Rotation Motion and its Effects on Near-Fault Ground Motions

Hung-Chie Chiu
Institute of Earth Sciences, Academia Sinica

Translation & Rotation Motions

A full description of a rigid body motion requires 3D translation motions and three components of rotation motions (roll, pitch and yaw)

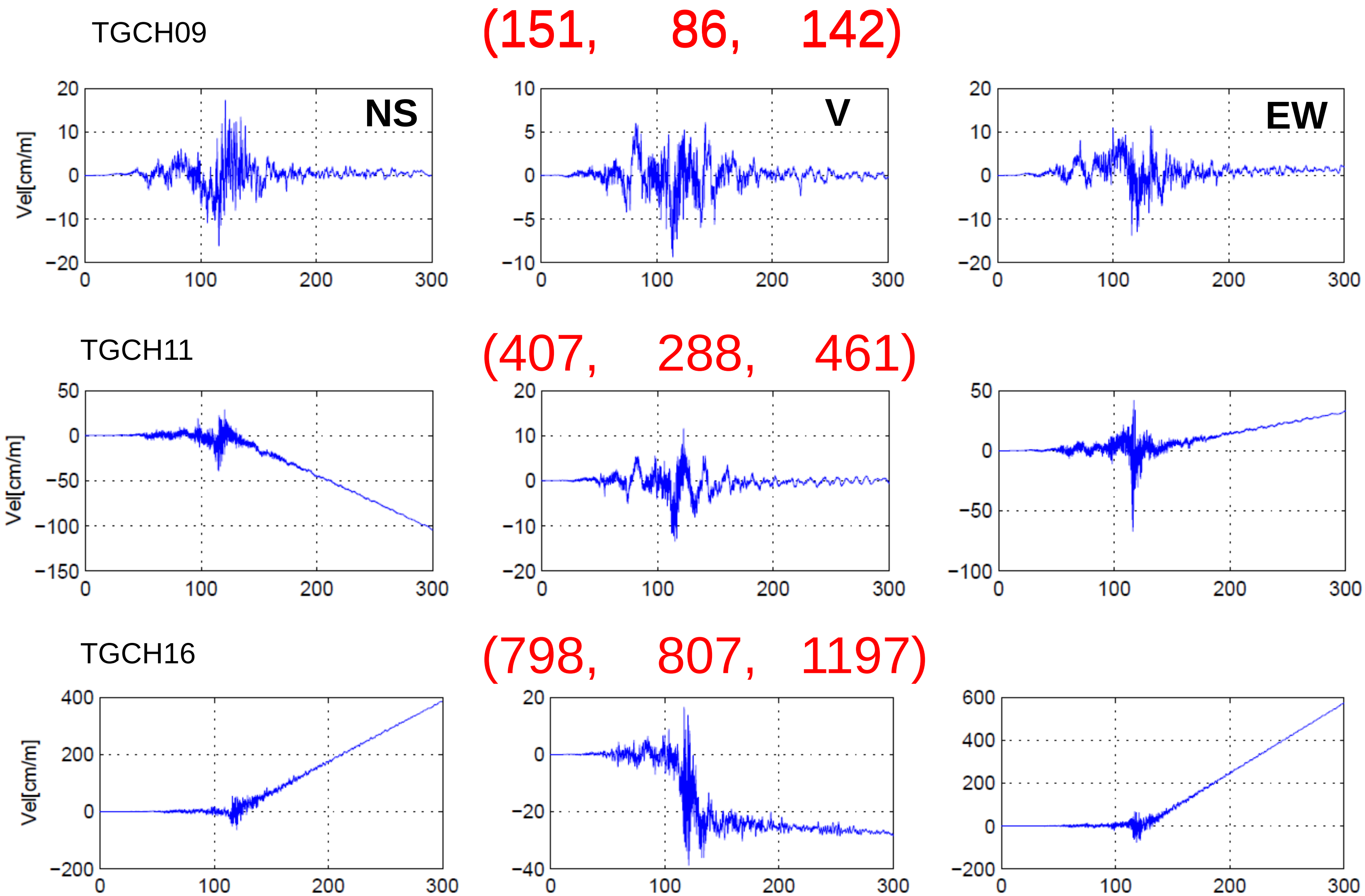
Rotation and translation motions are 6 independent measures, But they have a close connection, e.g.

- The amplitude of rotation motions is in propotional to translation motion in log-log scale,
- Rotation motion might contaminate the translation motion,
- Rotation motions might introduce additional signals to translation motions.

