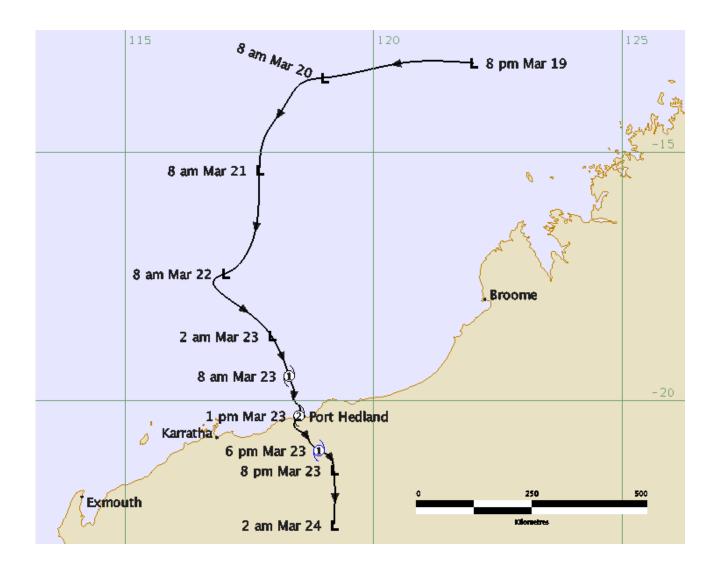


Tropical Cyclone *Unnamed (22U)*

19 – 23 March 2017 April 2017



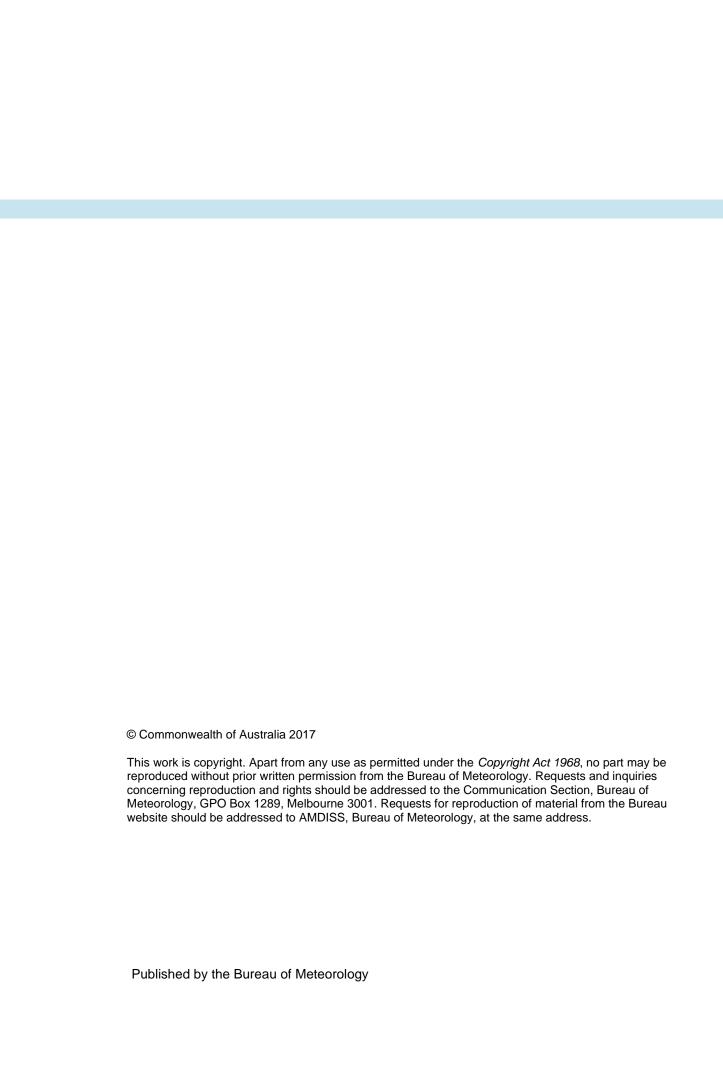


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1 Summary

The unnamed tropical cyclone 22U was a very small system that briefly reached cyclone intensity before crossing the Pilbara coast in the Port Hedland area. While the system did not meet cyclone intensity criteria using standard satellite techniques, a network of surface observation sites recorded gale-force winds. One site recorded storm-force winds and combined with Port Hedland radar images, the peak intensity was estimated at 50 knots (kn) (95 kilometres per hour), corresponding to category 2 intensity, just prior to reaching the coast.

