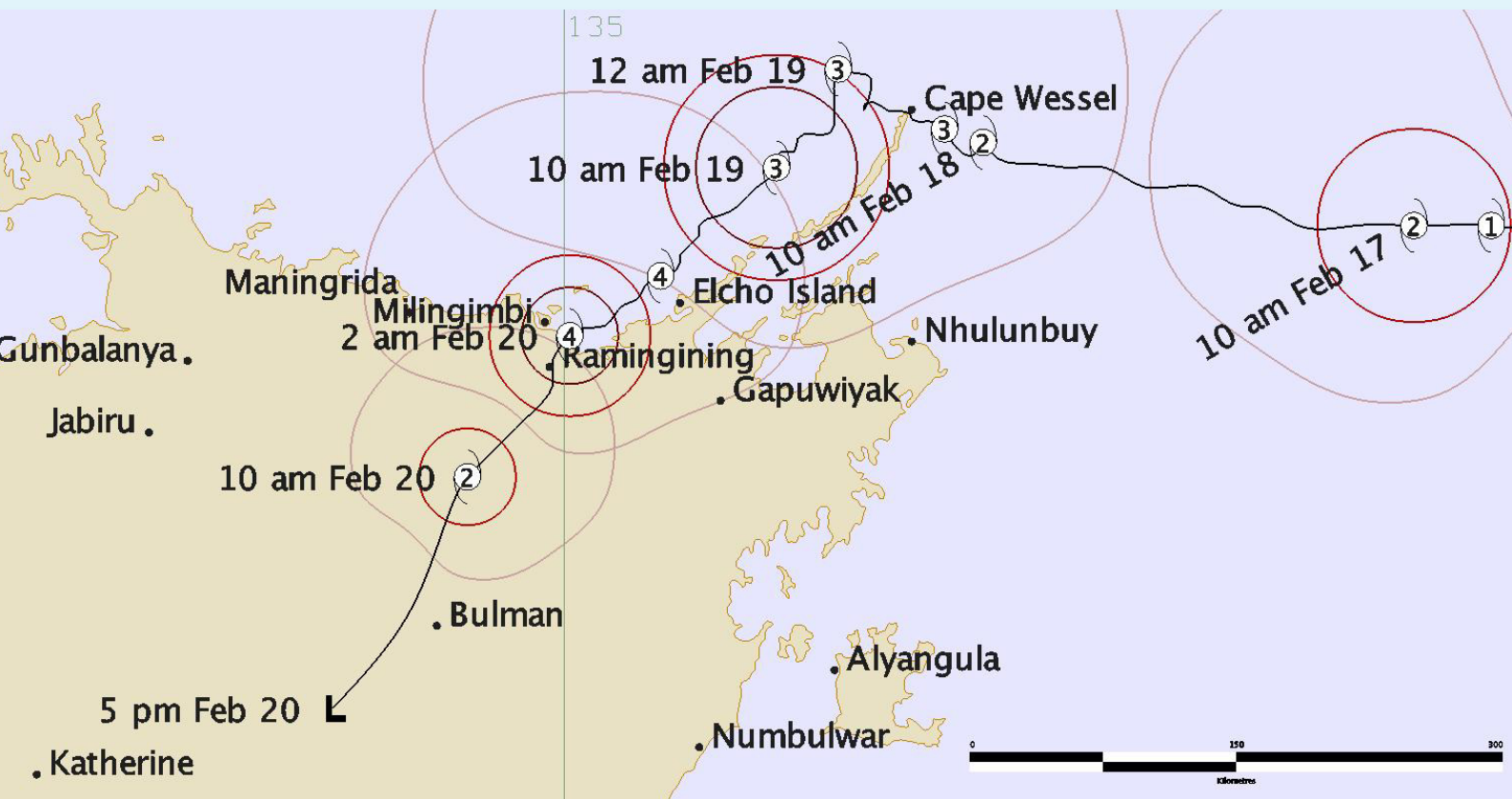




Australian Government
Bureau of Meteorology

Severe tropical cyclone *Lam* post-event report

Northern Territory Region



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Cover image: The observed track of severe tropical cyclone *Lam*.

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Executive summary

Severe tropical cyclone *Lam* was the first cyclone for the 2014–15 cyclone season in the Northern Region, and the first severe cyclone to cross the Northern Territory coast for nearly a decade. Perhaps most significantly, the destructive core of the cyclone impacted three relatively large Northern Territory communities—Galiwin'ku, Milingimbi and Ramingining.

The Bureau of Meteorology tracked the full life cycle of the system for some 11 days, issued 67 Tropical Cyclone Advises (including 54 consecutive hourly updates leading into landfall), 14 Severe Weather Warnings, 8 Flood Warnings and 7 Flood Watches.


The Gove and Warruwi radars provided high-quality, 10-minute radar image updates for forecasters and communities across north eastern Arnhem Land throughout the event.

Assessment of the recovered data from the Bureau's Automatic Weather Station network, as well as a survey of damage to infrastructure and vegetation in affected communities, suggests that Elcho Island and Milingimbi experienced low-end category 3 winds, while Ramingining likely experienced high-end category 3 winds.

An aerial survey of the remote areas surrounding the location of landfall suggests

that damage to coastlines and vegetation was more extensive than that observed in the communities of Galiwin'ku, Milingimbi and Ramingining. Indications from the damage assessment suggest that *Lam* was a category 4 cyclone at landfall.

The Bureau of Meteorology's Northern Territory Regional Office is pleased to present this report on severe tropical cyclone *Lam*.



Todd Smith
Northern Territory Regional Director

Scientific overview

Meteorology

On Sunday 15 February 2015, a tropical low over the northwest Coral Sea crossed Cape York Peninsula and entered the Gulf of Carpentaria. It developed quickly during Monday 16 and Tuesday 17 February as it moved slowly and steadily towards the west. The system was named tropical cyclone *Lam* at 3.30 am CST on Tuesday 17 February, whilst located over the northern Gulf of Carpentaria, about 340 km east of Nhulunbuy. *Lam* strengthened into a category 2 tropical cyclone by 9.30 am CST that same day.

Over the following 24 hours tropical cyclone *Lam* intensified slowly, continuing its westward movement towards the Wessel Islands, at a speed of 10–15 km/h. The nearest pass of tropical cyclone *Lam* to the major township of Nhulunbuy occurred at 10.00 am CST on Wednesday 18 February, when the category 2 cyclone was 115 km north of the township. At this time, mean winds in the destructive core of the intensifying cyclone were estimated to be 110 km/h, with gusts up to 155 km/h. However, gales were not reported at Gove Airport due to the compact nature of the cyclone.