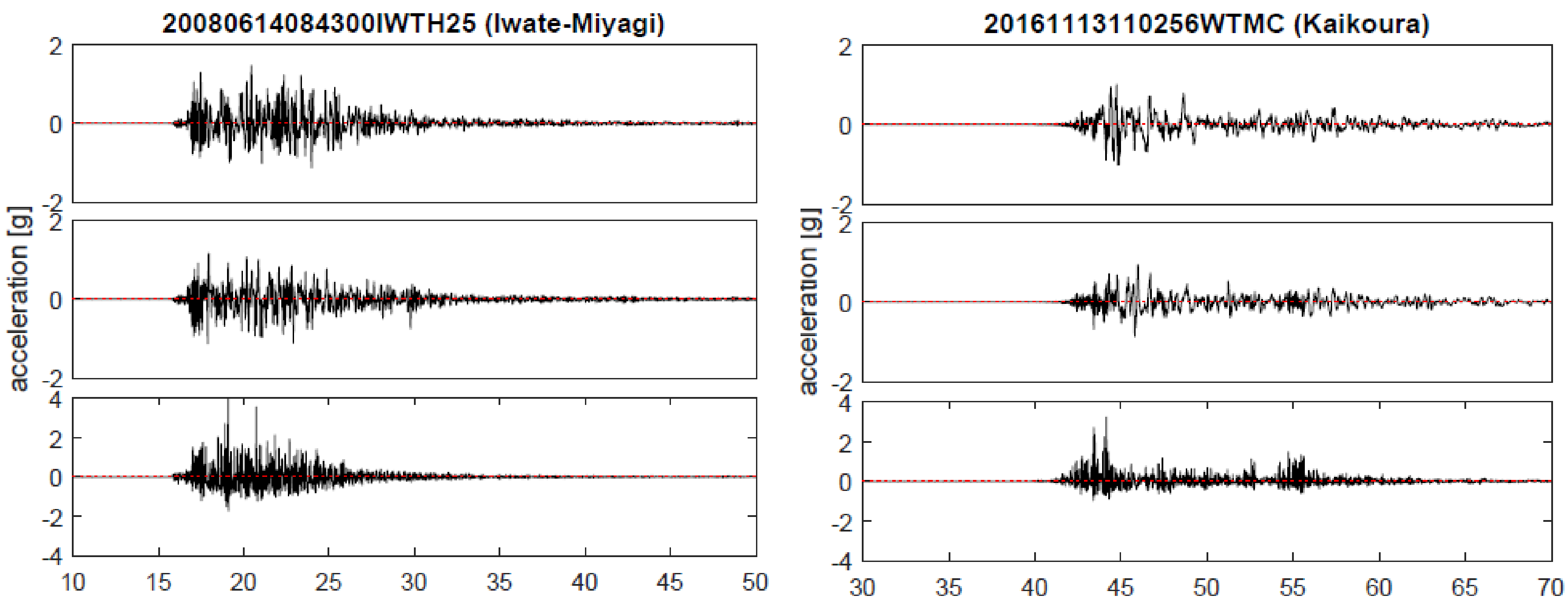
Rotation motion is not cosidered in most seismic analyses yet.

