

Seasonal climate summary southern hemisphere (summer 2010–2011): second-wettest Australian summer on record and one of the strongest La Niña events on record

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Introduction

This summary reviews the southern hemisphere and equatorial climate patterns for summer 2010–2011, 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 (SOI)

Strong positive values of the Troup Southern Oscillation Index¹ (SOI) which began in winter 2010 continued to persist throughout summer 2010–2011. Monthly values were +27.1 (December), +19.9 (January) and +22.3 (February). The December SOI value was the highest on record for any December and the highest for any month since November 1973 (+31.6). The February value was also a record for any February since records began in 1876 while the average August to December SOI (+21.1) was only exceeded once by the La Niña of 1917–1918 (+24.2) with the La Niña of 1975–1976 ranking third (+18.8). The strong SOI values are representative of the strong La Niña event in the Pacific which developed in autumn 2010 (Ganter 2011). Figure 1 shows the monthly SOI from January 2007 to February 2011, together with a five-month weighted moving average.

¹The Troup Southern Oscillation Index (Troup 1965) used in this article is ten times the standardised monthly anomaly of the difference in mean sea level pressure (MSLP) between Tahiti and Darwin. The calculation is based on a sixty-year climatology (1933–1992). The Darwin MSLP is provided by the Bureau of Meteorology, with the Tahiti MSLP being provided by Météo France inter-regional direction for French Polynesia.

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Composite monthly ENSO index

A composite monthly ENSO index, calculated as the standardised amplitude of the first principal component² of monthly Darwin and Tahiti MSLP³ and monthly NINO3, NINO3.4 and NINO4 sea surface temperatures⁴ (SSTs) (Kuleshov et al. 2008), continued a sequence of negative values which began in winter 2010 (Fig. 2).

Figure 2 shows all of the three monthly values in the season exceeded one standard deviation as is typically the case for moderate or strong positive phases of the Southern Oscillation and La Niña states. The monthly values for this index were –1.94 (December), –1.67 (January) and –1.63 (February). All of the summer 2010–2011 values exceeded one standard deviation with each monthly value ranking in the lowest five values on record (since 1950) for each respective month.

Multivariate ENSO index

The Multivariate ENSO Index⁵ (MEI), produced by the US Climate Diagnostics Center, is derived from a number of atmospheric and oceanic parameters typically associated with ENSO and is calculated as a two month mean (Wolter and Timlin 1993, 1998). Significant negative values indicate La Niña, while significant positive values indicate El Niño. The MEI values have been ranked over the 61 year record, beginning in 1950. The lowest value (1) signifies the strongest La Niña case for that particular two month pairing, while the highest number (61) signifies the strongest El Niño case. At the beginning of the year, the January–February 2010 pair was +1.502, ranked 57 (fifth strongest El Niño value). By the end of winter MEI reached its lowest point with –2.037, the lowest value on record for that time of year. The summer

²The principal component analysis and standardisation of this ENSO index is performed over the period 1950–1999.

³MSLP data obtained from <http://www.bom.gov.au/climate/current/soi-hm1.shtml>. As previously mentioned, the Tahiti MSLP data are provided by Météo France inter-regional direction for French Polynesia.

⁴SST indices obtained from <ftp://ftp.cpc.ncep.noaa.gov/wd52dg/data/indices/sstoi.indices>

⁵Multivariate ENSO Index obtained from <http://www.esrl.noaa.gov/psd/people/klaus.wolter/MEI/table.html>. The MEI is a standardised anomaly index.

2010–2011 values were -1.552 (November–December), -1.654 (December–January) and -1.552 (January–February) signifying the continuation of the strong La Niña conditions. These ranked fourth, second and second lowest respectively.

Outgoing long-wave radiation

Outgoing long-wave radiation (OLR) over the equatorial Pacific near the Date Line (5°S to 5°N and 160°E to 160°W) is a good measure of tropical deep convection, with increases (decreases) in OLR indicating decreases (increases) in convection. During La Niña events, OLR is often increased, meaning convection is suppressed over this region. El Niño events on the other hand, usually have decreased OLR, meaning convection is generally enhanced over this region. The Climate Prediction Center, Washington, computes a standardised monthly anomaly⁶ of OLR over the equatorial Pacific. Monthly values for December, January and February were $+2.4$, $+2.3$ and $+2.2$ respectively. The December value was the highest on record for any month with the seasonal average for summer of $+2.3$ ranking as the highest for any

Fig. 1 Southern Oscillation Index, from January 2007 to February 2011, 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

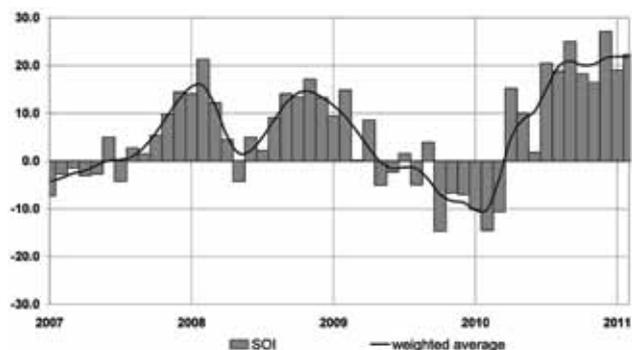
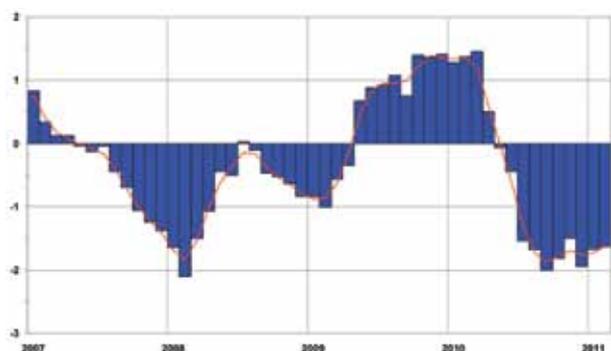


Fig. 2 Composite standardised monthly ENSO index from January 2007 to February 2011, together with a weighted three-month moving average. See text for details.

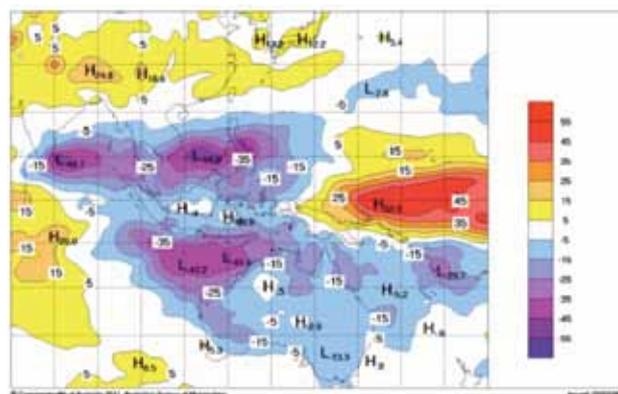


⁶Standardised monthly OLR anomaly data obtained from <http://www.cpc.ncep.noaa.gov/data/indices/olr>

season on record (records began in 1974). The strongly positive values are consistent with La Niña conditions, and indicate that there was markedly decreased convection over the equatorial Pacific.

