ALLCAL: AN EARTHQUAKE SIMULATOR FOR ALL OF CALIFORNIA

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We continue to improve understanding of earthquake predictability and hazard by designing and tuning of a California Earthquake Simulator. Our physics-based earthquake simulator produces spontaneous, dynamic rupture on geographically correct and complex systems of interacting faults. Recently, the simulator has seen several developments:

(1) In 2010, the geometry of the fault elements has continued to expand in scope (number of faults included) and scale (number of elements). This expansion offers a better representation of smaller quakes (~M5.5) but it comes with increased computational effort. The current simulator ALLCAL2, uses ~15,000 nearly square (3x3 km) fault elements arranged to avoid large tears and overlaps with depth on contorted faults.

(2) A new method to drive the system has been devised such that stresses and displacements both on and off the faults can be tracked. This involves finding a continuous interseismic velocity/stress field for Western North America that: (1) gives no shear stress on the free surface, (2) satisfies the static equations of force balance, (3) reasonably reproduces interseismic surface velocities at all geodetic sites and (4) stresses the faults such that they slip at rates close to those estimated geologically. The goal is to employ both geological and geodetic data to constraint ALLCAL and to progress toward a self-consistent system level model for stress accumulation by tectonic deformations and subsequent release by slip on faults.

(3) Since 2009 there has been a concerted effort by SCEC's *Earthquake Simulator Group* to shift the perception of simulators from a pie-in-the-sky theoretical product to a practical tool for hazard estimation. The shift being accomplished through tuning and testing. Tuning involves adjustment of simulator parameters (e.g. fault strength) such that computed and observed earthquake recurrence intervals coincide reasonably well. Testing involves comparing simulator predictions both with real earthquake information not directly built into the model, and with the predictions of other simulators.

[http://es.ucsc.edu/~ward/SAF3D.mov] shows a few of the 26 M7.7+ events that ruptured the San Andreas Fault during a 4000 year run of ALLCAL. The frames show current fault strength, current fault stress, slip and slip rate along strike and down dip of the curved fault versus time. You can see the complexity embodied in even a simple simulator –- ruptures stop, jump and sometimes reverse direction as dictated by the existing state of stress and the friction law. The stress state on the fault (bottom boxes) is strongly heterogeneous and the final stress state is much different from the starting one.

[http://es.ucsc.edu/~ward/ALLCAL3D-300.mov] shows a 300 year sample of a simulation in map view. Ancillary information includes observed and predicted earthquake rate versus magnitude (left), mean stress and M5.5+ rate versus time (bottom). Be aware that each of the flashes in this movie is a genuine 3-D dynamic rupture like those in the movie above.

[http://www.youtube.com/watch?v=iIuwAAPAEFw]is a tutorial on earthquake simulation using the "YouTube" format to introduce the concept to a general audience.

MULTI-HAZARD SIMULATION

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ACES's interest in the simulation of natural and man-caused hazards spans more than earthquakes. This talk presents several quantitative, physics-based simulations of natural and unnatural events both historical and hypothetical. Take a look at the movie links if you want a sneak preview.

(1) *Hurricane Forecasting*. Given 160 years of storm track data for the North Atlantic, it is possible to construct long term and real time probablistic forecasts for wind exceedence.
--Storms of the 70's:
[http://www.youtube.com/watch?v=daBmxkncaXE]

(2) *Tsunami Wave and Inundation Forecasting*. Rapid (~10 minutes) forecasting of trans-Pacific earthquake tsunami is made possible by combining tsunami modes and "network ray theory".
--Japan Tsunami Forecasts:
[http://es.ucsc.edu/~ward/japan2011-basinwide.mov]
[http://es.ucsc.edu/~ward/japan2011-close2.mov]
For after the fact, "final mile" simulations of inundation, purely numerical approaches like these are effective…
--Tsunami Run Up Basics:
[http://www.youtube.com/watch?v=Fee_nqqOygM] .

(3) *Dam breaks and Associated Floods* continue to pose real danger to downstream populations. Simulation of historical and potential flood events helps to characterize those hazards.
-- 1963 Vaiont Dam (Italy) Landslide and Flood:
[http://www.youtube.com/watch?v=g_t_xAGaU-c]
[http://www.youtube.com/watch?v=6COeNRToYqU]
-- 1928 St. Francis Dam, California Failure and Flood:
[http://www.youtube.com/watch?v=3MdB_s6KhwA]

(4) *Landslides and Mega-tsunami*. Simulations of massive landslides using lightly interacting granular material are computationally quick and fairly convincing.
--La Palma Island Collapse:
[http://es.ucsc.edu/~ward/lp-perspective.mov]
If the material falls into or under water, prospects of mega tsunami develop.
-- Paleo: Lake Tahoe California Mega Tsunami:
[http://www.youtube.com/watch?v=D8Py3XgRMkk&feature=channel]