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Seasonal climate summary southern hemisphere (summer 2003/04): a warm summer in the east and wet conditions in the northwest

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Atmospheric and oceanic conditions in the southern hemisphere are reviewed for the 2003/04 austral summer season. Particular emphasis is given to the Australian and Pacific regions. The neutral conditions in the tropical Pacific which arose after the end of the El Niño of 2002/03 persisted through the summer, although there was considerable fluctuation in some atmospheric indices. Sea-surface temperatures in the tropical Pacific were generally above average for the time of year, particularly so in the west. The tropical Indian Ocean was also generally warmer than average. Summer rainfall across Australia was generally near-average or above average. Apart from some areas in the tropical north, summer temperatures were generally above average with respect to the 1961/90 base period, with significant areas in the eastern half of the country having record high seasonal minimum temperatures.

Introduction

After the demise of the El Niño in the equatorial Pacific during autumn 2003 (Beard 2004), neutral conditions remained through the winter (Dawkins 2004), spring (Watkins 2004) and subsequent summer. In spite of considerable month-to-month fluctuation, the Southern Oscillation Index (SOI) had a seasonally averaged value of just +2.3. Against this, sea-surface temperatures in the tropical Pacific were slightly above average, as was the Multivariate ENSO Index (MEI). A strong pulse in the Madden Julian Oscillation was associated with the onset of the monsoon over northern Australia in mid-December.

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Rainfall was above average over most of the western and northern halves of Australia. Near-average rainfall predominated over the remainder of the country, with only small areas receiving below or very much below average rainfall. Some highest on record summer rainfalls were recorded in the northern half of the Northern Territory and adjacent parts of northeast Western Australia.

Seasonal maximum and minimum temperatures showed similar patterns, with positive anomalies being recorded across most of the country and negative anomalies along the southern coastal fringes. Only in the north of the country was there much difference in the patterns, with much stronger negative maximum temperature anomalies being recorded in northern Western Australia and northern parts of the Northern Territory.

Data

The main sources of information used for this summary were the *Climate Monitoring Bulletin – Australia* (Bureau of Meteorology, Melbourne, Australia) and the *Climate Diagnostics Bulletin* (Climate Prediction Center, Washington D.C., U.S.A.). Tropical cyclone information was obtained from the Bureau of Meteorology's *Monthly Significant Weather Summaries*. Data sources are given in the Appendix.

Pacific basin climate indices

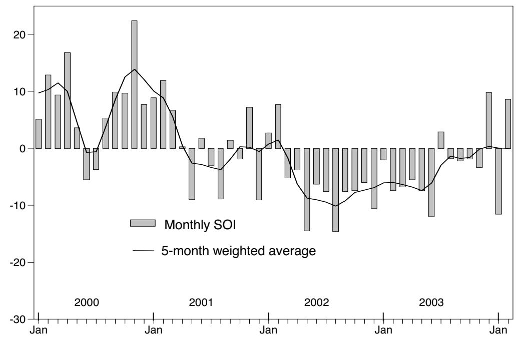
The Southern Oscillation Index (SOI)*

The neutral values of the Troup Southern Oscillation Index (SOI) during the austral spring of 2003 (Watkins 2004) were maintained through the summer. The December, January and February SOI values were +9.8, –11.6 and +8.6 respectively, resulting in a mean summer value of the SOI of +2.3 (Fig. 1). The running 30-day approximate values of the Tahiti-Darwin mean sea-level pressure (MSLP) difference were consistent with these values, rising above one standard deviation from climatological values in December before falling steeply in January to be more than one standard deviation below climatological values. By the end of the season, they had risen to almost one standard deviation above average.

During the season, daily MSLP values at Darwin were often close to average, with one strong excursion to strongly below-average values late in December and some weaker excursions in the first half of February. These fluctuations were associated with the passage of active phases of the Madden Julian Oscillation (MJO) and concomitant westerly wind bursts. In contrast, Tahiti's daily MSLP values stayed fairly consistently above average in December, only to drop steeply during the early part of January. This was followed by a steady rise in pressure through the second half of January and first half of February, although by the end of the season pressures had fallen again. Overall, the impact of the MJO active phases upon the Darwin, and arguably also the Tahiti, MSLP were the main cause of the large monthly differences in the value of the SOI. This weather impact upon the index suggests that the seasonal SOI value, rather than the individual monthly values, was more indicative of the background climatic state of the Pacific.

*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 February 2004 inclusive. Means and standard deviations based on the period 1933-92.



The neutral state of the tropical atmosphere suggested by the SOI is supported by the values of the Climate Diagnostics Center (CDC) Multivariate ENSO Index (MEI) (Wolter and Timlin 1993, 1998), a two-monthly index derived from a number of atmospheric and oceanic parameters typically associated with El Niño and La Niña, with negative values indicating cooler conditions and positive values indicating warmer conditions. The two MEI values covering the season were +0.312 (Dec/Jan) and +0.365 (Jan/Feb). The first of these two values was ranked 33.5 out of 55, while the second was ranked 35 out of 55. The authors of this index consider ranks above 38 to indicate weak to strong El Niño conditions (essentially the top third of the distribution), and ranks above 45 to indicate moderate to strong El Niño events (essentially the top fifth of the distribution).

Outgoing long wave radiation

The time series from January 2000 to February 2004 of monthly standardised Outgoing Long wave Radiation (OLR) anomalies for the region from 5ºN to 5ºS, 160ºE to 160ºW, is shown in Fig. 2. These data were provided by the Climate Prediction Center, Washington D.C. (CPC 2003, 2004). Negative (positive) values of the OLR index suggest cooler (warmer) black-body temperatures, which tend to be associated with an increase (decrease) in high cloud amount. (This may also signal increased rainfall.) Studies have shown that during El Niño events, OLR is generally reduced (i.e. convection is generally enhanced) along the equator, particularly near and east of the date-line. During La Niña events, OLR is often increased (i.e. convection is often suppressed) over the same region.

