briefing note 458 Jan 2022

Hunga Tonga-Hunga Ha'apai Eruption 15th of January 2022

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Eruption

The 5 km wide volcanic caldera underlying the Hunga Tonga and Hunga Ha'apai islands is situated 65km north of Nukuálofa. The caldera sits atop an underwater volcano that is about 20 km wide and stands about 1,800 m above the sea floor (Cronin, 2022). The volcano has a long history of eruptions (Cronin, 2022; Smithsonian Institution, 2022). The December 2014 – January 2015 eruption joined the Hunga Tonga and Hunga Ha'apai islands, creating the cone shown in Figure 1.

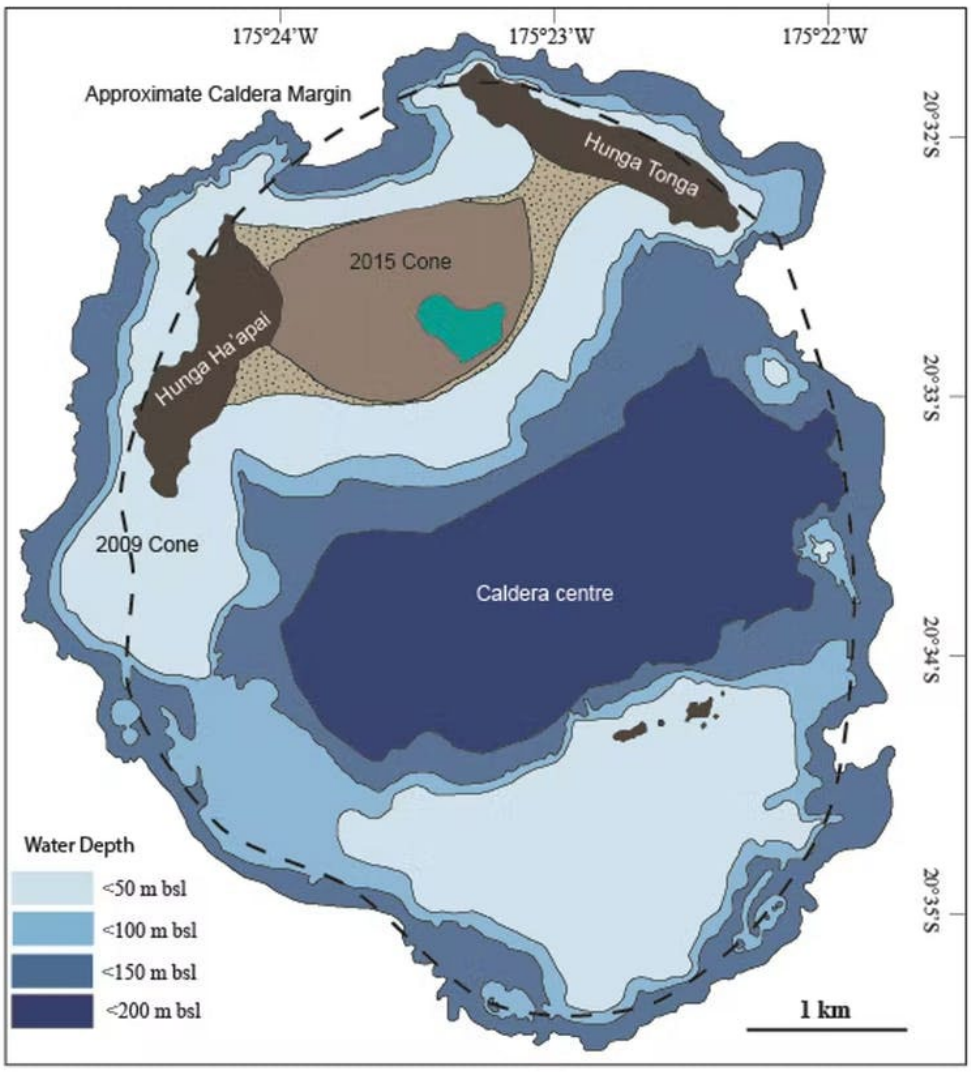

Figure 1. Map of the caldera showing the locations of the Hunga Tonga and Hunga Ha'apai volcanoes, which were joined together by the 2015 eruption. Source: Cronin, 2022.

