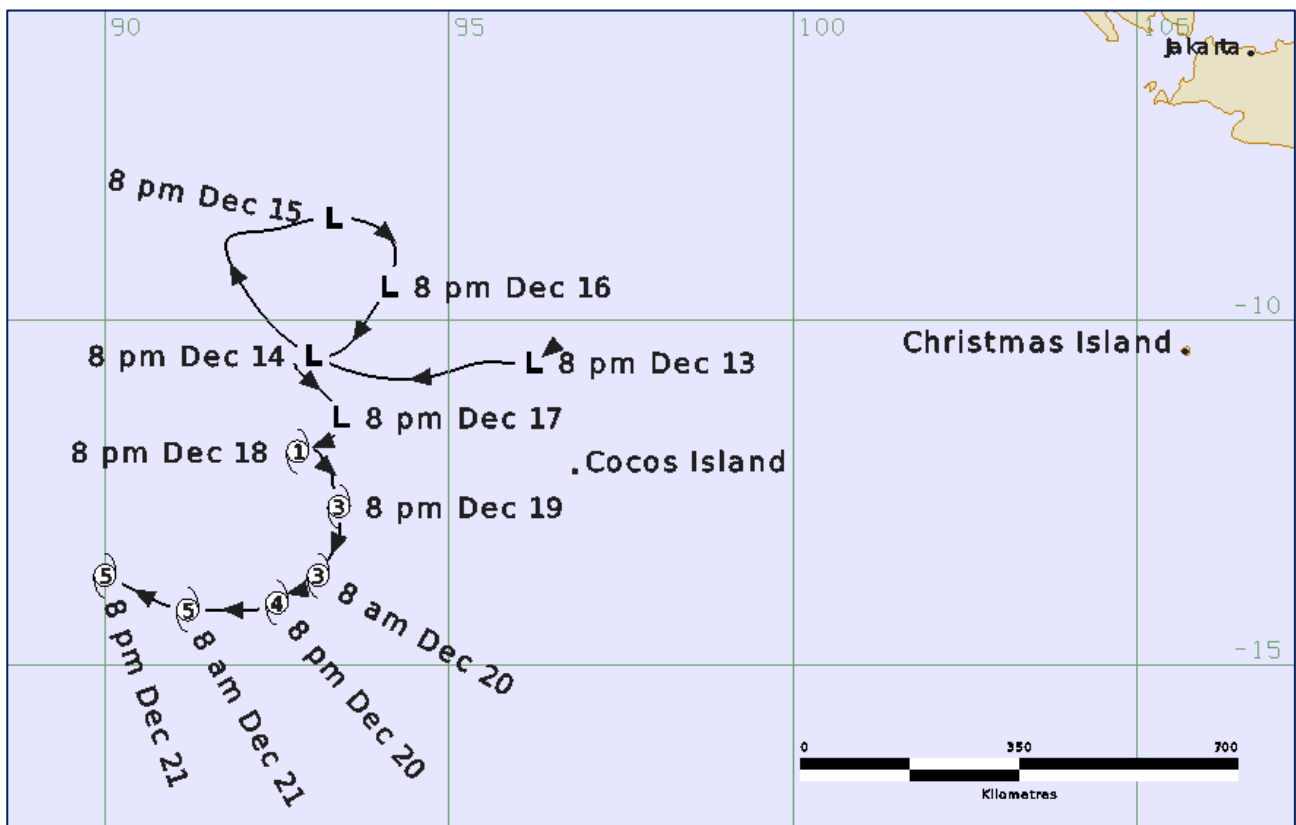


Severe Tropical Cyclone Darian

13 - 21 December 2022

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7 June 2023



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

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1. Summary

Severe Tropical Cyclone Darian was an Indian Ocean event that began to the north of Cocos (Keeling) Islands in the Australian Western Region, moving westwards out of the region without causing any impact to Australian communities. The cyclone reached category 5 intensity before moving into the RSMC La Reunion Area of Responsibility on 21 December, where it persisted as a severe tropical cyclone for a long time.

A tropical low formed to the north of Cocos Islands on 13 December and began to move westwards. The low remained as a weak system while doing a clockwise loop on 14 and 15 December. It began moving southwards on 16 December, while remaining well to the west of the Cocos Islands. On 18 December, the low reached tropical cyclone strength and was named Darian.

It began moving southeast on the night of 18 December and rapidly intensified to a category 3 cyclone within 24 hours. Late on 19 December, Darian was steered to the west by a strengthening mid-level ridge to the south.

Darian intensified to a category 5 cyclone overnight on 20 December and reached peak intensity in the morning on 21 December. It moved into RSMC La Reunion Area of Responsibility on 21 December evening.

There were no impacts to any island or coastal communities. The system remained to the west of Cocos Island causing heavy showers but with no significant impacts to the islands.

