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The tropical circulation in the Australian/Asian region - November 2003 to April 2004

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A summary of the broadscale tropical circulation from 70°E to 180°, for the six months November 2003 to April 2004, is presented. Overall, the season could be classified as continuing in an ENSO-neutral state. Indicators include mostly small atmospheric pressure anomalies over the near equatorial belt, five-month averaged values of the Southern Oscillation Index (SOI) were confined to small values, and near-average levels of tropical outgoing long wave radiation (OLR) across most of the longitude range. The north Australian summer monsoon was generally well developed, and seasonal rainfall over northern Australia was above average, particularly in the northwest. The signal of the Madden-Julian Oscillation (MJO) was strong during the summary period, with a periodicity during the season being quite regular at around 45 days. A total of 19 tropical cyclones developed during the period.

Introduction

This summary is part of a continuing series that reviews the broadscale tropical circulation in the Australian/Asian region, and is for the period November 2003 to April 2004. The area covered is the Darwin Regional Specialised Meteorological Centre (RSMC) analysis domain, which is 70°E to 180°, 40°N to 40°S. Seasons immediately prior to this were described by Shaik and Cleland (2004b) and Shaik and Cleland (2004a). The first section of this summary uses mostly six-month average charts to describe the overall seasonal circulation and anomalies. The second section uses time series to portray variations of the tropical circulation within the season. Intraseasonal variability of outgoing long wave radiation (OLR), 200-hPa velocity potential and mean sea-level pressure (MSLP) anomaly are analysed in this section. The third section briefly describes the occurrence of tropical cyclones in the six-month period. Data sources used in this study are detailed in the appendix.

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Broadscale seasonal features

The seasonally averaged diagnostics generally support a near-neutral El Niño Southern Oscillation (ENSO) phase. There was close to climatological tropical convection over most of the longitude range, near-normal values of the five-month smoothed Southern Oscillation Index (SOI), the wind and MSLP patterns over the tropical regions, which were generally close to their respective climatological means, though the MSLP anomaly field shows small positive anomalies in the central longitudes.

Southern Oscillation

Figure 1 shows the ten-year behaviour of the SOI from May 1994 and its symmetrical five-month running mean. Monthly values of the SOI from January 2002 are given in Table 1. Large fluctuations in the monthly SOI were evident during the season with the values oscillating between +10 and -15, seemingly in response to the strong signal of the MJO. The mean SOI for the current season was -2. It was -3.7 in the May to October 2003 season, and -6.3 in the November 2002 to April 2003 season (Shaik and Cleland 2004b, 2004a). The five-month mean during the season remained between zero and -2.

Convection and tropospheric circulation

The mean and anomaly of OLR - used as a proxy for convection - averaged for the six-month period, are shown in Figs 2(a) and 2(b) and for each individual month are shown in Figs 3(a) to (f) and 4(a) to (f) respectively. The convection, as inferred from the seasonally averaged OLR pattern, was about normal in the equatorial longitudes west of 140°E. Above-average convection over parts of the northwestern Pacific, including equatorial regions east of Papua New Guinea (PNG) persisted through most of the season. Despite the formation of several cyclones in the southern hemisphere, convection over maritime areas away from the near-equatorial belt was mostly below normal. The OLR anomalies (Fig. 4) for individual months show above average convection during December 2003, February and March 2004 over the maritime continent. Convection was above average near the equatorial date-line during January and April 2004.

Fig. 1 SOI time series for ten years to April 2004: monthly values (bars); five-month centred mean values (black line).

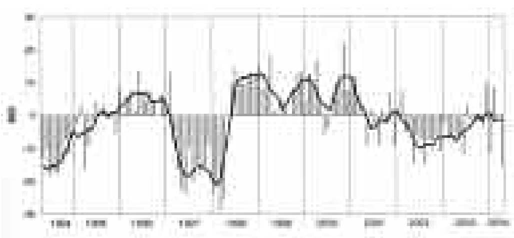


Fig.2 Six-month (November 2003 to April 2004) (a) mean OLR (W m^{-2}). 260 W m^{-2} and above yellow shading, 240 W m^{-2} and below blue shading: (b) OLR anomaly (W m^{-2}). > +5 W m^{-2} yellow shading, < -5 W m^{-2} blue shading.

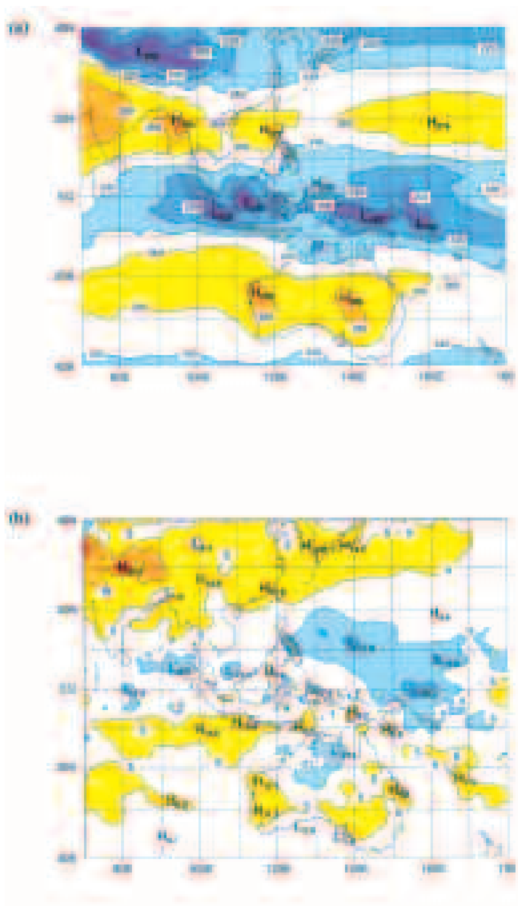


Table 1. Monthly values of Troup's SOI for the period January 2002 to April 2004.

