Aust. Met. Mag. 50 (2001) 123-135

The South Pacific and southeast Indian Ocean tropical cyclone season 1999-2000

L.A. Paterson
Severe Weather Section, Regional Office, Bureau of Meteorology, Perth
and
P.W. Bate
Climate and Consultancy Section, Regional Office, Bureau of Meteorology, Darwin

(Manuscript received December 2000)

Tropical cyclone occurrences were near average during the 1999/2000 season. During the middle months of 1999 the moderate La Niña phase which had persisted through 1998 showed signs of decline. However by November 1999 the Southern Oscillation Index had returned to strong positive values and remained positive throughout the cyclone season. A cool sea-surface temperature anomaly pattern, typical of La Niña, dominated the equatorial central and eastern Pacific for the season. Broadscale tropical convection was generally suppressed over the central and western Pacific near the equator and above average in the tropical Indian Ocean and throughout the maritime continent and South Pacific convergence zone region. Four major active phases of the 30 to 60-day intraseasonal oscillation were identified.

Introduction

This paper provides a summary of tropical cyclone activity in the southeast Indian Ocean (east of 80°E) and the South Pacific Ocean (west of 120°W) during the 1999/2000 cyclone season. The material has been gathered from information provided by the Australian Tropical Cyclone Warning Centres (TCWCs) in Perth, Darwin and Brisbane, the Fiji Regional Specialised Meteorological Centre (RSMC) and La Reunion RSMC. Wind speeds referred to are ten-minute averages which have been converted to metres per second from knots and then rounded. As this summary is primarily concerned with tropical cyclones no figures depicting circulation aspects are included. For more detail regarding the broadscale tropical circulation within the Darwin RSMC area of responsibility (70°E – 180°E) see the seasonal summary in Shaik and Bate (2000).

Corresponding author address: Linda A. Paterson, Bureau of Meteorology, PO Box 1370, West Perth, WA 6872, Australia.

Tropical cyclone occurrence

There were 26 tropical cyclone occurrences during the 1999/2000 season across the whole south Indian Ocean and South Pacific basins, compared to the long-term average of 28.5 (which includes some depressions of near cyclone intensity) quoted by McPherson and Stapler (1999). All occurred in the months December to April. Activity in the Australian (105°E-165°E) and South Pacific Ocean (east of 165°E) regions was above average and average respectively and was slightly below average in the southern Indian Ocean (west of 105°E) region (Table 1). Of the southeast Indian Ocean cyclones, six occurred west of 80°E and are not discussed in this summary. Of the twenty tropical cyclones east of 80°E, twelve developed within the Australian warning region (90°-160°E), only slightly above the mean of 10.6 (20 years, 1978/79-1997/98). Also, of the twenty tropical cyclones, eleven reached hurricane strength. Despite the prevailing La Niña conditions, one system developed near 140°W, a highly unusual event this far east and more characteristic of El Niño. Details of the 20 tropical cyclones that formed between 80°E and 120°W are given in Table 2.

Large-scale circulation features

Averaged over the six months November 1999 to April 2000, pressures were generally below average in the tropical eastern Indian Ocean, where the monsoon trough was deeper than normal. Westerly monsoonal flow over much of Indonesia and the adjacent Indian Ocean was stronger than average, as were cross-equatorial northerly wind components. Enhanced southeasterly flow was seen poleward of the monsoon trough, due in part to an enhanced subtropical ridge. With a strong subtropical ridge also evident over the southeastern Pacific, positive pressure anomalies affected virtually the entire South Pacific, with the exception of a limited area around the date-line. Enhanced equatorial easterlies across the Pacific were a feature of both hemispheres and are typical of La Niña. Together with enhanced monsoon westerlies over the Indian Ocean, this implies stronger than normal convergence into the maritime continent region.

In the upper troposphere, divergent equatorial easterly anomalies occurred over the region west of about 140°E, while southerly cross-equatorial flow was also generally above average in this region, providing the upper branch of an enhanced Hadley circulation. Westerly anomalies, typical of La Niña, were seen across most of the equatorial Pacific region.

Velocity potential analyses based on the seasonal wind fields indicated that diagnosed broadscale tropical up-motion was generally weak over most of the Pacific at low southern latitudes, but was enhanced further to the west.

Table 1. Occurrence of tropical cyclones in 1999-2000 vs climatology.

Basin	*W of 105°E*	*105°-165°E*	*E of 165°E*
Mean	12.7	9.6	5.6
1999-2000	10	11	5

Climatic indices

A moderate La Niña phase, with positive values of Troup's Southern Oscillation Index (SOI), developed during 1998. During the middle months of 1999 the La Niña phase showed signs of decline, the SOI eas-

Table 2. Tropical cyclones in the South Pacific and southeast Indian Oceans 1999-2000.

	Low first identified			*Initial tropical cyclone phase*			
Name	*Date*	*Lat.*	*Long.*	*Date*	*Time(UTC)*	*Lat.*	*Long.*
Ilsa	08 Dec	9.0°S	95.0°E	10 Dec	2200	10.5°S	99.6°E
John	09 Dec	10.5°S	122.5°E	11 Dec	1300	13.6°S	119.9°E
Babiola	03 Jan	11.9°S	82.6°E	05 Jan	1800	11.9°S	83.2°E
Iris	06 Jan	15.0°S	164.0°E	07 Jan	0000	15.5°S	164.3°E
Jo	23 Jan	14.5°S	171.7°E	24 Jan	0000	17.9°S	173.1°E
Kirrily	24 Jan	11.5°S	99.8°E	26 Jan	1600	15.5°S	111.1°E
Leon/ Eline	01 Feb	10.5°S	115.5°E	03 Feb	2200	12.2°S	107.0°E
Marcia	14 Feb	13.8°S	99.7°E	15 Feb	2200	14.8°S	102.4°E
Kim	23 Feb	23.0°S	132.8°W	24Feb	1800	23.2°S	135.6°W
Steve I	25 Feb	17.2°S	153.0°E	27 Feb	0000	16.5°S	147.0°E
Steve II				28 Feb	1200	17.1°S	140.4°E
Steve III				5 Mar	0400	18.6°S	120.6°E
Norman	28 Feb	17.3°S	123.0°E	29 Feb	1000	17.8°S	120.6°E
Leo	04 Mar	18.0°S	150.0°W	06 Mar	1200	24.7°S	163.4°W
Mona	06 Mar	15.1°S	171.3°W	08 Mar	1800	20.4°S	175.8°W
Olga	15 Mar	16.2°S	117.3°E	16 Mar	1000	16.6°S	114.8°E
Hudah	24 Mar	15.5°S	95.3°E	25 Mar	0000	15.1°S	90.3°E
Vaughan	28 Mar	20.0°S	168.0°E	03 Apr	1800	13.8°S	156.1°E
Tessi	31 Mar	14.8°S	156.2°E	31 Mar	1800	15.6°S	154.1°E
Paul	10 Apr	13.0°S	127.5°E	12 Apr	1000	13.5°S	118.3°E
Neil	13 Apr	17.0°S	178.0°W	15 Apr	1800	20.2°S	178.8°E
Rosita	14 Apr	9.5°S	127.0°E	17 Apr	2200	15.7°S	119.3°E

Table 2. Continued.

