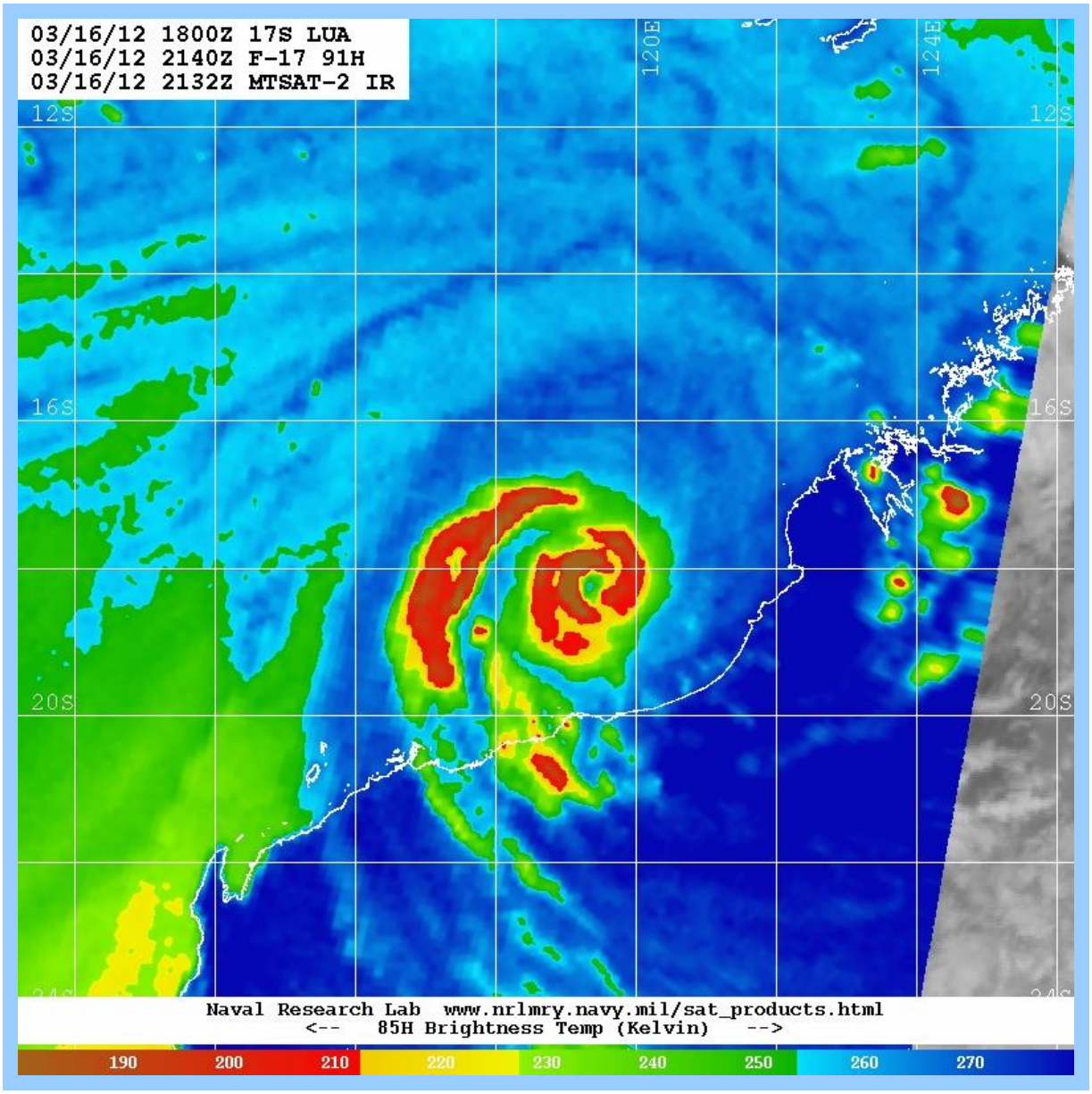
Australian Government
Bureau of Meteorology

