New model provides real-time, more accurate prediction of tsunami wave patterns

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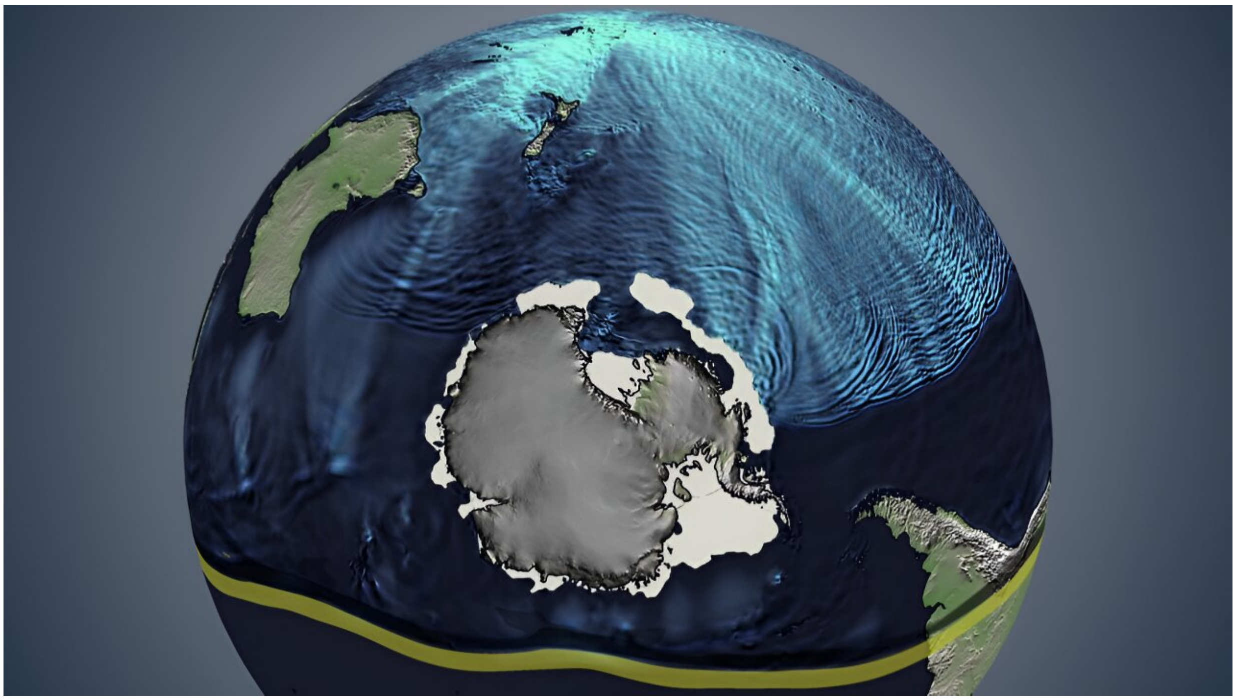

Credit: Okinawa Institute of Science and Technology

On January 15, 2022, the Hunga Tonga-Hunga Ha'apai volcano in Tonga exploded, releasing large amounts of energy into the atmosphere and ocean, causing tsunamis across the Pacific Ocean. Scientists from the Shocks, Solitons and Turbulence Unit at the Okinawa Institute of Science and Technology (OIST) have studied the disturbances in the atmosphere and ocean during this event and developed a model to improve current tsunami early warning systems. Their findings are published in the *Journal of Fluid Mechanics*.

Stephen Winn, a research technician in the unit and first author of the research article, stated, "It's important to know how the atmospheric wave changes in time to make accurate predictions that would be of use for warning systems."

Unlike a regular tsunami caused by a rapid movement of the seabed, the large waves caused by the Tonga explosion were also influenced by a pressure wave hundreds of kilometers wide released into the atmosphere. The atmospheric pressure wave first moved upwards and then spread outward traveling at 1,141 km/h on average, about 400km/h faster than a regular tsunami can travel in deep water.

It traveled around the Earth causing waves as far away as the Mediterranean Sea. "This was the first event of its kind recorded in detail by modern instruments," Prof. Emile Touber, leader of the Shocks, Solitons and Turbulence Unit stated.

As the atmospheric wave travels above the ocean, it displaces the body of water underneath, creating waves that travel faster than a regular tsunami. "Normally, a tsunami wave created in the Pacific would not reach the Mediterranean because it would have to travel around land masses to get there, but atmospheric waves are not restricted, traveling over those land masses," Dr. Adel Sarmiento, a postdoc researcher at the unit explained. This is why the wave can reach all around the world and has a wider impact than a regular tsunami.

The scientists used measurements from the Tonga event to validate their model and used a state-of-the-art code, dNami, co-developed by Dr. Nicolas Alferez at the Conservatoire National des Arts et Métiers in Paris, France, to rapidly simulate the Earth during the event using the supercomputer at OIST. The code (available on GitHub) allows them to create simulations in fine resolution, faster than real-time, so that they are useful for improving warning systems in the future.

Prof. Touber explained that they can now more accurately predict the arrival time and height of a wave at a specific location and rapidly identify areas at high risk.

Hurricanes and typhoons can also cause disturbances in the atmosphere that interact with the sea, causing significant water level changes that will affect coastlines.

"With our model, we can explore what might happen to the water flow as it approaches the coast if the sea level changes by a certain amount with certain typical storm conditions," Prof. Touber said. "This can help decide on the kind of coastal defense systems that should be put in place for storm related surges."

The hope is that this predictive model will allow coastal communities to better prepare for and react to tsunamis and save lives.

More information: S.D. Winn et al, Two-way coupled long-wave isentropic ocean-atmosphere dynamics, *Journal of Fluid Mechanics* (2023). DOI: 10.1017/jfm.2023.131

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