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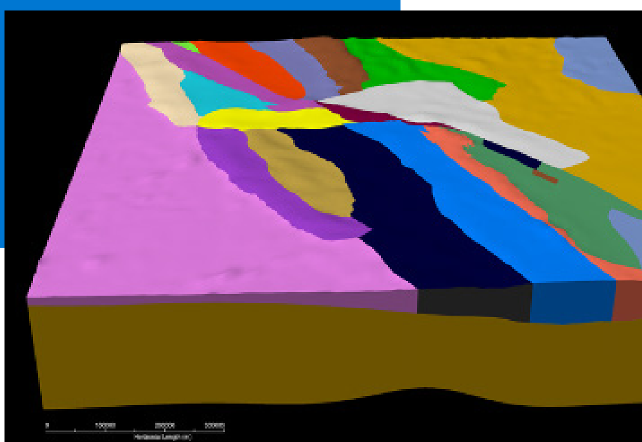
Unlocking the secrets of earthquakes

The Southern California Earthquake Center relies on the power of supercomputers to simulate why and how earthquakes occur, evaluate their effects, and help societies prepare for, survive and recover from quakes.



Geologic Framework provinces in the southern California crust. Image courtesy of Andreas Plesch (August, 2020).

Customer profile

SCEC
an NSF+USGS center

Scientific Research | United States

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Christine Goulet
Executive Director for Applied Science
Southern California Earthquake Center

Business needs

Researchers at the Southern California Earthquake Center need high performance computing solutions to power computationally intensive earthquake research.

Business results

- Producing dynamic models of earthquake processes
- Improving the predictability of earthquake system models
- Simulating earthquake events with high performance computing
- Promoting a safer society that’s more resilient to earthquakes

Solutions at a glance

- Frontera supercomputer at the Texas Advanced Computing Center
- Dell EMC PowerEdge C6420 servers with Intel® Xeon® Scalable processors
- Intel® Optane™ DC Persistent Memory
- NVIDIA® Mellanox® InfiniBand® HDR and HDR-100 interconnect

Exploring earthquake processes

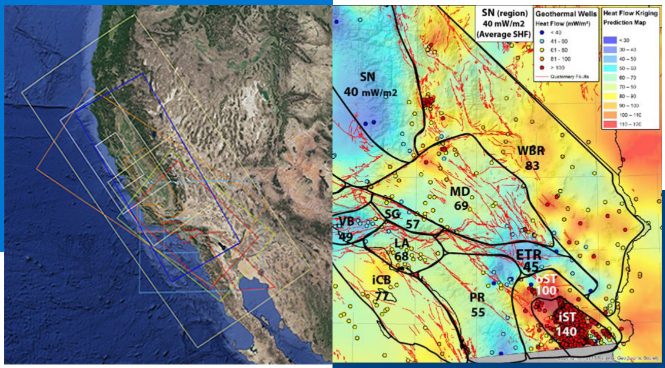
For California residents, the threat of earthquakes is part of everyday life. While the state experiences small quakes on a daily basis, the threat of a catastrophic quake is always there. And the hardest part of this problem is that scientists can't predict when and where an earthquake will strike.

We do, however, have the ability to prepare for quakes by developing early-warning systems, conducting earthquake preparedness drills, engineering buildings for earthquake resilience, and conducting scientific simulations to help us better understand what will happen the next time the earth will shake.

This is where the Southern California Earthquake Center (SCEC) makes a positive impact. The SCEC, based at the University of Southern California, coordinates fundamental research on earthquake processes using Southern California as its principal natural laboratory. It supports core research and education in seismology, tectonic geodesy, earthquake geology and computational science.

"We study earthquakes — why they occur, how they occur and what kind of impact they have," says Christine Goulet, Ph.D., Executive Director for Applied Science at SCEC. "We can't predict earthquakes at this time, but we can prepare better if we know what to expect."

The SCEC community advances earthquake system science through three basic activities: gathering information from seismic and geodetic sensors, geologic field observations and laboratory experiments; synthesizing knowledge of earthquake phenomena through physics-based modeling, including system-level hazard modeling; and communicating its understanding of seismic hazards to reduce earthquake risk and promote community resilience.



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Christine Goulet

Executive Director for Applied Science,
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Simulating earthquakes

For their scientific explorations, Dr. Goulet and her colleagues draw on the computational power of supercomputers to simulate what happens when faults rupture and the ground starts moving.

