ShakeMovie@Home

Li Zhao

Institute of Earth Sciences, Academia Sinica, Taipei 11529, Taiwan

Hsi-Kai Wang

Academia Sinica Grid Computing, Taipei 11529, Taiwan

A Computational Seismology Problem

Equation of motion (2nd Newton's Law) for continuum:

density → $\rho \ddot{\mathbf{u}} = \nabla \cdot \boldsymbol{\tau} + \mathbf{f}$ ← body force (earthquake)

acceleration ↑ stress ↑ elasticity tensor

Hooke's Law: $\boldsymbol{\tau} = \mathbf{C} : \boldsymbol{\varepsilon} = \mathbf{C} : \left\{ \frac{1}{2} [(\nabla \mathbf{u}) + (\nabla \mathbf{u})^T] \right\} = \mathbf{C} : (\nabla \mathbf{u})$

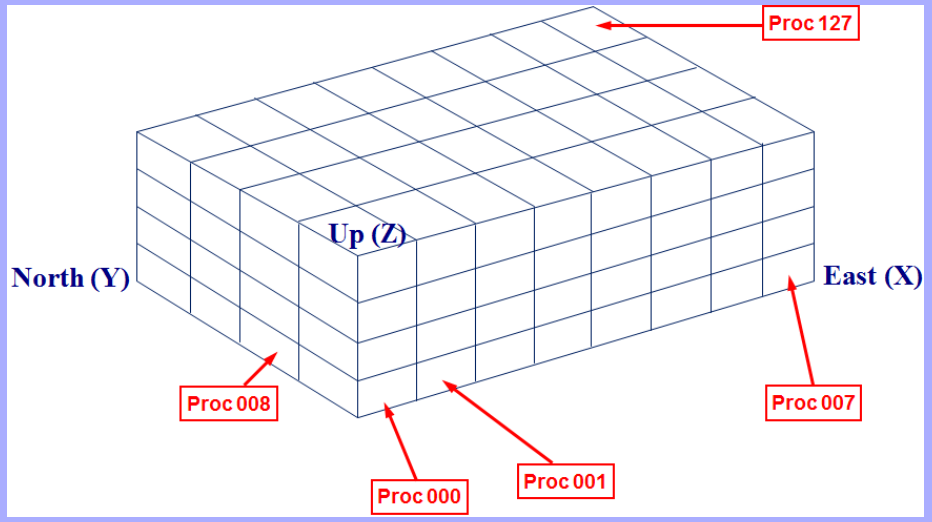
Wave Equation: $\rho \ddot{\mathbf{u}} - \nabla \cdot [\mathbf{C} : (\nabla \mathbf{u})] = \mathbf{f}$

Realistic Earth model: 3D, irregular geometry, topography

finite-difference method (FDM)

$$v_i^{n+1} = v_i^{n-1} + \frac{1}{\rho_i} \frac{\Delta t}{\Delta x} (\tau_{i+1}^n - \tau_{i-1}^n)$$

$$\tau_i^{n+1} = \tau_i^{n-1} + k_i \frac{\Delta t}{\Delta x} (v_{i+1}^n - v_{i-1}^n)$$



Finite-Difference Simulation Parameters

(1) Spatial grid size h: > 5 points per wavelength $\lambda = v \times T$

speed, period

$$\therefore\ h < \frac{1}{5} v_{\min} \times T_{\min}$$

For $v_{\min} = 1\,\text{km/s}$, $T_{\min} = 3\,\text{s}$, $h = 600\,\text{m}$. (We use $h = 400\,\text{m}$).

(2) Time step Δt: $\therefore\ \Delta t < \frac{1}{2} \frac{h}{v_{\max}}$

For $v_{\max} = 10\,\text{km/s}$, $h = 400\,\text{m}$, $\Delta t < 0.02$.

Modeling range:

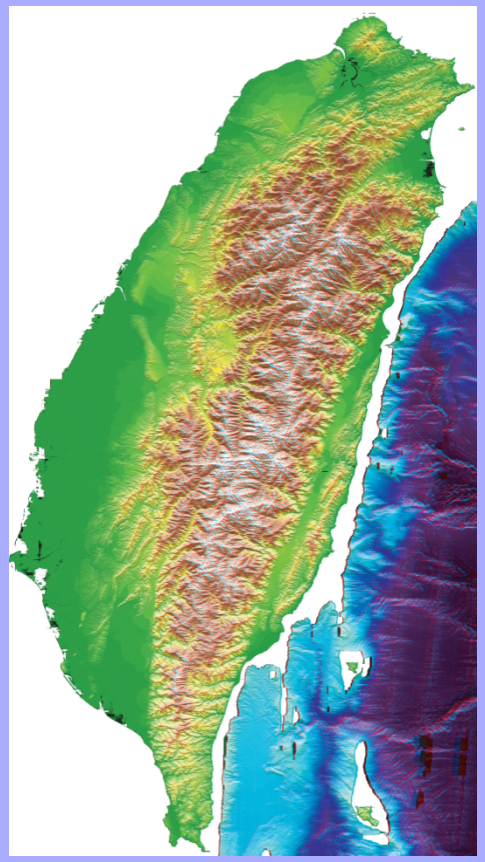
250 km × 400 km × 80 km × 90 s

Total # of spatial-temporal grids:

612 × 992 × 202 × 4500

CPU time and storage:

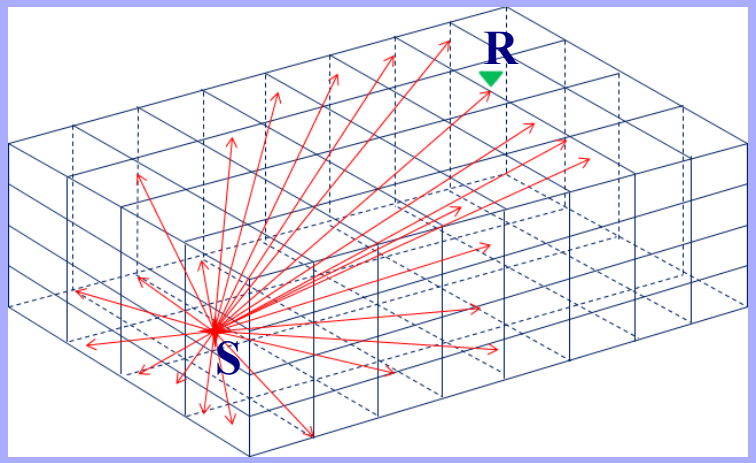
3 hours on 32 processes, 15 GB



From Y.-C. Chan

Two Ways to Compute a Seismogram

Forward Simulation



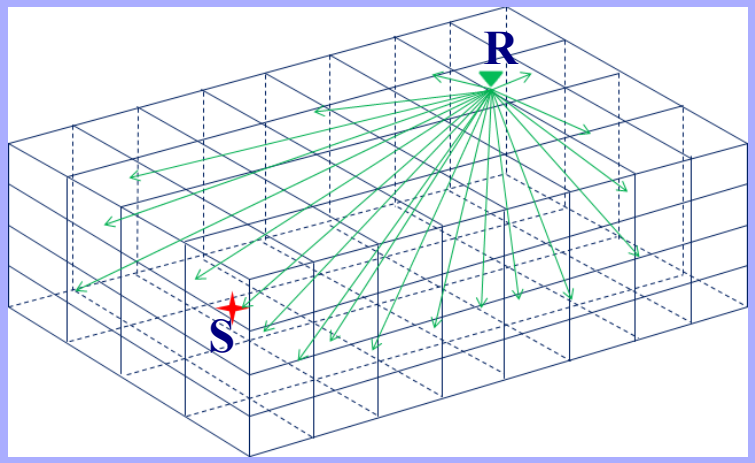
(1) Run simulation from earthquake S, output file includes waveforms at all grid points from the earthquake.

(2) For a given location R, retrieve its waveform u(S-R) from output file.

3 hrs x 32 CPUs

15 GB

Green's Function Reciprocity

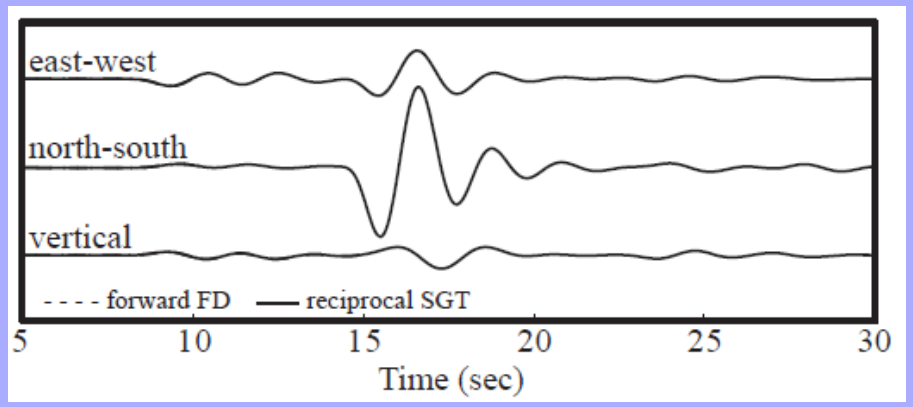


(1) Run simulation from a location R, output file includes Green's function **G** at all grid points from R.

(2) For earthquake S, retrieve Green's function from R to S, **G**(R-S). The waveform from S to R, u(S-R) can be easily calculated from **G**(R-S).

