CE03.98N

Soil Dynamics and Earthquake Engineering

#5 Seismic Hazard and Seismic Risk

February 5, 2003

Fumio Yamazaki

yamazaki@ait.ac.th

http://www.sce.ait.ac.th/people/faculty/~yamazaki

SEC/SCE, AIT.

Course Outline (1)

1. **Introduction**
   - 1.1 Earthquakes
   - 1.2 Consequences of Earthquakes

Jan. 8

2. **Engineering Seismology**
   - 2.1 Mechanism of Earthquakes
   - 2.2 Seismic Waves
   - 2.3 Earthquake Magnitude and Seismic Intensity
   - 2.4 Seismometers and Seismic Observation
   - 2.5 Tsunamis

Jan. 15

3. **Seismic Ground Motion**
   - 3.1 Fourier Spectrum
   - 3.2 Characteristics of Seismic Ground Motion

Jan. 22

   - 3.3 Response Spectrum
   - 3.4 Attenuation Relations and Effects of Soil Conditions
   - 3.5 Microtremor Observation

Jan. 29

Course Outline (2)

4. **Seismic Hazard and Seismic Risk**
   - 4.1 Seismic Hazard Analysis
   - 4.2 Damage Assessment

Feb. 5

By Prof. F. Yamazaki

By Prof. P.K. Basudhar

5. **Dynamic Soil Properties**
   - 5.1 Measurement of Dynamic Soil Properties
   - 5.2 Stress-Strain Behaviors

6. **Wave Propagation and Ground Response Analysis**
   - 6.1 Wave Propagation
   - 6.2 One-Dimensional Ground Response Analysis

7. **Liquefaction and Slope Stability**
   - 7.1 Liquefaction
   - 7.2 Slope Stability

4.1 Seismic Hazard Analysis

- **Deterministic** Seismic Hazard Analysis

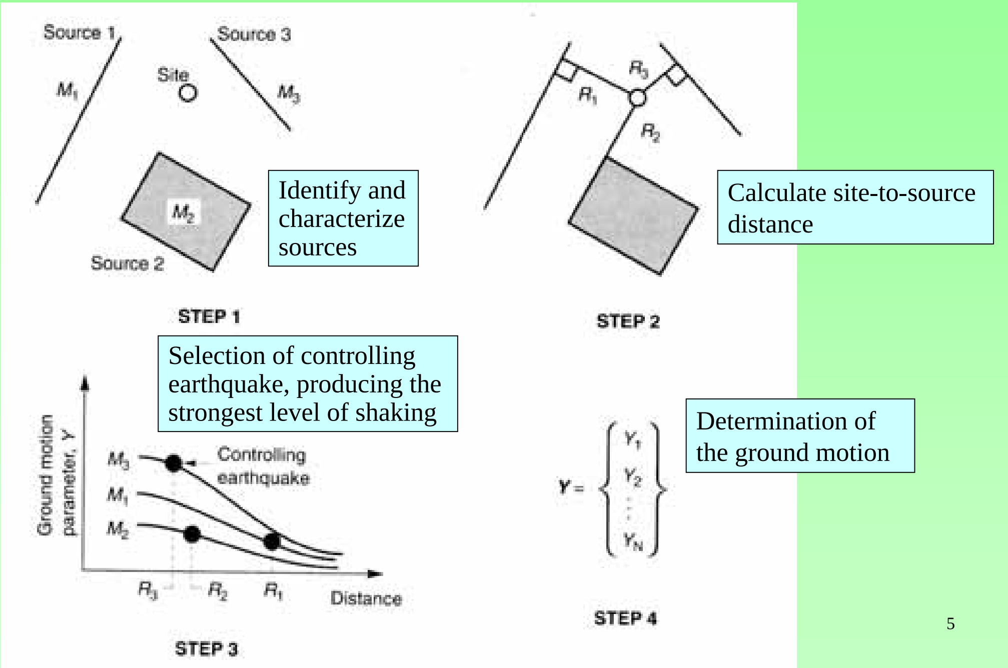
  Ground motion hazard evaluation based on a particular scenario earthquake

- **Probabilistic** Seismic Hazard Analysis

  Considering uncertainties in the size, location, and rate of recurrence of earthquakes.

  Developed by Cornell (1968).

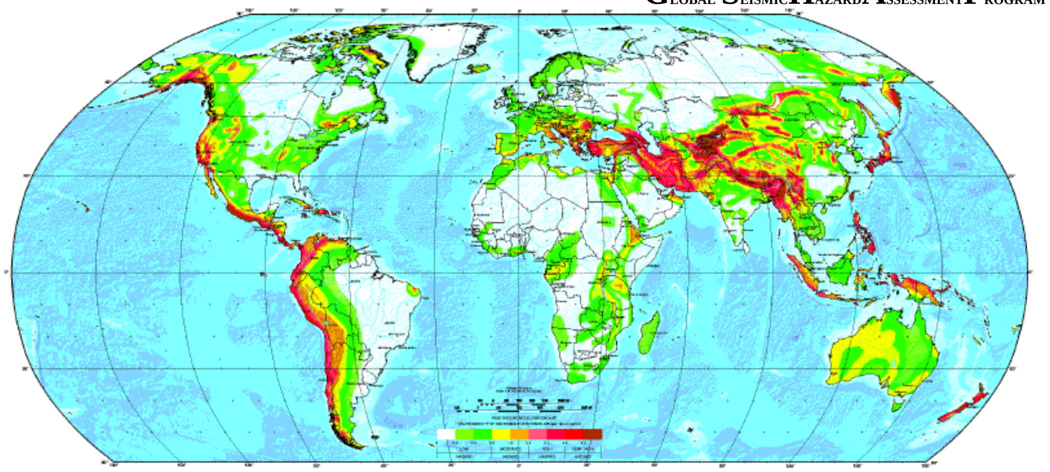
Deterministic Seismic Hazard Analysis



Earthquake Hazard Map

GLOBAL SEISMIC HAZARD MAP

GLOBAL SEISMIC HAZARD ASSESSMENT PROGRAM



http://seismo.ethz.ch/gshap/

Probabilistic Seismic Hazard Analysis

1. Determine potential earthquake sources around a site by points, lines and planes.-**(A)**
2. Assuming a *Poisson process*, the annual probability P that the intensity parameter Y exceed a value y is

