

# Seismic Hazard Assessment

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โครงการฝึกอบรมเชิงปฏิบัติการ เรื่องการแปลผลคลื่นแผ่นดินไหว 14-18 พฤศจิกายน 2559  
ณ กรมอุตุนิยมวิทยา กรุงเทพฯ

## Hazard & Risk

**Definition** (From Cambridge Advanced Learner's Dictionary)

**hazard** *noun* [C]

something that is dangerous and likely to cause damage.

**risk** *noun* [C or U]

the possibility of something bad happening



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## Seismic Hazard & Seismic Risk

- **Hazard** is a natural or man-made phenomenon that has the potential to cause harm (*i.e.*, social or economic consequences). Hurricanes, earthquakes, tornadoes, and floods, for example, are natural hazards, whereas car crashes, train derailments, and terror attacks are man-made hazards.
- **Risk**, on the other hand, is the probability of harm if someone or something is exposed to a hazard. Similarly, *seismic hazard* and *seismic risk* are fundamentally different.
- **Seismic hazard** is a natural phenomenon such as ground shaking, fault rupture, or soil liquefaction that is generated by an earthquake, whereas *seismic risk* is the probability that humans will incur loss or damage to their built environment if they are exposed to a seismic hazard (Wang, 2009).



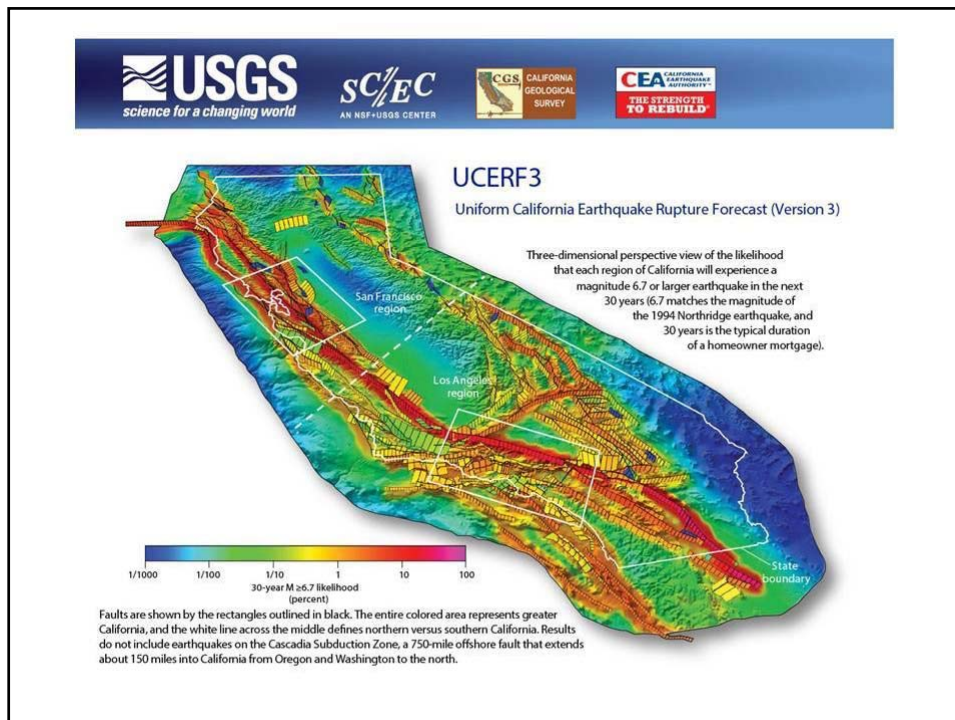
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## Seismic Hazard

- Seismic hazard analyses are conducted to evaluate potential loss and consequences a maximum earthquake event could have on a particular city or area (Chen et. al).
- Seismic hazard analyses involve the quantitative estimation of ground shaking hazards at a particular area (Sitharam & Anbazhagan).



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## Earthquakes Data

- The shallow earthquakes, 0-35 km focal depth that affect ground motion rather than deep focus earthquakes were selected.
- Altogether 6,822 events, after declustering (removal of foreshocks and aftershocks).
- However, in seismic hazard analysis, earthquakes magnitude equal or greater than completeness magnitude,  $M_c$  will be used.
- G-R frequency magnitude distribution, FMD (Gutenberg and Richter, 1954) were applied which gives  $b$ -value about  $0.74 \pm 0.01$  and  $M_c$  of 4.2.
- Finally, remaining 3,367 events or approximately 50% that magnitudes  $\geq 4.2$  were examined in hazard analysis, epicenter map depicted in Figure 1.

