MODELING AND ON-THE-FLY SOLUTIONS FOR SOLID EARTH SCIENCES: WEB SERVICES AND DATA PORTAL FOR EARTHQUAKE EARLY WARNING SYSTEM

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1. INTRODUCTION

We report on a unified on-the-fly, Web Services-based observation/analysis/modeling environment for crustal deformation and natural hazards research, intended as a plug-in service for early warning systems, transfer of rapid information to civilian decision makers and the media, and educational purposes. We demonstrate an early warning system for a large earthquake in southern California using the components developed under several NASA-funded projects, including real-time GPS network infrastructure, Geophysical Resources Web Services, and GPS Explorer data portal with its on-the-fly earthquake modeling software. We generate an on-the-fly earthquake fault model based on simulated real-time (dynamic and coseismic) displacements computed by the GPS network, and viewable through GPS Explorer. In addition, we implement a process to detect “slow earthquake” events and other transient signals. Our objective is to demonstrate an operational service that could be transitioned to appropriate civilian agencies in southern California.

2. APPROACH TO EARLY WARNING SYSTEM

We have experimented with several likely large earthquake scenarios in southern California that could be targeted by the Earthquake Early Warning System (EEWS). For example, Figure 1 shows an earthquake simulation on the San Jacinto fault segment, thought to be the active plate boundary in southern California, rather than San Andreas fault [1]. We assumed an Mw 7.0 event with 1 m of right-lateral slip at 15 km depth along a 90 km rupture.

An actual event would be captured by analyzing 1 Hz displacements from the California Real Time Network (CRTN) [2,3], whose stations (from PBO and SCIGN networks) span the major faults of the southern San Andreas Fault System. Stations stream over dedicated radio links 1 Hz GPS data, with a latency of a fraction of a second, and displacement waveforms are generated independently every second by instantaneous positioning [4,5]. By comparing the displacement field with a list of scenario earthquakes, we can establish quickly the main characteristics of the earthquake that would be useful for example for earthquake response in Riverside and LA County communities. This would be followed by more labor intensive inverse modeling of the actual measured displacements to produce a rapid coseismic model of the earthquake for researchers. The inversion engine would be, for example, ‘simplex’, a fault dislocation inversion program. The program is based on the downhill simplex optimization algorithm with the addition of simulated annealing. The simplex program has been adapted for a web interface that will enable users to invert for fault parameters from user-selected site displacements.
The EEWS has been simulated using a real event, the 2003 Mw 8.0 Tokachi-Oki thrust earthquake off Hokkaido Island in Japan detected by the 1200+ station Japan national network [6]. We have developed a scheme to create a Delaunay triangulation of the network every second, compute relative positions of each triangle, converted to principal components of strain (2D), establish detection criteria to isolate the event, and determine an anchor point for computing absolute displacements, which are input to the earthquake modeling program.

In recent years, there has been increasing evidence that GPS sensors are capable of detecting signals associated with "slow earthquakes" and stress transfer between faults. We have developed an approach by which such subtle signals can be detected using aggregated information from multiple sensors. Our method is based around a purely data-driven approach in which a hidden Markov model is trained on the data from each GPS station. Robust, unconstrained model fits are made possible by the regularized deterministic annealing expectation maximization (RDAEM) algorithm. Fitted models are used to detect discrete state changes in individual GPS stations based on the statistics of the observations; correlated state changes occurring at multiple stations are indications of regional activity. This technique has been integrated into our web portal/web services environment that provides a web-based interface to the method, and has been demonstrated on data from a small set of GPS stations providing daily position solutions from the Geophysical Resources Web Services [7]. We apply this approach to the 1 Hz position data coming from CRTN.

3. WEB SERVICES AND DATA PORTAL

We demonstrate the EEWS and detection of transient signals using the underlying Geophysical Resource Web Services and interactive GPS Explorer data portal environment [8].

4. REFERENCES


