Severe Tropical Cyclone Freddy

5 – 14 February 2023 (within Australian region)

Pete Clegg, Craig Earl-Spurr and Linda Paterson
Tropical Cyclone Environmental Prediction Services

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Contact details:

Tropical Cyclone Team Lead

Severe Weather Environmental Prediction Services

Bureau of Meteorology

PO Box 1370, West Perth WA 6872

Email: tcwc@bom.gov.au

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Cover image: Tropical Cyclone Freddy pictured from the International Space Station *Image Credit: Nasa/Nicole Mann*.

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1. Summary

Severe Tropical Cyclone Freddy developed south of Indonesia and crossed the entire width of the Southern Indian Ocean. Whilst there were no known impacts within the Australian region, there were devastating impacts to Madagascar and parts of southern Africa, particularly Mozambique and Malawi.

The low formed south of the Indonesian Archipelago on 5 February and developed into a tropical cyclone at 1200 UTC 6 February. After a brief period of southerly motion, Freddy turned west and moved over open waters to the north of Western Australia and to the south of both Christmas and the Cocos Islands. Freddy went through periods of intensification and weakening as it moved west. The tropical cyclone initially intensified rapidly and reached a 10-minute mean wind peak intensity of 80 kn (150 km/h) at 0000 UTC 8 February. Freddy then weakened before re-intensifying to a second peak intensity of 95 kn (175 km/h) at 1800 UTC 11 February and 0600 UTC 12 February. It continued moving westward out of the Australian region and into La Reunion's area of responsibility on 14 February.

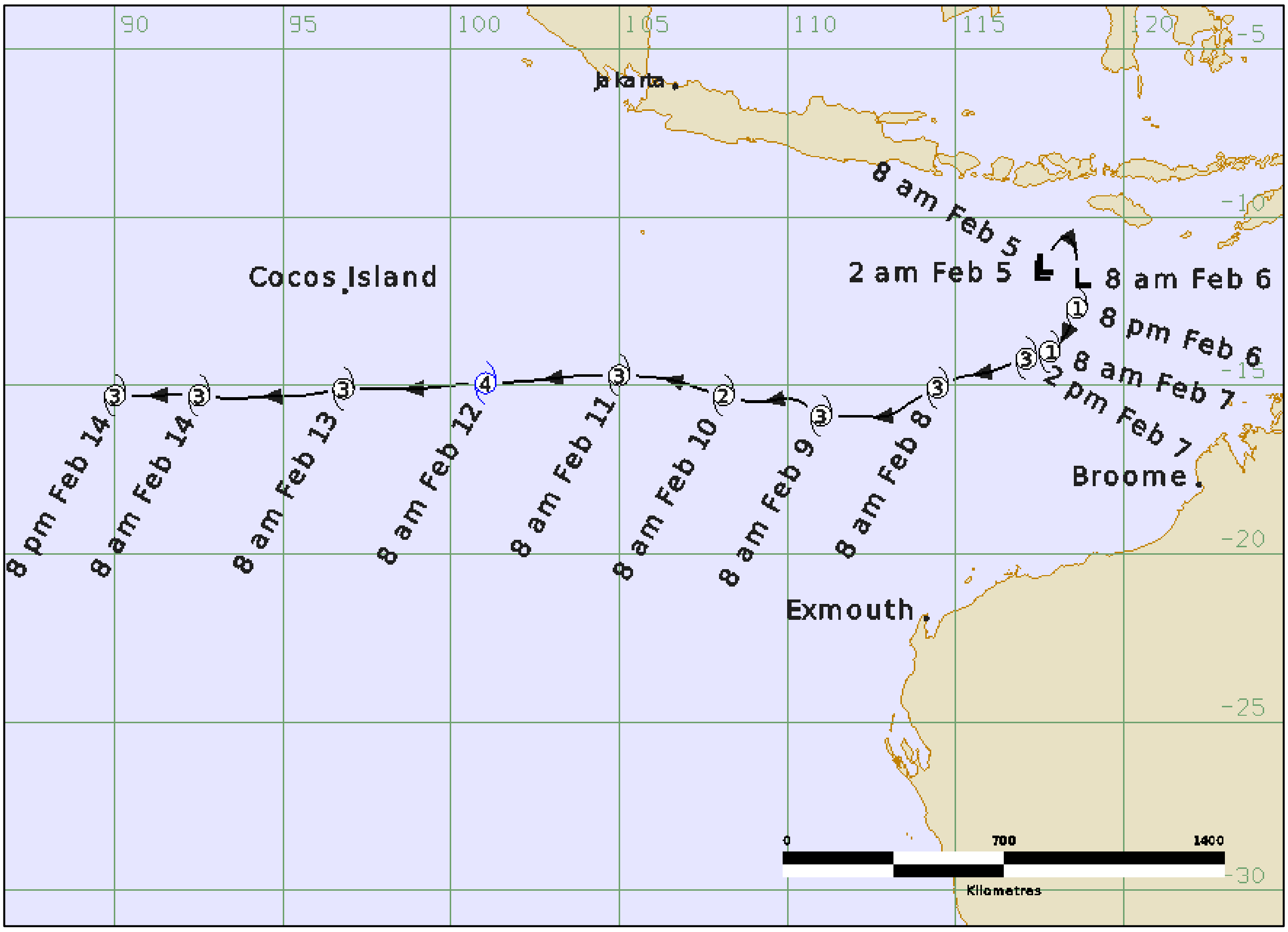

Figure 1. Track of Severe Tropical Cyclone Freddy whilst within the Australian region (times in AWST, UTC +8).

Table 1 Best track summary for Severe Tropical Cyclone Freddy, 5 – 14 February 2023.

UTC=AWST-8h. * Not at tropical cyclone intensity as gales less than halfway around centre.

