Building up Seismsic Models for Ground Motion Prediction of Taiwan: Problems and Challenges

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What approaches we can make toward a reliable PSHA map

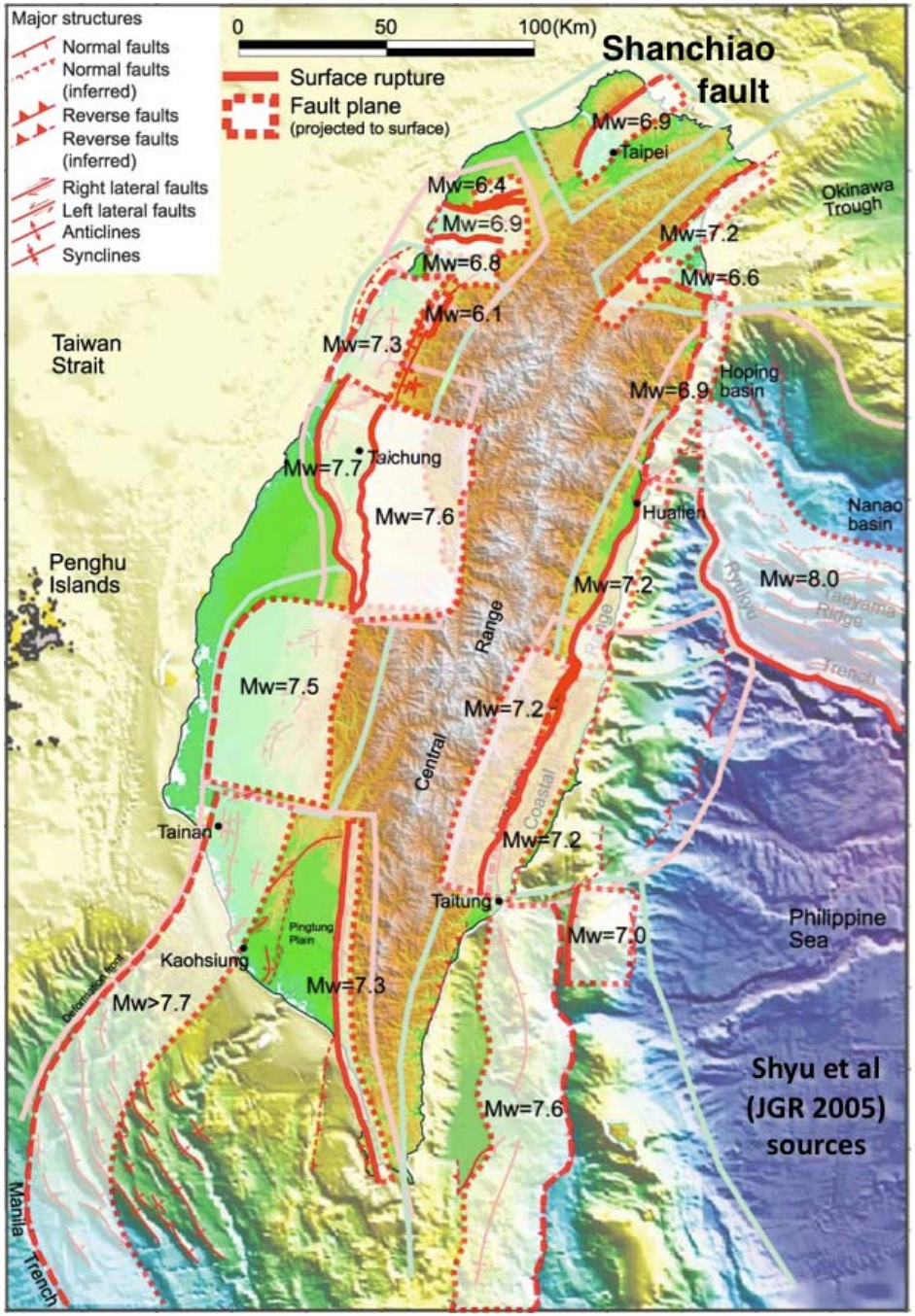
- How reliable is reliable? Definition? Can we provide the definition? to public? to government?

Approaches

1. Identifying the seismic source models
2. Estimation of the recurrence intervals of each source model
3. Ground Motion Prediction Equation (GMPE): Give an easy and quick reference number in PGA and PGV empirically, but, large variance in values (stress drops?)

   Finite-Fault Simulation: give a full waveforms from 0-10Hz (maybe), but, time consuming and many assumptions in fault model (fault geometry, asperities). A requirement of a fine 3D velocity structure for modeling of high frequency.

Seismic Source Models (Shyu et al., 2005)



Active Fault Mapping

How to characterize the earthquake scenario of the seismic source models

- Fault Segment, geometry, mechanism

  GMPE => PGA and PGV (now in PSHA, but, large variance in values)
- Slip distribution (Sa) on the fault=> near-fault PGD, PGV, and PGA (GMPE, and full-waveform simulations), and far-field long period wave and the duration of shaking. (Shall we consider this in PSHA?)

  If yes, how can we do it? => study of historical earthquakes.

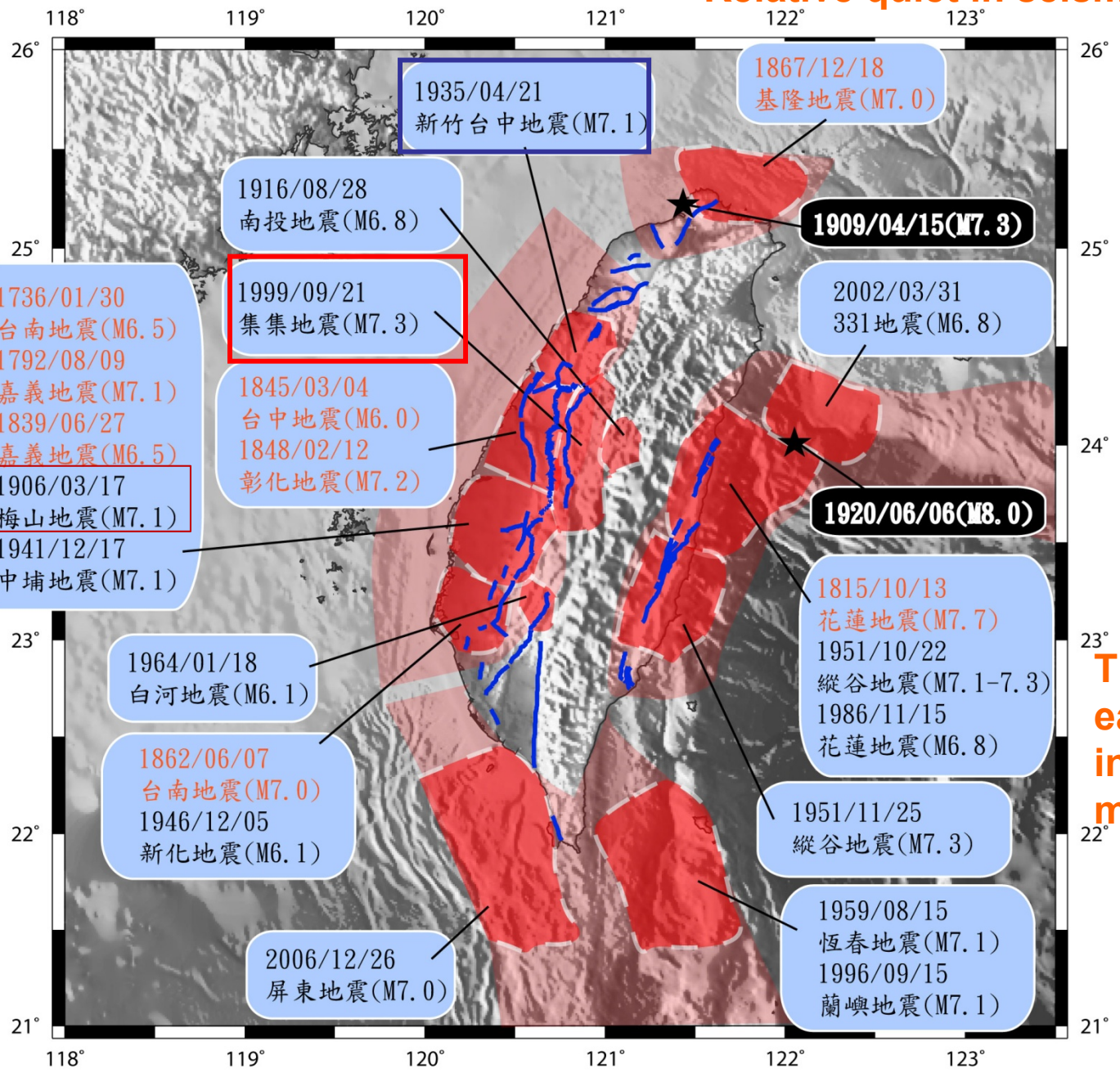
Steps: PSHA=>Deterministic PSHA (Japan)

