Australian Meteorological and Oceanographic Journal 58 (2009) 275-284

Seasonal climate summary southern hemisphere (summer 2008-09): a weak, brief La Niña returns. Bumper wet season in tropical Australia; exceptional heatwaves in southeastern Australia

Clare Mullen
National Climate Centre, Bureau of Meteorology, Australia

(Manuscript received November 2009)

Southern hemisphere circulation patterns and associated anomalies for the austral summer 2008-09 are reviewed, with emphasis given to the Pacific Basin climate indicators and Australian rainfall and temperature patterns. Atmospheric and oceanic indicators re-intensified to briefly reach weak La Niña levels during the austral summer 2008-09, with the event clearly of lesser magnitude than the mature 2007-08 La Niña event. A rotated 'V' pattern of warm anomalies in the western Pacific surrounded a cool equatorial tongue in the central and eastern Pacific. A positive phase of the Southern Oscillation was maintained throughout the summer, with cooler than average sea-surface temperatures in the NINO 3 and 4 regions. Strong warming in the western equatorial Pacific suggested that this La Niña would only be of short duration, with weakening of central Pacific cool anomalies noted in February 2009. Two exceptional heatwaves in southeastern Australia in late January and early February 2009 led up to the 'Black Saturday' bushfires outside Melbourne on 7 February 2009, which became Australia's worst natural disaster, with more than 170 people killed and 1800 homes lost. Temperature records were smashed across southeastern Australia. The tropical wet season boomed during the weak La Niña event, with Queensland and Australia as a whole recording the fifth wettest summer in the period of record (109 years).

Introduction

This summary reviews the southern hemisphere and equatorial climate patterns for summer 2008-09 (i.e. December 2008 to February 2009), with particular attention given to the Australasian and Pacific regions. The main sources of information for this report are analyses prepared by the Australian Bureau of Meteorology's National Climate Centre and the Centre for Australian Weather and Climate Research (CAWCR).

Corresponding author address: Clare Mullen, National Climate Centre, Bureau of Meteorology, GPO Box 1289, Melbourne, Vic. 3001, Australia. Email: c.mullen@bom.gov.au

Pacific Basin climate indices

The Troup Southern Oscillation Index

The Troup Southern Oscillation Index (SOI) (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 Tahiti MSLP data are provided by Météo France interregional direction for French Polynesia.

Figure 1 shows monthly SOI values from January 2005 to February 2009, together with a five-month weighted moving average. The means and standard deviations used in Fig. 1 are based on a sixty-year climatology (1933-1992). Monthly SOI values have been positive since August 2007, apart from May 2008 (–4.3). Monthly values for the summer were +13.3 (December), +9.4 (January) and +14.8 (February), resulting in

Fig. 1 Southern Oscillation Index, from January 2005 to February 2009, 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.

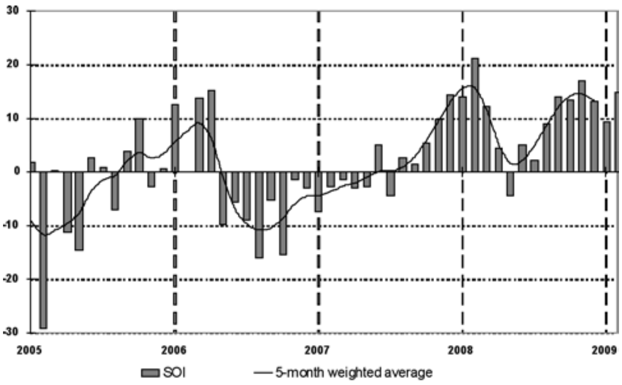
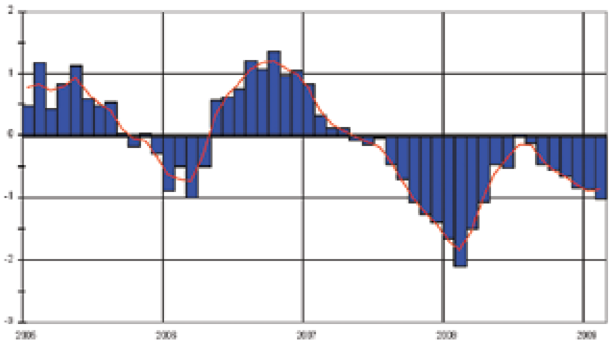


Fig. 2 Composite standardised monthly ENSO index from January 2005 to February 2009, together with a three-month moving average. See text for details.



a seasonal average of +12.5. These values, together with the values of the preceding spring (Qi 2009), indicated a definite positive phase of the Southern Oscillation.

The positive SOI values were largely the result of continuing above average MSLP at Tahiti since mid-July 2008. Daily Tahiti MSLP values (not shown) dipped briefly below climatology in early January and late February. Daily Darwin MSLP values fluctuated each month, and were generally below climatology for most of the season. The monthly MSLP anomalies[1] at Darwin were –0.9, –0.4 and –1.3 hPa for December, January and February, respectively; at Tahiti, the monthly anomalies were +1.7, +1.5 and +1.8 hPa, respectively.

A composite monthly El Niño–Southern Oscillation (ENSO) index, calculated as the standardised amplitude of the first principal component[2] of monthly MSLP[3] at Darwin and Tahiti, and monthly NINO3, NINO3.4 and NINO4 sea-surface temperatures (SSTs)[4] (Kuleshov et al. 2008), was consistent with the SOI during the summer, and remained negative from May 2007 to February 2009 (see Fig. 2), except for July 2008 (+0.03). Monthly values of the index during the summer were –0.83 (December), –0.84 (January) and –1.01 (February), respectively. These values were rather weaker than those of the previous austral summer during the established La Niña event of 2007-08 (Wheeler 2008).

