

Severe Tropical Cyclone Marcus

14 - 25 March 2018



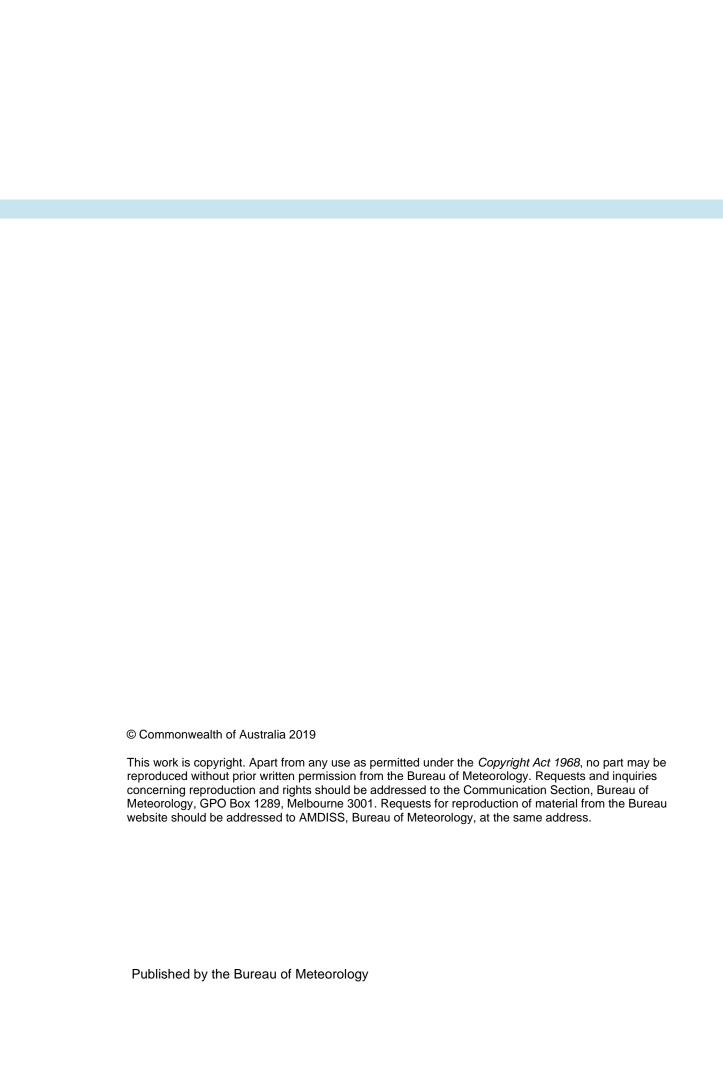


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1 Summary

Severe Tropical Cyclone Marcus was the strongest tropical cyclone to affect Darwin since Tropical Cyclone Tracy (category 4) in December 1974. While in the Western Australian area of responsibility (AoR) Marcus equalled the record set by Severe Tropical Cyclone Monica in April 2006 for the strongest tropical cyclone anywhere within the Australian Region.

A tropical low formed over the north-eastern Timor Sea within a strengthening monsoon trough on 14 March and moved southeast. The low developed and reached tropical cyclone strength at 1800 Universal Time Coordinated (UTC) 15 March (0330 Australian Central Standard Time (ACST) 16 March) (ACST = UTC + 9.5 hours). Marcus turned to the south southwest and passed across the western tip of the Cobourg Peninsular into the Van Diemen Gulf as a Category 2 tropical cyclone.

Marcus crossed the coast near Cape Hotham about 2200 UTC 16 March with a 10-minute wind peak intensity of around 55 knots (kn) (100 kilometres per hour (km/h)). Marcus continued to move west southwest and passed directly over the city of Darwin, Palmerston and surrounding suburbs. The tropical cyclone then crossed Darwin Harbour, Cox Peninsular, Bynoe Harbour and Dundee Beach causing significant impacts in the surrounding rural areas.

Although Marcus was small in size, the tropical cyclone caused widespread and significant impacts over the Darwin area. Thousands of trees were damaged or brought down. Many trees fell on buildings and cars. Around 430 powerlines were downed leaving some 26500 properties without power immediately after the cyclone. Fortunately, there were no injuries. The strongest wind gust recorded at this time was 70 kn (130 km/h) at 0121 UTC 17 March from the automatic weather station (AWS) located at Darwin Harbour AWS (Darwin National Tidal Centre (NTC)).

Tropical Cyclone Marcus moved off the western Top End coast north of Daly River Mouth into the Joseph Bonaparte Gulf during the afternoon of 17 March. Marcus made landfall for the third time on the remote northeast Kimberley coast at 0000 UTC 18 March, about 20 kilometres (km) north of the Berkeley River Mouth as a category 2 tropical cyclone. Marcus was quickly downgraded to category 1 as it moved south of Kalumburu around midday 18 March. A maximum wind gust of 43 kn (80 km/h) was recorded at Kalumburu at 0452 UTC 18 March. Felled trees and building damage were reported from Kalumburu.

