Australian Government
Bureau of Meteorology

Severe Tropical Cyclone *Kelvin*

12 – 21 February 2018

September 2018

Published by the Bureau of Meteorology

Table of Contents

1 Summary

A weak low formed to the northeast of Darwin on 12 February. The low moved southeast and then southwest across western inland parts of the Northern Territory. On 14 February the low tracked west across the Joseph Bonaparte Gulf. The low moved inland across the north Kimberley coast between Wyndham and Kalumburu and continued to move westwards across the north Kimberley.

By 16 February the low was located to the north of Broome. As the low tracked westward and off the Dampier Peninsular gale force winds were recorded at two observing sites located at the Broome Port. The low continued to move west southwest and developed into a tropical cyclone at 0000 Universal Time Co-ordinated (UTC) 17 February (8 am Australian Western Standard Time (AWST) = UTC + 8 hours). *Kelvin* became slow moving during the day before taking a sharp eastward turn towards the west Kimberley coast. As *Kelvin* approached the coast it intensified rapidly. The tropical cyclone made landfall along 80 Mile Beach near Anna Plains Station around 2300 UTC 17 February with a 10-minute maximum peak wind of 80 knots (kn) (150 kilometres per hour (km/h)). *Kelvin* maintained its peak intensity for a number of hours after landfall and then weakened only very slowly as it moved further inland, generally towards the south southeast. *Kelvin* weakened below tropical cyclone strength by 1200 UTC 19 February.

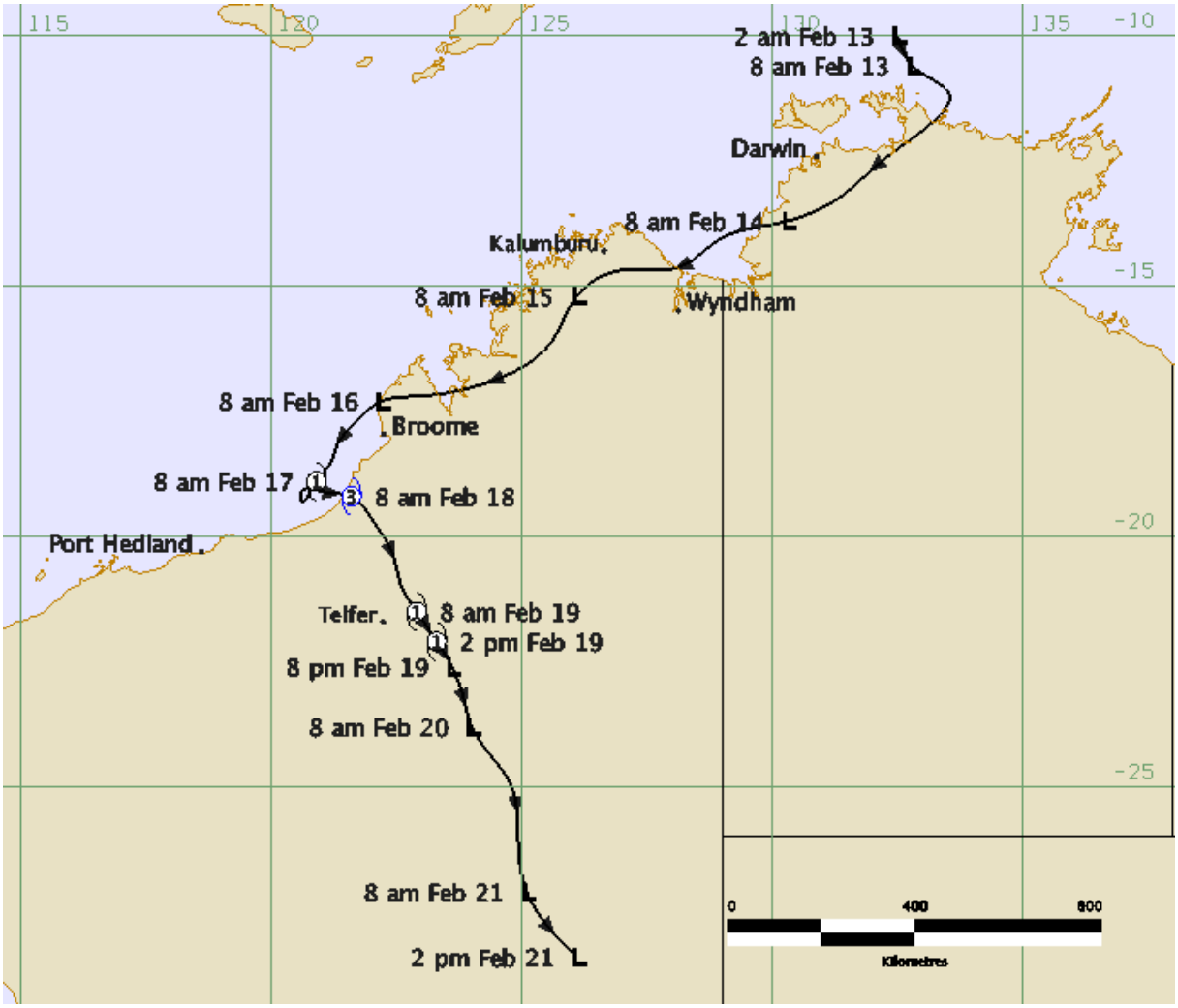
Kelvin was notable not only for its rapid intensification but for also being the third tropical cyclone to affect Broome and the west Kimberley area in three months. Heavy rainfall over the Kimberley during *Kelvin*, onto an already saturated catchment, contributed to significant flooding. Localised flooding occurred in Kalumburu in the north Kimberley. Widespread road flooding occurred throughout Broome. The Great Northern Highway sustained significant damage due to the flooding and was closed in parts between Sandfire Roadhouse and Willare Roadhouse, including into Broome and over the Roebuck Plains.

