Seasonal climate summary southern hemisphere (winter 2000): a near-neutral ENSO phase in the Pacific

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Southern hemisphere circulation patterns and anomalies for winter 2000 (June - August) are reviewed, with emphasis given to the tropical Pacific and the Australian region. The declining strength of ENSO indicators observed during autumn 2000, continued into winter with most indices in the neutral range. A strong three-wave pattern dominated the middle to high latitude circulation around the hemisphere, with higher than average atmospheric pressure observed over most of Australia. Consistent with this were below average rainfall totals and minimum temperatures, and above normal maximum temperatures.

Introduction

Most ENSO indicators became established in neutral values over winter following the demise of the 1999/2000 La Niña event in autumn. The mean SOI for the season was –1.3, tropical Pacific sea-surface temperature anomalies were mainly within about 0.5°C of the long-term average, and outgoing long wave radiation values near the equatorial date-line were mostly within one standard deviation of normal. An enhanced Walker Circulation did however persist in the western to central Pacific.

A persistent and well-defined three-wave pattern continued to dominate the mid-latitude atmospheric circulation of the southern hemisphere. Mean sea-level pressure was mainly above average across Australia, although not strongly so, and there were widespread areas of below to very much below average rainfall, particularly in Western Australia and the Northern Territory.

The main sources of information were the *Climate Monitoring Bulletin* (Bureau of Meteorology, Australia), and the *Climate Diagnostics Bulletin* (Climate Prediction Centre (CPC), Washington). Data sources are given in the Appendix.

Pacific Basin climate indices

The Troup Southern Oscillation Index (SOI)

The falling trend in the SOI seen at the end of autumn (Fawcett 2001), continued into early winter with a value of –5.5 in June, the first negative value since September 1999. The index then stabilised in neutral values for the rest of the season with readings of –3.7 in July and +5.3 in August (see Fig. 1). The steady increase in SOI values over winter, did however signal a trend that was to persist into the following season.

At Darwin, the mean sea-level pressure (MSLP) anomalies also showed a steady trend over winter, but in the opposite sense to the SOI. The monthly departures from average were +0.9 hPa, 0.0 hPa, and –0.5

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* The Troup SOI is ten times the monthly anomaly of the difference in mean sea-level pressure between Tahiti and Darwin, divided by the standard deviation of that difference for the relevant month, based on the period 1933-1992.

Fig. 1 **Southern Oscillation Index, January 1996 to August 2000 inclusive. Means and standard deviations based on the 60-year period 1933-1992 (inc).**

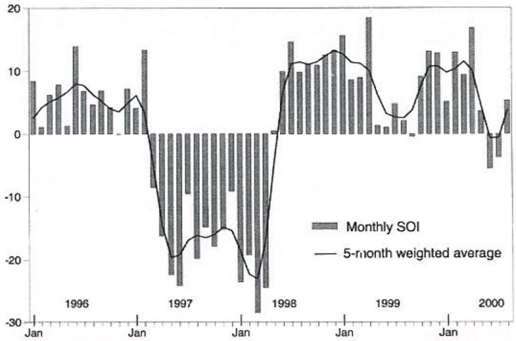
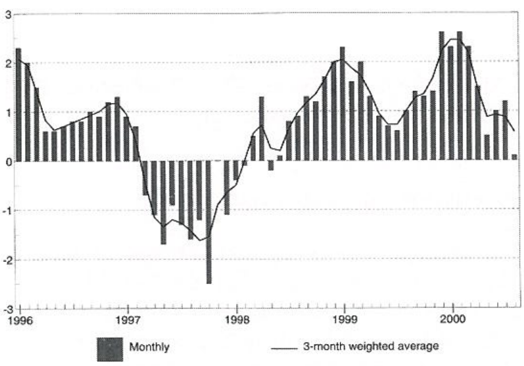


Fig. 2 **Standardised anomaly of monthly outgoing long wave radiation averaged over 5°N-5°S and 160°E-160°W, from January 1996 to August 2000. Negative (positive) anomalies indicate enhanced (reduced) convection and rainfall. Anomalies are based on a 1979-95 base period mean. After CPC (2000).**



hPa respectively for June, July, and August. At Tahiti the monthly MSLP anomalies were +0.2 hPa, –0.6 hPa, and +0.3 hPa.