Marcus continued to move in a westerly direction, moving offshore again to the west of Mitchell Plateau late on 18 March. Once over open water the tropical cyclone intensified to a 10-minute mean wind peak intensity of 135 kn (250 km/h) at 1200 UTC 21 March, equalling the record for the strongest tropical cyclone in the Australian region. During 22 March, Marcus began to turn to the southwest and then south as it began to weaken. This movement took Marcus over cooler sea surface temperatures and into more unfavourable environment and the intense tropical cyclone continued to steadily weaken. Marcus weakened below tropical cyclone intensity at 0600 UTC 24 March, well away from the coastline.

FIGURE 1. Best track of Severe Tropical Cyclone *Marcus* 14 - 25 March 2018 (times in AWST, UTC+8).

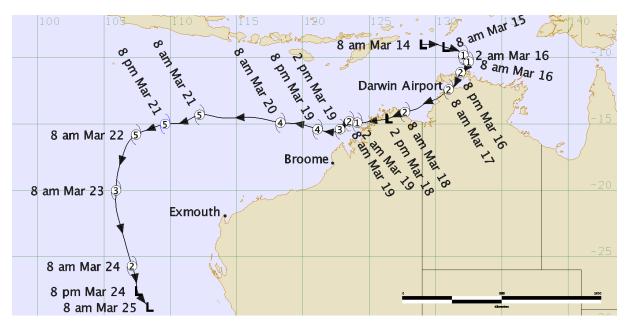
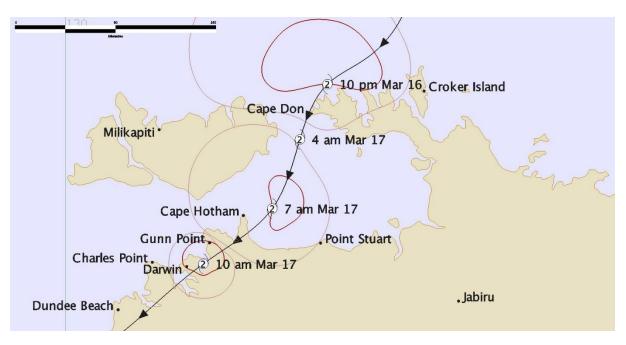


FIGURE 2. Best track enlargement of Darwin area (times in ACST, UTC+9.5).



2 Meteorological Description

2.1 Intensity analysis

A low developed within a strengthening monsoon flow on 14 March and was steered to the southeast. A Dvorak Data T number (DT) of 1.0 was assigned by 1800 UTC 14 March and the low reached tropical cyclone strength by 1800 UTC 15 March when it was about 320 km to the north of Darwin. A Soil Moisture Active Passive (SMAP) partial pass at 0917 UTC 16 March showed wind speeds of at least 40 kn (75 km/h) in the northern quadrants, refer Figure 3. Marcus continued to intensify as it moved south into the Van Diemen Gulf and a microwave pass at 2046 UTC 16 March (refer Figure 4) showed deep convection almost encircling the system centre. A comparison of subjective and objective intensity estimates is shown in Figure 5. The proximity of land would have affected the objective estimates from the Advanced Dvorak Technique (ADT) and the Satellite Consensus (SATCON) method during this period. A Synthetic Aperture Radar (SAR) pass while Marcus was located over water gave wind estimates as high as 60 -70 kn (100-120 km/h) in eastern quadrants, refer Figure 6. The 10-minute wind was set at 60 kn (100 km/h) but it is possible that it was as high as 65 kn (120 km/h) prior to landfall near Cape Hotham.

By 0000 UTC 17 March, Marcus was located over the city of Darwin. Surface observations from the surrounding sites showed at least gale force winds were present in all quadrants. Surface observations from the Darwin Airport and the Darwin Harbour (NTC) AWS increased to storm force winds as the centre of Marcus passed to the east. The 10-minute intensity was maintained at 55 kn (100 km/h) through this period.

By 1200 UTC 17 March Marcus was again located over water in the Joseph Bonaparte Gulf and was re-intensifying rapidly. A microwave pass showed deep, cold convection in all quadrants and SATCON estimates climbed quickly to over 70 kn (130 km/h). The intensity was set at 60 kn (110 km/h) at 1800 UTC 17 March. The development of Marcus was again interrupted by making landfall on the northeast Kimberley coast at 0000 UTC 18 March. The intensity fell quickly to below tropical cyclone strength by 1200 UTC 18 March as the system traversed land in a westerly direction.