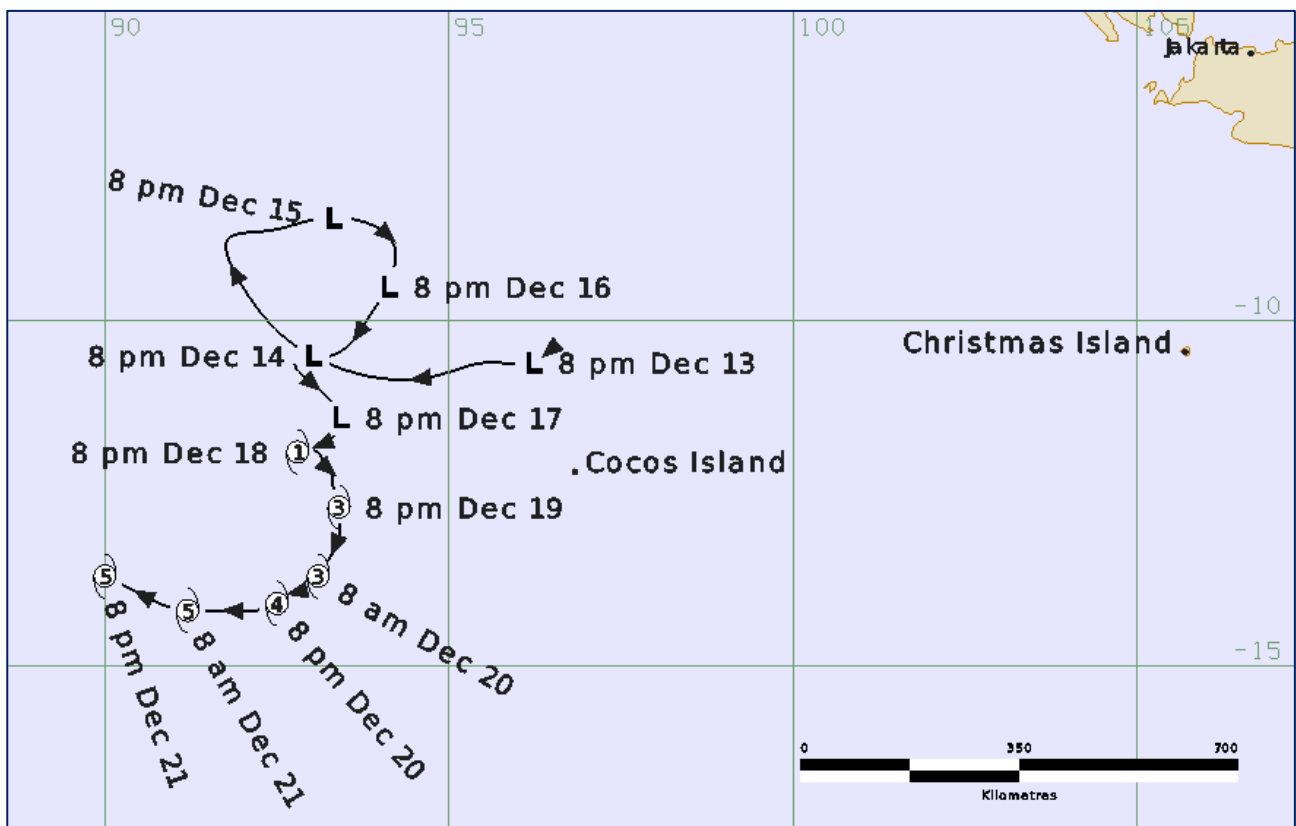


Figure 1. Best track of Severe Tropical Cyclone Darian (times in AWST, UTC +8).



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

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

Year	Month	Day	Hour UTC	Pos. Lat. S	Pos. Long. E	Pos. Acc. nm	Max Wind 10min kn	Max gust kn	Cent. Press. hPa	Rad. of gales (NE/SE/ SW/NW)	Rad. of storm (NE/SE/ SW/NW)	RMW nm
2022	12	12	0000	9.9	97.8	15	25	45	1009	0/0/0/0	0/0/0/0	-
2022	12	12	0600	10.3	98.0	20	25	45	1008	0/0/0/0	0/0/0/0	-
2022	12	12	1200	10.3	97.3	20	25	45	1008	0/0/0/0	0/0/0/0	-
2022	12	12	1800	10.3	97.2	20	25	45	1008	0/0/0/0	0/0/0/0	-
2022	12	13	0000	10.5	97.0	25	25	45	1007	0/0/0/0	0/0/0/0	-
2022	12	13	0600	10.5	96.2	25	25	45	1005	0/0/0/0	0/0/0/0	-
2022	12	13	1200	10.5	96.1	25	25	45	1004	0/0/0/0	0/0/0/0	-
2022	12	13	1800	10.6	96.0	25	25	45	1003	0/0/0/0	0/0/0/0	-
2022	12	14	0000	10.8	95.6	25	25	45	1003	0/0/0/0	0/0/0/0	-
2022	12	14	0600	10.8	94.1	25	25	50	1003	0/0/0/0	0/0/0/0	-
2022	12	14	1200	10.2	92.6	25	25	45	1003	0/0/0/0	0/0/0/0	-
2022	12	14	1800	9.5	91.5	20	25	45	1003	0/0/0/0	0/0/0/0	-
2022	12	15	0000	8.8	91.8	10	25	45	1003	0/0/0/0	0/0/0/0	-
2022	12	15	0600	8.6	92.4	10	25	45	1003	0/0/0/0	0/0/0/0	-
2022	12	15	1200	8.5	93.3	15	25	45	1002	0/0/0/0	0/0/0/0	-
2022	12	15	1800	8.4	93.8	25	25	45	1001	0/0/0/0	0/0/0/0	-
2022	12	16	0000	8.5	94.1	25	25	45	1000	0/0/0/0	0/0/0/0	-
2022	12	16	0600	8.7	94.5	20	25	45	1000	0/0/0/0	0/0/0/0	-
2022	12	16	1200	8.9	94.2	30	25	45	1000	0/0/0/0	0/0/0/0	-
2022	12	16	1800	9.2	93.3	35	25	45	999	0/0/0/0	0/0/0/0	-
2022	12	17	0000	9.9	92.9	30	30	45	999	0/0/0/0	0/0/0/0	-
2022	12	17	0600	10.5	93.3	25	25	45	998	0/0/0/0	0/0/0/0	-
2022	12	17	1200	11.2	93.7	30	25	45	998	0/0/0/0	0/0/0/0	-
2022	12	17	1800	11.6	93.4	25	25	45	997	0/0/0/0	0/0/0/0	-
2022	12	18	0000	11.7	92.7	20	30	45	997	0/0/0/0	0/0/0/0	-
2022	12	18	0600	11.8	92.6	20	35	50	996	50/40/70/60	0/0/0/0	30
2022	12	18	1200	11.8	93.0	20	40	50	996	60/60/70/70	0/0/0/0	30
2022	12	18	1800	12.1	93.2	15	45	65	990	60/60/70/70	0/0/0/0	30
2022	12	19	0000	12.2	93.2	15	50	70	986	60/60/70/70	0/0/40/40	25
2022	12	19	0600	12.3	93.3	15	55	75	982	70/60/90/70	40/40/50/40	22
2022	12	19	1200	12.7	93.4	15	65	90	975	70/60/110/70	40/40/60/50	18
2022	12	19	1800	13.1	93.4	15	75	105	967	70/70/100/80	40/50/60/50	17
2022	12	20	0000	13.5	93.1	10	80	110	964	80/100/100/80	50/60/60/50	17
2022	12	20	0600	13.8	92.9	8	90	125	954	70/100/100/90	50/60/60/50	15
2022	12	20	1200	14.0	92.6	6	110	155	932	70/100/100/90	50/60/60/50	15
2022	12	20	1800	14.2	91.8	6	120	170	923	70/100/100/90	50/60/60/50	12
2022	12	21	0000	14.1	91.3	6	125	175	915	70/100/100/90	50/60/60/50	12
2022	12	21	0600	13.9	90.4	6	125	175	917	70/100/100/90	50/60/60/50	12
2022	12	21	1200	13.7	90.0	6	120	170	921	70/100/100/90	50/60/60/50	12



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2. Meteorological description

2.1 Intensity analysis

An exposed low level circulation centre was evident on the satellite imagery to the north of Cocos (Keeling) Islands at 0000 Universal Coordinated Time (UTC, UTC=Australian Western Standard Time (AWST) + 8 hours) UTC 13 December. Deep convection temporarily persisted within 40-50 nm (74-93km) of the low-level centre in the western and northern quadrants during the morning on 13 December. Scatterometer and radiometer data showed maximum winds of 20-25 kn (37-46 km/h) in western and northern quadrants.

