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Progress of Seismology and its Application toward Seismic Disaster Risk Reduction

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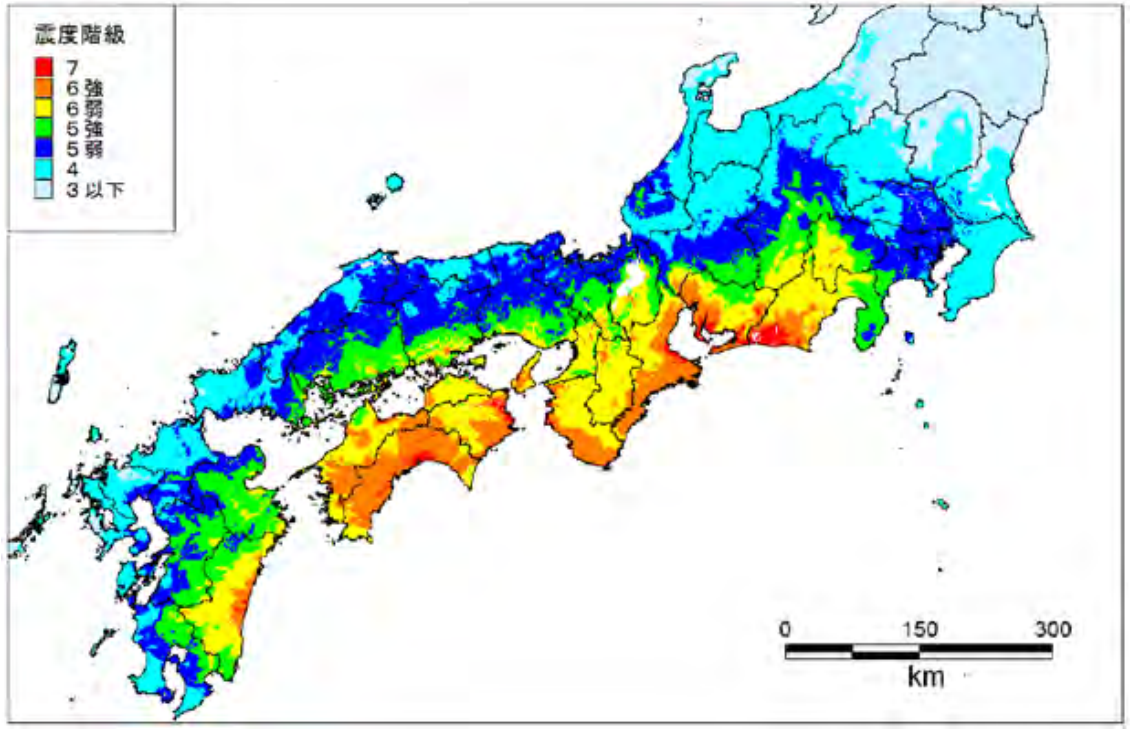
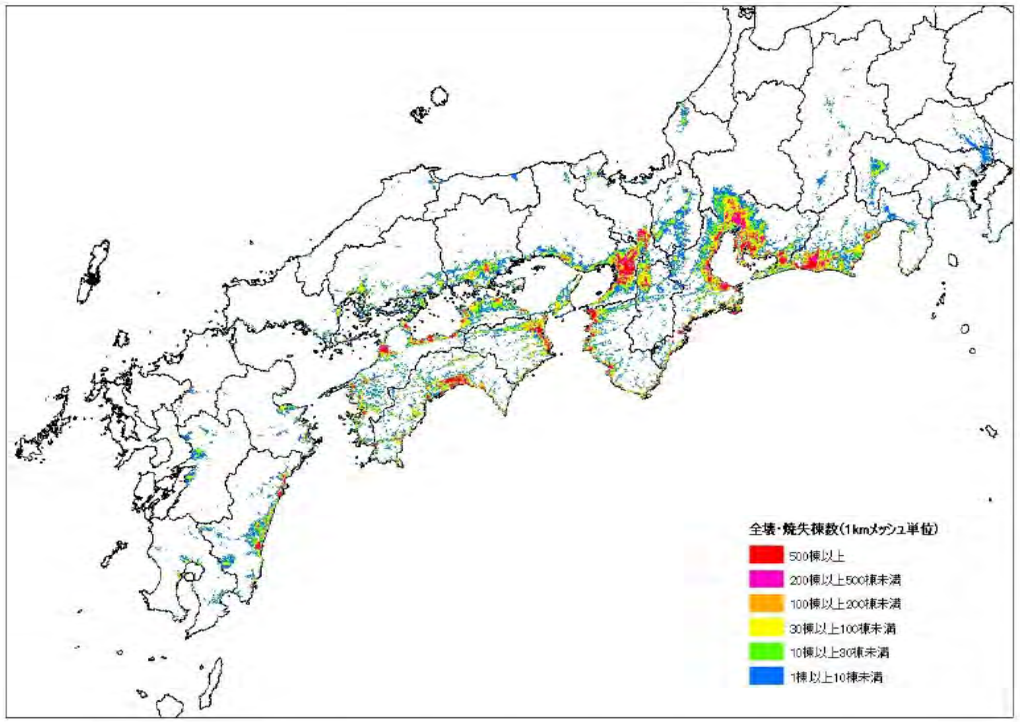
Anticipated megathrust earthquakes

Japan is surrounded by potential source areas of megathrust earthquakes (1923 Kanto, 2011 Tohoku, …)
Nankai trough earthquakes have repeatedly occurred with 10^1 ~10^2 years intervals in the history.





Prediction of seismic intensity and building severe damage for a scenario case of the anticipated Nankai Trough earthquake by the Cabinet Office of Japan (2012, 2019)