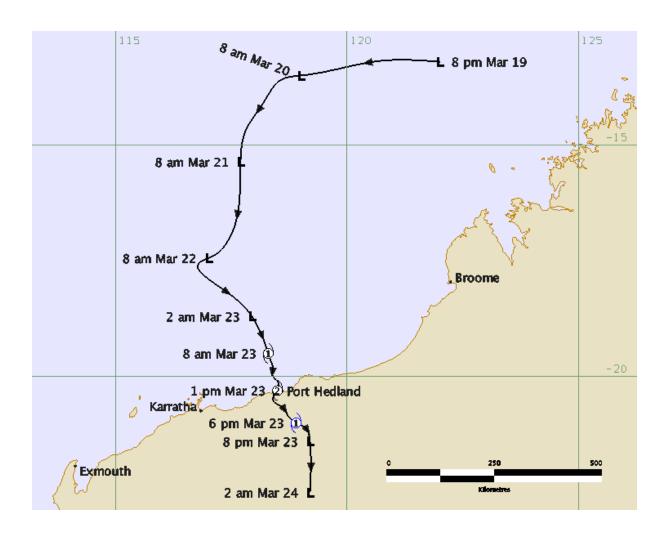
A low formed north of the Kimberley coast around 1200 Universal Time Coordinated (UTC) (2000 AWST=UTC+8 hours) 19 March and moved west and then southwest. The low appeared to have multiple centres and remained weak with poor organisation. Satellite imagery during 21 and 22 March showed what appeared to be a weak system with fluctuating deep convection. Later on 22 March convection increased and microwave imagery gave some indication of a low level curved band becoming organised around the system centre.

During the morning of 23 March a small but well developed circulation was observed on the Port Hedland radar. Observations from surrounding sites suggest the small system had gales around centre and that it was an extremely small tropical cyclone at 0000 UTC 23 March. The estimated peak ten-minute mean wind was 50 kn (95 km/h) between 0300 and 0600 UTC 23 March. The maximum wind gust recorded was 61 kn (113 km/h) at Beacon 47. Heavy rainfall with some minor damage was reported from the Port Hedland area as *Unnamed (22U)* crossed the coast at around 0500 UTC 23 March. Significant river rises occurred in the Pilbara coastal rivers, De Grey River and Fortescue River. The Fortescue River at Newman peaked at around 3.5 metres (close to the minor flood level of 4 metres) and minor flooding was recorded in the Yule River. Minor to major flooding was observed at some locations in the De Grey River catchment.

Guidance from various deterministic and ensemble computer models on 20 and 21 March indicated the system would likely develop into a tropical cyclone and Tropical Cyclone Advices were initiated on the afternoon of the 21 March. On 22 March model guidance changed and indications were it was less likely the low would develop into a tropical cyclone and the public Advices for *Unnamed* (22U) were cancelled. The Advices were replaced with a Severe Weather Warning to alert the community to the possibility of heavy rainfall as the low crossed the coast. The warning was upgraded on 23 March to include first damaging and then destructive winds.

FIGURE 1. Best track of Unnamed (22U) 20 -23 March 2017.

Times in AWST, to convert to UTC add 8 hours.



Meteorological Description

2.1 Intensity analysis

A low developed in an active monsoon trough near 13.2°S 122.0°E around 1200 UTC 19 March. A Dvorak Data-T number (DT) of 1.0 was assigned at 0000 UTC 20 March. By 1200 UTC a curved band wrap of 0.5 was analysed and the Final T (FT) and Current Intensity (CI) number reached 2.5 with intensity set at 30 kn. By 1800 UTC convection had decreased markedly and a Tropical Cyclone Special Sensor Microwave Image/Sounder (TC SSMIS) microwave pass around that time showed little convection near the analysed centre.

During 21 March Visible (VIS) and Enhanced Infrared Imagery (EIR) showed convection forming and then weakening. Microwave imagery through this period showed little organisation to the convection and locating the system centre was difficult. Subjective Dvorak curved band analyses yielded DTs of either 2.0 or 2.5, at some time steps a pattern could not be applied and FT/CI relied heavily on pattern adjusted Model Expected T (MET) and intensity remained set at 30 kn.

On 22 March the low began to move southeast towards the Pilbara coast. VIS imagery showed a broad circulation with some convection associated with the low level system centre however there were no well-developed curved bands associated with the centre. An 0149 UTC 22 March Advanced Scatterometer (ASCAT) pass (refer Figure 2) showed a low level circulation of 15 to 25 kn winds with a 25 to 35 kn northwest monsoon flow to the north of the low. Intensity was decreased to 25 kn based on the ASCAT pass despite Dvorak DT/CI being 2.5. A later pass at 1325 UTC 22 March (refer Figure 3) showed a circulation with mostly 15 to 20 kn winds three quarters the way around the centre and 20 to 30 kn winds to the north, most likely associated with the monsoon flow to the north. Intensity was increased to 30 kn based on this ASCAT pass.