The low remained well to the north of the Cocos (Keeling) Islands between 14 and 16 December with pulsating diurnal deep convection near the centre. A Dvorak T-number of 1.5 was assigned at 1200 UTC 14 December, increasing to 2.0 at 0600 UTC 15 December. The Current Intensity (CI) was held at 2.0 during 15 and 16 December. The Dvorak Final-T (FT) fluctuated between 1.5-2.0 during this time depending on the occurrence of deep convection.

Deep convection developed about 35 nm (64.8 km) of the centre on the southern side at 0000 UTC 17 December, and the Dvorak T-number was increased to 2.5. Once again, the convection weakened with warming of cloud tops by the evening. The T-number was dropped to 1.5, but the CI was held at 2.5 at 1200 UTC 17 December.

Deep convection with cold cloud tops once again developed near the centre on the morning of 18 December. The Global Change Observation Mission-W1 (GCOM-W1) Advanced Microwave Scanning Radiometer 2 (AMSR2RSS) 1914 UTC showed presence of gales in the southwest quadrant. Gales were picked up by the Soil Moisture Active Passive (SMAP) pass at 2340 UTC 17 December (Figure 2).

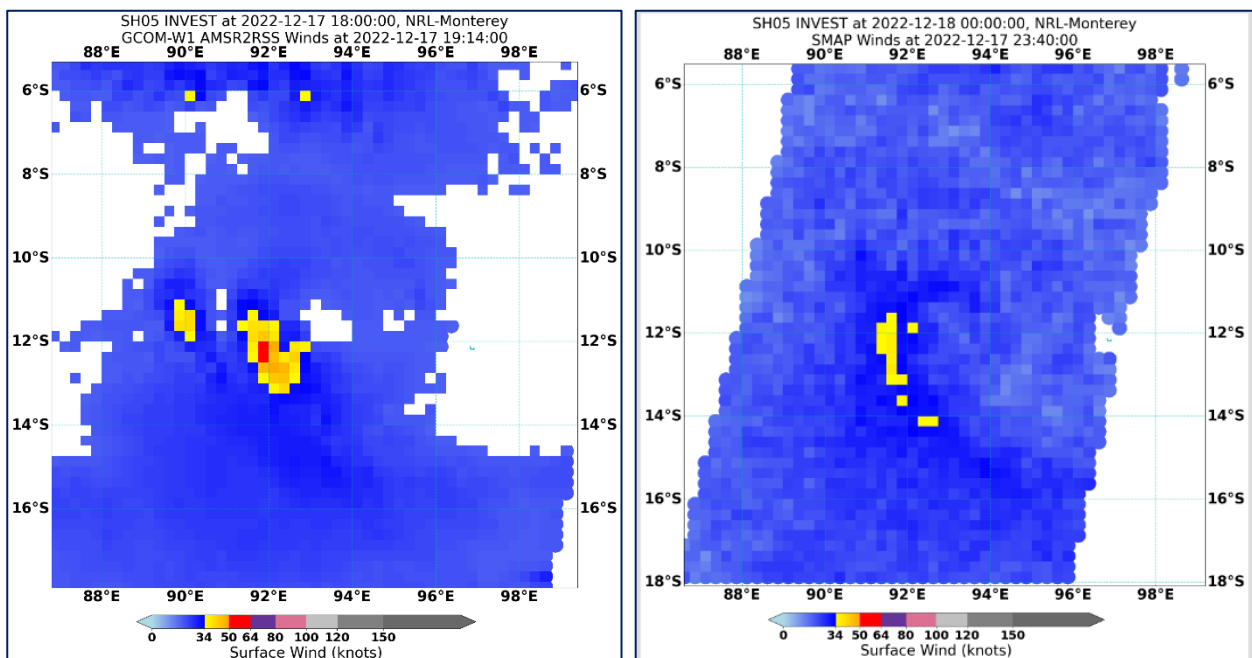


Figure 2. AMSR2RSS GCOM-W1 1914 UTC and SMAP at 2340 UTC 17 December. Images courtesy NRL: <https://www.nrlmry.navy.mil/TC.html>

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The Special Sensor Microwave Imager (SSMI) F17 at 0006 UTC 18 December displayed a closed circulation extending through the lower atmosphere (Figure 3). Three hours later, the Advanced Scatterometer (ASCAT) MetOp-B at 0343 UTC 18 December showed a broad swath of 30 kn in the southwest quadrant with 30-35 kn (55-65 km/h) in the northeast quadrant (Figure 3).

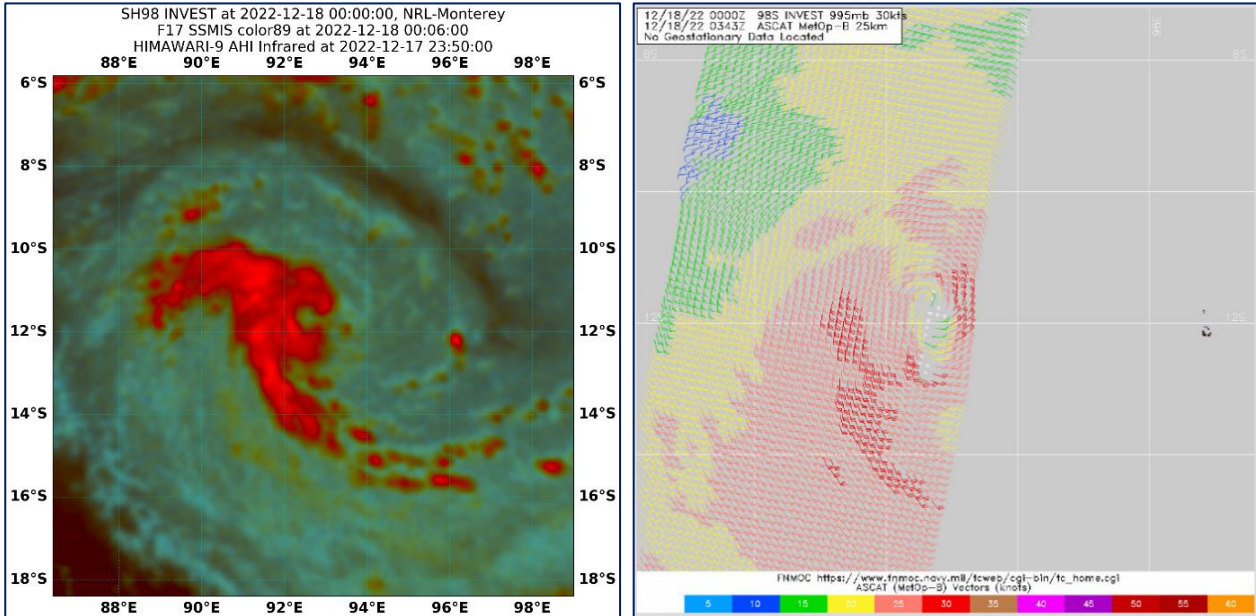


Figure 3. SSMI F17 0006 UTC 18 December and SSMI F17 0008 UTC 18 December

Images courtesy NRL: <https://www.nrlmry.navy.mil/TC.html>

The tropical low was named Tropical Cyclone Darian at 0600 UTC 18 December based on Dvorak intensity estimate of T3.0. The SMAP pass at 1152 UTC 18 December showed gales wrapping more than three quadrants (Figure 4).

