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Seasonal climate summary southern hemisphere (summer 2009–2010): an El Niño summer; wetter than average for east, north and central areas, dry in Western Australia and Tasmania

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Southern hemisphere circulation patterns and associated anomalies for the austral summer 2009–2010 are reviewed, with emphasis given to the Pacific Basin climate indicators and Australian rainfall and temperature patterns. Summer 2009–2010 saw the mature phase of an El Niño event and the beginning of its decline. Despite the El Niño the season was one of contrast—particularly wet for most of northern-central, eastern and northern Australia away from Cape York, southern South Australia, Victoria and the central east coast, yet dry over most of Western Australia and Tasmania. Australia's summer rainfall was twenty three per cent above normal in 2009–2010 and eight of the last eleven summers have ranked in the wettest 20 of the last 110 years. Summer was also generally warmer than normal with maximum temperature anomalies similar in pattern to rainfall anomalies; large areas of Western Australia around the inland Pilbara and in the southwest recorded record high temperatures, while nearly all of Victoria and Tasmania, as well as southern South Australia, were in the highest decile. Seasonal minimum temperatures were warmer than average for most of the country except far southwest Western Australia and the northwest coast, northern central Australia and inland Queensland, with areas of Western Australia's interior recording record warm nights. Combined with an extremely warm winter and spring, summer 2009–2010 marked Australia's warmest nine months on record.

Introduction

This summary reviews the southern hemisphere and equatorial climate patterns for summer 2009–2010, 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).

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Pacific Basin climate indices

Southern Oscillation Index

The negative values of the Troup Southern Oscillation Index[1] (SOI) which began in October 2009 continued, and the Southern Oscillation remained in a negative phase throughout the season. Monthly values were –7.0 (December), –10.1 (January) and –14.5 (February), resulting

[1]The 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 interregional direction for French Polynesia.

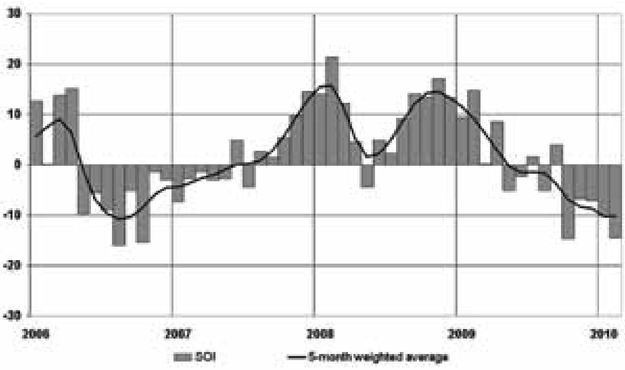
in a seasonal mean of –10.5 (ranked 12th of 134 across the period 1876–1877 to 2009–2010). Darwin's mean sea-level pressure (MSLP) fluctuated during the season ending moderately positive in February, with monthly anomalies of +0.46, –0.46 and +1.20 hPa. In contrast, Tahiti saw persistence of below average MSLP, the monthly anomalies being –0.83, –2.69 and –1.82 hPa. Fig. 1 shows the monthly SOI from January 2006 to February 2010, together with a five-month weighted moving average.

A composite monthly ENSO index, calculated as the standardized amplitude of the first principal component[2] of monthly Darwin and Tahiti MSLP[3] and monthly NINO3, NINO3.4 and NINO4 sea surface temperatures[4] (SSTs) (Kuleshov et al. 2008), continued a sequence of positive values which began in May 2009.

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 negative phases of the Southern Oscillation in El Niño states. Monthly values of this index were +1.42 (December), +1.28 (January) and +1.38 (February). The December value of +1.42 ranks alongside the +1.42 August 2002 value as the highest value of this index since +1.76 in March 1998, at the end of the 1997–1998 El Niño. The 1997–1998 El Niño peaked at +2.54 in August 1997.

The December–January and January–February values of the Climate Diagnostics Center (CDC) bi-monthly Multivariate ENSO index[5] (MEI; Wolter and Timlin 1993, 1998) were +1.157 and +1.502, respectively. The MEI remained consistently positive from the April–May 2009 value of +0.344, the first positive value after a sequence of nine negative values. The January–February value of this index was the most positive value since April–May 1998 (+1.982) during the 1997–1998 El Niño. The strength of these three ENSO indices over the summer months indicated a well developed El Niño event, the magnitude of which exceeded that of the 2006–2007 El Niño.

Fig. 1 Southern Oscillation Index (SOI), from January 2006 to February 2010, 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



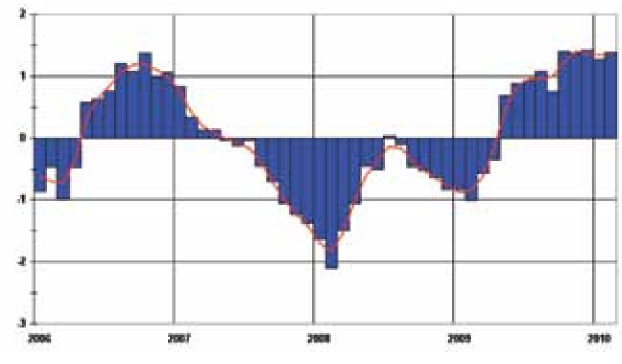
Outgoing long-wave radiation

The Climate Prediction Center, Washington, computes a standardised monthly anomaly[6] of outgoing long-wave radiation (OLR) for an equatorial region ranging from 5°S to 5°N and 160°E to 160°W (not shown). Tropical deep convection in this region is particularly sensitive to changes in the phase of the Southern Oscillation. During El Niño events, convection is generally more prevalent, resulting in a reduction in OLR. This reduction is due to the lower effective black-body temperature and is associated with increased high cloud and deep convection. The reverse applies in La Niña events, with less convection in the vicinity of the date-line (and consequently, positive anomalous OLR).

Monthly values for the season were –1.5 (December), –1.9 (January) and –2.3 (February). The seasonal mean of summer 2009–2010 was –1.9, the second strongest on record (records start in June 1974), the strongest being the summer 1986–1987 seasonal mean of –2.2. The monthly values were stronger than those for the summer of the 2002–2003 El Niño (–1.2, –2.1 and –1.0) (Reid 2003) and rather stronger than those of the 1997–1998 (–1.1, –0.4 and –0.1) (Mullen 1998) and 2006–2007 (–0.3, –1.2 and –0.1) summers (Fawcett 2007).

Fig. 3 shows the seasonal OLR anomalies for the Asia-Pacific region between 40°S and 40°N. Negative anomalies were observed on the equator centred around the date-line (which coincides with the right boundary of the map), but the strongest negative equatorial anomalies were seen between 150°E and 175°E, rather than on the date-line itself.