Lam was upgraded to a category 3 severe tropical cyclone at 11.30 am CST on Wednesday 18 February, shortly before it passed directly over the Cape Wessel

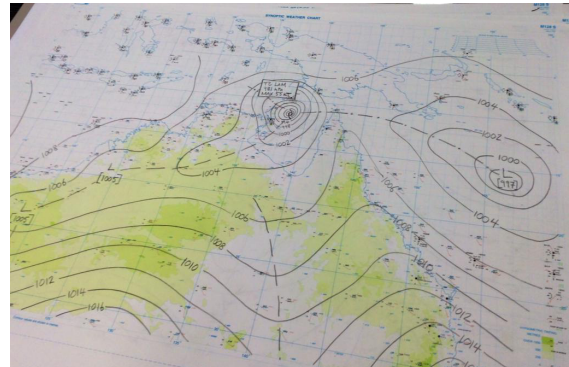


Figure 1. Weather chart for 3.30 am CST Wednesday 18 February 2015 showing tropical cyclone *Lam* located in the northern Gulf of Carpentaria.

Automatic Weather Station (AWS). Due to the slow movement of the cyclone, gale-force winds were experienced at Cape Wessel for a period of 30 hours, with a four-hour lull as the eye of the cyclone—50 km in diameter—passed over the station. Winds at Cape Wessel reached hurricane force (category 3) within both the leading and trailing eye walls. A minimum pressure of 971.1 hPa was recorded at 2.14 pm CST, and the maximum recorded wind gust was 170 km/h.

Severe tropical cyclone *Lam* took its predicted turn towards the southwest at around midnight on Wednesday 18 February. It then tracked parallel to the west coast of the Wessel Islands throughout Thursday 19 February, while intensifying further. Severe tropical cyclone *Lam* reached category 4 intensity at 7.30 pm CST that day, when located approximately 20 km north of Galiwin'ku, on Elcho Island.

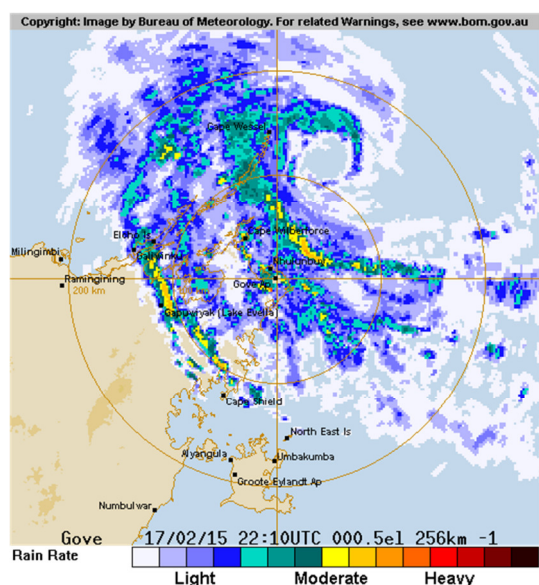


Figure 2. The Gove radar shows an impressive circulation as the eye of cyclone Lam approaches Cape Wessel on the morning of Wednesday 18 February.

Transmission of observations from the Automatic Weather Station (AWS) at Ngayawili, north of Galiwin'ku, was disrupted by a telecommunications failure during the impact of *Lam's* very destructive core. Fortunately, the observations were able to be retrieved several days after the event. Gales affected the Elcho Island community for approximately 21 hours from mid-afternoon Thursday until mid-morning Friday, with peak hurricane-force winds of 128 km/h, and a gust to 174 km/h, recorded at 9.30 pm CST Thursday 19 February. Importantly, Elcho Island was only 'grazed' by the outer bands of the core of the cyclone, as the inner eye wall remained just offshore. Therefore the Ngayawili AWS is unlikely to have sampled the

maximum winds from severe tropical cyclone
Lam.

Lam crossed the mainland coast around 2.00 am CST on Friday 20 February as a category 4 severe tropical cyclone, about 15 km northeast of Ramingining and 20 km southeast of Mililingimbi. At the time of landfall, estimated maximum mean winds were 185 km/h, with gusts reaching 260 km/h. Severe tropical cyclone *Lam*'s peak intensity was based on the emergence of a clear eye feature in satellite imagery shortly before landfall. Radars at Gove and Waruwi indicated that the eye wall may have contracted prior to landfall—a circular eye of 14 km in diameter was observed just to the east of Ramingining at around 3.30 am CST.

Over the course of the day on Friday 20 February, severe tropical cyclone *Lam* weakened rapidly as it moved southwest over central Arnhem Land. *Lam* was downgraded to

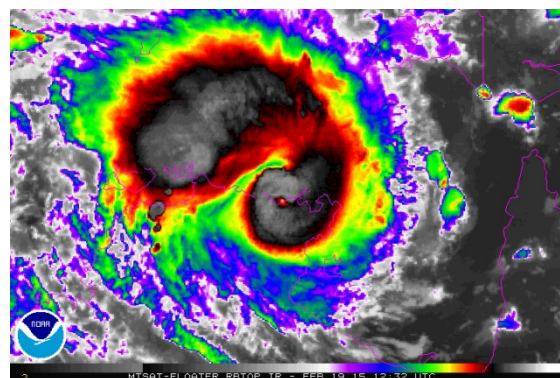


Figure 3. Colour enhanced MTSAT infra-red image of severe tropical cyclone Lam as it crossed the coast. (Source: NOAA/JMA)

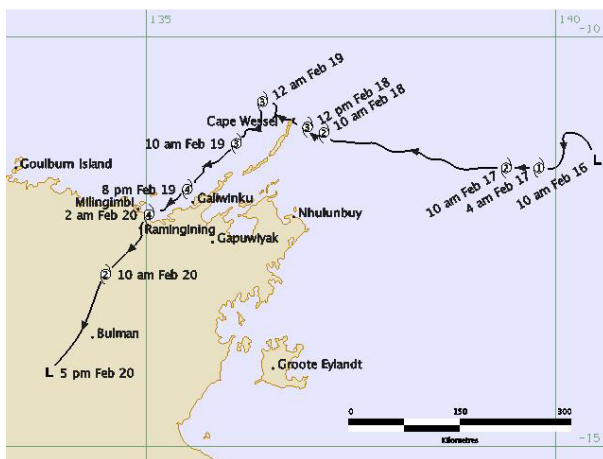


Figure 4. Observed track of severe tropical cyclone Lam over its lifetime.

below tropical cyclone strength at 4.30 pm CST on the Friday, approximately 75 km southwest of Bulman. The tropical system produced heavy rain over parts of the Arnhem, Carpentaria, Daly and Gregory forecast districts. 258.5 mm was recorded at Diljin Hill in the Waterhouse River catchment in the 24 hours to 9.00 am CST on Saturday 21 February. This contributed to moderate flooding of the Waterhouse River at Beswick Bridge.

