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The South Pacific and southeast Indian Ocean tropical cyclone season 2003-04

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Twelve tropical cyclones (TCs) formed in the combined southeast Indian Ocean and South Pacific Ocean basins, all of which formed between December and March. This was well below the long-term average of 18.9 and becomes the fifth consecutive year of below average occurrences of TCs over this region. However, of the 20 TCs to occur in the southern hemisphere as a whole, eight of those became intense tropical cyclones (ITC), resulting in an above average number of ITCs and ITC days in the southern hemisphere. The El Niño Southern – Oscillation (ENSO) should not have been a modulating influence, in this ENSO-neutral season. The majority of TCs coincided with active phases of the Madden-Julian Oscillation (MJO).

Introduction

This paper provides a summary of the tropical cyclone (TC) activity in the southeast Indian Ocean (east of 90°E) extending eastward to the South Pacific Ocean (west of 120°W) during the 2003-04 tropical 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.

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 within the Darwin RSMC area of responsibility (70°E to 180°E) see the seasonal summary by Shaik and Cleland (2004). Where not specified, wind speeds referred to are ten-minute averages.

Tropical cyclone occurrence

The 2003/2004 season saw just 12 tropical cyclones in the combined southeast Indian Ocean and South Pacific Ocean basins, all of which formed between December and March. This was well below the long-term average of 18.9 and becomes the fifth consecutive year of below average occurrences of TCs in these basins. In fact, between the 1970-71 season and the 2003-04 season, there have only been three years when there have been fewer (1994-95 (9), 1987-88 (10) and 1990-91 (11) (Bannister and Smith 1993)). Table 1 shows a summary of each TC that occurred during the season, while Table 2 compares the occurrence of TCs and TC days in each of the basins with the long-term mean. Additional data for Table 2 was obtained from La Reunion RSMC for TCs that occurred in the southwest Indian Ocean basin so that a comparison of TC activity across the southern hemisphere could be made.

TC occurrence in the South Pacific basin was much less than normal, with only two TCs developing between 160°E and 120°W and a third, *Grace*, moving into the area from west of 160°E. This compares to the long-term average of 8.6 and is in stark contrast

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Table 1. Tropical cyclones in the South Pacific and southeast Indian Oceans during the 2003-04 season.

	Low first identified			*Initial tropical cyclone phase*			
Name	*Date*	*Latitude*	*Longitude*	*Date*	*Time (UTC)*	*Latitude*	*Longitude*
Jana	6 Dec	7.0°S	93.2°E	7 Dec	0000	7.6°S	95.9°E
Debbie	16 Dec	10.0°S	140.4°E	18 Dec	1500	9.8°S	135.5°E
Heta	25 Dec	15.0°S	176.5°E	2 Jan	0000	8.0°S	174.2°W
Linda	28 Jan	7.2°S	91.5°E	30 Jan	0000	11.0°S	95.4°E
Fritz	10 Feb	13.8°S	146.7°E	10 Feb	1200	14.3°S	145.4°E
Ivy	21 Feb	16.2°S	173.0°E	23 Feb	0300	15.0°S	172.5°E
Monty	25 Feb	17.8°S	124.5°E	27 Feb	0900	19.2°S	119.8°E
Evan	27 Feb	12.8°S	141.5°E	1 Mar	0800	13.8°S	137.0°E
Nicky (Helma)	8 Mar	13.4°S	90.8°E	9 Mar	0600	13.3°S	90.6°E
Fay	12 Mar	11.0°S	146.0°E	16 Mar	0900	11.6°S	128.2°E
Grace	20 Mar	16.6°S	149.3°E	20 Mar	1800	16.6°S	149.3°E
Oscar (Itseng)	21 Mar	12.0°S	103.5°E	23 Mar	0900	14.3°S	98.9°E

	Maximum Intensity					*End tropical cyclone phase*			
Name	*Date*	*Time (UTC)*	*Latitude*	*Longitude*	*Mean wind m/s (knots)*	*Date*	*Time (UTC)*	*Latitude*	*Longitude*
Jana	9 Dec	1200	12.0°S	99.4°E	44 (85)	11 Dec	1200	14.9°S	95.6°E
Debbie	19 Dec	1500	10.4°S	134.4°E	33 (65)	21 Dec	0000	13.1°S	133.8°E
Heta	5 Jan	0000	13.9°S	174.1°W	59 (115)	8 Jan	0000	30.1°S	160.1°W
Linda	31 Jan	0000	14.7°S	95.9°E	26 (50)	1 Feb	0600	18.4°S	95.3°E
Fritz	12 Feb	0000	16.7°S	139.7°E	25 (49)	12 Feb	1500	17.0°S	138.1°E
Ivy	25 Feb	1800	16.3°S	167.8°E	46 (90)	28 Feb	1200	31.1°S	174.8°E
Monty	29 Feb	0900	19.7°S	115.7°E	51 (100)	2 Mar	2100	24.7°S	117.8°E
Evan	1 Mar	0800	13.8°S	137.0°E	18 (35)	1 Mar	1200	14.0°S	136.5°E
Nicky (Helma)	11 Mar	0000	17.2°S	88.8°E	31 (60)	13 Mar	0000	21.3°S	84.2°E
Fay	21 Mar	0600	13.6°S	122.8°E	59 (115)	28 Mar	1200	21.5°S	120.9°E
Grace	22 Mar	0000	20.3°S	155.3°E	26 (50)	23 Mar	1800	22.9°S	161.8°E
Oscar (Itseng)	26 Mar	0000	17.0°S	92.4°E	46 (90)	28 Mar	0600	19.5°S	89.2°E

Table 2. Tropical cyclone occurrence within the southern hemisphere during the 2003-04 season. Long-term means are based on data from the 1970-71 to 2003-04 seasons and are shown in parentheses. STC indicates severe tropical cyclones (maximum wind speed >=33 m s^{-1}) and ITC indicates intense tropical cyclones (maximum wind speed >44 m s^{-1}).

