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Seasonal climate summary southern hemisphere (summer 2000/01): a third successive positive phase of the Southern Oscillation continues

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Southern hemisphere circulation patterns and associated anomalies for the austral summer (December to February) 2000/01 are reviewed, with emphasis given to the Pacific Basin climate indicators, and Australian rainfall and temperature patterns. During summer, the atmosphere showed clear signs of being in a positive phase of the Southern Oscillation, but the oceanic indicators did not mirror this to any great extent.

The summer saw wet conditions across most of Western Australia, the Northern Territory and northern Queensland, but average to very much below rainfall across most of the rest of the country, particularly in those parts of southeastern Australia experiencing long-term rainfall deficiencies. Seasonal temperatures were below average across the northern half of the country, but generally above average in South Australia and the southeastern states. Heatwave conditions occurred across South Australia and New South Wales in January.

Introduction

The positive phase of the Southern Oscillation which had begun around August/September 2000 (Watkins 2001) continued through the southern hemisphere summer 2000/01. This positive phase, the third such phase in the wake of the substantial El Niño of 1997/98, was however weaker than the two preceding phases of 1998/99 and 1999/2000, and not strong enough in terms of the oceanic response to warrant being called a La Niña event.

This summary reviews the southern hemisphere and equatorial climate patterns for summer 2000/01, with particular attention given to the Australasian and Pacific Regions. The main sources of information for this report are the *Climate Monitoring Bulletin* (Bureau of Meteorology, Australia) and the *Climate Diagnostics Bulletin* (Climate Prediction Center, Washington). Further details regarding sources of data are given in the Appendix.

Pacific Basin climate indices

The Troup Southern Oscillation Index*

The set of three positive monthly values (+9.9, +9.7 and +22.4) of the Troup Southern Oscillation Index (SOI) for spring 2000 (Watkins 2001) was followed by +7.7 (December), +8.9 (January) and +11.9

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*The Troup Southern Oscillation Index (SOI) used in this article is ten times the standardised monthly anomaly of the difference in mean sea-level pressure between Tahiti and Darwin. The calculation is based on a sixty-year climatology (1933-1992).

Fig. 1 Southern Oscillation Index, from January 1997 to February 2001. Means and standard deviations used in the computation of the SOI are based on the period 1933-1992.

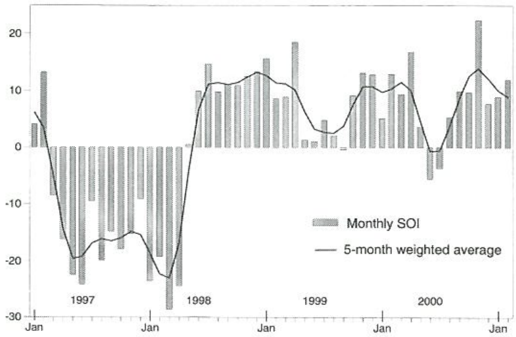
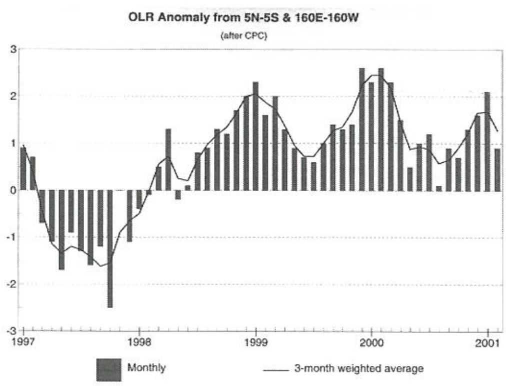


Fig. 2 Standardised anomaly of monthly outgoing long wave radiation averaged over the area 5°S to 5°N and 160°E to 160°W, from January 1997 to February 2001. Negative (positive) anomalies indicate enhanced (reduced) convection and rainfall in the area. Anomalies are based on the 1979-1995 base period. After CPC (2000, 2001).



(February). This confirmed the existence of the positive phase of the Southern Oscillation which began around August/September 2000. In terms of this index however, the Southern Oscillation was slighter during this summer (average value of the index +9.5) than it had been the two previous summers (+13.3 for summer 1998/99 and +10.3 for summer 1999/2000). Sequences of three consecutive positive phases like the present one are not common in the 125-year SOI record. Figure 1 shows the monthly SOI values from January 1997 to February 2001. A curve of five-month moving averages has been superimposed on the graph.