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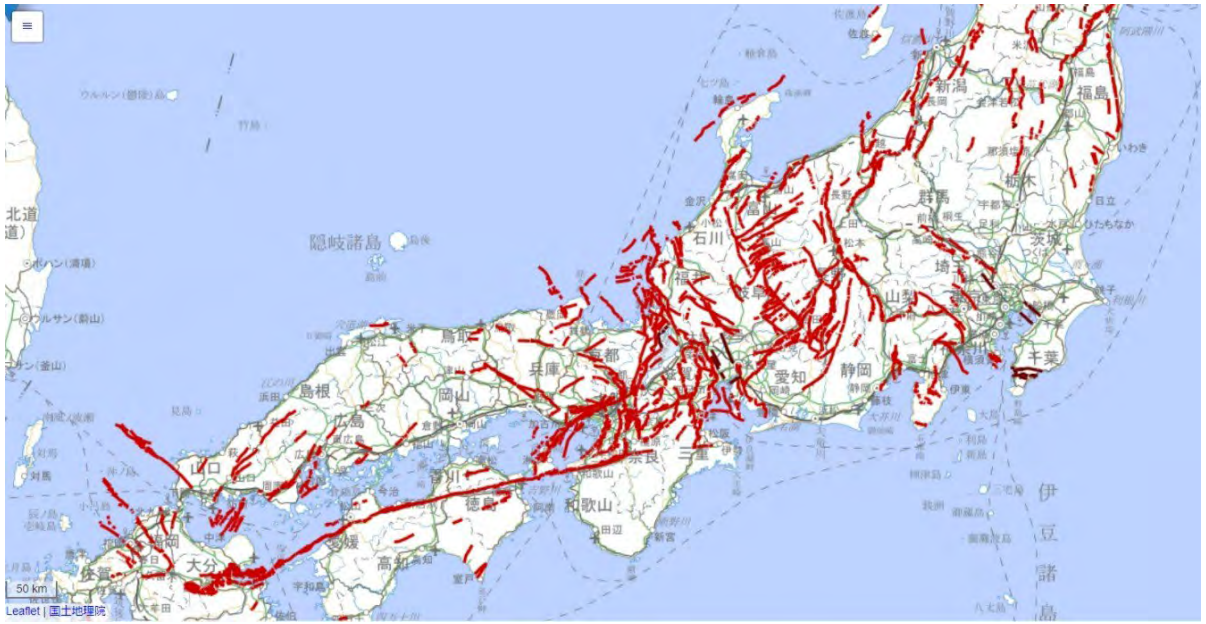
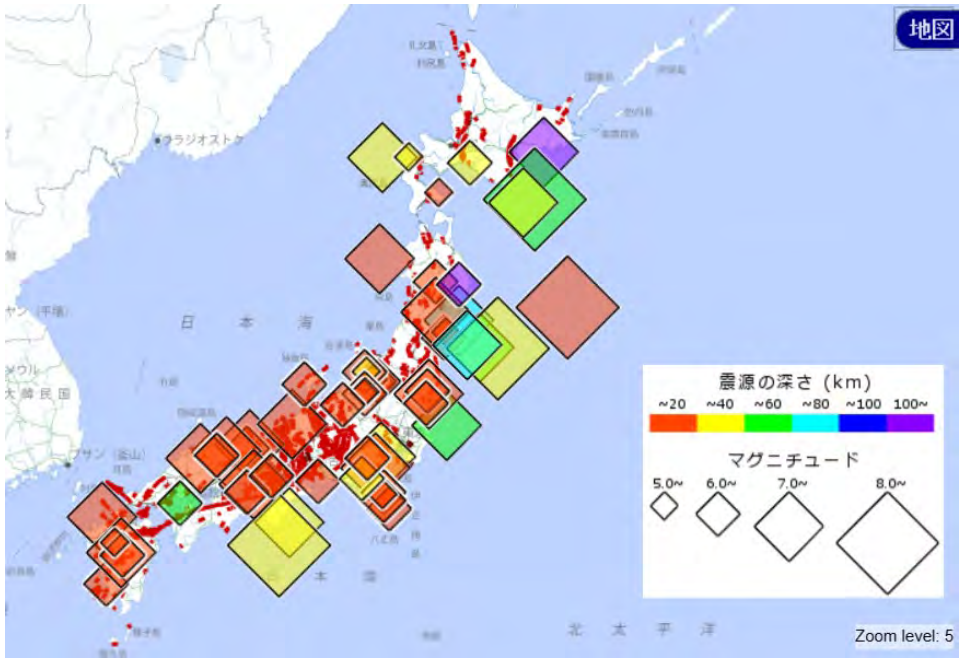
It is an urgent issue to predict and prepare for the catastrophic seismic disaster

Potential inland shallow earthquakes

There are numerous active faults in the inland part of Japan islands that can potentially cause destructive shallow earthquakes (ex. 1995 Kobe, 2016 Kumamoto, …)





Active faults and major earthquakes since 1923, from the Active Fault Database by Geological Survey of Japan, AIST. https://gbank.gsj.jp/activefault/index

Focus of this talk:
Current status and issues of prediction and preparedness for the future seismic disaster in Japan

(some of the) Milestones

1923 Great Kanto Earthquake, M7.9

1946 Nankai Earthquake, M8.0

1948 Fukui Earthquake, M7.1

1959 Typhoon Vera (Ise-wan)

1978 Miyagi Earthquake, M7.4

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

2011 Off the Pacific Coast of Tohoku Earthquake, M9.0

1925 Earthquake Research Institute, U Tokyo

1950 Building Standard Act

1953 Strong motion observation

1961 Disaster Countermeasures Basic Act

1981 Building Standard Act Amendment

1995 Act of Special Measures on Earthquake Disaster Countermeasures
Headquarters for Earthquake Research Promotion (HERP)

