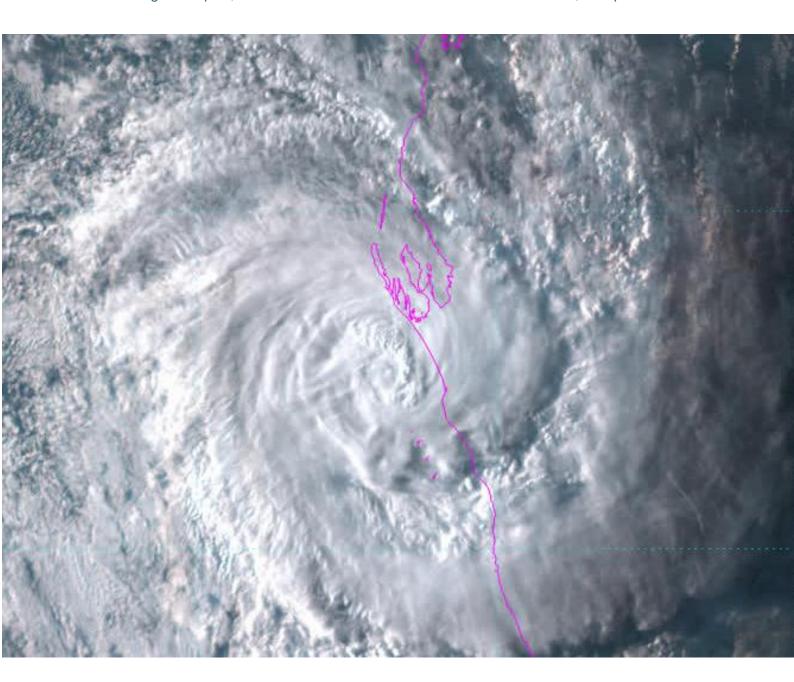


Severe Tropical Cyclone Seroja

2 - 12 April 2021

Craig Earl-Spurr, Severe Weather Environmental Prediction Services, 2 September 2022.



	Severe Tropical Cyclone Seroja
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1 Summary

Severe Tropical Cyclone Seroja was a notable event for several reasons. Firstly, during its initial formation, Seroja producing torrential rainfall and devastating floods in parts of Indonesia and Timor Leste. Later, it interacted with Tropical Cyclone Odette via the Fujiwara effect, a phenomenon rarely observed in the Australian region. Finally, it strengthened into a category 3 tropical cyclone producing a severe impact in the Mid-West region of Western Australia, unusually far south for a coastal crossing of a Severe Tropical Cyclone.

Seroja began as a slow-moving tropical low near the Indonesian Island of Rote on 2 April. It produced sustained heavy rainfall, which caused extensive flooding and landslides on Rote and neighbouring islands, particularly Timor. Widespread and devastating damage was reported by Indonesia's disaster agency Badan Nasional Penanggulangan Bencan (BNPB), including more than 150 fatalities.

The tropical low intensified and on 5 April it was named Seroja by Jakarta Tropical Cyclone Warning Centre (TCWC). It started moving west and quickly intensified into a category 2 tropical cyclone. Then, during 6 and 7 April, Seroja weakened back into a tropical low as it moved southwest. During 8 and 9 April it began to interact with another tropical low, that briefly intensified into Tropical Cyclone Odette. Over a period of approximately 36-48 hours the two tropical cyclones interacted via the Fujiwara effect.

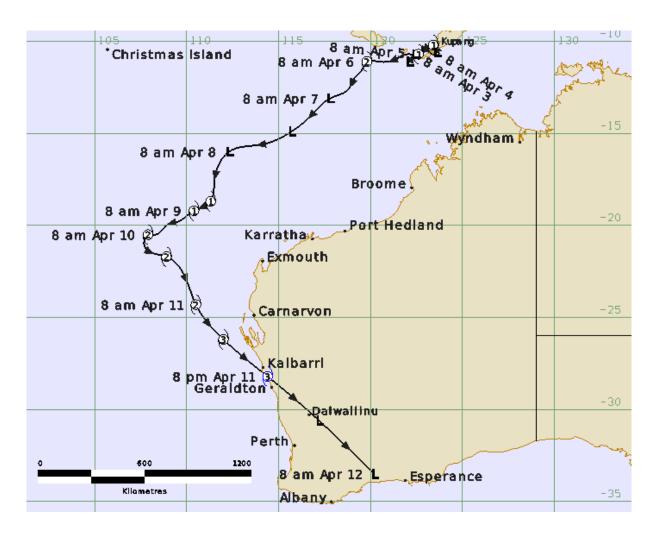
The interaction with Odette is likely to have been a factor in maintaining Seroja's track towards the southwest, rather than recurving into the west Pilbara coast. As Odette circled around to the north and then the east of Seroja, it also made conditions more favourable for intensification by replacing the dry air that had been limiting Seroja's intensity with moist air that could fuel its intensification. The increased moisture combined with lower vertical wind shear resulted in Seroja re-intensifying into a category 2 tropical cyclone while Odette weakened and eventually dissipated.

During 10 April, Seroja took a sharp turn towards the southeast and began to accelerate towards the Western Australian coast. Seroja further intensified into a severe category 3 tropical cyclone on 11 April and maintained this intensity through to its coastal crossing just south of Kalbarri around 8pm Australian Western Standard Time (AWST).

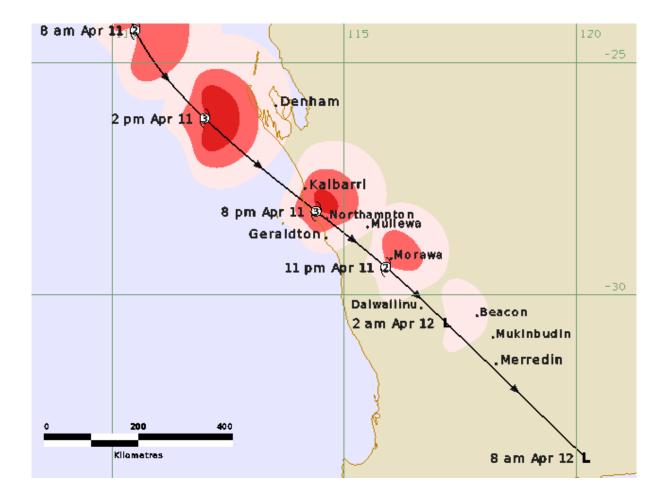
Impacts at Kalbarri and the nearby town of Northampton were severe with many buildings sustaining significant damage, mostly consisting of lost roofs but other structures were destroyed. Many locations recorded maximum wind gusts greater than 125km/h with the highest being 170km/h from Meanarra Tower near Kalbarri. Seroja weakened as it moved further inland, though due to its rapid motion destructive winds extended a long way inland before it eventually weakened below tropical cyclone intensity early on the morning of 12 April near the town of Dalwallinu.

