A satellite image of Tonga showing a volcanic eruption and tsunami. The image displays a large, dark, irregularly shaped area in the center, likely representing the volcanic eruption. The surrounding area is a mix of green and brown, indicating land and vegetation. The image is tilted slightly to the right.

Satellite Images of Tonga Volcanic Eruption and Tsunami 2022

Evolution of Disaster Risk Reduction Information Transmission

15 June 2022

ARAKIDA Masaru

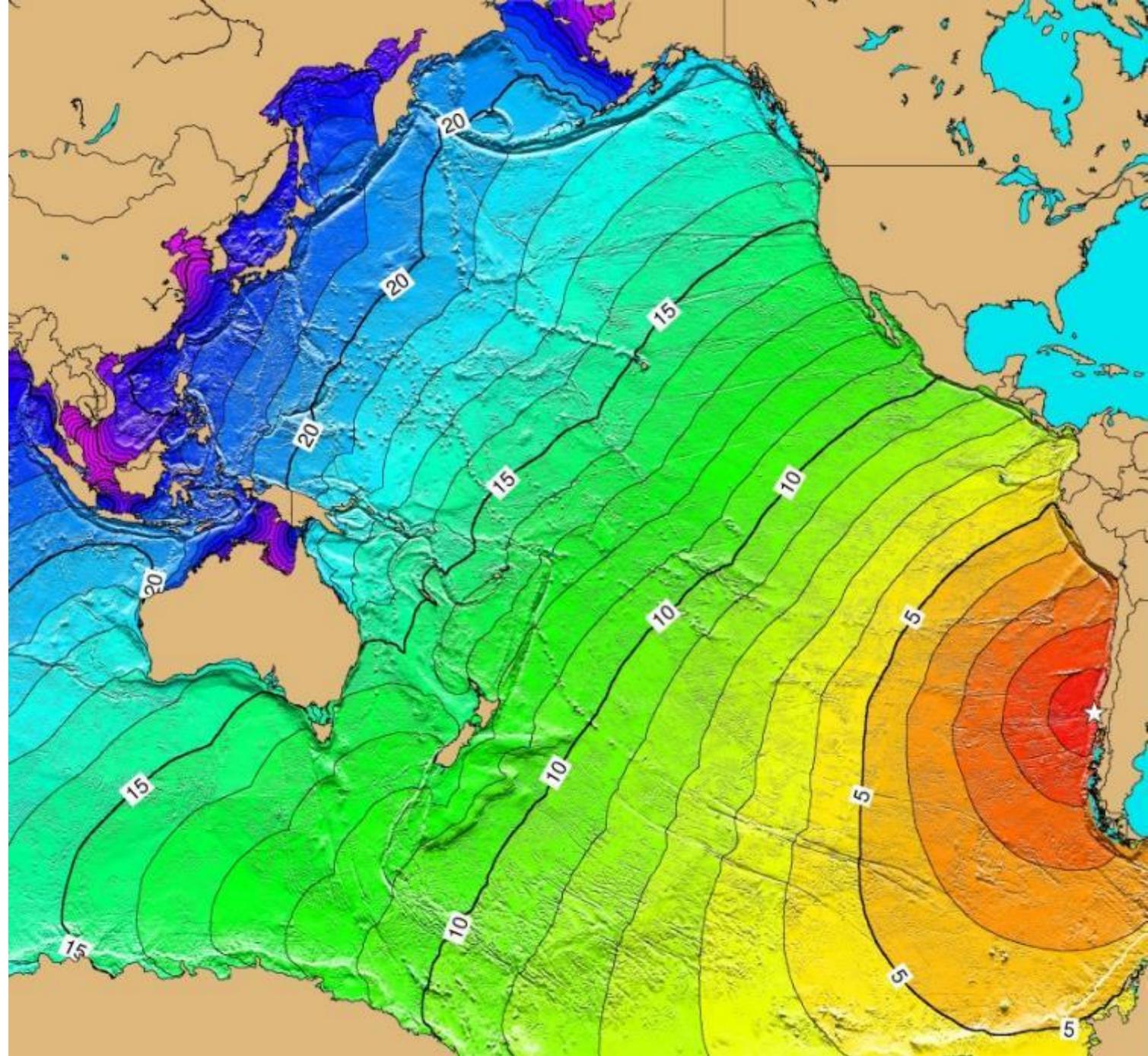
Asian Disaster Reduction Center (ADRC)

1960 Valdivia earthquake

- Local date 22 May 1960
- Local time 15:11:14
- Magnitude 9.5 Mw
- Depth 33 km
- Max. intensity IX
(Extreme)

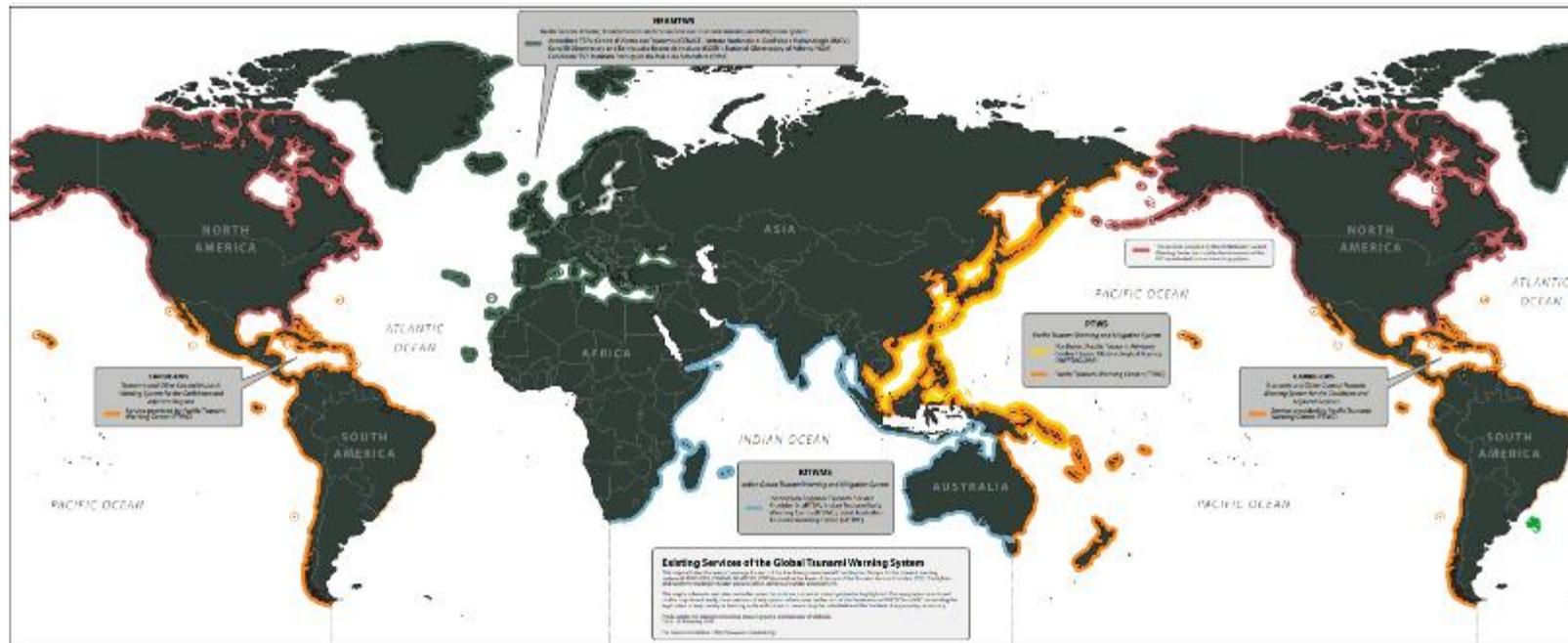
Japan

- Tsunami height: 6.1m
- Death : 154
- Reached 22.5 hours later
- Tsunami warning issued
after the first wave.



