Australian Government
Bureau of Meteorology

Severe Tropical Cyclone *Glenda*

27 - 31 March 2006

Perth Tropical Cyclone Warning Centre
Bureau of Meteorology

A. Summary

Severe Tropical Cyclone *Glenda* was a small and intense system that developed very rapidly after moving off the northwest Kimberley coast. *Glenda* reached category 5 intensity but weakened as it approached the Pilbara coast. Although threatening to cross the coast near the populated Dampier/Karratha region as a Category 4 system close to the time of high tide, *Glenda* took a more SW course towards Onslow and weakened before finally crossing the coast near Onslow at 2200 WST 30 March as a marginal category 3 system. Very destructive winds were recorded on the coast at Mardie prior to crossing.

A total of 206 mm of rain fell at Onslow in the 24 hours to 0900 WST 31 March, representing the sixth wettest day on record for the town. Other centres in the Pilbara also recorded cumulative totals of over 200mm, and although in general *Glenda* produced less than average rainfall for a landfalling tropical cyclone, rainfall was sufficient to cause problems for transport.

The weakening of TC *Glenda* prior to impact on Onslow, together with the preparedness of the town helped to avert major damage.

B. Meteorological Description

A weak low developed in the Gulf of Carpentaria during the middle of March and slowly progressed westwards over the Northern Territory. On 24 March it moved temporarily into the Joseph Bonaparte Gulf north of Wyndham, then accelerated across the Kimberley overnight. On 26 March vertical wind shear eased and by about 1200 UTC the system moved off the coast and developed rapidly. Cyclone intensity was estimated at 0000 UTC on 27 March.

Subsequent intensification was at the upper end of the development cycle. By 10 UTC 27 March *Glenda* passed near Adele Island where the pressure fell to 981 hPa with an easterly at 46 knots. At 12 UTC Adele registered a wind speed of 61 knots in the northerlies on the eastern side of the system. (Note only hourly observations are received from Adele Is). This suggests *Glenda* was at category 3 intensity especially as it appears the maximum winds were on the western side of the system (this breaks Dvorak constraints which technically constrains intensity to CI of 4.0 (corresponding to category 2).

Unfortunately given the inaccuracy of the position (not yet captured on radar) to Adele Is, and only having hourly observations it is difficult to infer the central pressure. The drop from 990 to 981 hPa and then the rise to 992.7h Pa using the estimated positions gives a pressure profile of approximately 1 hPa per nm and given the 981 hPa reading was when the centre was 7 nm from Adele Is this corresponds to a central pressure of approximately 974 hPa. While this is higher than the Atkinson and Holliday P-W relationship derived value of 966 hPa (based on 65 knot winds and using an environmental pressure of 1006 hPa), if one considers the small size of the system, a central pressure of 975 hPa may be reasonable for a 65 knot system.

Subsequent convection overnight was very deep with very cold cloud tops evident and an eye was developing on IR imagery by 00 UTC 28 March and a CI of 6.5 by 06UTC (see Fig. 2). A smooth round CDO and clear eye is shown on the visible imagery (see Fig. 3). Indeed the Dvorak DT estimates peaked at 7.0 (6.5 + 0.5 eye correction) at 0630 UTC, although time averaged, a CI of 6.5 is more representative. Peak intensity of *Glenda* is estimated between 06 and 12UTC when maximum winds were estimated at 110 knots. Broome radar shows a well-defined eye (see Fig. 4) when *Glenda* was about 230 km from Broome. Interestingly the strongest convection appears on the western side of the system (far side from Broome radar), a pattern that continued throughout much of *Glenda*'s lifetime.

A DT of 6.5 was sustained through to about 14 UTC with very low cloud top temps surrounding the eye. However, eye definition diminished overnight with an apparent increase in easterly shear. With such a small eye, combined with parallax, any shear would have an impact in obscuring the eye on IR imagery and thus reducing Dvorak based estimates. An eye returned on 29 March albeit weaker than the previous day and was short lived with the eye again becoming obscured overnight. Microwave imagery maintained a asymmetric eye pattern in the convection.

Glenda passed to the north of private operated buoy which registered winds to 90 knots some estimated 18 nm from the centre before reports ceased. Given that the radius of maximum winds is estimated at less than 10 nm, the estimated 100 knot intensity is reasonable.

Winds on the southern side of *Glenda* were enhanced by a synoptic scale easterly surge resulting from a strong ridge to the south of WA and Bedout Island registered gales on 29 March.

