Joint Symposium of Seismic Hazard Assessment
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Empirical Site Correction for Ground Motion Simulation

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OUTLINE

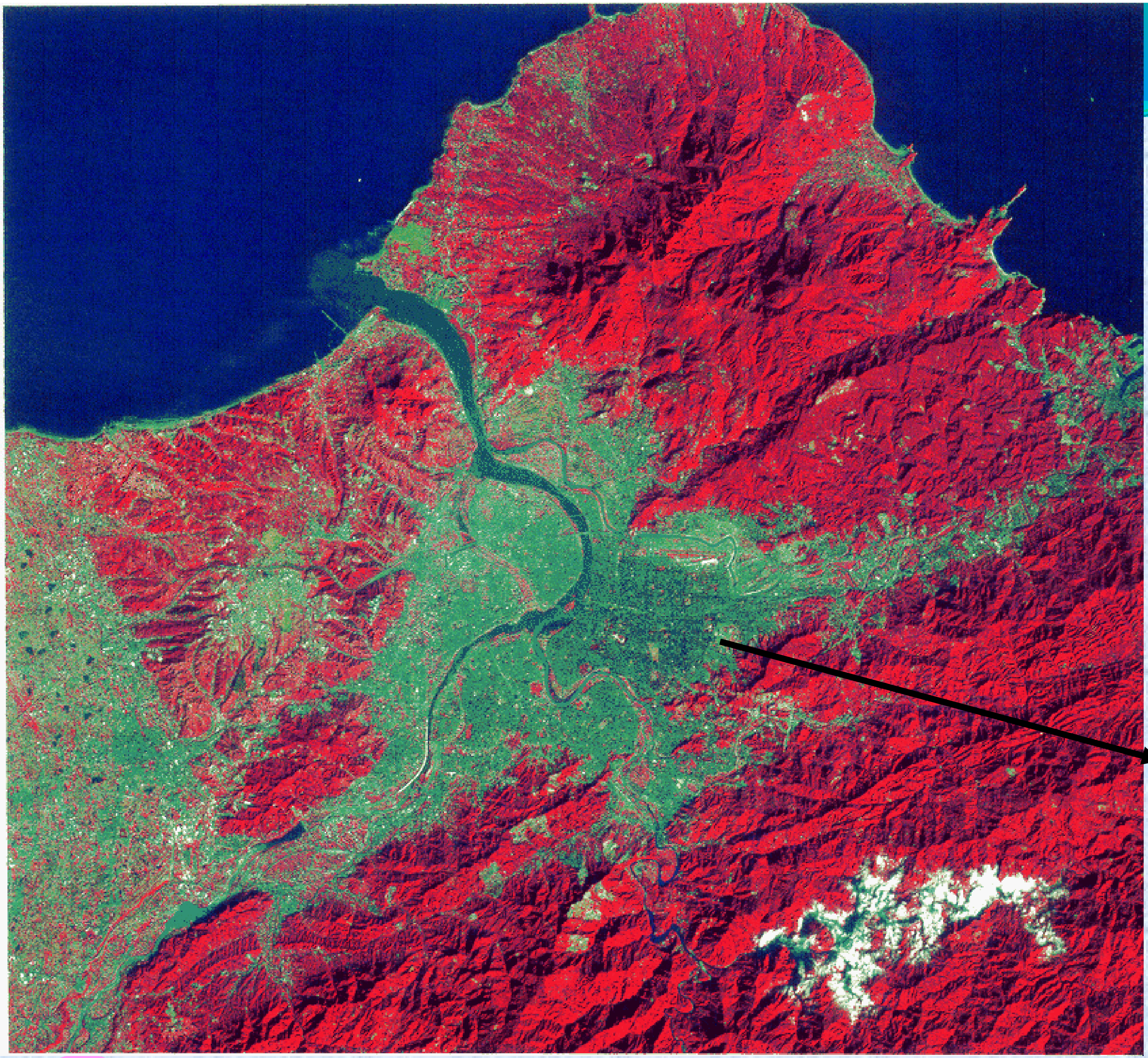
Introduction

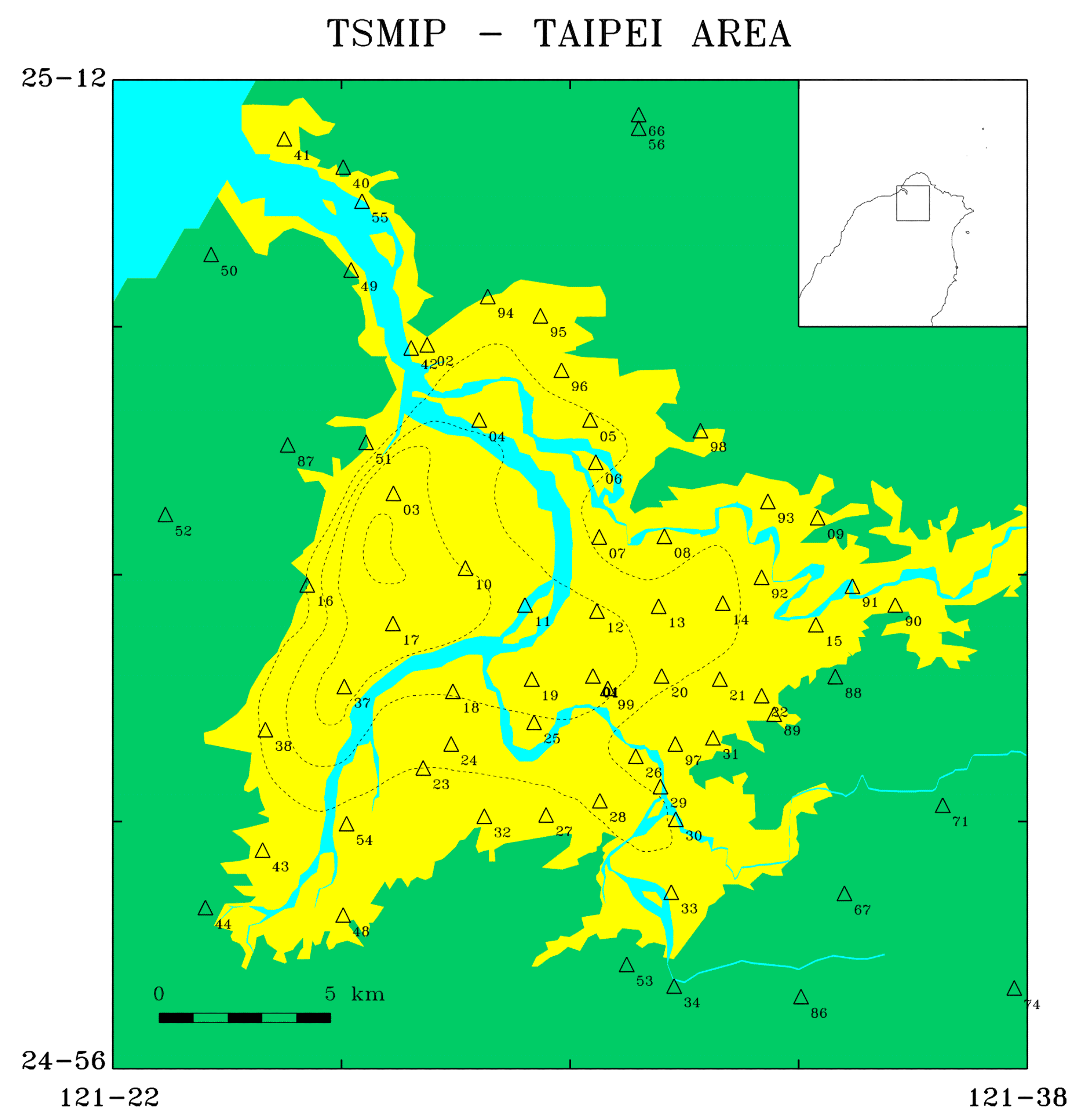
Data and Method

Empirical Site Effects

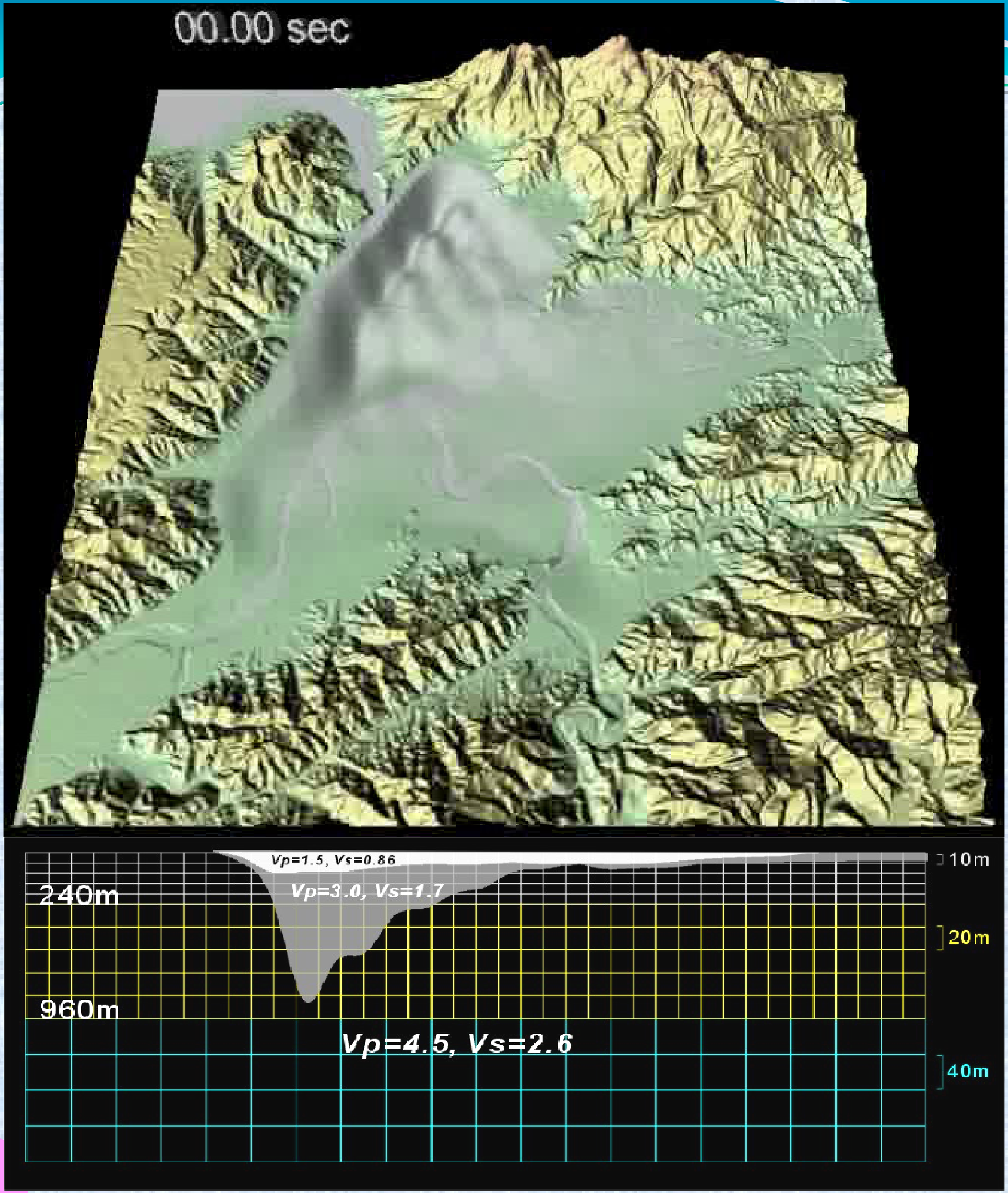
Ground Motion Simulation

Discussions and Conclusions

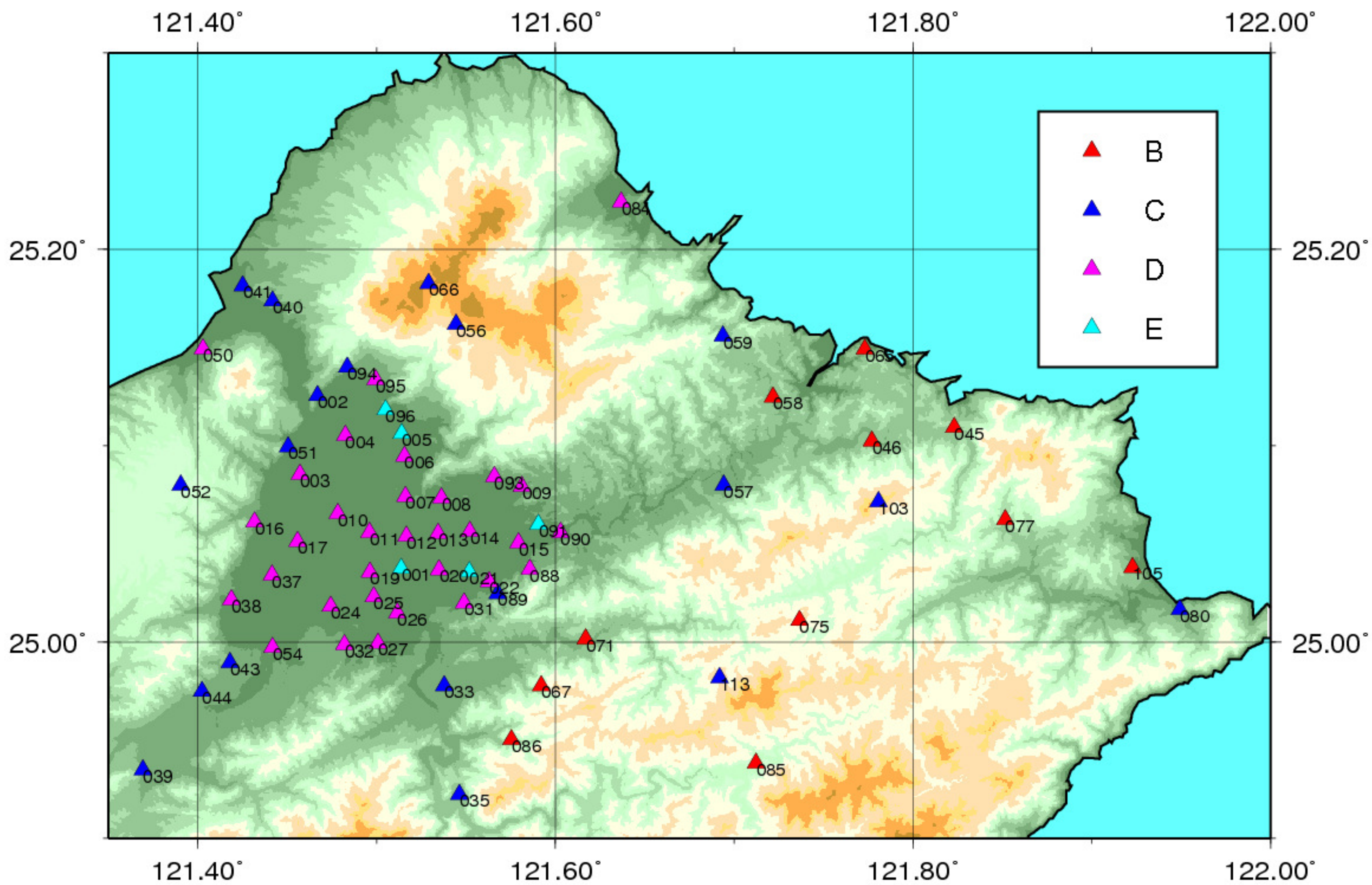




Locations of the strong motion stations in Taipei area. Numbers indicate the station codes of TSMIP network (CWB).

