Tsunami threats are greatly underestimated in current models, new research shows

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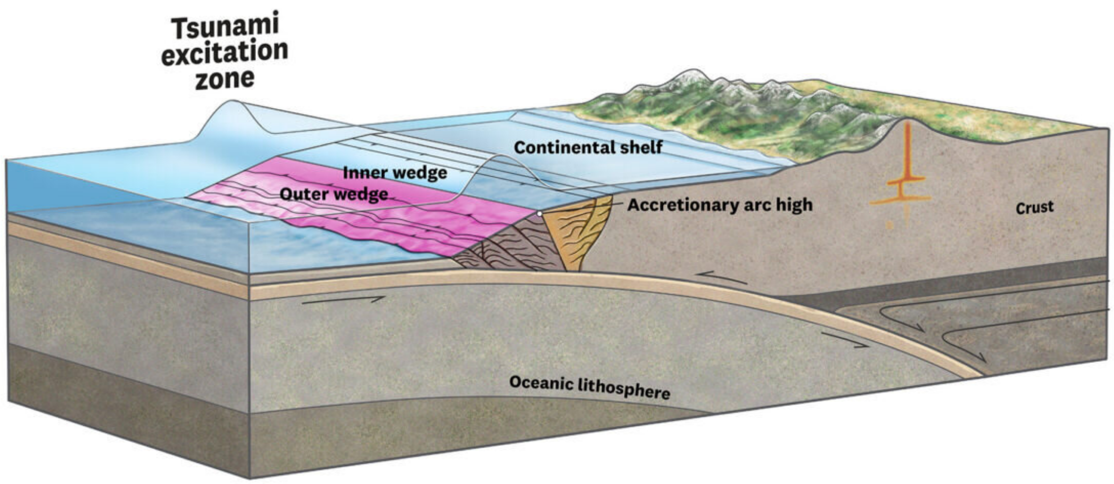

USC researchers found that large earthquake-generated tsunamis emerge after horizontal oceanic water movement is transferred to uplift in the tsunami excitation zone, the outer wedge of sediment between the continental shelf and the deep ocean trench. Credit: USC Graphic/Mesa Schumacher and Edward Soleto

The 2004 Sumatra earthquake generated one of the most destructive tsunamis ever recorded, with 100-foot waves that killed nearly 230,000 and resulted in an estimated $10 billion in damage. It also ushered in a new understanding that potent tsunamis are triggered by shallow earthquake ruptures of underwater fault lines. Future tsunamis are likely to be just as severe, if not worse, potentially killing even more people and wiping out whole communities. Although current research points to rupture depth as a key factor in predicting tsunami severity, those models fail to explain why large tsunamis still occur following relatively small earthquakes.

Now, USC researchers have found a correlation between tsunami severity and the width of the outer wedge—the area between the continental shelf and deep trenches where large tsunamis emerge—that helps explain how underwater seismic events generate large tsunamis. Drawing insights from a survey of previous tsunamis, the authors analyzed the geophysical, seismic and bathymetric data of global subduction zones to identify and discuss potential tsunami hazards.

Their latest study revealed that current predictive models underestimate tsunami severity by as much as 100%. The work appears in the journal *Earth-Science Reviews.*

"Close to half of the human population is coastal, leaving our population and infrastructure vulnerable to seismic and tsunami hazards," said USC's Sylvain Barbot, associate professor of Earth sciences at USC Dornsife College of Letters, Arts and Science sand co-author of the study. "To maintain our livelihoods and our economy, we need to protect ourselves from these very violent hazards that are relatively infrequent but still happen. We cannot stop this hazard, so we need to mitigate its effects.

"That means having evacuation plans for tsunamis and developing an urban development plan to avoid having schools and hospitals in inundation regions. There are preemptive measures we can take to protect ourselves against tsunamis and flooding long-term, and our study provides a description of how to define the area affected by these hazards."

Tsunami threat: Excitation zone width highly correlated with severity

To develop their new model, Barbot and co-author Qiang Qiu, now at the South China Sea Institute of Oceanology under the Chinese Academy of Sciences, analyzed the structural and tectonic settings of nearly a dozen global earthquake-generated tsunamis. Varying in location and intensity, the analysis found that particularly large tsunamis emerge after horizontal movement is transferred to uplift in the outer wedge of sediment located between the continental shelf and the deep ocean trench. The many faults and folds of the outer wedge of accretionary prisms efficiently redirect the sub-oceanic horizontal motion generated by great and giant trench-breaking earthquakes into potentially devastating tsunamis.

"We can very quickly determine where and how big earthquakes are at subduction zones," Barbot said. "If they happen to be fairly shallow, our results can quickly determine what tsunami height they can generate. This can help improve already existing short-term mitigation strategies for early warning systems."

The survey of earthquake-generated tsunamis illuminated a correlative relationship between the width of the outer wedge and maximum tsunami strength resulting from earthquakes measuring 7.1 to 8.2 in moment magnitude (Mw). In doing so, the researchers were able to generate estimates of future tsunami severity generated by a range of seismic events.

Middle East, Alaska and Pacific Northwest among regions facing tsunami threat

The authors investigated another 30 active subduction zones. Utilizing the correlation between the width of the outer wedge with tsunami run-ups, they shed light on the threat posed by potential tsunamis. The authors identified the Western Makran (Iran), Western Aleutian, Lesser Antilles, Hikurangi (New Zealand) and Cascadia subduction zones as having the potential to produce the highest tsunami run-ups. For instance, the Cascadia subduction zone—located off the U.S. West Coast near Oregon and Washington—could suffer tsunamis 160 feet high in the wake of a major quake, double what current models project.

"The region that should be the most alert to this is Iran and Pakistan," Barbot said. "Much of their industry and population is located on their southern coast, exposing them to the largest potential tsunami run-up hazard—perhaps up to 90 meters [nearly 300 feet] in the event of a 9.0 Mw earthquake. However, the threat is nearly as bad in other subduction zones. In the Pacific Northwest, they already have tsunami mitigation measures in place, but they may be preparing for a lower run-up than will happen."

While these findings better explain how severe tsunamis result from shallow seismic events, future efforts should incorporate three-dimensional imaging of the outer wedge, according to the authors. Understanding the pathway from earthquake to tsunami depends on identifying the structural and rheological controls that turn a rupture into a trench-breaking earthquake.

"With this study, we were able to find this correlation simply because we have a lot of data now," Barbot said. "It's the benefit of hindsight that allowed us to discover this really very simple correlation. There is much of this we don't know yet, so it needs more detailed research, but the relationship between outer-wedge width and tsunami run-up is clear enough that it can be extrapolated."

More information: Qiang Qiu et al, Tsunami excitation in the outer wedge of global subduction zones, *Earth-Science Reviews* (2022). DOI: 10.1016/j.earscirev.2022.104054

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