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The tropical circulation in the Australian/Asian region November 1988 to April 1989

R. Keith* and P.W. Bate
Regional Office, Bureau of Meteorology, Darwin, Australia
and
B.K. Cheang and P. Sankaran
Malaysian Meteorological Service, Kuala Lumpur, Malaysia

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This study investigates and summarises the tropical circulation between 70°E and the dateline for the period November 1988 to April 1989 – a period characterised by the normalisation of a major 'cool' El Niño-Southern Oscillation (ENSO) event. Seasonal circulation anomalies typical of the phase of ENSO are documented and discussed briefly. The northwest monsoon in the southern hemisphere had an early onset and produced above average rainfall in the Australian region. Tropical cyclone occurrence in the Australian region was below average whilst a near-normal number of cyclones occurred in the northern hemisphere sector. Low frequency oscillations which are associated with convection in the Malaysian and north Australian regions are also investigated.

Introduction

Following the methodology of the previous summary in this series (Butterworth et al. 1990), description of the broadscale seasonal circulation has been limited mostly to interannual changes and characteristics. However, since low frequency oscillations played an important role, these are also discussed. Previous summaries (e.g. Garden et al. 1989) have described most of the data sources. Monthly mean charts have been used in some instances as they describe variations within the season more appropriately than three and six-monthly composites, which were also available. The area studied is the tropical part of the area of analysis responsibility of Darwin Regional Specialised Meteorological Centre (RSMC).

The period under investigation was during a normalising phase of a strong 'cool' ENSO event. In terms of the Southern Oscillation Index (SOI), values of which are given in Table 1 from the start of 1987, it was the most marked positive excursion since the southern summer of 1975/1976. Its effect was reflected in the pattern of mean sea level (MSL) pressure and sea-surface temperature (SST) anomalies and an enhanced monsoon in the north Australian-Indonesian area. Pressures in the tropics were generally below average, while warm SST anomalies covered most of the region.

Corresponding author address: R. Keith, Meteorological Office, PO Box 5301, MSO, Townsville, Qld 4816.
*Present location: Bureau of Meteorology, Townsville.

The tropical circulation from November 1988 to April 1989

MSL pressure and SST patterns

Figure 1 shows three-month composite SST analyses for November 1988 to January 1989 and for February to April 1989. Positive anomalies covered most of the RSMC area, though their magnitude generally decreased in the tropics during the season. Negative anomalies of 2° to 3°C covered a significant part of the equatorial central

Table 1. Values of Troup's Southern Oscillation Index from January 1987 until April 1989.

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
1987	−7	−14	−15	−22	−20	−18	−18	−13	−11	−6	−1	−6
1988	−2	−6	+1	−1	+10	−4	+11	+14	+20	+16	+20	+10
1989	+12	+8	+5	+18								

Fig. 1 SST anomalies for (a) November 1988 to January 1989, (b) February to April 1989. Contour interval 1°C.

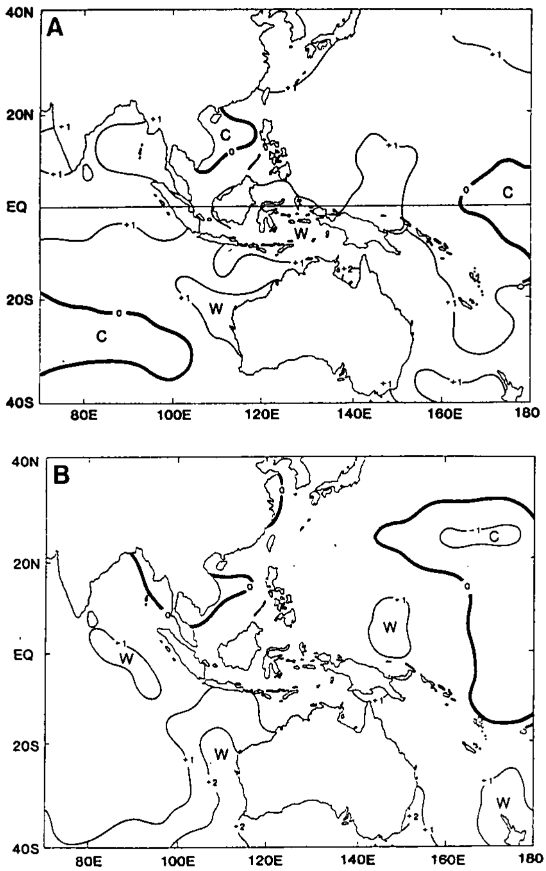
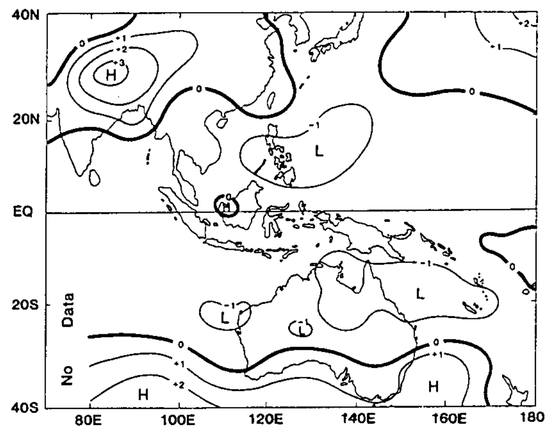


Fig. 2 MSL pressure anomaly (hPa) for period November 1988 to April 1989, synthesised from 10 degree grid-points in Monthly Report on Climate System (MRCS), Long-range Forecast Division, JMA, Tokyo (northern hemisphere), monthly CLIMAT mesages and interpolation of monthly MSL pressure anomaly analyses for Darwin RSMC.



and eastern Pacific Ocean (Climate Diagnostics Bulletins, November 1988–April 1989*). This broad pattern remained fairly constant in tropical waters during the six months; the negative anomalies in the Pacific peaked around February and March, then decreased steadily in the few months following.

