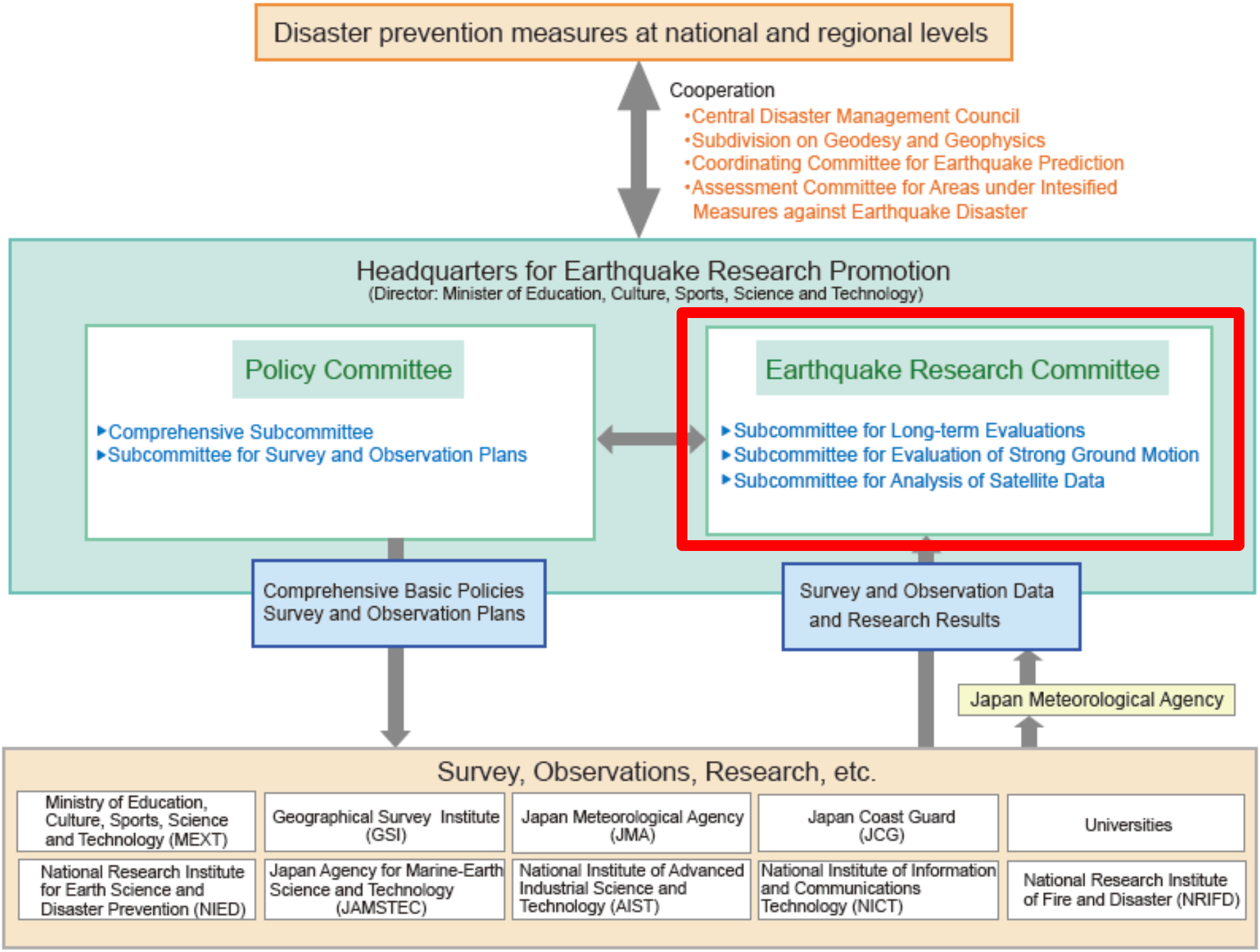
Some considerations towards improvement of the National Seismic Hazard Maps for Japan after the Great Tohoku Earthquake



Hiroyuki Fujiwara

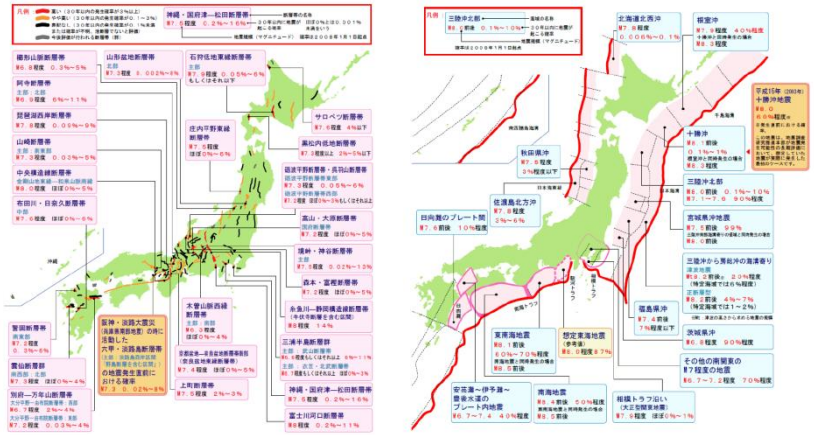
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Disaster prevention measures at national and regional levels
Cooperation
•Central Disaster Management Council
•Subdivision on Geodesy and Geophysics
•Coordinating Committee for Earthquake Prediction
•Assessment Committee for Areas under Intesified Measures against Earthquake Disaster
Headquarters for Earthquake Research Promotion
(Director: Minister of Education, Culture, Sports, Science and Technology)
Policy Committee
▸Comprehensive Subcommittee
▸Subcommittee for Survey and Observation Plans
Earthquake Research Committee
▸Subcommittee for Long-term Evaluations
▸Subcommittee for Evaluation of Strong Ground Motion
▸Subcommittee for Analysis of Satellite Data
Comprehensive Basic Policies
Survey and Observation Plans
Survey and Observation Data and Research Results
Japan Meteorological Agency
Survey, Observations, Research, etc.
Ministry of Education, Culture, Sports, Science and Technology (MEXT)
Geographical Survey Institute (GSI)
Japan Meteorological Agency (JMA)
Japan Coast Guard (JCG)
Universities
National Research Institute for Earth Science and Disaster Prevention (NIED)
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
National Institute of Advanced Industrial Science and Technology (AIST)
National Institute of Information and Communications Technology (NICT)
National Research Institute of Fire and Disaster (NRIFD)

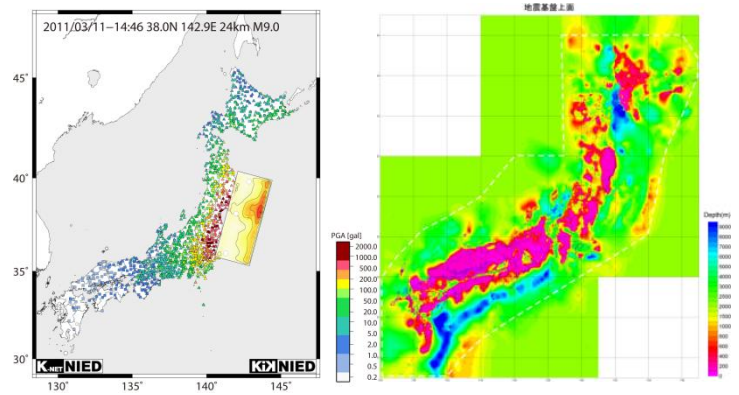
National seismic hazard maps for Japan

Long term evaluation



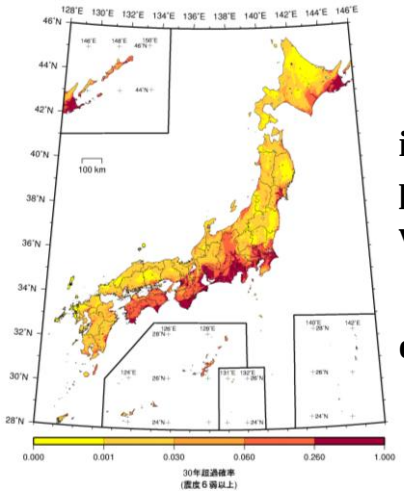
Probability of occurrence, magnitude, location

Strong-motion evaluation



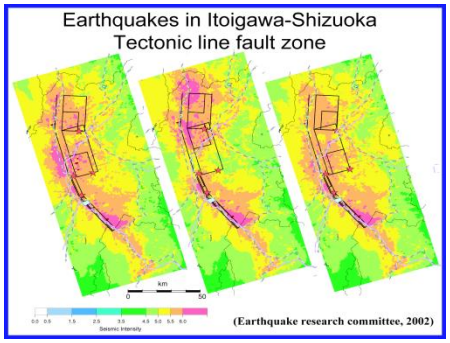
Strong-motion, underground structure

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.**

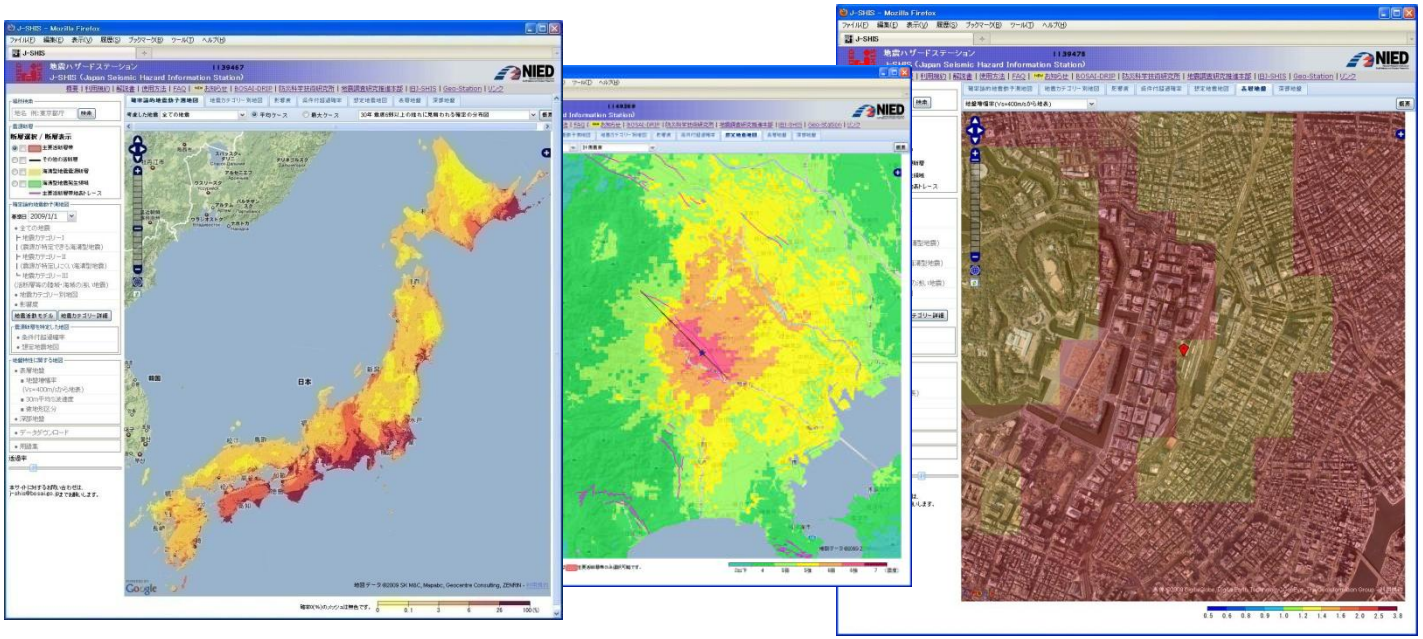
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Japan Seismic Hazard Information Station

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.

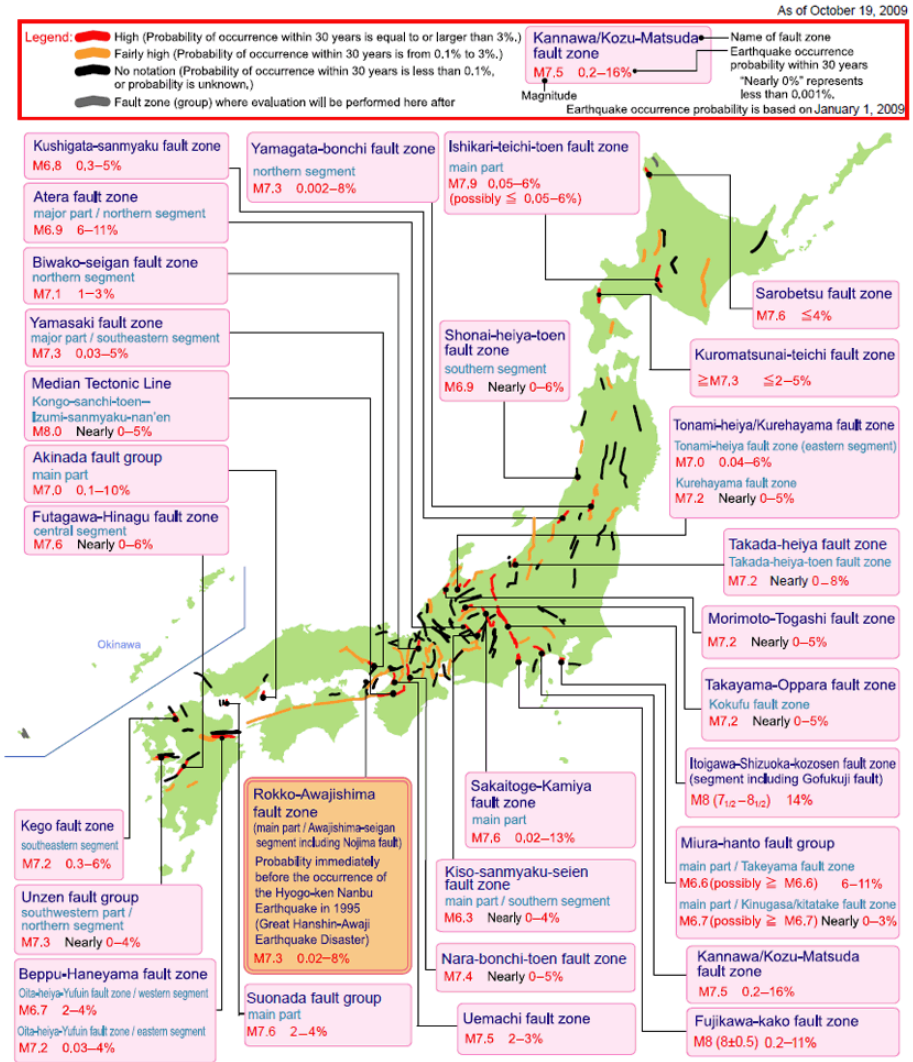
Our products are aimed to meet multi-purpose needs in engineering fields by providing information of the probabilistic seismic hazard analysis.

