

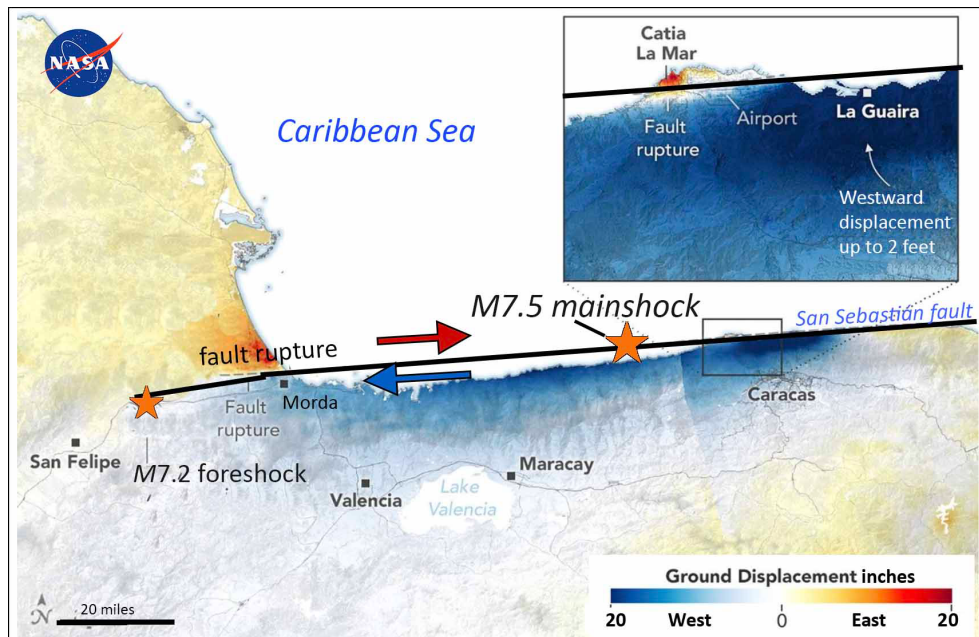
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Not My Fault: Post event reconnaissance studies add to our understanding of earthquakes and tsunamis

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Map of ground displacements from a NASA InSAR satellite analysis comparing before and after imagery to detect differences in locations. The two stars are the epicenters of the Venezuela M7.2 foreshock and M7.5 mainshock on June 24. The black line is the combined fault rupture zone as interpreted by the USGS. Movement was predominantly horizontal; blue tones show ground that moved to the west, and orange/red hues are areas that moved to the east. Note that the greatest displacements are not near the epicenters but are distributed along the entire rupture zone. Inset is an enlarged view of Catia La Mar, where the greatest damage and largest displacements were observed, modified from NASA.

An important part of the analysis of a major earthquake, tsunami, or other natural hazard event is reconnaissance field studies. Much can be learned from remote sensing imagery and eyewitness accounts but boots on the ground visits by experts are essential for both gathering quality data and understanding the complete scope of an event. As a participant in a number of such reconnaissance surveys, I can attest to how many valuable insights gained that would never have occurred to us beforehand.

There are many different types of post disaster studies. Organizations like the World Bank, World Health Organization, and the United Nations Development Program launch teams to estimate international aid needed for immediate response and relief. Reinsurers, businesses that insure insurance companies, like MunichRe and Lloyds of London send in groups to evaluate vulnerabilities to update their catastrophic loss models. The International Red Cross

and Red Crescent and other humanitarian groups not only deliver aid but also send teams to study the societal complexities of disasters to improve future relief operations.

Natural disasters always trigger a variety of discipline-specific reconnaissance efforts that vary depending on the type and scale of impacts. In the last month, several reconnaissance reports were released for the deadliest seismic event of the year, the June 24 earthquake magnitude 7.2 and 7.5 earthquakes in Venezuela. Located in a tectonic system not unlike California's San Andreas transform plate boundary, the mechanics and effects of those earthquake provide important lessons not only for Venezuela, but the U.S. as well.

I last wrote about Venezuela in my first half 2026 earthquake summary in early July only ten days after the earthquakes. At that time the death toll stood at about 3,000 and response efforts precluded visits by reconnaissance teams. Since then, at least seven international groups of scientists and engineers have visited the region and worked closely with Venezuelan professionals to map out the interplay between ground motions and structural response and understand why the scale of damage was so great.

Major earthquakes are not unusual in Venezuela. The north coast sits adjacent to the boundary between the Caribbean and South American plates. It's a complex system with four major fault systems and movement distributed over a 50 to 150 miles wide zone. About 80% of the Venezuelan population live within this zone and the region accounts for the country's ports and almost all of the industrial output. Thirteen earthquakes in the historic record have claimed 100 lives or more: the deadliest in 1812 claimed at least 26,000. The most recent major quake was in 1967 and killed at least 300 people.

