

Seasonal climate summary southern hemisphere (autumn 2001): a return to near-normal conditions in the tropical Pacific

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Southern hemisphere circulation patterns and associated anomalies for the austral autumn 2001 (March to May) are reviewed, with emphasis given to the Pacific Basin and Australian region. The 'weak' positive phase of the Southern Oscillation which began in spring 2000 went through a rapid change in autumn indicating a return to the neutral state.

Introduction

Autumn 2001 saw the demise of the weak positive phase of the Southern Oscillation (the third such phase since the El Niño of 1997/98), which began in August/September 2000 (Watkins 2001), as the atmospheric and oceanic conditions became consistent with a neutral state of the El Niño-Southern Oscillation (ENSO). Notably, the amplitude of this third positive phase was not strong enough to warrant it being called a weak La Niña (Fawcett 2002).

The Kelvin wave resulting from a westerly wind burst in late 2000, which propagated along the equator, did not have a significant impact on the east Pacific and did not generate warm anomalies. Though there was some indication of westward propagation of warm subsurface water during autumn 2001, probably due to weak westerly wind anomalies in the far west Pacific, it was not sufficient to cause an evolution toward warm ENSO conditions, as had been forecast by some models.

The main sources of information used for this summary were the Climate Monitoring Bulletin (Bureau of Meteorology, Australia), and the Climate Diagnostic Bulletin (Climate Prediction Center, Washington, USA). Data sources are given in the Appendix.

Pacific Basin climate indices

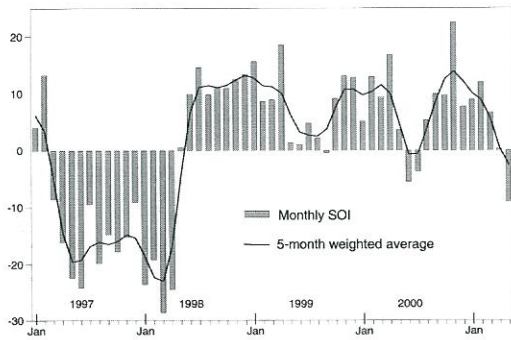
The Troup Southern Oscillation Index*

Figure 1 shows monthly SOI values with a superimposed five-month moving average from January 1997 to May 2001. There was a rapid change in the Southern Oscillation Index (SOI) during the austral autumn of 2001 with values of +6.7, +0.3 and -9.0 for March, April and May, respectively. The May SOI value was the lowest value since April 1998 and the seasonal mean SOI value was -0.7, a decrease of 10.2

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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, January 1997 to May 2001. Means and standard deviations based on the period 1933 to 1992.



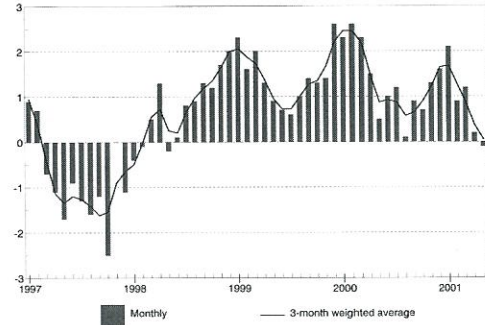
from the corresponding value for summer 2000/01. Also, it was significantly lower than it had been the two previous autumns (+9.6 for autumn 1999 and +9.9 for autumn 2000). The trend for the first half of 2001 was somewhat similar to the trend of the corresponding period in 2000.

Outgoing long wave radiation

Figure 2, adapted from the Climate Prediction Center (CPC), Washington (CPC 2001), shows the monthly standardised anomaly of outgoing long wave radiation (OLR) from January 1997 to May 2001, together with a three-month moving average. These data, compiled by the CPC, are a measure of the amount of outgoing long-wave radiation (OLR) emitted from an equatorial region centred about the date-line (5°S to 5°N and 160°E to 160°W). The tropical convection in this region is particularly sensitive to changes in the phase of the Southern Oscillation (SO). During the negative phase of the SO (El Niño), convection is generally enhanced in this area leading to negative OLR values because of the lower black-body temperature of high cloud. During the positive phase of the SO (La Niña), the reverse applies with less convection and increased OLR.

