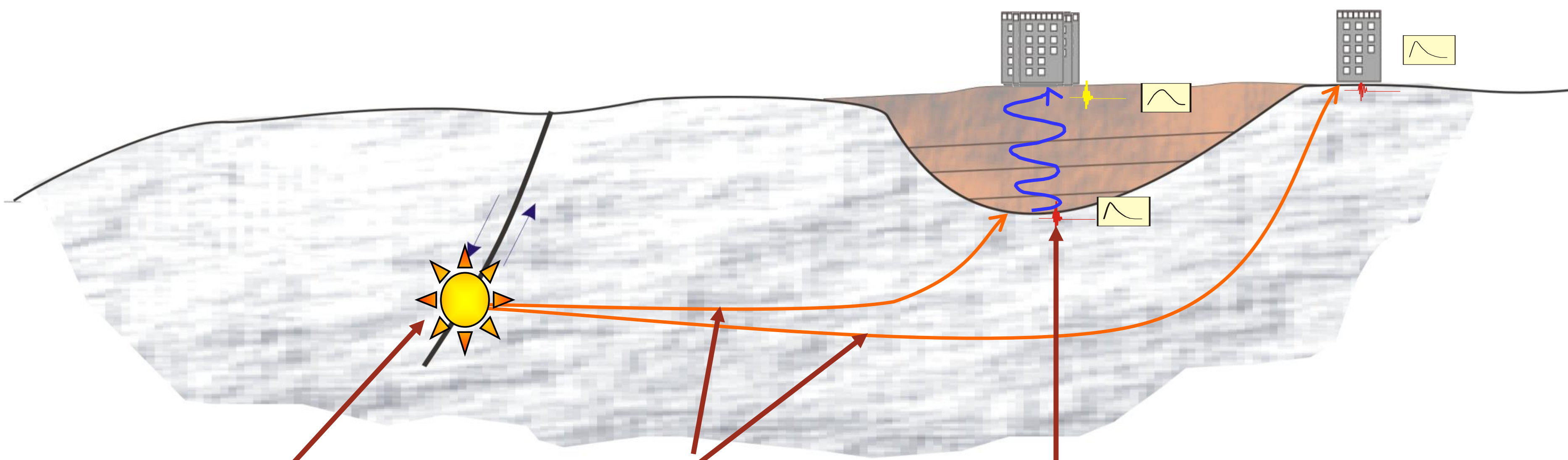
Dinamika dan Rekayasa gempa

Bagaimana Gempa sampai pada kita

Dosen: Ir. Nurly Gofar, MSCE., PhD.

Earthquake wave propagation

Epicenter ⇨ Bedrock ⇨ Surface



Earthquake Source Parameters
(Location, Magnitude, Mechanism)

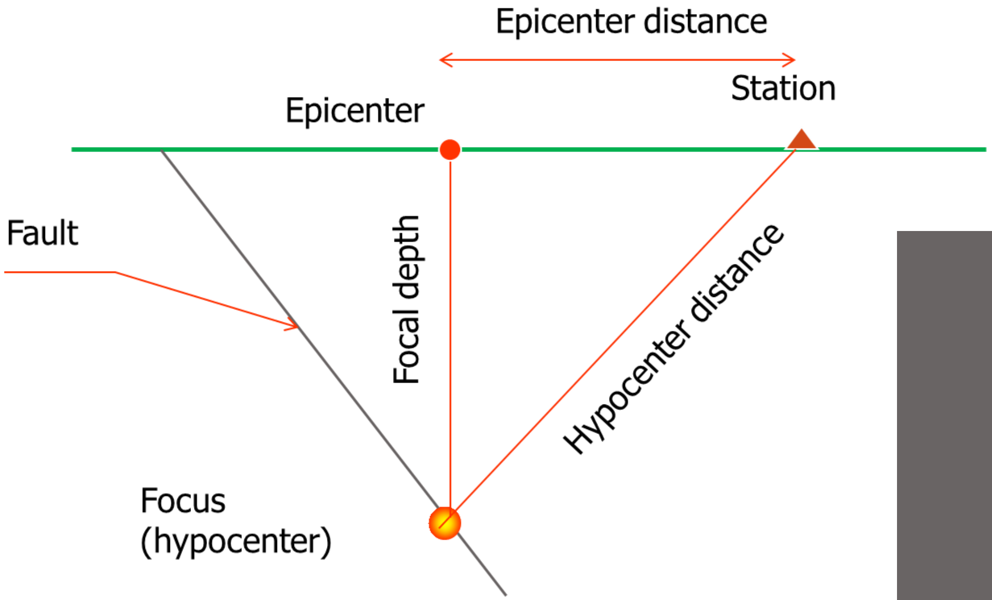
Attenuation Relationship formula

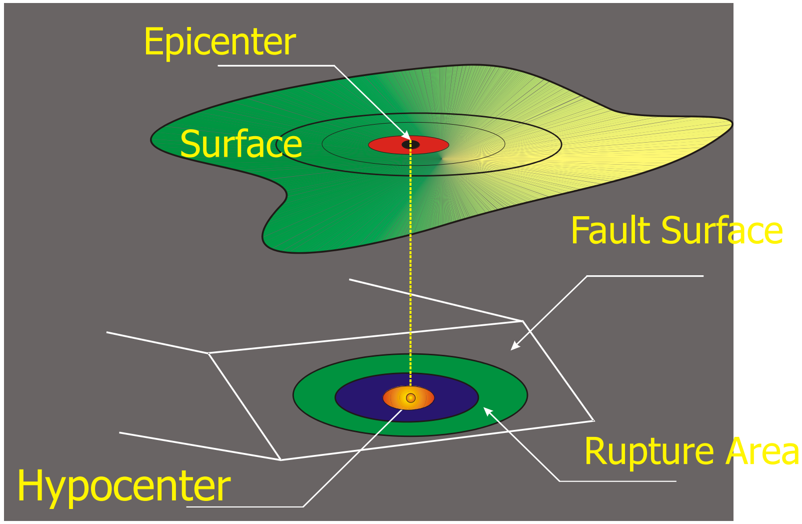
Ground Motion Parameters
(Acceleration, velocity, displacement)

Definisi

Attenuation Function is a simple mathematical model that relates a ground motion parameter (i.e. spectral acceleration, velocity and displacement) to earthquake source parameter (i.e. magnitude, source to site distance, mechanism) and local site condition (Campbell, 2002).