$$P(y) = 1 - \exp\left\{-\sum_{i=1}^{n} \nu_i q_i(y)\right\} \quad \text{-(D)}$$

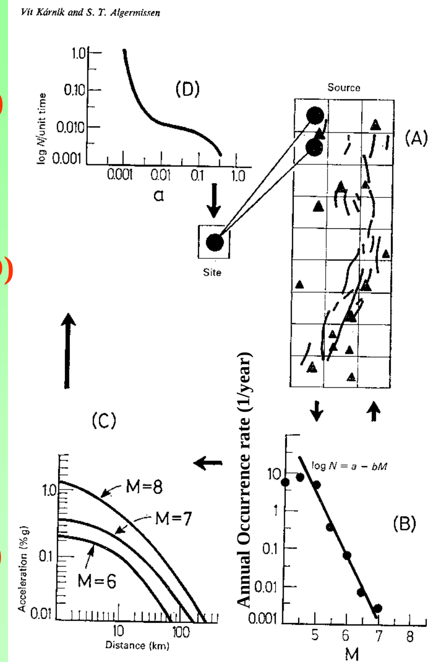
where n: number of source areas

ν_i: earthquake occurrence rate in source i - **(B)**

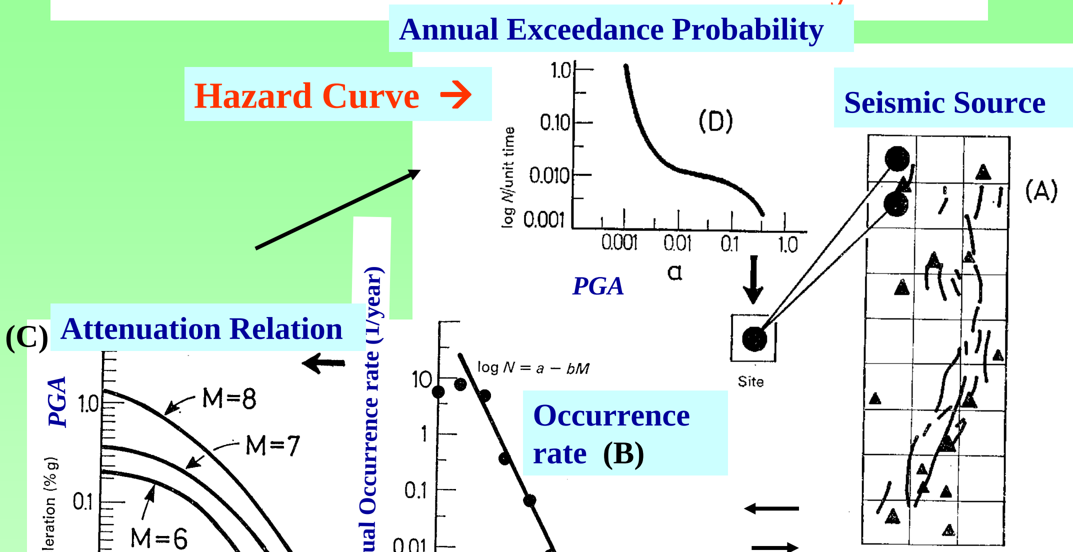
q_i: the probability that $Y>y$ when an earthquake occurs in source i

-- *based on an attenuation relation* **(C)** *and probability distributions of M and r*

3. Hazard curve for a site → **Hazard map**



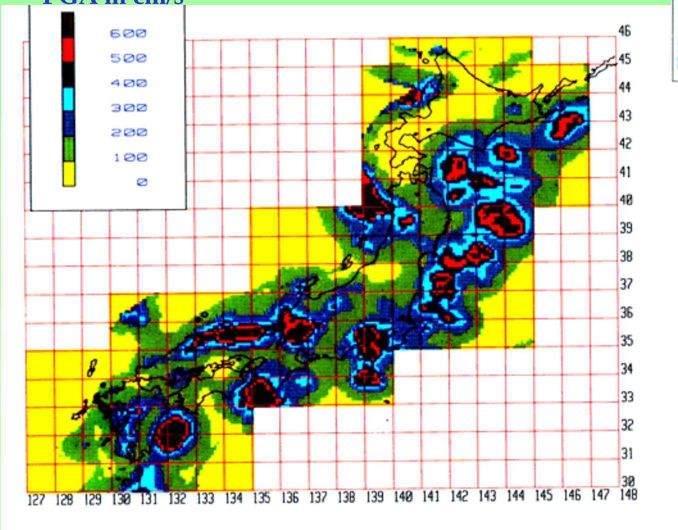
Probabilistic Seismic Hazard Analysis



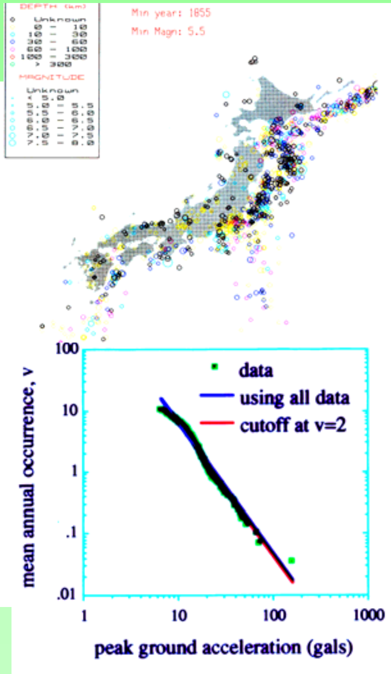
Poisson process: random occurrence

Seismic Hazard Map of Japan by Cumulative Distribution Method (100 year PGA)

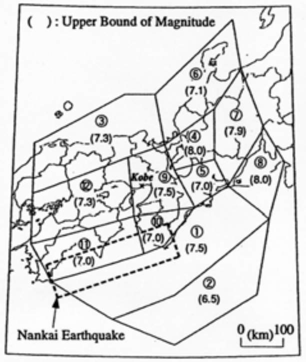
PGA in cm/s^2



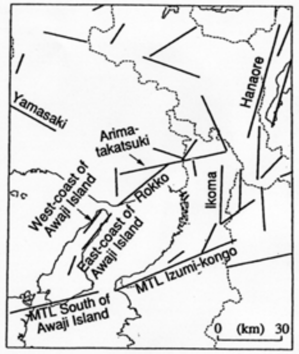
(Molas and Yamazaki, 1993)



Source-areas and seismogenic active faults in Kinki region, Japan and seismic hazard curve for Kobe (Ishikawa et al., 1998)

