Seasonal climate summary southern hemisphere (autumn 2004): continued neutral ENSO conditions, near-normal broadscale ocean and atmospheric conditions

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Southern hemisphere circulation patterns and associated anomalies for the southern hemisphere autumn 2004 are reviewed, with emphasis given to the Pacific Basin climate indicators and Australian rainfall and temperature patterns.

Most broadscale climate indicators were near climatological normals during autumn 2004, with few large anomalies reported in either ocean or atmospheric conditions. In particular, the El Niño-Southern Oscillation (ENSO) remained in a neutral state during autumn 2004.

In general, it was a rather dry season in much of eastern Australia, especially the southeast inland, and a rather wet season in most of Western Australia away from the southwest. Temperatures were slightly above normal, with the strongest anomalies in Queensland and, for maximum temperatures, New South Wales.

Introduction

The El Niño-Southern Oscillation (ENSO) remained in a neutral state during autumn 2004, continuing to settle back towards normal from the near El Niño conditions that occurred during late 2003 (Fawcett 2004). There was considerable intraseasonal activity in the western tropical Pacific but this had little impact east of the date-line. Elsewhere in the southern hemisphere, ocean temperatures and the broadscale circulation were generally close to climatological normals.

This summary reviews the southern hemisphere and equatorial climate patterns for autumn 2004, with particular attention given to the Australasian and Pacific regions. The main sources of information for this report are the *Climate Monitoring Bulletin* (Australian Bureau of Meteorology) and the *Climate Diagnostics Bulletin* (Climate Prediction Center, Washington D.C., USA). Further details regarding sources of data are given in the Appendix.

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Pacific Basin climate indices

The Troup Southern Oscillation Index (SOI)*

Averaged across the season as a whole, the Southern Oscillation Index (SOI) was near zero, with a mean value for the season of –0.7. This masked sharp month-

* The SOI used here 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 1933-92.

Fig. 1 Southern Oscillation Index, January 2000 to May 2004 inclusive. Means and standard deviations based on the period 1933-92.

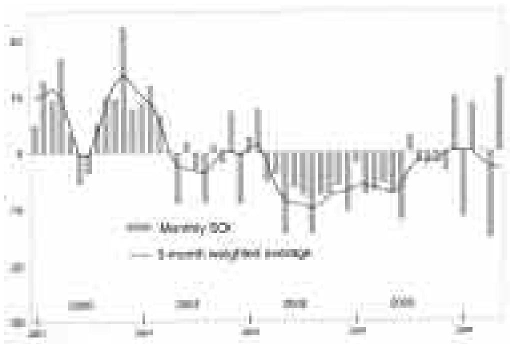
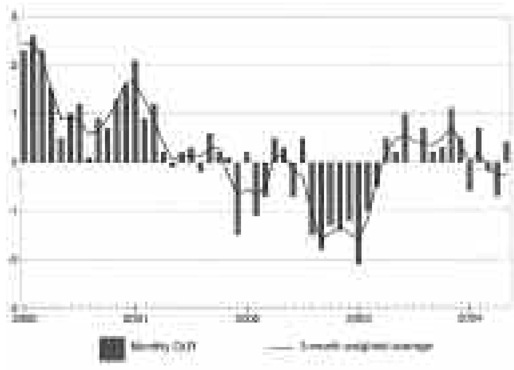


Fig. 2 Standardised anomaly of monthly outgoing long wave radiation averaged over 5°N-5°S and 160°E-160°W, for January 2000 to May 2004. Negative (positive) anomalies indicate enhanced (reduced) convection and rainfall. Anomalies are based on a 1979-95 base period. After CPC (2003, 2004).



to-month fluctuations (Fig. 1), with the SOI value for April being –15.4, and for May +13.1. The May value was the highest positive monthly value of the SOI since November 2000. These fluctuations, which had been occurring since December 2003, appear to have resulted from intraseasonal variability arising from several Madden-Julian Oscillation (MJO) events, and in particular from a tendency for the effects of these events to coincide with calendar months. (By contrast, in summer and autumn 2002-03, 30-day running means of the SOI fluctuated through a similar range of approximately 30 points, but in 2002-03 the extreme points of the 30-day SOI occurred mid-month and had little impact on the monthly values.)

The March/April and April/May values of the Climate Diagnostic Center Multivariate ENSO Index (MEI) (Wolter and Timlin 1993, 1998) were +0.281 and +0.428 respectively. These values indicate continued neutral conditions in the tropical Pacific.

Outgoing long wave radiation

Figure 2, adapted from the Climate Prediction Center (CPC), Washington (CPC 2004), shows the standardised monthly anomaly of outgoing long wave radiation (OLR) from January 2000 to May 2004, 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, 160°E to 160°W). Anomalously low OLR values are indicative of increased high cloud and deep convection, and are characteristic of warm ENSO events (El Niño). Conversely, cool ENSO events (La Niña) tend to be associated with suppressed convection near the date-line and anomalously high OLR values.