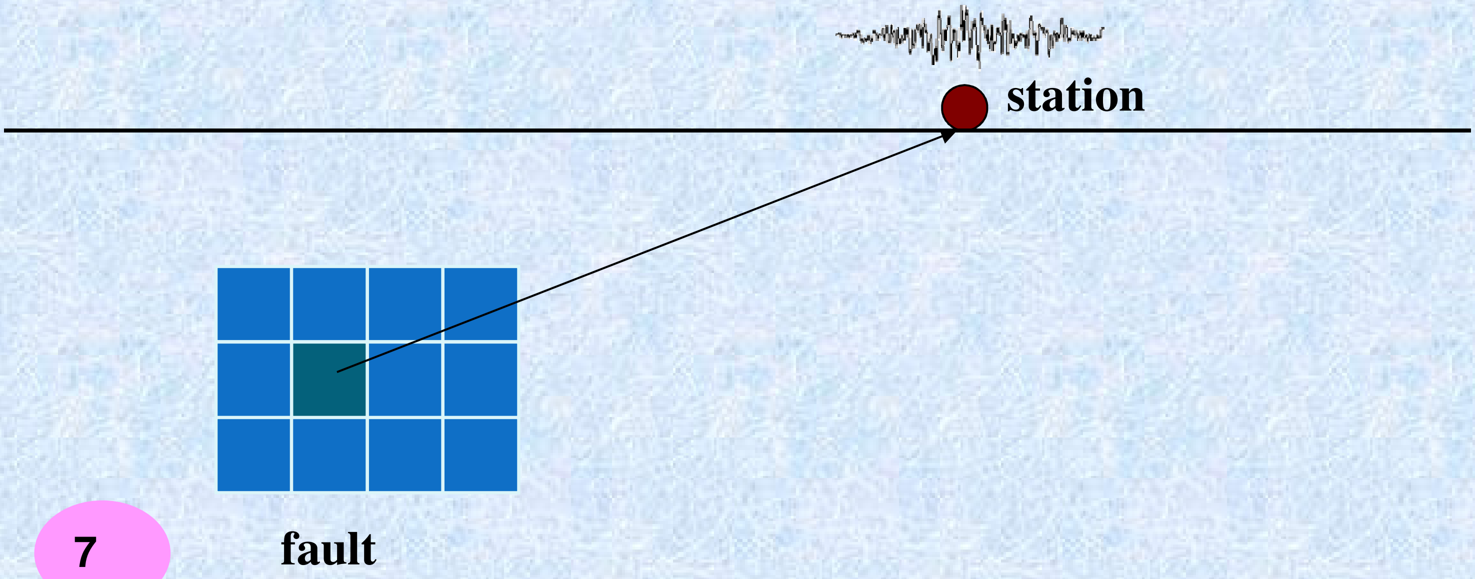


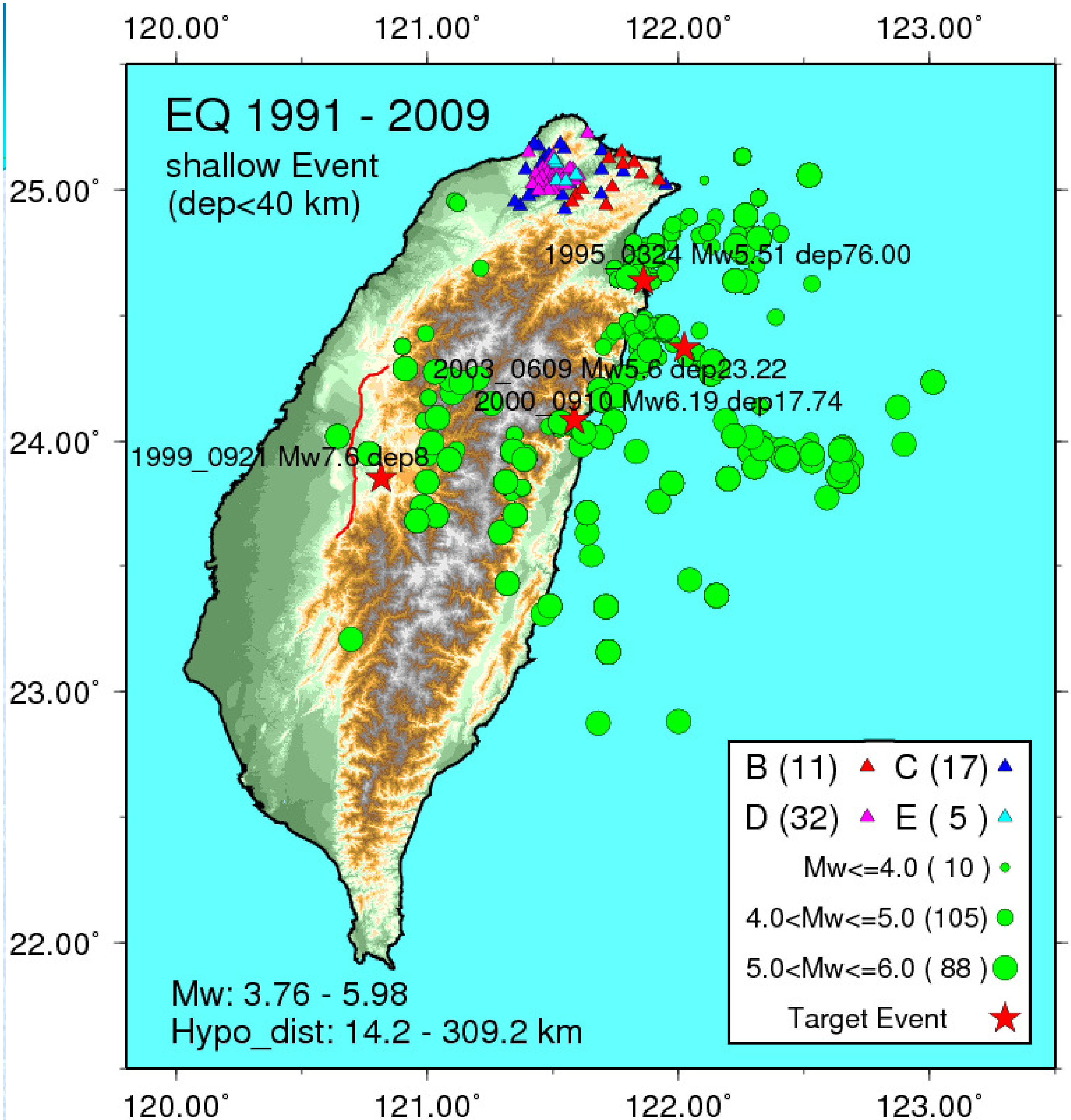
Basement + SunShang Formation


121.40˚
121.60˚
121.80˚
122.00˚
25.20˚
25.00˚
B
C
D
E
084
041
040
066
056
050
059
065
094
095
002
058
096
045
004
005
051
046
006
003
093
009
052
057
103
007
008
010
016
091
090
077
011
012
013
014
017
015
088
037
019
001
020
021
105
022
089
038
025
024
031
026
080
075
071
054
032
027
043
113
033
067
044
086
039
085
035

•Stocastic Method

- **SMSIM** (Boore, 2009) **: point source**
- **EXSIM** (Motazedian and Atkinson 2005; Assatourians and Atkinson 2007; Boore 2009)**: finite fault**





1991 ~ 2009

Mag. < 6

Dep. < 40 km

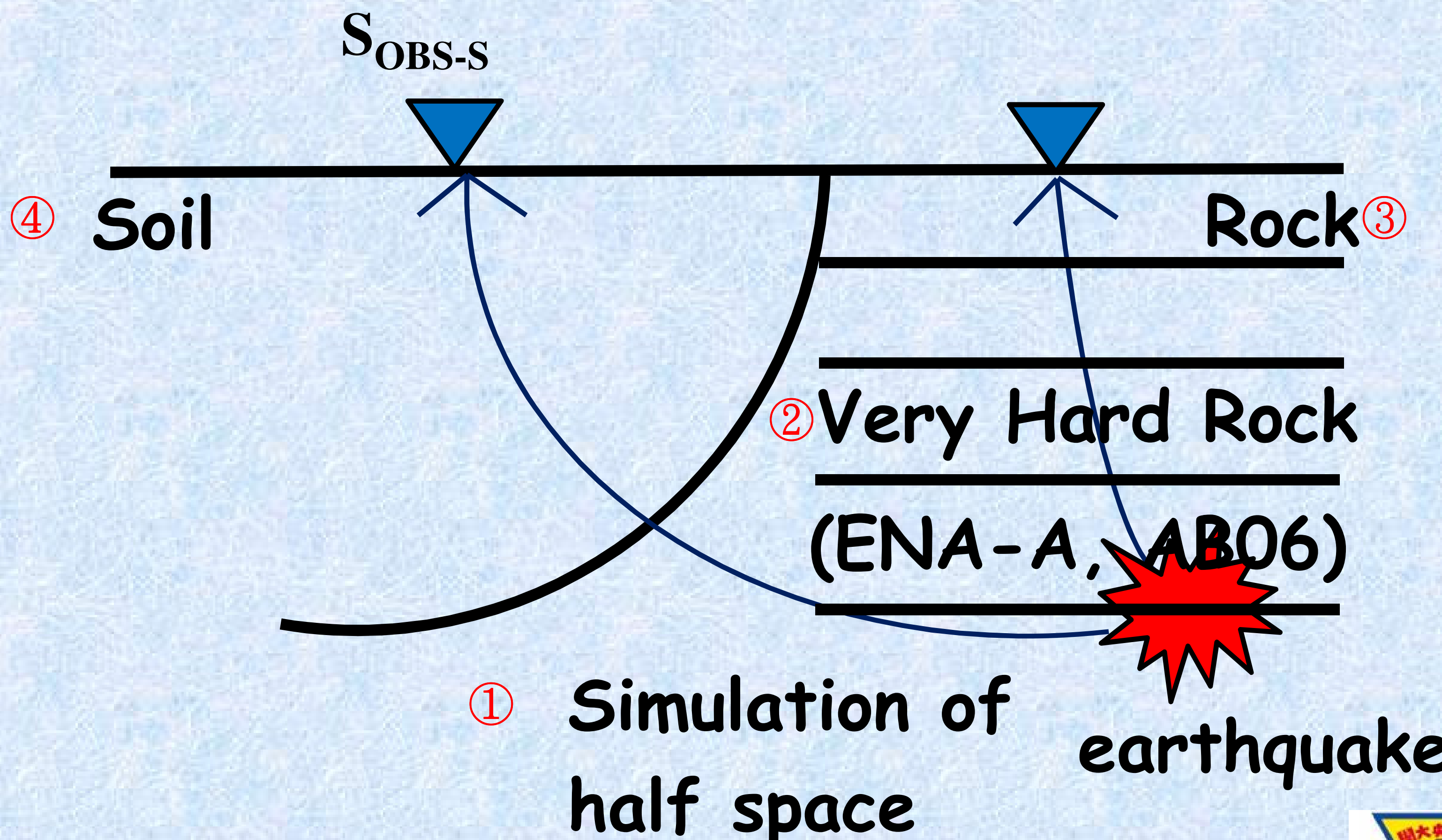
203 earthquakes

4 target events

- **Empirical Site Correction**

①$S_{SIM_HS} \times S_{ENA_A}$ ② $= S_{SIM\_VHR}$

$$S_{SIM\_VHR} \times \frac{S_{OBS\_R}}{S_{SIM\_VHR}} = S_{SIM\_R}$$ ③

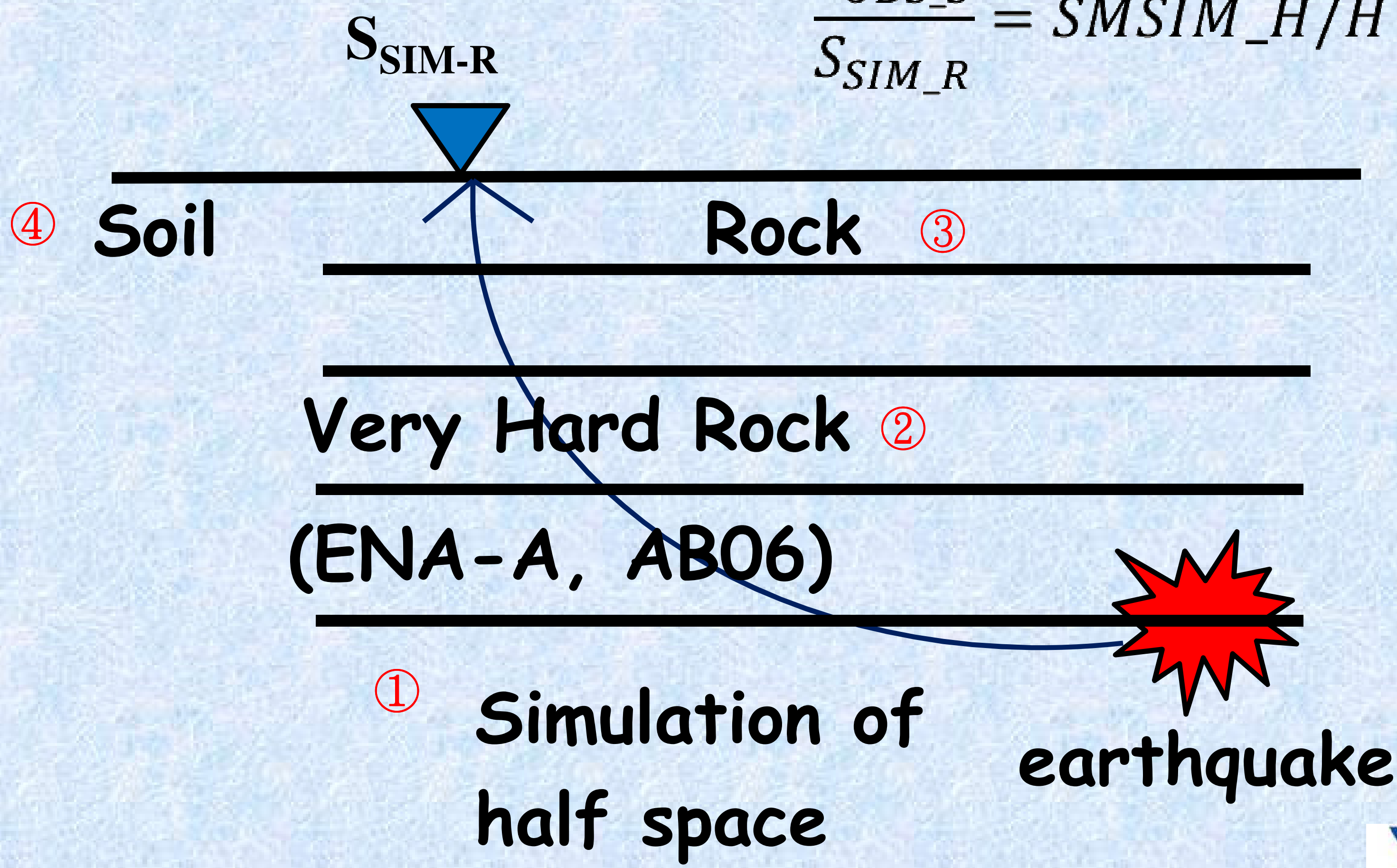


- **Empirical Site Correction**

① $S_{SIM\_HS} \times S_{ENA\_A} = S_{SIM\_VHR}$ ②

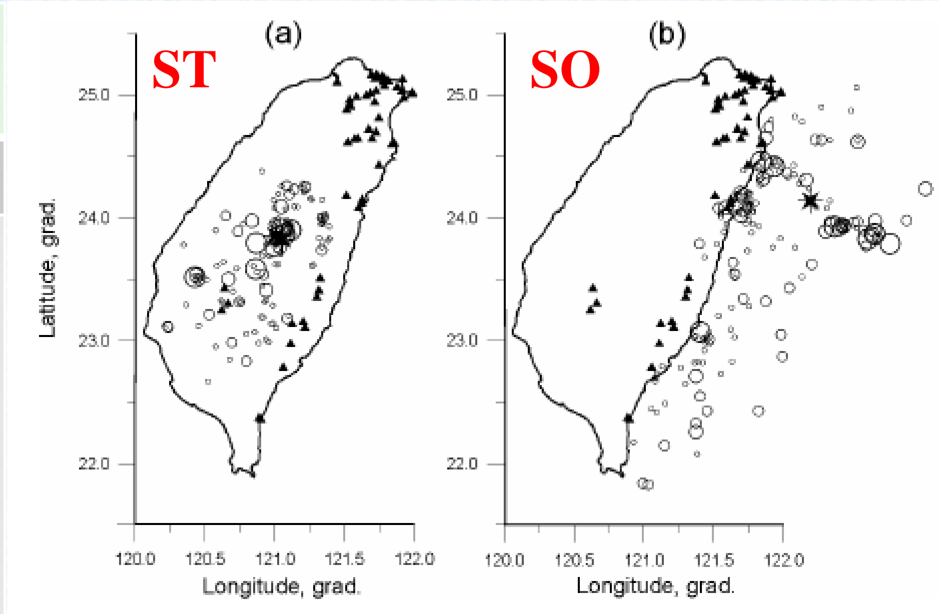
$$S_{SIM\_VHR} \times \frac{S_{OBS\_R}}{S_{SIM\_VHR}} = S_{SIM\_R}$$ ③