Severe Tropical Cyclone *Lua*
10-18 March 2012

Perth Tropical Cyclone Warning Centre
Bureau of Meteorology



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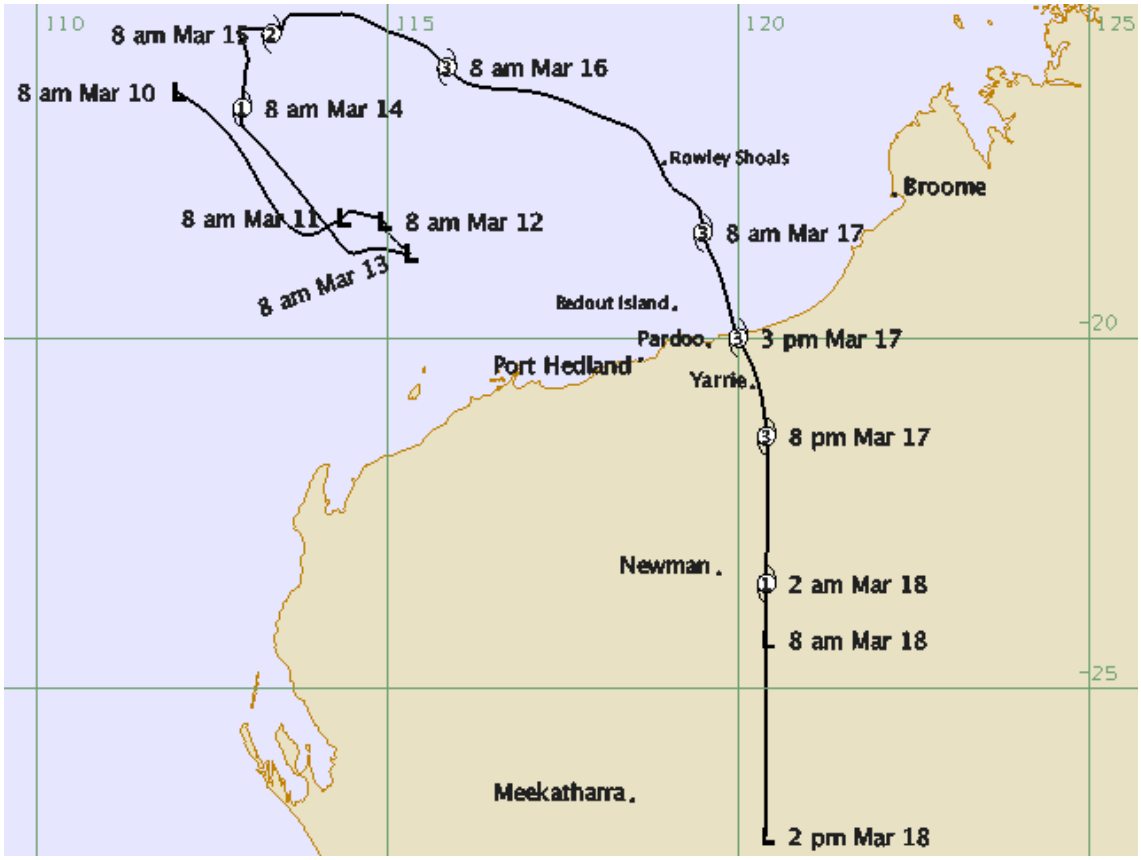
Summary

Severe Tropical Cyclone (STC) *Lua* formed off the northwest Australian coast on 14 March associated with a vigorous monsoon burst. *Lua* intensified to a category 3 cyclone late on 15 March, crossing the east Pilbara coast at the 80 Mile Beach near Pardoo Station around 0700 Coordinated Universal Time (UTC) (1500 WST=UTC+8 hours) 17 March. The cyclone weakened quickly as it moved inland and was downgraded to below cyclone strength on 18 March.