The December-January and January-February values of the Climate Diagnostics Center (CDC) bi-monthly Multivariate ENSO Index (MEI[5]; Wolter and Timlin 1993, 1998) were –0.695 and –0.725, respectively. The MEI continued with consistently negative values from July-August 2008 after the end of the 2007-08 La Niña. The consistent information from the SOI, the composite ENSO index and the MEI reinforced the return to a weak La Niña state during the austral summer 2008-09, with the event being clearly weaker and shorter than the established 2007-08 La Niña event.

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 enhanced near the date-line, 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). Standardised monthly values for the season were +2.3 (December), +1.8 (January) and +1.7 (February). Consistent with the development of a weak La Niña, these OLR anomalies indicate reduced convection around the equatorial date-line region, peaking in December 2008.

Figure 3 shows the seasonal OLR anomalies for the Asia-Pacific region between 40°N and 40°S. Positive anomalies were found over the equatorial Pacific, extending from east of Papua New Guinea out to the date-line. Maximum OLR anomaly values just west of the date-line increased from spring 2008 (24.4 W m^{-2}) to summer (38.9 W m^{-2}), with monthly val-

[1] Anomalies calculated with respect to the 1933-1992 period used in the SOI calculation.

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

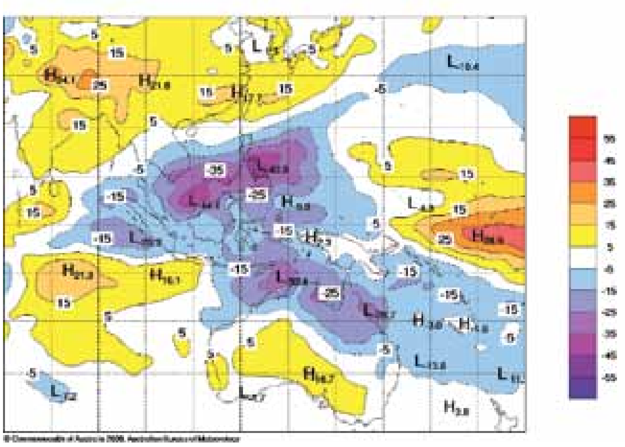
[3] Obtained from http://www.bom.gov.au/climate/current/soihtm1.shtml. As with the SOI calculation, the Tahiti MSLP data are provided by Météo France interregional direction for French Polynesia.

[4] Obtained from ftp://ftp.cpc.ncep.noaa.gov/wd52dg/data/indices/sstoi.indices.

[5] Obtained from http://www.cdc.noaa.gov/people/klaus.wolter/MEI/table.html. The MEI is a standardised anomaly index, with positive (negative) values indicative of El Niño (La Niña).

[6] Obtained from http://www.cpc.ncep.noaa.gov/data/indices/olr. The base period for the standardisation is 1979 to 1995.

Fig. 3 OLR anomalies for summer 2008-09 (W m^{-2}). Base period 1979 to 1998. The mapped region extends from 40°S to 40°N and 70°E to 180°E.



ues strongest in December 2008 (not shown). Slightly higher peaks in both seasons were present just east of the date-line (but not visible in this projection). In contrast, negative OLR anomalies extended from the central South Pacific to the maritime continent, south and west of the equatorial positive anomalies mentioned previously. These anomalies were consistent with an enhanced wet season over the maritime continent under weak La Niña conditions.

Oceanic patterns

Sea-surface temperatures

Figure 4 shows summer 2008-09 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. SST anomalies in the tropical Pacific Ocean during summer reflected a weak La Niña pattern, with cooling focussed in the central Pacific. Cooling continued from spring 2008 in the central and eastern near-equatorial Pacific Ocean, with anomalies dropping below –1.0°C in the central equatorial Pacific during the summer. This rapid intensification beyond La Niña thresholds late in the calendar year was the most unusual aspect of this event. Elsewhere the Pacific was generally warmer than normal, peaking in the central South Pacific. SST anomalies in the tropical western Pacific formed a warm 'rotated V' pattern almost symmetrical about the equator.

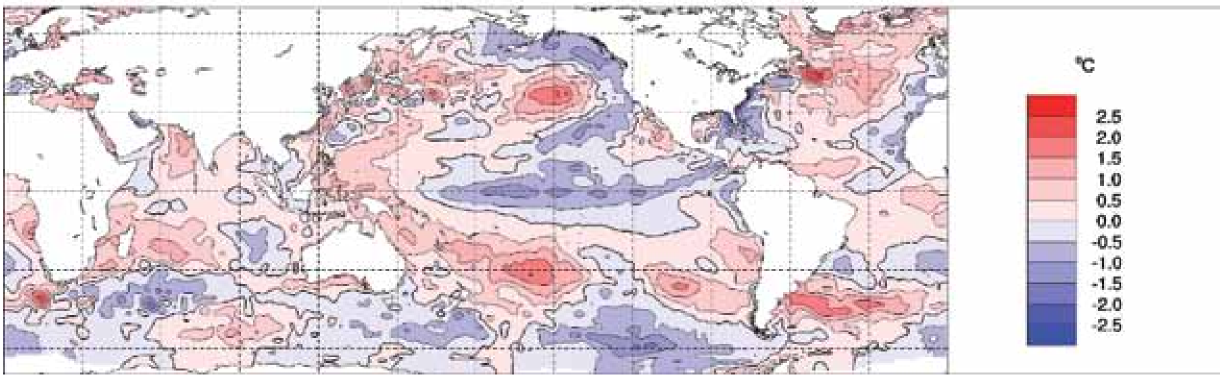
The monthly SST anomaly indices[7] (in °C) continued negative during the austral summer; NINO3 monthly anomalies were –0.42 (December), –0.49 (January) and –0.38 (February). Anomalies for the NINO3.4 and NINO4 regions continued negative from spring 2008. NINO3.4 anomalies (in °C) were –0.76 (December), –0.95 (January) and –0.62 (February); for the NINO4 region, monthly anomalies were –0.52 (December), –0.68 (January) and –0.66 (February). The stronger NINO3.4 and NINO4 anomalies, in comparison with NINO3, indicate the central Pacific nature of this event.

