Seasonal climate summary southern hemisphere (autumn 2002): onset of El Niño conditions

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Southern hemisphere circulation patterns and associated anomalies for the austral autumn 2002 are reviewed, with emphasis given to the Pacific Basin climate indicators and Australian rainfall and temperature patterns. Indications of the onset of a new El Niño event became apparent by the end of autumn, although this was much more evident in the atmospheric indicators than in the oceanic ones. In the middle of the season, however, it was far from certain that an El Niño would develop.

Autumn saw widespread below to very much below-average rainfall, accompanied by strongly elevated seasonal maximum temperatures. This below-average rainfall proved in hindsight to be the start of a particularly severe and widespread drought, whose effects were exacerbated by the persistence of the above-average temperatures seen during autumn.

Introduction

The neutral phase of the Southern Oscillation which began in autumn 2001 (Pahalad 2002), following the collapse of a weak and short-lived positive phase (Fawcett 2002), persisted through to summer 2001/02 (Gamble 2003). During autumn 2002, changes in the main indicators pointed to the onset of an El Niño (warm) event, although the data available at the end of May were still not sufficient in themselves for a definitive judgement on the matter. This onset was confirmed by subsequent developments in 2002, something beyond the scope of the present report.

This summary reviews the southern hemisphere and equatorial climate patterns for autumn 2002, with particular attention given to the Australasian and Pacific regions. The main sources of information for this report are the *Climate Monitoring Bulletin* (Commonwealth Bureau of Meteorology, Australia) and the *Climate Diagnostics Bulletin* (Climate Prediction Center, Washington). Further details regarding sources of data are given in the Appendix.

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Pacific Basin climate indices

The Troup Southern Oscillation Index*

The set of largely neutral monthly values (–9.1, +2.7 and +7.7) for summer 2001/02 (Gamble 2003) of the Troup Southern Oscillation Index (SOI) was followed by –5.2 (March), –3.8 (April) and –14.5 (May), pointing to the possible onset of a negative phase of the Southern Oscillation. The 30-day values of the un-normalised Tahiti-Darwin pressure difference were below the estimated climatological

*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).

values for most of the season, being only above average at the start of the season when February days contributed to the calculation. These 30-day values stayed within one standard deviation of the estimated average for almost the entire season, moving outside this range only at the end of May (consistent with the official May SOI value). Of the ten analogues for the nine monthly SOI values ending May 2002, calculated routinely for the National Climate Centre's Seasonal Climate Outlook, seven subsequently developed negative phases of the Southern Oscillation.

Darwin's MSLP anomalies were positive for all three months of the season (thereby contributing negatively to the SOI), whereas Tahiti's contribution to the falling SOI was only significant in May when its contribution equalled Darwin's. Figure 1 shows the monthly SOI values from January 1998 to May 2002. A curve of five-month moving averages has been superimposed on the graph.

The March/April and April/May values of the Climate Diagnostics Centre (CDC) Multivariate El Niño-Southern Oscillation (ENSO) Index (MEI) were +0.411 and +0.857 respectively. These values were higher than the two weakly negative values covering the summer period, and were consistent with the onset of El Niño conditions. The MEI is derived from a number of atmospheric and oceanic indicators, and typically shows positive values during El Niño events.

Outgoing long wave radiation

Figure 2, adapted from the Climate Prediction Center (CPC), Washington (CPC 2002), shows the standardised monthly anomaly of outgoing long wave radiation (OLR) from January 1998 to May 2002, 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 date-line (5°S to 5°N and 160°E to 160°W). Tropical deep convection in this region is particularly sensitive to changes in the phase of the Southern Oscillation. During warm (El Niño) ENSO 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 high cloud and deep convection. The reverse applies in cold (La Niña) events, with less convection expected in the vicinity of the date-line.

The monthly values –0.7 (March), +0.5 (April) and +0.3 (May) of this index were consistent with a neutral state of the Southern Oscillation. Weekly to fortnightly fluctuations in cloudiness around the date-line during the season were not very substantial.