Outgoing long wave radiation (OLR)

Figure 2, adapted from the CPC, Washington (CPC 2000), shows monthly standardised outgoing long-wave radiation (OLR) anomalies from January 1996 to August 2000, together with a three-month moving average. These data, compiled by the CPC, are an indication of the amount of long wave radiation emitted from an equatorial region centred about the date-line (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 the intensity of the OLR due to the lower effective black-body temperature, and the reverse applies in cold (La Niña) events. The waning of the 1999/2000 La Niña episode, observed during the austral autumn (Fawcett 2001), was confirmed by a continuation of the downward trend in OLR anomalies during winter. Although there was some month-to-month variation, the three-month average remained below one standard deviation throughout the season, and August's value was the lowest since mid-1998. Overall, the autumn-winter pattern of OLR anomalies in 2000 was similar to that observed in 1999.

Oceanic patterns

Sea-surface temperatures (SSTs)

The winter 2000 SST anomalies in degrees Celsius (°C) are shown in Fig. 3. The contour interval is 1°C. Positive anomalies are shown in orange and red shades, and negative anomalies in blue. The season was characterised by weak cool anomalies of around –0.5°C, across much of the tropical Pacific east of the date-line. There was very little intraseasonal trend in the anomaly pattern, except for a slight narrowing of the latitudinal spread of the cool anomalies, and an eastward contraction of these anomalies in the western Pacific. By August, most of the tropical Pacific west of 180° was slightly warmer than average.

In the mid to high latitudes of the southern hemisphere, an almost continuous band of negative anomalies surrounded Antarctica, a pattern that also occurred in autumn. The anomalies were around –2°C in a few areas – most notably in the Indian and Pacific oceans. Close to Australia the anomalies were generally weakly negative in the north, and weakly positive in the south. There were a few patches of +1 to +2°C anomalies off the southwest coast which were the remnants of a large area of positive anomalies that developed during summer (Della-Marta 2001), and then decayed somewhat during autumn.

Subsurface patterns

Figure 4 shows the anomaly in metres of the depth of the 20°C isotherm along the equatorial Pacific Ocean between January 1995 and August 2000. This isotherm is generally situated very close to the equatorial ocean thermocline, the region of greatest temperature gradient with depth. The thermocline effectively forms a boundary between the upper ocean warm water and the deep ocean cold water. Positive

Fig. 3 **Winter 2000 (June, July, August) sea-surface temperature anomaly (°C).**

