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IMPLEMENT ROUTINE AND RAPID EARTHQUAKE MOMENT-TENSOR DETERMINATION AT THE NEIC USING REGIONAL ANSS WAVEFORMS

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Abstract

A graphical user interface to the "Cut-and-Paste" (CAP) moment-tensor inversion compute codes has been developed and installed at the NEIC. It allows a user with very limited amount of training to process near-real-time seismic waveforms and determine the magnitude, focal mechanism, depth of an earthquake on a routine basis. Several other computer programs have also been created to retrieve real-time waveform and instrument response information. The whole package has been tested using about 50 earthquakes in the Intermountain West region and California. Satisfactory results have been obtained.

Non-Technical Abstract

A graphical user interface to the "Cut-and-Paste" (CAP) moment-tensor inversion compute codes has been developed and installed at the NEIC. It allows a user with very limited amount of training to process near-real-time seismic waveforms and determine the magnitude, focal mechanism, depth of an earthquake on a routine basis. Several other computer programs have also been created to retrieve real-time waveform and instrument response information. The whole package has been tested using about 50 earthquakes in the Intermountain West region and California. Satisfactory results have been obtained.

1 Introduction

The seismic moment tensor is one of the fundamental parameters of earthquakes that can be determined from seismic observations. It is directly related to earthquake fault orientation and rupture direction. The moment magnitude, M_w derived from the moment tensor magnitude, is the most reliable quantity for measuring the size of an earthquake compared with other earthquake magnitudes. Moment tensors have been routinely determined for many years for large earthquakes that occur worldwide. They are used in a wide range of seismological research fields such as earthquake statistics, earthquake scaling relationships, and stress inversion.

In this project, I worked with Dr. D. E. McNamara of USGS/NEIC to implement and install a moment tensor inversion package (CAP) at the NEIC. The goal is to make CAP an integral part of NEIC system for routine and rapid determination of moment tensors of all magnitude 4 or larger earthquakes in the US. We added a user-friendly graphical user interface (GUI) to CAP so that an NEIC staff member with basic seismology training can operate it with ease.

2 Investigation Undertaken

2.1 The graphical user interface of CAP

The "Cut-and-Paste" (CAP) moment-tensor inversion method was developed by the PI at the Seismological Laboratory of Caltech in Dr. D. V. Helmberger's research group in later 1990's [*Zhu and Helmberger*, 1996]. It has been used satisfactorily on the southern California TriNet system in both offline batch mode and real-time mode. For this project, the PI wrote a graphical user interface (GUI) for CAP using the Perl/Tk computer language. Figure 1 shows a screen snap-shot of the GUI. The following functions have been implemented:

1. The main window shows locations of events in dots and stations in squares. It also shows focal mechanism beach balls if available. The user can zoom in by holding the Shift key and dragging the left button of the mouse. To return to the original map view, the user can simply press the f key. Beach-ball locations can be adjusted by dragging it with the left button. They can also be scaled up/down by using the comma and period keys. Event solution can be discarded by press Delete.

2. To select an event for processing, double click on its ID or click on the event list to the right. This will bring up another window showing a list of depths for which the Green's functions are available. Click on a depth will start CAP inversion for the selected depth, or use "Do All" for all depths. The window also shows the obtained focal mechanisms. Press Done and the best solution will be plotted on the map.