Outgoing long wave radiation

Figure 2, adapted from the Climate Prediction Center (CPC), Washington (Climate Prediction Center 2000, 2001), shows the monthly standardised anomaly of outgoing long-wave radiation (OLR) from January 1997 to February 2001, together with a three-month moving average. These data, compiled by the CPC, are a measure of the amount of long-wave radiation emitted from an equatorial region centred about the dateline (5°S to 5°N and 160°E to 160°W). Tropical convection in this region is particularly sensitive to changes in the phase of the Southern Oscillation. During warm (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 cloudiness and convection. The reverse applies in cold (La Niña) events, with less convection in the region expected.

Values of this index for December, January and February were broadly consistent with the SOI in indicating a positive phase of the Southern Oscillation, the atmospheric conditions normally associated with La Niña events. The peak value (+2.1, in January) for the season was half a standard deviation weaker than the peak value recorded the previous summer (+2.6, in both December 1999 and February 2000). With the addition of the March 2001 value (+1.2), it could be seen that the third positive phase in the index was both weaker in intensity and shorter in duration than the two previous positive phases (the La Niñas of 1998/99 and 1999/2000). Even so, by February 2001, this index had been positive for 33 consecutive months.

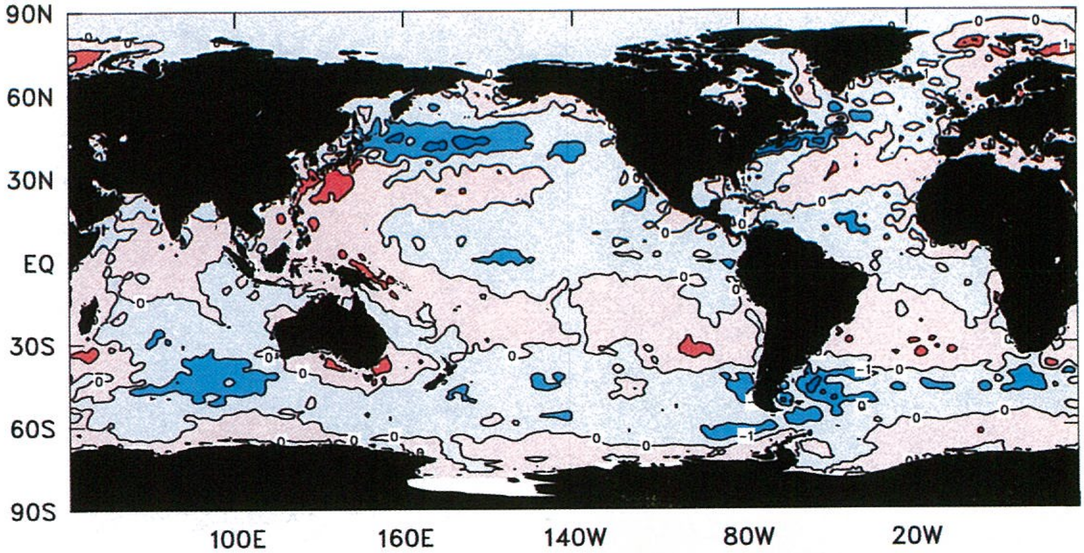
Oceanic patterns

Sea-surface temperatures

Figure 3 shows the summer 2000/01 sea-surface temperature (SST) anomaly in degrees Celsius (°C). The contour interval is 1°C. Positive anomalies are shown in orange and red shades, while negative anomalies are shown in blue shades.

The tropical Pacific Ocean in summer showed something of a La Niña pattern in that the anomalies in central and eastern parts were mostly negative, and surrounded by a rotated 'V' of positive anomalies. The amplitude of the pattern however was weak, and not strong enough even to warrant being designated a weak La Niña. As previously reported (Fawcett 2001), weekly time series (not shown) of the NINO3

Fig. 3 **Anomalies of sea-surface temperature for summer (December, January, February) 2000/01 (°C).**



and NINO4 SST anomaly indices, as calculated by the National Meteorological and Oceanographic Centre, Melbourne, showed the 1998/99 and 1999/2000 La Niñas as reaching similar peak intensities in the NINO4 region, but the second event being considerably stronger in the NINO3 region. The anomalies in both these regions during summer 2000/01 were only about half as strong as they had been the previous summer.

A small region with anomalies in the range –1 to –2°C was evident between the date-line and 160°W, and here the anomalies were stronger and formed a more coherent pattern than was the case during spring 2000 (Watkins 2001).

An interesting feature in southern latitudes is the band of negative anomalies between 40°S and 60°S stretching all the way around Antarctica.

