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The South Pacific and southeast Indian Ocean tropical cyclone season 1988–1989

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From 14 December 1988 to 10 May 1989, twenty tropical cyclones occurred in the South Pacific and southeast Indian Ocean. During the season a cold phase of the El Niño/Southern Oscillation (ENSO) was evident but the effects of this were offset by the rapid development of an active South Pacific convergence zone (SPCZ) over colder than normal sea-surface temperatures in January and February which contributed to the unusually large number of cyclones which developed east of the dateline.

This paper gives an overview of the large-scale circulation features, evaluates the available climatic indices and the effects of broadscale features on cyclone activity before examining the season's cyclones individually. Each cyclone is described together with its track; in addition, the major characteristics are tabulated. Regional verification statistics are also presented.

This season was significant in that it was the first with specialist severe weather forecasting centres within each Australian Tropical Cyclone Warning Centre; in addition several new analysis and forecasting techniques and equipment were introduced and the impact of these is discussed. Ongoing problems, such as difficulties in locating systems on the edge of satellite photo coverage, are also mentioned.

Introduction

Following the adoption of the Tropical Cyclone Operational Plan (TCOP) for the South Pacific and southeast Indian Ocean (WMO 1989), seasonal tropical cyclone summaries for the whole region (see Fig. 1(a) and caption) will be produced as one document. To this end, material was obtained from the regional centres that issued international tropical cyclone forecasts and warnings during the 1988–1989 season (used here to refer to the period from 14 December 1988 to 10 May 1989). The centres that provided this information were the Tropical Cyclone Warning Centres in Brisbane, Darwin, Nadi, Port Moresby and Perth, together with Wellington Regional Specialised Meteorological Centre.

With this being the first combined summary, problems have been encountered regarding non-standardised references to central pressure, winds etc. when describing cyclone intensity. This problem is being rectified.

Information on earlier cyclone seasons, and more details on individual cyclones, can be obtained from the appropriate forecasting centres. Each year since 1978–1979, Australian cyclone season summaries have been published in the *Australian Meteorological Magazine.* In addition, separate reports are available on both *Aivu* and *Orson* (currently in preparation); these are obtainable from the Bureau of Meteorology, Australia.

The tropical cyclones covered by this report occurred during the 1988–1989 season in the area indicated by Fig. 1(a). TCOP approved several definitions for use within this area; these and other definitions which are employed in this report are provided in the Appendix. All dates and times in this report are Coordinated Universal Time.

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Broadscale circulation during the 1988–1989 cyclone season

Large-scale circulation features

Over the summer of 1988–1989, the ascending branch of the Walker Circulation was located in the normal position over the maritime continent (Ramage 1968) and northern Australia. It was stronger than normal since east (west) of the ascending branch low-level easterly (westerly) and high-level westerly (easterly) wind component anomalies persisted throughout the season.

However, in January and February, when the Australian monsoon was unusually passive, there was an anomalously strong low-level inflow and high tropospheric outflow from the South Pacific convergence zone* (SPCZ; see Fig. 1(b)).

Reflecting these wind anomalies, mean sea level pressure was below average throughout the maritime continent and northern Australia, above average across the central and eastern Pacific while, in the SPCZ, pressure was well below average during January and February. Rainfall and outgoing long wave radiation (OLR) patterns showed enhanced convective activity over the maritime continent and the SPCZ, and suppressed activity in the central and eastern equatorial Pacific. Both wind and OLR anomalies showed a well formed southern intertropical convergence zone (ITCZ; see Fig. 1(b)) across the Pacific in the latter part of the season.

Climatic indices

The season was dominated by large positive values of the Southern Oscillation Index (SOI), defined as the normalised Tahiti minus Darwin pressure difference anomaly multiplied by ten, which peaked at 20 in both September and November. For the seven months, July to January, the SOI was more than one standard deviation (10) above its mean value (0). This season contrasted strongly to the previous summer when negative SOI values predominated, albeit with small magnitudes, and the upward branch of the Walker circulation was displaced eastward (Bate et al. 1989).

Over the last seven decades, there has been a fairly good correlation between the September SOI and the number of tropical cyclones between 105° and 165°E in the following season (Nicholls 1984, 1985; Solow and Nicholls 1990). Similarly the distribution of tropical cyclones across the south Pacific Ocean (Revell and Goulter 1986; Hastings 1990) has been reasonably consistent. A fairly uniform distribution of tropical cyclone genesis occurs between 145°E and 120°W when

*Darwin Tropical Diagnostic Statement, November 1988 to April 1989. Available from Northern Territory Regional Office, Bureau of Meteorology, PO Box 735, Darwin 0801, Australia.

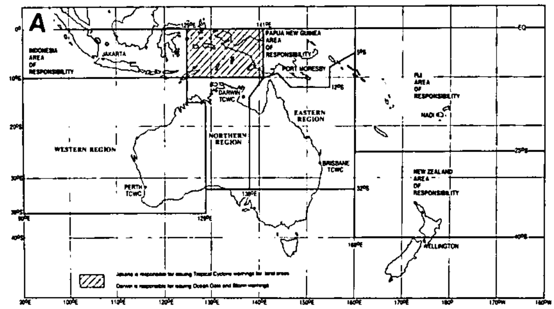


Fig. 1(a) **WMO tropical cyclone warning centres and their areas of responsibility in the South Pacific and southeast Indian Ocean. Note that the Fiji and New Zealand areas of responsibility extend to 120°W**

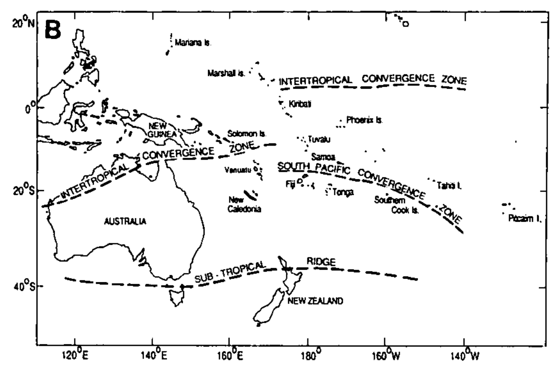


Fig. 1(b) **Semi-permanent synoptic features of the South Pacific and Australian summer mean sea level circulation.**

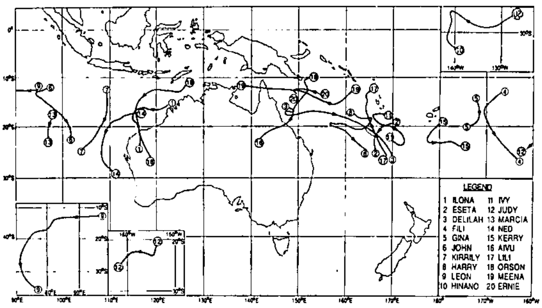
there is a negative SOI. However, when there is a positive SOI, there is a strong tendency for tropical cyclones to originate between 145°E and 180°. That is, very few cyclones originate between 180° and 120°W.

Sea-surface temperatures (SST) were colder than normal in the central and eastern equatorial Pacific throughout the season, with the largest anomalies of more than 3°C below normal occurring at the start of the season. Positive SST anomalies were evident in the eastern equatorial Indian Ocean and the western Pacific Ocean, including the Australian region*. Clearly a cold phase of ENSO was operating.

Based on past behaviour, the 1988–1989 summer tropical cyclone season was expected to pro-

*Climate Diagnostics Bulletins, November 1988 to April 1989. Available from the Climate Analysis Center, NOAA/NWS/NMC, Room 605, World Weather Building, Washington D.C. 20233, USA.

Fig. 2 1988–1989 tropical cyclone tracks.



duce a clustering of tropical cyclones originating between 145°E and 180°. From the September 1988 SOI, one would have expected 15 to 20 tropical cyclones to form in the Australian region; only nine occurred. Additionally, one would have expected a clustering of tropical cyclones originating between 145°E and 180° whereas five cyclones formed between about 180° and 140°W (see Fig. 2).

The major factor responsible for the unusual distribution of tropical cyclones appears to be the unforecast and relatively rapid development of an active SPCZ over colder than normal SST in January and February. Seven tropical cyclones developed in this region (see Fig. 2). As indicated by Revell and Goulter (1986), a major anomaly is usually required for tropical cyclones to form over French Polynesia, i.e. between 130° and 150°W. However, smaller anomalies do occur from time to time which permit the sporadic development of (usually minor) cyclones. This occurred in 1988–1989 in January and February when *Kerry*, *Gina*, *Fili*, *Liki*, *Judy* and *Hinano* developed.

More successful seasonal tropical cyclone forecasting for the South Pacific region must be able to predict these minor anomalies and obviously must include parameters other than SOI and sea-surface temperature.

Analysis by Krishna (1989) of the number of tropical cyclones originating between 150°E and 150°W since 1939 in relation to ENSO, reveals that more cyclones are likely to occur in extreme ENSO events when at least six consecutive months of a year have an absolute SOI value greater than nine. The mean number of cyclones is 10.3 with a standard deviation of 1.9 (nine events) for extreme ENSO events, whereas for weaker ENSO events the mean is 6.7 with a standard deviation of 2.5. The 1988–1989 season (not included in Krishna's analysis) was an extreme ENSO event during which twelve cyclones originated between 150°E and 150°W.

