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The tropical circulation in the Australian/Asian region — November 1989 to April 1990

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A summary of the tropical circulation from 70°E to the dateline, for November 1989 to April 1990, is presented. The Southern Oscillation was in an incipient warm phase and the Hadley circulation was underdeveloped. Monsoonal rainfall was below average in both hemispheres.

Introduction

This seasonal summary examines the circulation within the Darwin Regional/Specialised Meteorological Centre (RSMC) analysis domain, 70°E–180°, 40°N–40°S, during the period November 1989 to April 1990, with particular emphasis on the area between 20°S and 20°N.

Data sources include seven-year (1983–1989) mean wind analyses from the tropical analysis scheme of Davidson and McAvaney (1981), and the climatological mean winds of Atkinson and Sadler (1970) and Sadler (1975). Anomaly fields were averaged over two three-month periods: November 1989 to January 1990 (NDJ) and February 1990 to April 1990 (FMA). Such a division was appropriate since the monsoon in both hemispheres was active during the first three months and rather insipid throughout the latter period. Time series of velocity potential and outgoing long wave radiation (OLR) were adapted from those published in Darwin Tropical Diagnostic Statements (DTDS) (see Appendix), and sea-surface temperature (SST) anomalies were calculated from the climatology of Reynolds (1983). Mean sea level pressure (MSLP) anomalies were derived manually from monthly CLIMAT message and supplemented with grid-point values extracted from the Japan Meteorological Agency Monthly Report on Climate System (MRCS) and analysed data archived in the National Meteorological Centre, Melbourne. Other data sources are referred to in the text where appropriate.

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The tropical circulation of November 1989 to April 1990

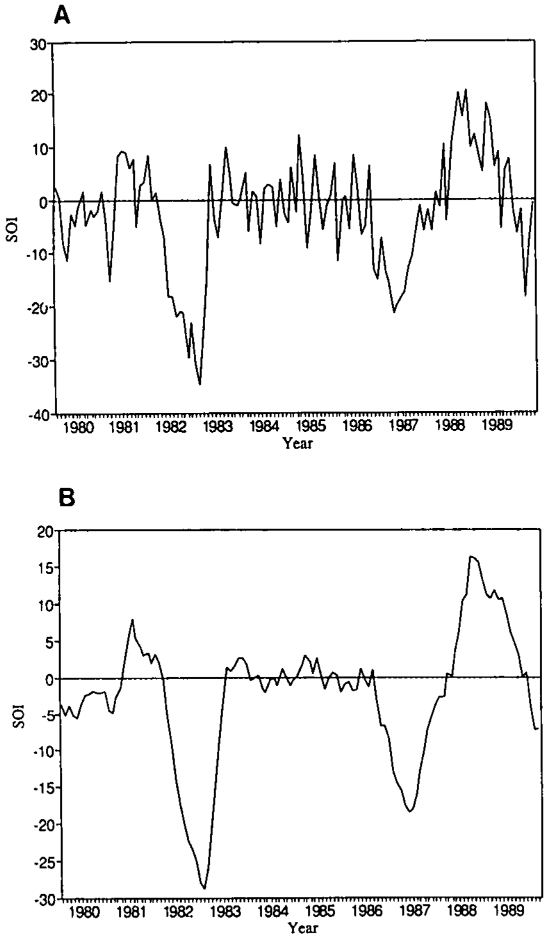
The cool El Niño/Southern Oscillation (ENSO) episode that started in March to May 1988 (Chelliah 1990) was in decline between May and October 1989 (Bate 1991).

Table 1 shows values of the Southern Oscillation Index (SOI); below zero values are evident for each month in the November 1989 to April 1990 period. The nadir occurred in February and was due in the main to a large positive MSLP anomaly (+3.5 hPa) at Darwin; otherwise, values fluctuated nearer to zero. The February MSLP anomaly at Darwin equalled the January 1983

Table 1. Southern Oscillation Index (SOI), November 1989–April 1990.

	Nov	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*
SOI	−2	−6	−2	−18	−8	−1

Fig. 1 SOI from January 1980: (a) monthly values to April 1990; (b) five-month running mean to February 1990.



value, and represented the second largest positive excursion of MSLP anomaly for any month since 1882; the highest (+3.8 hPa) was in February 1983, during the last major warm ENSO episode.

Figure 1 shows the fluctuation of SOI from January 1980 to April 1990 and its five-month running mean to February 1990, a period that includes the warm ENSO event of 1982/83. Janowiak (1990) noted that many atmospheric and oceanic features in the tropical Pacific during the December 1989 to February 1990 period were consistent with early stages of past warm ENSO episodes. He added however that the large SOI change between January 1990 and February 1990 does not necessarily imply that low values will persist. Large SOI changes between January 1978 (−3.8) and February 1978 (−25.7), and February 1981 (−4.0) and March 1981 (−15.4) were not immediately followed by warm ENSO events.

Table 2 compares Darwin MSLP anomalies for the 12-month periods May 1982 to April 1983 and May 1989 to April 1990. Little similarity between the periods is apparent. Furthermore, during the six months leading up to the respective November to April periods, anomalies were always positive in 1982 (a precursor to the El Niño of 1982/83) while they were mostly below zero in 1989 (during a cool El Niño phase in 1988/89). This lends support to Janowiak's earlier implication that an El Niño event was not necessarily developing.

Figures 2(a) and 2(b) show MSLP anomalies for the respective three-month periods NDJ and FMA. Positive anomalies over most of the Australian region tropics during the entire period are consistent with a negative SOI phase. Pressure anomalies peaked in February, and values of +4 hPa to +5 hPa were common about the northwest Australian continent and adjacent waters, indicating a weaker than normal heat trough and monsoon trough were in operation throughout most of the southern hemisphere, especially during FMA.

In the southern hemisphere subtropical ridge, pressures were below average to the west of the Australian continent and above average to the east where blocking was a contributing factor. Slightly deeper than normal troughing was evident in the South Pacific convergence zone (SPCZ) area southeast of Papua New Guinea in NDJ but a weak positive anomaly lay across that area in FMA.

Positive anomalies dominated the area normally occupied by the subtropical ridge in the northern hemisphere. At lower latitudes, deeper than normal troughing remained a feature of equatorial easterlies in the Pacific region. Negative anomalies over India and Indo-China reflect deeper than average heat low activity during the warmer months of the northern hemisphere autumn and spring.

