

# The South Pacific and southeast Indian Ocean tropical cyclone season 2000-01

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**Twelve tropical cyclones formed in the South Pacific and southeast Indian Ocean during the 2000-01 tropical cyclone season. Of these, four formed in the South Pacific east of 160°E. Cyclone numbers in the Australian region were slightly below average, while numbers in the South Pacific were significantly less than average. The season was characterised by moderate La Niña conditions, weakening towards the end of the season. Cyclone occurrences were linked to active phases of the 30 to 60-day intraseasonal oscillation.**

## Introduction

This paper provides a summary of the tropical cyclone activity in the southeast Indian Ocean (east of 90°E) extending eastward to the South Pacific Ocean (west of 120°W) during the 2000-01 cyclone season. Information has been provided by the Australian Tropical Cyclone Warning Centres (TCWCs) in Perth, Darwin and Brisbane and the Fiji Regional Specialised Meteorological Centre (RSMC) in Nadi. Where not specified wind speeds referred to are sustained winds, or ten minute averages. References to the climatology of tropical cyclone occurrences in the Pacific refer to the area 160°E to 120°W.

Tropical cyclone occurrence is set in the context of the broadscale circulation with particular reference to El Niño-Southern Oscillation (ENSO) and the Madden-Julian Oscillation (MJO). For more detail regarding the broadscale circulation in the southern hemisphere and tropical circulation within the Darwin RSMC area of responsibility (70°E to 180°E) see the seasonal summary by Shaik and Bate (2002).

## Tropical cyclone occurrence

Twelve tropical cyclones formed in the South Pacific and southeast Indian Ocean during the 2000-01 tropi-

cal cyclone season. This is below the 20-year average of near nineteen over the area between 90°E and 120°W. Four of these reached hurricane strength. Details of the life cycle of these events between 90°E and 120°W are given in Table 1. The four cyclones that formed in the south Indian Ocean west of 90°E are not discussed in this summary.

The 2000-01 cyclone season in the South Pacific and southeast Indian Ocean commenced at an average date and location when *Sam* formed in the Indian Ocean just near the Western Australian Kimberley coast at the start of December. The first cyclone of the Australian and South Pacific cyclone season occurs on average in late November and is most likely to form west of 125°E in the southeast Indian Ocean (author's analysis). The cyclone itself however was not average, reaching a maximum intensity of 53 m s<sup>-1</sup> prior to crossing the Kimberley coast of Western Australia, with the first coastal crossing of the season occurring quite early. Pre-Christmas severe coastal crossings off northwest Australia are generally associated with strong La Niña conditions (Broadbridge and Hanstrum, 1998) and may have been a reflection of the sharp increase in Troup's Southern Oscillation Index (SOI) to +22 for November. The rise in SOI in turn may have resulted from an active 30 to 60-day intraseasonal oscillation (Madden-Julian Oscillation, MJO) propagating into the region at this time, enhancing environmental conditions favourable for cyclogenesis.

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**Table 1. Tropical cyclones in the South Pacific and the southeast Indian Oceans, 2000-01.**

Name	Date	Low first identified		Date	Initial tropical cyclone phase		
		Lat.	Lon.		Time (UTC)	Lat.	Lon.
1. <i>Sam</i>	28 Nov	11.0°S	140.0°E	04 Dec	2200	14.1°S	125.1°E
2. <i>Terri</i>	28 Jan	14.2°S	124.8°E	29 Jan	1000	15.9°S	121.6°E
3. <i>Winsome</i>	08 Feb	11.0°S	138.7°E	10 Feb	1200	13.5°S	136.8°E
4. <i>Vincent</i>	05 Feb	11.0°S	115.0°E	12 Feb	0700	14.5°S	111.0°E
5. <i>Wylva</i>	14 Feb	13.5°S	141.5°E	16 Feb	0000	15.5°S	138.4°E
6. <i>Oma</i>	18 Feb	17.1°S	162.1°W	20 Feb	0600	21.3°S	163.9°W
7. <i>Abigail</i>							
(Coral Sea)	21 Feb	11.0°S	158.0°E	24 Feb	0000	16.6°S	146.1°E
(Gulf of Carpentaria)				25 Feb	1800	15.8°S	140.0°E
8. <i>Paula</i>	25 Feb	10.9°S	163.5°E	26 Feb	0600	12.2°S	164.9°E
9. <i>Rita</i>	27 Feb	19.5°S	139.0°W	01 Mar	0000	19.7°S	136.5°W
10. <i>Walter</i>	1 Apr	10.7°S	110.7°E	1 Apr	2200	9.9°S	109.0°E
11. <i>Sose</i>	4 Apr	13.5°S	170.0°E	5 Apr	1800	14.0°S	165.5°E
12. <i>Alistair</i>	15 Apr	7.5°S	137.0°E	16 Apr	1900	10.2°S	132.8°E

Cyclone activity was suppressed in the Coral Sea and South Pacific until mid February. Early in the season the Coral Sea was dominated by a semi-permanent upper trough with deep dry air feeding into the region. A hybrid system, *Oma*, formed from an upper cut off low east of the date-line in mid February. This pattern broke down late in February as an active MJO phase reached the Coral Sea, enhancing the monsoon trough in the region. Cyclones *Abigail*, *Paula* and *Rita* then formed in the Coral Sea and South Pacific.

An unusual feature of the season was the longevity of a distinct circulation, strong winds and central cloud features of four cyclones after landfall. The first cyclone for the season, *Sam*, was extremely intense at coastal crossing, weakening to below gale force 48 hours later and 500 km inland (refer Fig. 6). *Winsome*, *Wylva* and *Abigail* crossed the southern Gulf of Carpentaria coast during February. *Abigail* made landfall at hurricane strength while the other two were at minimal cyclone strength, though associated with a strong monsoon circulation. *Winsome* and *Abigail* both weakened on landfall, then deepened later over central Australia (*Winsome* to 988 hPa, *Abigail* to 992 hPa) as a result of the highly favourable environment. An upper ridge over the systems, with strong outflow, enhanced upper divergence, while strong monsoon westerlies to the north and southeasterlies to the south enhanced the lower vorticity. All three of these ex-cyclones remained identifiable and produced significant weather

(strong winds and flooding) for up to a week while moving southwest through the Northern Territory and Western Australia (refer Fig. 7).

Cyclone numbers over the Australian region were near to slightly below average. Eleven cyclones developed, re-developed or moved into the region 105°E to 165°E during the 2000-01 season, compared with an average of twelve in the area used by McBride and Keenan (1982) and Nicholls (1992) for cyclone climatology studies and a comparison between cyclone numbers and the pre-season SOI. This compares with 14 during the previous season (which included the second and third redevelopment of *Steve*, refer Paterson and Bate 2001). The pre-season SOI is defined as the average of the monthly SOI for July, August and September. The pre-season SOI was near neutral then rose to moderate positive values during the season for both 1999 and 2000. Nicholls suggests cyclone numbers in the Australian region are correlated with both the pre-season SOI and the SOI change from the previous season. Neutral values with little change from the previous season would suggest near average cyclone numbers, or little change from the previous season. Cyclone numbers were in fact near average, but reduced slightly from the previous season. The increase in SOI to moderate La Niña conditions during the 2000-01 season does not seem to have had an effect of producing greater than average cyclone numbers in the Australian Region, thus the pre-season forecast remained intact.

