How to use
Probabilistic Seismic Hazard Analysis, PSHA, Map ?

- from user's point of view -

如何使用概率地震危險性分析, PSHA, 圖？

Toshihiro Yamada

OYORMS Corporation

OYO**RMS**

- ■ Earthquake risk analysis for companies and real estate
- ■ Natural hazard analysis and simulation
- ■ Development of natural disaster risk model

OYO 応用地質

RMS®

- ■ Japan's leading geotechnical engineering firm
- ■ Disaster management / Environment / Social infrastructure / Energy / Instrument

- ■ World's leading natural catastrophe modeling company
- ■ Funded in 1989 at Stanford University, USA

Agenda

- What is risk and risk management?

- How is PSHA map used in the insurance industry?

- How is PSHA map used for the seismic design in Japan?

- Which seismic motion strength index is desirable for PSHA?

- What is easy-to-understand expression for the users?
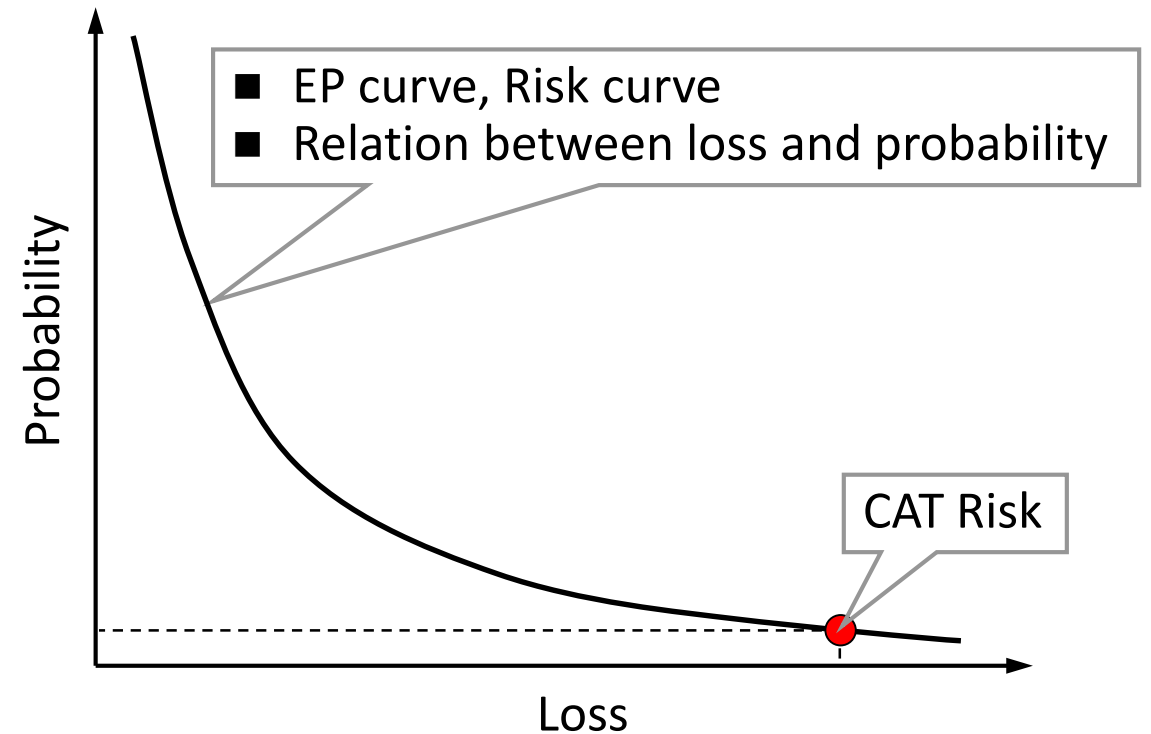
What is risk and risk management?

What is Risk? 什麼是風險？

- **Concept of Risk**
  - Negative impact　　　　負面影響　　　: Damage, Loss, …
  - Occurrence probability　發生概率　　　: Cyclic, Return period
  - Uncertainty　　　　　　不確定　　　　: Variance