Over mainland Australia, a feature of the season was the early southward progression of the monsoon trough and above average early season rain. The monsoon trough developed over the northern region during November and the first active period occurred during the last days of the month and early December. Significant westerly wind anomalies were evident during these months at gradient level, and an anticyclone became established over northern Australia at upper levels. During December the trough was often south of 15°S over the Australian continent.

The months of January and February are generally considered to be the peak of the 'wet' season in northern Australia. However, apart from an active period at the end of January, the monsoon trough was much less active than normal. Instead, most activity was associated with the SPCZ. A trend towards persistent upper troughs in the Australian region was evident during this period, which probably suppressed cyclone formation in the northern region during January and February.

By March the circulation had reverted to one with stronger monsoonal characteristics over northern Australia. Westerly anomalies at gradient level redeveloped. The surface trough and the upper-level ridge were in close proximity during late March and through April. This was a particularly active period for cyclones (including *Orson* and *Aivu*) and above average rainfall occurred. Flooding was widespread across central Australia due to two southern excursions of the monsoon trough with the third active period of the monsoon during March.

Intraseasonal modulation

Within the season there was considerable modulation of tropical weather activity. Several 40 to 50-day waves (Madden and Julian 1971, 1972) moved from the eastern Indian Ocean into the western Pacific Ocean*.

Effect of broadscale features on cyclone activity

The main period of cyclone activity in the South Pacific near the dateline was during January and February when the SPCZ was at its strongest and monsoonal westerlies extended eastward to 160°W†. Four systems developed east of the dateline during this period, including the unusually compact and intense system *Judy*, which formed near 155°W, and *Hinano* which developed at about the same time but to the east of Pitcairn Island.

*Monthly Report on Climate System, November 1988 to April 1989. Available from Long-range Forecast Division, Forecast Department, Japan Meteorological Agency, 1-3-4, Ote-machi, Chiyoda-ku, Tokyo 100, Japan.

†Fiji Meteorological Service Tropical Cyclone Reports 89/1–89/9. Available from Fiji Meterological Service, Private Mail Bag, Nadi Airport, Fiji.

System performance

General

Specialist Severe Weather Forecasting Sections were established within each Australian Regional Office prior to the 1988–1989 tropical cyclone season. These new sections provide the capability for year-round development and refinement of operational techniques as well as for strengthening the real-time operations of the Tropical Cyclone Warning Centres (TCWC).

The inability of Nadi TCWC to receive GOES WEST and polar-orbiting satellite imagery needs to be addressed. Cyclones *Fili*, *Hinano* and *Judy* occurred too close to the earth's terminator with respect to GMS to permit a reliable analysis of their position and intensity.

The requirement continues for a storm surge prediction facility for the many low-lying island populations in the South Pacific.

Several new forecasting and analysis techniques and equipment were also used this season. Their impact is discussed below.

New forecasting techniques

1. After a detailed study of past synoptic situations, the Regional Severe Weather Section in Perth developed a decision tree to identify tropical cyclones with the potential to rapidly accelerate. The technique successfully predicted the rapid acceleration of cyclone *Ned*. Rapidly accelerating cyclones have been a major problem in Western Australia and the ability to predict them successfully is regarded as an important achievement.
2. Following a detailed study of coastal vertical wind profiles relative to coast-crossing and non-crossing cyclones over the past 22 years, the Regional Severe Weather Section in Brisbane developed a technique for predicting the movement of tropical cyclones approaching the Queensland coast. This technique predicted 24 hours in advance that *Aivu* would make landfall between south of Townsville and north of Mackay and not, for example, recurve or cross north of Townsville (see Fig. 19).
3. The Brisbane Office also introduced a technique to predict movement of significant (970 hPa or less) cyclones in the Coral Sea using coastal upper winds, radar data and rainfall distribution. This aid performed well for all such cyclones during the 1988–1989 season. Research continues into adapting the method for use with weaker and sheared cyclones.
4. A personal computer-based cyclone strike probability system which was developed by James Kelly (personal communication 1990), based on work by Templeton and Keenan (1982), has been applied in Brisbane for commercial customers who receive the product through facsimile.

New equipment

Man-computer Interactive Data Access System (McIDAS). High resolution GMS visible band imagery made available through the Western Australian Severe Weather Section's McIDAS system proved extremely useful in locating the centre of *Ned*. This cyclone was difficult to locate because of shearing; the cyclone eye was located by com-

Table 1. Tropical cyclone location and prediction errors compared to best track positions over the South Pacific and southeast Indian Ocean in the 1988–1989 season. Error is the great circle error and number is the number of verification points. Blank entries indicate unavailable data.

Forecast lead time	*0 h*		*12 h*		*24 h*		*36 h*		*48 h*	
Name	*error (km)*	*number*	*error (km)*	*number*	*error (km)*	*number*	*error (km)*	*number*	*error (km)*	*number*
Ilona	48	21	143	20	86	6				
Eseta	46	8	109	4						
Delilah	74	7	268	5						
Fili	78	9								
Gina	21	9	99	7	246	5				
John	114	116								
Kirrily	63	17	130	15	176	10	284	8	415	6
Harry	23	40	94	24	207	22				
Leon/Hanitra	111	5	261	3						
Hinano										
Ivy	58	28	124	22	249	22				
Judy	33	6	87	4						
Marcia	54	5								
Ned	34	23	124	19	320	12	529	8	624	8
Kerry	102	12	161	6	282	4				
Aivu	26	12	103	11	189	9	228	9	286	9
Lili	37	16	103	15	188	13				
Orson	25	24	72	15	145	16	197	14	365	14
Meena	41	18	153	14	302	11	405	11	544	11
Ernie	77	8	197	6	323	4				

paring hourly visual and infrared imagery which is relatively easy to do using McIDAS.

McIDAS also proved invaluable in the Brisbane office when implementing Dvorak (1977) techniques for estimating cyclone intensity from cloud images; a running mean T number obtained from hourly pictures was found to be more reliable than assessing a T number from three-hourly imagery.

Stretched visible and infrared spin-scan radiometer (VISSR). The availability of hourly stretched VISSR imagery from the Japanese GMS for the first time significantly improved the analysis of cyclones in the region. The resolution of VISSR imagery (1 km) provides operationally important detail that was unavailable with the coarser resolution (5 km).

Verification statistics

One of the major innovations of this season was the introduction of uniform verification procedures throughout the region.

The standard verification parameters are now latitude, longitude and central pressure.

At the end of each cyclone season, it is normal practice to re-analyse all available tropical cyclone track information to establish the most likely actual track. Often, because of the influence of data that were unavailable in operational real-time, the redrawn tracks or best tracks differ from those used operationally. The verification undertaken here compares the operational tracks at various forecast lead times with the corresponding best tracks. Table 1 lists the mean Great Circle (GC) distance error and the number of location comparisons for each cyclone.

Different operational practices in the regional TCWCs prevent Table 1 from being complete; there is no verification of central pressure.

Figure 3, derived from Table 1, indicates that larger initial position errors corresponded to larger 12-hour and 24-hour forecast errors (Figs 3(a) and 3(b) respectively) and that larger initial position errors usually occurred with weaker cyclones (Fig. 3(c)).

Fig. 3(a) 12-hour forecast position errors as a function of analysis position error.

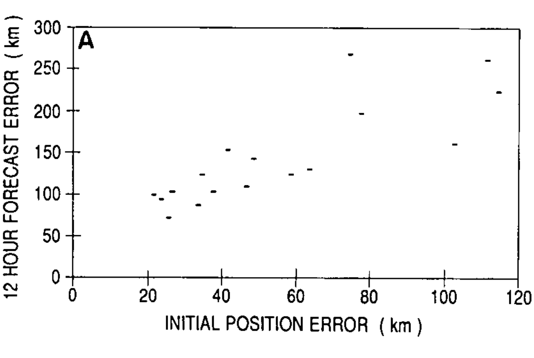


Fig. 3(b) 24-hour forecast position errors as a function of analysis position error.

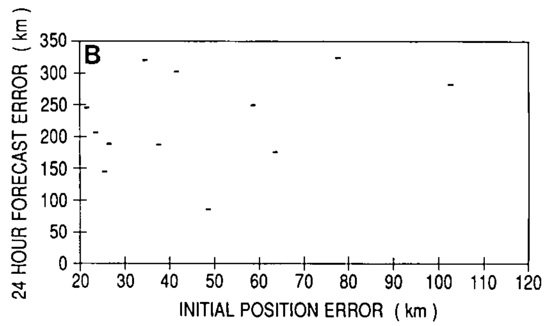
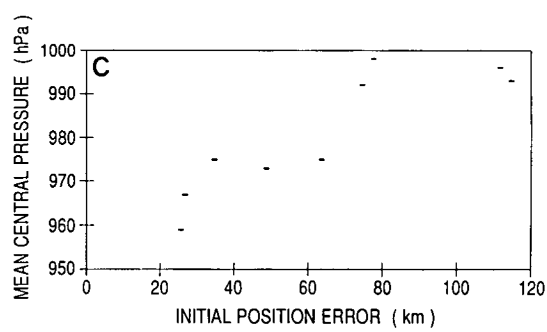


Fig. 3(c) Analysis position error as a function of cyclone intensity.