Subsurface patterns

Figure 4 shows a time-longitude diagram of the anomaly in metres of the depth of the 20°C isotherm along the equatorial Pacific Ocean between January 1996 and February 2001. This isotherm is generally situated very close to the equatorial ocean thermocline, the region of greatest temperature gradient with respect to depth. The thermocline can also be regarded as the boundary between the upper ocean warm water and the deeper ocean cold water. An abnormally shallow thermocline in the eastern Pacific Ocean is characteristic of La Niña events. Positive anomalies correspond to the 20°C isotherm being deeper than average, and negative anomalies to it being shallower than average.

The eastern equatorial subsurface of the Pacific Ocean during summer 2000/01 was characterised by a raised thermocline, although the strength of the anomalies was very much less than that observed during the La Niña events of 1998/99 and 2000/01. The situation in the western tropical Pacific during summer was similar to that of the previous summer.

Figure 5 shows a sequence of equatorial Pacific vertical temperature anomaly profiles for the four months ending February 2001, obtained from the Bureau of Meteorology Research Centre. In the figure, red (blue) shades indicate subsurface waters which are warmer (cooler) than average. The subsurface cool anomalies in the eastern half of the Pacific were at their strongest in December. During the summer, positive anomalies became established in the western Pacific.

Atmospheric patterns

Surface analyses

The summer 2000/01 mean sea-level pressure (MSLP) across the southern hemisphere is shown in Fig. 6, with the associated anomalies shown in Fig.

Fig. 4 **Time-longitude section of the monthly anomalous depth of the 20°C isotherm at the equator from January 1996 to February 2001. The contour interval is 10 m.**

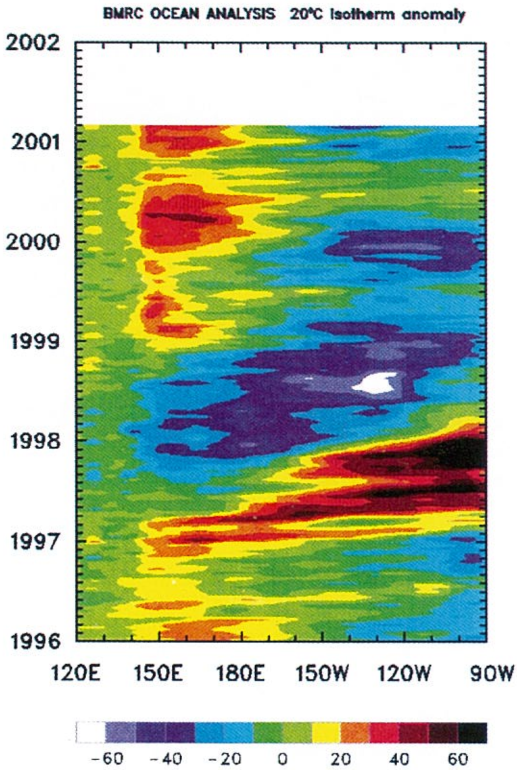


Fig. 5 **Four-month (November 2000 to February 2001) sequence of vertical temperature anomalies at the equator for the Pacific Ocean. The contour interval is 0.5°C.**

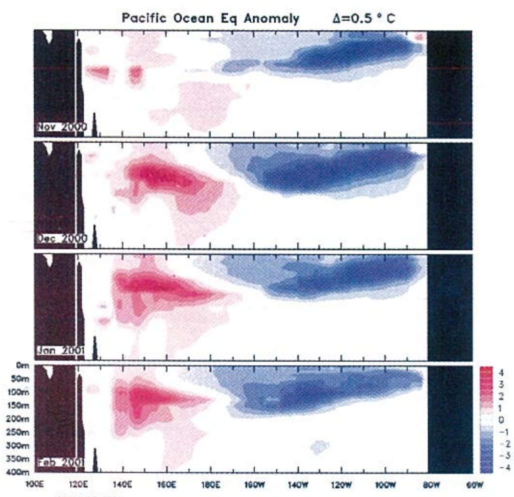


Fig. 6 **Summer 2000/01 mean sea-level pressure (hPa). The contours are spaced at 4 hPa intervals between 988 hPa and 1020 hPa.**

