Quakes cause faraway sloshing

By Sid Perkins / August 16, 2013

In March 2011, a killer earthquake shook the seafloor off the eastern coast of Japan. It triggered powerful tsunami waves. Some towered more than 40 meters (131 feet) by the time they hit the coast. Where the land was especially flat, those waves roared more than 10 kilometers (6 miles) into Japan, killing thousands of people. But Asian waters weren't the only ones that got sloshed around.

Right after the magnitude-9 quake, scientists knew that its tremors had set distant waters in northern Europe rocking and rolling. Now, in *Geophysical Research Letters,* they explain how ground motions caused this sloshing in some parts of Norway.

Fjords — like this one in Norway — are long, narrow and deep. Because of this, distant earthquakes can cause water in fjords to slosh back and forth in a motion called a seiche (SAYSH). Credit: Bondevik et al., Geophysical Research Letters

Long ago, ancient glaciers carved long, narrow inlets into northern coastlines. Norway hosts many of these inlets, called fjords (fee-YORDZ). The water in some of them started sloshing back and forth soon after the quake. This phenomenon, called a seiche (SAYSH), wasn't caused by some tsunami arriving from Japan. Instead, quake vibrations spread globally, through rock. These vibrations also sped much more quickly than did any tsunamis.

This video was recorded in the harbor of Flåm, Norway, the town at the end of the fjord in the above image. The movement of sloshing boats in this video helped scientists understand how ground motions from a distant earthquake caused the phenomenon. Credit: Bondevik et al., Geophysical Research Letters

Waters in the fjords along Norway's western coast were completely calm in the wee hours of March 11, 2011.

But soon after 7:00 a.m., people living along some shorelines witnessed an abrupt and frightening change: The water in some fjords suddenly began rolling back and forth, notes Stein Bondevik. He's a geologist at Sogn og Fjordane University College in Sogndal, Norway. Some people, he recalls, "said 'The sea was boiling.'" He recalls others saying that it seemed "the fjord changed between high and low tide continuously."

People snapped videos of the amazing sloshing water on their cell phones. Some outdoor security cameras captured the unexpected water motions as well. Together, these recordings gave scientists plenty of data about the seiches, such as their size and their timing.

For instance, the time needed for one forward-and-back slosh ranged between 67 and 100 seconds. The length, depth and shape of a fjord determined the timing of these seiche cycles, says Bondevik. At one site, the water along one pier moved up and down a ladder. Based on a video of this, his team now estimates that the water there rose and fell between 1.2 and 1.5 meters (4 and 5 feet) during each slosh. In some fjords, these seiches continued nonstop for nearly 3 hours.

One surprise that Bondevik's group found: These seiches were triggered by a type of ground vibration that causes smaller movements than most.

Quakes cause three major types of *seismic* vibrations, he explains. The ones that travel through Earth's crust fastest are called "P" waves. Similar to the sound waves that travel through air, these pressure waves vibrate very quickly. Another type of ground motion — called "S" waves — travel more slowly. The first S waves typically shake the ground back and forth sideways once every 50 to 60 seconds. The slowest ground motions, known as surface waves, travel along Earth's surface just like tsunamis crossing the ocean.

Although sluggish, surface waves typically move the ground farther back and forth than P waves and S waves. So most scientists had assumed surface waves triggered the seiches. But the video from Norway clearly showed that water in the fjords started sloshing long before the arrival of any surface waves from the Japanese quake. It now appears S waves triggered the seiches, the geologist says.

Where the seiches occurred provides even more support for that notion, he adds.

According to both cameras and eyewitness reports, the seiches affected just six locations. At five of these spots, an imaginary line down the middle of the fjord runs from southwest to northeast. On a globe, that line points directly toward the spot where the Japanese quake struck, more than 8,300 kilometers (5,160 miles) away. That's no coincidence, Bondevik concludes. The reason: "S" waves arriving from that direction would tend to shake the landscape from side to side, or back and forth from the northwest to the southeast. That would send water directly from one side of the fjord to the other. In fjords pointed in other directions, water wouldn't pile up against the shores so readily. Instead, it would flow up and down the fjord and not be so noticeable.

Seiches triggered by quakes have been reported many times before. But which type of seismic waves caused the sloshing water "hasn't been nailed down in detail before," says Daniel McNamara. He's a geophysicist (a scientist who studies Earth, including its motions and energy transfer within the ground) at the U.S. Geological Survey in Golden, Colo. "People just assumed [seiches] were caused by the largest ground motions."

watch a video of seiches in Norway.

Other things can cause seiches, McNamara notes. For instance, when strong storms move across an area, winds can blow some of the water in large lakes from one side to the other. That shoves water from the upwind side, he explains, boosting water levels on the downwind side. Then, when the winds slow or the storm moves on, the high water on the downwind begins to "run downhill," back to where it had been. Like a big splash in a bathtub, this causes sloshing. In a large enclosed body of water, like Lake Michigan, such a seiche can

move back and forth for hours, if not for a day or more.

Human activity can cause seiches too, especially in small, narrow bodies of water. A couple of years ago, McNamara studied seiches in Panama's Lake Gatun. That long, narrow lake is part of the Panama Canal system that links the Atlantic and Pacific Oceans. Because sloshing in the lake is more pronounced during the daytime hours, he now believes that ships passing through the canal are triggering some of the region's small seiches.

All bodies of water can experience seiches. Indeed, McNamara points out, even the water in swimming pools can slosh around in response to passing seismic waves.

Power words:

fjord A long, narrow inlet with steep sides, created in a valley carved by glacial activity.

magnitude (as in earthquakes) A measure of the energy released by an earthquake.

seiche A sloshing wave in a fully or partially enclosed body of water. Seiches have been observed in lakes, reservoirs and harbors — and even in swimming pools

seismic Related to, or caused by, an earthquake.

tsunami A large sea wave, especially one caused by an earthquake or a landslide under the sea. The word comes from the Japanese language, where the words "tsu nami" mean "harbor wave." Tsunamis are often incorrectly called "tidal waves"; they actually have nothing to do with the tides.