Australian Government
Bureau of Meteorology

Severe Tropical Cyclone *Laurence*

8 – 23 December 2009

Linda Paterson
Perth Tropical Cyclone Warning Centre
Bureau of Meteorology
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A. Summary

A tropical low formed in the monsoon trough in the Arafura Sea on 8 December and moved west. On 12 December the system passed very close to Darwin and although it had not reached tropical cyclone strength, it produced a brief period of gales, heavy rainfall and some minor tree damage in Darwin suburbs. The low continued to track west, moving into the Joseph Bonaparte Gulf during 13 December and reached tropical cyclone strength by 0800 WST 14 December. As *Laurence* intensified rapidly into a small but intense system, it passed over Troughton Island which recorded a wind gust to 187 km/h (101 kn) and a lowest pressure of 982 hPa. The cyclone moved in a south westerly direction, parallel to the Kimberley coast. Despite its proximity to the coast the system reached category 5 strength with a very small radius to gales of 40 km (20 nm) and radius to maximum wind (RMW) of 10 km (5 nm). It eventually crossed the Kimberley coast at Collier Bay, east of Koolan Island on 16 December.

As *Laurence* moved inland the system produced some heavy rainfall even as it rapidly weakened. The remains of the system moved initially south, and then west. A well defined circulation was maintained and once the system moved off the Dampier Peninsular (Kimberley coast) at 0800 WST 19 December it quickly reformed into a tropical cyclone. The system moved initially south west and then turned south southeast while intensifying rapidly. During this period *Laurence* had a radius to gales of approximately 90-110 km (50-60 nm) - much closer to the climatological average - and a radius to maximum winds of 15-20 km (8-10 nm). *Laurence* again reached category 5 strength at 1400 WST 21 December, just prior to crossing the coast around 1700 WST near Wallal, along the 80 Mile Beach, 230 km north east of Port Hedland. There was considerable damage to properties in the area and an estimated 1500 cattle perished. Mandora recorded a wind gust to 211 km/h (114 kn) and a lowest pressure of 929 hPa. Once *Laurence* moved inland the system steadily weakened and was below cyclone strength by 2000 WST 22 December. Heavy rain fell in the eastern parts of the De Grey river catchment causing minor flooding, road closures but no major damage to infrastructure.

B. Meteorological Description

Intensity analysis

Dvorak analyses showed that over the first 4 to 5 days the system fluctuated in intensity, but remained below tropical cyclone intensity. The system gained some degree of organisation as it passed close to Darwin on early on 12 December and microwave imagery showed a tight, curved band of convection which produced a period of gales at Darwin Airport (refer Fig. 2). However imagery showed only some 2 to 3 hours later the band had dissipated and the system weakened again.

The developing system moved into the Joseph Bonaparte Gulf during 13 December and by 14 December reached cyclone strength. During the 14 and 15 December *Laurence* intensified steadily and crossed into the Perth AOR as a category 4 cyclone. Microwave imagery showed a very small but intense system. At this time the radius to gales was estimated to be 55 km with a RMW of 10 km. *Laurence* was located only 30 kilometres offshore and it is probable the system was only able to continue to intensify because of its small size.

Laurence reached peak intensity of Category 5 at 0500 WST 16 December but began to weaken almost immediately (refer Fig. 3). The radius to gales of *Laurence* had decreased to 40 kilometres and as the eye wall of the now tiny system passed over some offshore islands at about 0630 WST 16 December convection immediately began to decrease. Infrared imagery (IR) showed the eye disappeared a few hours later.

CIMSS and CIRA AMSU intensity estimates and Advanced Dvorak Techniques (ADT) compared favourably with subjective Dvorak intensity estimates during the period 13 to16 December, in the lead up to the first coastal crossing.

The system moved inland east of Koolan Island about 2200 WST 16 December as a category 3 system and weakened below cyclone strength at 0800 WST 17 December. During 17 and 18 December the remaining low maintained some convection near the centre. Microwave passes showed the system had redeveloped a well defined circulation which then moved west off the Dampier Peninsular at about 0800 WST 19 December. As soon as the system moved over water a DT of 3.0 could be assigned and the system re-intensified into a tropical cyclone. The subsequent visible imagery showed a spiral band of a 0.6 to 0.8 wrap and by 1400 WST the system could be upgraded to a category 2 with a DT 3.5.

During 19 and 20 December microwave and radar imagery suggests that the system was in the process of reorganising under a light to moderate northeast shear. The system appeared to form a partial eye wall ('C' shaped with the strongest intensity on the southwest side) that occasionally appeared to consolidate towards a tighter coherent eye only to then weaken to a more ragged open eye. By 2000 WST 20 December an eye appeared on IR imagery. A raw DT of 7.0 was reached twice during the period 0800 WST to 1400 WST 21 December, and *Laurence* was at peak intensity (refer Fig. 4) as it crossed the coast at about 5pm WST 21 December.

Examination of the radar imagery showed that as *Laurence* crossed the coast, between1600 WST and 1800 WST 21 December (refer Fig. 5), the eye passed just to the west of Mandora and the eastern eye wall passed directly over Mandora. The Automatic Weather Station (AWS) at Mandora recorded a minimum pressure of 929 hPa at 1710 WST 22 December and a maximum wind gust of 211 km/h (114 kn) at 1810 WST 21 December (refer Fig. 6 and 7). Since the eye did not pass directly over the Mandora AWS the minimum pressure of Laurence could be estimated at 925 hPa. The minimum pressure of 929 hPa obtained from the Dvorak T number via the Courtney-Knaff relationship is in very good agreement with observations.