Definisi


Epicenter distance
Station
Epicenter
Fault
Focal depth
Hypocenter distance
Focus
(hypocenter)


Epicenter
Surface
Fault Surface
Rupture Area
Hypocenter

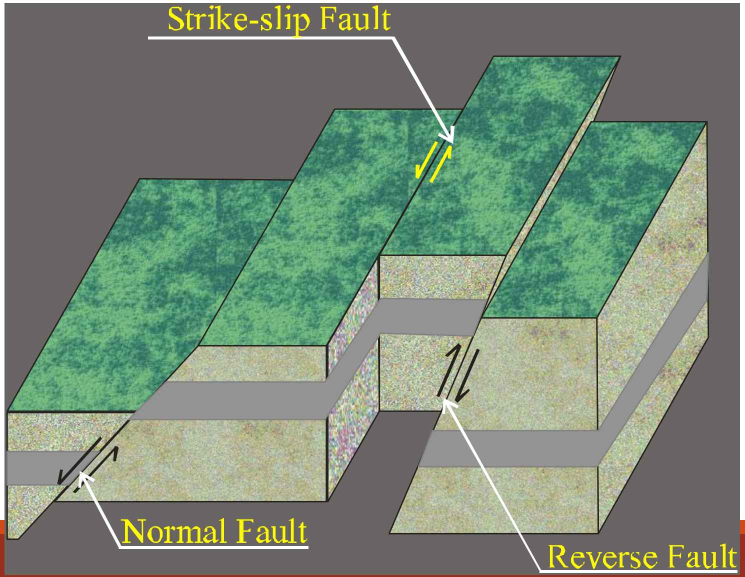
Definisi

The hypocenter is the point within the earth where an earthquake rupture starts.

The epicenter is the point on the earth's surface vertically above the hypocenter (or focus).

The focal depth refers to the depth of an earthquake hypocenter.

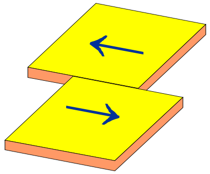
Types of Faults Motion



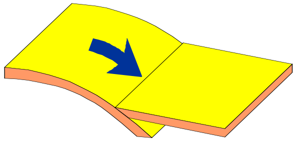
Attenuation Relationships

Classified into :

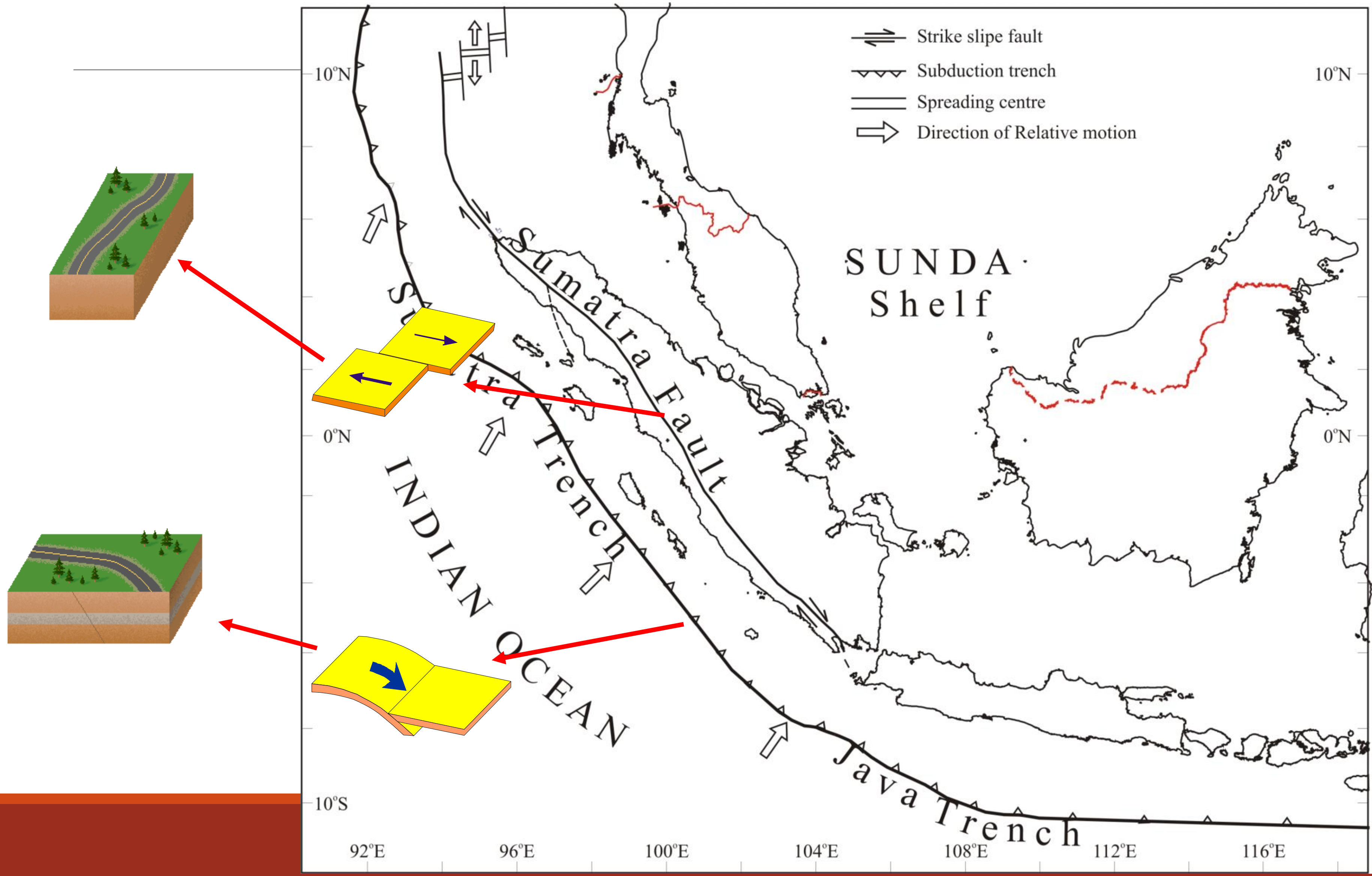
- Relation for shallow crustal earthquake
  (i.e. reverse faulting, strike slip faulting)



- Relation for subduction zone earthquake
  (i.e. interface, intraslab)



Tectonic Setting



Attenuation relationship

- First we have to collect historical earthquake data, i.e location, magnitude and mechanism followed by processing the data using statistic method,
- Second is to select or to develop appropriate attenuation function. This function correlate a ground motion parameter (i.e. spectral acceleration, velocity and displacement) to earthquake source parameter (i.e. magnitude, source to site distance, mechanism).
- Third is local site effect analysis to obtain the ground motion parameters at the surface such as PSA and Response Spectra.
- Finally is to develop elastic design response spectra

Input Data

Location: (Latitude, Longitude, Depth)

Magnitude (M_S, M_W, M_b, M_L)

Mechanism (strike slip, normal, reverse, thrust)

Output Data

- Peak Acceleration,
- Peak Velocity,
- Peak Displacement

Note: Peak Acceleration (PGA) is usually expressed in g or gal (cm/sec^2). 1 g $\approx$ 1000 gal