ICG/PTWS : Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System

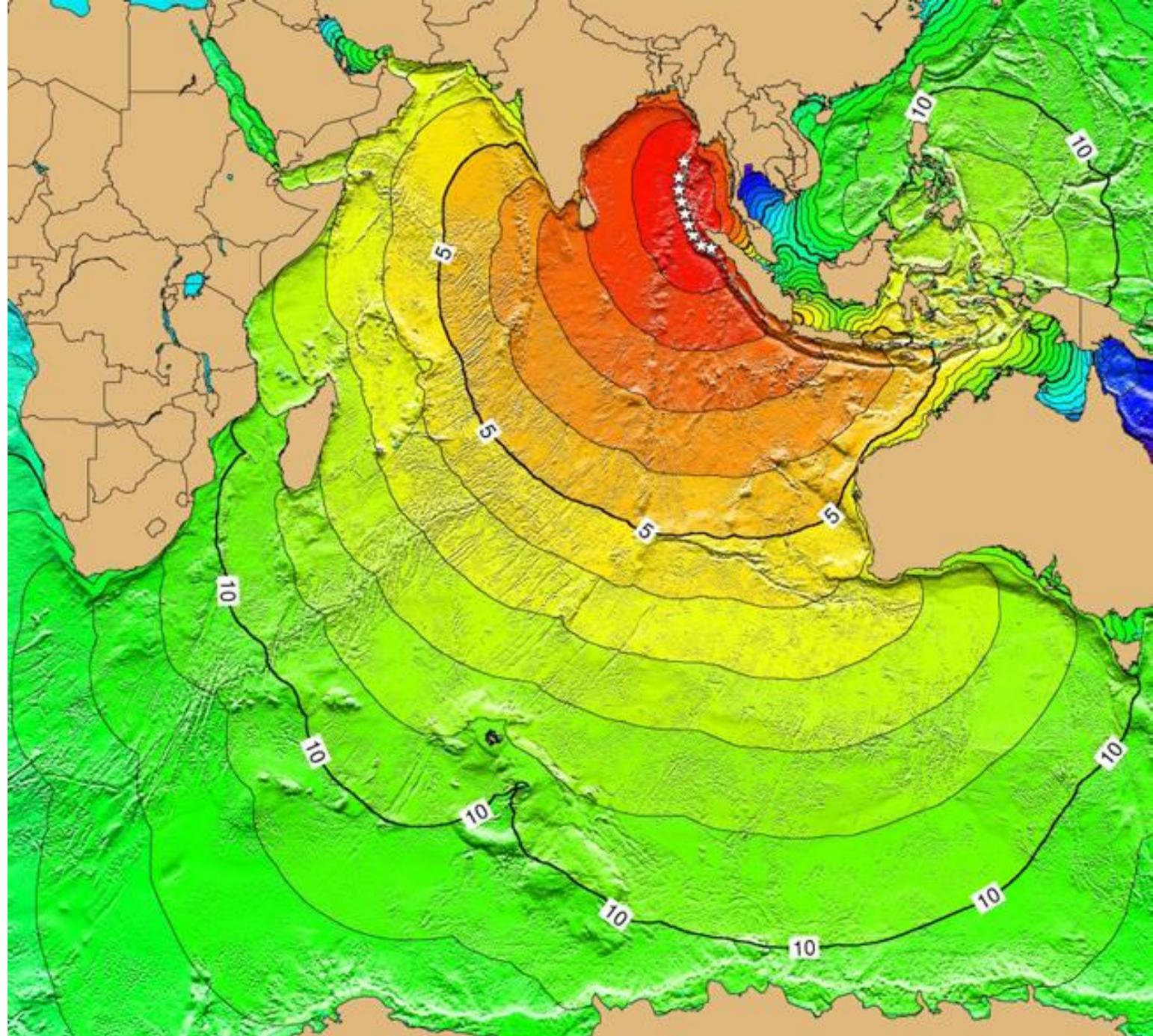
- After the 1960 Valdivia earthquake/tsunami, ICG/PTWS was established in 1965 as the ICG/ITSU for International Tsunami. It is one of the most successful international scientific programmes with the direct humanitarian aim of mitigating the effects of tsunami to save lives and property.



2004 Indian Ocean earthquake and tsunami

- Local date 26 Dec 2004
- Local time 07:58:53
- Magnitude 9.1-9,4 Mw
- Depth 30 km
- Max. intensity XII (Violent)

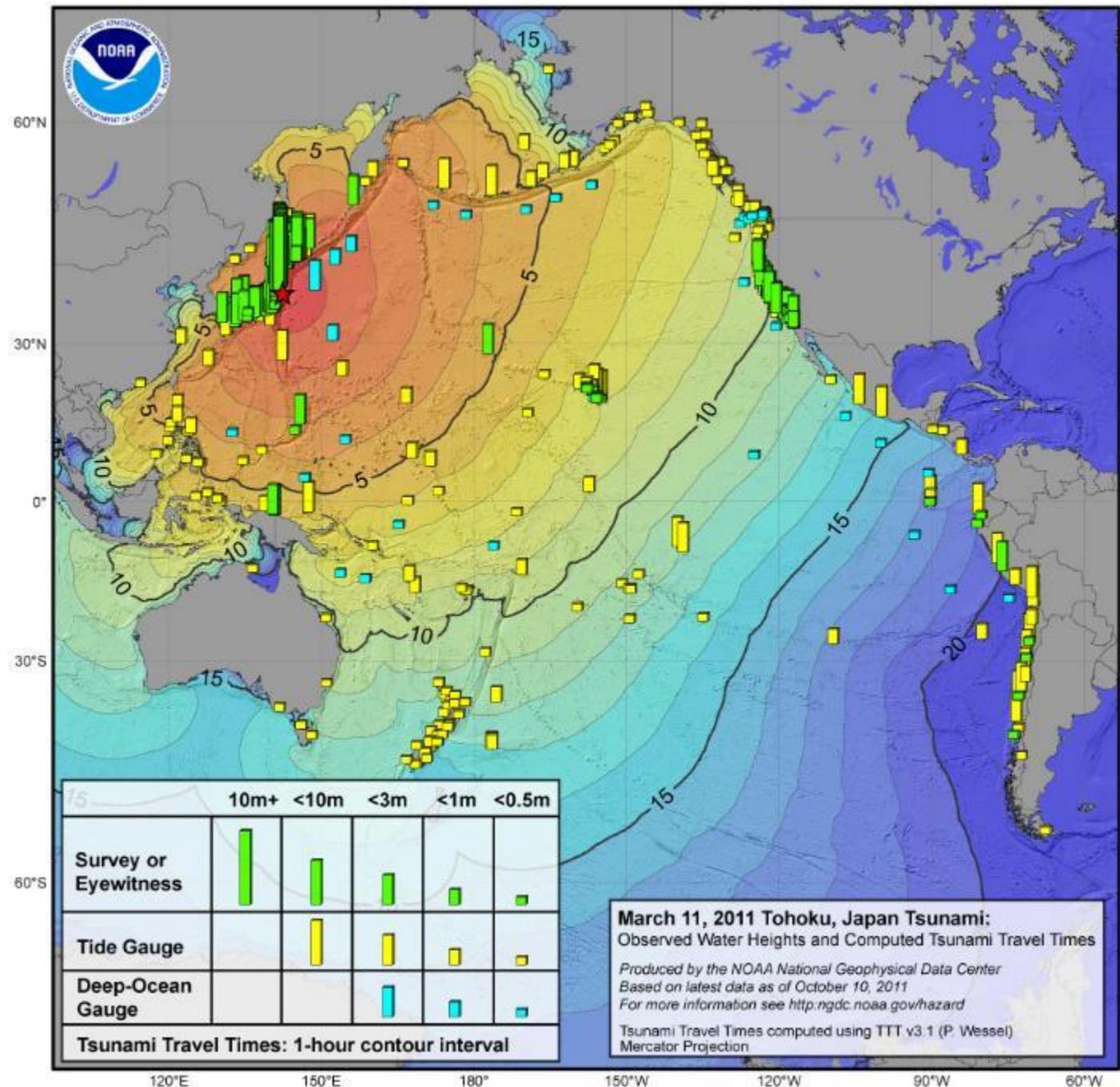
- No tsunami warning systems in the Indian Ocean
- IOTWS(Indian Ocean Tsunami Warning and Mitigation System) was established.