SST anomaly fields remained stable throughout the period; the three-month averages NDJ (Fig. 3(a)) and FMA (Fig. 3(b)) show gross features generally consistent with individual months. Warm anomalies maintained their dominance over most of the RSMC area, however magnitudes around

Table 2. Mean sea level pressure anomaly (hPa) at Darwin for 1982/83 and 1989/90.

	May	*June*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*
1982/83	+0.8	+1.6	+1.5	+1.9	+2.3	+1.8	+2.2	+2.1	+3.5	+3.8	+2.5	+0.6
1989/90	−1.0	+0.4	−0.9	+0.5	−0.3	−0.8	−0.2	+1.7	+0.6	+3.5	+0.7	+0.2

Fig. 2 MSL pressure anomaly (hPa): (a) NDJ; (b) FMA. Contour interval 1 hPa.

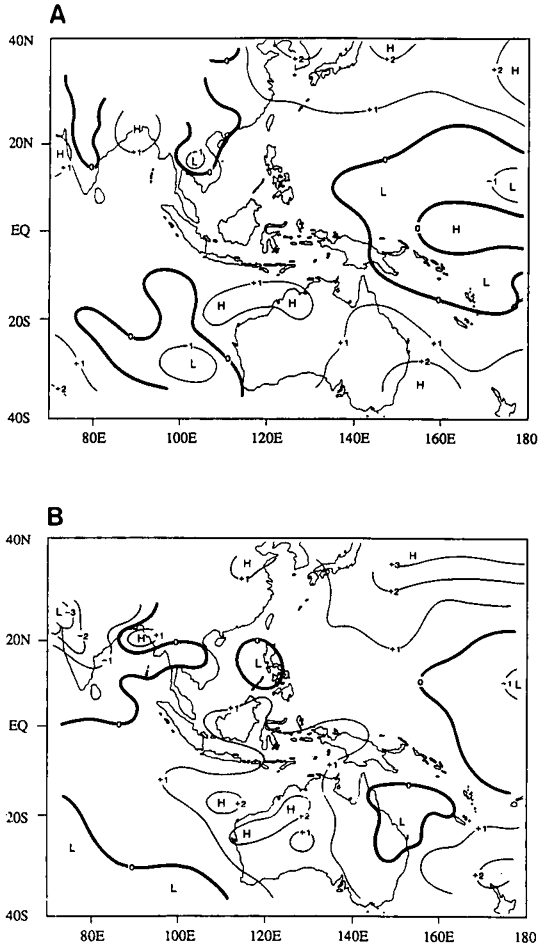
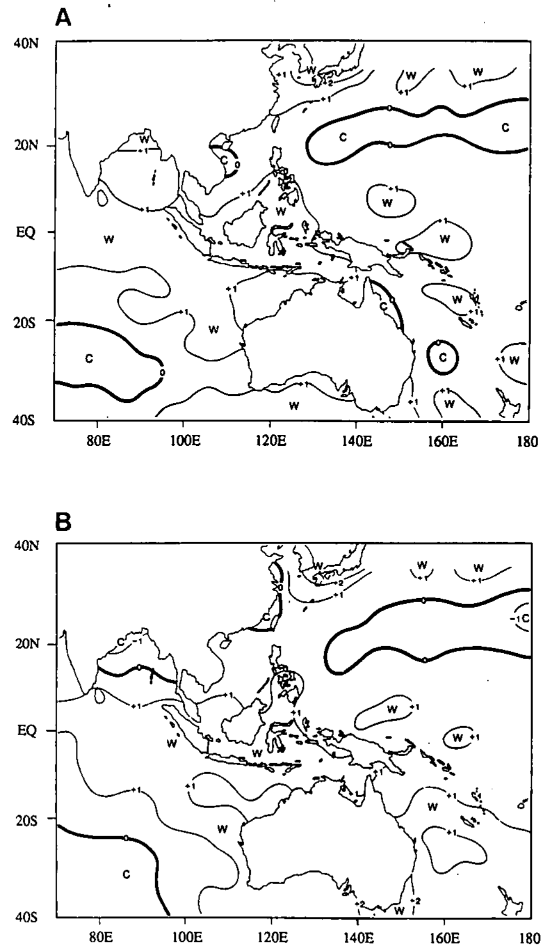


Fig. 3 Mean SST anomaly (°C): (a) NDJ; (b) FMA. Contour interval 1°C.



the Australian continent have gradually eased from their values twelve months ago (cf. Keith et al. (1991) and Bate (1991)).

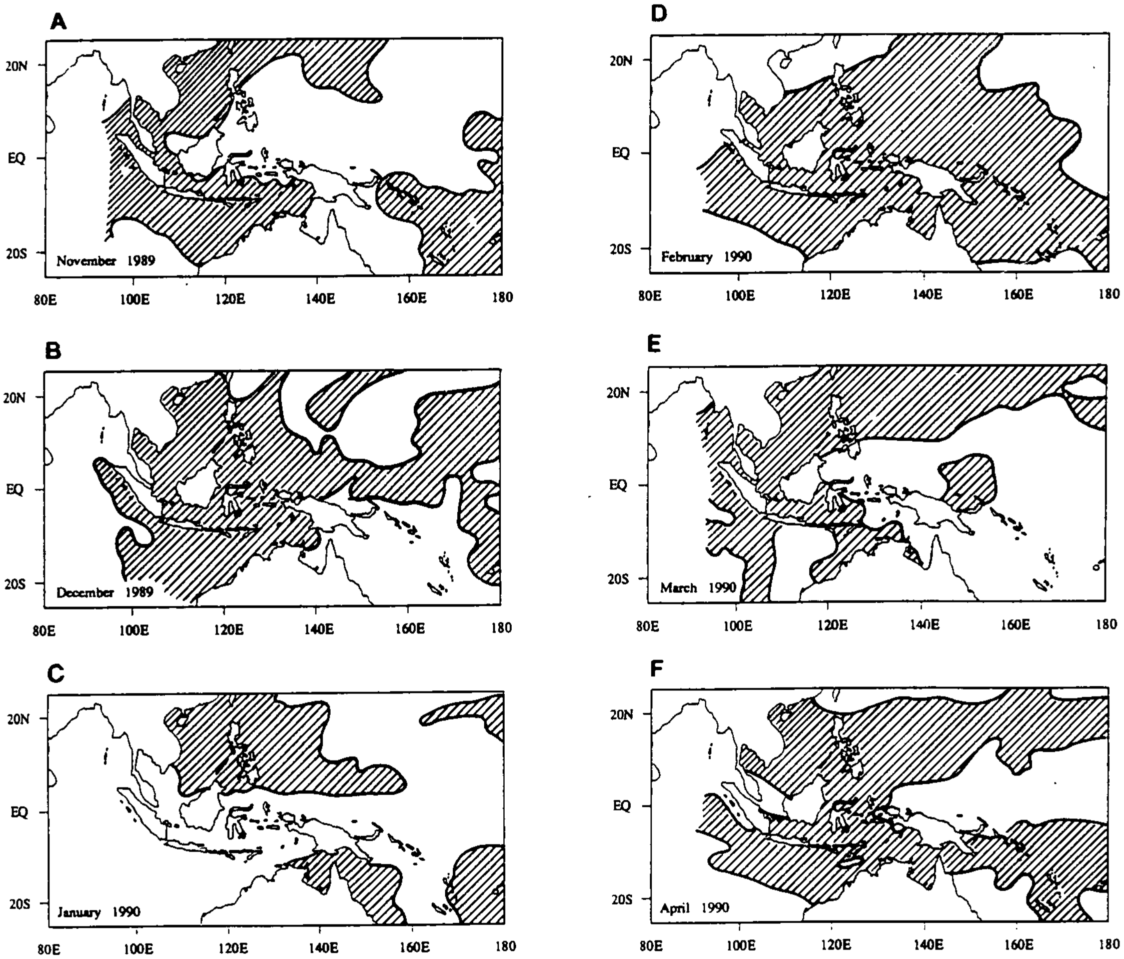
In the equatorial central Pacific, cold anomalies illustrated by Keith et al. (1991) during the same period in 1988/89 were noted to be in decline by Bate (1991) during May to October 1989. Janowiak (1990) observed that a warm water buildup in the equatorial western Pacific moved eastwards across the dateline during the period December 1989 to February 1990. Monthly SST anomaly fields in MRCS support this development and reveal a positive anomaly environment about the equator east of the dateline, continuing until April 1990, and are consistent with negative SOI values.

