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Relationship of anomalies of (anti)cyclonicity to some significant weather events over the Australian region

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Cyclonicity anomalies for February 1993, December 1993 and January 1994, and anticyclonicity anomalies for April 1993 are presented for the Australian region. The anomalies are based upon 23-year, monthly anticyclonicity and cyclonicity averages. Relationships between the synoptic systems which produced these anomalies, and resultant significant weather events, are discussed. These include: (a) a monsoon low centred in the Kimberley district of Western Australia, and resultant record rainfall registered in parts of the Kimberley plateau and central Northern Territory in February 1993; (b) a depression located in eastern Bass Strait, and resultant much above average rainfall recorded across most of Victoria in December 1993; (c) lows in the westerlies centred to the south of Tasmania, together with a heat low positioned across the northern interior of Western Australia, and resultant very high temperatures across eastern Queensland and New South Wales, with devastating bushfires over eastern parts of New South Wales in January 1994; and (d) anticyclones located in the western Tasman Sea, and resultant record high average temperatures registered across much of eastern Australia in April 1993.

Introduction

The term 'anticyclonicity' ('cyclonicity') is defined as the time in hours during which anticyclone (cyclone) centres occupy a given five-degree latitude-longitude 'square' in a given period. Anticyclonicity (cyclonicity) is computed from the locations of anticyclone (cyclone) centres in the Australian Bureau of Meteorology National Meteorological Centre's 0000 and 1200 UTC sea-level pressure analyses, assuming a uniform speed of movement for systems that can be tracked. Single centres which are not part of a track are assigned a lifetime of six hours.

Immobility of an anticyclone (cyclone) centre is defined as the time taken by the anticyclone (cyclone) centre to traverse a five degree square. The average immobility of anticyclone (cyclone) centres across a five degree square is calculated by dividing the anticyclonicity (cyclonicity) of a five degree square by the number of anticyclone (cyclone) centres which have occupied that square during the same period.

The representation of the surface circulation in the Australian region (including New Zealand) for long periods (months or seasons) by means of charts of anticyclonicity and cyclonicity was developed during 1951–53, in connection with the problem of extended-range forecasting in Australia. Charts of seven-year averages (1946–1952) of monthly and seasonal anticyclonicity and cyclonicity were presented and discussed by Karelsky (1954). Updated charts for the 15 years 1946–60 were later published (Karelsky 1961).

Since 1960, satellite imagery has substantially enhanced the database available to analysts in the National Meteorological Centre. Leighton and Deslandes (1991a) published monthly charts of anticyclonicity and cyclonicity for the 23 years 1965–87 for the Australian region including the eastern Indian Ocean. Synoptic discussions of the averages for this later period were also presented (Leighton and Deslandes 1991b).

This paper illustrates how (anti)cyclonicity anomalies can relate to significant prolonged

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weather events in the Australian region. Four such events have been selected, and the relationships between these events, and anomalies of (anti)cyclonicity are discussed.

Significant weather events*

February 1993

Rainfall for February 1993 was generally above to well above average over most of northern Australia (Fig. 1(a)). A deluge during February in the eastern Kimberley plateau (see Fig. 2 for all locations), and areas immediately to the south and northwest, caused flooding with rainfall totals which were the highest on record. Record high rainfall totals were also recorded in parts of the central Northern Territory.

April 1993

During April 1993, maximum temperatures were well above average over most of Australia (Fig. 3(a)). The largest departures, of two to three degrees, occurred over central and southeastern Australia, with many centres in Victoria registering record maxima for April. Minimum temperatures were also well above normal, by up to three degrees, over much of central Australia (Fig. 3(b)). Minima were generally close to or slightly below normal in the south, where the general lack of cloud contributed to enhanced nocturnal cooling.

*(Note: Data sources appear in the Appendix.)

