

The tropical circulation in the Australian/Asian region - November 2002 to April 2003

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(Manuscript received January 2004)

A summary of the broad scale tropical circulation from 70°E to 180°, for the six months November 2002 to April 2003, is presented. Transition from a moderate warm ENSO (El Niño) phase to near neutral conditions was evident during the season. Evidence for this includes transition to near average Walker circulation over the Australian region, slightly above average but weak atmospheric pressure over the central equatorial belt, negative values of the Southern Oscillation Index which were mostly confined to within one standard deviation of the mean and a zone of warm sea-surface temperature anomalies in the equatorial central Pacific. Overall convection over much of western Indonesia and northern Australia was below average, with the monsoon being poorly developed in the northern Australia and Papua New Guinea region for most of the season. Active phases of the Madden-Julian Oscillation (MJO) were clearly evident during the transition stages either side of the north Australian Monsoon, but more difficult to interpret during the middle part of the season. A total of 25 tropical cyclones developed during the period, close to the mean for the season.

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 2002 to April 2003. The area covered is the Darwin Regional Specialised Meteorological Centre (RSMC) analysis domain, that is 70°E to 180°, 40°N to 40°S. Seasons immediately prior were described by Shaik and Jackson (2003) and Shaik and Bate (2003). The first section of this summary uses mostly six-month average charts to describe the overall seasonal circulation and anomalies. The second

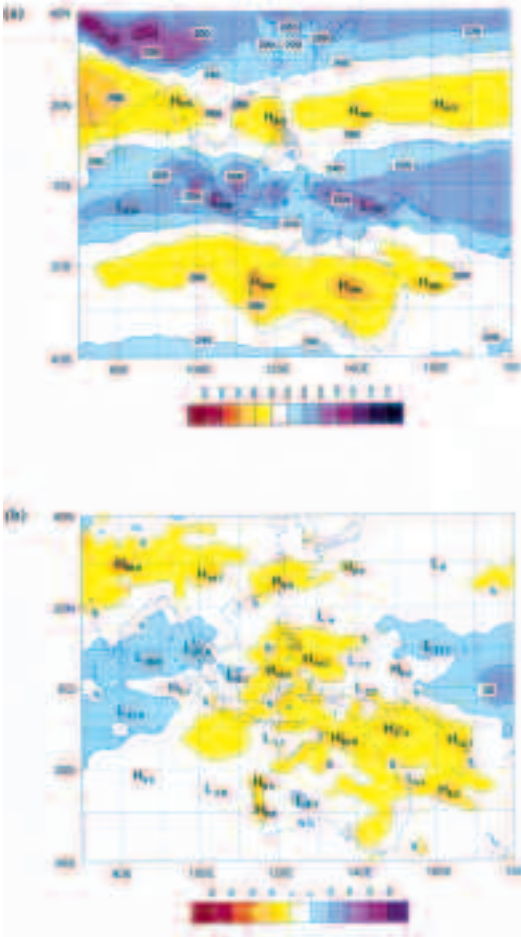
section uses time series to portray variations of the tropical circulation within the season. Intraseasonal variability of various elements such as outgoing long wave radiation (OLR), 200 hPa velocity potential and mean sea-level pressure (MSLP) anomaly are analysed in this section. The third section briefly describes the occurrence of tropical cyclones in the six-month period.

Data sources

The six-month seasonal charts were constructed using GASP, the Australian global numerical weather prediction model (see Appendix). Anomalies are derived from the European Centre for Medium-range Weather

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Fig. 2 Six-month (a) mean OLR (W m^{-2}), heavy line 240 W m^{-2} , 260 W m^{-2} and above yellow-red shading, 240 W m^{-2} and below, blue shading; (b) OLR anomaly (W m^{-2}), $> +5 \text{ W m}^{-2}$ yellow-red shading, $< -5 \text{ W m}^{-2}$, blue shading.



lation. The positions of both low and upper level axes were close to the mean. However, the centres of maximum low level convergence and upper level divergence shifted well to the east of their climatological locations, close to the pattern that appeared during the November 2001 to April 2002 season (Shaik and Bate 2003). The shift of the centres to the east is another feature of the El Niño event that was evident early in the season.

Mean sea-level pressure (MSLP) and anomalies are shown in Fig. 6. Pressures were generally above average over most of the tropics except to the east of 170°E , and in the equatorial Indian Ocean, where the anomalies were weakly negative. The anomalies were positive over Australia, in line with the persistent dry conditions over the continent. The subtropical ridges in both hemispheres were close to their respective mean locations. The negative pressure anomalies near the date-line, combined with positive anomalies across central RSMC longitudes are indicative of the El Niño event that was evident early in the season.

Vector wind analyses and anomalies at 850 hPa and 200 hPa levels are shown in Figs 7 and 8 respectively. The anomalies over most of the tropical Pacific at lower and upper levels were weaker than for the previous two successive seasons (Shaik and Bate 2003, Shaik and Jackson 2003). Anomalies at the lower levels were generally converging over the central Pacific and diverging from the maritime continent. Divergent anomaly flow over the central Pacific was evident at the upper levels. Stronger than normal upper-level easterlies in the tropical Indian Ocean supports the strong outflow from an active southern monsoon circulation in the area.

Diagrams depicting the cross-equatorial component of the flow and anomalies (Fig. 9) indicate a pattern close to the 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) indicates the southern monsoon trough was poorly organised and the onset of the monsoon over Darwin was close to the climatology, being just a few days later than normal. The normal monsoon onset over northern Australia is around 28 December (Drosowsky 1996).