Year	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
2002	+3	+8	-5	-4	-14	-6	-8	-15	-8	-7	-6	-11
2003	-2	-7	-7	-5	-7	-12	+3	-2	-2	-2	-3	+10
2004	-12	+9	0	-15								

Fig. 3 **Monthly mean OLR (W m^{-2}). 260 W m^{-2} and above yellow-red shading, 240 W m^{-2} and below blue shading: (a) November 2003; (b) December 2003; (c) January 2004; (d) February 2004; (e) March 2004; (f) April 2004.**

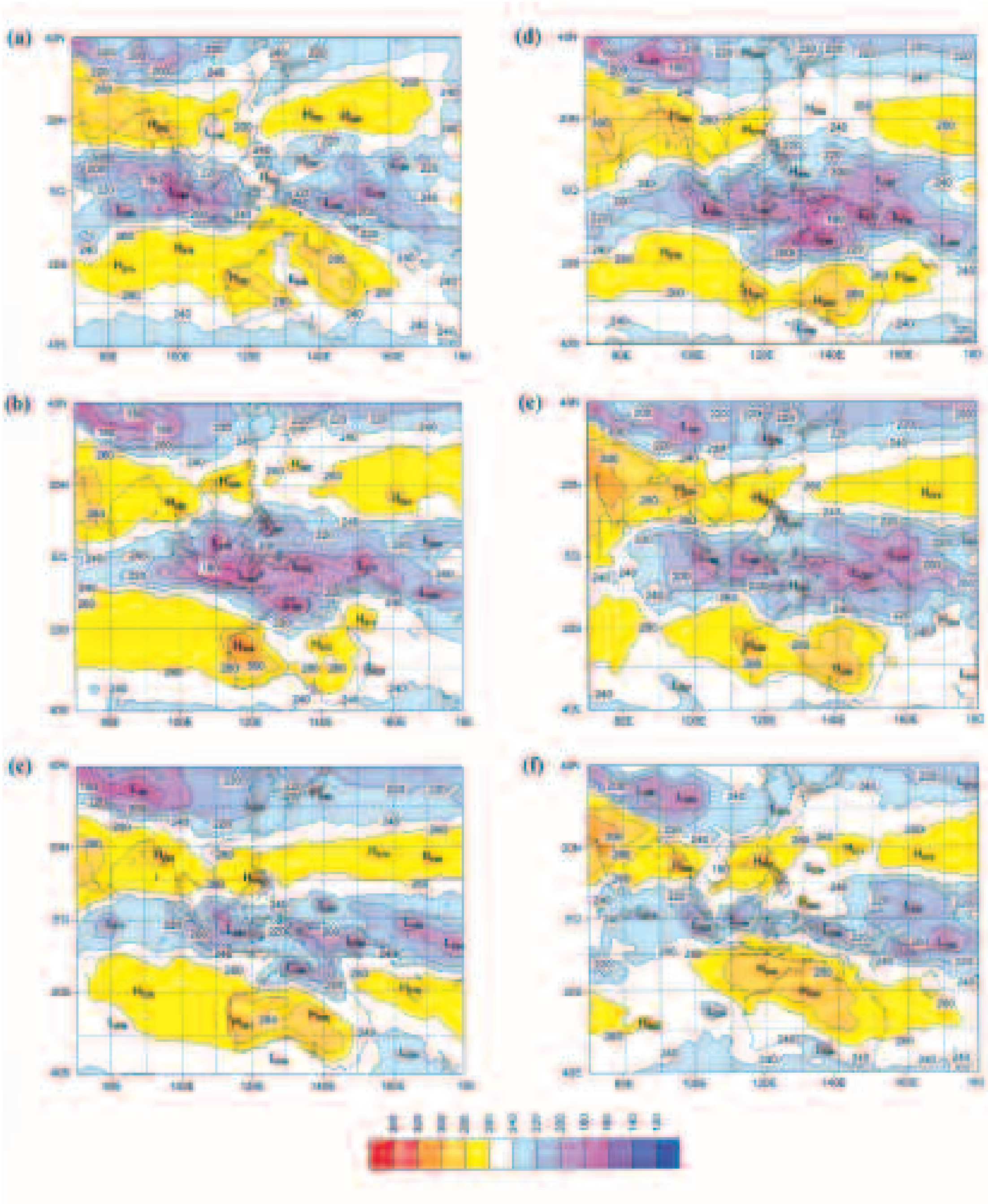
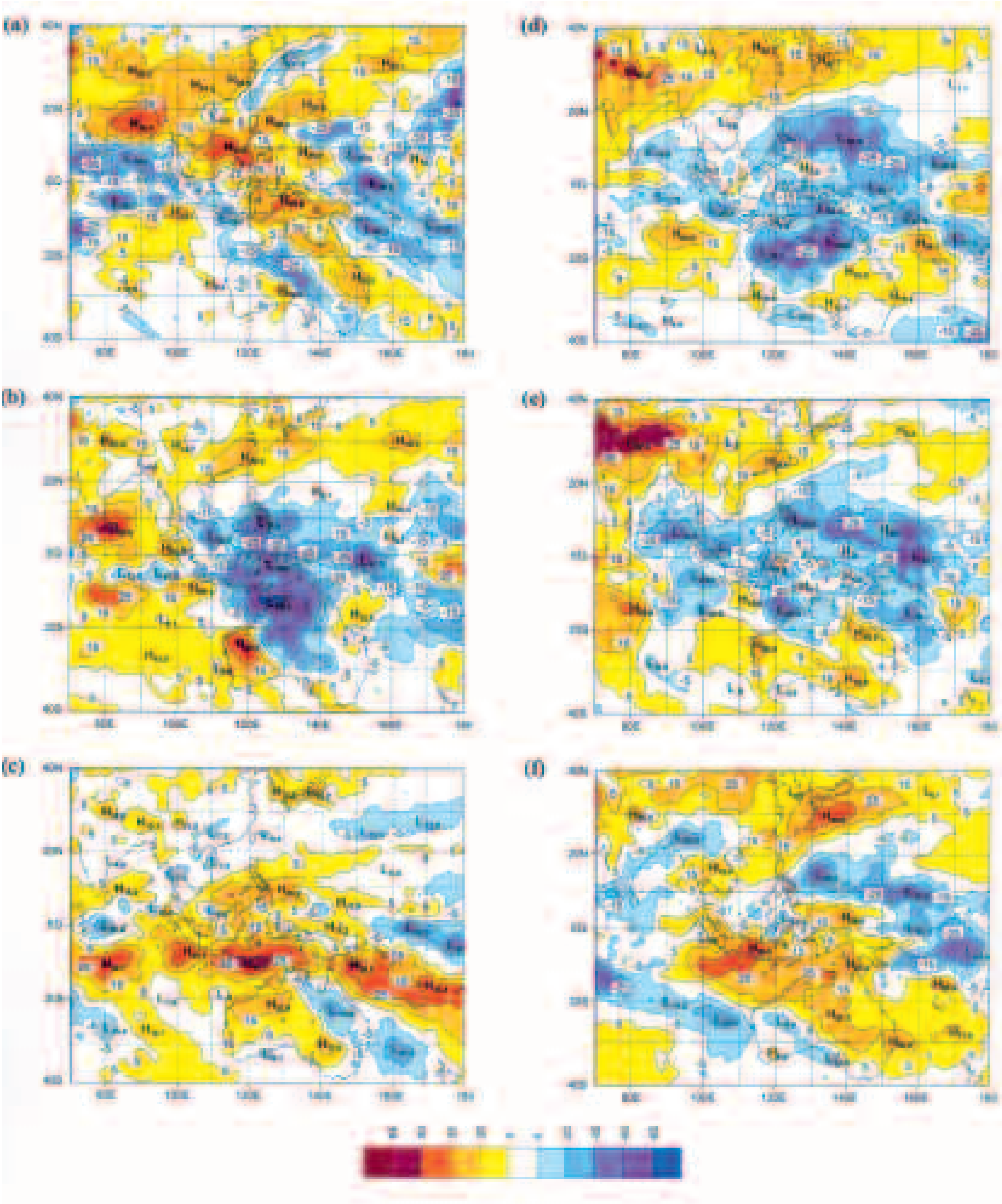


