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The tropical circulation in the Australian/Asian region - November 1997 to April 1998

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A summary of the broadscale tropical circulation from 70°E to 180°, for the six months November 1997 to April 1998, is presented. Warm-ENSO conditions that developed earlier in 1997 persisted during this period. Evidence for this included above average atmospheric pressure and below average convection over most of the region, and very low values of the Southern Oscillation Index. Tropical cyclone numbers in the South Pacific were also much higher than the long-term mean. By the end of the summary period there were indications of the likely demise of the event. Intraseasonal oscillations with an average period of about 30 days were noted.

Introduction

This summary reviews the broadscale tropical circulation in the Australian/Asian region during the period November 1997 to April 1998. The area covered is the Darwin Regional Specialised Meteorological Centre (RSMC) analysis domain, that is 70°E to 180°, 40°N to 40°S. The first section 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. The final section briefly describes the occurrence of tropical cyclones in the six-month period.

Most of the six-month seasonal charts were constructed using the Australian global model, GASP (Bourke et al. 1990). Anomalies are derived from the European Centre for Medium-range Weather Forecasts (ECMWF) climatology. Sea-surface temperature (SST) anomalies were calculated relative to the 1°x1° global SST climatology from the US National Centers for Environmental Prediction (Reynolds and Smith 1995). Further details of the data sources used are listed in the Appendix.

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Broadscale seasonal features

During the southern hemisphere winter of 1997, warm-ENSO conditions had become established (Cleland 1998). See Fig. 1 for the time series of Troup's Southern Oscillation Index (SOI) for ten years to April 1998. Table 1 shows actual values of the SOI back to January 1995. The very significant El Niño event persisted throughout this summary period, but by April there were indications (e.g. subsurface cool anomalies extending from the west into the eastern Pacific) of an impending breakdown of the event.

Fig. 1 SOI time series for ten years to April 1998: monthly values (bars); five-month centred mean values (black line).

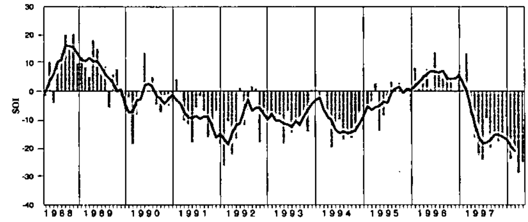
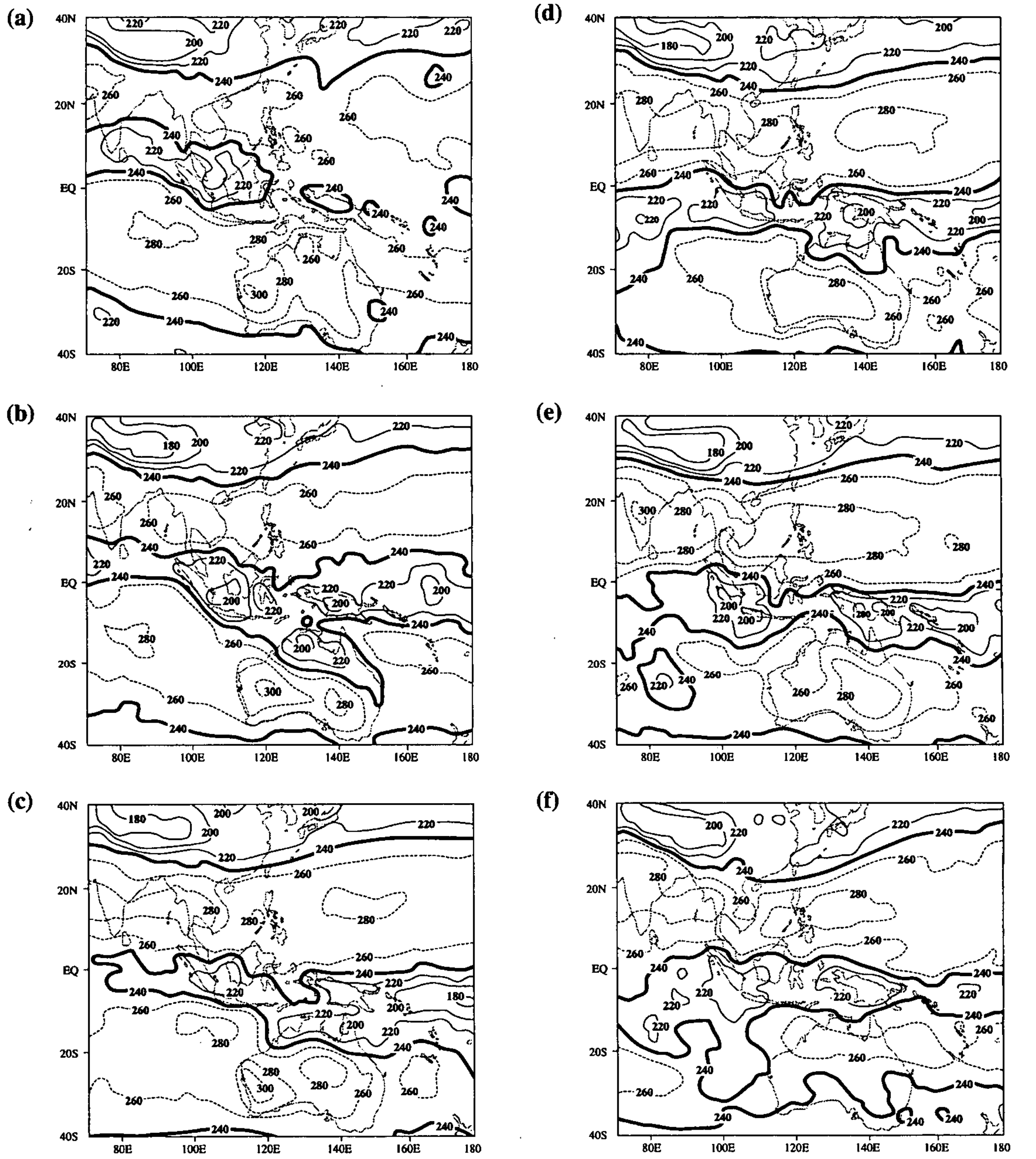


