Aust. Met. Mag. 43 (1994) 193–203

The tropical circulation in the Australian/Asian region — May to October 1991

P.T. Carello
Regional Office, Bureau of Meteorology, Darwin, Australia
and
Boon-Khean Cheang and Huvi-Vein Tan
Malaysian Meteorological Service, Kuala Lumpur, Malaysia

(Manuscript received May 1994)

A summary of the broadscale tropical circulation from May to October 1991 in the area 40°N–40°S, 70°E–180°, is presented. Oceanic and atmospheric anomalies observed within this region were characteristic of a negative ENSO event. While the summer monsoon was early over India, its seasonal penetration across South-East Asia into the northwest Pacific was late, particularly over the Philippines. Over the northwest Pacific tropical cyclone numbers were near normal. Three cyclones were observed in the southern hemisphere, two over the Indian Ocean and one over the Pacific Ocean.

Introduction

This summary discusses the broadscale circulation within the Darwin Regional/Specialised Meteorological Centre (RSMC) area of responsibility (AOR) for the period May to October 1991. While this region covers the area 40°N to 40°S, and 70°E to 180°, the emphasis is on the tropical circulation. An attempt has been made to standardise the format of this summary to attain some consistency with that of the monthly *Darwin Tropical Diagnostic Statement* (DTDS — see Appendix).

Data sources

All data sources used are listed in the Appendix, and are referred to in the text where appropriate. Seasonal mean charts, from the Tropical Analysis Scheme (TAS) of Davidson and McAvaney (1981), were averaged over the six months; climatology, from which anomalies are taken, is over six years (Lavery et al. 1991). Sea-surface temperature (SST) anomalies were calculated from the climatology of Reynolds (1983).

Corresponding author address: Mr P.T. Carello, Bureau of Meteorology, PO Box 735, Darwin, NT 0801, Australia.

Broadscale seasonal features

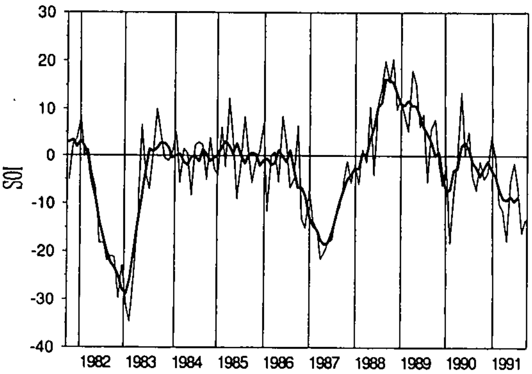
Southern Oscillation

Figure 1 shows the ten-year behaviour of Troup's Southern Oscillation Index (SOI) and its five-month running mean. While large fluctuations in the monthly SOI value were observed from May to October, the general downward trend in the five-month running mean continued. Large negative SOI values (−18 in May 1991) indicate that a negative ENSO event was underway.

Sea-surface temperature

Six-month mean SST and anomaly fields are presented in Fig. 2. In general both charts are similar to the corresponding six-month patterns from 1990 (Bate et al. 1993) with weak warm water anomalies dominating in most regions, particularly in the southern hemisphere. Over tropical latitudes, warm water anomalies were most significant across the Indian Ocean and near the equatorial date-line. Anomalies both north and east of the Australian continent, while positive, have weakened slightly since 1990. This cooling trend is consistent with the negative phase of the ENSO cycle. Monthly anomaly charts from the DTDS (May to October 1991) reveal that anomalies in this region were significantly cooler through June and October.

Fig. 1 Ten-year SOI to October 1991: monthly values thin line; five-month running mean thick line.



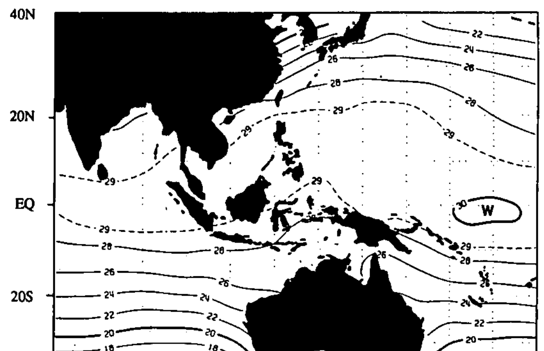
Mean sea level pressure and gradient level (950 hPa) flow

Figure 3 shows mean sea level pressure (MSLP) averaged over the six months, together with anomalies. Figure 3(a) was derived by averaging the daily 2300 UTC TAS charts over the six-month period; Fig. 3(b) is a composite of individual monthly anomalies taken from DTDS. (In DTDS the raw anomaly pattern from TAS is subjectively modified by station data obtained from monthly station summaries given in CLIMAT messages.)

In line with the developing negative ENSO event, positive pressure anomalies dominated over most tropical regions. This was most prominent over Australian and Indonesian longitudes. At higher latitudes pressures were generally below the climatological average. Once again this was most prominent in the southern hemisphere due to the unseasonal position of the STR (subtropical ridge), north of its mean position. The ridge was slightly weaker than normal.

Fig. 2 Six-month SST (°C), May to October 1991: (a) mean; (b) anomaly.