The OLR index remained near zero through autumn 2004, with monthly values of –0.2 (March), –0.7 (April) and +0.4 (May). This continued the pattern of near-zero values that has been in place since the breakdown of the 2002-03 El Niño event in early 2003.

Two significant MJO events propagated through the tropics during the autumn, one in mid to late March and one in late May (extending into June). These were both associated with marked local OLR anomalies, but neither event had much impact east of the date-line.

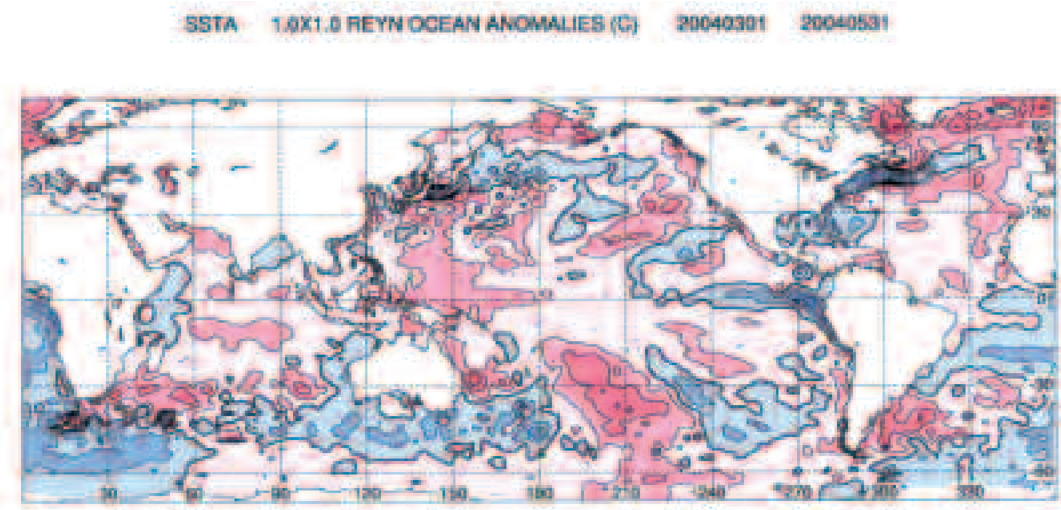
Oceanic patterns

Sea-surface temperatures

Figure 3 shows autumn 2004 sea-surface temperature (SST) anomalies (°C), obtained from the NOAA Optimum Interpolation analyses (Reynolds et al. 2002). Positive anomalies are shown in red shades, and negative anomalies in blue shades.

The eastern equatorial cold tongue was stronger than normal, with anomalies reaching –1.5°C locally off the South American coast. May was a particularly cool month in this area, with the Niño 2 index dropping to –1.12°C after being near –0.4°C in March and April. West of 150°W tropical SSTs were mostly above normal, although to a lesser extent than for some time – the seasonal mean Niño 4 anomaly (+0.50°C) was the lowest since winter 2001. By May, though, Niño 4 had started to warm again (+0.67°C), a prelude to continued warming later in 2004. The Niño 3 anomaly for the season was +0.22°C, indicative of neutral ENSO conditions.

Fig. 3 Anomalies of sea-surface temperature for autumn 2004 (°C). Contour interval is 0.5°C.



In the Indian Ocean, cool SST anomalies occurred over the waters close to Australia, but weak (less than 1°C) warm anomalies prevailed over most of the remainder of the tropical and subtropical Indian Ocean.

Cool SST anomalies were observed over most waters near the southern Australian coast, as well as near New Zealand. Warm anomalies prevailed off the Queensland coast, locally reaching +1.5°C off southern Queensland. Further east, a large area of warm anomalies exceeding 1°C was centred on latitude 30°S in the central South Pacific.

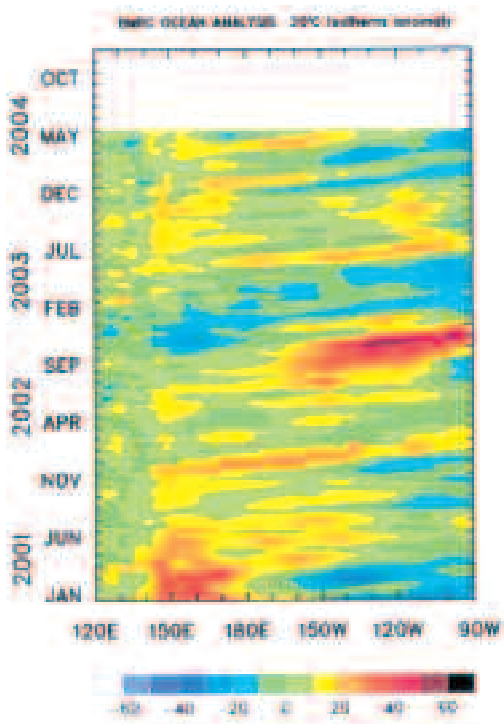
There were few other large SST anomalies elsewhere in the world, although the North Atlantic was generally warm (away from the North American coast) and the eastern South Atlantic cool.