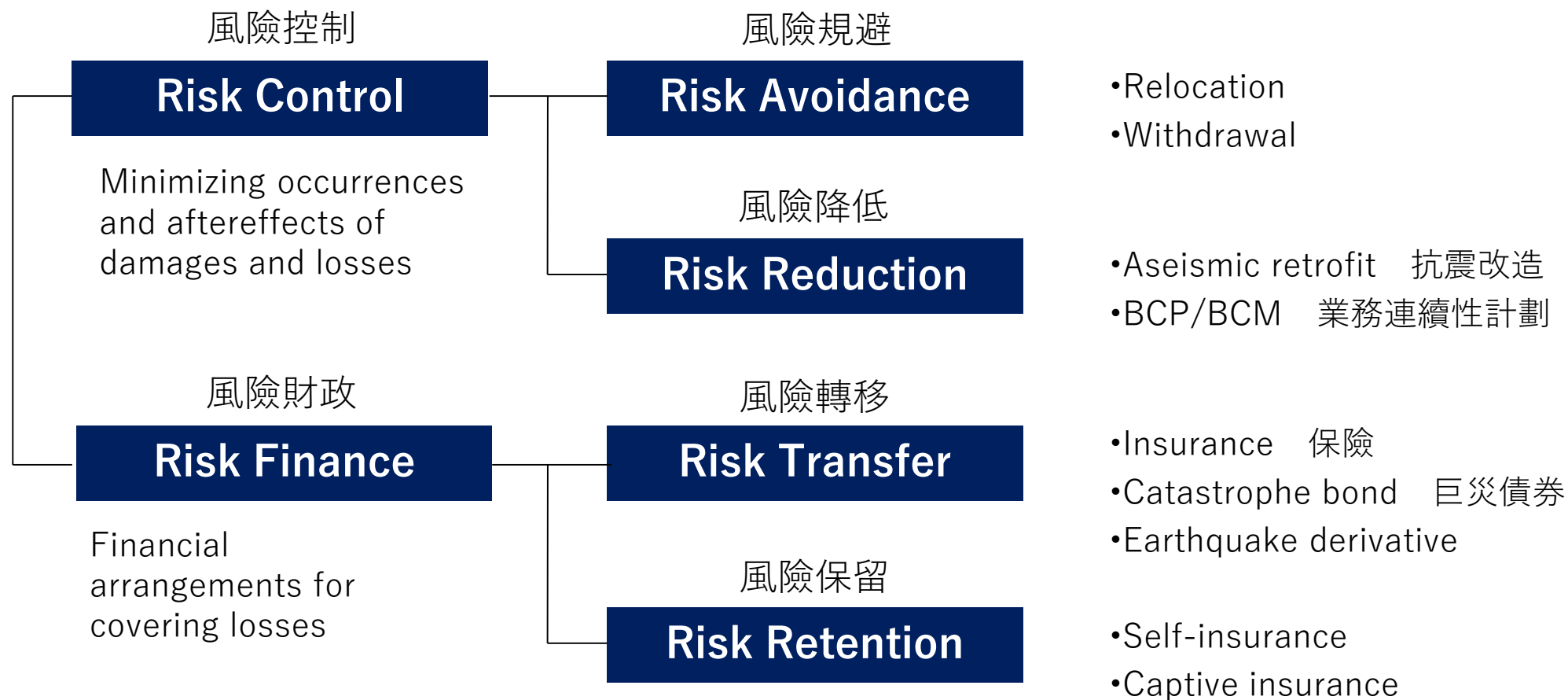- **What is CAT Risk?**
  - **Cat**astrophe Risk　浩劫風險
  - Low probability but big impact