Tropical cyclones in the south Pacific and southeast Indian Oceans 1988–1989

The cyclones that occurred in the south Pacific and southeast Indian Oceans during the 1988–1989 cyclone season are summarised in Tables 2 and 3 and are subsequently described in greater detail, listed chronologically with the office that issued warnings denoted as follows:

(B) Brisbane, Queensland, Australia
(N) Nadi, Fiji
(P) Perth, Western Australia
(PM) Port Moresby, Papua New Guinea
(W) Wellington, New Zealand
(T) Papeete, Tahiti.

If the responsibility for a cyclone was subsequently passed to another office then both are listed, in chronological order of responsibility. The dates cited denote the tropical cyclone period and all times are in UTC. The track diagrams indicate the tropical low, tropical cyclone and severe tropical cyclone phases as dashed lines, solid lines and asterisk lines, respectively.

Table 2. Tropical cyclones of the South Pacific and southeast Indian Ocean in the 1988–1989 season

	Initial tropical low phase				Start tropical cyclone phase			
Name	*Date*	*Time*	*Lat*	*Long*	*Date*	*Time*	*Lat*	*Long*
Ilona	12 Dec	0000	12.0 S	128.3 E	14 Dec	0300	16.4 S	117.8 E
Eseta	15 Dec	1800	13.0 S	169.0 E	23 Dec	1200	20.0 S	173.0 E
Delilah	31 Dec	2234	18.3 S	156.7 E	1 Jan	0001	17.5 S	154.5 E
Fili	1 Jan	0216	13.0 S	168.0 W	5 Jan	1800	22.5 S	167.0 W
Gina	5 Jan	1800	14.0 S	174.0 W	7 Jan	1200	15.5 S	172.0 W
John	12 Jan	0600	7.6 S	103.3 E	26 Jan	1800	12.2 S	96.0 E
Kirrily	3 Feb	1200	11.0 S	106.2 E	6 Feb	0001	13.0 S	109.3 E
Harry	7 Feb	1800	17.5 S	160.5 E	8 Feb	1200	18.0 S	162.0 E
Leon/Hanitra	13 Feb	0600	12.0 S	102.0 E	18 Feb	1800	12.8 S	92.7 E
Hinano					21 Feb	0000		
Ivy	23 Feb	0000	16.4 S	169.7 E	23 Feb	2100	17.5 S	167.0 E
Judy	24 Feb	1200	23.0 S	134.3 W	25 Feb	2050	22.5 S	156.5 W
Marcia	2 Mar	0001	15.5 S	101.5 E	3 Mar	0600	17.0 S	98.4 E
Ned	25 Mar	0600	17.4 S	119.8 E	26 Mar	1200	17.2 S	115.3 E
Kerry	29 Mar	0000	15.0 S	173.0 W	1 Apr	0001	22.5 S	178.0 E
Aivu	31 Mar	1200	10.0 S	153.0 E	1 Apr	0100	10.6 S	152.3 E
Lili	6 Apr	1800	12.5 S	161.5 E	7 Apr	0100	12.2 S	162.7 E
Orson	17 Apr	0001	10.0 S	12.0 E	18 Apr	0600	12.6 S	124.1 E
Meena	2 May	0600	11.0 S	164.0 E	4 May	1800	14.3 S	160.5 E
Ernie	9 May	2100	12.6 S	155.2 E	10 May	0600	13.6 S	153.5 E

	End tropical cyclone phase				Decay of tropical low			
Name	*Date*	*Time*	*Lat*	*Long*	*Date*	*Time*	*Lat*	*Long*
Ilona	18 Dec	1200	25.9 S	119.1 E	19 Dec	1600	26.7 S	127.0 E
Eseta	25 Dec	0001	24.0 S	174.5 E	27 Dec	0000	29.0 S	171.0 E
Delilah	4 Jan	0500	29.5 S	171.5 E	4 Jan	1800	32.5 S	171.5 E
Fili	7 Jan							
Gina	9 Jan	1800	20.5 S	174.5 W	9 Jan	2100	21.0 S	175.3 W
John	29 Jan	0300	19.2 S	100.9 E	2 Feb	0600	25.9 S	104.1 E
Kirrily	11 Feb	0001	25.0 S	103.0 E	11 Feb	1200	23.9 S	102.0 E
Harry	18 Feb	0600	27.5 S	166.0 E	19 Feb	1200	27.5 S	166.5 E
Leon/Hanitra	1 Mar							
Hinano	28 Feb	1200						
Ivy	1 Mar	1800	22.5 S	172.0 E	2 Mar	1200	22.5 S	169.4 E
Judy	27 Feb	1800	24.5 S	161.5 W				
Marcia	4 Mar	1200	21.9 S	97.1 E	6 Mar	0600	30.1 S	97.0 E
Ned	1 Apr	0000	32.7 S	116.6 E	1 Apr	0600	34.5 S	120.8 E
Kerry	3 Apr	0600	24.5 S	174.0 W	3 Apr	1800	27.0 S	171.0 W
Aivu	4 Apr	0600	20.0 S	146.3 E	5 Apr	1200	22.0 S	142.2 E
Lili	11 Apr	0600	23.8 S	167.8 E	11 Apr	1800	26.0 S	171.0 E
Orson	23 Apr	0900	24.6 S	124.9 E	24 Apr	1200	32.0 S	130.2 E
Meena	9 May	0001	12.4 S	143.2 E	10 May	0600	11.5 S	137.4 E
Ernie	12 May	0600	12.3 S	149.6 E	12 May	1200	12.3 S	148.8 E

Ilona **(P): 14 to 18 December 1988 (Fig. 4)**
Tropical cyclone *Ilona* formed as a tropical low to the north of Broome on 12 December and reached tropical cyclone intensity near 16.6°S, 121.4°E early on 13 December.

The cyclone steadily decelerated as it intensified. It began to recurve towards the Western Australian coast during 16 December crossing the coast between Dampier and Port Hedland at 1600 on the 18th. Maximum wind gusts of 174 km h^{-1} were reported near the centre with a barometer reading of 965.3 hPa.

Ilona weakened after landfall but still caused minor damage inland before decaying. The cyclone produced record December rainfall totals in central parts of Western Australia.

Eseta **(N): 23 to 25 December 1988 (Fig. 5)**
Eseta developed from a shallow area of low pressure within the monsoon trough just north of Vanuatu. On 15 December 1988, the low pressure system moved gradually southwest then south, with little change in intensity. During 20 to 21 December a high pressure cell developed poleward of the system preventing further southwards

Table 3. Maximum intensities and effects of the 1988–1989 season South Pacific and southeast Indian Ocean cyclones.

	Maximum estimated intensity					
Name	*Date*	*Time*	*Lat*	*Long*	*Pressure*	*Wind*
Ilona	12 Dec	0600	19.2 S	115.7 E	960	190
Eseta	24 Dec	2100	23.5 S	173.0 E		140
Delilah	2 Jan	1200	21.0 S	166.5 E		150
Fili	6 Jan	0600	24.0 S	166.0 W		150
Gina	8 Jan	0600	17.5 S	171.5 W		80
John	27 Jan	1200	13.0 S	94.2 E	990	110
Kirrily	9 Feb	1200	22.3 S	106.4 E	955	205
Harry	14 Feb	0001	19.0 S	158.8 E	925	250
Leon/Hanitra	19 Feb	1200	12.8 S	89.0 E	988	110
Hinano	25 Feb	0000				
Ivy	27 Feb	0001	21.0 S	170.7 E	970	140
Judy	26 Mar	1200	22.3 S	157.8 W		70
Marcia	3 Mar	0600	17.0 S	98.4 E	995	85
Ned	29 Mar	0001	20.7 S	109.1 E	941	235
Kerry	1 Apr	1800	22.5 S	179.0 E		90
Aivu	3 Apr	0600	17.0 S	149.2 E	935	175
Lili	8 Apr	1800	14.8 S	165.0 E	970	140
Orson	22 Apr	1600	19.6 S	116.1 E	905	249
Meena	6 May	0600	15.0 S	155.0 E	990	80
Ernie	11 May	0001	12.3 S	151.1 E	988	85

Name	*Cost (US$M)*	*Deaths*	*Surge (m)*	*Comments*
Ilona				
Eseta				Floods, landslide and crop damage
Delilah		1		Floods, landslides
Fili				
Gina				
John				
Kirrily				
Harry				
Leon/Hanitra				
Hinano				
Ivy				Floods, landslides
Judy				
Marcia				
Ned				
Kerry				Heavy crop damage
Aivu	70.5	1	3.3	US$27.5M agricultural losses, 20 injured
Lili				Floods, landslides, crop damage
Orson	16	4	3.1	Mostly property damage by wind
Meena				
Ernie				

movement and, by 1200 on 23 December, tropical cyclone intensity was reached.

Eseta caused widespread rain over Fiji from 22 December, when the system was still lying between Vanuatu and New Caledonia, until 27 December. The highest one-day rainfall during the period was 366 mm in the period ending 0100 24 December. *Eseta* reached peak intensity on 24 December with maximum winds of 100 km h^{-1} with gusts near its centre to 135 km h^{-1}.

By 0001 25 December, after maintaining tropical cyclone characteristics for only 36 hours, *Eseta* weakened into a depression which later, as an extratropical depression, caused major flooding over parts of the North Island of New Zealand.

***Delilah* (B) and (N): 1 to 4 January 1989 (Fig. 6)**
Towards the end of December 1988, the SPCZ was very active and westerlies to its north extended to 160°W. Two depressions formed in this zone; one in the Coral Sea near Australia developed into *Delilah* and the other, close to Samoa, developed into *Gina*.