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 February 2004. Negative (positive) anomalies indicate enhanced (reduced) convection and rainfall. Anomalies are based on a 1979-95 base period. After CPC (2003, 2004).**

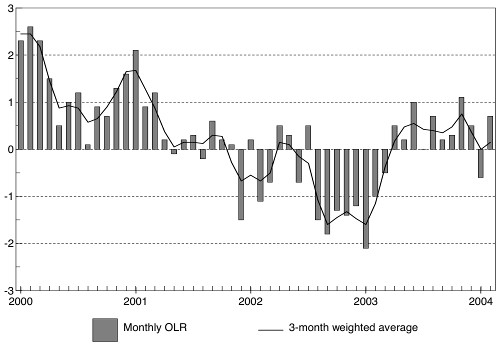
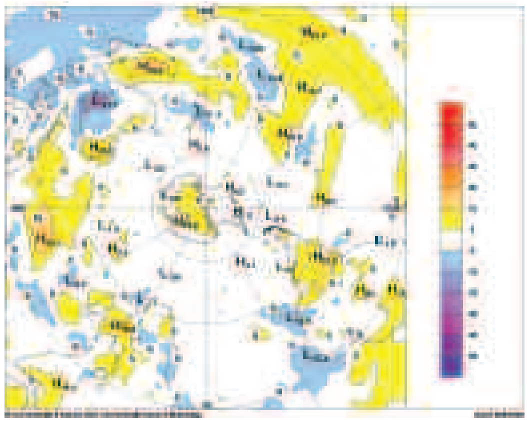


Fig. 3 **Anomalies of outgoing long wave radiation for summer 2003/04 (W m^{-2}), based on a base period of 1979-98.**



During the individual months of summer 2003/04, the standardised OLR anomaly for this region fell from +0.5 in December to –0.6 in January and rose again to +0.7 in February. This pattern followed closely the behaviour of the SOI through the three summer months, and arguably reflects to some degree the passage of active MJO phases. The summer values were in marked contrast to those of the previous summer, which showed negative but rising values consistent with the end of the El Niño.

Figure 3 shows the spatial pattern of OLR anomalies for the southern hemisphere observed during the season. The pattern of anomalies across the equatorial Pacific showed considerable similarity to that of the previous spring (Watkins 2004), with negative anomalies (increased convection) in the far western equatorial Pacific and positive anomalies (decreased convection) east of about 170°E. In both seasons, the region of increased OLR extended far to the east of the date-line. This pattern is arguably more typical of cool ENSO conditions.

A time-longitude section of OLR anomalies averaged between 7.5°S and 7.5°N (not shown) showed an active phase of the Madden Julian Oscillation (MJO) beginning around 80°E at the start of December, arriving at the date-line a month later. This active phase, which coincided with the onset of the monsoon over northern Australia in mid-December, propagated out to around 150°W before dissipating. It was followed by an inactive phase also beginning around 80°E and a second but shorter lived active phase. This latter phase propagated only as far as 160°E. For the last two weeks of the summer however, there was little MJO signal.

Over Australia, the OLR was below average (increased convection) over much of the north, consistent with the above average summer rainfall (see below), but near-average to below average across the southern half of the country and eastern coastal parts. The strongest anomaly was –31.5 W m^{-2}, immediately to the west of the Gulf of Carpentaria.

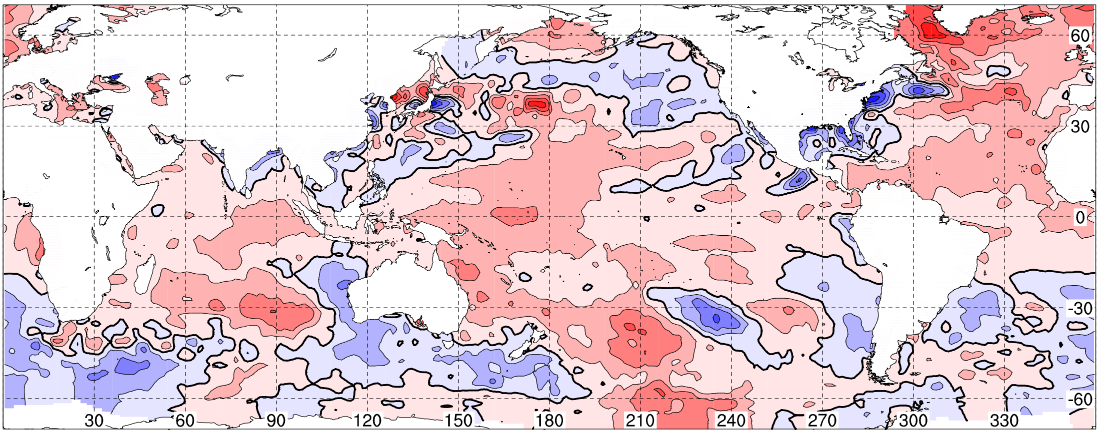
Ocean patterns

Sea-surface temperature (SST) patterns

Despite the generally neutral state of the equatorial atmosphere, indicated by the positive seasonal average of the SOI, the summer 2003/04 SST anomaly distribution (Fig. 4) showed weak to moderate positive anomalies across most of the tropical Pacific. East of about 170°W, the equatorial Pacific anomalies were generally between 0°C and +0.5°C. To the west however, there were widespread anomalies between +0.5°C and +1.0°C from about 10°S to about 15°N, with peak anomalies on the equator at about 165°E (exceeding +1°C).

The seasonal pattern in the western equatorial Pacific masks a general weakening of the monthly anomalies in this area through the summer, at the cost however of strong anomalous warming further south from the Coral Sea across the north of New Zealand

Fig. 4 Anomalies of sea-surface temperature for summer 2003/04 (°C). Positive anomalies are shown in red and negative anomalies are shown in blue. Contour interval is 0.5°C.



and down into the central South Pacific. The NINO4 index declined from +0.81°C in December to +0.58°C in February, while the NINO3 index declined from +0.52°C in December to +0.35°C in February. In the far east of the Pacific, there were mixed signals, with warming in the NINO1 region of nearly 1°C between the first and last weeks of summer (although this was less obvious in the monthly anomalies which rose from +0.19°C in December to +0.59°C in February), but cooling in the adjacent NINO2 region.

