Probabilistic Seismic Hazard Analysis Problem

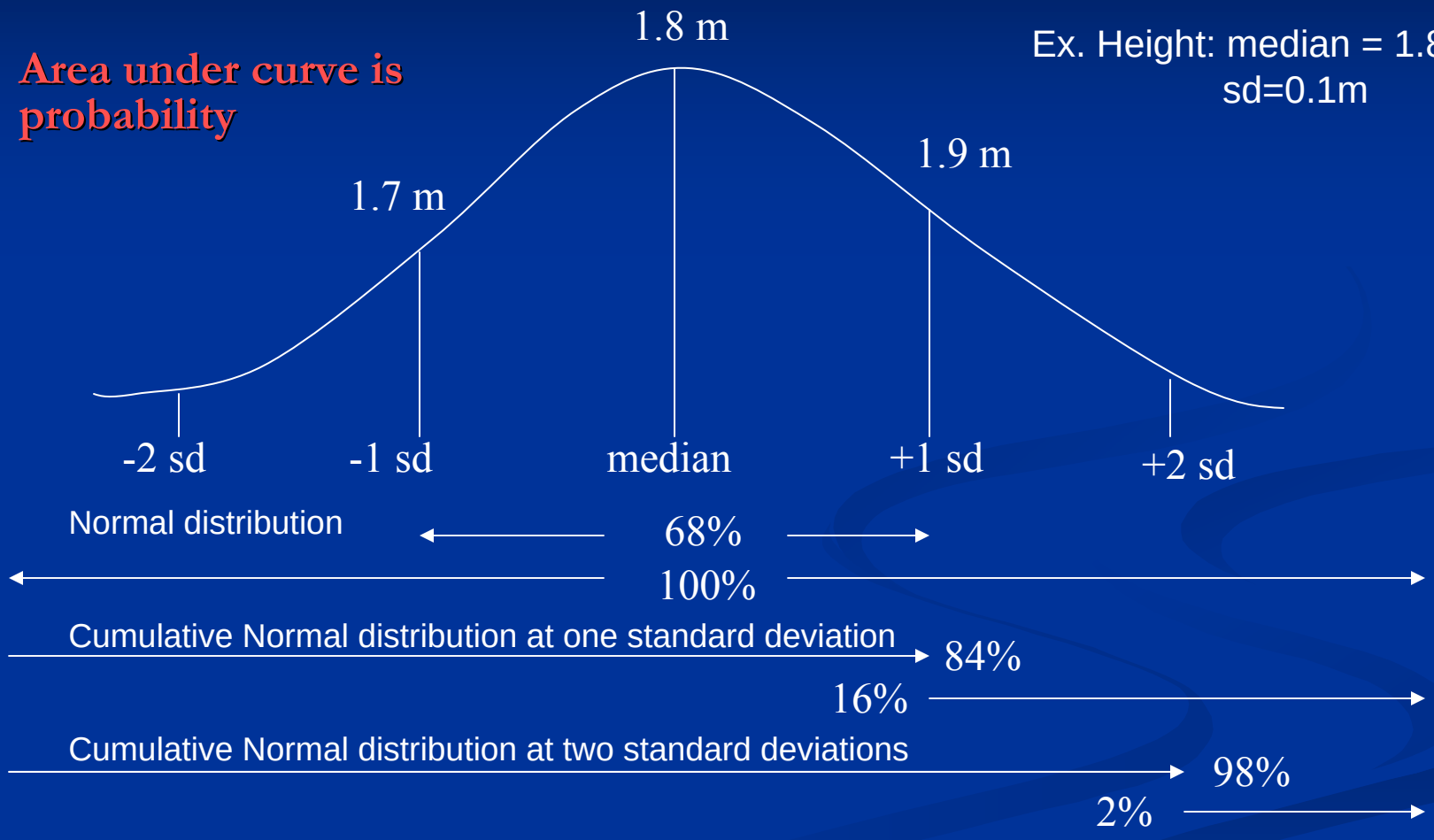
Hazard Analysis

- Definitions:
  - Hazard – anticipated ground motion at site
  - Risk – damage or losses to society
  - Probabilisitic – considers uncertainty in input parameters (e.g., magnitude, ground motion)
  - Uncertainty – aleatory (random), epistemic (variability in mean values for different models
  - Deterministic – considers average level for scenario
  - Hazard level – probability level used for building design
  - Disaggregation – magnitude and distance that contribute most
  - Magnitude-frequency distribution – sizes and rate of earthquakes
  - Time-dependence – probability increases with time since last earthquake

