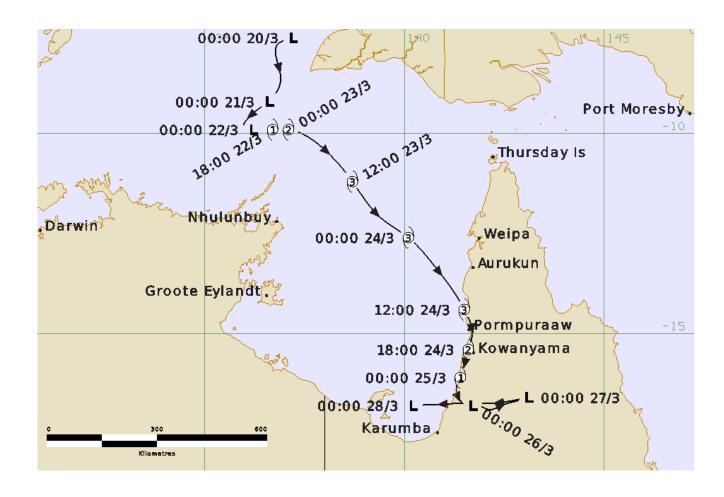


# **Severe Tropical Cyclone Nora**

### 20 - 28 March 2018

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#### **Revision history**

Date	Version	Author	Description
9/05/2023	1.0	Joe Courtney	Final draft ready

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#### Release history

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Cover image: Track of Severe Tropical Cyclone Nora. Times in UTC.

## **Table of contents**

1. Summary	4
2. Meteorological description	8
3. Impact	16
4. Observations	17
5. Forecast performance	19

## 1. Summary

Severe Tropical Cyclone Nora made landfall along the west coast of Cape York, just north of Pormpuraaw overnight from 24-25 March 2018, at category 3 intensity. Strong winds knocked down many trees and power lines in the towns of Pormpuraaw, Kowanyama and Mapoon, blocking roads and cutting power to more than 500 homes. Kowanyama experienced a brief period of gales and a peak wind gust of 54 kn (100 km/h) was recorded at 0354 AEST 25 March.

The overall track of Nora is shown in Figure 1a while a more detailed track near landfall with wind radii is shown in Figure 1b.

A tropical low was first identified and tracked in the Arafura Sea, near the West Papua coast on 20 March. The low drifted slowly south while only slowly developing before it adopted an eastwards track, coincident with a burst of monsoonal westerly winds to the north. The environment became highly conducive for development during 22 March as the vertical wind shear reduced. Deep convection increased around the circulation and tropical cyclone intensity was assigned in the overnight period from 22-23 March. Nora rapidly intensified into a very strong category three system late on 23 March as it tracked south-east into the Gulf of Carpentaria.

Nora continued on a south-eastward track through to landfall. The intensity fluctuated but was still estimated at category three intensity when it made landfall overnight from 24 to 25 March near Pormpuraaw. It then weakened as it tracked to the south close to the Cape York coast, passing near Kowanyama where the pressure fell to 983.3 hPa. Nora weakened below tropical cyclone intensity during 25 March and then became slow-moving over land. Although it did move to the west over the southern Gulf of Carpentaria on 28 March it failed to redevelop.

Widespread heavy rainfall occurred across the eastern parts of the Gulf Country district resulting in some flooding and road closures. In the 24 hours to 0900 AEST 26 March, the highest rainfall totals recorded in the area included 371 mm at Miranda Downs (north-east of Normanton), 321 mm at Upper Walker Creek (north-east of Normanton) and 233 mm at Croydon.

A 1.2 metre storm surge was recorded by the Weipa storm tide gauge north of where Nora made landfall, though the tide did not reach the Highest Astronomical Tide (HAT). Large waves were also observed at the Weipa wave monitoring gauge.

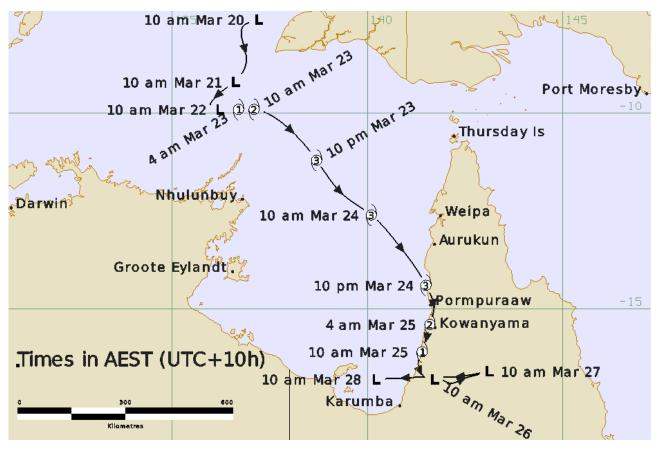


Figure 1a. Best track of Severe Tropical Cyclone Nora (times in AEST, UTC +10).