■ EP curve, Risk curve
■ Relation between loss and probability

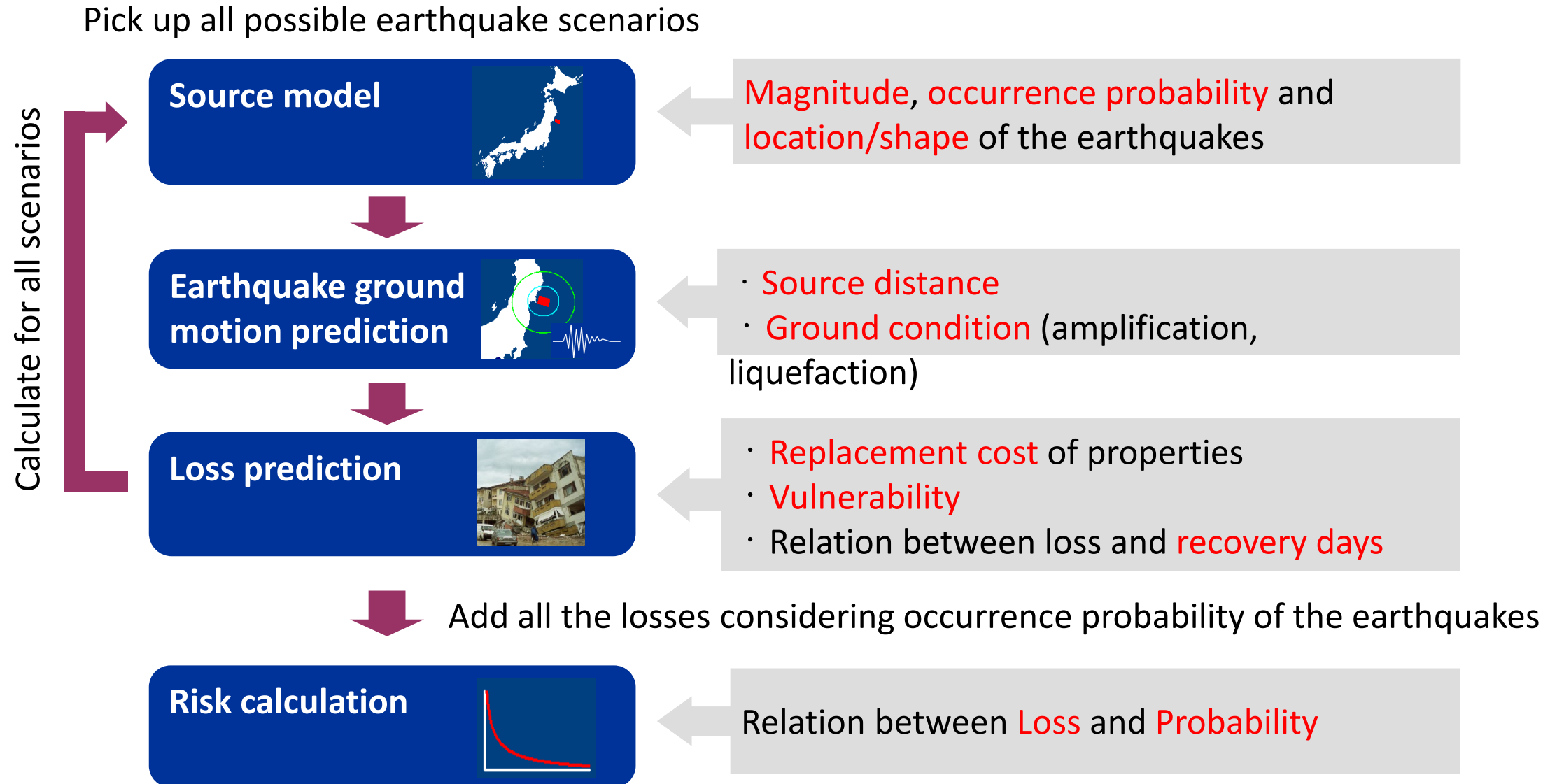CAT Risk

Probability

Loss

What is Risk Management？ 什麼是風險管理？

"Risk management" is the process of protecting assets, earning, debt, and human resources of the company with maximum effects and minimum costs.
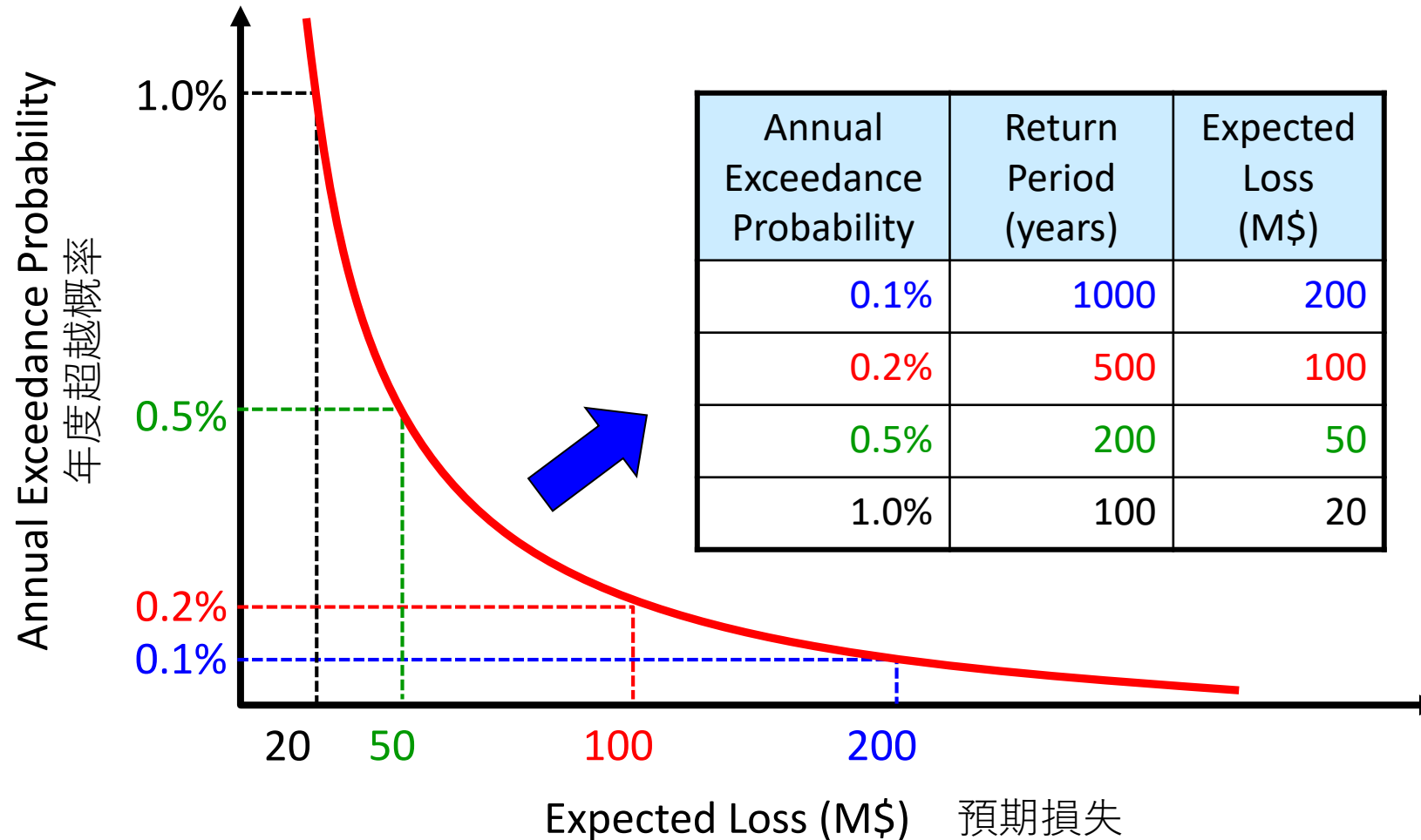
風險控制
Risk Control

Minimizing occurrences and aftereffects of damages and losses

風險規避
Risk Avoidance

•Relocation
•Withdrawal

風險降低
Risk Reduction

•Aseismic retrofit 抗震改造
•BCP/BCM 業務連續性計劃

風險財政
Risk Finance

Financial arrangements for covering losses

風險轉移
Risk Transfer

•Insurance 保險
•Catastrophe bond 巨災債券
•Earthquake derivative

風險保留
Risk Retention

•Self-insurance
•Captive insurance

How is PSHA map used in the insurance industry?