The OLR anomalies for March, April and May, together with the three-month moving average, were broadly consistent with the falling SOI, indicating a return to neutral conditions in the tropical Pacific. April had the first neutral standardised OLR anomaly (0.2, a decrease of 1 standard deviation from the March value) since August 2000, and May the first negative value (-0.1) since May 1998. The positive OLR phase over summer 2000/01 was both less intense and shorter in duration than the two preceding positive phases, associated with the La Niña events of 1998/1999 and

Fig. 2 Standardised anomaly of monthly outgoing long wave radiation averaged over 5°N to 5°S and 160°E to 160°W for January 1997 to May 2001. Negative (positive) anomalies indicate enhanced (reduced) convection and rainfall in the designated area. Anomalies are based on the 1979-95 base period. After CPC (2001).



1999/2000. However, the declining trend pattern of OLR anomalies, though on lesser scale, was similar to those observed in autumn 1999 and autumn 2000.

Oceanic patterns

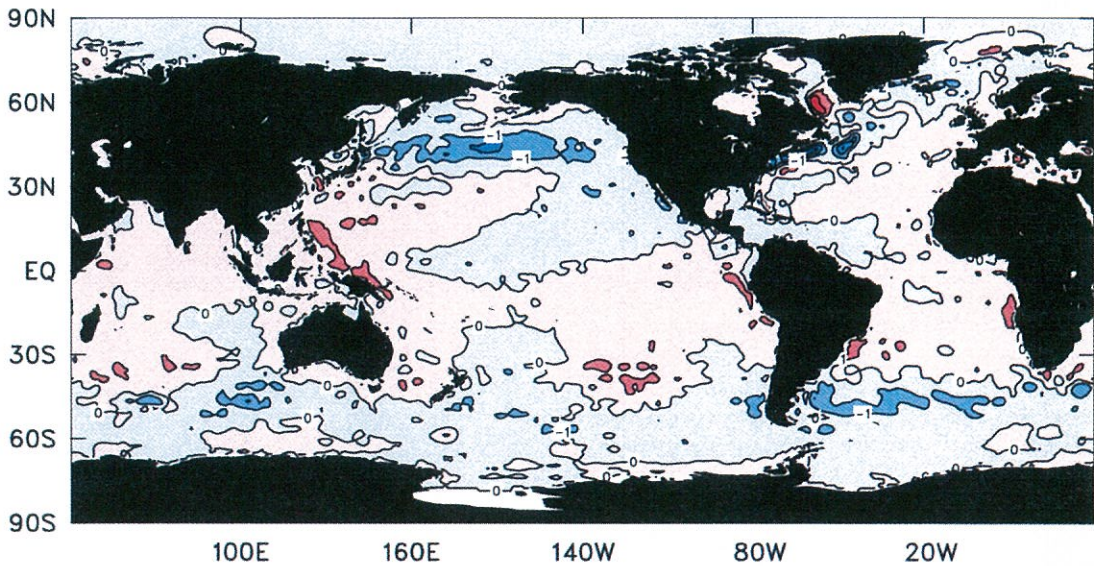
Sea-surface temperatures

Figure 3 shows the autumn 2001 sea-surface temperature (SST) anomalies in degrees Celsius, with a contour interval of 1°C. The positive anomalies are shown in shades of red and negative anomalies in blue.

The La Niña-type pattern that was still evident in summer 2000/01 diminished in autumn 2001 as the central and eastern equatorial Pacific SST values moved closer to average in April, and remained near average in May.