1996 Instrumental seismic intensity installed

2005 National Seismic Hazard Maps

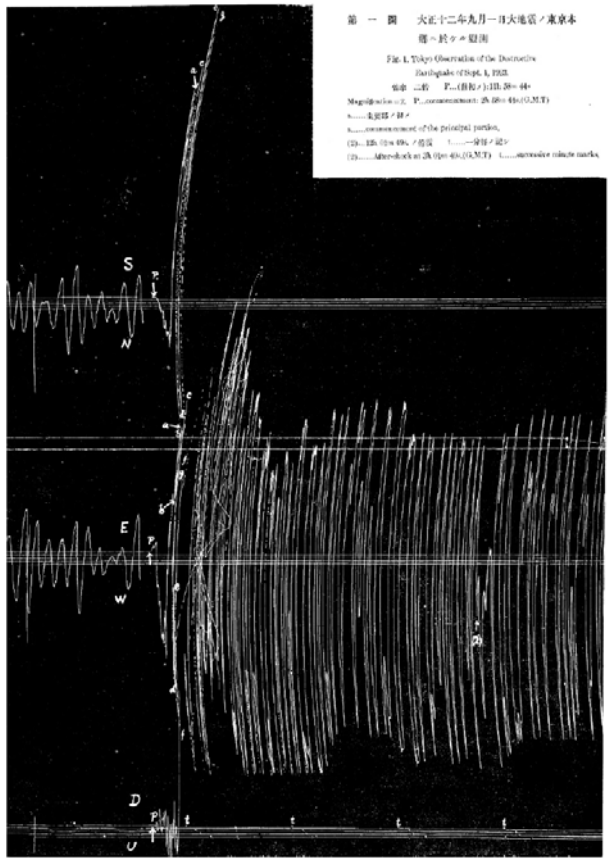
2007 Earthquake Early Warning

2011 Ocean-bottom seismic observation

2013 Long-period ground motion intensity scale

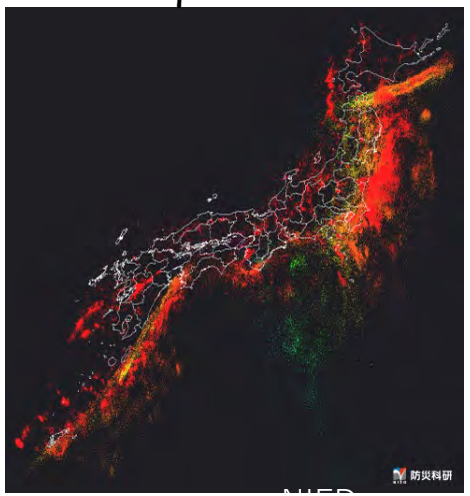
Progress of seismology with observation data

Modern seismology in Japan developed with the development of seismic observation since late 19th century.
Various kinds of observation systems provide essential data for earth science studies.

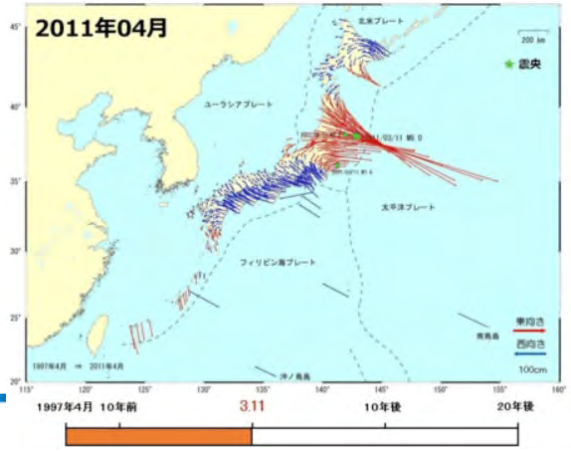


Imamura (1925)

Earthquake source

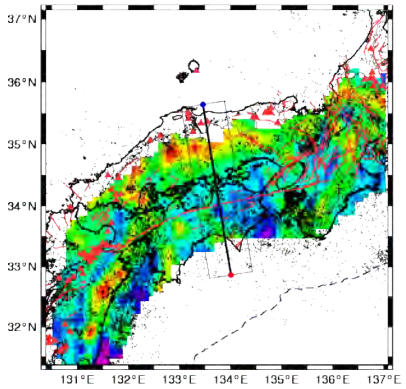


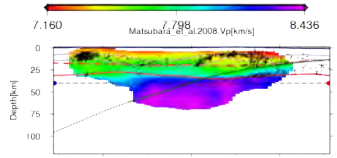
Crustal deformation



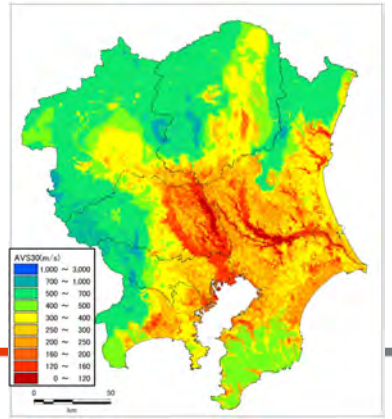
GSI

Earth structure

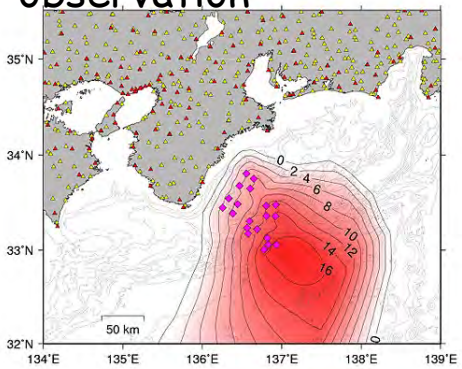




Compiled by AIST



Ocean-bottom seismic observation



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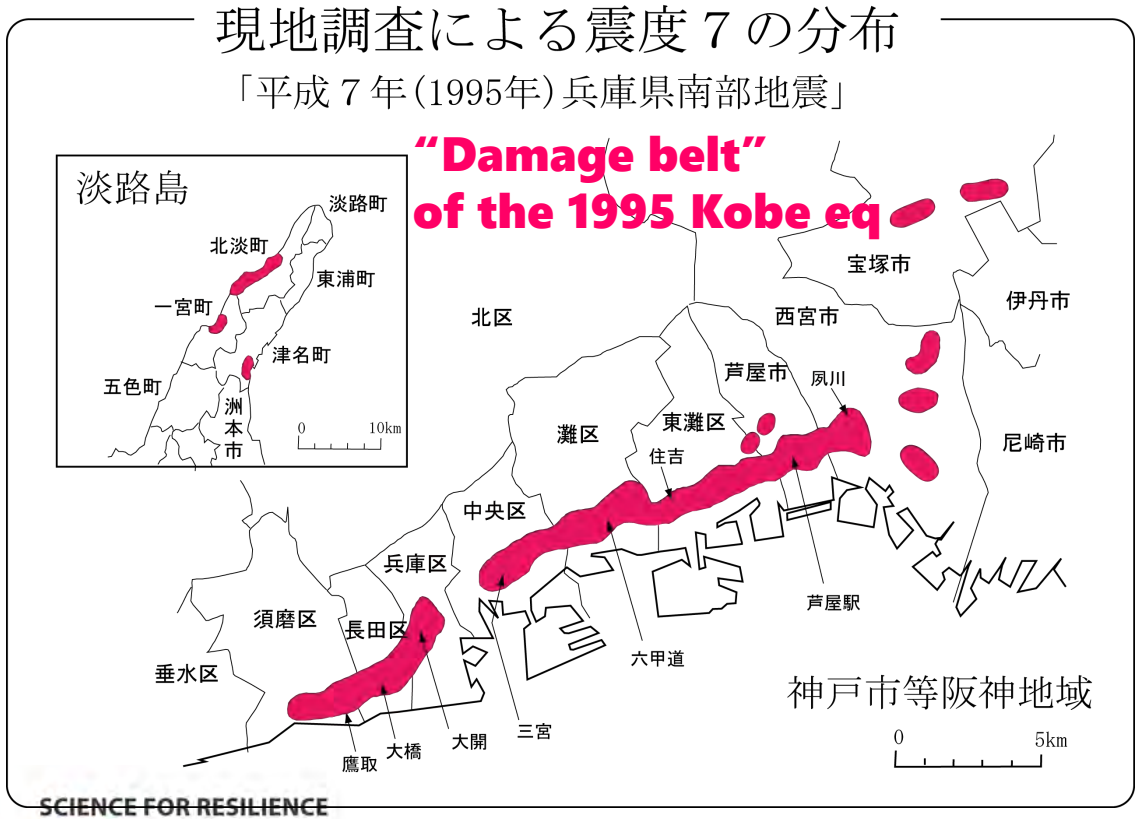
Enhancement of seismic observation

