Improved seismic hazard assessment for Japan after the 2011 Great East Japan Earthquake and the 2016 Kumamoto Earthquake

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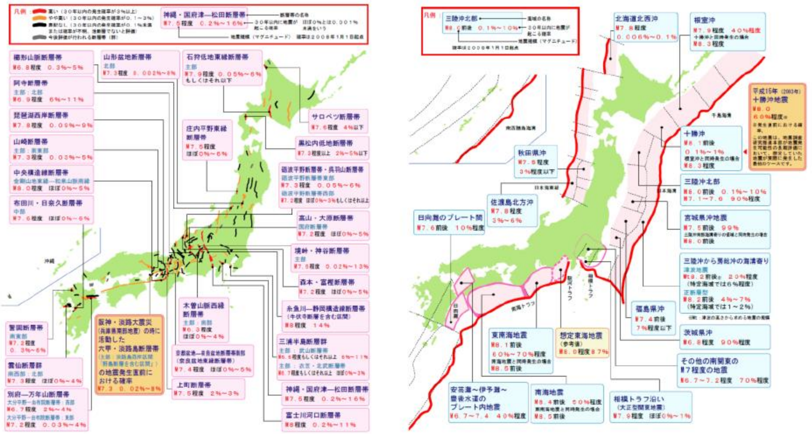
National Research Institute for Earth Science and Disaster Prevention

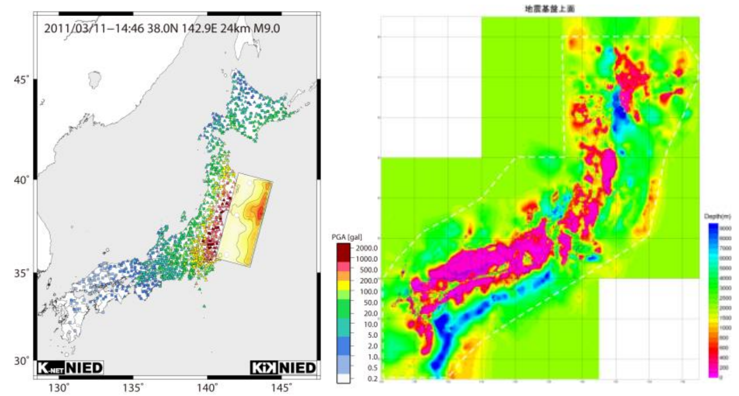
National seismic hazard maps for Japan

Long term evaluation



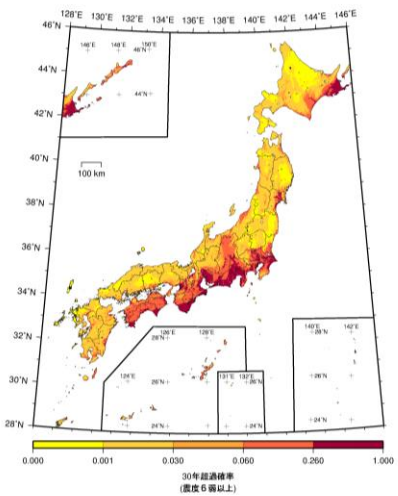
Probability of occurrence, magnitude, location

Strong-motion evaluation



Strong-motion, underground structure

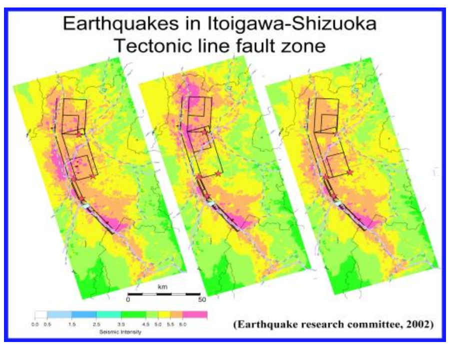
Probabilistic Seismic Hazard Maps



・Showing the strong-motion intensity with a given probability, or the probability with a given intensity.

・Considering all possible earthquakes.

Scenario Earthquake Shaking Maps



・Showing the strong-motion intensity around the fault for a specified earthquake.

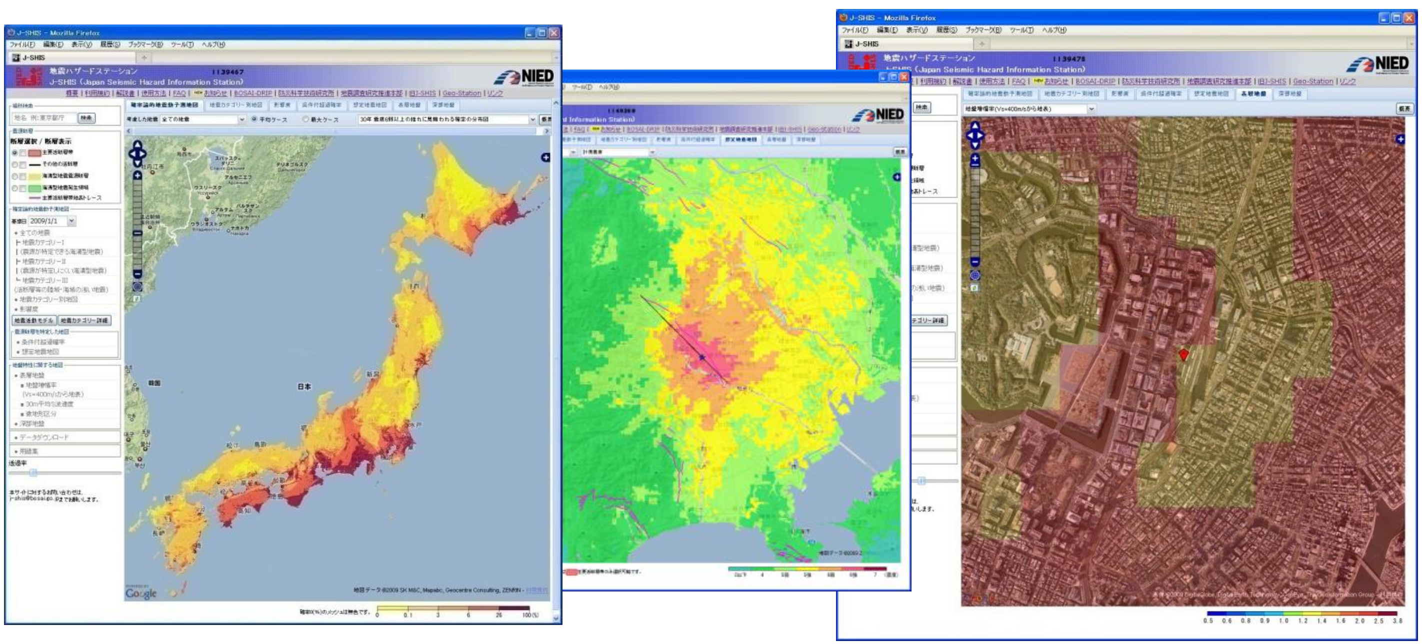
Recipe for strong motion prediction

Japan Seismic Hazard Information Station

http://www.j-shis.bosai.go.jp

In order to promote the use of the national seismic hazard maps, an engineering application committee (Chairman: Prof. H. Kameda) was established by NIED. Under the committee guidance, we developed an open web system to provide information interactively, and named this system as Japan Seismic Hazard Information Station, J-SHIS.

Our products are aimed to meet multi-purpose needs in engineering fields by providing information of the probabilistic seismic hazard analysis.



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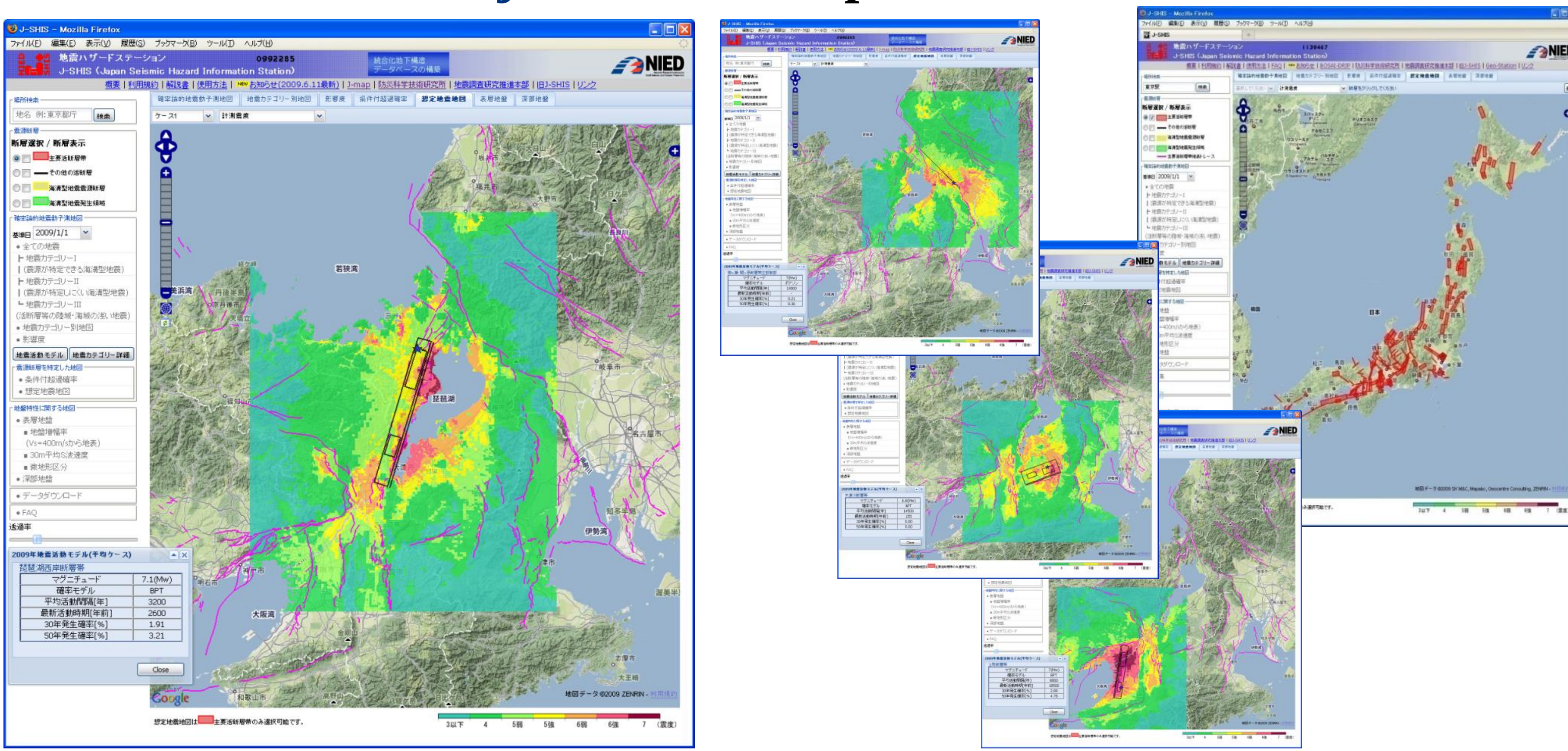
Scenario Earthquake Shaking Maps

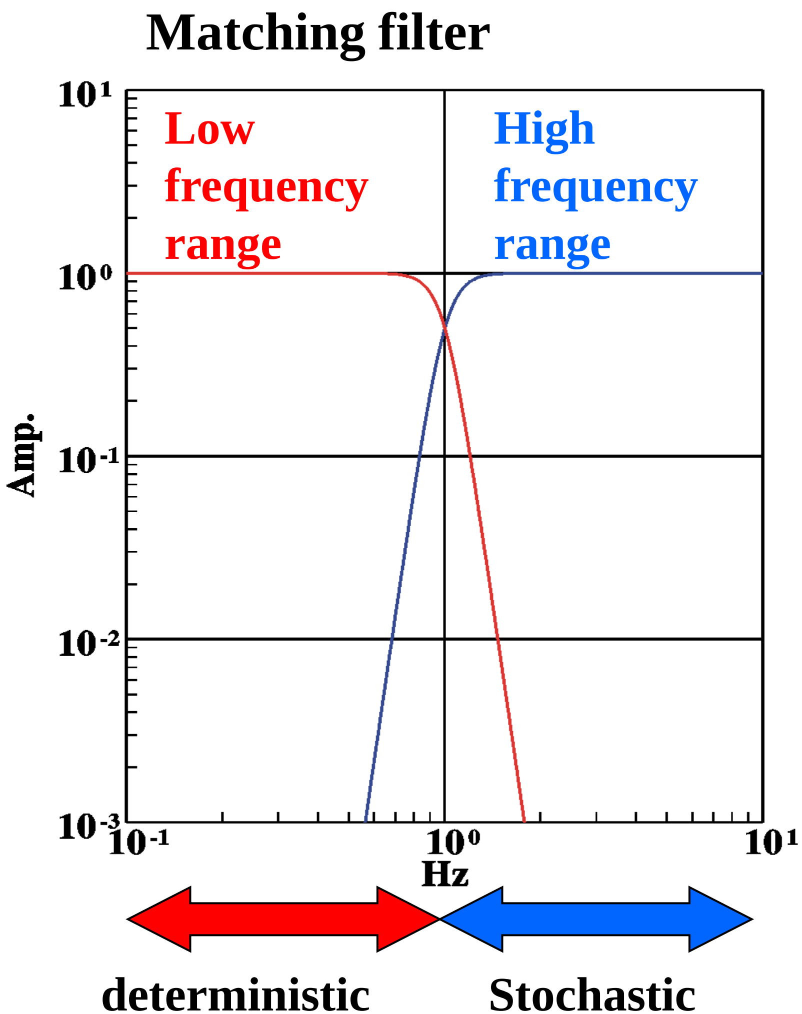
The shaking maps are evaluated for 490 scenario earthquakes of almost all of major faults in Japan.

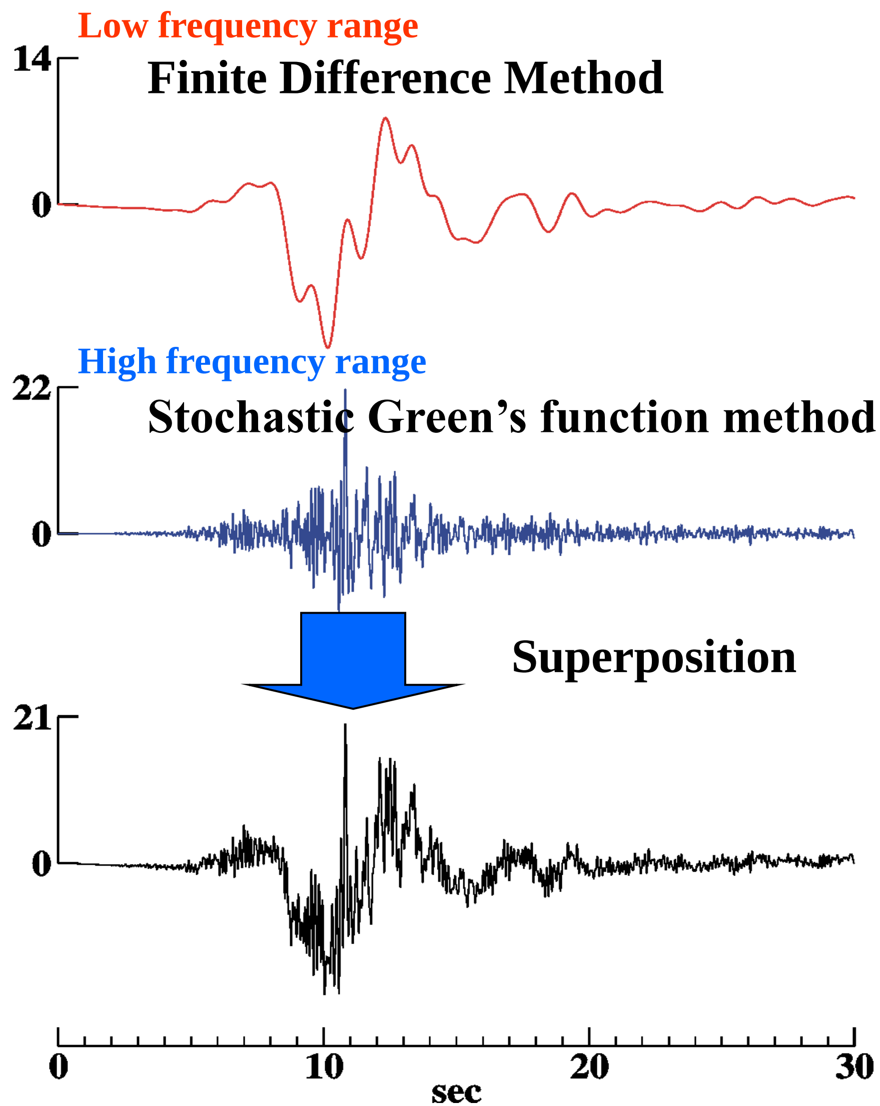


Selection of a specified scenario is essential to make a shaking map. The basic policy of the selection of a scenario earthquake is that we choose the most probable case.