Figure 2 is a six-month composite of MSL pressure anomaly. Pressure was generally 1 to 2 hPa below average across northern Australia. Most of the northern hemisphere tropics also exhibited below average pressure. As with the SST anomaly field, the pressure anomaly pattern remained broadly constant during the six months.

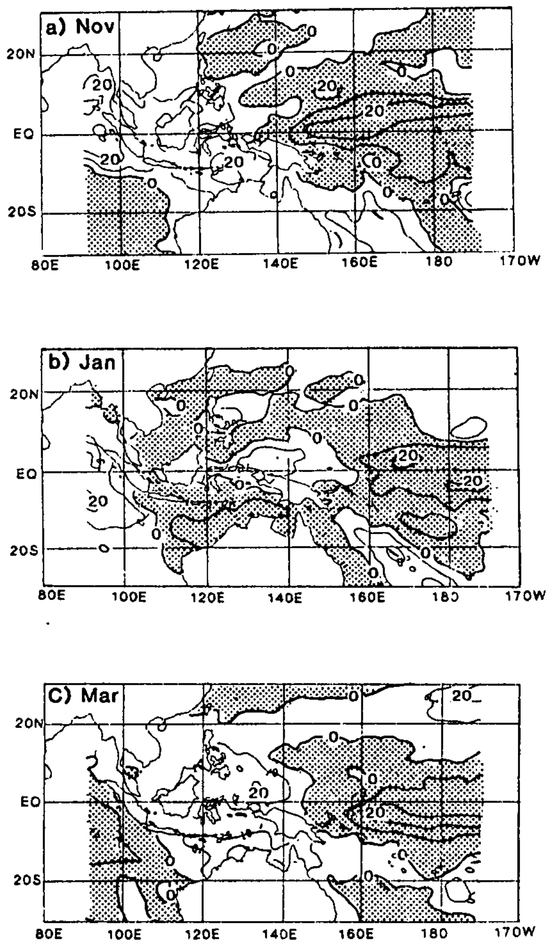
The summer monsoon in the Australian-Indonesian region

The period under study can be dissected into three quite different phases in the Australian region. Figure 3 shows monthly mean high cloud anomalies for November, January and March; these illustrate the temporal division of convection. Figure 4 contains 950 hPa (gradient level) and 200 hPa wind anomalies, from the tropical analysis scheme (TAS) of Davidson and McAvaney (1981), for December, February and April. Anomalies in these months best illustrate the three main regimes of wind flow during the six months.

During November and December, oceanic convection was above average over most of the tropics west of 140°E and below average further eastward. This is as would be expected in a 'cool' ENSO event. The South Pacific convergence zone was also active. Westerly gradient wind anomalies dominated the tropics south of 10°S during November and December and easterly wind anomalies at high levels covered most of the tropics south of about 5°S. These factors are consistent

*Climate Diagnostics Bulletin, available from Climate Analysis Center, NOAA/NSW/NMC, Room 605, World Weather Building, Washington DC 20233, USA.

Fig. 3 High cloud anomalies (from MRCS) for (a) November 1988, (b) January 1989, (c) March 1989. Contour interval 10% with negative areas stippled.



with an early onset of the southern summer monsoon season. The monsoon trough developed over northern Australia during November and the first active period of the monsoon commenced at the end of that month. This can be seen in the time-longitude section of 200 hPa velocity potential (Fig. 5); because of the way areas of convergence and divergence are depicted, velocity potential is commonly used in the literature as a proxy for convection (e.g., Kingston et al. 1987). Rainfall through the southern hemisphere tropics was above to well above average during November and December 1988. Figure 6 shows rainfall quintile ranges for December 1988 and February and April 1989. These values were taken from monthly CLIMAT messages received via the Global Telecommunication System.

During January and February, convection was below average over northern Australia, Indonesia and Malaysia, as the January high cloud anomaly in Fig. 3 illustrates. The area of below average convection near the equator persisted east of 150°E. A southerly component of the gradient-level wind anomaly over South-East Asia and northern Australia and a westerly component at 200 hPa south of 5°N during most of these months, suggest a poorly developed southern monsoonal circulation. During January and February the trough over northern Australia was a shallow 'heat' trough, with the exception of a brief period in late January when the second active period of the monsoon occurred. These factors are suggestive of suppressed monsoonal activity. Thus, during a period when the monsoon is typically at its peak, it was in a mostly suppressed state, reflected in the circulation and cloud anomalies of Figs 3 and 4. The rain produced by this second onset was in general less than in the first.