Fig. 2 Composite standardised monthly ENSO index from January 2006 to February 2010, together with a weighted three-month moving average. See text for details.



[2]The principal component analysis and standardisation of this ENSO index is performed over the period 1950-1999.
[3]Obtained from http://www.bom.gov.au/climate/current/soihtm1.shtml. As with the SOI calculation, the Tahiti MSLP data are provided by Météo France interregional direction for French Polynesia.
[4]Obtained from ftp://ftp.cpc.ncep.noaa.gov/wd52dg/data/indices/sstoi.indices .
[5]Obtained from http://www.esrl.noaa.gov/psd/people/klaus.wolter/MEI/table.html . The MEI is a standardised anomaly index.
[6]Obtained from http://www.cpc.ncep.noaa.gov/data/indices/olr

Oceanic patterns

Sea-surface temperatures

Fig. 4 shows summer 2009–2010 sea-surface temperature (SST) anomalies in degrees Celsius (°C). These have been obtained from the US National Oceanic and Atmospheric Administration (NOAA) Optimum Interpolation analyses (Reynolds et al. 2002). The base period is 1961-1990. Seasonal SSTs were above average across the equatorial Pacific except in the far west around the Maritime Continent. Peak anomalies between +1.5 °C and +2.0 °C were centrally located between 180°E and 130°W. The central equatorial Pacific cooled steadily over the season; the large area of warm anomalies, including significant areas above +2.0 °C, present in December had cooled substantially by February with anomalies above +2.0 °C only remaining in a small area around 170°W.

This cooling can also be seen in the standard SST indices. The monthly SST anomaly indices[7] for the NINO3 region were +1.65 °C (December), +1.11 °C (January) and +0.89 °C (February), continuing a sequence of positive values which began in April 2009. Those for the NINO3.4 region were +1.80 °C (December), +1.58 °C (January) and +1.28 °C (February), continuing a sequence of positive values which began in May 2009, while the corresponding values for the NINO4 region were +1.43 °C, +1.41 °C and +1.07 °C, continuing a sequence of positive values which also began in April 2009. These values are consistent with the equatorial pattern of the anomalies shown in Fig. 4, and illustrate the decline of the El Niño event from peak values in December for NINO3 and NINO3.4, and November for NINO4.

Fig. 3 OLR anomalies for summer 2009–2010 (W m^{-2}). Base period 1979 to 1998. The mapped region extends from 40°S to 40°N and from 70°E to 180°E.

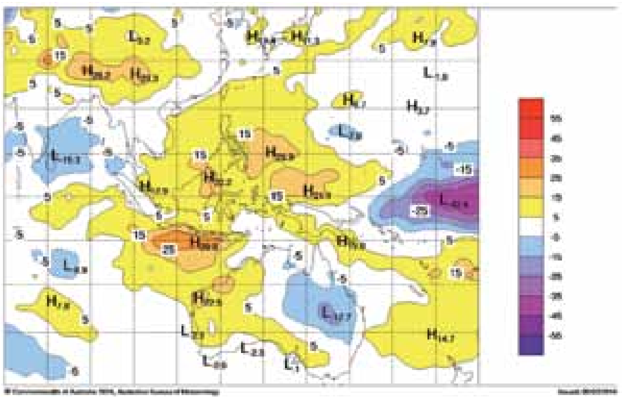
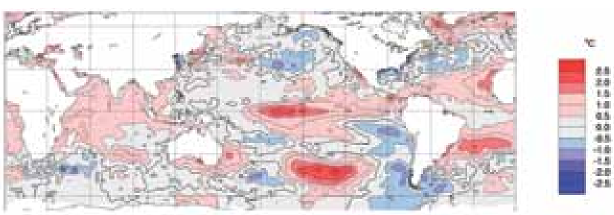


Fig. 4 Anomalies of SST for summer 2009–2010 (°C). The contour interval is 0.5 °C.

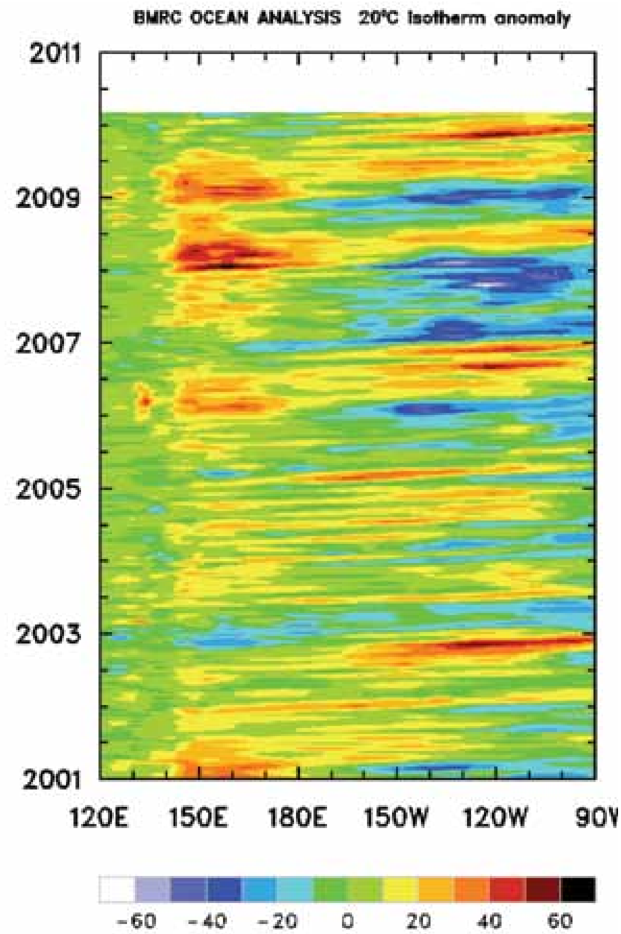


SSTs were also above average across the entire tropical Indian Ocean, with little gradient in anomalies along the equator, and hence near-neutral Indian Ocean Dipole (IOD) conditions. In the Australian region, SST anomalies were positive around most of the country, particularly the eastern and southern coasts, while negative anomalies were present around North West Cape (Western Australia) and off the western coast of Western Australia extending into the Southern Ocean.

Subsurface patterns

The Hovmöller diagram for the 20 °C isotherm depth anomaly (obtained from CAWCR) across the equator (January 2001 to February 2010) is shown in Fig. 5. The 20 °C isotherm is generally situated close to the equatorial thermocline, the

Fig. 5 Time-longitude section of the monthly anomalous depth of the 20 °C isotherm at the equator for January 2001 to February 2010. The contour interval is 10 m.