Fig. 4 **Monthly OLR anomaly (W m^{-2}). > +5 W m^{-2} yellow-red shading, < -5 W m^{-2} blue-purple shading: (a) November 2003; (b) December 2003; (c) January 2004; (d) February 2004; (e) March 2004; (f) April 2004.**



Velocity potential analyses at 850 hPa and 200 hPa levels (Fig. 5) show good vertical alignment of axes of maximum low-level convergence and upper-level divergence, indicating a well-organised upmotion of a vigorous Hadley circulation in the western Pacific, whereas the poor vertical alignment over the Indian subcontinent represents the below-average convection over that area. The positions of both low and upper-level axes were close to their respective climatological mean latitudes. However, the centres of maximum low-level convergence and upper-level divergence were displaced well to the east of their climatological locations, consistent with the areas of active convection and close to the pattern that appeared during November 2001 to April 2002 season (Shaik and Bate 2003).

Seasonally averaged mean sea-level pressure (MSLP) and anomalies are shown in Fig. 6. Pressures were generally above average over the central longitudes of the tropics, with small negative anomalies to the east of 170°E, and in the equatorial Indian Ocean. The anomalies were positive over Australia, in line with the persistent dry conditions over much of the continent, with a few exceptions such as the northwestern parts where the rainfall associated with the north Australian monsoon was above average. The subtropical ridges in both hemispheres were close to their respective mean locations. The pattern of MSLP anomalies over this region was similar to what could be expected in an El Niño event, however, the magnitude of the anomalies was only small and remained consistent with neutral ENSO conditions.

Vector wind analyses and anomalies at 850 hPa and 200 hPa levels are shown in Figs 7 and 8 respectively. Near normal cross equatorial flow was evident in the tropics over the Indian Ocean and the maritime continent in the low levels and the upper return flow was stronger than normal. The easterly flow at the

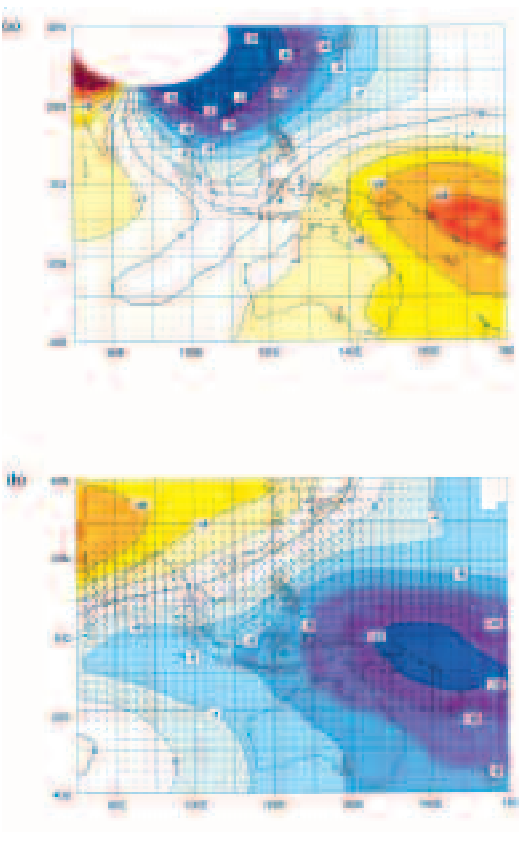


Fig. 5 Six-month mean velocity potential (10^6 m^2 s^{-1}) and vector winds, November 2003 to April 2004. < -2 blue-purple shading; > +2 yellow-red shading: (a) 850 hPa; (b) 200 hPa.

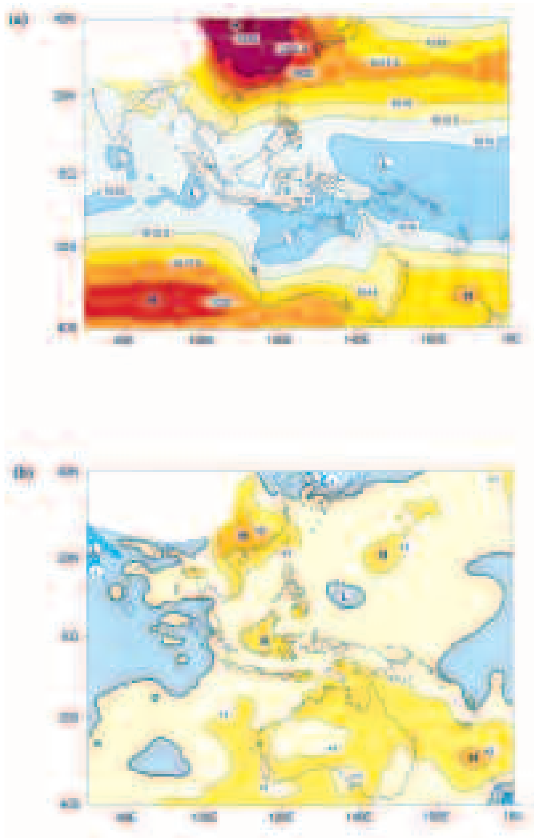


Fig. 6 Six-month MSL pressure (hPa), November 2003 to April 2004: (a) mean, isobar interval 2.5 hPa; (b) anomaly, contour interval 1 hPa, blue-shaded areas negative, yellow-shaded areas positive.