2011 Tohoku Japan tsunami

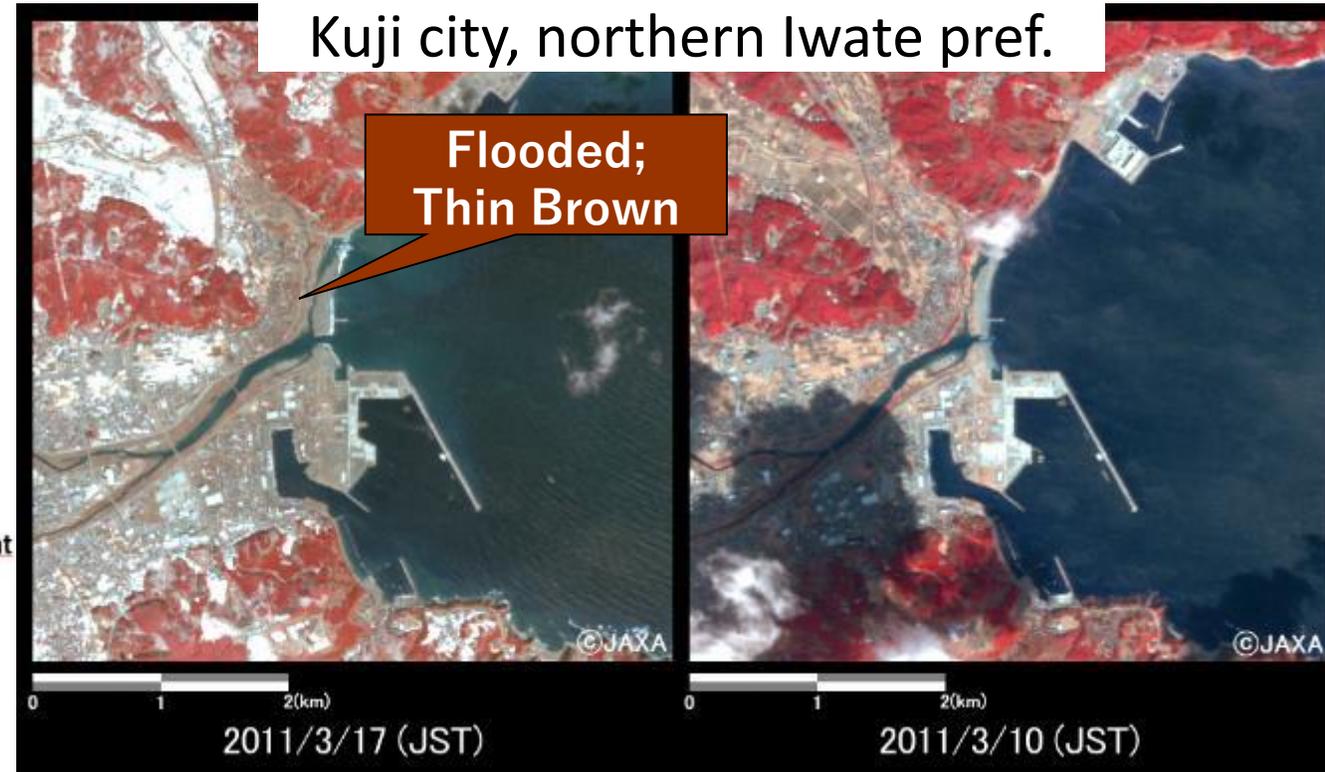
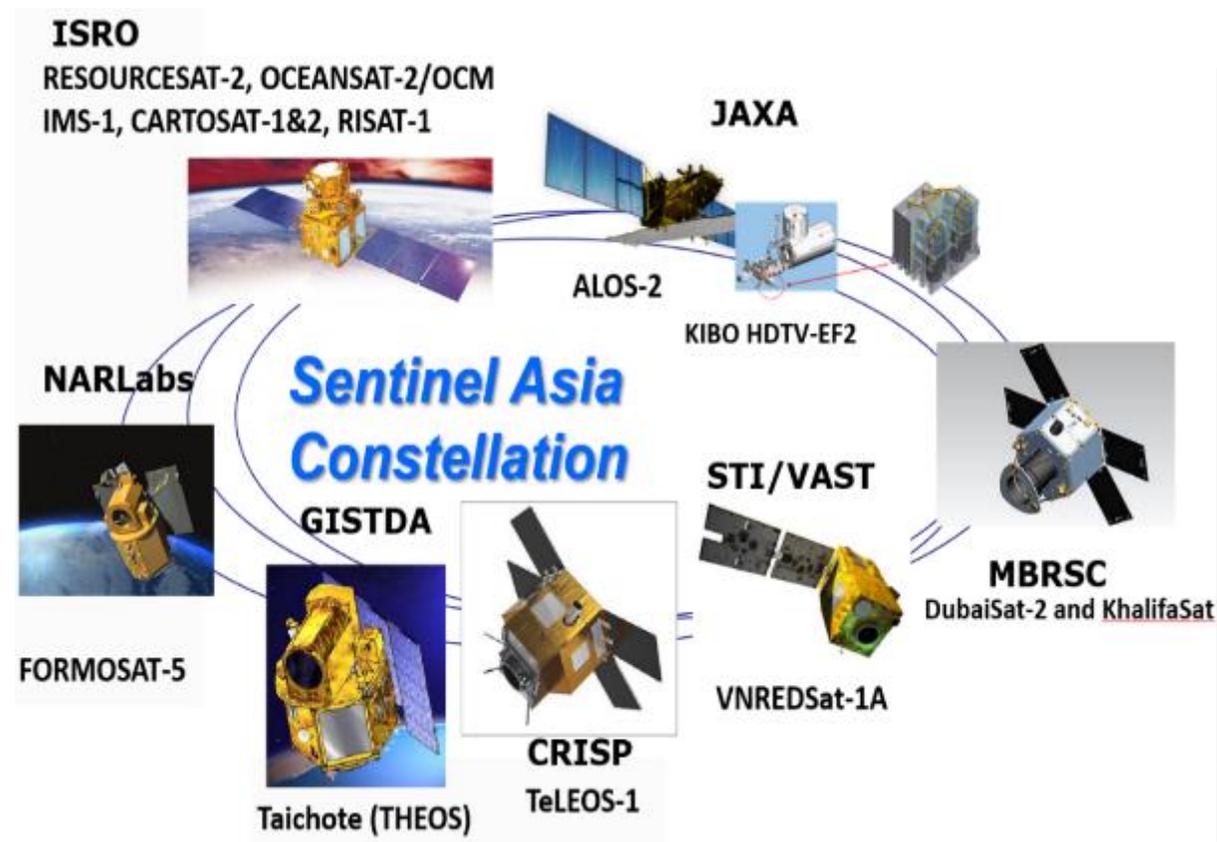
- Local date 11 Mar 2011
- Local time 14:46:24
- Magnitude 9.0-9.1 Mw
- Depth 29 km
- Max. intensity XII (Violent)

- Earthquake Early Warning was issued before S-wave reaching
- The estimated heights were lower than actual tsunami.
- Sentinel Asia project provided many satellite image and data for DRR/DRM

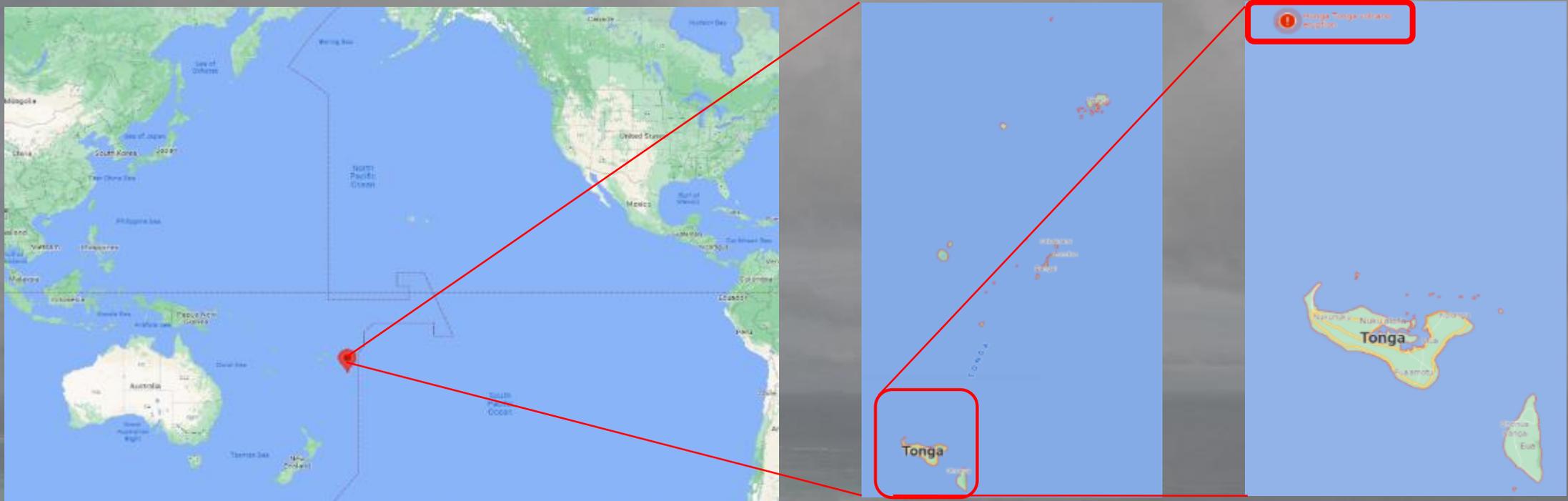


Sentinel Asia

The Sentinel Asia is a voluntary basis initiative led by the Asia-Pacific Regional Space Agency Forum (APRSAF) to support disaster management activity in the Asia-Pacific region by applying the WEB-GIS technology and space based technology, such as earth observation satellites data.



Emergency Observation Request (EOR): Tsunami, Japan on 11 March, 2011



©Google Map

Eruption of the Hunga Tonga-Hunga Ha'apai volcano (Tonga), 15 January 2022

The volcanic ash and the tsunami accompanying the eruption of the submarine volcano, Hunga Tonga-Hunga Ha'apai, located north of the main island of Tonga (GLIDE No. VO-2022-000005-TON) caused great damages to houses and serious shortage of drinking water in Tonga. Tsunami damages have also been reported in other Pacific countries.

