Computer models show significant tsunami strength for Ventura and Oxnard

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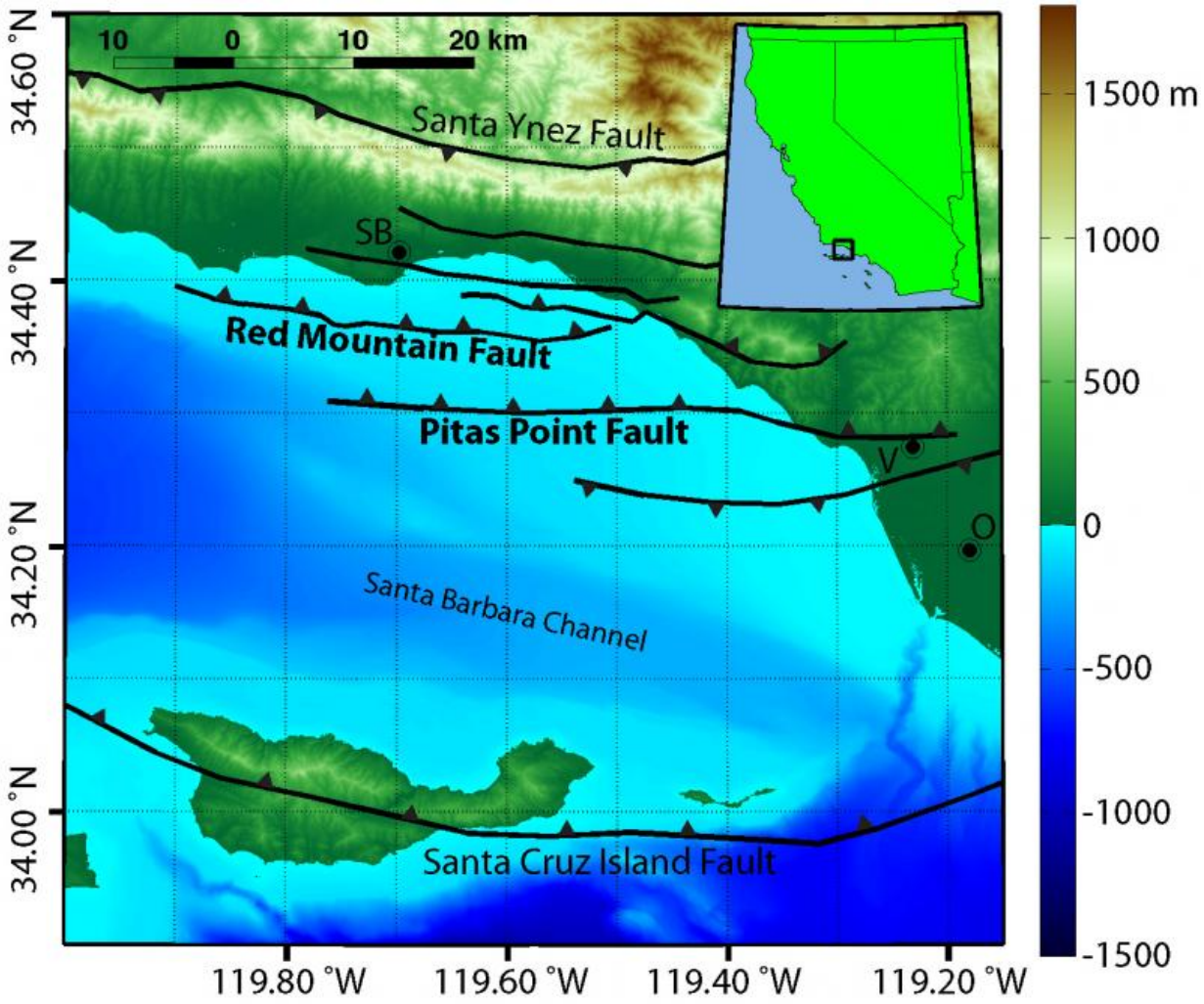


Topographic/bathymetric map of onshore/offshore Southern California, with height and depth in meters. The Red Mountain and Pitas Point faults are considered in this study. Triangles indicate direction of dip; faults without triangles are considered strike-slip. Letters show approximate (central) city

locations: SB = Santa Barbara; V = Ventura; O = Oxnard. Inset shows the map boundary in black. Credit: University of California - Riverside

Few can forget the photos and videos of apocalyptic destruction a tsunami caused in 2011 in Sendai, Japan. Could Ventura and Oxnard in California be vulnerable to the effects of a local earthquake-generated tsunami? Yes, albeit on a much smaller scale than the 2011 Japan earthquake and tsunami, according to computer models used by a team of researchers, led by seismologists at the University of California, Riverside.

