The τ_c-*Pd* method in earthquake early warning and its development in Earthworm system

Yih-Min Wu [1] and Hiroo Kanamori [2]

[1] Department of Geosciences, National Taiwan University, Taipei, Taiwan, E-mail: drymwu@ntu.edu.tw
[2] Seismological Laboratory, California Institute of Technology, Pasadena, CA, USA, E-mail: hiroo@gps.caltech.edu

Abstract: As urbanization progresses worldwide, earthquakes pose serious threat to lives and properties for urban areas near major active faults on land or subduction zones offshore. Earthquake Early Warning (EEW) can be a useful tool for reducing earthquake hazards, if the spatial relation between cities and earthquake sources is favorable for such warning and their citizens are properly trained to respond to earthquake warning messages. An EEW system forewarns an urban area of forthcoming strong shaking, normally with a few sec to a few tens of sec of warning time, i.e., before the arrival of the destructive S-wave part of the strong ground motion. Even a few second of advanced warning time will be useful for pre-programmed emergency measures for various critical facilities, such as rapid-transit vehicles and high-speed trains to avoid potential derailment; it will be also useful for orderly shutoff of gas pipelines to minimize fire hazards, controlled shutdown of high-technological manufacturing operations to reduce potential losses, and safe-guarding of computer facilities to avoid loss of vital databases. We explored a practical approach to EEW with the use of a ground-motion period parameter τ_c and a high-pass filtered vertical displacement amplitude parameter *Pd* from the initial 3 sec of the P waveforms. At a given site, an earthquake magnitude could be determined from τ_c (Fig. 1) and the peak ground-motion velocity (*PGV*) could be estimated from *Pd* (Fig. 2). In this method, incoming strong motion acceleration signals are recursively converted to ground velocity and displacement. A P-wave trigger is constantly monitored. When a trigger occurs, τ_c and *Pd* are computed. The earthquake magnitude and the on-site ground-motion intensity could be estimated and the warning could be issued. In an ideal situation, such warnings would be available within 10 sec of the origin time of a large earthquake whose subsequent ground motion may last for tens of seconds. Currently, we developed a series computer programs that combined this method with Earthworm system for real-time analysis and offline simulation for EEW purposes. Simulation using the K-Net records for the 2008 Iwate-Miyagi, Japan, M7.2

earthquake demonstrates that accurate earthquake information can be determined within 10 seconds after the earthquake occurrence.

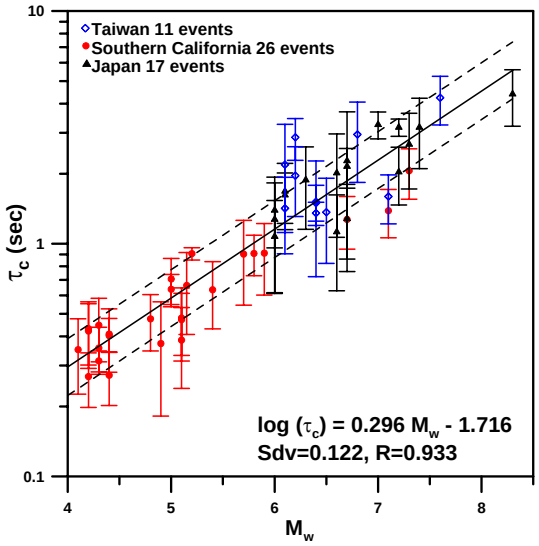

Figure 1. τ_c estimates for 54 events using the nearest stations for Japan (black triangles), southern California (red solid circles) and Taiwan (blue diamonds). Symbols show the event-average with standard deviation. Solid line shows the least squares fit and the two dashed lines show the range of one standard deviation.

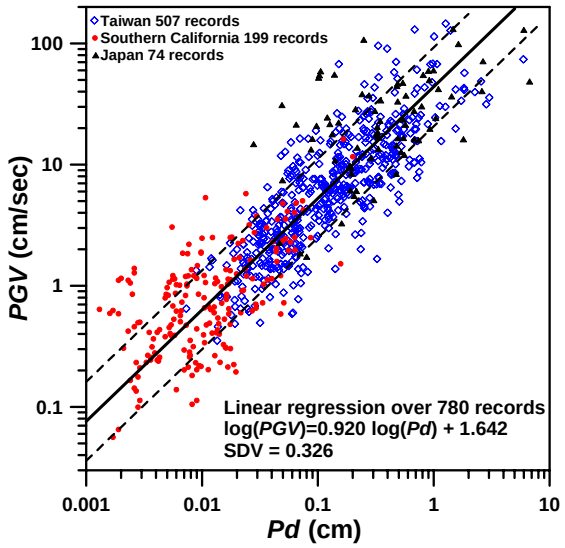

Figure 2. Relationship between peak initial three-second displacement amplitude (*Pd*) and peak ground velocity (*PGV*) for 780 records with the epicentral distances less than 30 km for Japan (black triangles), southern California (red solid circles) and Taiwan (blue diamonds). Solid line indicates the least squares fit and the two dashed lines show the range of one standard deviation.

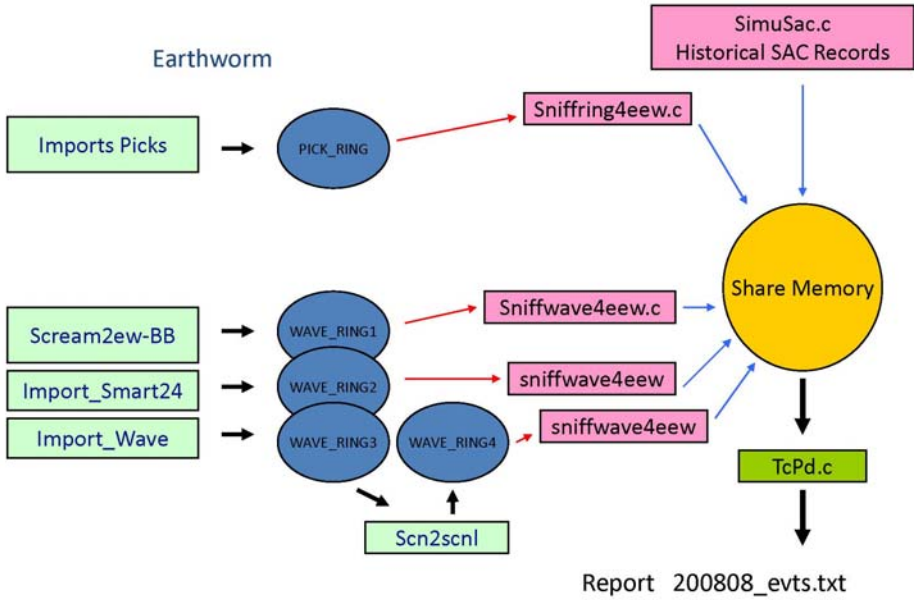

Figure 3. Diagrams show our earthquake early warning module running in Earthworm system. Two C codes named Sniffwave4eew.c and Simusac.c process real-time off-line signals and output P arrival, τ_c and *Pd* measurements into share memory. A C code named TcPd.c is an association program for earthquake trigger identification and calculates earthquake information from P arrival, τ_c and *Pd* measurements for earthquake early warning purposes.