From 1200 UTC 22 March EIR imagery showed a large convective blow up south of the system centre which continued to develop into a curved band by 1800 UTC. A microwave pass at 1706 UTC 22 March (refer Figure 4) showed a low level curved band extending from the northeast quadrant right around to the southwest quadrant with the deepest convection in the southwest quadrant. FT/CI remained at 2.5/2.5 with intensity at 30 kn. Further overnight microwave passes on 23 March gave no indication of the small, tight circulation which became evident on the Port Hedland radar early on 23 March. By 0000 UTC 23 March radar showed a small eye with a radius of only about 3 nautical miles (nm) with a C shaped convective band stretching from the southeast to southwest quadrant (refer Figure 5). Finding the tightest inner curvature of convection on satellite imagery of such a small tropical cyclone proved very difficult and raises the issue of the whether it is appropriate to apply the Dvorak technique to these very small systems. No pattern could be applied at 0000UTC 23 March but a very small, tightly wrapped convective band was evident at 0100 UTC which gave a wrap of 0.6. By 0300 UTC this was no longer apparent in the VIS imagery and no pattern was

applied. The MET was 3.0 but the pattern adjusted MET was 2.5. This gave a three hour average FT of 2.7, the highest *Unnamed* (22U) reached. By this standard cyclone intensity was not reached.

However, gale-force winds were recorded from a network of observation sites off the coast from Port Hedland confirming the system reached cyclone intensity. Refer to Figure 6 for the locations of surface observation sites. Sea and swell observations also support 22U having reached category two intensity.

The small tropical cyclone moved rapidly towards the town of Port Hedland and offshore observation sites indicated gales were present in most quadrants (refer Figure 7). The 0200 UTC 23 March radar image (refer Figure 8) showed a very small circulation with spiral convective bands around what appears to be a complete eye wall encircling the centre. Based on the surface observations recorded it is estimated *Unnamed* (22U) reached a peak ten-minute mean wind of 50 kn between 0300 and 0600 UTC 23 March. The maximum 10-minute mean wind recorded was 48.9 kn (90 km/h) at 0450 UTC 23 March and the maximum 3 second wind gust recorded was 61 kn (113 km/h) at 0440 UTC 23 March, both from an offshore site, Beacon 47. More details on the maximum observations recorded from all the sites can be found in section 3.

The tropical cyclone crossed the Pilbara coast just to the west of Port Hedland at 0500 UTC 23 March bringing heavy rain and a period of gales to the town (refer Figure 9). *Unnamed* (22U) quickly weakened after land fall and was below tropical cyclone strength by 1100 UTC 23 March. The remains of the low weakened over inland Western Australia.

2.2 Structure

TC Unnamed (22U) was an extremely small tropical cyclone. Initial gale radius was 15 nm (28 km) in southern quadrants and 10 nm (18 km) in northern quadrants. At Unnamed's largest and most intense the gale radius extended to 25 nm (46 km) in the southeast quadrant. The storm radius was estimated at 5 nm (9 km). Once the tropical cyclone crossed the Pilbara coast the gale radii contracted to 10 nm (18km) before it weakened below cyclone strength. The average gale radius for a category one tropical cyclone in the Western Australia area of responsibility is 70 nm (130 km). The radius to maximum wind (RMW) was 7 nm (13 km) which then decreased to 5 nm (9 km).

2.3 Motion

Initially the low pressure system was located north of the middle level ridge and drifted in a southwest direction. A significant mid-level trough amplified over the upper west coast on 21 March, this produced a northerly steering flow and *Unnamed* (22U) moved in a southerly direction. On 22 March *Unnamed* (22U) was steered in a south southeast

direction ahead of the upper trough until it crossed the Pilbara coast and weakened over land.

3 Impact

Unnamed (22U) produced a period of gale force winds at Port Hedland town site but only minor damage was reported. Heavy rainfall associated with the crossing of Unnamed (22U) produced significant river rises in the Pilbara coastal rivers, De Grey River and Fortescue River. The Fortescue River at Newman peaked at around 3.5 metres (close to the minor flood level of 4 metres) and minor flooding was recorded in the Yule River. Minor to major flooding was observed at some locations in the De Grey River catchment.

4 Observations

4.1 Wind

Port Hedland Automatic Weather Station (AWS) recorded gale force winds between 0348 -0401 and 0438 – 0530 UTC 23 March. A peak 10-minute mean wind of 39.3 kn (73 km/h) was recorded at 0502 UTC 23 March and a peak 3 second wind gust of 51 kn (95 km/h) was reported at 0457 and 0501 UTC 23 March.

Observation site Beacon C2 recorded gale force winds between 0130 and 0400 UTC 23 March. The maximum 10-minute mean wind recorded was 44.4 kn (82 km/h) at 0250 and 0340 UTC 23 March. The maximum 3 second wind gust recorded was 57.7 kn (107 km/h) at 0250 UTC 23 March. The elevation of this observation site is 13 metres (m) and observations have been corrected to take this into account.