Subsurface patterns

Figure 4 shows a Hovmöller diagram of the anomaly (metres) in the depth of the 20°C isotherm in the equatorial Pacific Ocean between January 2001 and May 2004, as calculated by the Bureau of Meteorology Research Centre (BMRC). This isotherm is normally situated very close to the equatorial ocean thermocline, the region of greatest temperature gradient with respect to depth and the boundary between the upper ocean warm water and the deeper ocean cold water. An abnormally deep thermocline (positive anomaly) in the eastern Pacific Ocean is characteristic of El Niño events.

The most prominent subsurface feature during autumn 2004 was the shallow thermocline in the far eastern Pacific, particularly in April and May, with anomalies in the –20 to –30 metre range. This mir-

Fig. 4 Time-longitude section of the monthly anomalous depth of the 20°C isotherm at the equator for January 2001 to May 2004. Base period: 1979-89. Contour interval is 10 m.



rored the surface patterns described above (Fig. 3). Further west, the thermocline location was generally fairly close to normal, except in March when anomalies in the -20 to -30 metre range occurred in an area centred on 135°W. A Kelvin wave developed in late March in response to an MJO event in the western Pacific, and led to a deeper-than-normal thermocline in the central Pacific during April, but associated anomalies were modest, only briefly reaching +20 metres.

An alternative view of the subsurface is shown in Fig. 5, a cross-section of equatorial subsurface temperature anomalies for the months from February to May 2004 (also obtained from BMRC). Red shades indicate warm anomalies, and blue shades cool anomalies. Early in the season cool anomalies existed through most of the subsurface east of the dateline and above depths of 200 metres, with weak warm anomalies further west. Later in the season the cool anomalies became increasingly concentrated in the far eastern Pacific, reaching –3°C in places, as they were eroded in the central Pacific by the effects of the March/April Kelvin wave. Weak warm anomalies in the western Pacific gradually extended eastwards through the season, reaching to 140°W by the end of May.

Atmospheric patterns

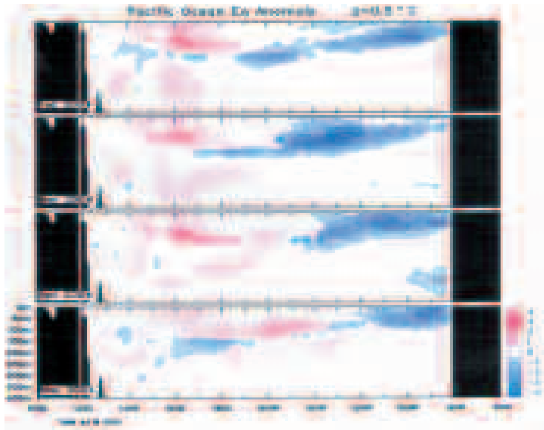
Surface analyses

The autumn 2004 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 a 1979-2000 climatology obtained from the National Centers for Environmental Prediction (NCEP). The MSLP analysis itself has been computed using data from the 0000 UTC daily analyses of the Australian Bureau of Meteorology's GASP model. The MSLP anomaly field is not shown over areas of elevated topography (grey shading).

The Antarctic circumpolar trough was somewhat stronger than usual, with negative MSLP anomalies over most of the region south of 50°S – the exception being south of Australia where anomalies were either positive or close to zero. There was little evidence of any anomalous wave activity.

There were few large MSLP anomalies anywhere else in the southern hemisphere, suggesting little anomalous blocking. Small positive anomalies occurred over most of the Australian continent and extratropical South America, while in contrast negative anomalies occurred over most of southern Africa. The strongest positive anomalies over the Australian continent were in the southeast, consistent with the dry autumn in that area.

Fig. 5 **Four-month (February to May 2004) sequence of vertical temperature anomalies at the equator. Contour interval is 0.5°C.**



Mid-tropospheric analyses

The mean 500 hPa geopotential height patterns for autumn 2004 are shown in Fig. 8, with anomalies shown in Fig. 9. As for the surface pattern, anomalies were mostly relatively small, with the most prominent features being a trough south of Africa (around 10°E), and another trough near New Zealand with some evi-

