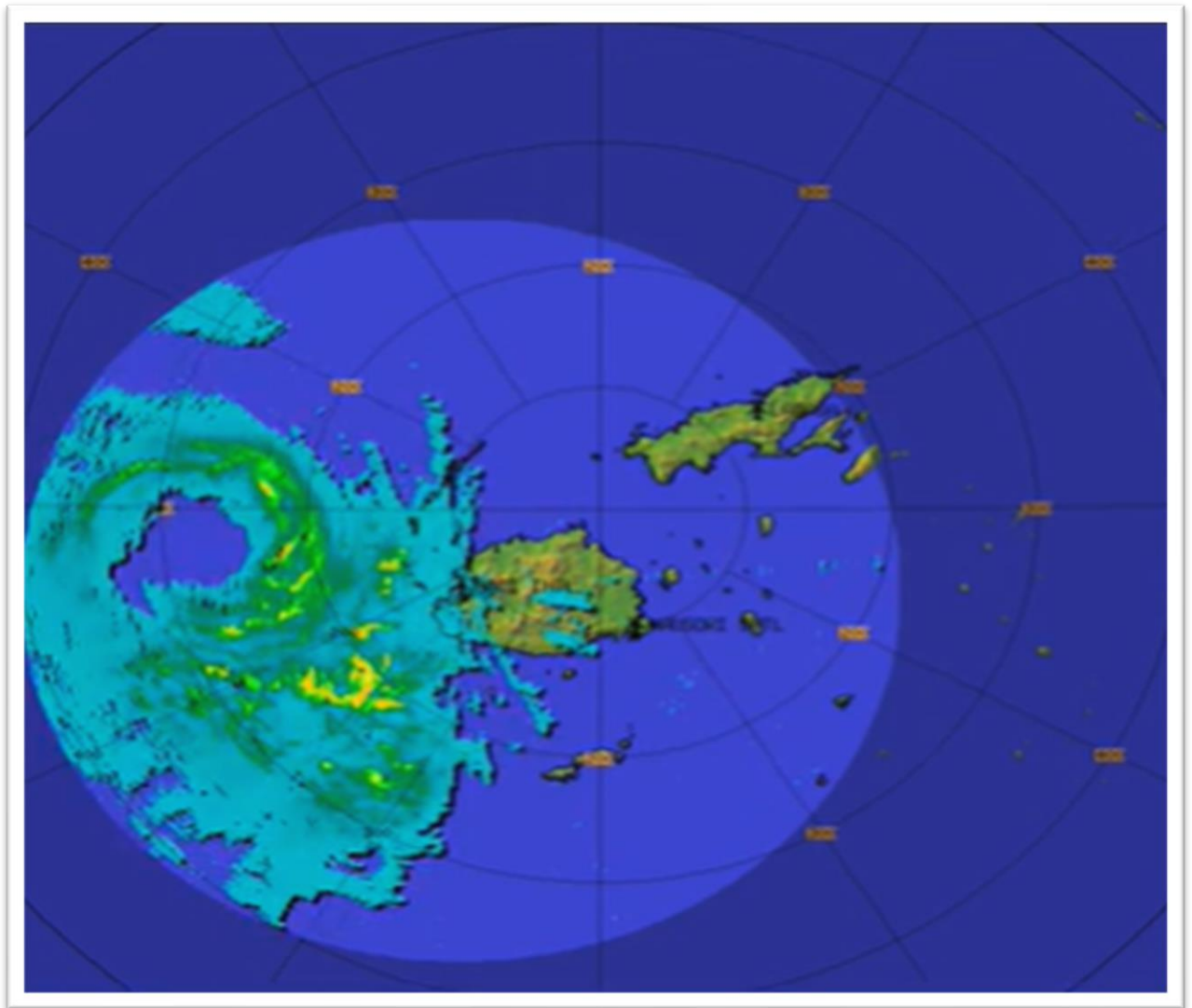


# **Tropical Cyclone Mal**

**13th – 16th November 2023**



Severe Tropical Cyclone Mal centre tracking into Radar range as a category 3 system at 120000UTC of 14 November 2023

Iosefo S. Cauravouvinaka

Senior Scientific Officer

**Contact details:**

Tropical Cyclone Warning Center

Regional Specialized Meteorological Center

Fiji Meteorological Service

PO Box 9198, Nadi Airport

Fiji

Email: [all-fcstrs@met.gov.fj](mailto:all-fcstrs@met.gov.fj)

Phone: +679 9905376

## TABLE OF CONTENT

<b>SECTION</b>	<b>TOPIC</b>	<b>PAGE(S)</b>
<b>1</b>	<b>Summary</b>	<b>4</b>
<b>2</b>	<b>Meteorological Description</b>	<b>5 – 11</b>
<b>3</b>	<b>Impacts</b>	<b>11 – 13</b>
<b>4</b>	<b>Observations</b>	<b>13 – 14</b>
<b>5</b>	<b>Forecast Performance</b>	<b>15</b>
	<b>Mean Position Error</b>	<b>15 -16</b>
	<b>Mean Intensity Error</b>	<b>16 - 17</b>
<b>6</b>	<b>Model Performance</b>	<b>18 - 19</b>
<b>7</b>	<b>Conclusion</b>	<b>19</b>
<b>8</b>	<b>International Best Track Data</b>	<b>20 - 21</b>
<b>9</b>	<b>References</b>	<b>21</b>

## 1.0 Summary

A tropical low initially developed from an active trough just east of the Solomon Islands and intensified into a Tropical Disturbance 02F on 10 November at 2100UTC<sup>1</sup>. The system further deepened into a tropical cyclone, became the second tropical cyclone to form in the South Pacific which was named Mal by the Nadi Regional Specialised Meteorological Centre<sup>2</sup> (RSMC) for the 2023/24 season. Mal reached category<sup>3</sup> 3 cyclone intensity with sustained winds estimated to be 70<sup>4</sup> knots and gusts to 100 knots while in RSMC Nadi's Area of Responsibility

The cyclone was monitored by the Nadi RSMC for about 72 hours or three days until it was handed over to TCWC Wellington on 16 November 0000UTC. Through its life span, Mal made a general south-eastward track as it approached the Fiji group (*figure 1*). Therefore, some isolated damages were inflicted over parts of Fiji including coastal communities of Yasawa-i-rara, Mamanuca group, Western Viti Levu, Kadavu and other parts of Viti Levu before dissipating away over open waters to the south of Fiji within TCWC Wellington area of responsibility.

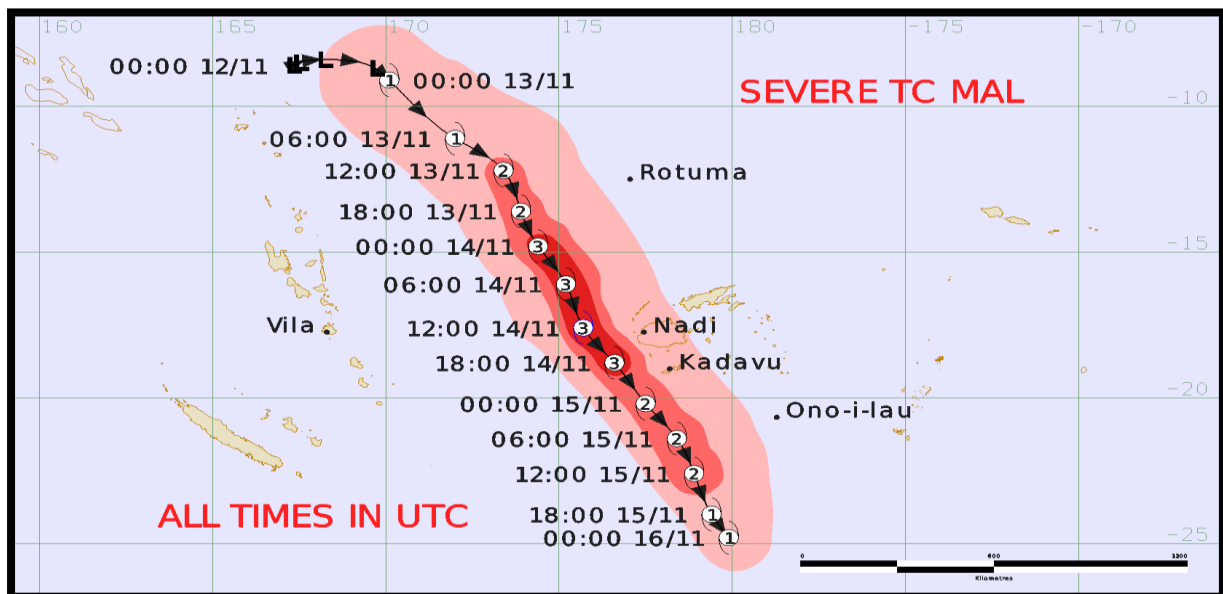
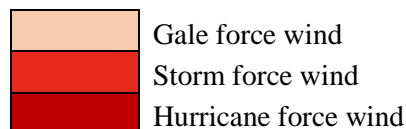


Figure 1: Post Event Best track of Severe Topical Cyclone Mal.

**Note:** The track highlights the extent of:



<sup>1</sup> Universal coordinated time (UTC to FJT; + 12)

<sup>2</sup> RSMC Nadi's area of responsibility is between equator and 25S and between 160E and 120W.