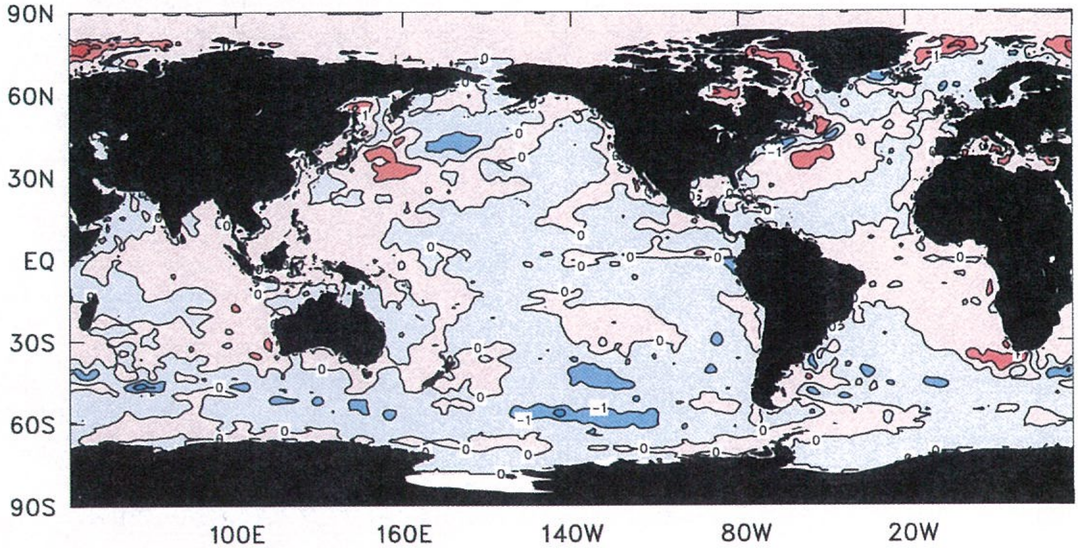
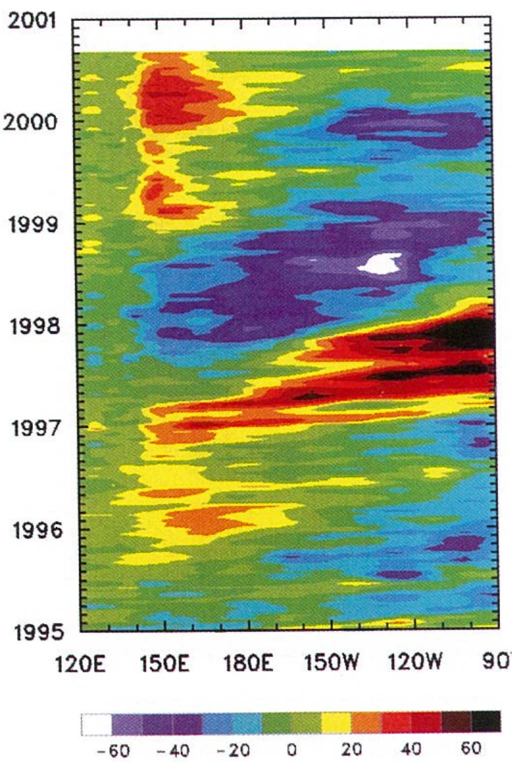


Fig. 4 **Time-longitude section of monthly anomalous depth of 20°C isotherm at the equator from January 1995 to August 2000. Contour interval is 10 m.**



anomalies correspond to the 20°C isotherm being deeper than average (i.e. increased upper ocean heat content), and negative anomalies to it being shallower than average (i.e. decreased upper ocean heat content). The 1997/98 El Niño event (strong positive anomalies in the east Pacific), and 1998/99 and 1999/2000 La Niña events (strong negative anomalies in the east Pacific) are clearly evident in this diagram. As with the SOI and OLR, the 20°C isotherm depth was close to neutral across most of the Pacific during winter 2000. A minor exception was the presence of positive anomalies near 150°E, although these weakened as the season progressed. There was also the hint at the end of August that negative anomalies near 150°W and 80°W had begun to re-intensify.

Atmospheric patterns

Surface analyses

Figure 5 shows the average winter 2000 mean sea-level pressure (MSLP) pattern, with the associated anomalies shown in Fig. 6. The anomalies are departures from an eleven-year (1979-1989) global climatology obtained from the European Centre for Medium-range Weather Forecasts (ECMWF). The MSLP analysis has been computed using data obtained from the Bureau of Meteorology's Global Assimilation and Prediction (GASP) model daily 2300 UTC analyses. The contours in Fig. 5 are spaced at 4 hPa intervals between 980 and 1032 hPa, and those in Fig. 6 occur at 2 hPa intervals

Fig. 5 Winter 2000 (June, July, August) mean sea-level pressure (hPa).

