

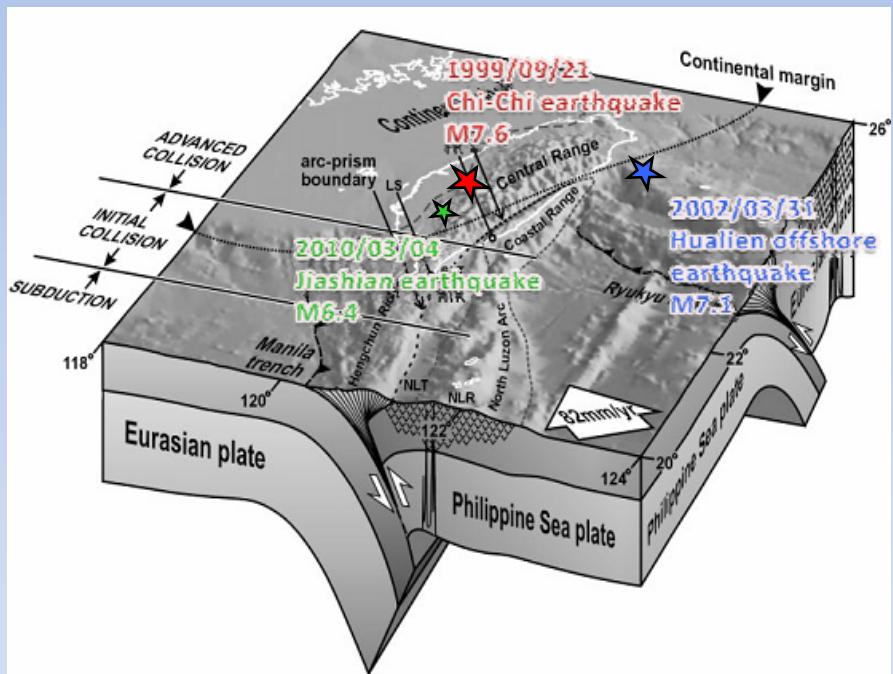
3D waveforms simulation for earthquakes and scenario events

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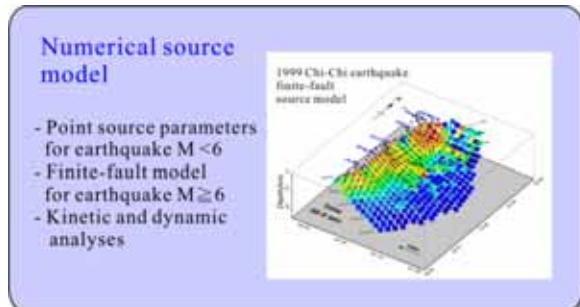
Introduction

- Taiwan is formed by a collision between the Philippine Sea plate and the Eurasian continental margin.
- In the last 20 years, numerous large hazardous earthquakes had caused remarkable damages with considerable casualties.
- It is therefore an important scientific mission to simulate and to understand the hazardous earthquakes by using high resolution, advanced numerical simulation techniques.



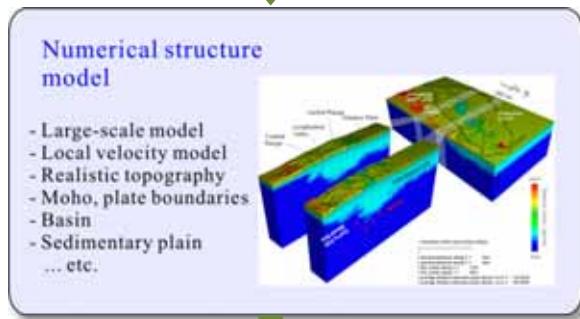
Block diagram showing arc-continent collision and tectonic setting of Taiwan (by CHANG,2001)

Earthquake simulation - Source, Path and Site



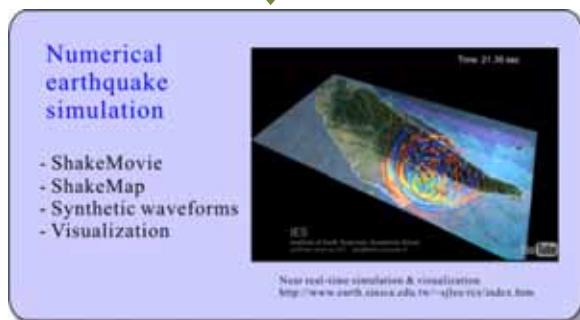
Source

- $M < 6$: Point source parameters
- $M > 6$: Finite-fault source model
- Fault and seismogenic zone
- Kinetic and dynamic analyses



Path and site

- Large-scale velocity model
- Local velocity model
- Surface topography
- Moho, plate boundary
- Basin, sedimentary plain, ... etc.



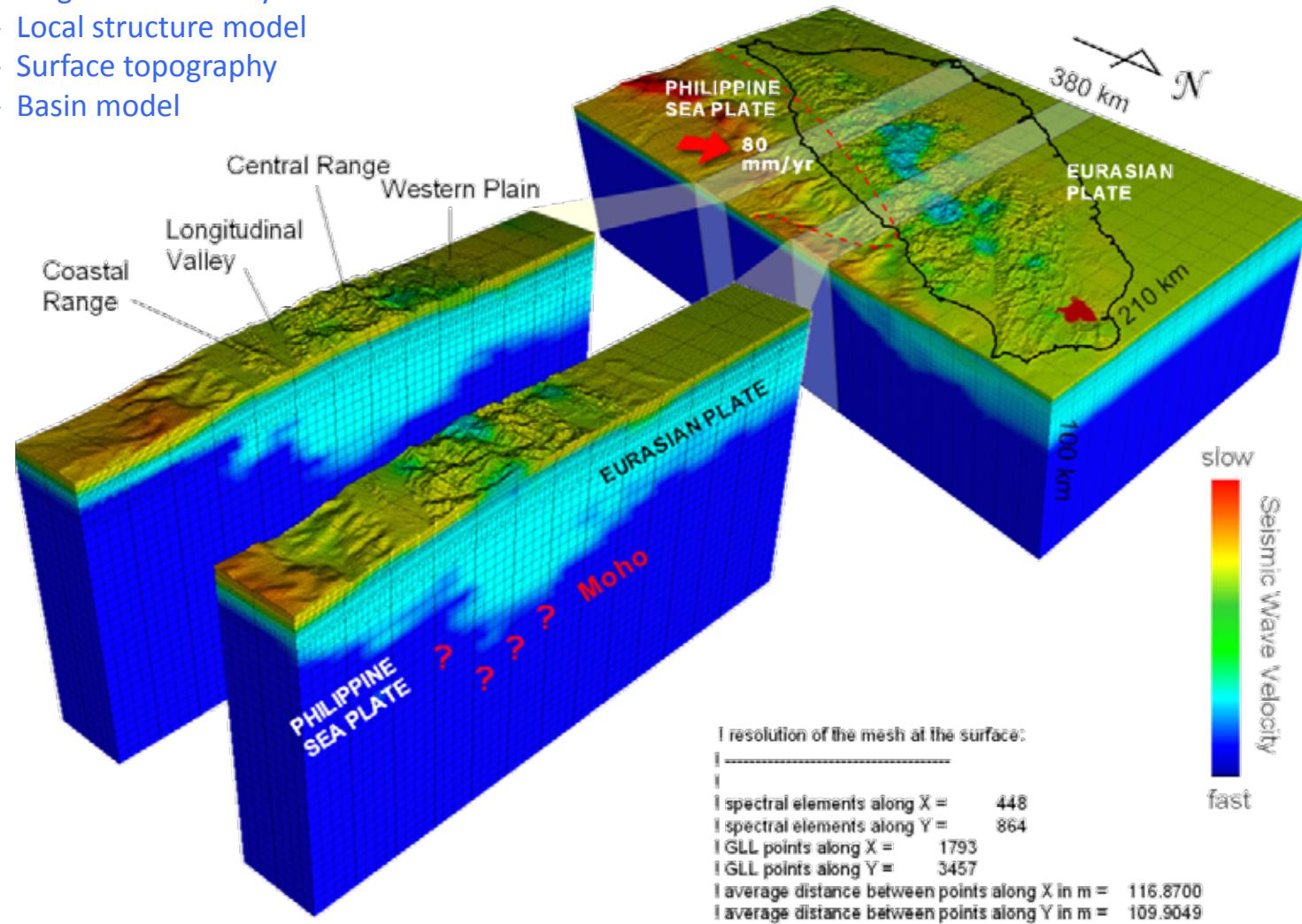
Earthquake simulation

- ShakeMovie: 3D wave propagation
- ShakeMap: PGA, PGV, Intensity map
- Synthetic waveforms
- Visualization