Glenda then passed close to North Rankin platform where winds of 94 knots were recorded some 13 nm from the centre. Subsequent imagery showed weakening as it neared the coast. Nevertheless winds were still recorded to 87 knots at Varanus Island when *Glenda* passed 10-15 nm from the centre.

Mardie recorded hurricane force winds from 0630-0730UTC 30 March when less than 25 nm from the centre (see Fig 5a). This is more impressive as winds were from overland and it is reasonable that the maximum winds at the time were higher over open water.

As *Glenda* moved closer to the coastline the radar signature became weaker from both Dampier and Learmonth. Onslow recorded storm-force winds from 0830-1310 UTC and a maximum sustained wind of 63 knots at 1230 UTC indicating that at

12UTC *Glenda* was still of category 3 intensity (see Fig. 5b). The barometer fell to 970.5 hPa at 1310UTC when winds were easterly at 51 knots indicating the system was still offshore. The fact that Onslow's winds were from overland indicated that offshore winds would have been higher even though the radar signature shows the only convection being to the southwest of the centre in the SSE'lies over land. While arguably the strongest winds are co-located with the convection in this region, the enhanced offshore flow effect.

Coastal crossing time is estimated as being 14 UTC when Onslow's wind lulled to 18 knots from the northeast and then returned to gale-force at 1430 UTC in the northeasterlies (max 40 knots). *Glenda*'s intensity rating at 15UTC is 60 knots (category 2) although it is possible winds in the western (offshore) quadrant were still hurricane force. It is therefore debatable as to whether *Glenda* crossed as a category 2 or 3 system even though it had a category 3 impact on the coast.

Glenda rapidly weakened as it moved southwards and by 18 UTC the radar showed a weak signature. In the absence of convection winds are likely to have rapidly weakened as *Glenda* moved over hilly terrain and the boundary layer stabilised overnight. Nevertheless Emu Creek station reported 30 knot sustained SE'ly winds and a MSLP of 995.6 hPa at 22 UTC as the system passed by. The barograph traced bottomed out for two hours at this pressure which suggested the central pressure wasn't much less than this value. Noting the difficulties in estimating the rate of weakening of *Glenda,* by 00 UTC 31 March the system was rated at below cyclone intensity.

C. Impact

Despite the potential for significant damage given the intensity of *Glenda* while offshore, damage on the mainland was only of a minor nature. In Onslow trees were felled and power lines brought down but damage to property was generally of a minor nature. Floodwaters cut roads for days. Vegetation damage also caused problems in Dampier and Karratha region.

Glenda posed a massive storm surge threat to the Dampier/Karratha area. At one stage there was the chance it would cross just west of Dampier as a category 4 cyclone at high tide prompting serious evacuation decision to be made. Fortunately *Glenda* moved away and weakened, although some inundation did occur from the east to northeasterlies during the day. King Bay registered a storm surge of 1.5m at about noon on 30 March causing a storm tide of about 5.8m (0.6m above HAT) while Cape Lambert and Port Hedland both registered a storm surge of 1.0 m a few hours later at low tide. Onslow registered a negative surge when winds were offshore until the cyclone moved inland.

Flooding occurred across the region exacerbated by floods in the previous months. Although some falls exceeded 200 mm, rainfall was not as great as is typical of a major landfalling cyclone especially over inland areas. This was owing to *Glenda* collapsing convection at landfall and also being a small system.

While damage to offshore industry infrastructure is unknown, the economic cost from production losses would be considerable given the widespread evacuations and closure of Pilbara ports.

D. Observations

Site	Maximum 10 min Wind (knots)	Maximum Wind Gust (knots)	Lowest Pressure (hPa)
North Rankin	94 @ 30/01:00 UTC	N/A	N/A
Mardie	73 @ 30/07:10 UTC	97 @ 30/07:00 UTC	972.7 @ 30/07:00 UTC
Onslow	63 @ 30/12:30 UTC	84 @ 30/12:10 UTC	970.5 @ 30/12:30 UTC
Karratha	53 @ 30/05:00 UTC	69 @30/05:00 UTC	989.5 @ 30/04:20 UTC
Adele Is*	61 @ 27/12:00 UTC	N/A	981.0 @ 27/12:00 UTC

*Note: Adele Island only reports hourly. North Rankin observations incomplete.

See Fig. 5 for graphs of wind and pressure data.