(a)



(b)

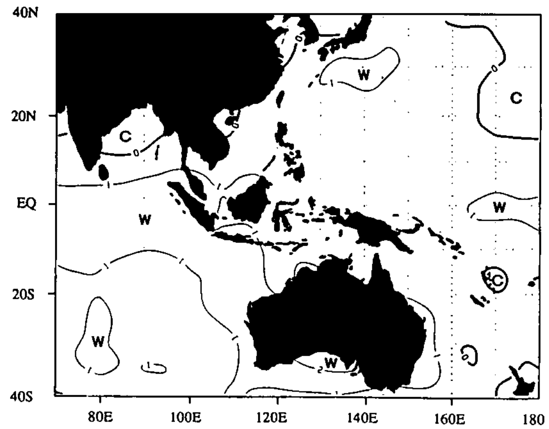
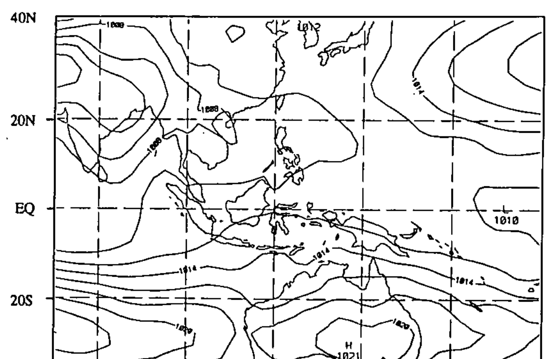
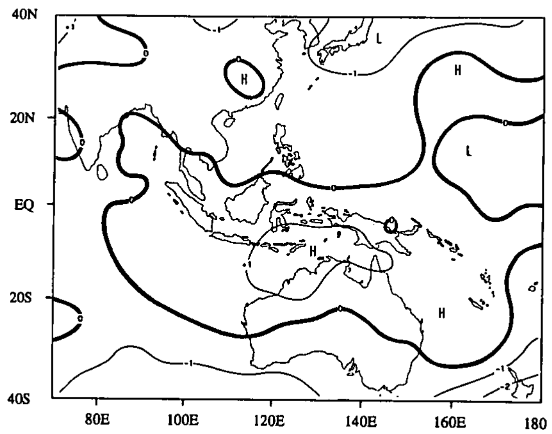


Fig. 3 Six-month MSL pressure (hPa), May to October 1991: (a) mean; (b) anomaly.

(a)



(b)



In general the gradient level flow, Fig. 4, reveals features consistent with those on the MSLP chart. Westerly anomalies near the equatorial date-line indicate a weak Walker circulation associated with the negative ENSO event. Over the South China Sea, monthly anomaly charts from the DTDS (May to October 1991) indicate that the eastward transition of the Asian summer monsoon towards the Philippines was unseasonally late, and weaker than normal. This is consistent with the north to northeast anomalies over the region. Elsewhere over the northwest Pacific the monsoon trough was generally stronger, and extended further east than normal.

Cross-equatorial interaction

The equatorial cross-section of meridional wind, Fig. 5(a), illustrates the operation of the monsoon Hadley circulation. The seasonal chart reveals the basic structure of the circulation; low-level southerlies dominate under upper level northerlies across the longitudinal domain. The anomaly chart, Fig. 5(b), indicates that the circulation was unseasonally active east of 120°E. This is consistent with the extended eastward reach of the monsoon trough across the northwest Pacific.

Upper level flow

Figure 6 shows the six-month streamline/isotach analyses and associated vector anomalies at the 200 hPa level. In response to the low-level cross-equatorial southwesterlies, upper level northeasterlies, associated with the upper arm of the Hadley circulation, dominated over tropical latitudes. While near-equatorial anomalies east of 120°E are consistent with the unseasonal strength

Fig. 4 **Six-month 950 hPa flow, May to October 1991: (a) mean, Isotachs dashed, interval 5 m s^{-1}; (b) anomaly.**

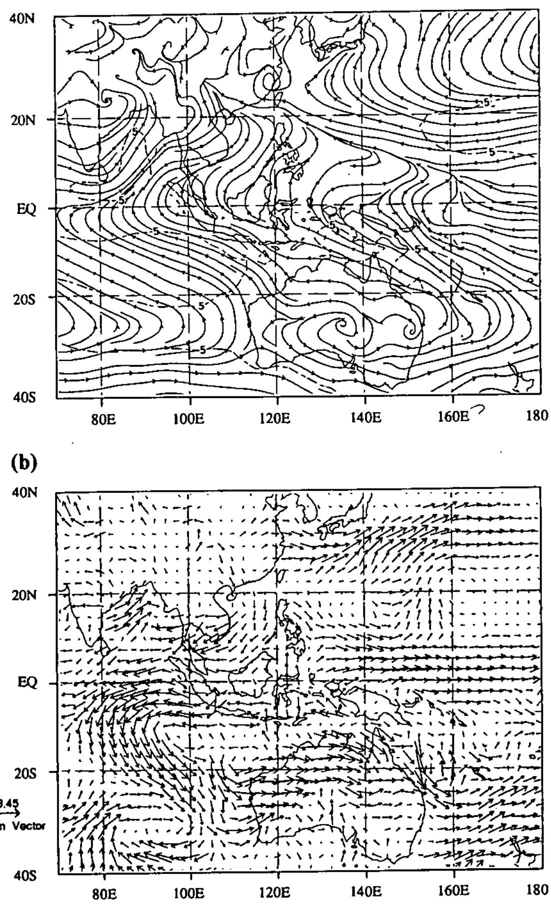


Fig. 5 **Equatorial cross-section of six-month meridional wind, May to October 1991: (a) mean; (b) anomaly. Isotach interval 2.5 m s^{-1}; negative (northerly) dashed.**