For treatment of uncertainties, we assume several cases of source model and compare the results of them to show deviation of strong-motion evaluation due to uncertainties.

Hybrid method for evaluation of strong-motion





The technical details on the hybrid method are summarized as the 'Recipe for strong-motion evaluation', which are published by the earthquake research committee of Japan.

Characterized Source Model

Long-term evaluation of earthquake activities

↓

Outer characteristics of source

- **Type of earthquake**
- ↓
- **Seismic moment, rupture area, average slip**
- ↓
- **High frequency level of acceleration source spectrum**

↓

Inner characteristics of source

- **Asperity**
  - **Number, location, area, average slip, effective stress**
- ↓
- **Background slip area**
  - **Area, average slip, effective stress**
- ↓
- **Slip velocity time function, fmax**

↓

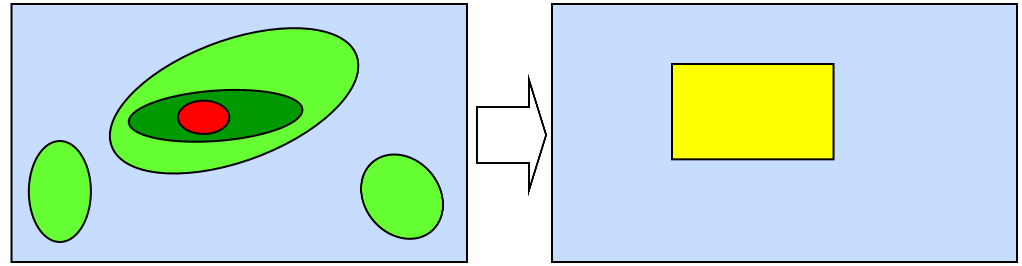
Other characteristics of source

- **Starting point of rupture**
- **Patern of rupture propagation**
- **Rupture velocity**

↓

Characterized Source Model

Complicated source model



The complicated source model is simplified by the characteristic source model for strong-motion prediction.

Characterized source models are composed of asperities and a background slip area surrounding the asperities. Asperities are the main rupture areas in the fault zone.

Source parameters required to evaluate strong-motions by using the characterized source model are classified into three parts.

The first part is the set of outer parameters that show the magnitude and the fault shape of the earthquake.

The second part is the set of the parameters that describe the degree of fault heterogeneity.

The third part is the set of the parameters to define the characteristics of the rupture propagation.

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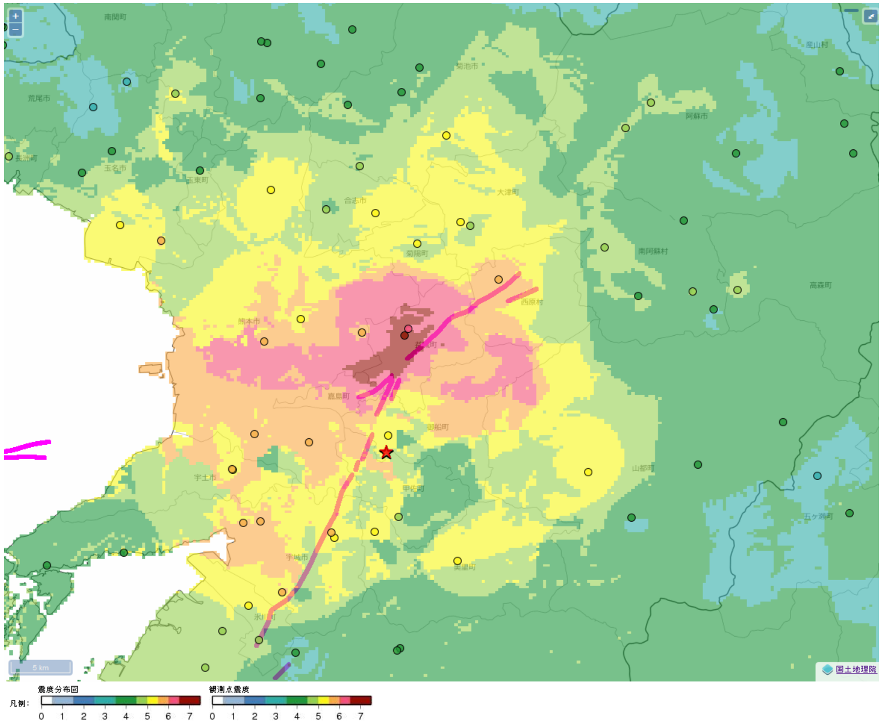
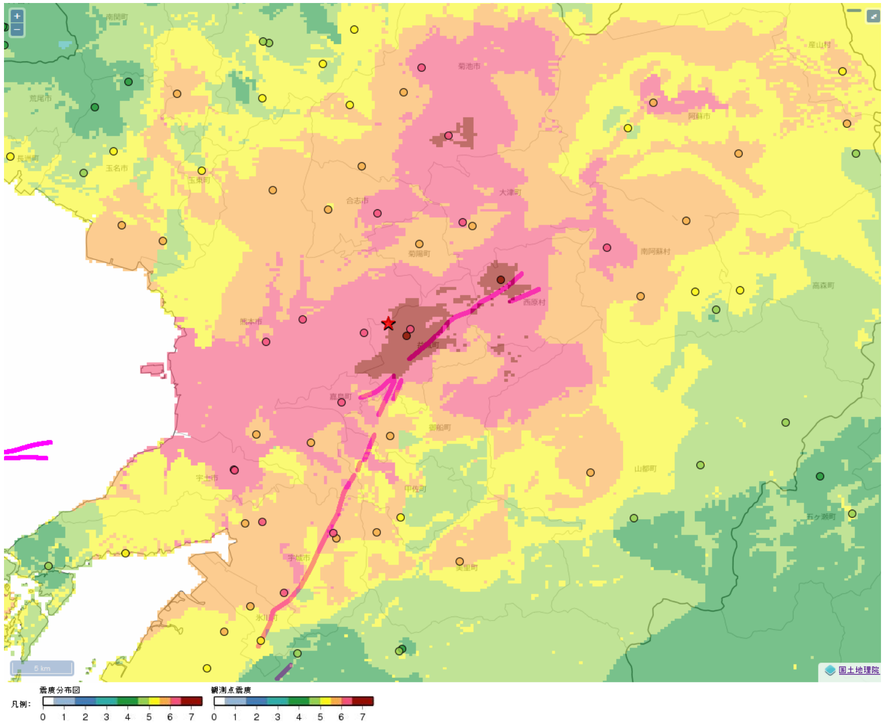
Kumamoto　Earthquakes

Distribution of JMA seismic intensity
by SIP real-time damage estimation system

2016/04/14　21:26
Mj6．5（Mw6．1）



2016/04/16　1:25
Mj7．3 （Mw7．0）



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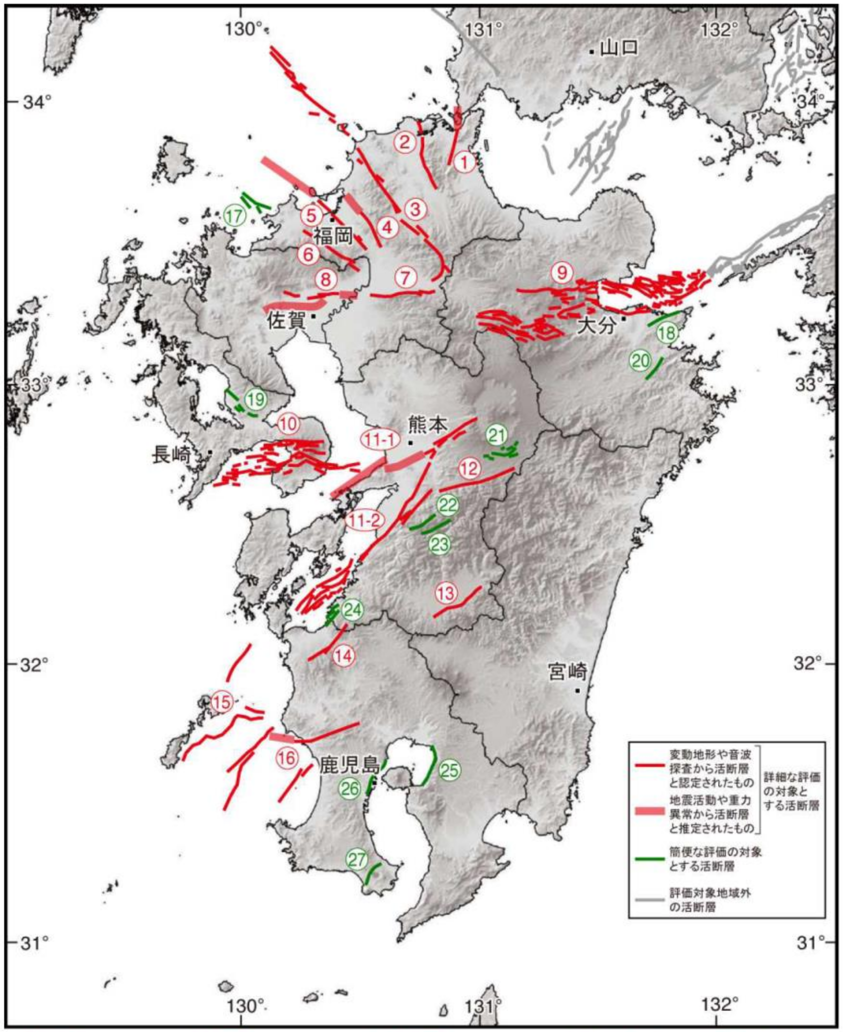
Active faults in kyushu



1:小倉東断層
2:福智山断層帯
3:西山断層帯
4:宇美断層
5:警固断層帯
6:日向峠−小笠木峠断層帯
7:水縄断層帯
8:佐賀平野北縁断層帯
9:別府−万年山断層帯
10:雲仙断層群
11-1:布田川断層帯
11-2:日奈久断層帯
12:緑川断層帯
13:人吉盆地南縁断層
14:出水断層帯
15:甑断層帯
16:市来断層帯
17:糸島半島沖断層群
18:佐賀関断層
19:多良岳南西麓断層帯
20:福良木断層
21:阿蘇外輪南麓断層群
22:鶴木場断層帯
23:国見岳断層帯
24:水俣断層帯
25:鹿児島湾東縁断層帯
26:鹿児島湾西縁断層帯
27:池田湖西断層帯

図2　九州地域（評価対象地域）において評価対象（注4）とする活断層の分布

Futagawa fault zone and Hinagu fault zone

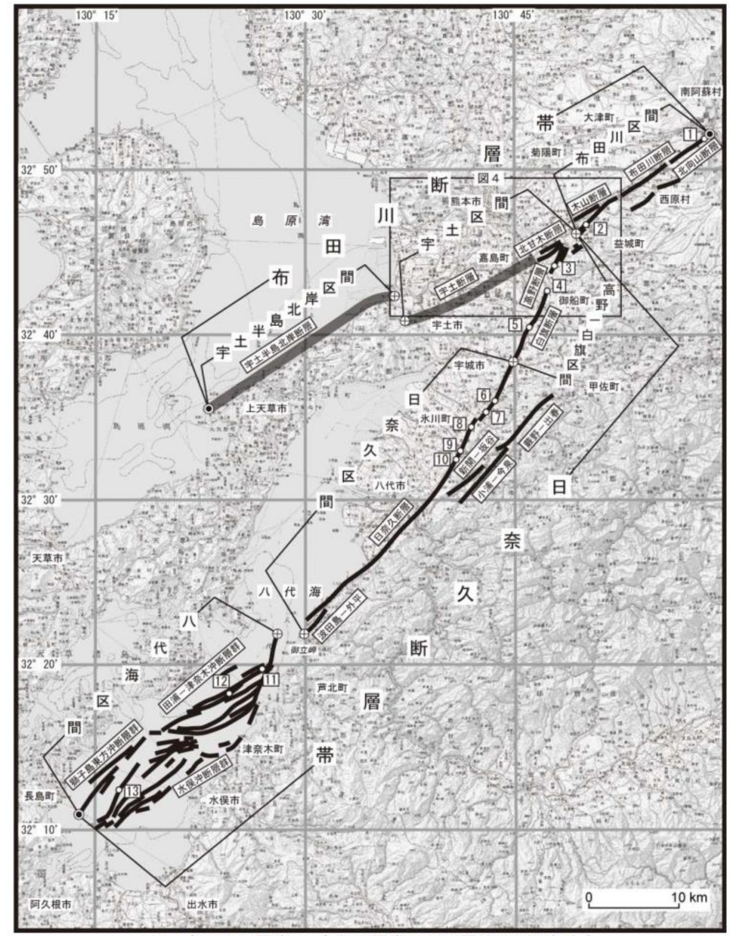


図2　布田川断層帯・日奈久断層帯の活断層位置と調査地点

1:白川左岸地点　2:田中地点　3:高木地点　4:白旗地点　5:鰐瀬地点　6:南小野地点　7:南部田地点　8:高塚B地点　9:腹巻田地点　10:栫地点　11:八代海白神岩地点　12:八代海津奈木沖地点　13:八代海南西部海底地点

◉:断層帯の北東端と南西端　⊕:活動区間の境界

Headquarters for Earthquake Research Promotion of Japan

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Long-term evaluation for Futagawa fault zone and Hinagu fault zone (2013)

Futagawa fault zone

Segment	Length	Magnitude	Probability (30 year)
Futagawa	About 19km	About Mj7.0	0～0.9 %
Uto	About 20km	About Mj7.0	-
North coast of Uto Peninsula	More than about 27km	More than about Mj7.2	-

Hinagu fault zone

Segment	Length	Magnitude	Probability (30 year)
Takano-Shirahata	About 16km	About Mj6.8	-
Hinagu	About 40km	About Mj7.5	0～6%
Yatsushiro Sea	About 30km	About Mj7.3	0～16%