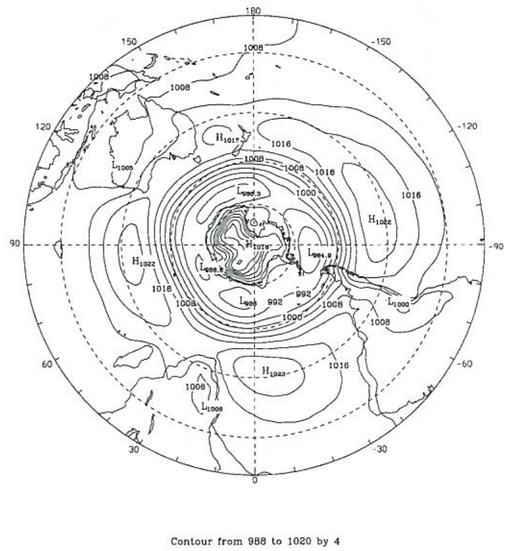
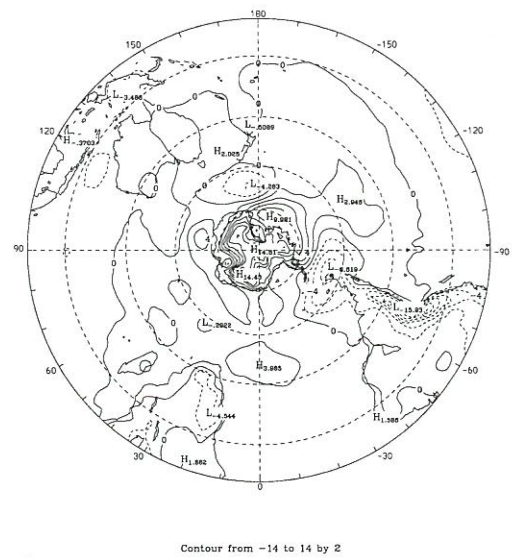


Fig. 7 **Summer 2000/01 mean sea-level pressure anomaly (hPa). The contours are spaced at 2 hPa intervals between –14 hPa and +14 hPa.**



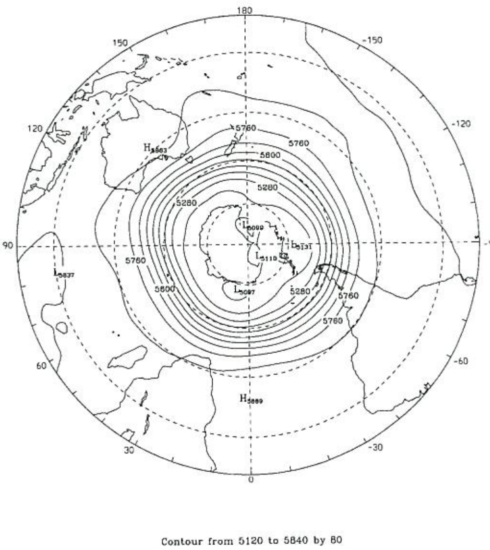
7. These anomalies are the departures from an eleven-year (1979-1989) climatology obtained from the European Centre for Medium-range Weather Forecasts (ECMWF). The MSLP analysis itself has been computed using data obtained from the Bureau of Meteorology's Global Assimilation and

Prediction (GASP) model daily 2300 UTC analyses. The low pressure anomaly over high elevation parts of South America in Fig. 7 is a persistent feature, and appears to result from a systematic difference between the GASP and ECMWF models and the way they extrapolate down to mean sea level, rather than as a meteorological consequence of the current state of the El Niño-Southern Oscillation.

As in the previous summer (Della-Marta 2001), the flow north of the southern hemisphere circumpolar trough (around 50°S in Fig. 6), was quite zonal, but the polar trough itself was wider and shallower in summer 2000/01 than in summer 1999/2000. Continuing the comparison of the two summers, the three main centres of the subtropical ridge were of similar strength.

MSLP anomalies were positive over the eastern Australian states, mainly due to the anomalously high pressure over the Tasman Sea. The effects of the Tasman Sea pattern can clearly be seen in the temperature anomaly patterns shown in Figs 16 and 17. MSL pressures were below average over most of the rest of the country.