Worldwide Strong Ground Motion Attenuation Relationships

Attenuation functions	Subduction Zone	Shallow crustal
Crouse (1991)	●	
Youngs (1997)	●	
Fukushima, Tanaka (1992)	●	●
Mc Verry (1998)	●	●
Si, Midorikawa (2000)	●	●
Boore, Joyner, Fumal (1997)		●
Sadigh (1997)		●
Campbell (1997)		●

Gail M. Atkinson and David M. Boore (1997)

$$\ln(y) = 1.841 + 0.686(M - 6) - 0.123(M - 6)^2 - \ln(r_{hyp}) - 0.00311 \cdot r_{hyp}$$

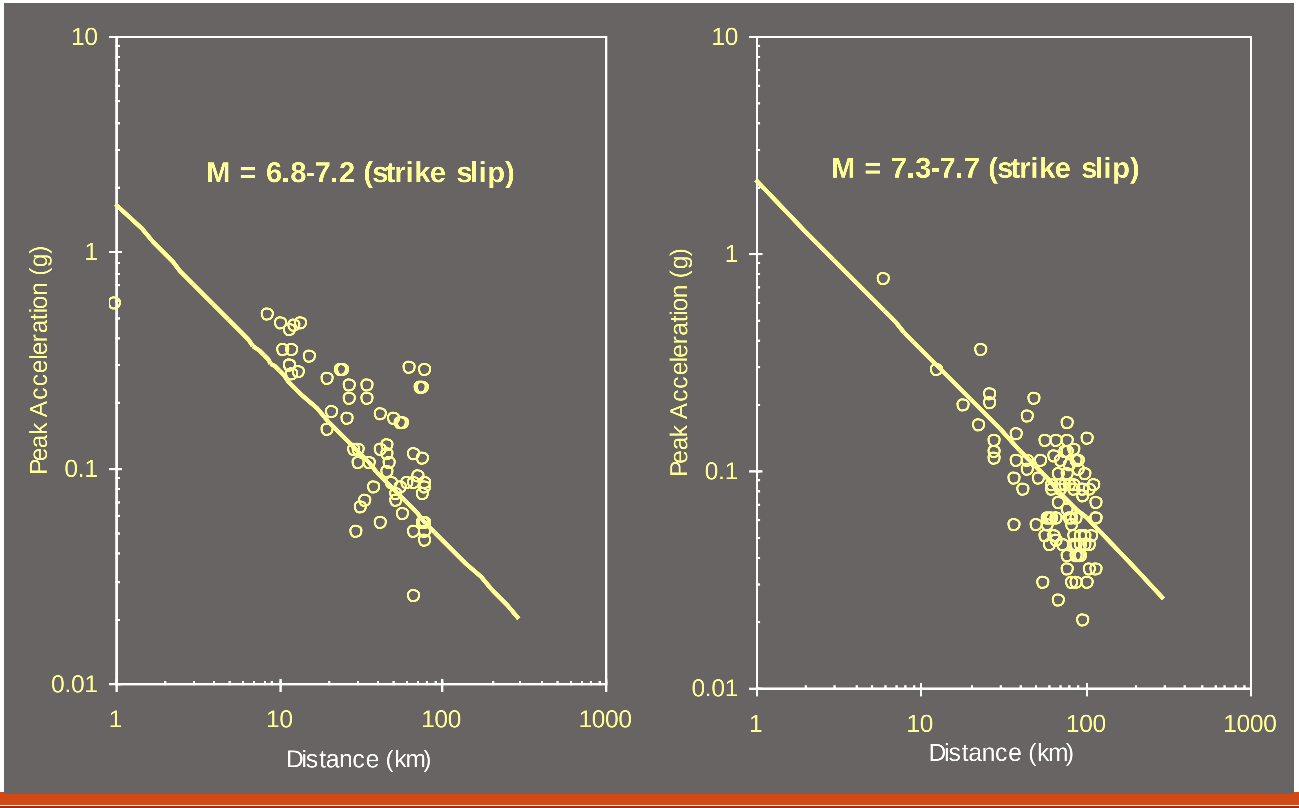
y is PGA in g,

M is moment magnitude;

r_{hyp} is the source to site distance in km.

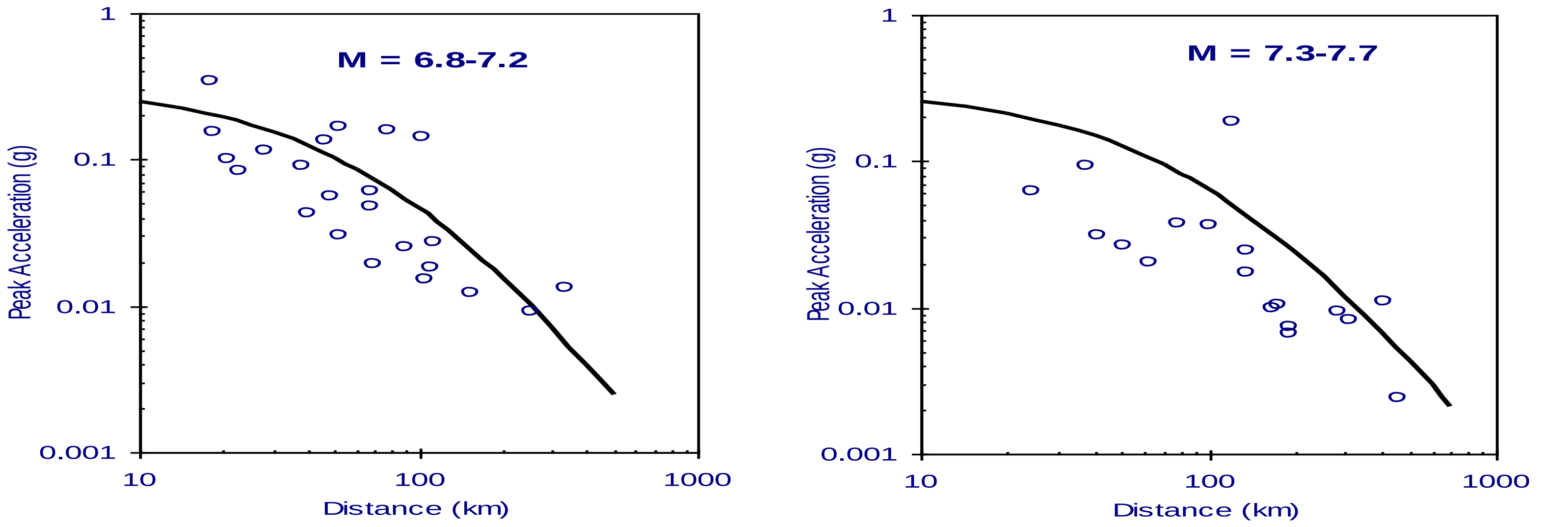
Attenuation Relationship BOORE *et al.* (1997)

Source Data: Shallow crustal earthquake in Western North America
California Earthquakes (Loma Prieta, Petrolia and Landers).