The spatial pattern of seasonal OLR anomalies across the Asia–Pacific tropics for summer 2010–2011 is shown in Fig. 3. Consistent with the standardised anomalies discussed above, very strong positive anomalies were present in the equatorial Pacific, just west of the Date Line, while very strong negative OLR anomalies were present over Indonesia. This is indicative of the suppressed convection over the areas with strongly positive anomalies and enhanced convection over areas with strongly negative values. This pattern is well aligned with that expected during La Niña events. Negative OLR anomalies were also present over all of Australia, which experienced its second-wettest summer on record.

Fig. 3 OLR anomalies for summer 2010–2011 (W m^{-2}). Base period 1979 to 1988. The mapped region extends from 40°S to 40°N and from 70°E to 180°E .

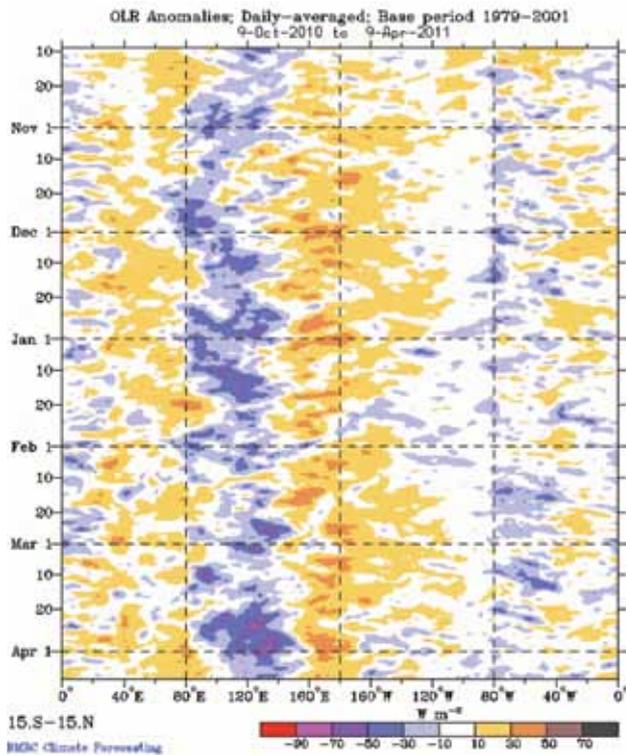


Madden–Julian Oscillation

The Madden–Julian Oscillation (MJO) is a tropical atmospheric anomaly which develops in the Indian Ocean and propagates eastwards into the Pacific Ocean (Donald et al. 2004). The MJO takes approximately 30 to 60 days to reach the western Pacific, with a frequency of six to twelve events per year (Donald et al. 2004). When the MJO is in an active phase, it is associated with increased tropical convection, with the effects at this time of year concentrated in the northern hemisphere. The evolution of tropical convection anomalies along the equator with time is shown in Fig. 4, starting from October 2010 through to April 2011. In the daily averaged OLR anomalies in Fig. 4, December 2010 and January 2011 was a weak period for the MJO. However, one eastward-propagating band of tropical convection was evident during the first halves of December and January, when an eastward-propagating band of MJO-related convection was located in the Pacific Ocean during both months. The MJO band in both December and January weakened and became indiscernible during the latter half of the months, and did not extend into the western Pacific.

As discussed in the previous section, positive OLR

Fig. 4 Time-longitude section of 7-day running mean OLR anomalies, averaged for 7.5°S–7.5°N, for the period October 2010 through to April 2011. Anomalies are with respect to a base period of 1979–2001.



anomalies over the central equatorial Pacific may also be seen in Fig. 4. These positive anomalies are associated with La Niña conditions, and became established during autumn and winter 2010.

Oceanic patterns

Sea surface temperatures

Summer 2010–11 global sea surface temperature (SST) anomalies, from the US National and Oceanic and Atmospheric Administration Optimum Interpolation

analysis (Reynolds et al. 2002), are displayed in Fig. 5, in degrees Celsius (°C). Positive (warm) anomalies are shown in red shades, while negative (cool) anomalies are shown in blue shades. During autumn, the SSTs were in a transition state, with the 2009–2010 El Niño breaking down (Campbell, 2011) with winter SSTs being indicative of an emerging La Niña (Ganter, 2011) which continued and intensified into spring. Summer 2010–2011 SSTs remained at strong La Niña levels throughout December and peaked during January. In February the cool anomalies in the central and eastern tropical Pacific Ocean warmed slightly, signalling the decay of the La Niña into autumn as is consistent with El Niño – La Niña events. Summer 2010–2011 peak SST anomalies of between $-1.5\text{ }^{\circ}\text{C}$ to $-2.0\text{ }^{\circ}\text{C}$ were predominantly located along the equator in the central and eastern Pacific (Fig. 5), while anomalies of $-1.0\text{ }^{\circ}\text{C}$ to $-1.5\text{ }^{\circ}\text{C}$ surrounded the cooler equatorial temperatures extending to higher latitudes in the eastern Pacific. SSTs surrounding Australia remained warmer than normal with particularly warm temperatures off the Gascoyne coast in Western Australia where temperature anomalies were between $+2.0\text{ }^{\circ}\text{C}$ to $+2.5\text{ }^{\circ}\text{C}$.

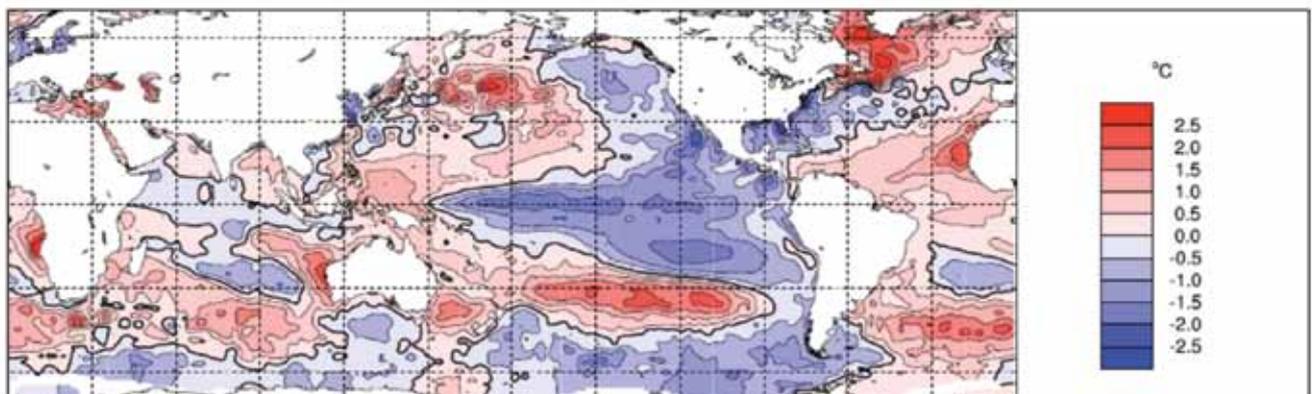
All three standard monthly NINO indices were strongly negative throughout summer. In the eastern Pacific, the negative NINO3 index values warmed throughout summer with a December value of $-1.20\text{ }^{\circ}\text{C}$ which warmed to $-0.54\text{ }^{\circ}\text{C}$ by February. NINO3.4, indicative of conditions in the central Pacific, continued to cool reaching the 2010–2011 La Niña peak of $-1.45\text{ }^{\circ}\text{C}$ before warming to $-1.00\text{ }^{\circ}\text{C}$ by February. Similarly, in the central to western Pacific, NINO4 peaked in January with $-1.26\text{ }^{\circ}\text{C}$ and warmed up to $-0.93\text{ }^{\circ}\text{C}$ in February. The largest cooling occurred between December and January for NINO3.4, where the region cooled by $0.08\text{ }^{\circ}\text{C}$, while NINO3 experienced the largest warming of $0.5\text{ }^{\circ}\text{C}$ between January and February.