Path: Numerical velocity and structure model

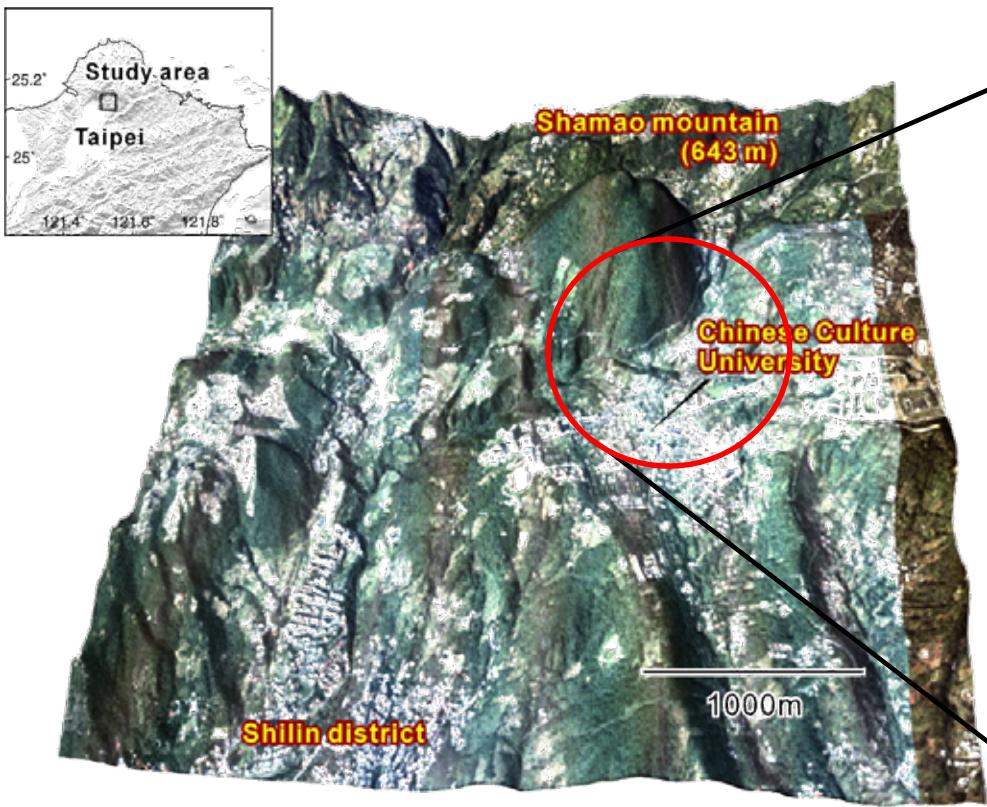
Spectral-element method mesh model

- Large scale velocity model
- Local structure model
- Surface topography
- Basin model

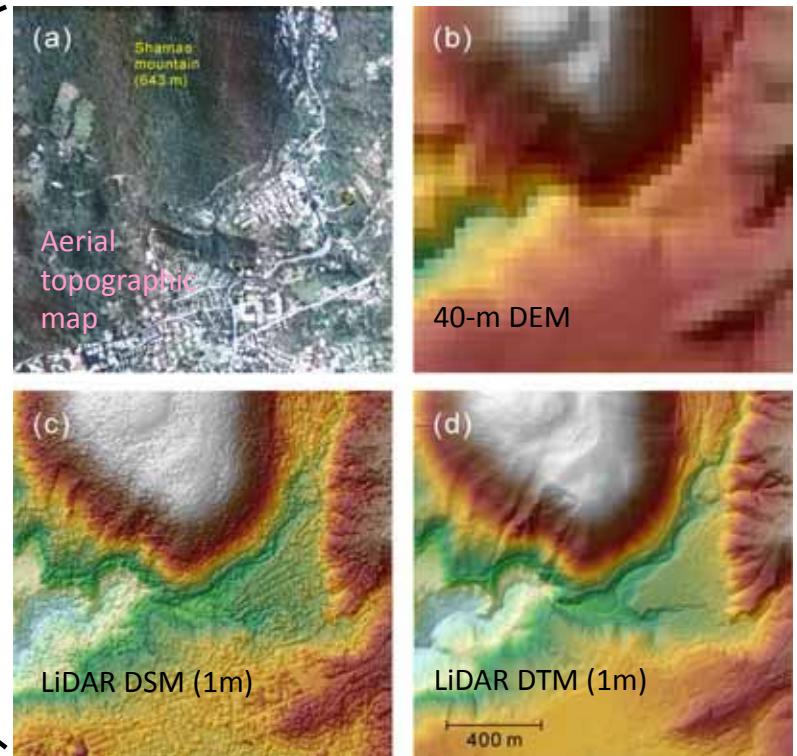


Path: Realistic topography effects

Shamao Mountain area

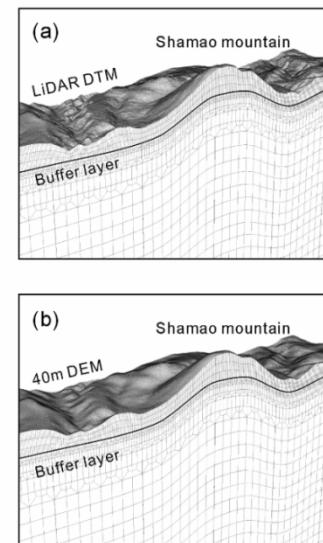
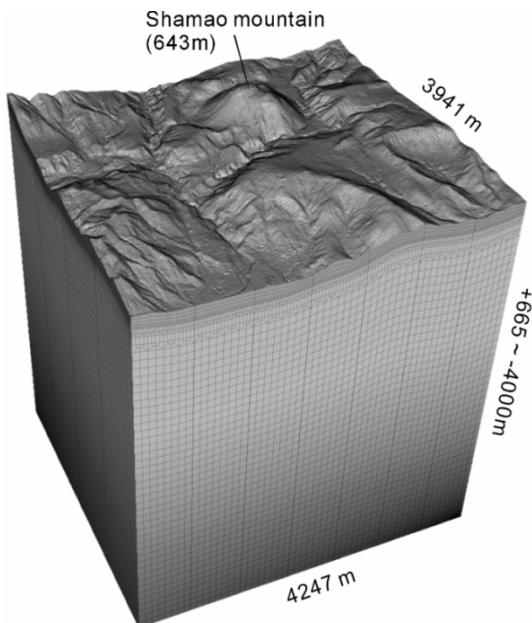


LiDAR DTM data (1m)



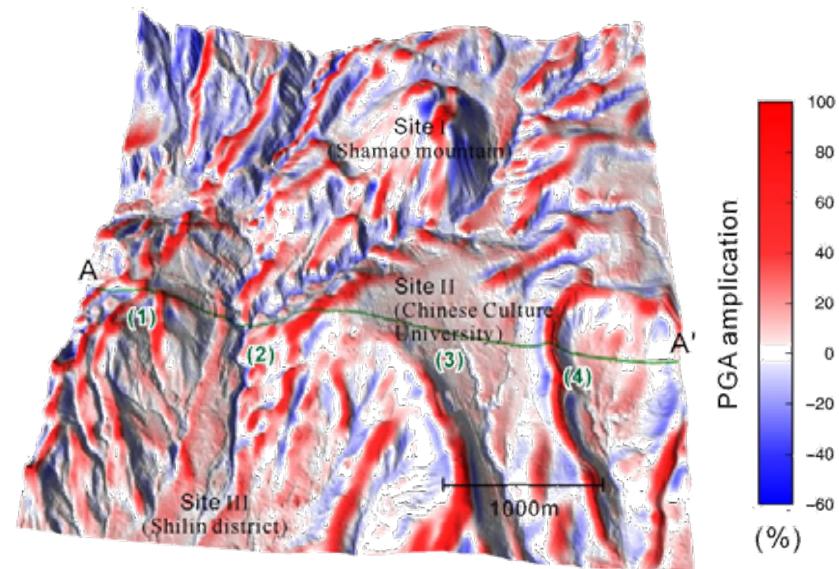
Path: Realistic topography effects

Spectral-element meshes
(LiDAR DTM, 2m SEM mesh at surface)