During *Delilah's* formation, pressure falls around the depression were very localised. At about 1800 30 December, an intensifying anti-

Fig. 4 **Track of *Ilona* (14 to 18 December 1988). Note: depression stage is denoted by a dashed line, tropical cyclone stage by a full line and a severe tropical cyclone stage by asterisks. Six-digit numbers along the track are in a ddhhmm format where dd is the day of the month, hh is the hour of the day and mm is the minute of the hour. All dates and times are UTC.**

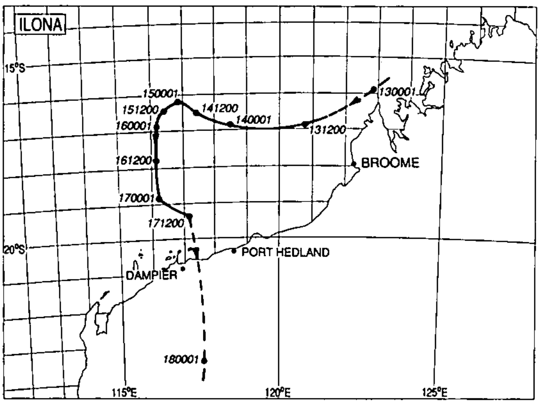
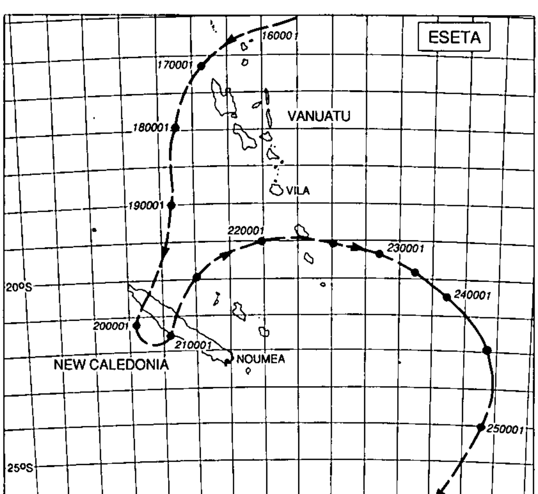


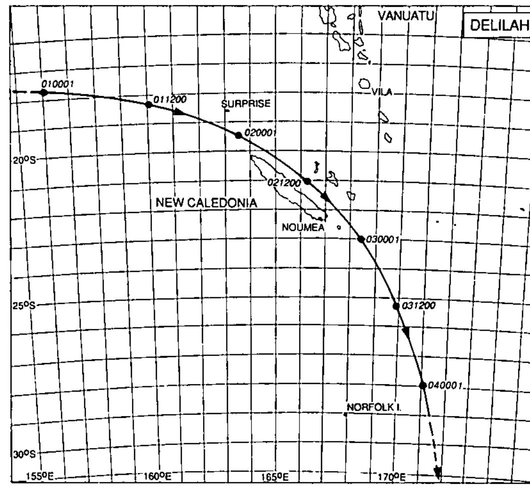
Fig. 5 **As Fig. 4 but for *Eseta* (23 to 25 December 1988).**



cyclone in the Tasman Sea caused significant pressure rises along the eastern Australian coast. This intensification appears to have increased the cyclonic shear on the southwest flank of the depression and, within the next six hours, the winds near its centre increased to about 55 km h^{-1}. Satellite pictures revealed enhanced convection and two very prominent spiral cloud bands feeding into the low-level centre.

The cyclone slowly intensified and moved east-southeast at 20 to 35 km h^{-1}. The wind distribution was asymmetric with average winds of 75 km h^{-1} near the centre with gales extending 320 km in the southern semicircle and 240 km elsewhere. Despite the replacement of the upper-level anticyclone over *Delilah* by increasing westerly winds, further intensification occurred.

Fig. 6 **As Fig. 4 but for *Delilah* (1 to 4 January 1989).**



After 1200 1 January, *Delilah* curved towards the southeast moving at 30 to 35 km h^{-1}. Winds near the centre had increased to 110 km h^{-1} with gusts around 145 km h^{-1} by 1200 2 January; satellite imagery revealed 'banding' characteristics (Dvorak 1977).

The intensifying upper-level westerlies gradually increased the vertical shear and, after 1800 2 January, east of Noumea, the cloud pattern started to become disorganised. At this time, winds around the centre were about 100 km h^{-1}. This intensity was maintained but the cyclone decelerated to 15 km h^{-1}. Twelve hours later the system became extratropical and moved southwards, passing close to the north of New Zealand, before merging with a cold front on 8 January.

***Fili* (N): 5 to 7 January 1989 (Fig. 7)**

Tropical cyclone *Fili* developed slowly from a shallow, ill-defined depression which formed about 400 km east of Samoa on 1 January 1989.

Soon after 0600 3 January, as the system began recurving to the south, it weakened a little and convection decreased; maximum winds near the centre were below gale force.

By 1200 4 January satellite imagery indicated that the system was reintensifying. As the depression continued on its southeastward track, intensification continued and the system acquired tropical cyclone characteristics. High cloud obscured the low-level circulation and positions were more difficult to determine as the system was approaching the eastern boundary of the GMS satellite picture coverage.

By 1800 5 January the system had intensified into a tropical cyclone. Maximum winds subsequently increased to storm force. The cyclone then moved steadily southeastwards and eventually decayed.

Fili attained peak intensity away from major land areas and no reports of damage were received.

Gina (N): 7 to 9 January 1989 (Fig. 8)

Dvorak analysis of satellite imagery (Dvorak 1977) indicated that a tropical cyclone had developed south of Western Samoa by 0600 7 January. Gales extended to about 145 km from its centre and were affecting some parts of Western Samoa by 1200 7 January.

An upper-level trough lying to the east of Fiji amplified as *Gina* intensified and curved towards the south. For the next 24 hours the cyclone remained east of the upper trough and steadily intensified.

Gina reached peak intensity around 0600 8 January when the maximum winds near its centre were estimated at 80 km h^{-1}. Intensification ceased as the upper trough moved eastwards and over the cyclone.

After 0001 9 January *Gina* curved to the southwest into a region of strong vertical shear and weakened rapidly. By 1800 9 January, *Gina* had lost its tropical cyclone characteristics.

Most damage occurred from the prolonged period of heavy rain over Western Samoa where floods and landslides caused about US $5 million worth of damage to roads and bridges.

John (P): 26 to 29 January 1989 (Fig. 9)

A convective cloud mass near Cocos Island on 20 January moved southeast within the general monsoon flow and gradually became more organised. A 1004 hPa low was analysed within the cloud mass near 7.6°S and 103.3°E on 23 January.

The low centre passed about 20 km to the north of Cocos Island at 0130 26 January when the pressure on the island was 999 hPa and winds were gusting to 70 km h^{-1}. Gales were not reported from the island as the low passed west-southwest, but by 1800 26 January, tropical cyclone strength was reached.

Based on 0001 29 January satellite imagery, *John* was located near 18.9°S, 100.8°E with a rather disorganised cloud structure.

Visual GMS imagery later on 29 January revealed a partially exposed low-level cloud centre with supporting convection restricted to the southern quadrants. This centre gradually became completely dissociated from the upper-level canopy and continued to be tracked by satellite imagery until it lost identity as a circulation on 2 February.

Fig. 7 **As Fig. 4 but for *Fili* (5 to 7 January 1989).**

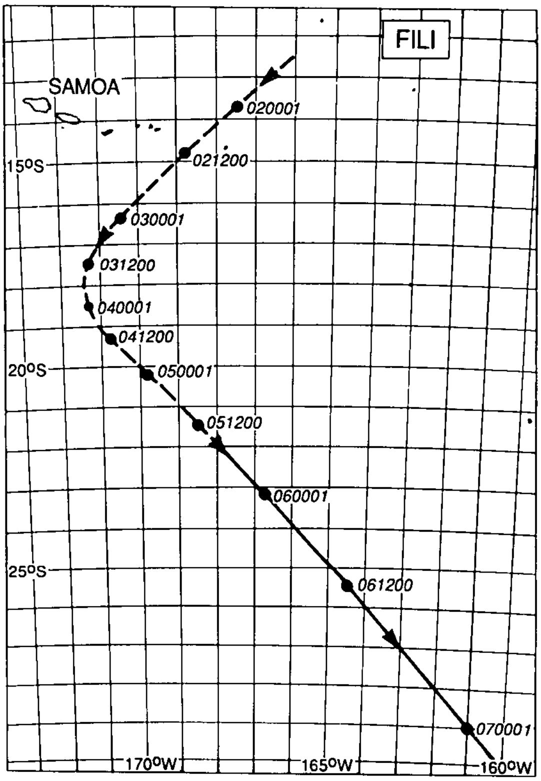


Fig. 8 **As Fig. 4 but for *Gina* (7 to 9 January 1989).**

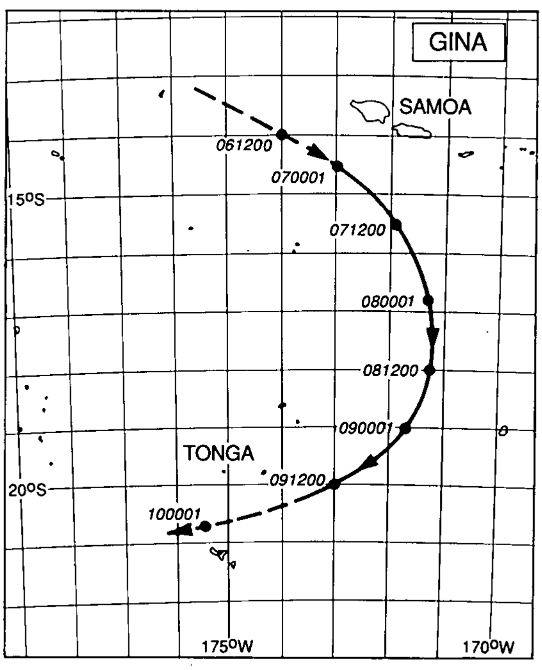


Fig. 9 As Fig. 4 but for *John* (26 to 29 January 1989).