Subsurface ocean patterns

The Hovmöller diagram for the $20\text{ }^{\circ}\text{C}$ isotherm depth anomaly along the equator from February 2008 to March 2011, obtained from NOAA’s TAO/TRITON data⁷, is shown

⁷Hovmöller plot obtained from <http://www.pmel.noaa.gov/tao/jsdisplay/>

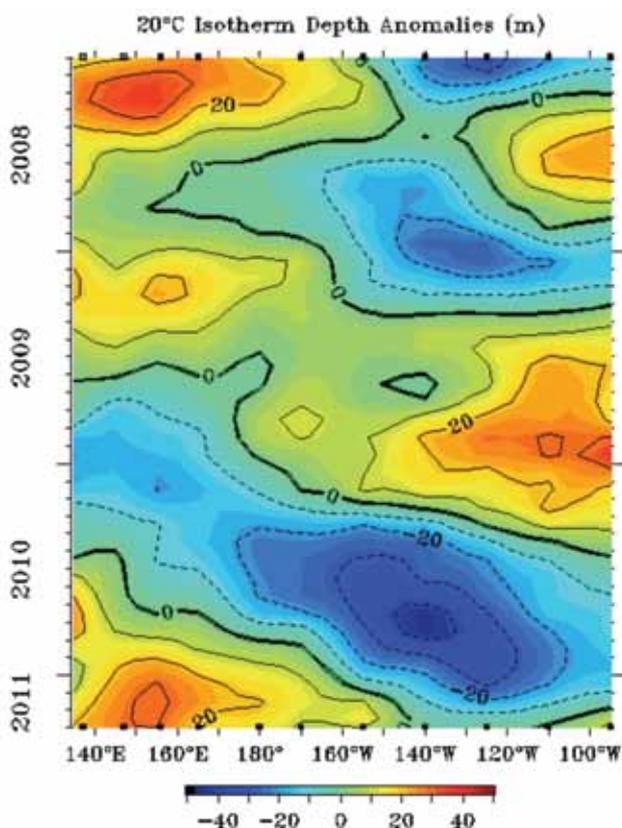
Fig. 5 Anomalies of SST for summer 2010–2011 (°C). The contour interval is $0.5\text{ }^{\circ}\text{C}$.



in Fig. 6. The 20 °C isotherm depth is generally located close to the equatorial thermocline, which is the region of greatest temperature gradient with depth, and is the boundary between the warm near-surface and cold deep-ocean waters. Therefore, measurements of the 20 °C isotherm depth make a good proxy for the thermocline depth. Positive (negative) anomalies correspond to the 20 °C isotherm being deeper (shallower) than average. Changes in the thermocline depth may act as a precursor to subsequent changes at the ocean surface. A shallow thermocline depth results in more cold water available for upwelling, and therefore a potential cooling of surface temperatures.

In late 2009 and early 2010 a mature El Niño event was in place: the 20 °C isotherm anomaly was positive in the central and eastern Pacific, while there were weak negative anomalies in the western Pacific. Through winter and spring the subsurface cooled across the central and eastern Pacific, while the far western Pacific warmed. During summer the strong negative 20 °C isotherm anomalies in the central and eastern Pacific warmed and returned to close to neutral conditions while the western Pacific continued to warm and remain strongly positive. The pattern of a shallower-than-normal 20 °C isotherm in the central and eastern Pacific and a deeper-than-normal 20 °C isotherm in the western Pacific during spring and summer is consistent with a strong La Niña event. The breakdown of the strong negative anomalies

Fig. 6 Time–longitude section of the monthly anomalous depth of the 20 °C isotherm at the equator for February 2008 to March 2011. The contour interval is 10 m.



in the eastern Pacific in early 2011 is consistent with the life cycle decay of past La Niña events.

Figure 7 shows a cross-section of monthly equatorial subsurface anomalies from November 2010 to February 2011. Red shading indicates positive anomalies, and blue shades indicate negative anomalies. The subsurface cross-section shows cool anomalies across the central and eastern Pacific in place throughout November to February, with warm anomalies present and increasing in the western Pacific during this time. The cool anomalies remained very strongly negative (in excess of -4 °C) throughout this period until February, which saw a rapid decline of the subsurface cold pool. During summer the warm subsurface anomalies in the western Pacific warmed to over $+4\text{ °C}$ with some warm anomalies extending to the central Pacific Ocean. The pattern of the decaying cool subsurface temperature anomalies in February is consistent with the decay of past La Niña events.

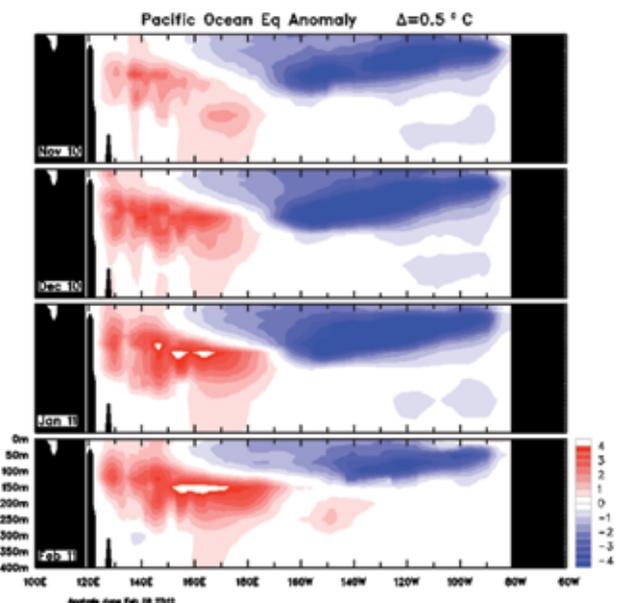
Global atmospheric patterns

Surface analyses

The southern hemisphere summer 2010–2011 Mean Sea Level Pressure (MSLP) pattern, computed from the Bureau of Meteorology’s Australian Community Climate and Earth-System Simulator⁸ (ACCESS) model (the previous GASP model having been phased out in August 2010), is shown in Fig. 8, with the associated anomaly pattern shown in Fig. 9. These anomalies are the difference from

⁸For more information on the Bureau of Meteorology’s ACCESS model, see <http://www.bom.gov.au/nwp/doc/access/NWPData.shtml>

Fig. 7 Four-month November 2010 to February 2011 sequence of vertical sea subsurface temperature anomalies at the equator for the Pacific Ocean. The contour interval is 0.5 °C (obtained from CAWCR).



a 1979–2000 climatology obtained from the National Centers for Environmental Prediction (NCEP) II Reanalysis data (Kanamitsu et al. 2002). The MSLP analysis has been computed using data from the 0000 UTC daily analyses of the ACCESS model. The MSLP anomaly field is not shown over areas of elevated topography (grey shading).