Fig. 1 **Southern Oscillation Index, from January 1998 to May 2002. Means and standard deviations used in the computation of the SOI are based on the period 1933-1992.**

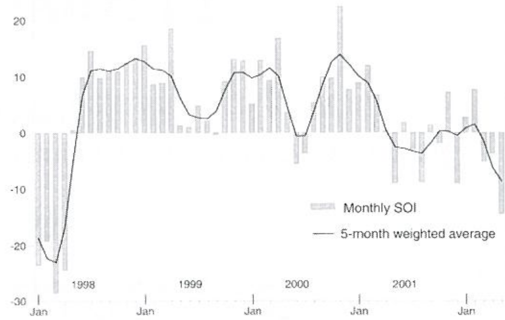
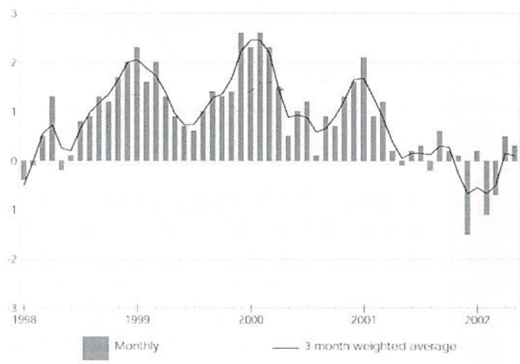


Fig. 2 **Standardised anomaly of monthly outgoing long-wave radiation averaged over the area 5°S to 5°N and 160°E to 160°W, from January 1998 to May 2002. Negative (positive) anomalies indicate enhanced (reduced) convection and rainfall in the area. Anomalies are based on the 1979-1995 base period. After CPC (2002).**

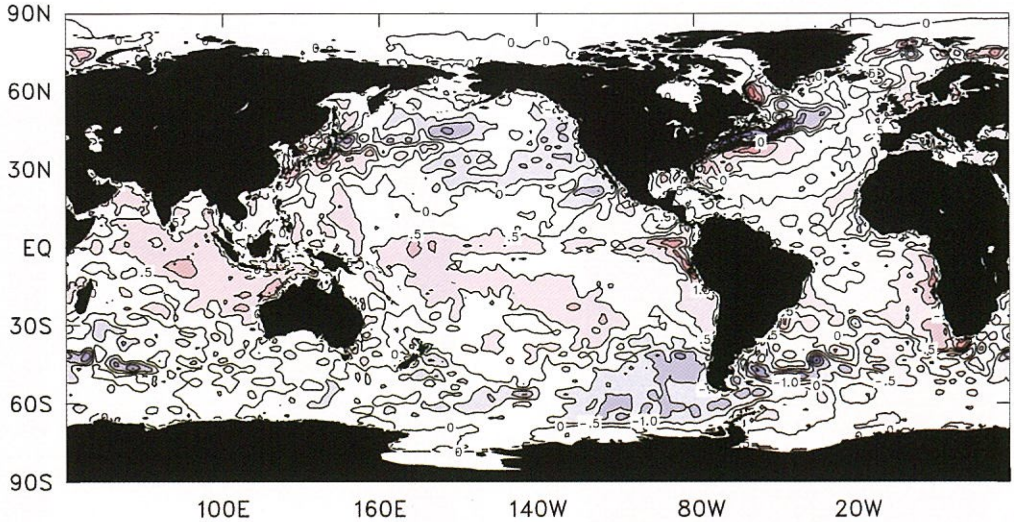


Oceanic patterns

Sea-surface temperatures

Figure 3 shows autumn 2002 sea-surface temperature (SST) anomalies in degrees Celsius (°C), as computed by the National Meteorological and Oceanographic Centre (NMOC). The contour interval is 0.5°C. Positive anomalies are shown in orange and red shades, while negative anomalies are shown in blue shades.

Fig. 3 Anomalies of sea-surface temperature for autumn (March, April, May) 2002 (°C). The contour interval is 0.5°C.



SSTs were above average across most of the tropical Pacific for autumn, although the areas where the anomalies exceeded +1°C were relatively small. These comprised a few patches around the date-line and a much more coherent pattern in the far eastern Pacific along the west coast of South America. Peak anomalies there reached +2°C for the season.

Anomalies in the +0.5 to +1.0°C range were much more widespread, covering most of the equatorial Pacific and most of the tropical and subtropical west coast of South America. The pattern of +0.5°C anomalies also extended from the western tropical Pacific southeast well into the central South Pacific.

The Indian Ocean north of latitude 30°S was warmer than average in autumn, with +0.5°C anomalies stretching from south of India southeast to the Western Australian coast. Along the northwest coast of Western Australia, the anomalies exceeded +1°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 2002, as calculated by the Bureau of Meteorology Research Centre (BMRC). 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.

A westerly wind burst late in 2001 (Gamble 2003) set off a Kelvin wave which is clearly evident in Fig. 4 (yellow and orange shades). The wave traversed the Pacific and led to surface warming in the far east (see Fig. 3). In consequence the NINO 1 and 2 SST indices rose rapidly through late summer and early autumn. The values of these indices peaked in mid-autumn and by the end of the season had declined considerably without a more general transition to El Niño conditions. It is worth noting that similar peaks in the NINO 1 and 2 indices occurred in the early part of 2001, again without a transition to El Niño conditions.