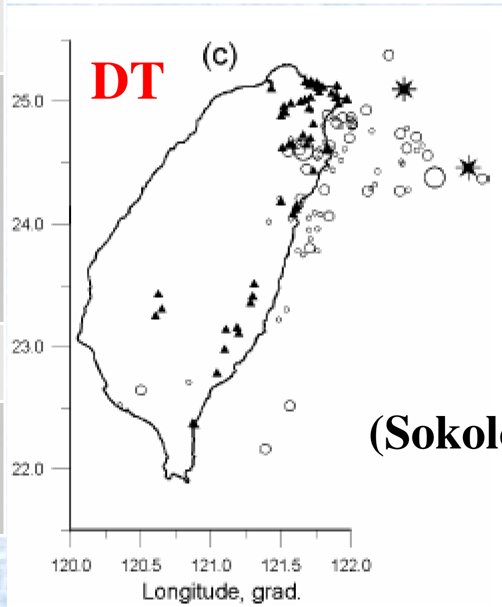
$$\frac{S_{OBS\_S}}{S_{SIM\_R}} = SMSIM\_H/H$$ ④



Parameters for SMSIM: (Sokolov et al., 2009)

Shear-wave velocity (VS)	3.6 km/s
Density (ρ)	2.8gm/cm^3
Geometric spreading R^b: b	-1.0 (1–50 km) 0.0(50–170 km) -0.5(>170 km) (Sokolov 2000;Sokolov et al. 2000;Sokolov et al. 2001;Sokolov et al. 2003;Sokolov et al. 2006;Sokolov et al. 2009)
Quality factor	Zone ST: 80f$^{0.9}$ Zone SO: 120f$^{0.8}$ Zone DT: 60f$^{1.0}$ (Sokolov et al., 2006; 2009)
κ (kappa)	0.05 sec.
Crustal amplification	ENA-A (Atkinson & Boore, 2006)

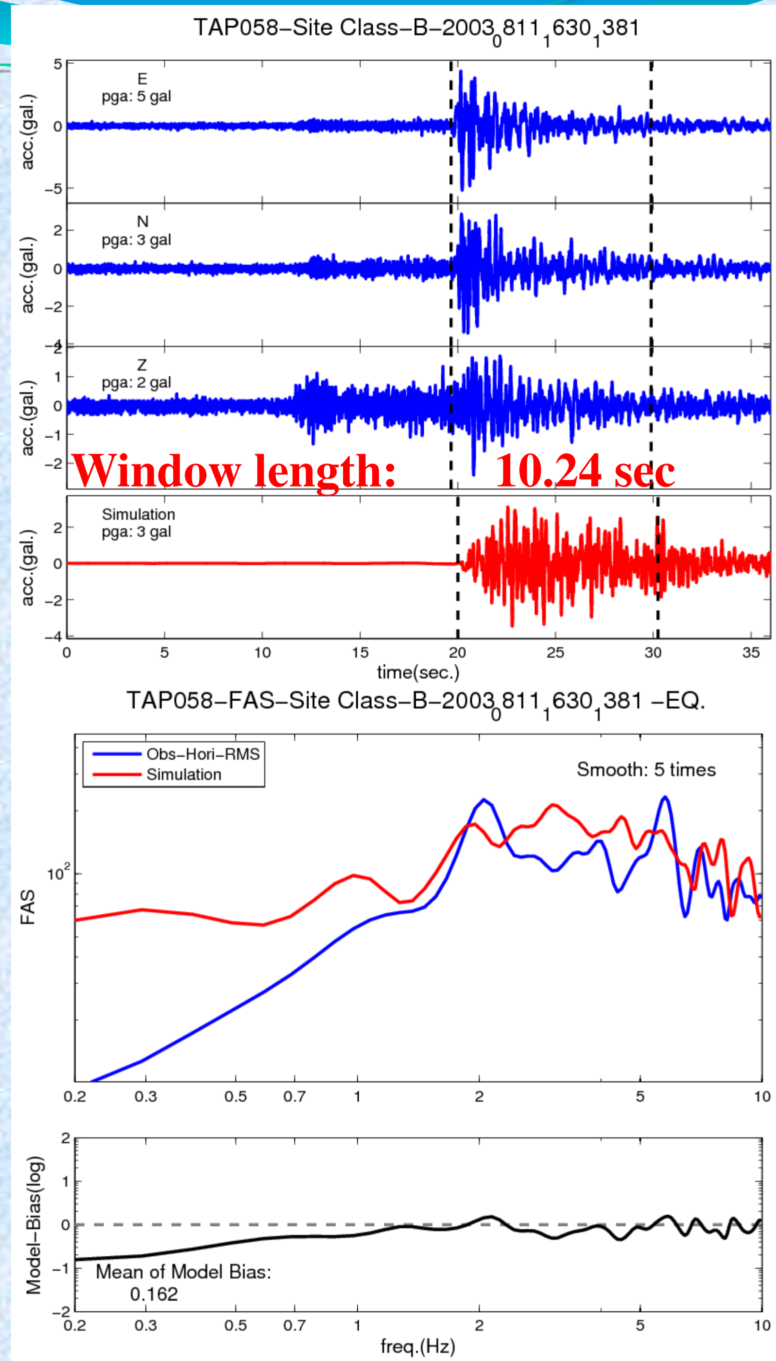




(Sokolov et al., 2006)

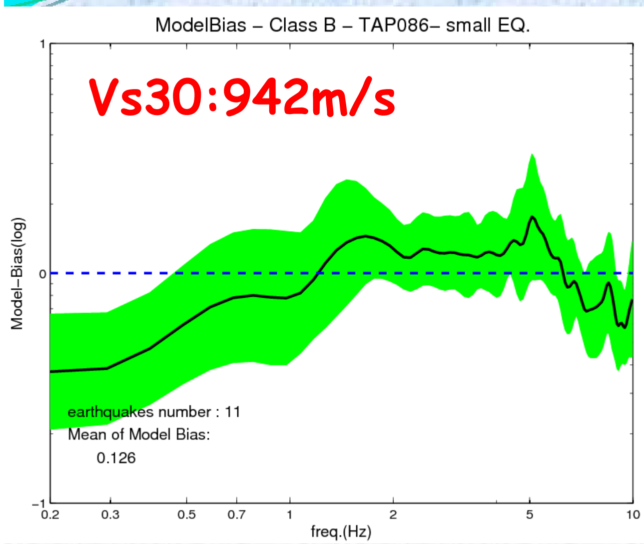
Parameters for SMSIM: (Sokolov et al., 2009)

M_W	*ML=1.961Mw+0.338+-0.256 , ML≦6.0* *ML=5.115*(ln(Mw))-3.131±0.379 , ML≧5.5* (Cheng et al., 2010)
Stress (bar)	**Zone ST:** magnitude dependent stress drop: Whole Taiwan region $\log_{10} M_0 = 1.27M_L + 17.23$ (Chen et al., 2007) $\log_{10}\Delta\sigma = -4.8670 + 0.2925(\log_{10} M_0)$ (Tsai, 1997) With upper-bound 300 bar. **Zone SO:** 100 bar. **Zone DT:** 300 bar. (Sokolov et al. 2009)

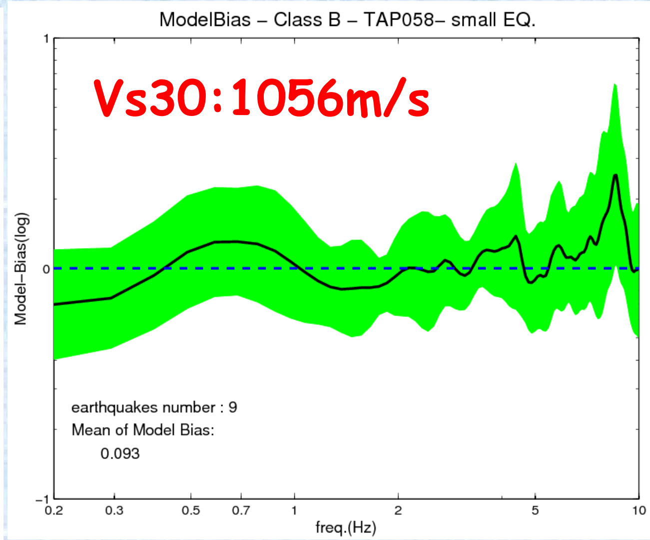


Class B:

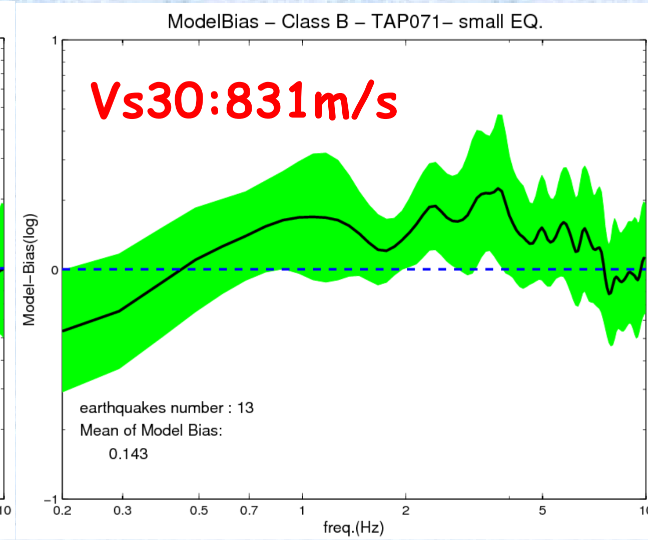
TAP086



TAP058

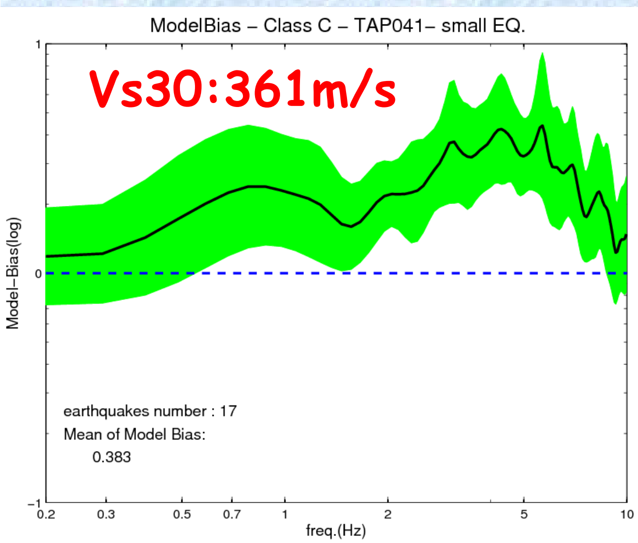


TAP071

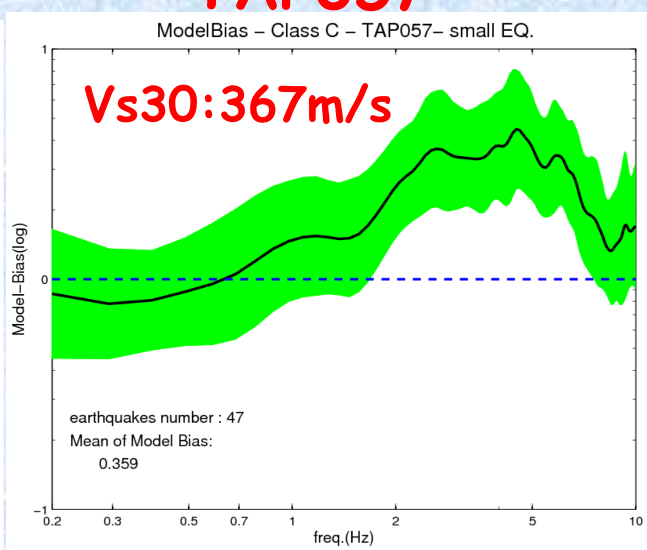


Class C:

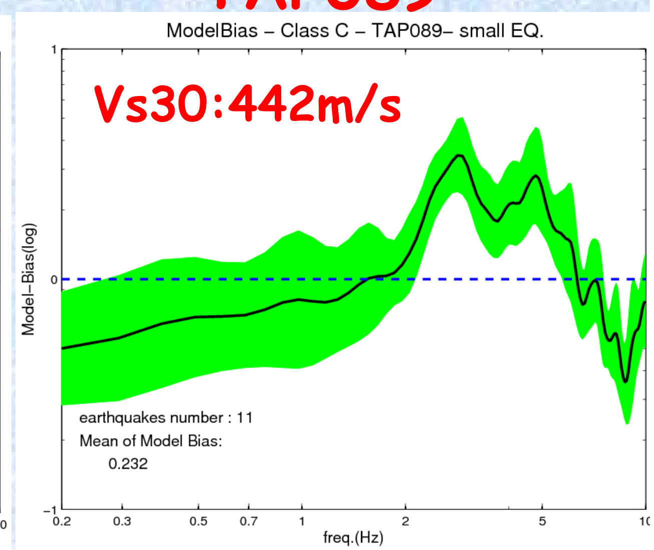
TAP041



TAP057

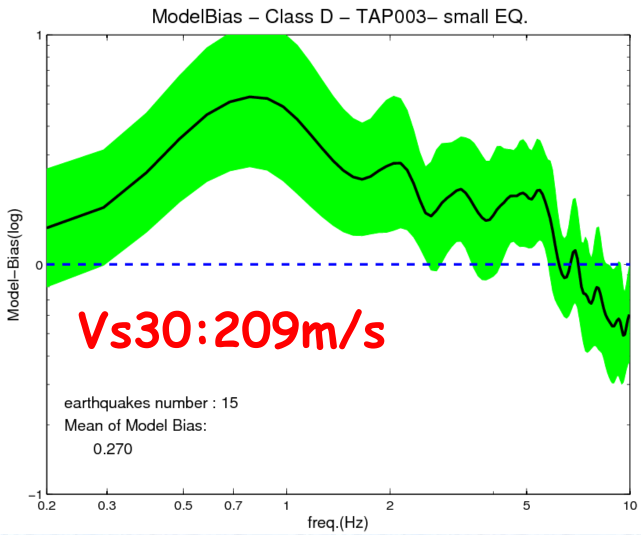


TAP089

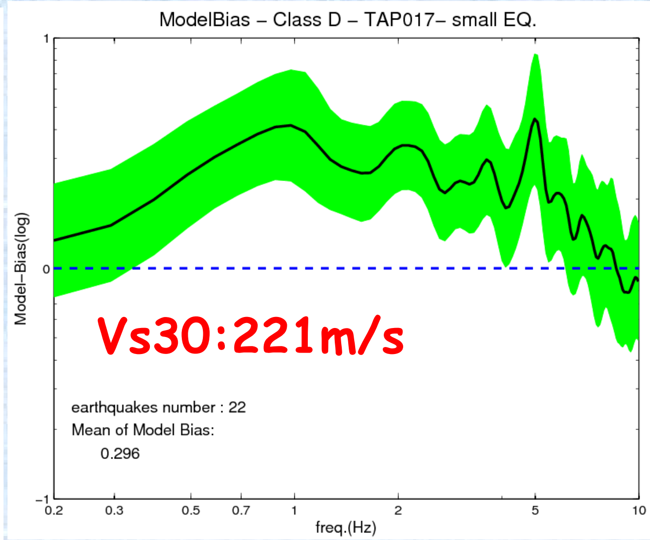


Class D:

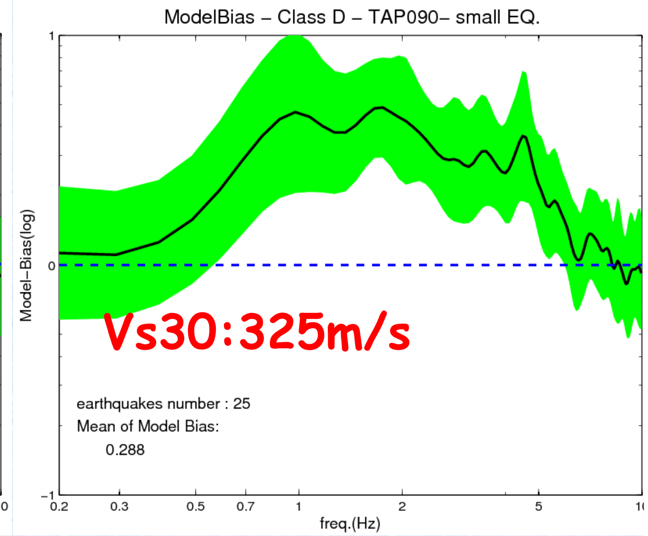
TAP003



TAP017

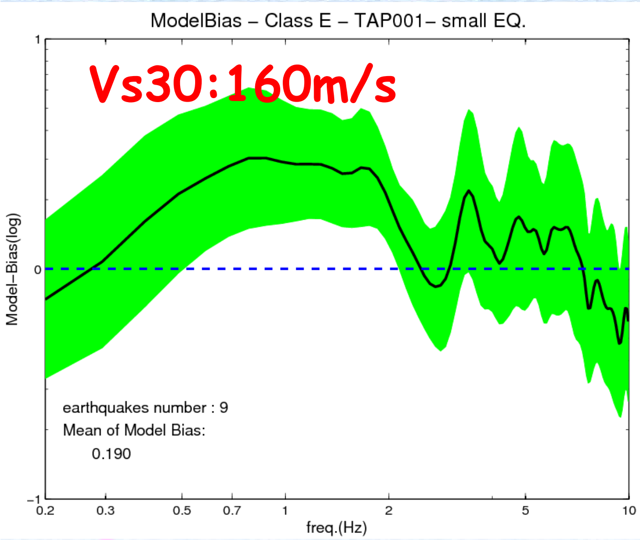


TAP090

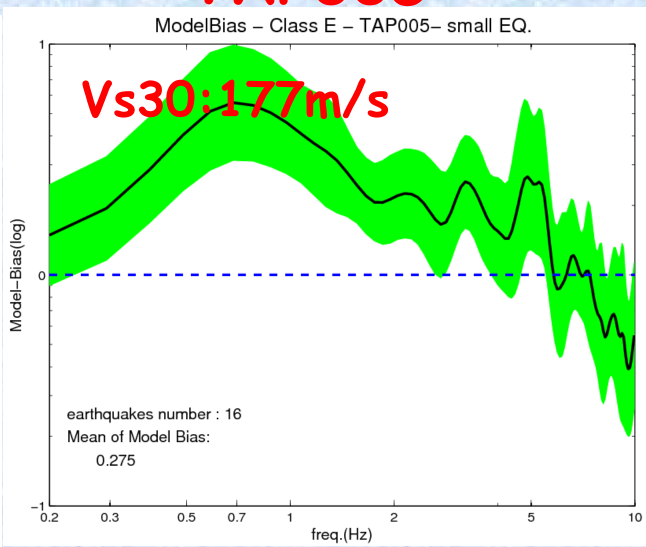


Class E:

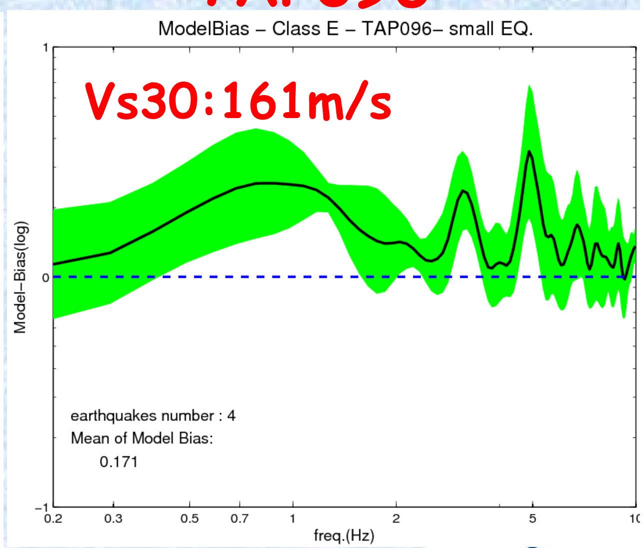
TAP001

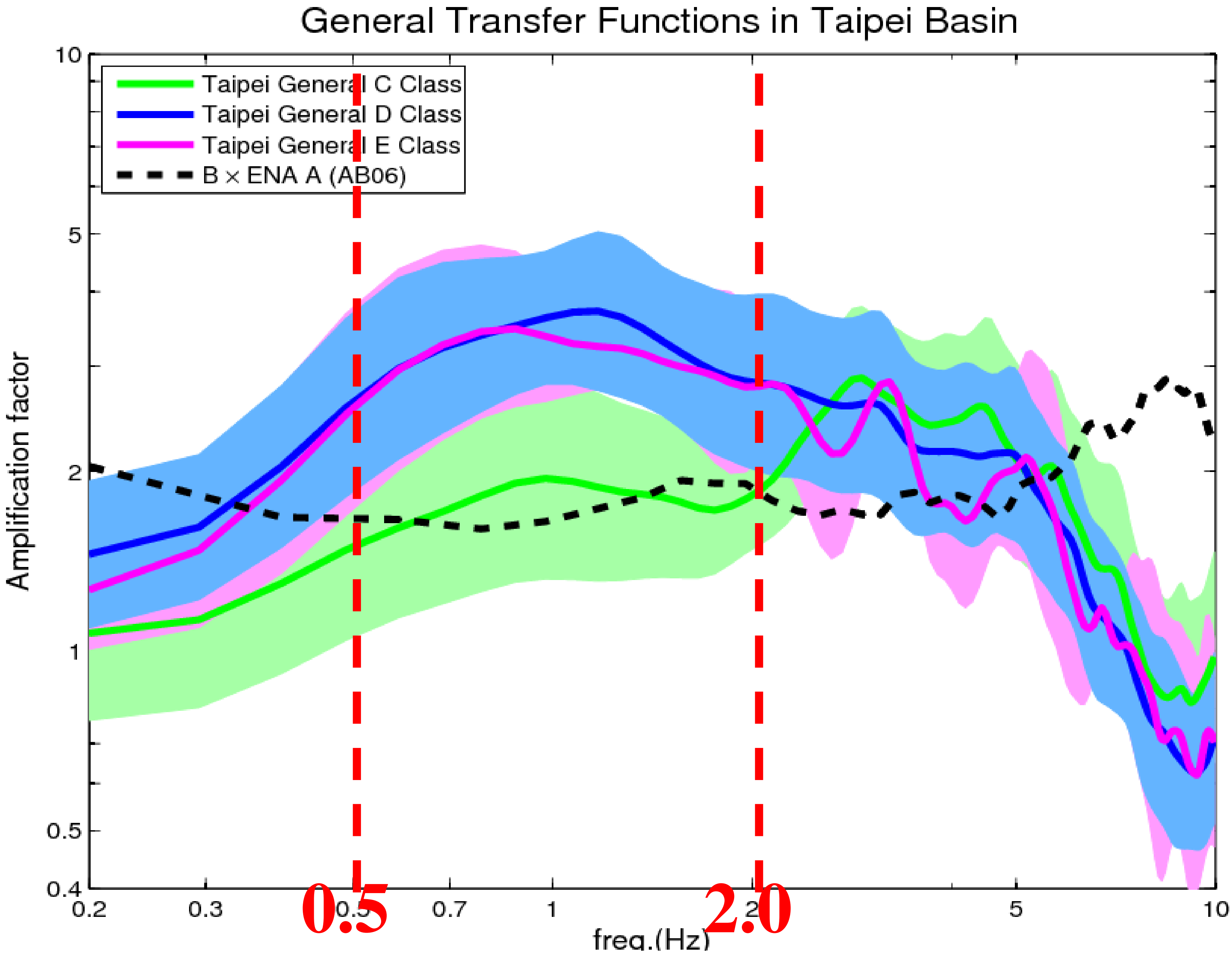


TAP005



TAP096

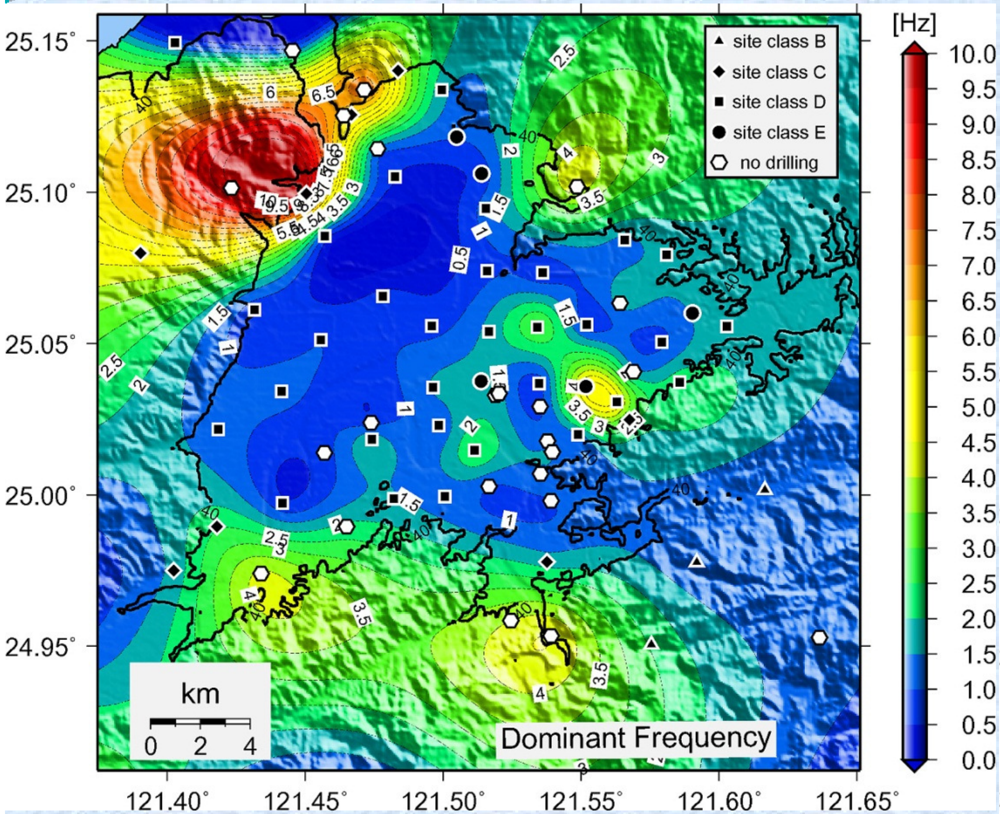




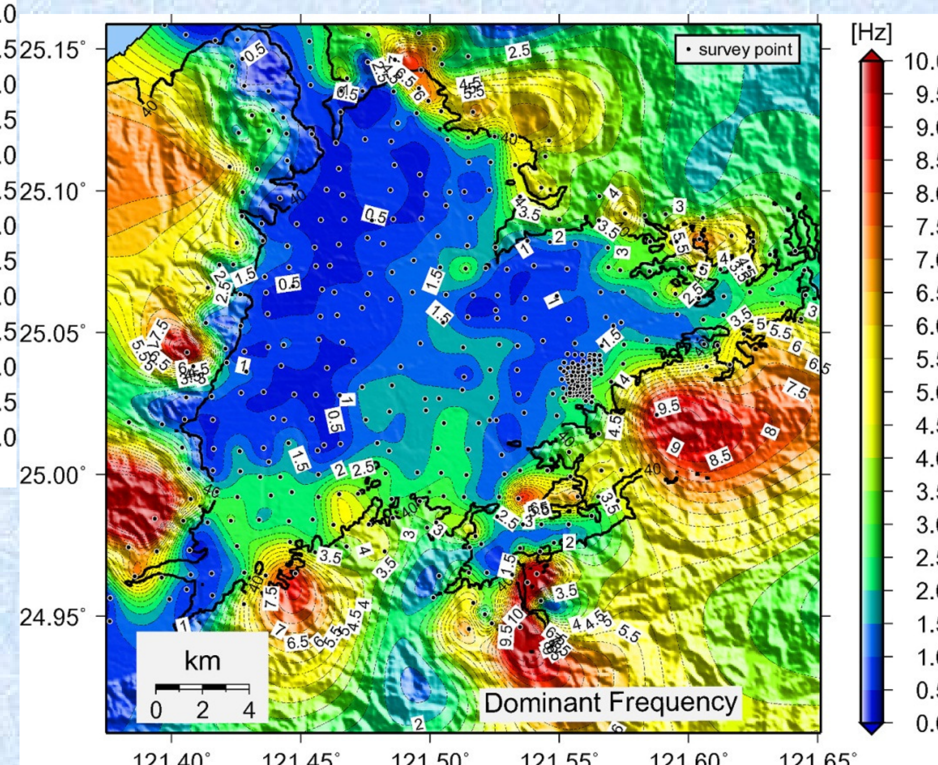
General Transfer Functions in Taipei Basin
Taipei General C Class
Taipei General D Class
Taipei General E Class
B × ENA A (AB06)
Amplification factor
10
5
2
1
0.5
0.4
0.2
0.3
0.5
0.7
1
2
5
10
freq.(Hz)
0.5
2.0

