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The tropical circulation in the Australian/Asian region May to October 2004

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A summary of the broadscale tropical circulation from 70°E to 180°, for the six months May to October 2004, is presented. ENSO indicators showed neutral conditions early in the season. By mid year mixed signals became evident. Throughout the season sea-surface temperatures in the eastern near-equatorial Pacific were near average. But within the vicinity of the maritime continent, mean sea-level pressures were above average, with less than average tropical convection. The warmest waters of the Pacific were located close to the near-equatorial dateline, rather then the climatological location of the northwest Pacific. Outgoing long wave radiation and mean sea-level pressure indicators over India were near average. Several active convective phases of the Madden-Julian Oscillation affected the region during the season. The periodicity remained close to the lower limit of the 30 to 60-day intraseasonal oscillation. A total of 26 tropical cyclones (16 typhoons) developed during the period, close to the mean (27) for the Darwin Regional Specialised Meteorological Centre (RSMC) area.

Introduction

This summary reviews the broadscale tropical circulation in the Australian/Asian region during the period May to October 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. Previous seasons have been described in earlier summaries of this series by Shaik and Cleland (2004a, 2004b and 2005). 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

Neutral El Niño-Southern Oscillation (ENSO) conditions have persisted since the demise of the 2002-03 El Niño event (Shaik and Cleland 2004a). However, some El Niño-like indicators developed during the second half of this summary period. Some atmospheric indicators, such as the low values of the Southern Oscillation Index (SOI) and near-average wind pattern over the equatorial western Pacific, sup-

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

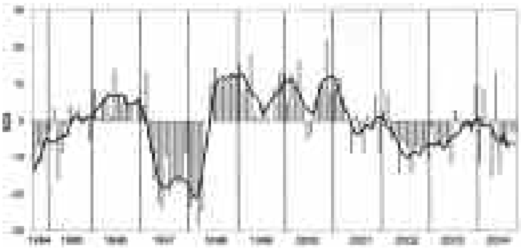
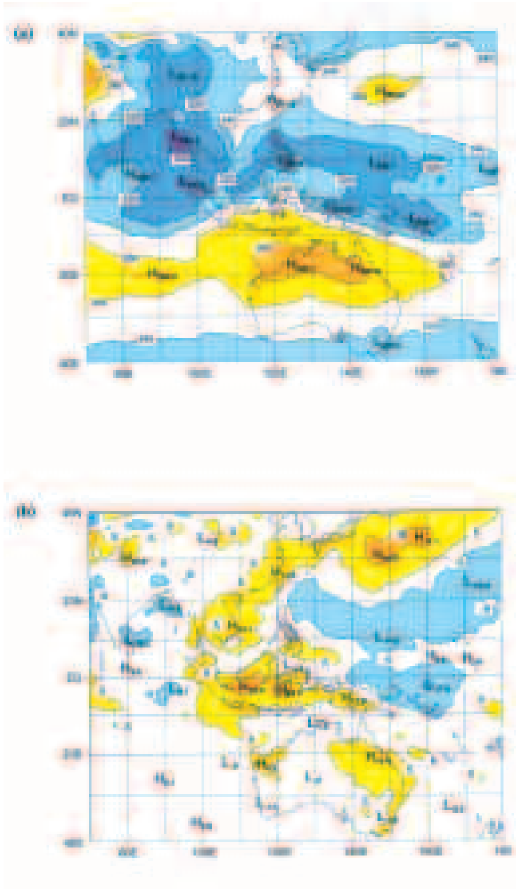


Fig. 2 **Six-month (May to October 2004): (a) mean OLR (W m^{-2}). 260 W m^{-2} and above yellow shading, 240 W m^{-2} and below blue shading; (b) OLR anomaly (W m^{-2}) > +5 W m^{-2} yellow shading and < -5 W m^{-2} blue shading.**



port neutral ENSO conditions, while some oceanic patterns were indicating El Niño-like conditions, such as relatively less convection and below-average rainfall over most of the central RSMC region.

Southern Oscillation

Figure 1 shows the ten-year behaviour of Troup's Southern Oscillation Index (SOI) from November 1994 and its symmetrical five-month running mean. Monthly values of the SOI from January 2002 are given in Table 1. Large oscillations in the SOI were evident during the southern hemisphere summer and autumn, in response to the cycle of active and inactive phases of the Madden-Julian Oscillation (MJO). The monthly SOI value remained negative from June. However, the values were confined to within one standard deviation between July and October. The five-month mean SOI during the season decreased from -1 during May to -7 in October. The mean SOI for the season was –3.8, similar to the previous dry season value of –3.7 (May – October 2003 season).

Convection and tropospheric circulation

The outgoing long wave radiation (OLR) mean and anomaly – used as a proxy for convection – for the six-month period are shown in Fig. 2(a) and 2(b) and for each individual month are shown in Figs 3(a) to (f) and 4(a) to (f) respectively. Convection associated with the northern monsoon was above average in the northwestern Pacific, east of Papua New Guinea and parts of the north Indian Ocean. Convection over the maritime continent remained less than average. In the southern hemisphere, most of the Australian continent remained drier than normal.