	Maximum intensity					End tropical cyclone phase			
Name	*Date*	*Time (UTC)*	*Lat.*	*Long.*	*Mean wind (m/s)*	*Date*	*Time (UTC)*	*Lat.*	*Long.*
Ilsa	12 Dec	1600	12.3°S	103.7°E	28	17 Dec	1000	20.2°S	121.3°E
John	14 Dec	0700	18.9°S	117.4°E	58	16 Dec	0100	23.4°S	120.6°E
Babiola	10 Jan	0000	20.3°S	67.3°E	44	12 Jan	1800	29.3°S	72.7°E
Iris	08 Jan	0600	16.6°S	166.5°E	41	10 Jan	0600	19.4°S	177.7°E
Jo	26 Jan	0000	23.2°S	176.8°E	33	27 Jan	1200	30.0°S	174.5°E
Kirrily	29 Jan	1000	20.7°S	107.2°E	30	31 Jan	1600	23.1°S	105.1°E
Leon/ Eline	22 Feb	0600	20.6°S	34.7°E	51	22 Feb	2200	20.2°S	33.8°E
Marcia	16 Feb	1000	15.1°S	102.6°E	18	17 Feb	1000	16.3°S	104.2°E
Kim	26 Feb	1200	25.7°S	139.9°W	49	27 Feb	1800	29.4°S	144.7°W
Steve I	27 Feb	0900	16.8°S	145.8°E	29	27 Feb	1800	17.3°S	143.5°E
Steve II	29 Feb	2100	15.6°S	136.9°E	25	1 Mar	0300	15.5°S	136.0°E
Steve III	06 Mar	0400	20.2°S	117.1°E	30	10 Mar	0400	27.8°S	116.6°E
Norman	02 Mar	2200	19.7°S	108.2°E	50	08 Mar	1600	23.8°S	92.6°E
Leo	07 Mar	0000	27.4°S	165.8°W	26	07 Mar	0600	29.5°S	166.0°W
Mona	10 Mar	1200	25.6°S	172.2°W	38	11 Mar	1200	29.5°S	171.8°W
Olga	18 Mar	0400	18.8°S	109.6°E	25	19 Mar	1600	23.3°S	103.9°E
Hudah	02 Apr	0600	15.6°S	52.9°E	62	09 Apr	0000	15.6°S	38.3°E
Vaughan	05 Apr	1800	15.2°S	148.5°E	30	06 Apr	0600	15.2°S	147.0°E
Tessi	02 Apr	2000	18.8°S	146.4°E	27	02 Apr	2200	18.8°S	146.3°E
Paul	15 Apr	1000	14.1°S	103.3°E	58	20 Apr	0800	15.0°S	94.3°E
Neil	16 Apr	0000	21.8°S	178.9°E	21	16 Apr	1200	22.7°S	179.4°E
Rosita	19 Apr	1600	18.2°S	122.0°E	51	20 Apr	2200	20.6°S	129.7°E

ing to near zero. However by November it had rebounded to +13 and it remained positive throughout the cyclone season, with a six-month mean of +11.7.

A cool sea-surface temperature (SST) anomaly pattern, typical of La Niña, dominated the equatorial central and eastern Pacific for the season, but began weakening in the east from February onward. Much of the tropical South Pacific was characterised by moderate warm anomalies from December onward, strongest departures being noted at central longitudes in the latter half of the season, particularly March. This was the southern arm of the 'warm v' which typically surrounds the eastern Pacific cool anomaly; it extended to eastern parts of the maritime continent near the equator while, to its south, waters off eastern Australia were generally slightly cooler than normal. In the equatorial eastern Indian Ocean and western parts of the maritime continent region SSTs were generally close to normal. Warm anomalies persisted over the southeastern tropical Indian Ocean throughout the six months.

Broadscale tropical convection, as indicated by outgoing long wave radiation (OLR), was generally suppressed (positive OLR anomalies) over the central and western Pacific near the equator. In contrast, low OLR values indicated above average convection over the tropical eastern Indian Ocean and throughout the maritime continent and South Pacific convergence zone region. Strongest departures from average were seen over the area between central Indonesia and northwestern Australia. East of the date-line active conditions at lower latitudes were most strongly evident in the latter half of the season.

Intraseasonal modulation

Intraseasonal activity is inferred from daily satellite imagery as well as time series of various parameters, including 200 hPa velocity potential, OLR, and sea-level pressure anomaly. Four major active phases were identified: late November to mid-December, much of January, late February to early March and most of April, the last being somewhat weaker than the first three. These active periods were clearly defined in upper velocity potential data, but much less clearly defined in OLR and surface pressures. The inferred average frequency of the 30 to 60-day intraseasonal (Madden-Julian) oscillation was about 45 to 55 days. However there was strong evidence of higher frequency westward-propagating disturbances between about mid-November and the end of March. Despite this it is evident that most tropical cyclones developed during the broad active phases.

Verification statistics

Position forecast verification statistics for each cyclone (Table 3) were derived by comparing the official warnings issued by the relevant warning centres with post-analysis best-track positions. For comparison, verification statistics for persistence forecasts based on 12-hour best-track movement vectors were also calculated. Initial position accuracy was slightly better than last season but overall slightly worse than the long term trend. This was in part due to the large inaccuracy with the positioning of *Olga*. Due to strong vertical wind shear the initial circulation was poorly defined and subsequently difficult to locate. The average +24-hour position accuracy was the best on record despite the large forecast error associated with *Rosita*.

Table 3. Position verification statistics for official warnings issued by relevant warning centres. Forecast positions are verified against the official best track. Figures in italics denote accuracy of persistence forecasts (figures in brackets denote accuracy of matching operational forecasts). Warnings for cyclones marked with an asterisk were issued by La Reunion RSMC.

