A New Tsunami Warning System

by Kate Madin

After successfully testing a long-range underwater communications system that worked under Arctic Ocean ice, an engineering team at Woods Hole Oceanographic Institution adapted it for a very different environment—the tropics—and for a different purpose—to provide warnings of impending tsunamis.

While the Arctic sound-signaling system lets researchers communicate with robotic vehicles operating beneath sea ice, the tropical system, tested in 2016 off Indonesia, is designed to relay signals "from an undersea sensor network to shore, where they can be used to estimate the level of the potential tsunami," said Lee Freitag, the WHOI engineer who led the project.

After the 2004 undersea Indian Ocean earthquake that generated a tsunami and extensive damage and death in Indonesia, scientists from many countries expanded the warning system called DART (Deep-ocean Assessment and Reporting of Tsunamis) to include more of the Indonesian archipelago. DART consists of pressure sensors on the seafloor that detect quakes and tsunamis. The sensors relay sound signals to buoys at the ocean surface, which transmit data via satellite to shorebased officials who can trigger an alert.

Courtesy of Lee Freitag, WHOI

WHOI engineers (from left) Keenan Ball, Peter Koski, and Lee Freitag showed how underwater sound signals can alert officials of impending tsunamis.

"There's a threat of nearshore tsunamis in this area," Freitag said of the Indonesian archipelago, which has large populations at sea level. "If there's an earthquake here, there's only thirty minutes before a tsunami reaches shore."

But instruments floating atop the ocean are vulnerable. In the Arctic, ice and polar bears can crush them. Fish can bite instruments, and wind, waves, and currents pummel them. If the equipment is visible and accessible, people may take instruments or even remove entire buoys. Several Indonesian DART buoys have met that fate, hobbling the network's ability to warn Indonesia's emergency disaster response agencies.

Freitag and his team are working with Indonesian and United States researchers, led by disaster researcher Louise Comfort at the University of Pittsburgh, to send tsunami alerts *without* the surface buoys. In early 2016, they successfully tested a new system off Indonesia that uses sound signals traveling under water, out of sight.

Cabell Davis, WHOI

Indonesia, a country of thousands of islands, is vulnerable to earthquakes and tsunamis. An earthquake off Sumatra in 2004 created a tsunami that killed 230,000 to 280,000 people.

The scientists are taking advantage of naturally occurring sound feataures in the ocean that efficiently channel sound waves, allowing them to travel farther without losing energy. These features consist of layers of water of different densities. The sound waves don't easily penetrate the boundaries between layers; instead, they refract away from them and continue on with minimal signal loss.

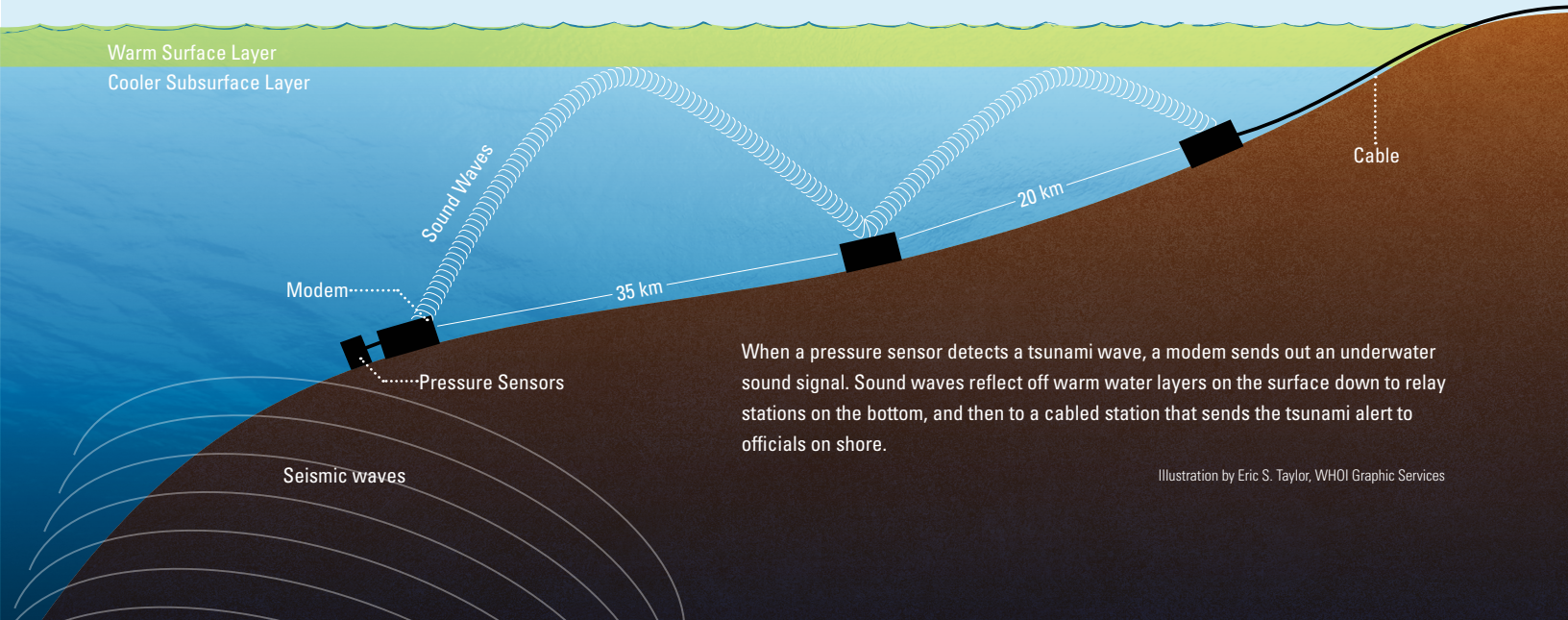
In Indonesia, surface water is always warmer and less dense than water near the bottom, which is colder and under higher pressure and therefore denser.

Freitag's team put a pressure sensor on the seafloor about a mile deep and about 60 miles from land. They sent sound signals from it at a frequency of 3 kilohertz. That's a higher frequency than they used in the Arctic, and so it doesn't travel as far under water, but it can carry more information.

The sound traveled upward, bounced off the warm layer boundary near the surface, and continued back down to the sea bottom some 12 to 22 miles away. There, another modem on the seafloor received the sound and sent it out again. In this way, the signal hopped, or jumped, from modem to modem toward shore.

"We think we've proved the acoustic side will work," Freitag said. "Now we just need a seafloor cable to link to shore and make the final connection to the rest of the Indonesian early-warning system. That's the next step."

This project was funded by the National Science Foundation's Interdisciplinary Research in Hazards and Disasters Program.



When a pressure sensor detects a tsunami wave, a modem sends out an underwater sound signal. Sound waves reflect off warm water layers on the surface down to relay stations on the bottom, and then to a cabled station that sends the tsunami alert to officials on shore.

Illustration by Eric S. Taylor, WHOI Graphic Services