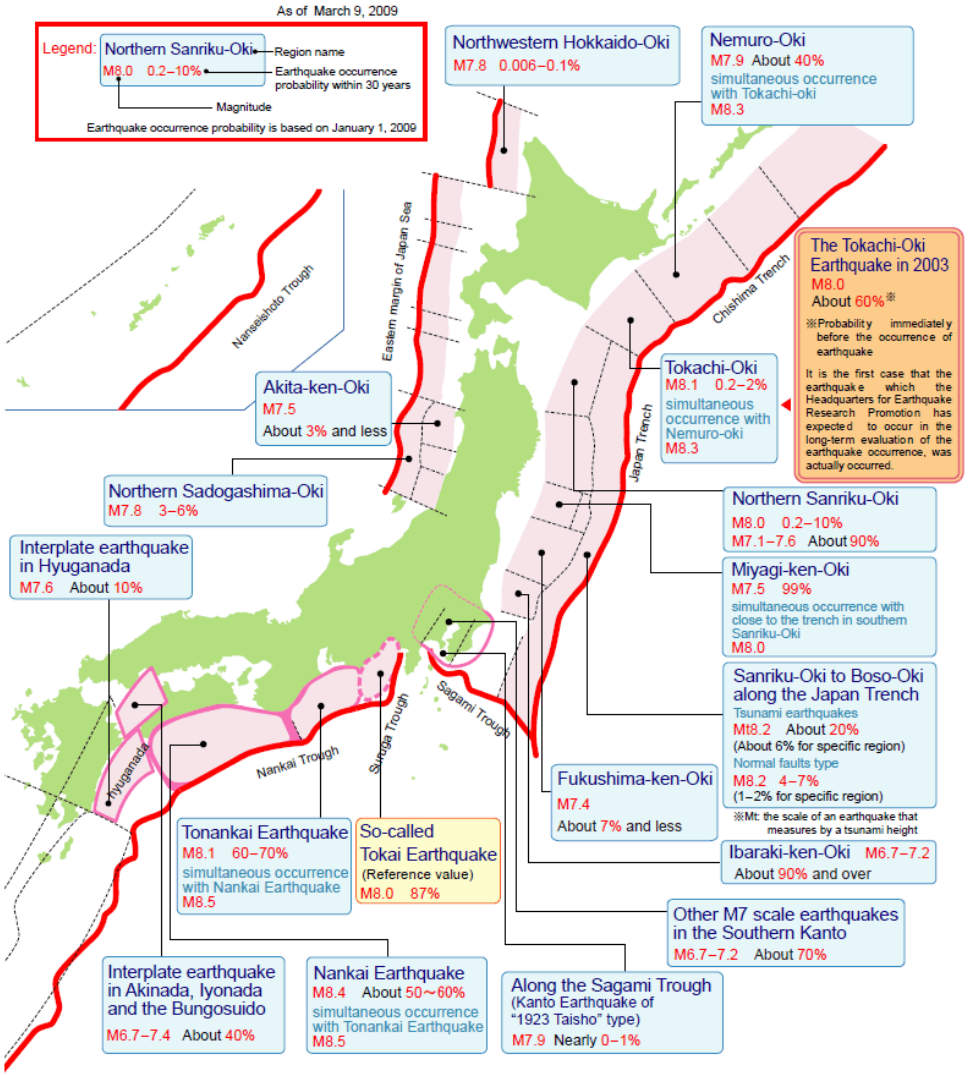




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Evaluation of occurrence probability of earthquakes by ERCJ





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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)**

↓

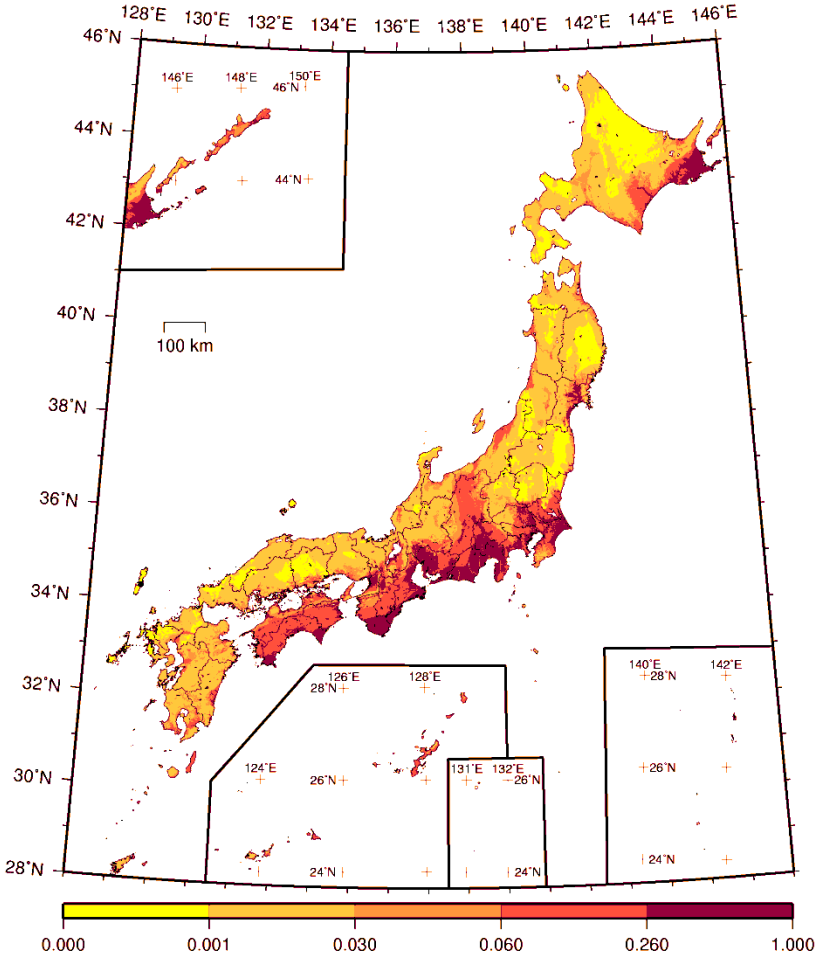
Evaluation of probabilistic seismic hazard
for each earthquake **P(Yi > y)= P(Ei) P(Yi > y|Ei)**

↓

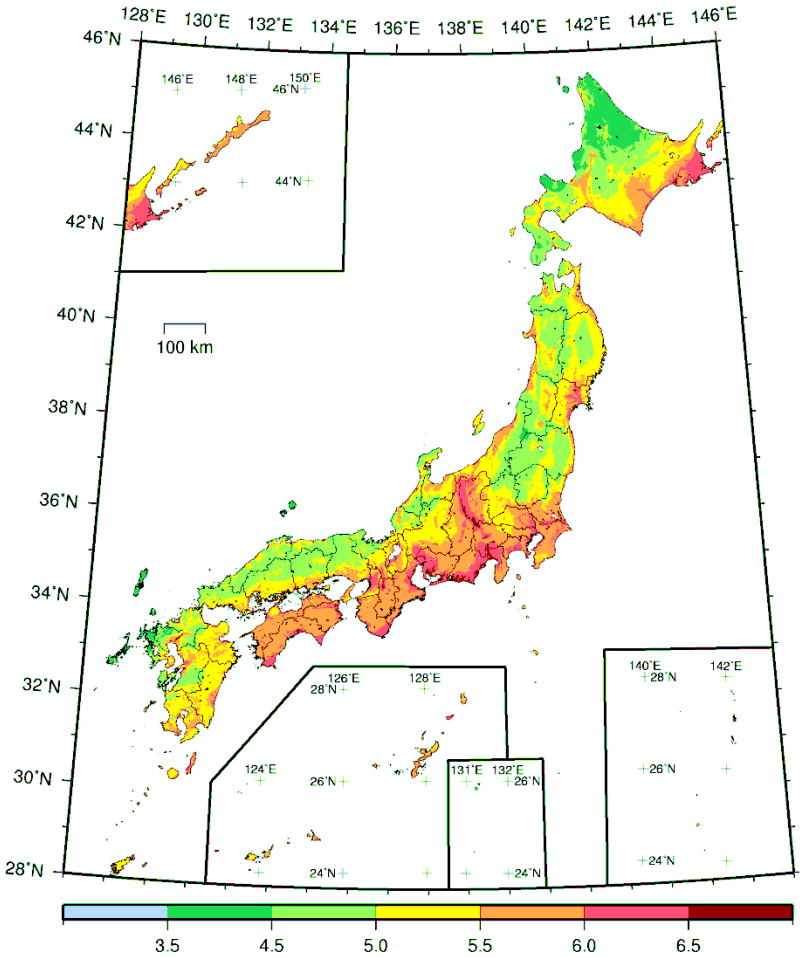
Evaluation of probabilistic seismic hazard
for all earthquakes **P(Y > y)=1-Π[1- P(Yi > y)]**

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Probabilistic Seismic Hazard Maps



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

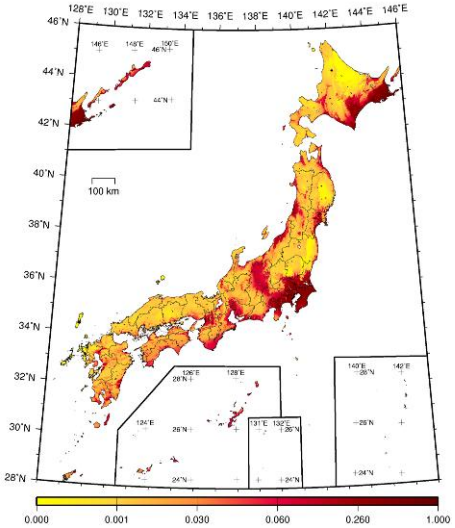


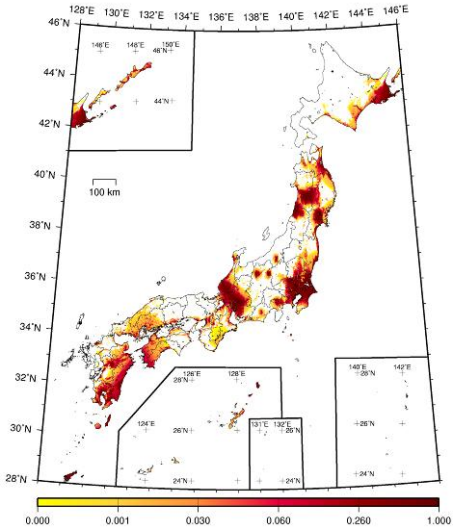
Seismic Intensity with 3% probability of exceedance in 30 year.

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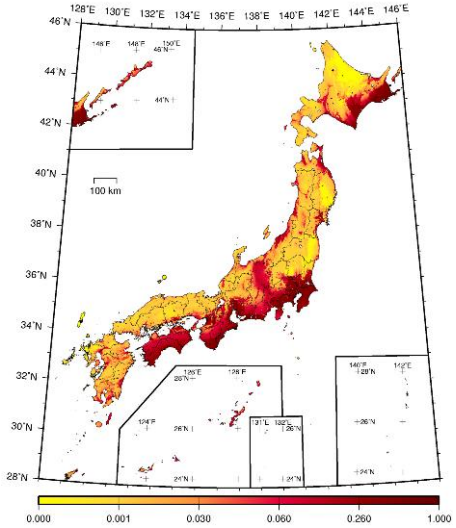
Comparison with the hazard maps of the past and the ground motion actually occurred (Exceedance probability of JMA seismic intensity 6- within 30 years)