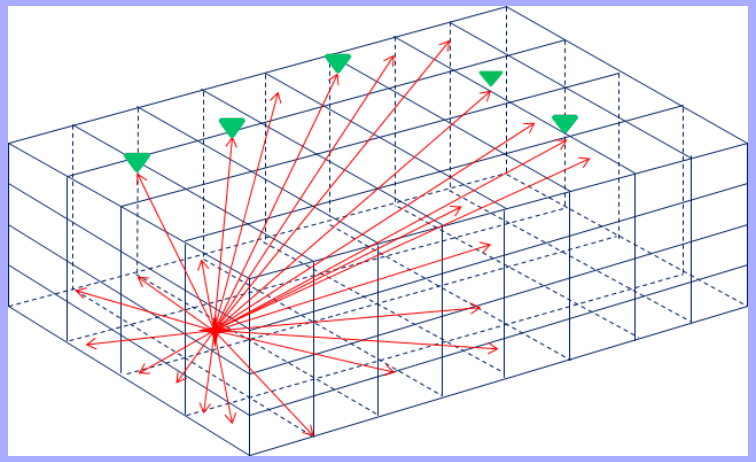
3 hrs x 32 CPUs

15 GB



For waveforms at 5 stations from 1 earthquake

Forward Simulation

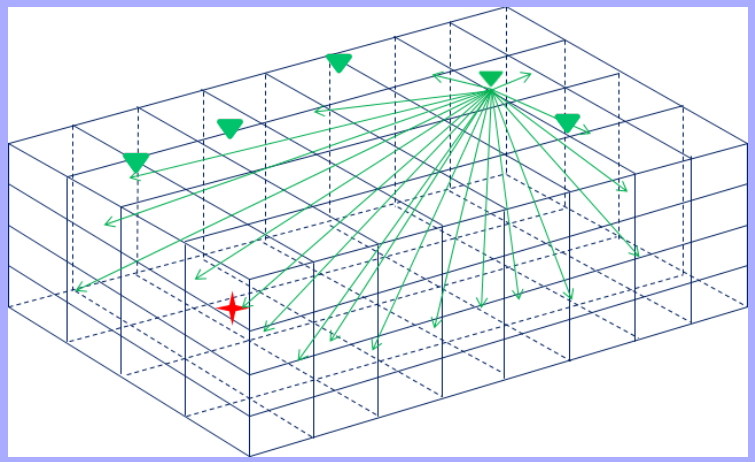


1 simulation, 5 retrievals

3 hrs x 32 CPUs

15 GB

Green's Function Reciprocity



5 simulations, 5 retrievals

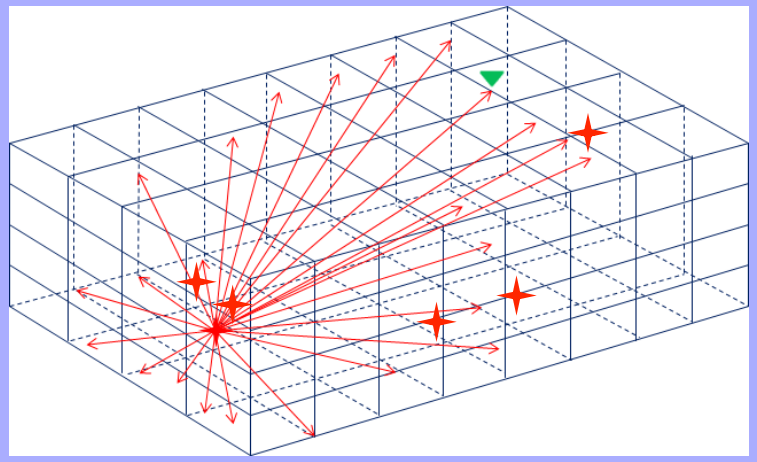
15 hrs x 32 CPUs

75 GB

Decision: Forward simulation!