Sea-surface temperature

Six-month mean and anomalous SSTs are shown in Fig. 10. Equatorial waters were almost entirely warmer than 29°C with a few patches of 30°C and above, which is above average for most of the area, similar to the previous May – October 2002 season (Shaik and Jackson 2003). Some areas in the Indian Ocean remained more than one degree warmer than climatology. The area in the northwestern Pacific near the China coast also remained warmer than normal. However, the zone of warmest waters in the equatorial Pacific remained close to the date-line with anomalies exceeding 1°C , consistent with the warm (El Niño) phase of the ENSO, which was evident over the early part of the summary period. The SST pattern near the South American coast and all the Niño indices (not shown) support the development of the neutral ENSO pattern.

Fig. 3 Monthly mean OLR (W m^{-2}), heavy line 240 W m^{-2} , 260 W m^{-2} and above yellow-red shading, 240 W m^{-2} and below, blue shading: (a) November 2002; (b) December 2002; (c) January 2003; (d) February 2003; (e) March 2003; (f) April 2003.

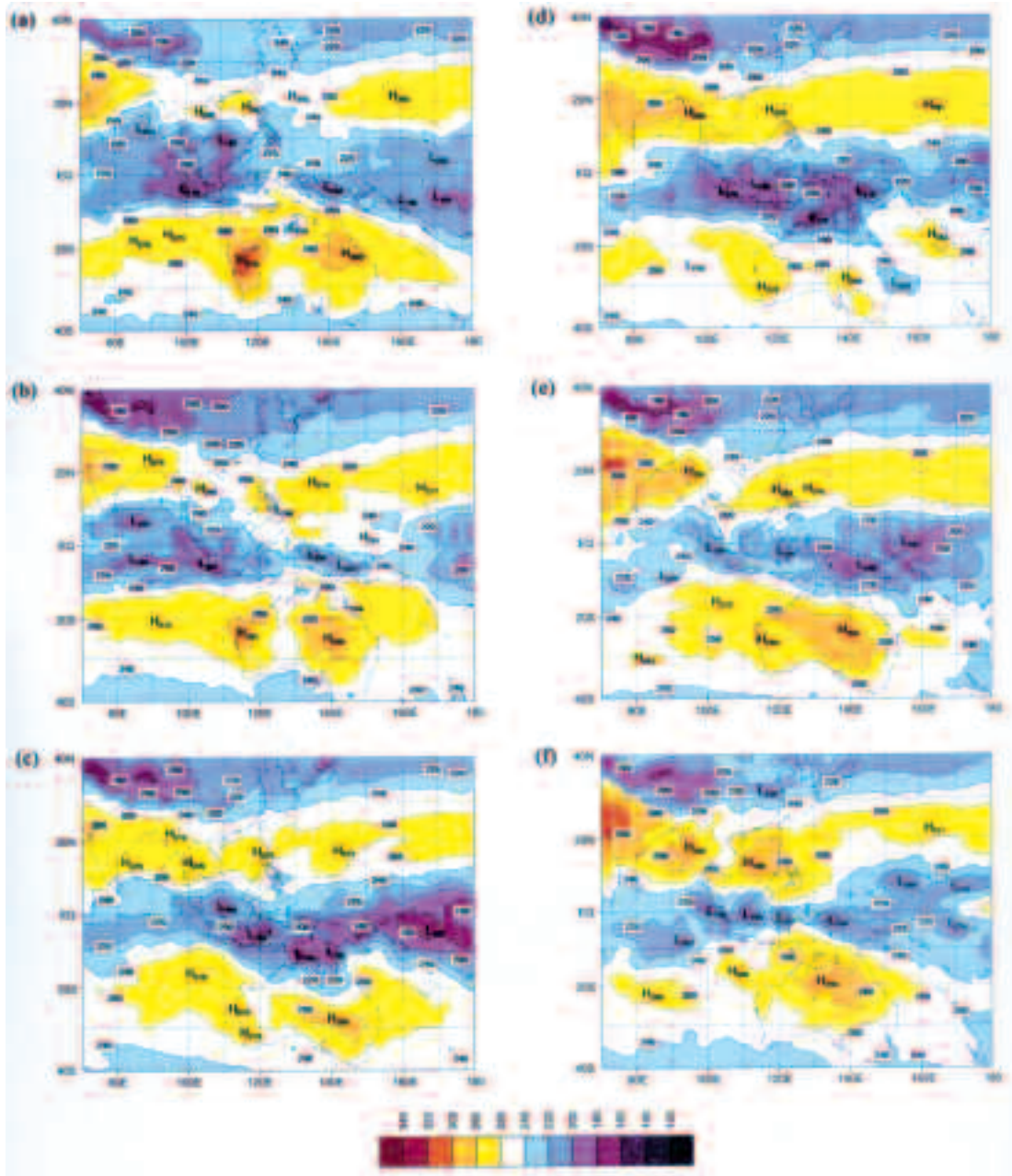


Fig. 4 Monthly OLR anomaly ($W m^{-2}$), heavy line zero, $> +15 W m^{-2}$ yellow-red shading, $< zero W m^{-2}$, blue shading: (a) November 2002; (b) December 2002; (c) January 2003; (d) February 2003; (e) March 2003; (f) April 2003. Anomalies from 1979-95 climatology.