However the estimated maximum wind speed derived from the Dvorak T number is significantly higher than that measured at the Mandora AWS. *Laurence* was analysed as a category 5 system as it crossed Mandora with wind gusts forecast to be 285 km/h. Despite careful re-analysis of the available data, there is no obvious explanation why this discrepancy exists.

The anemometer on the Mandora AWS was damaged during the passage of the cyclone. This occurred when the wind vane, which indicates wind direction, sheared off. However in terms of wind speed, subsequent testing of the wind head proved the equipment to still be functioning reliably. The timing of the sudden wind change as the vane sheared off indicates the damage took place at about 2000WST, well after the passage of the eye past Mandora. Therefore, damage to the anemometer does not appear to explain the discrepancy.

Subjective Dvorak analyses and objective intensity assessment techniques such as ADT and AMSU estimates from both CIRA and CIMSS were in good agreement throughout the lead up to the coastal crossing. All methods showed an intensifying trend and confirmed the subjective raw DT numbers of between 6.0 and 7.0 with a CI of 6.5 at impact.

Once the system moved inland *Laurence* weakened quickly, decreasing to below cyclone strength by 2000 WST 22 December. The weak remains of the system continued to move east into central Australia.

Motion

Initially *Laurence* was steered in a generally westerly direction by the mid-level ridge. During 16 December an approaching mid-level trough to the west of the system helped to erode the cradling ridge. *Laurence* then moved in a southerly direction ahead of the easterly moving trough, crossing the Kimberley coast. During 17 December steering flow appeared to be weak and the system was stationary. During this phase it is likely the system was steered more by the low to mid-level flow. A strong high pressure system moved into the Bight during 18 December and the remains of Laurence was moved in a westerly direction.

Once over water on 19 December *Laurence* moved initially southwest around a mid-level ridge. An approaching mid-level trough weakened the ridge and *Laurence* was steered in a south easterly direction on the 21 December. *Laurence* crossed the Pilbara coast and continued to be steered in a south easterly direction as it weakened inland.

Structure

Despite being in a low shear environment, imagery revealed an exposed low level cloud centre with convection only forming on the eastern side during the 13 December. Convection rapidly increased and by 15 December the system was symmetrical with an eye appearing on microwave imagery. *Laurence* was however a midget system. In its early stages the radius to gales was a more average figure of about 130 km but as the system intensified and got closer to the Western Australian coastline the radius to gales decreased. By 8am WST 15 December the system had a gale radius of 75 km (40 nm), storm radius of 40 km (20 nm), hurricane radius of 30 km (15nm) and a RMW of 18 km (10nm). At its smallest (refer Fig. 2) the radius to gales decreased to 40 km (20 nm) and the RMW to just 9 km (5 nm) with an eye diameter of just 15 km (8 nm).

As the system moved off the Kimberley coast and re-intensified it was under light north westerly shear. Initially the system struggled to maintain convection in the north east quadrant but as the system intensified it became symmetric.

During *Laurence*'s second period of intensification the radius to gales was closer to the long term average of 165 km (90 nm). At its largest *Laurence* had a radius to gales of 130 km (70 nm) and a RMW of 20 km (10 nm). This RMW is defined as very small by JTWC (Operational Techniques in Defining TC Structure, Mark Lander, Sixth International Workshop on TC's). At peak intensity (refer Fig. 3) the radius to gales had decreased to 65 km (35 nm) and a RMW of 20 km (10 nm) with an eye diameter of 20 km (12 nm).

C. Impact

Despite not yet reaching tropical cyclone strength as the system passed very close to Darwin on 12 December, it produced gales, heavy rainfall and some minor tree damage.

Laurence crossed the Kimberley coast in a remote location. There was some structural damage reported from Kuri Bay with many trees down. Windows were blown in at an office at Cockatoo Island and a storeroom was damaged at Koolan Island. Heavy rain fell in inlands parts as the low weakened inland.

Laurence crossed the Pilbara coast between Wallal and Mandora, east of Port Hedland (refer Fig. 8 and 9). Considerable damage was reported from properties in the area and an estimated 1500 cattle perished. Heavy rain in eastern parts of the De Grey River catchment caused minor flooding and road closures.

D. Observations

Pressure

The eye of *Laurence* passed over Troughton Island at 0915 WST15 when a minimum pressure of 982 hPa was recorded.

The eastern eye wall of *Laurence* passed over Mandora when a minimum pressure of 929 hPa was recorded at 1710 WST 22 December.

Winds

The eye of Severe TC *Laurence* passed over Troughton Island at 0915 WST15 December. The maximum mean wind of 120 km/h (65 kn) with a peak gust of 185 km/h (101 kn) was recorded at 0755 WST in the south west eye wall as the system approached from the north east.

Troughton Island recorded sustained gales from 0445 WST until 1125 WST 19 December, a period of 5 ¾ hours. Storm force winds were recorded for a period of 3 ½ hours from 0655 WST until 1035 WST 19 December. Hurricane force winds were only recorded at 0915 WST.