Widespread power outages were experienced through Western Australia's Mid-West region due to fallen trees and power lines.

Figure 1. Best Track of Tropical Cyclone Seroja, 02 - 12 April 2021 (times in AWST, UTC +8).







2 Meteorological Description

2.1 Intensity Analysis

Figure 3 is a plot of objective and subjective intensity estimates during the lifetime of Seroja. A low developed in an area of active thunderstorm on 2 April and an initial Dvorak Data T-number (DT) of 1.0 was assigned at 1200 UTC (AWST = UTC +8 hours).

Over the following 24 hours, the tropical low steadily intensified. An 1151 UTC 2 April ASCAT pass (refer Figure 4) showed a circulation with winds of 25 knots (kn) (45 km/h) near the low-level circulation centre (LLCC). Away from the centre 25-30 kn (45-55 km/h) winds were also evident in both the south-easterly winds to the south of the low and westerly winds in the monsoon flow over Indonesia.

Higher winds to 30 kn (55 km/h) were indicated, though may have been subjected to either heavy rain or land contamination of the data. This potential contamination was a persistent issue during the first 48 hours as the low remained near the islands of Rote, Timor and Savu with enhanced monsoon activity also continuing over the broader region. The Kupang radar showed the developing circulation as shown in Figure 5 at 2015 UTC 3 April.

As the tropical low deepened, the monsoon flow to the north strengthened with gale force winds indicated on a 0151 UTC 4 April ASCAT pass and the tropical low was analysed as having gales develop in the northwest quadrant. By 1200 UTC, as curved banding of the low improved, a Dvorak Final T-number (FT) of 3.0 was assigned and Seroja reached tropical cyclone intensity (Australian definition).

Seroja then continued to intensify during 5 April with a 0014 UTC ASCAT pass showing broad areas of winds at 40 knots (75 km/h) as shown in Figure 6. A high-resolution pass at 0127 UTC indicated winds had reached 50 kn (95km/h). Accordingly, Seroja reached 50 kn (category 2) intensity at 0600 UTC 5 April and continued intensifying until 0000 UTC 6 April when it reached 60 knots (110 km/h). This peak in intensity was indicated by a 2351 UTC 5 April ASCAT pass (Figure 7), though was once again subject to potential contamination from heavy rain. At these intensities, scatterometry data also becomes less reliable, however is usually considered an underestimate.

Dvorak analysis at this time produced a FT of 3.5, corresponding to an intensity of 50 knots (95 km/h). Objective guidance of 1-minute mean winds from SATCON reached a peak intensity of 72 kn (133 km/h) at 1130 UTC on 5 April while the CIMSS and NESDIS ADT showed peak intensities of 53 kn at 0030 UTC 6 April and 51 kn at 0630 UTC 5 April as respectively as shown in Figure 3.

Seroja then weakened quickly through the remainder of 6 April due to increasing vertical wind shear and dry air. By 0600 UTC Seroja had weakened to 45 kn (85 km/h) intensity (category 1) and by 1800 UTC was below tropical cyclone strength with gale force winds confined to only the northwest quadrant. The low continued to battle vertical wind shear and dry air during 7 April maintaining an intensity slightly below tropical cyclone strength. Figure 8 shows the centre east of the deep convection at 0900 UTC 7 April.

During 8 April the tropical low began to interact with another low further to the west. This second low would later become Tropical Cyclone Odette. This interaction replenished the moisture and eased the vertical wind shear which had been inhibiting the redevelopment of Seroja. During 8 and 9 April, Seroja re-intensified, reaching tropical cyclone intensity once more at 1800 UTC 8 April and 50 kn (category 2) intensity at 1800 UTC 9 April.

Figures 9, 10 and 11 show Seroja in relation to Odette on 9 April: a microwave image at 0649 UTC (Figure 9), a high resolution visible image at 0645 UTC (Figure 10) and the MSLP analysis at 1200 UTC (Figure 11).

Following the interaction with Odette, Seroja maintained a relatively steady intensity of 50 kn (95 km/h) during 10 April and then intensified further on 11 April as it accelerated southeast towards the Western Australian coast. It reached an intensity of 65 kn (120 km/h) (category 3) at 0600 UTC 11 April. An eye became apparent on the AMSR2 89 GHz microwave image 0635 UTC (Figure 12), and then also evident on the enhanced infra-red image at 1130 UTC (Figure 13) and on the Geraldton radar near landfall (Figure 14). Seroja then maintained this intensity until crossing the coast around 1200 UTC before weakening over land. By 1800 UTC Seroja's intensity had decreased to 45 kn (85 km/h) but having gales confined to the northeast quadrant.

Objective guidance from SATCON and CIMMS ADT also indicated continued intensification of Seroja right up to the time of coastal crossing when they both suggested a peak intensity of 82 kn (152 km/h).

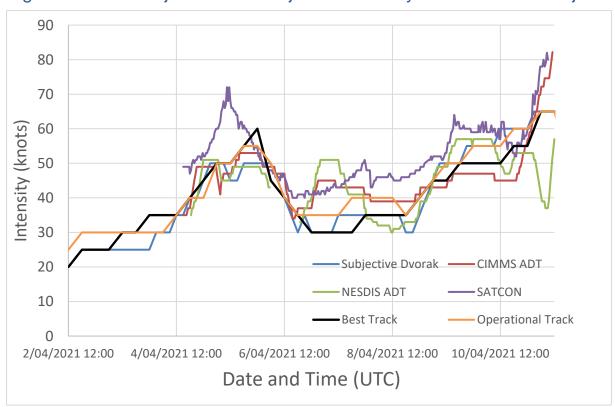


Figure 3. Plot of objective and subjective intensity estimates for Seroja.

2.2 Structure

As a tropical low, Seroja initially had gales form on the northern side to a radius of approximately 40 nautical miles (nm) (74 kilometres (km)), enhanced by the monsoon flow. As the gales wrapped around the southern side of the LLCC the radius of gales on the northern side expanded out to 90 nm (167 km). As Seroja continued to intensify, gales became more symmetric at a radius of approximately 75 nm (139 km) as storm force winds developed to a radius of 45 nm (83 km) on the northern side, while only developing briefly on the southern side to a radius of 30 nm (56 km). During the period Seroja was a tropical cyclone from 4 April to 6 April, Seroja maintained a relatively constant radius of maximum winds around 20 nm (37 km).

On 8 April, as Seroja began to intensify once more. Gales initially extended to approximately 45 nm (83 km) on the northern side. This expanded out to 60 nm (111 km) and then, as it interacted with Odette, the wind field of Seroja was more dynamic than a typical tropical cyclone. Gales extended to a maximum of 100 nm (185 km) from the centre during 9 April. However, this largest quadrant changed as the two cyclones moved around each other, with the most vigorous wind field being on roughly the opposite side of the centre of Seroja to the position of Odette. By 10 April, as Odette was weakening, Seroja's radius of gales was 75 nm (139 km) in the northwest quadrant, extending to 90 nm (176 km) in the southern semicircle and 100 nm (185 km) in the northeast quadrant. Storm force winds had initially formed out to 75 nm (139 km) on the western side of Seroja, though these quickly became more predominant on the northern side as Seroja began to turn towards the southeast.