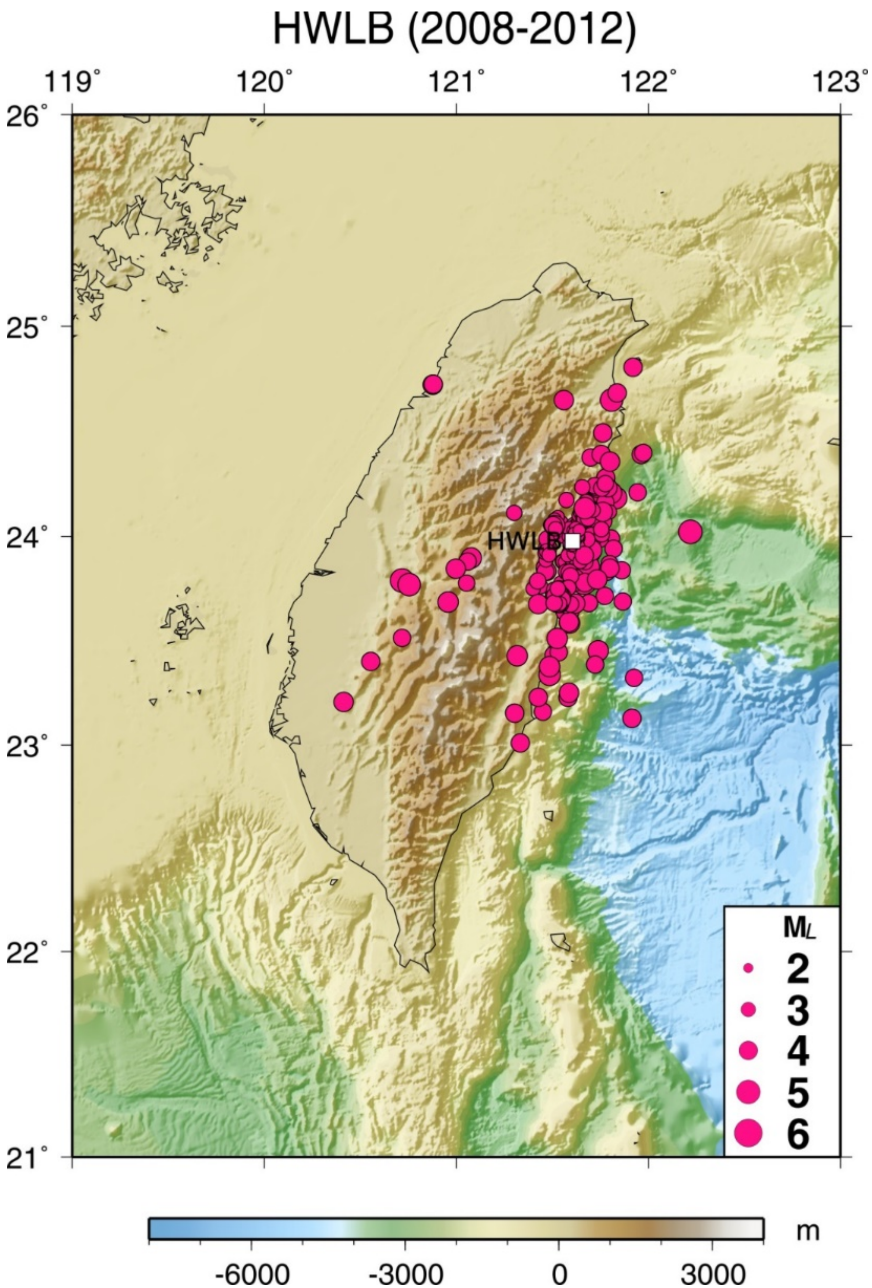
Rotation motions plays an important role in near-fault/extra large ground motions