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
2023	2	4	1800	11.6	117.5	45	20	45	1005	0/0/0/0	0/0/0/0	-
2023	2	5	0000	11.4	117.6	30	20	45	1005	0/0/0/0	0/0/0/0	-
2023	2	5	0600	10.9	117.9	45	20	45	1005	0/0/0/0	0/0/0/0	-
2023	2	5	1200	10.6	118.3	45	25	45	1003	0/0/0/0	0/0/0/0	-
2023	2	5	1800	11.2	118.6	45	25	45	1003	0/0/0/0	0/0/0/0	-
2023	2	6	0000	11.8	118.7	45	30	45	1001	0/0/0/0	0/0/0/0	-
2023	2	6	0600	12.3	118.8	25	35*	50	996	0/60/0/0	0/0/0/0	-
2023	2	6	1200	12.7	118.6	25	45	65	990	50/50/0/40	0/0/0/0	20
2023	2	6	1800	13.2	118.4	25	45	65	990	50/50/40/0	0/0/0/0	20
2023	2	7	0000	14.0	117.8	20	45	65	991	50/50/40/60	0/0/0/0	15
2023	2	7	0600	14.2	117.1	15	65	90	977	50/80/80/70	30/30/60/50	15
2023	2	7	1200	14.6	116.0	20	75	105	970	50/70/50/50	40/40/40/40	10
2023	2	7	1800	14.8	115.0	20	75	105	970	70/40/40/70	60/0/30/60	15
2023	2	8	0000	15.1	114.5	20	80	110	964	70/80/50/70	60/40/30/60	10
2023	2	8	0600	15.5	113.6	15	75	105	969	70/60/50/70	60/40/40/60	10
2023	2	8	1200	15.9	113.0	25	75	105	968	80/80/70/80	60/40/60/70	10
2023	2	8	1800	15.9	111.9	15	70	100	974	90/80/100/100	70/40/90/90	10
2023	2	9	0000	15.9	111.0	20	65	90	977	80/60/90/90	60/40/50/60	15
2023	2	9	0600	15.6	110.5	15	55	75	983	50/40/80/80	0/0/50/60	10
2023	2	9	1200	15.4	109.9	20	50	70	984	40/40/50/50	0/0/0/20	15
2023	2	9	1800	15.5	109.2	20	50	70	985	70/40/60/60	0/0/0/20	15
2023	2	10	0000	15.3	108.1	30	60	85	980	60/50/90/90	40/30/30/30	15
2023	2	10	0600	15.1	107.4	20	60	85	981	40/30/70/80	0/0/50/50	15
2023	2	10	1200	14.9	106.8	30	60	85	980	50/50/50/60	20/20/20/0	15
2023	2	10	1800	14.8	105.9	30	65	90	978	50/50/40/50	30/30/20/20	15
2023	2	11	0000	14.7	105.0	20	70	100	973	50/50/40/40	30/30/30/20	10
2023	2	11	0600	14.7	104.0	30	75	105	970	60/60/60/50	30/30/30/30	10
2023	2	11	1200	14.8	103.0	15	90	125	956	60/60/70/60	40/40/40/40	10
2023	2	11	1800	14.9	101.9	15	95	135	951	80/50/70/90	60/30/50/60	10
2023	2	12	0000	14.9	101.0	15	90	125	955	70/80/80/80	40/40/50/40	10
2023	2	12	0600	15.0	100.0	15	95	135	952	90/40/90/110	60/30/50/80	10
2023	2	12	1200	15.1	99.0	15	85	120	960	70/70/90/90	50/40/40/60	10
2023	2	12	1800	15.1	97.9	20	85	120	961	90/60/70/80	70/40/40/70	15
2023	2	13	0000	15.1	96.8	20	85	120	961	60/80/90/70	40/50/50/40	15
2023	2	13	0600	15.3	95.6	20	85	120	961	50/70/80/60	40/40/50/50	15
2023	2	13	1200	15.3	94.5	30	80	110	965	60/70/70/70	40/40/50/40	15
2023	2	13	1800	15.4	93.4	30	75	105	971	50/70/90/70	30/40/40/30	15
2023	2	14	0000	15.3	92.5	15	75	105	969	50/80/80/50	30/50/50/30	15
2023	2	14	0600	15.3	91.2	15	75	105	970	60/90/90/70	40/40/40/30	15
2023	2	14	1200	15.3	90.0	15	85	120	961	70/100/100/70	50/60/60/50	15

2. Meteorological description

2.1 Intensity analysis

An active phase of the Madden-Julian Oscillation combined with an equatorial Rossby wave to produce a low to the north of Western Australia on 5 February. Initially the circulation was poorly defined and elongated however persistent convection with improved signs of organisation occurred during the overnight period, and the low was assessed as reaching a Dvorak T number (DT) of 2.5 by 0000 UTC 6 February. This development continued through 6 February with curved banding apparent in visible and microwave imagery and the low reached tropical cyclone strength by 1200 UTC 6 February. At this time a DT of 3.0 could be assigned and an ASCAT pass at 1400 UTC 6 February (refer Figure 2) confirmed the Dvorak assessment with gales analysed in multiple quadrants.

Freddy intensified rapidly with a microwave eye apparent in imagery by early on 7 February. Dvorak T numbers climbed to 4.5 by 0600 UTC 7 February and Freddy reached hurricane strength, refer Figure 3. Freddy continued to intensify and reached its first 10-minute mean wind peak intensity of 80 kn (150 km/h) at 0000 UTC 8 February, refer figure 4 which is a plot of objective and subjective intensity estimates.

From 0000 UTC 8 February Freddy weakened over the next 48 hours. The system was located close to a strong shear gradient with dry air surrounding the tropical cyclone. Fluctuations in the magnitude of the vertical wind shear over the system combined with possible intrusions of dry air into the core were the likely cause of the decrease in intensity during the period from 0000 UTC 8 February to 1800 UTC 9 February. Microwave imagery showed deep convection decreased significantly and the southern eye wall was eroded. Subjective Dvorak and objective guidance also decreased, and Freddy weakened to an intensity of 50 kn by 1200 UTC 9 February, refer Figure 5.

Conditions became more favourable for development and Freddy began to gradually intensify from early on 10 February. Microwave imagery showed deep convection beginning to wrap around the centre. By 11 February deep convection had re-formed completely around the centre, refer Figure 6, as the vertical wind shear decreased and the upper divergence improved in all quadrants. By the evening of 11 February, the EIR imagery had a clear eye pattern which persisted through until about 0000 UTC 12 February. Freddy reached a second peak 10-minute mean intensity of 95 kn (175 km/h) at 1800 UTC 11 February and again at 0600 UTC 12 February, refer Figure 7. The intensity of Freddy continued to fluctuate between 85 kn (155 km/h) and 75 kn (140 km/h) until the system passed west of 90º E and into La Reunion's area of responsibility.