A major area of cold SST anomaly straddled 20°N and extended from the dateline to around 130°E, supporting a below average cloudiness bias in that area, espcially during FMA. Figure 4 (adapted from MRCS) traces monthly mean high-cloud amount anomalies for the period. With the exception of January, negative high-cloud anomalies dominated the oceanic areas to the west and northwest of tropical Australia, indicating the inactivity of the northeast (northern hemisphere) and northwest (southern hemisphere) monsoons. February in particular had below average high-cloud over most of the southern hemisphere tropics.

Above average cloudiness over parts of the northern hemisphere Pacific south of 20°N is likely to be associated with negative MSLP anomalies and tropical cyclone activity in that area, which coincides with an expanse of positive SST anomalies.

Low-level (950 hPa) vector wind anomalies for NDJ (Fig. 5(a)) and FMA (Fig. 5(b)) indicate a

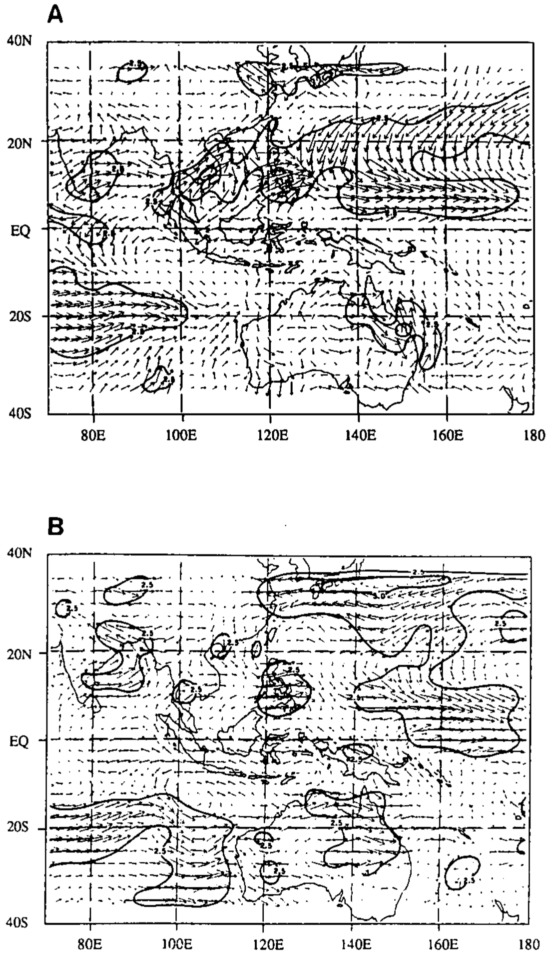
Fig. 4 Monthly mean high-cloud amount anomaly: (a) November 1989; (b) December 1989; (c) January 1990; (d) February 1990; (e) March 1990; (f) April 1990. Below zero anomalies hatched. (Note: no climatology over land.)



stronger than normal and more northerly situated northern hemisphere subtropical ridge. Stronger northeast trade winds and westerly anomalies in the near equatorial Pacific produced a cyclonic anomaly near 15°N. Cyclonic anomalies were also a feature of the southwest Pacific areas suggesting an active SPCZ and monsoon trough in that region. A stronger subtropical ridge in the east Tasman Sea and a weaker than normal ridge west of Australia produced weaker southeast trade flow over the Australian continent. In NDJ, cross-equatorial northeasterly vector wind anomalies predominated west of 130°E. An equatorial cross-section of mean meridional wind anomaly during NDJ (Fig. 6(a)) shows low-level northerly components to be most common between 70°E and 140°E. Southerly components can be seen to be weakly intruding on the cross-section east of 140°E; a stronger than normal monsoon flow in the low levels during NDJ is implied. Low-level southerly anomalies are scattered over a significant range of longitudes of the equatorial cross-section in FMA (Fig. 6(b)) and, together with a preponderance of near equatorial low-level southerly vector wind anomalies and anticyclonic anomalies over an area normally occupied by the monsoon trough to the northwest of Australia, they strongly indicate a weaker than normal low-level monsoon flow in FMA.