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Table 1. Best track summary for *Glenda,* 23-31 March 2006.
Note: Add 8 hours to convert to WST. Refer to best track database for complete track details.

Year	Month	Day	Hour (UTC)	Position Latitude S	Position Longitude E	Position Accuracy nm	Max wind 10-min knots	Max gust knots	Central Press. hPa	Rad. of gales nm	Rad. of storm force winds nm	Radius of hurricane force winds nm	Radius Max. Wind (RMW)
2006	3	25	0	14.8	127.8	15	25	45	996				
2006	3	25	6	14.8	127.6	15	25	45	996				
2006	3	25	12	14.7	127.4	15	25	45	996				
2006	3	25	18	14.9	126.6	15	25	45	996				
2006	3	26	0	14.9	125.6	20	25	45	996				
2006	3	26	6	14.9	125.3	25	25	45	996				
2006	3	26	12	14.7	125.1	25	25	45	996				
2006	3	26	18	14.6	124.8	25	35	45	994				
2006	3	27	0	14.9	124.4	20	40	55	990	35			5
2006	3	27	3	15.1	123.9	20	45	60	984	35			5
2006	3	27	6	15.2	123.5	20	50	70	980	40	10		5
2006	3	27	9	15.4	123.2	15	55	80	972	50	15		5
2006	3	27	12	15.5	123.0	15	65	90	970	50	20	10	5
2006	3	27	15	15.5	122.5	15	70	95	962	55	20	10	5
2006	3	27	18	15.5	122.3	20	80	110	950	55	25	15	5
2006	3	27	21	15.5	122.0	20	90	125	938	60	25	15	5
2006	3	28	0	15.6	121.8	20	100	145	924	60	35	20	5
2006	3	28	3	15.8	121.5	20	105	150	918	70	40	20	5
2006	3	28	6	16.0	121.1	20	110	160	910	70	50	20	5
2006	3	28	9	16.3	120.8	20	110	160	910	85	50	20	5
2006	3	28	12	16.7	120.4	15	110	160	910	90	50	25	5
2006	3	28	15	16.8	119.8	15	110	160	910	90	50	25	5
2006	3	28	18	17.0	119.4	15	110	160	910	95	55	25	5
2006	3	28	21	17.2	119.1	15	110	160	910	100	55	25	5
2006	3	29	0	17.4	118.7	15	105	150	918	110	55	30	5
2006	3	29	3	17.5	118.2	15	105	150	918	115	55	30	5
2006	3	29	6	17.7	117.8	15	105	150	918	120	55	30	5
2006	3	29	9	17.9	117.6	15	105	150	918	120	55	30	5
2006	3	29	12	18.3	117.4	15	105	150	918	120	55	30	8
2006	3	29	15	18.6	117.0	15	100	145	924	120	55	30	8
2006	3	29	18	18.8	116.7	15	100	145	924	115	55	30	8
2006	3	29	21	19.1	116.5	15	100	145	924	115	55	30	8
2006	3	30	0	19.6	116.4	15	100	145	924	110	55	30	8
2006	3	30	3	20.1	116.2	15	100	135	924	95	55	30	10
2006	3	30	6	20.7	115.8	15	95	125	932	80	50	30	10
2006	3	30	9	21.3	115.5	15	80	110	950	65	45	25	10
2006	3	30	12	21.5	115.3	15	70	95	962	50	35	20	10
2006	3	30	15	21.9	115.1	15	60	85	970	45	25		10
2006	3	30	18	22.2	115.1	20	50	70	980	35	10		10
2006	3	30	21	22.7	115.1	20	40	55	990	20			10
2006	3	31	0	23.3	115.0	20	30	45	994				
2006	3	31	3	24.0	114.9	20	30	45	994				
2006	3	31	6	24.6	114.8	20	25	40	996				

Figure 1. Track of Tropical Cyclone
All times in WST.