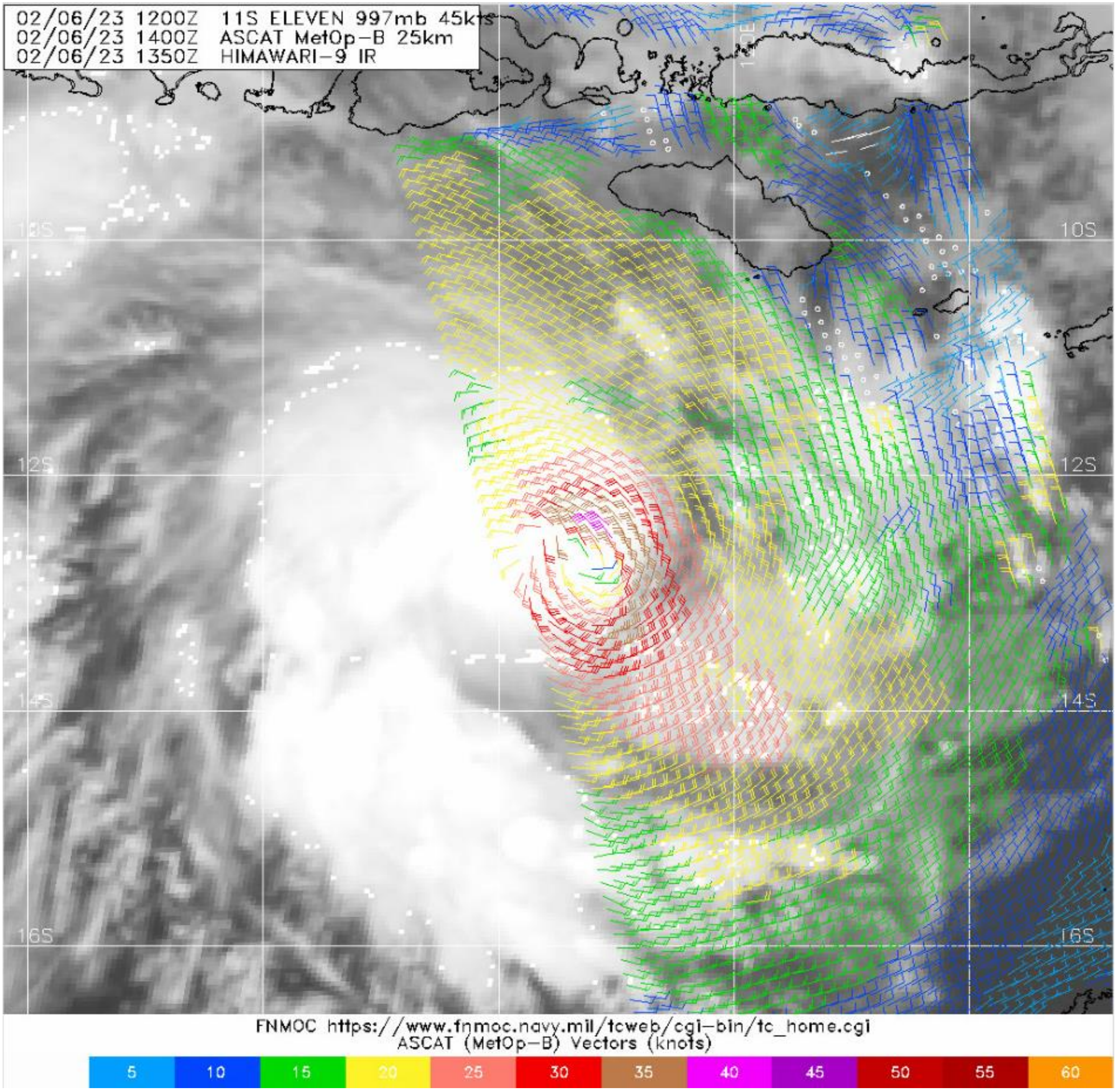

Figure 2. ASCAT pass at 1400 UTC 6 February indicating gale force winds in multiple quadrants.
Image courtesy NRL: https://www.nrlmry.navy.mil/TC.html