"We have a sense of how many large earthquakes will occur, and what their magnitudes will be, and so on, over the next several hundred years," Dr. Goulet says. "But we don't know exactly when they will occur, what they will look like and what they will do to our infrastructure. Computer-based simulations can really help with this by supplementing the recorded dataset, because we haven't experienced all the earthquakes we expect to have in the future. We run simulations to better understand what happens with earthquakes over time and also in a specific location."

For these simulations, the researchers at the SCEC use some of our nation's most powerful supercomputers. These high performance computing resources include multiple systems from Dell Technologies, including the Frontera supercomputer at Texas Advanced Computing Center (TACC).

Dr. Goulet and her colleagues run two main classes of simulations on Frontera — a big-picture long-range view of earthquakes occurring over time and close-up shaking from single events. The big-picture view models earthquakes as they happen over hundreds of thousands of years.

"We model the complex California fault system, impose stress on it, and then we let the stress transfer as earthquakes occur over time, triggering other earthquakes or releasing stress in different locations," Dr. Goulet says. "And we can see how the evolution of these earthquakes happens over time."

The other type of simulation the team runs on Frontera focuses on one single event at a time, where the researchers model a quake's rupture and wave propagation to the Earth's surface.

"An earthquake doesn't happen all at once," Dr. Goulet explains. "When the stress becomes too much, the crust breaks at its weakest point and the rupture propagates over several seconds or more, like a zipper if you will. It's a little bit like a crack that propagates after a rock hits a windshield. So we model the crust, known faults and stresses, and propagate waves that are generated as the fault breaks. The location, depth and speed of the rupture and the type of rock and soil we are on all affect ground motions we feel at the surface."

Validating the models

A big part of the research conducted at the SCEC involves validating the accuracy of models against observations. This is all part of the center's science program, which aims to provide new insight into earthquakes. New data is constantly collected to test the models and to provide a better understanding of model uncertainties and variabilities.

SCEC's long-range science vision is to develop models of earthquake processes that are comprehensive, integrative, verified, predictive and validated against observations.

"All these simulations have to be anchored in reality," Dr. Goulet notes. "And it's really important that they're consistent with data that we have collected and observed. We call this check that we do the validation process. Once the simulation methods have been validated where we have data, then we can use them to extrapolate for cases we haven't observed. In other words, we can approach events we haven't seen yet with the confidence that the predictions are reasonable."

"Then, we can use that to quantify the ground motions at a building or a bridge site to create a better design. The whole idea is that as we improve our models and validate them appropriately, we can rely on them more."

Big compute for big problems

It takes a lot of high performance computing to solve the types of problems that SCEC researchers tackle on a daily basis. And that's just what the center gets from the Frontera supercomputer at TACC.

Fueled by a $60 million award from the National Science Foundation (NSF), Frontera debuted on the TOP500 list in June 2019 as the nation's fastest academic supercomputer and the world's fifth most powerful high-performance computing system[1] — with a peak-performance rating of 38.7 petaFLOPS.

1 TOP500 List – June 2019.

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"Large earthquakes will happen in the future. There's no question about it. We cannot predict them, but if we can better understand and quantify what their impact will be, then we can create better designs and make better use of our limited resources. And that will lead to a society that's more resilient to earthquakes."

Christine Goulet

Executive Director for Applied Science,
Southern California Earthquake Center

Dell Technologies provided the primary computing system for Frontera, based on Dell EMC PowerEdge C6420 servers. The system has more than 8,000 two-socket nodes, more than 16,000 Intel Xeon Scalable Processors and 448,448 cores.[2] With its ability to run a variety of HPC and AI workloads required by TACC's vast user community, the Intel Xeon Scalable Processor was a clear choice.

In addition, Frontera incorporates several technical innovations, including Intel Optane DC Persistent Memory for some large-memory nodes, CoolIT Systems high-density Direct Contact Liquid Cooling and a high performance NVIDIA Mellanox HDR 200 Gb/s InfiniBand interconnect.

"The only way we can achieve these types of simulations is by using high-performance computers," Dr. Goulet says. "Most of our computational research at SCEC is driven by lots of researchers working together, and we need a fast turnaround to be able to discuss the results and improve them. So it's important for us to have access to these high-performance computers, such as Frontera."

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2 Intel case study, "Texas Advanced Computing Center Installs Frontera for Massive Scale Computing," August 2019.

Learn more about Dell EMC advanced computing

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