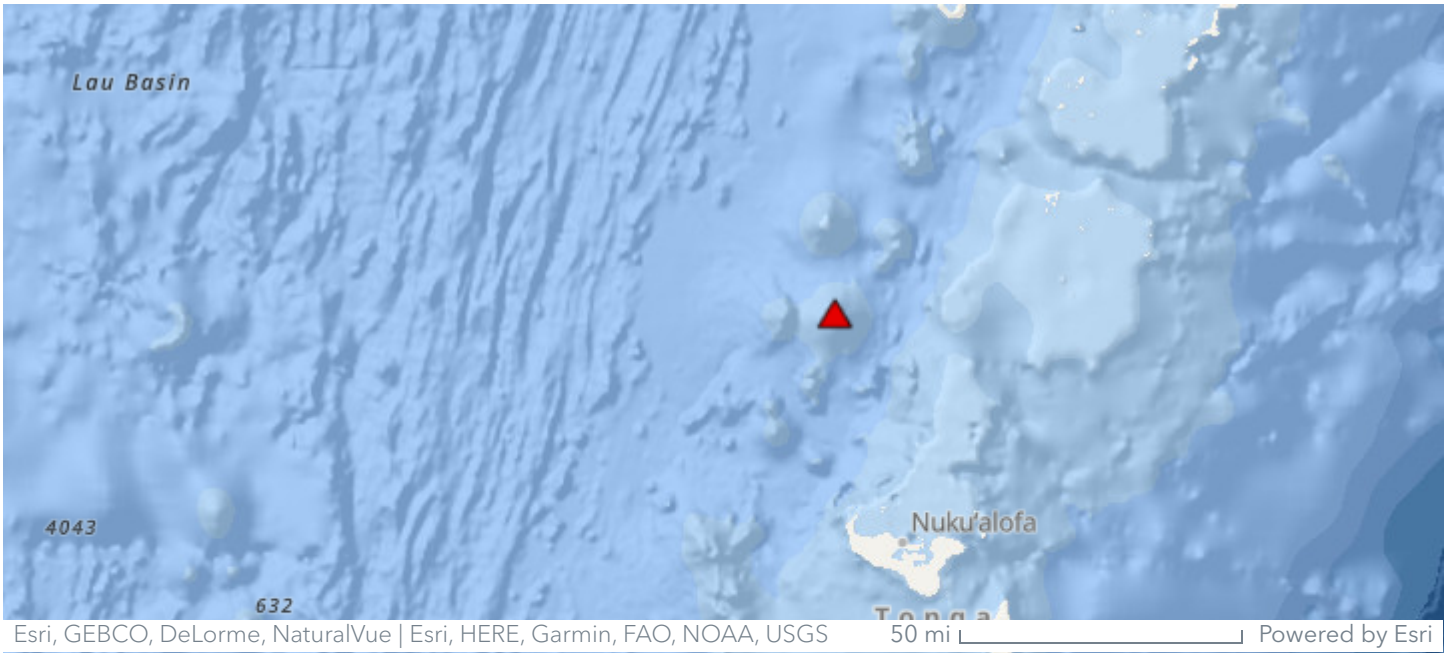
The 2022 Hunga Tonga-Hunga Ha’apai Eruption

Water Levels & Community Impacts on Pacific Island (Pasifika) Coasts

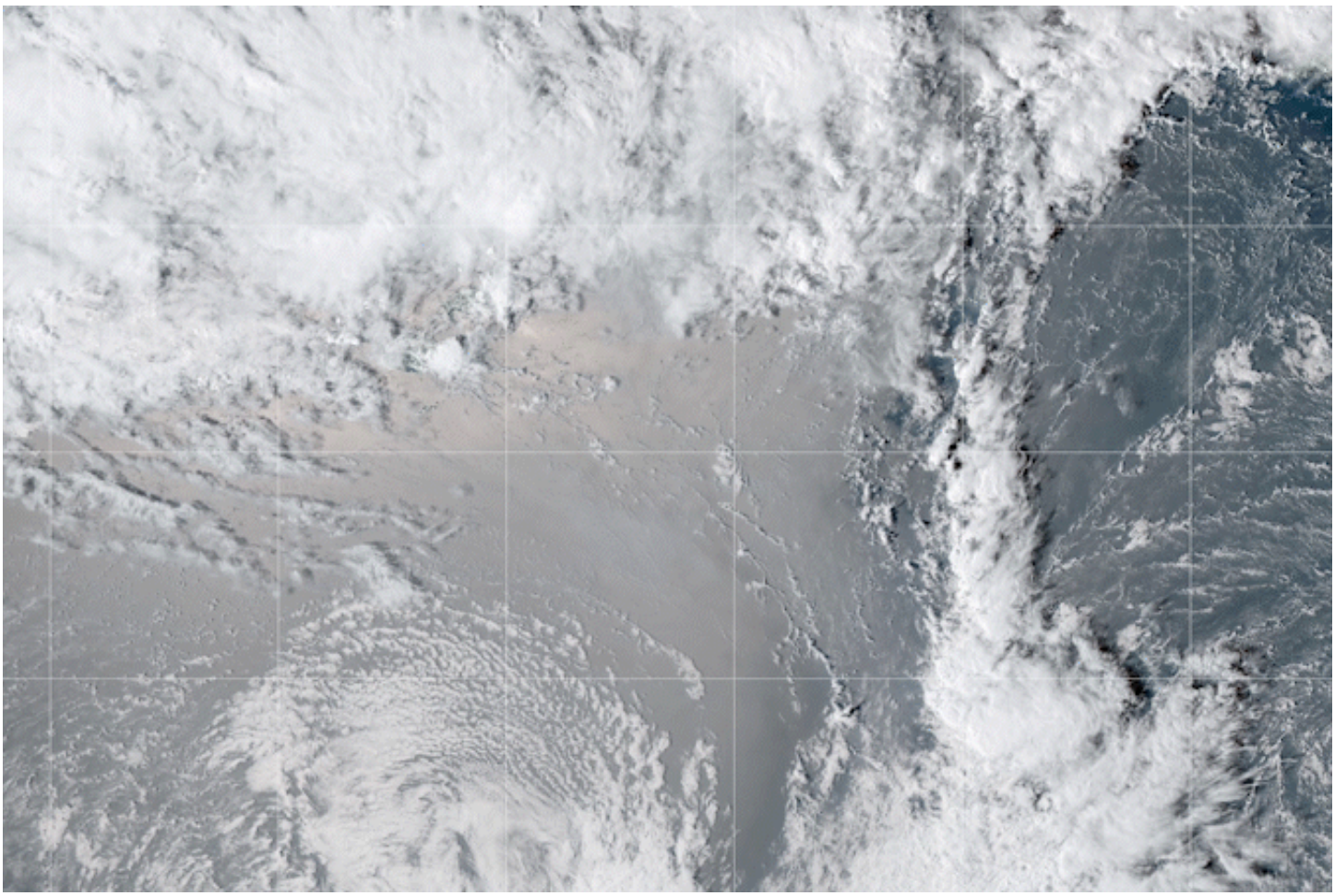
Talofa J. Fe'a

On January 15, 2022, the Hunga Tonga-Hunga Ha’apai volcano erupted shortly before 5 PM Tonga Time (TOT). The eruption triggered high sea levels and tsunami waves that struck shores around the Pacific. This story map illustrates the historic event from a coastal perspective, utilizing valuable accounts from impacted Pacific island (Pasifika) communities and significant water level data from NOAA’s Center for Operational Oceanographic Products and Services (CO-OPS).

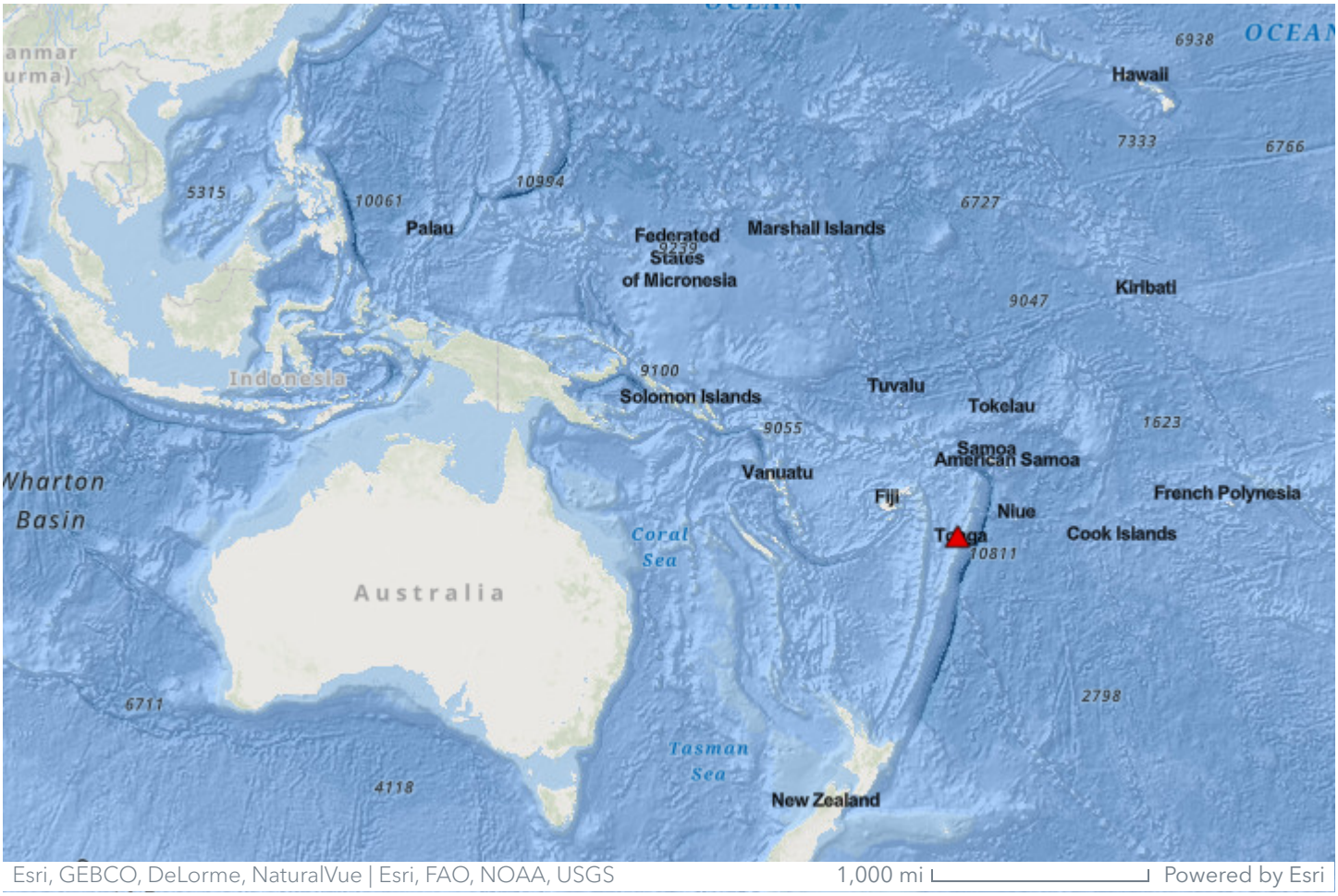
Hunga Tonga-Hunga Ha‘apai



Located 60 kilometers northwest of Tongatapu, Tonga, the Hunga Tonga-Hunga Ha'apai (HTHH) volcano is a submarine volcano along the Kermadec Arc. It sits within the Tonga-Kermadec subduction zone, as part of a chain of volcanoes stretching from New Zealand to Samoa. As indicated by its name, part of the volcano includes the small islands of Hunga Tonga and Hunga Ha'apai.