The eastern eye wall passed over Mandora where a wind gust of 211 km/h (114 kn) was recorded at 1810 WST 21 December as *Laurence* crossed the Pilbara coast. Mandora recorded sustained gales from 1350 WST 21 December until 0200 WST 22 December, a period of 11 hours. Storm force winds were recorded from 1500 WST until 2130, a period of 6 ½ hours. Hurricane force winds were recorded from 1600 WST until 2000 WST, a period of 4 hours.

Rainfall

Heavy rainfall was recorded in the Kimberley as *Laurence* crossed the coast east of Koolan Island.

Station	To 9am 17/12/2009	To 9am 18/12/2009	To 9am 19/12/2009
Kimberley Downs	99	310.6	162.4
Napier Downs	61	402	92

Laurence also produced some heavy falls as it crossed the Pilbara coast.

Station	To 9am 21/12/2009	To 9am 22/12/2009
Mandora	107	172
Warrawagine	8	244.5

E. Forecast Performance

The model guidance during the lifetime of *Laurence* was very good. The EC model performed exceptionally well and official forecast output was heavily biased to this model. The GFS model performed better than both the TCLAPS and the UK models which had large errors at time steps greater than 36 hours.

The stretch of coastline between Kuri Bay and Cockatoo Island where *Laurence* crossed the Kimberley coast on 16 December was placed on Watch at 1230 WST Sunday 13 December. The Warning area was extended to include Kuri Bay to Cockatoo Island at 0200 WST 15 December. *Laurence* crossed this part of the coastline at about 2200 WST 16 December.

The stretch of coast between Port Hedland and Broome where *Laurence* crossed the Pilbara coast late on 21 December was placed on Watch/Warning immediately Advice messages were recommenced on Friday 18 December. The Warning extended down to Wallal with a Watch to Port Hedland. The Warning was extended to Pardoo by 2100 WST 19 December and to Port Hedland by 1200 WST 20 December.

Table 1. Best track summary for Severe TC *Laurence,* December 2009.
Refer to the Australian Tropical Cyclone database for complete listing of parameters.

Year	Month	Day	Hour (UTC)	Position Latitude S	Position Longitude E	Position Accuracy nm	Max wind 10min knots	Max gust knots	Central Pressure hPa	Rad. of Gales nm	Rad. of storm force winds	Radius Max. Wind (RMW)
2009	12	15	06	14.3	125.4	20	90	125	958	30	20	10
2009	12	15	12	14.6	124.9	15	95	135	949	30	20	10
2009	12	15	18	15.1	124.5	15	100	140	945	30	15	10
2009	12	15	21	15.2	124.4	20	110	155	933	25	15	10
2009	12	16	00	15.3	124.2	20	110	155	932	20	15	10
2009	12	16	06	15.9	124.0	20	95	135	950	25	14	10
2009	12	16	12	16.1	124.0	20	80	115	961	25	15	10
2009	12	16	18	16.5	124.2	20	55	80	982	25	10	
2009	12	17	00	16.9	124.3	25	40	55	992	40		
2009	12	17	06	16.9	124.3	25	30	45	995			
2009	12	17	12	16.9	124.3	25	20	45	1000			
2009	12	17	18	16.9	124.3	25	15	40	1002			
2009	12	18	00	17.0	124.2	25	15	40	1003			
2009	12	18	06	17.2	123.9	20	20	45	1003			
2009	12	18	12	17.1	123.4	20	25	45	1001			
2009	12	18	18	16.7	122.7	20	30	45	999			
2009	12	19	00	16.6	122.6	15	35	50	995	39		
2009	12	19	06	16.9	122.2	10	50	70	985	35	13	
2009	12	19	12	17.2	121.8	10	50	70	987	35	13	
2009	12	19	18	17.5	121.3	10	55	80	984	42	22	
2009	12	20	00	17.8	120.9	15	60	85	980	52	25	
2009	12	20	06	18.3	120.6	15	70	100	966	52	26	15
2009	12	20	12	18.5	120.4	15	85	120	951	58	26	15
2009	12	20	18	18.7	120.4	10	100	140	938	50	30	20
2009	12	21	00	19.0	120.5	10	105	150	934	45	30	20
2009	12	21	06	19.4	120.6	10	110	155	929	35	22	18
2009	12	21	12	20.0	120.8	10	80	115	956	40	24	18
2009	12	21	18	20.5	121.0	15	55	80	976	49	20	
2009	12	22	00	21.1	121.2	30	40	55	986	40		
2009	12	22	06	21.9	121.7	30	35	50	987	40		
2009	12	22	12	22.6	122.8	35	30	45	991			
2009	12	22	18	23.4	123.8	50	30	45	995			
2009	12	23	00	24.5	125.2	60	25	45	998			
2009	12	23	06	25.3	126.9	60	20	45	1001			

Figure 1. Best track of Severe TC *Laurence* 8 – 23 December 2009.