Marcus maintained a strong circulation and when it moved over water again at 1200 UTC 18 March redevelopment occurred quickly. An Advanced Microwave Scanning Radiometer 2 (AMSR2) pass, refer Figure 7, showed a well-developed tropical cyclone with deep convection surrounding the centre by 0440 UTC 19 March. At this time an eye began to appear in the Enhanced Infrared Imagery (EIR). The intensity of Marcus climbed to 90 kn (165 km/h) by 1200 UTC 19 March but plateaued for twenty-four hours as Marcus underwent an eye wall replacement cycle (ERC). A Special Sensor Microwave Image/Sounder (SSMIS) pass at 0818 UTC 20 March showed a double eye wall structure, refer Figure 8. During this time objective intensity estimates also plateaued or in the case of ADT, decreased.

From 1800 UTC 20 March Marcus began to intensify again, microwave imagery showed the eye wall contracting and objective estimates climbed steadily. Subjective Dvorak estimates reached a maximum of DT 7.0 (maximum wind 125 kn (230 km/h)) at 1500 UTC 21 March. A SMAP pass at 1043 UTC 21 March showed an area of 135 kn (250 km/h) winds near the

centre, refer Figure 9, while SATCON estimates climbed as high as 150 kn (280 km/h) around 1200 UTC 21 March. The 10-minute peak intensity is estimated to be 135 kn (250 km/h) between 1200 – 1800 UTC 21 March, equalling the record for the strongest cyclone in the Australian AOR with Severe Tropical Cyclone Monica in April 2006. Figure 10 shows Marcus just prior to reaching peak intensity.

From 1800 UTC 21 March Marcus underwent a second ERC and intensity estimates began to decrease. From 0200 UTC 22 March the three-hour averaged DT numbers began to decrease as the eye temperatures cooled. A SMAP pass at 1118 UTC 22 March showed that peak wind speeds had decreased to about 100 kn (185 km/h), refer Figure 11. As Marcus moved on a more southerly track the tropical cyclone moved over cooler sea surface temperatures (SSTs) and encountered stronger vertical wind shear. This contributed to a rapid decrease in intensity. Marcus weakened below cyclone intensity by 0600 UTC 24 March with gales persisting in only the southeast quadrant at this time.

2.2 Structure

Marcus was initially a very small tropical cyclone. As it passed over the top end of Australia gale radii contracted from around 50-70 nautical miles (nm) to as small as 10-15 nm as it passed over Darwin. Storm radii contracted from 25-30nm to 5-10 nm. Radius to maximum wind (RMW) was initially 30 nm and decreased to 5nm over land.

As Marcus moved over the Joseph Bonaparte Gulf and re-intensified gale radii increased to 40-60 nm and storm radii 30-40 nm.

When Marcus moved offshore from the Kimberley coast gale radii increased to more climatological normal values. Gale radii extended out to 80-90 nm. As Marcus intensified gale radii increased to as large as 160 nm in the southeast quadrant. Storm radii extended to 80 nm and hurricane radii as large as 60 nm.

RMW decreased down to 10 nm during the most intense phase. The eye diameter was about 20nm.

2.3 Motion

Marcus was steered to the southeast during 14-15 March by the northwest flow north of Australia. On 16 March the 500 hectopascal (hPa) ridge to the south became the dominant steering and Marcus began to move south southwest. Over the next few days the steering became more westerly as Marcus was steered by the mid-level ridge located over central Australia. From 22 March a high amplitude mid-level trough located over the Indian Ocean eroded the influence of the ridge. As a result, Marcus turned to the south south-west in the northerlies ahead of the trough. As the trough amplified the steering regime became more north-westerly and Marcus moved in a south-southeast direction during 23 -25 March before dissipating.

3 Impact

Severe Tropical Cyclone Marcus was the strongest tropical cyclone to affect Darwin since Tracy in December 1974. Marcus completely traversed the city of Darwin as a category 2 cyclone with a peak 10-minute mean wind of 55 kn (100 km/h) and maximum 3-second wind gusts of 80 kn (150 km/h).

Despite the small size of Marcus, the tropical cyclone produced widespread and significant impacts across the city of Darwin. Thousands of trees were damaged or brought down. Many trees fell on buildings and cars. Around 430 powerlines were downed leaving some 26500 properties without power immediately after the cyclone.

The strongest wind gusts observed were 68 kn (126 km/h)) at Darwin Airport at 0121 UTC 17 March and 70.4 kn (130 km/h) at Darwin Harbour (NTC) at 0121 17 March.

The heaviest rainfall was confined to the coasts with 136.4 mm at Gunn Point, 60.0 mm at Darwin Airport and 31.4 mm at The Chase (Palmerston) in the 24 hours to 9 am ACST 18 March. A 90-centimetre (cm) storm surge was recorded at the Darwin tidal gauge as the cyclone passed, although coinciding with low tide, the Highest Astronomical Tide was not exceeded.

