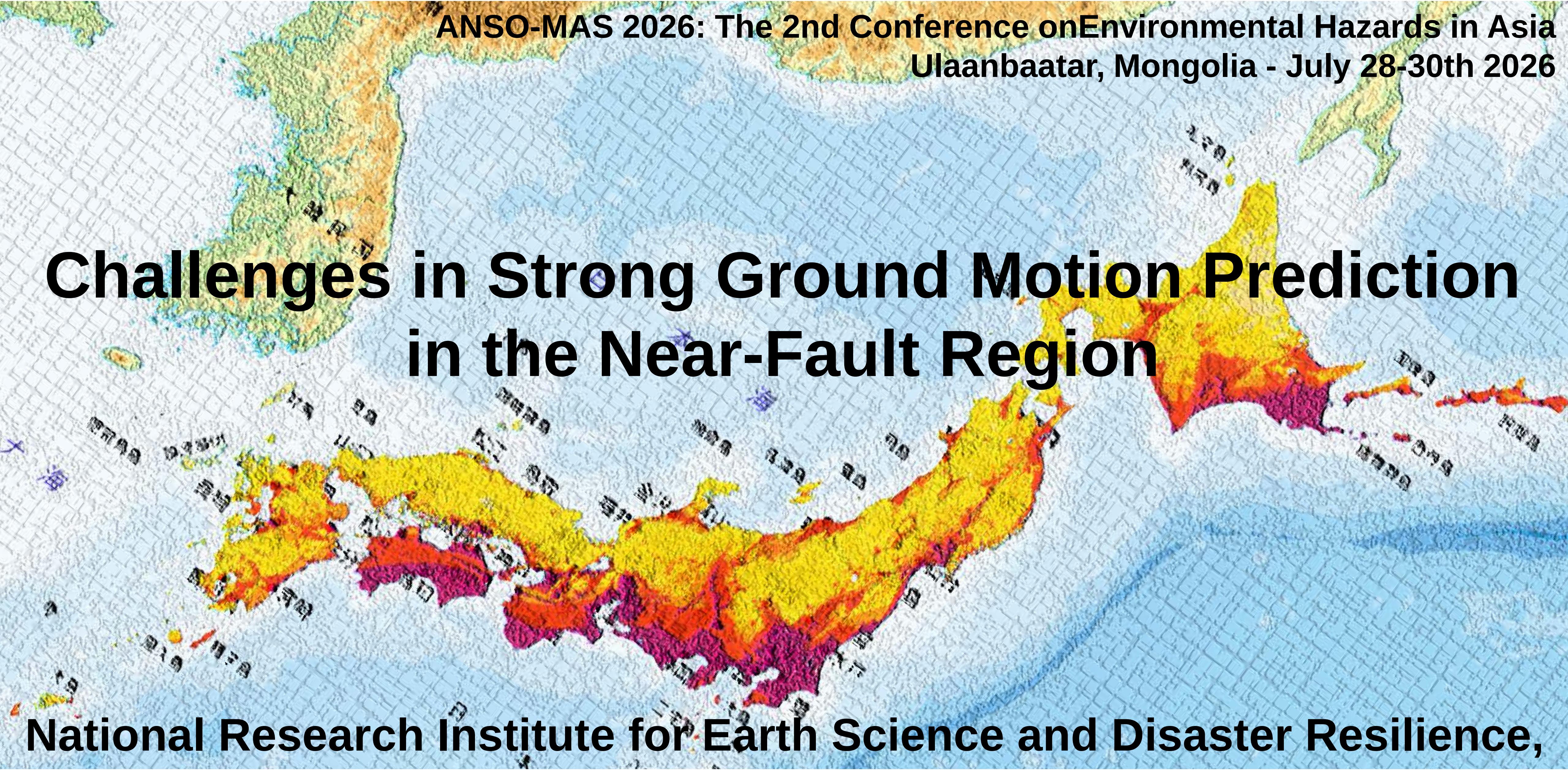


Challenges in Strong Ground Motion Prediction in the Near-Fault Region

National Research Institute for Earth Science and Disaster Resilience, Japan

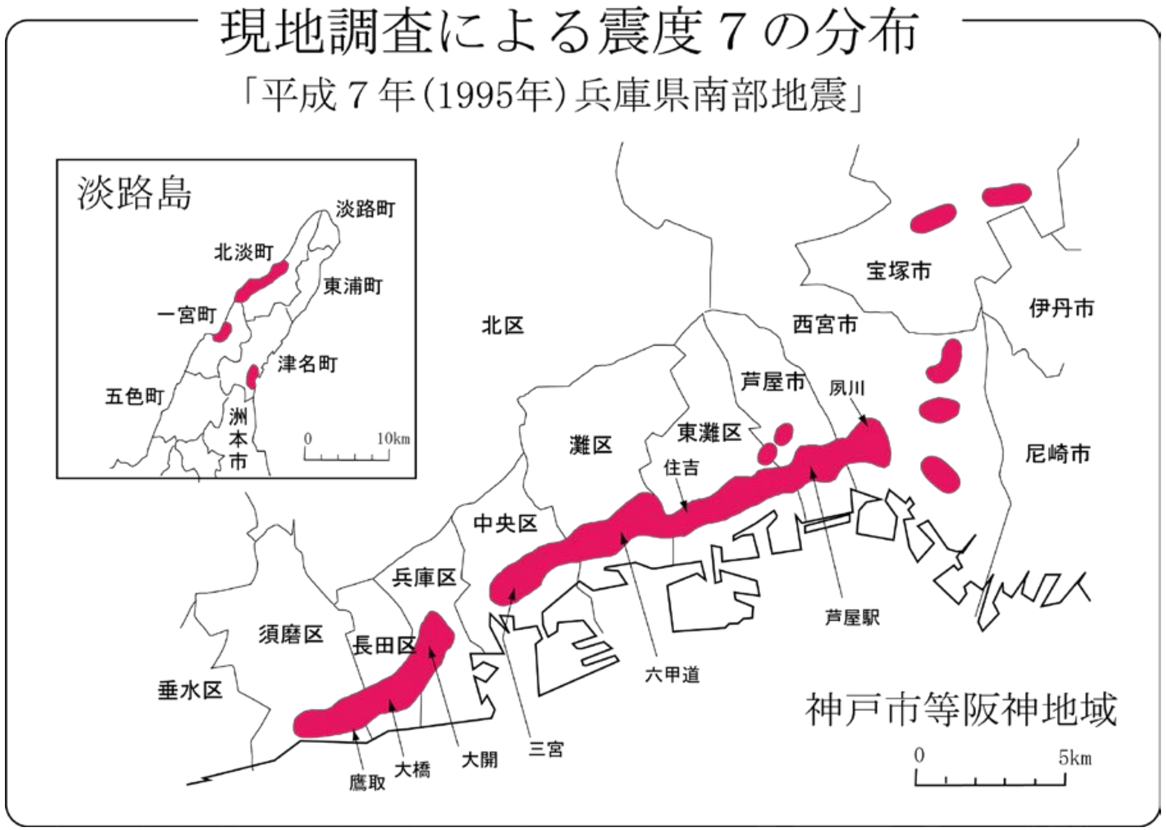
H. Fujiwara, A. Iwaki, N. Morikawa

Hyogo-ken Nanbu Earthquake (M7.3)， January 17, 1995

Kobe City Hall building

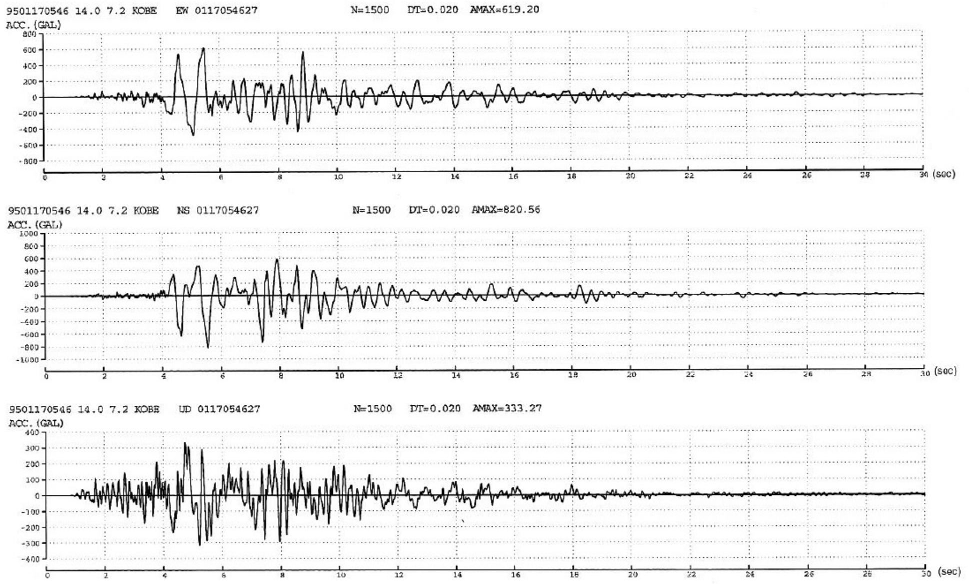
Photo by Hiroyuki Fujiwara

Characteristics of the ground motion and damage caused by the Hyogo-ken Nanbu Earthquake (M7.3) that occurred on January 17, 1995, at 5:46 a.m.



From the Japan Meteorological Agency's special website "20 Years After the Great Hanshin-Awaji Earthquake"

The observation records at the Kobe Marine Meteorological Observatory.



20 seconds

Pulse-like strong motion with a period of 1 to 2 seconds

Killer Pulse

Severe damage due to the collapse of wooden houses

6,434 fatalities, 3 missing persons, 43,792 injured, 689,776 buildings damaged, and total damage estimated at approximately 10 trillion yen

Headquarters for Earthquake Research Promotion

1995 1/17 Hyogo-ken nanbu (Kobe) earthquake occurred.
(Great Hanshin-Awaji Earthquake disaster)
1995 July Special Measure Law on Earthquake Disaster Prevention was enacted in order to promote the earthquake disaster prevention measures.

The Headquarters for Earthquake Research Promotion, a special governmental organization attached to the Prime Minister's office (now belongs to the Ministry of Education, Culture, Sports, Science and Technology), was established in accordance with this law.

Basic Objectives and Roles

To promote research into earthquakes with the goal of strengthening disaster prevention measures, particularly for the reduction of damage and casualties from earthquakes .

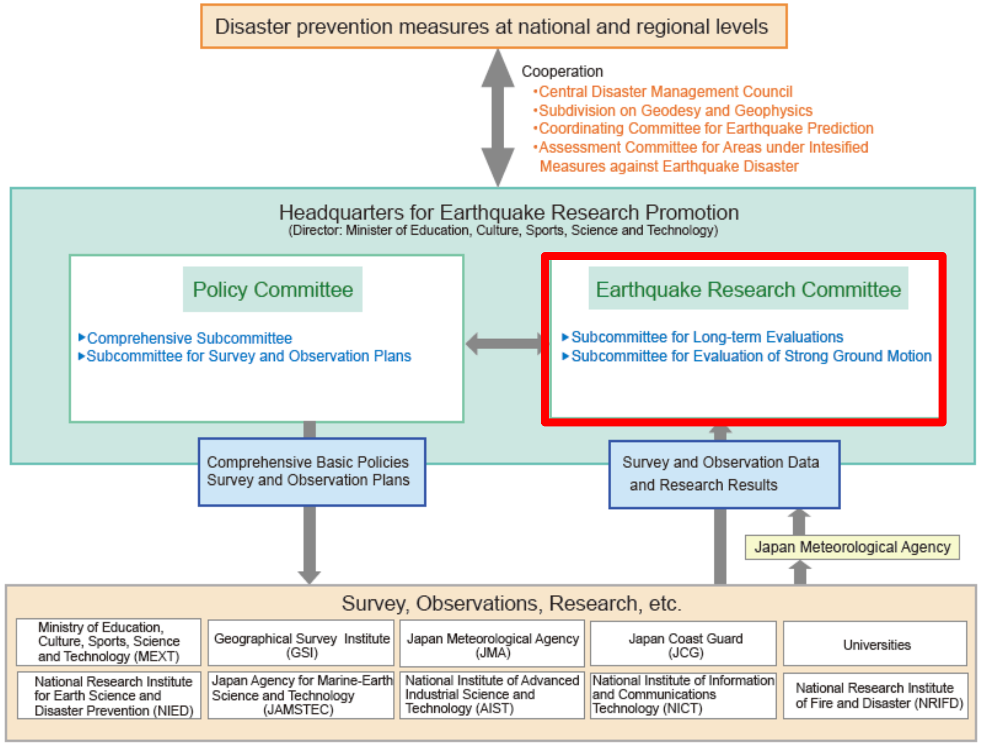
1.Planning of comprehensive and basic policies