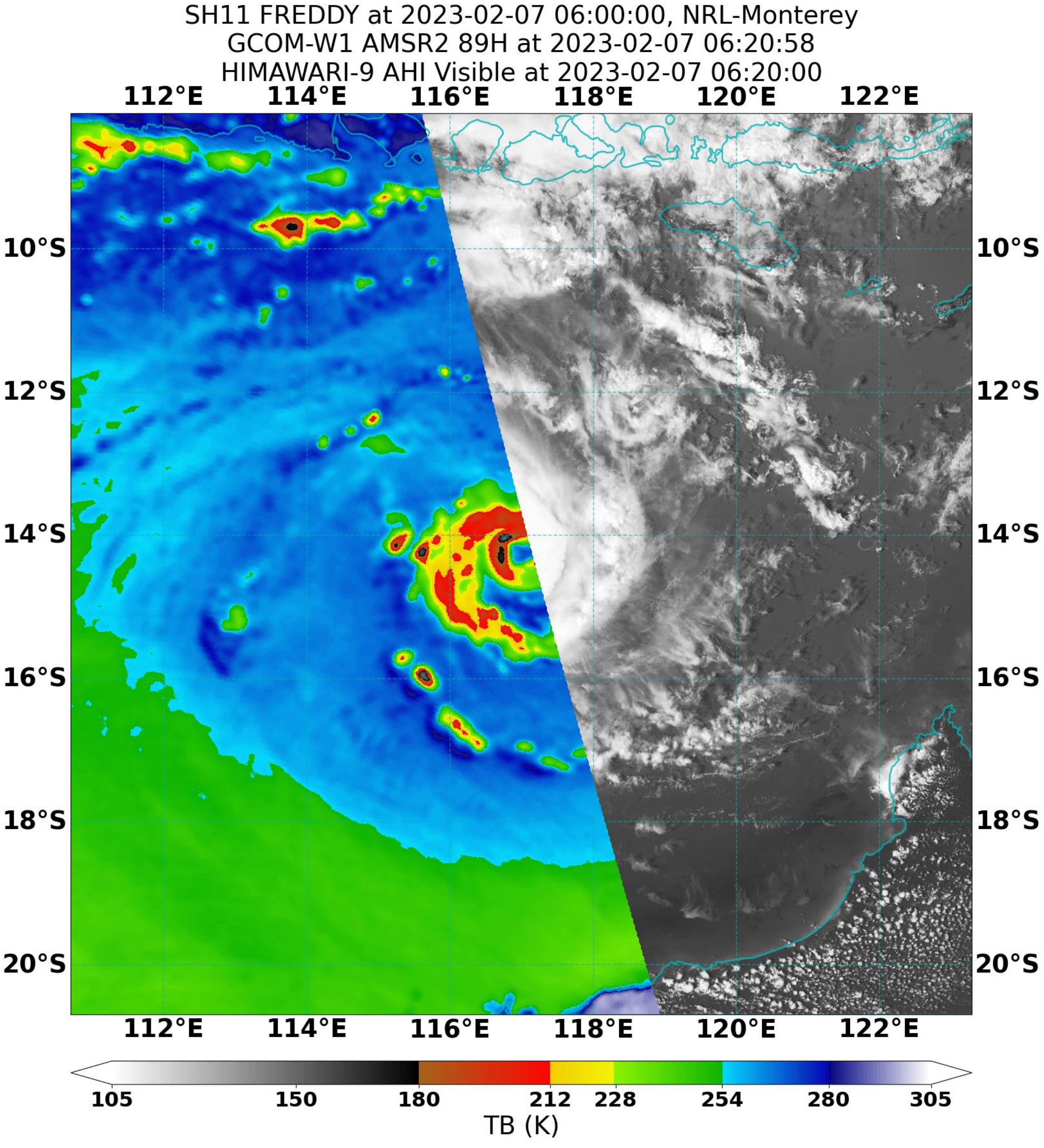

Figure 3 AMSR2 microwave pass at 0620 UTC 7 February showing deep convection surrounding a centre eye. Image courtesy NRL: https://www.nrlmry.navy.mil/TC.html

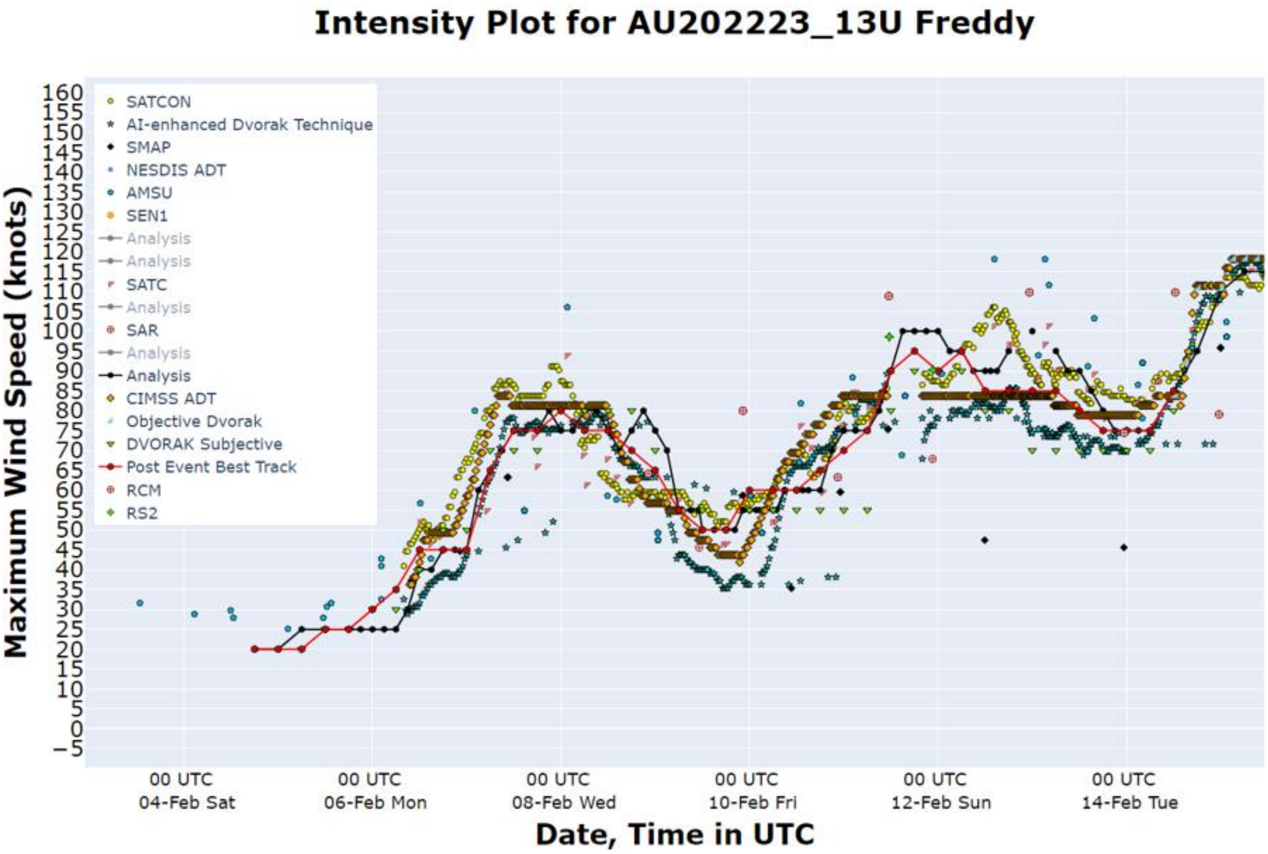

Figure 4. Intensity plot of objective and subjective guidance. SATCON, AiDT, NEDIS ADT, AMSU, SATC, CIMSS ADT, Objective Dvorak and SAR have been adjusted from 1-minute to 10-minute maximum mean winds.