The tropical Pacific Ocean SST in autumn showed the weakening of La Niña conditions as there were no distinct negative anomalies in the eastern equatorial Pacific. The weak cool and warm anomalies around the central and eastern equatorial Pacific were the dominant features, with a distinct rotated 'V' of positive anomalies in the north. Interestingly, the SST pattern was similar to the autumns of 1999 and 2000, but of lesser intensity. This similarity is also evident in the weekly time series of the NINO3 and NINO4 anomaly indices (not shown) as calculated by the National Meteorological and Oceanographic Centre, Melbourne. Moreover, patches of warm water of up to 1°C above average appeared off the northern coast of South America (once again, a similar feature but of lesser scale occurred during the previous two autumns).

Fig. 3 Anomalies of sea-surface temperature for autumn 2001 (°C).

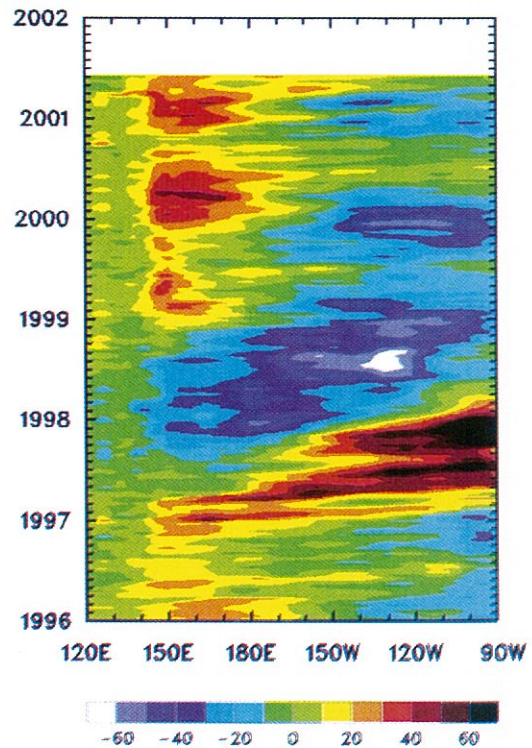


Subsurface patterns

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 May 2001. This isotherm is generally situated very close to the equatorial ocean thermocline, the region of greatest temperature gradient with depth. The thermocline forms the boundary between the upper ocean warm water and the deep ocean cold water. Positive anomalies correspond to the 20°C isotherm being deeper than average (characteristic of El Niño events), and negative anomalies to it being shallower than average (characteristic of La Niña events). Changes in the thermocline depth may be indicative of changes at the surface.

The onset of the weak third cold phase was evident from a slight increase in the thermocline depth in the western tropical Pacific and a corresponding decrease in the eastern tropical Pacific during spring 2000 (Watkins 2001). This cold phase intensified during summer 2000/01 but the strength of the eastern anomalies was very much less than that observed during the La Niña events of 1998/99 and 2000/01. In the western tropical Pacific, the situation was somewhat different, with the strength of the thermocline response being only slightly weaker in the third cool phase than in the second. The subsurface pattern at the end of autumn showed a near normal situation in the eastern tropical Pacific and moderate positive anomalies in the western tropical Pacific, with some indication of eastward propagation. There was a similar situation

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



in autumn 2000, but with stronger positive anomalies and less of an indication of eastward movement. Overall, there was a slight decrease in the thermocline depth in the western tropical Pacific, and a return to neutral values in the far eastern tropical Pacific during autumn 2001, which signalled the decline of the third cold phase in as many years.

Atmospheric patterns

Surface analyses

Figure 5 shows the autumn 2001 mean sea-level pressure (MSLP) pattern for the southern hemisphere, with the corresponding anomaly pattern in Fig. 6. The contour intervals are 4 hPa between 980 hPa and 1020 hPa, and 2 hPa between -12 hPa and +12 hPa for Figs 5 and 6, respectively. The pressure field is computed from the Australian Bureau of Meteorology's Global Assimilation and Prediction (GASP) model daily 2300 UTC analyses, and the anomalies are differences from an eleven-year (1979-89) climatology obtained from the European Centre for Medium-range Weather Forecasts (ECMWF).