Damaging Earthquakes in Taiwan since 1700s

Relative quiet in seismicity

M>7 inland earthquake ~ every 100 years

Western Taiwan ~every 30-40 years



Three M>7 earthquakes in two months

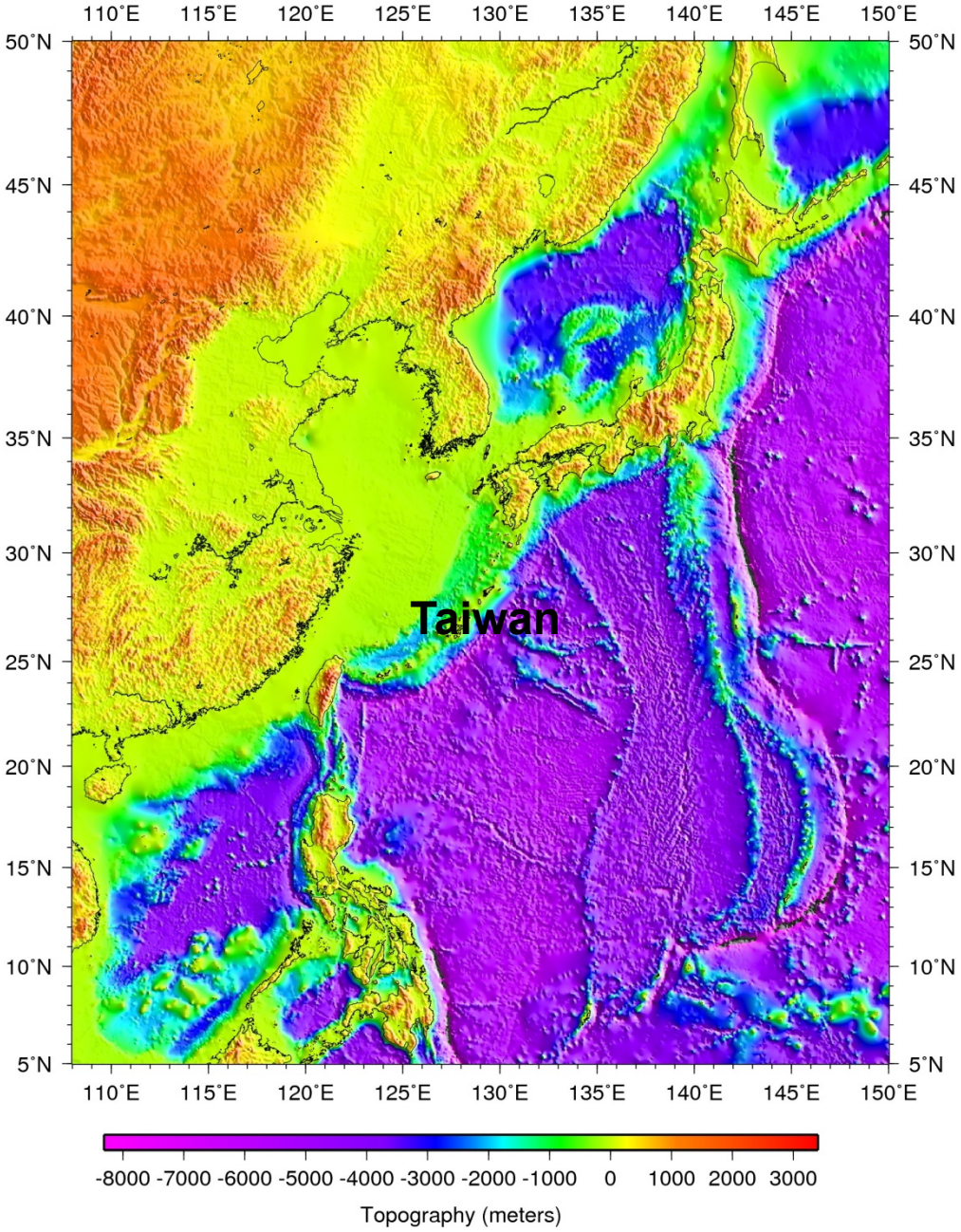
How to characterize the earthquake scenario of the seismic source models

- Slip distribution (Sa) on the fault=> near-fault PGD, PGV, and PGA (GMPE, and full-waveform simulations), and far-field long period wave and the duration of shaking. (Shall we consider this in PSHA?)

  If yes, how can we do it? => study of historical earthquakes

- **Offshore large events (un-expecting events in Ryukyu and Manila Trenches, analog to Tohoku earthquakes?), other un-expecting inland large event?**

Bathymetry and Tectonic Setting surrounding Taiwan



Outra-ordinary Earthquake Potential around Taiwan:

-1909 style moderate depth high stress drop intra-plate events

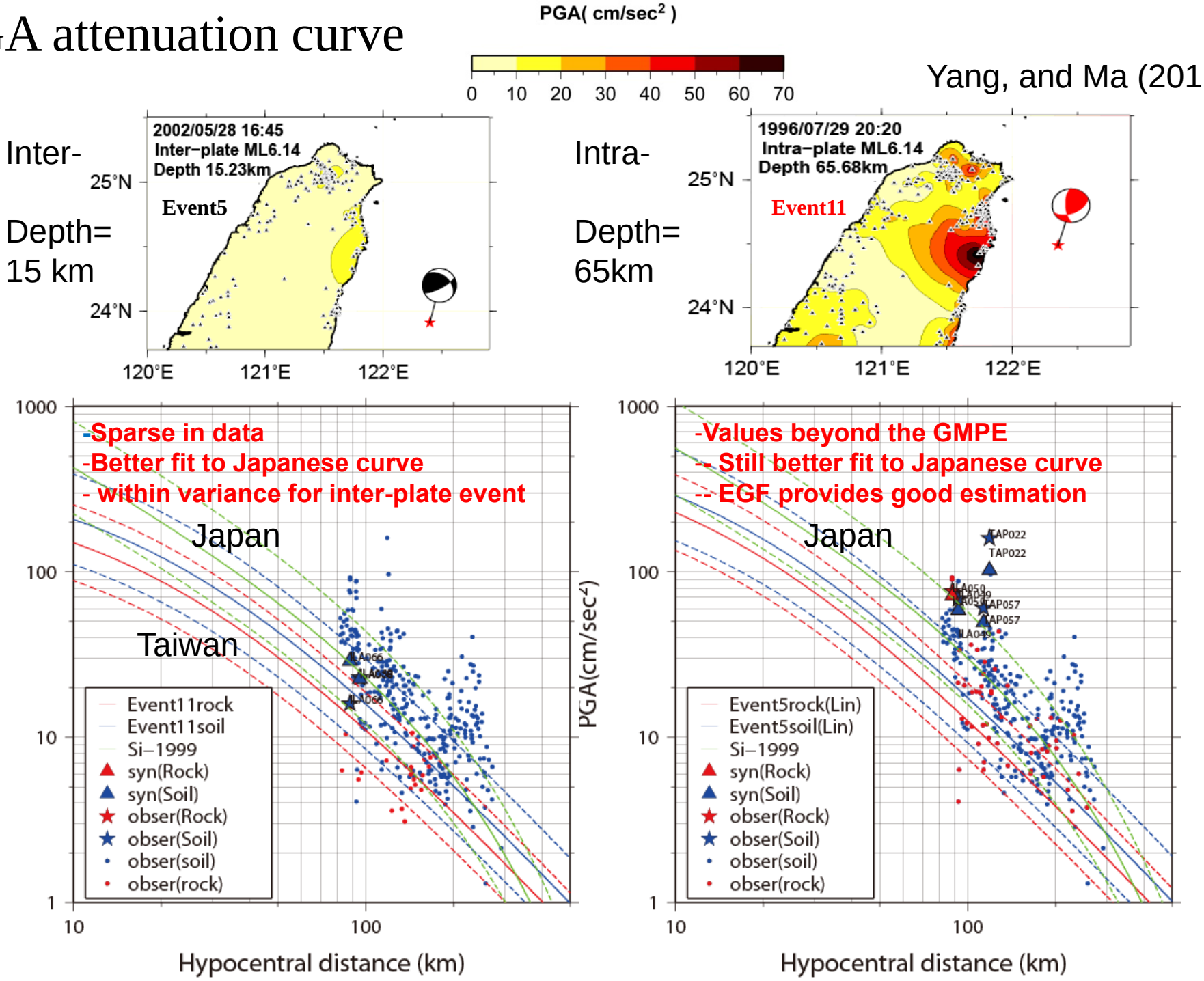
-1920 M8.0 earthquake, but, rupture all the way to the trench as Tohoku earthquake

-Possible rupture pattern along the Manila trench (1781 tsunamis?)