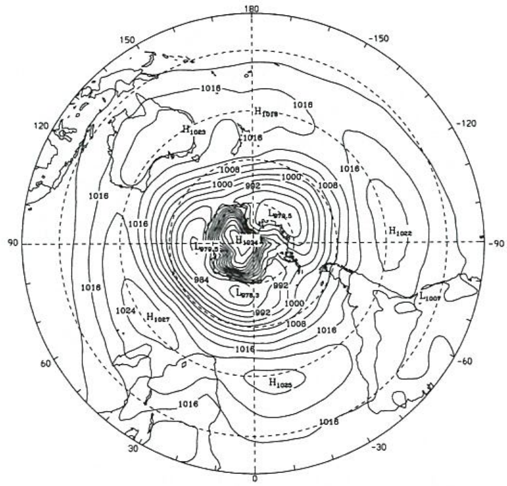
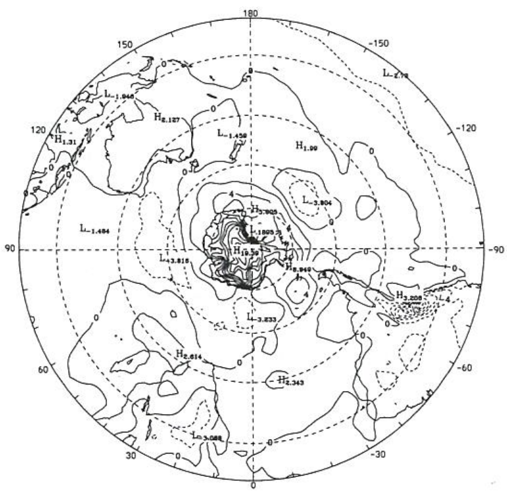


Fig. 6 Winter 2000 (June, July, August) mean sea-level pressure anomaly (hPa).



between –12 and +18 hPa. The low-pressure anomaly over the South American Andes results from systematic differences between the GASP analyses and the ECMWF climatology.

The mean winter MSLP circulation around the hemisphere in mid-latitudes was organised in a three-wave configuration with major troughs located at 0°, 120°E (which had a distinct southwest to northeast tilt) and 150°W. There was also a trough of smaller latitudinal spread over the Tasman Sea. The pattern persisted more or less intact through the entire winter, and was similar to, but more pronounced than, the mean field analysed in autumn. Another feature that persisted from the previous season was the anomalously intense Antarctic anticyclone, which is shown in Fig. 6 as being about 19 hPa stronger than normal. The actual central MSL pressure in the Antarctic high is open to conjecture because of the large height-related adjustment required, and the distinctive features of the polar atmosphere that are difficult to capture in numerical analyses. For example, the GASP analyses consistently had the central pressure near 1035 hPa during the season, whereas monthly means from CPC showed central pressures near 1050 hPa.

Over Australia MSLPs for winter were slightly above average, except across the southern fringe which came under the influence of the northeast-tilting trough mentioned above. The peak anomaly was about 2 hPa over Queensland. The Tasman Sea was a favourable location for cyclogenesis and slow-moving cut-off lows throughout the season.

500 hPa analyses

Figures 7 and 8 show the mean and anomalous geopotential height patterns at 500 hPa respectively for winter 2000. The isopleths in Fig. 7 are spaced at 80 geopotential metre intervals from 4880 gpm to 5840 gpm, while those in Fig. 8 are spaced at 40 gpm intervals from –40 gpm to 120 gpm. The flow at this level strongly reflects the patterns at MSLP described above. The major troughs in the mid-latitude westerlies were located a little to the west of their surface counterparts, as is to be expected, and a diffluent or split flow pattern was evident through eastern Australian and Tasman Sea longitudes.

Blocking

Figure 9 is a time-longitude section of the daily southern hemisphere Blocking Index (BI)* for winter 2000. The blocking index measures the strength of the 500 hPa flow at mid-latitudes (40°S to 50°S) relative to that at sub-tropical (25°S to 30°S) and high latitudes (55°S to 60°S). Regions of blocking are indicated by positive BI values. The horizontal axis of Fig. 9 shows degrees of longitude east of the Greenwich meridian. The days of the season are shown on the vertical axis starting from 1st June 2000 at the top of the Figure as day 1.