December 1993

Rainfall for December 1993 was well above average in most districts of Victoria. The rainfall deciles are shown in Fig. 4(a). Many districts of Victoria recorded their highest rainfalls for some time, and the East Central district recorded its highest ever district average. December 1993 was also the wettest December on record in Melbourne, and the total of 89.2 mm in the 24 hours to 9 am local time on the 28th was the second highest daily total for December.

January 1994

During hot and windy weather in the first eight days of January 1994, more than 200 bushfires blazed along the east coast and ranges of New South Wales. The major areas on fire were around Grafton, the Hunter Valley, the Sydney metropolitan area, the Blue Mountains and the South

Fig. 1(a) Preliminary distribution of decile range–rainfall February 1993.

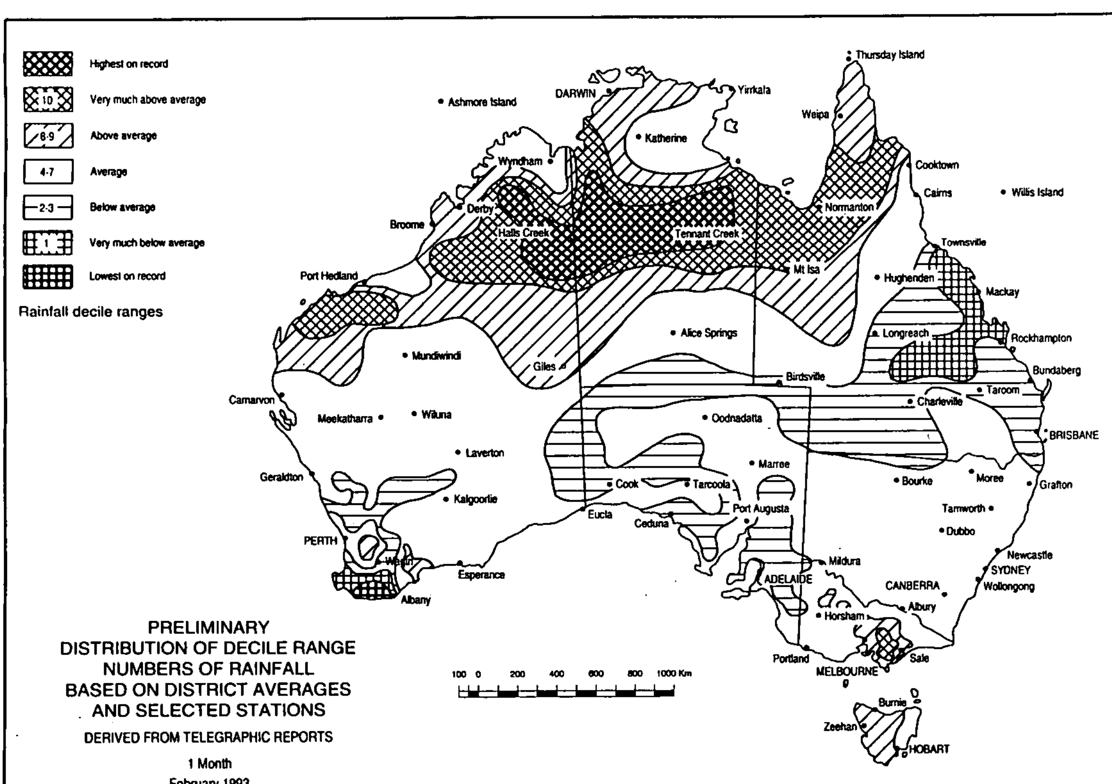


Fig. 1(b) Cyclonicity anomalies–February 1993 (hours).

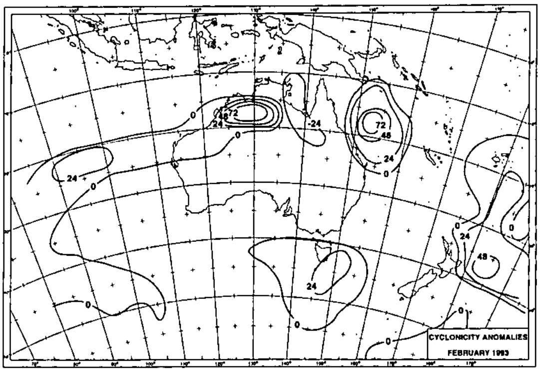


Fig. 3(a) Maximum temperature anomalies–April 1993 (K).

