Scientists provide explanation for exceptional Tonga tsunami

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Scientists say they have identified the exact mechanism responsible for the exceptional tsunami that spread quickly across the world after the colossal eruption of the Tonga volcano earlier this year.

In a new paper published today in *Nature*, an international team including researchers from Cardiff University say the exceptional event was caused by acoustic-gravity waves (AGWs) triggered by the powerful volcanic blast, which traveled into the atmosphere and across the ocean as the Hunga Tonga-Hunga Ha'apai volcano erupted.

As these waves converged with each other, energy was continuously pumped into the tsunami which caused it to grow bigger, travel much further, much quicker and for much longer.

The eruption of the Hunga Tonga-Hunga Ha'apai volcano on 15 January 2022 was the largest volcanic eruption of the 21st century and the largest eruption since Krakatoa in 1883.

It's been described as the biggest explosion ever recorded in the atmosphere and was hundreds of times more powerful than the Hiroshima atomic bomb.

The eruption was the source of both atmospheric disturbances and an exceptionally fast-traveling tsunami that were recorded worldwide, puzzling earth, atmospheric and ocean scientists alike.

"The idea that tsunamis could be generated by atmospheric waves triggered by volcanic eruptions is not new, but this event was the first recorded by modern, worldwide dense instrumentation, allowing us to finally unravel the exact mechanism behind these unusual phenomena," said co-author of the study Dr. Ricardo Ramalho, from Cardiff University's School of Earth and Environmental Sciences.

AGWs are very long sound waves traveling under the effects of gravity. They can cut through a medium such as the deep ocean or the atmosphere at the speed of sound and are produced by volcanic eruptions or earthquakes, among other violent sources.

A single AGW can stretch tens or hundreds of kilometers, and travel at depths of hundreds or thousands of meters below the ocean surface, transferring energy from the upper surface to the seafloor, and across the oceans.

"In addition to traveling across the ocean, AGWs can also propagate into the atmosphere after violent events such as volcanic eruptions and earthquakes," said co-author of the study Dr. Usama Kadri, from Cardiff University's School of Mathematics.

"The Tonga eruption was in an ideal location below the surface, in shallow water, which caused energy being released into the atmosphere in a mushroom-shape close to the water surface. Thus, the interaction of energetic AGWs with the water surface was inevitable."

Using sea-level, atmospheric and satellite data from across the globe at the time of the volcanic eruption, the team has shown that the tsunami was driven by AGWs that were triggered by the eruption, traveling fast into the atmosphere and, in turn, were continuously 'pumping' energy back into the ocean.

A comparison of atmospheric and sea-level data showed a direct correlation between the first sign of air disturbance caused by AGWs and the onset of a tsunami in many locations around the world.

The team say the transfer of energy back into the ocean was caused by a phenomenon known as nonlinear resonance, where the AGWs interact with the tsunami they generated, causing the latter to be amplified.

In the new study, they estimate that the tsunami traveled 1.5 to 2.5 times faster than a volcano-triggered tsunami would, crossing the Pacific, Atlantic and Indian oceans in less than 20 hours at speeds of around 1000 km/h.

"Moreover, because the tsunami was driven by a fast atmospheric source, it propagated directly into the Caribbean and the Atlantic, without having to travel around the South American landmass, as a 'normal' tsunami would. This explains why the Tonga tsunami arrived at the Atlantic shores almost 10 hours before what was expected by a 'normal' tsunami," added Dr. Ramalho.

"The Tonga tsunami has provided us with a unique opportunity to study the physical mechanism of formation and amplification of global tsunamis via resonance with acoustic-gravity waves. Such a resonance at this scale allows us to move beyond 'proof of concept' of the mechanism, and the development of more accurate forecasting models and real-time warning systems, into the potential of developing a new energy harnessing technology," Dr. Kadri concluded.

More information: R. Omira, Global Tonga tsunami explained by a fast-moving atmospheric source, *Nature* (2022). DOI: 10.1038/s41586-022-04926-4. www.nature.com/articles/s41586-022-04926-4

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