Fig. 6 **Mean sea-level pressure for autumn 2004 (hPa).**

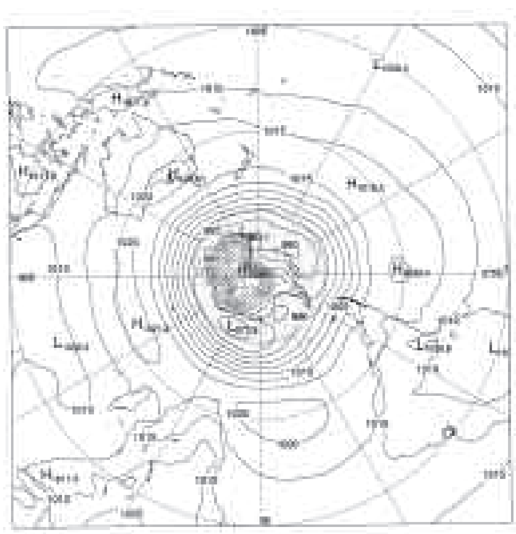


Fig. 7 **Anomalies of the mean sea-level pressure from the 1979-2000 National Centers for Environmental Prediction reanalysis II climatology, for autumn 2004 (hPa).**

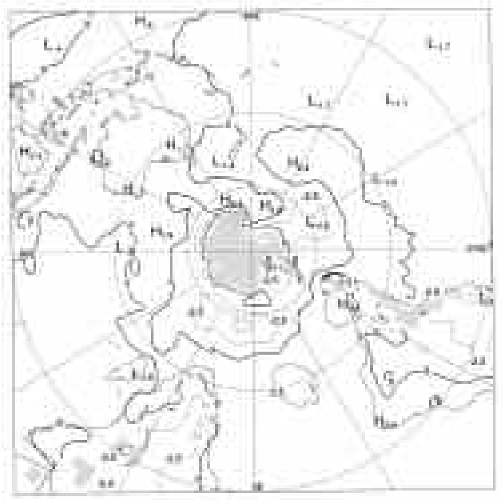
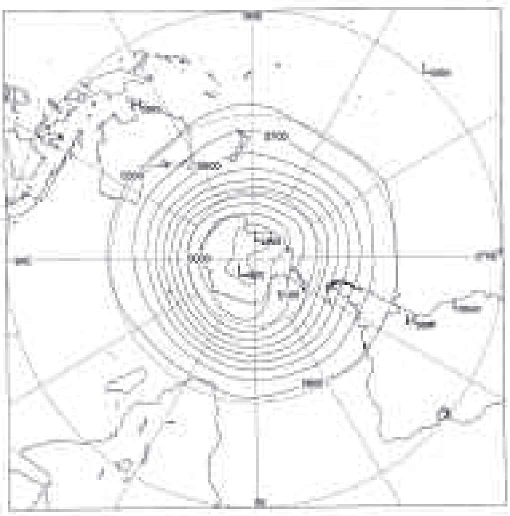


Fig. 8 **Mean 500 hPa geopotential heights for autumn 2004 (gpm).**



dence of associated blocking near 150°W. The split flow in the New Zealand region which was evident in the summer of 2003-04 (Fawcett 2004) also continued into autumn.

As for the surface pattern, high pressure occurred in the mid-troposphere over southeastern Australia. However, over Western Australia weak negative 500 hPa height anomalies occurred in the same areas covered by positive MSLP anomalies.

Fig. 9 **Anomalies of the 500 hPa geopotential height from the 1979-2000 National Centers for Environmental Prediction reanalysis II climatology, for autumn 2004 (gpm).**

Blocking

A daily southern hemisphere mid-level Blocking Index (BI) may be defined using the equation:

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

where u_x indicates the 500 hPa zonal wind component at latitude x°S. 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.

Figure 10 is a time-longitude section of the daily blocking index, while Fig. 11 is a section averaged across the season as a whole.

Blocking activity was near normal through most of the southern hemisphere mid-latitudes (Fig. 11). Slight negative anomalies (mostly around –5 m s^{-1}) prevailed around and south of Africa (between about 20°W and 45°E), indicating an enhancement of the already climatologically strong zonal flow in this sector. There were few strong positive anomalies anywhere. The only significant long-lived blocking episode was centred on 170°E, and ran from the second week of May to the season's end (Fig. 10).

Winds

Low-level (850 hPa) and upper-level (200 hPa) wind anomalies for autumn 2004 are shown in Figs 12 and 13 respectively. Low-level wind anomalies in the tropical Pacific were mostly weak, consistent with the neutral ENSO state, although there was some evi-

Fig. 10 Autumn 2004 daily blocking index: time-longitude section. Day 1 is 1 March.

