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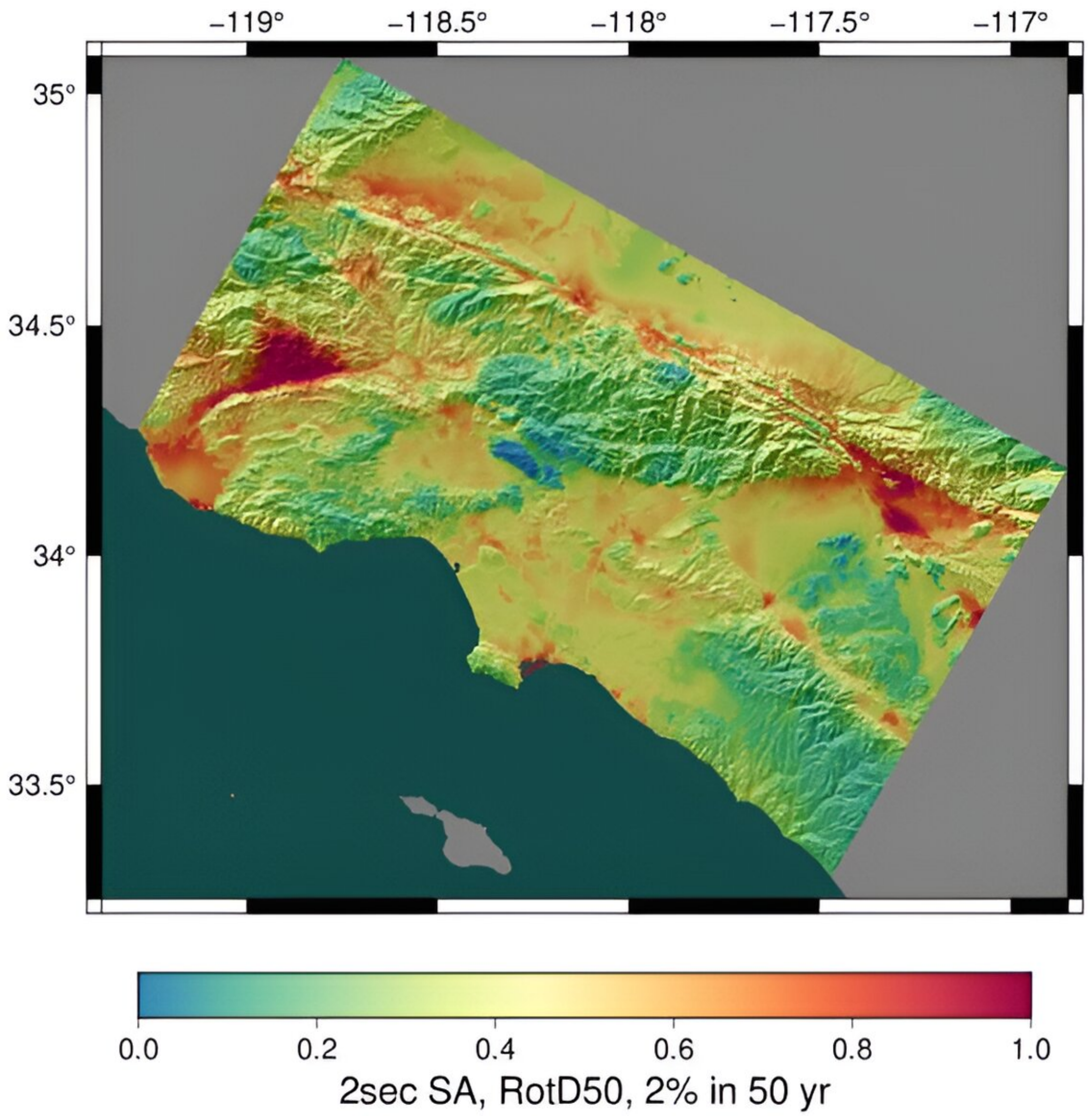
CyberShake study uses Summit supercomputer to investigate earthquake hazards

February 7 2024, by Quinn Burkhart



This CyberShake Study 22.12 seismic hazard model shows the Southern California regions, depicted in reds and yellows, expected to experience strong ground motions at least once in the next 2,500 years. Credit: Statewide California Earthquake Center

Researchers at the Statewide California Earthquake Center, or SCEC, are unraveling the mysteries of earthquakes by using physics-based computational models running on high-performance computing systems at the Department of Energy's Oak Ridge National Laboratory. The team's findings will provide a better understanding of seismic hazards in the Golden State.