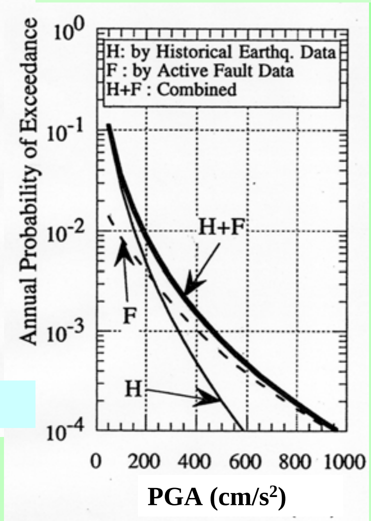


Area source model



Active faults model

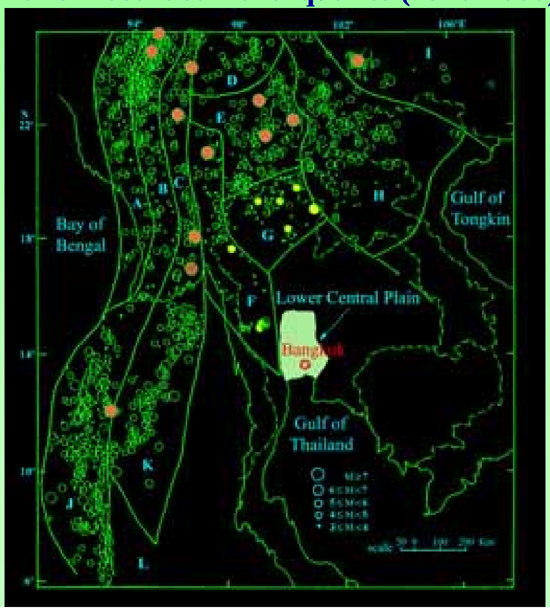
Hazard Curve for Kobe



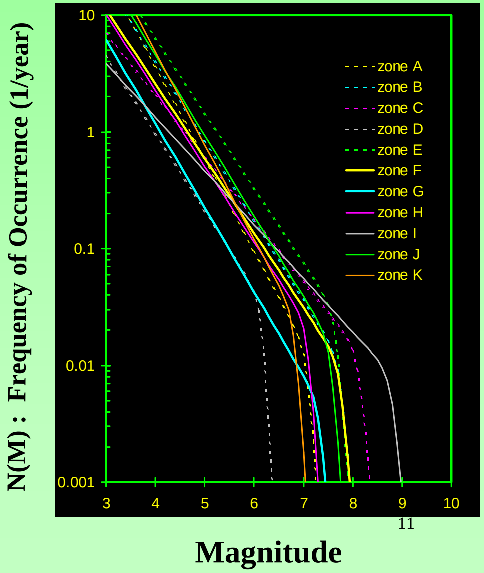
Seismic Hazard Analysis of Bangkok

(Warnitchai et al. 2000)

Twelve Regional Seismic Source Zones and Recorded Earthquakes (1910-2000)

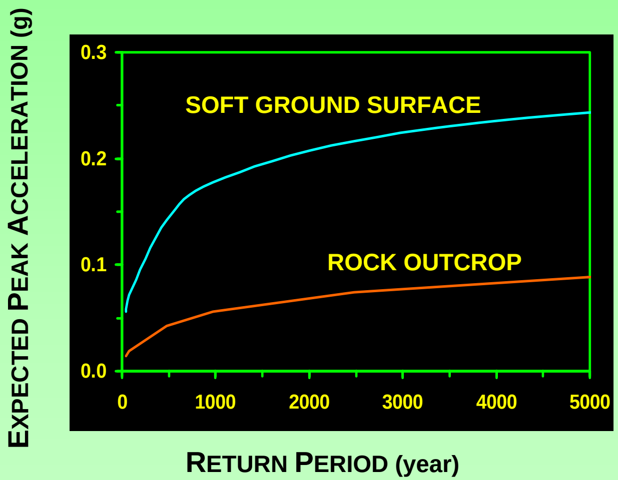


Magnitude-Recurrence relation



Seismic Hazard Analysis of Bangkok

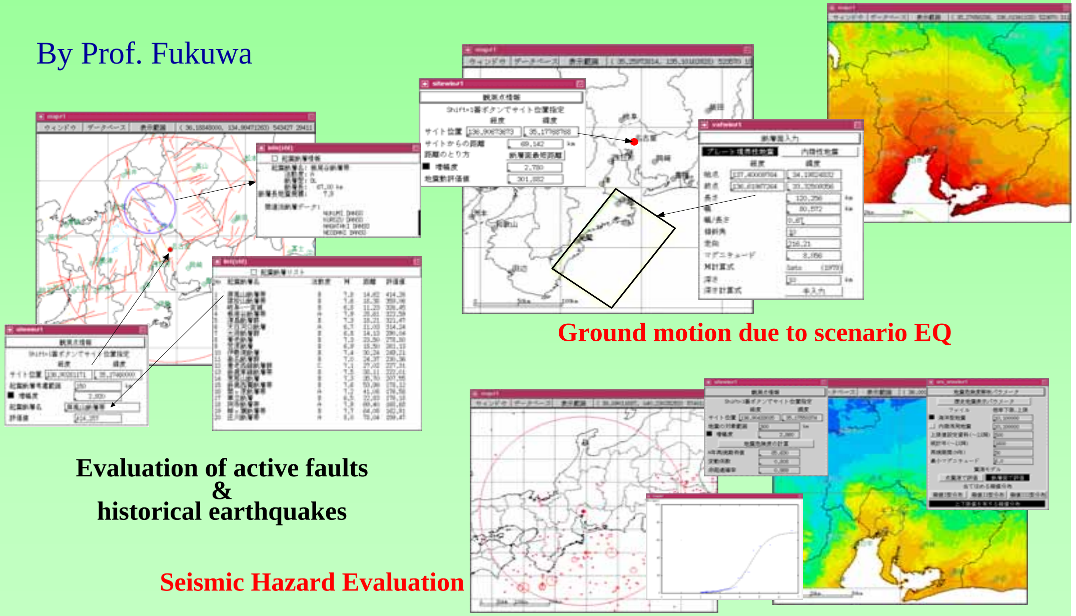
(Warnitchai et al. 2000)