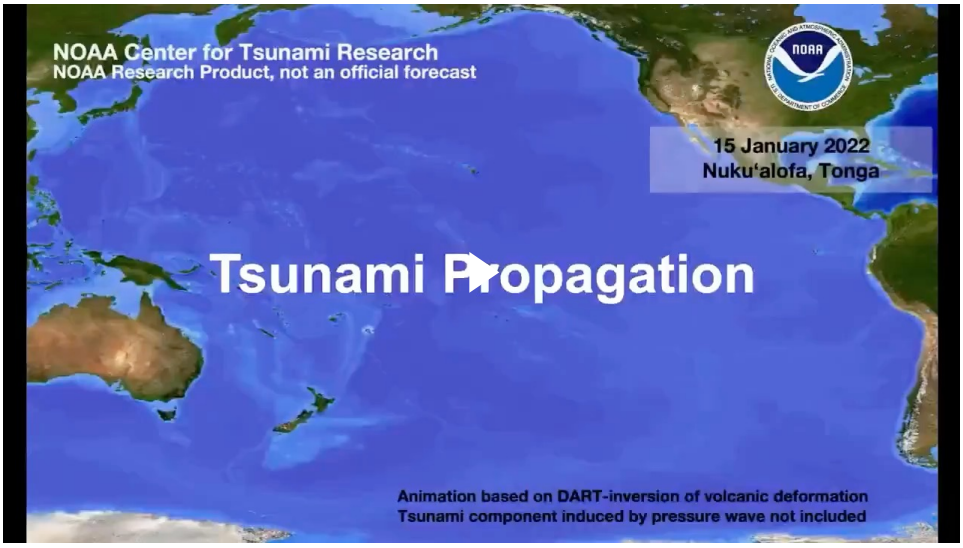


Although eruptive activities at the site were detected as early as December 2021, the January 15, 2022 event stands in marked contrast. At approximately 4:27 PM TOT (3:27 UTC), the HTHH volcano erupted violently. The explosion was responsible for a disaster of epic proportions, sending plumes as high as 36 miles into the atmosphere and tsunami waves as high as 65 feet above sea level around the world (USGS).



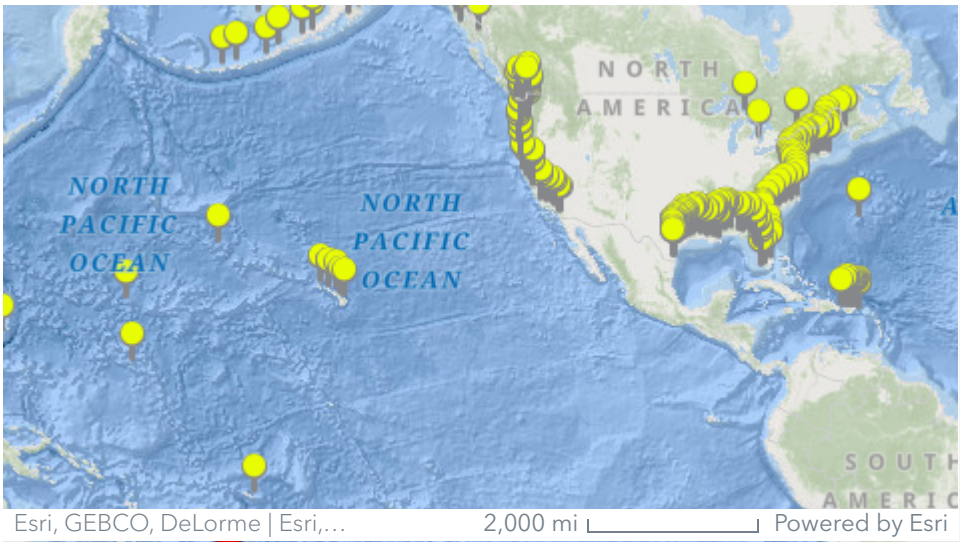
Communities at the Frontline

The Pasifika basin is no stranger to natural hazards. From tropical cyclones to droughts, the area faces numerous rapid-onset and slow-onset events. The HTHH volcanic eruption was among those that were rapid-onset, triggering a tsunami that caused local and regional damages across Pasifika.



January 15, 2022 HTHH volcano-generated tsunami propagation (Source: NOAA Center for Tsunami Research, located at NOAA PMEL in Seattle, WA)

NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) operates a network of coastal tide stations on all U.S. coasts in support of tsunami detection, warning, and modeling. During the eruption, CO-OPS' stations observed and measured the water levels, disseminating real-time one-minute water level data to the public through its Tsunami Capable Tide Station webpage. This web page allows users to view both six and one-minute data numerically or graphically for all tsunami-capable tide stations in increments of up to four days.

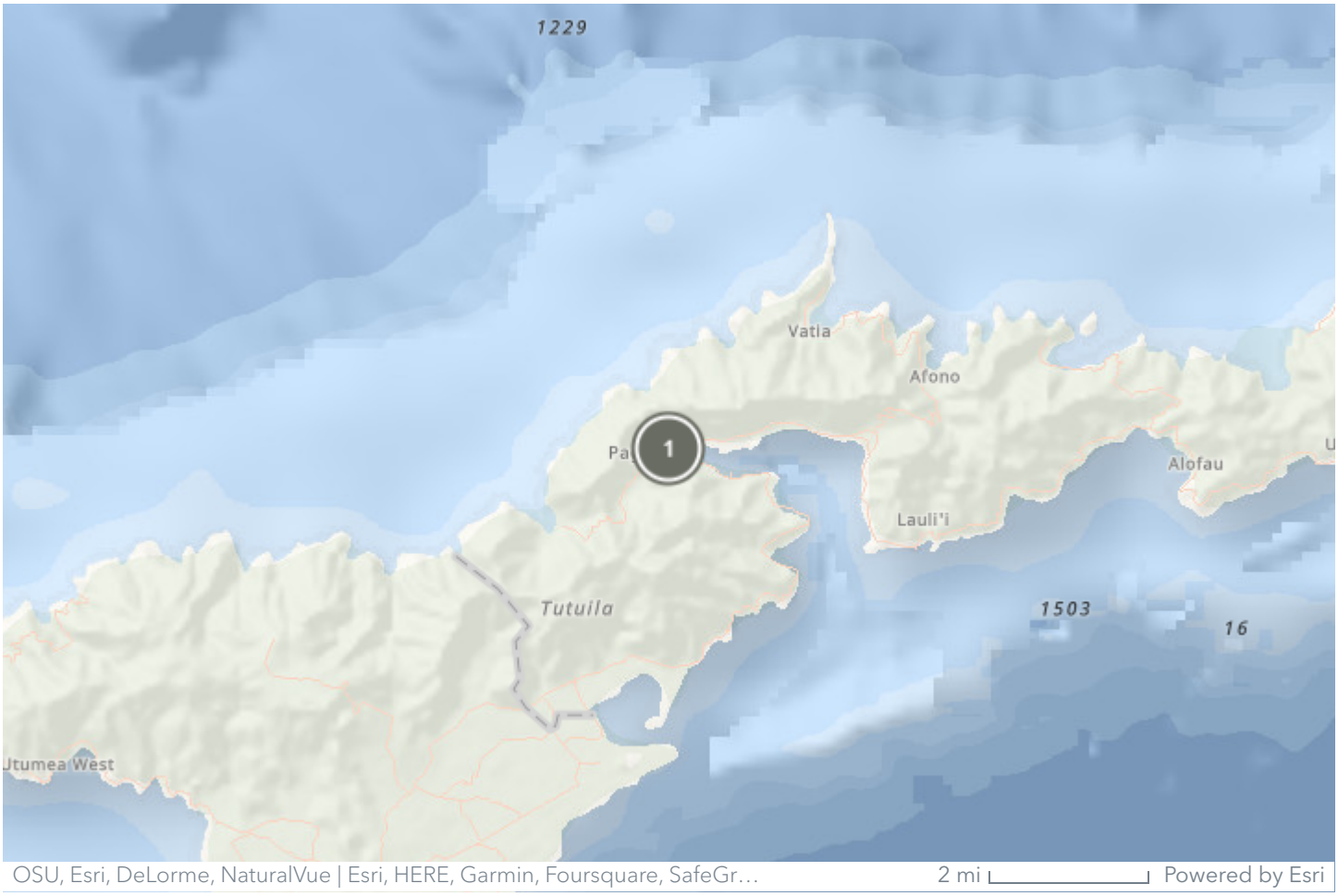


CO-OPS tsunami-ready water level stations

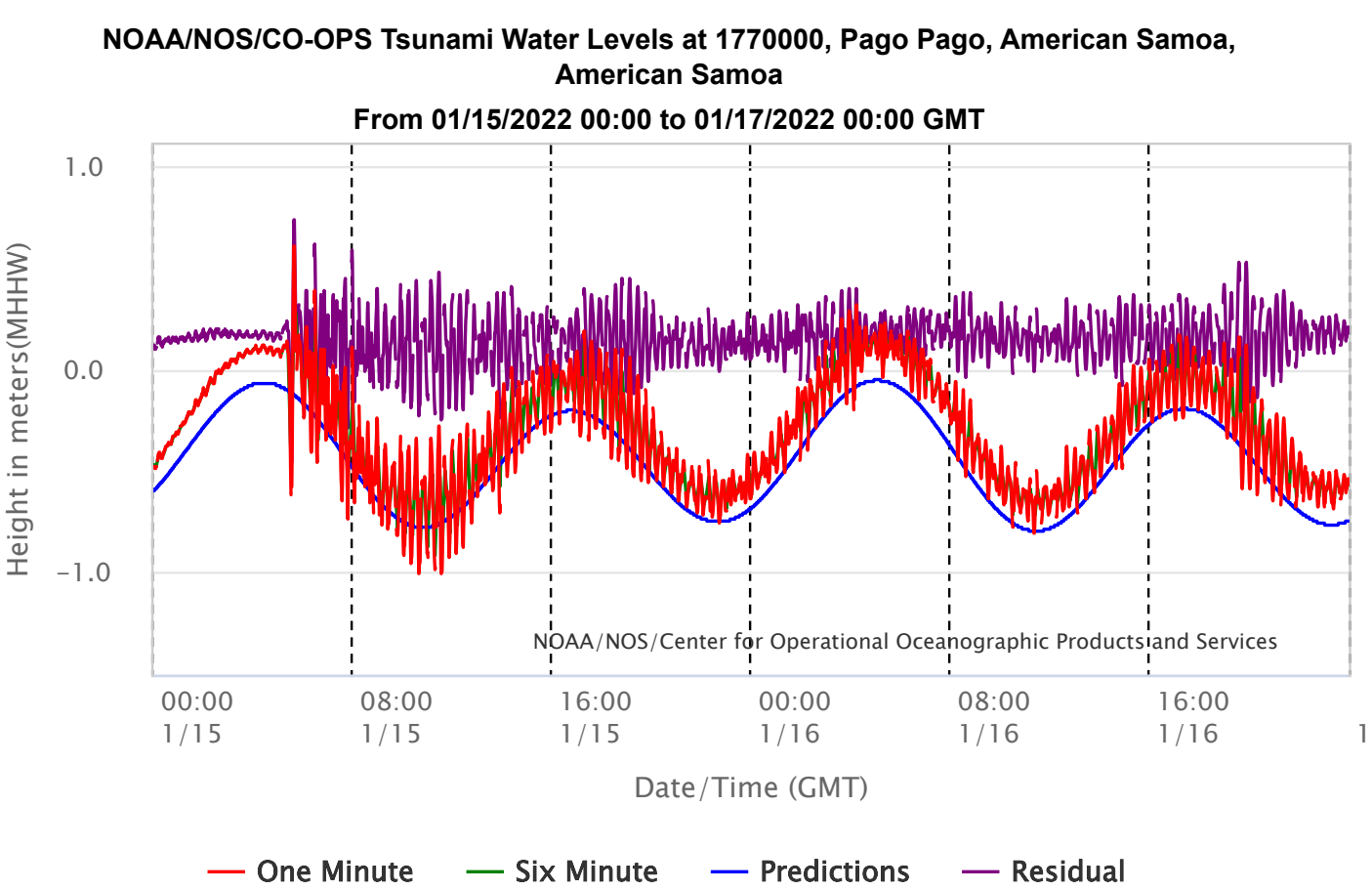
As a result of the January 15, 2022 eruption, CO-OPS measured significant preliminary peak water levels at the following stations in

the Pasifika *(Note: GMT time zone is the same as UTC time standard)*: (1) Pago Pago, American Samoa, (2) Nawiliwili, Hawaii, and (3) Kahului, Kahului Harbor, Hawaii.