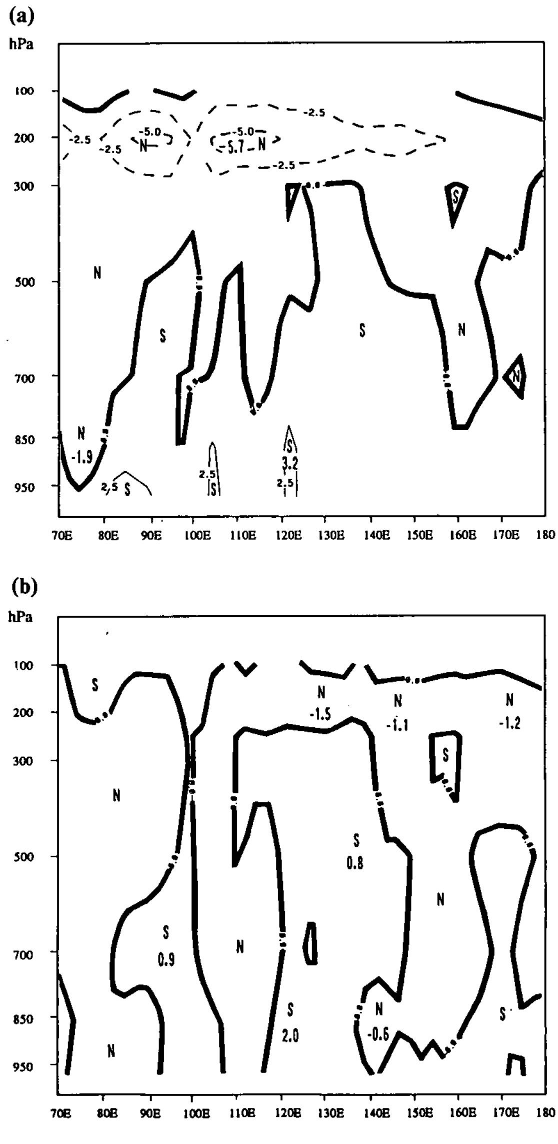


Fig. 6 Six-month 200 hPa flow, May to October 1991: (a) mean, Isotachs dashed, interval 20 m s^{-1}, lowest 10 m s^{-1}; (b) anomaly.

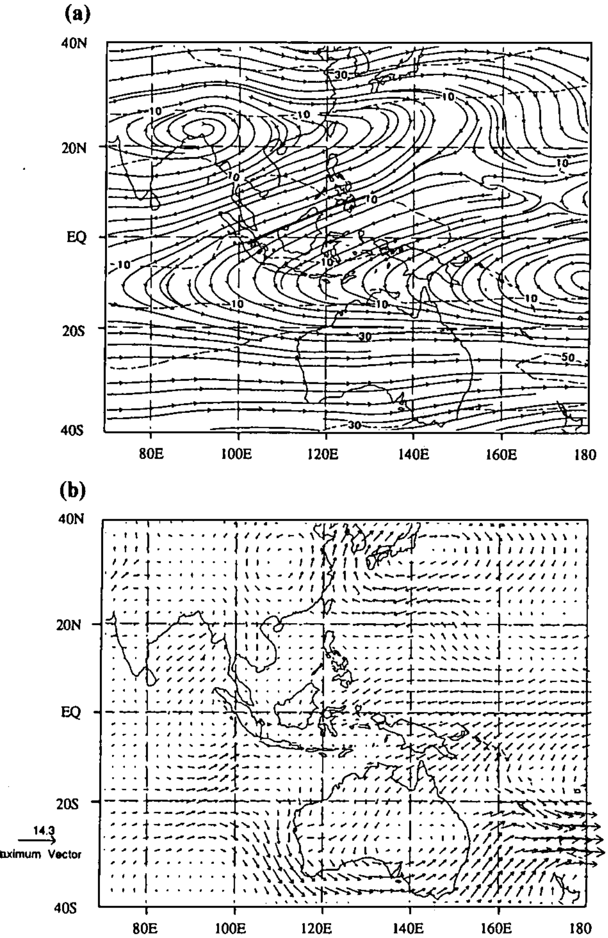
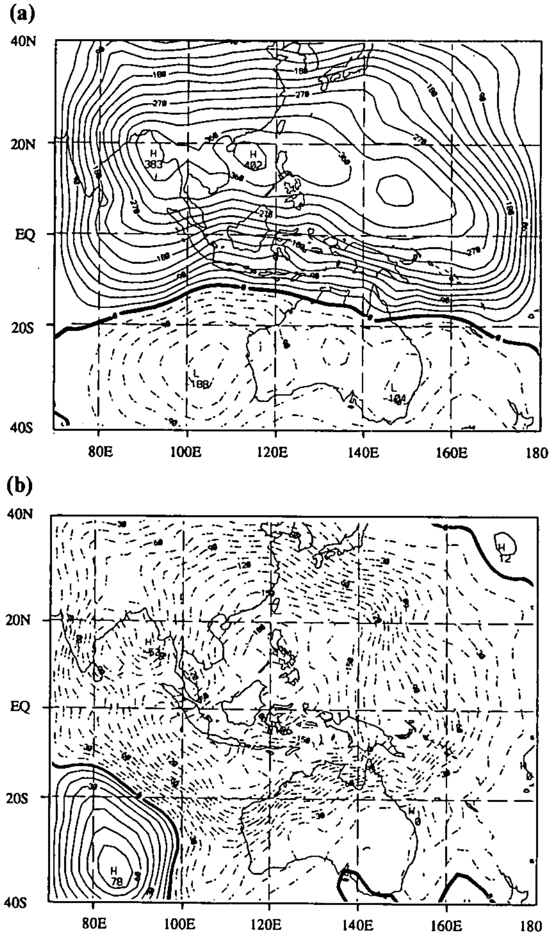


Fig. 7 Six-month 950 hPa velocity potential May to October 1991: (a) mean, contour interval 30 × 10^4 m^2 s^{-1}; (b) anomaly, contour interval 10 × 10^4 m^2 s^{-1}; negative dashed.



and eastward reach of the monsoon trough across the northwest Pacific, the anticyclonic anomaly pattern centred east of the date-line is also typical of the negative ENSO phase.

At higher latitudes anomaly patterns are primarily related to the unseasonal position of the STR in the northern hemisphere, north of its climatological position. Anomalous troughs are also evident over the southern Indian and Pacific Oceans and over northeastern China.

Broadscale vertical motion and convection

Figures 7(a) and 8(a) show velocity potential averaged over the six months at 950 hPa and 200 hPa respectively. Figures 7(b) and 8(b) display the associated anomalies. Note that all charts must be interpreted with caution near the edges of the analysis domain, due to model-imposed zero boundary conditions.

