Seasonal climate summary 
southern hemisphere (winter 1997): 
a developing El Niño event

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Southern hemisphere circulation patterns and anomalies for winter (June - August) 1997 are reviewed, with emphasis given to the Pacific Basin climate indicators, and Australian rainfall and temperature patterns. In autumn, an El Niño event began to develop. During winter, this El Niño event intensified, as indicated by sea-surface temperature patterns and negative values of the Southern Oscillation Index. The subtropical ridge in the Australian region was located much further south than is normal for this time of the year, resulting in dry conditions along most of the Australian southern coastline.

Introduction

The descent into El Niño conditions, which commenced at the start of autumn 1997, continued through winter 1997, as indicated by strongly negative values of the SOI. A strong positive sea-surface temperature anomaly pattern developed in the eastern equatorial Pacific ocean, with associated low-level westerly wind anomalies. Rainfall was reduced over most of southeastern Australia and contiguous regions extending into the Northern Territory. Extensive regions received very much below average rainfall. This reduced rainfall was associated with shifts in the mean sea-level pressure pattern over southern Australia.

This summary reviews the southern hemisphere and equatorial climate patterns of winter 1997, 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 (CPC), Washington). Further details regarding sources of data are given in the Appendix.

Pacific Basin climate indices

The Troup Southern Oscillation Index (SOI)*
A set of three positive values for the Troup Southern Oscillation Index (SOI) during summer 1996/97 (Beard 1997) was succeeded in autumn 1997 by dramatically falling values (Beard 1998). Winter saw a continuation of the strongly negative values, with -24.1 (June), -9.5 (July) and -19.8 (August), following on from a value of -22.4 for May. Subsequent monthly values through spring 1997 did not exceed the June extreme value for the present phase. This value (-24.1) was the most negative June value since 1905 (-31.4). Figure 1 shows the monthly SOI values from January 1993 to August 1997. A five-month moving average curve is superimposed on the graph.

Outgoing long wave radiation

Figure 2, adapted from Climate Prediction Center (1997), shows the monthly standardised anomaly of outgoing long wave radiation (OLR) from January 1993 to August 1997, together with a three-month moving aver-

*The Troup Southern Oscillation Index (SOI) used in this article 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 a sixty-year climatology (1933 – 1992).

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Fig. 1  Southern Oscillation Index, January 1993 to August 1997 inclusive. Means and standard deviations used in the computation of the SOI are based on the period 1933-1992.

Oceanic patterns

Sea-surface temperatures (SSTs). Figure 3 shows the winter 1997 sea-surface temperature 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 dominant feature in the analysis was the warming of the eastern to central equatorial Pacific Ocean, implying a well-developed El Niño event. The warming pattern was very coherent, and possessed a classic shape. Peak positive anomalies exceeded +4°C.

Much of the southern hemisphere Pacific and Indian Oceans, and the Southern Ocean showed cooling with negative anomalies of between -1°C and -2°C in places. Coastal Australian waters generally showed slightly negative anomalies, apart from the coasts of southern Queensland, New South Wales and Victoria.

Subsurface patterns. Figure 4 shows the anomaly in metres of the depth of the 20°C isotherm along the equatorial Pacific Ocean between January 1994 and August 1997. 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 deep thermocline in the eastern Pacific Ocean is characteristic of El Niño events. Positive anomalies correspond to the 20°C isotherm being deeper than average, and negative anomalies to it being shallower than average.

Eastward propagating Kelvin waves noted in Beard (1998) for the austral autumn of 1997, continued to be clearly evident (Fig. 4) for June and July of 1997. For these two months, the thermocline depth along the equator was greater than 60 m below average in places. For August 1997, there are some indications that these waves were reflected by the American coastline as westward propagating waves. The western Pacific continued to be characterised by negative anomalies in the range 0 m to -30 m. These observations are consistent with the well-developed El Niño pattern in the sea-surface temperatures (Fig. 3).

Surface analyses

Figures 5 and 6 show the mean and anomalous winter 1997 MSLP patterns respectively. The contours in Fig. 5 are spaced at 4 hPa intervals between 980 hPa and 1024 hPa, while the contours in Fig. 6 are spaced at 2 hPa intervals between -10 hPa and +10 hPa. The MSLP and MSLP anomaly analyses have been computed using data obtained from the Bureau of Meteorology's Global Assimilation and Prediction (GASP) model daily analy-
Fig. 3 Winter 1997 (June, July, August) sea-surface temperature anomaly (°C).

Fig. 4 Time-longitude section of monthly anomalous depth of the 20°C isotherm at the equator from January 1994 to August 1997. The contour interval is 10 m.

The anomalies have been computed as deviations from an eleven-year (1979 - 1989) global climatology obtained from the European Centre for Medium Range Weather Forecasts (ECMWF). The low pressure anomaly over South America is a persistent feature, and appears to result from a systematic difference between the GASP and ECMWF models, rather than a meteorological consequence of the current El Niño event.

The dominant feature in the southern hemisphere winter circulation was the strong high pressure (anticyclonic) anomaly in the southeastern Pacific Ocean (Fig. 6). A cyclonic anomaly located to the northwest of the positive anomaly gives the appearance of a blocking couplet in a pattern similar to that exhibited in the corresponding figures for autumn 1997 (Beard 1998). A reflection of this blocking couplet can be seen in the low-level wind anomalies (Fig. 10). The existence of the cyclonic anomaly together with the positive anomaly over northern Australia (greater than +2 hPa) was consistent with the negative values of the SOI observed during winter.

