Seasonal climate summary southern hemisphere (summer 1987-88): decline of the warm phase Southern Oscillation event

T.M. Casey
National Climate Centre, Bureau of Meteorology, Melbourne, Australia
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Climate anomalies during the austral summer of 1987/88 are summarised and an attempt is made to identify the dynamical processes associated with the establishment of the longer term circulation anomalies. A shift in the mid-latitude planetary wave train occurred in conjunction with a relocation of the zonal maximum in tropical convective activity from the western Pacific to the Indonesian region during a quiescent phase of the tropical 40 to 50-day oscillation in mid-summer. Stable patterns of pressure and tropospheric height anomalies in the periods before and after the reorganisation of the wave train produced persistent weather conditions in a number of locations around the hemisphere. Circulation anomalies which had characterised the warm phase Southern Oscillation (SO) during the preceding season weakened.

Introduction

This paper continues in the series of seasonal climate summaries for the southern hemisphere which are published at regular intervals in the Australian Meteorological Magazine (AMM). It describes the southern hemisphere circulation and main climate features for the austral summer from December 1987 to February 1988.

While the circulation for the whole hemisphere is described, there is an emphasis on the Australian region and the immediately adjoining regions of the Pacific and Indian Oceans.

Climatic summaries of the Australasian tropical region (e.g. Kingston et al. 1987) and summaries of tropical cyclone activity in the general Australian region (e.g. Manchur 1987) are published regularly in AMM. The tropical circulation in those regions is not discussed in detail here.

Data

The data used for the synoptic analyses in this summary were derived from hemispheric grid-point data produced by the National Meteorological Centre, Melbourne. Blocking index values were calculated from these same data. Sea surface temperatures (SST), out-going long wave radiation, and a number of other elements were obtained from the Climate Analysis Center (Washington) Climate Diagnostic Bulletins and Weekly Climate Bulletins* (referred to as CAC), Japan Meteorological Agency Monthly Reports on Climate System† (JMA), and Darwin Regional Meteorological Centre Tropical Diagnostic Statements§ (Darwin RMC).

* Obtainable from the Climate Analysis Center, National Weather Service, Washington D.C. 20233, USA.
† Obtainable from the Long-Range Forecasting Division, Japan Meteorological Agency, 1-3-4, Ote-machi, Chiyoda-ku, Tokyo, Japan.
§ Obtainable from the Regional Office, Bureau of Meteorology, PO Box 735, Darwin 5794, Australia.
Southern Oscillation and other climate indicators were prepared from real-time archival material held at the National Climate Centre (NCC). Data and information appearing in the NCC Climate Monitoring Bulletins are also used. SST anomalies are derived using the modified COADS-ICE climatology data set based on the climatology of Reynolds (1982). Details may be found in the CAC Climate Diagnostics Bulletin for September 1986.

**General circulation features**

Convective activity over the maritime continent is one of the major heat and mass sources for the tropical troposphere. Such sources are known to propagate higher latitude wave trains in the form of mixed Rossby-Kelvin waves which are planetary in scale (Silva Dias et al. 1983; Lim and Chang 1983). Monthly mean outgoing long wave radiation (OLR) values and upper-level velocity potential indicated that a major centre of convective activity was located in the tropical western Pacific in early summer. This centre shifted to the eastern Indian Ocean in January, and by February a maximum extended over the maritime continent from the western Pacific to the eastern Indian Ocean.

Figure 1 shows a time-longitude cross-section of 200 hPa velocity potential for the 5°N-5°S tropical strip for the period October 1987 through March 1988. Velocity potential is a measure of divergence and hence is directly related to vertical motion and convective activity. Oscillations of around 40 to 50-day intervals can be seen in the amplitude of the upper-level velocity potential with maxima occurring in the longitudes of the maritime continent between 90° and 150°E. Oscillations in tropical convective activity and pressure on the time-scale of 40 to 50 days, which were first described by Madden and Julian (1972), are thought to be eastward travelling Kelvin wave disturbances and produce a maximum of convective activity in their transit. One maximum occurred over the maritime continent during late December and a second, which was displaced further west, in early February. This is confirmed by equivalent black-body temperature values (a measure of cloud top temperatures and deep convection) which are presented as time-longitude sections in JMA.