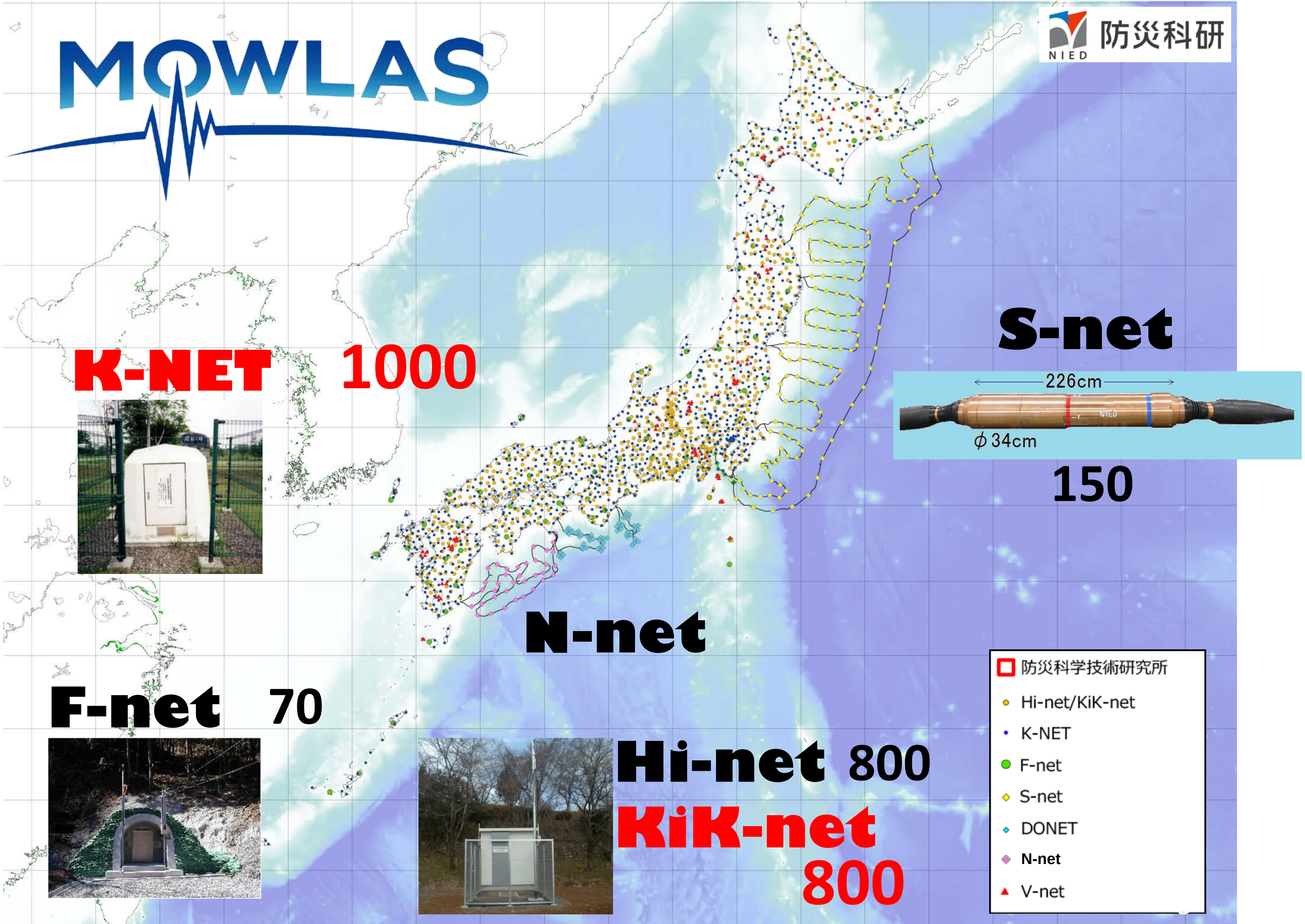
2. Coordination of budgets and other administrative works with related governmental organizations

3. Establishment of comprehensive survey and observation plans

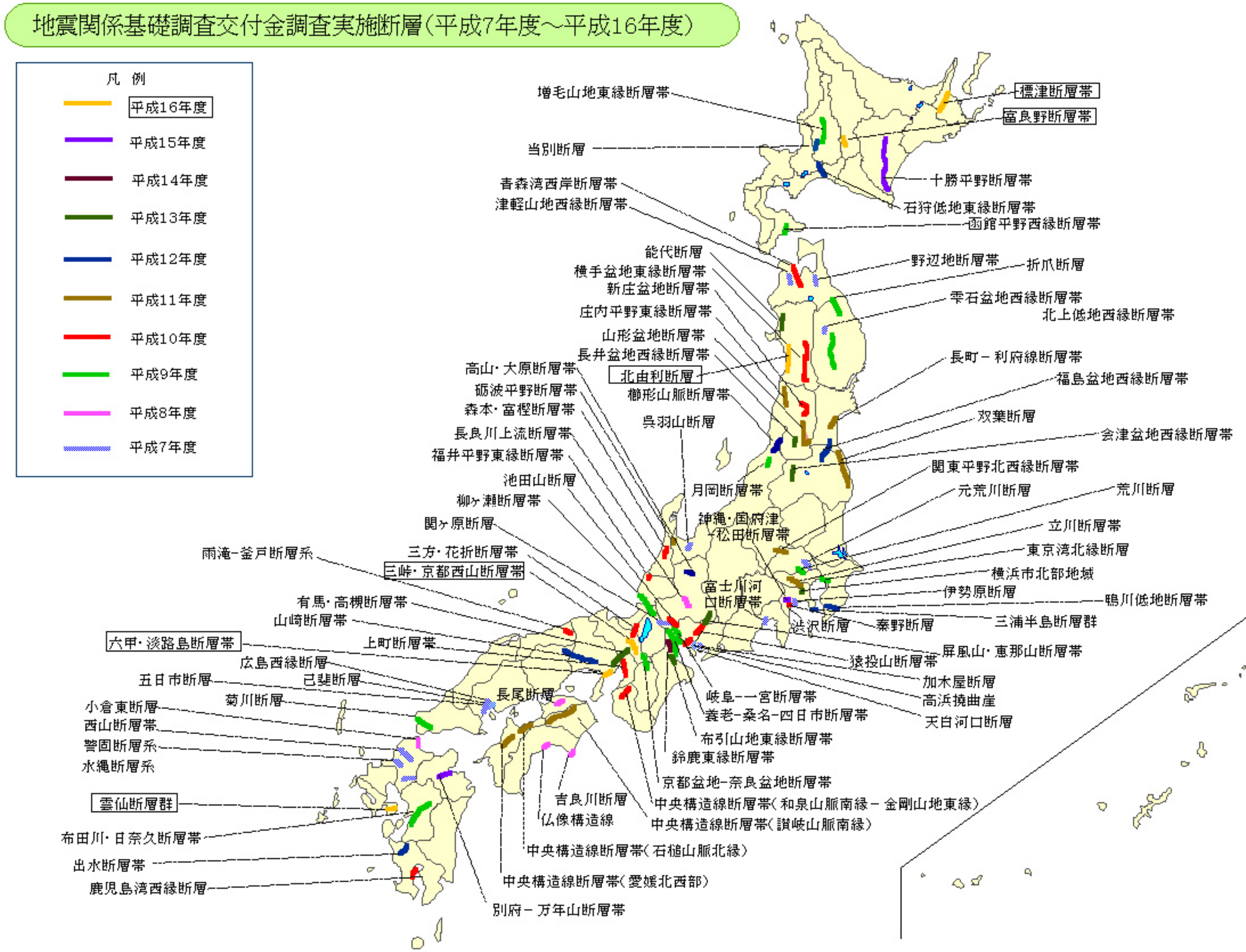
4. Collection, arrangement, analysis and comprehensive evaluation of survey results by related governmental organizations, universities, etc.

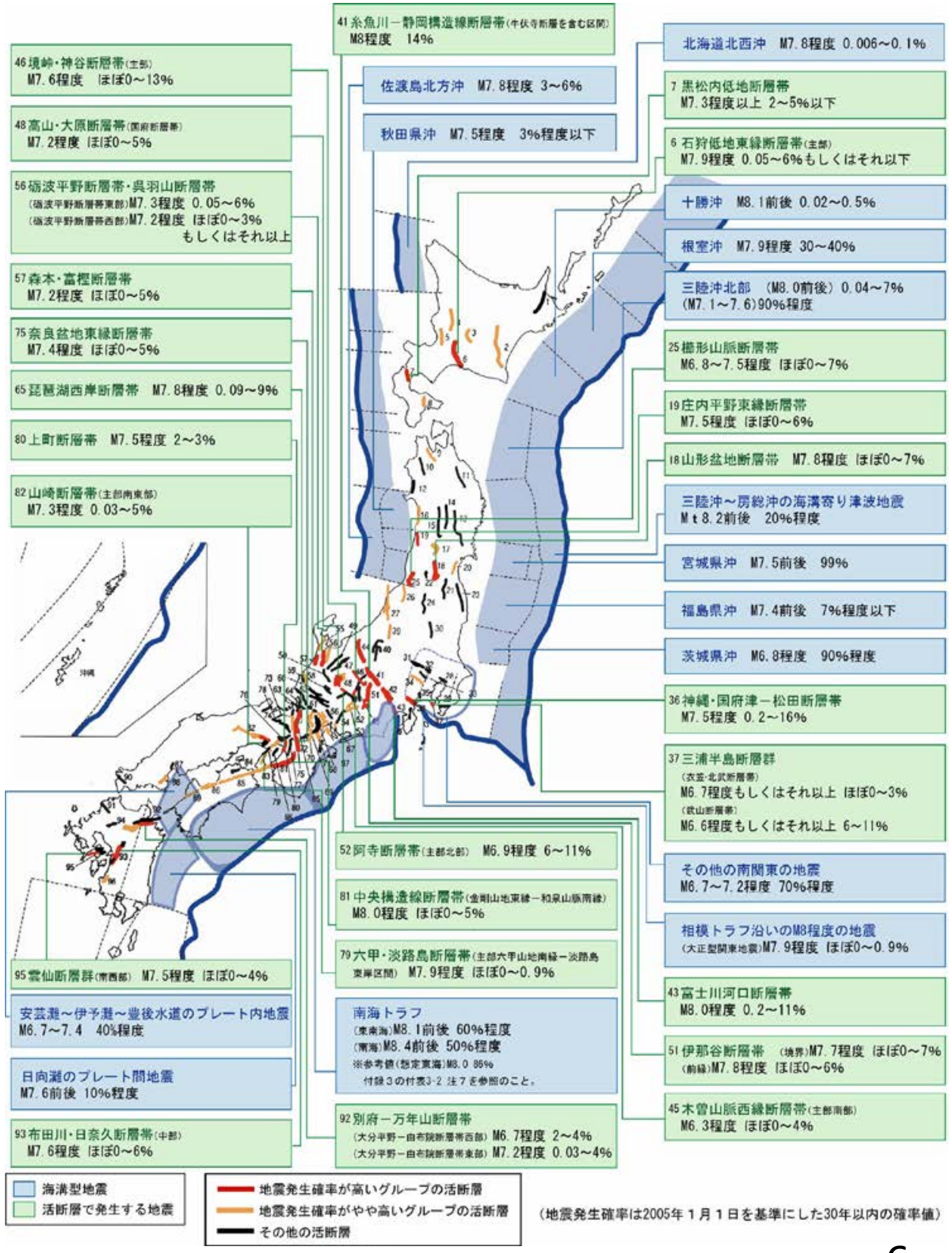
5. Public announcements based on the comprehensive evaluations




MOWLAS
防災科研
NIED
K-NET 1000
S-net
226cm
ϕ34cm
150
N-net
F-net 70
Hi-net 800
KiK-net
800
防災科学技術研究所
Hi-net/KiK-net
K-NET
F-net
S-net
DONET
N-net
V-net

Investigation and long-term evaluation in major active fault zones





Focusing primarily on approximately 100 major active faults (active faults that are considered to have significant social and economic impacts), grants are provided to local governments conducting active fault investigations, and active fault surveys are carried out across the country.