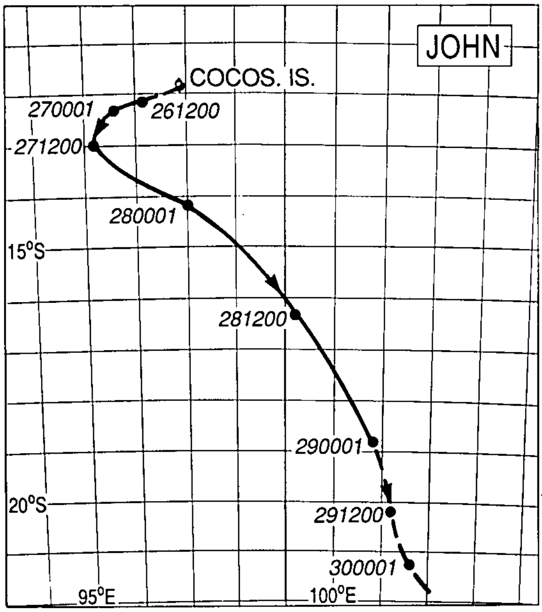
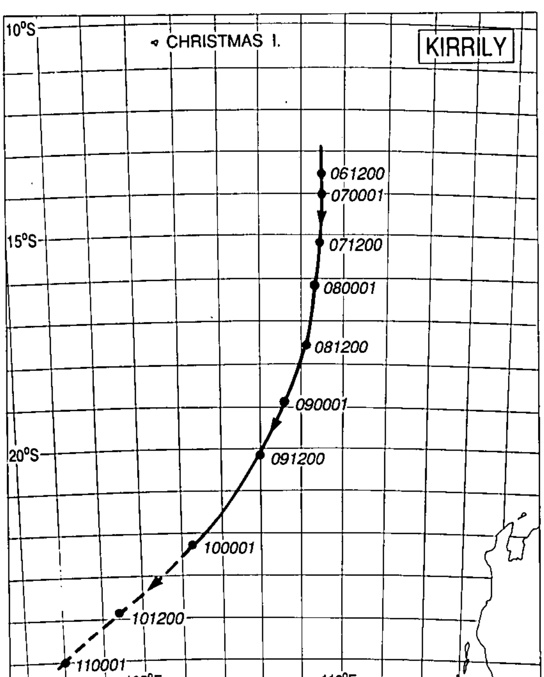


Fig. 10 As Fig. 4 but for *Kirrily* (6 to 11 February 1989).



***Kirrily* (P): 6 to 11 February 1989 (Fig. 10)**

Convection that steadily became more organised just southeast of Christmas Island on 3 February marked the formation of a tropical low with a central pressure of 1006 hPa. The low intensified and was named *Kirrily* at 0001 6 February near 13.0°S, 109.3°E.

An eye, visible on satellite imagery at 0001 9 February, remained until 1500 9 February. *Kirrily* was at its most intense over this period with an estimated central pressure of 955 hPa and maximum wind gusts near the centre of 205 km h^{-1}.

The cyclone moved towards the southwest and came under the influence of increasing vertical wind shear which shifted the middle and upper-level cloud canopy to the southeast of the low-level centre. Weakening of the cyclone by this process was quite dramatic; within 12 hours the cyclone degenerated from a fully mature cyclone to one with an exposed low-level cloud system without any vertical structure. Gales were estimated to still be associated with the well-defined low-level centre until 0001 11 February at 25.0°S, 103.0°E.

In its final stages the weakening low was buoyed northward by the strenthening subtropical ridge to its south before losing identity at 1200 11 February.

***Harry* (N) and (B): 8 to 18 February 1989 (Fig. 11)**

A shallow depression first appeared in the monsoon trough some 800 km to the west of Vanuatu on 7 February. It deepened by 8 February as it moved eastwards and reached cyclone intensity at around 1200 8 February. *Harry* was then centred about 730 km west of Vanuatu with average winds estimated at 65 km h^{-1} close to the centre; gales extended to about 160 km from the centre.

By 1800 9 February average winds were estimated to be 90 km h^{-1} close to the centre and, by 1200 10 February, eye development indicated that the cyclone had deepened into a severe tropical cyclone. *Harry* curved more southwestwards with further intensification and crossed the main island of New Caledonia on 11 February. There were no reports of significant damage.

By 0900 13 February *Harry* was at 19.5°S, 160°E with a central pressure of 966 hPa, moving west-northwest and deepening. At 0001 14 February the estimated minimum pressure of 925 hPa was reached. The intensity and direction of travel was maintained for a further 12 hours. *Harry* then remained almost stationary for a day before slowly accelerating to the southeast.

At 0900 16 February the system started weakening as it continued to accelerate towards the southeast under the influence of a trough to the southwest.

Thereafter the system continued to weaken with winds decreasing to storm force by 0600 17 February, weakening further to gale force 24

Fig. 11 As Fig. 4 but for *Harry* (8 to 18 February 1989).

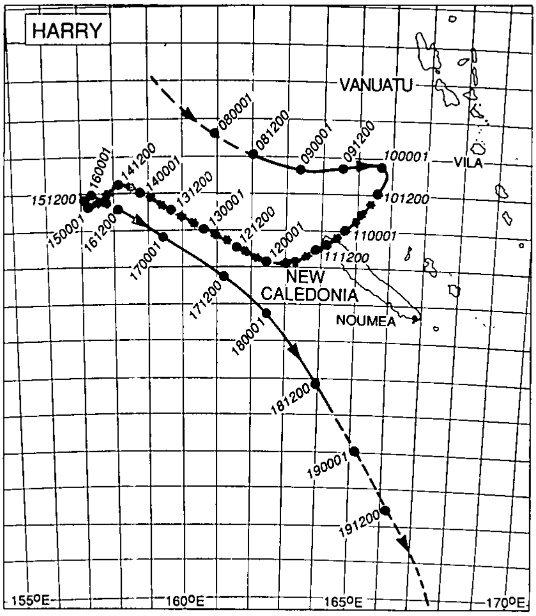
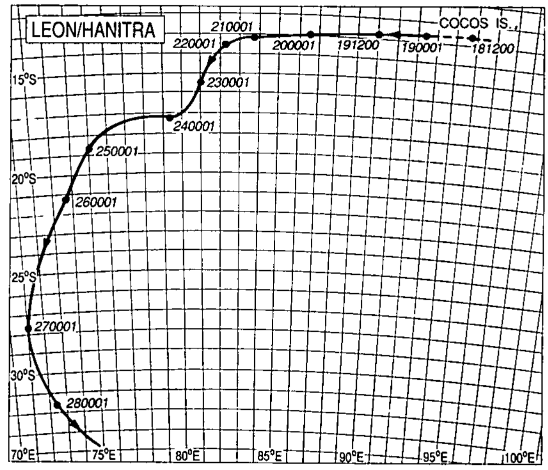


Fig. 12 As Fig. 4 but for *Leon/Hanitra* (18 February to 1 March 1989).



hours later. After moving into higher latitudes it regained storm strength, as an extratropical low, by 0600 19 February.

During the 12 hours that the estimated minimum central pressure of 925 hPa prevailed, the eye diameter, as seen on satellite, increased from 55 to 85 km. The estimated maximum mean wind was 185 km h^{-1} and the estimated maximum gust was 250 km h^{-1}. The strongest observed wind was 93 km h^{-1}.

Leon/Hanitra (P): 18 February to 1 March 1989 (Fig. 12)

A weak tropical low was discernible between Cocos and Christmas Islands from 13 to 17 February. The cloud pattern was poorly organised during the period but a slow deepening of the system occurred as it settled on a westward track. The low passed to the south of Cocos Island during the night of 17 February and produced 45 km h^{-1} mean winds with a pressure at the station of 1007 hPa.

The westward movement continued as the system slowly deepened to become a tropical cyclone on 1800 18 February, at 12.8°S, 92.7°E. At 0001 19 February a ship located some 230 km east of the centre reported gale force winds and a 3.5 metre northwest swell.

The cyclone was renamed *Hanitra* by Mauritius at 0600 20 February and reached its peak intensity on 23 February; minimum pressure was 940 hPa with maximum winds of 152 km h^{-1} and gusts of 228 km h^{-1}. *Leon/Hanitra* did not affect any land areas, became extratropical and decayed.

Hinano (T) and (W): 21 to 28 February 1989 (Fig. 13)

Hinano was a very small tropical cyclone whose lifetime was spent entirely over water. It developed close to *Judy* (see below) with the two cyclones being only 1600 km apart on 25 February.

