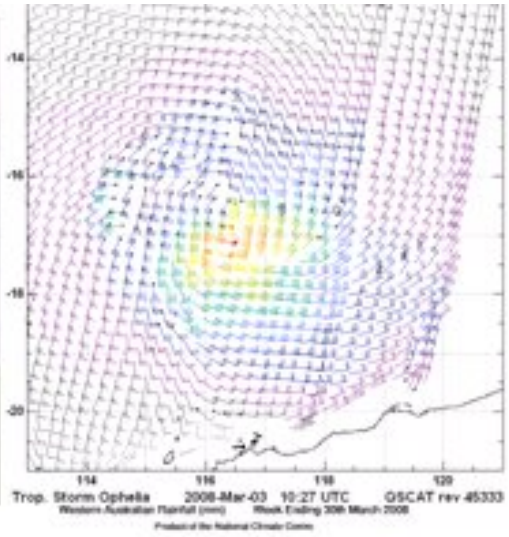
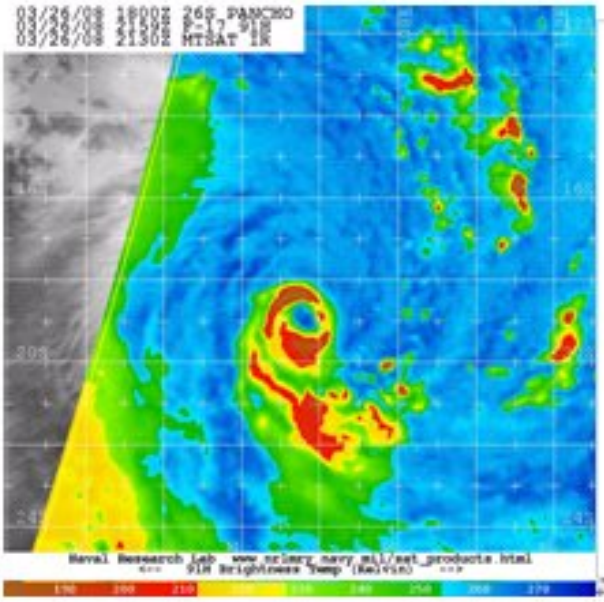
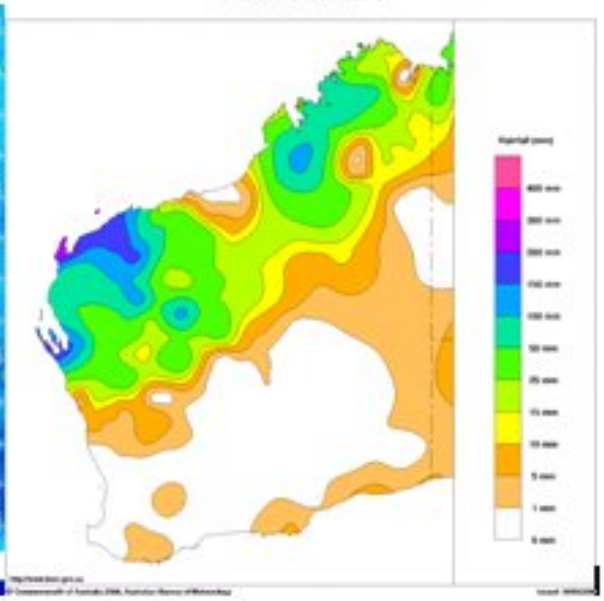
Australian Government

Bureau of Meteorology

# Tropical Cyclone Season Summary
# Western Australian Region
# 2007 – 2008



# Table of Contents

## Season Overview

There were a total of eight Tropical Cyclones (TCs) in the Perth TCWC area of responsibility from July 2007 to June 2008. Of these, *Melanie*, *Nicholas*, *Ophelia* and *Pancho* occurred in the Northwest region between 110-125°E. *Pancho* and *Nicholas* were the only severe TCs (category 3 or higher), *Pancho* reaching category 4 intensity. The only TC to cross the Western Australian coastline was *Nicholas* as a weak category 1 cyclone south of Coral Bay on the upper west coast, although there was only minimal damage.

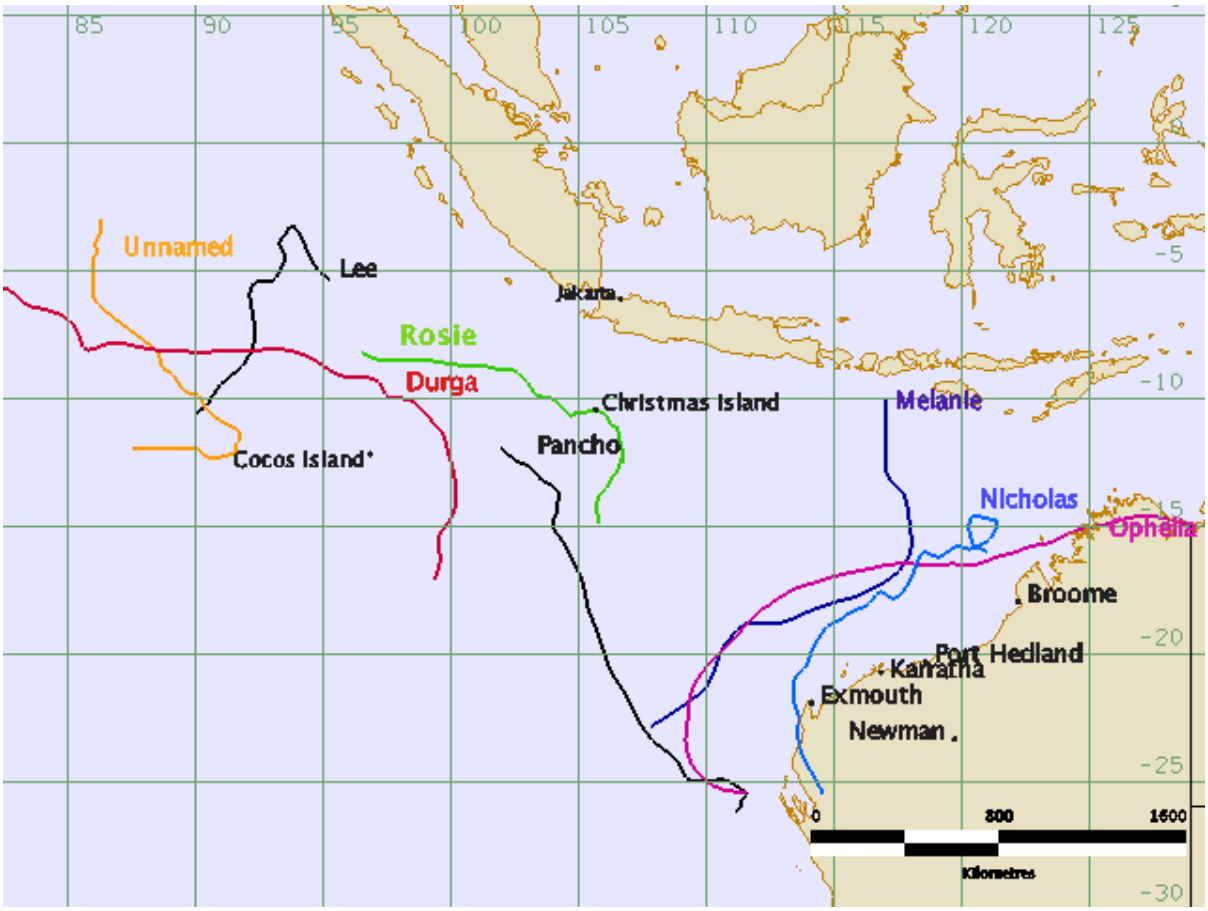
The most significant impacts were the financial losses associated with the disruption to industry during *Melanie*, *Nicholas*, *Ophelia* and *Pancho*. These losses amounted to many hundreds of millions of dollars.

Both *Nicholas* and *Pancho* produced heavy rainfall. *Nicholas* caused heavy rainfall in the west Gascoyne, Murchison and adjacent areas. *Pancho* caused heavy rainfall in the west Pilbara and Gascoyne, while the remnants of *Pancho* also caused unseasonal rainfall in the southwest of the state. Strong winds also caused some minor damage near Monkey Mia.

TCs *Lee*, *Rosie*, *Durga* and an Unnamed TC all occurred west of 110°E. *Rosie* passed close to Christmas Island causing large swells and some damage around the Port.

Aside from the Unnamed TC in July 2007, a TC occurred in every month from November to April – *Lee* in November; *Melanie* in December-January; *Nicholas* in February; *Ophelia* in February-March; *Pancho* in March; and *Rosie* and *Durga* in April.

Figure 1. Tracks of tropical cyclones, 2007-08 in the Perth TCWC area of responsibility.



# 1. Unnamed Tropical Cyclone

**29-30 July 2007**

## 1A. Summary

An out of season tropical low briefly reached cyclone intensity near 90°E but was not named operationally. Intensification was assisted by warmer than average sea surface temperatures exceeding 28°C, favourable low level shear and strong upper level outflow associated with the approach of a mid-latitude trough to the south. The estimate of cyclone intensity being reached was strongly influenced by Quickscat imagery rather than conventional Dvorak estimates. This was only the second tropical cyclone to be recorded in July in the Australian region since satellite records commenced. There was no known impact from this event.

## 1B. Meteorological Description

A low formed within the near equatorial trough on 26 July. Quickscat showed a broad trough near 4°S 86°E at 26/01UTC and then a tighter circulation with a well defined LLCC at 26/1241UTC. Convection however, remained largely unorganised. Convection was more widespread for a period on the 27th with the 27/12UTC Quickscat again showing a well-defined centre. This pattern of unorganised convection continued through the 28th although winds showed strengthening in southern quadrants. Convection improved in organisation on the 29th in response to ongoing favourable shear and strong outflow to the south associated with a strong mid-latitude trough. The low moved southeast moving east of 90°E into the western region at about 29/12UTC.

Cyclone intensity is estimated at 29/06UTC continuing to 30/06UTC. Initially a curved band pattern of 0.6 wrap could be analysed but this was not sustained on subsequent imagery. Indeed conventional Dvorak estimates during this period were in the region of 2.5-3.0. During operations the lower value was chosen but upon reanalysis the higher value was decided being biased from supporting Quickscat images at 29/11 and 29/2310UTC. The 29/11UTC Quickscat image only captures the eastern part of the system and although being on the edge of the swathe there are some 30-40 knot wind flags on the eastern flank. The corresponding NRCS image shows a well-defined low wind (dark) spot surrounded by high winds (bright) typical of a tropical cyclone. The fact that strong winds are more likely on the southern side suggests probable gales surrounding at least half the circulation. The various solutions for the 29/23UTC Quickscat have incorrect first choices, however, the ambiguity plots and the NRCS wind speed plots (see Figure 1.2) confirm that gales surround the centre. The coinciding imagery suggests the intensity was below DT3.0 although the Dvorak shear pattern carries considerable scope for subjectivity. The Quickscat is also supported by the 29/15UTC ASCAT imagery which showed 30-40 knots winds about the centre.

Early on the 30th there was some short-lived convection that developed to the west of the low level circulation centre that probably prolonged gales in that quadrant however after 30/06UTC the centre was well exposed and gales are estimated to have then been confined to southern quadrants as a ridge developed well to the south following the passage of the mid-latitude trough. CIMMS shows the shear increasing above 20 knots by the 30th with the passage of the upper trough.

During the 30th the weakening low became influenced by the low level easterly flow and recurved to the west crossing west of 90°E at about 31/06UTC.

The ADT showed raw values being above 3.0 from 29/2130 until 30/06UTC when using the shear pattern and the corresponding CI exceeded 2.7 from 30/0430-0730UTC.

**Sea Surface Temperatures**
The low formed over warmer than normal waters in excess of 28°C but as the system moved south of 10°S it encountered cooler water of less than 27°C and during the 30th when it reached 12°S the SSTs were estimated at being below 25°C.

**Historical significance**
This is only the second tropical cyclone to have formed during July in the Western region. TC *Lindsay* formed in a similar area on 10-11 July 1996 and briefly reached cyclone intensity for just 21 hours. In the TC database there are also two July events in the eastern region, one in 1935 that may have only been a tropical low or a hybrid given that the pressure was given as 1002hPa and the other in 1963 which was subtropical being south of 30°S.

It is arguable that without Quickscat imagery that this system would not have been classified a tropical cyclone going by imagery alone. This type of system may not be represented in the historical database which is significant when making conclusions about trends in the frequency of tropical cyclones.

**1C. Impact**
The low remained over open water and there were no known impacts.

**1D. Observations**
There were no surface observations available for this system.

**1E. Forecast Performance**
Computer model track guidance were generally of little use for this unnamed system and suggested the system would remain west of 90°E. As a result the three-day Tropical Cyclone Outlook issued on 28 and 29 July maintained that the low would remain west of 90°E.

The high seas warning was issued on 30 July initially for gales on the southern side of the low, and then for a potential cyclone to develop. Technical bulletins were issued on 30 July but a forecast track map was not produced.

Figure 1.1. Track of the Tropical Cyclone

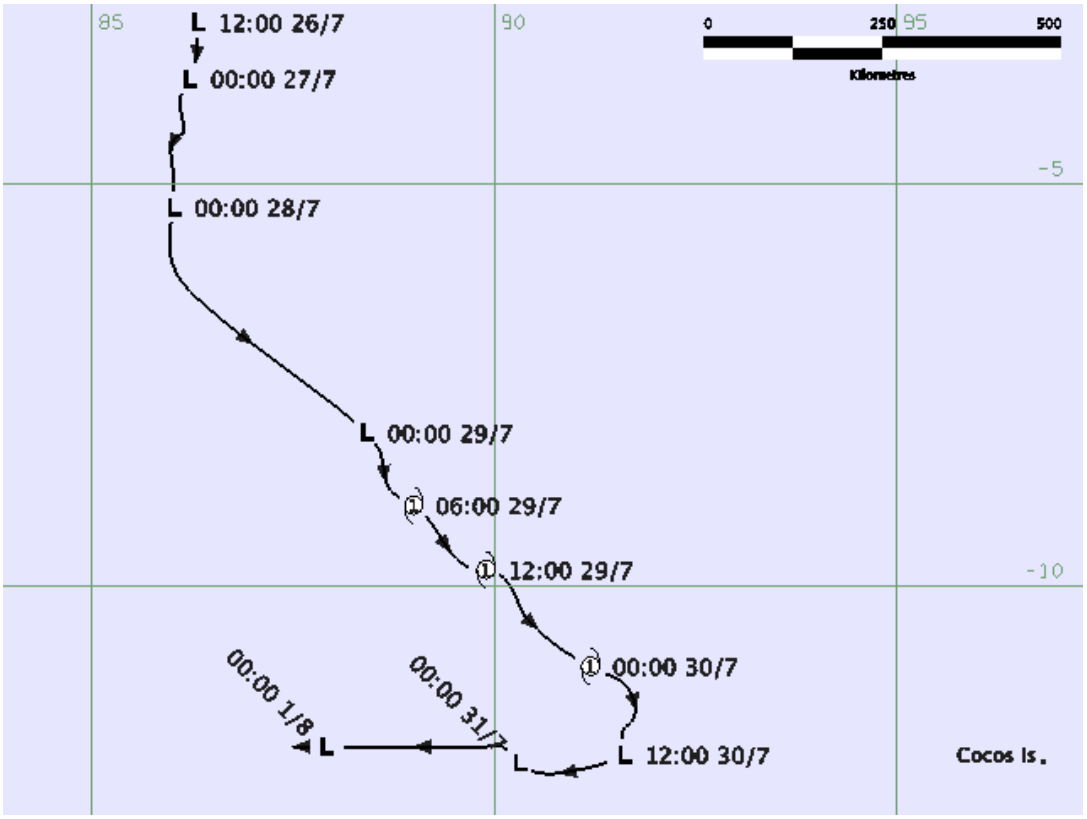



Table 1.1. Best track summary for Unnamed Tropical Cyclone 26 July –1 August 2007.