From Fig. 7(a), maximum low-level convergence is diagnosed in the region extending from the South China Sea, across Luzon, then east-southeast to the region of convergent easterlies east of 160°E and into the southern hemisphere in the region of the South Pacific convergence zone (SPCZ). Another axis is evident over Indo-China, the Bay of Bengal and northern India. This feature corresponds to the axis of the monsoon trough (see Figs 3(a) and 4(a)). In the upper levels, Fig. 8(a), maximum divergence is analysed along an axis which lies to the south of the low-level convergence axis. This implies that tropical uplift was strongest on the southern side of the monsoon trough. Note that uplift was also significant in the vicinity of the SPCZ. Long-term mean charts (not shown) indicate that, over the northwest Pacific, centres of maximum tropical upmotion were displaced east of their climatological positions.

Fig. 8 Six-month 200 hPa velocity potential, May to October 1991: (a) mean, contour interval 60×10^4 m^2 s^{-1}; (b) anomaly, contour interval 20×10^4 m^2 s^{-1}; negative dashed.

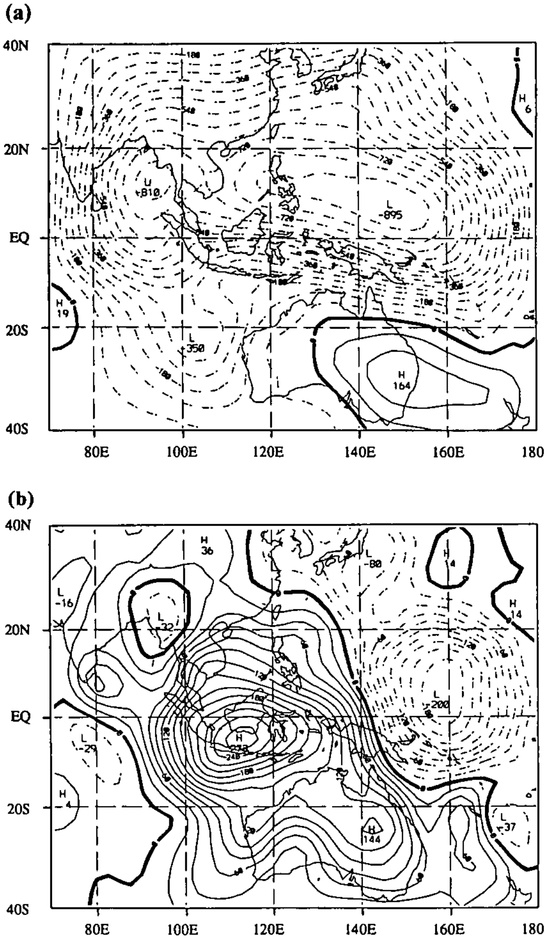
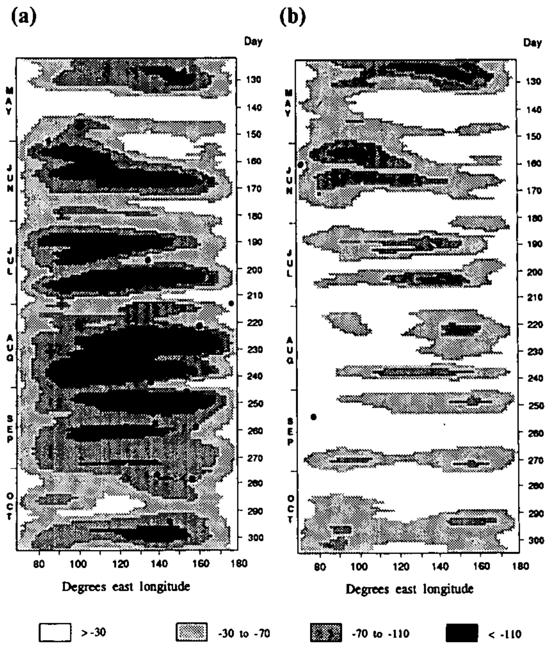


Fig. 9 Time-longitude section of five-day running mean 200 hPa velocity potential (10^5 m^2 s^{-1}), May to October 1991; day 150 = 30 May. (a) 5°N–15°N; (b) 5°S–15°S. Black circles signify tropical cyclone genesis events.



Anomaly charts, Figs 7(b) and 8(b), reveal a weakness in the Walker circulation over the Indonesian region. While this weakness is evident at the 950 hPa level, it is most prominent at 200 hPa. An easterly shift of the upper divergent arm of the circulation is reflected in the anomalous convergent-divergent dipole over Indonesia and the equatorial Pacific respectively.

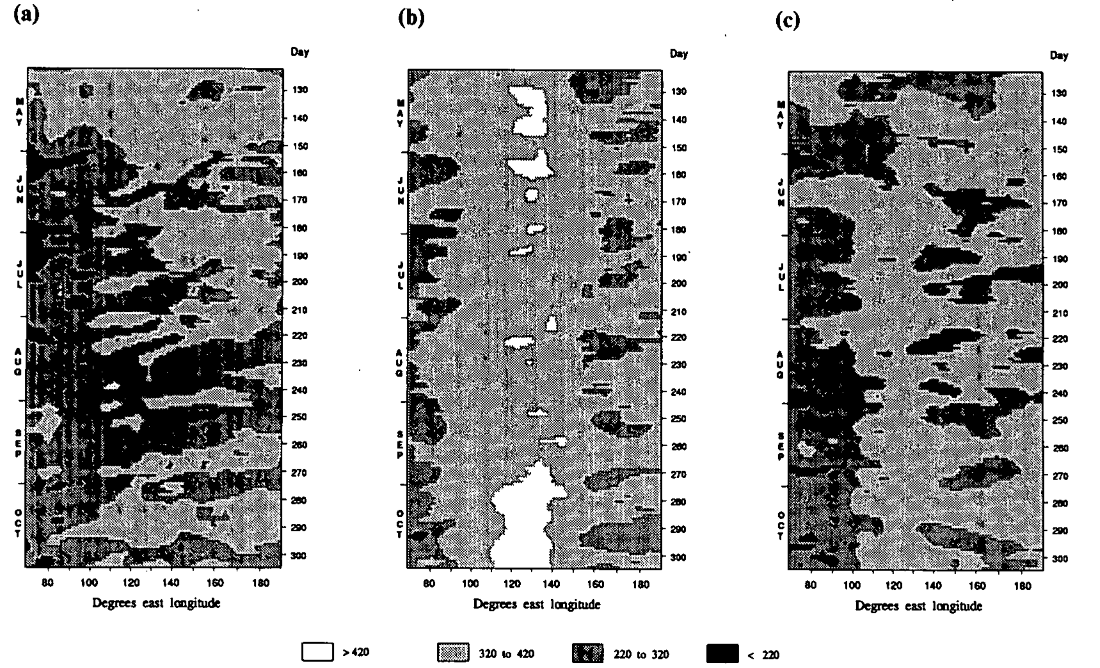
Tropical upmotion associated with the monsoon trough was slightly weaker than normal in the vicinity of the Philippines, and stronger than normal over the eastern Bay of Bengal and east of 150°E.

