Observations of Water-Level Fluctuations induced by Local and Distant Earthquakes at Two Wells in Hualien, Eastern Taiwan

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Outline

- **Introduction**
- **Geological logs of the two wells**
- **Dependence on Earthquake Magnitude and Hypocentral Distance**
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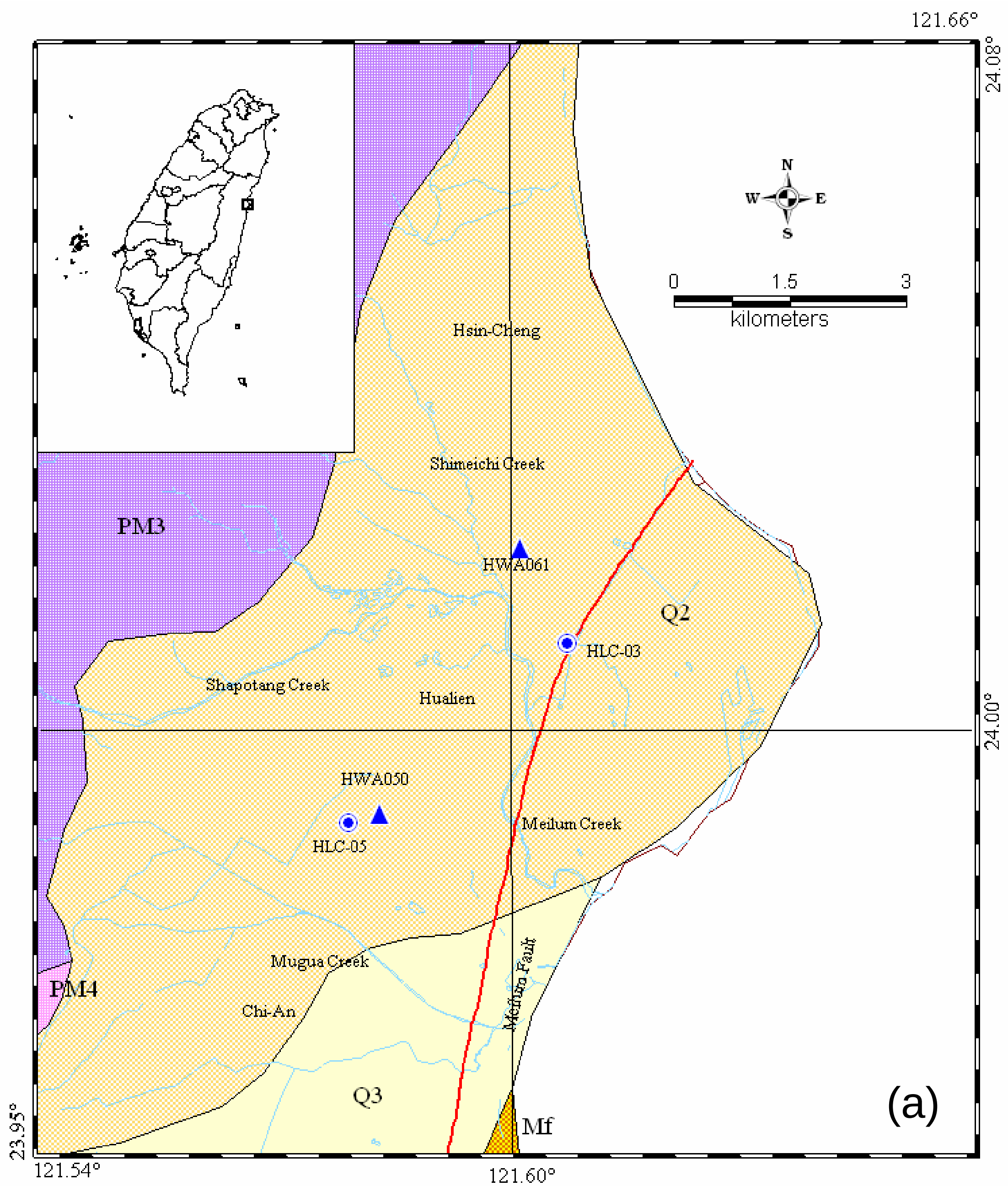
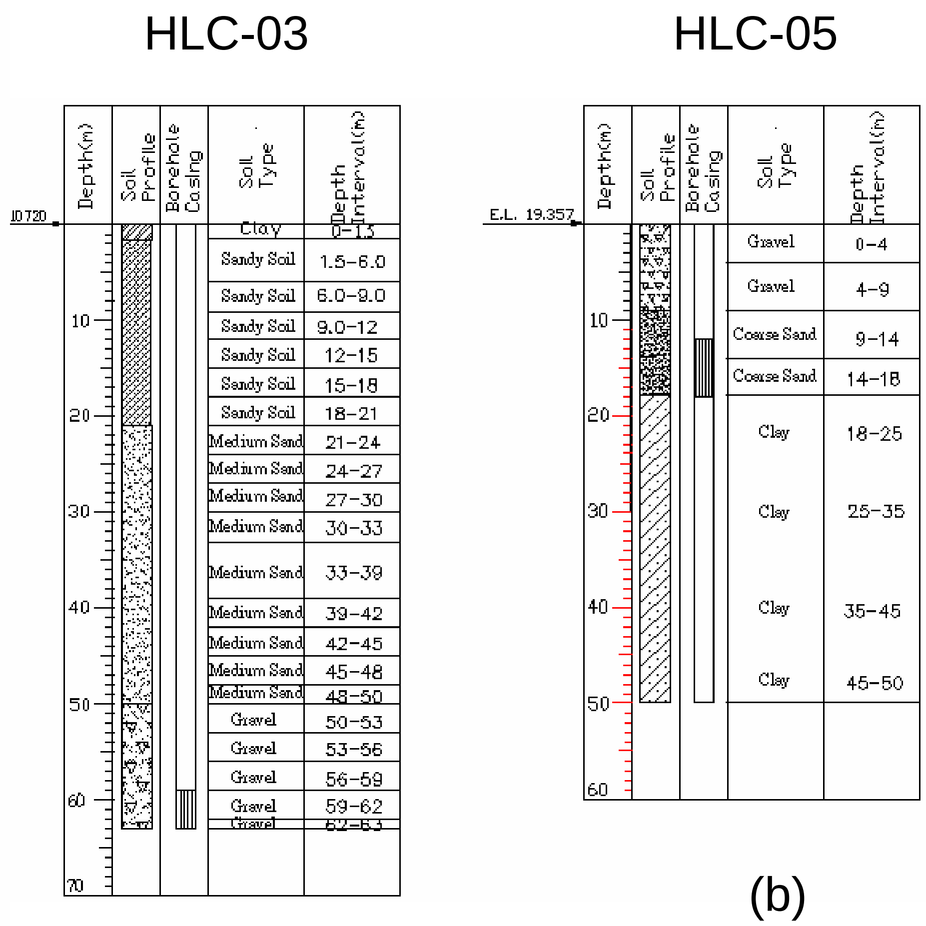
Introduction

1. Waterlevel changes are associated with the strain changes at a specified area.
2. The seismically induced water level changes are one of the most significant phenomena.
3. The amplitude of waterlevel flactuations are correlated with the amplitude seismic wave
4. The passage of seismic wave generated by the local earthquakes and distant ones simultaneously in response to the water level changes in the wells.

