
<td>0.00</td>
<td>10.8</td>
<td>34.5</td>
<td>0.1</td>
<td>0.00</td>
</tr>
<tr>
<td>New South Wales</td>
<td>0.00</td>
<td>0.0</td>
<td>0.0</td>
<td>6.7</td>
<td>0.00</td>
</tr>
<tr>
<td>Victoria</td>
<td>0.00</td>
<td>0.0</td>
<td>0.0</td>
<td>28.3</td>
<td>0.26</td>
</tr>
<tr>
<td>Tasmania</td>
<td>0.00</td>
<td>0.0</td>
<td>0.0</td>
<td>30.0</td>
<td>0.00</td>
</tr>
<tr>
<td>South Australia</td>
<td>0.00</td>
<td>1.0</td>
<td>1.7</td>
<td>20.4</td>
<td>0.00</td>
</tr>
<tr>
<td>Western Australia</td>
<td>0.00</td>
<td>3.8</td>
<td>10.9</td>
<td>16.7</td>
<td>1.08</td>
</tr>
<tr>
<td>Northern Territory</td>
<td>0.00</td>
<td>0.0</td>
<td>6.2</td>
<td>0.0</td>
<td>0.00</td>
</tr>
</tbody>
</table>
From 1900–2013, averaged across Australia, winter rainfall was 3% below the 1961–1990 average (Table 1), due to below average rainfall across Queensland, the eastern Northern Territory and southwest Western Australia, and despite wetter than average conditions between northwest Western Australia and the southeast of Australia.

Northern Australia is typically dry in winter, but Queensland was particularly dry (31st driest winter on record), 34.5% of the state recording winter rainfall in the lowest decile (driest 10% of years) and 10.8% of the state recording winter rainfall in the driest 5% of years (Table 2). In Western Australia, 10.9% of the state recorded rainfall in the lowest decile and 3.8% in the driest 5% of years. Conversely, 16.7% of Western Australia recorded rainfall in the 10th decile (wettest 10% of years), and 1.08% of the state was wettest on record for winter. This was largely due to heavy rainfall events across the northwest in June, which saw several sites break winter daily rainfall records. A cloud band produced the highest daily total of the season, with 223.6 mm recorded at Roebourne in the Pilbara over the 24 hours to 9am on 25 June, its wettest winter day on record and second-wettest day for any month. In the southeast, 30% of Tasmania, 28.3% of Victoria and 20.4% of South Australia recorded rainfall in the wettest 10% of years (highest decile). On a month-by-month basis, June was much wetter than average across the northern half of Western Australia, large areas of South Australia, New South Wales and Victoria (eighth-wettest June on record), consistent with a negative phase of the IOD. Much of Queensland, the southwest of Western Australia and Tasmania (13th-driest June on record) were drier than average.

July was wetter than average across Tasmania, southern South Australia, southeast Western Australia, and parts of central Australia and the north, whilst the southeast coast, west coast of Western Australia and pockets of central Australia were drier than usual.

August was drier than average in a band stretching across central Australia from the west coast to the east coast. Outside of this band, northern, southwest and southeast Australia, including Tasmania, recorded average to above-average rainfall in August (in southern areas this was associated with a negative phase of the SAM). Queensland recorded its fifth-driest August on record, whilst Tasmania recorded its fourth-wettest.

Drought
Above-average winter rainfall across southeast Australia eased rainfall deficiencies in Victoria and central New South Wales, and cleared them from Tasmania over both the 11-month (October 2012 to August 2013) and 17-month (April 2012 to August 2013) periods. Below-average winter rainfall across Queensland and northern New South Wales saw a worsening of deficiencies inland of the coastal ranges in Queensland, and in northern New South Wales. In Western Australia, rainfall deficiencies emerged along the west coast following below-average winter rainfall across the southern half of the state, with deficiencies persisting in the Nullarbor.

Temperature
Maximum and minimum temperature anomalies (relative to the reference period 1961–1990) for winter 2013 are shown in Fig. 18 and Fig. 20 respectively. Fig. 19 and Fig. 21 show the corresponding maximum and minimum temperature deciles, calculated using monthly temperature analysis between 1911 and 2013.

Winter days were much warmer than average across Australia, with the exception of northwest Western Australia where temperatures were close to average (as a result of heavy rainfall in that area). Nationally, the winter mean

Fig. 18 Winter 2013 maximum temperature anomalies (°C).