How to incorporate these into PSHA?

PGA attenuation curve

Yang, and Ma (2012)



1909 Taipei Earthquake

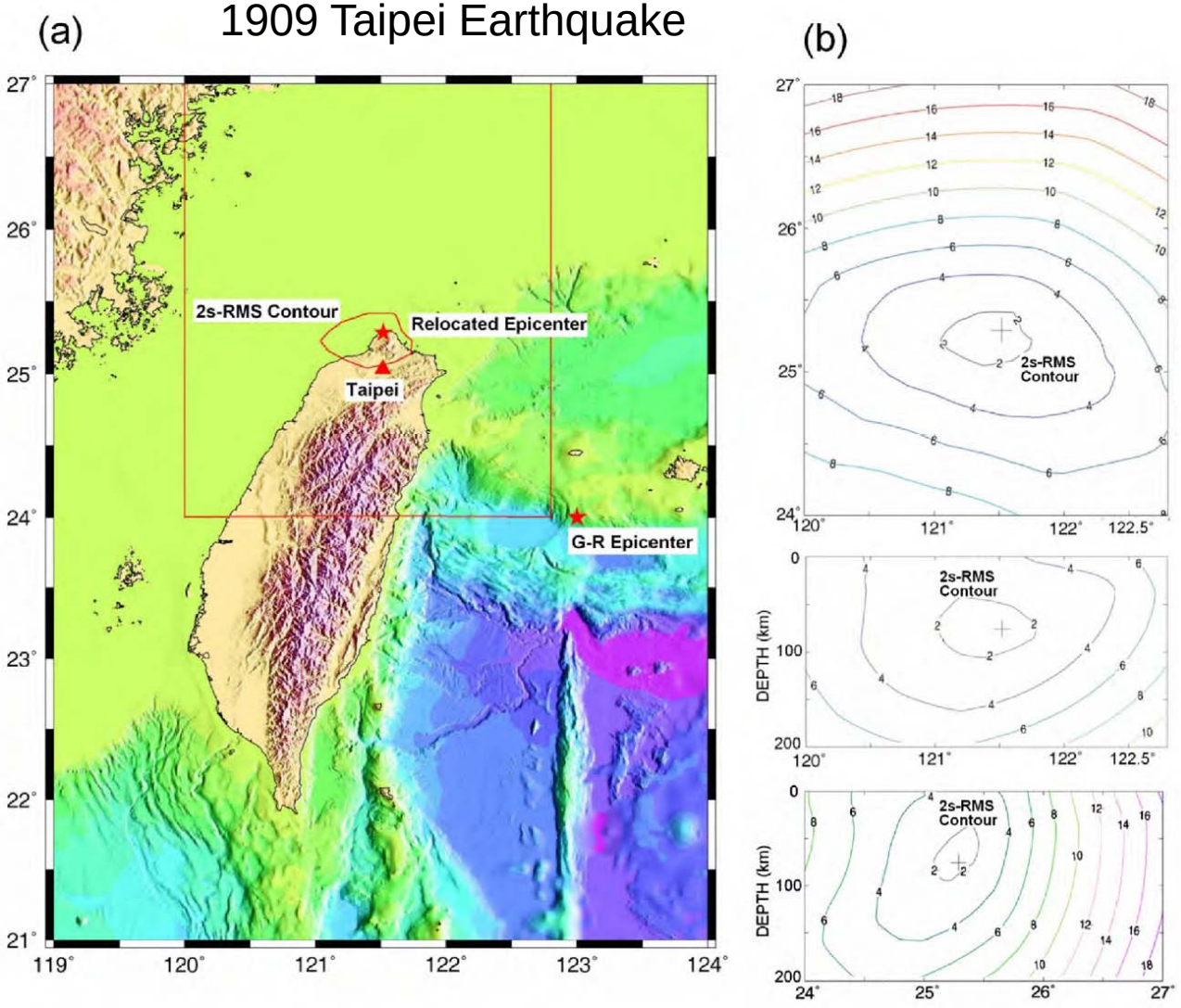
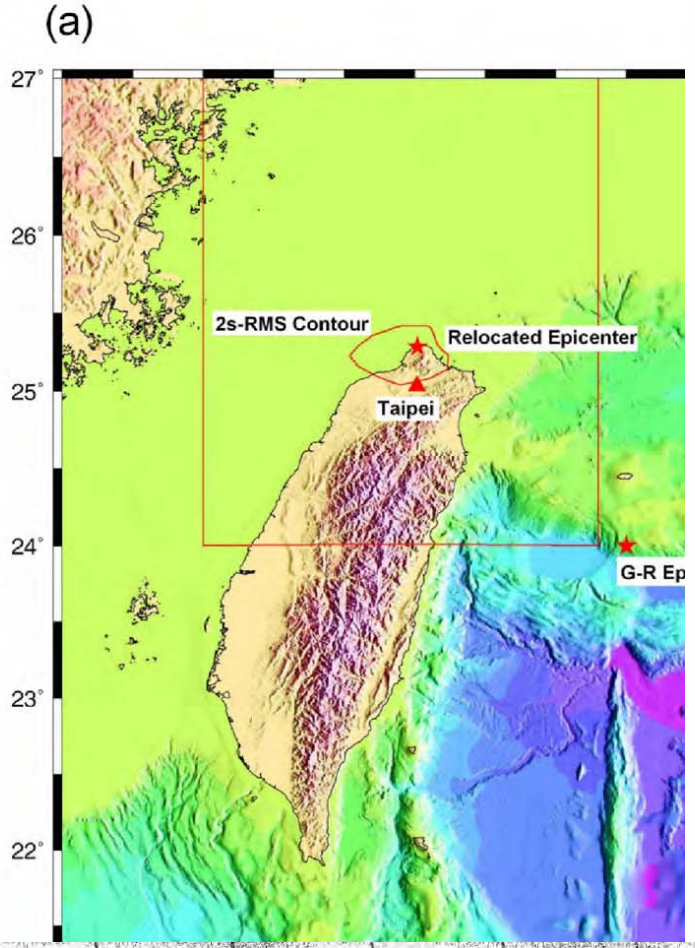


Fig. 1

(Kanamori, Lee and Ma, GJI, 2012)