For waveforms at 1 station from 5 earthquakes

Forward Simulation

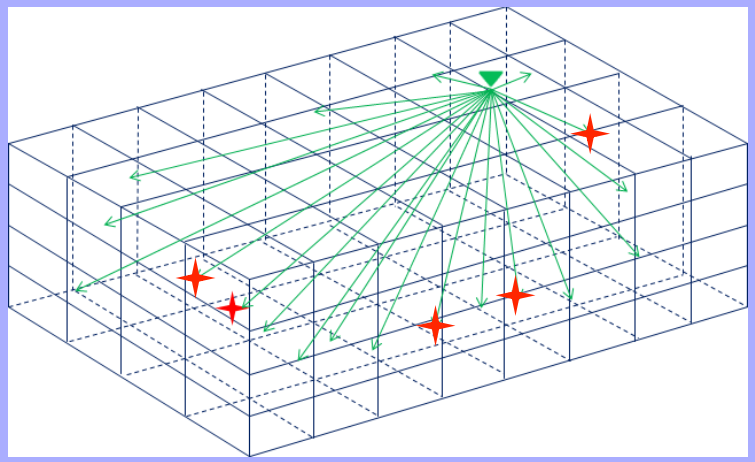


5 simulations, 5 retrievals

15 hrs x 32 CPUs

75 GB

Green's Function Reciprocity



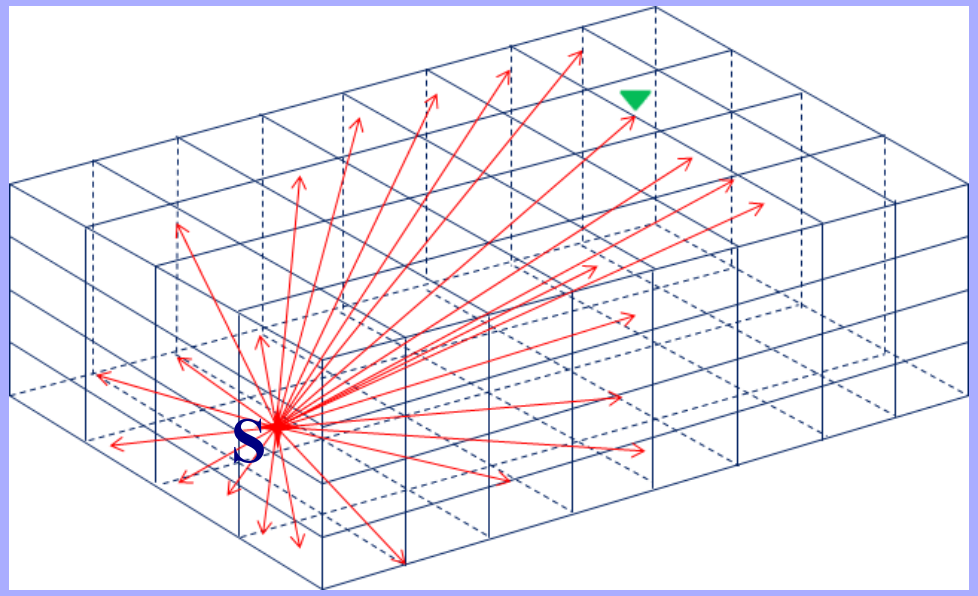
1 simulation, 5 retrievals

3 hrs x 32 CPUs

15 GB

Decision: Green's function!

Shake Movie Production



Given earthquake S, we need waveforms at a large number of points on the surface (7168 for Taiwan).

Forward simulation: 1 simulation (3hrs.) and 7168 retrievals.

Caltech's So. Cal. ShakeMovie

From: Notification of movies of recent seismic events. <shakemovie-notify@caltech.edu>
To: shakemovie-notify@caltech.edu
Subject: [ShakeMovie] Magnitude 4.1 :: 9 miles N of Ocotillo,CA :: Thu Nov 4 19:39:59 2010 UTC [Add Tag]
Date: Thu, 04 Nov 2010 14:32:00 -0700 (PDT)

EMAIL NOTIFICATION
shakemovie.caltech.edu
Event Id:10832573

There is new media now available for download on the recent seismic event:

Magnitude: 4.1
9 miles N of Ocotillo, CA
UTC: Thu Nov 4 19:39:59 2010
Latitude: 32.87
Longitude: -116.02

All movies for this event are available from:
http://shakemovie.caltech.edu/event?evid=10832573

The movies available include:

SOUTHERN CALIFORNIA
http://shakemovie.caltech.edu/dl?evid=10832573&product=socal&style=orange&size=small

LOS ANGELES BASIN
http://shakemovie.caltech.edu/dl?evid=10832573&product=la&style=orange&size=small

To unsubscribe, visit http://shakemovie.caltech.edu/signup.
You will see an Email Password and Unsubscribe buttons at the bottom left.

This email was automatically generated by Caltech's Southern California
Seismic Event Simulation Portal Notification System.

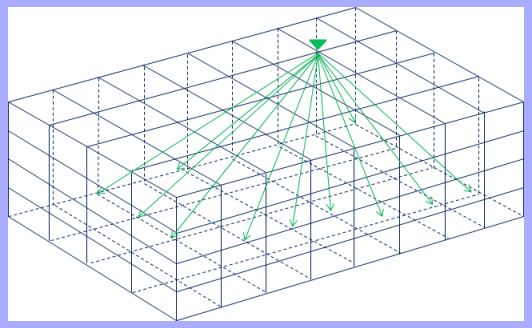
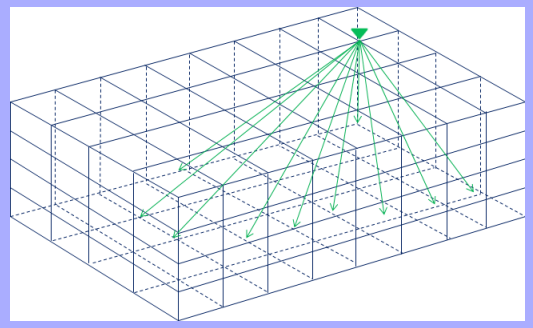
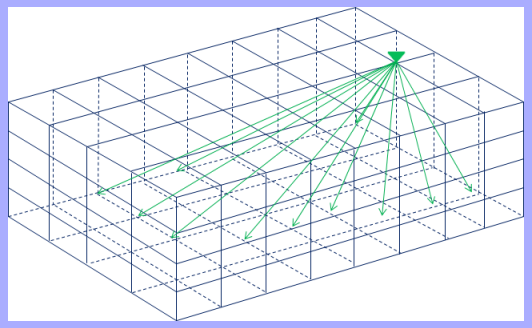
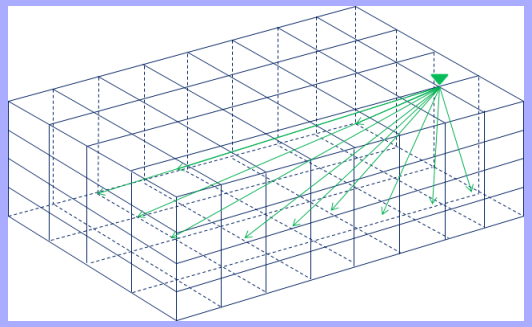
[shakemovie.caltech.edu]

(((shakemovie.caltech.edu)))

Near Real-Time Waveforms and ShakeMovie

Can we have shake movies faster?

