

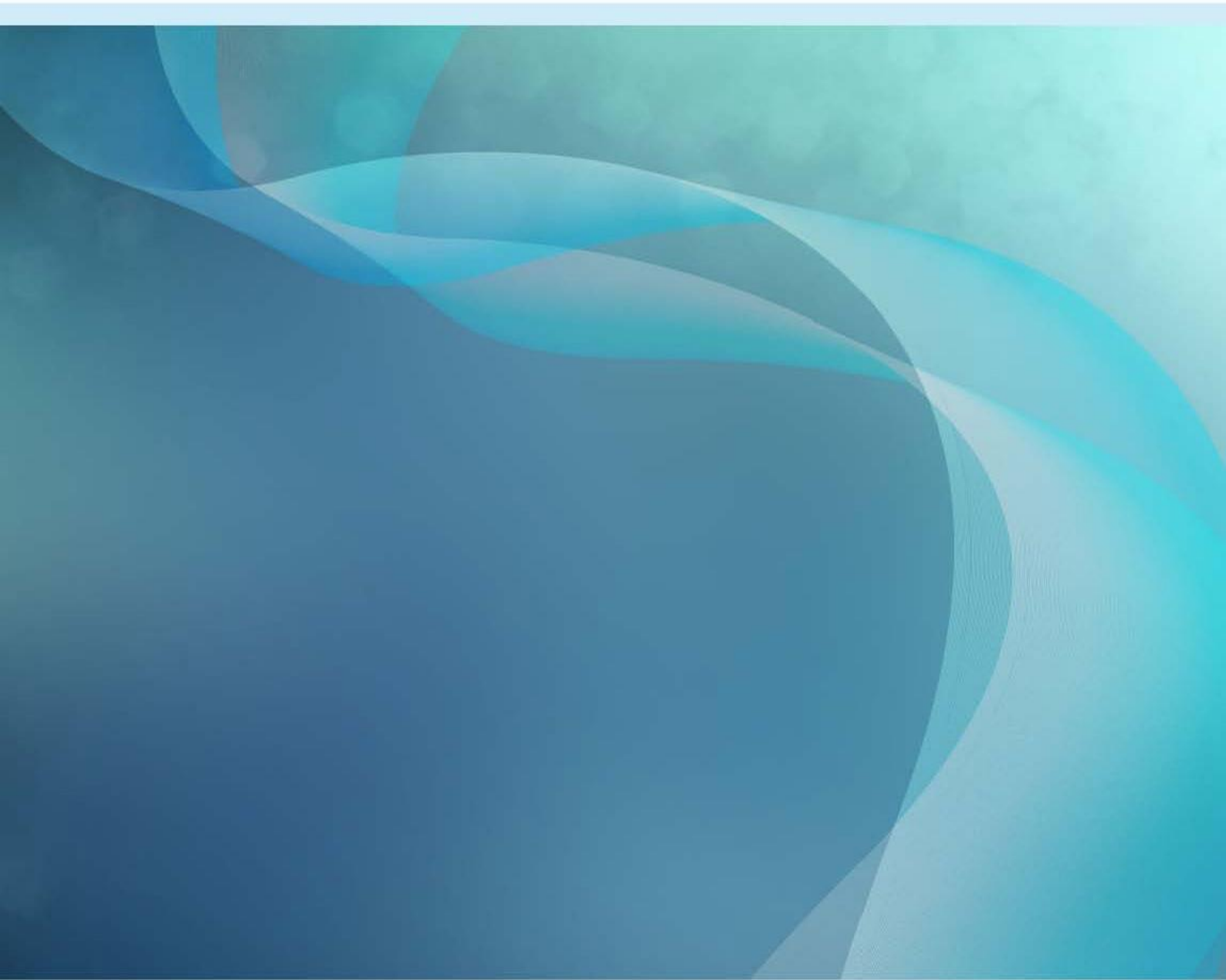


Australian Government

Bureau of Meteorology

Severe Tropical Cyclone *Christine*

August 2014



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1 Summary

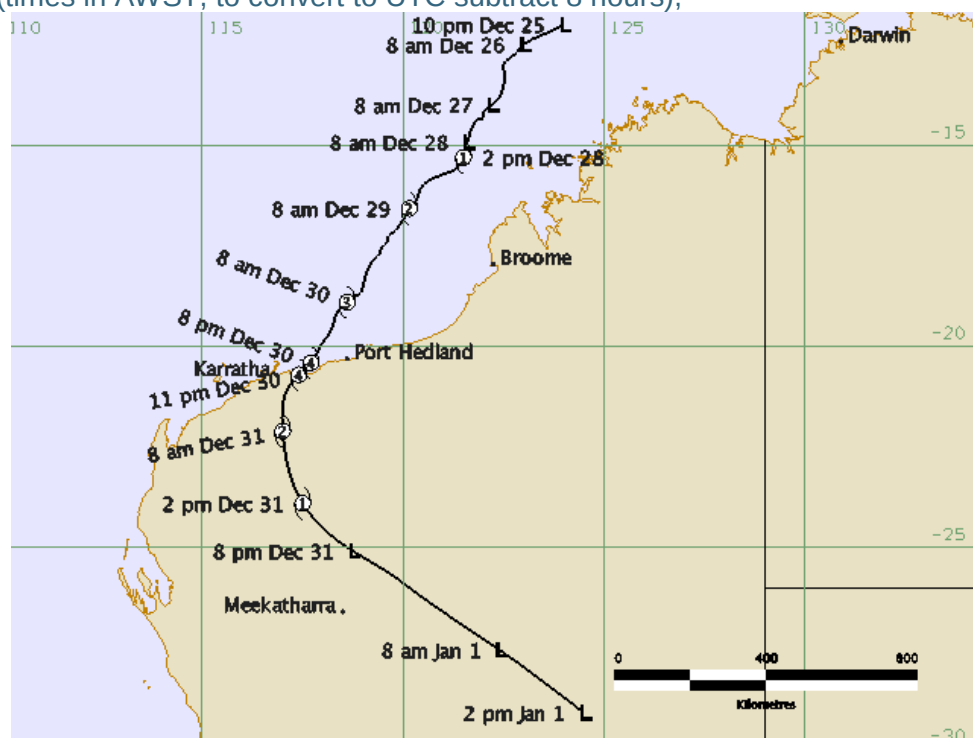
An active monsoon trough to the north of Western Australia produced a number of transient low pressure systems during mid-December 2013. A discrete low within this broad circulation formed late on 25 December and moved southwest. The low developed slowly and did not reach tropical cyclone strength until 0600 Universal Time Coordinated (UTC) 28 December (1400 AWST = UTC + 8 hours).

Christine steadily intensified while continuing on a south to southwest track, reaching Category 3 severe tropical cyclone intensity at 1800 UTC 29 December. A feature of the tropical cyclone was its large size, with gale force winds and heavy rainfall well away from the centre. Severe Tropical Cyclone *Christine* crossed the Pilbara coast as a Category 4 cyclone with a 10-minute mean wind peak intensity of 90 knots (kn)(167 kilometres per hour (km/h) between Roebourne and Whim Creek, around 1500 UTC 30 December. As *Christine* crossed the coast a very destructive wind gust of 93 kn (172 km/hr) was recorded at Roebourne Airport. Other notable wind gusts were 72 kn (133 km/h) at Karratha and 70 kn (130 km/h) at Port Hedland.

Christine began weakening once it crossed the coast and accelerated to the southeast. *Christine* maintained its tropical cyclone structure further inland than most tropical cyclones and was downgraded to below tropical cyclone strength at 1200 UTC 31 December. After weakening below tropical cyclone intensity, the low pressure system moved quickly across southeast WA, producing damaging winds and moderate to heavy rainfall.

Heavy rainfall was recorded in the vicinity of the cyclone path, with the heaviest 24 hour fall being 168 millimetres (mm) at Abydos North; a rain gauge to the southeast of Port Hedland. Other notable 24 hour falls were 134 mm at Roebourne airport, 123 mm at Port Hedland and 113 mm at Karratha. There was minor to moderate flooding in Pilbara river catchments, particularly of the De Grey River.