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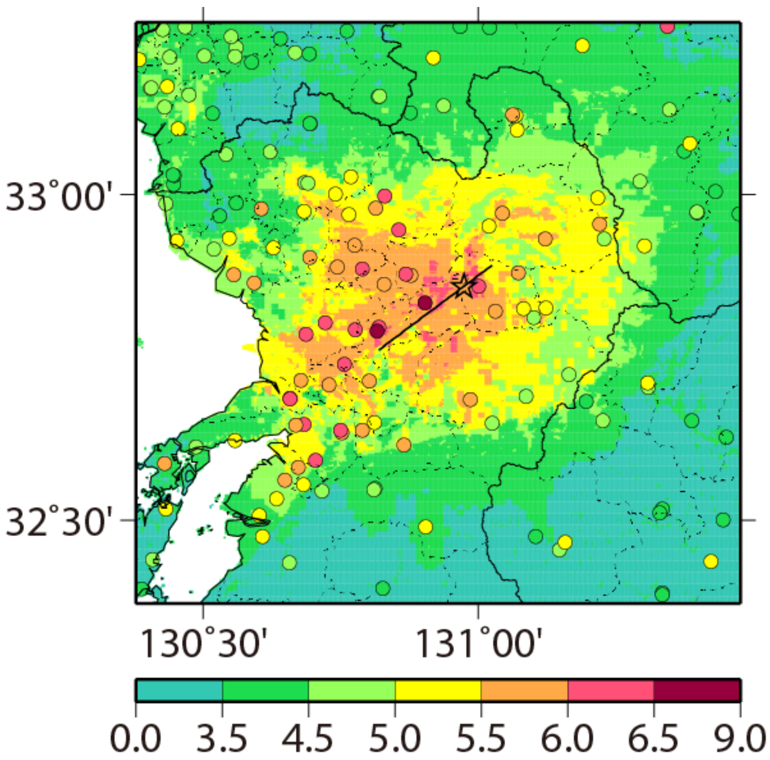
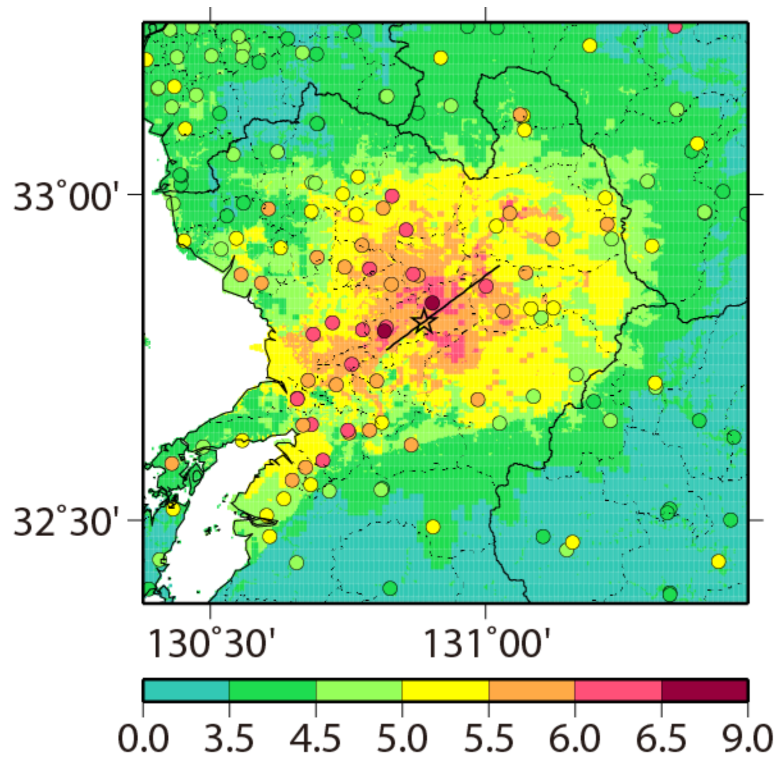
Scenario earthquake shaking maps for Futagawa fault zone （Mw6．5）
(HERP, 2014; Fujiwara et al., 2015)

case-1



case-2



Comparison of observation (○) and simulation (background)

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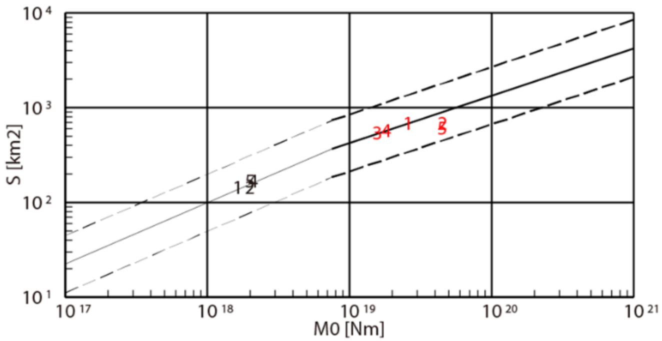
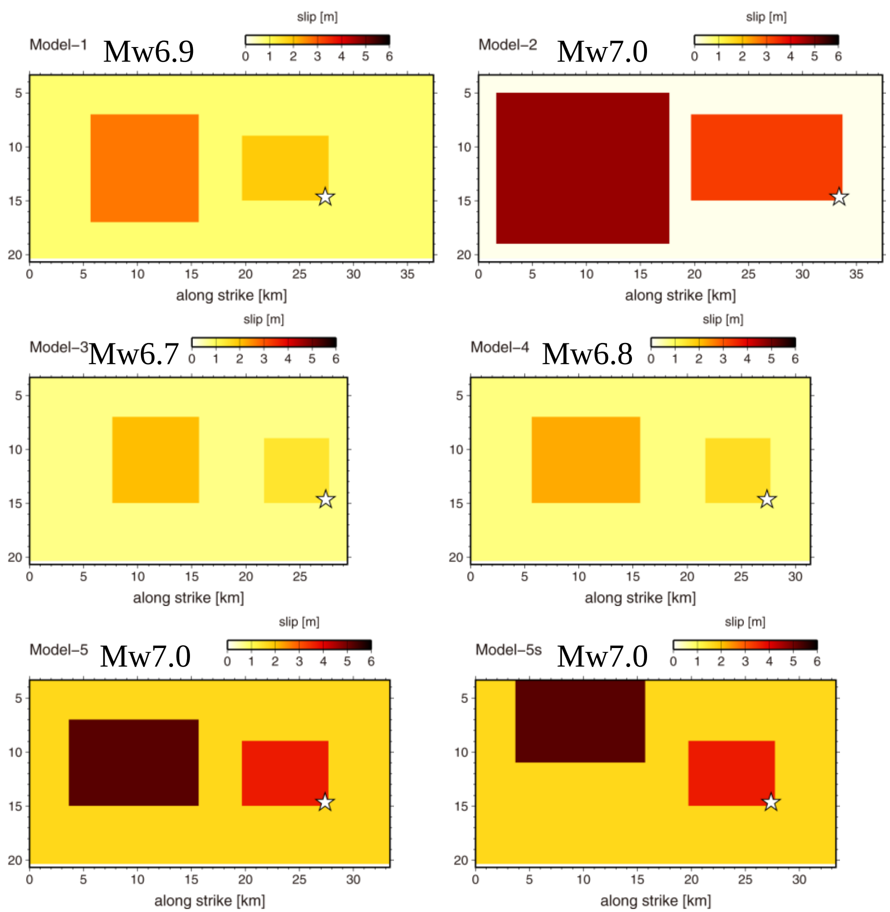
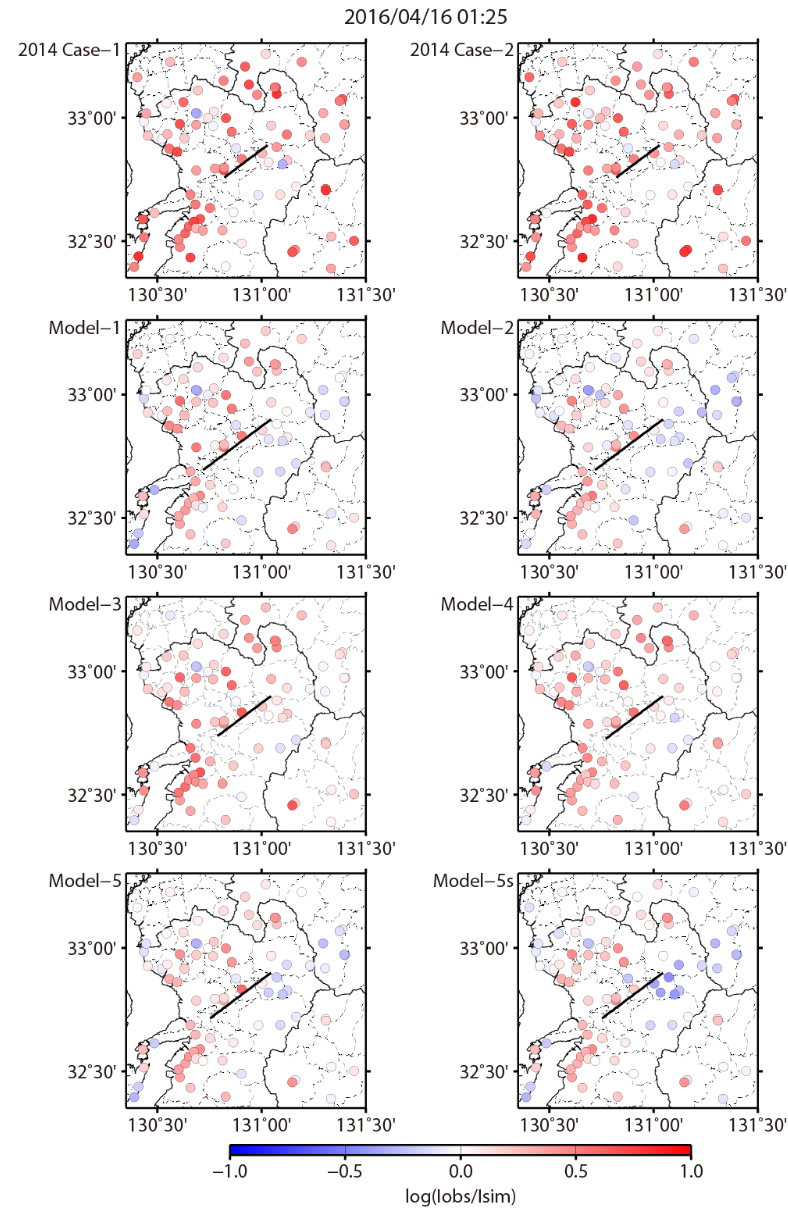


Scaling relation（Irikura and Miyake,2001）





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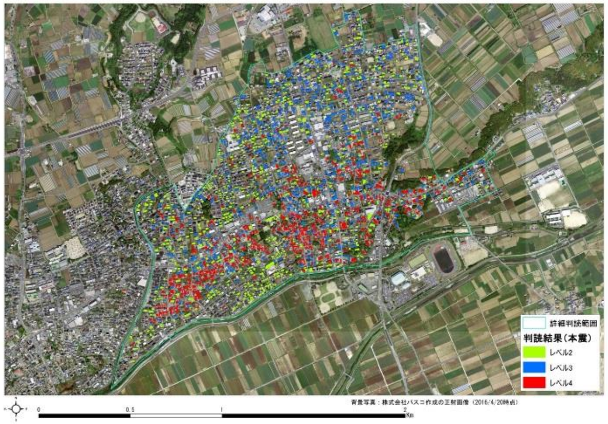
The length and width of the fault model was underestimated for the model based on the long-term evaluation.

The seismic moment was larger than the average value of the "recipe".

By using a source model that seismic moment has been properly set, ground motion distribution of wide area can be reproduced.

Large amplitude records observed in the vicinity of the source fault can not be reproduced.



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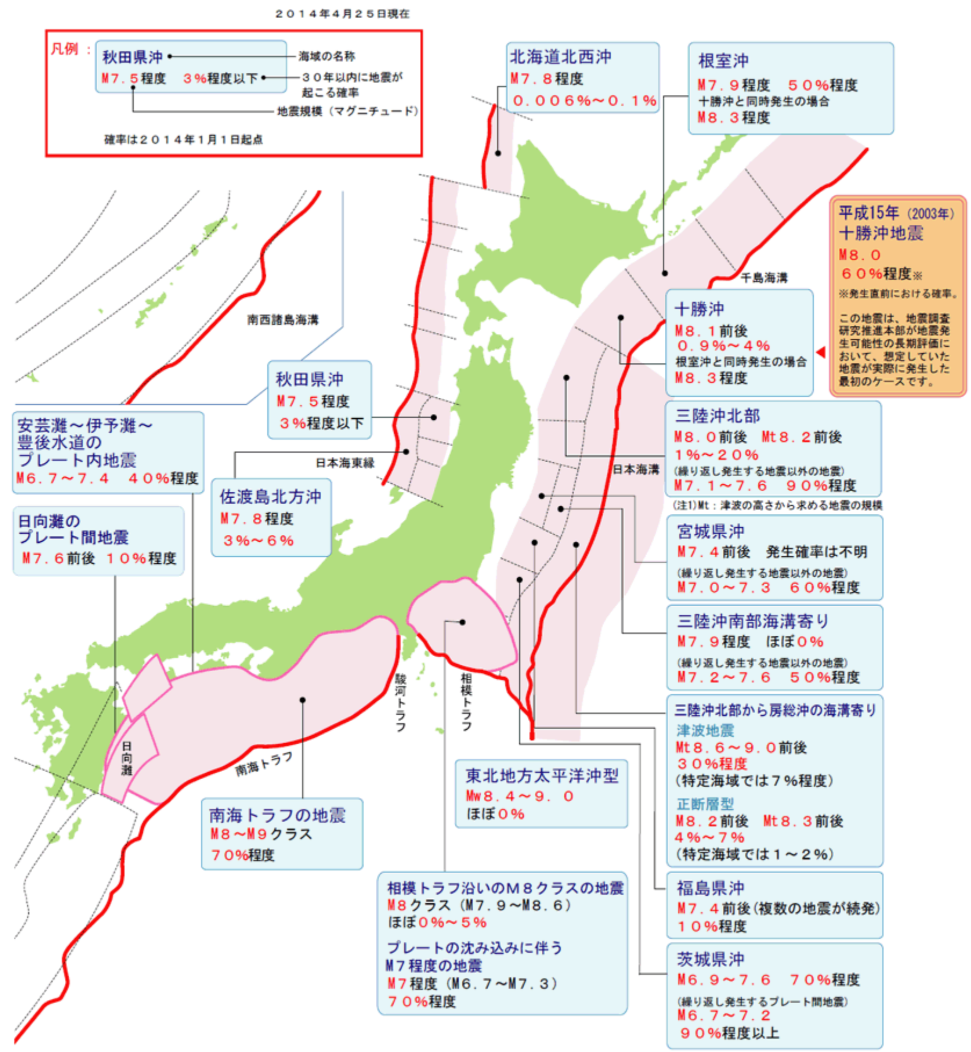
Evaluation of occurrence probability of earthquakes by ERCJ, HERP



Flowchart of PSHA

Modeling of seismic activity

↓

Evaluation of an EQ occurrence probability **P(Ei)**

↓

Probabilistic evaluation of an intensity level **P(Yi > y|Ei)**

↓

Evaluation of probabilistic seismic hazard
for each earthquake **P(Yi > y)= P(Ei) P(Yi > y|Ei)**

↓

Evaluation of probabilistic seismic hazard
for all earthquakes **P(Y > y)=1-Π[1- P(Yi > y)]**

