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This scientist is racing to predict deadly volcanic mudslides

One of the most deadly and dangerous volcano hazards isn't lava. Mudflows called lahars can come without clear warning.

In June 2024, early career geologist Gustavo Béjar López traveled to Guatemala for a project aimed at using artificial intelligence to automatically detect and potentially forecast deadly mudslides called lahars at Volcán de Fuego.
GUSTAVO BÉJAR LÓPEZ

By Angela Posada-Swafford
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Perched on the volatile slopes of Volcán de Fuego in western Guatemala, geologist Gustavo Béjar López listened to the heartbeat of one of the world's most restless mountains, as he dug holes to place seismometers. Fuego, which sits at an elevation of over 12,000 feet, erupts consistently every 15 to 20 minutes, sending ash and glowing ballistics into the air, and scarring the rainforest that blankets its steep slopes.

"It's just hard to comprehend the energy that is necessary for a volcano to keep spewing lava every 15 to 20 minutes," remarks Béjar, a National Geographic Explorer. "Sometimes you can't see the crater, but you hear the volcano's explosion, feel it in your chest, and then you hear rocks falling."

While its low-magnitude explosions are a draw for hikers on the neighboring dormant Acatenango volcano, Fuego is also capable of sudden, cataclysmic violence. In June 2018, a massive eruption sent out searing avalanches of hot gas and lava, wiping out the town of San Miguel Los Lotes and claiming hundreds of lives. But the immediate threat of eruptions isn't what first brought Béjar to the slopes of Fuego back in 2021. Instead, he was focused on another deadly and poorly understood volcanic hazard: *lahars*.

These are powerful mixtures of ash, debris and water with the consistency of wet concrete, that surge downhill, excavating new channels and transforming dry riverbeds into conduits for destructive mudflows. Now, Béjar has teamed up with local scientists in Guatemala to use artificial intelligence to try to better detect lahars —and save lives.

(*Volcanoes blow smoke rings. Here's how they do it.*)

This drone photograph shows Fuego's active crater. The volcano's eruption in 2018 killed hundreds of people.

GUSTAVO BÉJAR LÓPEZ

Two of Béjar's colleagues Amilcar Caldera of INSIVUMEH and Gregory Waite of Michigan Tech inspect real-time seismic waveforms generated by an active lahar along Fuego's slopes in an area called Barranca Ceniza.

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Detecting dangerous volcano threats

Though less well-known compared to eruptions, lahars are exceptionally dangerous. An explosive eruption of Colombia's Nevado del Ruiz in 1985 ejected hot sulfur dioxide gas and volcanic rocks that melted the mountain's glaciers, setting off a cascade of four large lahars. Flowing down the slopes at 30 miles per hour, the massive mudslides quickly engulfed the village of Armero, which was 37 miles away. It's considered the deadliest lahar-caused volcanic disaster in recorded history, killing at least 20,000 people.

But lahars don't require an eruption to happen. Instead, the trigger is usually heavy rainfall or snow melt, compounded by a steep incline and small fragments of loose debris, so these mudflows are a significant threat during the rainy season in the tropics. "You can have lahars happening 200 years after the last eruption of a volcano," says Béjar, who grew up in Ecuador. "They can be set in motion by climate change, through increased rainfall and even hurricanes, as has been the case in Guatemala in the past."

These mudslides have been the subject of Béjar's work since he was a Ph.D. student at Michigan Tech. He wanted to solve a critical problem: Lahars are notoriously difficult to detect in real-time. During the peak of Guatemala's rainy season, May through October, Volcán de Fuego's lahars can happen daily, but only the very large ones get reported.

Historically, lahar detection on the mountain has relied on a combination of manual seismic monitoring and sparse visual confirmations from local observers. While Guatemala's National Institute of Seismology, Volcanology, Meteorology, and Hydrology (INSIVUMEH) provides technical notices, the process is often hampered by limited visibility and the high cost of specialized equipment. "This means lahars can go undetected or they can be detected and verified mainly when they come close to communities," Béjar explains.

The researchers combined AI-enabled detection with in-person camera and drone observations of lahars, like this one in its final stage.
GUSTAVO BÉJAR LÓPEZ

Through grants from the National Science Foundation and the National Geographic Society, he and his team placed five seismic stations and used four additional existing ones at different altitudes on Fuego. Climbing was challenging, adding the weight of car batteries to power the stations and other equipment to an already difficult ascent. At each station they needed to dig a one-meter-deep hole to place the heavy cylinder-shaped sensor. "We would start with a small shovel and then at some point we just used our hands, which was so annoying because the ground there is full of ash, sand, and big logs."

Seismometers, says Béjar, "are like microphones for the ground." They sense vibrations not only coming from the volcano, but from surface vegetation moving with the wind, mechanical noises generated nearby, and even the steps of people walking. In the case of lahars, seismometers detect the energy generated when a mudflow interacts with the path it travels on.

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These signals provided Béjar with digital footprints of the flows' size, speed, and sediment concentration. He optimized and adapted a machine learning algorithm called K-Nearest Neighbors (KNN) to compare the new seismic data points against a curated training dataset of previously labeled "lahar" and "non-lahar" events.

Fuego volcano is a good training ground for an algorithm because seismic

characteristics of lahars in this mountain have remained relatively stable over several years. Previously, researchers thought that the relationship between the signal's frequency and the kind of lahar was mainly defined by the sediment concentration, grain size, and the way it flows. Béjar's recently-published study corroborates this. Low-frequency vibrations, for example, are associated with flows that have a lot of sediments, move more sluggishly, and carry larger boulders along the path of the avalanche.

"When lahars are significantly large, the signal can be detected up to 20 minutes before the mudslide reaches the monitoring station," says Béjar. This all depends on the AI's ability to correctly distinguish a lahar from another type of volcanic event generated inside the mountain, he cautions. The algorithm was very good at flagging medium and large lahars but struggled to identify smaller ones.

(*Volcano forecasts could soon be a reality.*)

Lahars pose threats beyond Guatemala

KNN is user-friendly, requires minimal processing power, and can be deployed on inexpensive computers employing existing seismic monitoring networks. This makes it an ideal solution for resource-constrained regions like Guatemala. Béjar says that INSIVUMEH is planning to incorporate the algorithm into their monitoring system this year. "The idea is that the work we do in Guatemala can directly benefit them as project partners."

But its implications extend far beyond the slopes of Fuego. Candidate volcanoes to work on with AI include Mount Rainier, close to Seattle, and Cotopaxi, next to Quito, Ecuador, because they share the same potential for dangerous mudflows to form. Béjar hopes to one day collaborate with other geologists and test his AI-based system on those, and other volcanoes.

And Béjar, who is currently a visiting professor at Albion College in Michigan, is not the only one working with artificial intelligence in volcanology, though he believes he is the first person to do it with Volcán de Fuego's lahars.

Artificial Intelligence is increasingly being used as an automated tool in the study of volcanoes—from using deep learning in pattern recognition, to exploring early warning systems, predictive modeling, monitoring from space, and understanding the inner workings of these mountains.

For Béjar, it is a way to keep visiting volcanoes, while doing beneficial, meaningful work. "My aspiration is to connect with other scientists and organizations to work together and modernize these risk prevention tools, not only for lahars, but for the multitude of volcanic other threats to which society is exposed today."

Gustavo Béjar López stands on the neighboring Volcán Acatenango with Fuego in the background.
GUSTAVO BÉJAR LÓPEZ

The nonprofit National Geographic Society, committed to illuminating and protecting the wonder of our world, funded Explorer Gustavo Béjar López's work. **Learn more** about the Society's support of Explorers.

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