Flow of earthquake risk analysis

Pick up all possible earthquake scenarios

Calculate for all scenarios

Source model

Magnitude, occurrence probability and location/shape of the earthquakes

Earthquake ground motion prediction

· Source distance
· Ground condition (amplification, liquefaction)

Loss prediction

· Replacement cost of properties
· Vulnerability
· Relation between loss and recovery days

Add all the losses considering occurrence probability of the earthquakes

Risk calculation

Relation between Loss and Probability

Annual Exceedance Probability	Return Period (years)	Expected Loss (M$)
0.1%	1000	200
0.2%	500	100
0.5%	200	50
1.0%	100	20

Annual Exceedance Probability 年度超越概率

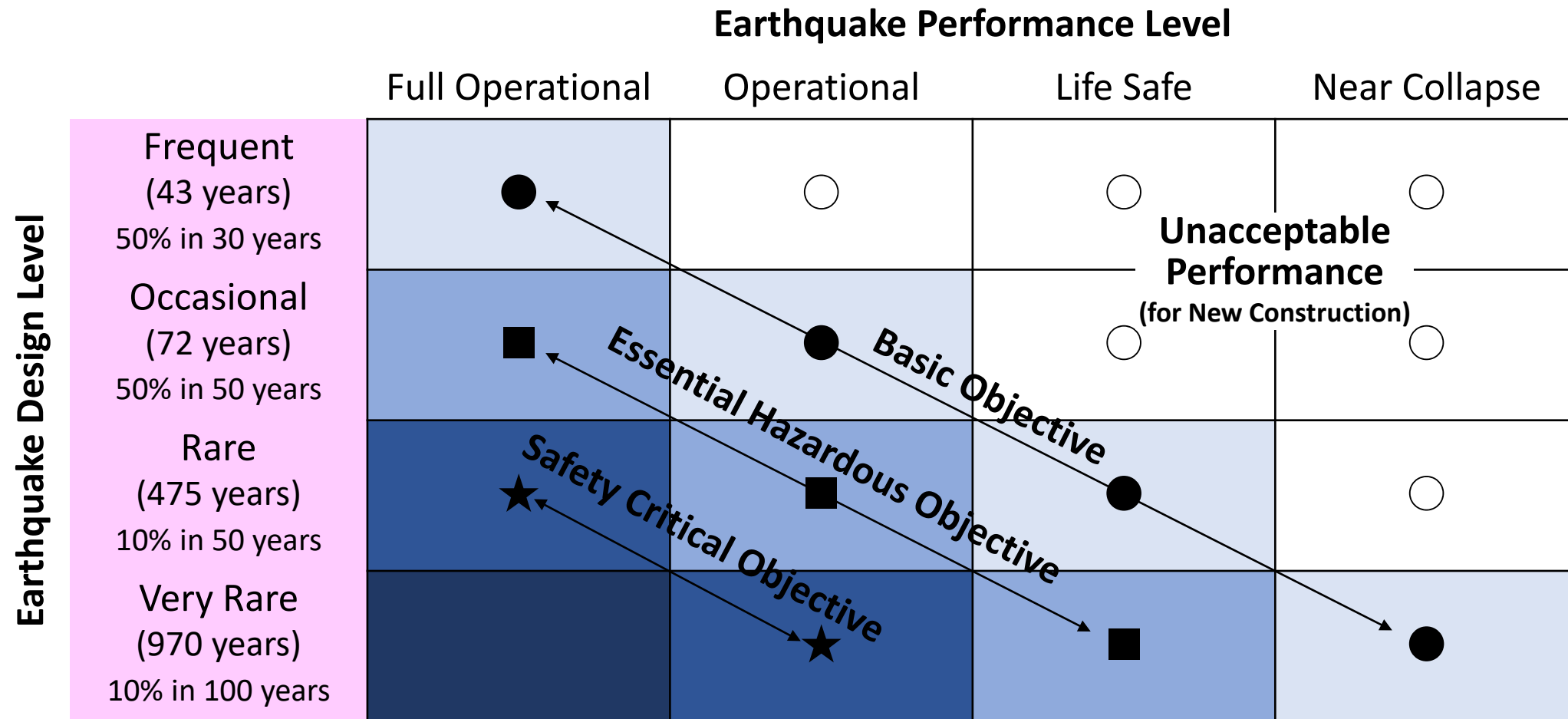Expected Loss (M$) 預期損失

How is PSHA map used for the seismic design in Japan?
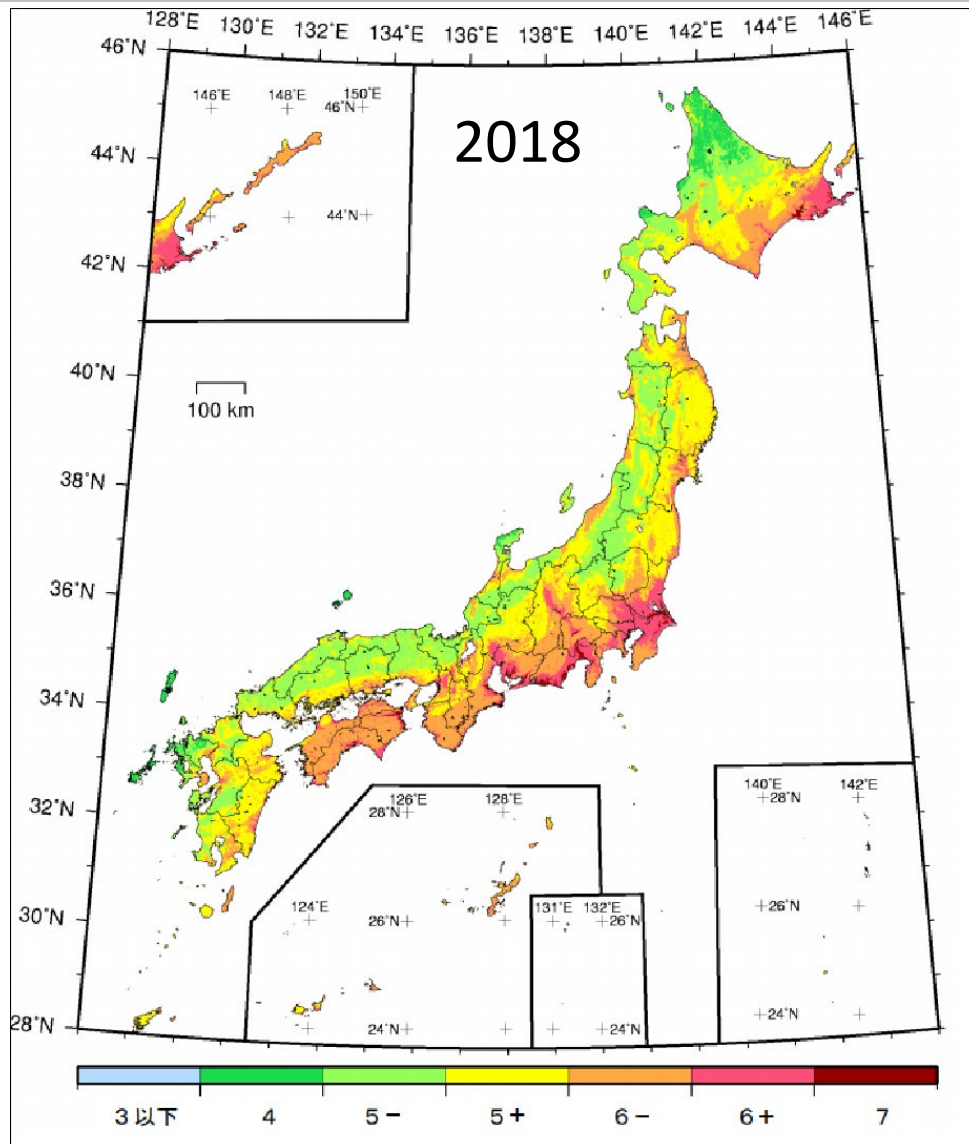
Performance-based seismic design

