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On December 26, 2004, the Earth rattled and the world came to an end for hundreds of thousands of unsuspecting people in Southeast Asia and East Africa. That day, shortly before 8 a.m. local time, a violent earthquake occurred 18.6 miles beneath the Indian Ocean near Sumatra, Indonesia. While most earthquakes last a few seconds, the Sumatra--Andaman Islands Earthquake, as it is now called, lasted several minutes. It rattled our planet with an energy equal to 23,000 atomic explosions and caused a vertical ground movement of as much as 0.4 inch everywhere on Earth's surface.

That was the power of the quake, which registered at magnitude 9.1 on the Richter Scale. The horror began when, at the onset of the activity, parts of the sea floor snapped some 16 feet upward like a diver's springboard. This action pushed the sea's surface up by a similar amount before gravity pulled it back down. As the sea flattened out, "ripples" of water measuring about two feet high--a wave system called a tsunami--raced outward.

**A Killer Strikes**

The tsunami traveled miles across the Indian Ocean without causing a noticeable stir, until the waves neared the shores of surrounding lands. As the water became shallow, the two-foot-waves swelled in places to 65 to 100 feet! Then, before most people could escape to high ground, the tsunami rushed onto shore like a watery freight train, destroying everything in its path.

The death toll was staggering. Together, the earthquake and tsunami waves caused more than 280,000 deaths in 11 countries (including those in East Africa). More than 14,000 people are still listed as missing, and more than a million people have been displaced. Perhaps as many as 250,000 people are thought to have died as a result of the tsunami alone--that's more casualties than caused by any other tsunami in recorded history. One-third of the victims were children.

**Tsunami Science**

A tsunami (tsue-NAH-mee) is a series of sea waves that result from a large earthquake, major underwater landslide, exploding volcanic island, or even a meteorite impact! It is not a tidal wave, which is caused by the forces of the Sun, Moon, and wind upon tide waters. The word "tsunami" is Japanese for "harbor (tsu) wave (nami)." It was named by fishermen who returned to port to find an area surrounding a harbor devastated, although they had not been aware of any large wave in the open water.

The most frequent cause of a big tsunami is submarine earthquakes, which can cause the sea floor to lift up and then drop down--just as it did during the Sumatra--Andaman Islands Earthquake. As we have seen, this action also pushes up an entire column of water.

When the pushed-up water drops back down to sea level, potential energy--the energy that was stored in the uplifted water (imagine a stretched rubber band)--is transferred to kinetic energy--the energy of motion (the stretched rubber band being released). The consequence? A series of concentric waves (a tsunami) moves horizontally outward from the earthquake's point of origin. A similar phenomenon (on a much smaller scale) occurs when you drop a stone in a pool of water.

The speed at which a tsunami travels varies as the square root of the water depth. In other words, a wave traveling out across the deep ocean (called a distant tsunami) will travel faster than a wave moving toward shore (a local tsunami). A distant tsunami forms only a small hump of water, two feet or less in height. It travels at a very high speed of 310 to 620 miles per hour, but ships sailing through it won't even notice it.

Not so with a local tsunami.

When a local tsunami approaches a coastline, its speed slows to only tens of miles per hour. The waves compress, increase in height, and then get steeper. The process of getting steeper is like the cracking of a tapered whip. As a wave travels down the whip from the wide handle to the narrow tip, the same energy is deposited in less and less material and then released with a crack. When the wave surges onto shore, it also unleashes a violent "snap" of energy. In the case of the December 2004 tsunami, the total energy of the waves that inundated the Indian Ocean was equal to that of about five megatons of TNT--more than twice the total explosive energy used during all of World War II (including the two atomic bombs).

**Warning?!**

If you're like most people, by now you're imagining loud sirens blaring as monstrous curling waves smash down on tropical shores. Guess again.

First, most tsunamis do not form such giant breaking waves. As a tsunami approaches land, it rushes forward as a viciously fast-rising tide--which is why tsunamis have been commonly (though incorrectly) called tidal waves. But if the tsunamis of December 2004 took, in some cases, hours to cross the ocean before they rushed onto shore, why were so many people killed?

The short answer is that in the Indian Ocean no systems were in place to detect or warn people about tsunamis. Why? Because destructive tsunamis in that region are relatively rare. The last major one was caused by the 1883 eruption and collapse of the Krakatau volcano, which destroyed 295 towns and villages in the Sunda Strait in western Java and southern Sumatra and claimed the lives of 36,417 people.

Distant tsunami waves are so small that detection is not easy. The infrastructure needed to communicate a warning also has been extremely complicated to establish in such a wide and politically diverse region as the areas surrounding the Indian Ocean.

By a remarkable coincidence, two NASA satellites, TOPEX/Poseidon and Jason 1, happened to pass over the December 26, 2004, tsunami as it was crossing the ocean. These satellites carry radar that can measure precisely the height of the water surface and detect anomalies of 20 inches or more. Unfortunately, the data they collected could not have been used to provide a warning, because the satellites were not being used for that purpose. It was, in fact, the first time satellites had ever observed a tsunami from space.

**But Help Is on the Way!**

If we've learned one lesson from the Sumatra--Andaman Islands Earthquake, it is that there's a need for a tsunami warning system for the Indian Ocean. Several organizations are now working on that problem, including the United Nations As of this writing, the first network of instruments to detect tsunami waves in the Indian Ocean and signal a warning is being installed off the coast of Indonesia. It was designed and built in Germany.

The two yellow-painted steel buoys, each the size of a small car, are part of a planned network of 40 new earthquake-registering stations that could be in place around the Indian Ocean by late 2007. Not only will the instruments be able to detect earthquakes on land or sea, but also, because they are on buoys, they will be able to register any tsunami waves moving past them--so real-time warnings can be sent to endangered regions within minutes.

Germany's National Research Centre for Geosciences and its partners devised the system, which German Research Minister Edelgard Bulmahn applauds, saying, "Our rapid response to this need will help bring hope and confidence to people in Indonesia." Of course, all of the high-tech ingenuity in the world is not enough to make the world a place safer from tsunamis--that is, as long as an increasing population continues to build and live in potentially catastrophic danger zones.

**Slip sliding away.**

A massive landslide into the ocean can also create distant and local tsunamis. It does so by changing the shape of the ocean bottom, just as an earthquake does. Gerard Fryer of the University of Hawaii's School of Ocean Earth Sciences and Technology says that instead of causing a lump of water to be pushed up at the surface, however, as in the case of tsunami-generating earthquakes, a landslide sucks water down from the surface, producing a trough. "Gravity doesn't like that either," Fryer says. "It tries to make the surface horizontal again."

The result is that water pushed aside returns to fill the trough. This, in turn, causes the water to swell and be pulled back down again by gravity, producing waves that radiate away from the affected area. Some waves rush onto shore (a local tsunami), while others radiate outward into deep water (a distant tsunami).

Fryer says that the "up-and-down" oscillations created by a landslide into the sea can create waves that are several minutes to tens of minutes apart.

"As with an earthquake," he says, "the first sea level change on land is a fall in water level [a "leading depression wave"], while out on the ocean the first change in sea level is a rise [a "leading elevation wave"]."

Take note! If you are ever by the ocean and see the ocean suddenly and rapidly being sucked away from shore ... run inland as fast as you can and get to the highest ground! Also, after the wave recedes, do not rush back to the scene--the danger is not yet over, as more waves may come!