Observation site Beacon 16 recorded gale force winds between 0230 and 0450 UTC 23 March. The maximum 10-minute mean wind recorded was 45.3 kn (84 km/h) at 0420 23 March. The maximum 3 second wind gust recorded was 57.2 kn (106 km/h) at 0430 UTC 23 March. The elevation of this observing site is 15 m and observations have been corrected to take this into account.

Observation site Beacon 47 recorded gale force winds between 0230 and 0530 UTC 23 March. The maximum 10-minute mean wind recorded was 48.9 kn (91 km/h) at 0450 UTC 23 March. Storm force winds were recorded at 0450 UTC 23 March. The maximum 3 second wind gust recorded was 61.0 kn (113 km/h) at 0440 UTC 23 March. The elevation of this observing site is 11.94 m and observations have been corrected to take this into account.

Observation site Port Hedland Tower recorded gale force winds between 0410 and 0500 UTC 23 March. The maximum 10-minute mean wind recorded was 37.1 kn (85 km/h) at 0450 UTC 23 March. The maximum 3 second wind gust recorded was 51.9 kn (111 km/h) at 0430 UTC 23 March. The elevation of this observing site is 40.484 m and observations have been corrected to take this into account.

4.2 Pressure

The minimum pressure recorded at the Port Hedland AWS was 993.5 hPa at 0507 UTC 23 March.

The minimum pressure recorded at Beacon C2 was 987.3 hPa at 0330 UTC 23 March.

The minimum pressure recorded at Beacon 16 was 986.2 hPa between 0420 and 0430 UTC 23 March.

The minimum pressure recorded at Beacon 47 was 989.3 hPa at 0450 UTC 23 March.

The minimum pressure recorded at Port Hedland Tower was 987.3 hPa at 0500 UTC 23 March.

4.3 Rainfall

The following 24 hour rainfall totals were recorded to 9am:

22 March: Port Hedland Airport - 103.2mm

23 March: Port Hedland Airport - 105.2mm.

24 March: Newman Aerodrome - 93.4mm, Port Hedland Airport - 69.8mm.

25 March: Leonora Aerodrome – 91.8mm, Laverton Aerodrome – 57.8mm.

4.4 Significant Wave Height

Significant wave data was recorded from Beacon C2, B15 and B16 during the passage of *Unnamed* (22U) over the sites, refer Figure 10.

Beacon C2 recorded a maximum significant wave height of 4.6 m at 1130 AWST.

Beacon B15 recorded a maximum significant wave height of 3.68 m at 1258 AWST.

Beacon B16 recorded a maximum significant wave height of 2.84 m at 1120 AWST.

5 Forecast Performance

The accuracy figures for *Unnamed* (22U) were large due to the difficulty in locating the tropical cyclone until it appeared on Port Hedland radar.

The accuracy statistics obtained by comparing the forecast positions against the best track positions for Tropical Cyclone *Unnamed* (22U) are

	0	06	12	18	24	36	48	72
Absolute error (km)	126	116	123	141	163	192	224	351
RMS error (km)	135	129	136	153	177	214	228	357

Figure 11 is a plot of the accuracy figures for *Unnamed* (22U) compared to the five year mean.

The Tropical Cyclone Outlook for the Western Region issued on 19 March indicated a moderate risk a low could develop north of Broome and track towards the Pilbara coast by 22 March. The Outlook issued on 20 March increased the risk to high. On 21 March a Tropical Cyclone Advice for a watch between Wallal and Onslow (including Port Hedland) was issued for a developing tropical low which may impact the Pilbara coast Thursday and Friday.

Later on 21 March computer models indicated that it was less likely the low would develop into a tropical cyclone and given the lack of development of the low, the risk was downgraded to moderate on the Outlook product. On 22 March models continued to indicate the low would not develop into a tropical cyclone, public advices were cancelled and the outlook product downgraded the risk to low. A Severe Weather Warning was issued on 22 March for heavy rainfall and flash flooding over the Pilbara region as the low approached the coast. At 0230 UTC 23 March, in response to the signature on the Port Hedland radar, the warning was upgraded to include damaging winds. At 0300 UTC it was further upgraded to include destructive winds in response to the observed winds. Warnings continued to be issued for heavy rainfall and flash flooding until 25 March, as the remains of the low moved over inland Western Australia.