Marcus crossed the northeast Kimberley coast as a category 2 tropical cyclone but few impacts were felt as the area is sparsely populated. Kalumburu reported some felled trees and building damage as the weakening tropical cyclone passed to the south on 18 March.

Marcus moved offshore and out into the Indian Ocean, there were no further impacts on mainland Australia.

4 Observations

4.1 Wind

McCluer Island AWS recorded periods of gale force winds between 0106-0448 and 0505-0543 UTC 16 March. The maximum 10-minute mean wind recorded was 40 kn (74 km/h) at numerous times. The maximum 3-second wind gust recorded was 49 kn (91 km/h) at 0157 16 March.

<u>Point Stuart AWS</u> recorded periods of gale force winds between 2104-2122 and 2132-2219 UTC 16 March. The maximum 10-minute mean wind recorded was 36 kn (67 km/h) at numerous times. The maximum 3-second wind gust recorded was 50.9 kn (94 km/h) at 2205 16 March.

<u>Darwin Airport AWS</u> recorded gale force winds between 2358 UTC 16 March to 0300 UTC 17 March. Storm force winds were recorded between 0124–0133 UTC 17 March. The maximum 10-minute mean wind recorded was 50 kn (93 km/h) at 0129 UTC 17 March. The maximum 3-second wind gust recorded was 68 kn (126 km/h) at 0121 17 March.

<u>Darwin Harbour (NTC) AWS</u> recorded gale force winds between 2331 UTC 16 March to 0132 UTC 17 March and from 0147-0220 17 March. Storm force winds were recorded between 0038–0127 UTC 17 March. The maximum 10-minute mean wind recorded was 53 kn (98 km/h) at 0111, 0122-0124 UTC 17 March. The maximum 3-second wind gust recorded was 70.4 kn (130 km/h) at 0121 17 March.

<u>Charles Point AWS</u> recorded periods of gale force winds between 0240-0247 and 0340-0356 UTC 17 March. The maximum 10-minute mean wind recorded was 38 kn (70 km/h) at 0345 17 March. The maximum 3-second wind gust recorded was 51.1 kn (94 km/h) at 0247 17 March.

Adele Island (AWS) recorded periods of gale force winds between 2202-2214, 2225-2221 UTC 18 March, 2236 UTC 18 March and 0828 UTC 19 March, 0902-0942 UTC 19 March. Storm force winds were recorded between 0149-0154, 0157, 0209-0221, 0318-0331, 0341-0612, 0627-0645 UTC 19 March. The maximum 10-minute mean wind recorded was 52 kn (96 km/h) at 0435, 0437 and 0438 UTC 19 March. The maximum 3-second wind gust recorded was 54 kn (100 km/h) at 0513 UTC 19 March.

Browse Island (AWS) recorded periods of gale force winds between 1935-1938, 2108-2112, 2120-2125, 2139-2140, 2142, 2153-2328 and 2339-2351 UTC 18 March, 0008-0017, 0043-0123 and 0249-0251 UTC 19 March. The maximum 10-minute mean wind recorded was 38 kn (70 km/h) at 2255 UTC 18 March. The maximum 3-second wind gust recorded was 48 kn (89 km/h) at 2254 UTC 18 March.

4.2 Pressure

McCluer Island AWS recorded a minimum mean sea level (MSL) pressure of 1000.5 hPa at 0450 UTC 16 March.

Point Stuart (AWS) recorded a minimum MSL pressure of 998.2 hPa at 2052, 2057 and 2101 UTC 16 March.

<u>Darwin Airport AWS</u> recorded a minimum MSL pressure of 981.5 hPa at 0109 UTC 17 March.

<u>Darwin Harbour (NTC) AWS</u> recorded a minimum MSL pressure of 981.5 hPa at 0127 UTC 17 March.

Charles Point AWS recorded a minimum MSL pressure of 995.9 hPa at 0144 UTC 17 March.

Adele Island AWS recorded a minimum MSL pressure of 993.8 hPa at 0434 UTC 19 March.

<u>Browse Island AWS</u> recorded a minimum MSL pressure of 999.3 hPa between 2122-2125 UTC 18 March.

4.3 Rainfall

The heaviest rainfall recorded in the Northern Territory was confined to the coast with 136.4 millimetres (mm) at Gunn Point, 60.0 mm at Darwin Airport and 31.4 mm at The Chase (Palmerston) in the 24 hours to 9 am ACST 18 March.

The heaviest rainfall in Western Australia was recorded from Theda Station with 127 mm and Kalumburu recorded 114.4 mm in the 24 hours to 9 am AWST 19 March.