**Table 1. Continued.**

Name	Date	Maximum intensity (m/s)			Mean wind (m/s)	End tropical cyclone phase			
		Time (UTC)	Lat.	Lon.		Date	Time (UTC)	Lat.	Lon.
1. <i>Sam</i>	08 Dec	1300	18.9°S	121.6°E	53	10 Dec	1400	21.5°S	124.9°E
2. <i>Terri</i>	30 Jan	2300	19.4°S	119.4°E	30	31 Jan	1000	22.3°S	120.5°E
3. <i>Winsome</i>	10 Feb	1800	13.8°S	136.2°E	21	11 Feb	1200	15.3°S	134.1°E
4. <i>Vincent</i>	12 Feb	1300	14.4°S	111.9°E	27	13 Feb	1300	15.5°S	116.1°E
5. <i>Wylva</i>	16 Feb	0600	16.0°S	138.4°E	18	17 Feb	0000	18.0°S	136.0°E
6. <i>Oma</i>	21 Feb	0600	24.8°S	158.9°W	28	22 Feb	1200	36.0°S	150.0°W
7. <i>Abigail</i>	26 Feb	1200	16.6°S	138.5°E	36	27 Feb	1200	18.0°S	135.5°E
8. <i>Paula</i>	02 Mar	0000	21.1°S	179.0°E	49	04 Mar	0600	29.0°S	172.0°W
9. <i>Rita</i>	02 Mar	0600	20.6°S	134.6°W	23	05 Mar	0600	32.0°S	134.0°W
10. <i>Walter</i>	04 Apr	2200	11.0°S	96.9°E	47	08 Apr	0400	20.6°S	94.8°E
11. <i>Sose</i>	08 Apr	0000	18.6°S	167.9°E	31	11 Apr	0600	26.5°S	169.5°E
12. <i>Alistair</i>	18 Apr	2200	15.5°S	122.4°E	30	23 Apr	2200	24.7°S	114.0°E

The 2000-01 cyclone season in the South Pacific was relatively inactive. A total of four cyclones formed in the area between 160°E and 120°W, compared with an average of eight. This was a continuation of the downward trend since the 1997-98 tropical cyclone season (refer Fig. 5) when the region was arguably at its most active phase, at least in the last 20 years or so. Of the four cyclones that formed, only one reached hurricane force. The average number of cyclones attaining hurricane intensity per season is four. The first half of the 2000-01 season (November, December and January) was tropical cyclone-free. From records available, the last time this occurred was during the 1944-45 season.

The South Pacific season also displayed characteristics of a neutral season rather than moderate La Niña. This was reflected in the fact that two of the total four cyclones developed over the Coral Sea region, *Paula* and *Sose*, while the other two, *Oma* and *Rita*, formed east of the date-line. Cyclone occurrence east of the date-line is generally far more likely during El Niño seasons (Hastings 1990). Similar to the previous season, both tropical cyclones which developed east of the date-line formed further south than their counterparts in the Coral Sea region. A factor in this may have been the persistence of a cold sea-surface temperature (SST) anomaly about the equatorial region, east of the date-line. Additionally, the eastern cyclones, *Oma* and *Rita* did not undergo extratropical transition until well into the subtropics, as opposed to

*Paula* and *Sose*. This may have been a consequence of colder SST anomalies and stronger upper westerlies west of the date-line throughout the season.

Several other lows within the tropics produced significant weather but were not categorised as cyclones. This included a subtropical low off the east coast of Australia during March. This system made landfall on the northern New South Wales coast with average wind speeds exceeding 26 m s<sup>-1</sup>, similar to a storm intensity cyclone. A tropical low in the Arafura Sea in early January produced strong winds along the Northern Territory coast; however the low crossed the coast before cyclone development could occur.

## Tropical cyclone impacts

Five of the eight cyclones to form in the Australian region crossed the Australian mainland coastline: *Sam*, *Terri*, *Winsome*, *Wylva* and *Abigail* (twice). Two crossed the Western Australian coast, three in the Gulf of Carpentaria and one crossed the eastern north Queensland coast. Two crossed the coast at hurricane intensity, *Sam* and *Abigail*. Communities in their path were small and well prepared. However as in previous seasons it was not the tropical cyclone winds that produced the major impact on the Australian continent, but flooding resulting from remnant lows. *Winsome*, *Wylva* and *Abigail* produced record or near record flooding of the Victoria River and Daly Rivers in the

Northern Territory and parts of Western Australia causing evacuation and isolation of many communities and damage to infrastructure.

In the southwest Pacific, Vanuatu suffered two cyclone impacts, *Paula* in February and *Sose* in April. *Paula* crossed the Vanuatu island chain with maximum mean winds of  $44 \text{ m s}^{-1}$  and much damage resulting to housing, crops, infrastructure and shipping. *Sose* primarily caused havoc through flooding and high seas. Heavy seas and swells damaged southern coasts of Fiji and Tonga after *Paula*'s passage. A strong pressure gradient between *Sose* and a high near New Zealand produced heavy swells along the southern Queensland coast. Some damage occurred to crops, vegetation and light structures in the Southern Cook Islands from *Oma* in February. Further east in early March *Rita* had little effect, producing gales through southeastern parts of French Polynesia.

## Climatic indices

Moderate La Niña conditions characterised the summary period, as they had for the previous two southern hemisphere tropical cyclone seasons (Paterson and Bate 2001). After falling below zero in mid 2000, the SOI regained positive values later in the year, reaching a peak of +22 in November. It subsequently declined to a value of zero in April 2001. By this time there were also other indications that the La Niña event was in decline, such as the weakening of Pacific sea temperature and broadscale atmospheric anomaly patterns. The six-month mean SOI for November 2000 to April 2001 was 9.6 compared with 11.7 for November 1999 to April 2000.

A cool SST anomaly pattern, typical of La Niña, again dominated the equatorial central and eastern Pacific for the season, but cool anomalies were generally weaker than in 1999-2000. Much of the tropical South Pacific was characterised by moderate warm anomalies, strongest in January and February. The south Indian Ocean was mostly a little warmer than average at lower latitudes. However, south of about  $10^{\circ}\text{S}$ , moderate cool anomalies predominated during the season, contracting to the southeast by April.

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, particularly from November to January. In contrast, above average convection occurred over the equatorial eastern Indian Ocean and throughout the maritime continent and South Pacific convergence zone (SPCZ) region. Strongest departures from average were seen over

eastern Indonesia and northern Australia. This pattern reflects a continuing La Niña influence though the anomalies were generally not as strong as during the 1999-2000 season.

## Large-scale circulation features

Averaged over the six months November 2000 to April 2001, moderate negative pressure anomalies dominated the tropics over the eastern Indian Ocean, and through Indonesia and northwestern Australia. This reflects a fairly well-developed monsoon at these longitudes, typical of this phase of ENSO. The majority of the cyclones formed in this region. Further east, there was no significant monsoonal influence and pressures were generally within 1 hPa of the long term mean. A stronger than normal subtropical ridge affected the central and southeast Pacific. Easterly winds which generally prevail east of Papua New Guinea were anomalously anticyclonic and the trough normally associated with the SPCZ was evidently displaced a little south of the mean.