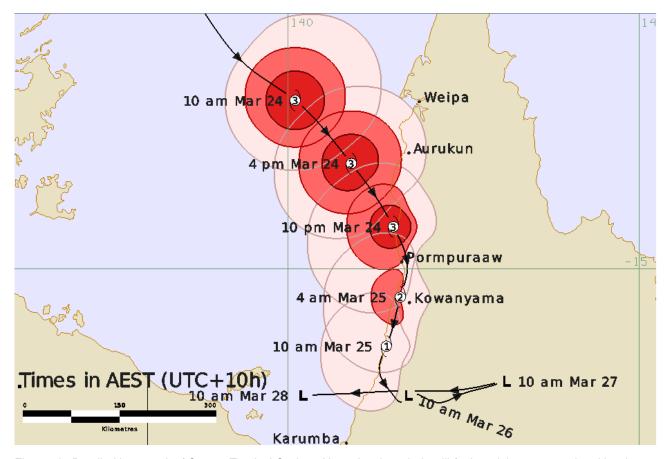


Figure 1b. Detailed best track of Severe Tropical Cyclone Nora showing wind radii (gale - pink, storm - red and hurricane force – dark red) 24-25 March (times in AEST, UTC +10).

Table 1. Best track summary for Severe Tropical Cyclone Nora, 20 - 28 March 2018.

UTC=AEST-10h.\* Not at tropical cyclone intensity as gales less than halfway around centre.

Year	Month	Day	Hour	Pos.	Pos.	Pos.	Max Wind	Max	Cent.	Rad. of gales	Rad. of storm	RMW
			UTC	Lat.	Long.	Acc.	10min	gust	Press.	(NE/SE/	(NE/SE/	nm
				S	E	nm	kn	kn	hPa	SW/NW)	SW/NW)	
2018	3	20	0000	7.6	137.2	25	15	45	1004	0/0/0/0	0/0/0/0	-
2018	3	20	0600	7.8	136.8	25	15	45	1002	0/0/0/0	0/0/0/0	-
2018	3	20	1200	8.3	136.9	20	15	45	1004	0/0/0/0	0/0/0/0	-
2018	3	20	1800	8.8	136.9	30	15	45	1002	0/0/0/0	0/0/0/0	-
2018	3	21	0000	9.2	136.6	25	20	45	1002	0/0/0/0	0/0/0/0	-
2018	3	21	0600	9.5	136.2	25	20	45	999	0/0/0/0	0/0/0/0	-
2018	3	21	1200	9.8	136.0	25	20	45	999	0/0/0/0	0/0/0/0	-
2018	3	21	1800	9.8	136.1	30	25	45	998	0/0/0/0	0/0/0/0	-
2018	3	22	0000	9.9	136.2	25	35*	45	997	0/0/0/90	0/0/0/0	-
2018	3	22	0600	9.9	136.4	25	35*	45	995	0/0/0/70	0/0/0/0	-
2018	3	22	1200	9.9	136.5	20	35*	45	994	80/0/0/60	0/0/0/0	-
2018	3	22	1800	9.9	136.7	20	40	55	992	80/30/40/60	0/0/0/0	25
2018	3	23	0000	9.9	137.1	20	50	70	985	80/40/60/60	20/0/0/20	18
2018	3	23	0600	10.4	138.0	15	60	85	980	80/60/60/60	30/20/20/30	15
2018	3	23	1200	11.2	138.7	10	85	120	960	80/70/60/70	40/30/30/40	12
2018	3	23	1800	12.1	139.4	10	85	120	960	80/70/60/70	45/40/40/45	12
2018	3	24	0000	12.6	140.1	15	80	110	963	80/60/60/60	45/40/40/45	15
2018	3	24	0300	13.0	140.5	15	70	100	970	80/60/70/60	45/40/45/45	18
2018	3	24	0600	13.5	140.9	15	70	100	970	70/60/70/60	45/40/45/45	18
2018	3	24	0900	13.9	141.2	10	75	105	968	40/40/80/60	30/30/40/40	15
2018	3	24	1200	14.4	141.5	10	75	105	968	40/30/80/60	20/20/40/40	15
2018	3	24	1500	15.0	141.7	15	65	90	978	30/20/80/60	15/15/30/30	15
2018	3	24	1800	15.4	141.6	20	55	75	982	25/25/70/60	0/0/25/25	15
2018	3	24	2100	15.8	141.5	20	50	70	984	20/20/70/60	0/0/0/0	18
2018	3	25	0000	16.1	141.4	20	40	55	987	20/20/60/50	0/0/0/0	20
2018	3	25	0300	16.5	141.3	20	35*	60	988	0/0/50/50	0/0/0/0	-
2018	3	25	0600	16.6	141.4	25	30	50	990	0/0/0/0	0/0/0/0	-
2018	3	25	1200	16.8	141.5	25	30	45	992	0/0/0/0	0/0/0/0	-
2018	3	25	1800	16.9	141.6	25	25	45	994	0/0/0/0	0/0/0/0	-
2018	3	26	0000	16.8	141.7	20	25	45	997	0/0/0/0	0/0/0/0	-
2018	3	26	0600	16.9	142.1	20	20	45	998	0/0/0/0	0/0/0/0	-
2018	3	26	1200	16.8	142.4	20	20	40	998	0/0/0/0	0/0/0/0	-
2018	3	26	1800	16.7	142.8	20	20	40	998	0/0/0/0	0/0/0/0	-
2018	3	27	0000	16.6	143.1	20	20	40	1000	0/0/0/0	0/0/0/0	-
2018	3	27	0600	16.7	142.6	20	20	40	999	0/0/0/0	0/0/0/0	-
2018	3	27	1200	16.7	141.8	20	20	40	1001	0/0/0/0	0/0/0/0	-
2018	3	27	1800	16.8	141.0	20	20	40	1002	0/0/0/0	0/0/0/0	-
2018	3	28	0000	16.8	140.2	20	20	40	1004	0/0/0/0	0/0/0/0	-