4.4 Storm Surge

The only storm surge recorded during Marcus came from Darwin Harbour. A 90 cm storm surge was recorded at the Darwin tidal gauge as the cyclone passed, although coinciding with low tide, the Highest Astronomical Tide was not exceeded.

5 Forecast Performance

The position accuracy figures for Severe Tropical Cyclone Marcus show that the forecast performed better than the five-year average at all time steps.

The accuracy statistics obtained by comparing the forecast positions against the best track positions for *Marcus* are

	00	06	12	18	24	36	48	72	96	120
Absolute error (km)	15	38	52	59	64	79	99	112	105	86
RMS Error (km)	21	44	61	68	73	92	106	117	117	104
Sample Size	39	39	39	38	37	35	33	29	25	21

Figure 12 is a plot of the position accuracy figures for *Marcus* compared to the five-year mean.

TABLE 1. Best track summary for Severe Tropical Cyclone Marcus

Refer to the Australian Tropical Cyclone database for complete listing of parameters. AWST is UTC + 8 hours.

Year	Month	Day	Hour UTC	Pos. Lat S	Pos. Long. E	Pos. Acc. nm	Max Wind 10 min kn	Max gust kn	Cent. Press. hPa	Rad. of gales (NE/SE/ SW/NW)	Rad. of storm (NE/SE/ SW/NW)	RMW n mi
2018	03	14	00	9.0	129.0	60	15	45	1005			
2018	03	14	06	9.0	129	60	15	45	1005			
2018	03	14	12	9.0	129.5	60	15	45	1005			
2018	03	14	18	9.0	130.0	60	20	45	1005			
2018	03	15	00	9.2	130.7	30	25	45	1005			
2018	03	15	06	9.3	131.1	30	25	45	1000			
2018	03	15	12	9.4	131.5	30	35	50	996	50/0/0/0		30
2018	03	15	18	9.8	132.1	30	35	50	996	50/0/60/7 0		15
2018	03	16	00	10.3	132.5	30	40	55	995	60/50/30/ 45		20
2018	03	16	06	10.9	132.2	15	45	65	993	50/45/25/ 50		30
2018	03	16	12	11.1	131.9	20	50	70	988	40/20/20/ 65	25/0/0/30	25
2018	03	16	18	11.5	131.7	15	55	75	25/20/1 5	35	15/10/0/0	10
2018	03	16	21	12.0	131.5	10	60	85	982	25/25/25/ 40	15/10/0/0	5
2018	03	17	00	12.4	131.0	5	55	75	980	10/15/15/	10/5/5/10	5

Year	Month	Day	Hour UTC	Pos. Lat S	Pos. Long. E	Pos. Acc. nm	Max Wind 10 min kn	Max gust kn	Cent. Press. hPa	Rad. of gales (NE/SE/ SW/NW)	Rad. of storm (NE/SE/ SW/NW)	RMW n mi
										15		
2018	03	17	06	13.1	130.1	15	50	70	988	30/0/50/5 0	0/0/040	30
2018	03	17	12	13.4	129.3	30	50	70	998	30/30/50/ 30	20/30/20/ 20	20
2018	03	17	18	13.8	128.7	10	60	85	983	40/40/60/ 40	30/40/30/ 30	15
2018	03	18	00	14.1	127.7	15	55	75	987	40/40/30/ 50	30/30/20/ 40	10
2018	03	18	06	14.6	126.4	15	40	55	992	0/0/20/20		15
2018	03	18	12	14.8	125.1	15	35	50	997	0/0/30/0		20
2018	03	18	18	14.9	124.1	15	40	55	994	40/30/60/ 40		15
2018	03	19	00	14.8	123.5	15	60	85	982	50/50/60/ 50	0/30/35/4 0	10
2018	03	19	06	15.4	122.8	15	75	105	969	70/70/65/ 60	30/35/20/ 40	10
2018	03	19	12	15.4	121.1	15	90	125	958	50/80/80/ 50	30/40/40/ 30	10
2018	03	19	18	15.0	119.7	10	90	125	961	60/90/80/ 60	40	10
2018	03	20	00	14.9	118.3	20	90	125	961	60/100/8 0/60	40	10
2018	03	20	06	14.6	116.9	15	90	125	959	70/110/9 0/70	40	10