Table 1. Monthly values of Troup's SOI for the period January 1995 to April 1998.

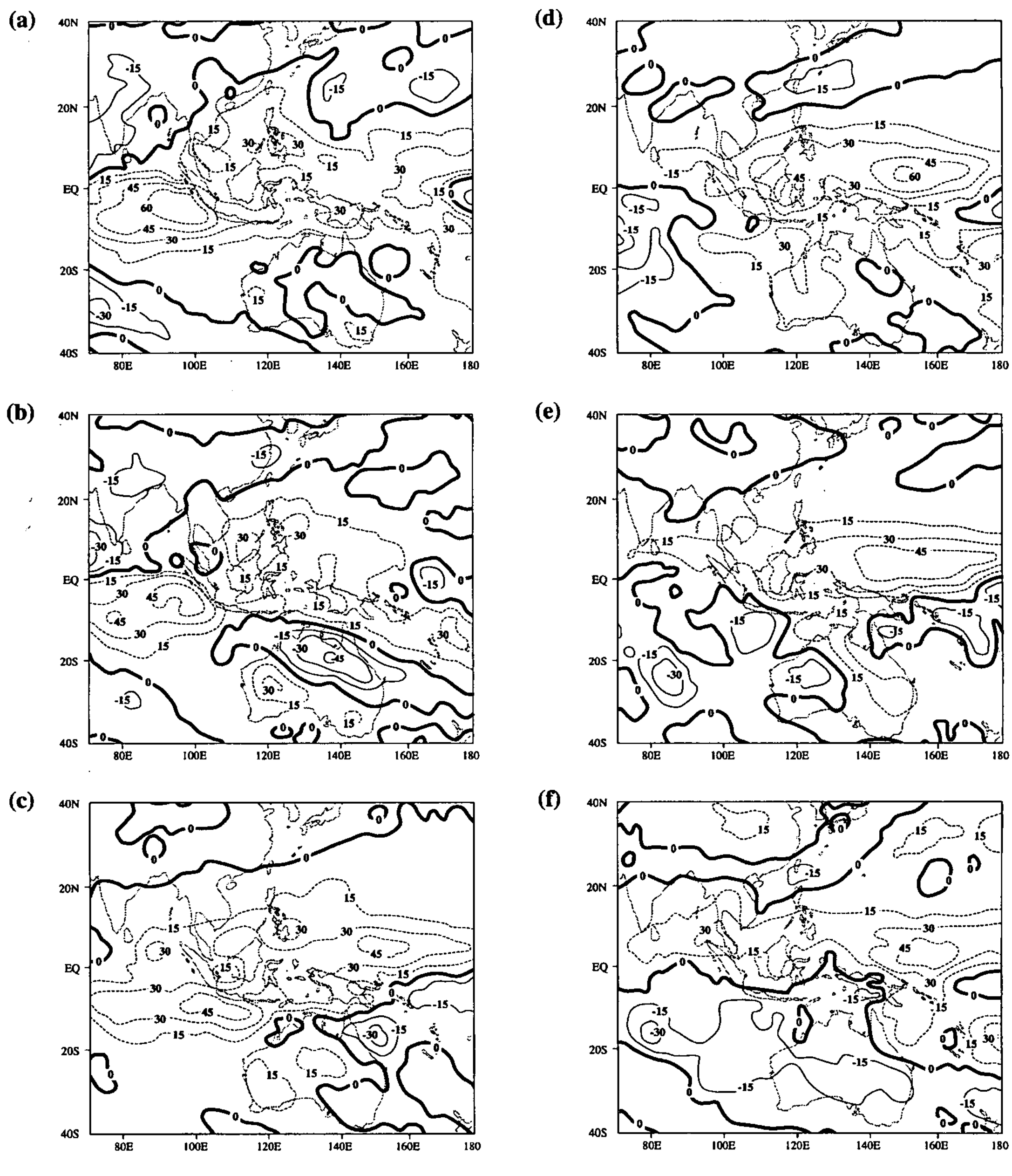
	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
1995	-5	-3	+3	-14	-8	-2	+4	+1	+3	-1	+1	-7
1996	+8	+1	+6	+8	+1	+14	+7	+5	+7	+4	0	+7
1997	+4	+13	-8	-16	-22	-24	-9	-20	-14	-17	-15	-9
1998	-24	-19	-29	-25								

Fig. 2 Monthly mean OLR (W m^{-2}), heavy line 240 W m^{-2}, 260 W m^{-2} and above dashed: (a) November 1997; (b) December 1997; (c) January 1998; (d) February 1998; (e) March 1998; (f) April 1998.