Baseline Drift of Integrated Velocity Waveforms

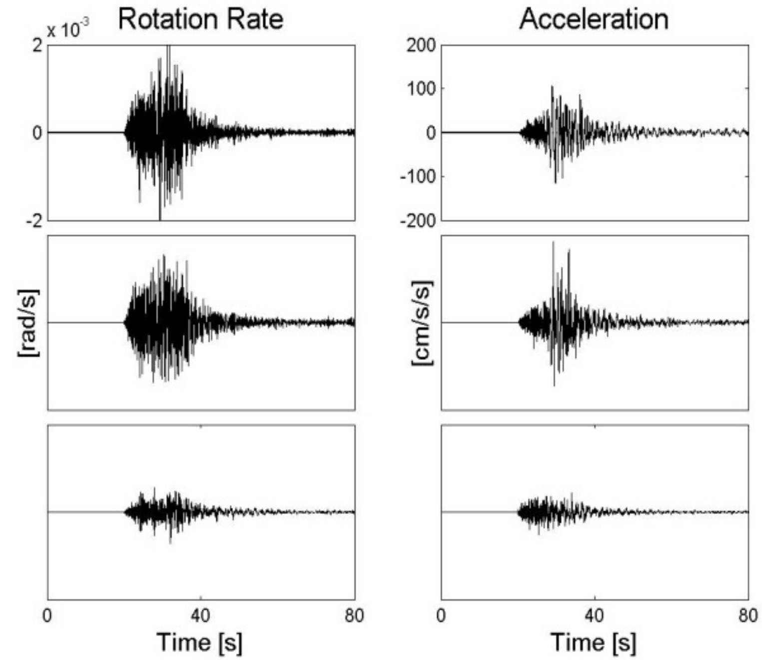


Asymmetric Extraordinary Large Waveform in the Vertical Component

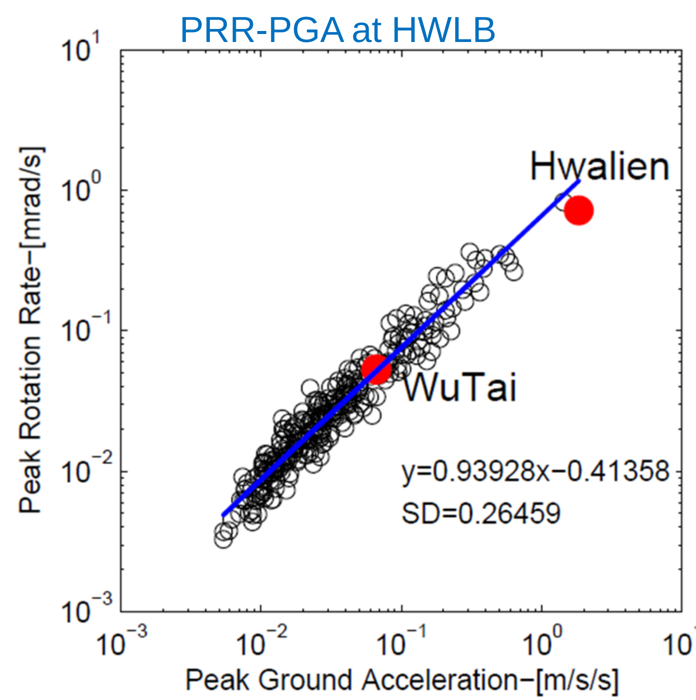




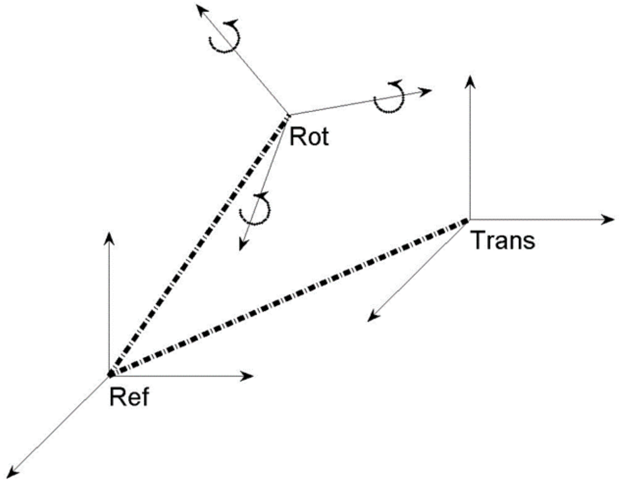
HWLB (2008-2012)
119°
120°
121°
122°
123°
26°
25°
24°
23°
22°
21°
HWLB
M_L
2
3
4
5
6
-6000
-3000
0
3000
m



Rotation Rate
Acceleration
x 10^-3
2
0
-2
200
100
0
-100
-200
[rad/s]
[cm/s/s]
0
40
80
Time [s]
0
40
80
Time [s]