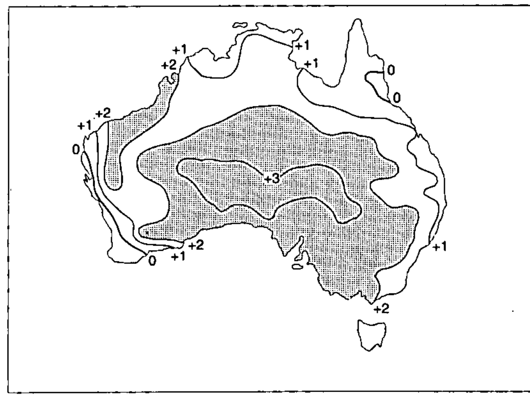


Fig. 1(c) Cyclonicity quintiles–February 1993.

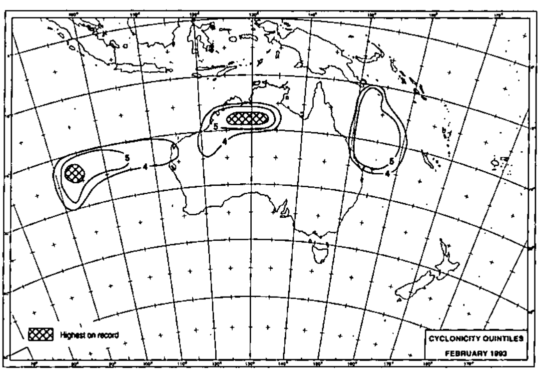


Fig. 3(b) Minimum temperature anomalies–April 1993 (K).

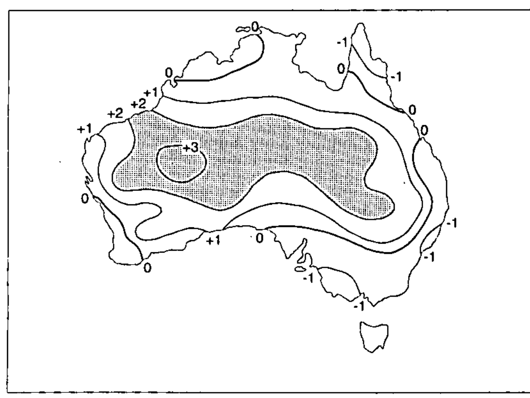


Fig. 2 Location map of places referred to in the text.

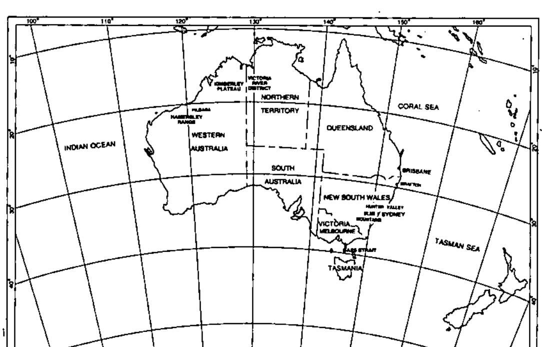


Fig. 3(c) Anticyclonicity anomalies–April 1993 (hours).

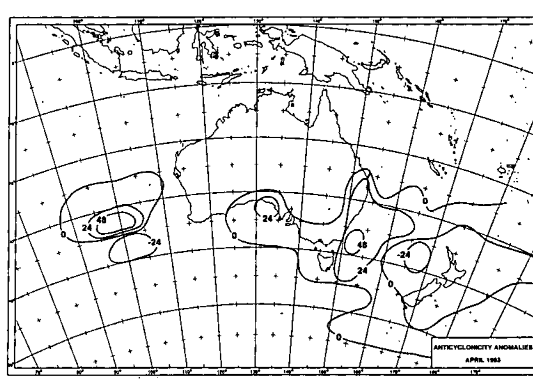


Fig. 3(d) Anticyclonicity quintiles–April 1993.