The mean and anomaly of outgoing long wave radiation (OLR - used as a proxy for convection) for each month are shown in Figs 2(a) to (f) and 3(a) to (f) respectively. Tropical convection was generally suppressed (positive OLR anomalies) throughout the period over the RSMC longitudes, except for the region about the near-equatorial date-line, consistent with the significant impact of the warm-ENSO event. Increased convection was apparent late in the period over parts of the southern Indian Ocean and western parts of Australia. This presumably resulted from very warm SSTs that developed in the tropical Indian Ocean during the period of suppressed convection and thus high insolation. It was interesting to note that while convection was generally suppressed over the region, several centres in northern Australia received very high to record rainfall totals.

Fig. 3. Monthly OLR anomaly (W m^{-2}), heavy line zero, positive contours dashed: (a) November 1997; (b) December 1997; (c) January 1998; (d) February 1998; (e) March 1998; (f) April 1998. Anomalies from 1979-95 climatology.



Velocity potential analyses (Fig. 4) depict the poor structure that was apparent in the monsoon circulation for much of the summary period. There was only a weak 'ridge' in the low-level velocity potential, indicating convergence, from the South Pacific through to Indonesia. The zone of maximum upper divergence was somewhat better defined, but apparently strongest east of the date-line, compared to the climatologically favoured location in central RSMC longitudes.

Six-month mean and anomalous sea-surface temperatures (SST) are shown in Fig. 5. The (broken) cool-V, which often surrounds the eastern Pacific warm anomaly (east of the Darwin RSMC area) during warm-ENSO events, was evident in the western Pacific. Elsewhere in the region warm anomalies dominated, including the near-equatorial band, all of the tropical Indian Ocean and most of the southwest and northwest Pacific. Much of the warm anomaly may have been due to increased solar insolation and reduced surface mixing resulting from less than average convection and monsoon flow.

Mean sea-level pressure (MSLP) and anomalies are shown in Fig. 6. Positive pressure anomalies dominated the Darwin RSMC area, except for continental Asia, where negative anomalies occurred. The subtropical ridge (STR) was much stronger than the long-term mean in each hemisphere, with greater than 4 hPa anomalies in the South Pacific. Positive pressure anomalies in the near-equatorial region are consistent with generally less than average convection in the Darwin RSMC area.

Streamline/isotach analyses and vector anomalies at 850 hPa are shown in Fig. 7. The intertropical convergence zone (ITCZ) was poorly defined west of longitude 130°E, which is consistent with the lack of convection over the maritime continent implied by the OLR anomaly diagrams. An easterly component to the anomalies was apparent through this area, strongest near the western boundary of the Darwin RSMC area. Combined with the westerly anomalies over the near-equatorial western Pacific, this suggests that the near-

Fig. 4 Six-month mean velocity potential (10^6 m^2 s^{-1}), November 1997 to April 1998, negative contours dashed: (a) 850 hPa; (b) 200 hPa.

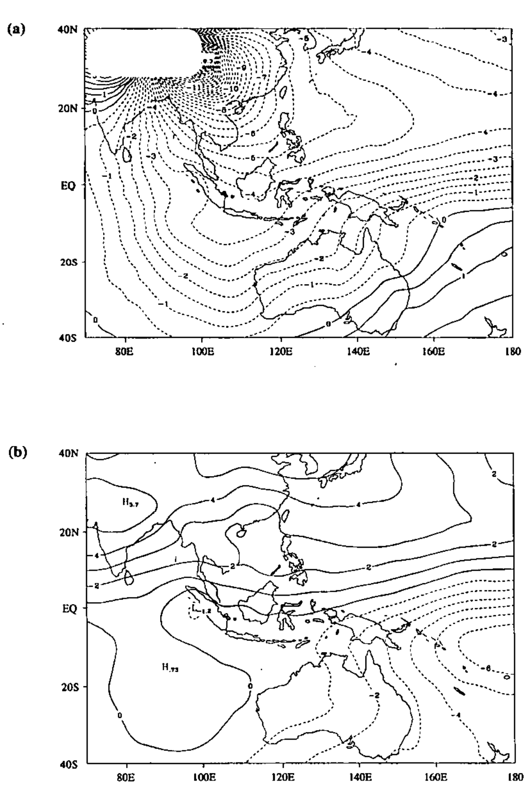
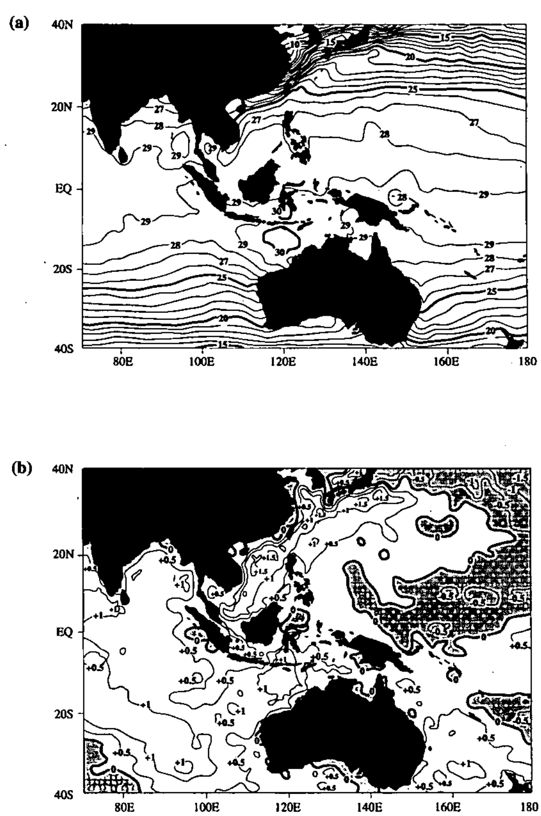