TABLE 1. Best track summary for Tropical Cyclone *Unnamed* (22U)

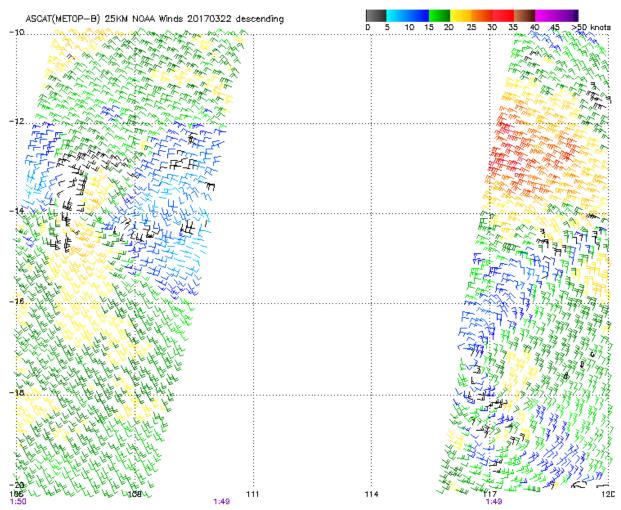
Refer to the Australian Tropical Cyclone database for complete listing of parameters. WST is UTC + 8 hours.

Year	Month	Day	Hour UTC	Pos. Lat S	Pos. Long. E	Pos. Acc. n mi	Max Wind 10 min kn	Max gust kn	Cent. Press. hPa	Rad. of gales (NE/SE/ SW/NW) nm	Rad. of storm (NE/SE/ SW/NW)	RMW nm
2017	03	19	1200	13.2	122.0	45	20	45	1007			
2017	03	19	1800	13.2	120.8	45	20	45	1007			
2017	03	20	0000	13.5	119.0	60	20	45	1007			
2017	03	20	0600	13.6	118.6	60	25	45	1005			
2017	03	20	1200	14.1	118.2	60	30	45	1005			
2017	03	20	1800	14.7	117.8	60	30	45	1005			
2017	03	21	0000	15.4	117.7	60	30	45	1005			
2017	03	21	0600	16.2	117.7	60	30	45	1004			
2017	03	21	1200	17.1	117.4	60	30	45	1003			
2017	03	21	1800	17.4	117.1	60	30	45	1003			
2017	03	22	0000	17.4	117.0	60	25	45	1002			
2017	03	22	0600	17.5	116.8	60	25	45	1002			
2017	03	22	1200	18.1	117.3	60	30	45	1002			
2017	03	22	1800	18.7	117.9	25	30	45	1002			
2017	03	23	0000	19.5	118.3	5	35	50	998	10/15/15/10		7
2017	03	23	0100	19.6	118.4	5	45	55	995	10/15/15/10		5
2017	03	23	0200	19.8	118.4	5	45	65	990	15/25/15/15		5

Year	Month	Day	Hour UTC	Pos. Lat S	Pos. Long. E	Pos. Acc. n mi	Max Wind 10 min kn	Max gust kn	Cent. Press. hPa	Rad. of gales (NE/SE/ SW/NW) nm	Rad. of storm (NE/SE/ SW/NW)	RMW nm
2017	03	23	0300	20.0	118.4	5	50	70	985	10/20/15/10	5	5
2017	03	23	0400	21.1	118.5	5	50	70	985	10/20/15/15	5	5
2017	03	23	0500	20.3	118.5	5	50	70	985	10/15/15/10	5	5
2017	03	23	0600	20.5	118.4	5	45	65	989	10/15/15/10		5
2017	03	23	0700	20.6	118.5	5	40	55	993	10		5
2017	03	23	0800	20.6	118.6	5	40	55	992	10		5
2017	03	23	0900	20.8	118.7	5	40	55	992	10		7
2017	03	23	1000	21.0	118.9	5	35	50	996	10		7
2017	03	23	1100	21.1	119.1	5	30	45	999			
2017	03	23	1200	21.4	119.2	10	30	45	998			
2017	03	23	1800	22.5	119.2	10	20	45	1000			

FIGURE 2. METOP-B ASCAT pass at 0149 UTC 22 March 2017

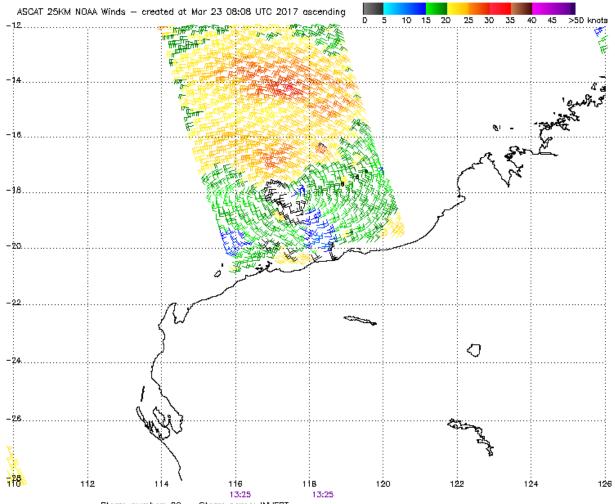
Image courtesy of https://manati.star.nesdis.noaa.gov/datasets/ASCATData.php