Geological logs of the two wells

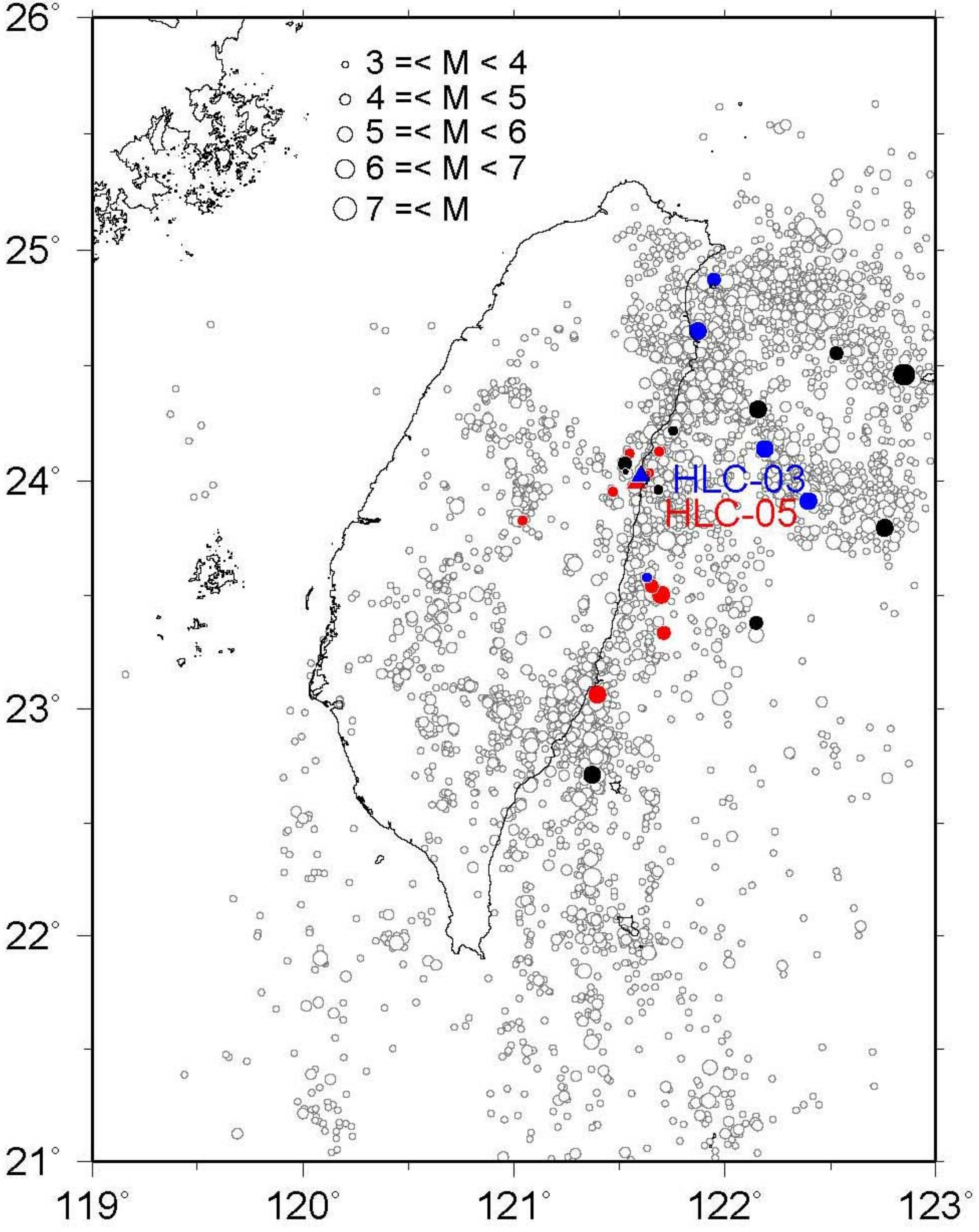
- The Observation time
- The instrument
- The parameters of the two wells


121.66°
24.08°
24.00°
23.95°
121.54°
121.60°
N
W
E
S
0
1.5
3
kilometers
Hsin-Cheng
Shimeichi Creek
PM3
HWA061
Q2
HLC-03
Shapotang Creek
Hualien
HWA050
Meilum Creek
HLC-05
Mugua Creek
PM4
Chi-An
Meilun Fault
Q3
Mf
(a)


HLC-03
Depth(m)
Soil Profile
Borehole Casing
Soil Type
Depth Interval(m)
Clay 0-1.5
Sandy Soil 1.5-6.0
Sandy Soil 6.0-9.0
Sandy Soil 9.0-12
Sandy Soil 12-15
Sandy Soil 15-18
Sandy Soil 18-21
Medium Sand 21-24
Medium Sand 24-27
Medium Sand 27-30
Medium Sand 30-33
Medium Sand 33-39
Medium Sand 39-42
Medium Sand 42-45
Medium Sand 45-48
Medium Sand 48-50
Gravel 50-53
Gravel 53-56
Gravel 56-59
Gravel 59-62
Gravel 62-63
10
20
30
40
50
60
70
HLC-05
E.L. 19.357
Depth(m)
Soil Profile
Borehole Casing
Soil Type
Depth Interval(m)
Gravel 0-4
Gravel 4-9
Coarse Sand 9-14
Coarse Sand 14-18
Clay 18-25
Clay 25-35
Clay 35-45
Clay 45-50
10
20
30
40
50
60
(b)

Dependence on Earthquake Magnitude and Hypocentral Distance

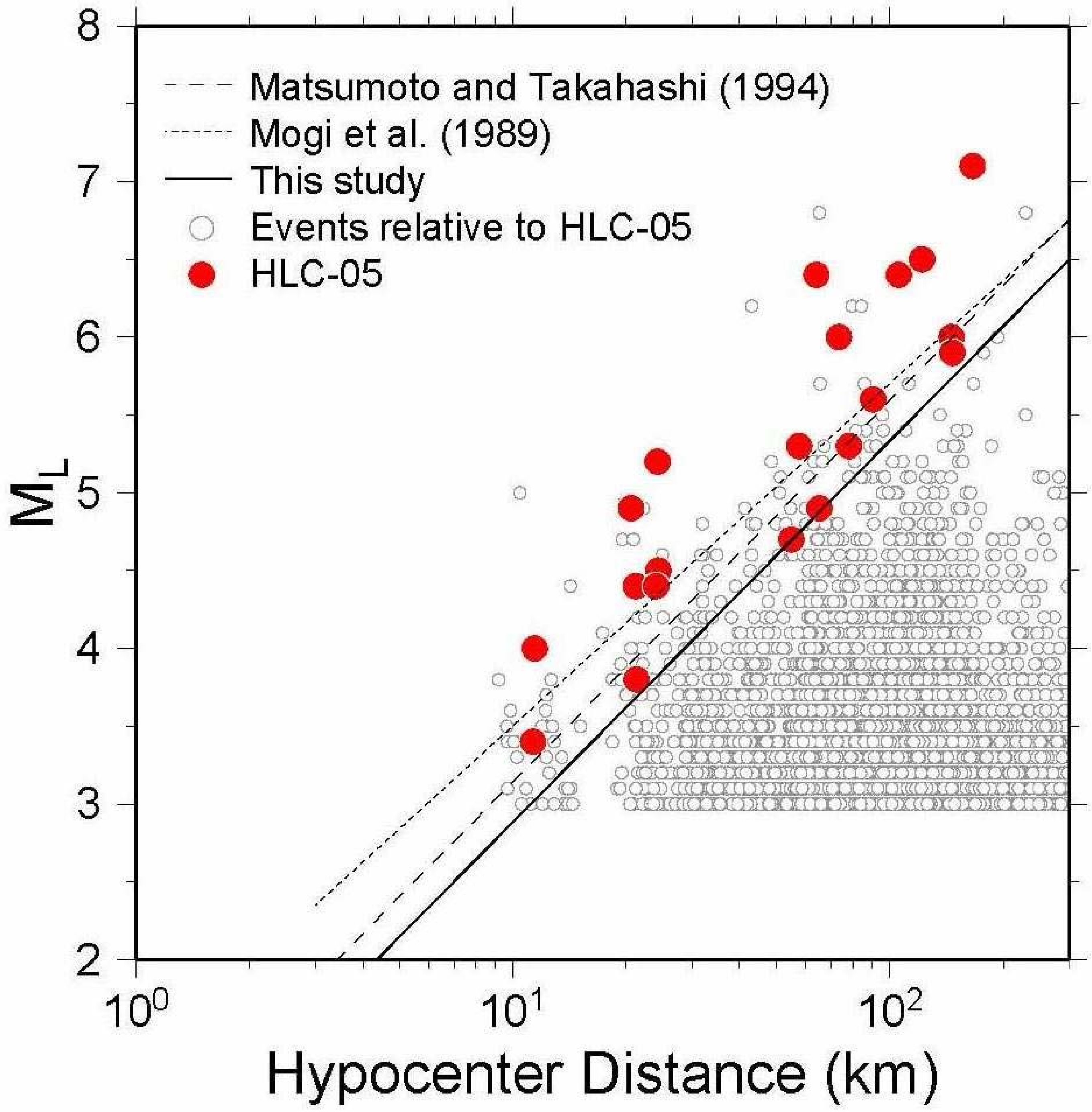
- The wells-monitoring durations of ： February 2002 ~ May 2005.
- The earthquake catalogs of the Central Weather Bureau (CWB) ： February 2002 ~ May 2005.