Figure 5 shows a sequence of equatorial Pacific vertical temperature anomaly profiles for the four months ending May 2002, also obtained from the BMRC. In the figure, red (blue) shades indicate subsurface waters which are warmer (cooler) than average. This view of the Pacific Ocean shows little sign of El Niño onset. The warm anomalies which were present in the far east and central-west at the end of summer persisted into March but weakened rapidly thereafter.

Following the Kelvin wave mentioned above, a wave of cooler than average conditions can be seen propagating eastward in Fig. 4, particularly in the

Fig. 4 **Time-longitude section of the monthly anomalous depth of the 20°C isotherm at the equator from January 1996 to May 2002. The contour interval is 10 m.**

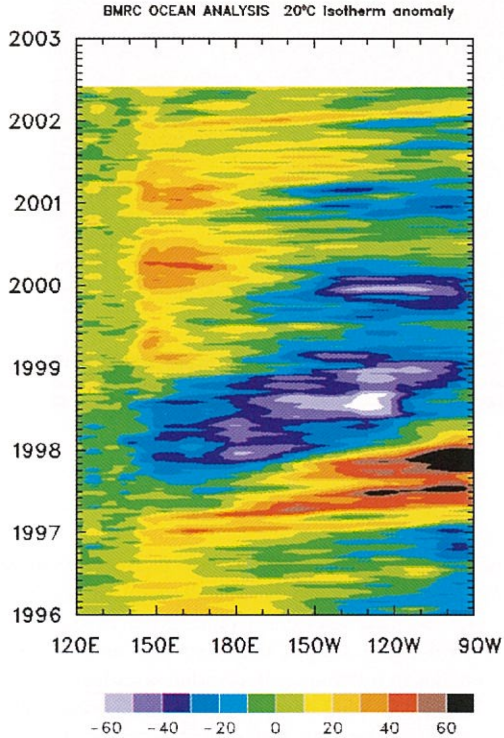
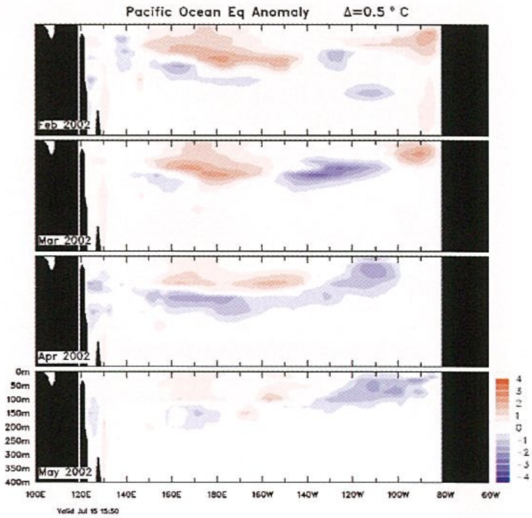


Fig. 5 **Four-month February to May 2002 sequence of vertical temperature anomalies at the equator for the Pacific Ocean. The contour interval is 0.5°C.**



eastern half of the equatorial Pacific, although it is by no means as obvious as the earlier wave of warming. Something of the latter progression can be seen in the March, April and May panels of Fig. 5.

During February the low-level winds of the western equatorial Pacific (west of about 170°E) had substantial westerly components, with the peak burst occurring at the end of the month. These westerlies persisted through the first half of March, although not penetrating as far east into the Pacific. There were two brief and fairly weak westerly bursts in the far west during April.

In May there was a dramatic change in the situation. Another westerly wind burst occurred west of the date-line, although weaker than the one observed in late February/early March. The May burst however was accompanied by a basin-wide collapse in the easterly trade winds, which lasted through the last two weeks of May and east of the date-line through the first two weeks of June. It was this widespread weakening of the trade winds which appears to have been the 'trigger' for a transition to El Niño, although undoubtedly the Kelvin wave of late 2001 and early 2002 played a significant role in 'priming' the tropical Pacific for such a transition.

Atmospheric patterns

Surface analyses

The autumn 2002 mean sea-level pressure (MSLP) across the southern hemisphere is shown in Fig. 6, with the associated anomalies shown in Fig. 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 and 0000 UTC analyses*.