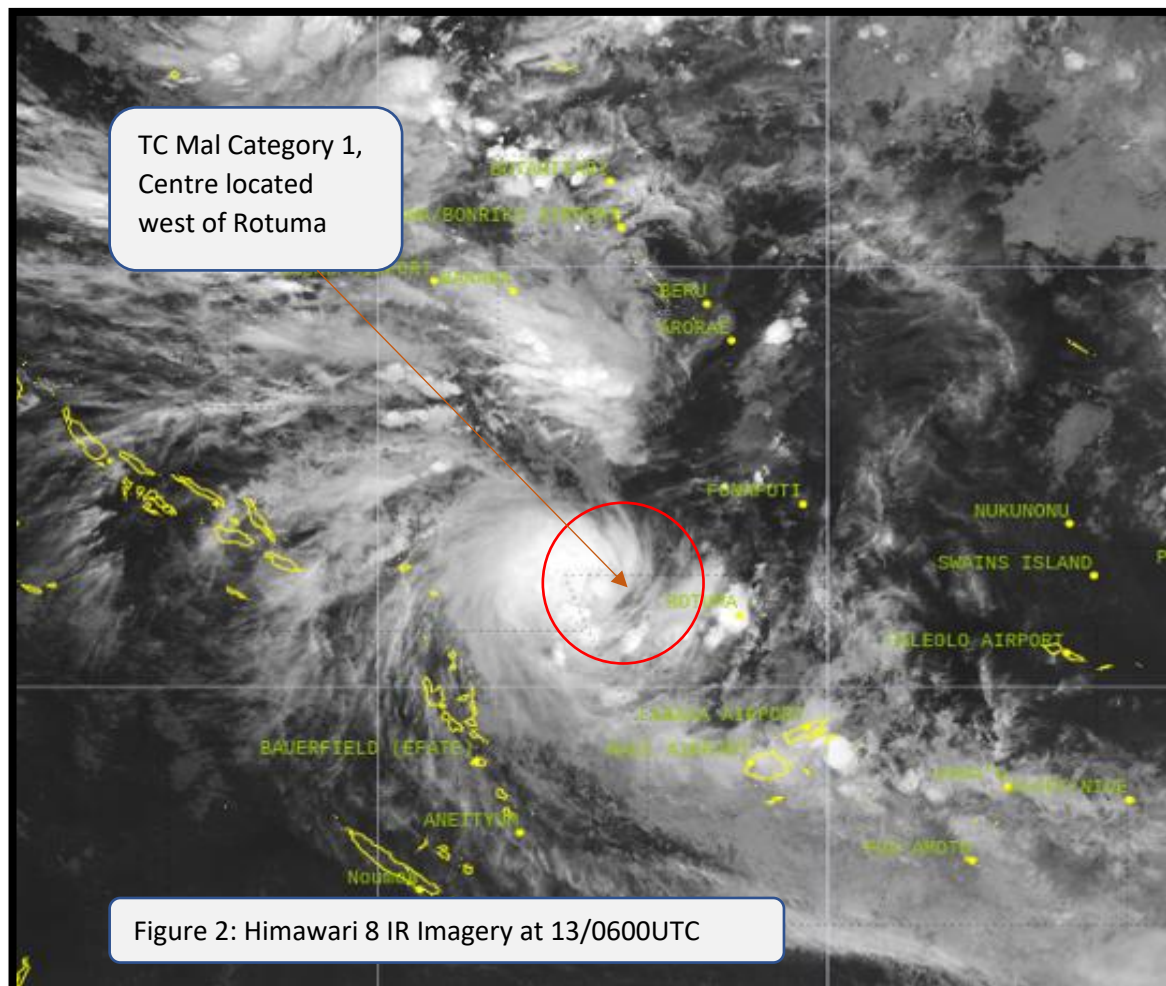
<sup>3</sup> The category system is based on the Australian Tropical Cyclone Category system. Category 1 cyclone has mean winds 34-47 knots, category 2 cyclone has mean winds 48-63 knots, category 3 cyclone has mean winds 64-85 knots, category 4 cyclone has mean winds 86-107 knots and category 5 cyclone has mean winds greater than 107 knots.

<sup>4</sup> 1 knot = 1.85 km/h

## 2.0 Meteorological Description

Severe Tropical Cyclone Mal had was monitored as a tropical low to the west of 160E and became the second numbered tropical disturbance, TD02F on 10 November 2100UTC whilst thirty-nine hours thereafter, the system intensified further into a tropical depression. Tropical depression, TD02F was later name Tropical Cyclone Mal at around 0600UTC on 13 November while located over open waters, about 650 kilometres northwest of Rotuma. RSMC Nadi continued monitoring Mal for about four days until weakening back into a category 1 system towards the border of the Nadi AOR and TCWC Wellington.

The system was primarily monitored for more than forty-eight hours east of the Solomon Island group from incipient (disturbance) stage while moving in a general southeast track with its centre located over open waters west-northwest of Rotuma or northwest of the Fiji group (*figure 2*). The infrared (IR) satellite imagery depicts spiral deep convective bands wrapping into a low-level circulation centre (LLCC) that was partially obscured by deep convection.

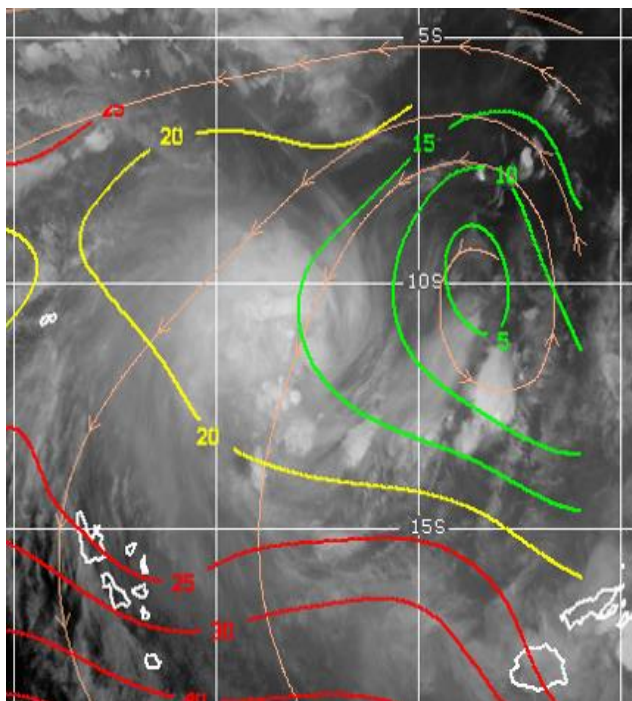


Mal had been generally breeding and slow moving over favourable atmospheric environment of ideal warm sea surface temperatures (SST) of 29 to 30 Degrees Celsius between Solomon Islands and Rotuma

during its incipient stage, thus aiding the system to reach category 3 within a day close to the Fiji group. The movement and steering of Mal was subjected to the existence of a predominant subtropical ridge to the east of Fiji which triggered the system to be fast moving along its western periphery when being a tropical cyclone (*figure 2d*) and also nudging the system centre to be situated over open waters to the west of Fiji.

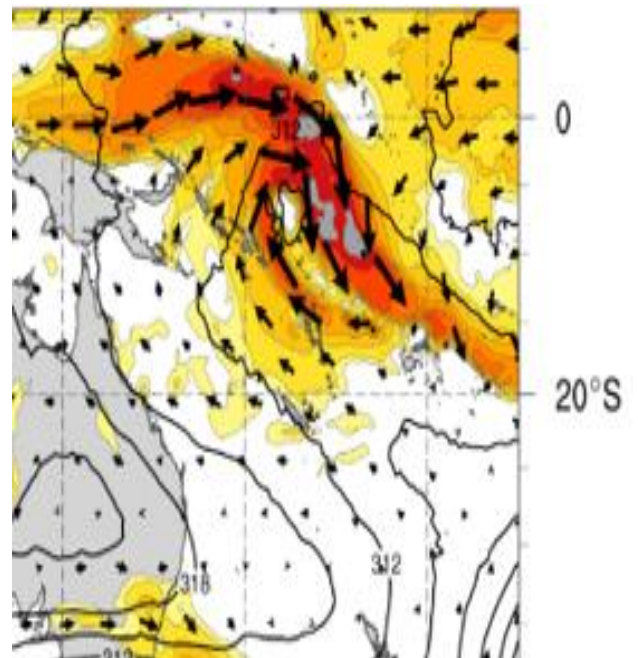
Additionally, figures 2a-c shows that TC Mal was situated over region of favourable mid- level moisture transport, low to moderate (10-15 kts) vertical wind shear and well-established poleward flow with increasing upper level divergence.