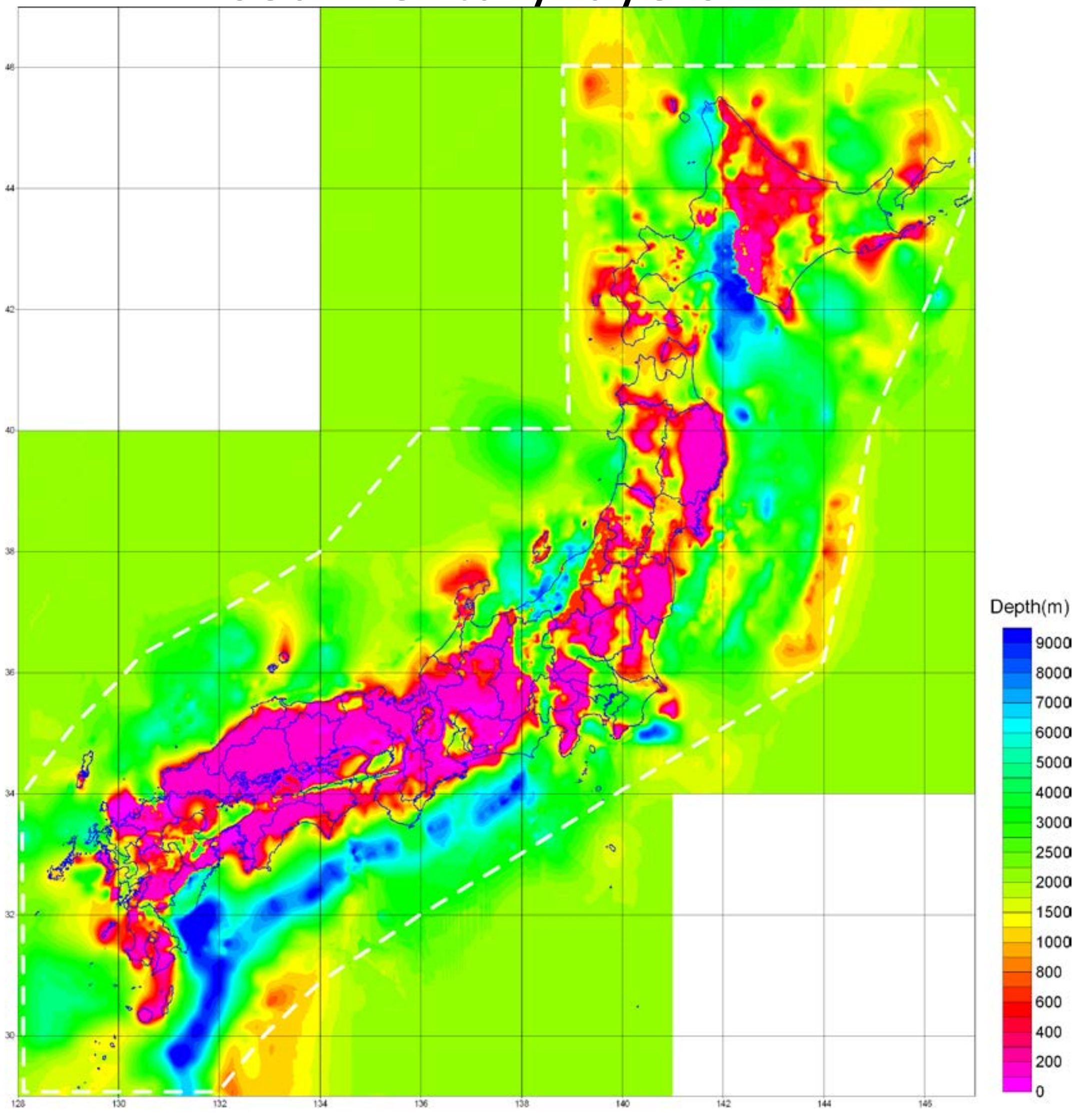
Subsurface structure investigation of sedimentary plains

Investigations funded by the Research Grants

自治体名	調査実施地域	調査年度						
		H10	H11	H12	H13	H14	H15	H16
宮城県	仙台平野南部地域					■	■	■
千葉県	関東平野(千葉県西部地域)	■	■	■				
	関東平野(千葉県中央部地域)				■	■	■	■
東京都	関東平野(東京都)					■	■	■
神奈川県	関東平野 (横浜市、川崎市を中心とする神奈川県地域)		■	■				
	足柄平野とその周辺地域				■	■		
山梨県	甲府盆地				■	■	■	
愛知県	濃尾平野		■	■	■	■		
	三河地域堆積平野				■	■	■	■
三重県	伊勢平野					■	■	■
大阪府	大阪平野					■	■	■
鳥取県	鳥取県西部地震関連地域				■	■		
札幌市	石狩平野北部				■	■	■	■
横浜市	関東平野(横浜市地域)	■	■	■	■			
川崎市	関東平野(川崎市地域)	■	■	■				
京都市	京都盆地	■	■	■	■	■		

One of the causes of the 'Heavy Damage Belt' has been attributed to the three-dimensional structure of the subsurface in the Kobe region, and it has been pointed out that understanding the subsurface structure is essential for predicting strong ground motions.

Velocity structure model of sedimentary layers



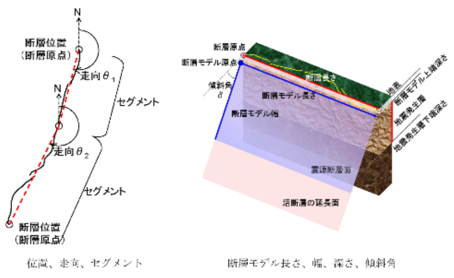
Depth distribution of the seismic bedrock

National seismic hazard maps for Japan

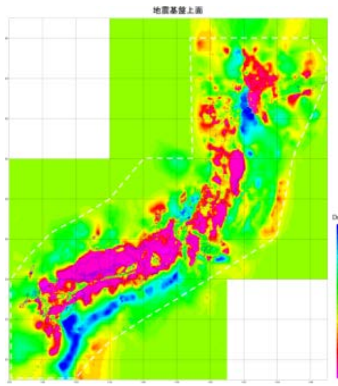
Long term evaluation

Probability of occurrence, magnitude, location

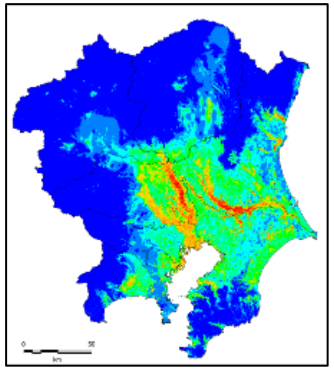
Strong-motion evaluation



Modeling of seismic fault



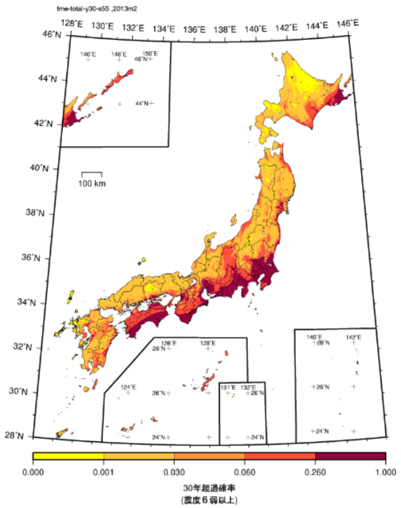
velocity structure



Shallow subsurface structure model

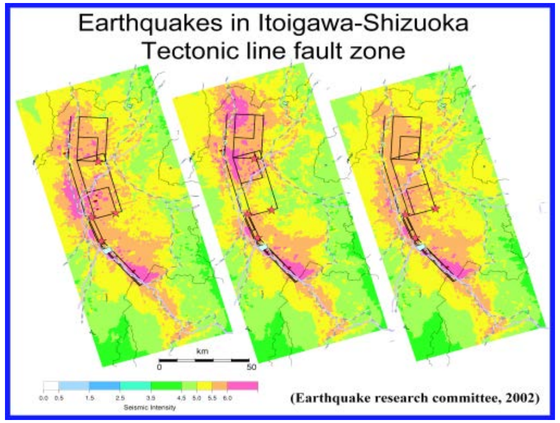
Calculation of strong-motion

Probabilistic Seismic Hazard Maps



- Adopting the methodology known as **probabilistic seismic hazard analysis**.
- 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.

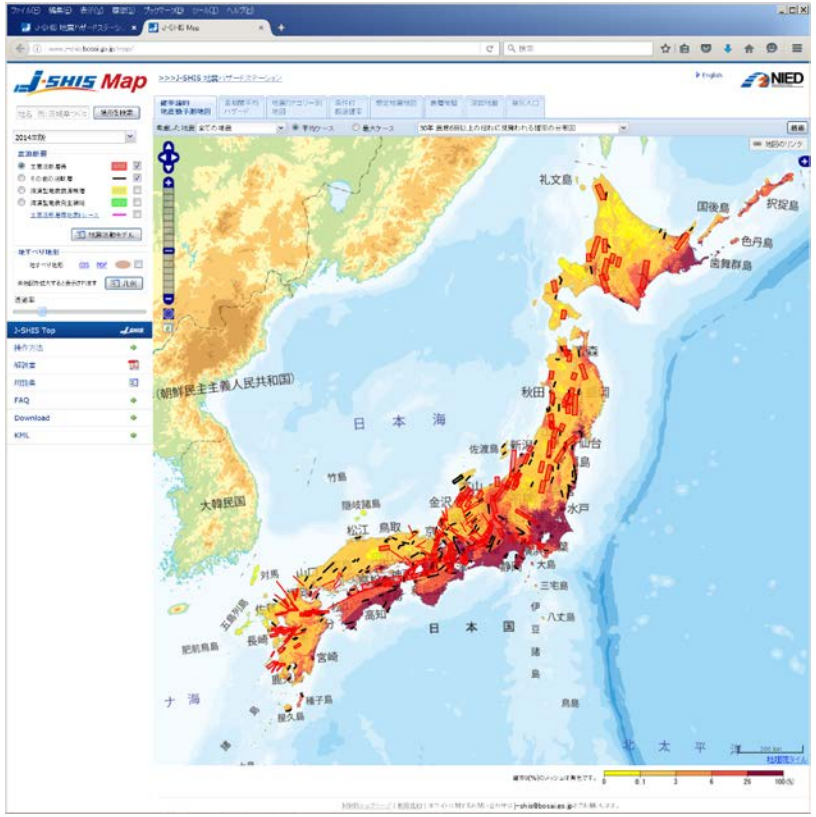
Recipe for strong motion prediction

Japan Seismic Hazard Information Station (J-SHIS)

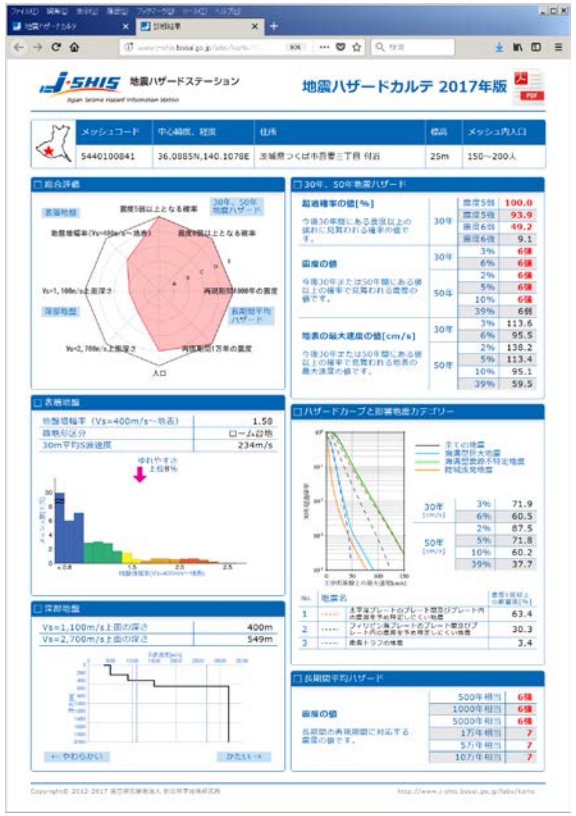
・**2002 Jun. Engineering Utilization Study Committee for National Seismic Hazard Maps for Japan (Chairman: Hiroyuki Kameda)**

Engineering Application of the National Seismic Hazard Maps for Japan
- Seismic Hazard Information Sharing Bases - Technical Note of the NIED, 258, 2004.