Fig. 7 Six-month 850 hPa vector wind field, November 2003 to April 2004, isotach (dashed) interval 5 m s^{-1}: (a) mean; (b) anomaly.

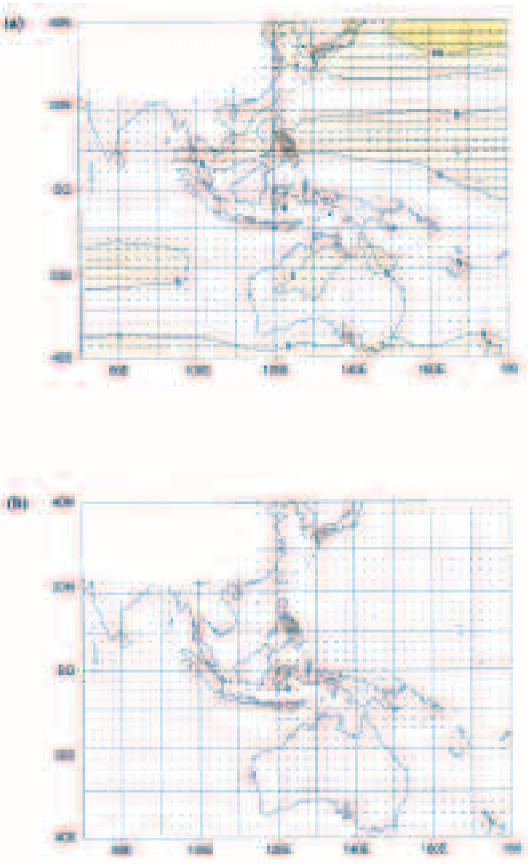
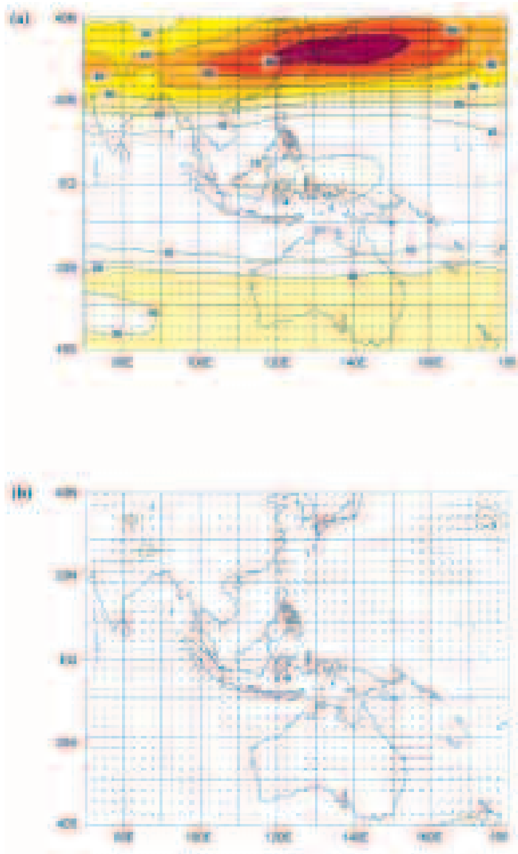


Fig. 8 Six-month 200 hPa vector wind field, November 2003 to April 2004: (a) mean, isotach (dashed) interval 10 m s^{-1}; (b) anomaly, isotach (dashed) interval 5 m s^{-1}.



lower levels was weaker than normal to the north of PNG. This gave rise to an apparent divergence over Indonesia and convergence over the northern tropical Pacific around 160°E. At the upper levels the flow gave a divergence effect northeast of PNG. This is consistent with above-average convection around 160°E. The weak wind anomalies over the equatorial western Pacific near the date-line are consistent with the neutral ENSO conditions. In the extratropical regions, the upper ridge in the southern hemisphere was located to the north of its mean position. Both the subtropical ridges had more meridional flow than the mean, indicating the passage of several long-wave systems during the period.

Diagrams depicting the cross-equatorial component of the flow and anomalies (Fig. 9) indicate a pattern close to mean with the anomalies more or less close to zero, pointing towards neutral ENSO conditions. Cross-equatorial flow for the individual months (*Darwin Tropical Diagnostic Statement* (DTDS) – see Appendix) also indicate the flow pattern of the southern monsoon trough was close to climatology. The monsoon over Darwin was earlier than climatology with onset occurring around the middle of December. The climatological date of monsoon onset over northern Australia is around the 28th of December (Drosdowsky 1996). The rainfall over much of northern Australia was above average for the season.

Sea-surface temperature

Six-month mean and anomalous sea-surface temperatures (SST) are shown in Fig. 10. The area shaded light green in the anomalies in Fig. 10(b) represents the anomalies range between +0.5°C and -0.5°C. This

Fig. 9 Equatorial cross-section of six-month meridional wind, November 2003 to April 2004; contour interval 2 m s^{-1}, negative (northerly) contours blue shading; positive (southerly) purple shading: (a) mean; (b) anomaly.