The tropical Indian Ocean was also warmer than average, with an area of +0.5°C to +1.0°C anomalies straddling the equator between 75°E and 100°E. Stronger anomalies were observed further south however, with peak anomalies reaching +1.5°C at 30°S 90°E. Anomalies were negative though along the southern and most of the western coasts of Australia, with anomalies below –1.0°C observed on the coast at Exmouth (WA).

The mid-latitudes showed mixed SST patterns. The Southern Ocean was mostly cooler than average between 30°S and 60°S. This contrasted with strong positive anomalies further east in the central South Pacific, peaking at +1.5°C around 35°S 150°W. The anomaly patterns were smaller in spatial scale between 130°W and 30°W, but a larger area of cooler than average waters was present between 30°W and 60°E.

Subsurface ocean patterns

The Hovmöller diagram for the 20°C isotherm depth anomaly across the equator from January 2001 to February 2004 is shown in Fig. 5. The 20°C isotherm depth is generally situated close to the equatorial ocean thermocline, the region of greatest temperature gradient with depth and the boundary between the warm near-surface and cold deep ocean water. Changes in the thermocline depth may act as a precursor to future changes at the surface.

The main patterns apparent for summer are two Kelvin waves, the first being an upwelling Kelvin wave (negative anomalies) which originated near the dateline in the middle of December and propagated across the Pacific reaching 90°W by late season.

A month later, a downwelling Kelvin wave (positive anomalies) originated further west at about 160°E, triggered by a westerly wind burst in the region in the first half of January. While this second Kelvin wave weakened more rapidly, a weak signature could be seen reaching the far eastern Pacific in early autumn.

The cooling in the western equatorial Pacific as the summer progressed is also visible in the equatorial Pacific temperature anomaly profile (Fig. 6) which shows temperature anomalies down to 400 metres for the months November 2003 to February 2004. While the situation in November consisted of average to slightly warm conditions near the surface, in December negative anomalies developed on the equator in the central Pacific at a depth of 100 to 200 m, probably as a result of strong easterly trade wind anomalies that propagated from the maritime continent to the central Pacific between early December and early January. In January these negative anomalies moved eastward, and towards the surface somewhat, whilst intensifying. The residual positive anomalies in the west between about 160°E and 180° also intensified from December to January, although this warming trend was entirely reversed by February. The cool anomalies however extended their spatial extent,

Fig. 5 **Time-longitude section of the monthly anomalous depth of the 20°C isotherm at the equator for January 2001 to February 2004. Base period: 1979-89. Contour interval is 10 m.**

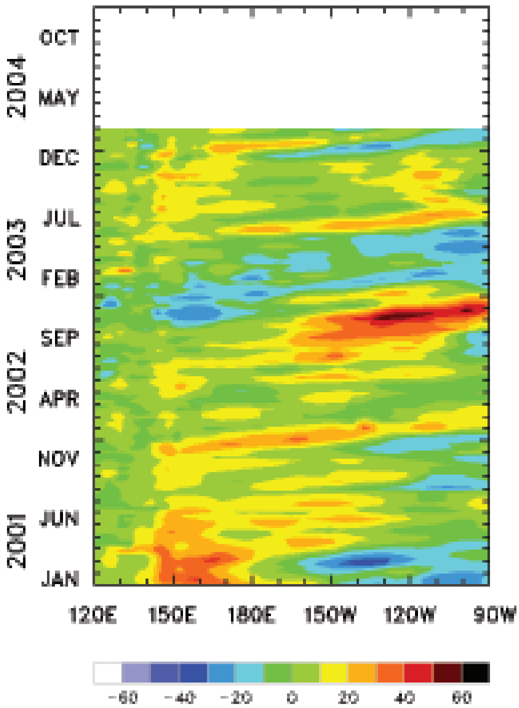
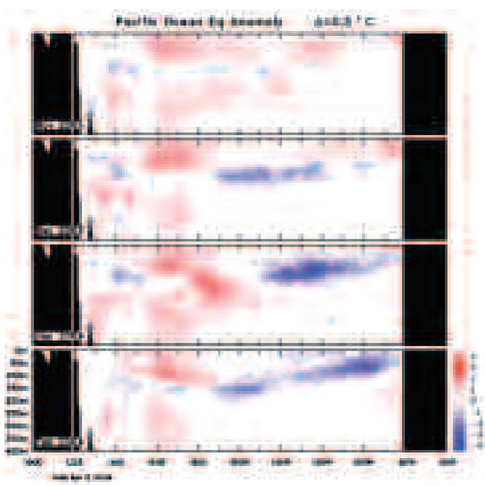


Fig. 6 **Four-month November 2003 to February 2004 sequence of vertical temperature anomalies at the equator. Contour interval is 0.5°C.**



so that in February they ranged from a depth of around 150 m at 170°W to near the surface at 90°W.

Surface analyses

The southern hemisphere summer 2003/04 mean sea level pressure (MSLP) pattern, computed from the Australian Bureau of Meteorology's Global Assimilation and Prediction (GASP) model, is shown in Fig. 7, with the corresponding anomaly pattern provided in Fig. 8. These anomalies are the difference from a 22-year (1979-2000) climatology obtained from the National Centers for Environmental Prediction (NCEP) II Reanalysis data (Kanamitsu et al. 2002).

The summer MSLP pattern in Fig. 7 displayed a three-wave pattern, with the trough axes located at around 110°E, 110°W and 10°E. The polar trough itself had minima at these longitudes, all three dropping to around 985 hPa. Peak values in the subtropical ridge were located at around 35°S to 40°S in the southern Indian and Pacific Oceans, but slightly further north in the southern Atlantic Ocean.

