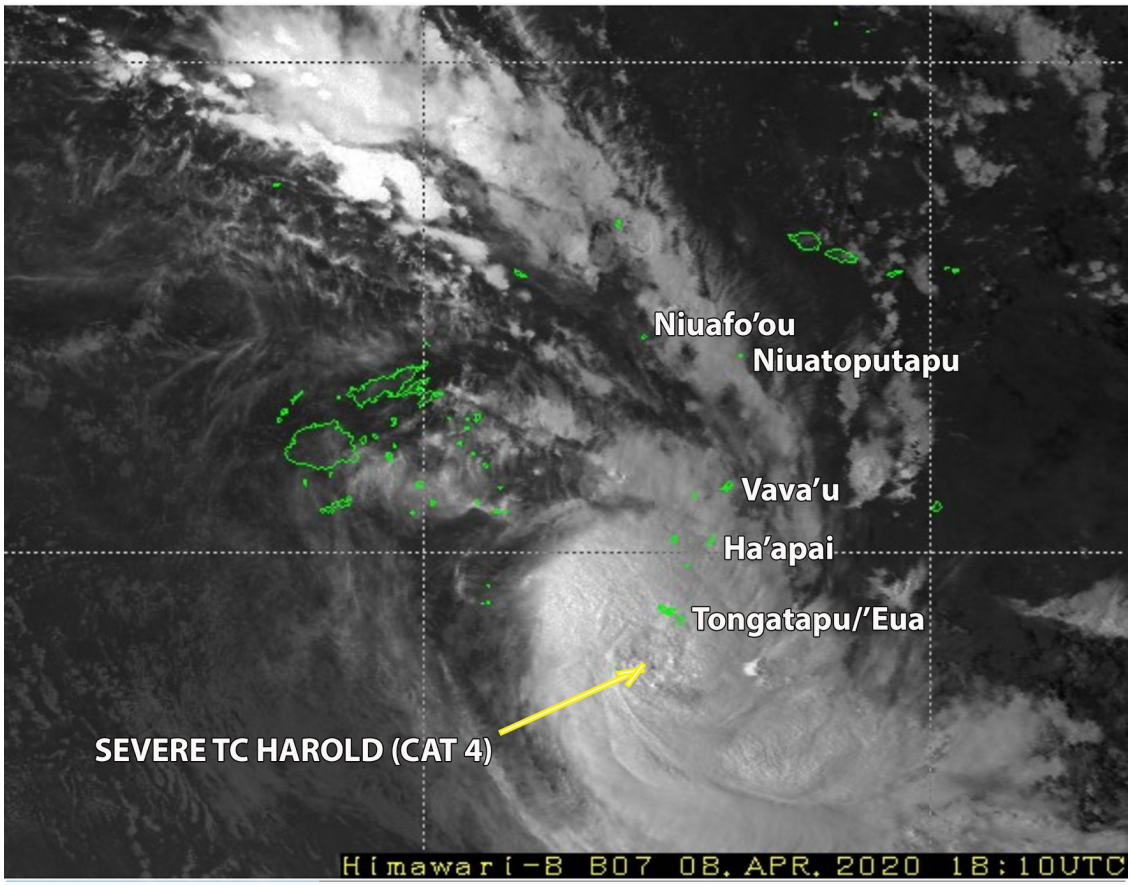
Meteorological report on

SEVERE TROPICAL CYCLONE "HAROLD" (Category 4) 7th – 9th April 2020



1. Introduction

Severe Tropical Cyclone "HAROLD" (Category 5) was the 8th Tropical Cyclone to occur in the Southwest pacific region during the Tropical Cyclone season 2019/2020. Severe Tropical Cyclone (TC) Harold had developed from a tropical low-pressure system that was located the Southeast of Port Moresby, PNG during the first week of April 2020. It had continued to develop into a Tropical Depression (TD) status and was officially named by the Brisbane Tropical Cyclone Warning Center as Tropical cyclone Harold (Category 1) at 10:00pm, Thursday 02nd April 2020 prior handing over to Fiji RSMC (Regional Specialize Meteorological Center) on the 3rd of April 2020.

Prior to landfall over the islands of Espiritu Santo and Pentecost Island in Vanuatu, the system had rapidly intensified into a category 5 system within 42 hours since it became a category 2 cyclone at 7am on the 4th of April 2020. The system continues to move ESE towards Fiji waters and fluctuation in strength. The activation of the Fua'amotu Tropical Cyclone Warning Center (FTCWC) was anticipated as the system was inspected to be in 24hours or less to affect Tongan waters.

Severe TC Harold was moving south at the speed of 09 knots (18km/hr) on Tuesday morning 07th April 2020 with maximum winds near the center is about 120 knots (240 km/hr). Based on the latest forecast track at 6am that morning, it was expected that Severe TC Harold's Gale force winds was to enter our Tongan waters by Thursday Morning (09th April 2019). Therefore, according to our standard operating procedures, the FTCWC was activated at 10:30am Tuesday 07th April 2020.
Once the FTCWC was activated, the operational staff was rostered into two teams of 12 hours rotational shift and as such, we continued to provide Tropical Cyclone Advisories (TCAs). TC Alerts and Warnings issued for Tonga was at every six hours, three hours and advisories was updated more often prior to its movement closing into Tongatapu and 'Eua.

With available meteorological information available at hand at 4am Wednesday 8th April 2020 indicating that Tropical Cyclone "Harold" would remain as a Severe Tropical Cyclone with an expected distance of about 90km Southwest of Tongatapu and 100km Southwest of 'Ohonua 'Eua at about 7am on Thursday 9th April. State of Emergency was declared by the Prime Minister on advice of the NEMC. Tropical Cyclone "Harold" was at its closest to Tongatapu and 'Eua between 6 to 8am.

Heavy rain, large waves and heavy swells accompanied with storm to hurricane-force winds as well as storm surges affected Tongatapu and 'Eua. Major structural damages to buildings located near coastal area such as resorts including Nafanua wharf ('Eua), power lines and fruit baring trees. Strong to Gale force winds with large waves and heavy rain also affected the rest of Tonga with some minor damages to the Ha'apai group.

Due to the damage of Fua'amotu Tropical Cyclone Warning Center Office that caused by Severe Tropical Cyclone "GITA" in February 2018, a back-up station was installed and well monitored from the NEMO department in MEIDECC Head-quarters.

2. Warnings

Fua'amotu Tropical Cyclone Warning Center (FTCWC) was activated at 10:30am Tuesday 7th April 2020 when Tropical Cyclone "Harold" was already a Category 5 system located 65km South Southwest of Santo, Vanuatu or 2040km West Northwest of Nuku'alofa. The FTCWC was deactivated at 6pm on Thursday when Gale or stronger destructive wind force is no longer affecting our Area of Responsibility (AoR).

A total of 20 Tropical Cyclone Advisories issued for Tonga on Severe Tropical Cyclone "Harold" with 3 Tropical Cyclone Alert, 19 were Tropical Cyclone Warning and 1 for the Cancellation of the warning.