Sea Level Data



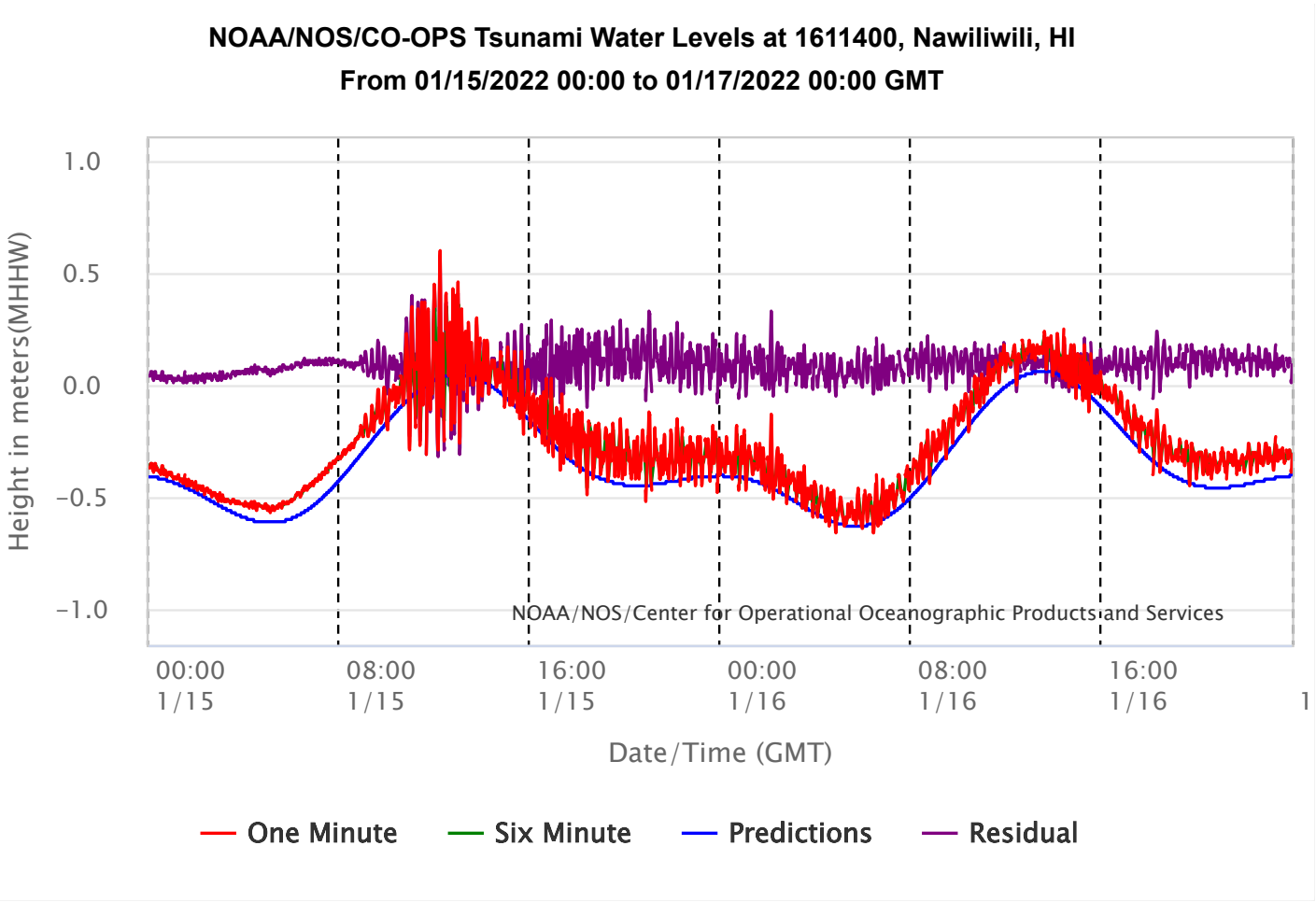
1 Pago Pago, American Samoa



Station ID 1770000

CO-OPS first observed the tsunami wave at its station in Pago Pago, American Samoa. Essentially the "watchstander" of CO-OPS, CORMS (Continuous Operational Real-Time Monitoring System) automated software and oceanographic technicians promptly detected high sea levels around 5:30 UTC (5:30 GMT on graph). Peak one-minute water level was 1.8 feet/0.74 m above Mean Higher High Water (MHHW) at 1/15/2022 5:38 UTC.

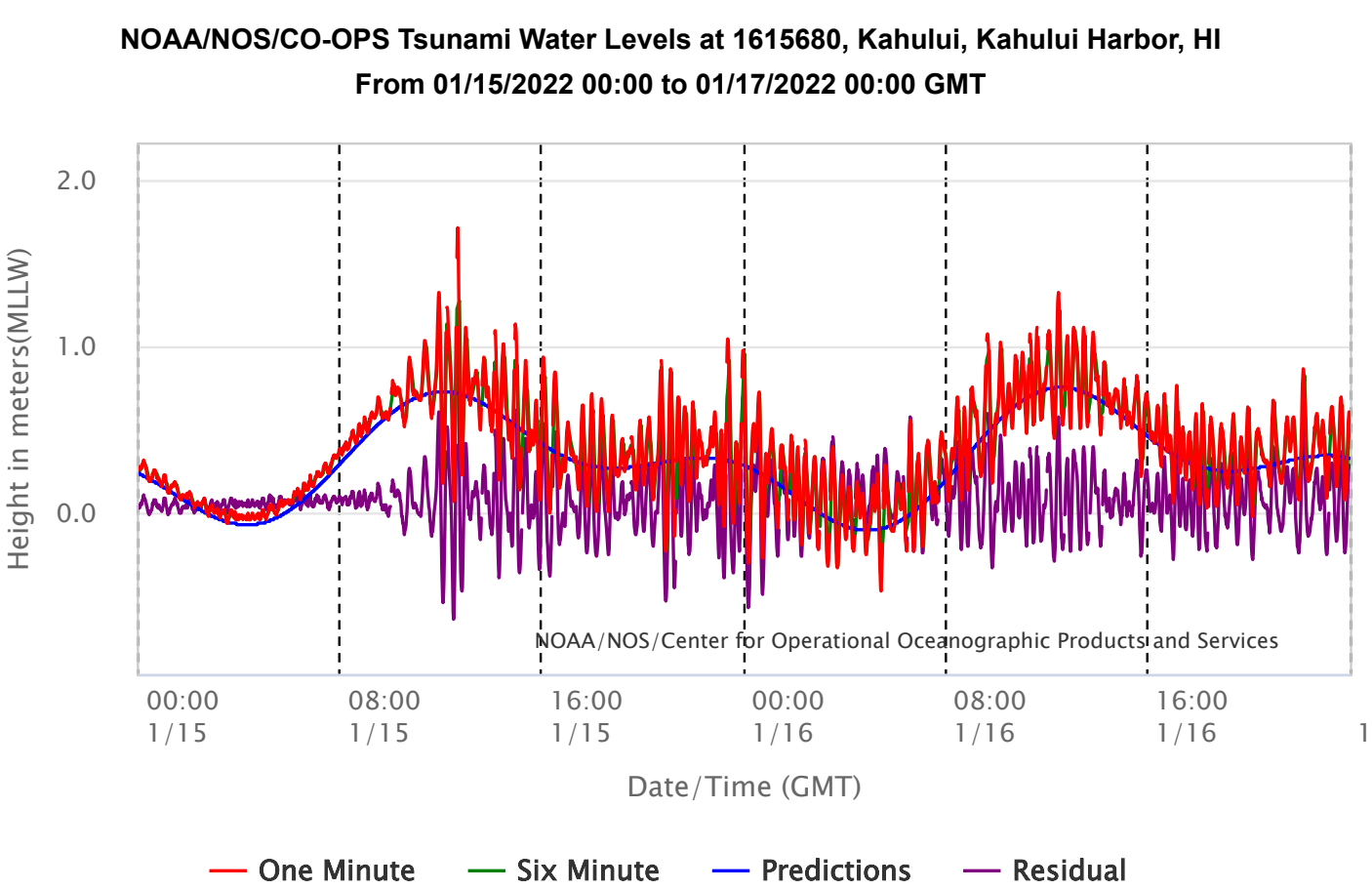
2 Nawiliwili, Hawaii



Station ID 1611400

Peak six-minute water level was 1.39 feet above MHHW at 1/15/2022 10:57 UTC. This is the second highest observed water level at this station behind only Hurricane Iniki (1992). The station dates back to 1954.

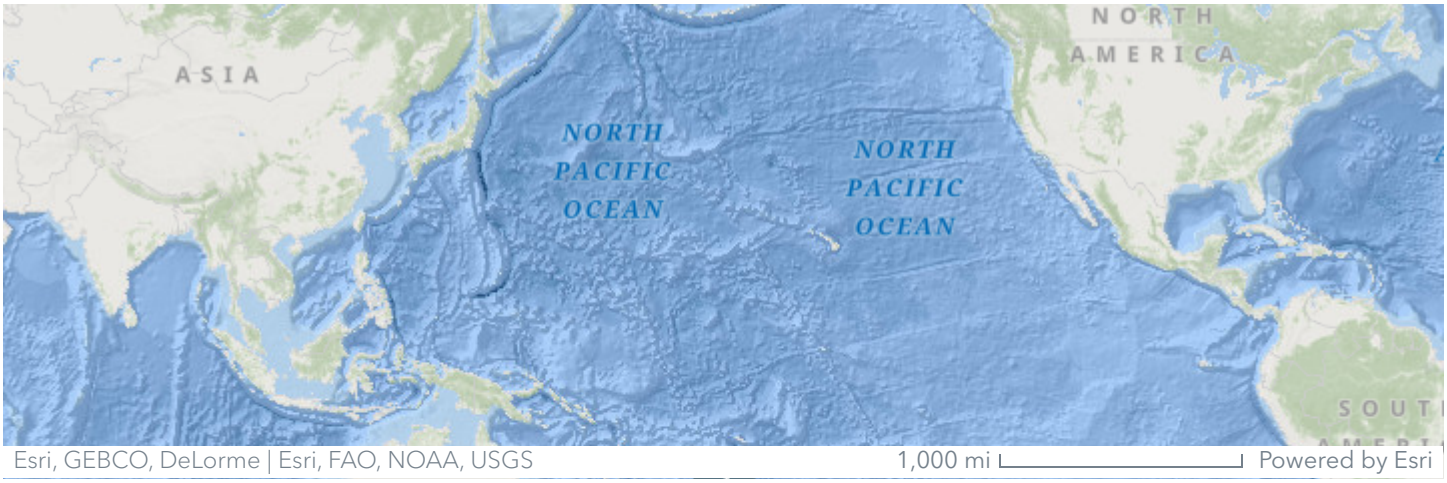
3 Kahului, Kahului Harbor, Hawaii



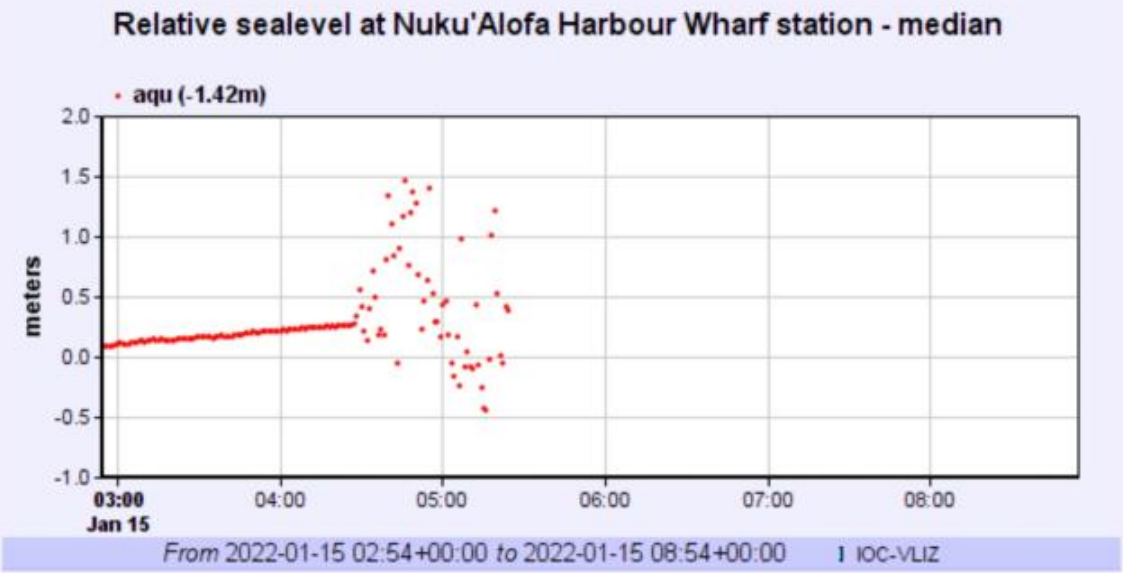
Station ID 1615680

Peak six-minute water level reached 1.99 feet above MHHW at 1/15/2022 11:36 UTC, which is a new record for this station. Verified hourly data dates back to 1954.