## Unified Magnitude

- Magnitude in earthquake catalogues is usually reported in several magnitude scales i.e.  $M_L$ ,  $M_S$ ,  $m_b$  and  $M_w$  etc.
- It is necessary to use only one magnitude scale for any analysis.
- The magnitudes were unified to  $M_w$  using the linear regression,

$$M_w = 0.74M_L + 1.27$$

$$M_w = 0.63M_S + 2.24$$

$$M_w = 1.13m_b - 0.60$$

## Seismic Hazard Analysis

- There are two basic philosophies for the seismic hazard analysis, the so-called *Deterministic seismic hazard analysis (DSHA)* and *Probabilistic seismic hazard analysis (PSHA)*.



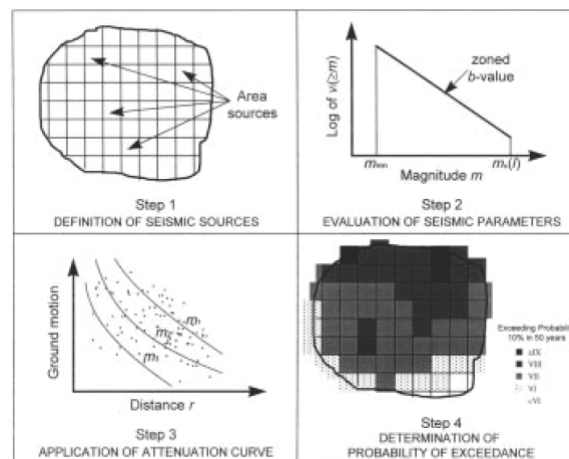
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## Deterministic seismic hazard analysis (DSHA)

- The DSHA approach proposes design either for the so-called "scenario" earthquakes, i.e., for only several (or only one) earthquakes that are estimated to produce most severe ground motion at a site.
- DSHA uses geology and seismic history to identify earthquake sources and to interpret the strongest earthquake each source is capable of producing regardless of time.
- Deterministic seismic hazard assessments seek to identify the maximum credible earthquake (MCE) that will affect a site.



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**Procedure of seismic hazard assessment (after Tera Corporation, 1978)**

# Earthquake Data

## Catalogs

- NEIC (National Earthquake Information Center, USGS)
- ISC (International Seismological Centre, UK)
- TMD (Thai Meteorological Department)

Period: 1912-2007

Area: 0-25N, 90-110E

Focal depth: Shallow earthquakes, 0-35 km (6,822 events)

Magnitudes ( $m_b$ ,  $M_s$ ,  $M_l$ ) were unified to moment magnitude ( $M_w$ )

*The 3,367 events ( $M \geq 4.2$ ) were used for an analysis*

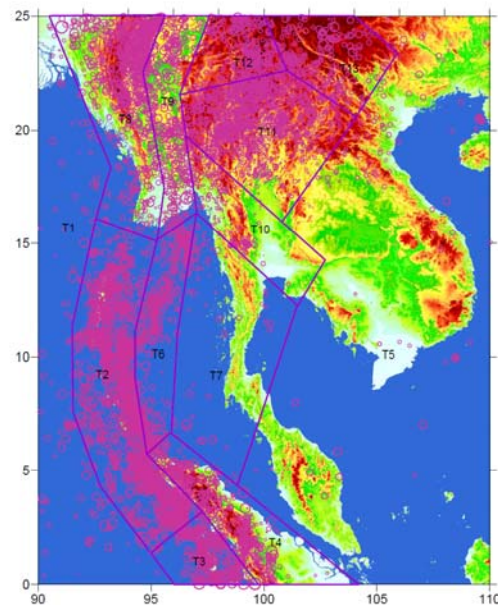
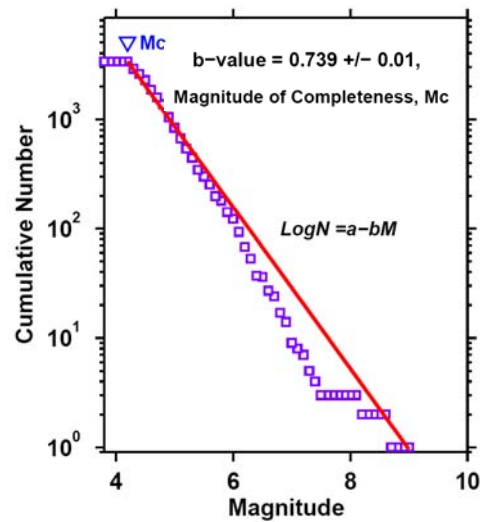


Figure 1. Seismicity map of Thailand for shallow focus (0-35 km depth) earthquakes, 1912-2007.