In the Australian region, SSTs were generally warmer than average around the continent during the summer, with continuing anomalous warmth in the Coral Sea and around the maritime continent. Indian Ocean SSTs were generally warmer than average across the basin, though cooler in central eastern parts. The monthly Indian Ocean Dipole (IOD) index[8] of Saji et al. (1999) was in a neutral phase for the austral summer 2008-09. In any case, the IOD is best seen from May to November, and has little impact during the austral summer (Risbey et al. 2009).

7 As before, obtained from ftp://ftp.cpc.ncep.noaa.gov/wd52dg/data/indices/sstoi.indices, but re-standardised with respect to 1961-1990. All anomaly values in °C and calculated with respect to the base period 1961-1990.

8 Obtained from http://www.jamstec.go.jp/frcgc/research/d1/iod/DATA/dmi_HadISST.txt, and consisting of monthly values from 1958 to 2008, derived from the HadISST data-set, supplemented by weekly values for January and February, calculated by the Australian Bureau of Meteorology.

Fig. 4 Anomalies of SST for summer 2008-09 (°C). The contour interval is 0.5°C.



Subsurface patterns

The Hovmöller diagram from January 2001 to February 2009 for the 20°C isotherm depth anomaly (obtained from CAWCR) across the equator is shown in Fig. 5. The 20°C isotherm is generally situated close to the equatorial thermocline, the 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 (orange and red shades), and negative anomalies to it being shallower than average (blue shades). Changes in the thermocline depth may act as a precursor to subsequent changes at the surface.

During summer 2008-09, the 20°C isotherm depth indicated an enhanced warm-cold pattern across the Pacific Ocean (Fig. 5), consistent with a maturing weak La Niña event. Positive anomalies in the western Pacific strengthened during the austral summer, reaching values similar to mid-2008. Cooling was observed in the central and eastern Pacific, although this trend had weakened slightly in the central Pacific by February 2009 indicating the probable end of the mature La Niña phase. Figure 5 shows an upwelling Kelvin wave (blue shades, negative anomalies) propagating eastwards from the central Pacific during the summer.

The enhanced warm-cold anomaly pattern across the Pacific was also supported by the vertical cross-section of equatorial subsurface temperature anomalies from November 2008 to February 2009 (Fig. 6). Anomalous warming at depth in the western Pacific peaked at more than +3°C in February, although surface warming was only reflected in the far western Pacific to +0.5°C. Subsurface cooling peaked in the central Pacific in December, with a large area of cool anomalies continuing in the eastern Pacific through to February.

To reiterate, these atmospheric and oceanic changes indicated the return of a weak, brief La Niña, for which the magnitude was clearly less than the cool equatorial Pacific Ocean conditions of 2007-08. The SOI was firmly in a positive phase, as previously noted, but other indicators indicated a borderline La Niña.

Atmospheric patterns

Surface analyses

The summer 2008-09 MSLP field, computed from the Bureau of Meteorology's Global Assimilation and Prognosis (GASP) model, is shown in Fig. 7, with the associated anomaly pattern in Fig. 8. These anomalies are the difference from a 1979-2000 climatology obtained from the US 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 in Fig. 8). In Fig. 7, there was a major polar low (979 hPa) near 90°W, with a second centre (980 hPa) around 20°E. Around Australia, the subtropical ridge had a maximum at about 90°E in the central Indian Ocean (1020 hPa), with a weaker maximum in the eastern Tasman Sea (1015 hPa).

Fig. 5 Time-longitude section of the monthly anomalous depth of the 20°C isotherm at the equator for January 2001 to February 2009. The contour interval is 10 m.

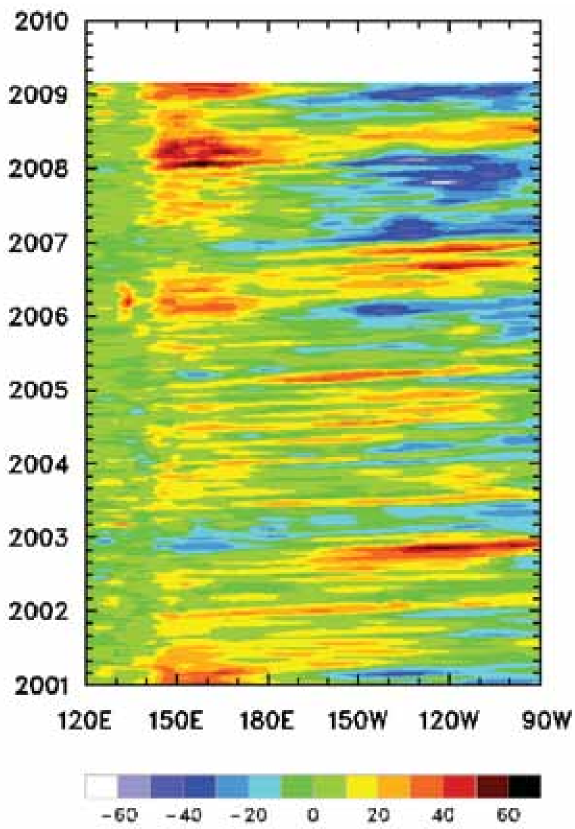


Fig. 6 Four-month November 2008 to February 2009 sequence of vertical temperature anomalies at the equator for the Pacific Ocean. The contour interval is 0.5°C.

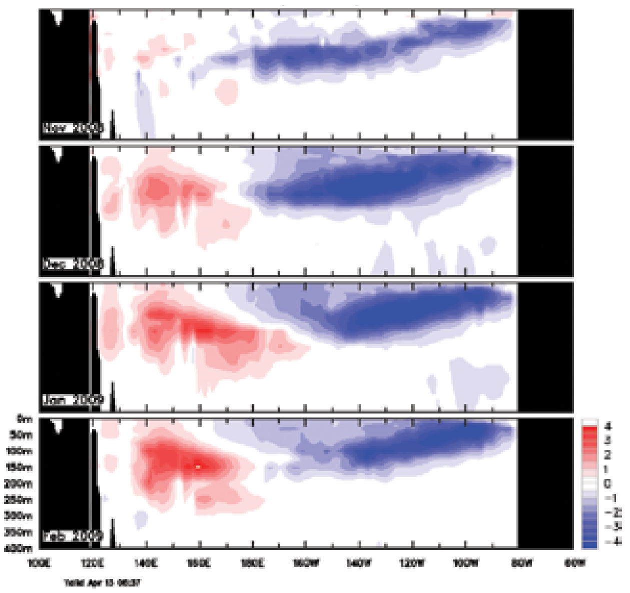


Fig. 7 Summer 2008-09 MSLP (hPa).