## 2. Meteorological description

### 2.1 Intensity analysis

A comparison of the intensity estimates is shown in Figure 2.

A tropical low formed in the Arafura Sea close to the West Papua coast on 20 March supported by the effects of a westwards-propagating Rossby wave and a weak but discernible pulse of the Madden-Julian Oscillation in the Maritime Continent. An increase in monsoonal westerlies on 21-22 March provided strong low-level inflow. ASCAT images near 00 UTC 22 March showed neargales to the north and west about an elongated (west-east) centre. As the east-south-easterly wind shear reduced during 22 March, deep convection consolidated about the centre resulting in rapid development. Tropical cyclone intensity was estimated at 18 UTC 22 March. The SSMIS 91 GHz microwave image at 1901 UTC 22 March in Figure 3, Visible image at 00 UTC 23 March in Figure 4 and the ASCAT-B image at 0033 UTC all indicate a tropical cyclone.

Rapid development continued during 23 March aided by a mid-latitude trough enhancing the outflow to the south and low wind shear over the circulation. A well-defined eye became evident as indicated by the Visible image at 0730 UTC 23 March in Figure 4 and particularly on the SSMIS 91 GHz microwave image at 0945 UTC. Nora's intensity was estimated to increase from 50 kn at 00 UTC to 85 kn at 12 UTC which is extremely rapid and at the limits of the Dvorak guidelines. The SATCON objective guidance in Figure 2 even shows the peak intensity around this time at 100 kn (category 4).

A subtle increase in north-easterly wind shear and possibly some associated entrained mid-level dry air led to some erosion of deep convection on the eastern side. Deep convection fluctuated from then on through to landfall. The enhanced infrared image (Dvorak enhancement) at 1140 UTC 24 March in Figure 7 showed very cold cloud tops about a poorly defined eye. Despite some evidence of weakening Nora is estimated to still have been at category 3 intensity as it made landfall on the Gulf coast of Cape York Peninsula near Pormpuraaw at around 15 UTC 24 March.

The Weipa radar also showed fluctuations in the eye definition during 24 March. Figure 8 shows comparison images from 0600 UTC and 1336 UTC 24 March that show the eyewall contraction to a well-defined eye near the coast just prior to landfall. This suggested some intensification was occurring.

Upon landfall around 15 UTC 24 March, Nora tracked south close to the coast, passing close to Kowanyama where the pressure fell to 983.3 hPa at 1835 UTC. Recorded winds reached galeforce for a period between 15-17 UTC 24 March and a maximum wind gust of 54 kn at 1754 UTC 24 March.

