



Australian Government
Bureau of Meteorology

Severe Tropical Cyclone *Carlos*

15 – 26 February 2011

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A. Summary

A tropical low formed within the monsoon trough over the Northern Territory's Top End near Katherine on 13 February 2011. The low drifted northwest towards Darwin during 14 and 15 February and underwent a period of strong intensification during the 15 and 16 February. The low moved into the Beagle Gulf early on 16 February and was declared a tropical cyclone at 2100 UTC 15 February (0630 CST (Central Standard Time)=UTC+9.5 hours) when centred near Darwin Harbour. Tropical Cyclone *Carlos* remained a Category 1 cyclone as it moved very slowly southeastwards over Darwin and surrounding rural suburbs during 16 February, before it was downgraded to a tropical low at 1500 UTC 16 February near Batchelor. Ex-tropical Cyclone *Carlos* tracked southwards over the Northern Territory's western Top End and by 19 February the tropical low crossed the border into Western Australia near Wyndham (Figure 1).

Very heavy rainfall associated with the tropical low broke many rainfall records in the region including Darwin's wettest day with 367.6 millimetres (mm) recorded in the 24 hours to 2330 UTC 15 February. The heavy rain caused widespread flooding and damage to roads and properties in the Darwin area. Squally winds felled many hundreds of trees, powerlines, cut roads and caused damage to property. In addition, most Government Departments and Darwin International Airport was closed during the worst weather. Heavy rain from Ex-Tropical Cyclone *Carlos* also caused major flooding in the Daly River, which led to the community of Nauiyu to be evacuated.

The tropical low pressure system steered rapidly west across the Kimberley region and moved offshore north of Broome during the early hours of 21 February. The tropical low redeveloped into a tropical cyclone by 0000 UTC 21 February (0800 WST= UTC+8 hours) and began a generally south-westward movement. *Carlos* intensified to Category 2 before it crossed the Pilbara coastline close to Karratha around 0400 UTC 22 February. *Carlos* then turned west and moved offshore north of Mardie. The cyclone then moved south west again, parallel to the Pilbara coastline before it crossed the North West Cape and weakened slightly. *Carlos* then moved out over open water to the west of the state. Observations indicated that the strongest winds associated with *Carlos* were located in the northeast (rear-right) quadrant.

Once *Carlos* passed to the west of the North West Cape the tropical cyclone began to intensify. Sea surface temperature (SST) analyses showed SSTs of between 26°C and 28°C extending well south and west of the West Australian coastline. This enabled *Carlos* to reach a maximum 10 minute mean wind of 65 knots (kn) (120 kilometres per hour (km/h)) by 1800

UTC 24 February despite being located a long way south. As *Carlos* moved steadily southwards over cooler SSTs the cyclone weakened and was downgraded to below cyclone strength by 0600 UTC 26 February (refer Figure 2).

Gale and storm force winds associated with Severe TC *Carlos* were experienced along parts of the Pilbara coastline and offshore islands however communities reported little damage. During the afternoon of 21 February, while *Carlos* was off the coast near Port Hedland, a tornado associated with severe thunderstorms in one of the outer rain bands caused extensive damage in the central business district of Karratha.

Figure 1: Best track of TC *Carlos* over the Northern Territory (14 – 19 February 2011)

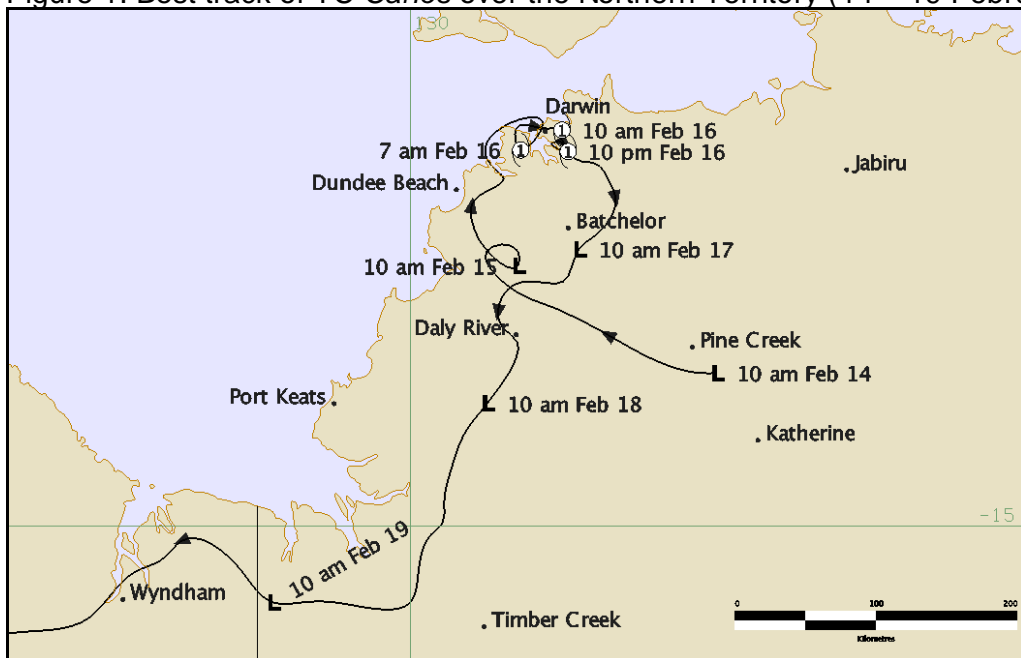
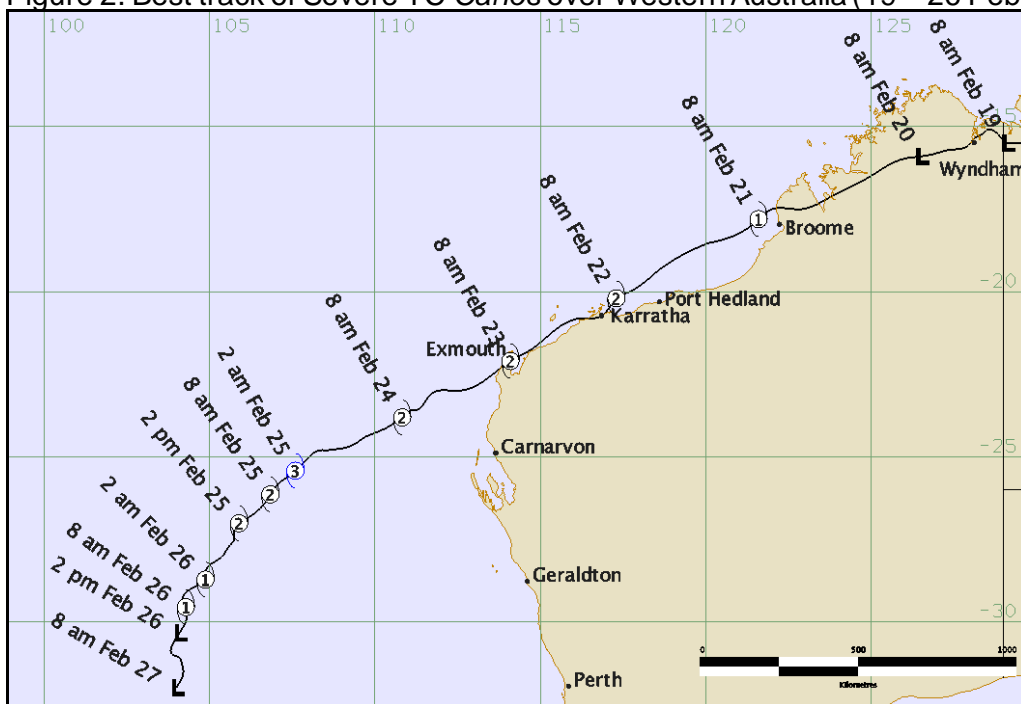