March and April exhibited above average convection over most of the area west of 150°E. An exception was the region around Malaysia (Fig. 3). Westerly gradient wind anomalies reappeared across Indonesia and northern Australia, and easterly anomalies dominated the region at 200 hPa. Figure 5 shows that the third active period of the north Australian monsoon occurred about a week into March. It produced widespread heavy rain. Areas of flooding occurred through inland Australia as a result of the development of depressions during two southerly excursions of the monsoon trough. As can be seen in Fig. 5, a fourth active period of the monsoon occurred in mid-April. The heavy rain with this event was limited mostly to the northern coastal fringe of Australia. This may be due partly to the lateness of the event within the 'wet' season with less continental heating further south, in line with the finding of Gadgil (1988), who showed that large-scale rainfall in the Indian monsoon is associated with the movement of tropical convergence zones onto the heated continent.

The northeast monsoon in the northern hemisphere tropics

An objective definition of the onset of the northeast monsoon applicable to South-East Asian countries north of the equator is the time when 850 hPa and 700 hPa zonal wind components become easterly and remain so for at least 20 days during the month that follows (Cheang and Tan 1988). Based on these criteria, the times of onset of the northeast monsoon for 1988–89 at Bangkok (Thailand), Bayan Lepas (northern Peninsular Malaysia), Kota Kinabalu (northeastern Borneo) and Kuching (western Borneo) are shown in Fig. 7.

The actual 1988–89 daily and long-term mean daily positions of the monsoon (or near-equatorial) trough over Malaysia and Indo-China at 103°E are shown in Fig. 8 in terms of zonal wind at

Fig. 4 950hPa and 200hPa vector wind anomalies from TAS, for (a) and (b) December 1988, (c) and (d) February 1989, (e) and (f) April 1989.

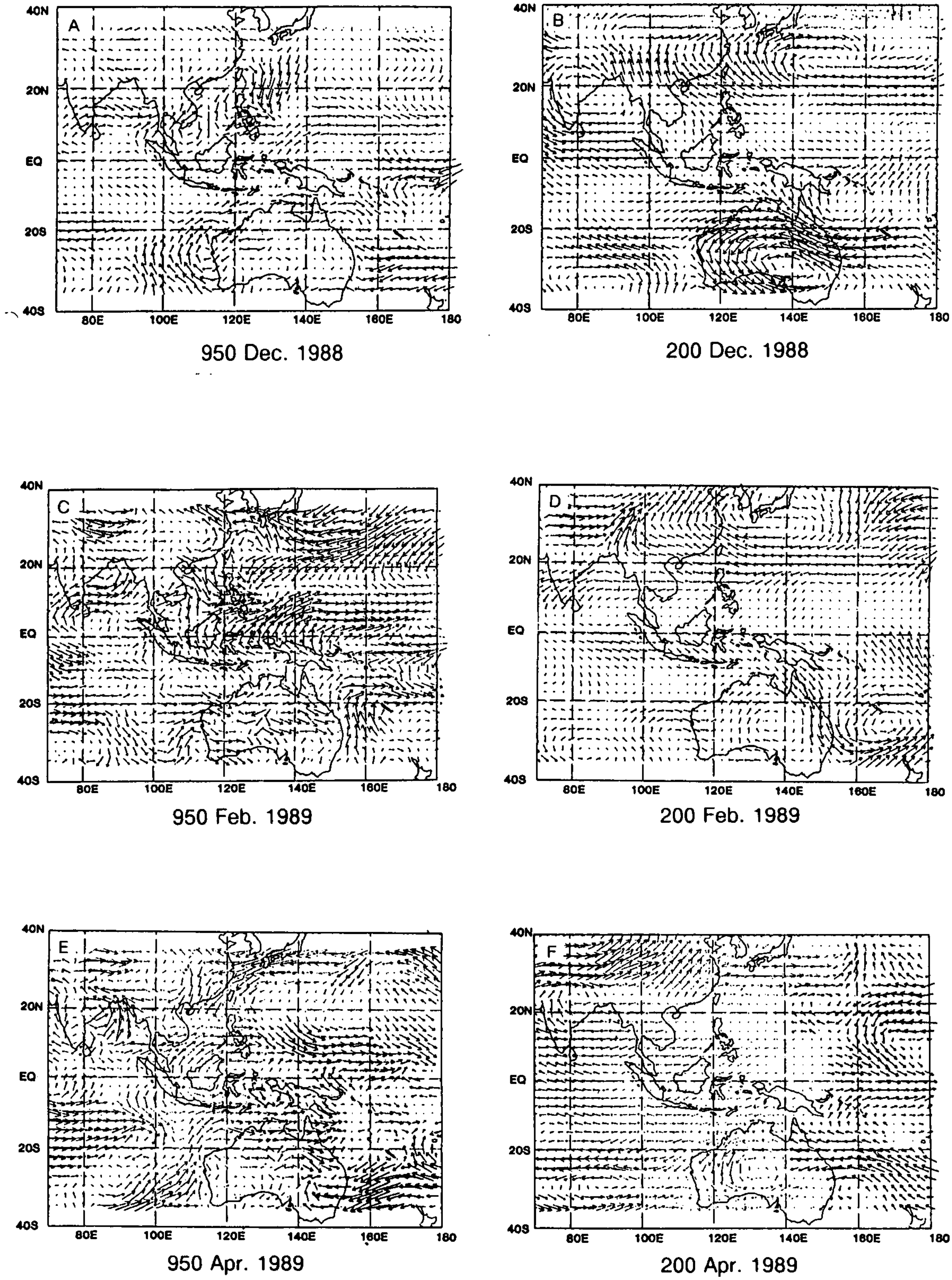


Fig. 5 Time-longitude section of 200hPa velocity potential, averaged between 5°S and 15°S, from TAS. Values 10^5 m^2 s^{-1}.

