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What makes a tsunami — and what to do if one comes

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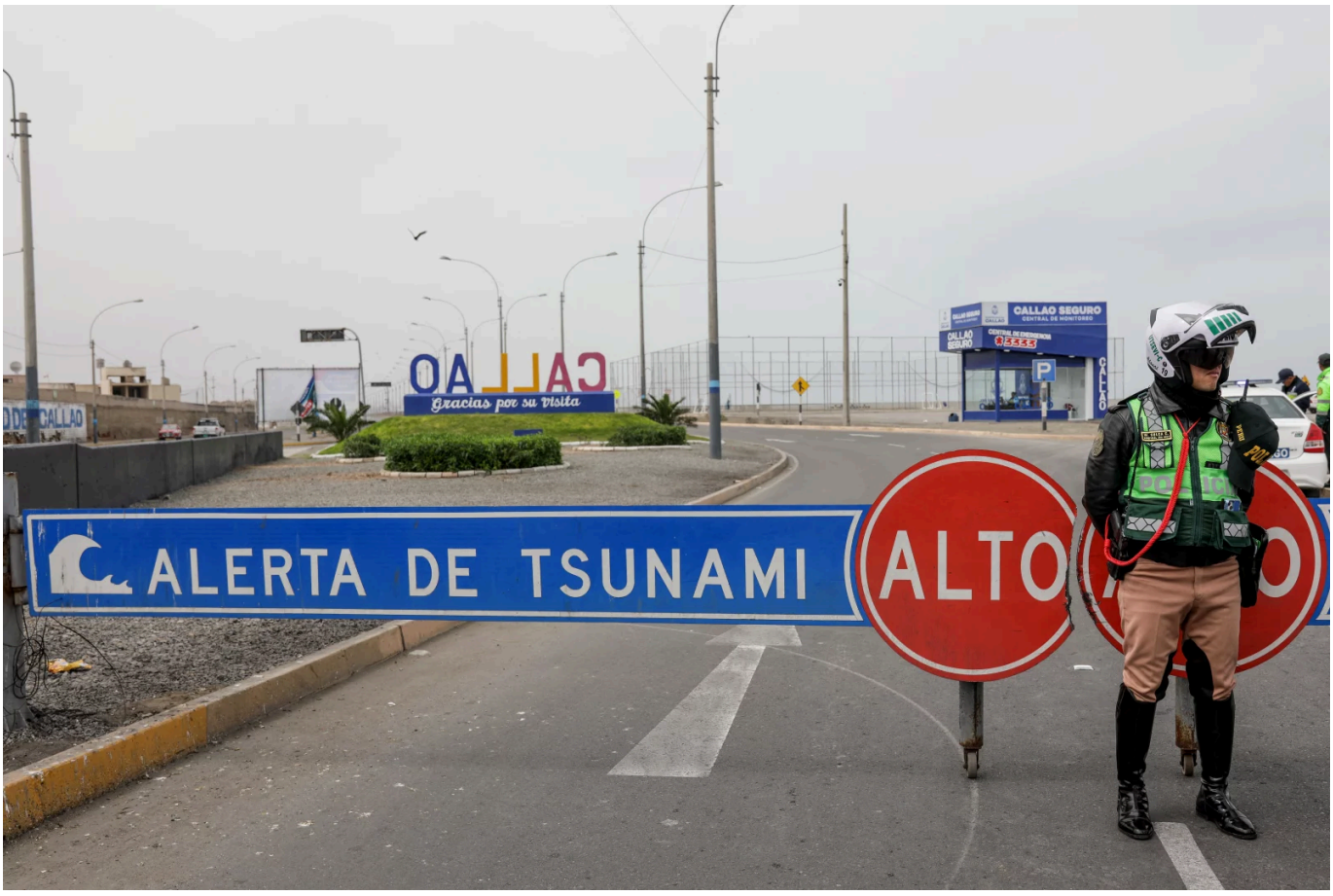

A traffic police officer in Peru sets up a roadblock during a tsunami warning in La Punta, Callao province on July 30, 2025. Alerts were issued in countries across the Pacific, following a massive 8.8-magnitude earthquake off the east coast of Russia.

Connie France/AFP via Getty Images

Tsunami alerts lit up Siri Zama's phone on Tuesday. The 28-year-old high school teacher in Kapolei, Hawaii, fled inland.

"It was raining, and the clouds got real dark. It was just a little scary. I was a little worried because everyone from here was stressing," Zama recalled.