Hinano developed from a tropical depression east of Pitcairn Island. The depression moved west-southwest prior to reaching cyclone strength late on 21 February 1989. *Hinano* subsequently recurved, probably due to the proximity of *Judy*.

Peak intensity occurred on 25 February with maximum sustained winds of 120 km h^{-1}; *Hinano* then moved abruptly into higher latitudes and gradually weakened.

Fig. 13 As Fig. 4 but for *Hinano* (21 to 28 February 1989).

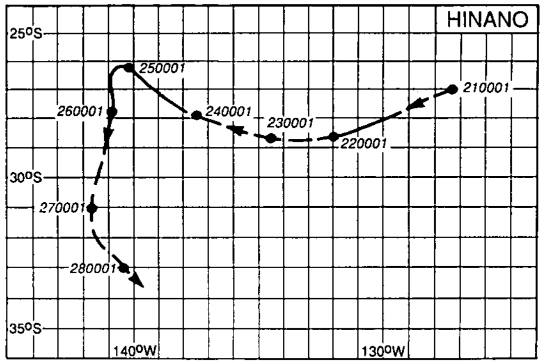
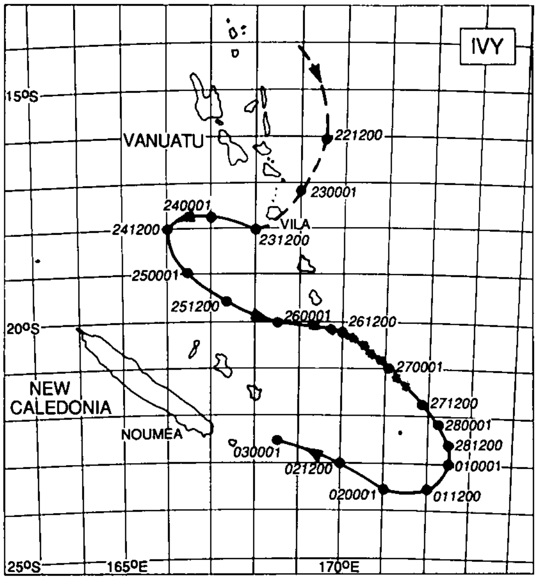


Fig. 14 As Fig. 4 but for *Ivy* (23 February to 1 March 1989).



Ivy (N): 23 to 01 March 1989 (Fig. 14)

A shallow depression developed in the monsoon trough north of Vanuatu on 21 February. After 1200 22 February, the depression started to curve towards the southwest and began to deepen. Satellite imagery showed an increase in cloud organisation and it was named *Ivy* at 2100 23 February.

After 1200 24 February *Ivy* curved sharply to the southeast into a region of weaker upper-level winds where it intensified further reaching storm intensity around 1200 25 February. Maximum average winds were 90 km h^{-1} near its centre, gales extended about 160 km from the centre in the northern semicircle and 320 km from the centre in the southern semicircle. After 1200 25 February *Ivy* curved towards the east-southeast and remained under the upper-level ridge axis where further intensification occurred.

GMS imagery at 1800 25 February indicated an ill-defined eye. During the next 24 hours the cyclone moved east-southeast and intensified steadily, developing tighter cloud banding features and a more distinct eye. The system reached severe tropical cyclone intensity at 0600 26 February with average winds of 120 km h^{-1} near its centre. Wind damage, floods and landslides occurred in southern Vanuatu.

Ivy moved over open waters southeast of Vanuatu and it reached its peak intensity at 0001 27 February. The cyclone weakened slightly over the next 24 hours and the eye gradually became more irregular and, after 1200 27 February, indiscernible.

Strengthening northwesterly vertical shear then caused *Ivy* to weaken rapidly. The convective cloud band sheared to the southeast leaving an exposed low-level centre which curved to the west and maintained gale intensity for a further 18 hours. The centre finally dissipated late on 3 March southeast of New Caledonia.

Judy (N): 25 to 27 February (Fig. 15)

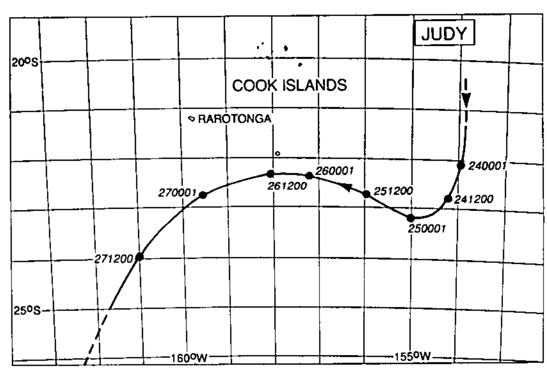
Judy was a very small but intense cyclone that originated from a depression east of Rarotonga on 24 February 1989. The depression moved southwards and was located about 600 km east-southeast of Rarotonga at 1200 on 24 February.

The system then curved towards the west-northwest and developed rapidly. By early 25 February an eye was discernible and large pressure falls over the southern Cook Islands indicated a small, tight circulation.

Judy reached peak intensity late on 26 February with maximum average winds of 120 to 130 km h^{-1}. Storm force winds extended to about 50 km from the centre while gales extended no more than 130 km from the centre.

Judy started to lose intensity after encountering strong vertical wind shear and moving into a cooler environment. By late on 27 February the system had weakened to a depression and finally dissipated.

Fig. 15 As Fig. 4 but for *Judy* (25 to 27 February).



Marcia (P): 3 to 4 March 1989 (Fig. 16)

Marcia began as a tropical low near 14.5°S, 102.1°E, southeast of Cocos Island, at 0001 2 March 1989. The low initially moved slowly to the west-southwest and was first classified as a weak tropical cyclone at 0600 3 March.

Satellite imagery located the centre near the northwestern edge of the main cloud mass. During the next 24 hours the cold cloud canopy continued to expand and extended southeastwards away from the centre. By 0600 4 March a clearly exposed low-level centre was evident near 20.7°S, 97.3°E indicating that the cyclone had weakened.

Marcia was a weak tropical cyclone with a minimum central pressure of 995 hPa during the period 0600 3 March to 0001 4 March. The cyclone weakened rapidly due to high-level wind shear associated with a cut-off low pressure system to its southwest.

Ned **(P): 26 March to 1 April 1989 (Fig. 17)**
A series of transient lows analysed within a broad low-pressure trough near the northwest Australian coast were resolved as one discrete circulation north of Port Hedland at 0600 25 March. The low moved west and deepened, reaching cyclone intensity at 1200 26 March near 17.2°S, 115.3°E.

An eye had developed by 0001 28 March and was discernible from satellite imagery until 1200 29 March. The cyclone reached maximum intensity at 0001 29 March with a central pressure of 941 hPa.

Ned began to weaken under increasing vertical shear, particularly after 0001 30 March, and satellite imagery revealed that the low-level circulation centre had separated from the upper-level cirrus canopy.

Although weakened by vertical shear, *Ned* continued to hold sufficient structure to generate gales as it moved slowly south, parallel to the coast. The approach of a strong cold front during 31 March caused the cyclone to move southeast and accelerate.

Ned crossed the coast near Perth at around 2300 31 March causing power disruptions and isolated roof damage; wind gusts of 110 km h^{-1} were recorded. The decaying remnants of *Ned* lost all identity near 34.5°S, 120.8°E at 0600 1 April.

Kerry **(N): 1 to 3 April 1989 (Fig. 18)**
Kerry developed from the monsoon trough on 29 March, underwent increased organisation with large pressure falls being reported and, by 0001 1 April near 22°S, became a tropical cyclone. *Kerry* began to recurve southeastwards and then eastwards with an average speed of about 20 km h^{-1}. Intensification continued during recurvature and, by 1800, its peak intensity was reached with a reported gust of 90 km h^{-1}.

An approaching upper trough increased the vertical shear through the system and weakening began to occur as *Kerry* encountered colder waters near 25°S.

By 1200 3 April, *Kerry* had weakened but still maintained near storm force winds close to its centre. Within the next 12 hours, *Kerry* had dissipated rapidly.

Overall, *Kerry* followed a relatively smooth track spending its entire life-span over water. Heavy rain caused flooding across low-lying areas of central and western Viti Levu (Fiji), while the gusty winds caused minor crop damage.

Fig. 16 As Fig. 4 but for *Marcia* (3 to 4 March 1989).

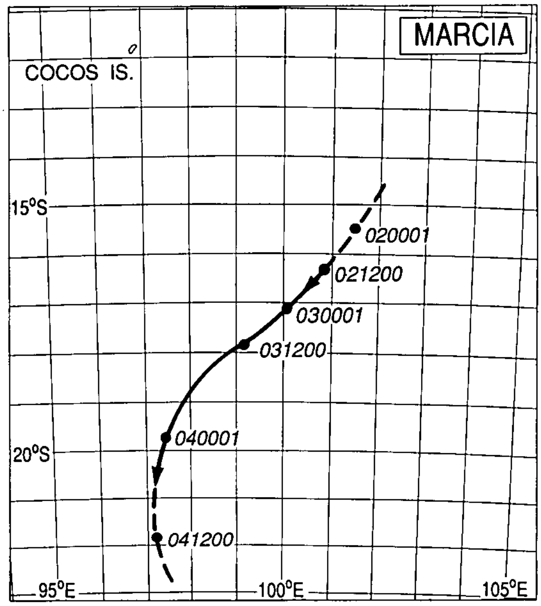


Fig. 17 As Fig. 4 but for *Ned* (26 March to 1 April 1989).