Cronin (2022) suggests that small eruptions (such as in 2009 and 2014-15) occur mainly at the edge of the caldera, but big ones such as this one come from the caldera itself (Figure 1). This is borne out in the image shown on the right side of Figure 2. Cronin (2022) suggests that in these big eruptions, the top of the erupting magma collapses inward, deepening the caldera. The small eruptions may represent the magma system slowly recharging itself to prepare for a big event. Cronin (2022) describes evidence of two huge past eruptions from the Hunga caldera in deposits on the two islands, suggesting that big caldera eruptions occur about every 1000 years, with the last one in AD1100.

Figure 2. Images of the volcano on January 7 (left) and January 15, 2:25 am UTC (right), showing that the 14th of January eruption resulted in the collapse of the caldera, leaving most of the volcano submerged. Source: Planet.

The volcano had been erupting intermittently between the 29th of December 2021 and the 4th of January 2022[1]. It had been declared dormant on the 11th of January only for activity to resume. On the 14th of January the Tonga Geological Services warned that an eruption was imminent with the possibility of significant emission of ash into the atmosphere[2].

Satellite images captured by Planet Labs since December 29 show how dramatically the volcano had been growing, indicating that the surface area of the islands appeared to have expanded by nearly 50%. The eruption on the evening of the 14th of January is shown in Figures 3 and 4 with associated ashfall deposits shown in Figure 5. This eruption occurred a day before the event that generated the earthquake and tsunami on January 15.

[1] https://volcano.si.edu/volcano.cfm?vn=243040
[2] Tonga Geological Services Facebook page

Figure 3. Eastward view at Hunga Haápai in the forefront and Hunga Tonga on the far right. Note the 5km wide plume of ash, steam and gas rising to altitude 18-20 kilometres above sea level. Photo taken 14/1/2022 (Source: Tonga Geological Service).

Eyewitnesses of the eruption report seeing a plume of ash about 5 km wide rising 20 km into the atmosphere (Figure 4), and the plume grew to a radius of about 130 km before being distorted by the wind. The underwater dimensions of the eruptive zone are not yet known, but the caldera has a diameter of about 5 km (Figure 1), consistent with the reported width of the ash plume. The initial eruption is estimated to have lasted about 8 minutes.

Figure 4. Volcano eruption. Source: Tonga Geological Service.

Figure 5. Ashfall in Tongatapu 14th of January 2022 (Source: Tonga Meteorological Services)

The large eruptions that occurred on 14 January, depicted in Figures 3 and 4, were evidently precursors to an event that generated a large earthquake and a trans- Pacific tsunami. The mechanism that caused these events is not yet known. In particular, it is unclear why the caldera collapse depicted on the right side of Figure 2, whose image was taken at 2:25 am (UTC) on January 15, preceded the occurrence of the earthquake at 4:14:45 am (UTC). The United States Geological Survey reported a preliminary surface wave earthquake magnitude of 5.8 for the event on 2022-01-15 04:14:45 (UTC), but did not report a moment tensor or focal mechanism (fault plane solution) which it routinely does, indicating that this was not an ordinary earthquake event on a fault.

The US National Tsunami Warning System used an origin time for the tsunami of 04:27 am (UTC) for the purpose of estimating tsunami arrival times around the Pacific Ocean; the reason for the discrepancy with the earthquake origin time is unclear. However, the tsunami that was generated is far larger than would be expected from an earthquake caused by rupture on a fault, indicating that the earthquake was probably generated by gravitational collapse rather than shear dislocation on a fault.

The Hunga Tonga-Hunga Ha'apai Volcano eruption at 4:10 am (UTC) on the 15th of January 2022 caused a trans-Pacific tsunami. The eruption was marked by a sudden large eruption cloud detected by satellites with large ash plumes visible covering Tongatapu and surrounding islands (Figure 6). Satellite images of the eruption show two components: a rising plume of ash and a horizontally spreading shockwave. Soon after the eruption started, the sky was blocked out on Tongatapu, with ash beginning to fall. Ashfall was also reported in parts of Fiji.

The eruption caused an air pressure wave (shock wave) that was observed across the Southwest Pacific including the east coast of Australia (Figure 7), New Zealand and Hawaii, as well as Anchorage, Alaska and Florida. The initial eruption could be heard as "loud thunder sounds" (presumably sonic booms) in Fiji, more than 800km away, according to officials in the capital, Suva, and some reported feeling the eruption. There are also reports of it being heard in New Zealand.