Figure 1: Best track of Severe Tropical Cyclone *Christine* 25 December 2013 - 1 January 2014 (times in AWST, to convert to UTC subtract 8 hours),



2 Meteorological description

2.1 Intensity analysis

A tropical low pressure system formed in an active monsoon trough late on 25 December. The tropical low could be assigned an initial Dvorak T-number (DT) 1.5 classification at 0600 UTC 26 December. Advanced Scatterometer (ASCAT) passes later on 27 December showed gales associated with convection located in only one quadrant. During 28 December satellite imagery showed increased curved banding associated with the low level centre and the tropical low reached cyclone intensity at 0600 UTC 28 December. Cooperative Institute for Meteorological Satellite Studies (CIMSS) and Cooperative Institute for Research in the Atmosphere Advanced Microwave Sounding Unit (CIRA AMSU) and Satellite Consensus (SATCON) intensity estimates were in the 40 to 50 knot (kn) (74 – 93 km/h) range at this time.

Christine continued to intensify steadily as it moved on a southwest path towards the Pilbara coastline. The centre of *Christine* passed around 45 kilometres (km) to the east of Rowley Shoals during the evening of 29 December. At this time 10 minute mean wind speeds were estimated to be around 60 kn (111 km/h). At 1800 UTC 29 December *Christine* was located around 185 km to the north of Port Hedland and could be tracked by radar. At this time the Dvorak analysis had reached DT 4.5 and the radar showed a poorly defined eye. The radius to maximum winds (RMW) had contracted to about 15 - 20 nautical miles (nm) (28 – 37 km). Figure 3 shows the intensity comparison from various objective and subjective techniques. SATCON was around 62 kn (115 km/h) 10-minute mean wind but CIMSS Advanced Dvorak Technique (ADT) was underestimating the intensity by around 10 kn (18 km/h), this was likely due to the method not using an eye scene type.

As *Christine* approached the coast it developed rapidly in the twelve hours prior to crossing. AMSU and Dvorak intensity estimates increased and the tropical cyclone reached a peak intensity of 90 kn (167 km/h) as it crossed the coast at 1500 UTC 30 December. Satellite and radar imagery showed *Christine* was symmetric with deep, cold convection evident completely encircling the tropical cyclone centre (refer Figure 4).

Once *Christine* crossed the coast it began to weaken, however it maintained tropical cyclone intensity until 0600 UTC 31 December. The remnant tropical low then tracked southeast across southern WA.

While *Christine* passed near several observing sites, the observations did not capture the maximum winds or lowest pressure of the tropical cyclone. The Roebourne Automatic Weather Station (AWS) was located about 25 kilometres (km) to the west of the crossing point but it is likely it captured winds on the lighter side of the eye. Microwave imagery also showed a solid red core around the tropical cyclone apart from the southwest quadrant where Roebourne was located (refer Figure 4).

2.2 Motion

Christine was located to the north of the mid-level ridge and was steered in a southwest direction around the ridge from 26 to 30 December. As the tropical cyclone crossed the Pilbara coast an amplifying trough to the west of the state captured it under a north westerly steering regime and *Christine* turned first south and then to the south east. During 1 January the remnants of the ex-tropical cyclone accelerated to the south east.

2.3 Structure

Initially the tropical low was broad with a large radius to gales of 120 nm (222 km) in the south east quadrant only and a radius to maximum wind (RMW) of around 85 nm (157 km/h). During 29 and 30 December wind shear was low over *Christine* and as the low pressure system intensified the radius to gales became symmetric at 120 nm (222 km) and the RMW contracted to 10 nm (18 km) at its smallest. The eye diameter measured on radar was initially 40 nm (74 km) which contracted to 10 nm (18 km) when *Christine* was most intense. Microwave imagery supports this contraction as *Christine* intensified.

3 Impact

Christine crossed the Pilbara coast between Roebourne and Whim Creek around 1500 UTC 30 December as a Category 4 tropical cyclone, with a 10-minute mean wind of 90 knots (167 km/h) with a maximum wind gust of 230 km/h near the centre. As *Christine* crossed the coast very destructive wind gusts were experienced, with a gust of 93 kn (172 km/h) recorded at Roebourne Airport. Other notable wind gusts were 72 kn (133 km/h) at Karratha and 70 knots (130 km/h) at Port Hedland. Fortunately it is likely that the maximum winds occurred in unpopulated areas just east of the crossing point.

A damage survey was conducted by a Bureau of Meteorology employee and the report of this survey follows.

