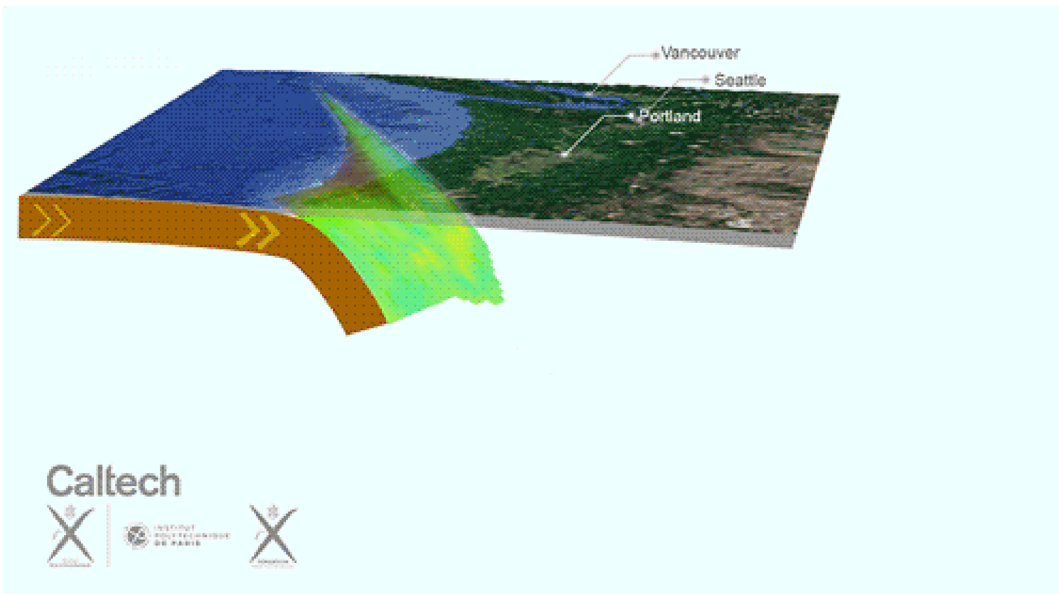
Earthquakes in slow motion: Studying 'slow-slip' events could shed light on destructive temblors

October 23 2019



GPS stations reveal activity beneath Cascadia where the oceanic floor slides beneath North America. The plate interface is locked at shallow depths (the shaded area), but we see recurring slow-slip events (in blue) that unzip the plate interface, generating tremors (the black dots). Credit: Jean-Philippe Avouac/Caltech

A new study from Caltech finds that so-called "slow slip" or "silent" earthquakes behave more like regular earthquakes than previously thought. The discovery opens the door for geoscientists to use these frequent and nondestructive events as an easy-to-study analog that will help them find out what makes earthquakes tick.

Slow-slip events were first noted about two decades ago by geoscientists tracking otherwise imperceptible shifts in the earth using GPS technology. They occur when faults grind incredibly slowly against each other, like an earthquake in slow motion. For example, a slow-slip event that occurs over the course of weeks might release the same amount of energy as a minute-long magnitude-7.0 earthquake. Because they occur deep in the earth and release energy so slowly, there is very little deformation at the surface, although the slow events might affect an area of thousands of square kilometers. As such, they were only noted when GPS technology was refined to the point that it could track those very minute shifts. Slow-slip events also do not occur along every fault; so far, they have been spotted in just a handful of locations including the Pacific Northwest, Japan, Mexico, and New Zealand.

As they have only just begun to be detected and cataloged, a lot remains unknown about them, says Jean-Philippe Avouac, Caltech's Earle C. Anthony Professor of Geology and Mechanical and Civil Engineering. "There's a lot of uncertainty. You can't study them using traditional seismological techniques because the signal they create is too faint and gets lost in the noise from human activities as well as from natural geological processes like ocean waves, rivers, and winds." Before Avouac's group began this study, there were not enough documented slow-slip events to determine their scaling properties reliably, he says.

Avouac's group designed and applied an innovative signal processing technique to detect and image the slow-slip events along Washington state's Cascadia Subduction Zone, where the North American tectonic plate is sliding southwest over the Pacific Ocean plate, using a network of 352 GPS stations. The researchers analyzed data spanning the years 2007 to 2018 and were able to build a catalog of more than 40 slow-slip events of varied sizes. Their findings appear in *Nature* on October 23.

Compiling data from these events, the researchers were able to characterize the features of slow-slip events more precisely than previously possible. One key finding from the study is that slow-slip events obey the same scaling laws as regular earthquakes.

In this context, the scaling law describes the "moment" of a slip event on a fault—which quantifies the elastic energy released by slip on a fault—as a function of the duration of slip. In practical terms, that means that a big slip across a broad area yields a long-lasting earthquake. It has long been known that the moment of an earthquake is proportional to the cube of the amount of time the earthquake lasts. In 2007, a team from the University of Tokyo and Stanford suggested that slow-slip events appear to be different, with the moment seemingly directly proportional to time.

Armed with their new fleshed-out catalog, Avouac's team argues that the magnitudes of slow-slip events also are proportional to the cube of their duration, just like regular earthquakes.

Since these events behave similarly to regular earthquakes, studying them could shed light on their more destructive cousins, Avouac says, particularly because slow-slip events occur more frequently. While a traditional magnitude-7.0 earthquake might only occur along a fault every couple of hundred years, a slow-slip event of that magnitude can reoccur along the same fault every year or two.

"If we study a fault for a dozen years, we might see 10 of these events," Avouac says. "That lets us test models of the seismic cycle, learning how different segments of a fault interact with one another. It gives us a clearer picture of how energy builds up and is released with time along a major fault." Such information could offer more insight into earthquake mechanics and the physics governing their timing and magnitude, he says.

The paper is titled "Similar Scaling Laws for Earthquakes and Cascadia Slow Slip Events."

More information: Sylvain Michel et al, Similar scaling laws for earthquakes and Cascadia slow-slip events, *Nature* (2019). DOI: 10.1038/s41586-019-1673-6

Provided by California Institute of Technology