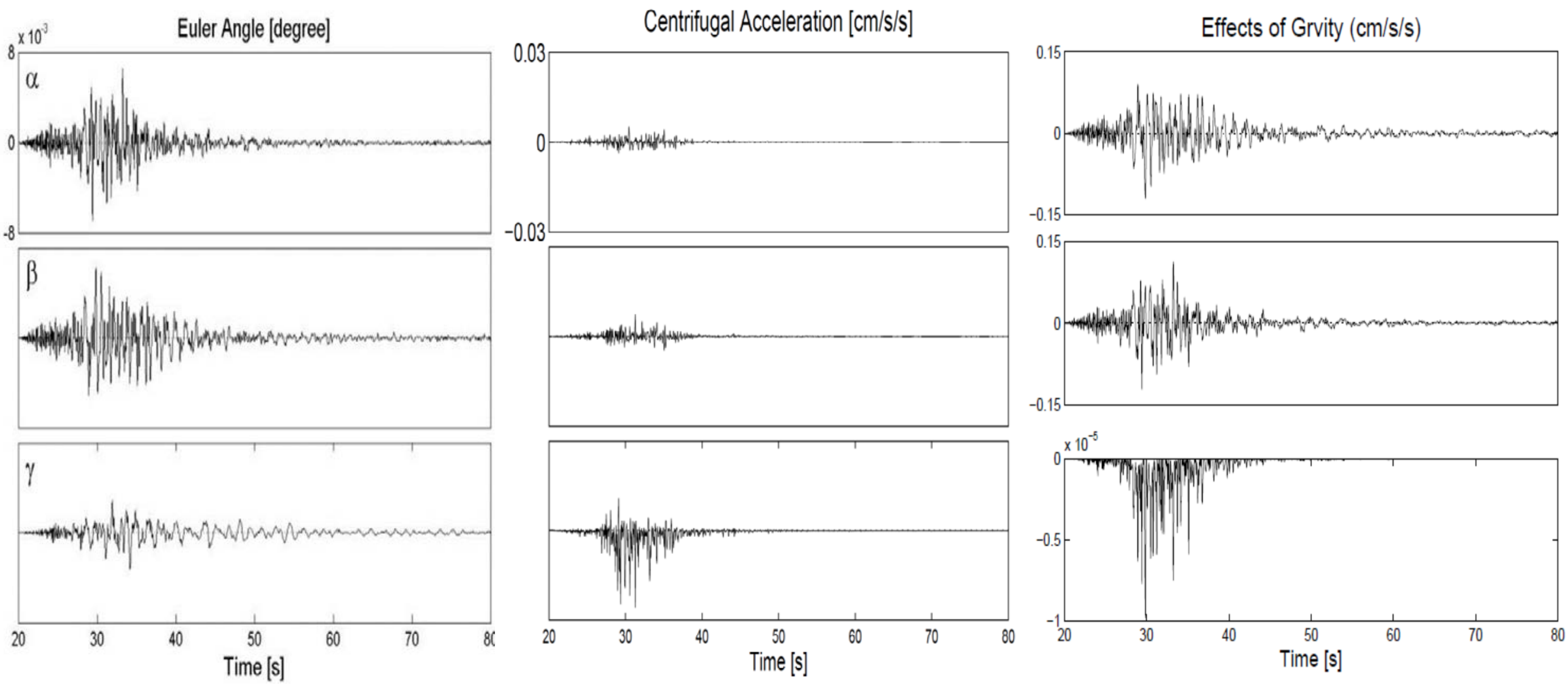


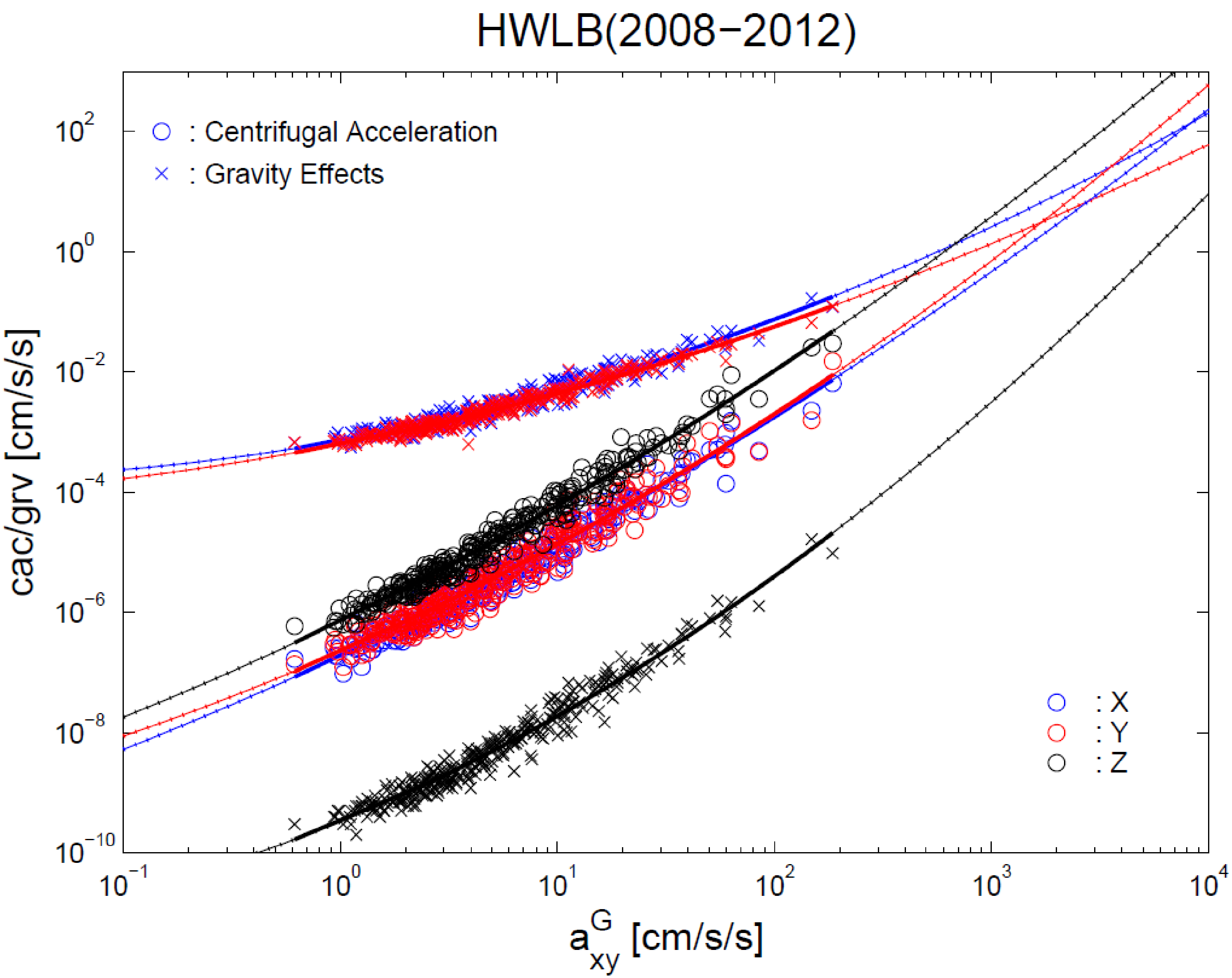
PRR-PGA at HWLB
Peak Rotation Rate−[mrad/s]
Peak Ground Acceleration−[m/s/s]
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
Hwalien
WuTai
y=0.93928x−0.41358
SD=0.26459