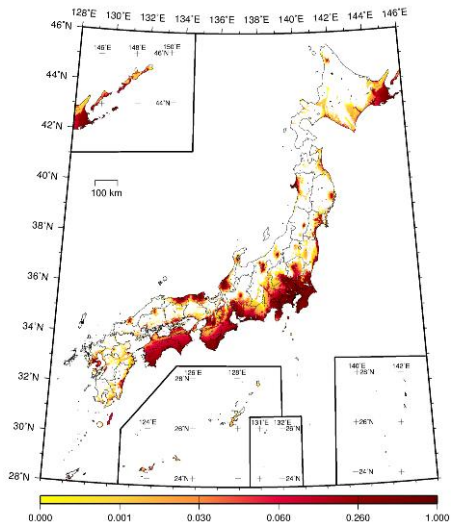
1890～



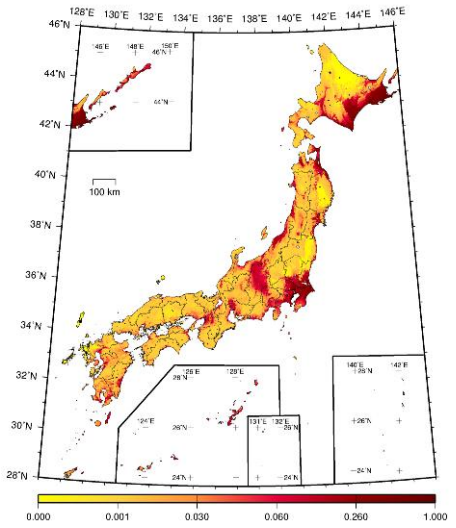


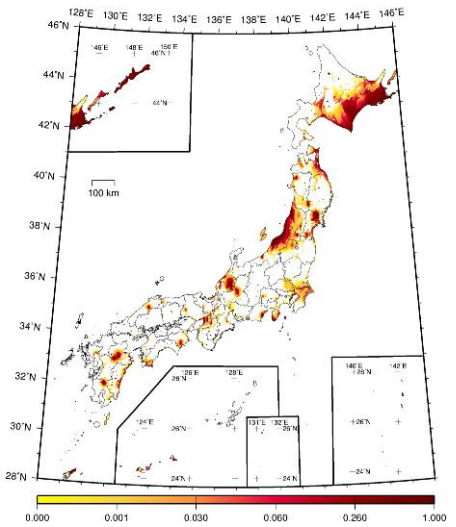
1920～



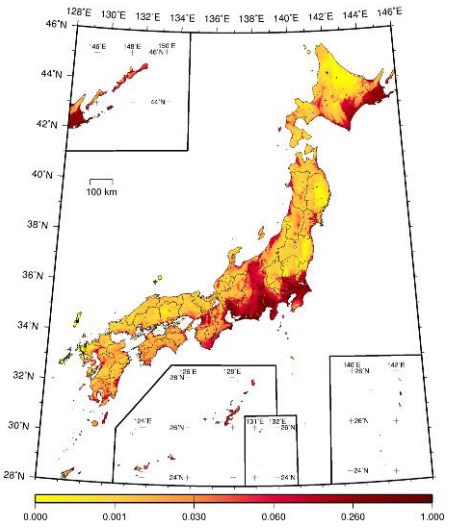


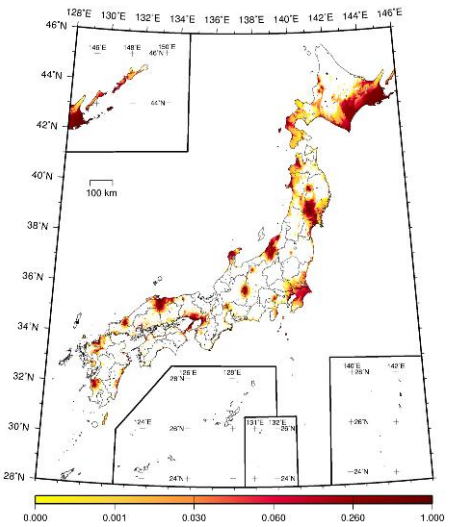
1950～





1980～

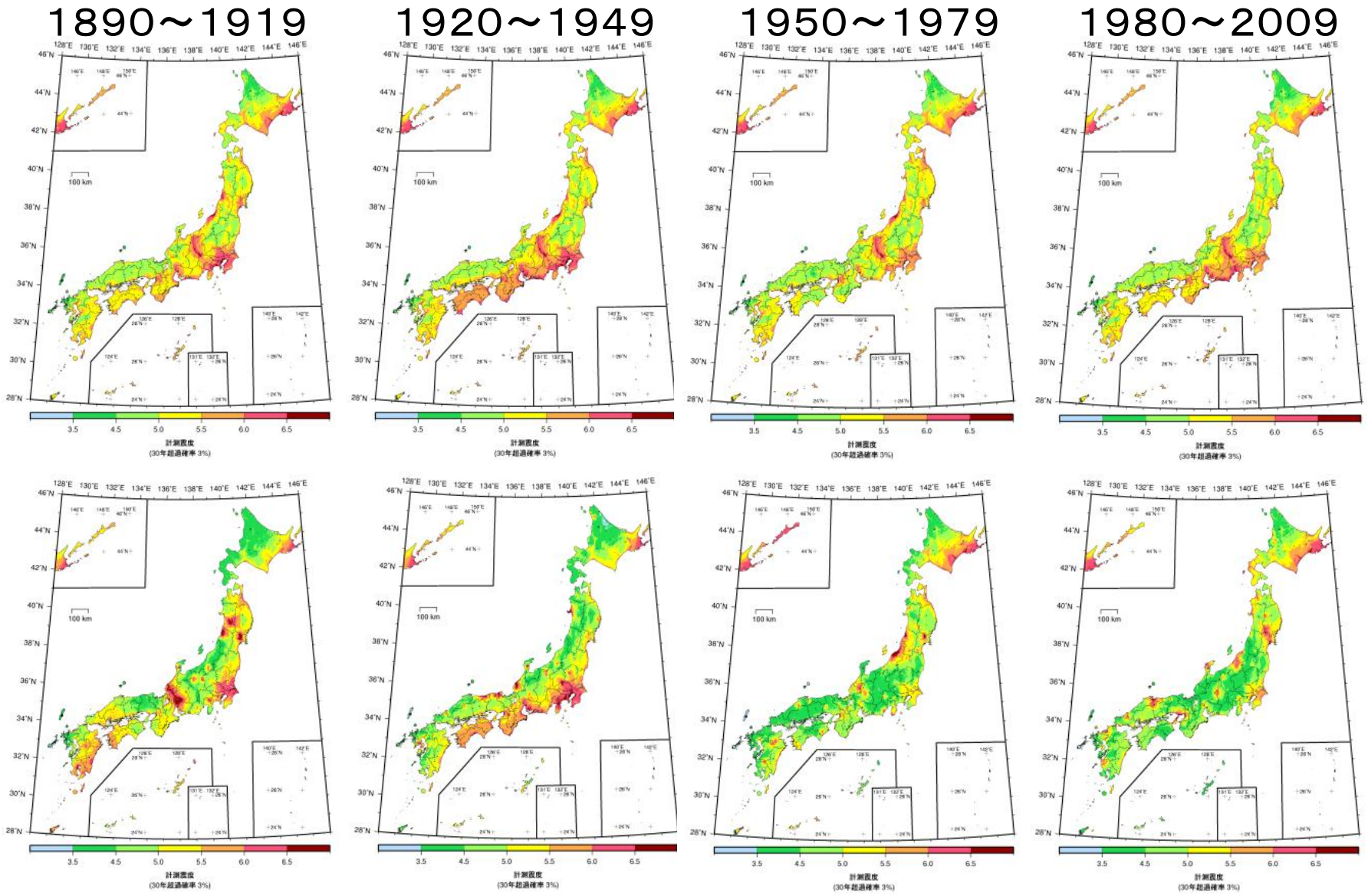




Upper: Hazard map　Lower: ground motion actually occurred

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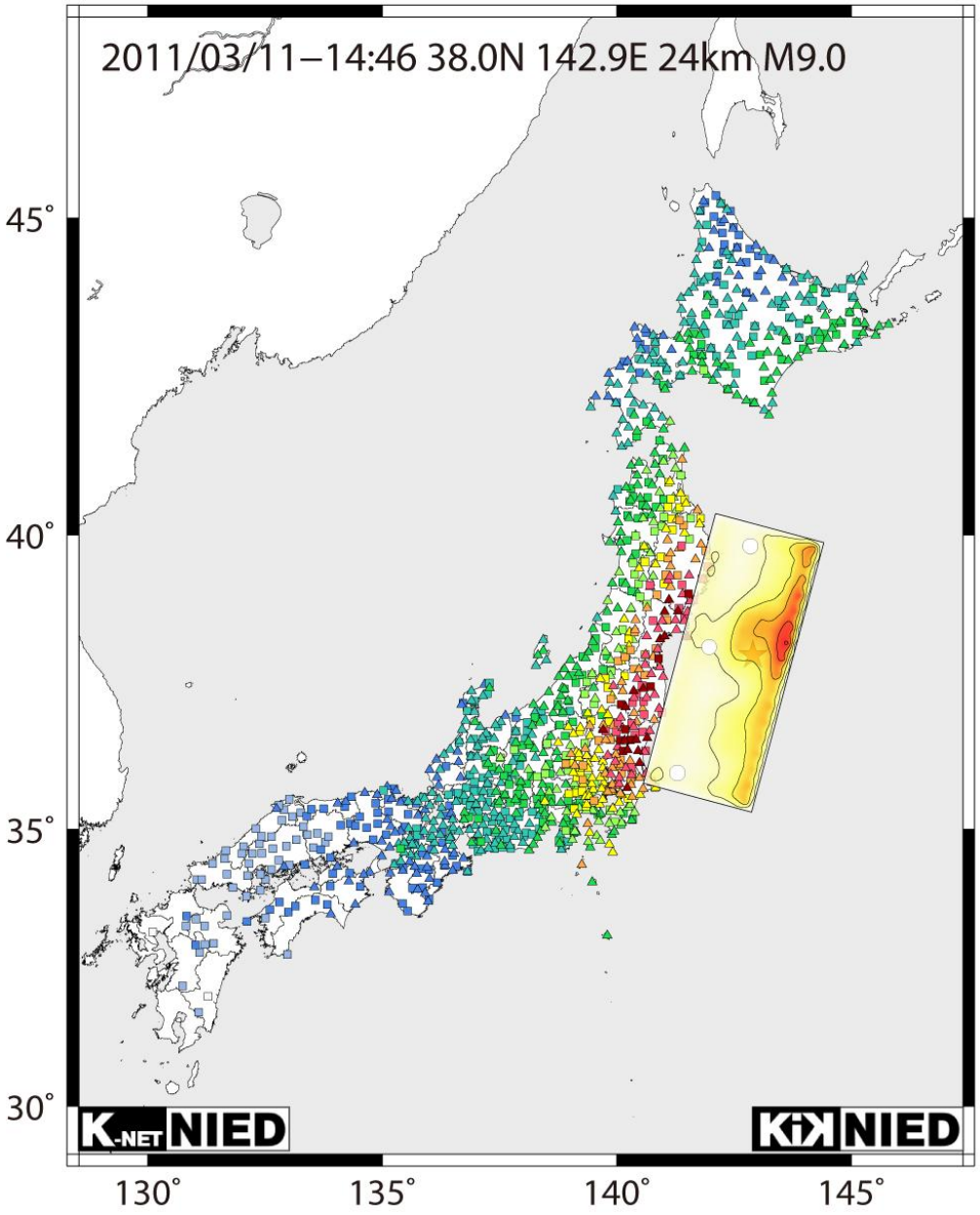
Compared with the hazard maps of the past and the earthquake actually occurred (JMA seismic intensity: Exceedance probability of 3% within 30 years)

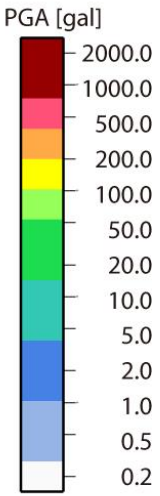


（Upper: Hazard assessment　Lower: Shaking caused by earthquakes）

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The 2011 Tohoku-oki earthquake





This magnitude 9.0 megathrust earthquake initiated approximately 100 km off-shore of Miyagi prefecture and the rupture extended 500 km along the subducting Pacific plate.

Due to the large ground motions and tsunami associated by this event, approximately 20,000 people were killed or missing and more than 220,000 houses and buildings were totally or partially destroyed.

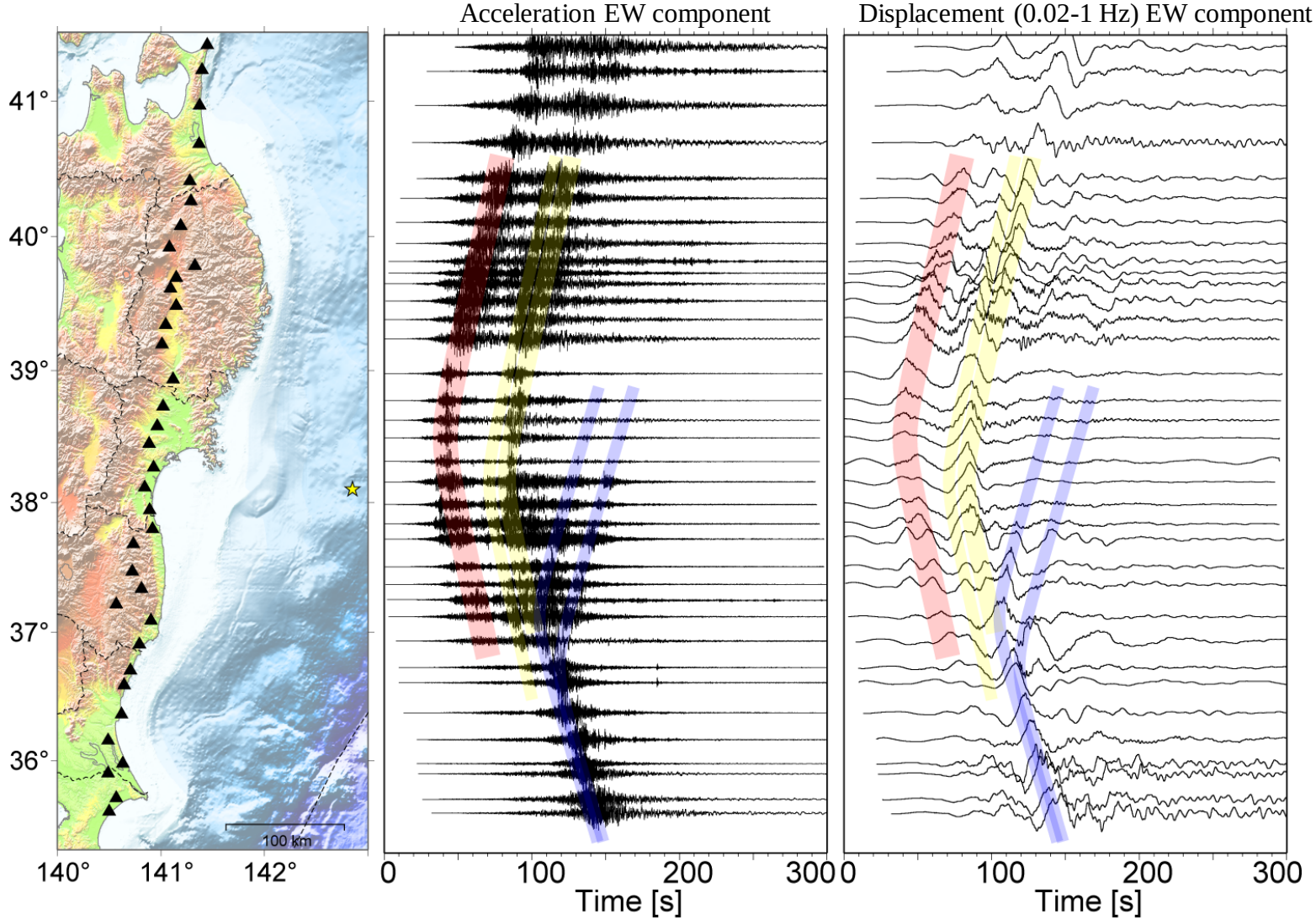
The Tohoku-oki earthquake was the first M9-class earthquake that is closely recorded by dense seismograph network.

The ground motions were recorded at more than 1200 K-NET and KiK-net.

The peak ground accelerations (PGA) exceeded 1g at 20 sites and the largest PGA, 2933 gal was observed at the K-NET Tsukidate station (MYG004).