Green's Function Database

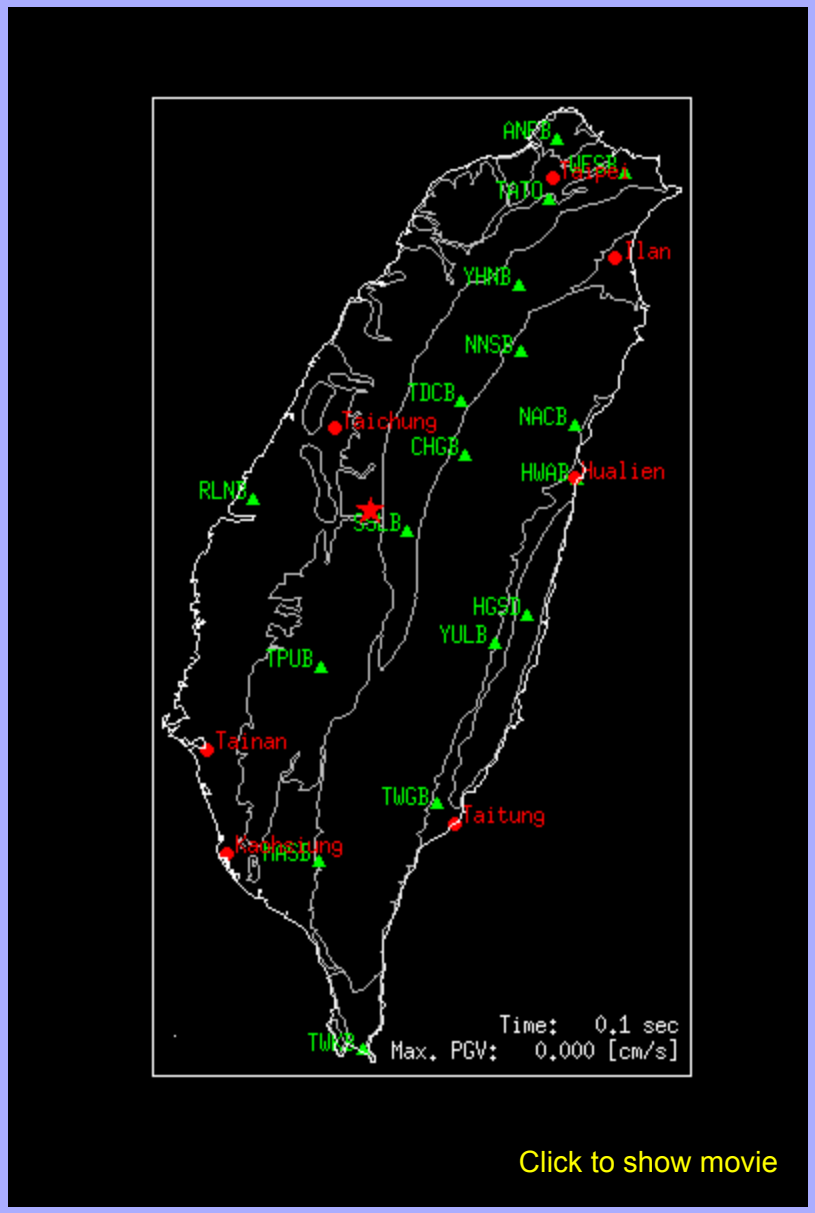
Run 7168 simulations to obtain Green's functions for all surface grid points. Establish Green's function database.

CPU: 7168 x 3 hrs. on 4 nodes (32 cores) or 45 days on 80 nodes.

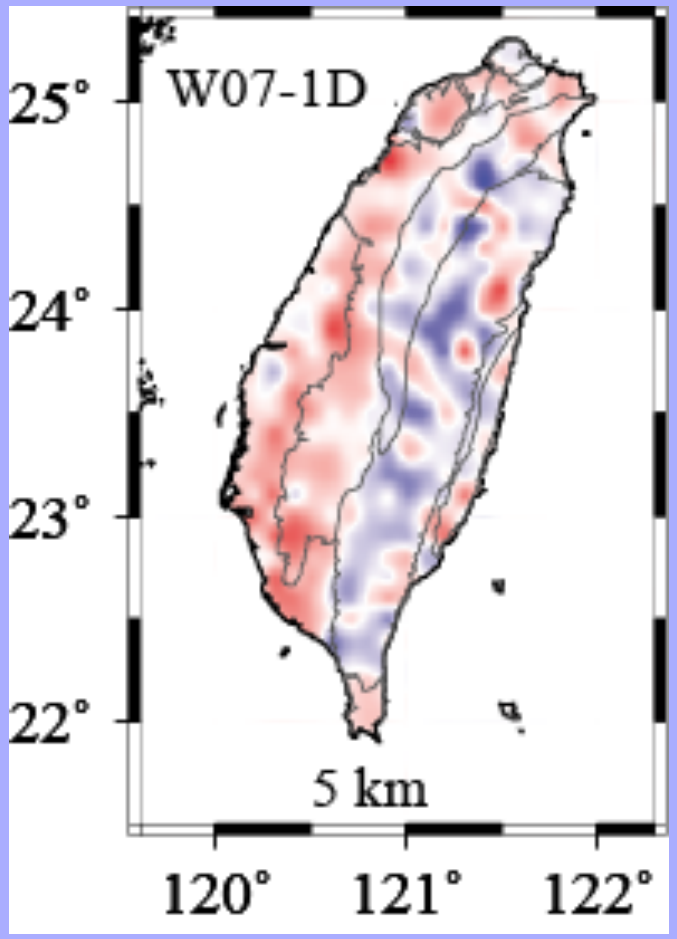
Storage: 7165 x 15 GB or ~100 TB.