In the upper troposphere, divergent equatorial easterly anomalies were noted over the region west of about  $130^{\circ}\text{E}$ , in line with the well-developed monsoon trough evident at low level. An anomalously strong high was evident over the Tasman Sea and Coral Sea. 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.

## Intraseasonal modulation

Intraseasonal activity is inferred from time-longitude sections of 200 hPa velocity potential, OLR, sea-level pressure anomaly, station pressure series and daily satellite imagery. The most convectively active periods across the region were from mid November into early December and for much of the month of February. These were the most obvious MJO enhanced pulses, the majority of cyclones developing during one or other of them. There were several other active periods, though not as well organised as the first two. They occurred in late December-early January (mostly near the equator) and during March and April.

## Verification statistics

**Table 2. Position forecast verification statistics for official warnings issued by relevant warning centres. Forecast positions are verified against the official best track. Persistence errors (in brackets) are included for comparison.**

Name	Forecast Lead Time							
	0 h		12 h		24 h		48 h	
	error (km)	number	error (km)	number	error (km)	number	error (km)	number
1. <i>Sam</i>	56	37	99 (118)	21	134 (184)	29	194 (340)	5
2. <i>Terri</i>	64	19	83 (122)	10	161 (185)	12		
3. <i>Winsome</i>	56	12	112 (146)	6	201 (310)	4		
4. <i>Vincent</i>	60	21	86 (146)	12	107 (164)	13	177 (208)	2
5. <i>Wylva</i>	33	11	123 (107)	3	339 (112)	2		
6. <i>Oma</i>	110	17	143 (247)	5	273 (741)	6		
7. <i>Abigail</i>	34	19	105 (118)	11	164 (248)	6		
8. <i>Paula</i>	19	23	80 (107)	18	176 (258)	15		
9. <i>Rita</i>	19	14	120 (120)	10	163 (219)	8		
10. <i>Walter</i>	56	42	111 (134)	23	181 (130)	33	428 (279)	9
11. <i>Sose</i>	18	22	98 (90)	19	170 (245)	17		
12. <i>Alistair</i>	31	35	111 (124)	23	174 (159)	30	186 (217)	5
Total		272		161		175		21
Weighted Average 2000-01	46		102 (124)		168 (205)		291 (272)	
Australian Region 10-year average 1987/88 to 1996/97	45		115		201		381	

Position forecast verification statistics for each cyclone (Table 2) were derived by comparing the official warnings issued by the relevant warnings centres with post analysed best-track positions. For comparison, verification statistics for persistence forecasts based on operational track movement vectors were also calculated. Warning responsibility for two cyclones in the Gulf of Carpentaria (*Wylva* and *Abigail*) was shared between Brisbane and Darwin TCWCs. Warning responsibility for two cyclones traversing the Arafura Sea, Timor Sea and Indian Ocean (*Sam* and *Alistair*) was shared between Darwin and Perth TCWCs.

Verification results of cyclone track forecasts for the 2000-01 tropical cyclone season were on average within 10 km of the previous season's error statistics, and an improvement on the ten-year Australian region average (1987-88 to 1996-97). The official TCWC and RSMC forecasts were on average 20 to 40 km better than the persistence forecasts for 12 and 24 hours forecasts, but 19 km worse at 48 hours. Forecast accuracy for *Terri*, *Vincent* and *Paula* was particularly good with errors at 12 hours near 80 km. This compares with the season average of 100 km, and the long term Australian average of 115 km. *Terri* and *Vincent* were relatively weak cyclones making initial position identification more difficult, however

their tracks were relatively uniform and slow changing. *Paula* was a severe cyclone with good forecast accuracy most likely a result of excellent average initial position errors (19 km), a relatively straight track, and the better ability of numerical models to capture the movement of a severe cyclone. At 24 hours, average errors for track forecasts for *Sam* and *Vincent* were 134 km and 107 km respectively. This compared with a season average of 170 km and the long-term Australian average of 200 km. *Sam*'s forecast was good perhaps due to its intensity, but despite its poor initial position error average, and a track recurvature.

Two systems produced errors significantly larger than the long-term averages, particularly at 24 hours. *Oma* in the southwest Pacific was a hybrid system developing under strong vertical shear. Initial position errors were consequently large leading to larger than average forecast errors. Also *Oma* was short lived and weak with only a small number of forecast positions available for error calculation. Similarly *Wylva* in the Gulf of Carpentaria was weak with only three forecasts verifiable before the cyclone crossed the coast.

The track forecast for *Sose* in the southwest Pacific displayed a relatively large easterly bias. This was attributed to difficulty in forecasting the cyclone's southeast turn when it was persistently heading south-



crossing. *Sam*, its precursor low and residual rain depression caused heavy rain and flooding over a wide area of northern Australia. The peak rainfall reported in the 48 hours to 9 am 11 December was 520 mm at Shelamar, inland from the coastal crossing point.

#### ***Terri* (Perth TCWC): 28 January – 1 February 2001**

*Terri* (Fig. 2) formed west of the Kimberley coast in Western Australia, late in January at the start of an active phase of the MJO. The cyclone tracked southwest parallel to the Kimberley coast for about 24 hours, reaching storm force before recurving and weakening as it crossed the Pilbara coast of Western Australia.

The initial low formed in the monsoon trough over the northern Kimberley region of Western Australia. A weak cross-equatorial burst in the lower levels on 28 and 29 January increased the low-level vorticity and provided the trigger for further development. A middle-level ridge over central Australia then steered the low southwest into the Timor Sea and Indian Ocean with cyclone intensity being reached during 29 January. The

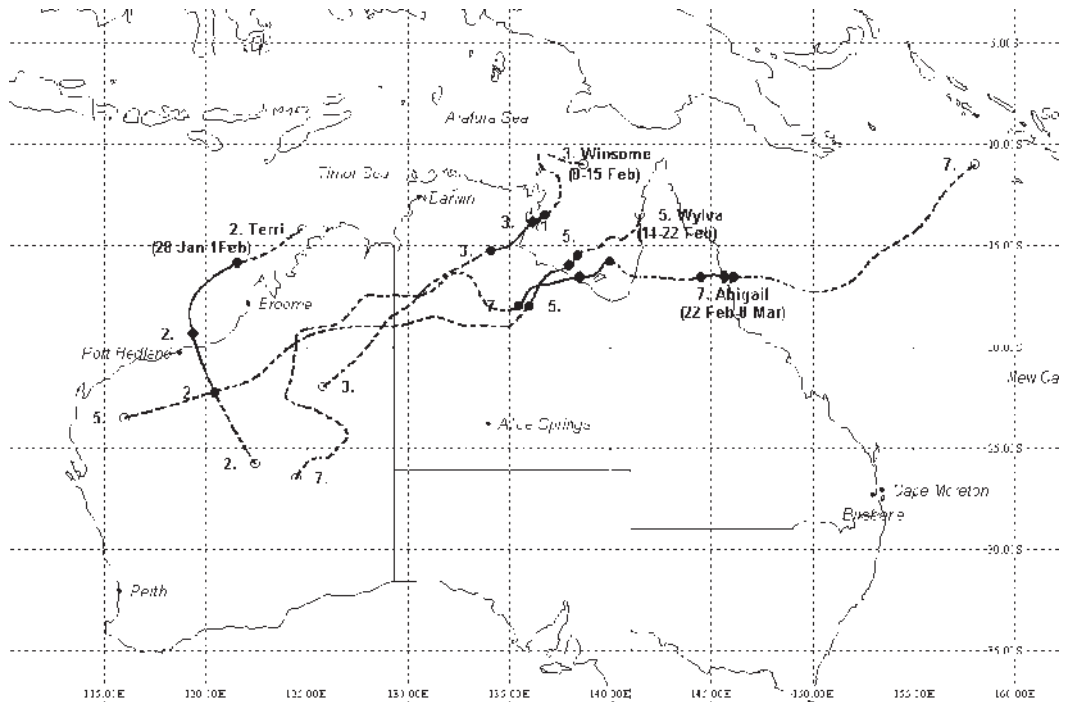
initial development of *Terri* was impeded by shear in the upper levels. The shear weakened briefly as the cyclone aligned beneath the upper ridge. This allowed the system to intensify to storm force as it travelled to the southwest. This was short lived however as the middle-level circulation became dislocated from the surface centre due to the influence of a large amplitude mid and upper-level trough to the west. Under this trough influence the low-level centre recurved to the southeast and crossed the Pilbara coast of Western Australia a day and a half after initial development. *Terri* weakened rapidly as it moved inland.

