Aust. Met. Mag. 36 (1988) 205-212

The Australian tropical cyclone season 1987-88

G.R. Foley, Regional Office, Bureau of Meteorology, Perth, Australia
(Manuscript received August 1988; revised September 1988)

One of the quietest seasons on record produced five tropical cyclones compared to an average over the most recent decade of nearly thirteen. Tropical cyclones *Frederic* and *Herbie* affected the Cocos Island group but caused little damage. Tropical cyclone *Charlie* made landfall near Upstart Bay in northern Queensland producing moderate crop damage. The remnants of tropical cyclone *Herbie* crossed the coast at Shark Bay in Western Australia on 21 May as an intense extratropical low causing considerable damage to the fishing town of Denham, crop and pastoral damage through the Gascoyne division, and the grounding and breakup of a 30 000 tonne freighter at Cape Cuvier.

Introduction

Even though Australian tropical cyclone warning centres nominally activate their routine monitoring phase in early November it was not until early January that the first tropical cyclone was observed in the region. The season extended through to late May due to the unusual events associated with tropical cyclone *Herbie*, giving the season similarities in temporal distribution and number of occurrences to the previous cyclone season (Manchur 1987).

The season was notable for the marked lack of tropical convection over the adjacent tropical regions. Infrequent episodes of tropical convective activity spawned several lows which dissipated before attaining tropical cyclone intensity. A major surge in the northwest monsoon which occurred late in March in the Western region produced a number of circulations within a broad elongated trough, however the principal low pressure centre eventually moved over land near Port Hedland before tracking through central Australia as a major rain bearing depression.

The most active period of the season was from early January through to the end of February when four of the five cyclones occurred. Of these only tropical cyclone *Charlie* crossed the coast, producing moderate crop damage from estimated maximum wind gusts of 165 km/h.

Tropical cyclone *Herbie* formed northwest of the Cocos Islands in mid-May and tracked southeast, briefly bringing gales to the island group. The cyclone weakened under strong vertical shear but shortly afterwards underwent an extratropical transition phase which saw an intense low accelerate towards the Western Australian coast. The storm caused wind damage to the small fishing town of Denham with further damage being caused by a moderate storm surge in the shallow bay waters. As the low moved inland it continued to produce gales through the Goldfields and even as it passed into the waters of the Great Australian Bight, where it amalgamated with a cold frontal system.

Two tropical cyclones were classified as severe (10-minute mean wind speed in excess of 120 km/h). Tropical cyclones *Frederic* and *Gwenda*, although small in areal extent, developed well-defined eye structures during their life cycles. Both were confined to ocean areas.

Seasonal statistics

The Australian Bureau of Meteorology undertakes international responsibility for tropical cyclone warnings for the area given in Fig. 1. Place names and localities mentioned in the text are also shown in this figure.

A statistical summary of tropical cyclone occurrence is presented in Table 1. A tropical cyclone day is defined as a day on which one or

Fig. 1 Australian tropical cyclone warning and advisory area of responsibility.