Climatologically, blocking is most favoured between about 130°E and 230°E, that is, from eastern

* BI = $0.5(U_{25}+U_{30}-(U_{40}+2U_{45}+U_{50})+U_{55}+U_{60})$ where, U_{xx} is the westerly component of the 500 hPa wind at latitude *xx*.

Fig. 7 **Winter 2000 (June, July, August) 500 hPa mean geopotential height (m).**

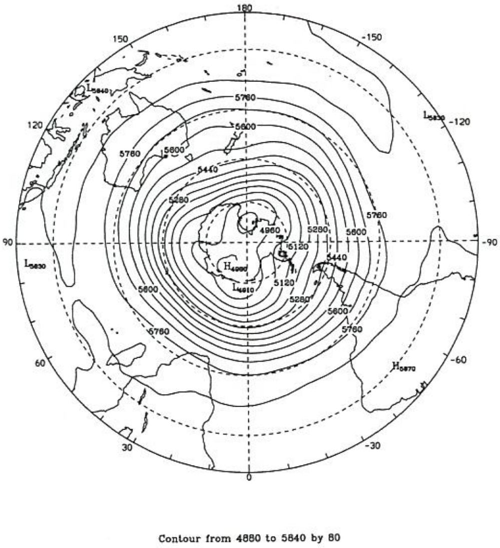
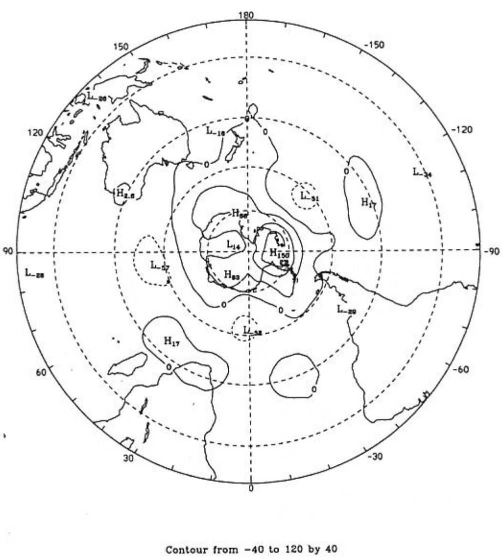
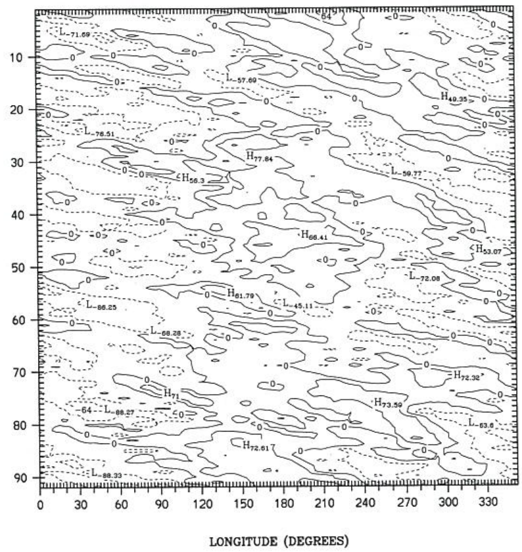


Fig. 8 **Winter 2000 (June, July, August) 500 hPa mean geopotential height anomaly (m).**



Australian to central Pacific longitudes. Winter 2000 was no exception with BI values being close to their long-term average around much of the hemisphere. The strongest blocking episode occurred near New Zealand at the end of June and start of July, and there was a similarly intense event in the same region in late August. Another notable block occurred in the far eastern Pacific in mid-August. Blocking was almost totally absent from the African and Indian Ocean sectors where zonal flow predominated.