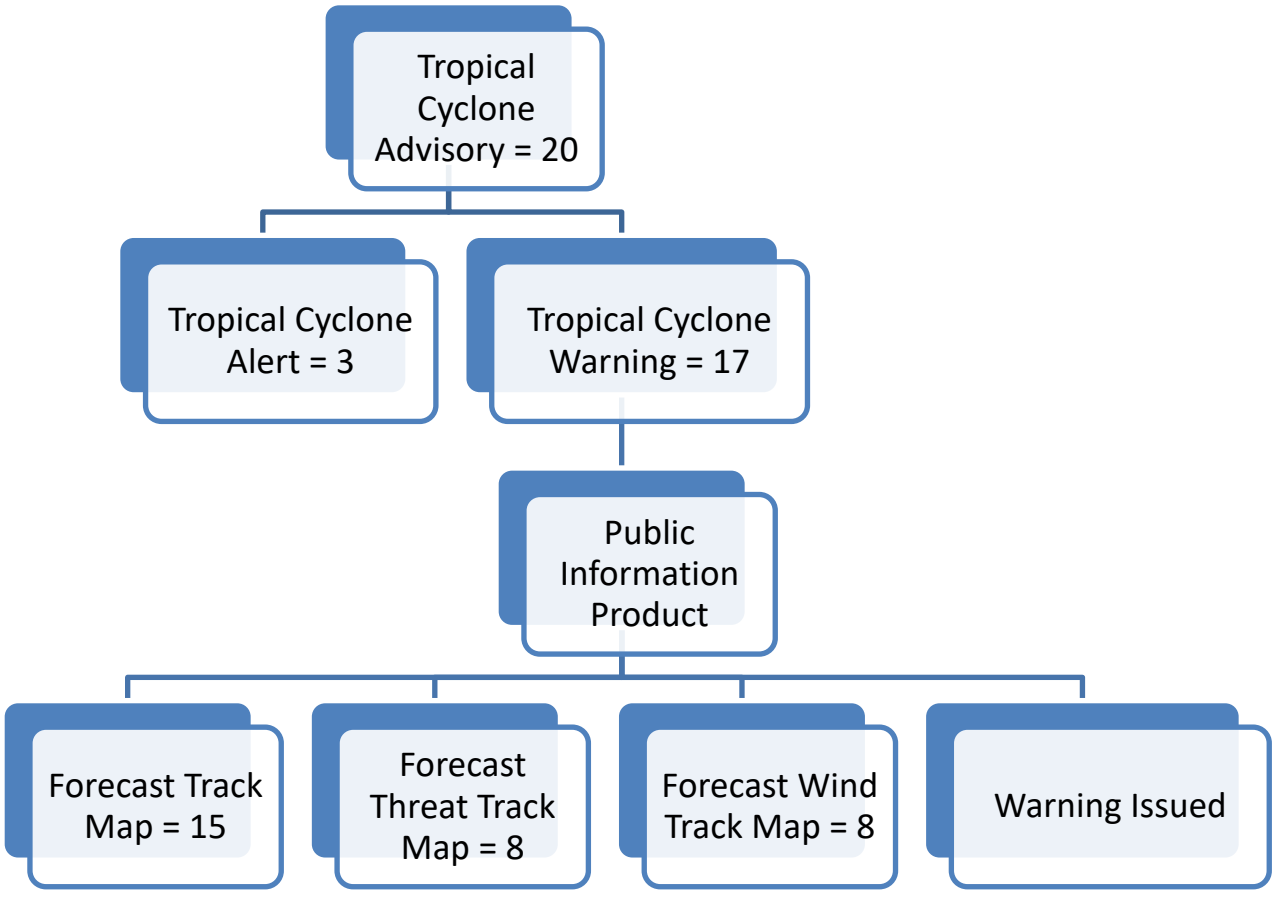


Diagram 1: All the product release to the public on TC "Harold"

Warning Issued;

- 5 Tropical Cyclone Alert, 8 Hurricane Force Winds, 4 Storm Force Winds, 16 Gale Force winds, 20 Strong winds, 17 Heavy rain & Flash Flood, 20 Small Craft Advisory, 18 Heavy Damaging Swell and 13 Extreme High Tide.

3. Early Warning System

Based on the indication of the Meteorological information available to FTCWC at 4am Wednesday 8th April 2020 about forecasting track and potential threat predicted by Numerical Weather Prediction models for Tropical Cyclone "Harold" to reach a Category 3 to 4 system as it approach Tongatapu and 'Eua. Hence, Director of Meteorology recommended to National Emergency Management Committee (NEMC) to consider declaring State of Emergency especially for Tongatapu and 'Eua in order to prevent and minimize the loss of human life, illnesses or injury, property loss or damage, and damage to the environment.

The State of Emergency was declared in Nuku'alofa at ____ on Wednesday 8th of April 2020 for Tongatapu and 'Eua by the Prime Minister Dr. Pohiva Tu'i'onetoa. Precautionary measures were carried out such as Tonga Power shutting down the electricity at 6:10am on Thursday 9th April 2020 and approximately 80 people were self-evacuated to Evacuation Center before gale, storm and hurricane force winds arrived.

Government officials such as the Minister of MEIDECC, Director of Meteorology and Director of NEMO regularly updated the people and providing advice on air to the public to take heed of the warnings and evacuate or prepared as soon as possible as there was a potential threat for Tongatapu and 'Eua from Tropical Cyclone "Harold" to remain as a Severe Tropical Cyclone as it approached.

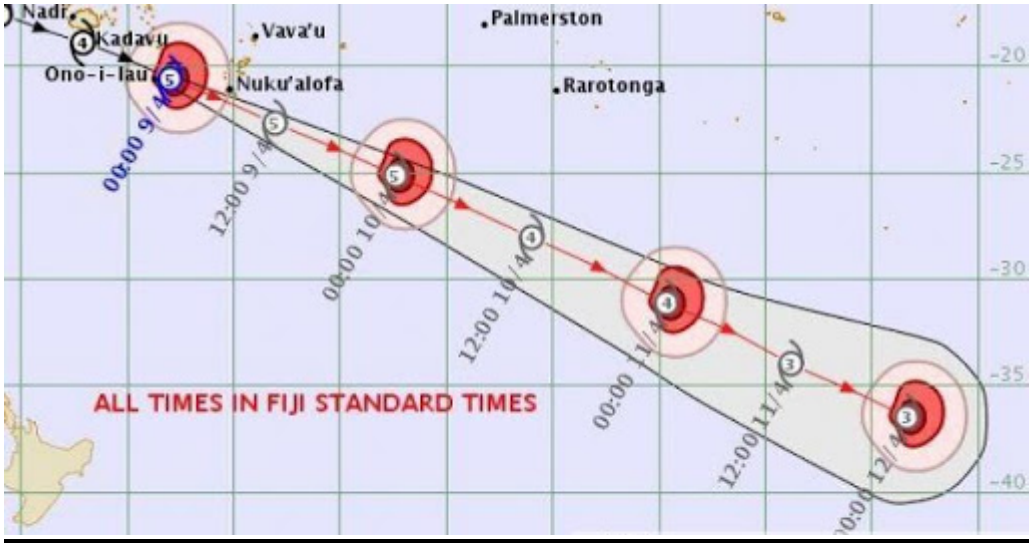


Figure 1: RSMC Nadi Forecasting Track issued at 1am Thursday April 2020. It is predicting TC "Harold" to be intensified in to remain as a Category 5 Cyclone when its approach Tongatapu and 'Eua.