International tide and DART station operated by the Intergovernmental Oceanographic Commission of UNESCO (IOC/UNESCO) and Pacific Tsunami Warning Center in Tonga also recorded elevated water levels induced by the volcano.



4 Nuku'Alofa Harbor Wharf, Tonga

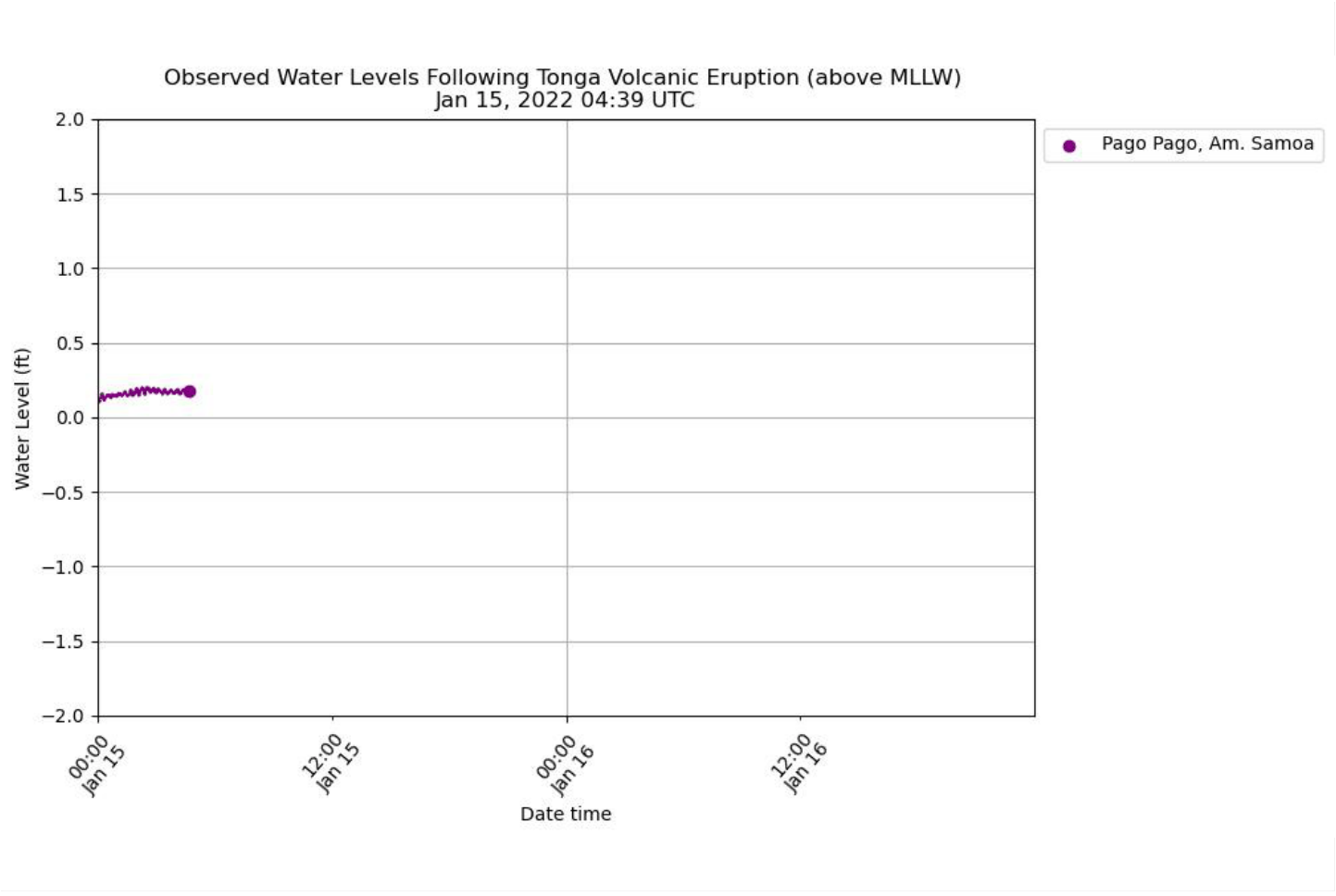


GLOSS ID 125

Tsunami waves reaching 9.44 feet/2.88 meters hit Nuku'alofa in the evening, around 1/15/2022 4:30 UTC. This relative sea level plot is from the UNESCO Intergovernmental Oceanographic Commission (IOC) Sea Level Station Monitoring Facility, using data from the Nuku'alofa Harbor Wharf, Tonga Island station monitored by National Tidal Centre/Australian Bureau of Meteorology (Australia).

Community Impacts

At the frontline of the explosion, low-lying coastal communities on Tongatapu, 'Eua, and the Ha'apai islands experienced major destruction. In addition to local damage, the eruption resulted in large waves and tsunami advisories that reached American Samoa, Hawaii, and other Pasifika coasts. **Scroll down to explore the hazard in real-time within these communities, starting with American Samoa.**



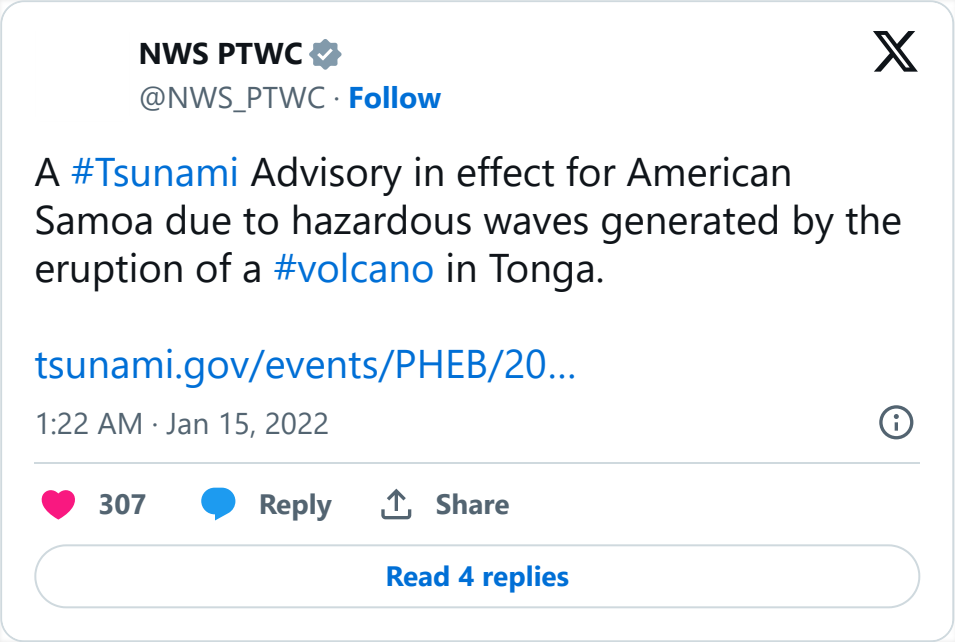
American Samoa

Friday, 1/14/2022

6:48 PM SST (Samoa Standard Time) *(5:48 UTC 1/15/2022)*

A tsunami advisory was in effect for American Samoa on Friday night, after the largest wave from the tsunami had already hit the

territory. Coastal villages were advised to stay out of the water and move away from the shore.



NWS PTWC on Twitter announcing tsunami advisory for American Samoa

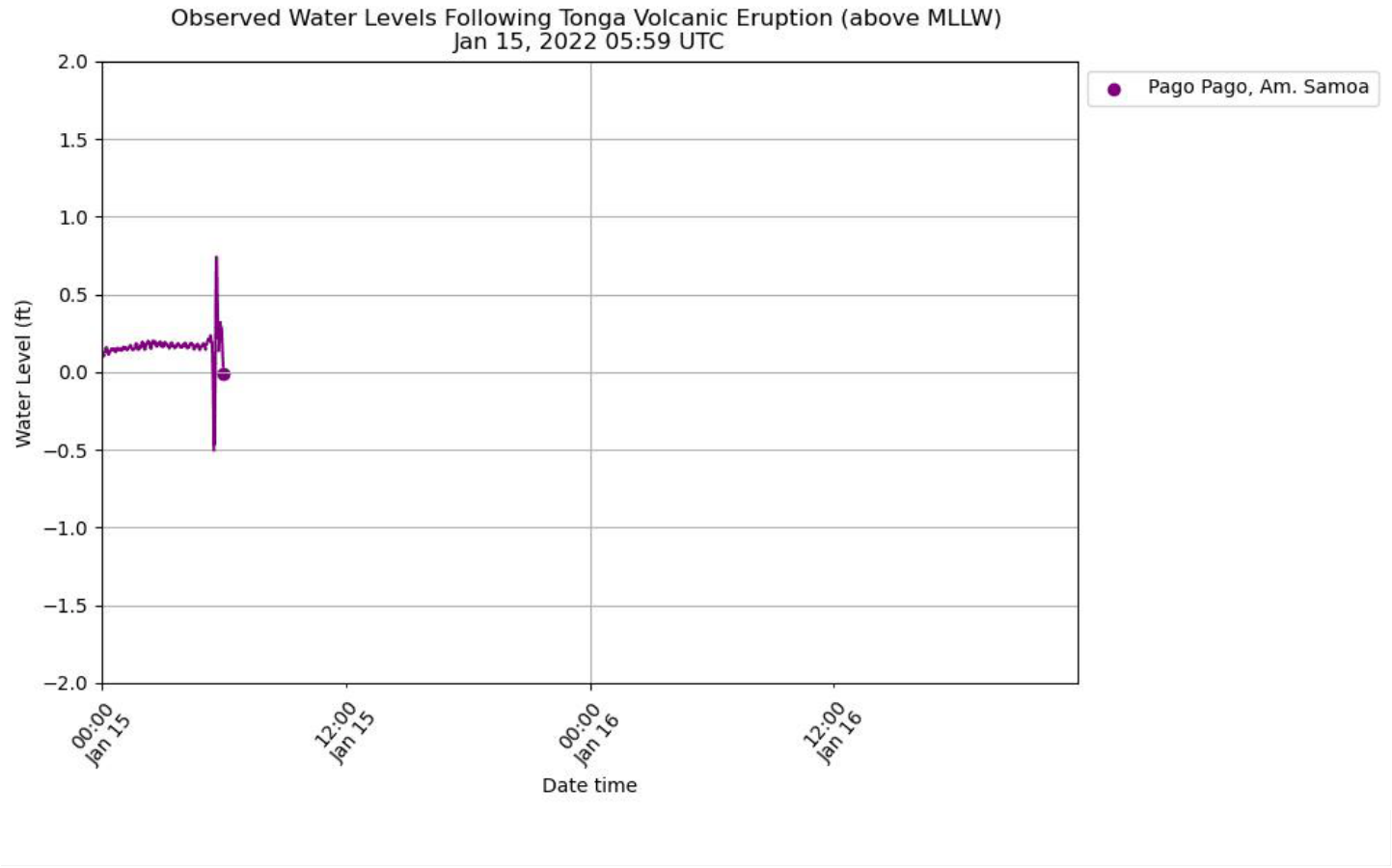
~ 7 PM SST *(6:00 UTC)*

After monitoring the threat for a while, the alert level escalated to a tsunami warning. By this point, families had observed fluctuating sea levels and strong currents. They were told by authorities to evacuate to higher ground or inland immediately.

US National Weather Service Pago Pago, AS announces tsunami warning on Facebook live

Word got around that some areas were experiencing coastal flooding. Roadways on Tutuila were quickly congested with vehicles, transporting families and households to the safe zone.

A resident in the village of Malaeimi films the resulting traffic jam



8:39 PM SST *(7:39 UTC)*

The tsunami warning was canceled. The PTWC reported that there is no further tsunami threat to American Samoa, based on all available data.

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WEZS40 PHEB 150739
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BULLETIN
TSUNAMI MESSAGE NUMBER 4
NWS PACIFIC TSUNAMI WARNING CENTER HONOLULU HI
839 PM SST FRI JAN 14 2022

...THE TSUNAMI WARNING IS NOW CANCELLED FOR
AMERICAN SAMOA...

IN THIS MESSAGE ARE REVISED ALERTS.


AUDIENCE
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EMERGENCY MANAGERS... MEDIA... GENERAL PUBLIC


EVALUATION
----------

  * A VOLCANIC ERUPTION OCCURRED IN
    THE TONGA ISLANDS AROUND 527 PM SST ON
FRIDAY JANUARY 14 2022.