| Year | Month | Day | Hour (UTC) | Position Latitude S | Position Long. E | Position Accuracy nm | Max wind 10min knots | Max gust knots | Central Pressure hPa | Rad. of Gales nm | Rad. of storm force winds | Radius of Hurricane force winds | Radius Max. Wind (RMW) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 7 | 26 | 12 | -3.0 | 86.3 | 30 | 20 | 45 | 1004 | | | | |
| 2007 | 7 | 26 | 18 | -3.4 | 86.3 | 30 | 20 | 45 | 1004 | | | | |
| 2007 | 7 | 27 | 00 | -3.7 | 86.2 | 30 | 25 | 45 | 1002 | | | | |
| 2007 | 7 | 27 | 06 | -4.1 | 86.1 | 30 | 25 | 45 | 1000 | | | | |
| 2007 | 7 | 27 | 12 | -4.4 | 86.1 | 20 | 25 | 45 | 1000 | | | | |
| 2007 | 7 | 27 | 18 | -4.8 | 86.0 | 30 | 25 | 45 | 1000 | | | | |
| 2007 | 7 | 28 | 00 | -5.3 | 86.0 | 30 | 25 | 45 | 1000 | | | | |
| 2007 | 7 | 28 | 06 | -6.0 | 86.0 | 30 | 25 | 45 | 1000 | | | | |
| 2007 | 7 | 28 | 12 | -6.6 | 86.5 | 30 | 25 | 45 | 1000 | | | | |
| 2007 | 7 | 28 | 18 | -7.3 | 87.4 | 40 | 25 | 45 | 1000 | | | | |
| 2007 | 7 | 29 | 00 | -8.1 | 88.4 | 30 | 30 | 45 | 998 | | | | |
| 2007 | 7 | 29 | 06 | -9.0 | 89.0 | 30 | 35 | 50 | 994 | 90 | | | 30 |
| 2007 | 7 | 29 | 12 | -9.8 | 89.9 | 20 | 40 | 55 | 992 | 90 | | | 30 |
| 2007 | 7 | 29 | 18 | -10.4 | 90.4 | 30 | 40 | 55 | 992 | 90 | | | 30 |
| 2007 | 7 | 30 | 00 | -11.0 | 91.2 | 20 | 40 | 55 | 992 | 90 | | | 30 |
| 2007 | 7 | 30 | 03 | -11.2 | 91.6 | 20 | 35 | 50 | 994 | 85 | | | 30 |
| 2007 | 7 | 30 | 06 | -11.7 | 91.7 | 20 | 35 | 50 | 994 | 70 | | | 30 |
| 2007 | 7 | 30 | 12 | -12.1 | 91.6 | 20 | 30 | 45 | 998 | | | | |
| 2007 | 7 | 30 | 18 | -12.3 | 91.0 | 20 | 30 | 45 | 998 | | | | |
| 2007 | 7 | 31 | 00 | -12.2 | 90.3 | 20 | 25 | 45 | 1000 | | | | |
| 2007 | 7 | 31 | 06 | -12.0 | 89.9 | 20 | 25 | 45 | 1000 | | | | |
| 2007 | 7 | 31 | 12 | -12.0 | 89.6 | 20 | 25 | 45 | 1000 | | | | |
| 2007 | 7 | 31 | 18 | -12.0 | 88.8 | 20 | 25 | 45 | 1004 | | | | |
| 2007 | 7 | 1 | 00 | -12.0 | 87.9 | 20 | 25 | 45 | 1004 | | | | |

# 2. Tropical Cyclone *Lee*

**11-15 November 2007**

## 2A. Summary

On 11 November a weak low developed in the monsoon trough, approximately 800 km to the north of Cocos Islands. Over the next three to four days, the system drifted slowly towards the south southwest, and reached cyclone intensity at 1800 UTC 14 November, when it was about 700 km to the west northwest of Cocos Islands. Tropical Cyclone *Lee* continued to intensify, reaching category two intensity at 0000 UTC 15 November, and crossed 90°E into La Reunion's area of responsibility at 0600 UTC 15 November.

Once west of 90°E, the cyclone was renamed *Ariel*. The cyclone remained at category two intensity for about another two days as it drifted slowly westward, and thereafter rapidly weakened to below cyclone intensity.

## 2B. Meteorological Description

The low developed within an active monsoon trough on 11 November. Early in its life, wind shear imposed an inhibiting factor to its development, and convection was significantly removed from the systems centre. Convection increased near the system centre early on 13 November as shear conditions improved, resulting in gradual intensification over the following two days. By 1800 UTC 14 November, upper level outflow to the southeast had improved, and the IR imagery showed a small system that had just reached tropical cyclone intensity. The "best track" is shown in Figure 2.1. The best track positions and intensities are listed in Table 2.1.

A strong low-level ridge cradled the newly formed cyclone, increasing the extent of gales in southern quadrants. Gales to the south of the system extended for some 100 nautical miles, and 60 nautical miles on the northern side. After passing west of 90°E a mid-level ridge developed to the south, steering the cyclone steadily towards the west for the next two days.

## 2C. Impact

There were no known impacts resulting from Tropical Cyclone *Lee*.

## 2D. Observations

### Wind/Pressure

There were no reports of gale force winds from island locations.

### *Rainfall*

Being a small system in a remote part of the Indian Ocean, there were no reports of significant rainfall from island locations.

Figure 2.1 Track of Tropical Cyclone *Lee*.

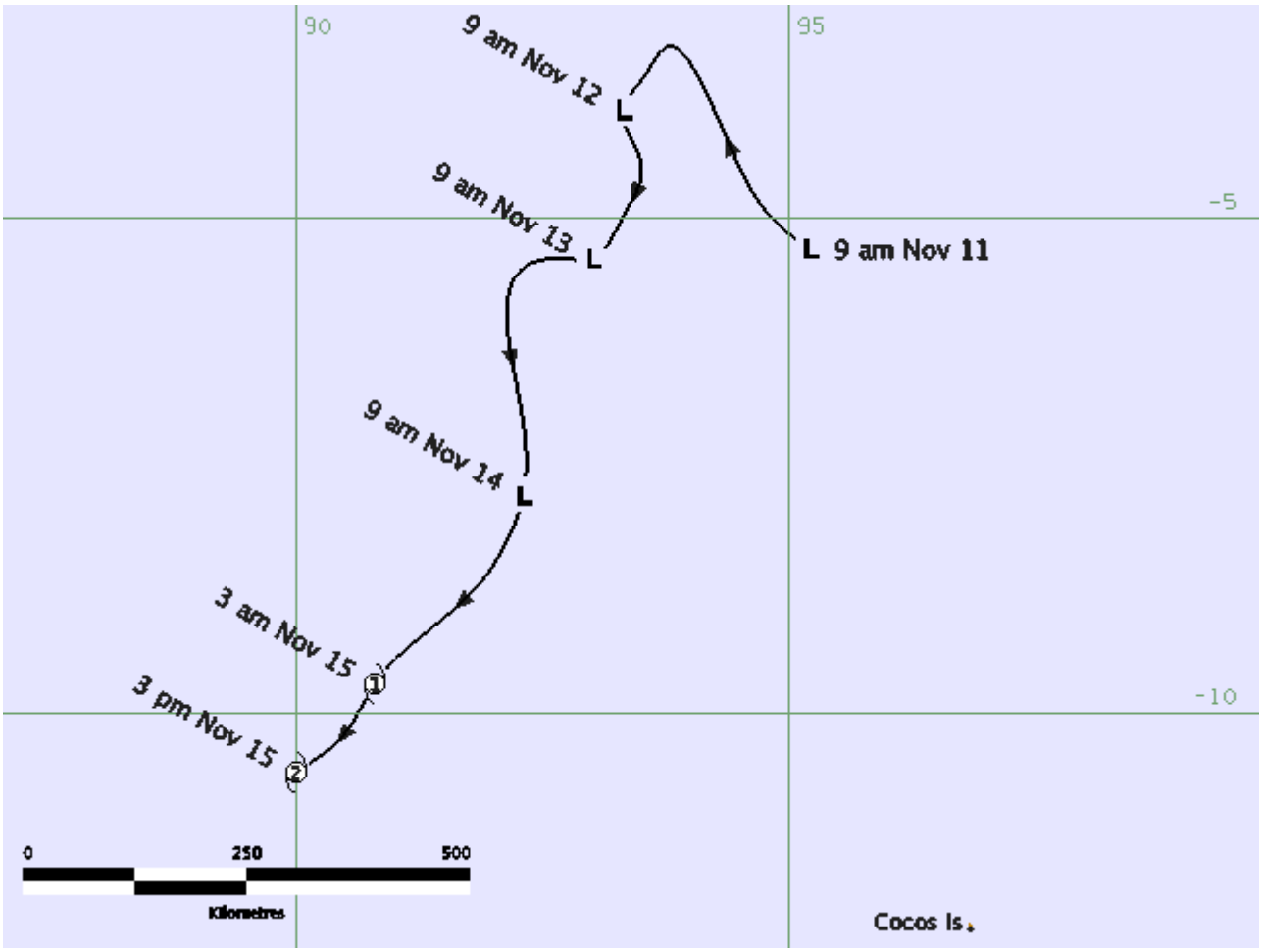



Table 2.1. Best track summary for Tropical Cyclone *Lee*, 11-15 March 2007

| 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 11 | 11 | 0 | 5.3 | 95.2 | 30 | 15 | 35 | 1004 | | | |
| 2007 | 11 | 11 | 6 | 4.5 | 94.5 | 50 | 15 | 35 | 1004 | | | |
| 2007 | 11 | 11 | 12 | 3.3 | 93.7 | 50 | 15 | 35 | 1004 | | | |
| 2007 | 11 | 11 | 18 | 3.6 | 93.5 | 50 | 15 | 35 | 1004 | | | |
| 2007 | 11 | 12 | 0 | 3.9 | 93.3 | 30 | 20 | 45 | 1004 | | | |
| 2007 | 11 | 12 | 6 | 4.2 | 93.4 | 30 | 20 | 45 | 1002 | | | |
| 2007 | 11 | 12 | 12 | 4.5 | 93.5 | 30 | 20 | 45 | 1002 | | | |
| 2007 | 11 | 12 | 18 | 5.0 | 93.3 | 50 | 20 | 45 | 1002 | | | |
| 2007 | 11 | 13 | 0 | 5.4 | 93.0 | 50 | 20 | 45 | 1002 | | | |
| 2007 | 11 | 13 | 6 | 5.4 | 92.7 | 30 | 25 | 45 | 998 | | | |
| 2007 | 11 | 13 | 12 | 5.5 | 92.3 | 30 | 25 | 45 | 998 | | | |
| 2007 | 11 | 13 | 18 | 6.5 | 92.2 | 50 | 25 | 45 | 998 | | | |
| 2007 | 11 | 14 | 0 | 7.8 | 92.3 | 50 | 25 | 45 | 998 | | | |
| 2007 | 11 | 14 | 6 | 8.5 | 92.0 | 50 | 25 | 45 | 998 | | | |
| 2007 | 11 | 14 | 12 | 9.2 | 91.3 | 30 | 30 | 45 | 996 | | | |
| 2007 | 11 | 14 | 18 | 9.7 | 90.8 | 30 | 40 | 55 | 992 | 60 | | 15 |
| 2007 | 11 | 15 | 0 | 10.2 | 90.5 | 30 | 50 | 70 | 984 | 100 | 40 | 15 |
| 2007 | 11 | 15 | 6 | 10.6 | 90.0 | 30 | 50 | 70 | 984 | 100 | 40 | 15 |

# 3. Tropical Cyclone *Melanie*

**26 December 2007 – 2 January 2008**

## 3A. Summary

A developing low formed near Sumba Island on December 27 and moved southwards. The low reached tropical cyclone intensity at 0900 WDT 28 December 2007 and reached category 2 at 0300 WDT 28 December 2007. After its initial southerly motion *Melanie* turned to the west southwest and moved parallel to the Pilbara coastline until 31 December 2007. The system weakened to category 1 as it turned more southerly and finally weakened to below cyclone strength early on 2 January 2008, dissipating over the ocean well offshore from Exmouth later that day.

Throughout the event forecasts indicated the most likely track would have *Melanie* remain off the coast, although at times the uncertainty area did indicate that landfall was possible. It was for this reason that Advices were issued for a period while *Melanie* was offshore from the Pilbara coastline. However based on Bureau advice Emergency Management authorities did not issue community alerts for coastal communities.

*Melanie* did remain far enough offshore to not to have any direct impact on the WA coast. However, there was a significant economic impact to industry resulting from port closures, production shut downs and evacuations from offshore installations. Preliminary information suggests these costs amounted to hundreds of millions of dollars.

## 3B. Meteorological Description

*Intensity analysis*

An active monsoon trough was evident on satellite imagery across northern Australia towards the end of December. Persistent convection along the trough to the southwest of Indonesia showed no low or middle level circulation until 26 December. Initially the circulation appeared in the mid-levels and during 27 December microwave and satellite imagery showed increasing curvature. By early 28 December a low level circulation with deep convection in the south western quadrant was clearly evident on microwave imagery. Despite the development of *Melanie* being inhibited by moderate to strong northerly shear, analysis showed it had developed into a tropical cyclone and Quickscat passes showed some 30 to 35 knot winds evident in southern quadrants by 0900 WDT 28 December.

Overnight 28 December convection increased and wrapped around the low level circulation centre (LLCC) and an eye became apparent on microwave imagery by early 29 December. *Melanie* reached peak intensity at about 1200 WDT 29 December and by the evening 28 December the system became more strongly sheared again with the LLCC displaced to the east of the cold convection. This intensity was maintained for about 24 hours and then *Melanie* began to weaken further under the effects of vertical shear. By 2100 WDT 30 December cold convection decreased and microwave imagery showed the low to mid level circulation becoming larger in diameter.

During 31 December and 1 January *Melanie* remained sheared with deep convection persisting in the south western quadrant and an exposed broad LLCC. By late on 1 January *Melanie* weakened below cyclone strength as it moved over colder sea surface temperatures (SST's) and under increasing vertical shear associated with the approach of a mid-latitude trough to the southwest.

***Motion***

Initially *Melanie* was steered by a northerly flow associated with a mid-level trough laying back from eastern Australia to Indonesia. By 29 December a mid-level ridge became established over eastern Australia and *Melanie* began to move in a west southwesterly direction, parallel to the Western Australian coastline. *Melanie* eventually moved in a southwesterly direction around the shoulder of the ridge during 1 January but quickly weakened to below cyclone strength with the low level centre drifting of in a westerly direction and dissipating.

***Structure***

*Melanie* was an average sized system at peak intensity with a radius of gales of about 180 kilometres but for most of its lifetime it was very asymmetric with the strongest winds in the southwest and northwest quadrants.

**3C. Impact**

*Melanie* remained far enough offshore to not to have any direct impact on the WA coast. However, there was a significant economic impact to industry resulting from port closures, production shut downs and evacuations from offshore installations. Preliminary information suggests these costs amounted to hundreds of millions of dollars.

**3D. Observations**

Wind/Pressure
Gales were recorded at Rowley Shoals Automatic Weather Station (AWS) for a period of about 3 hours from midnight – 0300 29 December 2007 as *Melanie* passed within 180 kilometres of the AWS at its closest point.

*Melanie* passed close to Buoy No 56520 located near 18.6 S 112.0 E at 0300 WDT 31 December where the minimum hourly pressure of 982.8 hPa was recorded.

**3E. Forecast Performance**

Throughout the event forecasts indicated the most likely track would have *Melanie* remain off the coast, although at times the uncertainty area did indicate that landfall was possible. It was for this reason that Advices were issued for a period while *Melanie* was offshore from the Pilbara coastline. However based on Bureau advice Emergency Management authorities did not issue community alerts for coastal communities.

A Tropical Cyclone Watch was initiated for coastal areas between Broome and Exmouth as *Melanie* initially moved south. At 1000 WDT 29 December a Tropical Cyclone Warning was declared for coastal areas from Mardie to Wallal [including Port Hedland and Karratha/Dampier] with a watch extending to the remaining areas between Broome and Coral Bay and inland to Nanutarra and Marble Bar. The warning area was adjusted westwards as *Melanie* took a more southwesterly track and the warning was finalised at 1600 WDT Sunday 30 December when *Melanie* moved away from the coast on a general southwest track. A summary is provided in Table 3.2.

Shipping warnings and Information Bulletins were continued until 1000 WDT 2 January when operationally Tropical Cyclone *Melanie* was downgraded to a low.