* For many years, the GASP analyses (Figs. 6-13 inclusive) used in the preparation of these seasonal summaries were issued for a 2300 UTC base time. From 17 March 2002, the analysis time was placed one hour later, so as to occur at 0000 UTC 'on the following day'. In order to obtain a complete set of 92 analyses covering the season, sixteen 2300 UTC analyses covering the period 1 to16 March 2002 have been combined with seventy-six 0000 UTC analyses covering the period 18 March to 1 June 2002.

Fig. 6 **Autumn 2002 mean sea-level pressure (hPa). The contours are spaced at 4 hPa intervals between 984 hPa and 1028 hPa.**

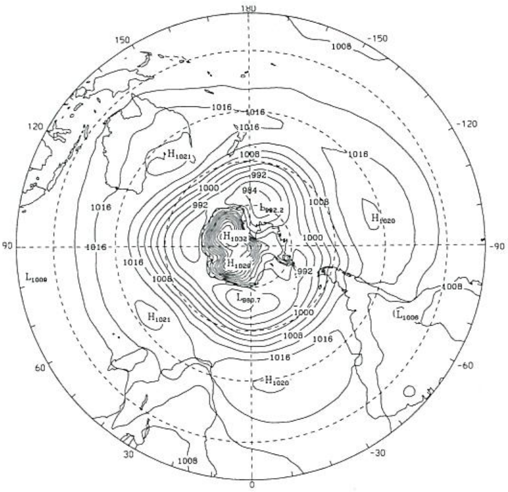
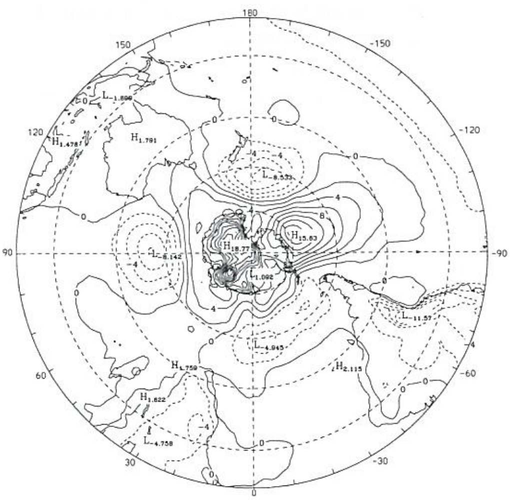


Fig. 7 **Autumn 2002 mean sea-level pressure anomaly (hPa). The contours are spaced at 2 hPa intervals between –10 hPa and +22 hPa.**



The Antarctic circumpolar trough showed three substantial minima, located at 10°E, 110°E and 160°W. These centres of low pressure, coupled with a weak trough located just east of South America and a weak low between Antarctica and South America, gave four-wave characteristics to the flow around Antarctica.

Around Australia, the pressure anomaly pattern was dominated by two substantial (8 hPa) negative anomalies, located southwest of Australia and southeast of New Zealand. Between them, a ridge of anomalously high pressure extended up from Antarctica towards southeast Australia, and pressure anomalies over the continent were weakly positive. In the mean pressure field, this manifested as a local maximum of the sub-tropical ridge being located approximately over Adelaide.

A third centre of anomalously low pressure was located on the Greenwich meridian, almost diametrically opposite the second centre mentioned above. This third centre extended some distance to the west, thereby lending the combined arrangement three-wave characteristics. This view of the anomalies was supported by a weak ridge extending north from Antarctica at about 40°E and a very much stronger ridge at about 110°W which extended well into the mid-latitude South Pacific. The central anomaly in this last pattern was +16 hPa.

Pressures over the tropical Pacific were below average for the season.

The low pressure anomaly over high elevation parts of South America and the high pressure anomaly over the Antarctic plateau are persistent features, and appear to be the result of a systematic difference between the GASP and ECMWF models and the way they extrapolate to mean sea level. Therefore, the indicated low pressure over parts of South America should not be treated as a meteorological consequence of the current state of the El Niño-Southern Oscillation.

Mid-tropospheric analyses

The mean 500 hPa geopotential height patterns for autumn 2002 are shown in Fig. 8, with anomalies shown in Fig. 9. The four-wave characteristics in the MSLP pattern (Fig. 6) were also present in the mid-latitude flow (Fig. 8), with the troughs located in similar positions. There were negative anomalies over the tropical eastern and central Pacific, and weak positive anomalies (below 40 gpm) over all of the Australian continent.

As for surface pressure anomalies, the positive 500 hPa height anomalies over the Antarctic continent appear to be an artefact of systematic differences between the GASP and ECMWF models, rather than a real climatic feature.

