Probabilistic Approach to Natural Hazards Assessment

Seismic hazard analysis and map

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Contents

Introduction

Nishijima, K. (2003), Multi-site Hazard Analysis for Optimal Design of Building Portfolio, master thesis, the University of Tokyo.

- Probabilistic assessment
- Typhoon and **earthquake**
- **Joint hazard analyses for multiple sites**
- Portfolio optimization

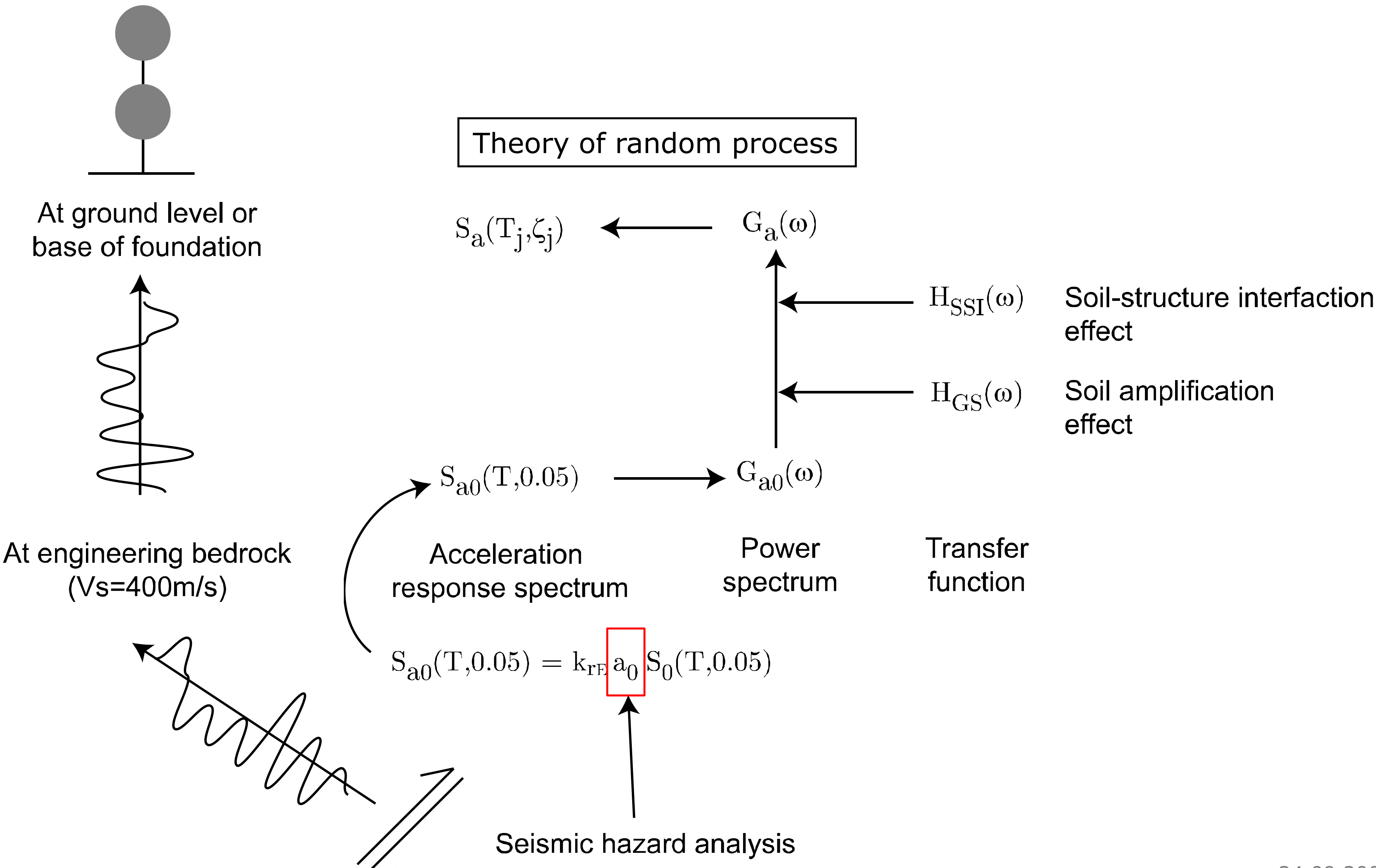
Seismic hazard analysis in building design context

Methodology on seismic hazard analysis for building design, Architectural Institute of Japan (2004).