Fig. 9 **Winter 2000 (June, July, August) daily Blocking Index: time-longitude section. Day 1 is 1st June.**



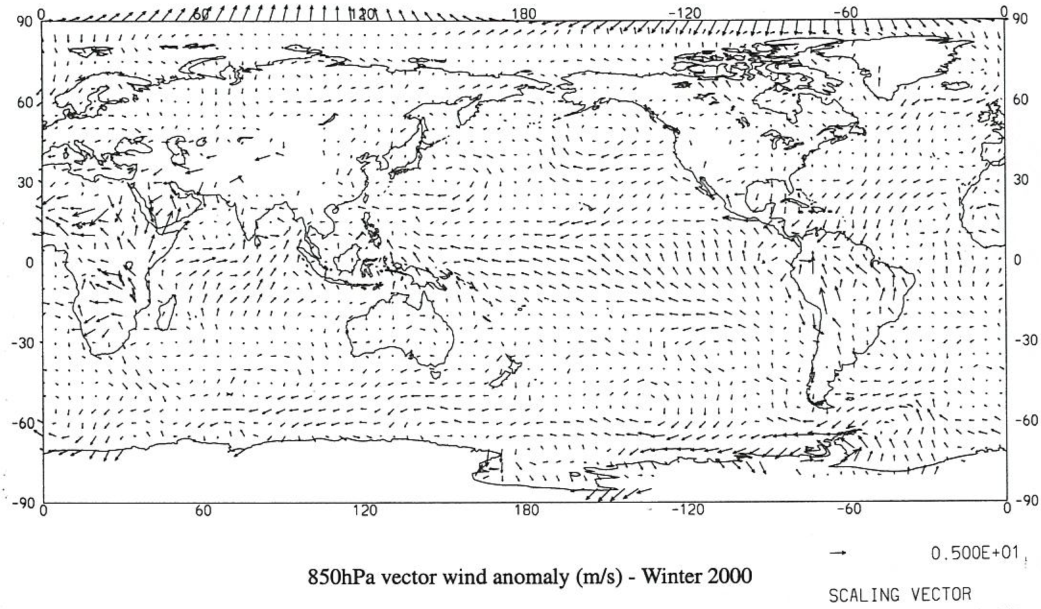
Winds

Low-level (850 hPa) and upper-level (200 hPa) wind anomalies for winter 2000 are shown in Figs 10 and 11 respectively. These have been computed from the Bureau of Meteorology's GASP analyses. Averaged over the season, low-level easterly anomalies were evident over the western tropical Pacific west of about 150°W. However, inspection of the individual monthly means (not shown) together with zonal wind indices compiled by CPC, shows that there was a gradual tapering in the strength of the easterly anomalies as the season progressed. This continued the trend observed in autumn (Fawcett 2001). Further east, the anomaly field was characterised by southerly, rather than easterly, anomalies. Overlaying the easterly anomalies in the western Pacific were upper-level westerly anomalies, indicating an enhanced Walker circulation; a result somewhat at odds with the near-zero SOI and weak OLR anomalies.

Over Australia, the 850 hPa anomalies were mostly weak in strength and variable in direction, indicating near-average flow for the season. However, the region to the south of Australia was dominated by easterly low-level anomalies indicating a general weakening of the characteristic westerly flow at mid-latitudes.

