Australian Government
Bureau of Meteorology

Severe Tropical Cyclone *Heidi*
9 – 13 January 2012

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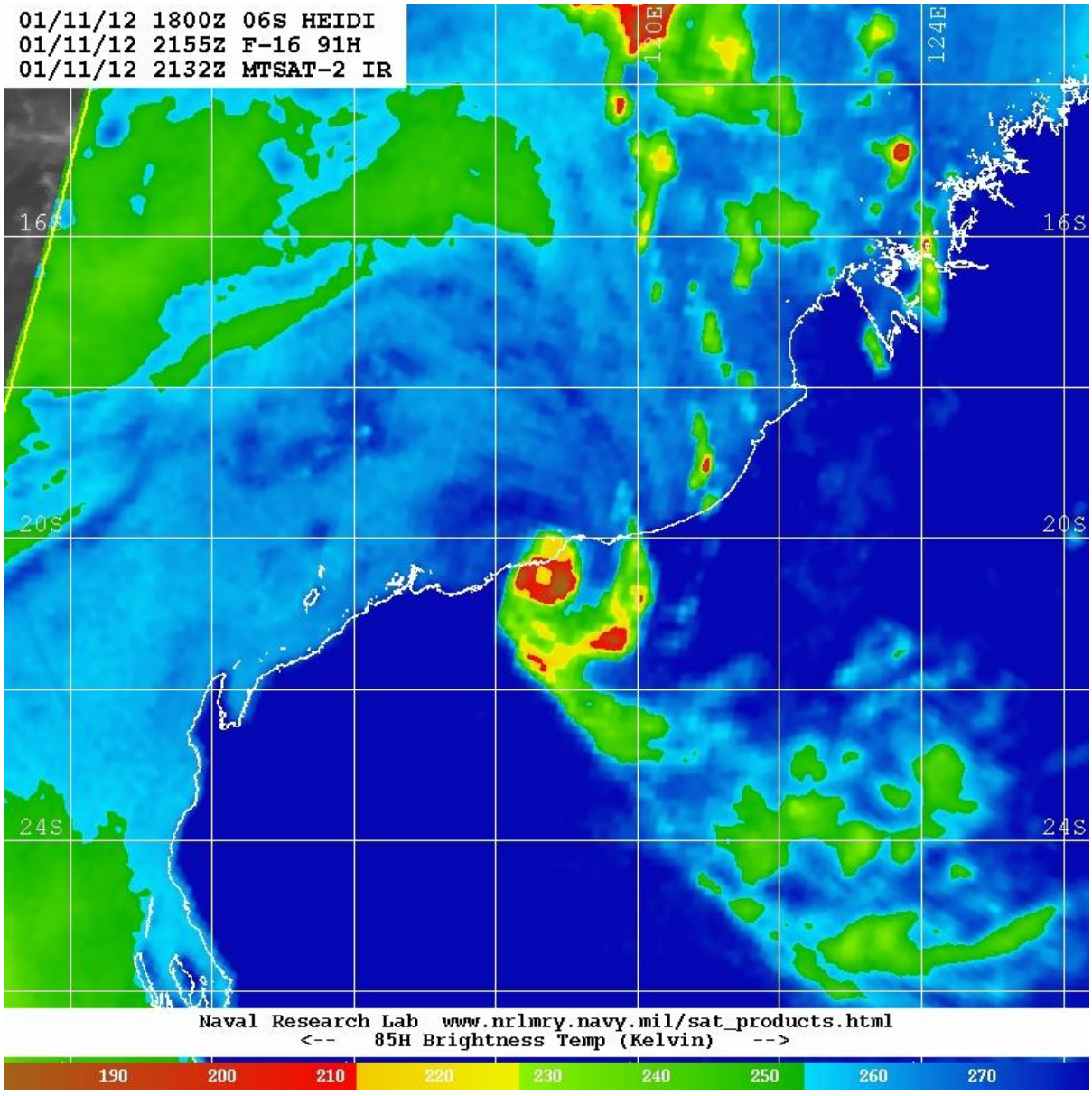

Image courtesy of of NOAA NRL: http://www.nrlmry.navy.mil/

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Summary

Severe Tropical Cyclone (STC) *Heidi* was a very small system that rapidly developed and passed 15 kilometres (km) to the east of Port Hedland. *Heidi's* destructive core passed to the east of Port Hedland, and so a Category 2 impact was experienced at the town. The post analysis best track is shown in Figure 1.

On 9 January 2012 a tropical low formed south of Indonesia, around 290 kilometres southwest of Sawu. The low formed in a supressed phase of the Madden-Julien Oscillation, with a high amplitude Equatorial Rosby Wave aiding development. Initial movement was reasonably fast towards the south, with the system taking a more southwest motion and slowing down as it intensified and approached the coast. Category 1 intensity was reached at 1200 UTC (2000 Australian Western Standard Time (AWST) as AWST = UTC + 8 hours) on 10 January. Due to the system's small size, *Heidi* maintained rapid intensification throughout its life. Peak intensity is estimated to be 80 knots (150 km/h, 10-minute mean wind, 1 knot=1.852 km/hr) as Severe Tropical Cyclone *Heidi* reached the coast.

The crossing location was 15 km to the east of Port Hedland early in the morning on 12 January (between 2000 and 2100 UTC on 11 January). Port Hedland experienced storm force winds with 53 kn (99 km/h) recorded at the aerodrome (10 metre elevation), 57 kn (106 km/h) recorded at the Port Authority tower (at around 30 m elevation) and 54 kn (100 km/h) recorded at Beacon 15 located 20 km offshore (20 m elevation). A map of these observation locations is given in Figure 7.

Heavy rainfall occurred across the Pilbara and west Kimberley. Pardoo Station recorded 168.5 millimetres (mm) in 24 hours and Port Hedland Aerodrome recorded 108.4 mm. The Fire and Emergency Services (FESA) reported that *Heidi* uprooted trees across properties and roadways with minor flooding on roads and large scale power outages in South Hedland and Wedgefield. The majority of damage was caused by very strong winds and heavy rainfall.