Figure 2. Best track of Severe TC *Carlos* over Western Australia (19 – 26 February 2011)



B. Meteorological Description

Intensity analysis

A weak tropical low located over land and embedded within a monsoon trough strengthened over the northwestern Top End of the Northern Territory during the 14 and 15 February as it moved northwestwards towards the coast. Strong convective activity occurred just offshore from the western Top End to the northwest of the low overnight during the 14 February and early on the 15 February. Surface observations at Darwin Airport and Fish Reef Marine Automatic Weather Station (AWS), 47 kilometres (km) west of Darwin, indicated wind speeds of 10-15 kn (19-28 km/h) early on 14 February (local time), which increased steadily to 15-20 kn by the evening, 20-25 kn (37-46 km/h) by early on 15 February and 25-30 kn (46-55 km/h) later that morning. Maximum sustained winds at 0000 UTC on 15 February were estimated at 30 kn (56 km/h).

The low strengthened further during 15 February. Doppler winds from Berrimah (Darwin) radar showed wind speeds of 65-70 kn (120-130 km/h) at 200-600 metres above ground level between approximately 0600 UTC and 1500 UTC. A squall line that passed over Darwin Airport at 1144 UTC 15 February produced at 38 knot (70 km/h) mean wind with a gust to 53 kn (98 km/h) from the north.

The structure of the low level centre improved overnight, aided by a strong equatorward outflow channel in the upper levels and a poleward outflow channel caused by a mid-latitude trough extending into the tropics. A convective band wrapped into the centre from the northeast quadrant (Figure 3). Maximum sustained winds were estimated between 35-40 kn (65-74 km/h) beneath this convective band between 0900 UTC and 2100 UTC 15 February. Winds were estimated to be less than gale force (34 kn or 63 km/h) in other quadrants. Hence, the low was assessed below the Australian tropical cyclone definition¹ at this time. However the northeast quadrant was located directly over Darwin, which resulted in Category 1 impacts being felt during this period, prior to tropical cyclone formation.

Tropical Cyclone *Carlos* met the definition of a tropical cyclone with gales of maximum sustained winds to 35 kn (65 km/h) in the southwest, northwest and northeast quadrants by 2100 UTC on 15 February. Operationally, *Carlos* was named by Darwin TCWC at 0000 UTC on 16 February. Gales were observed at Fish Reef Marine AWS between 2230 UTC 15 February and 0000 UTC 16 February and again between 0700 UTC and 0900 UTC 16 February. Peak sustained winds of 37 kn (69 km/h) and gusts to 47 kn (87 km/h) from the southwest at 0730 UTC were reported. Near gales persisted for a longer duration at Fish Reef Marine AWS. During this same period, average wind speeds at Darwin Airport fluctuated between 10-25 kn (19-46 km/h).

Carlos reached tropical cyclone Category 1 intensity in the Northern Territory with peak 10-minute average wind speeds of 40 kn (74 km/h) between 0700 UTC and 1000 UTC 16 February. Of significance for Darwin however, was that the winds had reached 40 kn (74 km/h) during the previous evening between 1200 UTC and 1800 UTC 15 February in coastal areas, prior to the low forming into a tropical cyclone.

Carlos weakened as it tracked inland from Darwin during the evening of 16 February with a deteriorating structure as indicated by radar. *Carlos* was downgraded to a tropical low at 1500 UTC 16 February, although at this time, gales were still inferred to have continued in the western half of the low, based on radar Doppler winds and 31 kn (57 km/h) observed at Darwin Airport. By 1800 UTC 17 February winds in all quadrants had weakened to 30 kn (55

¹ A tropical cyclone is defined as a non-frontal low pressure system of synoptic scale developing over warm waters having organised convection and a maximum mean wind speed of 34 kn or greater extending more than half-way around near the centre and persisting for at least six hours.
<http://www.bom.gov.au/cyclone/faq/index.shtml#definitions>

km/h) or less. Operationally, *Carlos* was downgraded by Darwin TCWC at 2100 UTC 16 February. Ex-tropical cyclone *Carlos* continued to weaken as it moved southwards then westwards over land towards Western Australia during the 17 and 18 February.

Although most of *Carlos*' lifetime occurred over land, subjective Dvorak assessments were still performed. An initial classification of Dvorak Data T-number (DT) 1.0 was assigned at 1730 UTC 13 February. A curved band pattern was applied with curvature increasing steadily between about 1730 UTC 14 February and 0530 UTC 16 February. DT3.0 was assigned at 0530 UTC 15 February and a peak subjective Dvorak assessment of DT3.5 was made between 2030 UTC 15 February and 0530 UTC 16 February. Final intensity estimates were based on additional information such as observations from AWSs and factoring in the influence of land friction.