The locations surveyed included the townships of Karratha, Roebourne and Wickham. The coastal stretch between Cape Lambert and Point Samson was also surveyed for signs of significant damage. In each of the townships visited there was widespread low-level vegetation damage with localised examples of more severe damage, particularly in Roebourne and Wickham. Damage to vegetation ranged from branches snapped off trees of various sizes to uprooting of moderate to large size trees. This occurrence was also the primary cause for structural damage within the region - roof damage due to contact by fallen trees. In Roebourne and Wickham there were isolated instances of structural damage due to wind but, almost invariably, such instances were confined to older dwellings which appeared to be in a relative state of disrepair. Some dwellings in this category were completely de-roofed. Besides uprooting of trees, there was no incidence of severe vegetation damage; ie. there were no instances of snapping of large branches or tree trunks. In Karratha, the vegetation damage was consistent with the strongest winds coming from the west, whilst in Roebourne and Wickham the damage was consistent with winds coming from the south.

Apart from vegetation and structural damage to house rooves and occasionally walls, other examples of significant damage were apparent at the Harding River Caravan Park at Roebourne. At this site two well-constructed vans which were chained to buried concrete blocks were torn from their tie-downs and flipped on their side. In the same location a donga, which had not been properly secured, was overturned such that it lay on its roof, some 10m away from its initial resting point. The account of one of the Park owners indicated that the main part of the storm was ... "extended periods of sustained winds with occasional stronger gusts". It was their first cyclone encounter, having only recently taken ownership of the Park and he had no hesitation in relaying his sentiments that he "...did not want to go through that again!" He and his wife had sheltered in the kitchen block of the Park and while they felt relatively secure, it was a harrowing night for them both.

Also included in the survey was an estimate of the storm surge which occurred along the stretch of coastline between Cape Thouin and West Moore Island (refer Figure 5). *Christine* crossed the coast around the time of high tide along the Pilbara coast.

An account of this survey follows.

The overriding impression of the survey was that vegetation damage was almost unnoticeable. Mangrove areas displayed little to no effects of the tropical cyclone whilst larger, more exposed shrubs/trees showed signs of being 'sand-blasted' but very little structural damage due to winds. There was some evidence of damage to exposed sand dunes, but not widespread or severe. A structure (generator shed) on West Moore Island (just to west of Depuch Is.) was demolished, but it was clearly a shoddily constructed dwelling. The main building on the island, a fishing lodge, exhibited signs of sand-blasting, but was structurally sound. This dwelling was shelter for one person during the passage of the TC, and despite claims by them that they felt some gusts were '150 knots', there was no evidence to support such claims. Two fishing vessels were also located on the shores of the island, totally destroyed - however, this was due to wave action as the vessels broke their moorings during the storm and were dashed against the coast.

Besides landing on West Moore Is. for a viewing of the fishing lodge and to take measurements of debris for storm tide calculations, the survey party landed on another stretch of coastline just west of Cape Thouin - an area presumed to have experienced maximal storm surge effects during the TC passage. There was a distinct debris line and appropriate measurements were taken. Results have yet to be calculated but 'back of the envelope' estimations indicated the surge was likely within bounds forecast by the model. Based on the aerial view of the coastal debris there were no locations where extreme surges took place.

Preliminary results suggest a storm surge (inundation level above event tide) of approx. 2.5 – 3 m along this stretch of coast.

Heavy rainfall was recorded in the vicinity of the cyclone path, with the heaviest 24 hour fall being 168 mm at Abydos North, a rain gauge to the southeast of Port Hedland. Other notable 24 hour falls were 134 mm at Roebourne airport, 123 mm at Port Hedland and 113 mm at Karratha. There was minor to moderate flooding in catchments of the De Grey River and Pilbara Coastal Rivers.

4 Observations

4.1 Wind

Rowley Shoals METAR¹ data recorded gale force winds for a period of 26 hours between 2158 UTC 28 December and 0300 UTC 30 December. Storm force winds were recorded for a period of 5 hours between 0930 UTC and 1430 UTC 29 December.

Port Hedland 10-minute METAR data recorded gale force winds (winds equal to or greater than 34 kn or 63 km/h) for a period of 19.5 hours between 0200 UTC and 2130 UTC 30 December. Storm force winds (winds equal to or greater than 48 kn or 89 km/h) were recorded for a period of 2.5 hours between 0830 UTC and 1100 UTC 30 December.

Bedout Island 10-minute METAR data recorded gale force winds for a period of 37.5 hours between 0530 UTC 29 December and 1900 UTC 30 December. Storm force winds were recorded for a period of 20 hours between 1200 UTC 29 December and 0800 UTC 30 December.