	SWI (West of 90°E)	*AUW (90°E-135°E)*	*AUE (135°E-160°E)*	*AUS (90°E-160°E)*	*South Pacific (East of 160°E)*	*AUS-SPA (90°E-120°W)*	*Southern hemisphere*
TC	10 (11.4)	7 (8.4)	4 (5.1)	10 (12.8)	3 (8.6)	12 (18.9)	20 (28.9)
STC	4 (5.7)	5 (4.3)	0 (2.0)	5 (6.3)	2 (4.1)	7	11 (14.7)
ITC	3 (2.5)	3 (1.9)	0 (0.7)	3 (2.5)	2 (1.7)	5	8 (6.4)
TC days	47 (57.2)	29 (32.6)	8 (17.5)	33 (49.7)	15 (31.7)	43	77 (138.8)
STS days	14 (19.6)	16 (10.8)	0 (4.3)	16 (15.1)	8 (10.9)	24	40 (45.8)
ITC days	9 (4.9)	6 (2.7)	0 (0.9)	6 (3.6)	5 (2.7)	11	20 (11.4)

to the previous season, in which there were 10 TCs (Courtney 2005) within the basin. This shortfall is a large contributor to the below average TC numbers for the broader region, although it is worth noting that TC numbers were below the long-term mean in each of the regions discussed. Of the three TCs to occur within the South Pacific basin, two of these (*Heta* and *Ivy*) developed into intense TCs (ITC), which was just above the long-term average for ITCs in that area. Similarly, the occurrence of TCs in the Australian region (90°E to 160°E) was below the long-term average but the occurrence of ITCs was above the long-term average. This was similar throughout the southern hemisphere, with only 1990-91 recording less than this season, with 19 TCs. Interestingly, of the four TCs to develop over eastern Australia (135°E to 160°E) none were severe TCs (STC) or ITCs, although *Debbie*, which developed in the eastern Australian region, later intensified into a STC after moving further west.

Both the Australian and South Pacific areas experienced a below-average number of TC days. In particular, eastern Australia and the South Pacific were well below their long-term mean number of TC days. The number of TCs in western longitudes (western Australia and the southwest Indian Ocean) was closer to the average. Strikingly, aided by the deficiency in TC days in eastern longitudes, the southern hemisphere as a whole recorded its lowest number of TC days on record (since 1970/1971) with just 77 days. This compares to the long-term average of 138.8 days. However, of the 20 TCs to occur in the southern hemisphere, eight of those became ITCs, resulting in a total of 20 ITC days in the southern hemisphere and this was the fifth highest on record (since 1970-71).

Impacts

Of the twelve tropical cyclones that occurred in the southeast Indian and South Pacific Oceans for 2003-04, eight cyclones are known to have had some impact on land areas. Of these, several caused extensive flood damage, often occurring as the system moved over land and persisted as a rain depression. Seemingly, the two most destructive tropical cyclones for the season were *Ivy* and *Heta*, both resulting in human fatality and extensive structural and agricultural damage.

TC *Heta* appears to have had the most widespread and destructive impact. *Heta* formed just north of Fiji, rapidly developing and passing close to Tokelau, Wallis and Futuna, Samoa, American Samoa, Tonga and Niue while at its most intense. The island nation of Niue suffered severe and extensive damage as a result of Heta, including to the commercial area of the capital. Buildings one hundred metres from the coast were destroyed by destructive seas, and two fatalities were reported. The damage to Niue was estimated at NZD50 million. *Heta* also caused significant damage to Samoa, where there was another reported fatality. Much of the destruction caused by *Heta* was a result of high seas and flooding, in addition to the destructive winds.

The tropical depression which developed near Fiji around 7 April (22P) was responsible for several deaths in Fiji as flooding caused by heavy rainfall associated with the system resulted in significant damage north of the city of Suva. It has been included in this discussion because of its high impact.

TC *Ivy* formed in the South Pacific and reached Australian intensity category four before tracking over the islands of Vanuatu. There was one recorded fatality as a result of the impact of *Ivy*. Over 2000 residents had to be evacuated from their homes in the city of Port Vila. Many of the 24 000 residents of Vanuatu's central islands lost their homes and most if not all mango and banana crops were damaged. Other crops such as coconut and cocoa suffered, with around 75 per cent of these crops destroyed.

The remaining land-falling cyclones all made landfall over northern Australia along relatively sparsely inhabited parts of the coastline. TCs *Debbie*, *Fritz*, *Monty*, *Evan* and *Fay* all caused significant flooding after landfall, affecting some communities and often causing roads to be cut. Minor structural damage occurred in two north coast communities due to the winds associated with *Debbie*, while *Monty* caused a couple of vessels to break their moorings and run aground. *Evan* caused a boat to sink as well as some structural damage to the community on Groote Eylandt. *Fay* caused significant damage to some reef systems off the Kimberley coast and also disruption to some remote pastoral and mining operations.

Broadscale features

The season was characterised by an ENSO-neutral phase. Multi-month means of the Troup Southern Oscillation Index (SOI) were confined to small values, however large fluctuations in the monthly SOI were evident during the season, with values oscillating between +10 and –15. Such fluctuations are suggested to be in response to the strong signal of the MJO (Shaik and Cleland 2004). The five-month mean SOI for the season remained between zero and –2.