Table 1. Monthly values of Troup's SOI for the period January 2002 to October 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	+13	-14	-7	-8	-3	-4		

Fig. 3 **Monthly mean OLR (W m^{-2}). 260 W m^{-2} and above yellow-red shading, 240 W m^{-2} and below blue-purple shading: (a) May 2004; (b) June 2004; (c) July 2004; (d) August 2004; (e) September 2004; (f) October 2004.**

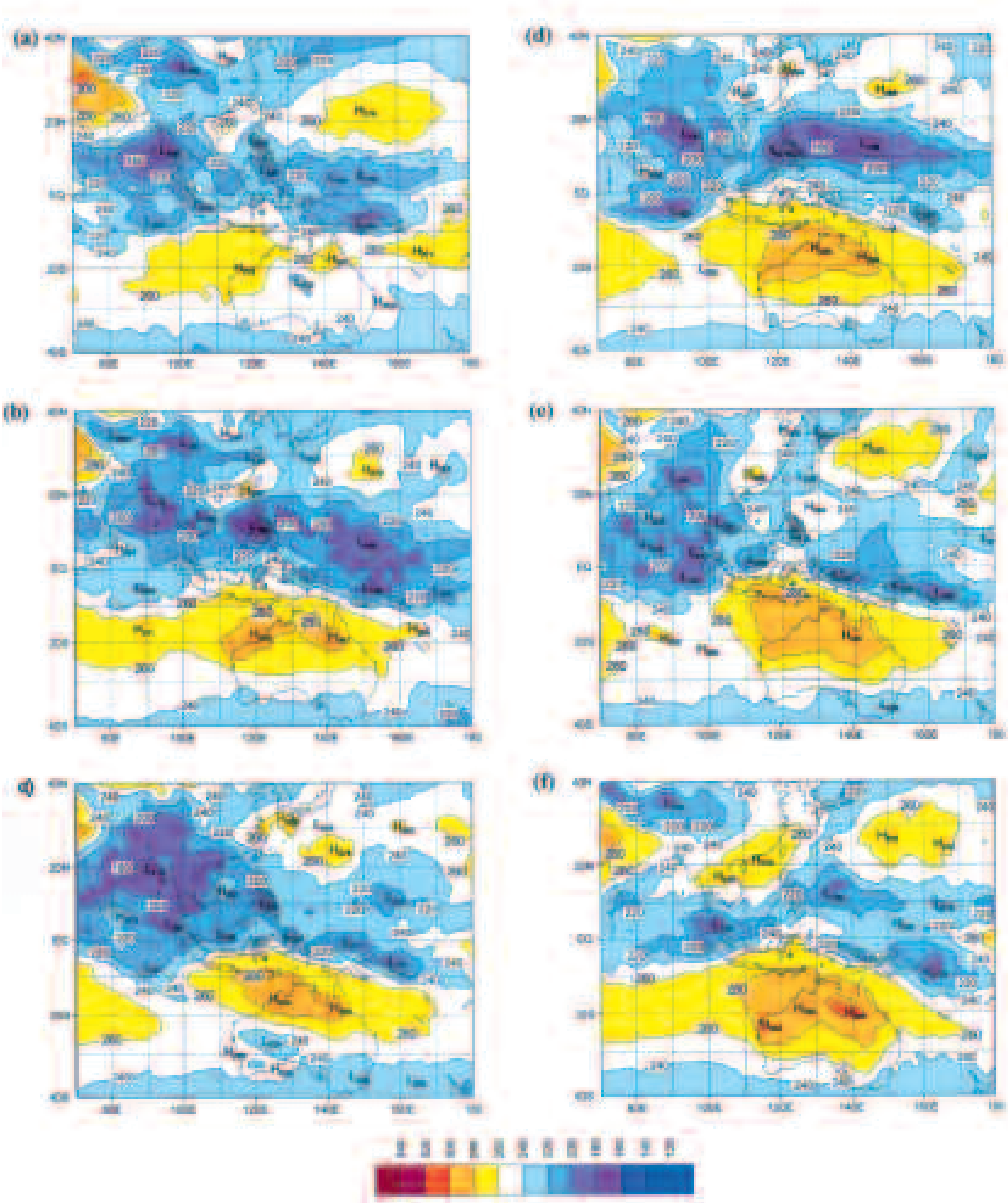


Fig. 4 **Monthly OLR anomaly (W m^{-2}). > +5 W m^{-2} yellow-red shading, < -5 W m^{-2} blue-purple shading: (a) May 2004; (b) June 2004; (c) July 2004; (d) August 2004; (e) September 2004; (f) October 2004.**