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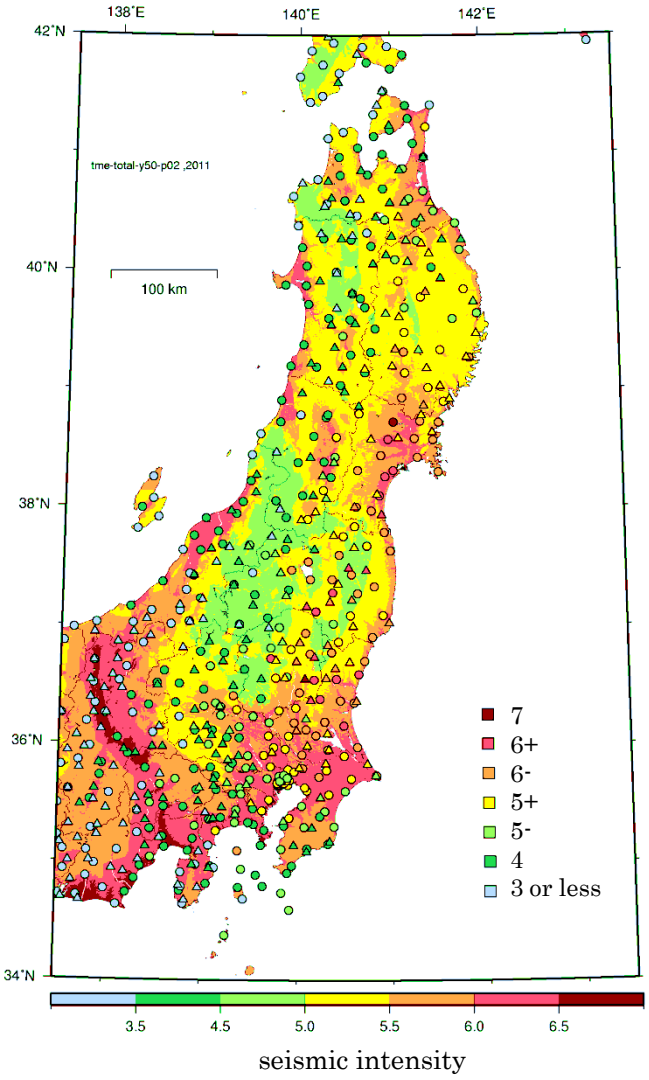
Paste-up of the observed waveforms



Normalized acceleration and displacement (0.02 - 1.0 Hz) paste-up of the waveforms observed by K-NET and KiK-net ordered by latitude which reveal a very complex source process; An initial strong phase originating near the hypocenter is clearly observed. A subsequent seismic phase uniformly delayed by approximately 40s suggests a second event at nearly the same location. A later seismic phase is strongly observed to the south 50 - 60 s after the initial phase. This phase suggests that a third strong event took place off-shore of Fukushima-Ibaraki.

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Comparison between the hazard maps and observed strong motions



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

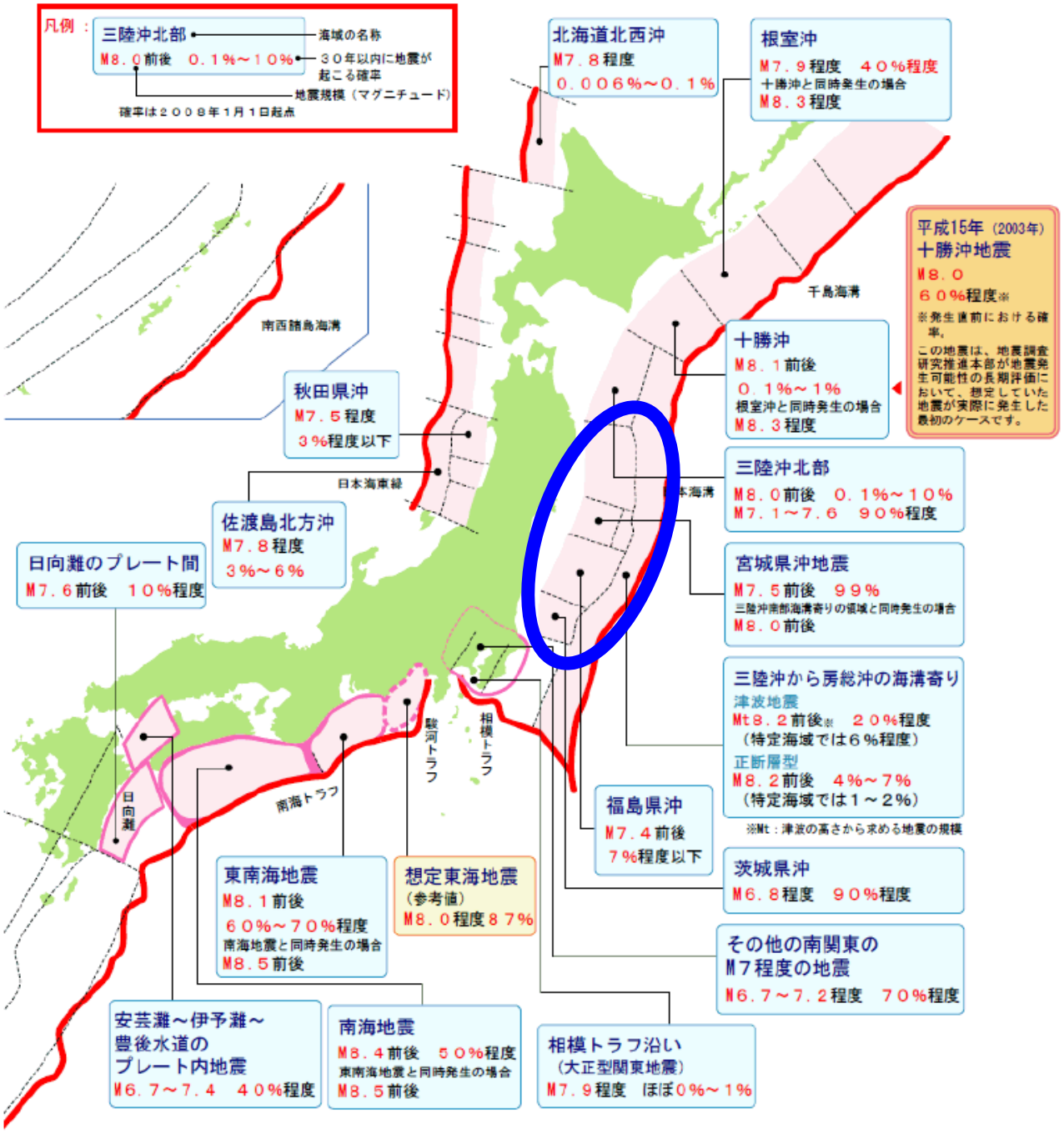
Comparison between the observed seismic intensities（○：K-NET, △：KiK-net）of the Tohoku earthquake and seismic intensity distribution for 2% probability of exceedance in 50 years, which is one of the probabilistic seismic hazard map.

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-oki earthquake (M9.0).

This is primarily because, in the long-term evaluation that has been the basis of the seismicity model for the probabilistic seismic hazard map, the occurrence of great earthquakes M9.0 has not been evaluated.

On the other hand, the cause of underestimate also lies in the inability to function well the whole framework of probabilistic seismic hazard assessment methods under the circumstances that many issues are left unresolved in seismology.

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Seismic activity model for hazard assessment

Earthquakes with specified fault

Earthquakes in major or other fault zones
Return period < 100,000 year

Earthquakes in subduction zones
(Interplate or intraplate)
Return period < 500 year

Background earthquakes

Urgency of earthquake occurrence had been too much emphasized for subduction zone earthquakes!

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Seismic activity model for hazard assessment

Earthquakes with specified fault

- Earthquakes in major or other fault zones
- Earthquakes in subduction zones (Interplate or intraplate)

Background earthquakes

- Inland earthquakes
- Earthquakes in subduction zones (Interplate or intraplate)

In order to construct a probabilistic seismic activity model that encompasses the seismic activity of all possible earthquakes, it is necessary for the complement the long-term evaluation to use a different methodology.
It may be necessary to promote proper modeling of background earthquakes that encompasses all earthquakes without long-term evaluation.

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Classification of uncertainty factors

● Aleatory Uncertainty

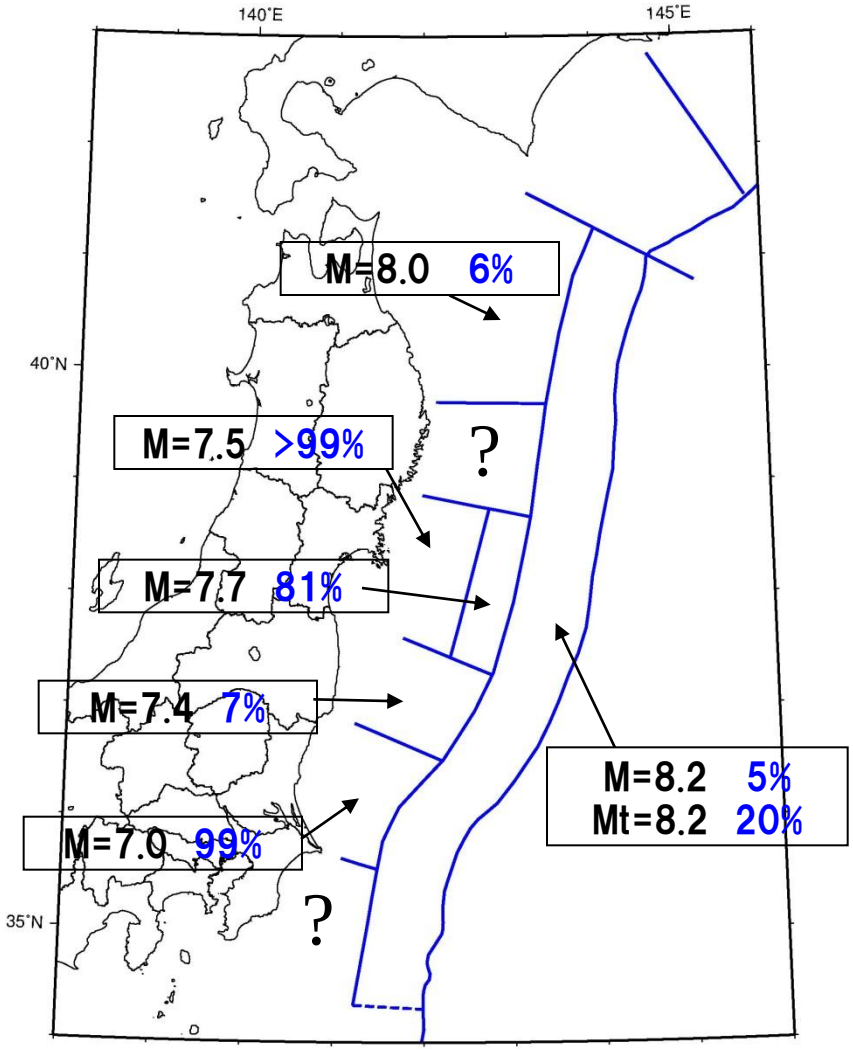
- Intrinsic uncertainty.
- It is represented by a random variable in the prediction model.
- Uncertainty caused by a limitation of model to explain phenomena.
- Uncertainty used to calculate a hazard curve.

● Epistemic Uncertainty

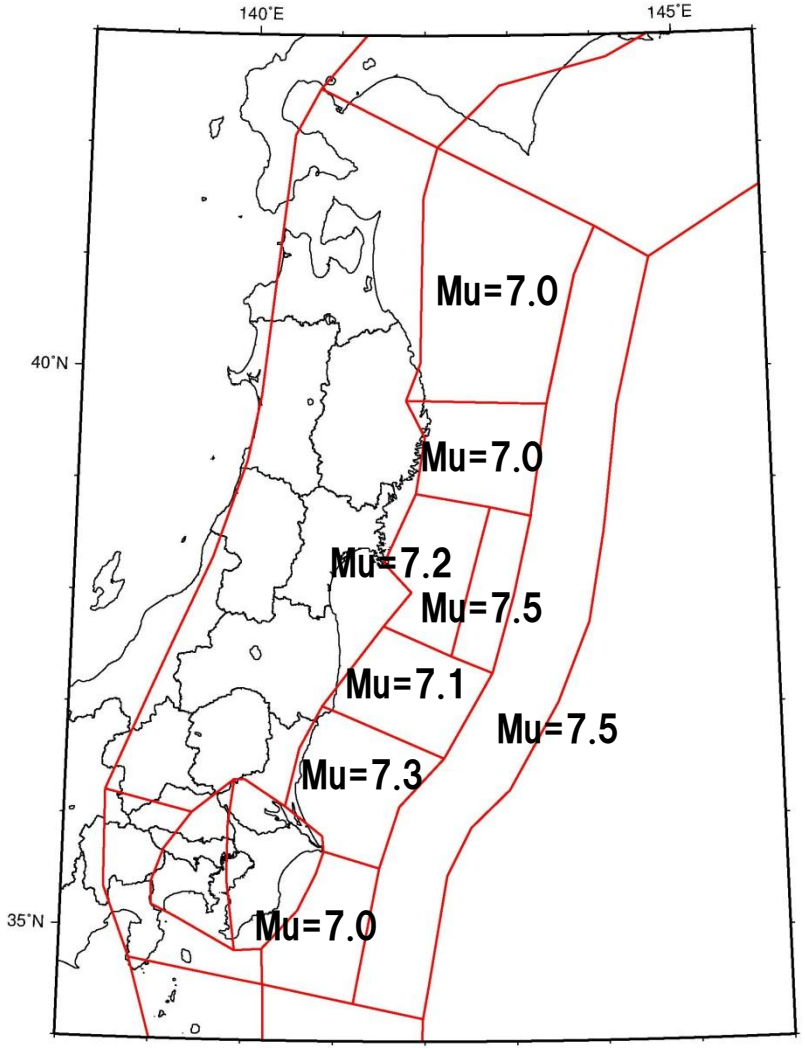
- Uncertainty due to a lack of knowledge and data.
- Uncertainty due to differences in judgment for modeling
- It is evaluated by using a logic tree.
- Represented by more than one hazard curve.

