

Great timing and supercomputer upgrade lead to successful forecast of volcanic eruption

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In the fall of 2017, geology professor Patricia Gregg and her team had just set up a new volcanic forecasting modeling program on the Blue

Waters and iForge supercomputers. Simultaneously, another team was monitoring activity at the Sierra Negra volcano in the Galapagos Islands, Ecuador. One of the scientists on the Ecuador project, Dennis Geist of Colgate University, contacted Gregg, and what happened next was the fortuitous forecast of the June 2018 Sierra Negra eruption five months before it occurred.

Initially developed on an iMac computer, the new modeling approach had already garnered attention for successfully recreating the unexpected eruption of Alaska's Okmok volcano in 2008. Gregg's team, based out of the University of Illinois Urbana-Champaign and the National Center for Supercomputing Applications, wanted to test the model's new high-performance computing upgrade, and Geist's Sierra Negra observations showed signs of an imminent eruption.

"Sierra Negra is a well-behaved volcano," said Gregg, the lead author of a new report of the successful effort. "Meaning that, before eruptions in the past, the volcano has shown all the telltale signs of an eruption that we would expect to see like groundswell, gas release and increased seismic activity. This characteristic made Sierra Negra a great test case for our upgraded model."

However, many volcanoes don't follow these neatly established patterns, the researchers said. Forecasting eruptions is one of the grand challenges in volcanology, and the development of quantitative models to help with these trickier scenarios is the focus of Gregg and her team's work.

Over the winter break of 2017-18, Gregg and her colleagues ran the Sierra Negra data through the new supercomputing-powered model. They completed the run in January 2018 and, even though it was intended as a test, it ended up providing a framework for understanding Sierra Negra's eruption cycles and evaluating the potential and timing of future eruptions—but nobody realized it yet.

"Our model forecasted that the strength of the rocks that contain Sierra Negra's magma chamber would become very unstable sometime between June 25 and July 5, and possibly result in a [mechanical failure](#) and subsequent [eruption](#)," said Gregg, who also is an NCSA faculty fellow. "We presented this conclusion at a scientific conference in March 2018. After that, we became busy with other work and did not look at our models again until Dennis texted me on June 26, asking me to confirm the date we had forecasted. Sierra Negra erupted one day after our earliest forecasted mechanical failure date. We were floored."

Though it represents an ideal scenario, the researchers said, the study shows the power of incorporating high-performance supercomputing into practical research. "The advantage of this upgraded model is its ability to constantly assimilate multidisciplinary, real-time data and process it rapidly to provide a daily forecast, similar to weather forecasting," said Yan Zhan, a former Illinois graduate student and co-author of the study. "This takes an incredible amount of computing power previously unavailable to the volcanic forecasting community."

Bringing the moving parts into place to produce a modeling program of this strength requires a highly multidisciplinary approach that Gregg's team did not have access to until working with NCSA.

"We all speak the same language when it comes to the numerical multiphysics analysis and high-performance computing needed to forecast mechanical failure—in this case of a volcanic magma chamber," said Seid Koric, the technical assistant director at NCSA, a research professor of mechanical sciences and engineering and a co-author of the study.

With Koric's expertise, the team said they hope to incorporate [artificial intelligence](#) and machine learning into the forecasting model to help make this computing power available to researchers working from

standard laptop and desktop computers.

The results of the study are published in the journal *Science Advances*.

More information: Patricia M. Gregg, Forecasting mechanical failure and the 26 June 2018 eruption of Sierra Negra Volcano, Galápagos, Ecuador, *Science Advances* (2022). DOI: [10.1126/sciadv.abm4261](https://doi.org/10.1126/sciadv.abm4261).
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