ADRC as the secretariat of the Sentinel Asia Initiative, aiming for utilization of space technology for DRR, requested emergency observation to assess the damage in Tonga, which is the center of the damage, and to collect the latest information of the situation.



Basic Information



Photo 1: Hunga Tonga-Hunga Ha'apai island before the eruption (the outer rim of the huge caldera submarine volcano formed the island) (Source: Google Maps)

<https://www.google.com/maps/@-20.5447141,-175.4000813,4330m/data=!3m1!1e3?hl=en>

- The Kingdom of Tonga is located in South Pacific Polynesia and consists of 171 islands (45 of which are inhabited). It has a population of about 100,000, of whom 70% live on Tongatapu Island.
- The volcano Hunga Tonga-Hunga Ha'apai is part of the volcanic arc that extends from Fiji to New Zealand with eruptions recorded as far back as the 12th century. In recent years, the volcano erupted in March 2009 and November 2014-January 2015, and has been active since December 2021.

Volcanic activity on 22 January 2022

On 15 January 2022, at around 17:00 (TOT, UTC+13) (13:00 JST), Hunga Tonga-Hunga Ha'apai submarine volcano erupted on a large scale (volcanic explosion index of about VEI 6). This generated tsunamis. Large tidal level fluctuations due to air vibration were also observed in Japan and other Pacific countries.

Tonga time	Japan time	Natural phenomena	Status of response
15 JAN			
17:10	13:10	Massive eruption occurs□	
17:30	13:30	1.2m Tsunami in Nuku Alofa, Tonga	
18:31	14:31	60cm Tsunami in American Samoa□	
18:48	14:48		Tsunami Advisory for American Samoa
19:36	15:36		Tsunami Warning for American Samoa
22:29	18:29	10cm Tsunami in Hawaii□	
23:01	19:01		Japan Meteorological Agency: Slight Sea Level Change
23:43	19:43		Tsunami Advisory for Hawaii
23:58	19:58	First wave of tsunami in Chichijima, JAPAN□	
23:56	19:56		ADRC to SPC: Contact for Sentinel Asia activation.
16 JAN			
0:20	20:20	First Tsunami Wave at Katsuura, JAPAN	
1:53	21:53		Tsunami Advisory for Aleutian Islands from west coast of US
3:55	23:55	1.2m tsunami in Amami, JAPAN□	
4:15	00:15		JMA: Tsunami Warning and Tsunami Advisory
6:00	02:00		JMA: Press conference
6:26	02:26	1.1m Tsunami in Kuji, JAPAN□	
12:35	08:35		UNITAR activates international disaster charter based on UNOCHA's request
18:00	14:00		JMA: Tsunami warning and advisory cancelled Sentinel Asia activated based on ADRC's request

Table 1: Natural phenomena such as volcanoes, tsunamis, and sea level changes and the status of response (Source: extracted from the relevant organizations' websites)



Eruption records by Himawari 8 (13:10-14:00)

The meteorological satellite Himawari-8 acquires global images every 10 minutes and those images revealed the radius of the plume was about 260 km and that air vibration had occurred.

Photo 2: Images of eruption recorded by Himawari 8 (13:10-14:00)
(Source: JAXA Himawari) Monitor)

Plume Altitude

According to the Ozone Mapping Program (OMPS) aboard NOAA's Suomi NPP satellite, the maximum altitude of the plume is estimated to be 30 km, indicating that it has reached the stratosphere.

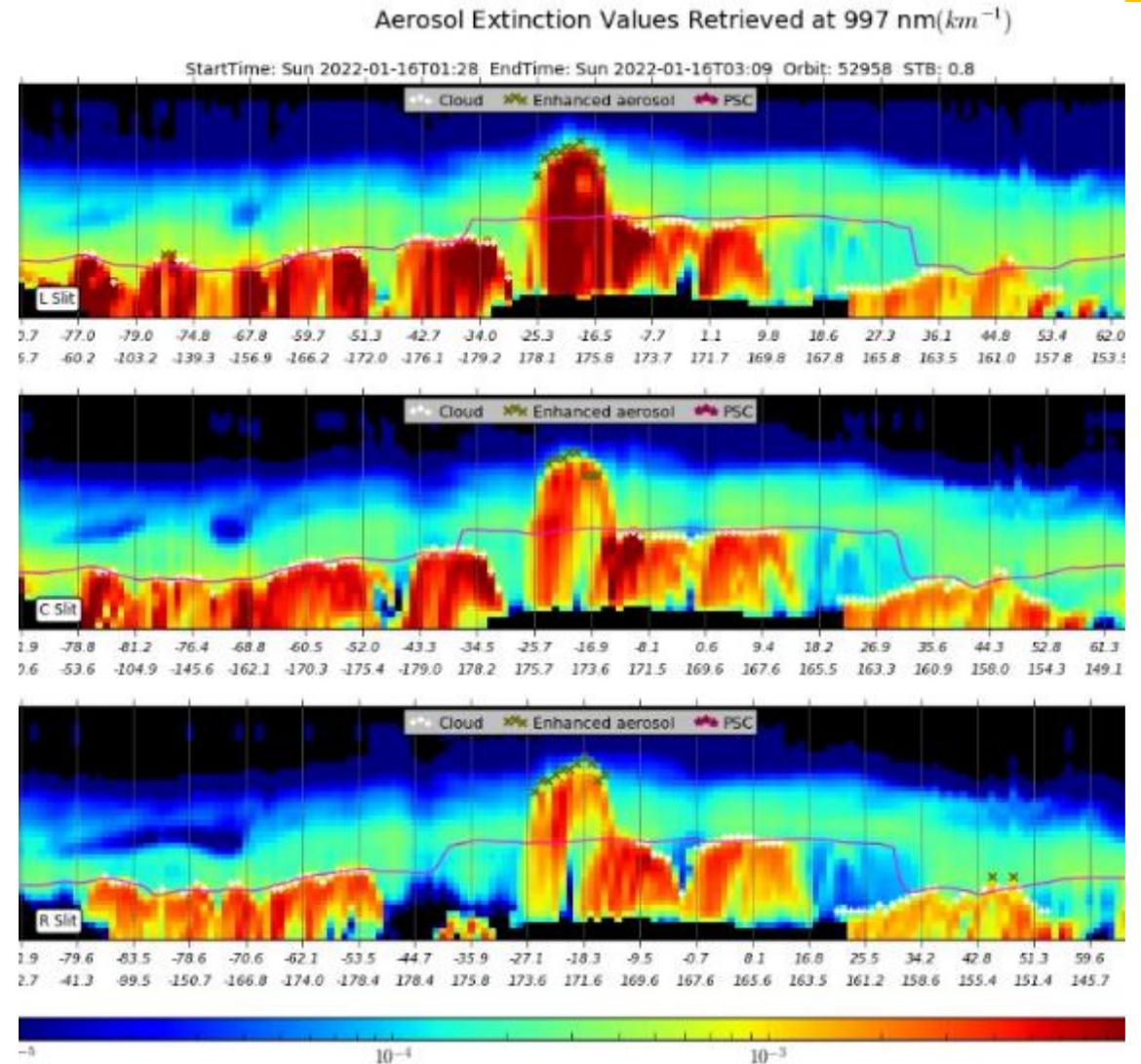


Figure 2: Altitude of the plume (Source: Volcano Discovery)

<https://www.volcanodiscovery.com/hunga-tonga-hunga-haapai/news/170639/Hunga-Tonga-Hunga-Haapai-volcano-Tonga-activity-update-latest-measurements-confirmed-30-km-column-h.html>

Tsunami, atmospheric vibration generation and tidal level fluctuations

- The tsunamis and tidal changes observed in the Pacific Ocean are as follows: Amami, Kagoshima 1.2m; Kuji, Iwate 1.1m; Chichijima 0.9m (JMA); New Caledonia 1.13m; Vanuatu 1.41m; Jackson Bay, New Zealand 0.91m; Chañaral, Chile 1.74m; Galapagos, Chile 0.75m; Maui, Hawaii 0.83m, Port San Luis, California 1.31m, King Cove, Alaska 1.0m (NOAA)
- According to the official announcement by the Government of Tonga (@ConsulateKoT, Twitter, Jan. 18), the tsunami reached up to 15 meters on the west coast of Tongatapu and Eua-Ha'apai islands.



GOVERNMENT OF TONGA

MEDIA RELEASE

(18th January, 2022)

“FIRST OFFICIAL UPDATE FOLLOWING THE VOLCANIC ERUPTION”

An unprecedented disaster hit Tonga caused by the Hunga-Tonga-Hunga-Ha'apai volcanic eruption on Saturday evening 15th January, 2022 followed by a tsunami warning issued which triggered a mass evacuation. As a result of the eruption, a volcanic mushroom plume was released reaching the stratosphere and extending radially covering all Tonga Islands, generating tsunami waves rising up to 15 metres, hitting the west coasts of Tongatapu Islands, 'Eua, and Ha'apai Islands.