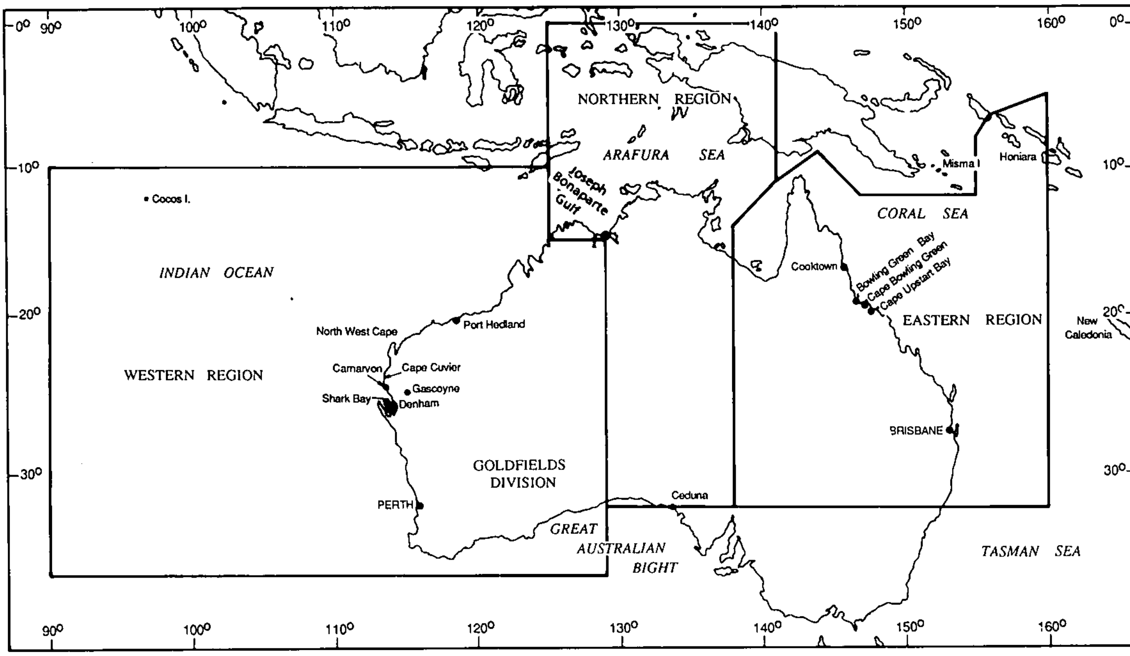


Table 1. Summary of the 1987-88 tropical cyclone season in the Australian region.

	Australian region	Western region	Northern region	Eastern region
Number of cyclones (1987-88)	5	3	0	2
Average number of cyclones (1978-79 to 1987-88)	12.8	7.9	2.2	4.1
Tropical depression initial location.	3	1†	0	2
Coastal crossing at cyclone intensity (sea to land)	1*	0*	-	1
Tropical cyclone days (one active)	24	14	-	10
Tropical cyclone days (two active)	0	0	-	0
Severe tropical cyclones	2	2	-	0

* does not include remains of *Herbie* which crossed as an extratropical cyclone.
† two developed in the Indonesian region.

more tropical cyclones (10-minute mean wind of 63 km/h or more) existed in the Australian region for any part of the day commencing 0000 UTC. Twenty-four cyclone days occurred during the 1987-88 season which is 44 per cent of the seasonal mean value.

The seasonal average number of tropical cyclones within the three regions during the ten-year period up to 30 June 1988 has been derived from data in Lourensz (1981), Manchur (1987) and records held in the Perth Tropical Cyclone Warning Centre.

The occurrence of five tropical cyclones was well below the annual mean of nearly thirteen, with the northern region recording no cyclones at all, and the other regions recording less than half of their average number. Since 1963 when the practice of naming tropical cyclones was implemented throughout Australia and the use of meteorological satellites has ensured almost certain identification, there have not been so few observed. Prior to the advent of the satellite the 1953-54 season was the most recent to have recorded fewer than five cyclones but, given the sparsity of the data of the period, some doubt must exist as to the completeness of the records (Holland 1981).

One tropical cyclone made a coastal crossing compared to the 21-year average of 4.8 (Lourensz 1981), while a system formed from the remnants of tropical cyclone *Herbie* crossed as an intense extratropical low.

Table 2 provides a precis of some of the more salient aspects of individual cyclones. Estimates of central pressure and maximum wind speed have been based on satellite interpretation techniques developed by Dvorak (1984) with modifications in some regions to take into account local conditions.

Table 2. Tropical cyclones in the Australian region during the 1987-88 season.

No.	Name and life span as a tropical cyclone	Initial location of tropical depression	First reached tropical cyclone intensity	Estimated lowest central pressure (hPa)	Weakened below tropical cyclone intensity
1.	*Agi* 11-14 Jan	15.0°S, 157.0°E 080000	10.4°S, 153.7°E 110600	980	20.1°S, 162.3°E 142100
2.	*Frederic* 30 Jan-2 Feb	6.9°S, 99.5°E 280000	10.0°S, 97.7°E 300000	950	18.6°S, 95.0°E 020000
3.	*Gwenda* 7-15 Feb	12.8°S, 109.0°E 060000	15.4°S, 104.5°E 071200	941	17.8°S, 82.9°E 152100
4.	*Charlie* 22 Feb-1 Mar	12.8°S, 159.3°E 210000	14.7°S, 156.5°E 221800	972	21.0°S, 147.9°E 010600
5.	*Herbie* 18-19 May	6.8°S, 91.6°E 170000	8.9°S, 93.8°E 180000	990+	13.6°S, 97.5°E* 190900

* reintensification of the *Herbie* system occurred near 16.4°S, 97.0°E.
+ intensification of the extratropical cyclone produced a minimum pressure at Denham of 982 hPa.