No simulation is required for waveform and shakemovie calculations for future earthquakes! Only retrievals are needed.

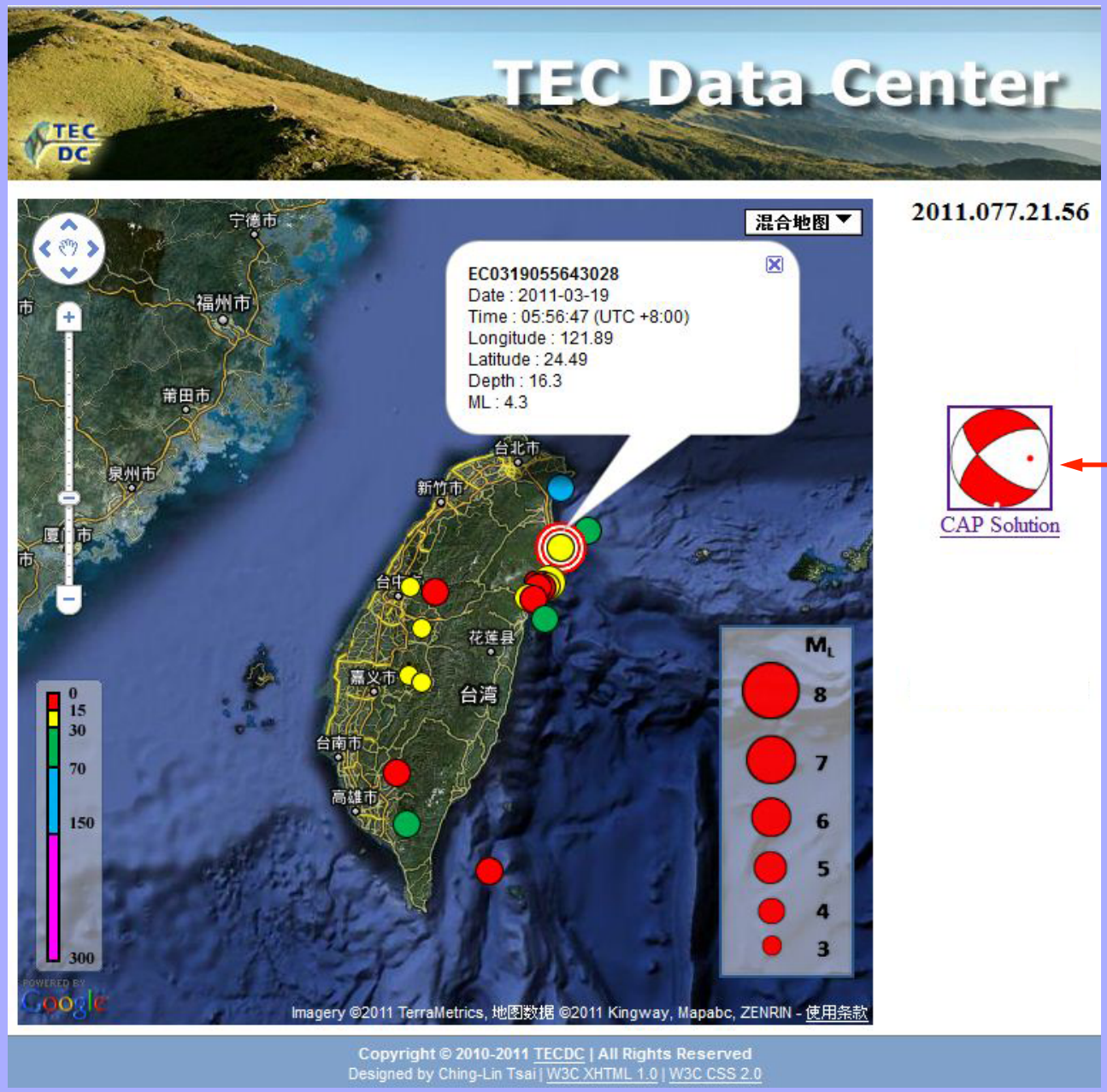
Shake Movie: Chi-Chi (Taiwan) Earthquake