ATENUATION FUNCTION YOUNGS et al. (1997)

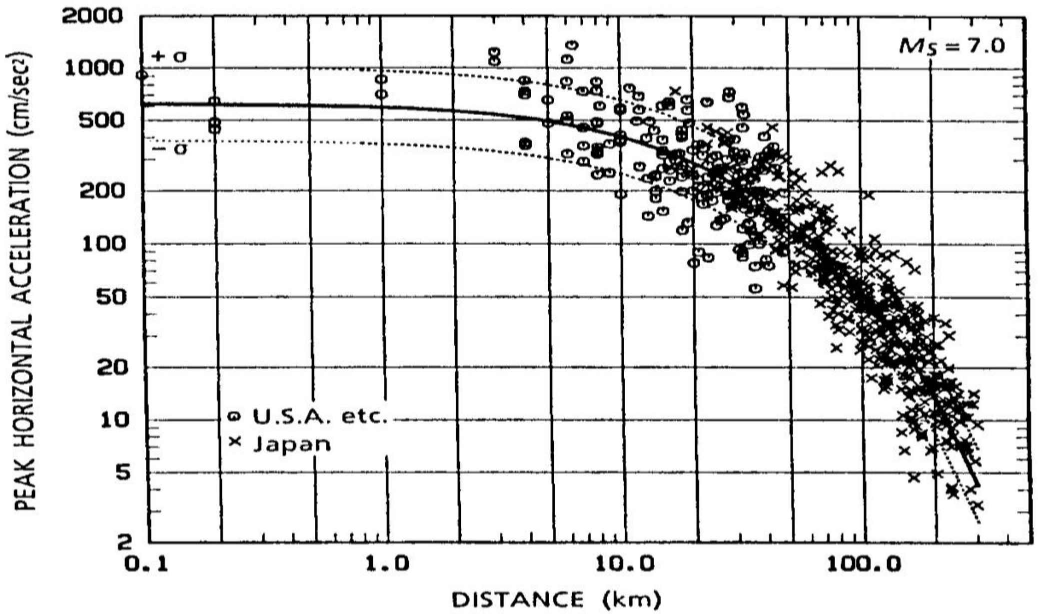
Sources: Alaska, Chile, Cascadia, Jepang, Mexico, Peru dan Solomon Islands.



FUNGSI ATENUASI FUKUSHIMA (1992)

Data Source: Japan for medium distance (R>50km), US for short distance (R<50 km).

$\log A = aM - \log(R + d.10^{eM}) - b.R + c$



Regression results for M_W, M_s, & M_J :

$\log A = 0,42\ M_w - \log_{10}(R + 0,025.10^{0.42M_w}) - 0.0033R + 1.22$

$\log A = 0,41\ M_S - \log_{10}(R + 0,030.10^{0.41M_s}) - 0.0033R + 1.28$

$\log A = 0,51\ M_J - \log_{10}(R + 0,006.10^{0.51M_j}) - 0.0033R + 0.59$

Standard deviation = 0.30

	s_{logA} (reverse slip earthquakes)				
Mw	Fukushima	Campbell	Midorikawa	Boore JF	Sadigh
5.3 - 5.7	0.31	0.39	0.33	0.30	0.35
5.8 - 6.2	0.29	0.28	0.28	0.26	0.27
6.3 - 6.7	0.26	0.23	0.26	0.22	0.23
6.8 - 7.2	0.20	0.21	0.21	0.21	0.19

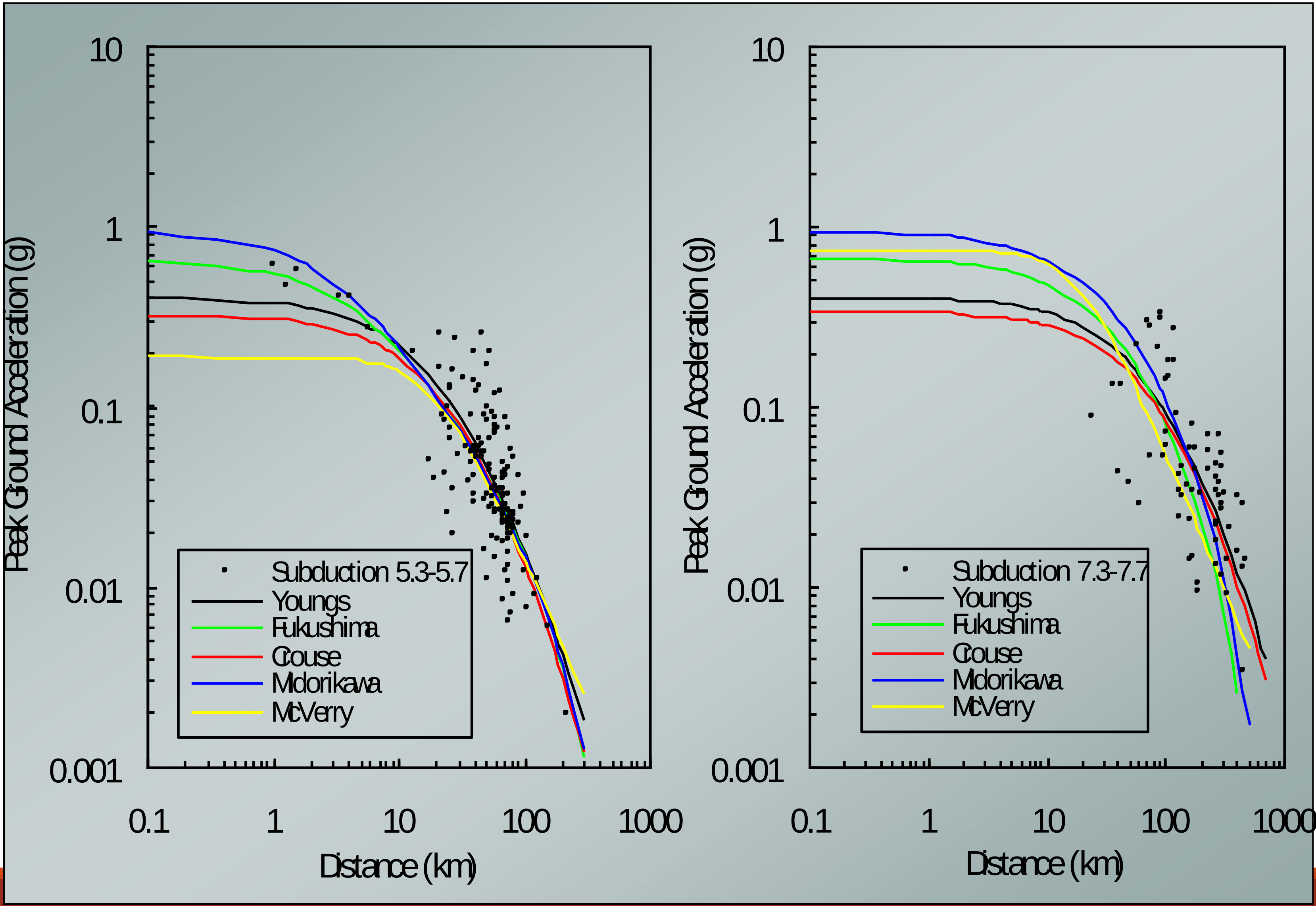
	s_{logA} (strike slip earthquakes)				
Mw	Fukushima	Campbell	Midorikawa	Boore JF	Sadigh
5.3 - 5.7	0.34	0.28	0.32	0.24	0.26
5.8 - 6.2	0.29	0.28	0.27	0.27	0.27
6.3 - 6.7	0.24	0.18	0.24	0.19	0.18
6.8 - 7.2	0.20	0.19	0.23	0.22	0.19