In the Antarctic region, the MSLP pattern had some similarity to that of autumn 2000. The pattern around the hemisphere in the mid-latitudes was distinctly zonal in structure with weak three-wave characteristics, the three major troughs being located at 155°W, 5°E and 95°E. The actual central MSLP in the Antarctica high can only be estimated due to high altitude and distinctive features of the polar atmosphere that are difficult to incorporate into numerical analyses. Another distinct feature, as expected from climatology, was the subtropical ridge at 30°S with maxima located at 100°W, 5°W and 90°E. MSLP anomalies were negative over the Tasman Sea which caused above to very much above rainfall for autumn 2001 on the northeast coast of New South Wales (Fig. 14).

Mid-tropospheric analyses

Figure 7 shows the autumn 2001 mean geopotential height pattern at 500 hPa for the southern hemisphere, with the corresponding anomaly pattern in Figure 8. The contour intervals are 80 gpm between 4960 gpm to 5840 gpm, and 40 gpm between -40 gpm to +40 gpm for Fig. 7 and Fig. 8, respectively. The flow at 500 hPa level reflected the pattern that was described at MSL. The major axes of the troughs at 500 hPa height were located in similar regions to those observed at MSLP levels.

Blocking

Figure 9 shows a time-longitude section of the daily southern hemisphere Blocking Index (BI) for autumn 2001. This is defined as

Fig. 5 Mean sea-level pressure (hPa) for autumn 2001.

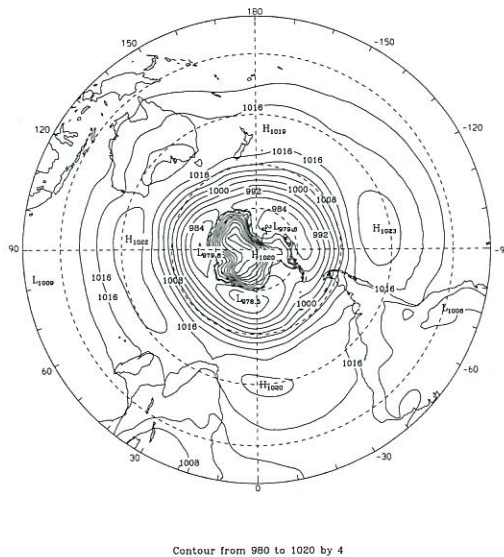
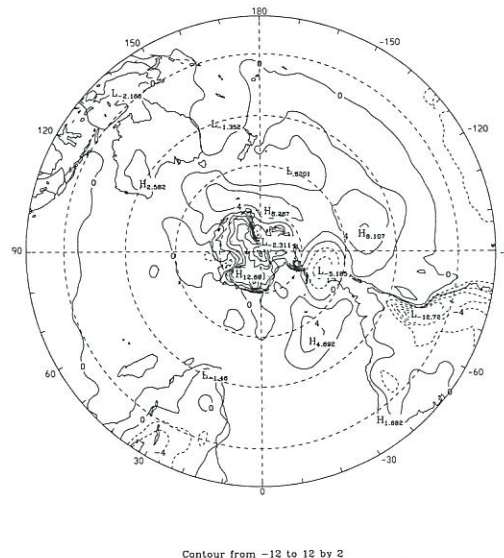


Fig. 6 Mean sea-level pressure anomaly (hPa) for autumn 2001.



$$BI = 0.5[(U_{25}+U_{30}) - (U_{40}+2U_{45}+U_{50}) + (U_{55}+U_{60})],$$

where U_{λ} indicates the monthly zonal wind at λ degree of southern latitude. The BI is a measure of the strength of the zonal flow at 500 hPa in mid-latitudes (40°S to 50°S) relative to that at subtropical (25°S to 30°S) and high latitudes (55°S to 60°S). Higher (lower) values indicate regions of enhanced (reduced) blocking.