Lee et al. 2009a, BSSA
Lee et al. 2009b, BSSA

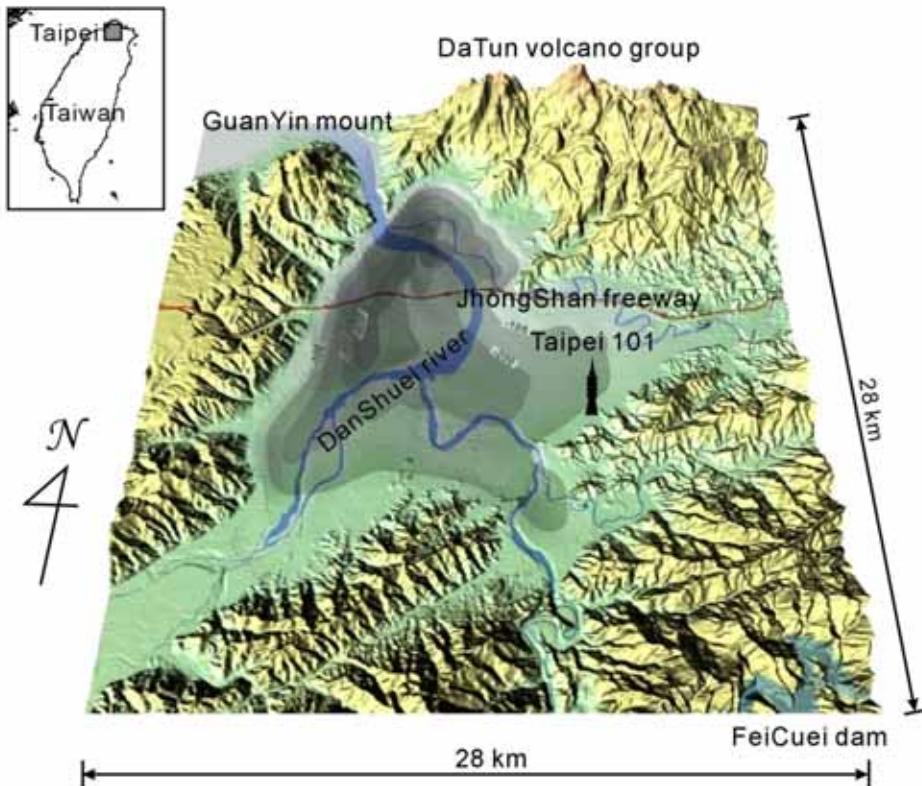
Relative change in PGA
(Determined from 10 Hz simulation)



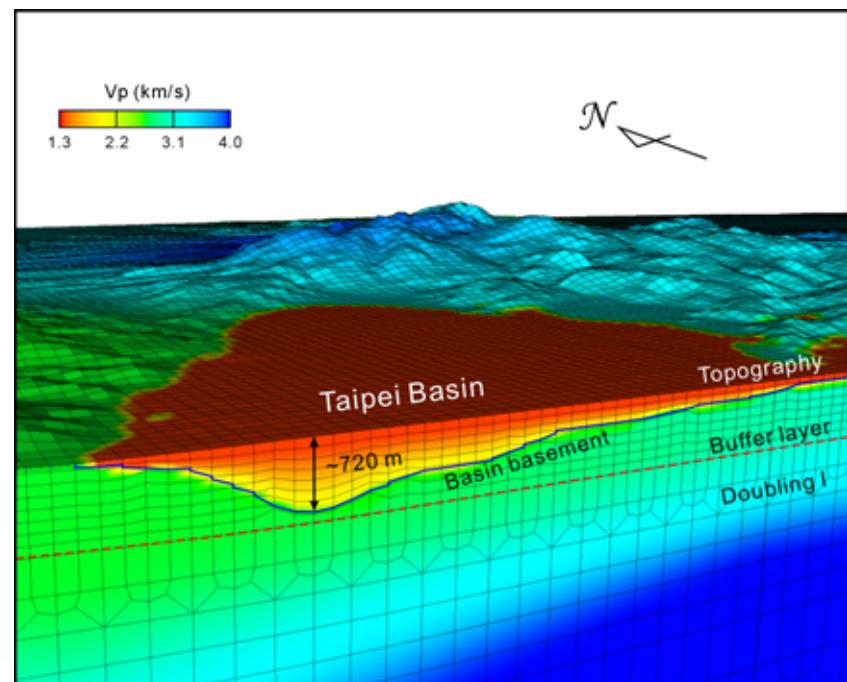
PGA amplification factor: subtract the PGA value for the model without topography from the value for the model with topography, dividing the result by the PGA value for the model without topography, and multiplying it by 100 to obtain a percentage