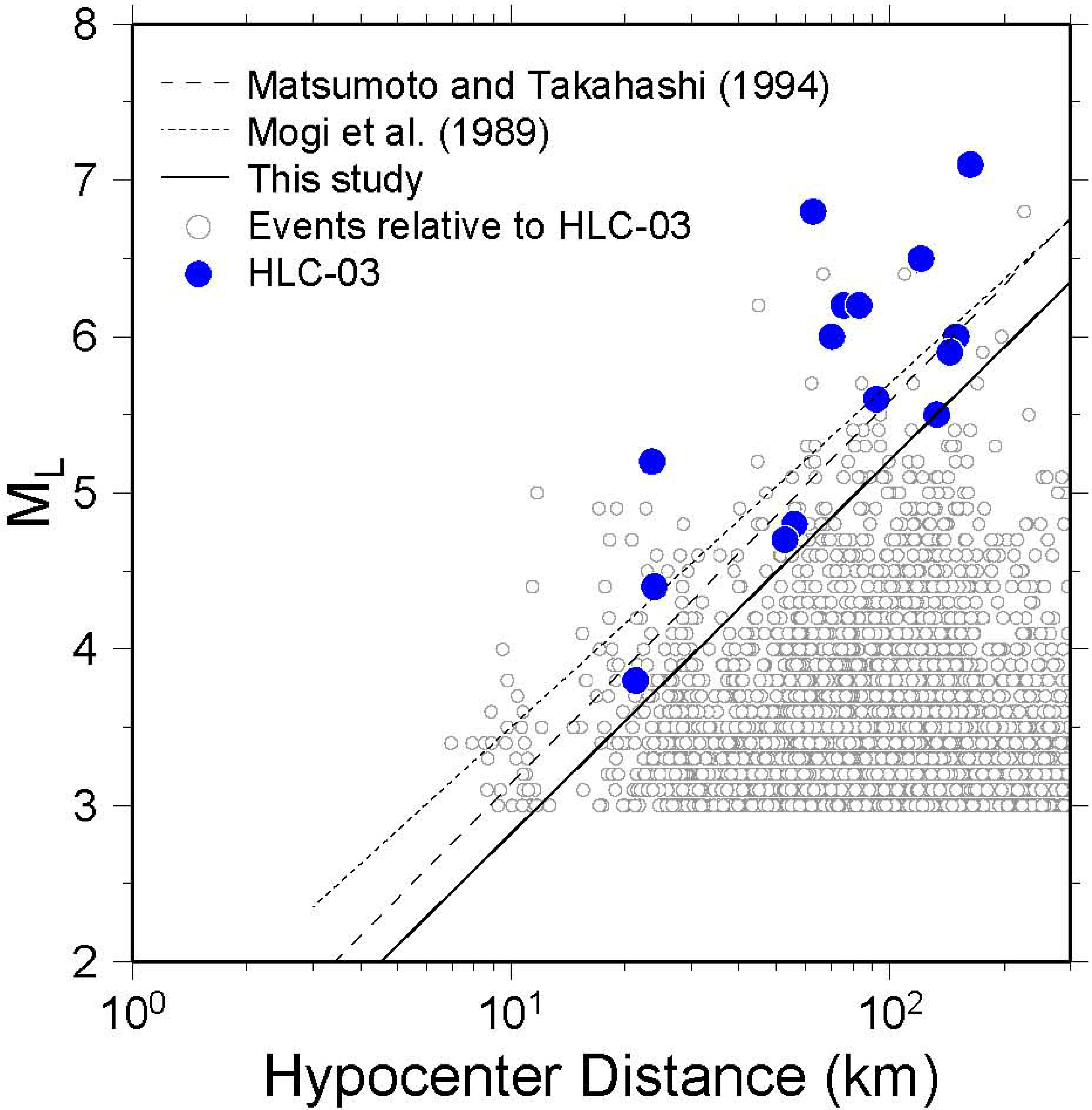
3 =< M < 4
4 =< M < 5
5 =< M < 6
6 =< M < 7
7 =< M
HLC-03
HLC-05
26°
25°
24°
23°
22°
21°
119°
120°
121°
122°
123°

Empirical Equation

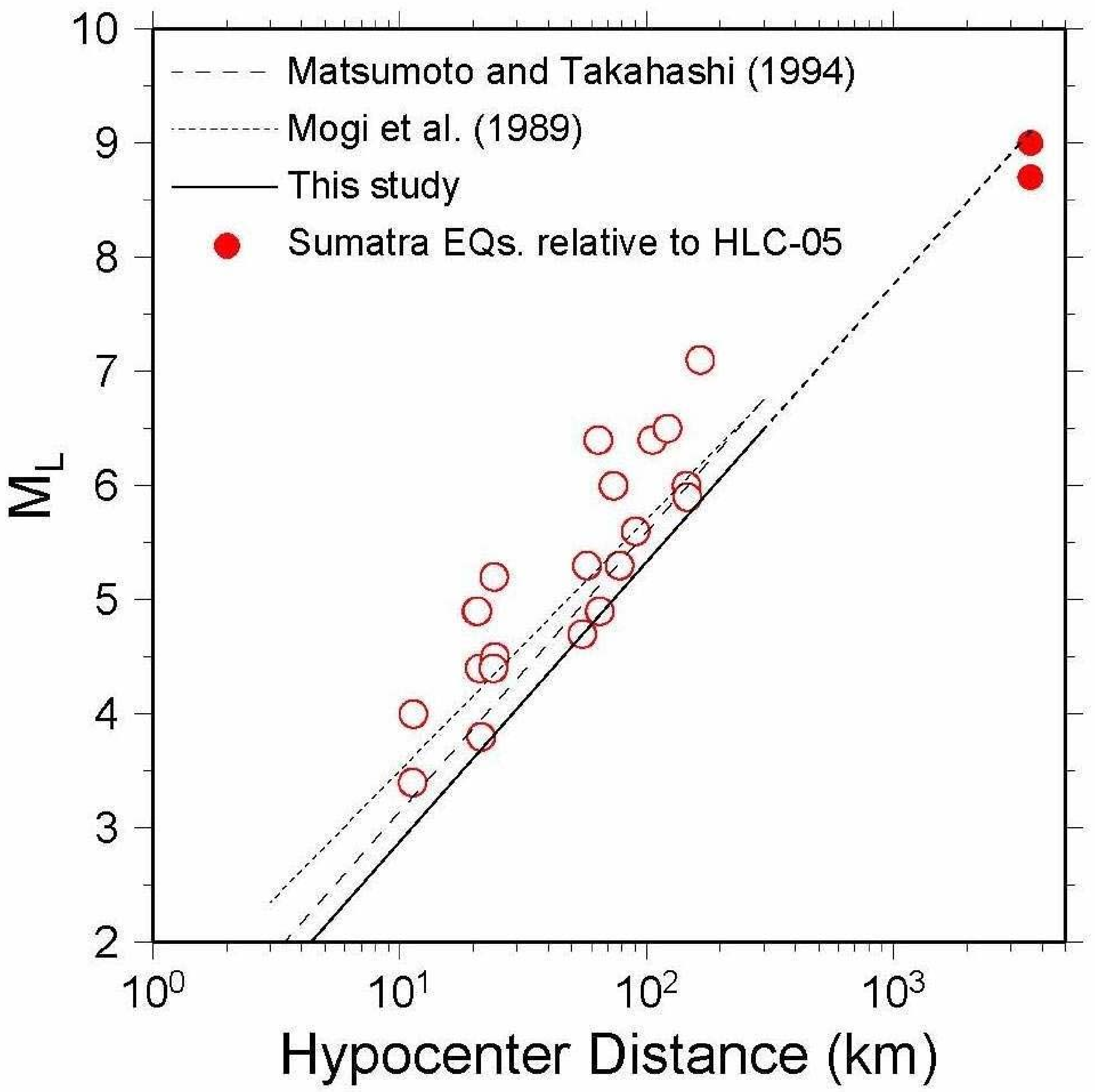
- Matsumoto and Takahashi (1994)
  - $M \geqq 0.69 + 2.45\log10(D)$
  - where M and D are the earthquake magnitude and hypocentral distance, respectively.
- Mogi et al. (1989)
  - $M \geqq 1.3 + 2.2\log10(D)$