As Seroja accelerated towards the southeast, a radius of storm force winds of 60-70 nm (111-130 km) was maintained on the eastern side of the LLCC compared to 40 nm (74 km) on the western side. Hurricane force winds then also developed to 45 nm (83 km) on the eastern side. The radius of maximum winds during the 8-11 April was relatively steady at 30 nm (56 km) before contracting down to 10 nm (19 km) as Seroja approached the coast and a small eye became apparent on IR satellite and radar imagery from Geraldton as shown in Figures 13 and 14.

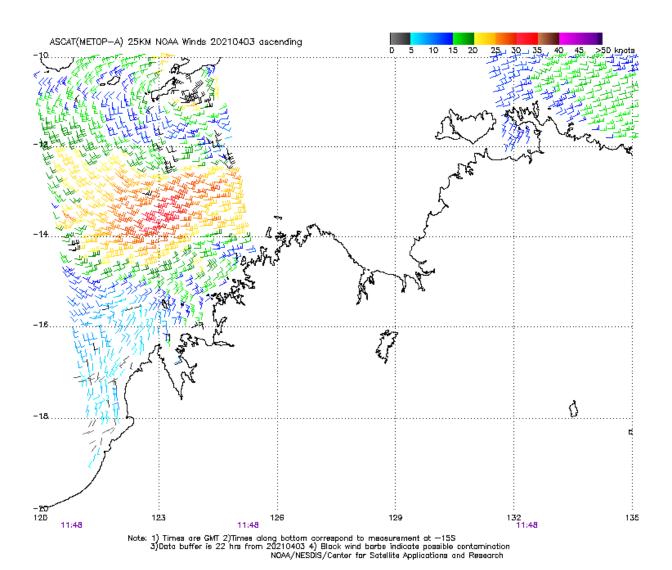
2.3 Motion

Prior to becoming a tropical cyclone, Seroja was slow moving with competing monsoonal westerly winds to the north and trade easterly winds to the south negating each other's steering influence. As Seroja strengthened, the deeper easterly winds steered it towards the west. During 6 and 7 April, while the easterly steering persisted, a near stationary trough over the Indian Ocean provided a northerly steering influence resulting in Seroja taking a more southwest track.

As Seroja approached the developing Tropical Cyclone Odette the two interacted via a mechanism known as the Fujiwara effect, rarely witnessed in the Australian region. Seroja moved initially south and then west as the two cyclones began circling around each other. As Tropical Cyclone Odette then weakened, a mid-level trough approaching from the Indian Ocean steered Seroja towards the southeast, accelerating as it did so. Seroja maintained this motion through to its coastal crossing and movement over the South West Land Division of Western Australia, until its remnants continued to dissipate in the Great Australian Bight.

Figure 4. METOP-A ASCAT image at 1148 UTC 2 April 2021.

Image courtesy of NOAA: https://manati.star.nesdis.noaa.gov/datasets/ASCATData.php



8

Figure 5. Radar Image from Kupang radar 2015 UTC 3 April.

Image courtesy of Badan Meteorologi, Klimatologi, dan Geofisika (BMKG))

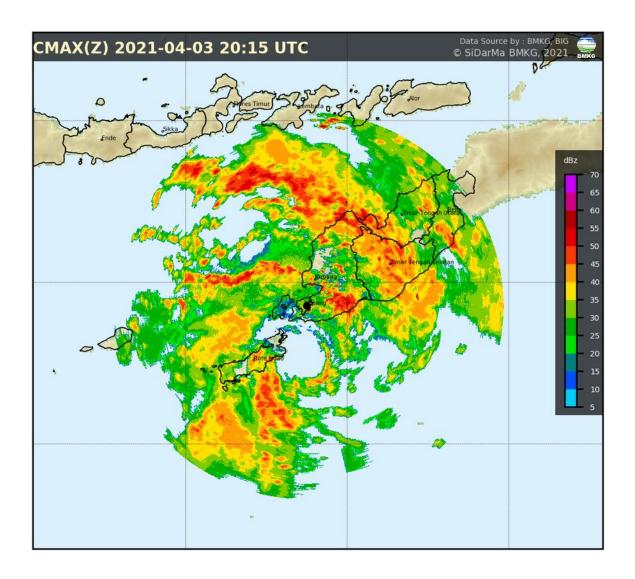


Figure 6. METOP-A ASCAT pass at 0014 UTC 5 April 2021.

Image courtesy of NRL: https://www.nrlmry.navy.mil/TC.html

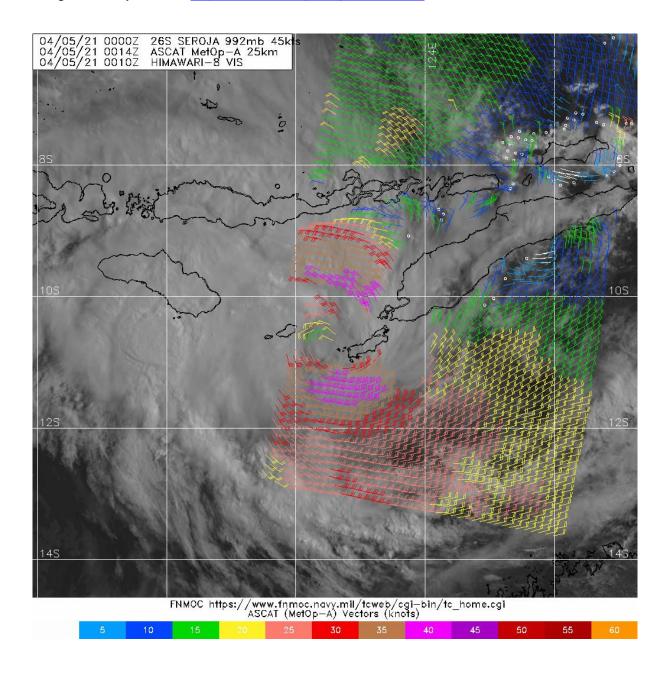


Figure 7. METOP-B UHR ASCAT pass at 2351 UTC 5 April 2021.