Note: 1) Times are GMT 2)Times along bottom correspond to measurement at —15S 3)Data buffer is 22 hrs from 20170322 4) Black wind barbs indicate possible contamination NOAA/NESDIS/Center far Satellite Applications and Research

FIGURE 3. METOP-A ASCAT pass at 1325 UTC 22 March 2017

Image courtesy of https://manati.star.nesdis.noaa.gov/datasets/ASCATData.php



Storm number: 99 Storm name: INVEST
Note: 1) Times are GMT 2) Times along bottom correspond to measurement at -20S
3) Data buffer is 22 hrs from Mar 23 08:08 UTC 2017 4) Black wind barbs indicate possible contamination

FIGURE 4. AMSR2 37 GHz Microwave pass at 1706 UTC 22 March.

Image courtesy of https://www.fnmoc.navy.mil/tcweb/cgi-bin/tc_home.cgi

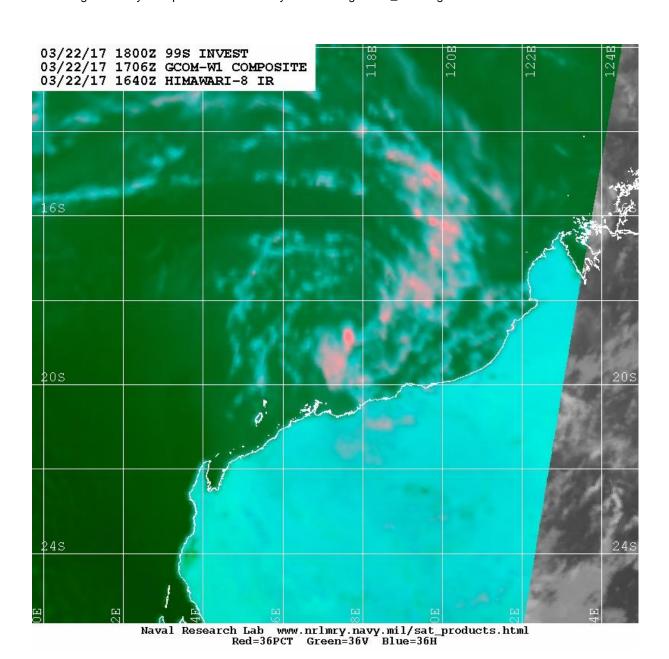


FIGURE 5. Radar image from Port Hedland at 0010 UTC 23March 2017 as the tropical cyclone became evident on radar.

The red circle indicates the location of the centre of *Unnamed*.

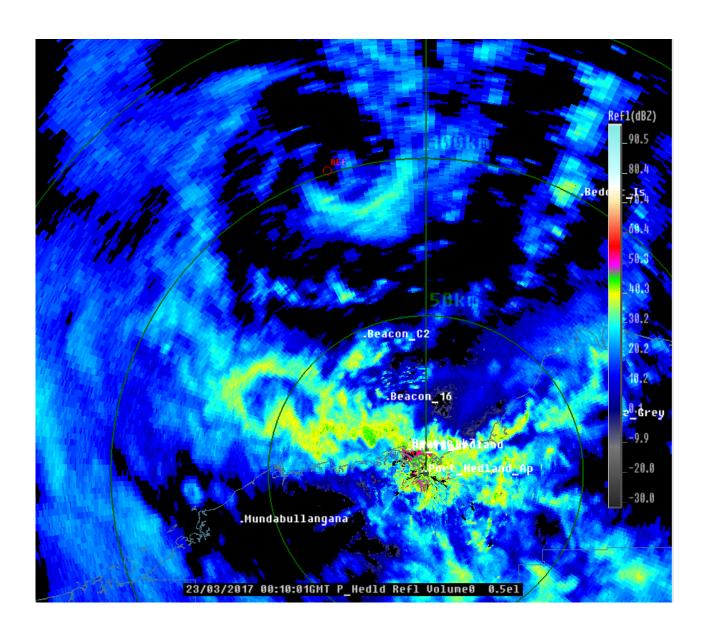


FIGURE 6. Map of location of surface observation sites.

The sites are located at the bottom left of the leading letter of the name.

