Seasonal climate summary
southern hemisphere (summer 1986-87):
a season of characteristic ENSO anomalies
and low planetary wave numbers

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(Manuscript received May 1987, revised June 1987)

An analysis of the southern hemisphere circulation for the summer months of December 1986 to February 1987, inclusive, is undertaken. Emphasis is given to the Australian region; an area roughly bounded by Antarctica, the equator, the dateline and 90°E.

Extratropical anomalies in the atmospheric circulation which developed following the establishment of the tropical El Nino Southern Oscillation (ENSO) related anomalies are discussed, in particular, the ENSO-induced weakening of the mid-latitude westerlies in the Australian region.

Introduction

This is the first of a series of seasonal climate summaries prepared at three-monthly intervals by the National Climate Centre (NCC) of the Australian Bureau of Meteorology.

A seasonal summary of the Australian/Asian area tropics is being produced on a semi-annual basis by the Darwin Regional Meteorological Centre and so the tropical circulation will not be dealt with in detail here. For tropical analyses, reference should be made to the monthly Darwin Tropical Diagnostic Statements and Climate Analysis Center (Washington) Climate Diagnostic Bulletins (see References).

The data used in this study were derived from the archived real-time data produced by the National Meteorological Centre (NMC), Melbourne, and from monthly mean data prepared by NCC and issued monthly in the Climate Monitoring Bulletin (CMB).

Overview

The dominant influence on climatic conditions during the southern hemisphere summer can be attributed to the ENSO episode of 1986/87. Weakly anomalous warm sea surface temperatures, which were already evident in the central Pacific prior to December, expanded to the east and increased slightly during the season reaching values of around 1.5°C above average in the eastern Pacific by February. An eastward shift in the South Pacific Convergence Zone (SPCZ) towards the region of anomalously warm water in the central Pacific was accompanied by a reorganisation of the Walker Circulation with a descending branch becoming established over northern Australia and the Coral Sea area. Enhanced tropical cyclogenesis during December and January was observed near and to the east of the dateline associated with the shift in the SPCZ.

Values of the Southern Oscillation Index (SOI) as seen in Table 1 which had been fluctuating about zero up until November began to show a sustained downward trend through the summer period. The SOI as used here is ten times the standardised Tahiti minus Darwin pressure difference anomaly for each month based on the period 1882 to 1985.

The relatively weaker monsoonal convection and reduced latent heat release into the upper troposphere over Indonesia and northern Australia, appears to have been responsible for a weakening of the latitudinal temperature gradient through the region, in turn causing an easing of the mid-latitude westerlies and the development of a less progressive circulation regime. This region, which is on average an area of maximum convective activity around the tropical belt during the austral summer, has importance in the establishment of the higher latitude wave structure. The reduction in tropical forcing may be seen as a higher proportion of energy being available in the lower order planetary
Table 1. Values of the Southern Oscillation Index (SOI) for the period January 1985 to February 1987. The index is 10 times the Tahiti minus Darwin MSL pressure anomaly divided by the standard deviation for the month based on the period 1882 to 1985.

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Figures 1 and 2 show the seasonal mean and anomaly patterns at 200 hPa. There is a resemblance to the composite anomaly of previous ENSO summer events shown in Fig. 3 (after Karoly 1986), particularly the strong anomaly located in the Southern Ocean near the Ross Sea. It could be inferred that the anomalies at middle and high latitudes in the western Pacific are due to a stronger Ferrel cell induced by the more actively forced Hadley circulation in those longitudes.

Fig. 2 Summer 200 hPa height anomaly in decametres.

Fig. 1 Mean summer (December, January, February) 200 hPa height in decametres.

Fig. 3 Composite summer mean anomaly of 200 hPa height for 1972, 76, 77, 82 ENSO events (after Karoly 1986).

wave numbers as has been suggested by several authors, including Simmons (1982), Puri (1983), and Coughlan (1985).

In the extratropics a predominantly four-wave upper-level mean December pattern gave way to a three-wave pattern in January and February. Wave numbers one and three were seen to be the dominant modes in both January and February. A reduction in transient eddy kinetic energy anomalies over the Pacific region occurred during January with the establishment of the weaker zonal circulation, further confirming the role of tropical forcing in producing the higher latitude anomalies. The action of the transient eddies in transporting heat and momentum towards the poles is closely linked to the latitudinal distribution of the zonal westerlies (Trenberth 1986) and is significant in this context.
Seasonal rainfall was above average in much of the west and northwest of the continent (Fig. 10(a)), even though the Australian tropics were characterised by a late onset and short duration of the summer monsoon. Rainfall was below average in the northeast of the continent, most notably in the northeastern coastal areas. This pattern was characteristic of rainfall anomalies associated with ENSO conditions (McBride and Nicholls 1983).