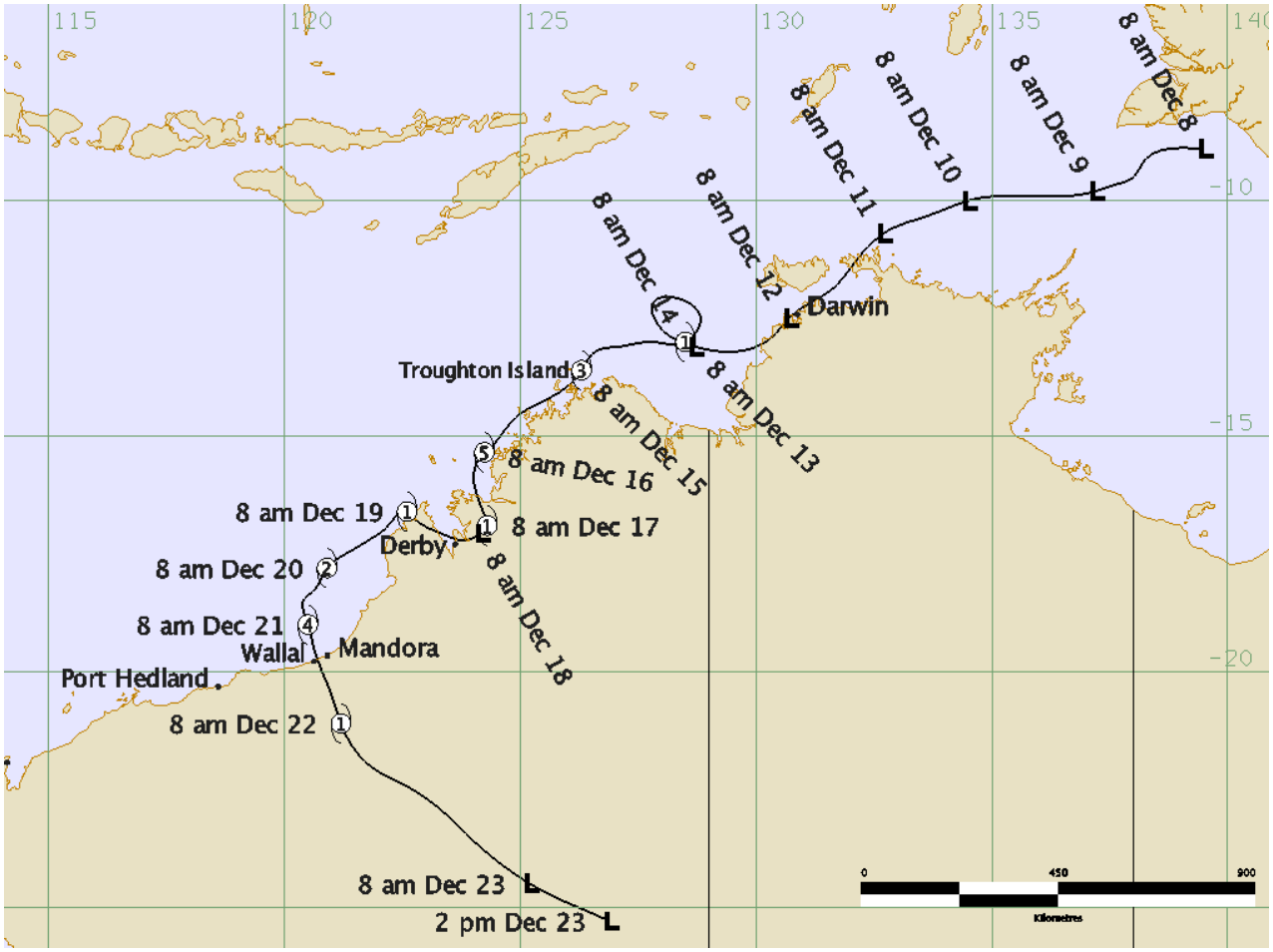

Figure 2. Microwave (TC SSMIS 91GHz) image at 0630 WST 11 December (2228 UTC 11 December).
(image courtesy of US NRL: http://www.nrlmry.navy.mil/)