Intraseasonal oscillations

In regard to the 30 to 60-day intraseasonal oscillation (ISO), Figs 9(a) and (b) show time-longitude plots of 200 hPa velocity potential. The charts refer to a 10° latitudinal strip across the longitudinal domain of the Darwin RSMC area of responsibility, in the northern and southern hemispheres respectively. Once again these charts must be interpreted with care due to the zero boundary conditions set at the eastern and western extremities. While the phase relationship between the two series is generally good, as expected, pulses in upper level divergence were strongest and most prominent in the northern series. Ignoring the higher frequency oscillation, a 30 to 60-day periodic pulse is clearly evident from May to September. The classical eastward propagation of these pulses, while evident, is masked to some degree by the imposed zero boundary conditions and the westward movement of individual tropical cyclones and/or depressions.

Figure 10 shows the corresponding time-longitude series of outgoing long wave radiation (OLR — used as a proxy for convection) for the same northern and southern latitudinal strips, as well as an equatorial strip. The linkage with broadscale features is best seen in the northern series, which is well coupled to the corresponding velocity potential series. Once again note that the westward propagation of individual systems (cyclones and tropical depressions) masks the general eastward propagation of broadscale convection, characteristic of the classical ISO.

Fig. 10 Time-longitude section of five-day running mean OLR (Wm^2), May to October 1991; (a) 5°N–15°N; (b) 5°N–5°S; (c) 5°S–15°S.



Tropical cyclones

In the six-month period May to October 1991, 25 tropical cyclones (defined as having maximum 10-minute mean winds of at least 18 m s^{-1}, or named systems) were analysed within the Darwin RSMC area of responsibility. While the majority of tropical cyclones were confined to the northwest Pacific, three systems were observed in the southern hemisphere, and another over the Bay of Bengal.

Table 1 lists the occurrence dates of each named system in the RSMC area, and also gives maximum wind and minimum pressure information, from Rudolph and Guard (1992). A factor of 0.88 was used to convert maximum winds from the US one-minute mean convention to the Australian ten-minute mean. Wind maxima associated with *Enrique* and *Doug* were below the TC threshold; however they were classified as tropical storms by the responsible meteorological authority. Operational TC tracks based upon Darwin RSMC manual analyses are shown in Fig. 11.

Tables 2 and 3 show the 1960–1991 and 1891–1989 monthly mean occurrence of tropical cyclones over the northwest Pacific and Bay of Bengal respectively. The small discrepancy in the six-month totals of the 1960–91 means arises from rounding errors. No comparative figures were available for other regions.

In the northern hemisphere, Table 2 reveals that TC numbers over the northwest Pacific were near average over the six-month period and slightly below average through the months of May, June, July and October. In line with climatology, August and September were the most active months. The general west to northwest movement of these systems is clearly illustrated in the northern OLR time-longitude series (Fig. 10(a)). Table 3 shows that TC numbers over the Bay of Bengal were below average over the six-month period. In the southern hemisphere, comparative climatological figures for the six-month period, as derived from the Rudolph and Guard (1992), reveal that cyclone numbers over the combined Pacific and Indian Oceans were near the long-term mean of 2.5. In contrast, monthly climatology reveals that cyclones *Gritelle* and *01S* were unseasonal. Note that the Darwin RSMC AOR is a subset of the climatological domain used by the JWTC which extends westward from the date-line to the African coast.

Figures 9(a) and (b) show TC genesis events on the relevant 200 hPa velocity potential time-series. Keeping the zero boundary condition in mind, genesis showed a strong correspondence with the active phase of the ISO, with all occurrences during periods of strong broadscale upper level divergence.

Table 1. Tropical cyclones within the Darwin RSMC area May to October 1991. (T) = typhoon; (ST) = super-typhoon.

TC name	Dates (UTC) at TC intensity in Darwin RSMC AOR	Maximum 10-min mean wind ($m\ s^{-1}$)	Minimum MSLP (hPa)
Northwest Pacific/South China Sea			
Walter (ST)	06 May–16 May	63	898
Yunya (T)	13 Jun–15 Jun	48	938
Zeke (T)	10 Jul–14 Jul	36	963
Amy (T)	16 Jul–20 Jul	56	916
Brendan (T)	21 Jul–24 Jul	32	972
[1] *Caitlin* (T)	24 Jul–30 Jul	43	949
[3] *Enrique*	01 Aug–01 Aug	16	997
[3] *Doug*	09 Aug–10 Aug	16	997
Ellie (T)	11 Aug–18 Aug	39	958
Fred (T)	13 Aug–18 Aug	43	949
Gladys (T)	16 Aug–23 Aug	29	973
Harry	30 Aug–31 Aug	18	994
[1] *Ivy* (T)	03 Sep–10 Sep	52	927
Joel	04 Sep–07 Sep	25	982
Kinna (T)	11 Sep–14 Sep	40	954
Luke	15 Sep–19 Sep	23	987
[1] *Mireille* (ST)	16 Sep–27 Sep	59	910
[2] *Nat* (T)	16 Sep–01 Oct	50	933
[1] *Orchid* (T)	04 Oct–13 Oct	52	927
[1] *Pat* (T)	06 Oct–12 Oct	56	916
Ruth (ST)	21 Oct–29 Oct	66	892
Northern Indian Ocean			
03B	01 Jun–02 Jun	23	987
Southern Indian Ocean			
Gritelle	09 Jun–11 Jun	18	994
[4] *01S*	11 Sep–13 Sep	13	1000
Australian Region			
Lisa	08 May–12 May	32	972

[1] Left Darwin RSMC AOR as a cyclone.
[2] Nat degenerated to a TD on the 25th before reintensifying to cyclone intensity on the 29th.
[3] Maximum winds below tropical cyclone threshold but named by responsible meteorological authority.
[4] Maximum winds post-analysed below tropical cyclone threshold but labelled operationally by JTWC, Guam, and analysed operationally by Darwin RSMC as a minimal tropical cyclone.