*b*-value of shallow focus earthquakes in Thailand and adjacent areas

## Seismic Source Zones

- Seismic hazard assessment requires that the distribution of earthquakes shall be defined in space with epicenter distance from the site of interest.
- This can be accomplished through the geographic delineation of seismic source zones and seismically active faults.
- Definitions of the sources are based on interpretation of available geological and seismological data with respect to earthquake mechanisms and source structures in the regions.

## Maximum Credible Earthquake, $M_{max}$

- The Maximum Credible Earthquake were estimated by using by using K-S and K-S-B estimators given by Kijko and Graham (1998) for the seismic source zones T1-T13, parameters are listed in Table 1.

$$\text{K-S} \quad m_{\max} = m_{\max}^{obs} + \frac{E_1(n_2) - E_1(n_1)}{\beta \exp(-n_2)} + m_{\min} \exp(-n) .$$

K-S-B

$$\hat{m}_{\max} = m_{\max}^{obs} + \frac{\delta^{1/q} \exp[nr^q / (1-r^q)]}{\beta} [\Gamma(-1/q, \delta r^q) - \Gamma(-1/q, \delta)] .$$

## The Maximum Credible Earthquake

Table 1. Parameters of seismic source zones, T1-T13 and the whole region (TTH).

Source zone (event number)	b-value	$M_c$	Maximum observed magnitude ( $m_{\max}^{obs}$ )	Maximum magnitude ( $m_{\max}$ )
T1 (38)	0.91±0.1	4.8	6.7	7.3
T2 (842)	0.89±0.05	4.8	9.0	9.3
T3 (208)	0.90±0.09	4.8	8.6	8.9
T4 (125)	0.91±0.1	4.8	6.8	7.1
T5 (48)	0.84±0.1	4.2	5.6	6.2
T6 (255)	0.77±0.04	4.2	6.2	6.3
T7 (21)	1.07 ±0.1	4.2	6.3	6.7
T8 (274)	0.92±0.06	4.5	7.0	7.3
T9 (232)	0.85±0.06	4.2	7.2	7.5
T10 (34)	1.21±0.3	4.2	6.1	6.5
T11 (445)	1.26±0.06	4.2	6.7	6.7
T12 (310)	1.15±0.1	4.5	6.9	7.4
T13 (535)	1.17±0.1	4.5	6.2	6.9
TTH (3,367)	0.74±0.01	4.2	9.0	9.3

## Return Period

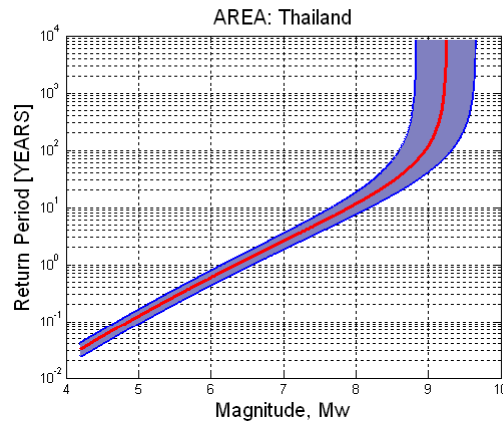


Figure 2. The mean return period (red line) and standard deviation (blue lines) of magnitude expected for Thailand and surrounding regions.

## Predict Ground Motion at Site

- NGA models (Next Generation Attenuation) that developed by Boore & Atkinson, 2008 (BA08); Campbell & Bozorgnia, 2008 (CB08) and Chiou & Youngs, 2008 (CY08) was used
- The general functional form of the NGA is given by the equation,
- $\ln(\text{PGA}) = f_1(M) + f_2(R) + f_3(F) + f_4(\text{HW}) + f_5(S) + f_6(D) + \varepsilon_T$  (2)
- In this equation,  $f_i$  are functions of magnitude (M), source-to-site distance (R), style of faulting (F), hanging-wall effects (HW), shallow site conditions (S), sediment depth (D) and  $\varepsilon_T$  is a random error term (Campbell and Bozorgnia, 2006).
- An average value from the 3 models was display in seismic hazard maps.