- Design seismic loads
  - (equivalent) static load for the design of common buildings based on the response spectrum method.
  - dynamic load for the design of e.g. high-rise buildings based on simulated seismic motions.

Architectural Institute of Japan (2004), Recommendations for Loads on Buildings (version of 2004).

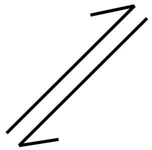
Seismic hazard analysis in building design context



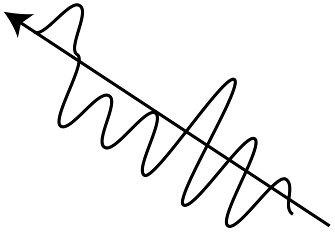
Overview of seismic hazard analysis

Probabilistic assessment of basic peak acceleration or velocity at engineering bedrock or surface.

- Modelling of earthquake source



- Modeling of wave propagation



Pioneering work by Cornell (1968).

Cornell, C. A. (1968). Engineering seismic risk analysis. Bulletin of the Seismological Society of America, 58(5), 1583-1606.

Modelling of earthquake occurrence

- Time dependency

  Time-independent occurrence (Poisson process)

  Quasi-periodic occurrence (Non-Poisson process)

- Magnitude

  Magnitude-frequency relation (Gutenberg-Richter formula)

  Deterministic magnitude

  Bounds of possible magnitude

Other source parameters:

asperity, directivity, stress etc.

Example of earthquake source modelling

Earthquake source modelling based on "earthquake catalog."

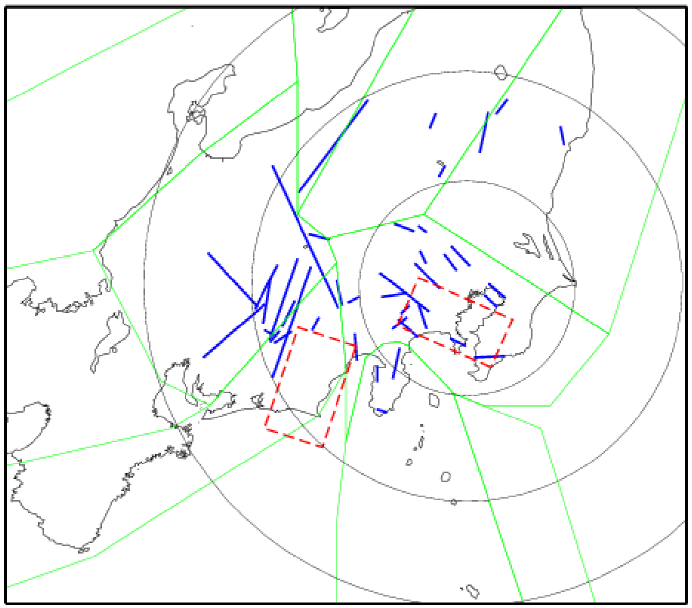


Plate earthquake
- -non Poisson renewal process
- -deterministic magnitude

Active fault earthquake
- -Poisson process
- -deterministic magnitude

Background earthquake
- -Poisson process
- -Gutenberg-Richter formula

日本地震学会, 新編　日本被害地震総覧 [増補改訂版416-1995].
気象庁, 気象庁地震月報・別冊.
松田時彦, 塚崎朋美, 萩谷まり (2000) 日本陸域の主な起震断層と地震の表ー断層と地震の地方別分布関係ー, 活断層研究, Vol.19, pp.33-54.
萩原尊禮編, (1991) 日本列島の地震 地震工学と地震地体構造, 鹿島出版会.
宇津徳治 (1982) 日本付近のM6.0以上の地震および被害地震の表:1885～1980年,地震研究所彙報,57,p401.

Modelling of wave propagation

- Attenuation law

  Statistical relationship between peak acceleration or velocity and the earthquake source parameters.