A proposal to position the “National Seismic Hazard Maps for Japan" as the common information infrastructure for seismic hazard.

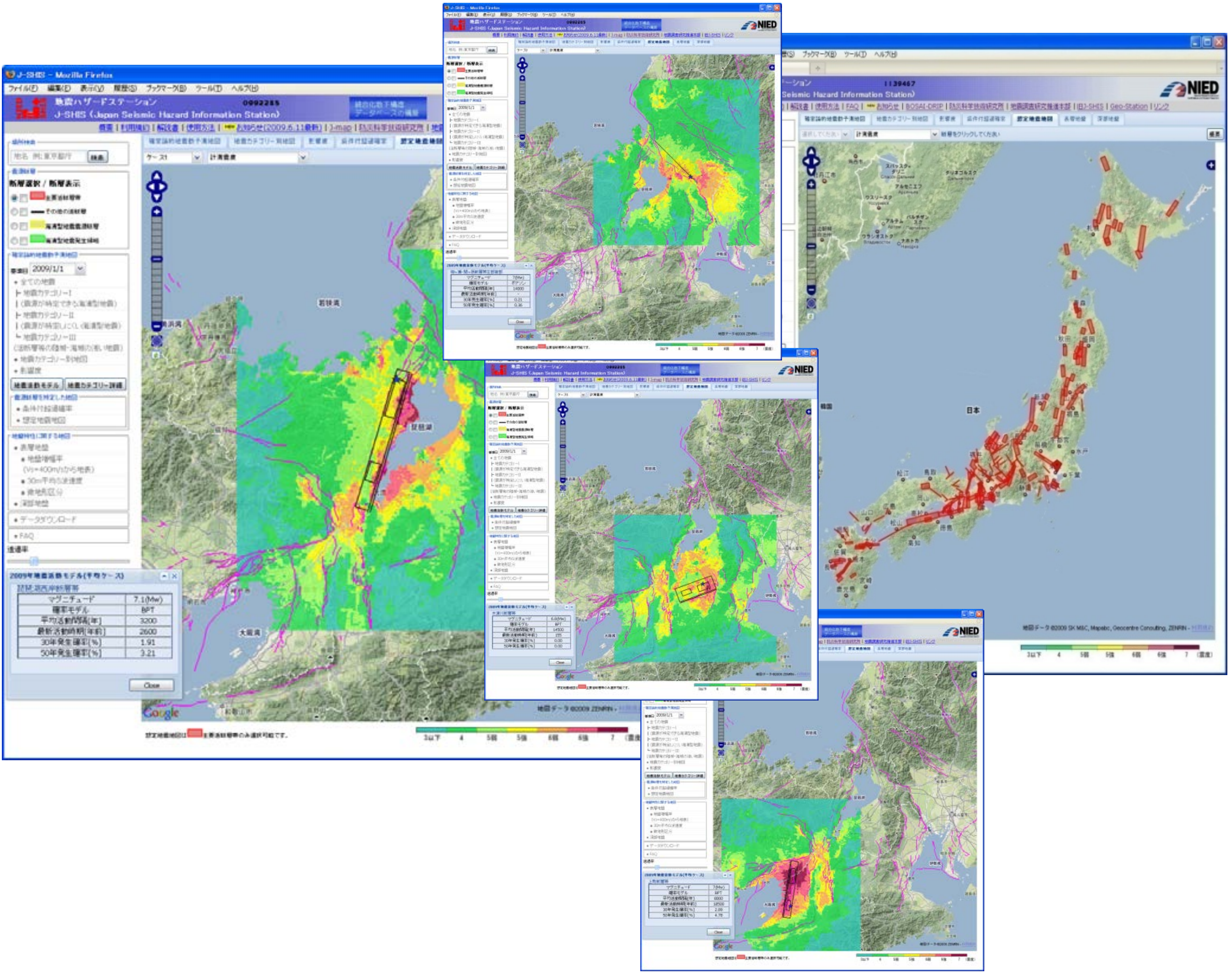


https://www.j-shis.bosai.go.jp



Seismic Hazard Karte

Scenario Earthquake Shaking Maps



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

‘Recipe’ for Strong Motion Prediction

The ‘Recipe’ aims to establish a ‘standardized methodology whereby anybody can obtain the same results’ for predicting the strong ground motions that occur in the case of earthquakes with specified source faults. The ‘Recipe’ is to be reviewed and revised in the future through further studies on strong ground motion evaluations.

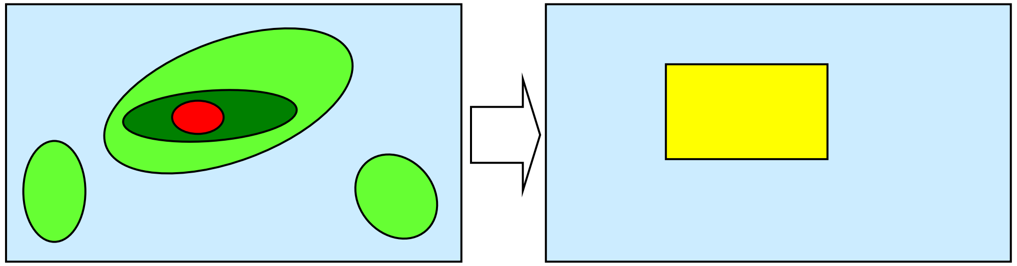
Current version is released on June, 2016 (HERP, 2016)

1. Characterized source model

- EQs occurring on active faults ← Irikura & Miyake (2001)
- Subduction inter-plate EQs
- Subduction intra-slab EQs ← Arai et al. (2015)

    Outer source parameters
    Inner source parameters
    Other source parameters

2. Velocity structure model
3. Strong-motion calculation
4. Validation of results



Scenario Earthquake Shaking Maps

'Recipe' for Strong Motion Prediction by HERP

This document summarizes the methodology for setting seismic source fault parameters based on detailed considerations such as active fault investigations, past earthquake records, seismic activity, and the implementation of strong ground motion assessments in accordance with long-term evaluations by the Earthquake Headquarters.

→ Published as an appendix to the strong ground motion assessment. From the 2009 edition, it is indicated as method (A).

In the process of collectively creating Scenario Earthquake Shaking Maps for earthquakes with identified faults for the major active fault zones (110 fault zones), a method has been added to simplify the setting of seismic source fault parameters. This is done by taking into account the surface length of active faults based on long-term evaluations.

→ Published as an appendix to the 2009 edition of the National Seismic Hazard Maps for Japan indicated as method (B)

Revised on June 10, 2016

- Reevaluation of the methodology regarding long active faults exceeding approximately 80 km in length.
- Addition of a methodology for intraslab earthquakes.

Revised on December 9, 2016

- Revision of the explanation regarding the positioning of methods (A) and (B).

Revised in April 2017

- With the construction of the shallow-deep integrated subsurface structure model, an update has been made to the description regarding the subsurface structure model.

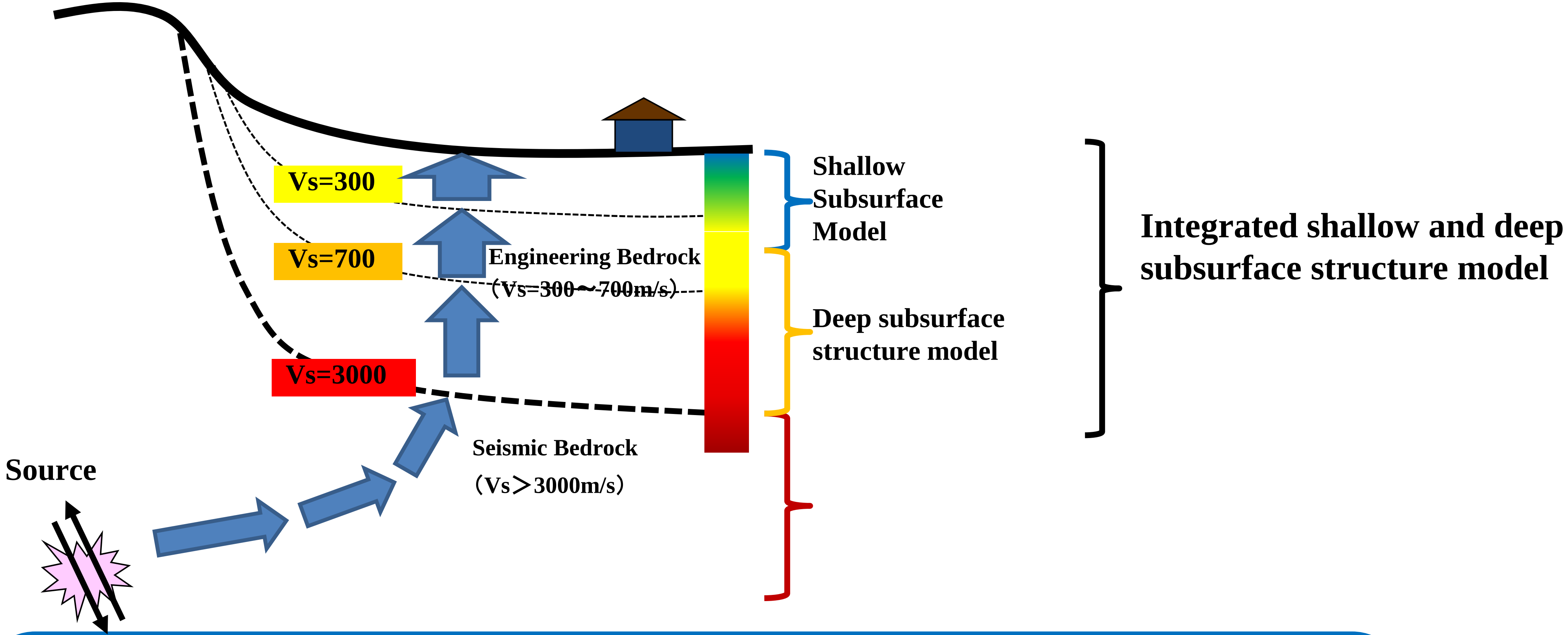
Revised in March 2020

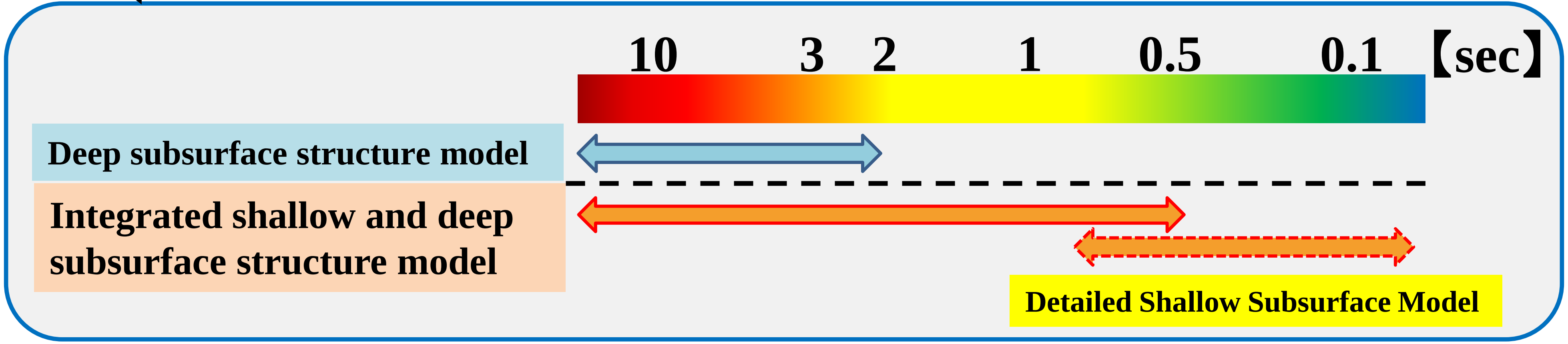
- Revision of the amplification factor and correction of the calculation formula.

