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Not My Fault: Back to basics: the earthquake - tsunami connection

Lori Dengler/For the Times-Standard
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I appreciate people making comments about what I write. It's nice to know that the column is being read and I often get ideas of other things to write about from what they say. A friend stopped me at the market and asked why a large quake the previous week hadn't caused a tsunami. I'm glad she asked, because it's a question that is often overlooked because it seems too basic. In the spirit of gearing up for California's Tsunami Week (last week in March) and the North Coast Tsunami Communication Test on March 25th, here's a short explanation.

Yes there is a link between earthquakes and tsunamis, but like many things in the tsunami world, it's complicated. Nearly three-quarters of global tsunamis are the direct result of earthquakes and another sizeable chunk are caused by landslides triggered by earthquakes. To understand the connection, think about how a tsunami is produced and how they differ from other waves.

The waves you see on the beach are caused by wind and air pressure variations. They only affect the upper part of the water column. Any diver can tell you that by depths of 50 feet or more, the water is very calm, even with a stiff chop or strong swells at the surface. These ordinary waves are caused by the forces on the ocean surface and don't penetrate into the depths. Oceanographers call them "deep water waves" because it doesn't matter where the bottom is. The mathematics to describe their behavior assumes the water depth is infinite.

That changes when the waves near the coast, where they begin to interact with the sea floor and the mechanics completely change. Now it's the ocean depth that controls how fast the wave moves and the spacing of troughs and crests. The swallowing water slows the speed causing the water behind to catch up, bulge and eventually break. Mathematically, the waves are now "shallow water waves," because the depth to the bottom now controls many aspects of the wave. Next time you are at the beach, look for the transition from deep water to shallow water mechanics – it's where the waves build and break.

Tsunamis are different than these normal beach waves. They are all shallow water waves. What you say? If they travel across the deepest part of the ocean, how can they be shallow? It's all in the physics and how shallow is defined. Tsunamis aren't caused by pressures from above the ocean. Their generation comes from below. All tsunamis are caused by an abrupt change in the depth of the sea floor bottom. That sudden up or down displacement causes the entire water column, from the very deepest areas all the way up to the surface, to become part of the wave. Unlike normal wind waves, the tsunami doesn't need to reach the coast to feel the sea floor bottom. It feels it from the moment it is first produced whether the water is 12,000 feet deep or even greater.

To produce a tsunami, the entire water column needs to be moved. There are a number of ways to do this – from an asteroid impact to volcanic eruptions and submarine landslides. The most common source on our planet is a large earthquake beneath the sea floor. But only a tiny percentage of all earthquakes produce tsunamis. Where, how large and what type of faulting all make a difference. The where eliminates almost all large earthquakes beneath land. Just cross them off the list.

Except – not always. The exception is an earthquake on land but near the coast that, in rare cases, can cause offshore deformation. Shaking can produce submarine landslides and subsurface deformation and a tsunami nearby. The deadliest tsunami of 2018 was caused by an earthquake on the island of Sulawesi in Indonesia. The epicenter was on land but only a few miles from the coast, and earthquake deformation in Palu Bay about 35 miles away resulted in tsunami more than 30 feet high.

We can also eliminate really deep earthquakes, some reaching nearly 400 miles beneath the surface. At these great depths, even a magnitude 8 earthquake won't affect the sea floor and hence no tsunami. What is the depth cutoff? The USGS separates earthquakes into three depth categories – deep (190 miles or more), intermediate (between 45 and 190 miles) and shallow (<45 miles). The deep quakes don't pose a tsunami threat, the intermediate ones are unlikely but worth taking a closer look and the shallow ones are of the greatest concern.

It's easy to eliminate small and moderate earthquakes as tsunami threats. Anything smaller than about magnitude 6.5 just doesn't have the fault dimensions to cause a tsunami. The majority of tsunami statements issued by the US tsunami centers are for earthquakes that may be large enough to be felt by people near the coast but are

too small to pose any tsunami threat. At the opposite end of the scale, magnitude 8 or larger earthquakes will automatically will get flagged as having a tsunami potential. I will get into the details of the types of messages next week in revisiting the 2010 Chile earthquake and tsunami.

And what about the tweeners – the earthquakes between magnitude 6.5 and 8? It will depend on where they are located and how close population centers are. Both the Pacific and National Tsunami Warning Centers have a detailed grid of locations and magnitude thresholds. An earthquake in the low to mid 7s in Alaska's remote Aleutian Islands won't be large enough to pose a threat. There are no population centers nearby and the source isn't large enough to pose a risk to coastlines far away. But if that 7 is close to the West Coast, Hawaii or in the Caribbean, an alert will likely be issued.

The type of faulting is also important. Not all magnitude 7.5 or 8 earthquakes are equal when it comes to producing a tsunami, even when located in exactly the same place. There needs to be up or down fault slip to displace the water above the fault. Horizontal or strike-slip movement on its own won't move enough water to cause a significant tsunami threat unless the secondary effects of shaking cause deformation as in the case of the 2018 Indonesia earthquake. In January 2018 a magnitude 7.9 earthquake occurred in the Gulf of Alaska, certainly large enough to be of concern to both Alaska coastlines and to us. Fortunately it was a strike-slip earthquake and the tsunami was less than five inches high.

The earthquake my friend asked me about two weeks ago had two counts against it. It was only a magnitude 7 in an unpopulated area of the Kuril Islands north of Japan and it was 90 miles deep. That was an easy one to cross of the tsunami threat list. But had I been in Kurilisk and felt that earthquake, I wouldn't have worried about what type of fault it was on or how deep it was. The long duration of shaking would be my clue to evacuate now and learn the details later.

Next week, revisiting the M 8.7 Chile earthquake and tsunami alerts near and far.

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