![Image of Winter 2013 maximum temperature anomalies (°C)](http://www.bom.gov.au)
maximum temperature was 1.42 °C above average, the second-highest on record; 65.9% of the country recorded maximum temperatures in the highest decile (warmest ten percent of years), with 100% of Tasmania, 92.5% of the Northern Territory and 89.1% of Queensland also in the highest decile (Table 3). Every State and the Northern Territory, with the exception of Tasmania, recorded mean maximum temperature anomalies of at least +1 °C (Table 4). Maximum temperatures were second warmest on record for Queensland and New South Wales, third warmest for South Australia and the Northern Territory, and fifth warmest for Victoria.

Numerous sites recorded their highest mean winter maximum temperature on record, and some their warmest winter day on record. On 20 August Timber Creek reached 39.7 °C, breaking the Northern Territory’s temperature record for both August and winter, and equalling Australia’s second-warmest August temperature record (observed at Wyndham Aero in Western Australia on 31 August 2009). On 31 August Australia recorded its warmest winter day on record with a mean maximum temperature of 29.92 °C (previous record of 29.73 °C on 23 August 1995) during a period of unusual warmth that developed during the last week of winter (see Special Climate Statement 46, Bureau of Meteorology 2013).

Australia’s winter mean minimum temperature was also above average, by 1.14 °C (sixth warmest on record; Table

Fig. 19. Winter 2013 maximum temperature deciles: decile ranges based on grid-point values over the winters 1911–2013

Fig. 20. Winter 2013 minimum temperature anomalies (°C).
All States and the Northern Territory, with the exception of Western Australia, recorded minimum temperature anomalies in the top ten, including Victoria where minima were fourth warmest on record; 47.1% of Australia had minimum temperatures in the highest decile, including 89.9% of Victoria and 89.2% of Tasmania. Several sites in Victoria recorded their highest winter mean minimum temperature on record, as did sites in New South Wales and South Australia. Despite the general warmth, mean minima were below average in pockets of northern Australia, western Western Australia and northeast Queensland. In Tasmania, Liawenee recorded a low of −12.2 °C on 9 July, its lowest temperature ever recorded and Tasmania’s second-lowest July temperature on record.

Overall, Australia’s mean winter temperature (average of the maximum and minimum) was 1.29 °C above average; third highest on record.

Fig. 21. Winter 2013 minimum temperature deciles: decile ranges based on grid-point values over the winters 1911–2013.

Table 3. Percentage areas in different categories for winter 2013. Areas in ‘decile 1’ include those which are ‘lowest on record’. Areas in ‘decile 10’ include those which are ‘highest on record’. Percentage areas of highest and lowest on record are given to two decimal places because of the small quantities involved; other percentage areas to one decimal place. Grid-point deciles calculated with respect to 1911–2013.
Table 4: Summary of the seasonal maximum temperature ranks and extremes on a national and State basis for winter 2013. The ranking in the last column goes from 1 (lowest) to 104 (highest) and is calculated over the years 1910–2013. 13

<table>
<thead>
<tr>
<th>Region</th>
<th>Highest seasonal mean maximum (°C)</th>
<th>Lowest seasonal mean maximum (°C)</th>
<th>Highest daily temperature (°C)</th>
<th>Lowest daily maximum temperature (°C)</th>
<th>Area-averaged temperature anomaly (°C)</th>
<th>Rank of area-averaged temperature anomaly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>33.9 at Douglas River (NT) and at Wyndham Aerodrome (WA)</td>
<td>1.2 at Mount Hotham (VIC)</td>
<td>39.7 at Timber Creek (NT), 20/08</td>
<td>−5.4 at Thredbo Top Station (NSW), 21/07</td>
<td>1.42</td>
<td>103</td>
</tr>
<tr>
<td>Queensland</td>
<td>32.2 at Kowanyama</td>
<td>15.7 at Applethorpe</td>
<td>37.5 at Birdsville, 31/08</td>
<td>8.4 at Applethorpe, 25/06</td>
<td>1.74</td>
<td>103</td>
</tr>
<tr>
<td>New South Wales</td>
<td>22.8 at Mungindi</td>
<td>1.5 at Thredbo Top Station</td>
<td>34.1 at Wanaaring, 29/08</td>
<td>−5.4 at Thredbo Top Station, 21/07</td>
<td>1.64</td>
<td>103</td>
</tr>
<tr>
<td>Victoria</td>
<td>17.8 at Mildura</td>
<td>1.2 at Mount Hotham</td>
<td>27.6 at Mildura, 29/08</td>
<td>−5.2 at Mount Hotham, 19/08</td>
<td>1.03</td>
<td>100</td>
</tr>
<tr>
<td>Tasmania</td>
<td>15.1 at Bicheno</td>
<td>3.5 at Mount Wellington</td>
<td>19.8 at Bushy Park, 19/07</td>
<td>−3.0 at Mount Wellington, 06/07</td>
<td>0.54</td>
<td>94</td>
</tr>
<tr>
<td>South Australia</td>
<td>22.8 at Moomba</td>
<td>10.7 at Mount Lofty</td>
<td>34.5 at Oodnadatta, 28/08</td>
<td>5.5 at Mount Lofty, 20/07</td>
<td>1.43</td>
<td>102</td>
</tr>
<tr>
<td>Western Australia</td>
<td>33.9 at Wyndham River</td>
<td>15.7 at Rocky Gully</td>
<td>39.5 at Warmun, 20/08</td>
<td>9.3 at Yeelirrie, 07/07</td>
<td>1.04</td>
<td>95</td>
</tr>
<tr>
<td>Northern Territory</td>
<td>33.9 at Douglas River</td>
<td>20.7 at Kulgera</td>
<td>39.7 at Timber Creek, 20/08</td>
<td>9.8 at Kulgera, 09/07 and 19/06</td>
<td>1.70</td>
<td>102</td>
</tr>
</tbody>
</table>