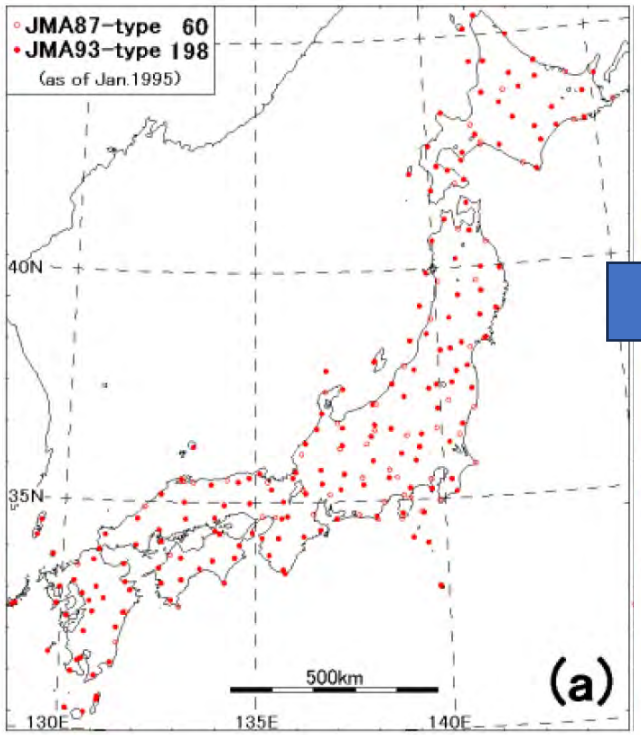
At the time of the 1995 Kobe earthquake, the number of observation stations was not enough to represent the “damage belt”.

→ Observation networks have been drastically enhanced after the 1995 earthquake.



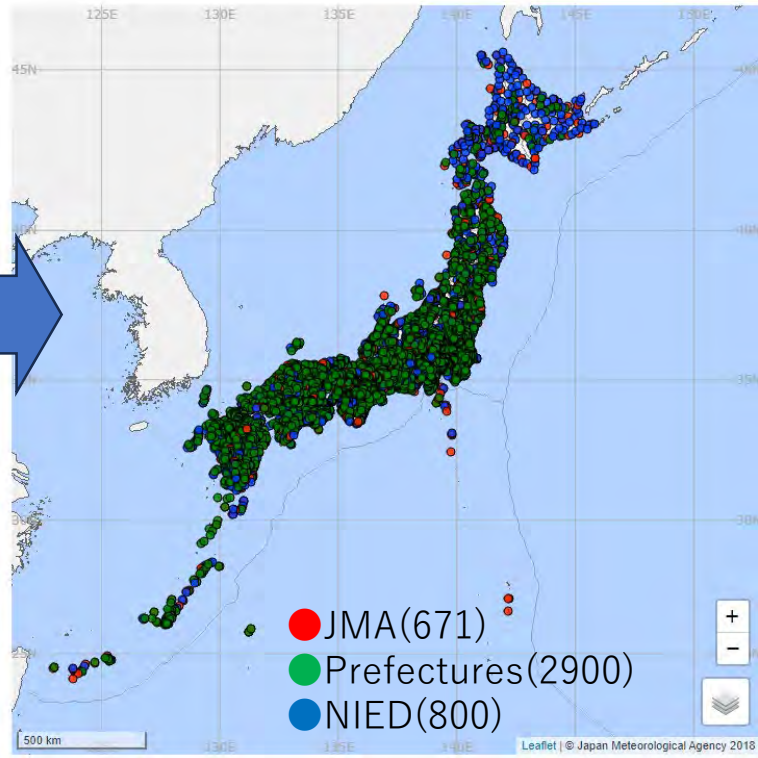
“Damage belt” estimated by field survey (JMA, 1995)

Before 1995 earthquake



Strong-motion observation stations by JMA as of Jan 1995 (Okada et al. 2004)

Present



Current seismic intensity observation system (JMA)

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Seismic hazard/risk assessment

Seismic hazard assessment (SHA), or quantification of ground-motion intensity level with associated uncertainty, is achieved by assembling all fields of seismology and related studies

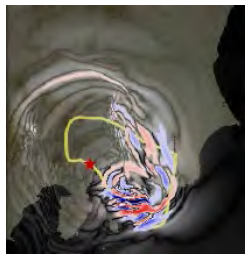
Earthquake source

Source models

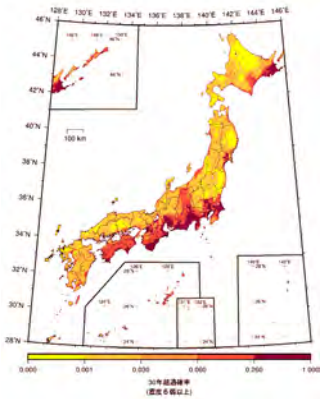
Seismic activity models

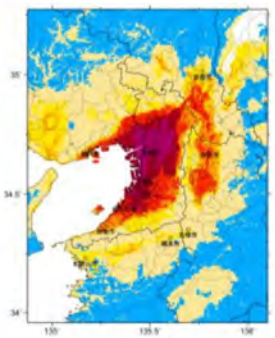
Earth structure

Propagation models



Wave propagation





Ground-motion prediction
Shaking maps

Probabilistic seismic hazard assessment (PSHA)

