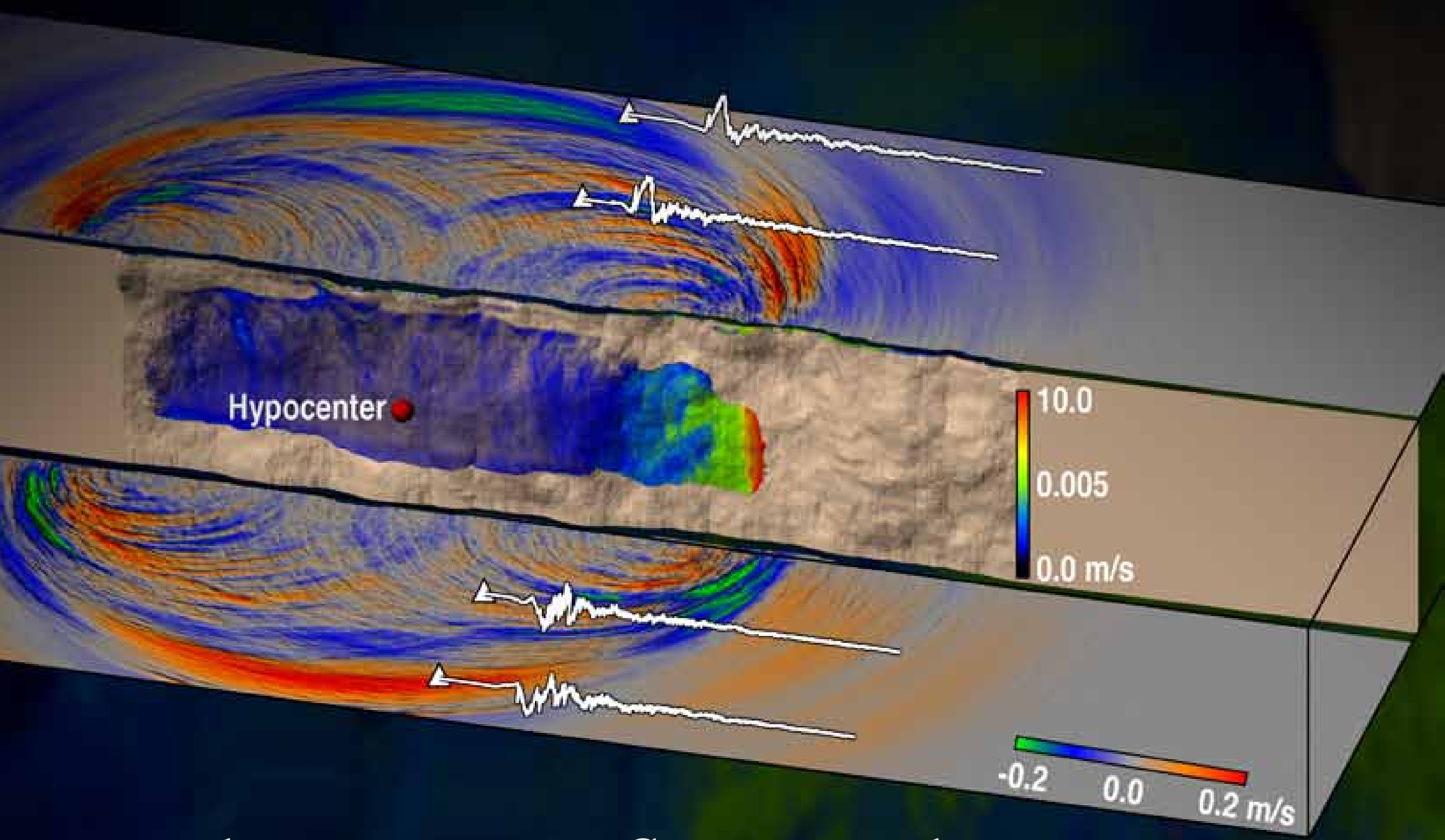
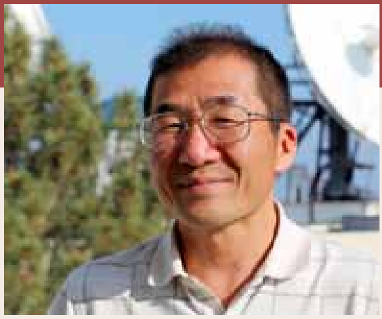


Achieving Petaflop-Level EARTHQUAKE SIMULATIONS on GPU-Powered Supercomputers

Image of a 10-Hz rupture propagation and surface wavefield for a crustal model with a statistical model of small-scale heterogeneities. Simulation by Yifeng Cui and Efecan Poyraz; visualization by Amit Chourasia, SDSC.



