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Tsunami simulation an inexact science
Even knowing undersea floor, it's tough developing wave-effect maps for S.F. Bay

- Keay Davidson, Chronicle Science Writer
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Scientists studying tsunamis have their computers "crunching" as fast as they can -- yet they still can't quite figure out how the super- waves behave, or predict when and where they'll strike next.

Like the atmosphere, the ocean is a fluid medium whose fickleness has fascinated computer modelers for decades. The use of computers in meteorology is now a routine practice -- yet it's still hard to reliably foresee the weather's antics more than several days in advance. By contrast, devastating tsunamis -- like the recent cataclysm in Asia -- are rare. Thus, ocean modelers have much less experience simulating them on computers and even less success than their cousins in meteorology.

"Computer modeling of tsunamis is tricky, because solving for the full 3- D motion of water is impossibly complicated," says Gerard Fryer, a modeler at Hawaii Institute of Geophysics and Planetology. "We can do pretty well, though, but (by) making simplifying assumptions."

Some tsunami researchers incorporate historical and prehistorical records of past tsunamis into their computer models. Unfortunately, these records -- based on everything from old shipping logs to Native American legends -- are of limited value, partly because many lack details such as the exact time and epicenter of a quake that causes a tsunami.

Still, using computer models of wave motions based on the known terrain of the undersea floor, scientists have managed to generate tentative maps that show how a major tsunami could damage the Northern California coastline. They've had much more trouble, however, developing maps that simulate how tsunami water might affect water heights around San Francisco Bay, inside the Golden Gate. An inside-the-bay model is in the works at the University of Southern California -- under contract to the state Office of Emergency Services and the state Lands Commission -- and is expected to be released later this year.

But to improve tsunami-casts, it isn't enough to simply understand the behavior of water better. The unpredictability of tsunamis is due partly to the unpredictability of their main causes, which range from earthquakes, undersea landslides and volcanic eruptions to once-in-a-blue-moon asteroid impacts.

And tsunami-casting is made even tougher by our ignorance of the detailed topography of the ocean floor, especially along coastlines, which influences tsunami flow. Detailed topographic data is missing for the coastlines of many economically underdeveloped nations.

One reason is that in many cases, no one's mapped them. But there's another, more strategic reason. Some nations, especially those in politically tense regions, hesitate to reveal such coastal topographic data. They fear that such data could be exploited by enemy navies, particularly submarines, whose sonar guidance systems tend to be confused in the noisy acoustic environment of coastlines.

Emile Okal, a leading tsunami scientist at

Northwestern University, said "better mapping of ocean floors -- mostly in the vicinity of coastlines, the last few kilometers (before shore)" is one of the key elements needed to aid computer modelers. "This is a problem," he said, "because you are getting into the privileged zones protected by each individual country, and this bathymetry is often classified."

Indeed, we have a better idea of how frequently asteroids have hit the moon over the last few billion years -- asteroids leave a clear record of their impacts, gouged into the lunar surface -- than we have of the frequency of super-tsunamis, which leave hard-to-interpret geological records.

"What we sorely need is better maps at high resolution of the seafloor to identify potential hazards we don't know. We don't want to be surprised again, as we were with this (Asian) earthquake," said Costas Synolakis, a leading tsunami expert at the University of Southern California.

Still, modelers have made real progress over the last decade. Eric Geist of the U.S. Geological Survey in Menlo Park is developing a spectacular-looking, George Lucas-like 3-D simulation of the recent tsunami.

But modeling "is difficult for where it counts: on the beach and near the coast," Geist said. For example, an undersea landslide -- say, in an aquatic canyon akin to the one just off Monterey -- can unleash a dangerous tsunami. Slight, hard-to-detect differences in the behavior of landslides can determine whether they unleash a killer tsunami or barely a ripple.

"Tsunamis generated by landslides ... are very sensitive to the duration or speed of the slide," Geist said. "If it is a creeping slide -- no tsunami. If the slide moves at the same speed as tsunami waves, then you can potentially get a very large tsunami, primarily in the direction of slide movement. Unfortunately, there are very few direct or instrumental measurements of slide movement beneath the ocean."