Effects of the Volcanic Activity



GOVERNMENT OF TONGA
MEDIA RELEASE
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An unprecedented disaster hit Tonga caused by the Hunga-Tonga-Hunga-Ha'apai volcanic eruption on Saturday evening 15th January, 2022 followed by a tsunami warning issued which triggered a mass evacuation. As a result of the eruption, a volcanic mushroom plume was released reaching the stratosphere and extending radially covering all Tonga Islands, generating tsunami waves rising up to 15 metres, hitting the west coasts of Tongatapu Islands, 'Eua, and Ha'apai Islands.

Initial Damage Assessment is now underway with reports to the National Emergency Management Committee (NEMC) which met on Saturday night to discuss and approve immediate response operations and planning. NEMC has been meeting daily since.

Communications both international and domestic were severed due to damage sustained by the submarine cable from the eruptions and there was no further communication with the outer islands until the morning of Monday 17 January after the deployment of His Majesty Armed Forces patrol boats. As of today, limited communication has been made with Vava'u and Ha'apai through satellite phones and HF radio. There has been no communication with the Niuaus as yet. The Niuaus are considered low risk because of their relative distance to the Hunga-Tonga-Hunga-Ha'apai volcano.

Domestic phone calls operate only within Tongatapu and 'Eua.

Due to the damage to the international fibre optic cable, internet is down. The two communications operators are working on satellite options to restore some services including the internet. Priority will be given to international calls and communication services such as emails. Efforts have been made to restore full communication capabilities.

The search and rescue operation began immediately on Sunday morning to 'Atata island and 'Ahaia village. Of the two reported missing, one has been found alive and the other, a British national, was unfortunately the first fatality. To date, there are 3 confirmed fatalities including the British national, a 65 year-old female from Mango Island, and a 49-year old male from Nukunua Island. There are also a number of injuries reported.

HMAF VOA Ngalau Kouls was deployed the day after the eruption with first responders including a health team and experts to the 'Onuenu' group in Ha'apai with some relief items including water, food and tents. Due to the severity of the damages observed, the HMAF's VOA Late was also deployed on Tuesday 18th January with another health team, additional resources and emergency responders based on reports from the initial mission for Mango, Fonofua and Nukunua. The first assignment is headed

Issued by the Prime Minister's Office, P.O. Box 62, Nuku'alofa, Tonga. Tel: (676) 7401251 Fax: (676) 27 880. For media enquiries Email: pressoffice@pmo.gov.to Website: www.pmo.gov.to



Sidraivili,
Kingdom of Tonga

PHIMENIVETER

DECLARATION OF A STATE OF EMERGENCY (VOLCANIC ERUPTION AT HUNGA TONGA HUNGA HA'APAI)

PURSUANT to sections 32 of the Emergency Management Act (Cap 7:02), and having been satisfied that an emergency is happening in the Kingdom due to the impact of the Hunga Tonga Hunga Ha'apai volcanic eruption that triggered tsunami waves on Saturday 15 January 2022 that caused loss of human life, illness and injury, loss and damage to property, and damage to the environment and that it is necessary for emergency powers to be exercised,

ACCORDINGLY, I hereby declare that a State of Emergency exists in all land and sea areas of Tonga commencing from 8:00am, Sunday 16 January 2022 to 8:00am Sunday 13 February 2022, unless further removed in accordance with the law.

DECLARED at Nuku'alofa on this 18th day of January 2022.

Honorable His Excellency
PRIME MINISTER

for these islands as all houses were destroyed on Mango Island; only 2 houses remain on Fonofua island with extensive damage on Nukunua Island.

The evacuation process has also been begun for other affected areas from the small islands of 'Atata into Tongatapu and from Mango Island and Fonofua Island into Nukunua Island. Parts of the western side of Tongatapu including Kanokapulu (21 houses were completely damaged and 35 severely damaged) has also been evacuated to the evacuation centers and are supplied with necessary relief items by the Government. In the central district, Kolomota's reported 8 houses completely damaged and 20 severely damaged. The island of 'Eua has also reported 2 houses completely damaged and 45 severely damaged.

Water supplies have been seriously affected by the volcanic ash. Government efforts have been made to ensure the continuity of the supply of safe drinking water. An Initial Damage Assessment (IDA) team comprised of various representatives from government and non-government departments was deployed immediately on Sunday to coastal villages in Tongatapu to assess damages to private households and their needs. The cluster system has been activated and are compiling reports on needs to be addressed. Challenges to sea and air transportation remain due to damage sustained by the wharves and the ash that is covering the runways. Domestic and international flights have been deferred until further notice as the airports undergo clean-up.

Even though the tsunami warning has been cancelled and volcanic activity has significantly decreased, monitoring efforts continue.

- According to an official announcement by the Government of Tonga (@ConsulateKoT, Twitter, 18 January), communications (including calls and internet) were disabled until 17 January due to damage to the submarine cable. Communication via satellite phone and wireless communication was partially restored on 18 January. Domestic communication was possible only in Tongatapu and Eua.
- Search and rescue operations in the affected areas (Atata Island and Ahau Village) began on the 16 January.
- Evacuation from Atata Island to Tongatapu Island and from Mango Island and Fonofua Island to Nukunua Island began.
- In the western part of Tongatapu Island, 21 houses were completely destroyed, 35 houses were badly damaged, and other damages occurred in many places.
- The supply of drinking water has been severely affected by volcanic ash.
- On 19 January, the Prime Minister officially declared a state of emergency.

Emergency Observation by Space Satellites

- In response to the news of the eruption and tsunami, ADRC, who serves as the Sentinel Asia Secretariat, approached SPC, the organization in charge of the South Pacific region, to inquire about the possibility of activating Sentinel Asia. SPC was unable to confirm due to the local communication situation, so ADRC acted as the requestor and activated Sentinel Asia on 16 January.
- The international disaster charter covering the entire world was also activated on the 16th.

The screenshot shows the Sentinel Asia website interface. At the top, the date "2022-01-15" is displayed. The main heading is "Volcano eruption in Tonga on 15 January, 2022". Below this, there is a section titled "Emergency Obs. Request Information". On the left, there is a map of Tonga with a red circle highlighting the location. On the right, there is a list of details:

- Disaster Type: Volcano eruption and tsunami
- Country: Tonga
- Occurrence Date (UTC): 15 January, 2022
- SA activation Date(UTC): 16 January, 2022
- Requester: Asian Disaster Reduction Center (ADRC)
- Disaster to the International Charter: No
- GLIDE Number: VN2022-000005-TONGA

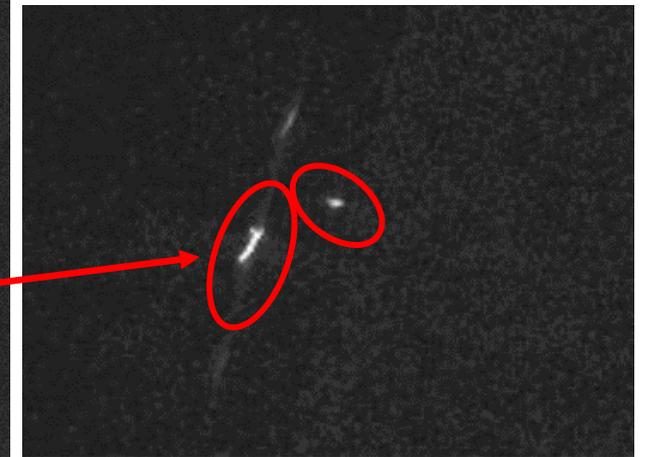
The screenshot shows the "Satellite Image" section of the Sentinel Asia website. It features a search bar labeled "Before Disaster" and a "NARL" button. Below this, there are three satellite images showing the volcano eruption in Tonga. Each image has a date and time stamp: "2021-11-24 22:14:27". The images are labeled "FORMOSAT-5 Level4 FSS 6000 MS L4U1M" and "FORMOSAT-5 Level4 FSS 6000 PMS L4U1M". Below each image, there are "DOWNLOAD" and "VIEW" buttons. At the bottom, there is a section labeled "After Disaster".

Figure 1: Sentinel Asia's emergency observation request information and pre-disaster archive

<https://sentinel-asia.org/EO/2022/article20220115TO.html>

Images of Hunga Tonga-Hunga Ha'pai Island After the Eruption by ALOS2 Satellite

Analysis of data taken by JAXA's ALOS2 earth observation satellite confirmed that the Hunga Tonga-Hunga Ha'pai island disappeared after the eruption, leaving only part of the island.