**Figure 2a:** CIMMS wind shear(kts) at 13/0600UTC



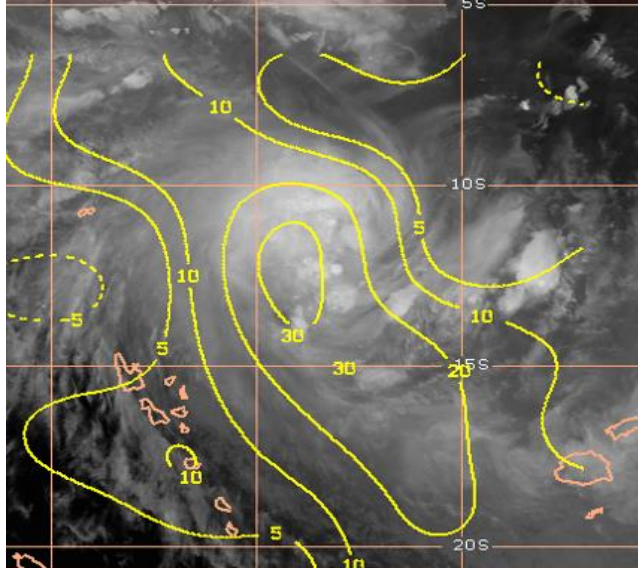
TC Mal under low to moderate (10-20knots) shear environment. The system developed further and shifted the high shear (red line) environment away from it.

**Figure 2b:** Integrated mid-level water vapour transport valid till 12 November



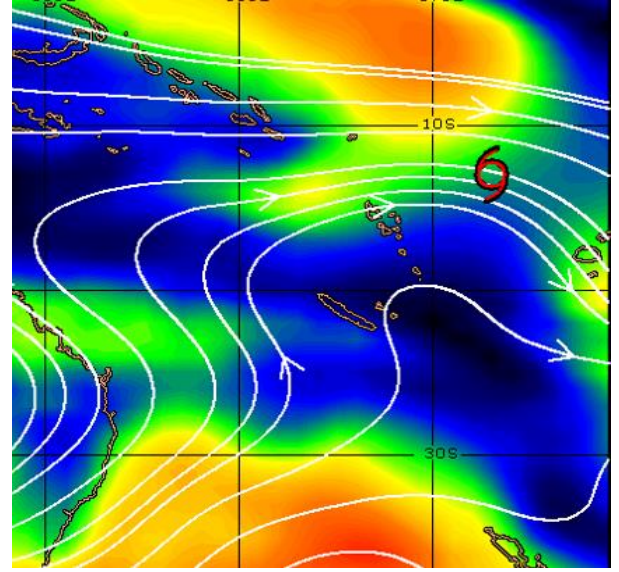
Favourable mid-level moisture got enhance with surface westerly wind burst.

**Figure 2c:** CIMMS Upper level winds at 13/0600UTC



Upper level divergence of about 10 to 30 knots over the system, aiding in further development of TC Mal with poleward flow.

**Figure 2d:** CIMMS Deep Layer mean steering at 13/1200UTC



TC Mal being controlled (steered) by the subtropical ridge to the east of the system.

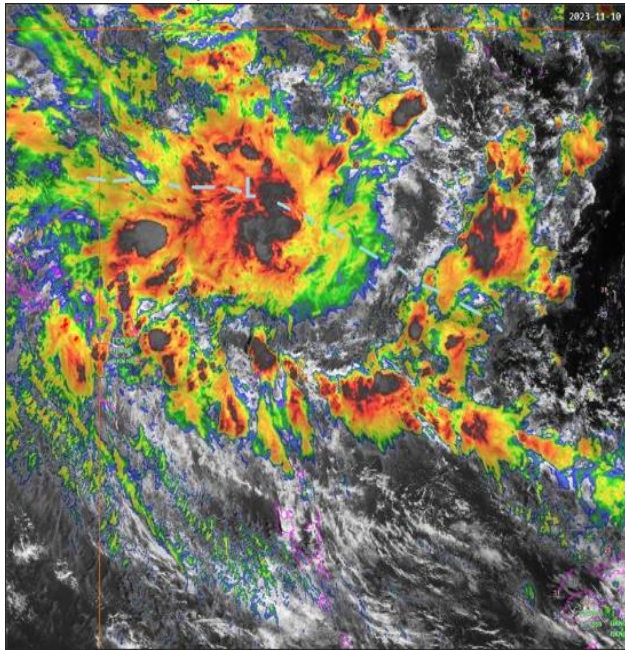
At around 1800UTC on the 13<sup>th</sup> of November, Mal was upgraded to category 2 with estimated sustained winds of 95 km/hr close to its centre while rapidly drifting south-southeastwards at about 27km/hr. The system then supposedly made a rapid southeastward track due to the interaction between the southwestern periphery of the steering subtropical ridge (Figure 2d) to the east of the system.

TC Mal, further intensified into a severe category 3 tropical cyclone at 1200UTC on 14 November as it continued into a south-southeastwards track of about 30km/hr towards a slight window of favourable environment at about 180 kilometres west of Nadi in the Fiji group. Severe TC Mal reached peak intensity after six hours while located about 170 kilometres west of Kadavu or 140 kilometres southwest of Nadi with estimated sustained wind speed of up to 130 km/hr with momentary gust of 185 km/hr.

Thereafter, Severe TC Mal gradually weakened into a category 2 system at 0000UTC on 15 November while situated to the far south of Kadavu and further weakened to category 1, 18 hours later while located at about 410 kilometres to the south-southwest of Ono-I-Lau. TCWC Wellington eventually continued the monitoring of TC Mal at 0000UTC 16 November as the system was anticipated to move out of the RSMC Nadi AOR.

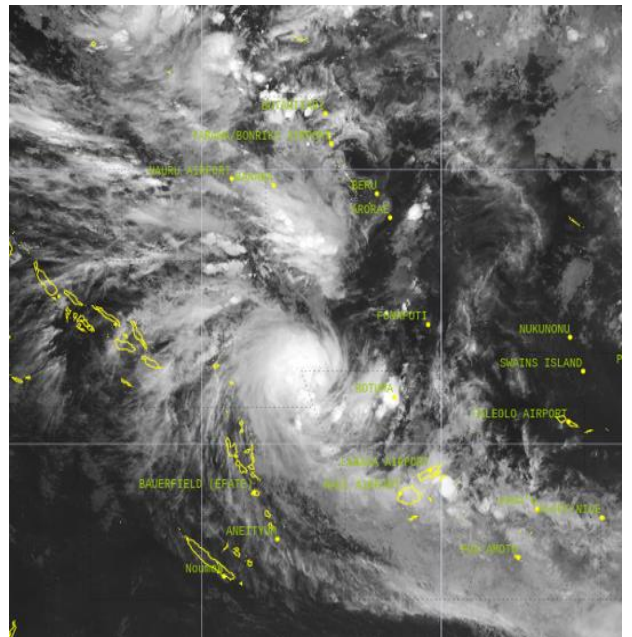
Severe Tropical cyclone Mal was one of those exceptional cyclones that rapidly developed from a category 1 to a category 3 in close to 30 hours from 13/0600UTC to 14/1200UTC. Figure 3a to 3d below shows the Himawari satellite imagery on the development of Mal.

**Figure 3a:** Enhanced IR imagery on 11 November while still a low pressure.



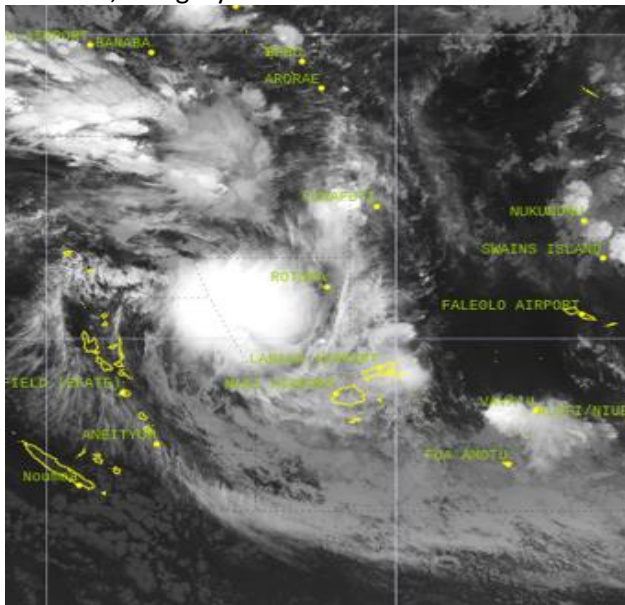
Enhanced thunderstorm activity continues along the trough to the east of the Solomon Islands.

**Figure 3b:** Himawari- IR imagery at 13/0600UTC with Mal, category 1



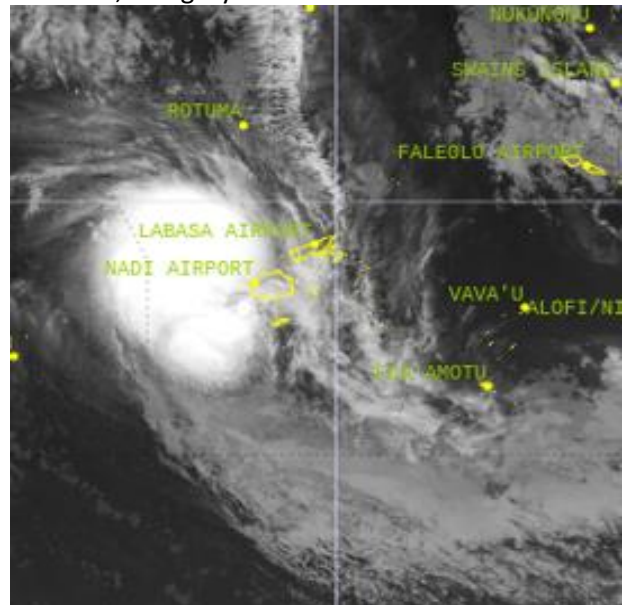
Tropical Depression 02F named Tropical Cyclone MAL (6pm FJST).  
TC Mal was located at about 655km West-northwest of Rotuma and at about 945km Northwest of Yasawa-I-Rara.