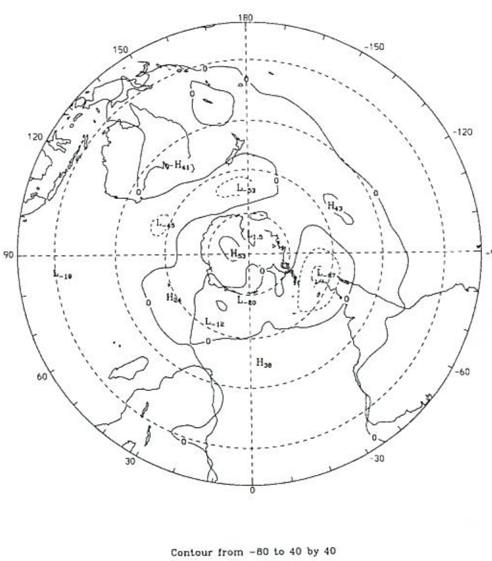
Fig. 8 **Summer 2000/01 500 hPa mean geopotential height (m). The contours are spaced at 80 geopotential metre intervals from 5120 gpm to 5840 gpm.**



Mid-tropospheric analyses

Figures 8 and 9 show the mean and anomalous geopotential height patterns at 500 hPa respectively for summer 2000/01. North-south oriented troughs at the 500 hPa level were present at around 100°E and 170°E, southwest and southeast of Australia respectively (Fig. 8). Centres of negative anomalies were associated with these troughs (Fig. 9). The patterns at this level were broadly consistent with the MSLP patterns, including the presence of anomalously high heights over eastern Australia.

Fig. 9 **Summer 2000/01 500 hPa mean geopotential height anomaly (m). The contours are spaced at 40 gpm intervals from –80 gpm to +40 gpm.**



Blocking

Figure 10 is a time-longitude section of the daily southern hemisphere mid-level Blocking Index,

$$BI=1/2[(u_{25}+u_{30}) - (u_{40}+2u_{45}+u_{50}) + (u_{55}+u_{60})].$$

Here, u_λ indicates the 500 hPa level zonal wind component at λ degrees of southern hemisphere latitude ranging from 0° at the equator to +90°S at the South Pole. The blocking index measures the strength of the 500 hPa flow at the mid-latitudes (40°S to 50°S) relative to that at subtropical (25°S to 30°S) and high (55°S to 60°S) latitudes.

Taken across the entire season in the form of a seasonal mean (Fig. 11), blocking for the summer was below average for most longitudes, including the Australian. Climatologically, maximum blocking for the season occurs at around 175°E. During summer 2000/01, the maximum blocking was located slightly to the east, around 180°. The strongest contribution to the decrease in blocking in Australian longitudes came in December, with a slightly less strong contribution in February.

Fig. 10 **Summer 2000/01 daily blocking index: time-longitude section. The horizontal axis measures degrees of longitude east of the Greenwich meridian. Day one is 1st December.**

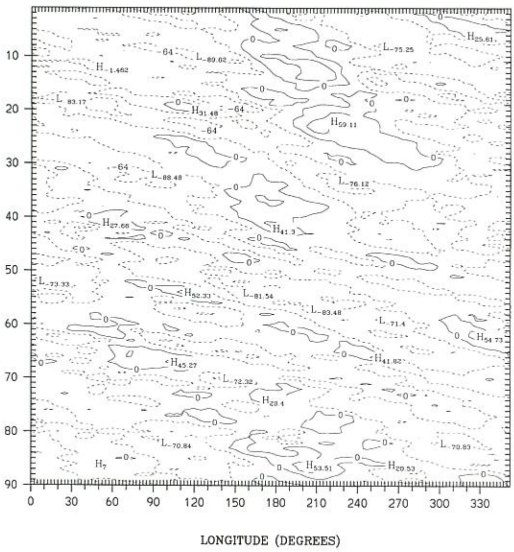
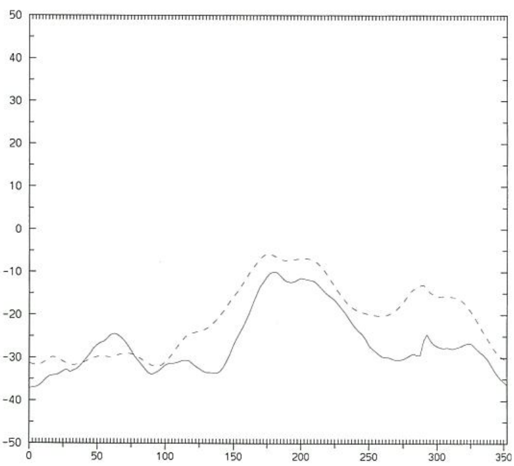


Fig. 11 **Mean southern hemisphere blocking index for summer 2000/01 (bold line). The dashed line shows the corresponding long-term average. The horizontal axis shows degrees east of the Greenwich meridian.**



Winds

Low-level (850 hPa) and upper-level (200 hPa) wind anomalies for summer are shown in Figs 12 and 13 respectively. The low-level easterly anomalies over the central and western tropical Pacific Ocean and the corresponding upper-level westerly anomalies over the central and eastern tropical Pacific point to an enhanced summer Walker circulation, consistent with the SOI and OLR index values. In terms of the individual months, the signs of an enhanced Walker circulation were more apparent in January and February than in December (Bureau of Meteorology 2000, 2001).