Blocking

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

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

Fig. 8 Autumn 2002 500 hPa mean geopotential height (m). The contours are spaced at 80 geopotential metre intervals from 5040 gpm to 5840 gpm.

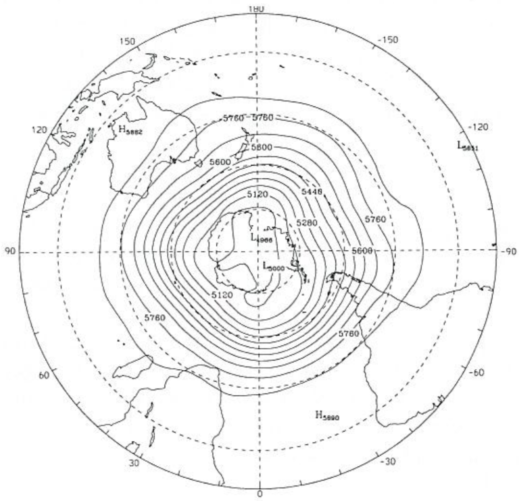
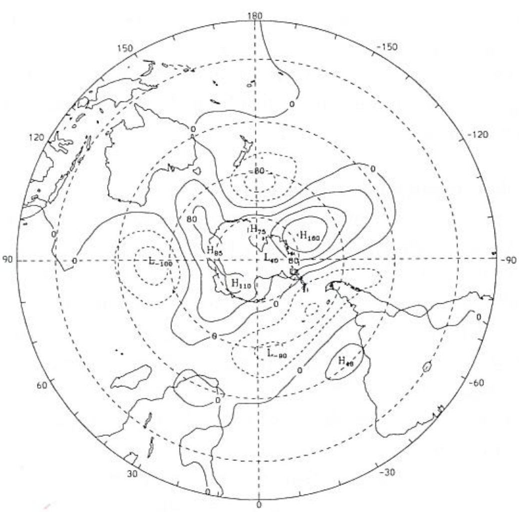


Fig. 9 Autumn 2002 500 hPa mean geopotential height anomaly (m). The contours are spaced at 40 gpm intervals from –80 gpm to +160 gpm.



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.

Fig. 10 Autumn 2002 daily blocking index: time-longitude section. The horizontal axis measures degrees of longitude east of the Greenwich meridian. Day one is 1st March.

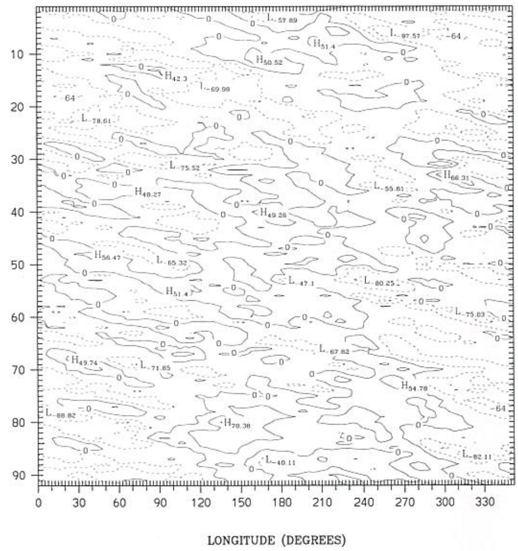
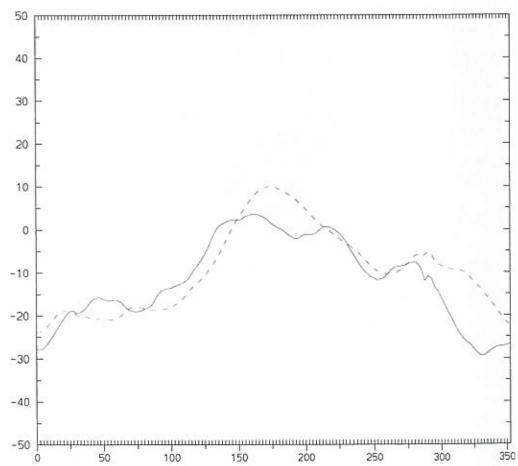


Fig. 11 Mean southern hemisphere blocking index for autumn 2002 (solid line). The dashed line shows the corresponding long-term average. The horizontal axis shows degrees east of the Greenwich meridian.



Taken across the entire season in the form of a seasonal mean (Fig. 11), blocking was quite close to average for most longitudes, being slightly weaker than average around the date-line and somewhat more so between 80°W and the Greenwich meridian, particularly in the second half of the season. The positive/negative anomaly pair in Fig. 9 off the east coast of southern South America and the associated anomalous westerly flow at about 40°S (Fig. 12) are consistent with the decreased blocking in this area.