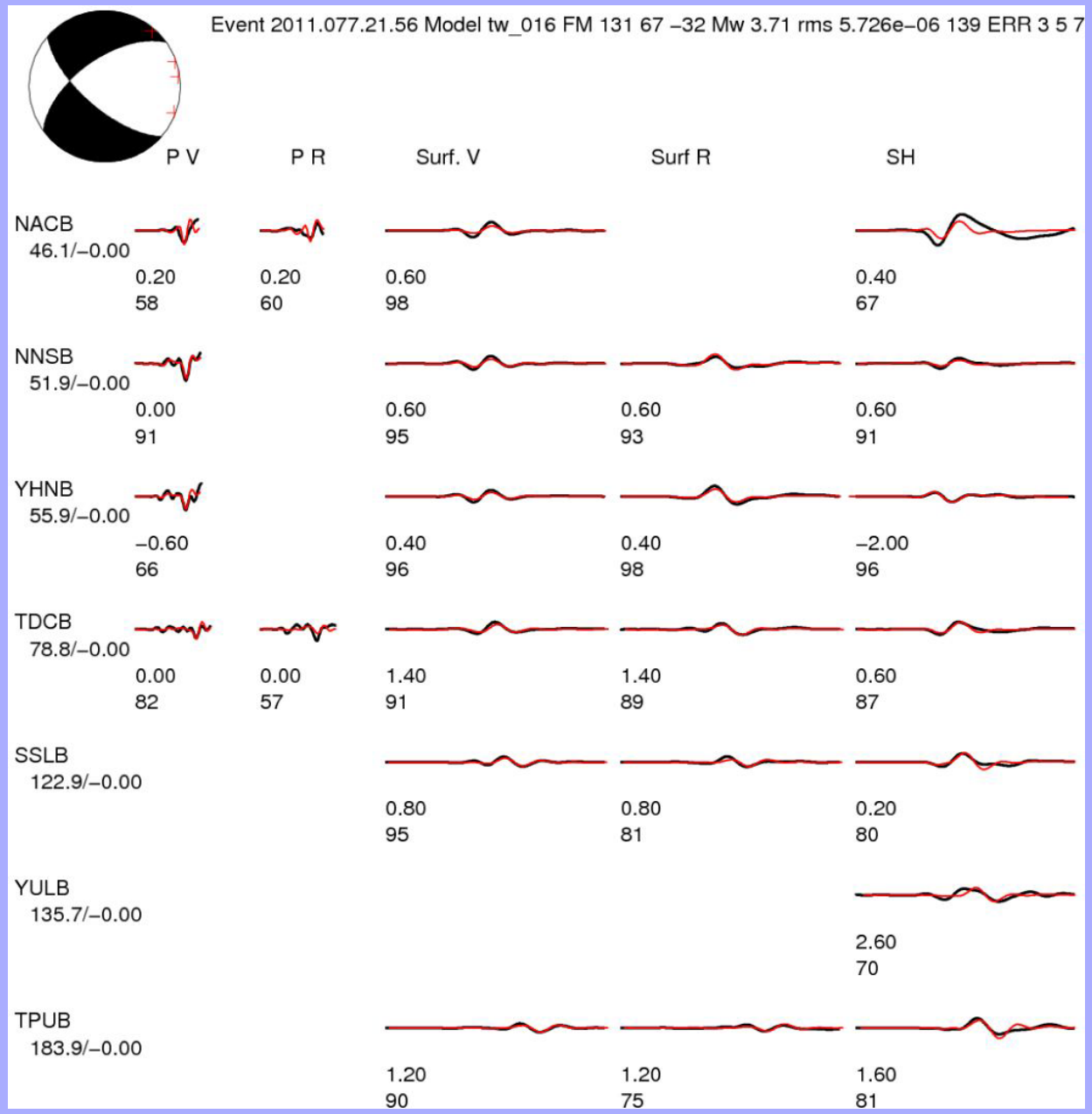
Near-surface velocity



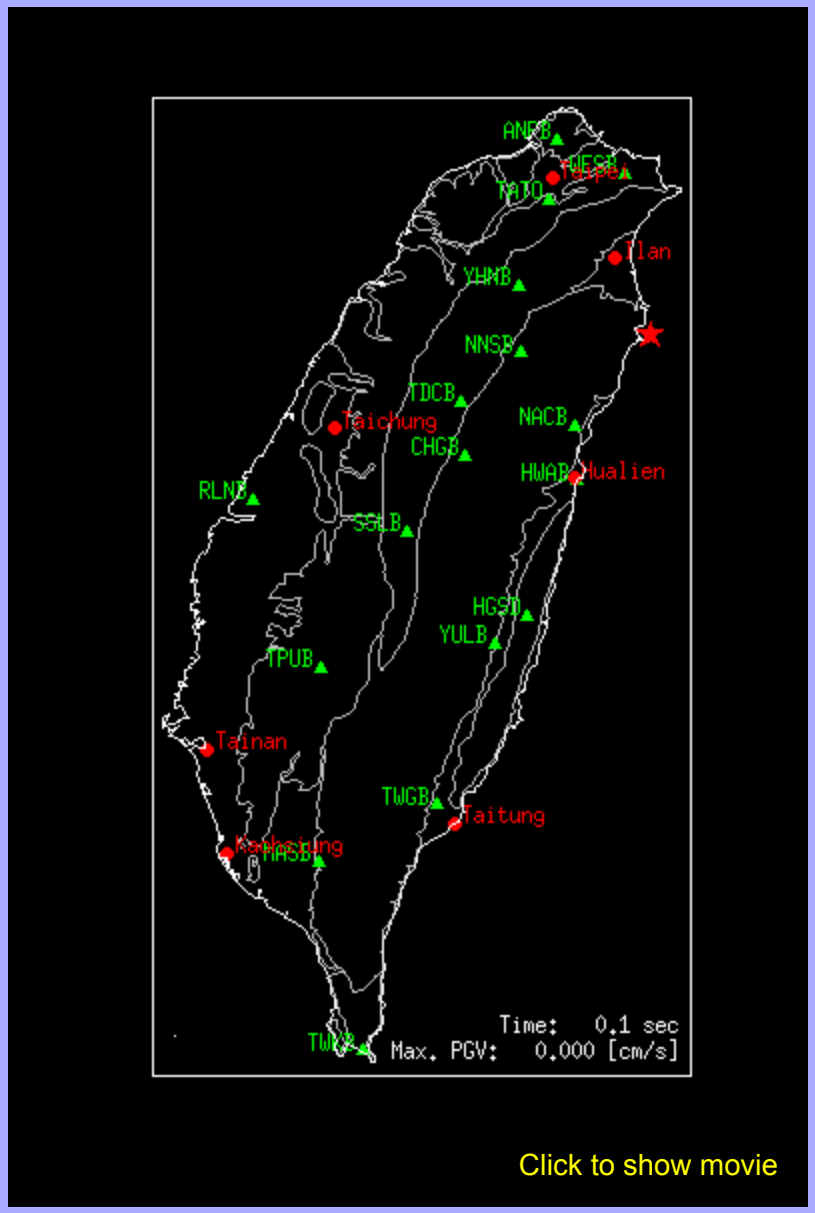
CMT Solutions at Taiwan Earthquake Center