* Obtainable from the Bureau of Meteorology, PO Box 1289K, Melbourne 3001, Australia.

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**Fig. 1** Time-longitude section of 5-day mean 200 hPa velocity potential 5°N to 5°S, October 1987 to March 1988. Contour interval $4 \times 10^4$ m s$^{-1}$, hatched $> 8 \times 10^4$ m s$^{-1}$; speckled $< 8 \times 10^4$ m s$^{-1}$, 0 line omitted. (Reproduced from March 1988 issue of Japan Meteorological Agency Monthly Report on Climate System.)

The symmetrical arrangement of the 40 to 50-day oscillation in the velocity potential and hence upper divergence and convective maxima over the period suggested the division of the hemispheric analyses into two 45-day periods—one covering December to mid-January and the other, mid-January to the end of February. Averaging the daily analyses over these periods has the advantage of centrally containing the maxima of convective activity within each period, when it might be expected that the strongest development in the wave train of higher latitude anomalies would have occurred. In addition, given that the planetary-scale wave trains responded to the 40 to 50-day oscillation in the main source of convective activity over the maritime continent, sampling at around 45 days avoids the aliasing which might arise through calculating means and anomalies at the traditional but somewhat arbitrary period of the calendar month.

Mean sea level pressure (MSLP) analyses for the first 45 days of summer and second 45 days are presented as Figs 2 and 3 respectively. The mean high pressure centres in the subtropical ridge were located over the oceans and heat troughs in the easterlies were situated over the main continental land masses as would be expected from the temperature differential between land and sea in summer. Major troughs at middle to high latitudes, particularly through the south Atlantic, Indian and western Pacific Oceans, were rotated noticeably westward in the later summer period. The MSLP anomaly charts shown in Figs 4 and 5 reveal a deep negative anomaly in the
Southern Ocean near the Antarctic Peninsula which was maintained throughout the season. This feature appears to be common to both warm and cold phase SO events but manifests at different longitudes in each case. In the warm phase this anomaly is situated, on average, near the Ross Sea. The early summer period showed indications of a wave number two structure while the later period exhibited a strong wave number four structure. Pressures in the circumpolar trough were deeper than average and pressures over the Antarctic continent were slightly above average. Figures 6 to 8 show, in order, the mean 500 hPa height analyses for the full season, for early summer and late summer.
The mean seasonal mid-troposphere circulation fundamentally had a three to four-wave shape with mid-latitude troughs in the western south Atlantic, central Indian Ocean and western Pacific. A major trough was situated in the central Pacific. From the relative locations of the long wave troughs, the mean seasonal circulation most closely resembled the December long-term mean.

The early and late summer period charts displayed similar features to the mean seasonal chart but, as in the case of the surface charts, some of the major troughs were repositioned in the latter half, notably the troughs in the western Pacific, Indian Ocean and eastern south Atlantic which were further west.

The mean seasonal 500 hPa height anomaly chart (Fig. 9) shows a strong negative anomaly at high latitudes in the eastern Pacific sector of the Southern Ocean followed by a train of negative anomalies running into the Atlantic and Indian sectors. Heights of the pressure surface were above average in the Australian region and below average in the central Pacific—a typical warm phase SO pattern.

In the early part of the season (Fig. 10), there was a dominant wave number two structure in the anomaly pattern with wave number four secondary lobes. The deepest of the negative anomalies was located in the central Pacific sector of the Southern Ocean. In the second half (Fig. 11), a near symmetric four-wave structure was evident, but rotated about 45 degrees of longitude to the west. The wave train of height anomalies at middle to high
Fig. 9 500 hPa geopotential height anomaly contours in decametres. Summer (DJF).

Fig. 10 500 hPa geopotential height anomaly contours in decametres, 1 December 1987 to 15 January 1988.

Fig. 11 500 hPa geopotential height anomaly contours in decametres, 16 January to 29 February 1988.