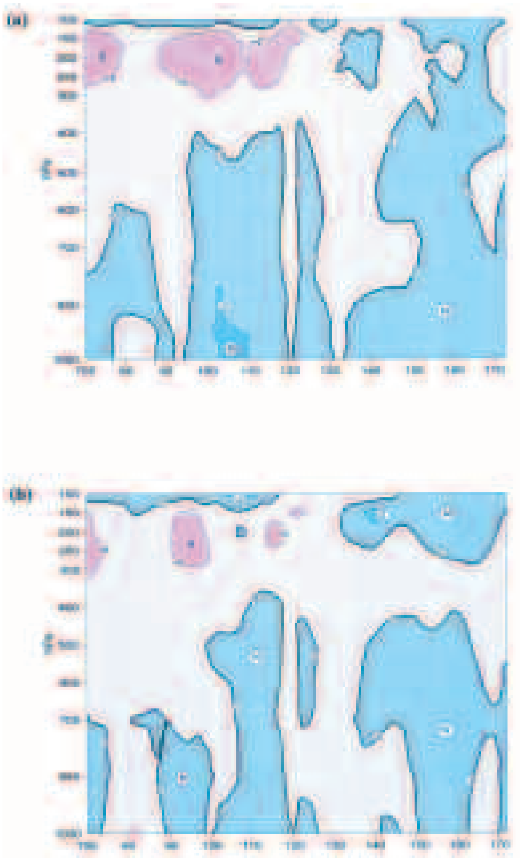
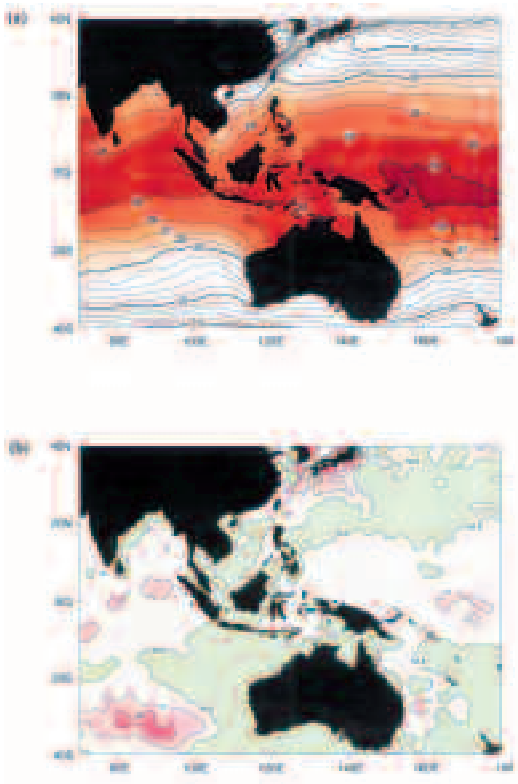


Fig. 10 Six-month SST (°C), November 2003 to April 2004: (a) mean, isotherm interval 1°C, >25°C red shading; (b) anomaly, contours -0.5°C to 0.5°C green shade; > +0.5°C pink - red shade; < - 0.5°C blue shade.



range was selected to emphasise the more significant SST anomalies of more than 0.5°C. Most of the Indian Ocean west of 100°E and the equatorial western Pacific east of Indonesia and Northwestern Pacific remained warmer than normal. These warm temperature anomalies have been more or less a feature of the past three seasons. The warmest anomalies in the Indian Ocean were over the southern Indian Ocean where the MSLP remained higher than normal, as with the past two seasons, May - October 2003 and November 2002 - April 2003, respectively (Shaik and Cleland 2004b, 2004a). The warmest waters in the equatorial Pacific remained mostly west of the dateline, the SST pattern near the South American coast was close to climatology, and all the Niño Indices were close to zero (not shown), consistent with neutral ENSO conditions.

Intraseasonal variability

Figures 11 to 13 show time/longitude plots of (a) 200hPa velocity potential, (b) OLR and (c) MSLP anomaly, averaged over 10° latitude bands, across the Darwin RSMC longitude range. The southern and northern OLR plots (Fig. 11(b) and Fig. 13(b)) also indicate the date and longitude of tropical cyclone genesis events during the season. The time-longitude plots clearly indicate three major active phases of the MJO progressing through the RSMC region; one in mid-December, another in early February and the third during mid-March. The periodicity of these active events remained around 45 days. In addition to these major events, there were several weak convective pulses, which occurred in the eastern half of the region, at least once in each month, which may well

Fig. 11 Time-longitude sections, latitude band 5°S-15°S, 1 November 2003 to 30 April 2004 of five-day backward running mean: (a) 200 hPa velocity potential (10^6 m^2 s^{-1}); (b) OLR (W m^{-2}); 'X' denotes time and longitude of TC genesis events in the latitude band; '0' denotes events poleward, outside of the latitude band; (c) MSLP anomaly (hPa).

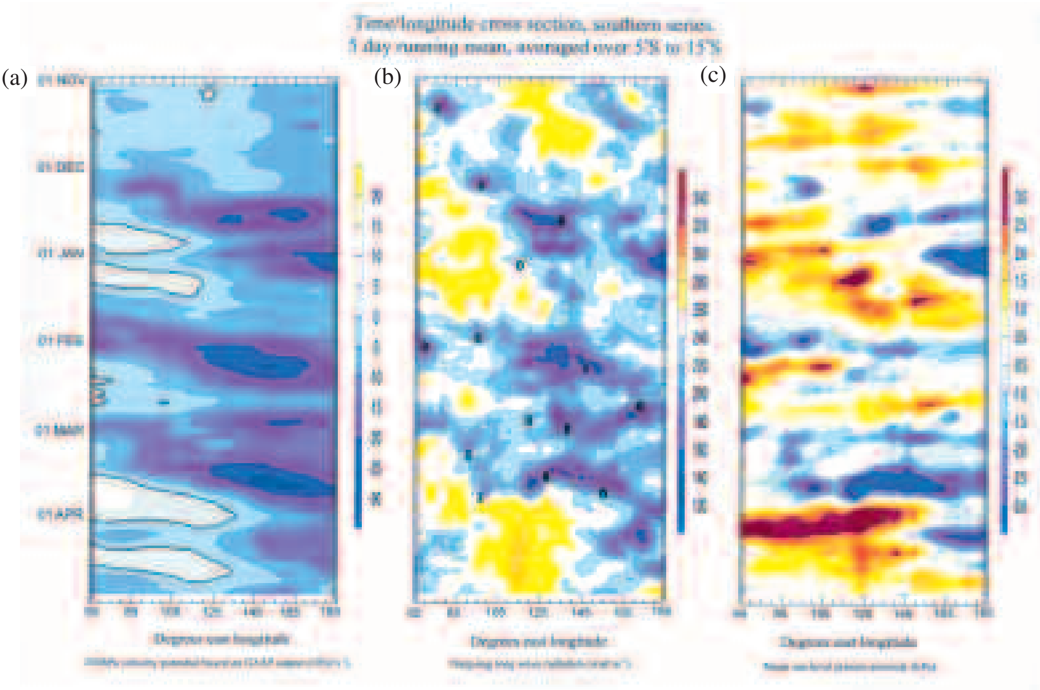


Fig. 12 Time-longitude sections, latitude band 5°S-5°N, 1 November 2003 to 30 April 2004 of five-day backward running mean: (a) 200 hPa velocity potential (10^6 m^2 s^{-1}); (b) OLR (W m^{-2}); (c) MSLP anomaly (hPa).