Severe tropical cyclone *Lam* was the first tropical cyclone in the Northern Region for the 2014–15 season, and the first severe tropical cyclone to impact the Northern Territory coast since severe tropical cyclone *Monica* in April 2006.

Hydrology

Initial forecasts for tropical cyclone *Lam* indicated that significant rainfall totals were likely to be recorded in the Arnhem and Carpentaria Coastal Rivers basins. As the event unfolded and the forecast track for *Lam* became clearer, attention focused on the Waterhouse and Katherine Rivers as the main catchments likely to be affected. Flood watches issued for the Arnhem and Carpentaria Coastal Rivers basins on Tuesday 17 February indicated the potential for rainfall totals in the range of 200–300 mm.

Rainfall totals of 110–260 mm were recorded throughout the Waterhouse River catchment on 20 February 2015, following the landfall of severe tropical cyclone *Lam*.

River levels in the Waterhouse River at Beswick Bridge reached minor flood level (7.7 metres) early on the morning of Saturday 21 February 2015. The river peaked just under major flood level (8.30 m) at 8.298 m at 5.10 pm CST later that day, before receding below minor flood level on the morning of Sunday 22 February.

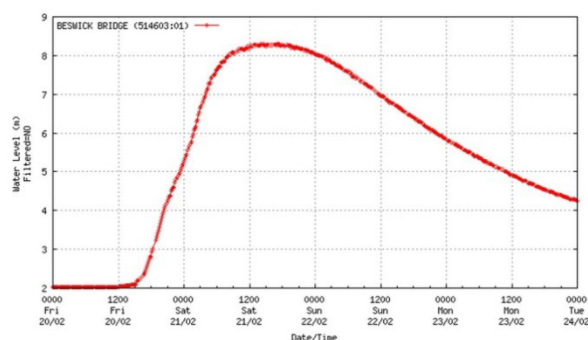


Figure 5. Time series of observed river heights at Beswick Bridge on the Waterhouse River. Moderate flooding resulted from heavy rain in the catchment.

Climate

The Madden–Julian Oscillation (MJO) was weak or indiscernible in the weeks prior to and including the development of tropical cyclone *Lam*, and is unlikely to have influenced tropical activity during this period.

The increase in monsoonal weather and tropical cyclone activity in the Australian region in the week of 16–22 February was likely due to a slow-moving equatorial Rossby wave. These atmospheric waves move slowly westwards and act to temporarily enhance thunderstorm activity and rainfall as they pass over a region. They also increase the likelihood of cyclone formation.

Tropical cyclones typically require sea surface temperatures (SSTs) of at least 26 °C to form. SSTs in the Gulf of Carpentaria and the Arafura Sea were in excess of 28 °C during the

cyclone *Lam* event, with some locations greater than 30 °C. These temperatures were near the climatological average for this time of year.

Records Broken

Tropical cyclone *Lam* brought heavy rainfall to eastern Arnhem Land. Gove Airport and the Alcan Mine Site both reported over half a metre of rainfall for the month, mostly attributed to tropical cyclone *Lam*.

Two sites set new daily rainfall records for February on Wednesday 18th as outer rainbands of the cyclone swept across the northeast coast:

- Yirrkala Tropical Gardens 178.0 mm
- Alcan Minesite 137.6 mm

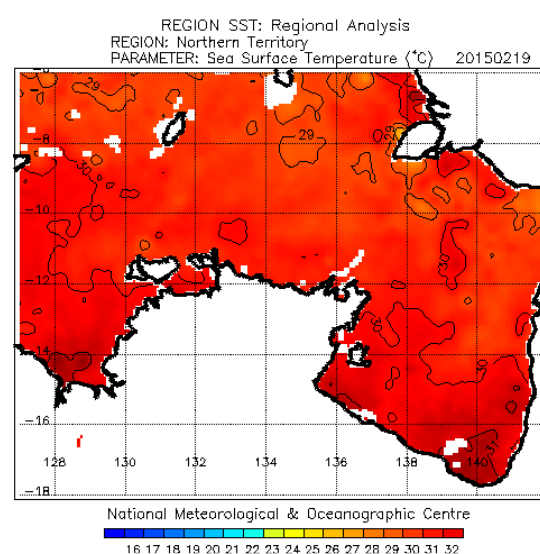


Figure 6. Observed sea surface temperatures in the Gulf of Carpentaria and Arafura Sea during cyclone *Lam*.

As tropical cyclone *Lam* moved inland after crossing the coast, two other Arnhem Land stations set new daily rainfall records for February on Thursday 20th:

- Bulman 105.8 mm
- Flying Fox 153.0 mm

A number of others set daily rainfall records for February on Friday 21st:

- West Waterhouse 135.8 mm
- Upper Waterhouse River 133.6 mm
- Cave Creek Station 140.0 mm
- Yeuralba Ridge 83.2 mm
- Mataranka Homestead Resort 136.2 mm

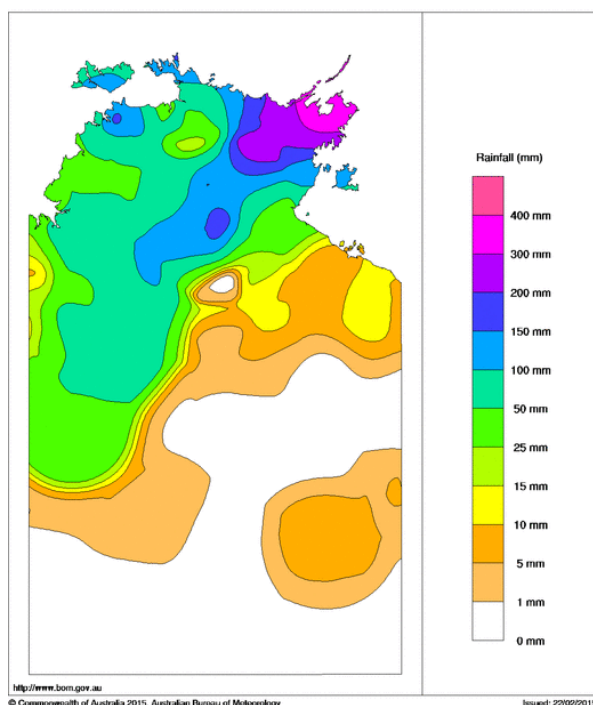


Figure 7. Northern Territory one-week rainfall totals for the week ending Sunday 22 February 2015.