Sea-surface temperatures (SSTs) near the South American coast were close to climatology and all Niño indices were close to zero, consistent with a neutral ENSO phase. The warmest anomalies in the Indian Ocean were over the southern Indian Ocean where the MSLP remained higher than normal, whilst the warmest waters in the equatorial Pacific remained mostly west of the date-line (Shaik and Cleland 2004).

The mean anomaly of outgoing long wave radiation (OLR), which is used as a proxy for convection is shown in Shaik and Cleland (2004). The figure indicates there was roughly normal convective activity over the equatorial longitudes west of 140˚E, whilst in the northwestern Pacific including equatorial regions east of Papua New Guinea, convective activity was above average throughout most of the season. The OLR anomalies indicate above average convection during December 2003, February and March 2004 over the maritime continent and near the equatorial date-line during January and April 2004 (Shaik and Cleland 2004).

Pressures were generally above average over the central longitudes of the tropics with small negative anomalies to the east of 170°E and in the equatorial Indian Ocean (Shaik and Cleland 2004).

The velocity potential analyses showed good vertical alignment of the axes of maximum low-level convergence and upper-level divergence, indicating a well-organised up-motion of a vigorous Hadley circulation in the western Pacific whereas poor vertical alignment over the Indian subcontinent represented the below average convection over that area (Shaik and Cleland 2004).

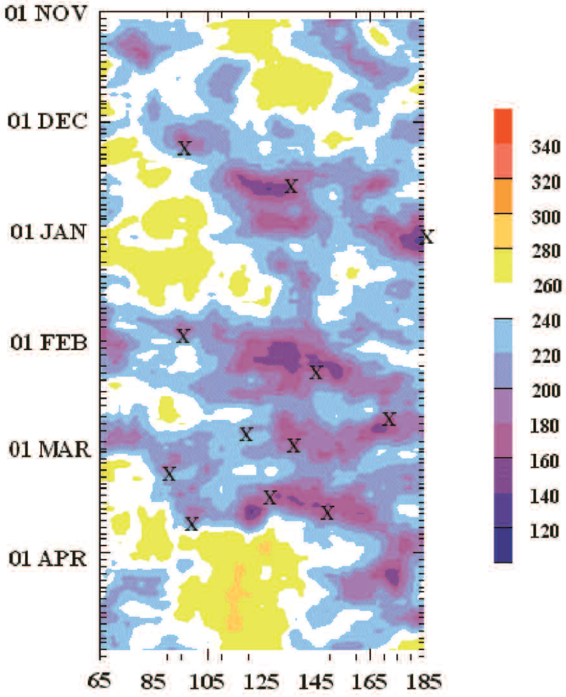
Further details of the seasonal features are discussed in Shaik and Cleland (2004).

Intraseasonal modulation

Intraseasonal variability can be identified from time-longitude plots of OLR, 200 hPa velocity potential and sea-level pressure anomaly all shown in Shaik and Cleland (2004). The time-longitude plots clearly indicated three major active phases of the MJO progressing through the RSMC region. One occurred during mid-December, another during early February whilst the third during mid-March (Shaik and Cleland 2004). The period of these active events remained about 45 days and in addition to these major events there were several weak convective pulses which occurred in the eastern half of the region. Shaik and Cleland (2004) suggest this may have been related to the progression of equatorially trapped Rossby waves through the region. The mean sea-level pressure anomaly series suggested the three distinct active phases of the MJO as described above, however it also suggested another weaker event during early to mid-November (Shaik and Cleland 2004).

Jana, *Debbie* and *Heta* can all be associated with the active MJO phase that progressed across the region in December. Similarly *Linda*, *Fritz* and *Ivy* developed during the progression of the next active phase, and *Nicky*, *Fay* and *Grace* during the March active MJO phase. Three TCs formed outside of active MJO phases. *Monty* and *Evan* both formed in what may have been a westward-propagating equatorial Rossby wave, emanating from the 'tail-end' of an active MJO phase in the western Pacific, while *Oscar* formed outside of an MJO envelope, when the convective activity in the Indian Ocean persisted even as the MJO envelope propagated away to the east.

Fig. 1 Filtered anomalies of outgoing long wave radiation, averaged over latitudes 2.5°S to 17.5°S for November 2003 to end April 2004. Contour interval is 20 Wm^{-2}. Locations of cyclogenesis events are indicated.



Tropical cyclones in the South Pacific and southeast Indian Oceans 2003-04

Jana (Perth) 6 December – 11 December

Jana (Fig. 2) was the first cyclone to form for the season 2003-04. A tropical low developed within an active monsoon trough north of the Cocos Islands on 6 December. The low developed rapidly, reaching tropical cyclone intensity on 7 December as it tracked eastwards. On 8 December *Jana* reached severe tropical cyclone intensity and began tracking southwards for the next 48 hours, passing 280 kilometres to the east of Cocos Islands. On 10 December *Jana* began to weaken and track westwards, decaying to a tropical low late on 11 December.

Jana formed within an active phase of the MJO that moved into these latitudes early in December. An active monsoon trough, combined with favourable low-level cross-equatorial inflow, a low shear envi-

Table 3. Position forecast verification statistics for official warnings issued by relevant warning centres. Forecast positions are verified against the official best track.