4. Track of Severe Tropical Cyclone "Harold"

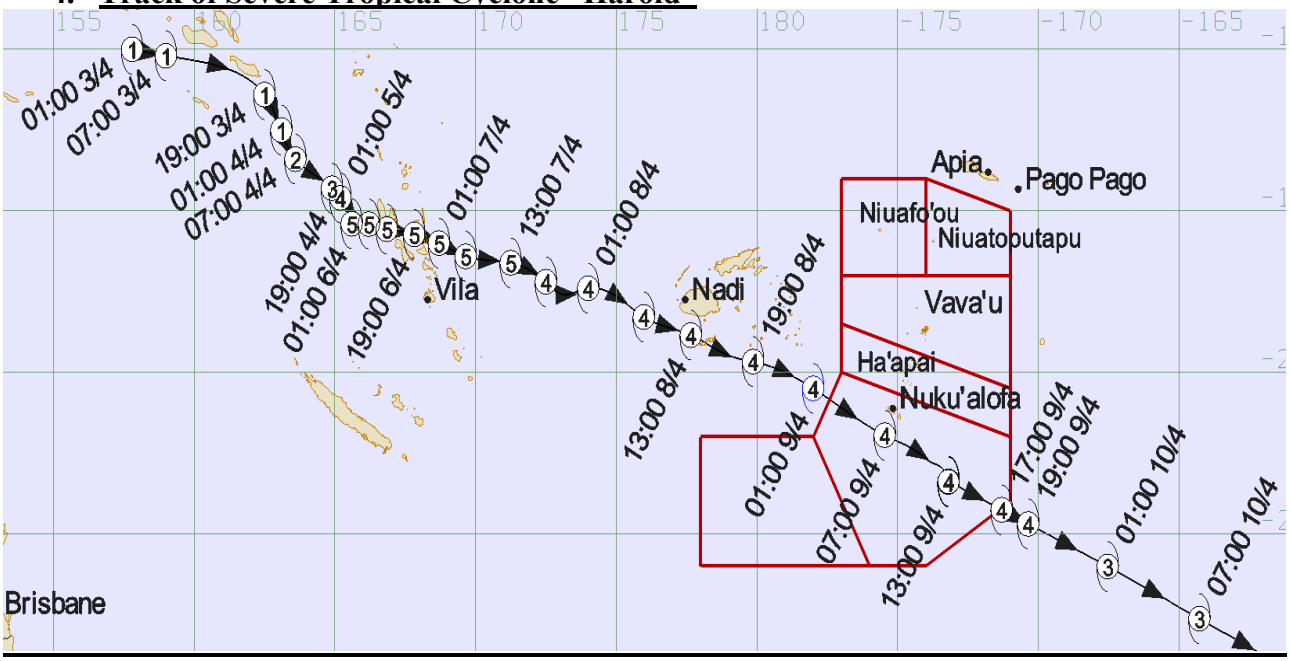


Figure 2: Analysis Track (actual track) of Tropical Cyclone "Harold" issued from FTCWC.

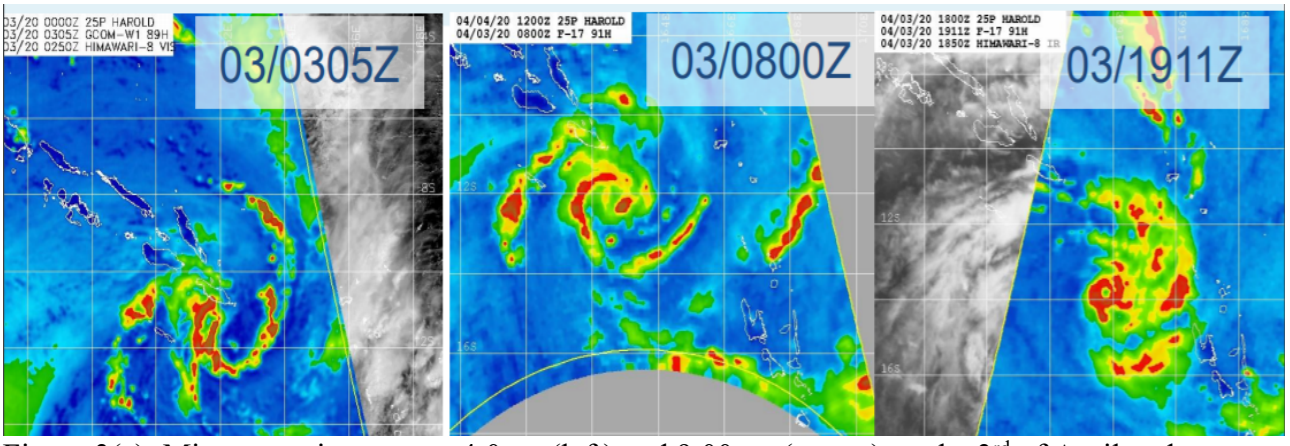


Figure 3(a): Microwave imagery at 4:0pm (left) and 9:00pm (center) on the 3rd of April and 8:11am (right) on the 4th the next day.