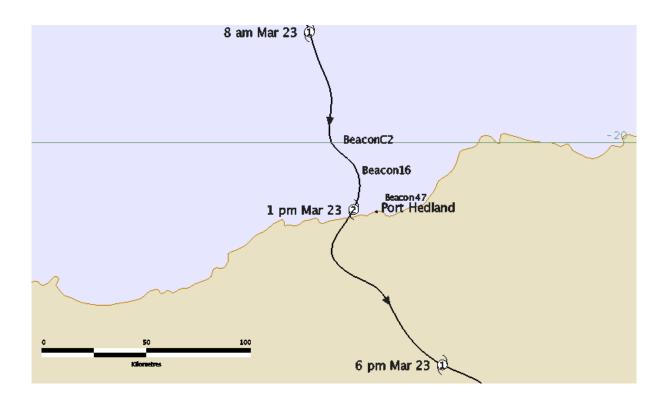
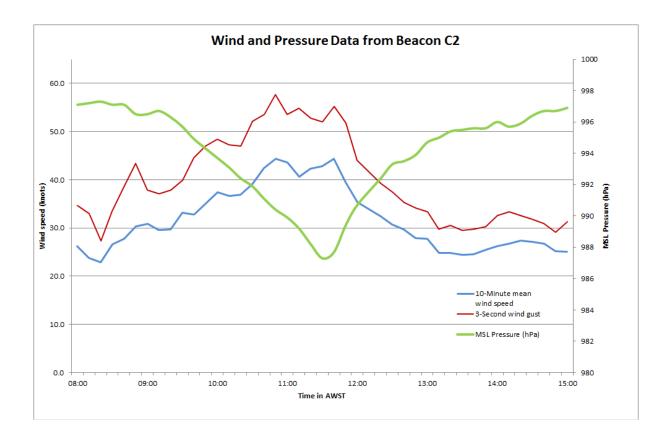
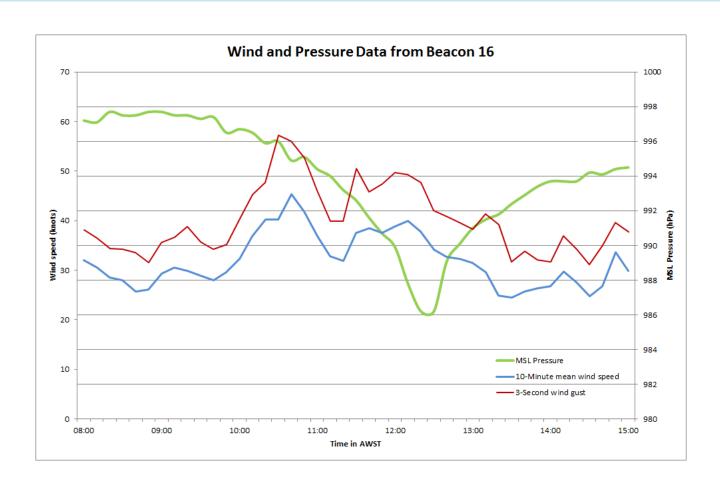
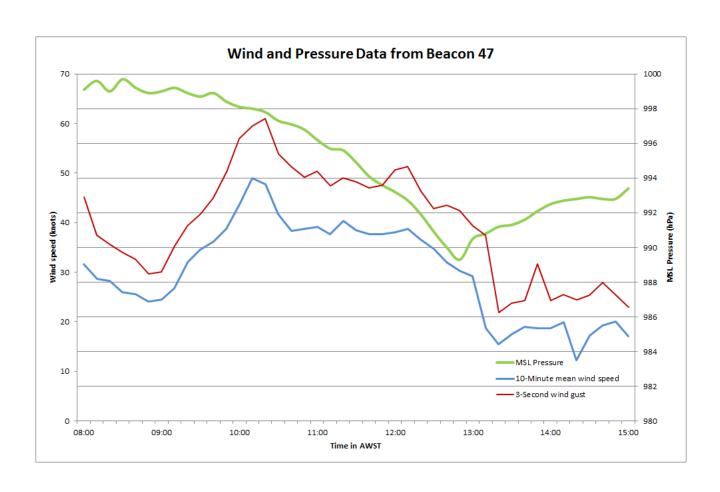


FIGURE 7. Surface observation plots from sites near Port Hedland around the time of the coastal crossing.

Time is AWST, to convert to UTC minus 8 hours. A break in data occurred at 1210 AWST.z