Table 3.1. Best track summary for *Melanie,* December 2007 – January 2008.

| 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 12 | 26 | 06 | 10.0 | 117.0 | 60 | 20 | 40 | 1000 | | | |
| 2007 | 12 | 26 | 12 | 10.7 | 117.0 | 60 | 20 | 40 | 1000 | | | |
| 2007 | 12 | 26 | 18 | 11.5 | 117.0 | 60 | 25 | 45 | 1000 | | | |
| 2007 | 12 | 27 | 00 | 12.2 | 117.0 | 60 | 25 | 45 | 998 | | | |
| 2007 | 12 | 27 | 06 | 13.0 | 117.1 | 60 | 25 | 45 | 998 | | | |
| 2007 | 12 | 27 | 12 | 13.4 | 117.4 | 60 | 25 | 45 | 994 | | | |
| 2007 | 12 | 27 | 18 | 13.7 | 117.7 | 40 | 30 | 45 | 990 | | | |
| 2007 | 12 | 28 | 00 | 13.9 | 117.8 | 30 | 35 | 50 | 986 | 90 | | 25 |
| 2007 | 12 | 28 | 06 | 14.4 | 117.9 | 30 | 40 | 55 | 982 | 90 | | 25 |
| 2007 | 12 | 28 | 12 | 15.1 | 118.0 | 30 | 45 | 65 | 976 | 90 | | 20 |
| 2007 | 12 | 28 | 18 | 16.3 | 117.9 | 20 | 50 | 70 | 970 | 90 | 30 | 20 |
| 2007 | 12 | 29 | 00 | 16.7 | 117.6 | 20 | 55 | 80 | 962 | 90 | 30 | 20 |
| 2007 | 12 | 29 | 06 | 17.3 | 116.8 | 20 | 60 | 85 | 962 | 90 | 30 | 15 |
| 2007 | 12 | 29 | 12 | 17.7 | 116.0 | 20 | 60 | 85 | 962 | 90 | 30 | 15 |
| 2007 | 12 | 29 | 18 | 18.0 | 115.0 | 20 | 55 | 80 | 964 | 90 | 30 | 15 |
| 2007 | 12 | 30 | 00 | 18.4 | 113.9 | 20 | 55 | 80 | 964 | 90 | 30 | 20 |
| 2007 | 12 | 30 | 06 | 18.7 | 113.2 | 20 | 55 | 80 | 964 | 90 | 30 | 20 |
| 2007 | 12 | 30 | 12 | 18.8 | 112.8 | 20 | 55 | 80 | 964 | 90 | 30 | 20 |
| 2007 | 12 | 30 | 18 | 18.8 | 112.4 | 20 | 50 | 70 | 972 | 90 | 30 | 20 |
| 2007 | 12 | 31 | 00 | 18.8 | 112.0 | 20 | 50 | 70 | 972 | 90 | 30 | 20 |
| 2007 | 12 | 31 | 06 | 18.8 | 111.7 | 20 | 45 | 65 | 976 | 90 | | 30 |
| 2007 | 12 | 31 | 12 | 19.0 | 111.3 | 20 | 45 | 65 | 976 | 90 | | 30 |
| 2007 | 12 | 31 | 18 | 19.2 | 111.1 | 20 | 40 | 55 | 984 | 90 | | 30 |
| 2008 | 1 | 1 | 00 | 19.7 | 110.7 | 20 | 40 | 55 | 984 | 90 | | 30 |
| 2008 | 1 | 1 | 06 | 20.4 | 110.4 | 20 | 40 | 55 | 984 | 90 | | 30 |
| 2008 | 1 | 1 | 12 | 21.3 | 110.0 | 20 | 35 | 50 | 986 | 60 | | 30 |
| 2008 | 1 | 1 | 18 | 21.9 | 109.3 | 20 | 30 | 45 | 990 | | | |
| 2008 | 1 | 2 | 00 | 22.5 | 108.4 | 20 | 25 | 45 | 992 | | | |
| 2008 | 1 | 2 | 06 | 22.9 | 107.8 | 20 | 25 | 45 | 992 | | | |

Table 3.2 Tropical Cyclone Advice summary for TC *Melanie.*

| Date/Time (WDT) | Action | Location |
|---|---|---|
| 4 pm 28/12/2007 | TC Watch issued. | Exmouth to Broome |
| 10 am 29/12/2007 | Warning issued. | Mardie to Wallal |
| 4 pm 29/12/2007 | Warning area changed | Exmouth to Port Hedland |
| 10 pm 29/12/2007 | Warning area changed | Exmouth to Whim creek |
| 4 am 30/12/2007 | Warning area changed. | Exmouth to Karratha |
| 7 am 30/12/2007 | Warning area changed. | Coral Bay to Mardie |
| 1 pm 30/12/2007 | Warning area changed. | Coral Bay to Onslow |
| 4 pm 30/12/2007 | Warning and Watch cancelled | |

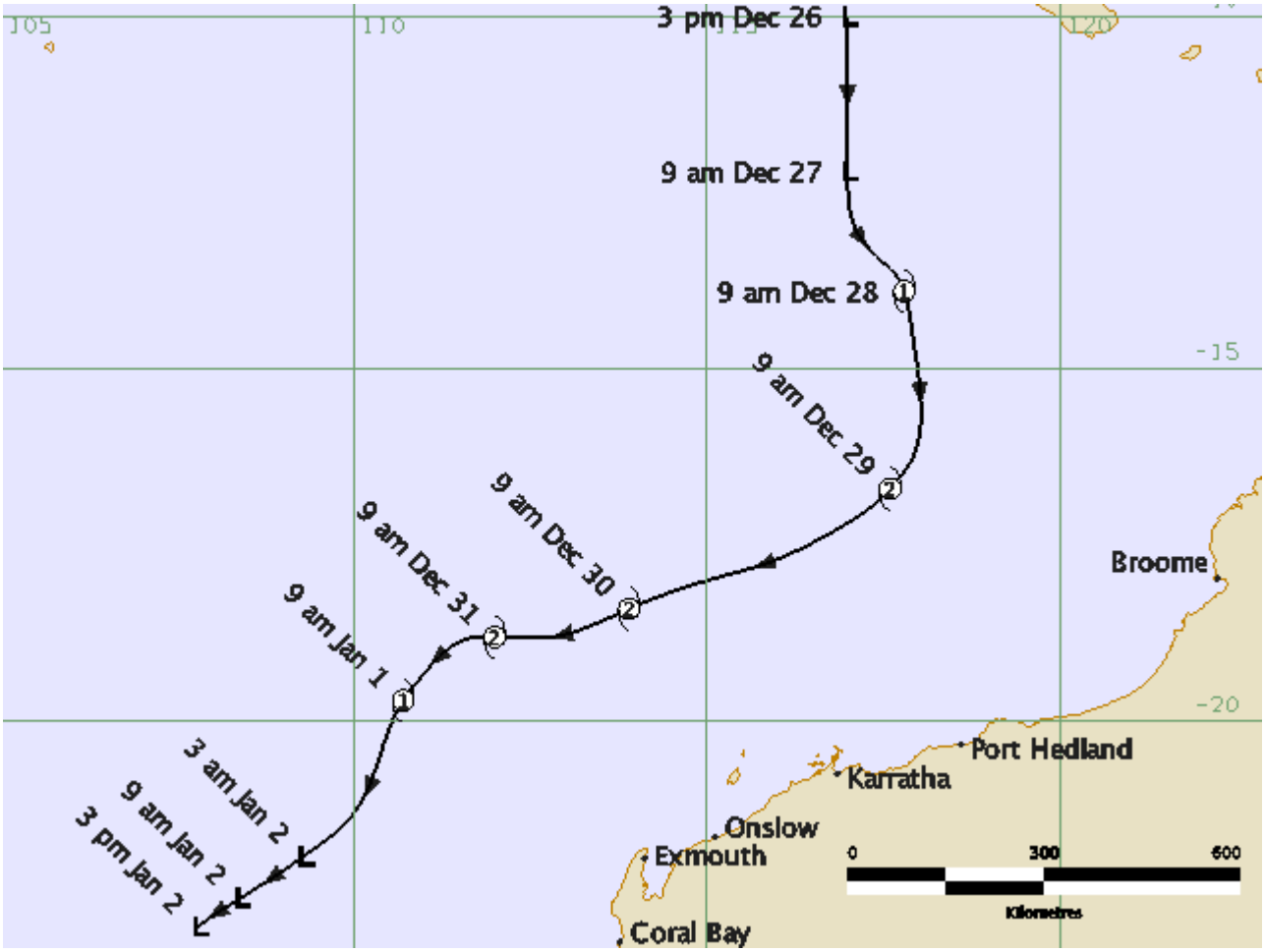



Figure 3.1. Track of Tropical Cyclone *Melanie*, 26 December 2007 – 2 January 2008.

# 4. Severe Tropical Cyclone *Nicholas*

**11 – 20 February 2008**

## 4A. Summary

A low that developed off the Kimberley coast on 11 February reached cyclone strength late on 12 February. The system experienced a period of weakening during 13 February as it began to move to the south east before re-intensifying to cyclone strength and moving in a south westerly direction, executing a loop in its track.

*Nicholas* then continued in a south westerly direction, paralleling the Pilbara coastline and intensifying to category 3 strength. *Nicholas* began to weaken to the north of Exmouth before turning to the south and then south east, finally crossing the upper west coast approximately 60 kilometres south southwest of Coral Bay on the morning of 20 February. *Nicholas* was a category 1 cyclone as it crossed the coast and dissipated to below cyclone strength some 6 hours later.

*Nicholas* was an unusually slow moving system, the average speed of movement until 16 February was between 4 and 10 km/h. In the later stages the speed increased to about 10 to 13 km/h. The system was also long lived, lasting nine days as a cyclone.

Heavy rain fell through the west Gascoyne and Murchison extending into the adjacent Goldfields and northern parts of the South West Land Division. There were scattered falls in excess of 100 mm and Burnerbinmah in the Murchison recorded 203 mm of rain over three days.

Advices were issued for the Kimberley coastline as *Nicholas* formed. The watch/warning area was moved down the Pilbara coastline as *Nicholas* tracked south westerly and FESA issued community alerts for the appropriate communities. The impact to industry was significant with *Nicholas* affecting, at differing times, the entire Pilbara coastline and offshore rigs for a total period of 10 days.

## B. Meteorological Description

### *Intensity analysis*

Initially an active trough offshore from the Kimberley coast was evident on satellite imagery during 10 February. By 11 February a circulation could be seen in the convection which continued to develop until cyclone strength was reached by 9 pm WDT (1200 UTC) 12 February. Shear analyses show a strong shear gradient to the north of the system with about 35 km/h (20 knots) of NE shear over the centre.

During 13 February a secondary vortex became apparent about 4 degrees to the west of *Nicholas*. This vortex moved northwards for about 12 hours before dissipating but during this time it appeared to have some effect on the intensity of *Nicholas*. *Nicholas* seemed to be developing at a normal rate until the vortex became evident on imagery at 1500 WDT (0600 UTC) 13 February where upon development stopped and the system showed signs of weakening. About 12 hours later the secondary vortex dissipated and *Nicholas* developed a Central Cold Cover (CCC) pattern which generally indicates arrested development. By 0300 WDT (1800 UTC) 13 February *Nicholas* had weakened to below cyclone strength. During the morning of 14 February the CCC pattern weakened and *Nicholas* showed signs of re-intensifying, quickly reaching cyclone strength again by 1500 WDT (0600 UTC) 14 February.

From 14 February *Nicholas* continued to develop despite being under 35 km/h (20 knots) of north easterly shear. Microwave imagery showed a clear low level cloud centre (LLCC) with convection in the western quadrants. During 15 February convection wrapped around the LLCC and a small microwave eye appeared on the 1511 WDT (0611 UTC) 16 February image. A small, ragged eye was also apparent on a single visible satellite image on 16 February (refer Fig. 4.2). *Nicholas* appeared to reach peak intensity of 150 km/h (80 knots) at this time which it maintained until 1500 WDT (0600 UTC) 18 February. After this *Nicholas* weakened steadily under 35 to 55 km/h (20 to 30 knots) of easterly shear until finally dissipating over land on 20 February.

***Motion***

*Nicholas* moved very slowly though most of its lifetime. Initially the steering influence was very weak as *Nicholas* was located between the 500 hPa ridge to the south and the westerlies to the north. During this time *Nicholas* was stationary and then subsequently drifted northwards. During 13 February its motion appeared to be influenced by a secondary vortex to the west and *Nicholas* moved south southeast in response to the other vortex moving northwards. This resulted in *Nicholas* completing a loop.

Once the second vortex dissipated *Nicholas* began to move slowly in a south westerly direction, steered by the 500 hPa ridge. *Nicholas* continued to move south westerly and increased slightly on speed until 18 February when a middle level trough approached the west coast. *Nicholas* then turned southerly and eventually south easterly ahead of the trough before crossing the coast and dissipating.

***Structure***

*Nicholas* was an average sized cyclone which experienced moderate to strong shear from the east for its entire lifetime. During its early stages the LLCC was located to the north east of the deep convection and the system was strongly asymmetric. Gales only extended about 55 km (30 nm) in eastern quadrants and 110 km (60 nm) in western quadrants. After *Nicholas* had re-intensified on 14 February the LLCC was more closely associated with the deep convection and the system had well developed spiral bands. The system was still slightly asymmetric with gales extending 130 km (70 nm) in eastern quadrants and up to 220 km (120 nm) in western quadrants. During 15 and 16 February convection became wrapped around the LLCC and a small microwave eye appeared. *Nicholas* became more symmetric until 18 February when shear effects became apparent again. Microwave imagery showed at times deep convection was in western quadrants only. By the time *Nicholas* crossed the coast nearly all deep convection had dissipated.

**4C. Impact**

*Nicholas* crossed the upper west coast at Gnarloo Station, about 60 kilometres south southwest of Coral Bay with little impact on communities. However, *Nicholas* had significant impact to industry both along the Pilbara coastline and to offshore operations. Dampier Port was closed for 39 hours and Port Hedland was closed for 56 hours. Many offshore operators were evacuated or put into lock down mode as *Nicholas* passed by. Total losses are estimated to run in the hundreds of millions of dollars.

**4D. Observations**
***Wind***

Exmouth reported gale force winds for a period of 4 and ½ hours from 0720 to 1150 WDT 19 February.

***Rainfall***

Burnerbinmah in the Murchison recorded 203 mm of rain over three days.

## 4E. Forecast Performance

Table 4.2 is a summary of advices issued by Perth TCWC. A watch was first issued at 1000 WDT 10 February for coastal areas between Kalumburu and Mardie. The first warning was issued at 1600 WDT 13 February for the coast between Kuri Bay and Bidyadanga. This warning area was updated in the following days as Nicholas moved to the southwest then south. Once *Nicholas* crossed the coast and weakened below cyclone intensity advices were cancelled at 1500 WDT 20 February.

Table 4.1 Best track summary for *Nicholas,* 11 – 20 February 2008.

| 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2008 | 2 | 11 | 00 | 16.0 | 121.0 | 60 | 20 | 45 | 996 | | | 40 |
| 2008 | 2 | 11 | 06 | 16.0 | 121.0 | 60 | 25 | 45 | 996 | | | 40 |
| 2008 | 2 | 11 | 12 | 16.0 | 121.0 | 60 | 25 | 45 | 994 | | | 40 |
| 2008 | 2 | 11 | 18 | 15.9 | 120.8 | 60 | 25 | 45 | 994 | | | 40 |
| 2008 | 2 | 12 | 00 | 15.8 | 120.5 | 60 | 25 | 45 | 992 | | | 40 |
| 2008 | 2 | 12 | 06 | 15.6 | 120.4 | 60 | 30 | 45 | 990 | | | 30 |
| 2008 | 2 | 12 | 12 | 15.1 | 120.3 | 60 | 35 | 50 | 986 | 45 | | 20 |
| 2008 | 2 | 12 | 18 | 14.9 | 120.3 | 60 | 35 | 50 | 986 | 45 | | 20 |
| 2008 | 2 | 13 | 00 | 14.6 | 120.4 | 30 | 35 | 50 | 986 | 45 | | 20 |
| 2008 | 2 | 13 | 06 | 14.7 | 120.9 | 10 | 35 | 50 | 986 | 45 | | 20 |
| 2008 | 2 | 13 | 12 | 14.8 | 121.4 | 20 | 35 | 50 | 986 | 45 | | 20 |
| 2008 | 2 | 13 | 18 | 15.3 | 121.3 | 20 | 30 | 45 | 990 | | | 20 |
| 2008 | 2 | 14 | 00 | 15.6 | 121.0 | 20 | 30 | 45 | 992 | | | 20 |
| 2008 | 2 | 14 | 06 | 15.8 | 120.7 | 20 | 45 | 65 | 986 | 89 | | 20 |
| 2008 | 2 | 14 | 12 | 15.9 | 120.4 | 20 | 50 | 70 | 978 | 89 | 30 | 20 |
| 2008 | 2 | 14 | 18 | 15.8 | 119.9 | 15 | 50 | 70 | 974 | 88 | 30 | 20 |
| 2008 | 2 | 15 | 00 | 15.8 | 119.8 | 15 | 55 | 80 | 970 | 89 | 40 | 20 |
| 2008 | 2 | 15 | 06 | 16.0 | 119.5 | 15 | 65 | 90 | 964 | 90 | 40 | 20 |
| 2008 | 2 | 15 | 12 | 16.2 | 119.0 | 20 | 65 | 90 | 960 | 105 | 40 | 15 |
| 2008 | 2 | 15 | 18 | 16.0 | 118.6 | 25 | 70 | 100 | 958 | 105 | 40 | 15 |
| 2008 | 2 | 16 | 00 | 16.4 | 118.3 | 15 | 75 | 105 | 956 | 105 | 40 | 15 |
| 2008 | 2 | 16 | 06 | 17.1 | 118.0 | 15 | 80 | 115 | 948 | 98 | 40 | 10 |
| 2008 | 2 | 16 | 12 | 17.8 | 117.2 | 20 | 80 | 115 | 948 | 98 | 40 | 10 |
| 2008 | 2 | 16 | 18 | 17.6 | 116.9 | 20 | 80 | 115 | 948 | 98 | 40 | 10 |
| 2008 | 2 | 17 | 00 | 18.0 | 116.4 | 15 | 80 | 115 | 948 | 98 | 40 | 10 |
| 2008 | 2 | 17 | 06 | 18.3 | 115.8 | 25 | 80 | 115 | 948 | 105 | 40 | 10 |
| 2008 | 2 | 17 | 12 | 18.6 | 115.3 | 20 | 75 | 105 | 956 | 105 | 40 | 10 |
| 2008 | 2 | 17 | 18 | 18.9 | 114.8 | 15 | 80 | 115 | 948 | 113 | 40 | 10 |
| 2008 | 2 | 18 | 00 | 19.4 | 114.4 | 15 | 75 | 105 | 956 | 113 | 40 | 15 |
| 2008 | 2 | 18 | 06 | 20.0 | 114.1 | 20 | 75 | 105 | 956 | 90 | 40 | 20 |
| 2008 | 2 | 18 | 12 | 20.4 | 113.9 | 15 | 60 | 85 | 968 | 90 | 40 | 20 |
| 2008 | 2 | 18 | 18 | 20.9 | 113.5 | 20 | 60 | 85 | 970 | 90 | 40 | 20 |
| 2008 | 2 | 19 | 00 | 21.5 | 113.4 | 20 | 55 | 80 | 970 | 90 | 40 | 20 |
| 2008 | 2 | 19 | 06 | 22.0 | 113.5 | 20 | 55 | 80 | 972 | 90 | 40 | 20 |
| 2008 | 2 | 19 | 12 | 22.4 | 113.6 | 15 | 50 | 70 | 980 | 70 | 30 | 20 |
| 2008 | 2 | 19 | 18 | 23.0 | 113.6 | 15 | 45 | 65 | 980 | 50 | | 25 |
| 2008 | 2 | 20 | 00 | 23.6 | 113.7 | 20 | 40 | 55 | 988 | 40 | | 30 |
| 2008 | 2 | 20 | 06 | 24.6 | 114.1 | 20 | 35 | 50 | 994 | | | 40 |
| 2008 | 2 | 20 | 12 | 25.5 | 114.6 | 25 | 30 | 45 | 996 | | | |