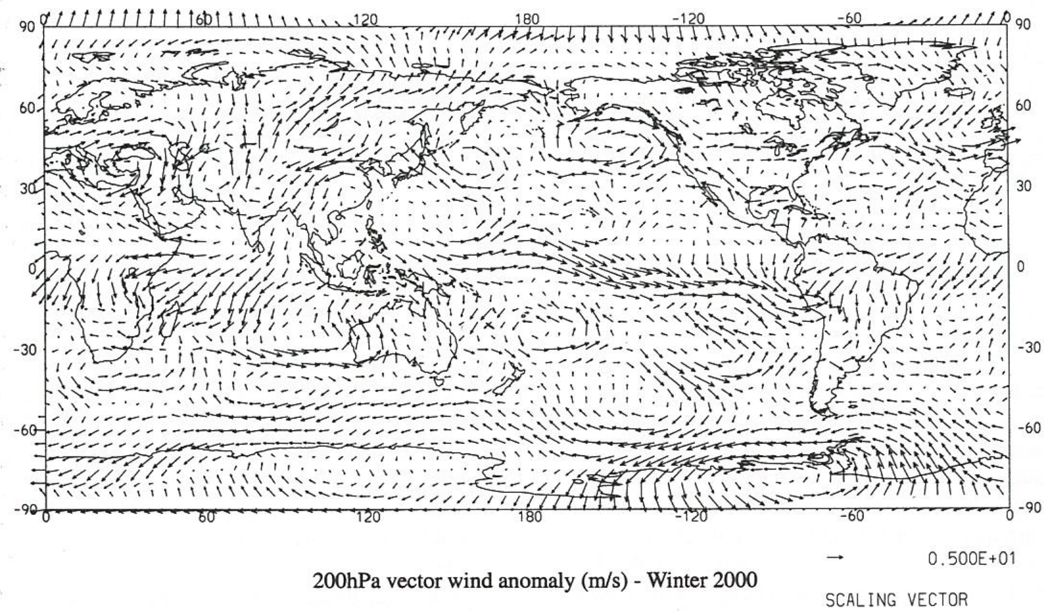
Easterly anomalies were also the dominant feature at the upper levels between about 40°S and 60°S. Upper-level anomalies near Australia featured an

Fig. 10 **Winter 2000 (June, July, August) 850hPa vector wind anomalies (m s^{-1}).**



850hPa vector wind anomaly (m/s) - Winter 2000

Fig. 11 **Winter 2000 (June, July, August) 200hPa vector wind anomalies (m s^{-1}).**



200hPa vector wind anomaly (m/s) - Winter 2000 anticyclonic circulation over the eastern Indian Ocean near 25°S, and a cyclonic centre over the Tasman Sea that was consistent with 500hPa height anomalies shown in Fig. 8.

Australian region

Circulation and rainfall

The distribution of Australian winter rainfall totals is shown in Fig. 12, while Fig. 13 shows the distribution of winter rainfall decile ranges, based on gridded data for the period 1900 – 2000. Seasonal totals were below to very much below average in a broad region covering nearly all of Western Australia together with the southern half of the Northern Territory, northern South Australia, western Queensland and the far northwest of NSW. Large parts of both WA and the NT recorded less than 2 mm of rain for the winter. In addition, below average winter totals also featured in much of northern and eastern NSW, and in a large part of southeast Queensland. Below normal falls in southern Victoria added to the long-running period of deficits that began in late 1996. The pattern of below average totals reflects the general dearth of tropical-extratropical interactions or 'northwest cloudbands', which are extensive cloud masses that typically extend from the ocean northwest of Australia to the southeast of the continent. However, this lack of northwest cloudbands (and associated higher freezing levels) in combination with frequent cold outbreaks in the southeast, resulted in an excellent snow season in the highlands of Victoria and NSW.

There were patchy areas of above average falls along the southern coast, and a more substantial region around the Gulf of Carpentaria. This latter area resulted from unseasonable rain generated by an upper-level trough in June, but the totals were not high in absolute terms, being of the order of 50 to 100 mm.

Temperatures

Mean maximum and minimum temperature anomalies for winter 2000 are shown in Figs 14 and 15 respectively. The anomalies were calculated with respect to the 1961-90 reference period.

Apart from the tropics and parts of the southeast where weak negative anomalies were observed, most of the country experienced a marginally warmer than average winter with the peak anomalies of +1°C to +2°C being mainly confined to western Queensland and the southern Northern Territory. In the tropics the negative departures were mainly less than 1°C in magnitude, but a small region near the Gulf of Carpentaria recorded anomalies in the –1°C to –2°C

Fig. 12 Winter 2000 (June, July, August) rainfall totals (mm) in Australia.

