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Multihazard Simulation and Cyberinfrastructure

Andrea Donnellan,[1,2] Charles Williams,[3] and Marlon Pierce[4]

The integration of multihazard simulations and remotely sensed observations is providing enormous benefits to earthquake and tsunami research. Integrating data and models through cyberinfrastructure is enabling understanding of earthquake and tsunami generation mechanisms in the Asia Pacific region and improving assessment strategies for mitigating risk.

Earthquake rupture processes occur on all scales from microns to global and from sub-seconds to millions of years. Earthquakes cause damage, but also generate tsunamis, which create additional damage. Remotely sensed observations coupled with geologic field measurements and simulations contribute to our understanding of earthquake processes, which is necessary for mitigating loss of life and property from these damaging events. Remotely sensed observations play a unique role in the mitigation of natural hazards. Measurements of surface motions can be used to infer strain accumulation and transfer within interacting fault systems, as well as the mechanisms of earthquakes, which is an important input to tsunami generation models and disaster response. Remotely sensed geodetic imaging data include interferometric synthetic aperture radar (InSAR), the Global Positioning System (GPS), and other techniques such as lidar or optical imaging. Geodetic imaging can be used to understand aspects of earthquakes including the tectonic plate motions that drive earthquakes (GPS), regional and local crustal deformation associated with faults or other sources (GPS, InSAR lidar, optical), and detailed motions associated with earthquakes at a resolution of 1 Hz (GPS).

The United States hosted the 8th International Symposium of the APEC Cooperation of Earthquake Simulation (ACES) October 22–26, 2012 in Maui, Hawaii. The workshop focused on assimilation of remotely sensed observations to advance multihazards simulation. The APEC Cooperation for Earthquake Simulation (ACES) is a multilateral grand challenge science research cooperation of APEC (the Asia Pacific Economic Cooperation). ACES aims to develop realistic simulation models for the complete earthquake generation process and to assimilate observations into such models. This capability provides a powerful virtual laboratory to probe earthquake behavior and the earthquake cycle. Hence, it offers a new opportunity to gain understanding of the earthquake nucleation process, precursory phenomena, and space–time seismicity patterns needed for breakthrough advances in earthquake forecasting and hazard quantification. 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. ACES symposia provide unique opportunities for the APEC economies to work together on the topics important for the hazard mitigation of natural disasters. This volume follows earlier PAGEOPH topical volumes based on ACES Symposia (see references below).

This topical volume reflects the 4-day workshop, which consisted of plenary talks, technical sessions, working sessions, and poster sessions. It brought together an interdisciplinary set of researchers. It brings together remote sensing experts, modelers, and computer scientists. The symposium and this

[1] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109-8099, USA. E-mail: andrea.donnellan@jpl.nasa.gov
[2] Zumberge Hall of Science (ZHS), University of Southern California, Los Angeles, CA 90089-0740, USA.
[3] GNS Science, Lower Hutt 5040, New Zealand. E-mail: c.williams@gns.cri.nz
[4] Indiana University, 2709 East 10th Street, Bloomington, IN 47408, USA. E-mail: marpierc@iu.edu

topical volume facilitate the open exchange of ideas and through the interdisciplinary nature expose investigators to new subject areas. They address four topics: (1) simulation of multihazards, including tsunamis, storm surges, flooding, landslides, wildfires, and climate change; (2) applications of simulation technology to seismic early warning, forecasting, and urban hazard mitigation; (3) enabling technologies including cloud computing, radar interferometry, and geographic information systems; and (4) advances in complex fault-based system-level simulations of plate boundaries and the science that underlies them. Improving understanding requires (1) tools and approaches for earthquake simulation; and (2) integrating geodetic and seismicity data into improved forecasts. Integrating models and data more realistically represent earthquake and tsunami generation processes. Cyberinfrastructure enables model runs, data browsing, analysis, and assimilation, and visualization of both data and models.

Seismic hazard estimation is moving beyond fault-based forecasts. Seismicity analysis is not fault based, while current official forecasts, such as the Uniform California Earthquake Rupture Forecast (UCERF-3) are based on fault geology and crustal deformation. In Japan, geodetic data are interpreted for hazard by estimating slip deficits on faults, making use of regional geometry. Seismicity analysis is not fault based, but rather looks for emergent patterns in seismicity observations. Are faults a necessary constraint? Many earthquakes occur on “unknown” faults. Geodesy shows velocity gradients and strain that are not necessarily due to movements on known faults. GPS can provide the complete moment from an earthquake and InSAR provides synoptic data sets. Probabilities should be communicated with a timescale.

There is a general correspondence between strain and earthquakes. A strain rate map of the globe highlights where earthquakes generally happen. However, this assumption breaks down for smaller scales. Seismicity and strain rates both reflect the state of stress of the crust. Geodetic data are noisy and inconsistent at fine scales, but work well on large scales. Relating geodetic observations with seismicity is a means of integrating the large-scale differences in earthquake processes. Additionally, geodetic interpretation to date has focused on 3D deformation, but not on time-dependent deformation. There are not yet reliable workflow methods that guide temporal interpolation of the geodetic data. Including borehole strain data might provide additional short timescale information. Strain anomalies observed in geodetic data evolve slowly and transiently. These strain anomalies could possibly trigger an event. Separating anomalies that will or will not trigger large earthquakes could provide key information for earthquake forecasting.

Integrate multiple data types improves forecasting of earthquakes and tsunamis. The scale problem is the most important and limiting factor in understanding earthquakes. GPS station spacing is sparse and at best is 15–20 km. Seismicity locations are good to 1 km for earthquakes $<$M1. InSAR is sparsely sampled in time and the data decorrelate. A key question is what changes overall risk patterns in time? Geodetic imaging data provide additional information to seismicity data and an effort needs to be made to integrate multiple data types. At a theoretical level strain patterns can be observed by geodetic imaging, seismicity, and microseismicity, which all have identifiable elastic energy. A data exchange format for crustal deformation and seismicity data would facilitate data fusion. Simulators should continue to be developed for analysis of synthetic data, which allows filling in of observational gaps and should adhere to the common data standards.

This issue contains 16 papers, presenting work on tsunami hazards, earthquakes, and related computational infrastructure. It is organized into three general areas. Papers on tsunami hazards are presented first, followed by papers on earthquake ground motions and slip, earthquake fault systems, and earthquake potential. The volume concludes with three papers related to cyberinfrastructure applied to earthquake response, decision support, and InSAR analysis through better visualization.

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