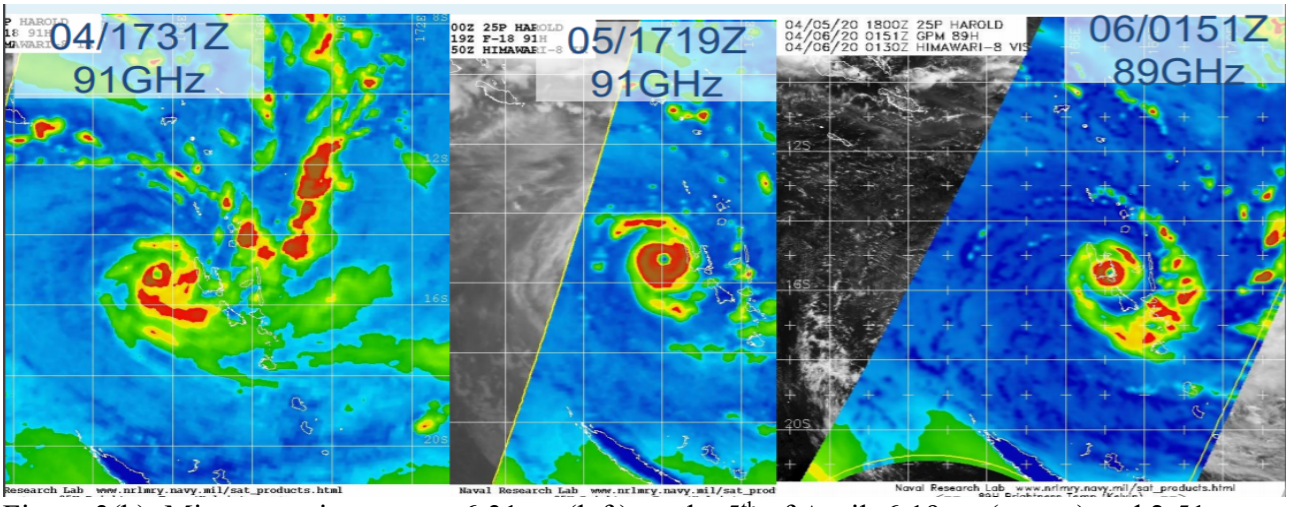


Figure 3(b): Microwave imagery at 6:31am (left) on the 5th of April, 6:19am (center) and 2:51pm (right) on the 6th.

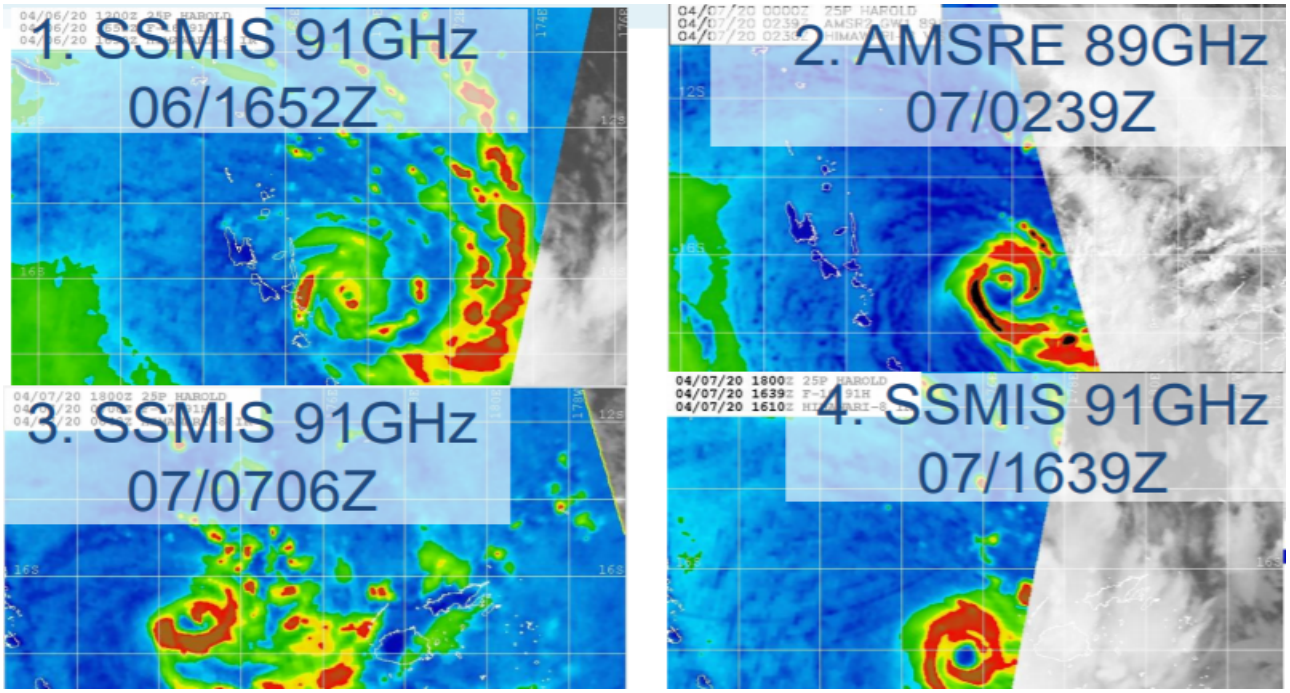


Figure 3(c): Microwave imagery at 5:52am (1), 3:39pm (2) and 8:06pm (3) on the 7th of April and 5:39am (4) on the 8th.

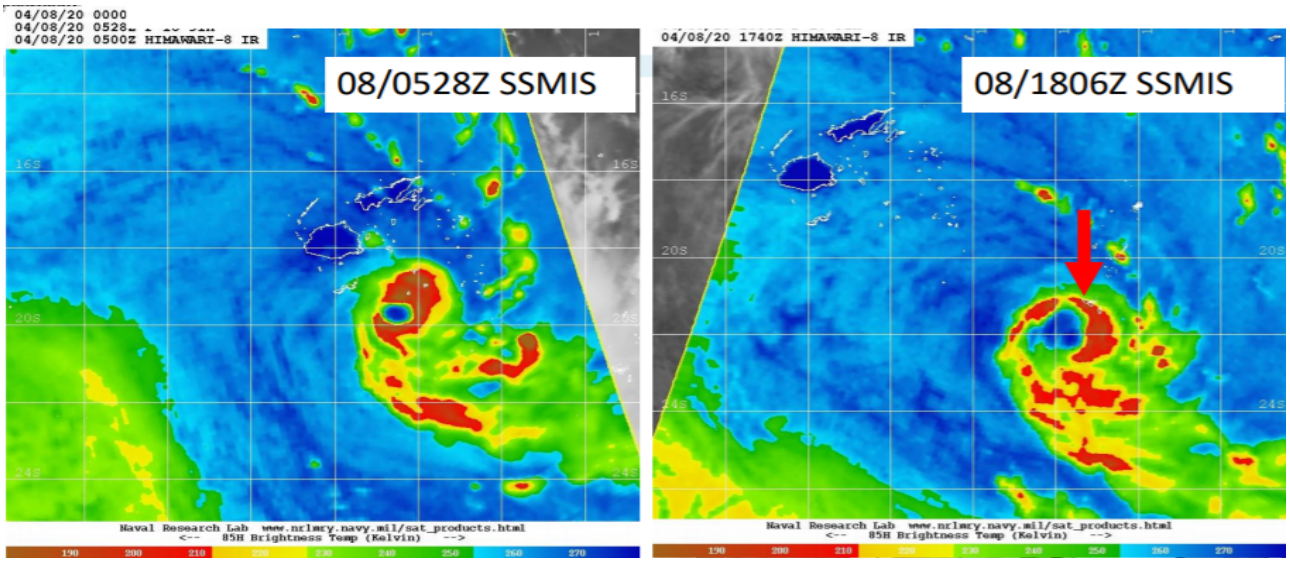


Figure 3(d): Microwave imagery at 6:28pm on the 8th of April (left) and 7:06am on the 9th (right)

In comparison of figures above, it well indicated that the system eye-wall was dis-organized. This indicates that the system was weakening as it approached Tongatapu (Figure 3(d)).