Temperatures were generally above normal in the northeast and below normal in the south.

**December**

The main features of the mean monthly circulation in the Australian region (Figs 4, 5, 6 and 7) were an anomalously strong tilting trough extending from high latitudes south of the Great Australian Bight into the Tasman Sea, a positive height anomaly over the northwest of the continent, and a weak negative anomaly over the Bight and southeastern Australia. An anticyclonic anomaly was situated well to the southwest of Western Australia in the southern Indian Ocean in a...
'blocking type' couple with a low height anomaly to its north. Positive anomalies were evident in Tasman Sea/New Zealand longitudes at middle latitudes reflecting enhanced blocking activity throughout most of the month. Low-level easterly wind anomalies over Indonesia together with southwesterly anomalies over Indochina (as may be seen in Darwin Tropical Diagnostic Statement, December 1986) were evidence of the weaker than average monsoonal circulation over the northwest and north of Australia.

Although the December analyses clearly show a four-wave pattern in the monthly mean, a Fourier decomposition of the major long waves at 55°S as seen in Table 2 shows that wave number three was the main contributor to the daily variance. The slow movement of systems through the month combined with the low constancy figure, which is the ratio of the monthly mean amplitude to the mean of the daily amplitudes, suggest that the variation in amplitude of wave number three occurred in a fixed location rather than from progression. The total variance due to all waves was close to average.

Zonal flow through the region exhibited a split structure during the first half of the month with the establishment of the block in the Tasman Sea, but reverted to a more summer-type structure of a single maximum at higher latitudes in the latter half. Figure 8 is a Hovmoeller plot of the blocking index which shows the blocking activity through the month, notably near and to the east of the dateline during most of the month and in the southeastern Indian Ocean after the middle of the month. In addition, a minor block occurred in the extreme eastern South Pacific early in the month. The Blocking Index as used in NCC is defined as the sum of the mean zonal wind components at 27.5°S and 57.5°S, minus twice the value of the component at 45°S.

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**Table 2. A summary of the southern hemisphere long waves at 55°S.** The text above contains some explanation of the variables shown.

| Statistics of southern hemisphere major long waves based on NMC, Melbourne analyses at 55°S |
|---------------------------------------------------------------|-----------------|-----------------|-----------------|
| **Total Variance – All waves**                              | **December**    | **January**     | **February**    |
| Anomaly (1976-1985)                                         | 54.3            | 60.1            | 82.5            |
| **Zonal Wave Number**                                       |                 |                 |                 |
| Amplitude of Monthly Mean                                   | 1.2 3.7         | 1.4 1.4         | 2.1 2.1         |
| Anomaly                                                      | -3.5            | -3.5            | -3.5            |
| Mean of Daily Amplitude                                     | 10.0            | 7.2 5.5         | 12.6 8.3        |
| Anomaly                                                      | -1.1 3.5        | -1.0 0.4        | 4.8 0.6         |
| % of Total daily variance                                   | 19.4 21.8       | 19.4 21.8       | 21.8 17.1       |
| Anomaly                                                      | -3.7 2.2        | -3.7 2.2        | -3.7 2.2        |
| Constancy                                                    | 0.85 0.63       | 0.96 0.74       | 0.96 0.74       |
| Anomaly                                                      | 0.08 0.11       | 0.23 0.11       | 0.23 0.11       |
| Phase of 1st ridge East of 0°E                              | 201 189         | 215 189         | 215 189         |
| Average (1976-1985)                                         | 208 224         | 212 224         | 212 224         |
Rainfall over much of the north and northwest of Australia was well below average (Fig. 10(b)), mainly in the first and second deciles and chiefly from isolated thunderstorm activity. Migratory lows developing in the long-wave trough south of the Bight were responsible for above average rains in southern and inland eastern South Australia, western Victoria and western Tasmania. A persistent high pressure system associated with the blocking system in the Tasman Sea and New Zealand region led to well below average rainfall along eastern coastal areas. Several districts along the central New South Wales coast received record low December totals (Fig. 10(b)). Existing long-term rainfall deficiencies along parts of the east and southeast coasts were exacerbated.