$$\ddot{U}^R(t) = A^R(t) - \dot{\Theta}^R(t) \times \dot{U}^R(t) - G^R(t)$$

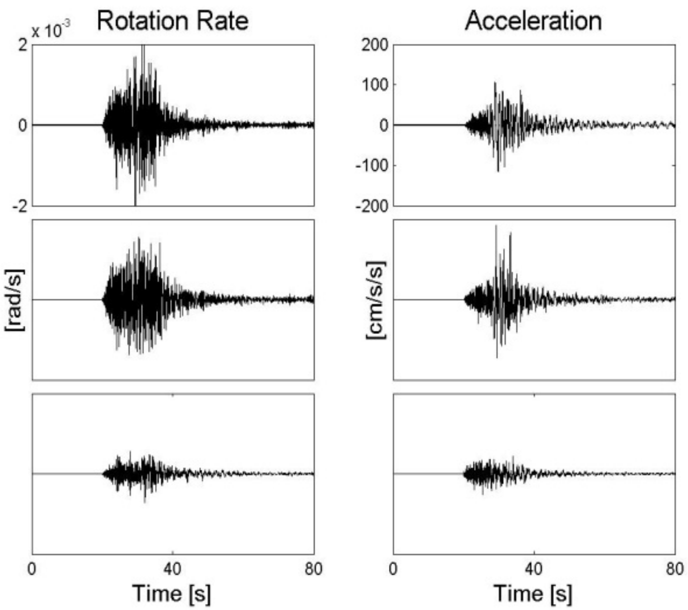
$$\frac{d\dot{U}^R(t)}{dt} = A^R(t) - \dot{\Theta}^R(t) \times \dot{U}^R(t) - G^R(t)$$



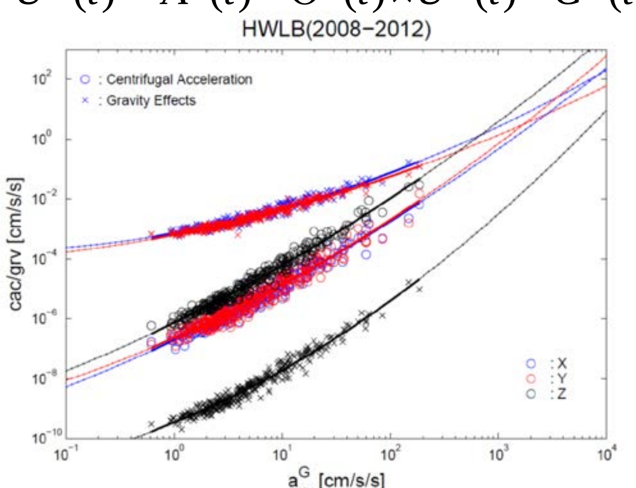

HWLB(2008−2012)
: Centrifugal Acceleration
: Gravity Effects
: X
: Y
: Z
cac/grv [cm/s/s]
a_{xy}^{G} [cm/s/s]
10^{2}
10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}