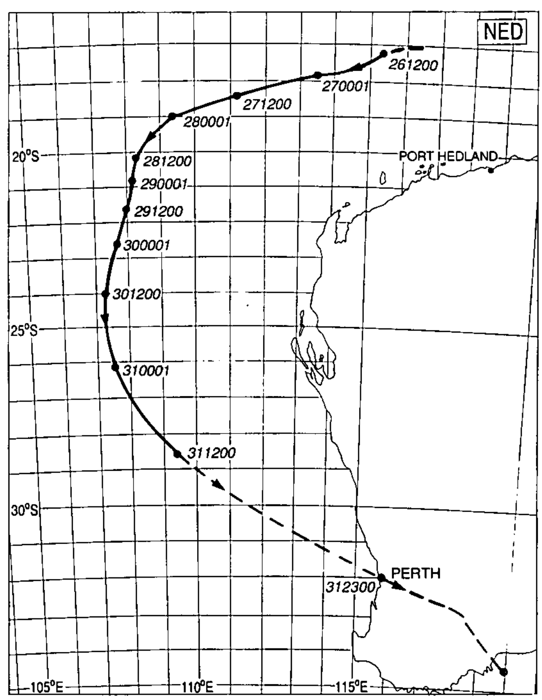
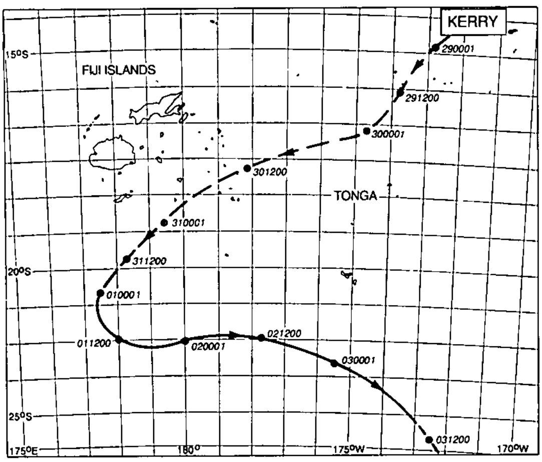


Fig. 18 As Fig. 4 but for *Kerry* (1 to 3 April 1989).



***Aivu* (PM and B): 1 to 5 April 1989 (Fig. 19)**
A tropical low developed to the east of the southeastern tip of Papua New Guinea on 31 March 1989. As it moved slowly west-southwest, the system deepened from its initial 1003 hPa at 1200 31 March until it reached tropical cyclone intensity at 0100 1 April. *Aivu* tracked southeast and then southwest at 15–20 km h^{-1} and continued to intensify over the next 30 hours.

By 1500 2 April at 15.7°S, 149.9°E *Aivu* had become a severe tropical cyclone. Maximum intensity of 935 hPa occurred at 0600 3 April near 17.0°S, 149.2°E.

Aivu gradually weakened but maintained severe tropical cyclone intensity until landfall near Townsville at 0030 4 April when the central pressure was 957 hPa with wind gusts to 200 km h^{-1} and a storm surge of 3 metres.

The system continued to move west-southwest after landfall and degenerated into a rain depression during the next six hours losing all identity two days later.

The lowest observed pressure was 959 hPa at 0045 4 April. The highest recorded mean wind was 118 km h^{-1} at 0530 3 April.

Aivu produced record and near record April rainfall totals over large parts of the coastal and central interior districts. The maximum total for the 72-hour period to 2300 5 April was 1082 mm recorded inland from Mackay where the 24-hour rainfall was 581 mm (topographical effects contributed).

Severe local flooding occurred between Townsville and Mackay during 4 April with a flood peak at Mackay of 7.8 metres on 5 April; the major flood peak measured 13.2 metres on the Pioneer River upstream from Mackay.

The wind damage from *Aivu* was only moderate. The worst overall damage was caused by the 2.5 to 3.0 metre storm tide surge which destroyed numerous beachfront properties. One death was reported. Quantifiable losses attributable to *Aivu* are approximately US$70.5 million.

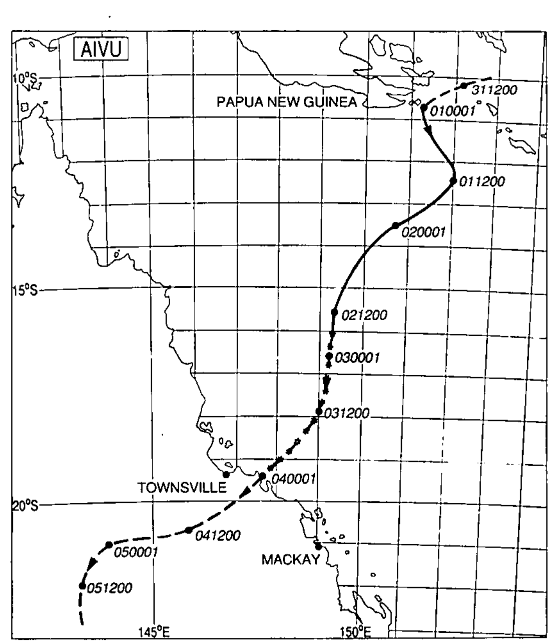
***Lili* (N): 7 to 11 April 1989 (Fig. 20)**
The monsoon trough over the Coral Sea gradually intensified from 4 April as the low-level equatorial westerlies over the region increased. A shallow low pressure area developed between 5°S and 10°S about 800 km northwest of New Caledonia along the east/west oriented monsoon trough on 5 April. The associated broad area of cloud became increasingly organised with spiral banding on 5 April and a depression forming on 6 April. The depression curved slowly towards the east and continued to intensify.

Lili intensified slowly over the next 18 hours and tracked southeastwards at 10 to 20 km h^{-1} whilst remaining under a relatively light upper-level northwesterly flow. It is estimated to have reached storm intensity by 1800 7 April.

The system intensified further and a large ragged eye became evident at 0530 8 April when it reached severe tropical cyclone intensity. The peak intensity occurred at 1800 8 April with average winds of 135 km h^{-1} close to its centre. Storm and gale force winds were estimated to be within about 50 and 130 km of the centre respectively.

Lili maintained intensity and tracked southwards until 1200 9 April when it started accelerating towards the south-southeast and weakened under a strong upper-level northwesterly flow. *Lili* was centred about 95 km to the north-northwest of Noumea at 1200 10 April with estimated winds of 120 km h^{-1} close to the centre. As

Fig. 19 As Fig. 4 but for *Aivu* (1 to 5 April 1989).



the cyclone moved closer to New Caledonia it weakened further as a result of increased vertical shear and interaction with land. The eye of the cyclone was not detectable with high resolution satellite imagery after 0600 10 April.

Around 1800 10 April *Lili*, with winds of about 100 km h^{-1} near its centre, passed close to Noumea. Storm force winds affected the eastern half of New Caledonia with the rest of the group experiencing gales.

Lili then moved towards the south-southeast at between 20 and 30 km h^{-1} and, due to increased vertical shear, the low-level circulation became displaced to the northwest of the convection. By 0600 11 April *Lili* had lost its tropical cyclone characteristics and continued moving towards the southeast, dissipating rapidly soon after crossing 25°S.

Lili caused considerable structural and crop damage in New Caledonia with widespread flooding and landslides. There were no reports of casualties.

***Orson* (P): 18 to 23 April 1989 (Fig. 21)**

Orson was one of the most severe of all documented cyclones in the Australian region and, at its most intense, the central pressure of 905 hPa was the lowest on record for an Australian cyclone.

A tropical low was first located at 0001 17 April within a convective cloud mass near 10.6°S, 128.5°E. The low moved west-southwest and deepened, reaching cyclone intensity at 0600 18 April. The cyclone then moved westwards. On 19 April, several ships near the cyclone reported 65 km h^{-1} winds and, during this period several Indonesian fishing boats sank and four fishermen were drowned.

The cyclone eye was discernible on satellite imagery from 0001 20 April until 1200 22 April, by which time the cyclone was well within range of the Dampier radar. During 20 and 21 April the cyclone began to recurve, shifting southwesterly and then southerly; it steadily intensified. On 22 April, *Orson* moved south towards the north Western Australian coast and began to accelerate ahead of an approaching, vigorous cold front to the southwest.

The centre of the cyclone passed a few kilometres west of the North Rankin A gas platform (19.6°S, 116.1°E) at 1630 22 April, where a pressure of 905 hPa and 249 km h^{-1} wind gusts reduced to 10 m level were recorded prior to the destruction of the anemometers by the cyclone. This constitutes the lowest MSL pressure on record for an Australian cyclone. The offshore platform was in the eye of the cyclone for approximately 40 minutes, at which stage the eye diameter was measured by radar to be approximately 40 km. Wind speed and pressure profiles recorded at the gas platform are shown in Fig. 22.