Recommended performance objectives for buildings (Vision 2000)

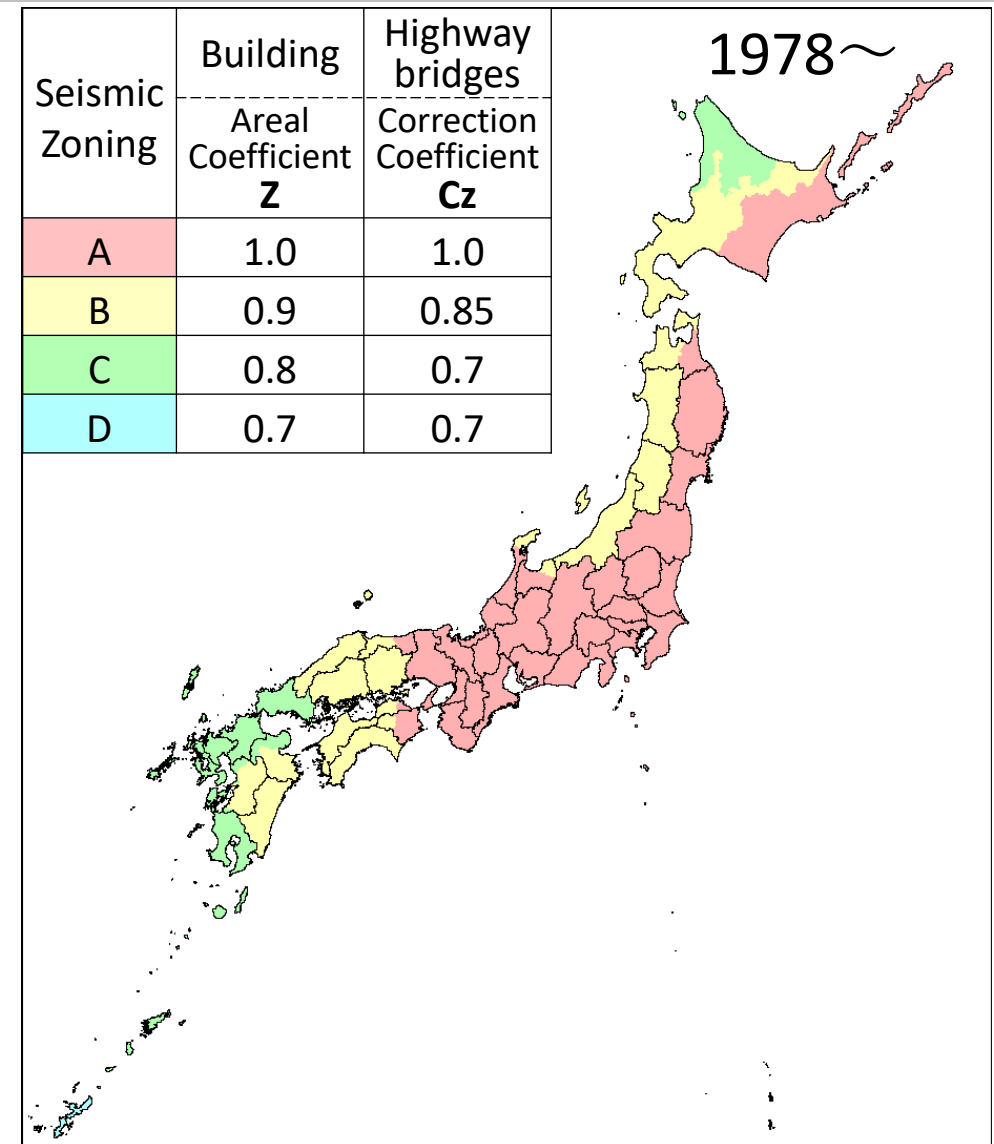SEAOC Vision 2000 Committee (1995). Performance-based seismic engineering of buildings