Dominant frequency

SMSIM



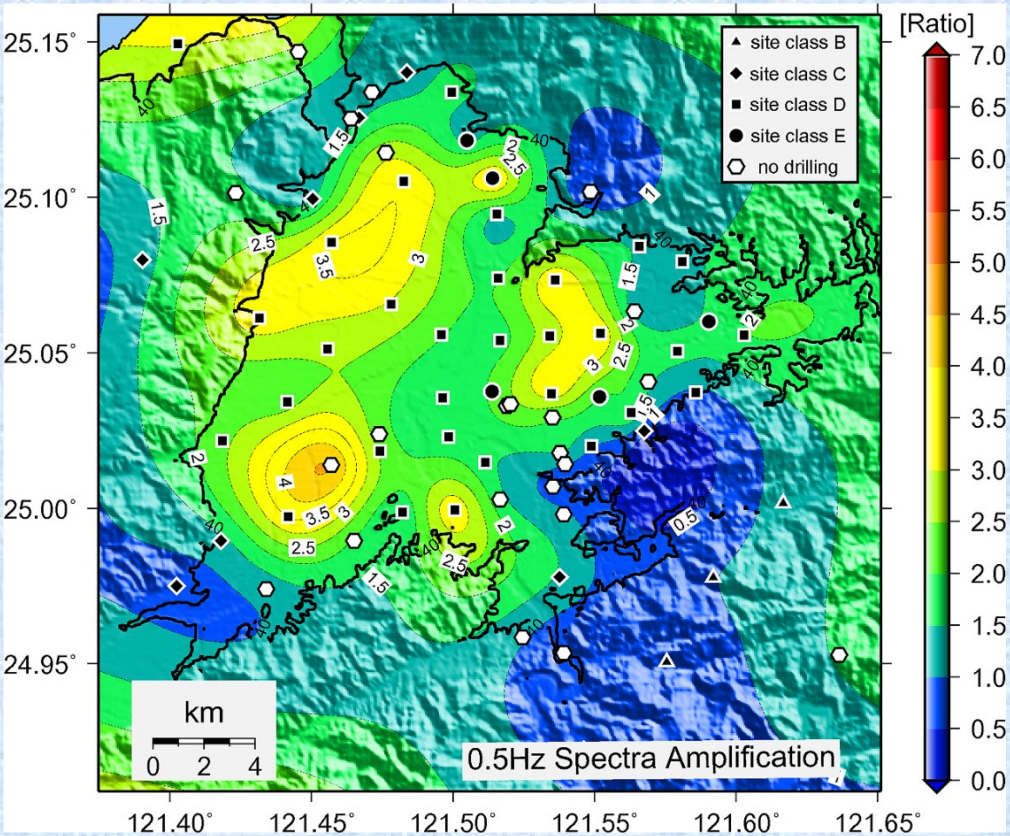
Microtremor



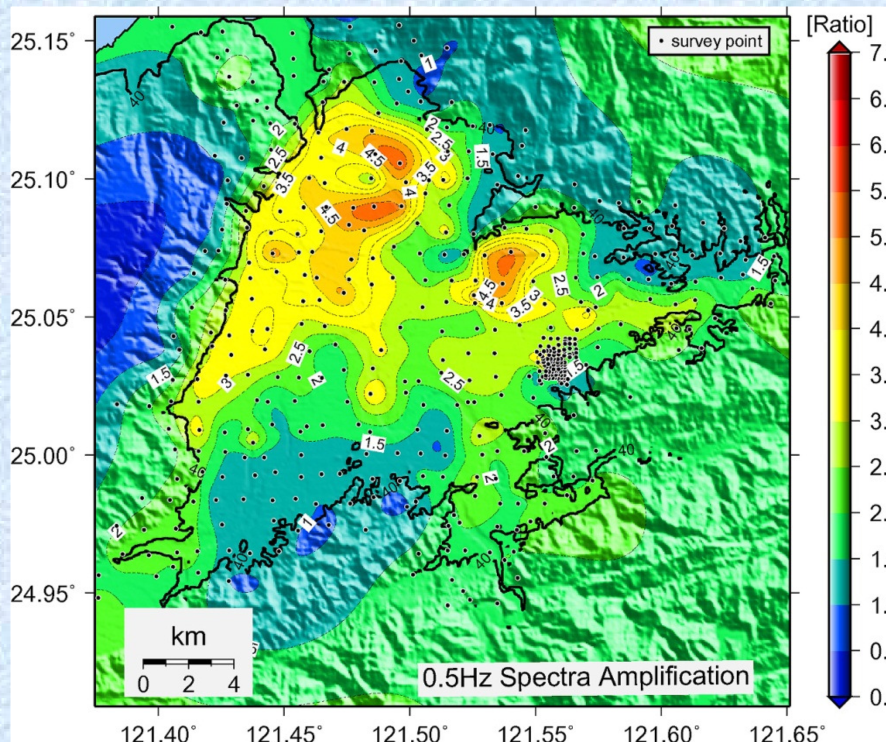
(redraw of Wen and Huang, 2012)

Amplification of 0.5 Hz

SMSIM



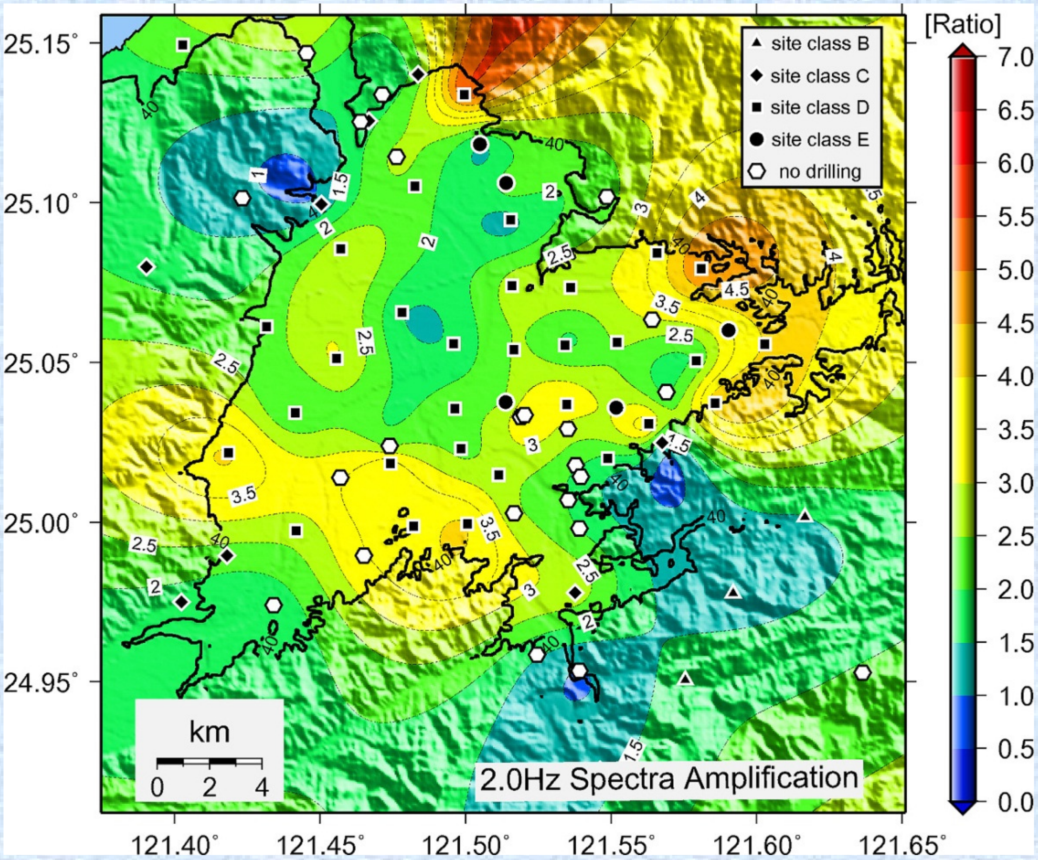
Microtremor



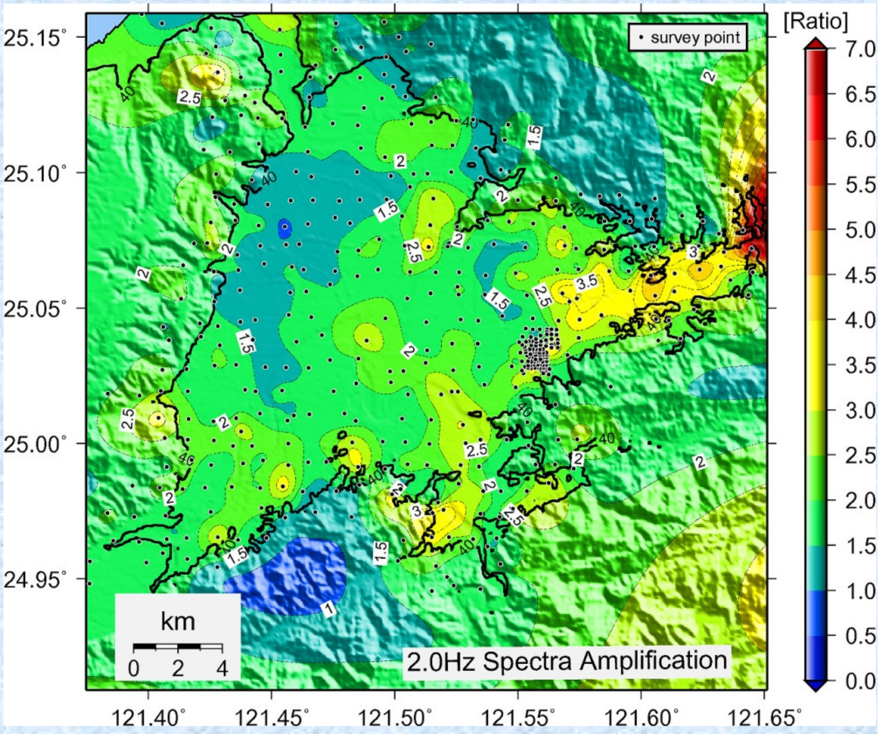
(redraw of Huang, 2009)

Amplification of 2.0 Hz

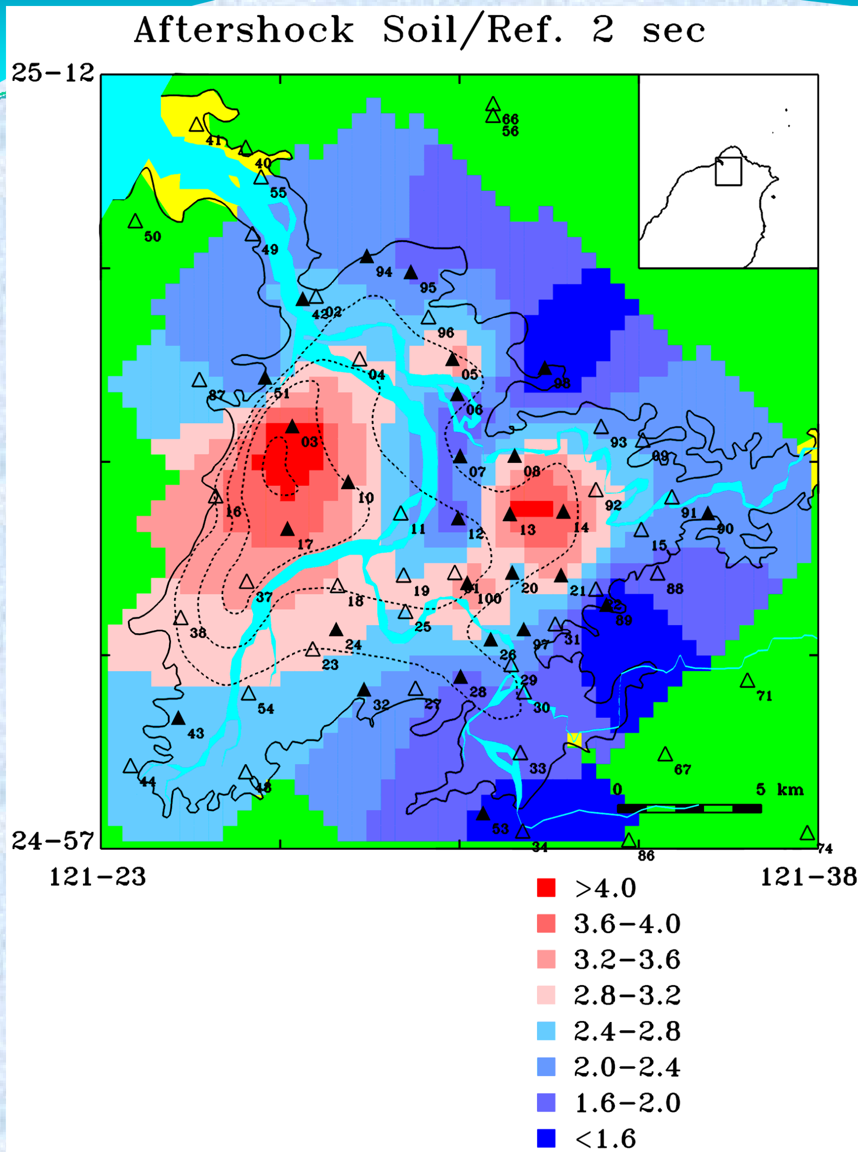
SMSIM

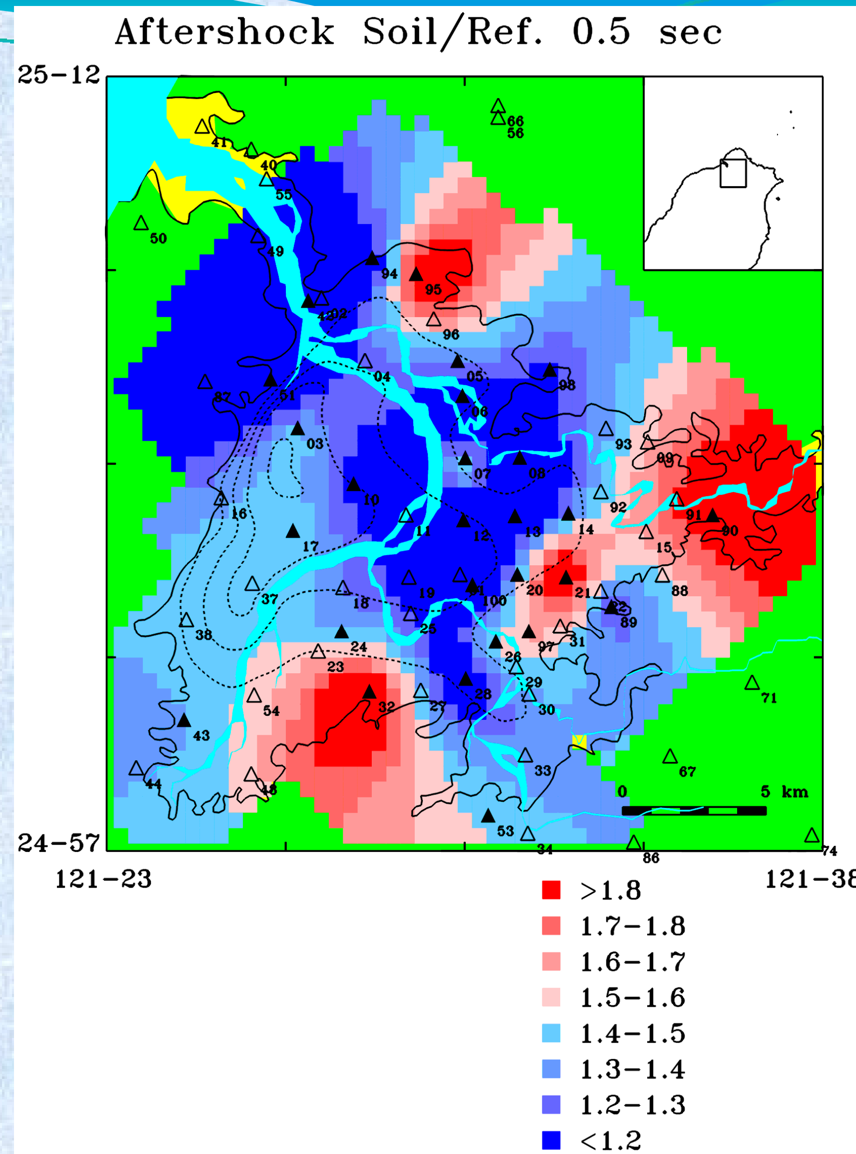


Microtremor



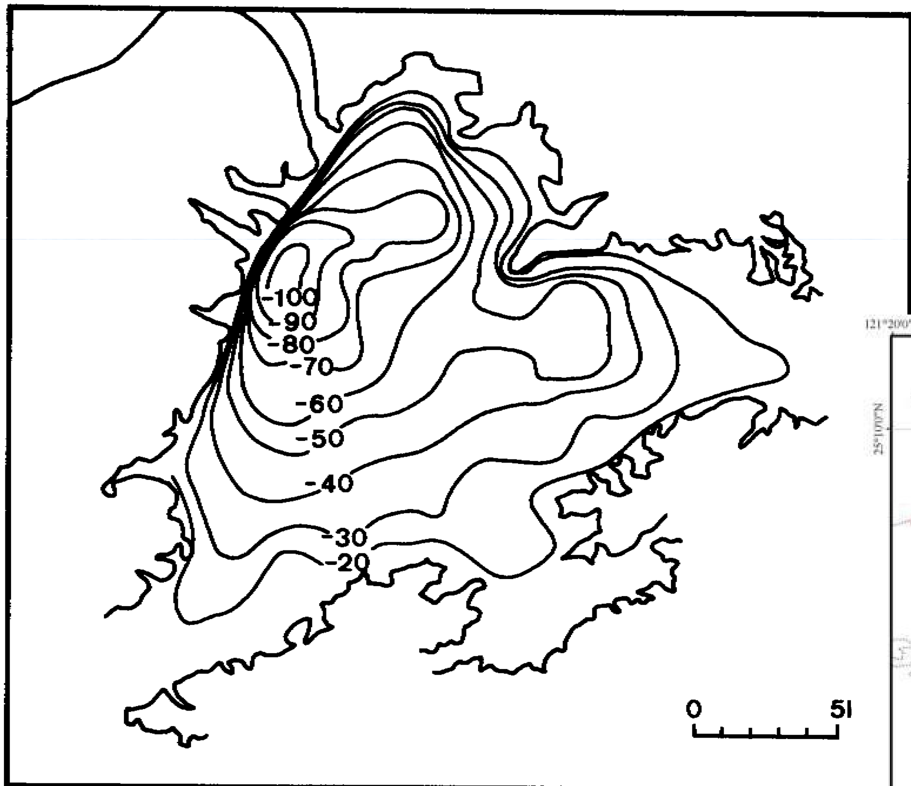
(redraw of Huang, 2009)