The contribution of the two half-season analyses to the seasonal pattern is readily apparent. The positive height anomalies over southern Africa in the full seasonal analysis (Fig. 9) were predominantly due to anomalies in the first half of the season, while the negative anomalies in the Indian Ocean were due to those in late summer. Some features of the whole season's anomalies are common to both periods. From this, it can be derived that the pattern of anomalies in each period was relatively stable and that there was only the one major reorganisation of the planetary wave pattern during the season. This occurred at the time of the shift in the area of maximum convective activity from the western Pacific to the eastern Indian Ocean during the quiescent phase of the 40 to 50-day oscillation in January. It can be inferred that the static nature of the anomaly pattern in each period was the cause of the persistent climatic conditions experienced at a number of places around the hemisphere.

Sea surface temperatures

The three-month SST analysis in Fig. 12 shows a longitudinally extensive area of warm water around 30°C centred on the equator and the dateline. Temperatures in the tropical Indian Ocean were slightly less warm. The anomaly chart for the same period (Fig. 13) delineates an area of above average SSTs extending along
Fig. 12 Sea surface temperature mean analysis for summer (DJF). Main contour interval is 2°C. Odd contours > 20°C dashed.

and south of the equator from around the dateline to the eastern Pacific. Smaller regions of positive anomalies were situated at middle latitudes in the south Atlantic and Indian Oceans.

The extent and magnitude of warm anomalies of SST associated with the warm ENSO episode in the equatorial Pacific decreased markedly over the summer period. In December, a large area of positive anomalies extended along and south of the equator from the far western Pacific to the Peruvian coast. Maximum anomalies were of the order of two degrees above average near 110°W in the eastern Pacific just south of the equator. The area of positive anomalies diminished and weakened in January; maximum anomalies were around +1°C in the central equatorial Pacific and a warm area near the dateline weakened and contracted. By February, the excess of warm upper-layer volume had dissipated latitudinally and ocean surface temperatures had returned to normal through most of the tropical Pacific.

In the south Atlantic Ocean an area of warm anomalies, of around 1 to 2°C, became established near 20°S in December; it then expanded and spread westward, eventually extending from the tip of South Africa to the Brazilian coast by February. Maximum positive anomalies exceeded 2°C in subtropical latitudes.
SSTs in the Indian Ocean were generally close to average during December, but began to show signs of a warming in subtropical latitudes during January and February which resulted in positive anomalies exceeding 1°C over much of the southern tropical and subtropical area.

**Southern Oscillation**

The mean Walker circulation, as indicated by the pressure and wind distributions, appeared to divide into several cells across the Indian-Pacific sector during the relocation of convective activity in January. SO warm phase conditions in December produced a single Pacific Walker circulation with a descending region over the eastern equatorial Pacific and a major ascending region over the central and western Pacific to the east of the dateline. West of this a single cell extended to the Indian Ocean. In January a descending node became established to the north of Australia and another ascending node developed in the eastern Indian Ocean, resulting in three cells spanning the Indian-Pacific sector. In February there was a return towards a single circulation from the western Pacific to the maritime continent. This was located further west than the December circulation.

Tahiti minus Darwin pressure differences, although smaller than average, were nevertheless positive throughout the season, indicating a net mass flux towards the Indian Ocean at low levels and a flux towards the Pacific in the upper-level return flow. The major mass source was from the western Pacific in the early part of the season, from the maritime continent region in January and then moved back towards the western Pacific in late summer.

The Southern Oscillation Index (SOI), as measured by the normalised Tahiti minus Darwin pressure difference anomalies and shown in Fig. 14, returned to near normal values over the summer period after a sustained negative excursion during the preceding twelve months. The index reached a minimum value in the autumn of 1987.

**Tropical convective activity**

Enhanced tropical convective activity in December, as measured by outgoing long wave radiation, was at a maximum just south of the equator near the dateline. Further anomalous but weaker activity was observed over central Brazil and southern Africa during the month. Of note was a large area of positive OLR anomaly indicating generally clear conditions over the western Indian Ocean, northern Mozambique and Madagascar. Convective clusters were active in the eastern Indian Ocean to the southwest of Sumatra.