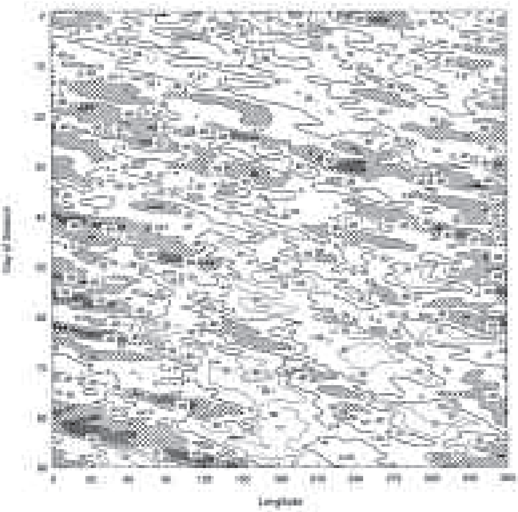
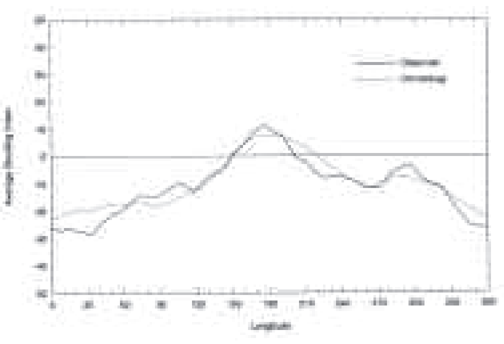


Fig. 11 Mean southern hemisphere blocking index for autumn 2004 (bold line). The dashed line shows the corresponding long-term average. The horizontal axis shows the degrees east of the Greenwich meridian.



dence of anomalous southerly (cross-equatorial) flow in the eastern Pacific. Trade wind strength was near normal through most of the tropical southern Pacific, although easterly flow extended slightly further south than normal in the central Pacific, resulting in an area of easterly anomalies near 30°S, 150°W.

There were also few significant 850 hPa wind anomalies in mid and high latitudes, indicating that the mid-latitude westerlies were close to climatological strength through most of the southern hemisphere. Weak northerly anomalies existed over central Australia.

At upper levels, there was enhanced westerly flow over most of the central and eastern tropical Pacific, with anomalies exceeding 5 m s^{-1} in places. There was also a marked anticyclonic anomaly near 30°S, 150°W. At higher latitudes there were generally enhanced upper-level westerlies in the African sector between about 30°W and 45°E, whilst south of Australia the westerlies were mostly weaker than the climatological normal.

Australian region

Rainfall

Figure 14 shows autumn 2004 rainfall totals for Australia. Figure 15 shows the autumn rainfall deciles, calculated based on gridded data for the period 1900-2004.

Autumn 2004 was a rather dry season in much of eastern Australia, as well as in southwest Western Australia. In contrast, it was a wet season in much of the western half of the country away from the southwest, particularly in interior Western Australia where rainfall totals were widely in the highest decile, and reached record levels in a few places. Near the coast these high rainfall totals were largely attributable to tropical cyclones *Monty* and *Fay*. *Fay* brought the heaviest falls, with 701 mm at Nifty Copper Mine, east of Port Hedland, over the two days 28-29 March (including 525 mm on 28 March, the third-highest daily fall on record in Western Australia), and 358 mm at nearby Telfer compared with its long-term annual mean of 313 mm. *Monty* brought falls in the 200-400 mm range in parts of the Pilbara from Port Hedland westwards over the period 29 February – 2 March. Further inland, a succession of several rain events in May, each with widespread falls in the 25-50 mm range, were significant contributors to high seasonal rainfall totals.

It was notably dry in much of the southeast, particularly in southern inland New South Wales and northern Victoria. Around and north of Canberra it was the driest autumn on record, and at Canberra itself, where only 13.4 mm fell (nine per cent of normal), it was the driest season of any name (records commenced in 1939). March and April were particularly dry months in this region, although conditions returned to nearer normal in May. Autumn was also fairly dry in northern and eastern Tasmania.

It was a rather dry autumn in much of Queensland, thanks mainly to an early finish to the wet season through most of the tropics. In contrast, it was wetter than normal along the north tropical coast around

Fig. 12 **Autumn 2004 850 hPa vector wind anomalies with contours of vector magnitude overlayed. The contour interval is 5 m s^{-1}, with values above 5 m s^{-1} stippled.**