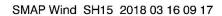
Year	Month	Day	Hour UTC	Pos. Lat S	Pos. Long. E	Pos. Acc. nm	Max Wind 10 min kn	Max gust kn	Cent. Press. hPa	Rad. of gales (NE/SE/ SW/NW)	Rad. of storm (NE/SE/ SW/NW)	RMW n mi
2018	03	20	12	14.5	115.5	15	90	125	959	90/110/1 00/90	45	10
2018	03	20	18	14.5	113.6	15	100	140	951	90/100/1 00/90	50	10
2018	03	21	00	14.3	112.2	15	110	155	935	100/140/ 140/100	60	10
2018	03	21	06	14.9	110.9	10	130	180	913	100/140/ 140/100	60	10
2018	03	21	12	15.0	109.6	10	135	190	905	140/160/ 120/120	80	10
2018	03	21	18	15.4	108.4	10	135	190	905	140/160/ 120/120	80	10
2018	03	22	00	15.8	107.4	10	130	180	907	140/160/ 120/120	80	10
2018	03	22	06	16.6	106.7	10	110	155	931	150/160/ 130/130	80	10
2018	03	22	12	17.4	106.4	15	100	140	942	160/160/ 150/130	80	10
2018	03	22	18	18.8	106.0	15	90	125	953	140/140/ 130/110	70	10
2018	03	23	00	20.0	105.9	15	85	120	960	110/120/ 110/90	60	10
2018	03	23	06	21.3	105.9	20	80	110	964	90/120/1 00/70	40	15
2018	03	23	12	22.2	106.1	20	75	105	967	70/140/1	40	15

Year	Month	Day	Hour UTC	Pos. Lat S	Pos. Long. E	Pos. Acc. nm	Max Wind 10 min kn	Max gust kn	Cent. Press. hPa	Rad. of gales (NE/SE/ SW/NW)	Rad. of storm (NE/SE/ SW/NW)	RMW n mi
										00/50		
2018	03	23	18	24.0	106.6	30	65	90	976	70/140/1 00/50	40	20
2018	03	24	00	25.7	107.1	30	60	85	977	50/140/8 0/40	0/60/0/0	40
2018	03	24	06	26.8	107.4	30	45	65	985	0/140/0/0		60
2018	03	24	12	27.6	107.5	30	30	45	998			
2018	03	24	18	28.3	107.9	30	30	45	997			
2018	03	25	00	28.8	108.4	30	25	45	998			

FIGURE 3. SMAP partial pass at 0917 UTC 16 March.

Note wind speeds in metres per second

Image courtesy of Remote Sensing Systems (www.remss.com)



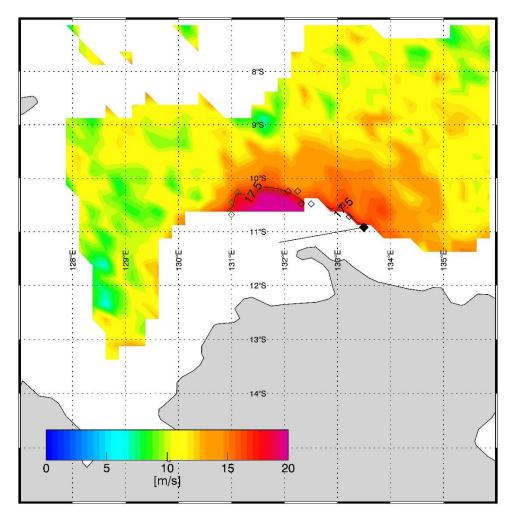


FIGURE 4. Global Precipitation Measurement Microwave Imager (GMI) at 2046 UTC 16 March showing Marcus located in the Van Diemen Gulf, just prior to landfall.

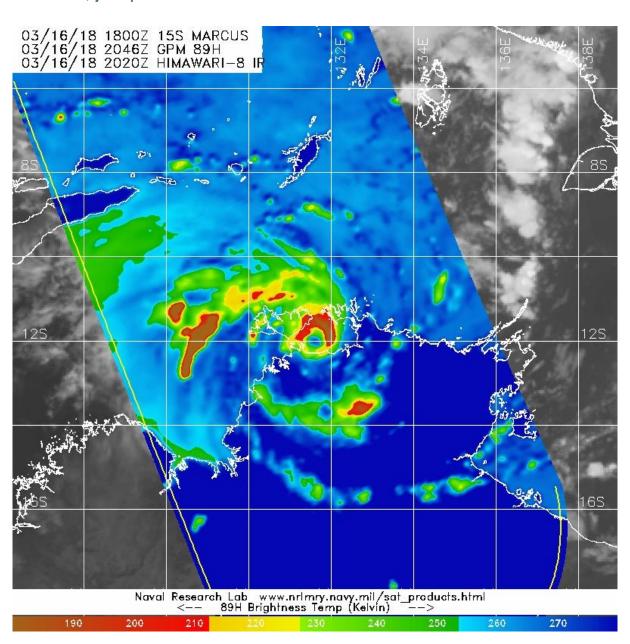


FIGURE 5. Plot of objective and subjective intensity estimates for *Marcus*.

