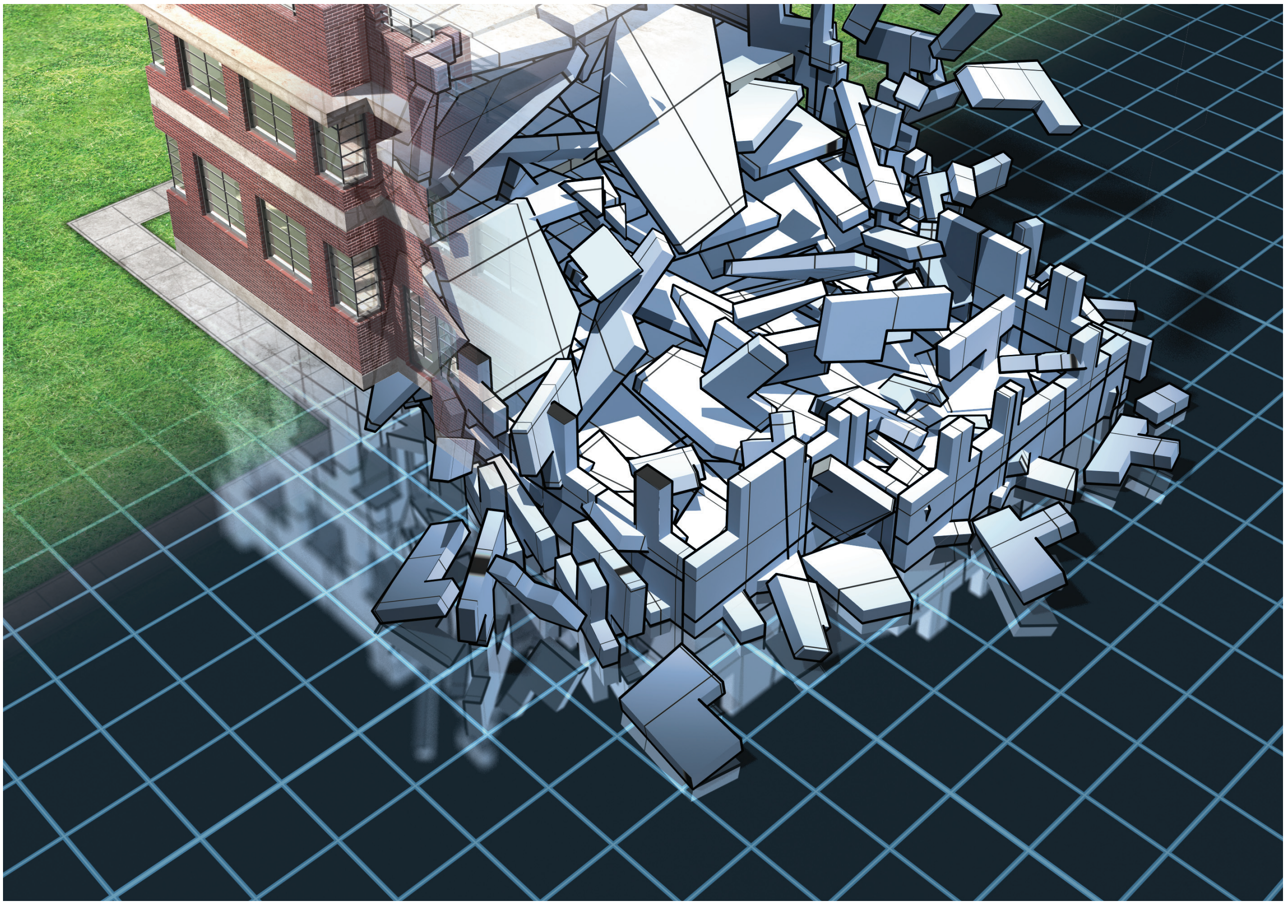
Computational Earthquake Science



The APEC Cooperation for Earthquake Simulation (ACES) was founded and approved at the 1997 Singapore meeting of the Asia Pacific Economic Cooperation (APEC) Industrial Science and Technology Working Group. Since that time, there have been seven international ACES symposia, organized by one of the four original ACES economies: Australia, China, Japan, and the US. Two additional APEC economies have also joined—Canada and Chinese Taipei. Further information on these meetings and the various publications and activities that have resulted from these meetings can be found at http://quakes.earth.uq.edu.au. In addition to the major international symposia, smaller working group meetings have also been held, the most recent being on 1–5 May 2011 in Maui, Hawaii. The research in this issue of *CiSE* represents the research of collaborations that grew out of that meeting.