[7]As before, obtained from ftp://ftp.cpc.ncep.noaa.gov/wd52dg/data/indices/sstoi.indices . All anomaly indices in °C and calculated with respect to the base period 1961–1990. The NINO3 region is 5°S to 5°N and 150°W to 90°W. The NINO3.4 region is 5°S to 5°N and 170°W to 120°W. The NINO4 region is 5°S to 5°N and 160°E to 150°W.

region of greatest temperature gradient with depth and the boundary between the warm near-surface and cold deep-ocean waters. Positive anomalies correspond to the 20 °C isotherm being deeper than average, and negative anomalies to it being shallower than average. Changes in the thermocline depth may act as a precursor to changes at the surface.

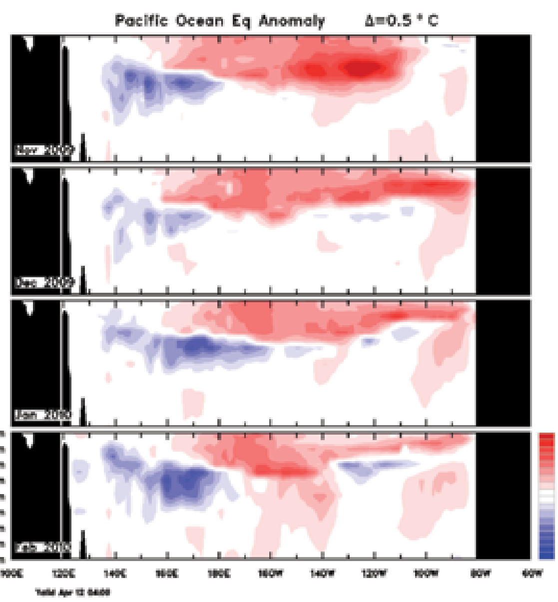
The down-welling Kelvin wave (positive anomalies in Fig. 5) seen initially in mid to late spring continued to proceed eastward across the equatorial Pacific. This Kelvin wave was the strongest one seen in the eastern equatorial Pacific since the 2002–2003 El Niño event. Its passage can also be seen in Fig. 6, which shows a vertical cross section of equatorial subsurface temperature anomalies from November 2009 to February 2010. The Kelvin wave is illustrated by the area of warm anomalies progressing eastward and reaching the far eastern Pacific by December.

Atmospheric patterns

Surface analyses

The summer 2009–2010 mean sea-level pressure (MSLP) pattern, computed by the Bureau of Meteorology's Global Assimilation and Prognosis (GASP) model, is shown in Fig. 7, and the associated anomaly pattern in Fig. 8. These 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 analysis has been computed using data from the 0000 UTC daily analyses of the GASP model. The MSLP anomaly field is not shown over areas of elevated topography (grey shading).

Fig. 6 Four-month November 2009 to February 2010 sequence of vertical sea subsurface temperature anomalies at the equator for the Pacific Ocean. The contour interval is 0.5 °C.



The summer 2009–2010 MSLP pattern (Fig. 7) was distinctly zonal in the southern hemisphere mid to high latitudes. The subtropical ridge was evident south of Australia, with centres of high pressure over New Zealand (1018.6 hPa) and over the Indian Ocean to the southwest of Australia (1021.4 hPa). A polar low can be seen in Fig. 7, with a peak low pressure of 984.0 hPa around 80°W to 150°W, with a second centre (985 hPa) at about 20°E. MSLP was generally slightly higher than normal (anomalies above +2.50) over the Antarctic region (Fig. 8), with an area of stronger negative anomalies (–3.79) present south of South America. Weak positive anomalies of around +2.50 hPa were located over the Tasman Sea and inland southern Australia as well as anomalies of +3.11 hPa at around 110°W.

Mid-tropospheric analyses

The 500 hPa geopotential height (an indicator of the steering of surface synoptic systems) across the southern hemisphere for summer 2009–2010 is shown in Fig. 9, with the associated anomalies in Fig. 10. The seasonal 500 hPa height field in the

Fig. 7 Summer 2009–2010 MSLP (hPa).

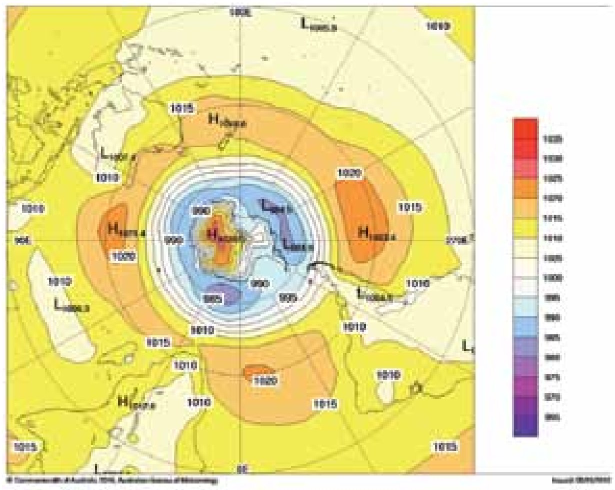
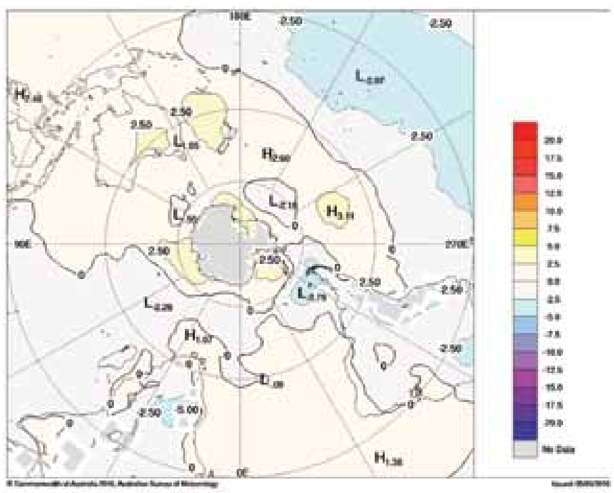


Fig. 8 Summer 2009–2010 MSLP anomalies (hPa).



southern hemisphere was characterised by zonal flow, with a trough located east of New Zealand between the date-line and about 140°W. The negative pressure anomaly south of South America at the surface (Fig. 8) was also evident at the mid-levels (Fig. 10). The positive anomalies at the surface east of Australia and in the central southern Pacific Ocean were also evident at this level. Aside from these areas of positive anomalies and central Antarctica the anomalies over the high latitudes were weakly negative.