Ex-tropical cyclone *Carlos* crossed into Western Australia near Wyndham as a well-developed circulation clearly visible on Wyndham radar around 0000 UTC 19 February. Surface observations showed the ex-tropical cyclone had approximately 15 kn (28 km/h) mean winds near the centre and a central pressure of approximately 1000 hectopascals (hPa). The low tracked west over land and microwave imagery showed a decrease in cold, convective cloud during this time. Low level spiral banding around the centre persisted and when the low moved over water north of Broome it quickly re-intensified into a Category 1 tropical cyclone by 0000 UTC 21 February.

A microwave pass in the early afternoon 21 February showed a circulation with deep convection in western quadrants. Cooperative Institute for Meteorological Satellite Studies (CIMSS) shear analyses showed 20 to 30 kn (37-55 km/h) of easterly shear over the cyclone. Despite this usually inhibiting factor *Carlos* continued to intensify. At 0000 UTC 22 February subjective Dvorak analyses gave a DT of 3.5 with an associated maximum 10 minute mean wind of 50 kn (93 km/h). Objective intensity estimates between 1800 UTC 21 February and 0600 UTC 22 February gave maximum 10 minute mean wind speeds of between 45 kn and 55 kn (83-102 km/h). Based on this information intensity at 0000 UTC 22 February was set at 50 kn (93 km/h). Satellite and radar imagery showed deep convection predominantly located in the northern quadrants as *Carlos* approached the Pilbara coast. Wind observations from Karratha Airport did not show any gale force winds as *Carlos* passed just to the west of the observing site between 0400 UTC and 0500 UTC 22 February. Roebourne AWS, located 30 km to the east of Karratha, recorded gale force winds for a few hours but not storm force. Legendre Island was the only observing site to report storm force winds (mean winds greater than 47 kn (87 km/h)) when the wind direction was from the northwest, between 0730 UTC and 0820 UTC 22 February. At this time Legendre Island was located in the northeast (rear right) quadrant of the tropical cyclone. It is likely that storm force winds were located only offshore in the northern quadrants during this period.

Carlos turned west and moved offshore again during the early evening. Winds at offshore observing sites reached storm force during the evening of 22 February, particularly in the north eastern quadrant of the tropical cyclone, and based on this the intensity of *Carlos* was upgraded to 60 kn (111 km/h) mean winds at 1200 UTC 22 February. The tropical cyclone moved in a west southwest direction along the coastline and crossed the North West Cape about 0000 UTC 23 February. Wind observations at Learmonth Weather Service Office reached gale force but did not reach storm force, even in the rear quadrants as *Carlos* passed close to the station. For this reason the intensity of *Carlos* was decreased through this period.

Once *Carlos* moved offshore it began to slowly re-intensify. It is not typical for a tropical cyclone to intensify at latitudes higher than 25°S but a strong La Nina event had caused warmer SSTs to extend further south and west than normal off the Western Australian coastline (refer Figure 4 and Figure 5). During 23 and 24 February *Carlos* became more symmetrical with deep, cold convection surrounding the low level circulation. *Carlos* may

have briefly developed an eye around 1800 UTC 23 February but a definite eye appeared some 24 hours later around 1800 UTC 24 February. This is when *Carlos* reached a peak intensity of 65 kn (120 km/h) (refer Figure 6). Wind shear analyses from this period indicate the *Carlos* predominantly experienced 10 to 20 kn (19-37 km/h) of easterly shear, however this seemed to have decreased from 1200 UTC 24 February enabling *Carlos* to obtain its peak intensity.

From this time *Carlos* moved over cooler SSTs and the tropical cyclone began to weaken steadily. CIMSS wind shear analyses showed shear remained below 20 kn (37 km/h) during 25 February indicating it was likely that cooler SSTs played a greater role in the demise of *Carlos*. By 0000 UTC (8 am WST) 26 February marginal gales may still have been present around the centre of *Carlos*. Dvorak re-analysis gave *Carlos* a DT-number of 2.0 but the final intensity was assessed by averaging other intensity estimates and the morning ASCAT pass. *Carlos* was downgraded to below cyclone strength by 2 pm 26 February and the low level circulation dissipated slowly over the next 48 hours.

Figure 7 shows the available intensity estimates from many methods for *Carlos*. Dvorak reanalysis is at the lower end of intensity estimates. CIMSS Advanced Microwave Sounding Unit (AMSU) intensity estimates were at times very high compared to others and this may have been due to some tilt in the tropical cyclone caused by the easterly shear at various times of its life. Generally other intensity estimates were clustered together.

Motion

Prior to tropical cyclone formation, the low was steered west-northwest from near Katherine towards the coast during the 14 February by a low to middle level ridge across southern and central Australia. Between 1500 UTC 14 February and 0300 UTC 15 February the low stalled approximately 40 km inland from Daly River Mouth. This was due to an increase in the monsoon westerly winds at the low to middle levels, which counteracted the easterly steering influence from the ridge. During the remainder of the day on 15 February the low adopted an unusual northerly track 20-30 km inland of the coast (climatology for the region is for a west-southwesterly track). This was the result of the easterly and westerly steering influences remaining in balance but the ridge axis across southern Australia shifting northwards, which caused the monsoon trough and low to also shift northwards. The low reached its most northern extent at approximately 1800 UTC 15 February, located over the Cox Peninsula and the entrance to Darwin Harbour.

Steering stayed in balance during the 16 February and *Carlos* completed a number of small loops over Darwin. From 1200 UTC 16 February *Carlos* tracked slowly southeast and inland as the middle level ridge weakened slightly. During the 17 and 18 February, ex-tropical cyclone *Carlos* tracked south-southwest slowly (at less than 5 kn (9 km/h)) over the western Top End of the Northern Territory due to the influences of a high near southern New Guinea and weakened ridge across central Australia. This slow movement contributed to the heavy rainfall in the Daly River catchment. From the 19 February, ex-tropical cyclone *Carlos* adopted a westerly track as a new ridge developed across central Australia.