**Figure 3c:** Himawari- IR imagery at 13/1800UTC with Mal, category 2



Tropical Cyclone MAL (6am FJST, 14 November) was located at about 420km West-southwest of Rotuma and at about 580km Northwest of Yasawa-I-Rara.

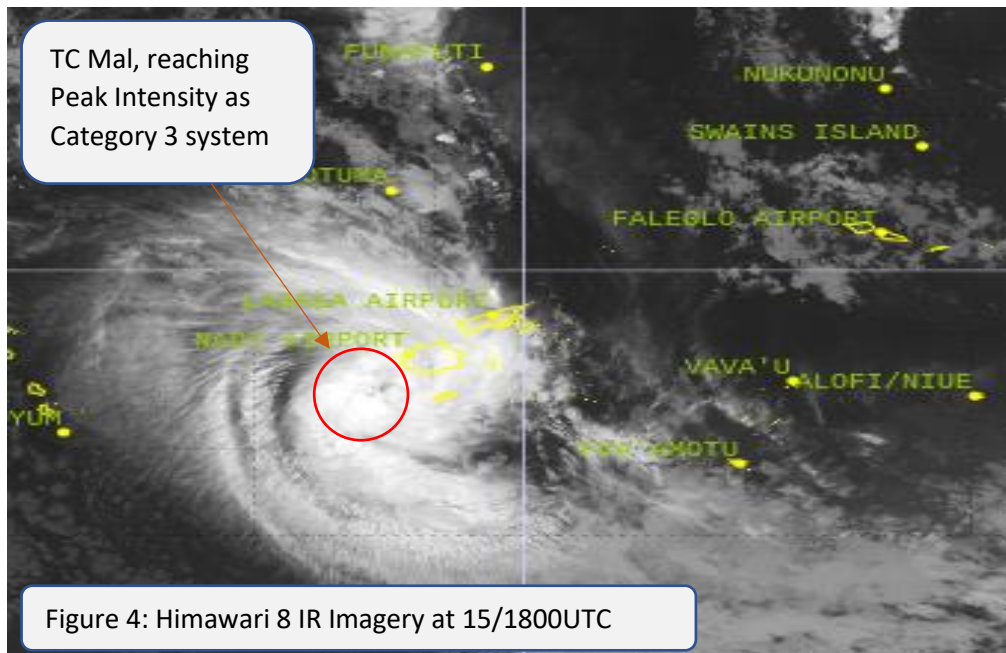
**Figure 3d:** Himawari- IR imagery at 14/1200UTC with Mal, category 3



Tropical Cyclone MAL (12am midnight FJST, 15 November) was located at about 180km West of Nadi and at about 220km West-southwest of Yasawa-I-Rara.



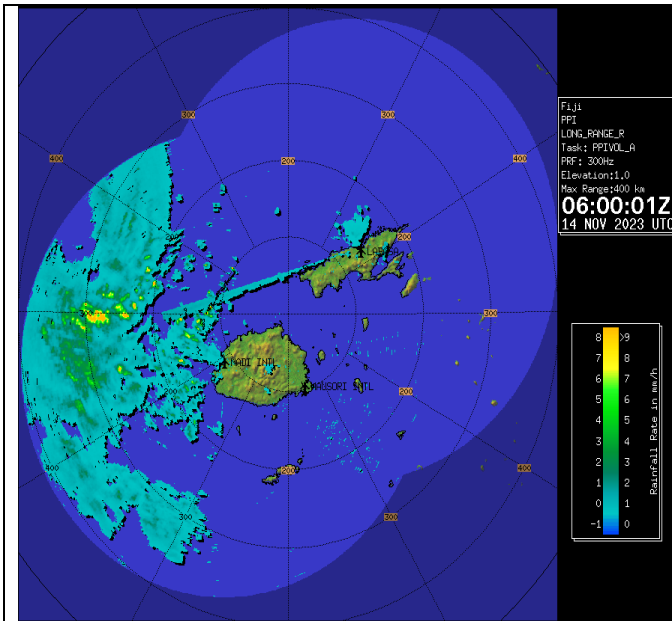
Severe TC Mal developed an embedded centre pattern (Figure 4) while over the Fiji waters. Subsequently, for 9 hours, Mal remained as a category 3 system, reaching peak intensity of sustained wind speed of up to 130 km/hr with momentary gust of 185 km/hr at 1800UTC 15 November.



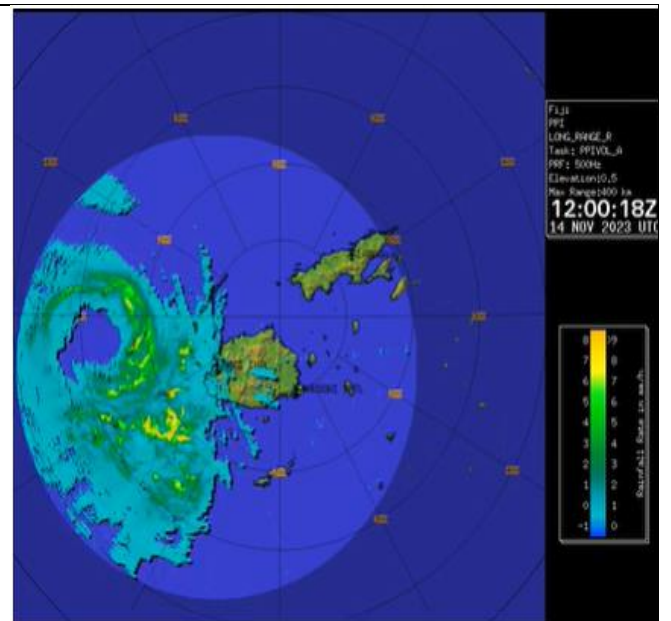
Meanwhile, on the 14<sup>th</sup> of November at 0600UTC, the Yasawa group of islands, began experiencing near gale<sup>5</sup> force winds as the centre of TC Mal was located to the west-northwest of Yasawa-i-rara. On entering the Fiji waters, Mal centre was observed on the radar imagery (Figure 5a-5d: Radar imagery when Mal was in Fiji's Radar range), with gale force winds extending to the whole of Viti Levu, Beqa and Lomaiviti group. Winds further increased to destructive storm force winds estimated to be 110 km/hr and momentary gust of 155km/hr from 1500UTC (14 November) especially over Manamuca group, parts of Southwestern Viti Levu, Vatulele, Kadavu and nearby smaller islands. Meanwhile, during the systems severe stage as the centre remain over open waters, hurricane force of sustained winds up to 130 km/hr and momentary gusts of 185km/hr was over the far southwestern Fiji waters while gradually easing after 0600UTC on 15 November as it dive south-eastwards towards 25S .

Sea conditions was very rough to high seas with damaging heavy swells especially over open waters along the track of Mal with coastal inundation also expected especially along low lying coastal areas of Yasawa and Mamanuca group, southwestern VitiLevu, Kadavu and nearby smaller islands.

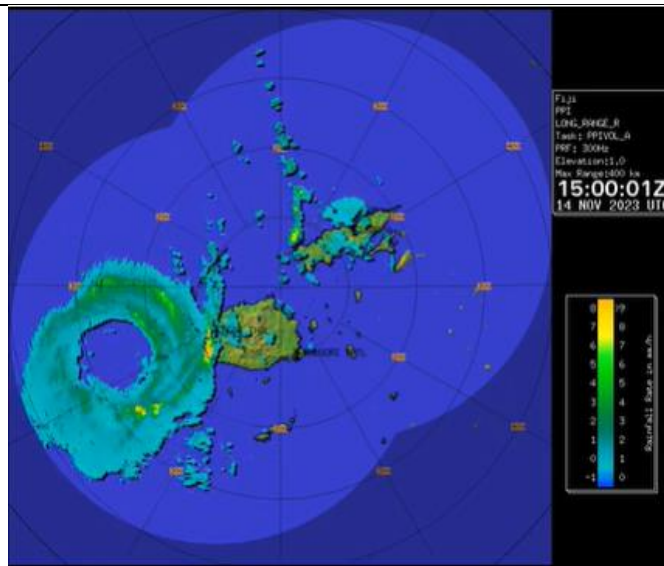
<sup>5</sup> Gale force winds: 10-minute average winds between 34 to 47 knots. Storm force winds: 10-minute average winds between 48-63 knots. Hurricane force winds: 10-minute average winds more than 63 knots.