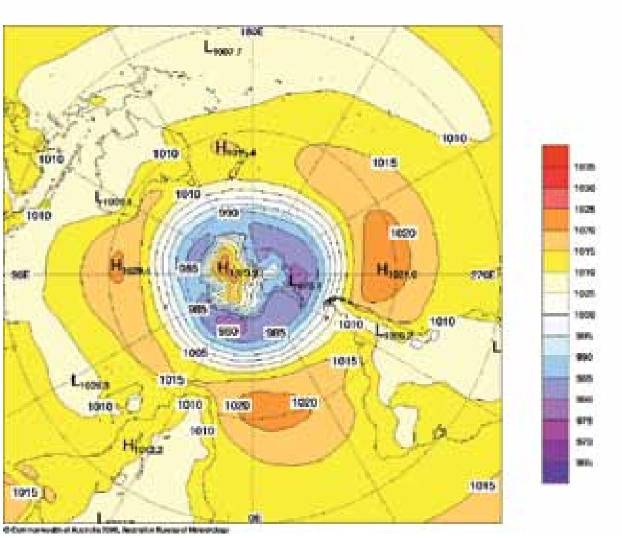
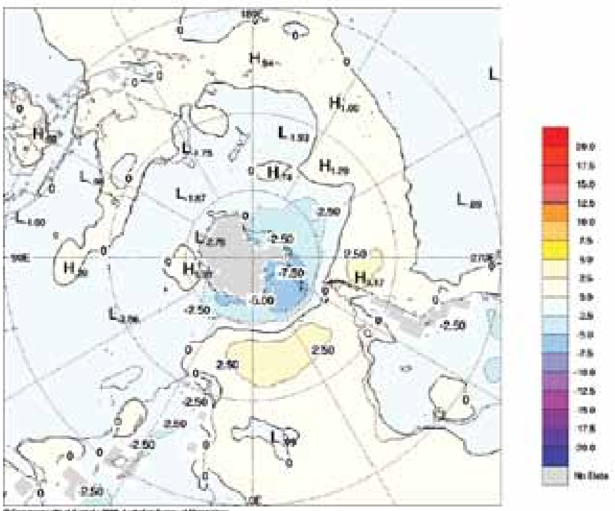


Fig. 8 Summer 2008-09 MSLP anomaly (hPa).



The most significant feature of the MSLP anomaly pattern (Fig. 8) was an enhanced polar low circulation, with the largest anomaly (–7.5 hPa) south of South America at around 60°W. This minimum was observed south of South America during both austral spring 2008 (Qi 2009) and summer, although the magnitude receded across seasons from –14.4 hPa to –7.5 hPa. The subtropical ridge was anomalously strong during spring 2008 across the southern hemisphere, although it dissipated slightly during the summer. Maximum positive MSLP anomalies continued in the southern Atlantic Ocean in the mid-latitudes across the seasons, reducing in magnitude from spring to summer (from +7.5 hPa to +3.5 hPa). Over Australia, MSLP anomalies were fairly weak during the summer, with negative values in the southeast and positive values over most of the remainder of the country.

The monthly SAM index[9] continued the run of positive values since June 2008, peaking in September 2008 at +1.39. The SAM index values for the season were +1.19, +0.96 and +0.46 in December, January and February, respectively.

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. 9, with the associated anomalies shown in Fig. 10.

Fig. 9 Summer 2008-09 500 hPa mean geopotential height (gpm).

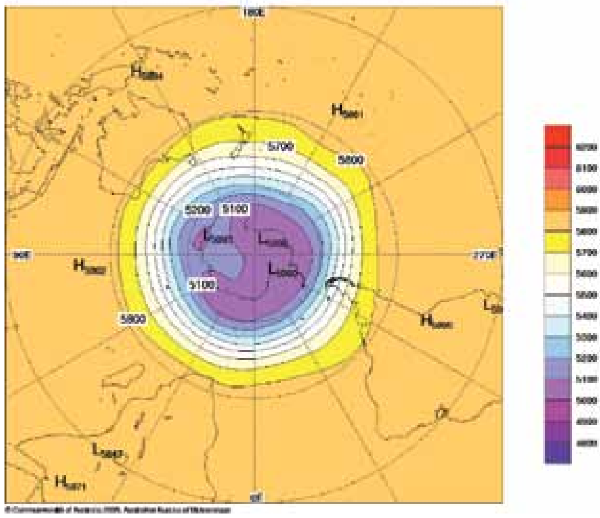
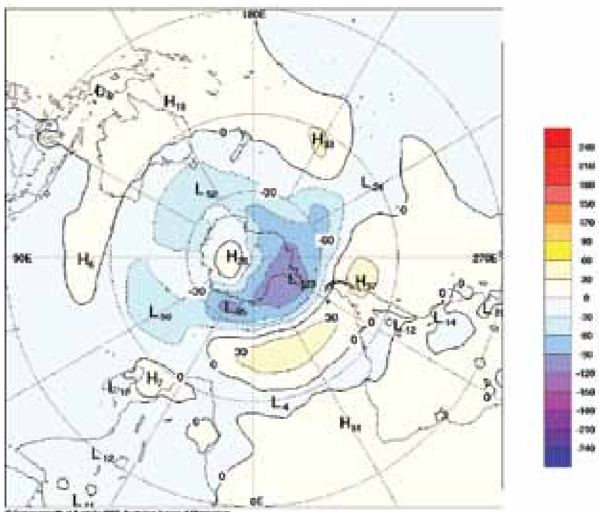


Fig. 10 Summer 2008-09 500 hPa mean geopotential height anomaly (gpm).