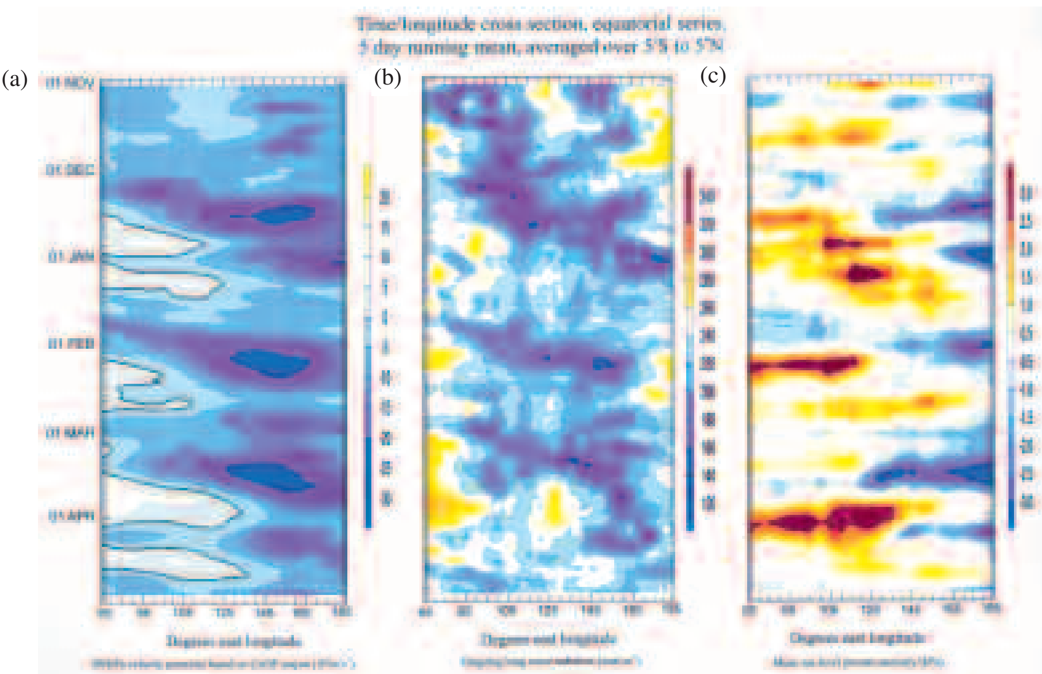


Fig. 13 As for Fig. 11, except latitude band 5°N-15°N.

(a) (b) (c)

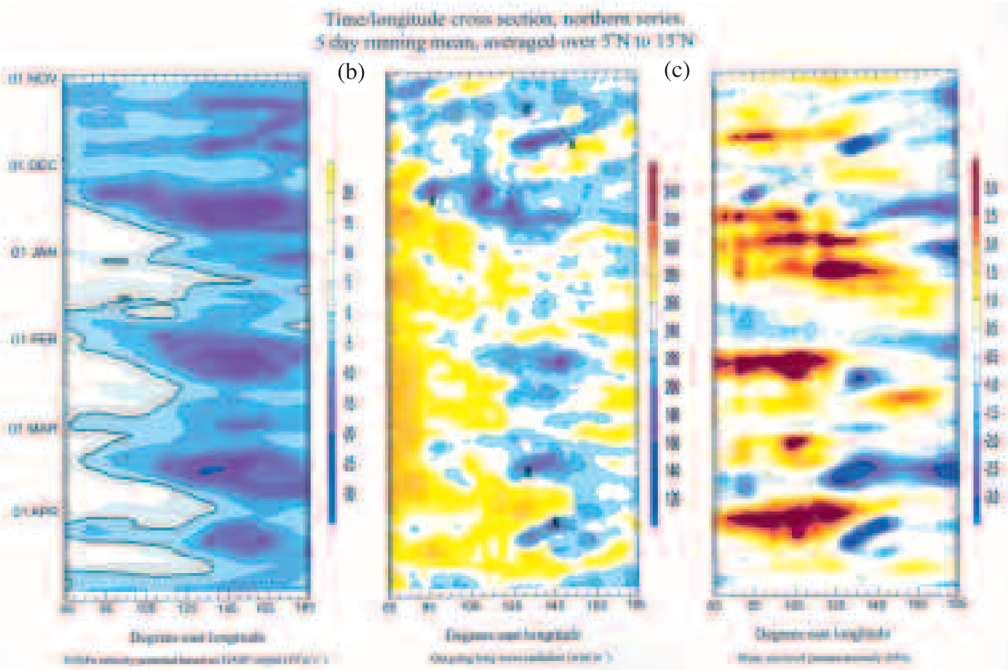
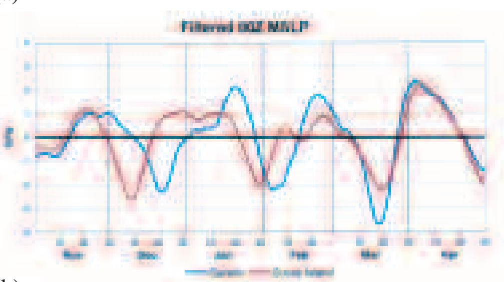


Fig. 14 Normalised MSLP anomalies for two tropical stations in each hemisphere, (a) southern hemisphere, Cocos Island (red) and Darwin (blue); (b) northern hemisphere, Singapore (red) and Yap (blue); (c) Darwin plus Cocos Is. four days earlier (red) and Yap plus Singapore four days earlier (blue).