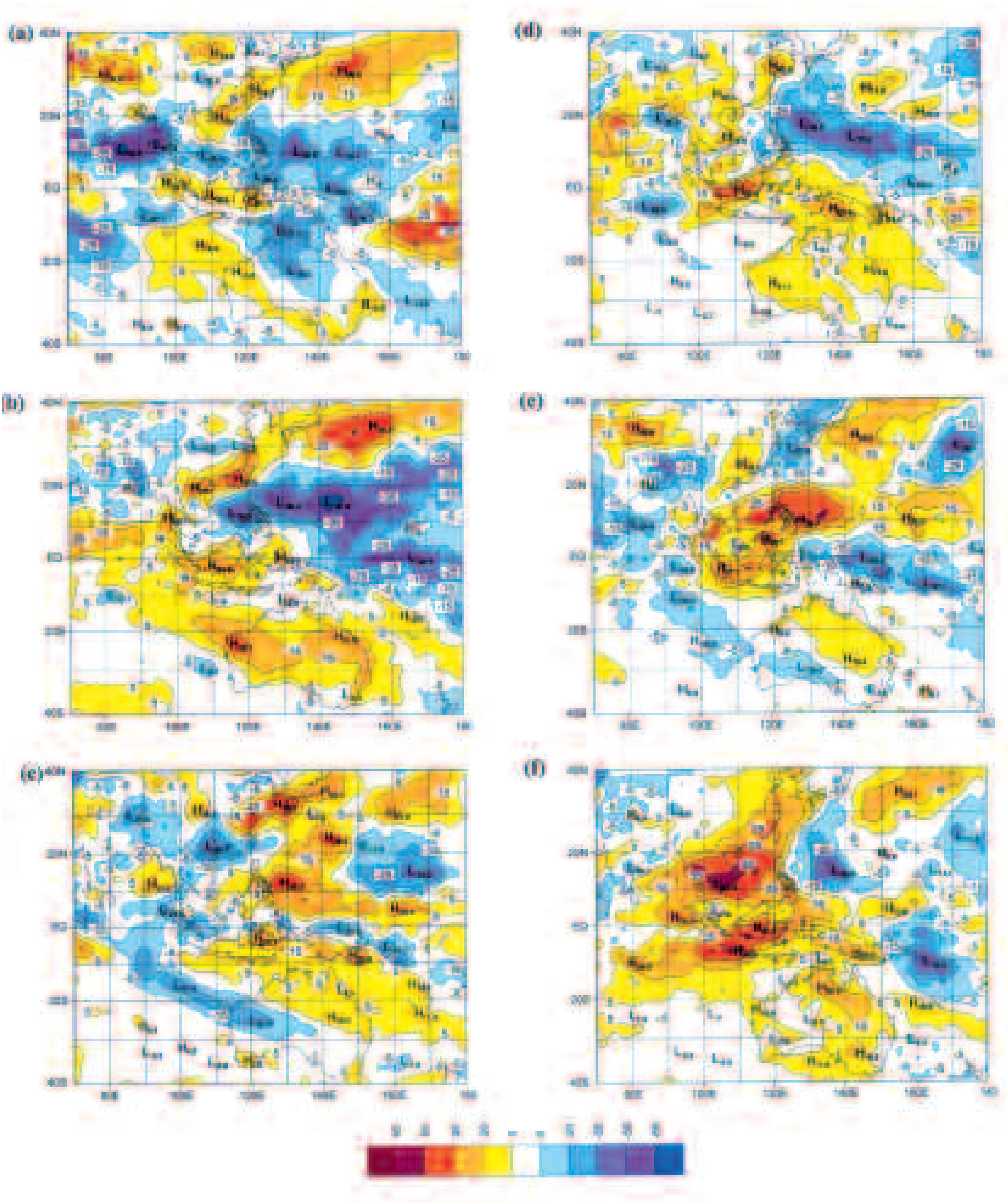


Fig. 5 **Six-month mean velocity potential (10^6 m^2 s^{-1}) and vector winds, May to October 2004. > 0 yellow-red shading and < 0 blue-purple shading: (a) 850 hPa, contour interval 1; (b) 200 hPa, contour interval 2.**

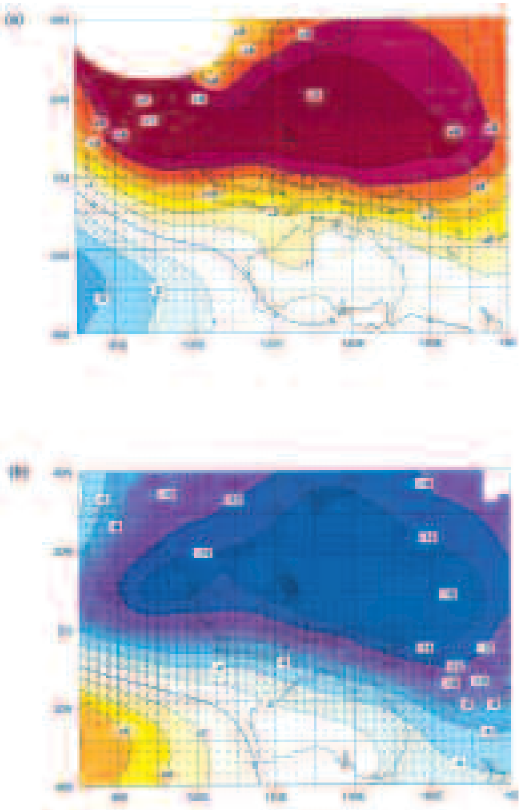
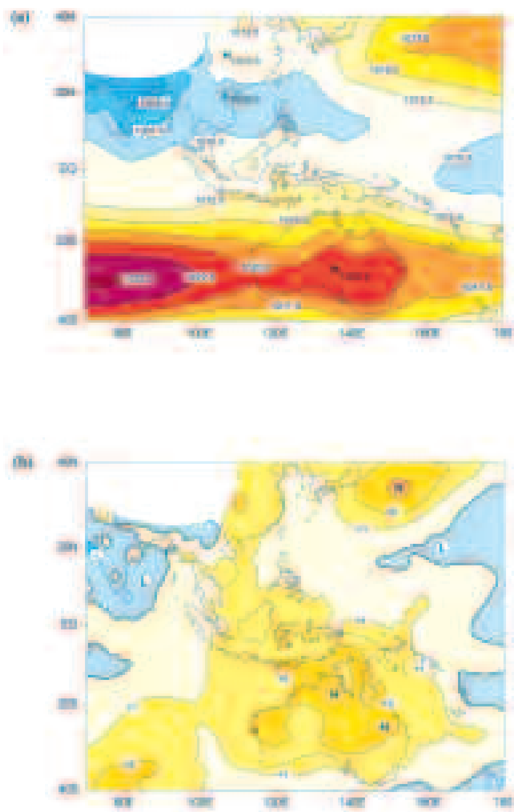


Fig. 6 **Six-month MSL pressure (hPa), May to October 2004: (a) mean, isobar interval 2.5 hPa; (b) anomaly, contour interval 1 hPa, blue-shaded areas negative, yellow-shaded areas positive.**



The axes of low-level convergence and upper-level divergence, as indicated by the velocity potential analyses at 850 hPa and 200 hPa levels respectively (Fig. 5), remained close to their respective climatological mean latitudes, similar to the May – October 2002 season (Shaik and Jackson 2003) and May - October 2003 (Shaik and Cleland 2004b). However, the centres of strong low-level convergence and upper-level divergence were positioned east of their respective mean locations (means not shown). The good vertical alignment of the centres of low-level convergence and upper-level divergence in the western Pacific indicate a well-organised upmotion of a vigorous Hadley circulation in the area.