Image courtesy of NRL: https://www.nrlmry.navy.mil/TC.html

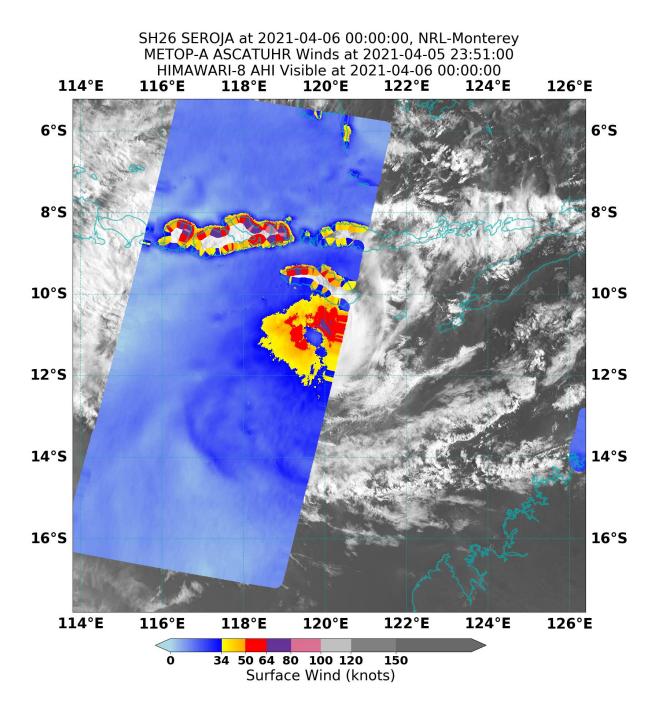


Figure 8. Visible Himawari-8 satellite image at 0900 UTC 7 April showing the exposed circulation of Seroja with deep convection displaced to the west due to the impact of easterly vertical wind shear.

Image courtesy of NRL: https://www.nrlmry.navy.mil/TC.html

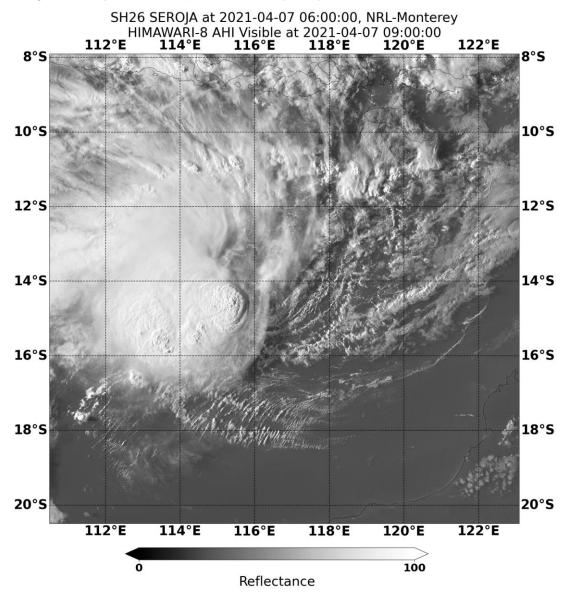


Figure 9. GCOM 89 GHz microwave image of Tropical Cyclone Seroja and Tropical Cyclone Odette at 0649 UTC 09 April.

Image courtesy of FNMOC: https://www.fnmoc.navy.mil/tcweb/cgi-bin/tc home.cgi)

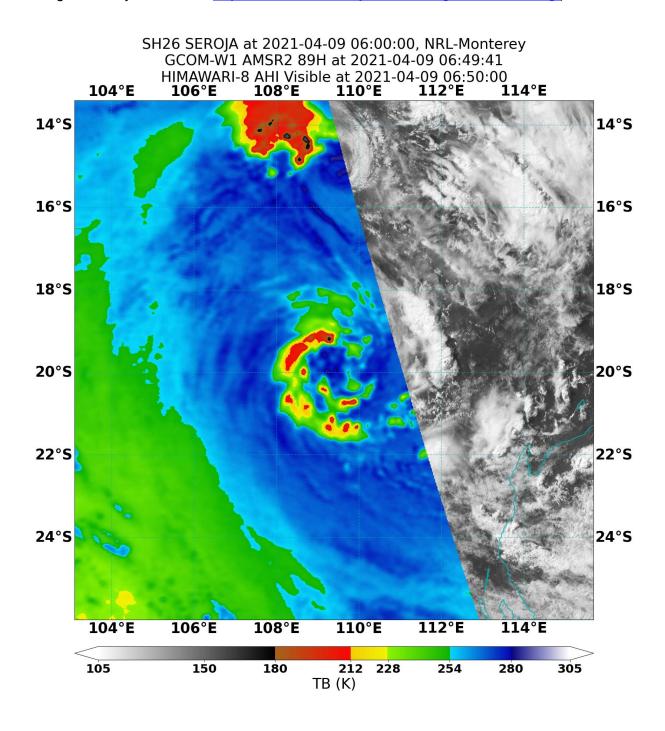


Figure 10. True Colour Suomi NPP visible satellite image of Tropical Cyclone Seroja and Tropical Cyclone Odette from 09 April.

Image courtesy NASA: https://worldview.earthdata.nasa.gov

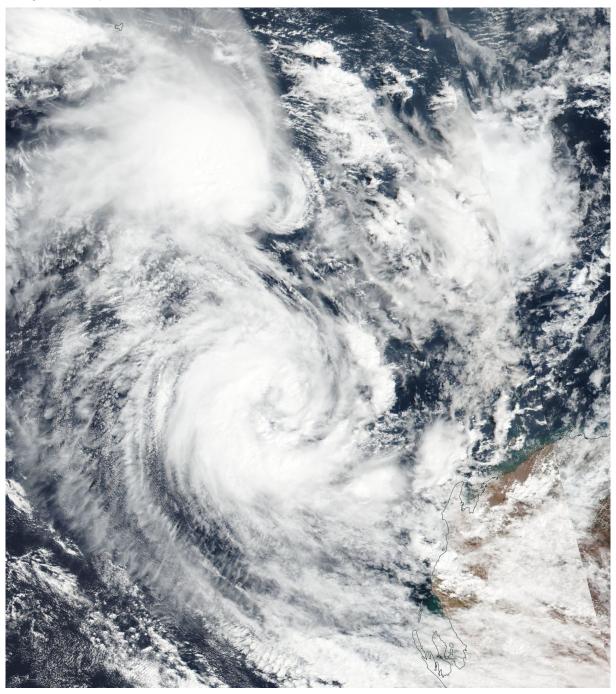


Figure 11. MSLP Analysis from 1200 UTC 9 April, during the period of Fujiwara interaction between Seroja and Odette.