Fig. 5 Six-month SST (°C), November 1997 to April 1998: (a) mean, contour interval 1°C; (b) anomaly, contour interval 0.5°C, shaded areas negative.

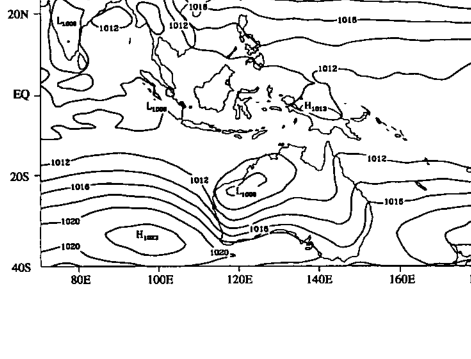


equatorial wind anomalies tended to diverge from the maritime continent, consistent with below average convective activity. There was, however, an increased northerly cross-equatorial component to the anomaly field about western Indonesia. These anomalies were relatively small and, given the generally suppressed convection over that region, possibly an artifact of using two different analysis schemes (ECMWF for climatology, GASP for the wind fields) to create the anomaly diagrams.

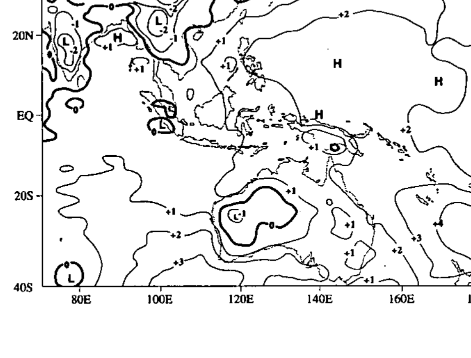
Streamline/isotach analyses and vector anomalies at 200 hPa are shown at Fig. 8. Divergent anomalies were noted near the date-line at low latitude, typical of warm-ENSO events and consistent with enhanced convection in the central Pacific east of the Darwin RSMC area.

Fig. 6 Six-month MSL pressure (hPa), November 1997 to April 1998: (a) mean, contour interval 2 hPa; (b) anomaly, contour interval 1 hPa, zero contour highlighted.

(a)



(b)

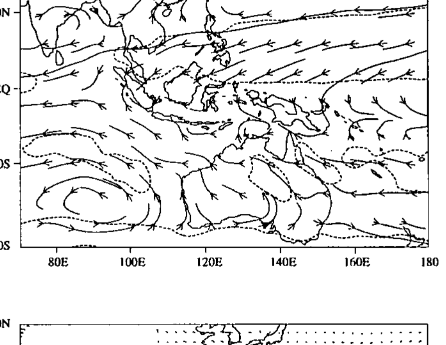


West of eastern Australia, the upper ridge was mostly 2-5° latitude equatorward of the climatological location. The westerly component to the anomalies over most of the southern hemisphere maritime continent area suggest the upper ridge was less vigorous than average, despite the increased southerly component to cross-equatorial flow. The easterly anomalies near the climatological location of the subtropical jet in each hemisphere also suggest a weaker than average Hadley circulation in the Darwin RSMC longitudes.

The diagrams depicting cross-equatorial component of the flow and anomalies (Fig. 9) show that low-level northerly and upper-level southerly components to the cross-equatorial flow were both stronger than the long-term mean over most of the RSMC longitudes. In the east this was a result of enhanced convection near and east of the date-line. In the west this is difficult to explain, given that convection was suppressed through most of the season.

Fig. 7 Six-month 850 hPa wind field, November 1997 to April 1998: (a) mean, isotach (dashed) interval 5 m s^{-1}; (b) anomaly, areas greater than 5 m s^{-1} shaded.