Normal Distribution

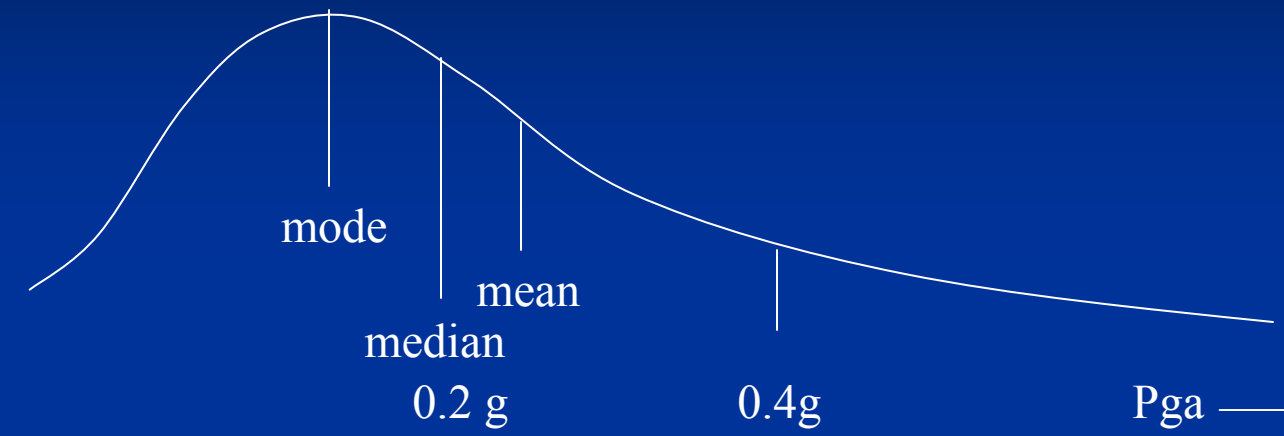
- **Area under curve is probability**

Ex. Height: median = 1.8m
sd=0.1m

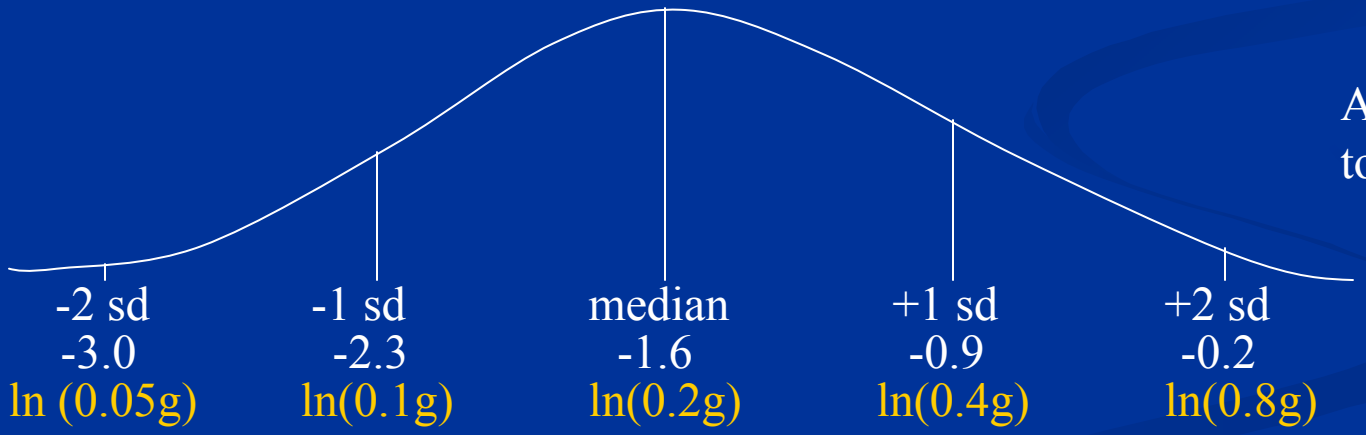


Lognormal Distribution

HOWEVER GROUND MOTION FOLLOWS A LOGNORMAL DISTRIBUTION



Standard deviation is factor of two

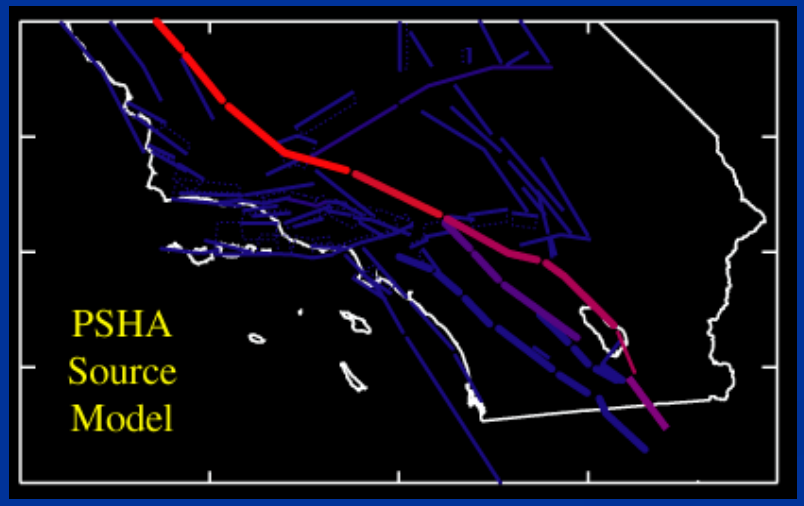


Add 0.7 to ln(median) to get the +1sd

Seismic hazard analysis has two model components:

(1) Earthquake-Rupture Forecast (ERF)

Probability of all possible fault-rupture events (M≥~5) for region & time span

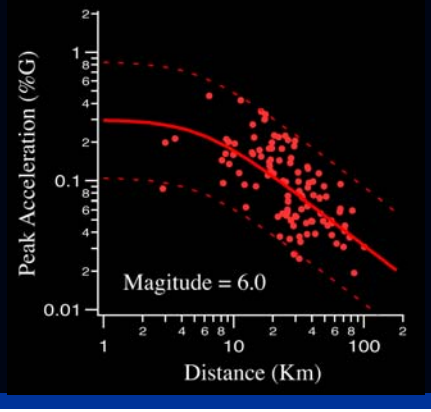


(2) Intensity-Measure Relationship (IMR)

Gives Prob(IMT≥IML) for a given site and fault-rupture event

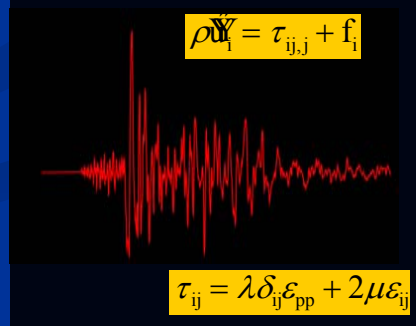
Attenuation Relationships

(traditional)
(no physics)

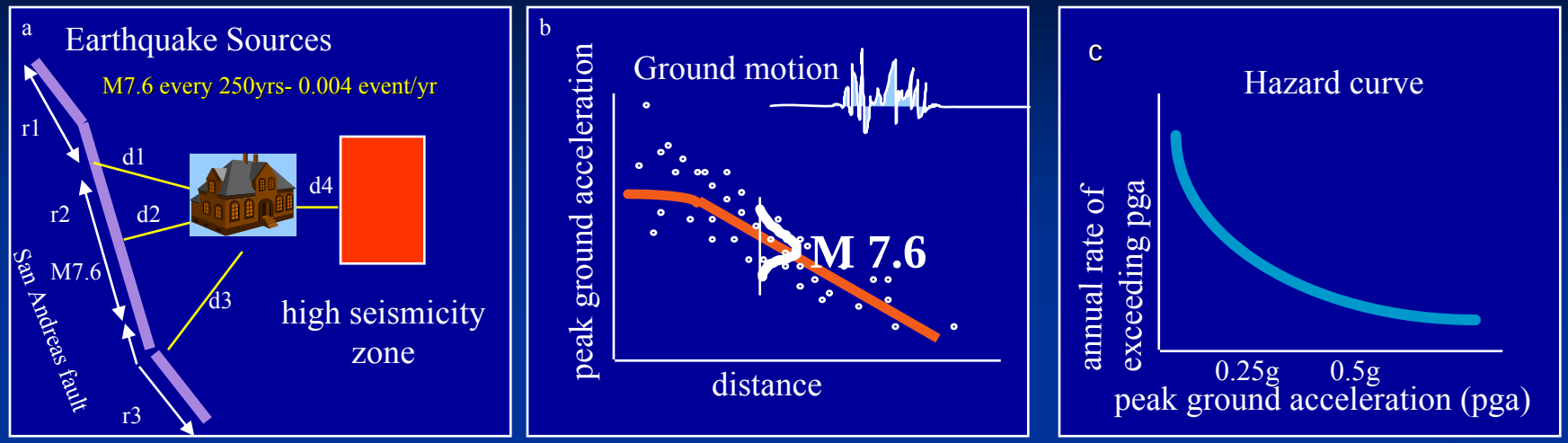


Full-Waveform Modeling

(developmental)
(more physics)



PROBABILISTIC SEISMIC HAZARD METHODOLOGY



To calculate the hazard curve (annual rate of exceeding ground motions) we:

1. Determine magnitude, and distance, and rate of earthquake
2. Calculate ground motion distribution for that m and d.
3. Calculate the product:

   annual rate of earthquake *probability that earthquake will exceed certain ground motion level

4. Sum these rates for all earthquakes in the model at each ground motion to get

   a hazard curve. This curve shows the rate of exceedance of each ground motion.