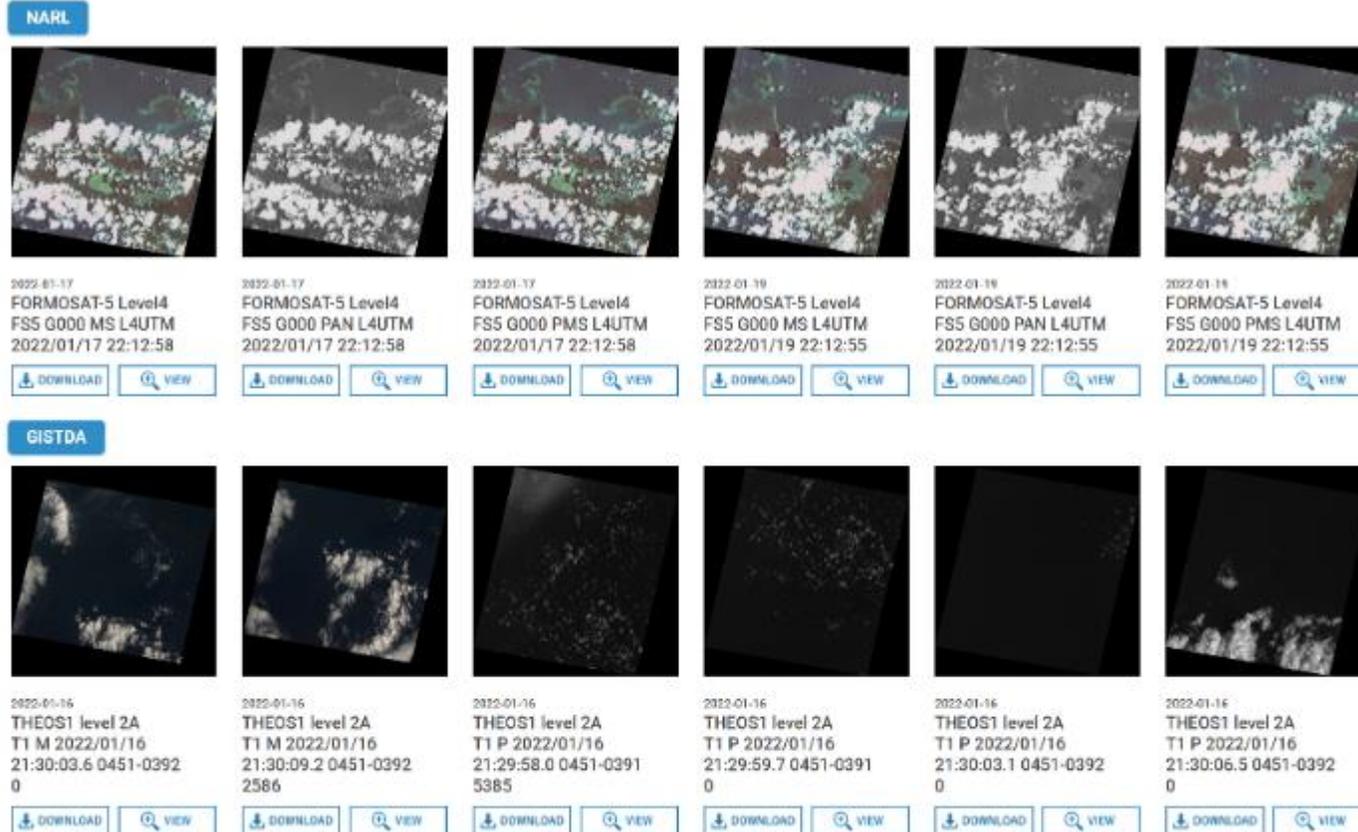
<https://sentinel-asia.org/EO/2022/article20220115TO.html>



<https://www.google.com/maps/@-20.5447141,-175.4000813,4330m/data=!3m1!1e3?hl=en>

Photo 3: Hunga Tonga-Hunga Ha'pai island after the eruption
(Source: Sentinel Asia)

Various data provided by the participating organizations of Sentinel Asia



Taiwan's space agency, NARL and Thailand's space agency, GISTDA, also provided a series of post-disaster images to the Sentinel Asia website.

Figure 2: Data provided by Sentinel Asia.
<https://sentinel-asia.org/EO/2022/article20220115TO.html>

Analysis by Remote Sensing Organizations

The results of damage analysis by EOS and MBRSC are available.

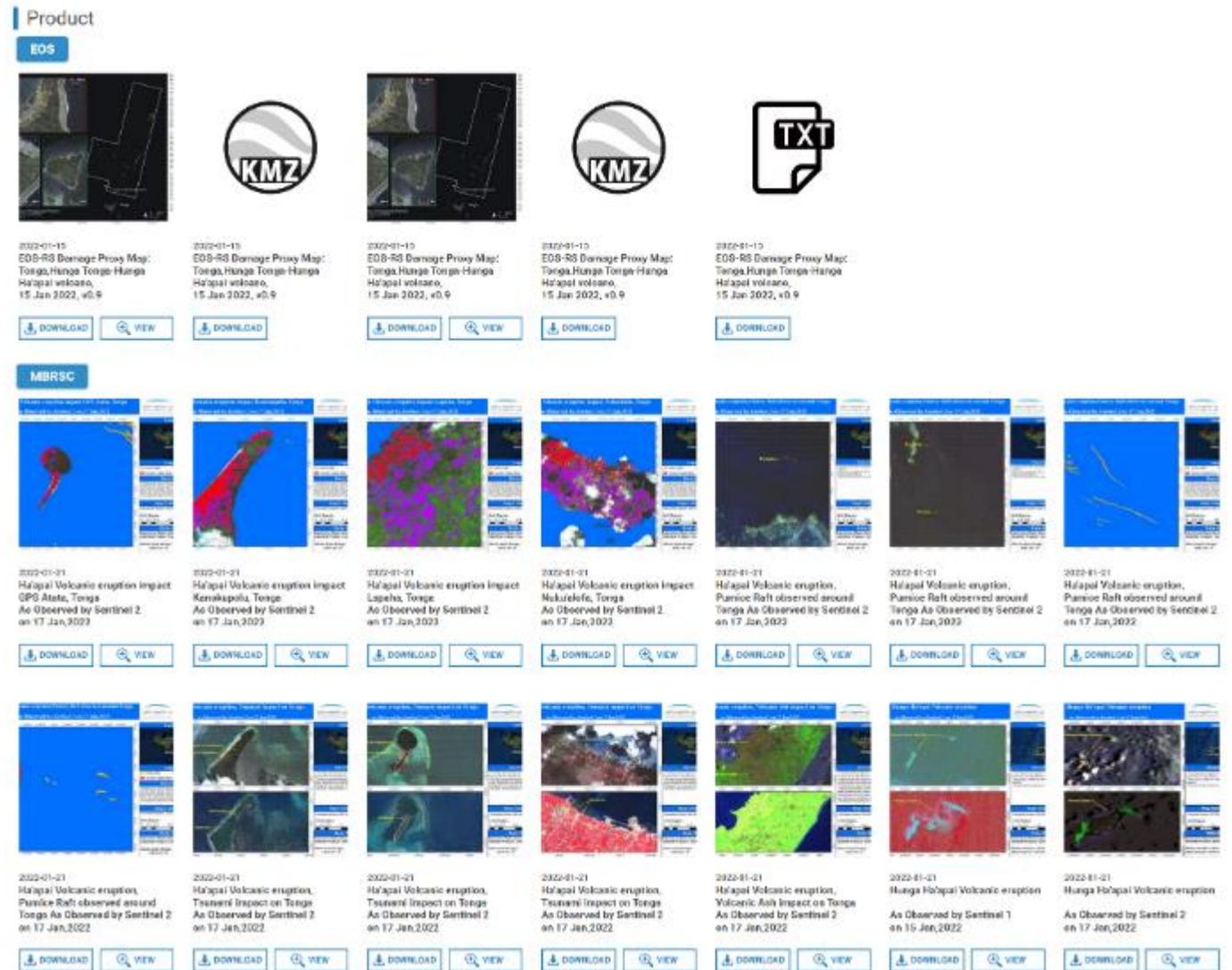
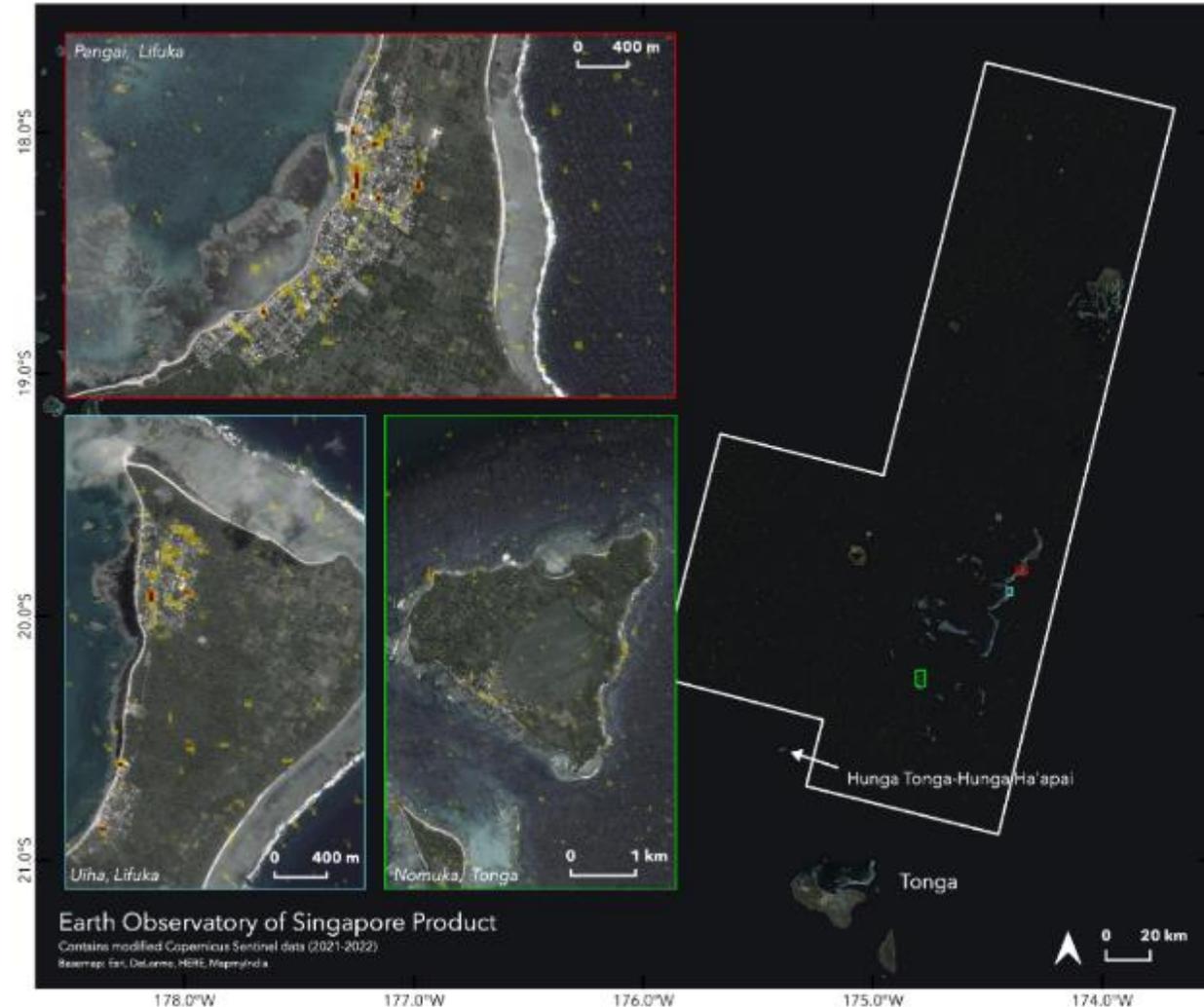