Observed impacts

Cyclone impacts

Severe tropical cyclone *Lam* caused significant damage to infrastructure and vegetation at Galiwin'ku, Milingimbi, Ramingining and nearby outstations on the mainland. Immediate impacts to these communities following the passage of the cyclone included: loss of power, water and communications; contamination of water supplies by sewerage overflows; uninhabitable houses; and blocked access roads. Nhulunbuy and the Gove Peninsula escaped significant damage as *Lam* passed further to the north.

An assessment of damage at Galiwin'ku, Milingimbi and Ramingining was undertaken by Bureau of Meteorology staff on Wednesday 25 February, in conjunction with the Northern Territory Police and Emergency Services.



Figure 8. NT Chief Minister Adam Giles, Nathan Barrett MLA, NTES Director, Andrew Warton, and NT Police commissioner, Reece Kershaw in Galiwin'ku during the recovery from cyclone *Lam*. (Source: NT Government)



Figure 9. Rachel Yunupingu, Erica Dhamarnandji, Vivien D, Rosita Gurriwiwi and Abigail D in Galiwin'ku during recovery from cyclone *Lam*. (Source: ABC News—Steven Schubert)

Residents in these three communities were hardest hit, but remarkably no deaths and only a few minor injuries were recorded. This is testament to the communication of warnings and assistance provided in these communities by Police, Emergency Services and community leaders. Several residents reported that severe tropical cyclone *Lam* was the worst in living memory, apart from those who had experienced Cyclone Tracy in Darwin, in 1974.

Hurricane-force winds caused damage to older structures in all three communities. However, most modern housing came through the event largely unscathed.

Significant damage was also inflicted on houses, power lines and other infrastructure by downed trees and airborne branches. The surrounding savanna vegetation was severely affected, with felled and snapped trees

widespread throughout the area near the path of the cyclone core.

Aerial photos were taken during transit between the three communities, as well as on the ground, to aid assessment of vegetation and building damage together with storm surge impacts.

Galiwin'ku

Beach erosion around smaller islands on the approach to Galiwin'ku suggested a storm tide exceeding Highest Astronomical Tide (HAT). On the ground, debris lines were identified around 2 m above HAT level along the bay to the west of the community.

Savanna trees still had some foliage and small branches, with defoliation estimated at around 30 per cent. Aerial views of the area suggested that less than 50 per cent of trees in the surrounding savanna were felled by the cyclone.



Figure 10. Debris extending approximately 2m above HAT along the shoreline at Galiwin'ku.



Figure 11. Damage to vegetation and infrastructure in Galiwin'ku.

Trees had been snapped in half in some locations around the community, primarily in open areas exposed to the strongest wind gusts. Several coconut palms had fronds crimped and forced through the crown of the tree. The direction of tree fall was consistently from the southeast. This suggests that damage was inflicted during the onset of hurricane-force wind gusts as the cyclone approached, probably assisted by tree root failure in wet soil.

Overall, the damage assessment was indicative of a low category 3 impact at Galiwin'ku, using the vegetation damage indicators described in [Cook and Goyens 2008](#) and [Guard and Lander \(1999\)](#). This impact assessment is consistent with the speed of the maximum wind gust recorded at the Ngayawili AWS of 174 km/h.

Milingimbi

Fewer trees were felled, and defoliation was lesser in extent around Milingimbi itself, when

compared to Galiwin'ku. Most felled trees were in exposed locations and had shallow root systems. Some coconut trees had some palm fronds crimped and pushed backwards, but not all the way through the crown. Damage to weak structures was clearly evident but most buildings remained intact, except where trees had fallen on them. The direction of tree fall was consistently from the southwest.

An assessment of debris at the high tide mark suggested a storm surge of around 0.5-1 m above HAT. The smaller surge than at Galiwin'ku is not surprising given that the community was on the western flank of the cyclone, where winds were directed offshore.

Ramingining

Aerial views en route to Ramingining from Milingimbi indicated extensive damage to savanna vegetation. An estimated 50 per cent of trees close to Ramingining were felled or



Figure 12. Debris extending approximately 0.5–1.0 m above HAT along the shoreline at Milingimbi.



Figure 13. Defoliation and felled trees just north of Ramingining.

snapped, while the other half remained standing with some small branches remaining attached.

Defoliation was quite evident in the community itself, with some trees missing branches and otherwise stripped completely. Most larger trees were felled or damaged, with a consistent direction of fall from the south. Large, exotic trees such as the African mahogany caused significant damage as they toppled onto houses, vehicles and power lines.

Anecdotal reports from residents in Ramingining confirmed an easing in strength, and change of direction, of the wind during the passage of the eye of the cyclone.

One resident described the noise of the wind as similar to a freight train or jet engine, sufficient to mask the sound of the roof of his house being lifted off.



Figure 14. Damage to infrastructure and vegetation in Ramingining. (ABC News—Steven Schubert)

The duration of very destructive winds at Ramingining may have been shorter than at Galiwin'ku, but slightly greater damage to vegetation at Ramingining indicates winds were at the high end of the category 3 range.

Severe tropical cyclone *Lam* crossed the coast to the west of Howard Island, at a remote location approximately 15 km northeast of Ramingining. Initial aerial views of this area were obtained while en route from Galiwin'ku to Milingimbi.



Figure 15. Felled trees in Ramingining.

Beach scarps present in this area were indicative of erosion associated with the storm tide. It is likely that a full survey at ground level of vegetation damage in this remote area may indeed reveal that even stronger winds were experienced near the point of coastal crossing.

Flooding

Three homes in low-lying parts of Beswick in southwest Arnhem Land reported water entering the premises during moderate flooding of the Waterhouse River on Saturday 21 February. This riverine flooding was caused by heavy rainfall in the Waterhouse catchment as *Lam* tracked inland across Arnhem Land and weakened into a tropical low.

Forecast and warning services

Tropical Cyclone Warning Centre

The Darwin Tropical Cyclone Warning Centre began tracking a developing low pressure system in the Coral Sea on Tuesday 10 February. The likelihood of cyclone formation in the Gulf of Carpentaria was first communicated in the Tropical Cyclone Outlook issued on Thursday 12 February, indicating a moderate chance (20–50 per cent) of a cyclone forming on Tuesday 17 February.