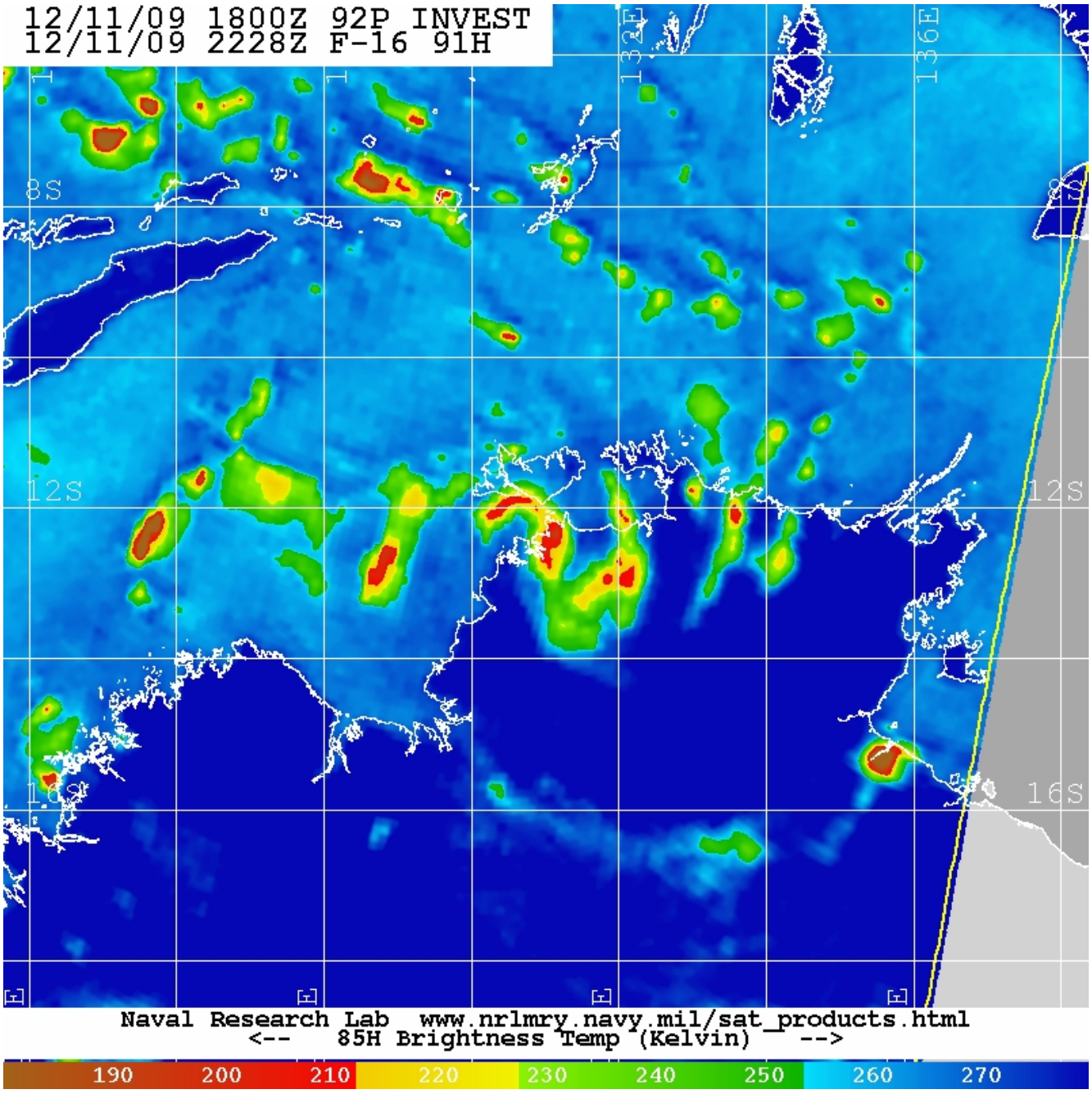

Figure 3. Microwave (TMI 85GHz) image at 0630 WST 16 December (2232 UTC 15 December).
(image courtesy of US NRL: http://www.nrlmry.navy.mil/)