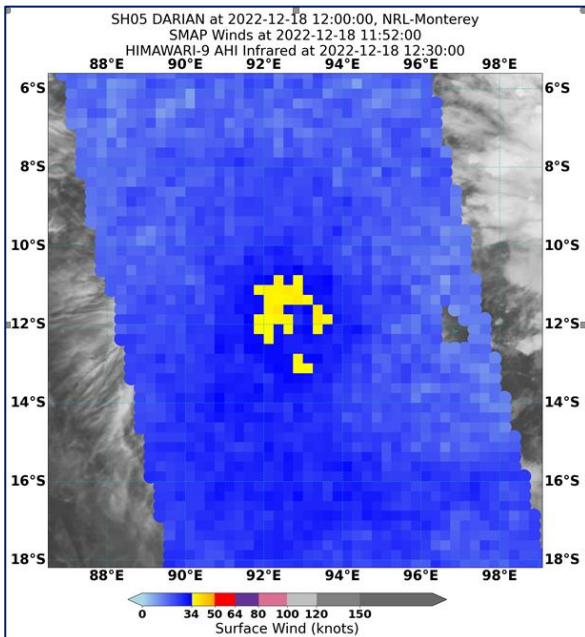


Figure 4. SMAP 1152 UTC 18 December, 6 hours after TC Darian was named. Images courtesy NRL:

<https://www.nrlmry.navy.mil/TC.html>

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Tropical Cyclone Darian was named five days after initial classification of Dvorak T1.0 on 13 December. The initial stages of the cyclone, between 13 and 19 December was influenced by moderate easterly shear with deep convection managing to persist only during diurnal hours.

There was lack of deep cold cloud tops (Dvorak Black or colder) on the morning of 19 December, 12 hours after Darian was named (Figure 5, 1800 UTC 18 December). The Dvorak estimate of T3.0 was maintained based on curved pattern applied to Medium Grey (MG) shade (as opposed to the usual Black or colder shade) giving a wrap of 0.6-0.8 degrees on a Log 10 spiral.

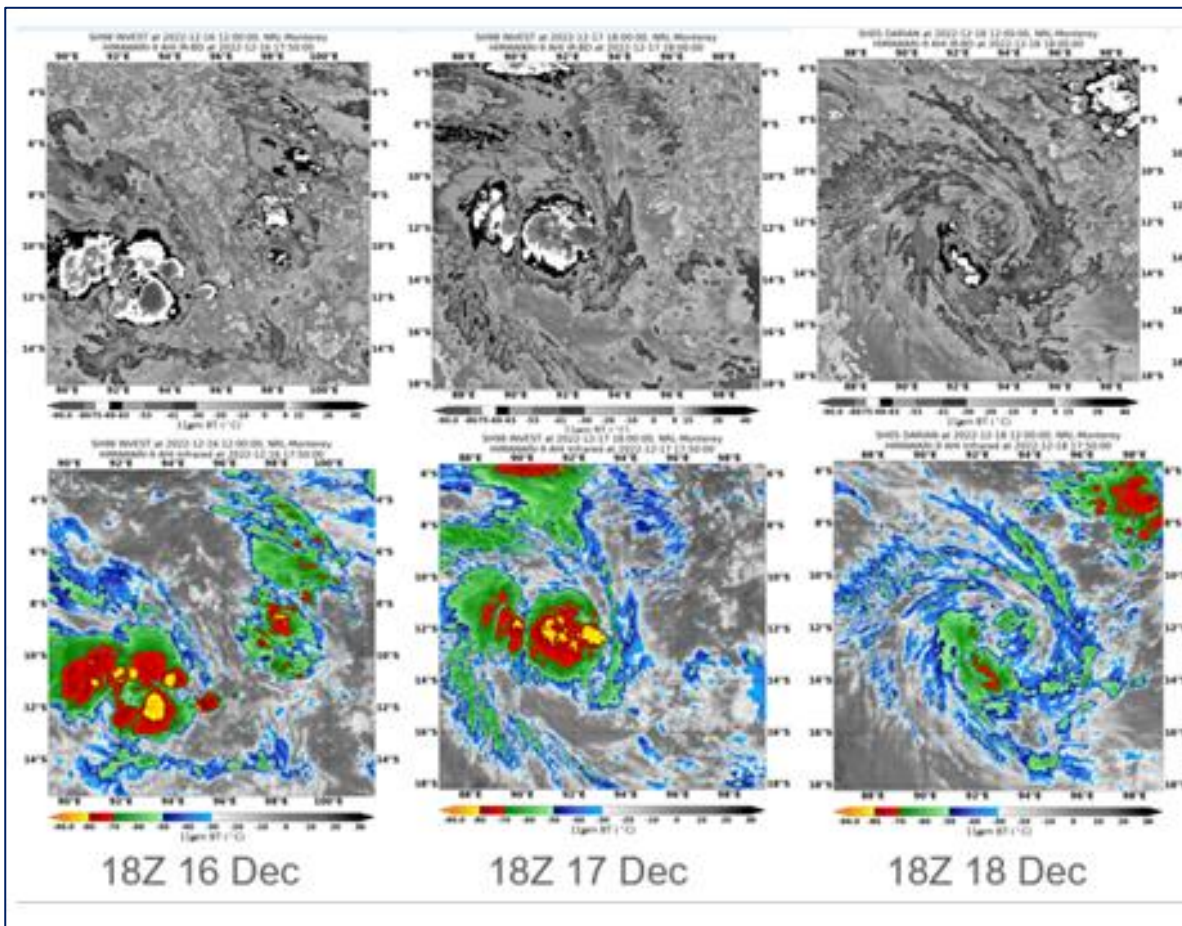


Figure 5. 1800 UTC enhanced Infrared satellite image showing lack of black of colder cloud tops on the morning of 19 December, 12 hours after Darian was named.

It's possible that the lack of deep convection on 1800 UTC 18 December may have negated the effects of deep shear, allowing the system to intensify due to strong low-level monsoonal inflow. As a result, Darian went through a phase of rapid intensification between 0000 UTC 19 December and 0600 UTC 20 December, developing from a category 1 to 4 cyclone in under 30 hours.

Radiometer data indicated this trend through the sensors; SMOS 1133 UTC, AMSR2 1902 UTC, SMOS 2357 UTC 19 December 2022 and AMSR2 0716 UTC 20 December (Figure 6).