Blocking

The time-longitude section of the daily southern hemisphere blocking index[8] is shown in Fig. 11, with the start of the season at the top of the figure. 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 of the subtropical (25°S to 30°S) and high (55°S to 60°S) latitudes. Positive values of the index are generally associated with a split in the mid-latitude westerly flow near 45°S and mid-latitude blocking activity. Fig. 12 shows the seasonal index for each longitude.

Southern hemisphere blocking during summer 2009–2010 was below average across the greater Australian region (90°E to 170°E) and South America and the western South Atlantic (80°W to 20°W), but above average in the Southern Ocean between Africa and Australia (40°E to 90°E). Blocking was near normal in most of the Pacific. Peak values of the blocking index were seen over the central Pacific in mid December and mid January.

Fig. 9 Summer 2009–2010 500 hPa mean geopotential height (gpm).

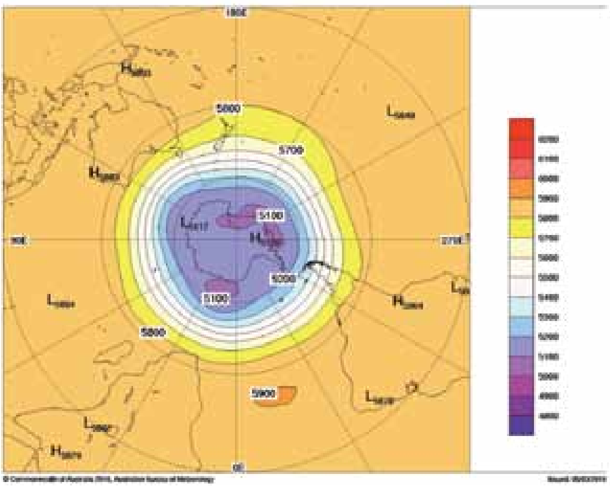


Fig. 10 Summer 2009–2010 500 hPa mean geopotential height anomalies (gpm).

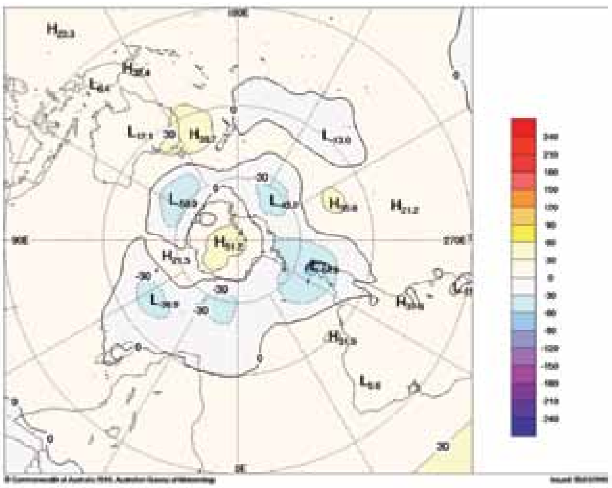


Fig. 11 Summer 2009–2010 daily southern hemisphere blocking index (ms^{-1}) time-longitude section. The horizontal axis shows degrees east of the Greenwich meridian. Day one is 1 December.

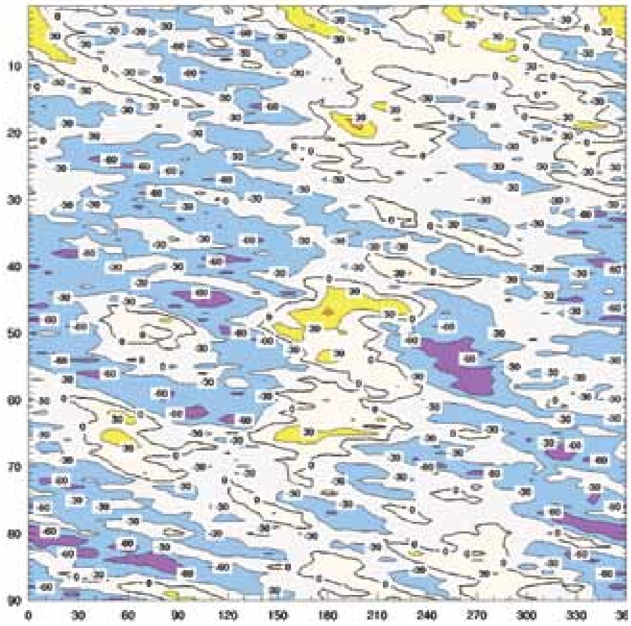
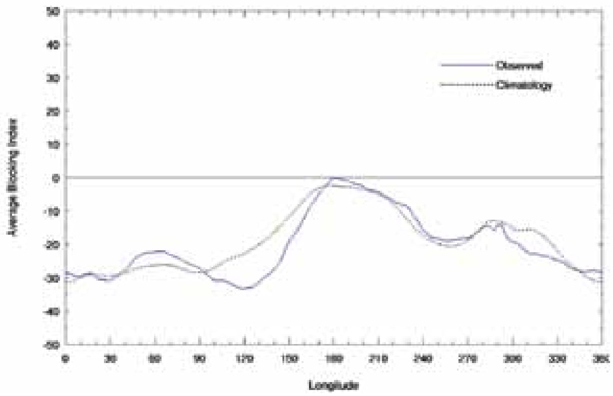


Fig. 12 Mean southern hemisphere blocking index (ms^{-1}) for summer 2009–2010 (solid line). The dashed line shows the corresponding long-term average. The horizontal axis shows degrees east of the Greenwich meridian.



[8]The blocking index is defined as BI = 0.5 $[(u_{25} + u_{30}) - (u_{40} + 2u_{45} + u_{50}) + (u_{55} + u_{60})]$, where u_x is the westerly component of the 500 hPa wind at latitude x.

Winds

Summer 2009–2010 low-level (850 hPa) and upper-level (200 hPa) wind anomalies (from the 22-year NCEP II climatology) are shown in Fig. 13 and Fig. 14 respectively. Isotach contours are at 5 ms^{-1} intervals, and in Fig. 13 regions where the surface rises above the 850 hPa level are shaded. Moderate westerly anomalies were present over the central and eastern Pacific while winds were near neutral over the western tropical Pacific Ocean. This weakening of the Walker circulation is characteristic of an El Niño. A weak anti-cyclonic anomaly was also seen off the east coast of Australia during the season.

In the upper levels (Fig. 14), an anti-cyclonic anomaly pattern covered much of the North Pacific Ocean with a much weaker anti-cyclonic anomaly just south of the equator.