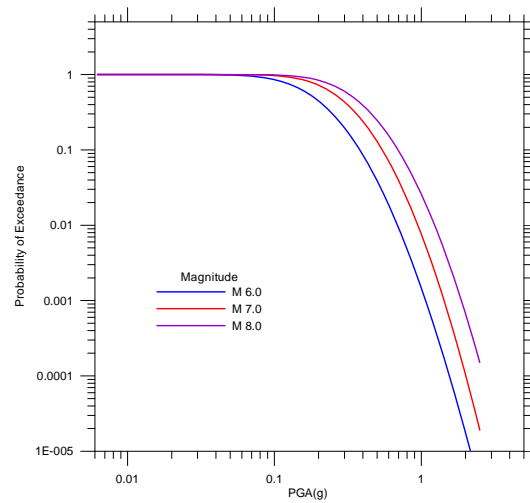


Figure 3. Hazard curves for earthquake magnitudes  $M$  6, 7 and 8 ( $V_s \approx 500$  m/s) at distance 10 km.

## Probabilistic Seismic Hazard Assessment, PSHA

The conventional PSHA implies an integration of all the potential magnitudes and source distances to estimate the mean frequencies of earthquake ground motions occurring at the site in any given time period. According to Cornell (1971), McGuire (1995), and Kramer (1996), the heart of PSHA is

$$P(Y \geq y) = \sum_j \nu_j \iint P_j[Y \geq y \mid m, r] f_{M,j}(m) f_{R,j}(r) dm dr$$

$$P(Y \geq y) = \sum_j \nu_j \iint P_j[Y \geq y \mid m, r] f_{M,j}(m) f_{R,j}(r) dm dr$$

where  $P(Y \geq y)$  is annual probability of exceedance of a ground-motion  $y$ ,  $\nu_j$  is the annual rate of occurrence of earthquakes generated by source  $j$  with magnitude greater than lower bound ( $m_0$ );  $f_{M,j}(m)$  and  $f_{R,j}(r)$  are the probability density function (PDF) for earthquake magnitude ( $M$ ) and source to site distance ( $R$ ), respectively; and  $P_j(Y \geq y/m, r)$  is the conditional probability that  $Y$  exceeds  $y$  (exceedance probability) for given  $m, r$  for seismic source  $j$ .