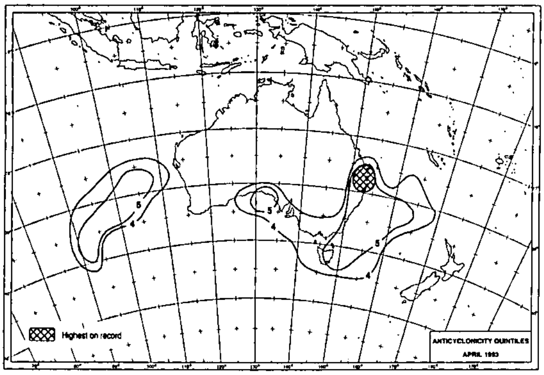


Fig. 4(c) Cyclonicity quintiles–December 1993.

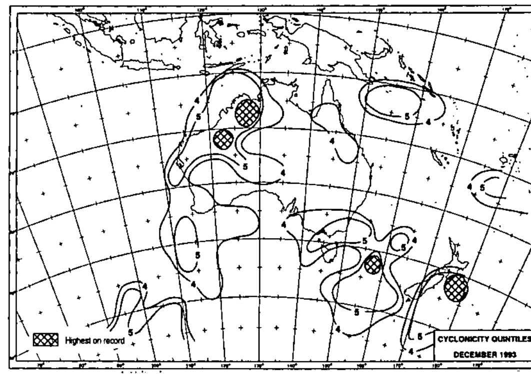


Fig. 4(a) Rainfall deciles–December 1993.

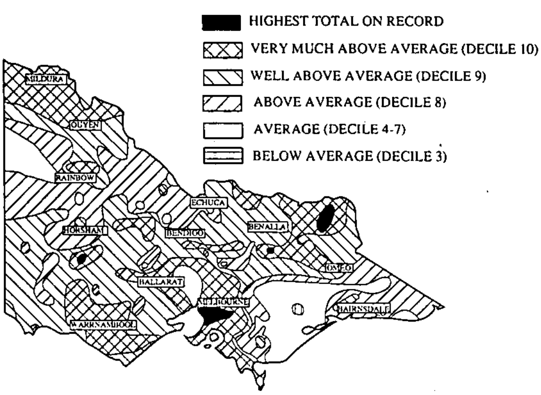
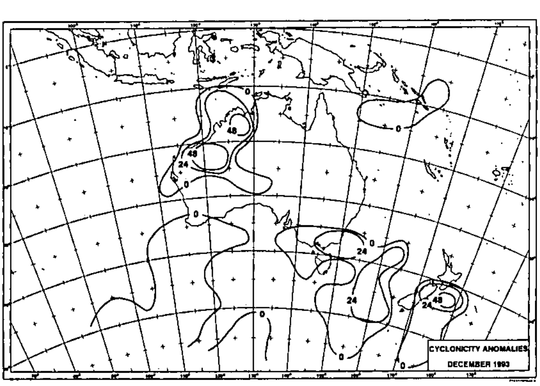


Fig. 4(b) Cyclonicity anomalies–December 1993 (hours).



Coast. Rail services were disrupted, roads were closed in many areas of the State and only one road was open into or out of Sydney. High temperatures affected most of eastern New South Wales and Queensland, with some places having the highest mean maximum temperature on record. The maximum temperature anomalies are shown in Fig. 5(a).

Variability of anti(cyclonicity)

(Anti)cyclonicity, like rainfall, but unlike many other meteorological elements such as temperature and pressure, is discontinuous in space and time. An (anti)cyclonicity anomaly can take an extreme value in just one five-degree square; this often occurs with very slow-moving systems such as tropical cyclones. When drawing anomaly isopleths, such discontinuities result in a 'bulls-eye' effect. On other occasions an anomaly may not be restricted to one square but can be moderate or even large covering several adjoining squares. This happens in the case of slow-moving anticyclones or cyclones.