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ACES and Computational Earth System Science

ACES is a multilateral grand challenge science research cooperation of APEC. The project involves leading international earthquake simulation and prediction research groups. Funding of the US involvement has originated over the years from NASA and the US National Science Foundation. ACES's goal is to develop tools from cloud-based data analytics through realistic supercomputer simulation models for the complete earthquake-generation process, thus providing a virtual laboratory that probes earthquake behavior. This capability will provide a powerful way to study the earthquake cycle, and hence, offers a new opportunity to gain an understanding of the earthquake nucleation process and precursory phenomena, leading to new methods of earthquake forecasting. The project represents a grand scientific challenge because of the complexity of phenomena and range of scales from microscopic to global involved in the earthquake-generation process. It's a coordinated international effort linking complementary nationally based programs, centers, and research teams.

In the days leading up to the most recent Maui meeting, the world was struck by a series of major catastrophic earthquakes. Two of the largest earthquakes in recorded history occurred—the magnitude 8.8 (*M*8.8) 27 February 2010 Chile earthquake, and the *M*9.1, 11 March 2011 Tohoku, Japan earthquake and tsunami. Since 1900 AD, there have been only 17 earthquakes having magnitudes larger than 8.5. In addition to the two events listed here, there were also the following earthquakes:

- the *M*7.2 Haiti earthquake on 12 January 2010;
- the 4 September 2010 *M*7.2 Christchurch, New Zealand earthquake;
- the second Christchurch earthquake (*M*6.3, 22 February 2011) that destroyed Christchurch; and
- the 4 April 2010 *M*7.2 El Major-Cucupah (Baja), Mexico earthquake.

As a result of these events, more than 300,000 people have died, and total damages to the infrastructure and economic loss is likely to exceed US$1 trillion.

What can computational science contribute to the mitigation of effects from these events? In May 2000, *CiSE* published a special issue on computational earth system science (http://cise.aip.org/dbt/dbt.jsp?KEY=CSENFA&Volume=2&Issue=3). These publications made a lasting impact on the earth system modeling community.

About the Articles

The four articles in this issue of *CiSE* represent a cross section of the type of research conducted under the ACES program. The first article, by Eric M. Heien and Michael Sachs, is a description of one of the earthquake simulation code collections that's now being used for a variety of research purposes. More specifically, "Understanding Long Term Earthquake Behavior through Earthquake Simulation" describes the code of Virtual California, a topologically realistic, system-level earthquake fault code. Codes such as Virtual California are now being used to construct ensemble forecasts similar to those used in weather and climate studies.

The second article, "Using Service-Based GIS to Support Earthquake Research and Disaster Response" by Jun Wang and his colleagues, describes the use of geographic information systems and portal technology to produce standards-compliant products that can be used by emergency response communities. Two such programs funded by NASA are the QuakeSim project and the E-Decider project.

"A Distributed Approach to Computational Earthquake Science: Opportunities and Challenges" by Andrea Donnellan and her colleagues is a more detailed look at the QuakeSim project, a decade-long effort that represents the first modern computational effort to bring together Web-based protocols for data retrieval and analysis, modeling, and information dissemination. As an example of the impact of this effort, a start-up company called Open Hazards (www.openhazards.com) was spun off to provide the public with practical tools and information for disaster preparedness. Open Hazards is also described in a recent short American Institute of Physics documentary (http://aip.org/dbis/report5.html) and a *CiSE* interview (www.computer.org/portal/web/computingnow/cise). In fact, the QuakeSim project was recently nominated by the Jet Propulsion Laboratory, where it's based, for the NASA Software of the Year award (the decision is pending at the time of this writing).

The fourth and final article, "Forecasting Earthquakes: The RELM Test" by Michael Sachs and his colleagues, discusses a recent earthquake forecast study comparing the results of an ensemble of forecasts produced in association with the Relative Earthquake Likelihood Models

(RELM) test. These were a group of truly prospective forecasts assembled and published in the journal *Seismological Research Letters* in January 2007. The idea was to then observe the locations of future earthquakes over the next five years, and compare the accuracy of the forecasts using a variety of different forecast verification and validation tests.

The next symposium of the ACES group is planned for October 2012, again in Maui, where representatives from at least six ACES economies plan to be present, along with many others from Asia-Pacific economies and elsewhere. We plan to have presentations and working group meetings in the form of code hackathons.

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