	s_{logA} (subduction zone earthquakes)				
Mw	Fukushima	Midorikawa	Youngs	Crouse	Mc Verry
5.3 - 5.7	0.25	0.29	0.28	0.30	0.25
5.8 - 6.2	0.27	0.28	0.28	0.28	0.29
6.3 - 6.7	0.37	0.37	0.37	0.37	0.36
6.8 - 7.2	0.40	0.37	0.37	0.34	0.34
7.3 - 7.7	0.54	0.45	0.34	0.35	0.45
7.8 - 8.2	0.40	0.36	0.37	0.35	0.42

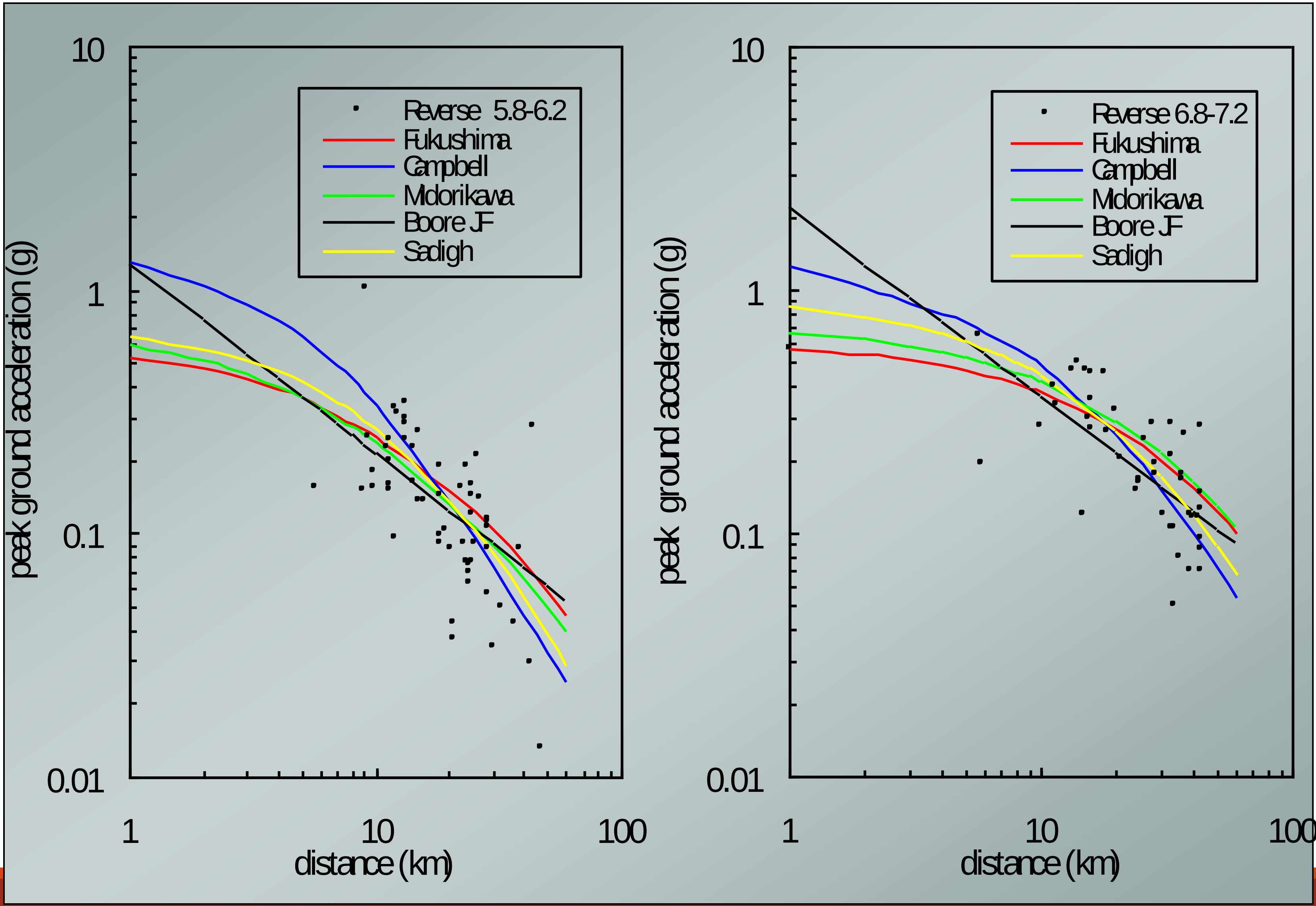
RECOMMENDATION :

- All attenuation relationships are comparable in the case of standard error
- Relations for shallow crustal earthquakes show a decrease in standard error with magnitude, while those for subduction show the opposite
- Boore, Joyner, Fumal has a relatively low standard error and an advantage of having a quantitative parameter to represent a particular site condition
- Youngs has a relatively low standard error and its site classification is considered consistent with that of NEHRP 1994, UBC, and Boore 1993