  * A TSUNAMI WAS GENERATED BY THIS ERUPTION.

  * ALL AVAILABLE DATA NOW INDICATE THAT THE
TSUNAMI THREAT HAS
    PASSED ALTHOUGH SMALL SEA LEVEL
FLUCTUATIONS MAY CONTINUE.

  * BASED ON ALL AVAILABLE DATA... THERE IS NO
FURTHER TSUNAMI
    THREAT TO AMERICAN SAMOA FROM THIS
EARTHQUAKE ALTHOUGH MINOR
    SEA LEVEL FLUCTUATIONS MAY CONTINUE.


RECOMMENDED ACTIONS
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  * DO NOT RETURN TO EVACUATED AREAS UNTIL THE
ALL CLEAR IS GIVEN
    BY LOCAL AUTHORITIES.

  * FOLLOW ANY INSTRUCTIONS FROM GOVERNMENT
AGENCIES.

  * BE OBSERVANT AND EXERCISE NORMAL CAUTION IF
YOU ARE NEAR OR
    IN THE OCEAN.

  * OTHERWISE... NO FURTHER ACTION IS REQUIRED.
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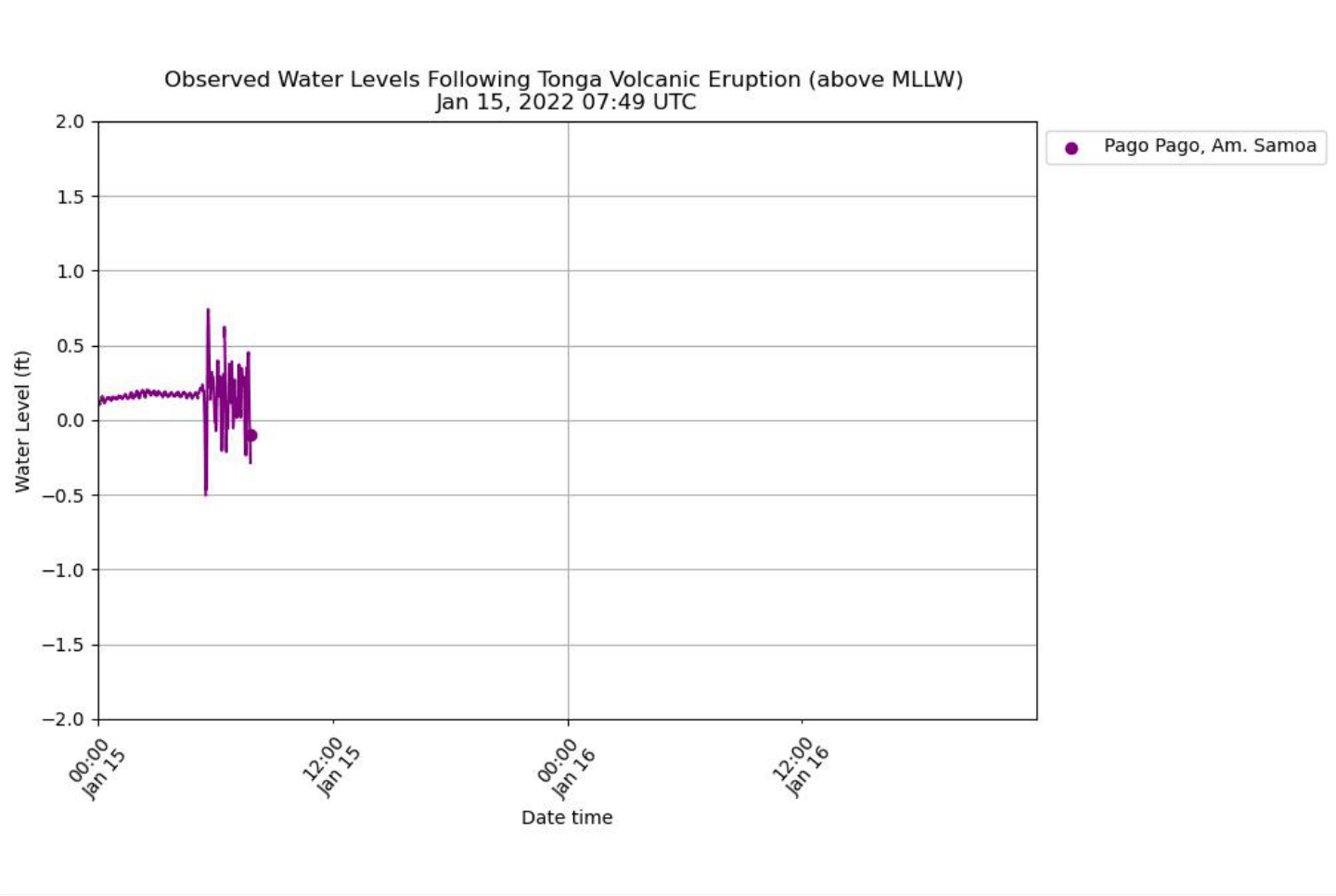
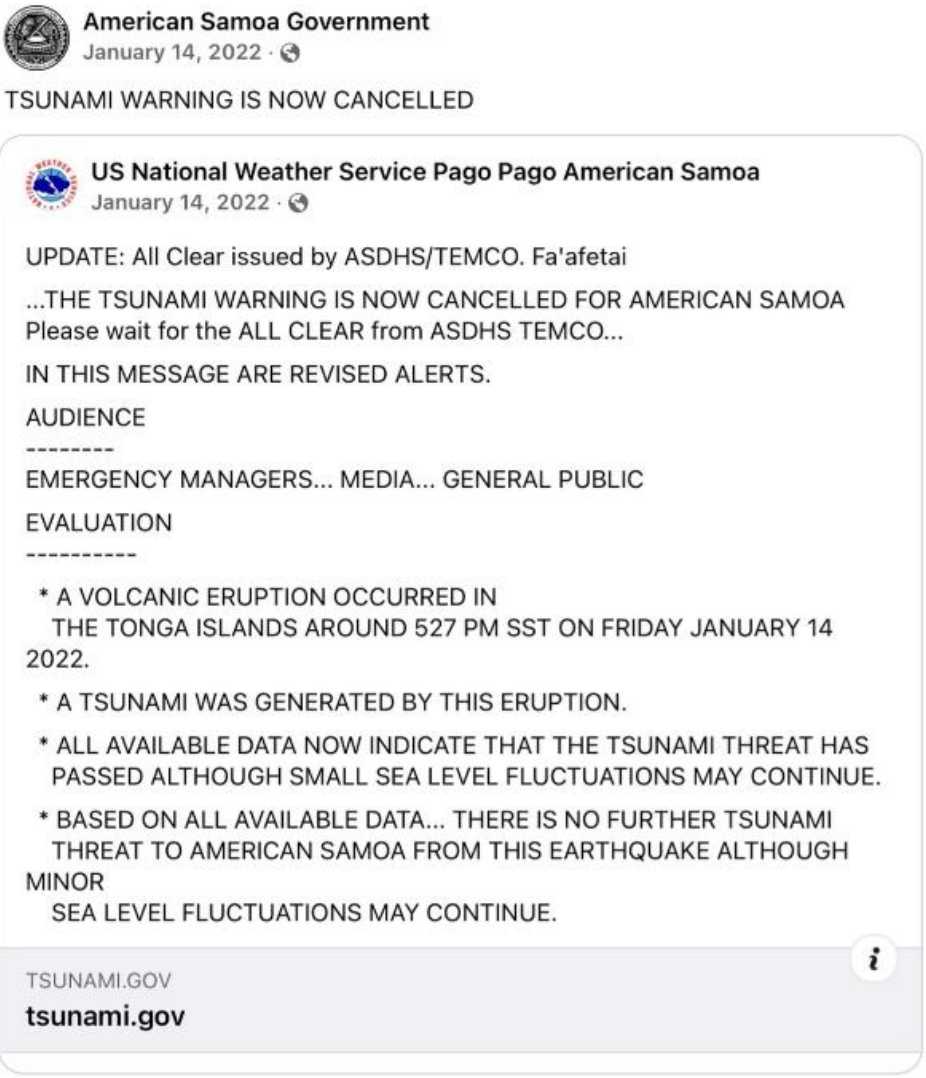
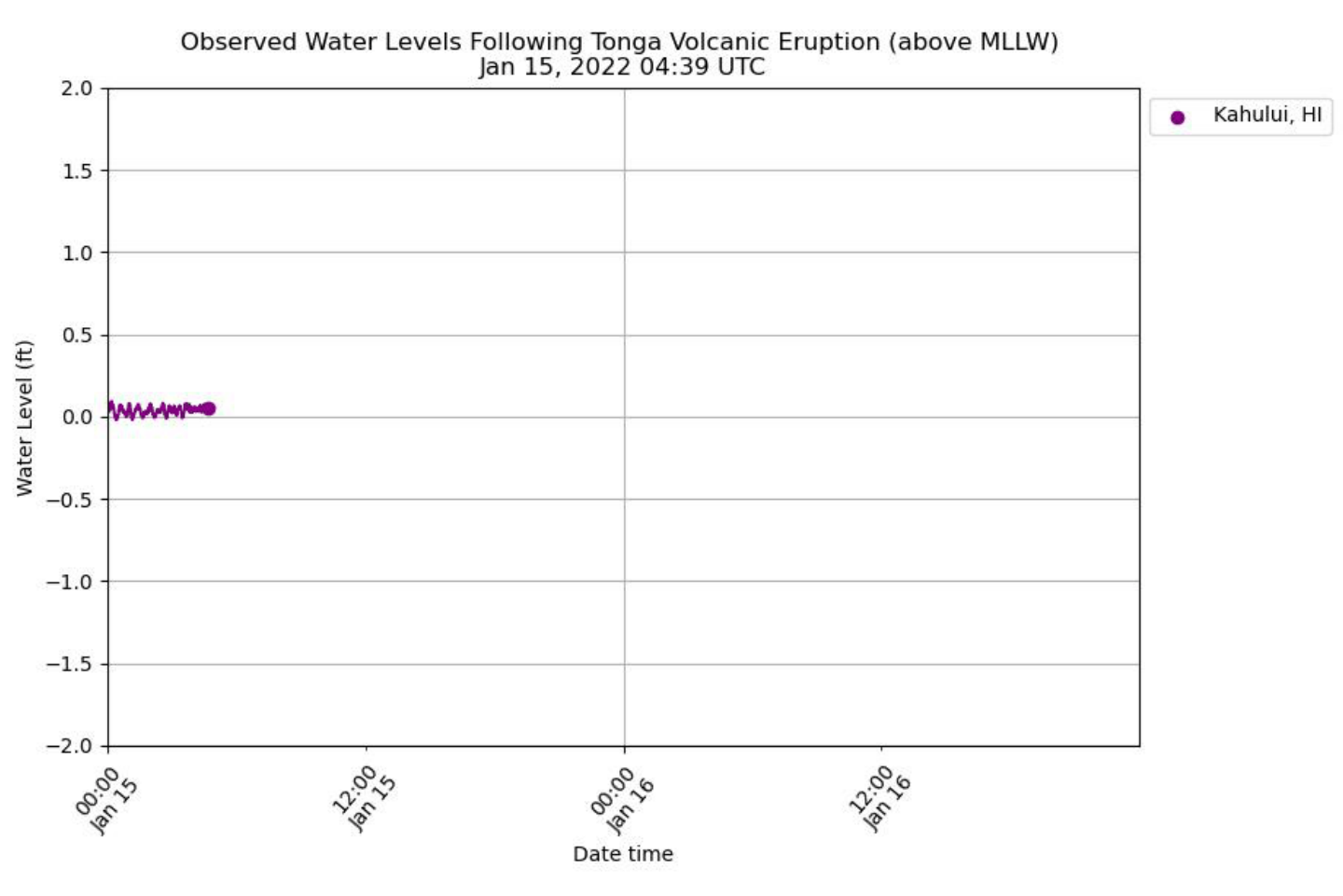


After the cancellation of the tsunami warning, sea levels continued to fluctuate. Residents were asked not to return to evacuated areas until local authorities have provided a clearance notice to the public.



Clearance was issued a few minutes later by the American Samoa Department of Homeland Security after the tsunami warning cancellation



Hawaii

Saturday, 1/15/2022

12:40 AM HST (Hawaii Standard Time) *(10:40 UTC 1/15/2022)*

A few hours after the tsunami warning was lifted for American Samoa, the Pacific Tsunami Warning Center (PTWC) issued a tsunami advisory for the State of Hawaii due to potential sea level changes and strong currents. The public was advised to stay alert of the situation.