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Modeling of seismic activity in the Pacific plate before the 311 Tohoku earthquake



M for characteristic earthquakes



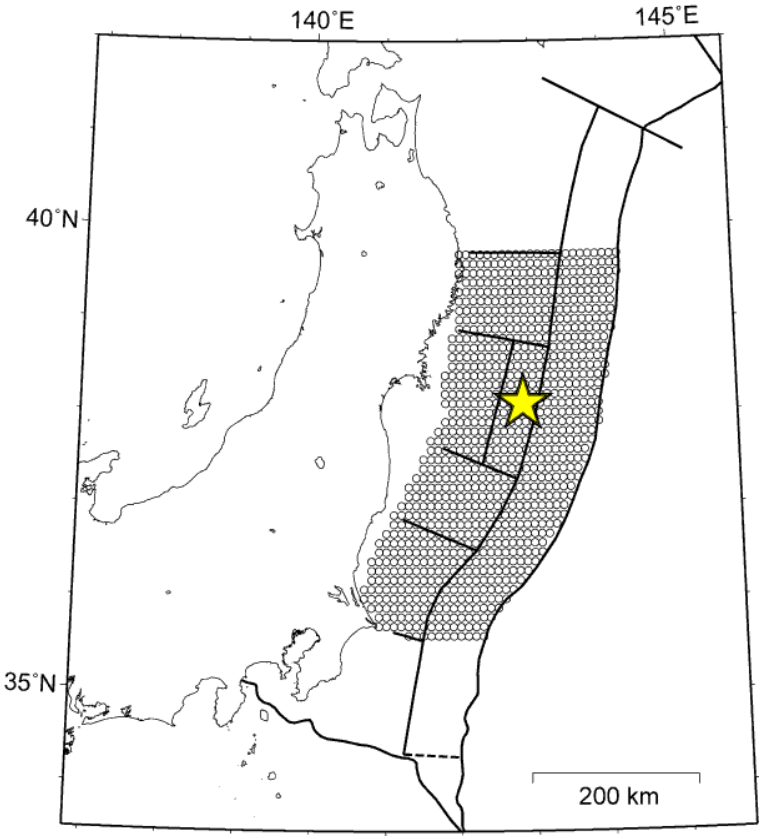
Max M for background earthquakes

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PSHM taking into account the Tohoku earthquake (M9)

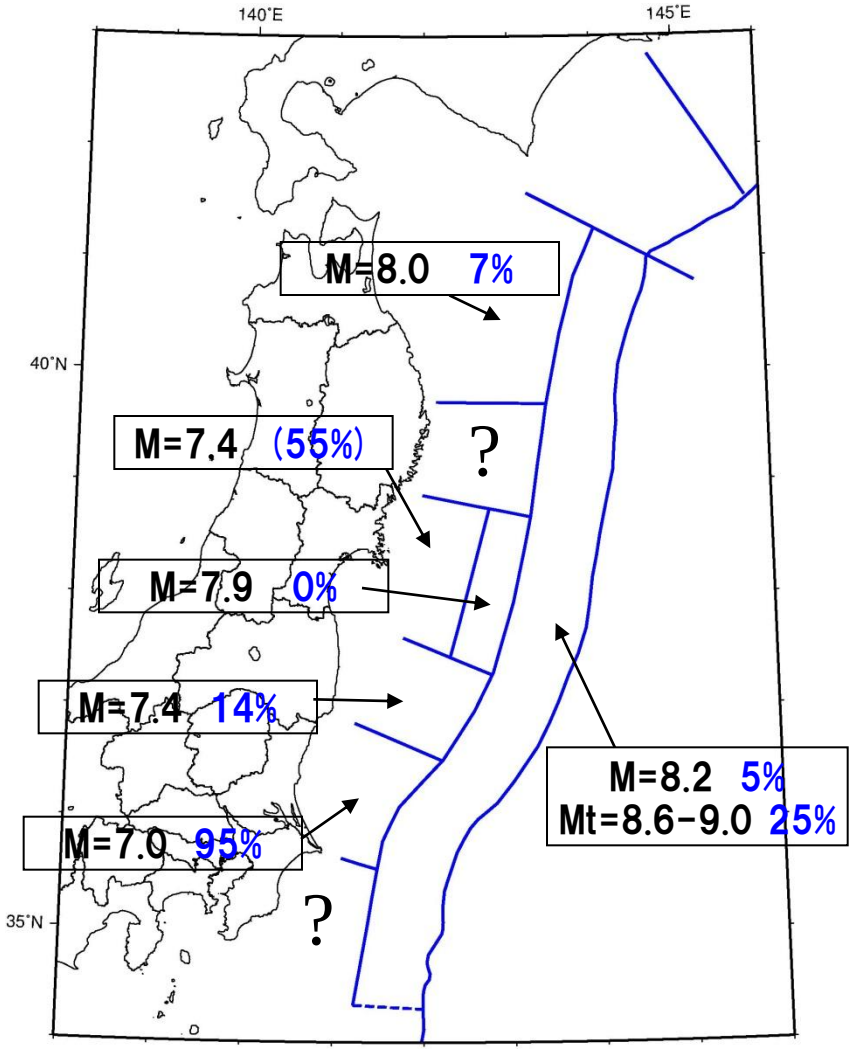
■ **Setting conditions for the Tohoku EQ**

- **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)

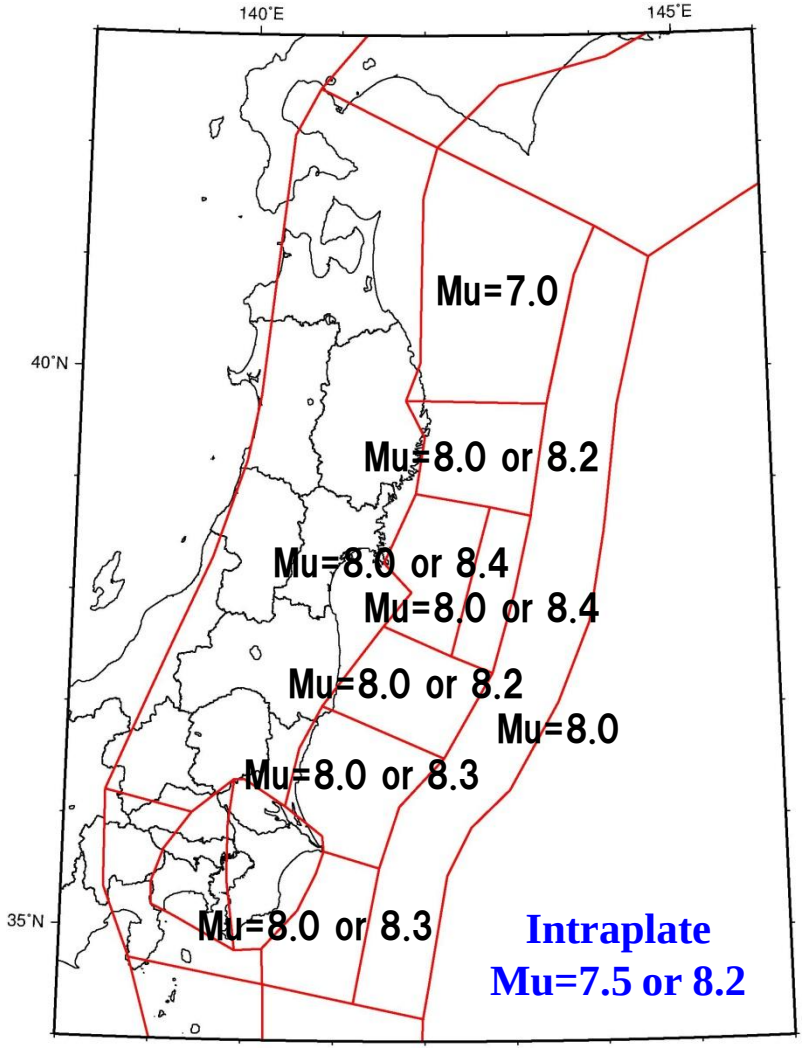


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Modeling of seismic activity in the Pacific plate after the 311 Tohoku earthquake



M for characteristic earthquakes

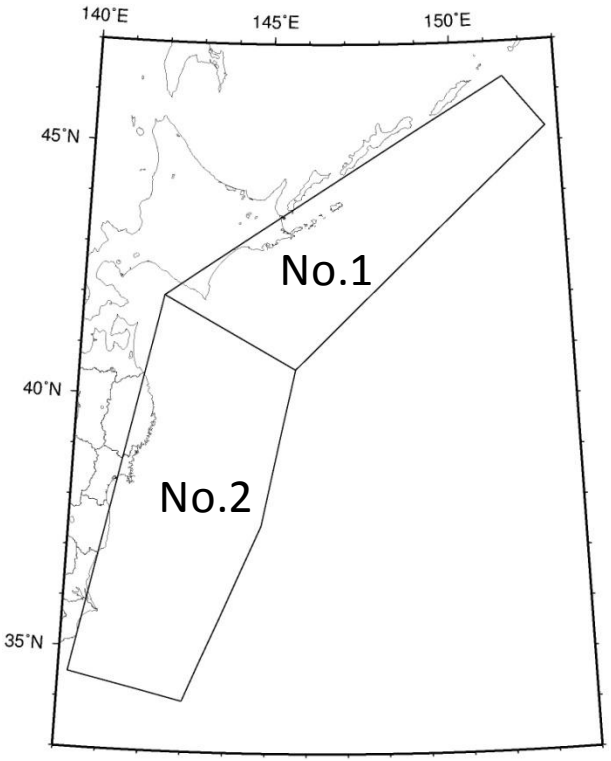


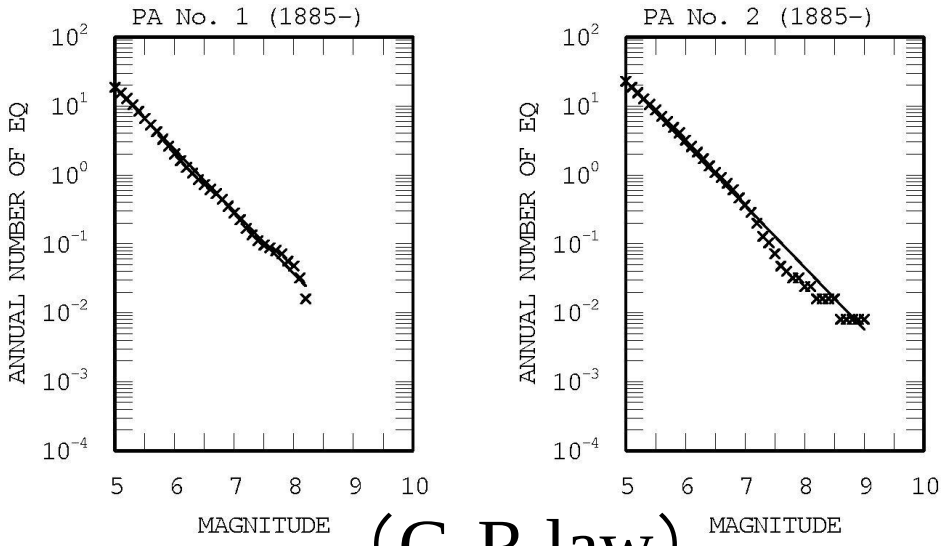
Max M for background earthquakes

(Model 1 or Model 2)

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Seismic activities in the Pacific plate





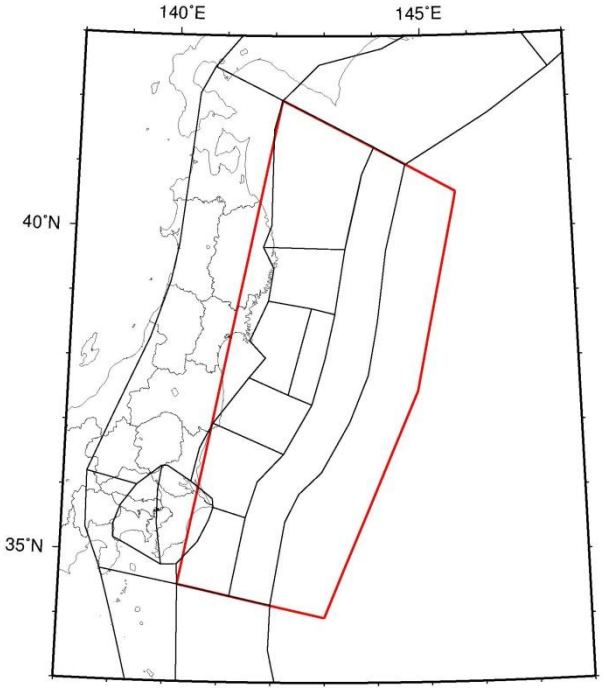
(G-R law)

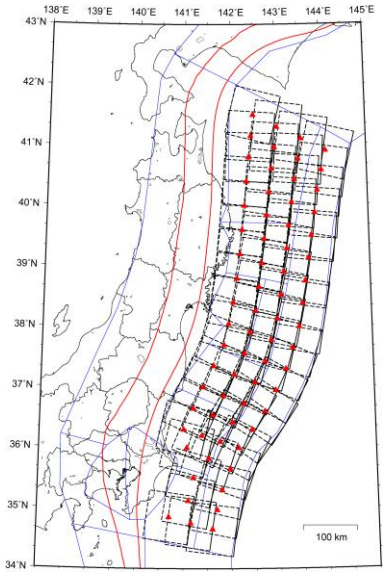
It may be necessary to promote proper modeling of background earthquakes that encompasses all earthquakes without long-term evaluation.

For example, it may be possible to evaluate the magnitude of earthquakes from the area of the plate boundary that can be considered to cause earthquakes, and to assess the frequency of occurrence of earthquakes by using the Gutenberg-Richter formula that shows the relationship between the number of earthquakes and their magnitude.