Large-scale features

During the 1987-88 summer, the Hadley circulation was much weaker than normal in both hemispheres. The monsoon circulation over the Indonesian-Australian region was very weak, and displaced some 5 degrees north of its mean position over Indonesian longitudes and the Indian Ocean. Over Australian waters and the Indian Ocean east of 100°E, cyclone activity was considerably suppressed. The ascending branch of the Walker circulation was displaced eastwards towards the Solomon Islands area. This was unusual, since an El Niño type influence was apparently exerting some control over the circulation in spite of the small value of the Southern Oscillation Index (SOI), (Troup 1965). It was noted in Darwin Tropical Diagnostic Statements* that there were continuing warm sea surface temperature (SST) anomalies in the central Pacific and possibly these were still having a significant 'local' effect on convection near the dateline, but were not affecting the broadscale circulation over the eastern Pacific.

The eastward shift of the Walker circulation and associated persistence of a favourable upper-level outflow triggered a number of genesis events east of 160°E.

Climatic indices

The wet season occurred while the El Niño event of 1986-87 was continuing its 1987 winter decline. The SOI, although negative, was within half a standard deviation of zero. Darwin's pressure anomaly was above average during the season, except for March when a monsoon depression was located for a time in the Joseph Bonaparte Gulf. Sea surface temperatures over the Australian region were generally near or a little higher than the mean values of Reynolds (1983), except off the northwest of Western Australia in the early part of the season. Nevertheless, broadscale suppression of vertical motion over the Australian region was reflected by a generally inactive monsoon. The corresponding reduction in broadscale low-level vorticity (weaker monsoon westerlies and easterlies), and the absence of strong trade surges from winter and summer hemispheres appeared to inhibit the genesis of tropical cyclones over most of the Australian region.

Low-level wind anomaly

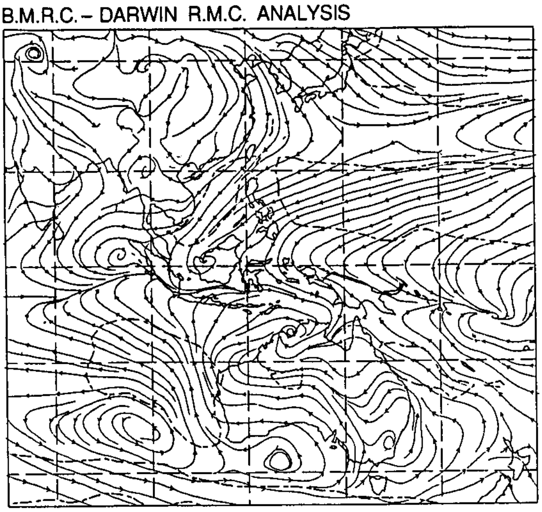
Figure 2 shows the mean 950 hPa streamline charts for December 1987 through to March 1988 analysed from an automated tropical analysis scheme (Davidson and McAvaney 1981). The southern hemisphere monsoon trough axis was near normal latitudes east of Cape York Peninsula compared to the long-term mean charts of Atkinson and Sadler (1970), but was about 5 degrees north of the mean position over the Indian Ocean. Over northern Australia, the monsoon trough was not well developed, and typically had the character of a heat trough. As a result, in the Western and Northern regions the northwest monsoon flow was more of southern than northern hemisphere origin. In particular, the flow off northwest Western Australia was mainly anticyclonic compared to a climatic mean cyclonic flow — a further contributor to the marked suppression of cyclogenesis.

Pressures over northern China were generally higher than average, however surges through the South China Sea tended to stagnate and manifest as a mean inflow near the latitude of northern Borneo, rather than propagate across the equator. Although the latitude of the northwest Pacific subtropical ridge was near normal, mid-latitude westerlies to the north were weaker than usual. Over South-East Asia (i.e. India to Indo-China)

* Darwin Tropical Diagnostic Statements issued monthly by Darwin RMC, and obtainable from Northern Territory Regional Office, Bureau of Meteorology, PO Box 735, Darwin 5794, Australia.

Fig. 2 1987-88 December to March streamlines at 950 hPa.