West Roebuck recorded 370.0 mm to 9am AWST 17 February, Nita Downs 235.0 mm and Wallal Downs 223.5 mm to 9am AWST 18 February. Broome Airport recorded 376.8 mm in the 24 hours to 9am AWST 17 February, contributing to Broome recording 1506.0 mm for 2018 up to 9am AWST 19 February, which set a new record for its wettest ever year in 129 years of records.

On 18 February Broome Port recorded a 0.5 metre surge and higher than normal tides were observed at Cable Beach in Broome.

Felled trees, branches stripped of leaves and building damage were reported at Nita Downs and Anna Plains Station, about 250km southwest of Broome where *Kelvin* crossed the coast. A person was stranded at Eco Beach Resort and Broome sustained minor storm related damage.

FIGURE 1. Best track of Severe Tropical Cyclone *Kelvin* 13 -18 February 2018 (times in AWST, UTC+8).



2 Meteorological Description

2.1 Intensity analysis

The tail end of a strong Madden Julian Oscillation (MJO) pulse combined with an Equatorial Rossby (ER) wave to form an area of low pressure to the north east of Darwin on 11 February. There were several low-level centres associated with this area and it wasn't until late on 12 February that it consolidated into one centre. The low initially moved southeast and a T1.0 was applied at 0600 UTC 13 February as convection had been persistent near the centre for 12 hours. The low then moved southwest across western parts of the Northern Territory.

By 0000 UTC 14 February a well-developed low was evident on Wyndham radar. The low moved out over open water in the Joseph Bonaparte Gulf during the day. A morning microwave pass showed a developing curved band of deep convection to the west of the centre and a three hour averaged Data T (DT) reached 2.5 by 0600 UTC 14 February. Subsequent scatterometer passes recorded 20 – 30 kn (37 - 55 km/h) winds in the eastern quadrants. This occurred as the western half of the low made landfall on the western side of the Joseph Bonaparte Gulf during the evening.

During 15 February the low tracked steadily west across the Kimberley until it was located just to the northeast of Broome by 0000 UTC 16 February. Despite traversing land for more than 24 hours the low had managed to maintain significant structural integrity. As the low moved offshore the town of Broome was in the southeast quadrant under a band of developing deep convection, refer Figure 2. Observations from the Broome National Tidal Centre (NTC) site located on the port jetty recorded a period of gale force winds between 0317-0611 UTC 16 February. A second comparison site nearby also recorded a period of gale force winds. Based on these observations intensity was set at 35 kn at 0000 UTC 16 February and increased to 40 kn at 0600 UTC with gales assigned to the southeast quadrant.

Kelvin tracked slowly south over the next 24 hours with surprisingly little change in appearance or estimated intensity by subjective or objective methods. Despite Kelvin maintaining a good structure as it moved offshore from land and the low being located in a favourable environment, radar and satellite images did not indicate that the system was showing any great degree of organisation. By 0000 UTC 17 February partial ASCAT passes showed gales in the southeast quadrant, as convection was located on the western side of the low with gales assumed in those quadrants *Kelvin* was determined to have reached tropical cyclone strength.

The tropical cyclone turned east and began to move towards the west Kimberley coast. Visible (VIS) satellite imagery during the morning indicated a large convective blow up developing on the western side of the centre. *Kelvin* was located equal distance from the Port Hedland and Broome radars at this time and both radar's imagery was poor. An 0642 UTC Special Sensor Microwave Imager (SSMI) pass showed a curved band structure with deep convection located to the west of the centre, refer Figure 3. Port

Hedland radar images showed some improvement in the structure of *Kelvin* as the day progressed and the tropical cyclone tracked further east.

Enhanced Infrared Imagery (EIR) showed a large area of deep convection but without any particular structure. By 1200 UTC 17 February DT was at 3.0 but this was based on a pattern adjusted model expected T number (MET). The Broome radar at this time showed an open spiralling curved band structure without a high degree of organisation. Around 1900 UTC the radar began to show a more symmetric structure with an almost complete deep convective band encircling the centre. A subsequent 1932 UTC Tropical Cyclone SSM Imager/Sounder (TCSSMIS) 17 February image showed a dramatic change had occurred over the preceding 12 hours, refer Figure 4.

From 2200 UTC 17 February EIR imagery showed an eye pattern and DT increased from 3.5 to 5.5. *Kelvin* had begun to cross Eighty Mile Beach near the station of Anna Plains at this time. Despite making landfall satellite and radar imagery showed the tropical cyclone improving in structure, refer Figure 5. At 0200 UTC 18 February the hourly DT reached a peak of 6.0 with a Dark Grey eye in a White surround with a surrounding ring of Black. Final T (FT) was constrained to 5.0 at this time. DT/FT reached a peak of 5.5 at 0400 UTC 18 February, by this time *Kelvin* was located approximately 70 kilometres (km) inland and Dvorak intensity assessments were ceased. The ten-minute peak wind intensity was set at 80 kn (150 km/h) at the time of landfall.