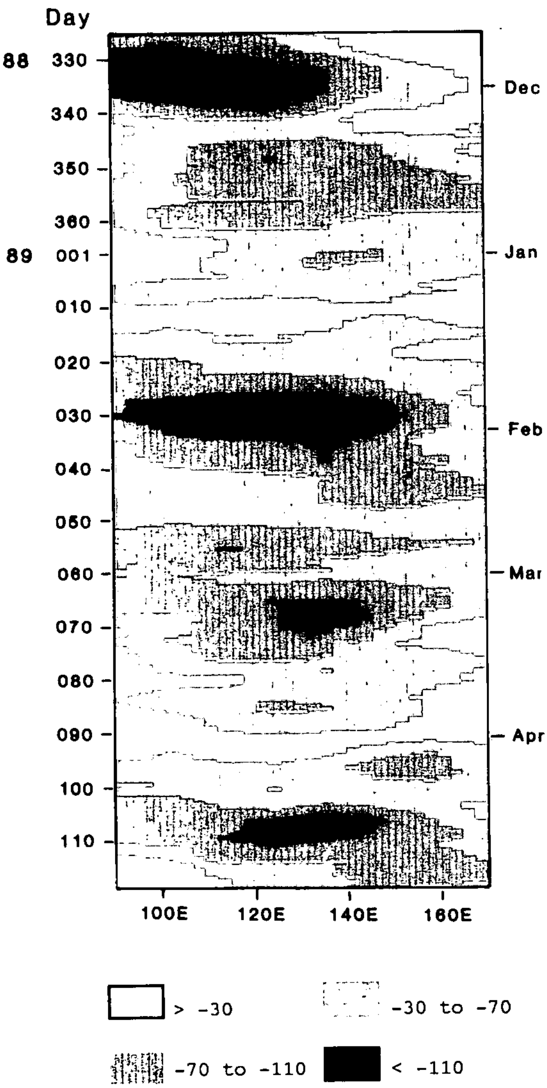


Table 2. Tropical cyclones within the Darwin RSMC analysis area November 1988–April 1989.

Tropical cyclone name	*Duration (UTC) of storm above cyclone strength in Darwin RSMC area*	*Maximum sustained (10 min) wind ($m\ s^{-1}$)*
North Indian Ocean		
'03B'	18 Nov	25
'04B'	24 Nov–29 Nov	45
'05B'	07 Dec–08 Dec	20
Western north Pacific Ocean		
Skip	03 Nov–12 Nov	45
Tess	04 Nov–06 Nov	29
Val	23 Dec–24 Dec	20
Winona	18 Jan–19 Jan	25
Andy	17 Apr–23 Apr	63
South Indian Ocean (west of 105°E)		
Adelinina	01 Nov–05 Nov	34
Barisaona	05 Nov–17 Nov *	43
Edme	19 Jan–25 Jan	34
John	27 Jan–30 Jan	23
Gizela	18 Feb–22 Feb	32
Leon/Hanitra	19 Feb–28 Feb	54
Krissy	30 Mar–03 Apr *	48
Marcia	03 Apr–04 Apr	21
Lezissy	06 Apr–08 Apr *	20
Australia (105°E–165°E)		
Ilona	13 Dec–18 Dec	44
Delilah	01 Jan–04 Jan	31
Kirrily	06 Feb–10 Feb	39
Harry	08 Feb–19 Feb	51
Ned	27 Mar–31 Mar	44
Aivu	01 Apr–04 Apr	46
Lili	07 Apr–11 Apr	39
Orson	19 Apr–23 Apr	51
South Pacific (165°E–180°)		
Eseta	23 Dec - 25 Dec	28
Ivy	23 Feb - 01 Mar	39
Kerry	01 Apr - 02 Apr *	26

Note: Cyclones marked * moved out of the Darwin RSMC area after reaching peak intensity.

850 hPa. Note that the onset was later than normal over Indo-China, but that the trough moved rapidly southward in early November so onset over Peninsular Malaysia was near normal.

During November 1988, rainfall in much of Malaysia was above average. An above average incidence of northeasterly surges from Siberia, and the proximity of the near-equatorial trough were major contributing factors.