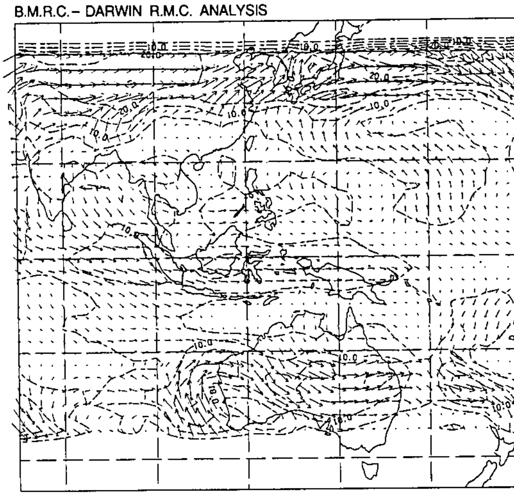
B.M.R.C.- DARWIN R.M.C. ANALYSIS



TROP STRL 950 871200 2300

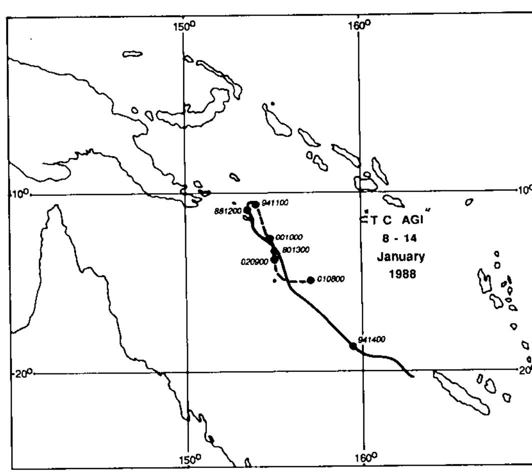
Fig. 3 1987-88 December to March vector wind anomalies at 200 hPa.

B.M.R.C.- DARWIN R.M.C. ANALYSIS



TROP VECT 200 871200 2300

Fig. 4 Track of cyclone *Agi*. Broken line denotes pre- and post-cyclone stage. Key to numbers along track in code form PPYGG – PP central pressure (tens and units of hectopascals); YY – dates; GG – time (UTC whole hours).



and the northwest Pacific, the wintertime subtropical ridge was weaker than normal. Associated with this was a broad band of westerly anomalies between 10°N and 2°N which reflected a weaker than normal northwest trade flow approaching the equator from the northern hemisphere.

Upper-level wind anomaly

The axis of the 200 hPa ridge was near normal in comparison with the mean charts of Sadler (1975), though the major area of outflow was displaced eastwards towards the dateline rather than being over northern Australia and the Solomons. As a result, cross-equatorial flow was enhanced only east of 160°E. Indeed, over the Indonesian-Australian area, anomalously strong westerlies reflected much reduced cross equatorial return flow into the northern hemisphere (Fig. 3). Westerly anomalies over Australia, the Tasman Sea and over the northern hemisphere subtropical jet axis show stronger jets than in the mean, particularly in the northern hemisphere, suggesting overall more baroclinicity in the area at the expense of barotropy.

Tropical cyclones of the 1987-88 season

1. Tropical cyclone *Agi*, 8 to 14 January 1988 (Fig. 4)

The circulation that was to become tropical cyclone *Agi* was first identified as a low at 0000 UTC 8 January some 1200 km east of Cooktown. During the next two days this circulation drifted slowly northwestwards without significant development. The low continued to move northwestwards into the Papua New Guinea region and the central pressure then began to fall until at 0600 UTC 11 January it became a tropical cyclone. The system was then about 100 km east of Misima with a central pressure of 994 hPa.

Tropical cyclone *Agi* moved first west-southwest and then very slowly southeast while gradually deepening. At about 1500 UTC 12

January the system moved back into the Eastern Australian region near 12°S, 154°E with a central pressure of 980 hPa. It continued to move southeastwards without further deepening for the next 24 hours.

At about 1800 UTC 13 January the system began to fill. It was beginning to interact with tropical cyclone *Anne*, which had formed to the east of Fiji at about the time of the formation of tropical cyclone *Agi*, and moved generally southwest to be south of New Caledonia. At around 0000 UTC 14 January tropical cyclone *Agi* began to track in a more easterly direction and passed into the Fiji region two hours later at 19°S with a central pressure of 994 hPa.