Simulation with Rotational Motions

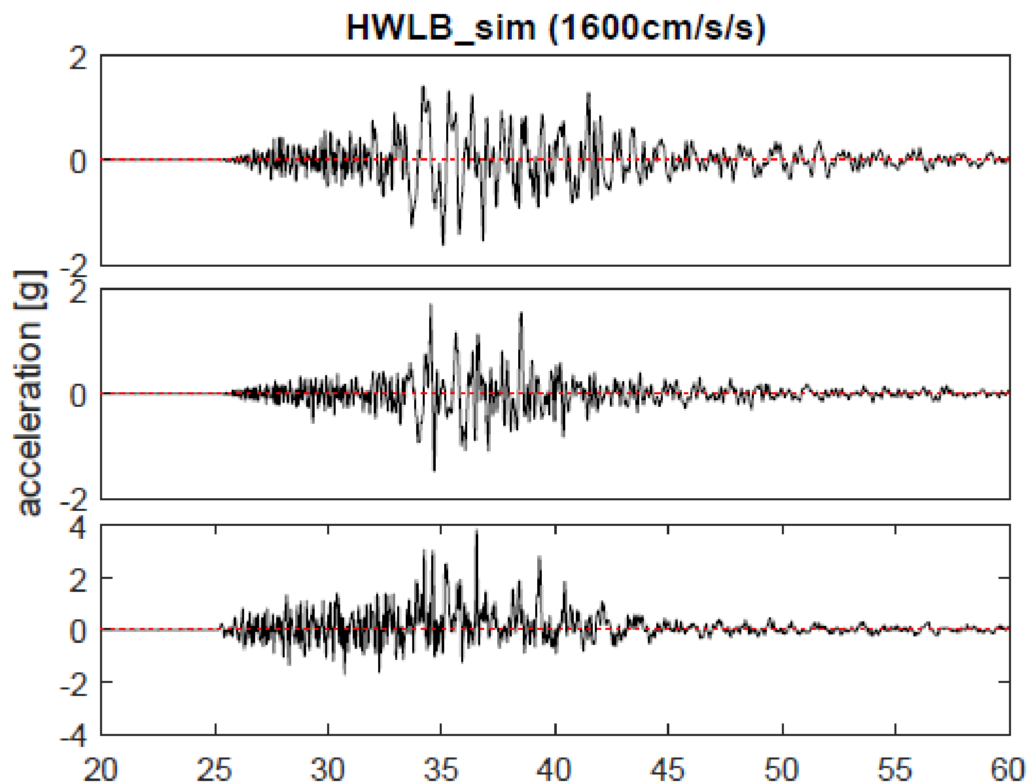
Observed

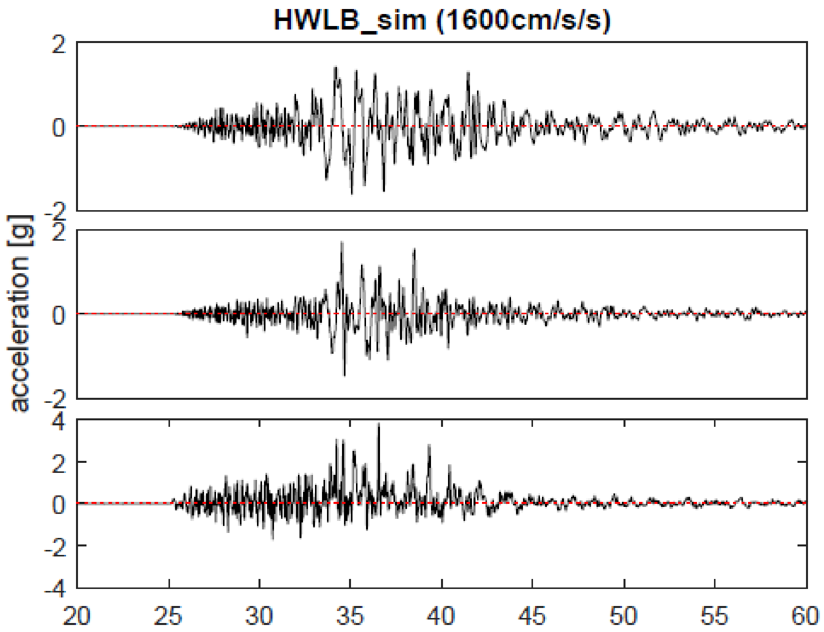


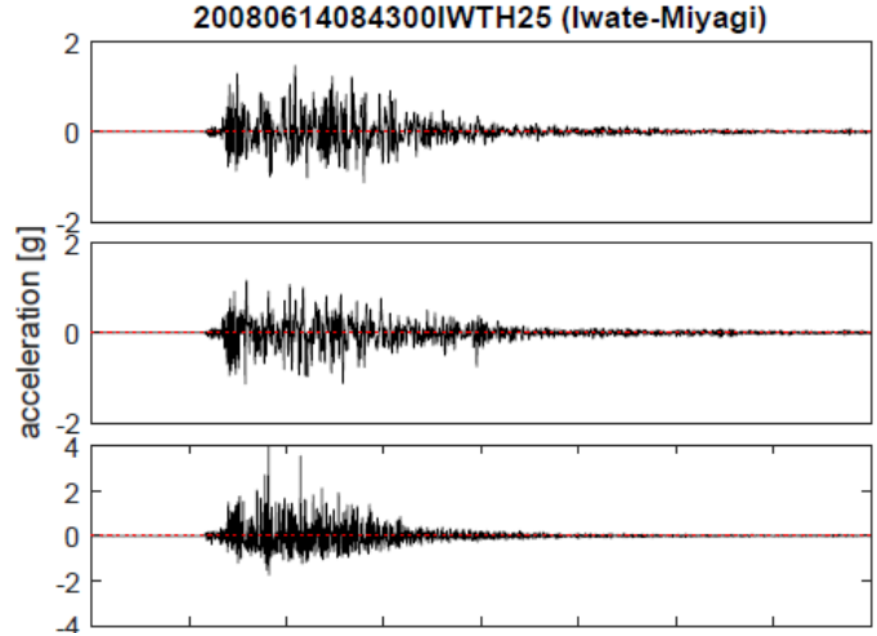
$$\ddot{U}^R(t) = A^R(t) - \dot{\Theta}^R(t) \times \dot{U}^R(t) - G^R(t)$$

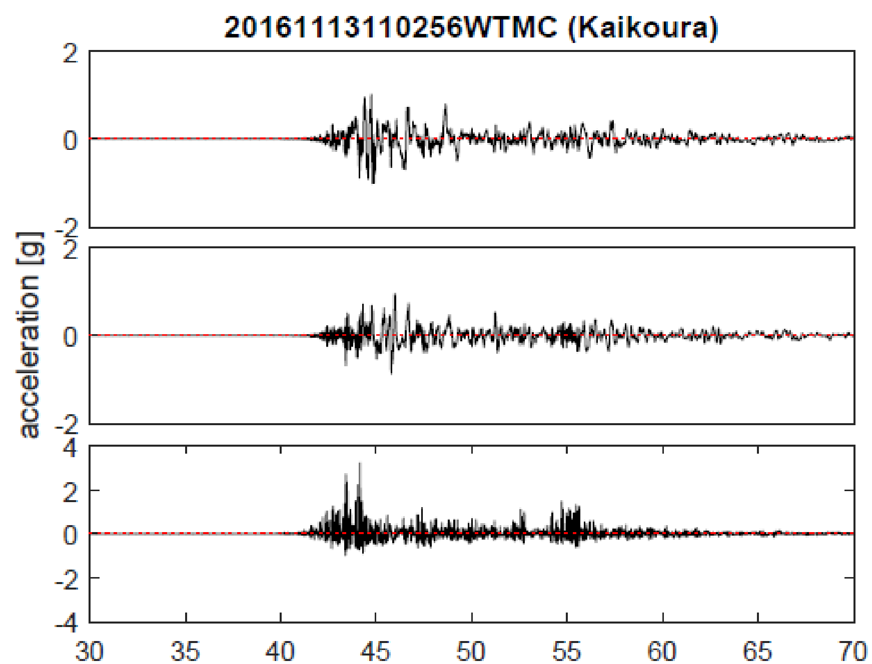


Synthetic accelerograms




HWLB_sim (1600cm/s/s)
acceleration [g]
2
0
-2
4
-4
20
25
30
35
40
45
50
55
60


20080614084300IWTH25 (Iwate-Miyagi)
acceleration [g]
2
0
-2
4
-4


20161113110256WTMC (Kaikoura)
acceleration [g]
2
0
-2
4
-4
30
35
40
45
50
55
60
65
70