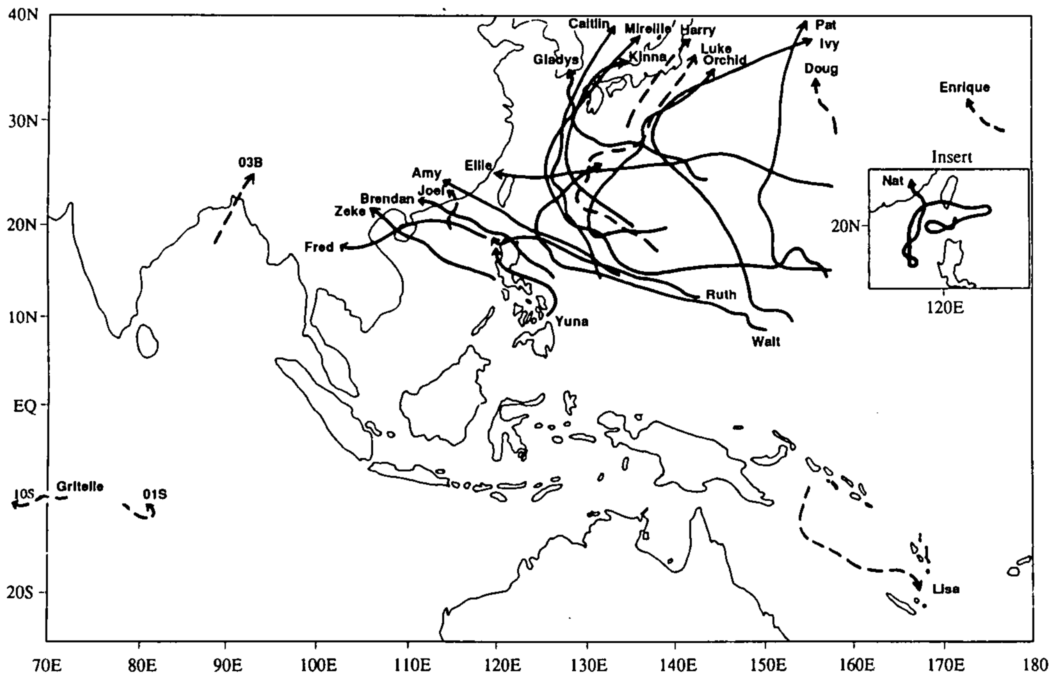
Table 2. Unofficial northwest Pacific tropical cyclone occurrences during May to October 1991, compared with long-term averages from Rudolph and Guard (1992).

	May	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*six-month*
All TC							
1991	1	1	4	6	6	3	21
1960–91 mean	1.1	1.8	4.2	5.3	5.0	4.2	21.6
Typhoons							
1991	1	1	4	3	4	3	16
1960–91 mean	0.7	1.1	2.7	3.2	3.2	3.1	14.1

Table 3. Unofficial Bay of Bengal tropical cyclone occurrences during May to October 1991, compared with long-term averages from Mandal (1991).

	May	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*six-month*
All TC							
1991	0	1	0	0	0	0	1
1891–1989 mean	0.5	0.4	0.4	0.3	0.4	0.8	2.8
Severe TC							
1991	0	0	0	0	0	0	0
1891–1989 mean	0.3	0	0.1	0	0.2	0.4	1.0

Fig. 11 Unofficial tropical cyclone tracks, May to October 1991. Dashed line = tropical cyclone/storm; firm line = severe tropical cyclone/typhoon.



Asian summer monsoon

Rainfall

Detailed rainfall data in the Asian monsoon region for May to October 1991 were not available. Figure 12, from the *Monthly Report on Climate System* (MRCS), October 1991 (see Appendix), shows percentage of climatological rainfall for the central four months of the six-month period under consideration. Monthly charts from the DTDS (May to October 1991) show that the monsoon was most active during this four-month period (refer also to northern OLR time series, Fig. 10(a)). The monsoon produced average to above average rainfall over most parts of southern India, southern China and the northwest Pacific. Rainfall maxima in the region bordering the northwest Pacific generally reflect the passage of tropical cyclones (compare Fig. 11). Northern India, northern Thailand, southeast China, and parts of northern and central China were, on the other hand, drier than average.

Fig. 12 **Percentage of climatological rainfall over Asian monsoon region, June to September 1991 (after MRCS, October 1991). Contour interval 40 per cent; >160 per cent oblique shading; <40 per cent horizontal shading.**

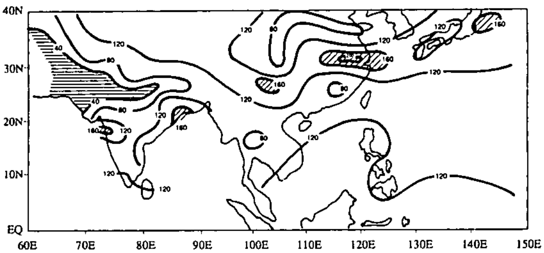
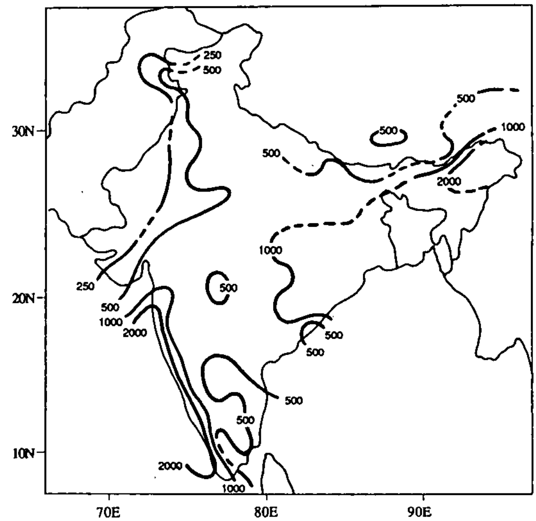