The MSLP anomaly distribution (Fig. 8) for summer showed patterns which were not especially strong, with anomalies only exceeding 5 hPa in magnitude around the Ross Sea. A broad area of lower than average pressure covered New Zealand and southeastern Australia, with the peak anomaly of –4 hPa located south of New Zealand.

Apart from the previously mentioned area of below average pressure across southeastern Australia, pressures in the Australian region were mostly above average. The major exception was a small area of below average pressure covering inland southern Western Australia extending eastward into the centre of the continent.

Mid-tropospheric analyses

The 500 hPa geopotential height (an indicator of the steering of surface synoptic systems) across the southern hemisphere is shown in Fig. 9, and anomalies in the 500 hPa field are displayed in Fig. 10.

The 500 hPa height field (Fig. 9) showed a three-wave pattern similar to that of Fig. 7. Once again there was a split in the flow east of Australia, although this summer it was further eastward than on some previous occasions.

As with the MSLP values, the anomaly field (Fig. 10) was not particularly strong. To the south of Australia, there was a broad region of below average heights, with a peak anomaly of –54 gpm located at around 150°E.

Fig. 7 Mean sea-level pressure for summer 2003/04 (hPa).

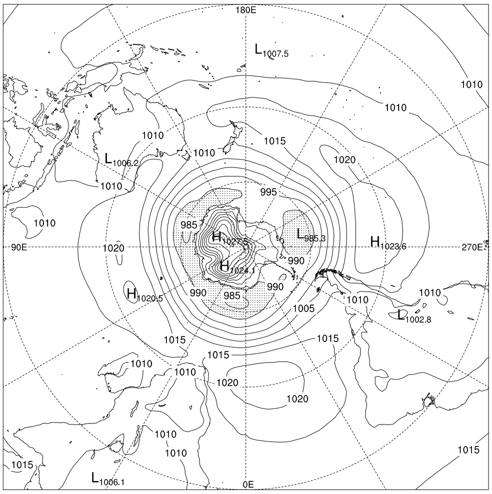
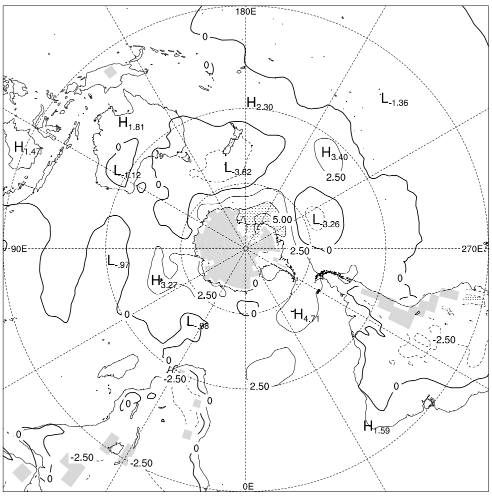


Fig. 8 Anomalies of the mean sea-level pressure from the 1979-2000 National Centers for Environmental Prediction reanalysis II climatology, for summer 2003/04 (hPa).



Blocking

The time-longitude section of the daily southern hemisphere blocking index (BI)* is shown in Fig. 11. This index is a measure of the strength of the zonal 500 hPa flow in the mid-latitudes relative to that at subtropical and high latitudes. Positive values of the blocking index are generally associated with a split in the mid-latitude westerly flow centred near 45°S and mid-latitude blocking activity.

The BI values during the summer showed only one relatively strong blocking event (as indicated by BI values exceeding +60 m s^{-1}). This was at the end

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

Fig. 9 Mean 500 hPa geopotential heights for summer 2003/04 (gpm).

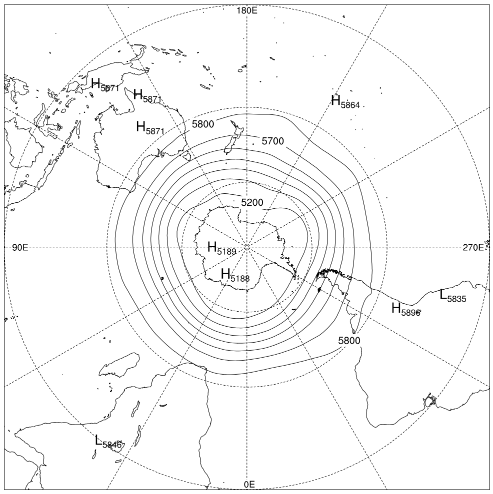


Fig. 10 Anomalies of the 500 hPa geopotential height from the 1979-2000 National Centers for Environmental Prediction reanalysis II climatology, for summer 2003/04 (gpm).

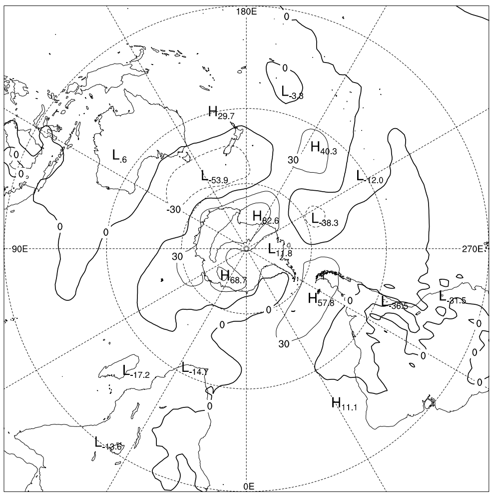


Fig. 11 Summer 2003/04 daily blocking index: time-longitude section. Day 1 is 1 December.