- Seismic ground motion simulation

Attenuation law

For instance, Annaka et al. (1997):

$$\log_{10} v = 0.725M + 0.00318H - 1.918\log_{10} d - 0.519$$

$$d = R + 0.334\exp(0.653M)$$

v: Mean peak acceleration at engineering bedrock(cm/s)

M: JMA magnitude

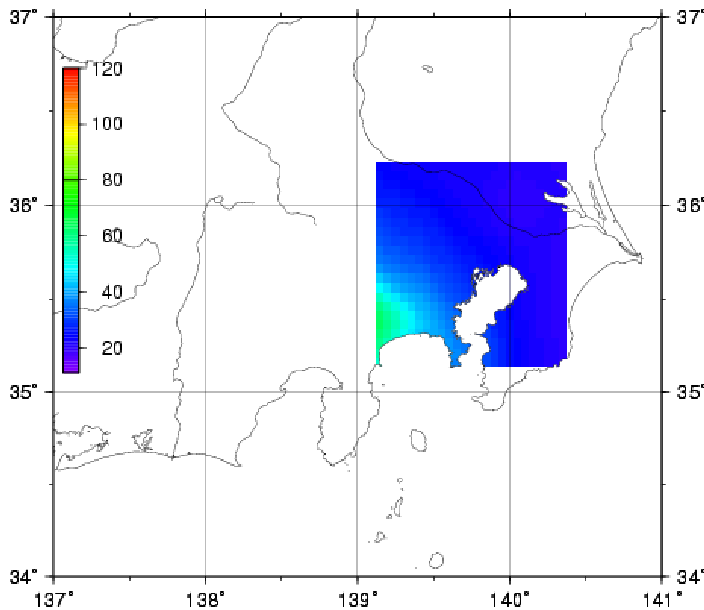
R: distance to seismic source (km)

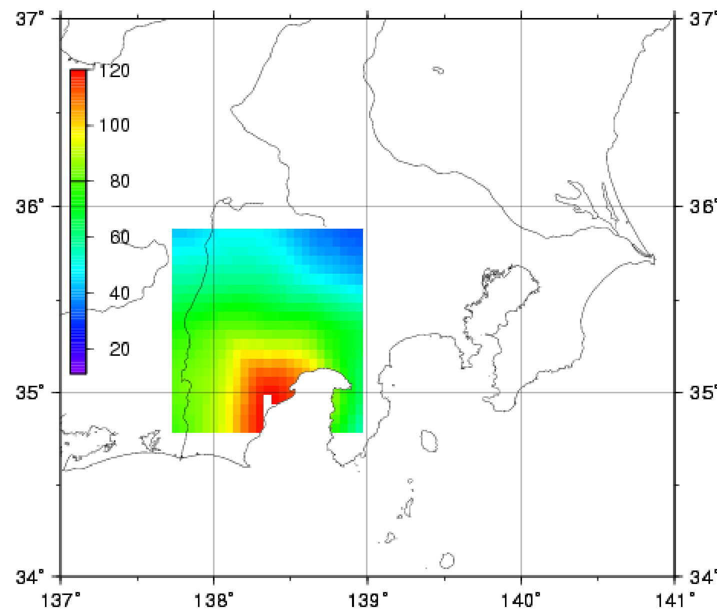
H: source depth (km)

Annaka, T., Yamazaki, F., and Katahira, F. (1997) Proposal of peak ground velocity and response spectra based on JMA 87 type accelerometer records, *Proceedings, 24th JSCE Earthquake Engineering Symposium. Vol. 1, pp. 161–164 in Japanese.*

Example of seismic hazard map

Peak velocity (cm/s) corresponding to 10% exceedance probability in the next 50 years from 2003.