Fig. 13 **Total rainfall (mm) over Indian monsoon region, 1 May to 21 September 1991 (after CSMMB, September 1991). Isopleths drawn for 250, 500, 1000 and 2000 mm only.**



Indian summer monsoon

Precipitation aggregates over the Indian subcontinent for the five-month period, May to September 1991, are shown in Fig. 13. Note that heavy rain (exceeding 2000 mm) drenched India's far northeast corner and west coast. In contrast rainfall totals were abnormally low over central and northwest parts, particularly over regions bordering Pakistan.

The Climate Analysis Center, Washington, (refer *Climate System Monitoring Bulletin* (CSMMB), September 1991 — see Appendix) stated that the 1991 monsoon rains were unusually early and heavy over southern and eastern parts of India and across Bangladesh. The typical northwest advance of rains across the subcontinent abruptly stalled around mid-June, leaving central and northwest India relatively dry. Nepal experienced an exceptionally dry monsoon season, many stations recording less than half of their normal seasonal rainfall. Despite the flooding reported in portions of north-central and west-central India, seasonal totals of only 450–900 mm were reported, indicating a late start and early end to the monsoon in these regions.

Fig. 14 **Latitude-time cross-section of 700 hPa zonal wind along 103°E from 0° to 20°N; zero contour shown. W=westerly; E=easterly.**

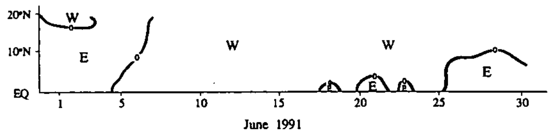
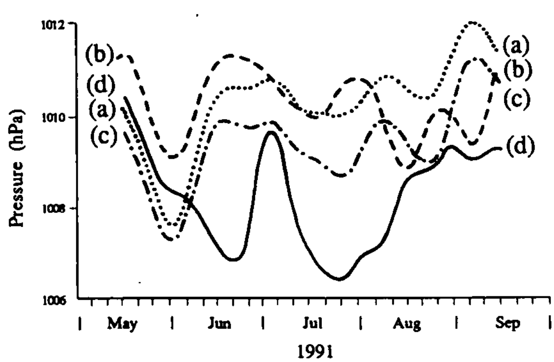


Fig. 15 **Gaussian low-pass filtered time series of surface pressure (hPa) over: (a) Peninsular Malaysia; (b) west Pacific; (c) northern Sumatra and southern Thailand; (d) Indo-China.**



South-East Asia summer monsoon

Onset. Based on the definition of Orgill (1967), the latitude-time plot of Fig. 14 shows onset of the 1991 southwest monsoon was complete over Peninsular Malaysia (PM) by 6 June. While the monsoon onset was late over all regions of South-East Asia, its arrival over Indo-China and Malaysia occurred within the 33-day range centred on 17 May, as determined by Orgill. The seasonal penetration of southwesterlies into the northwest Pacific saw the monsoon establish itself over northern Borneo and the southern Philippines on 9 and 13 June respectively. Onset over the central and northern Philippines was exceptionally late and was not observed until 17 July.

Rainfall pattern. Rainfall data were derived from 33 stations distributed throughout Peninsular Malaysia, Sabah and Sarawak. Data from other regions were not available. Records for the six-month period reveal that while monthly totals were highest in May and September, 80 per cent of stations reported above average falls in May and 70 per cent of stations reported below average falls in September. Drier conditions from June to August inclusive were associated with low-level southwesterlies. Monthly charts from the DTDS (May to October 1991) indicate that this was primarily related to a weakness in the summer monsoon.

Low frequency oscillations of the summer monsoon. Upper wind anomalies over South-East Asia typically change direction over a 20 to 50-day cycle. This is in response to the active/break cycle of the monsoon, associated with north-south movement in the monsoon trough. The westward intrusion of disturbances from the northwest Pacific also contributes to this cycle.

To examine oscillations in this mode, a Gaussian low-pass filter was applied to the time series of (a) average surface pressure at stations in a number of regions, (b) average zonal upper and lower winds over PM and (c) total daily rainfall over PM, Sabah and Sarawak. These filtered series are graphed at Figs 15 to 17 respectively. In order to facilitate the comparison between the upper and lower zonal winds in Fig. 16, easterly winds at 200 hPa are shown as positive.

Oscillations in the 20 to 50-day mode are identifiable in the filtered time series of 850 hPa winds over PM (Fig. 16(b)) and surface pressure over South-East Asia (Fig. 15). A lag correlation is apparent in the pressure series between west Pacific and Indo-China and between PM and north Sumatra/southern Thailand (Fig. 15).

Figures 16 and 17 reveal the relationship between rainfall and the filtered 850 and 200 hPa winds over PM and northern Borneo. Heavy falls in late May were associated with low-level easterlies and weak upper level easterlies. These falls decreased sharply in June as the upper level easterlies and low-level westerlies strengthened. Rainfall remained suppressed throughout July and August. A break in the low-level westerlies saw falls increase again in September.

North Australian rainfall

Figure 18 shows district average rainfall over Australian rainfall districts (dashed) lying wholly or mostly north of the 26th parallel. Decile values are given for each district to facilitate a comparison of the six-month average, May to October 1991, with climatology. Note that decile values are based on the interval from 1913 to 1992.

Fig. 16 Gaussian low-pass filtered time series of zonal winds (m s^{-1}) over Peninsular Malaysia; (a) 200 hPa, easterly component shown positive; (b) 850 hPa.