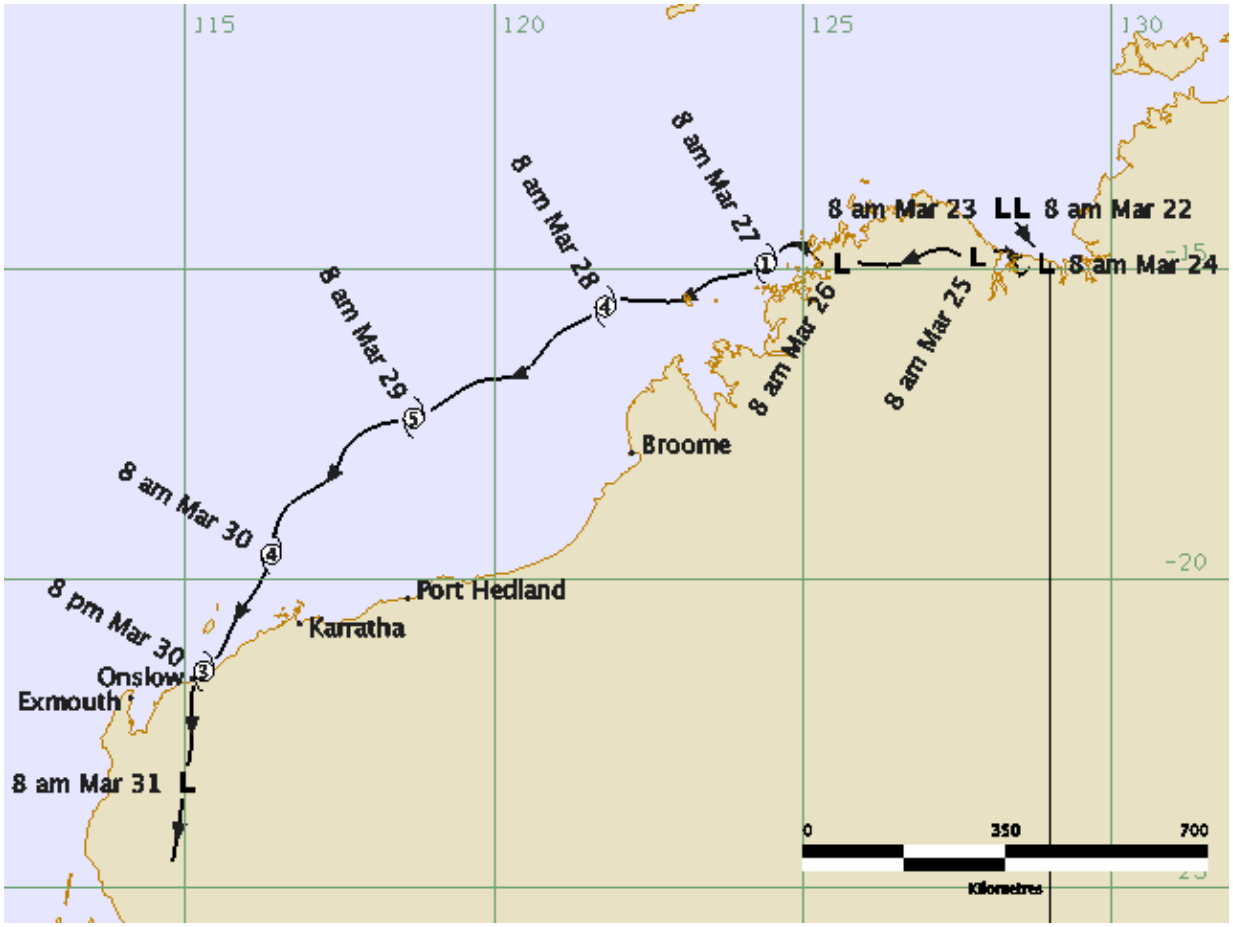

Figure 2. TRMM 85GHz Microwave image of Tropical Cyclone *Glenda* close to maximum intensity, 0627 UTC 28 March 2006.
(image courtesy of US NRL: http://www.nrlmry.navy.mil/)