1:51 AM HST *(11:51 UTC)*

The PTWC sent out a message indicating that the tsunami advisory would be continued in effect for Hawaii.

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WEHW40 PHEB 151151
TSUHWX

HIZ001-003-006>007-009-016>018-023-026-029>035-
037>050-051>054-
151351-
/O.CON.PHEB.TS.Y.0000.000000T0000Z-
000000T0000Z/

TSUNAMI MESSAGE NUMBER   3
NWS PACIFIC TSUNAMI WARNING CENTER HONOLULU HI
151 AM HST SAT JAN 15 2022

TO - EMERGENCY MANAGEMENT IN THE STATE OF
HAWAII

SUBJECT - TSUNAMI ADVISORY SUPPLEMENT

A TSUNAMI ADVISORY CONTINUES IN EFFECT FOR THE
STATE OF HAWAII.

A VOLCANIC ERUPTION OCCURRED WITH THESE
PRELIMINARY PARAMETERS

   ORIGIN TIME - 0627 PM HST 14 JAN 2022
   COORDINATES - 20.5 SOUTH  175.4 WEST
   LOCATION    - TONGA

MEASUREMENTS OR REPORTS OF TSUNAMI WAVE
ACTIVITY

 GAUGE LOCATION         LAT   LON    TIME
AMPL         PER
 -------------------  ----- ------  -----  ----
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 KAHULUI MAUI          20.9N 156.5W  1136Z
0.24M /  0.8FT  34MIN
 HONOLULU OAHU         21.3N 157.9W  1112Z
0.12M /  0.4FT  14MIN
 KAWAIHAE HAWAII       20.0N 155.8W  1132Z
0.37M /  1.2FT  10MIN
 BARBERS PT HI         21.3N 158.1W  1135Z
0.19M /  0.6FT  04MIN
 MAKAI PIER WAIMANAL   21.3N 157.7W  1128Z
0.28M /  0.9FT  10MIN
 HILO HAWAII           19.7N 155.1W  0929Z
0.10M /  0.3FT  16MIN
 NAWILIWILI KAUAI      22.0N 159.4W  1057Z
0.31M /  1.0FT  12MIN

 LAT  - LATITUDE (N-NORTH, S-SOUTH)
 LON  - LONGITUDE (E-EAST, W-WEST)
 TIME - TIME OF THE MEASUREMENT (Z IS UTC IS
GREENWICH TIME)
 AMPL - TSUNAMI AMPLITUDE MEASURED RELATIVE TO
NORMAL SEA LEVEL.
        IT IS ...NOT... CREST-TO-TROUGH WAVE
HEIGHT.
        VALUES ARE GIVEN IN BOTH METERS(M) AND
FEET(FT).
 PER  - PERIOD OF TIME IN MINUTES(MIN) FROM ONE
WAVE TO THE NEXT.

 NOTE - DART MEASUREMENTS ARE FROM THE DEEP
OCEAN AND THEY
        ARE GENERALLY MUCH SMALLER THAN WOULD
BE COASTAL
         MEASUREMENTS AT SIMILAR LOCATIONS.

EVALUATION

 TSUNAMI WAVES THAT CAN BE A HAZARD TO SWIMMERS
AND BOATERS AS
 WELL AS TO PERSONS NEAR THE SHORE AT BEACHES
AND IN HARBORS AND
 MARINAS ARE NOW AFFECTING THE STATE OF HAWAII.
THIS HAZARD COULD
 CONTINUE FOR SEVERAL HOURS. THE SITUATION IS
BEING MONITORED
 CLOSELY AND THE ADVISORY WILL END WHEN THE
HAZARD HAS PASSED.

FURTHER MESSAGES WILL BE ISSUED HOURLY OR
SOONER AS CONDITIONS
WARRANT UNTIL THE THREAT TO HAWAII HAS PASSED.

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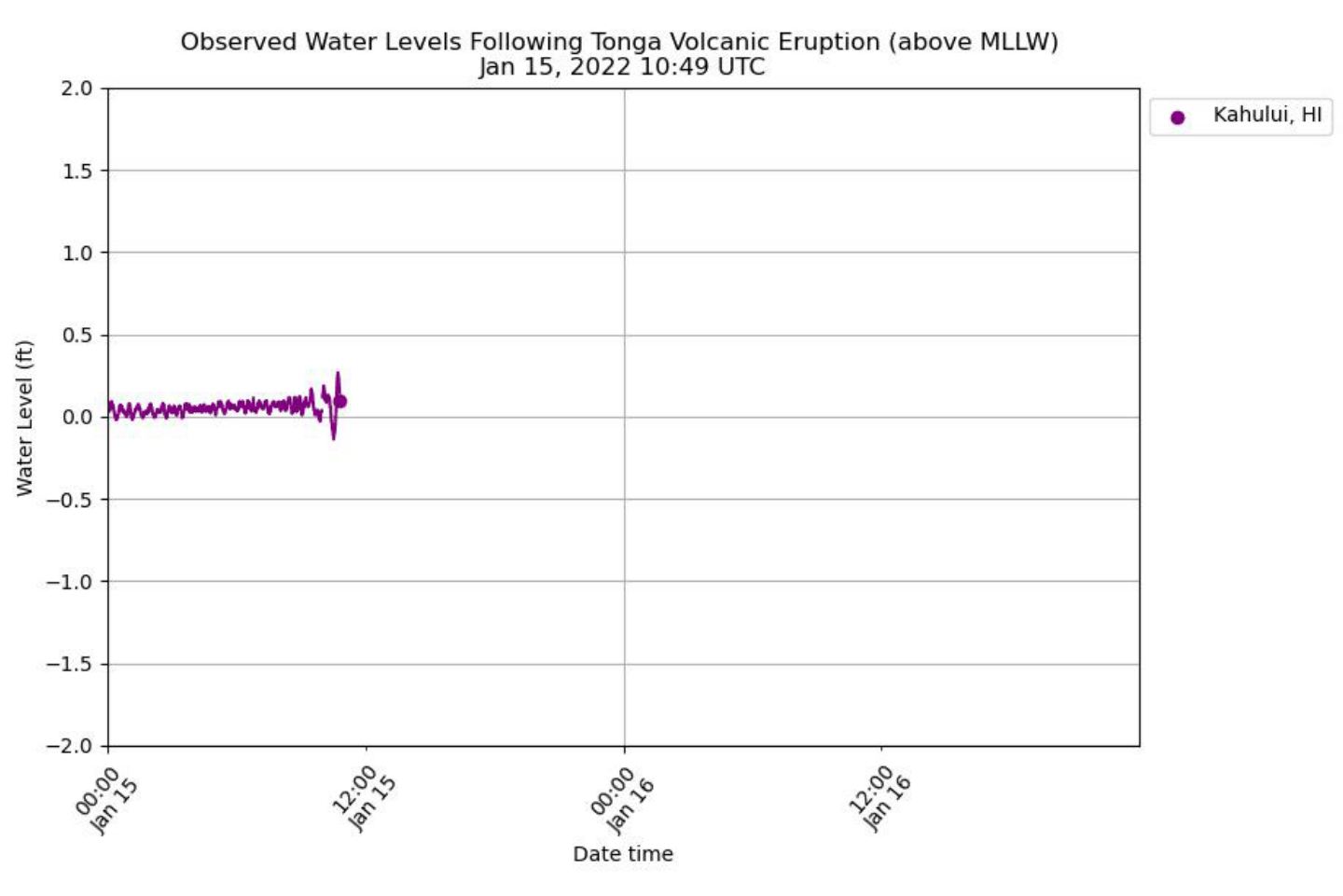
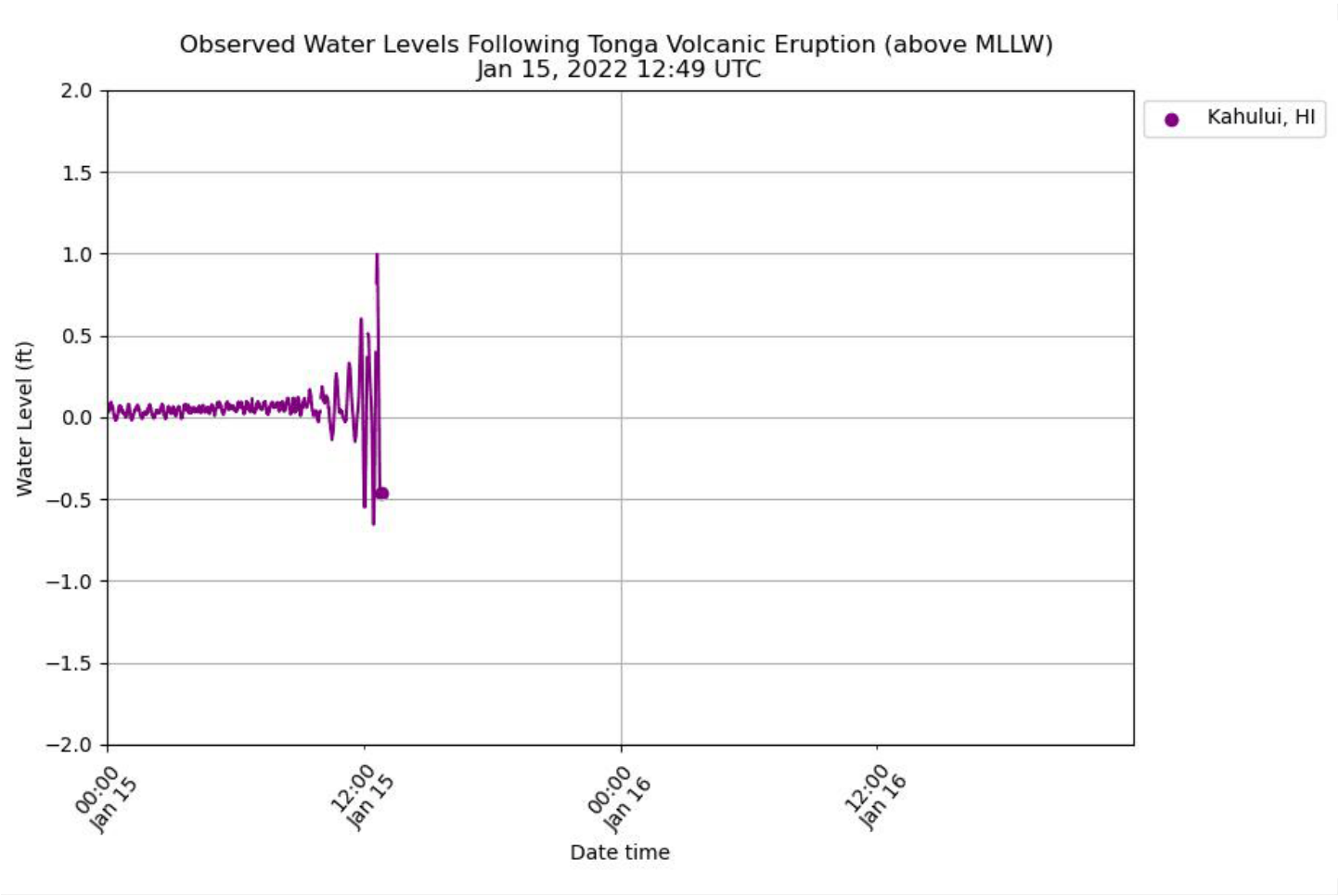


2:40 AM HST *(12:40 UTC)*

Hazardous waves were tracked and observed. In response, the State Emergency Operations Center at the Hawaii Emergency Management Agency (HI-EMA) was partially activated to monitor the evolving situation.

