Science Results from the US General Earthquake Models Program

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Abstract

The United States General Earthquake Models (GEM) program is successfully integrating data, models, and information technology, to produce state-of-the-art earthquake simulations. Results are being produced that show how faults interact and that are validated with data. Hints of a new forecast technology are being uncovered through the progress of this work.

Introduction

GEM is a program to construct physically realistic simulations of earthquake processes. The simulations are critical to understanding the behavior of fault systems because earthquakes occur at irregular intervals on timescales of hundreds to thousands of years. The simulations generate arbitrarily long seismicity catalogues and provide a numerical laboratory in which the physics of earthquakes can be investigated from a systems viewpoint. The great wealth of earth science data being collected today provides the means to validate the simulations. Information technology provides the tools for developing clearly defined accessible data formats and code protocols under a three-tiered user/web server/program model.

Information Technology

Progress has been made in the GEM program on several fronts. We are developing XML standards for describing data and model parameters. We are also integrating codes that into a distributed computing type platform, and we are developing visualization tools. We are also applying the latest in information theory and statistical analysis to classify and describe both real and simulated data. Pattern dynamics analysis is revealing some interesting results that show anomalies associated with later earthquakes. Hidden Markov Modeling is being used to classify earthquakes and show how classes transition to other classes. The method shows promise for rigorously declustering earthquake catalogues, separating swarms from on-fault events, and for forecasting large events.

Simulations

We are developing both analytic and numerical simulations of earthquakes and fault interactions. The simulations show clearly that certain typical events are either correlated with events on other faults, or turn off seismicity on associated faults. The simulations currently take into account friction on faults, elasticity, and viscoelasticity. We are in the process of expanding a two-dimensional finite element code to three-dimensions. The code will run on parallel machines making detailed simulations with millions of unknowns possible. Other work involves the propagation of seismic waves through realistic earth structures and nucleation processes on faults.

Data

Seismic, GPS, InSAR, and Paleoseismic data are providing important constraints to the models being developed under GEM. All of these data are being compared to simulated data. The seismic data are revealing important patterns that can be compared to geodetic data. The geodetic data are showing previously unobserved aseismic (and seismic) motions, while the paleoseismic data are revealing detailed histories about past earthquakes on faults.

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