Table 4.2 Tropical Cyclone Advice summary for TC *Nicholas.*

| Date/Time (WDT) | Action | Location |
|---|---|---|
| 10/2/2008 1000 | TC Watch issued. | Kalumburu to Mardie |
| 11/2/2008 1600 | Watch area changed. | Kalumburu to Pardoo |
| 13/2/2008 1000 | Watch area changed. | Kuri Bay to Pardoo |
| 13/2/2008 1600 | Warning issued | Kuri Bay to Bidyadanga |
| 14/2/2008 2200 | Warning area changed. | Cockatoo Island to Bidyadanga |
| 14/2/2008 1600 | Warning area changed. | Cape Leveque to Bidyadanga |
| 15/2/2008 1000 | Warning area changed. | Wallal to Whim Creek |
| 16/2/2008 1600 | Warning area changed. | Mardie to Pardoo |
| 16/2/2008 2200 | Warning area changed | Pardoo to Exmouth |
| 17/2/2008 0400 | Warning area changed | Whim creek to Exmouth |
| 17/2/2008 1600 | Warning area changed | Dampier to Exmouth |
| 18/2/2008 0700 | Warning area changed | Dampier to Coral Bay |
| 18/2/2008 1000 | Warning area changed | Mardie to Minilya |
| 19/2/2008 0100 | Warning area changed | Mardie to Cape Cuvier |
| 19/2/2008 1000 | Warning area changed | Mardie to Carnarvon |
| 19/2/2008 1300 | Warning area changed | Onslow to Carnarvon |
| 19/2/2008 2200 | Warning area changed | Exmouth to Carnarvon |
| 20/2/2008 0100 | Warning area changed | Coral Bay to Carnarvon |
| 20/2/2008 1500 | Warning cancelled | |

Figure 4.1 Track of Tropical Cyclone *Nicholas* 11 – 20 February 2008.

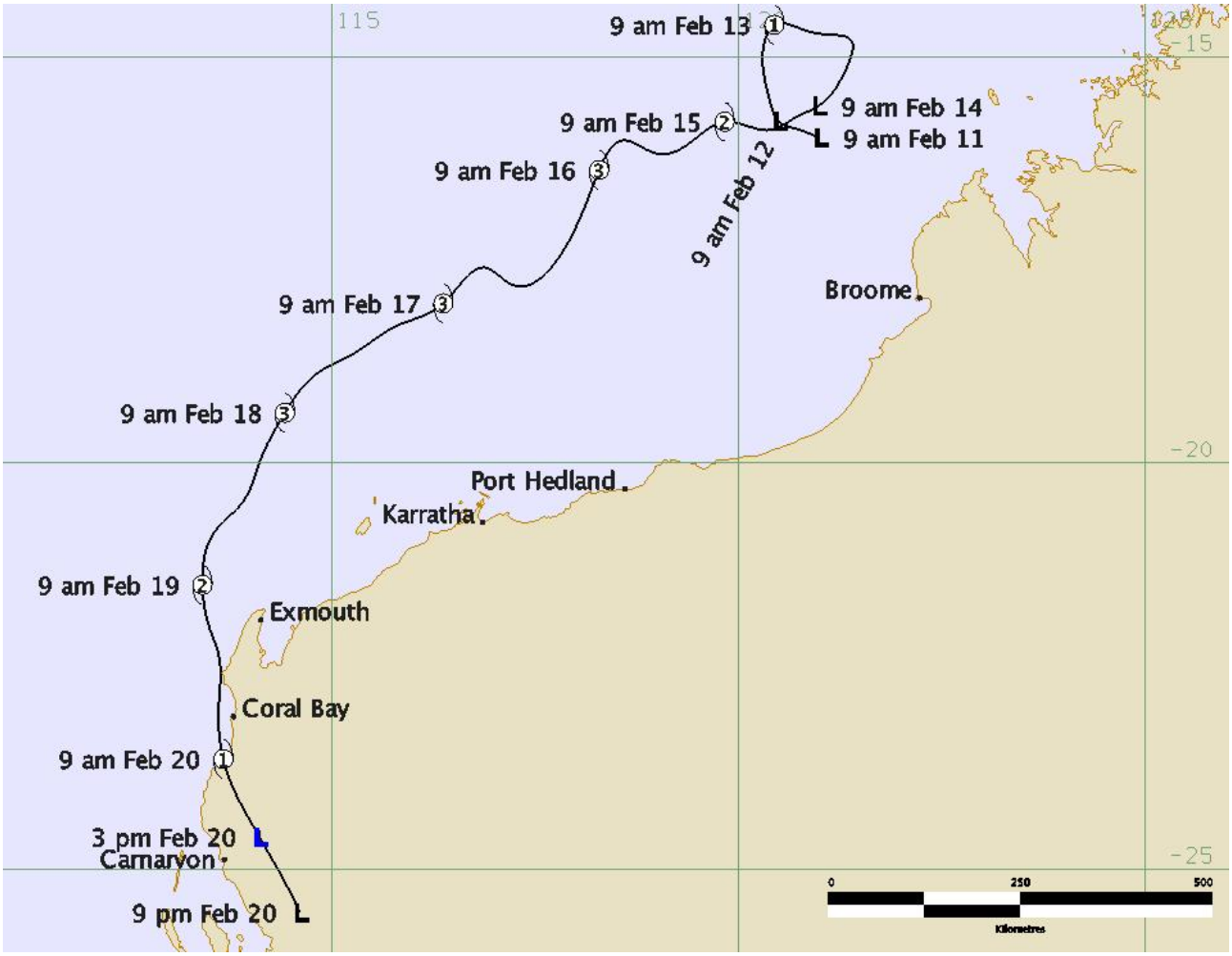
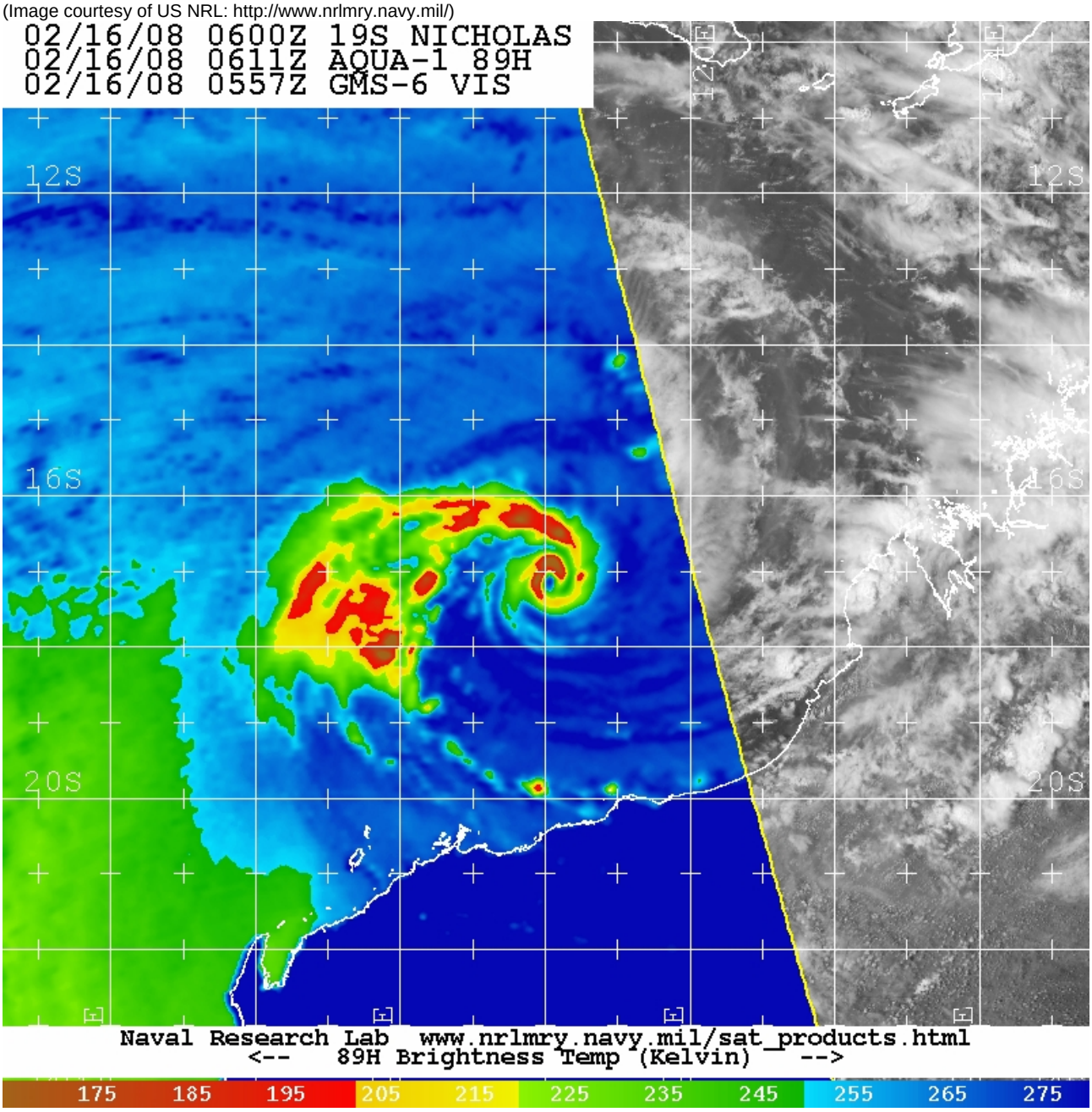


Figure 4.2 Microwave (85 GHz) image at 1511 WDT (0611UTC) 16/02/2008, near peak intensity.

(Image courtesy of US NRL: http://www.nrlmry.navy.mil/)



# 5. Tropical Cyclone *Ophelia*

**1 - 6 March 2008**

## 5A. Summary

A low moved from the Northern Territory across the north Kimberley then developed after moving off the northwest Kimberley coast on the morning of 1 March reaching cyclone intensity that evening about 80 km north of Cape Leveque. The midget cyclone *Ophelia* quickly developed to category 2 intensity on the morning of 2 March *Ophelia* and remained a category 2 cyclone through to 5 March as it moved to the west to west southwest well off the Pilbara coast. *Ophelia* then weakened as it changed track to the south southwest and finally weakening below cyclone intensity late on 6 March well west of Carnarvon (see figure 5.1).

Although advices were issued for the Kimberley coast north of Broome prior to *Ophelia* moving away from the coast, there were no community alerts issued and no impact to coastal areas. Some offshore industry installations were evacuated as a precautionary measure resulting in some economic losses, however the confidence in the forecast track allowed coastal and near coastal facilities to continue operations during the cyclone event.

## 5B. Meteorological Description

### *Intensity analysis*

A weak low formed over the central Northern Territory on 25 February and tracked west moving across the Kimberley on 29 February. When the low finally moved offshore from the northwest Kimberley coast on the morning of 1 March, development occurred rapidly with convection becoming more organised that evening prompting the upgrade to tropical cyclone *Ophelia*.

Overnight satellite imagery showed an increase in curvature in the deep convection sufficient for *Ophelia* to reach category 2 intensity on the morning of 2 March. Maximum intensity is estimated later that day when an eye emerged on microwave imagery as shown in figure 5.3. The faster than standard development rate (low to category 2 within 30 hours) was supported by low environmental shear, a pre-existing deep level vorticity structure prior to moving offshore and the small-scale nature of the low allowing a rapid spin-up process to occur.

Subsequent imagery showed that development was not sustained and convection about the eye weakened despite the wind shear remaining low. Imagery on 3 March showed the low level circulation centre (LLCC) exposed to the north of a diminished area of convection suggesting the system was highly vulnerable to fluctuations in wind shear. Later on 3 March convection increased about the LLCC and Quickscat image (in figure 5.4) showed storm-force winds near the centre.

During 4 March convection became more organised for a period but overnight the convection weakened and became limited to the southern side although Quickscat imagery showed storm-force winds were maintained. A tight LLCC remained evident during 5 March although convection remained only partly organised.

*Ophelia* commenced a more southerly track on 6 March towards a region of higher NW wind shear and over cooler SSTs below 27°C heralding the weakening phase. During the day convection weakened and the evening Quickscat image showed gales restricted to the southwest quadrant only, followed by the absence of gales on the subsequent AScat

image. These confirmed that *Ophelia* had weakened below cyclone intensity. This weakening was also consistent with the Dvorak intensity estimates.

The low level circulation then moved to the southeast towards the Shark Bay coast with some convection again redeveloping on the southern side of the system early on 7 March and near-gales were observed by a ship prior to sustained weakening during the day.

While *Ophelia* developed quickly to category 2 intensity a factor limiting further intensification were the cooler than normal SSTs off the West Kimberley and Pilbara coasts following the earlier passage of TC *Nicholas*. *Ophelia* moved over water of about 28-29°C until it reached cooler waters south of 24°S off the west coast. Waters off the upper west coast were much warmer than is typical, which would have assisted *Ophelia* maintaining cyclone intensity as long as it did in this area.

Based upon Dvorak methodology, *Ophelia* was maintained at T3.5/4.0 (50-55 knots) from the morning of 2 March through to late on 5 March. It is highly likely that the actual intensity of such a small system underwent considerable variation that is difficult to detect or assess without observations.

***Motion***

A persisting deep level mid-level ridge was responsible for the steady west to west southwest motion from 27 February to 3 March. On 4 March the system moved around the northwest shoulder of the anti-cyclone resulting in a more southwest motion. The approach of a mid-latitude trough on 6 March threatened to capture the system in the northwest flow. However, the trough was not of sufficient amplitude and the weakening circulation quite small to result in any accelerated motion to represent a true 'capture' situation. Nevertheless the system was steered to the south then southeast as it weakened. Had *Ophelia* been of much greater strength and size then there would have been a serious risk of a west coast impact.

***Structure***

*Ophelia* was a midget cyclone having a radius of gales less than 150 km. The system was also quite asymmetric with the strongest winds being evident on the southern side throughout much of its lifetime.

**5C. Impact**

Aside from some economic impact due to the loss of production at some offshore oil and gas facilities, there was no reported impact or damage to coastal parts. Parts of the Kimberley received heavy rainfall but no flooding was reported.

**5D. Observations**

***Wind/Pressure***

As *Ophelia* was developing off the northwest Kimberley coast it passed just south of Adele Island. The minimum pressure was 1001.4hPa at 1500 WDT 1 March while the highest recorded winds were 57 km/h (31 knots) in northwesterlies at 1900 WDT 1 March.