The summer 2010–2011 MSLP pattern (Fig. 8) was zonal in the southern hemisphere mid- to high latitudes. The subtropical ridge was evident south of Australia, with centres of high pressure over the central-eastern Pacific (1024.4 hPa) and Indian Ocean (1021.2 hPa). A polar low can be seen in Fig. 8, with a peak low pressure of 981.1 hPa around 70°W to 130°W, with a second centre (985 hPa) at about 15°E. MSLP was generally higher than normal (anomalies up to and above +5.0 hPa) over the region south of 50°S (Fig. 9) with the exception of an area in the high latitudes from 30°W to 160°W where they were below normal (anomalies around -2.5 hPa). All of Australia was within 2.5 hPa of the average with stronger negative MSLP anomalies present in

the Indian Ocean off the west coast of Western Australia.

Mid-tropospheric analyses

The 500 hPa geopotential height, which is an indicator of the steering of surface synoptic systems across the southern hemisphere, is shown in Fig. 10 for December 2010 to February 2011. The associated anomalies are shown in Fig. 11. Figure 10 shows that the summer 500 hPa height pattern displays the characteristic zonal structure in the mid- to high latitudes, with weak three-wave characteristics. Similarly to the MSLP anomalies the 500 hPa gpm anomalies over Australia were weak with most of the country being within 30 gpm of the average. Slightly stronger positive anomalies were present in the Tasman stretching across New Zealand and the southern Pacific to 80°W. The strongest anomalies were present in the polar region with the largest positive anomalies present between 60°E and 105°E and the largest negative anomalies between 60°W and 120°W with higher-than-normal pressure recorded over the Antarctic continent.

Fig. 8 Summer 2010–2011 MSLP (hPa). The contour interval is 5 hPa.

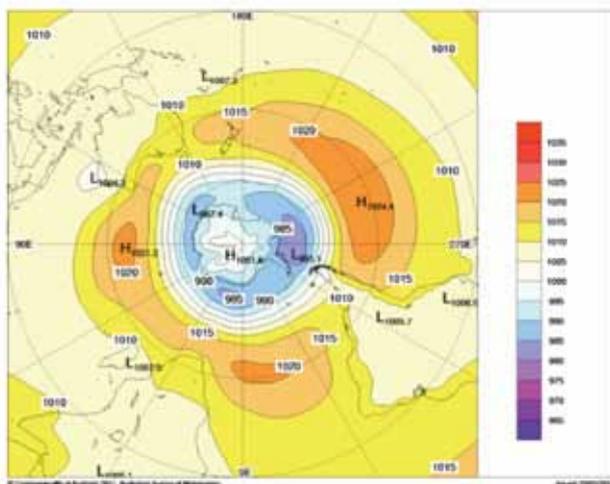


Fig. 9 Summer 2010–2011 MSLP anomalies (hPa).

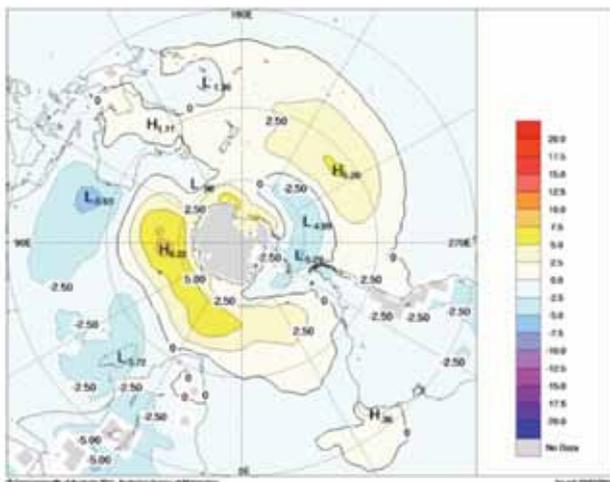


Fig. 10 Summer 2010–2011 500 hPa mean geopotential height (gpm).

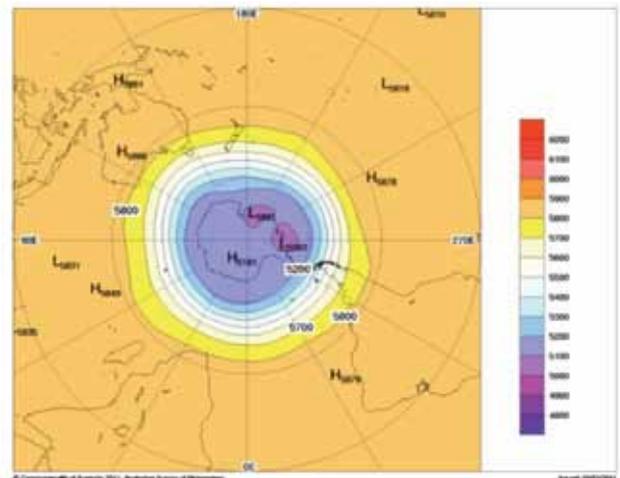
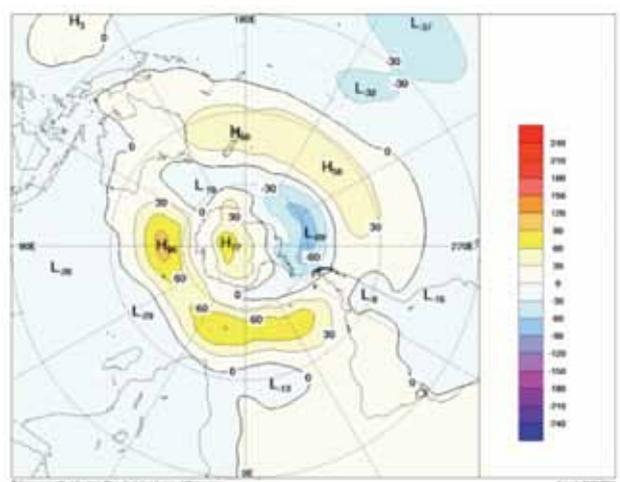


Fig. 11 Summer 2010–2011 500 hPa mean geopotential height anomalies (gpm).