Carlos was steered in a generally south west direction for most of its lifetime from the 20 February onwards by a mid-level ridge located across central Australia. During the period 21 to 23 February the mid level pattern became complicated with a ridge over eastern Australia, a deepening low in the Bight and a mid-level trough to the west over the Indian Ocean. *Carlos* moved at times southwest and west until 23 February. From 24 February the low in the Bight weakened and *Carlos* moved southwest again predominantly under the influence of the mid-level ridge. From 25 February *Carlos* was steered south by the mid-level trough to the west until the low finally dissipated.

Structure

Carlos was located in a moderate (15-20 kn or 28-37 km/h) southeasterly wind shear environment on 15 February when intensification of the low first began. This was enough to displace the middle level centre over water to the northwest of the low level centre. As such, a strong outbreak of convection occurred over maritime areas to the north of the low, which wrapped inwards towards the low level centre, overnight on the 15 February. The gales that were observed during this period of tropical cyclogenesis were limited to the northeast quadrant of the low, co-located with the deep convection.

The wind shear environment decreased to less than 10 kn (19 km/h) for the remainder of its lifetime in the Northern Territory from the 16 February. As the structure of the low level centre strengthened, it became more symmetrical. Radar imagery showed an eye-like feature develop from approximately 1800 UTC 15 February and persisted through most of the 16 February (Figure 8). Gales extended to the northwest and southwest quadrants as the structure became more symmetrical. Due to the proximity of *Carlos* to land, gales were never deemed to have occurred in the southeast quadrant while located in the NT.

Carlos was a small sized tropical cyclone near Darwin with gale radii ranging between 30 and 60 nm (55 – 111 km).

Carlos experienced moderate wind shear until 24 February after which shear values dropped to below 20 kn (37 km/h) for the remainder of its lifetime. At times during 20 February the low level circulation was exposed with the convection to the west. By 23 February the tropical cyclone seemed vertical with well-developed cold cloud surrounding the centre. During 25 February the *Carlos* became more sheared again as it weakened. This may have been due to the weakening structure being more susceptible to shear rather than an increase in the absolute value of the shear.

From surface observations wind structure was not symmetrical while the tropical cyclone traversed the Pilbara coastline. The strongest winds were observed in the northeast (rear right) quadrant. As *Carlos* crossed the Pilbara coast near Karratha observations suggested the strongest winds were located away from the centre with Varanus Island and Roebourne AWS recording stronger winds than Karratha airport. A similar structure was observed at around 1200 UTC 22 February when *Carlos* was located over water west of Mardie. It should be noted that both the strongest observations were reported from Legendre Island AWS and Varanus Island AWS, both exposed offshore sites. It is possible that the winds closer to the centre were affected by the proximity of the centre to land.

Carlos had an eye for a period during 24 and 25 February with an eye diameter of 25 nm (45 km) to 30 nm (60 km).

C. Impact

The heavy rain from *Carlos* had a major impact on Darwin and surrounding areas, causing widespread flooding of low lying areas, inundating many houses and damaging roads and properties. Flooding of coastal suburbs was exacerbated by some of the largest astronomical tides of the year.

Squally winds with gusts reaching 53 kn (98 km/h) lashed the Darwin area during the night of the 15 February and again on the 16 February, felling many hundreds of trees, cutting roads, powerlines and damaging properties. Most Government departments, schools and businesses were closed for two days during the event. Darwin International Airport was also closed during the worst weather conditions on 16 February.

Ex-tropical cyclone *Carlos* caused widespread flooding elsewhere in the Daly District of the Northern Territory, including a major flood in the Daly River, inundating the community of

Naiyu about 150 km south of Darwin. Three hundred people were evacuated to the nearby town of Batchelor.

Despite *Carlos* crossing the Pilbara coastline twice and moving parallel to the coastline for a period of time no significant damage directly associated with *Carlos* was reported in Western Australia. There was significant damage done to the Karratha central business district when a tornado associated with a severe thunderstorm in one of the outer rain bands passed across the area.

D. Observations

Wind

Darwin Airport recorded a maximum sustained wind speed and gust for *Carlos* in the Northern Territory with a gale of 38 kn (70 km/h) and a wind gust of 53 kn (98 km/h) with a squall line at 1143 UTC 15 February. A period of near-gales (28-33 kn or 52-61 km/h) was observed on multiple periods between 2243 UTC 14 February and 1500 UTC 16 February.

Fish Reef Marine AWS recorded sustained gales (winds equal to or greater than 34 kn or 63 km/h) from 0330 UTC to 0358 UTC 15 February, again from 2153 UTC 15 February and 0030 UTC 16 February and then again from 0700 UTC to 0930 UTC 16 February.

Port Hedland recorded sustained gales from 1750 UTC to 1810 UTC 21 February, a period of 1 hour, and then again from 2010 UTC to 2020 UTC 21.

Legendre Island recorded sustained gales from 2150 UTC 21 February to 1540 UTC 22 February, a period of 18 hours. Sustained storm force winds (winds equal to or greater than 48 kn or 89 km/h) were recorded from 0730 UTC to 0820 UTC 22 February, a period of 50 minutes.

Roebourne recorded sustained gales from 0350 UTC to 0550 UTC and again from 0750 UTC to 0820 UTC 22 February.

Varanus Island recorded the maximum wind gust during *Carlos* of 75 kn (139 km/h) at 1820 UTC 21 February. Varanus Island recorded sustained gales at 1540 UTC 21 February, 0510 UTC 22 February and 0900 UTC 22 February to 0050 UTC 23 February, a period of nearly 14 hours. Sustained storm force winds were recorded at 0940 UTC, 1100 UTC to 1200 UTC and 2100 UTC to 1600 UTC 22 February.

Barrow Island recorded sustained gale force winds from 1540 UTC 22 February to 1850 UTC 22 February, a period of about 4 hours.

Thevenard Island recorded sustained gales from 1200 UTC to 1510 UTC 22 February and from 2000 UTC 22 February to 0330 UTC 23 February. Sustained storm force winds were recorded from 2130 UTC to 2140 UTC 23 February. Note: the direction on the anemometer was not functioning through this period but the wind speed was reliable.

