# Macro seismic hazard analysis

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# Seismic hazard analysis

What is actually seismic hazard analysis?

- ?
- ?
- ?

# Seismic hazard vs. risk

**Seismic risk** = **seismic hazard** * exposure * vulnerability * cost

**Seismic hazard** – The probability of experiencing a specific ground shaking at a specific site or region due to earthquakes.

# Seismic risk analysis

- Macro seismic hazard analysis
  - Deterministic seismic hazard analysis (DSHA)
  - Probabilistic seismic hazard analysis (PSHA)
- Micro seismic hazard analysis
  - Soft ground effects analysis
  - Liquefaction analysis
- Vulnerability and risk analysis
  - Building vulnerability, vulnerability curves
  - RADIUS, HAZUS approach
  - Case studies

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# Seismic hazard analysis

Which factors do you need to investigate to perform a seismic hazard analysis

- ?
- ?
- ?

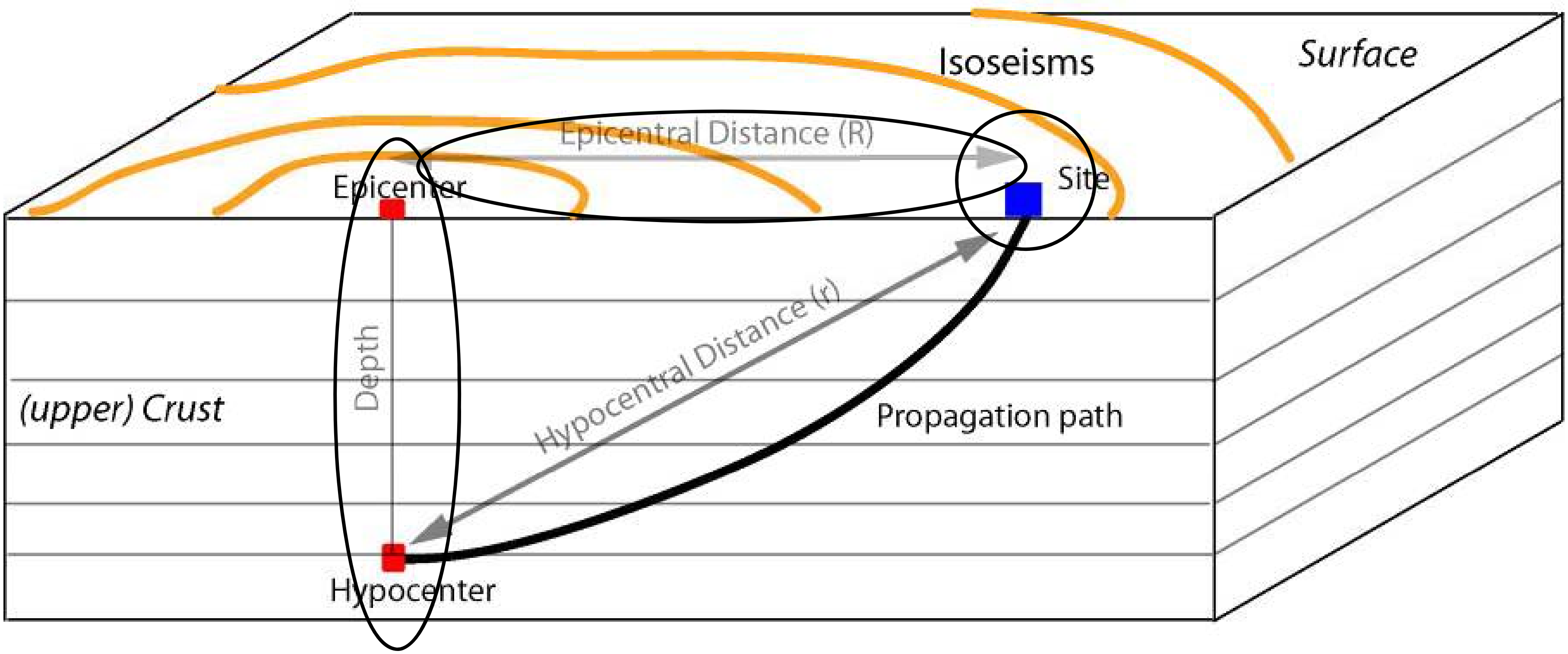
# Macro seismic hazard analysis

- Deterministic seismic hazard analysis (DSHA)
  - Use a single scenario
    - Select a single magnitude, M
    - Select a single distance, R
    - Assume effects due to M, R

- Probabilistic seismic hazard analysis (PSHA)
  - Assumes many scenarios
    - Consider all magnitudes
    - Consider all distances
    - Consider all effects