*Ophelia* also passed close by to a buoy (56520) located at 16.9°S 115.9°E late on 3 March where the minimum hourly pressure was recorded at 992.6 hPa (no winds recorded).

***Rainfall***

Heavy rain fell as the tropical low moved across the northern Kimberley. A swathe of rainfall in excess of 100 mm was registered, the highest being in the northeast Kimberley where Wyndham recorded a daily fall of 135 mm to 0900 WDT 29 February (see figure 5.2).

**5E. Forecast Performance**

Table 5.2 is a summary of advices issued by Darwin and Perth TCWCs. Darwin TCWC issued advices on 27-28 February for coastal areas of the Joseph Bonaparte Gulf on the basis of potential northwest movement that failed to eventuate. Advices were then issued for the northwest Kimberley coast between Mitchell Plateau and Cape Leveque prior to the low moving offshore. Warnings commenced at 0430 WDT 29 February. Perth assumed responsibility for the developing low at 1000 WDT 1 March. As *Ophelia* moved away from the coast the warning area was revised and eventually advices were cancelled at 1000 WDT 2 March.

For the remainder of *Ophelia*'s lifetime shipping warnings, technical summaries and track maps were issued but no advices were issued based on the confidence in the model guidance.

Table 5.1 Best track summary for *Ophelia,* March 2008.

| 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2008 | 2 | 29 | 18 | 15.1 | 124.8 | 20 | 25 | 45 | 1003 | | | |
| 2008 | 3 | 1 | 0 | 15.4 | 124.0 | 20 | 30 | 45 | 1000 | | | |
| 2008 | 3 | 1 | 06 | 15.7 | 123.3 | 15 | 30 | 45 | 1000 | | | |
| 2008 | 3 | 1 | 12 | 15.8 | 122.7 | 20 | 35 | 50 | 998 | 30 | | |
| 2008 | 3 | 1 | 18 | 16.0 | 122.2 | 20 | 45 | 65 | 992 | 35 | | |
| 2008 | 3 | 2 | 00 | 16.2 | 121.4 | 15 | 50 | 70 | 988 | 50 | 15 | 10 |
| 2008 | 3 | 2 | 06 | 16.5 | 120.6 | 15 | 55 | 80 | 985 | 55 | 20 | 15 |
| 2008 | 3 | 2 | 12 | 16.5 | 120.0 | 20 | 55 | 80 | 985 | 55 | 20 | 15 |
| 2008 | 3 | 2 | 18 | 16.5 | 119.1 | 20 | 55 | 80 | 985 | 40 | 20 | 15 |
| 2008 | 3 | 3 | 00 | 16.5 | 118.4 | 15 | 50 | 70 | 989 | 40 | 10 | 15 |
| 2008 | 3 | 3 | 06 | 16.5 | 117.3 | 15 | 50 | 70 | 988 | 55 | 10 | 15 |
| 2008 | 3 | 3 | 12 | 16.7 | 116.3 | 20 | 50 | 70 | 988 | 65 | 10 | 15 |
| 2008 | 3 | 3 | 18 | 16.9 | 115.3 | 20 | 50 | 70 | 988 | 70 | 15 | 15 |
| 2008 | 3 | 4 | 00 | 17.2 | 114.3 | 20 | 50 | 70 | 988 | 70 | 15 | 15 |
| 2008 | 3 | 4 | 06 | 17.5 | 113.4 | 15 | 50 | 70 | 988 | 70 | 15 | 15 |
| 2008 | 3 | 4 | 12 | 18.0 | 112.6 | 15 | 50 | 70 | 988 | 60 | 15 | 20 |
| 2008 | 3 | 4 | 18 | 18.5 | 111.9 | 15 | 50 | 70 | 987 | 60 | 15 | 20 |
| 2008 | 3 | 5 | 00 | 19.3 | 111.2 | 20 | 50 | 70 | 987 | 55 | 15 | 20 |
| 2008 | 3 | 5 | 06 | 20.1 | 110.4 | 20 | 50 | 70 | 987 | 60 | 15 | 15 |
| 2008 | 3 | 5 | 12 | 20.8 | 109.8 | 20 | 50 | 70 | 988 | 60 | 10 | 15 |
| 2008 | 3 | 5 | 18 | 21.6 | 109.4 | 20 | 45 | 60 | 993 | 45 | | 15 |
| 2008 | 3 | 6 | 00 | 22.4 | 109.3 | 25 | 40 | 55 | 995 | 50 | | 15 |
| 2008 | 3 | 6 | 06 | 23.4 | 109.2 | 20 | 40 | 55 | 996 | 40 | | 15 |
| 2008 | 3 | 6 | 12 | 24.0 | 109.3 | 20 | 30 | 45 | 1001 | | | |
| 2008 | 3 | 6 | 18 | 24.8 | 109.8 | 20 | 30 | 45 | 1001 | | | |
| 2008 | 3 | 7 | 00 | 25.3 | 110.6 | 15 | 30 | 45 | 1001 | | | |
| 2008 | 3 | 7 | 06 | 25.4 | 111.6 | 15 | 25 | 45 | 1004 | | | |

Table 5.2 Tropical Cyclone Advice summary for TC *Ophelia.*

| Date/Time (WDT) | Action | Location |
|---|---|---|
| 27/2/2008 1631 | TC Watch issued. | Kalumburu to Port Keats (NT) |
| 28/2/2008 1616 | Watch area changed. | Mitchell Plateau to Cape Leveque |
| 29/2/2008 1621 | Warning issued. | Mitchell Plateau to Cape Leveque |
| 01/3/2008 1631 | Warning area changed | Kuri Bay to Broome |
| 1/3/2008 1600 | Warning area changed. | Cockatoo Island to Broome |
| 1/3/2008 2145 | Warning area changed. | Cape Leveque to Broome |
| 2/3/2008 1000 | Warning cancelled. | |

Figure 5.1 Track of Tropical Cyclone *Ophelia*, 29 Feb-7 March 2008.

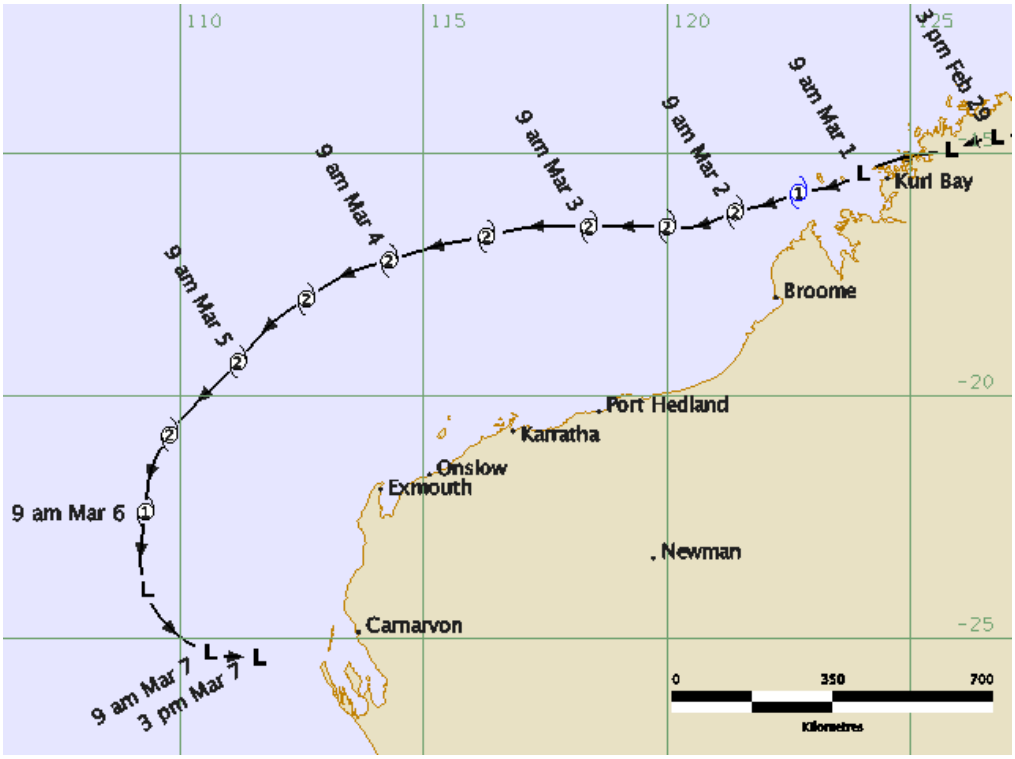



Figure 5.2 Weekly rainfall to 9am 1 March showing rainfall associated with the tropical low (pre-*Ophelia*).

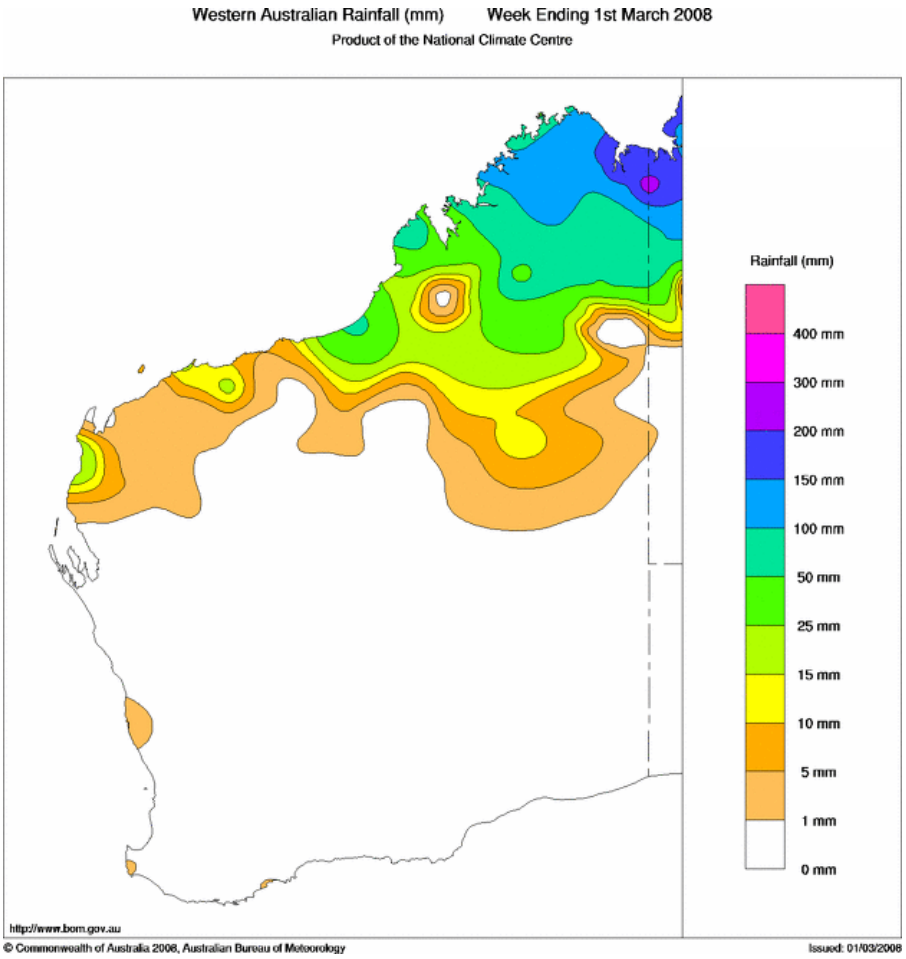



Figure 5.3 Microwave (AMSRE colour 89GHz) image at 02/0528UTC.
(image courtesy of US NRL: http://www.nrlmry.navy.mil/)

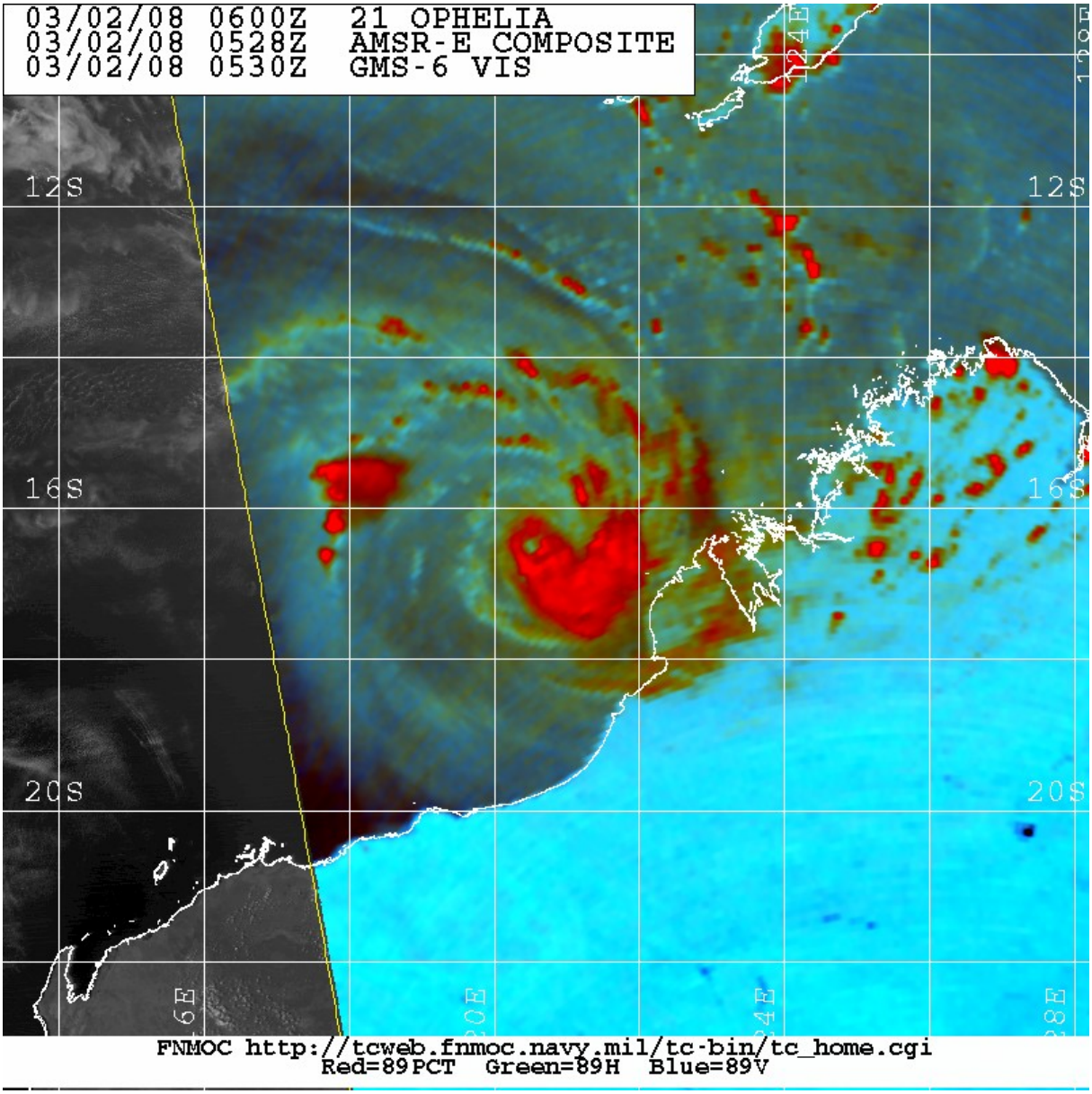
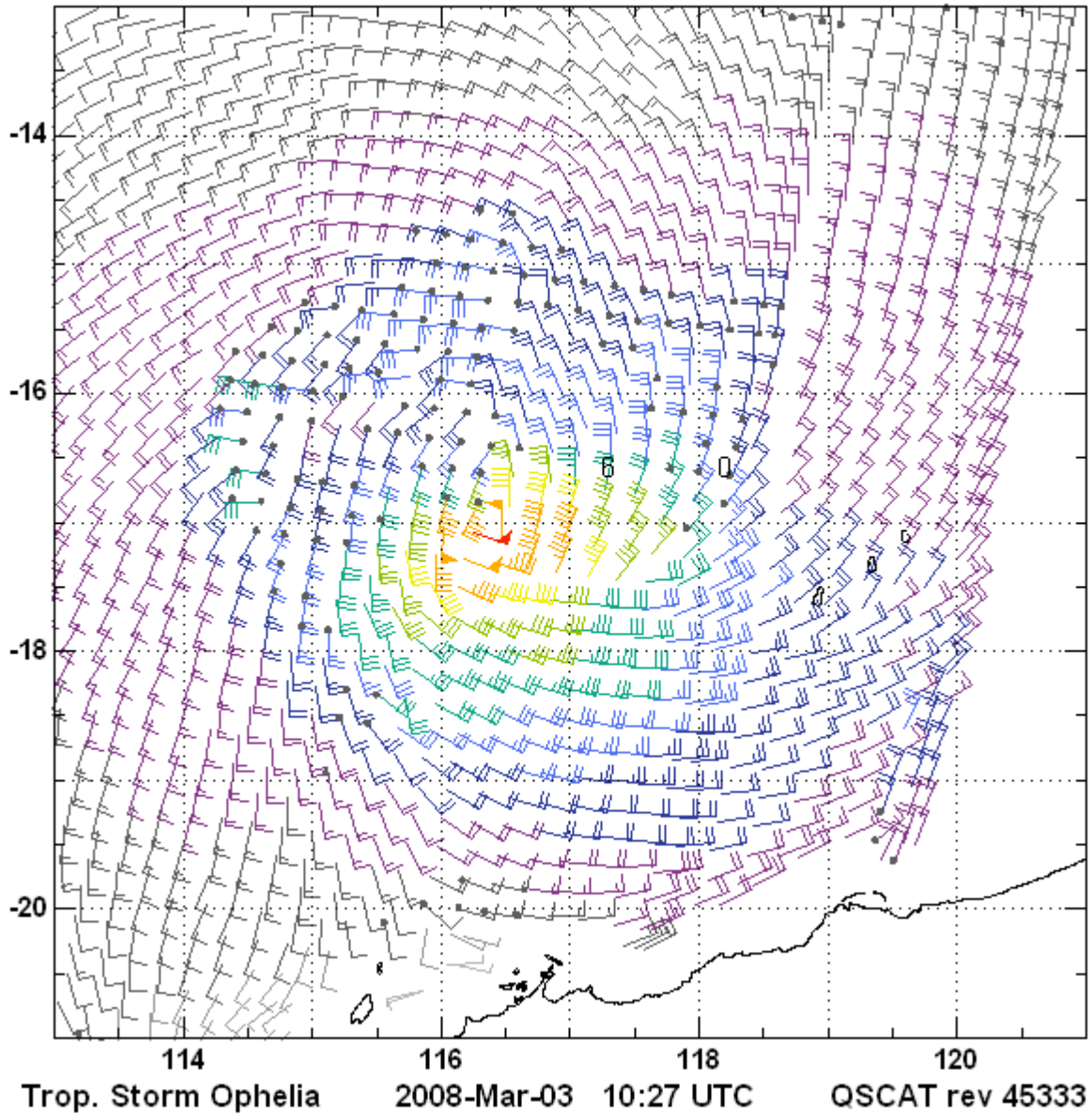