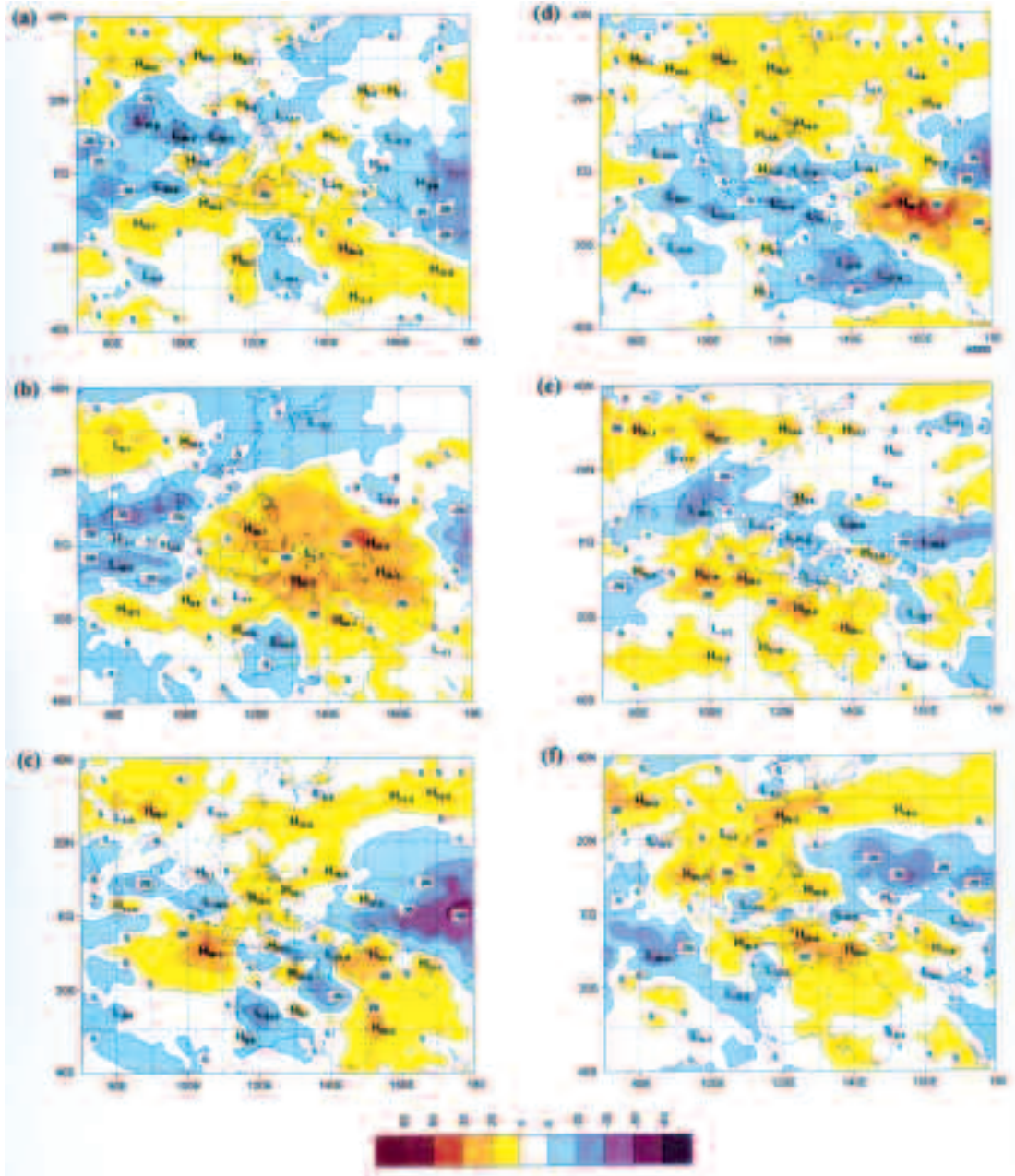


Fig. 5 Six-month mean velocity potential ($10^6 \text{ m}^2 \text{ s}^{-1}$), November 2002 to April 2003, negative contours dashed: (a) 850 hPa; (b) 200 hPa.

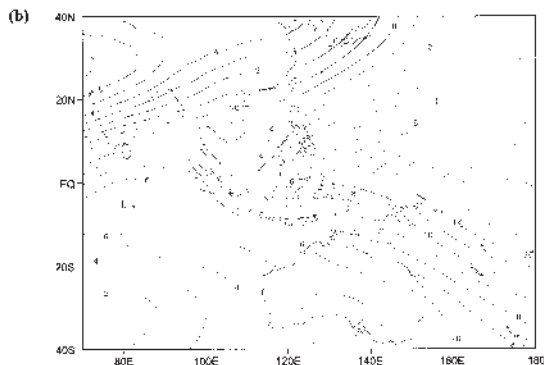
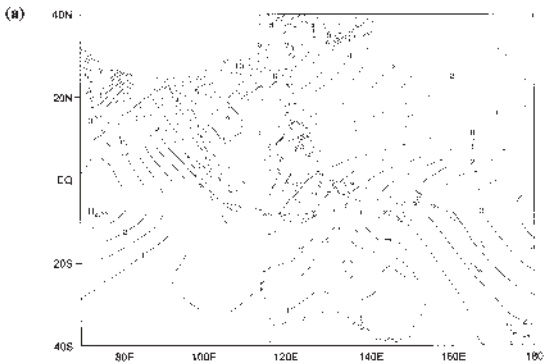
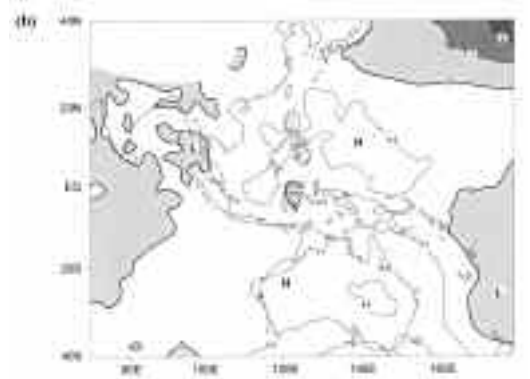
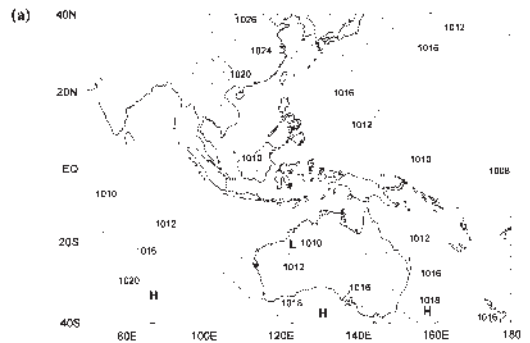