Forecast lead time	*0 h*		*12 h*		*24 h*		*36 h*		*48 h*	
Name	*accuracy (km)*	*number*	*accuracy (km)*	*number*	*accuracy (km)*	*number*	*accuracy (km)*	*number*	*accuracy (km)*	*number*
Ilsa	42	27	83	26	124	24	-	-	-	-
			91 (79)		*178 (124)*		-	-	-	-
John	19	16	56	16	100	14	-	-	-	-
			56 (46)		*143 (71)*		-	-	-	-
*Babiola**										
Iris	15	17	119	9	236	7	-	-	-	-
			92 (119)		*267 (236)*		-	-	-	-
Jo	35	19	118	12	185	10	-	-	-	-
			120 (118)		*226 (185)*		-	-	-	-
Kirrily	35	28	92	26	161	24	-	-	-	-
			125 (95)		*280 (170)*		-	-	-	-
*Leon/Eline**	60	22	109	22	161	20	-	-	-	-
			127 (110)		*161 (155)*		-	-	-	-
Marcia	38	8	96	8	136	7	-	-	-	-
			124 (100)		*163 (160)*		-	-	-	-
Kim	9	16	55	11	116	9	-	-	-	-
			63 (55)		*196 (126)*		-	-	-	-
Steve	25	50	72	37	120	34	165	4	288	4
			85 (74)		*148 (130)*		-	-	-	-
Norman	35	30	102	30	205	30	-	-	-	-
			97 (105)		*247 (219)*		-	-	-	-
Leo	70	14	294	2	-	-	-	-	-	-
			251 (294)		-		-	-	-	-
Mona	39	18	130	11	216	9	-	-	-	-
			139 (130)		*293(216)*		-	-	-	-
Olga	102	20	139	18	179	17	-	-	-	-
			158 (137)		*213 (149)*		-	-	-	
*Hudah**										
Vaughan	46	14	79	12	118	10	136	8	128	6
			130 (81)		*252 (134)*		*460 (178)*	-	-	-
Tessi	14	7	73	5	-	-	-	-	-	-
			86 (60)	-	-		-	-	-	-
Paul	26	29	68	27	136	25	-	-	-	-
			63 (70)		*142 (138)*		-	-	-	-
Neil	14	8	146	3	253	2	-	-	-	-
			134 (146)	-	-		-	-	-	-
Rosita	54	15	121	15	220	13	-	-	-	-
			134 (102)		*275 (227)*		-	-	-	-
Mean	38		108		167		150		208	
Weighted Mean	38		94		157		146		192	

Tropical cyclones in the South Pacific and southeast Indian Ocean 1999-2000

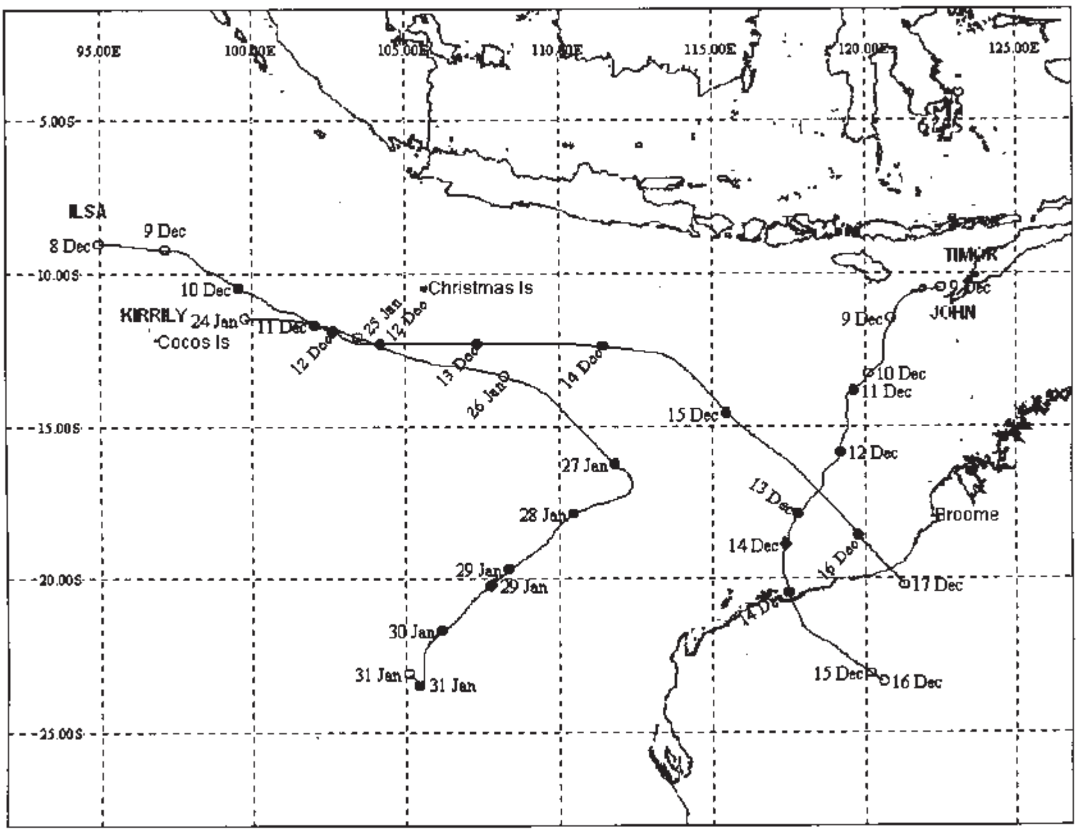
Ilsa (Perth TCWC): 8 to 17 December 1999

A low developed northwest of the Cocos Islands on 8 December, following a broad cross-equatorial surge in the northwesterlies, north of the monsoon trough. Once upper divergence improved *Ilsa* (Fig.1) was named on the morning of 10 December. Despite *Ilsa* being under the influence of vertical wind shear it slowly intensified as it moved southeast. This movement was due to *Ilsa* being located on the northern side of the monsoon trough in a strong low-level northwest flow. The tropical cyclone's movement was later influenced by the development of *John* (Fig. 1), forcing *Ilsa* on a more easterly track between 12 and 14 December. From 15 December onwards *Ilsa* moved south-southeast and weakened, eventually crossing the Western Australian coastline on 17 December. The cyclone quickly dissipated over land.

John (Perth TCWC): 9 to 16 December 1999

During early December the monsoon trough north of Australia intensified in part due to a strong cross-equatorial surge in the South China Sea. A separate low formed southwest of Timor. Improving upper divergence assisted the low to reach tropical cyclone status as *John* (Fig. 1) on the evening of 11 December. The system formed on the western side of the 500 hPa ridge and remained under its influence until 14 December. *John* reached peak intensity on 14 December with maximum mean winds of 58 m/s before interacting with a mid-latitude trough to its southwest. This resulted in vertical wind shear weakening *John* slightly and turning its motion south-southeast just prior to making landfall on the Western Australian coastline. The cyclone quickly weakened over land, dissipating on the morning of 16 December. As *John* passed over a sparsely populated region, damage was limited.

Fig. 1 Tracks of tropical cyclones *Ilsa*, *John* and *Kirrily*. Open circles indicate tropical low phase, filled circles indicate tropical cyclone phase. Filled diamond indicates the time at which the maximum intensity was reached. Plots are at 2200 UTC for cyclones in the Perth TCWC area of responsibility, 0000 UTC for all other figures.



Babiola (La Reunion RSMC): 3 to 12 January 2000

During January the monsoon trough was active in the central Indian Ocean. By 3 January a circulation formed to the east of a persistent convective cluster near 80°E. *Babiola* (Fig. 2) was named on 5 January and intensified slowly, reaching peak intensity on 10 January. The tropical cyclone moved towards the southwest under the influence of the mid-level ridge. Stronger ridging to the south later caused *Babiola* to move more westward. *Babiola* eventually dissipated on 12 January when it moved into an area of stronger wind shear and cooler sea-surface temperatures.

