NASA researchers measure sinking land in American Samoa

September 5 2023, by Tayler Gilmore

Landsat image of American Samoa's Tutuila Island, acquired on July 22, 2022, with the Operational Land Imager (OLI) on Landsat 8. Credit: NASA Earth Observatory/Lauren Dauphin

On Sept. 29, 2009, an 8.1-magnitude earthquake struck near American

Samoa, Samoa, and Tonga, triggering a tsunami that caused human casualties and $200 million in property damage on the islands. The earthquake also exacerbated another problem in American Samoa: subsidence, or the sinking of land. When combined with relative sea level rise, land sinking can increase the frequency and amount of coastal flooding.

Protecting against flooding on islands requires reliable measurements of how much the ground is sinking and where, said Jeanne Sauber, a geophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "You need to know in detail where the land is going down the fastest," she said. Sauber and several NASA colleagues are combining remote sensing tools to figure that out.

Historically, subsidence measurements on small tropical islands have been difficult to make for two reasons. Islands often have few resources for acquiring detailed measurements at the land surface, and dense midday clouds and vegetation can make good satellite data difficult to get.

Using the island of Tutuila in American Samoa as an example, a team of NASA scientists last year published a study on how to better map ground changes on earthquake-prone islands. They found that using a combination of satellite and ground-based observations could result in a more nuanced and comprehensive map.

In the past, scientists had used data from two points of measurement on Tutuila: a GPS station and the island's one tide gauge. They typically coupled those points with satellite altimetry, which allows scientists to broadly monitor the surface height of the ocean. But these data provided only a limited picture.

In the study, the researchers added InSAR, or interferometric synthetic aperture radar, which allowed them to see where the ground was changing. InSAR is a technique that involves comparing satellite radar images of the same area collected at different times to spot movement on Earth's surface and track changes in ground height.

The study found that Tutuila sank an average of 0.24 to 0.35 inches (6 to 9 millimeters) per year between 2015 and 2022 compared to 0.04 to 0.08 inches (1 to 2 millimeters) per year before the 2009 earthquake. The highest rates of sinking occurred right after the earthquake, especially along the coastlines.

"We knew how much the ground is deforming at this one point because of the GPS station there, but with the radar remote sensing technique, we can get a much denser map of what's going on across the island," said Stacey Huang, a fellow with NASA's Postdoctoral Program at NASA Goddard and the study's lead author.

Building a better map

Synthetic aperture radar data is collected from planes or satellites. It works by sending out microwave pulses from the satellite to Earth's surface and then measuring the time it takes for the pulses to bounce back and the strength of that reflection, or "backscatter." Unlike many satellite instruments, this kind of radar can pierce through clouds and dense vegetation, allowing researchers to accurately measure relative elevation and changes in the land surface. Huang and Sauber's study used data from the ESA (European Space Agency) Copernicus Sentinel-1A satellite.

The researchers also used satellite altimeter data to assess sea level and correlate it with measurements from the island's Pago Pago tide gauge station. The gauge measured sea level relative to Tutuila, while the altimeter measured the absolute sea level. The difference between them shows, among other signals, Tutuila's land motion, or movement, relative to Earth's center.

One of the challenges for evaluating land subsidence on remote islands is understanding how the island motions may be influenced by the broader movement of tectonic plates. By including measurements from Tutuila's GPS station, the researchers could monitor the rate of vertical motion.

"So not only can we say what is one point doing relative to another on an island, we can say what is this island doing relative to other locations around the world," said Sauber, a co-author of the study.

Why the land sinks

Land subsidence in this part of the western Pacific Ocean results from the movement of the Pacific and Australian tectonic plates. When one plate passes under the other, a phenomenon called subduction occurs along the Tonga Trench, a deep canyon in the Pacific Ocean. Earthquakes frequently result from this process, creating vertical movement of the island's surface, along with ground-surface changes.

To understand how much the land has changed after each earthquake, scientists measure something called vertical land motion—the up-and-down movement of the land from the removal and rearrangement of materials in the Earth's subsurface.

"Over hundreds of thousands of years, or even millions of years, these volcanic islands tend to sink as they cool off," said Eric Fielding, a geophysicist from NASA's Jet Propulsion Laboratory in Southern California. "This long-term geologic process applies to the Samoan Islands, and the earthquake cycle adds to that."

Sea level rise compounds the problem, said Richard Ray, the study's third author and a geophysicist at NASA Goddard. In Tutuila, for example, the relative sea level is rising by as much as five times the global average, according to a previous study including Ray and Sauber.

The average global sea level rose by 0.11 inches (2.7 millimeters) from 2021 to 2022, according to a NASA analysis of satellite data. In that 2019 study, scientists found that the region's sea level rise relative to the land was 0.04 to 0.08 inches (2 to 3 millimeters) per year before the earthquake, but now, relative sea level rise is several times the global average.

"Three millimeters may not sound like much, but it makes a difference over time as it builds up," Ray said.

Many islands around the world are facing rising sea levels and share similar features with Tutuila. Researchers hope to apply what they learned from Tutuila to other islands for coastal resilience planning, including collaborative efforts between NASA and the United Nations to inform decisions across Pacific Island nations.

Slated to launch in early 2024, NISAR—short for NASA-ISRO Synthetic Aperture Radar—jointly developed by NASA and ISRO (Indian Space Research Organization), will track movements of Earth's land and ice surfaces in extremely fine detail, and will help identify and track vertical land motion around the world.

Coastal resilience planning is necessary to protect people who live on smaller islands, and it requires reliable data.

"We really need to know how fast that land is sinking so that policy decisions can be based on scientific data," Sauber said. "You do not want to move people away from their homes unless they're really going to be in a dire situation."

Provided by NASA's Goddard Space Flight Center