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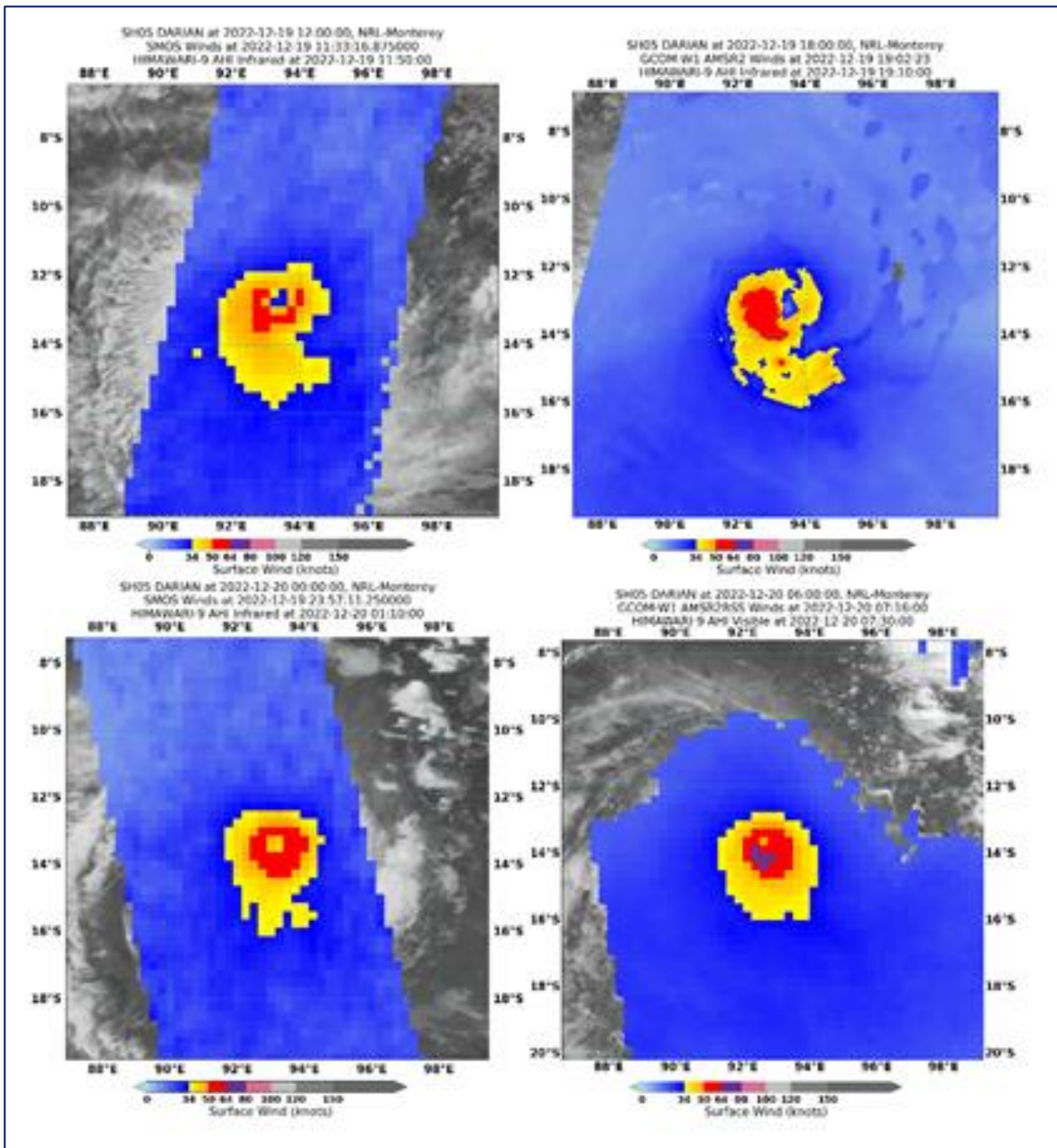


Figure 6. (L-R) SMOS 1133 UTC, AMSR2 1902 UTC, SMOS 2357 UTC 19 December 2022 and AMSR2RSS 0716 UTC December. Images courtesy NRL: <https://www.nrlmry.navy.mil/TC.html>

The Dvorak intensity was estimated at 55 kn (101 km/h) with FT4.0 at 0600 UTC 19 December increasing to 90 kn (167 km/h) with FT5.5 at 0600 UTC 20 December. The objective guidance indicated a similar trend with Cooperative Institute for Meteorological Satellite Studies (CIMSS) Advanced Dvorak Technique (ADT) and AI-enhanced ADT (AiDT) estimates increasing from 51 kn (94 km/h) and 43 kn (80 km/h) at 0600 UTC 19 December to 104 kn (193 km/h) and 97 kn (180 km/h) at 0600 UTC 20 December respectively.

Severe TC Darian went through a second phase of rapid intensification during the period 0600 UTC 20 December to 1900 UTC 20 December (Figure 7), increasing from 90 kn (167 km/h) to peaking in intensity at 125 kn (232 km/h).

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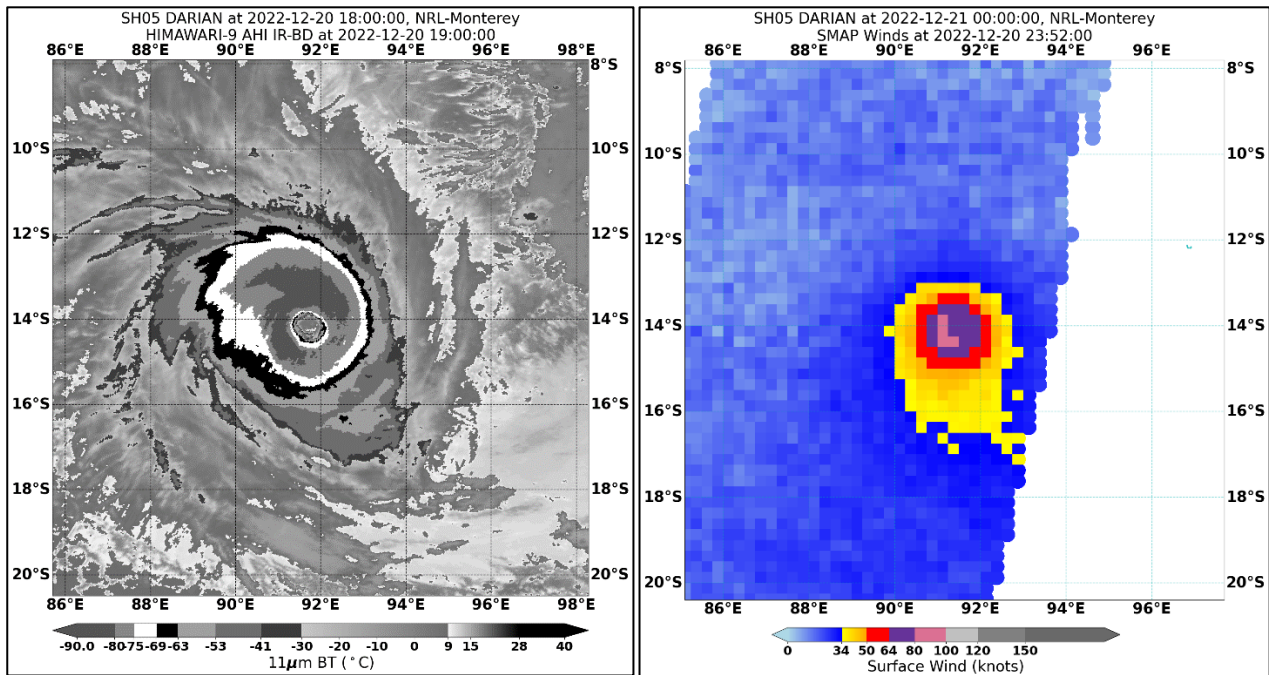