The discontinuous character of (anti)cyclonicity must be taken into account when quantifying how unusual was an observed (anti)cyclonicity during a particular significant weather event relative to (anti)cyclonicities that have occurred in the past. An appropriate way to measure the spread or variability of a discontinuous variable such as (anti)cyclonicity or rainfall is by means of quintile ranges (or in the case of rainfall, decile ranges). When it is stated in later discussion, or indicated in a figure, that an observed cyclonicity in February 1993 (for example) was in quintile range five, the meaning is that the observed cyclonicity in that February was in the top 20 per cent of recorded February cyclonicities in the relevant

Fig. 5(a) Maximum temperature anomalies–January 1994 (deg K).

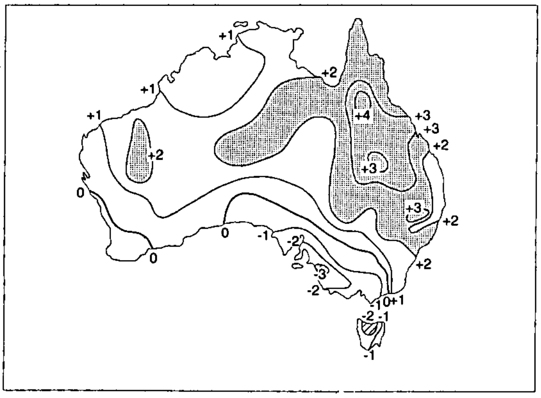


Fig. 5(b) Cyclonicity anomalies–January 1994 (hours).

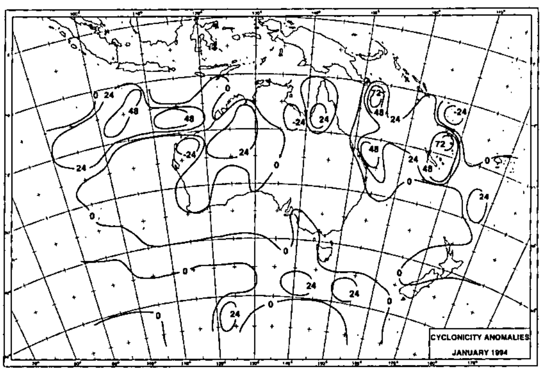
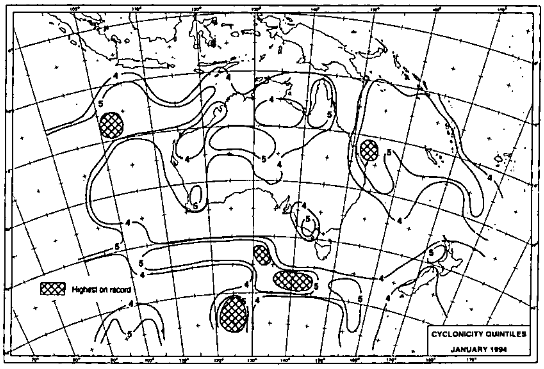


Fig. 5(c) Cyclonicity quintiles–January 1994.



five-degree square. In addition to the use of quintile ranges, it will also be indicated in the figures when a particular observed (anti)cyclonicity was the highest or lowest on record.

Significant weather events in relation to (anti)cyclonicity

Because (anti)cyclonicity depends upon the positions of systems, but does not depend upon the intensity of systems, and because (anti)cyclonicity is a relatively broadscale index (being based on five-degree squares), large anomalies of (anti)cyclonicity could be expected to be related to significant weather which lasts for substantial periods of time. When located in a region for a substantial period, anticyclones and cyclones may direct a continuing airstream across areas either near or at some distance from the system centre. Weather resulting from persistent airstreams could include an extended period of rain, a continuing dry spell or drought, a prolonged heat-wave, or just continuing stream weather. Very large positive or negative (anti)cyclonicity anomalies could therefore be related to record or near record monthly or yearly temperature and rainfall averages over affected regions. The events discussed in this section will illustrate the preceding remarks.