[9] Obtained from http://www.cpc.noaa.gov/products/precip/CWlink/daily_ao_index/aao/monthly.aao.index.b79.current.ascii.table, and derived from daily 700 hPa height anomalies south of 20°S.

In general, the field of geopotential height at 500 hPa level appeared quite zonal, although a weak three-wave pattern could be found. There was a slight divergence in the seasonal flow from Australia to New Zealand, which was also reflected at the surface with slightly higher MSLP in the eastern Tasman Sea (Fig. 7). The seasonal anomaly pattern (Fig. 10) is consistent with the MSLP anomaly field shown in Fig. 8, with the major minimum centre (–123 gpm) at about 60°W. The enhanced subtropical ridge at 500 hPa noted in spring 2008 (Qi 2009) had also weakened by summer, similar to the surface changes. Weak positive anomalies were noted over most of Australia at 500 hPa, although with weak negative anomalies in southern parts.

Blocking

The time-longitude section of the daily southern hemisphere blocking index[10] (BI) 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 (yellow shading) 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. Negative values (purple shading) indicate enhanced zonal flow.

The austral summer 2008-09 was generally distinguished by zonal flow and lack of blocking, shown in Fig. 11 by negative index values and blue-purple shading of the blocking index (BI). Short periods of enhanced blocking (yellow shading) were observed over Australian longitudes (115°E-150°E) in early December 2008, and in the western Pacific during the second half of February 2009. Figure 12 shows the seasonal average blocking index for each longitude, which was slightly below average over Australia and the Pacific Ocean for the summer 2008-09 season. The seasonal BI was slightly above average over Africa and South America for the season. Peak BI values occurred briefly in the central Pacific (170°W) in mid-February 2009.

Fig. 11 Summer 2008-09 daily southern hemisphere blocking index (m s^{-1}) time-longitude section. The horizontal axis shows degrees east of the Greenwich meridian. Day one is 1 December 2008.

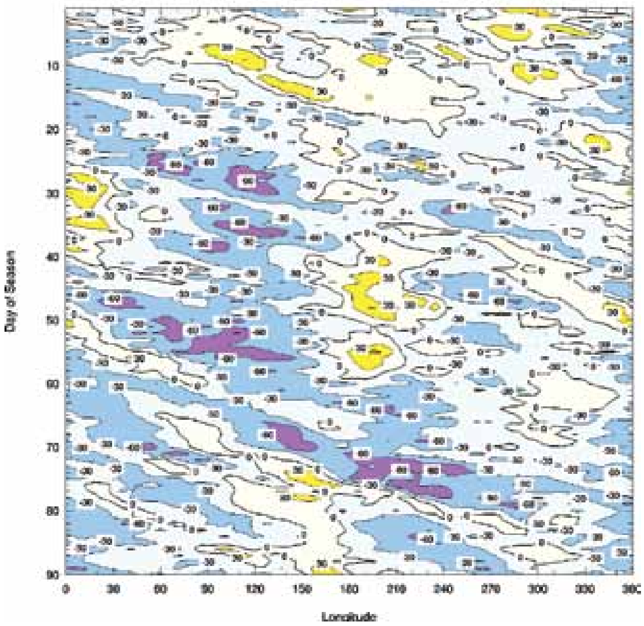
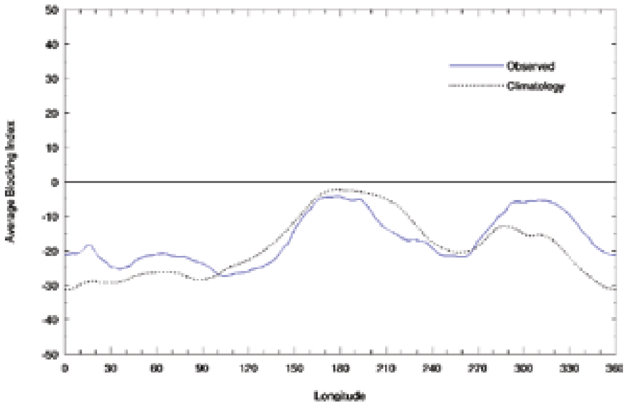


Fig. 12 Mean southern hemisphere blocking index (m s^{-1}) for summer 2008-09 (solid line). The dashed line shows the corresponding long-term average. The horizontal axis shows degrees east of the Greenwich meridian.



Winds

Summer 2008-09 low-level (850 hPa) and upper-level (200 hPa) wind anomalies from the 22-year NCEP II climatology are shown in Figs 13 and 14 respectively. Isotach contours are at 5 m s^{-1} intervals, and in Fig. 13, regions where the surface rises above the 850 hPa level are shaded grey.

At the 850 hPa level, enhanced low-level easterlies over the western and central parts of the equatorial Pacific were observed. Easterly anomalies were also present in spring 2008, indicative of La Niña conditions, but strengthened during the summer. Maximum easterly anomalies were located near the date-line, with a minimum located over eastern Papua New Guinea, indicative of an enhanced Walker cell. Westerly anomalies over Indonesia also fed into this cell, peaking in early February (not shown). Easterly anomalies at the date-line also showed a distinct peak in early February 2009, and then weakened (not shown). Over Australia, generally northerly anomalies were observed, which matched heatwave conditions in southern Australia (described later in this summary).

At the 200 hPa level (Fig. 14), anomalies across the Pacific Ocean were the most significant feature for the season. Westerly anomalies were generally observed across the equatorial Pacific, with a strong maximum (16.0 m s^{-1}) in the

[10] The blocking index is defined as $BI = ½ [u_{25} + u_{30} – (u_{40} + 2 u_{45} + u_{50}) + u_{55} + u_{60}]$, where u_x is the zonal (east-west) component of the 500 hPa wind at latitude x.