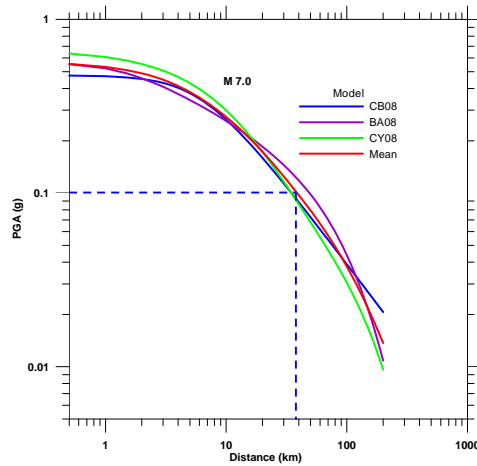
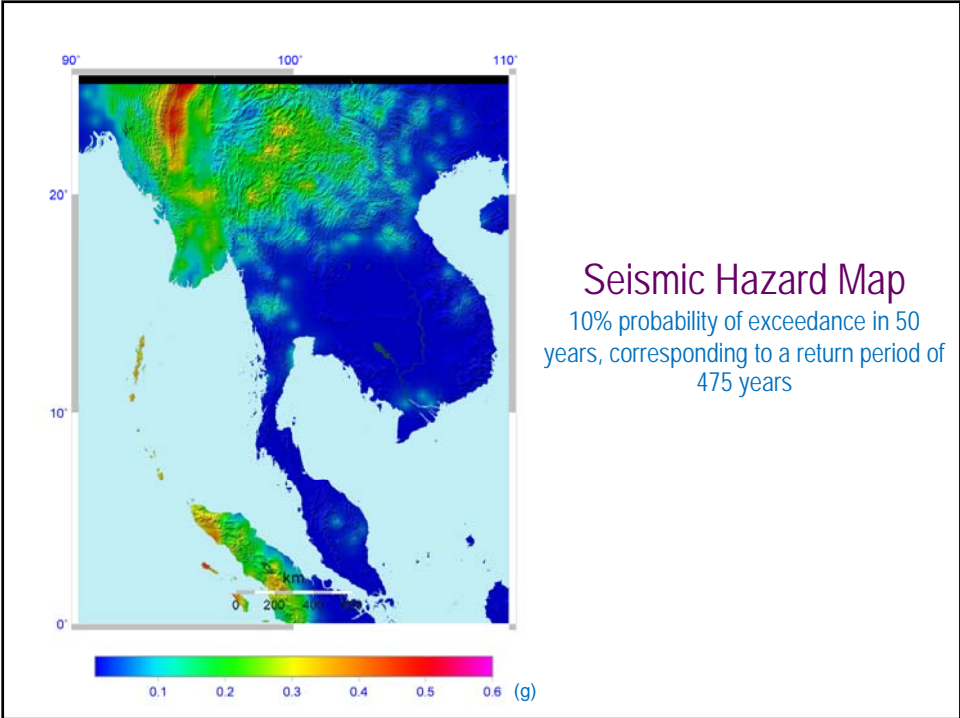
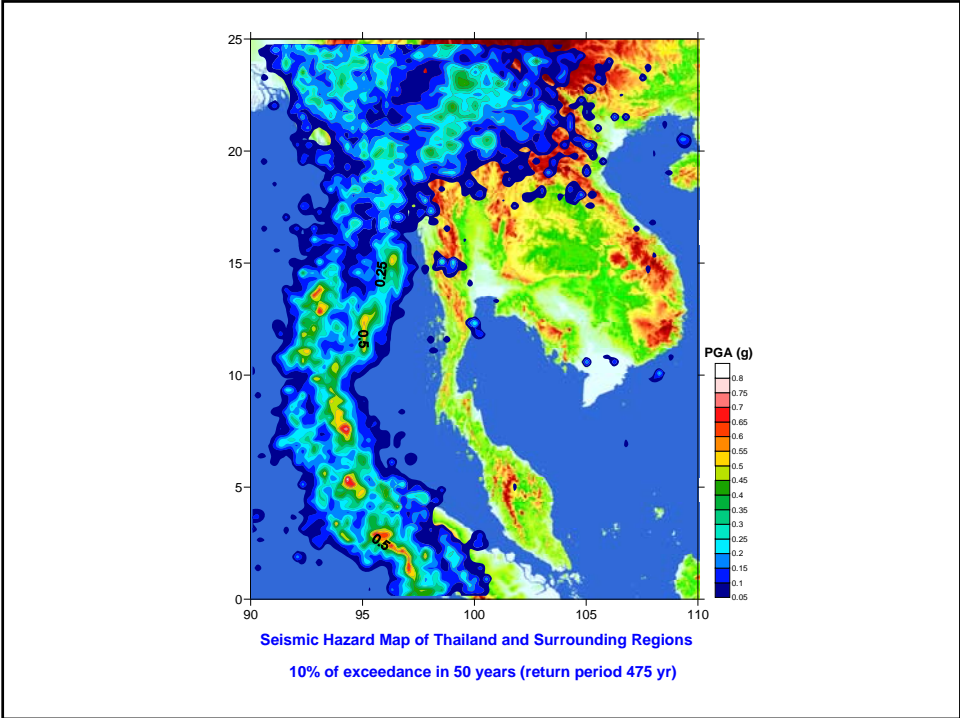
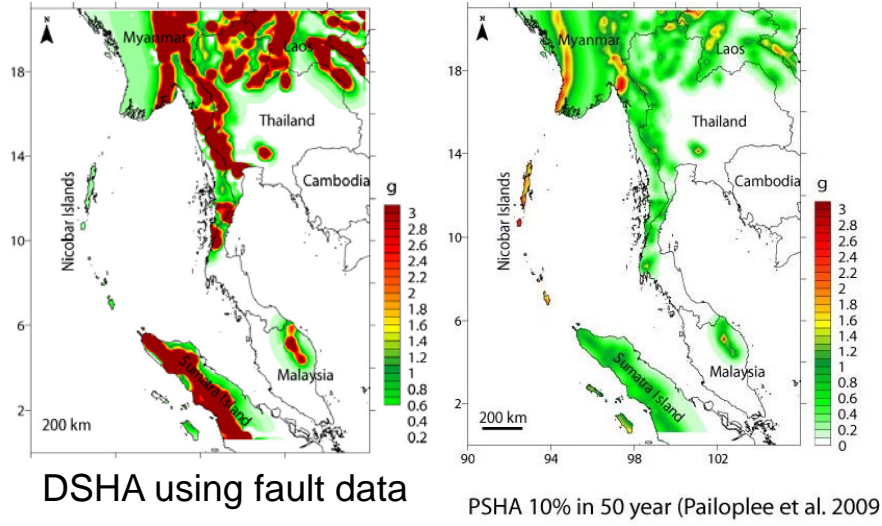