Fig. 7 Mean 500 hPa geopotential height (gpm) for autumn 2001.

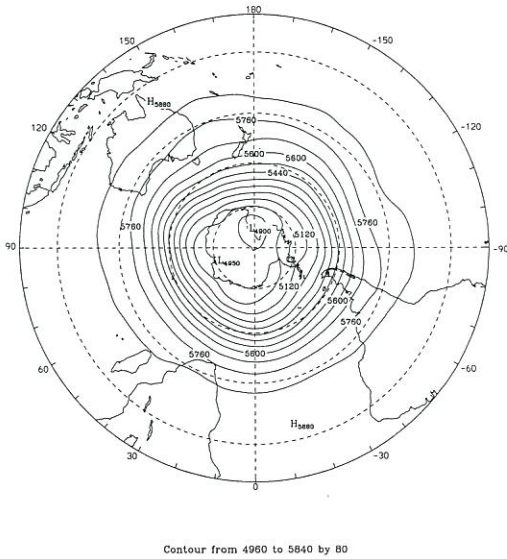
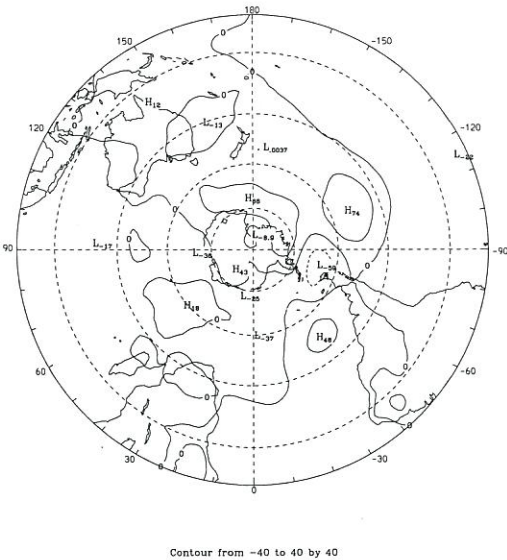


Fig. 8 Mean 500 hPa geopotential height anomaly (gpm) for autumn 2001.



In contrast to summer 2000/01, the seasonal mean zonal blocking values were close to their long-term averages for most latitudes (Figure 10). Blocking was absent from the Australian region for most of the season, except in the latter half of March and mid-April when some significant blocking was observed (Figure 9). Maximum blocking for the season was located just east of the dateline in mid-March.

Fig. 9 Daily blocking index: time longitude section for autumn 2001. The horizontal axis represents degrees of longitude east of the Greenwich meridian. Day 1 is 1 March.

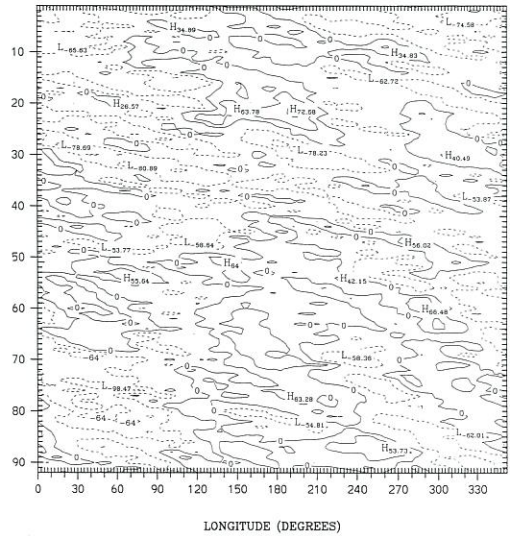
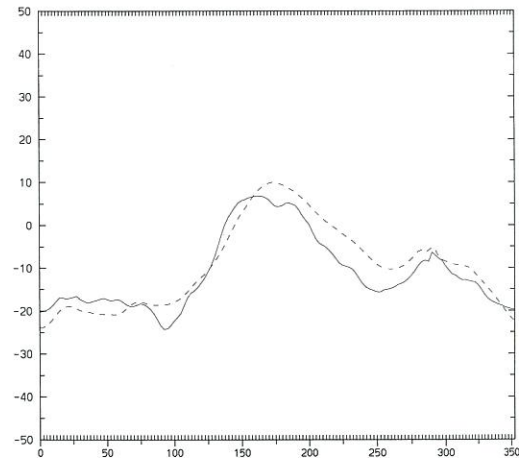