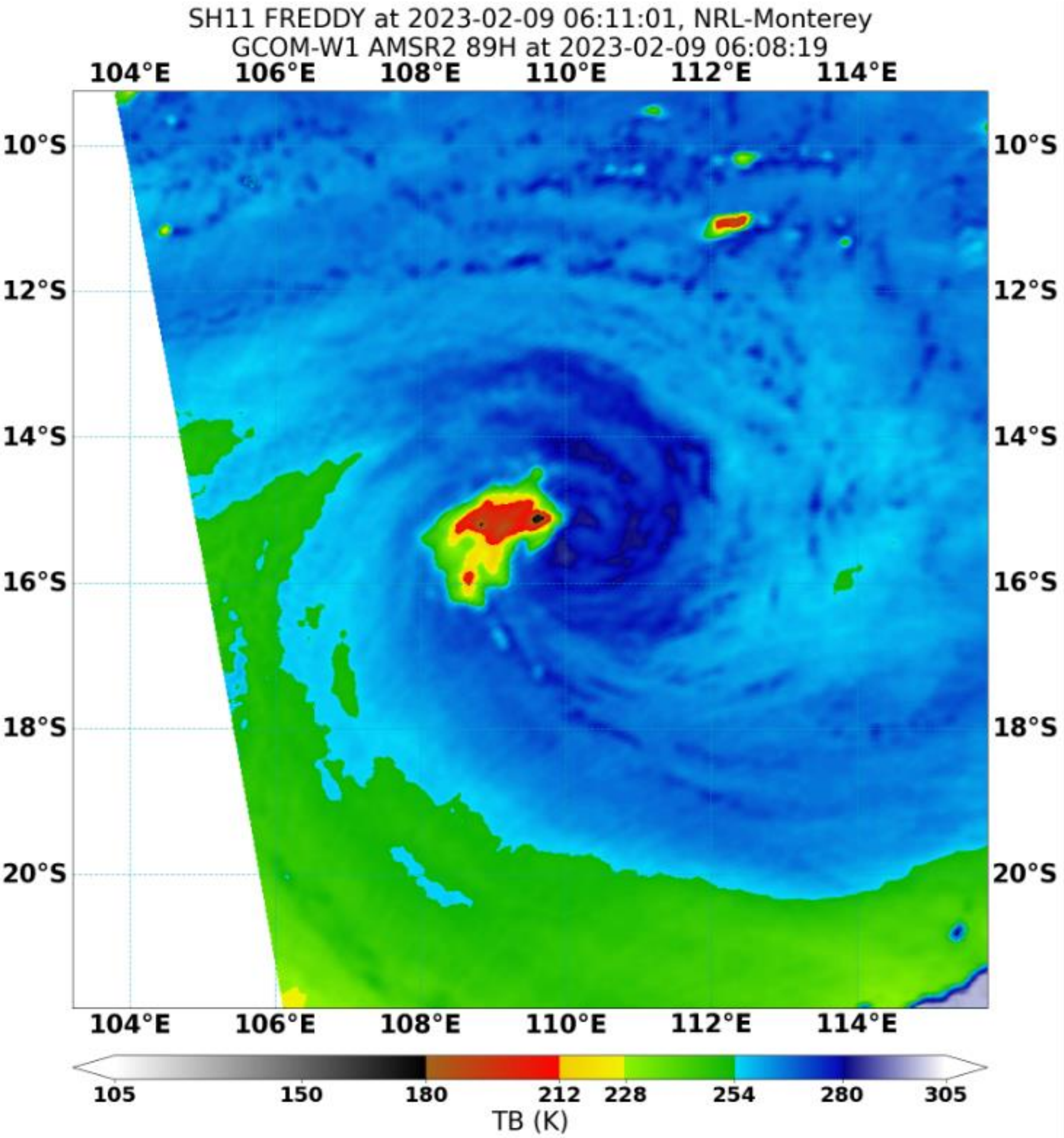

Figure 5 AMSR2 image at 0610 UTC 9 February showing a significant decrease in convection occurred. Image courtesy NRL: https://www.nrlmry.navy.mil/TC.html

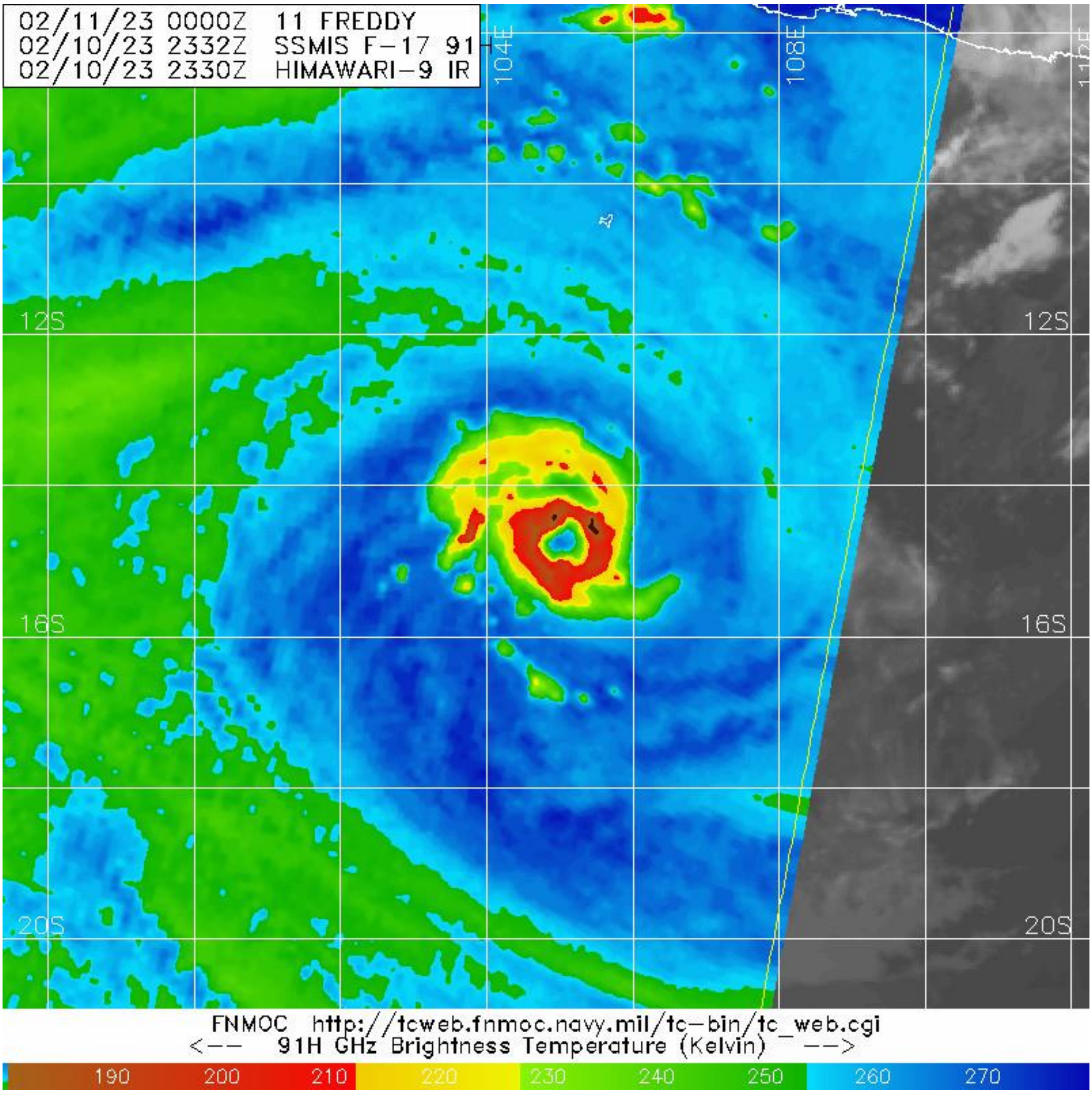

Figure 6 2332 UTC 10 February SSMIS 91 GHz pass showing convection surrounding the centre as Freddy re-intensified. Image courtesy NRL: https://www.nrlmry.navy.mil/TC.html