Mardie recorded sustained gales at 1030 UTC, 1220 UTC to 1230 UTC and 1400 UTC to 1550 UTC 22 February.

Onslow recorded sustained gales at 1200 UTC 22 February, 1930 UTC 22 February to 0050 UTC 23 February and at 0140 UTC, 0150 UTC and 0230 UTC 23 February. Sustained storm force winds were recorded from 2140 UTC to 2210 UTC and at 2240 UTC 22 February.

Learmonth recorded sustained gales from 2150 UTC to 2220 UTC 22 February, 0140 UTC, 0300 UTC to 0330 UTC and 0410 UTC to 0820 UTC 23 February.

Pressure

Darwin Airport barograph observed a minimum pressure of 992 hPa at approximately 1930 UTC 15 February.

Darwin Airport AWS observed a minimum pressure of 993.1 hPa between 1916 UTC to 1929 UTC 15 February.

Roebourne recorded a minimum pressure of 982.2 hPa at 0400 UTC 22 February as *Carlos* crossed the Pilbara coast.

Onslow recorded the minimum pressure of 979.4 hPa at 1650 UTC 22 February.

Rainfall

Darwin Airport recorded 367.6 mm in 24 hours to 2330 UTC 15 February, which was a new 24 hour record for Darwin Airport. Other records to occur at Darwin Airport included 684.8 mm in the 3 days until 2330 UTC 16 February, a new 3 day record; 847.4 mm in the 7 days until 2330 UTC 18 February, a new 7 day record; 1110.2 mm for February (new monthly record for any month).

Dum In Mirrie Island recorded 244.6 mm in 24 hours to 2330 UTC 14 February.

Leanyer recorded 344 mm, Stokes Hill Wharf 343 mm, Channel Island 311 mm and Palmerston 300 mm in 24 hours to 2330 UTC 15 February.

Fort Hill Wharf recorded 297 mm in 24 hours to 2330 UTC 16 February.

Daly River Police Station reported 442.5 mm in 24 hours to 2330 UTC 17 February.

Daly River Police Station reported 103.5 mm in 24 hours to 2330 UTC 18 February.

Varanus Island recorded the highest rainfall in Western Australia with 288.2 mm recorded to 0100 UTC 23 February.

E. Forecast Performance

Forecasts for the movement and intensification of *Carlos* while in the NT brought many challenges. The (3-day) TC Outlook rated the chance of TC development as Low until 14 February when ratings were upgraded to Moderate for 17 February. On 15 February the outlook was updated to Moderate for 16 February and this was subsequently updated later on 15 February to High for the following three days.

A Flood Threat Advice was issued on 11 February, which provided up to four days lead time prior to significant flooding.

At 2337 UTC 14 February a Severe Weather Warning was issued for the Daly District and Tiwi Islands for Locally Damaging Winds and Flash Flooding. This was about 10 hours prior to when the first wind gust greater than 49 kn (90 km/h) was observed at Darwin Airport, although Doppler winds at Berrimah radar indicated wind gusts greater than 49 kn (90 km/h) developed much earlier in the day. Throughout the afternoon and evening of 15 February Severe Thunderstorms Warnings were also issued for Damaging and Destructive Wind Gusts in the Darwin region.

At 0150 UTC 15 February the first Tropical Cyclone Advice for a Watch was issued between Goulburn Island and Daly River Mouth, including Darwin and the Tiwi Islands for the expectation of a tropical cyclone developing by approximately 1200 UTC 16 February between Darwin and the Tiwi Islands. This was about 19 hours prior to when *Carlos* actually formed.

At 0730 UTC 15 February the Tropical Cyclone Advice was upgraded to a Warning between Point Stuart and Daly River Mouth, including Darwin and the Tiwi Islands and the Watch was extended to Port Keats for the expectation of a tropical cyclone developing by approximately 0600 UTC 16 February. This was about 13 hours prior to when *Carlos* actually formed.

At 2230 UTC 16 February the Tropical Cyclone Advice for a Warning was cancelled. However a Watch was maintained between Daly River Mouth in the NT to Kalumburu in WA for the risk of Ex-tropical Cyclone *Carlos* moving over the Joseph Bonaparte Gulf and reforming. At 1930 UTC 18 February the Tropical Cyclone Advice was subsequently upgraded to a Warning between Port Keats in NT and Kalumburu in WA.

By 0130 UTC 19 February Ex-tropical Cyclone *Carlos* was expected to remain over the Kimberley in WA rather than move over the Joseph Bonaparte Gulf. However, the low was expected to move off the West Kimberley coast late on 20 February or early on 21 February. The Tropical Cyclone Advice between Port Keats and Kalumburu was cancelled but a Watch was declared between Mitchell Plateau and Bidyadanga in WA.

The first Tropical Cyclone for *Carlos* issued by Perth TCWC was at 0100 UTC 20 February for a warning from Mitchell Plateau to Bidyadanga and a watch from Bidyadanga to Onslow. At 0700 UTC 20 February the warning area was extended to De Grey and the watch area was extended down to Exmouth. At 1300 UTC 20 February the watch area was extended south to Coral Bay. The warning area was extended down to Exmouth by 0000 UTC 21 February.

The warning area was gradually reduced along the Pilbara coast as *Carlos* moved west with the final Tropical Cyclone cancelled at 2200 UTC 23 February as *Carlos* moved away into the Indian Ocean.