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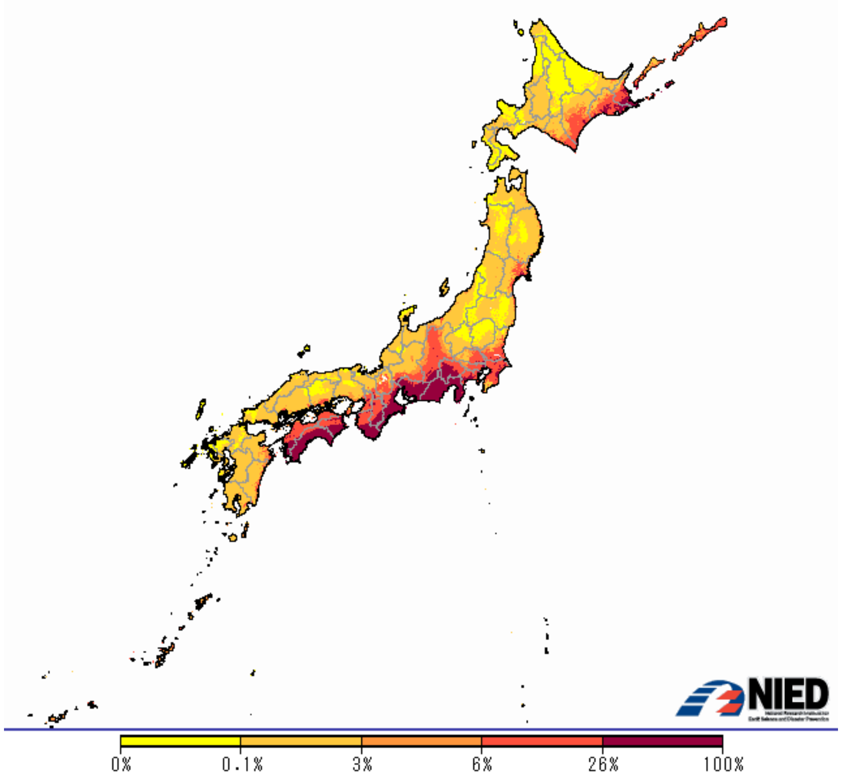
Example of seismic hazard map

Probability of ground motions >= JMA intensity 6$^-$ in the next 30 years (from 2008):



Japan Seismic Hazard Information Station, NIED, http://www.j-shis.bosai.go.jp/j-shis/index_en.html

Problem setting

Standard seismic hazard analysis:

- Marginal seismic hazard analysis for individual sites.
- Correlation of seismic hazards is not considered.

⇓

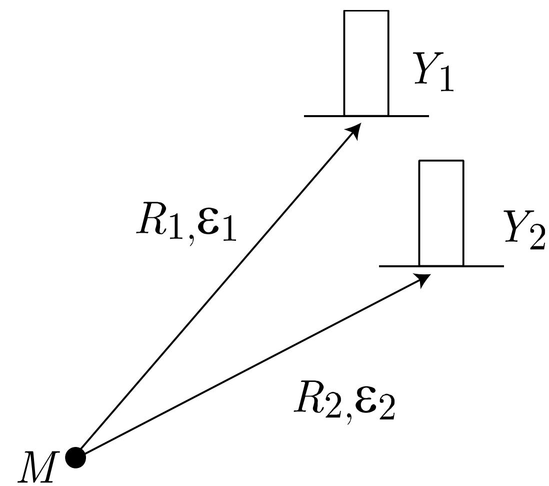
- Multi-site hazard analysis for portfolio optimization.

Spatial correlation of peak ground motions

Peak ground motions Y_1 and Y_2 at site 1 and 2 given an earthquake:

$$Y_1 = \varepsilon_1 \overline{Y}(M, R_1)$$

$$Y_2 = \varepsilon_2 \overline{Y}(M, R_2)$$



where M is magnitude, R_1 and R_2 are the distance from sites 1 and 2 to the earthquake source. ε_1 and ε_2 are the uncertainties concerning the attenuation law$\overline{Y}(\cdot,\cdot)$.

Spatial correlation of peak ground motions

$$Y_1 = \varepsilon_1 \bar{Y}(M, R_1)$$

$$Y_2 = \varepsilon_2 \bar{Y}(M, R_2)$$

R_1 and R_2 are correlated (as a function of the relative positions to earthquake sources).