	Forecast Lead Time							
	0 hour		*12 hour*		*24 hour*		*48 hour*	
Name	*error (km)*	*number*	*error (km)*	*number*	*error (km)*	*number*	*error (km)*	*number*
Jana	33	27	74	16	145	21	255	5
Debbie	18	16	82	16	139	15	-	-
Heta	3	21	63	18	112	16	-	-
Linda	44	23	67	14	132	17	233	3
Fritz	29	8	116	8	151	6	-	-
Ivy	7	20	89	18	129	14	-	-
Monty	15	27	45	15	85	20	168	5
Evan	40	2	93	2	-	-	-	-
Nicky (Helma)	34	13	66	8	97	7	-	-
Fay	27	62	72	41	116	55	217	14
Grace	34	10	126	8	128	6	240	2
Oscar (Itseng)	39	27	63	17	96	21	169	4
Total		256		181		198		33
Weighted mean	26		75		118		212	

ronment and good upper-level outflow to the south resulted in the initial rapid development of the system. The steering flow associated with a mid-level ridge to the east-southeast caused *Jana* to track southward, and it was during this southward movement that *Jana* reached its maximum intensity of approximately 85 knots, with gusts to 120 knots. At this stage an eye could be identified on microwave imagery, but was obscured in infrared satellite pictures.

As *Jana* moved south over cooler waters conditions became less favourable, and the system began to weaken. Its position from beneath the upper ridge shifted, with a decrease in upper level divergence and an increase in northerly wind shear. A decrease in convection exposed the low-level centre of the system, and *Jana* weakened to below cyclone intensity on 11 December. The system continued to move westwards as an identifiable low for another week, but never re-intensified.

Jana remained over water for its entire duration. Tropical Cyclone Advices were issued for Cocos Islands, though maximum winds recorded at Cocos were 25 knots while *Jana* was at its most intense and closest to the Islands. No known damage was caused.

***Debbie* (Darwin) 16 December – 23 December**

Debbie (Fig. 3) formed on 18 December in the Arafura Sea, within 250 kilometres of the northern Australian coast. *Debbie* tracked southwest, intensifying to severe tropical cyclone strength early on 20 December. During the afternoon of 20 December, *Debbie* shifted to a more southerly track, began to weaken slightly and then crossed the Northern Territory coast in the evening between Goulburn Island and Maningrida. *Debbie* continued to move south over land, decaying into a rain depression on the morning of 21 December and continuing southwestwards over land for the next few days.

A tropical low formed within the monsoon trough on 16 December, as an MJO pulse propagated into the region. Under the influence of a low to mid-level easterly airstream the low moved slowly west. A deep easterly surge, combined with decreasing upper-level shear, created favourable conditions for the low to slowly develop while continuing westward. On 18 December the low slowed and began moving to the southwest, as it came under the increasing influence of the monsoonal westerlies. *Debbie* reached cyclone intensity on 18 December and continued tracking to the southwest. Just prior to landfall *Debbie* began to weaken as a result of restricted upper outflow. *Debbie* also came under the influence of some weak vertical wind shear, and sustained possible entrainment of dry air before landfall. During the evening of 20 December *Debbie* crossed the northern Australian coast and weakened to a rain depression early on 21 December.

As *Debbie* crossed a sparsely populated section of the coast, no significant structural damage occurred to townships. The communities of Warruwi (on Goulburn Island) and Maningrida suffered some minor structural damage such as lifted sheets of roofing iron. Warruwi sustained tree damage to power lines, with interruptions to both power and water supplies following *Debbie*'s landfall. The region exposed to *Debbie*'s core sustained severe vegetation damage, with 30-40 per cent of trees felled in the area. As the rain depression tracked southwest over the Northern Territory Top End and finally into the Kimberley region of Western Australia, heavy rainfall caused significant rises in river levels with localised flooding in many areas. Charles Point, near Darwin, received 197 mm on 22 December, while Tindal, near Katherine, received 284 mm on 23 December. Roads were cut at the Cullen and Waterhouse Rivers due to flooding.

***Heta* (Nadi) 28 December – 8 January**

Heta (Fig. 4) developed into a very intense tropical cyclone in the southwest Pacific, causing widespread destruction. *Heta* was the most damaging of all the cyclones in the 2003-04 season in this region. It affected a number of regions, including Tokelau, Wallis and Futuna, Samoa, American Samoa, Tonga and Niue. Samoa and Tonga sustained significant damage, but it was the island of Niue that suffered the most severe damage and flooding due to the impact of *Heta*.

A tropical depression was analysed on 28 December just north of Fiji, with development coincident with an active MJO phase. The system moved northeastward while steadily intensifying. In an environment of low shear and favourable upper-level divergence the system deepened and was named *Heta* on 2 January. *Heta* continued to rapidly intensify, with the establishment of extensive dual outflow channels. It began to track slowly southwards as it moved into a weak northerly steering flow, attaining severe tropical cyclone intensity on 3 January.

Heta was passing within 80 nautical miles to the southwest of Savai'i in Samoa on 5 January when it reached its peak intensity, with mean winds of about 115 knots and gusts to 160 knots. This intensity was maintained for the next 24 hours as *Heta* tracked to the southeast and its speed of movement accelerated to 20 knots. During this period, *Heta* passed within 50 nautical miles to the northeast of Niuatoputapu in the northern Tonga Group, and then passed within 40 nautical miles to the west of Niue. Following its destructive path over these regions, *Heta* began to gradually weaken as it continued to the southeast and eventually moved into Wellington's area of responsibility on 7 January. The system then transitioned to an extratropical low on 8 January.

The severe impact from *Heta* was a combination of the destructive winds and storm surge. Niuatoputapu experienced storm force winds, while Niue suffered the brunt of very destructive hurricane force winds. Prior to the failure of meteorological instruments on Niue, average winds of 80 knots and a maximum gust of 107 knots were recorded.