# Earthquake source, wave propagation and site effect

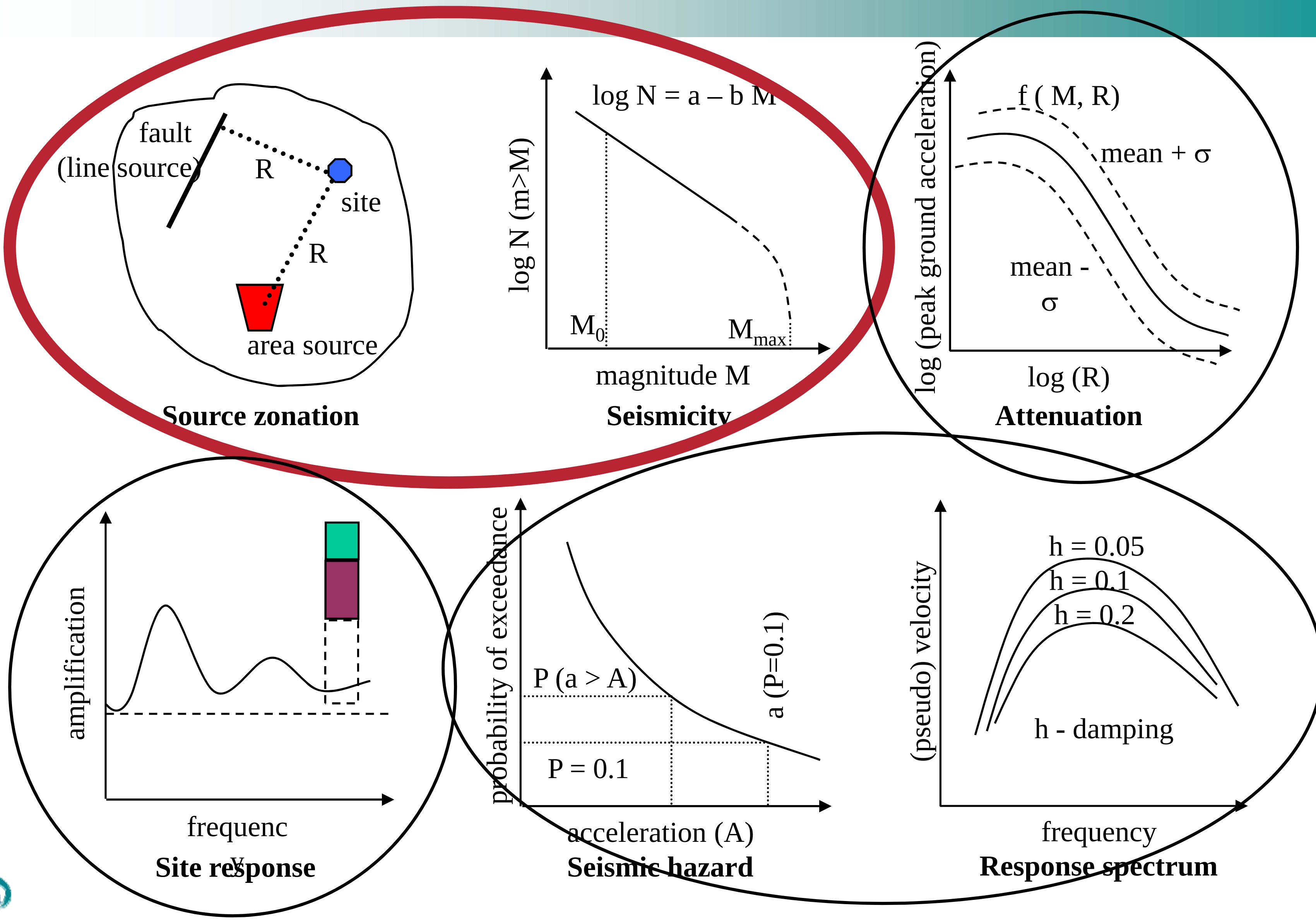
**Site:**
Ground motion vibration
(acceleration, velocity, displacement)




**Hypocenter:**
Earthquake Magnitude

**Wave propagation path:**
Energy loss and geometrical spreading

# Seismic hazard analysis model




After Cornell

# Deterministic Seismic Hazard Analysis

# DSHA

# Deterministic seismic hazard analysis (DSHA)

- Earliest approach taken to seismic hazard analysis
- Originated in nuclear power industry applications
- Still used for some significant structures
  - Nuclear power plants
  - Large dams
  - Large bridges
  - Hazardous waste containment facilities

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# DSHA: methodology

1. Identification and characterization of all sources
2. Selection of source-site distance parameter
3. Selection of "controlling earthquake"
4. Definition of hazard using controlling earthquake

# Zonation

# Zonation using RS

Almost no region in the world is free of tectonic activitiy

Seismic/tectonic activity leaves marks in the landscape

These landmarks indicate neo-tectonic activity and movements

Map these landmarks through RS for fault identificaton

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# Zonation

- Factors related to zonation
  - Occurrence of earthquakes
  - Visible faults
  - Earthquake mechanism
  - Frequency of earthquakes

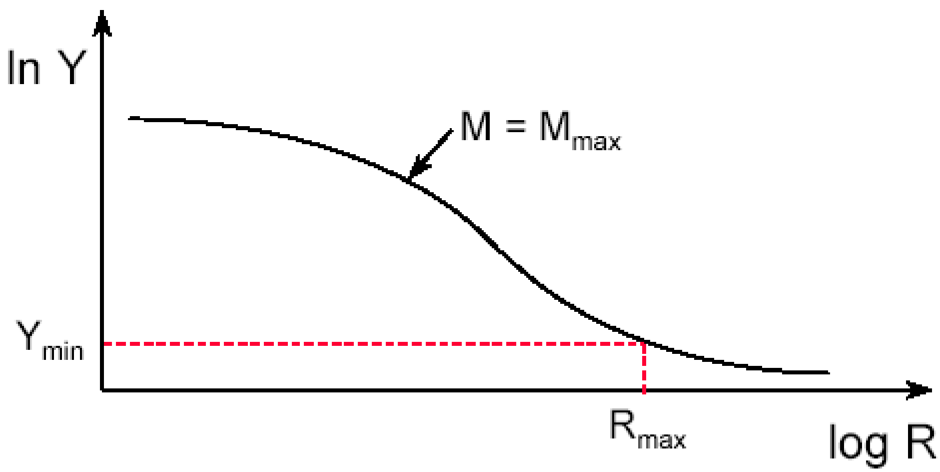
→ Often iterative process between the various steps in SHA

# DSHA: Identification and characterization of all sources (1)

- Identification of all sources capable of producing significant ground motion at the site
  - Large sources at long distances
  - Small sources at short distances
- Data sources:
  - Earthquake catalogs
  - Seismo-tectonic studies
- Characterization
  - Definition of source geometry
  - Establishment of earthquake potential