Perhaps the most important feature in the Australian region was the anticyclonic anomaly centred over southeastern Australia. This feature was associated with the subtropical ridge being located further south than normal for many days during winter, and consequently reduced rainfall along the southern Australian coastline. Virtually the entire Australian continent is located within the +2 hPa contour of Fig. 6.
Fig. 5 Winter 1997 (June, July, August) mean sea-level pressure (hPa).

Fig. 6 Winter 1997 (June, July, August) mean sea-level pressure anomaly (hPa).

Fig. 7 Winter 1997 (June, July, August) 500 hPa mean geopotential height (gpm).

Fig. 8 Winter 1997 (June, July, August) 500 hPa mean geopotential height anomaly (gpm).
Upper-level analyses

500 hPa analyses
Figures 7 and 8 show the mean and anomalous geopotential height patterns at 500 hPa respectively for winter 1997. The contours in Fig. 7 are spaced at 80 geopotential metre intervals from 4720 gpm to 5840 gpm, while the contours in Fig. 8 are spaced at 40 gpm intervals from -80 gpm to 120 gpm. The mean flow shows similar features to the MSLP analysis, particularly in respect of the blocking couplet described above (Fig. 6). The anticyclonic anomaly over southern Australia is also reflected in the 500 hPa anomaly map, although centred somewhat further westward than at the surface.

Blocking
Figure 9 is a time-longitude section of the daily southern hemisphere Blocking Index (BI) (Wright 1993), which measures the strength of the 500 hPa flow at mid-latitudes relative to that at subtropical and high latitudes. The horizontal axis of Fig. 9 measures degrees of longitude east of the Greenwich Meridian. The top of the figure represents the start of winter, with the bottom of the figure representing the end of winter.

Blocking Index values were generally positive between 180°W and 120°W (180° and 240° in Fig. 9), consistent with the low-level wind anomaly feature (see Fig. 10) in the southeastern Pacific Ocean described below.

Winds
Low-level (850 hPa) and upper-level (200 hPa) wind anomalies for winter are shown in Figs 10 and 11 respectively. These also have been computed from the Bureau of Meteorology’s GASP model analyses. In the
Fig. 11  Winter 1997 (June, July, August) 200 hPa vector wind anomalies (m s⁻¹).

Fig. 12  Winter 1997 (June, July, August) rainfall totals (mm) in Australia.
lower levels, westerly anomalies existed over the equatorial Pacific Ocean, consistent with the development of an El Niño and the associated degradation of the Walker circulation. Over southern Australia, and the Southern Ocean, the anomalies are predominantly anticyclonic in character, consistent with the anticyclonic MSLP anomaly described above. The ridging associated with this pattern also produced anticyclonic anomalies in the Tasman Sea.

In the upper levels (Fig. 11), an obvious feature was the strong anticyclonic anomaly above the southern Pacific ocean. This feature was also reflected in the low-level anomalies (Fig. 10), and is consistent with the MSLP anomaly (Fig. 6). In the Australian region, there were strong northerly anomalies across the Top End and Papua New Guinea, suggesting that the winter hemisphere Hadley cell was stronger than usual in these latitudes. This suggestion is supported by the low-level southerly anomalies north of Papua New Guinea.

Australian region

Circulation and rainfall

Figure 12 shows the winter rainfall totals for Australia, while Fig. 13 shows the winter rainfall deciles, based on gridded rainfall data for the period 1900-1996. The effects of the current El Niño event can be seen in the generally dry conditions that occurred over Victoria, New South Wales, the northeastern half of Tasmania, the southern half of Queensland, and central Northern Territory. Comparatively small areas of Australia received falls classified as being ‘above average’ (deciles 8 to 10). These were in central Western Australia and the Top End.

Of the three months (June, July and August), July rainfall totals (not shown) most closely mirrored the overall pattern for the season, with most of Victoria, western New South Wales, and southeastern South Australia receiving falls that were very much below
average (decile 1). This area of dryness extended north-eastwards, with eastern New South Wales and the south-east corner of Queensland receiving below average falls (deciles 2 and 3). There were scattered above average falls across central Australia.

June saw scattered areas of above average falls in northern Australia, with generally average to drier than normal conditions occurring in southern Australia. This latter result was due to slow-moving high pressure systems through the month. The onshore airflow generated by these systems brought very much above average falls to southern New South Wales coastal districts. Northwest cloudband activity was reduced compared with autumn months (Beard 1998).

In contrast, August saw above average falls over much of Western Australia and central South Australia. A major shift in the high pressure belt to a more normal winter pattern allowed some active fronts to cross southern Australia and produced some of the best rains for many months. A cut-off low pressure system developed over inland Western Australia and interacted with tropical moisture, resulting in beneficial rains from the southeast of Western Australia to northwest Victoria.

**Temperatures**

Figures 14 and 15 show the maximum and minimum temperature anomalies respectively for winter 1997. The anomalies have been computed with respect to the 1982-1996 period. Maximum temperatures were below average over most of Australia, apart from the southwest corner of Western Australia, and a broad strip of eastern Australia extending from the eastern half of Tasmania, through eastern Victoria and New South Wales, into central Queensland. In this warmer region, maximum temperatures were more than 1°C above average in places. In central Australia, maximum temperatures were more than 1°C below average.

Minimum temperatures were generally below average across most of Australia, apart from regions around the northern coastline. Minimum temperatures were more than 2°C below average in parts of New South Wales.

**Appendix**

Data sources used for this review were:
National Climate Centre, Climate Monitoring Bulletin - Australia. +
Climate Prediction Center (CPC), Climate Diagnostics Bulletin. *

Obtainable from:
+National Climate Centre, Bureau of Meteorology, GPO Box 1289K, Melbourne Vic. 3001, Australia.
*Climate Prediction Center (CPC), National Weather Service, Washington D.C., 20233, USA.