Samoa suffered extensive damage to housing, power lines and crops as a result of both the winds and the heavy swells and storm surge produced by *Heta*. Significant to this system was the proportion of damage that occurred as a result of the heavy swells, enormous waves and coastal flooding of the Pacific Island nations it affected. In Samoa one person was swept out to sea and presumed dead.

In Niue, the capital Alofi suffered extensive damage. Two fatalities were reported. Communication to and from Niue was completely cut off for a number of days following the passage of *Heta*. Much of the island infrastructure was damaged. Total damage on Niue has been estimated at NZD50 m.

***Linda* (Perth) 28 January – 1 February**

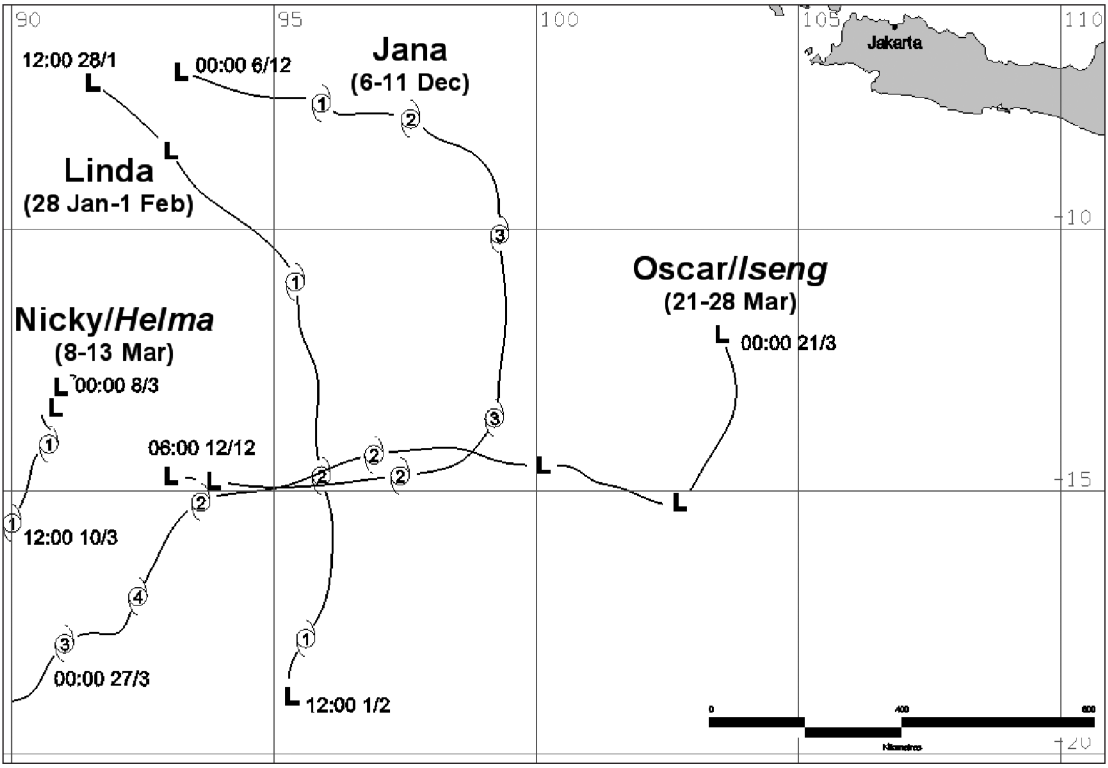
Linda (Fig. 2) was a short-lived system that remained over the Indian Ocean for its lifetime. On 28 January a weak low was identified in the monsoon trough to the northwest of the Cocos Islands. The environment was initially not ideal for development, with moderate easterly shear. Under the influence of a strong ridge to the east and a mid-latitude trough to the south the tropical low tracked to the south, moving into a weaker shear environment. This weaker shear combined with favourable upper-level divergence, resulted in *Linda* developing to cyclone intensity early on 30 January.

Linda continued to track southwards, slowly intensifying, and passed about 110km west of the Cocos Islands at about 1000 UTC on 30 January. Wind observations at Cocos were less than 20 knots, and no damage occurred. On 31 January, *Linda* briefly attained Australian cyclone category 2 intensity. Continuing southward, *Linda* then moved into an environment of increasing shear and over cooler sea-surface temperatures, decaying below cyclone intensity on 1 February. As it remained over open waters throughout its lifetime, no known impact occurred as a result of *Linda*.

***Fritz* (Brisbane) 10 February – 14 February**

A low formed in the Coral Sea within a complex trough extending from the north Queensland coast to the Solomon Islands. The low rapidly developed in a favourable upper atmosphere environment, and briefly attained tropical cyclone intensity on 10 February while east of Cape York. *Fritz* (Fig. 3) was steered to the southwest and crossed the Queensland coast near Cape Melville early on 11 February, decaying to a tropical low soon after. The

Fig 2. Tracks of tropical cyclones over the eastern Indian Ocean. Unless otherwise stated, positions at 24-hour intervals are at 0000 UTC. The number inside the cyclone symbol indicates the intensity category used in the Australian region.



low moved out over the waters of the Gulf of Carpentaria early on 12 February. *Fritz* was renamed and continued to intensify as it tracked westwards across the Gulf, reaching Australian category two at its peak.

From the afternoon of 12 February *Fritz*'s movement became somewhat erratic, with several direction changes causing less confidence in the forecast track. *Fritz* passed over Mornington Island, in the southern Gulf of Carpentaria, causing trees to be uprooted but without causing any significant structural damage. Eventually *Fritz* made landfall to the west of Mornington Island and continued to track west-southwest as a rain depression over the Northern Territory and into the southern Kimberley region of Western Australia.