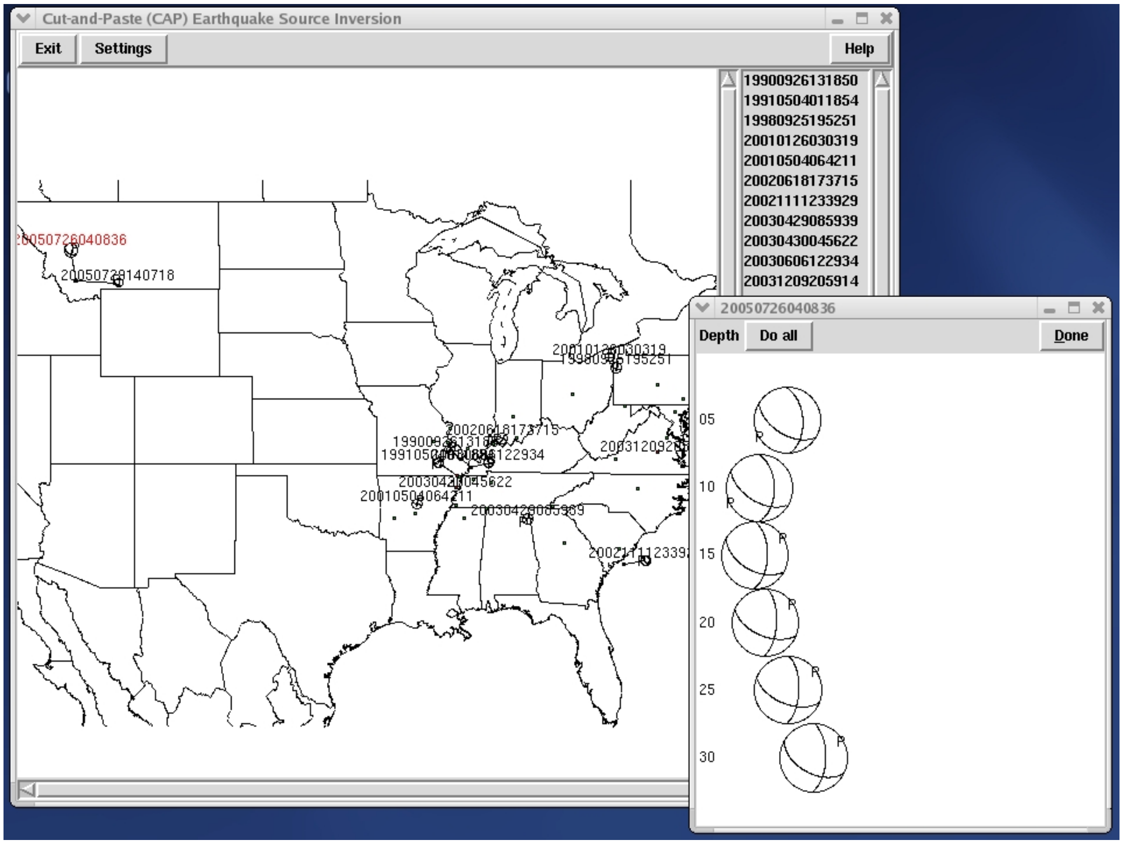

Figure 1: Layout of the capGUI. It allows a user to set various input parameters, select earthquakes, and interactively inspect output results.

3. Clicking on a beach ball for one depth will bring up another window of waveform fits (Fig. 2). Red colored traces are synthetics. Amplitude scale can be changed using the Period and Comma keys. Data traces can be turned on/off by clicking on it or on the station name. Time shift can be changed by selecting and dragging the synthetics. The change can be saved using the Save button.

To use the GUI, a user need to put all three-component waveforms in a single directory named by the event ID. The data should be velocity (in cm/s) or displacement (in cm) in the SAC format, with the reference time set at the origin time.

2.2 Installation at NEIC

In August 2004, Dr. Zhu traveled to Golden, CO and worked with Dr. McNamara and graduate student Jeff Fox at the NEIC headquarter for 4 days. They transfered all source codes of CAP and the GUI to a NEIC computer and successfully compiled the codes. They also created a Green's function library using the Central US velocity model [*Herrmann*,

Figure 2: capGUI displays waveform fits in a separate window.

1979]. Green's functions were computed for every 5 km up to 600 km in epicentral distance using a frequency-wavenumber integration method [*Zhu and Rivera*, 2002]. The computation was repeated for earthquake source depths of 5, 10, 15, 20, 25, and 30 km.

Two computer scripts were also developed to retrieve and process real-time seismic waveforms and instrument responses from the EarthWorm system. The first one, proc_qdds.pl, reads in a QDDS message that contains the origin time and location of an event in a selected area and above a magnitude threshold. It then finds all available stations within the specified distance range and retrieve their waveform records and instrument responses. The second script, Proc_quakes.sh, merges multiple data segments into a single trace for each station, synchronizes all three components, and rotates the two horizontals to the radial and transverse directions. It also desamples the data to the same sampling rate as in the Green's functions. After the above pre-processing, the event is ready for moment-tensor determination using the capGUI.

3 Results

Jeff Fox used the capGUI and processed approximately 50 earthquakes in the Intermountain West (IW) region and California. Most of the seismograms come from the Jackson Hole Regional Seismic Network. The network consists of nine seismic stations in the vicinity of the Teton Range as well as two stations in south central Wyoming near Laramie and Rawlins, and one station in Dillon Montana. Each station is equipped with a Guralp CMG3-ESP broadband sensor. Of particular interest is the earthquake swarm that occurred in July of 2005 near Dillon. The mainshock was 5.6 in magnitude (M_w), which was followed by several large aftershocks from 3.5–3.8. So far the lower bound of getting a good waveform fit, and thereby obtaining a reliable moment-tensor solution, is about 3.7. Fig. 3 shows waveform fits for the mainshock produced by the capGUI. The event is determined to be at a depth of 15 km. The moment tensor shows dominant thrusting focal mechanism.