Winds

Low-level (850 hPa) and upper-level (200 hPa) wind anomalies for autumn 2002 are shown in Figs 12 and 13 respectively. The low-level pattern in the central Pacific shows a slightly enhanced trade wind regime on and just south of the equator, but in the western and eastern equatorial Pacific regions, the wind anomalies were small.

Low-level wind anomalies in the Australian region followed the MSLP anomaly pattern, with cyclonic anomaly patterns located southwest of Australia and southeast of New Zealand and a weak anti-cyclonic anomaly pattern directly south of the Australian continent. Over the continent itself, the anomalies were northwesterly to northeasterly over the western half, but weak and variable in direction over the eastern half.

The two low-level cyclonic anomaly patterns described in the preceding paragraph were also present in the upper levels (Fig. 13), along with the anomalous anti-cyclonic pattern directly south of the continent. North of the two cyclonic anomaly patterns were two anti-cyclonic anomaly patterns which were not appreciably present in the low levels. The western one of the two contributed to upper-level easterly anomalies over the Indian Ocean equatorial region, with a pattern of divergence present in both hemispheres over the east coast of Africa.

Australian region

Rainfall

Figure 14 shows the autumn rainfall totals for Australia, while Fig. 15 shows the autumn rainfall deciles, where the deciles are calculated with respect to gridded rainfall data for all autumns from 1900 to 2002.

Autumn rainfall was below average across most of the continent (Fig. 15). In areal terms, one-third of the country recorded very much below average (decile 1) rainfall for the season, while for Tasmania the corresponding figure was 90%. In area-averaged terms, this was the third driest autumn across Australia in the post-1900 period. For Tasmania, it was the second driest autumn in this period.

Rainfall very much below average occurred across large areas of tropical and subtropical Australia away from the west coast (with significant areas in the southern Northern Territory receiving no rain for the season), and across virtually all of Tasmania, where an area of lowest on record occurred northwest of Hobart. Water storages in the northwest of Tasmania

Fig. 12 Autumn 2002 850 hPa vector wind anomalies (m s^{-1}).

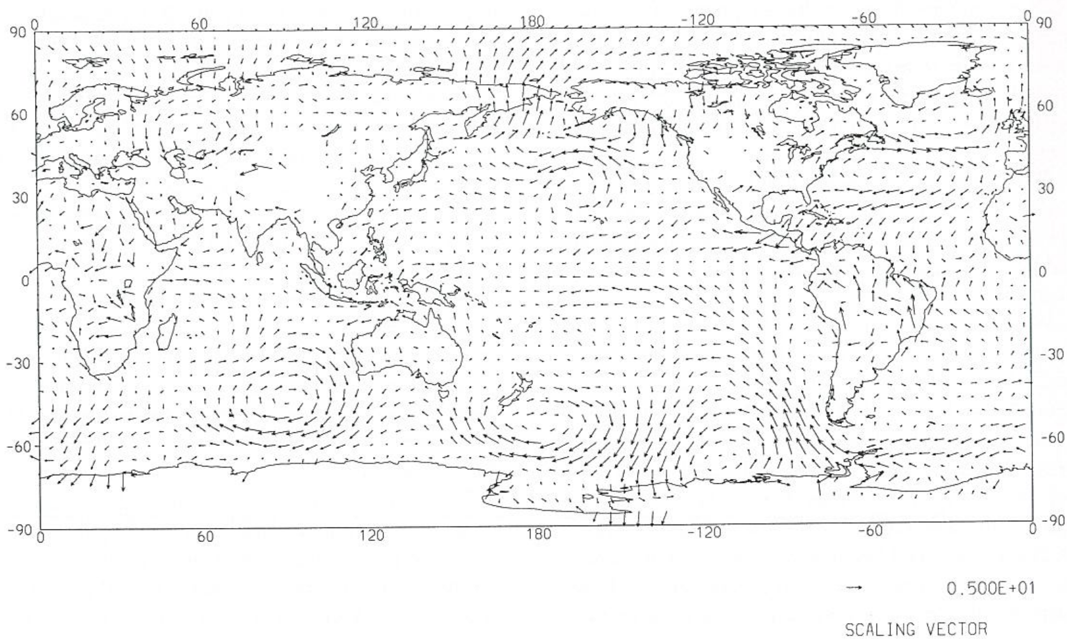
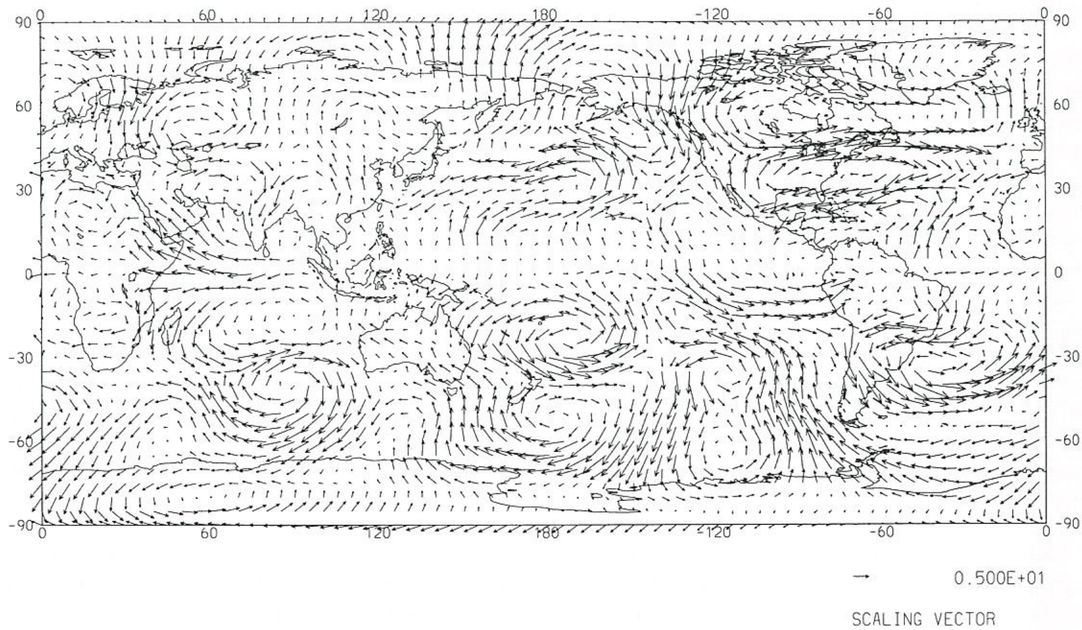