From December 1988 to March 1989, rainfall was near or below average in Malaysia. This can be attributed largely to the southern displacement of the near-equatorial trough from its normal position as well as its frequent withdrawal from the southern South China Sea-Malaysia region (Fig. 8). These conditions in turn resulted from above average convection associated with tropical storm and typhoon activity over the northern Philippines-western north Pacific region. An unpublished investigation by two of the authors has shown that tropical storms near the Philippines interact with northeasterly surges, enhancing convection over the region and suppressing convection over the South China Sea-Malaysia region.

Note that although the total of two tropical cyclones in the north Pacific basin west of the dateline from December 1988 to March 1989 (Table 2) was below the 30-year average of 2.6 (Joint Typhoon Warning Center (JTWC) 1989) both these cyclones affected the area adjacent to the Philippines (Fig. 10); high cloud anomalies in Fig. 3 show positive values there also.

Yap et al. (1982) found that the wet and dry cycle over the South China Sea-Malaysia region

Fig. 6 Rainfall quintile analyses for (a) December 1988, (b) February 1989, (c) April 1989. Vertical hatching ≤1; diagonal hatching ≥ 5.

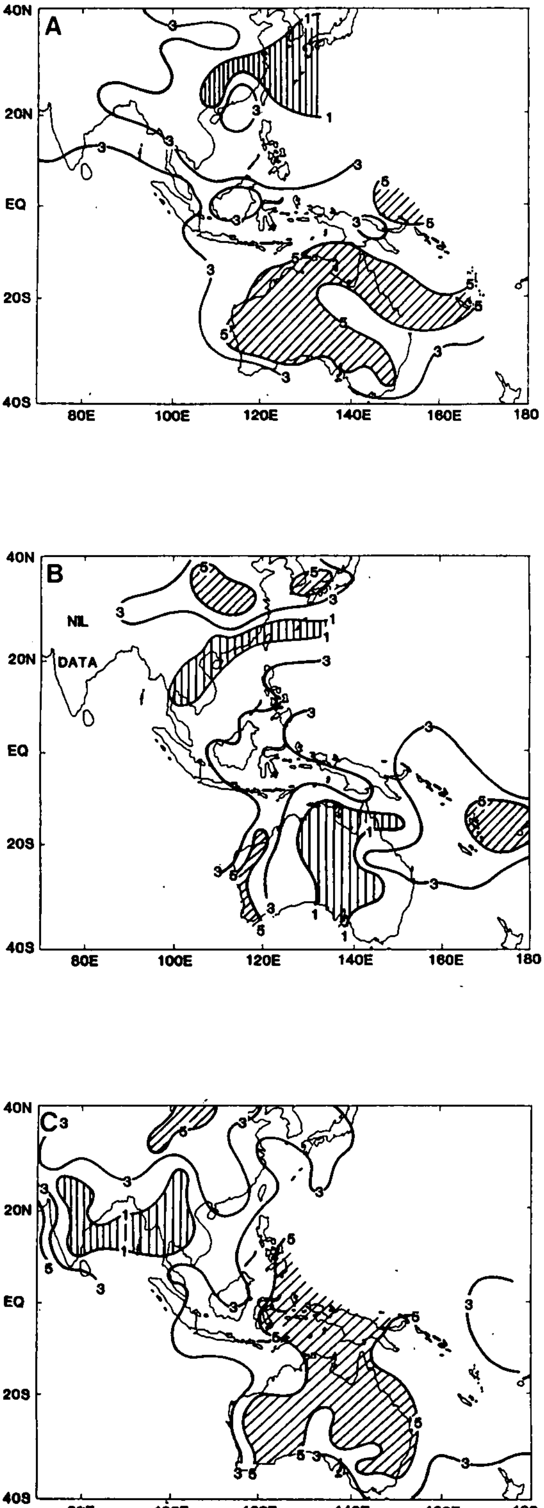


Fig. 7 Time-height section of zonal wind components at Bangkok, Bayan Lepas, Kota Kinabalu and Kuching. Westerly components stippled.

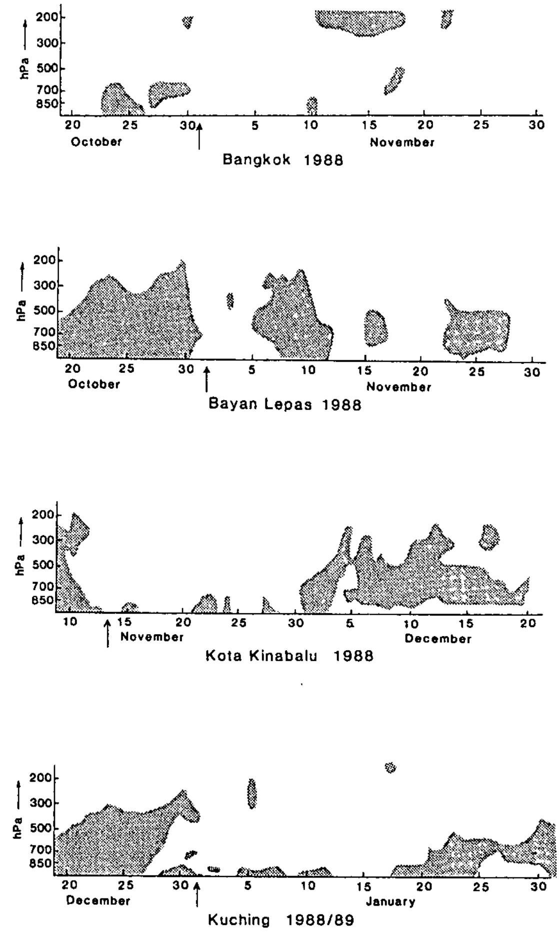
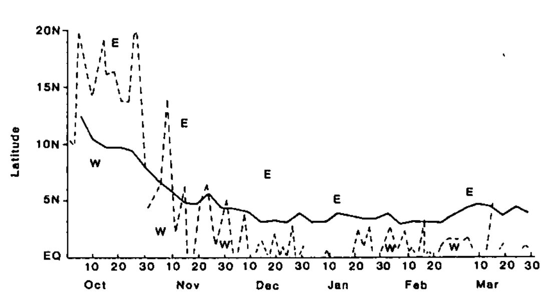


