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Not My Fault: Earthquakes and climate change

Lori Dengler/For the Times-Standard
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I recently gave a talk for HSU's Osher Lifelong Learning Institute (OLLI) about human-caused earthquakes. The talk focused mainly on earthquakes related to resource extraction and the filling of large reservoirs. Afterwards someone asked about climate change and if it could cause earthquakes. The short answer is no, but, as I think more about the question, it's worth some clarification.

First, there is no doubt that climate change is real and human activity plays the major role. I'm not going to use this space to weigh the preponderance of evidence behind that statement. The question is whether increased sea levels, warmer waters or other consequences of climate change in any way affect the nature of earthquake activity on the planet.

Step one is to consider the cause of earthquakes. My OLLI talk was about human-caused seismic activity. My first point was that natural tectonic forces cause the overwhelming majority of earthquakes and all of the really large ones. I made a rough back-of-the-envelope calculation that perhaps 3% of the earthquakes in 2021 could be ascribed to a human cause.

Tectonic earthquakes are caused by the heat within the earth that drives plate motion. "Within the earth" is the crux of the matter. Earthquakes occur at miles beneath the surface in an environment where the thermal regime is entirely controlled by heat flowing upwards from the deeper parts of our planet. When people ask if there is such a thing as earthquake weather, I say of course just name it – snow, sleet, frost, rain, wind, drought, heat wave – are all earthquake weather. Earthquakes occur in every season, every time of day and under any weather condition. A one-, two- or even ten-degree change in average surface temperatures won't make a bit of difference to earthquake generation.

But temperature is not the only consequence of climate change. What about sea level rise? Could the additional weight of all that water trigger earthquakes? The evidence says no. The earth's surface is stressed twice a day by much larger variations in sea level height. The tides predictably load and unload the sea floor twice daily, adding far more weight than current sea level increase. Many studies have looked for a correlation between seismic activity and tidal cycles; a few link levels of microseismicity (tiny quakes too small to be felt) with tidal forcing but there is no credible connection to larger quakes.

It's not just the weight of water that can have an affect on earthquakes. All crustal rock has space (pores) between the grains. Earthquakes occur at depths well below the water table and the fluid pressure is what makes fault slip possible, allowing rocks on either side of the fault to slip relative to one another.

There is ample evidence that increasing the pressure of fluids in these pores can trigger earthquakes. The USGS conducted an experiment in the early 1970s injecting water into deep wells and measuring pore pressure and earthquake activity in Western Colorado. The correlation was striking; earthquakes occurred when pore pressure exceeded a certain value and abruptly stopped when the pressure was reduced. In the last decade, a similar but uncontrolled experiment has been playing out in the Midwest as waist fluids from well drilling and hydraulic fracturing operations are injected into deep underground wells as a disposal method. The increase in earthquake activity led the USGS to redraw hazard maps of the region (see Not My Fault 12/13/20).

We can rule out increased pore pressures as an earthquake trigger beneath the ocean for the same reason as the weight – tidal forcing would create much larger pressure changes than the slow increase in ocean level. But pore pressure may play a role in a secondary way. A warming planet increases demand for water and the need for larger and larger reservoirs. The majority of reservoirs on the planet have not affected earthquake activity but circumstantial evidence points to several exceptions – notably the M6.7 Lake Koynanagar, India and the M5.7 Oroville earthquake in 1975 that followed large changes in reservoir water levels. Some scientists have proposed that the 2008 M7.9 Sichuan earthquake was related to the filling of a nearby dam.

Another localized effect is due to the melting of glaciers. Melting removes weight and changes stress. Several studies suggest this could affect both fault and volcanic activity. The tsunami threat from great earthquakes is unlikely to change, although even modest sea level rise will expose more ports and low lying areas to a tsunami threat. The tsunami hazard due to landslides is likely to increase, especially in areas like Alaska where glacial retreat destabilizes hillslopes.

The ocean is the critical piece of the climate change picture, storing nearly 95% of trapped greenhouse gasses. It's easy to measure ocean surface temperatures with buoys, ships and satellites. Probing the ocean depths is much more difficult. Oceanographers can send probes to the bottom, but that only provides information in a small area.

Seismology to the rescue! Seismic wave velocities are very sensitive to temperature. A study last fall (https://www.sciencemag.org/news/2020/09/ocean-s-hidden-heat-measured-earthquake-sounds) utilized sound waves from undersea earthquakes to study the Indian Ocean. No surprise that temperatures were rising but the study suggested the warming rate is nearly 70% higher than previously believed.

My answer to the OLLI question still stands. Climate change is not going to affect the incidence and severity of earthquakes. But that should not put your mind at ease. We can't stop earthquakes but we can learn to live with them by building earthquake resilient structures and knowing what to do when the ground shakes. Climate change is the opposite story. It will be nearly impossible for human societies, as we know them, to adapt to climate change without profound and disruptive change. But unlike earthquakes, we actually can do something to put on the brakes. The big question is whether we will.

For more on climate change and earthquakes, visit https://climate.nasa.gov/news/2926/can-climate-affect-earthquakes-or-are-the-connections-shaky/

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