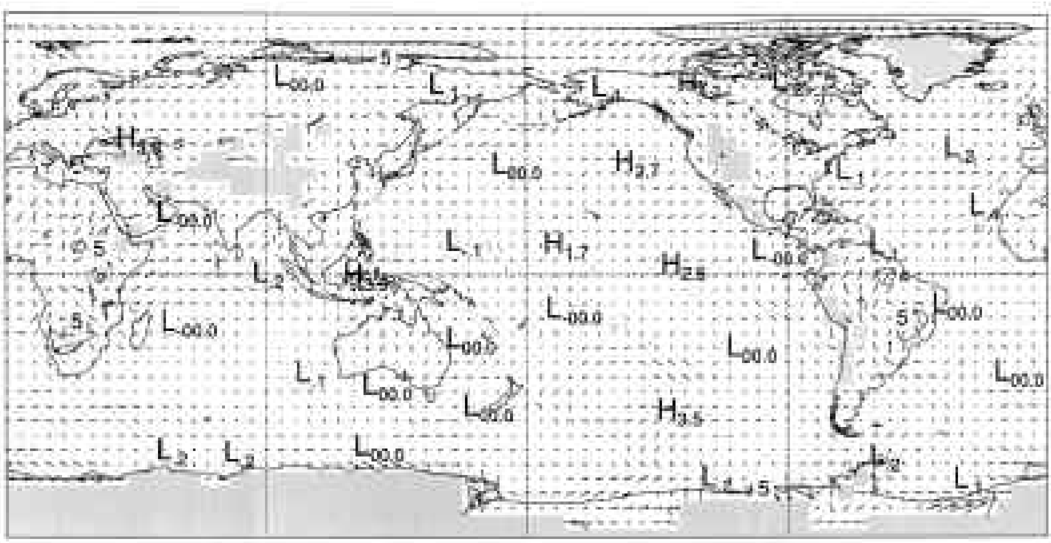
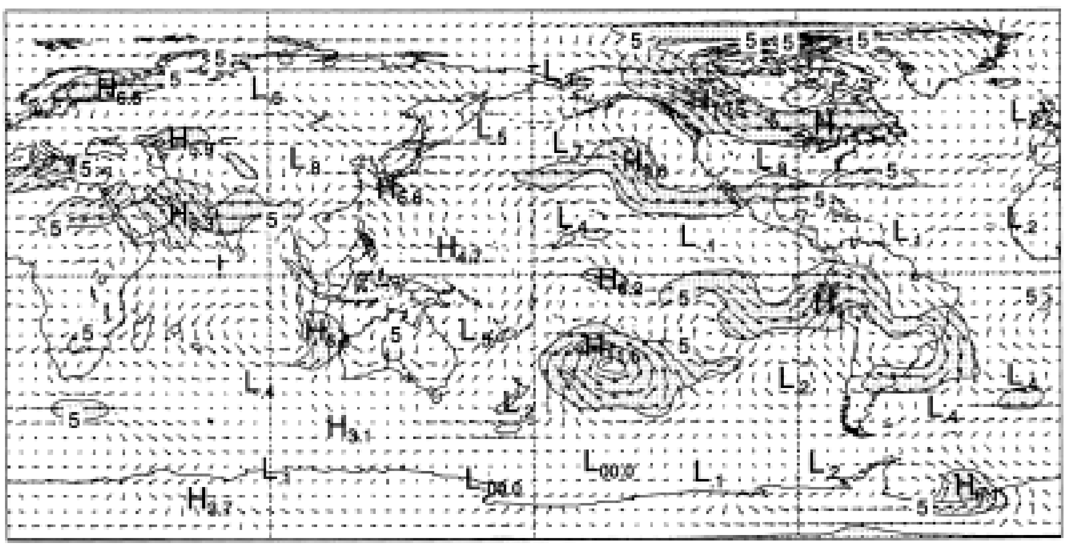


Fig. 13 **Autumn 2004 200 hPa vector wind anomalies with contours of vector magnitude overlayed. The contour interval is 5 m s^{-1}, with values above 5 m s^{-1} stippled.**



Cairns, as a result of a very wet March (Cairns Airport received 1102 mm for the month, 262 per cent of normal and just short of a record).

The year 2004 saw a dry start to the winter wet season in the southwest of Western Australia. April was particularly dry as a percentage of normal, although this is a month with high natural rainfall variability in this region. Perth Airport only received 15.6 mm (19 per cent of normal) for the period from January to April.

At the end of May, severe rainfall deficiencies for the five months from January to May existed through

Fig. 14 **Rainfall totals over Australia for autumn 2004 (mm).**

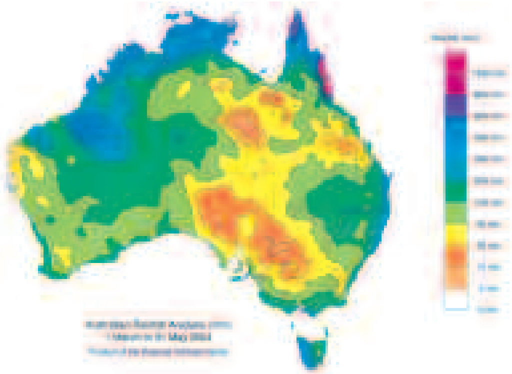


Fig. 16 **Autumn 2004 maximum temperature anomalies for Australia based on a 1961-90 mean (°C).**

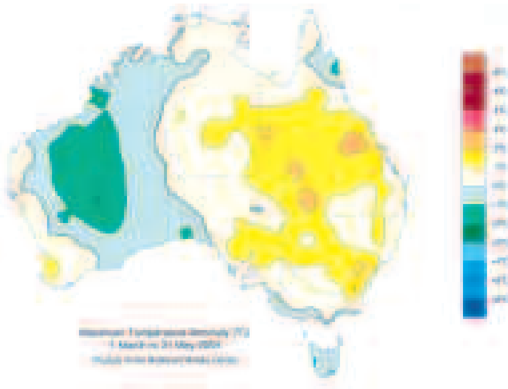


Fig. 15 **Autumn 2004 rainfall deciles for Australia: decile range based on grid-point values over the autumn periods from 1900 to 2004.**