> Although no major tsunami was expected to strike Hawaii, the water displaced by the volcanic activity caused unusual sea level changes and alterations to typical sea currents. *HI-EMA, 2022*

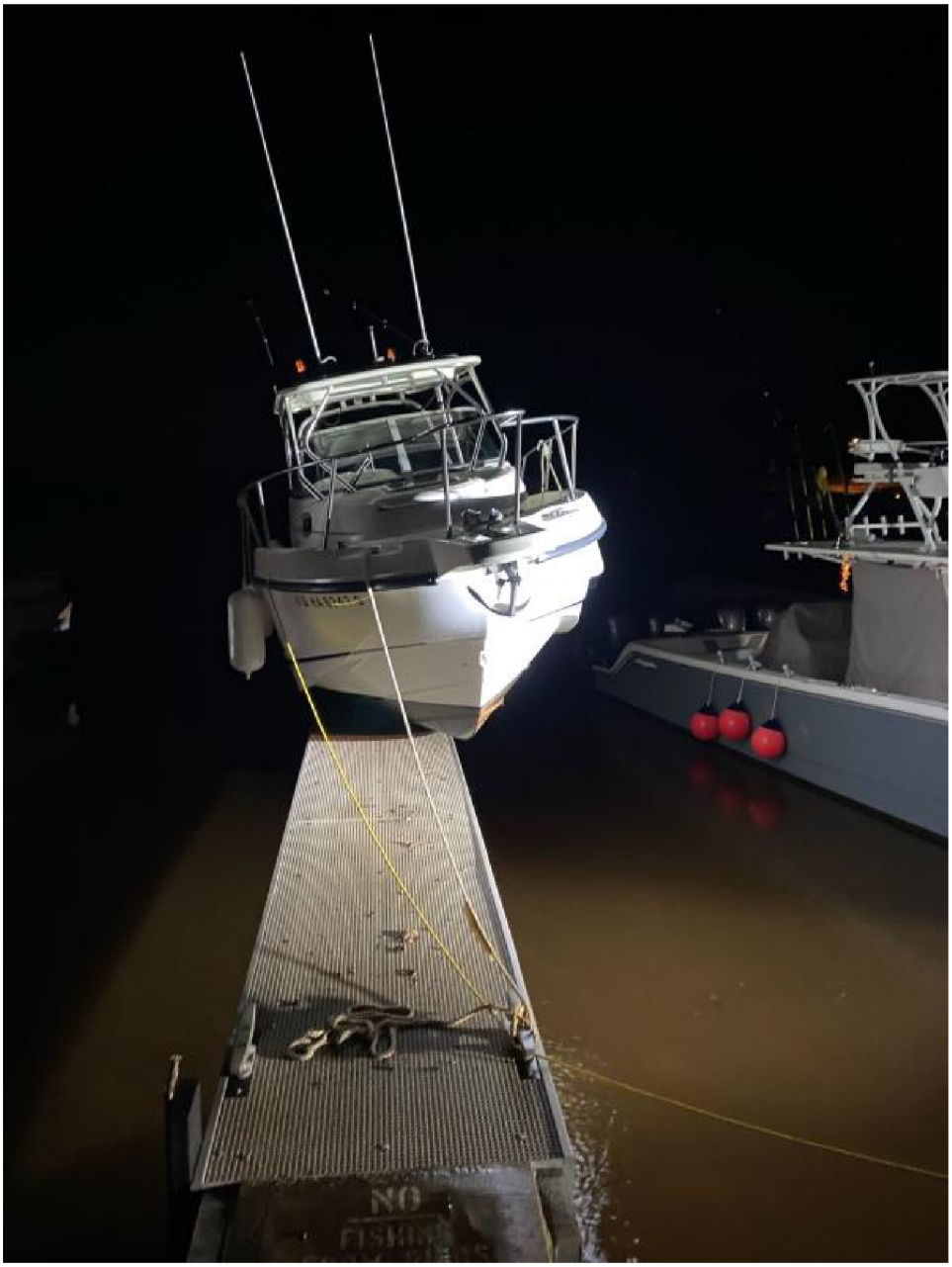


5:30 AM HST *(15:30 UTC)*

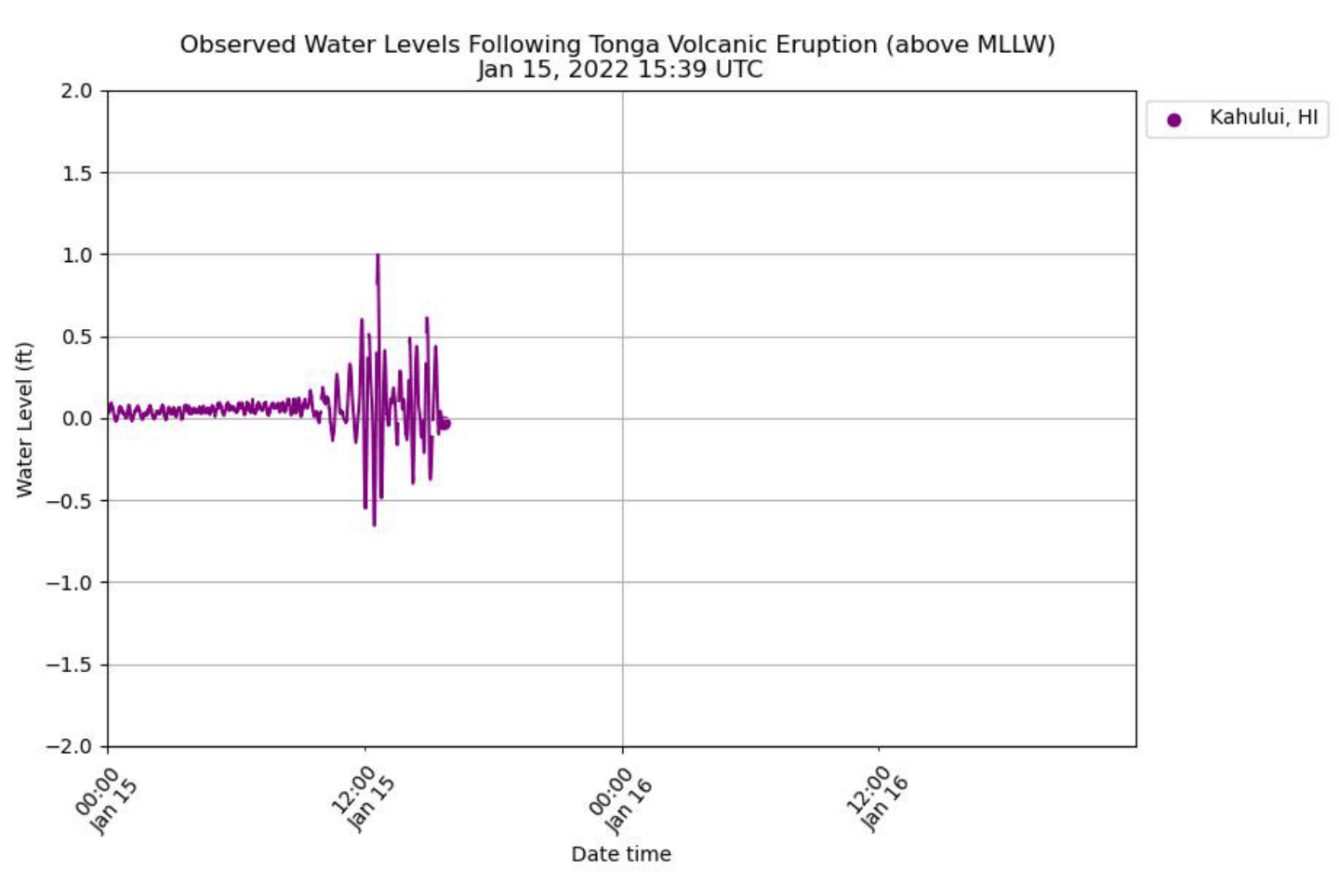
According to reports by the Maui Police, the water surge washed numerous tree logs and debris ashore. This caused the closure of the Haneoʻo Road in Hāna between Koki Beach and Hāmoa Beach, before reopening before 6 AM HST (16:00 UTC).

Tsunami waves reached Haneoo Road on Maui

Some areas experienced minor coastal flooding. On Maui, waves reportedly lifted a boat from its moorings.



Boat lifted by water surge at Manele Harbor in Maui



8 AM HST *(18:00 UTC)*

The tsunami advisory was canceled for Hawaii. The PTWC ensured the public that tsunami wave heights across the state were below advisory levels and progressively diminishing.

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 ZCZC
WEHW40 PHEB 151754
TSUHWX

HIZ001-003-006>007-009-016>018-023-026-029>035-
037>050-051>054-
151954-
/O.CAN.PHEB.TS.Y.0000.000000T0000Z-
000000T0000Z/

TSUNAMI MESSAGE NUMBER   8
NWS PACIFIC TSUNAMI WARNING CENTER HONOLULU HI
754 AM HST SAT JAN 15 2022

TO - EMERGENCY MANAGEMENT IN THE STATE OF
HAWAII

SUBJECT - FINAL TSUNAMI ADVISORY

THE TSUNAMI ADVISORY IS ENDED FOR THE STATE OF
HAWAII EFFECTIVE
AT 0752 AM HST.

A VOLCANIC ERUPTION OCCURRED WITH THESE
PRELIMINARY PARAMETERS

   ORIGIN TIME - 0627 PM HST 14 JAN 2022
   COORDINATES - 20.5 SOUTH  175.4 WEST
   LOCATION    - TONGA

EVALUATION

 TSUNAMI WAVE HEIGHTS ACROSS THE STATE OF
HAWAII ARE NOW BELOW
 ADVISORY LEVELS AND ARE CONTINUING TO
DIMINISH. BASED ON ALL
 AVAILABLE DATA THE PACIFIC TSUNAMI WARNING
CENTER IS NOW
 CANCELLING THE TSUNAMI ADVISORY. SMALL SEA
LEVEL CHANGES AND
 STRONG OR UNUSUAL CURRENTS MAY PERSIST FOR
SEVERAL ADDITIONAL
 HOURS IN SOME COASTAL AREAS AND APPROPRIATE
CAUTION SHOULD BE
 EXERCISED BY BOATERS AND SWIMMERS.

THIS WILL BE THE FINAL MESSAGE ISSUED FOR THIS
EVENT UNLESS
ADDITIONAL DATA ARE RECEIVED.

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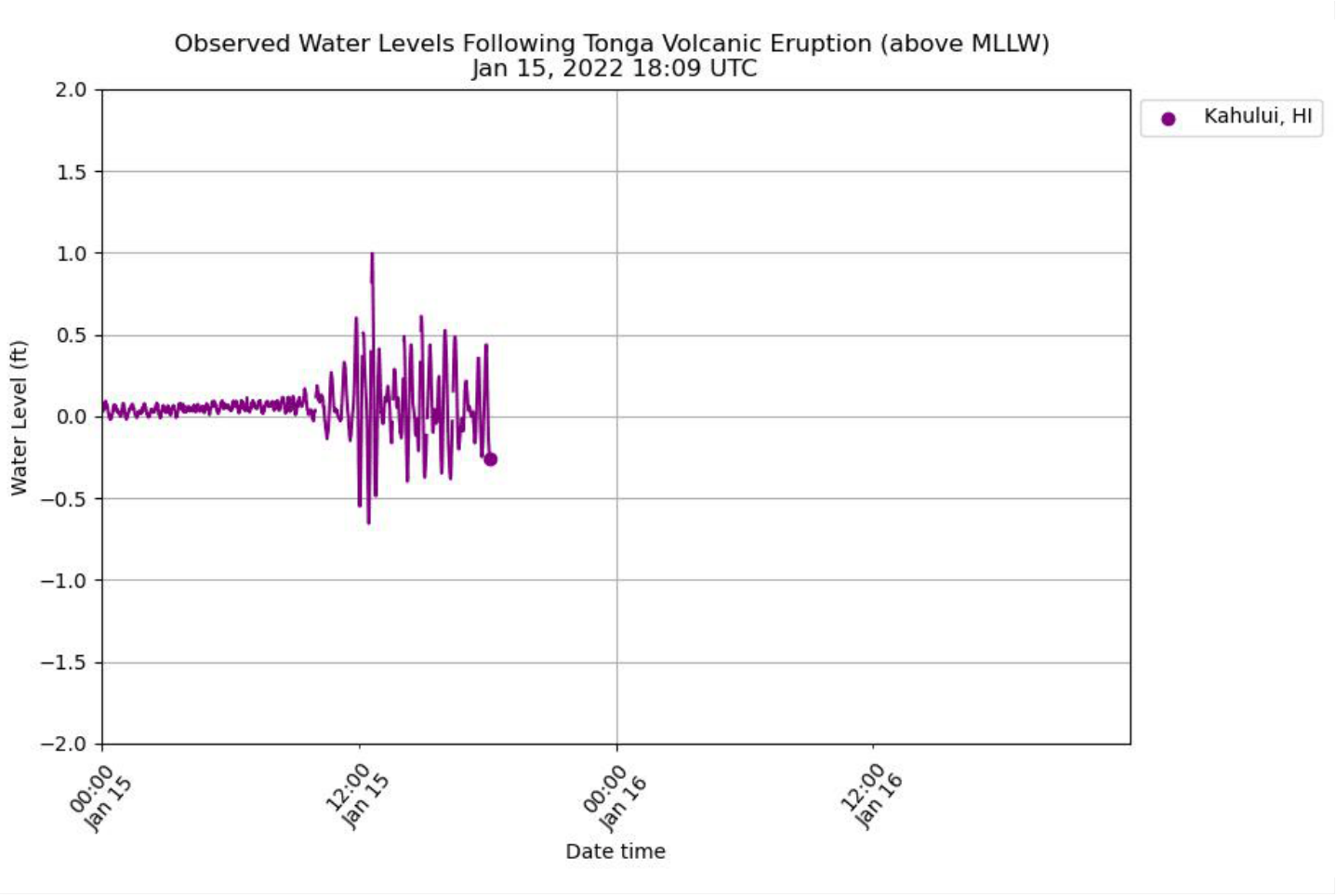
Source: Tsunami.gov

People were still warned that small changes in the sea level and strong currents could continue for several hours in some spots. Boaters and swimmers were especially advised to stay cautious.