03/02/08 0600Z 21 OPHELIA
03/02/08 0528Z AMSR-E COMPOSITE
03/02/08 0530Z GMS-6 VIS
12S
16S
20S
124E
FNMOC http://tcweb.fnmoc.navy.mil/tc-bin/tc_home.cgi
Red=89PCT Green=89H Blue=89V

Figure 5.4 Quickscat at 10:27UTC 3 March 2008.
(image courtesy of RSS: http://www.ssmi.com/)



# 6. Severe Tropical Cyclone *Pancho*

**23 - 30 March 2008**

## 6A. Summary

A low formed in the Indian Ocean during an active phase of the monsoon trough which developed into *Pancho* by 25 March 2008. *Pancho* quickly intensified under favourable conditions as it moved in a south southeasterly direction towards the Western Australian coastline. The system reached category 4 intensity on 26 March before rapidly weakening as it experienced increased wind shear and moved over cooler sea surface temperatures (SST's).

*Pancho* was associated with heavy rainfall in the west Pilbara and Gascoyne. The remnants of *Pancho* moved further south passing near Perth on 31 March and resulting in heavy unseasonal rain across the southwest. The heavy rain was generally welcomed by pastoralists and farmers.

## 6B. Meteorological Description

### *Intensity analysis*

A low formed in the monsoon trough over the Indian Ocean during 23 March 2008. Initially the low experienced unfavourable shear with the low level centre located well to the east of the mid level circulation. By 25 March the wind shear had decreased and *Pancho* reached tropical cyclone strength by 0900 WDT (0000 UTC) 25 March.

Wind shear remained low and aided by strong upper outflow to the south of the system *Pancho* intensified rapidly following formation. By 26 March *Pancho* had formed a tight circulation and an eye appeared in visible imagery later in the day. *Pancho* reached peak intensity at 0700 WDT (2200 UTC) 26 March as it moved on a southerly track towards the Western Australian coastline (refer Fig. 6.3). Although microwave imagery showed the eye had expanded by this time convection was more intense and more concentric pattern than earlier.

From 1500 WDT (0600 UTC) 27 March *Pancho* began to weaken rapidly as the effects of increased wind shear and motion over cooler seas surface temperatures took effect. Subsequent microwave imagery showed the convection decreased in the northern quadrants and by the next morning convection persisted only in the southern quadrants with a low level centre exposed to the northwest. The system weakened to category 1 strength the following day at 2100 WDT (1200 UTC) 28 March and then to a tropical low by 0900 WDT (0000 UTC) 29 March although gales persisted in the southeast semi-circle for some time after.

### *Motion*

Initially *Pancho* was located to the north of the mid-level ridge and its motion was very slow. During 24 March a mid level trough approached from the southwest and began to steer *Pancho* on a more southerly course with an increase in speed. A second, more intense mid level trough formed to the southwest which continued *Pancho* on its south

southeasterly path. *Pancho* temporarily took an easterly course towards Shark Bay late on 28 March as it weakened.

***Structure***

Gales were most extensive in the southern quadrant, extending to about 400 kilometres (200 nm) in the early stages of development and to 360 kilometres (180 nm) at peak development, although the average gale radius was 220 kilometres (120-125 nm) for most of its cyclone stage.

An eye emerged on 26 March then expanded and dissipated on 27 March.

A strong ridge well to the south enhanced the easterly flow and combined with the weakening system to prolong gales on the southern side of the system after it had weakened below cyclone intensity.

**6C. Impact**

*Pancho* weakened to below cyclone intensity over the ocean. However strong easterly winds were experienced near Monkey Mia on 29 March with some damage reported from the area. Heavy rain was experienced in the west Pilbara and Gascoyne. Heavy rain was also experienced across the southwest of the state as the remnants of *Pancho* passed near Perth on 31 March. Northam recorded 21.6mm in just 19 minutes and local flooding forced the evacuation of a nursing home and resulted in many callouts to the SES. Strong winds fanned duststorms in the central wheatbelt and there were even reports of raining mud. The heavy rain was generally welcomed by pastoralists and farmers. The mid-latitude transition resulted in a deep low that passed just south of Tasmania causing strong winds across southeastern Australia.

**6D. Observations**

***Wind/Pressure***

Several ships recorded gale-force winds in the southeastern quadrant of the system near the Western Australian coastline during the morning of 28 March.

***Rainfall***

Heavy rain was recorded about the west Pilbara coast on 25-29 March (refer Fig. 6.2). Accumulated falls exceeded 200 mm at some stations and some of the higher daily rainfall totals included:

*24 hours to 0900 WDT 27 March*

Barrow Island 181 mm
Minderoo 157 mm;
Exmouth 119 mm;
Onslow Airport 95 mm;

*24 hours to 0900 WST 30 March in the Pilbara*
Yalleen 147 mm
Karratha 118 mm

Heavy rain extended into the Gascoyne on 27-28 March and then the Shark Bay region experienced heavy rain from late on 28 March through the 29 March when *Pancho* weakened off the coast. The heaviest falls included:

*24 hours to 0900 WST 30 March in the Gascoyne*
Tamala 96 mm
Denham 87 mm;

*24 hours to 0900 WST 1 April in Southwest Land Division*
Mandurah 63 mm
Dwellingup 61 mm

**6E. Forecast Performance**

The first shipping warning was issued for the developing low at 1219 WDT (0319 UTC) 24 March continuing until *Pancho* was downgraded to a tropical low at 1329 WDT (0429 UTC) 29 March. Subsequently a non-tropical cyclone gale warning remained for areas south of the system.

Tropical cyclone advices were not issued for the Western Australian coastline, however a Severe Weather Warning was issued for the southwest Gascoyne district including the Shark Bay region for potential flash flooding and damaging winds on the afternoon of 29 March.

Table 6.1 Best track summary for *Pancho,* March 2008.

| 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2008 | 3 | 23 | 06 | 12.0 | 102.0 | 40 | 20 | 45 | 1000 | | | |
| 2008 | 3 | 23 | 12 | 12.1 | 102.2 | 40 | 20 | 45 | 1000 | | | |
| 2008 | 3 | 23 | 18 | 12.3 | 102.4 | 40 | 25 | 45 | 1000 | | | |
| 2008 | 3 | 24 | 00 | 12.5 | 102.6 | 25 | 25 | 45 | 998 | | | |
| 2008 | 3 | 24 | 06 | 12.7 | 103.1 | 25 | 25 | 45 | 998 | | | |
| 2008 | 3 | 24 | 12 | 13.1 | 103.5 | 20 | 25 | 45 | 998 | | | |
| 2008 | 3 | 24 | 18 | 13.4 | 103.9 | 25 | 30 | 45 | 996 | | | |
| 2008 | 3 | 25 | 00 | 13.7 | 104.2 | 30 | 35 | 50 | 990 | 125 | | 30 |
| 2008 | 3 | 25 | 06 | 14.1 | 104.2 | 30 | 50 | 70 | 982 | 125 | 20 | 30 |
| 2008 | 3 | 25 | 12 | 14.6 | 104.1 | 35 | 50 | 70 | 982 | 102 | 20 | 20 |
| 2008 | 3 | 25 | 18 | 14.9 | 104.0 | 25 | 50 | 70 | 982 | 120 | 30 | 20 |
| 2008 | 3 | 26 | 00 | 15.5 | 104.3 | 20 | 55 | 80 | 974 | 120 | 40 | 20 |
| 2008 | 3 | 26 | 06 | 16.2 | 104.7 | 15 | 75 | 105 | 968 | 120 | 50 | 20 |
| 2008 | 3 | 26 | 12 | 17.2 | 105.1 | 15 | 90 | 125 | 940 | 120 | 60 | 15 |
| 2008 | 3 | 26 | 18 | 18.2 | 105.4 | 15 | 90 | 125 | 940 | 125 | 60 | 10 |
| 2008 | 3 | 27 | 00 | 19.3 | 105.8 | 20 | 95 | 135 | 934 | 125 | 60 | 20 |
| 2008 | 3 | 27 | 06 | 20.6 | 106.2 | 20 | 90 | 125 | 940 | 127 | 62 | 20 |
| 2008 | 3 | 27 | 12 | 21.6 | 106.8 | 20 | 85 | 120 | 952 | 125 | 60 | 20 |
| 2008 | 3 | 27 | 18 | 22.7 | 107.4 | 15 | 75 | 105 | 964 | 122 | 60 | 20 |
| 2008 | 3 | 28 | 00 | 23.6 | 108.1 | 20 | 60 | 85 | 974 | 120 | 60 | 25 |
| 2008 | 3 | 28 | 06 | 24.3 | 108.9 | 30 | 50 | 70 | 982 | 112 | 50 | 30 |
| 2008 | 3 | 28 | 12 | 24.9 | 109.3 | 30 | 40 | 55 | 986 | 110 | | 40 |
| 2008 | 3 | 28 | 18 | 25.0 | 110.0 | 25 | 35 | 50 | 990 | 90 | | 40 |
| 2008 | 3 | 29 | 00 | 25.0 | 110.9 | 15 | 35 * | 50 | 996 | | | 40 |
| 2008 | 3 | 29 | 06 | 25.2 | 111.3 | 20 | 35 * | 50 | 996 | | | 40 |
| 2008 | 3 | 29 | 12 | 25.5 | 111.6 | 40 | 30 | 45 | 996 | | | |
| 2008 | 3 | 29 | 18 | 25.7 | 111.4 | 45 | 30 | 45 | 996 | | | |
| 2008 | 3 | 30 | 00 | 26.1 | 111.3 | 25 | 25 | 45 | 998 | | | |
| 2008 | 3 | 30 | 06 | 26.2 | 111.1 | 25 | 25 | 45 | 998 | | | |

* Note: System below tropical cyclone intensity as gales extend less than halfway around the centre (only in the southeastern semi-circle).

Figure 6.1 Track of Tropical Cyclone *Pancho* 23 - 30 March 2008.

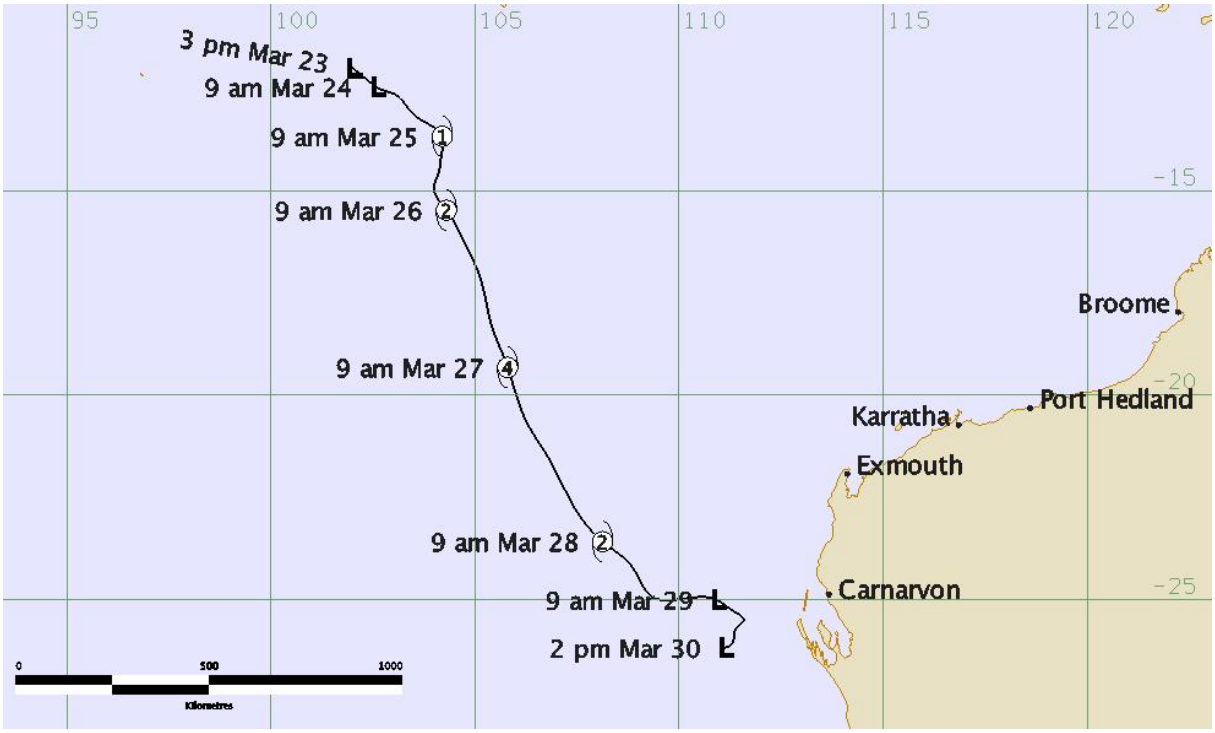



Figure 6.2 Weekly rainfall to 0900 WST 30 March showing rainfall associated with *Pancho*