Lua reached a peak intensity of 85 knots (10-minute mean wind) at 1800 UTC 16 March and maintained this intensity as it crossed the Western Australian coastline to the east of Pardoo. *Lua* began to weaken quickly as it tracked south, directly over the Yarrie mine site. *Lua* decreased to below cyclone strength early on 18 March to the east of Meekatharra. Significant damage was reported from Pardoo Roadhouse and Yarrie with both sites reporting uprooted trees and damage to buildings. The cyclone caused moderate to major flooding of the De Grey river system in the east Pilbara, particularly in the vicinity of Tumbinna Pool and Nullagine.

Also during this time, the intense monsoon caused gale force northwesterly winds to extend a long way to the north and east of the cyclone, extending as far north as 10ºS. Numerous ship observations in that area reported 8 to 9 metre swells from the northwest during this period.

Figure 1. Best track of Severe TC *Lua* (10 – 18 March 2012).



Meteorological Description

Intensity analysis

Lua continued to intensify throughout 16 March. From 0930 UTC 16 March a Dvorak embedded centre pattern was applied to obtain a Dvorak Data T-number (DT) of 5.0. This method of obtaining DT is considered not as reliable as other pattern matches so final Dvorak T-number was biased towards pattern adjusted Model Expected T-number (MET), this constrained the Final T-number (FT) to 4.5 up until the cyclone crossed the coast. Other intensity estimates throughout this period were as low as 70 knots and as high as nearly 100 knots. Taking an average of all these estimates gave a peak intensity of 85 knots through the period 1800 UTC 16 March until 0600 UTC 17 March. Microwave satellite imagery suggests *Lua* may have been at its most intense late on 16 March, early on 17 March when deep, cold convection encircled the centre (refer Figure 3).

An active Madden-Julian Oscillation (MJO) moved across the Indian Ocean during March. Several transient lows within a monsoon trough were evident on satellite imagery during the early part of March. An Oceansat-2 Scatterometer (OSCAT) pass on 10 March showed an elongated troughwith a band of 20 to 50 knot north westerly winds to the northeast of the trough. Also evident was a band of 20 to 50 knot east north easterly winds to the north of the Pilbara coast, well removed from the trough and the circulation. The stronger winds are likely to be overestimates as they were rain affected (refer Figure. 2).

A weak circulation, most likely mid-level, in the infrared imagery (IR) became evident near 16.5^{o}S 112^{o}E on 10 March. No persistent curvature was evident until during 11 March and a T1.0-1.5 was assigned at 0000 UTC 12 March. Visible imagery (VIS) during 12 March showed a large extent of deep, cold convection with some curvature on the eastern side of the low centre. An 0411 UTC OSCAT pass on 12 March showed a circular system with rain affected gales well removed from the centre in the eastern quadrants.

An Advanced SCATterometer (ASCAT) pass at 0203 UTC 13 March showed 30 knot winds in the south eastern quadrant with much lighter winds in the northwest quadrant. A subsequent pass at 1433 UTC confirmed that 30 knot winds were present in the southern quadrants, but no gales were present.

By 0000 UTC 14 March IR imagery yielded a DT of 2.5/3.0 and VIS imagery a DT of 3.0. A 10-minute mean wind intensity of 35 knots was assigned at 00 UTC 14 March using all available objective and subjective guidance (refer Figure. 5). The Advanced Microwave Sounding Unit (AMSU) intensity estimates may have been biased towards higher values through 14 March as the tropical low showed evidence of being affected by shear. The VIS imagery from the morning of 14 March showed a well developed central dense overcast with several large curved bands on the western side. The low-level centre was located on the eastern edge of the Central Dense Overcast (CDO) and the tropical low appeared to be influenced by easterly shear. No ASCAT passes were available. OSCAT passes during the 14 March showed a well-developed circulation with gales in at least 3 quadrants.