In Addition, Ono-i-Lau is located at 20.7S, 178.7W. Severe Tropical Cyclone "Harold" was approaching Ono-i-Lau at about 1am on Thursday 9th April 2020. Observation recorded in Ono-i-Lau will be shown below in Section 6: Meteorological Observation.

5. Tropical Cyclone Warning Center

The Office operated on a generator when the power was off at around 2:30am on Thursday 9th April 2020. This was caused by up-root of the 'Ovava tree near the domestic terminal parking to fell on the power line to the terminal with some minor flooding in the office.

Outside on the airside, the Stevenson Screens were blown away and the Himawari Dish's receiver was filled with water from the rain.

The main power was restored just before mid-day on 10th April 2020, together with the Himawari SATAID was back online.

6. Meteorological Observation

Observation from our automatic weather stations (AWS) around the island of Tongatapu and 'Eua including manned observation conducted by the observer shows the time of the maximum winds being recorded with time. This indicates the time Tropical Cyclone "Harold" lies closer to Tongatapu and 'Eua as shown below;

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Latest Fua'amotu Aerodrome - NFTF METAR/SPECI for 09/04/2020.

METAR NFTF 081100Z 06012KT 9999 FEW015CB SCT017TCU OVC100 26/25 Q1005 RMK SPECI CONDX CEASE=
METAR NFTF 081200Z 05016KT 9999 -RA FEW015CB BKN017TCU OVC100 26/25 Q1005=
SPECI NFTF 081215Z 05015G30KT 4000 -RA FEW015CB BKN017TCU OVC100 26/25 Q1003=
SPECI NFTF 081300Z 06012G30KT 9999 FEW015CB BKN017TCU OVC100 26/25 Q1001=
SPECI NFTF 081320Z 05015G30KT 9999 SCT006 BKN015TCU OVC100 26/25 Q1001=
SPECI NFTF 081400Z 04018G29KT 9999 SCT006 BKN015TCU OVC100 26/25 Q1000=
SPECI NFTF 081435Z 04020G36KT 3000 RA BKN006 BKN015TCU OVC100 26/25 Q0998=
SPECI NFTF 081500Z 01022G45KT 3000 RA BKN006 SCT015CB OVC090 26/26 Q0998=
SPECI NFTF 081600Z 02030G50KT 5000 -RA BKN006 SCT015CB OVC090 26/26 Q0995=
SPECI NFTF 081615Z 02037G55KT 1000 +RA BKN006 SCT015CB OVC090 26/26 Q0992=
SPECI NFTF 081700Z 01035G66KT 1000 +RA BKN006 SCT015CB OVC090 26/26 Q0991=
SPECI NFTF 081710Z 36042G63KT 0900 +TSRA BKN006 BKN015CB OVC090 26/26 Q0991=
SPECI NFTF 081715Z 36040G67KT 0300 +TSRA BKN006 BKN015CB OVC090 26/26 Q0990=
SPECI NFTF 081720Z 36041G71KT 0300 +TSRA BKN006 BKN015CB OVC090 26/26 Q0990=
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SPECI NFTF 081900Z 33050G77KT 0100 +TSRA BKN005 BKN014CB OVC090 25/25 Q0990=
SPECI NFTF 081930Z 32046G72KT 0100 +TSRA BKN005 BKN014CB OVC090 25/25 Q0993=
SPECI NFTF 082000Z 30041G81KT 0800 TSRA BKN005 BKN014CB OVC090 24/24 Q0994=
SPECI NFTF 082100Z 29038G51KT 0900 -TSRA BKN005 BKN014CB OVC090 25/25 Q0997=
SPECI NFTF 082200Z 27032G48KT 3000 -TSRA SCT005 BKN014CB OVC090 24/24 Q0999=
SPECI NFTF 082300Z 27029G43KT 9999 -RA SCT006 BKN014CB OVC090 26/25 Q1001=
SPECI NFTF 090000Z 26025G35KT 9999 SCT009 SCT017 BKN270 28/25 Q1002=
SPECI NFTF 090100Z 25020G30KT 9999 FEW009 SCT017 BKN270 27/25 Q1003=
METAR NFTF 090200Z 27020KT 9999 FEW009 FEW017TCU SCT270 28/25 Q1003=
METAR NFTF 090300Z 25018KT 9999 FEW017TCU BKN110 28/24 Q1004=
METAR NFTF 090400Z 24019KT 9999 FEW017TCU BKN110 27/24 Q1004=
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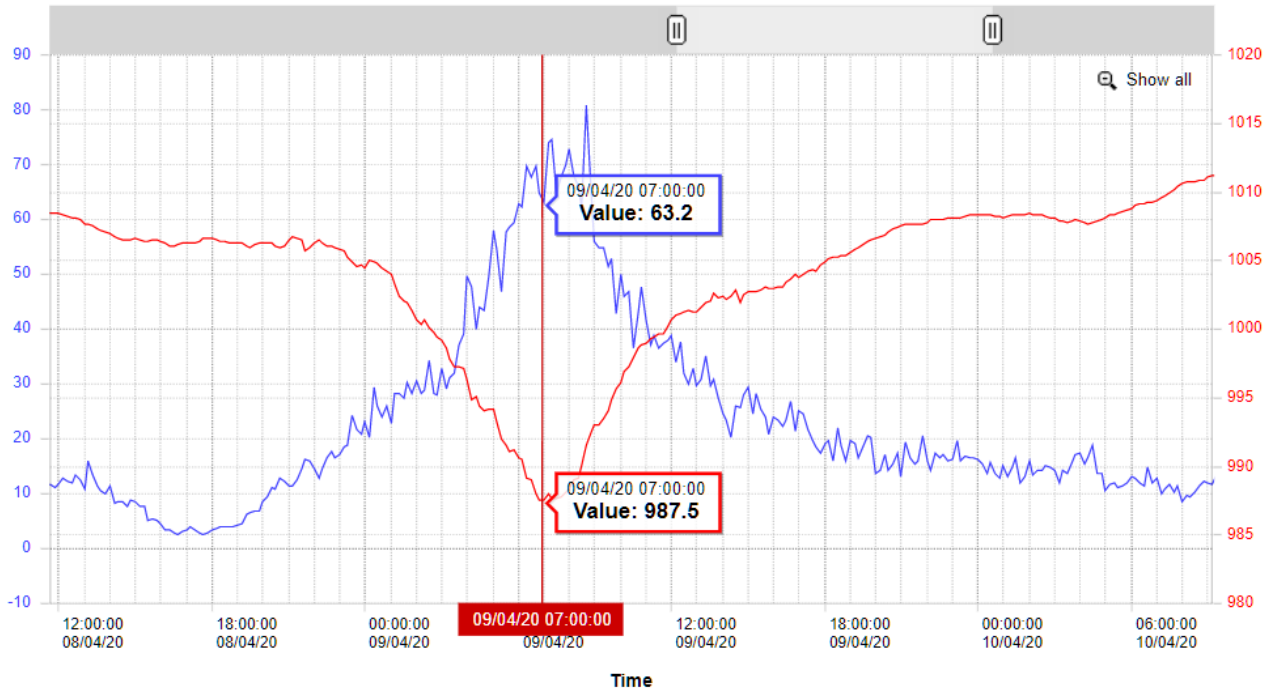

Figure 4 (a) – Above trend is the Wind speed gust in blue, while Mean Sea Level pressure (MSLP) is in red in Fua'amotu (Tongatapu Aerodrome) Automatic Weather Station (AWS).