Site: Taipei Basin

Map view of the Taipei



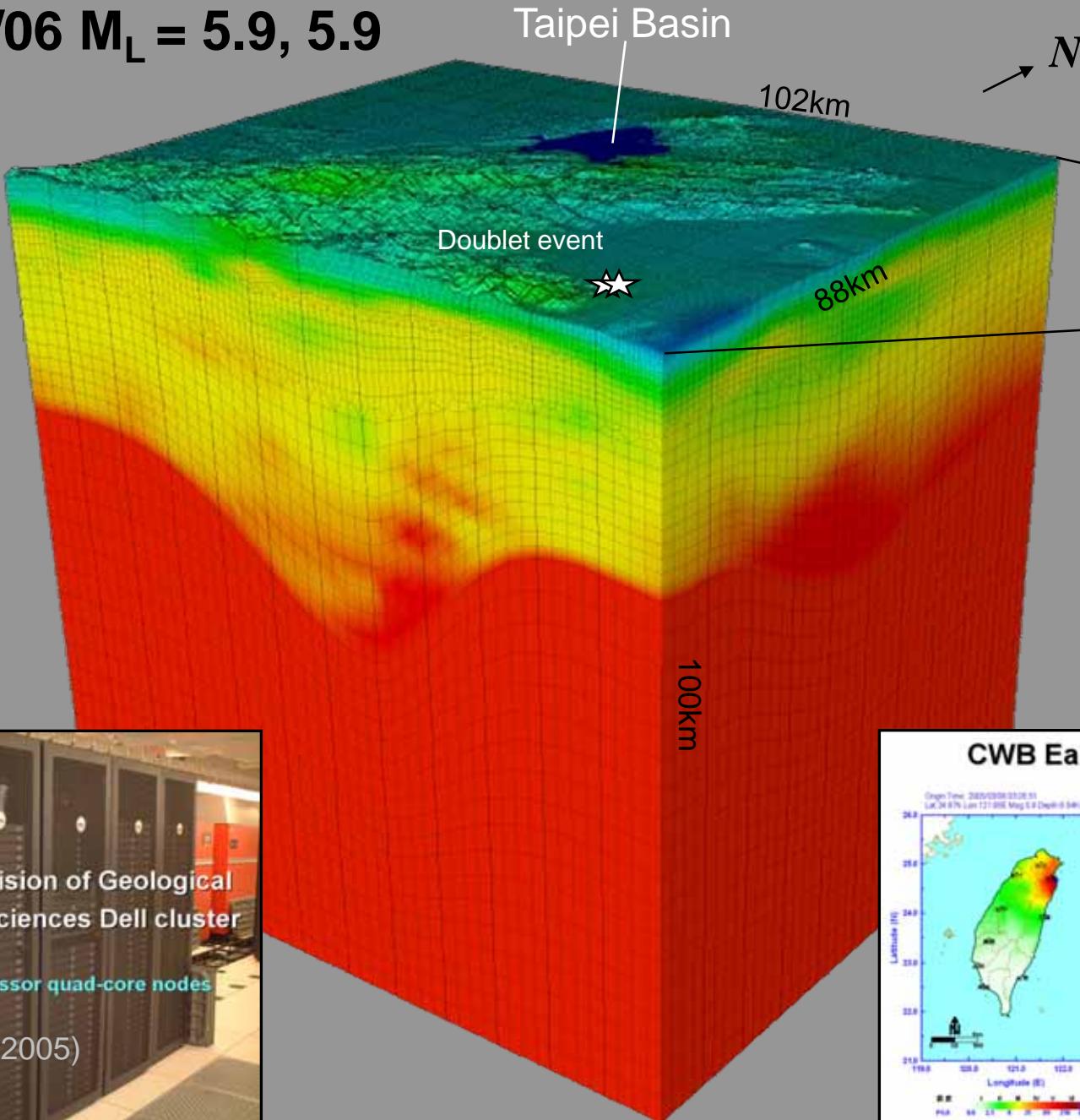
Taipei basin SEM mesh



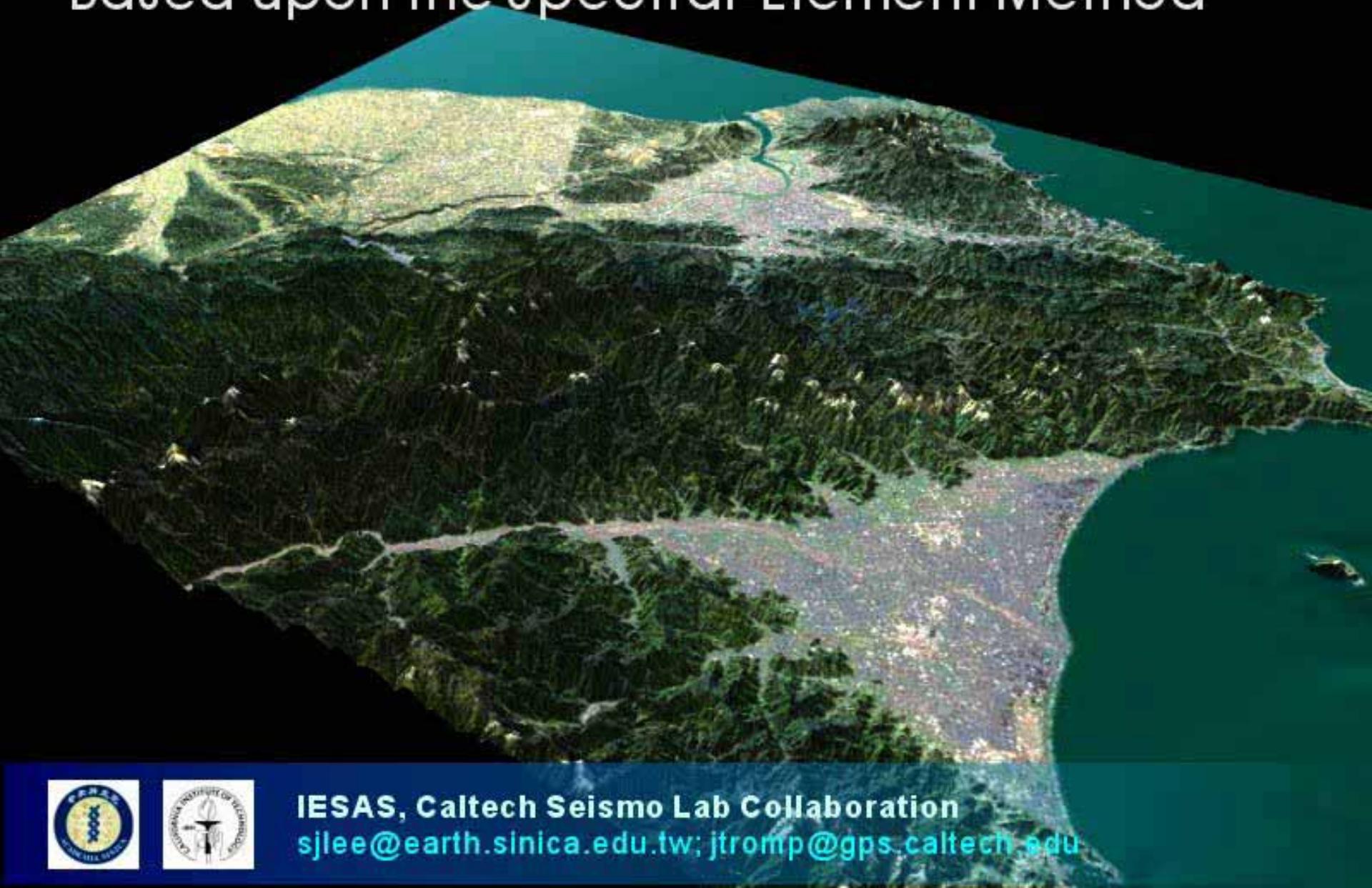
Lee et al. 2008a; 2008b, BSSA

I-Lan Doublet Event

2005/03/06 $M_L = 5.9, 5.9$



Simulation of Ground Motion in the Taipei Basin Based upon the Spectral-Element Method



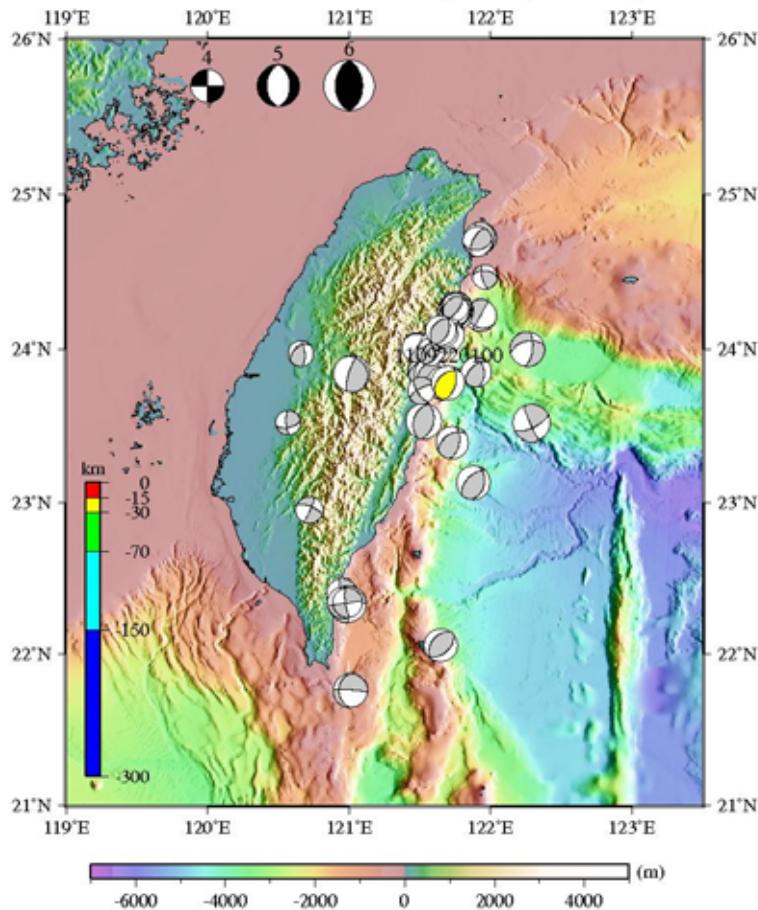
IESAS, Caltech Seismo Lab Collaboration
sjlee@earth.sinica.edu.tw; jtromp@gps.caltech.edu

