The 2017 update of TEM PSHA

Ya-Ting Lee\textsuperscript{1}, Yu-Ju Wang\textsuperscript{2}, Chung-Han Chan\textsuperscript{3}, J Bruce H Shyu\textsuperscript{4}, Ruey-Juin Rau\textsuperscript{5} and Kuo-Fong Ma\textsuperscript{1}

\textsuperscript{1}Department of Earth Sciences, National Central University
\textsuperscript{2} Institute of Nuclear Energy Research, Taiwan Power Company, Taipei City, Taiwan, R.O.C.
\textsuperscript{3}Earth Observatory Of Singapore, Nanyang Technological University
Damaging Earthquakes in Taiwan since 1700s

- 1935/04/21 新竹台中地震 (M7.1)
- 1867/12/18 基隆地震 (M7.0)
- 1909/04/15 (M7.3)
- 1920/06/06 (M8.0)
- 2002/03/31 331地震 (M6.8)
- 1815/10/13 花蓮地震 (M7.7)
- 1959/08/15 恆春地震 (M7.1)
- 1996/09/15 蘭嶼地震 (M7.1)

1736/01/30 台南地震 (M6.5)
1792/08/09 嘉義地震 (M7.1)
1839/06/27 嘉義地震 (M6.5)
1906/03/17 梅山地震 (M7.1)
1941/12/17 中埔地震 (M7.1)
1964/01/18 白河地震 (M6.1)
1862/06/07 台南地震 (M7.0)
1946/12/05 新化地震 (M6.1)
2016/02/06 美濃地震 (M6.6)
2006/12/26 屏東地震 (M7.0)
2015 TEM Hazard Maps
(recurrence interval: 475 years)

The seismic hazard maps in 50 years with 10% exceedance probability

Hazard maps of PGA, Sa at 0.3 s (SA-0.3), and Sa at 1.0 s (SA-1.0) for 10% probability of exceedance in 50 years (corresponding to a recurrence interval of 475 years) based on the parameters of TEM seismogenic structures

*based on TEM seismogenic structures*
source models of 2015 Taiwan PSHA

**shallow sources**

Earthquakes without specific fault sources  
(SinoTech Consultant Inc.)

Earthquakes with specific fault sources  
TEM(Shyu et al., 2014)

**subduction zone sources**

inter-/intra-slab earthquake  
(SinoTech Consultant Inc.)

28 area+38 seismogenic structures
Ground motion Prediction Equations

- **Crustal events:**

\[
\ln(\text{PGA or } Sa) = C_1 + F_1 + C_3 (8.5 - M)^2 + [C_4 + C_5 (M - 6.3)] \ln(\sqrt{R_2 + (e^H)^2} + C_6 F_{NM} + C_7 F_{RV} + C_8 \ln(V_{s30}/1130) \\
\begin{cases} 
F_1 = C_2 (M - 6.3) \text{ where } M \leq 6.3 \\
F_1 = (-HC_5)(M - 6.3) \text{ where } M > 6.3
\end{cases}
\]

\[(\text{Lin, Ph. D. dissertation, 2009})\]

- **Subduction zone (Inter-/intra-slab earthquakes):**

\[
\ln(\text{PGA}) = C_1 + C_2 M + C_3 \ln(R + C_4 e^{C_5 M}) + C_6 H + C_7 Z_t + \ln \varepsilon \\
\ln(Sa) = C_1 + C_2 M + C_3 \ln(R + \alpha_1 e^{\alpha_2 M}) + \alpha_3 H + \alpha_4 Z_t + \ln \varepsilon
\]

\(Z_t=0 \text{ for interface earthquakes}\)
\(Z_t=1 \text{ for intraslab earthquakes}\)

\[(\text{Lin & Lee, BSSA, 2008})\]
2015 TEM Hazard Maps (recurrence interval: 475 years)

- based on TEM seismogenic structures

- Six metropolitan cities
Hazard curves of 6 metropolises
Spectral acceleration of the 6 metropolises

- Sa in Tainan is highest.
- Sa in Taichung is highest.
- Sa in New Taipei City is the third-highest.

Periods < 0.6 sec.

Periods > 0.6 sec.

Periods > 1.0 sec.:
Meinong earthquake

2016/02/06 (M_L = 6.6)
120.54° E, 22.92° N

(Site effect)
Hazard contribution of Meinong earthquake

(a) PGA

(b) SA 0.3

(c) SA 1.0

Contribution (%)
PSHA for Japan, New Zealand, and Taiwan

[Pagani et al. 2016]
Next generation of PSHA

✓ Update high resolution with 500m×500m
✓ Considering site effect
✓ Applying 3D fault geometry of seismogenic structures (on-land)
  – Considering both on-land and offshore faults
  – Considering multiple-segment ruptures (linking of faults, parameter uncertainty)
  – Time dependent PSHA (long term & short term: historical earthquake and the paleo-seismic active fault record, aftershock activity)
Next generation PSHA
Applying 3D fault geometry of seismogenic structures

TEM(Shyu et al., 2017)
2017 Hazard maps for 475 years recurrence interval

With considering 3D seismogenic structures and site effect (Vs30)
The residual between 2015 and 2017 TEM PSHA considering 3D seismogenic structures and site effect (Vs30)
Taiwan Earthquake Model (TEM) 2012~

Hazard (PSHA 2015) (faulting & shaking)
- Active faults 活動斷層
- Historical earthquakes 歷史地震
- Geodetic strain 大地變形
- Ground motion prediction equations and simulation 地動預估及地震景況模擬
- Shaking amplification in soil and basins 放大效應

Risk (deaths & damage) (NCDR)
- Exposure 暴露性
  - Population
  - Buildings
  - Remote sensing
- Vulnerability 脆弱性
  - Damage data
  - Fragility functions

Social Impact (change actions)
- Decision tools 政策 防救災
- Urban scenarios 景況 防救災
- Risk transfer tools 轉移 保險
- Building design codes 耐震 工程

Improve the TEM PSHA
Taiwan 、Japan、 New Zealand international cooperation
Summary

- Taiwan Earthquake Model (TEM), established in 2012, published the first version of the public PSHA for Taiwan, named ‘TEM PSHA2015’

- The observed hazard of the 2016 Meinong earthquake corresponds to the area sources. However, more than about 80% of the seismic hazard potential still exists in southern Taiwan that are mainly from fault sources.

- For the current version of PSHA map, we have considered higher resolution (500m×500m), site effect (Vs30) and 3D fault geometry of 44 onland seismogenic structure. Higher strong ground motions were obtained in SW Taiwan, and Ilan plain relative to the TEM PSHA2015.

- For the next generation of PSHA, we will include 3D fault geometry of offshore seismogenic structures, multiple-segment ruptures, and time dependent PSHA.

- We look forward to improve the TEM PSHA map through international cooperation and apply the up-to-date PSHA model for the seismic risk evaluation to bring the close link from hazard to risk.
Thank you~