ε_1 and ε_2 can be respectively decomposed into:

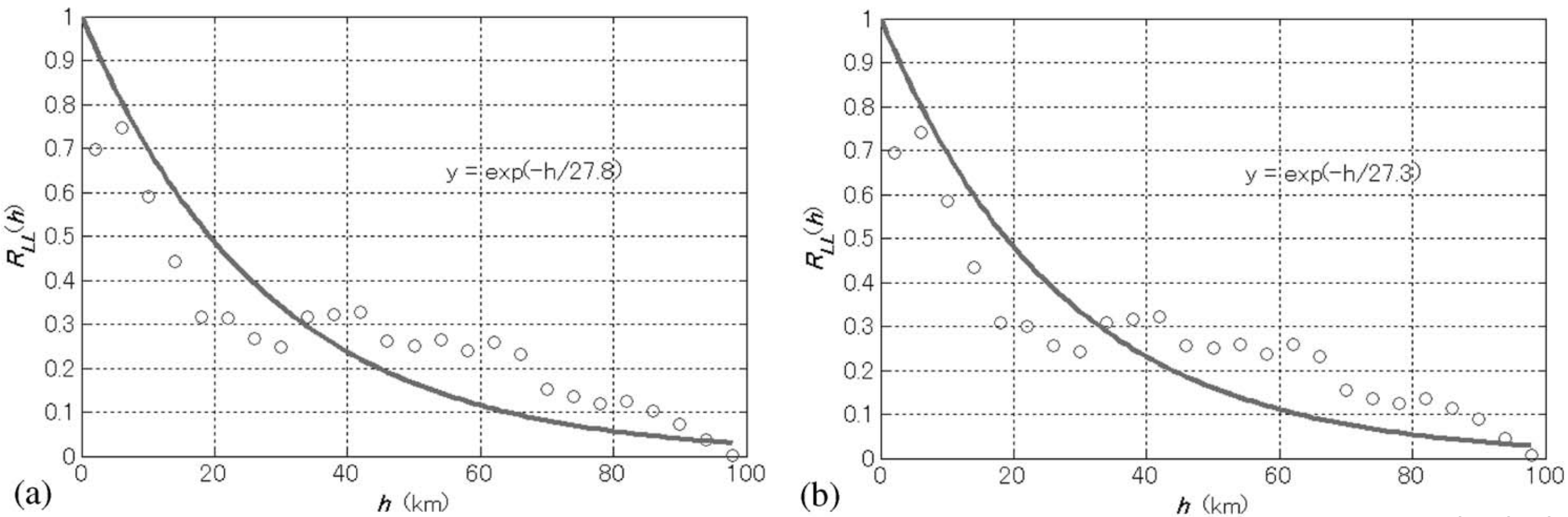
$$\varepsilon_1 = \varepsilon_S \varepsilon_{p,1}$$

$$\varepsilon_2 = \varepsilon_S \varepsilon_{p,2}$$

$\varepsilon_{p,1}$ and $\varepsilon_{p,2}$ are correlated (as a function of distance).

Correlation between $\varepsilon_{p,1}$ and $\varepsilon_{p,2}$

Wang and Takada (2005):



Wang and Takada (2005)

$$\rho_{\ln\varepsilon_{p,1}\ln\varepsilon_{p,2}} = \exp\left(-\frac{L}{d}\right)$$

where L is the distance between site 1 and 2.

Wang, M. and Takada, T. (2005) Macrospatial Correlation Model of Seismic Ground Motions, Earthquake Spectra, 21(4), pages 1137–1156.

Multiple sites hazard analysis

Based on Monte Carlo simulation technique.

EQ_Monte.m, HAZARD_analysis.m (Main programs)

Programs	Stage	Data files	
fault_load.m plate_load.m site_load.m zone_load.m	Data preprocess	fault zone plate building fault_considered.dat zone_considered.dat plate_considered.dat	Import data files
GR_rand.m polygon_uniform_rand2.m non_poisson.m occurrnd.m	Occurrence simulation		
attenuation.m distance_calculate.m fault_distance_calculate.m plate_distance_calculate.m zone_distance_calculation.m covariance_calculate.m	Peak ground motions simulation		