Seasonally averaged mean sea-level pressure (MSLP) and anomalies are shown in Fig. 6. Pressures were high over central RSMC longitudes, particularly northern Australia and Southeast Asia. Weak negative anomalies persisted in the northern Indian Ocean and areas close to the date-line in the equatorial Pacific. Mostly positive anomalies persisted in the southern hemisphere, which are consistent with the relatively dry conditions over the Australian continent.

Vector wind analyses and anomalies at 850 hPa and 200 hPa are shown in Figs 7 and 8 respectively. Westerly anomalies were evident in the equatorial Indian Ocean and western Pacific Ocean between 130°E and 160°E. Winds elsewhere over the tropics remained close to the mean. The net effect gave rise to apparent areas of low-level divergence near 110°E and convergence east of 160°E, consistent with the OLR pattern. The low-level cross-equatorial flow was weaker than that in the previous southern hemisphere dry season (Shaik and Cleland 2004b) over most of

Fig. 7 **Six-month 850 hPa vector wind field, May to October 2004, isotach (thin lines) interval 5 m s^{-1}, > 5 m s^{-1} shaded yellow : (a) mean; (b) anomaly.**

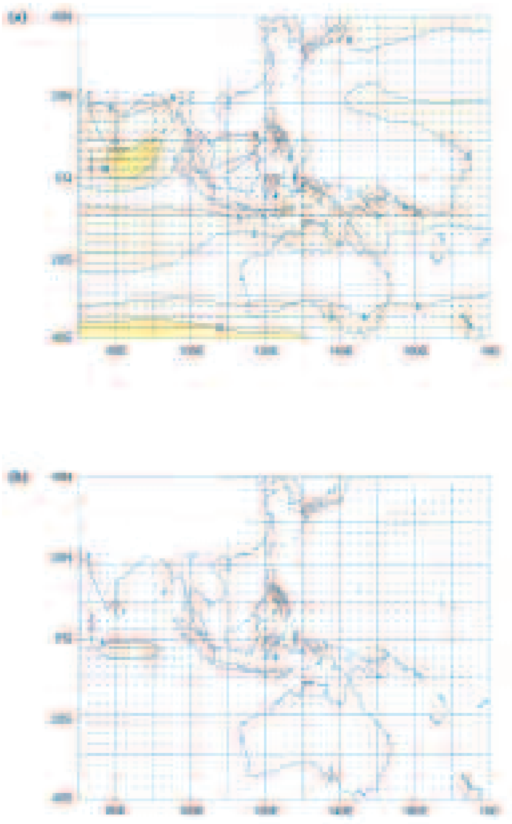
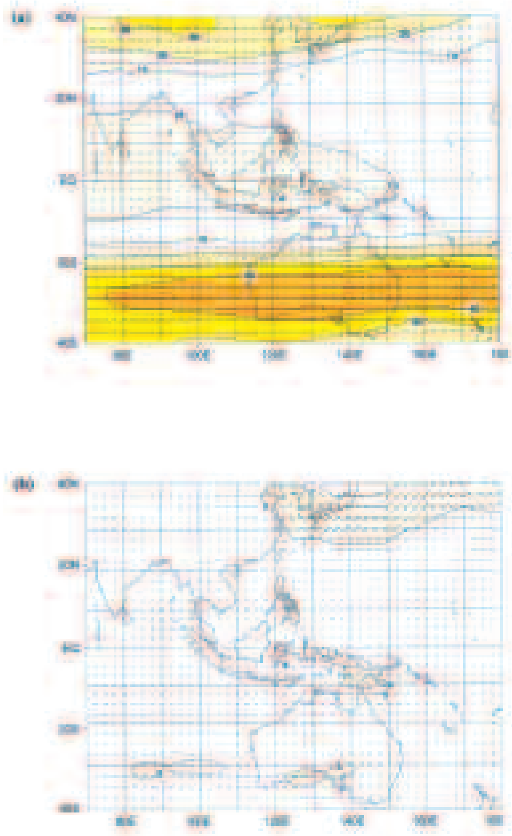


Fig. 8 **Six-month 200 hPa vector wind field, May to October 2004: (a) mean, isotach (thin lines) interval 10 m s^{-1}, > 10 m s^{-1} shaded yellow; (b) anomaly, isotach (thin lines) interval 5 m s^{-1}, > 5 m s^{-1} shaded yellow.**



the RSMC longitude range except the equatorial western Pacific near the date-line. Winds at the upper levels were close to climatology except over the Indian Ocean where the flow was stronger than normal. The upper-level subtropical jet in the northern hemisphere remained north of its climatological location and contributed to the easterly anomalies in the northwestern Pacific.

The cross-equatorial components of the flow and anomalies are shown in Fig. 9. These diagrams indicate that the flow pattern is similar to that in the previous May – October 2003 season (Shaik and Cleland 2004b). Stronger than average low-level southerlies and upper-level northerlies prevailed west of 140°E. The cross-equatorial component to the east of 140°E was close to normal.

Sea-surface temperature

Six-month mean and anomalous sea-surface temperatures (SST) are shown in Fig. 10. The SST configuration in the western tropical Pacific shares some similarities to the previous seasons, May – October 2003 and November 2003 – April 2004 (Shaik and Cleland 2004b, 2005). The patches of +2°C warm anomalies were confined east of 160°E. A few patches of +1°C remained in the tropical Indian Ocean. The warmest waters in the equatorial Pacific were located near the date-line from July onwards.