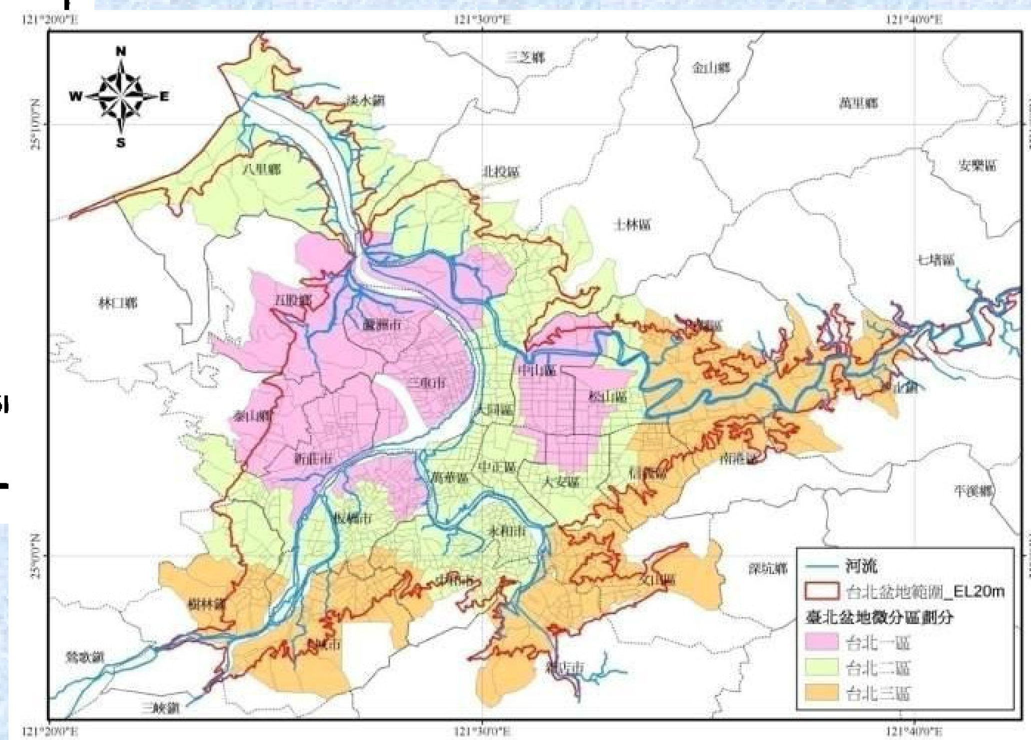
Spectral ratio contours of the Chi-Chi aftershocks in the Taipei basin.

Sungshan Formation Bottom --- Taipei Basin

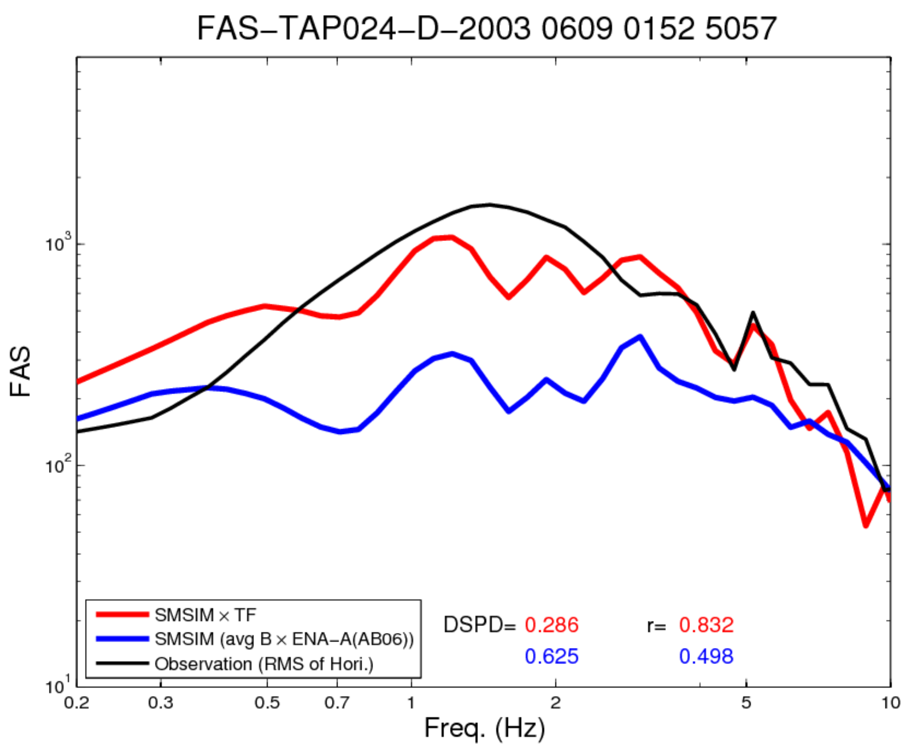


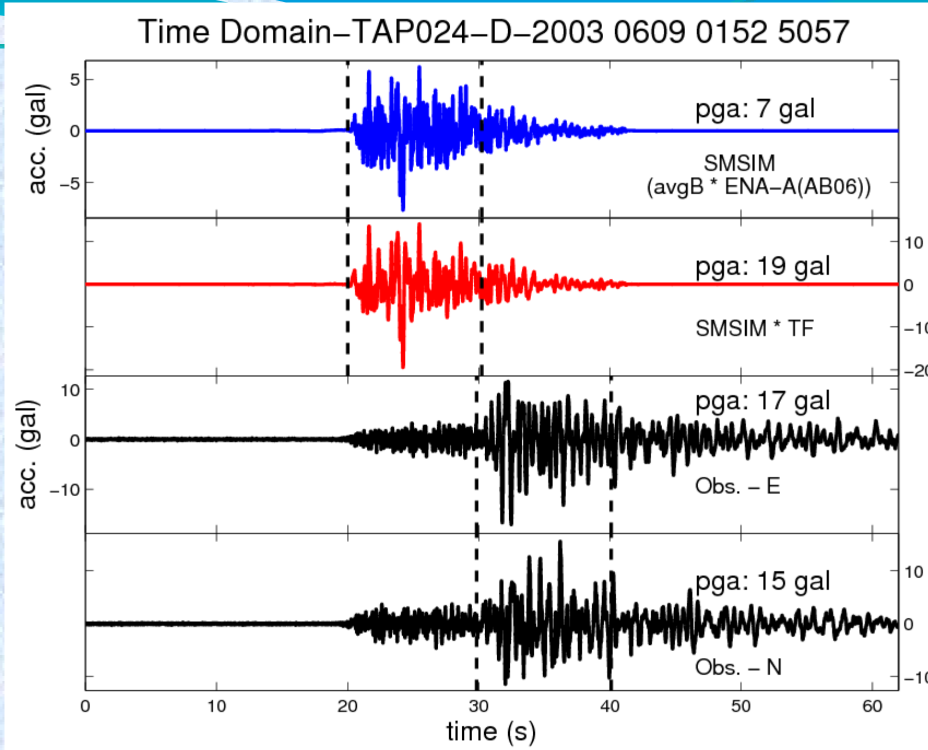
2011.1修訂後公告之臺北盆地設計地震微分區圖

Microzonation Map of Taipei Basin in the Building Code Modified on 2011.



TAP024





$$DSPD = \sum_{i=0.2}^{10}\left(\left|\log_{10}\frac{FAS_o}{FAS_s}\right| \times df\right)$$

$$df = \log_{10}(f_{i+1}/f_i)$$

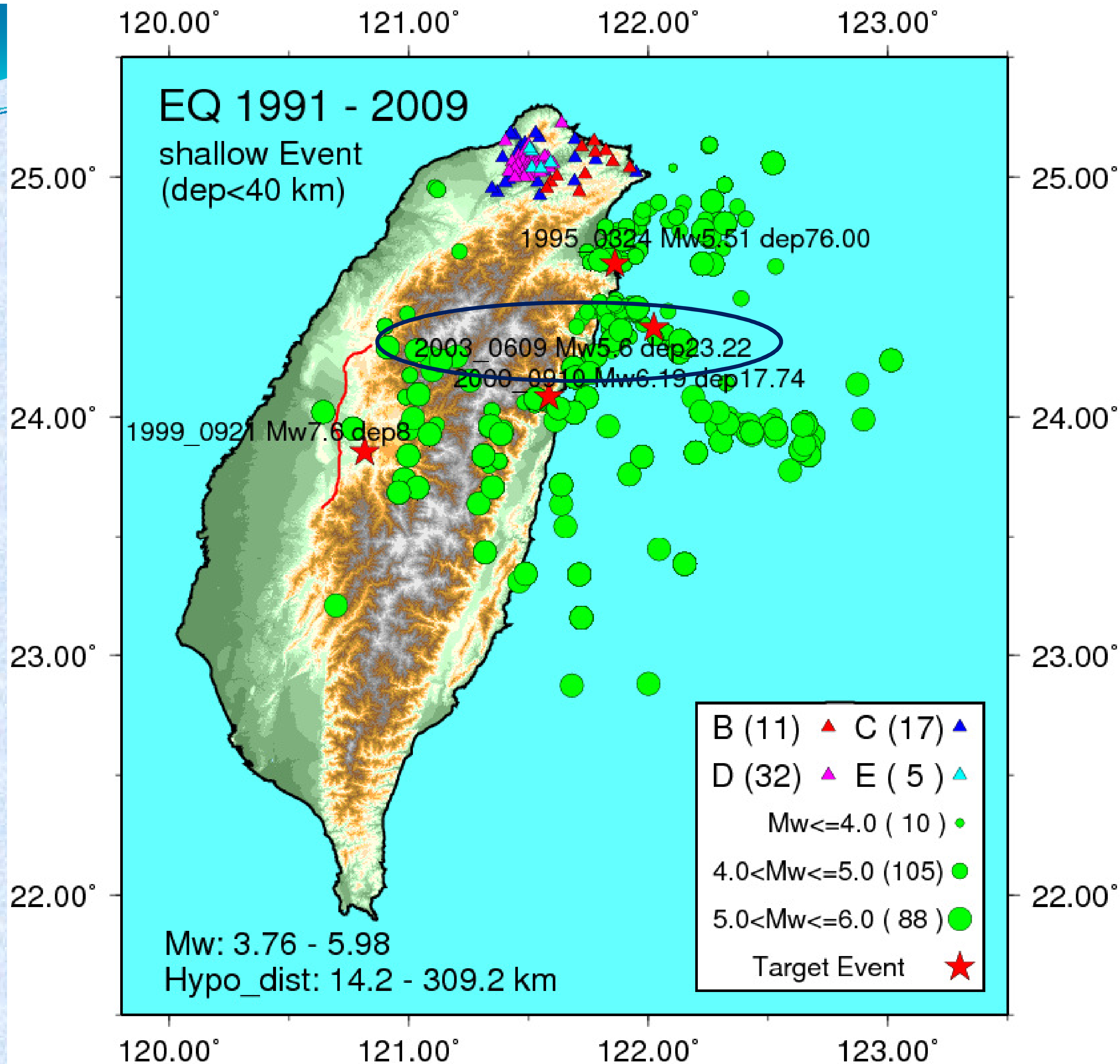
Residual = lnPGA$_o$-lnPGAs

$$\sigma_{\ln Err} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Residual_i)^2}$$

r = Correlation Coefficient

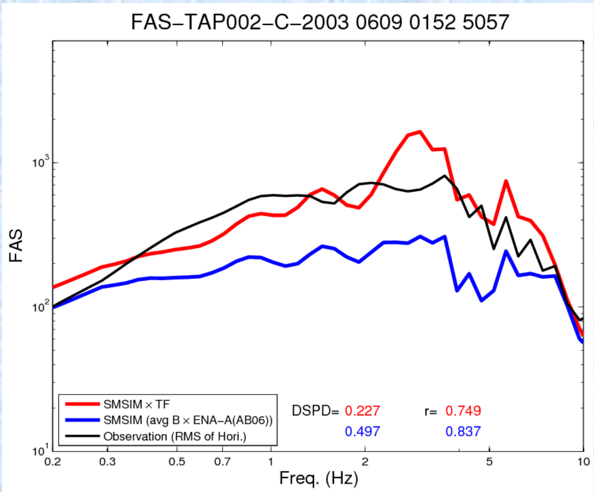
$$Y_{att} = 0.00369e^{1.75377M}[R + 0.12220e^{0.78315M}]^{-2.05644}$$

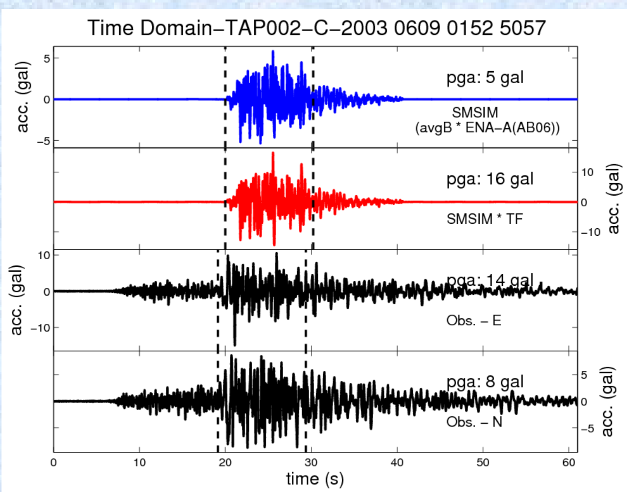
$$\sigma_{\ln Err} = 0.78$$


EQ 1991 - 2009
shallow Event
(dep<40 km)
120.00°
121.00°
122.00°
123.00°
25.00°
24.00°
23.00°
22.00°
1995_0324 Mw5.51 dep76.00
2003_0609 Mw5.6 dep23.22
2000_0910 Mw6.19 dep17.74
1999_0921 Mw7.6 dep8
B (11)
C (17)
D (32)
E (5)
Mw<=4.0 (10)
4.0<Mw<=5.0 (105)
5.0<Mw<=6.0 (88)
Target Event
Mw: 3.76 - 5.98
Hypo_dist: 14.2 - 309.2 km