M6.5-7.0
Depth~ 80km

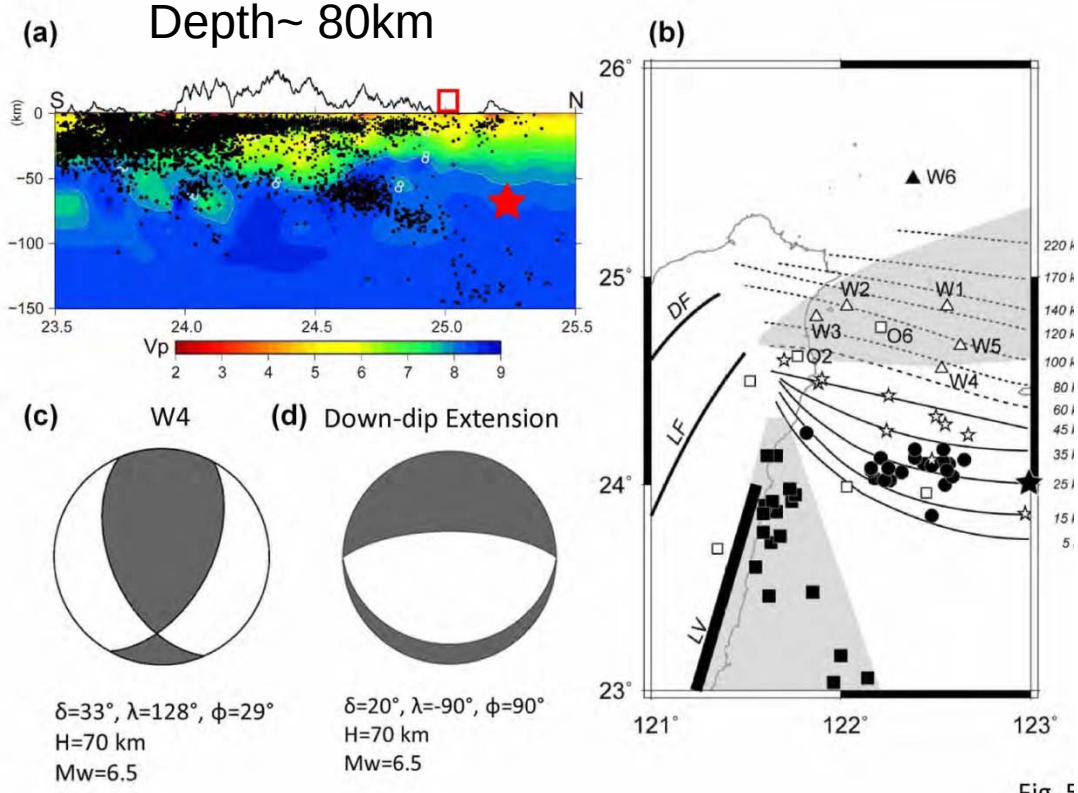
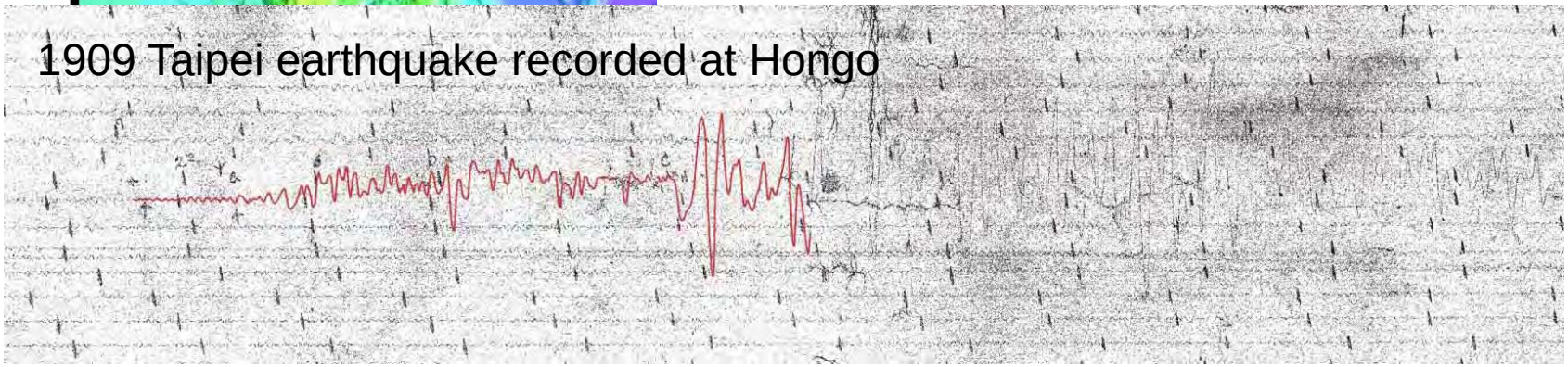
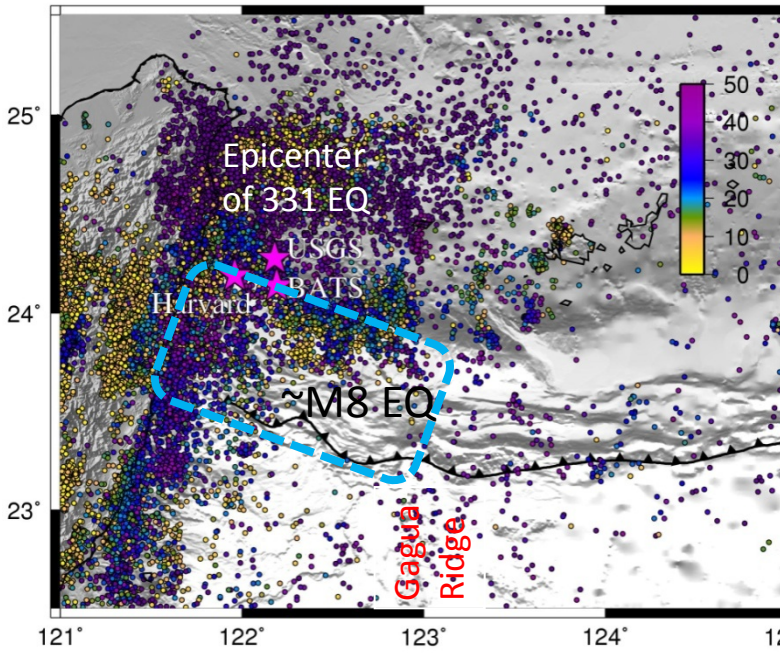


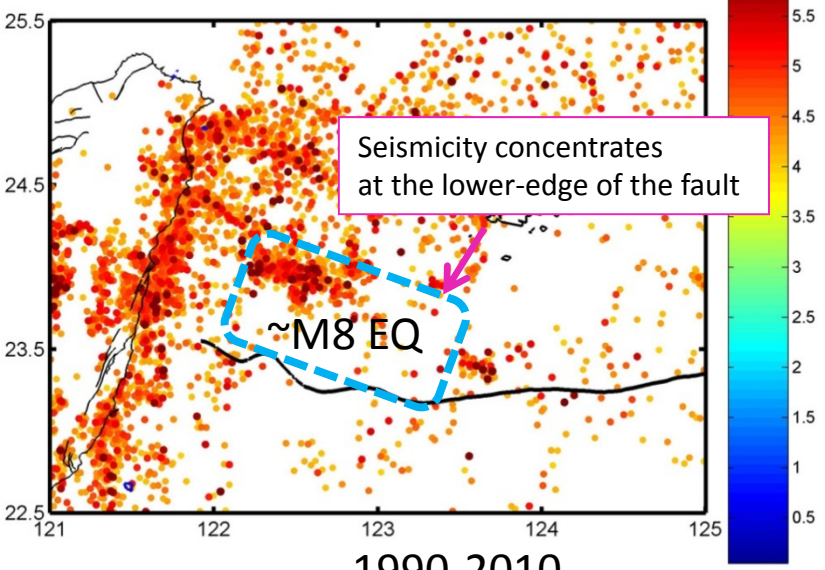
Fig. 5





Seismicity with focal depth < 30 km

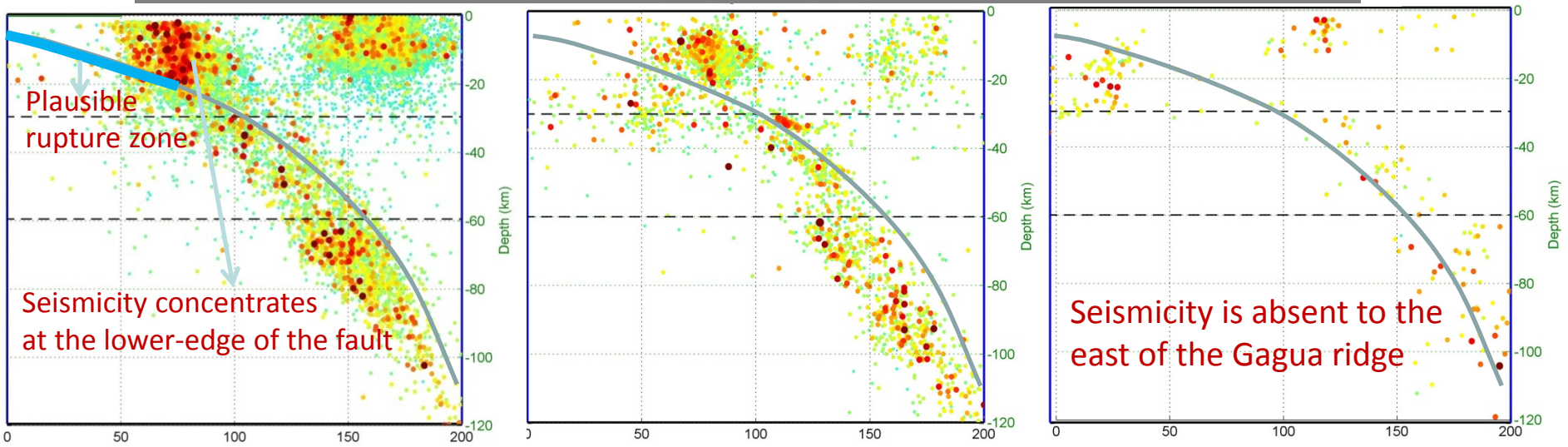
M_L



1990-2010

Yaru Hsu (personal communication)

122.5° E 123° E 124° E



Distance from trench (km)