Temple in Chiang Mai damaged by EQ in 1545

Database for Seismic Hazard Assessment

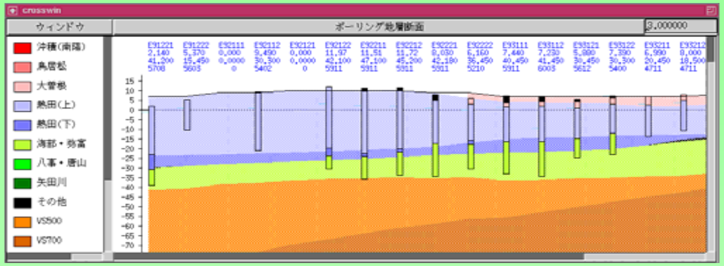
By Prof. Fukuwa



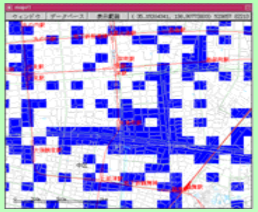
Geological Data for Hazard Assessment

By Prof. Fukuwa

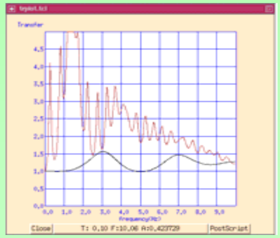
Geologic section



Boring points



Plot with digital map

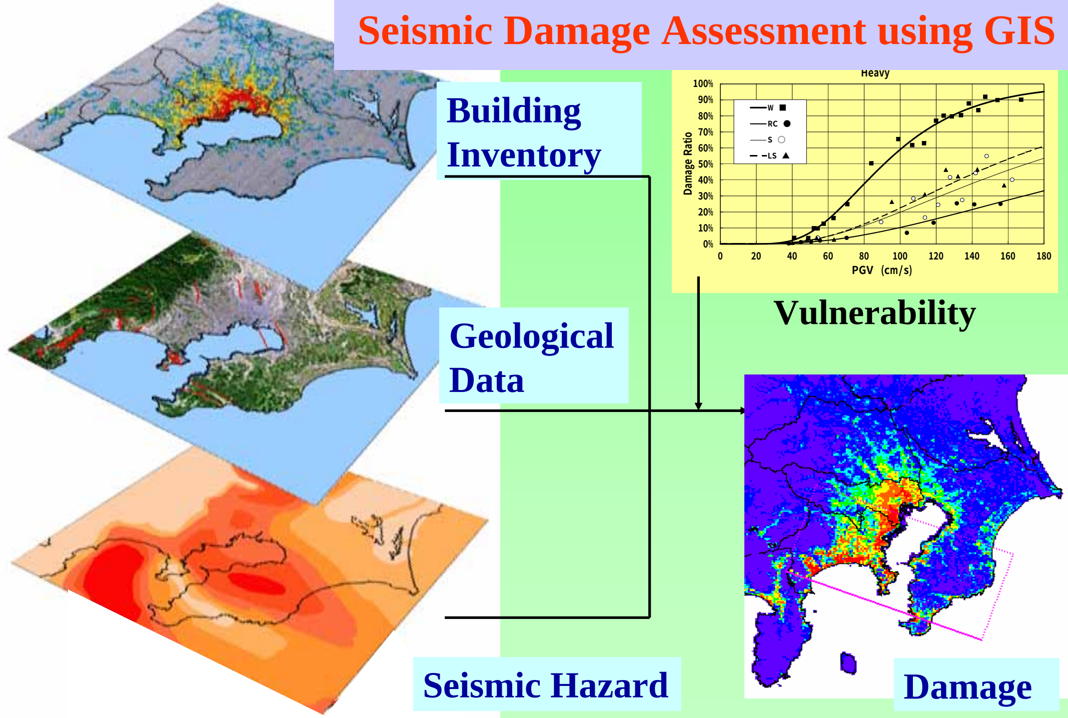


Soil amplification

Boring log

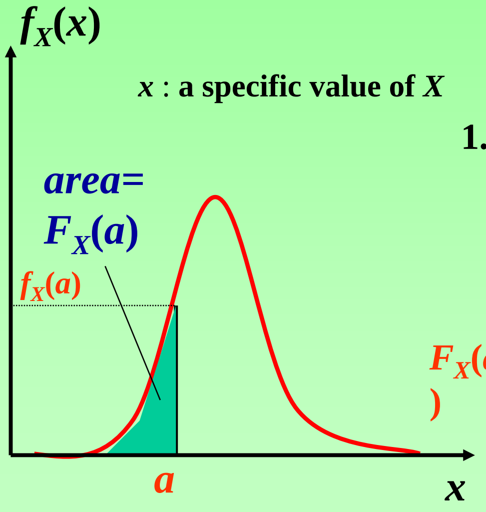
4.2 Damage Assessment

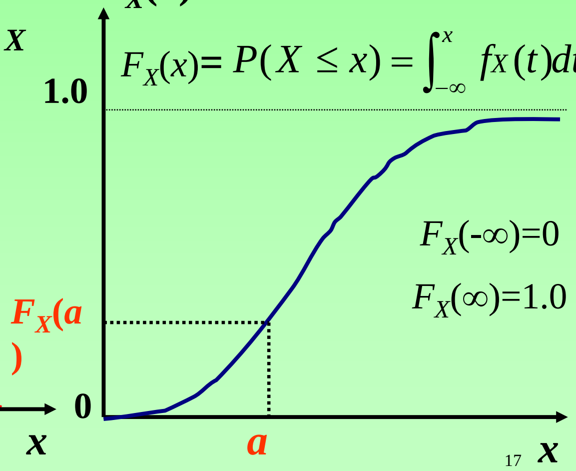
Seismic Damage Assessment using GIS



Probability distribution of a continuous random variable *X*

Probability Density Function | **Cumulative Distribution Function**



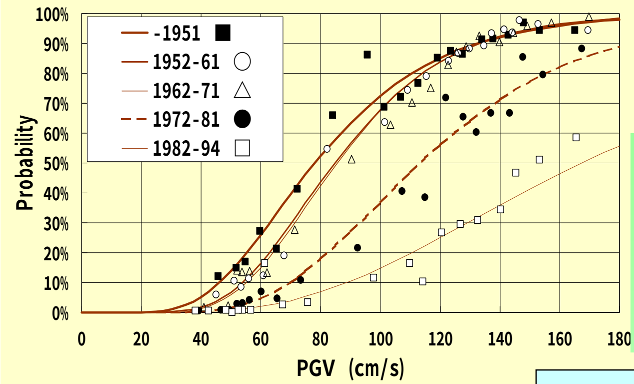


$$F_X(x) = P(X \le x) = \int_{-\infty}^{x} f_X(t)\,dt$$

$F_X(-\infty)=0$

$F_X(\infty)=1.0$

Fragility Curve
: Vulnerability Function



The cumulative distribution function of strength as a function of strong motion indices = Fragility Curve

Log-normal distribution: ln *x* is normal dist.

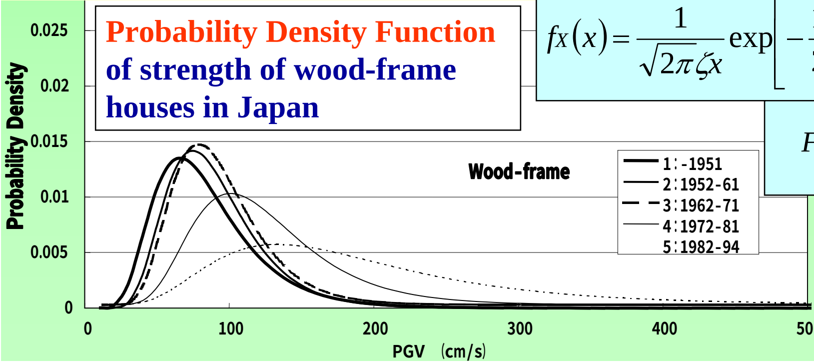
$$f_X(x) = \frac{1}{\sqrt{2\pi}\zeta x}\exp\left[-\frac{1}{2}\left(\frac{\ln x-\lambda}{\zeta}\right)^2\right]$$

$$F_X(x) = \Phi\left(\frac{\ln x-\lambda}{\zeta}\right)$$

Φ: the standard normal distribution N(0, 1)