13 A high-quality subset of the temperature network is used to calculate the spatial averages and rankings shown in Table 4 (maximum temperature) and Table 5 (minimum temperature). These averages are available from 1910 to the present. As the anomaly averages in the tables are only retained to two decimal places, tied rankings are possible.
Table 5: Summary of the seasonal minimum temperature ranks and extremes on a national and State basis for winter 2013. The ranking in the last column goes from 1 (lowest) to 104 (highest) and is calculated over the years 1910–2013.

<table>
<thead>
<tr>
<th>Region</th>
<th>Highest seasonal mean minimum (°C)</th>
<th>Lowest seasonal mean minimum (°C)</th>
<th>Highest daily minimum temperature (°C)</th>
<th>Lowest daily temperature (°C)</th>
<th>Area-averaged temperature anomaly (°C)</th>
<th>Rank of area-averaged temperature anomaly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>24.3 at Coconut Island (QLD) and at Cape Wessel (NT)</td>
<td>−3.5 at Thredbo AWS (NSW)</td>
<td>27.1 at Troughton Island (WA), 01/06 and 06/06</td>
<td>−12.2 at Liawenee (TAS), 09/07</td>
<td>1.14</td>
<td>99</td>
</tr>
<tr>
<td>Queensland</td>
<td>24.3 at Coconut Island</td>
<td>2.8 at Stanthorpe</td>
<td>26.4 at Coconut Island, 05/06</td>
<td>−5.6 at Stanthorpe, 22/08 and at Oakey, 21/08</td>
<td>1.47</td>
<td>97</td>
</tr>
<tr>
<td>New South Wales</td>
<td>13.5 at Cape Byron</td>
<td>−3.5 at Thredbo Top Station</td>
<td>18.3 at Cape Byron, 31/08</td>
<td>−11.1 at Perisher Valley, 09/07</td>
<td>1.30</td>
<td>97.5</td>
</tr>
<tr>
<td>Victoria</td>
<td>9.9 at Wilsons Promontory</td>
<td>−2.7 at Mount Hotham</td>
<td>15.3 at Point Hicks, 19/07</td>
<td>−7.2 at Mount Hotham, 20/08</td>
<td>1.09</td>
<td>101</td>
</tr>
<tr>
<td>Tasmania</td>
<td>9.2 at Swan Island</td>
<td>−1.1 at Liawenee</td>
<td>14.4 at Friendly Beaches, 01/06, and Flinders Island Airport, 19/07</td>
<td>−12.2 at Liawenee, 09/07</td>
<td>0.94</td>
<td>97</td>
</tr>
<tr>
<td>South Australia</td>
<td>12.6 at Neptune Island</td>
<td>3.8 at Yongala</td>
<td>20.8 at Marree Comparison, 29/08</td>
<td>−4.9 at Gluepot Reserve, 10/07</td>
<td>1.39</td>
<td>98</td>
</tr>
<tr>
<td>Western Australia</td>
<td>24.1 at Troughton Island</td>
<td>3.8 at York</td>
<td>27.1 at Troughton Island, 01/06 and 06/06</td>
<td>−4.8 at Wandering, 08/07</td>
<td>0.59</td>
<td>87</td>
</tr>
<tr>
<td>Northern Territory</td>
<td>24.3 at Cape Wessel</td>
<td>5.9 at Arltunga</td>
<td>26.3 at Cape Don, 07/06</td>
<td>−3.4 at Arltunga, 22/06</td>
<td>1.49</td>
<td>98</td>
</tr>
</tbody>
</table>
References