(a)



(b)

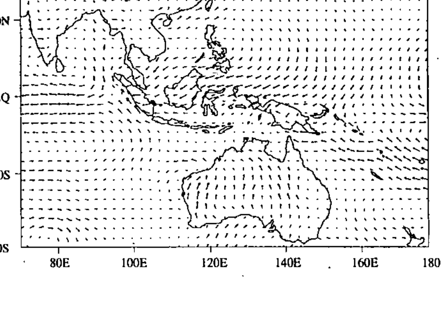


Fig. 8 **Six-month 200 hPa wind field, November 1997 to April 1998: (a) mean, isotach (dashed) interval 10 m s^{-1}, greater than 50 m s^{-1} shaded; (b) anomaly, areas greater than 10 m s^{-1} shaded.**

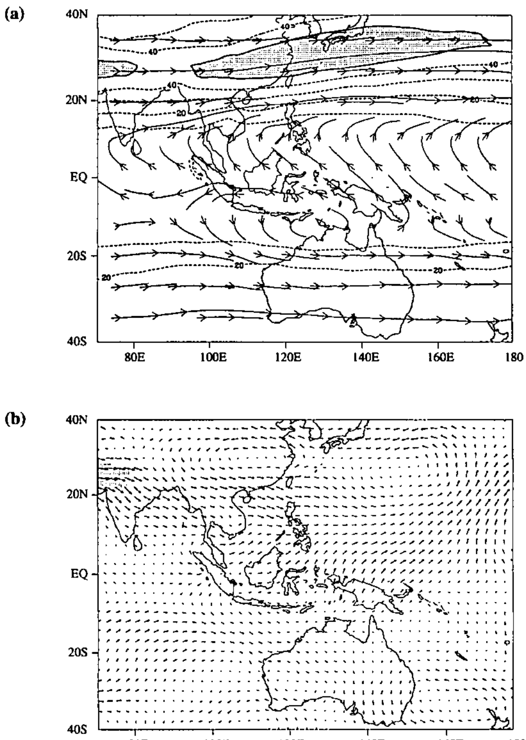
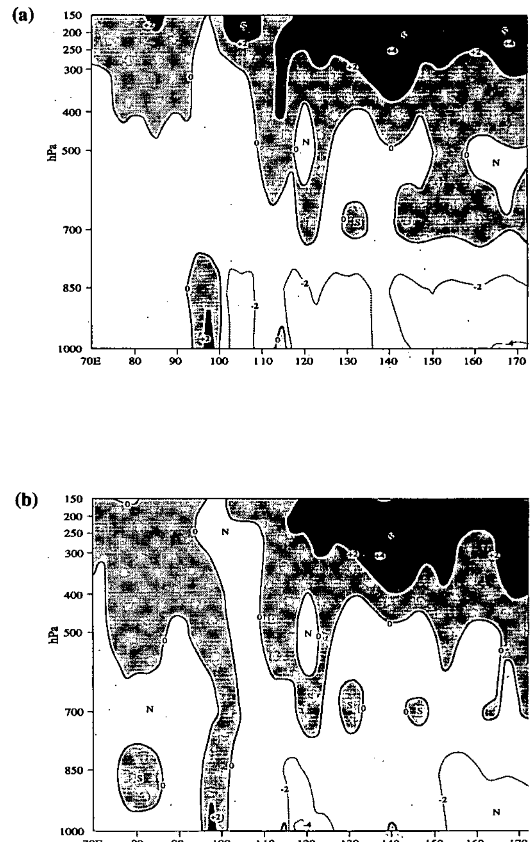


Fig. 9 **Equatorial cross-section of meridional wind, November 1997 to April 1998; contour interval 2 m s^{-1}, positive (southerly) shaded, negative contours dashed: (a) mean; (b) anomaly.**



Intraseasonal variability

Figures 10 to 12 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 10(b), 12(b)) also indicate the date and longitude of tropical cyclone genesis events in their respective hemispheres. The plots of velocity potential, particularly the near-equatorial and southern hemisphere series, indicate active phases of the 30 to 60-day intraseasonal oscillation entered the RSMC area close to the middle of each month during the summary period, suggesting a recurrent period of about 30 days. The events in February and March were less conclusive, especially in the MSLP series. Most tropical cyclones developed during these active phases.

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 are shown in Fig. 13, 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, see Appendix) and are based on Darwin RSMC operational manual analyses, with limited post-analysis in a few cases. Maximum wind details were obtained from the operational warnings issued by the agencies responsible. Following WMO guidelines (Neumann 1993), winds are assumed to be averaged over ten minutes except those from the Joint Typhoon Warning Center, Guam (JTWC), which uses one-minute means. A co-

Fig. 10 Time-longitude sections, latitude band 5°S-15°S, 1 November 1997 (day 305) to 30 April 1998 (day 120), of five-day running mean: (a) 200 hPa velocity potential (10^5 m^2 s^{-1}); (b) OLR (W m^{-2}), black circles denote time and longitude of TC genesis events, crosses denote TC genesis events poleward of the latitude band; (c) MSLP anomaly (hPa).