The cyclone continued to intensify reaching 50 knot 10-minute mean wind by 1200 UTC 14 March. Overnight on 14 March IR imagery showed a sharp temperature gradient on the eastern side consistent with at least moderate easterly shear. Early on 15 March this sharp gradient relaxed and the cyclone appeared to become more symmetrical. Most subjective and objective intensity estimates were clustered around a 55 knot 10-minute mean wind at 0000 UTC 15 March. From about 0730 UTC through until 1730 UTC 15 March a weak eye pattern could be analysed with adjustment made due to an elongated eye. At 1800 UTC 15 March, an intensity of 65 knot mean wind was assigned.

Lua passed within 10 kilometres of Rowley Shoals Automatic Weather Station (AWS) around 1800 UTC 16 March. A peak 10-minute mean wind speed of 75 knots was recorded in the hourly synoptic observations though it is likely that the AWS failed to sample the maximum 10-minute wind. There was a break in the 10-minute METAR[1] data being transmitted from the AWS between 1800 UTC 16 March and 0400 UTC 17 March. A lowest pressure of 938.8 hPa was recorded in the synoptic observations. This did not fit well with the 954 hPa pressure obtained from the Courtney-Knaff-Zehr pressure wind relationship using a maximum wind of 85 knots and other synoptic parameters. At this time most subjective and objective intensity estimates were indicating the cyclone had a maximum 10-minute mean wind of between 70 and 90 knots with the exception of the CIMMS AMSU estimate. This gave a peak intensity of near 100 knots.

If the Courtney-Knaff-Zehr pressure wind relationship is applied in reverse, then a pressure of approximately 935 hPa near the centre implies a maximum 10-minute mean wind of 105 knots. It is certainly possible that the intensity was nearer 100 knots at this time and that the observed wind failed to sample the maximum wind. However, the best track intensity is obtained by taking an average of all reliable subjective and objective intensity estimates and at this time the average was about 85 knots (refer Figure 4.).

Lua weakened quickly after land fall and using the inland decay model the system decreased below 35 knots by 0000 UTC 18 March.

Motion

Initially *Lua* was steered to the south east by the well-established mid-level northwesterly flow to the north of the system. On 12 March a mid-level ridge to the southwest of *Lua* strengthened and the system drifted slowly to the northwest. This pattern influenced the steering through until 15 March. During 15 March a mid-level trough located from the Great Australian Bight through to the west coast of Australia continued to push north. This weakened the ridge and brought the cyclone back under a westerly steering regime. The system began to move to the east, then the southeast and finally directly south, gradually accelerating on 16 and 17 March as the mid-level trough amplified.

Structure

Lua's structure was heavily influenced by the surrounding strong and active monsoon the system formed in. Throughout the system's lifetime the gale radii in the northern quadrants were much larger than the southern quadrants and most ASCAT or OSCAT passes confirmed the presence of a large area of 35 to 50 knot north westerlies to the north of the system. These persisted for so long that 8 to 9 m swells were regularly reported from ships in the area during this period.

During 13 and 14 March CIMSS shear analyses showed 10 to 20 knots of easterly shear over *Lua*. This may have slowed down the development in the initial stages. During 15 March shear analyses showed shear decreased to 10 knots. *Lua* became reasonably symmetric and a ragged eye briefly formed. Shear remained between 10 and 20 knots from the northeast during 16 and 17 March as the system approached the coast and at times enhanced IR imagery displayed a sharp temperature gradient on the eastern side. Microwave satellite imagery suggested that the cyclone may have had some tilt with the low-level circulation located to the north or northeast of the upper level circulation as it approached the coast. The imagery also showed that there was cold, deep convection almost completely surrounding the eye.

Coastal observations also indicated that the southern gale radii contracted as land impacted on the structure but that the northern radii remained large, even after the centre had crossed the coast.

[1] A METAR is a standard observation report for aviation

Impact

STC *Lua* crossed the Pilbara coast about 45 kilometres (km) to the east northeast of Pardoo Roadhouse. Reports from Pardoo Station (further to the west than the Roadhouse) described the winds in the western eye wall as being stronger than the southern eye wall.