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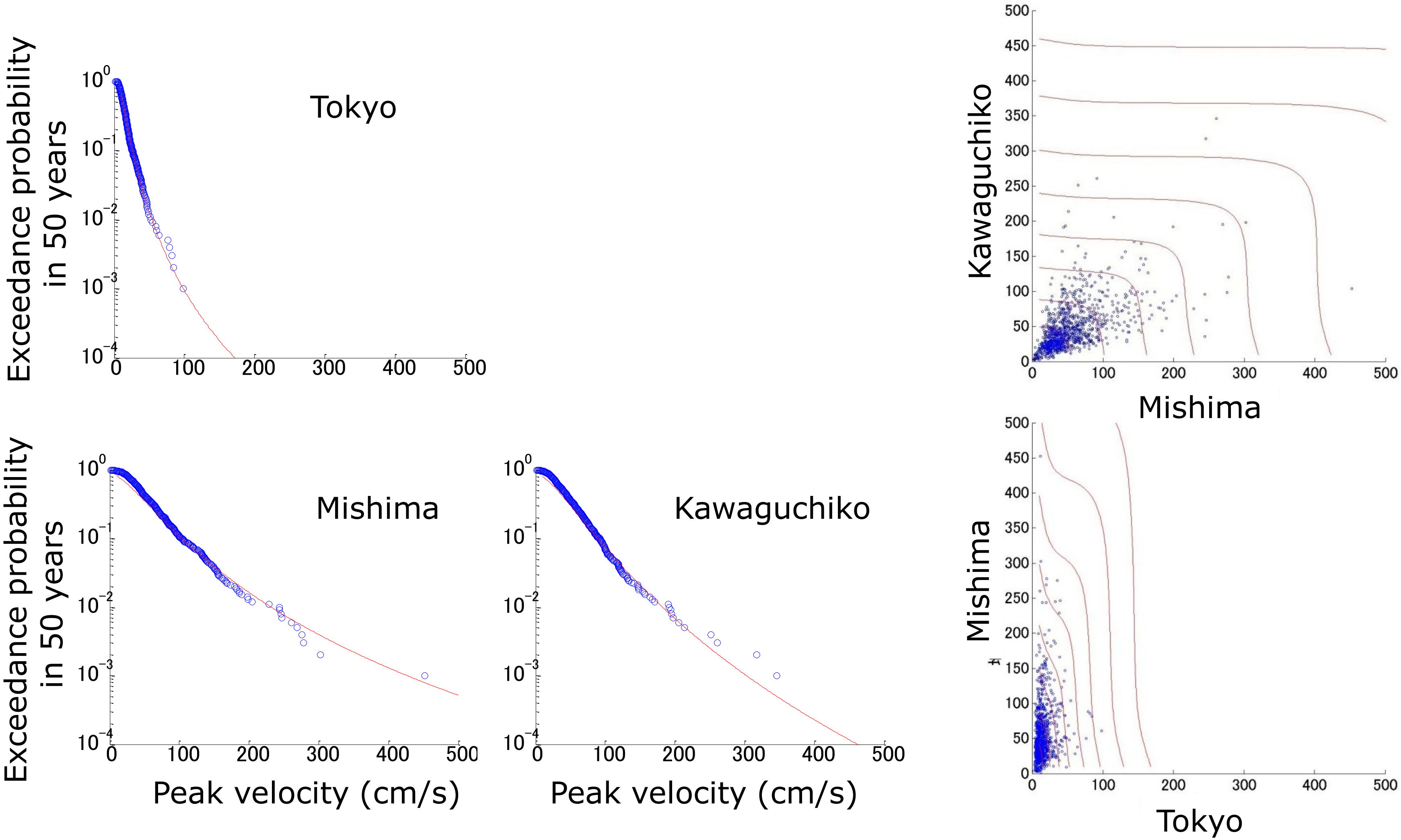
Marginal hazards and joint hazards