The first Tropical Cyclone Watch for the developing tropical low in the northeastern Gulf of Carpentaria was issued at 2.27 pm CST on Monday 16 February. The areas under watch covered the northwestern coast of Cape York Peninsula (Queensland) and the eastern coast of Arnhem Land, including Groote Eylandt.

Although the Tropical Cyclone Watch for the Queensland area was cancelled later the same evening, a Tropical Cyclone Watch was maintained for the Arnhem coast. A marine Strong Wind Warning for the western Gulf of Carpentaria commenced earlier that day, at 4.45 am CST Monday 16 February. This was upgraded to an ocean gale warning at 5.00 pm CST that afternoon, and then further to a storm force wind warning at 5.30 am CST on Tuesday 17 February.

The first Tropical Cyclone Warning for the northeast Arnhem Land coast was issued at

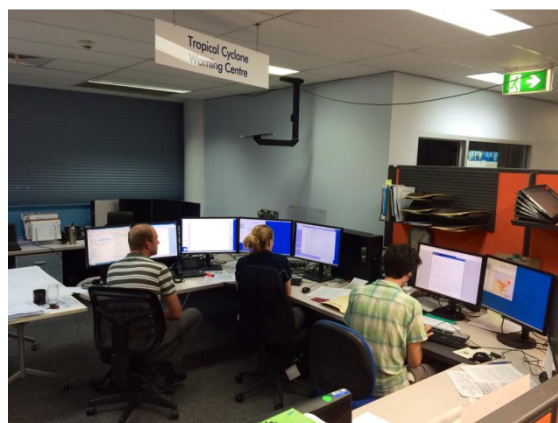


Figure 16. Darwin Tropical Cyclone Warning Centre forecasters at work at around 6.00 am CST Wednesday 18 February.

10.57 am CST on Tuesday 17 February, as tropical cyclone *Lam* intensified into a category 2 system. A corresponding Marine Hurricane-force Wind Warning was issued at the same time.

Hourly Tropical Cyclone Warnings were initiated at 6.00 am CST on Wednesday 18 February as *Lam* moved into range of the Gove radar, and the potential threat to the township of Nhulunbuy increased. The warning also included the first advice of dangerous storm tides in coastal regions near the forecast landfall location, which at that time was expected to be between Elcho Island and Nhulunbuy.

In total, a continuous series of 54 hourly warnings for *Lam* were issued between 6.00 am CST Wednesday 18 February and 11.00 am CST Friday 20 February.

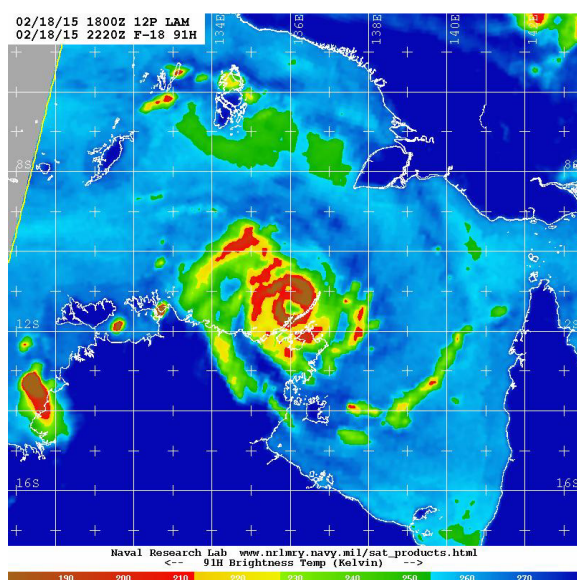


Figure 17. Microwave satellite image of severe tropical cyclone *Lam* as it approached the northeast Top End coast on Thursday 19 February (Source: US NRL/NOAA)

Tropical Cyclone Advises ended at 4.15 pm CST Friday 20 February as *Lam* was downgraded to a tropical low.

Severe Weather Warnings for flash flooding across the Top End and abnormally high tides along the Gulf of Carpentaria coast continued until 4.00 pm CST Sunday 22 February.

Flood Forecasts and Warnings

An initial Flood Watch for the Arnhem and Carpentaria Coastal River basins was issued at 11.56 am CST on Tuesday 17 February, indicating the potential for rainfall totals of 200–300 mm.

A Flood Warning for the Waterhouse River was first issued at 6.46 pm on Friday 20 February 2015. This was upgraded to a warning for moderate flooding at 7.52 am CST the following morning.

The Flood Warning for the Waterhouse River was ended at 6.58 pm CST on Sunday 22 February. The Flood Watch was ended at 12.53 pm CST on Monday 23 February.

Over the course of the event, a total of eight Flood Warnings and seven Flood Watches were issued for basins including the Bonaparte, North West, Arnhem and Carpentaria Coastal Rivers.

Forecast verification

Overview

The tropical cyclone warning system performed well during the severe tropical cyclone *Lam* event. Both the track and intensity of the cyclone were particularly well forecast by the Darwin Tropical Cyclone Warning Centre during the critical 48 hours prior to landfall along the Arnhem Land coast (e.g. Fig. 18).

The primary forecasting challenges during severe tropical cyclone *Lam* were associated with the forecast track in the early stages, and then the intensity and gale radii in the later stages.

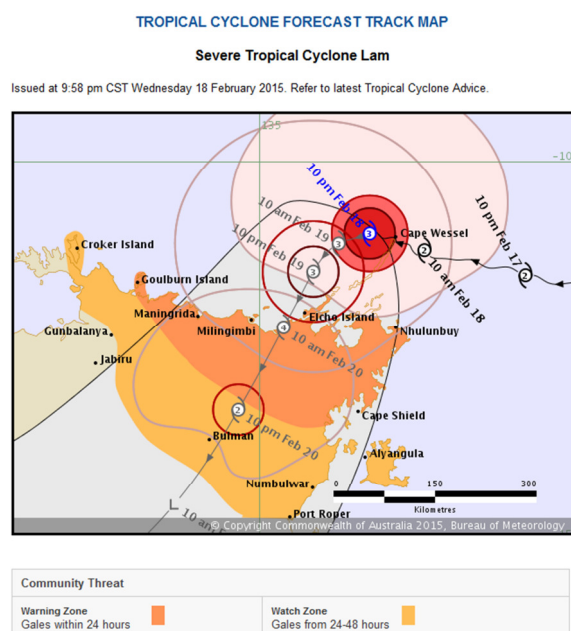


Figure 18. Forecast track map for severe tropical cyclone *Lam* issued at 9.58 pm CST Wednesday 18 February—36 hours prior to landfall—showing the projected impact of a category 4 cyclone along the northeast Top End coast between Milimbi and Elcho Island.