Fig. 6 Six-month MSL pressure (hPa), November 2002 to April 2003: (a) mean, isobar interval 2 hPa; (b) anomaly, contour interval 1 hPa, shaded areas negative.



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. 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 to enhance the portrayal of eastward propagating signals.

The time-longitude plots and filtered MSLP series clearly demonstrate an active phase of the intraseasonal oscillation (ISO) over the central RSMC longitude range in late November, and another event about late December/early January. Following this, the diagnostic material is less definitive, though it appears that an active MJO over the central RSMC longitude range, enhanced convection for about two to three weeks from the middle of February. Another active event was evident about the end of March.

Fig. 7 Six-month 850 hPa vector wind field, November 2002 to April 2003, isotach (dashed) interval 5 m s^{-1} : (a) mean; (b) anomaly.

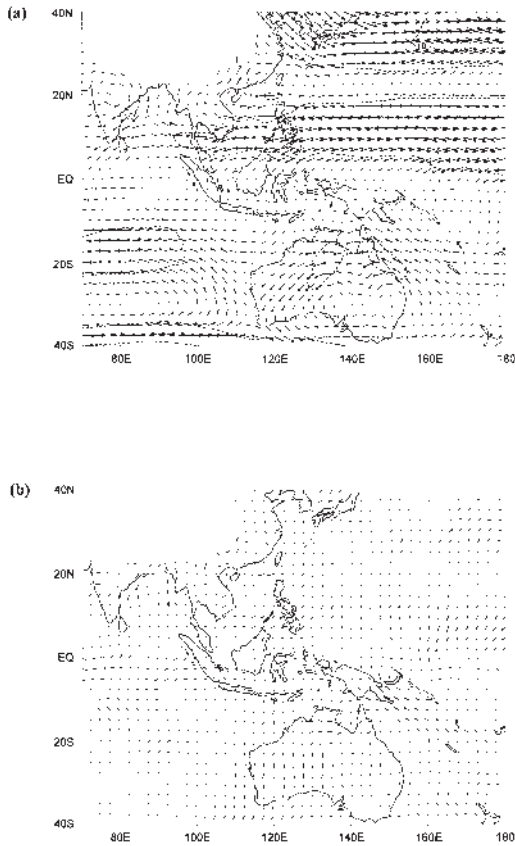
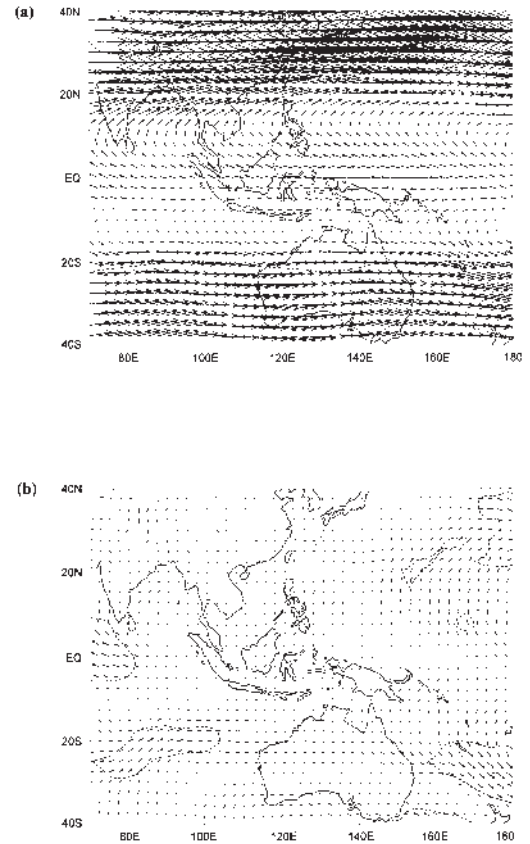


Fig. 8 Six-month 200 hPa vector wind field, November 2002 to April 2003: (a) mean, isotach (dashed) interval 20 m s^{-1} ; (b) anomaly, isotach (dashed) interval 5 m s^{-1} .



Tropical cyclones

Tropical cyclones (TCs) are defined as having maximum ten-minute mean winds greater than 17 m s^{-1} , or named systems. Operational tracks for the summary period 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.

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 Pete and Gregory (2003) for the northwest Pacific and southern hemi-

Fig. 9 Equatorial cross-section of six-month meridional wind, November 2002 to April 2003; contour interval 2 m s^{-1} , negative (northerly) contours dashed, positive (southerly) blue shading: (a) mean; (b) anomaly.