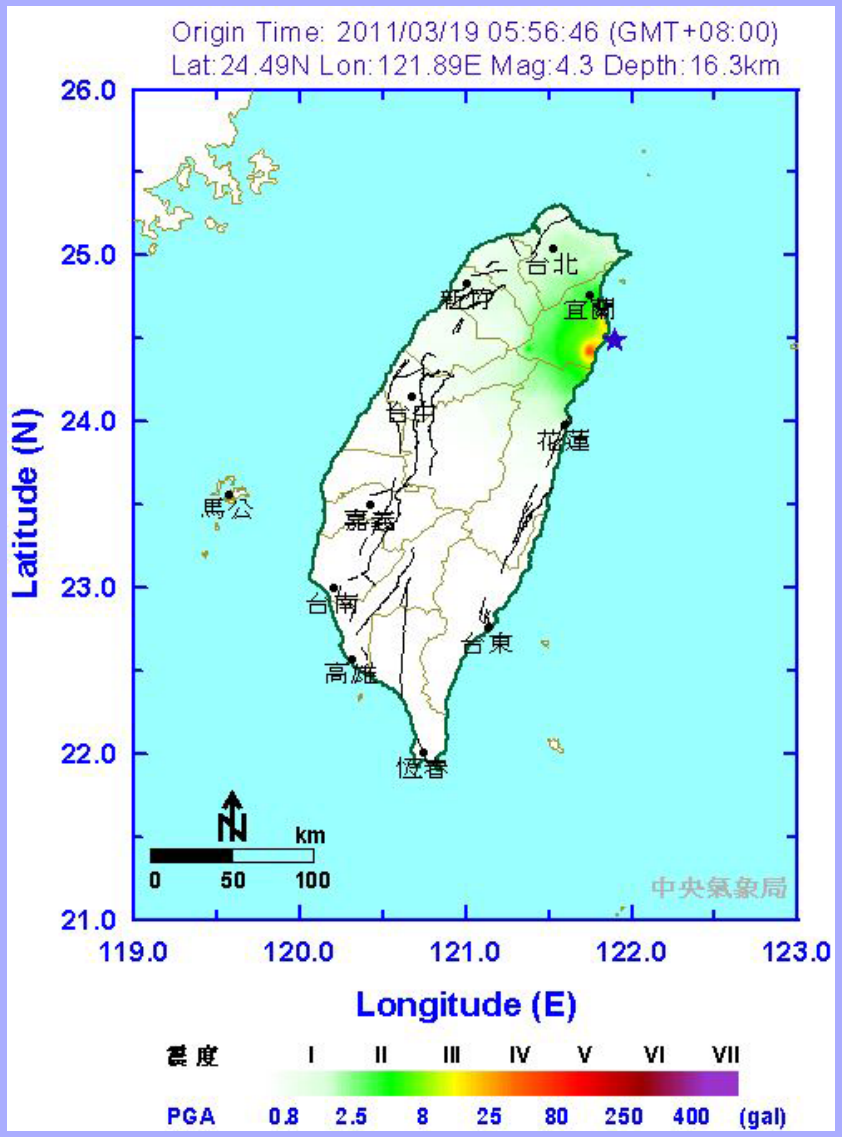
Observed (black) and Predicted (red) Waveforms



Shake Movie



CWB Strong Motion Observation



ShakeMovie@Home

- Distribute the 7168 Green's functions (15GB each): up to 7168 sites.
- Distribute Green's function retrieval (21KB each): up to 7168 volunteers' desktops/laptops.
- Greater distribution enables consideration of more detailed features (higher frequency/resolution).
- All waveforms and shake movies can be available within minutes after earthquake alert.

Further Improvements

- Improve I/O performance.
- Higher frequency and resolution: smaller grid size.
- Accuracy: near-surface site condition, topography.

Thank you!