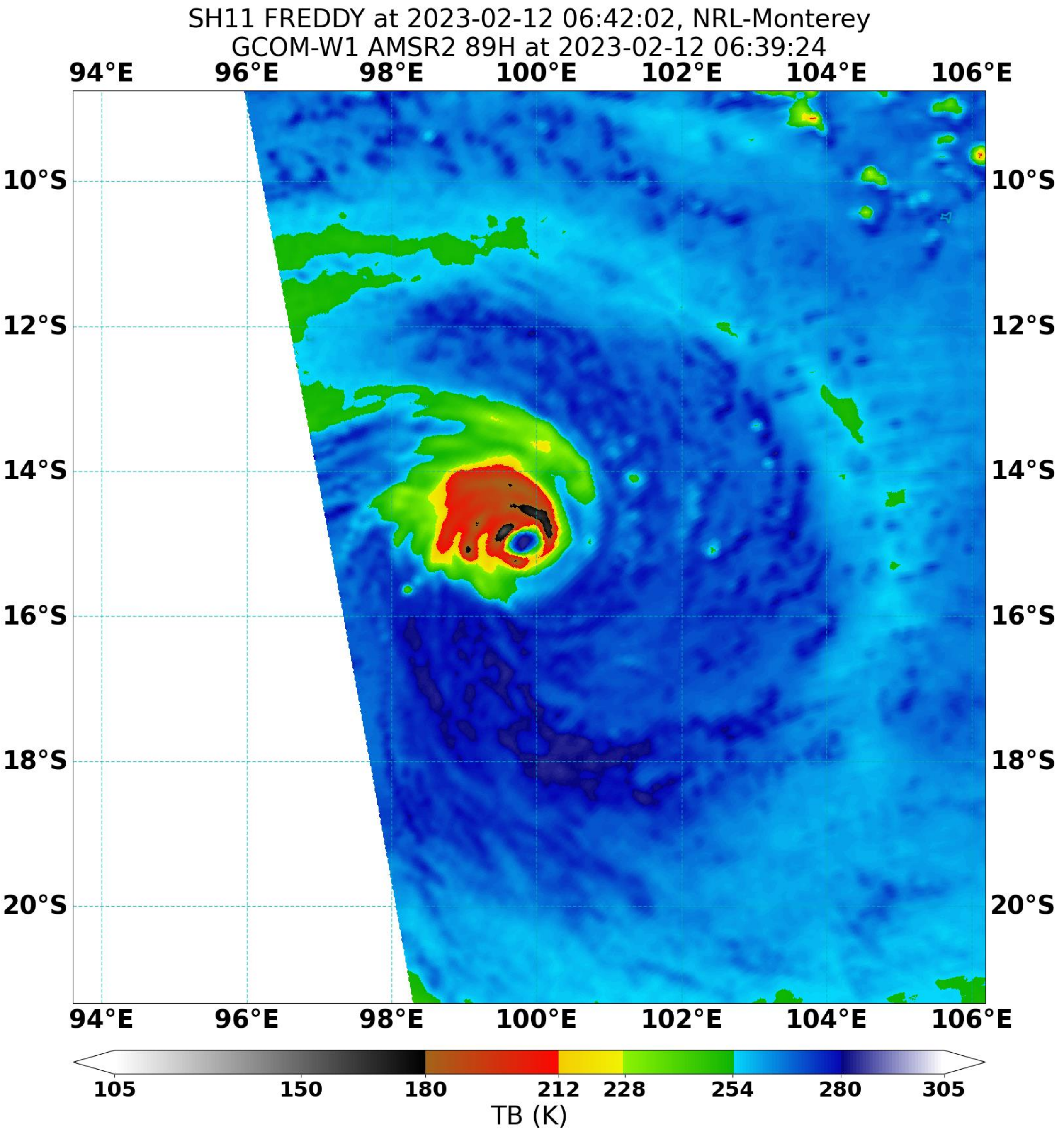

Figure 7. 89 GHz AMSR2 microwave pass at 0642 UTC 12 February as Freddy was near peak intensity.

2.2 Structure

Freddy was a small system initially with gale radii from 40 to 50 nm. As Freddy intensified it became more average sized with gale radii from 70 to 100 nm by 1800 UTC 8 February. Between 1800 UTC 7 February and 0000 UTC 9 February hurricane winds were only present in the northern quadrants, refer Figure 8. As Freddy weakened during 9 February gale radii contracted to between 40 and 50 nm again. Similarly, as Freddy re-intensified during 11 February gale radii expanded to between 70 and 90 nm by 12 February with hurricane winds present in all quadrants.