Design seismic motion and expected performance in Japan

Document	Building Standards Act	Specifications for highway bridges	
Legislation	1981	2002	
Seismic load	base shear coefficient (C_0)	acceleration response spectrum (Sa)	
Lower level	**Primary design**	**Level 1**	
Design seismic motion level	● low occurrence probability ● middle class load ● $C_0 >= 0.2 - 0.3$ ☐ allowable stress design	● high occurrence probability during service ● middle class earthquake, conventional level ● Sa = 200 - 300 gal (T=1 sec)	
Performance level	no damage in main structure	operational	
Higher level	**Secondary design**	**Level 2**	
Design seismic motion level	● very low occurrence probability ● the largest class load ● $C_0 >= 1.0$ ☐ calculation of lateral load carrying capacity	Type I	● low occurrence probability ● large subduction earthquake (Kanto EQ) ● Sa = 700 - 1000 gal (T = 1 sec)
		Type II	● very low occurrence probability ● inland earthquake (Kobe EQ) ● Sa = 1500 - 2000 gal (T = 1 sec)
Performance Level	no collapse	short time recovery / non-fatal damage	

PSHA map and seismic zoning for structural design

2018

JMA Intensity for 10% occurrence probability in 50 years

Seismic Zoning	Building	Highway bridges
	Areal Coefficient Z	Correction Coefficient Cz
A	1.0	1.0
B	0.9	0.85
C	0.8	0.7
D	0.7	0.7

1978～

Seismic zoning for structural design

Which seismic motion strength index is desirable for PSHA?

Which seismic motion strength index is desirable for PSHA?

- Many indices: PGA, PGV, seismic intensity(MMI, JMA), SI, Sa(t), etc.

- For users, the desirable index is what can explain structural damage and social impact caused by the seismic motion.

- However, it is not clear which index is best fit for fragility/vulnerability function. Why?

- One reason is the seismic motion at the damaged structure location is usually unknown, though damage or loss of the structures can be investigated after the earthquake.

- But, it is not so easy to install seismometer in all structures.

- So we tried to predict the seismic motion at any location as accurately as possible from the observed data for developing better fragility/vulnerability function.

STEP-1: Calculate seismic motion strength index from the observed waveforms
- PGA, PGV, JMA Intensity, SI, and Sa (0.05 to 10 sec)