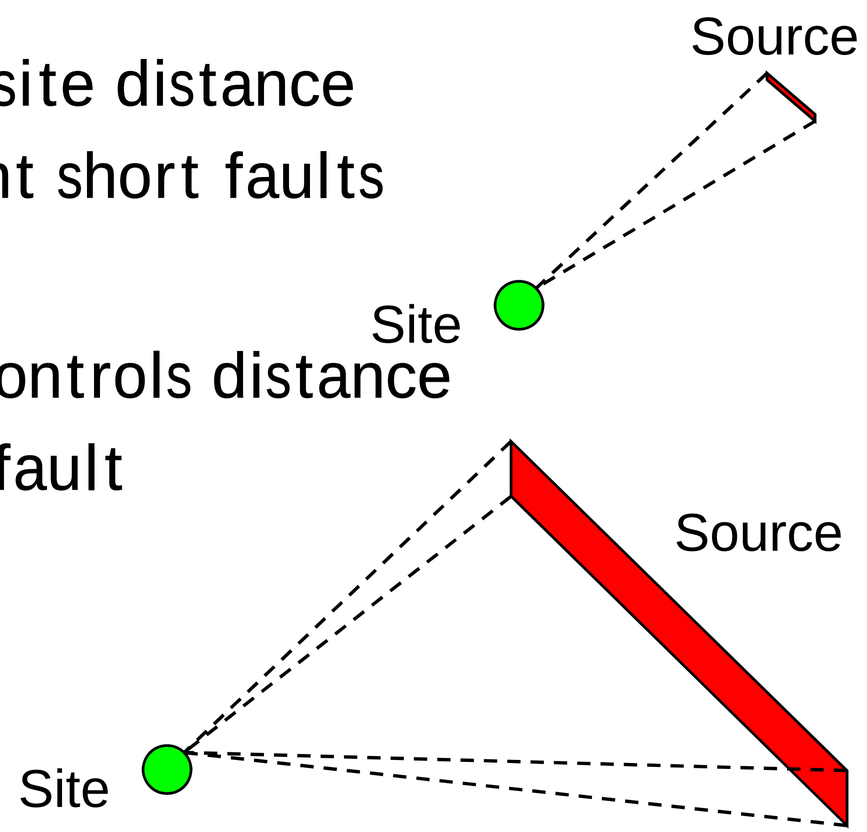
# DSHA: Identification and characterization of all sources (3)

- Estimate maximum magnitude that could be produced by any source in vicinity of site
- Find value of $R_{max}$ - corresponds to $M_{max}$ at threshold value of parameter of interest: $Y_{min}$



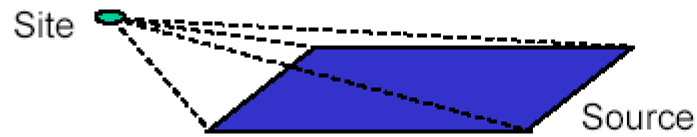
# DSHA: Identification and characterization of all sources (4)

- Characterize geometry
  - Point source
    - Constant source-site distance
    - Volcanoes, distant short faults
  - Linear source
    - One parameter controls distance
    - Shallow, distant fault

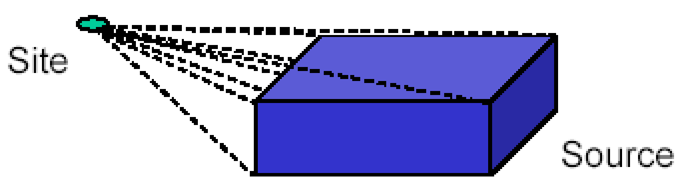


# DSHA: Identification and characterization of all sources (5)

- Characterise geometry
  - Areal source

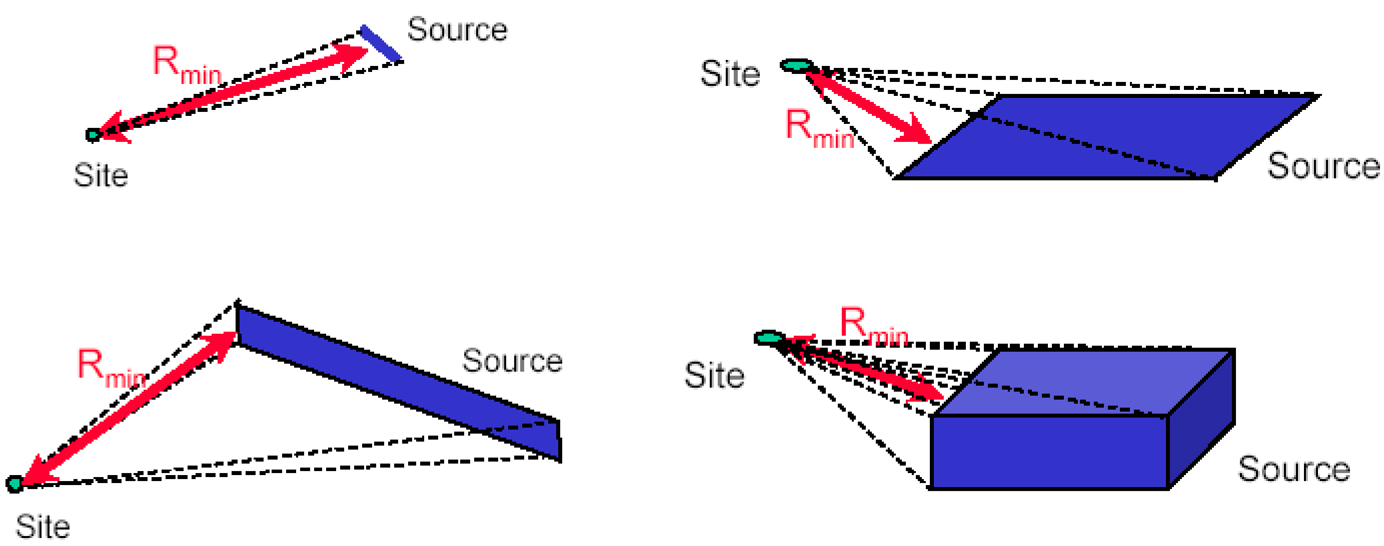



    - Two geometric parameters control distance
    - Constant depth crustal source
  - Volumetric source
    - Three parameters control distance



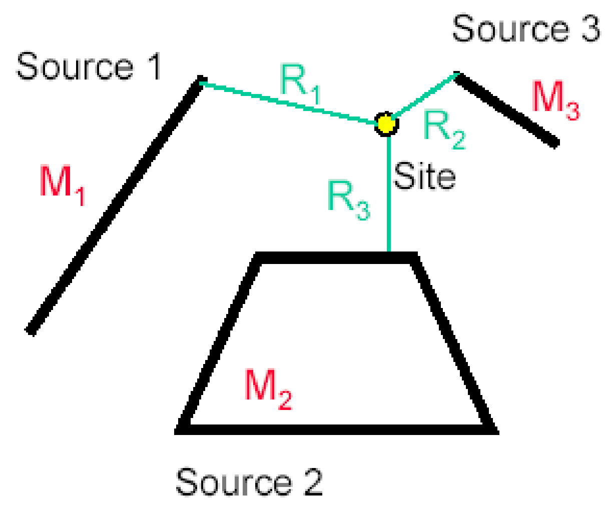
# DSHA: Select source-site distance parameters