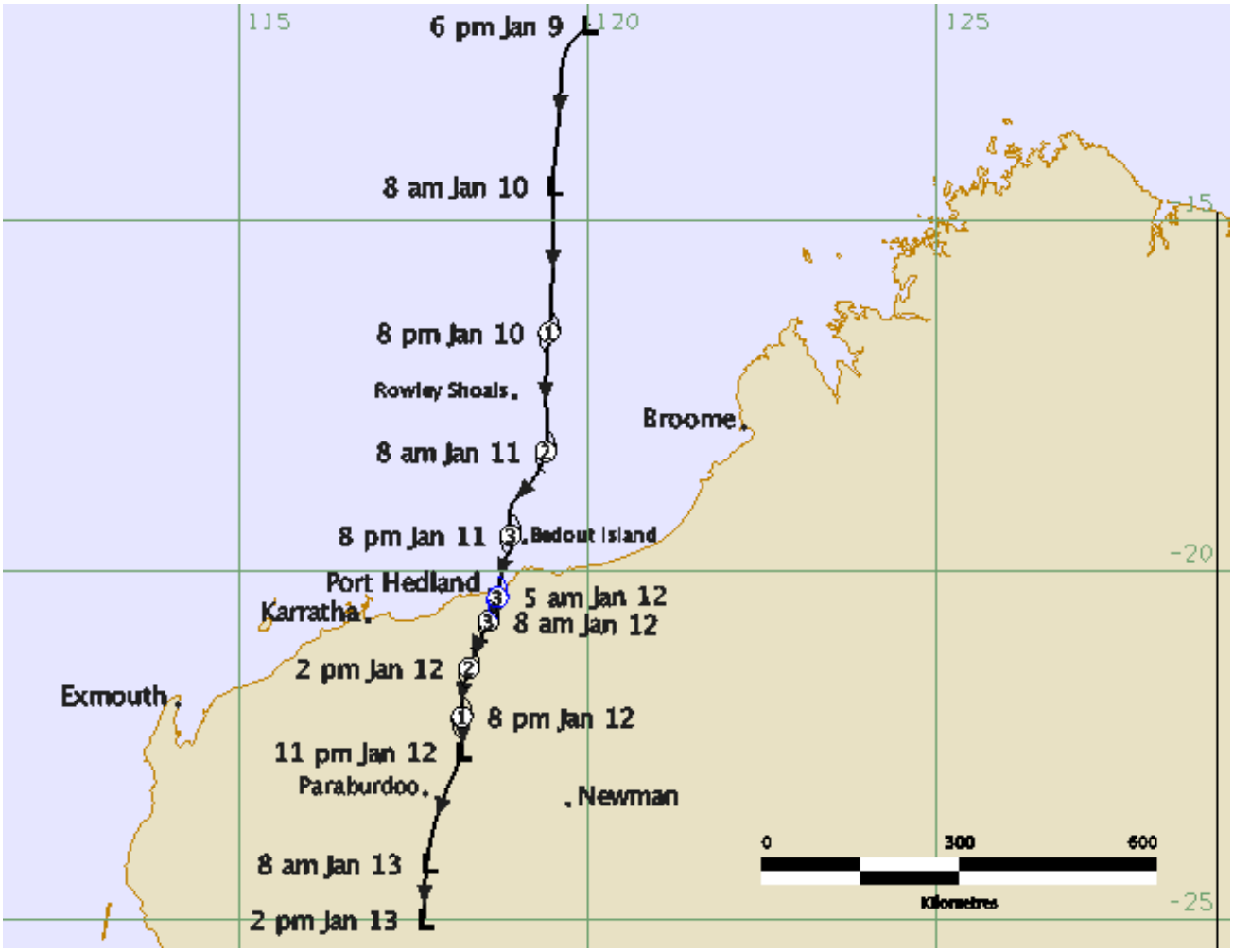

Figure 1: Post event best track of STC *Heidi*.

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Meteorological Description

Environment

On 9 January 2012 a tropical low formed south of Indonesia. Wind shear was low, under the influence of an upper level ridge, and remained low until *Heidi* was well inland. As the direction of the wind shear was northerly and *Heidi* took a southerly track, storm relative wind shear was low. An upper level trough was situated to the south over central parts of Western Australia, with a mid-level low off the southwest coast. The upper level trough to the south provided strong upper divergence with poleward outflow on the southern side.

Sea Surface Temperature (SST) was approximately 31degrees Centigrade (°C), with SSTs 28-30°C extending all the way to the Pilbara coast.

Overall, the environment was favourable for *Heidi* to develop and remained favourable throughout the event.

Intensity Analysis

Due to *Heidi's* small size and the favourable environment, development was rapid. Dvorak T-number 1 (T1) classification was estimated at 1000 UTC 9 January. Curvature of the deep convective bands subsequently improved and Category 1 cyclone intensity was reached at 1200 UTC on 10 January. Development continued, with *Heidi* reaching Category 2 intensity at 1800 UTC 10 January. *Heidi* reached Category 3 intensity by 1200 UTC 11 January and peak intensity of 80 kn (150 km/h) is estimated as STC *Heidi* reached the coast. A Dvorak Enhanced infrared (EIR) satellite image at peak intensity is shown in Figure 2. An Embedded Centre pattern gives a Data T-number (DT) of 5.0, a Model Expected T-number (MET) of 4.5, a Pattern adjusted T-number (PT) of 5.0 and the Final T-number (FT) of 5.0.

The peak intensity estimated for *Heidi* is largely based on the Dvorak Analysis. Nearby surface observations mostly recorded storm force winds, with a peak gust of 88 kn (163 km/h) recorded at the Port Hedland Port Authority Tower (See Observations section for more details). However, these observations occurred beyond the zone of maximum winds as shown on the Port Hedland radar (Figure 4). Other intensity guidance didn't perform well due to *Heidi's* small size. A graph comparing the intensity guidance is given in Figure 11, which shows that the Cooperative Institute for Meteorological Satellite Studies (CIMMS) Advanced Microwave Sounding Unit (AMSU) had the highest estimate of winds at 65 kn (120 km/h). The intensity guidance from Advanced Dvorak Technique (ADT) suggested that *Heidi* was a weaker system. A limitation on the ADT was that the intensity was constrained because the Joint Typhoon Warning Centre (JTWC) had analysed a system with a peak intensity of less than 55 kn (100 km/h) intensity (). This resulted in an ADT peak intensity () of 41 kn (76 km/h). There were also complications with the early time that ADT analysed landfall. If these constraints were not placed, ADT would have reached 63 kn (117 km/h) (Chris Velden, University of Wisconsin, personal communication).

The evolution of STC *Heidi* in high resolution Visible (VIS) satellite images is shown in Figure 3. The bottom right image shows the cyclone maintaining an eye at 0559 UTC 12 January, even though *Heidi* is over land. The structure of the tropical cyclone was maintained after landfall due to low wind shear and this suggests that STC *Heidi* was a strong Category 3 tropical cyclone when crossing the coast.