Figure 4. Ground-motion attenuation relationships for  $M$  7.0 earthquake,  $V_s \approx 500$  m/s





### Pailoplee et al., 2009



### Comparable results

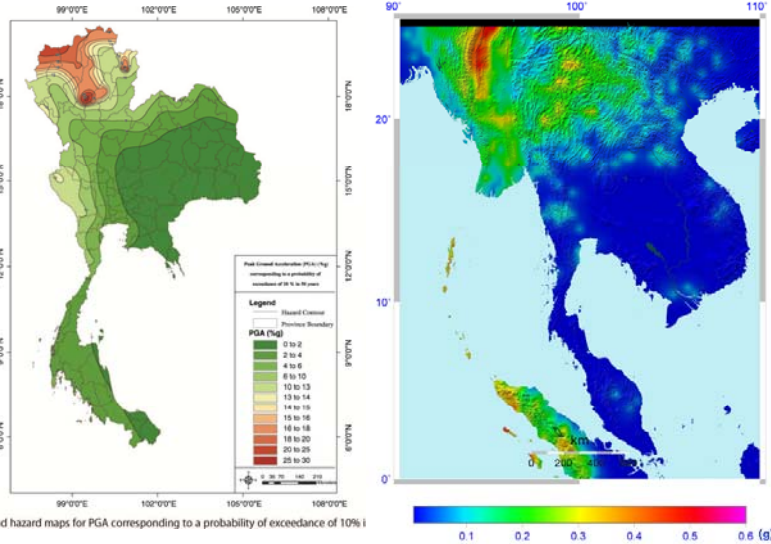
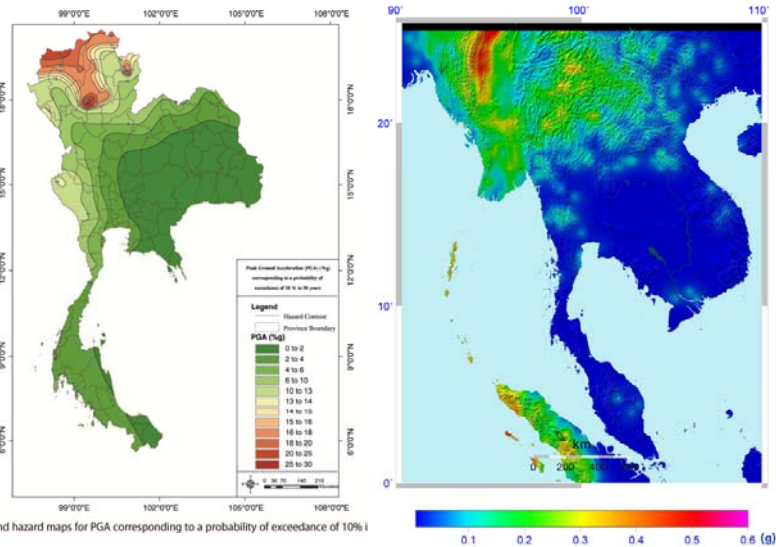


Fig. 8 Thailand hazard maps for PGA corresponding to a probability of exceedance of 10% i

Ornthammarath et al., 2010

PGA map for 10%, 50 year,  
Nuannin 2011.

## Comparable results



Ornthammarath et al., 2010

PGA map for 10%, 50 year,  
Nuannin 2011.