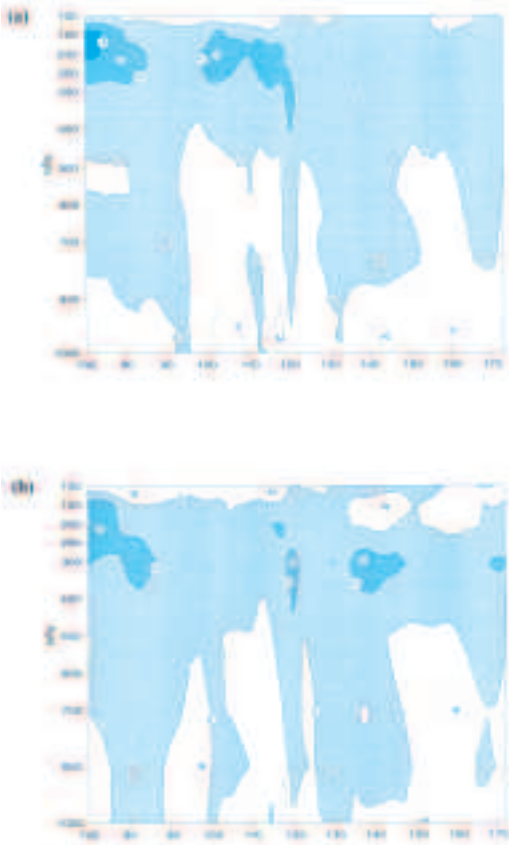
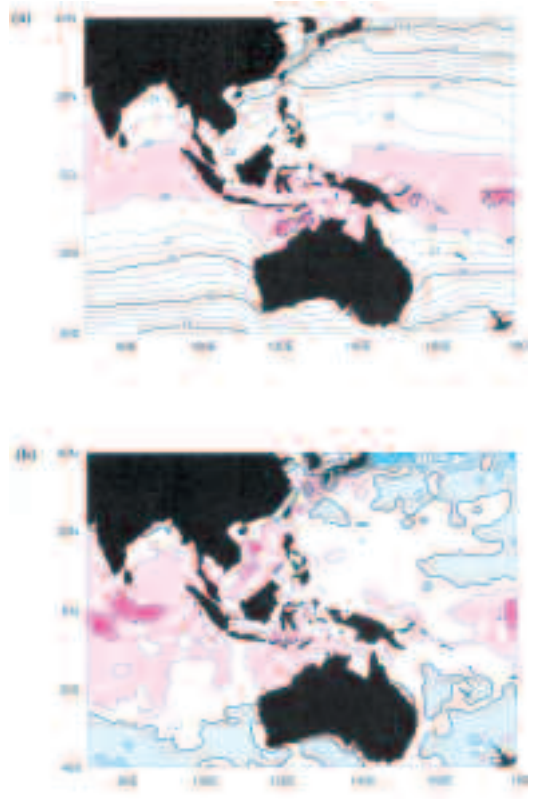


Fig. 10 Six-month SST ($^{\circ}\text{C}$), November 2002 to April 2003: (a) mean, isotherm interval 1°C , $>29^{\circ}\text{C}$ pink shading; (b) anomaly, contour interval 0.5°C , $< 0^{\circ}\text{C}$ blue shading, $> +0.5^{\circ}\text{C}$, pink shading.



sphere 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.

A total of 25 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, at least three TCs formed to the west of 70°E and another three 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 26. Of the total cyclones

which formed in the region, five tropical storms, including four of typhoon intensity, developed in the northwestern Pacific and three (nil severe tropical cyclones) in the north Indian Ocean including Bay of Bengal, compared with the averages of 5.7 (3.4 Typhoons) and 2.3 respectively. In the Australian region eight storms occurred, compared with the long-term mean of 9.8 (note this average includes tropical depressions, with maximum mean wind of 13 to 16 m s^{-1}). Of these eight, two cyclones were analysed to have reached tropical cyclone intensity only during post analysis, and hence left unnamed. In the other

Fig. 11 Time-longitude sections, latitude band 5°S-15°S, 1 November 2002 to 30 April 2003 of five-day backward running mean: (a) 200 hPa velocity potential ($10^5 \text{ m}^2 \text{ s}^{-1}$); (b) OLR (W m^{-2}); Red dots denote time and longitude of TC genesis events in the latitude band; White dots with a red cross denote events poleward, outside of the latitude band. (c) MSLP anomaly (hPa).