Those stress-inducing alerts had been triggered by an event thousands of miles away: An 8.8-magnitude earthquake that struck Russia's Far East early Wednesday, one of the strongest earthquakes ever recorded. It sent tsunami waves toward Japan, Hawaii and other areas across the Pacific.

Areas along the Kamchatka Peninsula in Russia — near the quake's epicenter — were flooded while people rushed to higher ground, and in nearby Japan, waves crashed onto the shore. In Hawaii's capital, residents rushed into their cars to travel inland.

SHORT WAVE

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While no deaths or substantial damage have been reported from the tsunami, an advisory is still in effect in parts of the U.S. West Coast as of 7:20 p.m. Eastern time.

Recipe for a tsunami

It turns out that it doesn't take much to make a tsunami.

Perhaps the most important ingredient is a strong earthquake. Eric Geist, a research geophysicist with the United States Geological Survey, said an earthquake's magnitude plays a key role. Generally, the quake has to be at least magnitude 6.5 to 7 to generate a tsunami.

"You need a large enough earthquake that gives enough motion to generate upwards and downwards motion on the ocean sea floor," Geist explained.

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But not all strong earthquakes cause tsunamis. It also depends on the location of the quake, and the kinds of motion it creates.

Geist said an earthquake that occurs inland is less likely to produce a tsunami. Instead, underwater earthquakes or those that happen close to shore increase the chances of triggering a wave. He added that the Ring of Fire, the location of about 90% of the world's earthquakes, is a hot spot for tsunamis because those earthquakes create large shifts in tectonic plates.

Vertical movements during a quake help to generate large waves. Another important factor, according to Harold Tobin, a professor of seismology and geohazards at the University of Washington and director of the Pacific Northwest Seismic Network, is how close the earthquake originates to the Earth's surface.

If it occurs closer to the surface — causing what's known as a shallow earthquake — it's more likely to cause a tsunami.

Tuesday's quake, Tobin said, fit that bill.

"It's a shallow earthquake, exactly the type that tends to produce large and damaging tsunamis," he said. "The reason the tsunami warnings were immediately issued is that they were very much warranted by the type of earthquake that occurred."

The duration of tsunamis varies. Geist said tsunamis that originate in the Pacific Ocean seem to last longer, with some producing waves for as long as 22 hours.

"They are actually trapped along the coast, but they're also reflecting back and forth across the ocean basin," Geist said.

Tuesday's quake had all three ingredients. It was strong enough to generate a tsunami, it occurred underwater and it had vertical motion. In 1952, an earthquake in the same area, one that Geist says was "quite similar" — formed a large tsunami that caused widespread damage in Hawaii.

ENVIRONMENT

As Tsunami Debris Crosses Pacific, Dangers Emerge

But accurately predicting tsunamis is challenging because of the many factors at play. Tobin said scientists are still trying to figure out why the earthquake didn't produce an even bigger tsunami.

"Every earthquake is kind of unique," Tobin said. "Every earthquake is like a unique snowflake. This one didn't produce quite as big a tsunami as was initially feared."

Another factor that's difficult to predict is a tsunami's power. Generally, tsunamis start off as long wavelengths that move as fast as an airplane through the deep ocean. The deeper it is, the faster the waves travel.

As a tsunami travels through these areas, the height of the wave is low, meaning someone on a ship in the middle of the ocean might not even notice the tsunami passing through.

Once a tsunami reaches shallow water, its wave speed slows to about 20 to 30 miles per hour, but the speed of water below the wave increases. That's also when the height of the wave increases.

"That's when they become very dangerous," Geist said. "You probably see pictures of tsunamis just lifting train engines up. They're just extremely powerful, mainly because of the volume of water involved."

Predicting a tsunami

While tsunami forecasting remains a challenge, Geist said the field is at a "turning point" in being able to more accurately predict the height and timing of waves. Two sensors help scientists learn more about what to expect: tide gauges and deep ocean pressure sensors.

The former have been around since the 1850s to help harbor masters predict ocean tides. The latter were introduced in the early 2000s.

"[Deep ocean pressure sensors] are critical because you can place them near the seismic reactive areas," Geist said. "It's no small feat to put these instruments out. It takes a lot of technology."

Once a tsunami forms, it spreads perpendicular to the rupture of the quake. The perpendicular energy from Tuesday's earthquake went toward Hawaii. However,

that energy was refracted in other directions because of variations in ocean depth. This can generate secondary waves that travel toward other parts of the ocean, like Alaska or Papua New Guinea.