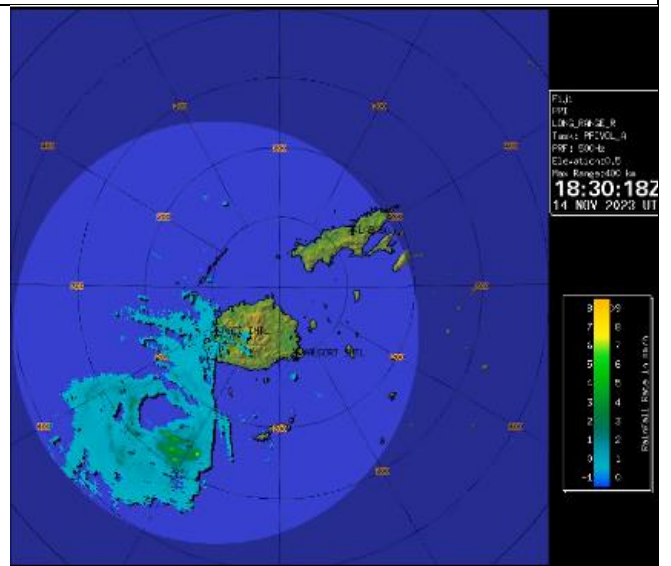
**Figure 5a:** TC Mal centre moving into radar range with sustained winds of 60 knots (110 km/hr) and gusts of 85 knots (155 km/hr) close its centre. Time is 0600UTC of 14 November or 0600pm Fiji Standard Time(FST).



**Figure 5b:** TC Mal intensified into a Category 3 system at mid-night with maximum sustained winds of 65 knots (120 km/hr) and gusts of 90 knots (165 km/hr) close its centre. Time is 1200UTC of 14 November or 1200am midnight on the 15<sup>th</sup> Fiji Standard Time(FST).



**Figure 5c:** Severe tropical cyclone Mal was located west-southwest of Nadi at 3am this morning. At this stage however, hurricane force winds were not expected over the land areas. On its current projected path, Yasawa and Mamanuca Groups, western and southern Viti Levu, Vatulele, Kadavu and nearby smaller islands are at greatest risk of getting gale to storm force winds. Time is 1300UTC of November or 0300am on the 15<sup>th</sup> Fiji Standard Time (FST).



**Figure 5d:** TC Mal still a Category 3 system west of Kadavu, with weakening evident. As the centre is close to Kadavu, storm to gale force winds is likely over southern Viti Levu, Vatulele, Kadavu and nearby smaller islands with periods of rain and thunderstorms. Time is 1830UTC of November or 0630am on the 15<sup>th</sup> Fiji Standard Time (FST).

The system swiftly tracked through the Fiji waters as a category 3 system for about 9 hrs. On its track, Mal created havoc over parts of Fiji with moderate to significant impacts especially over Yasawa and Mamanuca groups, Southwestern Viti Levu (Sigatoka-Nadi-Lautoka), Kadavu and nearby smaller

islands. The land interaction couple with cooler SST, high sheared environment and unfavourable conditions to the south of the group had an immediate effect on the system rapidly weakening. Ultimately, Mal weakened to a category 1 system in less than 24 hours at 1800UTC 15 November while 180 km south-southwest of Ono-i-Lau.

### 3.0 Impacts

Mal swiftly tracked through the western parts of Fiji waters while sustaining itself as a category 3 system for about 9 hrs. Along its track, according to reports, some significant damages were inflicted over land and coastal communities especially over Yasawa-i-rara, Mamanuca group, Western Viti Levu, Kadavu and other parts of Viti Levu. Meanwhile, most of the heavy rain lashed through the interior and eastern parts of Viti Levu, Lau and Lomaiviti group (figure 7) 48 hrs earlier to the onset of gale force winds with flash flooding of low-lying areas.

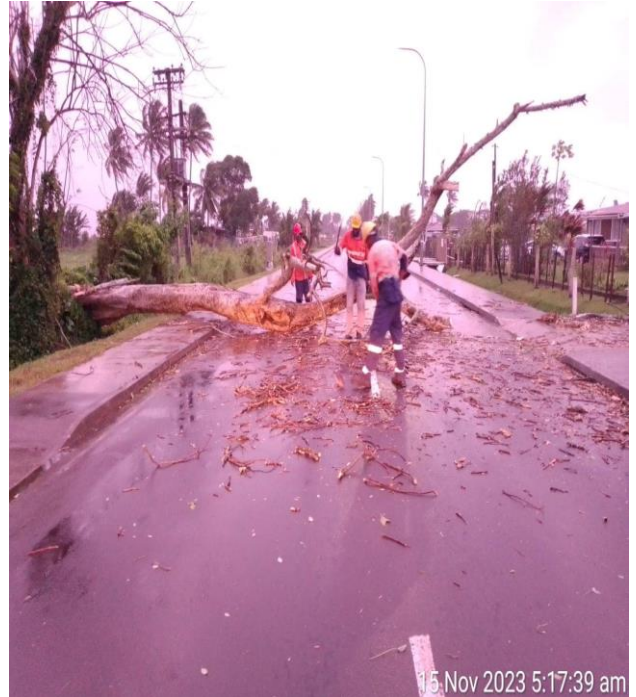
Moderate to significant damages were detected on some weak structured properties and infrastructures, livestock and agriculture, isolated disruption in communication networks and power shut down, disruption in transportation route, communities being cut off due to flooding and coastal inundation due to damaging heavy swells and wind driven waves that created havoc over parts of Fiji.

Meanwhile, on analysis the estimated lowest pressure was 965hpa around 1800UTC on November 15th and the maximum wind at 70 knots gusting to 110 knots.

**Figure 6a:** Isolated disruption in electricity supply due to damaged power lines (Sabeto, Highway)



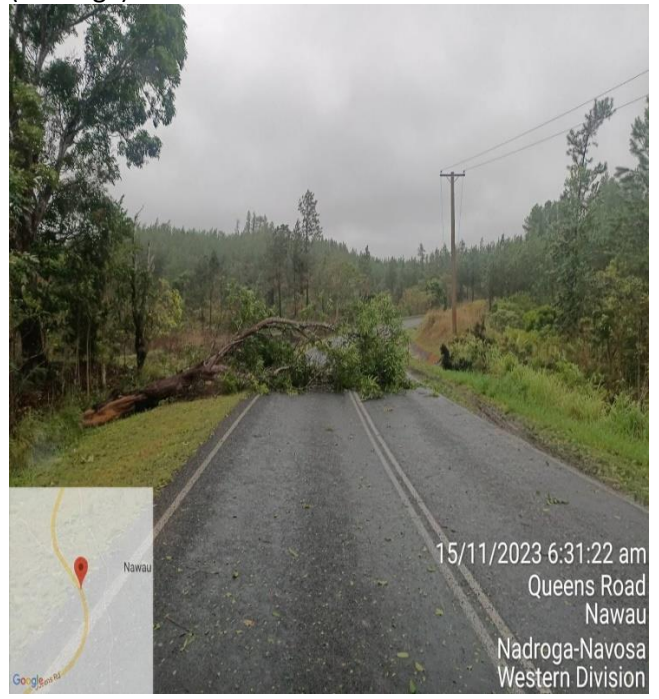
**Figure 6b:** Fallen trees on road– disrupting transportation (Suva)



**Figure 6c:** Fallen trees on roadside (Matawailevu, Rakiraki)



**Figure 6d:** Fallen trees on road Queens Road (Nadroga)

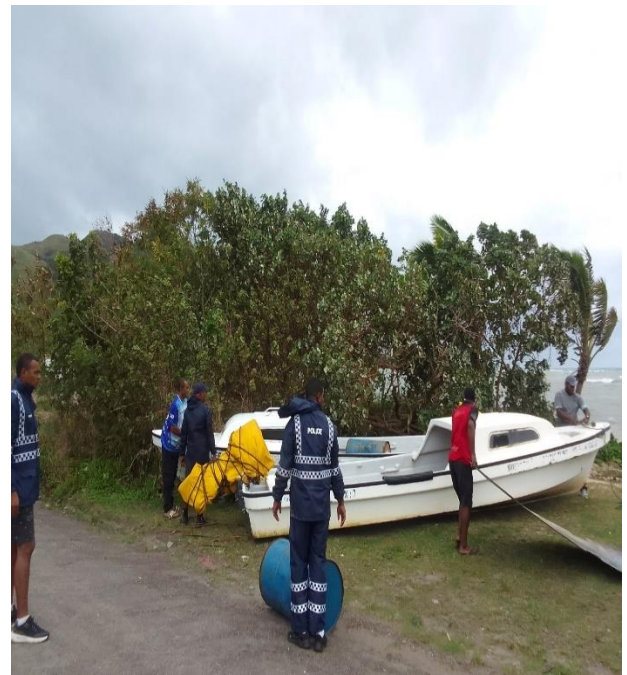


b)

**Figure 6e:** Fallen trees on road - Coral Coast (Queens Road)



**Figure 6f:** Coastal inundation due to swells and wind driven waves (Coral Coast)



**Figure 6g:** Fallen trees (Kings road)



**Figure 6h:** Landslide from heavy rainfall (Suva – Wailoku)



#### 4.0 Observation

##### a) **Maximum sustained winds**

The maximum sustained winds with the relevant gust from Fiji's manual and automatic weather stations during the passage of Severe Tropical Cyclone Mal over Fiji waters is tabulated below:

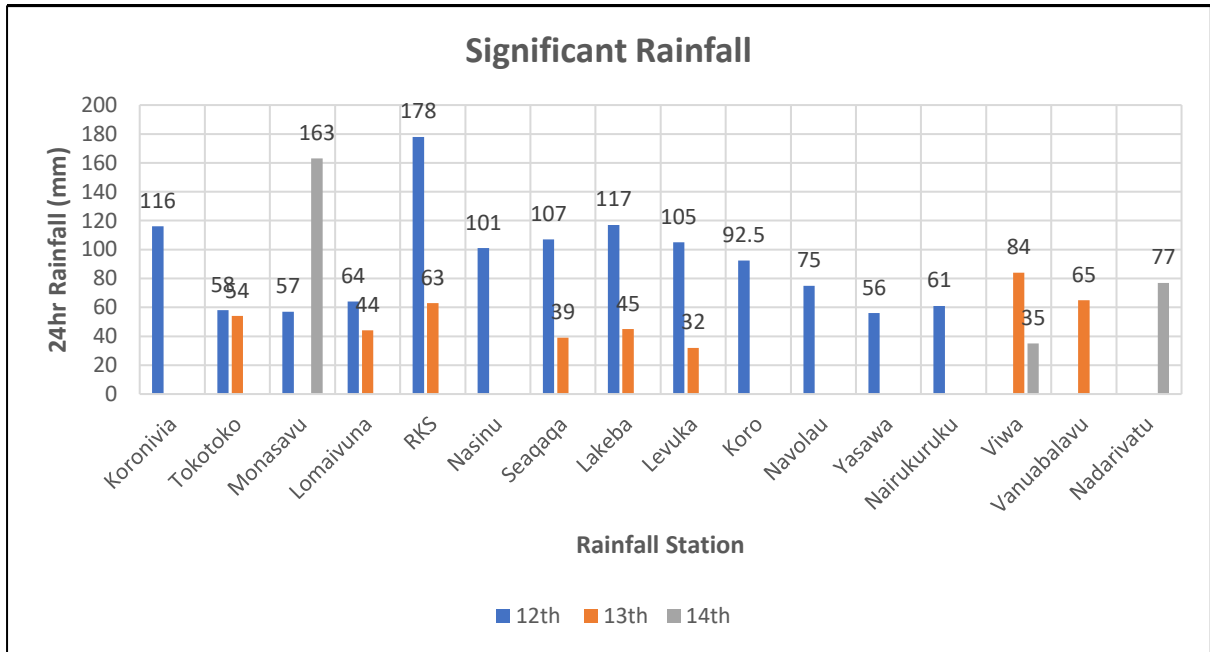
##### **Maximum winds recorded in Fiji during the passage of TC Mal**

Tabulated below are the maximum mean winds with the relevant gusts recorded from Fiji's manual and automatic weather stations close to Severe Tropical Cyclone Mal's track.

**Table 1:**

Time of Report	Station	Max. winds recorded (dddssKT)	Pressure recorded (HPA)
140400Z	Rotuma	35028KT	1003HPA
141400Z	Yasawa I Rara	35042KT	1000HPA
141500Z	Nadi	04035G55KT	997HPA
141600Z	Nadi	01020KT	<b>994HPA</b>
141700Z	Viwa	29026KT	999HPA
141800Z	Vunisea	09027KT	999HPA
142100Z	Vunisea	09027KT	999HPA
150100Z	Vunisea	06033KT	1000HPA

**Figure 7:** Total rainfall recorded in 24 hours during the passage of TC Mal from 12th to 14<sup>th</sup> November.

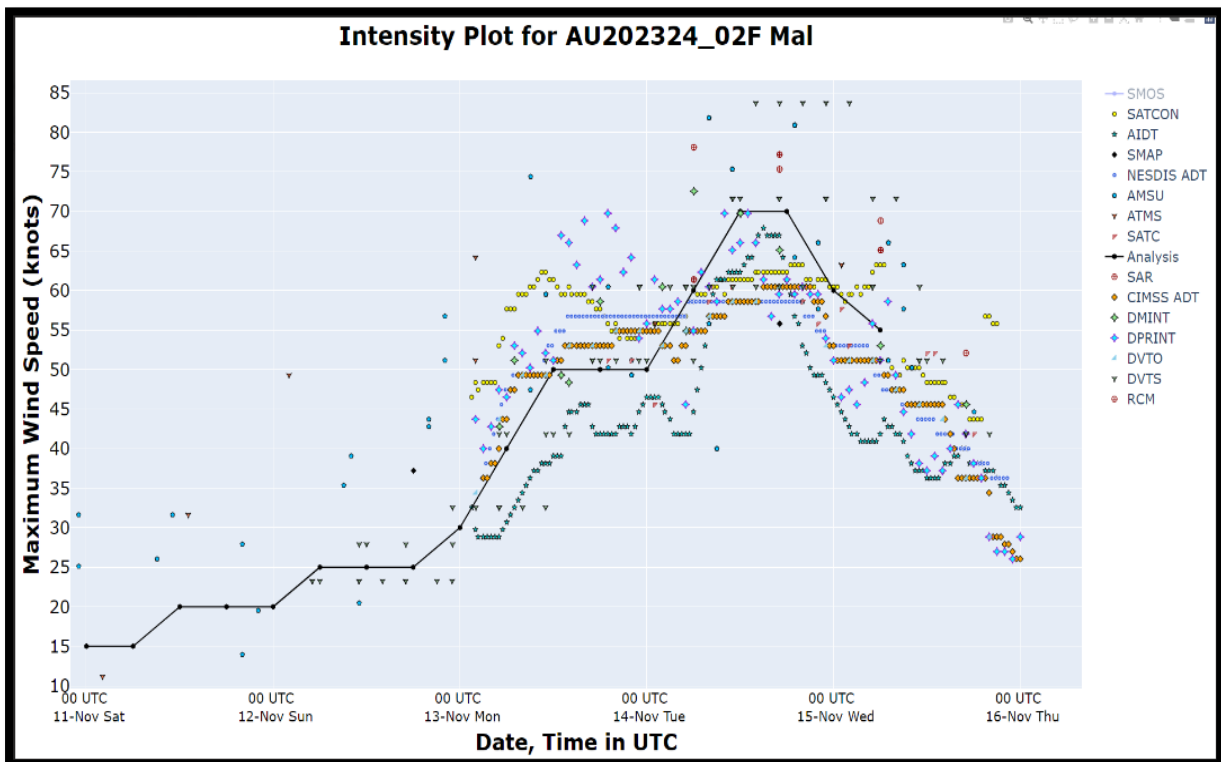


## 5.0 Forecast Performance

### a) Intensity Analysis Comparison of Objective and Subjective Technique

Figure 8 shows that the performance of the objective technique with relation to the subjective intensity analysis technique are in close agreement to the trend after the system was named till 0000UTC 13 November.

*Figure 8: Intensity Analysis Comparison of Objective and Subjective Technique*



### b) Mean Position Error

The result below highlights that beyond 12 hours; the track position error for Mal was comparably close or even better than the 6 years' average due to the lower spread in the model guidance, which were in close proximity to the best track. This close relationship of tracking Mal was also due to the existence of the subtropical ridge to the east of the system which was the dominant driver, hence great confidence was on determining the position of the system.

However, the position error had significant variation during its initial stages with model showing diverging characteristics.

a) FIGURE 9a: 6 Years average position accuracy 2016/17-2022/23

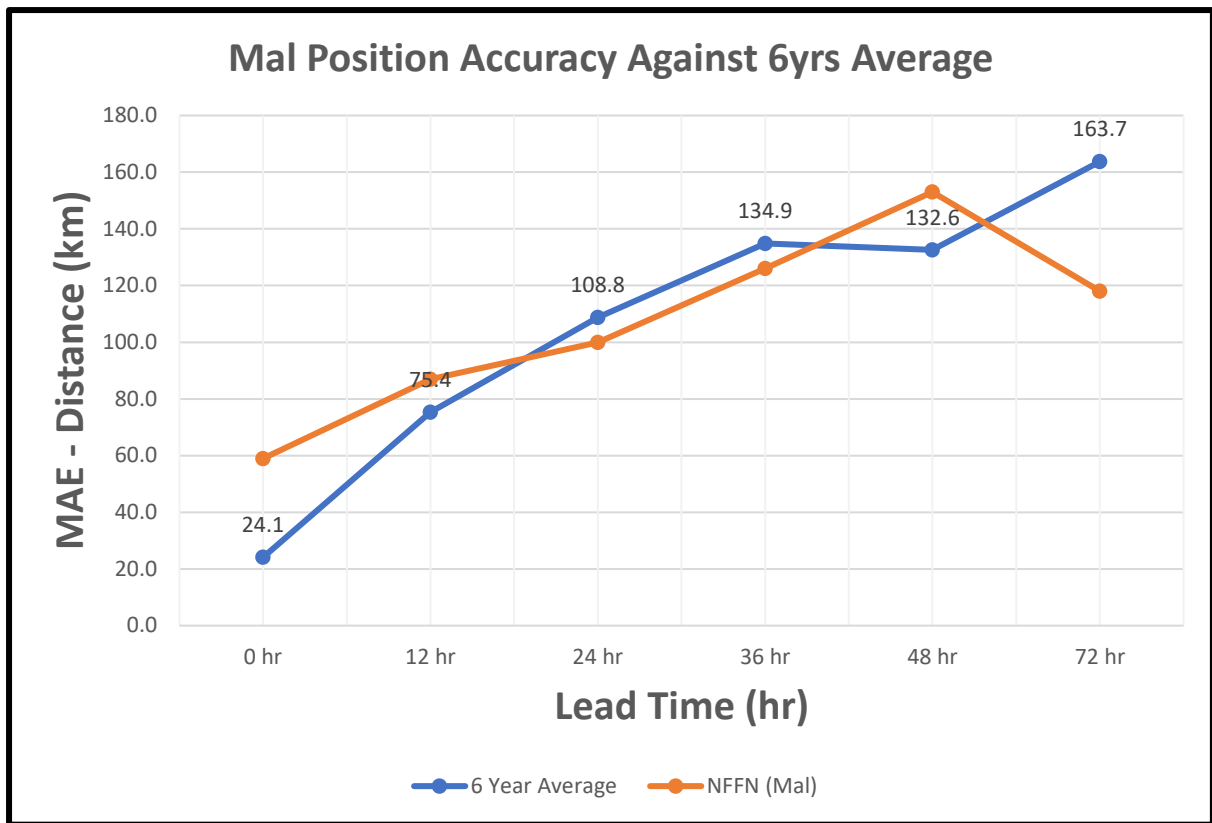


Figure 9a above shows the mean error position forecast for TC Mal in comparison to the 6 years mean position average from 2016/17 to 2022/23 TC Season.