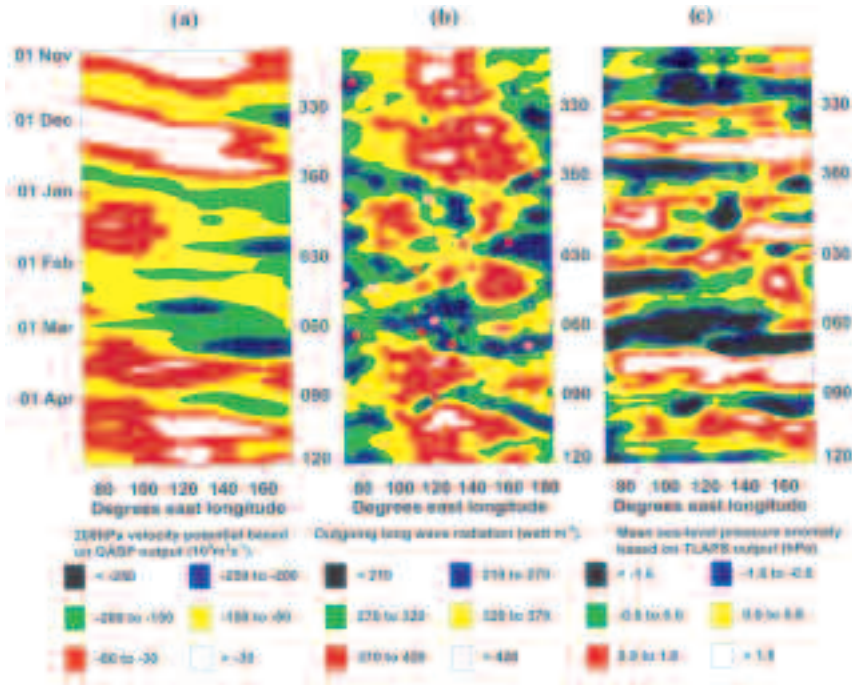


Fig. 12 Time-longitude sections, latitude band 5°S-5°N, 1 November 2002 to 30 April 2003 of five-day backward running mean: (a) 200 hPa velocity potential ($10^5 \text{ m}^2 \text{ s}^{-1}$); (b) OLR (W m^{-2}); (c) MSLP anomaly (hPa).

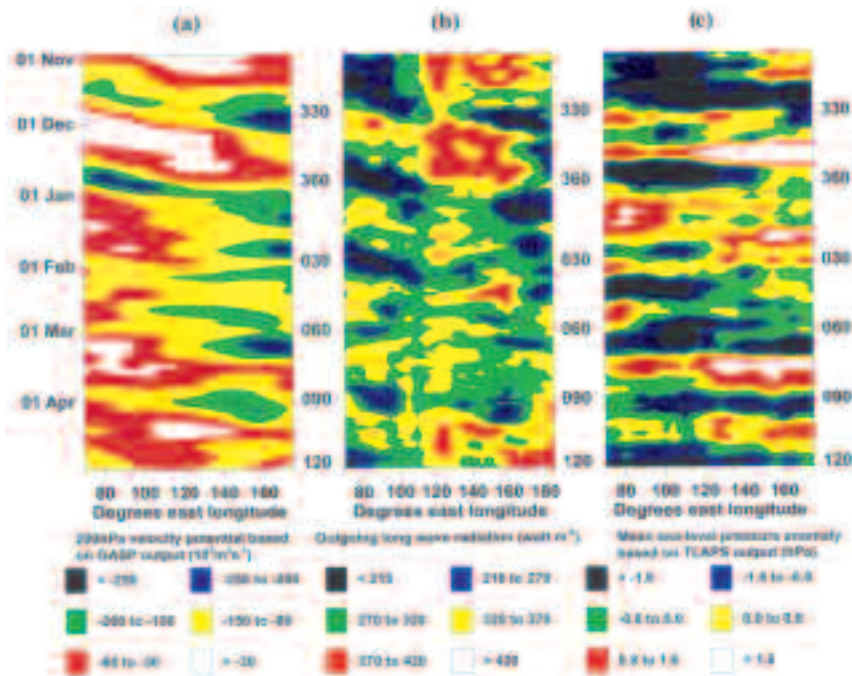
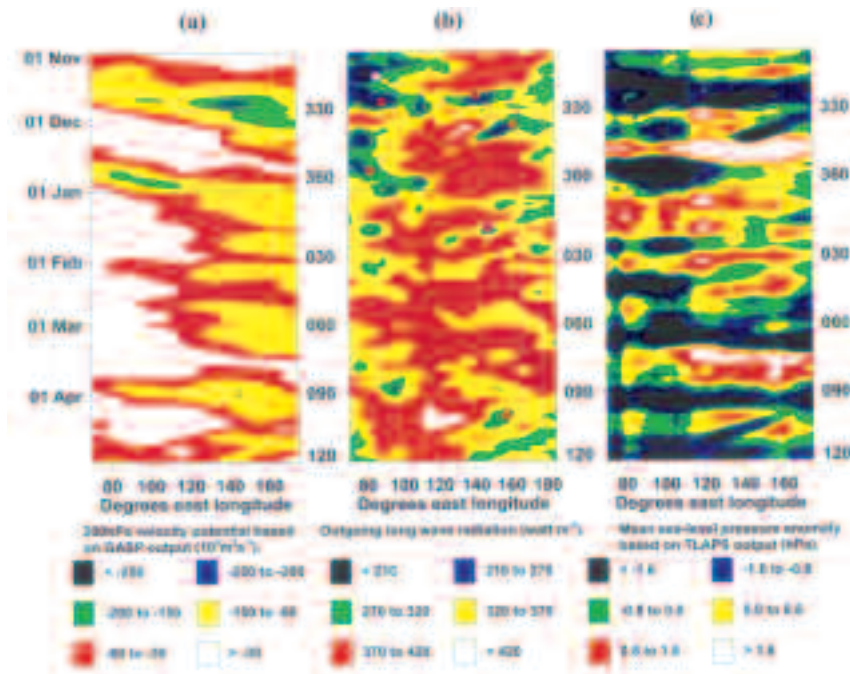


Fig. 13 As for Fig. 11, except latitude band 5°N-15°N.



southern hemisphere sub-regions, three cyclones formed to the east of 165°E including the two that formed east of the date-line and moved into the RSMC area (5.8 mean) and six cyclones formed west of 105°E (mean 12.5) which includes the one that formed west of 70°E and moved into the RSMC area.