Deep convection weakened near the centre and gales are estimated to reduce to less than half-way around the centre and hence below tropical cyclone intensity at 03 UTC 25 March. The system remained over land and weakened further over following days. The low did move to the west and over the southern Gulf of Carpentaria on 28 March but was very weak by this stage.

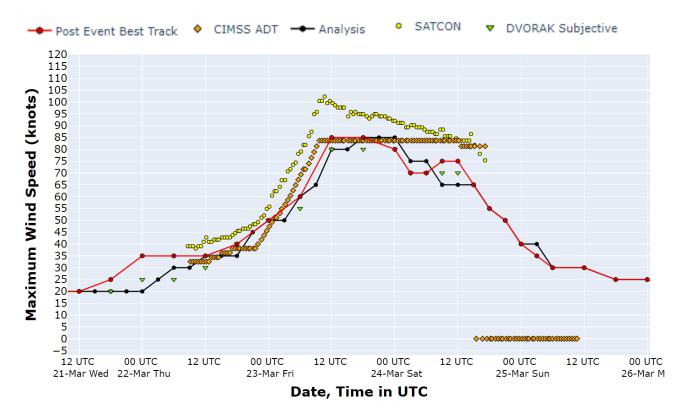


Figure 2. Intensity comparison plot showing the best track intensity (red) against the operational estimate, subjective Dvorak and objective estimates (SATCON and CIMSS ADT).

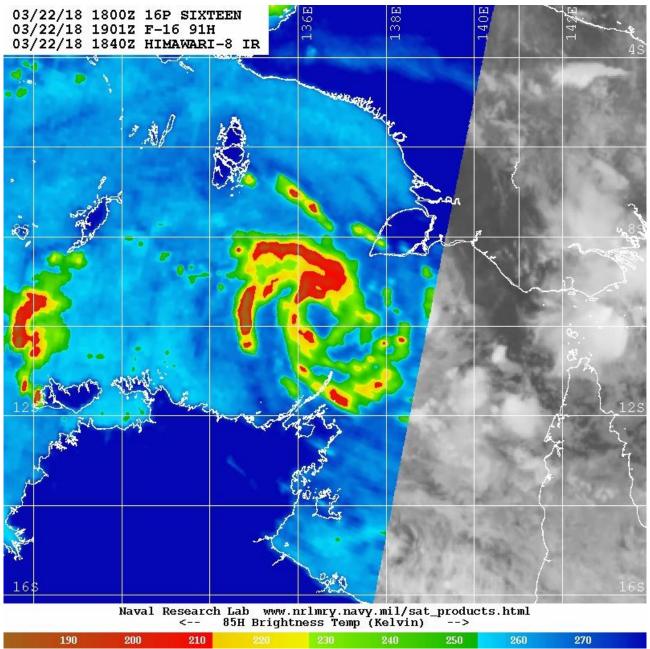


Figure 3. Special Sensor Microwave Imager/Sounder (SSMIS) microwave image at 1901 UTC 22 March, showing strong curvature in deep convection about the centre indicating that tropical cyclone intensity had been attained. Image courtesy NRL: <a href="https://www.nrlmry.navy.mil/TC.html">https://www.nrlmry.navy.mil/TC.html</a>

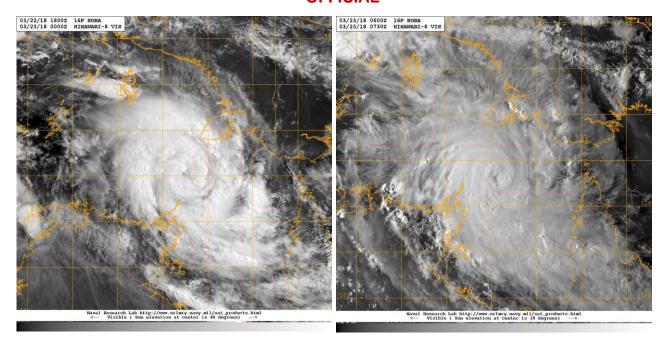


Figure 4. Visible image at 0000 UTC 23 March (left) showing well defined curvature in deep convection when Nora was estimated at category 2 intensity (maximum winds of 50 kn) and at 0730 UTC 23 March (right) showing the formation of an eye. Image courtesy NRL: <a href="https://www.nrlmry.navy.mil/TC.html">https://www.nrlmry.navy.mil/TC.html</a>