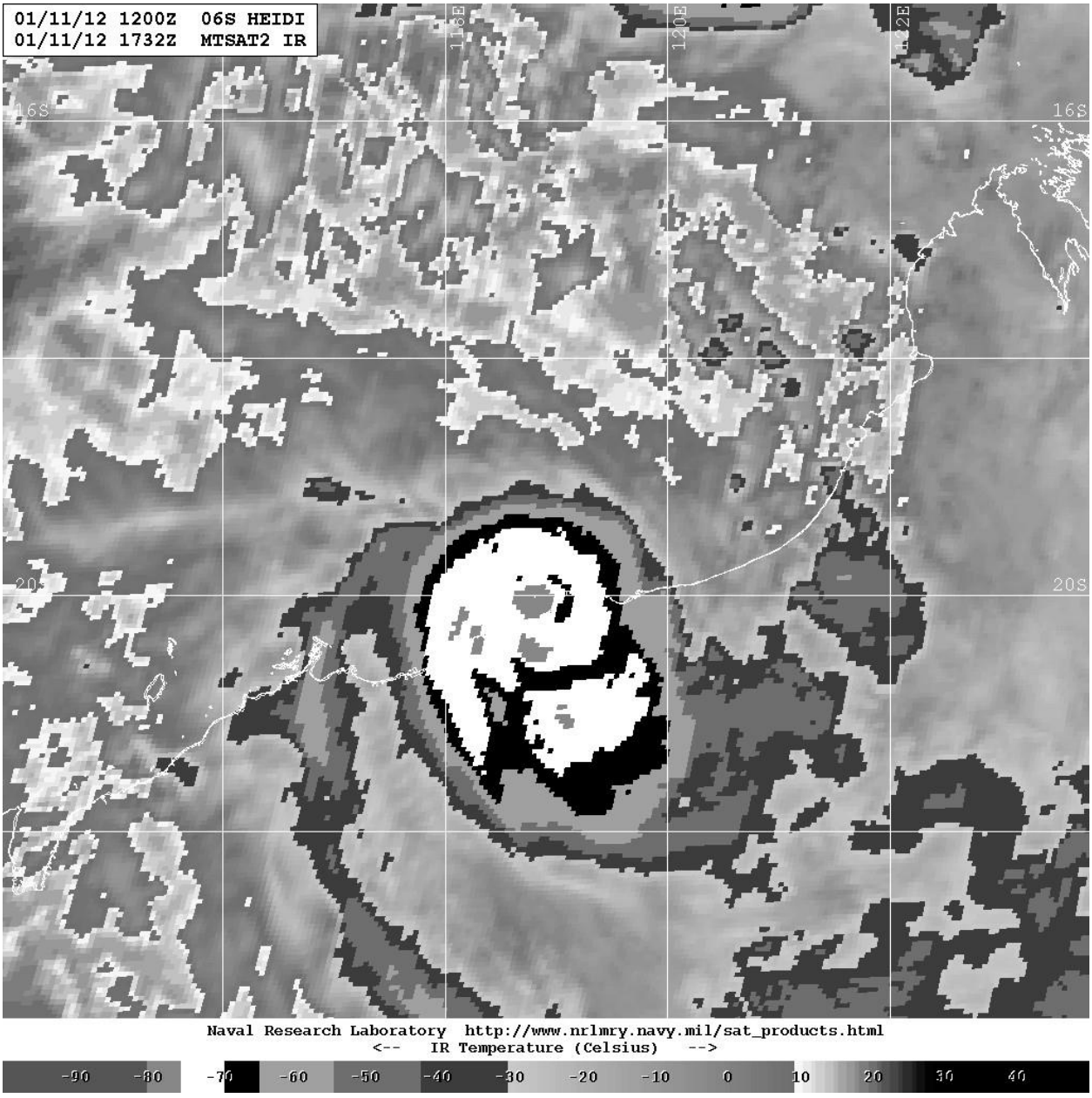

Figure 2: Dvorak enhancement for 1730 UTC 11 January (0130 AWST 12 January), when STC *Heidi* was at peak intensity of 80 kn (150 km/h). Centre is embedded in the black shading giving a DT of 5.0. Image courtesy of Naval Research Laboratory (http://www.nrlmry.navy.mil/TC.html).

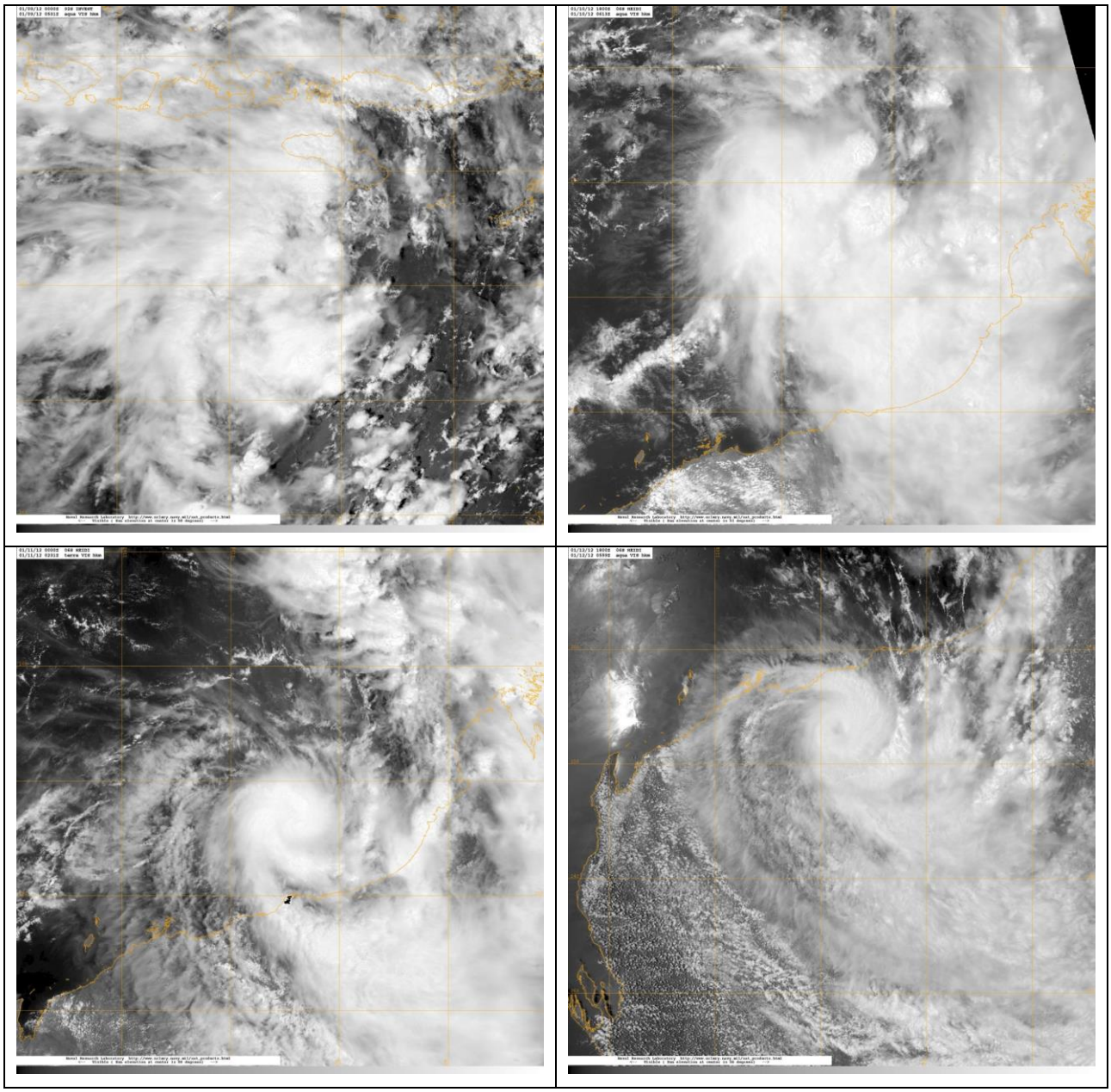

Figure 3: Evolution of *Heidi* from Modis Visible images at 0531UTC 9 January (top left), 0613UTC 10 January (top right), 0231UTC 11 January (bottom left) and 0559UTC 12 January (bottom right). Images courtesy of Naval Research Laboratory (http://www.nrlmry.navy.mil/TC.html).

Motion

The middle and upper level features described in the Environment section caused the system to move directly southwards, with a more south-southwest motion after the system passed Rowley Shoals. Initial motion was fast (approximately 10-12 kn (18-22 km/h) when this system was below cyclone intensity). As *Heidi* developed motion gradually slowed down with average speed around 5 kn (9 km/h) as *Heidi* approached and crossed the coast.

Structure

Heidi started out as a small system. The average gale radii was around 65 nm (average of quadrants) when *Heidi* first reached Category 1 intensity. *Heidi* contracted in size as it rapidly intensified, with a gale radii of 30 nm and Radius of Maximum Winds of 6 km (3 nm) at coastal crossing. Figure 5 shows *Heidi*'s structure as a Category 1 system from the Tropical Rainfall Measuring Mission (TRMM) microwave imagery. In comparison, about an hour after crossing the coast *Heidi* has contracted in size significantly and has a tight inner core (Figure 6). *Heidi*'s small size and asymmetrical wind structure (Figure 12) meant that the destructive core narrowly missed Port Hedland, a major town 15 km away.

