

Organizations

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Science & Innovations Campus
Warrington, UK
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Science & Technology
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National Autonomous University of
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Mexico City, Mexico
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Use of Cray XT4™ supercomputer

HECToR (High-End Computing Terascale Resource) is the UK's national supercomputing service and available for use by academia and industry. The system is funded by the UK Research Councils and administered by the University of Edinburgh, the Engineering and Physical Sciences Research Council, the Science and Technologies Facilities Council (STFC) and NAG Ltd.

"HECToR is a great machine. It's quite easy to use. You don't have to do anything special to get things done on it."

— Dr. Mike Ashworth
Associate Director
STFC Daresbury Laboratory

Predicting the Impact of Large Magnitude Earthquakes

Situation

It may be scientifically impossible to predict the specific day and time of an earthquake, but researchers at the National Autonomous University of Mexico (UNAM) aren't taking no for an answer. They're just asking a different question.

Instead of looking for "when," the UNAM researchers are asking "what if." "We're not predicting that an earthquake will actually happen," says lead researcher Mario Chavez. "We're posing 'what if' type scenarios such as, if an earthquake of a given magnitude does hit a specific area how much and how fast will the earth surface move and what is the probable impact of the earthquake given the region's existing or projected infrastructure."

Using a 3D seismic wave propagation code, the researchers have studied major historic earthquakes, modeling how seismic waves move through the earth's crust. As well as accurately modeling past events, this simulation technology will enable scientists to study ground motions from hypothetical earthquakes and identify where ground-shaking shocks would be centered in the event of an earthquake.

"Our research means that governments, developers and planners could soon have access to vital earthquake ground motion data that will enable them to assess the impact of large or extreme magnitude earthquakes in their own region," says Dr. Chavez. "This kind of information could play a major role when working on risk assessment for a facility site or when designing homes, hospitals, schools."

Challenge

While realistic 3D modeling of the propagation of large subduction earthquakes has vast potential, it also poses a numerical and computational challenge, particularly because it requires enormous amounts of memory and storage as well as an intensive use of computing resources. At UNAM, the team only had access to a small cluster that limited them to runs on tens or hundreds of processors for a few hours at a time, and producing only coarse simulations. For their code to be effective, they needed finer resolutions only obtainable with more powerful parallel computing.

Solution

Through a collaboration made possible through the Scientific Computing Advanced Training project (SCAT), a European Commission-funded project bringing together researchers from six countries, Chavez connected with computational scientists at the Science & Technology Facilities Council's (STFC) Daresbury Laboratory. With access to the Cray XT4 supercomputer HECToR, the UK's largest, fastest and most powerful academic supercomputer, the Daresbury and UNAM teams worked together to optimize the code for high performance computing and scale it up to more than 8,000 simultaneous processes. "For this project we have made use of the highest levels of performance on parallel machines, allowing Chavez to perform one of the few high resolution simulations to an accuracy and magnitude that has not been done before for this kind of research," says Mike Ashworth, associate director of the computational science and engineering department at STFC Daresbury Laboratory.

Using HPC to model seismic waves

Capturing earthquakes in high-resolution 3D

The research team led by Chavez from UNAM's Institute of Engineering set out to study the propagation of seismic waves through the earth's crust during major earthquakes, including the devastating magnitude scale 8 events in Mexico City in 1985 and Sichuan, China in 2008.¹ Their main objective was to produce 3D models of the low-frequency wave propagation of the particular earthquake and compare the synthetic seismograms with actual observations.

To do this they applied a 3D parallel finite difference code to simulate synthetic seismograms. The code is highly suitable for parallel execution on a distributed memory parallel computer like HECToR that uses explicit message passing parallelization. In fact, the Cray XT™ systems are designed to optimize MPI message passing; the SeaStar2+™ chip combines communications processing and high-speed routing on a single device.

The cluster system, on the other hand, didn't have the scalability to maximize the code. "On a cluster computer you can only get a coarse simulation," says Dr. Ashworth. "We took it onto the HECToR Cray XT4 system and scaled it up to thousands of processors. We got very fine resolutions of the Sichuan earthquake."

The high resolutions only obtainable on an extremely scalable system like the Cray XT machine give a much finer, detailed view. "The results are much more realistic and plausible and do a much better job of convincing people that the results are right," says Ashworth.

Exploiting the Cray XT4 system's extreme processor counts did take a few intermediary steps, however. The code required some optimizations in order to take full advantage of the machine's scalability, including vectorization, halo exchange, boundary conditions and function inlining. But the work paid dividends. "The ultra high resolution we were able to achieve enables simulations with unprecedented accuracy," says Chavez.

Still, the resulting high-resolution simulations would be for naught if the results weren't satisfactory. The observed and synthetic velocity seismograms need to show reasonable agreement both in time and frequency. In other words, for the code to be useful as a damage-predicting tool for future earthquakes, the models and actual results of the past seismic event being studied need to match. Ashworth reports success in modeling both the Mexico City and Sichuan earthquakes: "The experiments we've done are in hindcast. We've run the model and compared it to actual results and it has matched up."

The work of fine tuning the code, scaling up to even larger problems and achieving finer resolutions continues. It's a process that will be helped along by recent Cray XT6 upgrades to HECToR. The new Cray XT6 components are contained in 20 cabinets and comprise a total of 464 compute blades each with two 12-core AMD Opteron processors for a total of 44,544 cores.

"This research is leading stuff," says Ashworth. "What this model allows to do is to show if an earthquake happens in the region, where the potential damage would be most likely to occur. We think that's pretty useful in informing policymakers and governments."

System Overview

- ➔ **60-cabinet Cray XT4 scalar supercomputer (upgraded to a Cray XT6 system since time of seismic wave project)**
- ➔ **1,416 compute blades, each with four dual-core AMD Opteron™ processors for a total of 11,328 cores**
- ➔ **Each dual-core socket shares 6 GB of memory, giving a total of 33.2 TB**
- ➔ **59 teraflops theoretical peak performance**

"The ultra high resolution we were able to achieve enables simulations with unprecedented accuracy."

—Dr. Mario Chavez
Researcher

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¹ "Low Frequency 3D Wave Propagation Modeling of the Mw 7.9 Wenchuan 12 May 2008 Earthquake," M. Chavez et al, to appear in the Bulletin of the Seismological Society of America