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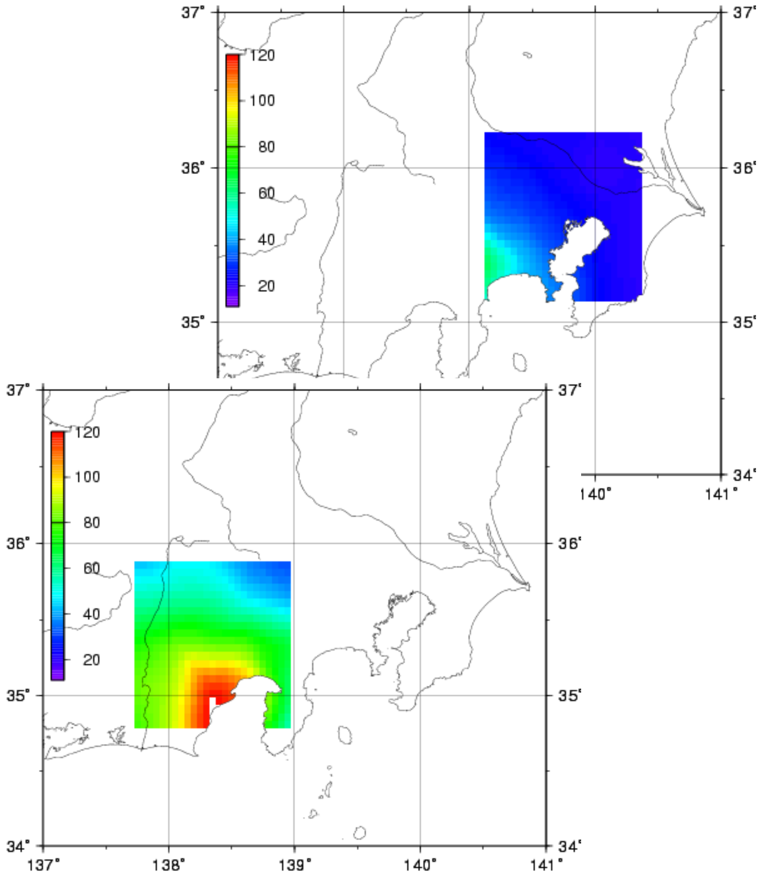
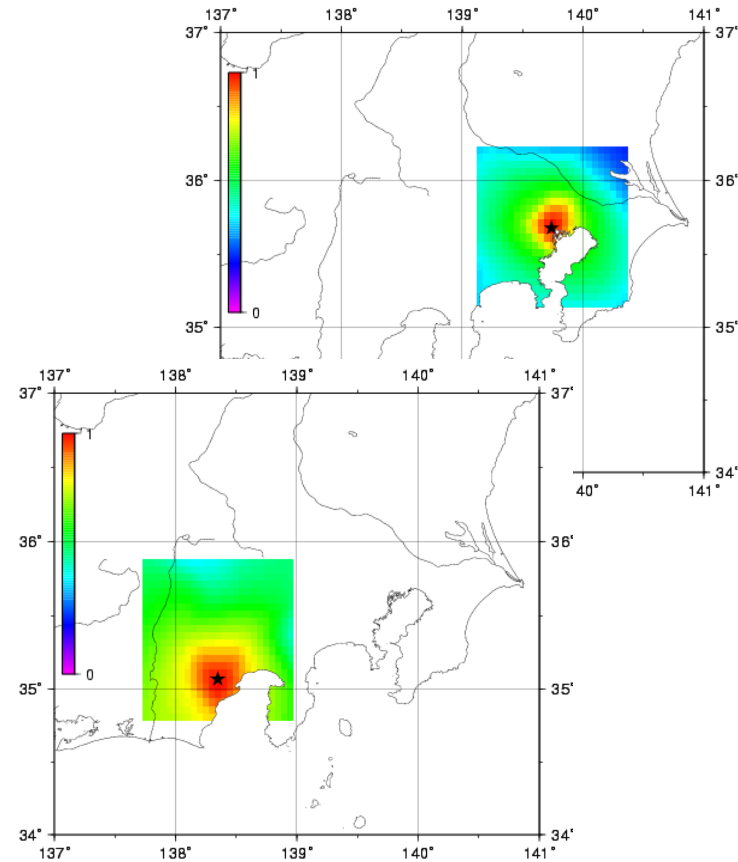
Probabilistic hazard map and correlation map



Probabilistic hazard map



Correlation map

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