Tree damage occurred at Pardoo and Marble Bar with a maximum observed wind speed of  $31 \text{ m s}^{-1}$  with a gust of  $39 \text{ m s}^{-1}$ . Rainfall was generally unexceptional in the path of the system, with 24-hour falls recorded of less than 100 mm, however this did cause the closure of the Great Northern Highway and roads into Marble Mar.

#### ***Winsome* (Darwin TCWC): 8-15 February 2001**

*Winsome* (Fig. 2) formed in the Gulf of Carpentaria in

**Fig. 2** Tracks of Australian region tropical cyclones *Terri*, *Winsome*, *Wylva* and *Abigail*. Symbols as in Fig. 1.



early February from a large circulation within the monsoon trough. *Winsome* lasted less than 24 hours and crossed the Northern Territory coast near Groote Eylandt. Coastal crossing was preceded by several days of near gale-force winds associated with a large radius monsoon circulation within the trapped Gulf of Carpentaria basin. This in combination with peak spring tides resulted in a damaging storm surge on coastal crossing. The remnant low pressure system persisted for nearly a week as it tracked inland across the Northern Territory, with gale-force monsoon westerly winds causing damage and disruption in the Darwin area and along the northwest Northern Territory coast, and flooding across the Top End, Gulf and Victoria River Regions of the Northern Territory. The ex-cyclone finally decayed over the Pilbara region of Western Australia as it merged with ex-cyclone Vincent from the Indian Ocean.

The monsoon trough became active through the Arafura Sea to the north of the Northern Territory in early February as an active phase of the MJO propagated into the region. A high pressure system over southeastern Australia produced a strong easterly surge through the Coral Sea on 7 February. This surge focussed a broad monsoon circulation in the south-eastern Arafura Sea on 8 February, with convection and strong winds five degrees from the centre of the system. The system was in a region of low vertical wind shear and strong upper divergence favourable for development: strong return flow cross-equatorial easterlies and a sharp upper trough leaning back from the Coral Sea to an upper low at the base of the Gulf of Carpentaria. A 50 knot wind maximum near 15 degrees south in the vicinity of the Coral Sea on 8 February strongly aided the upper outflow. In addition, a westward-propagating equatorial Rossby wave interacted with the monsoon low during 8 and 9 February, significantly increasing vorticity in the low as it slowly drifted south into the Gulf of Carpentaria. Convection gradually increased near the centre of the system and *Winsome* developed into a tropical cyclone near 9.30 pm local time 10 February. Cyclone intensity was attained at an unusually low central pressure of 986 hPa, due to the already low surrounding environmental pressures within the broad and deep monsoon trough. At the time of genesis *Winsome* was 50 km north of Groote Eylandt and 150 km south of Nhulunbuy, both moderate-sized population and mining centres. The radius of gales extended to 300 km, with winds and seas affecting a large portion of the Gulf of Carpentaria. It moved south-southwest, crossing the coast of the Northern Territory within 24 hours of development near the community of Numbulwar.

A broad area of gales in the Gulf of Carpentaria

was associated with the low. These winds produced above-normal seas and water levels in the trapped basin of the Gulf. The cyclone's lifetime corresponded with peak spring tides, and the coastal crossing in the Gulf occurred near the high tide. A 2 m storm surge caused damage estimated at A\$1 million in the coastal community of Numbulwar. Workshops and facilities along coastal roads sustained the major damage. The port of Bing Bong, 200 km south of the cyclone centre, and towns of Alyangula and Nhulunbuy were also affected by flooding from storm surges. *Winsome* caused one death: a fisherman was lost from his vessel south of Groote Eylandt at the mouth of the Roper River. Two men were rescued after eight hours in a life raft when their trawler capsized in the southeastern Gulf of Carpentaria near Karumba. In Alyangula on Groote Eylandt, falling trees brought down power lines and a 2 m storm surge covered the golf course, washed boats onto rocks and a car off Shoreline Road. A 2 m storm surge was also reported at Bing Bong Port (Port McArthur), 200 km south of the cyclone centre, which raised the water level over the wharf at high tide. A storm tide at Nhulunbuy also covered the Perkins shipping company wharf and dislodged boats moored on the beach.

As *Winsome* moved inland it remained a significant system for five days as it crossed northern Australia. Gale-force monsoon westerlies persisted at a large radius north of the low's centre. In Darwin, strong to gale-force winds and severe wind gusts knocked trees onto power lines, causing blackouts, road accidents and damaging cars, as ex-*Winsome* moved 300 km to the south on 12 and 13 February. Large swell combined with high tides to produce coastal erosion and dangerous conditions at Darwin beaches. One man was rescued after spending twenty hours in Darwin Harbour mangroves after his dinghy was swamped in rough seas.

Heavy rain caused flooding in many parts of the Northern Territory, cutting the Victoria and Buntine Highways, access roads to Batchelor, Borroloola, Daguragu and causing the closure of many National Parks around the Top End of the Northern Territory including Litchfield Park, Douglas Hot Springs and Eley National Park. The Daly River community was threatened but no evacuations were necessary. Two cars were lost at a flooded river crossing near Timber Creek.

#### ***Vincent* (Perth TCWC): 5-15 February 2001**

*Vincent* (Fig. 1) developed in early February in the Indian Ocean. The cyclone reached storm force intensity briefly as it tracked eastward towards the Western Australian coast. It weakened below cyclone intensity however, before reaching the coast and dissipated

near Broome.

A low embedded in an active monsoon trough in the Indian Ocean was prevented from developing for several days due to strong vertical wind shear. This weakened sufficiently to allow *Vincent* to develop on 12 February. A strong westerly monsoon steered the system to the east-southeast as it intensified to storm force. A resumption of vertical wind shear weakened *Vincent* during 14 February. The low-level centre continued to track east-southeastwards in the monsoon trough while the deep convection became increasingly displaced to the west through shear. The system weakened to below cyclone strength on 15 February prior to the low-level centre crossing the coast south of Broome. At this time there was still a large area of monsoonal gales to the north of the trough, however winds on the southern side of the trough were only moderate. For most of its lifetime this system had the characteristics of a monsoon low, with the strongest winds being somewhat displaced from the centre, and a band of strong monsoonal winds evident well to the north.