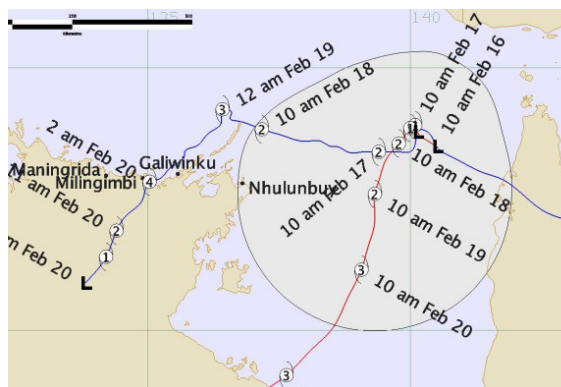
There was also a simultaneous increase in the potential for rapid intensification of the cyclone prior to landfall.

Track forecasts

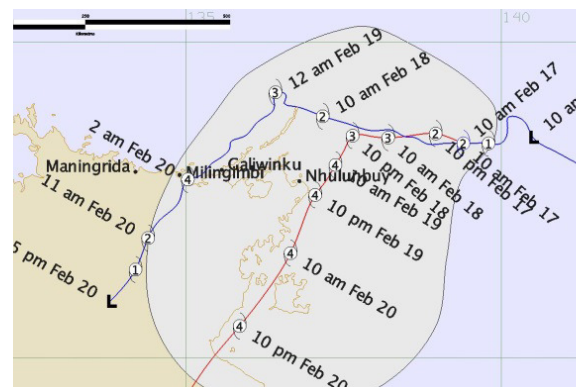
During the early stages of the event in the Gulf of Carpentaria, there was a high level of uncertainty in the forecast track for *Lam*.

The forecast track map at 10.00 am CST Monday 16 February (Fig. 19a) showed that the developing tropical low, later to become tropical cyclone *Lam*, was most likely to move in a southwesterly direction towards the southern Gulf of Carpentaria coast. A very broad three-day uncertainty area was included to account for large variations in computer model forecasts, which included possible tracks west towards northeast Arnhem Land, and even back towards Cape York Peninsula to the east. Despite the forecast track map accounting for these uncertainties, the actual track eventually taken by *Lam* departed from the three-day uncertainty area after approximately 48 hours (Fig. 19a).

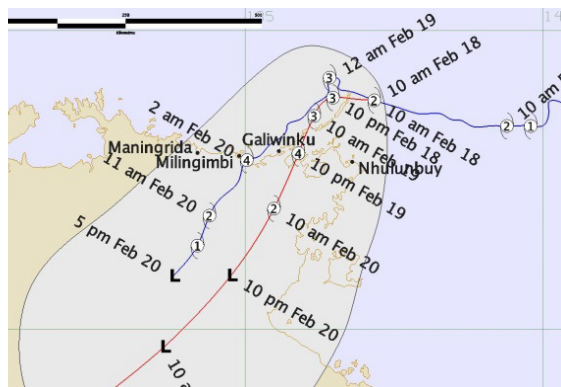
Across the remainder of Monday 16 February and during Tuesday 17 February, confidence increased that *Lam* would take a track towards the west and then make a sharp turn towards the southwest. The extent of the threat to northeast Arnhem Land communities from



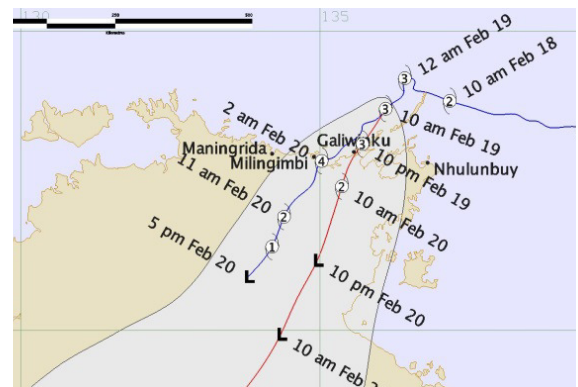
(a)



(b)



(c)



(d)

Figure 19. Red lines show official forecast tracks for Lam issued at: (a) 10.00 am CST Monday 16 February, (b) 10.00 am CST Tuesday 17 February, (c) 10.00 am CST Wednesday 18 February and (d) 10.00 am CST Thursday 19 February. Blue lines show the actual observed track taken by Lam. Grey shading shows the three-day forecast track uncertainty area for each forecast.

severe tropical cyclone *Lam* depended on the timing and location of the cyclone's southwest turn towards the coast. The timing and location of the turn proved challenging to forecast because of uncertainty in the forecast speed of westward movement through the northern Gulf of Carpentaria.

Tropical Cyclone Advises issued prior to 10.00 pm CST Tuesday 17 February reflected a forecast of initially slow westward movement,

placing coastal areas along the Gove Peninsula and western Gulf of Carpentaria under threat. The forecast track uncertainty area in these forecasts remained large.

Tropical cyclone track forecasts issued from 10.00 pm CST Tuesday 17 February onwards incorporated a faster speed of westward movement, and an increasingly reduced forecast track uncertainty area, as computer model guidance settled on a consistent outlook.

After 10.00 pm CST Tuesday 17 February, successive official forecast tracks (see Fig. 19b–d) consistently projected landfall of a category 4 cyclone along a small section of coast between Milingimbi and Gapuwiyak, with a significant risk of impact on Elcho Island and adjacent mainland communities, either late night Thursday 19 February or early morning Friday 20 February.

The timing of the critical southwest turn of the cyclone track towards the coast was accurately forecast with a lead time of 36 hours.

Track and intensity forecast verification statistics

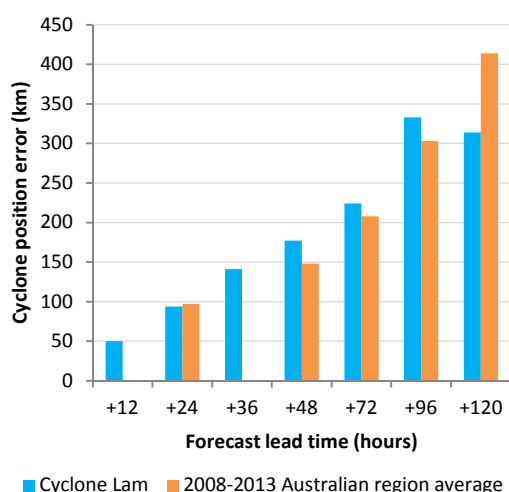
The performance of track position and intensity forecasts for severe tropical cyclone *Lam* was consistent with the current Australian region forecast error statistics (Table 1).