Kelvin maintained an eye structure for a remarkable period of time after making landfall. The terrain it traversed is extremely flat and uniform with a very warm landmass at that time of year. EIR imagery maintained an eye pattern until around 1900 UTC 18 February. A 1556 UTC 18 February Global Precipitation Measurement Microwave Imager (GMI) pass showed that *Kelvin* still had a solid core of deep convection surrounding the centre, refer Figure 6.

Lack of surface observations and any objective intensity guidance makes assessing the intensity of *Kelvin* after landfall problematic. The structure of the tropical cyclone suggests that it did not decay as fast as the land-decay model would suggest. The best track held *Kelvin* as a cyclone until 0600 UTC 19 February. *Kelvin* passed about 70 km to the east of Telfer on the morning of 19 February but no gales were recorded.

Figure 7 is a plot of all the objective and subjective intensity estimates available during *Kelvin*'s lifetime. The Advanced Dvorak Technique (ADT) estimates were too low throughout the lifetime. An eye did not emerge until close to landfall which would have compromised the ability of ADT techniques to assess the intensity correctly. The estimates from the Satellite Consensus (SATCON) technique climbed quickly from 1200 UTC 17 February as satellite and radar images indicated the tropical cyclone was undergoing rapid intensification.

2.2 Structure

Kelvin was a small and asymmetric tropical cyclone initially. Gales extended out to 35 nm (65 km) in the southeast quadrant in the early stages. By 1800 UTC 16 February gales had developed in the southwest and northwest quadrants (but had weakened in the southeast quadrant) as the tropical cyclone slowly developed over water. Gales extended to three quadrants by 0000 UTC 17 February. *Kelvin* became more symmetric with gales extending to 30 nm (55 km) in the western quadrants and 20 nm (37 km) in the eastern quadrants. A storm radius of 15 nm (28 km) was estimated at this time.

Kelvin became very symmetric as it intensified and by the time it crossed the coast it had a gale radius of 30 nm (55 km), a storm radius of 20 nm (37 km) and a hurricane radius of 15 nm (28 km).

The radius to maximum wind (RMW) was initially estimated from radar to be 25 nm (46 km), this contracted to 10 nm (18 km) at its smallest.

Eye radius was measured from radar and satellite images, this ranged from 7-10 nm (13 - 18 km).

2.3 Motion

Kelvin initially drifted southeast before being steered to the southwest by the mid-level ridge located to the east of the developing low. The west-southwest motion continued through until 16 February. The mid-level ridge was eroded by a mid-level trough which amplified over southern Western Australia and *Kelvin* became slow moving in the modified steering regime. The steering remained light through 17 February and *Kelvin* drifted around off the Pilbara coast. By 1800 UTC 17 February the northwesterly steering produced by the amplifying mid-level trough to the south became the dominating steering mechanism and *Kelvin* began to move towards the west Kimberley coast. *Kelvin* continued under this steering regime until the remains of the tropical cyclone dissipated over land on 21 February.

3 Impact

Severe tropical cyclone *Kelvin* followed directly after *Hilda* in December and *Joyce* in January. This significantly increased the impact that *Kelvin* had on the west Kimberley and Broome areas. The catchment areas were already saturated and further heavy rainfall associated with *Kelvin* exacerbated the flooding problem.

Broome Airport recorded 376.8 mm in the 24 hours to 9am AWST 17 February, contributing to Broome recording 1506.0 mm for 2018 up to 9am 19 February. This set a new record for Broome's wettest ever year in 129 years of records.

The Great Northern highway was significantly damaged by the flooding and was closed in parts between Sandfire Roadhouse and Wilare Roadhouse including into Broome. The highway remained closed for some time as repairs were carried out.

Kelvin crossed the west Kimberley coast directly over Anna Plains Station. Both Anna Plains and Nita Downs reported significant damage to buildings and sheds caused by the Category 3 wind speeds experienced at these locations. Numerous trees were felled and branches stripped of leaves. A person was stranded at Eco Beach Resort, further north in Roebuck Bay. Broome also reported some minor damage and a 0.5m storm surge was recorded at the Broome Port.

4 Observations

4.1 Wind

Broome NTC Automatic Weather Station (AWS) height adjusted data recorded gale force winds between 0317 - 0611 UTC 16 February. The maximum 10-minute mean wind recorded was 40 kn (74 km/h) at 0602 UTC 16 February and the maximum 3-second wind gust recorded was 49 kn (91 km/h) at 0601 UTC 16 February.

Broome NTC Comparison AWS recorded gale force winds between 0318 - 0521 UTC 16 February. The maximum 10-minute mean wind recorded was 40 kn (74 km/h) at 0446 and 0447 UTC 16 February and the maximum 3-second wind gust recorded was 49 kn (91 km/h) at 0441 UTC 16 February.

4.2 Pressure

Broome NTC AWS recorded a minimum mean sea level (MSL) pressure of 997.5 Hectopascals (hPa) at 0554, 0555 and 0557 UTC 16 February.

Broome NTC Comparison AWS did not record the MSL pressure during this event.

4.3 Rainfall

West Roebuck recorded 370.0 millimetres (mm) to 9 am AWST 17 February.

Nita Downs recorded 235.0 mm to 9 am AWST 17 February.

Wallal Downs recorded 223.5 mm to 9 am AWST 17 February.

Broome Airport recorded 376.8 mm to 9 am AWST 17 February.