Upper-level (200 hPa) westerly vector wind anomalies (Figs 7(a) and 7(b)) along most of the equatorial belt suggest a weak monsoon return flow. Anticyclonic anomalies east of Australia and a cyclonic anomaly over the continent are reflections of a surface blocking pair in the Tasman Sea. This interruption of the upper subtropical ridge over Australia led to suppressed convective activity in the Australian tropics as indicated pre-

Fig. 5 Mean 950 hPa vector wind anomaly: (a) NDJ; (b) FMA. Isotach (solid lines) interval 2.5 m s^{-1}.



viously by high-cloud anomalies. The subtropical jet in the northern hemisphere was stronger than normal over Indo-China, China and Japan during NDJ but weaker than normal through almost the entire mid-latitude band in FMA.

Negative low-level velocity potential anomalies for NDJ (Fig. 8(a)) show an area of below average convergence in the far west Pacific, with branches extending west over South-East Asia, Indo-China and India, and south through Indonesia to northwest Australia. Notable are positive low-level velocity potential anomalies, indicating above average convergence, over Japan and in the southwest Pacific around the area normally occupied by the SPCZ. Above average upper-level divergence is reflected by positive velocity potential anomalies in NDJ (Fig. 8(b)) and complements the low levels over most areas except near Japan, where a below average divergence lies over above average convergence. This, however, is consistent with above average winter rainfall in the area and its likely association with cold-cored systems. In FMA below average low-level convergence dominated the RSMC area and is shown by negative low-level velocity potential anomalies in Fig. 9(a). A significant exception was around eastern Australia where three tropical cyclones in March and a locally forced area of instability for a large part of April were likely contributing factors. FMA upper-level divergence was below average over the full range of RSMC latitudes between 110°E and 160°E. Below average low-level convergence and upper-level divergence over areas normally affected by the monsoons further highlight the underdevelopment of tropical flow systems, especially in FMA.

Fig. 6 Equatorial cross-section of mean meridional wind anomaly (m s^{-1}): (a) NDJ; (b) FMA.

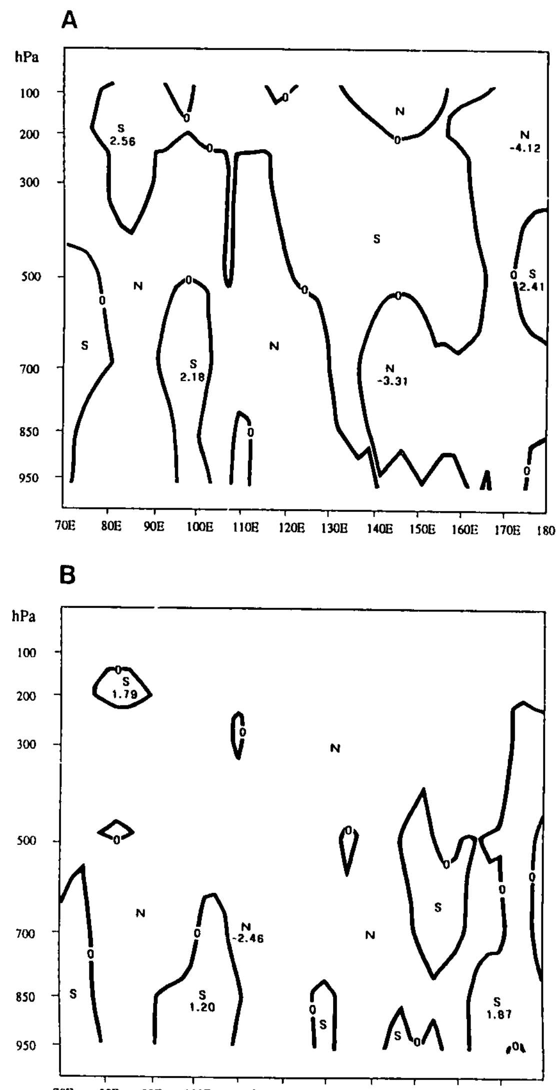


Fig. 7 Mean 200 hPa vector wind anomaly: (a) NDJ; (b) FMA. Isotach (solid lines) interval 2.5 m s^{-1}.

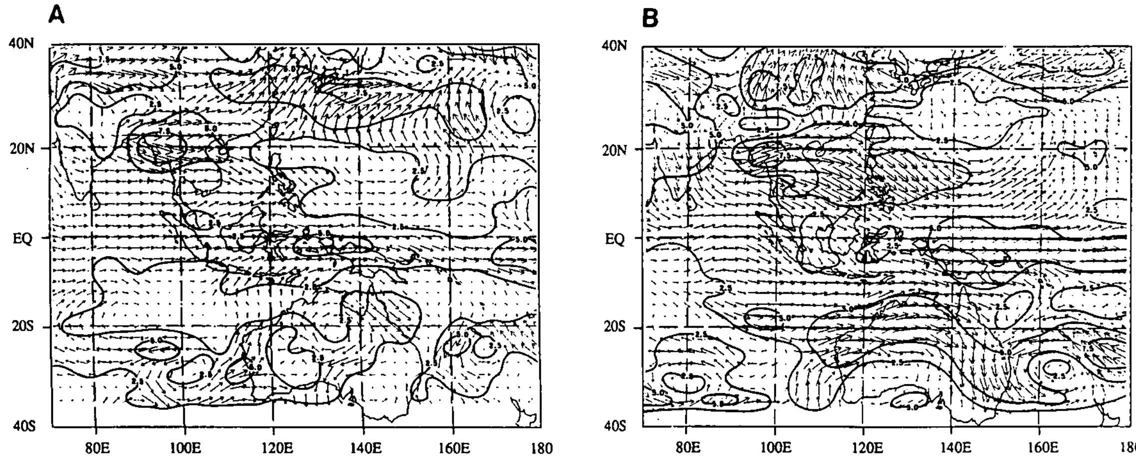


Fig. 8 Mean velocity potential anomalies for NDJ; (a) 950 hPa; (b) 200 hPa. Contour interval 10 × 10^4 m^2 s^{-1}, negative dashed.