$M \geqq 0.43 + 2.39\log10(D)$ --(3)



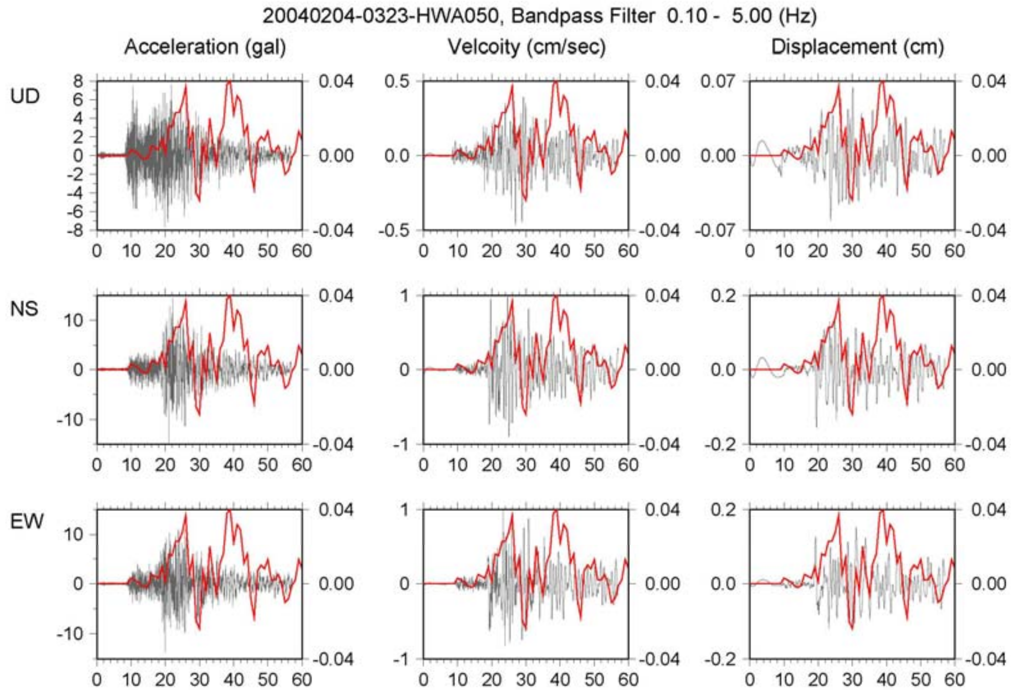
$M \geqq 0.43 + 2.39\log10(D)$ --(3)