- Typically assume shortest source-site distance $R_{min}$ ("worst case" scenario)



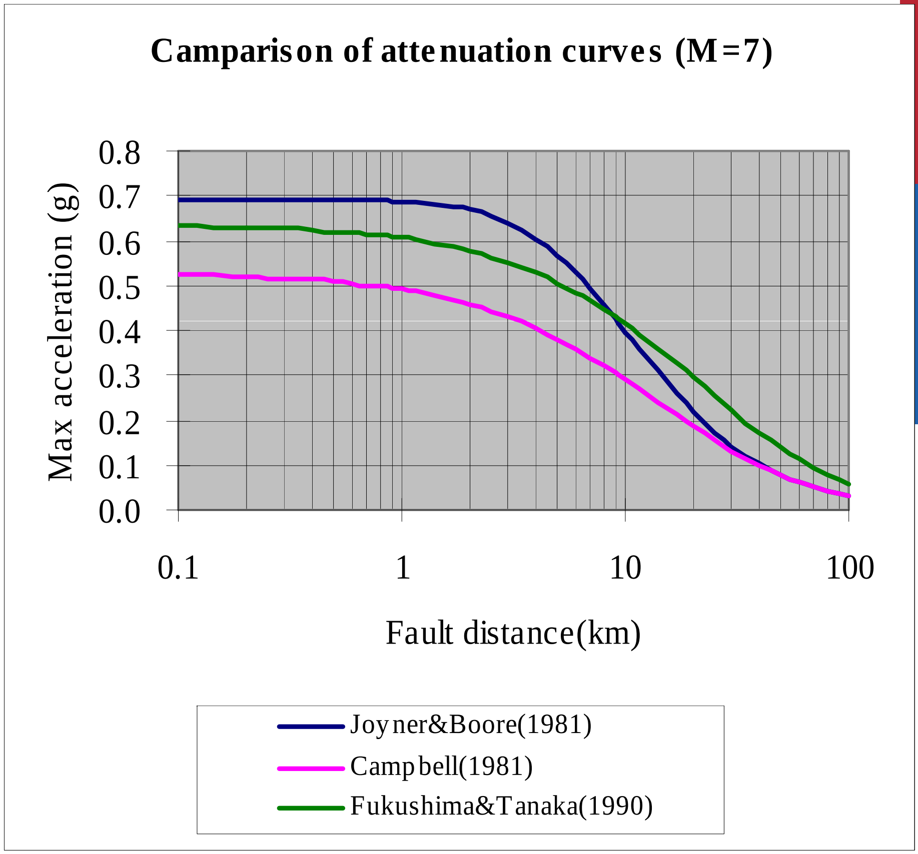
# DSHA: Select controlling earthquake

- Calculate using attenuation relationships what the expected PGA or SA will be at the site (function of R and Magnitude)
- The earthquake that produces the highest PGA or SA will be the “controlling earthquake”
- Typical GIS analysis



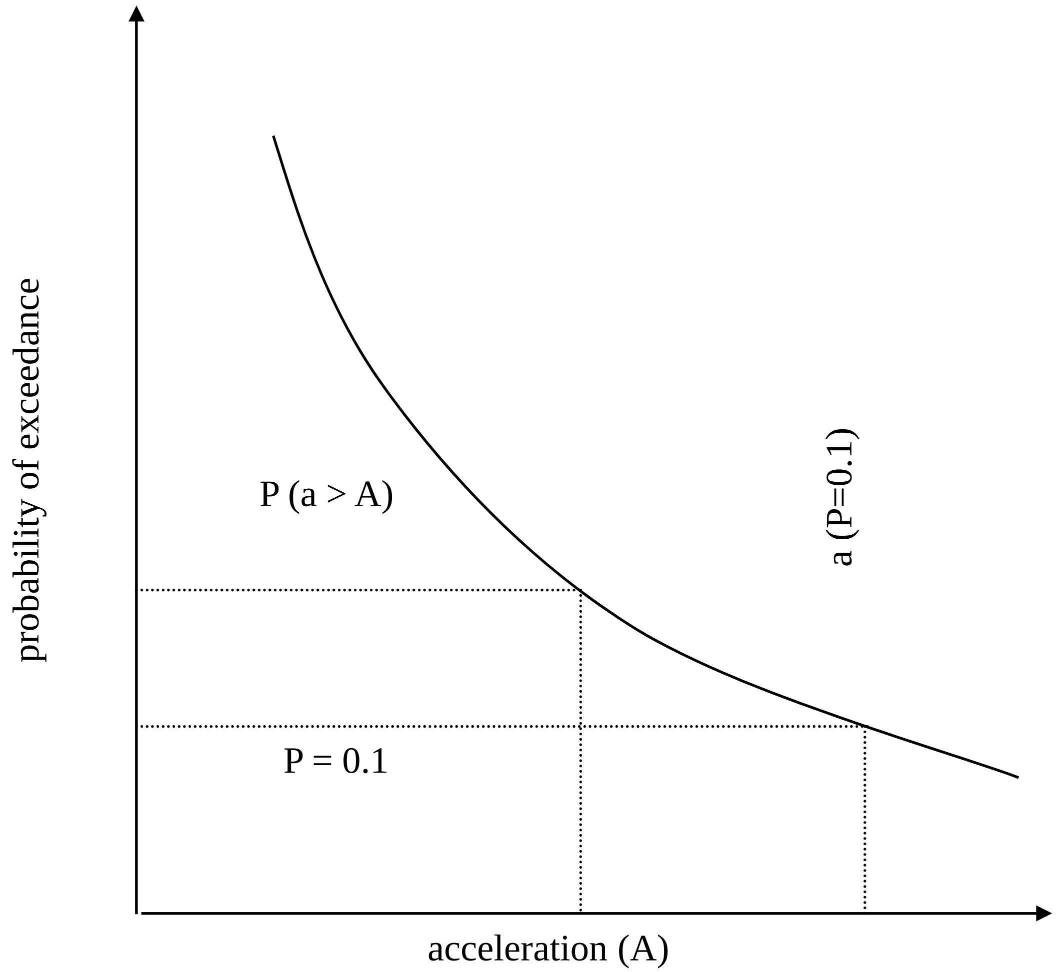
# Attenuation

- Attenuation: seismic waves become weaker as they travel outward from the source
- Various models possible for attenuation
  - local vs. regional vs. continental
  - Different sources (type and size of earthquake
- Joyner & Boore (1981) seismic wave attenuation function used in Indian subcontinent