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Strong-motion evaluation in PSHA

Modeling of seismic activity

↓ ← GMPE (Si & Midorikawa 1999)

PV on the engineering bedrock

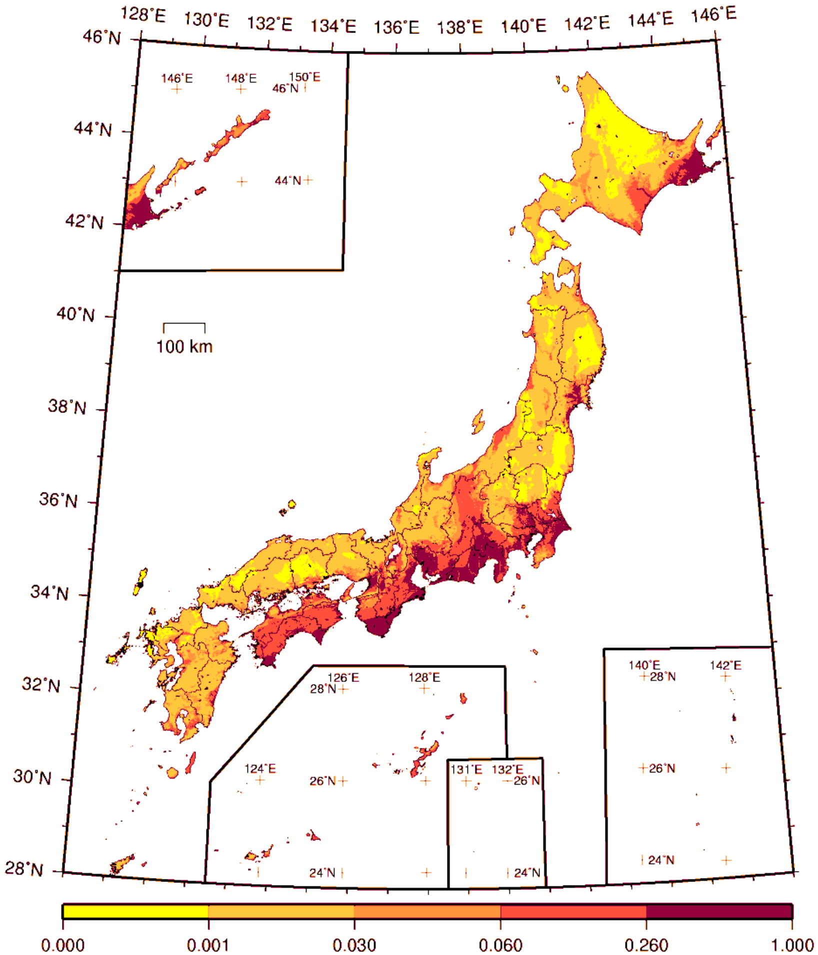
↓ ← Site amplification (Wakamatsu & Matsuoka 2008, Matsuoka & Wakamatsu2008, Fujimoto & Midorikawa 2006)

PGV

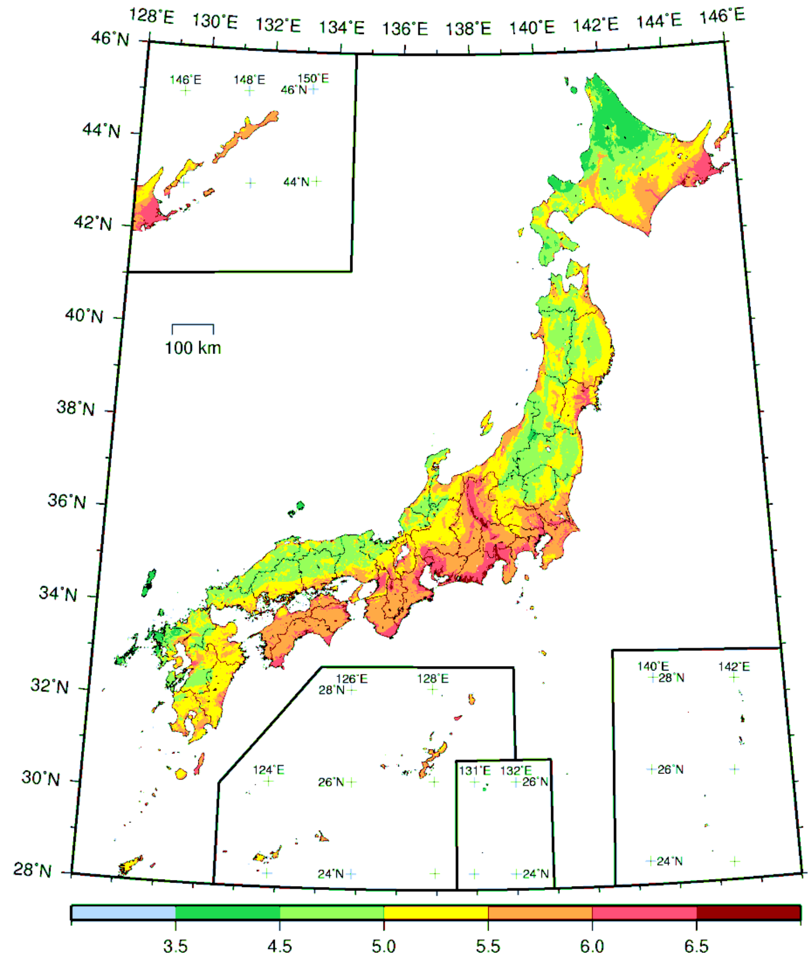
↓ ← Empirical relation (Fujimoto & Midorikawa 2005 or Midorikawa et al., 1999)

JMA seismic intensity

Probabilistic Seismic Hazard Maps



Probability in 30 years.
(≧JMA Seismic Intensity 6-)



Seismic Intensity with 3% probability of exceedance in 30 year.

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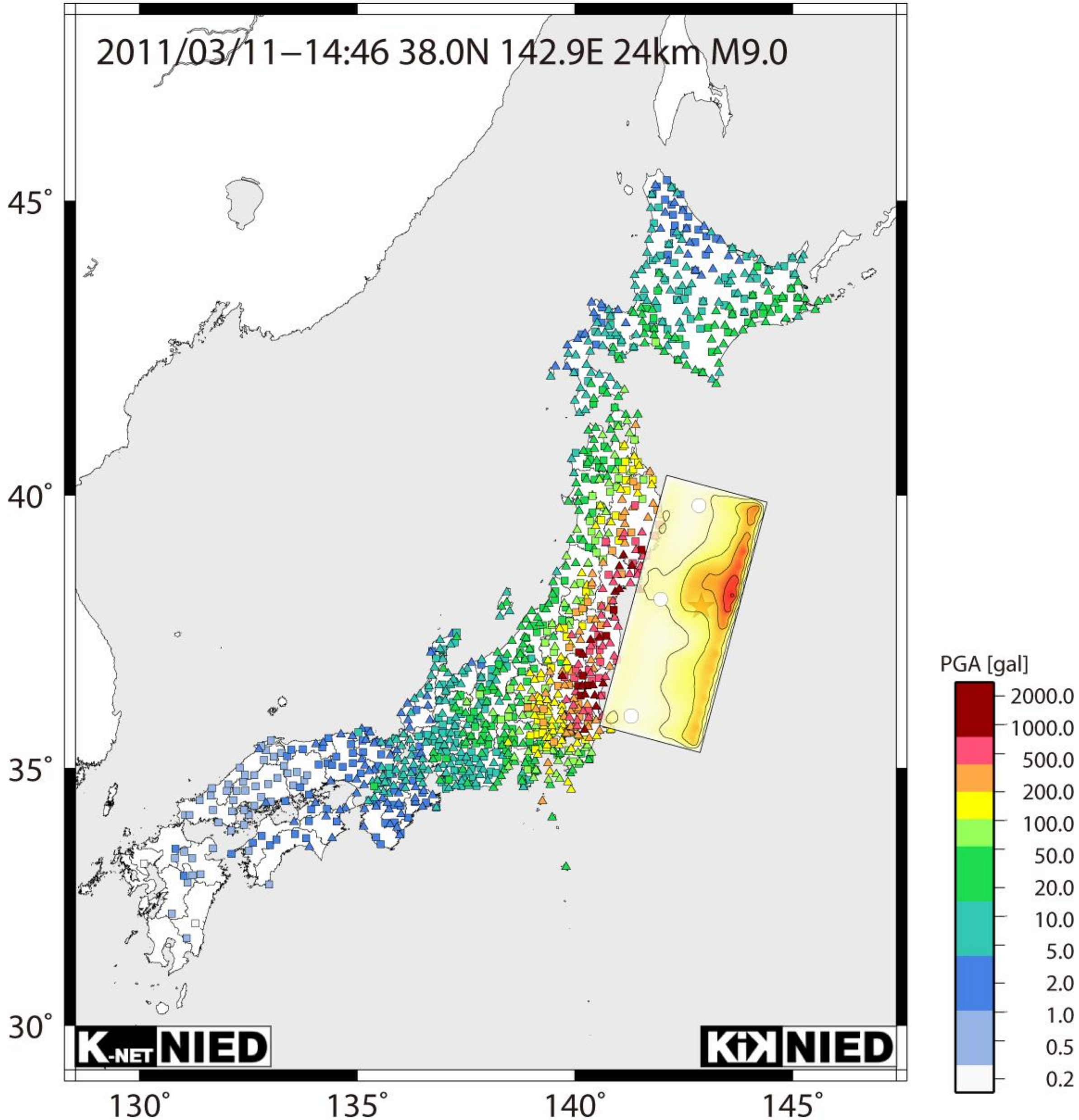
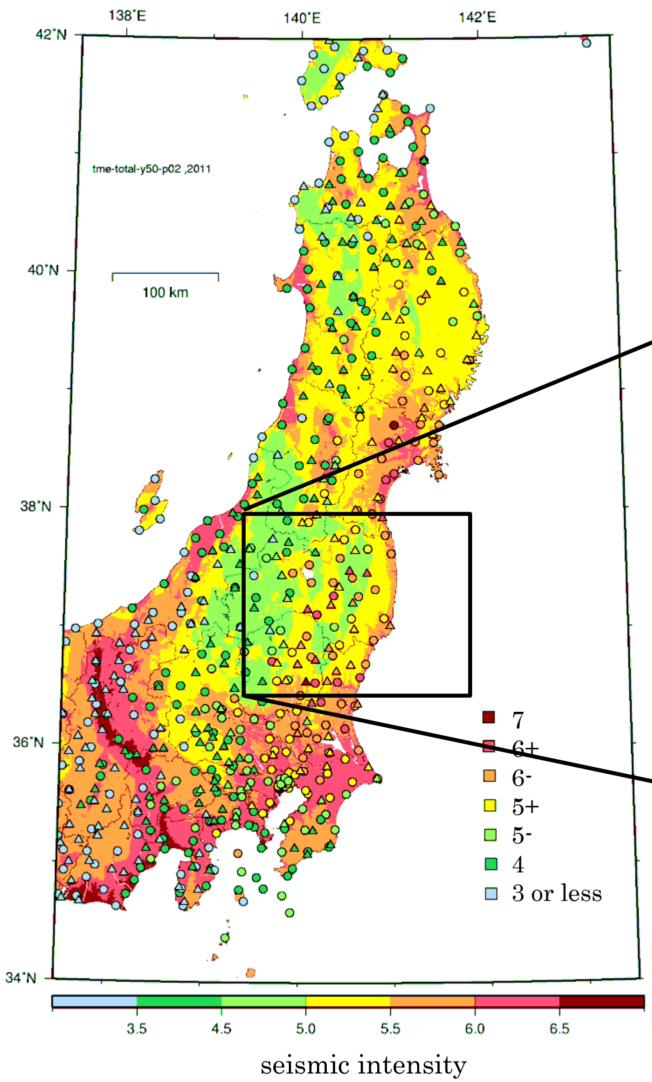
The 2011 Tohoku earthquake (M9.0)

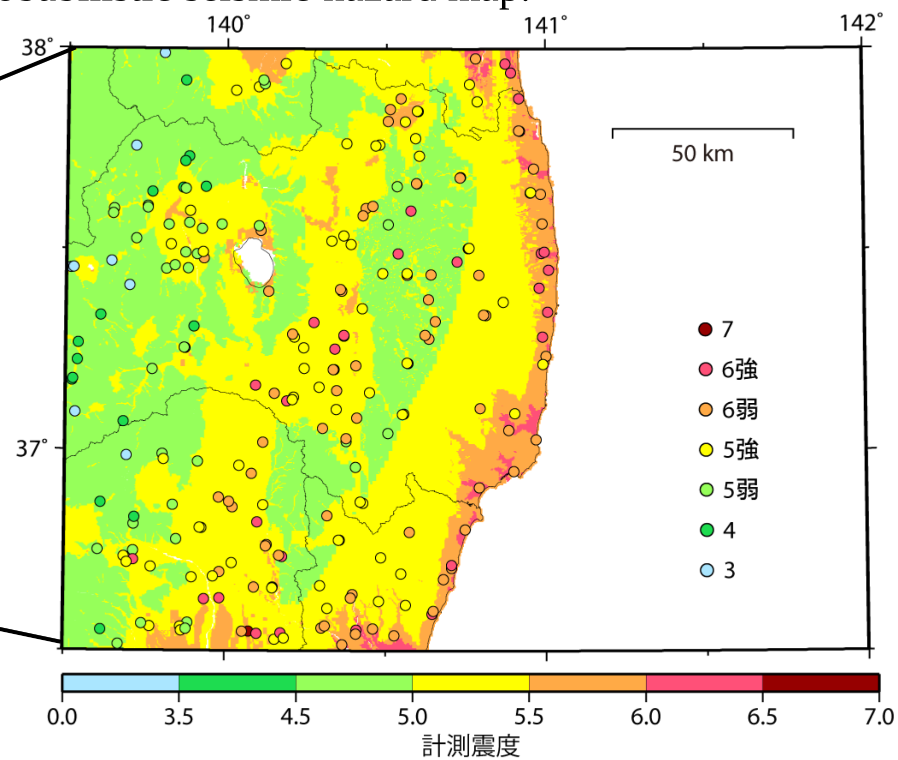


Comparison between the hazard maps and observed strong motions

Comparison between the observed seismic intensities (○：K-NET, △：KiK-net) of the Tohoku earthquake and seismic intensity distribution for 2% probability of exceedance in 50 years, which is one of the probabilistic seismic hazard map.



Seismic Intensity with 2% probability of exceedance in 50 year.



As you can see from this comparison, predicted ground motion level in the probabilistic seismic hazard map was clearly underestimated in Fukushima Prefecture and the northern part of Ibaraki Prefecture for the Tohoku earthquake (M9.0).