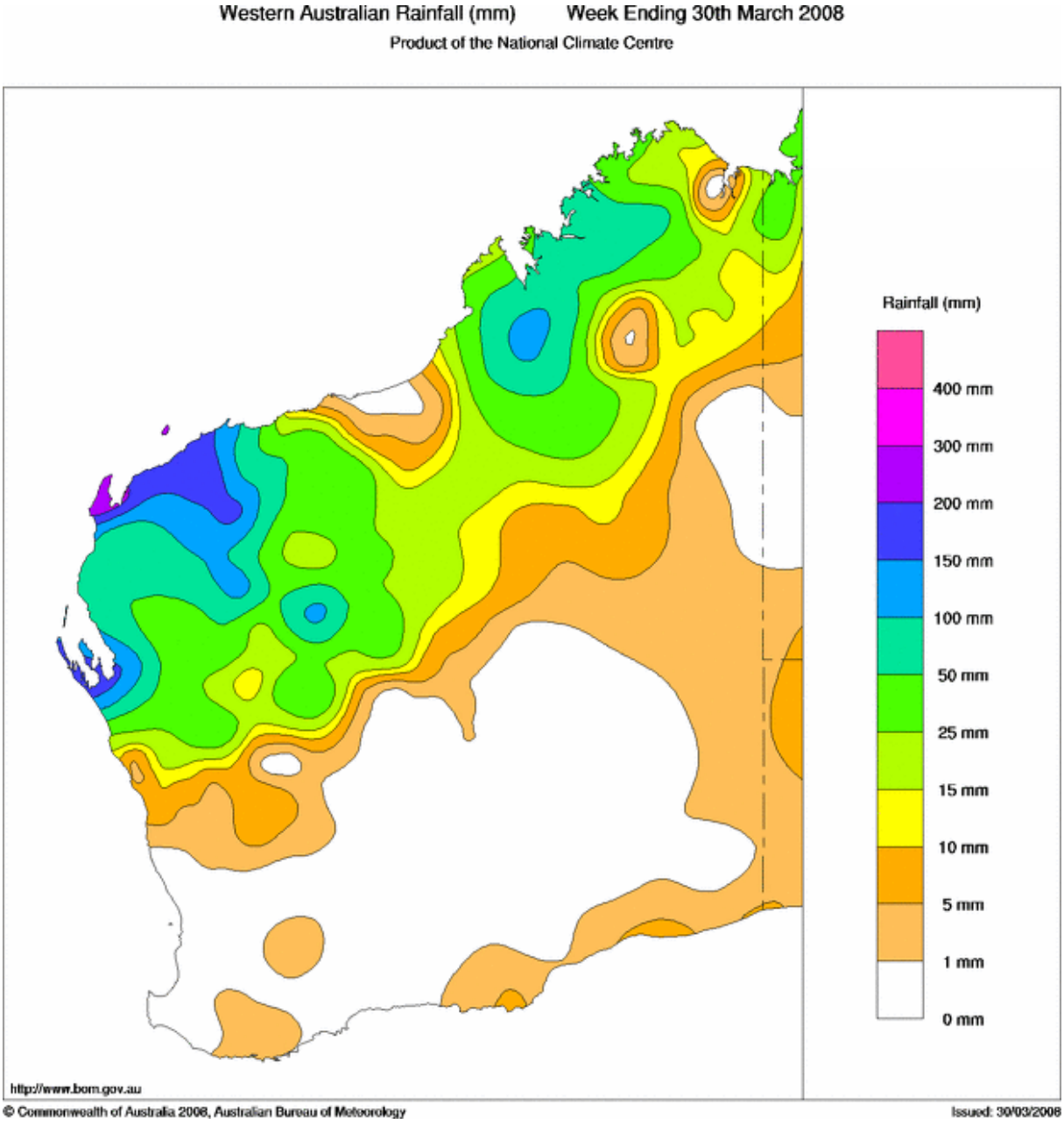
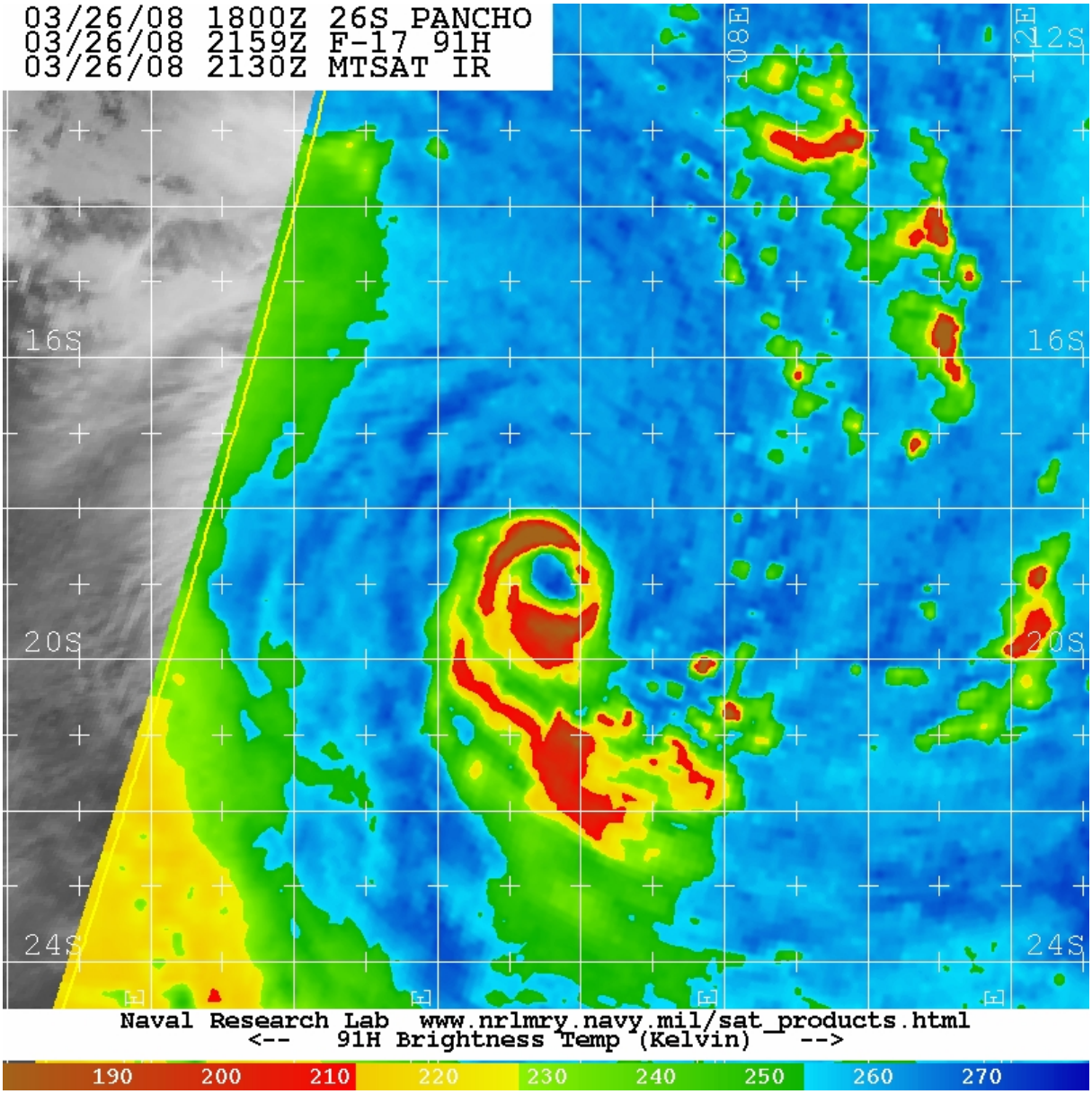



Figure 6.3 Microwave (AMSRE colour 89GHz) image at 2043 WDT (1143 UTC) 27 March 2008.
(image courtesy of US NRL: http://www.nrlmry.navy.mil/)


03/26/08 1800Z 26S PANCHO
03/26/08 2159Z F-17 91H
03/26/08 2130Z MTSAT IR
108E
112E
12S
16S
20S
24S
Naval Research Lab www.nrlmry.navy.mil/sat_products.html
<-- 91H Brightness Temp (Kelvin) -->
190 200 210 220 230 240 250 260 270

# 7. Tropical Cyclone *Rosie*

**20-24 April 2008**

## 7A. Summary

*Rosie* was a small cyclone that developed rapidly overnight from 21 to 22 April quickly reaching category 2 intensity before weakening as it passed near Christmas Island.

The most significant impact was the heavy swell at high tide at the port area of Christmas Island at about 0000 UTC on 22 April. The Harbour master reported waves of 5-7 m that damaged some facilities on the shore and tore a long-line mooring from its anchor.

This was the first tropical low monitored by the newly established Jakarta Tropical Cyclone Warning Centre (TCWC). While it was named by Perth TCWC once it moved south of 10°S, the reanalysis shows it reached cyclone intensity just north of 10°S in Jakarta TCWC's area of responsibility.

## 7B. Meteorological Description

### *Intensity analysis*

Convection about the monsoon trough was very active on 18 and 19 April with vigorous NW winds to the north. Quickscat showed an elongated trough during this period. Convection became more sustained and organised during 21 April and AScat at 0221 UTC showed 30 knot winds to the southwest, then the Quickscat at 1054 UTC showed gales evident to the southwest. The maximum intensity at 21/1200 UTC is given at 35 knots but system rated below TC intensity based upon the QScat evidence. Subsequently, a strengthening curved band pattern emerged and TC intensity is estimated at 21/1500 UTC when the Dvorak DT Curved Band pattern was estimated at 0.9 degree wrap on the IR image.

Development peaked at 22/0000 UTC when a clear eye became evident on microwave imagery (see Figure 7.2) and a ragged eye was briefly discernible on the 21/2330 UTC IR image. *Rosie* was estimated at 50 knot intensity on the basis of Dvorak FT=3.5 (category 2) and the 21/2327 UTC QScat image and AScat 22/0200 UTC. The estimated DT of 3.5 at 1800 UTC and 4.0 at 22/0000 UTC are 0.5 higher than the corresponding CI. Potentially *Rosie* was a case where the maximum winds increased faster than the Dvorak rules allow especially given its small size. It is also possible that the QScat could not resolve the maximum winds.

Gales were briefly observed at Christmas Island some 53 nm to the east of the LLCC. This corresponded with the high tide causing a considerable impact to the Port facilities as described below.

As dramatically as *Rosie* developed overnight, so did it weaken by day. During 22 April convection weakened dramatically and the low level circulation became devoid of convection.

The LLCC passed just south of Christmas Island just after 22/1200 UTC. Christmas Island registered just 33 knots at 22/1100 UTC but as the AWS is somewhat sheltered in northwesterlies it is likely that gales occurred at more exposed parts of the island. As winds

shifted to the southwest a maximum of 36 knots was recorded (10-minute mean) just after 22/1600 UTC. Given that only hourly observations were available it is possible that higher winds occurred and hence the maximum intensity is estimated at 40 knots. The pressure fell to 994.8 hPa at 22/1200 UTC on the hourly observations. Given the close proximity of the LLCC at this time, this is in agreement with the derived 993 hPa pressure from the modified Knaff-Zehr wind-pressure relationship. In contrast the Atkinson-Holliday equivalent was 988 hPa for a 40 knot maximum wind intensity.

Convection subsequently redeveloped overnight after about 22/1500 UTC but failed to become sustained or organised. By 23/0000 UTC convection was displaced to the southeast of the centre. Gales were only evident in the SE quadrant and hence the system was downgraded below TC intensity despite Dvorak CI still rated at 3.0 and the maximum intensity estimated at 35 knots. At 23/0600 UTC, the LLCC was located under some sustained convection indicating that gales may extend more than 50 per cent about the centre.

The AScat 23/1413 UTC pass clearly does not show gales. By 23/1800 UTC convection was displaced to the east of the LLCC, and while the Dvorak CI is still maintained at 3.0 on the basis of the proximity of the LLCC to the convection (using shear pattern), the intensity is rated at 30 knots. During 24 April convection weakened and the circulation became ill-defined.

***Motion***

A low formed within an active monsoon trough on 20 April well to the north of Cocos Island and moved in a general east southeast direction in the following days reaching tropical cyclone intensity. The 500 hPa flow shows a vigorous NW flow associated with a deep mid-latitude low and the monsoon. Following peak intensity being attained early on 22 April *Rosie* slowed and moved to the east in response to a deeper steering level. Following subsequent weakening it then moved to the south southeast.

**Structure**

*Rosie* was a small TC with gales being only on the order of 40-70 nm from the centre. Initially the combination of the strong NW monsoon and storm motion combined to produce 30 knot winds some distance from the centre, however the gales were most evident in southern quadrants owing to the extent of the convection.

The combination of the tight low-level circulation with convection during the overnight period provided the impetus for rapid development. The radius of maximum winds was estimated at about 15 nm although this did increase during the weakening phase. At peak intensity microwave imagery indicated an eye diameter of about 15 nm. Being of small size, *Rosie* was prone to weakening with unfavourable upper level winds that appear to have occurred during 22 April.

## 7C. Impact

The most significant impact was the heavy swell at high tide at the port area of Christmas Island. The Harbour master reported waves of 5-7m that damaged some facilities on the shore and tore a long-line mooring from its anchor. See Figure 7.3.

Fortunately *Rosie* weakened in intensity before it passed near to Christmas Island at 22/1200 UTC.

## D. Observations

### *Wind/Pressure*

Christmas Island AWS registered a minimum pressure of 994 hPa as *Rosie* passed by at 22/1200 UTC. Winds reached 33 knots prior to the passage As the AWS is somewhat sheltered in northwesterlies it is likely that gales occurred at more exposed parts of the island. As winds shifted to the southwest a maximum of 36 knots was recorded (10-minute mean). Given that only hourly observations were available it is possible that higher winds occurred. Fortunately this coincided with a minimum in convection otherwise winds are likely to have been significantly higher.

### *Rainfall*

Despite the potential for very heavy rainfall, Christmas Island registered only 33.2 mm between 21/1300 UTC to 22/0000 UTC and then another 19.6 mm from 22/1500 to 2300 UTC.

## 7E. Forecast Performance

A watch was issued for Christmas Island at 1500 WST 20 April when the tropical low was some 960 km to the west northwest. This was upgraded to a warning at 1515 WST 21 April as the low moved closer and a Blue Alert was issued by the Christmas Island Emergency Management Committee. The alert was upgraded to Yellow when the tropical cyclone was named *Rosie* at 0800 WST 22 April, at which stage large waves were impacting the island's port area. The warning was cancelled at 1400 WST, although a Blue alert remained in force for some time later.

Operationally the system was not named *Rosie* until it moved south of 10S into Perth TCWC's area of responsibility. Prior to this time Jakarta TCWC had official responsibility for the system.

Table 7.1 Best track summary for Tropical Cyclone *Rosie*.

| Year | Month | Day | Hour (UTC) | Position Latitude S | Position Longitude E | Position Accuracy nm | Max wind 10-min knots | Max gust knots | Central Pressure hPa | Rad. of Gales nm | Rad. of storm force winds | Radius Max. Wind (RMW) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2008 | 4 | 20 | 12 | 8.5 | 97.7 | 60 | 25 | 45 | 1000 | | | |
| 2008 | 4 | 20 | 18 | 8.5 | 99.0 | 50 | 30 | 45 | 1000 | | | |
| 2008 | 4 | 21 | 00 | 8.7 | 100.3 | 40 | 30 | 45 | 998 | | | |
| 2008 | 4 | 21 | 06 | 8.8 | 101.6 | 30 | 30 | 45 | 998 | | | |
| 2008 | 4 | 21 | 12 | 9.2 | 102.8 | 25 | 35 | 50 | 997 | | | 15 |
| 2008 | 4 | 21 | 15 | 9.7 | 103.2 | 25 | 40 | 55 | 995 | 40 | | 15 |
| 2008 | 4 | 21 | 18 | 10.0 | 103.9 | 25 | 45 | 65 | 992 | 50 | | 15 |
| 2008 | 4 | 22 | 00 | 10.6 | 104.8 | 15 | 50 | 70 | 988 | 57.5 | 20 | 15 |
| 2008 | 4 | 22 | 06 | 10.6 | 105.1 | 20 | 50 | 70 | 988 | 47.5 | 17.5 | 15 |
| 2008 | 4 | 22 | 12 | 10.5 | 105.6 | 15 | 40 | 55 | 993 | 37.5 | | 15 |
| 2008 | 4 | 22 | 18 | 10.7 | 106.1 | 25 | 40 | 55 | 993 | 37.5 | | 15 |
| 2008 | 4 | 23 | 00 | 11.1 | 106.4 | 20 | 35 | 50 | 996 | | | 20 |
| 2008 | 4 | 23 | 06 | 11.6 | 106.6 | 25 | 35 | 50 | 996 | 30 | | 20 |
| 2008 | 4 | 23 | 12 | 12.4 | 106.7 | 25 | 35 | 50 | 997 | | | 25 |
| 2008 | 4 | 23 | 18 | 13.0 | 106.4 | 25 | 30 | 45 | 999 | | | |
| 2008 | 4 | 24 | 00 | 13.7 | 105.9 | 25 | 30 | 45 | 999 | | | |
| 2008 | 4 | 24 | 06 | 14.9 | 105.8 | 40 | 25 | 40 | 1000 | | | |

Note: At 1200 UTC 21 April, 0000 UTC 23 April and 1200 UTC 23 April, the maximum wind is 35 knots, however no radius of gale value is entered as gales only occurred in one or two quadrants. As gales are required to extend more than half way around the centre to be called a tropical cyclone in the Australian region, the system is below tropical cyclone intensity at these times.

Table 7.2 Tropical Cyclone Advice summary for Tropical Cyclone *Rosie.*

| Date/Time (WST) | Action | Location |
|---|---|---|
| 20 April 1500 WST | TC Watch issued | Christmas Island |
| 21 April 1515 WST | TC Warning issued | Christmas Island |
| 22 April 1400 WST | TC Warning cancelled | Christmas Island |

Figure 7.1 Track of Tropical Cyclone *Rosie*.