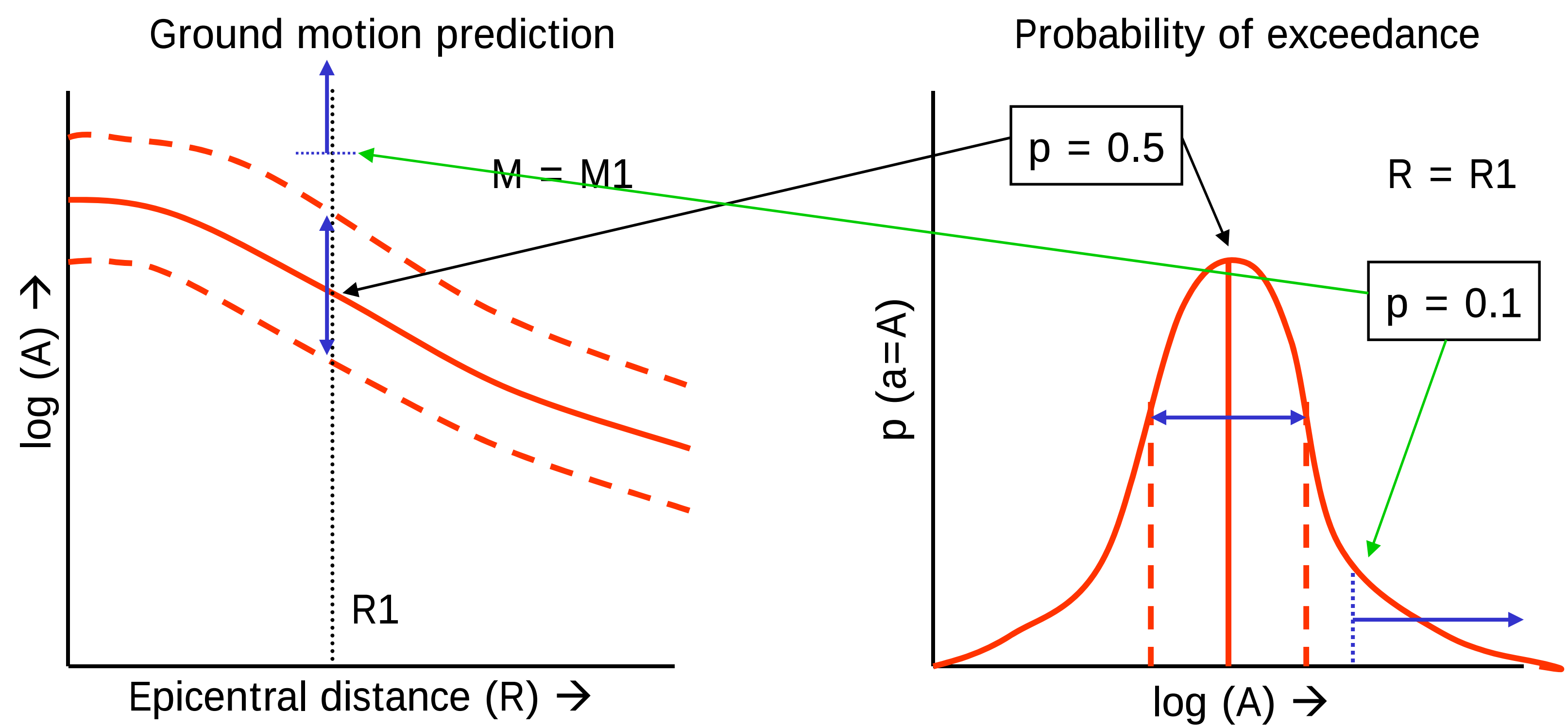

PGA=10^(0.249*M-Log(D)-0.00255*D-1.02)
PGA = Peak Ground Acceleration (in g)
D = Hypocentral distance (in km)
M = Magnitude

# Probability of exceedence




**Seismic hazard**

# Ground motion prediction




A – Peak Ground Acceleration (PGA) or Peak Ground Velocity (PGV)
Hazard = probability of exceeding a ground motion level within time period T.
→ P(a>A) = ♦♦ f(a>A|m,r) p(m) p(r) dm dr

# DSHA: Comments

- DSHA produces “scenario” earthquake for design (design earthquake)
- As commonly used, produces worst-case scenario
- DSHA provides no indication of how likely design earthquake is to occur during life of structure
- Design earthquakes may occur every 200 yrs in some places, every 10 000 in other
- DSHA can require subjective opinions on some input parameters
- Variability in effects not rationally accounted for

# Probabilistic Seismic Hazard Analysis

# (PSHA)

# PSHA

- Goal: to quantify the rate (or probability) of exceeding various ground-motion levels at a site, given all possible earthquakes
- Traditionally: Peak Ground Acceleration (PGA) used to quantify ground motion
- Today: Response Spectral Acceleration (SA) preferred – expected SA in accordance to the natural frequency of the building

# PSHA (cont'd)

**Input:**

- Seismicity model:
    - o seismicity distribution in space (area) and time
    - o magnitude-frequency distribution
    - o $M_{max}$ – maximum possible earthquake
- Ground motion prediction equation (given M and hypocenter)
- Site response model (not discussed here)

**Output:**

- probability of exceeding a ground motion level within time period T.