Australian region

Rainfall

Fig. 15 shows the summer rainfall totals for Australia, while Fig. 16 shows the summer rainfall deciles, where the deciles are calculated with respect to gridded rainfall data for all summers from 1900–1901 to 2009–2010.

Summer rainfall averaged over Australia was 28.9 per cent above the 1961-1990 normal (12th highest in a record of 110 years—see Table 1). Summer rainfall was above to very much above average across the majority of the Northern Territory (the Territorial area average of 472 mm was 49.4 per cent above mean), Queensland (the State area average of 462

Fig. 13 Summer 2009–2010 850 hPa vector wind anomalies (ms^{-1}). The anomaly field is not shown over areas of elevated topography.

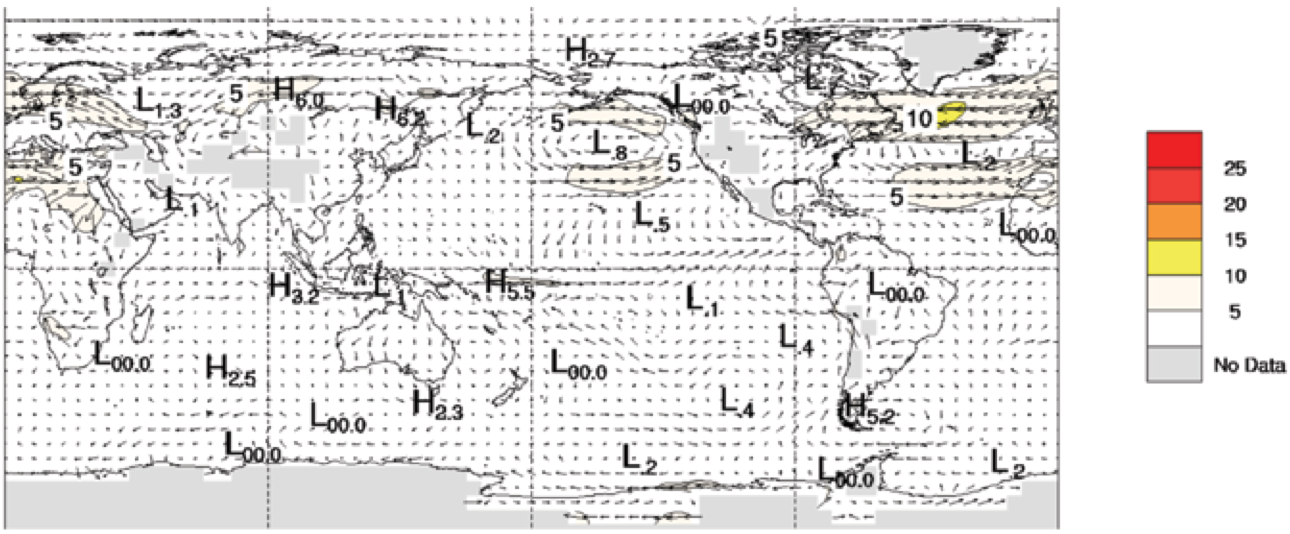
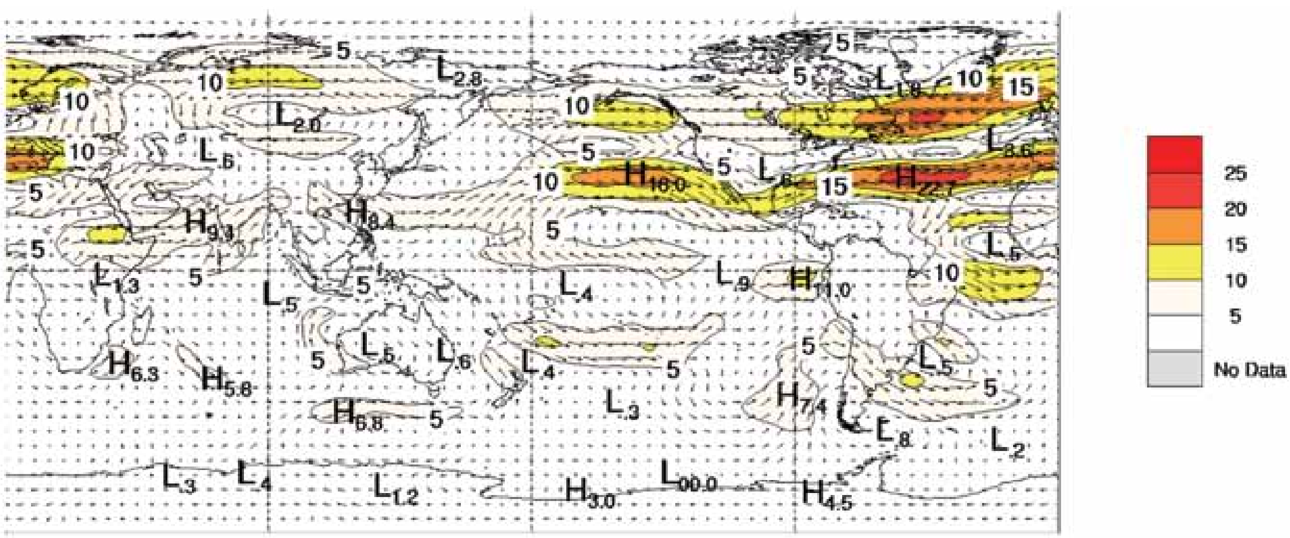


Fig. 14 Summer 2009–2010 200 hPa vector wind anomalies (ms^{-1}).



mm was 42.1 per cent above mean) and New South Wales (the State area average of 241 mm was 40.8 per cent above mean) apart from areas of southeast Queensland (especially the Darling Downs) and north-eastern New South Wales, and some of Cape York Peninsula. These widespread above-normal falls across much of northern Australia were counter to what is usually expected in an El Niño summer—summer rainfall in northern Australia is negatively correlated with summer seasonal means of the monthly ENSO index.

Rainfall was also above average in northern and western South Australia and parts of northeastern and north-central Victoria. A small area of southwest Victoria also received above average rainfall as did areas of the Kimberley and Pilbara in Western Australia, coinciding with the track of tropical cyclone Laurence in December.

Conversely, most of Tasmania saw rainfall below or very much below average over summer (the State area average of 180 mm was 26.0 per cent below normal) and totals were in the lowest decile in southwest Tasmania, and on the north coast of the State where several sites had their driest summer for many years. Large areas of Western Australia were also below average (the State area average of 125 mm was 16.6 per cent below mean), with most of Western Australia's west coast between Geraldton and Albany in the lowest decile and records set around Perth. Perth Airport was one of a number of places where no rain was recorded during the summer, experiencing a record 122-day dry spell (from 21 November 2009 to 22 March 2010). Parts of southern South Australia were also below average and there was an isolated area of below to well below average rainfall on the west coast of far northern Queensland.