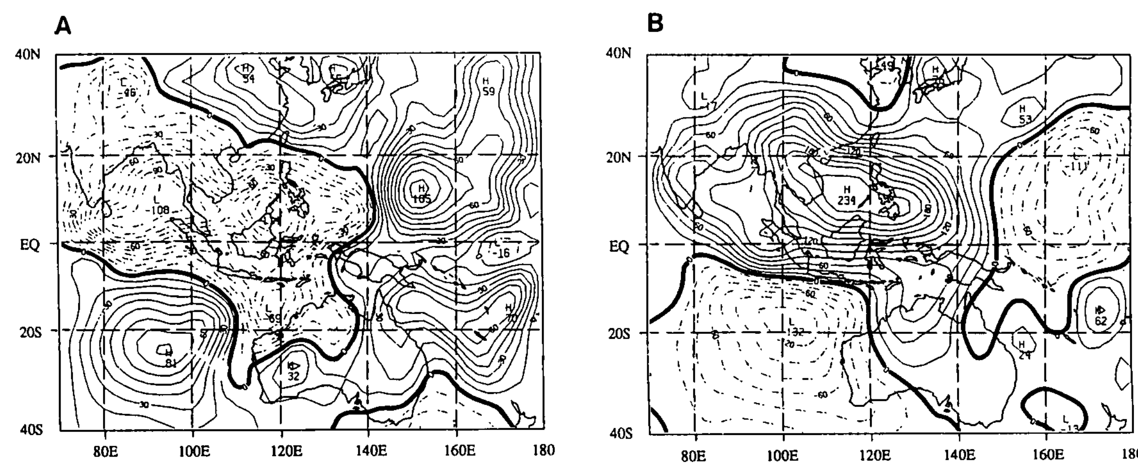


Fig. 9 Mean velocity potential anomalies for FMA: (a) 950 hPa; (b) 200 hPa. Contour interval 20 × 10^4 m^2 s^{-1}, negative dashed.

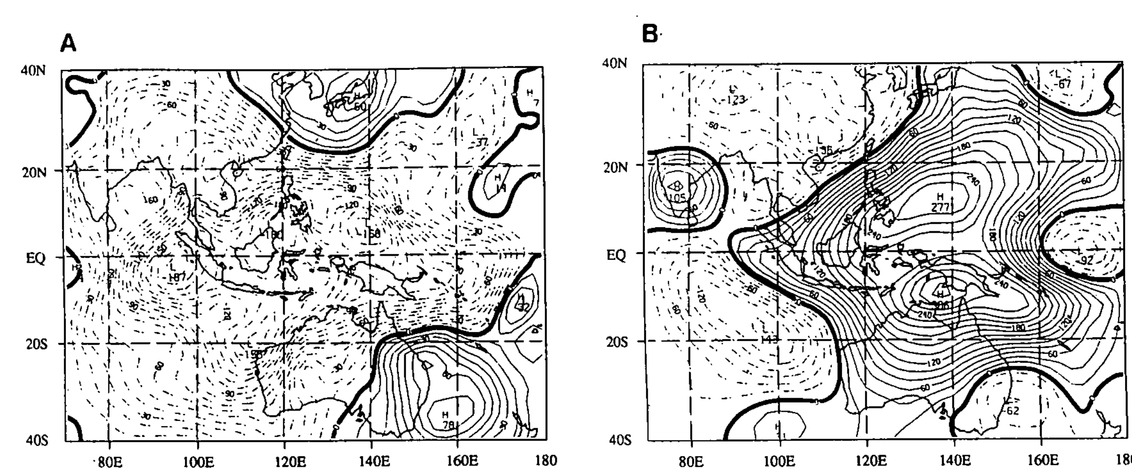


Fig. 10 Time-longitude cross-section of 200 hPa velocity potential (10^4 m^2 s^{-1}) for November 1989 to April 1990 averaged between: (a) 5°N and 15°N; (b) 5°S and 15°S. Adapted from DTDS.

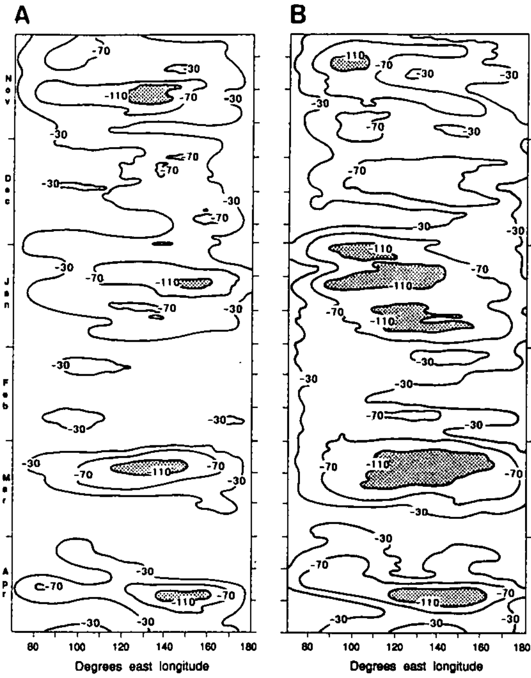


Fig. 11 Onset dates of northeast monsoon at seven stations in South-East Asia in 1989.

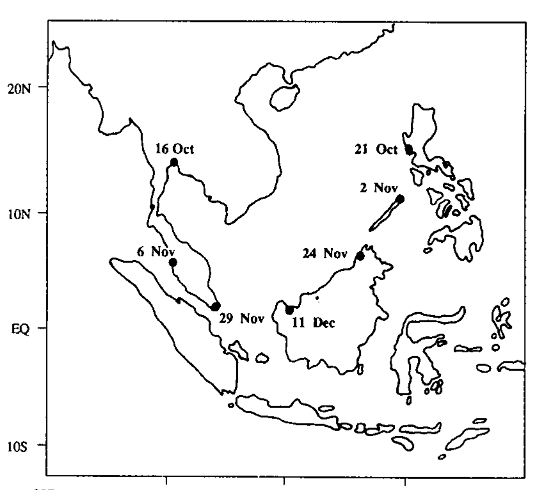
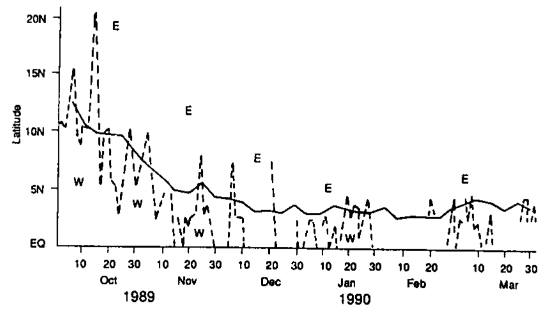


Fig. 12 Latitude-time cross-section of 850 hPa zonal winds across Indo-China and Peninsular Malaysia. E: easterly component winds; W: westerly component winds. Monsoon (near-equatorial) trough during 1989–90, dashed line; long-term mean monsoon (near-equatorial) trough, solid line.