STEP-2: Calculate the index on the engineering basement (Vs=400 m/sec)
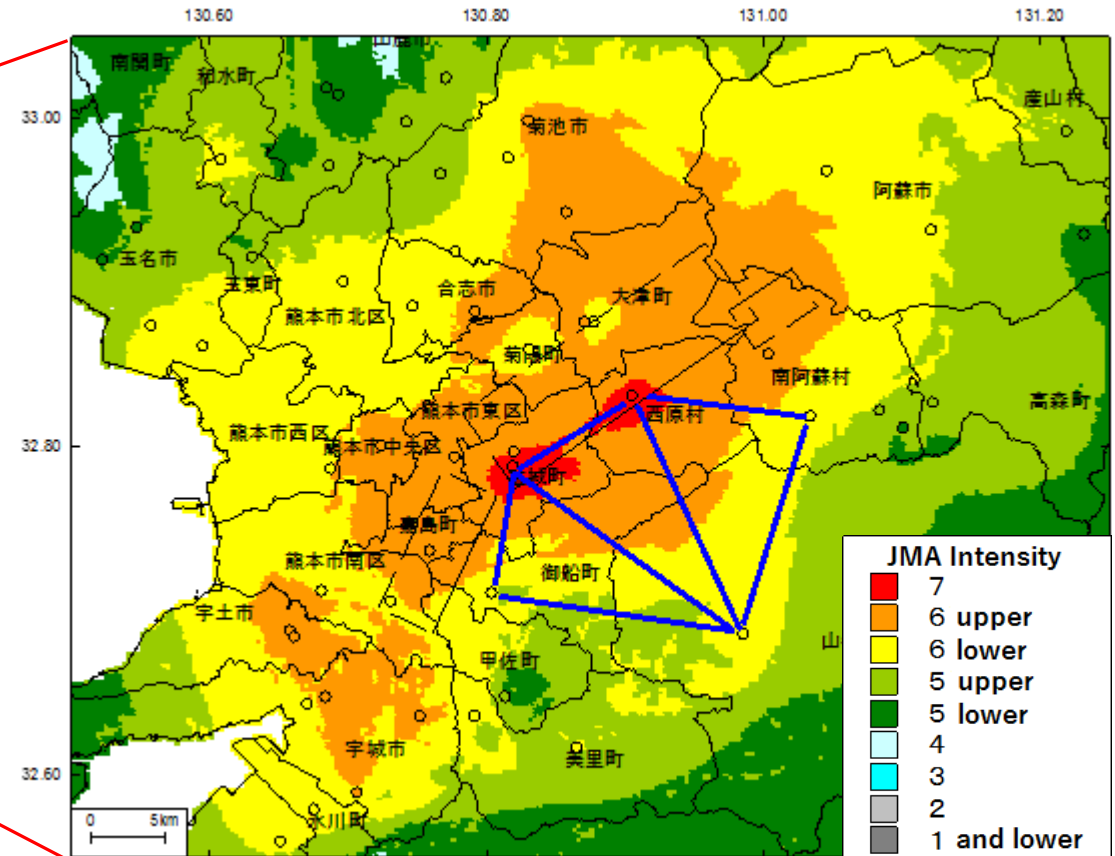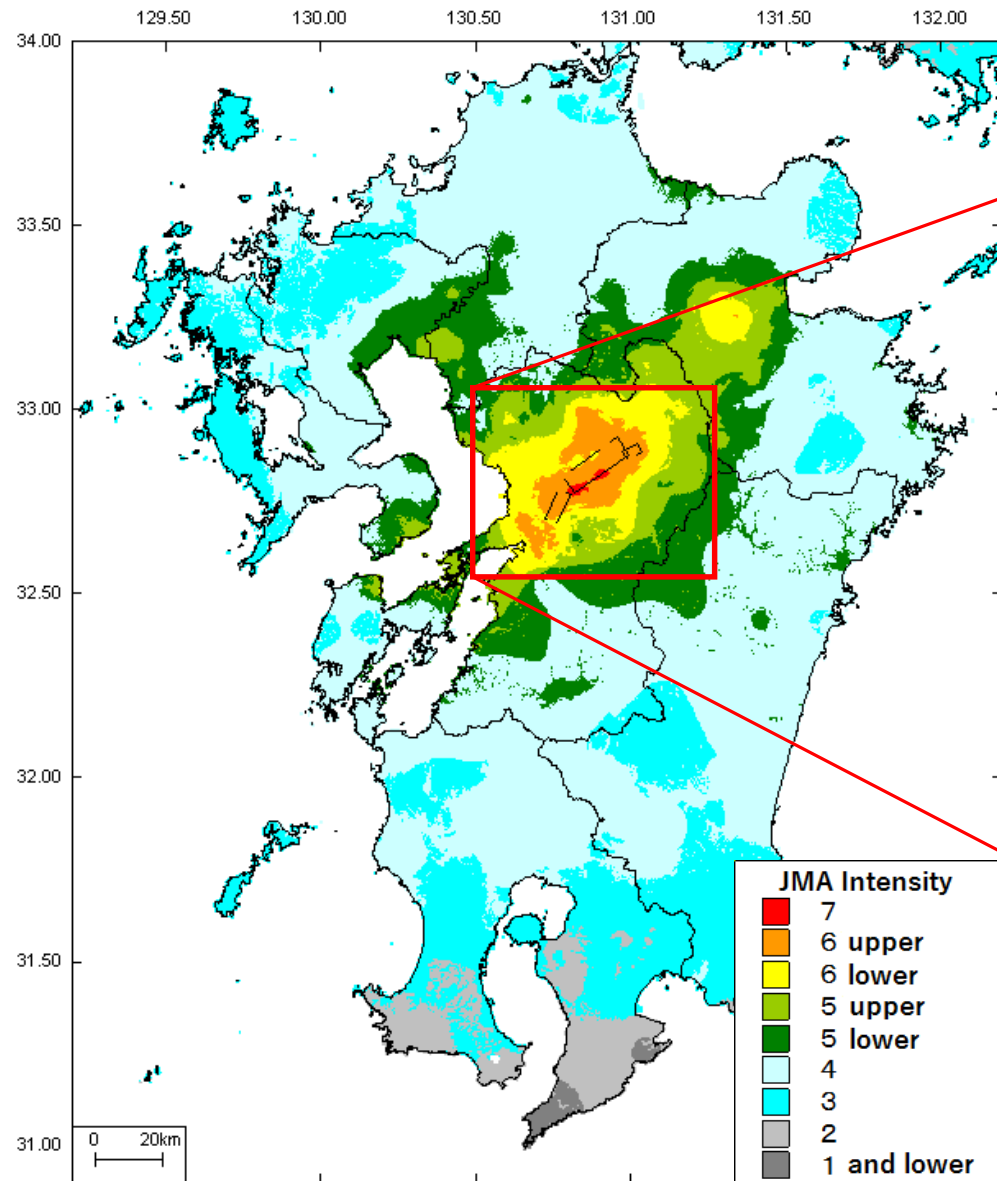- Use non-liner amplification factor of the subsurface ground (AVS30)

STEP-3: Spatial interpolation on the engineering basement (center of mesh)
- Simple Kriging method: Consider attenuation trend from the fault model

STEP-4: Calculate seismic index on the ground surface

Calculation point (center of 250m mesh)

Observation point

Ground surface

Engineering basement
(Vs=400m/sec)
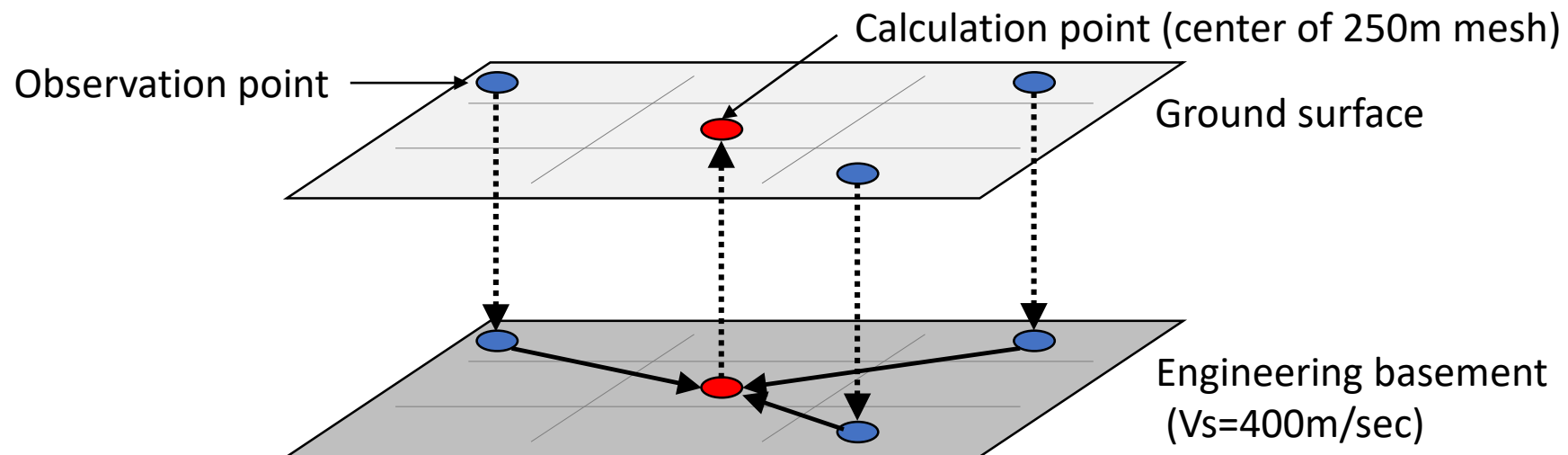
Spatial interpolation result of Kumamoto earthquake

https://kakoyure.oyorms.co.jp/top/

What is an easy-to-understand expression?