Fig. 20 **As Fig. 4 but for *Lili* (7 to 11 April 1989).**

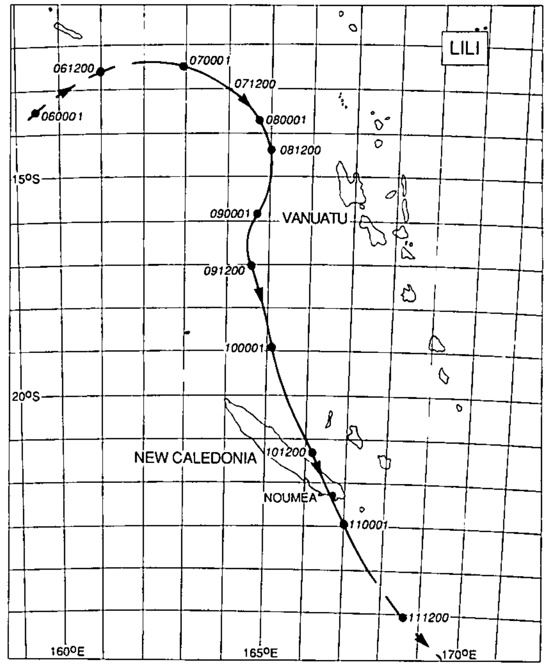


Fig. 21 **As Fig. 4 but for *Orson* (18 to 23 April 1989).**

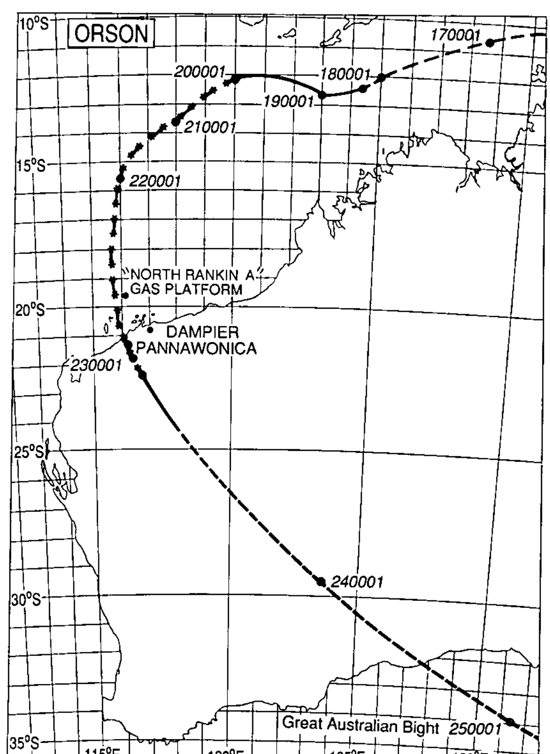
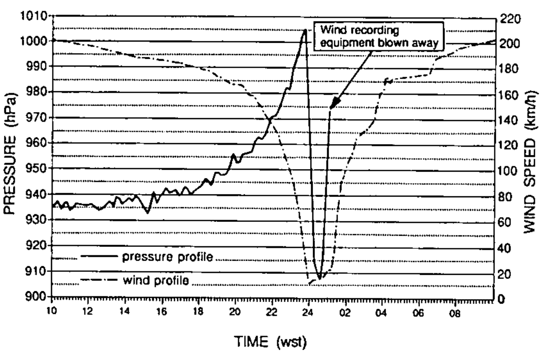


Fig. 22 Wind speed and pressure profiles recorded at the North Rankin A gas platform during cyclone *Orson* between 10 am on 22 April 1989 and 9 am on 23 April 1989 Western Standard Time (WST). Note WST is eight hours ahead of UTC.



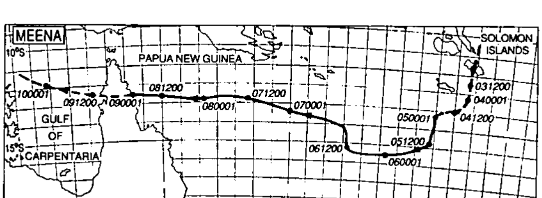
Orson crossed the coast at 2045 22 April. The maximum wind gust at Dampier was 183 km h^{-1}. A nearby station, located to the west of the cyclone centre, reported a maximum wind gust of 211 km h^{-1}.

A storm surge of 3.1 metres was recorded at Dampier, but as the cyclone crossed near the time of low tide, inundation of coastal areas was minimised. The cyclone moved overland and began weakening. It passed over Pannawonica (about 80 km inland) at approximately 2200 22 April and caused significant structural damage to the town; 70 per cent of homes were damaged.

Orson took on a south-southeast and then southeasterly track through the data-sparse inland area of the State during 23 April and was moving at speeds of between 40 and 50 km h^{-1}. It ceased generating gales by 0900 23 April but continued as a discernible low pressure circulation through 24 April when it moved into the Great Australian Bight, slowed and filled.

In all, *Orson* is estimated to have caused approximately US$16 million worth of damage. The damage included the partial destruction of the Bureau of Meteorology Weather Watch radar at Dampier which was being used to track the cyclone.

Fig. 23 As Fig. 4 but for *Meena* (4 to 9 May 1989).



***Meena* (N) and (B): 4 to 9 May 1989 (Fig. 23)**

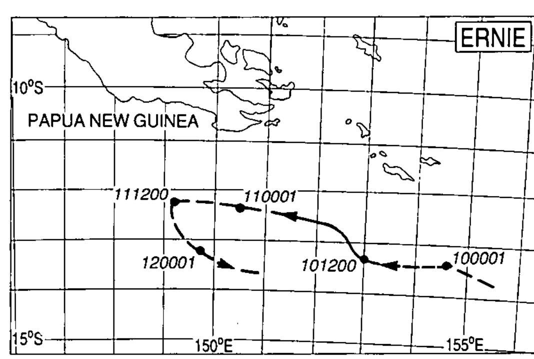
A shallow depression developed in the monsoon trough over the southeastern parts of the Solomon Islands late on 1 May. It moved slowly southwards and remained weak and ill-defined until 4 May when it started reintensifying gradually as it curved towards the southwest. Cloud convection and organisation increased and the system was named at 1800 4 May.

By 0001 5 May *Meena* was at 13.4°S, 160.0°E with a central pressure of 994 hPa. It moved southwest at around 20 km h^{-1} for 18 hours with little change in intensity to a position 15.5°S, 158.0°E then moved westerly for 12 hours, northwesterly for 12 hours and then west-northwesterly for 18 hours to 12.8°S, 149.7°E at 1200 7 May. The lowest central pressure during this period was 990 hPa at about 0600 6 May.

The final part of the track to landfall, on Cape York Peninsula, was almost due west. The system continually weakened and was barely a tropical cyclone at landfall at 0001 9 May when it had a central pressure of 1000 hPa. The system continued to weaken as it crossed Cape York Peninsula and dissipated in the central Gulf of Carpentaria 21 hours later.

The lowest observed pressure (1000 hPa) and strongest wind (93 km h^{-1}) were reported at 0600 on 6 May from a ship at 14.3°S and 154.7°E. No damage was reported.

Fig. 24 As Fig. 4 but for *Ernie* (9 to 10 May 1989).



***Ernie* (B): 9 to 10 May 1989 (Fig. 24)**

A tropical depression developed 150 km off the southeast tip of Papua New Guinea on 9 May, deepened and was named *Ernie* at 0600 10 May at 13.3°S, 153°E.

By 0001 11 May *Ernie* had reached its lowest pressure of 998 hPa. It subsequently moved west-northwest and decayed.

From ship reports, the maximum reported wind was 72 km h^{-1} at 0600 10 May at 14.7°S, 153.9°E and the minimum reported pressure was 1006 hPa at 0600 11 May at 11.3°S, 149.5°E. No damage was reported.

Acknowledgments

The authors wish to acknowledge the assistance in the preparation of this summary of the staff of the Australian Bureau of Meteorology's TCWCs as well as those of the Fiji and New Zealand Meteorological Services.

The descriptions of each cyclone were submitted by the staff of the offices responsible for the issuing of warnings. The climatological summaries were principally prepared by Ross Keith when attached to the Darwin Regional Office and much of the El Niño/Southern Oscillation information was supplied by Dr Neville Nicholls of the Bureau of Meterology Research Centre (BMRC), Melbourne.

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Appendix

Glossary

Depression	A synoptic low pressure area with extratropical characteristics where the average wind speed may exceed 63 km h^{-1}.
Gales	Winds above 63 km h^{-1}.
GMS	Japanese Geostationary Meteorological Satellite III.
Gust	An instantaneous peak value of the surface wind.
Hurricane	See severe tropical cyclone.
ITCZ	Intertropical convergence zone; see monsoon trough.
McIDAS	Man-computer Interactive Data Access System: displays and manipulates real-time data on a screen allowing various forecasting applications to be utilised.
Monsoon trough	The region of low-level convergence and convection located equatorward of the primary trade wind flow. Also referred to as the intertropical convergence zone (ITCZ).
Severe tropical cyclone	A tropical cyclone with average surface wind of 118 km h^{-1} or more.
SOI	Southern Oscillation Index; relates to the difference in surface pressure between Tahiti and Darwin.
Storm force wind	Average surface wind of 89 to 102 km h^{-1}.
SPCZ	The South Pacific convergence zone; an extension of the monsoon shear line in the eastern part of the Australian region.
TCWC	Tropical Cyclone Warning Centre.
Tropical cyclone	A non-frontal cyclone of synoptic scale developing over tropical waters and having a definite organised wind circulation with average wind of 63 km h^{-1} or more surrounding the centre.
UTC	Coordinated Universal Time.
VISSR	Visible and infrared spin-scan radiometer; generates full-earth disc images.
Wind speed	A 10-minute average wind speed given in km h^{-1}.