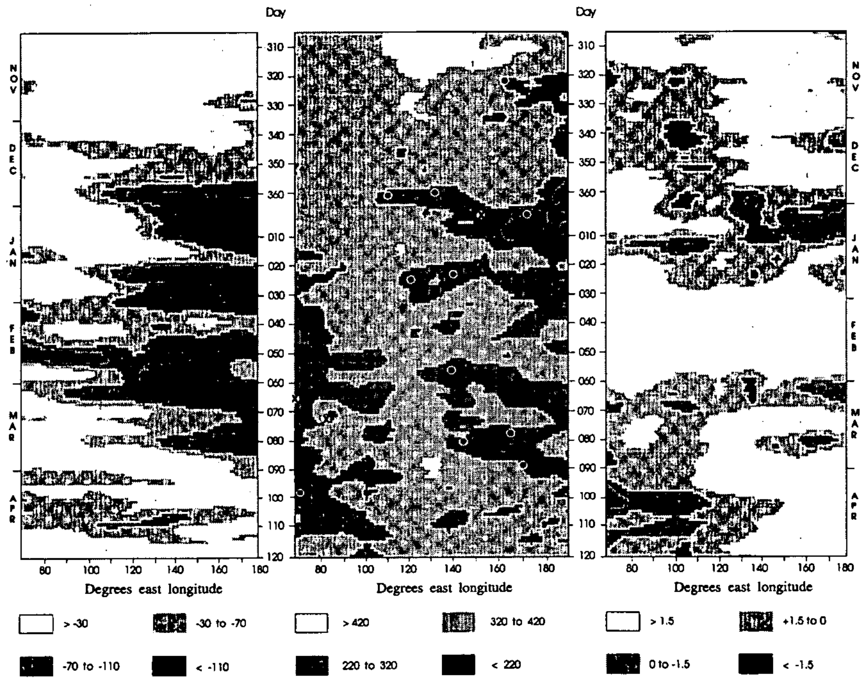


Fig. 11 Time-longitude sections, latitude band 5°S-5°N, 1 November 1997 (day 305) to 30 April 1998 (day 120) of five-day running mean: (a) 200 hPa velocity potential (10^5 m^2 s^{-1}); (b) OLR (W m^{-2}); (c) MSLP anomaly (hPa).

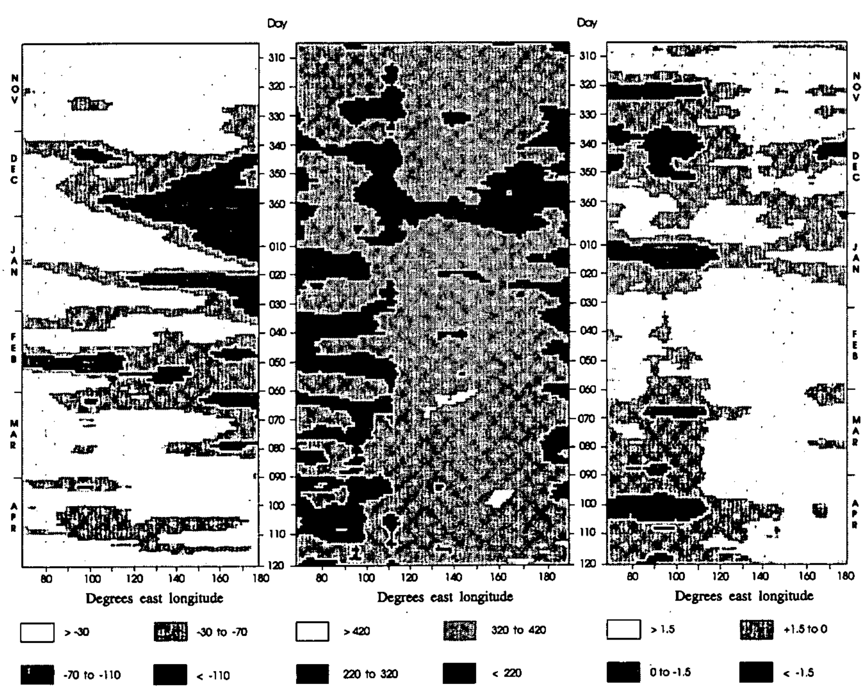


Table 2. Tropical cyclones within the Darwin RSMC area, November 1997 to April 1998. TC = tropical cyclone, TS = tropical storm, STC = severe tropical cyclone, TY = typhoon, * = pressure given by warning agency.