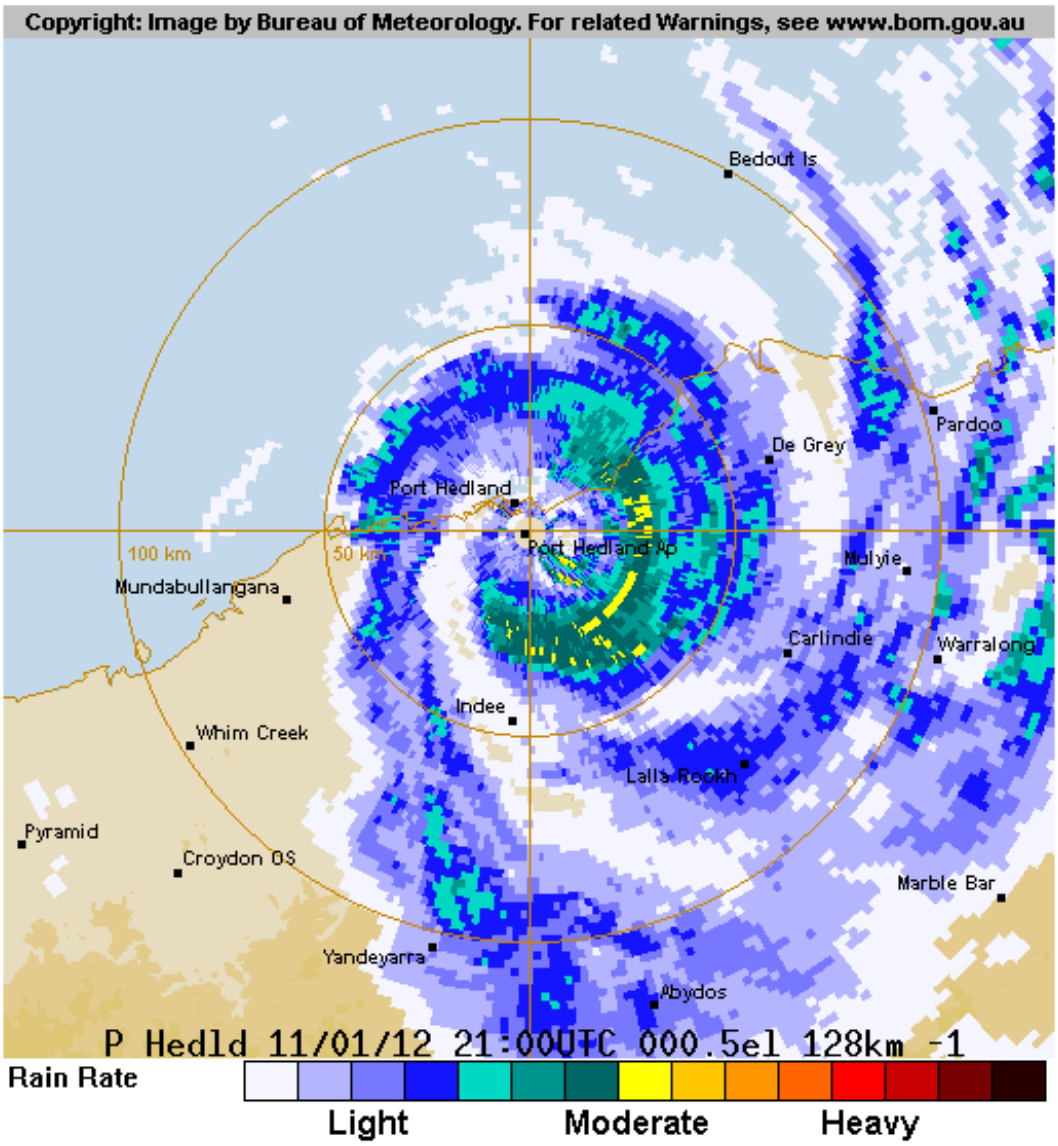

Figure 4: Port Hedland Airport RADAR at 2100 UTC (0500 AWST 12 January) 11 January that shows the heaviest precipitation area to the southeast of Port Hedland. Note the "false eye" over Port

Hedland Airport with the actual eye passing just to the east of Port Hedland Airport.

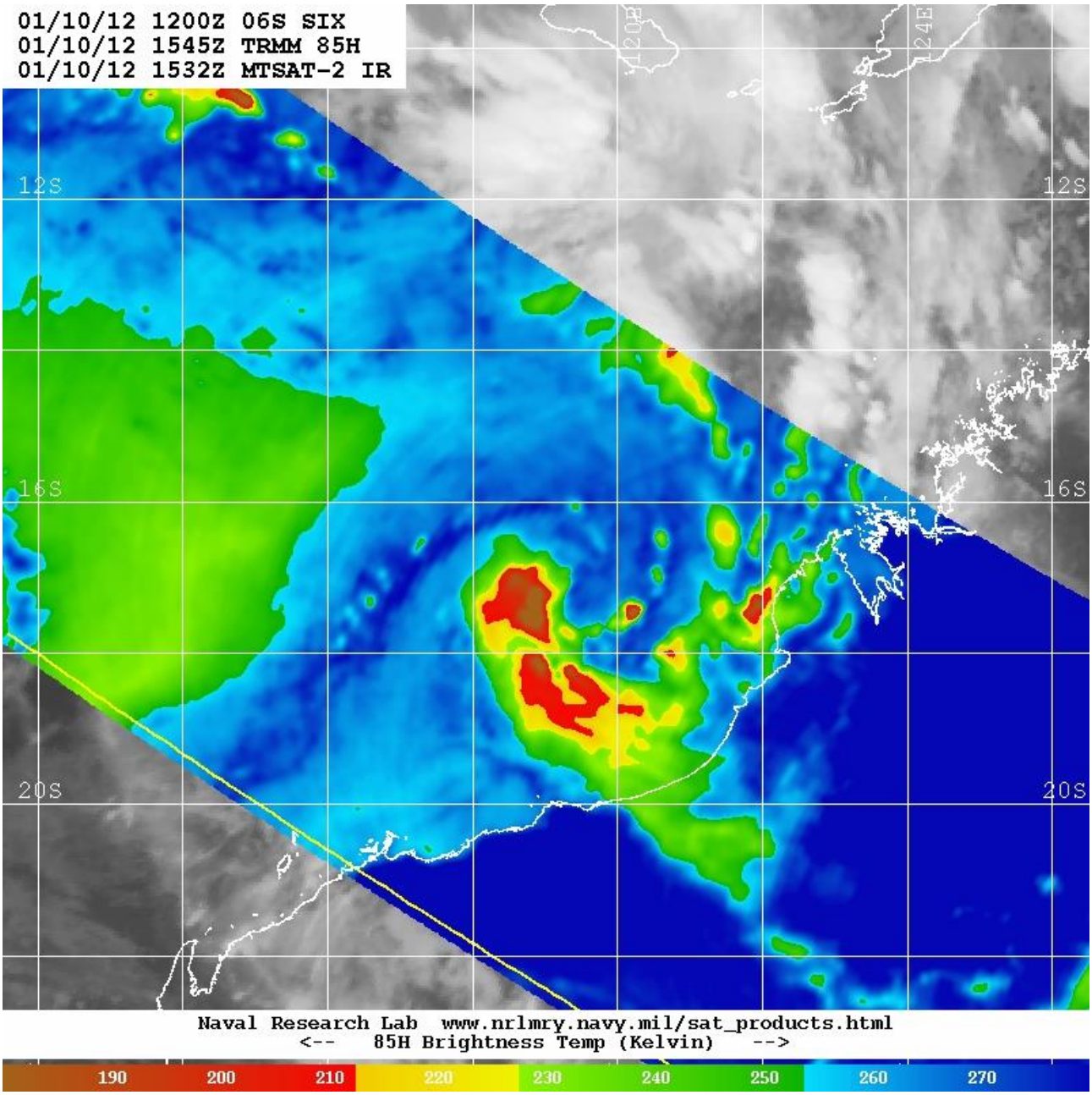

Figure 5: TC *Heidi* at 45 kn (85 km/h) intensity.

Image courtesy of Naval Research Laboratory (http://www.nrlmry.navy.mil/TC.html).