Table 2 shows percentage areas of summer rainfall in various categories. 21.3 per cent of Australia had summer rainfall at or above the 90th percentile. Summer rainfalls were in the highest decile (wettest ten per cent of all years) over most of the southern Northern Territory (39.4 per cent of the Territory), adjacent areas of northeast South Australia (15.0 per cent of the State), and most of southern inland Queensland (38.6 per cent of the State) west of the Darling Downs (with records locally around Longreach). Falls in the highest decile also extended in a band through central New South Wales running from Walgett to Canberra, and to parts of that State's south coast (covering 36.0 per cent of the State in total). Further north, they occurred locally in Western Australia on the Laurence track, in parts of the Northern Territory Top End (especially around and east of Darwin), and in northwest Queensland. Rainfalls in the lowest decile were almost entirely confined to western Western Australia and Tasmania.

Drought

Above to very much above average rainfall across central and eastern Australia during summer 2009–2010, especially in February, eased short-term deficiencies across most of eastern Australia, removing deficiencies that had existed in eastern Queensland, the Northern Territory and parts of northern Western Australia. However, the summer also saw deficiencies expanding around the Pilbara and Gascoyne and a large area of severe deficiency emerging in that State's far southwest.

For the three months of summer, ending February 2010, 2.9 per cent of Australia had experienced rainfall at or below the 10th percentile (serious deficiency), with 1.0 per cent of the country experiencing severe deficiency (rainfall at or below the 5th percentile) for the period. The areas of serious and severe deficiencies were almost totally confined to Tasmania (25.1 and 11.7 per cent of the State respectively) and western Western Australia (8.1 and 2.7 per cent of the State respectively).

The area of Tasmania in serious deficiency eased over the season and was 9 per cent lower for summer than the figure for the six months ending February 2010.

At the end of February 2010, 2.9 per cent of Australia had experienced rainfall at or below the 10th percentile (serious deficiency) for the six months of spring and summer, with 1.0 per cent of the country experiencing severe deficiency

Fig. 15 Summer 2009–2010 rainfall totals (mm) for Australia.

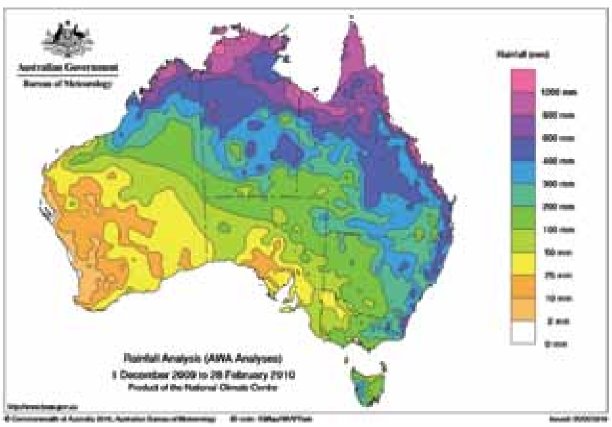


Fig. 16 Summer 2009–2010 rainfall deciles for Australia. Decile ranges based on grid-point values over the summers 1900–1901 to 2009–2010.

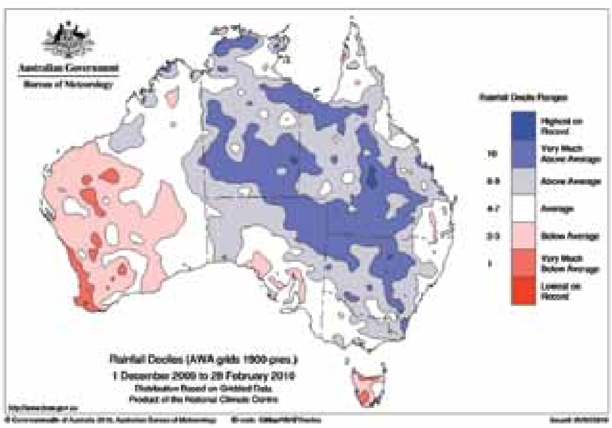


Table 1. Summary of the seasonal rainfall ranks and extremes on a national and State basis for summer 2009–2010. The ranking in the last column goes from 1 (lowest) to 110 (highest) and is calculated over the years 1900–1901 to 2009–2010.

Region	*Highest seasonal total (mm)*	*Lowest seasonal total (mm)*	*Highest daily total (mm)*	*Area-averaged rainfall (mm)*	*Rank of area-averaged rainfall*
Australia	2611 at Bellenden Ker	Zero at several locations	402 at Napier Downs, 18 December	269	99
Queensland	2611 at Bellenden Ker	64 at Cluny	372 at Mt Tamborine, 7 February	462	102
New South Wales	1173 at Yarras	32 at Wentworth	332 at Tuross Head, 16 February	241	98
Victoria	451 at Falls Creek	28 at Werrimull	131 at Falls Creek, 1 January	132	70
Tasmania	605 at Mount Read	52 at Tomahawk	112 at Mount Barrow, 5 February	180	18
South Australia	328 at Innamincka	3 at Thurlga	131 at Moomba, 13 February	86	92
Western Australia	1128 at Theda	Zero at several locations	402 at Napier Downs, 18 December	125	42
Northern Territory	1781 at Walker Creek	32 at Avon Downs	290 at Channel Island, 13 December	472	104

Table 2: Percentage areas in different categories for summer 2009–2010 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.

Region	*Lowest on record*	*Severe deficiency*	*Decile 1*	*Decile 10*	*Highest on record*
Australia	0.14	1.0	2.9	21.3	0.60
Queensland	0.00	0.0	0.1	38.6	1.59
New South Wales	0.00	0.0	0.0	36.0	0.32
Victoria	0.00	0.0	0.0	0.8	0.00
Tasmania	0.00	11.7	25.1	0.0	0.00
South Australia	0.00	0.0	0.2	15.0	0.00
Western Australia	0.41	2.7	8.1	0.1	0.00
Northern Territory	0.00	0.0	0.0	39.4	1.21

(rainfall at or below the 5th percentile) for the period. 34.1 per cent of Tasmania was affected, with 21.5 per cent in severe deficiency and 7.1 per cent lowest on record.

Over the slightly longer period of the nine months ending February 2010, 4.4 per cent of the country was in serious deficiency (1.3 per cent in severe deficiency), comprising 12.6 per cent of Western Australia (4.0 per cent in severe deficiency), 0.9 per cent of Queensland (0.2 per cent in severe deficiency) and 0.9 per cent of Tasmania (none in severe deficiency).