## Deterministic Seismic Hazard Assessment, DSHA

- The DSHA is usually performed by first identifying the magnitude of the largest possible earthquake  $m_{max}$  (also termed as maximum credible earthquake) that each of the seismic sources is capable of generating.
- This earthquake is then assumed to occur at the closest possible distance to the site.

Table 2. Parameters for worst case scenarios

Zone	Magnitude (USGS)	Source	$m_{max}$	Worst case scenario magnitude
T7	7.5	Klong Marui fault	6.7±0.4	7.5
T10	7.5	Three Pagodas fault	6.5±0.2	7.5

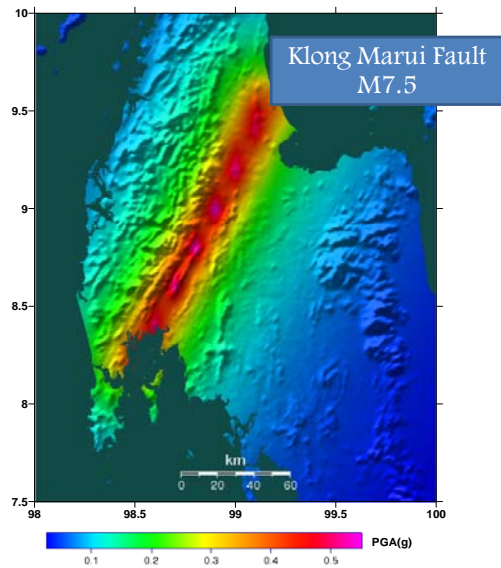


Figure 6. Hazard map for worst case scenarios, Klong Marui Fault M 7.5

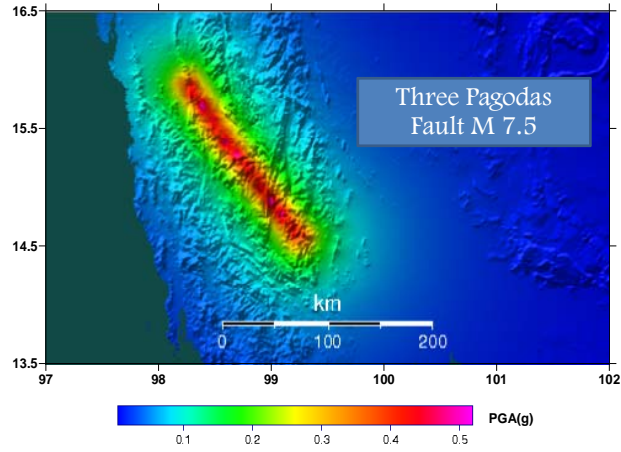
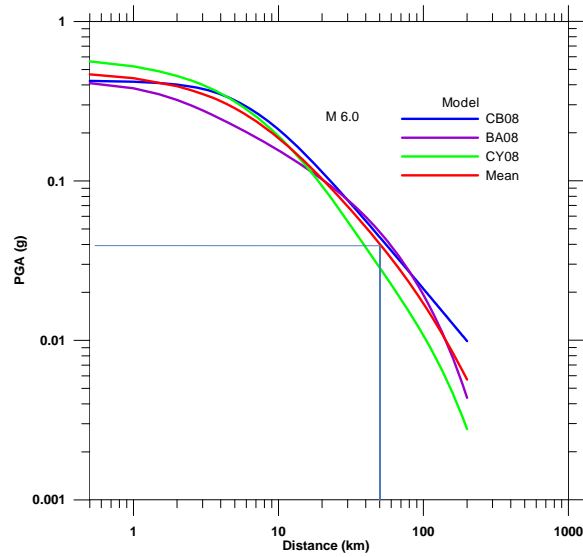


Figure 7. Hazard map for worst case scenarios, Three Pagodas Fault M7.5



PGA = 0.04g for the event M6 that occurred at 50 km from Srinagarind Dam in 1983

## Conclusions

- Seismic Hazard map of Thailand was generated and can be used for structural engineering design, i.e. nuclear power plant, dam, bridge and high-rise building.
- Maximum credible earthquake magnitude in Thailand is  $M_{max} = 6.7$  with return period 8,000 years, located in northern Thailand.
- PGA at Srinagarind dam site approximately 0.3-0.4 g and 0.4-0.5g, for the earthquake magnitude 6.7 and 7.5 that occurs in Three Pagodas Fault Zone.

## Acknowledgements

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