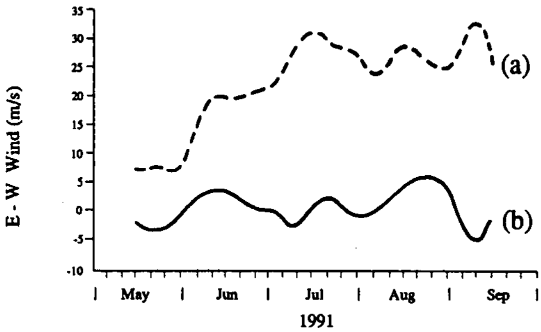


Fig. 17 Gaussian low-pass filtered time series of rainfall (mm) over: (a) Peninsular Malaysia; (b) Sabah and Sarawak.

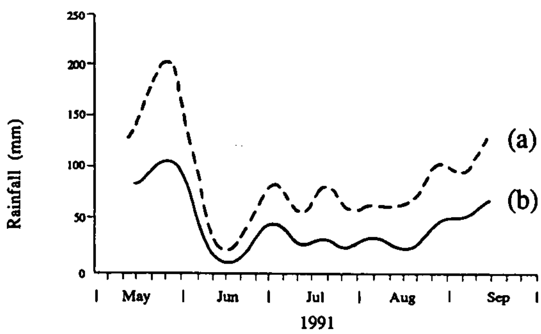
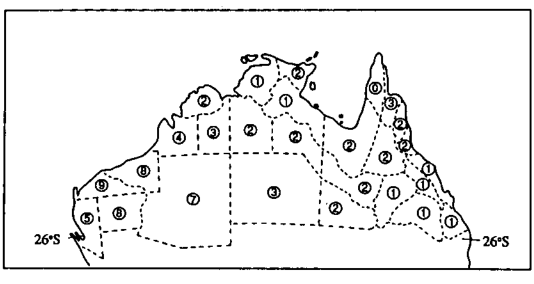


Fig. 18 Six-month district average May to October 1991 rainfall (deciles) for Australian districts north of 26°S. Circled numbers represent deciles.



District average rainfall over central and eastern districts was generally below average, consistent with the negative phase of the SOI. In contrast, high district averages were noted over parts of western Australia.

Summary

Averaged over the six-month season, atmospheric patterns were typical of a developing El Niño event. Positive surface pressure anomalies over Indonesia and northern Australia saw the equatorial easterlies weaken over the Pacific, highlighting a weakness in the Walker circulation. District average rainfall over Australia was generally below average, particularly over eastern districts.

In spite of the average to above average rainfall over the northern Philippines, Vietnam and Cambodia, the southwest monsoon was late and generally weaker than normal in the region. East of the Philippines the monsoon trough was comparatively strong and extended further east than normal. Tropical cyclone numbers were near average over the northwest Pacific; however, genesis was predominantly confined to waters east of the Philippines. In the southern hemisphere three tropical cyclones were observed, one over the Pacific and two over the Indian Ocean.

Acknowledgments

The authors would like to thank Peter Bate for his guidance and scientific support in the writing of this paper and Rob Porteous for his painstaking drafting of the figures. Further thanks are also extended to the Long-range Forecasting Division, JMA, Tokyo, and the World Climate Programme of WMO for their permission to reproduce diagrams. Two of the authors, BKC and HVT, who provided input for the South-East Asia region, would also like to thank the Director, Malaysian Meteorological Service, for permission to contribute.

References

Bate, P.W., Cheang, B.K. and Tan, H.V. 1993. The tropical circulation in the Australian/Asian region May to October 1990. *Aust. Met. Mag.*, *42*, 117–27.

Davidson, N.E. and McAvaney, B.J. 1981. The ANMRC tropical analysis scheme. *Aust. Met. Mag.*, *29*, 155–68.

Lavery, B.M., Davidson, N.E., Karoly, D.J. and McAvaney, B.J. 1991. A climatology of the western Pacific region based on the Australian tropical analysis scheme. *BMRC Research Report No. 28*, Bur. Met., Australia, 26 pp.

Mandal, G.S. 1991. *Tropical cyclones and their forecasting and warning systems in the north Indian Ocean*. World Meteorological Organisation Technical Document No. 430 (Tropical Cyclone Program Report No. TCP-28). Secretariat of the WMO, Geneva Switzerland, 430 pp.

Orgill, M.M. 1967. Some aspects of the onset of summer monsoon over South-East Asia. *Technical Report*, Dept of Atmospheric Science, Colorado State University, Fort Collins, Colorado, USA, 35 pp.

Reynolds, R.W. 1983. *A monthly averaged climatology of sea surface temperature*. Climate Analysis Center, National Meteorological Center, NWS, Washington D.C., USA, 35 pp.

Rudolph, D.K. and Guard, C.P. 1992. *1991 Annual Tropical Cyclone Report*. US Naval Oceanographic Command Centre/Joint Typhoon Warning Center, COMNAVMAR, PSC 489, Box 12, FPO AP 96540-00, USA, 238 pp.

Appendix

Data sources used in this review were:

Darwin Tropical Diagnostic Statement, May to October 1991, 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 the National Meteorological Centre, Melbourne.

Darwin RSMC weekly manual ship/buoy SST analyses, converted to grid-point format at 5° × 5° resolution; six-month means calculated at each grid-point.

Monthly CLIMAT messages received via the Global Telecommunications System.

District average rainfall from the National Climate Centre, Bureau of Meteorology, Melbourne.

District average rainfall deciles from the National Climate Centre, Bureau of Meteorology, Melbourne.

Monthly Report on Climate System (MRCS), October 1991, issued monthly by Long-range Forecast Division, Japan Meteorological Agency, 1-3-4, Ote-Machi, Chiyoda-Ku, Tokyo 100, Japan.

Climate System Monitoring (CSM) Monthly Bulletin, September 1991, issued monthly by World Climate Programme, WMO Secretariat, Case Postale No. 2300, 1211 Geneva 2, Switzerland.