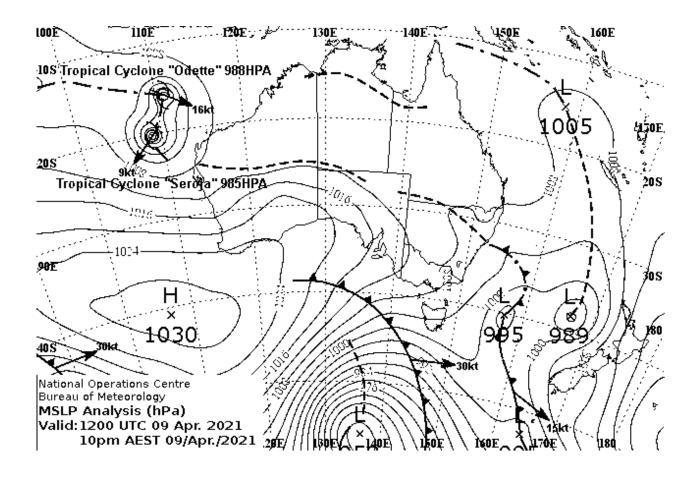


Figure 12. AMSR2 89 GHz microwave image of Severe Tropical Cyclone Seroja approaching the WA coast at 0635 UTC 11 April.

Image courtesy of FNMOC: https://www.fnmoc.navy.mil/tcweb/cgi-bin/tc home.cgi

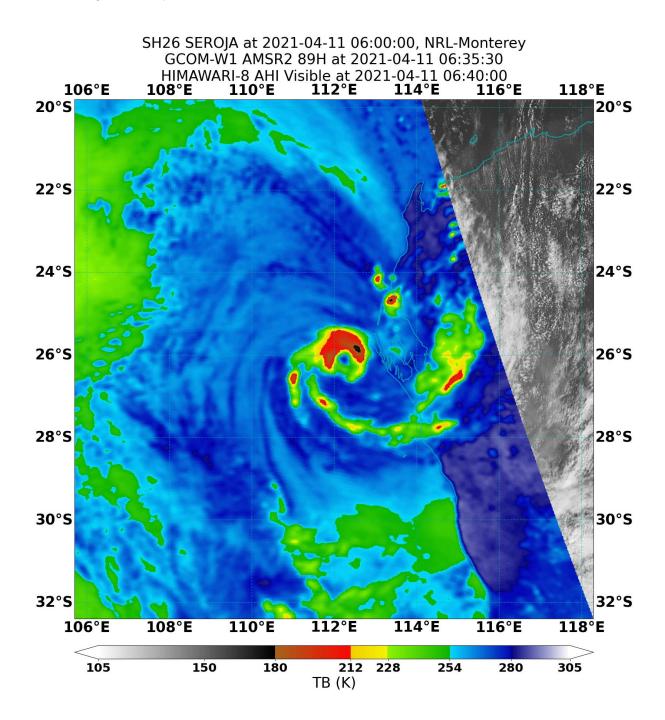


Figure 13. Enhanced Infrared satellite image of Severe Tropical Cyclone Seroja at 1130 UTC 11 April, showing a ragged eye around the time of peak intensity and coastal crossing.

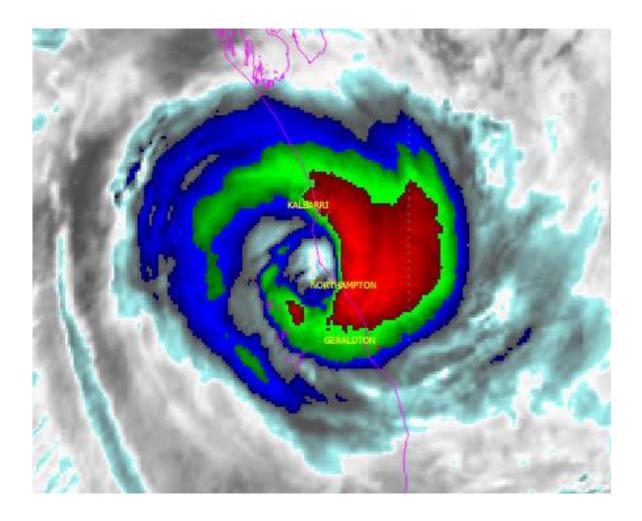
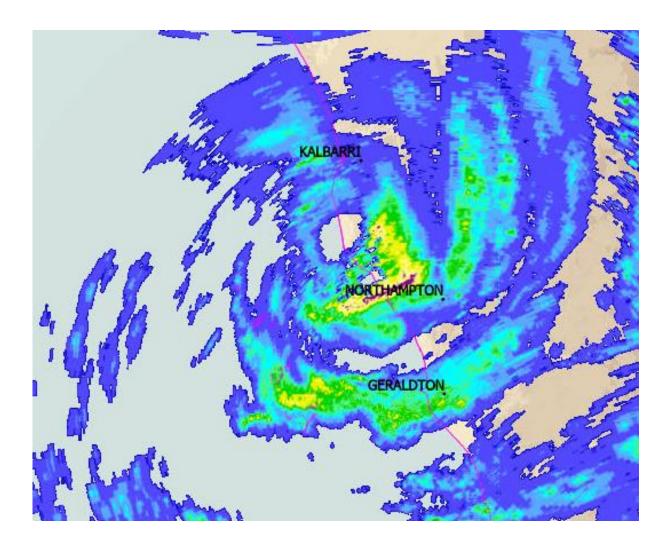


Figure 14. Geraldton radar image of Severe Tropical Cyclone Seroja at 1130 UTC 11 April, showing a ragged eye around the time of peak intensity and coastal crossing.



3 Impact

During its initial formation, the active thunderstorm and monsoonal activity associated with Seroja caused extensive heavy rainfall across the nearby islands of Indonesia and Timor Leste. Widespread flooding and landslides were reported as well as more than 150 fatalities.

In the days prior to Seroja crossing the Western Australian coast, school holidays had commenced. National Parks near the forecast crossing area were closed as holiday makers, especially campers, were told to leave. Similar actions were taken across other popular holiday areas.

As Seroja crossed the Western Australia coast on the night of 11 April, destructive winds tore through the towns of Kalbarri and Northampton, quickly moving further inland and impacting numerous other farming communities.

DFES received about 1478 requests for assistance (RFAs), 665 from Kalbarri, 235 from Northampton, 103 from Morawa, 63 from Mingenew, 46 from Perenjori and 110 from the Greater Geraldton area. The affected area spans around 35 000 square kilometres. The towns of Kalbarri and Northampton were the most impacted where around 70% of buildings sustained significant damage mostly consisting of lost roofs. Around 10% of buildings had damage classified as severe or total. Many buildings that were not affected by wind damage sustained water damage from wind driven rain entering the structures. The effects of Seroja have been long lasting with sustained clean-up and recovery work required, including dealing with the removal of large amounts of asbestos. The WA government estimated that it would take two years to rebuild the town of Kalbarri and insurance claims across affected areas topped \$368 million dollars as of May 2022.

Widespread power outages were experienced through Western Australia's Mid-West region due to fallen trees and power lines. It is estimated that about 32000 customers located in the area from Kalbarri to Dongara and inland to Mullewa were without power during the event. Due to the nature and large aerial extent of the damage, power was not able to be quickly restored with many people without power for up to 72 hours after Seroja crossed the coast. Some 16 days after the event about 2300 customers remained without power and the final repairs in the Shire of Northampton took until late June to complete.