No significant damage occurred from *Vincent*; however subsequent monsoon rains caused flooding as the remains of *Vincent* merged with those of *Winsome* over northern Western Australia.

#### ***Wylva* (Brisbane/Darwin) 14-22 February 2001**

*Wylva* (Fig. 2) was a short-lived cyclone, which formed in the southern Gulf of Carpentaria close to the coast. The cyclone had little effect on the remote coastal area it crossed, however record flood levels resulted from the ex-cyclone's rainfall as it traversed the Northern Territory and northern Western Australia.

The monsoon trough remained active across northern Australia in mid-February as ex-cyclones *Winsome* and *Vincent* decayed over Western Australia. Strong westerly monsoon flow persisted across northern Australia, with a circulation forming in the monsoon trough over Cape York Peninsula on 14 February. A firm mid-level ridge to the south steered the low steadily towards the southwest, and over Gulf of Carpentaria waters on 15 February. A favourable upper ridge to the southwest and a good vertical structure helped the low's steady development, and tropical cyclone *Wylva* developed early on 16 February. At this time the system was about 180 km northwest of Mornington Island in the southern Gulf of Carpentaria. The system continued to move southwest and crossed the southwestern Gulf of Carpentaria coast on 16 February, less than 24 hours from initial formation. Coastal crossing was complex, with an apparent eye observed on the Mornington Island radar crossing the coast, possibly a middle-level centre,

leaving the low-level centre behind. The low-level circulation then tracked westwards over the Australian continent. The system maintained its cloud structure quite well, like *Winsome* before it and *Abigail* afterwards. Ex-*Wylva* finally decayed over the Pilbara region of Western Australia on 22 February.

As a cyclone it had little impact, due to the remoteness of the area affected, but the remnants of the system produced a record flood in the upper Victoria River in the Northern Territory which inundated the Kalkarindji, Daguragu, Mistake Creek and Pigeon Hole communities. Around 700 people were evacuated, and damage to infrastructure was estimated at A\$13 million. Many areas were isolated by the floods, and required aerial food drops.

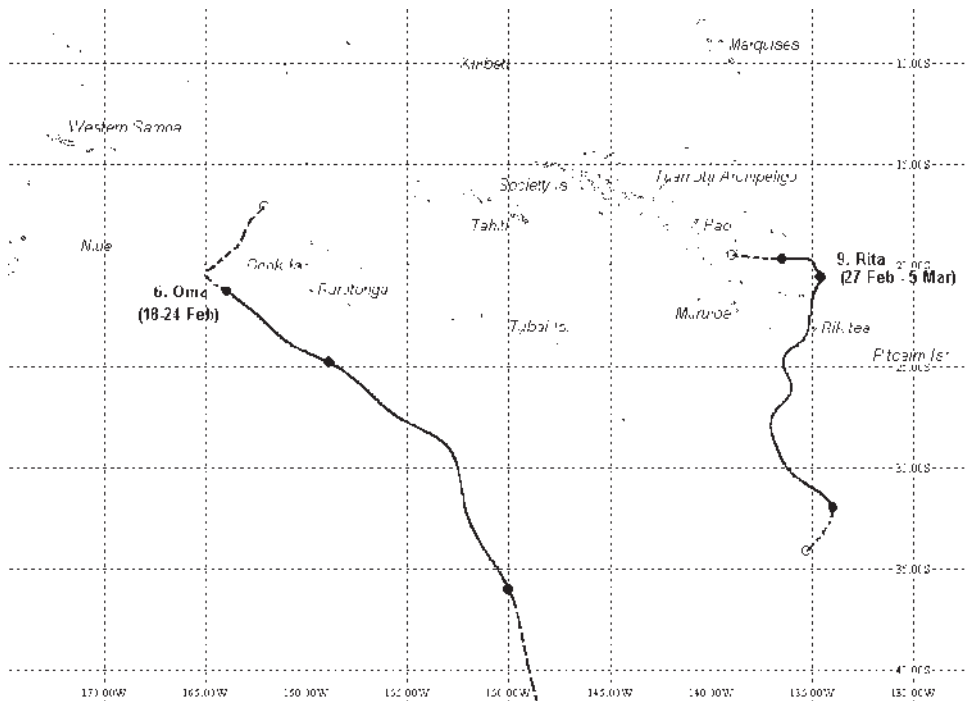
#### ***Oma* (Nadi) 18-24 February 2001**

After a quiet start to the tropical cyclone season in the South Pacific, the region became active with the formation of four tropical cyclones at the end of February. Three of these were in Fiji's area of responsibility, one of which reached hurricane intensity. *Oma* (Fig. 3) developed at relatively high latitudes east of the date-line and reached storm intensity. The cyclone lasted two days before an extratropical transition. Gale-force winds affected Rarotonga in the southern Cook Islands.

An upper-level cut-off low located about 500 km to the west-northwest of Rarotonga in the Cook Islands extended down to the surface during 18 and 19 February. In an environment of warm sea surface temperatures near 30°C and weak vertical wind shear the low began developing. Overnight on 20 February rapid development occurred with convection erupting over the low level centre. Cloud tops cooled, central convection concentration increased and cold convective bands began to wrap tightly around the centre. During this time the low commenced southeast movement, and was located about 450 km west of Rarotonga as it developed into a tropical cyclone. *Oma* continued to accelerate to the southeast and intensify, reaching storm intensity within 18 hours of tropical cyclone development. Peak intensity was then reached six hours later, before the cyclone weakened back to gale force a further six hours later. Under a strong northwesterly steering regime, *Oma* rapidly moved into New Zealand's area of responsibility and was declared extratropical by 1200 UTC 22 February, 2000 km south-southeast of Rarotonga. The extratropical circulation was tracked as far as 60°S on 24 February. During its lifecycle most of the deep convection remained in *Oma*'s eastern semicircle, with gales extending farther out in the east and northeast sectors.

Gale-force winds were recorded at Rarotonga with

Fig. 3 Tracks of Pacific tropical cyclones east of the date-line *Oma* and *Rita*. Symbols as in Fig. 1.



gusts to  $36 \text{ m s}^{-1}$ . Damage over the Southern Cooks was mainly to crops, vegetation and a couple of houses used for outside cooking which were unroofed.