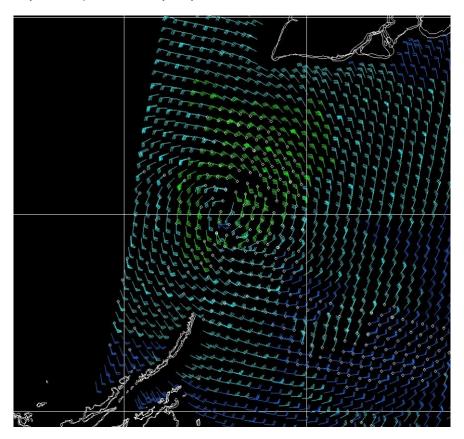


Figure 5. Advanced Scatterometer (ASCAT-B) wind distribution at 0033 UTC 23 March showing gales in green around the centre and an extensive region of 30+ kn winds to the north. Grid lines are every 2 degrees. Image courtesy NRL: <a href="https://www.nrlmry.navy.mil/TC.html">https://www.nrlmry.navy.mil/TC.html</a>

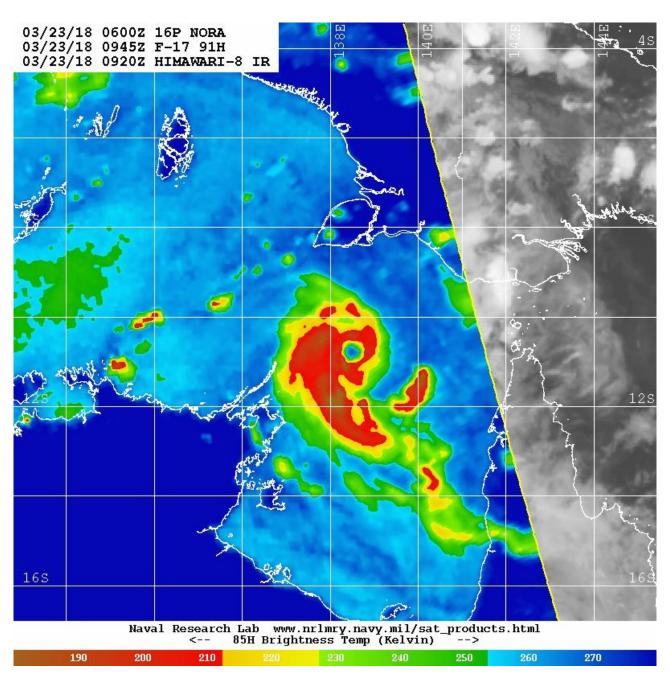


Figure 6. Special Sensor Microwave Imager/Sounder (SSMIS) microwave image at 0945 UTC 23 March, showing a well defined eye as Nora approached peak intensity. Image courtesy NRL: <a href="https://www.nrlmry.navy.mil/TC.html">https://www.nrlmry.navy.mil/TC.html</a>

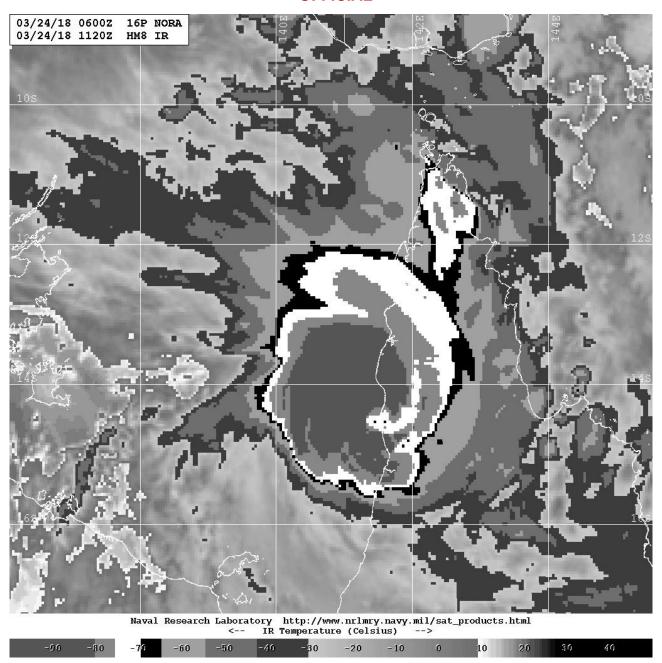


Figure 7. Enhanced Infrared image (Dvorak enhancement) at 1120 UTC 24 March 2018 as Nora made landfall. Image courtesy NRL: <a href="https://www.nrlmry.navy.mil/TC.html">https://www.nrlmry.navy.mil/TC.html</a>