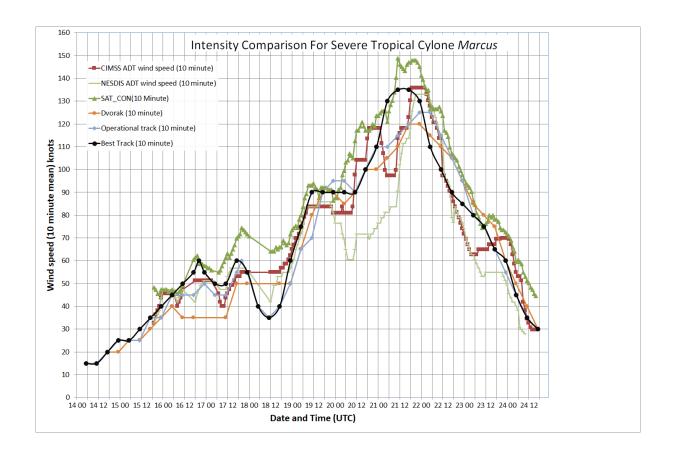


FIGURE 6. SAR pass when Marcus was located in the Van Diemen Gulf, just prior to landfall.

Note wind speeds in metres per second

Image courtesy of IFREMER

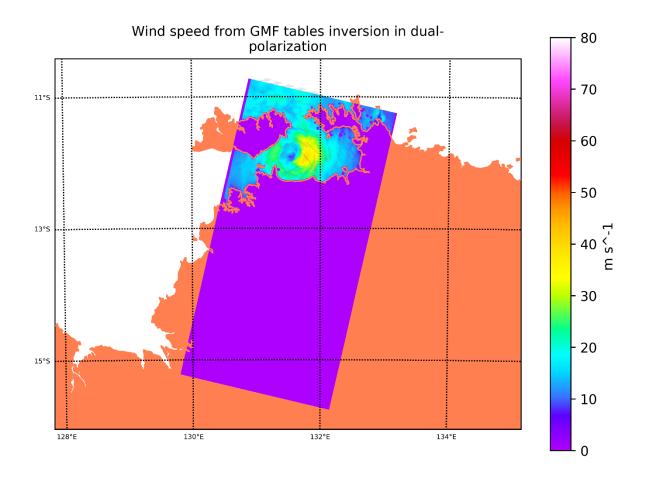


FIGURE 7. AMSR 2 pass showing Marcus re-intensifying at 0440 UTC 19 March after traversing the northern part of Western Australia.

Image courtesy of https://www.nrlmry.navy.mil/TC.html

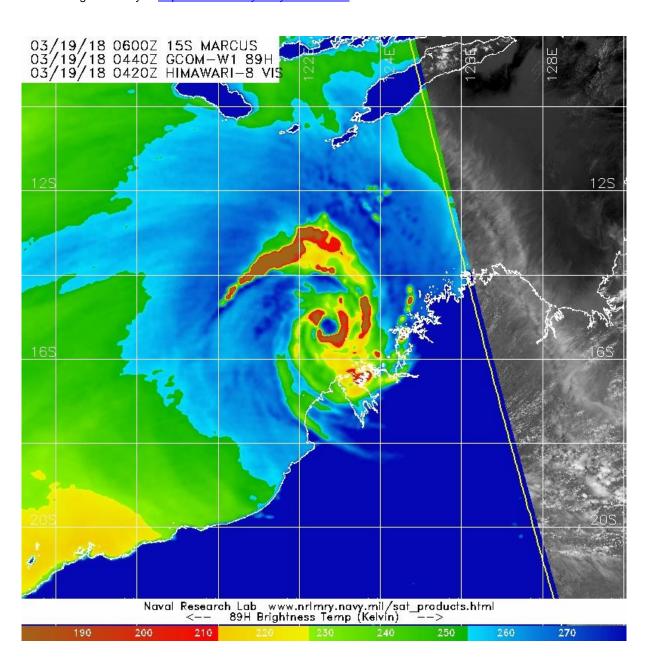


FIGURE 8. SSMI/S image at 0818 UTC 20 March showing the double eye wall structure as Marcus underwent an ERC.