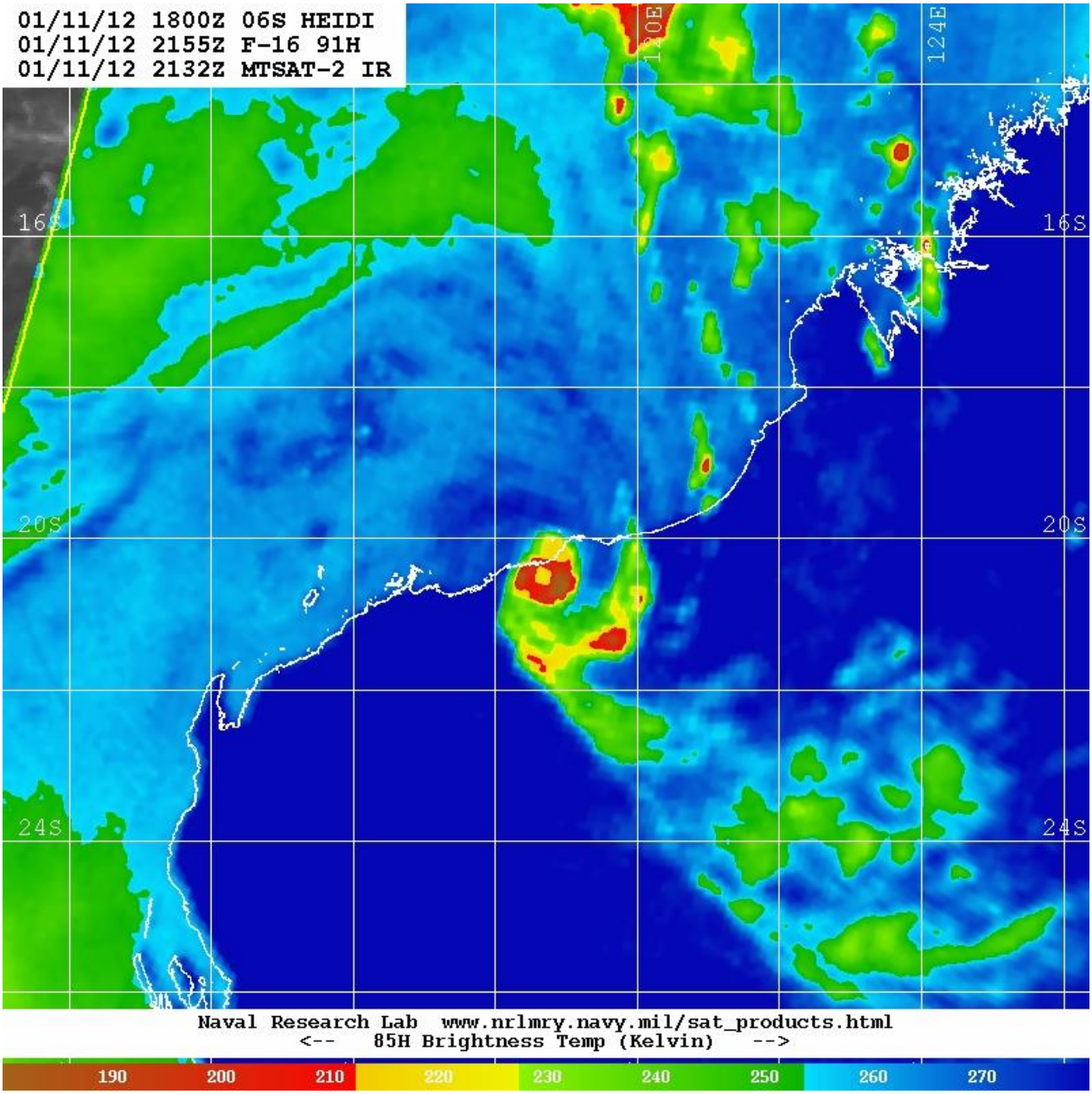

Figure 6: STC *Heidi* at 75 kn (140 km/h) intensity, about an hour after crossing the coast.

Image courtesy of Naval Research Laboratory (http://www.nrlmry.navy.mil/TC.html).

Impact

STC *Heidi* crossed the coast about 15 km to the east of Port Hedland. The maximum winds would have been experienced over a small area east of Port Hedland and west of De Grey.

The Fire and Emergency Services (FESA) reported that *Heidi* uprooted trees across properties and roadways with minor flooding on roads and large scale power outages in South Hedland and Wedgefield. FESA reported 70 requests for assistance at Port Hedland for 40 different premises. This required 687 hours of State Emergency Services (SES) time. Karratha SES provided 43 hours of support. The majority of damage was caused by very strong winds and heavy rainfall.

Observations

Wind

Rowley Shoals was the first site to record gale force winds at 1200 UTC on 10 January, which was the time that *Heidi* reached cyclone intensity. The time that gale and storm force winds were first recorded is given in Table 1 and the location of these observation sites is shown in Figure 7. The location of Rowley Shoals and Bedout Island is shown in Figure 1. A wind flight at Port Hedland Airport at 1700 UTC 11 January recorded 73 kn (135 km/h) winds at a height of 1500 feet (1 foot = 0.3 metres) above ground level. At this time 44 kn (81 km/h) mean winds were being observed at the surface. The system was about 50 km away and Port Hedland was outside the destructive bands of the eye wall.

Table 1: Surface observations displaying times winds of cyclone intensity were reached. Note that Beacon 15 and the Tower are maintained and owned by the Port Hedland Port Authority (PHPA) and are not at the standard 10 metre height.

Site (elevation)	*Onset of Gale Force (10 min)*	*Onset of Storm Force (10 min)*	*Maximum Wind gust reached (3 sec)*
Rowley Shoals (10m)	1200UTC 10/01	-	
Bedout Island (10m)	~1800UTC* 10/01	1000UTC* 11/01	78kn at 1247UTC 11/01
PHPA Beacon 15 (20m)	1135UTC 11/01	1640UTC 11/01	72kn at 1755UTC 11/01
PHPA Tower (30m)	1530UTC 11/01	1820UTC 11/01	88kn at 2045UTC 11/01
Port Hedland Airport (10m)	1550UTC 11/01	1856UTC 11/01	64kn at 1913UTC 11/01

* Exact time is uncertain due to an issue with the time stamping of 1-minute messages.

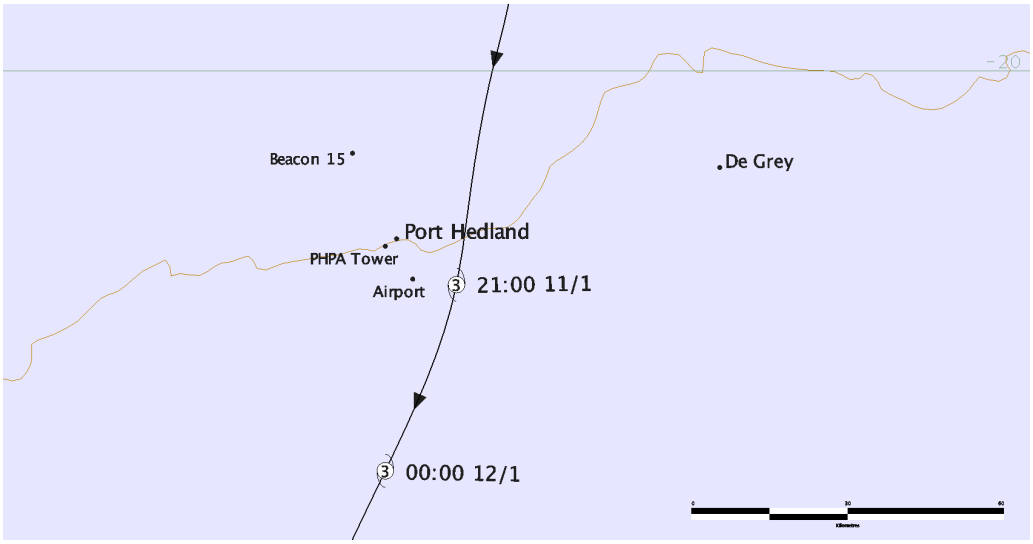

Figure 7: Map of locations around Port Hedland.

Pressure

The Modified Knaff & Zehr pressure wind equation (Courtney & Knaff, 2008) was used to estimate the pressure with 2 Hectopascals (hPa) added to every estimate to account for *Heidi's* small size and match in better with surrounding observations. The minimum observed pressure was 978 hPa just beyond the eye wall at Port Hedland Airport at 2100 UTC on 11 January.

Rainfall

Heavy rainfall was reported at various locations in the Pilbara and western Kimberley associated with Severe Tropical Cyclone *Heidi*. Pardoo Station recorded 168.5 mm in 24 hours and Port Hedland Aerodrome recorded 108.4 mm. Figure 8 and Figure 9 show the spatial analysis of rainfall for 12 and 13 January.

Storm Tide

Due to the slow movement and intensity of *Heidi*, there was potential for a dangerous storm tide at Port Hedland and nearby areas if the cyclone approached the coast closer to the time of high tide.The Department of Transprt's Port Hedland tide gauge recorded a 75 centimetre residual tide, but this occurred at the time of low tide. Cape Lambert, another reporting site was too far west to record a significant storm tide.