On the other hand, short-lasting but nevertheless significant weather, including widespread rain and shower activity related to the passage of a front, local severe thunderstorm activity, some cold outbreaks, occasional widespread frosts and fogs, passing stream weather and short periods of hot weather are probably more likely to be related to features such as mobile fronts, trough and ridges, or to result from the effect of local topography on a passing airstream. Such events would therefore probably be only weakly or not at all associated with (anti)cyclonicity anomalies.

February 1993

During February 1993, the positive cyclonicity anomalies across the east Kimberley region of Western Australia and the Victoria River district of the Northern Territory were in excess of 80 hours (Fig. 1(b)). Quintile range 5 (Fig. 1(c)) covered the entire Kimberley region and the Victoria River district, with the cyclonicity value in these regions being the highest on record (records starting in 1965). The high cyclonicity value was related to the presence of a monsoon low during the latter half of the month. The cyclone immobility of the monsoon low was in excess of 130 hours in the east Kimberley and near 90 hours in the Victoria River district. In the western areas of the Kimberley the immobility was near 50 hours.

When a monsoon low is present in or near a climatological heat low region, heat low activity is reduced or absent. This reduction is caused in part by the circulation of the monsoon low and increased cloudiness often covering an extensive area. Dynamic tropical systems such as monsoon lows, tropical depressions and tropical cyclones have an extended lifetime and have large immobility values, whereas heat lows can vary in depth diurnally. The presence of monsoon lows in a climatological heat-low region may not always be reflected in a positive monthly cyclonicity anomaly, even though a monsoon low may spend considerable time in the region, because the average cyclonicity in such areas is already large. In the present case, however, the immobility of the monsoon low was sufficient to cause a positive cyclonicity anomaly of over 80 hours, indicating how extreme the event was.

Earlier in February, a monsoon low which formed in the Kimberley district in late January had brought much above average rainfall to areas of the Pilbara region in Western Australia. This low spent nearly 30 hours in both the eastern and western areas of the Pilbara before drifting westwards into the mid-Indian Ocean. However, in contrast to the monsoon low discussed in the previous paragraph, the positive cyclonicity anomaly of nearly 20 hours was not excessive, indicating that this earlier significant weather event was not extreme from the aspect of cyclonicity.

April 1993

During April 1993, the positive anticyclonicity anomalies were generally above 30 hours across the western and northern Tasman Sea, with a peak value in excess of 48 hours east of Bass Strait (Fig. 3(c)). Quintile range 5 covered most of the western Tasman Sea and southeastern Queensland (Fig. 3(d)). Across waters to the east of Brisbane the anticyclonicity was the highest on record.

The anticyclonicity anomaly in the eastern Tasman Sea was strongly negative, suggesting that during the month anticyclones were displaced westward from their normal locations. Anticyclone replacement occurred for most of the month in the western Tasman Sea, where anticyclones remained for up to 36 hours in areas in which the average immobility time is about 9 to 10 hours.

The location of anticyclones in the western Tasman Sea inhibited movement of cold fronts through southeastern Australia and was associated with anomalous northeasterly air-flow across most of Australia. This northeast airstream helped produce the above average temperatures over much of Australia.

December 1993

The cyclonicity anomaly for December 1993 across Bass Strait and waters to the east was in excess of 30 hours (Fig. 4(b)). This was significant because the average cyclonicity for the region is 13 to 15 hours. Quintile range 5 covered the region and a significant area of the central and southern Tasman Sea (Fig. 4(c)). Much of the large cyclonicity value east of Bass Strait was due to an intense low-pressure system which spent up to 70 hours in the region before moving slowly into the central and southern Tasman Sea.