Fig. 10 Mean southern hemisphere blocking index for autumn 2001 (solid line) with the corresponding long-term average (dashed line). The horizontal axis represents degrees of longitude east of the Greenwich meridian.



Winds

Figure 11 and 12 show low-level (850 hPa) and upper-level (200 hPa) wind anomalies for autumn 2001. These have also been computed from the GASP analyses.

Fig. 11 Anomalies of the vector wind (m s^{-1}) at 850 hPa level for autumn 2001.

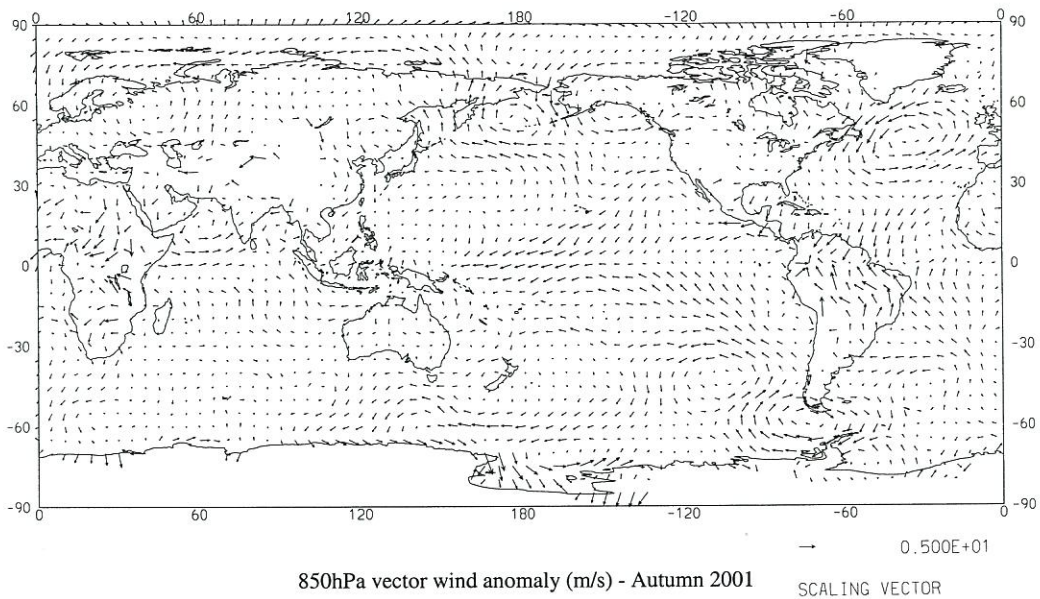
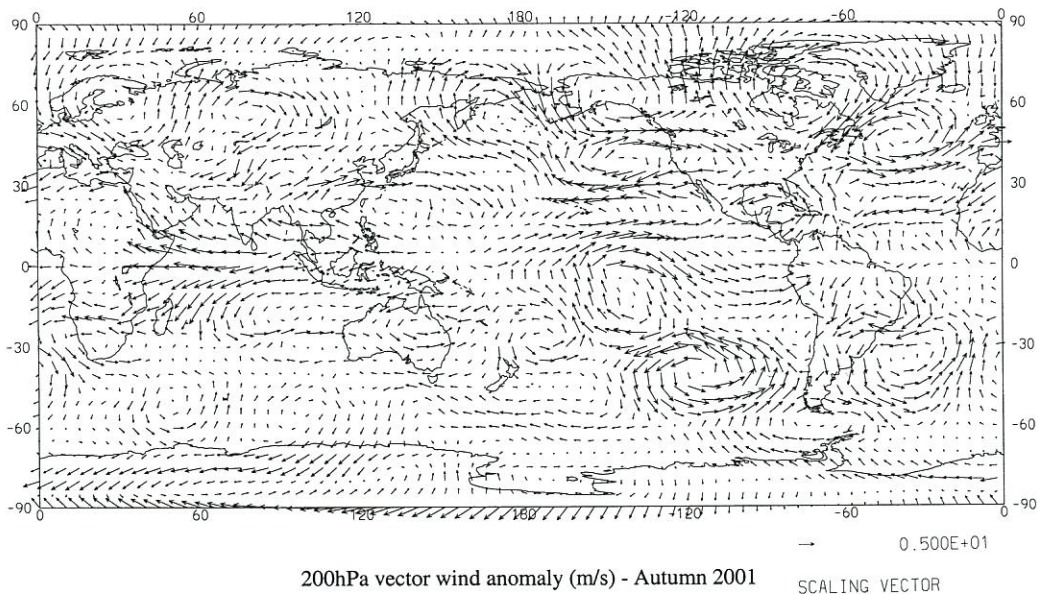