In March 2022

・Validation of Strong Ground Evaluation Methods Based on Observational Records of the 2016 Kumamoto Earthquake (Mj 7.3) (Interim Report)

Integrated shallow and deep subsurface structure model





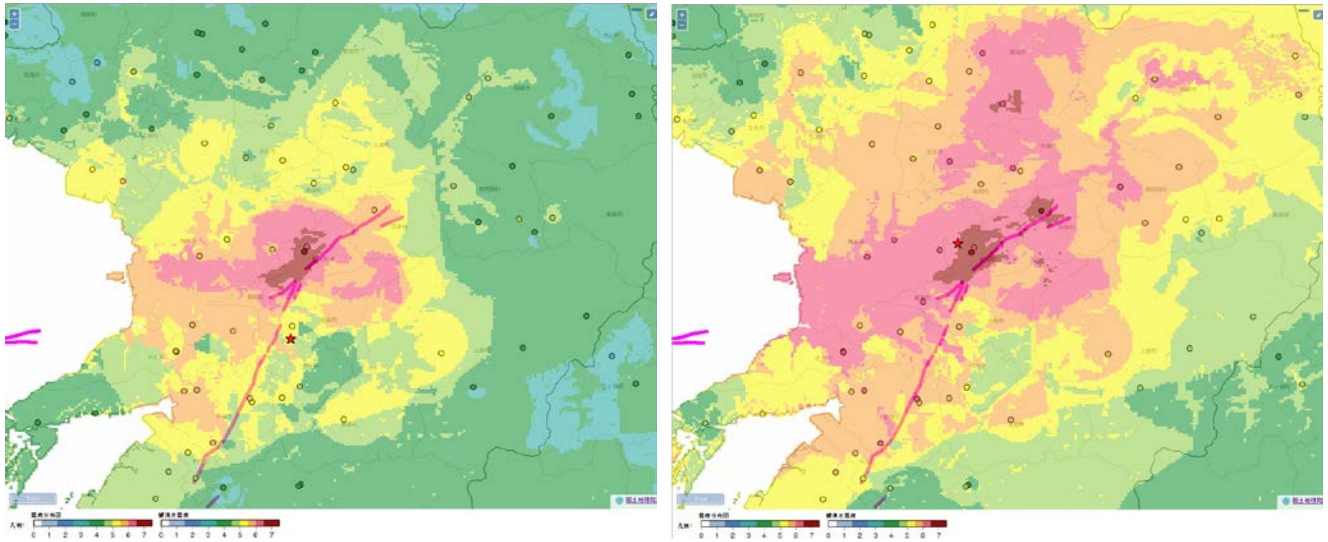
Validation of Strong Ground Evaluation Methods Based on Observational Records of the 2016 Kumamoto Earthquake

Kumamoto　Earthquakes

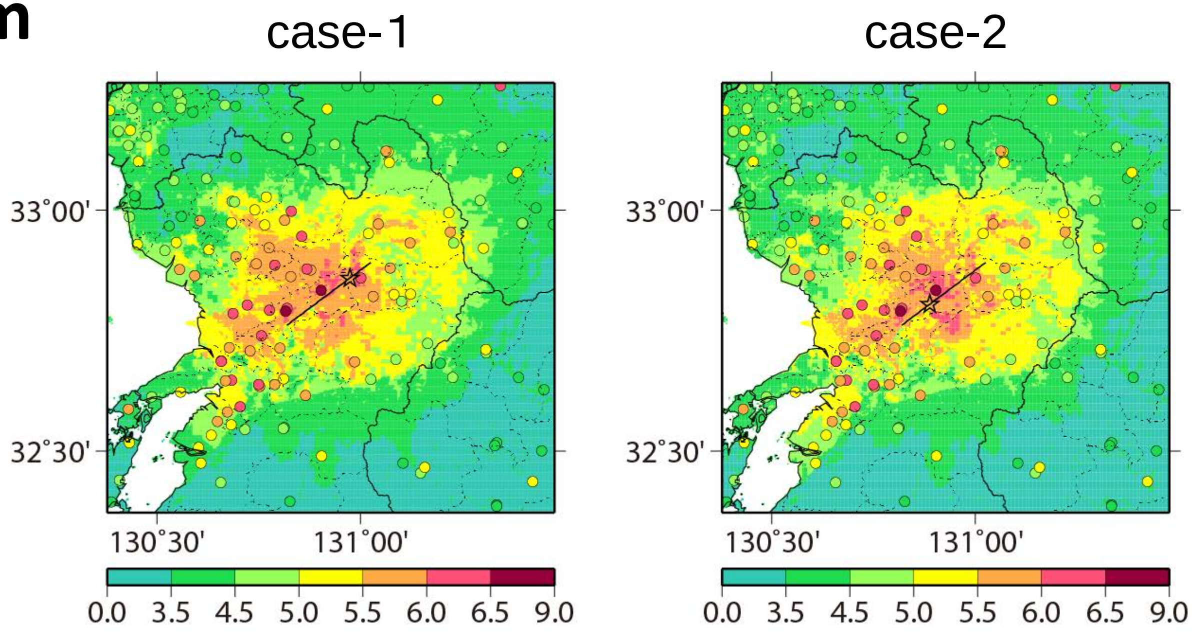
Distribution of JMA seismic intensity by SIP real-time damage estimation system

2016/04/14　21:26
Mj6．5 (Mw6．1)

2016/04/16　1:25
Mj7．3　(Mw7．0)

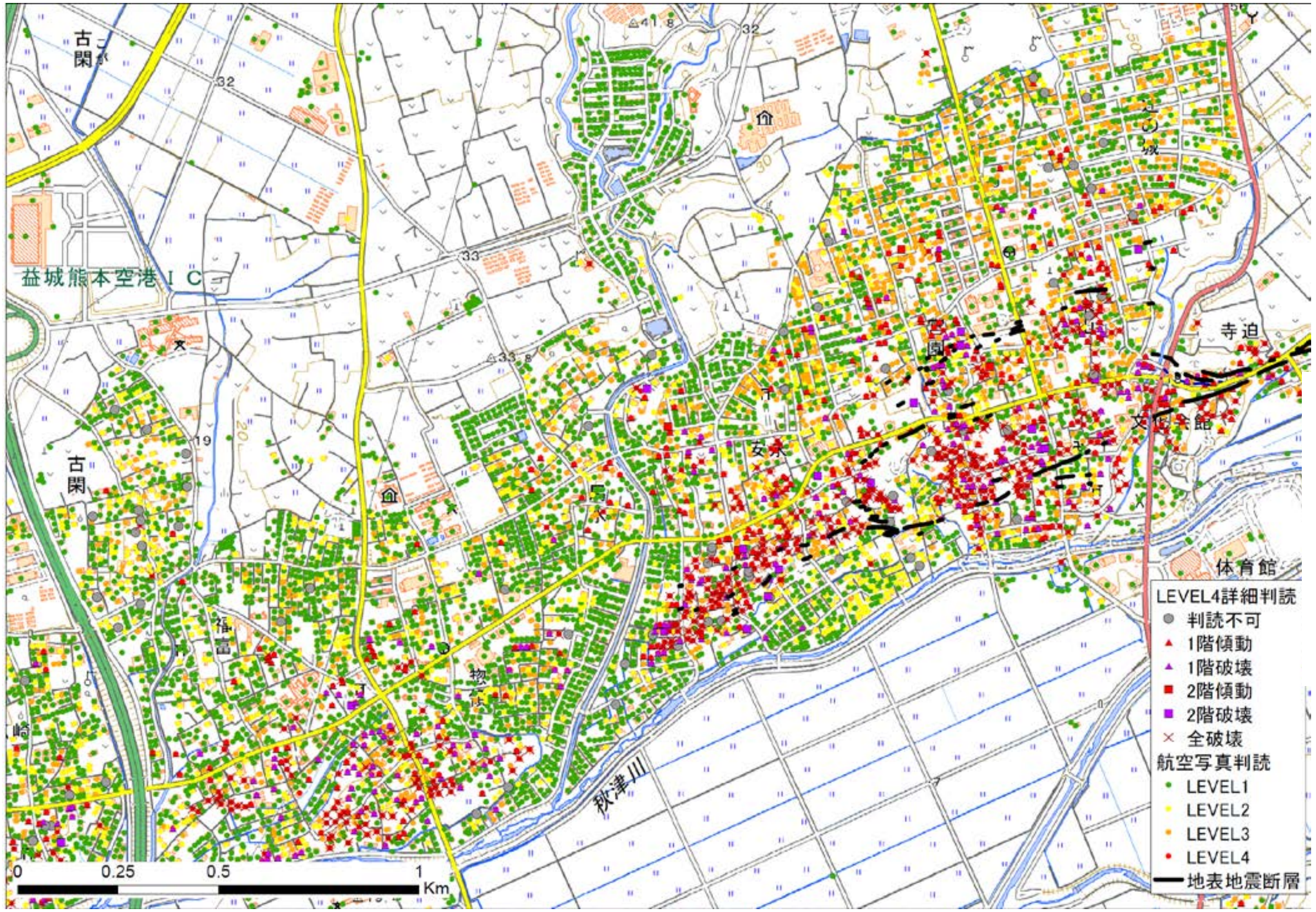


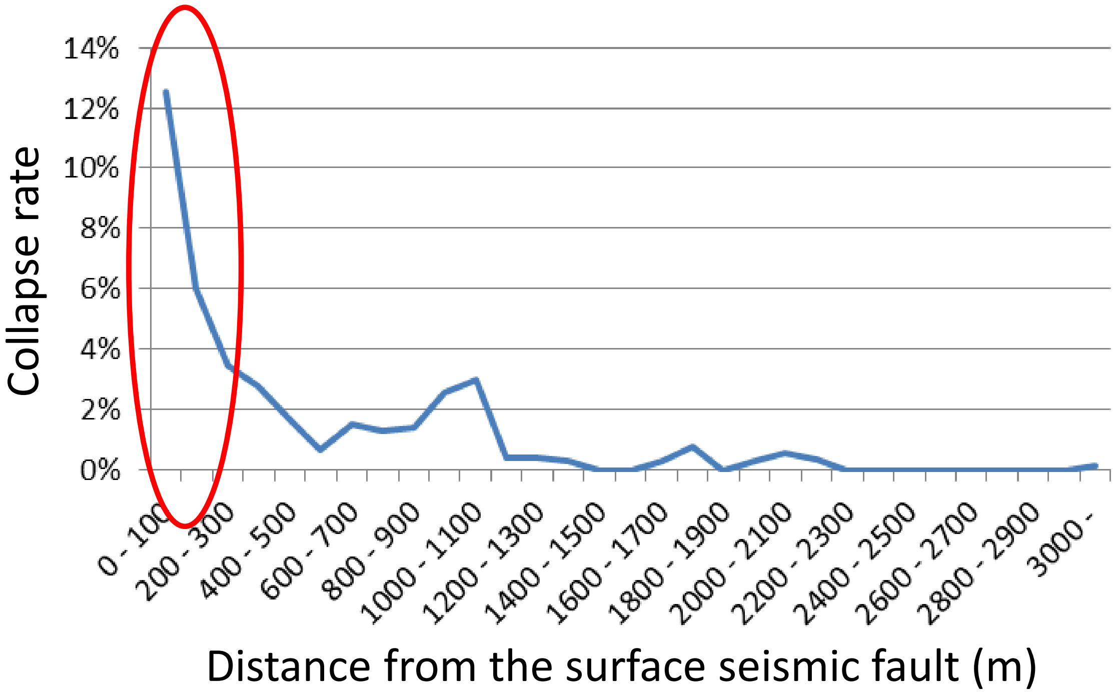
Scenario earthquake shaking maps for Futagawa fault zone (HERP, 2014; Fujiwara et al., 2015)