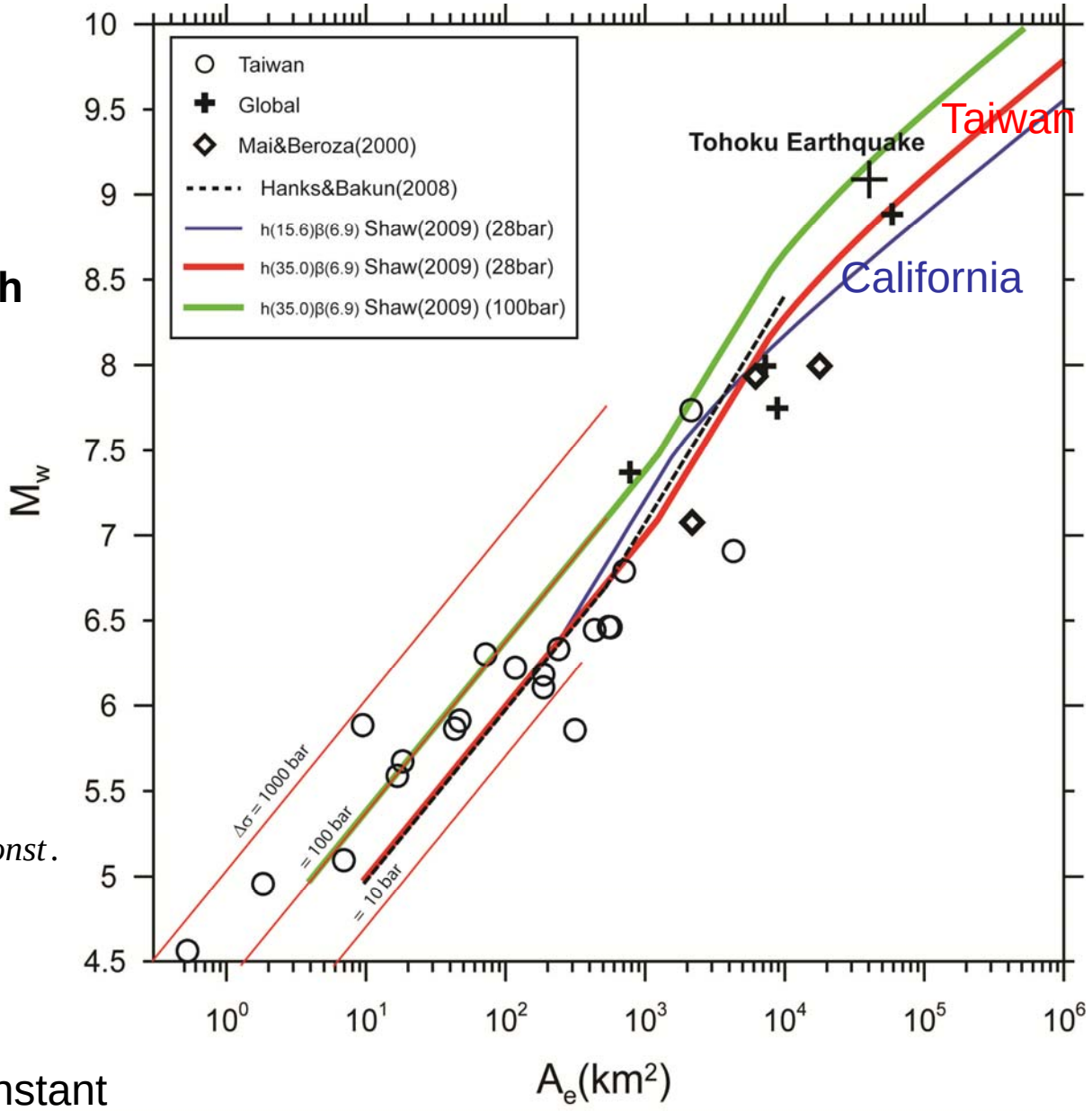
Scaling using AREA and STRESS DROP

h : seimogenic depth
β: scaling parameter related to the effective fault width

- Small-Moderate earthquakes
  Mw ~ LogA
- Large earthquakes
  Mw ~ 4/3logA
- Extra largest earthquakes
  Mw ~ 2/3logA

$$M = \log A + \frac{2}{3}\log \frac{\max(1, \sqrt{\frac{A}{H^2}})}{[1 + \max(1, \frac{A}{H^2 \beta})]/2} + const.$$

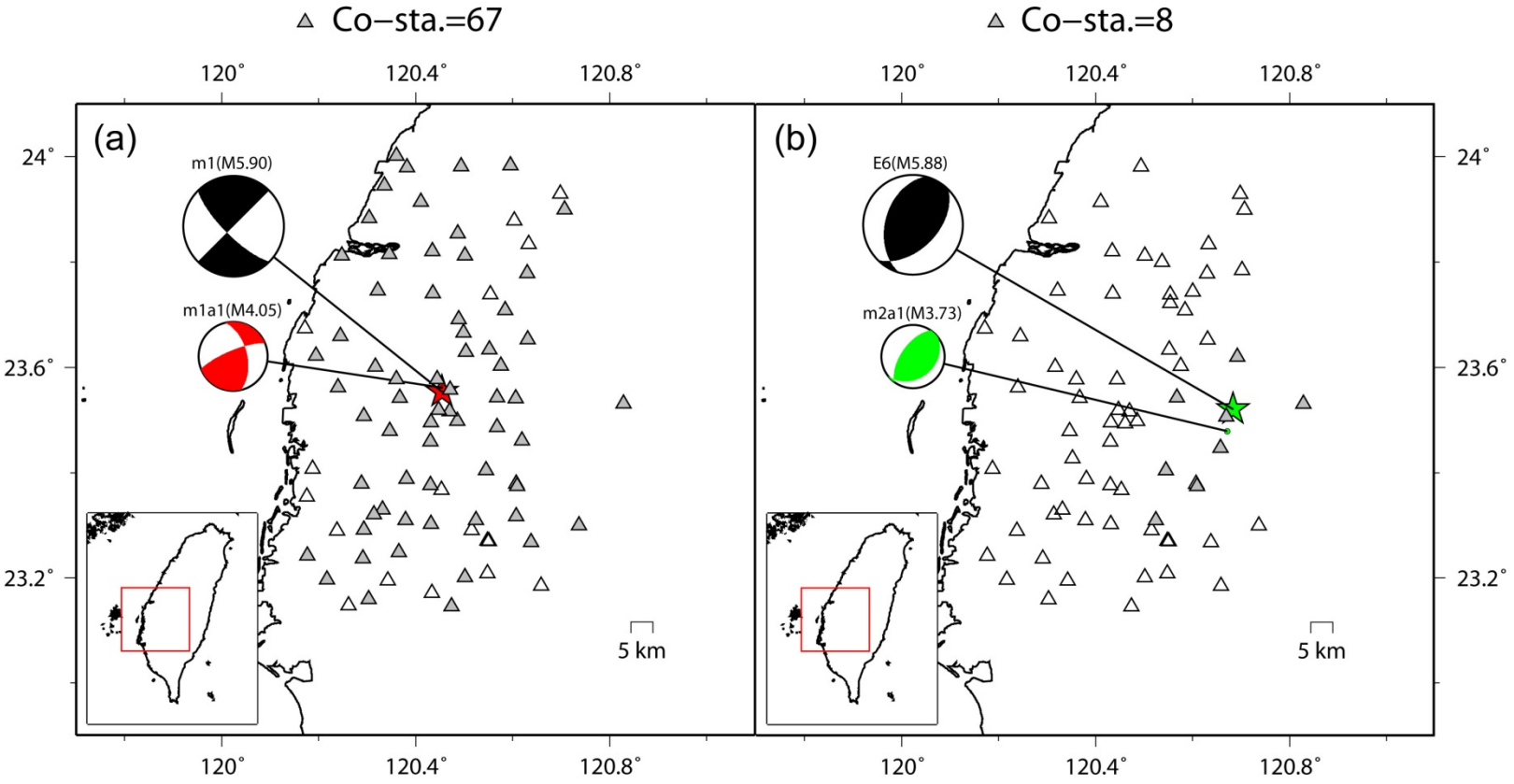
(Shaw, 2009)