Acknowledgments

The authors would like to express their sincere thanks to Dr Rob Dahni, Bureau of Meteorology, Melbourne, for his generous IDL help in generating some of the time series figures. Sincere thanks are due to Rob Porteous, Russell Gilliland and Fiona Phillipps for drafting of various figures and Gordon Jackson for generating the six-month averages. Sincere thanks to Dr. Andrew Watkins of the National Climate Centre, Bureau of Meteorology, for generating OLR 6-monthly and monthly maps, using data collected from the NOAA-16 satellite through the Climate Prediction

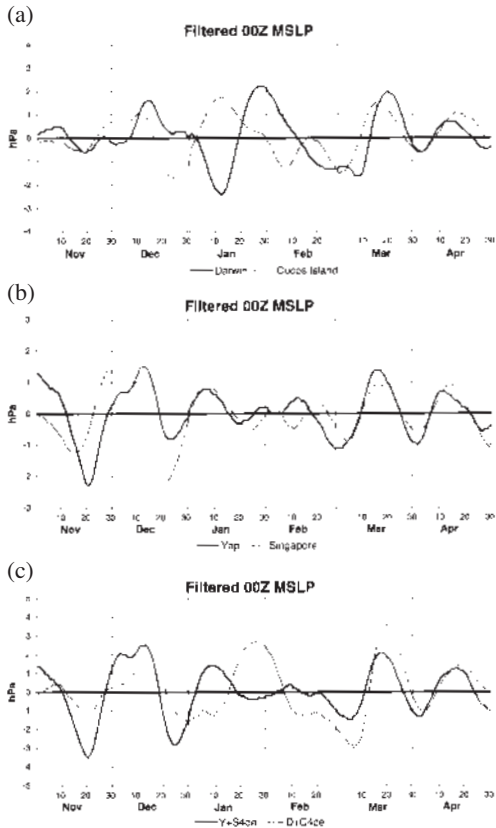
Center, Maryland, USA. Thanks are also due to other National Climate Centre staff, for their generous help in archiving and providing numerical weather prediction data used in producing various maps. Thanks are also expressed to the Climate Prediction Center, Camp Springs, Maryland, USA and the Bureau of Meteorology Research Centre for permission to use OLR figures.

Appendix

Data sources used in this summary were:

- *Darwin Tropical Diagnostic Statement (DTDS)*, November 2002 to April 2003 (issued monthly), and *Weekly Tropical Climate Note*, 31 October 2002 to 1 May 2003 (current issue on web at <http://www.bom.gov.au/climate/tropnote/tropnote.shtml>). Bureau of Meteorology, PO Box 40050, Casuarina, NT 0811, Australia.
- MSLP, upper wind and velocity potential map

Fig. 14 MSLP anomalies for two tropical stations in each hemisphere, normalised then passed through a 40-day Butterworth filter, 50% response at 23 and 70 days: (a) southern hemisphere, thin line Cocos Island, (12.2°S, 96.8°E) thick line Darwin (12.4°S, 130.9°E); (b) northern hemisphere, thin line Singapore (1.4°N, 104.0°E), thick line Yap (9.5°N, 138.1°E); (c) Darwin plus Cocos I. four days earlier (thin line) and Yap plus Singapore four days earlier (thick line).



fields from the Australian Bureau of Meteorology's Global Assimilation and Prediction system (GASP - Bourke et al. 1990; Bureau of Meteorology 1998); anomalies derived from the ECMWF 30-year climatology. MSLP and velocity potential data for Hovmoeller series from the Limited Area Prediction System (LAPS - Puri et al. 1998), nested within GASP.

- OLR six-monthly and monthly map figures are generated at the National Climate Centre, Bureau of Meteorology using NOAA data. OLR data for Hovmoeller diagrams are from Japan

Meteorological Agency's GMS-5 geostationary satellite.

- Sea-surface temperature analysis derived from the operational global analysis of 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 Environmental Prediction (Reynolds and Smit, 1995) was used to calculate anomalies.
- Tropical cyclone climatology for the northwest Pacific Ocean calculated from figures given in Pete and Gregory (2003). For the north Indian Ocean the climatology is from Mandal (1991).

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Fig. 15 Tropical cyclone tracks, November 2002 to April 2003. Solid line denotes system reached severe tropical cyclone (typhoon) intensity; dashed line denotes system reached only tropical cyclone/storm intensity.