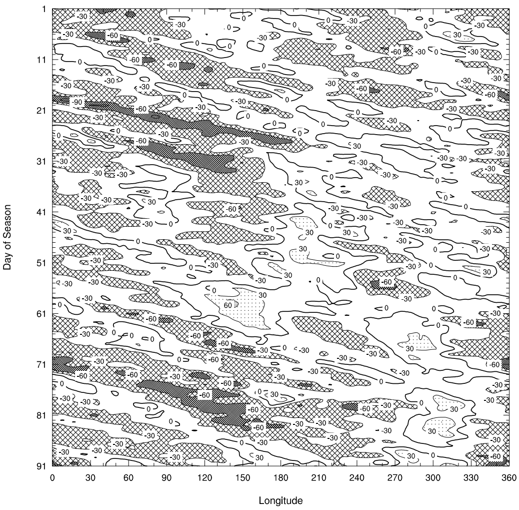
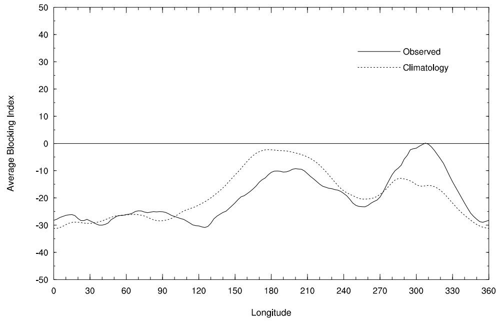


Fig. 12 Mean southern hemisphere blocking index for summer 2003/04 (bold line). The dashed line shows the corresponding long-term average. The horizontal axis shows the degrees east of the Greenwich meridian.



of January/beginning of February, and peak BI values were located around 140°E, east of the region of peak climatological blocking (see Fig. 12). Towards the end of the season, there were two weaker blocking events in the western hemisphere (around 60°W to 70°W).

In contrast, there were three episodes of relatively strongly suppressed blocking (as indicated by BI values well below –60 m s^{-1}). Two of these were in late December, almost forming a combined event, the third in mid-February. The first and third of these three episodes were preceded by weaker blocking events about 10 days prior (as indicated by BI values peaking around –60 m s^{-1}).

The seasonal mean blocking index is shown in Fig. 12. The region of peak climatological blocking (160°E to 120°W) saw reduced blocking during the season. This was consistent with Fig. 10, with its implied anomalous mid-level westerlies at around 40°S to 45°S south of Australia and across New Zealand. Instead, the peak blocking for the season was located in the western hemisphere (around 50°W). Between 0°E and 100°E, seasonal blocking was very close to average.

Low and upper-level winds

Summer 2003/04 low-level (850 hPa) and upper-level (200 hPa) wind anomalies (from the 22-year NCEP II climatology) are shown in Figs 13 and 14 respectively.

At the low levels the wind anomalies generally reflected the MSLP anomalies (Fig. 8). The strongest anomalies (exceeding 5 m s^{-1}) in the southern hemisphere were located over central and eastern South America, although the Pacific Ocean between 60°S and 70°S exhibited easterly anomalies peaking at just under 5 m s^{-1}. Anomalies along the equatorial Pacific region were quite weak, with cross-equatorial characteristics in the far western and far eastern parts. In the western equatorial Indian Ocean, there was weak anomalous southwesterly cross-equatorial flow.

The western half of Australia saw generally northerly anomalies in the low levels. Across eastern Australia, these tended westerly, forming the northern part of an anomalous cyclonic circulation centred south of the Tasman Sea.

The upper levels also exhibited generally weak anomalies across the equatorial Pacific region, although in the far east just south of the equator westerly anomalies in excess of 10 m s^{-1} were observed.

An anticyclonic anomaly pattern was located just off the west coast of Australia, while an anomalous cyclonic pattern covered much of the Southern Ocean. This latter pattern corresponded to a similar pattern at the surface, possibly indicating a southward shift of the subtropical jet across Australian longitudes.

Australian region

Tropical cyclones

In the second half of December, tropical cyclone (TC) *Debbie* formed in the Arafura Sea, reached category 3 intensity and crossed the coast of the Top End of the

Fig. 13 Summer 2003/04 850 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.

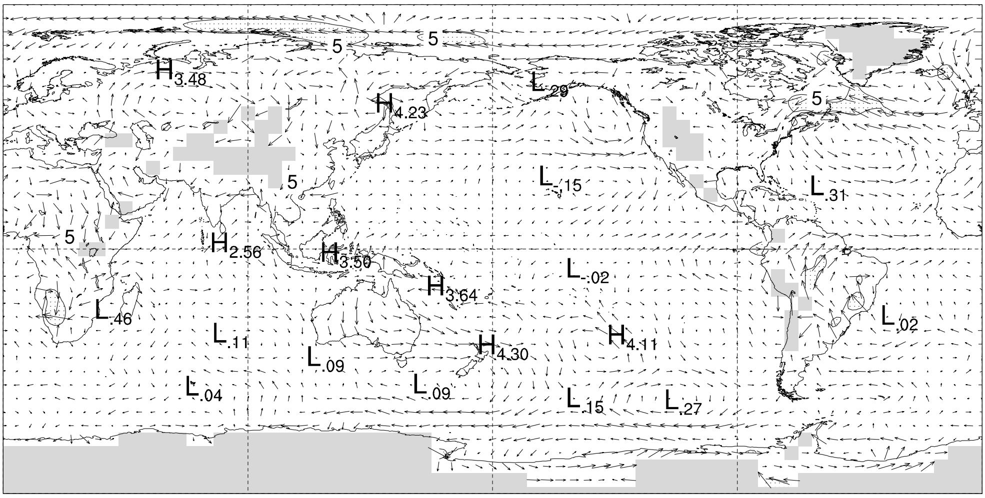
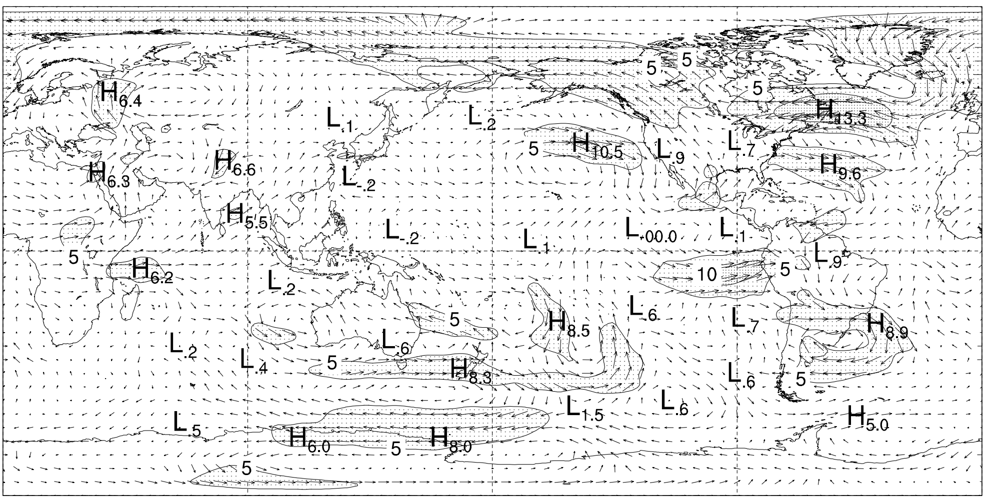