5 Forecast Performance

The accuracy figures for Severe Tropical Cyclone *Kelvin* show that the forecast performed better than the five-year average at every time step.

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

	00	**06**	**12**	**18**	**24**	**36**	**48**	**72**	**96**	**120**
Absolute error (km)	16	34	53	62	67	89	112	178	291	369
RMS Error (km)	22	38	59	68	77	99	120	185	296	374
Sample Size	21	21	21	21	21	21	21	17	13	9

Figure 8 is a plot of the accuracy figures for *Kelvin* compared to the five year mean.

TABLE 1. Best track summary for Severe Tropical Cyclone *Kelvin*

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. 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	02	12	18	10.0	132.5	30	15	45	1006			
2018	02	13	00	10.6	132.8	30	15	45	1006			
2018	02	13	06	11.1	133.5	15	15	45	1004			
2018	02	13	12	12.4	132.3	30	20	45	1004			
2018	02	13	18	13.2	131.3	20	20	45	1004			
2018	02	14	00	13.7	130.3	20	25	45	1004			
2018	02	14	06	14.1	128.9	10	30	45	1003			
2018	02	14	12	14.6	128.2	15	30	45	1001			
2018	02	14	18	14.7	126.9	10	25	45	1001			
2018	02	15	00	15.2	126.1	15	25	45	1002			
2018	02	15	06	16.1	125.6	20	25	45	1002			
2018	02	15	12	16.9	124.4	20	25	45	1003			
2018	02	15	18	17.2	122.9	15	25	45	1003			
2018	02	16	00	17.3	122.2	15	35	50	998	0/30/0/0		25
2018	02	16	06	17.8	121.6	10	40	55	991	0/35/0/0		25
2018	02	16	12	18.2	121.3	15	40	55	989	0/0/35/0		25
2018	02	16	18	18.5	121.2	10	40	55	989	0/0/35/35		25

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	02	17	00	18.9	120.9	15	45	65	986	0/25/30/30		20
2018	02	17	06	19.3	120.6	15	50	70	983	20/20/30/30	15	15
2018	02	17	12	19.1	120.6	10	60	85	974	25/25/45/30	20	15
2018	02	17	18	19.1	121.0	10	70	100	966	25/25/45/35	20	10
2018	02	18	00	19.2	121.6	10	80	110	959	30	20	10
2018	02	18	06	19.8	122.1	10	80	110	955	30	20	10
2018	02	18	12	20.3	122.4	10	70	100	965	30	20	10
2018	02	18	18	21.0	122.6	10	60	85	973	30	20	10
2018	02	19	00	21.5	122.9	10	40	55	984	25/40/20/25		15
2018	02	19	06	22.1	123.3	10	35	50	987	25/40/25/25	20	
2018	02	19	12	22.6	123.6	20	30	45	990			
2018	02	19	18	23.1	23.8	10	25	45	996			
2018	02	20	00	23.8	124.0	10	20	45	997			
2018	02	20	06	24.4	124.4	20	20	45	997			
2018	02	20	12	25.0	124.8	20	20	45	997			
2018	02	20	18	26.1	124.9	20	20	45	997			

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	02	21	00	27.1	125.1	20	20	45	998			
2018	02	21	06	28.4	126.1	15	20	45	1000			

FIGURE 2. Special Sensor Microwave Imager (SSMI) 85 GHz pass at 0658 UTC 16 February 2018 as *Kelvin* moved offshore from the town of Broome.