Figure 7. Severe Tropical Cyclone Darian at 1900 UTC 20 December Dvorak enhanced infrared satellite image and SMAP at 2352 UTC 20 December near peak intensity.

Images courtesy NRL: <https://www.nrlmry.navy.mil/TC.html>

Severe Tropical Cyclone Darian reached peak intensity of 125 kn (232 km/h) at 1900 UTC 20 December with a Dvorak estimated Current Intensity (CI) of 7.0. Intensity estimates from National Environmental Satellite, Data, and Information Service (NESDIS) ADT and CMISS ADT, including CIMSS AiDT, Deep learning - Multispectral Intensity of TCs (D-MINT) and Deep learning - IR Intensity of TCs (D-PRINT) were all in agreement with Darian peaking in the morning on 21 December (Figure 8). The Advanced Microwave Sounding Unit (AMSU) and Satellite Consensus (SATCON) were much lower than every other guidance during this time.

The peak intensity of 125 kn (232 km/h) was held till 0600 UTC 21 December then dropped to 120 kn (222 km/h). The Dvorak FT number was estimated to be 6.5 at 0600 UTC 21 December. The CIMSS M-PERC Hovmoller Eyewall Replacement Cycle (ERC) display showed a secondary eyewall forming at a radius of 50 km from about 0000 UTC 21 December, with a secondary eyewall becoming established from about 0600 UTC 21 December. The CIMSS shear values had also increased from 12 kn (22 km/h) to 22 kn (41 km/h) between 0600 UTC and 1200 UTC 21 December.

Darian was estimated to be at 120 kn (222 km/h) at 1200 UTC 21 December as it moved into RSMC La Reunion area of responsibility.

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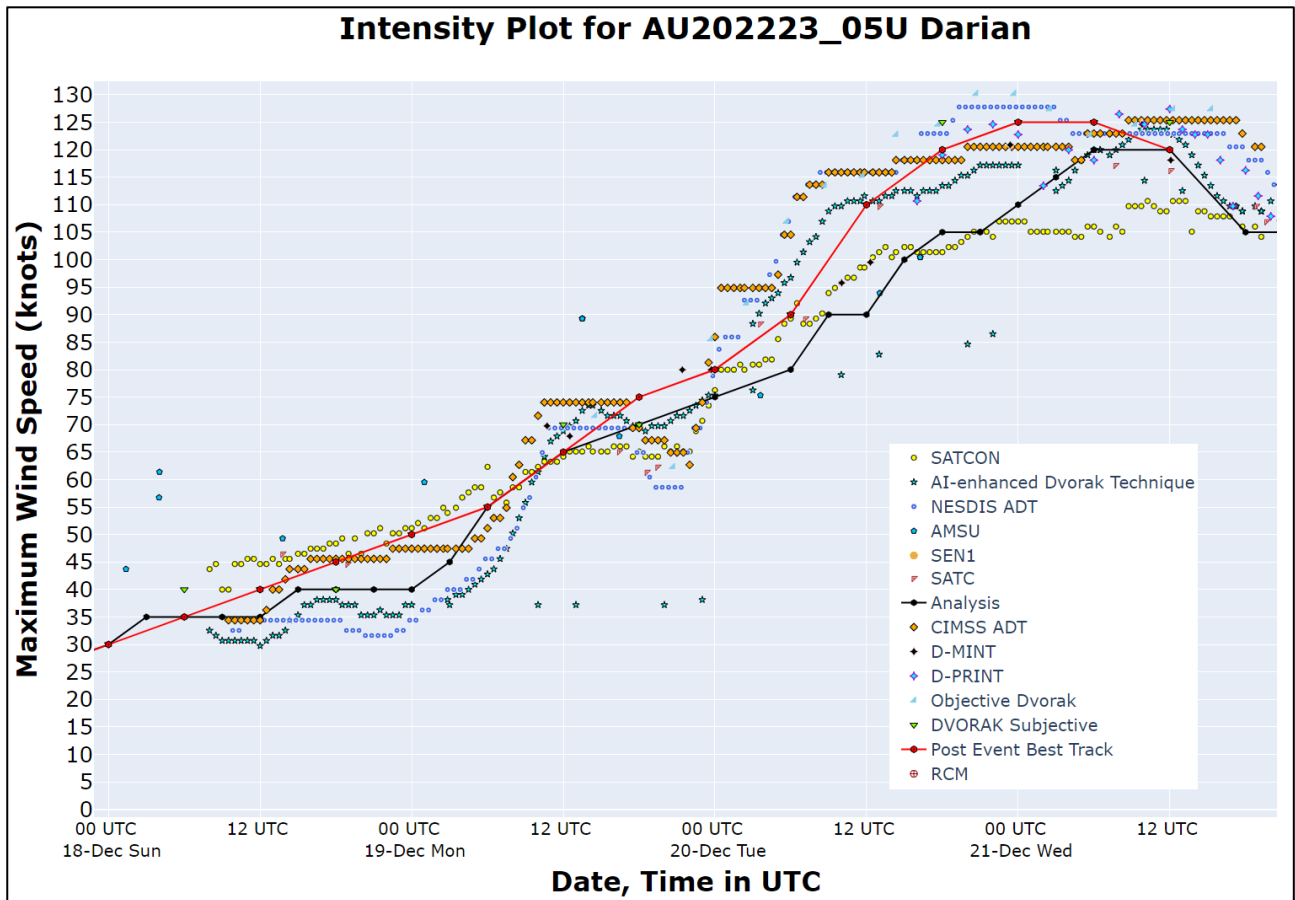


Figure 8 . Plot of objective and subjective intensity estimates for Darian from 18 to 22 December. SATCON, AiDT, NEDIS ADT, AMSU, SATC, CIMSS ADT, D-MINT, D-PRINT, Objective Dvorak have been adjusted from 1-minute to 10-minute maximum mean winds.