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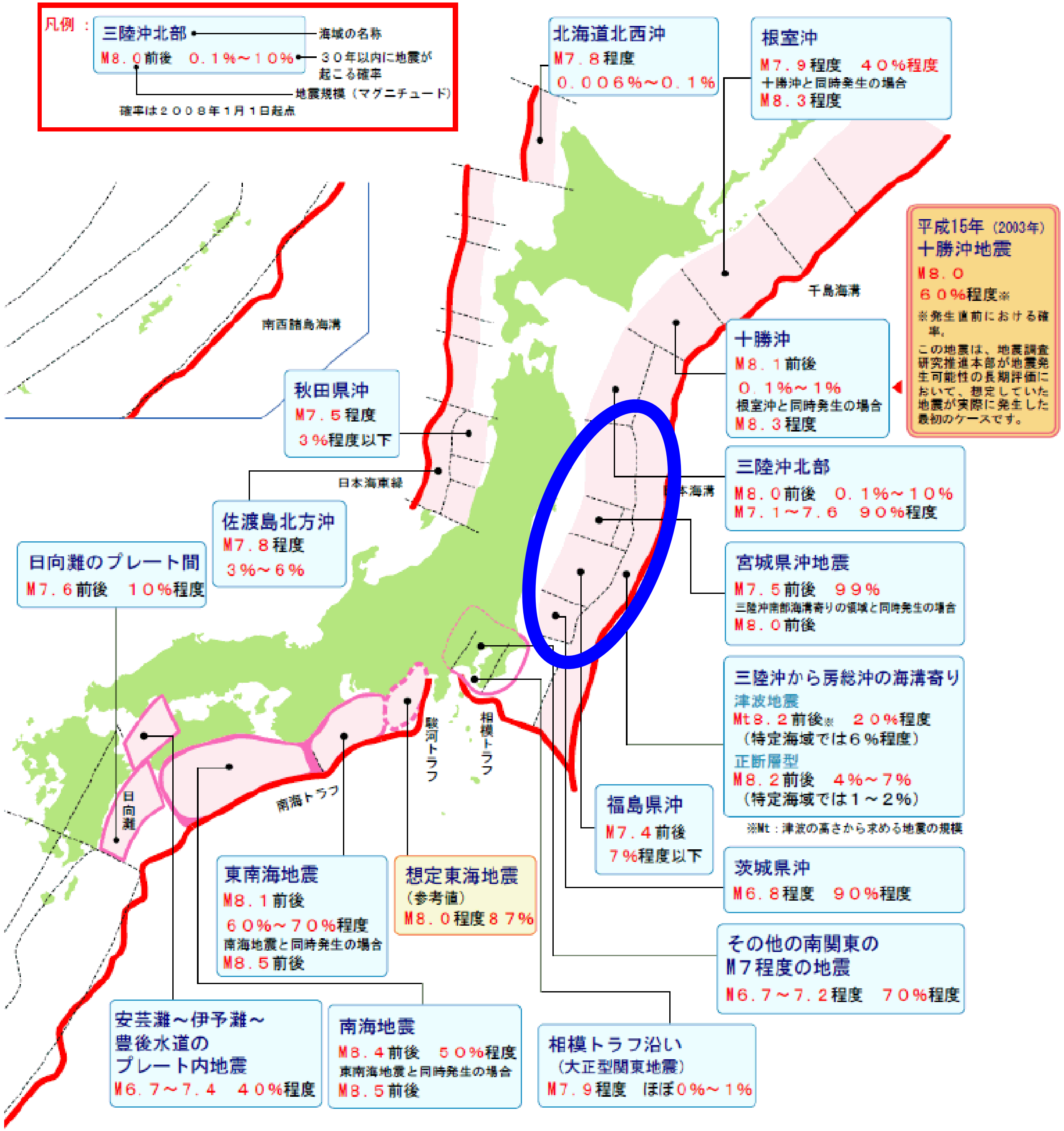

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Seismic activity models for reconsideration of seismic hazard assessment

Model 1

（Traditional model based on the long-term evaluation）

A model created by conventional methods based on the long-term evaluation for comparison with the improved model.

Model 2

（Improved model that takes into account the lessons of 311）

A model that incorporates a new way of thinking and is improved by taking into account the uncertainty, based on the experience of the Tohoku Earthquake.

Model 3

（Reference model using the G-R law）

A model on the basis of G-R law as a reference for checking the validity of the model that was built based on long-term evaluation.

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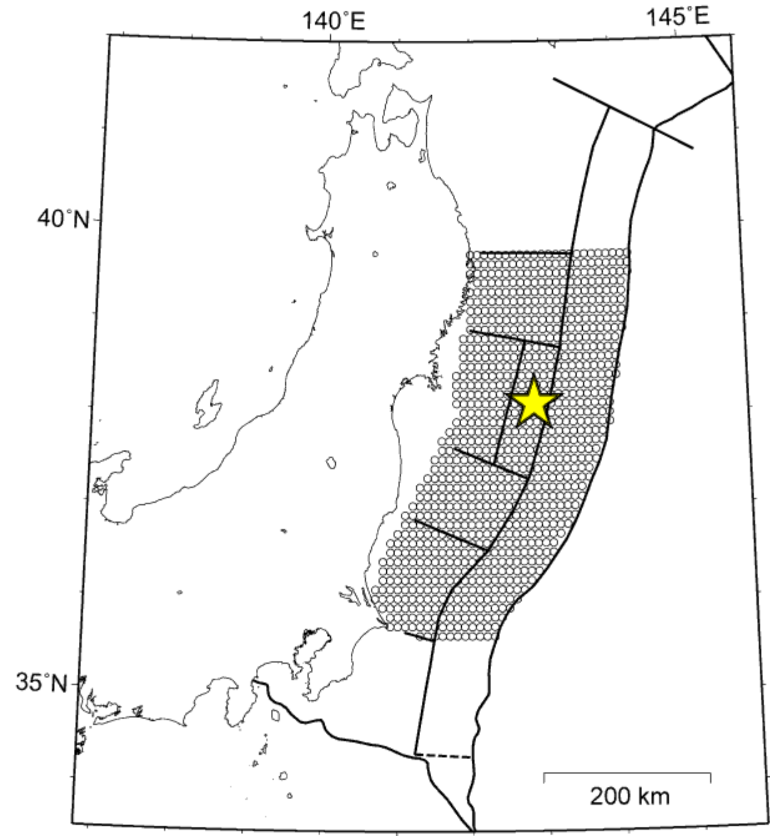
PSHM taking into account the Tohoku earthquake (M9)

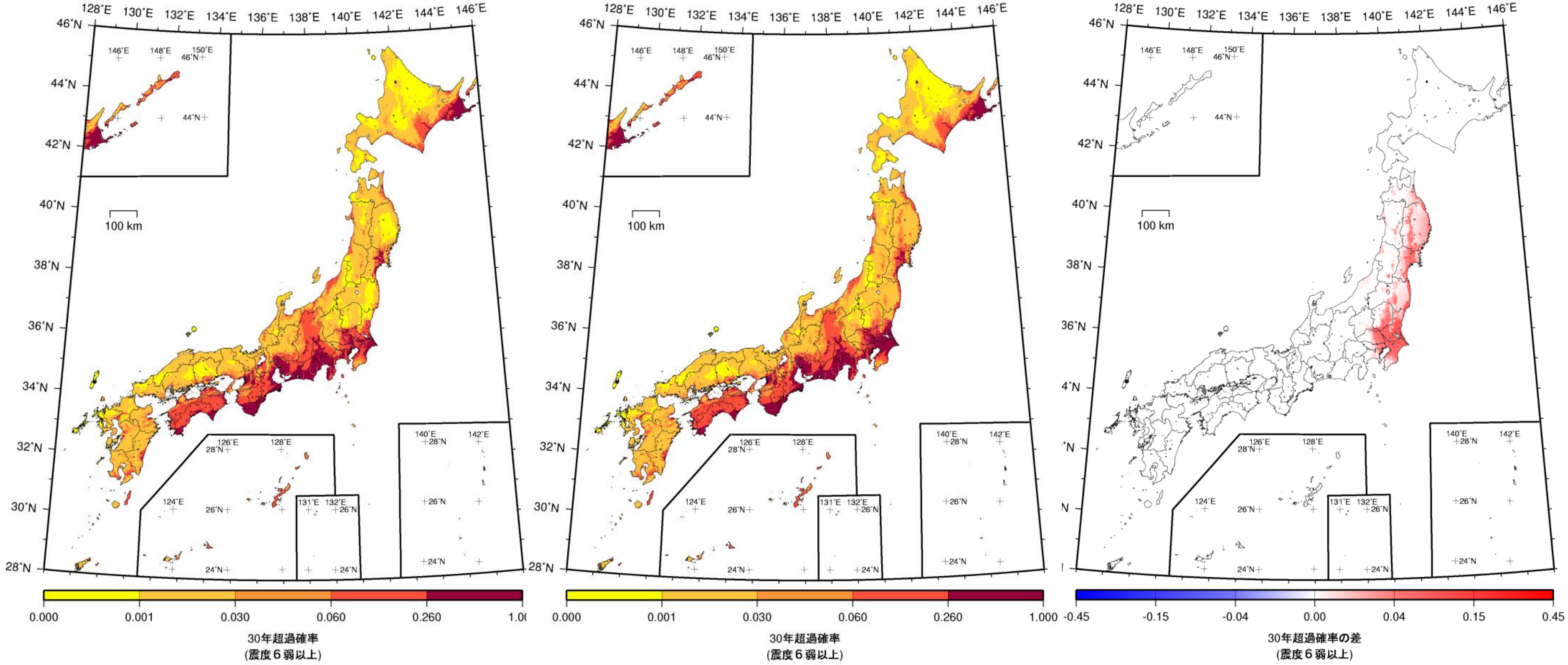
■Setting conditions for the Tohoku EQ

- ・Source area：Aftershock area
- ・The origin of the time：01/01/2011
- ・Average interval：600 years
- ・Latest activity period：
  15th century
- ・Occurrence probability in 30 years：
  15.4% (01/01/2011)
  0.0% (01/01/2012)
- ・Ground-motion equation：
  Si and Midorikawa(1999)
  (Saturated with Mw8.3)

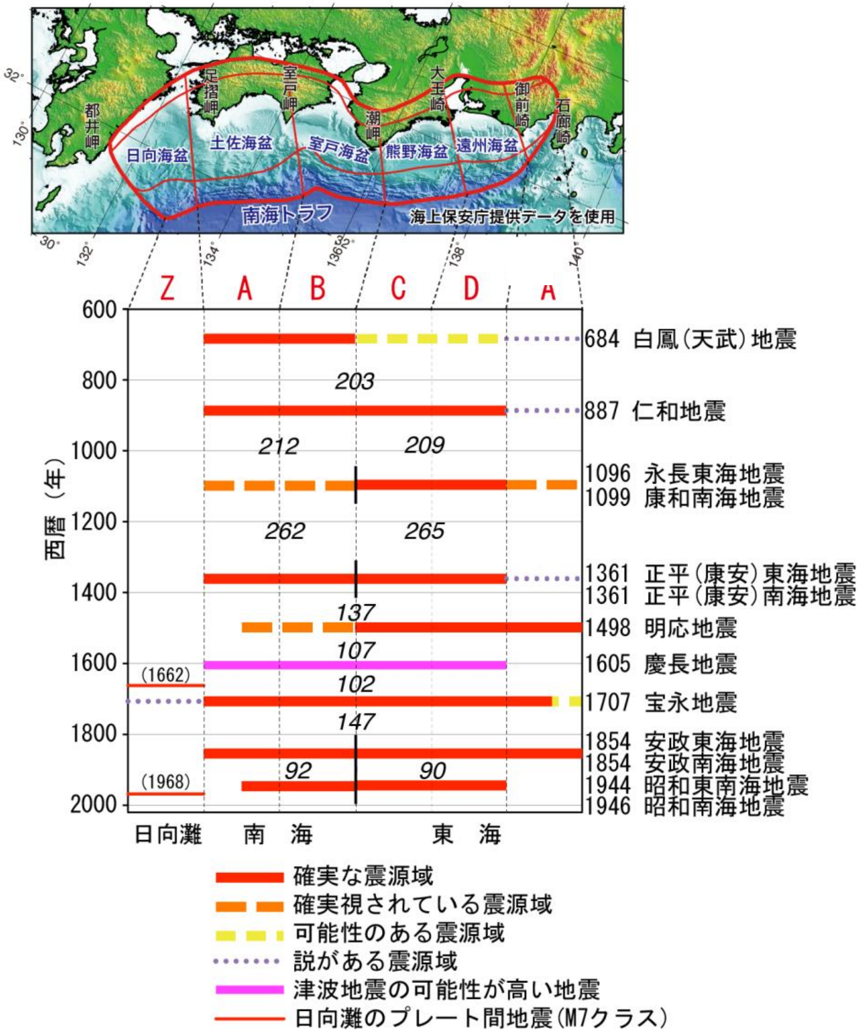


PSHMs considering the Tohoku type earthquake

(a) PSHM2011　(b) PSHM2011＋TohokuM9



Modeling for Nankai-trough earthquakes



Occurrence probability in 30 years
66.5%　(Time Predictable Model)

	日向灘	南海	東南海	東海	重み（暫定）	*Mw*	深さ
1地震	←			→	0.0125	8.9	A
	←			→	0.0125	9.0*[1]	B
	←			→	0.0125	9.0	C
	←			→	0.0125	9.1*[2]	D
	×	←		→	0.1625	8.8	A
	×	←		→	0.1625	9.0	C
	←		→	×	0.0125	8.9	A
	←		→	×	0.0125	9.0	C
	×	←	→	×	0.025	8.8	A
	×	←	→	×	0.025	8.9	C
	×	←	→	×	0.05	8.4	E
2地震	←	→	←	→	0.05	8.7, 8.4	A
	×	←→	←	→	0.325	8.6, 8.4	A
	←	→	←→	×	0.025	8.7, 8.3	A
	×	←→	←→	×	0.1	8.6, 8.3	A
	0.15	1.0	1.0	0.75	1.0		