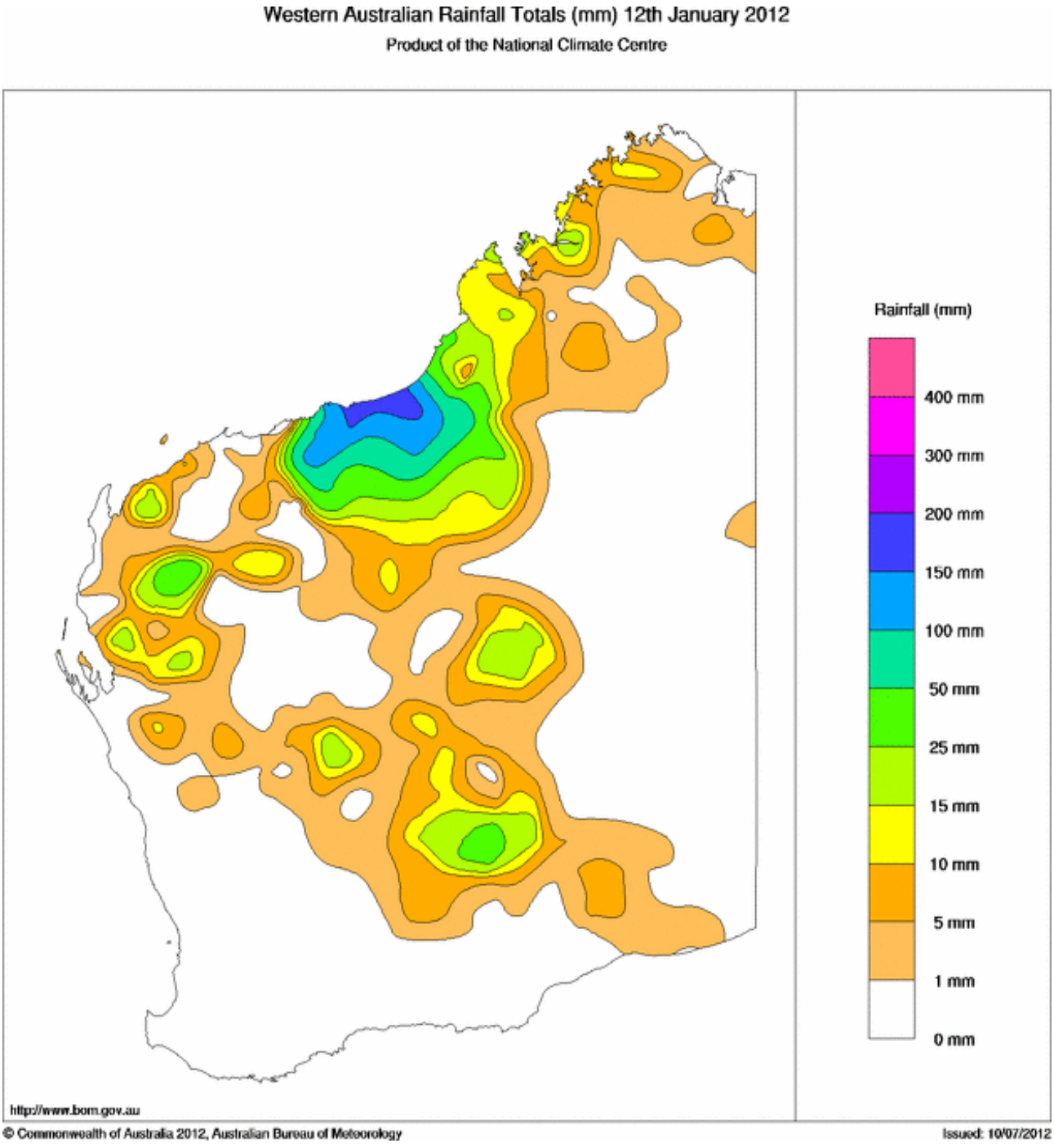

Figure 8: Rainfall analysis in the 24 hours to 0900 AWST on 12 January 2012.

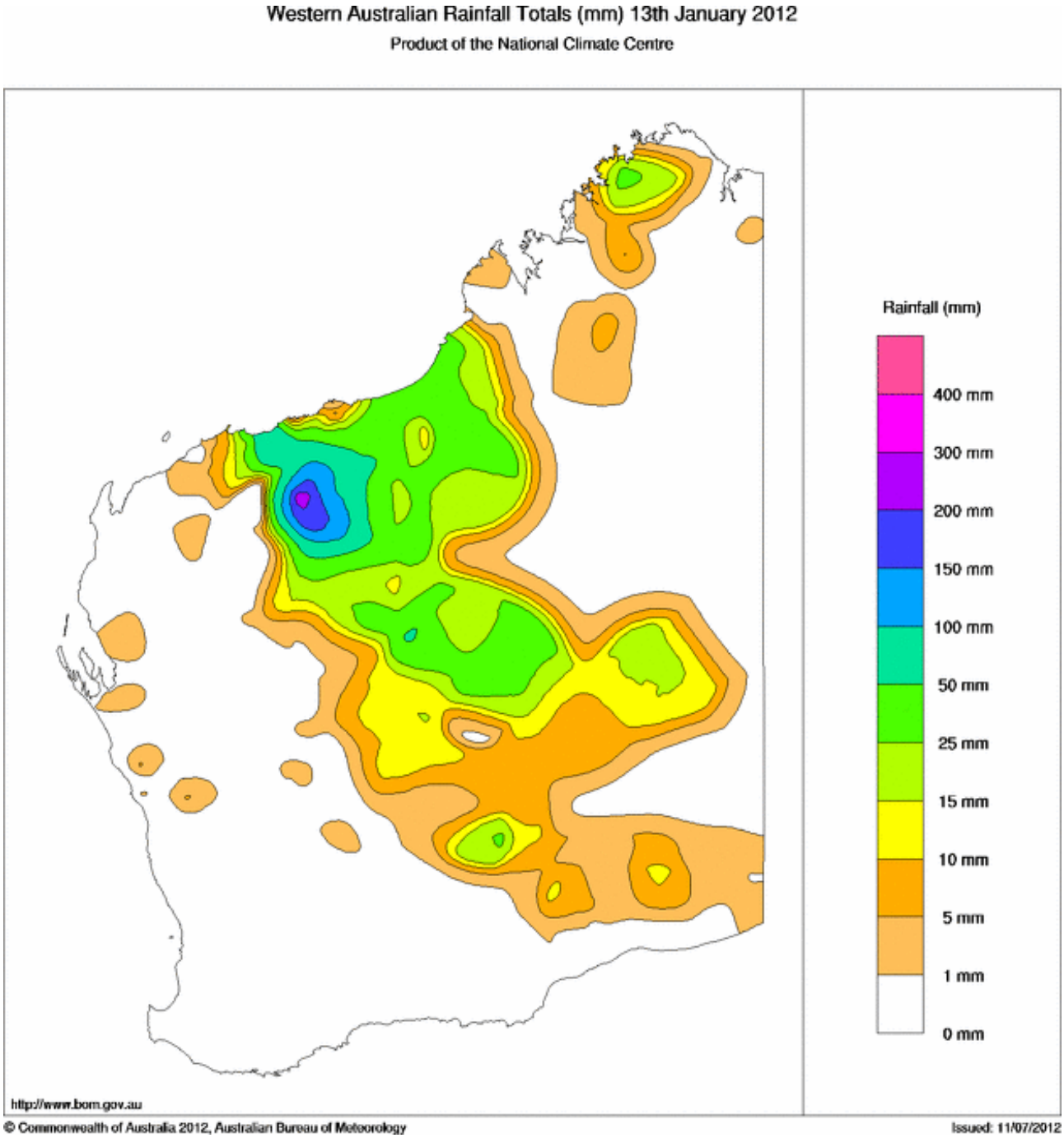

Figure 9: Rainfall analysis in the 24 hours to 0900 AWST on 13 January 2012.