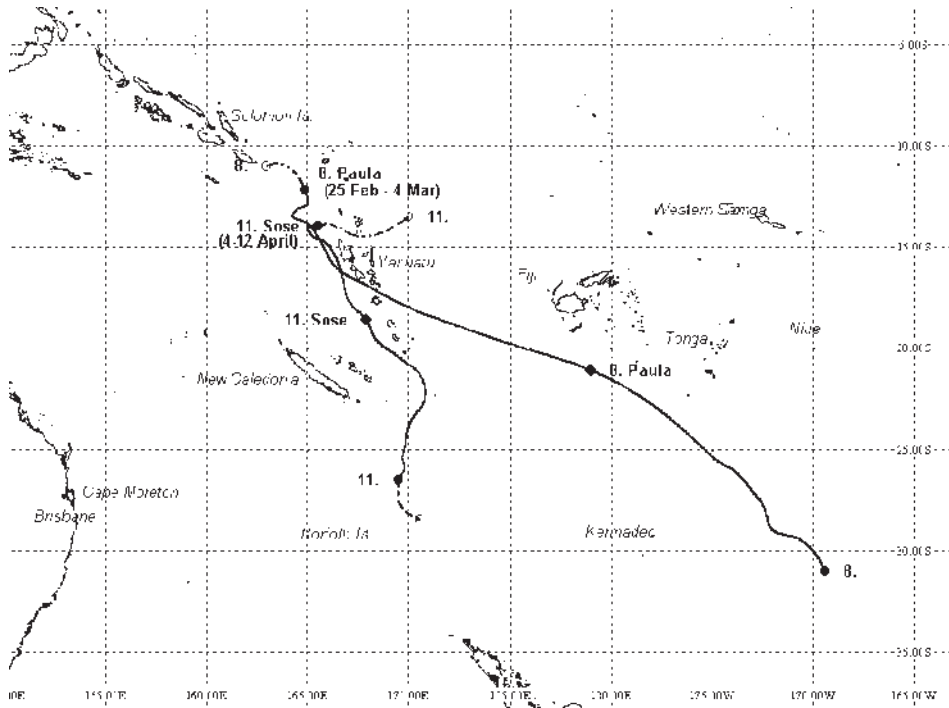
#### ***Abigail* (Brisbane/Darwin) 21 February-8 March 2001**

*Abigail* (Fig. 2) initially developed in the Coral Sea in late February, and tracked southwestward for its entire lifetime. The cyclone crossed the north Queensland coast shortly after genesis, and then redeveloped in the southern Gulf of Carpentaria. *Abigail* reached hurricane intensity before crossing the southern Gulf of Carpentaria coast. The ex-cyclone then followed a similar track to *Winsome* and *Wylva*, and traversed inland parts of the Northern Territory and Western Australia before decaying in central Western Australia.

On 21 February a broad area of low pressure lay across the northern Coral Sea. During 22 February two centres were identified. Over the following 24 hours the two centres merged and the low began to move westward towards the Queensland coast in an environment of favourable upper divergence, steered by the subtropical ridge to its south. Shortly before

reaching the north Queensland east coast, the system intensified. *Abigail* developed early on 24 February, located about 60 km east-northeast of Cairns. The cyclone crossed the coast shortly afterwards at minimal cyclone strength, and weakened quickly during landfall.

*Abigail* weakened as its middle-level circulation decoupled from the surface circulation while crossing the base of Cape York Peninsula. However it maintained its strong middle-level circulation and the cyclone quickly redeveloped upon entering the Gulf of Carpentaria by 1800 UTC 25 February. With an upper anticyclone almost overhead and a strong westerly monsoonal inflow, *Abigail* intensified rapidly as it moved to the southwest and reached hurricane strength within 12 hours of redevelopment. The eye wall of *Abigail* crossed Mornington Island, before the cyclone crossed the southern Gulf of Carpentaria coast and moved inland late on 26 February. The high over southern Australia maintained its intensity and as a result ex-*Abigail* continued to track in a general westerly direction, crossing inland through the Northern Territory and Western Australia while main-

**Fig. 4** Tracks of southwest Pacific tropical cyclones *Paula* and *Sose*. Symbols as in Fig. 1.

taining its upper structure and satellite signature for over a week. *Abigail* followed a similar inland track to that of *Winsome* and *Wylva*.

*Abigail* caused minimal impact on Cairns with local flooding and trees brought down in the northern suburbs. The centre of *Abigail* passed close to Mornington Island township in the southern Gulf of Carpentaria on 26 February. A maximum wind gust of  $33 \text{ m s}^{-1}$  was recorded at the island at the sheltered observation site. Estimated gusts were thought to be closer to  $40 \text{ m s}^{-1}$ . On Mornington Island, *Abigail* caused widespread damage to trees, with trees bringing power lines down. The impact on buildings was restricted to roofing damage. A similar strength cyclone, *Warren* in 1995, caused significantly more building damage; however it is believed that work carried out on buildings since then helped prevent widespread damage. The total estimated damage cost was \$245 000, including additional cost for transport to remote communities. At Mornington Island a storm surge reached 1.3 m and further east at Karumba there was a 1.2 m storm surge. As ex-*Abigail* moved inland through northern Australia the remnant low brought further heavy rainfall and associated extensive floods

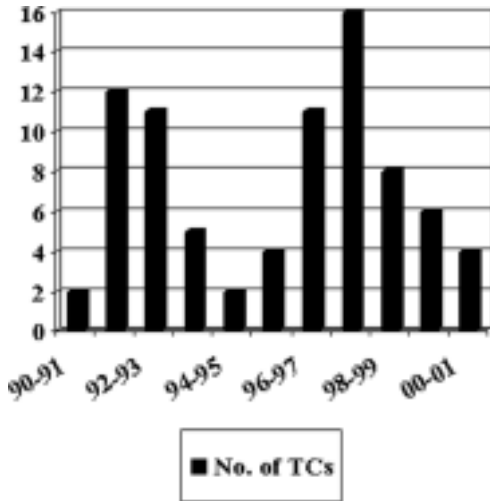
to northern Australia. Many communities cut off by the previous events remained isolated. Heavy rainfall in central Western Australia from the remnants of *Abigail* flooded the Kiwirrkurra community, and required the evacuation of 160 residents.

#### ***Paula* (Nadi) 25 February – 4 March 2001**

*Paula* (Fig. 4) developed in the South Pacific in late February during a particularly active phase of the MJO. The cyclone was the only South Pacific cyclone for the season to reach hurricane intensity. During its five day existence *Paula* caused much damage to Vanuatu and the capital Port Vila as it crossed over the centre of the island nation. The cyclone also caused damage to the Solomon Islands, Fiji and Tonga from the effects of both wind and high seas pounding coastlines.

A low was first identified embedded within the active monsoon trough located between the Solomon Islands and Vanuatu on 25 February. The low was located under an upper outflow centre. Convection began concentrating around the system with increased curvature appearing in the convective bands on 26 February. Gales were observed in the northeastern

**Fig. 5 Tropical cyclone Activity in RSMC Nadi area of responsibility in the last 10 seasons.**



semicircle only as *Paula* developed on 26 February while located 350 km northwest of the northern Vanuatu island of Espiritu Santo.

*Paula* initially moved to the south, then under a weak steering current began to describe a clockwise loop. While completing the loop storm, intensity was reached and the cyclone developed a small central dense overcast with a ragged eye-like feature during 27 February. At 1200 UTC 27 February hurricane intensity was attained, within 30 hours of initial cyclone development, as the eye was becoming better defined and with marked increase in overall organisation and convection. The cyclone was then located about 170 km northwest of Espiritu Santo and beginning to accelerate southeast while still intensifying.

The cyclone tracked southeast, towards and then through Vanuatu's island chain as it rapidly intensified. *Paula* moved just north of Vanuatu's capital Port Vila with a maximum mean wind speed of  $44 \text{ m s}^{-1}$  recorded at Port Vila meteorological station at 1200 UTC 28 February. Gales extended 250 km from the centre in the northeast quadrant and 180 km elsewhere.