Probabilistic Seismic Hazard

Annual rate of exceedance for a given ground motion, z

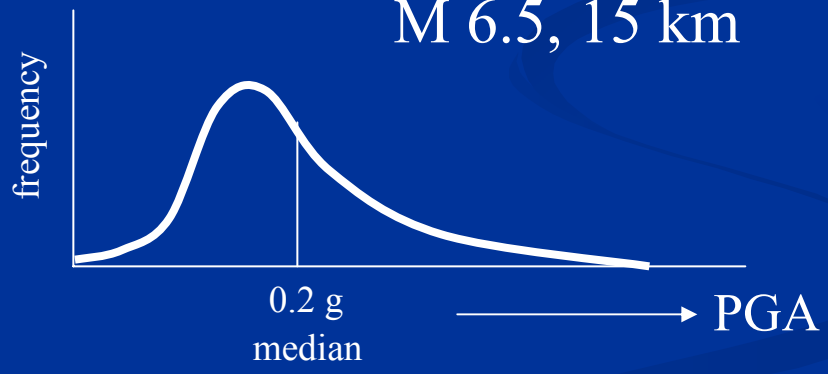
$$E(z) = \sum_{i=1}^{N} \alpha_i \int_{m_o}^{m_u} \int_{r=0}^{r=\infty} f_i(m)\, f_i(r)\, P(Z > z \mid m, r)\, dm dr$$

- Sources (already discussed)
- Normal distribution
- Lognormal distribution
- Multiplying source rates and probability of exceeding ground motion level
- Adding exceedances for a ground motion level to get total hazard curve
- Applying Poisson relation to get 10% probability of exceedance in 50 years

Example 1

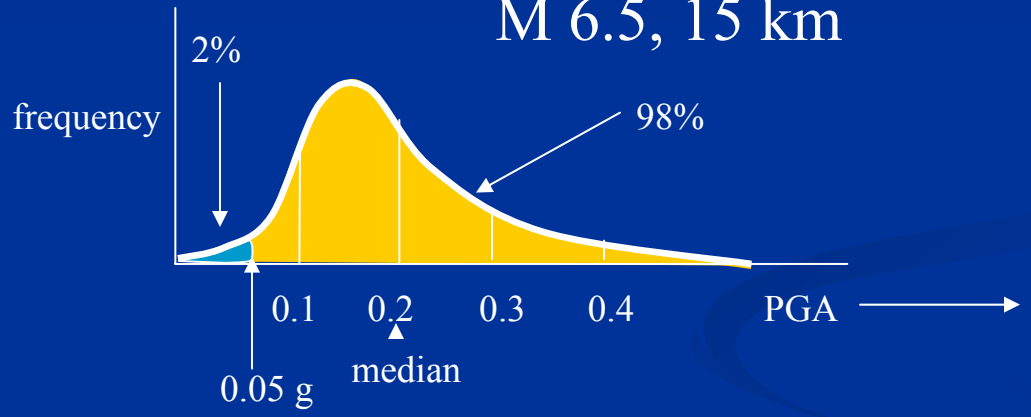
- Earthquake source

- Ground motion



Annual Rate of Exceedance

- What is the annual rate that ground motion will exceed 0.05 g pga given M 6.5 earthquake occurs?



- Almost all earthquakes (98%) of M 6.5 at a distance of 15 km will cause ground motion that will exceed 0.05g.

Annual Rate of Exceedance

- Recall the equation for the annual rate of exceedance and simplify for a single source, distance and magnitude:

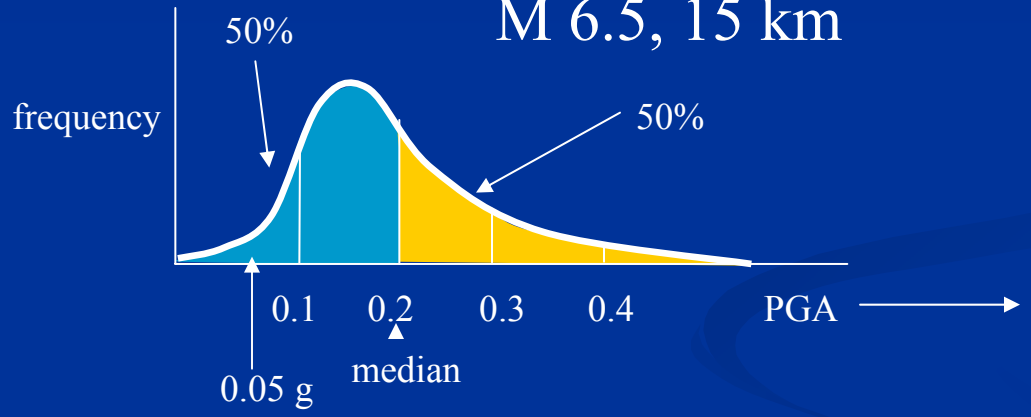
$$E(z) = \alpha P(Z > z \mid m, r)$$

$$E(0.05) = 0.02 * 0.98 = 0.02$$

- Ground motion: 0.05g
- Rate of 0.05 g exceedance: 0.02

Annual Rate of Exceedance

- What is the annual rate that ground motion will exceed 0.2 g pga given M 6.5 earthquake occurs?