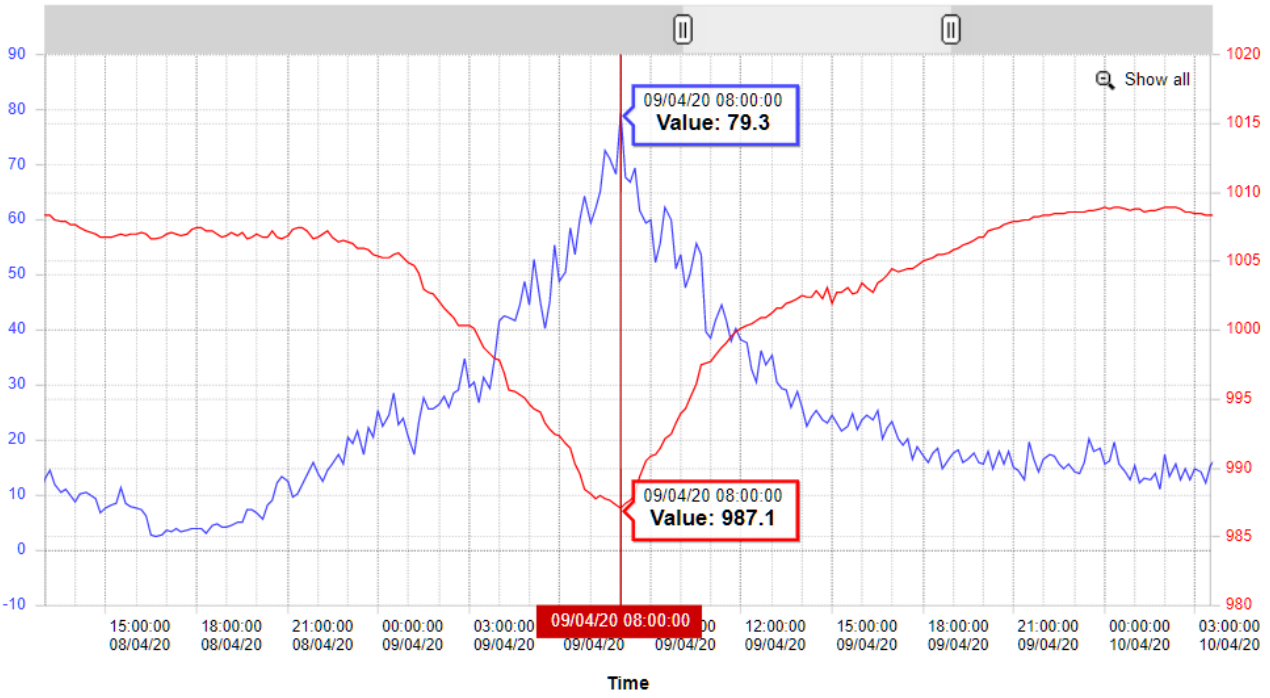

Figure 4 (b) – Above trend is the Wind speed gust in blue, while Mean Sea Level pressure (MSLP) is in red in Kaufana ('Eua Aerodrome) AWS.

Above figures show that the TC "Harold" was nearest to Tongatapu at 7am on Thursday 9th April 2020 with a pressure of 987.5hPa with maximum wind gusts recorded of 80.9 or 81 knots. For 'Eua, it was nearest at around 8am on the same day with MSLP of 987.1hPa and wind gusts of 79.3knots.

Date	Station	Time	Average winds	Wind Gusts	Wind Classifications
09/04/2020	Fangatongo AWS	12:10pm	19 knots	34 knots	Gale force winds
09/04/2020	Fatai AWS	10:00am	9 knots	26 knots	Strong force winds
09/04/2020	Fua'amotu AWS	8:40am	51 knots	81 knots	Hurricane force winds
09/04/2020	Ha'ano AWS	08:10am	18 knots	43 knots	Gale force winds
09/04/2020	Houma AWS	06:50am	33 knots	71 knots	Hurricane force winds
09/04/2020	Kaufana AWS	08:00am	48 knots	79 knots	Hurricane force winds
09/04/2020	Koloa AWS	07:00am	16 knots	36 knots	Gale force winds
09/04/2020	Lapaha AWS	08:00am	35 knots	62 knots	Storm force winds
09/04/2020	Lifuka AWS	08:10am	21 knots	40 knots	Gale force winds
09/04/2020	Longomapu AWS	10:50am	17 knots	35 knots	Gale force winds
09/04/2020	Lupepau'u AWS	01:00pm	21 knots	36 knots	Gale force winds
09/04/2020	Matatoa AWS	08:50am	36 knots	62 knots	Storm force winds
09/04/2020	Mo'unga'olive AWS	08:00am	44 knots	76 knots	Hurricane force winds
09/04/2020	Niuafo'ou AWS	04:20am	18 knots	32 knots	Strong force winds
09/04/2020	Nomuka AWS	06:30am	36 knots	60 knots	Storm force winds
09/04/2020	Nuku'alofa AWS	06:20am	33 knots	60 knots	Storm force winds
09/04/2020	Pilolevu AWS	07:40am	28 knots	44 knots	Gale force winds
09/04/2020	Toloa AWS	07:50am	32 knots	61 knots	Storm force winds

Table 1: Winds observation tables from the Tonga MET AWS Network

Date	Station	Time	Lowest Pressure
09/04/2020	Kaufana AWS	08:00am	987.1 millibars
09/04/2020	Fua'amotu AWS	07:00am	987.5 millibars
09/04/2020	Lapaha AWS	07:00am	989.2 millibars
09/04/2020	Matatoa AWS	07:00am	988.9 millibars
09/04/2020	Mo'unga'olive AWS	07:00am	992.9 millibars
09/04/2020	Nuku'alofa	07:00am	990.9 millibars

Table 2: Lowest Mean Sea Level Pressure observation tables recorded from the Tonga MET AWS Network