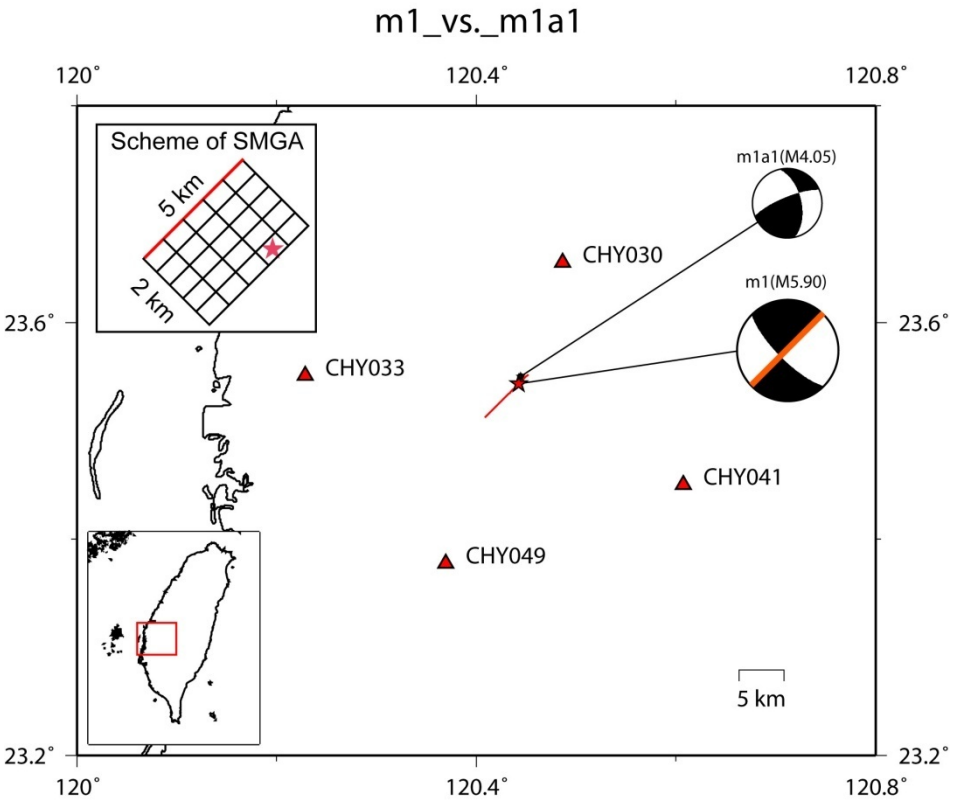
Const.: Stress drop related constant

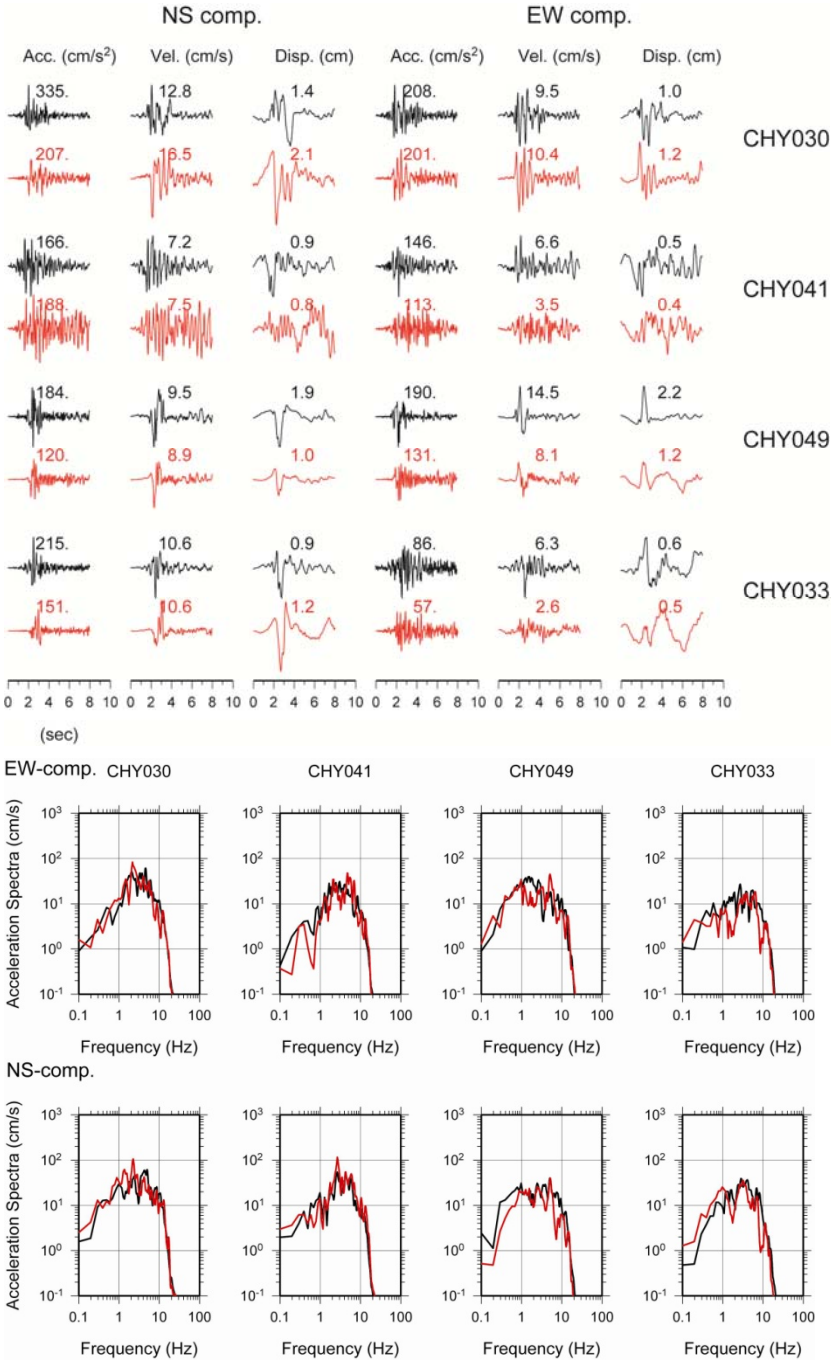
Predict Ground Motion of a large event from smaller event
Simulation from EGF (high and regular stress drop events)

NO.	Date(UTC)	Latigude (deg)	Longitude (deg)	depth (km)	ML	Mw	strike	dip	rake
M1 (16)	1999/10/22 03:10	120.431	23.533	16.74	6.00	5.90	45.00	90.00	170.00
m1a1	1999/10/23 21:53	120.433	23.540	14.83	4.46	4.05	346.76	56.41	16.18
M2 (6)	1998/07/17 04:51	120.660	23.500	2.80	6.20	5.88	45.00	50.00	110.00
m2a1	2004/01/23 07:51	120.648	23.458	13.06	4.34	3.73	51.97	30.37	104.56



Results of assessed SMGA, Simulated ground motions and spectra





608.60 bars (10.00 km^2)
643.00 bars (9.64 km^2) Yen&Ma, 2011

Problems and Challenges (I)

PSHA (I), using GMPE from seismic source model (logic trees)

How to reduce the variance of GMPE

What's the variance the Engineers can bear?

PSHA (I.1), GMPE- Considering AREA, STRESS DROP for inland events

- GMPE for INTER- INTRA- (Collaboration with JAPAN)
- Historical Earthquakes

Scenario Earthquake of Historical Earthquakes, 1906 Meishan Earthquake

$\Rightarrow$Full waveform simulations, 0-10Hz

- Construction of a fine reliable 3D velocity structure
- Mapping shallow structure (seismic layer, engineering layer)
- hybrid (EGF+3D, Stochastic + 3D)
- Simulation of long-period wave (Duration)

=> PSHA (II) Deterministic PSHA

Problems and Challenges (II)

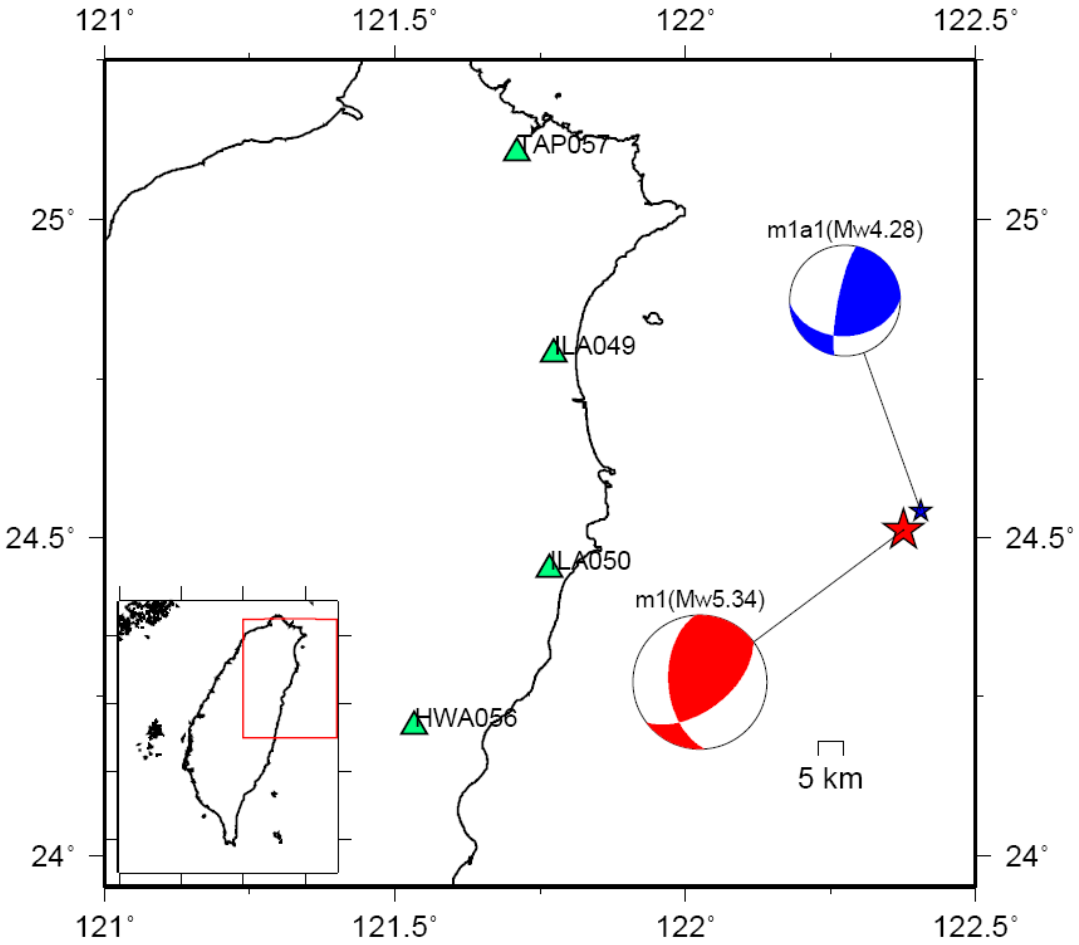
•How to incorporate the extreme event (as the events not yet occurred in history), and less seismicity events (e.g. 1909 Taipei, 1867 Keelung earthquakes) into PSHA,