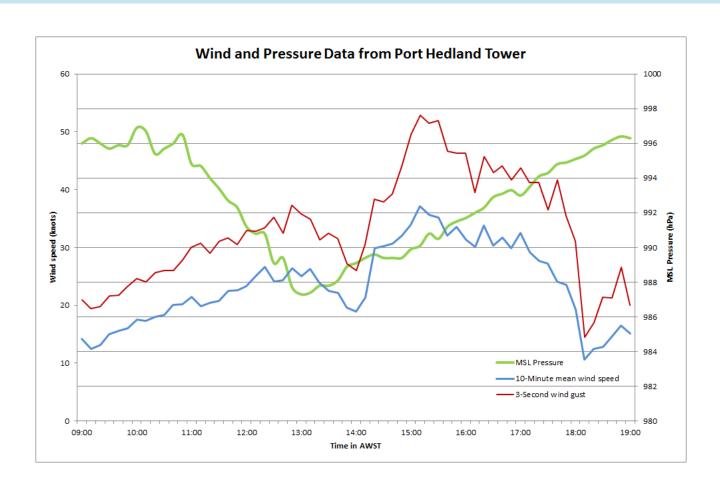


FIGURE 8. Radar image from Port Hedland at 0200 UTC 23March 2017

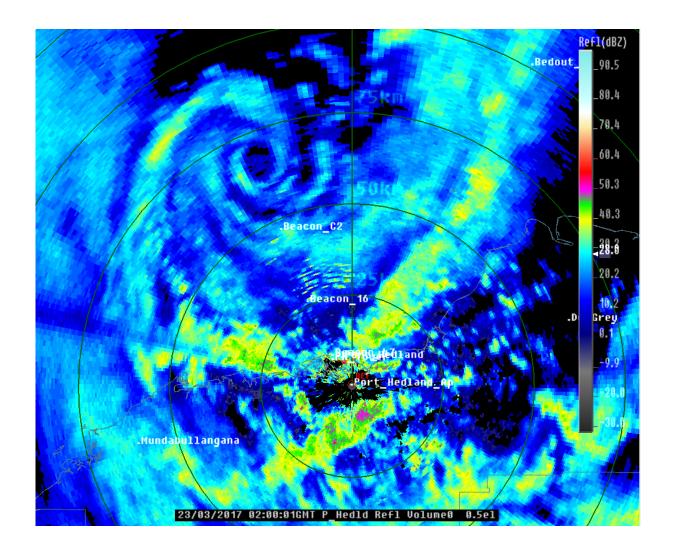


FIGURE 9. Radar image from Port Hedland at 0450 UTC 23March 2017 as *Unnamed* crossed the coast west of the Port Hedland Airport.

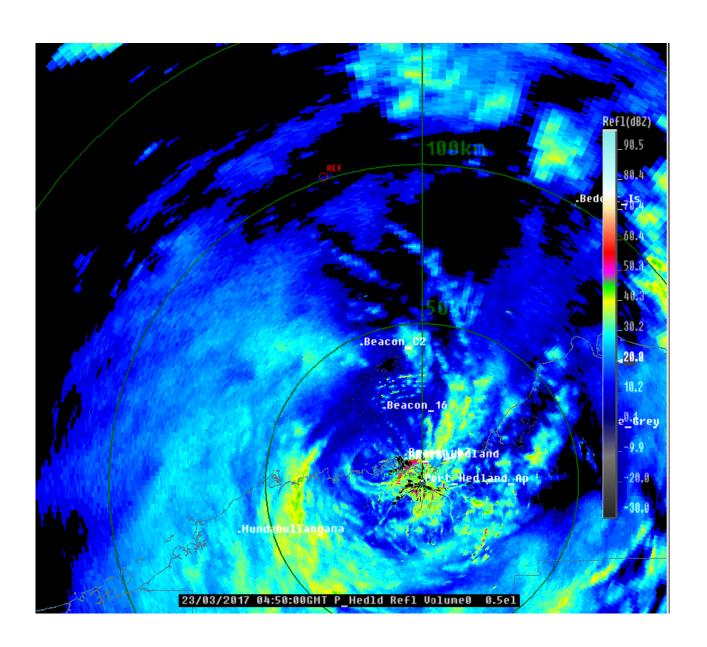


FIGURE 10 A plot of significant wave heights in metres from Beacon C2, Beacon B15 and Beacon B16. Time is in AWST.

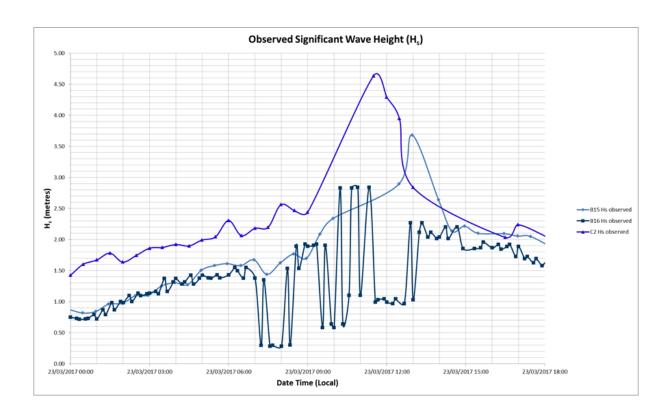


FIGURE 11 A plot of the accuracy figures for *Unnamed* (22U) compared to the five year mean.