Table 1. Best track summary for Severe Tropical Cyclone *Carlos*.
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 kn	Max gust kn	Central Pressure hPa	Rad. of Gales # nm	Rad. of storm force winds #	Radius Max. Wind ^ (RMW)
2011	2	19	00	15.5	129.1	15	15		1000			
2011	2	19	06	15.1	128.5	20	15		998			
2011	2	19	12	15.3	128.2	45	15		998			
2011	2	19	18	15.7	127.4	40	20	45	998			
2011	2	20	00	15.9	126.5	30	15		998			
2011	2	20	06	16.4	125.2	45	15		996			
2011	2	20	12	17.2	123.6	45	25	45	994			
2011	2	20	18	17.5	122.0	15	30	45	994			
2011	2	21	00	17.8	121.6	40	35	50	994	67.5		15
2011	2	21	06	18.5	120.2	15	35	50	994	80		25
2011	2	21	12	19.0	119.1	15	40	55	992	77.5		15
2011	2	21	18	19.5	118.4	15	45	65	987	77.5		10
2011	2	22	00	20.2	117.3	20	50	70	984	77.5	20	15
2011	2	22	03	20.6	117.0	30	50	70	980	70	45	15
2011	2	22	06	20.8	116.3	30	50	70	980	55	45	15
2011	2	22	12	21.2	115.4	15	60	85	978	62.5	40	10
2011	2	22	18	21.7	114.8	15	55	75	978	57.5	40	10
2011	2	23	00	22.1	114.1	10	50	70	978	70	45	10
2011	2	23	06	22.7	113.3	10	50	70	978	75	20	15
2011	2	23	12	23.0	112.5	15	55	75	978	75	20	15
2011	2	23	18	23.1	111.7	20	55	75	978	80	20	15
2011	2	24	00	23.8	110.8	15	55	75	978	80	20	15
2011	2	24	06	24.4	109.7	15	55	75	978	80	20	15
2011	2	24	12	24.8	108.6	15	60	85	974	80	20	15
2011	2	24	18	25.4	107.6	20	65	90	970	80	30	15
2011	2	25	00	26.1	106.8	20	60	85	969	80	30	15
2011	2	25	06	27.0	105.9	10	55	75	981	45	25	20
2011	2	25	12	27.8	105.5	15	50	70	980	80	25	15
2011	2	25	18	28.7	104.9	10	40	55	990	90		20
2011	2	26	00	29.6	104.3	20	35	50	993	60		20
2011	2	26	06	30.3	104.1	25	30	45	994			
2011	2	26	12	31.0	103.9	30	30	45	994			
2011	2	26	18	31.3	104.2	30	25	45	996			
2011	2	27	00	32.0	104.0	10	20	45	1000			

#Average of non-zero quadrants.

^Minimum distance to maximum mean wind in any quadrant.

Figure 3. Microwave (TC SSMIS 91GHz) image at 1135 UTC 15 February near time of gales and 53 knot wind gust at Darwin Airport.
Image courtesy of US NRL: <http://www.nrlmry.navy.mil/>