Lua then moved over the Yarrie minesite where a maximum gust of 100 knots was recorded by the instrument at the mine site.

Significant damage was reported from Pardoo Roadhouse and Yarrie with both sites reporting uprooted trees and damage to buildings. No storm surge reports were received after the event. The system also caused moderate to major flooding of the De Grey river system in the east Pilbara, particularly in the vicinity of Tumbinna Pool and Nullagine. Rainfall reports were not high, so it is possible that the heaviest rain fell away from gauge locations.

Observations

Wind

Rowley AWS 10-minute METAR data recorded a period of gale force winds from 1040 UTC 16 March through until 0910 17 March, however there was a large break in data from 1800 UTC 16 March to 0400 UTC 17 March.

Rowley AWS hourly synoptic data recorded a period of gale force winds from 1100 UTC 16 March through until 100 17 March, storm force winds from 1500 UTC 16 March until 0300 UTC 17 March and hurricane force between 1700 UTC and 2100 UTC 16 March. (Refer Table 2.)

Bedout AWS hourly synoptic observations recorded a period of gale force winds from 2000 UTC 15 March through until 2100 UTC 17 March and storm force winds from 0600 UTC until 0800 UTC 17 March.

Pressure

Rowley 10-minute METAR data recorded a minimum pressure of 939.3 hPa at 1800 16 March, however there was a large break in data from 1800 UTC 16 March to 0400 UTC 17 March.

Rowley AWS hourly synoptic data recorded a minimum pressure of 938.8 hPa at 1700 UTC 16 March.

Bedout AWS hourly synoptic observations recorded a minimum pressure of 976.8 hPa at 0500 UTC 17 March.

Rainfall

Yarrie recorded 73 mm of rainfall until 9 am WST 18 March.

Tumbinna Pool recorded 59.8 mm of rainfall until 9 am WST 18 March.

Forecast Performance

The first Tropical Cyclone Advice for Severe TC *Lua* was issued at 9 am 14 March for the coastal area between Mardie and Cape Leveque. At 3 pm WST 15 March a warning was declared for the coastal area between from Bidyadanga to Mardie, including Port Hedland, Karratha and Dampier. At 3 am 16 March this area was extended north to include Cape Leveque. This area was contracted slightly to Dampier and extended inland as the cyclone approached the coast. From midday 17 March advices were issued hourly until 9 pm WST. The last Tropical Cyclone Advice was issued at midday 18 March when the system was downgraded to below cyclone strength.

Table 1. Best track summary for Severe Tropical Cyclone *Lua*.

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)	Radius Max. Wind (RMW)
2012	3	10	00	16.5	112.0	60	20	45	999			
2012	3	10	06	17.5	113.0	60	20	45	1000			
2012	3	10	12	18.5	114.0	60	20	45	1000			
2012	3	10	18	18.4	114.2	60	20	45	1000			
2012	3	11	00	18.3	114.3	60	25	45	1001			
2012	3	11	06	18.2	114.5	60	25	45	1001			
2012	3	11	12	18.2	114.7	60	25	45	1001			
2012	3	11	18	18.3	114.8	60	25	45	998			
2012	3	12	00	18.3	114.9	60	25	45	996			
2012	3	12	06	18.4	115.0	60	25	45	996			
2012	3	12	12	18.5	115.0	60	25	45	996			
2012	3	12	18	15.6	115.1	60	25	45	996			
2012	3	13	00	18.8	115.3	30	30	45	996			
2012	3	13	06	18.7	114.8	20	30	45	996			
2012	3	13	12	18.2	114.0	15	30	45	996			
2012	3	13	18	17.3	113.3	20	30	45	996			
2012	3	14	00	16.7	112.9	20	35	50	993	150/90/ 90/150		20
2012	3	14	06	16.1	113.0	20	45	65	985	150/90/ 90/150		20
2012	3	14	12	15.6	112.9	20	50	70	980	180/90/ 90/180	40	20
2012	3	14	18	15.6	113.1	25	55	75	975	180/90/	40	20