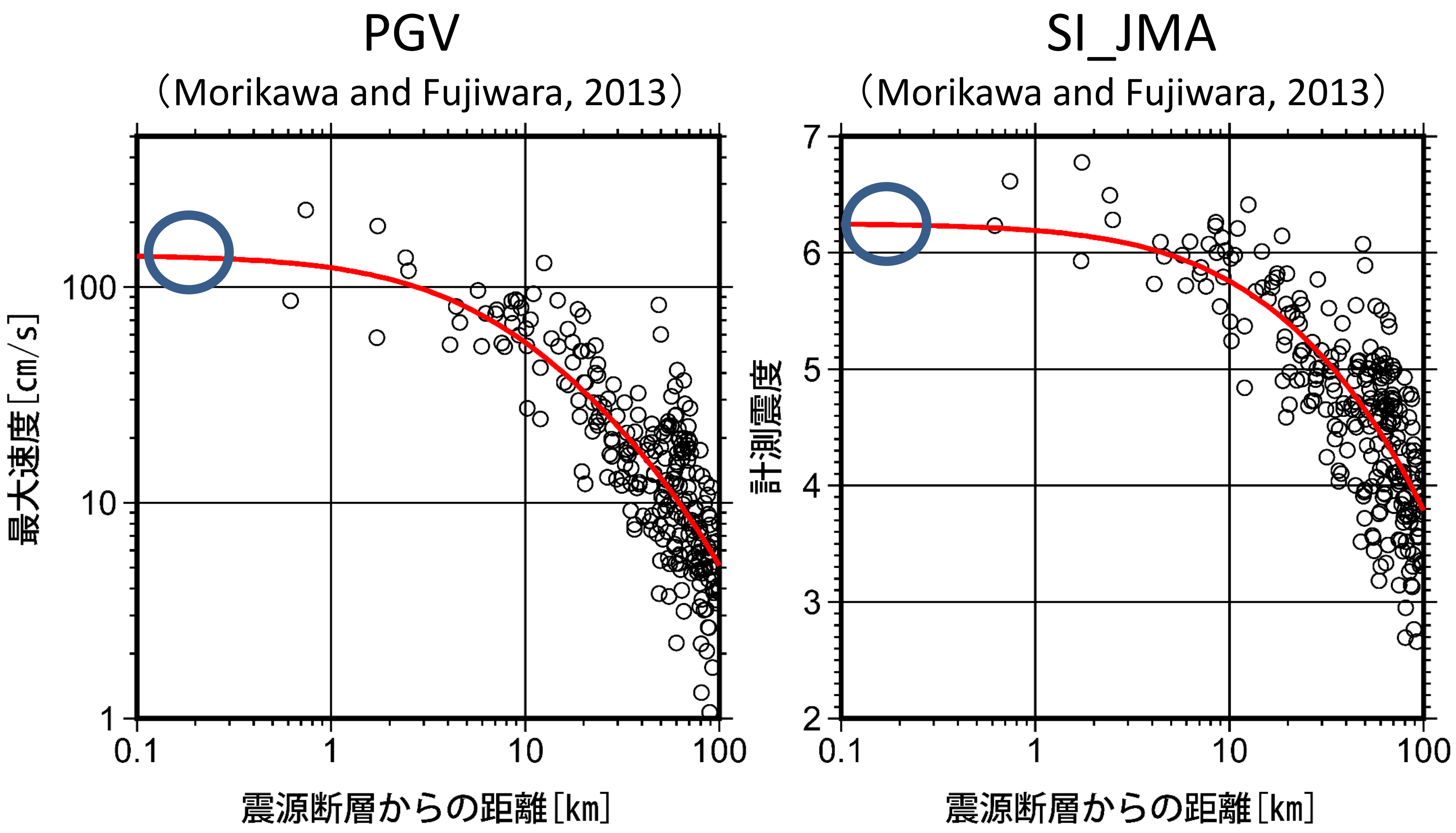
Comparison of observation (○)
and simulation (background)

Distribution of building damage in Mashiki Town





Increase in collapse rate near the surface seismic fault.



Conventional GMM cannot explain the increase in collapse rate near the fault.

$$u = \int_{\Sigma_D} \Delta u \frac{\partial G}{\partial n} dS + \boxed{\int_{\Sigma_S} \Delta u \frac{\partial G}{\partial n} dS} + \boxed{\int_{V_F} f dV}$$

deep part shallow part deformations

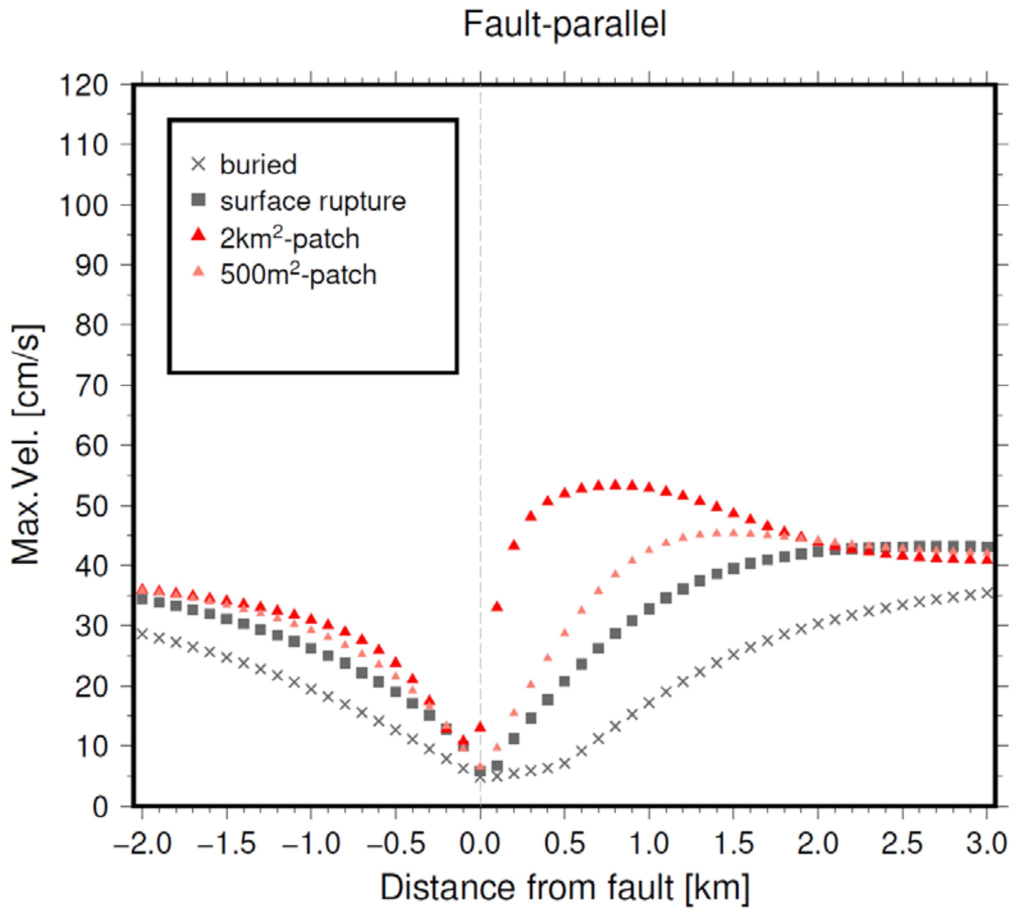
Here, the **first term** on the right-hand side represents the surface integral over the fault plane corresponding to the **contribution from the deep part of the fault**, the **second term** represents the surface integral over the fault plane corresponding to the **contribution from the shallow part of the fault**, and the **third term** is a **volume integral** representing **deformations in the shallow part of the fault**.

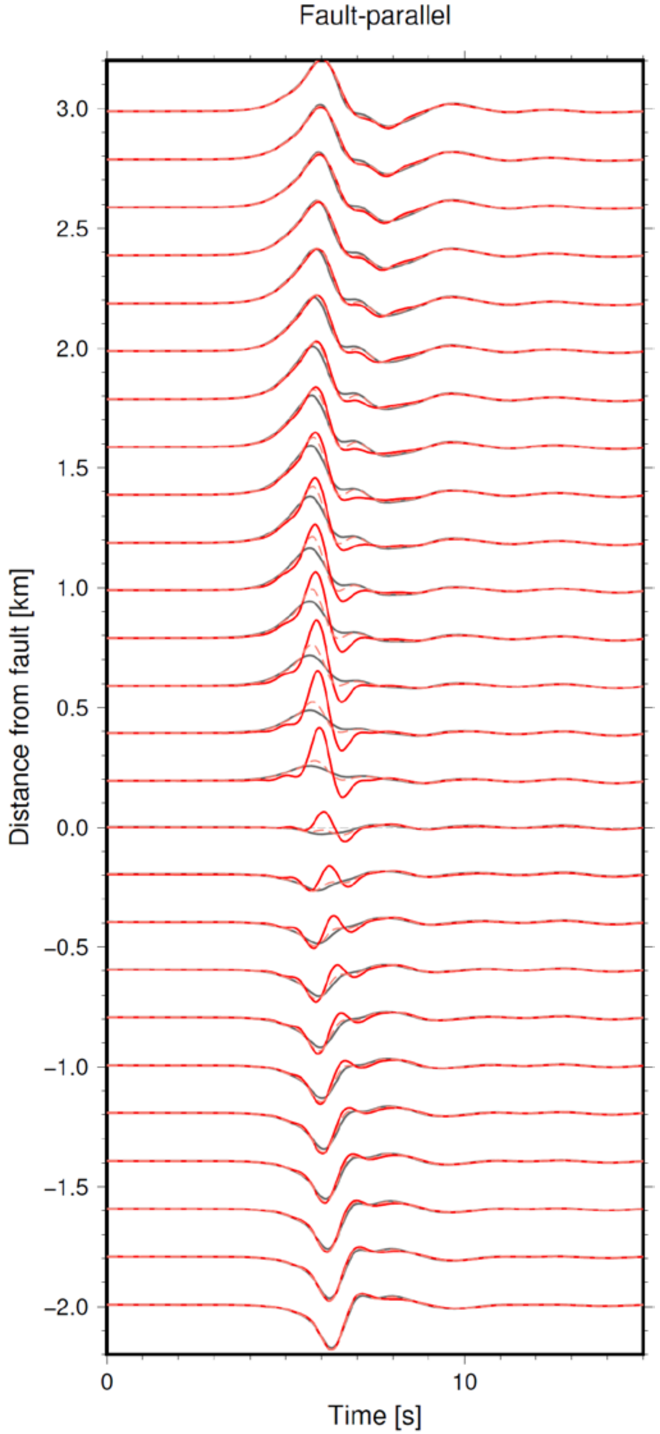
The integrals for **the first and second terms** can be **approximated by double-couple forces** and expressed as a collection of double-couple point sources distributed over the fault plane. **Considering only the first and second terms makes it difficult to explain the localized amplification of ground motion within a region about 100 meters from the surface earthquake fault, even when accounting for shallow faulting extending to the ground surface.**

On the other hand, **the volume integral of the third term expresses the deformation occurring within the fault zone existing only in the immediate vicinity of the surface earthquake fault as an integral of single forces acting at each point.** The influence of the third term is considered to be confined within the fault zone and to decay rapidly outside it. **Although the third term acts as a non-double-couple seismic source that affects only the immediate vicinity of the fault**, its effect is thought to be negligible at distances somewhat farther from the surface earthquake fault.