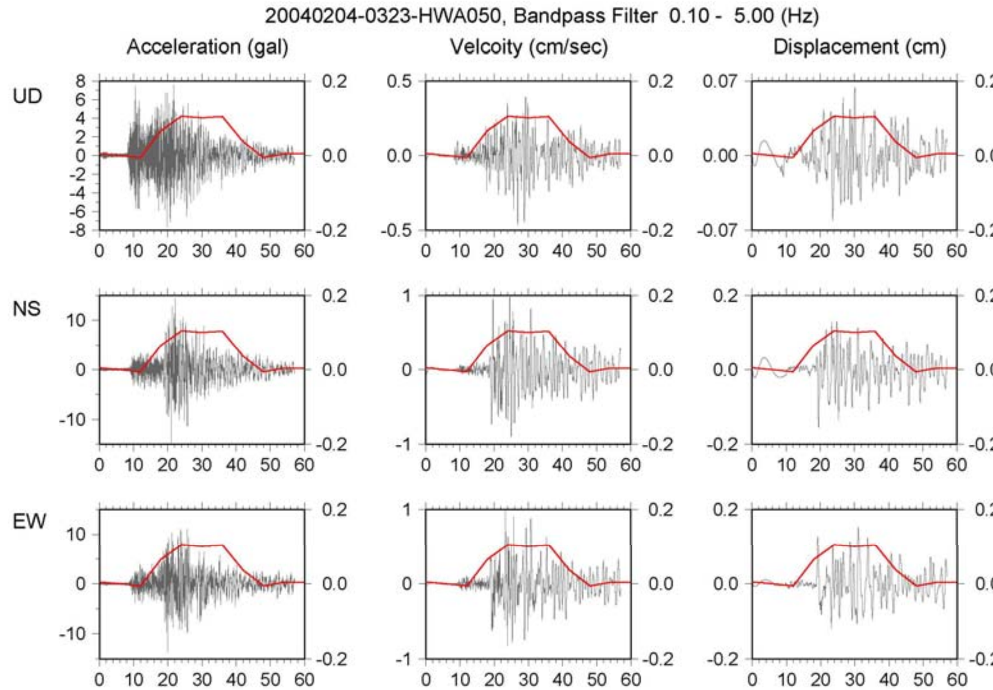


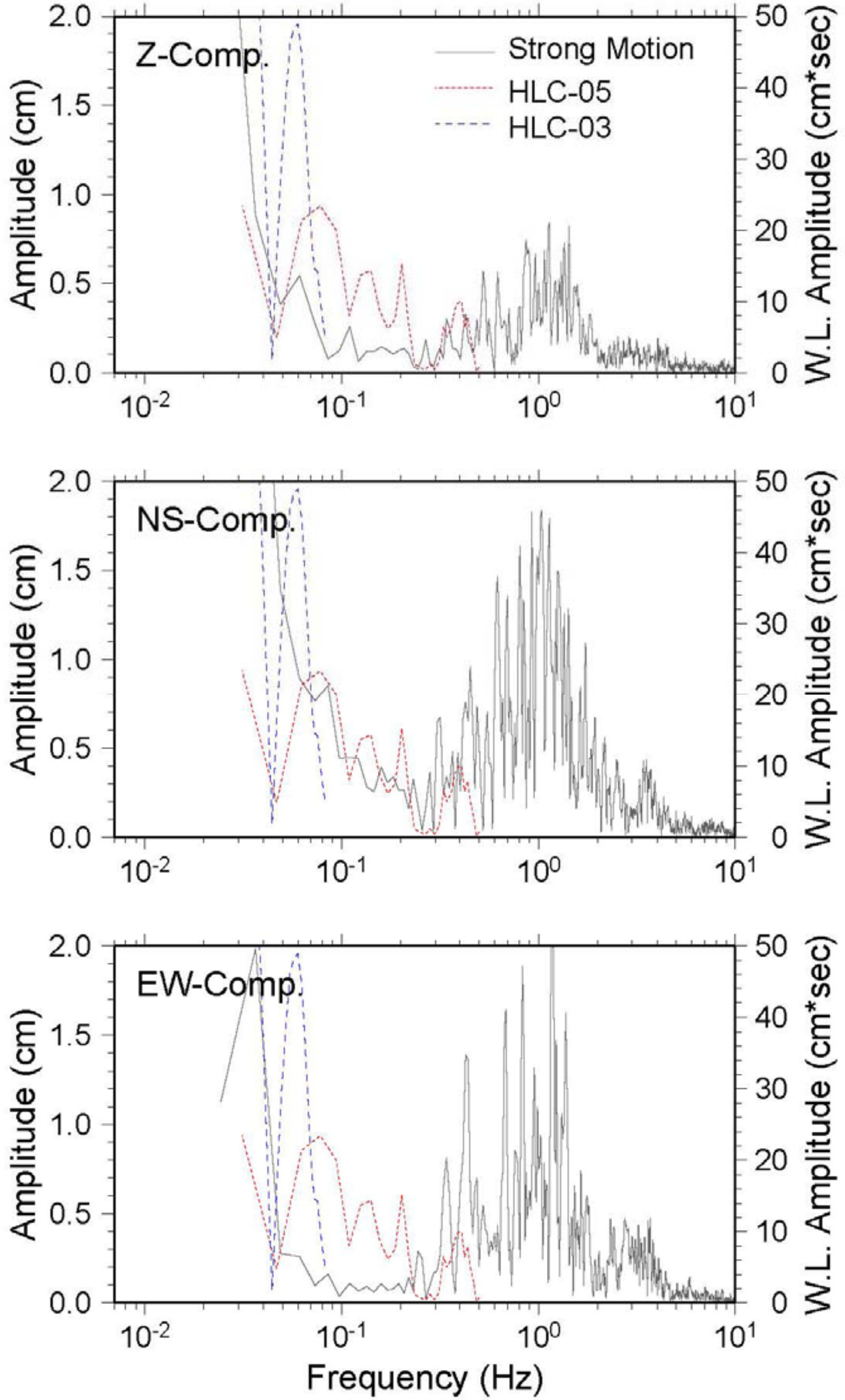
$M \geqq 0.43 + 2.39 \log 10(D)$ --(3)

Water level fluctuations

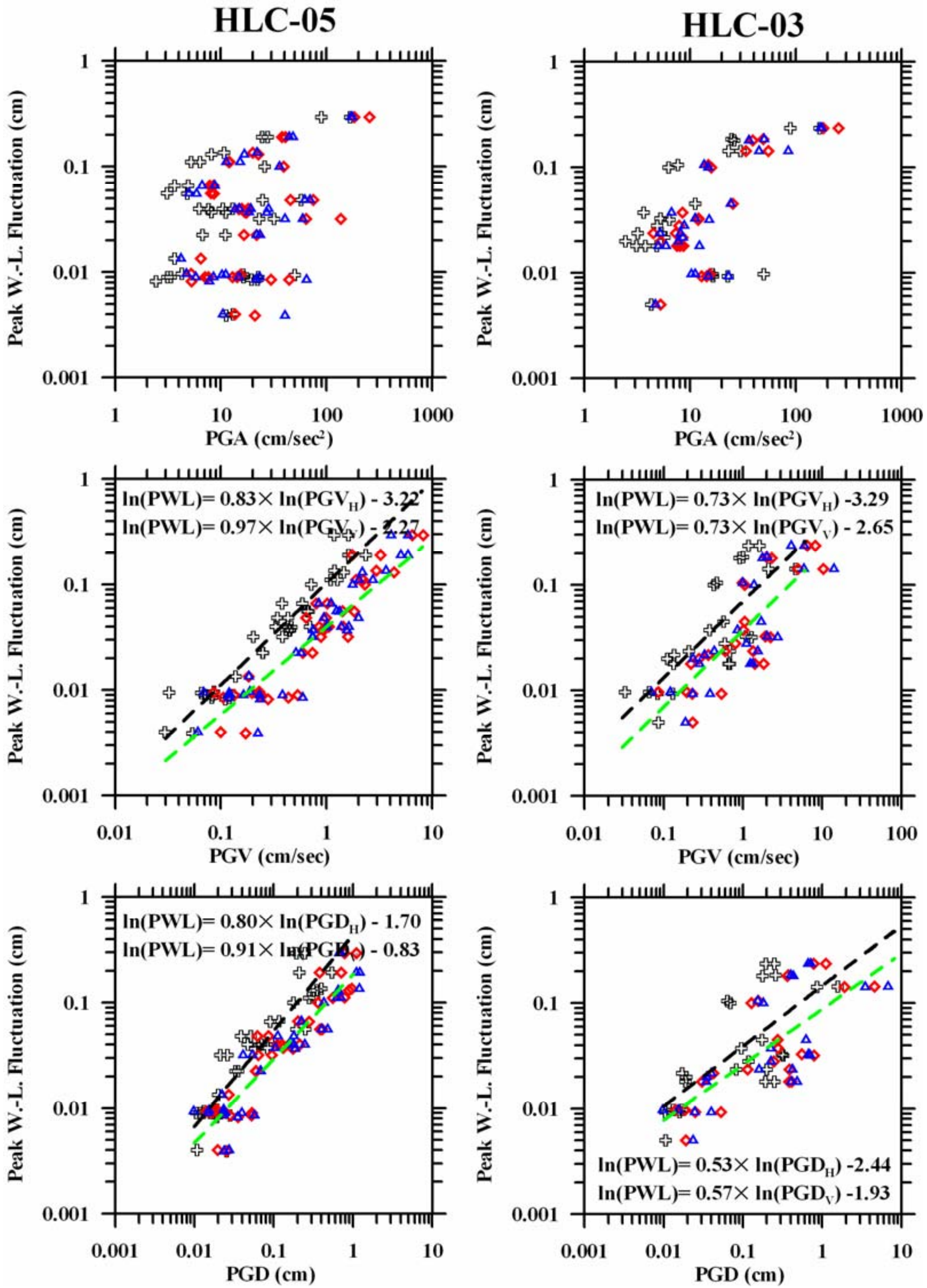
- **Induced by local earthquakes**
  - Waterlevel：HLC03 and HLC-05
  - Seismograms：HWA061(CWB) and HWA050(CWB)
- **Induced by Distance earthquakes**
  - Waterlevel：HLC03 and HLC-05
  - Seismograms：NACB(BATs)


20040204-0323-HWA050, Bandpass Filter 0.10 - 5.00 (Hz)
Acceleration (gal)
Velcoity (cm/sec)
Displacement (cm)
UD
NS
EW