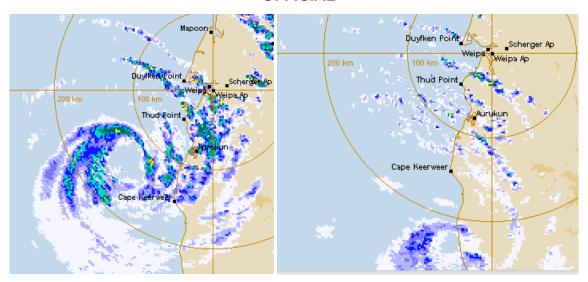


Figure 8. Weipa weather radar at 0600 UTC 24 March (left) and 1336 UTC 24 March (right) 2023 showing a contraction of the eyewall as Nora neared the coast.

### 2.1 Structure

A broad band of monsoonal west-north-westerlies north of the centre were influential in the system's early development. Deep convection was predominantly west of the centre influenced by moderate easterly wind shear. A region of near gales to the north and west were evident in scatterometry imagery on 22 March.

The ASCAT-B pass at 0033 UTC 23 March shown in Figure 5 showed gales around the centre with a broad region of 30 kn winds extending well to the north of the circulation. As the wind shear reduced and the system intensified, the strongest winds became more symmetric as shown by the circular eyewall on the SSMIS 91 GHz microwave image at 0945 UTC 23 March in Figure 6. The eyewall then fluctuated in appearance as the circulation battled a slight increase in wind shear and dry air entrainment in an otherwise favourable environment for development.

As Nora approached land the extent of gales to the east reduced. The strongest winds occurred over water as Nora moved to the south near the coast. By 03 UTC 26 March gales were estimated to be confined to the western sectors over water.

Aside from the times being influenced by land, the gale radii varied from about 50-80 nm (93-148 km), being highest in the north-east quadrant. The radius to maximum winds (RMW) varied from about 12 nm (22 km) near peak intensity to about 20 nm (37 km). The Weipa radar showed some contraction in the eyewall as Nora neared the coast, possibly associated with a short period of intensification.

The swathe of gales, storm-force and hurricane-force winds is shown in Figure 1b.

### 2.2 Motion

Initially the developing low drifted slowly to the south. The burst of monsoonal west-north-westerlies then helped steer the circulation to the east-south-east on 22-23. As Nora strengthened and extended in depth through the atmosphere, it became influenced by the mid-level north-westerly flow associated with the mid-latitude trough to the south. Hence Nora accelerated to the south-east towards the Cape York Peninsula. As the mid-latitude trough weakened to the south, a mid-level ridge over the Coral Sea became the more dominating steering influence that resulted in a slower more southerly track following landfall near the coast on 25 March. The low meandered over land on 26-27 March before a strengthening ridge to the south steered the weak circulation to the west over the southern Gulf of Carpentaria on 28 March.

## 3. Impact

Squally showers and storms affected north-east Arnhem Land as Nora was developing to the north during 22 March and a wind gust to 78 km/h was observed at Groote Eylandt Airport but there were no reports of any damage.

Strong winds knocked down many trees and power lines in the towns of Pormpuraaw, Kowanyama and Mapoon, blocking roads and cutting power to more than 500 homes. Damage was caused to houses, council buildings, personal property and other buildings. Very heavy rainfall occurred across most of Cape York Peninsula and Far North Queensland. Many communities became isolated by floodwaters after roads were either blocked or damaged.

Although not directly related to Nora, extreme rainfall fell in parts of Queensland's east coast. Flash flooding occurred in the Cairns region as a result of the intense rainfall, including in car parks, shopping centres and hotels. The torrential rain caused landslides that blocked highways in the region. Agricultural losses in crops and livestock, as well as damage to infrastructure, were also sustained when farms were flooded.

Source: https://en.wikipedia.org/wiki/Cyclone Nora

## 4. Observations

#### 4.1 Winds

Nora passed over Kowanyama early on 25 March. Kowanyama recorded a period of gales between 15-17 UTC 24 March (01 - 03 AEST 25 March). The maximum wind gust was 54 kn (100 km/h) at 1754 UTC 24 March (0354 AEST 25 March).

Cape Wessel (off north-east Arnhem Land, NT) observed a period of gales in the hour prior to 0000 UTC 23 March when Nora was 65 nm to the north-north-east.