$$u = \int_{\Sigma_D} \Delta u \frac{\partial G}{\partial n} dS + \boxed{\int_{\Sigma_S} \Delta u \frac{\partial G}{\partial n} dS}$$

deep part shallow part

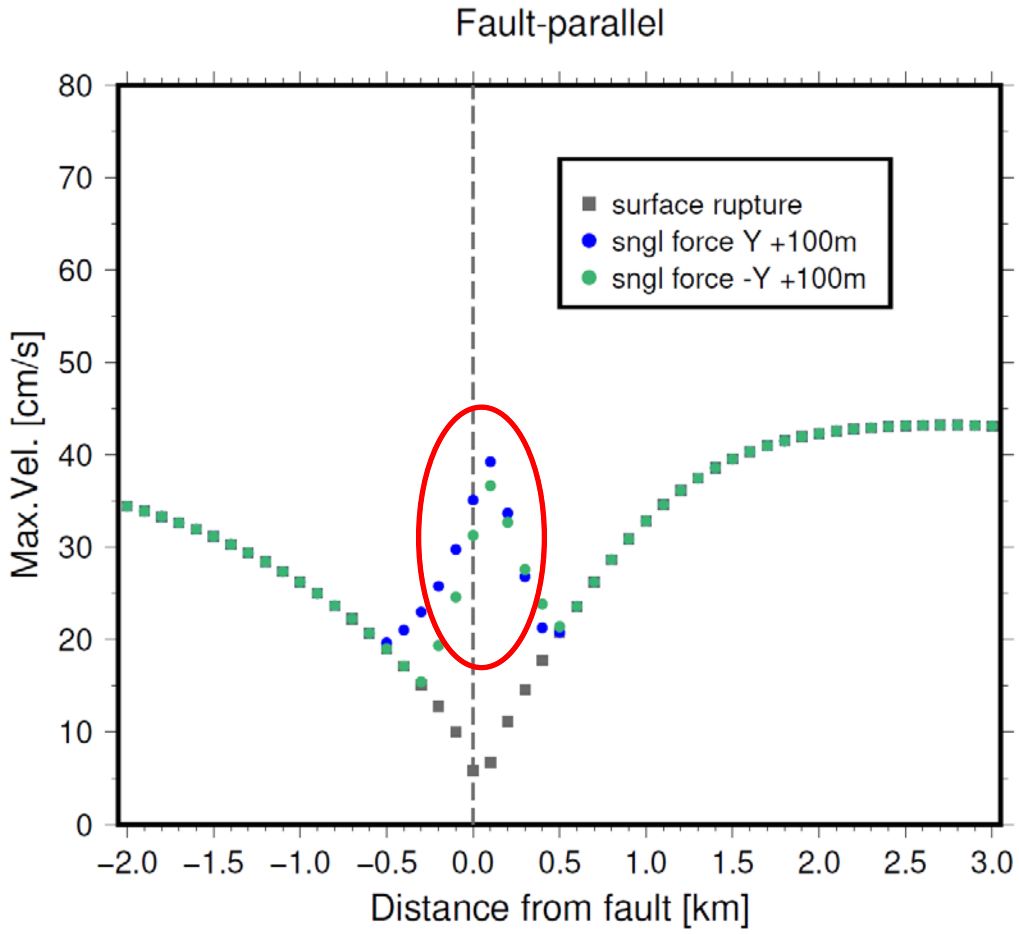


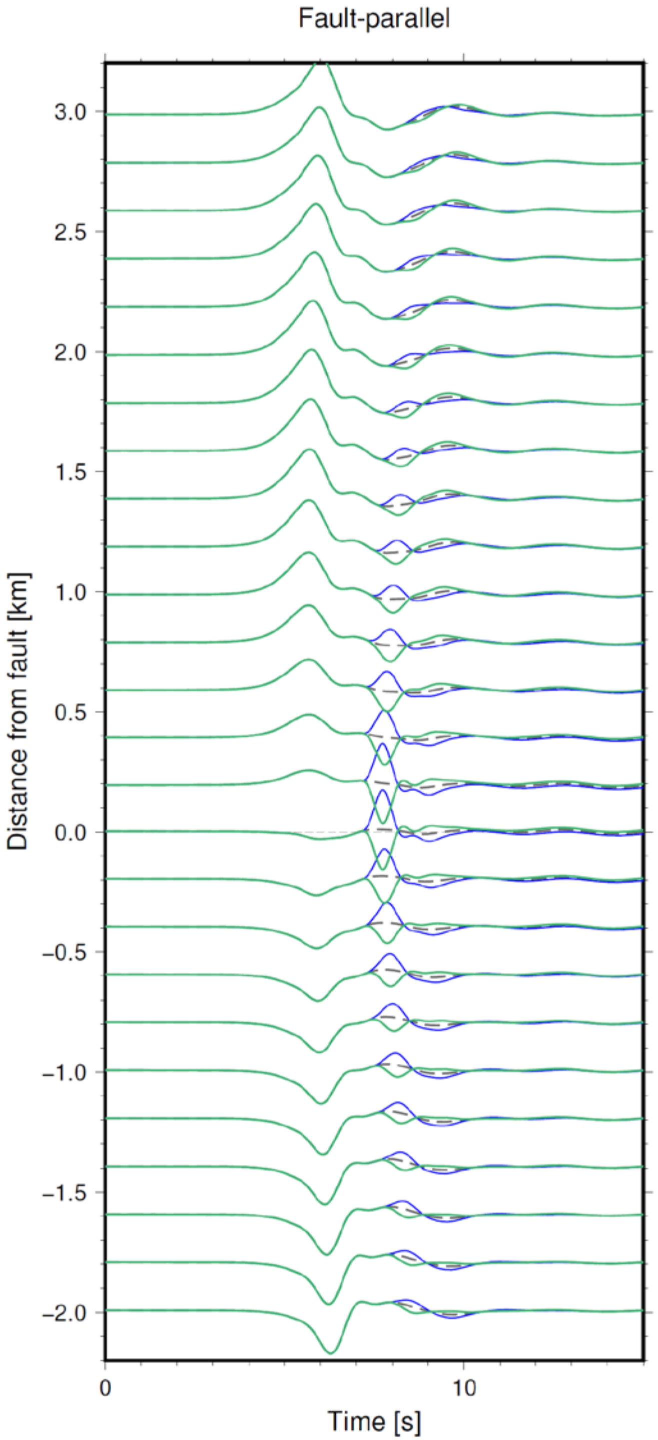


Considering only the first and second terms makes it difficult to explain the localized amplification of ground motion within a region about 100 meters.

$$\mathrm{u} = \int_{\Sigma_D} \Delta u \frac{\partial G}{\partial n} dS + \boxed{\int_{\Sigma_S} \Delta u \frac{\partial G}{\partial n} dS} + \boxed{\int_{V_F} f dV}$$

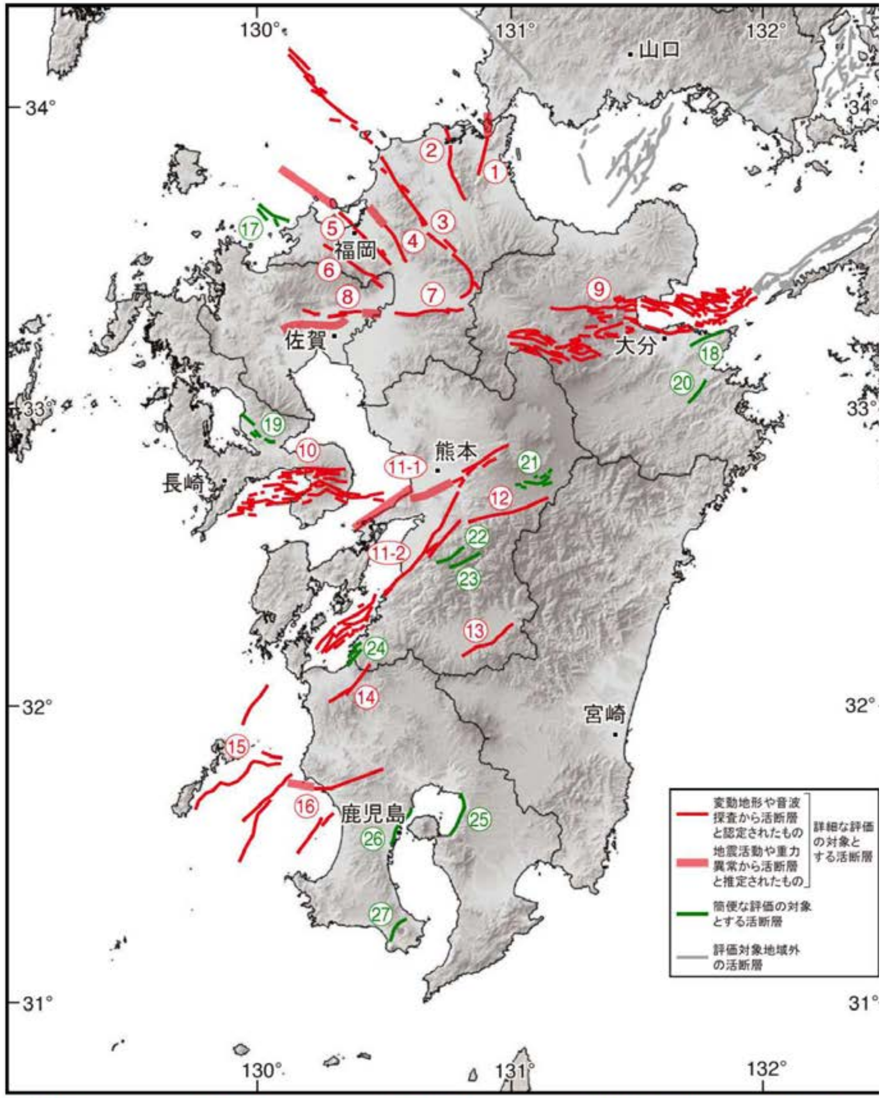
deep part　　shallow part　　deformations





The third term acts as a non-double-couple seismic source that affects only the immediate vicinity of the fault.

九州地域評価



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

布田川断層帯･日奈久断層帯の評価

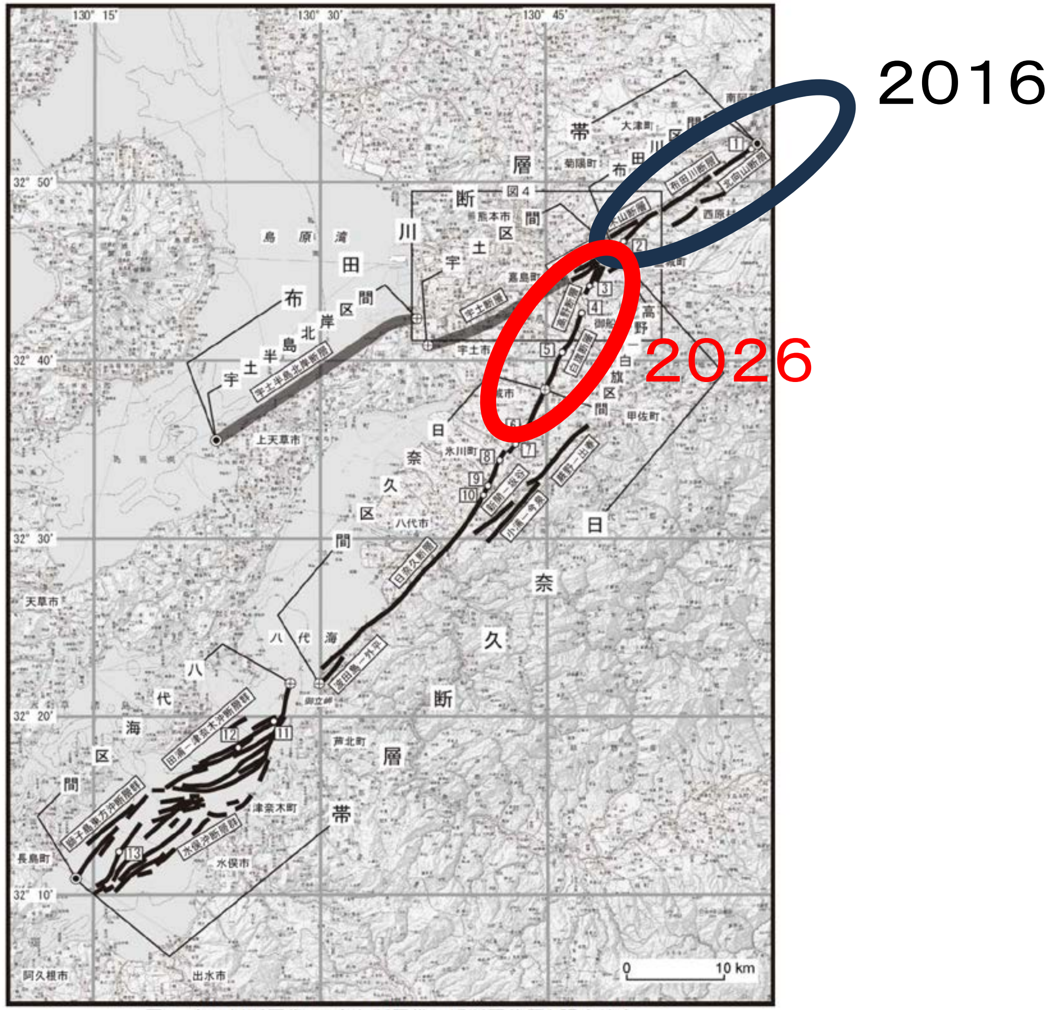


図2　布田川断層帯･日奈久断層帯の活断層位置と調査地点

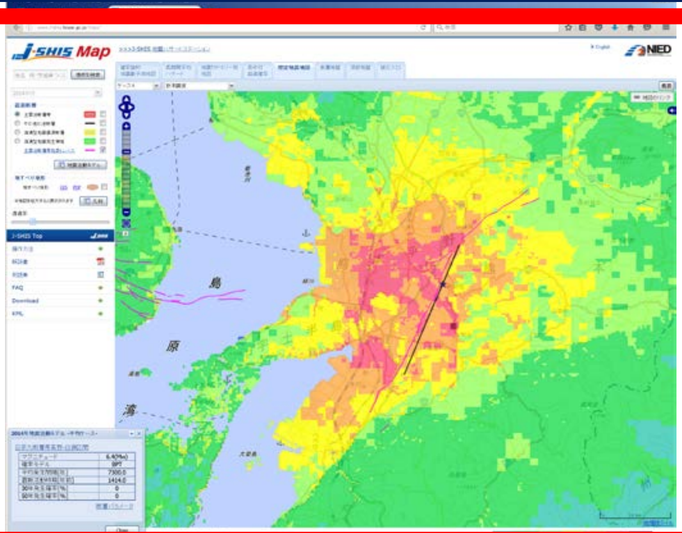
1:白川左岸地点　2:田中地点　3:高木地点　4:白旗地点　5:鰐瀬地点　6:南小野地点　7:南部田地点　8:高塚B地点　9:腹巻田地点　10:栫地点　11:八代海白神岩地点　12:八代海津奈木沖地点　13:八代海南西部海底地点