# PSHA

- PSHA characterises uncertainty in location, size, frequency and effects of earthquakes and combines all of them to compute probabilities of different levels of ground shaking

# PSHA: methodology

1. Identification and characterization of all sources
2. Characterization of seismicity of each source
3. Determination of motions from each source
4. Probabilistic calculations

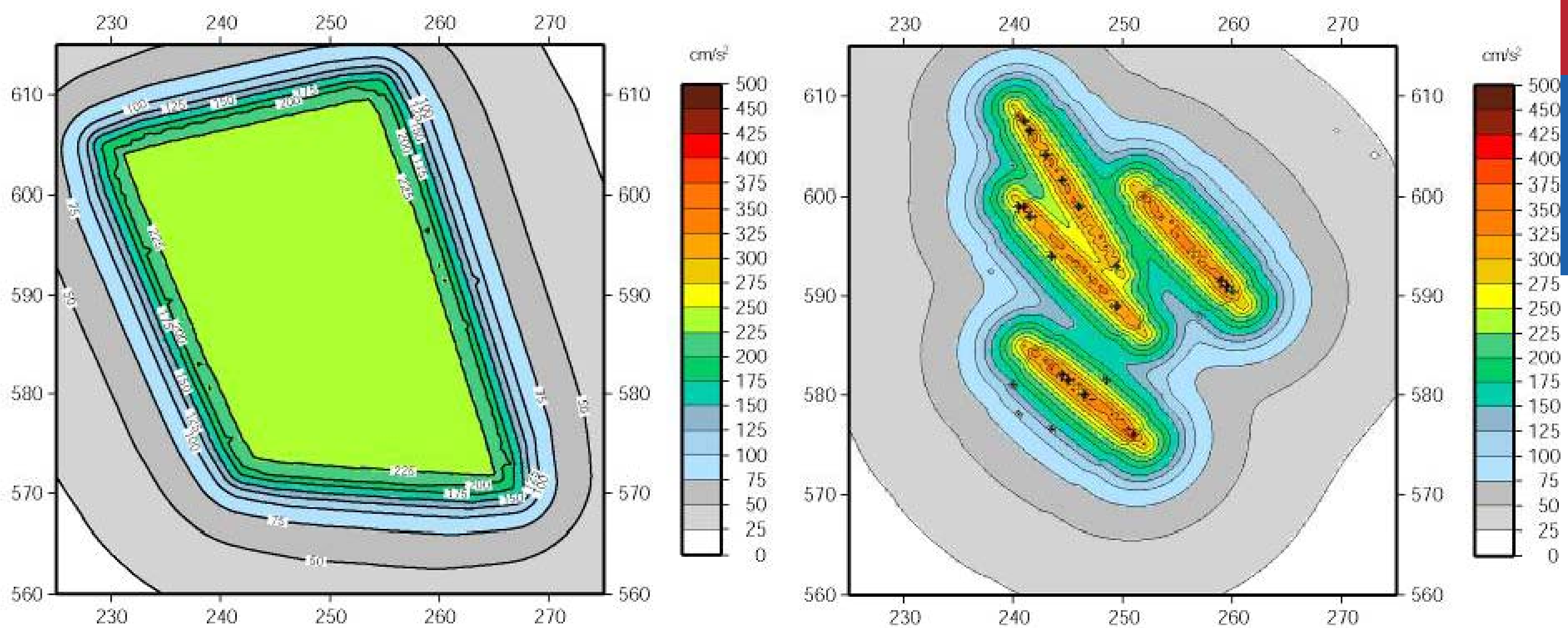
# PSHA: uncertainties

- Uncertainty in source-site distance
- Distribution of earthquake magnitudes
  - Gutenberg-Richter Recurrence law
- Predictive relationships
- Temporal uncertainty
- Combining uncertainties – probability computations

# Examples

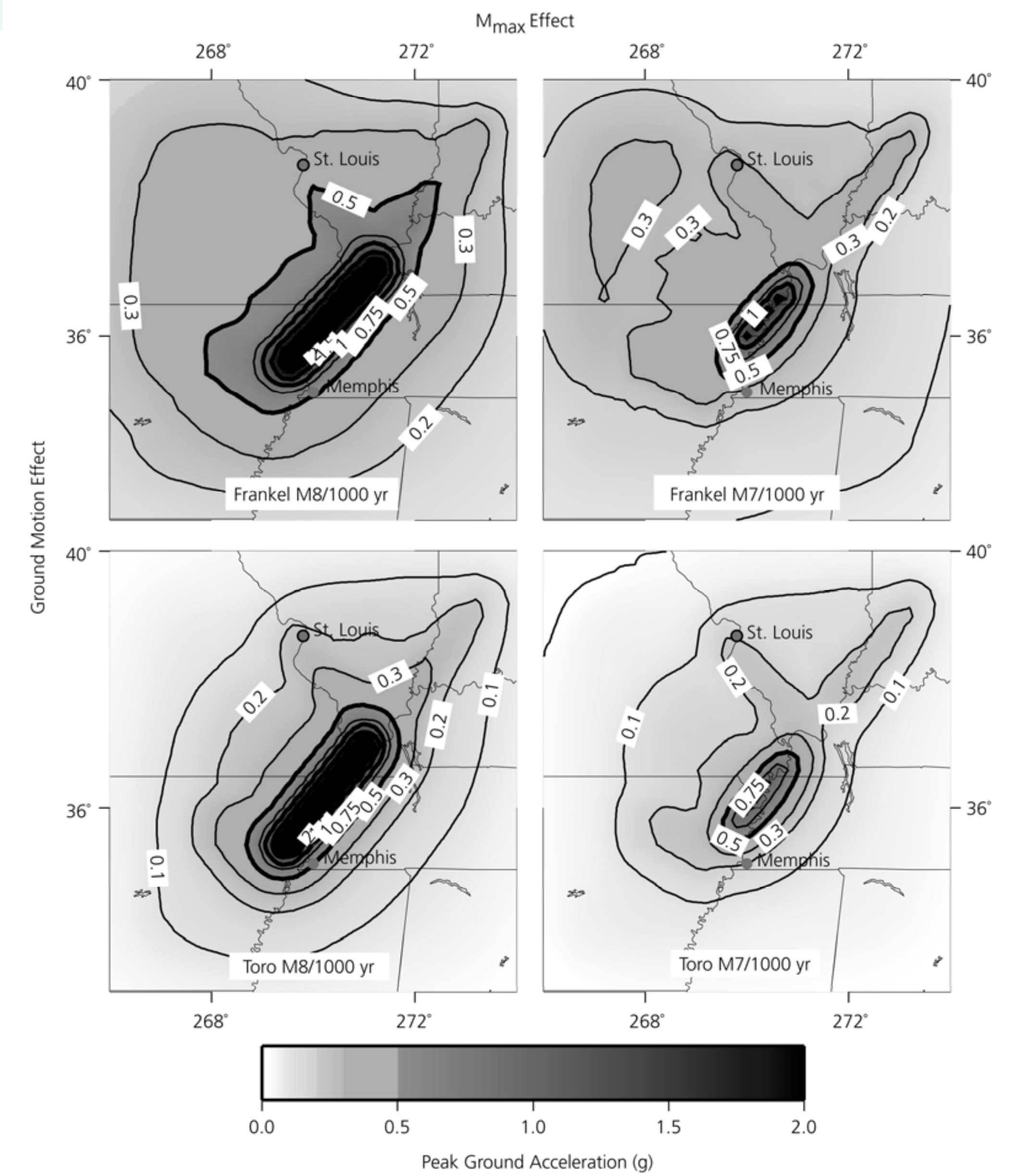
# Influence of seismicity areal distribution