2.2 Structure

Darian had a reasonably symmetrical structure in the early stages as gales developed within 60-70 nm (111-129 km) of the centre in the northwest and northeast quadrants and within 60 nm (111 km) elsewhere around 0600 UTC 18 December.

As the low deepened, asymmetries in the gale radius were evident from 1200 UTC 19 December with the radius to 100 nm (185 km) in the southwest quadrant and then extending to 100 nm (185 km) in the southeast quadrant by 0000 UTC 20 December. The northwest quadrant gales extended to 90 nm (167 km) by 0600 UTC 20 December.

The hurricane and storm wind radii were mostly symmetrical, extending from 30 nm (55 km) to 50-60 nm (92 - 111 km). The eye diameter was measured to be between 15 and 10 nm (28 to 18.5 km) between 1200 UTC 19 December and 0600 UTC 21 December.

The radius of maximum winds (RMW) was estimated to be near 30 nm (55 km) at 0600 UTC 18 December dropping to 12 nm (22 km) from 1800 UTC 20 December. Refer to Table 1 for wind radii estimates.



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2.3 Motion

A weak tropical low was steered to the west on 13 and 14 December under the influence of a mid-level ridge. On 15 and 16 December, it was picked up by the monsoon surge and steered to the east and then south.

The low deepened slightly on 17 December and began to respond to a developing upper trough to the far southwest and a mid-level ridge to the east. Hence, it moved in a general southward's direction.

The mobile upper trough moved eastwards on 18 December, leaving a deepening Darian to be caught by the mid-level ridge once again. Hence, Darian moved westwards and out of the Western Region around 1200 UTC 21 December.

3. Impact

There was no impact to any island or coastal communities.

4. Observations

There were no significant observations available during this event.

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5. Forecast performance

Ocean wind warnings and official Tropical Cyclone Forecast Track Maps were issued from 0000 UTC 18 December to 0600 UTC on 21 December. Tropical Cyclone Advices were issued for the Cocos (Keeling) Islands as the system took a slight southeast track towards the islands on 18 and 19 December. Tropical Cyclone Information Bulletins commenced 0600 UTC 19 December (after the TC Advices had ceased) and continued until 0600 UTC 21 December.

The accuracy statistics for the intensity and track are shown in Table 2 below.

Figure 11 shows that the position accuracy was close to or slightly better than five-year mean for lead times up to 24 hours but increases rapidly for lead times beyond 36 hours. The large position errors in the longer term were due to the system being surrounded by relatively weak steering influence for majority of its life span. This was reflected in the large spread of tracks received from both, the deterministic and ensemble model guidance.

Intensity forecasts for Darian were close to or slightly higher than the 5-year historical skill up to 12-hour lead times (Figure 12). Beyond that, the intensity error increased rapidly reaching a difference of 71.7 kn (132.7 km/h) at 72-hour lead time. Relatively cooler Sea Surface Temperatures (SST) and possibility of mid-level dry air intrusion were given as the reasons for subjective reluctance in forecasting Darian's peak intensity. The errors were also attributed to poor intensity forecasts produced by the numerical guidance at the time (Figure 13). None of the global deterministic, ensemble guidance, dynamical cyclone or statistical models picked the intensification of the development of Darian.

Table 2. Position and Intensity accuracy statistics for Severe Tropical Cyclone Darian.

	0	6	12	18	24	36	48	72	96	120
Position										
Absolute error (km)	20	33	46	65	91	156	245	400		
Intensity										
Absolute error (kn)	6.8	10.0	14.2	20.8	28.6	41.1	50.0	71.7		
Sample Size	14	14	13	12	11	9	7	3		

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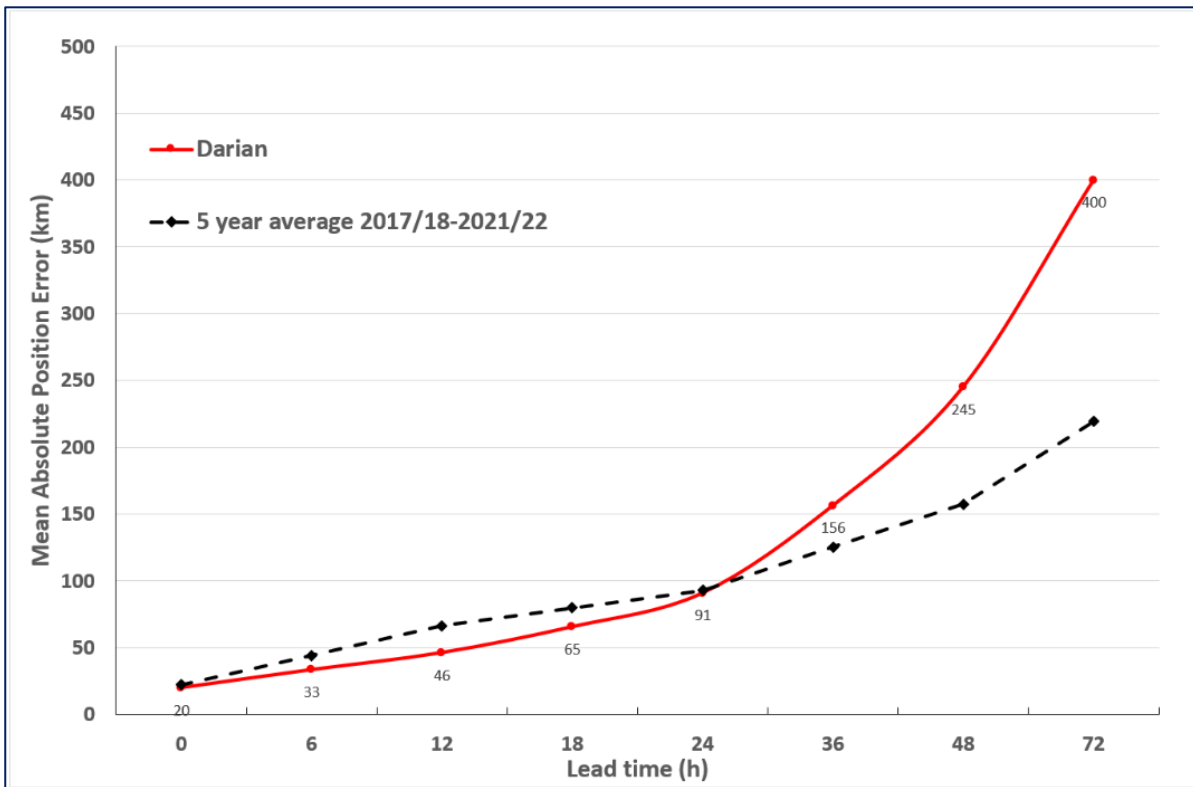


Figure 9. Position accuracy for Severe Tropical Cyclone Darian.