The system continued to move slowly east-southeast and gradually filled until at 2100 UTC 14 January it was no longer of cyclone intensity.

The highest estimated mean wind speed was 95 km/h with estimated gusts to 135 km/h. The lowest estimated central pressure was 980 hPa. The lowest reported pressure was 995.9 hPa at Misima at 1800 UTC 11 January 1988. Apart from producing strong winds along the Queensland coast this system had no effect on the Australian mainland.

2. Tropical cyclone *Frederic*, 28 January to 1 February 1988 (Fig. 5)

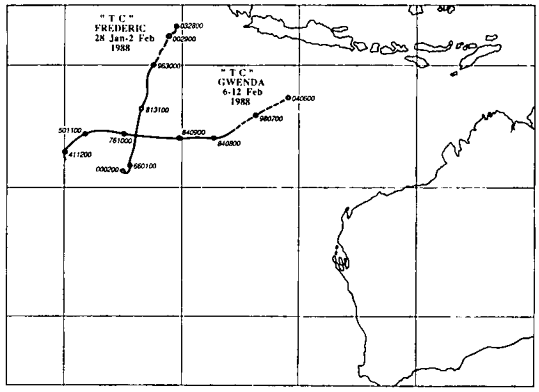
Tropical cyclone *Frederic* was the first cyclone to form in the Western Australian region in the 1987-88 season. The initial tropical low was first discernable at 0001 UTC 28 January near 6.9°S, 99.5°E. It moved slowly west at first before settling onto a south-southwestward course which it maintained from 0001 UTC 29 January until its decaying stages. The low attained tropical cyclone intensity at about 0001 UTC 30 January near 10.0°S, 97.7°E, some 240 km north-northeast of Cocos Island.

The centre of the cyclone passed very close to the Cocos group at about 1500 UTC 30 January. The meteorological office on the Island reported a lowest pressure reading of 993 hPa and a maximum wind gust of 113 km/h. The community experienced gale force winds for a period of about eight hours but sustained little damage.

After leaving Cocos, *Frederic* continued to intensify and Japanese Geostationary Meteorological Satellite (GMS) imagery indicated a small, intense system had developed by 31 January with tightly banded features. An eye became visible for a brief period about 2100 UTC 31 January when *Frederic* was at its most intense. Dvorak intensity analyses suggested a central pressure near 950 hPa with maximum wind gusts of 205 km/h.

After 0001 UTC 1 February the tropical cyclone came under the influence of increasing vertical wind shear which rapidly weakened the system. By 1800 UTC 1 February the low-level centre was clearly divorced from the middle-level canopy. The low-level centre then drifted west-northwest before filling completely during 2 February.

Fig. 5 Tracks of cyclones *Frederic* and *Gwenda* (nomenclature as in Fig. 4).



3. Tropical cyclone *Gwenda*, 6 to 13 February 1988 (Fig. 5)

Tropical cyclone *Gwenda* began as a tropical low over the ocean area to the northwest of the continent near 12.8°S, 109.0°E at 0000 UTC 6 February. The low moved slowly southwest from this position, gradually intensified and reached tropical cyclone intensity at 1200 UTC 7 February near 15.4°S, 104.5°E,approximately 1200 km northwest of North West Cape. The cyclone continued to intensify for another 12 hours but its development was much slower as it moved westward at 18 km/h for the next 48 hours.

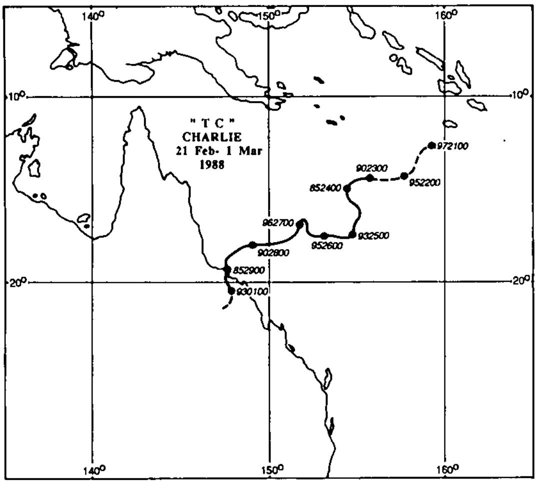
By 0000 UTC 10 February the cyclone was near 15.8°S, 95.0°E and in the following 48 hours significant intensification resumed. An eye was first observed at 2100 UTC 10 February. During this period the cyclone decelerated and moved initially west at 15 km/h and then southwest at 9 km/h to be near 17.0°S, 90.0°E at 0000 UTC 12 February. At this time a modified Dvorak analysis indicated a central pressure of 941 hPa with maximum wind gusts to 235 km/h.