Fig. 9 **Equatorial cross-section of six-month meridional wind, May to October 2004, contour interval 2 m s^{-1}, northerlies (negative values) shaded blue, southerlies (positive values) shaded pink-red: (a) mean; (b) anomaly.**

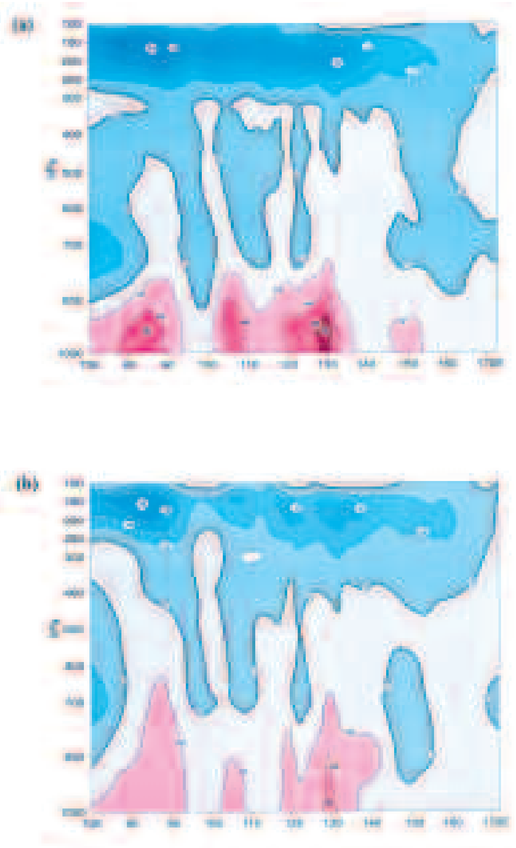
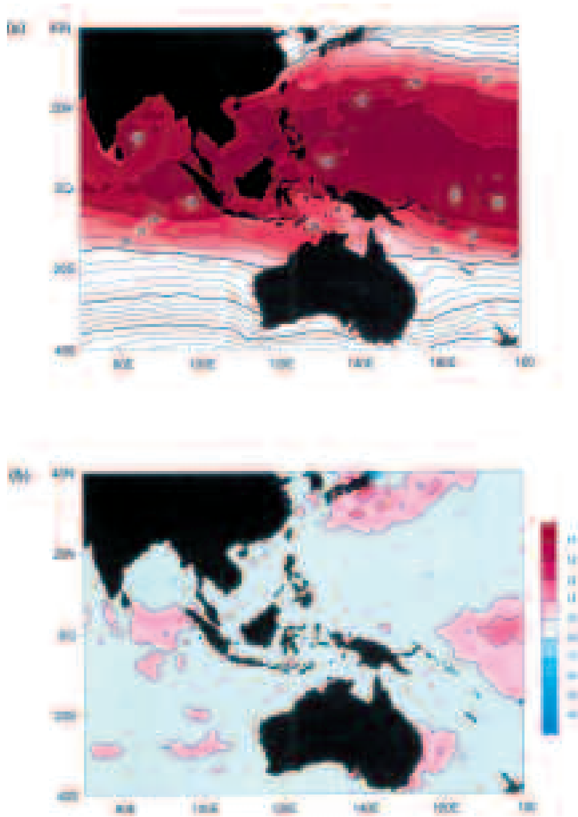


Fig. 10 **Six-month SST (°C), May to October 2004: (a) mean, isotherm interval 1°C, >25°C red shading; (b) anomaly, contours -0.5°C to 0.5°C green shade; > +0.5°C pink - red shade; < -0.5°C blue shade.**



Intraseasonal variability

Figures 11 to 13 show time/longitude plots of (a) 200 hPa 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 (Figs 11(b) and 13(b)) also indicate the tropical cyclone genesis events.

The 200 hPa velocity potential series for the three latitude bands suggest active MJO events were initiated late each month in the western parts of the RSMC area since July. Eastward propagation was generally evident in these events, though the late August/early September event was particularly weak over the maritime continent.

Figure 14 shows filtered station pressure anomaly series for four stations, two in each hemisphere. 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. A four-day period was chosen, as this is approximately the time that an eastward-moving global wave with a period of 45 days will take to travel over this longitude range.

In the individual pressure series for each of the four stations, Darwin and Singapore series picked up most of the MJO events. A 30-day periodicity is evident in the pressure series from late July.

Fig. 11 **Time-longitude sections, latitude band 5°S-15°S (southern series), 1 May to 31 October 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).**

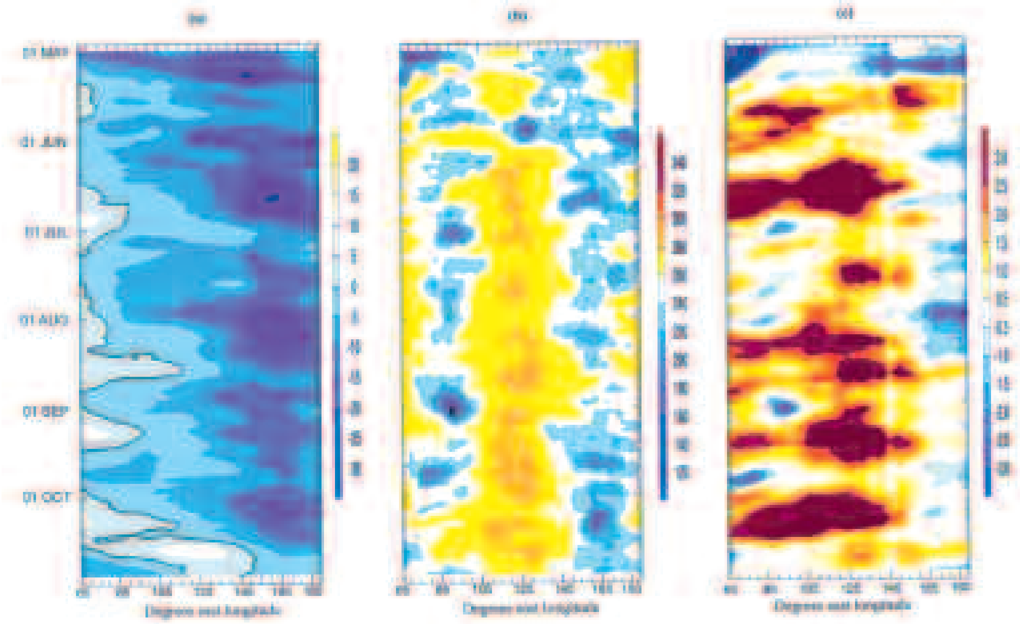


Fig. 12 **Time-longitude sections, latitude band 5°N-5°S (equatorial series), 1 May to 31 October 2004 of five-day backward running mean: (a) 200 hPa velocity potential; (b) OLR; (c) MSLP anomaly.**