Certain coastal areas, known as "strong wave guides," face a higher tsunami risk because their shallower waters amplify wave height. One of those areas is Crescent City, Calif., which is why tsunami alerts were also issued for parts of the Pacific Northwest on Tuesday.

Right before a tsunami hits, the ocean typically recedes, indicating that the main wave is coming.

Previous reports have suggested that certain animals, like elephants and snakes, may feel an earthquake or tsunami coming their way. But Geist said it's unclear if it's just a coincidence.

Tsunamis can even come with a smell because they pick up vast amounts of ocean material. Unless the tsunami starts to destroy structures, it's usually hard to hear the waves coming. Geist said people probably didn't hear — or even see — the tsunami from Tuesday's earthquake.

Even so, he said it's crucial to take alerts seriously.

"By the time you realize what's going on, it's moving so fast, it'll just overtake you," Geist said.

What to do when a tsunami hits

"If you're on a beach and you see a tsunami, it's too late to outrun it," Geist said.

That's why it's important to act on tsunami warnings immediately. In general, it's good to be about 30 feet above sea level, but 100 feet is ideal. That's like walking two blocks uphill, according to Tobin.

"Thirty feet is not a lot above sea level, but that can really be the difference" between safety and danger, Tobin said.

Coastal states also have tsunami evacuation maps, which may recommend a higher elevation depending on local geography.

"You might be a mile inland, but you might still be in a danger zone," Geist explained. "You really have to look at those maps to understand where the safe zones are for a tsunami."

Tobin emphasized that tsunamis are not like regular waves. Some can be as wide as 100 miles.

"It's a hump of water that is tremendously long in its wavelength," Tobin explained. "It can be a few feet high, but it travels at the speed of a jet airliner."

Even tsunamis that are a couple of feet high can cause a lot of damage. They don't usually look like the tsunamis portrayed in films.

"That's really not what a tsunami looks like," Tobin said. "Even a 2-foot-high tsunami can be really dangerous."

Some of the danger also comes from the debris tsunamis pick up as they plow through land.

"It's bringing debris from the sea floor, even stuff that's already picked up along the way, like pieces of wood and chunks of buildings," Tobin said. "You can be in serious danger."

It's also important to follow all tsunami warnings, even if it seems like the tsunami is over.

"It's not a single wave. It lasts for a very long time," Geist said. "It's important just to be patient and wait until the all-clear is given before you go back to the coast."

After the wave

While tsunamis may last hours, their effects are felt for months to even years.

Once a tsunami hits a community, it can cause devastating flooding. Flooding can lead to immediate disruptions to clean water, food and healthcare access.

Days after a tsunami, water damage can lead to structural damage in homes, causing mold growth. People with allergies to mold are more likely to be displaced from their homes, which can exacerbate other factors.

"People who are allergic to mold can be really affected by this," Dr. Jyothi Tirumalasetty, an allergist and immunologist at Stanford, said. "Their asthma can also get worse, and we know that damp and moldy environments can actually promote respiratory symptoms in people."

Changes that aren't visible to the human eye also occur. Standing water can increase the risk of vector-borne outbreaks such as malaria and waterborne infections like cholera.

Long term, flooding impacts mental health and disrupts access to treatment for chronic diseases like diabetes. Tirumalasetty's family was impacted by the 2004 tsunami that hit communities in the Indian Ocean. She said it had long-lasting mental health effects on her uncle in India.

"There's that constant worry about, 'Is this going to happen again, and how are we going to deal with it?'" Tirumalasetty said. "In an area like that where there may not be the same preparedness and ability to assess damage and rebuild as quickly, I think that they were impacted for many, many years."

Vulnerable patients, including the elderly, kids and those with preexisting conditions, should prepare for tsunamis and have what Tirumalasetty calls a "go bag." For certain patients, that could mean a small bag with extra asthma inhalers and masks.

"Having all that ready to go and packed, ready to jump in your car, that's going to get you away from a disaster safely and really provides peace of mind," she said. "It's also going to take care of you during something like [a tsunami], where you have limited access to medications."

While it's unclear if this week's tsunami was related to climate change, some experts argue that a warming planet increases the risk of extreme weather events like earthquakes and tsunamis. Tirumalasetty, who studies how climate change affects human health, said her field is actively adapting to these changes.

"In the medical community, there's a growing awareness [of climate change], and we are doing our best to include climate change education for medical students," she said. "The younger physicians are really leading the way in this, and they really care deeply about the environment and making our most vulnerable patients safe from these types of disasters. As we continue to grapple with this and the

best ways to manage it, I think we're going to have better, long-term solutions for patients."

Geoff Brumfiel contributed to this report.

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