An optimist is Ahmet Cevdet Yalciner, a civil engineer at Middle East Technical University in Ankara, Turkey, who is a leader in efforts to protect coastlines from tsunamis.

"The accuracy of available computer modeling of tsunamis is satisfactory except the motion of waves" as they hit the land, he said by e-mail. He says he thinks a few more years are needed to develop acceptable accuracy in modeling how tsunamis are affected once they strike land, by coastal irregularities such as vegetation and buildings.

In the meantime, tsunami modeling remains very, very difficult, says Floyd McCoy of the University of Hawaii -- which, he jokes, explains "why I am not a model-maker."

Instead, he is busy studying the effects of an ancient tsunami "generated by the enormous Late Bronze Age eruption of Santorini, Greece. That combination, eruption and effects, led to the destruction of a civilization and changed the course of Western civilization."

McCoy cites the difficulties that face modelers, ranging from inadequate oceanographic data to inadequate political interest:

-- A tsunami "is not like a rock falling into the water with waves radiating out with equal amplitudes in all directions." Rather, a quake shoves the seafloor in a particular direction, or starts a landslide that does so; either way, the shove focuses the energy in a particular direction, "so that (tsunami) waves in one direction could be huge and in another slight."

-- To simulate the resulting tsunami in a computer, scientists need to know exactly what happened on the undersea floor -- that is, how it shifted -- but they don't usually find that out until "much, much later, if ever. We are still searching for the source of the 1946 Alaskan tsunami," which caused significant destruction in far-off Hawaii.

-- Wave behavior is significantly affected by offshore topography. On the one hand, McCoy said, "We know what happens when any wave enters shallow water" -- for example, its height increases, its speed drops hugely, and the distance between wave crests diminishes. On the other hand, he said, we know so little about coastal topography, "and in Indonesia or off Sri Lanka? Forget it."

-- "Bring the wave ashore -- now what? ... All those trees, roads, buildings, hills, valleys, and what-all," he said, break up the wave's energy and affect the flow of the water. "Trying to model that is awesome. Tough."

-- Finally, politics again: "Where does the money come from to pay for those who do the modeling and the computer time? It is not there," McCoy said. "The feds, instead, seem to think that NASA and the space station are more important."

Then there's the problem of tsunami-watching instruments that, like snoozing guard dogs, aren't working when they're needed.

Since the tragedy in southern Asia, U.S. news media have reassured Americans: The country is protected by the U.S. National Oceanic and

Atmospheric Administration's DART (Deep-ocean Assessment and Reporting of Tsunamis) network of tsunami-monitoring buoys scattered across the Pacific. In theory, if a tsunami heads our way -- perhaps at a speed of several hundred miles per hour, as reported of the Asian tsunami -- the buoys will send radio signals to emergency planners, who will then alert residents of coastlines: Head for the hills!

But does DART really provide adequate warning, or will future generations remember it as a strategy that gave a false sense of security?

"So far, there are only six (DART) instruments: three south of the Aleutians, two off the Pacific Northwest and one south of the Equator in the eastern Pacific," said Fryer, the Hawaii Institute modeler . "A seventh instrument has been installed by the Chileans off their coast, and an eighth is to be installed off the Kona Coast of Hawaii.

"These instruments are expensive, however, and are costly to maintain. At high latitudes, the surface buoys really take a beating -- of the three instruments off the Aleutian Islands, two are currently out of action, apparently because of breakdowns of the surface equipment.

"The DART instruments are exquisitely sensitive to tsunamis and everybody loves them," Fryer said, "but to increase their numbers to where we'd like them would require a fleet of dedicated ships just for maintenance. Cheaper technologies are under consideration, such as disposable, golf-ball-size, free- floating sensors which measure the horizontal motion of a tsunami rather than its far smaller vertical motion. ... But so far, these exist only on the drawing board."

The ocean's terrors hold personal meaning for McCoy: "We so worry here in Hawaii. I grew up in Hilo. I saw my hometown destroyed by the 1946, 1953, 1957 and 1960 tsunamis. I barely remember the 1946 (tsunami), but do recall that about a third of the seats in my third-grade class were empty -- (the students) had been killed. ... The question here in Hawaii is not if, it is when."

E-mail Keay Davidson at kdavidson@sfchronicle.com.