Image courtesy of https://www.nrlmry.navy.mil/TC.html

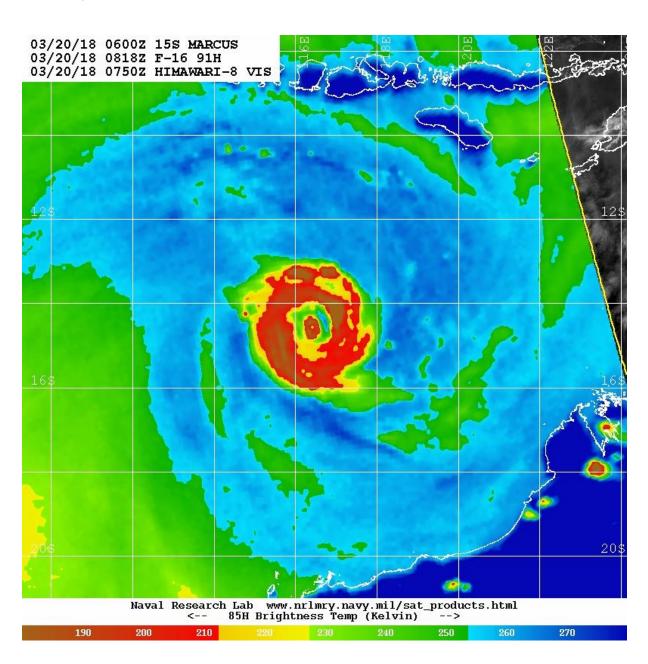


FIGURE 9. SMAP pass at 1043 UTC 21 March as Marcus neared peak intensity.

Note wind speeds in metres per second

Image courtesy of Remote Sensing Systems (www.remss.com)

SMAP Wind SH15 2018 03 21 10 43

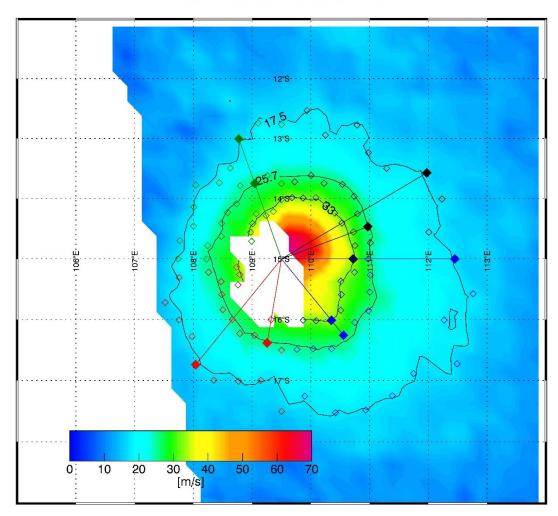


FIGURE 10. A 0751 UTC 21 March GMI pass of Marcus approaching a 10-minute mean wind peak intensity of 135 kn.

Image courtesy of https://www.nrlmry.navy.mil/TC.html

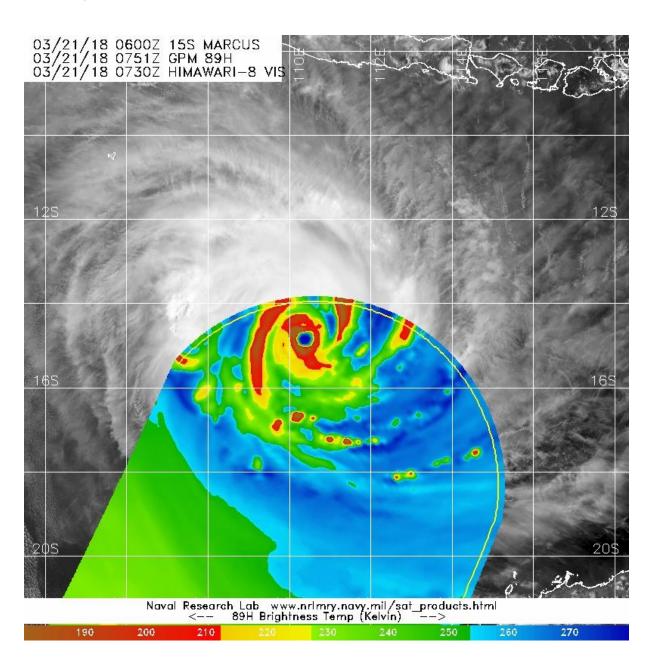
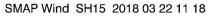


FIGURE 11. SMAP pass at 1118 UTC 22 March as Marcus began to weaken after a second ERC.

Note wind speeds in metres per second

Image courtesy of Remote Sensing Systems (www.remss.com)



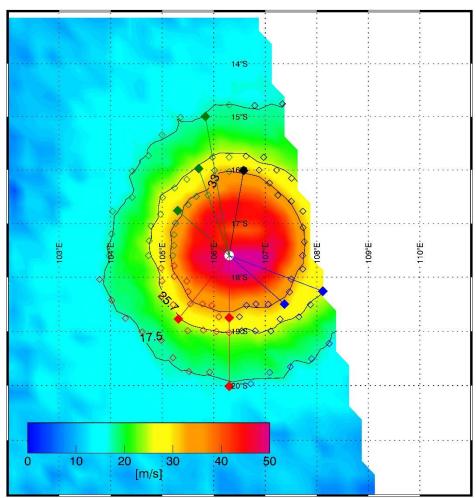


FIGURE 12. Position accuracy plot of Marcus compared to the fiveyear average.