Figure 3: Products provided by Sentinel Asia.
<https://sentinel-asia.org/EO/2022/article20220115TO.html>

Analysis by Earth Observatory of Singapore-Remote Sensing Lab (18 January)

- By analyzing data from the Sentinel-1 satellite, buildings that showed great change before and after the disaster were colored from yellow to red.
- Colors in residential areas are considered to be damaged buildings, while colors in agricultural areas may not represent damage.



EOS-RS Damage Proxy Map: Tonga, Hunga Tonga-Hunga Ha'apai volcano, 15 Jan 2022, v0.9

The Earth Observatory of Singapore - Remote Sensing Lab (EOS-RS) created this preliminary Damage Proxy Map (DPM) depicting areas that are likely damaged in the Vava'u and Ha'apai islands of Tonga due to the eruption of Hunga Tonga-Hunga Ha'apai volcano on 15 Jan 2022. This map was derived from synthetic aperture radar (SAR) images acquired by the Copernicus Sentinel-1 satellites operated by the European Space Agency (ESA) from 17 Sept 2021 to 15 Jan 2022.

The image covers an area indicated by the large white polygon. Each pixel measures about 30 meters across. The colour variation from yellow to red indicates increasingly more significant surface change. Preliminary validation was done by comparing with high-resolution optical imagery. This damage proxy map should be used as a guide to identify damaged areas, and may be less reliable over vegetated areas. Scattered pixels over vegetated areas may be false positives, and a lack of coloured pixels over vegetated areas may not mean no damage.

Sentinel-1 data were accessed through the Copernicus Open Hub. The product contains modified Copernicus Sentinel data (2021-2022), processed by ESA and analyzed by the Earth Observatory of Singapore - Remote Sensing Lab (EOS-RS), using the Advanced Rapid Imaging and Analysis (ARIA) system originally developed at NASA's Jet Propulsion Laboratory, California Institute of Technology, and modified at EOS-RS.

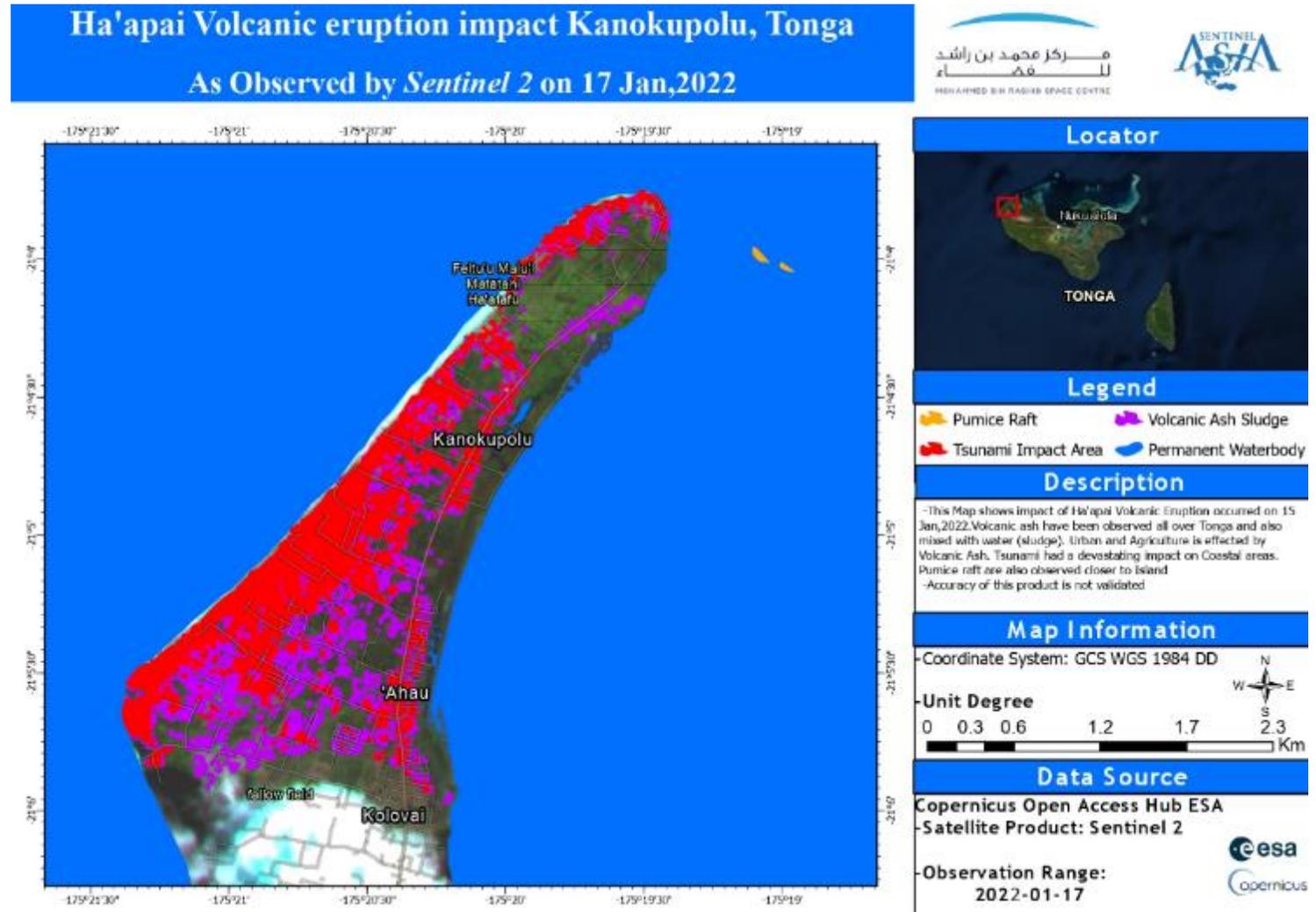
More map details and files at: http://eos-rs-products.earthobservatory.sg/EOS-RS_202201_Tonga_HungaTonga_Volcano

EOS-RS Twitter: [@eos_rs](https://twitter.com/eos_rs)

https://sentinel-asia.org/EO/2022/article20220115TO/EOS-RS_20220115_DPM/EOS-RS_20220115_DPM_S1_Tonga_HungaTonga_Volcano_v0.9_MAIN.png