Fig. 13 Summer 2008-09 850 hPa vector wind anomalies (m s⁻¹).

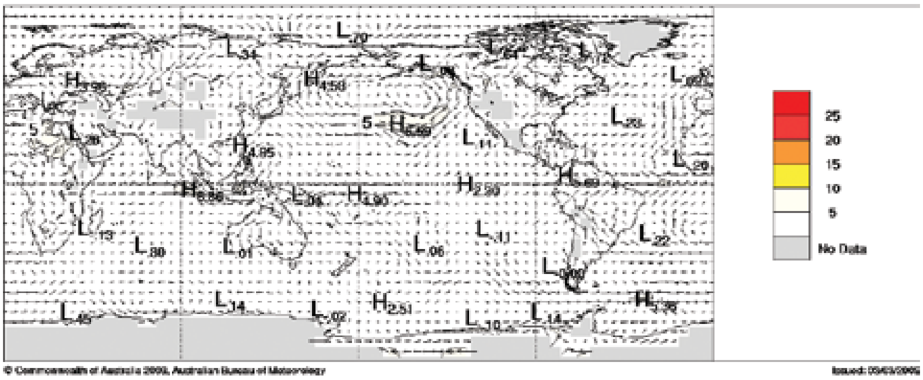
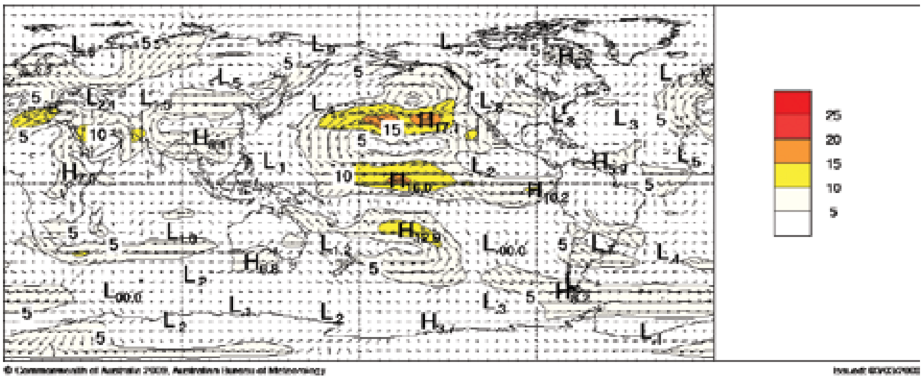


Fig. 14 Summer 2008-09 200 hPa vector wind anomalies (m s⁻¹).



central Pacific. Such a pattern is indicative of the strengthened Walker circulation and corresponding positive phase of the Southern Oscillation. There were also easterly anomaly maxima observed in both hemispheres at mid-latitudes, located either side of this equatorial maximum. This pattern across the Pacific was generally noted in spring, but enhanced in magnitude during summer. A maximum of westerly anomalies was also noted to the southwest of Australia.

Australian region

Rainfall

Figure 15 shows the summer 2008-09 rainfall totals[11] 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 1900-01 to 2008-09.

Summer rainfall deciles (Fig. 16) showed an enhanced wet season, under the weak La Niña event[12], for much of tropical Australia, one exception being a small region around the Cobourg Peninsula in the far north of the Northern Territory (NT). Across central and southern parts of the country, rainfall was somewhat patchy, with widespread areas of near-average (deciles 4 to 7) rainfall. In area-averaged terms, the summer was nationally the fifth wettest of the 109-year period (1900-01 to 2008-09) covered by the gridded analyses, with large areas of Queensland (Qld) (34%) and the NT (30%) receiving decile 10 rainfall for the season. Queensland also experienced its fifth wettest summer in areally averaged terms, being the wettest summer since 1990-91. Significant flooding was recorded in northern Queensland in January and February 2009.

Four tropical cyclones (TCs) affected the Australian coastline during the summer: TC *Billy* (WA, 18 to 23 December); TC *Charlotte* (NT/Qld, 10 to 12 January), TC *Dominic* (WA, 26 to 28 January) and TC *Ellie* (Qld, 31 January to 2 February).

[11] The Bureau of Meteorology has recently moved to a new analysis method for area-averaged rainfall (AAR). This has had the effect of substantially increasing both current and historical totals for Tasmania but has had a negligible impact on totals for other regions and for Australia as a whole.

[12] Summer rainfall is positively correlated with summer SOI across the northern half of the country.

Fig. 15 Summer 2008-09 rainfall totals (mm) for Australia.

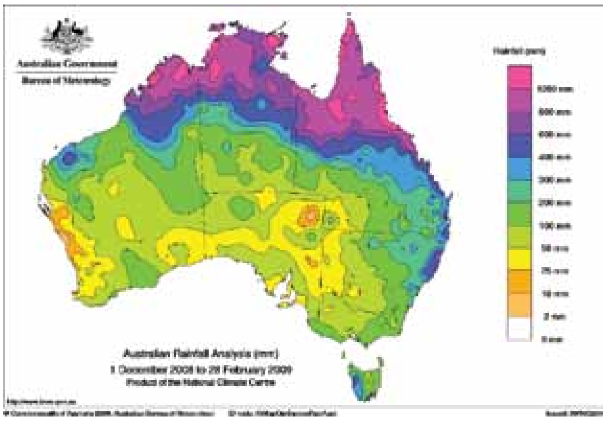
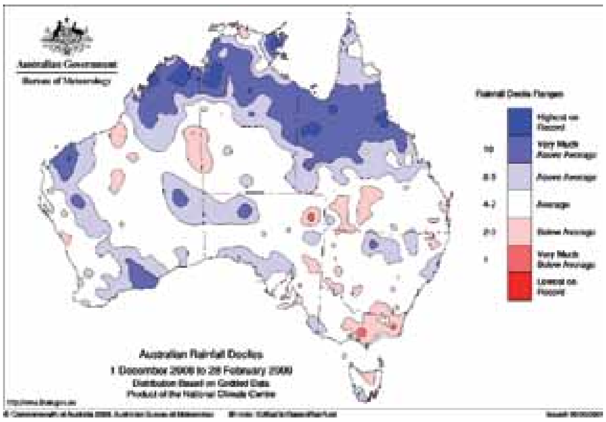


Fig. 16 Summer 2008-09 rainfall deciles for Australia. Decile ranges based on grid-point values over the summers 1900-01 to 2008-09.



