Published on *EOSDIS - Earth Data Website* (https://earthdata.nasa.gov)

Making Waves in Tsunami Research [1]

by Amanda Leigh Haag

Data from Jason and TOPEX/Poseidon give scientists the first detailed profile of a major tsunami event.

- About NASA's Physical Oceanography (PO DAAC) [2]

It was pure coincidence that in the early morning light of December 26, 2004, within hours of the 9.0 earthquake that shook the floor of the Indian Ocean, two joint NASA/French Space Agency satellites watched from high overhead while tsunami waves silently raced across the Bay of Bengal. Half a world away, U.S. Geological Survey geophysicist Peter Cervelli came home from a Christmas dinner with friends to find seismometer readings heralding ominous news.

Sadly, scientists had no way to warn officials or the public about the deadly force that was minutes away from surging ashore. More than 220,000 lives were lost to the tsunami.

Today, scientists are gathering data from a variety of sensors in an effort to reconstruct the event and see what lessons they can learn from it. Serendipitously, as the tsunami waves were rolling toward the shore, the "Jason" and "TOPEX/Poseidon" satellites recorded the height changes of the waves as they formed — the first detailed measurements of their kind during a major tsunami.

While satellites cannot provide an early warning, their data hold great promise for helping scientists improve computer models of wave behavior during tsunamis. Scientists say that better models will be the first line of defense against the havoc tsunamis can cause on coastal areas. The data obtained from Jason and TOPEX/Poseidon — archived at NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC) in Pasadena, California — are enabling scientists to look at the mechanisms that produced the killer waves in the Indian Ocean.

In Mankerni, Sri Lanka, four eyewitnesses to the December 26, 2004 tsunami stand on the remains of the house where they were when they first realized a tsunami was about to strike. (Image courtesy of the U.S. Geological Survey)

Jason and TOPEX/Poseidon are assembling a global, long-term record of sea surface height, which is helping scientists better understand ocean circulation and climate variability. Sea surface height reflects the storage of heat in the ocean: when the ocean warms, it expands, thus raising the sea level, explained Lee-Lueng Fu, chief scientist of the satellite missions from NASA's Jet Propulsion Laboratory in Pasadena. But detection of the recent tsunami is a good example of their secondary benefits, said Fu. "This happened by chance, because the

Feedback

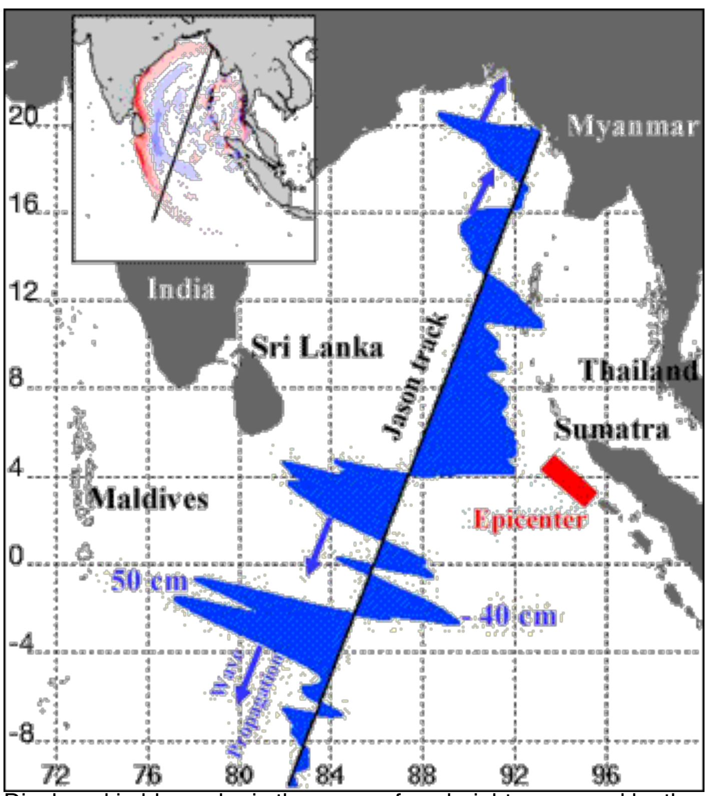
satellites were not designed to make observations of waves moving as fast as a tsunami, which attain the speed of a jet plane in the open ocean," said Fu. "At 500 miles per hour, the waves are moving very quickly and are very hard to detect."