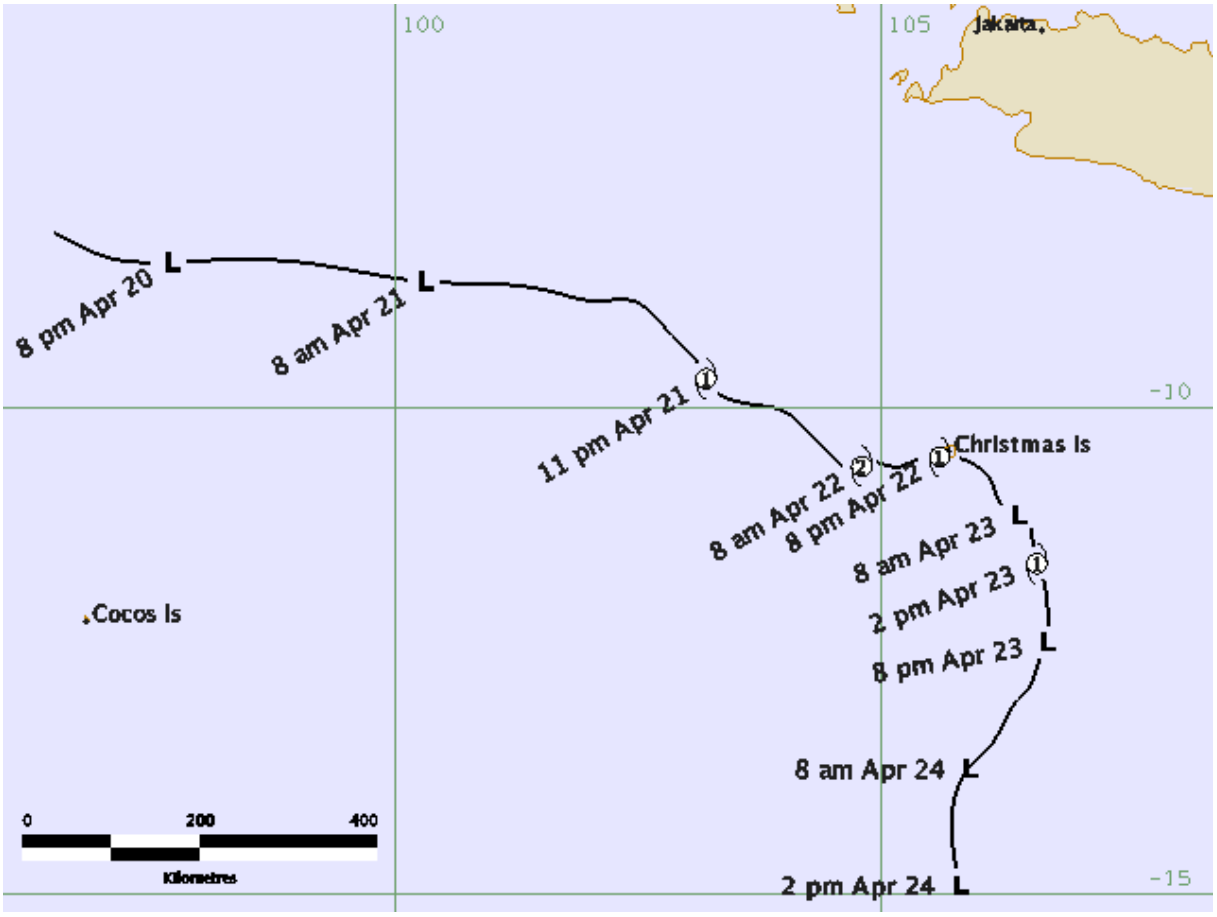


Figure 7.2 SSMI 85GHz microwave image at 21/2354 UTC.
(image courtesy of US NRL: http://www.nrlmry.navy.mil/)

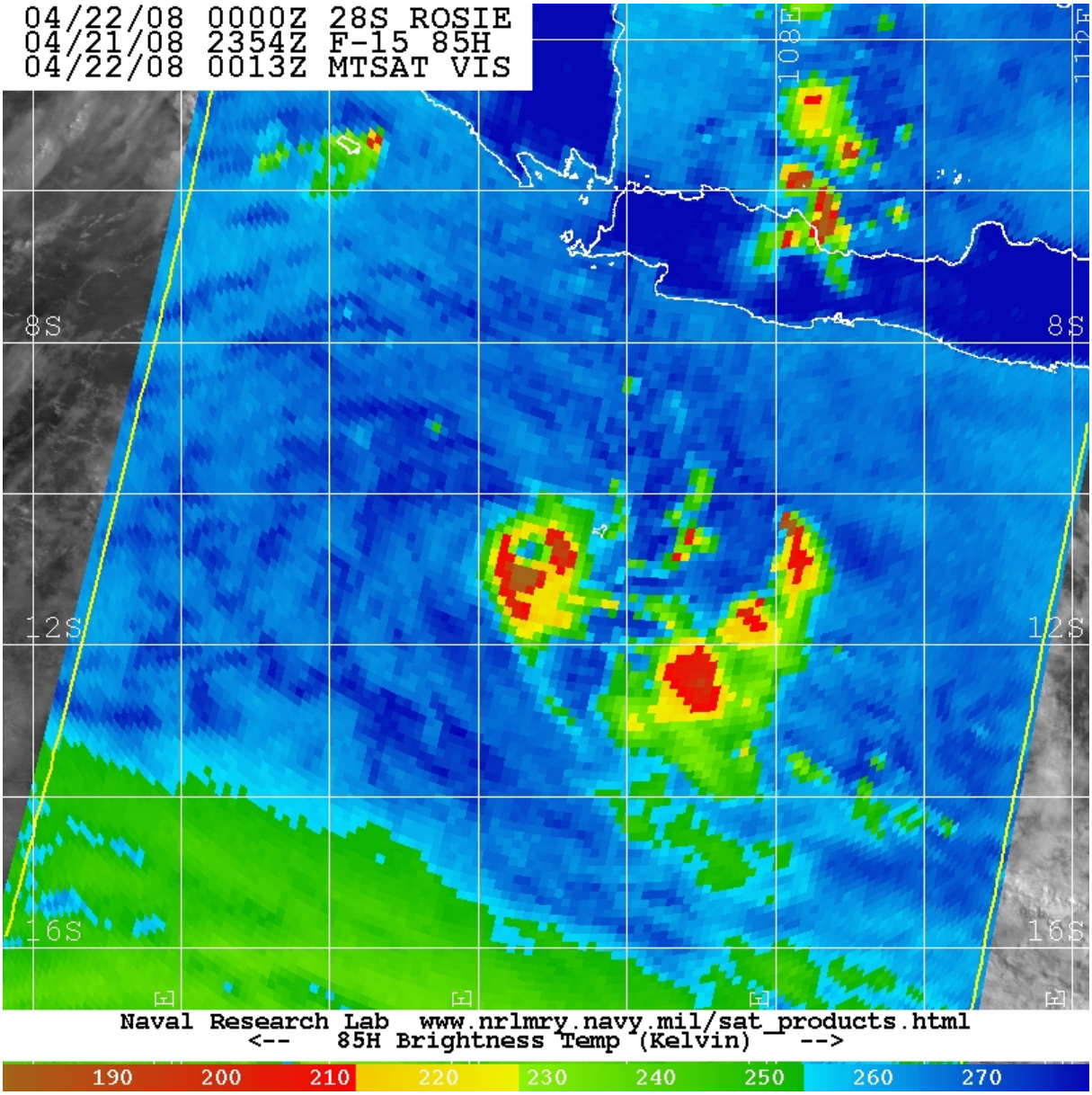


Figure 7.3 Large waves at the Christmas Island Port.
Photo provided by Dave Robertson, Harbourmaster, Christmas Island Port.

# 8. Tropical Cyclone *Durga*

**20-26 April 2008**

## 8A. Summary

A low which formed in an active monsoon trough during 20 April moved southeast and reached cyclone intensity on 22 April. This was the first tropical low named by the newly established Jakarta Tropical Cyclone Warning Centre (TCWC). It crossed into Australia's area of responsibility late on 23 April and weakened below cyclone strength by the morning of 25 April.

## 8B. Meteorological Description

### *Intensity analysis*

Convection about the monsoon trough was very active on 18 and 19 April with vigorous NW winds to the north. Quickscat showed an elongated trough during this period. During 20 April a circulation became evident in the western portion of the trough however moderate northerly shear hampered the development of the system. Microwave imagery showed the convection located to the south of the LLCC.

During 22 April shear over the system weakened which allowed convection to wrap around the LLCC and the system attained a DT/CI of 3.0. *Durga* continued to intensify over the next 6 hours reaching category 2 by 2100 WDST (1200 UTC) 22 April (refer Fig. 8.2).

From 23 April northerly wind shear increased and the convection became located mainly on the southern side of the system. *Durga* maintained a FT/CI of 3.5 for another 12 hours before beginning to weaken. Despite this convection continued to be sustained in the southern quadrants and it wasn't until early on 25 April that the LLCC became totally separated from the cold cloud and *Durga* weakened below cyclone strength.

### *Motion*

A low formed within an active monsoon trough on 20 April well to the north west of Cocos Island and moved in a general east southeast direction in the following days reaching tropical cyclone intensity. The 500 hPa flow shows a vigorous NW flow associated with a deep mid-latitude low and the monsoon. During 23 April a mid-latitude trough approached from the west and *Durga* began to move in a south easterly direction before turning south on 25 April and weakening to below cyclone strength.

### *Structure*

*Durga* was a small TC with gales being only on the order of 60 nm from the centre in most quadrants. However gale and storm force winds extended much further south (at times gales up to 120 nm and storm force winds up to 70 nm) in the south western quadrant where most of the convection persisted during its lifetime.

Radius to maximum winds was difficult to estimate and at times was large due to the separation of the convection from the LLCC.

## 8C. Impact

*Durga* had no impact on any communities.

## 8E. Forecast Performance

There were no watch/warnings issued for any island communities.

Table 8.1 Best track summary for Tropical Cyclone *Durga*

| Year | Month | Day | Hour (UTC) | Position Latitude S | Position Longitude E | Position Accuracy nm | Max wind 10-min knots | Max gust knots | Central Pressure hPa | Rad. of Gales nm | Rad. of storm force winds | Radius Max. Wind (RMW) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2008 | 4 | 20 | 00 | 5.7 | 82.2 | 30 | 20 | 45 | 1004 | | | |
| 2008 | 4 | 20 | 06 | 5.7 | 82.6 | 30 | 20 | 45 | 1004 | | | |
| 2008 | 4 | 20 | 12 | 6.4 | 83.5 | 30 | 20 | 45 | 1002 | | | |
| 2008 | 4 | 20 | 18 | 6.5 | 83.9 | 30 | 20 | 45 | 1002 | | | |
| 2008 | 4 | 21 | 00 | 7.4 | 85.4 | 30 | 25 | 45 | 1000 | | | |
| 2008 | 4 | 21 | 06 | 8.1 | 85.7 | 30 | 25 | 45 | 1000 | | | |
| 2008 | 4 | 21 | 12 | 7.9 | 86.5 | 30 | 25 | 45 | 998 | | | |
| 2008 | 4 | 21 | 18 | 8.0 | 87.7 | 20 | 30 | 45 | 996 | | | |
| 2008 | 4 | 22 | 00 | 8.1 | 88.9 | 20 | 30 | 45 | 996 | | | |
| 2008 | 4 | 22 | 06 | 8.2 | 90.3 | 10 | 40 | 55 | 990 | 75 | | 15 |
| 2008 | 4 | 22 | 12 | 8.1 | 92.6 | 10 | 50 | 70 | 984 | 75 | 40 | 15 |
| 2008 | 4 | 22 | 18 | 8.1 | 93.4 | 15 | 50 | 70 | 984 | 75 | 40 | 20 |
| 2008 | 4 | 23 | 00 | 8.6 | 94.8 | 20 | 50 | 70 | 984 | 70 | 35 | 40 |
| 2008 | 4 | 23 | 06 | 9.2 | 95.9 | 20 | 50 | 70 | 984 | 70 | 35 | 20 |
| 2008 | 4 | 23 | 12 | 9.4 | 97.2 | 20 | 50 | 70 | 984 | 60 | 25 | 30 |
| 2008 | 4 | 23 | 18 | 9.9 | 97.5 | 20 | 50 | 70 | 984 | 55 | 25 | 20 |
| 2008 | 4 | 24 | 00 | 10.0 | 98.3 | 10 | 50 | 70 | 984 | 55 | 25 | 30 |
| 2008 | 4 | 24 | 06 | 10.8 | 99.2 | 10 | 50 | 70 | 984 | 55 | 25 | 30 |
| 2008 | 4 | 24 | 12 | 11.4 | 99.7 | 30 | 35 | 50 | 990 | 55 | | 80 |
| 2008 | 4 | 24 | 18 | 11.8 | 99.8 | 30 | 35 | 50 | 990 | 45 | | 30 |
| 2008 | 4 | 25 | 00 | 12.7 | 100.1 | 20 | 35 | 50 | 990 | | | 15 |
| 2008 | 4 | 25 | 06 | 13.9 | 100.2 | 30 | 30 | 45 | 996 | | | |
| 2008 | 4 | 25 | 12 | 14.7 | 100.0 | 30 | 30 | 45 | 996 | | | |
| 2008 | 4 | 25 | 18 | 15.4 | 99.6 | 30 | 25 | 45 | 1000 | | | |
| 2008 | 4 | 26 | 00 | 16.4 | 99.6 | 30 | 25 | 45 | 1000 | | | |
| 2008 | 4 | 26 | 06 | 17.1 | 99.3 | 30 | 20 | 45 | 1000 | | | |

Figure 8.1 Track of Tropical Cyclone *Durga*.

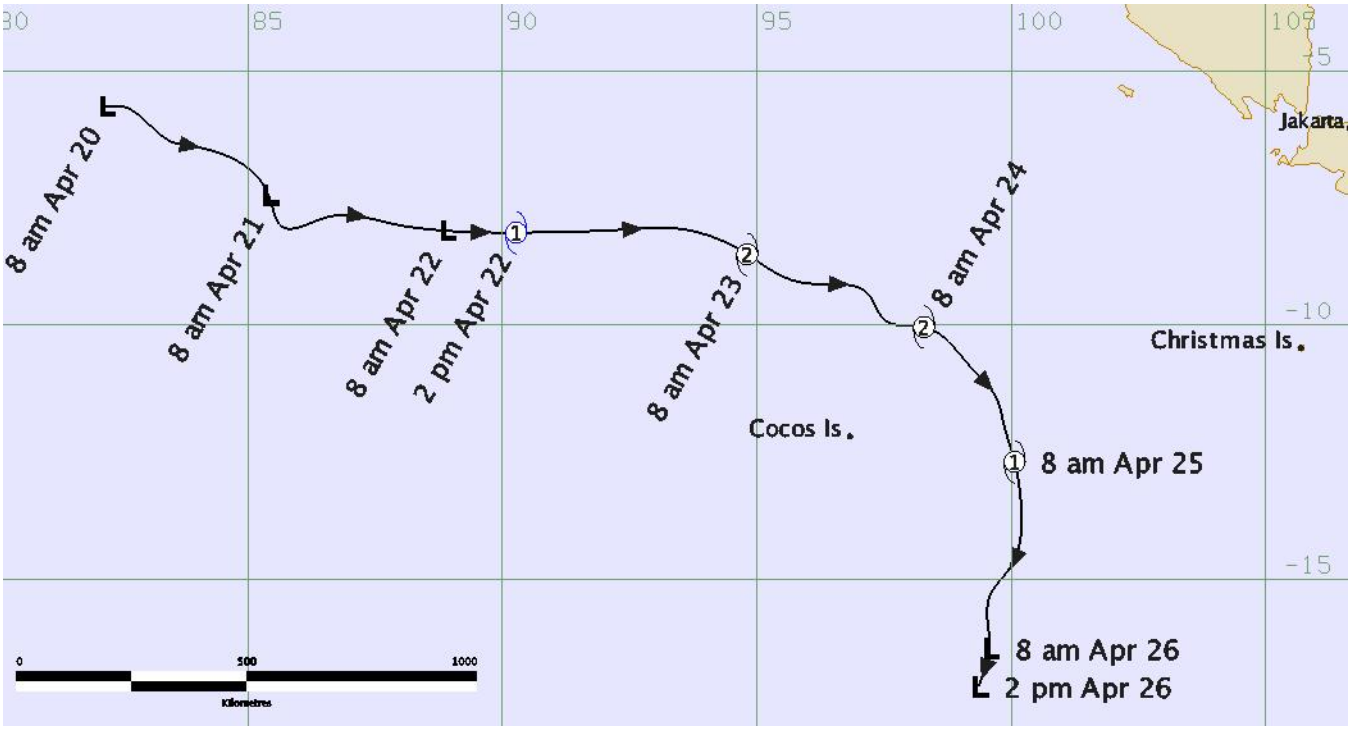



Figure 8.2 SSMI 91GHz microwave image at 22/1151 UTC.
(image courtesy of US NRL: http://www.nrlmry.navy.mil/)