The cylone then entered the Mauritian area of responsibility, was renamed *Ezenina*, and gradually weakened as it approached 80.0°E.

4. Tropical cyclone *Charlie*, 21 February to 1 March 1988 (Fig. 6)

For several days before the formation of the low which was to become tropical cyclone *Charlie* there were diffuse thunderstorm clusters over the northern Coral Sea. The low eventually became recognisable at 0000 UTC 21 February some

Fig. 6 Track of cyclone *Charlie* (nomenclature as in Fig. 4).



400 km south-southwest of Honiara. This system moved slowly west-southwest and gradually deepened from a central pressure of 997 hPa and reached cyclone intensity at 1800 UTC 22 February with a central pressure of 993 hPa and positioned at 14.6°S, 156.2°E.

Tropical cyclone *Charlie* continued to intensify gradually for another 30 hours and deepened to have a central pressure of 985 hPa when at 15.2°S, 154.5°E. During this period the system altered course to the south. *Charlie* then began to decay and tracked first southeast, then southwest and finally west. By 1200 UTC 25 February it had filled to 996 hPa and was centred at 17.5°S, 153.8°E. There was little or no change for the next 36 hours other than a slow west-southwest drift.

The system then began to intensify once more and a general westward movement was maintained for a further 36 hours. At about 1200 UTC 28 February the final major turn occurred, this time to the south. Intensification continued while the cyclone tracked through Bowling Green Bay, across Cape Bowling Green and through Upstart Bay. *Charlie* made landfall in the southern part of Upstart Bay around 1600 UTC 29 February with a central pressure of 972 hPa. The cyclone continued to move inland and weakened to less than cyclone intensity at 0600 UTC 1 March. It was unrecognisable as a distinct system by 1500 UTC on the same day.

The lowest recorded pressure was 981 hPa at 1930 UTC 29 February at Cape Bowling Green A.W.S. and the highest recorded wind speed was 139 km/h at the same site 30 minutes later.

The estimated maximum wind speed was 115 km/h with maximum gusts to 165 km/h. The lowest central pressure was estimated to be 972 hPa and the mean eye diameter at the time of peak intensity was 37 km. Structural damage caused by *Charlie* was minor but there was moderate crop damage, mainly to sugar cane.

5. Tropical cyclone *Herbie*, 18 to 19 May 1988 (Fig. 7)

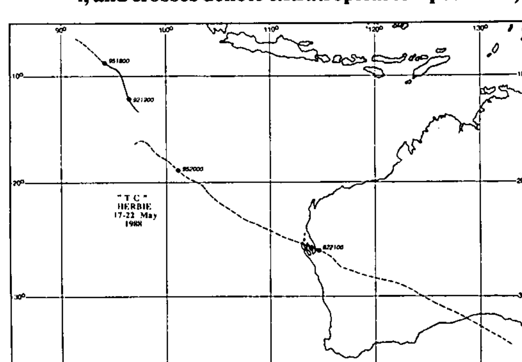
Tropical cyclone *Herbie* developed on 17 May in a convective cloud cluster which had drifted slowly eastward from the central Indian Ocean during the previous 3 to 4 days. Apart from a few ship reports from the periphery of the storm the main observational evidence for the development of the system to cyclone intensity came from a brief period of gales at Cocos Island.

Despite the observations from Cocos, the analyses of the system's intensity and track are almost totally dependent on the interpretation of High Resolution GMS imagery. The dense cirriform cloud cover and the poor organisation of the system limited the confidence which could be attached to the satellite interpretation, particularly while the centre was north of about 16°S. Given these difficulties, it is possible to imagine different analysts deriving different tracks.

During 17 to 18 May the developing low moved southeast and probably reached cyclone intensity at about 0000 UTC 18 May. Twelve hours later the cyclone attained its maximum intensity with a central pressure of about 990 hPa near 10.5°S, 95.8°E.

