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Not My Fault: Reflections on the Hunga Tonga eruption six months later

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It's been nearly half a year since the violent eruption of Hunga Tonga–Hunga Ha'apai volcano in the southwestern Pacific. It was clear when I wrote about this eruption in January that something unusual had occurred. Over the past months, peer-reviewed journal articles have come out and that initial assessment has been confirmed. It was an extraordinary event and is changing perceptions of both volcanic and tsunami hazards.

What do we know now and have any of those first assessments changed? The biggest additional piece to the story is the phenomenal amount of data that has been collected. The eruption and the pressure pulse it produced has been recorded in the highest parts of the atmosphere down to the sea floor. All of that data shows it was a complex event with several parts.

Volcanic eruptions are nothing unusual in the Tonga Islands area. NOAA's National Center for Environmental Information (NCEI) identifies 22 Tonga volcanoes, but only 15 that are tall enough to breach the ocean surface. The Tonga Islands owe their existence to volcanic activity. They are in the northern part of the Tonga-Kermadec island arc produced by the volcanism produced as the Pacific plate subducts beneath the Australian plate. It is one of the most volcanically active areas of the planet.

But most historic eruptions in the Tonga region have been relatively benign affairs. NCEI documents only four eruptions prior to the Hunga Tonga eruption and only the two eruptions of Niuafo'ou in the mid 1800s caused a significant ash cloud or produced any damage. It had been more than a century since any documented eruptions.

Hunga Tonga–Hunga Ha'apai volcano is about 40 miles north of Tonga's capital and largest city, Nuku'alofa and remaining beneath the sea floor and largely unrecognized until a submarine eruption in 2009 produced steam and ash plumes that were visible at Nuku-alofa. Five years later another eruptive episode began with ash plumes as high as 30,000 feet, high enough to divert air traffic. The eruption built the volcanic edifice high enough to push it above the ocean, officially becoming a new island. By January 2015, the eruption had ended.

Eruptive activity resumed in late December 2021 with explosions that could be seen heard on Nuku'alofa. By January 11 when the eruptive activity appeared to be over, the island had grown. Up to this point, the Hunga Tonga eruptions had been relatively modest. There was nothing in the previous 12 years of off and on activity that suggested something untoward was on its way.

The eruption resumed on January 14th with more explosions in growing intensity, but no one was prepared for what happened at 5:14 PM local time in Tonga the next day. The earlier eruptions somehow produced pathways for sea water to come into contact with the magma chamber, flashing an enormous volume to steam. A combination of steam and gasses escaping from the magma propelled a millions of tons of rock into the air.

Since the eruption, teams of scientists have examined the eruption from the sea floor to the edge of space. Oceanographic teams from New Zealand's National Institute of Water and Atmospheric Research (NIWA) and a group from the Tonga Geological Services and the University of Auckland probed the sea floor around the volcano and found that the eruption produced a chasm three miles wide and a quarter mile deep in the top of the volcano and strewed debris on the sea floor over a radius of 30 miles. From the shape of the chasm, they conjecture the eruptive blast went straight up.

The blast was the highest ever recorded on modern instruments and reached heights of 36 miles, exceeding the 1991 eruption of Mt. Pinatubo in the Philippines, and perhaps equaling the great 1883 eruption of Krakatoa in the Sunda Strait of Indonesia. The blast induced pressure waves extended from the outer reaches of earth's atmosphere to the sea floor.

Satellite and acoustic instruments have now detailed an incredible suite of waves that, in some cases, circled the earth for days. First a correction. Some of the media and on-line reports call these shock waves. Shock waves travel in excess of the speed of sound and the detailed measurements of the Tonga eruptive signals show they traveled at the speed of sound. A better description is pressure waves or sound waves.

NASA's Ionospheric Connection Explorer (ICON) and European Space Agency Swarm satellites detected hurricane-speed winds and electric currents in the

ionosphere. It is considered the largest disturbance ever detected in the outer parts of earth's atmosphere. According to NASA, "ICON clocked the windspeeds at up to 450 mph – making them the strongest winds below 120 miles altitude measured by the mission since its launch."

In a paper published in Science (https://www.science.org/doi/10.1126/science.abo7063), a group led by Robin Matoza of the University of California, Santa Barbara document pressure waves that circled the earth in both directions for as long as a week after the eruption. Called atmospheric Lamb Waves, these low-frequency signals are believed responsible for generating an unusual tsunami. The oscillating pressure differences in the atmosphere, triggered waves in the ocean traveling at the same speed as the atmospheric waves, more than 1.5 times faster than tsunamis caused by sea floor deformation.

The tsunami that was unusual, the atmospheric pressure-induced signal arriving ahead of the conventional sea floor deformation tsunami. On California's coast, it meant the first tsunami waves arrived nearly an hour earlier than what was predicted by conventional tsunami travel-time calculations. The atmospheric pressure pulse easily passed over land masses triggering tsunami signals in the Caribbean.

This won't be the last word on the Hunga Tonga eruption. Work continues in many areas, including the eruptive composition and the coupling of the atmosphere – ocean system. And of course, Mother Nature may still have more to say – the is some evidence that eruptive activity is continuing.

Note: read NASA's study of atmospheric waves produced by the Tonga eruption at https://www.nasa.gov/feature/goddard/2022/sun/nasa-mission-finds-tonga-volcanic-eruption-effects-reached-space

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