A comprehensive damage survey was conducted by the Cyclone Testing Station at James Cook University, refer to Technical Report No 66 Tropical Cyclone Seroja – Damage to buildings in the Mid-West Coastal Region of WA.

4 Observations

4.1 Wind

Selected observations are detailed below. They come from a variety of standard anemometers, operated by the Bureau, and non-standard anemometers operated by either Department of Biodiversity, Conservation and Attractions (DBCA) or Department of Primary Industries and Regional Development (DPIRD). Those operated by third parties may not be subjected to the same calibration and sighting standards of Bureau stations, notably DPIRD anemometers are typically at 3m above ground level.

Meanarra Tower (DBCA) an elevated and exposed location near the town of Kalbarri, recorded periods of gale force winds from 0810 UTC to 1212 UTC 11 April including storm force winds from 1038 UTC to 1142 UTC. The maximum 10-minute mean wind recorded was 62 kn (115 km/h) at 1109 UTC and the maximum 3-second wind gust recorded was 92 kn (170km/h) at 11:03 UTC.

Binnu West (DPIRD) recorded gale force winds from 1123 UTC to 1210 UTC 11 April including storm force winds from 1146 UTC to 1152 UTC. The maximum 10-minute mean wind recorded was 52 kn (96 km/h) at 1148 UTC and the maximum 3-second wind gust recorded was 75 kn (139 km/h) at 1147 UTC.

Binnu (DPIRD) recorded gale force winds from 1123 UTC to 1210 UTC 11 April including storm force winds from 1146 UTC to 1152 UTC. The maximum 10-minute mean wind recorded was 52 kn (96 km/h) at 1148 UTC and the maximum 3-second wind gust recorded was 70 kn (130 km/h) at 1147 UTC.

Northampton West (DPIRD) recorded gale force winds from 1154 UTC to 1257 UTC 11 April including storm force winds from 1226 UTC to 1233 UTC. The maximum 10-minute mean wind recorded was 51 kn (94 km/h) at 1228 UTC and the maximum 3-second wind gust recorded was 71 kn (131 km/h) at 1231 UTC.

Geraldton Airport (BOM) recorded gale force winds from 1155 UTC to 1305 UTC 11 April including storm force winds from 1252 UTC to 1253 UTC. The maximum 10-minute mean wind recorded was 49 kn (91 km/h) at 1253 UTC and the maximum 3-second wind gust recorded was 65 kn (120 km/h) at 1251 UTC.

Chapman Valley (DPIRD) recorded gale force winds from 1202 UTC to 1250 UTC 11 April when the observations ceased reporting. This included storm force winds from 1223 UTC to 1245 UTC. The maximum 10-minute mean wind recorded was 54 kn (100 km/h) at 1232 UTC and the maximum 3-second wind gust recorded was 73 kn (135km/h) at 1240 UTC.

Yuna (DPIRD) recorded gale force winds from 1215 UTC to 1336 UTC 11 April. The maximum 10-minute mean wind recorded was 48 kn (89 km/h) at 1301 UTC and the maximum 3-second wind gust recorded was 68 kn (126 km/h) at 1240 UTC.

Dudawa (DPIRD) recorded gale force winds from 1349 UTC to 1442 UTC 11 April when the observations ceased reporting. This included storm force winds from 1424 UTC to 1442 UTC. The maximum 10-minute mean wind recorded was 56 kn (104 km/h) at 1441 UTC and the maximum 3-second wind gust recorded was 75 kn (139 km/h) at 1429 UTC.

Mingenew NW (DPIRD) recorded gale force winds from 1312 UTC to 1454 UTC 11 April including storm force winds from 1355 UTC to 1408 UTC. The maximum 10-minute mean

wind recorded was 52 kn (96 km/h) at 1402 UTC and the maximum 3-second wind gust recorded was 66 kn (122 km/h) at 1359 UTC.

Morawa Airport (BOM) recorded gale force winds from 1424 UTC to 1617 UTC 11 April. The maximum 10-minute mean wind recorded was 47 kn (87 km/h) at 1520 UTC and the maximum 3-second wind gust recorded was 64 kn (119 km/h) at 1519 UTC.

Perenjori (DPIRD) recorded gale force winds from 1446 UTC to 1641 UTC 11 April including storm force winds at the single observation time of 1551 UTC. The maximum 10-minute mean wind recorded was 49 kn (90 km/h) at 1551 UTC and the maximum 3-second wind gust recorded was 66 kn (122 km/h) at 1515 UTC.

Carnamah East (DPIRD) recorded gale force winds from 1546 UTC to 1610 UTC 11 April. The maximum 10-minute mean wind recorded was 41 kn (76 km/h) at 1603 UTC and the maximum 3-second wind gust recorded was 63 kn (117 km/h) at 1602 UTC.

Dalwallinu (BOM) recorded gale force winds from 1611 UTC to 1652 UTC 11 April. The maximum 10-minute mean wind recorded was 42 kn (78 km/h) at 1647 UTC and the maximum 3-second wind gust recorded was 58 kn (107 km/h) at 1650 UTC.

Goodlands (DPIRD) recorded gale force winds from 1625 UTC to 1830 UTC 11 April. The maximum 10-minute mean wind recorded was 44 kn (81 km/h) at 1752 UTC and the maximum 3-second wind gust was 61 kn (113 km/h) at 1732 UTC.

Mukinbudin (DPIRD) recorded gale force winds from 1841 UTC to 1845 UTC 11 April. The maximum 10-minute mean wind recorded was 34 kn (63 km/h) at 1842 UTC and the maximum 3-second wind gust was 48 kn (89 km/h) at 1838 UTC.

4.2 Pressure

North Island AWS recorded a minimum mean sea level (MSL) pressure of 986.9 Hectopascals (hPa) from 1110 UTC to 1113 UTC 11 April.

Geraldton Airport AWS recorded a minimum MSL pressure of 975.9 hPa at 1303 UTC 11 April.

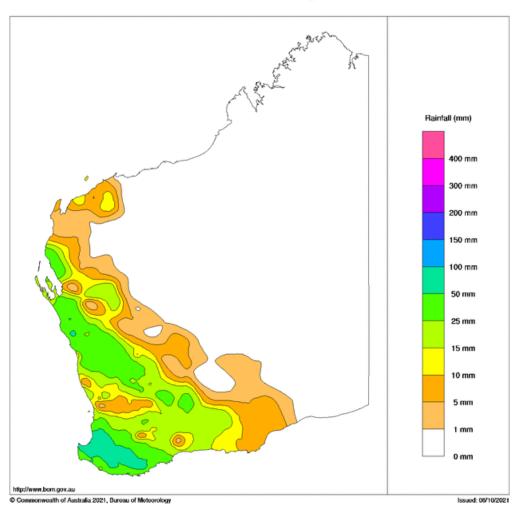
Morawa Airport AWS recorded a minimum MSL pressure of 987.3 hPa at 1507 UTC 11 April. Dalwallinu AWS recorded a minimum MSL pressure of 980.1 hPa at 1647 UTC 11 April.