- 50% of earthquakes of M 6.5 at a distance of 15 km will cause ground motion that will exceed 0.2g.

Annual Rate of Exceedance

- Recall the equation for the annual rate of exceedance and simplify for a single source, distance and magnitude:

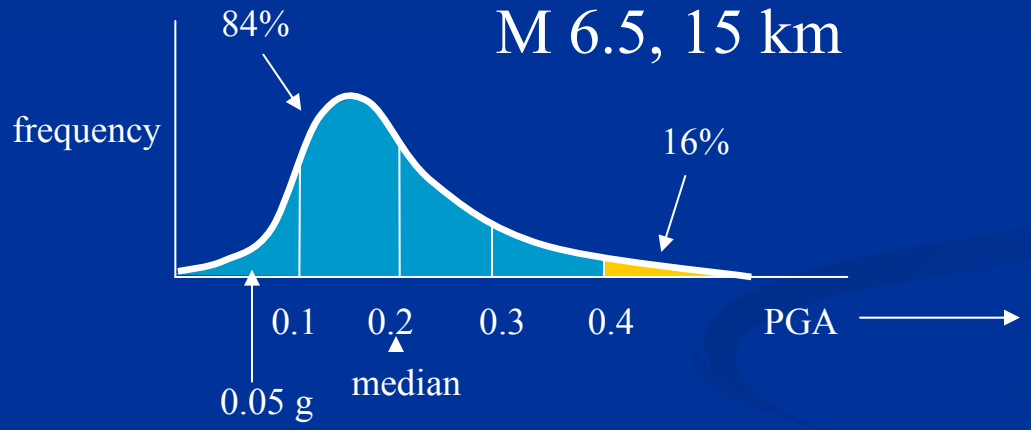
$$E(z) = \alpha P(Z > z \mid m, r)$$

$$E(0.2) = 0.02 * 0.50 = 0.01$$

Ground motion:	0.05g	0.2g
Rate of 0.05 g exceedance:	0.02	0.01

Annual Rate of Exceedance

- What is the annual rate that ground motion will exceed 0.4 g pga given M 6.5 earthquake occurs?



- 16% of earthquakes of M 6.5 at a distance of 15 km will cause ground motion that will exceed 0.4g.

Annual Rate of Exceedance

- Recall the equation for the annual rate of exceedance and simplify for a single source, distance and magnitude:

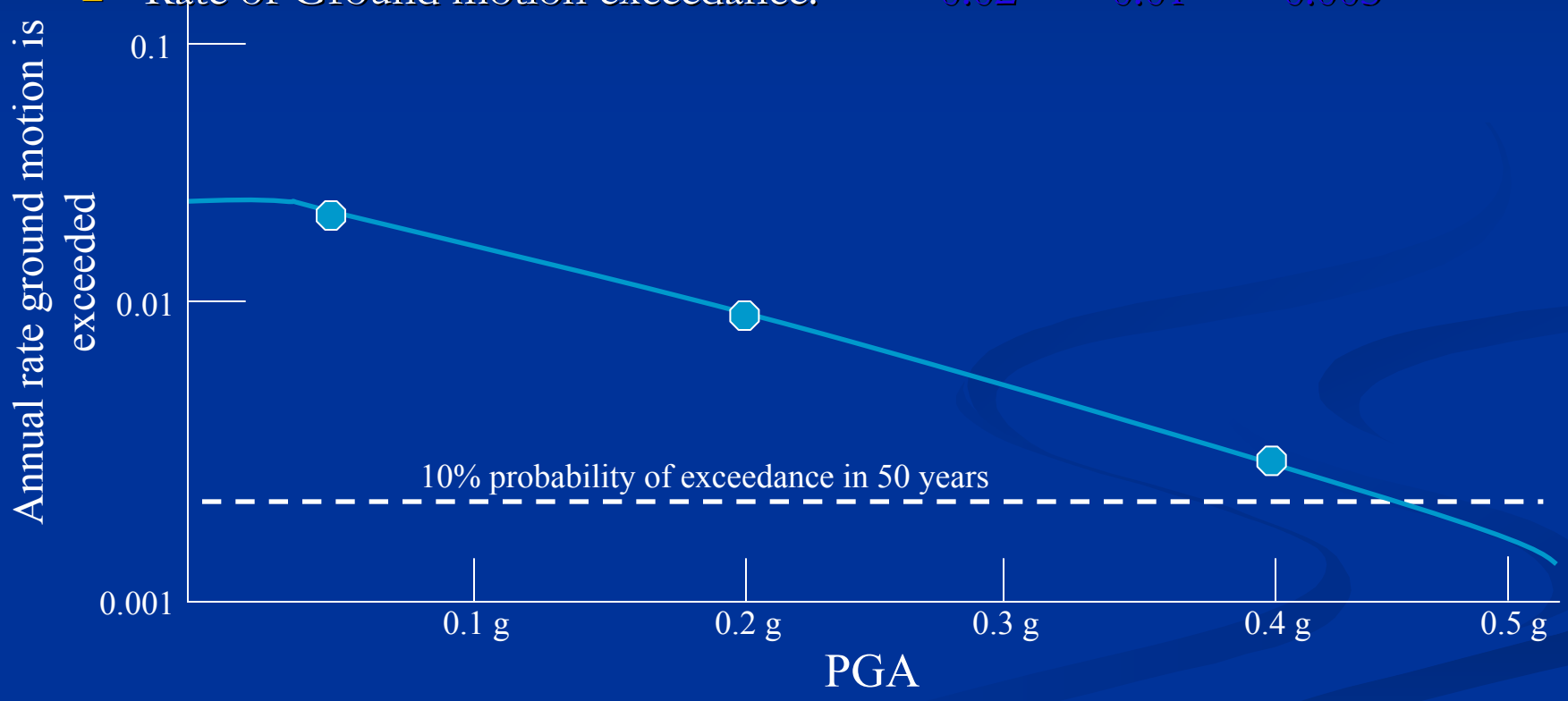
$$E(z) = \alpha P(Z > z \mid m, r)$$

$$E(0.4) = 0.02 * 0.16 = 0.003$$

Ground motion:	0.05g	0.2g	0.4g
Rate of 0.05 g exceedance:	0.02	0.01	0.003

Hazard Curve

- Ground motion: 0.05g 0.2g 0.4g
- Rate of Ground motion exceedance: 0.02 0.01 0.003



Example 2

- Earthquake sources

- Ground motion

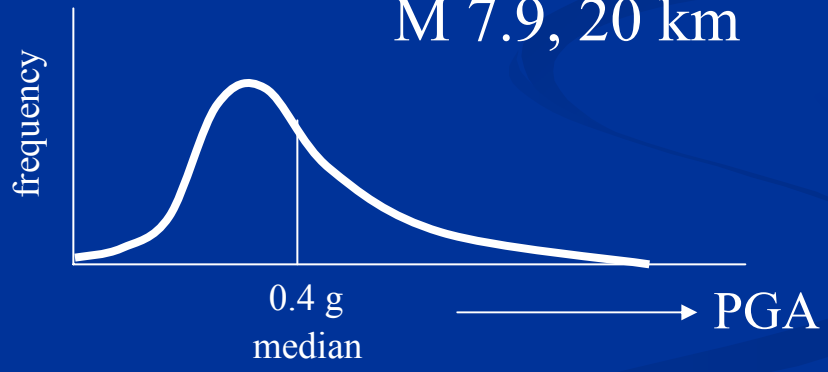
20 km

15 km

M 7.9, 20 km

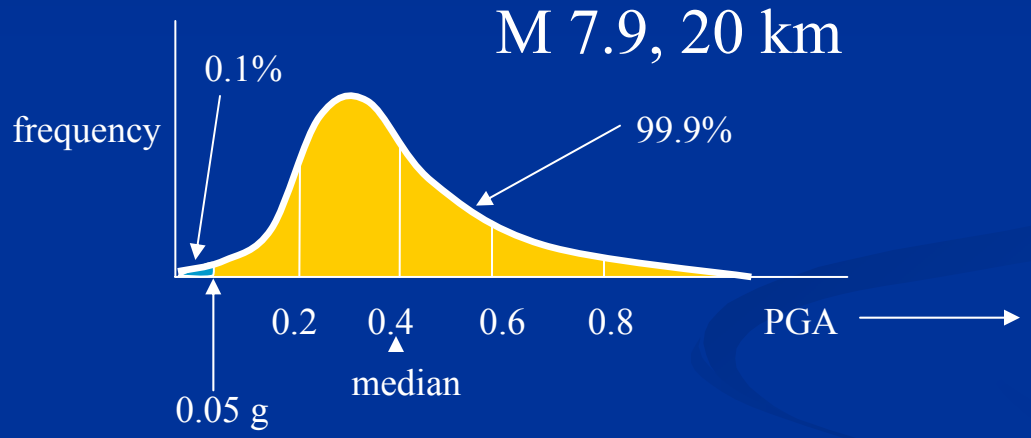
Fault 1
M 6.5, 15 km
Recurrence: 50 years
Annual rate: 0.02

Fault 2
M 7.9, 20 km
Recurrence: 250 years
Annual Rate: 0.004



Annual Rate of Exceedance

- What is the annual rate that ground motion will exceed 0.05 g pga given M 6.5 and M 7.9 earthquakes occur?



- Almost all earthquakes (99.9%) of M 7.9 at a distance of 20 km will cause ground motion that will exceed 0.05g.