The cyclone continued on a southeasterly track and by 0000 UTC 19 May was located near 12.3°S, 96.5°E, approximately 65 km west-southwest of Cocos Island where the maximum recorded wind gust was 87 km/h and the minimum recorded pressure was 995 hPa at 0000 UTC. No damage was reported from the island group.

Fig. 7 Track of cyclone *Herbie* (nomenclature as in Fig. 4, and crosses denote extratropical low positions).



The visual GMS image at 0300 UTC 19 May could be interpreted as indicating that the low-level circulation was divorced from the strongly convective area associated with the cyclone, and that a trough line had developed southward from the low centre. The NOAA-10 visual imagery at 0840 UTC showed two small circular cloud patterns in this trough. One of these patterns may have been the remnants of *Herbie* and the other a new development some 315 km to the south.

By 1200 UTC 19 May *Herbie* was no longer identifiable as a tropical cyclone and successive three-hourly GMS images showed an increase in the curvature of cloud features near the new low, signalling an intensification of the system. This intensification is thought to have occurred via an extratropical process, in which the low's primary kinetic energy source was enhanced by baroclinic conversion of potential energy, generated by an increase in the thermal gradient over the ocean area to the southwest of the system. This occurred as the result of a northward intrusion of cold air into low latitudes behind a cold front which traversed the Indian Ocean to the south of the system in the preceding twelve hours. A process similar to this has been noted by Brand and Guard (1978) in which they discuss extratropical storm evolution from tropical cyclones in the northwestern Pacific Ocean.

The deepening extratropical low accelerated as it moved southeastward along the northern side of the strengthening baroclinic zone and by 0000 UTC 20 May was located near 19.0°S, 101.2°E approximately 1500 km northwest of Shark Bay. Visible imagery at 0300 UTC (Fig. 8) showed a cloud signature with marked similarities to a developing mid-latitude baroclinic wave. The storm continued to accelerate and deepen, and crossed the coast near the town of Denham at 2230 UTC 20 May. At this time it was moving at 75 km/h and had a central pressure of 980 hPa.

Satellite imagery at 0001 UTC 21 May 1988 (Fig. 9) shows the typical signature of an extratropical cyclone with an almost total absence of convection near the centre and the major rain echoes displaced to the southern quadrants.

No wind recordings are available from Denham but the station barograph trace is shown in Fig. 10. Carnarvon, 100 km to the north, reported a maximum wind gust of 120 km/h. The winds caused some structural damage along the coastal strip from Carnarvon to Denham, some crop losses in Carnarvon and a 30 000 tonne freighter the *Korean Star* ran aground and split in two near Cape Cuvier. A storm surge occurred within the semi-enclosed waters of Shark Bay, and caused inundation to parts of Denham.

The low continued in a southeasterly direction at 75 km/h through central Western Australia and

Fig. 8 GMS visual image 0300 UTC 20 May 1988 showing cloud features similar to a developing mid-latitude baroclinic wave.

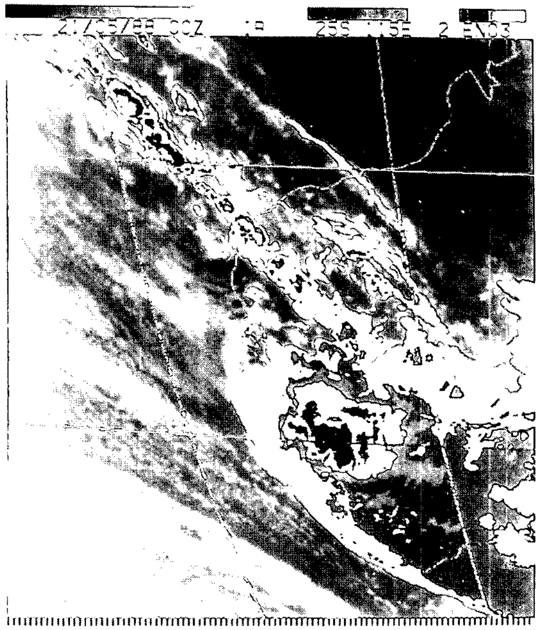


Fig. 9 Enhanced IR image 0001 UTC 21 May 1988 of extratropical cyclone just inland from Shark Bay. Note the marked lack of cloud near the low centre, with major precipitation displaced to the south of the system.