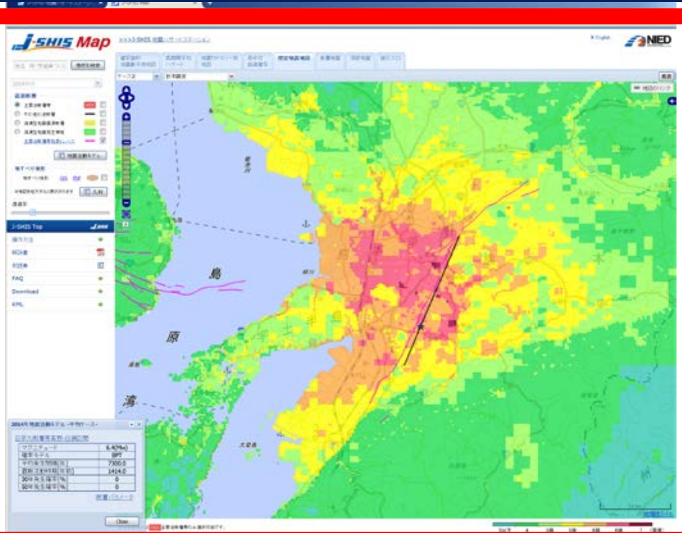
◉:断層帯の北東端と南西端　⊕:活動区間の境界

地震調査研究推進本部
地震調査委員会　公表資料より

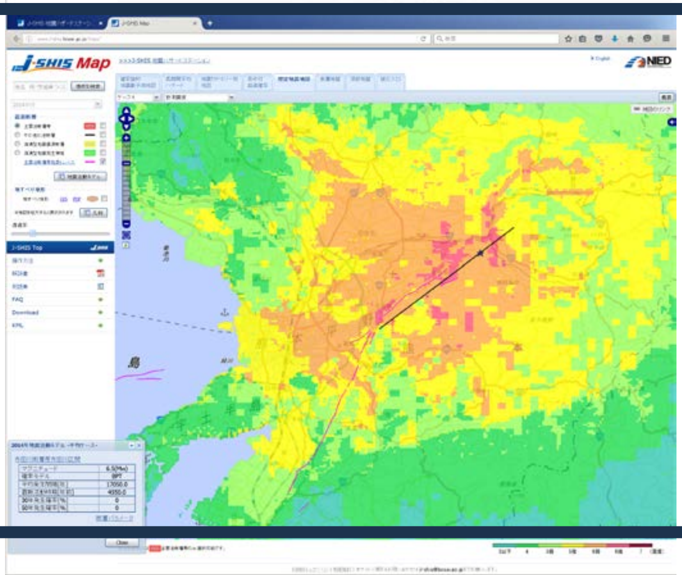
Scenario Earthquake Shaking Maps

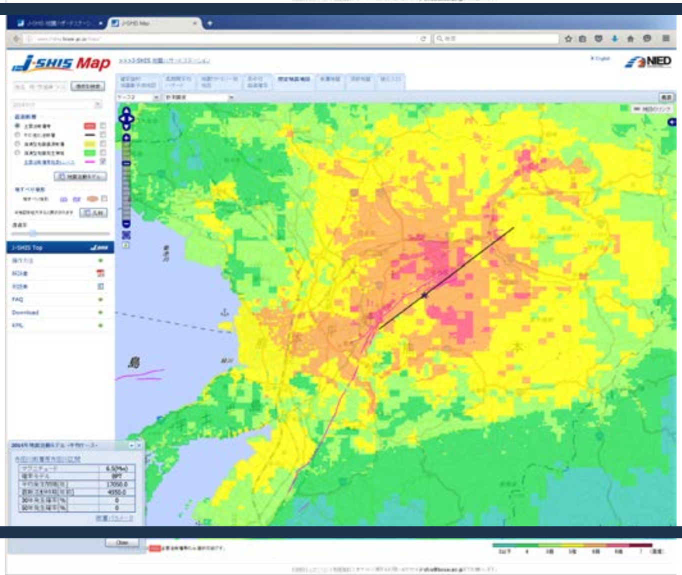
2026





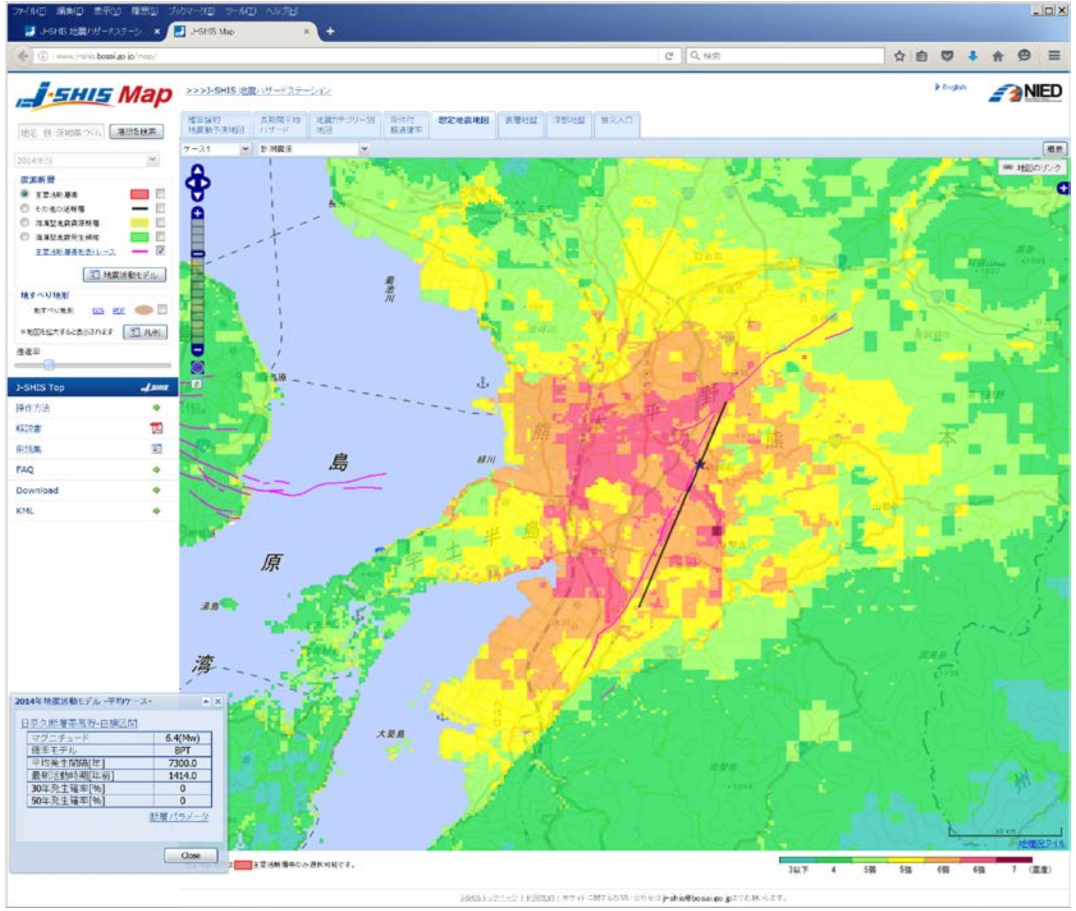
2016



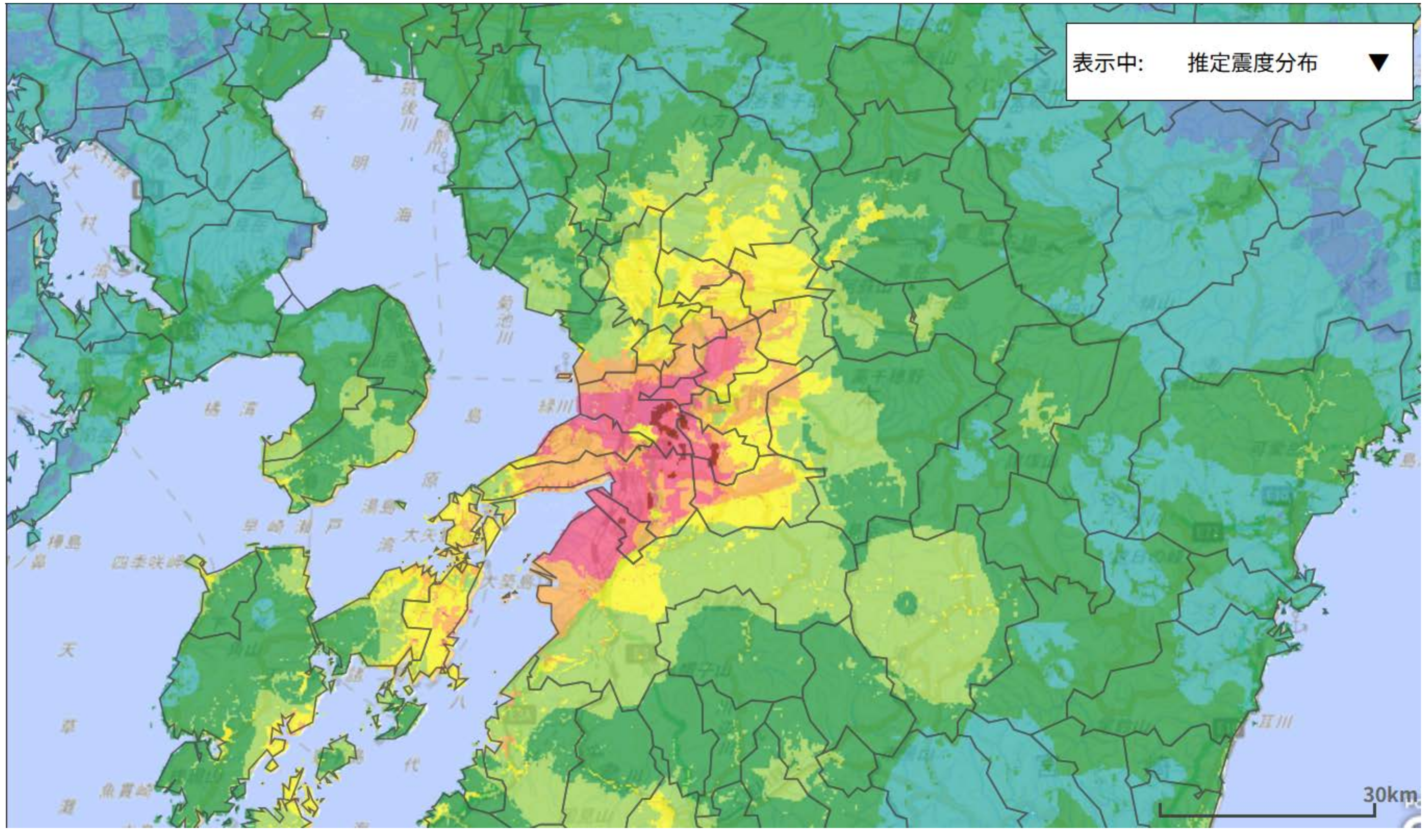


過去の評価
防災科学技術研究所研究資料　第256号　藤原・他（2004）
布田川・日奈久断層帯の地震を想定した地震動予測地図作成手法の検討

Hazard Map



2026 Kumamoto EQ



Thank you for your kind attention