Forecast Performance

Small systems such as *Heidi* can pose many forecasting challenges due to rapid intensity changes and rapid response to changing environmental conditions. Model guidance did not perform very well in the lead up to this event. The European Centre for Medium-Range Weather Forecasts (ECMWF) Tropical Cyclone strike rate ensemble did not give any suggestion of increased cyclone probability until 48 hours before *Heidi* reached cyclone intensity, and then rapidly increased probabilities in the model runs leading up to *Heidi's* development. Deterministic forecast tracks from Numerical Weather Prediction models initially forecast the tropical cyclone's path towards the west Pilbara coast. Once *Heidi* had formed the ECMWF deterministic forecast track moved the TC towards Port Hedland and accuracy improved, while other models continued to take the track westwards until *Heidi* had just about reached the coast.

TC *Heidi* became evident on Port Hedland radar on the morning of 11 January and uncertainty in the analysis positions decreased from this time. Verification of the operational forecast track positions is given in Table 2 and Figure 10. Figure 10 shows that the error in positions is much lower than the 5 year average.

Operationally, *Heidi* was analysed as a strong Category 2 system with 10-minute mean winds at 60 kn (110 km/h) peak intensity. Upon post event reanalysis, STC *Heidi* is estimated to have reached Category 3 with 80 kn (150 km/h) peak intensity.

The first Tropical Cyclone Advice was issued at 0720 UTC on 10 January, placing the coastline between Wallal and Dampier into Cyclone Warning.

Table 2: Forecast performance of Official Forecast Tracks from TC Module Verification.

Forecast hour (h)	*0*	*6*	*12*	*18*	*24*	*36*	*48*	*72*
Mean absolute error (km)	20	35	61	85	115	194	270	420
RMS Error (km)	26	44	67	93	122	198	272	424
Sample size	11	11	11	11	10	8	6	2

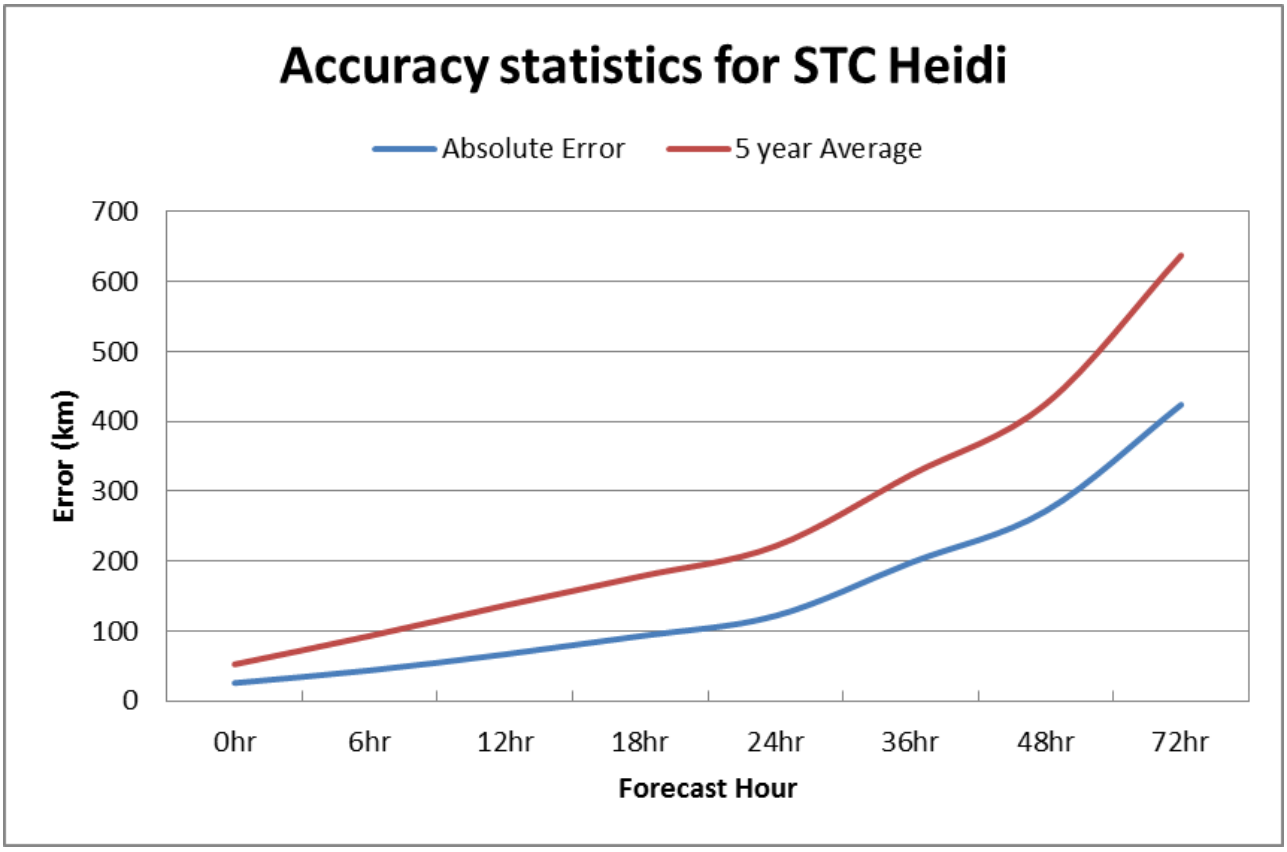

Figure 10: Forecast accuracy of the Official Forecast Track (OFT) positions compared with the post analysis best track positions.

Table 3: Best track summary for Severe Tropical Cyclone *Heidi.*

Refer to the Australian Tropical Cyclone database for complete listing of parameters.

Year	Month	Day	Hour UTC	Pos. Lat. S	Pos. Long. E	Position Accuracy nm	Max wind 10min knots	Max gust knots	Central Pressure hPa	Rad. of Gales nm (NE/SE/ SW/NW)	Rad. of storm force winds (NE/SE/ SW/NW)	Rad. of hurricane force winds (NE/SE/ SW/NW)	Radius Max. Wind (RMW)
2012	01	09	1000	12.20	120.0	60	20	45	1004				
2012	01	09	1200	12.30	119.9	50	20	45	1004				
2012	01	09	1800	13.30	119.6	60	25	45	1002				
2012	01	10	0000	14.50	119.5	40	25	45	1002				
2012	01	10	0600	15.45	119.5	50	30	45	1000				
2012	01	10	1200	16.60	119.45	30	40	55	995	10/90/60/ 50			30
2012	01	10	1800	17.56	119.40	30	50	70	990	50/125/ 120/50	20		15
2012	01	11	0000	18.30	119.40	15	55	75	984	60/100/ 90/40	20		15
2012	01	11	0600	19.10	118.9	10	55	75	980	60/60/50/ 40	20		15
2012	01	11	1200	19.50	118.90	10	65	90	972	50/50/40/ 30	20	12	10
2012	01	11	1800	20.07	118.76	10	80	110	960	40/30/30/ 30	16	10	8
*2012	01	11	2000	20.26	118.73	10	80	110	960	40/30/30/ 30	14/14/14/ 9	8/8/5/4	3
*2012	01	11	2100	20.39	118.71	10	75	105	964	40/30/30/ 25	14/14/14/ 8	4/6/5/4	3
2012	01	12	0000	20.73	118.58	10	65	90	974	25/30/25/20	15/12/12/ 8	5/5/4/4	3
2012	01	12	0600	21.40	118.30	15	50	70	982	25	12		10
2012	01	12	1200	22.10	118.20	15	35	50	995	25/25/15/15			15
2012	01	12	1800	23.10	118.00	20	30	45	1000				
2012	01	13	0000	24.20	117.70	20	25	45	1000				
2012	01	13	0600	25.00	117.65	20	25	45	1000				

*Position added for time of coastal crossing.