#### 4.2 Rainfall

Following landfall, Nora caused widespread heavy rainfall across the eastern parts of Queensland's Gulf Country district. In the 24 hours to 0900 AEST 26 March, the highest rainfall totals recorded in the area included 371 mm at Miranda Downs (north-east of Normanton), 321 mm at Upper Walker Creek (north-east of Normanton) and 233 mm at Croydon. The weekly rainfall map 22-28 March for Queensland in Figure 9 shows broad regions over Cape York Peninsula and the Gulf District having rainfall exceeding 100 mm.

#### 4.3 Pressure

Kowanyama recorded a minimum pressure of 983.3 hPa at 1835 UTC 24 March (0435 AEST 25 March) as Nora passed by.

## 4.4 Storm surge

A 1.2 metre storm surge was recorded by the Weipa storm tide gauge to the north of the point of landfall, though the level of the Highest Astronomical Tide was not exceeded. Large waves were also observed at the Weipa wave monitoring gauge.

Queensland Rainfall Totals (mm) Week Ending 28th March 2018
Australian Bureau of Meteorology

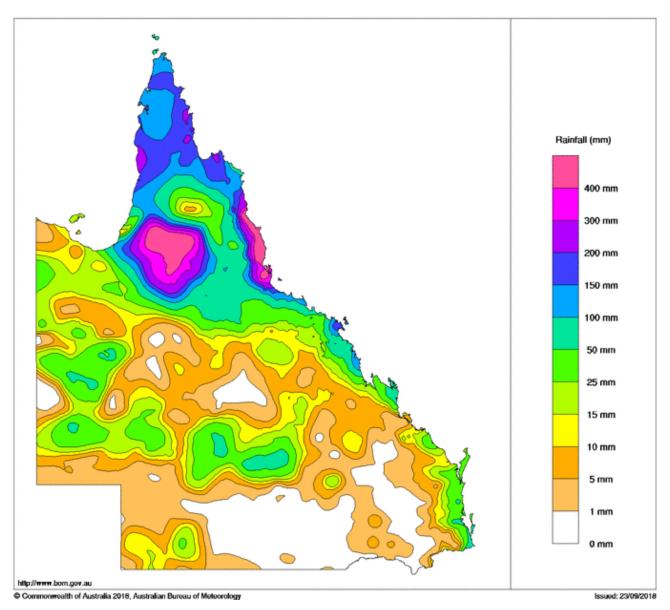


Figure 9. Weekly rainfall totals, 22 to 28 March 2018.

## 5. Forecast performance

Tropical Cyclone Advices were initiated from 04 UTC 21 March until 18 UTC 25 March.

Tropical Cyclone Advices were issued initially on 21 March for the north-east Northern Territory coast for possible gales on 23 March. A watch for the Queensland Cape York peninsula west coast (Gulf of Carpentaria coast – Thursday Island to Gilbert River Mouth) was issued on the morning of 22 March for possible gales on 24 March. Advices were cancelled for the Northern Territory region the night of 23 March after the threat of gales diminished. Advices continued through to landfall and even continued after Nora weakened below tropical cyclone overland on 25 March for the risk of redeveloping in the southern Gulf.

The accuracy figures for Severe Tropical Cyclone Nora are below and also shown in Figures 10 a and 10 b. These show that the forecast position was slightly better than the five-year average at all time steps. The intensity forecasts were not as good as the five-year average and significantly worse at longer lead times. Figure 11 shows the forecast intensity issued at 0000 UTC from 21-24 March compared to the best track intensity. The forecasts issued during the developing stages correctly identified intensification but not at the right time, missing the initial rapid development during 23 March. The forecast peak from 21-23 March was accurate at 80-85 kn but it was expected to be reached on 25 March and be sustained for several days on the expectation that Nora would remain over water. As it was Nora made landfall earlier than expected and weakened, albeit being just inland over Cape York. By the time it emerged into the Gulf of Carpentaria it had weakened beyond recovery This highlights the importance of the track forecast upon the intensity skill.

Table 2. Verification statistics for Severe Tropical Cyclone Nora.

	0	6	12	18	24	36	48	72	96	120
Position Absolute error (km)	19	37	52	61	71	95	111	170	246	271
Intensity Absolute error (kn)	2.8	5.7	10.3	15.3	19.3	23.5	27.9	36.4	53.3	56.7
Sample Size	20	20	20	20	20	20	20	17	13	9

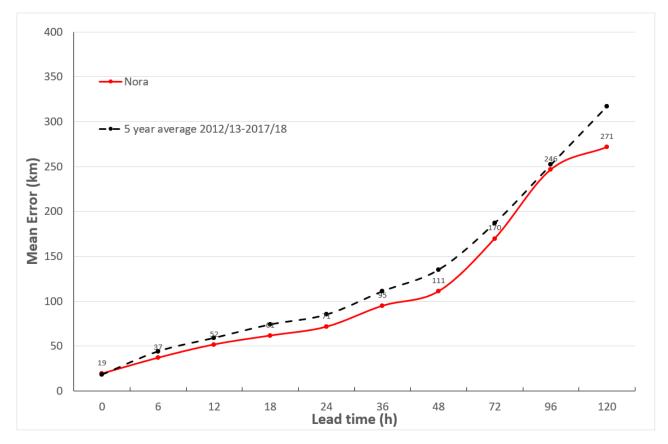


Figure 10 a. Position accuracy figures for Severe Tropical Cyclone Nora.