Iris (Nadi RSMC): 6 to 10 January 2000

Iris (Fig. 3) was first identified northwest of Vanuatu embedded in a stationary monsoon trough on 3 January. Due to vertical wind shear the system didn't reach tropical cyclone status until 7 January. Under more favourable conditions *Iris* then intensified rapidly to a peak intensity of 41 m/s on 8 January. *Iris* tracked southeast slowly at first, accelerating as a mid-level ridge extended westwards. The tropical cyclone passed directly over Vanuatu on 8 January, about 110 kilometres north of Port Vila and then weakened slightly. *Iris* was a midget tropical cyclone and despite its close proximity, Port Vila was unaffected by strong winds. As a mid-level trough to the southwest produced west-northwest steering flow the system continued to track southeast. As vertical shear increased *Iris* weakened and dissipated to the southeast of Fiji on 10 January.

_Jo_ (Nadi RSMC): 23 to 27 January 2000

After a lull in activity during mid-January a disturbance in the monsoon trough became apparent near Vanuatu on 19 January and by 23 January a low had formed. The vertical wind shear that inhibited early development decreased and organisation of the system increased. By 24 January tropical cyclone *Jo* (Fig. 3) formed about 450 kilometres west of Nadi and had a south-southeast movement. As a mid-level trough moved eastward on 25 January, *Jo* accelerated to the southeast, and continued to intensify. The system reached a peak intensity of 33 m/s early on 26 January and then crossed into Wellington's area of

Fig. 2 Tracks of tropical cyclones _Babiola_, _Leon/Eline_ and _Hudah_. Symbols as in Fig. 1.

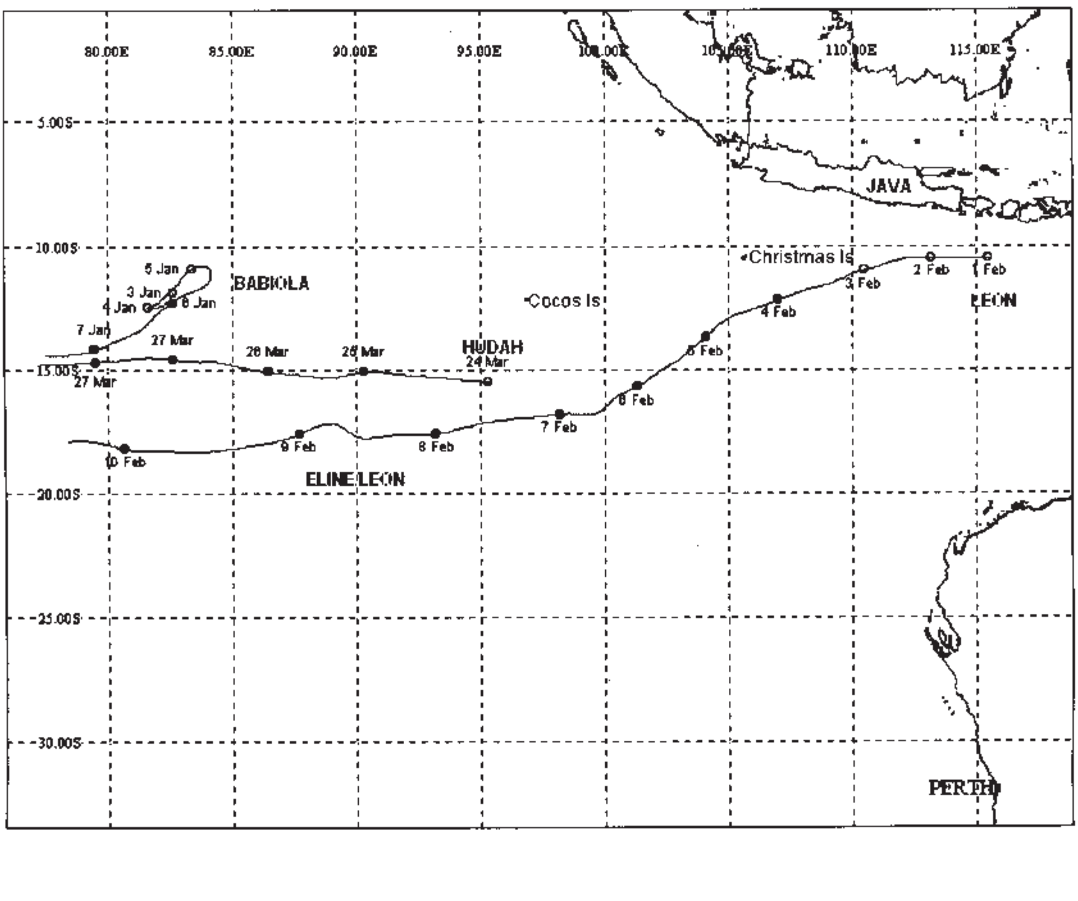
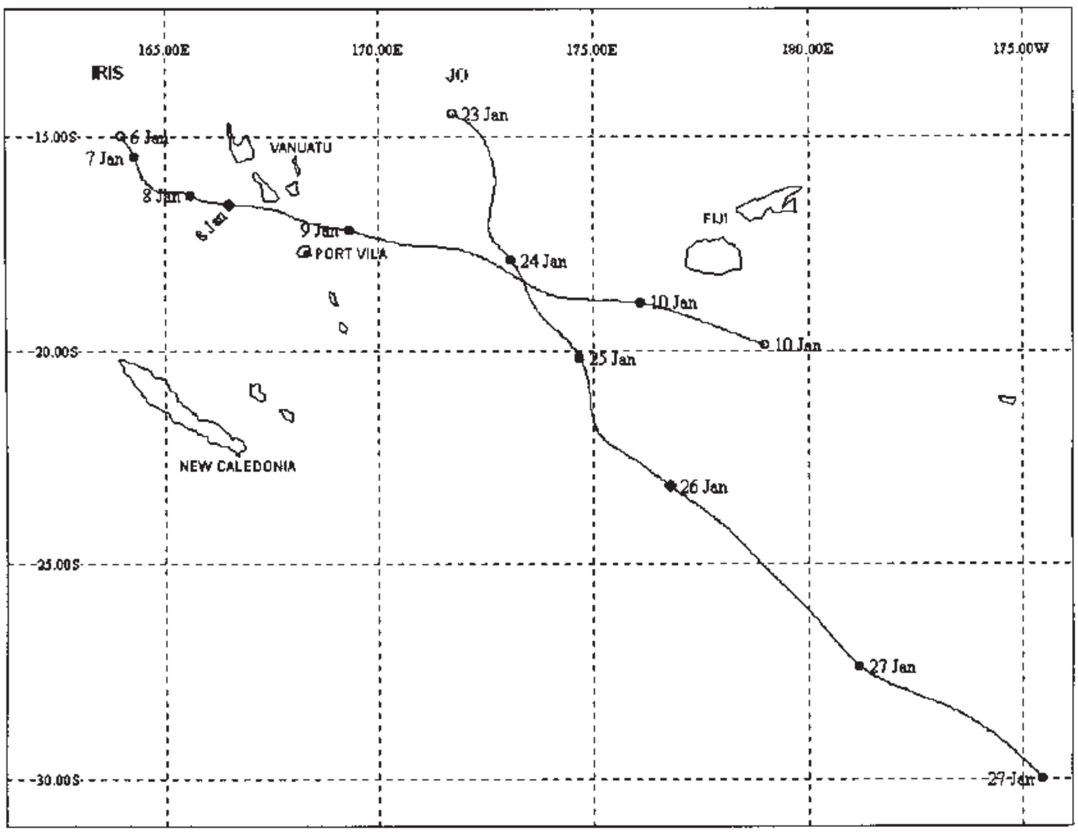


Fig. 3 Tracks of tropical cyclones *Iris* and *Jo*. Symbols as in Fig. 1.



responsibility. During 26 January *Jo* experienced increasing vertical shear and cooler sea-surface temperatures, consequently weakening. The system became extratropical well to the east of New Zealand.