Seismic hazard estimate for two different source zonations

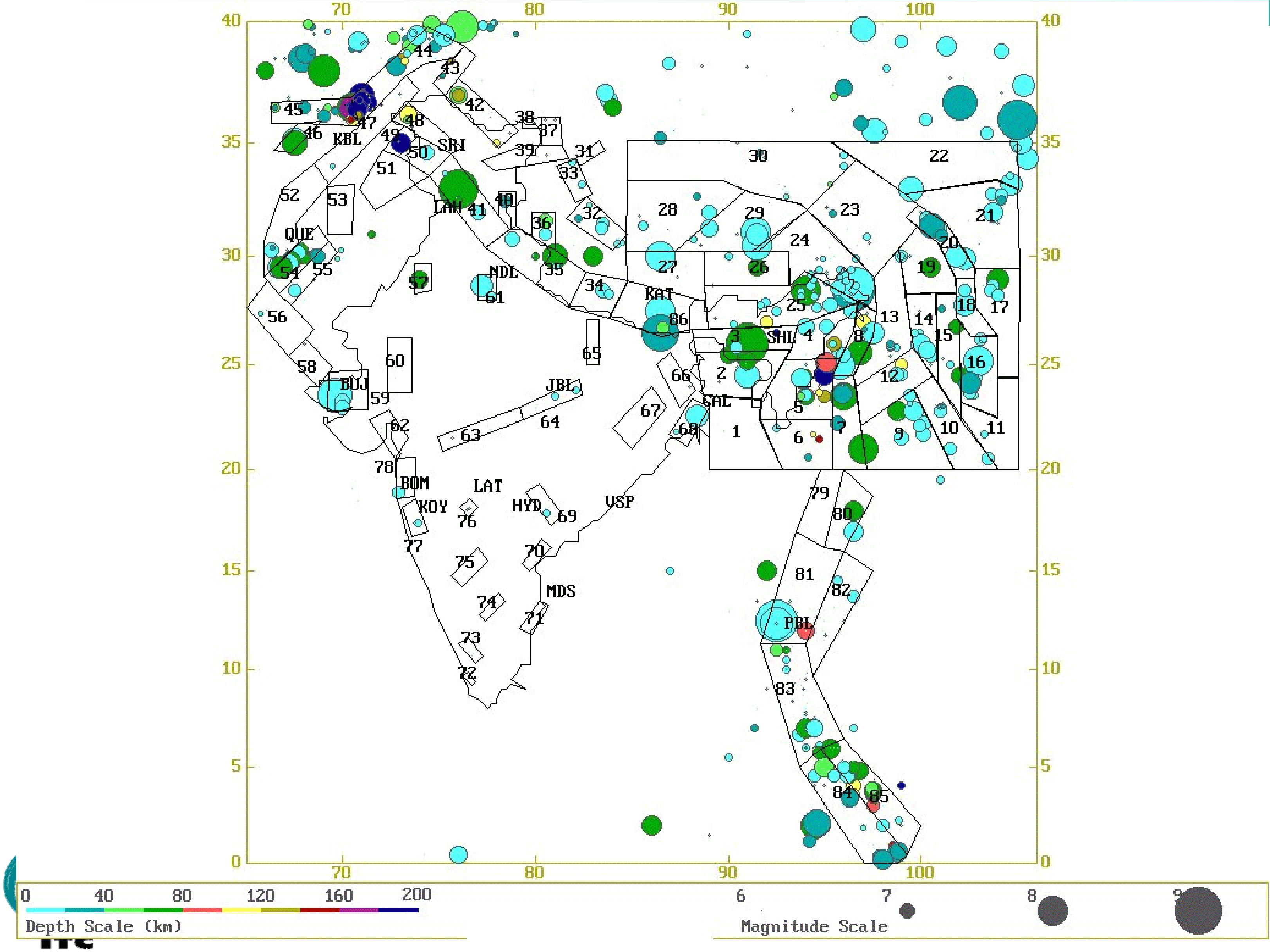



Observe the very large difference between the zonations!