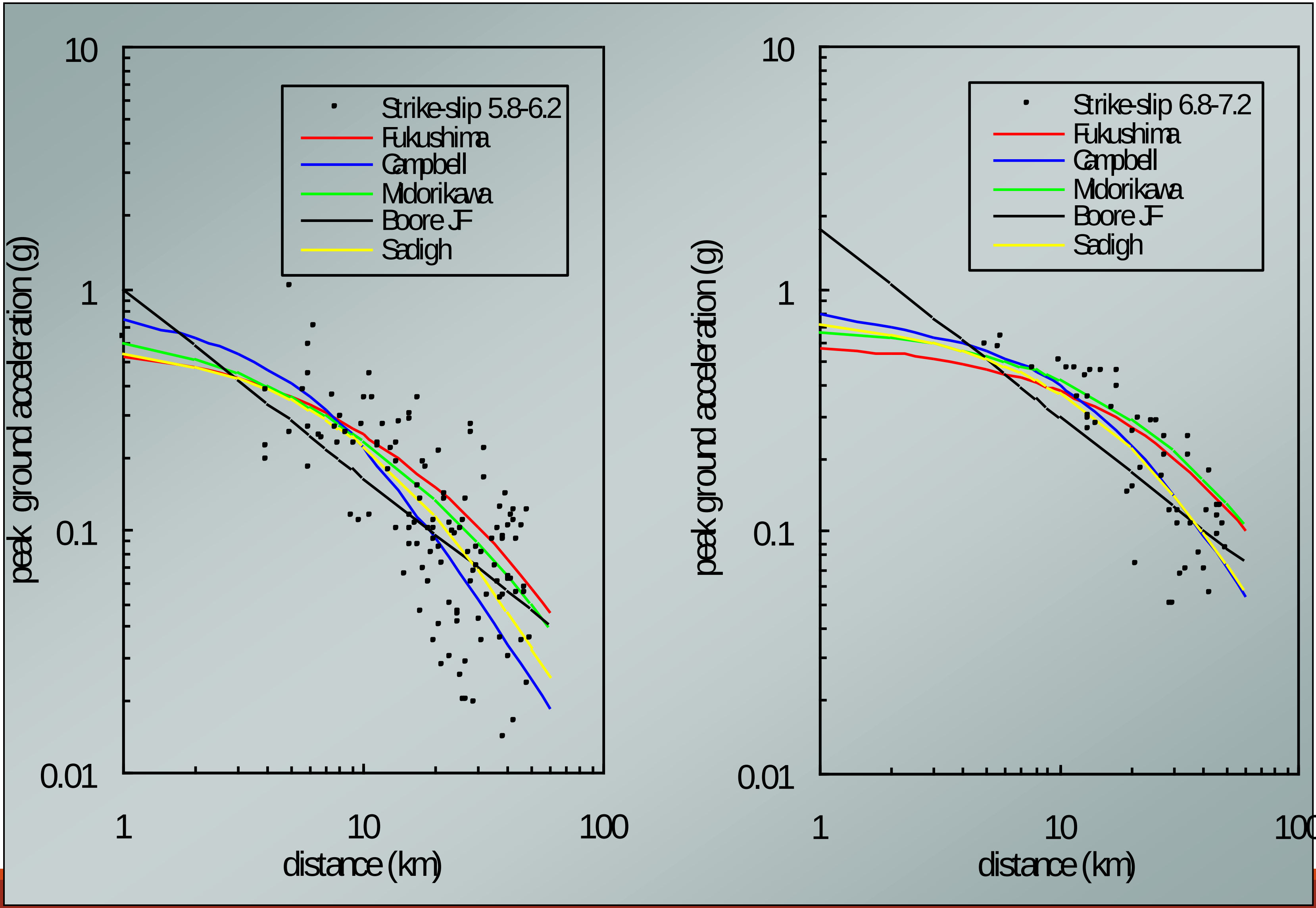
Comparison of observed data and median attenuation relationships for
SUBDUCTION ZONE EARTHQUAKES



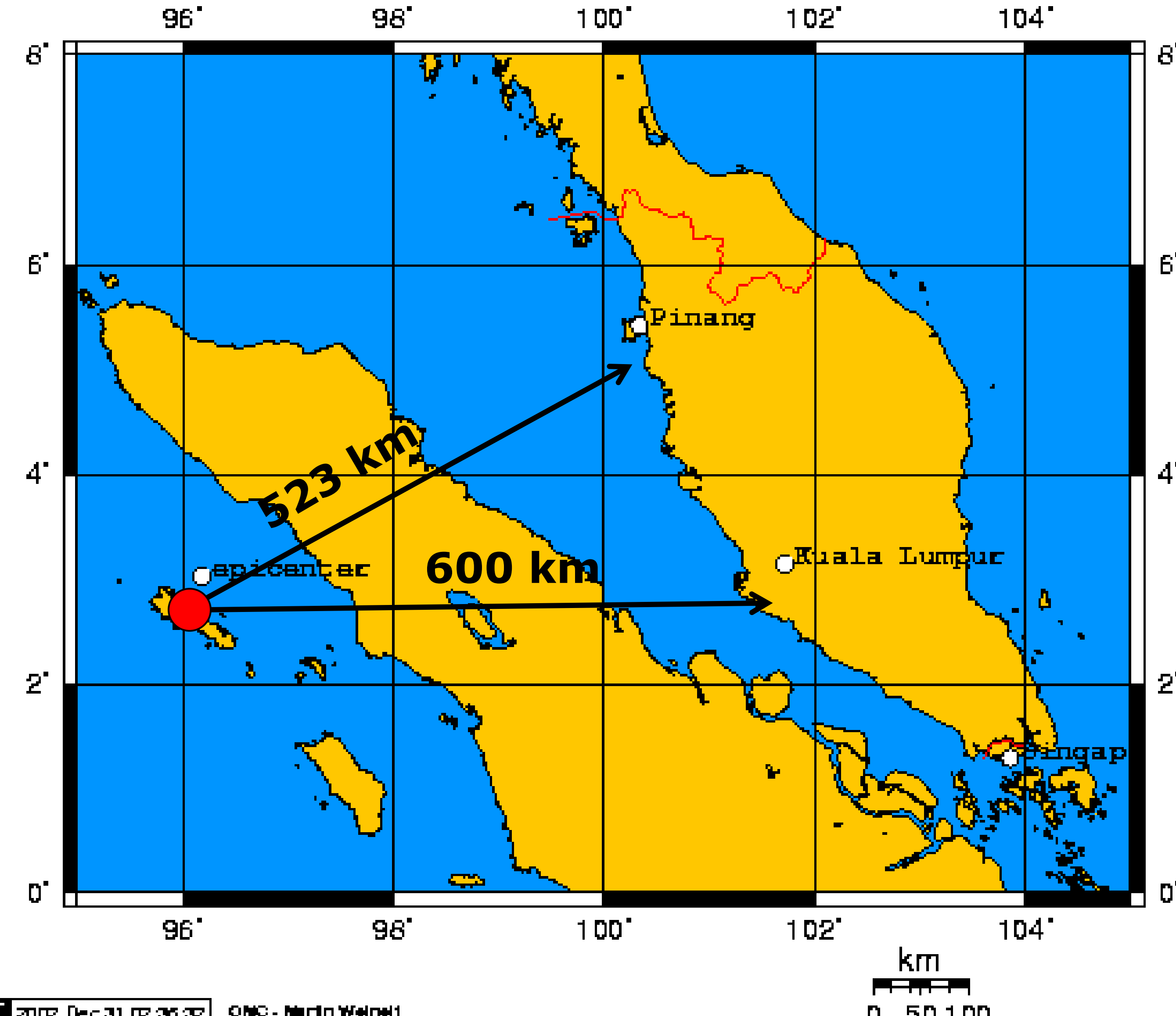
Comparison of observed data and median attenuation relationships for REVERSE SLIP EARTHQUAKES



Comparison of observed data and median attenuation relationships for STRIKE SLIP EARTHQUAKES



Case Study 1:
SUMATRA EARTHQUAKE - 2 NOVEMBER 2002



Mechanism:
Subduction Earthquake event

Location:
96.18E ; 3.024 N

Depth:
33 km

Magnitude:
7.4 (M_w)

Atkinson & Boore (1997)

$$\ln(y) = 1.841 + 0.686(M-6) - 0.123(M-6)^2 - \ln(r_{hyp}) - 0.00311 \cdot r_{hyp}$$

y is PGA in g,

M is moment magnitude;

r_{hyp} is the source to site distance in km.