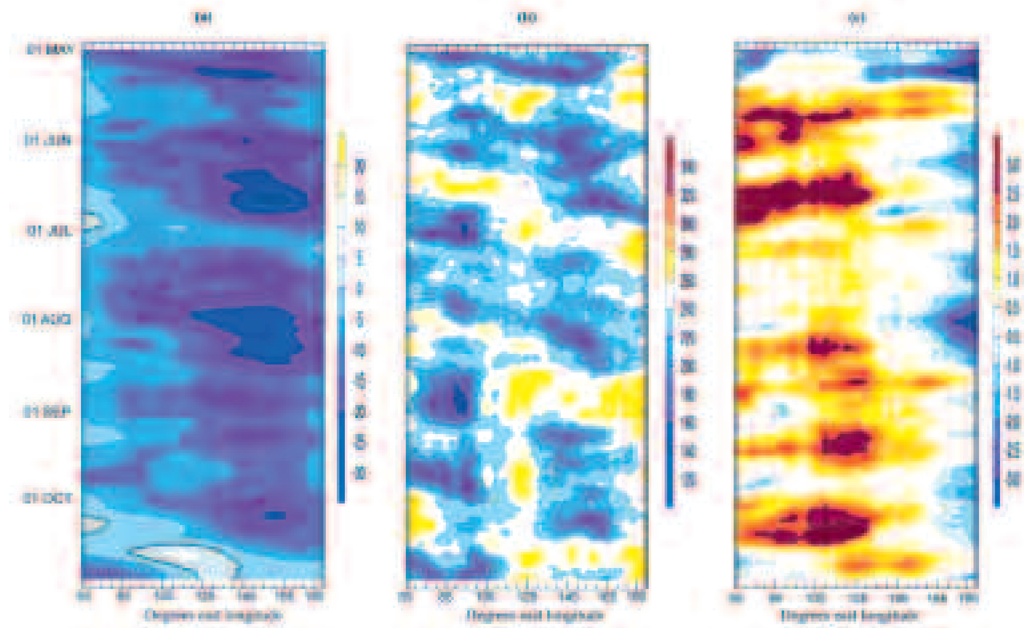


Fig. 13 **As for Fig. 11, except latitude band 5°N-15°N (northern series).**

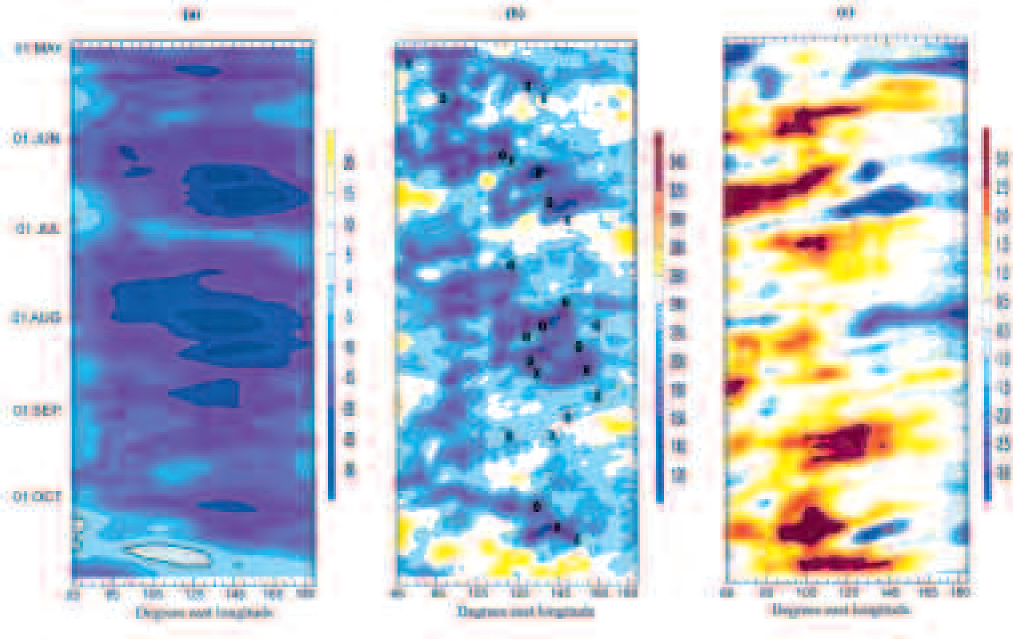
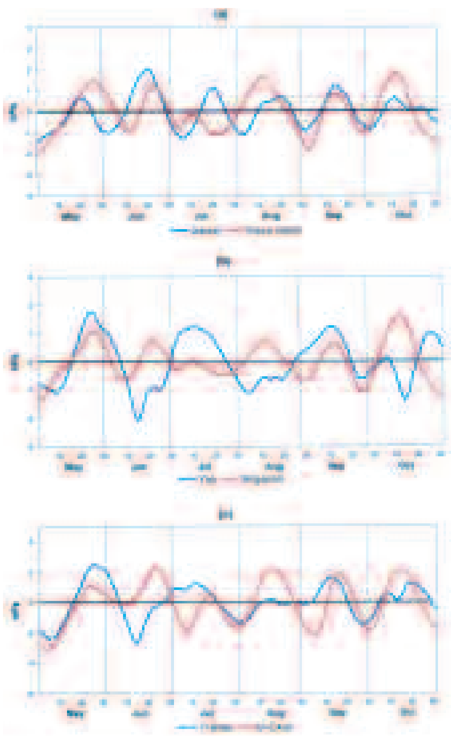