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

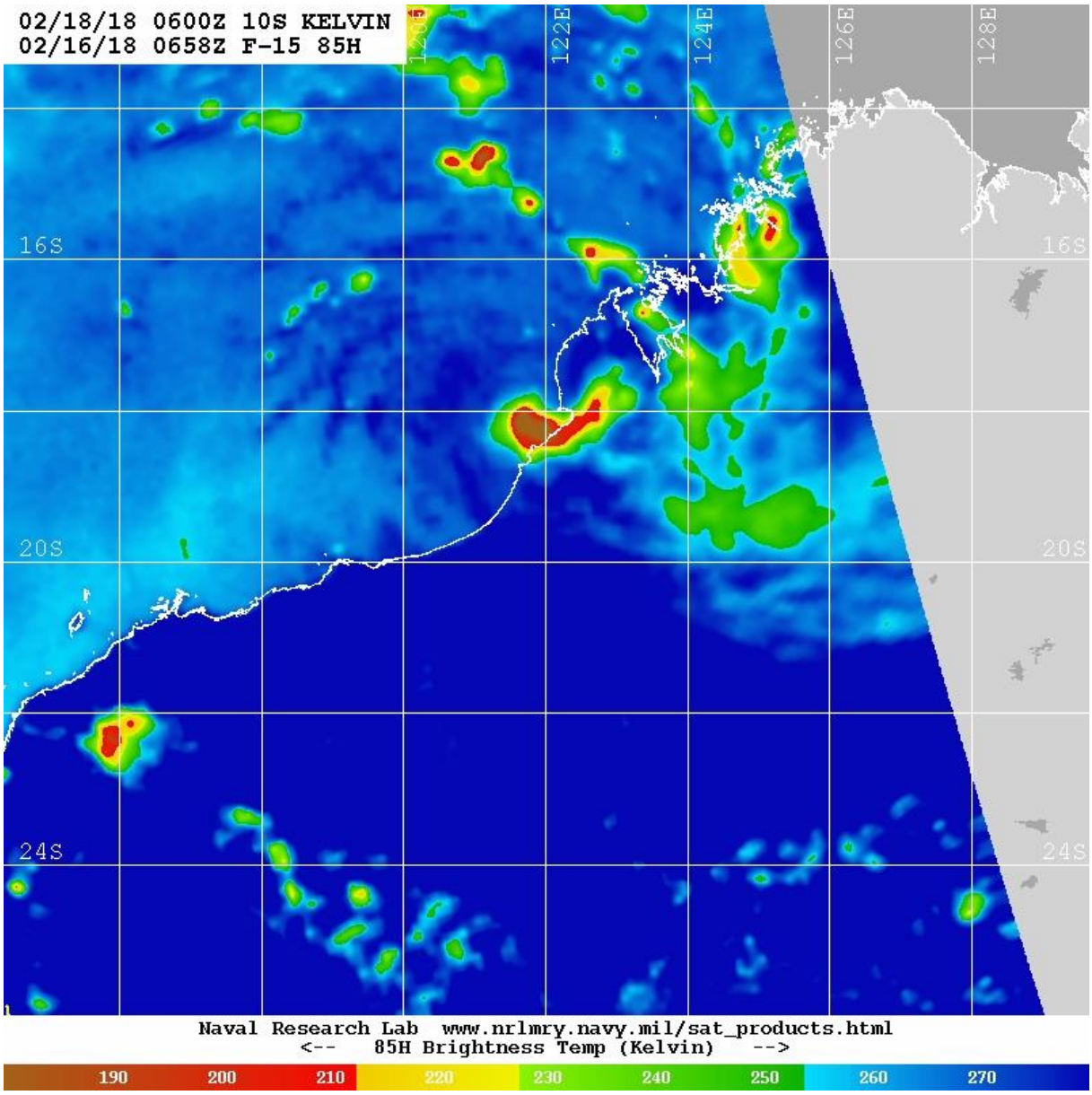


FIGURE 3. SSMI image at 0642 UTC 17 February.

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

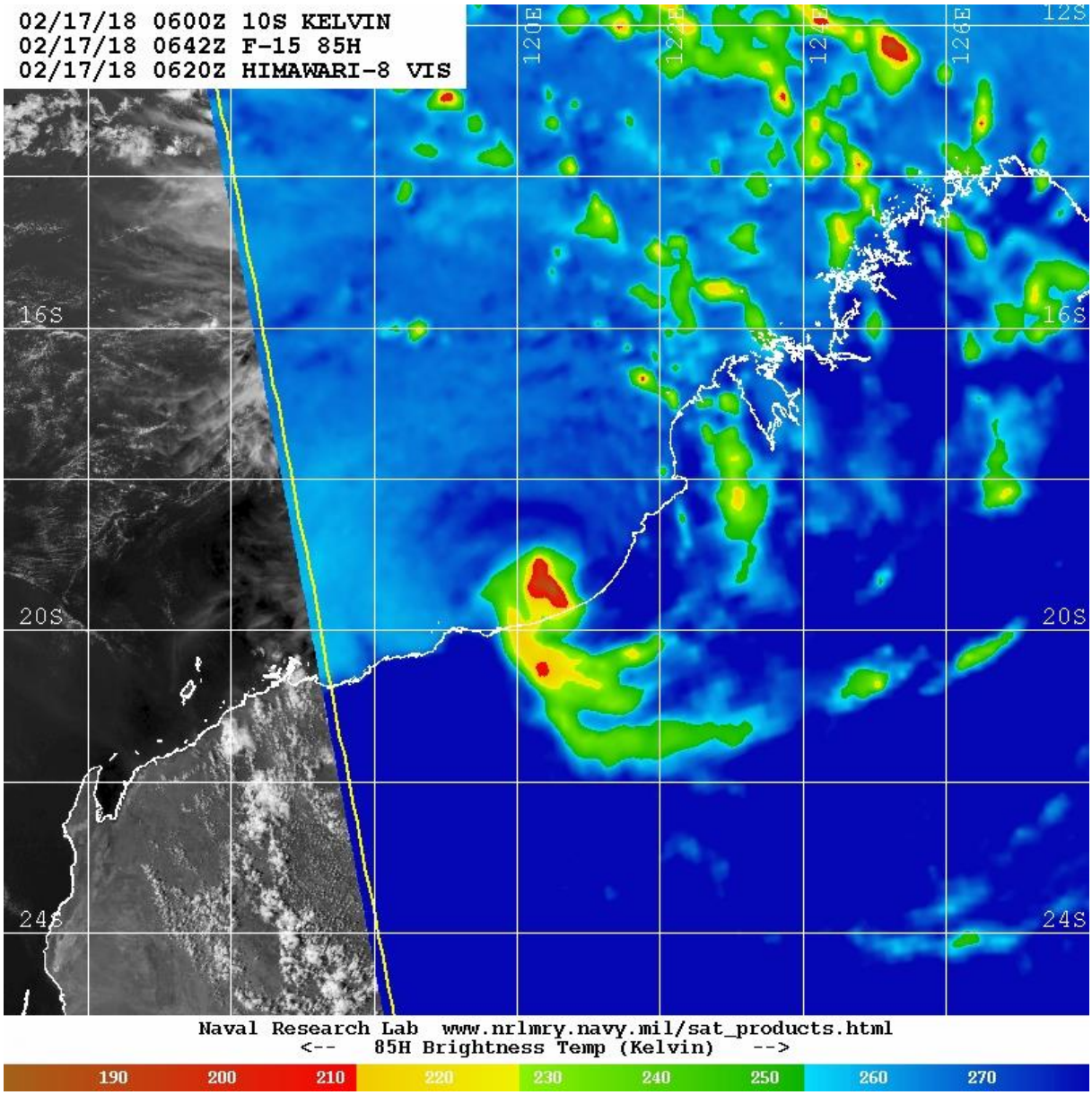


FIGURE 4. TCSSMIS image at 1932 UTC 17 February which shows significant development of the tropical cyclone had occurred over a 12 hour period.