With such a history of earthquakes, it's not surprising that Venezuela built robust engineering and scientific programs focused on seismic safety. Elite universities and government programs funded by its oil wealth put Venezuelan science advances in the top tier of South American institutions in the latter half of the 20th century. My colleague and friend Jim Dewey worked with many Venezuela experts for his PhD studies in the late 1960s and has nothing but praise for the quality of their work.

The Chavez/Maduro era has not been kind to the Venezuelan scientific community. The Bolivarian revolution began by Hugo Chavez in the 1990s viewed traditional universities and institutions as elitist and replaced a merit-based system with a state-directed one. According to Science, personnel purges, infrastructure declines, and lack of autonomy have driven over 70% of research engineers and scientists to leave the country. This has resulted in an unusual diaspora with few experts within the country but a strong well-connected group of expatriate Venezuelans holding prominent positions in academia and industry around the world. This cadre of highly respected earthquake professionals played an important role in the post event studies.

On June 24th, it didn't take long to get a snapshot of what happened on that deadly evening. Two major earthquakes had occurred in rapid succession: a M7.2 earthquake at 6:04 PM (local time) followed 33 seconds later by a M7.5. It was easy to pin down the location of the 7.2 but took four days for USGS seismologists to nail down the larger earthquake as its seismic waves were mixed in with those of the first earthquake. According to the USGS finite fault model, the two earthquakes ruptured a 130-mile-long segment of the San Sebastián fault system. Fault

motion was strike-slip with land to the north of the fault moving to the east and areas south of the fault moving west.

Post earthquake reconnaissance teams focused on a number of issues. While most of the rupture was just offshore and not directly observable, the fault did cut through land near Catia La Mar where geologists examined the ground for signs of surface fault rupture. Other geologic questions included how many faults were involved and the role of regional geology in amplifying shaking and triggering landslides. Engineering groups were interested in the doublet effect of how two earthquakes so close together affected structures and how did different types and ages of construction withstand the shaking.

Geotechnical Extreme Events Reconnaissance (GEER) is an organization that focuses on gathering perishable geologic data of interest to the engineering community. Engineers, geologists, and seismologists from around the world volunteer to participate in event reconnaissance and sponsored by NSF. A GEER team studied satellite interpretations of ground deformation such as the figure reproduced here and carefully examined the Catia La Mar area for surface rupture.

Surprise number one was the lack of surface faulting. The satellite before and after InSAR (Interferometric Synthetic Aperture Radar) imagery showed nearly six feet of horizontal slip, yet there was no clear offset on the ground surface. An earthquake of this size and at a depth of less than ten miles beneath the surface almost always reaches the surface and leaves obvious offsets. What the GEER team found instead was a widespread zone of cracks with small displacement, liquefaction, and disturbed soils. The interpretation is that the weak alluvial cover distributed and amplified shaking, rather than allowing a single rupture plane to reach the surface.

Surprise number two was how the weak and saturated sediments in the Catia La Mar area amplified the shaking strength. GEER scientists called this the “bowl of Jello” effect and resulted in extremely strong vibrations and loss of soil strength. Large structures were particularly vulnerable to foundation distress and nearly one-third of all buildings in this area were damaged. This is not an effect limited to Venezuela. San Francisco’s Marina District experienced a similar insult during the 1989 Loma Prieta earthquake and other parts of California including the Sacramento River delta area, Los Angeles coastal basins, and the Humboldt Bay area are also vulnerable.

The Earthquake Engineering Research Institute (EERI) oversaw a number of reconnaissance studies. I was particularly interested in what types of construction were most vulnerable and if lack of government code enforcement had contributed to the over 800 total building collapses and more than 10,000 badly damaged structures. The vast majority of high-rise failures were in buildings built before 1970. These non-ductile reinforced concrete buildings are no longer allowed with current building codes as the columns can collapse and the structure pancake. But all cities in the world, including those in California, are filled with similar buildings.

I hadn’t thought much about the timing of the two earthquakes. Doublets, when two major quakes occur within hours or days of each other, are not uncommon. But a doublet with two pulses only a half minute apart is unusual and creates a shaking duration equivalent to a much larger magnitude earthquake. Each cycle of wave motion exerts stress on a structure,

potentially causing small failures. Most buildings, especially those built to current codes, can easily resist 30 or 40 seconds of cycling. But if the shaking length is extended by back-to-back earthquakes there may be vulnerabilities, a question California scientists and engineers are taking a second look at. I predict more code modifications in the next year.

The scale of loss in Venezuela is hard to imagine. The official death toll is 6,509 but as many as 50,000 people are still unaccounted for. The reports published in the past month are only the beginning of what I hope will be a sustained effort to fully understand the Venezuela earthquakes and take actions to build more resilient communities.

Note: a summary and link to the GEER report on the Venezuela earthquakes is at <https://geerassociation.org/?view=geerreports&id=117&layout=default>, EERI's summary page of Venezuela reconnaissance and reports is <https://www.eeri.org/about-eeri/news/31158-eeri-response-to-june-24-2026-m7-2-m7-5-yumare-venezuela-earthquakes> .

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