Significant flood damage occurred over parts of the Northern Territory as a result of the rain depression. The town of Borroloola was split in two as the Rocky Creek flooded. Residents were evacuated from low-lying parts of the Robinson River community. The McArthur River mine was closed for three days as the waters of the McArthur River rose. A number of highways were cut by flood waters, with the Victoria River waters remaining over the Victoria Highway bridge for the remainder of February.

Ivy (Nadi) 21 February – 29 February

Ivy (Fig. 4) began as a low pressure centre forming in an active monsoon trough at the tail end of main activity associated with an active phase of the MJO in the southwest Pacific. The system reached cyclone intensity on 23 February, and continued to steadily intensify before tracking over the islands of Vanuatu and causing significant damage. *Ivy* then began to weaken and transitioned to extratropical on 28 February, passing by the East Cape of New Zealand on its path southward.

By 22 February, a low-level circulation centre was clearly exposed to the southeast of an area of deep convection. The organisation of this system gradually improved over the next day in an environment of low shear and good upper-level outflow. *Ivy* reached cyclone intensity as convective bands wrapped increasingly tightly around the central feature. The system continued to track slowly northwest. The persistence of favourable conditions for development resulted in a rapid deepening of the system and *Ivy* reached hurricane intensity on 24 February.

Ivy was an intense TC as it neared Port Vila, Vanuatu on 24 February. At this time, the system came under the influence of a strengthening northwest steering flow and began to accelerate and recurve, tracking near many of the islands of Vanuatu. As such *Ivy* caused moderate to severe damage to many parts of the islands. Heavily affected areas included the islands of Paama, Epi, Ambrym, the eastern coast of Malekula and the northern tips of Ambae (Aoba) and Maewo. There was one recorded fatality as a result of the impact of *Ivy*. The eye of the system passed close to Port Vila, with over 2000 residents evacuated. Many of the 24,000 residents of Vanuatu's central islands lost homes and most if not all mango and banana crops were damaged. Other crops such as coconut and cocoa suffered, with around 75 per cent of these crops destroyed. Cocoa is a significant cash crop in the country so such a loss had impact on inhabitants of the islands who rely on agriculture for their livelihood.

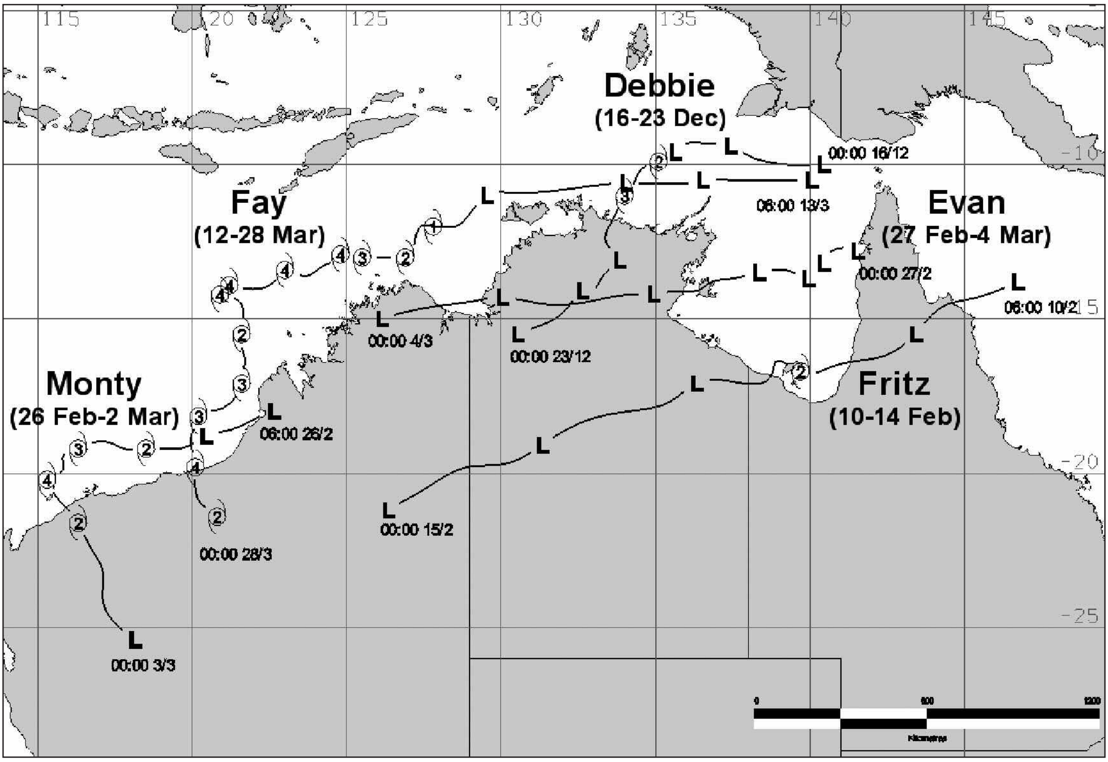
Late on 27 February, responsibility for *Ivy* was handed over to Wellington RSMC and the system became extratropical on 28 February. Ex-*Ivy* maintained a good structure as it passed close to the northeast coast of New Zealand. The system survived for quite some time, and was sustained well into the deep southern latitudes following its extratropical transition.

Monty (Perth) 26 February – 2 March

A low pressure system formed over the Pilbara region of Western Australia before moving offshore near Broome on 26 February. The system rapidly intensified and *Monty* (Fig. 3) reached tropical cyclone intensity during the evening of 27 February, just 24 hours after moving over water. *Monty* moved nearly parallel to the coast, reaching a peak intensity of Australian category four before weakening to category three and making landfall between Onslow and Dampier on 1 March.