Near-equatorial time-longitude cross-sections of velocity potential at 200 hPa (close to the convective outflow level) are shown in Fig. 10. Notable is the reduced convective activity during February on either side of the equator. Comparatively reduced activity is also implied during December in the northern hemisphere section. Madden-Julian (1971, 1972) oscillations, generally in the 40 to 50-day range, were evident throughout the season with strong coherence between the hemispheres. Higher frequency modes also appeared, manifested most strongly in the southern hemisphere in NDJ.

Based on the objective definition of Cheang and Tan (1988), dates of the onset of the northeast monsoon at seven northern hemisphere South-East Asian centres are illustrated in Fig. 11. Onset normally occurs along the northeast coast of Peninsular Malaysia in mid-November and on the northwest coast of Borneo in late December (Cheang 1980). The onset time over Malaysia in 1989 was near normal. Figure 12, a latitude-time cross-section of 850 hPa zonal wind along 103°E, clearly depicts the southward advance of the monsoon (or near-equatorial) trough over Malaysia and Indo-China during the northern winter of 1989/90; also shown are the long-term daily mean positions. The trough was located south of its mean position for most of October and November. Thereafter, it frequently disappeared from the Peninsular Malaysia/equatorial South China Sea region but, when detectable, the trough was generally located further south than normal.

Oscillations of active and break phases in the northeast monsoon over the South China Sea/Malaysia region are strongly associated with cold surges in the South China Sea and normally occur on a 10 to 20-day time-scale (Yap et al. 1982; Bate et al. 1989). To examine oscillations of this mode, a recursive 10 to 20-day band-pass filter was applied for the period October 1989 to March 1990 to time-series of: average surface pressure in China; surface pressure at Hong Kong; surface pressure at Kota Bharu (6°N, 102.5°E); and total daily rainfall averaged over four stations along the east coast of Peninsular Malaysia. Both the raw and filtered series are graphed in Fig. 13. Oscillations in the 10 to 20-day mode are not very distinct in the filtered pressure series, they are however clearer in the rainfall series. Lower frequency oscillations, in the 20 to 40-day mode, are identifiable in the average China and Kota Bharu unfiltered series. Rain spells along the east coast of Peninsular Malaysia in October through early November 1989 coincided with periods of lower pressures at Kota Bharu.

Cheang (1987) has shown that dry spells in South-East Asia are significantly enhanced by the existence of eastward-moving 500 hPa north-south orientated large amplitude troughs over the Bay of Bengal and Indo-China. Table 3 shows the frequency of 500 hPa troughs, which extended south of 10°N and appeared upward to 200 hPa over the Bay of Bengal/Indo-China region from November 1989 to March 1990, compared with long-term averages. It is clear that occurrences were very much above normal except in January. According to Cheang and Sankaran (1989), convective activity over the equatorial South China Sea/Malaysia region is suppressed if northerly surges interact with tropical storms over the northern South China Sea/Philippines/west Pacific region. The incidence of northerly surges over the South China Sea was below normal from November 1989 to January 1990. They returned to normal during February and were above average in March, but during those two months were weak and had little effect on convective activity over the Malaysia/South China Sea region.

Tropical cyclone tracks in the RSMC area during the entire period are shown in Fig. 14; Table 4 lists the systems in order of occurrence, within respective basins, together with their duration and maximum sustained wind. Detail for 1989 was adapted from the Joint Typhoon Warning Centre (1990); information relating to 1990 systems was extracted from Darwin RSMC operational analyses and DTDS (November 1989 to April 1990).

There were twenty-one cyclones (systems having maximum 10-minute mean winds of at least 17 m s^{-1}; a factor of 0.88 was used to convert maximum winds for northern hemisphere cyclones from one-minute to ten-minute means) in the RSMC area (DTDS showed an additional system was analysed in the Australian region during January 1990; it was, however, downgraded after post-analysis), ten of which achieved severe tropical cyclone (typhoon) status. Eight occurred in the Australian region (105°E–165°E) compared with an annual average of 10.0 (JTWC 1989). Six occurred in the western north Pacific compared with an annual average of 5.9, and all but one achieved typhoon status against an average of 3.5. The north Indian Ocean basin was inactive with no cyclogenesis being recorded or analysed (typhoon *Gay* was spawned in the Gulf of Thailand but spent a large proportion of its life in the

Table 3. Occurrence of 500 hPa north-south orientated troughs over the Bay of Bengal/Indo-China region during the period November 1989 to March 1990.

	Actual 1989/90	*Long-term average*
November	8	2.8
December	12	5.2
January	0	9.9
February	24	10.6
March	14	9.3
Total	58	37.8

Table 4. Tropical cyclones within the Darwin Regional/Specialised Meteorological Centre (RSMC) analysis area, November 1989–April 1990.

Tropical cyclone name	*Duration (UTC) of storm above cyclone strength in Darwin RSMC area*	*Maximum sustained (10 min) wind m/s*
Western north Pacific Ocean:		
*Gay**	02 Nov–10 Nov	63
Hunt	17 Nov–23 Nov	40
Irma†	27 Nov–04 Dec	63
Jack	23 Dec–28 Dec	56
Koryn	13 Jan–17 Jan	53
Lewis	29 Apr–30 Apr	17
South Indian Ocean (70°E–105°E):		
Pedro	08 Nov–13 Nov	28
Baomavo	03 Jan–07 Jan	44
Rosita	14 Jan–15 Jan	23
Dety§	03 Feb–08 Feb	33
Walter/Gregoara†	06 Mar–23 Mar	51
Bessie	16 Apr–18 Apr	26
Australia (105°E–165°E):		
Felicity	15 Dec	28
Sam	14 Jan–20 Jan	31
Nancy	31 Jan–03 Feb	28
Greg	03 Mar–05 Mar	23
Vincent	03 Mar–06 Mar	31
Hilda	05 Mar–08 Mar	28
Alex‡	16 Mar–24 Mar	51
Ivor	16 Mar–21 Mar	36
South Pacific Ocean (165°E–180°):		
Rae§	22 Mar–24 Mar	26

Cyclones marked:
*moved into north Indian Ocean on 5 November.
†regenerated.
‡moved into south Indian Ocean.
§moved out of RSMC area.

Fig. 13 Recursive 10 to 20-day band-passed filtered time-series (solid line): (a) surface pressure averaged over six stations in China; (b) Hong Kong surface pressure; (c) Kota Bharu surface pressure; (d) total daily rainfall at four stations along the east coast of Peninsular Malaysia. Raw data, dashed lines.