Damage estimation
buildings, economy, …

Risk assessment/management
Response measures

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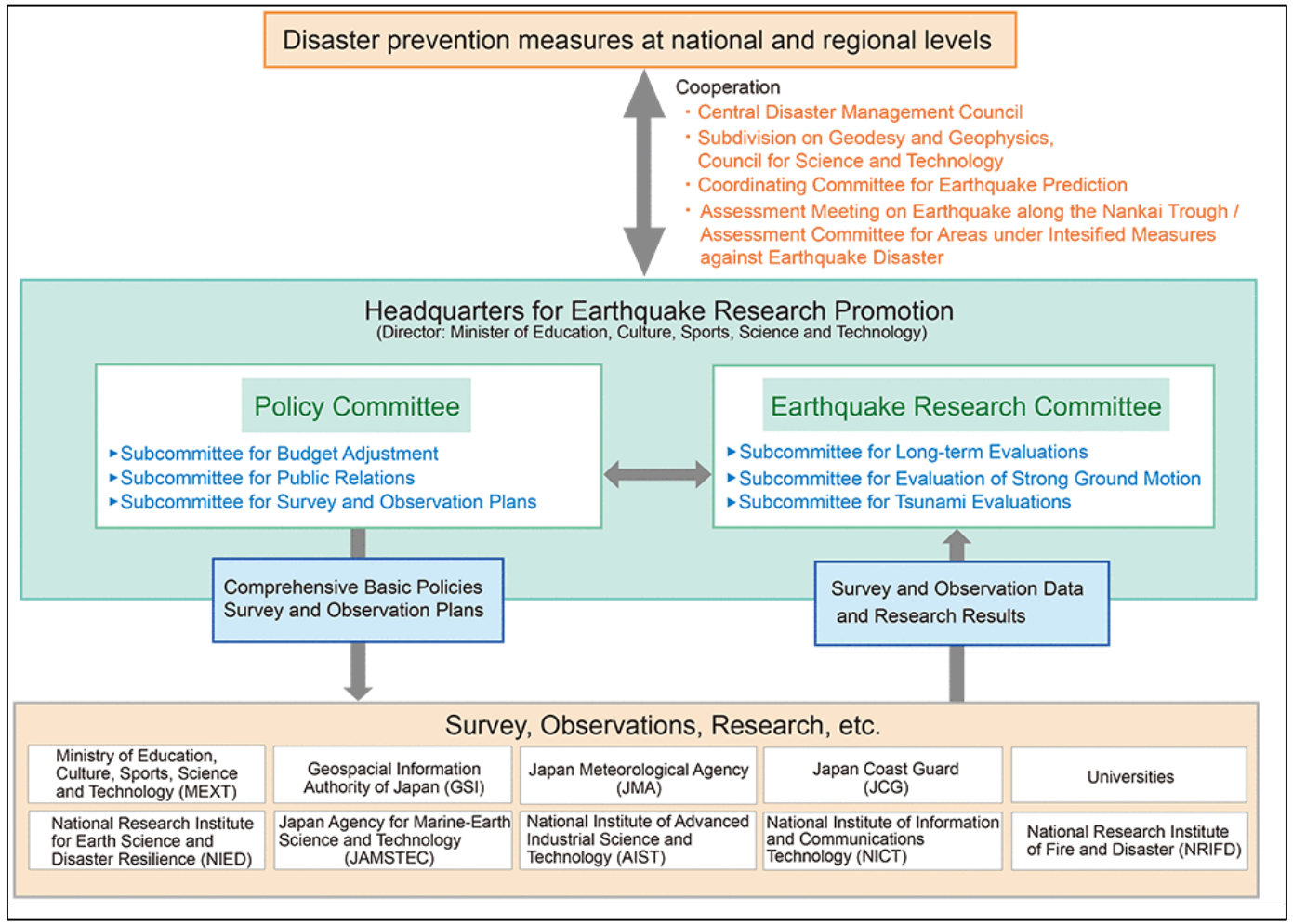
Headquarters for Earthquake Research Promotion (HERP)

1995 January 17 Hyogo-ken Nanbu (Kobe) earthquake
1995 July – Act on Special Measures on Earthquake Disaster Countermeasures

→ **Establishment of HERP** as a special governmental organization attached to the Prime Minister's Office (it now belongs to MEXT)

(Basic objective of HERP)
To promote research of earthquakes in order to strengthen earthquake disaster prevention measures, especially for the reduction of damages from earthquake.

- Planning of comprehensive and basic policies
- Coordination of budgets and other administrative work with related governmental organizations
- Establishment of comprehensive survey and observation plans
- Collection, arrangement, analyses and comprehensive evaluation of survey results by related governmental organizations, universities, etc.
- Publication based on the above evaluations