Source: Numerical source model

M < 6.0: Point source

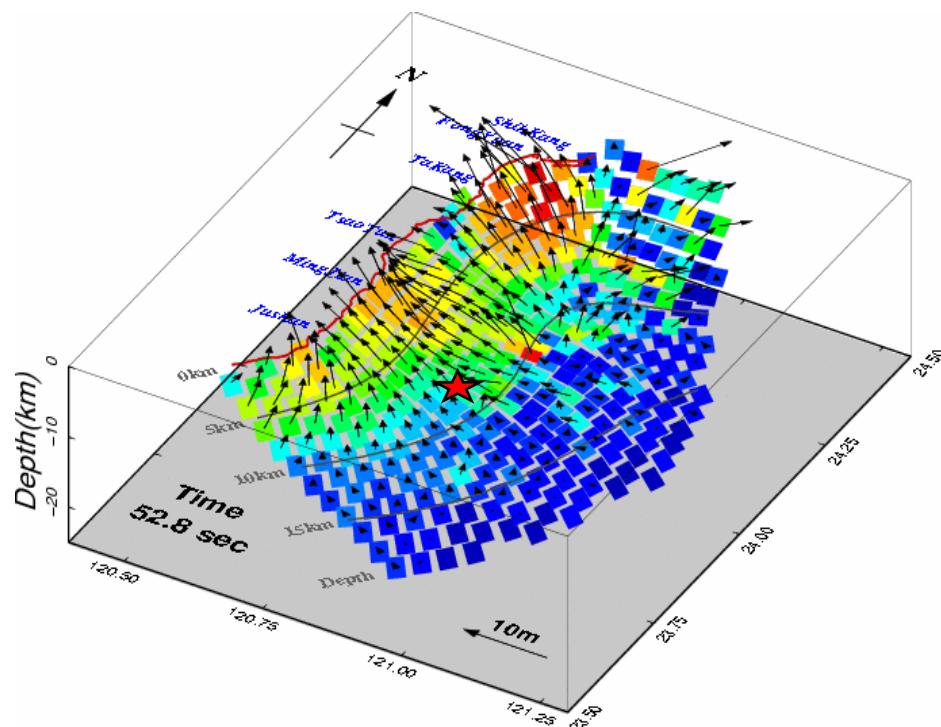
Broadband array in Taiwan for seismology:

<http://bats.earth.sinica.edu.tw>



M > 6.0: Finite-fault source model

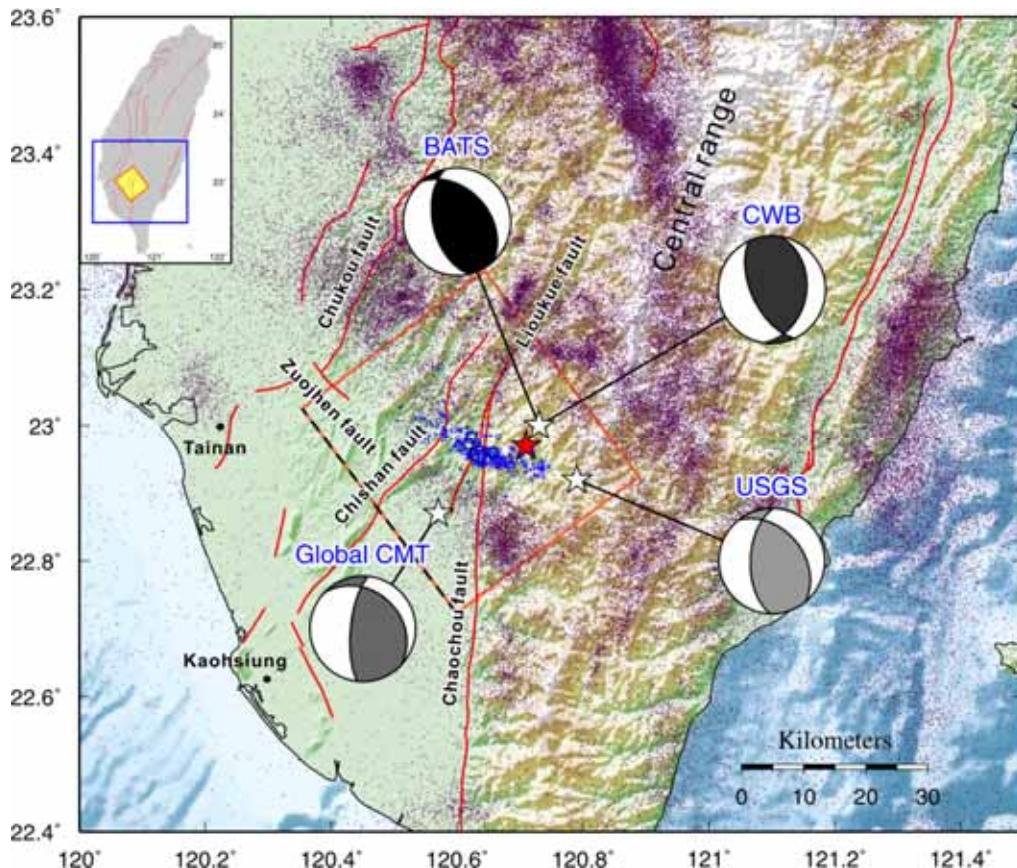
1999 Chi-Chi earthquake (M7.6) finite-fault source model



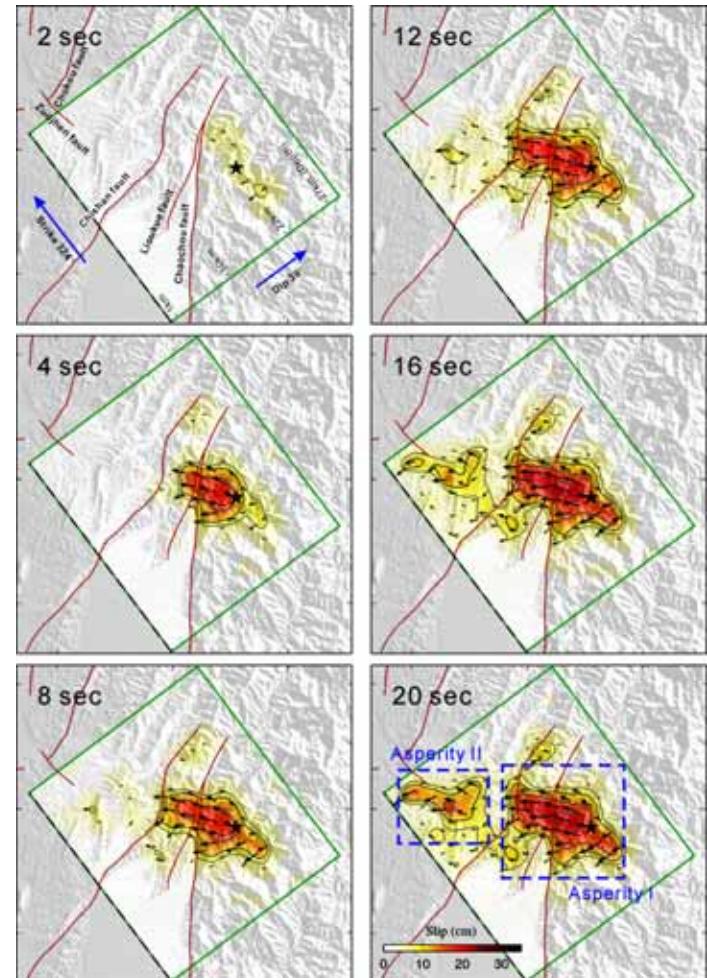
Lee et al. 2006 (Updated 2009)

Source: Numerical source model

March 3, 2010 Jiashian earthquake ($M_L 6.4$)