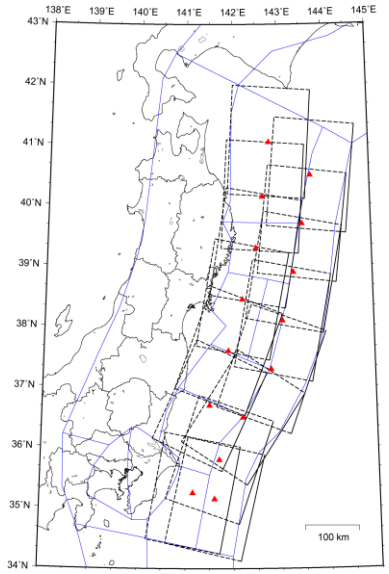
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Model3 (G-R model)

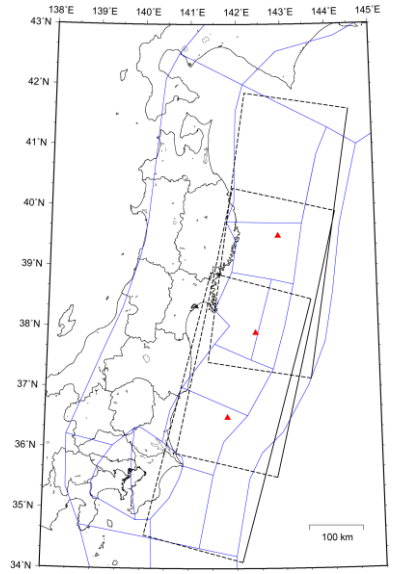




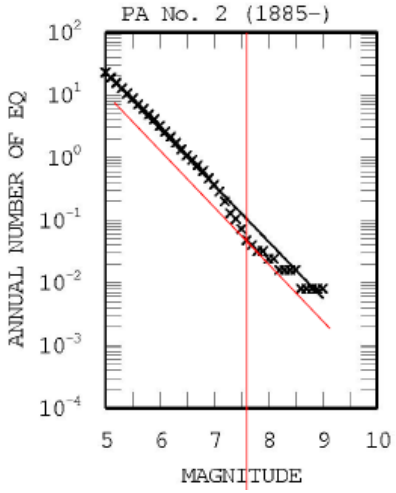
M7.6～M8.2



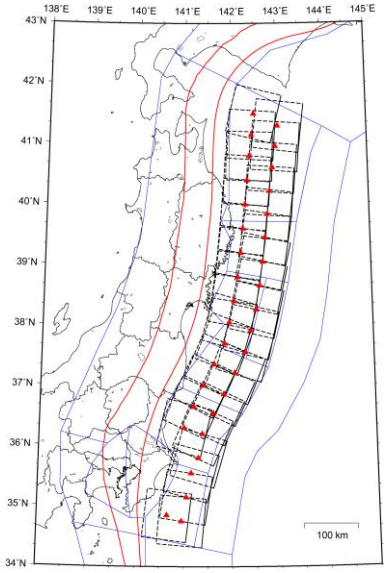
M8.3～M8.9

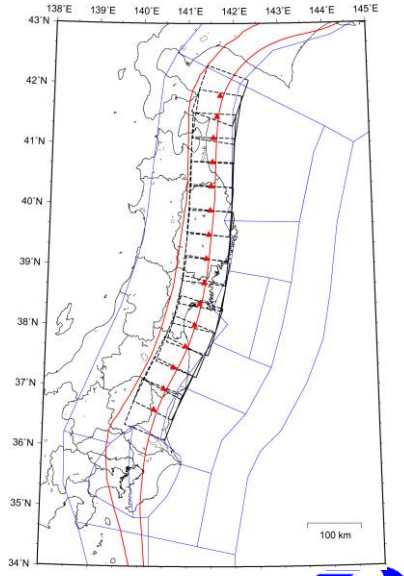


M9.0～M9.5)



mi	v (mi)	Tr(mi)
7.6	9.13E−03	109.5
7.7	7.42E−03	134.8
7.8	6.03E−03	165.8
7.9	4.90E−03	204.0
8.0	3.98E−03	250.9
8.1	3.24E−03	308.7
8.2	2.63E−03	379.8
8.3	2.14E−03	467.3
8.4	1.74E−03	574.9
8.5	1.41E−03	707.3
8.6	1.15E−03	870.1
8.7	9.34E−04	1070.5
8.8	7.59E−04	1317.0
8.9	6.17E−04	1620.3
9.0	5.02E−04	1993.4
9.1	4.08E−04	2452.4
9.2	3.31E−04	3017.1
9.3	2.69E−04	3711.8
9.4	2.19E−04	4566.5
9.5	1.78E−04	5618.0



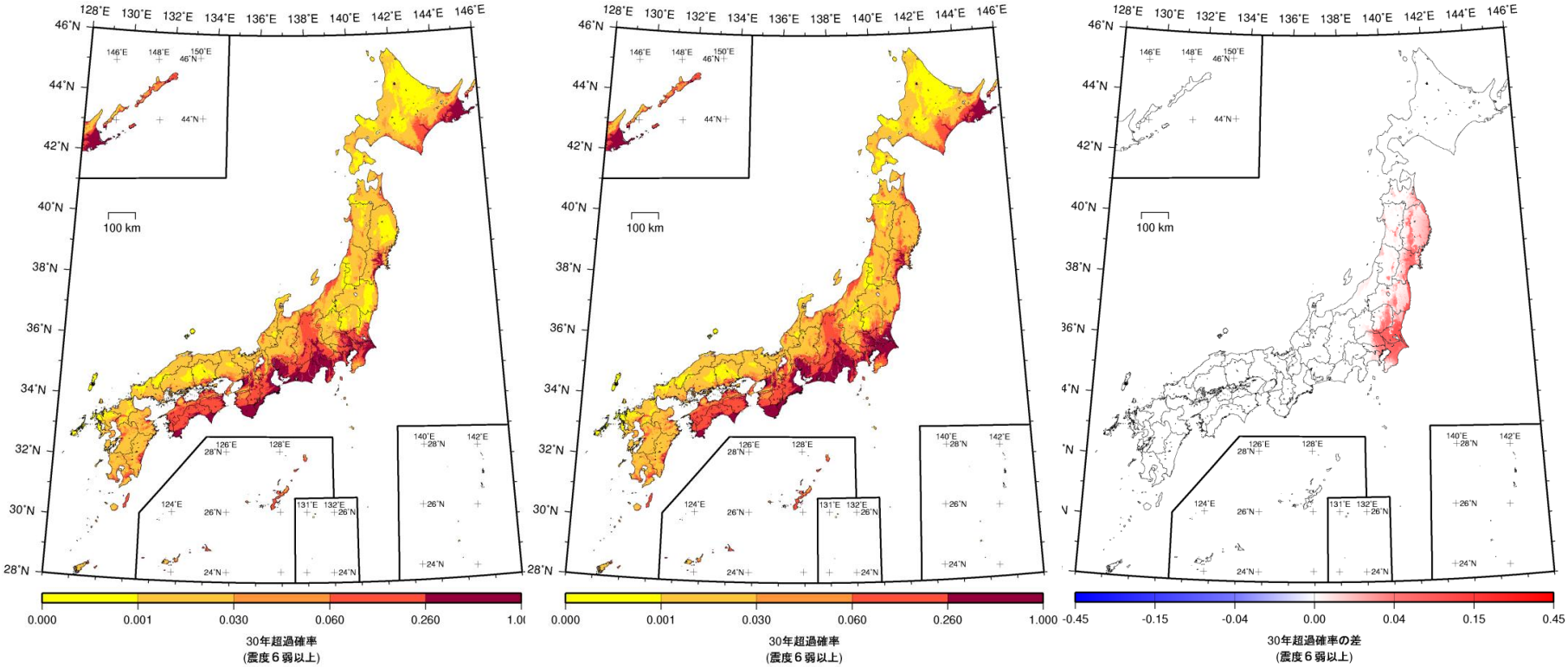


Intraplate（M7.6～M8.2）

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PSHMs considering the Tohoku type earthquake

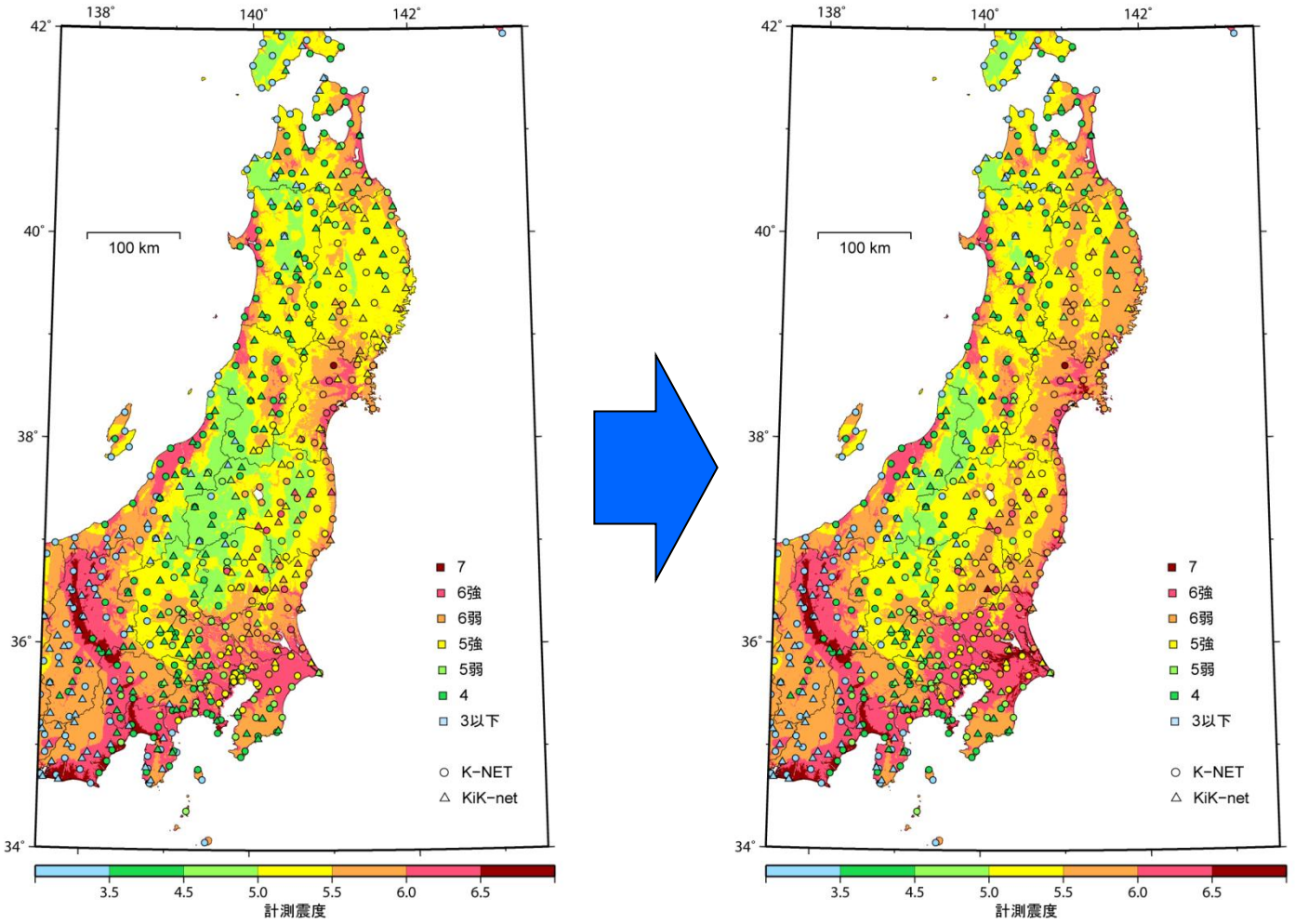
(a) PSHM2011　(b) PSHM2011＋TohokuM9



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(a) PSHM2011

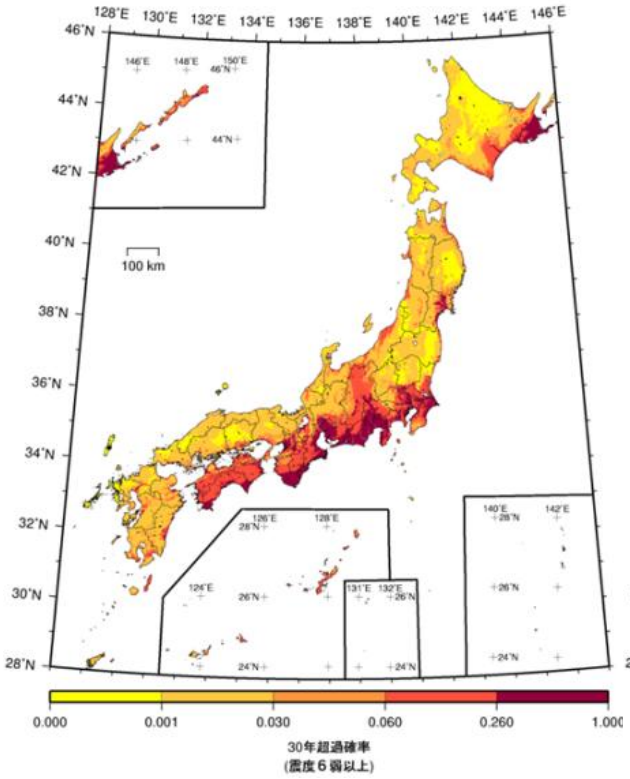
(b) PSHM2011＋TohokuM9



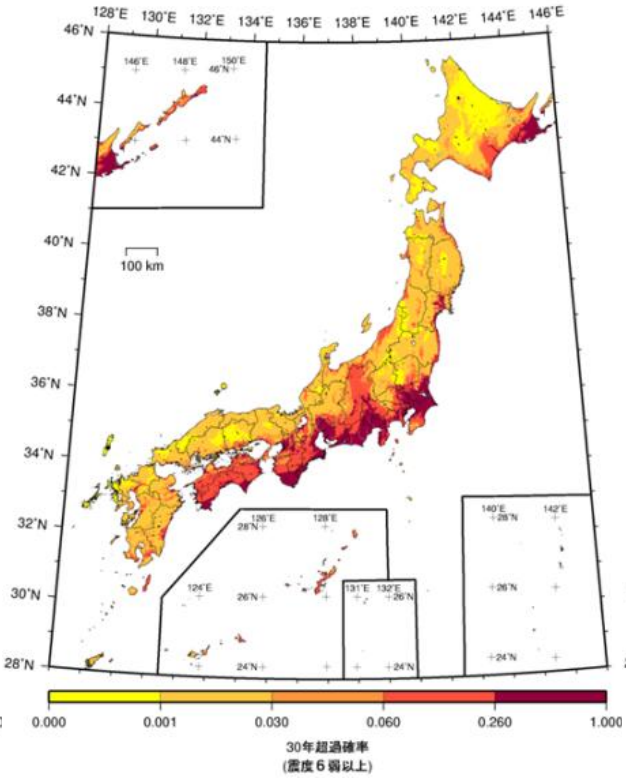
JMA seismic intensity: Exceedance probability of 2% within 50 years

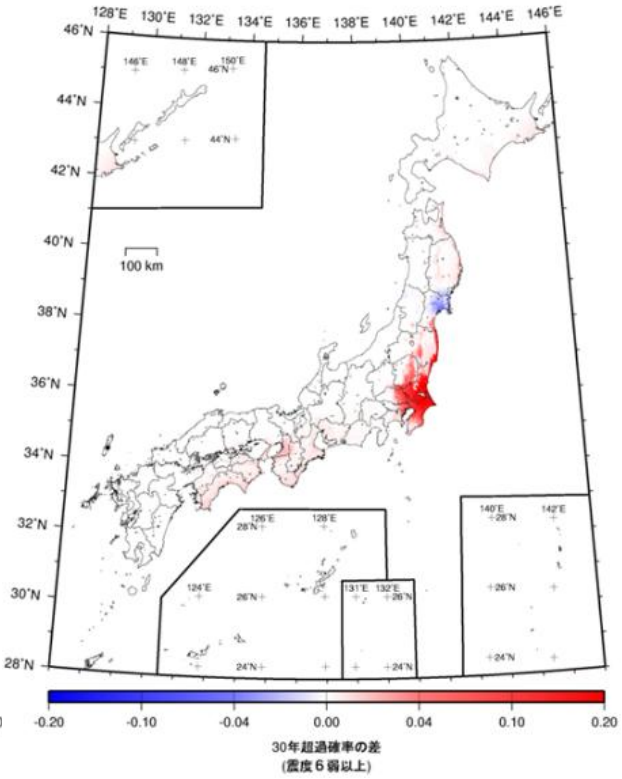
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(a) PSHM2011