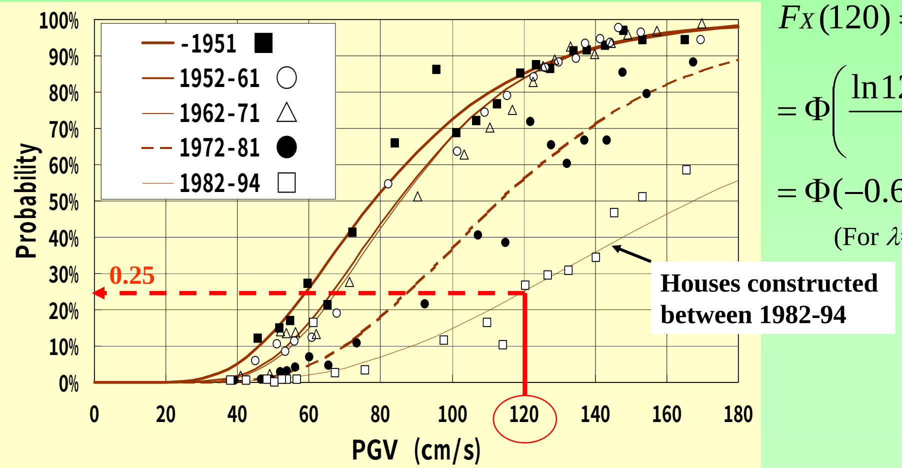
λ: mean of ln x

ζ: standard deviation of ln x



Damage probability of buildings when seismic motion (PGV) is given *deterministically*
(a normal case of damage assessment)

If seismic motion is given as PGV=120cm/s, the damage probability of **wood-frame houses** (1982-94) becomes 25%.



$$F_X(120) = \int_0^{120} f_X(t)\,dt$$

$$= \Phi\left(\frac{\ln 120-\lambda}{\zeta}\right)$$

$$= \Phi(-0.675) = 0.25$$

(For λ=5.12, ζ=0.50)

The normal (Gaussian) distribution and the standard normal distribution

PDF (probability density function) of **a normal distribution**: N(μ, σ²)

PDF of **the standard normal distribution**: N(0, 1)

$$f_X(x) = \frac{1}{\sqrt{2\pi}\sigma}\exp\left[-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right]$$

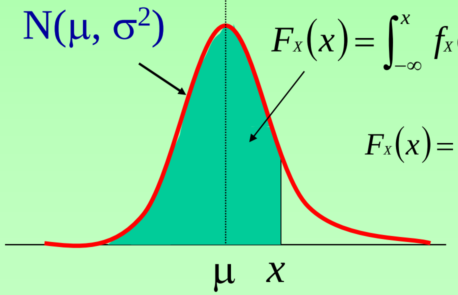
$$\phi(s) = \frac{1}{\sqrt{2\pi}}\exp\left[-\frac{1}{2}s^2\right]$$

$$f_x(x) = \frac{1}{\sigma}\phi\left(\frac{x-\mu}{\sigma}\right)$$

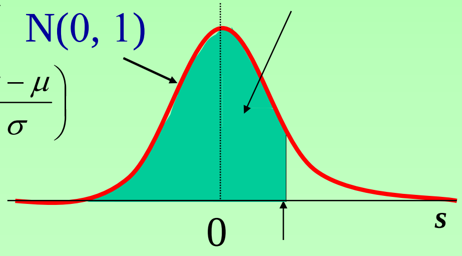
$$\Phi(s) = \int_{-\infty}^{s}\phi(z)\,dz$$

$$F_x(x) = \int_{-\infty}^{x} f_x(t)\,dt$$

$$F_x(x) = \Phi\left(\frac{x-\mu}{\sigma}\right)$$

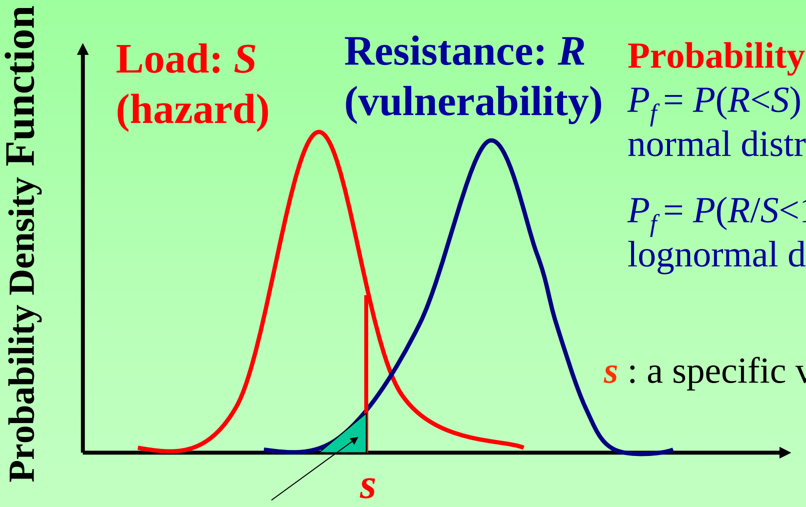


=



$s=(x-\mu)/\sigma$

Probabilistic Modeling of Load and Resistance and Probability of Failure



Probability of Failure

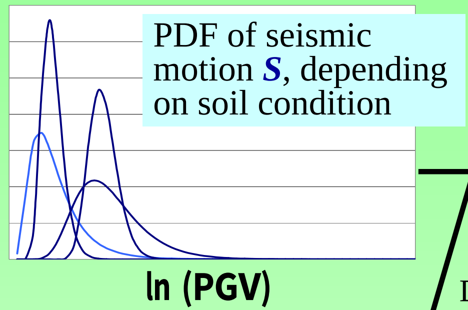
$P_f = P(R<S)$ for the normal distribution

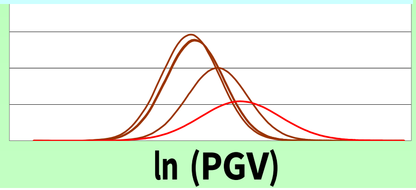
$P_f = P(R/S<1)$ for the lognormal distribution

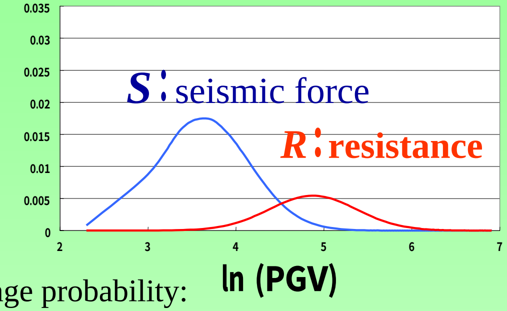
s : a specific value of S

$F_R(s)$: the probability such that $R < s$

Damage probability of buildings when seismic motion (PGV) is given *probabilistically*







Damage probability:

Products and quotients of LN random variables are LN.