Southern Annular Mode

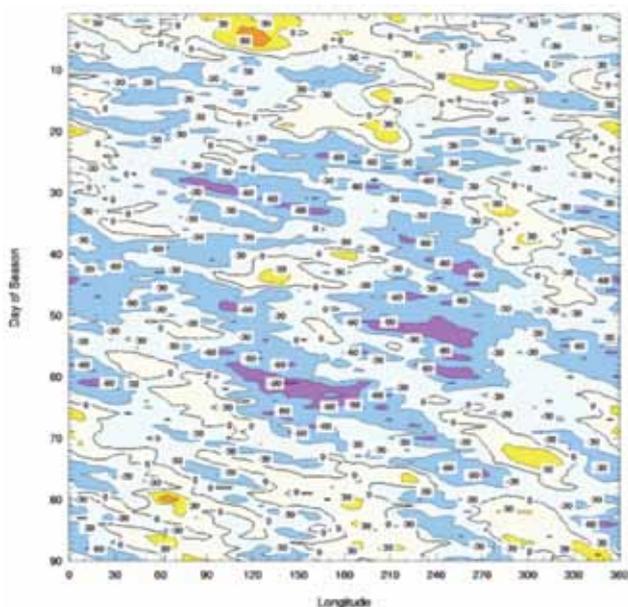
The Southern Annular Mode (SAM) describes the periodic, approximately ten-day, oscillation of atmospheric pressure between the polar and mid-latitude regions of the southern hemisphere. Positive phases of SAM are characterised by increased mass over the extra-tropics, decreased mass over Antarctica and a poleward contraction of the mid-latitude band of westerly winds. Conversely, negative phases of SAM relate to reduced mass over the extra-tropics, increased mass over Antarctica and an equatorward expansion of the mid-latitude band of westerly winds. A similar oscillation exists in the northern hemisphere, the Northern Annular Mode, or NAM (also known as the Arctic Oscillation). After being strongly positive during winter and spring, the Climate Prediction Center standardised monthly SAM index (Climate Prediction Center 2010) dropped to neutral values. The December and January values were +0.61 and +0.05 respectively, with the February value increasing to +1.07.

Blocking

The time–longitude section of the daily southern hemisphere blocking index (BI, Wright 1993) is shown in Fig. 12, with the start of the season beginning at the top of the plot. This index is a measure of the strength of the zonal 500 hPa flow in the mid-latitudes (40°S to 50°S) relative to that at lower (25°S to 30°S) and higher (55°S to 60°S) latitudes. Positive values of the blocking index are generally associated with a split in the mid-latitude westerly flow centred near 45°S and mid-latitude blocking activity. Blocking activity most commonly occurs in the Australian and western Pacific latitudes. Figure 13 shows the seasonal index for each longitude.

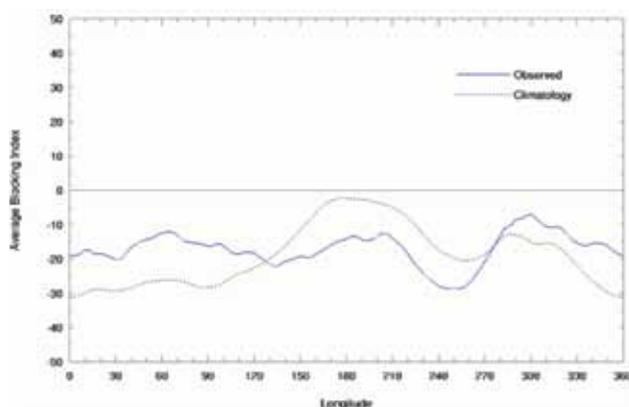
The seasonal index shows that blocking was below

Fig. 12 Summer 2010–2011 daily southern hemisphere blocking index (ms^{-1}) time-longitude section. The horizontal axis shows degrees east of the Greenwich meridian. Day one is 1 December.



average in Australian longitudes and through most of the South Pacific. Negative daily BI values were fairly consistent throughout the summer season between 120°E to 90°W, with the strongest negative values in the 120°W to 90°W longitudes (approximately the eastern Pacific Ocean, Fig. 13). The remainder of the southern hemisphere recorded negative BI values which were above the summer average. Peak negative BI values were recorded in Australian longitudes during the start of February (Fig. 12).

Fig. 13 Mean southern hemisphere blocking index (ms^{-1}) for summer 2010–2011 (solid line). The dashed line shows the corresponding long-term average. The horizontal axis shows degrees east of the Greenwich meridian.



Winds

Summer 2010–2011 low-level (850 hPa) and upper-level (200 hPa) wind anomalies (as per the surface analyses, computed from ACCESS and anomalies with respect to the 22-year NCEP II climatology) are shown in Figs. 14 and 15, respectively. Isotach contours are at 5 ms^{-1} intervals.

Easterly low-level wind anomalies were present over the central and western tropical Pacific while winds were near normal over the eastern tropical Pacific Ocean. The enhanced easterlies in the tropical Pacific (anomalies reached 5 ms^{-1} in the western Pacific), in combination with enhanced upper-level westerlies across the same region, were indicative of a stronger-than-normal Walker Circulation, which is characteristic of a La Niña. Most of Australia had a dominant northerly flow which brought moisture to much of the continent, with the exception of southwest Western Australia which experienced a mostly southeasterly flow during the season.

Australian region

Rainfall

Australian rainfall totals for summer 2010–2011 are shown in Fig. 16, while the rainfall deciles for the same period are shown in Fig. 17. The rainfall deciles are calculated using all summers from 1900–1901 to 2010–2011.

Australia experienced a very wet summer with all States

Fig. 14 Summer 2010–2011 850 hPa vector wind anomalies (ms^{-1}).

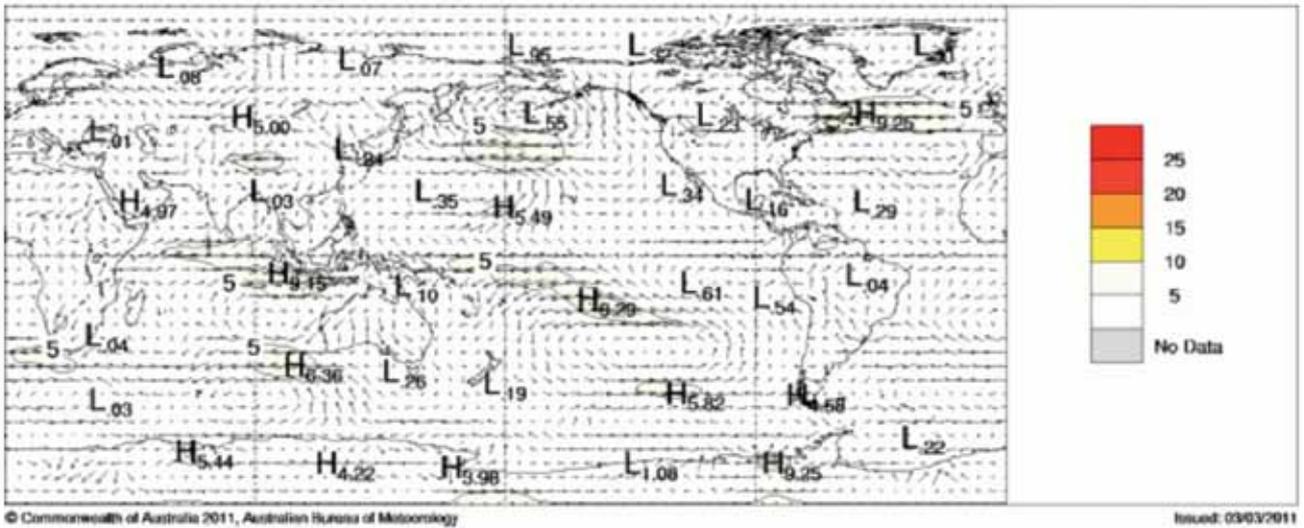


Fig. 15 Summer 2010–2011 200 hPa vector wind anomalies (ms^{-1}).