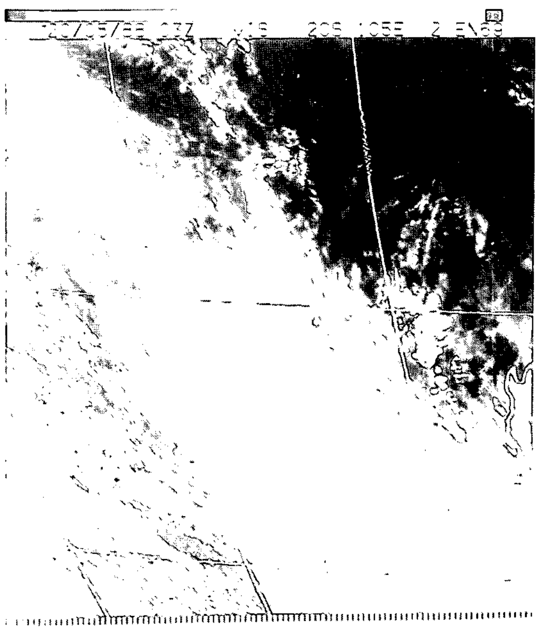
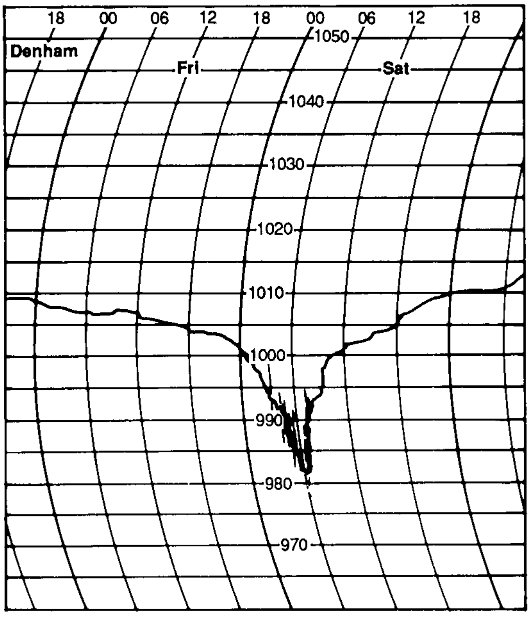


Fig. 10 Barograph trace from Denham, WA, showing the passage of the extratropical low at 2230 UTC 21 May.



caused gales, extensive duststorms and sand blasting in areas on the northern side of the storm and heavy rains and flooding on the southern side near the west coast. By 2100 UTC 21 May the low had moved over the Great Australian Bight, where it amalgamated with a Southern Ocean cold front and was lost as a discrete system on satellite imagery.

Acknowledgment

This report was prepared from material supplied by the staff of the Severe Weather Sections in Brisbane, Darwin and Perth. Mr Alan Scott provided many useful comments.

References

Atkinson, G.D. and Sadler, J.C. 1970. Mean cloudiness and gradient level wind charts over the tropics. *Tech. Report 215*, Air Weather Service, Scott AFB, Illinois. 70 pp.

Brand, S. and Guard, C.P. 1978. Extratropical storm evolution from tropical cyclones in the western North Pacific Ocean. *Tech. Report TR 78-02*, NEPRF. Monterey Ca. 19 pp.

Davidson, N.E. and McAvaney, B.J. 1981. The ANMRC tropical analysis scheme. *Aust. Met. Mag., 29*, 155-68.

Dvorak, V.F. 1984. Tropical cyclone intensity analysis using satellite data. *NOAA Tech. Rep. NESDIS 11*. 47 pp.

Holland, G.J. 1981. On the quality of the Australian tropical cyclone data base. *Aust. Met. Mag., 29*, 169-81.

Lourensz, R.S. 1981. Tropical cyclones in the Australian region, July 1909 to June 1980. *Met. Summary*, AGPS, Canberra.

Manchur, W. 1987. The Australian tropical cyclone season 1986-87. *Aust. Met. Mag., 35*, 95-102.

Reynolds, R.W. 1983. A monthly averaged climatology of sea surface temperature. Climate Analysis Center, National Meteorological Center, NWS, Washington DC 20233. 35 pp.

Sadler, J.C. 1975. The upper tropospheric circulation over the global tropics. *UHMET 70-05*, University of Hawaii, Honolulu. 35 pp.

Troup, A.J. 1965. The 'southern oscillation.' *Q. Jl R. met. Soc., 91*, 490-506.