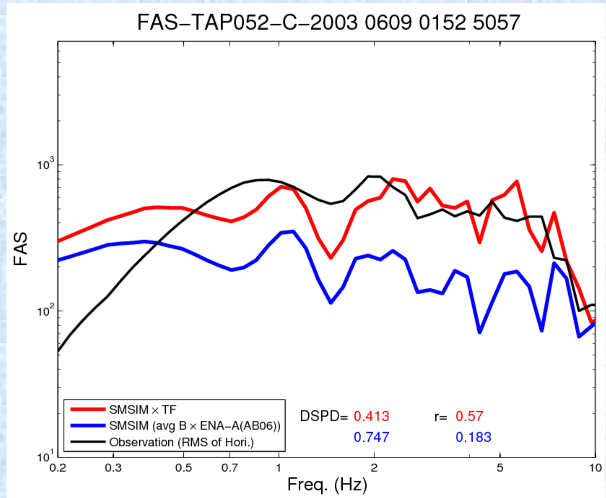
Class C: 2003_0609 Mw5.6 dep23.22 km

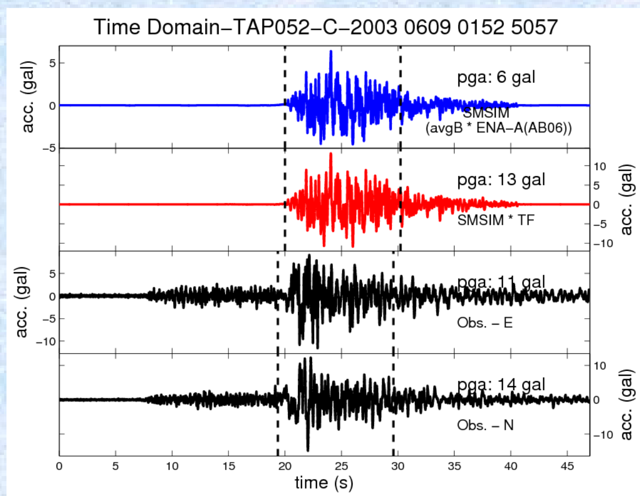
TAP002



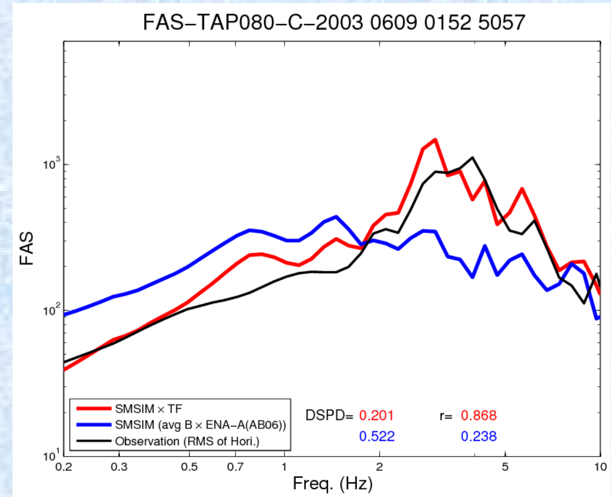


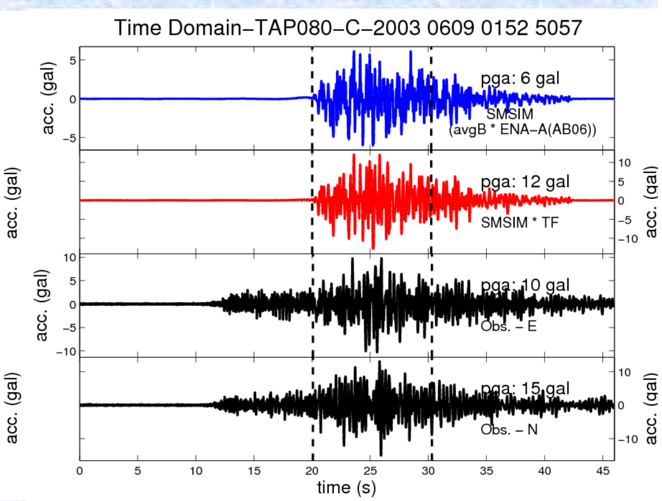
TAP052





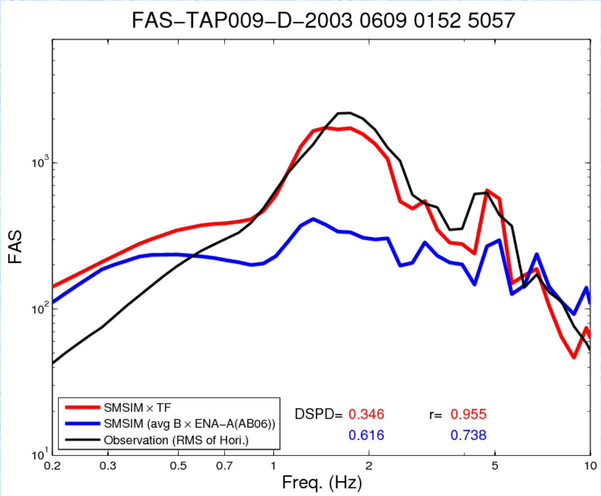
TAP080

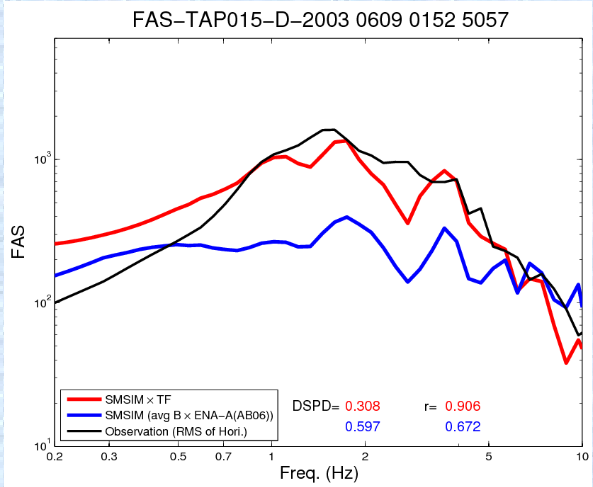


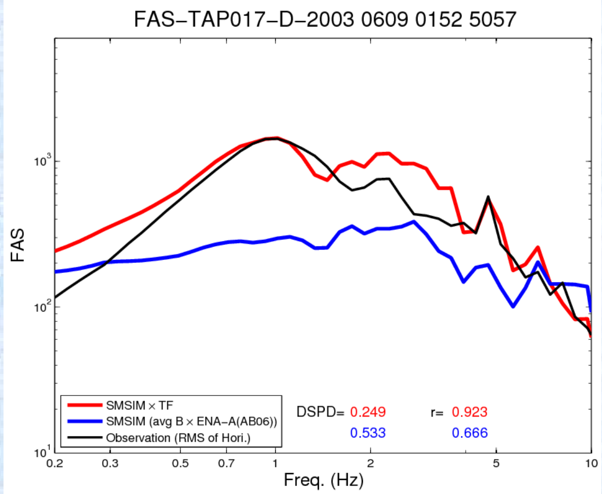


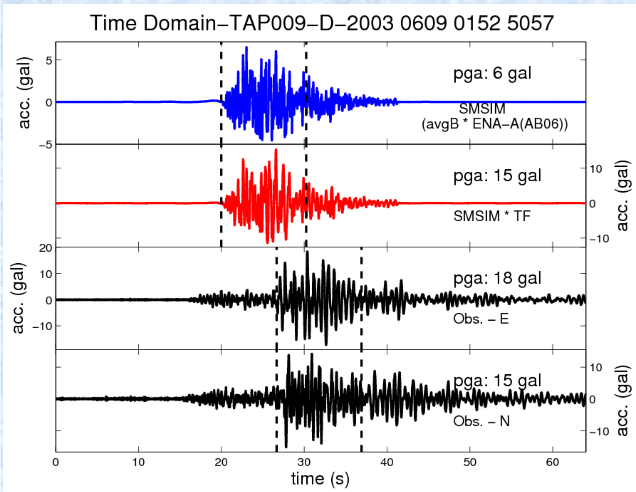
Class D: 2003_0609 Mw5.6 dep23.22 km

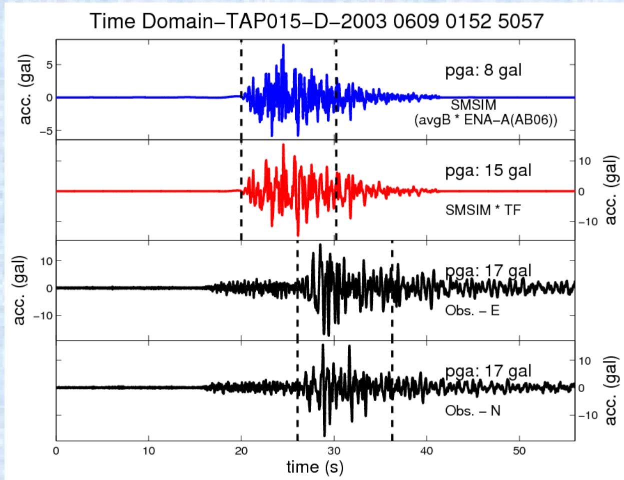
TAP009 TAP015 TAP017

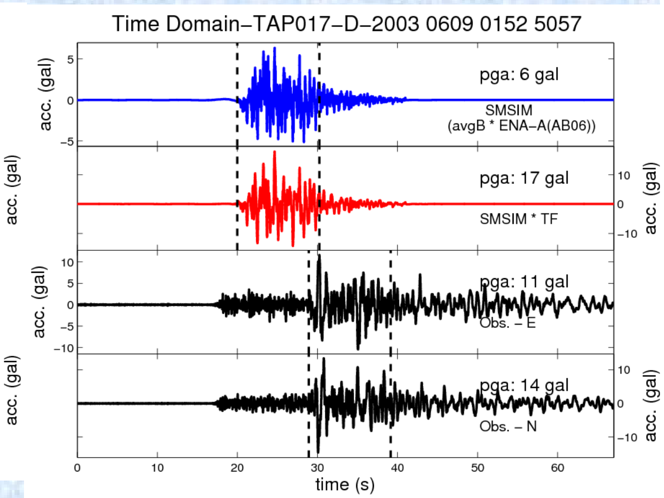






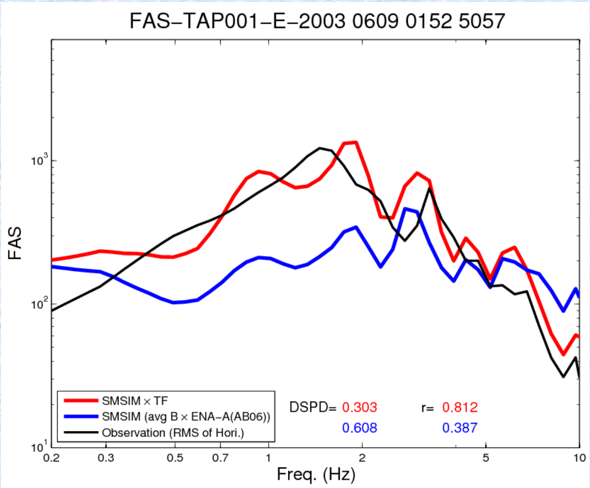


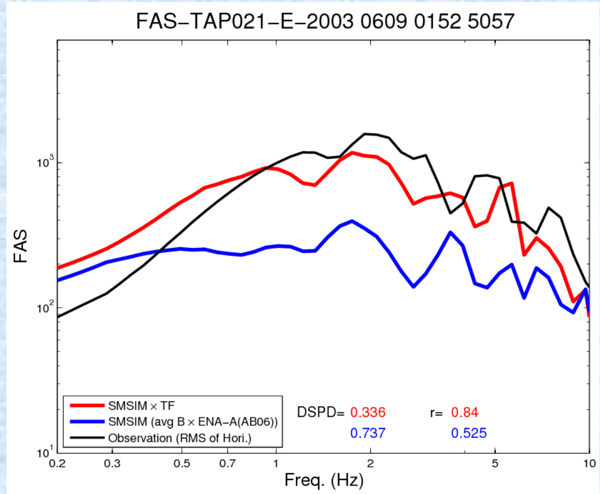


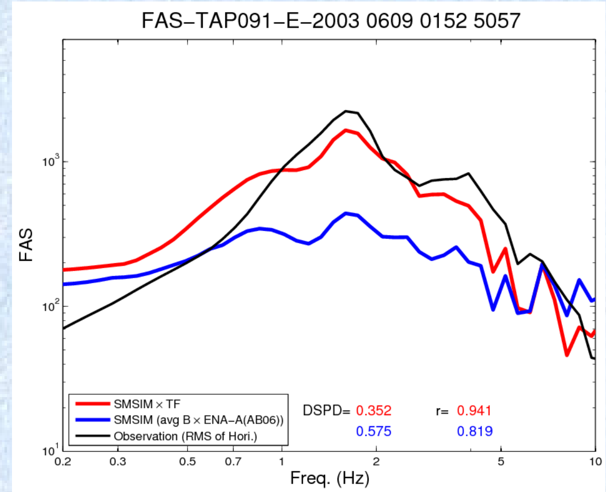


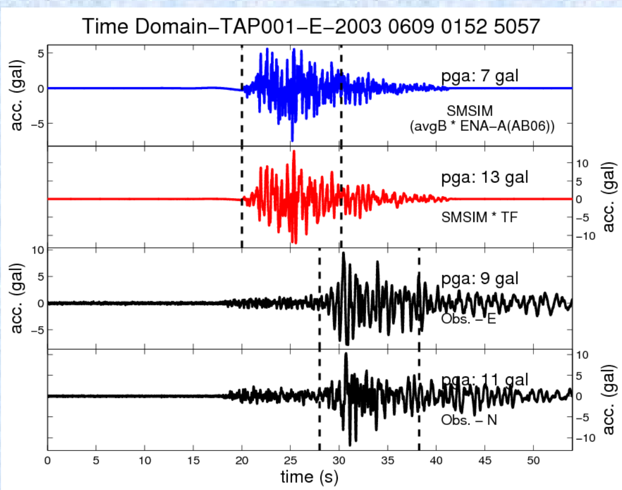
Class E: 2003_0609 Mw5.6 dep23.22 km

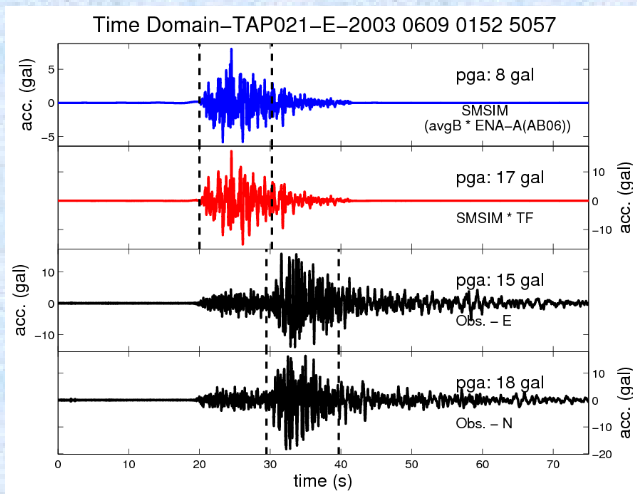
TAP001 TAP021 TAP091

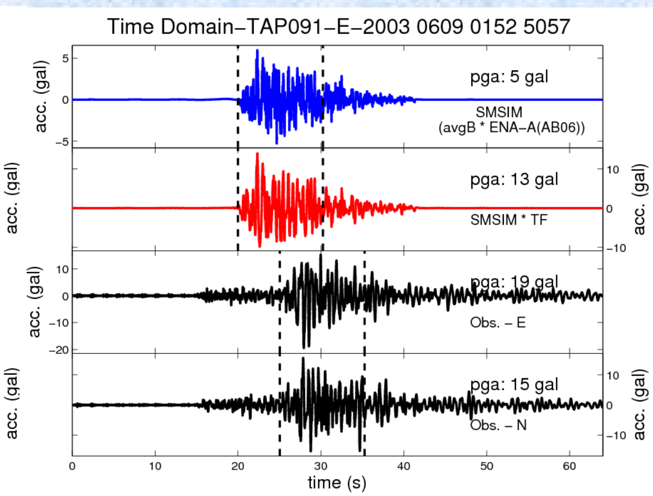




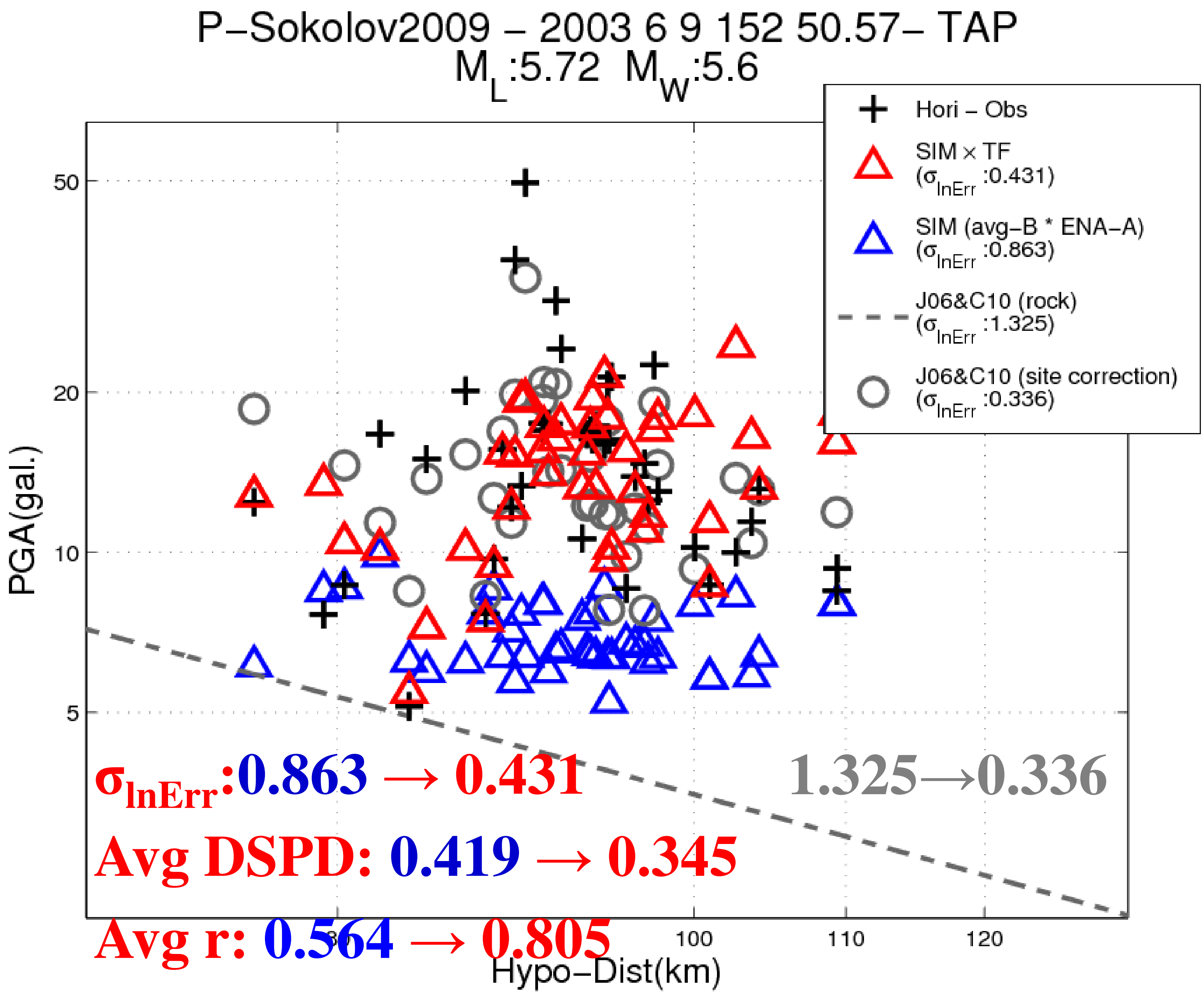








2003_0609 Mw5.6 dep23.22 km

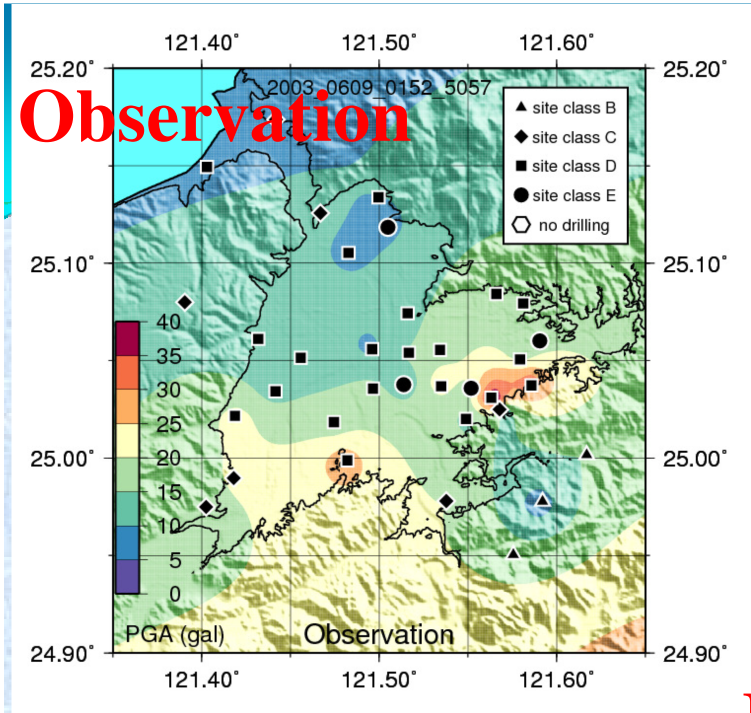


σ_{lnErr}:0.863 → 0.431 1.325→0.336

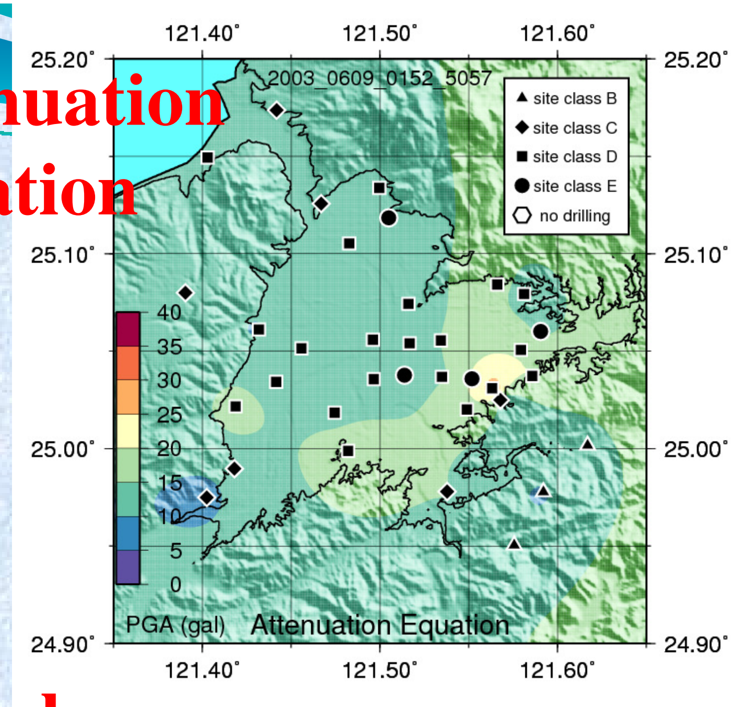
Avg DSPD: 0.419 → 0.345

Avg r: 0.564 → 0.805

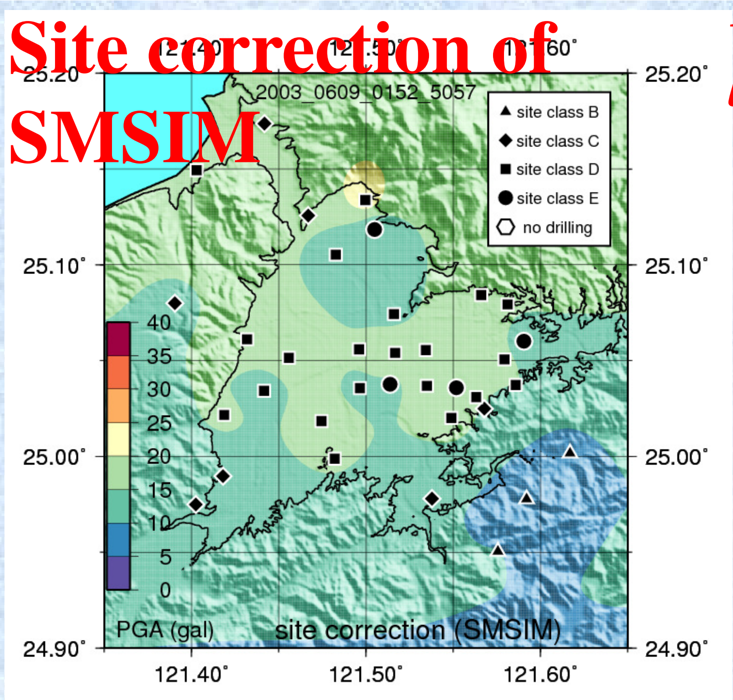
Observation



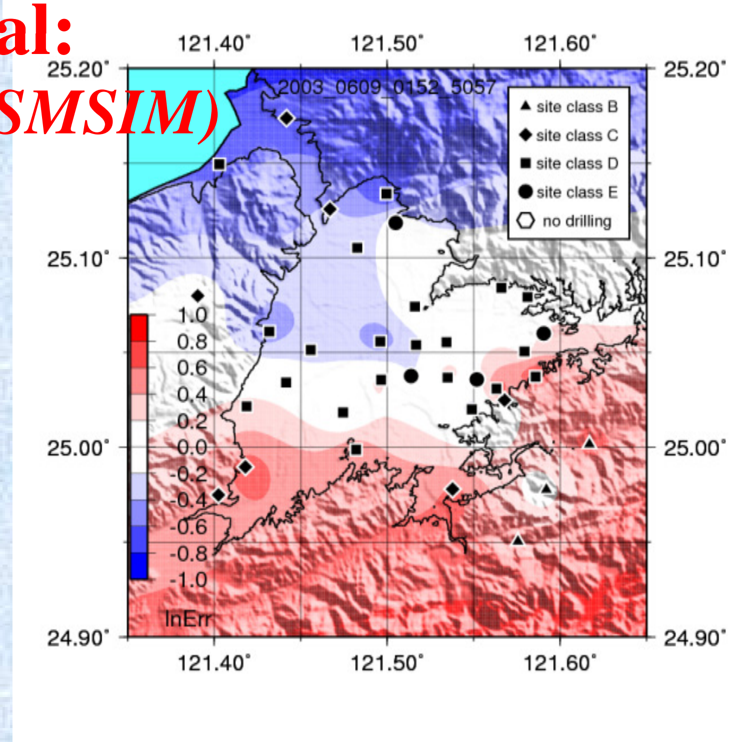