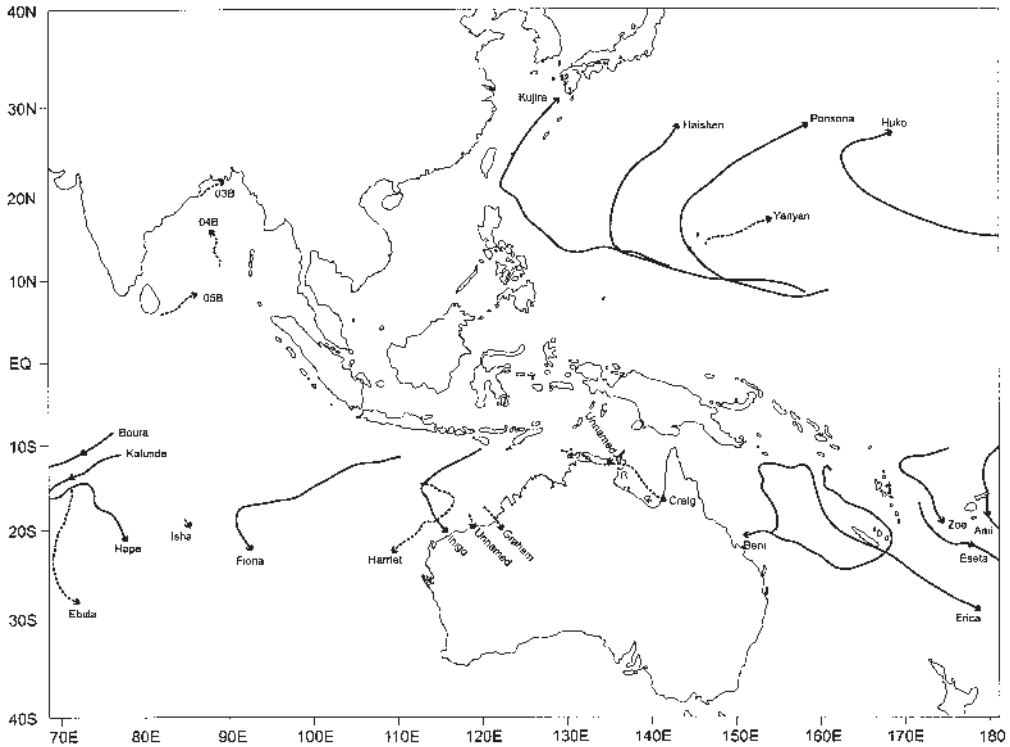


Table 2. Tropical cyclones within the Darwin RSMC area, November 2002 – April 2003. TC = tropical cyclone, STC = severe tropical cyclone, TS = tropical storm, Ty = typhoon.

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 03B (TC)	12 Nov – 12 Nov	18 (35)	996	BMD
Unnamed 04B (TC)	23 Nov – 26 Nov	23 (45)	991	JTWC
Unnamed 05B (TC)	23 Dec – 26 Dec	18 (35)	996	JTWC
Northwest Pacific / South China Sea				
Huko (Ty) ¹	03 Nov – 06 Nov	36 (70)	965	JMA
Haishen (Ty)	20 Nov – 25 Nov	39 (75)	960	JMA
Pongsona (Ty)	03 Dec – 11 Dec	46 (90)	940	JMA
Yanyan (TS)	18 Jan – 21 Jan	18 (35)	1000	JMA
Kujira (Ty)	10 Apr – 24 Apr	46 (90)	930	JMA

Table 2. Continued.

<i>Name</i>	<i>Dates (UTC) at TC intensity in Darwin RSMC area</i>	<i>Maximum 10-min. Mean wind (while in Darwin RSMC area) $m s^{-1}$ (knots)</i>	<i>Estimated minimum MSLP (hPa)</i>	<i>Warning Agency*</i>
South Indian Ocean (70°E - 105°E)				
<i>Boura</i> (TC) ²	15 Nov – 17 Nov	28 (55)	975	La Réunion
<i>Ebula</i> (TC) ³	09 Jan – 13 Jan	31 (60)	975	La Réunion
<i>Fiona</i> (STC) ⁴	05 Feb – 13 Feb	54 (105)	930	BoM, Perth
<i>Hape</i> (STC) ⁴	11 Feb – 15 Feb	36 (70)	965	La Réunion
<i>Isha</i> (TC)	13 Feb – 13 Feb	18 (35)	995	La Réunion
<i>Kalunde</i> (STC) ⁵	05 Mar – 08 Mar	52 (100)	927	La Réunion
Australian (105°E - 165°E)				
Unnamed 1 (TC)	05 Jan – 05 Jan	18 (35)	995	BoM, Darwin
<i>Beni</i> (STC)	24 Jan – 04 Feb	57 (110)	920	NTCC
Unnamed 2 (TC)	25 Jan – 25 Jan	18 (35)	995	BoM, Perth
<i>Graham</i> (TC)	27 Feb – 01 Mar	23 (45)	985	BoM, Perth
<i>Harriet</i> (TC)	04 Mar – 09 Mar	28 (55)	980	BoM, Perth
<i>Erica</i> (STC)	04 Mar – 15 Mar	59 (115)	915	BoM, Brisbane
<i>Craig</i> (TC)	09 Mar – 12 Mar	28 (55)	980	BoM, Darwin
<i>Inigo</i> (STC)	1 Apr – 8 Apr	62 (120)	900	BoM, Perth
South Pacific Ocean (165°E - 180°)				
<i>Zoe</i> (STC)	25 Dec – 31 Dec	67 (130)	890	NTCC
<i>Ami</i> (STC) ⁶	11 Jan – 14 Jan	39 (75)	970	NTCC
<i>Eseta</i> (STC) ⁷	10 Mar – 13 Mar	49 (95)	930	NTCC

* NTCC = Nadi Tropical Cyclone Centre, Fiji Meteorological Service, Nadi; BoM = Bureau of Meteorology, Australia; JTWC = Joint Typhoon Warning Center, Pearl Harbor, Hawaii; JMA = Japan Meteorological Agency, Tokyo; BMD = Bangladesh Meteorological Department, Dhaka; La Réunion = Météo France, Le Centre Régional de la Réunion, LE CHAUDRON, B.P. 4, La Réunion.

Notes

- Huko* formed east of the date-line and moved into the RSMC area.
- Boura* moved westward out of the RSMC area (70°E) while still intensifying. It reached hurricane force (winds ≥ 65 kn) outside the RSMC area.
- Ebula* formed in the RSMC area close to the western boundary, moved westwards out of the RSMC region and re-entered.
- Hape* formed west of the RSMC area and reached its maximum intensity of 70 knots prior to crossing into the RSMC area.
- Kalunde* moved westwards out of the RSMC area while intensifying.
- Ami* formed east of the date-line and moved into the RSMC area. Later it moved out of the region towards the east while intensifying.
- Eseta* moved out of the RSMC region crossing the date-line while tracking southeast and intensifying.

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).