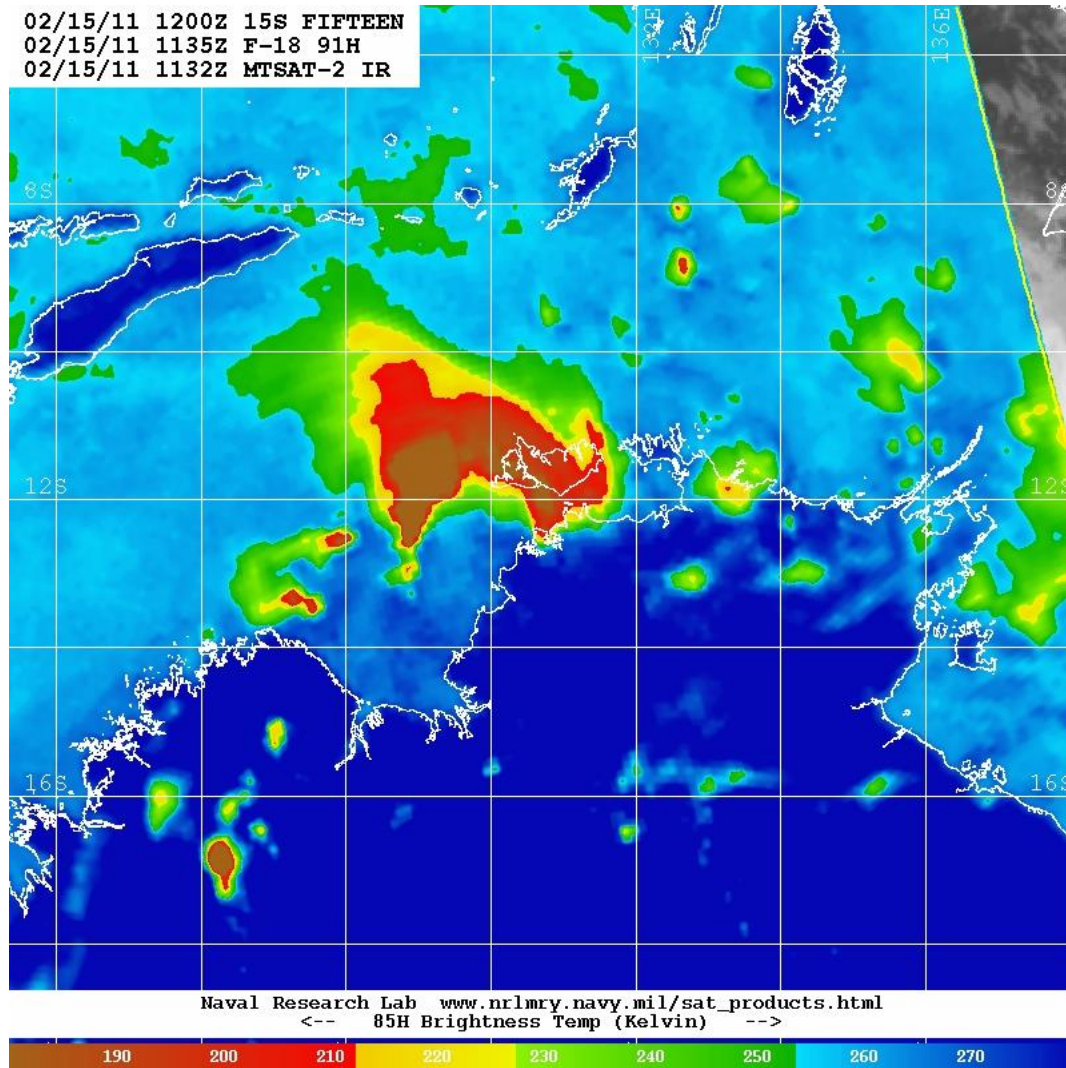


Figure 4. Sea surface temperatures for the period 21 – 27 February 2011

SST 1.0X1.0 NMOC OCEAN ANALYSIS (C) 20110221 20110227

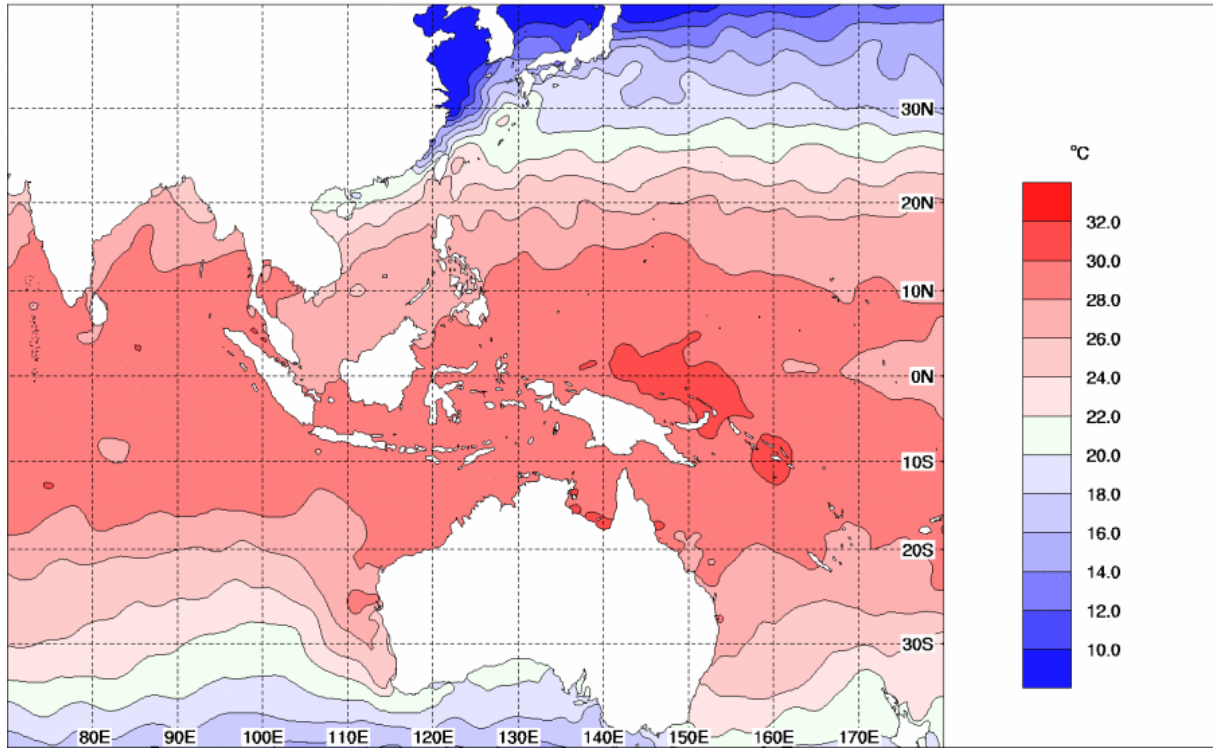


Figure 5. Seas surface temperature anomalies for the period 21 – 27 February 2011

SSTA 1.0X1.0 NMOC OCEAN ANOMALIES (C) 20110221 20110227

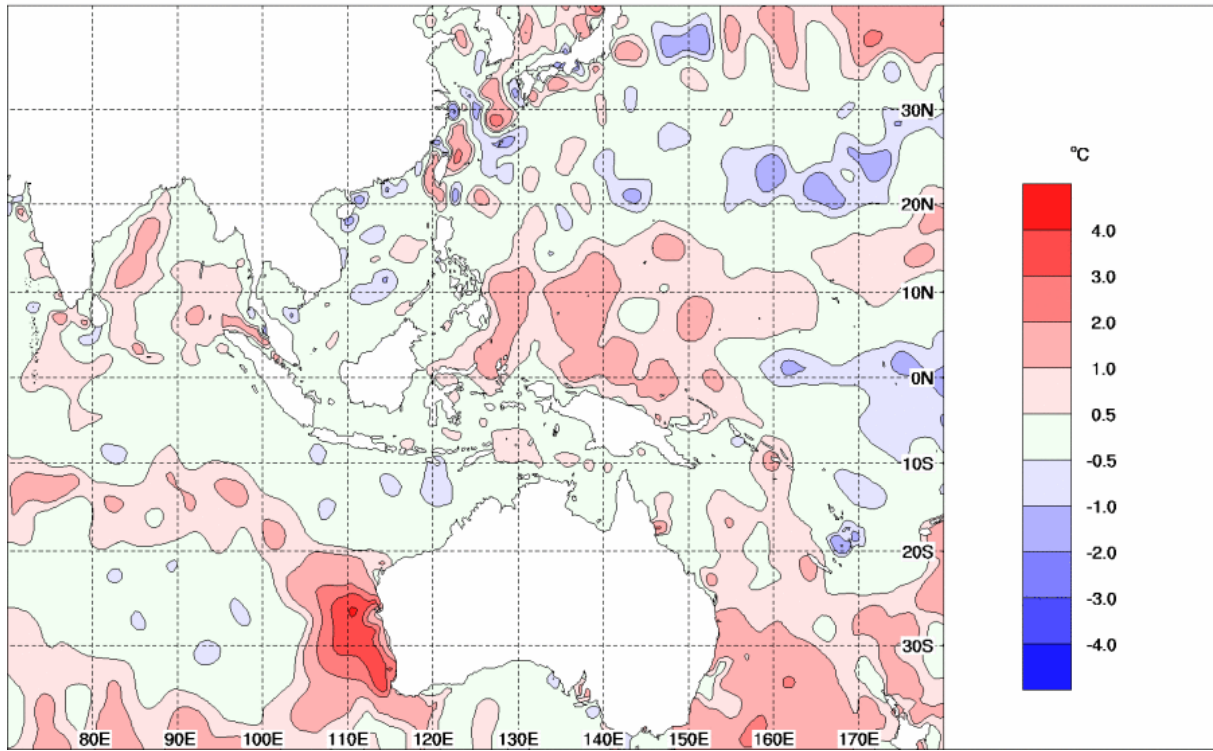


Figure 6. Microwave (TC SSMIS 91GHz) image at 1307 UTC 24 February near time of maximum intensity.