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

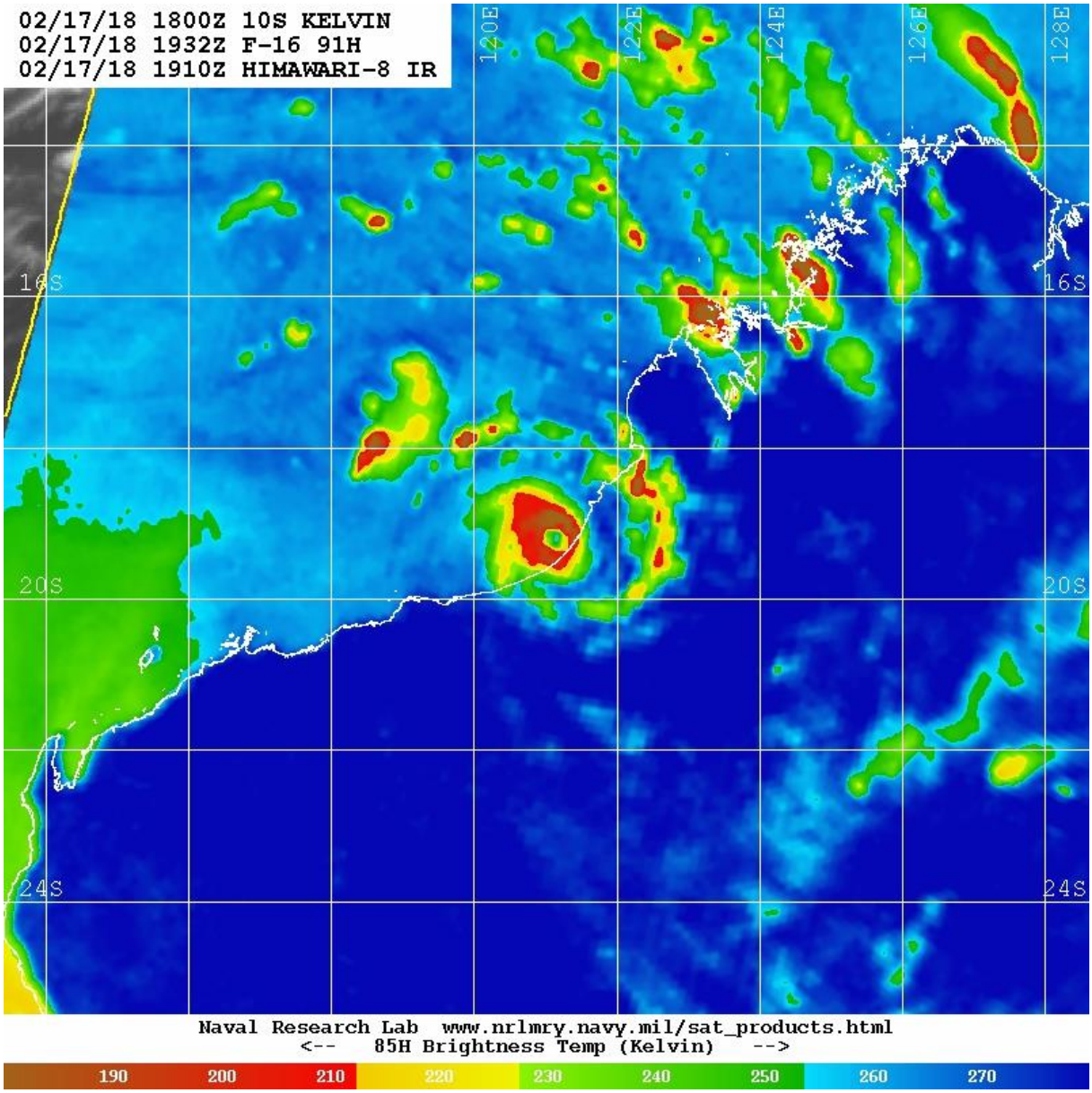


FIGURE 5 Broome radar image at 2300 UTC 17 February during landfall along the Eighty Mile Beach near Anna Plains.