(a)



(b)

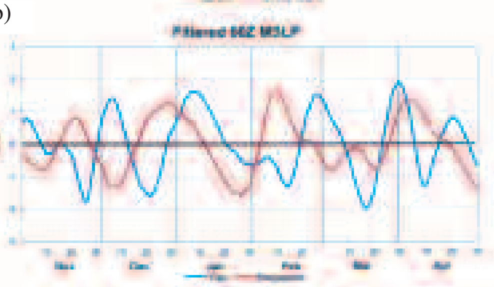
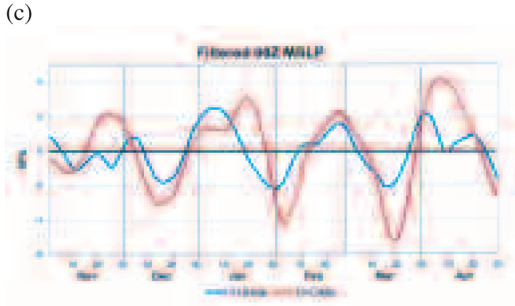


Fig. 14 Continued.

(c)



be related to the progress of Rossby waves through the region.

Figure 14 shows filtered mean sea level pressure anomaly series for four stations, two in each hemisphere (see appendix). In Fig. 14(c) the signal for the eastern station in each hemisphere has been added to that for the western station four days earlier to enhance the portrayal of eastward propagating signals. The combined filtered series (Fig. 14(c)) indicates a good phase agreement between the combined pressure signals. Among the individual pressure series, the Darwin and Cocos Island graph shows about a 10-day lag between the phases whereas the

Yap and Singapore series (Fig. 14(b)) has less phase agreement. These pressure series are consistent with the time-longitude plots in suggesting the 3 distinct active phases of the MJO centred about mid-December, early February and mid-March. Another weaker event was indicated early to mid-November.

Tropical cyclones

The definition of tropical cyclone (TC) and details of cyclone data and analysis are presented in the appendix.

Operational cyclone tracks are shown in Fig. 15, while Table 2 lists TCs in order of occurrence within the various basins, showing duration and estimated maximum intensity details.

A total of 19 TCs were analysed in the Darwin RSMC area during the summary period. Of these, 13 reached severe tropical cyclone or typhoon intensity while within the RSMC boundaries. In addition to the above, several cyclones formed to the west of 70°E and a few formed east of the date-line in the southern hemisphere outside the RSMC boundary. The climatological average number of cyclones in the region for the season is about 21. Out of the total cyclones which formed in the region, four tropical systems, including three of typhoon intensity, developed in the north-western Pacific and one severe tropical cyclone in the north Indian Ocean, including the Bay of Bengal, compared with the averages of 5.7 (3.4 typhoons) and 2.2 (0.5 severe tropical cyclones) respectively. In the southern hemisphere, six storms (four severe tropical cyclones) occurred to the west of 105°E, seven cyclones (three severe tropical cyclones) between 105°E and 165°E and one (severe tropical cyclone) to the east of 165°E. The long-term mean for the southern Indian and Pacific Oceans combined is 12.7 (note this average includes tropical depressions, with maximum mean wind of 13 to 16 m s^{-1}).

Fig. 15 Tropical cyclone tracks, November 2003 to April 2004. Solid line denotes system reached severe tropical cyclone (typhoon) intensity; dashed line denotes system reached only tropical cyclone/storm intensity.

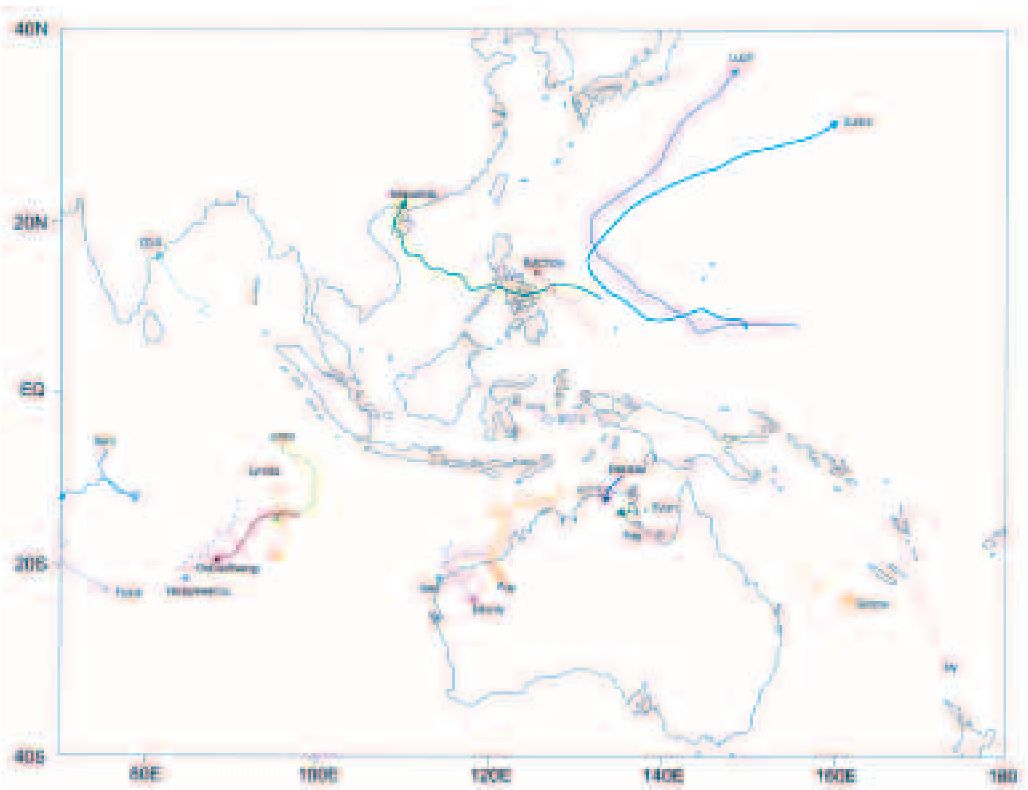


Table 2. Tropical cyclones within the Darwin RSMC area, November 2003 – April 2004. TC = tropical cyclone, STC = severe tropical cyclone, TS = tropical storm, SCS = Severe Cyclonic Storm, Ty = typhoon.