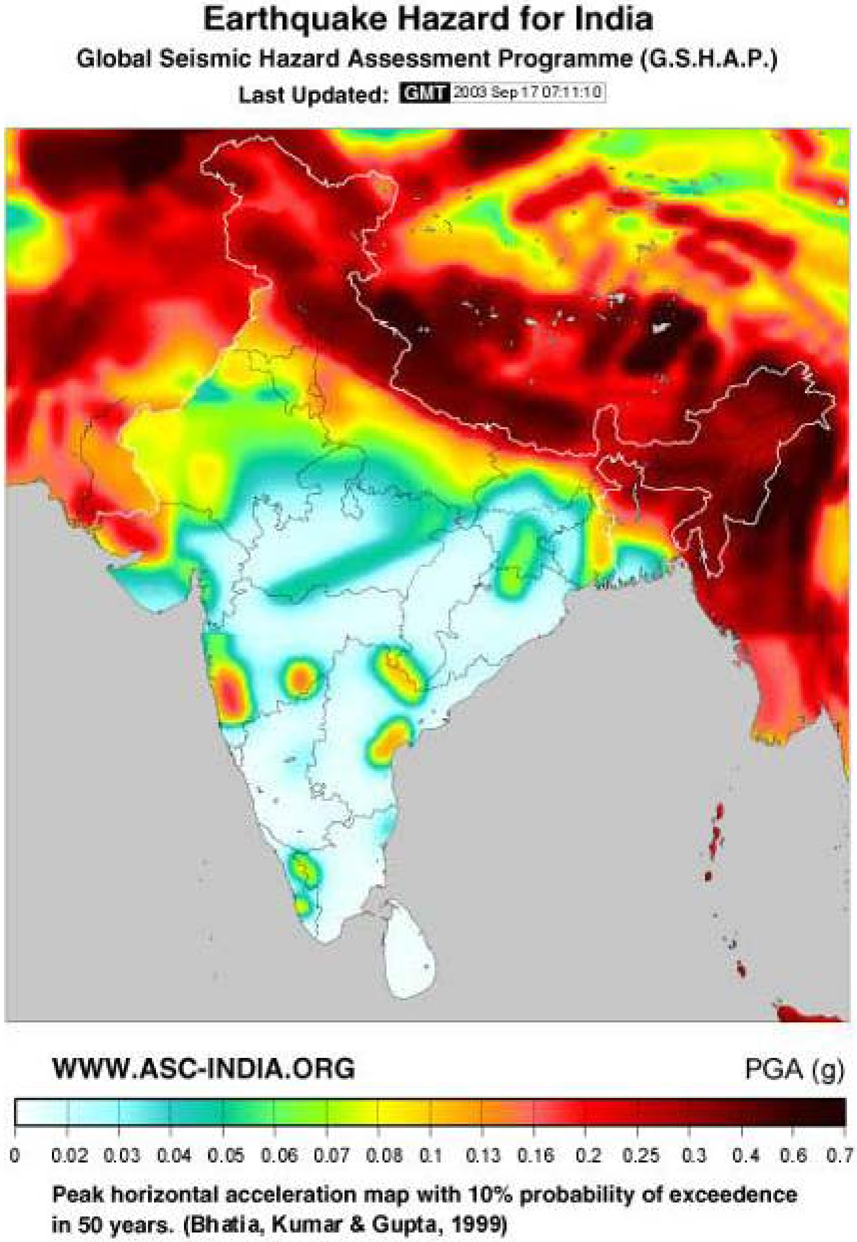
# Different approaches for DSHA analysis

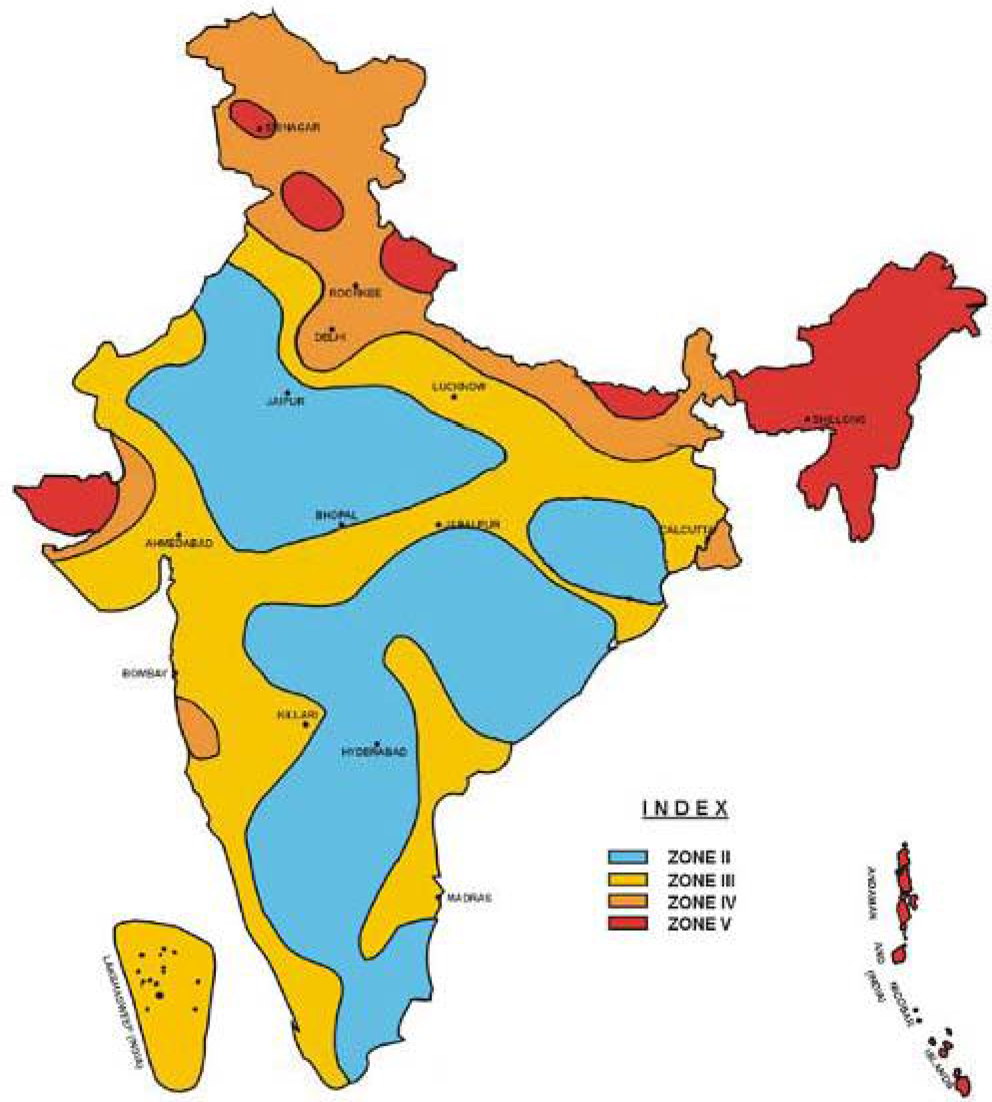


# Example India



# Example India



# Exercises

See separate document in data folder for exercise