The national figure of 2.9 percent for the six months ending February 2010 is significantly smaller than the corresponding figure of 13.1 per cent for the three months ending November 2009, while the figure of 4.4 per cent for the nine months ending February 2010 shows an even greater reduction from the corresponding figure of 20.2 per cent for the six months ending November 2009. Together these suggest summer rainfall brought relief from short term deficiencies for much of the country, particularly in the north and northeast.

Temperature

Fig. 17 and Fig. 19 show the summer maximum and minimum temperature anomalies, respectively, for summer 2009–2010. The anomalies have been 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. Fig. 18 and Fig. 20 show summer maximum and minimum temperature deciles, respectively, calculated using monthly temperature analyses from 1911–1912 to 2009–2010. Combined with an extremely warm winter and spring, summer 2009–2010 marked Australia's warmest nine month June–February mean temperature on record (an anomaly of +1.03 °C).

For seasonal maximum temperature, summer 2009–2010 was warmer than average across large parts of the country (Fig. 17). Summer maximums in the Northern Territory (excluding the Top End), Queensland (excluding Cape York and the southeast coast), northern South Australia and northern and inland New South Wales were average or below average. Anomalies in excess of +1 °C were

Fig. 17 Summer 2009–2010 maximum temperature anomalies (°C).

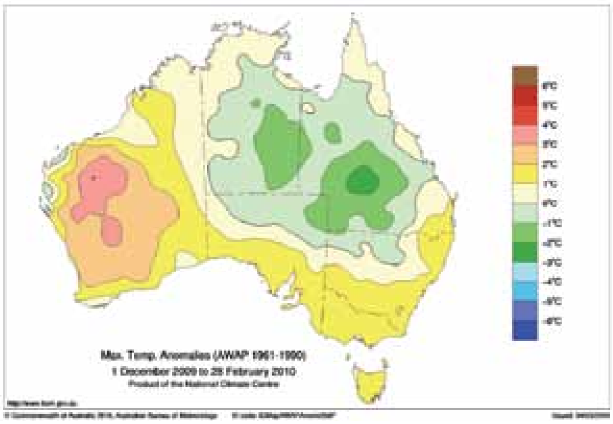


Fig. 18 Summer 2009–2010 maximum temperature deciles. Decile ranges based on grid-point values over the summers 1911–1912 to 2009–2010.

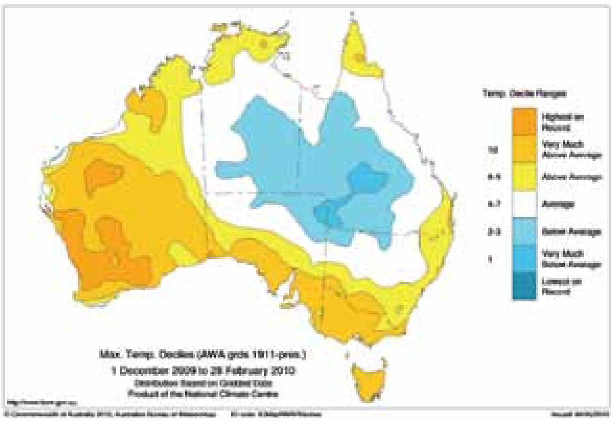


Fig. 19 Summer 2009–2010 minimum temperature anomalies (°C).

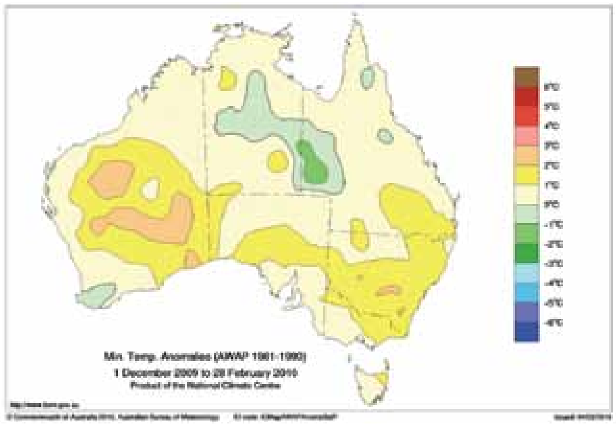
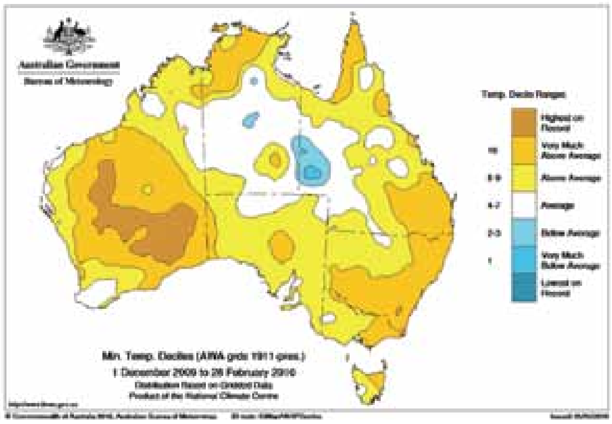


Fig. 20 Summer 2009/2010 minimum temperature deciles. Decile ranges based on grid-point values over the summers 1911–1912 to 2009–2010.



seen across much of the south of the country and most of Western Australia (covering 39.7 per cent of Australia). The State area average for Western Australia was 36.7 °C, 1.5 °C above the long-term average and equal highest on record with summer 1997-1998. A large area of anomalies in excess of +2 °C covered central and western Western Australia, reaching up to 5 °C above normal in the inland Pilbara with many other locations in the Goldfields, Eucla and southwest also recording record high temperatures. Maximum temperatures were below average through much of inland and interior north-eastern Australia, including the bulk of Queensland and the Northern Territory. Anomalies greater than 1 °C below average were seen in south-western and central Queensland and the southeast of the Northern Territory, reaching 2 °C below average around Longreach.

Table 3 shows percentage areas in 'decile 10' (i.e. at or above the 90th percentile) for summer seasonal maximum temperature for each State and Territory. Six per cent of the country saw a record summer maximum temperature with much of southwest Western Australia and areas of the Pilbara reaching record high temperatures, while nearly all of Victoria and Tasmania and southern South Australia were in the highest decile.