*Paula* continued to track to the southeast, passing about 170 km south-southwest of Kadavu Island, Fiji, on 1 March. A peak intensity of  $49 \text{ m s}^{-1}$  was reached shortly after this time, with gales extending up to 260 km from the centre, and storm-force winds extending up to 120 km from the centre. The northwesterly steering flow strengthened further and *Paula* weak-

ened rapidly as it became sheared in this environment south of Fiji. *Paula* passed about 350 km south of Tonga and weakened to minimal hurricane intensity by 3 March. The cyclone became extratropical on 4 March, 1700 km east-northeast of the northern tip of New Zealand.

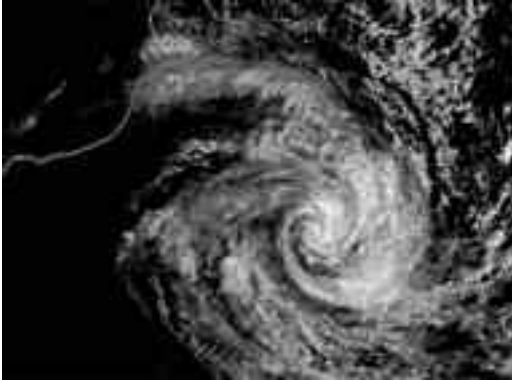
The destructive eyewall of *Paula* passed over the Vanuatu islands of Espiritu Santo, southern Malakula, Epi, the Shepherd group (including Emae and Tongoa) and North Efate late on 27 February and during 28 February. Many locally styled houses, gardens and tree crops were destroyed. Around 45-50% of homes and gardens, 35% of water supplies, 20% of schools, 15% of medical centres and 25% of other infrastructure items were destroyed in the most affected provinces of Malampa and Shefa provinces in central Vanuatu. Many yachts in Port Vila were either sunk or set adrift and a number of small coastal ships were forced aground. One death was reported in central Vanuatu. As *Paula* passed to the south of Fiji, damage to the country was primarily sustained from the effects of storm surge and high seas along the coastline. Heavy rainfall also caused havoc with associated flooding and landslides. Strong winds and high waves caused the destruction of homes and damage to crops along the Coral (southern) Coast of Viti Levu. A preliminary assessment in these areas estimated a damage total of around \$2-3 million (Fijian). Minor landslides were also reported, and roads were closed due to floods, fallen trees and sea-borne debris. Some damage to buildings and crops was also experienced in the Southern Lau group in the eastern division of Fiji. While at peak intensity *Paula* was located about 650 km west of Tonga, and passed about 350 km to the south as it was weakening during 2 and 3 March. In Tonga extensive damage resulted from pounding surf to the Good Samaritan Resort at Kolovai on the west coast of Tongatapu and a wharf on the nearby island of 'Eau.

#### **Rita (Nadi) 27 February – 5 March 2001**

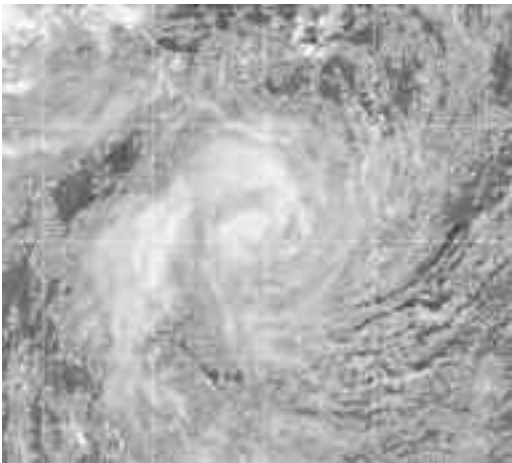
*Rita* (Fig. 3) formed in early March well east of the date-line in the Tuamotu Archipelago east of Tahiti. The cyclone never intensified beyond gale force, being sheared most of its lifetime. *Rita* formed during an active ISO phase as *Paula* was intensifying to the west.

A low was first identified in the active SPCZ on 27 February just southeast of Hao in the Tuamotu Archipelago. The system was drifting to the southeast and experiencing slight shear, being positioned slightly to the north of a diffluent upper ridge. During the next day the system was significantly influenced by southerly wind shear, which displaced its cloud canopy to the north and exposed the low

**Fig. 6** Tropical cyclone *Sam*, inland over Western Australia (GMS-5).



**Fig. 7** Ex-tropical cyclone *Winsome*, inland near the Northern Territory/West Australia border, 13 February 0130 UTC, 36 hours after coastal crossing (visible imagery GMS-5).



level circulation centre to the south. Deep convection developed near the centre overnight on 28 February against the shear. With an active MJO in the south Pacific, sea-surface temperatures near 30°C, and central convection deepening, tropical cyclone *Rita* formed on 1 March located about 400 km to the northeast of Mururoa in French Polynesia. *Rita* continued to move slowly south-southeast, with northwesterly upper shear slowing intensification

during 2 March as peak intensity was attained. The cyclone then came under the influence of a strong subtropical ridge, which now steered *Rita* to the south-southwest. The island of Rikitea experienced gales as the centre of *Rita* passed 25 km to the north-west. The system continued at gale-force intensity for several days as it tracked to the south-southwest, becoming extratropical on 5 March 1000 km south-southwest of Pitcairn Island.

No reports of significant damage were received from the Tuamotu Islands and Rikitea.

#### **Walter (Perth) 1-8 April 2001**

*Walter* (Fig. 1) developed in the Indian Ocean between Christmas Island and the Indonesian island of Java in early April. *Walter* travelled westward and reached hurricane intensity before passing northwest of Cocos Island. The cyclone then travelled south before dissipating in the central Indian Ocean.

A middle-level low tracked westwards from northern parts of Australia late in March. A surface low developed below this feature in the northern Indian Ocean, just south of Java. Convection associated with the middle-level low developed cyclonic banding within 24 hours of the surface low developing. A middle-level ridge to the south of the system pushed the low westward. The low intensified with increasing low-level vorticity which, combined with a slight weakening in upper-level shear, led to the intensification of the system to cyclone intensity on 2 April. *Walter* continued to track westward and passed just to the north of Christmas Island. Hurricane intensity was reached on 4 April as *Walter* steered to the southwest and before the cyclone passed to the north and west of Cocos Island. A trough in the middle levels approached from the west, steering *Walter* towards the south-southwest. This trough continued to amplify in the middle levels and captured the system on 7 April. The system began to weaken through the effects of an increasing upper-level northerly shear. On 8 April, the low-level circulation was exposed as the deep convection was completely sheared. *Walter* fell below cyclone intensity on 8 April in the central Indian Ocean.

During the passage of *Walter* 70 km to the north-west of Cocos Island, maximum mean wind speed recorded at the airport was 23 m s<sup>-1</sup> with a gust of 29 m s<sup>-1</sup> recorded at 3 pm WST on 5 April. Cocos Island recorded a total of 170 mm, with 121.6 mm falling in 24 hours to 9 am WST on 6 April. Minor tree damage was reported.

#### **Sose (Nadi) 4-12 April 2001**

The final tropical cyclone in the South Pacific for the 2000/01 season occurred during April. *Sose* (Fig. 4)

formed just to the north of Vanuatu, moved southeastward and reached storm intensity near southern Vanuatu, before passing to the east of New Caledonia, moving further south and becoming extratropical. Two deaths were reported from Vanuatu and New Caledonia, and two from the southern Queensland coast where huge easterly swells resulted from the tight pressure gradient between *Sose* and a strong high pressure system near New Zealand.