Image courtesy of US NRL: <http://www.nrlmry.navy.mil/>

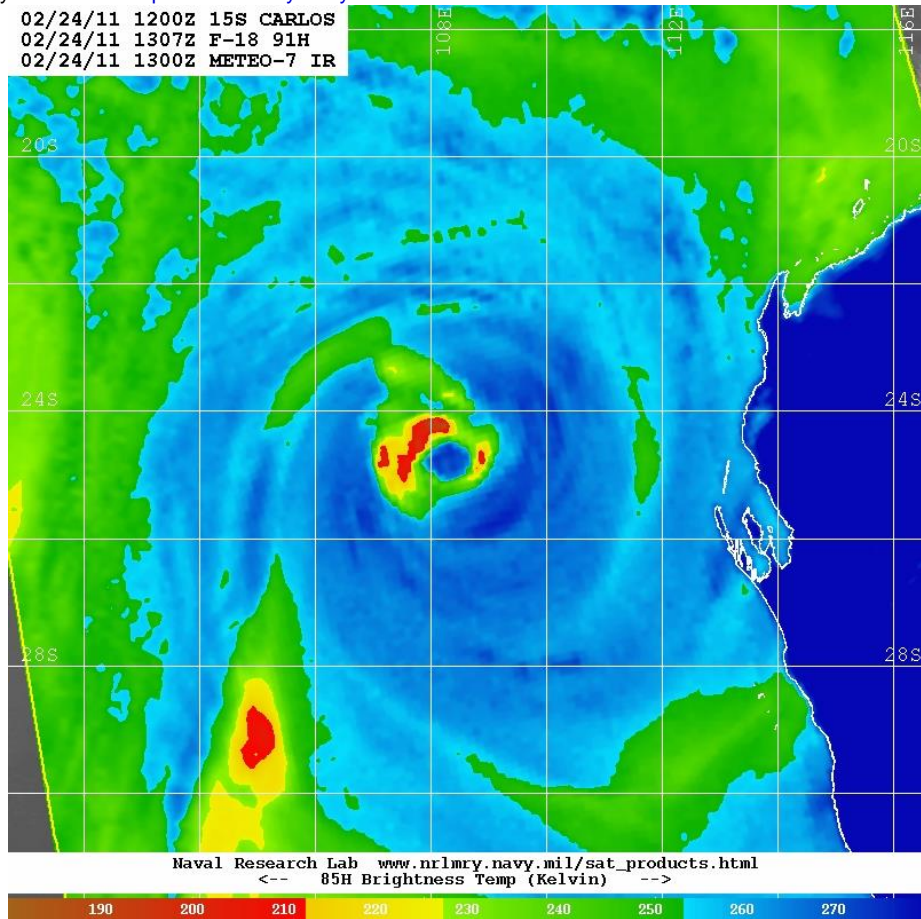


Figure 7. Comparison of objective and subjective intensity analysis techniques.

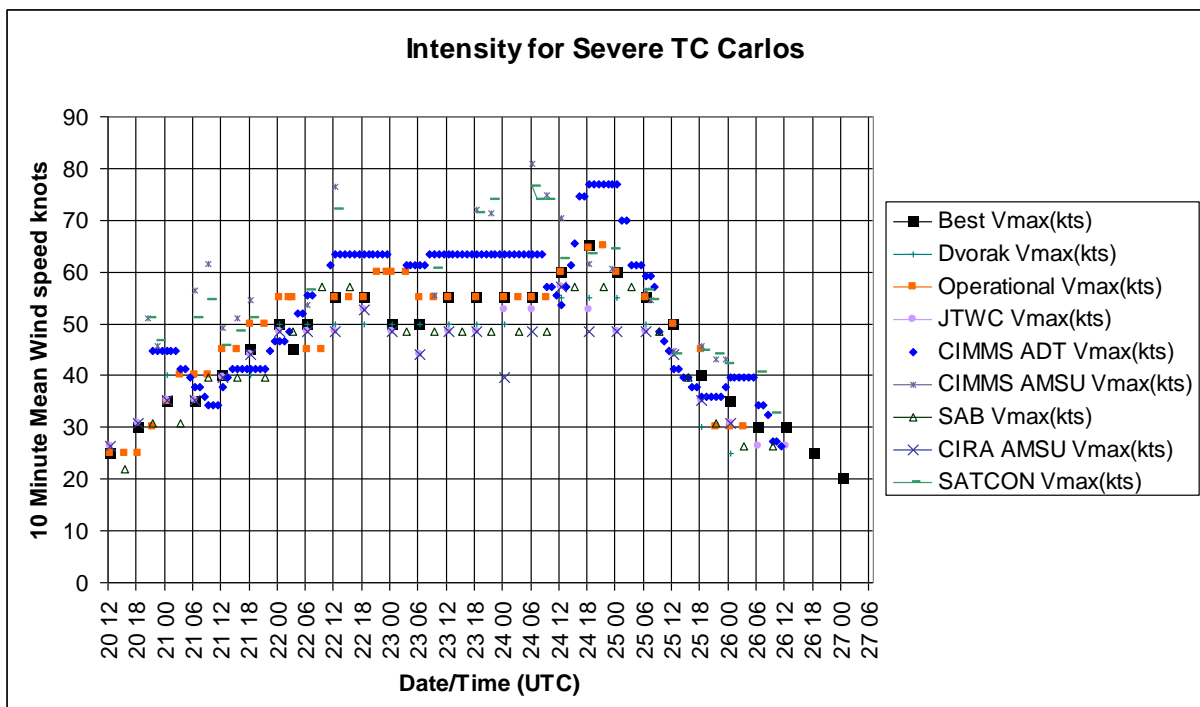


Figure 8. Berimah (Darwin) radar reflectivity image at 0830 UTC 16 February at the time of maximum intensity near Darwin and observed 35-40 kn gales at Fish Reef Marine AWS. Image courtesy of US NRL: <http://www.nrlmry.navy.mil/>