Analysis by MBRSC, UAE Space Agency (21 January)

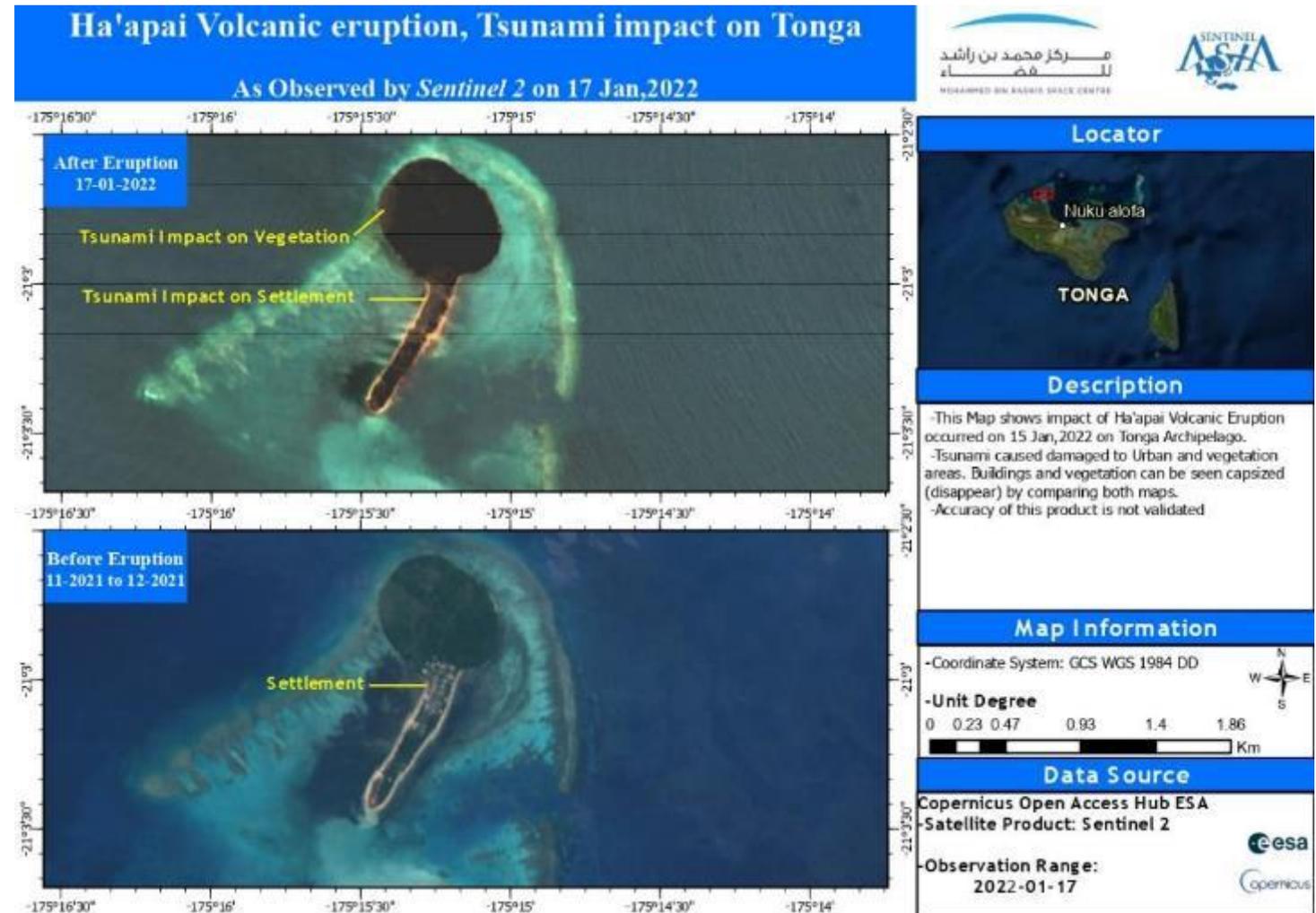
- Data analysis from the Sentinel-2 satellite was used to create a damage map of western Tongatapu island.
- Areas in red are areas estimated to be damaged by tsunami. Areas in purple are areas covered by volcanic ash.
- Areas in orange are areas considered to have observed pumice rafts.



<https://sentinel-asia.org/EO/2022/article20220115TO/MBRSC/Kanokupolu-Map.jpg>

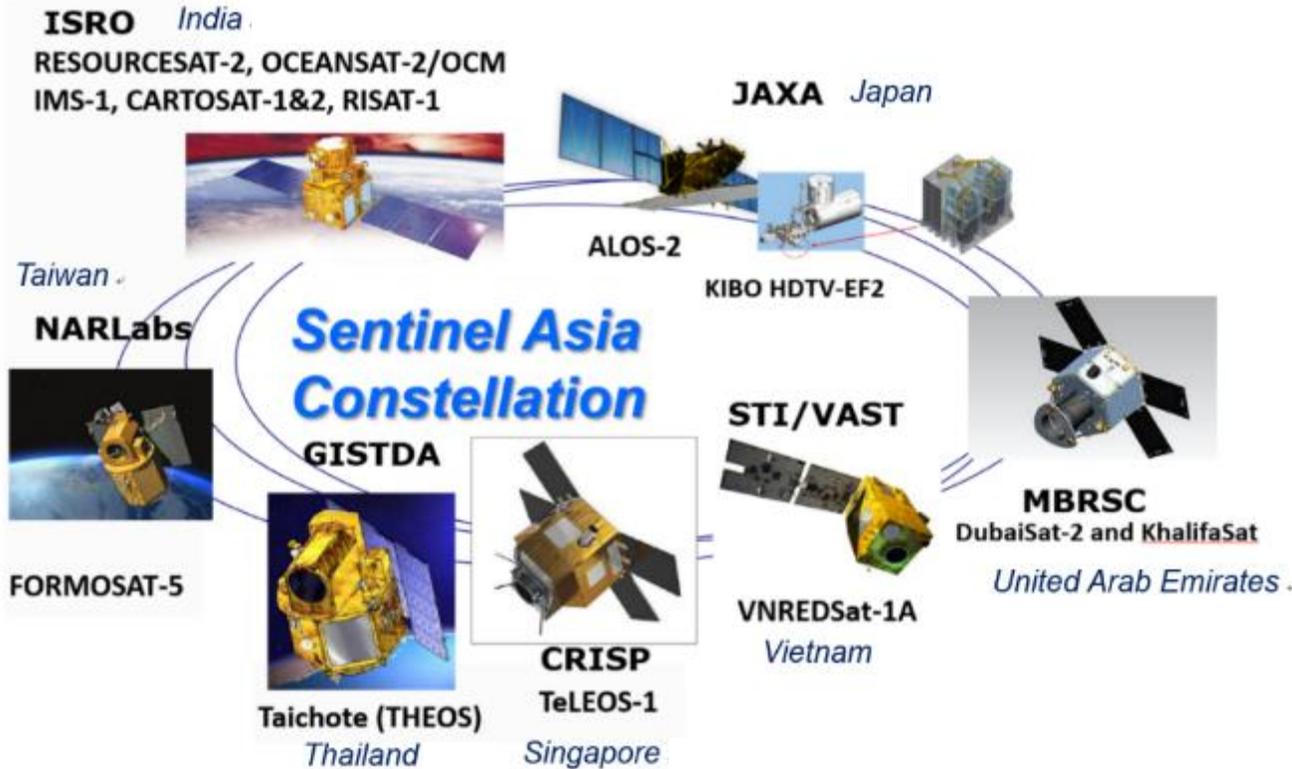
Analysis by MBRSC, UAE Dubai Government Space Agency (21 January) (cont.)

- By analyzing data from Sentinel-2 satellite, pre- and post-disaster damage maps of western Tongatapu island were created.
- It can be estimated from the maps that vegetation has been lost and buildings have been washed away.



<https://sentinel-asia.org/EO/2022/article20220115TO/MBRSC/Tsunami-Impact-Map-2.jpg>

[Ref.] Sentinel Asia project



- In the event of a disaster, it is important to be able to quickly assess the disaster area for emergency response. Earth observation satellites effectively serve this purpose by analysing the disaster area and providing those data to the local community.
- ADRC continues to participate in the Sentinel Asia project, which was launched in 2006 with an objective of establishing a disaster risk management system in Asia utilizing the satellite images. ADRC functions as the focal point to receive emergency observation request in the framework of the Sentinel Asia.
- Upon receiving a request, ADRC decides whether the request is appropriate and whether the emergency observation should be implemented mainly by assessing the damages and casualties.
- Based on its own judgement, ADRC will forward the request to space agencies that participate in the Sentinel Asia Project, namely: ISRO (India), JAXA (Japan), GISTDA (Thailand), NARL (Taiwan), CRISP (Singapore), and MBRSC (United Arab Emirates).