A weak disturbance was first identified on 4 April located about 400 km east-northeast of Espiritu Santo, Vanuatu. Shear over the system eased over several days allowing organisation of the deep convection, with cyclone development occurring on 5 April about 140 km northwest of the northern tip of Espiritu Santo, as *Sose* moved slowly westward. During 6 April *Sose* slowly intensified, development being limited by shear and frictional interference from the mountainous landmass of Espiritu Santo, about 180 km to the east-southeast. The cyclone remained near stationary in this area for about 24 hours, before an intense middle-level subtropical ridge to the south was eroded by an approaching middle-level trough. Under this influence *Sose* commenced moving to the southeast. Upper outflow improved and storm intensity was reached on 7 April while *Sose* was located about 100 km due west of the northernmost tip of Espiritu Santo. Convection had erupted around the central area, resulting in the formation of a central dense overcast, which by 8 April had become more compact with spiral bands wrapping tightly around it. *Sose* reached its peak intensity of  $31 \text{ m s}^{-1}$  at this time. Concurrently a slow-moving surface subtropical high near New Zealand tightened the pressure gradient 700 to 1000 km south of the system. Consequently, gales developed outside the cyclone's circulation; however, this area of gales gradually diminished as *Sose* lost intensity while continuing further poleward. As *Sose* steadily tracked to the southeast, increasing vertical shear resulted from an approaching upper trough. A strong middle-level ridge blocked the cyclone's southeast track, steering it due south. This resulted in the shearing off of central convective tops to the southeast while the low-level centre was steered southward. *Sose* then weakened to gale force on 10 April when it was about 350 km to the southeast of New Caledonia, drifting south-southwestward. *Sose* then became extratropical roughly 300 km north-northeast of Norfolk Island.

A six-year-old boy was swept away whilst trying to cross a swollen river at Nawalala Village on Espiritu Santo with his father. An inter-island vessel, the *M.V. Omale*, sank in heavy seas off the coast of Malo Island near Espiritu Santo. All 16 passengers and crew made it ashore safely after four hours in the

water. Villages on the south coast of Espiritu Santo and in the vicinity of Luganville, the main town, suffered flooding which cut off roads and further damaged crops, particularly bananas, yams, taro and manioc, already adversely affected by the previous tropical cyclone, *Paula*. Sixty people were evacuated from flooded areas, some 59 houses were completely destroyed and 101 houses partially damaged by the wind. On tiny Ahamb Island next to Malekula, four classrooms and all food crops left after tropical cyclone *Paula*, plus those planted since, were destroyed. On Ambae, buildings were damaged and at least two schools lost classrooms. In Port Vila, the capital on Efate Island, 50 people were evacuated as the waters rose. Power lines were brought down and roads were blocked by debris and floodwaters. Water catchment areas and reservoirs were also blocked by debris and damaged. Schools were particularly affected, as many lost their subsistence plots and a number of classrooms. On the island of Mare in New Caledonia, a 37-year-old man was missing and feared drowned after he was swept away by a large wave while watching huge waves crash into the island's high cliffs. *Sose*'s large circulation, combined with the effect of a high pressure system near New Zealand, generated huge waves that battered portions of Australia's east coast. Waves up to 8 metres were recorded at Cape Moreton and 4-5 metre waves battered the Gold and Sunshine Coasts. There were two cases of drowning reported on the southern Queensland coast on 8 April when large swells were forced into an area usually protected from southeasterly swells.

#### ***Alistair* (Darwin and Perth) (15-24) April 2001**

*Alistair* (Fig. 1) developed in the Arafura Sea and traversed over 3000 km through the Arafura Sea, Timor Sea and Indian Ocean parallel to the Australian coastline, without a coastal crossing. The cyclone reached storm force during its lifetime, with further intensification being inhibited by easterly shear in the middle levels.

Following the demise of *Walter* the major focus of monsoonal activity shifted to the north of Australia. An equatorial westerly wind burst developed by mid-April and this spawned twin depressions – one on each side of the Equator. The northern system did not develop to tropical cyclone intensity. The southern system first appeared as a low to mid-level circulation in the eastern Arafura Sea near Irian Jaya on 14 April. A strong ridge persisted with depth over the Australian continent and maintained easterly winds into the monsoon trough, enhancing convergence and convection in the area and keeping the trough to the north of Australia. The low was in a weak-to-moder-

ate easterly wind shear environment with the upper ridge located just to the south of the trough. Convection increased during 15 April with banding improving on 16 April and the circulation being analysed from the surface to 500 hPa. The low commenced moving to the west southwest and reached cyclone strength at 1900 UTC on 16 April while located in the southern Arafura Sea.

The system tracked steadily southwest and brushed past the Cobourg Peninsula and Tiwi Islands in the Northern Territory as it deepened. *Alistair* continued its southwest track under the influence of a strong middle-level high over the Australian continent. It moved through the Timor Sea while intensifying to storm force. The cyclone passed close to Troughton Island and the northwest Kimberley coast on 18 April, with peak recorded mean winds of  $24 \text{ m s}^{-1}$  gusting to  $30 \text{ m s}^{-1}$ .

As *Alistair* moved into the Indian Ocean it experienced increasing shear and the deep convection became displaced to the southeast of the low-level centre. At this time *Alistair* encountered a weakness in the ridge that caused it to slow and move in a more southerly direction. By 22 April the low-level centre was completely exposed and convection was limited to outbursts in the southeast quadrant. Although the system had very limited deep convection for several days it maintained a well organised low-level circulation. The system then began to move southeast under the influence of middle-level northwesterly winds, indicating that it was still being steered by mid-level winds despite having little deep convection associated with it. Convection began to rebuild on the southeast side as it moved towards the Western Australian coast, crossing close to Carnarvon on 24 April. The centre passed just to the north of the town with a peak wind gust of  $25 \text{ m s}^{-1}$  from the southeast. *Alistair* weakened rapidly upon landfall.

*Alistair* caused minor damage to vegetation on the Tiwi Islands in the Northern Territory. Ellavalla Station reported 114 mm of rainfall, with falls of 70 mm at Calagiddy Station and 24 mm in Carnarvon. Crop losses of 30-40 per cent were reported in plantations to the north of town, with wind gust estimates of  $28\text{-}30 \text{ m s}^{-1}$ .

## Acknowledgments

The authors would like to thank the staff of the Fiji RSMC and the Australian TCWCs for providing individual cyclone reports, a seasonal report in the case of Fiji, plus clarification and additional information when requested. The climatology of tropical cyclone occurrences for the Pacific extending over the last 30

years was obtained from the Fiji RSMC (A. Waqaicelua, personal communication). The Australian region average error statistics were obtained from the Australian Bureau of Meteorology's database (J. Gill, personal communication). The Australian Tropical Cyclone Workstation was used in the preparation of the cyclone track diagrams. Satellite imagery displayed in figures 6 and 7 was from Japan Meteorological Agency's geostationary meteorological satellite GMS-5.

## Appendix

### Data sources

- *Darwin Tropical Diagnostic Statement*, October 2000 to April 2001 (Volume 19, Nos 10-12, Volume 20 Nos 1-4) Bureau of Meteorology, Northern Territory Region, PO Box 40050, Casuarina, Northern Territory, 0811, Australia.
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