https://jishin.go.jp/

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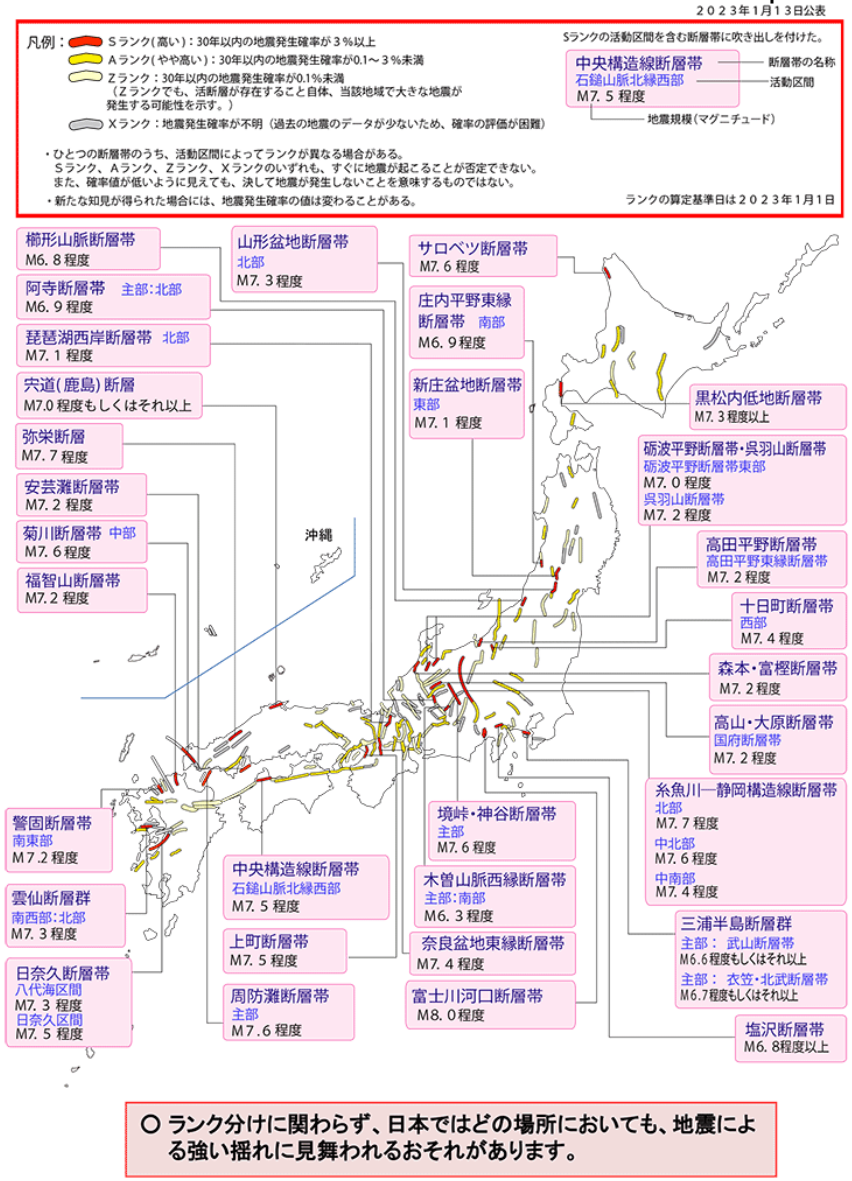
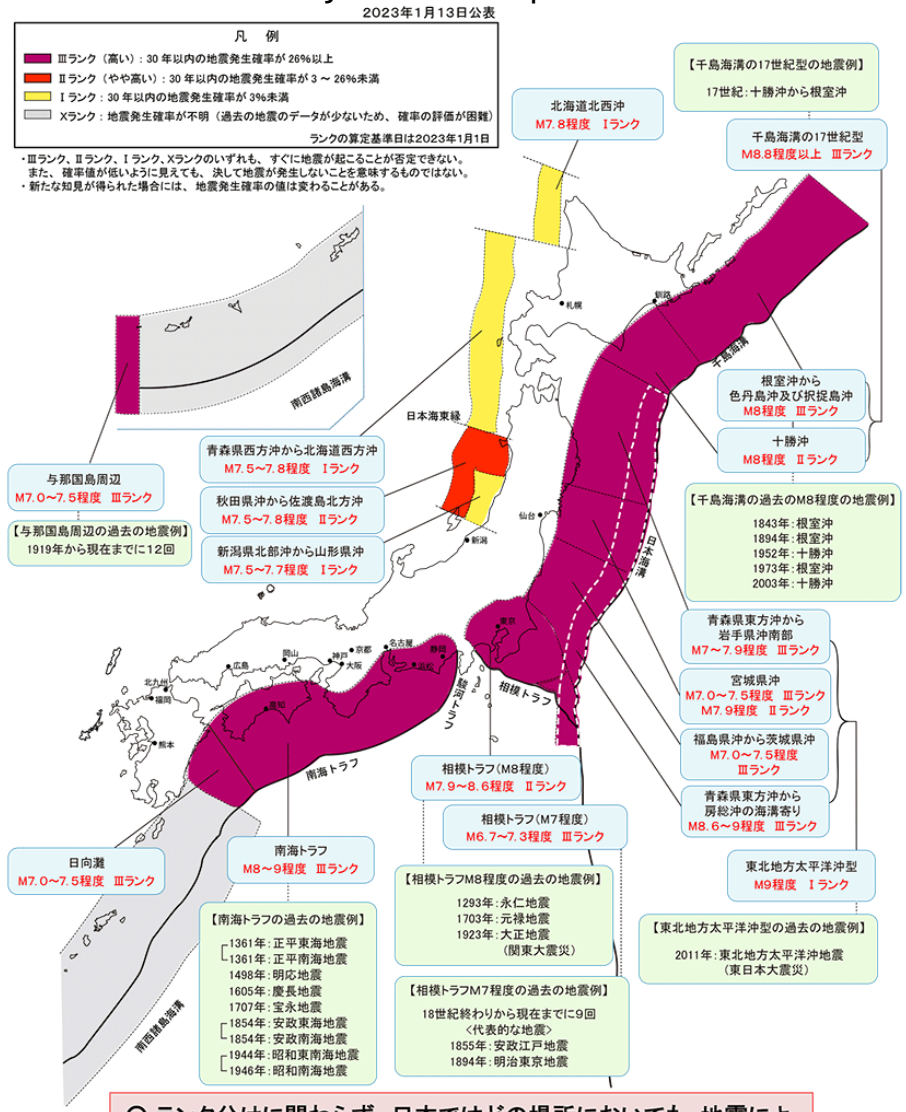
Long-term evaluation by HERP

Seismic activity and long-term occurrence probabilities for the **major active faults** and **subduction-zone earthquakes** are evaluated using research results from observation, historical data, geological/geomorphological survey, etc.

Classification for the occurrence probabilities for major earthquake sources



○ ランク分けに関わらず、日本ではどの場所においても、地震による強い揺れに見舞われるおそれがあります。



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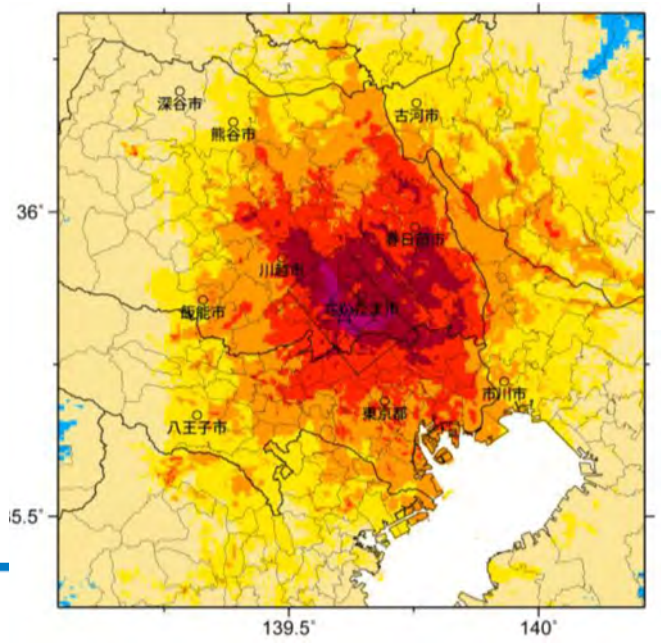
National Seismic Hazard Maps