Monty formed outside of an active MJO period. The rapid development seen in *Monty* once over water was largely due to the warm sea-surface temperatures of about 29.5°C, with much of the tropical

Fig. 3 **Tracks of tropical cyclones over northern Australia. Symbols as in Fig. 2.**



Indian and Pacific Oceans experiencing warm temperature anomalies at this time. The shear environment was not particularly favourable, with easterly shear evident on satellite imagery.

Monty began to weaken before making landfall, perhaps as a result of cooler sea-surface temperatures caused by precipitation and mixing of the ocean waters. During its passage over water, *Monty* affected some offshore oil and gas infrastructure. *Monty* crossed the coast near Mardie station, with only minimal property damage. Two vessels broke their moorings in Mermaid Sound and ran aground resulting in significant damage. Another impact from *Monty* was the flooding associated with the subsequent widespread rainfall over the Pilbara, causing an end to a long-running drought over the west Pilbara. A number of towns were cut off as floodwaters rose to some of the highest levels on record, a bridge was destroyed and many roads were flooded.

Evan (Darwin) 27 February – 4 March

A middle-level circulation was identified on radar within the monsoon trough on 27 February near Weipa (on Cape York Peninsula). By 28 February a surface low became evident, and began to move slowly west across the Gulf of Carpentaria. On 1 March the low began to rapidly deepen and shift west-southwest. *Evan* (Fig. 3) briefly reached tropical cyclone intensity before making landfall on Groote Eylandt, in the western Gulf of Carpentaria. After weakening, the tropical low passed over the Top end and out into far southern parts of the Joseph Bonaparte Gulf, but conditions were not favourable for the system to redevelop.

Evan formed in the monsoon trough, assisted by an upper-level trough in the region and the subsequent low shear environment. Development of the low was hampered by the position of the upper-level ridge at 15-20°S, resulting in good outflow in only the southern section. A low-level easterly wind surge on 1 March, in combination with good northwest monsoon low-level convergence, resulted in a more favourable environment. Upper-level outflow improved and the easterly vertical wind shear reduced during the day, causing the system to deepen rapidly before reaching cyclone intensity in the afternoon. *Evan* made landfall on Groote Eylandt only a few hours later, then progressed onto the mainland coast.

Groote Eylandt sustained some wind damage, with trees falling on power lines and a boat sinking in the harbour. On 2 and 3 March the resultant rain depression moved westward across the Top End, causing flooding in many catchments. Residents were evacuated from the outskirts of Katherine and the Stuart Highway was cut south of Katherine on 2 March.

Nicky/Helma (Perth/La Reunion) 8 March – 13 March

A persistent area of convection in the monsoon trough developed into a low west of the Cocos Islands on 8 March. The low was over warm waters, but the shear environment was not particularly favourable for development and a band of westerly gales were only identifiable in the northern quadrant of the system. As the low moved south, it moved into an environment of low shear and began to slowly develop.

The system was estimated to have reached cyclone intensity at 0600 UTC on 9 March when deep convection appeared to be wrapped around the low level circulation. *Nicky* began to develop more rapidly on 10 March with central winds reaching 50 knots before it moved west into La Reunion's area of responsibility, and was renamed *Helma*. The system continued to develop, eventually reaching near-severe tropical cyclone intensity. *Nicky* remained over open waters throughout its lifetime and there were no known impacts.

Fay (Darwin and Perth) 12 March – 28 March

A weak tropical low formed in the monsoon trough east of Cape York Peninsula on 12 March. It drifted westwards over the Arafura Sea, before tracking southwestwards and passing close to the Tiwi Islands north of Darwin. *Fay* (Fig. 3) reached tropical cyclone intensity on 16 March in the Timor Sea, and first reached severe tropical cyclone intensity late on 18 March, as it approached close to the north Kimberley coast of Western Australia. *Fay* remained over parts of the Indian Ocean for many days, weakening and re-intensifying, before finally making landfall along the Pilbara coast on 27 March at category 4 intensity.

As the tropical low passed near the Tiwi Islands the system intensified with improved convection near the centre of the low, and moved into a less sheared environment under the upper ridge and a surge in the monsoon westerly flow. *Fay* approached within 135 kilometres of Kalumburu, on the north Kimberley coast, before turning northwest and moving away from the coast. Strong to gale force winds were reported along this stretch of coast. *Fay* continued to intensify under weakening easterly shear before reaching a peak intensity of category 5 on March 21, with mean winds equal to those of *Heta*, and wind gusts near the centre estimated to up to 160 knots.

Fay entrained a substantial amount of dry air at this point and subsequently weakened and turned to the southeast towards the Kimberley coast. The slow looping movement of *Fay* caused mixing of the ocean waters and a cooling of the sea-surface temperature below 26 degrees, weakening the system further. As *Fay* moved away from this area, the sea temperatures increased again and *Fay* intensified to severe tropical cyclone once more and came within 90 kilometres of Broome. *Fay* then turned to the southwest, moving away from the coast. On 26 March *Fay* turned southwards while slowly intensifying, then finally crossed the Pilbara coast on 27 March, weakening to below cyclone intensity by late on 28 March.