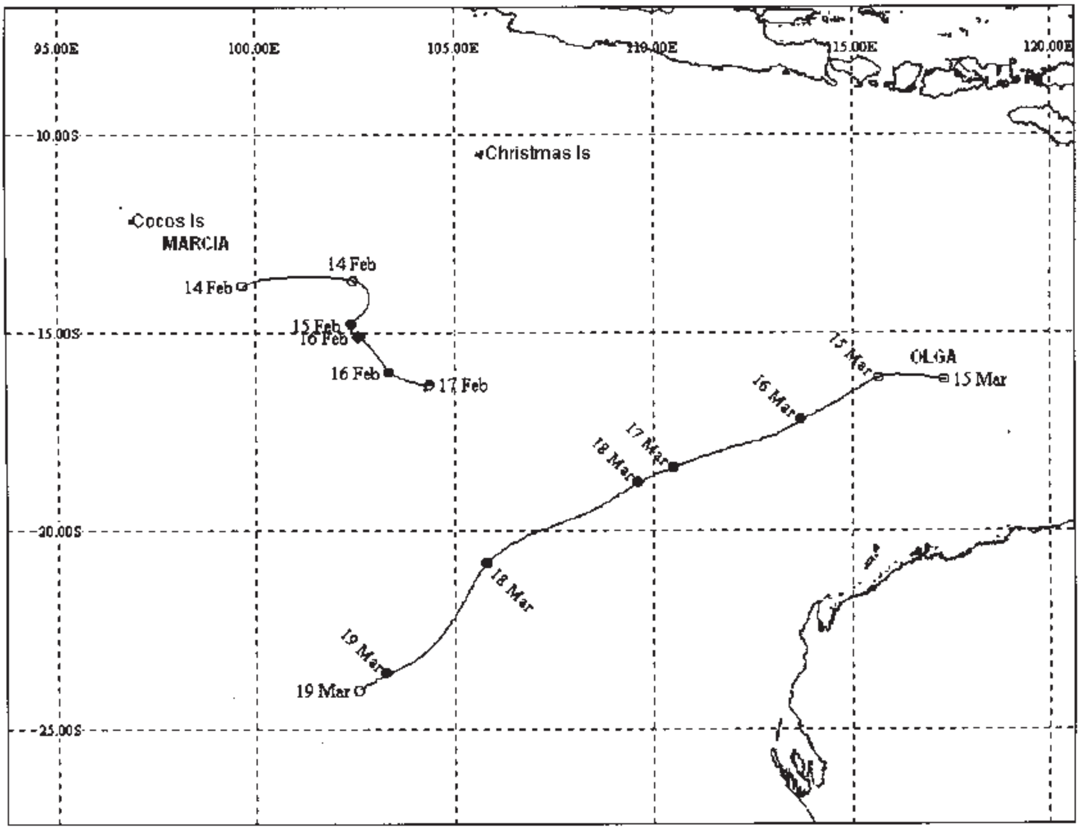
Kirrily (Perth TCWC): 24 to 31 January 2000

During the second half of January the active monsoon trough persisted in the Indian Ocean. By 24 January a low had separated from the main monsoon cloud mass to the east of the Cocos Islands. The development of this low was hindered by wind shear until early on 27 January, when tropical cyclone status was reached. From this point the middle-level ridge developed and the shear being experienced by *Kirrily* (Fig. 1) decreased, allowing the system to intensify. *Kirrily*'s eastward movement halted on 27 January and under the influence of the mid-level ridge the system began to move southwest. As *Kirrily* experienced increasing shear the system weakened, eventually dissipating on 31 January. The remaining low-level system was steered away to the northwest.

Leon/Eline (Perth TCWC/La Reunion RSMC): 1 to 22 February 2000

A monsoonal surge combined with an intensifying upper ridge promoted the development of a low south of Java despite significant vertical shear. The low reached tropical cyclone strength on 3 February and steadily intensified over the next 72 hours. *Leon* (Fig. 2) moved southwest initially as it was steered around the northwest flank of a mid-level anticyclone over Australia. From 7 February *Leon* began to weaken under increasing wind shear and move on a more westerly track as the ridge to the south strengthened following the passage of a short wave trough. The tropical cyclone continued on a west-southwest course and was renamed *Eline* by La Reunion RSMC upon crossing 90°E. *Leon/Eline* moved through the La Reunion RSMC region affecting Mauritius, then re-intensified as it crossed the island of Madagascar. The system moved into the Mozambique channel and again re-intensified to a peak intensity of 51 m/s before making landfall on the coast of Mozambique

Fig. 4 Tracks of tropical cyclones Marcia and Olga. Symbols as in Fig. 1.



where it contributed to an already widespread and serious flooding situation.

Marcia (Perth TCWC): 14 to 17 February 2000

Marcia (Fig. 4) formed from a low in the monsoon trough southeast of the Cocos Islands. It deepened only slowly due to the influence of moderate vertical shear. *Marcia* briefly attained tropical cyclone status late on 15 February but quickly weakened through the effects of vertical wind shear on 16 February. The system dissipated over water on 17 February. *Marcia* moved east and then east-southeast due to a combination of the northwest monsoon stream and the approach of a short wave trough from the southwest.