Risk management at various levels

Scale	Organization	Purpose of use	Risk management
Global ↕ Country-wide ↕	Reinsurance company	Portfolio management	Probabilistic risk Portfolio risk Risk finance
	Multinational company	Supply chain management	
	National government	Security and lives of citizens	
	Insurance company	Ceded reinsurance	
	Country-wide company	Supply chain management	
Regional ↕ Local ↕ Location	Lifeline company	Early recovery, BCP/BCM	Scenario risk Risk control
	Railway company	Early recovery, BCP/BCM	
	Highway company	Early recovery, BCP/BCM	
	Local government: City, Town	Protection of residents	
	Hospital, fire station	Maintain operation	
	Local company	Business continuity, survival	
	Resident	Maintaining life and living	

- **Comparison**
  - seismic intensity of the top 5 earthquakes and probabilistic assessment

Souce Name

Instrumental Seismic Intensity

| | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 |

Uemachi fault zone (M7.6)

10% in 50 years

Rokko-Awaji fault zone (main part)(M8.0)

Arima-Takatsuki fault zone (M7.7)

Ikoma fault zone (M7.5)

Nankai trough (whole area No.4) (M9.1)

around Osaka

- **Familiar expression for the users**
  - Extent of damage and/or loss

around Osaka
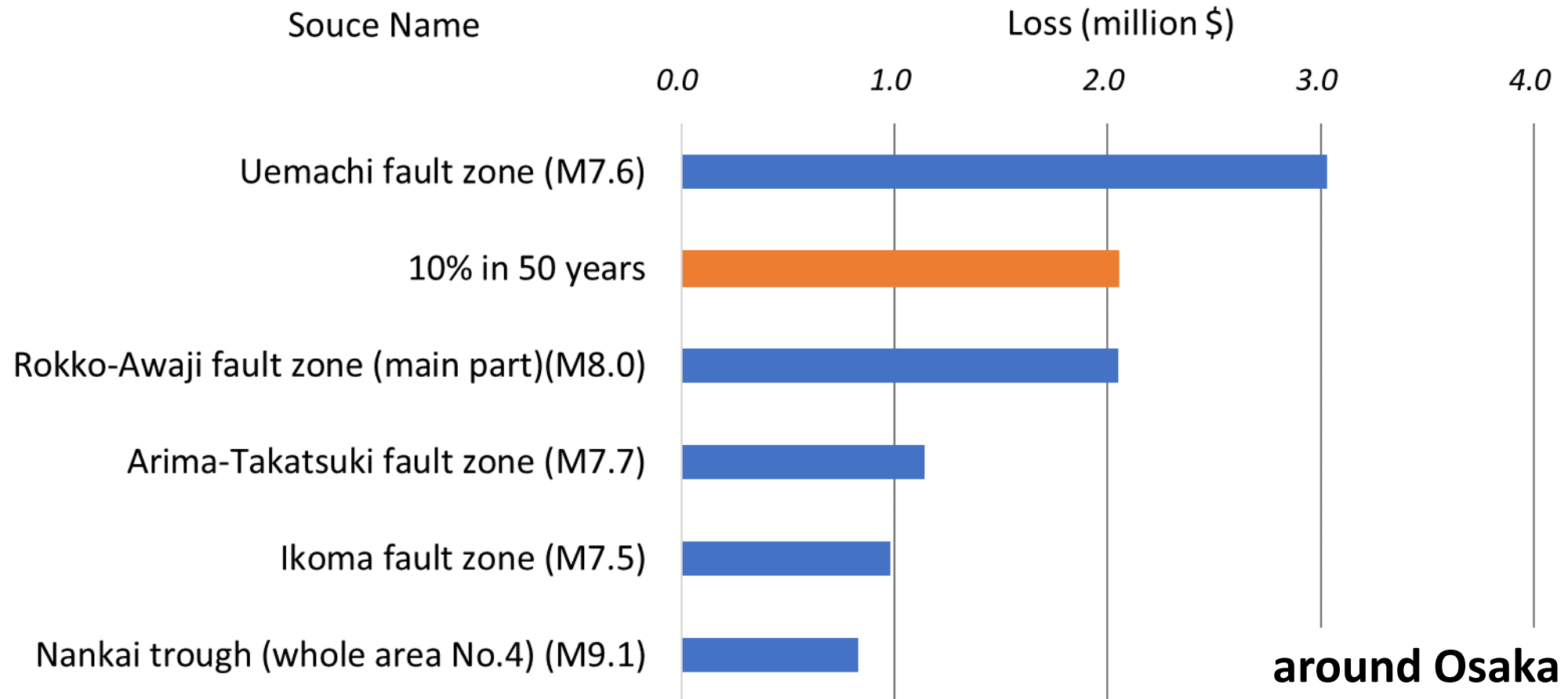
Thank you! 謝謝你的關注！

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