Building on more than a decade of experience, CyberShake Study 22.12 is the largest set of earthquake simulations ever conducted by the SCEC. The study was run on the Oak Ridge Leadership Computing Facility's Summit supercomputer. The OLCF is a DOE Office of Science user facility located at ORNL.

CyberShake 22.12 leveraged updated models of Earth's structure and new computational methods to refine broadband (0–20+ Hz) ground motion simulations for earthquakes. The team's goal is to reduce uncertainties in current earthquake-hazard estimates for California. Large earthquakes cause the most damage but also happen less frequently, making their evolution more difficult to study.

"Accurate estimates of the strength and duration of future earthquake ground motions are essential for understanding seismic hazards," said Philip Maechling, CyberShake software developer and the associate director for information technology at the SCEC. "We've relied on historical observational data to help us estimate what levels of shaking are possible, but there isn't enough near-fault ground motion observation for current or future needs."

CyberShake generates seismic hazard models by incorporating a vast array of existing seismic data. Using the probabilistic seismic hazard analysis method, CyberShake estimates the intense ground motions that a specific site is likely to experience in the future. Those estimates are incorporated into regional hazard maps and used to inform scientists, civil engineers and the public of earthquake risks.

To calculate the CyberShake 22.12 hazard model, Maechling's team used Pegasus, a workflow management system designed by research director Ewa Deelman and her team at the University of Southern California, or USC, Information Sciences Institute. Maechling's team continuously ran a diverse collection of jobs on Summit over 10 weeks. Pegasus automatically managed 2.5 petabytes of data, which is equal to about 500 billion pages of standard printed text, including an automated transfer of 70 terabytes to USC's archival storage.

CyberShake uses an updated list of all active faults in California and a 3D seismic velocity model to describe the Earth's structure in Southern California. The region's combination of mountainous landscape and sediment-filled valleys causes wide variations in the geographical distribution of strong ground motions produced by large-magnitude earthquakes.

Maechling's team updated the codes for CyberShake 22.12 to more accurately model earthquake ruptures and to include higher-frequency ground motions. The team simulated broadband ground motions for 620,000 earthquakes at 335 locations in Southern California.

CyberShake uses detailed information about Earth's structure from fault models and seismic velocity models with physics-based computational modeling to produce information about where strong shaking is most likely to occur. This method has proven to be more accurate than previous methods that were based on observation, which were simpler, less computationally expensive and less accurate.

Since the project's beginning, Maechling's team has realized the value of collaborating across multiple scientific disciplines, including geophysics, civil engineering and computer science. CyberShake integrates science and technology from these fields by adapting the best available data into physics-based models of the Earth's active crust. CyberShake data is public and provided to other researchers and end-users in various formats to suit their needs.

The team presented CyberShake 22.12 results at the 2023 SCEC Annual Meeting in Palm Springs, California.

CyberShake's previous results have proven beneficial to the public. For example, the U.S. Geological Survey used data from 2020 simulations to inform the National Earthquake Hazards Reduction Program in 2023. Additionally, the Building Seismic Safety Council and the American Society of Civil Engineers used CyberShake results in their updated building code recommendations for Southern California in 2020.

It's too early to determine what impact CyberShake 22.12 will have, but Maechling anticipates similar developments from this most recent study. The CyberShake collaboration is actively working to develop a new seismic hazard model that uses a consistent methodology for the state of California.

"We can do a lot of work to produce useful information about seismic hazards without waiting for the next big earthquake," Maechling said. "Our top goal is to use high-performance computing to produce accurate seismic hazard information that advances public safety."

Provided by Oak Ridge National Laboratory

Citation: CyberShake study uses Summit supercomputer to investigate earthquake hazards (2024, February 7) retrieved 28 April 2024 from https://phys.org/news/2024-02-cybershake-summit-supercomputer-earthquake-hazards.html