Fig. 12 Anomalies of the vector wind (m s^{-1}) at 200 hPa level for autumn 2001.



Low-level easterly anomalies over the central and western tropical Pacific and corresponding high-level westerly anomalies over most of the tropical Pacific were observed during autumn but of lesser magnitude than the ones observed during summer 2000/01. Consistent with the SOI values, this indicated slight weakening of the enhanced

Walker Circulation. The strongest anomalies in monthly values (not shown) occurred during March and they began to weaken towards the end of the season. Low-level anomalies were generally weak over the Australian region. Also, upper-level anticyclonic anomalies were observed over eastern Australia.

Fig. 13 Australian Rainfall totals (mm) for autumn 2001.

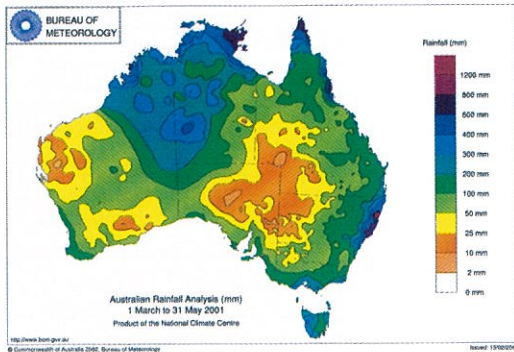
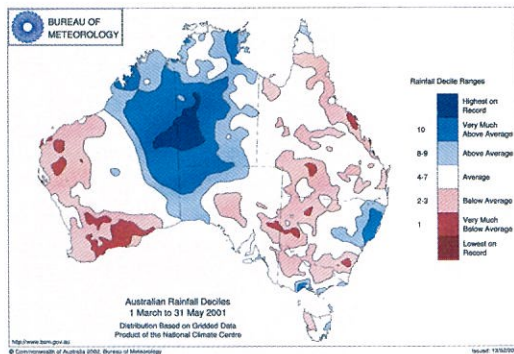


Fig. 14 Australian rainfall deciles for autumn 2001 based on grid-point values over the autumns from 1900 to 2001, inclusive.



Australian region

Rainfall

Figure 13 shows the distribution of autumn 2001 rainfall for Australia, with corresponding distribution of rainfall deciles (based on gridded rainfall data for the autumns from 1900 to 2001) in Figure 14. Autumn was dominated by intense tropical rains in March that caused very much above average to highest on record rainfall totals over a large area from western Northern Territory to eastern Western Australia. Northeast New South Wales, northwest South Australia and parts of southern Victoria also recorded very much above average rainfall. Several intense low pressure systems including a tropical depression (ex-tropical cyclone *Abigail*), TC *Alistair* and an active monsoon trough lying over northwest Australia contributed to the seasonal rainfall. Most of the rain in northeast NSW (caused by an east coast low coming ashore), and the northwest and centre of the country fell during March.