Fig. 14 **Normalised MSLP anomalies for two tropical stations in each hemisphere: (a) southern hemisphere, Darwin (blue) and Cocos Island (red); (b) northern hemisphere, Yap (blue) and Singapore (red); (c) Yap plus Singapore four days earlier (blue) and Darwin plus Cocos Island four days earlier (red).**



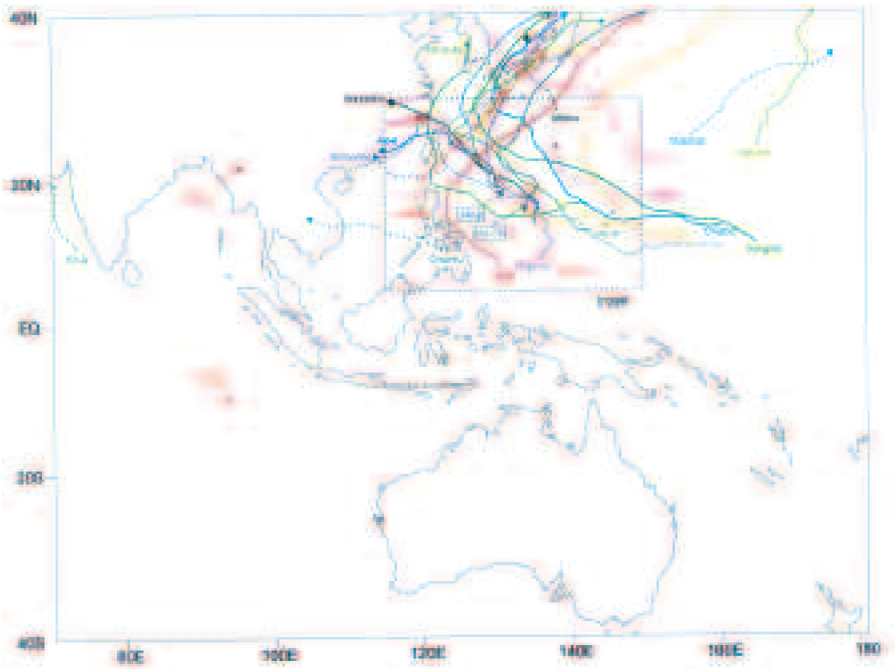
Tropical cyclones

Tropical cyclones (TC) are defined here as systems having maximum ten-minute mean winds greater than 17 m s^{-1}, or having been named. Operational 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. Tracks are from the near real-time publication *Darwin Tropical Diagnostic Statement* (DTDS), and are based on Darwin RSMC operational manual analyses, with limited post-analysis in a few cases. A brief discussion and more information of each cyclone can be found in the DTDS for the relevant month. Other details about the cyclone data analysis are presented in the appendix.

A total of 26 TCs were analysed in the Darwin RSMC area during the summary period; of these sixteen reached severe tropical cyclone or typhoon intensity. Two unnamed cyclones formed in the Bay of Bengal (3.6 average), one developed in the south Indian Ocean, none in the south Pacific (average 2.7 for the south Indian and Southern Pacific Oceans combined) and the remaining 23 formed in the north-west Pacific (20.5 average). In addition at least one TC formed in the southern Indian Ocean west of the RSMC area and 17 cyclones formed in the north Pacific east of the date-line, most of them being close to the American coast. On average 27 TCs form in the RSMC region between May and October.

Fig. 15 **Tropical cyclone tracks, May to October 2004. Solid line denotes system reached severe tropical cyclone (typhoon/hurricane) intensity, dashed line denotes system reached only tropical cyclone/storm intensity: (a) RSMC area; (b) inset.**

(a)



(b)

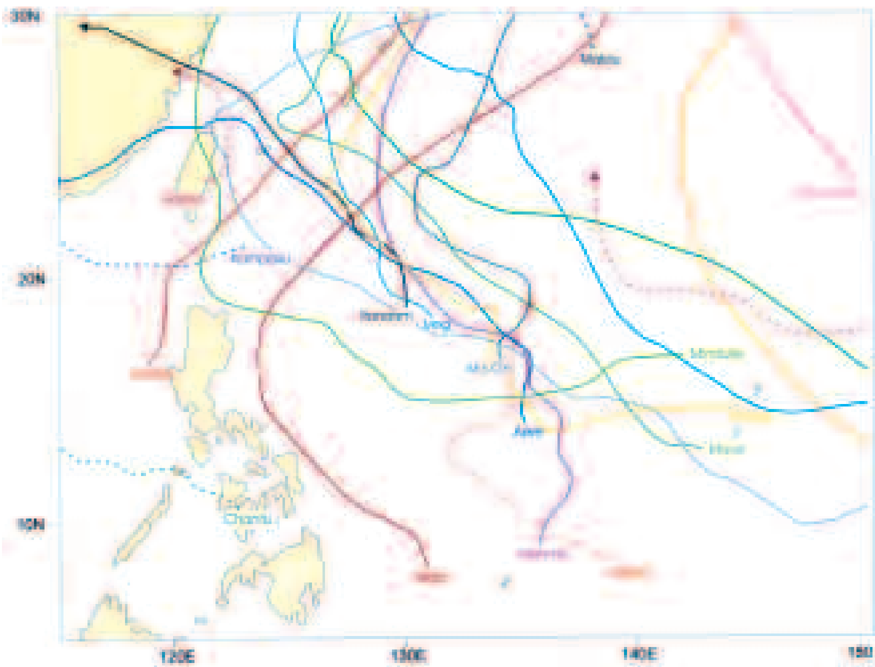


Table 2. Tropical cyclones within the Darwin RSMC area May – October 2004. TC = tropical cyclone, TS = tropical storm, Ty = typhoon.