Name	*Dates*[1]	*Mean wind*[2] *m s^{-1} (knots)*	*Estimated minimum MSLP (hPa)*	*Warning Agency**
Bay of Bengal / North Indian Ocean				
Unnamed O3B (SCS)	12 - 15 Dec	28 (55)	984	JTWC
Northwest Pacific / South China Sea				
Nepartak (Ty)	12 - 19 Nov	34 (65)	975	JMA
Lupit (Ty)	21 - 30 Nov	52 (100)	915	JMA
Butchoy (TS)	18 - 20 Mar	23 (45)	991	PAGASA
Sudal (Ty)	5 - 17 Apr	49 (95)	945	JMA
South Indian Ocean (70°E - 105°E)				
Beni (STC)	11 - 20 Nov	52 (100)	935	La RéUnion
Jana (STC)	7 - 11 Dec	39 (75)	960	BoM, Perth
Linda (TC)	30 Jan - 1 Feb	28 (55)	978	BoM, Perth
Frank (STC)	2 - 7 Feb	44 (85)	942	La RéUnion
Nicky/Helma (SCS)	9 -13 Mar	31 (60)	972	BoM, Perth / La RéUnion
Oscar/Itseng (STC)	23 - 28 Mar	49 (95)	935	BoM, Perth / La RéUnion
Australian (105°E - 165°E)				
Debbie (STC)	18 - 20 Dec	34 (65)	970	BoM, Darwin
Ken (TC)	4 - 5 Jan	21 (40)	992	BoM, Perth
Fritz (TC)	10 - 12 Feb	23 (45)	985	BoM, Brisbane
Monty (STC)	27 Feb - 3 Mar	49 (95)	935	BoM, Perth
Evan (TC)	1 - 4 Mar	21 (40)	994	BoM, Darwin
Fay (STC)	16 28 Mar	57 (110)	910	BoM, Darwin
Grace (TC)	20 - 24 Mar	26 (50)	985	BoM, Brisbane
South Pacific Ocean (165°E - 180°)				
Ivy (STC)	23 - 28 Feb	46 (90)	935	NTCC

Notes:
1 Dates (UTC) at TC intensity in Darwin RSMC area
2 Maximum 10-min. Mean wind (while in Darwin RSMC area)

* NTCC = Nadi Tropical Cyclone Centre, Fiji Meteorological Service, Nadi; BoM = Bureau of Meteorology, Australia; Perth = Western Australia Regional Office, Perth; Darwin = Northern Territory Regional Office, Darwin; Brisbane = Queensland Regional Office, Brisbane; JTWC = Joint Typhoon Warning Center, Pearl Harbor, Hawaii; JMA = Japan Meteorological Agency, Tokyo; La RéUnion = Météo France, Le Centre Régional de la Réunion, Le Chaudron, B.P. 4, La RéUnion; PAGASA = Philippine Atmospheric, Geophysical and Astronomical Services Administration, Manila.

Note that where the central pressures are not available from the warnings, the wind has been obtained from the warnings and pressures are estimated from the relationship of Atkinson and Holliday (1977).

Appendix

Data sources used in this summary were:

- MSLP, upper wind and velocity potential six-month seasonal charts were constructed using data from the Bureau of Meteorology's Global Assimilation and Prediction system (GASP – Bourke et al. (1990); Bureau of Meteorology (1998)); anomalies derived from the ECMWF 11-year climatology. MSLP and velocity potential data for Hovmoeller series from the Limited Area Prediction System (LAPS - Puri et al. 1998), nested within GASP.
- Filtered mean sea-level pressure anomaly series (Fig. 14) for two tropical stations in each hemisphere, normalised then passed through a 40-day Butterworth filter, 50 per cent response at 23 and 70 days: southern hemisphere, Cocos Island, (12.2°S, 96.8°E) and Darwin (12.4°S, 130.9°E); northern hemisphere, Singapore (1.4°N, 104.0°E) and Yap (9.5°N, 138.1°E).

- OLR six-monthly and monthly map figures and time-longitude plots for the period November 2003 to April 2004 are derived from the data generated by NOAA, Climate Prediction Center, W/NP52, Room 605, WWBG, 5200 Auth Road, Camp Springs, Maryland, 20746-4304 USA. OLR anomalies are derived using 1979-95 climatology dataset.
- Sea-surface temperature analysis derived from the operational global analysis of the National Meteorological and Oceanographic Centre, Bureau of Meteorology, Melbourne. Includes blended *in situ* and satellite data, 1°C resolution. The 1°x1° global SST climatology from the US National Centers for Environment Prediction (Reynolds and Smith 1995) was used to calculate anomalies.
- *Darwin Tropical Diagnostic Statement*, November 2003 to April 2004 (issued monthly), and *Weekly Tropical Climate Note*, 28 October 2003 to 4 May 2004 (current issue on web at http://www.bom.gov.au/climate/tropnote/tropnote.shtml). Bureau of Meteorology, PO Box 40050, Casuarina, NT 0811, Australia.

Tropical cyclones

Tropical cyclones (TC) are defined as having maximum ten-minute mean winds greater than 17 m s^{-1}, or named systems. Operational tracks shown in Fig. 15 are from the near real-time publication *Darwin Tropical Diagnostic Statement*, and are based on Darwin RSMC operational manual analyses, with limited post-analysis in a few cases.

Following WMO guidelines (Neumann 1993), winds are assumed to be averaged over ten minutes except those from the JTWC, which uses one-minute means. A conversion factor of 0.88 to relate one-minute to ten-minute means was applied to advices issued from the JTWC. Minimum pressures were also obtained from advices, except for those issued by the JTWC and PAGASA Manila. In these cases minimum pressures were estimated using the relationship of Atkinson and Holliday (1977). Since most agencies use the unit of knots (kn) in warnings, wind speeds are shown in Table 2 in knots as well as m s^{-1}. Climatological numbers are from Furze and Preble (2004) for the northwest Pacific and southern hemisphere and Mandal (1991) for the Bay of Bengal. A brief discussion and further details of each cyclone can be found in the DTDS for the relevant month.

Acknowledgments

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