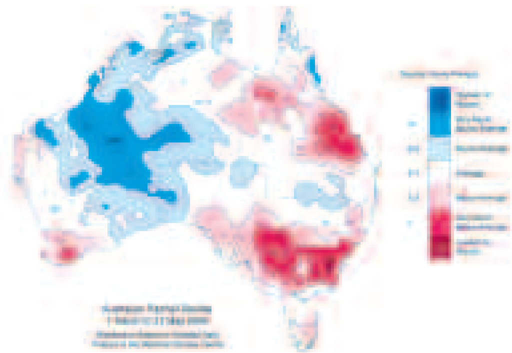
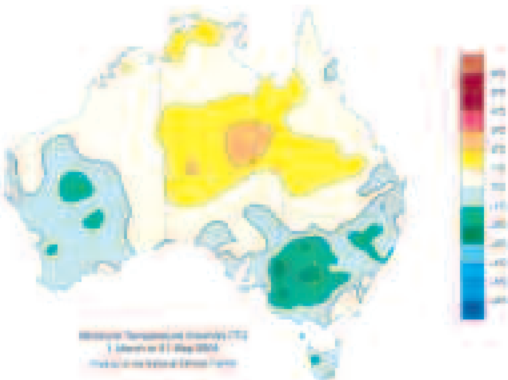


Fig. 17 **Autumn 2004 minimum temperature anomalies for Australia based on a 1961-90 mean (°C).**



much of southern inland New South Wales, northern Victoria and the agricultural areas of South Australia. Longer term (23-month) deficiencies were concentrated in the southeast of New South Wales, particularly in the Monaro district from Canberra southwards, and southern Victoria from Melbourne eastwards. Long-term deficiencies also persisted along the Queensland coast around and north of Mackay.

Table 1 summarises seasonal rainfall ranks and extremes on a national and State basis.

Temperatures

Maximum and minimum temperature anomalies for autumn 2004, calculated with respect to the 1961-90 period, are shown in Figs 16 and 17 respectively. These analyses use the entire temperature observation network. A subset of the network consisting only of high-quality stations is used for generating parallel analyses, from which area averages and rankings have been calculated (Tables 2 and 3).

Averaged across Australia as a whole, both maximum and minimum temperatures for autumn were slightly above average, with seasonal anomalies of +0.41°C and +0.17°C respectively. It was a generally cool season in Western Australia and Tasmania and a warm one in most of Queensland and the Northern Territory, whilst in much of the southeast maximum temperatures were above normal and minimum temperatures below normal, which was consistent with the generally dry conditions. April was a warm month through most of the country, with record high mean maximum temperatures in parts of inland New South Wales, whereas March and May saw cool maximum temperatures in interior Western Australia, and cool minimum temperatures across most of southern Australia.

Table 1. Summary of the seasonal rainfall ranks and extremes on a national and State basis.

	Highest seasonal total (mm)	*Lowest seasonal total (mm)*	*Highest 24-hour fall (mm)*	*Area-averaged rainfall (AAR) (mm)*	*Rank of AAR**
Australia	4842 at Bellenden Ker (Top Station) (Qld)	0 at several locations (Queensland)	525 at Nifty Copper Mine (WA) on 28 March	121	71
WA	836 at Nifty Copper Mine	6 at Warroora	525 at Nifty Copper Mine on 28 March	152	95
NT	850 at Alcan Minesite (Groote Eylandt)	0.4 at Elkedra	313 at Groote Eylandt on 2 March	148	70
SA	257 at Piccadilly	3 at Lilydale	68 at Piccadilly on 18 May	42	52
QLD	4842 at Bellenden Ker (Top Station)	0 at several locations	448 at Mourilyan Harbour on 20 March	119	40
NSW	595 at Upper Orara	1 at Kars	352 at Mount Numinbah on 6 March	82	17
VIC	453 at Wyelangta	7 at Lake Cullulleraine	154 at Lindenow on 24 April	93	11
TAS	878 at Mount Read	63 at Austin Vale	108 at St Marys on 12 April	241	35

* The rank goes from 1 (lowest) to 105 (highest) and is calculated on the years 1900 to 2004 inclusive.

Table 2. Summary of the seasonal maximum temperature ranks and extremes on a national and State basis.