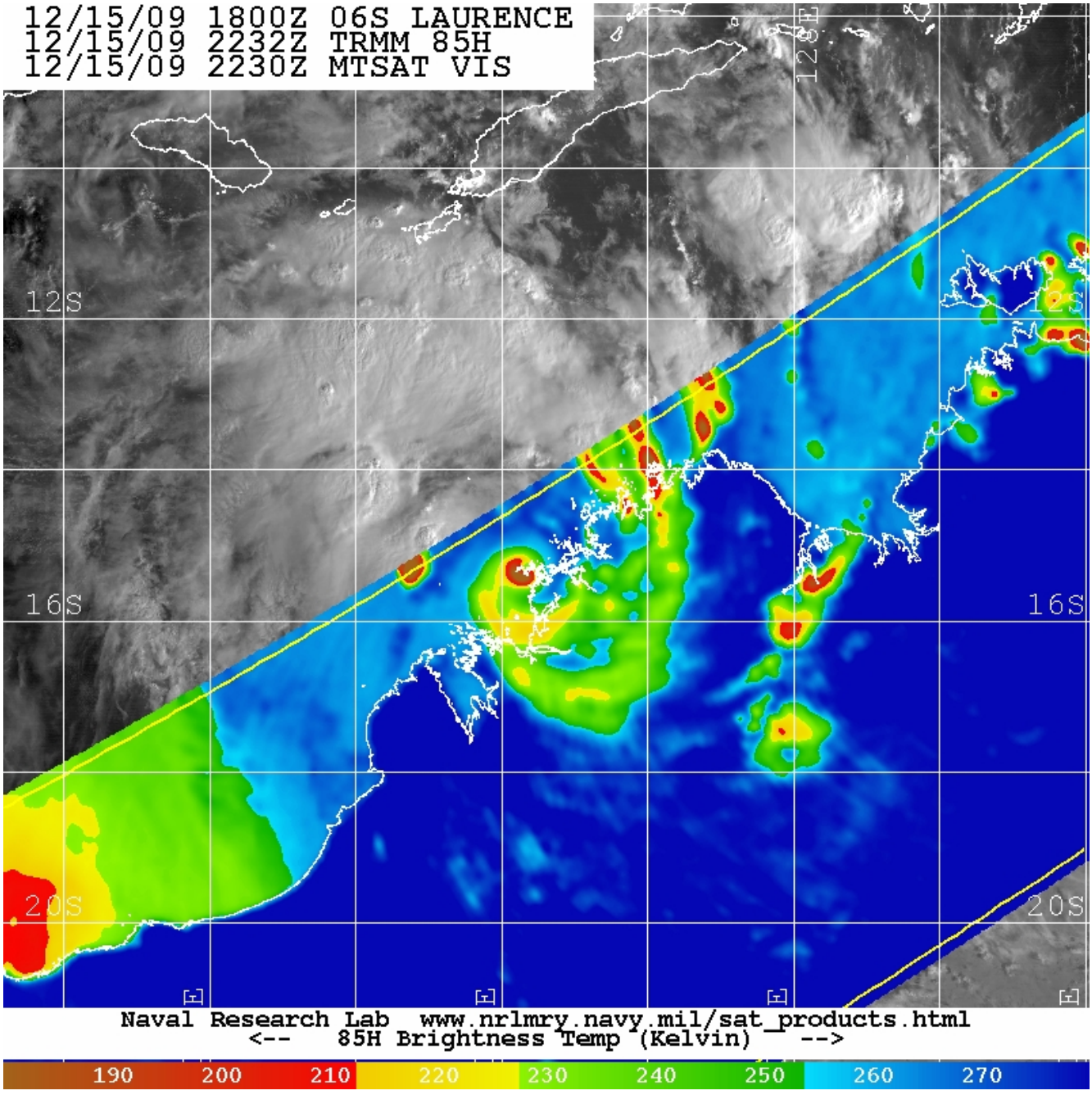

Figure 4. Microwave (AMSRE 89GHz) image at 1400 WST 21 December (0601 UTC 21 December).
(image courtesy of US NRL: http://www.nrlmry.navy.mil/)

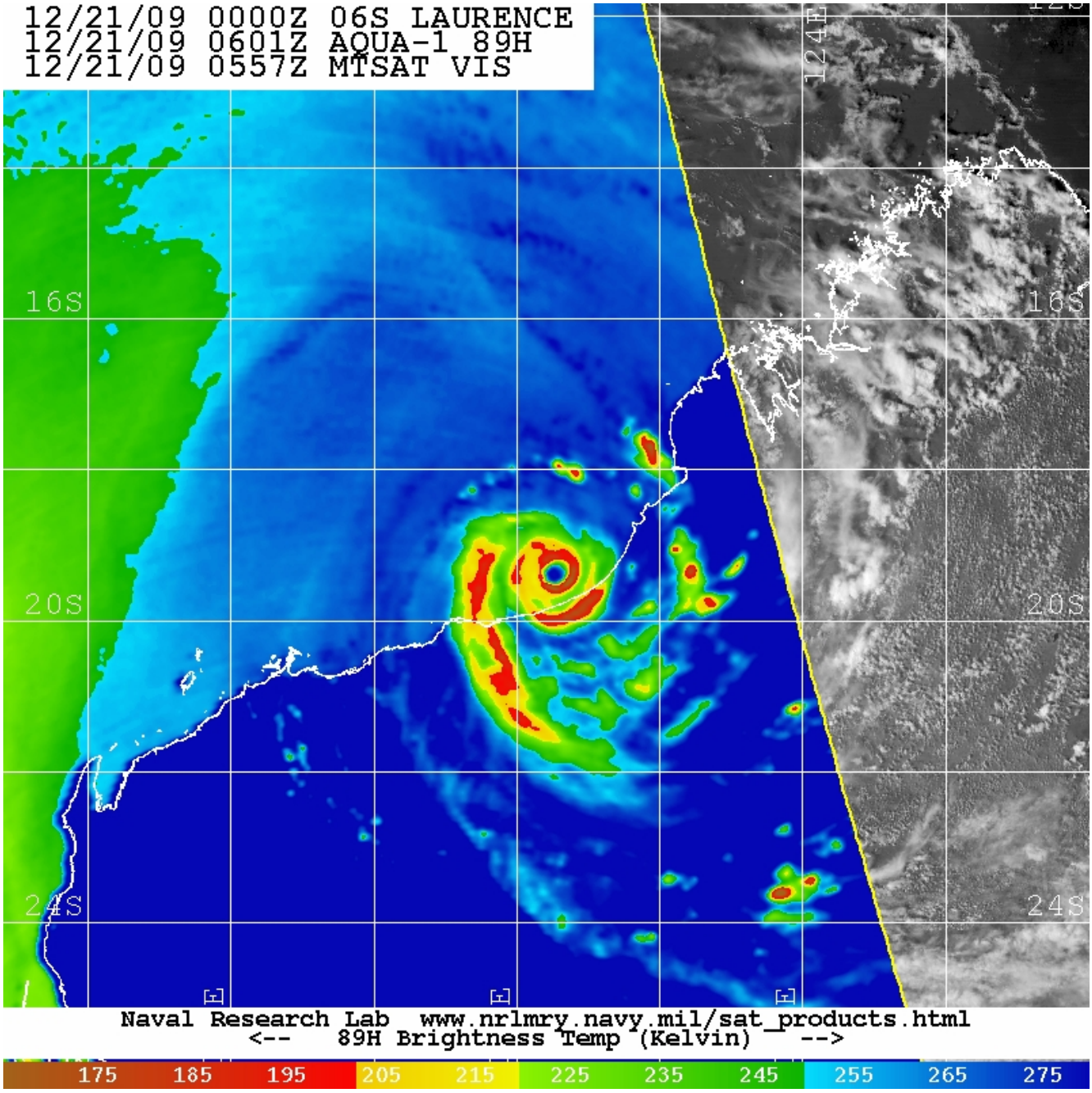

Figure 5. Image from Port Hedland radar of Severe TC *Laurence* at time of peak wind gust recorded at Mandora at 1810 WST 22 December.