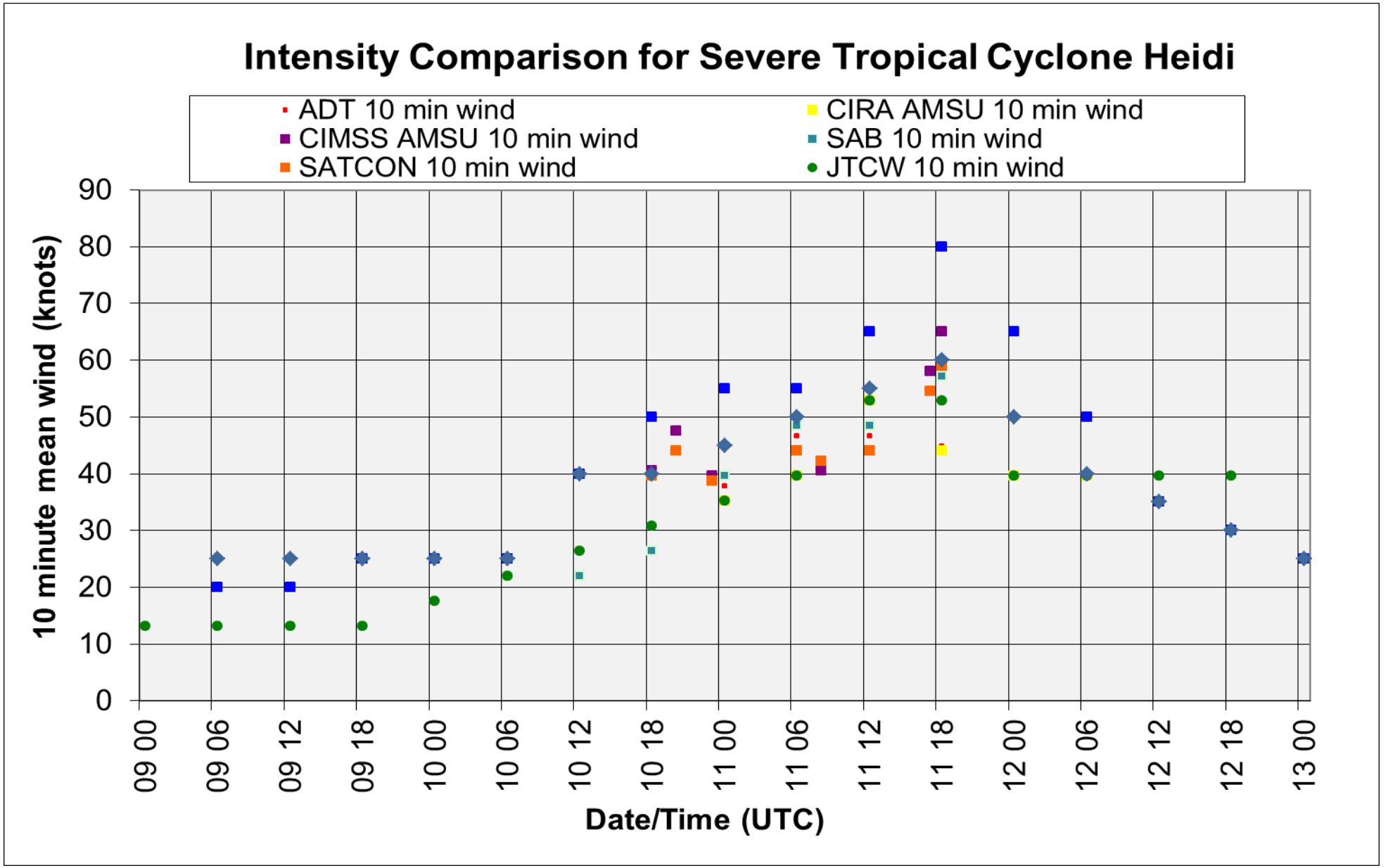

Figure 11: Objective and subjective intensity guidance.

Appendix 1: Ascat Scatterometry winds

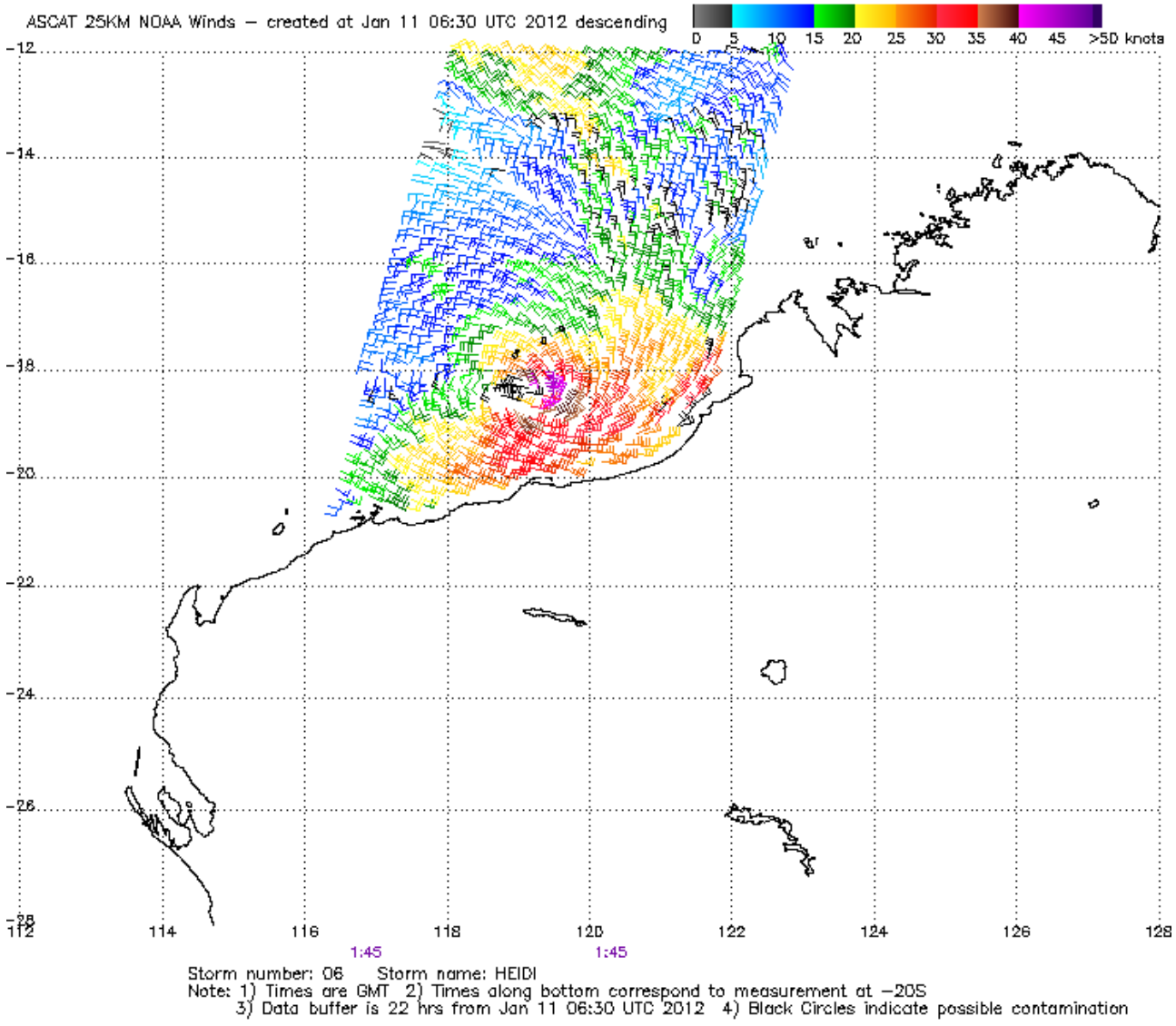

Figure 12: Ascat scatterometry winds at 0145 UTC (0945 AWST) 11 January displaying *Heidi's* Asymmetrical structure.

Image courtesy of NOAA NESDIS STAR http://manati.star.nesdis.noaa.gov/datasets/ASCATData.php/