Yifeng Cui (left) is an SDSC computational scientist specializing in high-performance earthquake simulations, as well as parallelization, optimization, and performance evaluation on both massively parallel and vector machines.

Dong Ju Choi (right) is a senior computational scientist with diverse expertise in high-performance computing software, programming, optimization, and visualization.

To save lives and minimize property damage resulting from earthquakes, researchers are seeking to rapidly assimilate vast quantities of information from earthquake cascades to improve operational forecasting and provide early warning systems.

A step toward that goal was achieved last year by a team of researchers at SDSC and the Department of Electronic and Computer Engineering at UC San Diego with the development of a highly scalable computer code that promises to dramatically cut both research times and energy costs needed to simulate seismic hazards throughout California and elsewhere.

The team, led by Yifeng Cui, a computational scientist at SDSC, developed the scalable GPU (graphical processing units) accelerated code for use in earthquake engineering and disaster management through regional earthquake simulations at the petascale level as part of a larger computational effort coordinated by the Southern California Earthquake Center (SCEC). San Diego State University (SDSU) is also part of this collaborative effort in pushing toward extreme-scale earthquake computing.

"The increased capability of GPUs, combined with the high-level GPU programming language CUDA, has provided tremendous horsepower required for acceleration of numerically intensive 3D simulation of earthquake ground motions," said Cui, who presented the team's new development at the NVIDIA 2013 GPU Technology Conference (GTC) in San Jose, Calif. A technical paper based on this work was also presented June 5-7 at the 2013 International Conference on Computational Science in Barcelona, Spain.

The accelerated code, done using GPUs as opposed to CPUs, or central processing units, is based on a widely-used wave propagation code called AWP-ODC, which stands for Anelastic Wave Propagation by Olsen, Day, and Cui. It was named after Kim Olsen and Steven Day, geological science professors at SDSU, and SDSC's Cui. The research team restructured the code to exploit high performance and throughput, memory locality, and overlapping of computation and communication, which made it possible to scale the code linearly to more than 8,000 NVIDIA Kepler GPU accelerators.

The team performed GPU-based benchmark simulations of the 5.4 magnitude earthquake that occurred in July 2008 below Chino Hills, near Los Angeles. Compute systems included *Keeneland*, managed by Georgia Tech, Oak Ridge National Laboratory (ORNL) and the National Institute for Computational Sciences (NICS), and also part of the National Science Foundation's (NSF) eXtreme Science and Engineering Discovery Environment (XSEDE); and *Blue Waters*, based at the National Center for Supercomputing Applications (NCSA). Also used was the *Titan* supercomputer, based at ORNL and funded by the U.S. Department of Energy. *Titan* is equipped with Cray XK7 systems and NIVIDIA's Tesla K20X GPU accelerators.

The benchmarks, run on *Titan*, showed a five-fold speedup over the heavily optimized CPU code on the same system, and a sustained performance of one petaflop per second (one quadrillion calculations per second) on the tested system. A previous benchmark of the AWP-ODC code reached only 200 teraflops (trillions of calculations per second) of sustained performance.

By delivering a significantly higher level of computational power, researchers can provide more accurate earthquake predictions with increased physical reality and resolution, with the potential of saving lives and minimizing property damage.

"This is an impressive achievement that has made petascale-level computing a reality for us, opening up some new and really interesting possibilities for earthquake research," said Thomas Jordan, director of SCEC, which has been collaborating with UC San Diego and SDSU researchers on this and other seismic research projects, such as the simulation of a magnitude 8.0 earthquake, the largest ever simulation to-date.

Additional members on the UC San Diego research team include Jun Zhou and Efecan Poyraz, graduate students with the university's Department of Electrical and Computer Engineering (Zhou devoted his graduate research to this development work); SDSC researcher Dong Ju Choi; and Clark C. Guest, an associate professor of electrical and computer engineering at UC San Diego's Jacobs School of Engineering.