(b) PSHM2012

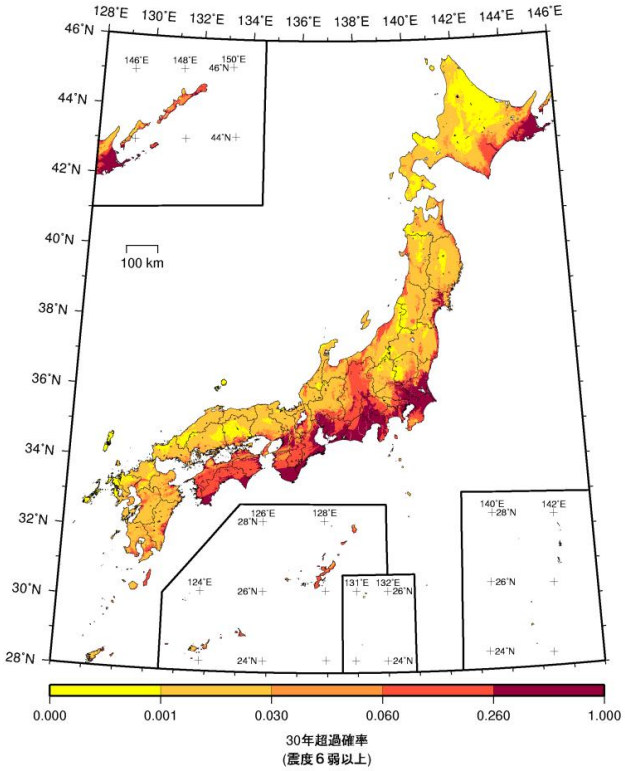




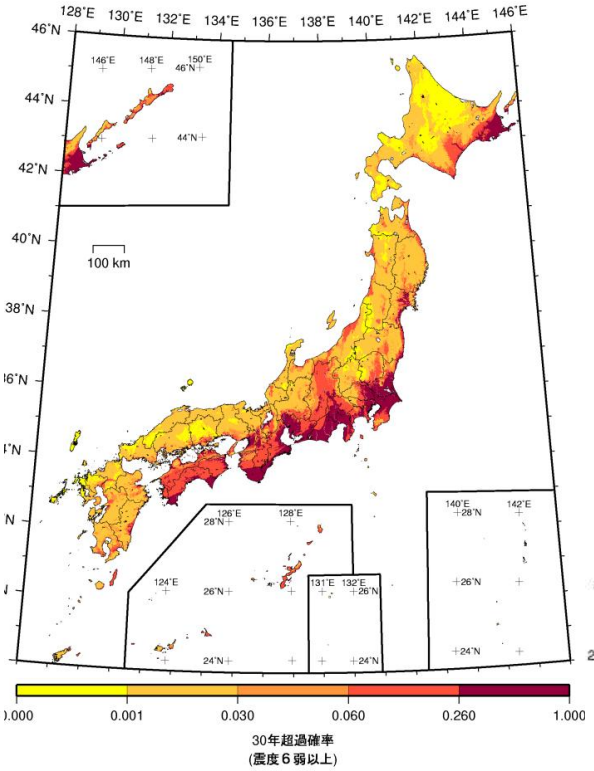
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PSHMs for 2012

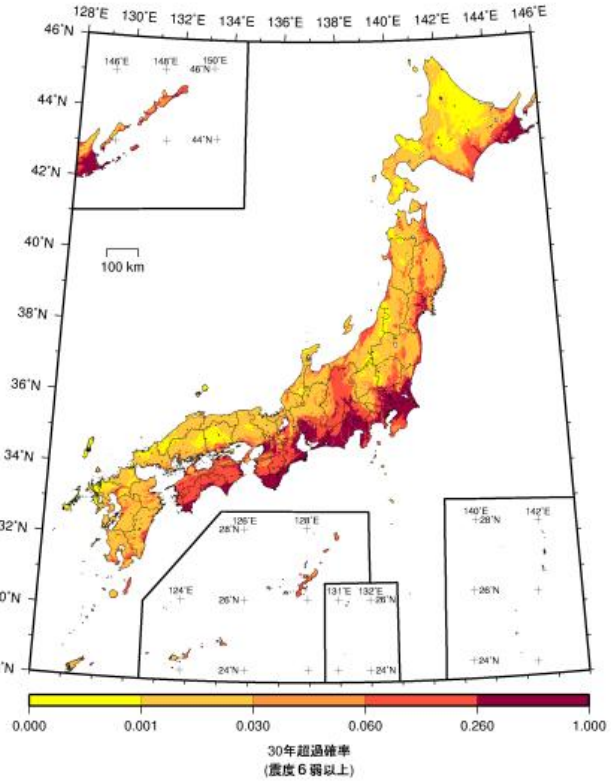
Model 1



Model 2



Model 3

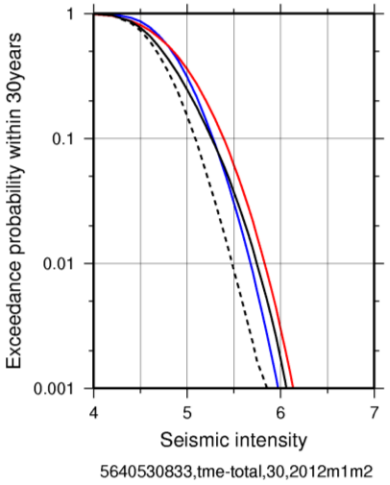


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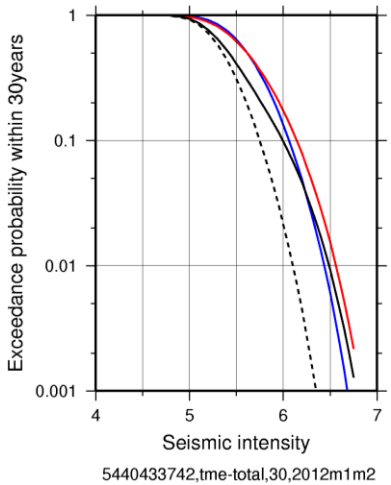
Comparison of hazard curves

Black dashed curve：PSHM2011, Black curve：PSHM2011 with M9

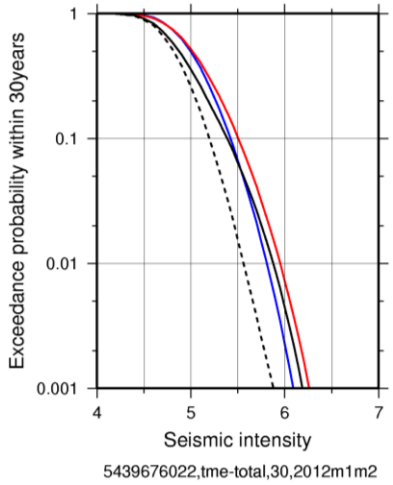
Blue line：PSHM2012(Model1), Red curve：PSHM2012(Model2)



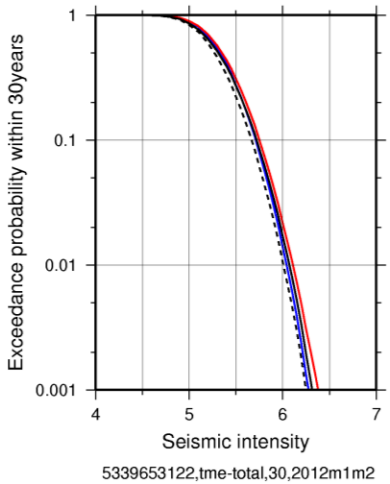
(a) Fukushima



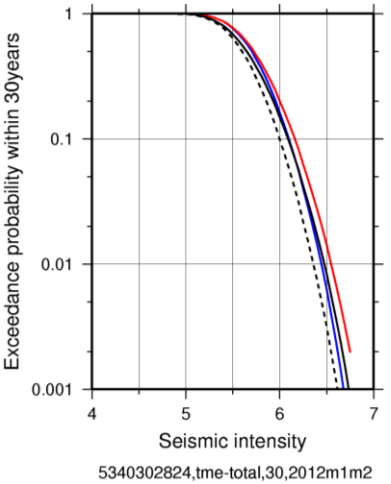
(b) Mito



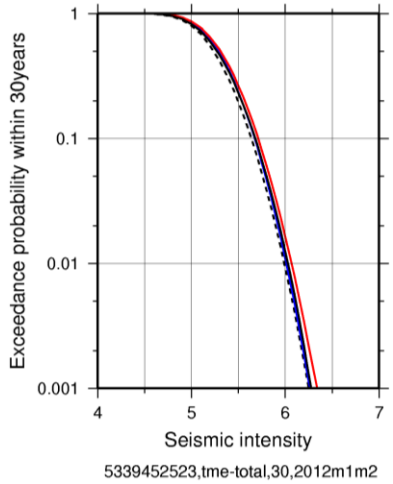
(c) Utsunomiya



(d) Saitama



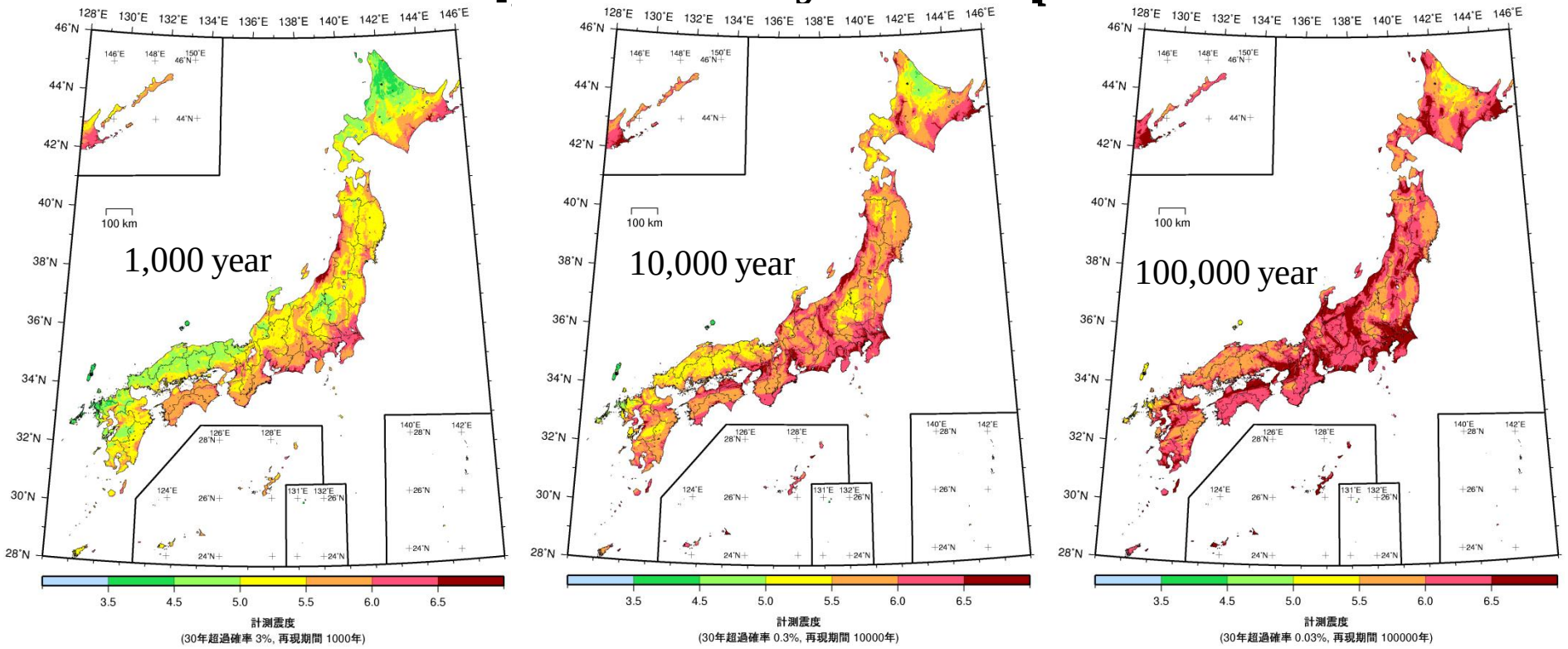
(e) Chiba



(f) Tokyo

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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.