Fig. 8 Actual daily (dashed line) and long-term mean daily (solid line) positions of the monsoon trough, in terms of zonal wind components, at 103°E in the northern hemisphere.



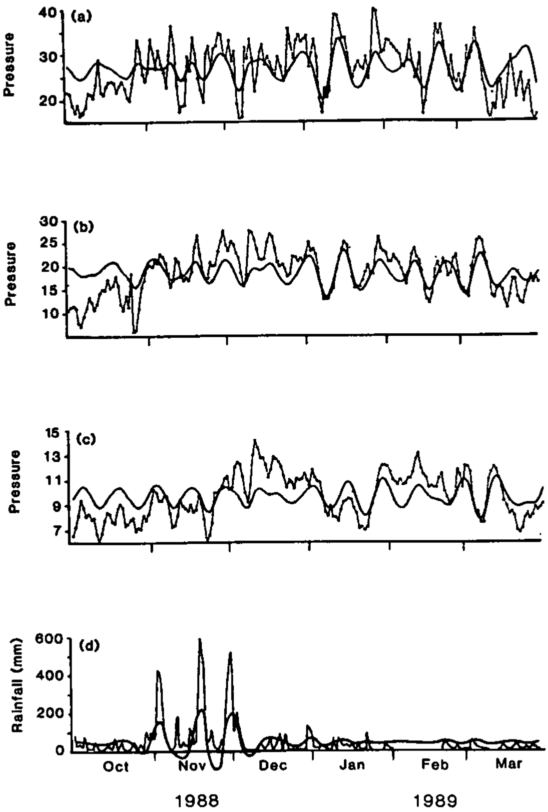


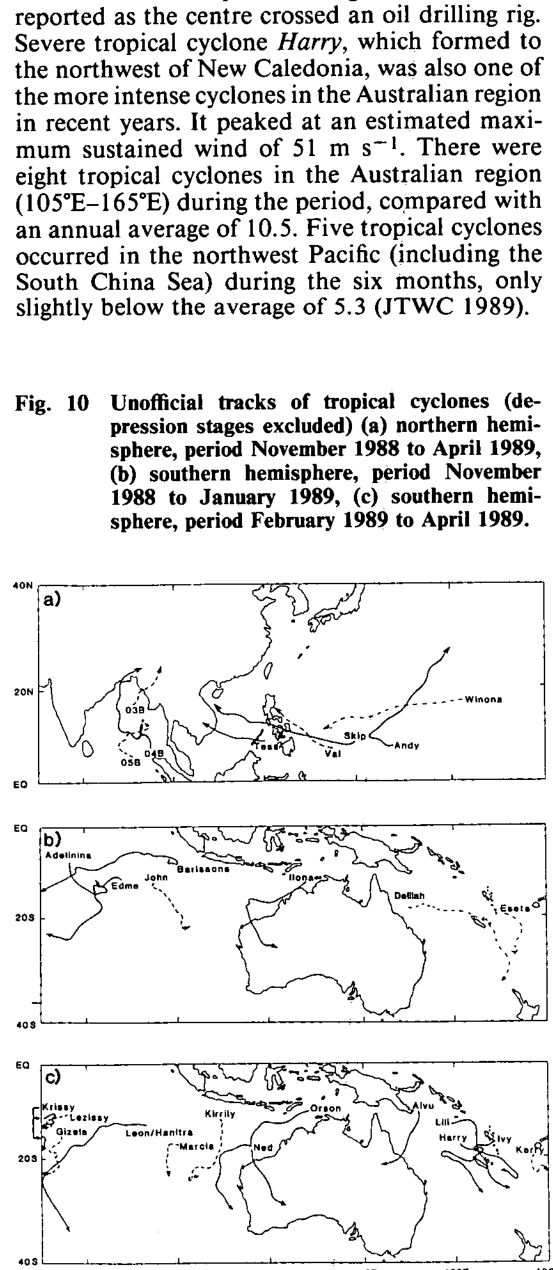
Fig. 9 Recursive 10 to 20-day band-passed filtered time-series (heavy line) of (a) average surface pressure in China, (b) surface pressure at Hong Kong, (c) surface pressure at Kota Bharu (in Peninsular Malaysia, 6°N, 102.5°E) and (d) total daily rainfall at four stations along the east coast of Peninsular Malaysia. Thin lines are raw data. Pressures are hPa minus 1000.

during the 1978–79 northern winter monsoon was strongly influenced by the major cold surges, which occur on a 10 to 20-day time-scale. To examine such oscillations, a recursive 10 to 20-day band-passed filter was applied to the time-series of (a) average surface pressure in China, (b) surface pressure at Hong Kong, (c) surface pressure at Kota Bharu and (d) total daily rainfall at four stations along the east coast of Peninsular Malaysia. These filtered series are depicted in Fig. 9. Oscillations with periods between 10 and 20 days are very prominent in the filtered series, except for the rainfall series which do not show any significant fluctuations from January to March. The series are generally in phase.