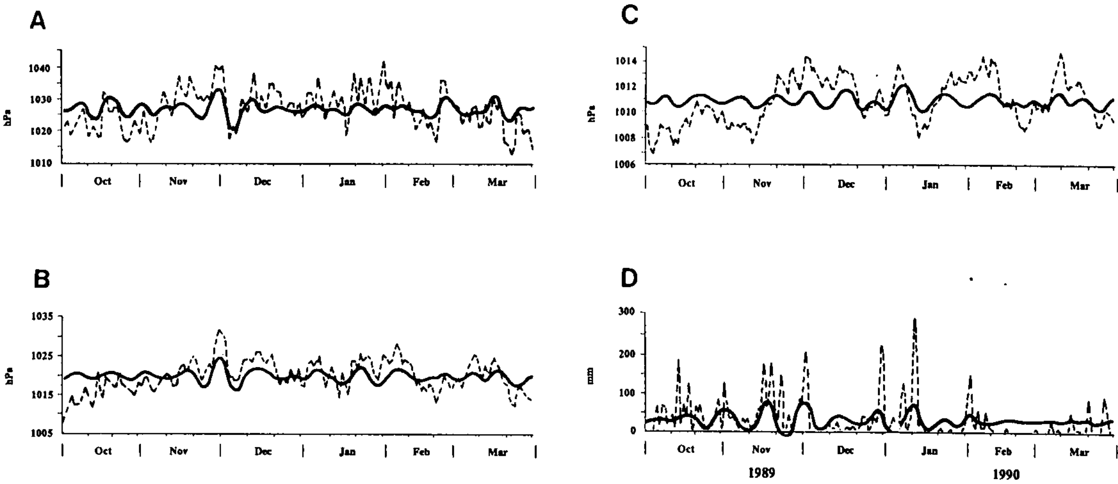


Fig. 14 Tracks of tropical cyclones in Darwin RSMC area for November 1989 to April 1990. Tracks are adapted from Joint Typhoon Warning Center (1990), Darwin operational RSMC analyses and DTDS.

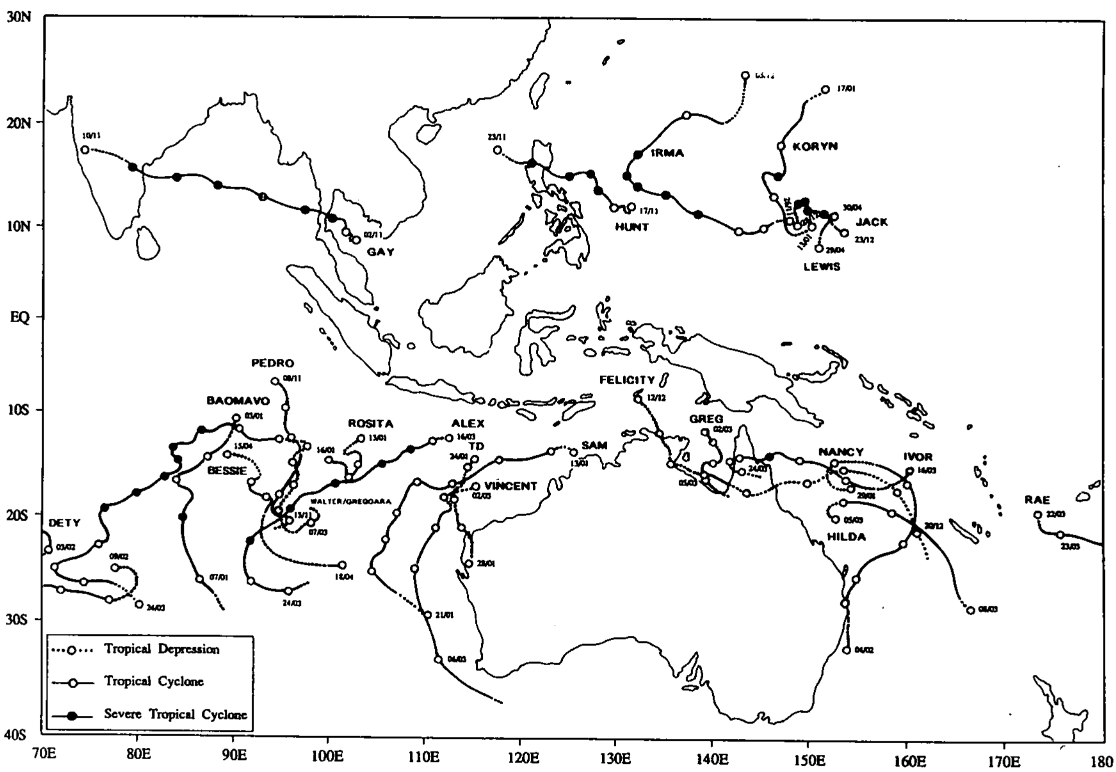
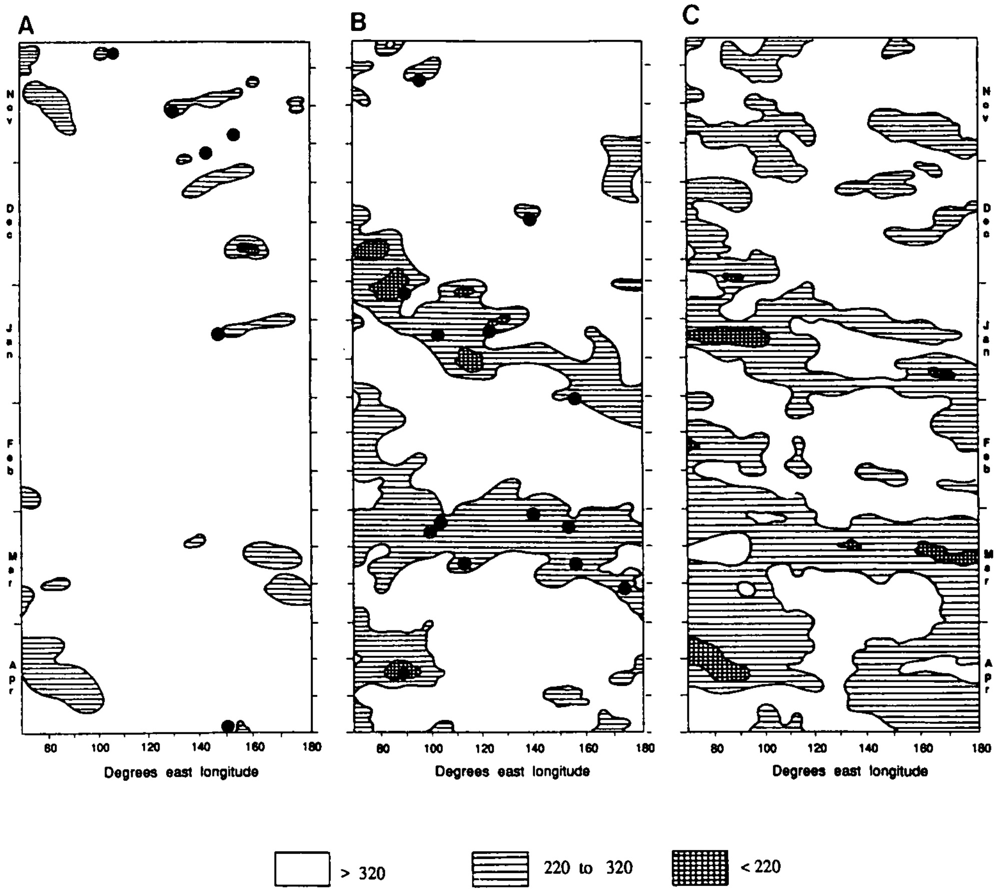