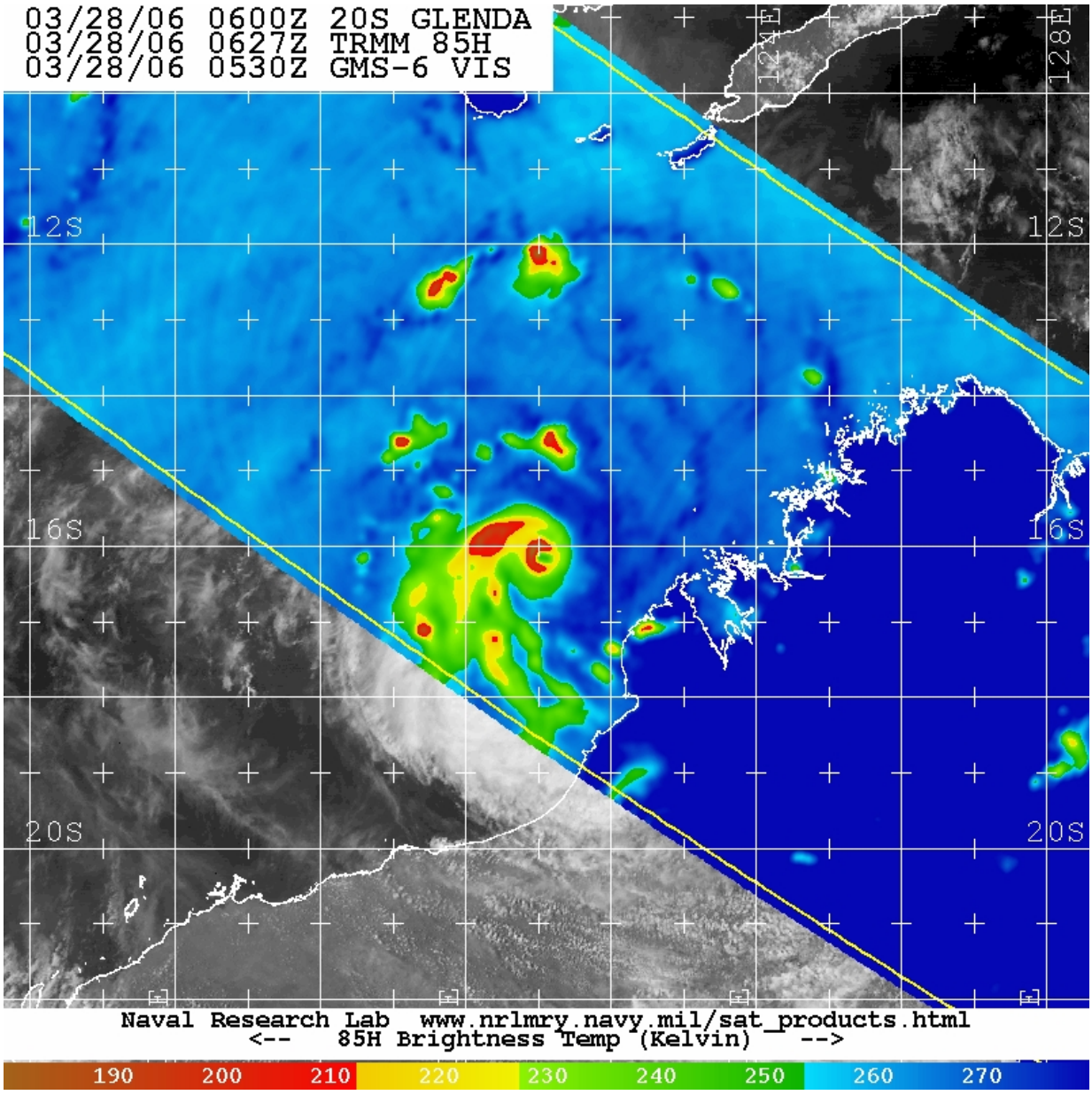

Figure 3. MODIS Visible image of Tropical Cyclone *Glenda* close to maximum intensity, 0200 UTC 28 March 2006. Image courtesy of NASA.