Fig. 13 Autumn 2002 200 hPa vector wind anomalies (m s^{-1}).



were very low at the end of the period. There were also smaller areas of very much below average rainfall in western and central Victoria and adjoining areas of South Australia, and the wheatbelt of Western Australia. Below-average falls covered most of the rest of the country, except for a belt running from the Pilbara to the Nullarbor in Western Australia, and scattered patches in the south-east quarter of the continent. No part of the country received consistent above-average rainfall through autumn, although a handful of stations exceeded average for the season, largely as a result of one or two major local rain events.

Essentially the tropical monsoonal inflow over northern Australia ended by March, and during April and May broad highs over the continent blocked the mid-latitude westerlies, causing the restricted rainfall for the period.

While the low autumn rainfall proved in hindsight to represent the start of a particularly severe and widespread El Niño drought, none of the autumn months was individually especially dry. In March, widespread below to very much below average rainfall occurred across South Australia, Queensland and the Northern Territory. In April, it was Tasmania's turn with more than half the state recording very much below average rainfall. Widespread below to very much below average rainfall occurred in eastern Queensland and the northwest quarter of the continent. In May, the below-average rainfall occurred across Tasmania, southwest Western Australia, from northern New South Wales extending north to Cape York Peninsula, and the northwest quarter of the continent.

Temperatures

Figures 16 and 17 show the maximum and minimum temperature anomalies respectively for autumn 2002. The anomalies have been calculated with respect to the 1961-1990 period.

Maximum temperatures were above average for the season across almost all of the country (Fig. 16), the only exception being in the far southeast of the continent. The peak anomalies exceeded +4°C in the southern half of the Northern Territory, while a band of +2 to +3°C anomalies stretched from west to east along the Tropic of Capricorn.

Maximum temperatures in April and May were especially warm, with large parts of central and western Australia having their highest mean maximum temperatures on record for one or both months. Peak April anomalies in central Australia exceeded +5°C, whilst during May much of the west recorded anomalies above +3°C.

In historical terms, most of the country recorded seasonal mean maximum temperatures in the highest decile. In areally-averaged terms for Australia 2002 was the warmest autumn of the post-1950 period by a substantial margin, with a seasonal anomaly of

Fig. 14 Autumn 2002 rainfall totals (mm) in Australia.