Southern Australia received mostly above average falls in December, flipping back to dry conditions in January and February. The positive SAM values were at their highest for the season in December 2008 (+1.2), as was rainfall in southeast Australia (Hendon 2007). January was particularly dry in southeastern Australia, south of a line from the top of the Bight east to Lakes Entrance, Victoria (Vic.). Exceptions were average falls through central WA in January and in northeastern NSW in February 2009.

In area-averaged terms, State and national rainfalls are ranked against 109 years of records in Table 1, which also shows the local extremes of daily and seasonal rainfall.

Drought

At the end of summer 2008-09, 5.5% of Australia was in serious rainfall deficiency (decile 1) for the 14 months ending February 2009. This area comprised parts of all states and the Northern Territory, but was mostly concentrated in the southeast: Victoria[13] (54.2%), Tasmania (34.3%), South Australia (13.1%) and New South Wales (3.6%); also the Northern Territory (4.3%). For this period, 1.8% of the country was in severe deficiency (below the 5th percentile).

For shorter or longer drought assessment periods, the total national area in serious rainfall deficiency was less than this local temporal maximum, with another local temporal maximum at a period length of 21 months for periods ending February 2009 in which 9.0% of the country was in serious rainfall deficiency (with 4.6% being in severe deficiency and 0.3% lowest on record). For this longer period, the main regions affected were Victoria (61.7%), Tasmania (62.4%), South Australia (30.7%) and New South Wales (8.5%).

[13]Percentages in parentheses in this section denote the percentage of the entire State/Territory experiencing serious rainfall deficiencies. The percentage area calculation for NSW is based on the combined NSW/ACT region.

Table 1. Summary of the seasonal rainfall ranks and extremes on a national and State basis for summer 2008-09.

	Highest seasonal total (mm)	*Lowest seasonal total (mm)*	*Highest 24-hour fall (mm)*	*Area-averaged rainfall (AAR) (mm)*	*Rank of AAR**
Australia	3386 at Bulgun Creek (Qld)	Zero at several locations in WA	497 at Hawkins Creek (Qld), 4 February	290.2	105**
WA	1877 at Kuri Bay	Zero at several locations	300 at Yalleen, 17 February	202.6	91
NT	1721 at Bradshaw	35 at Anningie Station	240 at Claravale, 24 December	462.8	101
SA	154 at Nangwarry	7 at Tantanna Station	101 at Nangwarry, 13 December	59.1	71
Qld	3386 at Bulgun Creek	23 at Ballera Gas Field	497 at Hawkins Creek, 4 February	515.4	105**
NSW	1236 at Yarras	10 at Waterbag Station	319 at Crystal Creek, 17 February	145.4	56
Vic.	296 at Tanybryn	28 at Morkalla North	112 at Tanybryn, 13 December	87.2	29
Tas.	782 at Mt Read	61 at Hamilton	125 at Strathgordon, 24 February	230.1	40

* The rank goes from 1 (lowest) to 109 (highest) and is calculated over the summers 1900-01 to 2008-09 inclusive.
** Fifth wettest.

Temperatures

Figures 17 and 18 show the maximum and minimum temperature anomalies, respectively, for summer 2008-09. The anomalies have been calculated with respect to the 1961-1990 period, and use all temperature-observing stations for which a 1961-1990 normal is available. A high-quality subset of the network is used to calculate the spatial averages and rankings shown in Tables 2 and 3. These averages are available from 1950 to the present. All ranking of the summer temperatures against the historical record is done in terms of this high-quality subset, which therefore comprises the summers 1950-51 to 2008-09.

Seasonal maximum temperatures (Fig. 17) were generally 1 to 2°C above average for summer in southern parts of the country. In contrast, temperatures were more than 1°C below average across much of the tropical north, with anomalies in the –3 to –4°C range in western Queensland and central eastern parts of the Northern Territory. These negative summer anomalies arose principally from well below average temperatures during January, and were accompanied by above-average rainfall in that month. In seasonal and area-averaged terms (Table 2), summer was unremarkable, with maximum and minimum temperature anomalies showing small departures from normal. State minimum temperature anomalies

Fig. 17 Summer 2008-09 maximum temperature anomalies (°C) for Australia.

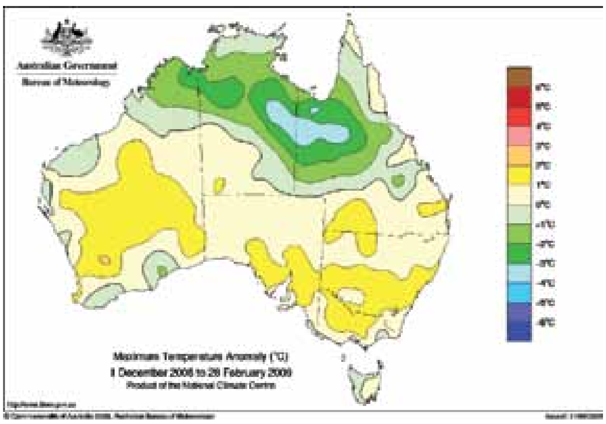


Fig. 18 Summer 2008-09 minimum temperature anomalies (°C) for Australia.