Fig. 14 Summer 2003/04 200 hPa vector wind anomalies with contours of vector magnitude overlayed. The contour interval is 5 m s^{-1}, with values above 5 m s^{-1} stippled.



NT. After decaying into a tropical low pressure system, it tracked into northern Western Australia. In the first week of January, TC *Ken* formed briefly off the Kimberley coast of WA and decayed into a tropical low before crossing the coast. TC *Fritz* formed in the Coral Sea in the first half of February, crossed the Queensland coast just south of Cape Melville, weakening to tropical low status before re-intensifying in the southern Gulf of Carpentaria. As an ex-TC, it moved from the NT/Qld border across the Gulf country, northern Barkly and Victoria River districts, producing heavy rain and flooding. It then moved across the southern Kimberley of WA, through the Pilbara and eventually off the Gascoyne coast. The system brought much-needed rains to the drought affected regions of the Gascoyne.

The strongest tropical cyclone of the summer occurred at the end of February. TC *Monty* formed into a tropical cyclone late on 27 February off the Kimberley coast near Broome. It moved roughly parallel to the Pilbara coast, developing to category 4 intensity before moving toward the west Pilbara coast on the 1 March. It crossed the coast as a category 3 system later that day near Mardie station, between Onslow and Dampier, and produced widespread rainfall over the Pilbara with significant flooding.

Rainfall

The distribution of Australian rainfall totals for summer 2003/04 is shown in Fig. 15, whilst Fig. 16 shows the associated decile ranges based on gridded rainfall data for all summers from 1900/01 to 2003/04.

Highest rainfall totals for the season were recorded in the north of the country, with several locations in coastal and near coastal parts of the Northern Territory recording more than 1200 mm. Several locations in northern Queensland, including Cape York, Weipa and Cairns-Innisfail-Tully also recorded more than 1200 mm. Most areas north of 17°S recorded more than 600 mm.

Lowest rainfall totals for the season were recorded along the southwest coast of Western Australia, near Geraldton and Perth, where less than 10 mm was recorded. Much of the northeast of South Australia recorded less than 25 mm.

Rainfall for the season was above average (deciles 8, 9) to very much above average (decile 10) across much of the country, including most of central and eastern Western Australia, western and northern parts of the Northern Territory, and a band stretching from the southern Gulf of Carpentaria into northeastern New South Wales. (This band was mainly the result of a monsoon low drifting southeast from the southern Gulf to northern New South Wales during the middle of January. The rain was sufficient for declarations of the end of drought conditions in some parts.) The area of very much above-average rainfall covered much of the northern half of the Northern Territory and most of the border area with Western Australia. An area immediately to the south of Katherine (NT) recorded highest on record rainfall for the summer, as did an area on the border with Western Australia to the northeast of Halls Creek (WA). Smaller areas of highest on record rainfall were recorded to the west and east of Balgo Hills (WA) and over Arnhem Land (NT).

In area-averaged terms, the summer rainfall across the Northern Territory was the fourth highest of the past 104 years with the area-averaged December rainfall being the third highest of the past 104 years and the February rainfall being the fifth highest of the past 105 years. Nationally, the area-averaged rainfall for summer was 295 mm, the eighth highest summer average of the past 104 years.

Fig. 15 **Rainfall totals over Australia for summer 2003/04 (mm).**

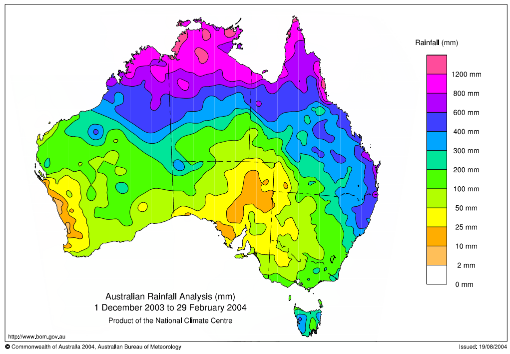
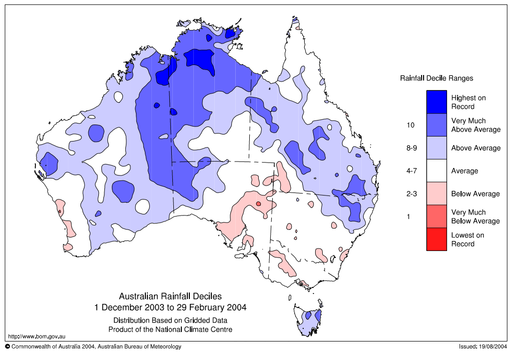


Fig. 16 **Summer 2003/04 rainfall deciles for Australia: decile range based on grid-point values over the summer periods from 1900/01 to 2003/04.**



The monthly area-averaged rainfalls used in these assessments begin in 1900.

Most of the rest of the country recorded near average rainfall (deciles 4 to 7), although there were scattered small areas recording below-average rainfall (deciles 2, 3) in the southwest of Western Australia, eastern South Australia, western Victoria, New South Wales and southwest Queensland.