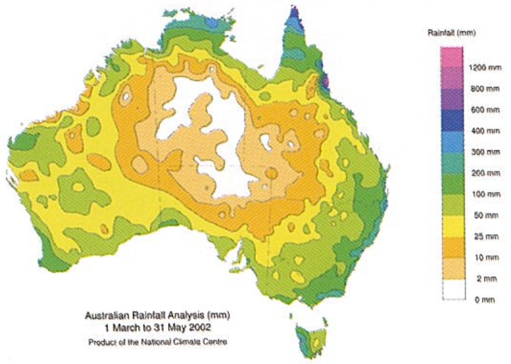


Fig. 15 Autumn 2002 rainfall in Australia: decile range values based on grid-point values over the autumns 1900 to 2002.

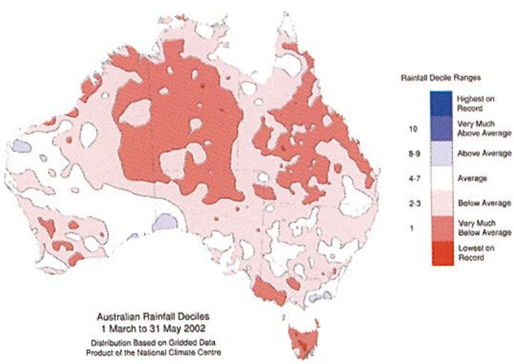


Fig. 16 Autumn 2002 maximum temperature anomalies (°C) for Australia based on a 1961-1990 mean.

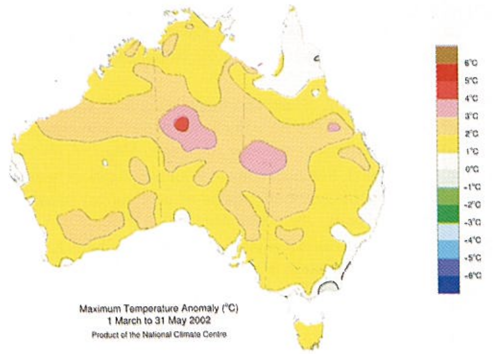
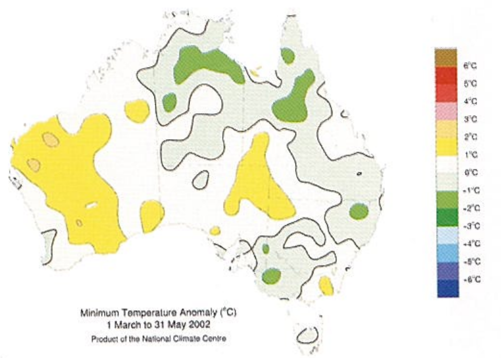


Fig. 17 Autumn 2002 minimum temperature anomalies (°C) for Australia based on a 1961-1990 mean.



+1.83°C, compared with the previous record of +1.39°C, set in 1986. April (+2.41°C) and May (+2.21°C) also set monthly records. Regionally it was the warmest of the post-1950 period for Queensland, Victoria, South Australia, Western Australia and the Northern Territory, and the second-warmest for New South Wales and Tasmania.

The pattern of minimum temperature anomalies (Fig. 17) was much weaker. While most of Western Australia and South Australia recorded above-average temperatures, weak negative anomalies (generally below 1°C) occurred across much of eastern Australia. The most notable local minimum temperature anomalies occurred along the coast of south-eastern Western Australia, where some stations recorded their warmest minimum temperatures of the post-1950 period. The all-Australian minimum temperature anomaly was +0.33°C, which ranks thirteenth in 53 years of records. March was generally cool, and April warm, through most of the country. April's national anomaly of +1.05°C was the fifth-highest on record.

The strongest minimum temperature anomalies during the season were recorded in May in parts of Western Australia, with anomalies exceeding 3°C in much of the Pilbara and Gascoyne, and reaching +5°C in a few places. This was offset by negative anomalies through much of eastern Australia.

Combining maximum and minimum temperatures, the seasonal mean temperature anomaly for autumn for Australia was +1.08°C, the second-highest of the post-1950 period behind +1.10°C in 1958.

References

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Gamble, F.M. 2003. Seasonal climate summary southern hemisphere (summer 2001/02): a continuation of near-normal conditions in the tropical Pacific. *Aust. Met. Mag., 52*, 63-72.

Pahalad, J. 2002. Seasonal climate summary southern hemisphere (autumn 2001): a return to near-normal conditions in the tropical Pacific. *Aust. Met. Mag., 51,* 117-124.

Appendix

Data sources used for this review were:

- National Climate Centre, C*limate Monitoring Bulletin - Australia*. Obtainable from the National Climate Centre, Commonwealth 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.