	Highest seasonal mean (°C)	*Lowest seasonal mean (°C)*	*Highest daily recording (°C)*	*Lowest daily recording (°C)*	*Anomaly of area-averaged mean (AAM) (°C)*	*Rank of AAM**
Australia	34.9 at Wyndham (WA)	8.2 at Mount Read (Tas)	44.0 at Eneabba (WA) on 22 March	-2.5 at Thredbo (Top Station) (NSW) on 27 May	+0.41	40
WA	34.9 at Wyndham	20.8 at Albany	44.0 at Eneabba on 22 March	8.9 at Corrigin on 31 May	–0.51	13
NT	34.6 at McArthur River Mine	27.7 at Kulgera	42.5 at Jervois on 8 March	9.2 at Yuendumu on 29 May	+0.52	37
SA	29.5 at Oodnadatta	16.1 at Mount Lofty	43.0 at Nullarbor on 3 March	7.6 at Mount Lofty on 27 May	+0.66	44
QLD	34.7 at Julia Creek	21.5 at Applethorpe	42.9 at Birdsville on 8 March	13.0 at Applethorpe on 27 and 29 May	+1.15	50
NSW	28.3 at Wanaaring	9.9 at Thredbo (Top Station)	43.2 at Brewarrina on 9 March	-2.5 at Thredbo (Top Station) on 27 May	+1.20	52
VIC	24.5 at Mildura	9.2 at Mount Hotham	39.3 at Nhill on 4 March	-1.8 at Mount Hotham on 27 May	+0.43	45
TAS	18.2 at Flinders Island AP	8.2 at Mount Read	32.7 at King Island on 4 March	-0.8 at Mt Wellington on 28 May	–0.44	18

* The temperature ranks go from 1 (lowest) to 55 (highest) and are calculated on the years 1950 to 2004 inclusive.

In Queensland autumn mean temperatures (anomaly +0.92°C) were the fourth-highest on record, with March (+1.11°C) ranked third, consistent with the early end to the wet season in much of the State. Both maximum and minimum temperatures were generally above normal in all three months. The warmth was most significant in central and southwestern parts of the State but influenced most areas apart from Cape York Peninsula.

Maximum temperatures were above normal throughout the southeast mainland, except along exposed parts of the Victorian coast. An area north and west of the Australian Capital Territory had its highest mean maximum temperatures on record for autumn. In contrast, much of this region saw minimum temperatures well below normal. May was a particularly cool month with anomalies locally reaching –4°C around Renmark. Whilst few records were

Table 3. Summary of the seasonal minimum temperature ranks and extremes on a national and State basis.

	Highest seasonal mean (°C)	*Lowest seasonal mean (°C)*	*Highest daily recording (°C)*	*Lowest daily recording (°C)*	*Anomaly of area-averaged mean (AAM) (°C)*	*Rank of AAM**
Australia	26.4 at Troughton Island (WA)	0.9 at Liawenee (Tas)	30.2 at Nyang (WA) on 6 March	-9.1 at Charlotte Pass (NSW) on 11 May	+0.17	39
WA	26.4 at Troughton Island	7.9 at Collie East	30.2 at Nyang on 6 March	-2.1 at Southern Cross on 14 May	–0.19	23
NT	26.1 at McCluer Island	13.9 at Alice Springs	9.2 at Jervois on 17 March	1.6 at Kulgera on 3 May	+0.83	46
SA	16.0 at Moomba	6.9 at Yongala	29.0 at Port Pirie and Noarlunga on 4 March	-4.6 at Gluepot on 12 May	+0.34	35
QLD	25.7 at Coconut Island	9.7 at Applethorpe	29.3 at Mornington Island on 24 March	-3.4 at Warwick on 31 May	+0.68	45
NSW	17.9 at Byron Bay	1.0 at Thredbo Village	24.3 at Narrabri on 9 March	-9.1 at Charlotte Pass on 11 May	–0.70	16
VIC	13.6 at Gabo Island	2.7 at Mount Hotham	24.9 at Cape Nelson on 4 March	-6.7 at Mount Hotham on 2 May	–0.99	9
TAS	12.4 at Swan Island	0.9 at Liawenee	20.1 at Maatsuyker Island on 4 March	-5.3 at Tunnack on 4 April	–0.75	6

* The temperature ranks go from 1 (lowest) to 55 (highest) and are calculated on the years 1950 to 2004 inclusive.

set, large parts of northern Victoria and southwestern New South Wales had minimum temperatures in the lowest decile, as did northern Tasmania.

Conditions were rather cool in most of Western Australia but not exceptionally so, with only a few locations in the lowest decile for either maximum or minimum temperature, and no seasonal records set. The largest anomalies occurred in March, where maximum temperatures were around 3°C below normal in parts of the southern interior.

Appendix

The main sources for data used in this review were:

- National Climate Centre, *Climate Monitoring Bulletin - Australia*. Obtainable from: National Climate Centre, Bureau of Meteorology, GPO Box 1289K, Melbourne, Vic. 3001, Australia.
- The Bureau of Meteorology's *Monthly Significant Weather Summaries*. Obtainable from: http://www.bom.gov.au/inside/services_policy/public/sigwxsum/sigwmenu.shtml
- Climate Prediction Center, *Climate Diagnostics Bulletin*. Obtainable from: Climate Prediction Center, National Weather Service, Washington D.C., USA, 20233.

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