The figures also show evidence of anomalous low-level convergence and associated anomalous upper-level divergence over Indonesia and northern Australia. This was indicative of a well-developed monsoon circulation that contributed to above average rainfall in northern Australia and below average outgoing long-wave radiation in the region, and consistent with the positive SST anomalies in the region (Fig. 3).

Australian region

Rainfall

Figure 14 shows the summer rainfall totals for Australia, while Fig. 15 shows the summer rainfall deciles, based on gridded rainfall data for the summers 1900/01 to 2000/01. Summer rainfall was generally above average to well above average for Western Australia, the Northern Territory, and western and far northern Queensland. This rainfall derived from the very active northern wet season which saw a strong monsoon trough sitting over the top of the continent and six cyclones (*Sam* (WA) in December and *Terri* (WA), *Winsome* (NT), *Vincent* (WA), *Wylva* (NT) and *Abigail* (Qld and NT) in February) cross the northern coastline for the period. The highest on record rainfall areas in the western, northern, and Gulf region of the Northern Territory were largely the result of cyclonic rainbands. Averaged across the Northern Territory, the summer rainfall was the second highest summer total in the post-1890 period, although well behind the summer of 1973/74.

Significant below average to well below average rainfall was recorded in far southwest Western Australia, northwest South Australia, and in a broad sweep southeast from the Eyre Peninsula to southern Victoria and Tasmania. Another region of below average rainfall covered northern and central New South Wales and an adjacent region of Queensland extending northeast to the coast near Rockhampton.

Temperatures

Figures 16 and 17 show the maximum and minimum temperature anomalies respectively for summer 2000/01. The anomalies have been calculated with respect to the 1961-1990 period.

Maximum temperature anomalies for the summer showed a strong bipolar pattern with below average

Fig. 12 Summer 2000/01 850 hPa vector wind anomalies (m s^{-1}).

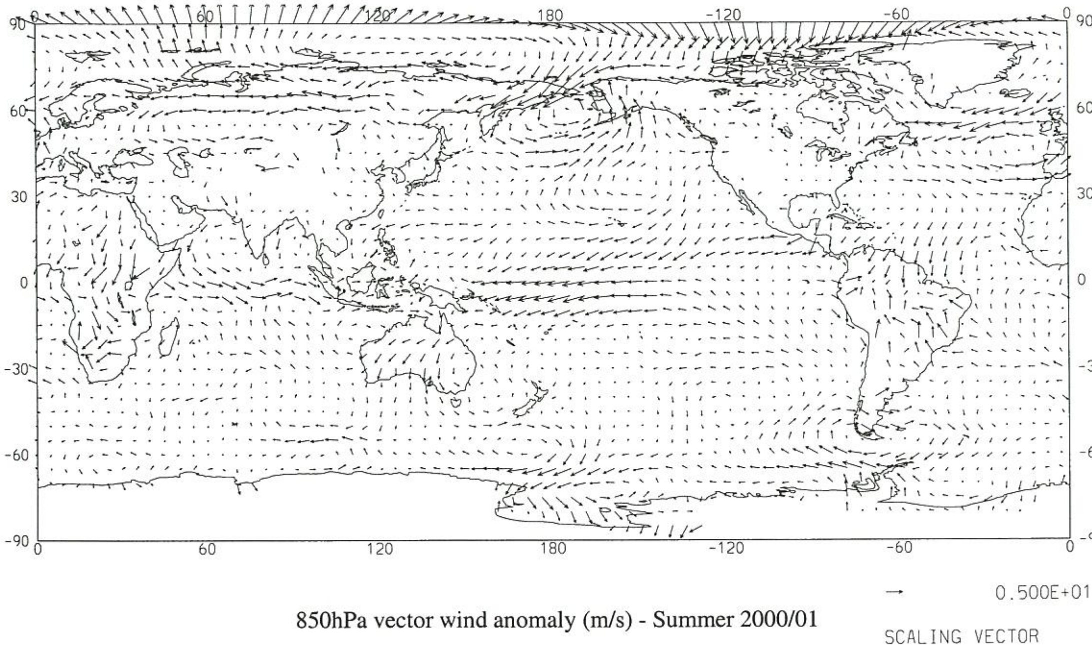


Fig. 13 Summer 2000/01 200 hPa vector wind anomalies (m s^{-1}).