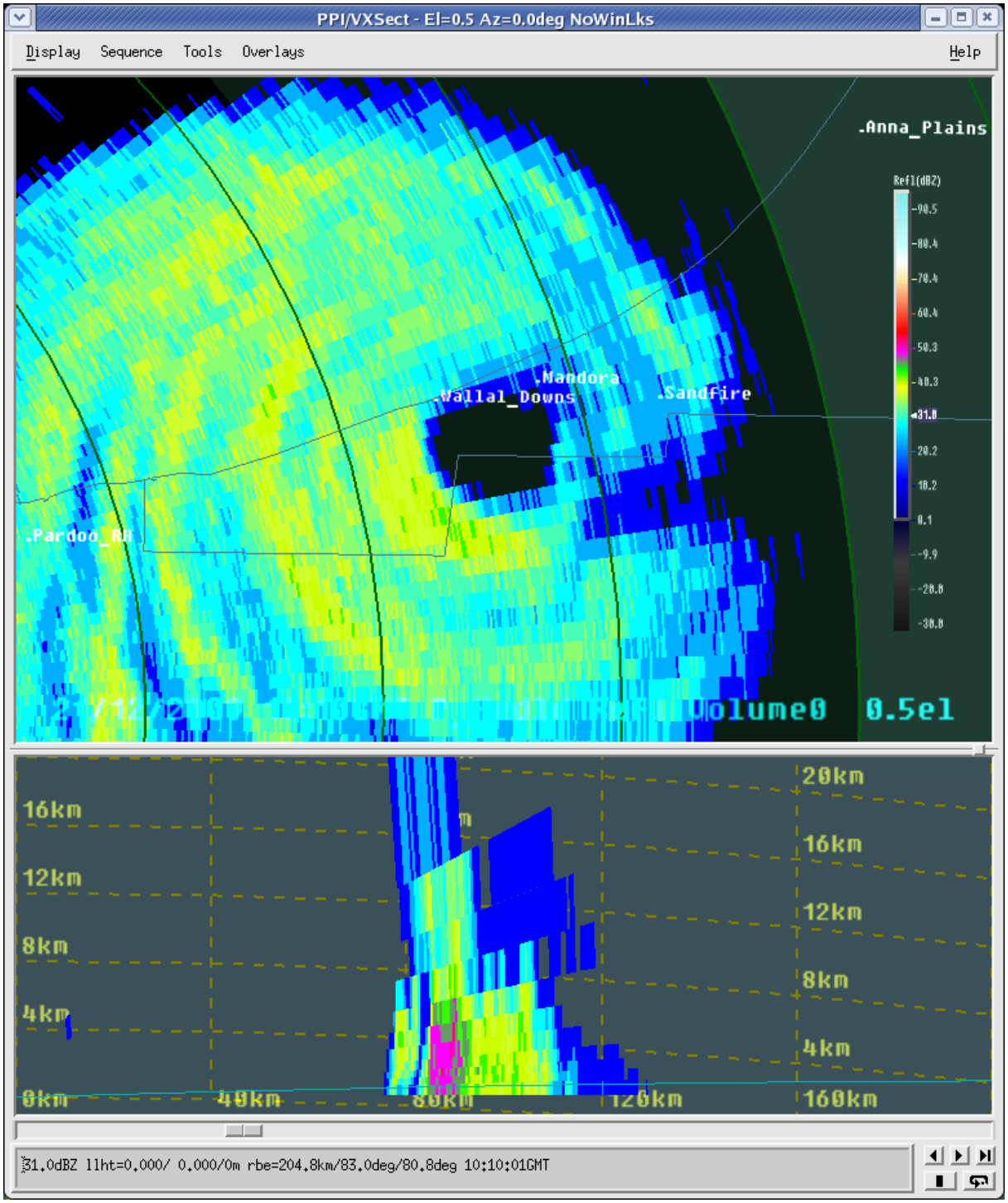

Figure 6. Wind profile from Mandora AWS 21 and 22 December 2009 as Severe TC *Laurence* crossed the Pilbara coast. Wind direction data ceased at 2000 WST 21 December.