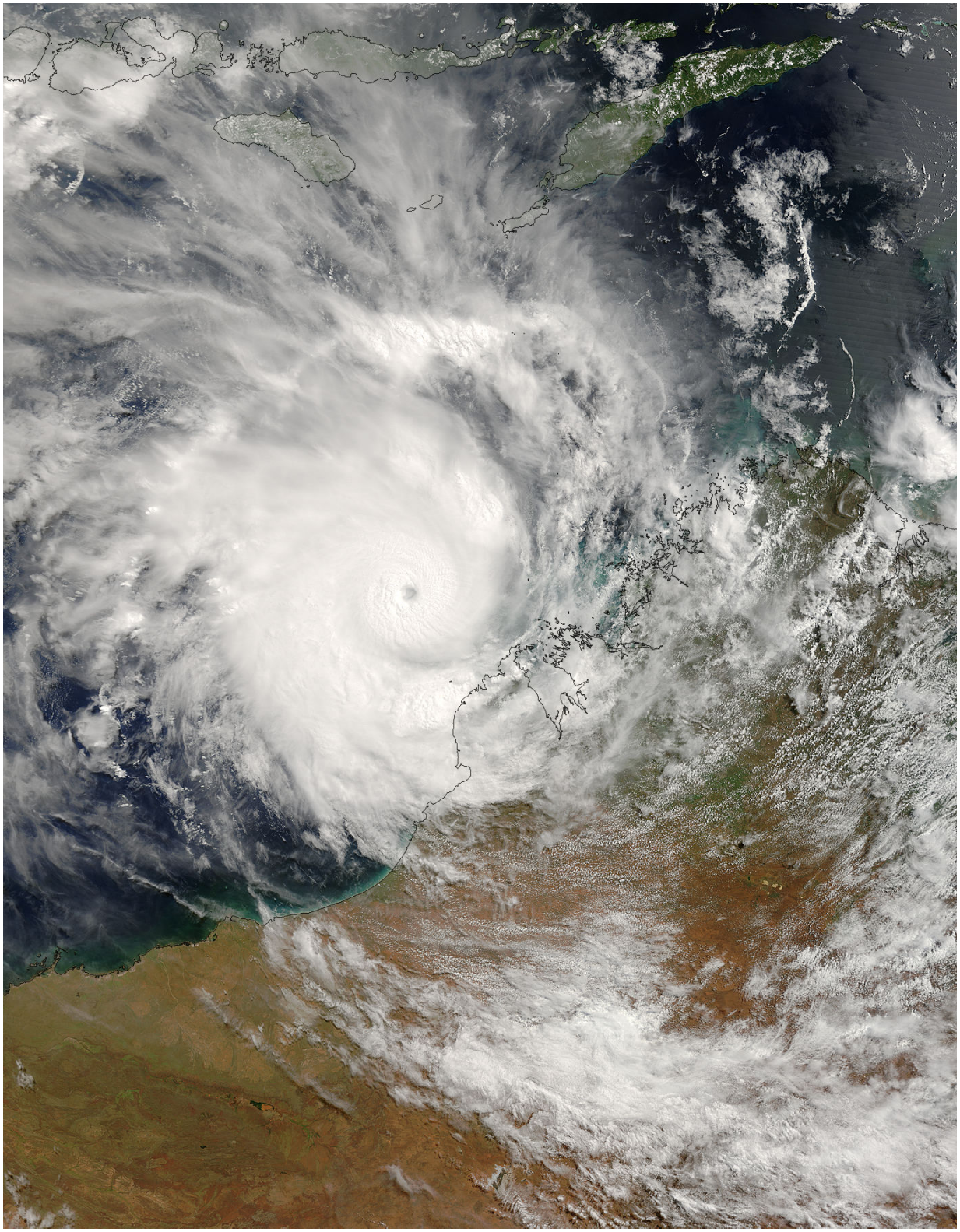

Figure 4. Broome radar image 0930 UTC 28 March 2006 when Glenda was near peak intensity about 230 km from Broome.