										90/180		
2012	3	15	00	15.7	113.3	30	55	75	970	200/90/ 90/200	40	25
2012	3	15	06	15.5	113.5	30	55	75	965	200/90/ 90/200	40	25
2012	3	15	12	15.4	113.8	30	60	85	960	200/90/ 60/200	40	25
2012	3	15	18	15.6	114.9	20	65	90	955	200/90/ 60/200	60	20
2012	3	16	00	16.1	115.8	15	65	90	950	280/90/ 80/200	90/40/ 40/90	15
2012	3	16	06	16.5	116.9	20	70	100	945	280/90/ 180/200	90/40/ 40/90	12
2012	3	16	12	16.8	118.0	20	75	105	940	280/90/ 200/200	70/40/ 40/70	10
2012	3	16	18	17.6	118.9	10	85	120	935	280/90/ 200/200	70/40/ 40/70	12
2012	3	17	00	18.5	119.5	15	85	120	935	280/90/ 200/200	70/40/ 60/85	10
2012	3	17	06	19.7	119.9	15	85	120	935	280/70/ 100/200	60/30/ 50/60	10
2012	3	17	*07	20.0	120.0	10	85	120	935			
2012	3	17	12	21.4	120.4	15	70	100	964	250/45/ 70/200	60/30/ 50/60	20
2012	3	17	18	23.5	120.4	30	45	65	980	250/40/ 100/270		30
2012	3	18	00	24.3	120.4	45	30	45	989			
2012	3	18	06	27.1	120.4	60	25	45	995			

*Position added for time of coastal crossing.

Table 2. Hourly synoptic surface observations for Rowley Shoals.

The period of gale force winds are highlighted.

Date	Time UTC	Wnd dir	Wnd spd kn	Temp C	MSL Pressure hPa
20120316	0000	10	22	26.8	995.2
20120316	0100	10	18	28.5	994.8
20120316	0200	360	20	27.3	994.1
20120316	0300	10	15	26.7	993.6
20120316	0400	360	19	27.4	992.1
20120316	0500	10	25	29.4	989.8
20120316	0600	10	28	29.2	988.3
20120316	0700	10	29	28.7	987.2
20120316	0800	20	28	28.1	986.3
20120316	0900	20	30	28.9	984.9
20120316	1000	30	32	28.7	984.3
20120316	1100	30	34	28.3	982.7
20120316	1200	30	38	28.5	981.1
20120316	1300	50	39	27.7	979.1
20120316	1400	50	41	27.4	976.4
20120316	1500	60	50	27.3	970.4
20120316	1600	60	59	26.8	959.8
20120316	1700	10	73	27.2	938.8
20120316	1800	330	46	28.6	940.4
20120316	1900	290	75	26.8	950.1
20120316	2000	280	69	26.9	960.9
20120316	2100	270	59	26.8	970.2
20120316	2200	270	50	26.4	976.4
20120316	2300	270	58	25.2	980.2
20120317	0000	260	51	25	982.8

20120317	0100	240	59	24.8	981.9
20120317	0200	260	48	25.1	986.5
20120317	0300	270	46	24.6	989.1
20120317	0400	260	45	25.7	988.8
20120317	0500	260	41	26.3	989.8
20120317	0600	270	38	27.4	990.9
20120317	0700	270	38	27.6	991.6
20120317	0800	270	34	27.8	992.8
20120317	0900	270	34	27.8	993.8
20120317	1000	280	31	28	994.9
20120317	1100	280	31	28.1	996
20120317	1200	280	31	28.2	997.3

Figure 2. OSCAT pass 1627 UTC 10 March 2012.