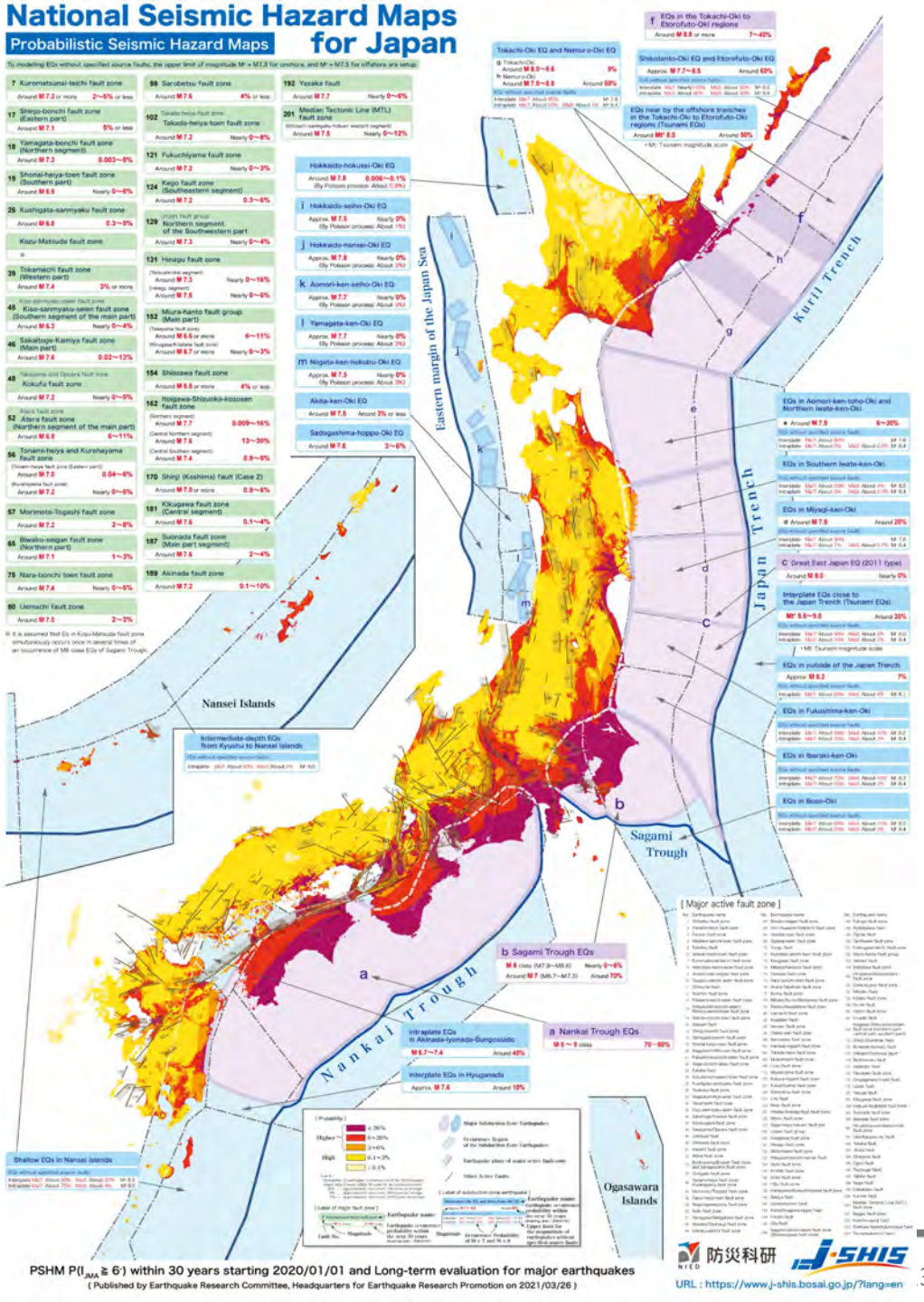
As a product of long-term evaluation and strong-motion evaluation of HERP, the first NSHMs were released in 2005.

NSHMs have been continuously updated and improved adopting the state-of-the-art evaluation and research results.

Probabilistic seismic hazard map

Scenario shaking map for major active faults

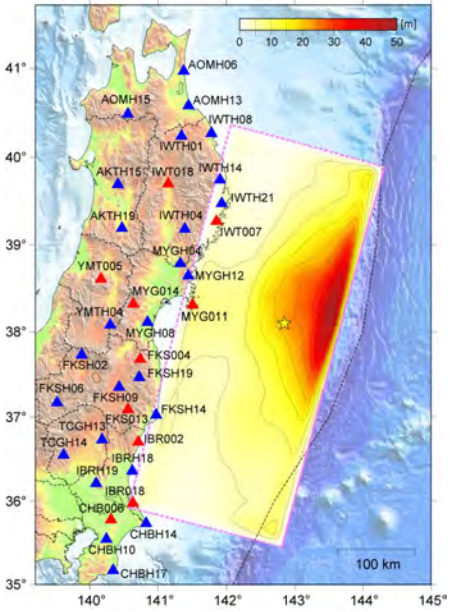




Revision of NSHMs after the 2011 M9.0 Tohoku earthquake

The 2011 Tohoku earthquake exhibited *unanticipated* natural phenomena, including the earthquake magnitude, ground motion and tsunami.

We learned how we had not known.



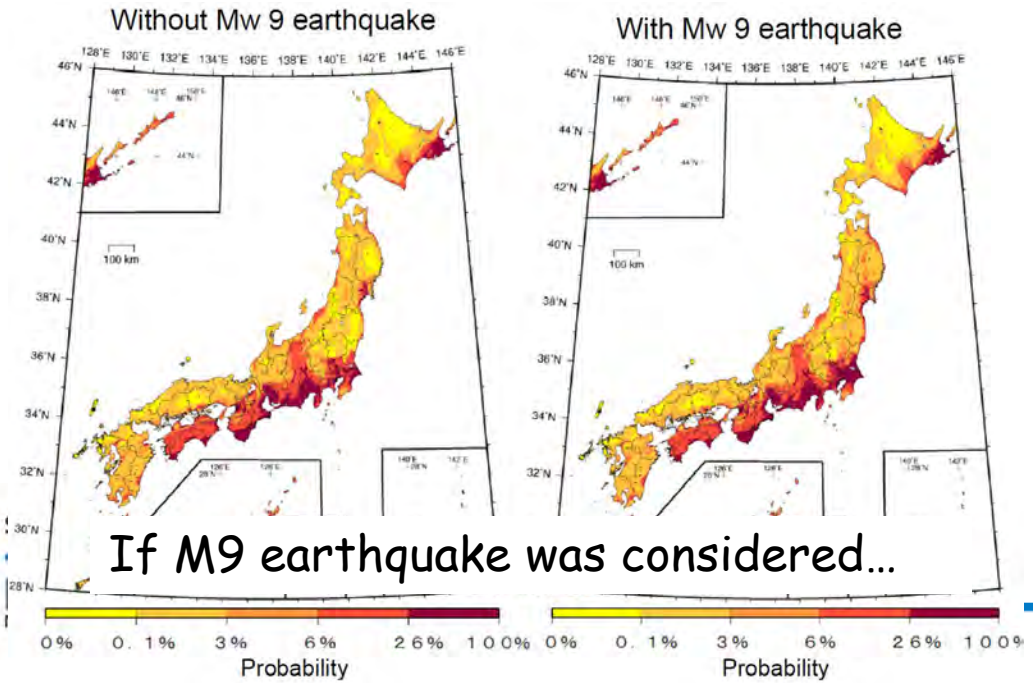
Suzuki et al. (2011)