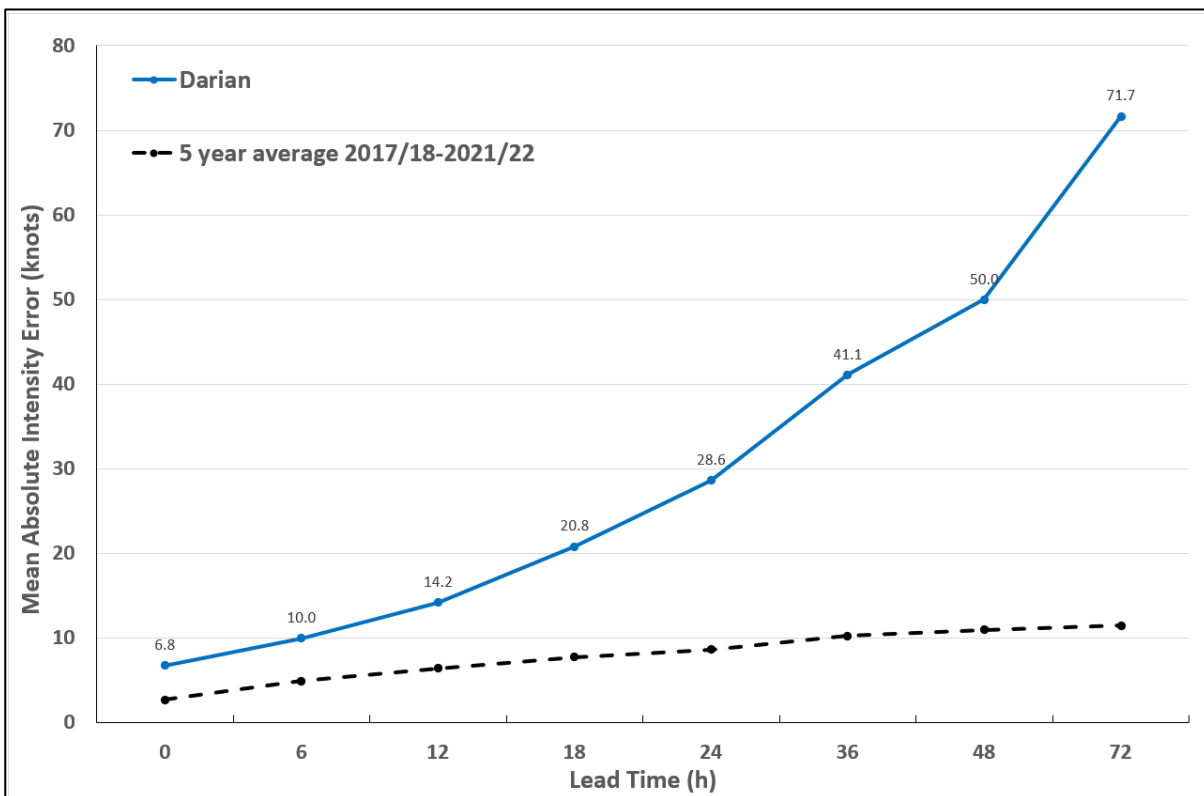


Figure 1210. Intensity accuracy for Severe Tropical Cyclone Darian.

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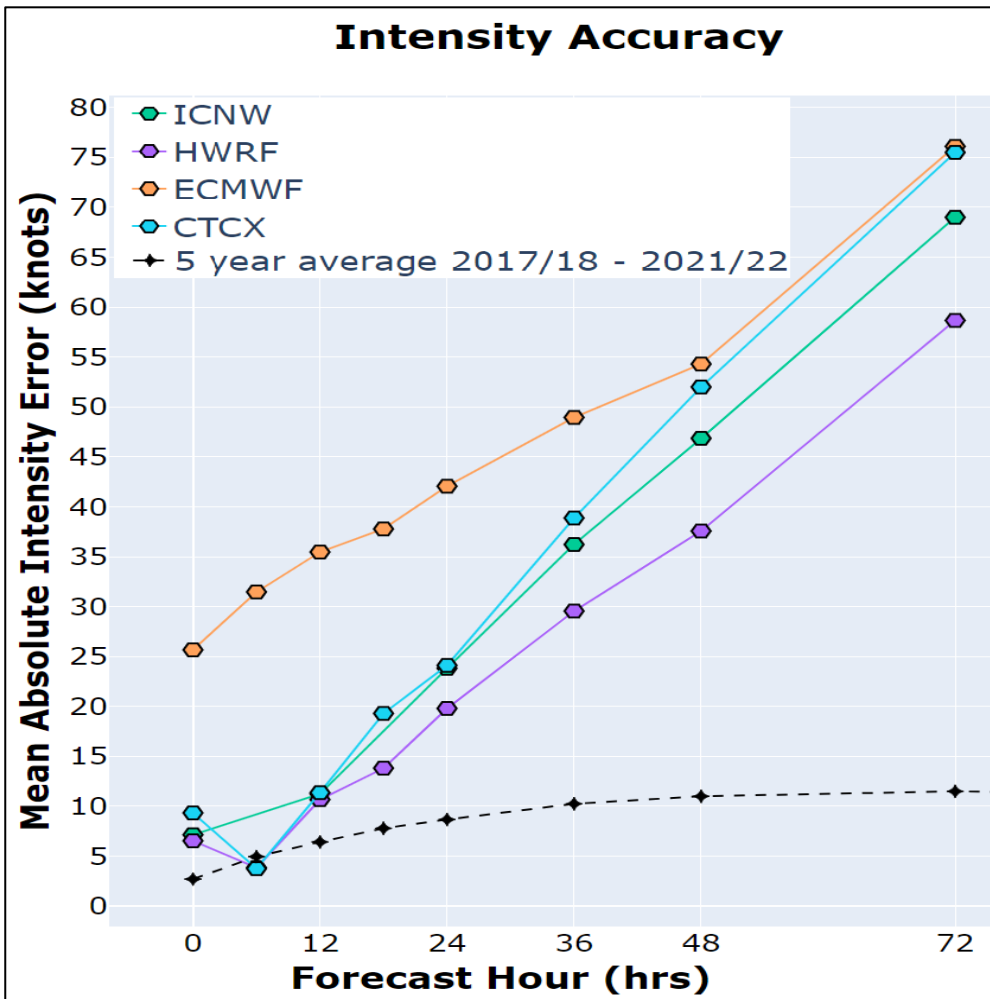


Figure 1311. Intensity forecast errors from numerical guidance for Severe Tropical Cyclone Darian. These models include the European Centre for Medium-Range Weather Forecasts (ECMWF), the Hurricane Weather Research and Forecasting Model (HWRF), the NRL's Coupled Ocean/Atmosphere Mesoscale Prediction System for Tropical Cyclones (CTCX), and the Intensity model consensus (ICNW).

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6. 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



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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