The decreased monsoon activity and reduced cloudiness in the north and northwest, led to maximum daytime temperatures which were 2°C to 3°C above average with a maximum recorded departure of 3.7°C above normal at Kununurra in the far north of Western Australia. Temperatures over the south of the continent however, were generally well below average particularly over inland areas of the southeast, as a result of colder air being advected around the transient low pressure systems tracking from the Great Australian Bight into the western Tasman. The maximum and minimum temperature anomalies have been consolidated in Fig. 11, for ease of comparison.

Sea surface temperatures as shown in Fig. 9 were slightly above average along northern coastal areas after having shown a substantial fall from November values when positive anomalies of up to 3°C were observed in the Gulf of Carpentaria. Negative anomalies of 2°C were seen in the Bight with another area of negative departures extending from the Western Australian coast into the Indian Ocean.

Fig. 9 December mean SST anomaly in °C, based on the USN Marine Climatic Atlas of the World (1969).
Fig. 10  Distribution of decile range numbers for the Australian continent: (a) summer (b) December (c) January (d) February.

A

**DISTRIBUTION OF DECILE RANGE NUMBERS OF RAINFALL**
**BASED ON DISTRICT AVERAGES**

3 months: 1 December 1986 to 28 February 1987

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B

**DISTRIBUTION OF DECILE RANGE NUMBERS OF RAINFALL**
**BASED ON DISTRICT AVERAGES**

December 1986
Fig. 11  Monthly maximum and minimum temperature anomalies for the Australian continent:

a) December maxima  d) January minima
b) December minima  e) February maxima
c) January maxima   f) February minima.

January

This month saw the first tropical cyclone activity in the Australian region and the belated onset of the northern Australian monsoon. The mean circulation for the month depicted in Figs 12 and 14 shows a tilting long-wave trough extending from the south of eastern Australia to the eastern Tasman Sea. The main anomalies shown in Figs 13 and 15 are the strong negative departure centred over Tasmania and the positive anomaly over the northeast which extends into the Coral Sea. Brief blocking episodes were observed in the central southern Indian Ocean early in the month and to the east of the dateline late in the month (Fig. 8).
Split flow in the Australian sector was evident for a few days in the first half of the month (refer NCC CMB January 1987). Enhanced convection in the tropical north with the onset of the monsoon and a strengthening of the Hadley circulation coincided with an increase in the zonal flow through the region at around latitudes 40°S to 45°S through the middle and later part of the month.

The January wave analysis figures seen in Table 2, again show the major contribution of wave number three to the daily variance, however, the variation was more evenly spread through all of the longer waves compared to the previous month. The amplitudes of waves two and three were above average in the monthly mean. Total variance of all long waves was close to average.
Tropical cyclone *Connie* which formed off the northwest coast was responsible for well above average rains over the inland southwest as it tracked across that area as a rain depression (Fig. 10c). The short-lived tropical cyclone *Irma* which formed in the Gulf of Carpentaria brought only moderate rain to Arnhem Land in the Northern Territory, but caused well above average falls about the southwest Gulf coast where it made landfall and quickly dissipated. Monsoonal low-level westerlies became established over the north and northwest of the country around the middle of the month bringing the delayed ‘wet-season’ rains. Rainfall along the Queensland and northern New South Wales coasts, however, was again well below average as a result of the high pressure anomalies and subsidence over Queensland and the Coral Sea area. An area of above average rain was notable in inland southern Queensland and northern New South Wales from a combination of frontal activity, tropical moisture from the remains of *Irma* and a heat trough. The southwest of Tasmania received well above average rain from transient lows and associated fronts forming in the long-wave trough to the south of eastern Australia.

Anomalous low-level westerly and northwesterly flow over central parts of eastern Australia held temperatures well above average over the southeast of the Northern Territory, all of Queensland and the northern half of New South Wales. Cold air being transported in the low pressure systems associated with the negative height anomaly extending through the Southern Ocean kept temperatures below normal over southern parts with departures of minus 4°C in the mean daily maximum experienced in parts of the southeast, as shown in Fig. 11.