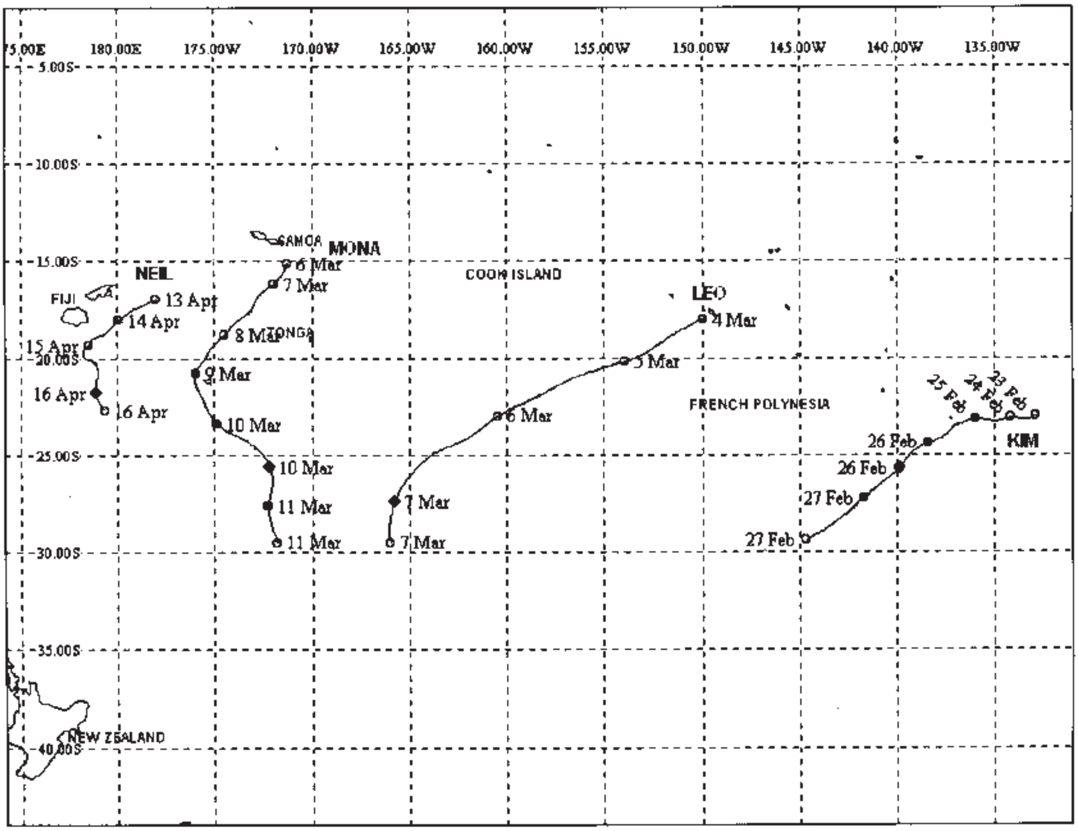
Kim (Nadi RSMC): 23 to 27 February 2000

Kim (Fig. 5) was first identified as a tropical low on 23 February over southeastern parts of French Polynesia and moved slowly northwest. Initially the low-level centre was located well away from any deep convection, however during 24 February convection formed around the centre and the system reached tropical cyclone status. The system continued to intensify rapidly on 25 February and moved first west-southwest and then south-southwest. By 26 February the middle-level northeast steering pattern had strengthened and *Kim* accelerated and moved into Wellington's area of responsibility. *Kim* reached a peak intensity of 49 m/s on 26 February and then gradually began to weaken on 27 February, becoming extratropical by 29 February.

Steve (Brisbane/Darwin/Perth TCWCs): 25 February to 10 March 2000

Monsoon conditions extended across Australia and into the southwest Pacific during the end of February. A small circulation east of Willis Island moved west and deepened and on the morning of 27 February the low was named *Steve* (Fig. 6). The system developed rapidly in close proximity to the Queensland coast, then weakened the same day as it moved inland near Cairns. The system remained

Fig. 5 Tracks of tropical cyclones *Kim*, *Leo*, *Mona* and *Neil*. Symbols as in Fig. 1.



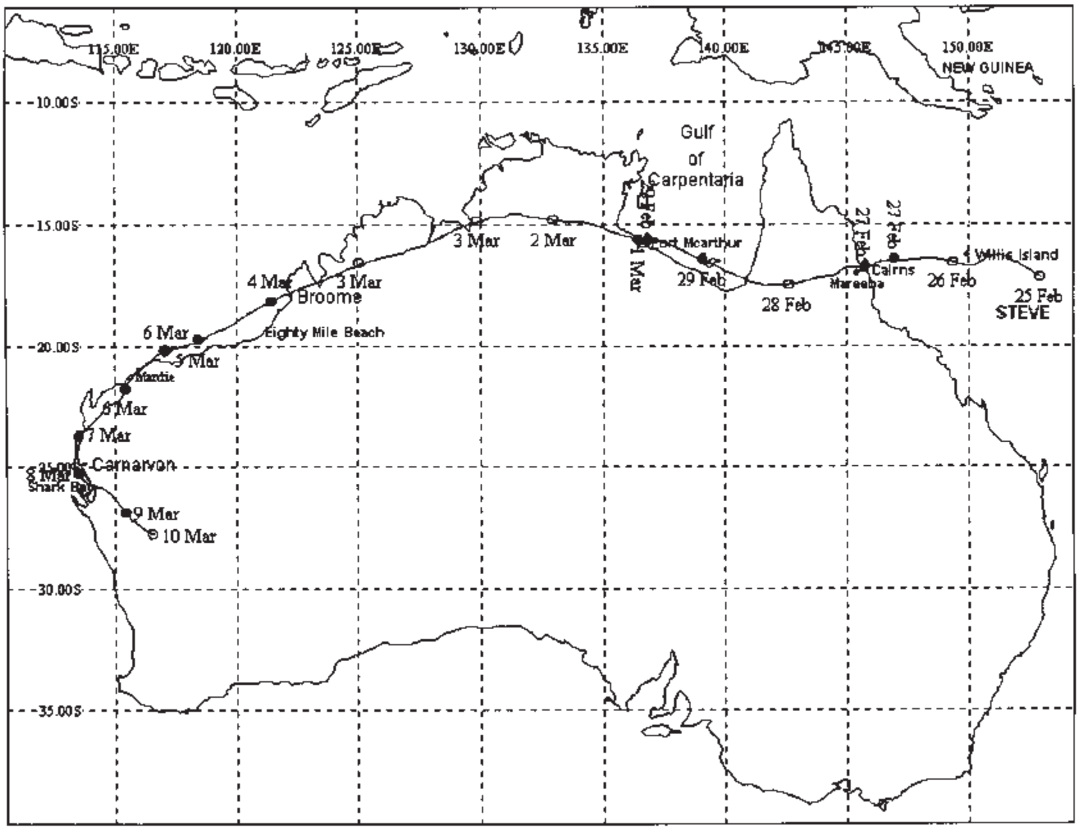
organised while crossing the Cape York Peninsula and re-intensified to cyclone status in the Gulf of Carpentaria. *Steve* re-crossed the Northern Territory coast north of Port McArthur on 1 March. The circulation was then steered west across the northern part of Australia by a strong middle-level ridge. It moved offshore west of Broome and re-intensified into a tropical cyclone on 5 March. *Steve* moved west-southwest parallel to the Pilbara coast and crossed the coast near Mardie on 6 March near peak intensity. Early on 8 March *Steve* again moved out to sea re-intensifying and reaching its most westward point before moving slowly around the upper ridge. *Steve*'s final landfall was over Shark Bay on 9 March. The system then accelerated to the southeast and became extratropical.

Steve had a significant impact over a large area of Australia. As *Steve* crossed the Queensland coast it caused major flooding between Cairns and Mareeba. A record flood level of 12.4 meters was reached at Mareeba on 28 February. Ninety people were evacuated from the town and the railway bridge was washed away. Strong wind gusts produced some building damage and many trees and powerlines were brought down in the district. There was severe crop damage caused by winds and floods.

As the low tracked over the Northern Territory strong squalls produced mainly minor damage however widespread flooding from heavy rain was experienced in the Katherine, Daly and Victoria River regions. Several communities were evacuated and numerous roads and highways were cut.