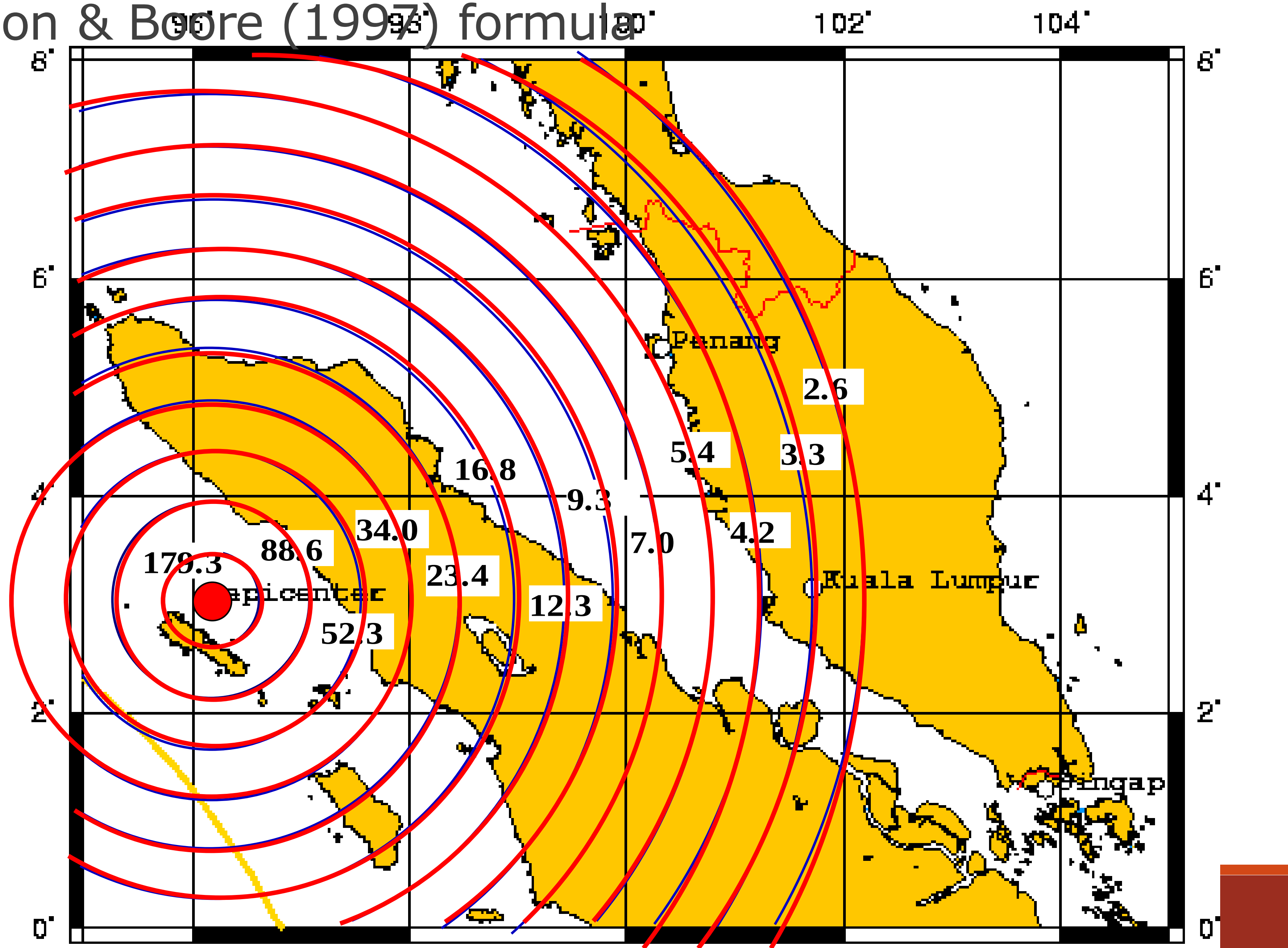
Determine PGA in KL!

R epicenter	: 600 km	Rhyp = 601 km
Depth	: 33 km	
Magnitude	: 7.4 (M_w)	