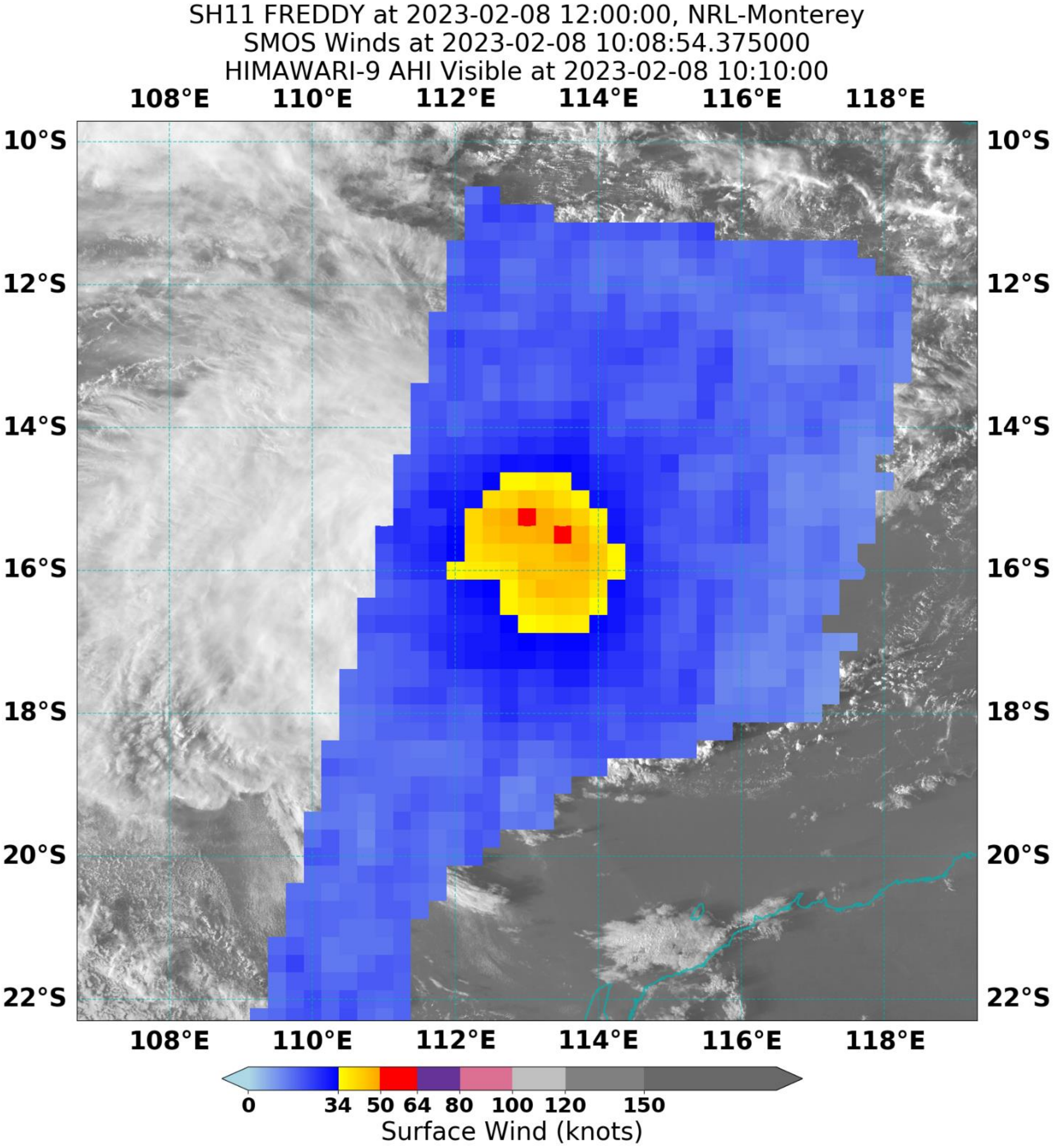

Figure 8 SMOS pass at 1008 UTC 8 February showing hurricane winds present in the northern quadrants. Image courtesy NRL: https://www.nrlmry.navy.mil/TC.html

2.3 Motion

Initially the low drifted east and then south in the monsoon trough and was slow moving between 5 and 7 February. During 7 February Freddy came under the influence of the mid-level ridge and began to move in a westward direction. The mid-level ridge was the dominant steering mechanism for the remainder of the period Freddy was in the AoR and this westward motion continued through until Freddy moved east of 90oE on 14 February.

3. Impact

There were no impacts within the Australian region.

There were significant impacts from Severe Tropical Cyclone Freddy on the western side of the Southern Indian Ocean. After crossing the Southern Indian Ocean Freddy first made landfall in Madagascar on 21 February and then, after crossing the Mozambique Channel, in Southern Mozambique on 24 February. After spending days bringing heavy rainfall to inland parts of Mozambique and Zimbabwe it moved back offshore over the Mozambique Channel on 1 March. Over the warm waters of the channel Freddy re-intensified and then made landfall again in northern Mozambique on 11 March. The passage of the severe tropical cyclone over Madagascar and eastern Africa was responsible for at least 1434 deaths and caused significant flooding to many already vulnerable regions. At the time of publication Freddy was under consideration to be named the longest-lasting tropical cyclone on record.

Sources: https://public.wmo.int/en/media/news/tropical-cyclone-freddy-may-set-new-record

https://en.wikipedia.org/wiki/Cyclone_Freddy

4. Observations

There were no observations within the Australian region.

5. Forecast performance

Forecast tracks were issued for Freddy from 0600 UTC 6 February to 0600 UTC 14 February. Verification is performed using the Official Forecast Tracks for the standard times of 0000UTC, 0600UTC, 1200UTC and 1800UTC. The accuracy figures for Severe Tropical Cyclone Freddy are below in Table 2 and are also shown in Figure 9.

The position accuracy for Freddy performed better than the 5-year average at all time steps. This was assisted by the unvarying westwards motion which was well modelled. The intensity accuracy was poorer than the 5-year average at all time steps and between 36 and 48 hours lead times the error was particularly large. Model guidance on the changes in intensity for Freddy, particularly from the favoured ECMWF model, were poor which in turn contributed to the large forecast errors in intensity seen in the table. The forecast failed to capture the rate or timing of the first period of rapid intensification between 6 – 8 February. From 8 February the forecast failed to capture the subsequent weakening of Freddy and from 10 February the forecast failed to capture the re-intensification of the cyclone.

	0	**6**	**12**	**18**	**24**	**36**	**48**	**72**	**96**	**120**
Position Absolute error (km)	23	27	35	38	44	62	80	131	179	222
Intensity Absolute error (kn)	3.0	6.4	8.9	12.7	16.8	21.1	23.5	20.9	16.9	23.6
Sample Size	33	33	32	31	30	28	26	22	18	14