(image courtesy of NOAA US NOAA http://manati.orbit.nesdis.noaa.gov/datasets/OSCATData.php/))

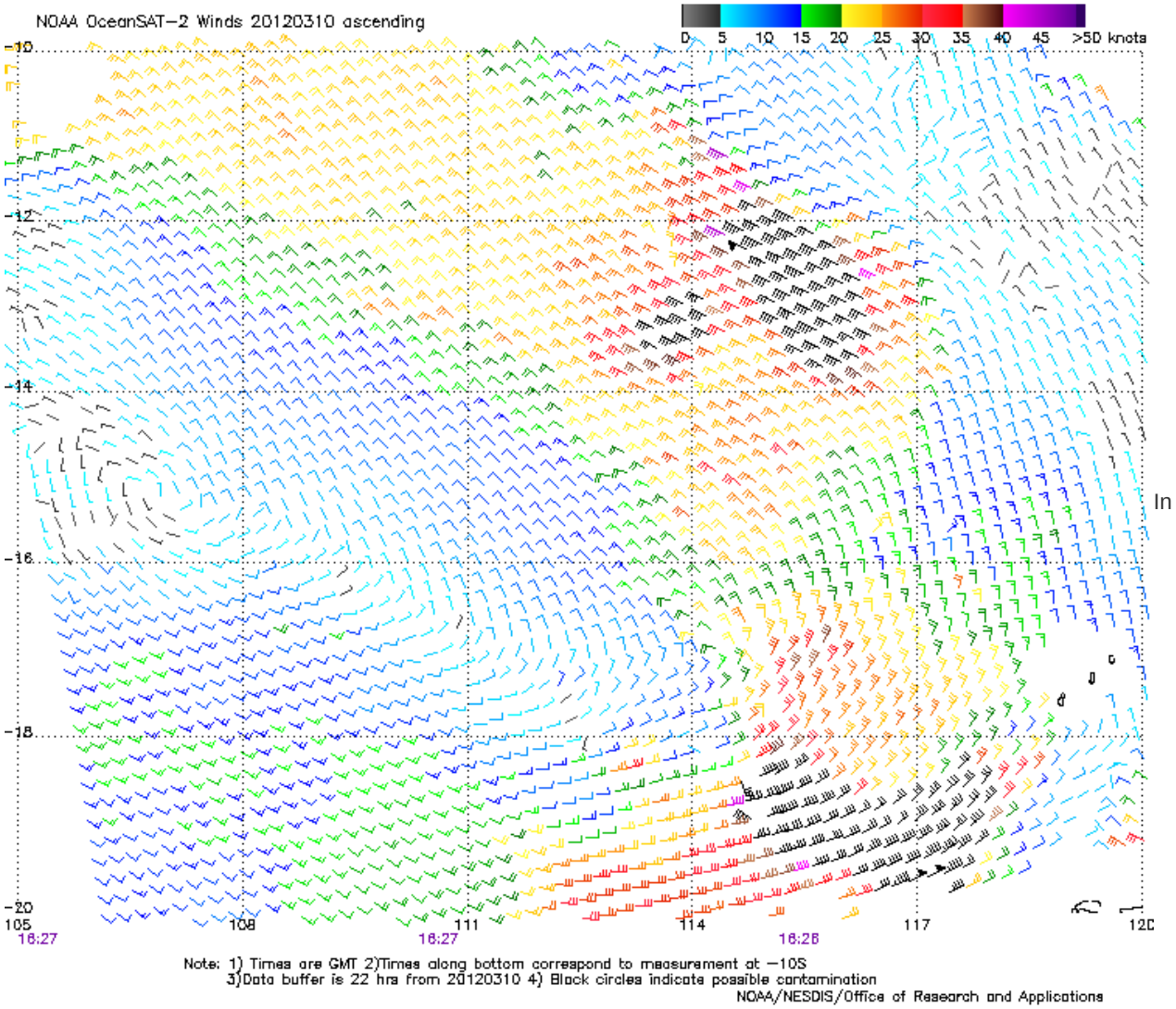


Figure 3. 91 GHz microwave image 2140 UTC 16 March 2012.