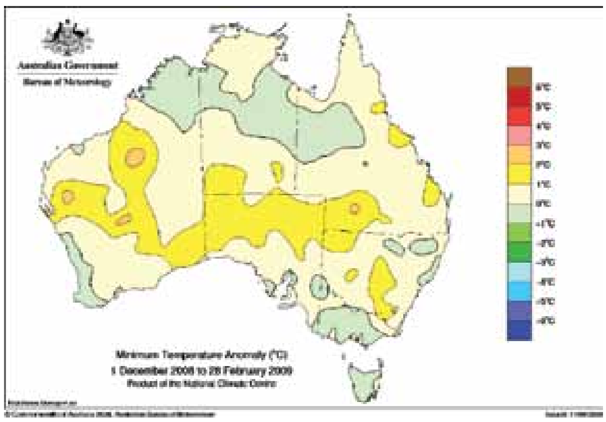


Table 2. Summary of the seasonal maximum temperature ranks and extremes on a national and State basis for summer 2008-09.

	Highest seasonal mean (°C)	*Lowest seasonal mean (°C)*	*Highest daily recording (°C)*	*Lowest daily recording (°C)*	*Anomaly of area-averaged mean (°C) (AAM)*	*Rank of AAM**
Australia	40.9 at Telfer (WA)	12.1 at Mt Wellington (Tas.)	49.0 at Emu Creek Station (WA), 10 January	2.1 at Mt Wellington (Tas.), 16 January	–0.03	29=
WA	40.9 at Telfer	22.3 at Albany	49.0 at Emu Creek Station, 10 January	16.2 at Jacup, 10 December and at Manjimup, 25 February	+0.17	37
NT	38.8 at Walungurru	31.2 at McCluer Island	44.2 at Yulara, 6 February	22.0 at Yuendumu, 18 January	–1.08	10
SA	37.8 at Marree	21.5 at Cape Willoughby	48.2 at Kyancutta, 28 January and at Renmark, 7 February	11.3 at Mt Lofty, 14 December	+0.95	45=
Qld	38.5 at Ballera Gas Field	26.2 at Applethorpe	46.3 at Birdsville, 4 December	17.5 at Stanthorpe, 13 February	–0.71	16
NSW	36.4 at Wanaaring	15.5 at Thredbo Top Station	47.0 at Ivanhoe, 2 February	2.7 at Thredbo Top Station, 14 December	+1.06	47
Vic.	32.6 at Mildura	15.3 at Mt Hotham	48.8 at Hopetoun, 7 February #	2.8 at Mt Hotham, 14 December	+0.72	44
Tas.	24.1 at Cressy	12.1 at Mt Wellington	42.2 at Scamander, 30 January	2.1 at Mt Wellington, 16 January	+0.20	30

*The temperature ranks go from 1 (lowest) to 59 (highest) and are calculated over the summers 1950-51 to 2008-09 inclusive. Ranks with ‘ =’ result from the presence of tied values within the time series.
#All-time State record

Table 3. Summary of the seasonal minimum temperature ranks and extremes on a national and State basis for summer 2008-09.

	Highest seasonal mean (°C)	*Lowest seasonal mean (°C)*	*Highest daily recording (°C)*	*Lowest daily recording (°C)*	*Anomaly of area-averaged mean (°C) (AAM)*	*Rank of AAM**
Australia	26.6 at Telfer (WA)	3.3 at Mt Wellington (Tas.)	33.9 at Adelaide (SA), 29 January	–4.5 at Liawenee (Tas.), 10 December	+0.46	47
WA	26.6 at Telfer	11.8 at Jarrahwood	32.4 at Meekatharra, 12 January	3.3 at Eyre, 21 January	+0.51	52
NT	26.4 at McCluer Island	21.2 at Kulgera	31.5 at Yulara, 25 January	8.6 at Arltunga, 14 February	+0.01	28
SA	23.8 at Moomba	10.7 at Naracoorte	33.9 at Adelaide, 29 January	0.6 at Keith, 8 December	+1.11	50
Qld	25.9 at Sweers Island	14.6 at Applethorpe	31.7 at Boulia, 29 December	7.0 at Applethorpe, 1 December	+0.31	39=
NSW	23.0 at Tibooburra	4.5 at Charlotte Pass	32.7 at White Cliffs, 7 February	–4.4 at Charlotte Pass, 17 January	+0.68	46=
Vic.	16.2 at Mildura	6.6 at Mt Hotham	30.5 at Melbourne Airport, 29 January	–3.7 at Dinner Plain and Mt Hotham, 2 January	+0.13	32
Tas.	13.6 at Swan Island	3.3 at Mt Wellington	24.0 at Melton Mowbray, 30 January	–4.5 at Liawenee, 10 December	–0.18	23

*The temperature ranks go from 1 (lowest) to 59 (highest) and are calculated over the summers 1950-51 to 2008-09 inclusive. Ranks with "=" result from the presence of tied values within the time series.

(Table 3) were all positive except for Tasmania (–0.18°C); summer maximum temperature anomalies (Table 2) were positive except for Queensland (–0.71°C) and the Northern Territory (–1.08°C). The all-Australian seasonal average maximum (–0.03°C) was right on median for summer 2008-09.

However, summer 2008-09 will be long remembered for two short but exceptional heatwaves in southeastern Australia in late January and February: the first being 28 to 31 January, and the second 6 to 8 February 2009. The 'Black Saturday' bushfires outside Melbourne on 7 February 2009 became Australia's worst natural disaster, with more than 170 people killed and 1800 homes lost. Many temperature records were smashed across southeastern Australia, particularly in Victoria, on 7 February. Hopetoun (Vic.) set a new State record of 48.8°C, believed to be the highest ever recorded temperature in the world so far south. Further details of these exceptional heatwaves can be found in *Special Climate Statement 17* (Bureau of Meteorology 2009).

The highest daily maximum temperature in summer 2008-09 was 49.0°C at Emu Creek Station (WA) on 10 January 2009. The highest daily minimum temperature was 33.9°C at Adelaide (SA) on 29 January 2009. Various records are listed in Tables 2 and 3.

Acknowledgments

The author would like to thank colleagues in the Climate Analysis Section of the Bureau of Meteorology for their valuable inputs; particular thanks to Robert Fawcett and Grant Beard.

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