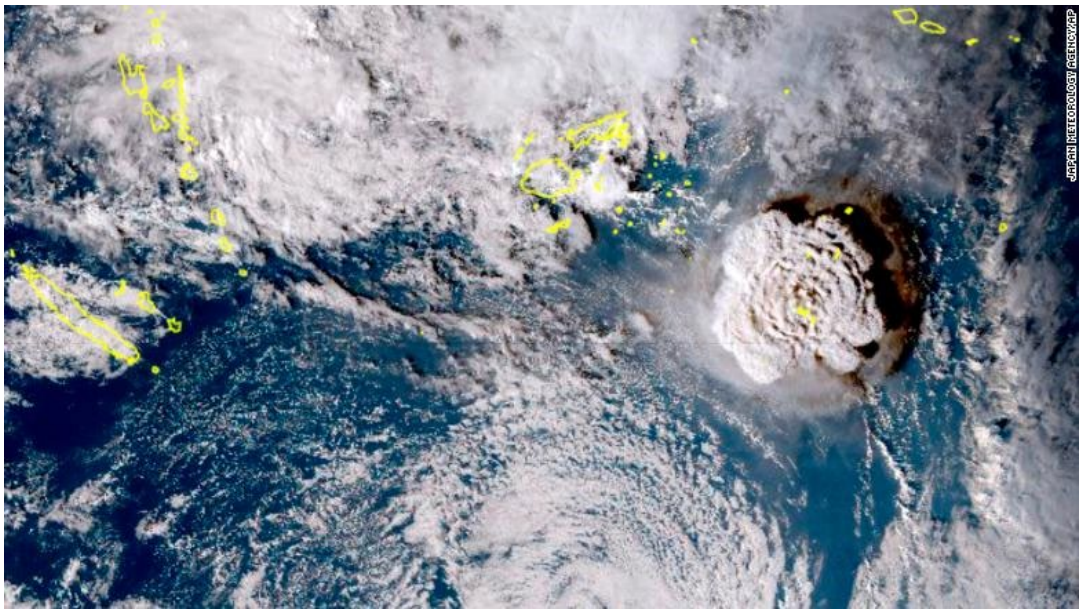

Figure 6. Japan's Himawari-8 weather satellite image showing the volcanic eruption; yellow lines mark island locations. Source: JMA.

Figure 7. Sydney recording of pressure wave of the volcanic eruption. Source: BOM.

A timeline of the eruption is provided in Appendix 1

Pacific wide tsunami event

Tsunami are readily caused by submarine landslides and caldera collapses due to the displacement of seawater, but they can also be generated by coupled atmospheric and ocean shock waves during volcanic explosions (Cronin, 2022). In reports by the Japanese broadcaster NHK, Japanese scientists noted that the tsunami characteristics of this event are different from those of earthquake generated events, making it difficult to forecast the tsunami impacts in Japanese ports and harbours.

The eruption followed activity at the volcano over recent days that had resulted in a tsunami estimated to have been some 30cm in height the previous day.

Following the eruption tsunami warnings and advisories were issued for Tonga, America Samoa, Fiji, Vanuatu, New Zealand, United States, Canada, Japan, Chile and Australia. For Australia land threat warnings were issued for Norfolk Island and Lord Howe Island, whilst marine threat warnings were issued for the area south of Sandy Cape (Queensland) to Southeast Cape (Tasmania) (Figure 8). An evacuation order was issued for low lying parts of Lord Howe Island. Warnings were downgraded the following day.