$$P_f = P\left(\frac{R}{S} < 1\right)$$

$$= P(Z<1) = \int_0^1 fz(z)dz = \Phi\left(-\frac{\lambda_z}{\zeta_z}\right)$$

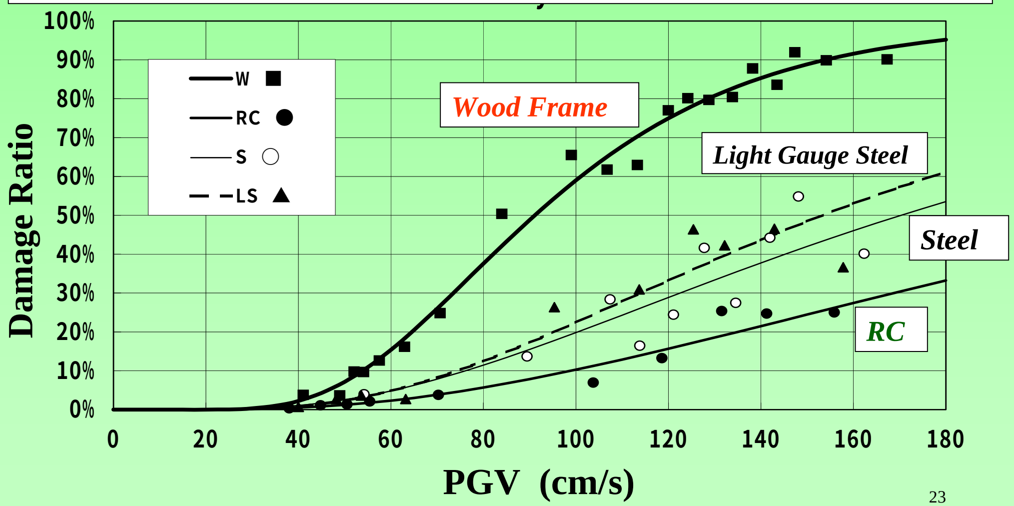
$$\lambda_z = \lambda_r - \lambda_s$$

$$\zeta_z = \sqrt{\zeta_r^2 + \zeta_s^2}$$

Φ: the Standard Normal Distribution

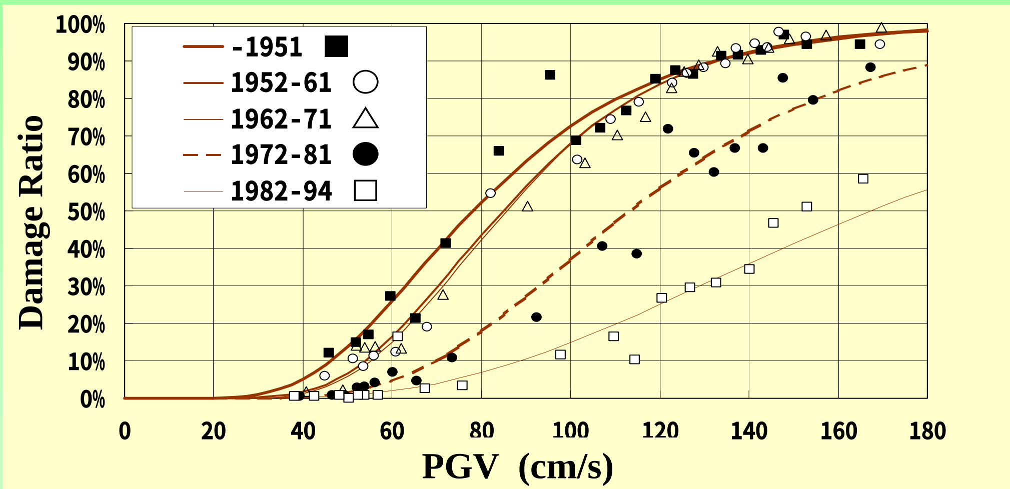
Fragility Curves for different building structures based on the 1995 Kobe EQ

Damage Rank= ***Severe Damage*** *(equal or more than severe damage)*

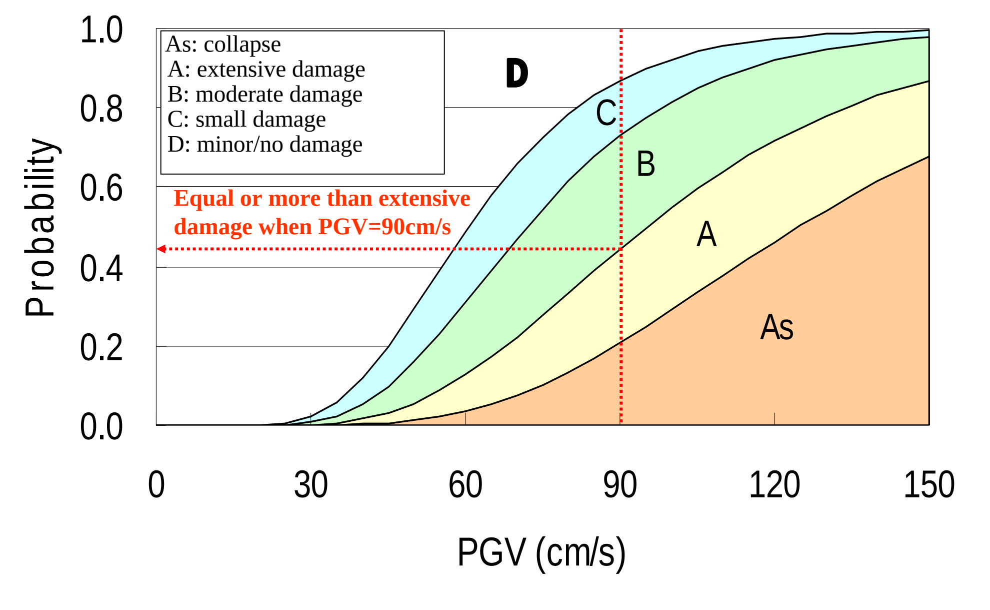


Fragility Curves for Wood-frame Buildings of Different Construction Periods based on the 1995 Kobe EQ

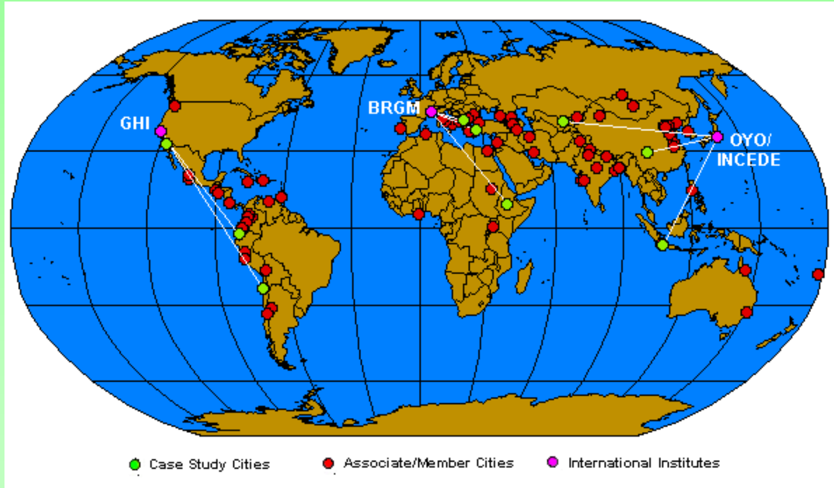
Damage Rank= ***Severe Damage*** *(equal or more than severe damage)*