The northern Australia and New Guinea region, part of the global maximum of convective activity which extends over the maritime continent from the western Pacific to the Bay of Bengal, was an area of very much reduced convective activity in January, denoting a break in the northern Australian monsoon and an early retreat of the equatorial trough through that region. Negative OLR anomalies near the equatorial dateline were weaker than in the previous month, and stronger convective activity became apparent over the equatorial Indian Ocean near 90°E. This occurred in conjunction with the tendency for the upper-level velocity potential maximum to shift from the western Pacific into the eastern Indian Ocean. Weak positive OLR anomalies were seen over eastern Brazil and southern Africa. Small areas of negative OLR anomalies were observed over Kenya and Tanzania, consistent with wet conditions there late in the month.

By February an area of strong negative OLR anomalies extended from the equatorial western Pacific across the maritime continent towards Indo-China and was associated with a second active burst of the northern Australian monsoon. The South Pacific convergence
zone (SPCZ) became well defined and the south Atlantic convergence zone also became active. Convective activity was enhanced over northeast Brazil, the eastern part of southern Africa and Madagascar.

The SPCZ exhibited above average activity in December. It was located close to its climatological mean position, in contrast to the large eastward displacement that had been noted during the mature phase of the warm ENSO episode in winter and spring. Activity was quieter and more disorganised in this region during January, but by February a distinct SPCZ signature was again evident both in the OLR analyses and from satellite cloud photographs.

**Blocking**

A blocking dipole, evident in the central Pacific on the 500 hPa seasonal mean chart (Fig. 6), was largely due to the contribution from late summer when this feature was more pronounced (Fig. 8). Anomalous blocking activity, as measured by the strength of mid-latitude flow compared with that at higher and lower latitudes (Fig. 15), was slightly above average in the eastern Pacific region, but well below average through the Indian Ocean and Australian sector. The deeper than average circumpolar trough and positive anomalies in the subtropical ridge produced stronger zonal flow in that region.

Weak blocking dipoles occurred in the early part of the season in the Australian-western Pacific region although these were highly progressive (Fig. 16). There was a brief blocking episode in the Indian Ocean towards the end of December, although middle latitude flow through the region was generally strongly zonal over most of the season. In mid-January a difference in the flow became established over the eastern Pacific and was followed by a major separation of the flow in the western Pacific which lasted for most of February.

**Fig. 16** Time-longitude section of daily blocking index values December 1987 to February 1988. Day 1 is 1 December 1987.

**Fig. 15** Longitude—Blocking Index anomaly December 1987 to February 1988. Blocking Index is defined as sum of mean 500 hPa zonal wind at 27.5°S and 57.5°S minus twice that at 45°S.
Winds

In December there was a weakening of the upper-level anticyclonic couplet straddling the equator to the east of the dateline, which had been a key signature of the warm phase SO event through much of 1987. There was a consequent reduction in the upper-level equatorial easterly anomalies and low-level westerly anomalies in the western Pacific. The upper-level subtropical westerlies across the Pacific weakened and low-level easterly anomalies became established on the equator in the central Pacific. Flow at both low and upper tropospheric levels was anomalously meridional in middle latitudes over the Pacific and Atlantic regions due to the well developed wave train of height anomalies. Maximum upper-level jet streaks were located to the south of Africa and to the southwest of Australia. A weaker jet streak maximum was located at subtropical latitudes over the Tasman Sea.

A strengthening of low-level easterly flow took place over the central equatorial Pacific in January. Anomalous cross-equatorial flow became established in the upper levels in the central Pacific and in the western Atlantic. Low-level northeastward anomalies were seen over Brazil and easterly anomalies over northern Australia. Flow was again strongly meridional in the middle latitude Pacific region. Upper-level northwest oriented jet streaks were located to the south of Australia and in the western south Atlantic.