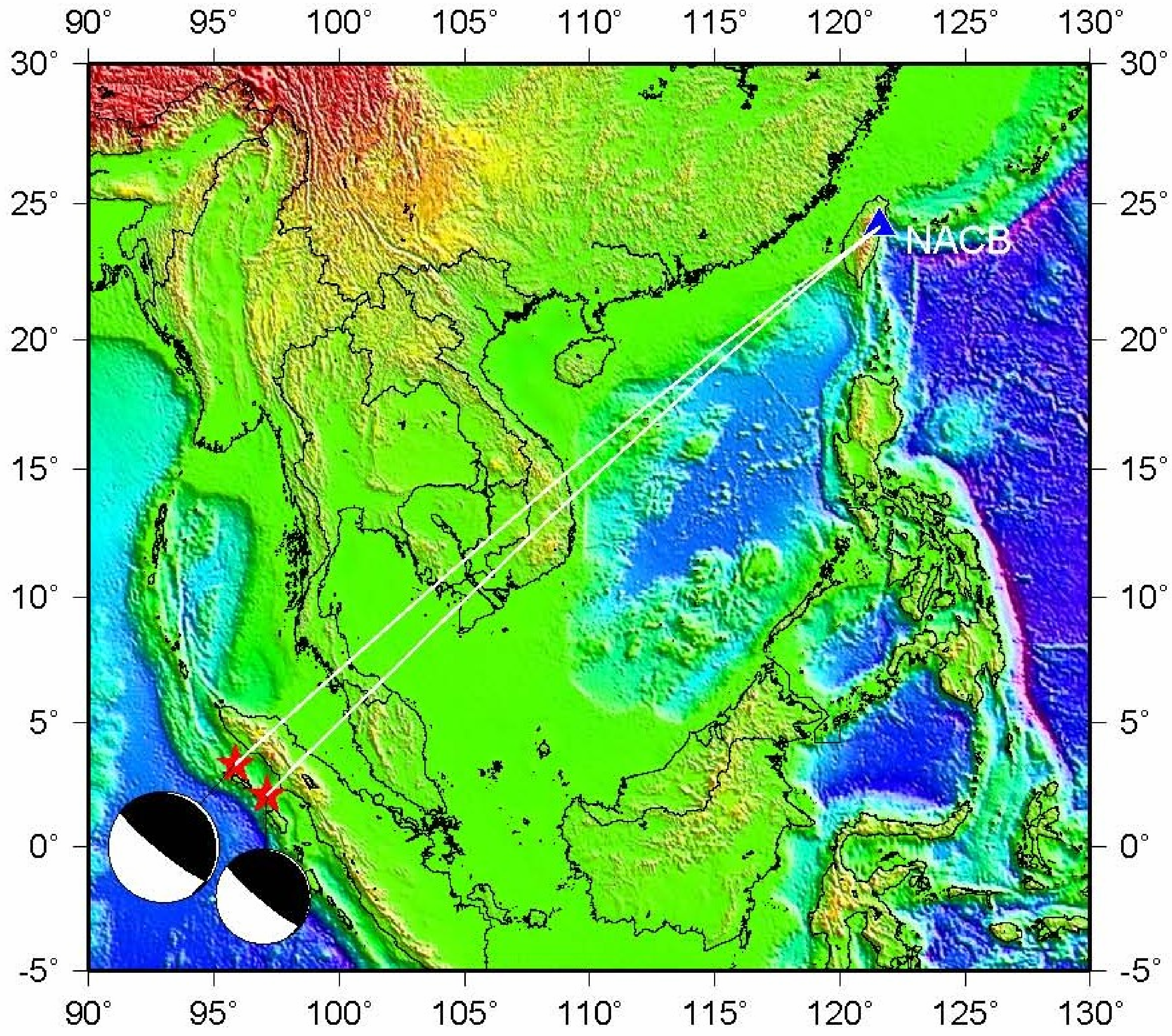

20040204-0323-HWA050, Bandpass Filter 0.10 - 5.00 (Hz)
Acceleration (gal)
Velcoity (cm/sec)
Displacement (cm)
UD
NS
EW

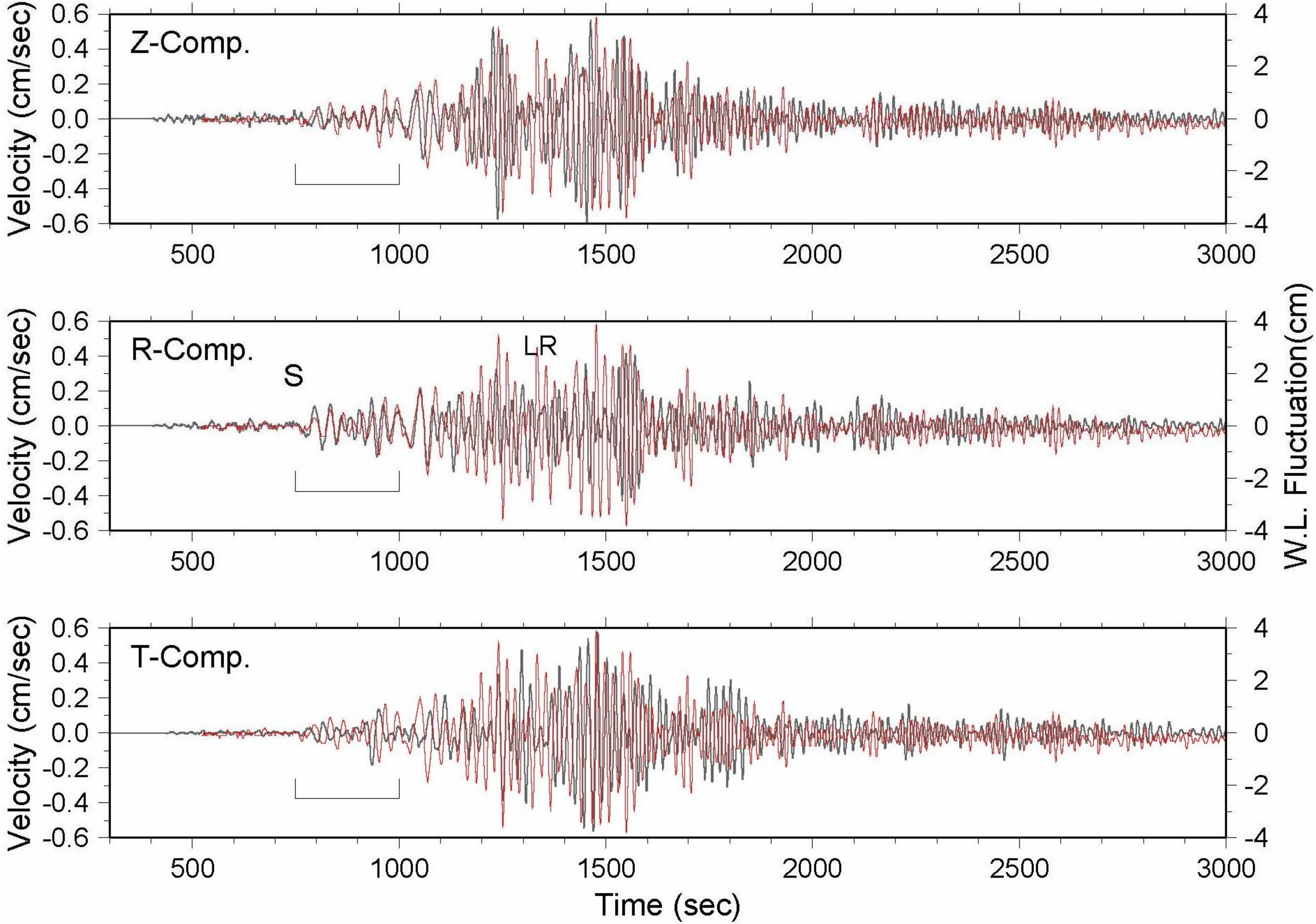


Z-Comp.
NS-Comp.
EW-Comp.
Strong Motion
HLC-05
HLC-03
Amplitude (cm)
W.L. Amplitude (cm*sec)
Frequency (Hz)