### c) Mean Intensity Error

The forecast intensity errors for TC Mal in comparison to the 6 years mean intensity from 2016/17 to 2022/23 TC Season (*figure 9b*) shows relatively better performance. This is evident in the low values of the mean absolute error (MAE) beyond 6 hours where it suggests that subjective analysis techniques were confidently in alignment to atmospheric condition with model assessment incorporated.



b) FIGURE 9b: 6 Years average intensity accuracy 2016/17-2022/23

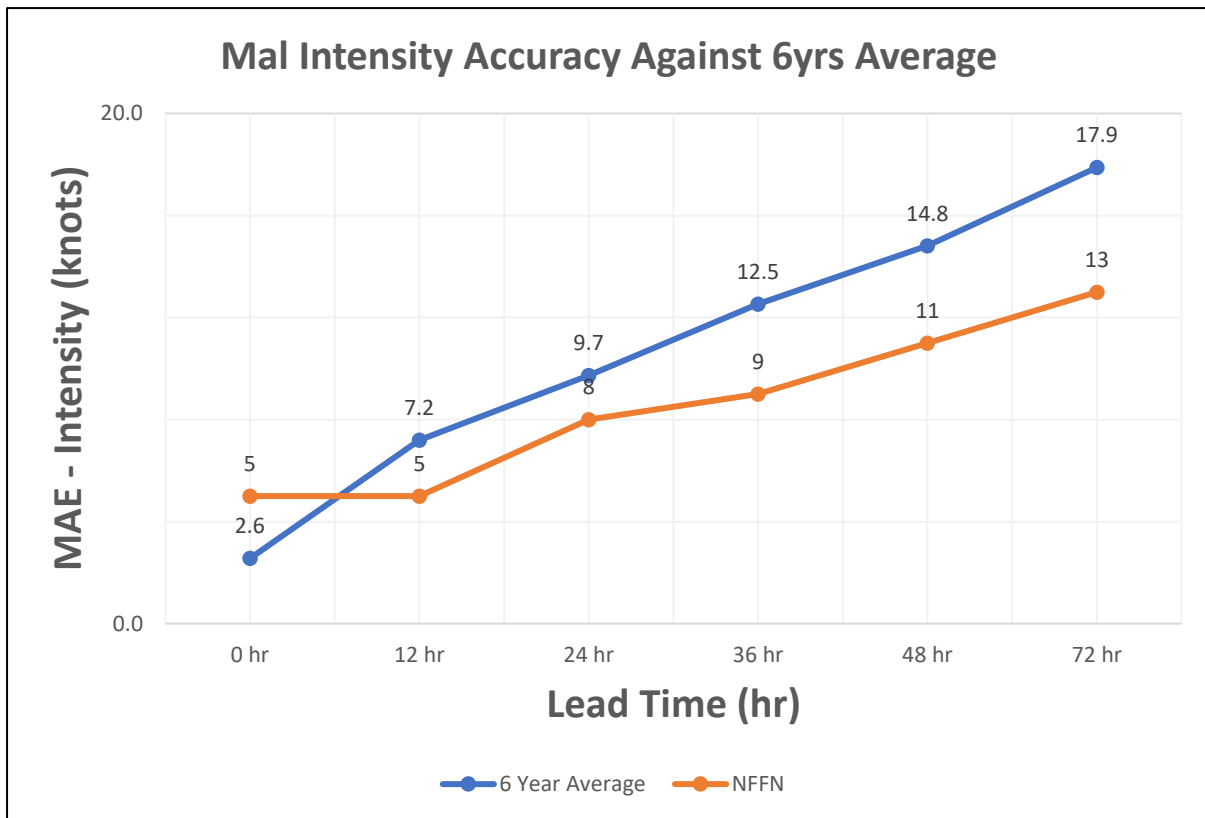


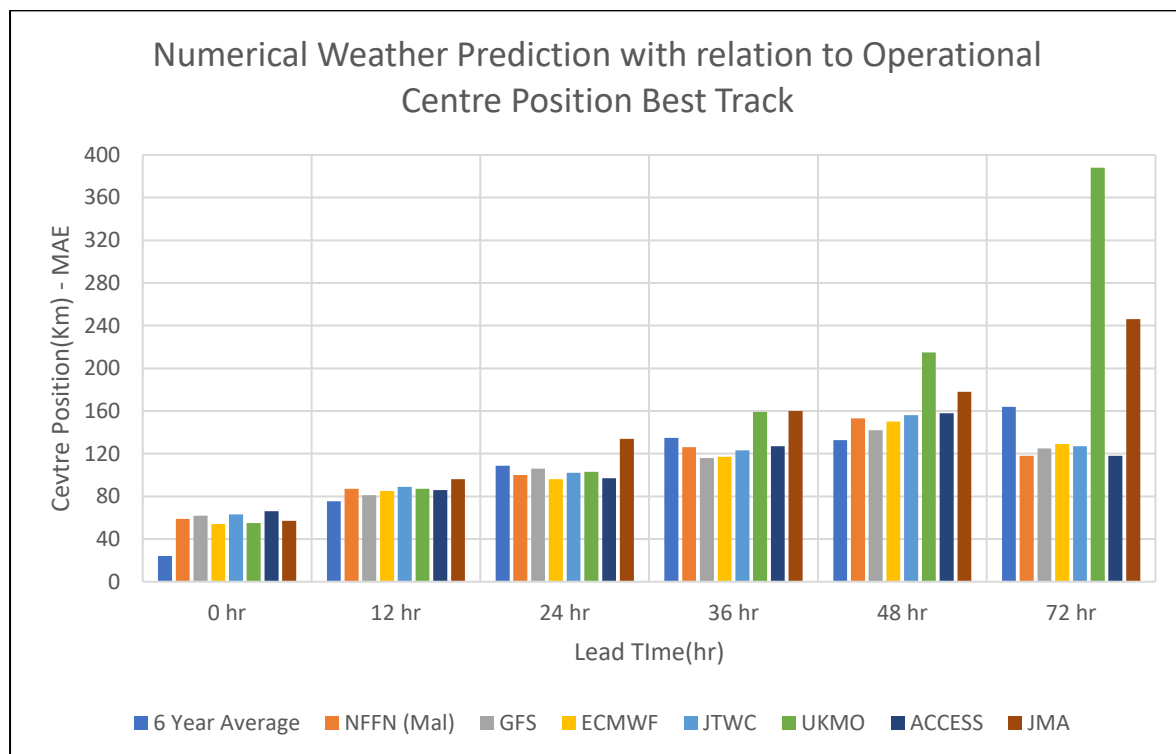
Figure 9b shows the mean absolute error intensity forecast for TC Mal in comparison to the 6 years mean position average from 2016/17 to 2022/23 TC Season.

## 6.0 MODEL PERFORMANCE

### a) Numerical Weather Prediction with relation to Position and Intensity operational best track

i) The forecasts of centre position for Cyclone Mal issued by the Nadi RSMC (*figure 10a*) highlights favourable relationship with the 6 years average and most of the models apart from UKMO and JMA which had great deviation from 36hours. According to the figure, apart from UKMO and JMA most of the other models was better than 6 years average.