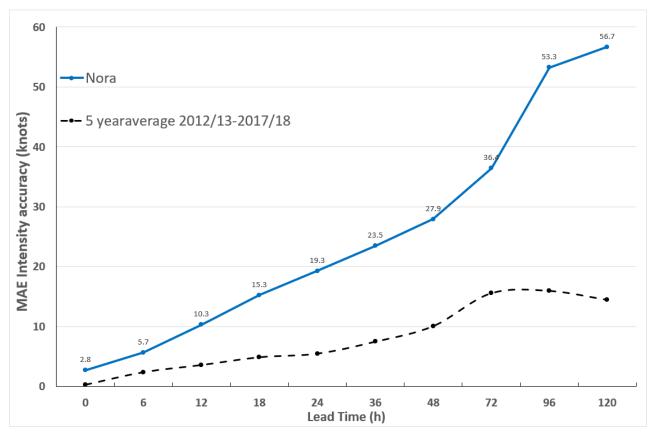


Figure 10 b. Intensity accuracy figures for Severe Tropical Cyclone Nora.

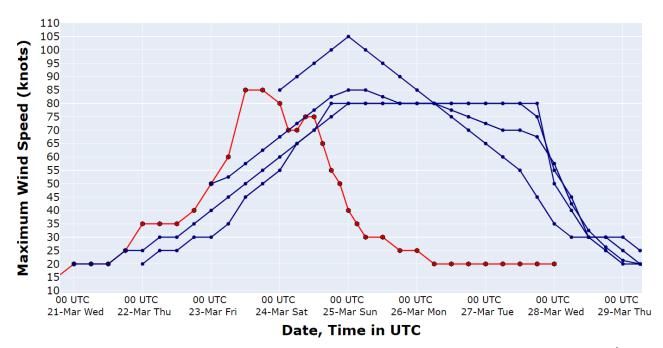


Figure 11. Intensity forecasts (blue) issued at 00 UTC on 21, 22, 23, 24 March against the best track intensity (red).

# 1. Appendix: List of abbreviations

Abbreviation	Term
ADT	Advanced Dvorak Technique
ACST	Australian Central Standard Time
AEST	Australian Eastern Standard Time
AMSR2	Advanced Microwave Scanning Radiometer
ASCAT	Advanced Scatterometer
ATMS	Advanced Technology Microwave Sounder
AWS	automatic weather station
AWST	Australian Western Standard Time
°C	Celsius
CI	Current intensity
CIMSS	Cooperative Institute for Meteorological Satellite Studies (USA)
CIRA	Cooperative Institute for Research in the Atmosphere (USA)
EIR	Enhanced InfraRed
ERC	eyewall replacement cycle
FNMOC	Fleet Numerical Meteorology and Oceanography Centre (USA)
FT	Final T-number
GCOM	Global Change Observation Mission
GHz	Gigahertz
GMI	Global Precipitation Measurement Microwave Imager
h	hour
hPa	hectopascal
HSCAT	Hai Yang 2 Scatterometer (HY-2B, HY-2C)
km	kilometres
km/h	kilometres per hour
kn	knot
LLCC	LLCC
MET	Model Expected T-number

METOP	Meteorological Operational Satellite
MJO	Madden-Julian Oscillation
mm	millimetres
MSLP	mean sea level pressure
nm	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NRL	Navy Research Lab (USA)
PAT	Pattern T-number
RH	relative humidity
RMW	radius of maximum winds
RSMC	Regional Specialised Meteorological Centre
SAR	Synthetic Aperture Radar
SATCON	satellite Consensus
SMAP	Soil Moisture Active Passive
SMOS	Soil Moisture and Ocean Salinity
SSMIS	Special Sensor Microwave Imager/Sounder
TC	Tropical Cyclone
TCWC	Tropical Cyclone Warning Centre
UTC	Universal Time Co-ordinated