Since the satellites make 13 revolutions around Earth each day, the probability of catching a tsunami in the way that Jason and TOPEX/Poseidon did is about one chance in 50, said Fu. But their ability to detect minute changes in sea surface height enabled them to spot subtle changes in the wave behavior. When the tsunami passed through the Bay of Bengal, the satellites picked up a sea height change of half a meter, which is a huge signal, according to Fu. "This kind of first-hand knowledge is helping researchers better understand how waves propagate in the ocean," he said, "so they can refine their ability to pinpoint where the wave is going to crash over beaches and with how much energy."

To make their measurements, Jason and TOPEX/Poseidon continually bounce radar pulses off the sea surface and record the time it takes for the signal to return. Each radar pulse gives a measure of the satellites' exact location and altitude above the sea surface. Using these measurements, scientists can also calculate the velocity at which ocean currents are moving.

Jason is the satellite credited with making such precise measurements of the recent tsunami event, according to Fu. Its observations included detailed ripples — on the order of 10 centimeters high — spread over a 200-kilometer area. Previously scientists believed tsunamis to be single, fast-moving elevations of the sea surface over a span of several hundred kilometers, according to Fu. Such movement would be akin to the simple rhythmic rise and fall of taking in a deep breath and expelling it. But scientists have learned from Jason's recent observations that tsunami waves in the open ocean are more complicated than that. "This kind of measurement is telling us that a tsunami has a much more complex structure than we used to think," said Fu.

Fu is quick to point out, however, that satellites will never be able to provide a warning system from space because the cost of deploying enough satellites to be at any given point over the ocean within half an hour is prohibitive. "I don't want to give people the impression, 'oh, we caught this tsunami, therefore we should launch more satellites to catch tsunamis.' We just cannot afford to do that," said Fu. Moreover, since Jason and TOPEX/Poseidon data take a minimum of five hours to process, there is a low likelihood of using their data in time to warn coastal residents of an approaching tsunami. But in the rare case that the satellites do record the profile of a tsunami, they provide excellent hindsight because they have a continuous profile of the sea surface height change. "There's no other measurement that can produce such a record," said Fu. Ocean buoys, which are often separated by more than 500 kilometers, don't record a continuous profile.



Displayed in blue color is the sea surface height measured by the Jason satellite two hours after the initial magnitude 9 earthquake hit the region southeast of Sumatra (shown in red) on December 26, 2004. The data were taken by a radar altimeter onboard the satellite along a track traversing the Indian Ocean when the tsunami waves had just filled the entire Bay of Bengal. The maximum height of the leading wave crest was about 50 cm (1.6 ft), followed by a trough of sea surface depression of 40 cm. The blue arrows indicate the directions of wave propagation along the satellite track. (Image courtesy of NASA/JPL/CNES/National Institute of Advanced Industrial Science and Technology, Japan)

The key for early warning is to have more bottom-mounted pressure sensors in the ocean, according to Fu. But experts agree that even having such scientific instrumentation in place won't be sufficient if the communication and education components of a warning system are missing, as was the case on December 26. Cervelli, who's based at the Alaska Volcano Observatory in Anchorage, recalled the moment on Christmas night when the seismometer readings came in. "I remember thinking to myself, 'this is going to create a large tsunami that is going to kill a lot of people,'" he said. "Hundreds of people around the world — when they saw the information — knew that to be the truth, but there was nothing that we could do," he said.

Satellites carrying specialized radar instruments are making it possible for scientists, like Cervelli, to understand the geologic processes that could lead to undersea landslides and potentially devastating tsunamis in the future — perhaps in time to see them coming and to adequately prepare.