Ocean surface temperature anomalies to the north of Australia showed a warming of around 1°C to 2°C from the previous month as can be seen in Fig. 16. When examined from the seasonal perspective, this was a short-term fluctuation only, and it might be surmised that it was due to greater re-radiation from the increase in cloud through the region, and less evaporative cooling of the surface because of the substantial rainfall and higher atmospheric moisture content. This warming ran counter to the downward summertime trend that has often been associated with the developing phase of an ENSO event as reported by Nicholls (1985).

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**Fig. 16** January mean SST anomaly in °C, based on the USN *Marine Climatic Atlas of the World* (1969).
Cold anomalies off the Western Australian coast appeared to shift south and weaken while a negative anomaly in the Bight remained. A warm anomaly in the Tasman Sea increased in area and intensity as shown in Fig. 16.

February

Figures 17, 18, 19 and 20 show that a broad long-wave trough was situated south of Australia on the mean 500 hPa analysis at high latitudes in a similar location to the corresponding January analyses, however the mid-latitude sector of this trough tilted northeast. A laterally extensive negative height anomaly running from the Bight into the central Pacific was associated with this system. A positive height anomaly was located off the southwest corner of Western Australia. At the surface, a high pressure anomaly was located over the east coast and another over the northwest. Figure 8 shows the anomalous blocking activity which occurred east of the dateline in two major episodes, one from around the 8th to the 17th and another from the 19th to the 25th of the month. Minor blocks were also observed in the far eastern South Pacific and southern Indian Ocean associated with the latter episode. This indicated a change in the general wave structure around the hemisphere in the last week of the month. Low-level easterly wind anomalies were seen south of the equator to the north of Australia and over Indonesia suggesting a weaker than average general monsoonal circulation. There were, however, concentrations of low-level northwesterlies over the northeast and the northwest of the continent.

The zonal strength of the upper-level westerlies was decreased, when integrated through middle latitudes in the Australian region, as can be inferred from the 500 hPa anomalies. The weakening of the zonal flow can be attributed to both the reduction in convective activity to the north and the related ENSO characteristic of the broadened westerlies associated with the expansion of the polar vortex.
Table 2 shows that planetary wave number one became more dominant although wave number three was a significant mode. Both were close to their preferred locations. The month witnessed a large increase in the total variance from all major waves.

Tropical cyclones Damien and Elsie formed off the northwest coast at the beginning and towards the end of the month respectively, causing above average rains over the northwest and central parts of the continent as they injected moisture into the middle and upper levels. Tropical cyclone Jason which formed in the Gulf of Carpentaria brought record February rains to parts of Arnhem Land and over the northern tip of Cape York in Queensland (Fig. 10(d)). East-coast rainfall was again very much below average as a result of subsidence in the anticyclonic anomaly located in that area.

Maximum temperatures over the north and northwest, and through the central part of the country, where the rainfall was above average, were several degrees below normal. This can be attributed to the higher soil moisture content which requires a greater input of solar radiation to raise ground temperatures, the cooling effect of evaporation and the increased cloudiness. Clearer conditions were experienced over
the far southwest of Western Australia and over the eastern coastal areas where daytime temperatures were generally one to two degrees above average. In the far southeast temperatures were below average where cooler west and southwesterly airstreams prevailed (Fig. 11).

Sea surface temperatures to the north of Australia fell by a degree or so from the previous month, particularly in the Gulf of Carpentaria, where tropical cyclone activity may have played a significant role in exporting heat energy. Figure 21 shows that negative anomalies remained off the northwest coast and in the Bight. The positive anomalies which had increased during January in the Tasman became more concentrated to the west along the eastern seaboard.

Summary

Figure 10(a) shows the season's distribution of rainfall. The areas of above normal falls about the Gulf of Carpentaria and to the southwest of Giles are associated with tropical cyclones which subsequently became rain depressions.

Figure 11 shows the monthly maximum and minimum temperature anomalies. The most interesting feature is the constancy of the negative anomalies in the southeast of the continent.

The main features of the hemispheric circulation were dominated by the ENSO event which prior to the summer had given only weak indications but became firmly established during the season. The rainfall, temperature and wind anomalies were to a large extent related to this event and the comparative lateness with which it developed.

Acknowledgments

The authors wish to thank Dr Michael Coughlan for helpful discussions in the preparation of the text, as also Arthur Downey, and Dr David Karoly for assistance in the preparation of the seasonal figures and provision of the composite ENSO material.

References