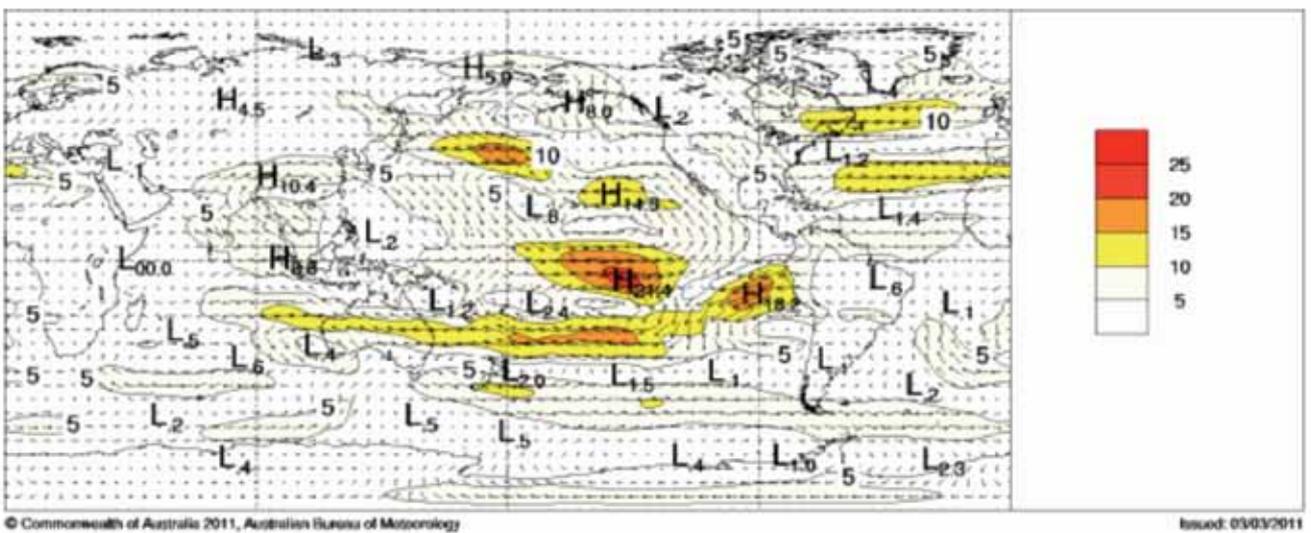


Fig. 16 Summer 2010–2011 rainfall totals (mm) for Australia.

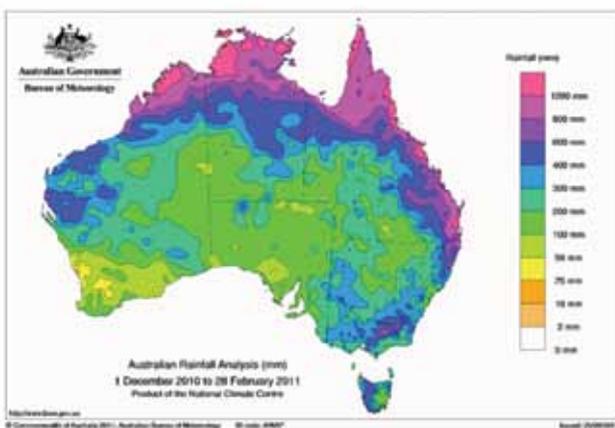
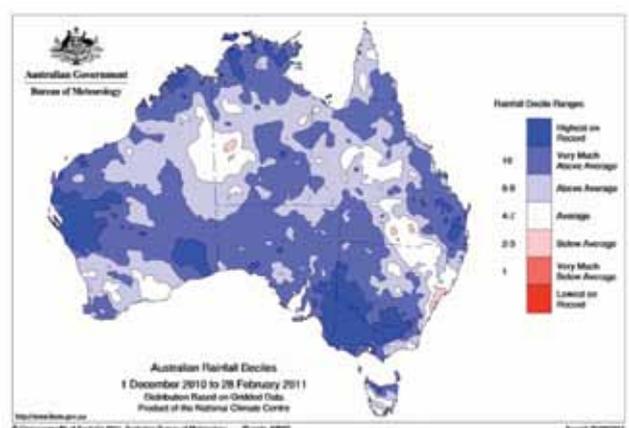


Fig. 17 Summer 2010–2011 rainfall deciles for Australia. Deciles ranges based on grid-point values over the summers 1900–1901 to 2010–2011.



and Territories recording above-average falls (Fig. 17, Table 1). Nationally averaged rainfall was 367.1 mm (76 per cent above normal) which is second only to the summer of 1973–1974 when 419.8 mm was recorded. Victoria recorded its wettest summer on record with a statewide average of 339.0 mm (184 per cent above normal). Western Australia had its wettest summer on records with 306.2 mm (105 per cent above mean), and South Australia had its third wettest summer on record with 155.1 mm recorded (150 per cent above mean). New South Wales also recorded its fifth wettest summer on record with 279.9 mm (64 per cent above mean). Tasmania was the only State not to have a summer in the wettest ten on record.

Areas of very-much-above-average rainfall were widespread across Australia; the southern half of Australia had a particularly wet summer with only a few small areas recording below-average rainfall. Much of Victoria, southern New South Wales, eastern South Australia, and parts of Western Australia, as well as small areas in northern Australia and southeast Queensland, had falls which ranked as the highest on record. The wet conditions during summer resulted in major flooding in many areas across the country including Queensland, parts of New South Wales, Victoria and northern Tasmania, and the Gascoyne region of Western Australia.

One of the strongest La Niña events on record has driven the above-average falls across much of the country. Tropical cyclone activity was above average in the Australian region during the summer months which is typical during a La Niña event. This summer, a number of tropical cyclones resulted in heavy rainfall, flooding, and damage across the tropical north. Most notably this includes tropical cyclone Yasi which crossed the coast between the regional centres of Townsville and Cairns as a category 5 cyclone. Other tropical cyclones in the Australian region which were associated with significant rainfalls included tropical cyclones *Tasha*,

Vince, *Anthony*, *Bianca*, and *Carlos*, although none caused major wind damage. A total of ten tropical cyclones occurred during the cyclone season by the end of summer 2010–2011, which was already near the long-term seasonal average with two months remaining in the main cyclone season.