Fig.15 Australian maximum temperature anomalies (°C) for autumn 2001 based on 1961 to 1990 mean.

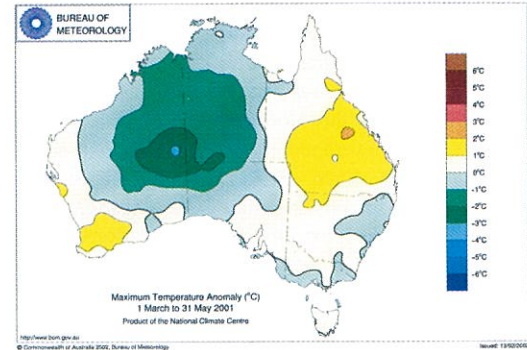
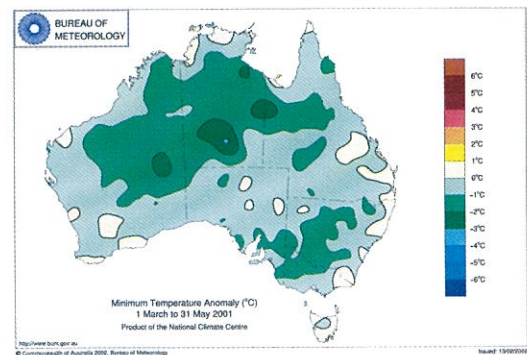


Fig. 16 Australian minimum temperature anomalies (°C) for autumn 2001 based on 1961 to 1990 mean.



In contrast, below average to lowest on record rainfall was recorded in western parts of Western Australia, and in some isolated areas of New South Wales and Queensland. A large area of southwest Queensland, northwest New South Wales and northeast South Australia recorded less than 25 mm, with some patches receiving less than 10 mm of rain for autumn. A similar situation was observed in western WA which marked a poor start to the southern wet season. Autumn 2000 had also been notable for a poor start to the southern wet season in South Australia.

Temperatures

Figures 15 and 16 show the mean maximum and mean minimum temperature anomalies respectively for autumn 2001. The anomalies were calculated with respect to the 1961-1990 reference period.

Maximum temperatures varied across the country, with generally below average values in the western

half and above average values in the eastern half. Notably, a large area around the intersection of the borders of Western Australia, the Northern Territory and South Australia, which was also excessively wet, had negative anomalies ranging from -1°C to -4°C . In conjunction with the high rainfall, many low maximum temperatures were recorded in March in this area. This gave the Northern Territory its coolest March in area-averaged terms, and WA its second coolest March since 1950. In contrast, central Queensland had positive anomalies ranging from $+1^{\circ}\text{C}$ to $+3^{\circ}\text{C}$ with extreme daily values for the season reaching 45°C (not shown). Also, part of south-western Western Australia had 1°C to 2°C above average readings. For the rest of the country, seasonal maximum temperatures were within around 1°C of average.

Most of the country experienced cooler than average autumn nights in 2001, with widespread negative anomalies across the country. There were however many isolated patches of weak positive anomalies. A large area extending from eastern Western Australia, across the Northern Territory into eastern Queensland had negative anomalies ranging from -1°C to -3°C . Some parts of the Northern Territory and Queensland recorded monthly mean anomalies from -5°C to -6°C in May, which resulted in Queensland having its coolest May since 1950, averaged over the State.

References

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- Bureau of Meteorology 2001. *Climate Monitoring Bulletin - Australia*. March 2001, April 2001 and May 2001 issues. National Climate Centre, Bureau of Meteorology, Australia.
- Climate Prediction Center 2001. *Climate Diagnostic Bulletin*. March 2001, April 2001 and May 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.