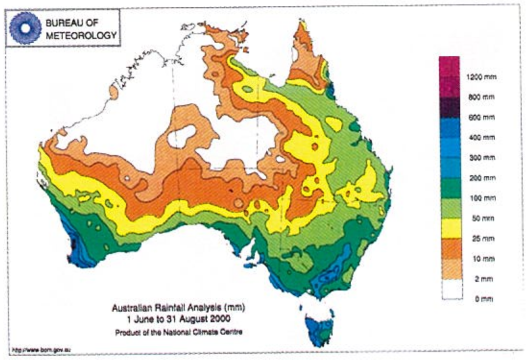


Fig. 13 Winter 2000 (June, July, August) rainfall in Australia: decile range values based on grid-point values over the period 1900 to 2000.

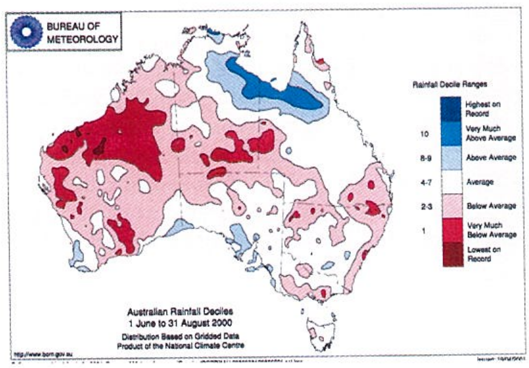


Fig. 14 Winter 2000 (June, July, August) maximum temperature anomalies (°C) for Australia based on a 1961-1990 mean.

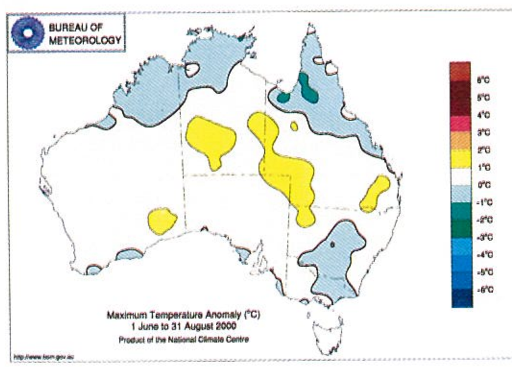
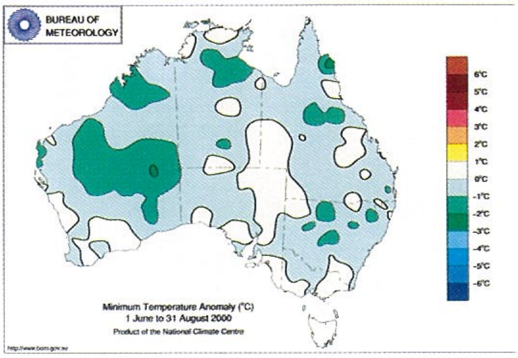


Fig. 15 Winter 2000 (June, July, August) minimum temperature anomalies (°C) for Australia based on a 1961-1990 mean.



range. The cooler than average conditions in the far north resulted from a markedly cool June, because positive anomalies dominated in this part of the country for the remainder of winter.

In contrast, winter mean minimum temperatures were below normal over most of the country, with several areas of substantial size recording anomalies in the –1°C to –2°C range, the most significant being in central Western Australia. Positive anomalies, on the other hand, were rather patchy spatially, and weak in intensity. The largest area covered much of eastern South Australia and adjacent border regions of New South Wales, Queensland and the Northern Territory. The pattern of generally warmer than average days and cooler than average nights is consistent with below average cloudiness, a condition that could be inferred from the drier than average season observed through much of the interior.

References

Climate Prediction Centre 2000. *Climate Diagnostics Bulletin,* June 2000, July 2000, August 2000. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, Washington D.C.

Della-Marta, Paul M. 2001. Seasonal climate summary southern hemisphere (summer 1999/2000): a second successive weak cool episode (La Niña) reaches maturity. *Aust. Met. Mag., 50,* 65-75.

Fawcett, R.J.B. 2001. Seasonal climate summary southern hemisphere (autumn 2000): end of La Niña. *Aust. Met. Mag., 50,* 115-22.

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