Name	*Dates (UTC) at TC intensity in Darwin RSMC area*	*Maximum 10-min mean wind (while in Darwin RSMC area) m s⁻¹ (kn)*	*Estimated minimum MSLP (hPa)*	*Warning agency (at time of maximum wind)*
South Indian Ocean (70°E-105°E)				
Donaline (TC)	07 Mar-09 Mar	21 (40)	987*	La Reunion
Elsie (TC)	13 Mar-15 Mar	31 (60)	970*	La Reunion
Gemma (TC)	08 Apr-12 Apr	23 (45)	984*	La Reunion
Australian (105°E - 165°E)				
Nute (TC)	18 Nov-20 Nov	31 (60)	975*	Nadi
Sid (TC)	26 Dec-28 Dec	26 (50)	985*	Darwin
Selwyn (STC)	27 Dec-31 Dec	36 (70)	966*	Perth
Katrina/Victor/ Cindy (STC) [1]	03 Jan-17 Feb	46 (90)	940*	Brisbane
Les (TC)	23 Jan-31 Jan	31 (60)	976*	Darwin
Tiffany (STC)	25 Jan-30 Jan	52(100)	930*	Perth
May (TC)	25 Feb-26 Feb	21 (40)	990*	Brisbane
Yali (STC)	19 Mar-24 Mar	36 (70)	965*	Nadi
Nathan (TC)	21 Mar-26 Mar	26 (50)	990*	Brisbane
Southwest Pacific (165°E-180°)				
Susan (STC)	03 Jan-08Jan[2]	64 (125)	900*	Nadi
Zuman (STC)	30 Mar-05 Apr	41 (80)	955*	Nadi
Northwest Pacific / South China Sea				
Keith[3] (TY)	28 Oct-08 Nov	73(141)	872	Guam
Linda (TY)	01 Nov-09 Nov	29 (57)	976	Guam
Mort (TS)	11 Nov-15 Nov	25 (48)	984	Guam
Paka[4] (TY)	07 Dec-21 Dec	73(141)	872	Guam

Notes.
1 *Katrina* was first named in the South Pacific by Brisbane TCWC. It briefly crossed into Nadi's area of responsibility before turning westward again. It then tracked over the northern extremity of the Australian continent as a tropical low. It redeveloped to tropical cyclone intensity in the area of Perth TCWC in the Indian Ocean, and was renamed *Victor*. When it reached the area of La Reunion it was renamed *Cindy*.
2 *Susan* continued east of the Darwin RSMC area above tropical cyclone intensity beyond this date.
3 *Keith* formed prior to the summary period but persisted into it. It was also included in the previous summary of this series (Cleland 1998).
4 *Paka* formed east of the Darwin RSMC area of responsibility and subsequently crossed the date-line.

version factor of 0.88 to relate one-minute to ten-minute means was applied to warnings issued from Guam. Since most agencies use the unit of knots in warnings, wind speeds are shown in Table 2 in knots as well as m s^{-1}. Where not given by the responsible warning agency, minimum pressures were estimated for operational analyses using the relationship of Atkinson and Holliday (1977). Details may be derived from JTWC warnings when warnings were not received from the responsible local warning agency. A brief discussion and further details of each of the cyclones can be found in DTDS for the relevant month.

A total of 18 tropical cyclones were analysed in the Darwin RSMC area during the summary period. One of these (*Paka*) formed east of the area, while another (*Keith*) first developed prior to the summary period but persisted into it. This system was also included in the previous summary of this series (Cleland 1998).

Four of the systems (including *Paka* and *Keith*) were analysed in the northwest Pacific, compared to the long-term mean of 5.7. At least another six systems formed west of the Darwin RSMC area in the southern Indian Ocean, while another ten formed east of the date-line in the South Pacific. This brought to 30 the number of systems named in the southern Indian Ocean and South Pacific combined, compared to the long-term mean of 24.9. The biggest deviation from average occurred in the South Pacific, where 12 tropical cyclones formed co-

Fig. 12 As for Fig. 10, except latitude band 5°N-15°N.