Attenuation Equation



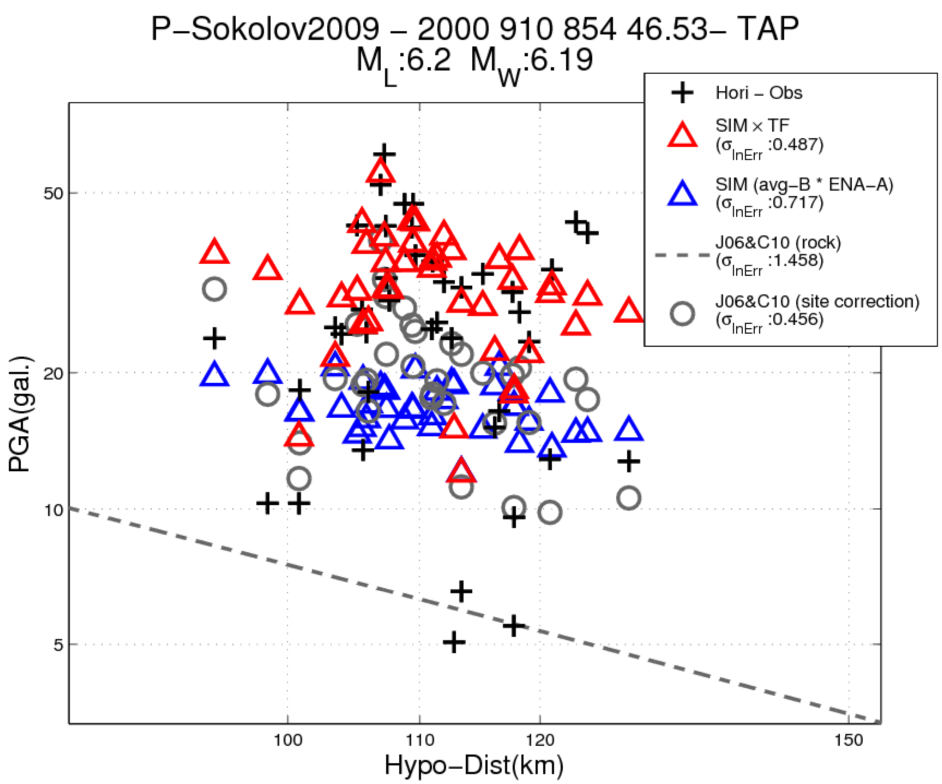
Site correction of SMSIM



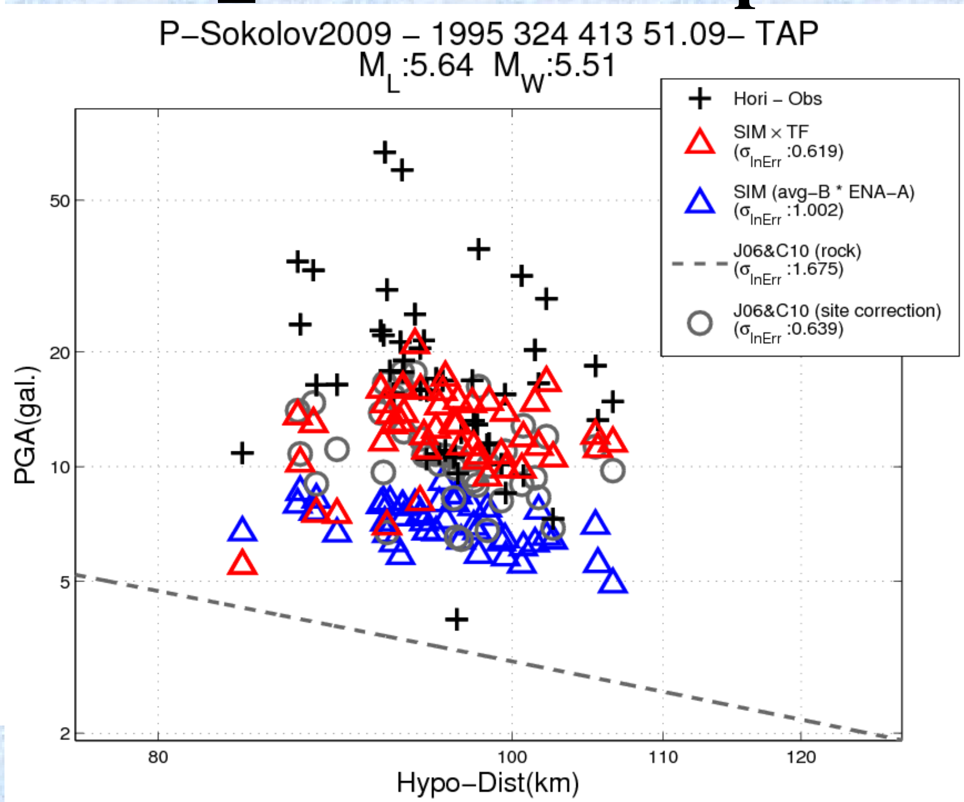
Residual:
ln(OBS/SMSIM)



2000_0910 Mw6.19 dep17 km



1995_0324 Mw5.5 dep76 km



σ_{lnErr}: 0.717 → 0.487

1.458 → 0.456

Avg DSPD: 0.629 → 0.559

Avg r: 0.430 → 0.666

σ_{lnErr}: 1.002 → 0.619

1.675 → 0.639

Avg DSPD: 0.473 → 0.418

Avg r: 0.560 → 0.669

Discussions and Conclusions

- The stochastic point source model was used to obtain the empirical site transfer function for each soil site within the Taipei basin.   (203 mag. < 6.0 and depth < 40 km)
- Ground motion simulation can be performed for moderate magnitude earthquakes by the stochastic point source simulation to rock basement and added the empirical site correction to get the final ground motion simulation.
- The biases of the stochastic simulation results compared with observation are around the same compared with the GMPE simulation.
- Effects from the magnitude level for source effects, ground motion level for nonlinear site effects, and focal depth for propagation path or direction should be considered in the future study.

Thank you for your attention!

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