Karratha METAR data recorded gale force winds for a period of 10.5 hours between 1200 UTC and 2230 UTC 30 December. Storm force winds were recorded for a period of 3.5 hours between 1525 UTC and 1900 UTC 30 December.

Legendre Island METAR data recorded gale force winds for a period of 16 hours between 0600 UTC and 2200 UTC 30 December. Storm force winds were recorded for a period of 7.5 hours between 1030 UTC and 1800 UTC 30 December.

Roebourne 1-minute data recorded 10-minute mean gale force winds for a period of 32.5 hours between 1030 UTC 30 December and 1900 UTC 31 December. Storm force winds were recorded for a period of 2.5 hours between 1300 UTC and 1530 UTC and 1 hour between 1700 UTC and 1800 UTC 30 December. Hurricane force winds were recorded for a period between 1405 and 1412 UTC and between 1431 UTC and 1505 UTC 30 December. The maximum wind gust recorded at Roebourne Airport was 93 knots (172 km/h). This was recorded four times in the period 1446 to 1455 UTC 30 December.

4.2 Pressure

Rowley Shoals METAR data recorded a minimum pressure of 980.1 hPa at 1200 UTC 29 December.

¹ A METAR is an standard observation format made for aviation services

Port Hedland one minute data recorded a minimum pressure of 982.9 hPa at 0912 UTC 30 December.

Bedout Island one minute data recorded a minimum pressure of 984.5 hPa between 2010 and 2022 UTC 30 December.

Karratha METAR data recorded a minimum pressure of 976.0 hPa at 1700 UTC 30 December.

Legendre METAR data recorded a minimum pressure of 980.6 hPa at 1430 UTC 30 December.

Roebourne one minute data recorded a minimum pressure of 951.9 hPa at 1600 UTC 30 December.

4.3 Rainfall

Abydos North recorded 168 mm in the 24 hours to 9 am WST 31 December.

Roebourne airport recorded 134.2 mm in the 24 hours to 9 am WST 31 December.

Port Hedland airport recorded 123.2 mm in the 24 hours to 9 am WST 31 December.

Karratha airport recorded 112.8 mm in the 24 hours to 9 am WST 31 December.

5 Forecast Performance

The first Tropical Cyclone Advice for a Watch for a developing tropical low was issued on 26 December for coastal parts between Troughton Island and Sandfire Roadhouse. The first Warning was declared on 27 December for coastal parts between Kuri Bay and Broome. As the tropical cyclone moved southwest the Watch/Warning areas were extended and contracted as appropriate. On 29 December the Warning area was extended west to Mardie including the eventual crossing point for the first time.

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

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

Year	Month	Day	Hour UTC	Pos. Lat S	Pos. Long. E	Pos. Acc. nm	Ma x Wi nd 10 mi n kn	Max gust kn	Cent. Press. hPa	Rad. of gales (NE/SE/ SW/NW)	Rad. of storm (NE/SE/ SW/NW)	RMW nm
2013	12	25	14	12.0	124.0	60	20	45	1005			
2013	12	25	18	12.2	123.6	60	20	45	1004			
2013	12	26	00	12.5	123.0	60	25	45	1002			
2013	12	26	06	12.5	123.0	60	30	45	1003			
2013	12	26	12	12.8	122.7	60	30	45	1003			
2013	12	26	18	13.1	122.5	60	30	45	1002			
2013	12	27	00	14.0	122.2	60	30	45	1002			
2013	12	27	06	14.2	122.0	60	30	45	998			
2013	12	27	12	14.4	121.8	60	35	50	990	0/120/0/0		85
2013	12	27	18	14.6	121.7	60	35	50	990	0/120/0/0		85
2013	12	28	00	14.9	121.6	45	35	50	992	0/120/0/0		85
2013	12	28	06	15.3	121.5	45	40	55	990	120		60
2013	12	28	12	15.8	120.8	30	40	55	990	100		40
2013	12	28	18	16.1	120.4	30	45	65	986	100		25
2013	12	29	00	16.6	120.1	30	50	70	984	120	30	30