According to their numerical 3D models of an earthquake and resultant tsunami on the Pitas Point and Red Mountain faults – faults located offshore Ventura, Calif. – a magnitude 7.7 earthquake would result in many parts of the regional coastline being inundated a few kilometers inland by a tsunami wave, with inundation in places greater than that indicated by the state of California's current reference inundation line.

Study results appear in *Geophysical Research Letters*.

"The hazard from earthquake-generated tsunamis in the Ventura/Oxnard area has received relatively little attention," said Kenny J. Ryan, a graduate student in the Department of Earth Sciences at UC Riverside and the first author of the research paper. "For our study, the shape of the coastline and seafloor produce the most interesting effects on the tsunami, causing a southward moving tsunami to refract – and therefore rotate – and focus on the Ventura/Oxnard area. Unfortunately, the Ventura/Oxnard area has relatively flat topography along the coast, so a tsunami can inundate that area quite effectively."

Tsunamis are mainly generated by earthquakes. Sustained by gravity,

they are long ocean waves that increase in amplitude (the tsunamis become larger) as water depth decreases. Since water depth is generally shallow near coastlines, the tsunami can grow in size as it approaches land, becoming particularly hazardous along heavily populated coastlines such as the Southern California coastline. Capable of achieving propagation speeds of about 435 miles per hour in deep water, tsunamis can get reflected and refracted due to changes in topography/bathymetry along shorelines.

In their study, the researchers used two different modeling codes: one for the earthquake and one for the tsunami. The vertical seafloor deformation from the earthquake model was used as input into the tsunami model to generate the tsunami. The tsunami code then calculated tsunami propagation and inundation.

"Our study is different in that we use a dynamic earthquake model to calculate seafloor displacement from the earthquake," said coauthor David D. Oglesby, a professor of geophysics in whose lab Ryan works. "Dynamic models such as these calculate movement in time by looking at the forces on and around the fault in time. They are physics-based, and fault slip distribution and ground motion are calculated results of the models."

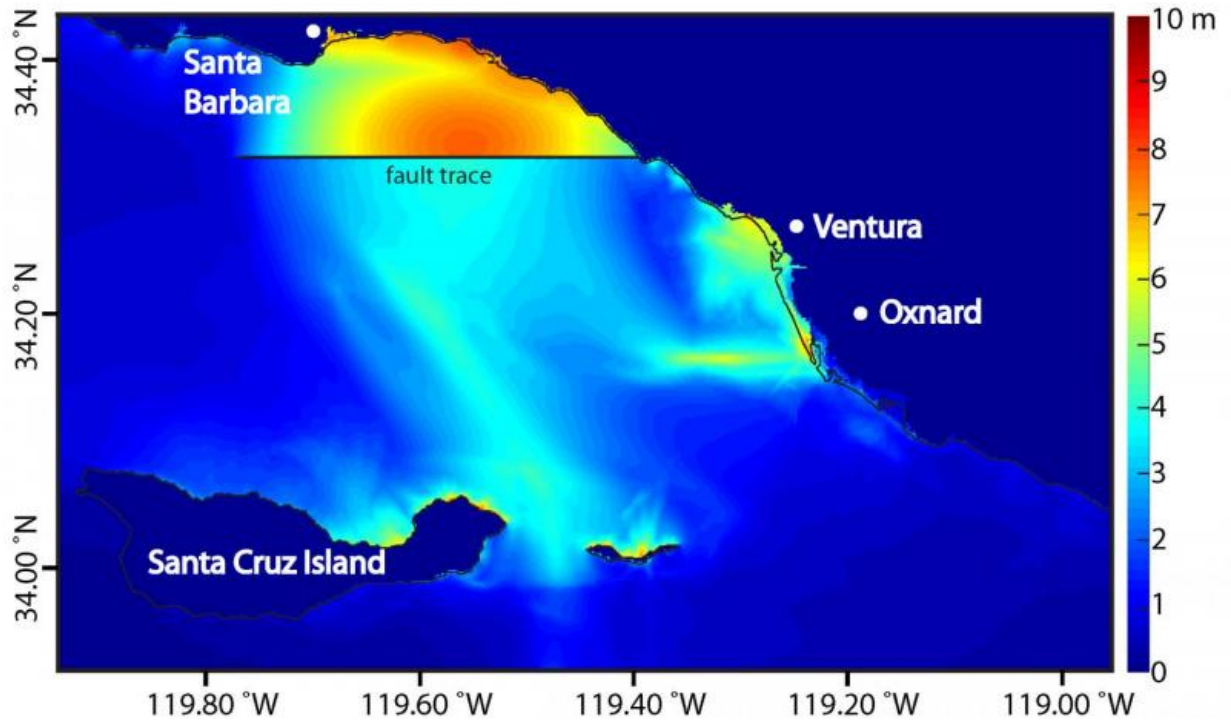
A magnitude 7.7 earthquake generated by the researchers' models along the Pitas Point and Red Mountain faults results in the following scenario:

1. The earthquake occurs much more rapidly than the tsunami. First, the fault slips (within the first 20 seconds of the model) and seismic waves propagate outward in all directions. The seafloor is permanently deformed from the earthquake. This happens in less than a minute.
2. The tsunami is generated by the permanent vertical displacement of the seafloor, and begins to propagate outward through the

ocean.

3. Part of the tsunami propagates north and arrives at the northward coastline, where Santa Barbara is located, in approximately five minutes. Also, part of the tsunami propagates south toward the deeper water in the Santa Barbara Channel. Because of deeper water here and the local bathymetry, this southward propagating tsunami begins to refract after five to ten minutes, rotating counterclockwise in the direction of Ventura and Oxnard. Meanwhile, some of the tsunami waves are being reflected off the regional coastline. These refracted and reflected waves focus toward Ventura and Oxnard in 15-20 minutes and begin to inundate that area in less than 30 minutes.
4. The entire regional coastline sees a tsunami wave train that inundates many parts of the coastline in the region. The tsunami inundation in Ventura/Oxnard is significant in the model owing to a combination of factors: large slip and seafloor displacement from the modeled earthquake scenario, refraction, focusing, and Ventura/Oxnard's flat topography that facilitates water flowing inland.

"The models result in large tsunami amplitudes northward and eastward of the fault due to the shape of the coastline and seafloor," Ryan explained. "The probability of such an event in a given time frame is low compared to smaller earthquake events. Nonetheless, it is crucial to investigate the possible effects from such rare but plausible earthquake and tsunami scenarios so that a full hazard assessment can be made. Results from such modeling efforts can help reveal potential regions of high tsunami hazard."



Map of regional peak tsunami amplitude in meters resulting from an earthquake on the Pitas Point and Lower Red Mountain fault system. The thin solid black line indicates the coastline and the thick black line indicates the Pitas Point fault trace. The fault trace is where the fault surface intersects the seafloor; it is seen as a straight line in the east-west direction. Note that significant regional tsunami inundation occurs. Credit: Kenny Ryan, UC Riverside.

Research has shown that the faults in the Ventura basin in Southern California are capable of generating earthquakes of magnitude 7 or greater as well as significant local tsunamis. Research has also shown that tsunamis generated locally by faulting and landslides offshore California can impact the California coastline in a matter of minutes.

"Our study describes one potential earthquake and tsunami scenario along the Pitas Point and Red Mountain faults, and is designed to illustrate the usefulness of rupture modeling in determining tsunami

inundation," Ryan cautioned. "It is not intended to give an overall distribution of all possible earthquakes and tsunami hazards in this region. Our models simply give an indication of what may be possible in this region."

Ryan and Oglesby were joined in the research by Eric L. Geist at the U.S. Geological Survey and Michael Barall at Invisible Software, San Jose, Calif. Geist applied the tsunami models and serves as Ryan's tsunami mentor. Barall wrote the earthquake software and guided Ryan through the use of the software.

More information: *Geophysical Research Letters*, onlinelibrary.wiley.com/doi/10 … 02/2015GL064507/full

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