Exceptional rainfall conditions also affected four of Australia's capital cities: Darwin, which broke its record for wettest day, week and month in February with a monthly total of 1110.2 mm; Brisbane, which experienced very heavy falls that led to severe flooding in early January; Canberra, which recorded its second wettest summer on record; and Melbourne, which experienced exceptionally heavy rainfall in early February that resulted in flash flooding in the greater metropolitan area.

Drought

Above- to very-much-above-average rainfall across most of Australia during summer eased short-term deficiencies. Rainfall in previous seasons in southwest Western Australia was very much below average with the area experiencing persistent rainfall deficiencies, and with summer rainfall insufficient to make significant inroads into those deficiencies.

A way in which the Bureau of Meteorology presently assesses drought is by considering the extent of areas of the country which contain accumulated rainfall in the lowest decile for varying timescales. To the end of February 2011, local temporal maxima in the areal extent of rainfall deficiencies occurred at periods of 8, 17, 28, 40, 52 and 68 months. For the eight-month period ending February 2011, 1.3 per cent of Australia, almost entirely in southwest Western Australia, was experiencing serious rainfall deficiencies (i.e. rainfall totals below the tenth percentile). These deficiencies were a result of general dryness over this period, associated with the strong positive SAM which occurred during winter and spring 2010.

For the seventeen-month period ending February 2011,

Table 1. Summary of the seasonal rainfall ranks and extremes on a national and State basis for summer 2010–2011. The ranking in the last column goes from 1 (lowest) to 110 (highest) and is calculated over the years 1900–1901 to 2010–2011.

<i>Region</i>	<i>Highest seasonal total (mm)</i>	<i>Lowest seasonal total (mm)</i>	<i>Highest daily total (mm)</i>	<i>Area-average rainfall (mm)</i>	<i>Rank of area-averaged rainfall</i>
Australia	4512.8 at Bellenden Ker Top (Qld)	11.0 at Lake Nammen (WA)	540.0 at Giddi Giddi (Qld) on 29/01	367.2	110
Queensland	4512.8 at Bellenden Ker Top	63.0 at Wallen	540.0 at Giddi Giddi (Qld) on 29/01	515.5	106
New South Wales	1223.4 at Rosebank	87.3 at Grawin	209.8 at Cangai on 11/01	279.9	107
Victoria	995.2 at Falls Creek	172.6 at Paynesville	182.0 at Falls Creek on 09/12	339.0	111
Tasmania	688.4 at Mount Read	74.8 at Cranbrook	282.0 at Falmouth on 13/01	342.7	97
South Australia	376.6 at Paringa	36.9 at Moonaree	173.6 at Ernabella on 07/02	155.1	109
Western Australia	1542.2 at Theda	11.0 at Lake Nammen	388.6 at Kuri Bay on 11/01	306.2	111
Northern Territory	2320.6 at Leanyer	93.0 at Walungurru	367.6 at Darwin on 16/02	508.9	107

2.8 per cent of Australia, or 8.3 per cent of Western Australia, experienced serious rainfall deficiencies. The seventeen-month rainfall deficiencies encompass a similar area to the eight-month period, with a wider extent of the severe deficiencies (i.e. rainfall totals below the 5th percentile) in the longer period. The deficiencies discussed above occurred against a backdrop of decade-long rainfall deficits in southwest Western Australia and high temperatures that have stressed water supplies.

Temperature

Figure 18 shows maximum and minimum temperature anomalies for summer 2010–2011. Seasonal anomalies are calculated with respect to the 1961–1990 period, and use all stations for which an elevation is available. Station normals have been estimated using gridded climatologies for those stations with insufficient data within the 1961–1990 period to calculate a station normal directly. Figure 19 shows maximum and minimum temperature deciles, calculated using monthly temperature analyses from 1911 to 2010.

Maximum temperatures averaged over Australia were

0.72 °C below normal for summer, making it the coolest summer since 2000–2001. Most of Australia recorded below-average maximum temperatures. Daytime temperatures were more than 1 °C below normal in northeast and southern Western Australia, a large part of Northern Territory and Queensland, as well as in an area in southeast Australia. The northwest coast of Western Australia also recorded maximum temperatures more than 1 °C below normal. The Northern Territory and Queensland recorded the most pronounced cool anomalies of more than 2 °C below normal. This area, as well as an area in northern Queensland and parts of Western Australia, ranked in the coolest ten per cent of records, with record lows set locally on the coast of northern Western Australia. The cool conditions in the Northern Territory and Queensland resulted in the coolest summer in a decade with anomalies of –1.40 °C and –0.97 °C recorded respectively in each State.

In contrast, areas in southwest Queensland, on the New South Wales central coast, and over the eastern interior and west coast of Western Australia, recorded maximum temperatures of over 1 °C above normal. Temperatures

Fig. 18 Summer 2010–2011 temperature anomalies (°C): (a) maximum temperature anomalies; and (b) minimum temperature anomalies.

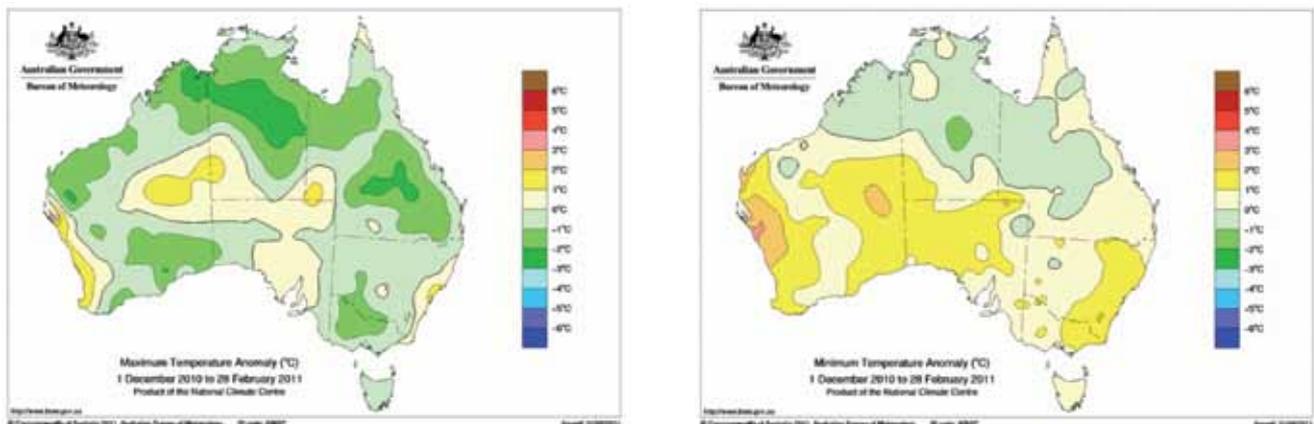


Fig. 19 Summer 2010–2011 temperature deciles for Australia—decile ranges based on grid-point values over the summer periods for 1900–1901 to 2010–2011: (a) Maximum temperature deciles; and (b) Minimum temperature deciles.