•Sharing Japan's experience on the thoughts and questions stated above.

•Can GEM provide the global guideline to the questions above?
e.g.
- How to reduce the variance in GMPE
- What to give in PSHA for public and government (no miss-leading)
- Steps toward Deterministic model.

THANK YOU!

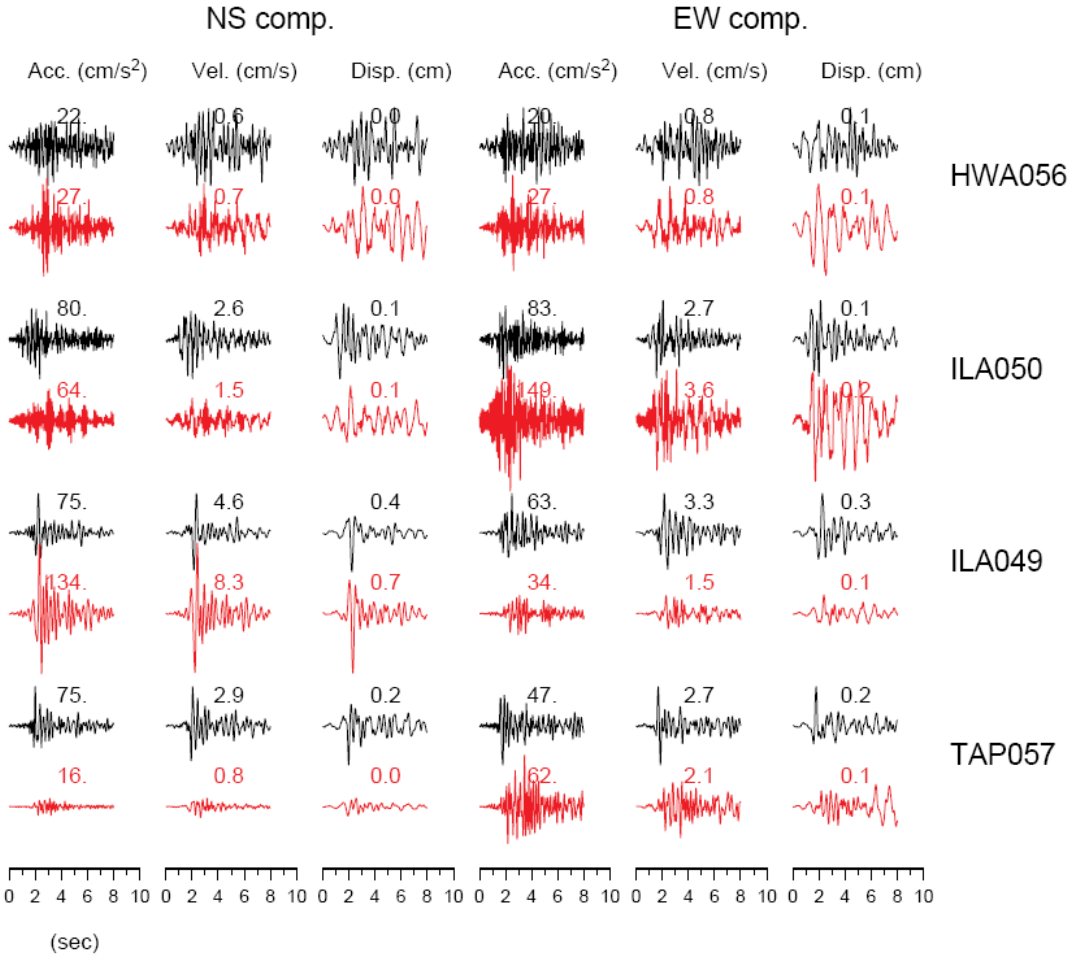
Ground Motion Prediction from EGF

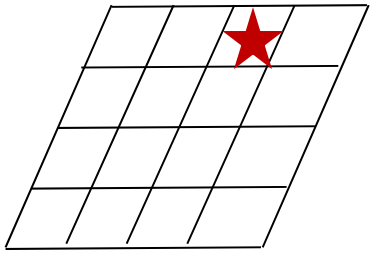


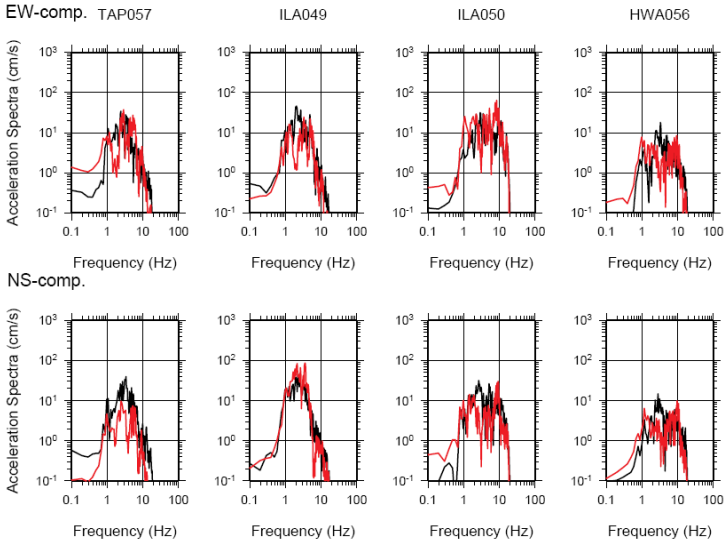
m1
1996/07/29 Global CMT
Lon: 122.35 ；Lat:24.49
Depth:63km
Mw5.34
M_L6.14