Name	*Dates (UTC) at TC intensity in Darwin RSMC area*	*Maximum 10-min. mean wind (while in Darwin RSMC area) m s^{-1} (knots)*	*Estimated minimum MSLP (hPa)*	*Warning agency**
Bay of Bengal /North Indian Ocean				
Unnamed 01A (TC)[1]	05 - 10 May	23 (45)	992	JTWC
Unnamed 02B (TC)	17 - 19 May	21 (40)	990	JTWC
South Indian Ocean				
Phoebe (TC)	1 - 3 Sep	26 (50)	990	La Réunion
South Pacific				
	Nil			
Northwest Pacific/South China Sea				
Nida (Ty)[2]	13 - 22 May	46 (90)	930	PAGASA
Omais (TS)	18 - 21 May	26 (50)	985	JMA
Conson (Ty)	6 - 11 Jun	39 (75)	960	Hong Kong
Chantu (TS)	10 - 13 Jun	28 (55)	980	Hong Kong
Dianmu (Ty)[3]	13 - 21 Jun	52 (100)	925	Hong Kong
Mindulle (Ty)	23 Jun- 4 Jul	46 (90)	940	JMA
Tingting (Ty)[4]	26 Jun - 4 Jul	44 (85)	945	JMA
Kompasu (TS)	14 - 16 Jul	23 (45)	986	Hong Kong
Namtheun (Ty)	25 Jul - 1 Aug	44 (85)	945	JMA
Malou (TS)	4 - 5 Aug	21 (40)	994	JMA
Meranti (Ty)[5]	4 - 9 Aug	39 (75)	960	JMA
Rananim (Ty)	8 - 13 Aug	41 (80)	950	JMA
Malakas (TS)	11 - 13 Aug	23 (45)	990	JMA
Megi (Ty)[6]	16 - 20 Aug	34 (65)	970	JMA
Chaba (Ty)[7]	19 - 31 Aug	57 (110)	910	JMA
Aere (Ty)	20 - 26 Aug	41 (80)	955	JMA
Songda (Ty)[8]	27 Aug - 7 Sep	46 (90)	925	JMA
Sarika (TS)	4 - 7 Sep	28 (55)	980	JMA
Haima (TS)	11 - 13 Sep	21 (40)	996	JMA
Meari (Ty)	20 - 30 Sep	46 (90)	940	JMA
Ma-On (Ty)[9]	4 - 10 Oct	52 (100)	920	JMA
Tokage (Ty)[10]	12 - 21 Oct	44 (85)	940	JMA
Nock-Ten (Ty)	16 - 26 Oct	44 (85)	945	JMA

* PAGASA = Philippine Atmospheric, Geophysical and Astronomical Services Administration, Manila; JTWC = Joint Typhoon Warning Center, Pearl Harbor, Hawaii; JMA= Japan Meteorological Agency, Tokyo; Hong Kong = Hong Kong Observatory, Hong Kong. La Réunion = Météo France, Le Centre Régional de la Réunion, Le Chaudron, B.P. 4, La Réunion.

Notes

1 *01A* moved west out of the RSMC area and dissipated soon after.
2 *Nida* moved northeastward out of the RSMC area (40°N) and merged into the extratropical flow.
3 *Dianmu* moved northeastward out of the RSMC area (40°N) and merged into the extratropical flow.
4 *Tingting* moved northeastward out of the RSMC area (40°N) and merged into the extratropical flow.
5 *Meranti* moved northwards out of the RSMC area (40°N) and merged into the extratropical flow.
6 *Megi* moved northwards out of the RSMC area (40°N) with typhoon intensity.
7 *Chaba* moved northeastwards out of the RSMC area (40°N) and merged into the extratropical flow.
8 *Songda* moved northeastwards out of the RSMC area (40°N) and merged into the extratropical flow.
9 *Ma-On* moved northeastwards out of the RSMC area (40°N) and merged into the extratropical flow.
10 *Tokage* became an extratropical cyclone by 21 October (within the RSMC area) and moved northeastwards out of the RSMC region.

Note that central pressures are not available from PAGASA Manila and JTWC warnings; in these cases the wind has been obtained from the warnings and pressures are estimated from the relationship described in Atkinson and Holliday (1977).

Acknowledgments

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Appendix

Data sources

MSLP, upper-wind and velocity potential data from the Bureau of Meteorology's Global Assimilation and Prediction system (GASP – Bourke et al. 1990, Bur. Met., Australia, 1998); anomalies derived from the European Centre for Medium-Range Weather Forecasts (ECMWF) 11-year climatology.

OLR six-monthly and monthly map figures and time longitude plots for the period May to October 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 a 1979-95 climatology dataset.

Sea-surface temperature analyses were derived from the operational global analyses 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 (DTDS), May to October 2004 (issued monthly), and *Weekly Tropical Climate Note*, for the period 4 May 2004 to 2 November 2004, Northern Territory Regional Office, Bureau of Meteorology, PO Box 40050, Casuarina, NT 0811, Australia, were used for reference.

Tropical cyclones

Following WMO guidelines (Neumann 1993), winds were assumed to be averaged over ten minutes except those from the Joint Typhoon Warning Center (JTWC), which uses one-minute means. A conversion factor of 0.88 to relate one-minute to ten-minute means was applied to warnings issued from JTWC. Minimum pressures were also obtained from the warnings, except for those issued by 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 Atangan and Preble (2005) for the northwest Pacific and southern hemisphere and Mandal (1991) for the north Indian Ocean. The cyclone information for the regions outside RSMC area is derived from a web site http://www.solar.ifa.hawaii.edu/Tropical/tropical.html, maintained by T.R. Metcalf.

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