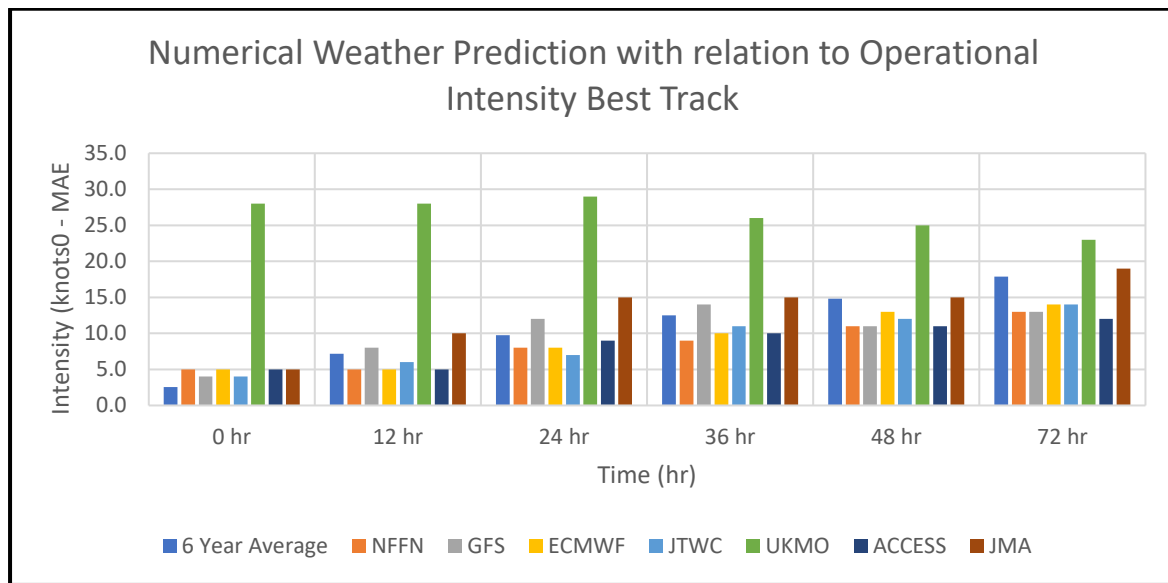
**FIGURE 10a: Numerical Weather Prediction (NWP) performance with relation to center position operational best track.**



ii) The forecasts intensity for Cyclone Mal issued by the Nadi RSMC highlights favourable trend (*figure 10b*) for model performance with most of the model also better performing in comparison to the 6 years average.

The intensity Mean absolute error for most of the model except UKMO fairly showed minimal variation below 15 knots for the first 48 hours.

**FIGURE 10b: Numerical Weather Prediction (NWP) performance with relation to operational intensity best track.**



## 7.0 Conclusion

Tropical Cyclone Mal lifespan was spent mostly over open waters, where most parts of the western half of Viti Levu were battered with gale force and gusty winds as the system tracked through the western parts of Fiji waters. Prior to onset of impacts from winds, heavy rain and flash flooding were also experienced over parts of Fiji. Therefore, on the combine impact of these hazards moderate to significant damages were inflicted on exposed coastal communities and high-risk communities. As a result, few evacuation centres were activated by the National Disaster Management Office (NDMO) with expected disruption to communication networks, power shut down and communities being cut off due to very destructive winds and flooding.

Mal intensity was well estimated using the subjective Dvorak technique. Guidance from numerical models and other meteorological tools all aided in the analysis for the dissemination of effective warnings and advisories with timely forecast track and threat maps by RSMC Nadi. Although, delays in the availability of some of the real time observations such as the scatterometer data, microwave imagery with model run lagging from the JTWC source were some challenges during analysis times. Consequently, led to few deviations in the wind intensity estimation.

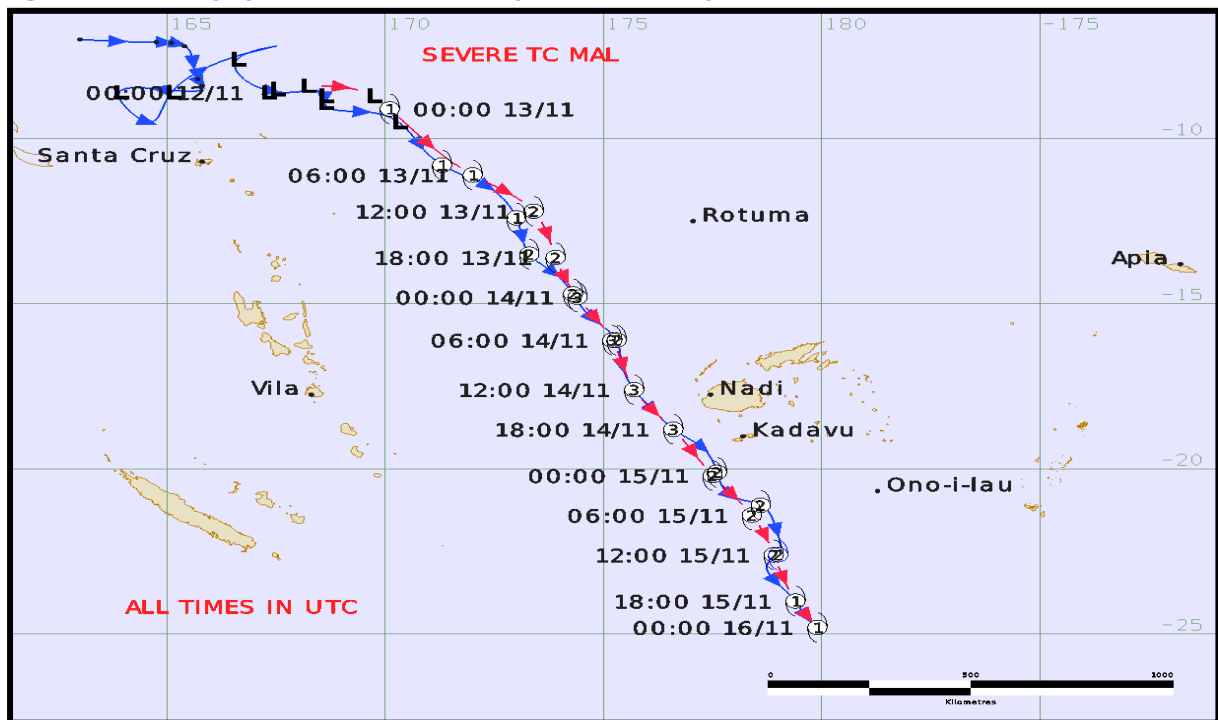
## 7.0 Intensity Best Track Format

a) Table 2

Time	Latitude (South)	Longitude (East)	Uncertainty (Nm)	Mean Wind (Knots)	Wind Gust (knots)	Category	Pressure (hpa)	POCI	Radius of Max. Winds (Nm)	ROCI	Rad. of Gales (Nm)			Rad. of Storm (Nm)	Radius of Hurricane (Nm)
											(NE /SE /SW /NW )				
12/0000Z	-8.6	167.3	90	25	45	0	1000	1006		300					
12/0600Z	-8.5	167.5	90	25	45	0	1000	1004	30	150					
12/1200Z	-8.4	168.2	80	30	45	0	999	1004	60	150					
12/1800Z	-8.7	169.7	60	30	45	0	1000	1004	60	150					
13/0000Z	-9.1	170.1	50	35	50	1	995	1004	60	150	100/150/120/120				
13/0600Z	-11.1	172	50	45	65	1	993	1004	60	150	120/130/100/130				
13/1200Z	-12.2	173.4	50	50	70	2	989	1004	50	150	135/120/100/120	30/30/30/30			
13/1800Z	-13.6	173.9	50	60	85	2	982	1004	20	240	130/130/90/120	40/35/30/30			
14/0000Z	-14.8	174.4	30	65	90	3	978	1004	20	300	150/140/80/120	60/55/40/45	30/30/20/20		
14/0600Z	-16.1	175.2	30	65	90	3	982	1008	30	300	150/140/70/120	60/55/40/40	30/30/20/20		
14/1200Z	-17.6	175.7	30	70	100	3	979	1008	30	240	150/140/70/120	50/55/40/40	30/30/25/25		
14/1800Z	-18.8	176.6	30	65	90	3	980	1008	30	260	140/130/70/120	50/55/40/40	30/25/20/20		
15/0000Z	-20.2	177.5	30	60	85	2	984	1008	25	190	130/130/70/100	45/50/30/30			
15/0600Z	-21.4	178.4	40	55	75	2	985	1006	40	160	130/120/70/100	50/50/40/40			
15/1200Z	-22.6	178.9	90	50	70	2	991	1010	40	160	130/120/60/90	50/50/40/40			
15/1800Z	-24	179.4	90	40	55	1	996	1008	20	180	100/110/30/30				
16/0000Z	-24.8	179.9	90	35	50	1	998	1008	20	180	70/70/20/30				

b) Post Event/Best Track (Overlay)

Figure 11: Overlay of Severe TC Mal and Operational Analysis



Key:

 Analysis Track  Post Event Best Track

## 10.0 REFERENCES

- <http://www.bom.gov.au/oceanography/forecasts/>
- <https://www.facebook.com/FijiPolice/posts/pfbid02R8p6p8hJhx7CSjmjD15d29gVpLv4bneq n5xsgAjmpBb2sXwZZ31r9zGJHiLzsSi3l>
- <https://manati.star.nesdis.noaa.gov/datasets/ASCATData.php>
- <https://tropic.ssec.wisc.edu/archive/>
- <https://tropic.ssec.wisc.edu/real-time/adt/archive2023/02P-list.txt>
- <https://tropic.ssec.wisc.edu/real-time/adt/AiDT/archive2023/02P.listing.txt>
- [https://tropic.ssec.wisc.edu/real-time/DPRINT/2024/2024\\_02P\\_history\\_IR.html](https://tropic.ssec.wisc.edu/real-time/DPRINT/2024/2024_02P_history_IR.html)
- [http://rammb-data.cira.colostate.edu/tc\\_realtime/storm.asp?storm\\_identifier=sh022024](http://rammb-data.cira.colostate.edu/tc_realtime/storm.asp?storm_identifier=sh022024)