Tropical cyclones

Unofficial tracks of tropical cyclones (defined as having maximum 10-minute mean winds ⩾ 17 m s^{-1}, or named systems) for the period are shown in Fig. 10. Twenty-eight cyclones occurred in Darwin RSMC's analysis area and they are listed in Table 2, together with their duration above cyclone strength and maximum sustained wind. Sixteen of these reached severe tropical cyclone (typhoon) status. Only one, typhoon *Andy* in the northwest Pacific, attained 'super-typhoon' status. Two severe cyclones crossed the Australian coast, *Aivu* on the Queensland coast and *Orson* on the north coast of Western Australia. *Orson* was a particularly intense storm, with a central pressure of 905 hPa and a peak wind gust of 69 m s^{-1} reported as the centre crossed an oil drilling rig. Severe tropical cyclone *Harry*, which formed to the northwest of New Caledonia, was also one of the more intense cyclones in the Australian region in recent years. It peaked at an estimated maximum sustained wind of 51 m s^{-1}. There were eight tropical cyclones in the Australian region (105°E–165°E) during the period, compared with an annual average of 10.5. Five tropical cyclones occurred in the northwest Pacific (including the South China Sea) during the six months, only slightly below the average of 5.3 (JTWC 1989).

Fig. 10 Unofficial tracks of tropical cyclones (depression stages excluded) (a) northern hemisphere, period November 1988 to April 1989, (b) southern hemisphere, period November 1988 to January 1989, (c) southern hemisphere, period February 1989 to April 1989.



Comparison of the north Australian monsoon with that of 1987–1988

The southern summer of 1987–88 was, in contrast to 1988–89, preceded by a significant warm El Niño event. As can be seen in Table 1, the SOI reached a minimum of −22 in April 1987. Although the values were rising leading up to the following monsoon season, and were small throughout the season, Bate et al. (1989) state: '. . . some of the circulation anomalies associated with the ENSO event persisted well into the season. The monsoon in the southern hemisphere was weaker than normal, resulting in below average rainfall over north Australia.' In 1988–89, as with the previous summer monsoon, ENSO anomalies (only this time, anomalies of a cool ENSO event) such as high cloud and wind (Figs 3 and 4) persisted into the period under study. Figure 11 shows percentage of average rainfall for the period November 1988 to April 1989 at those stations where a complete record of monthly rainfall is available. Most stations in the region normally affected by the monsoon received above average rainfall.

The marked contrast between the two seasons in the distribution of convection can be seen in Fig. 12, which presents time-longitude sections of 5-day mean equivalent black-body temperature. The classical eastward displacement of the pattern of convection toward the dateline (e.g., Rasmusson and Carpenter 1982) during an El Niño event (1987–88), compared with the pattern during a positive excursion of the SOI (1988–89), is clearly evident.

Fig. 11 Percentages of climatological average rainfall for period November 1988 to April 1989 for those stations with a complete record of CLIMAT messages.