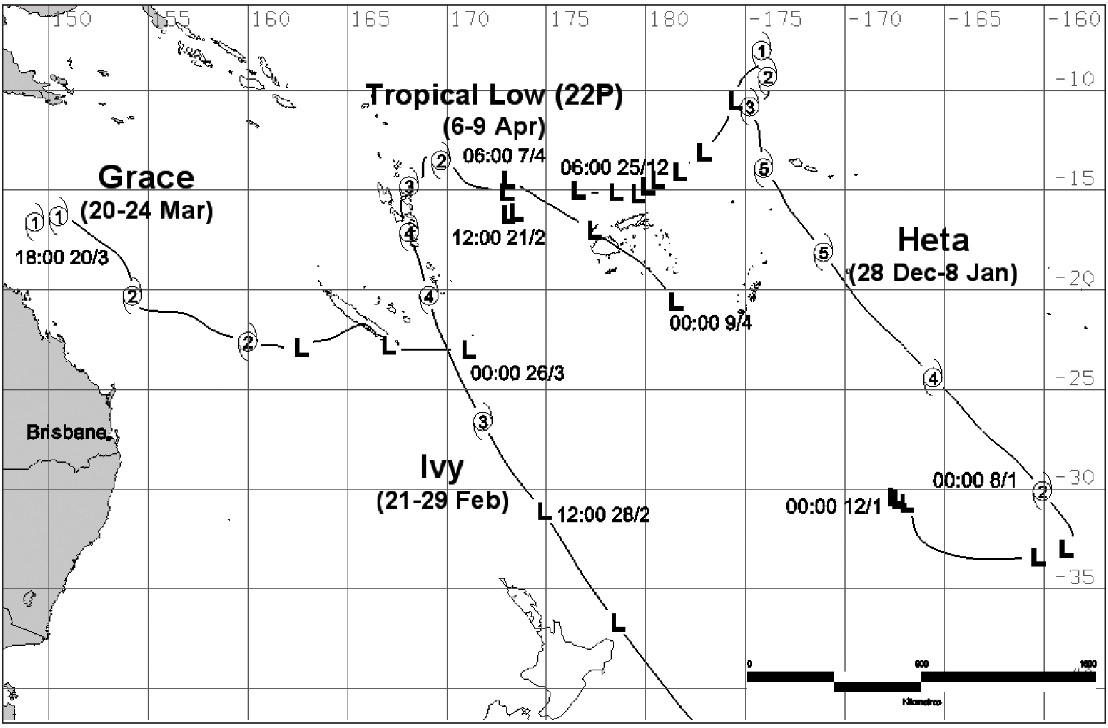
At its peak intensity, *Fay* crossed over Scott Reef, causing extensive damage with exposed coral communities obliterated and half the sandy cay washed away. Broome experienced strong winds, heavy rain and high seas, but escaped serious damage. *Fay* made landfall in a sparsely populated area of the Pilbara, and as such affected only remote pastoral and mining operations. Two hundred workers were locked down for eight hours at Yarrie mine, while accommodation units were overturned, water tanks destroyed and power lines cut. Some 140 residents in the town of Nullagine were evacuated as heavy rainfall caused the Nullagine River to flood.

Grace (Brisbane and Nadi) 20 March – 24 March

Mid-March saw an active MJO phase move over northern Australia, resulting in the development of an active monsoon and of several tropical cyclones. A low-level circulation formed in the active monsoon trough on 17 March and began to drift slowly to the southeast. The monsoon flow provided good low-level convergence which, combined with a fairly favourable upper-level flow, resulted in a slow intensification of a complex low pressure area. *Grace* (Fig. 4) was estimated at tropical cyclone strength on 20 March. *Grace* reached its peak intensity on 22 March, with winds up to 50 knots. On 23 March, *Grace* moved into Nadi's area of responsibility, and continued to move southeast into a less favourable extratropical environment.

As *Grace* underwent extratropical transition, increased shear led to the dissipation of the vertical structure of the system. A vertical circulation remained at lower levels of the atmosphere, but the upper-level structure did not persist and *Grace* was downgraded to a tropical depression at 1800 UTC on 23 March, 240 nautical miles southwest of New Caledonia. The low continued to the east, producing a broad area of gales to its south and Nadi continued to issue warnings for another 24 hours following the decay of *Grace*.

Fig. 4 **Tracks of tropical cyclones over the western South Pacific. Symbols as in Fig. 2.**



***Oscar/Itseng* (Perth/La Reunion) 21 March – 28 March.**

A low-level circulation became evident in the Indian Ocean between Christmas Island and the Cocos Islands on 21 March. The circulation was separated from a region of deep convection to the west, and was in an environment of strong northeasterly shear. On 22 March the low tracked westward towards the convection and on 23 March the shear reduced and the system became more organised. The system was estimated to have reached cyclone intensity later on 23 March. *Oscar* (Fig. 2) continued westward and the shear environment continued to improve. On 25 March *Oscar* tracked southwest and an eye became apparent on visible satellite imagery. *Oscar* reached peak intensity at 0000 UTC on 26 March, with winds to 90 knots at the centre of the system.

The continued southward movement of *Oscar* resulted in the system moving over cooler waters. *Oscar* moved into an area of increasing shear and was possibly affected by the intrusion of dry air from the south, and as a result the system began to weaken late on 26 March. On 27 March the shear continued to increase, and *Oscar* rapidly weakened before crossing west of 90°E and into La Reunion's area of responsibility. *Oscar* was renamed *Itseng* before weakening to below cyclone intensity on 28 March. *Oscar* remained over open waters for the duration of its lifetime and there were no known impacts.

Tropical low 22P - (Nadi) 6 April – 9 April

A low (Fig. 4) developed within the South Pacific convergence zone just north of Fiji on 6 April and began to rapidly intensify and track southeastward. 22P made landfall northeast of Lautoka, Fiji and moved quickly over the island during 8 January. The heavy rains associated with 22P caused flooding in the districts north of Suva, with reports of at least three deaths and nine missing people.

On 9 April 22P merged with a mid-latitude trough and transitioned to an extratropical low.

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