Ex-*Steve* continued to produce heavy falls in the Kimberley with greater than 300 mm recorded in the Eighty Mile Beach area. Many communities remained isolated for up to two weeks. Several sites reported highest on record daily rainfall amounts including Mandora (281.0 mm on 6 March) and Mount Narryer (152.0 mm on 9 March). Carnarvon reported its highest March daily rainfall (100.6 mm on 9 March). The Gascoyne River recorded its highest flood level since 1961.

Fig. 6 Track of tropical cyclone *Steve*. Symbols as in Fig. 1.



Norman (Perth TCWC): 28 February to 8 March 2000

A depression developed in the active monsoon trough over northwest Australia and moved west offshore, reaching tropical cyclone status on the evening of 29 February. *Norman* (Fig. 7) rapidly intensified in an environment of low shear and continued to move west-southwest under the influence of the mid-level ridge to the south. *Norman* reached a peak intensity of 50 m/s on 2 March exhibiting a very symmetrical structure and a large eye. From 3 March *Norman* began to weaken as the system experienced increased vertical wind shear. On 6 March *Norman* moved south, then southeast, as the system crossed the mid-level ridge axis and became embedded in westerlies. Renewed ridging to the south further increased vertical shear and *Norman* dissipated on 8 March.

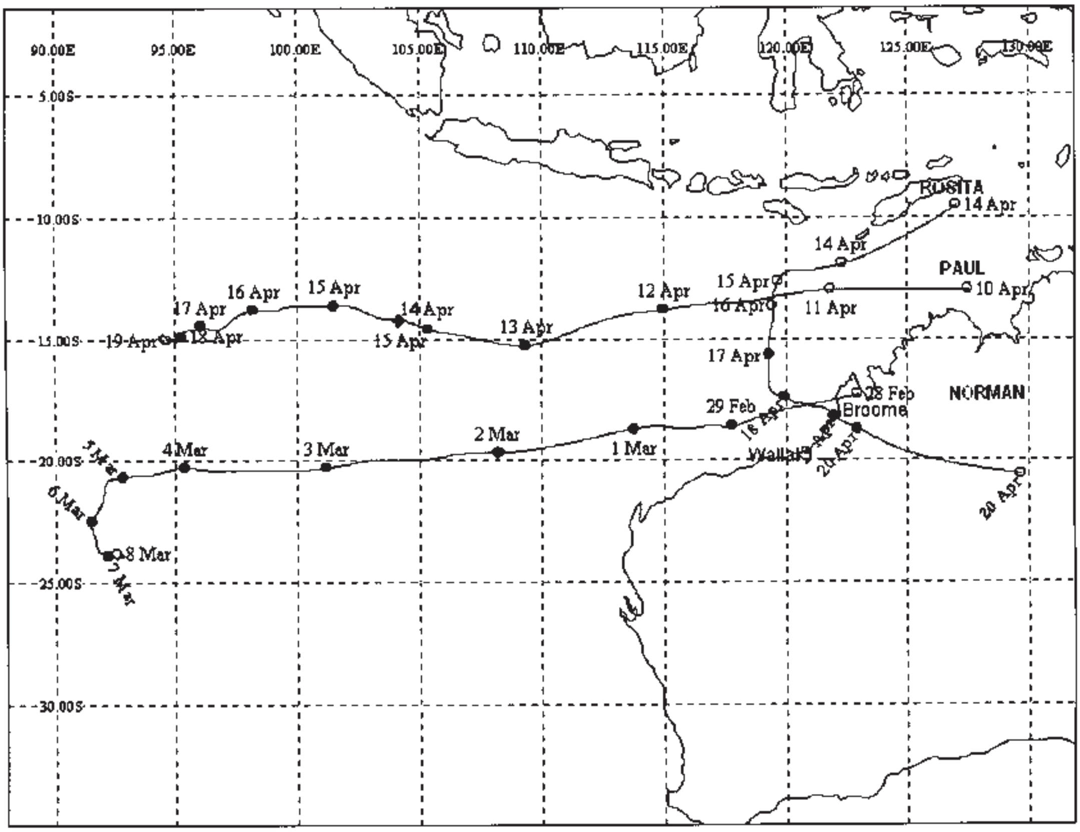
Leo (Nadi RSMC): 4 to 7 March 2000

A low was first identified west-northwest of French Polynesia on 4 March. The system developed slowly on 5 March and moved through the Southern Cook Islands. The system experienced increasing shear as it moved under an upper trough. By 6 March convection and organisation improved and the system reached tropical cyclone status about 200 kilometres southwest of the Southern Cook Islands. *Leo* (Fig. 5) intensified rapidly before it entered the Wellington area of responsibility late on 6 March. By 8 March *Leo* became extratropical as it experienced strong shear and cooler sea-surface temperatures.

Mona (Nadi RSMC): 6 to 11 March 2000

A disturbance initially near Western Samoa became organised into a low by 7 March. The system was well organised but the effect of shear inhibited development. By 8 March the low-level centre had moved under increasing deep convection and the system reached tropical cyclone strength. *Mona* (Fig. 5) moved slowly south-southwest and intensified further while located 55 kilometres northwest of Tongatapu. The cyclone continued this move-

Fig. 7 Tracks of tropical cyclones *Norman*, *Paul* and *Rosita*. Symbols as in Fig. 1.



ment, increasing in speed and intensifying as it moved away from the island. The increase in speed combined with diffluence from a retrogressing upper trough helped further intensify *Mona*. The cyclone weakened as it accelerated further south and became extratropical by 11 March. Damage from *Mona* was mainly to crops however moderate house and building damage was sustained on Tongatapu. The unofficial estimate of damage to Tonga was T$6 million.