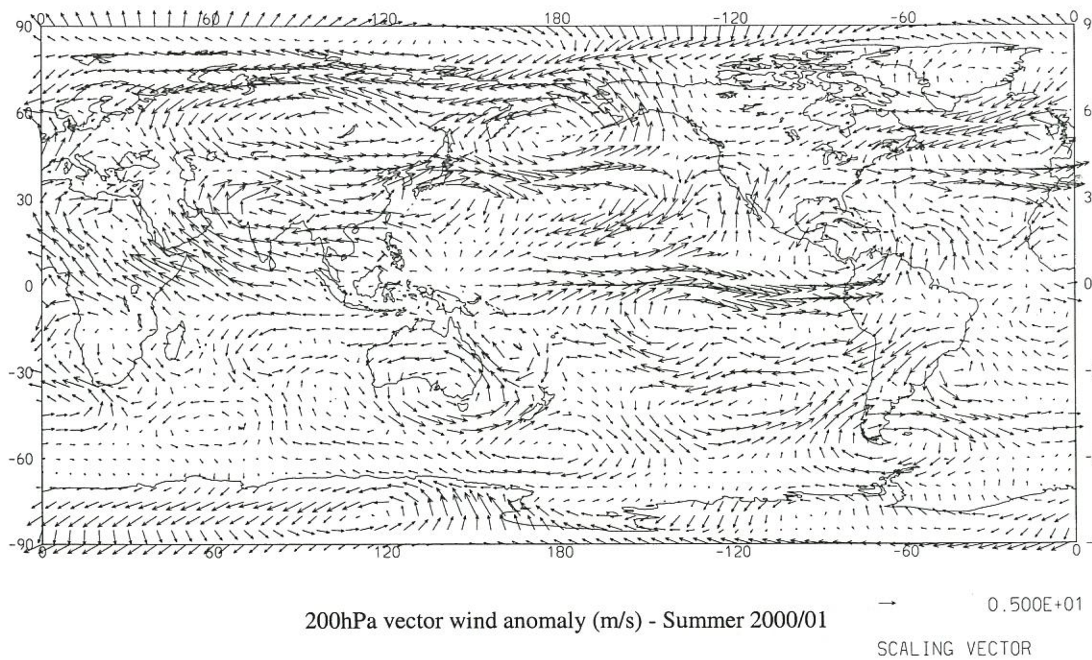


Fig. 14 Summer 2000/01 rainfall totals (mm) in Australia.

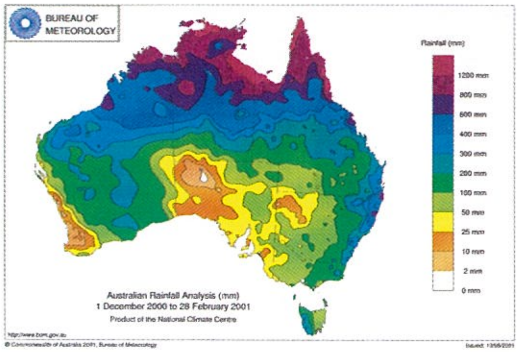


Fig. 15 Summer 2000/01 rainfall in Australia: decile range values based on grid-point values over the summers 1900/01 to 2000/01.

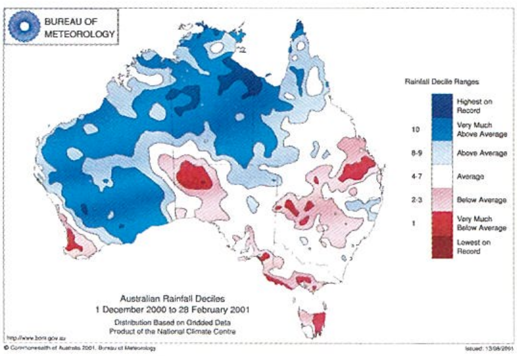


Fig. 16 Summer 2000/01 maximum temperature anomalies (°C) for Australia based on a 1961-1990 mean.