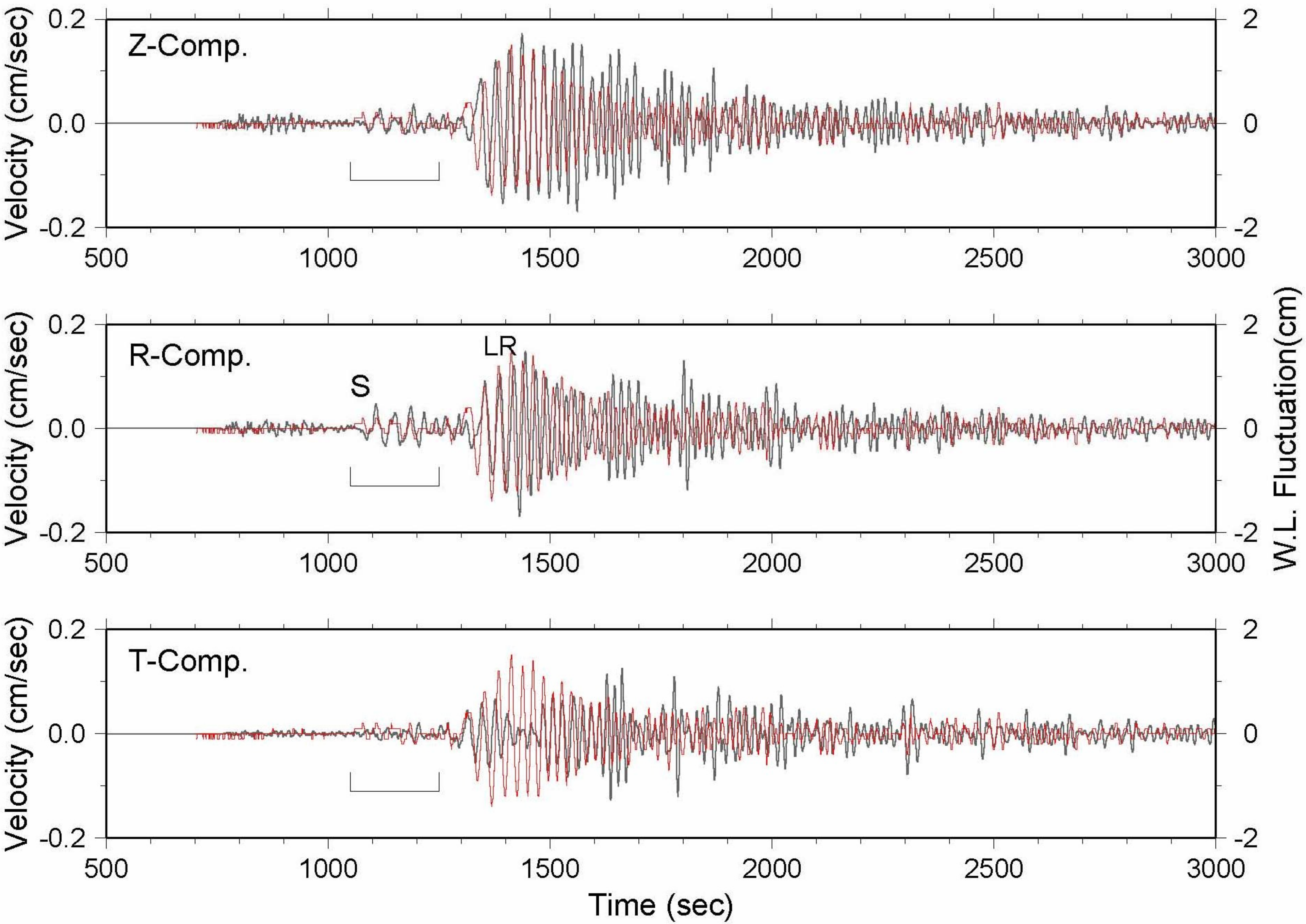


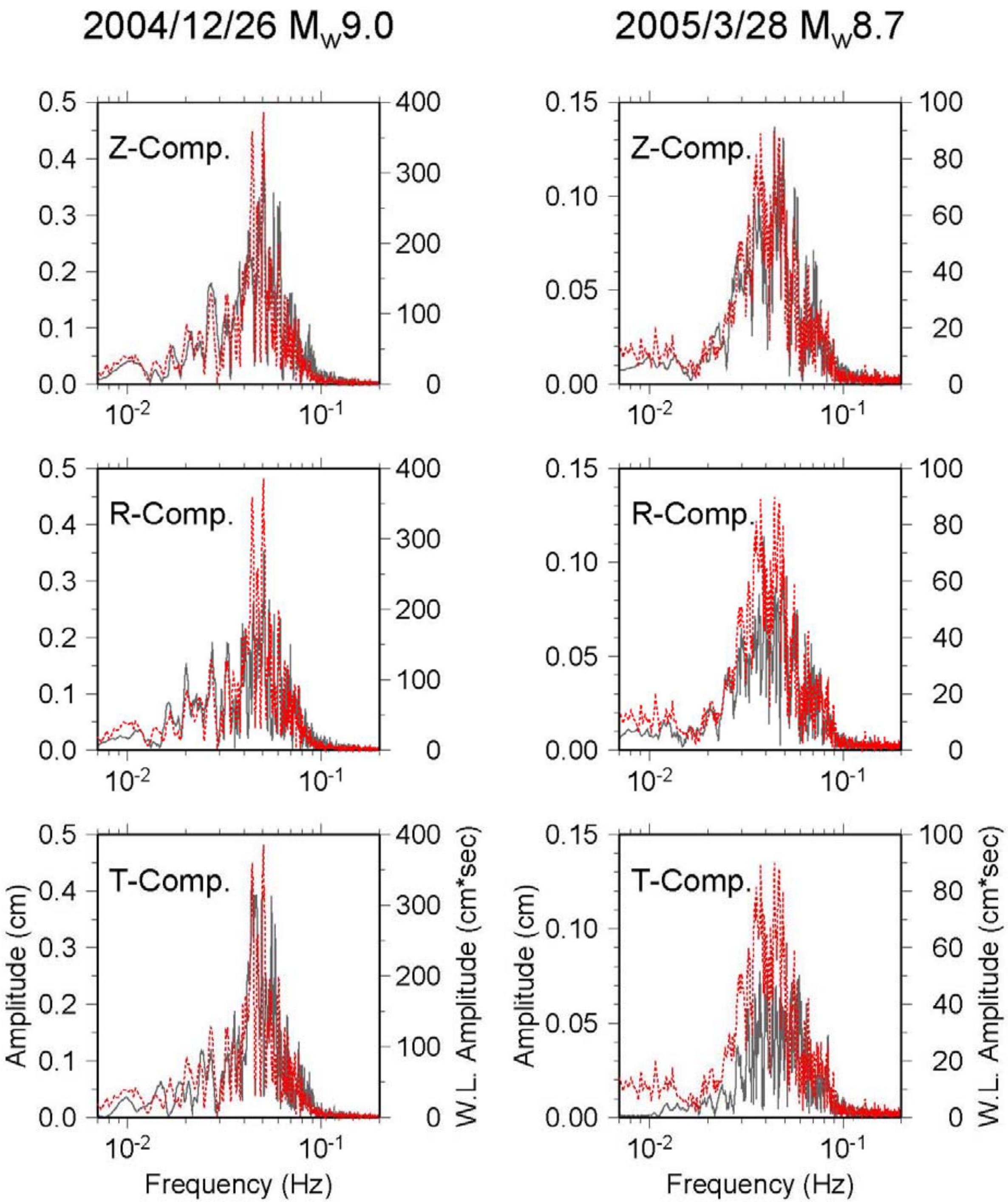
HLC-05
HLC-03
Peak W.-L. Fluctuation (cm)
PGA (cm/sec²)
PGV (cm/sec)
PGD (cm)
ln(PWL)= 0.83× ln(PGV_H) - 3.22
ln(PWL)= 0.97× ln(PGV_V) - 2.27
ln(PWL)= 0.73× ln(PGV_H) -3.29
ln(PWL)= 0.73× ln(PGV_V) - 2.65
ln(PWL)= 0.80× ln(PGD_H) - 1.70
ln(PWL)= 0.91× ln(PGD_V) - 0.83
ln(PWL)= 0.53× ln(PGD_H) -2.44
ln(PWL)= 0.57× ln(PGD_V) -1.93