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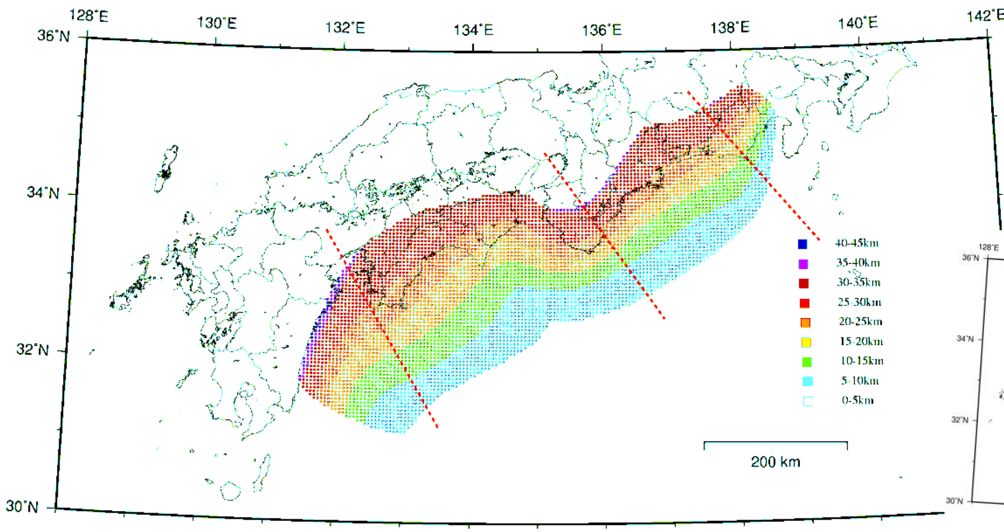
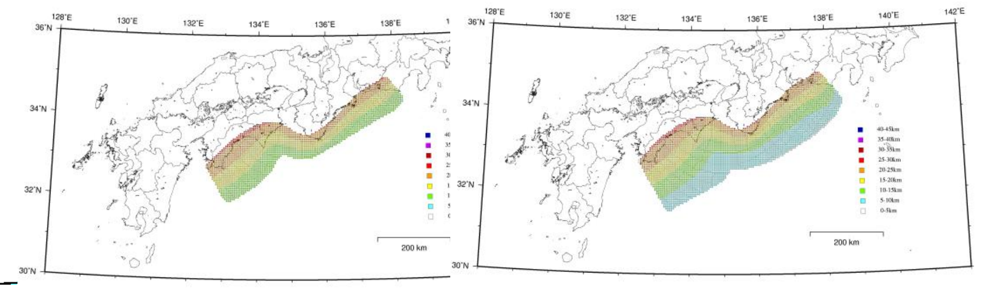
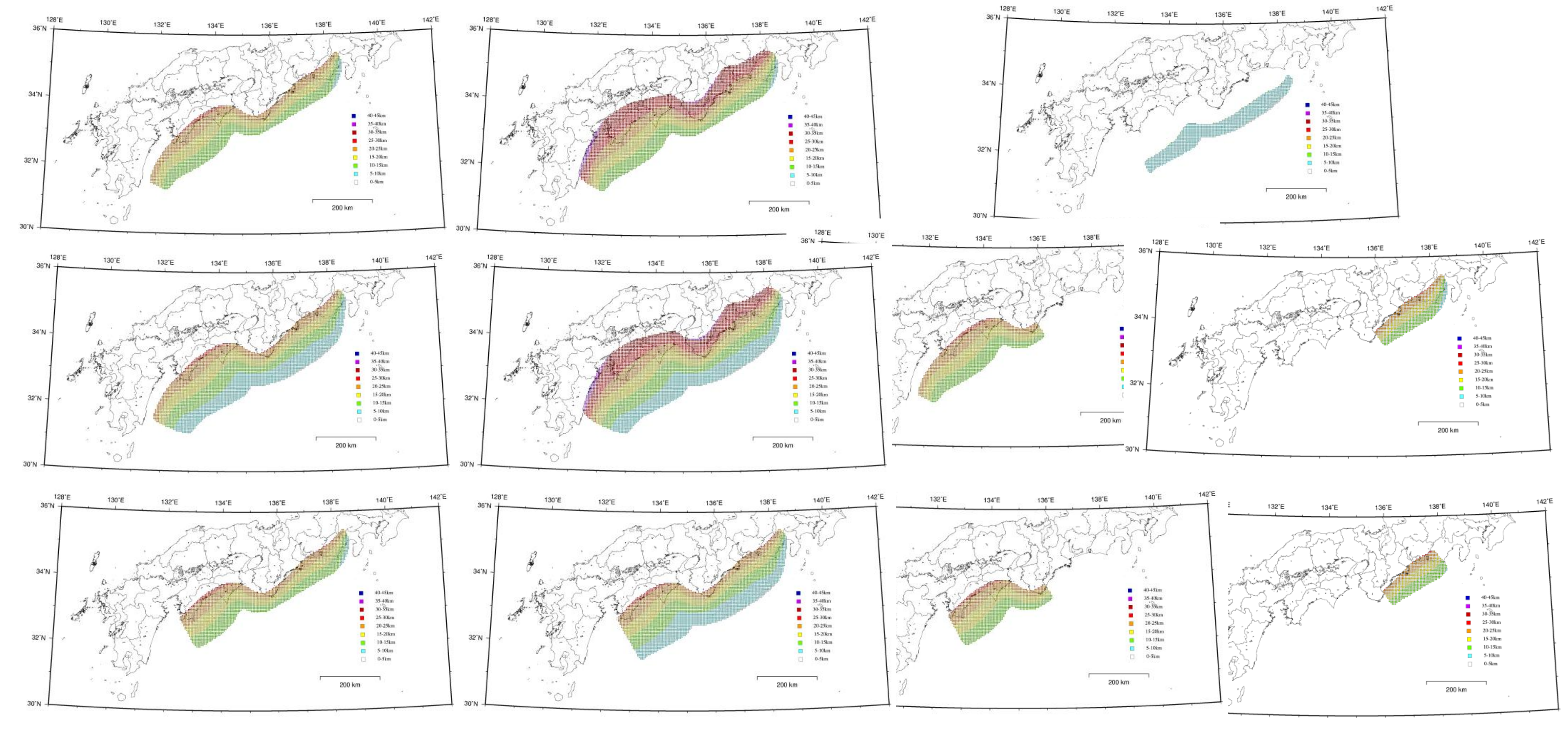
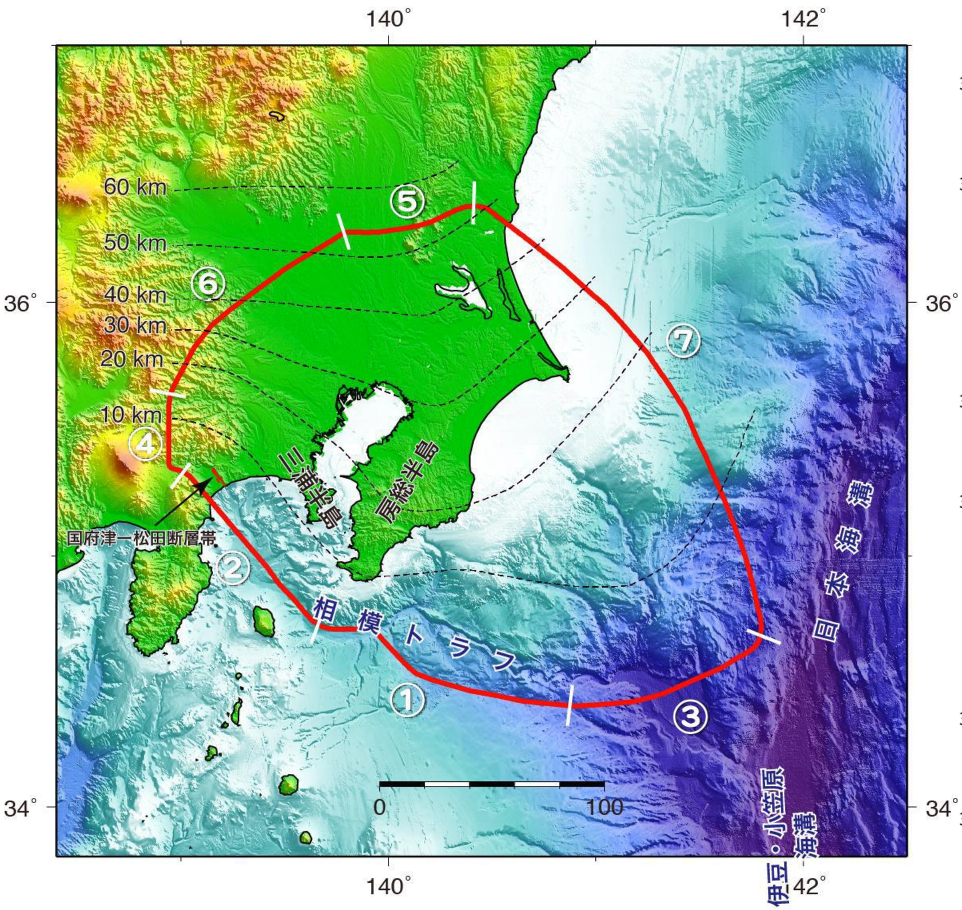
Earthquake models with diversity

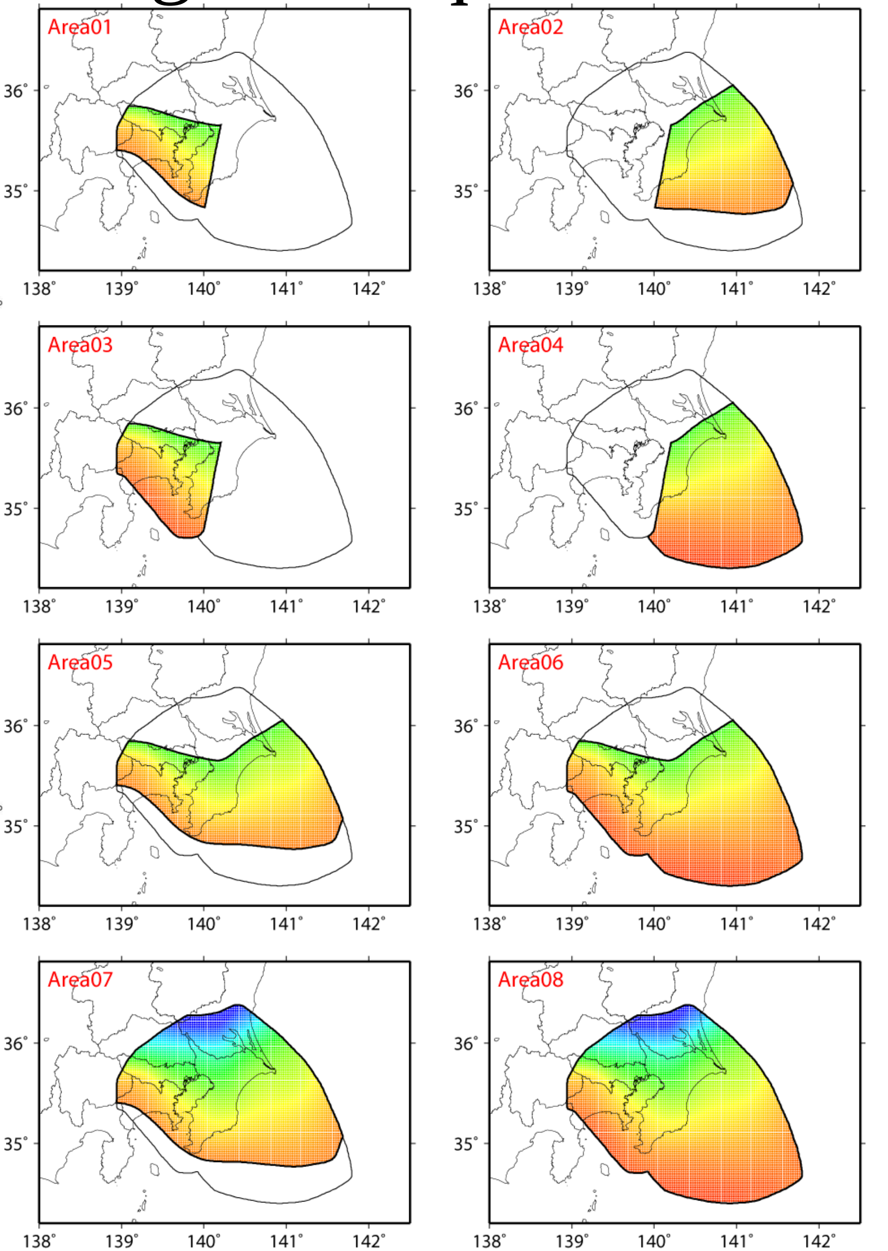


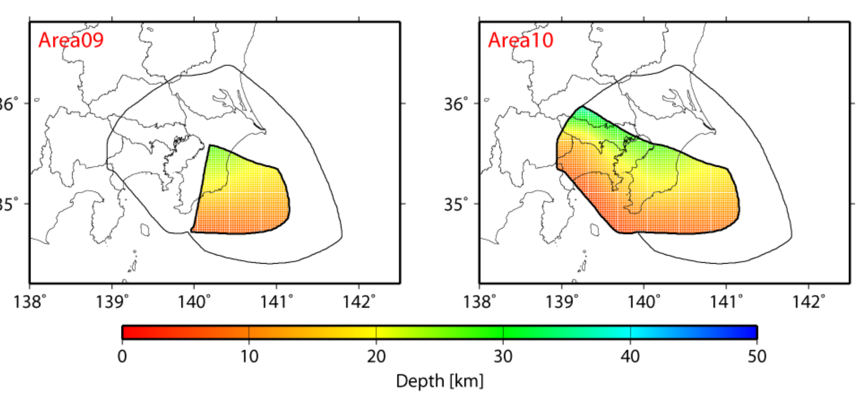




Modeling for Sagami-trough earthquakes







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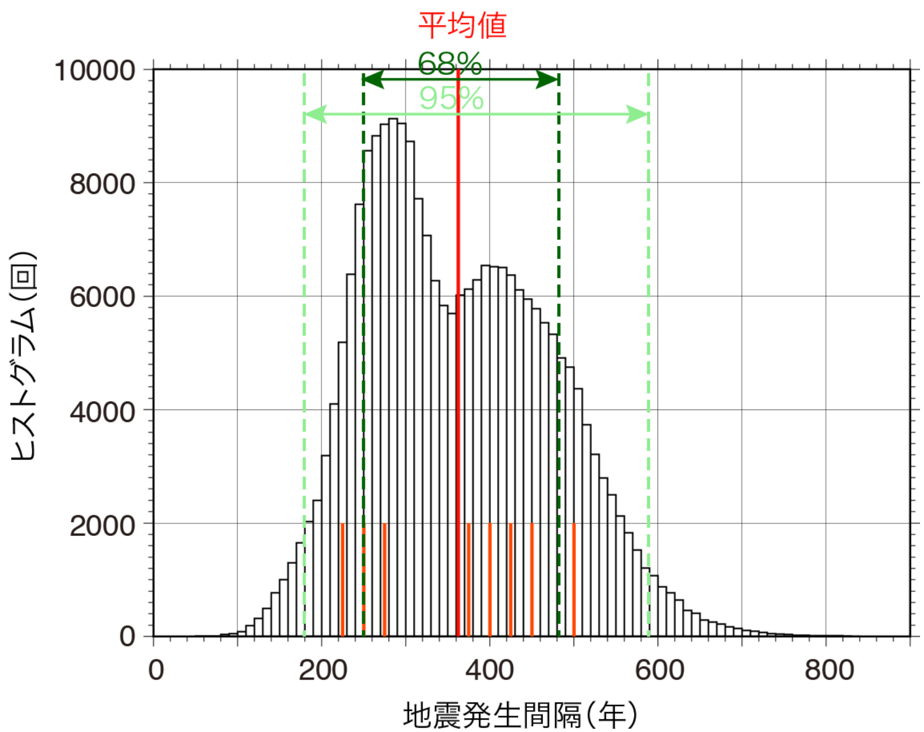
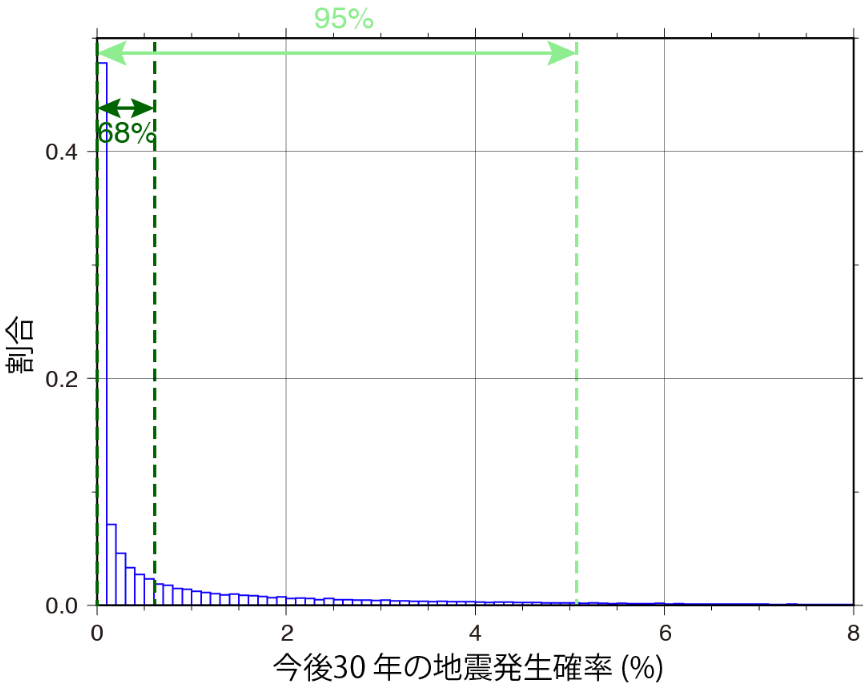
Sagami-trough earthquakes > M8.0