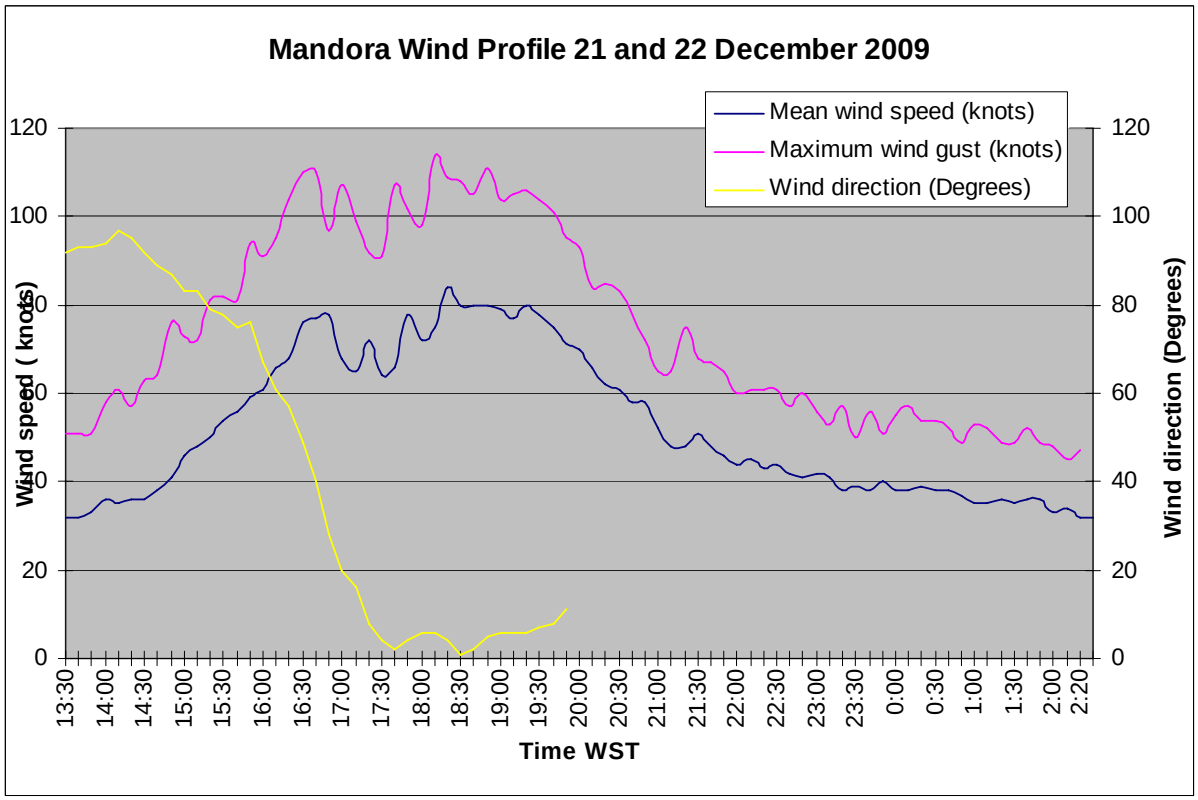

Figure 7. Pressure profile from Mandora AWS 21 and 22 December 2009 as Severe TC *Laurence* crossed the Pilbara coast.

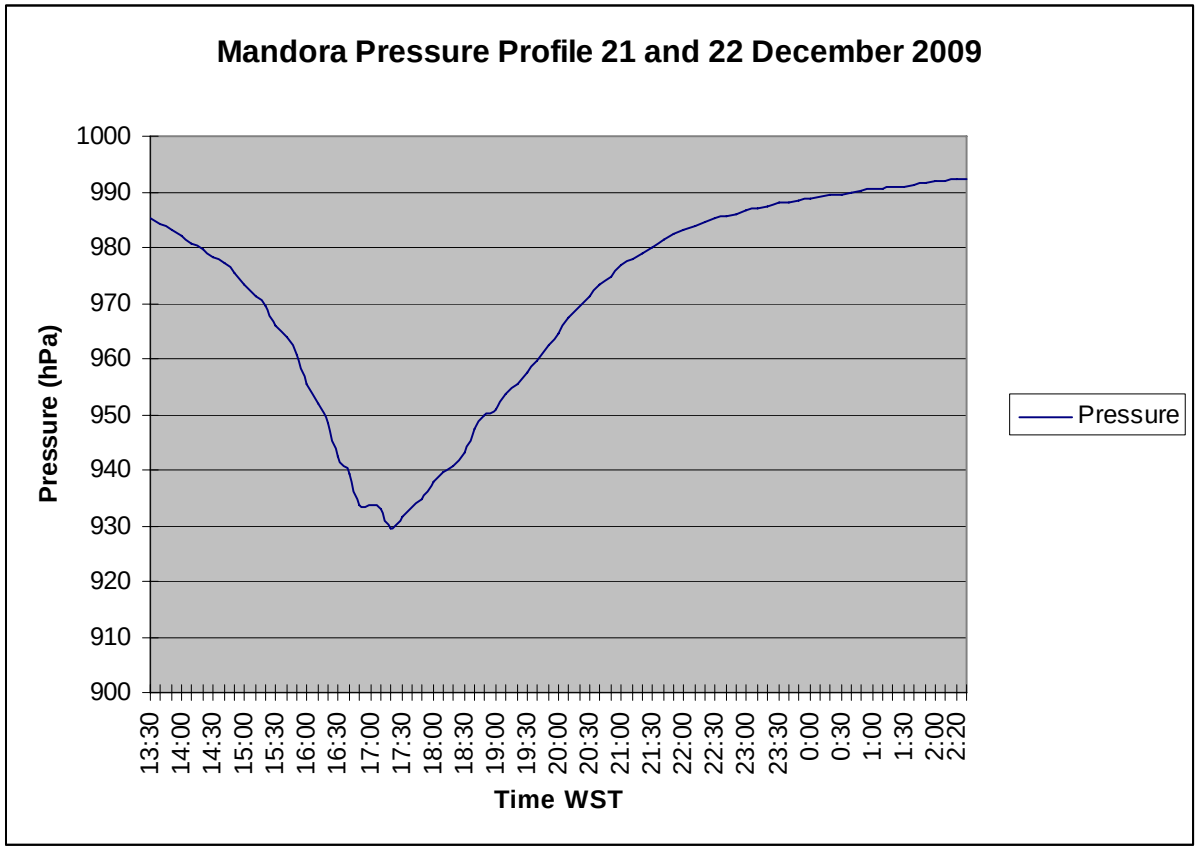

Figure 8. Damage at Wallal from Severe TC *Laurence* (photo courtesy of Lana Reed, ABC).

Figure 9. Damage along 80 Mile Beach (photo courtesy of Lana Reed, ABC).