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 nm
2013	12	29	06	17.2	119.6	30	55	75	982	120	30	20
2013	12	29	12	17.8	119.3	20	60	85	976	120	40	15
2013	12	29	18	18.5	119.0	20	65	90	970	120	60	20
2013	12	30	00	18.9	118.6	10	70	100	966	120	60	20
2013	12	30	03	19.1	118.4	10	70	100	967			
2013	12	30	06	19.6	118.2	10	75	105	963	140/80/80/140	60	15
2013	12	30	09	19.9	118.0	15	80	110	959	140/80/80/140	60	15
2013	12	30	12	20.4	117.7	10	90	125	948	140/80/80/140	60/30/30/60	10
2013	12	30	15	20.7	117.4	10	90	125	948	140/80/80/140	40	10
2013	12	30	18	21.1	117.1	10	70	100	965	100/60/60/100	40	12
2013	12	30	21	21.5	117.0	10	60	85	973	50/40/40/50	20	15
2013	12	31	00	22.1	117.0	15	50	70	981	40/30/30/40	20	15
2013	12	31	06	23.9	117.5	30	40	55	989	40/30/30/40		15
2013	12	31	12	25.1	118.8	60	30	45	993			
2013	12	31	18	26.1	120.3	45	30	45	992			
2014	01	01	00	27.5	122.4	60	25	45	998			
2014	01	01	06	29.1	124.5	60	25	45	997			

FIGURE 2. Enlarged map of best track of Severe Tropical Cyclone *Christine* at point of coastal crossing, around 1500 UTC 30 December.