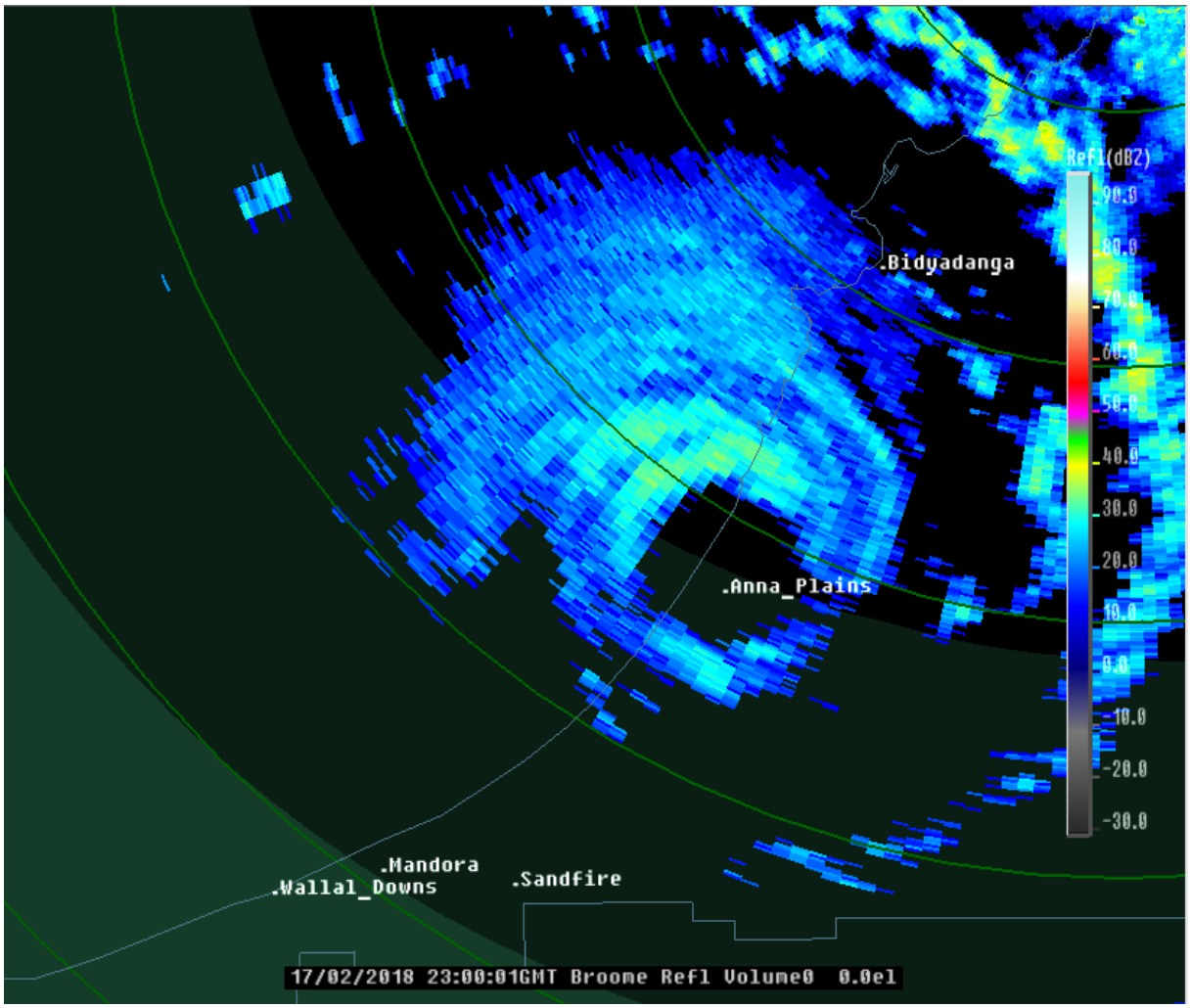


Figure 6. GMI image from 1556 UTC 18 February showing *Kelvin* had maintained its structure some 21 hours after making landfall.