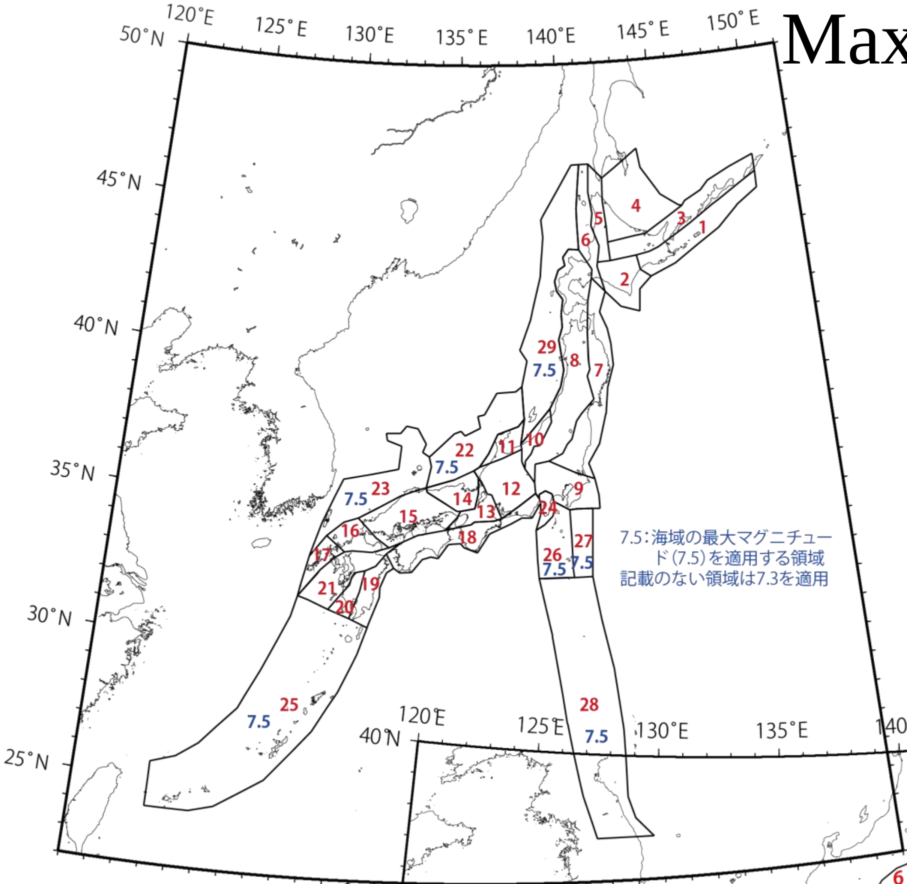


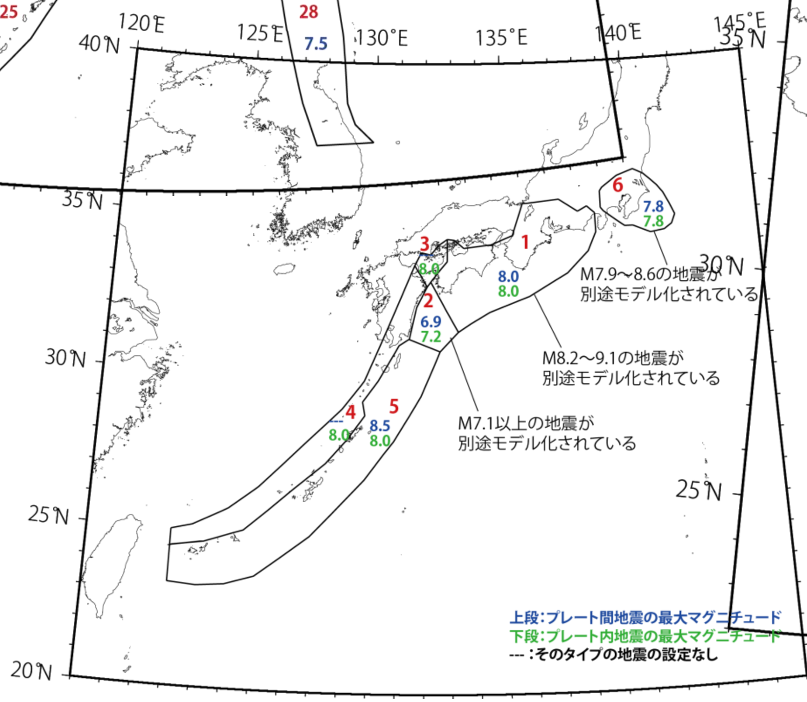
Interval of occurrence

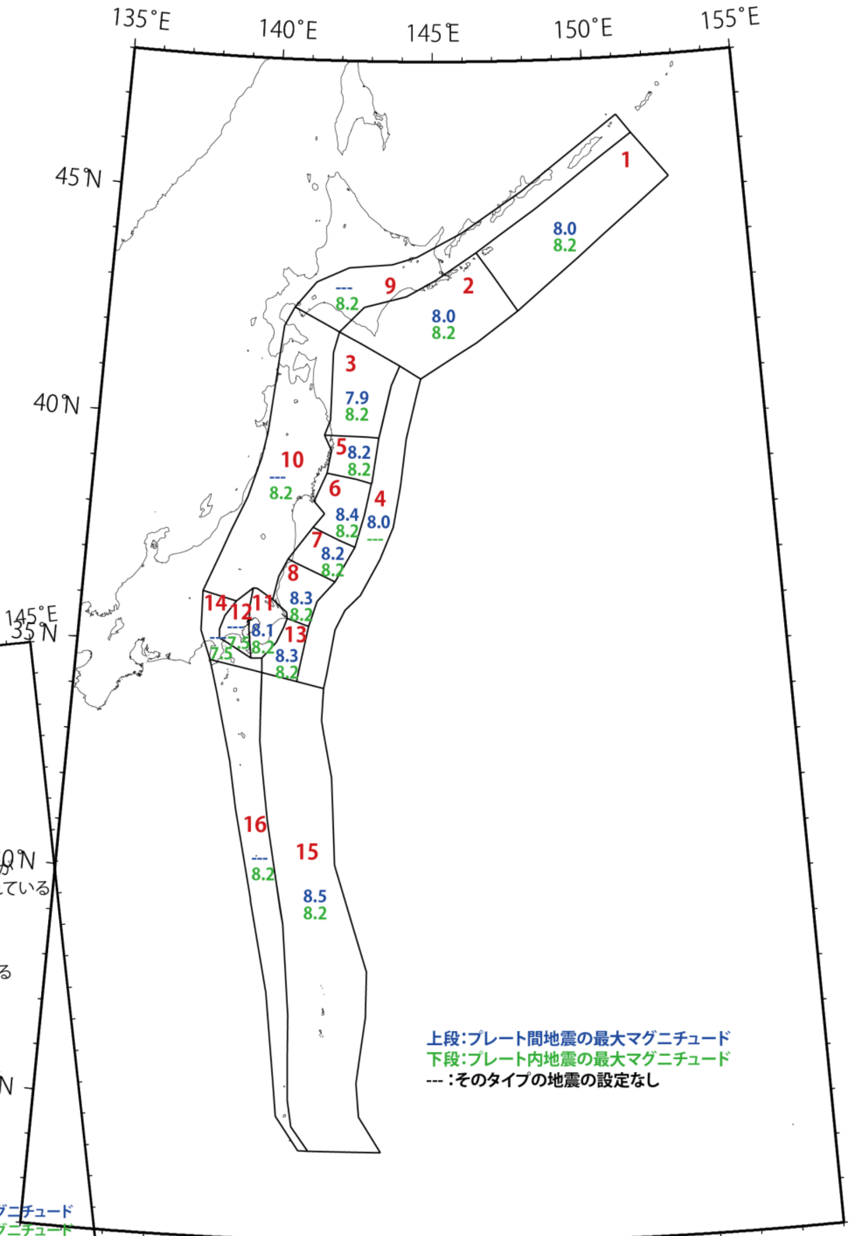


Probability of occurrence within 30 years

Max M for background earthquakes







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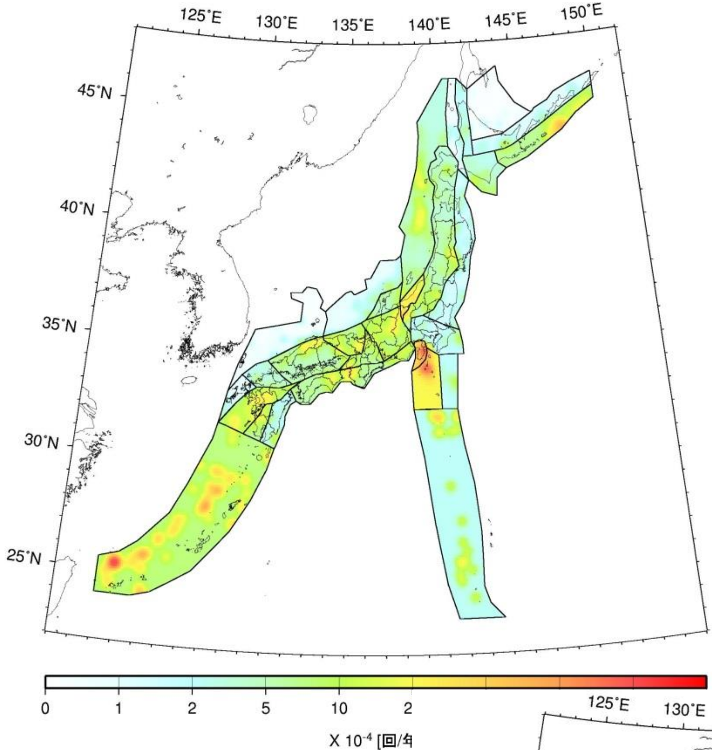
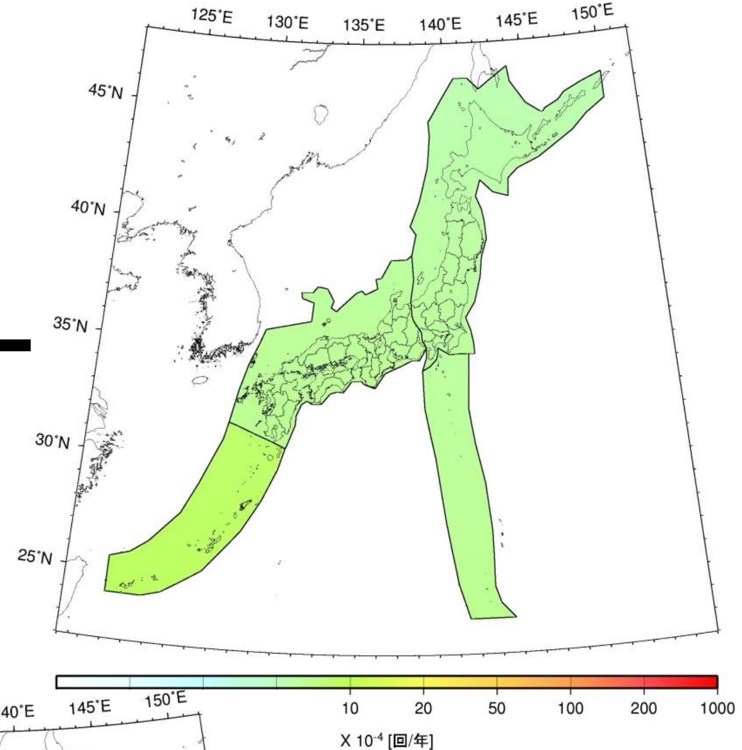
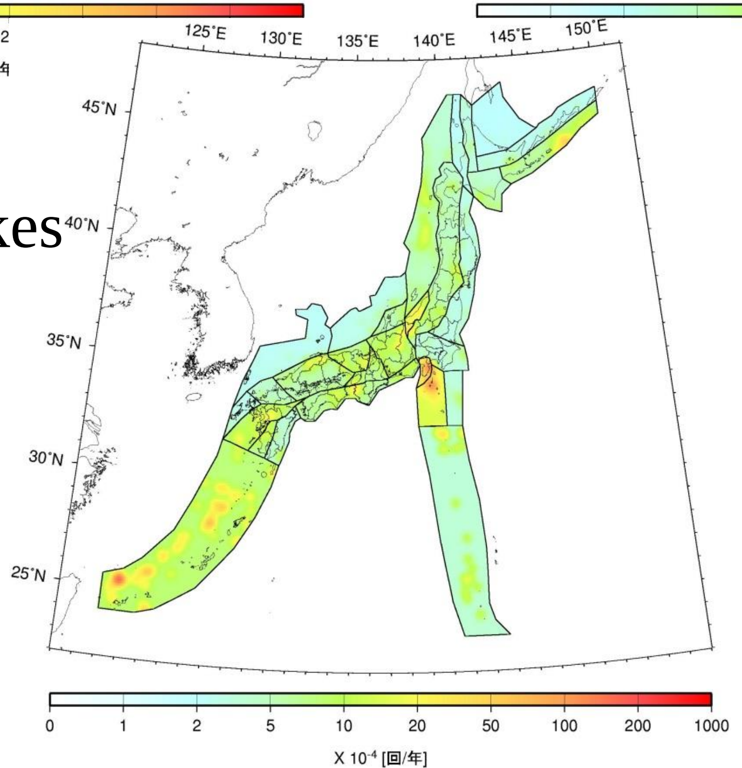