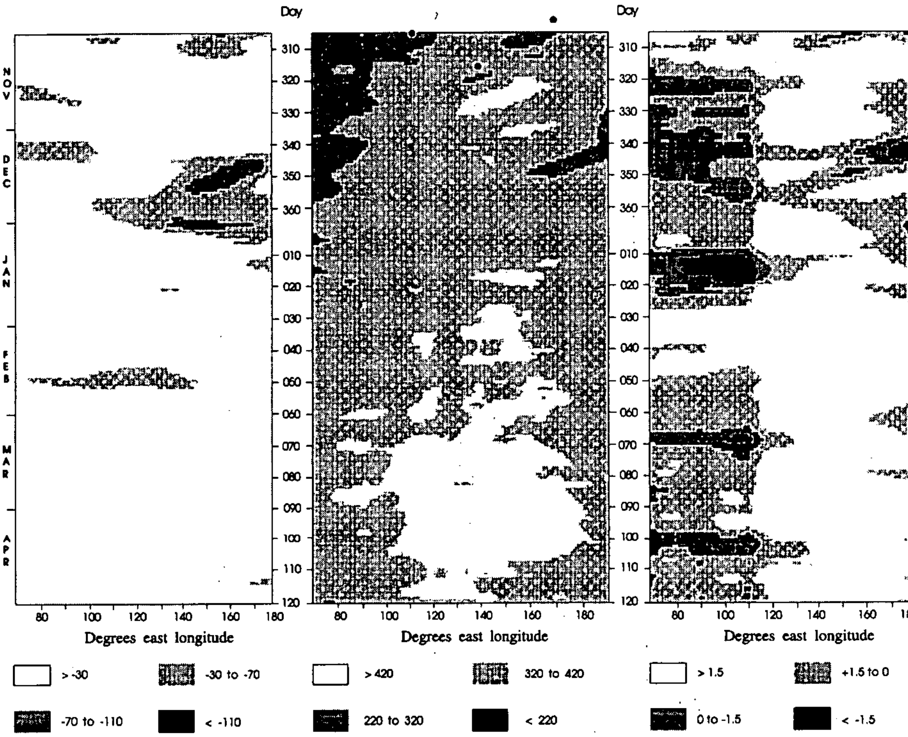
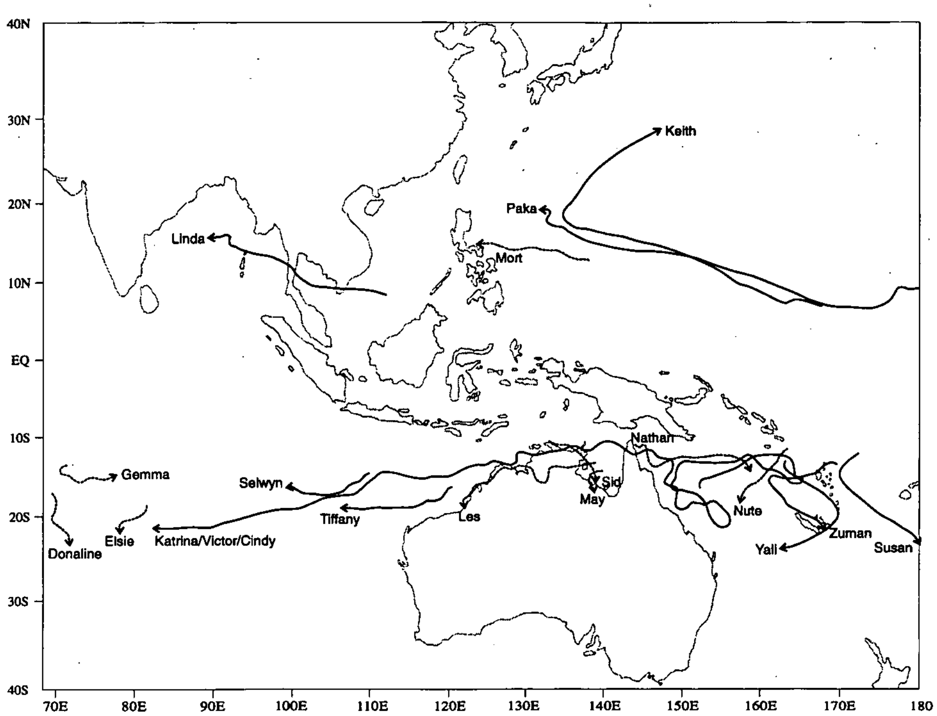


Fig. 13 Tropical cyclone tracks, November 1997 to April 1998. Solid line denotes system reached severe tropical cyclone/typhoon intensity; dashed line denotes system reached only tropical cyclone/storm intensity.



pared to the annual average of 5.1, consistent with the El Niño event (Revell and Goulter 1986). No named systems were analysed in the northern Indian Ocean, compared to the long-term mean of 1.7.

Acknowledgments

The author would like to express sincere thanks to Rob Porteous for his drafting of figures, Gordon Jackson for generating the six-month averages and Peter Bate for advice and suggestions. Thanks are also expressed to the Climate Prediction Center, Washington DC, for permission to use OLR figures.

Appendix

Data sources used in this summary were:

Darwin Tropical Diagnostic Statement, November 1997 to April 1998 (issued monthly), and *Weekly Tropical Climate Note,* 4 November 1997 to 5 May 1998. Bureau of Meteorology, PO Box 40050, Casuarina, NT 0811, Australia.

MSLP and upper wind and velocity potential data from the Australian Bureau of Meteorology's GASP model (Global Assimilation and Prediction System, Bourke et al. (1990)). Anomalies derived from ECMWF climatology.

OLR figures from *Climate Diagnostics Bulletin,* November 1997 to April 1998, issued monthly by Climate Prediction Center, W/NP52, 4700 Silver Hill Rd, Rm 605, Stop 9910, Washington, D.C., 20233-9910 USA.

Sea-surface temperature analysis derived from Melbourne Specialised Oceanographic Centre operational global analysis. 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.

Tropical cyclone climatology for the northwest Pacific, south Indian and South Pacific Oceans calculated from figures given in Dillon and Andrews (1997). For the north Indian Ocean the climatology is from Mandal (1991).

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Mandal, G.S. 1991. Tropical cyclones and their forecasting and warning systems in the Indian Ocean. *Technical Document WMO/TD - No. 430* (Report No. TCP-28), WMO, Geneva, 430pp.

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Revell, C.G. and Goulter, S.W. 1986. South Pacific Tropical Cyclones and the Southern Oscillation. *Mon. Weath. Rev., 114,* 1138-45.

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