Average forecast position errors for *Lam* (Table 1; shown graphically in Fig. 20a) were close to the Australian region five-year average error for most forecast time steps. For forecasts beyond the +48h time step, errors in forecasts for *Lam* were generally larger than the five-year averages, which may be attributable to the significant uncertainty associated with the timing of *Lam*'s turn towards the southwest.

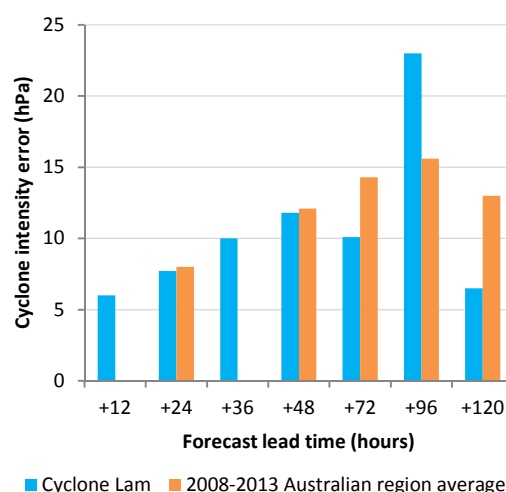
Average intensity forecast errors for severe tropical cyclone *Lam* (Table 1; shown graphically in Fig. 20b) were less than the Australian region five-year average error at most time steps. With the exception of the +96 h forecast time step, the longer lead time intensity forecast errors for *Lam* at +72 h and +120 h outperformed the five-year averages significantly, while the short-term +24 h and +48 h forecast intensity errors were comparable to the five-year average errors.

Forecast lead time (hours)	+12	+24	+36	+48	+72	+96	+120
Position error (km)							
<i>Lam</i> average	50	94	141	177	224	333	314
Australian region average (2008–2013)	n/a	97	n/a	148	208	303	414
Intensity error (hPa)							
<i>Lam</i> average	6.0	7.7	10.0	11.8	10.1	23.0	6.5
Australian region average (2008–2013)	n/a	8.0	n/a	12.1	14.3	15.6	13.0

Table 1. Verification statistics for +12h to +120h forecasts. Track position and intensity forecast error magnitudes for severe tropical cyclone *Lam* are compared to the Australian region five-year average (2008–2013) cyclone position and intensity forecast error magnitudes. Position errors at each forecast time step are rounded to the nearest whole km.



(a)



(b)

Figure 20. Average forecast error statistics for cyclone *Lam*, compared to the Australian region five-year average cyclone forecast error statistics: (a) forecast track position error statistics, in km, and (b) average forecast intensity error statistics, in hPa.

Marine forecasts and warnings

The first Marine Gale Warning was issued at 4.50 pm CST Monday 16 February for gales to develop within 12–18 hours. Gales were observed at 3.30am CST Tuesday 17 February, when category 1 tropical cyclone *Lam* was first named. This was approximately 11 hours after the warning was first issued.

The first Storm-force Wind Warning was issued at 5.30 am CST Tuesday 17 February for storm-force winds to develop within 12 hours. Storm-force winds were observed approximately four hours later at 9.30 am CST Tuesday 17 February as tropical cyclone *Lam* reached category 2 intensity.

The first Hurricane-force Wind Warning was

issued at 11.00 am CST Tuesday 17 February for hurricane-force winds to develop within 24 hours. Hurricane-force winds were first observed 24 hours later at 11.00 am CST Wednesday 18 February as *Lam* reached category 3 intensity.

Very high seas of around 8–9 m were forecast close to the centre of severe tropical cyclone *Lam* at its maximum intensity on 18 and 19 February, decreasing to 3–4 m around the periphery of the cyclone. No observations exist from close to the cyclone centre to verify these predictions, but reports on 17, 18 and 19 February from ships on the periphery of the cyclone provided sea state estimates of 3–5 m in the northern semicircle, at a range of 110–150 nautical miles from the cyclone centre.

Tropical Cyclone Watches and Warnings for specific locations

During the course of the event, Tropical Cyclone Watches were issued for the Top End coastline between Croker Island and Port Roper, as well as offshore islands including Goulburn Island, Elcho Island and Groote Eylandt. Tropical Cyclone Warnings were issued for coastal areas from Goulburn Island to Groote Eylandt and areas of Arnhem Land inland as far as Bulman. This included the major communities of Waruwu, Maningrida, Milingimbi, Ramingining, Galiwin'ku, Gapuwiyak, Nhulunbuy and Alyangula.

Nhulunbuy

The first Tropical Cyclone Watch for Nhulunbuy was issued at 2.00 pm CST Monday 16 February, approximately 40 hours before the strongest winds were observed at Gove Airport.

A Tropical Cyclone Warning for Nhulunbuy was issued at 5.00 am CST Tuesday 17 February in anticipation of gale force winds developing within the following 24 hours, and for the possibility of very destructive winds with gusts greater than 170 km/h (category 3 threshold) developing within 36 hours. The warning was maintained throughout Tuesday, and Wednesday morning, because of the risk that the outer perimeter of *Lam*'s very destructive

core could impact Nhulunbuy as it turned towards the southwest.

Tropical cyclone *Lam* passed 115 km to the north of Nhulunbuy at around 10.00 am CST Wednesday 18 February at category 2 intensity, with the area of strongest winds remaining offshore. The warning for very destructive winds for Nhulunbuy was downgraded to a warning for gale-force winds at 11.00 am CST Wednesday 18 February, and then maintained until 8.00am CST Friday 20 February once the cyclone had made landfall well to the west of the township.

At the conclusion of the event, the area of cyclone-strength, gale-force winds surrounding *Lam* traversed just to the north and west of Nhulunbuy, meaning that the township and surrounding nearby communities experienced only fresh and squally winds, accompanied by very heavy rainfall.

Galiwin'ku (Elcho Island)

The first Tropical Cyclone Watch for Galiwin'ku, on Elcho Island, was issued at 5.00 am Tuesday 17 February. This provided the community with a lead time of approximately 54 hours before gale-force, cyclone-strength winds were observed at the Ngyawili AWS, located close to the town.

The first Tropical Cyclone Warning for Galiwin'ku was issued at 11.00 am Tuesday 17

February, approximately 50 hours prior to the commencement of observed gales. This advice also indicated the possibility of very destructive winds with gusts greater than 170 km/h developing within the following 36 hours, as well as warning for a very dangerous storm tide.