4.3 Rainfall

The highest rainfall totals in the 24 hours to 9am AWST 12 April were 166.8 millimetres (mm) at Meanarra Tower (DBCA), 122 mm at Mumby, 75.6 mm at Binnu West (DPIRD), 74.2 mm at Gutha West (DPIRD), 62.8 mm at Carnarvon (DPIRD), 60 mm at Three Springs (DPIRD), 57.4 mm at Wicka, 55.8 mm at Canna East (DPIRD) and 55.6 mm at Eradu (DPIRD). Refer Figure 15 for a plot of the 24-hour rainfall to 9am.

Figure 15. Rainfall total analysis for the 24 hours to 9am AWST 12 April.

Western Australian Rainfall Totals (mm) 12th April 2021 Australian Bureau of Meteorology



4.4 Storm Surge

The recorded maximum storm surge at Geraldton was 1.66 m at 1210 UTC 11 April, corresponding with a peak Total Water Level (TWL) of 2.45 m above the Lowest Astronomical Tide (LAT) or 1.19 m above Highest Astronomical Tide (HAT) as shown in Figure 16. A peak storm surge of 1.03 m was recorded at Carnarvon at 0835 UTC 11 April as shown in Figure 17. The peak TWL however was at 0430 UTC, shortly after the predicted high tide, reaching 2.25m above LAT or 0.20 m above HAT.

Damage surveys conducted at Kalbarri by the Cyclone Testing Station found evidence based on marine sediment deposits and debris that storm surge, including wave run-up, reached approximately 2 m above HAT.

Figure 16. Observed tide and Storm Surge Geraldton.



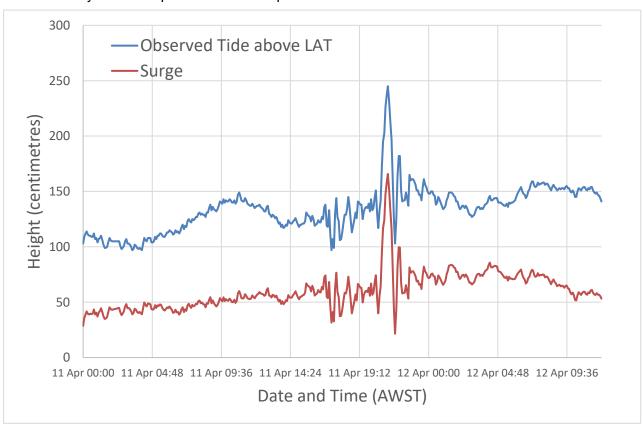
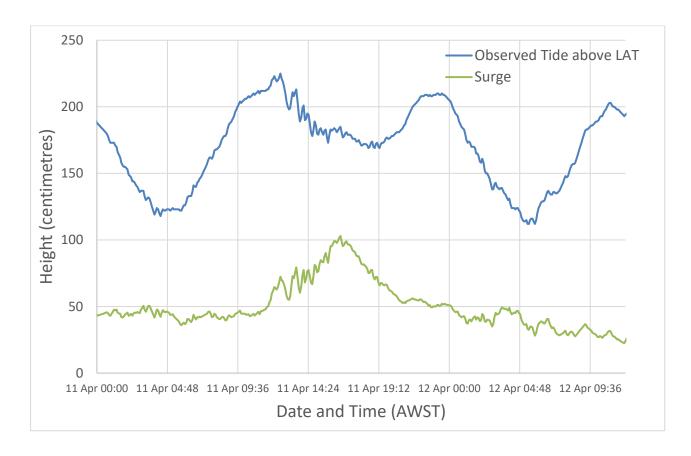


Figure 17. Observed Tide and Storm Surge at Carnarvon.

Data courtesy of WA Department of Transport.



5 Forecast Performance

The first Tropical Cyclone Advice for Severe Tropical Cyclone Seroja was issued at 9:04 am AWST 9 April including a Watch for Coral Bay to Lancelin including Carnarvon, Denham, Kalbarri, and Geraldton. This was then upgraded to a Warning for Cape Cuvier to Geraldton at 2:59 pm AWST on 10 April, extending to adjacent inland areas at 8:53pm AWST that day.

The earliest recorded gales were at Meanarra Tower (Kalbarri) at 4:10pm AWST, 55 hours after the first Watch was issued and 25 hours after the first Warning.

The accuracy statistics obtained by comparing the forecast positions against the best track positions are shown in the table below and in Figures 18 (position) and 19 (intensity). Figure 18 shows the forecast position was close to the 5-year average at all lead times. This is quite remarkable given the complexity of the track including the interaction with tropical cyclone Odette and the rapid acceleration to the southeast at the end of the track. The landfalling location in the Kalbarri region was well forecast seven days ahead of landfall which provided plenty of time for advanced preparations in a region infrequently visited by tropical cyclones.

Figure 19 shows that the forecast intensity was near the 5-year average for the shorter lead times but then a little worse at longer lead times. It is notable that the forecast intensity was initially at category two, reduced to category one, and reinstated to category 2 several days in advance which again provided sufficient time for preparations.

	0	6	12	18	24	36	48	72	96	120
Position Absolute	10	38	56	76	95	126	158	195	188	249
error (km) Intensity										
Absolute error (kn)	0.2	2.4	4.4	5.6	6.5	10.6	14.0	22.7	21.3	16.2
Sample Size	34	34	33	32	31	29	27	23	19	15

Figure 18. Position accuracy statistics for Severe Tropical Cyclone Seroja.

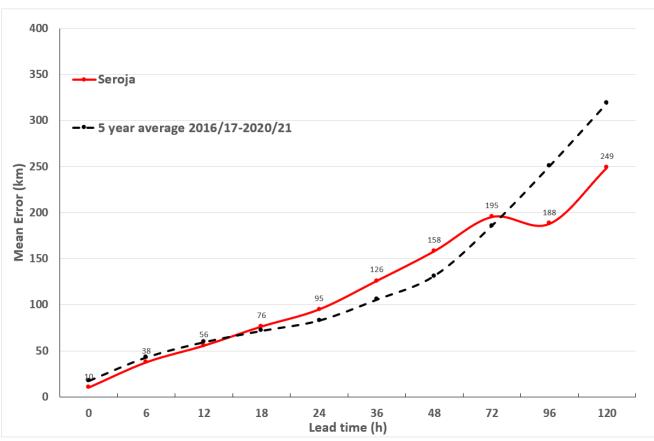


Figure 19. Intensity accuracy statistics for Severe Tropical Cyclone Seroja.