Fig. 15 Time cross-section of monthly mean OLR anomaly for November 1989 to April 1990 (adapted from DTDS): (a) 5°N–15°N; (b) 5°S–15°S; (c) 5°N–5°S. Cyclone geneses, solid dots.



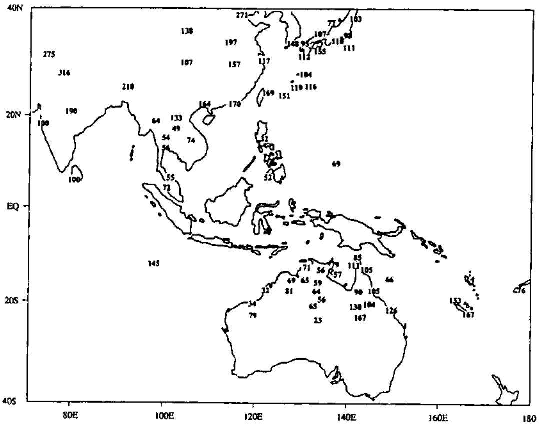
Bay of Bengal). The annual average number for that basin is 2.3.

Annual average figures are not available to adequately describe RSMC parts of the south Indian Ocean and South Pacific Ocean tropical cyclone numbers. Between November 1989 and April 1990, those basins had six cyclones and one cyclone respectively.

Figure 15 shows tropical cyclone genesis positions overlaid on outgoing long wave radiation (OLR) time cross-sections; there is good agreement between cyclone activity and smaller OLR values. Cyclone genesis events are clearly grouped in the time mode. Some periodicity of groups is also evident, a feature noted by Gray (1988) who found that tropical cyclone genesis events were grouped, and the groups have a degree of correspondence with the Madden and Julian (1971, 1972) 40 to 50-day oscillation which has also been detected in OLR.

Rainfall as a percentage of the six-month climatological total is illustrated in Fig. 16 (the data base is by no means exhaustive, especially across equatorial areas between 10°N and 10°S and the Philippines). Data sources comprise MRCS, Monthly Weather Review (MWR) and Monthly Climatic Data for the World (see Appendix). Rainfall deficiencies are clearly identifiable over most of the Australian tropics. The exception is over the northeast where the below average trend was markedly reversed in March due to the impact of three tropical cyclones on the area — record high totals were recorded over large areas during that month. Broad surface troughing, moist low-level winds and an unstable upper air environment during the first three weeks of April ensured maintenance of extreme high rainfall over the area. The dominance of the event is reflected in an area of above average cloudiness along the Australian east coast in April — note

Fig. 16 Percentage of accumulated rainfall for November 1989 to April 1990 compared with climatological mean.



that high-cloud anomalies are not shown over land. Below average totals were also recorded in the west Pacific, the Philippines and in Thailand.

Above average rainfall was recorded along the east coast of Peninsular Malaysia during October and the first half of November 1989. These early rains were associated with vortices in the monsoon trough which was east-west orientated across the Gulf of Thailand. After the onset of the monsoon over Peninsular Malaysia, rainfall-inhibiting effects described earlier became dominant and totals were below normal till the end of March 1990.

Rainfall totals in excess of normal were recorded over northwest Pacific islands, most of Japan and throughout China, parts of Indo-China and across northern India. Above average cloudiness was a feature of those areas.

Summary

This paper has summarised the tropical circulation from 70°E to the dateline from November 1989 to April 1990. The period was characterised by a negative SOI phase and persistent high pressure anomalies over northern Australia, each a precursor to El Niño. However, SST patterns within the study area, and especially in the eastern Pacific, provide strong contrary evidence indicating that anomalies may have been a reflection of local effects. The northern hemisphere monsoon, although timely, was less developed than normal resulting in below average rainfall over a large part of South-East Asia and Indo-China. The monsoon in the southern hemisphere was also underdeveloped, particularly across Australian longitudes; convection and consequently seasonal rainfall were generally below average. Tropical cyclone occurrences were slightly below the long-term mean except in the northwest Pacific, where the number of storms to achieve typhoon status was above average.

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Appendix

Data sources used in this review include:

Monthly Weather Review (November 1989-April 1990), issued monthly by the Bureau of Meteorology, GPO Box 735, Darwin NT 0801; GPO Box 413, Brisbane Qld 4001; PO Box 6070, East Perth WA 6892, Australia.

Darwin Tropical Diagnostic Statement (November 1989–April 1990), issued monthly by Bureau of Meteorology, GPO Box 735, Darwin NT 0801, Australia.

Darwin RSMC grid-point analysis data from the Tropical Analysis Scheme and Australian region grid-point analysis data from National Meteorological Centre, GPO Box 1289K, Melbourne Vic 3001, Australia.

Darwin RSMC weekly manual ship/buoy sea-surface temperature analyses, converted to grid-point format at 5° x 5° resolution.

Monthly CLIMAT messages received via Global Telecommunications System.

Monthly Report on Climate System (November 1989–April 1990), prepared by the Long-range Forecast Division, Forecast Department, Japan Meteorological Agency, 1–3–4, Ote-machi, Chiyoda-ku, Tokyo 100, Japan.

Monthly Climatic Data for the World (November 1989–April 1990), prepared by National Climatic Data Center, Federal Building, Asheville, North Carolina, USA 28801–2696.