Destructive winds commenced at Galiwin'ku at approximately 4.00 pm Thursday 19 February, but the strongest winds associated with the very destructive core of the category 4 cyclone are estimated to have remained offshore as it passed just to the west of Galiwin'ku. The strongest wind gust recorded at Ngyawili AWS was 174 km/h, which corresponds to a low-end category 3 cyclone intensity impact.

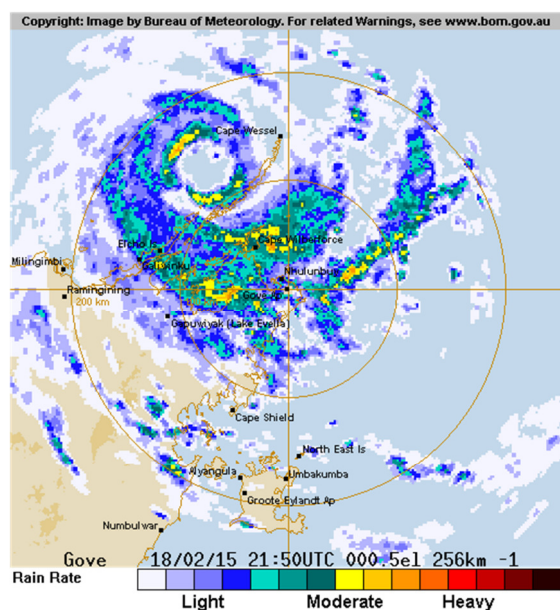


Figure 21. The Gove radar showed the eye wall of cyclone Lam tracking along the Wessel Islands, towards Elcho Island, on Thursday 19 February.

Milingimbi

Milingimbi was placed under a Tropical Cyclone Watch at 5.00 am CST Tuesday 17 February, which was upgraded to a Tropical Cyclone Warning at 5.00 pm CST the same day. Very destructive winds with gusts greater than 170 km/h were first warned for Milingimbi at 11.00 pm CST Tuesday 17 February, and then upgraded on Thursday 19 February for gusts up to 230 km/h (category 4 intensity) near the intensifying cyclone centre as it approached the coast.

It is estimated that the Milingimbi community was provided with approximately 66 hours lead time from the time of issue of the Tropical Cyclone Watch, and 54 hours lead time from the time of issue of the Tropical Cyclone Warning, ahead of the commencement of gale-force, cyclone-strength winds. However, the timing of gale onset at Milingimbi is an estimate only, due to the cessation of data transmission from the Milingimbi AWS at 11.00pm CST Thursday 19 February, shortly after winds became dangerously gusty.

A post-event damage assessment suggested that peak wind gusts in Milingimbi were associated with the periphery of the cyclone, within the category 2 intensity range (125–155 km/h). However this is an estimation only, in the

absence of AWS wind observations from Milingimbi during the period of strongest winds.

Ramingining

Due to its close proximity, the timings and details of Tropical Cyclone Watches and Warnings for Ramingining were the same as for Milingimbi. In contrast to Milingimbi, though, Ramingining was impacted directly by the very destructive core of the cyclone. A post-event damage assessment indicated peak winds at high-end category 3 intensity range, and accordingly, significantly greater damage to trees and structures than at Milingimbi.

There is no AWS located near Ramingining to provide wind speed observations.

Maningrida, Warruwi (South Goulburn Island) and Minjilang (Croker Island)

Tropical Cyclone Warnings for Maningrida and Warruwi, and Tropical Cyclone Watches for Minjilang, were issued at various times on

Wednesday 18 February and Thursday 19 February as cyclone *Lam* tracked westward, offshore.

Cyclone-strength winds were not observed at these communities, and there were no significant impacts from severe tropical cyclone *Lam*.

Alyangula, Numbulwar and Port Roper

Groote Eylandt and the western Gulf of Carpentaria coast were placed under a Tropical Cyclone Watch early on Tuesday 17 February, and then under Warning at various times until Friday 20 February, accounting for the possibility that *Lam* may have turned southward and moved over Gulf of Carpentaria waters.

As *Lam* eventually tracked to the west, and away from the Gulf of Carpentaria, these communities did not experience cyclone-strength winds and were not directly affected by *Lam*.

Location	Lead time provided to communities ahead of observed cyclone-strength winds	
	Cyclone Watch	Cyclone Warning
Galiwin'ku (Elcho Island)	54 hours	50 hours
Milingimbi	66 hours	54 hours
Ramingining	66 hours	54 hours

Table 2. Lead time provided to communities ahead of onset of cyclone-strength winds (gale force) at each location, from the issue times of the first Cyclone Watch and Cyclone Warning products.

Observing systems

Radar network

High-quality radar image updates at ten-minute frequency were available for forecasters and communities across northeast Arnhem Land.

Routine maintenance performed on the three Bureau radars at Gove, Waruwi and Tindal in the lead-up to the cyclone season contributed to consistent and uninterrupted operation throughout the event.

Automatic weather station network

Both Milingimbi and Cape Wessel AWSs experienced outages due to low battery voltage. Dense cloud cover for several days reduced the capability of the solar panels to recharge the batteries during daylight hours.

The interruption to transmission of data from the AWS at Ngayawili (Elcho Island) was primarily due to a telecommunications failure during the cyclone. Technicians were able to recover the untransmitted data manually once communications were restored.

Flood monitoring network

The flood monitoring network of rain gauges and river-level gauges performed well and experienced no outages.

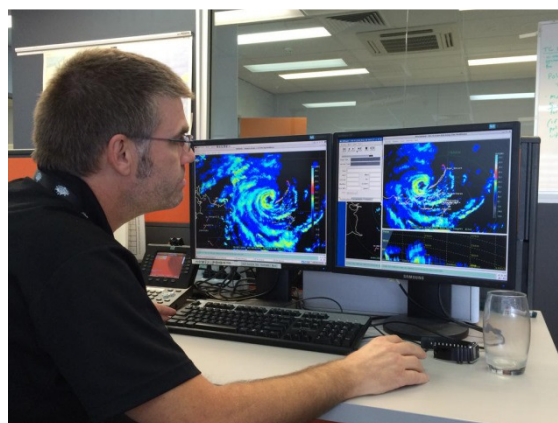


Figure 22. A specialist tropical cyclone forecaster monitoring severe cyclone Lam on radar.

The Northern Territory Department of Land Resource Management increased the frequency of reporting from the river gauge at Beswick Bridge during the event, providing more precise and timely updates of river levels. This greatly assisted the prediction and monitoring of moderate flooding in the Waterhouse River.

References

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