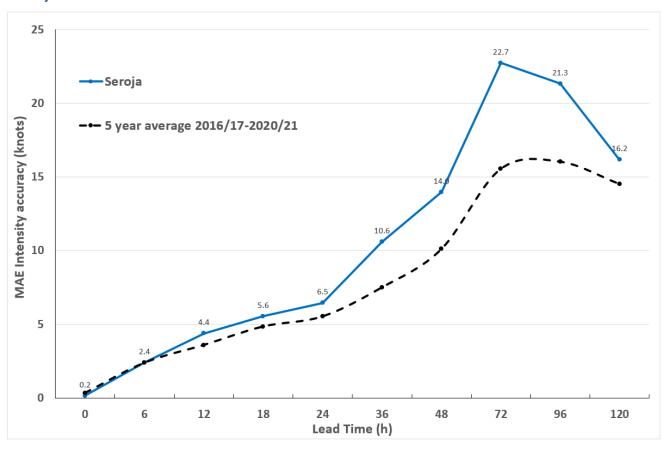


Table 1. Best track summary for Severe Tropical Cyclone Seroja.

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

Year	Mon	Day	Hour UTC	Pos. Lat S	Pos. Long. E	Pos. Acc. nm	Max Wind 10 min kn	Max gust kn	Cent. Press hPa	Rad. of gales (NE/SE/ SW/NW)	Rad. of storm (NE/SE/ SW/NW)	RMW nm
2021	04	2	12	11.1	122.1	45	20	45	1002			
2021	04	2	18	11.0	122.2	45	25	45	1002			
2021	04	3	00	10.7	122.4	45	25	45	1003			
2021	04	3	06	10.5	123.0	45	25	45	1001			
2021	04	3	12	10.7	123.7	45	30	45	1001			
2021	04	3	18	10.6	123.7	15	30	45	997	-/-/40		
2021	04	4	00	10.6	123.6	15	35	50	995	-/-/40		
2021	04	4	06	10.4	123.6	30	35	50	995	45/45/-/-		
2021	04	4	12	10.2	123.4	30	35	50	995	45/45/45/-		30
2021	04	4	18	10.2	123.3	30	40	55	990	75/60/45/-		20
2021	04	5	00	10.7	122.6	15	45	65	991	90/60/60/90		20
2021	04	5	06	10.7	122.0	20	50	70	987	90/60/60/90	30/-/-/30	20
2021	04	5	12	11.0	121.3	15	50	70	988	90/70/60/70	45/30/-/45	20
2021	04	5	18	11.1	120.4	20	55	75	985	75/75/75/75	45/-/30/45	20
2021	04	6	00	11.1	119.8	25	60	85	980	75/75/75/75	45/-/30/45	20
2021	04	6	06	11.6	119.5	20	45	65	988	45/45/60/75		20
2021	04	6	12	11.9	119.2	45	40	55	993	45/-/60/60		30
2021	04	6	18	12.6	118.8	45	35	50	997	-/-/-60		
2021	04	7	00	13.1	117.8	25	30	45	1000			
2021	04	7	06	14.1	116.7	20	30	45	1000			
2021	04	7	12	14.9	115.7	60	30	45	1000			
2021	04	7	18	15.6	114.1	30	30	45	999			
2021	04	8	00	16.0	112.3	30	35	50	994	45/-/-/45		
2021	04	8	06	16.8	111.7	15	35	50	993	60/-/-/-		
2021	04	8	12	17.7	111.5	30	35	50	993	60/60/-/-		
2021	04	8	18	18.7	111.3	30	35	50	993	45/60/60/-		20
2021	04	9	00	19.2	110.4	30	40	55	989	-/75/90/45		25
2021	04	9	06	19.8	109.5	20	45	65	986	-/90/90/90		30
2021	04	9	12	20.0	108.9	25	45	65	984	60/45/90/90		30
2021	04	9	18	20.5	108.3	15	50	70	981	75/75/100/90	-/-/75/60	30

Year	Mon	Day	Hour UTC	Pos. Lat S	Pos. Long. E	Pos. Acc. nm	Max Wind 10 min kn	Max gust kn	Cent. Press hPa	Rad. of gales (NE/SE/ SW/NW)	Rad. of storm (NE/SE/ SW/NW)	RMW nm
2021	04	10	00	20.5	107.9	25	50	70	980	100/90/90/75	-/-/75/60	30
2021	04	10	06	21.1	107.7	30	50	70	980	100/90/75/75	-/-/60/60	30
2021	04	10	12	21.7	108.9	25	50	70	980	100/90/60/45	60/-/-/-	30
2021	04	10	18	22.4	109.7	30	55	75	977	100/100/45/75	60/60/-/30	30
2021	04	11	00	24.3	110.5	30	55	75	978	120/100/45/60	70/70/-/30	30
2021	04	11	06	26.2	112.0	25	65	90	970	120/100/45/60	70/70/30/30	20
2021	04	11	12	28.2	114.4	5	65	90	967	100/60/40/50	60/30/20/30	10
2021	04	11	18	30.6	117.2	15	45	65	979	60/40/-/-		15
2021	04	12	00	33.5	120.2	25	25	45	992			

6. Appendix: List of abbreviations

ADT	Advanced Dvorak Technique	km/h	kilometres per hour
ACST	Australian Central Standard Time	kn	knot
AEST	Australian Eastern Standard Time	LLCC	low level cloud centre
AMSR2	Advanced Microwave Scanning Radiometer	MET	Model Expected T-number
ASCAT	Advanced Scatterometer	METOP	Meteorological Operational
ATMS	Advanced Technology Microwave Sounder	MJO	Satellite Madden-Julian Oscillation
AWS	automatic weather station	mm	millimetres
AWST	Australian Western Standard Time	MSLP	mean sea level pressure
С	Celsius	nm	nautical mile
CI	Current intensity	NOAA	National Oceanic and
CIMSS	Cooperative Institute for Meteorological	NRL	Atmospheric Administration Navy Research Lab (USA)
CIRA	Satellite Studies (USA) Cooperative Institute for Research in the	PAT	Pattern T-number
EIR	Atmosphere (USA) Enhanced InfraRed	RH	relative humidity
ERC	eyewall replacement cycle	RMW	radius of maximum winds
FNMOC	Fleet Numerical Meteorology and	RSMC	Regional Specialised
FT	Oceanography Centre (USA) Final T-number	SAR	Meteorological Centre Synthetic Aperture Radar
GCOM	Global Change Observation Mission	SATCON	satellite Consensus
GHz	Gigahertz	SMAP	Soil Moisture Active Passive
GMI	Global Precipitation Measurement	SMOS	Soil Moisture and Ocean Salinity
h	Microwave Imager hour	SSMIS	Special Sensor Microwave
hPa	hectopascal	TC	Imager/Sounder Tropical Cyclone
HSCAT	Hai Yang 2 Scatterometer (HY-2B, HY-2C)	TCWC	Tropical Cyclone Warning
km	kilometres	UTC	Centre Universal Time Co-ordinated