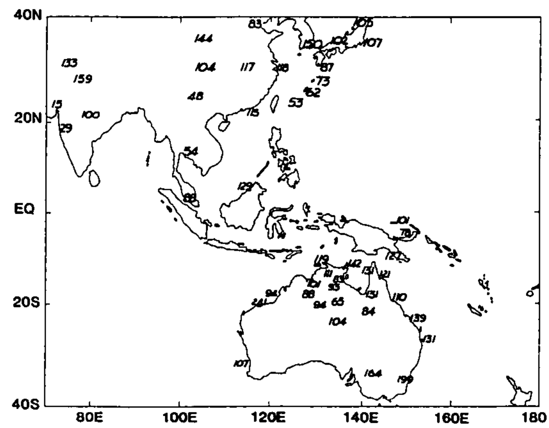
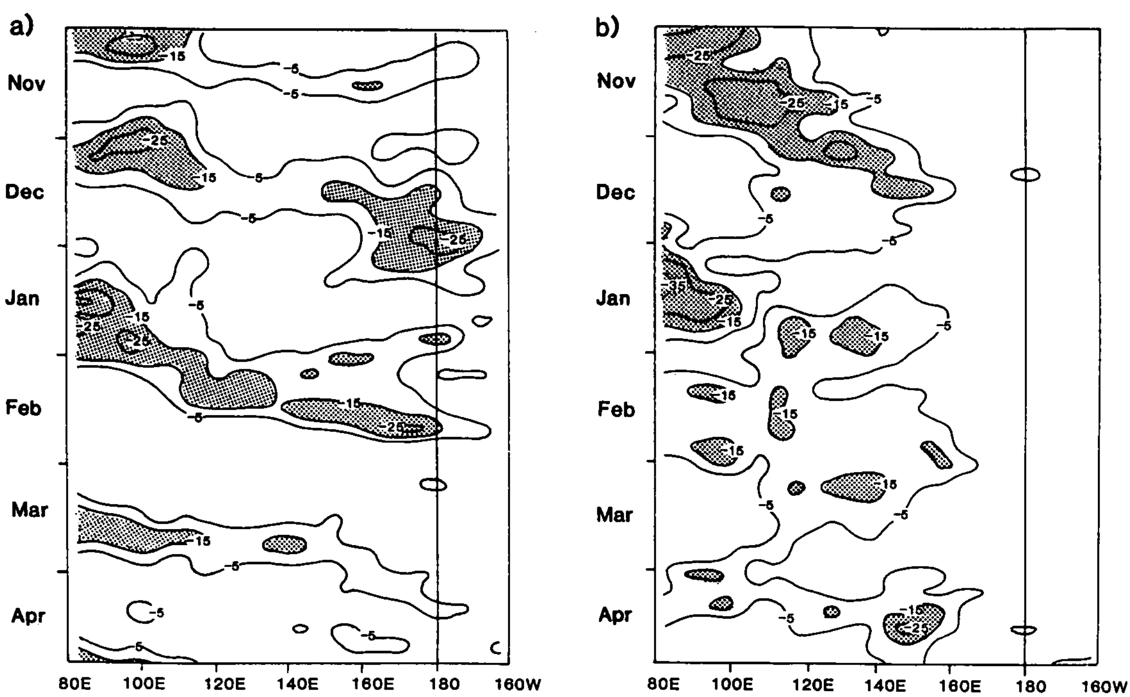


Fig. 12 Time-longitude sections of equivalent black-body temperature (adapted from MRCS) for periods (a) November 1987 to April 1988 and (b) November 1988 to April 1989. Contour interval 10°C, with colder than −15°C stippled.

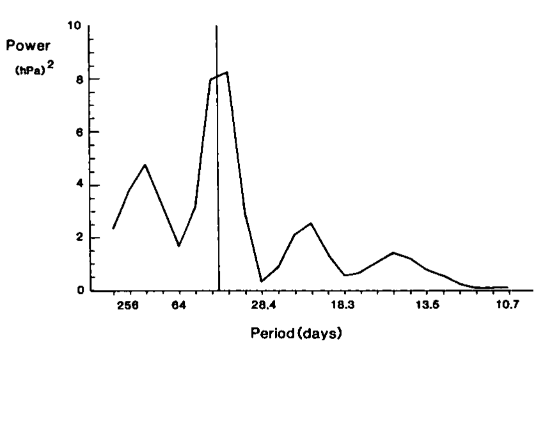


The temporal pattern of tropical circulations
Figure 12 also shows four distinct convectively active periods between November 1988 and April 1989. These are evidently a reflection of the 40 to 50-day oscillations described in the benchmark papers of Madden and Julian (1971, 1972) and others. Krishnamurti and Subrahmanyam (1982) related such oscillations to 'active' and 'break' periods of the Indian monsoon.

Holland (1986), using north Australian rainfall and Darwin 850 hPa wind data from 1952 to 1982, found that each 'wet' season is characterised by a number of 'active' periods, varying between one and four, but most commonly two or three. The period between them averages 40 days. A qualitative inspection of rainfall records over fifteen years shows that the duration of heavy rain episodes is typically 4 to 8 days.

Following on from this the 1988–89 seasonal data were examined for oscillations in the 40 to 60-day mode. Such periodicities are clearly evident in the time-series presented in Figs 5 and 12. A power spectrum of MSL pressure at Darwin is given in Fig. 13. This was compiled using data from 20 November 1988 to 17 May 1989. The vertical line indicates a maximum signal contribution at a period of 40 days; clearly the 40 to 60-day oscillation is strongly in evidence at Darwin. Combining the work of Holland (1986) and the above results it is apparent that these oscillations had a major influence during the 1988–1989 summer monsoon.

Fig. 13 Power spectrum of 0000 UTC Darwin MSL pressure over the period 20 November 1988 to 17 May 1989.



Summary

This climatological summary has examined the tropical circulation in the Darwin RSMC area during the period November 1988 to April 1989. A 'cool' phase of the ENSO, which began early in 1988 and was at its peak from September to November, exhibited a return towards normal throughout the season. Some anomalies associated with the state of ENSO persisted through the season. Among these were generally positive SST anomalies and negative surface pressure anomalies in tropical parts, and below average convection in the east of the region. The northwest monsoon in the north Australian region had an early onset and produced above average rainfall. The monsoon was modulated by oscillations in the 40 to 60-day mode. The number of tropical cyclones in the Australian region was below the long-term mean despite the comparatively active monsoon.

In the northeast monsoon area of south Asia the number of northeasterly surges, associated with cold outbreaks over Siberia, was above the climatological mean. In the vicinity of the Philippines convective activity was enhanced by interactions of such surges with tropical cyclones, while further to the southwest convection was suppressed.

Acknowledgments

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