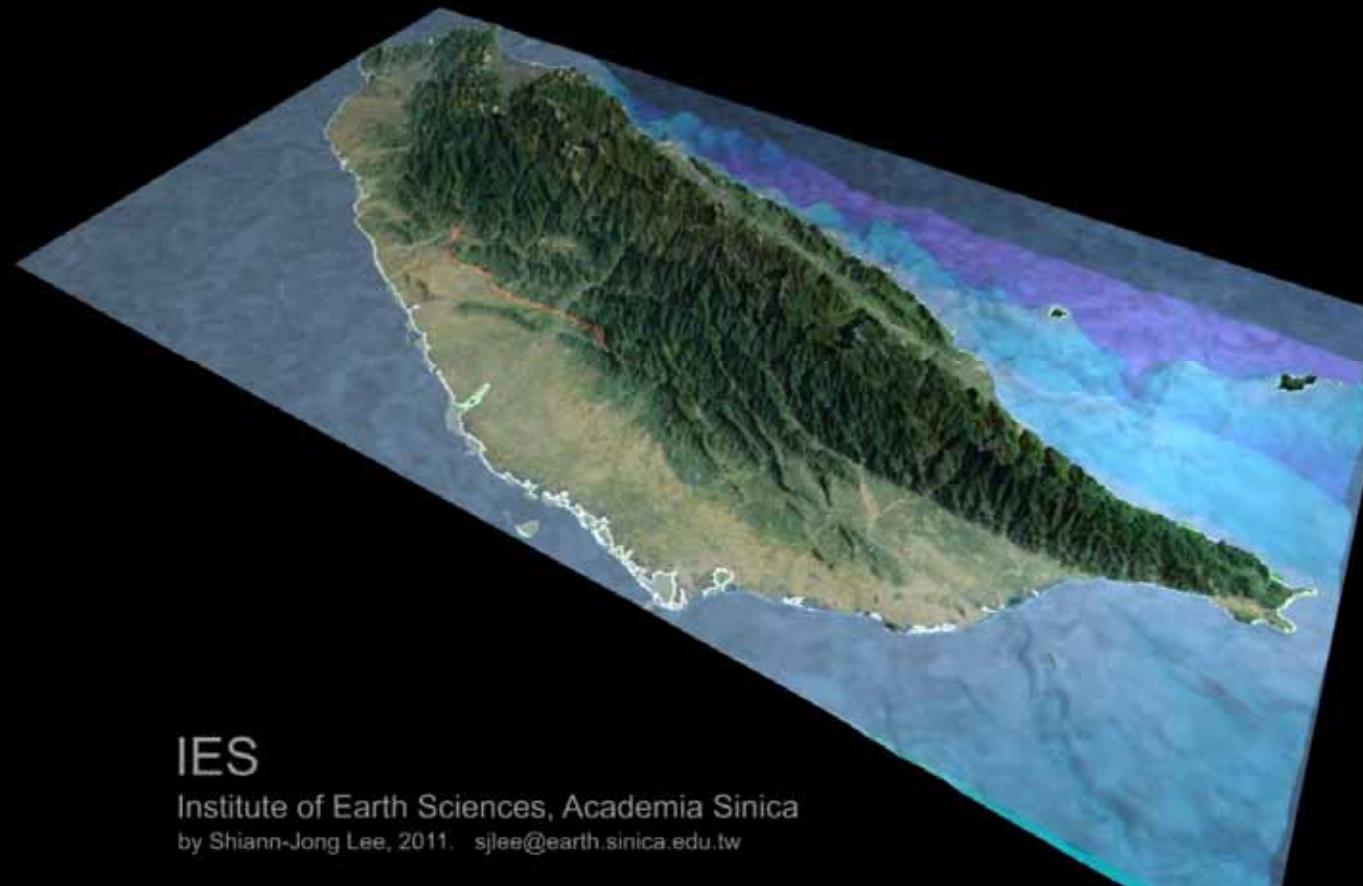
Rupture snapshots



Numerical earthquake simulation and visualization

ShakeMovie: Example of 2010 Jiashian earthquake

Time: -1.35 sec



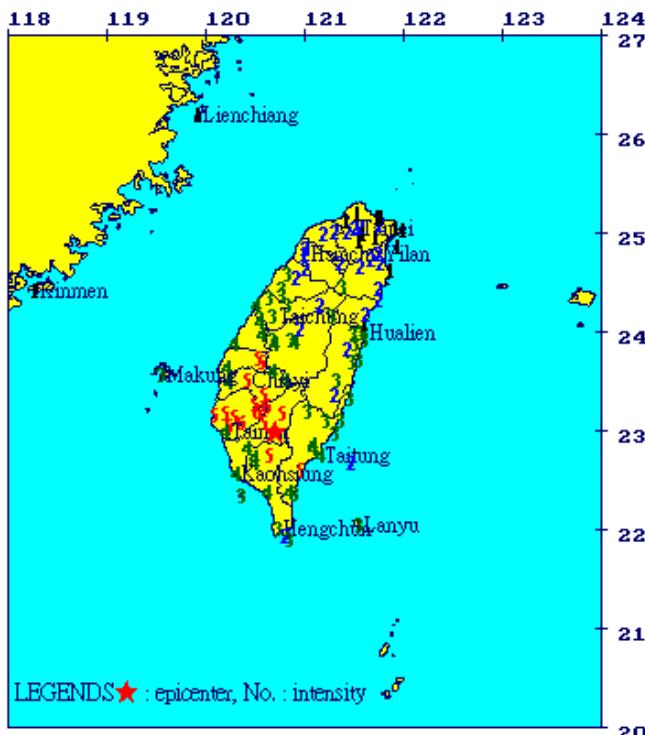
IES

Institute of Earth Sciences, Academia Sinica
by Shiann-Jong Lee, 2011. sjlee@earth.sinica.edu.tw

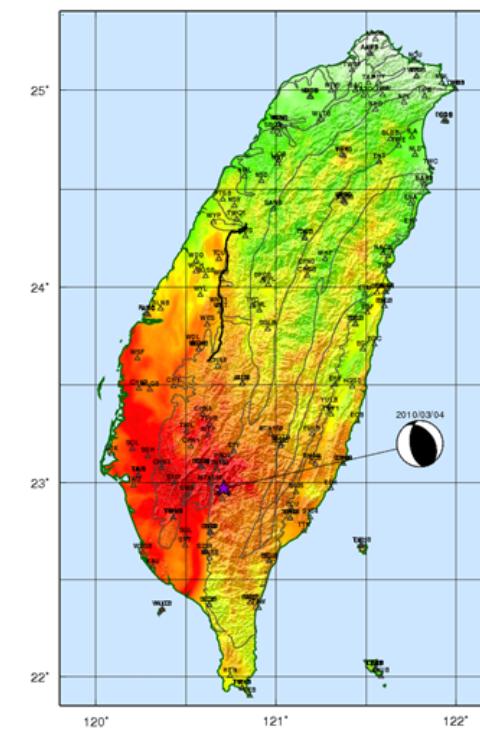
Numerical earthquake simulation

ShakeMap : Example of Jiashian earthquake

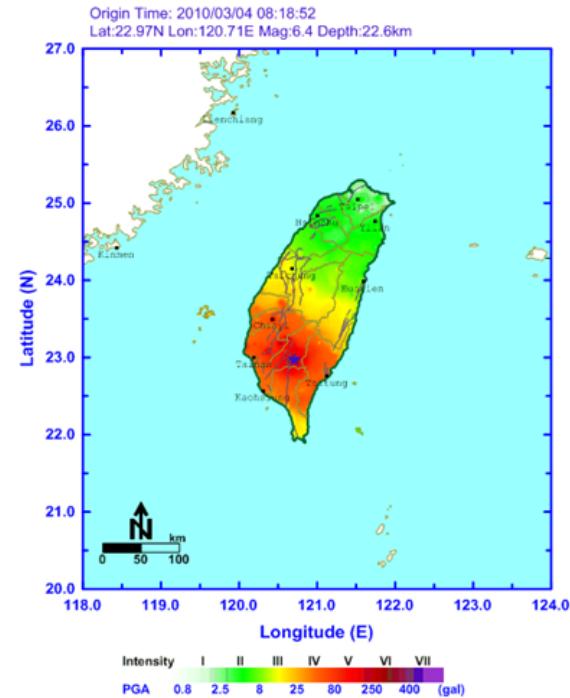
CWB intensity observation



ShakeMap
(Simulation)

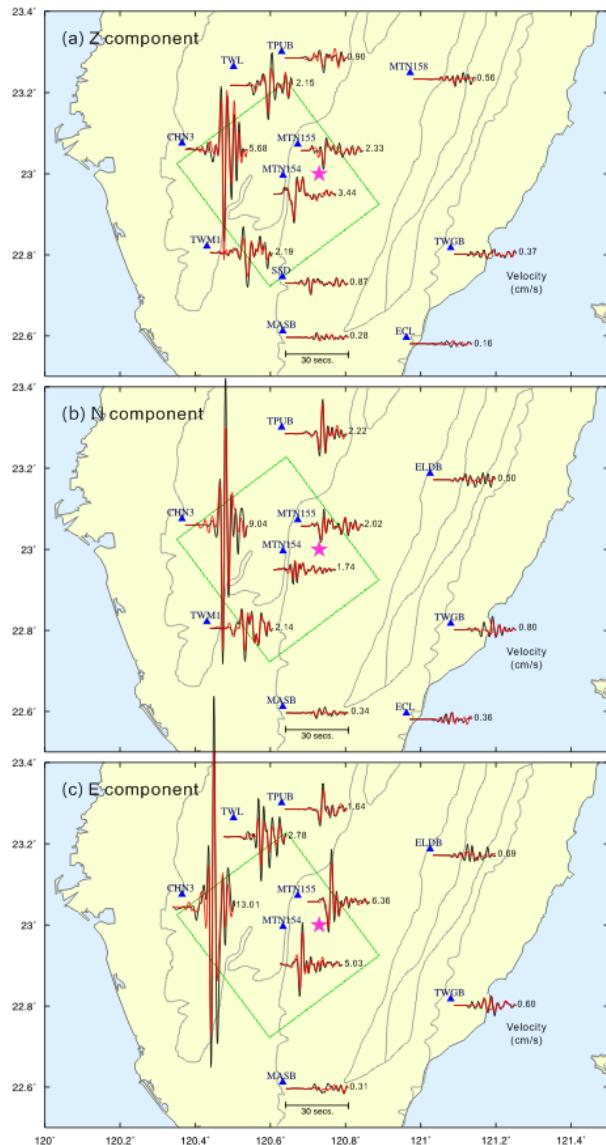


ShakeMap
(CWB report)