Central and eastern Tasmania recorded above to very much above average rainfall for the summer. This overall result masked the fact that most of the summer rainfall fell in January, with December and February recording only near average or below average rainfall. In contrast, January rainfall was very much above average across most of Tasmania, with highest on record January totals being recorded in the state's northeast and central north. In area-averaged terms, this was the wettest January for the State in the past 105 years.

Table 1. Rainfall

	Highest seasonal total (mm)	*Lowest seasonal total (mm)*	*Highest 24-hour Fall (mm)*	*Area-Averaged rainfall (AAR) (mm)*	*Rank of AAR**
Australia	2759 at Bellenden Ker Top Station (QLD)	Zero at several locations (WA)	370 at Bellenden Ker Top Station (QLD) on 12 February	295	97
WA	1241 at Kuri Bay	Zero at several locations	179 at Kuri Bay on 25 December	235	92
NT	1709 at Tindal	44 at Andado	284 at Tindal on 23 December	555	101
SA	328 at Kanypi	6 at Umberatana	114 at Kanypi on 27 December	62	67
QLD	2759 at Bellenden Ker Top Station	17 at Nappa Merrie	370 at Bellenden Ker Top Station on 12 February	405	86
NSW	1022 at Mount Seaview	14 at Pine View	250 at Chillingham on 25 February	163	64
VIC	379 at Mount Hotham	21 at Avoca	120 at Waterford on 3 December	102	38
TAS	709 at Mount Read	97 at Lake Flannigan	237 at Gray on 29 January	273	88

* The rank goes from 1 (lowest) to 104 (highest) and is calculated on the summers of 1900/01 to 2003/04 inclusive.

Temperatures

The summer 2003/04 mean maximum and minimum temperature anomalies, calculated with respect to the reference period 1961-90, are shown in Figs 17 and 18 respectively. These analyses use the entire temperature observation network.

Two large areas, one covering much of inland Western Australia, the other stretching from the far south of the Northern Territory across the northeastern half of South Australia and covering almost all of New South Wales, and then into southern parts of Queensland, recorded maximum temperature anomalies above +1°C (Fig. 17). A substantial band stretching across the middle of New South Wales and into eastern South Australia recorded anomalies above +2°, reaching +3°C in western New South Wales. In contrast, cool conditions were recorded across much of the north of the country, with a large area in the centre of the Northern Territory with anomalies below –2°C, coinciding with the area of decile 10 rainfall totals.

A similar pattern was observed in the minimum temperature anomalies for summer (Fig. 18), with +1°C anomalies extending from central Western Australia across northern South Australia and southern parts of the Northern Territory into the southern half of Queensland and most of New South Wales. Peak anomalies of more than +3°C were recorded around and to the west of Birdsville in southwest Queensland. There were scattered areas of weak negative anomalies in all States except Queensland.

A subset of the network consisting only of high quality stations is used for generating parallel analyses, from which area averages and percentile rankings have been calculated. The Australia-wide mean maximum temperature anomaly for the summer (relative to the 1961-90 mean) was +0.42°C, which is the 13th highest summer value of the post-1950 period. Two states, New South Wales and South Australia, stood out with area-averaged maximum temperature anomalies of +2.06°C and +1.35°C respectively, both third highest in their time series over this period. For a wide area of the east coast from central Queensland to southern New South Wales and extending across far northern New South Wales into northern SA and southeastern parts of the Northern Territory, this was a one-in-ten-year warm summer, with scattered areas recording highest on record values. In contrast, parts of the central Northern Territory and adjacent parts of northern Western Australia, as well as the coastal fringes around Coral Bay and Albany, recorded a one-in-ten-year cool summer.

For the individual months, in area-averaged terms, Victoria and Tasmania recorded their third highest December maximum temperatures (anomalies of +2.47°C and +2.02°C respectively), and New South Wales its highest February temperature (with an anomaly of +2.92°C).

The Australia-wide mean minimum temperature anomaly for the summer was +0.75°C, which was the fourth highest of the post-1950 period. Queensland's area-averaged minimum temperature anomaly,

Fig. 17 **Summer 2003/04 maximum temperature anomalies for Australia based on a 1961-90 mean (°C).**

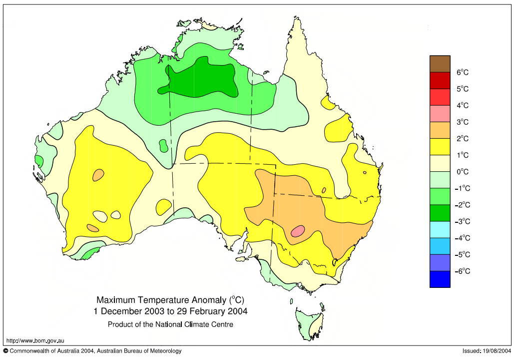
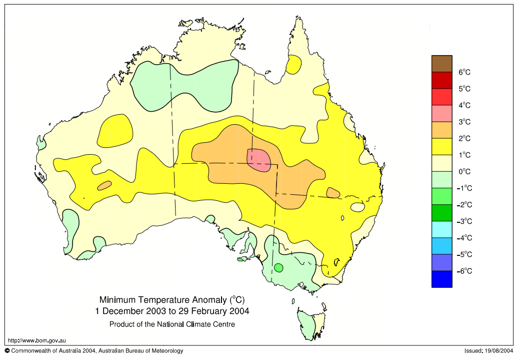


Fig. 18 **Summer 2003/04 minimum temperature anomalies for Australia based on a 1961-90 mean (°C).**



+1.19°C, was the second highest of this period for that state, while South Australia's anomaly, +1.43°C, was the third highest. As with maximum temperature, a broad area covering the northern halves of South Australia and New South Wales, the southern third of the Northern Territory and most of Queensland recorded a one-in-ten-year warm summer with respect to minimum temperature. Two large areas, one covering much of Cape York Peninsula, the other covering southwest Queensland and adjacent southeast parts of the Northern Territory recorded highest on record values.