90°
95°
100°
105°
110°
115°
120°
125°
130°
30°
25°
20°
15°
10°
5°
0°
-5°
NACB

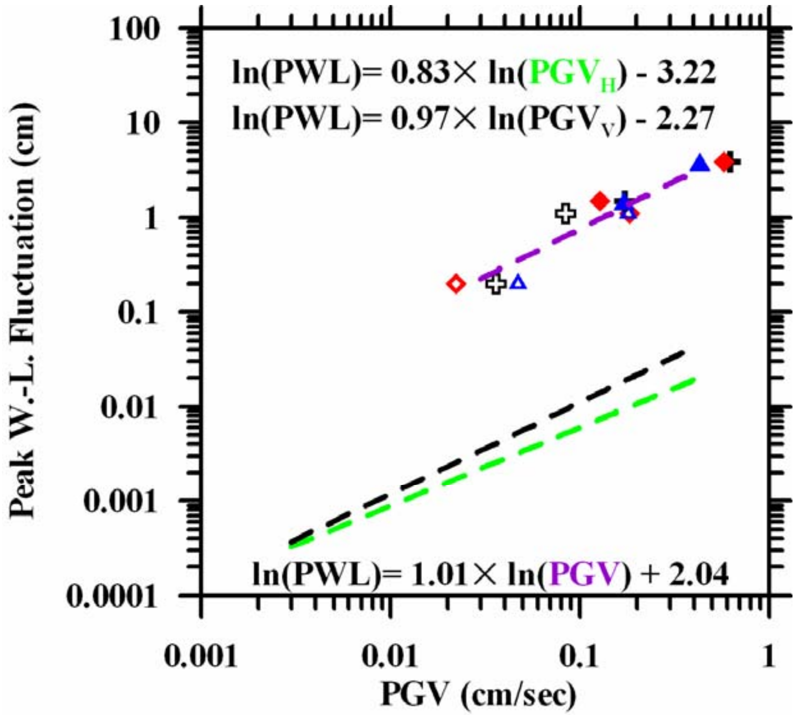


Z-Comp.
R-Comp.
T-Comp.
S
LR
Velocity (cm/sec)
W.L. Fluctuation(cm)
Time (sec)
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
4
2
0
-2
-4
500
1000
1500
2000
2500
3000

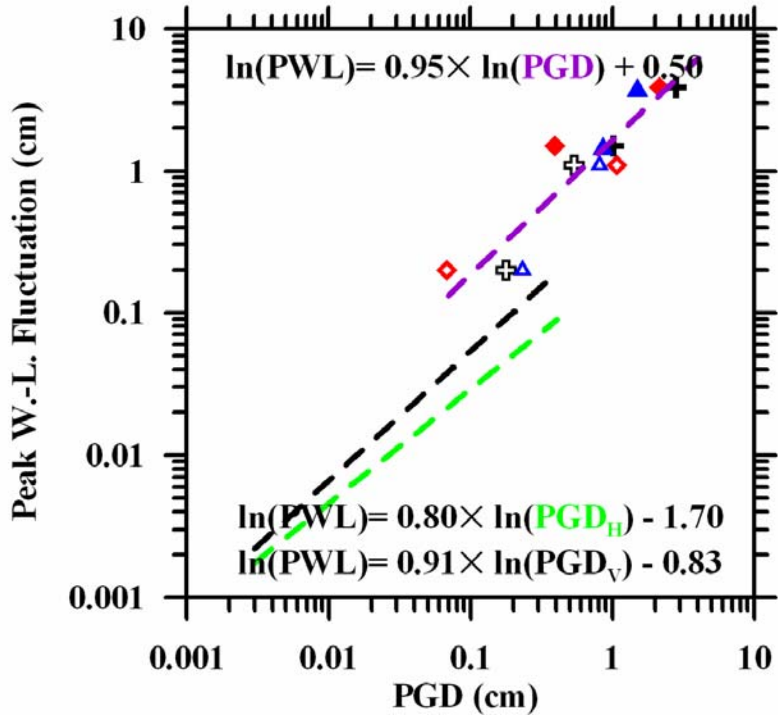

Z-Comp.
R-Comp.
T-Comp.
S
LR
Velocity (cm/sec)
W.L. Fluctuation(cm)
Time (sec)
0.2
0.0
-0.2
2
0
-2
500
1000
1500
2000
2500
3000



2004/12/26 M_w9.0
2005/3/28 M_w8.7
Z-Comp.
R-Comp.
T-Comp.
Amplitude (cm)
W.L. Amplitude (cm*sec)
Frequency (Hz)



ln(PWL)= 0.83× ln(PGV_H) - 3.22
ln(PWL)= 0.97× ln(PGV_V) - 2.27
ln(PWL)= 1.01× ln(PGV) + 2.04
Peak W.-L. Fluctuation (cm)
PGV (cm/sec)
100
10
1
0.1
0.01
0.001
0.0001
0.001
0.01
0.1
1



ln(PWL)= 0.95× ln(PGD) + 0.50
ln(PWL)= 0.80× ln(PGD_H) - 1.70
ln(PWL)= 0.91× ln(PGD_V) - 0.83
Peak W.-L. Fluctuation (cm)
PGD (cm)
10
1
0.1
0.01
0.001
0.001
0.01
0.1
1
10

1. Brodsky et al. (2003) shows that the amplification x(*f*), to be the ratio of water level changes and velocity seismograms, is function of frequency and can be formulated as

$$\chi(f) = A\Gamma\left|1 - \frac{4\pi^2 Hf^2}{g} + \frac{\pi}{2}\left(\frac{r}{l}\right)^2\sqrt{\frac{\pi f}{KS_s}}(1+i)\right|^{-1}$$

where *A* is the ratio of the dilatational strain to the vertical ground velocity, G is tidal response (Rojstaczer and Agnew, 1989), *f* is frequency, *H* is the water level height, *r* is the well bore radius, *l* is the fracture length, *Ss* is hydraulic conductivity, and *K* is specific storage.

2. For the case of NVIP-3 well in America (Brodsky et al., 2003), it provides that the x(*f*) values reach a value of about 240 at frequency less than 0.1 Hz and gradually decay to about 40 at frequency greater than 0.1 Hz. Most of the parameters can be obtained from the results of the pumping test. However, the detailed information is not available for the HLC-05 well, because the preliminary purpose of installation of the well is not for monitoring the water level changes. Hence, the only two known parameters are the *H* and *r* values. Nevertheless, the rest of the unknown parameter can be considered to be constant for a specified well during a specified time, and the c(*f*) curves will resemble the computation of Brodsky et al. (2003), for which the seismic waves with high frequency contents resulting in smaller c(*f*) values than those with low frequency contents. In general, distance earthquake contains longer period of seismic waves than the local ones because of the filtration of the path (Fig. 6 and Fig. 9). Hence, the PWL values can be generated larger values by the distance earthquakes than by the local ones

Summary

1. In this study we observe that the earthquake-related water level changes, which depend on the earthquake magnitudes and hypocenters, are more susceptible than other well observations from Matsumoto and Takahashi (1994) and Mogi et al. (1989).
2. A new equation formulated as Equation (3) to fit in with the data of both the HLC-05 and the HLC-03 well over the monitoring period. As follows

$$M \geqq 0.43 + 2.39\log10(D)$$

3. It seems that the PGV of horizontal component could be more appropriate for correlating the peak water level fluctuation.
4. The relation between PGA and PWL not found any good mode of fitting.

Thanks for
your attention