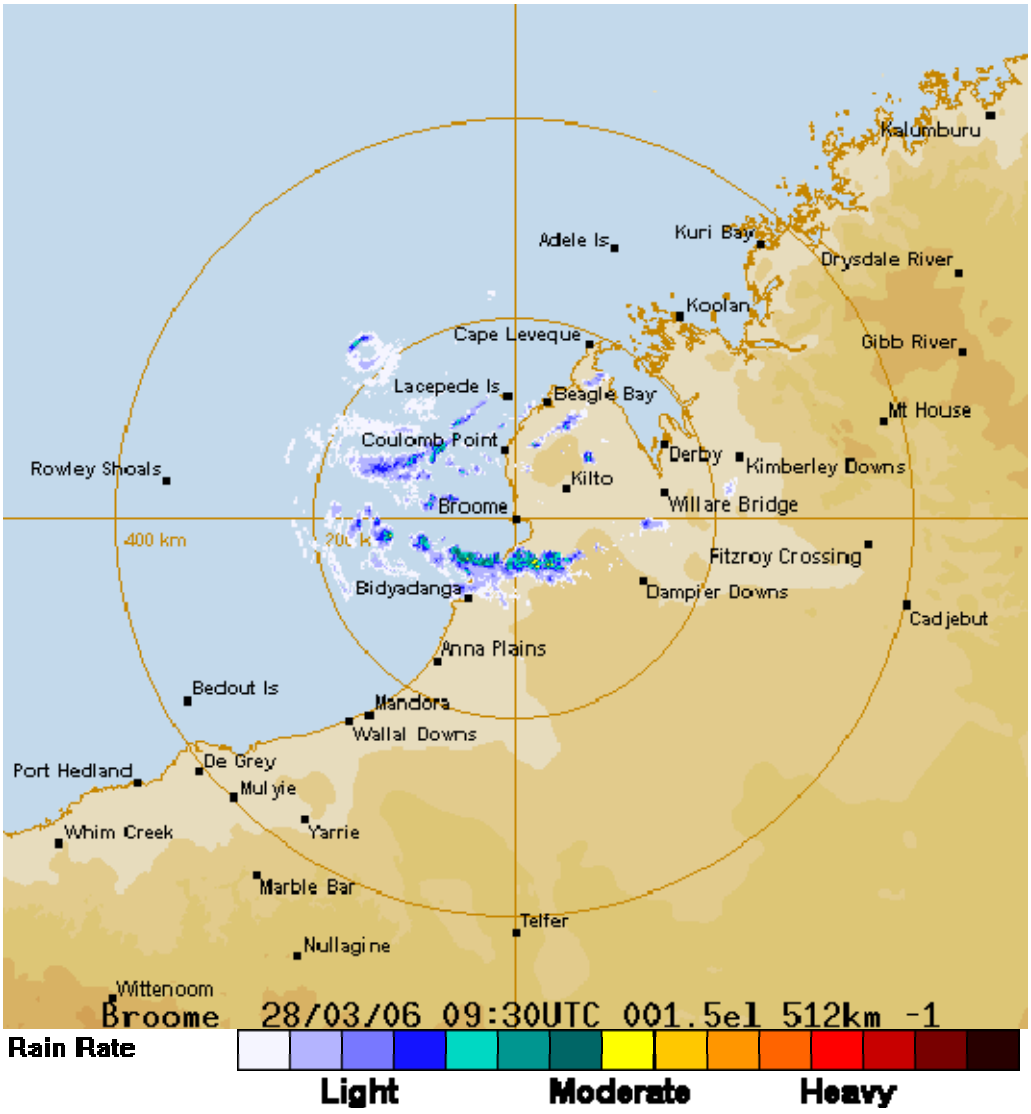

Figure 5a Winds and pressure at Mardie during TC *Glenda* 29-31 March 2006.