Northeasterly anomalies in the lower levels developed on the equator in the western Pacific in February. Northerly flow over Brazil continued and was associated with wettter conditions over the Amazon region. Meridional anomalies were strongest in the Pacific and Atlantic regions. Jet maxima were located to the southwest of Australia and in the southwest Indian Ocean.

Rainfall

Dry conditions were experienced over Mozambique, southern Tanzania and Madagascar more or less continuously for the first half of summer, consistent with the persistence of positive pressure anomalies in the western Indian Ocean. These anomalies weakened during January when unusually heavy rain fell in Tanzania and tropical storm Calidora brought relief to the dryness in Madagascar. Heavy rain again fell in eastern southern Africa late in February. Convective activity and tropical storms became much more active in the Indian Ocean during the later part of the season as negative height anomalies became relocated over the region.

Rainfall in Australia was well above average in a central strip extending from north to south and also in the southwest during December. However, a retreat of the monsoon trough in January resulted in well below average rainfall over a large area of the northeast and central parts. In February, rainfall was again below average over central and northern areas because of high pressure anomalies over the region. Rainfall was suppressed in the southwest of the continent during the later part of the season.

The moderately active SPCZ in December, a relatively quiescent period in January and the re-intensification in February was reflected in the rainfall over Oceania generally. Falls were mostly due to scattered shower and thunderstorm activity early in the season and brought some relief to dry conditions which had been persisting for some months in the Fiji group. Rainfall decreased over Fiji during January but returned to wetter conditions in February. Vanuatu and New Caledonia received little rain in the early part of summer but well above average rains in January. Further east in Polynesia, disturbances in the equatorial trough produced above average rain in the region north of the Cook Islands but southern Polynesia remained mostly dry, causing rainfall deficiencies to extend to the seventh consecutive month by February.

The eastern Pacific was generally very dry as a result of persistent high pressure anomalies over the region. Bolivia and Paraguay experienced a dry two months during January and February.

Temperatures

No significant areas of maximum temperature anomalies for any appreciable period were noted over the southern hemisphere land masses in December.

Above average daily maximum temperatures were recorded in central and southeastern Australia during the middle part of January due to dry clear conditions. The northeast region of South Africa was also warmer than average during that time as a result of high pressure anomalies and clearer conditions. Coastal areas of Peru experienced above average temperatures through the middle of January.
Warm conditions were experienced in southeastern and central Australia, South Africa, northern Argentina and Peru in the first two weeks of January. Warm, dry conditions extended over most of northeastern Australia by the end of the month and above average temperatures were experienced in southern Brazil, Zimbabwe and Mozambique.

The first two weeks of February saw warm conditions continue in parts of South Africa, while colder temperatures were experienced over northern Argentina. The middle two weeks of the month were warm in New Zealand as a result of clear conditions and increased insolation.

Summary
Warm sea surface temperatures in the tropical Pacific Ocean cooled to near normal values over the summer period, leading to a reduction in low pressure anomalies and a weakening of the upper-level anticyclonic couplet straddling the equator to the east of the date-line. There was a concurrent reduction in the strength of the tropical Walker circulation anomalies over the Pacific-Indonesian region. Low-level westerly anomalies in the western Pacific, which had been well established during the peak of the warm phase SO in winter and spring, decreased substantially and easterly anomalies developed along the equator in the central Pacific.

Tropical convective activity over the maritime continent exhibited a 40 to 50-day oscillation, peaking in late December and in early February. The centre of maximum convective activity migrated from the western Pacific to the eastern Indian Ocean during a quiet phase of the oscillation in January.

Well developed wave trains of middle latitude height anomalies became established at the times of peak activity in the 40 to 50-day oscillation. Both of these trains showed similar wave number two and four configurations but were rotated from each other by an amount commensurate with the longitudinal shift in the centre of convective activity. Each was seen to be stable for an appreciable period and led to a number of climatic anomalies in pressure, temperature and rainfall at various locations in the hemisphere. Notably, dry conditions over southern Africa in the first part of summer and dry conditions in northern Australia and central South America during the latter part were attributable to positive height and pressure anomalies over those regions.

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References


