

## Secrets of tsunamis not easily revealed

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COLOMBO, Sri Lanka -- Before an audience hungry for answers, a group of American tsunami scientists spoke of some tantalizing findings, but said they remain far away from understanding and explaining the massive Dec. 26 tsunamis that have killed more than 160,000 in Southern Asia.

"We still don't have all the data we need," cautioned Phil Liu, a tsunami expert from Cornell University and leader of the scientific team sponsored by the National Science Foundation.

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The scientists presented their findings over the weekend to Sri Lanka's minister of science and about 100 engineers, academics and other dignitaries after a hectic week of observation and analysis amid chaos and misery.

One location on the other side of the planet with a similar risk profile kept coming up in the discussion -- the Pacific Northwest.

Costas Synolakis, a University of Southern California tsunami researcher who led studies on the southern coast of Sri Lanka last week, cited the network of deep-ocean tsunami detectors designed and built in Seattle at the Pacific Marine Environmental Laboratory as a critical element needed for a warning system in the Indian Ocean.

Bruce Jaffe, a U.S. Geological Survey scientist from Santa Cruz, Calif., who is on a U.S. team that assessed the east coast, showed the Sri Lankans slides depicting research that revealed tsunami sand deposits on Washington's coast. Jaffe noted that these findings, made less than two decades ago, ultimately awakened Northwest residents to their own risk of major subduction quakes and killer waves.

The Sri Lankans have no definitive written record of a previous tsunami, but the scientists emphasized that this doesn't mean it hasn't happened before here.

"You don't really have a good record (geologically) of how often these things happen," said James Goff, a New Zealand scientist on the American team. He and Jaffe urged the Sri Lankans to conduct the same kind of "paleoseismic" studies done in the Northwest to build such a record.

Many in the crowd came hoping that the visiting scientists would provide them with information and specific recommendations on how to accurately predict a tsunami and completely protect against the next one.

Could there be another such killer wave in this lifetime? What about the theory that these massive subduction quakes, like the one off Sumatra that spawned these waves, tend to happen in clusters? Is Sri Lanka also at risk of massive quakes? Should this island nation, so connected to the sea, wall itself off from the threat of tsunamis? Why were some areas hit so hard while other regions nearby suffered much less?

But without better seafloor mapping and near-shore topography, Liu said, it will be difficult to completely explain the variable and unpredictable behavior of the killer wave that hit here on the morning after Christmas Day.

Undersea canyons off the coast of Sri Lanka, one near Galle in the south and another near Trincomalee in the northeast, may have played major roles in the tsunami's behavior, Liu said. In the especially tragic case of Galle, he said, such a canyon likely focused the wave into a greater force for destruction.

It was near Galle, a coastal city in southwestern Sri Lanka, that researchers found evidence of massive waves with run-up heights in some areas nearing 40 feet.

"It looked like Hiroshima," Synolakis said. He agreed that more information is needed before some actions should be taken, adding that much of this information is still lacking for much of the U.S. coastline -- including many areas on the West Coast that are more likely than Sri Lanka to be hit by a tsunami.

"We know more about the surface of Venus than we do the seafloor," Synolakis said. He urged the Sri Lankans to pursue bathymetric mapping off their coast (an expensive proposition, however, for this country) but added that public education and evacuation planning is perhaps the most important action to take now.

Of interest more to the scientists, perhaps, than for this crowd were all the eyewitness reports that the ocean here in Sri Lanka receded before the arrival of the deadly high walls of water.

Given the assumed nature of the deep-sea earthquake and the standard theory of tsunami behavior, Liu said, this should have happened only in Indonesia or other areas generally east of the fault.

When the seafloor erupted from the quake, he explained, the geometry of the Sumatran fault should have first produced a negative wave (a decline in sea level) on the Indonesian side of the fault and a positive wave sent toward Sri Lanka first -- at about 500 mph. A tsunami is a series of both negative and positive waves, but Sri Lanka should have been hit first by a positive wave.

"According to many eyewitnesses, this isn't what happened," Liu said. "Maybe the standard model is not quite right."

That's the point of this unprecedented international effort to study the impact of these tsunamis, the greatest one in more than 40 years. The models are almost certainly not quite right when it comes to these massive tsunamis.

Just as magnitude-9 earthquakes can overwhelm and confuse the seismic monitors -- as they appear to have done in this case, given the initial estimates of the Sumatran quake as magnitude 8 -- tsunamis at this scale may be completely different from smaller, more frequent tsunamis.

"Tsunamis are much more complex and unpredictable than many realize," said Joe Fernando, a Sri Lankan scientist on Liu's team from Arizona State University.

These killer waves cause massive destruction yet leave surprisingly little lasting evidence of their terrible visitation.

Liu's team in Sri Lanka is just one of a number of teams that have spread out along the coastal areas of the Indian Ocean to talk to eyewitnesses, measure wave heights, areas of inundation or run-up lengths and study sand deposits for clues.

Tsunami researchers from all around the globe have come to these areas of destruction after some initial debate about whether it was appropriate, given the human tragedy. They decided it was critical to gather up as much data as they can before they disappear like sand seeping back into the sea.

Bretwood Higman, a University of Washington sedimentologist on Liu's team, gathered some tsunami sand and is taking it back to Seattle for analysis. Precise examination of the sand-grain sizes and locations in the column, he said, can reveal a surprising amount of information about the velocity and nature of a tsunami.

"The water's gone, but sand deposits can tell us a lot about what the water did when it was there," Higman said.

Liu's team has dispersed after a week of driving all over Sri Lanka to collect their precious tsunami data, sometimes having to forgo a data point to avoid land mines or areas of "sensitivity" in the currently tabled civil war between the government and members of the Tamil minority.

Most, like Higman, headed home to start the less glamorous work of analyzing their samples and data. Liu was asked by the U.S. Embassy in Thailand to go to Bangkok today to consult with the Thais on tsunami mitigation, early warning systems and other matters.

Synolakis and Hermann Fritz, a fluid-mechanics scientist from Switzerland based at Georgia Tech's campus in Savannah, are headed for the Maldives -- a series of islands west of southern India that were completely swamped by a tsunami.

After that, Synolakis will meet up in New Delhi with Frank Gonzalez, director of tsunami research for the Pacific Marine Environmental Laboratory. The Seattle lab is a branch of the National Oceanic and Atmospheric Administration, which developed the tsunameter system now used in some parts of the Pacific Ocean to detect the pressure change of a passing tsunami and issue an alert.

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