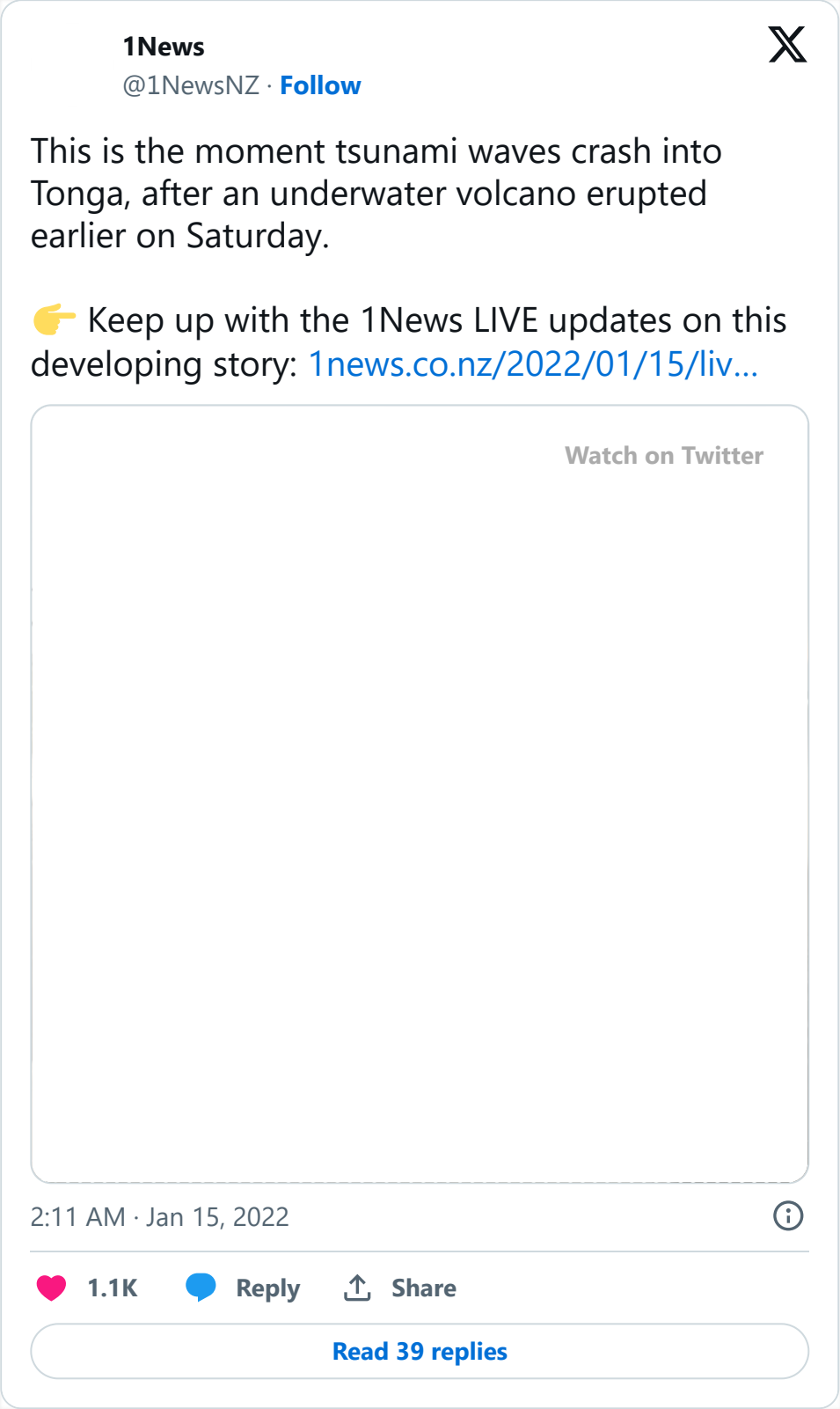
Unusual currents were still being reported statewide, even after the advisory was lifted. Assessment of impacts were ongoing according to local news outlets. Damage was relatively minimal in Hawaii overall.

> "The waves were going quite far but not quite so large, not the kind we saw in 2011 like Japan or like in 2009 in American Samoa… But certainly it is a hazard even at those smaller levels, pretty much on all coasts throughout the Pacific. *PTWC Director Chip McCreery, Hawaii News Now*

Tonga

Saturday, 1/15/2022

Unlike other parts of Pasifika, the physical, social, and economic aftermath of the eruption was severe.



1News on Twitter sharing video of tsunami waves reaching Tonga

More than half of Tonga's population were affected by the eruption, and the cascading tsunami and ashfall. Around 600 buildings were damaged or destroyed by the tsunami waves. Houses, roads, water

tanks, and other infrastructure on the west coasts of Tongatapu and 'Eua, and the Ha'apai island group were hard hit.

Livelihoods were disrupted as crops, livestock, and fisheries were impacted. Food insecurity was prevalent in areas most heavily hit, especially among low-income households.

There were three direct and one indirect fatalities attributed to the volcano and tsunami. Around 3000 people were displaced, including evacuations from seriously affected areas in Tongatapu and Ha’apai. While many subsequently returned to their communities, other families had to relocate.

The eruption consequently broke international and domestic undersea telecommunications. Therefore, most of the island nation was stranded without internet access and other forms of communication. This made external response and aid challenging, as little information from/to affected communities was available.

Tonga was still recovering from Cyclone Harold (2020), and Gita (2018), as well as the memory of Cyclone Ian (2014). The eruption also occurred in the middle of the COVID-19 pandemic, when flights and ferries were temporarily shut down to decrease exposure. The first local outbreak of the disease actually happened right after the disaster, thus exacerbating the effects of the eruption on residents.

Response & Resilience

Every year, the low-lying island communities of Pasifika are faced with natural disasters. From cyclones and earthquakes to tsunamis and volcanic eruptions, they are among the most vulnerable to natural hazards. Although highly vulnerable and limited in preparation and response means, Pasifika communities are also among the most resilient in such cases.

> "
>
> Okay hearing village bells for tsunami warning now.
> *Villager from Nu'uuli via Facebook 7:08 PM SST 1/14/2022 (6:08 UTC 1/15/2022)*

Upon receiving the news of a tsunami warning, villagers in American Samoa quickly spread the word by utilizing their traditional *sā*/curfew bell system. Traffic jams were observed as families started evacuating inland and to higher ground. Other locals made their way to the safe zone by foot. Evacuees

The island of Ta'u alerts villagers by ringing aumaga bells.
Source: Manu'atele Community Worldwide

temporarily stayed at their church facilities, relatives' homes, or within their vehicles until the warning was canceled.

When modern sirens in the tsunami warning system failed to alert the public, the village became the system as per usual. Bells clanged from almost every village and drivers on the road honked their car horns to let everyone else know about the emergency. Others shouted and called people within their districts to evacuate. Police sirens were also activated around the same time with patrol cars on the road informing as many people as possible.

While waiting for further updates, evacuees from some villages (i.e. Laulii) shared feelings of hope and gratitude. It is evident that many villagers remained God-fearing and faithful, while waiting for further updates and instructions from the Pacific Tsunami Warning Center (PTWC) and local authorities.

> "For this natural hazard that we are waiting for, let's not be frightful. We just need to be steadfast and immovable. When things like this happen, it is necessary that we keep our heads up high. *Evacuee in Lauli'i via Soleeh I-Films*

Soleeh I-Films managed to interview locals and film clips of evacuees at the Assembly of God facility in Lauli'i during the tsunami warning. Featured here are some snapshots of his work, allowing us to experience evacuation from the perspective of one coastal community. **Click to expand each of the images. Full video is linked in the caption.**

Residents of Lauli'i evacuated to the Assembly of God church facility after being informed about the tsunami warning on the island of Tutuila. Watch full video here.

According to personal accounts, not all sirens in Tonga worked either. Many of the people had to react as soon as they saw a sign or two of the disaster. Whether it be the first wave approaching them or hearing the explosion itself, the residents on the affected islands took notice immediately and evacuated.

> "This is before the first bang. The waves pushed in, went out, and came back a bit stronger. I called (my husband), 'Pick me up; the sea is very weird. I think there's going to be a tsunami.' *Tukuafu via Ordinary Tongan Lives*

"Ordinary Tongan Lives," a social media platform for Tongans to share their stories, provide crucial insights into community

resiliency. Mothers sheltered their children from the cascading ashfall using the clothes off their backs. Men were out rescuing those who were swept away by the tsunami. Rescue boats transferred people to temporary shelters and/or back to their homes. Families started cleaning right after the disaster. Local communities sought to help those who were severely impacted, by sending clothes and food inter-island. Through probably the most agonizing days of their lives, Tonga remained faithful, compassionate, and resilient.

Residents of Mu'a donating clothes and food to send to Ha'apai (Ordinary Tongan Lives)

Check out the stories of some of the survivors, as collated and transcribed by Haitelenisia Afemui 'Uhila Angilau (Creator/Founder of Ordinary Tongan Lives), by using the left and right arrows to scroll through the pictures. These personal accounts truly encompass how people of Pasifika communities often see beauty and strength through these occurrences. Links to full interview transcriptions are embedded in the slideshow.

Now, we don't talk of injuries or inabilities, we just count blessings. (Ordinary Tongan Lives)

All we have to do is move forward. (Ordinary Tongan Lives)

We will rebuild. It's where we live and what we do.

(Ordinary Tongan Lives)

Together, we gathered for another prayer of thanksgiving. (Ordinary Tongan Lives)

We see so much devastation yet we also see a lot of beauty. (Ordinary Tongan Lives)

We're just grateful we're alive. The important thing is that we didn't wait to see it before we left. (Ordinary Tonga Lives)

Lessons Learned

Besides highlighting the resiliency of the Pasifika islands, the 2022 HTHH eruption also revealed the vulnerabilities of our global tsunami warning and telecommunication systems. Here are some of

the things we can learn from utilizing Pasifika narratives and NOAA data collaboratively:

- Forecasting models and warning systems do not account for the shockwave caused by the underwater volcanic eruption that boosted water levels and waves. Consequently, forecasters at the responding to this event had to modify the forecast models on the fly, in order to alert coastal communities of the potential arrival times of tsunami waves. This event may precipitate understanding and integration of shockwaves into current tsunami hazard and wave modeling efforts to improve accuracy.
- There is a need for more resilient critical infrastructure. If communication networks, transportation systems, and power utilities were not disrupted, the disaster would not have exacerbated as it did.
- The knowledge, lived experiences, and connections of communities is equally important to disaster response and resiliency as our scientific capabilities.

Additional Information

Understanding a unique tsunami event caused…

On January 15, 2022, the Hunga Tonga-Hunga Ha'apai volcano erupted off the coast of Tonga in the South…

https://www.pmel.noaa.gov/news-story/understanding-unique-tsunami-event-caused-tonga-volcano-eruption

In depth: Surprising tsunamis caused by explo…

A volcanic eruption in Tonga on 15 January 2022 surprised scientists by triggering two types of tsunamis:…

https://www.usgs.gov/centers/pcmsc/news/depth-surprising-tsunamis-caused-explosive-eruption-tonga

Global Volcanism Program | Hunga Tonga-Hu…

The small andesitic islands of Hunga Tonga and Hunga Ha'apai are part of the western and northern remnants…

https://volcano.si.edu/volcano.cfm?vn=243040

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Tides & Currents Home Page. CO-OPS provides the national infrastructure, science, and technical expertise…

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