On 25 and 26 December an active upper cold pool in association with a strong polar front jet penetrated northwards from water well to the southwest of Tasmania. Early on 26 December a surface depression formed to the east of Bass Strait over warmer waters and the cold pool continued to move northwards reaching central New South Wales on 27 December. The depression deepened and the circulation of the low brought warm air westward across Tasmania and through Bass Strait. The centre of the low regressed into Bass Strait by the morning of 27 December. Large 24-hour rainfall totals across central Victoria were registered on 28 December.

January 1994

During January 1994, the cyclonicity anomalies to the south of Tasmania were very much above normal (Fig. 5(b)). Quintile range 5 (Fig. 5(c)) covered much of this region with areas to the southwest of Tasmania having the highest cyclonicity recorded for January. Much of this anomaly was due to a series of low-pressure centres moving slowly across waters to the south of Tasmania from the 2nd to the 8th of the month. At higher latitudes, south of 50 and between longitudes 130 and 150, the cyclonicity anomalies were negative suggesting that the lows in the westerlies were tracking further northwards than normal.

The mean cyclonicity south of Tasmania for January is not high in absolute terms (approximately 15 hours per month) therefore cyclonicity anomalies in excess of 24 hours become significant. The immobility of the cyclones which moved through the region from the 2nd to the 8th was about six hours greater than normal, indicating that the centres were slow moving. This cyclonicity and cyclone immobility reflects the extended period of time when westerly stream weather affected eastern Australia.

Off the northwest coast of Western Australia the high cyclonicity anomaly was partly due to the presence of tropical cyclone *Oscar* from 1 to 8 January. Another positive cyclonicity anomaly was located across the northern interior of Western Australia. The presence of *Oscar* helped weaken the heat low in the Hamersley due to increased cloudiness, and effectively shifted the heat low further eastwards to the northern interior of Western Australia and the southwestern Northern Territory. Across coastal South Australia and Victoria the westerly airstream was relatively cool, but rapidly warmed while moving overland. The airstream was sufficiently far north to inhibit high pressure ridging into the Bight from the eastern Indian Ocean, and the heat low region over the northern interior of Western Australia became influenced by the westerly stream. Abnormally high 1000–500 hPa thickness values were maintained eastwards as far as the east coast of Queensland and the Coral Sea, and the resulting surface temperatures across the eastern regions of Queensland and northern New South Wales became extremely high.

From 9 January the southern lows moved to the southeast allowing a high-pressure cell to move into the Bight and the westerly airstream contracted into the southern Tasman Sea. Tropical cyclone *Oscar* also weakened at this time, which allowed the heat low to return to the Hamersley, and a more normal summer synoptic pattern developed across the Australian region.

Conclusion

The four cases presented illustrate how anomalies of (anti)cyclonicity can be related to significant weather occurrences. In two cases (February 1993 and December 1993) the cyclonicity anomalies were related to cyclone centres located in or near the region where notable rainfall events occurred. In April 1993 an anticyclonicity anomaly was caused by anticyclones remaining more westward than normal in the western Tasman Sea. The corresponding circulation pattern in turn resulted in substantial maximum and minimum temperature anomalies for the month across a large area both near and distant from the anticyclonicity anomaly. In January 1994 cyclonicity anomalies were associated with lows in the westerlies centred to the south of Tasmania and a heat low positioned across the northern interior of Western Australia. These anomalies were centred some distance from the associated weather event (extreme heat and resulting bushfires), indicating that in some instances a remote effect can result from a combination of cyclonicity anomalies. In summary, all four cases illustrate how an (anti)cyclonicity anomaly can be located either near or far from an associated significant weather event.

Acknowledgments

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Appendix

Data sources (all obtainable from Bureau of Meteorology, GPO Box 1289K, Melbourne Victoria 3001):

Monthly Rainfall Review Australia (February 1993).

Climate Monitoring Bulletin Australia (Issue No. 87—April 1993).

Monthly Rainfall Bulletin Victoria (December 1993).

Climate Monitoring Bulletin Australia (Issue No. 96—January 1994).

Bureau of Meteorology Services Circular 70/262.