Annual Rate of Exceedance

- Recall the equation for the annual rate of exceedance and simplify for a single source, distance and magnitude:

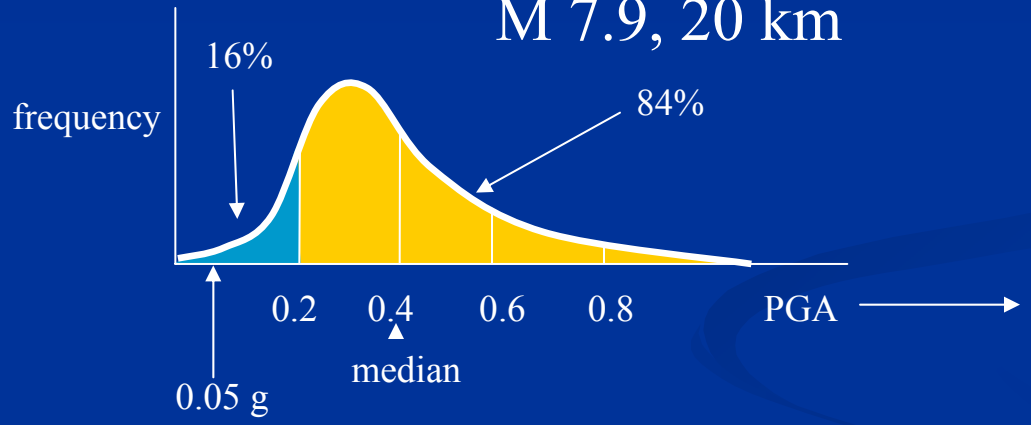
$$E(z) = \sum_{i=1}^{2} \alpha_i P(Z > z \mid m, r)$$

$$E(0.05) = 0.02 * 0.98 + 0.004 * 0.999 = 0.024$$

- Ground motion: 0.05g
- Rate of 0.05 g exceedance: 0.024

Annual Rate of Exceedance

- What is the annual rate that ground motion will exceed 0.2 g pga given M 6.5 and M 7.9 earthquake occur?



- 84% of M 7.9 at a distance of 20 km will cause ground motion that will exceed 0.2g.

Annual Rate of Exceedance

- Recall the equation for the annual rate of exceedance:

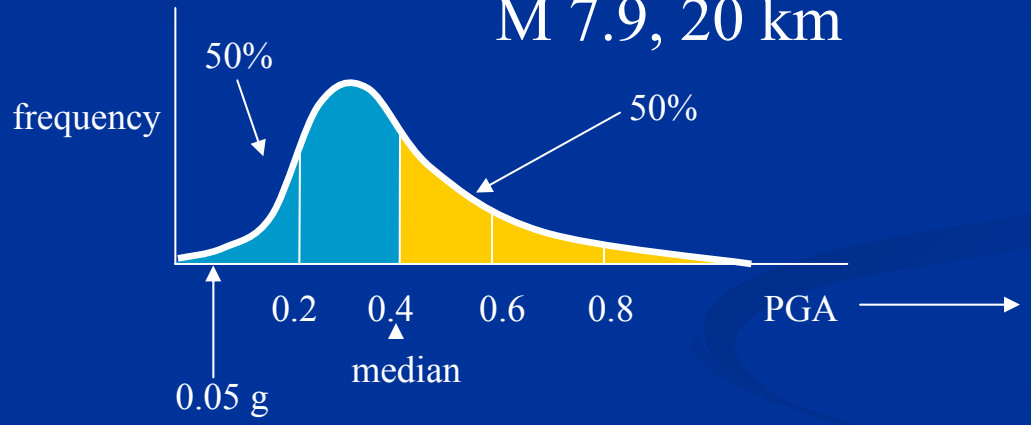
$$E(z) = \sum_{i=1}^{2} \alpha_i P(Z > z \mid m, r)$$

$$E(0.2) = 0.02 * 0.50 + 0.004 * 0.84 = 0.013$$

Ground motion:	0.05g	0.2g
Rate of 0.05 g exceedance:	0.024	0.013

Annual Rate of Exceedance

- What is the annual rate that ground motion will exceed 0.4 g pga given M 6.5 and M 7.9 earthquake occur?



- 50% of M 7.9 at a distance of 20 km will cause ground motion that will exceed 0.4g.

Annual Rate of Exceedance

- Recall the equation for the annual rate of exceedance:

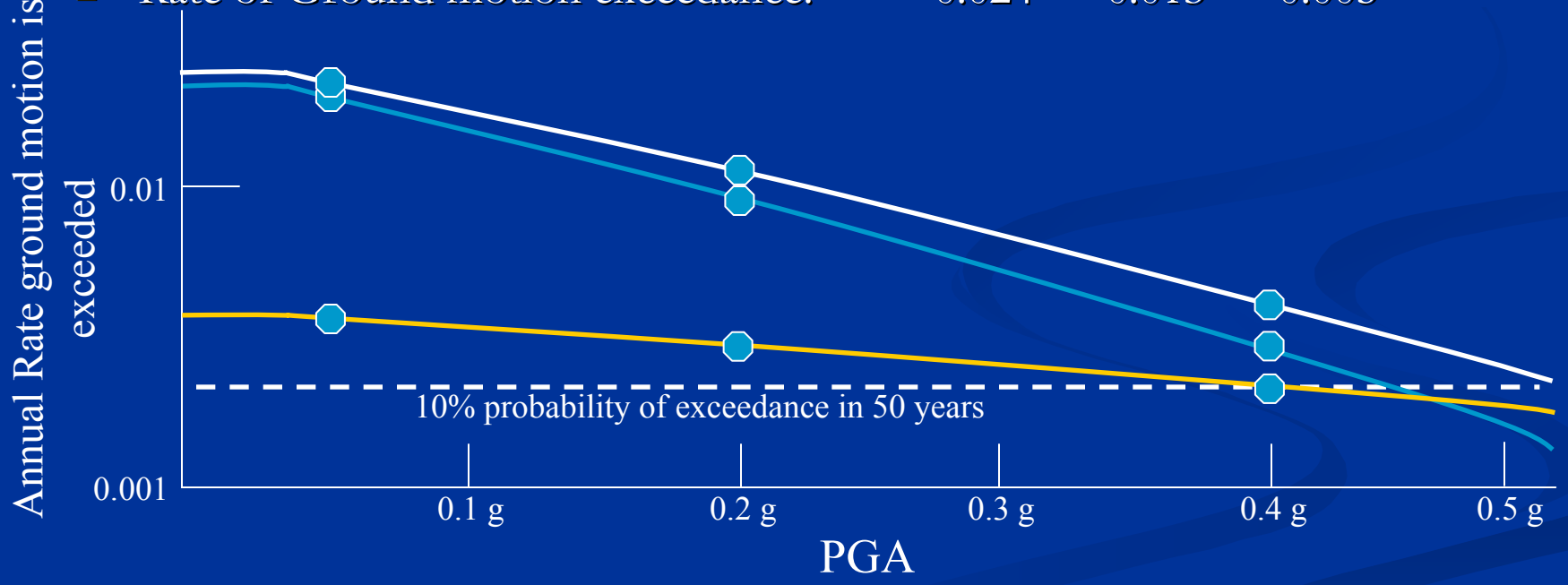
$$E(z) = \sum_{i=1}^{2} \alpha_i P(Z > z \mid m, r)$$

$$E(0.2) = 0.02 * 0.16 + 0.004 * 0.50 = 0.005$$

Ground motion:	0.05g	0.2g	0.4g
Rate of 0.05 g exceedance:	0.024	0.013	0.005

Hazard Curve

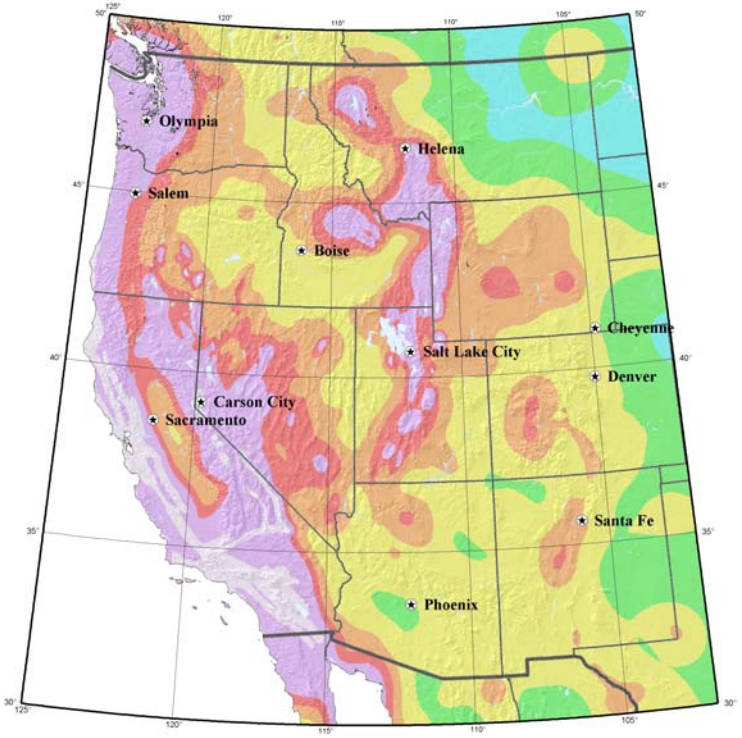
	0.05g	0.2g	0.4g
Ground motion:			
Fault 1:	0.02	0.01	0.003
Fault 2:	0.004	0.003	0.002
Rate of Ground motion exceedance:	0.024	0.013	0.005



HAZARD PRODUCTS

http://eqhazmaps.usgs.gov

2002 Hazard Maps - PGA-rock
2% probability of exceedance in 50-years



Purple-0.3g and greater
Yellow -0.1g and greater

Deaggregations