m1a1
2001/12/16 BATS
Lon: 122.38 ；Lat:24.52
Depth:53km
Mw4.28
M_L5.1

Black:observations
Red: synthetics





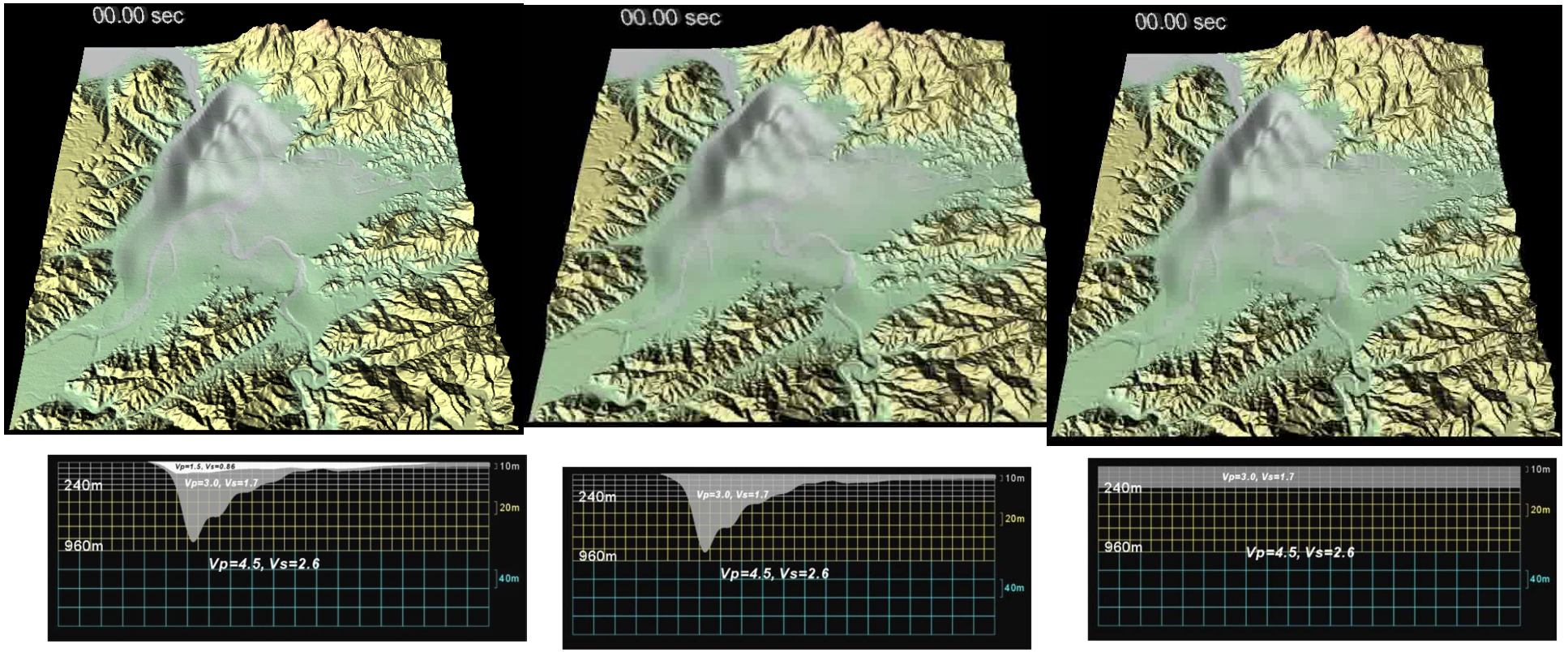


Development of 3D wave propagation modeling: 3D Ground Motion Simulation For Taipei Basin in different Models

Basement + SunShang Formation

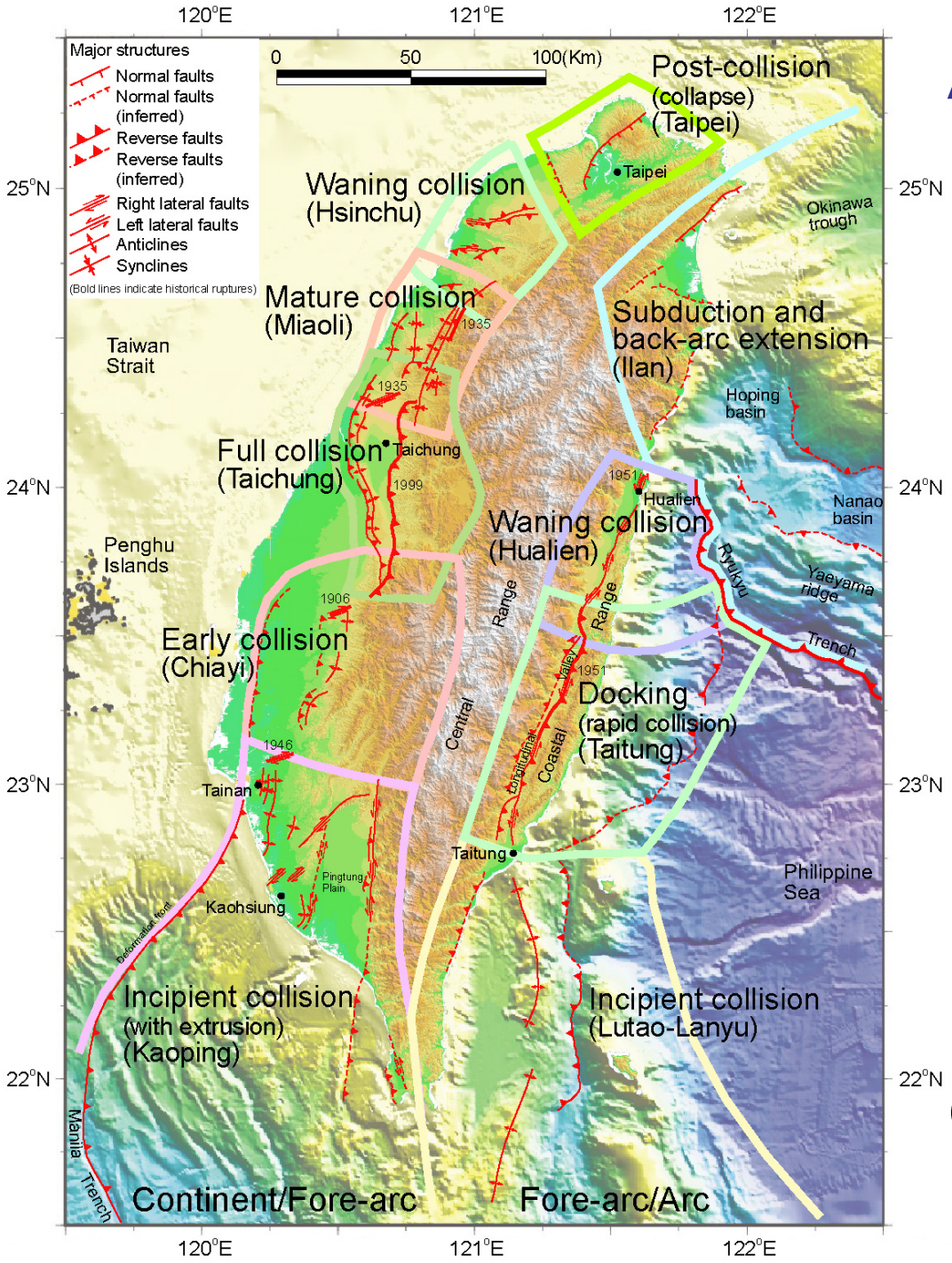
Only Basement

Layered Half-Space



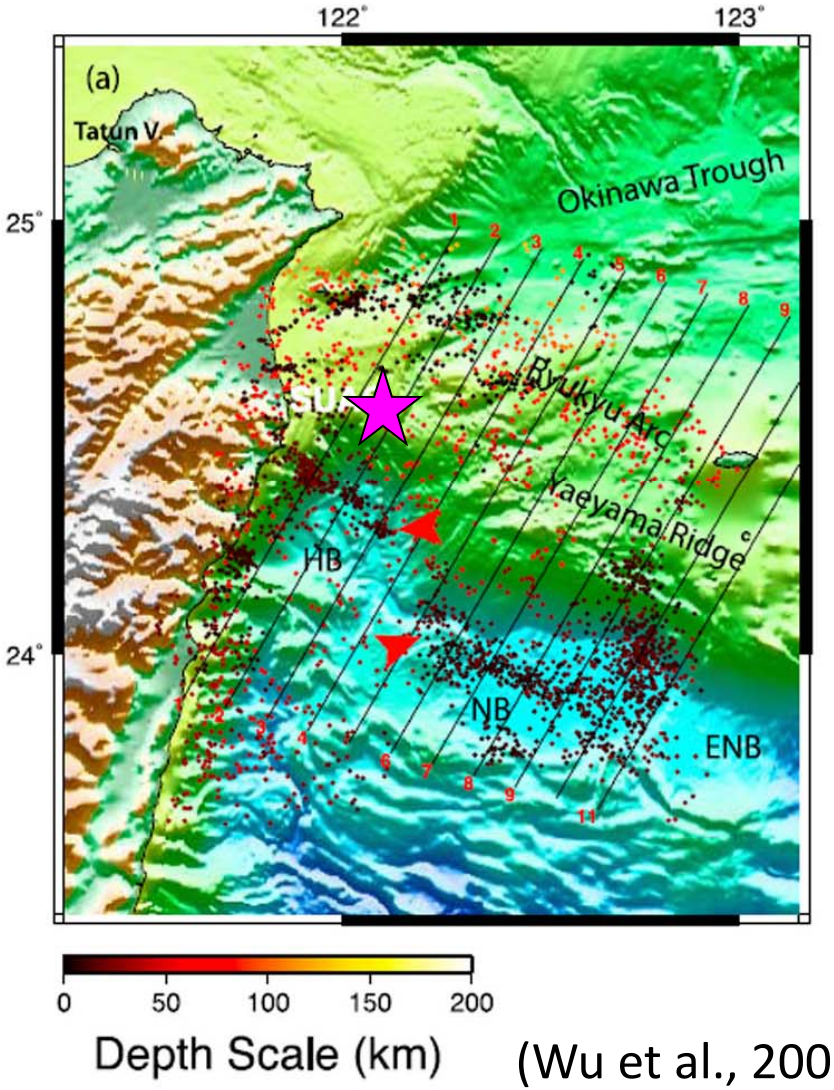
By 李憲忠 Lee et al. (2009)

Active Fault Mapping



（by 徐澔德, Shyu et al., 2005）

Ryukyu Trench Seismicity (1997-2003)



(Wu et al., 2009)