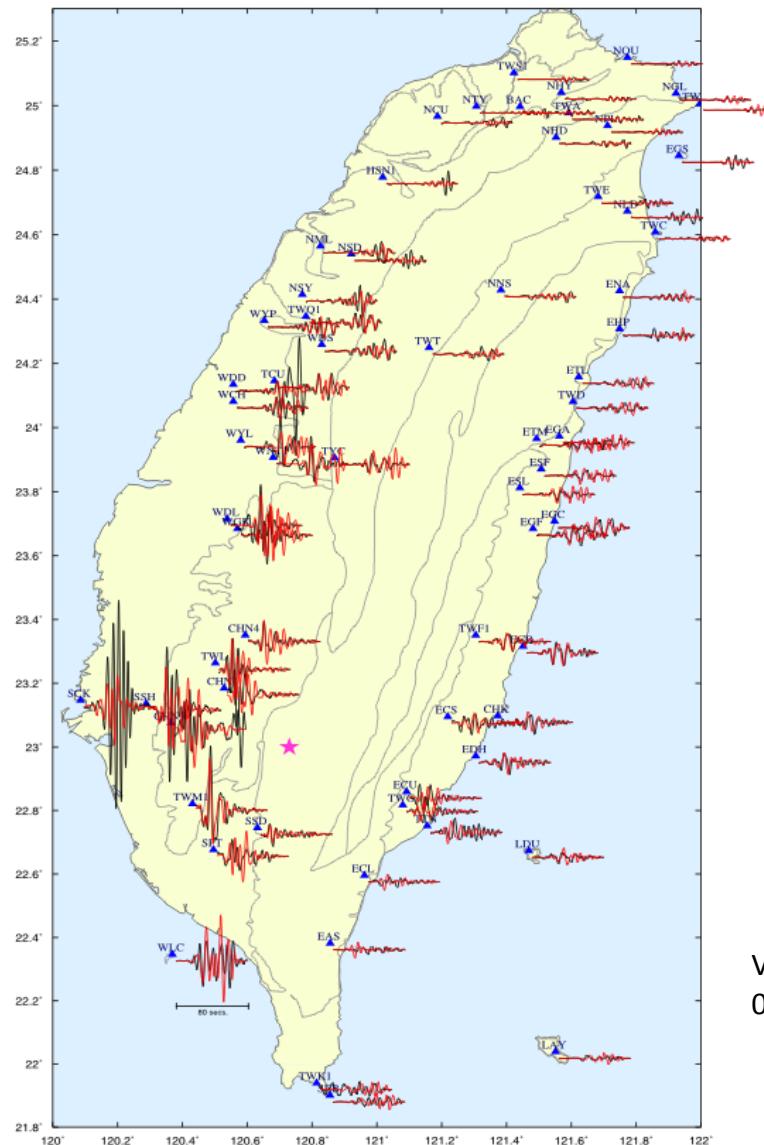


Ground motion simulation and prediction

Stations used in the inversion

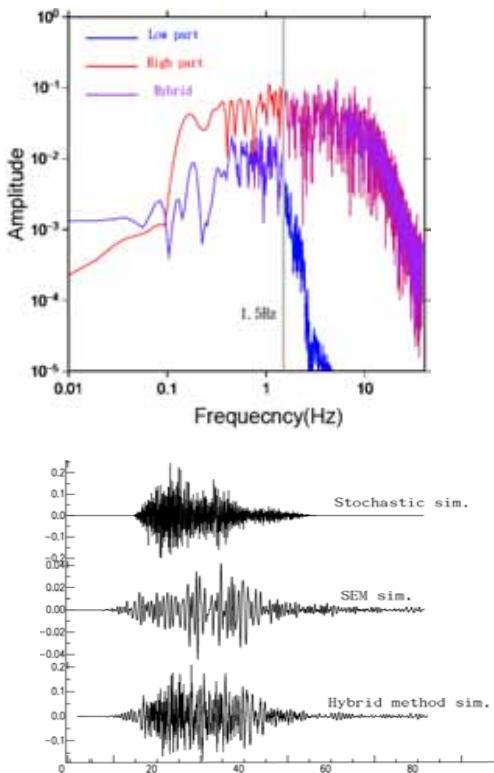


All CWB RTD stations in Taiwan

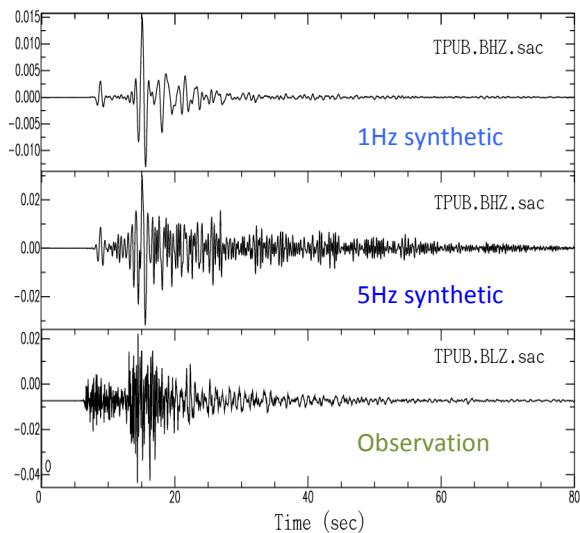


Realistic ground motion simulation and prediction

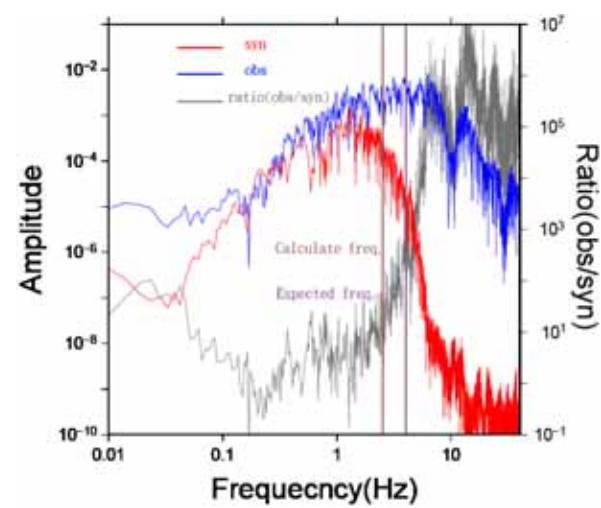
Hybrid
Numerical +
Stochastic



High frequency
Numerical simulation

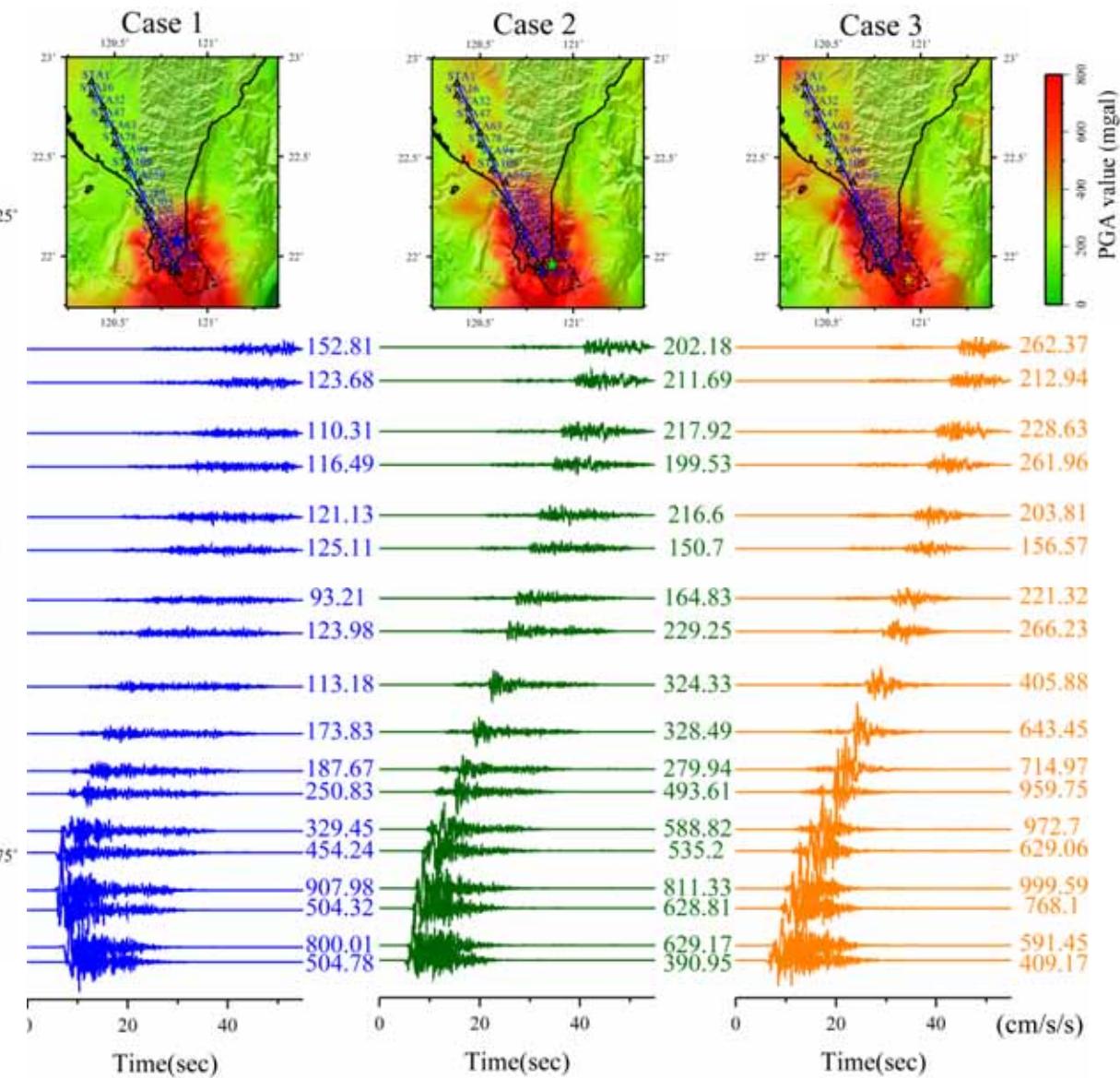
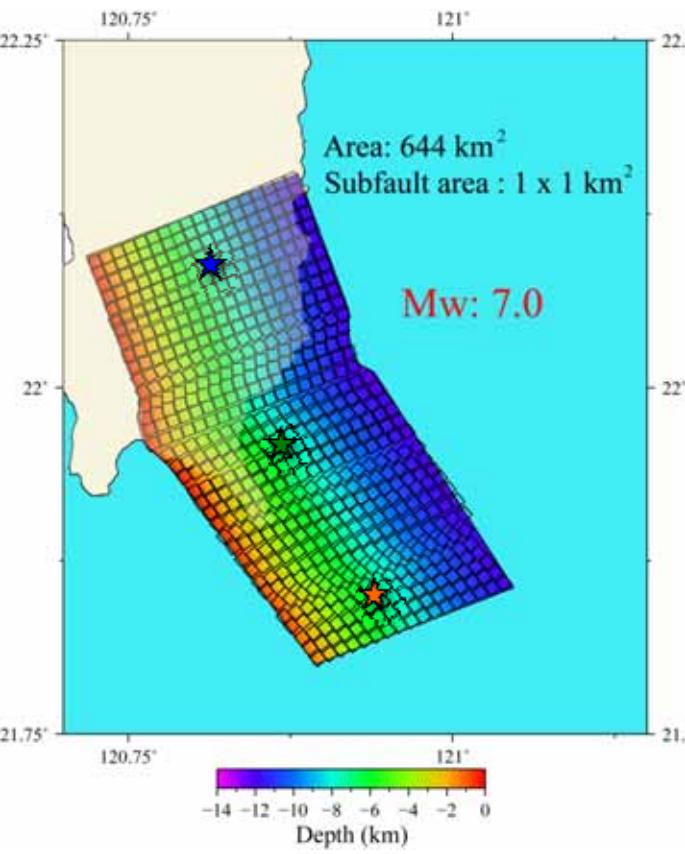


Frequency Ratio
Numerical vs.
Observation



Hengchun earthquake scenario

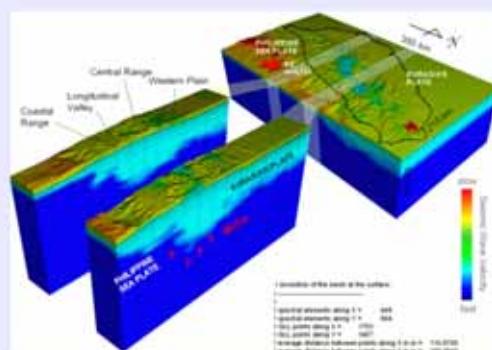
Hengchun fault



Summary

A. Community numerical model

- Large-scale velocity model
 - Local velocity model
 - Realistic topography
 - Moho, plate boundaries
 - Basin
 - Sedimentary plain
 - ... etc.



- Realistic surface topography
 - Large scale velocity model
 - Local velocity model
 - Moho, plate boundaries
 - Basin, sedimentary plain, ... etc
 - Travel-time, Finite-frequency,

Adjoint tomography

- Accomplish
- routine