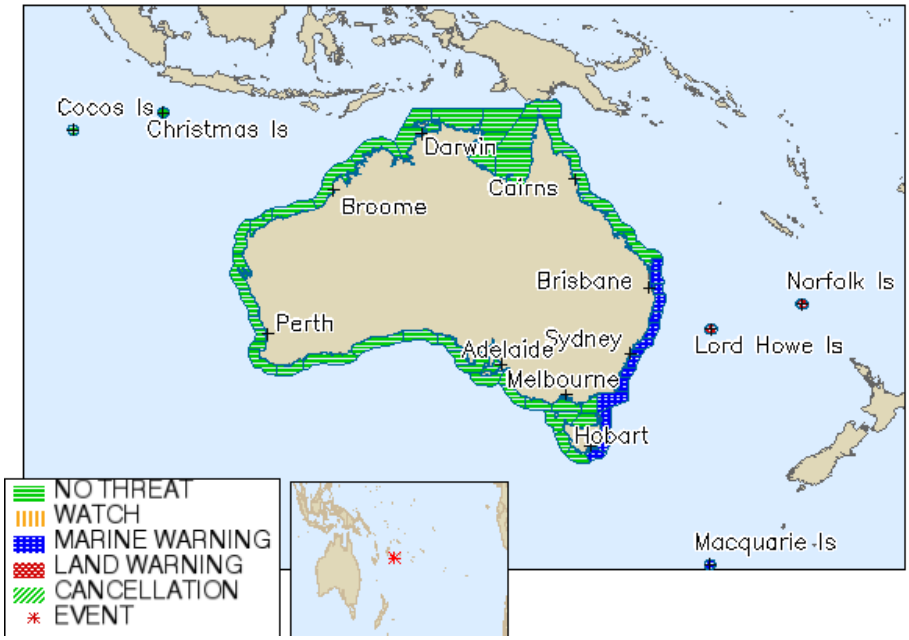

Figure 8: Warnings issued by the Australian Tsunami Warning Centre (Source: Bureau of Meteorology)

The tsunami was recorded on tidal measurement instruments across the Pacific as shown in Table 1.

Table 1: Recorded tsunami wave heights

Location	Maximum tsunami height (metres)
Port Villa (Vanuatu)	1.18
Suva Viti Levu (Fiji)	0.36
Rarotonga (Cook Islands)	0.74
Nukualofa (Tonga)	1.19
Pago Pago (American Samoa)	0.55
Jackson Bay (New Zealand)	1.14
Australia: Norfolk Island Gold Coast Twofold Bay Port Kembla Lord Howe Island	 1.27 0.82 0.77 0.65 0.5
Japan: Kochi, Shikoku Ilsand Kagoshima Iwate Northern Okinawa Iwate	 0.80 1.2 1.2 3.0 - Warning 3.0 - Warning
United States: Hanalei, Hawaii Kauai, Hawaii Adak, Alaska Monterey, California	 0.8 0.5 0.3 0.2

Source: Bureau of Meteorology, JMA, NOAA, Pacific Tsunami Warning Centre

Tsunami Impacts

The tsunami was initially recorded in Tonga where videos posted to social media showed large waves washing ashore in coastal areas, swirling around homes, a church and other buildings. Social media reports identified inundation of foreshore areas of the capital city Nuku'alofa including surrounding the Royal Palace, central business district and port. The largest waves were recorded 36 minutes after the eruption. There are yet to be reports from other parts of Tonga.

Parts of Fiji experienced inundation including Ketei Village, Kiobo Village, Moala, Lakeba, Viani Bay, Vanua Balavu Island, Oneata Island and Galoa Island.

Evacuations occurred in Vanuatu where tsunami waves between 1 and 2.5 metres were reported. Low-lying parts of the island of Efate experienced inundation whilst impacts were also reported from the islands of Tanna, Erromango and Aneytum. At Port Vila the harbour water receded exposing the harbour floor.

In Samoa homes were reported as flooded in the villages of Vailoa and Palauli.

Residents in Hawaii, Alaska and along the U.S. Pacific coast were advised by the National Tsunami Warning Center to move away from the coastline to higher ground. Minor inundation was observed on the west coast of the United States near Santa Cruz (California) and Neskowin (Oregon). Strong currents and unusual wave activity were reported at other locations. There were multiple reports of

rescues including two injuries near San Gregorio, California, when the tsunami swept two people into the ocean[3].

In Hawaii there were reports of boats getting pushed up in docks. There was no reported damage and only minor flooding throughout the islands.

In South America ocean drawbacks and strong currents were reported along the Chilean coast. Strong currents too were reported at the Galapagos Islands west of Ecuador. There was flooding of some low-lying foreshore areas in Peru and northern Chile. In Central America strong currents were observed at Manzanillo, Colima State, Mexico.

In New Zealand significant damage to boats in Tutukaka marina were reported[4].

The Japan Meteorological Agency initially did not issue a warning, but then said there may be a slight swelling of the water along the coast that was not expected to cause any damage. It has since been reported that at-least five fishing boats were sunk in Kochi harbour, Shikoku Island, where the recorded wave height was 80 cm.

The largest tsunami waves at Norfolk Island were recorded close to six hours after the eruption. At Lord Howe Island the Bureau of Meteorology reported observations of 1.10m waves at Ned's beach and unusual currents and waves. Whilst at Derwent Park, Hobart a 50cm surge was observed in a marina. Unusual tidal activity was also reported at Crescent Head, Lord Howe Island, Gunnamatta Bay (Sutherland), Maroubra, Sawtell and Mogareeka Inet (Bermagui). The Bureau of Meteorology reported that a mass rescue had occurred at Sawtell due to the sudden drop in tide. A tsunami warning remained current for the NSW coast at 7:02pm AEDT on the 16th of January.