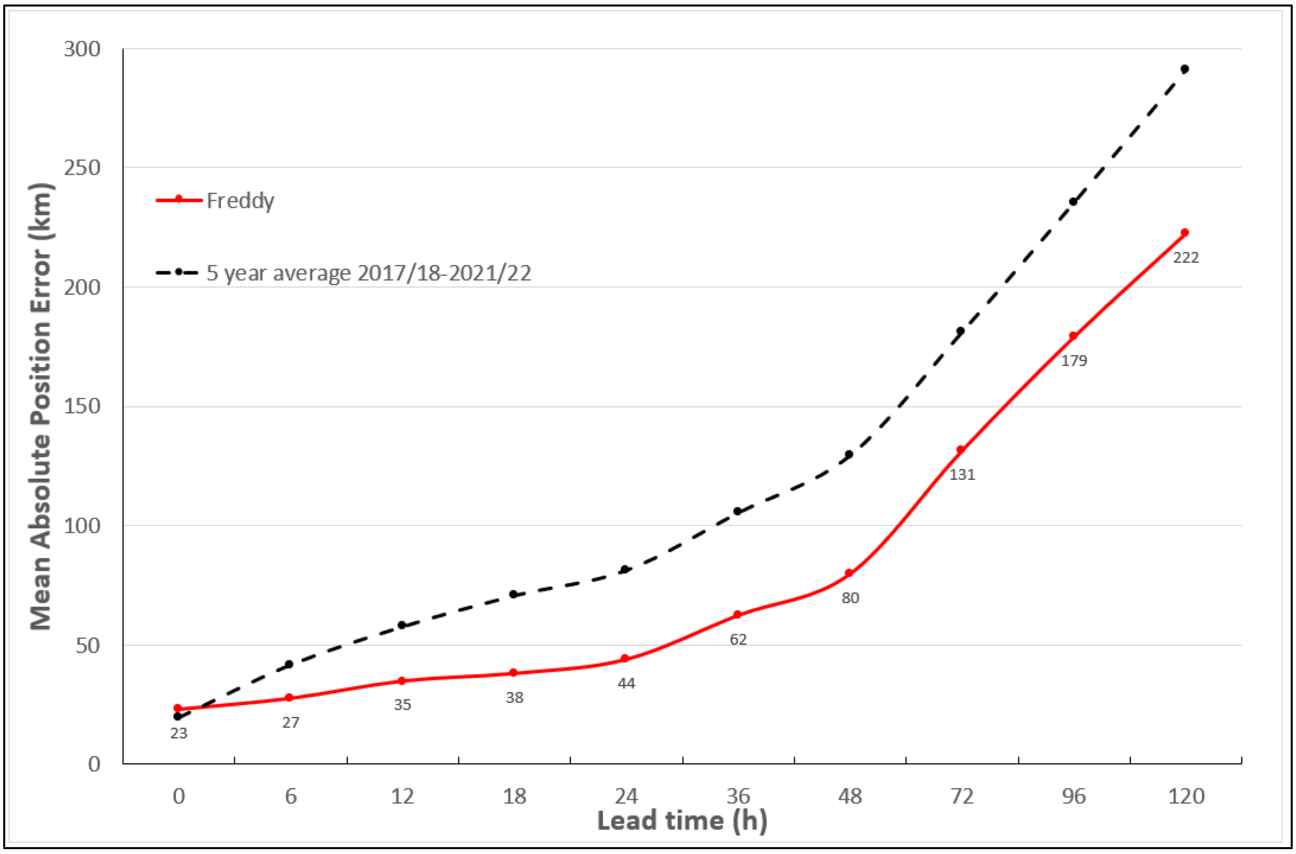

Figure 9 a Position accuracy figures for Severe Tropical Cyclone Freddy.

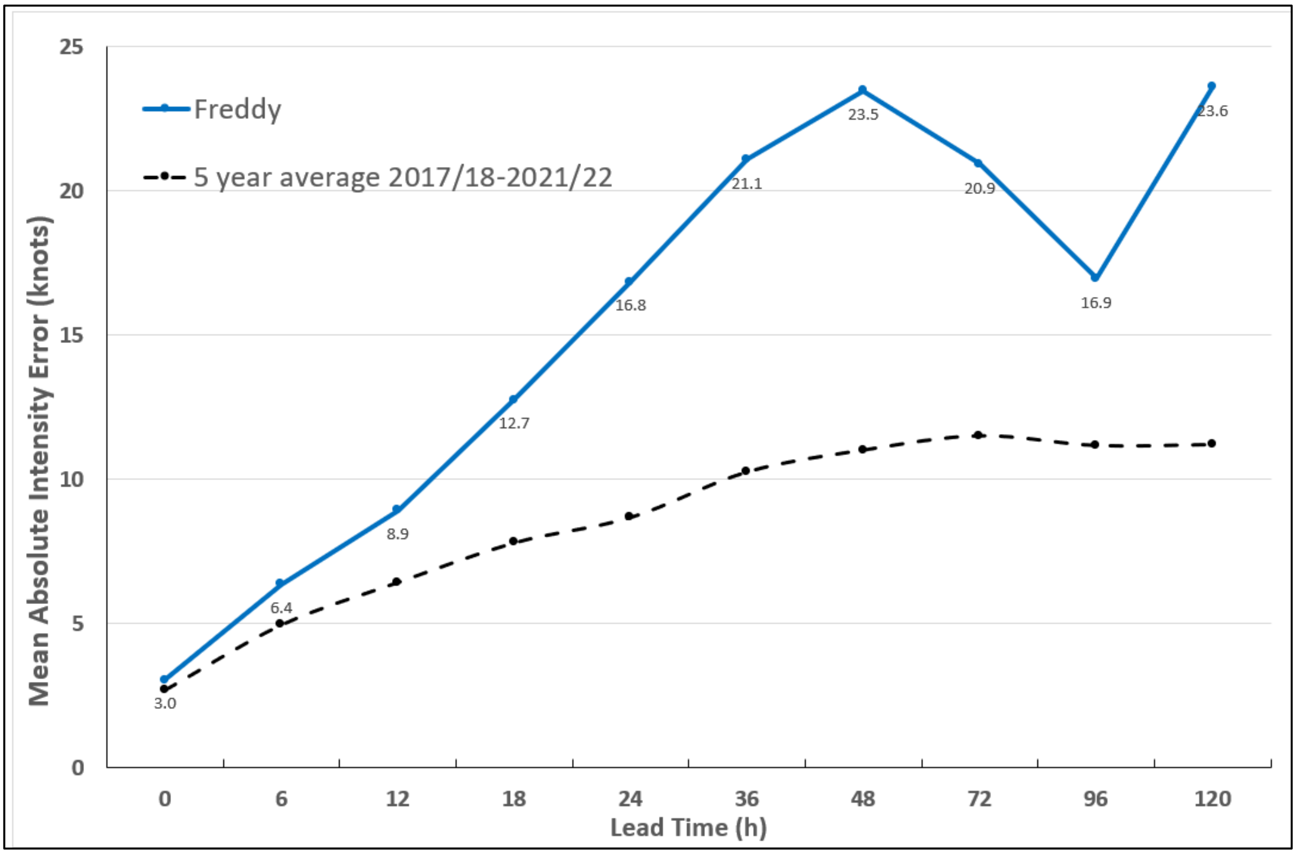

Figure 9 b Intensity accuracy figures for Severe Tropical Cyclone Freddy.

6. Appendix: List of abbreviations

Abbreviation	Term
ADT	Advanced Dvorak Technique
ACST	Australian Central Standard Time
AEST	Australian Eastern Standard Time
AiDT	AI-enhanced Dvorak Technique
AMSR2	Advanced Microwave Scanning Radiometer
AMSU	Advanced Microwave Sounding Unit
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)
D-MINT	Deep learning - Multispectral Intensity of TCs (formerly known as DMN)
D-PRINT	Deep learning - IR Intensity of TCs (formerly known as OPEN-AIIR)
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
NESDIS	National Environmental Satellite, Data, and Information Service
nm	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NRL	Navy Research Lab (USA)
OPEN-AiiR	Ordered Pattern Encoding AI Infrared
PAT	Pattern T-number
RCM	RadarSat Constellation Mission – Synthetic Aperture Radar
RH	relative humidity
RMW	radius of maximum winds
RSMC	Regional Specialised Meteorological Centre
SAR	Synthetic Aperture Radar
SATC	CIMSS Advanced Dvorak Technique
SATCON	Satellite Consensus
SEN1	Sentinel-1A – Synthetic Aperture Radar
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