The pattern of summer seasonal minimum temperatures (Fig. 19) showed more areas warmer than average than that for maximum temperature, with the area of near-average or below average temperatures largely confined to the southern Northern Territory and the far west of Queensland. While the far southwest of Western Australia had near-average minimum temperatures, most of the interior of Western Australia and the Nullarbor had night time temperatures 1-2 °C above average. Similar anomalies also occurred over most of New South Wales (except the far northwest and northeast), eastern and northern Victoria, and north-eastern Tasmania.

Areas in a wide band along the east coast from Rockhampton (Queensland) to Gippsland (Victoria), as well as all of southern inland New South Wales and northeast Tasmania, had minimum temperatures in the highest decile (Table 3). Minimum temperatures were also in the highest decile over large parts of the northern tropics. Western Australia's State area average of 22.47 °C (an anomaly of +1.15 °C) was the warmest summer minimum on record; temperatures 2 °C above average were reached in the inland

Table 3. Percentage areas in different categories for summer 2009–2010. 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 1911–1912 to 2009–2010.

Region	*Maximum temperature*				*Minimum temperature*			
	Lowest on record	*Decile 1*	*Decile 10*	*Highest on record*	*Lowest on record*	*Decile 1*	*Decile 10*	*Highest on record*
Australia	0.00	1.7	30.1	6.00	0.00	0.3	36.5	5.70
Queensland	0.00	6.5	0.5	0.00	0.00	1.1	24.4	0.00
New South Wales	0.00	0.0	9.3	0.00	0.00	0.0	58.7	0.23
Victoria	0.00	0.0	90.3	0.00	0.00	0.0	30.4	0.27
Tasmania	0.00	0.0	87.4	0.00	0.00	0.0	24.5	0.00
South Australia	0.00	1.8	28.0	0.40	0.00	0.0	10.1	0.00
Western Australia	0.00	0.0	66.8	18.20	0.00	0.0	59.8	17.24
Northern Territory	0.00	0.0	0.3	0.00	0.00	0.0	15.9	0.17

Table 4. Summary of the seasonal maximum temperature ranks and extremes on a national and State basis for summer 2009–2010. The ranking in the last column goes from 1 (lowest) to 60 (highest) and is calculated over the years 1950–1951 to 2009–2010[9]

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	42.9 at Paraburdoo (WA)	13.7 at Mount Read (Tas)	49.2 at Onslow (WA), 1 January	2.7 at Mount Baw Baw (Vic), 18 January	+0.55	50
Queensland	37.4 at Birdsville and Bedourie	27.2 at Maleny	46.3 at Birdsville, 8 December	19.6 at Toowoomba, 2 December	-0.58	22
New South Wales	35.1 at Mungindi	16.4 at Thredbo	45.1 at Pooncarie, 10 January	4.7 at Thredbo, 18 January	+0.94	46
Victoria	33.3 at Mildura	16.0 at Mount Hotham	45.7 at Avalon, 11 January	2.7 at Mount Baw Baw, 18 January	+1.54	55
Tasmania	25.5 at Bushy Park	13.9 at Mount Read	40.7 at Ouse, 11 January	4.7 at Mount Wellington, 28 February	+1.96	59
South Australia	36.9 at Marree	22.6 at Cape Willoughby	45.8 at Murray Bridge and Keith, 11 January	13.6 at Mount Lofty, 10 December	+0.75	44
Western Australia	42.9 at Paraburdoo	22.3 at Albany	49.2 at Onslow, 1 January	16.4 at Rocky Gully, 20 January	+1.52	59=
Northern Territory	38.0 at Rabbit Flat	31.9 at Dum In Mirrie	46.0 at Rabbit Flat, 8 December	16.0 at Arltunga, 11 December	-0.44	19

Pilbara and Gascoyne, Goldfields, southern Interior and Eucla, with extensive areas throughout the region marking seasonal records (Fig. 20). The only area with minimum temperatures in the lowest decile was around Birdsville and Bedourie in the far west of Queensland. Despite the well-above-normal seasonal mean temperatures in the region, a brief cold outbreak in mid January brought a

[9]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 1950 to the present. As the anomaly averages in the tables are only retained to two decimal places, tied rankings are possible and are indicated by =.

Table 5. Summary of the seasonal minimum temperature ranks and extremes on a national and State basis for summer 2009–2010. The ranking in the last column goes from 1 (lowest) to 60 (highest) and is calculated over the years 1950–1951 to 2009–2010.

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	27.5 at Troughton Island (WA)	4.6 at Mount Wellington (Tas)	34.6 at Paraburdoo (WA), 2 January	-4.1 at Charlotte Pass (NSW), 2 December	+0.76	56
Queensland	26.4 at Sweers Island	15.5 at Applethorpe	31.8 at Birdsville, 26 January	5.4 at Applethorpe, 19 January	+0.30	38=
New South Wales	22.2 at Tibooburra	6.7 at Charlotte Pass	31.6 at Fowlers Gap and Ivanhoe, 12 January	-4.1 at Charlotte Pass, 2 December	+1.15	52
Victoria	17.2 at Mildura	7.9 at Mount Hotham and Mount Baw Baw	30.1 at Swan Hill, 24 December	-3.5 at Mount Hotham, 18 January	+1.18	53=
Tasmania	15.0 at Swan Island	4.6 at Mount Wellington	22.0 at Friendly Beaches, 1 January	-2.8 at Butlers Gorge, 27 January	+0.09	32
South Australia	23.2 at Moomba	10.9 at Naracoorte	32.0 at Port Pirie, 11 January	3.0 at Naracoorte, 4 December	+1.05	50
Western Australia	27.5 at Troughton Island	11.7 at Rocky Gully	34.6 at Paraburdoo, 2 January	0.2 at Eyre, 9 December	+1.12	60
Northern Territory	26.9 at Centre Island	21.0 at Alice Springs	32.2 at Jervois, 24 December and Rabbit Flat, 9 December	12.1 at Kulgera, 12 December	+0.16	32

number of January record low temperatures in eastern Australia, including a Queensland January record (5.4 °C) at Applethorpe on 19 January.

In area-averaged terms for maximum temperature, the summer was nationally the eleventh warmest since 1950, the second warmest for Tasmania and Western Australia, and the sixth warmest for Victoria. Western Australia was consistently warm during all months in the season, with December and January being the third warmest since 1950 (+1.14 °C and +1.39 °C respectively) and February the fourth warmest (+2.02 °C)

In area-averaged terms for minimum temperature, the summer was nationally the fifth warmest since 1950, and the warmest for Western Australia. As with maximum temperature, Western Australia was consistently warm during all months in the season, with December and February being the fourth warmest since 1950 (+0.90 °C and +1.45 °C respectively) and January the second warmest (+1.00 °C). February was also the second warmest since 1950 in Victoria (+2.36 °C).

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