Ono-i-Lau (Fiji Observation)
Location: 20.7S, 178.7W

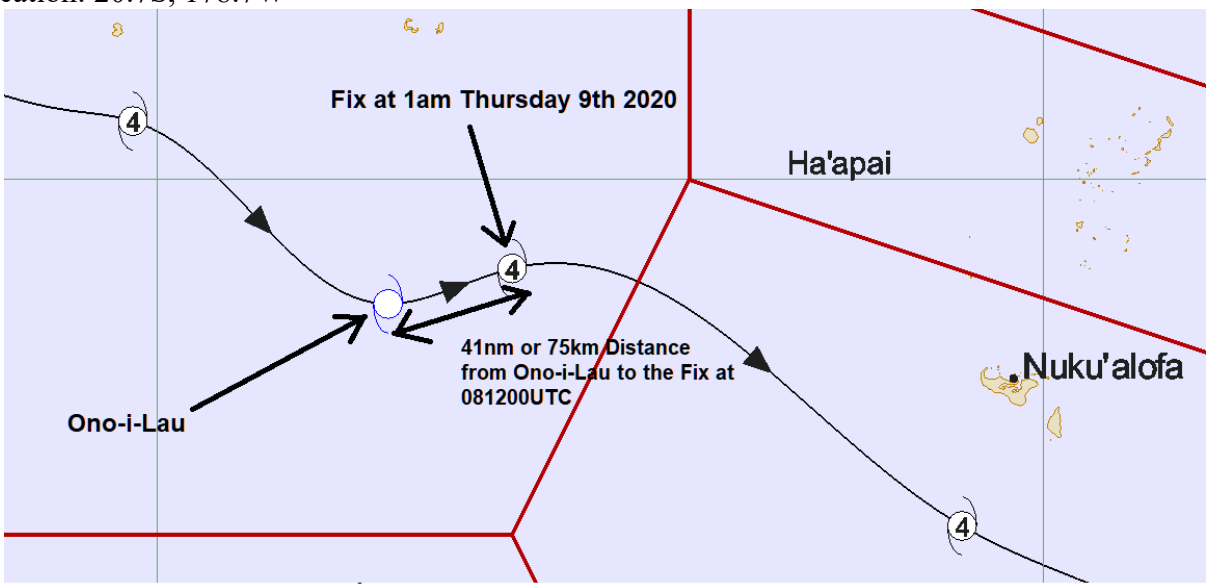

Figure 5: Above figure display the differences in distance between Ono-i-Lau and the Fix at 1am on Thursday 9th April 2020.

08/04/2020 18:00->	AAXX 08184 91699 16/// /2214 10257 20240 30000 40032 53059 60091==
08/04/2020 15:00->	AAXX 08154 91699 14/// /2226 10264 20242 39941 49972 53251=
08/04/2020 12:00->	AAXX 08124 91699 16/// /2062 10255 20252 39690 49721 50150 60831==
08/04/2020 09:00->	AAXX 08094 91699 46/// /0642 10264 20258 39840 49871 55108==
08/04/2020 06:00->	AAXX 08064 91699 16/// /0623 10259 20252 39948 49979 55030 60401==

Figure 7: This is the 3-hourly synoptic reports from Ono-i-Lau. It shows that the maximum winds and lowest MSLP recorded at 12UTC or 1am on Thursday 9th 2020. The winds recorded was 20062KT with a pressure of 972.1hPa.

One of the most significant meteorological observations that was also noted during Severe TC Harold's passage close to Tongatapu and 'Eua was the occurrence of Extreme High Tides and the storm surges (coastal tsunami) was about 0.86 Meters (86cm).

Queen Salote wharf Tide Gauge readings

Actual sea level = 2.492m at 7:16am
Predicted sea level = 1.788m at 7:22am
Residual = 0.783m at 9:43am

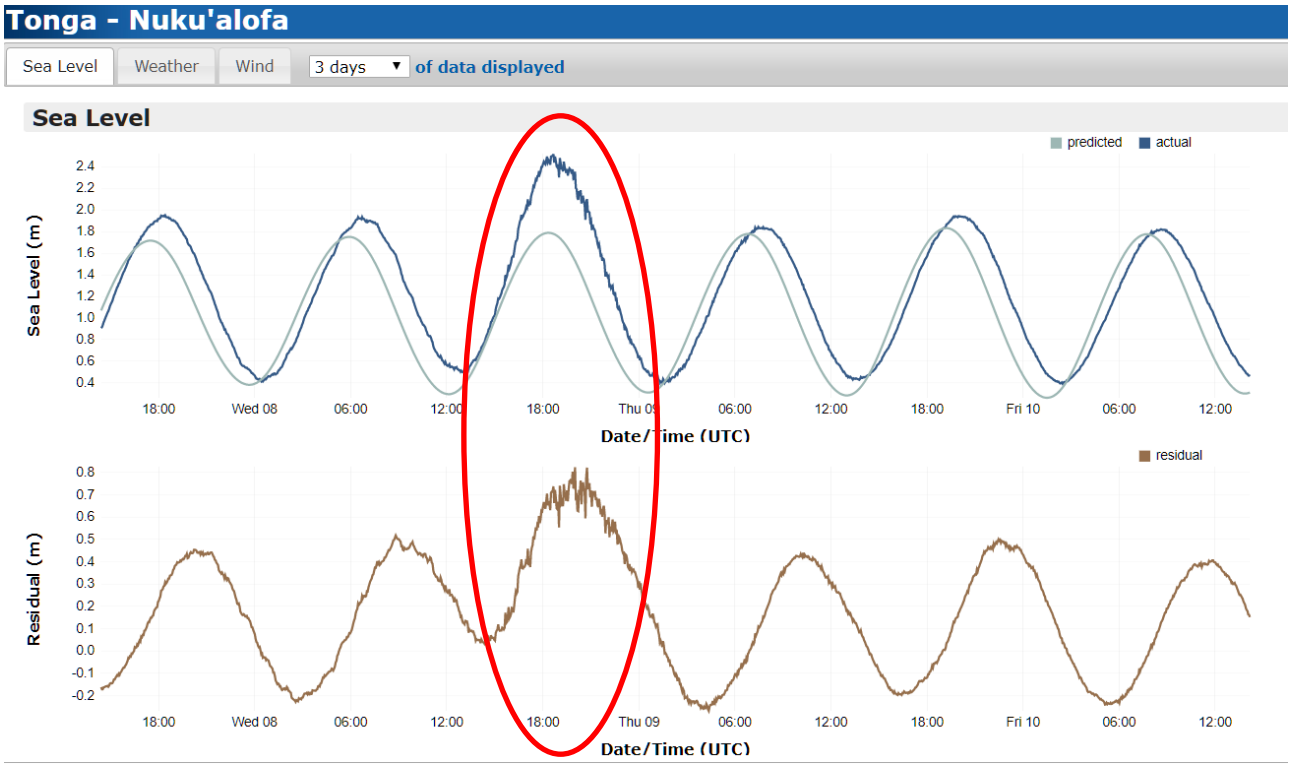

Figure 6 (a): The tide gauge readings at the Queen Salote wharf at Thursday morning (09.04.2020)

Vuna Wharf Tide Gauge Readings

Actual Sea Level= 2.463m at 7:38am
Predicted Sea Level= 1.831m at 8:14am
Residual = 0.692m at 7:11am