(image courtesy of NOAA NRL: http://www.nrlmry.navy.mil/))

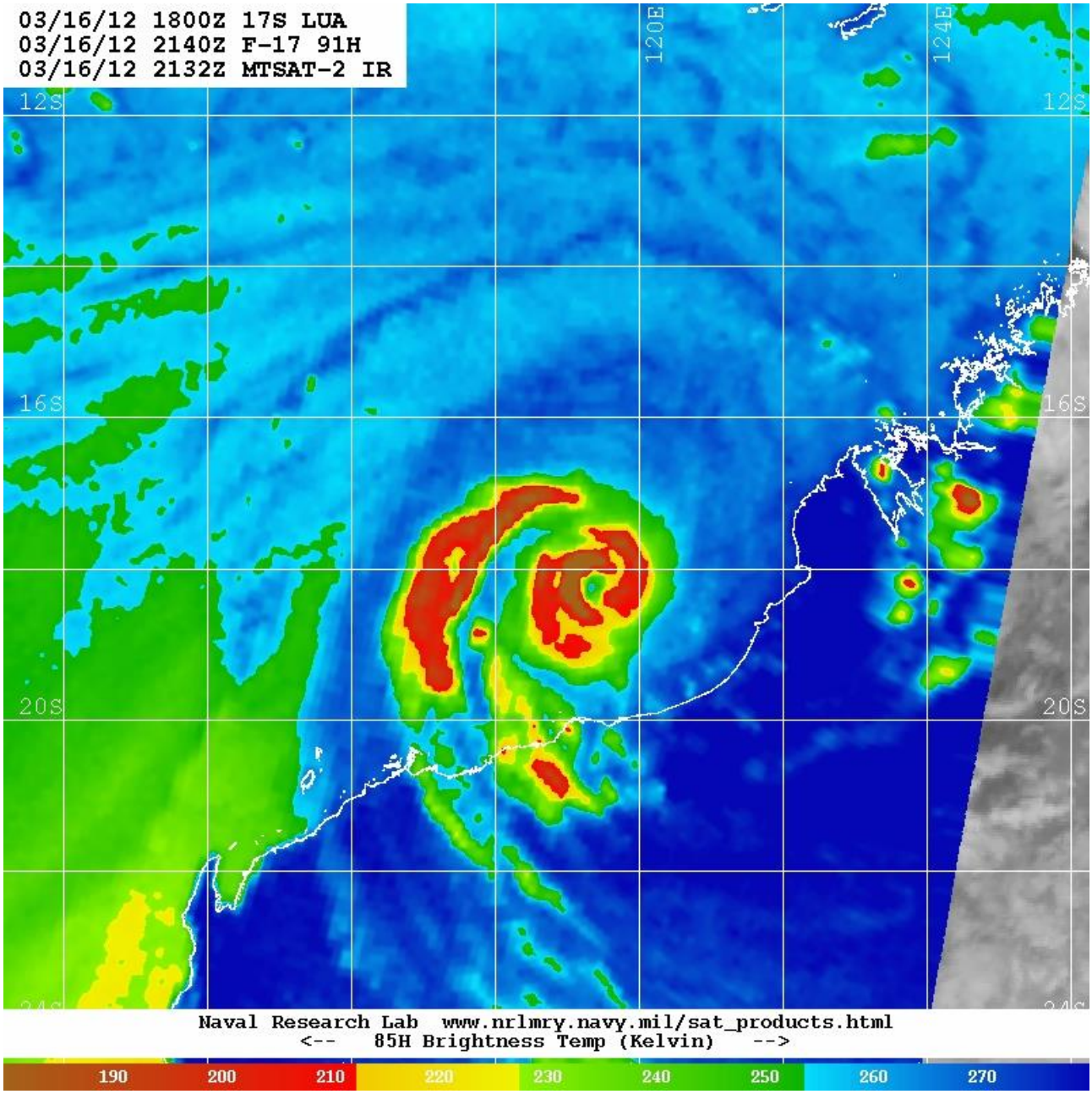


Figure 5. Comparison of objective and subjective intensity analysis techniques.