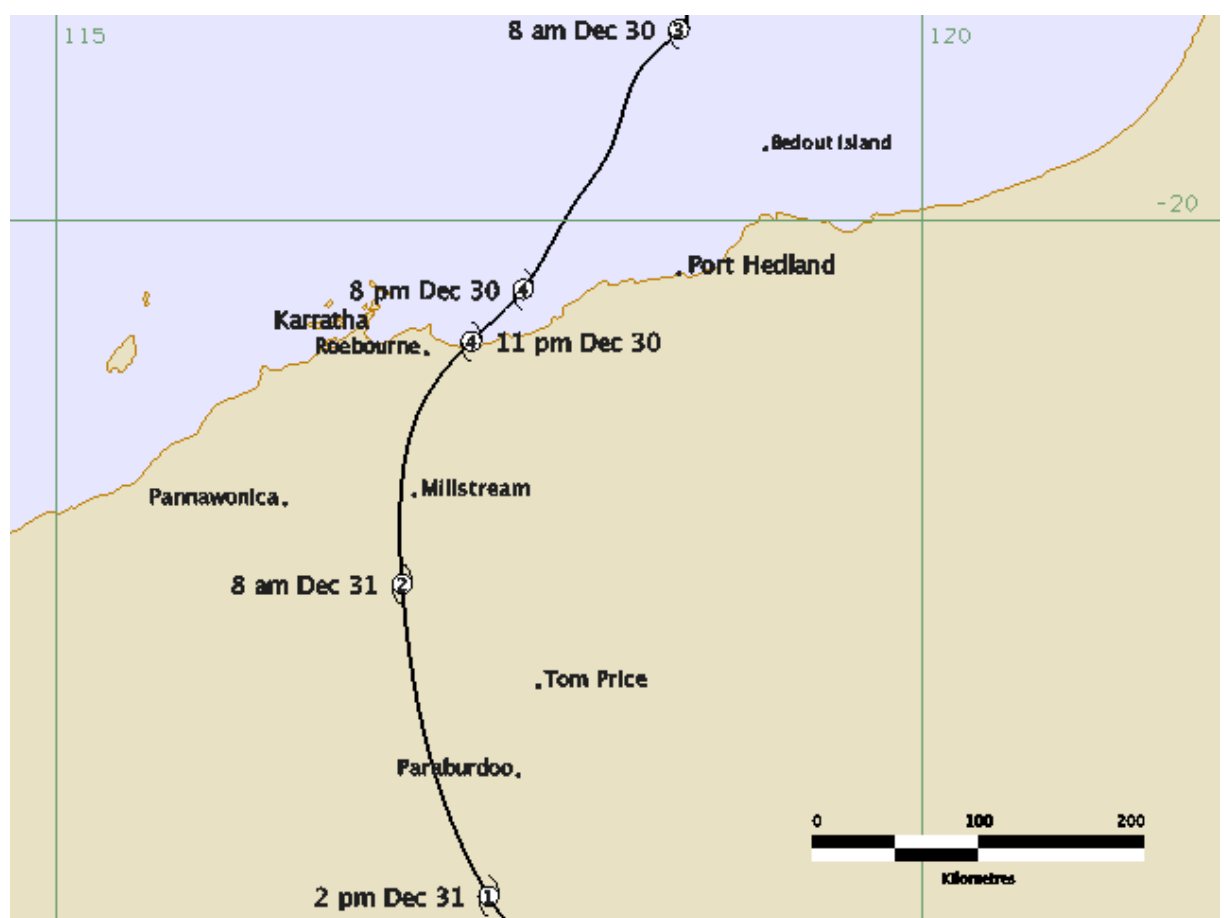


FIGURE 3. Comparison of objective and subjective intensity analysis techniques.

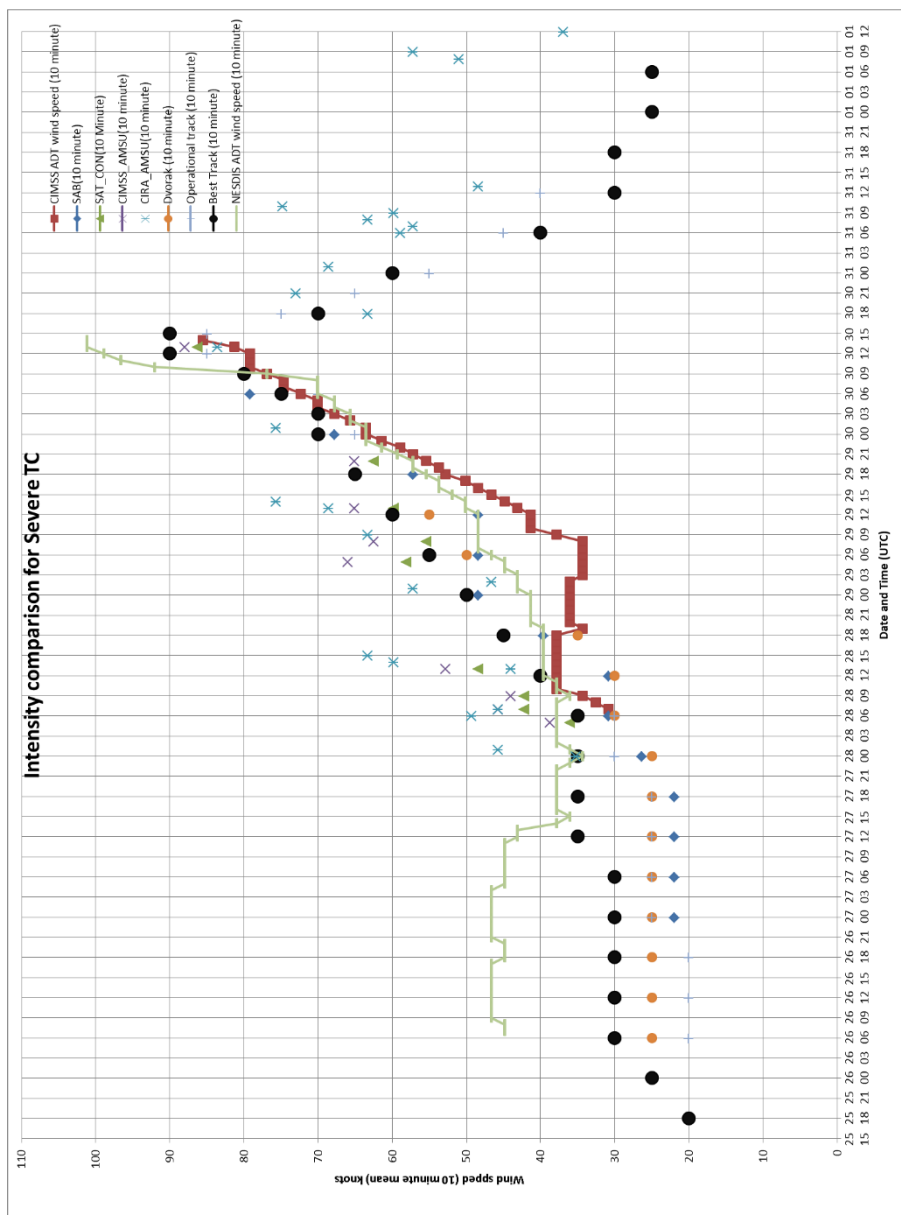


FIGURE 4. 85 GHz Tropical Rainfall Measuring Mission (TRMM) microwave image 1114 UTC 30 December 2013 of *Christine* near peak intensity.