Communications Disruptions

There were no immediate reports of injuries or on the extent of the damage in Tonga because all internet connectivity with Tonga was lost at about 4:40 AEDT. local time. Tonga gets its internet via an undersea cable from Suva, Fiji.

Discussion

Some 5% of all historic tsunami have been produced by volcanos. An example was the Krakatoa event in Indonesia in 1883 that resulted in tsunami impacts across the Indian Ocean. Previous Risk Frontiers analysis identified some 130 volcanic centres known to have erupted in the last 10000 years between New Zealand and New Guinea with a large proportion of these having some tsunamigenic potential[5].

Small tsunami are not an unusual feature along the NSW coast with over 50 reported since European settlement. The most notable of these events occurred in 1960 resulting from the magnitude 9.5 earthquake offshore of Chile, which is the largest recorded earthquake in the world. Observations of the tsunami included rapidly oscillating water levels in bays and harbours and grounding of some boats and minor inundation of foreshores.

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[3] CALFIRE

[4] https://www.nzherald.co.nz/world/tonga-tsunami-hunga-tonga-hunga-haapai-eruption-surging-waves-hit-island-nation/3XYZ6SL6QG7DTWZP35PICVMA3A/

[5] Somerville, P., Gissing, A., Hanslow, D., (2009) NSW Tsunami Risk – An Overview of the NSW Risk Assessment Scoping Study. [Available Online] https://www.researchgate.net/publication/258918663_NSW_Tsunami_Risk_-_An_Overview_of_the_NSW_Risk_Assessment_Scoping_Study

Significant advances in tsunami warning capability have occurred since the devastating Indian Ocean tsunami in 2004, including the development of the Australian Tsunami Warning System operated jointly by the Bureau of Meteorology and Geoscience Australia.

More effort is required though to improve community understanding of tsunami risk both in Australia and elsewhere. Whilst the warning was still current in the Sydney region many people were seen in foreshore areas (Figure 9) resulting in social media users expressing concern.

Figure 9: Manly Beach morning of 16th of January whilst tsunami warning was current. (Photo Credit: Peter Roberts)

What Next?

Cronin (2022) notes that it remains unclear if this is the climax of the eruption, but if it represents a major magma pressure release, it may settle the system. However, geological deposits from the volcano's previous eruptions show that each of the previous 1000-year major caldera eruption episodes involved many separate explosion events. This suggests that there could be several weeks or even months or years of major volcanic unrest from the Hunga-Tonga-Hunga-Ha'apai volcano.

References

Cronin, S. (2022). Why the volcanic eruption in Tonga was so violent, and what to expect next. https://theconversation.com/why-the-volcanic-eruption-in-tonga-was-so-violent-and-what-to-expect-next-175035

Smithsonian Institution, National Museum of Natural History, Global Volcano Program. https://volcano.si.edu/

Annex 1 – Eruption timeline

Date	Time	Activity
29th of December 2021 to 4th of January 2022		Volcano erupting intermittently for 15 days
2nd of January 2022		Satellite imagery shows the island area between Hunga Tonga and Hunga Ha'apai had increased from 2 sq. km in 2015 to 3.6 sq. km in 2022, extending almost 600m on the eastern side.
11th of January 2022		Volcano declared dormant. Seven days had passed since the last volcanic activity
14th of January 2022	2:20am AEDT	Observations of significant eruption underway with significant emission of ash into the atmosphere. Ashfall observed in Tongatapu.
14th of January 2022	2:20am AEDT	Hunga eruption begins captured on satellite.
14th of January 2022	3:00am AEDT	Small tsunami waves first observed – approx. 30cm in height
14th of January 2022	9:12am AEDT	Marine tsunami warning issued for Tonga
14th of January 2022	9:30am AEDT	Abnormal tidal activity observed at Nuku'alofa Domestic Wharf
14th of January 2022	3:10pm to 9:30pm AEDT	Observations note that eruption is continuous, maintaining a 5km wide column plume of ash, steam and gas rising to 18-20km altitude above sea level.
15th of January 2022	3:00am to 10:40am AEDT	The eruption continues, with ash emitted
15th of January 2022	8:00am AEDT	Marine tsunami warning cancelled.
15th of January 2022	1:25pm AEDT	Satellite image shows volcano has lost much of its previous above water landmass
15th of January 2022	3:10pm AEDT	Major eruption reported
15th of January 2022	3:46pm AEDT	Largest recorded tsunami wave impacts Nuku'alofa