For the individual months, in area-averaged terms, Queensland, New South Wales and South Australia all recorded their second warmest Decembers with respect to minimum temperature, and Queensland its fourth warmest January.

February saw a notable heatwave across southern and southeastern Australia. The monthly maximum temperature anomaly exceeded +3°C in a band stretching from central South Australia eastward to the central New South Wales coast. In several areas the anomaly exceeded +4°C. The corresponding anomaly for the fortnight ending 19 February 2004 saw a band of +8°C anomalies covering much the same area. The +6°C anomaly area for this period covered most of New South Wales and more than half of South Australia.

As a result of the heatwave, February daily maximum temperature records were set at various locations in SA, NSW, Victoria and Queensland, with annual (i.e., all months) daily maximum temperature records set at Dubbo (NSW) and Brisbane Airport (Qld). New State February records were set for NSW (Ivanhoe, 48.5°C, 15 February) and Victoria (Ouyen, 46.7°C, 14 February). The SA February record of 47.9°C was equalled at Marree on 16 February. On 14 February, 11 Victorian stations exceeded 45°C, compared with only nine previous instances of 45°C or higher in February in the entire historical record. February daily minimum temperature records were also set at various locations in SA, NSW, Victoria and Queensland, with annual daily minimum temperature records being set at Amberley and Brisbane Airport (Qld).

Records were also broken for numbers of consecutive days above specified thresholds, for both maxima and minima. For example, Oodnadatta (SA) recorded nine consecutive nights over 30°C, a result without precedent in the Australian climate record, prior to February various stations having recorded 7 such consecutive nights. Adelaide (SA) recorded 17 days over 30°C, while Wilcannia (NSW) recorded 16 days over 40°C.

More detailed descriptions of this heatwave have been published in the February 2004 issue of the *Climate Monitoring Bulletin – Australia*, and in the *Bulletin of the Australian Meteorological and Oceanographic Society (Volume 17, number 2, April 2004)*.

Table 2 summarises the seasonal maximum temperature ranks and extremes on a national and State basis, whilst Table 3 gives the corresponding summary for the seasonal minimum temperatures.

Table 2. Maximum temperature.

	Highest seasonal mean (°C)	*Lowest seasonal mean (°C)*	*Highest daily recording (°C)*	*Lowest daily recording (°C)*	*Anomaly of area-averaged mean (°C) (AAM)*	*Rank of AAM**
Australia	41.1 at Paraburdoo (WA)	12.3 at Mount Read (TAS)	48.5 at Birdsville (QLD) on 5 and 6 January, and at Ivanhoe (NSW) on 15 February	2.3 at Mount Hotham (VIC) on 8 January	+0.42	42
WA	41.1 at Paraburdoo	21.8 at Albany	48.2 at Nyang on 1 January	14.4 at Mount Barker on 5 January	–0.04	27
NT	38.6 at Jervois	31.1 at Central Arnhem Plateau	46.3 at Jervois on 5 January	20.5 at Kulgera on 27 December and 23 February	–0.76	13
SA	39.0 at Marree	21.4 at Cape Willoughby	48.0 at Marree on 2 January	11.8 at Mount Lofty on 5 December	+1.35	52
QLD	39.9 at Birdsville	27.3 at Stanthorpe	48.5 at Birdsville on 5 and 6 January	16.0 at Stanthorpe on 6 December	+0.67	41
NSW	37.9 at Tibooburra	16.3 at Thredbo Top Station	48.5 at Ivanhoe on 15 February	7.1 at Thredbo Top Station on 7 and 8 January	+2.06	52
VIC	32.5 at Ouyen	16.0 at Mount Hotham	46.7 at Ouyen on 14 February	2.3 at Mount Hotham on 8 January	+0.56	39
TAS	23.6 at Cressy	12.3 at Mount Read	36.6 at Swansea on 30 December	2.6 at Mount Wellington on 29 February	–0.14	24

* The temperature ranks go from 1 (lowest) to 54 (highest) and are calculated on the summers of 1950/01 to 2003/04 inclusive.

Table 3. Minimum temperature.

	Highest seasonal mean (°C)	*Lowest seasonal mean (°C)*	*Highest daily recording (°C)*	*Lowest daily recording (°C)*	*Anomaly of area-averaged mean (°C) (AAM)*	*Rank of AAM**
Australia	26.8 at Troughton Island (WA)	3.3 at Mount Wellington (TAS)	35.0 at Moomba (SA) on 17 February	–4.6 at Charlotte Pass (NSW) on 6 December	+0.75	51
WA	26.8 at Troughton Island	12.5 at Rocky Gully	33.7 at Paraburdoo on 1 January	2.1 on Salmon Gums on 11 December	+0.29	40
NT	26.4 at McCluer Island	22.7 at Yuendumu	32.9 at Jervois on 7 January	13.5 at Kulgera on 4 February	+0.36	39
SA	24.7 at Moomba	10.2 at Naracoorte	35.0 at Moomba on 17 February	1.8 at Coonawarra on 18 January	+1.43	52
QLD	26.6 at Birdsville	15.5 at Stanthorpe	34.4 at Ballera on 6 January	9.0 at Stanthorpe on 1 February	+1.19	53
NSW	23.7 at Tibooburra	6.7 at Thredbo Top Station	33.2 at Ivanhoe on 15 February	–4.6 at Charlotte Pass on 6 December	+1.34	50
VIC	16.1 at Mildura	7.4 at Mount Baw Baw	30.0 at Mildura on 15 February	–3.2 at Mt Hotham on 18 January	–0.15	23
TAS	14.3 at Swan Island	3.3 at Mount Wellington	20.2 at Flinders Island on 15 February	–3.9 at Liawenee on 19 January	+0.01	26

* The temperature ranks go from 1 (lowest) to 54 (highest) and are calculated on the summers of 1950/01 to 2003/04 inclusive.

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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.