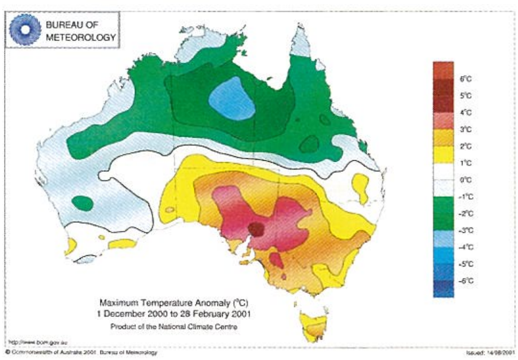
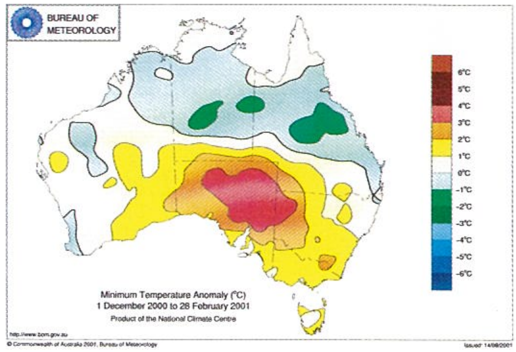


Fig. 17 Summer 2000/01 minimum temperature anomalies (°C) for Australia based on a 1961-1990 mean.



temperatures in the north and above average readings in the south. Such a pattern appears to be common in strong wet seasons (see for example, the corresponding summaries in this journal for the summers 1996/97, 1998/99 and 1999/2000). Summer maximum temperatures have been shown to be negatively correlated with the SOI across the northern half of the continent (Jones and Trewin 2000), and positively correlated in the far southeast.

Negative anomalies were lower than –1°C over much of the tropics, reaching about –4°C southwest of the Gulf of Carpentaria, a region that was excessively wet (Fig. 15). In contrast, departures of +1 to +3°C were common in the south and southeast, nearing +5°C north of Spencer Gulf in South Australia. In fact South Australia recorded its hottest summer since 1950, and probably very much longer, with an average maximum temperature anomaly of +2.6°C, a full one degree higher than the next warmest summer of 1990/91. It was also the hottest summer since at least 1950 in New South Wales and Victoria, and the second hottest summer in Tasmania behind the summer of 1960/61. Reliable Australia-wide temperature records only became available in 1950.

January 2001 was especially notable for the heat wave conditions in South Australia and western New South Wales. Anomalies over +3°C were widespread across New South Wales, Victoria and South Australia, reaching a remarkable +6 to +7°C around the northern Spencer Gulf and surrounding regions. The main period of heat occurred in the middle of the month, when most of central and eastern Australia was baked by a merciless fourteen-day heatwave starting on the 10th of January. The temperature reached 45°C somewhere in the country on all but one day during this period, peaking at 48°C at several locations including Ceduna and Kyancutta in South Australia, and White Cliffs and Tibooburra in New South Wales. January State-averaged maximum temperatures were highest on record in New South Wales and South Australia in the post-1950 period, with Victoria recording its second highest January average (behind January 1981).

Summer minimum temperature anomalies followed a similar pattern to that of the maximum temperatures, but one which was less intense. Overnight temperatures were about a degree below normal over the central areas of the Northern Territory and Queensland, but 3 to 4 degrees above average over central South Australia and far western New South Wales. With regard to average minimum temperatures, this summer was also the hottest summer for South Australia since at least 1950, again exceeding the previous hottest summer 1996/97 by more than one degree. For New South Wales and Victoria, this summer had the second highest average minimum temperature in the post-1950 period, in both cases behind the summer of 1980/81.

In view of these outcomes, it will come as no surprise to readers that the mean temperature (the average of the maximum and minimum temperatures) when averaged across South Australia was likewise the highest for summers in the post-1950 period, with New South Wales and Victoria recording their second highest mean temperatures over this period.

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Bureau of Meteorology 2000, 2001. *Climate Monitoring Bulletin,* December 2000, January 2001, February 2001 issues. National Climate Centre, Bur. Met., Australia.

Climate Prediction Center 2000, 2001. *Climate Diagnostics Bulletin,* December 2000, January 2001, February 2001 issues. US Department of Commerce, National Oceanic and Atmospheric Administration, Washington D.C.

Appendix

Data sources used for this review were:

National Climate Centre, *Climate Monitoring Bulletin - Australia.* Obtainable from the National Climate Centre, Bureau of Meteorology, GPO Box 1289K, Melbourne, Vic. 3001, Australia.

Climate Prediction Center (CPC), *Climate Diagnostics Bulletin.* Obtainable from the Climate Prediction Center (CPC), National Weather Service, Washington D.C., 20233, USA.