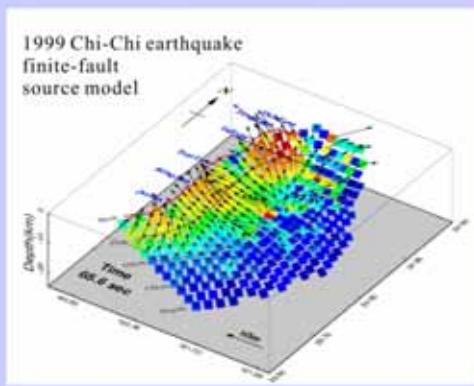
- Update
- refining

- Ongoing
- In plan

Summary

B. Source representation

- Point source parameters for earthquake $M < 6$
- Finite-fault model for earthquake $M \geq 6$
- Kinetic and dynamic analyses



- Point source parameters for earthquake $M < 6$
- Finite-fault source rupture model for earthquake $M > 6$
- Kinetic source rupture analysis
- Dynamic source rupture analysis
- Fault and seismogenic zone model

- Accomplish
- routine

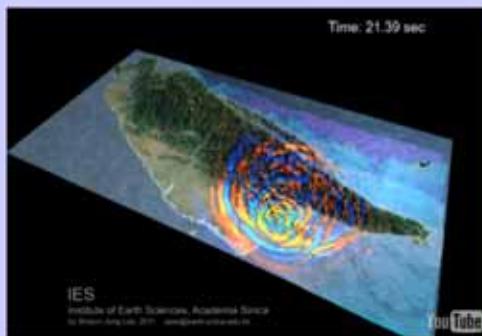
- Update
- refining

- Ongoing
- In plan

Summary

C. Near real-time ground motion simulation

- ShakeMovie
- ShakeMap
- Synthetic waveforms
- Visualization



Near real-time simulation & visualization
<http://www.earth.sinica.edu.tw/~sjlee/ras/index.htm>

- ShakeMovie
- ShakeMap
- Synthetic waveforms
- Computational visualization
- Realistic ground motion simulation
- Realistic ground motion prediction for scenario earthquake

- Accomplish
- routine

- Update
- refining

- Ongoing
- In plan

Thank you for your attention