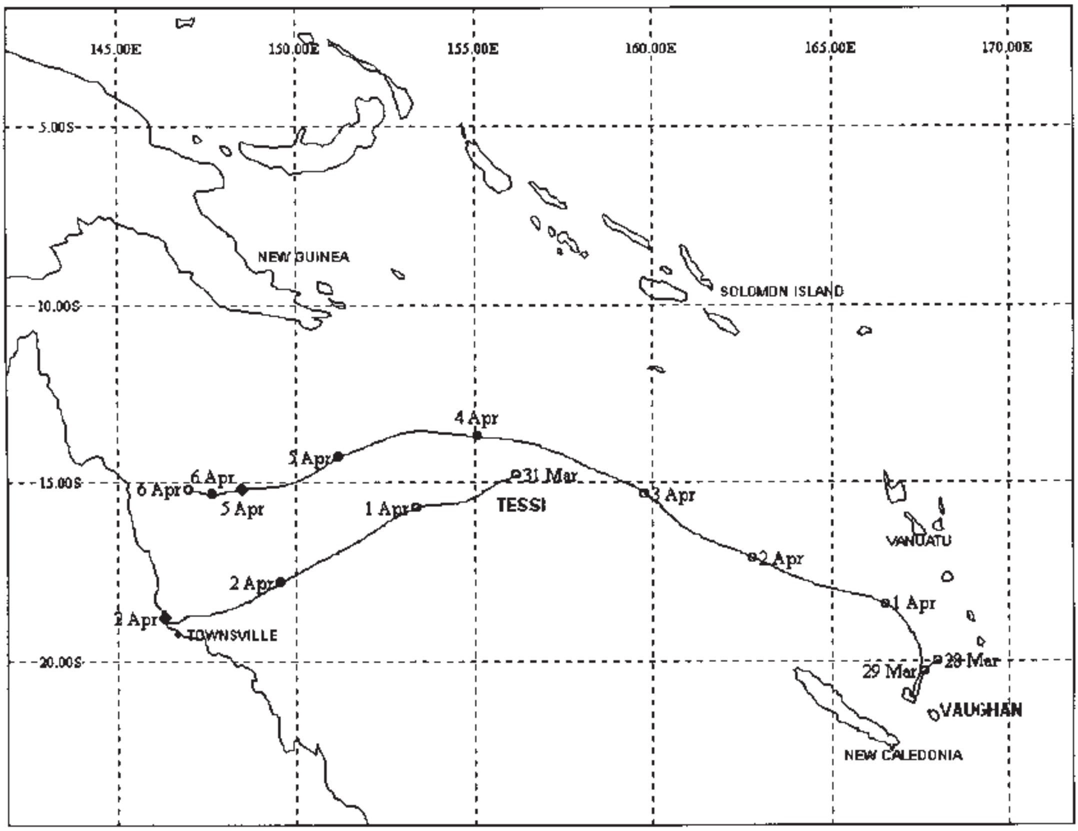
Olga (Perth TCWC): 15 to 19 March 2000

Surges in the westerlies to the north of the monsoon trough and in the easterlies to the south assisted a circulation to develop to the northwest of Australia. The system was located on the northern side of the middle-level ridge and moved west, intensifying only slowly. *Olga* (Fig. 4) reached tropical cyclone status late on 16 March but its intensification was inhibited by vertical wind shear. A series of mid-level troughs produced a more southerly motion and the cyclone eventually weakened over water on 19 March.

Hudah (La Reunion RSMC): 24 March to 9 April 2000

The monsoon trough continued to remain active all through March and a low developed near Christmas Island and moved westward under the influence of the middle-level ridge. Cyclogenesis occurred on 25 March as the system crossed 90°E. *Hudah* (Fig. 2) subsequently maintained its westward track and developed into one of the most intense tropical cyclones in the southern Indian Ocean, reaching a peak intensity of 62 m/s on 2 April. *Hudah* made landfall over northern Madagascar on 2 April and began to weaken. The tropical cyclone continued its westward track and re-intensified as it moved into the Mozambique channel. *Hudah* crossed the Mozambique coastline and weakened. The tropical cyclone destroyed the city of Antalaha on Madagascar and was responsible for 20 deaths.

Fig. 8 Tracks of tropical cyclones *Vaughan* and *Tessi*. Symbols as in Fig. 1.



Vaughan (Brisbane TCWC): 28 March to 6 April 2000

A monsoon low was identified near New Caledonia and initially moved southwest before it began a north and then northwest movement. *Vaughan* (Fig. 8) intensified rapidly due to favourable upper diffluence and was named on 3 April. The system tracked westward and started to weaken, being downgraded to tropical low intensity on 6 April. The low moved further west and caused heavy rainfall along the Queensland coast.

Tessi (Brisbane TCWC): 31 March to 2 April 2000

Tessi (Fig. 8) was first identified as a tropical low in the northern Coral Sea on 31 March. The low tracked southwest around the northern side of a middle-level ridge and intensified to tropical cyclone strength late on 31 March. *Tessi* continued to track west-southwest reaching peak intensity of 27 m/s close to the Australian coast. *Tessi* crossed the coast about 75 kilometres northwest of Townsville and rapidly weakened inland, causing widespread though minor wind damage and a significant landslide in the community.

Paul (Perth TCWC): 10 to 20 April 2000

Paul (Fig. 7) started as a low in the monsoon trough to the north of Australia. The system was located north of the mid-level ridge axis and moved west. *Paul* experienced little vertical shear and quickly intensified to cyclone strength on 12 April and reached a peak intensity of 58 m/s on 15 April. During 17 April the middle-level ridge split and *Paul* moved into this col area. The system subsequently slowed and then weakened as vertical shear increased, dissipating over water on 20 April.

Neil (Nadi RSMC): 13 to 16 April 2000

A disturbance which was embedded in a trough northeast of Fiji on 13 April moved southwest and developed into a low about 220 kilometres northeast of

Vanuatalava Island. Convection and organisation increased and the system reached cyclone status on 15 April. *Neil* (Fig. 5) experienced increasing wind shear during 16 April due to a deep 250 hPa trough upstream of the system and was downgraded to a tropical depression before moving out of Nadi's area of responsibility. Damage attributed to *Neil* on the islands of Fiji was negligible, with the southernmost islands affected by winds that barely exceeded gale force.

***Rosita* (Perth TCWC): 14 to 19 April 2000**

As *Paul* tracked westward a second low formed to the northwest of Australia. The system slowly tracked southwest under the influence of the middle-level ridge and intensified to tropical cyclone strength on 17 April. *Rosita* (Fig. 7) was a very small tropical cyclone and intensified rapidly between 17 and 18 April. It moved through the ridge axis on the 18 April and began a southeasterly movement under the influence of a westerly steering flow. *Rosita* impacted the Western Australian coastline about 40 kilometres south of Broome at peak intensity of 51 m/s. *Rosita* continued inland on a southeasterly path, eventually weakening to below tropical cyclone strength late on 20 April, approximately 700 kilometres inland. The cyclone severely damaged a tourist resort and pastoral station in the region of Cape Villaret but damage to property in the town of Broome was mostly minor.

Acknowledgment

The cyclone track figures were prepared by Mr Kevin Smith from the Severe Weather Section, Regional Office, Bureau of Meteorology, Perth using the Australian Tropical Cyclone Workstation.

References

McPherson, T. and Stapler, W. 2000. *1999 Annual Tropical Cyclone Report*. U.S. Naval Pacific Meteorology and Oceanography Center/Joint Typhoon Warning Center, Pearl Harbor, Hawaii. Available from the Web at: http://www.npmoc.navy.mil/.

Shaik, H.A. and Bate, P.W. 2000. The tropical circulation in the Australian/Asian region - November 1999 to April 2000. *Aust. Met. Mag., 49*, 331-42.

Appendix

Data sources

The 'Circulation summary', 'climatic indices' and 'Intra-seasonal modulation' sections were composed using the facilities of Darwin Regional Specialised Meteorological Centre and its monthly publication *Darwin Tropical Diagnostic Statement*. Extensive use has also been made of data from the NOAA_CIRES Climate Diagnostics Center, Boulder, Colorado, USA, available from their Website at http://www.cdc.noaa.gov/.

Darwin Tropical Diagnostic Statement, December 1999 to April 2000 (Volume 18 No. 12, Volume 19 Nos 1-4) Bureau of Meteorology, Northern Territory Region PO Box 40050, Casuarina, Northern Territory 0811, Australia.

Monthly Global Tropical Cyclone Summary, December 1999 to April 2000. Compiled by Gary Padgett, Colorado State University. Disseminated via email.