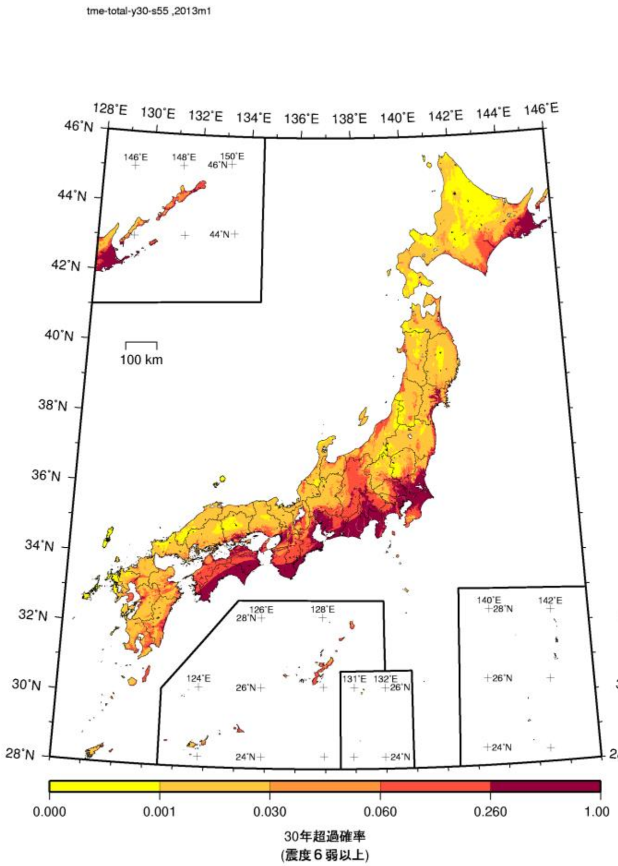


annual ratio for
background earthquakes

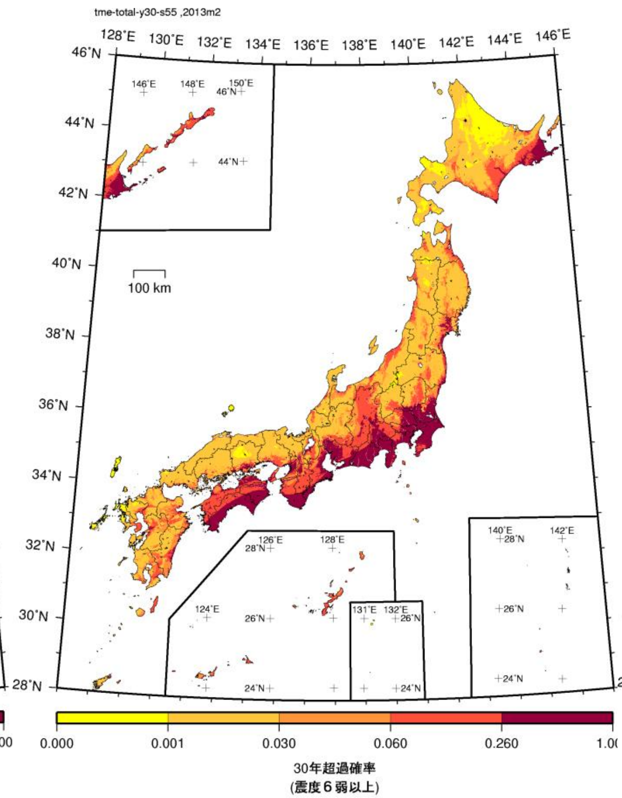


PSHMs for 2013

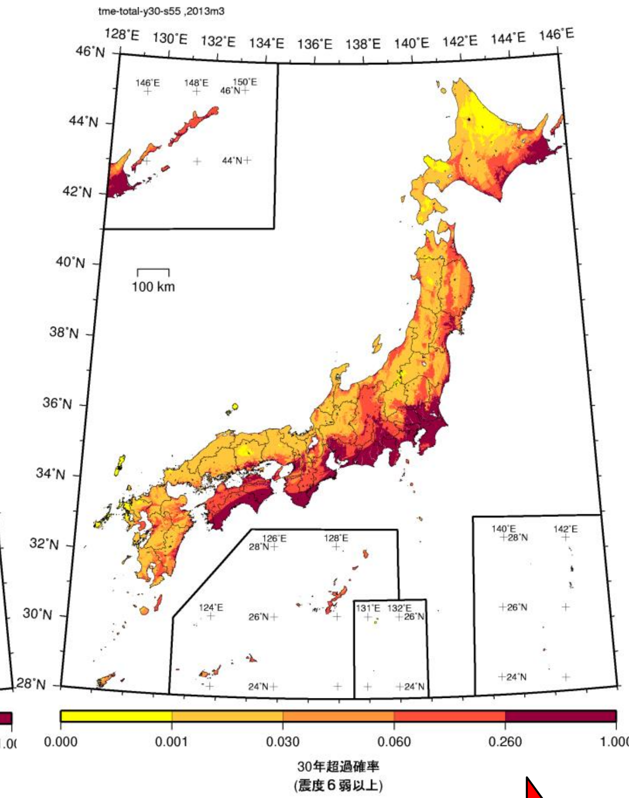
Model 1



Model 2



Model 3



Uncertainty increases.

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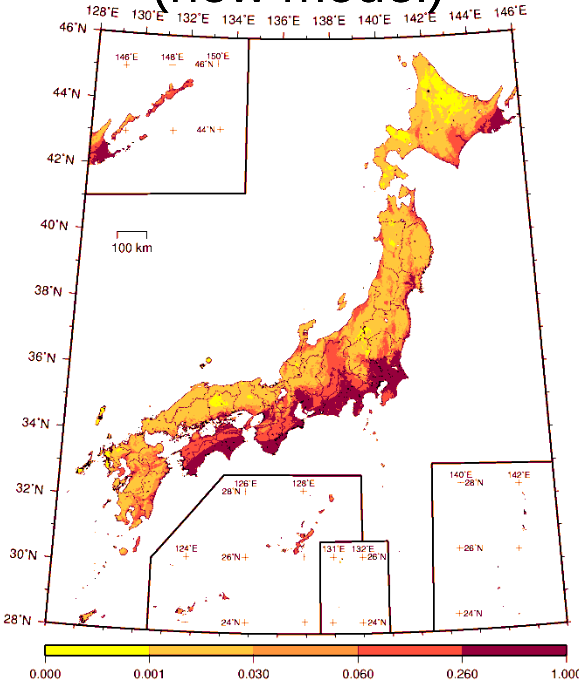
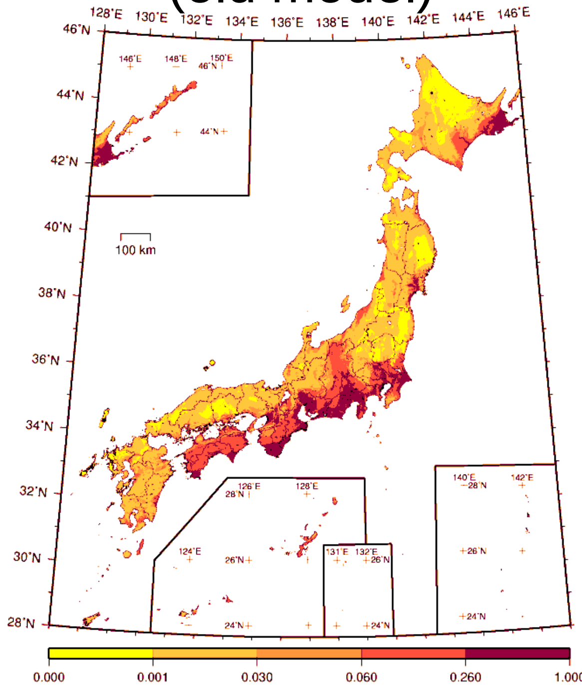
Revised probabilistic seismic hazard maps (2014 version; published on Dec.19, 2014)

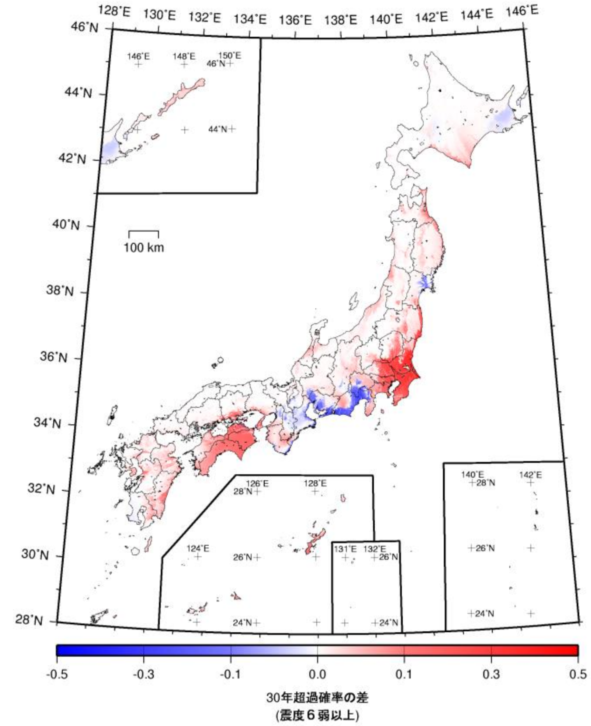
2014 version
(new model)



2010 version
(old model)



2014ver.－2010ver.



Probability in 30 years.
(≧JMA Seismic Intensity 6-)

HERP (2014)

The hazard level in a new (2014) version of probabilistic seismic hazard map is higher than that in old version. This tendency is remarkable in the range of low-probability because large magnitude with low-frequency earthquakes are considered in the revised 2014 version.

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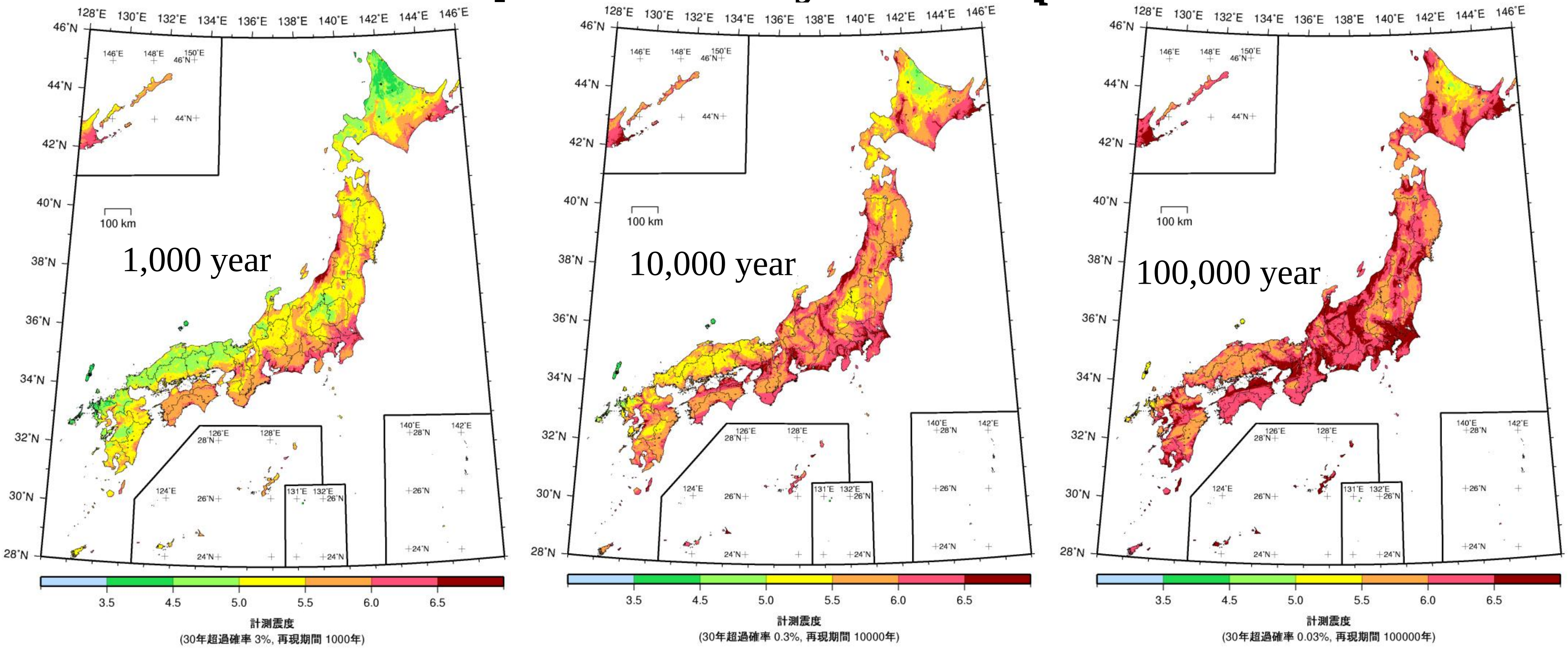
Strong-motion maps considering low-probability earthquakes



Based on the averaged long-term seismic hazard assessment, evaluating strong-motion level for 10,000 ~100,000 years return period, we should prepare the maps that show the distribution of strong-motion level, which represent effect of major earthquakes on active faults and subduction zone earthquakes with low-probability.

Regarding the seismic hazard assessment for low probability, at present, it is insufficient to evaluate the uncertainty for low probability M8 class earthquakes and it is necessary to improve techniques for them.

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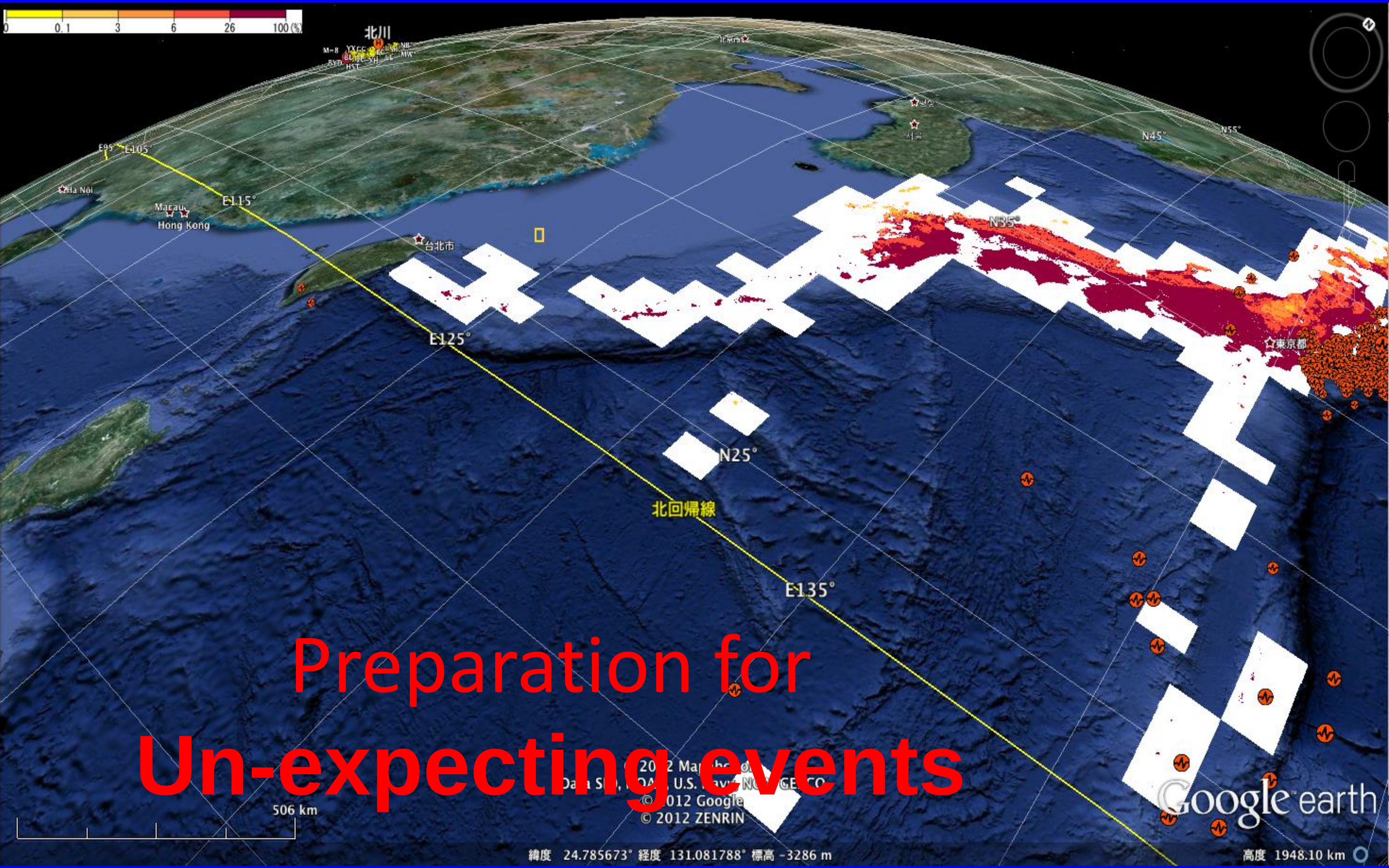

Preparation for **Un-expecting events**

Thank you for your attention

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