4 Reports published

Zhu, L., 2005, Implement Routine and Rapid Earthquake Moment-tensor Determination at the NEIC Using Regional ANSS Waveforms, Annual project summary, USGS-NHRP.

5 Data availability

All source codes of the CAP and the GUI have been delivered and installed at the NEIC. Moment-tensor solutions obtained are available (in ASCII format) in ftp.eas.slu.edu/pub/lupei/ For detailed information, contact Lupei Zhu (email: lupei@eas.slu.edu, Tel: 314 977-3118).

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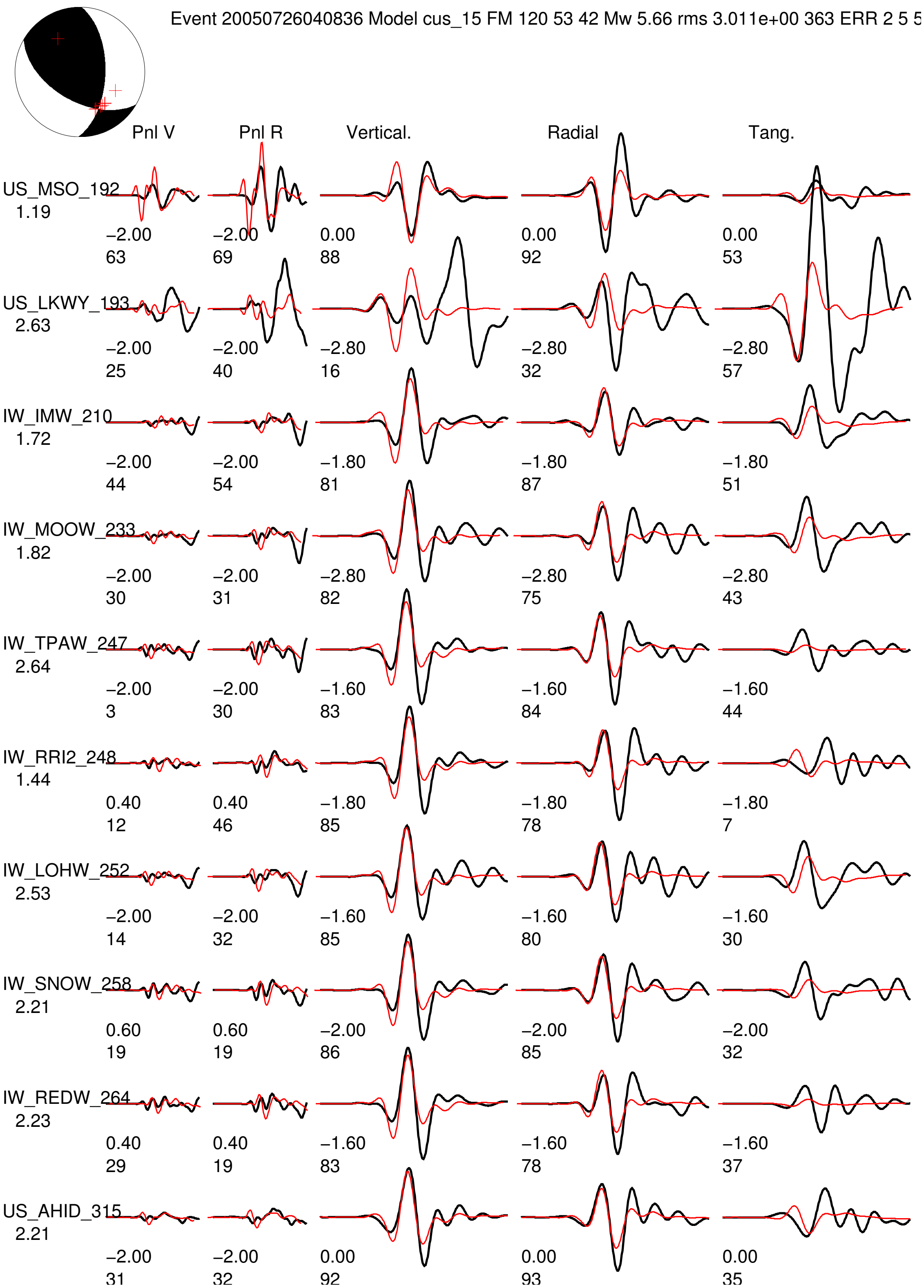

Figure 3: Waveform fits of a magnitude 5.6 earthquake near Dillon, Montana, on July 26, 2005.