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

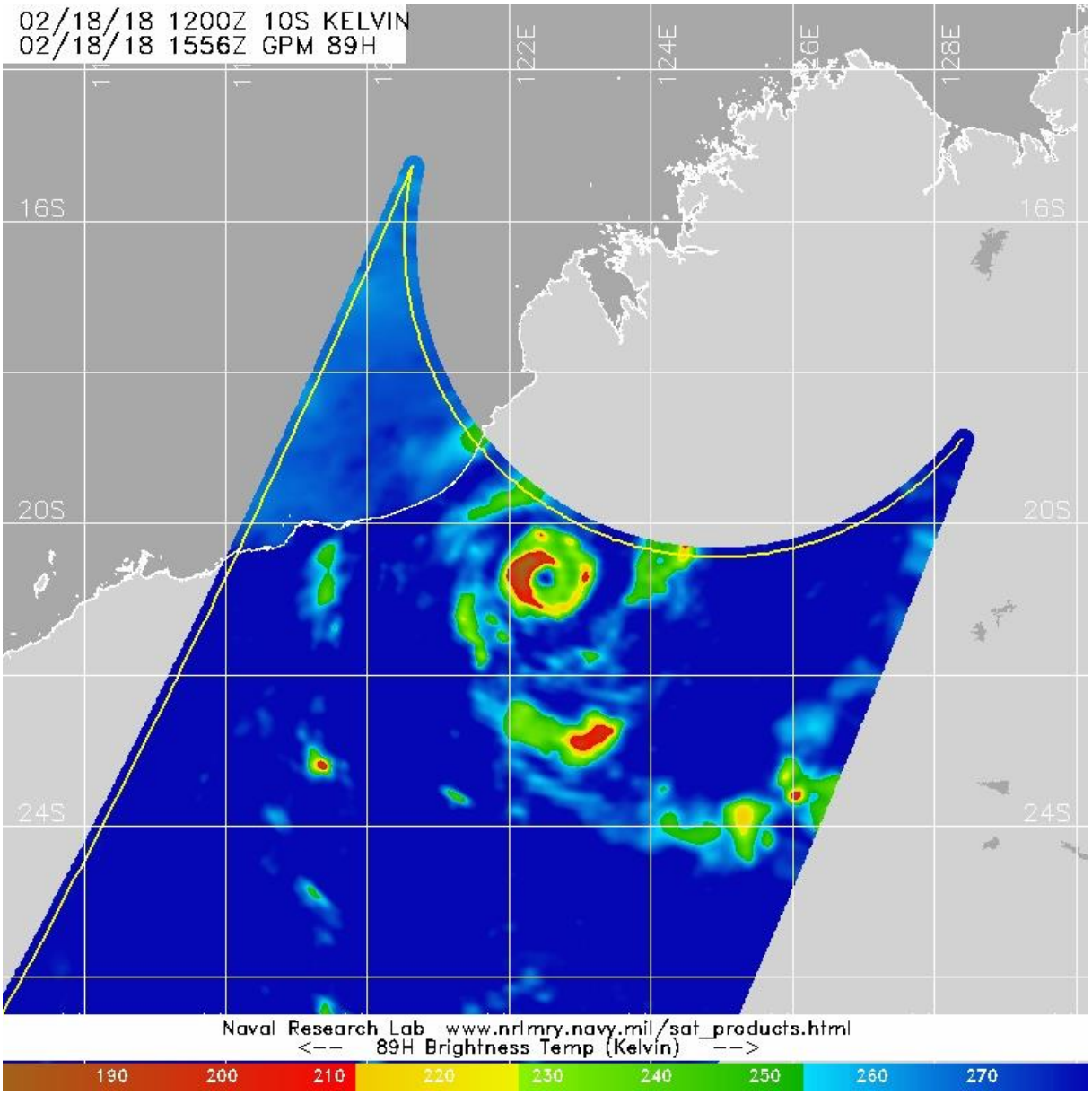


Figure 7. Plot of objective and subjective intensity estimates for *Kelvin*.

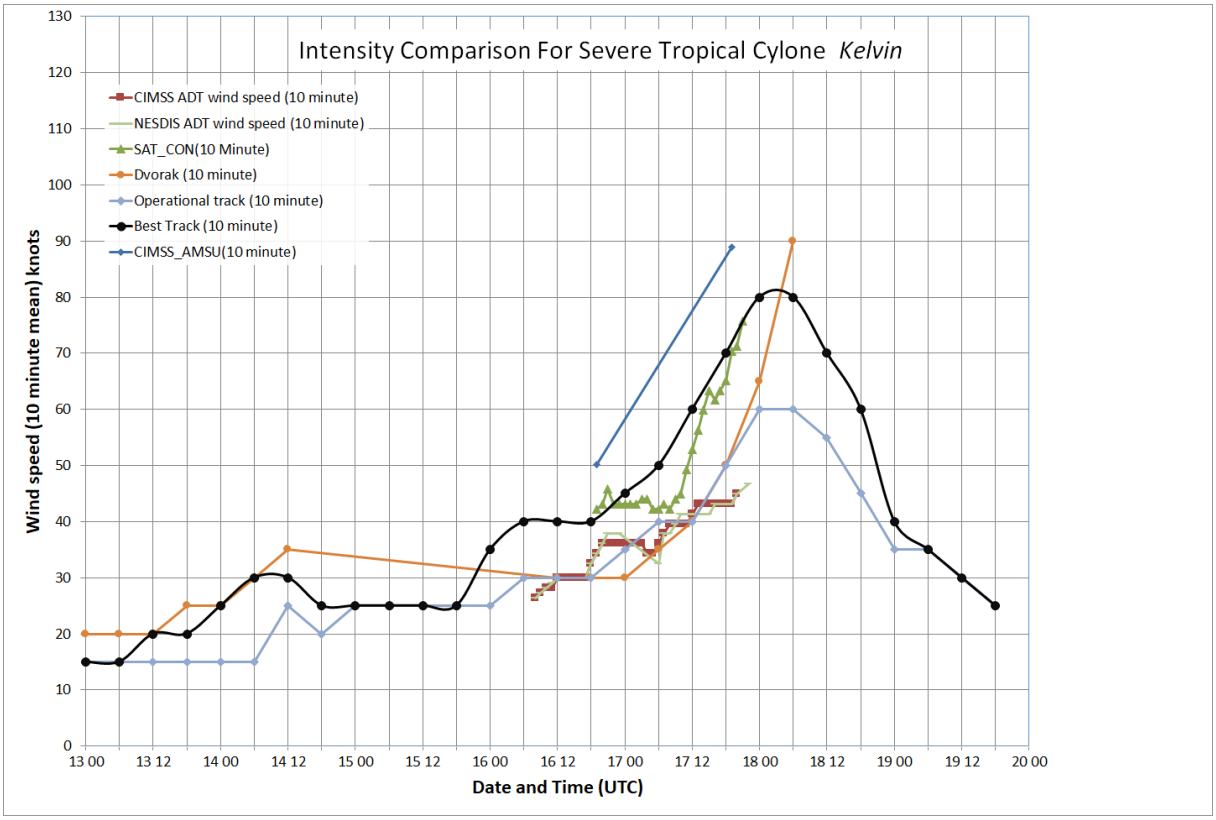


Figure 8. Accuracy figures for Severe Tropical Cyclone *Kelvin*