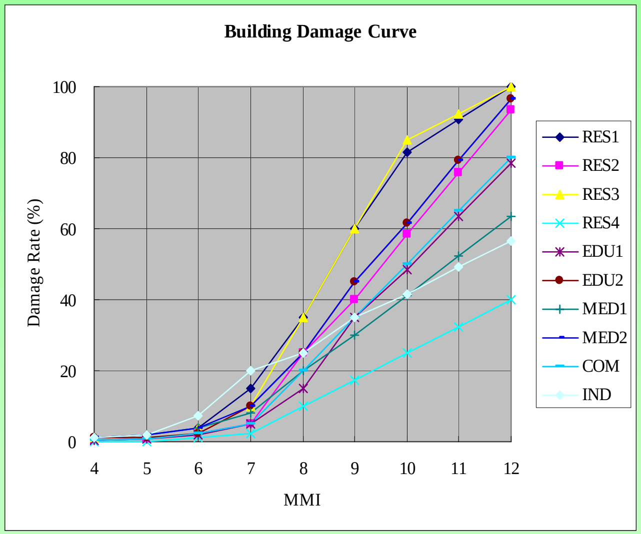
Fragility curves of highway bridges in Japan for various damage levels



RADIUS (**R**isk **A**ssessment Tools for **Di**agnosis of **U**rban Areas against **S**eismic Disasters) Project by United Nations



Building fragility curves in a simplified damage assessment tool of RADIUS



ES1--- Informal construction: mainly slums, row housing etc. made from unfired bricks, mud mortar, loosely tied walls and roofs

ES2--- URM-RC composite construction: substandard construction, not complying with the local building code provisions. Height up to 3 stories. URM = Unreinforced Masonry, RC = Reinforced Concrete

ES3--- URM-RC composite construction: old, deteriorated construction, not complying with the latest building code provisions. Height 4 - 6 stories

ES4--- Engineered RC construction: newly constructed multi-story buildings, for residential and commercial purposes

DU1--- School buildings, up to 2 stories: generally, the percentage of this type of building should be very low

DU2--- School buildings, greater than 2 stories: office buildings should also be included in this class; generally, the percentage of this type of buildings should be very low

ED1--- Low to medium rise hospitals: generally, the percentage of this type of building should be very low

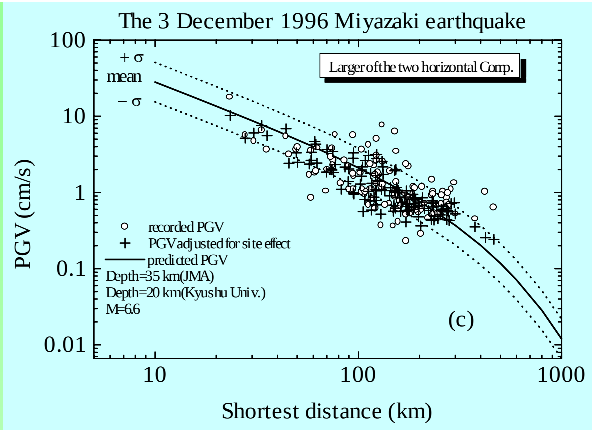
MMI (Modified Mercalli Intensity)

Attenuation Model

Intensity of Seismic Motion

Y = f (Source, Path, Site)

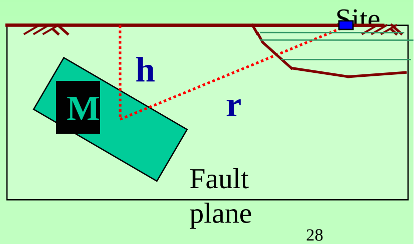
M, h — *r* — *soil classification*



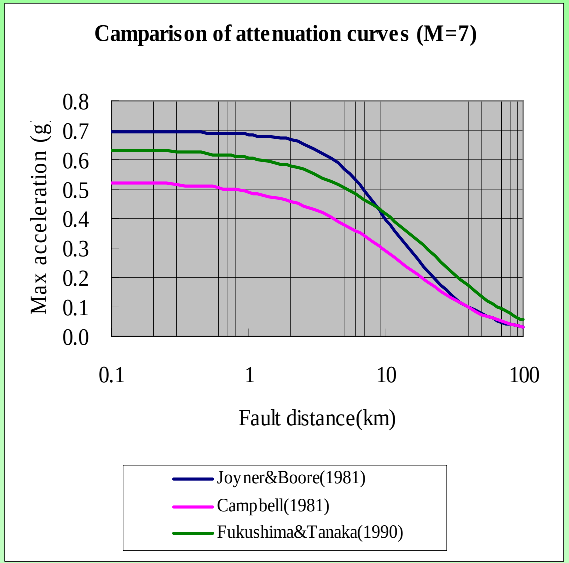
$$Y = b_0 + b_1 M + b_2 r + b_3 \log_{10} r + b_4 h + c_i$$

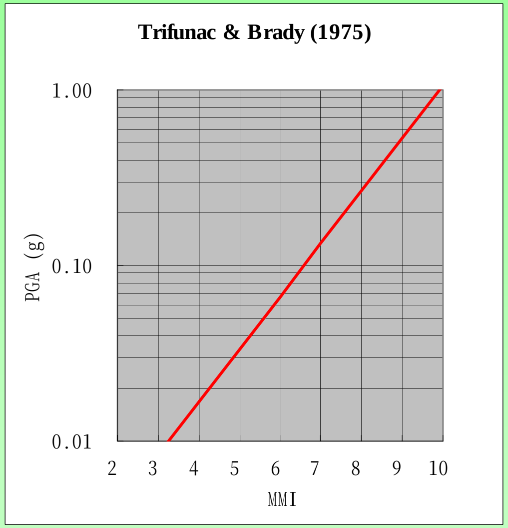
where

Y is $\log_{10}$PGA, $\log_{10}$PGV, or JMA seismic intensity,
M is the magnitude
r is the shortest distance to the fault rupture
h is the depth
b_i are the coefficients to be determined
c_i is the station coefficient of the recording station i