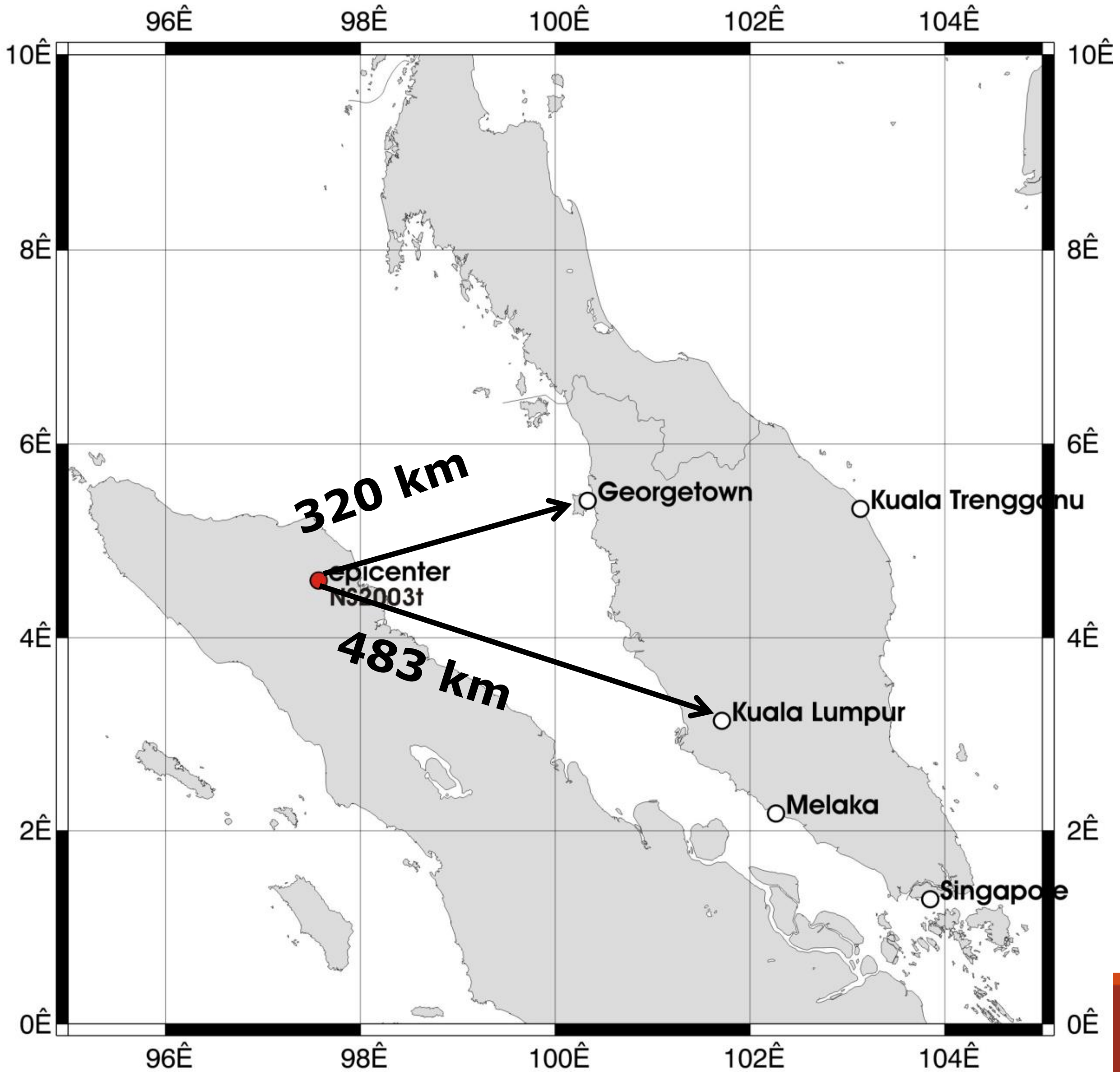
ln (PGA) = 1.841+0.686 (7.4-6)-0.123 (7.4-6)^2-ln(601)-0.00311*601

PGA = 0.00332 g = 3.32 gal

Peak Acceleration Contour At Bedrock
Atkinson & Boore (1997) formula



Study case 2: SUMATRA EARTHQUAKE - JANUARY 2003



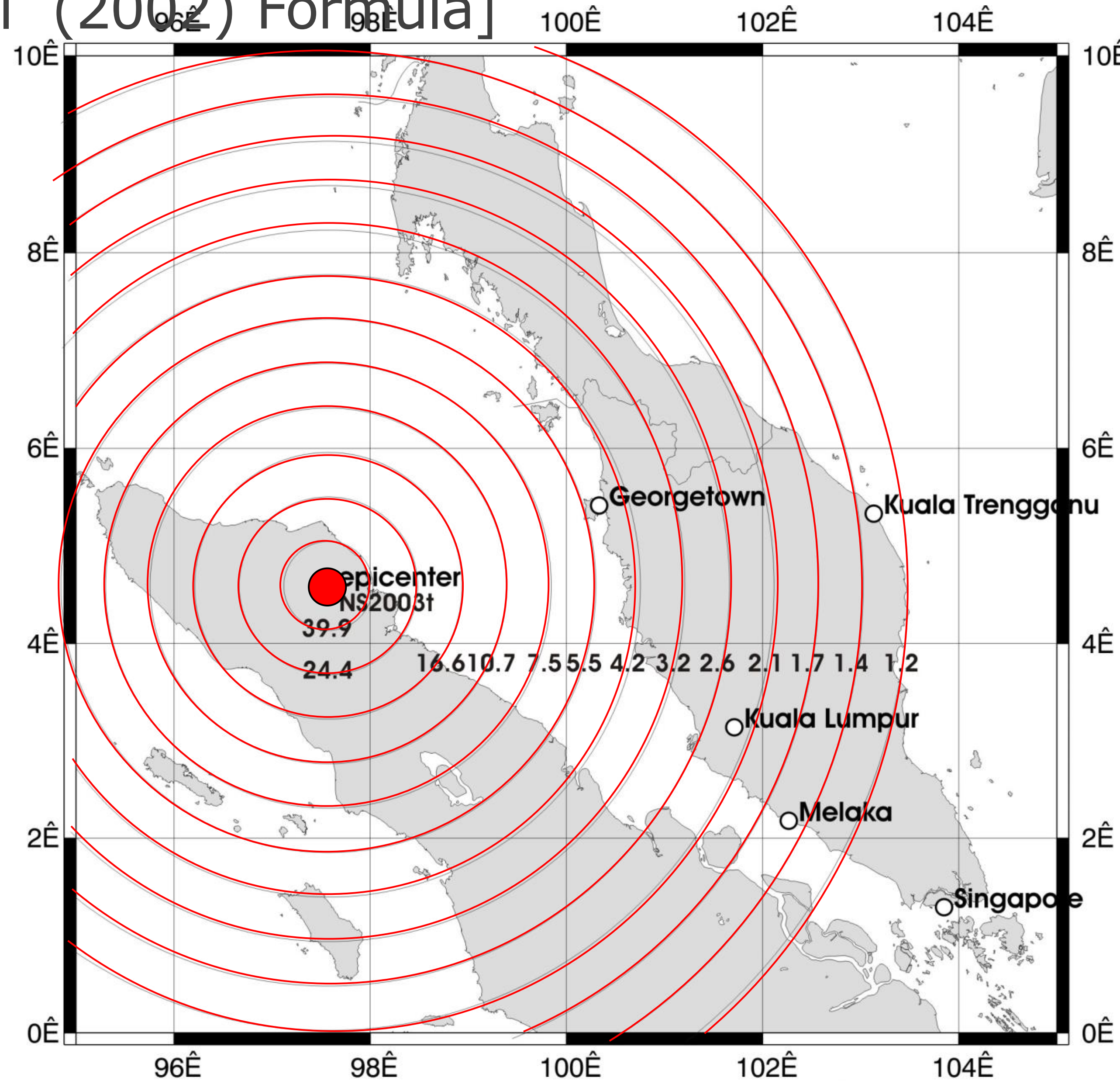
Mechanism: Shallow Crustal Event

Location: 97.57E and 4.59N

Depth: 33 km

Magnitude: 5.8 (M_w)

Peak Acceleration Contour At Bedrock [Campbell (2002) Formula]



Further Reading

Kramer, S. L. 1996. Geotechnical Earthquake Engineering, Prentice Hall, New Jersey

Hu, Y.X. 1996. Earthquake Engineering. E & FN Spon. London.

National Earthquake Information Center United Stated Geological Survey, http://neic.usgs.gov/neis/epic/epic.html.