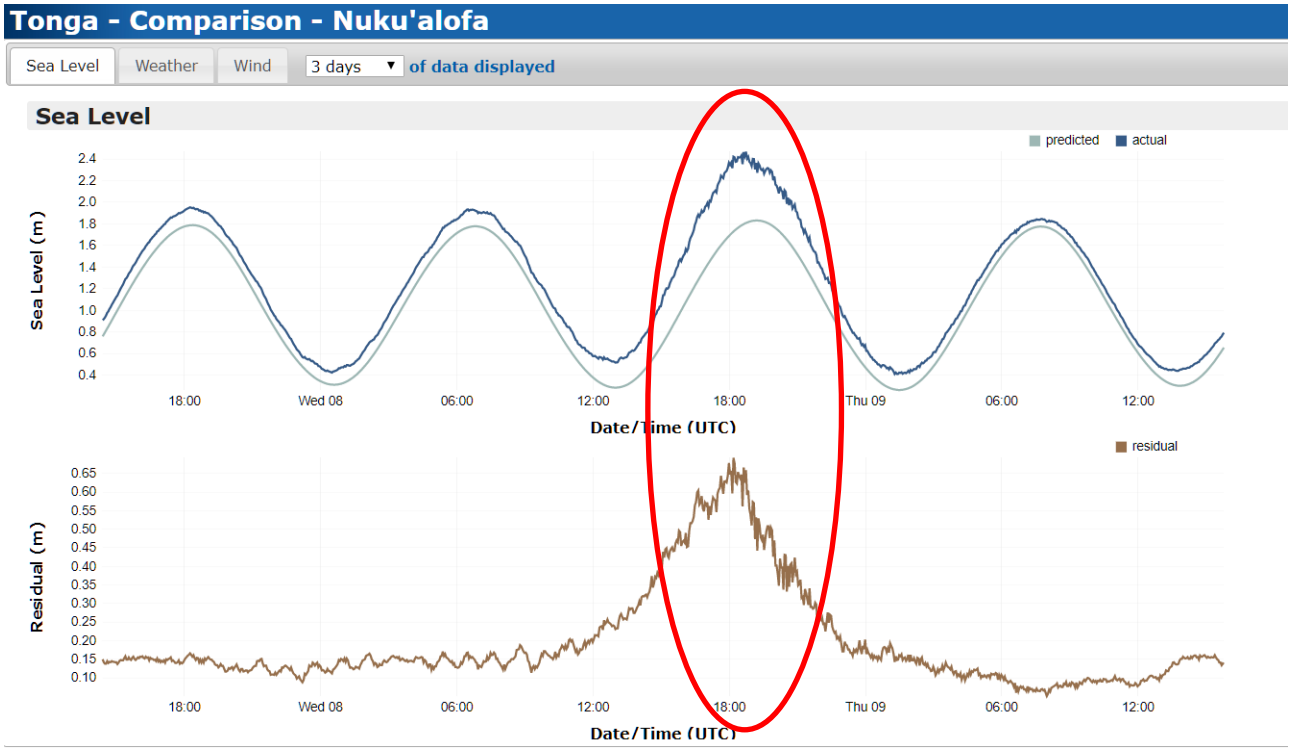

Figure 6 (b): The tide gauge readings at the Vuna wharf at Thursday morning (09.04.2020)

7. Severe Tropical Cyclone "Harold" Impact

Figure 7(a): Below are the major damages caused by Tropical Cyclone "Harold" to Tongatapu

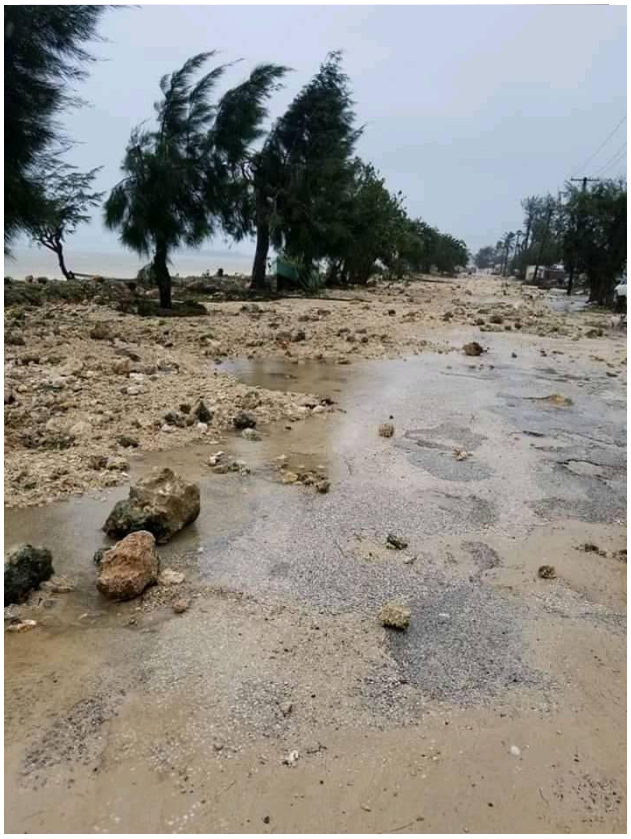

Figure 7(b): ‘Eua coastal damages

8. Meteorological Summary

Tropical Cyclone "Harold" maximum wind gusts recorded over Fua'amotu AWS were 81 knots when its center moved closer approximately 7 to 8am on the 9th of April 2020. The lowest MSLP recorded was 987.1hPa.

Analyzing the microwave imagery in Figures 3 that well indicates that the system was not well organized in comparison to what has been displayed in figure 3 (d). In addition, it has been well displayed from Ono-i-Lau observations that the maximum mean winds recorded was 62 knots with a MSLP of 972.1hPa.

After combined all these data, it indicates that the system approach FTCWC Area of Responsibility with a strength of less than a Category 5 system.

Severe Tropical Cyclone "Harold" was the strongest tropical cyclone to cross the Tonga waters this 2019/2020 Season. It also inflicted major structural damages to buildings near the coastal areas and foreshores, including Nafanua wharf and very extensively to fruit bearing trees.

A State of Emergency was declared and no casualty. With scale of damage seen indicated that it was well based-informed decision made by the Government.

9. Recommendations:

Based on our experiences and encounters during the operations of TC "Harold", this report puts forward the following recommendations to be considered and to be noted:

- IT technician standby at all times in the FTCWC in-case of any unforeseen IT related technical problems.
- Needs of putting one observer in a team to ease workload.
- A priority and the need to carry out TC trainings with experts from the Bureau of Meteorology on a yearly basis before the start of any TC Season.
- The need for our TC forecasters to familiarize with and to carry out Dvorak Analysis and more TC module hands on practical session.
- Competency assessments on TC forecasters to be implemented during TC operations.
- The need to review our current Tropical Cyclone SOPs.
- The effectiveness of putting other members of the team on Stand-by.
- The need for a media training for those who recorded TV Weather and radio live broadcasting.