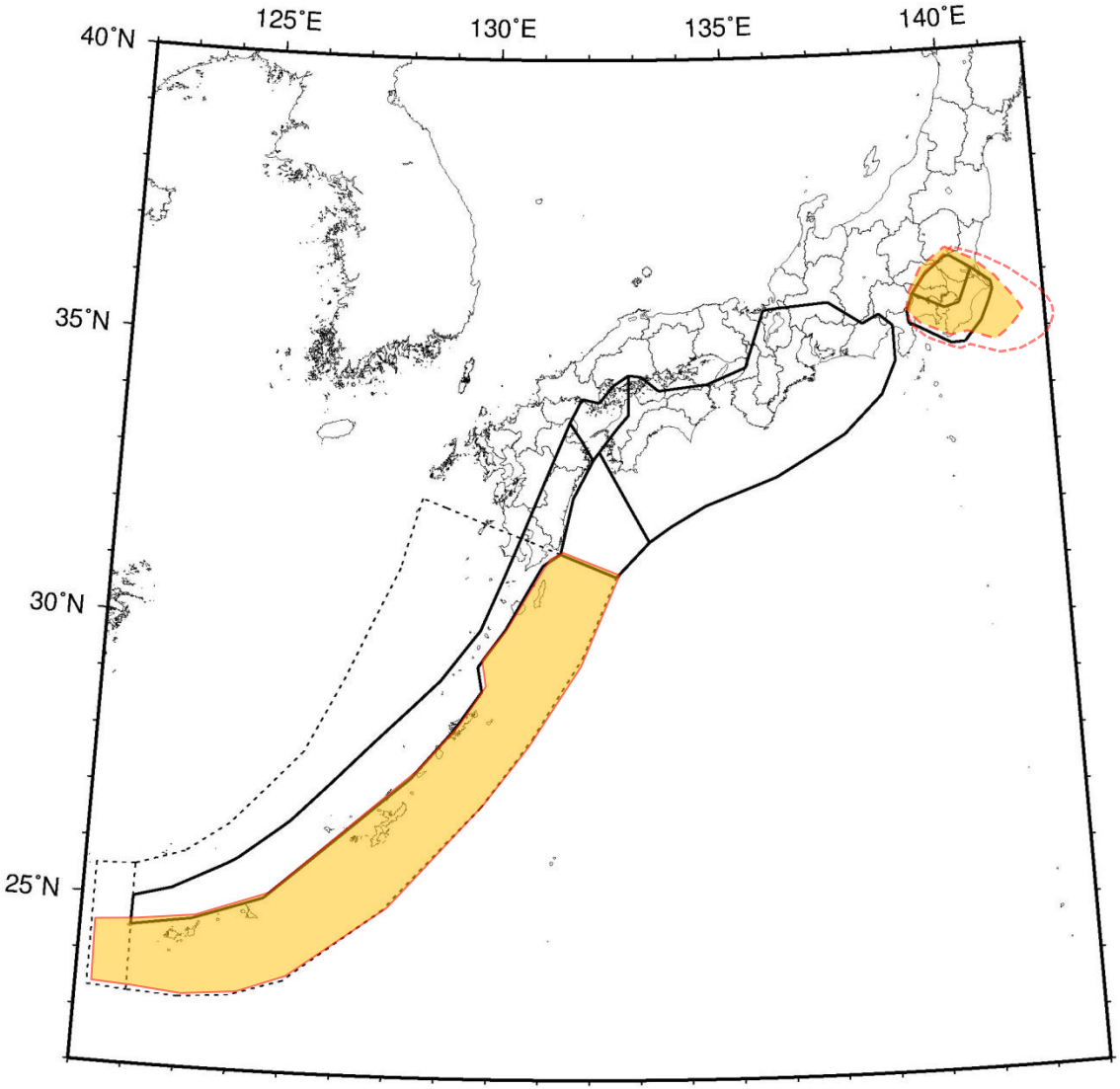
Regarding the seismic hazard assessment for low probability, at present, it is insufficient to evaluate the uncertainty for low probability M8 class earthquakes and it is necessary to improve techniques for them.

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Problems that must be overcome for improvement of seismic hazard assessment

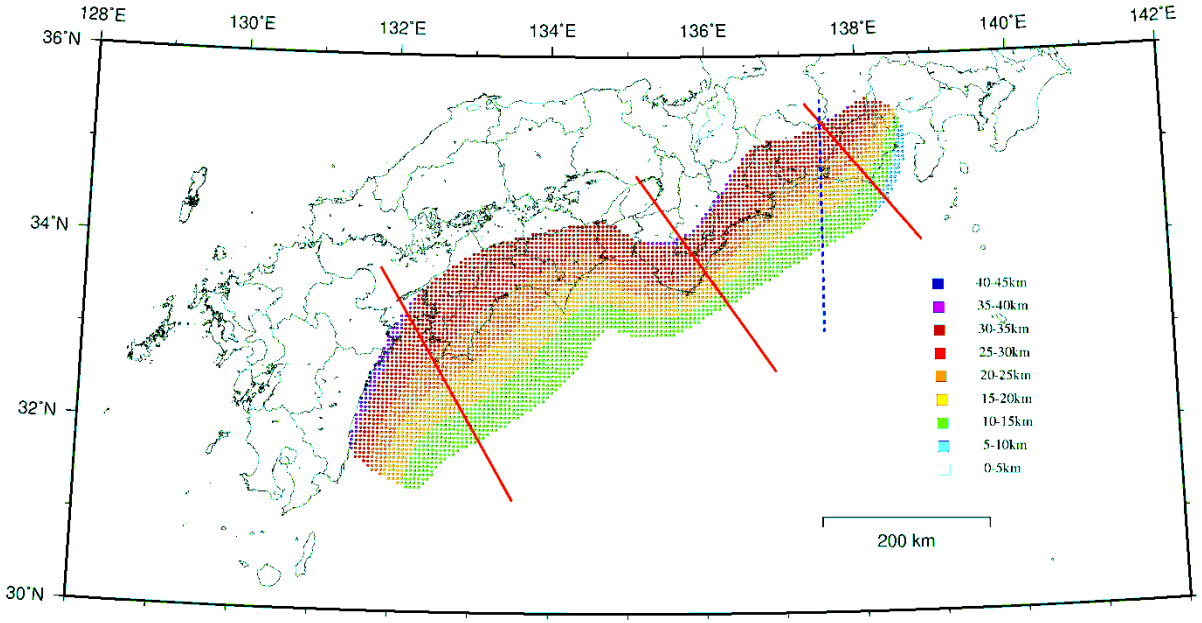
1) Modeling of seismic activity with no oversight to low-probability earthquakes.
2) Preparation of strong ground motion maps considering low-probability earthquakes.
3) Development of methodology for selecting appropriate scenario earthquakes from probabilistic seismicity model.
4) Development of methodology for prediction of strong ground motions for mega-thrust earthquakes.

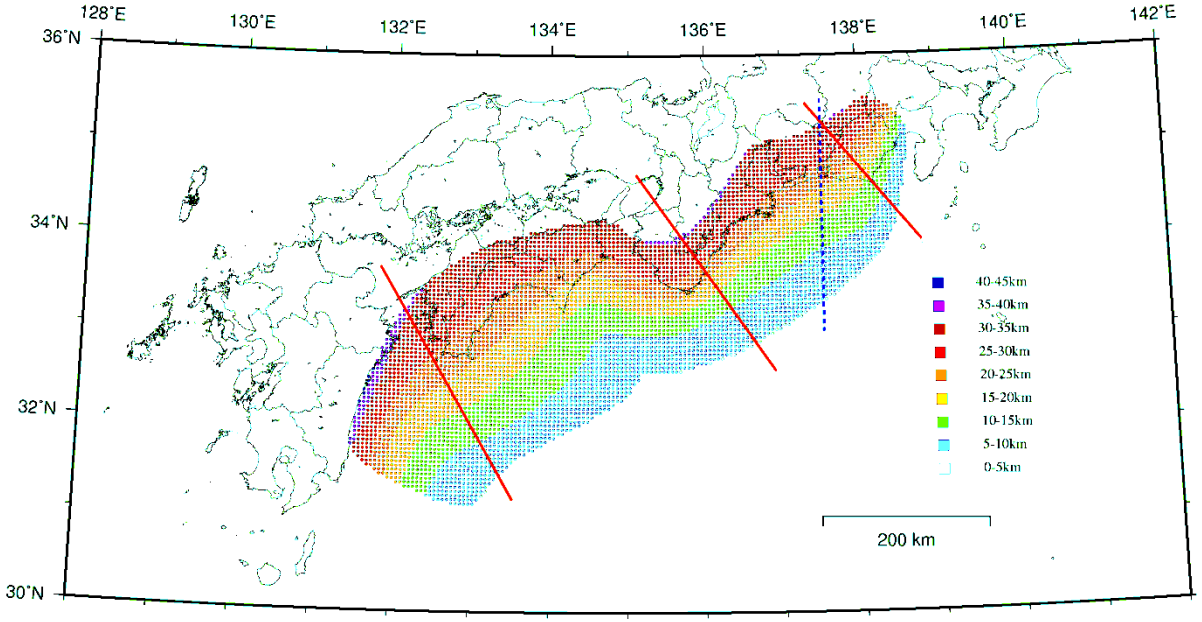
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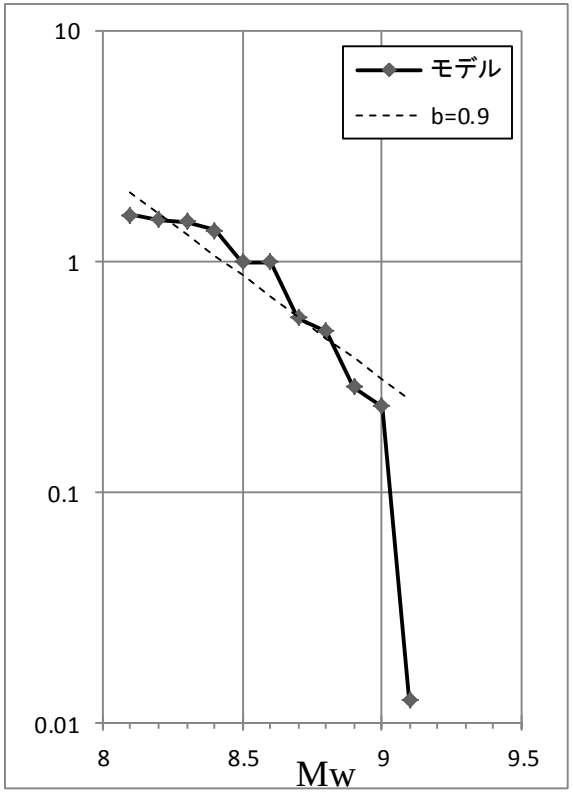
Nankai-trough earthquake





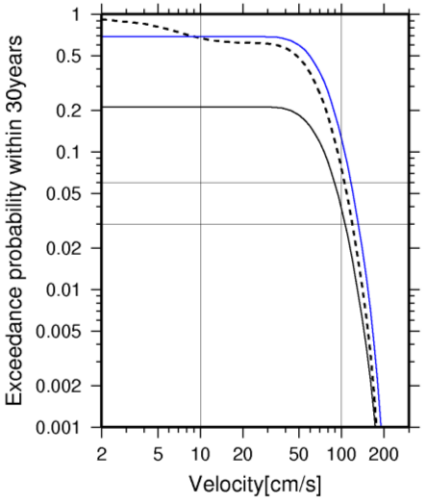
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	Hyuga-nada	Nankai	To-nankai	Tokai	Weight	*Mw*	Depth Type
Type1	←	←	←	→	0.0125	8.9	A
	←	←	←	→	0.0125	9.0*[1]	B
	←	←	←	→	0.0125	9.0	C
	←	←	←	→	0.0125	9.1*[2]	D
	×	←	←	→	0.1875	8.8	A
	×	←	←	→	0.1875	9.0	C
	←	←	←	×	0.00625	8.9	A
	←	←	←	×	0.00625	9.0	C
	×	←	←	×	0.0125	8.8	A
	×	←	←	×	0.0125	8.9	C
Type2A	←	←	←	↔	0.00625	8.9, 8.1	A
	←	←	←	↔	0.00625	9.0, 8.2	C
	×	←	←	↔	0.0125	8.8, 8.1	A
	×	←	←	↔	0.0125	8.9, 8.2	C
Type2B	←	←	↔	→	0.05	8.7, 8.4	A
	×	←	↔	→	0.325	8.6, 8.4	A
	←	←	↔	×	0.0125	8.7, 8.3	A
	×	←	↔	×	0.05	8.6, 8.3	A
Type3	←	←	↔	↔	0.0125	8.7, 8.3, 8.1	A
	×	←	↔	↔	0.05	8.6, 8.3, 8.1	A
	0.15	1.0	1.0	0.875	1.0		

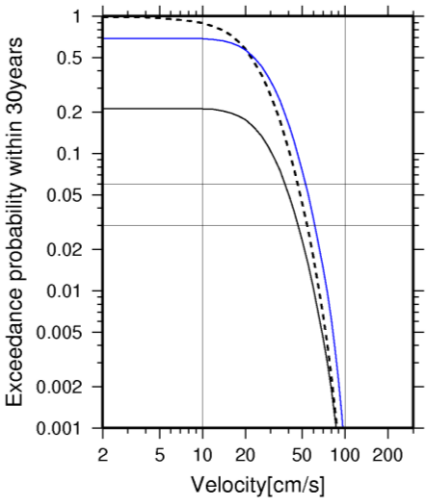


Hazard curves for Nankai-trough earthquakes

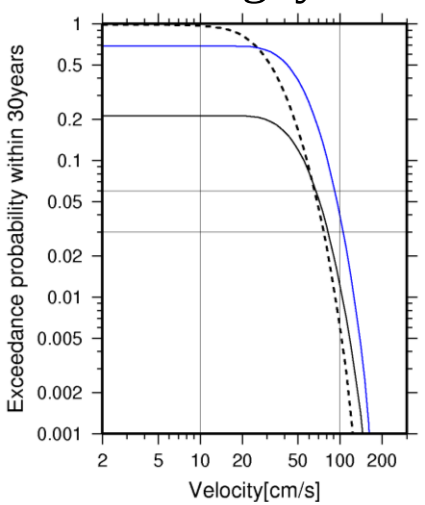
Kochi



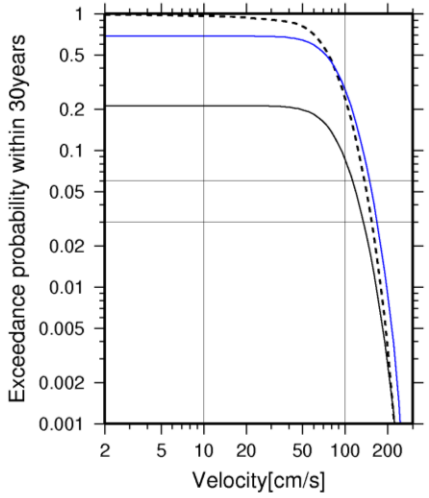
Osaka



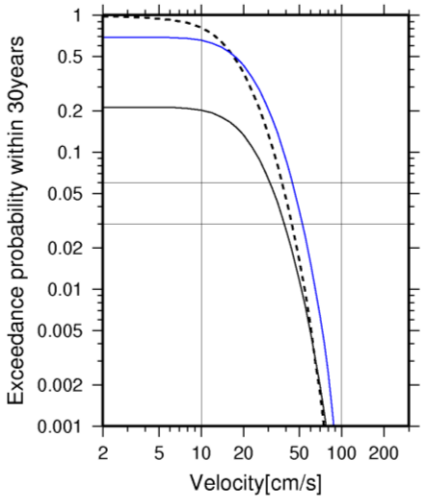
Nagoya

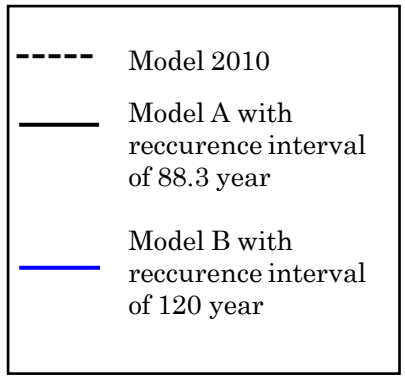


Shizuoka



Yokohama





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Thank you for attention.

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