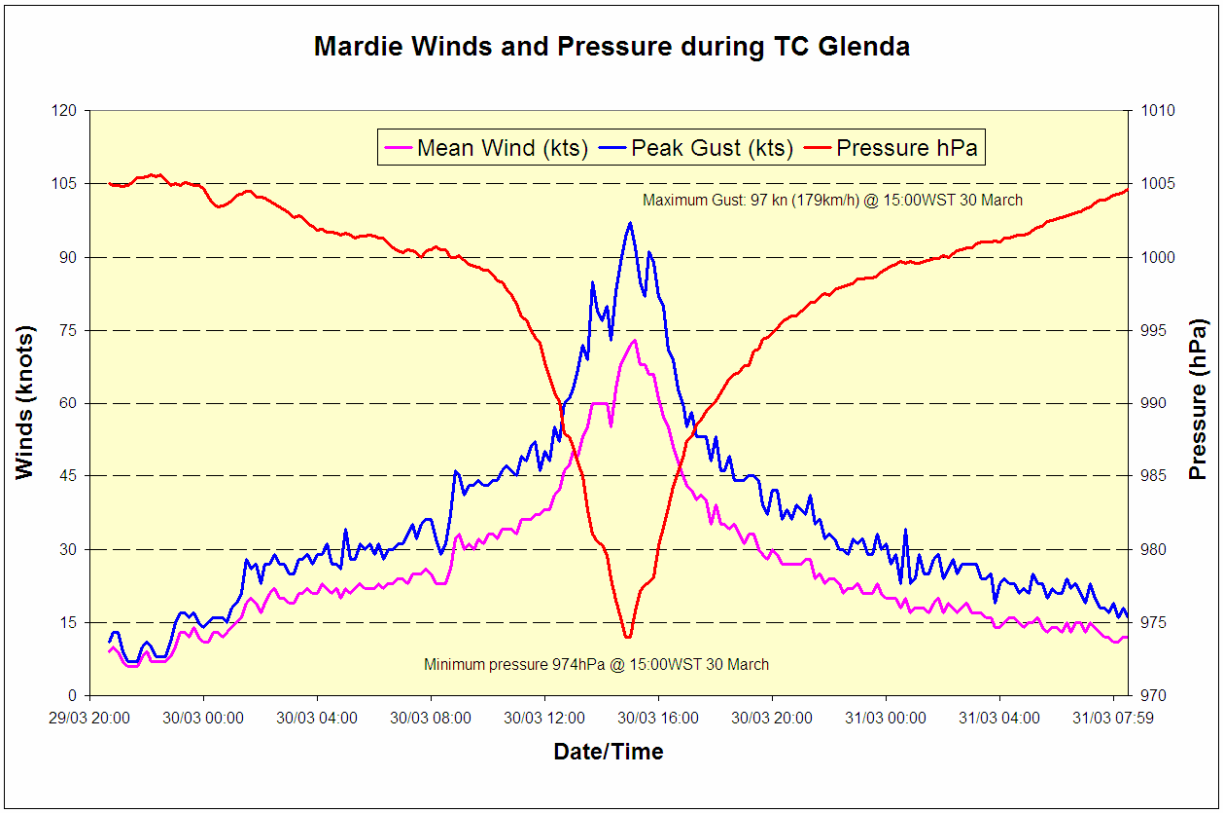

Figure 5b Winds and pressure at Onslow during TC *Glenda* 29-31 March 2006.

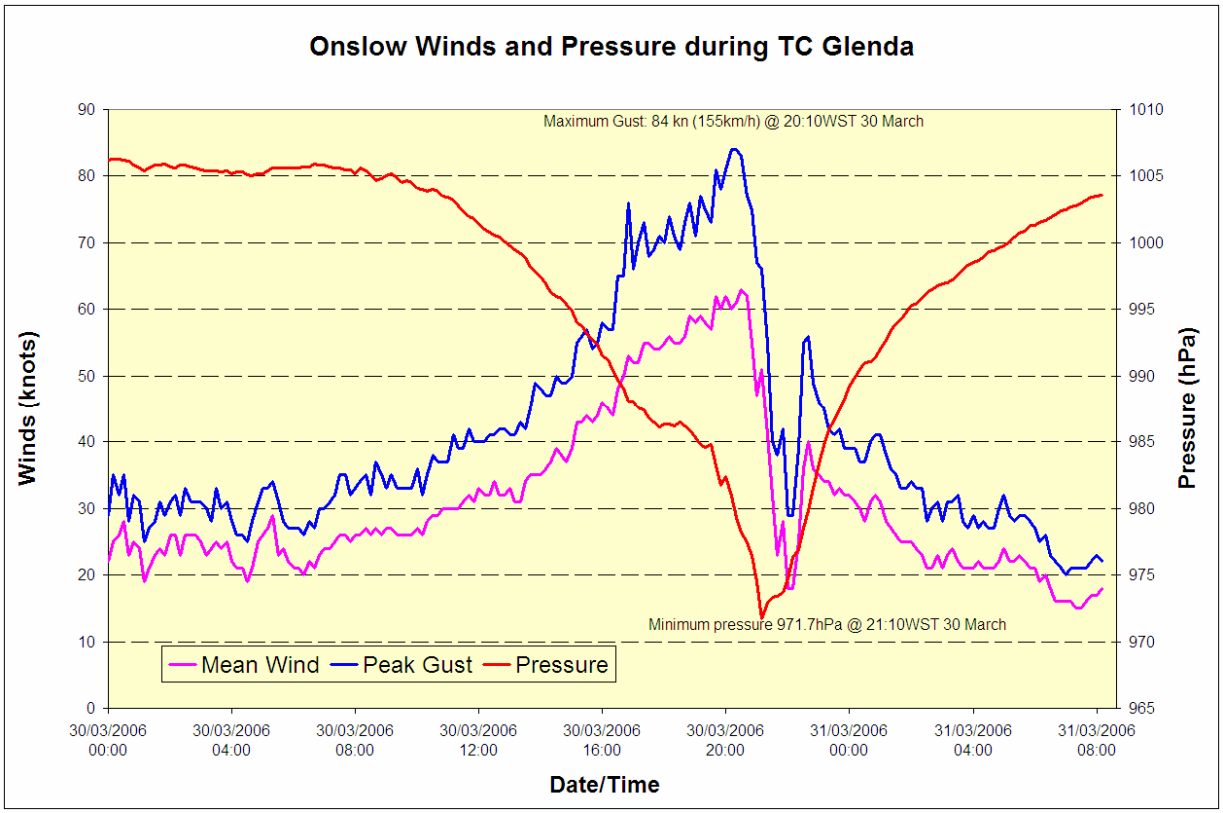

Figure 5c Winds and pressure at Karratha during TC *Glenda* 29-31 March 2006.