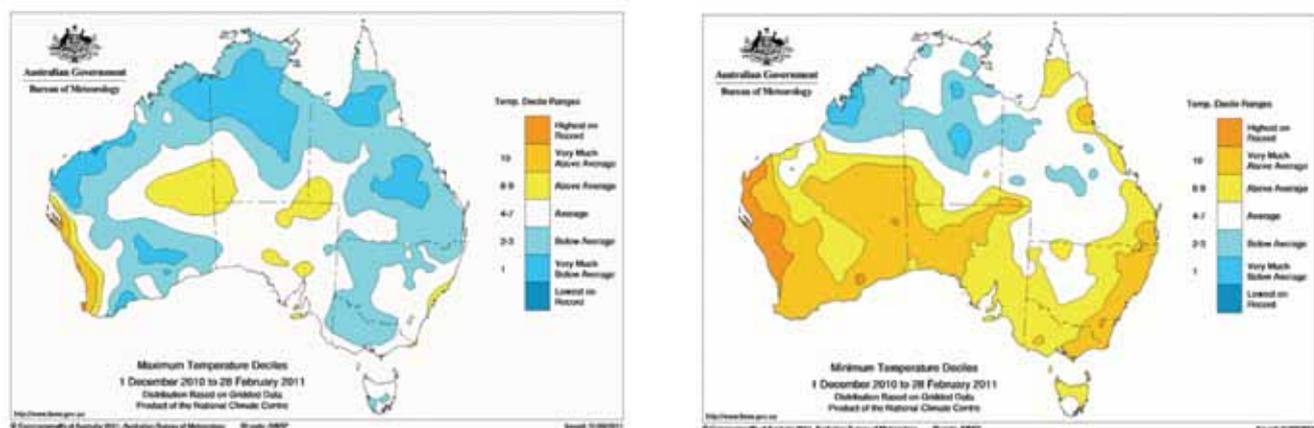


Table 2. Summary of the seasonal maximum temperature ranks and extremes on a national and State basis for summer 2010–2011. The ranking in the last column begins from 1 (lowest) to 61 (highest) and is calculated over the years 1950–1951 to 2010–2011.

Region	Highest seasonal mean maximum (°C)	Lowest seasonal mean maximum (°C)	Highest daily temperature (°C)	Lowest daily maximum temperature (°C)	Area-averaged temperature anomaly (°C)	Rank of area-averaged temperature anomaly
Australia	39.2 at Telfer (WA) and Birdsville (Qld)	11.9 at Mount Wellington (Tas.)	48.5 at Roxby Downs (SA) on 25/01	1.2 at Mt Hotham (Vic.) on 19/12	-0.72	8
Western Australia	39.2 at Telfer	22.1 at Albany	48.4 at Forrest on 30/01	15.5 at Ravensthorpe on 02/12	-0.66	12
Northern Territory	38.1 at Rabbit Flat	30.9 at Central Arnhem Plateau	46.4 at Yulara on 28/01	22.4 at Watarrka on 06/02	-1.40	6
South Australia	37.5 at Oodnadatta	21.4 at Cape Willoughby	48.5 at Roxby Downs on 25/01	11.3 at Mt Lofty on 10/12	+0.10	30
Queensland	39.2 at Birdsville	24.9 at Applethorpe	47.4 at Birdsville on 27/01	16.5 at Applethorpe on 19/12	-0.97	11
New South Wales	34.8 at Tibooburra	17.4 at Perisher Valley	45.8 at Condobolin on 26/01	4.2 at Charlotte Pass on 20/12	-0.32	22
Victoria	30.2 at Ouyen	14.1 at Mount Hotham	43.3 at Hopetoun on 31/12	1.2 at Mt Hotham (Vic.) on 19/12	-0.76	Equal 13
Tasmania	23.0 at Launceston	11.9 at Mount Wellington	35.0 at Fingal on 01/02 and at Flinders Island on 01/02	2.9 at Mt Wellington on 21/12	+0.02	27

Table 3. Summary of the seasonal minimum temperature ranks and extremes on a national and State basis for summer 2010–2011. The ranking in the last column begins from 1 (lowest) to 61 (highest) and is calculated over the years 1950–1951 to 2010–2011.

Region	Highest seasonal mean minimum (°C)	Lowest seasonal mean minimum (°C)	Highest daily minimum temperature (°C)	Lowest daily temperature (°C)	Area-averaged temperature anomaly (°C)	Rank of area-averaged temperature anomaly
Australia	27.0 at Bedout Island (WA)	3.7 at Mount Wellington (Tas.)	34.2 at Oodnadatta (SA) on 28/01	-4.4 at Mt Hotham (Vic.) on 28/12	+0.49	49
Western Australia	27.0 at Bedout Island	13.5 at Jacup	32.1 at Warburton on 31/12	1.7 at Salmon on 10/12	+0.70	56
Northern Territory	26.2 at Centre Island	20.6 at Alice Springs	31.6 at Papunya on 28/01	7.5 at Arltunga on 01/12	-0.40	14
South Australia	23.6 at Oodnadatta	11.7 at Mount Gambier	34.2 at Oodnadatta on 28/01	2.2 at Coonawarra on 07/02	+1.44	58
Queensland	25.7 at Sweers Island	15.2 at Applethorpe	31.5 at Birdsville on 28/01	3.7 at Applethorpe on 21/12	+0.06	Equal 32
New South Wales	22.1 at Tibooburra	6.8 at Charlotte Pass	29.6 at Tibooburra on 26/01	-3.0 at Thredbo Top Station on 28/12	+0.86	48
Victoria	16.4 at Mildura	7.2 at Mount Baw Baw	27.3 at Nhill on 01/02	-4.4 at Mt Hotham 28/12	+1.20	Equal 55
Tasmania	14.1 at Swan Island	3.7 at Mount Wellington	20.8 at Flinders Island on 06/01	-3.3 at Mt Wellington on 27/12	+0.41	Equal 41

along the western coast of Western Australia ranked in the top 10 per cent of warmest summers on record, with records set locally in the far southwest and around Shark Bay. A significant heatwave affected much of southern Australia in late January and early February, with a record seven consecutive days above 30 °C at Sydney.

Nationally averaged minimum temperatures were 0.49 °C above normal with most States recording above-average minimums, with the exception of the Northern Territory. Overnight minima were particularly above normal in the southern half of the country. This included large areas in the interior and on the west coast of Western Australia and large parts of South Australia, as well as the coast and tablelands of eastern New South Wales and far eastern Victoria, which all ranked in the warmest ten per cent of summers on record. The west coast of Western Australia between Perth and Karratha recorded its warmest minimum temperatures on record, with temperatures more than 3 °C above normal, while South Australia recorded its fourth warmest summer on record statewide for minimum temperatures (+1.44 °C).

Parts of northeast Western Australia and the inland Northern Territory recorded minimum temperatures of around 1 °C below normal which rank in the coolest ten per cent of summers on record. Most of the Northern Territory and northeast Western Australia, as well as a large area of inland Queensland, recorded temperatures up to 1 °C below normal, with the rest of the State recording above average overnight minima.

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