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

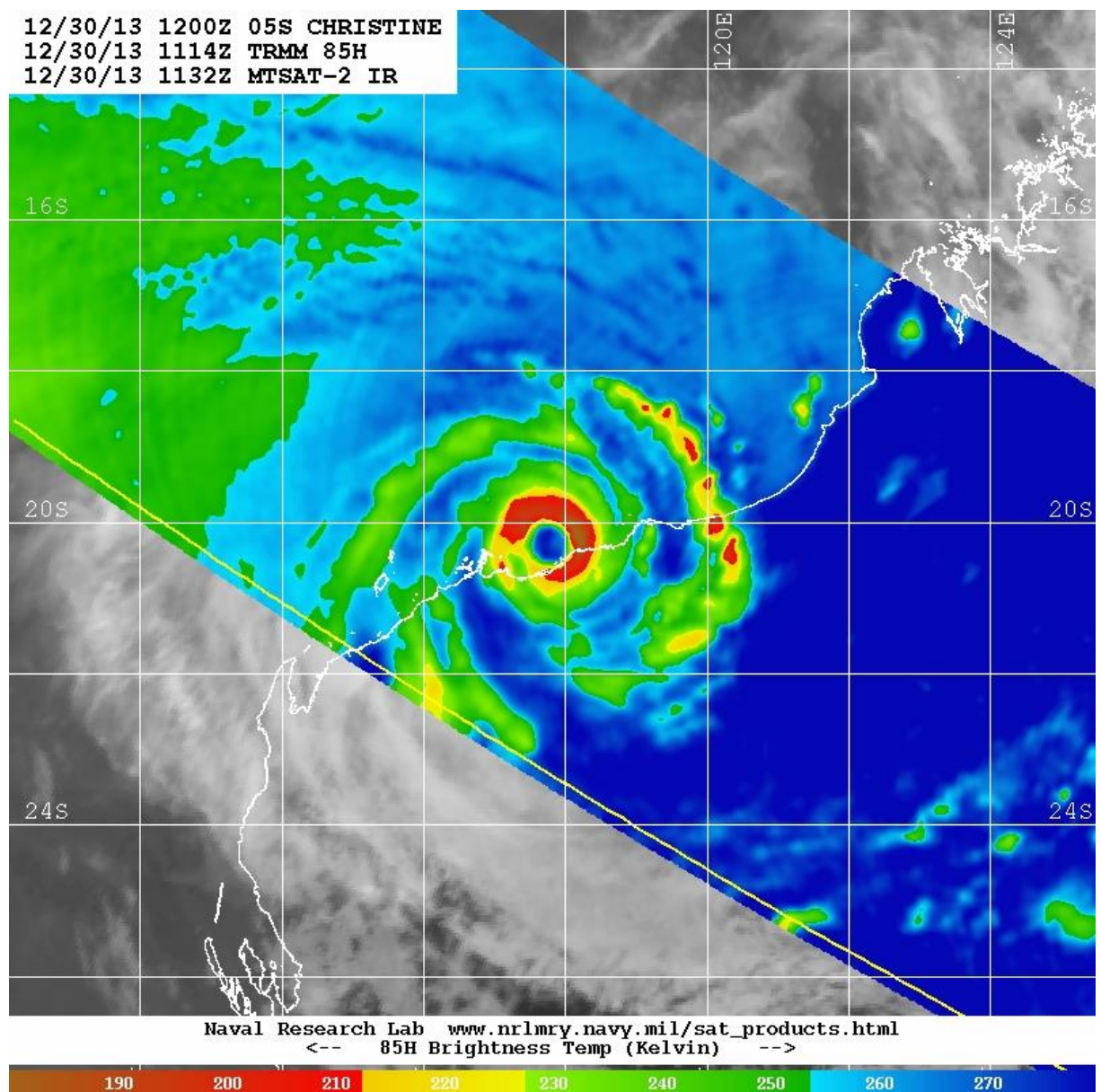


FIGURE 5. Map showing sites of storm surge survey undertaken.