Cervelli, who has worked extensively on understanding the volcanic processes of Kilauea Volcano, noted that in Hawaii, the government has made a concerted effort to educate the public about what to do in case of a tsunami. Beginning in kindergarten, children are taught in school and through the newspaper about what to do if they hear a tsunami warning siren. "All of these things are now second nature to most Hawaiian residents, but Hawaii's a relatively small population in a first world country," said Cervelli. "The most challenging thing for establishing a warning system in the Indian Ocean is going to be the education and communication components."

Installing more buoys around the islands hit hard by the recent tsunami would not be too costly or difficult to do, Cervelli said. "But all of that is useless if there is no way to get that information to officials in the countries that will be affected, and it's also useless if you get the information to an official, but the officials are powerless to do anything about it. If people aren't educated about what to do when the tsunami horn goes off, if there even is a tsunami horn, then it doesn't really matter," said Cervelli.

Cervelli's research is one example of the way that scientists are using satellite data to understand tsunami-forming processes before they wreak havoc. The south flank of Kilauea Volcano on the island of Hawaii (the "Big Island") has been moving towards the sea at a rate of six centimeters per year for at least a decade. The fact that there's been so much motion has left some people to wonder whether the south flank is a candidate for "catastrophic flank failure," which would probably lead to a very large tsunami, Cervelli said. If it did occur, it would threaten the Hawaiian Islands, and under some models, the west coast of the United States, South America, and possibly Japan.

Some evidence suggests that very large tsunamis caused by massive undersea landslides have hit the Hawaiian Islands in the not-too-distant geologic past. Researchers have found anomalous corals and marine shells deposited hundreds of meters high above the shoreline of some islands. If it has happened before, some experts wonder whether giant tsunamis may plague the Hawaiian Islands from time to time.

Peter Cervelli of the U.S. Geological Survey installs a global positioning system receiver on the south flank of Hawaii's Kilauea volcano. A steam plume caused by lava entering the ocean is visible on the horizon (far left). (Image courtesy of Peter Cervelli)

So scientists like Cervelli are using a technique known as Synthetic Aperture Radar Interferometry (InSAR) to understand tectonic systems and, hopefully, identify high-risk areas. Satellites carrying InSAR instruments beam a radar signal down onto a given location of the Earth's surface at two different points in time. The second measurement reveals whether the ground has shifted either toward or away from the satellite, explained Cervelli.

While these data can provide a glimpse into the geologic future, they are by no means a crystal ball. "I'm not suggesting that we can predict earthquakes. That, so far, has proven very difficult, if not impossible. But we can give you an idea that 'well, this fault is slipping or it's accumulating strain, so eventually it's going to result in an earthquake,'" said Cervelli. "The trick is telling you on what day and at what time it's going to happen."

So for now, scientists will take what they can get. Such fine resolution and detail from satellite data will help fortify the defense against tsunamis in the future. Computer modelers will be better equipped to compute the strength and pattern of the tsunami waves, explained Fu. "That's a critical link," he said. "Our data will aid researchers by improving their understanding of tsunami dynamics in order to make better models. So that's the benefit of quite a serendipitous measurement."

Reference(s)

Cervelli, Peter. 2004. The Threat of Silent Earthquakes. *Scientific American*.

Fu, L.-L., and A. Cazenave, editors, 2001. *Satellite Altimetry and Earth Sciences: A Handbook of Techniques and Applications*. San Diego, CA: Academic Press

Related Link(s)

Feedback

- Physical Oceanography (PO) DAAC [3]
- Ocean Surface Topography From Space [4]
- USGS Earthquake Hazards Program [5]
- USGS Hawaiian Volcano Observatory [6]
- Pacific Tsunami Museum [7]

Source URL: https://earthdata.nasa.gov/featured-stories/featured-research/making-waves-tsunami-research

Links:
[1] https://earthdata.nasa.gov/featured-stories/featured-research/making-waves-tsunami-research
[2] https://earthdata.nasa.gov/data/data-centers/po-daac
[3] http://podaac.jpl.nasa.gov/
[4] http://topex-www.jpl.nasa.gov/
[5] http://earthquake.usgs.gov/eqcenter/
[6] http://hvo.wr.usgs.gov/
[7] http://www.tsunami.org/