Attenuation relations of PGA and PGA vs MMI relation used in a RADIUS tool

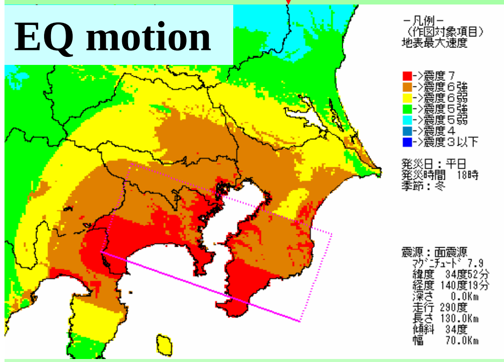




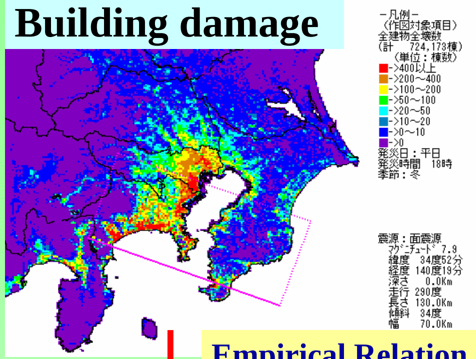
Damage Assessment for Scenario EQ

Scenario EQ: Location , Magnitude, Occurrence time, Season

EQ motion

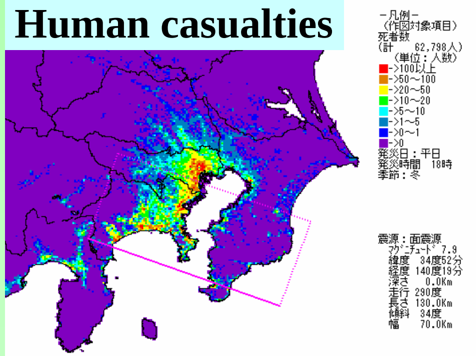


Building damage



Empirical Relation

Human casualties



Building Inventory and Fragility Curves

Early Damage Assessment Systems

Accelerometers for expressways networks in Japan and traffic control by seismic monitoring

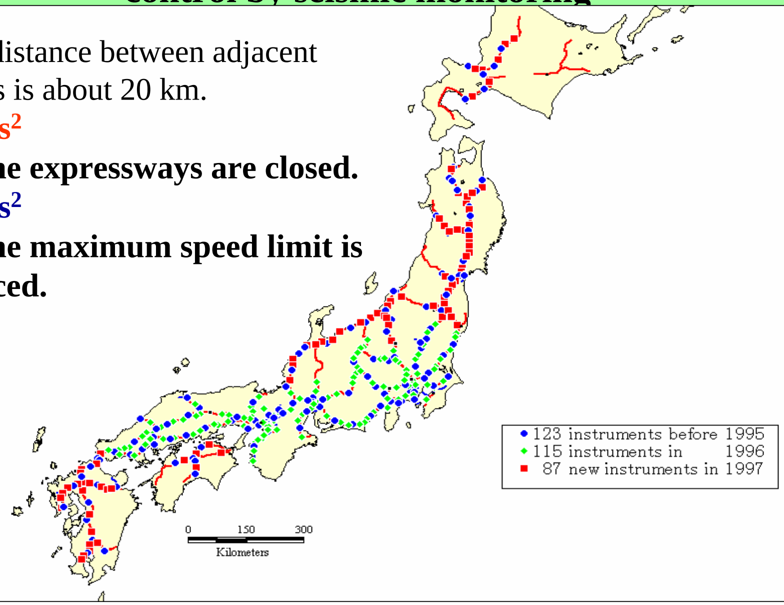
The average distance between adjacent seismometers is about 20 km.

PGA≥80cm/s²

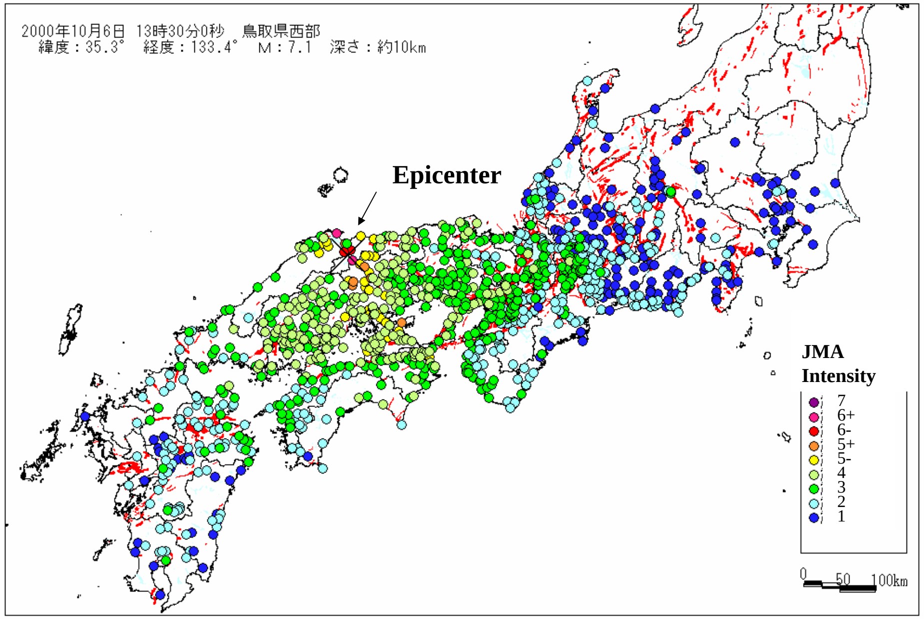
→ **The expressways are closed.**

PGA≥50cm/s²

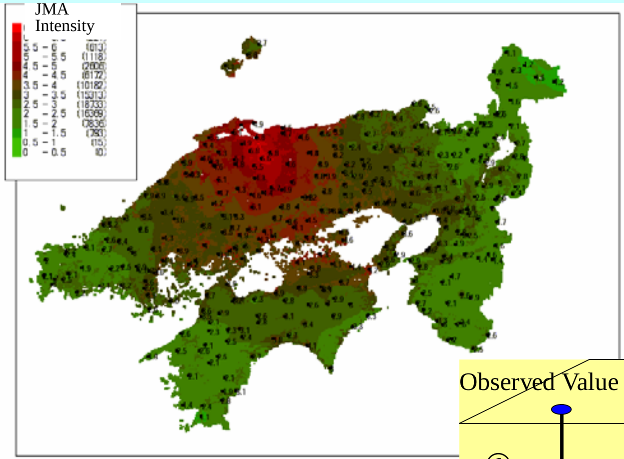
→ **The maximum speed limit is reduced.**



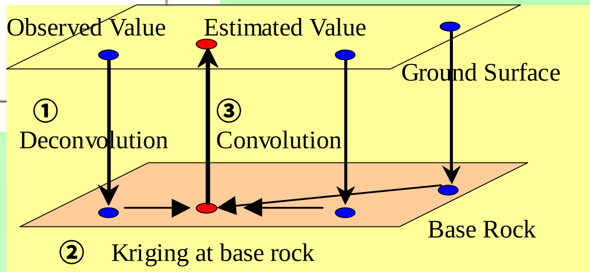
JMA instrumental intensity recorded by national seismic networks in the October 6, 2000 Tottori EQ



Distribution of JMA seismic intensity in the 2000 Tottori EQ estimated by Kriging technique



Kriging at base rock to remove site amplification effect



Kriging: a stochastic interpolation technique

Flow of seismic loss estimation for scenario earthquakes and for real earthquakes