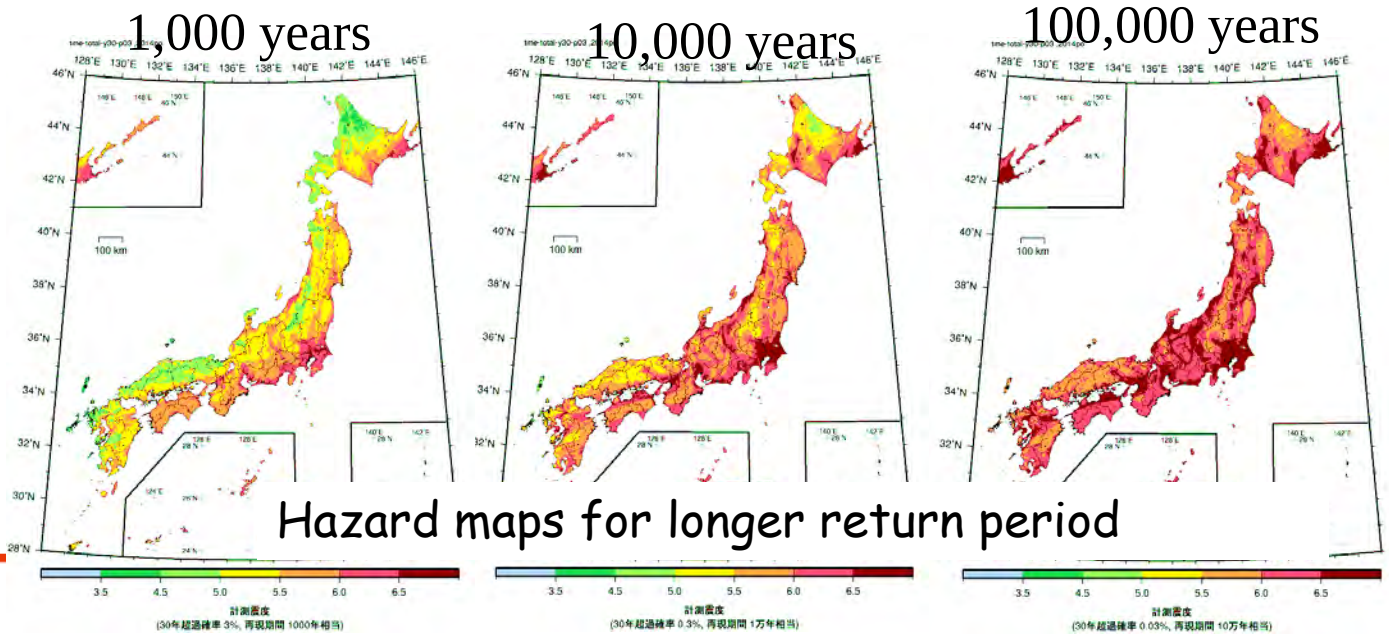
Revision based on the lessons from the 2011 M9.0 Tohoku earthquake:

→ Revision of seismic activity model and SHA with appropriate quantification of uncertainty, considering potential source area with low-frequent activity

→ Revision of the ground-motion prediction model for large-scale fault

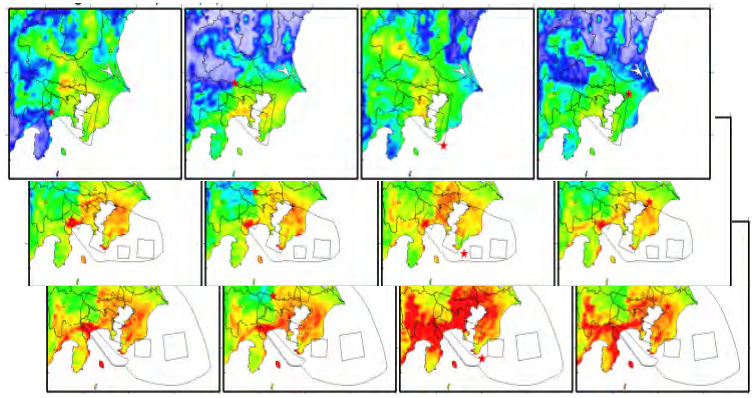
→ Review of representation of hazard information

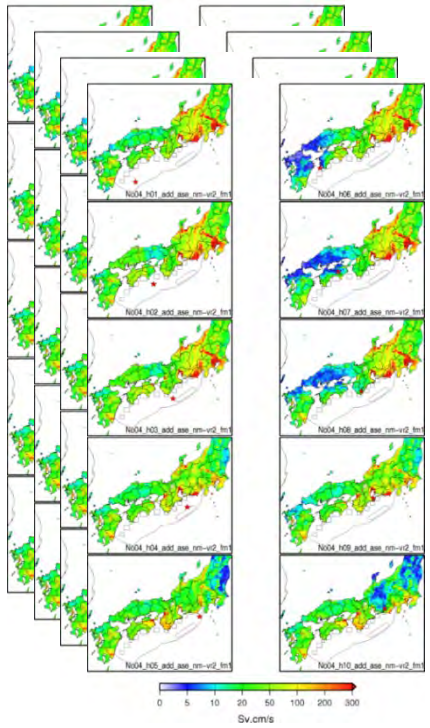




Summary

- In the last 100 years since the 1923 Great Kanto earthquake, confronting the risk from the future earthquakes, progress of seismology have contributed to various technologies and systems for seismic hazard assessment and disaster mitigation
- Establishment of the Headquarters for Earthquake Research Promotion (HERP) after the 1995 Kobe earthquake further accelerated seismological research and its application, including the enhancement of seismic observation.
- The first national seismic hazard maps (NSHMs) of Japan were released by HERP in 2005.
- The 2011 Tohoku earthquake was an unanticipated huge event. Based on the lessons from this earthquake, major revision was made to NSHMs, considering the uncertainty of both the natural phenomena and our knowledge.





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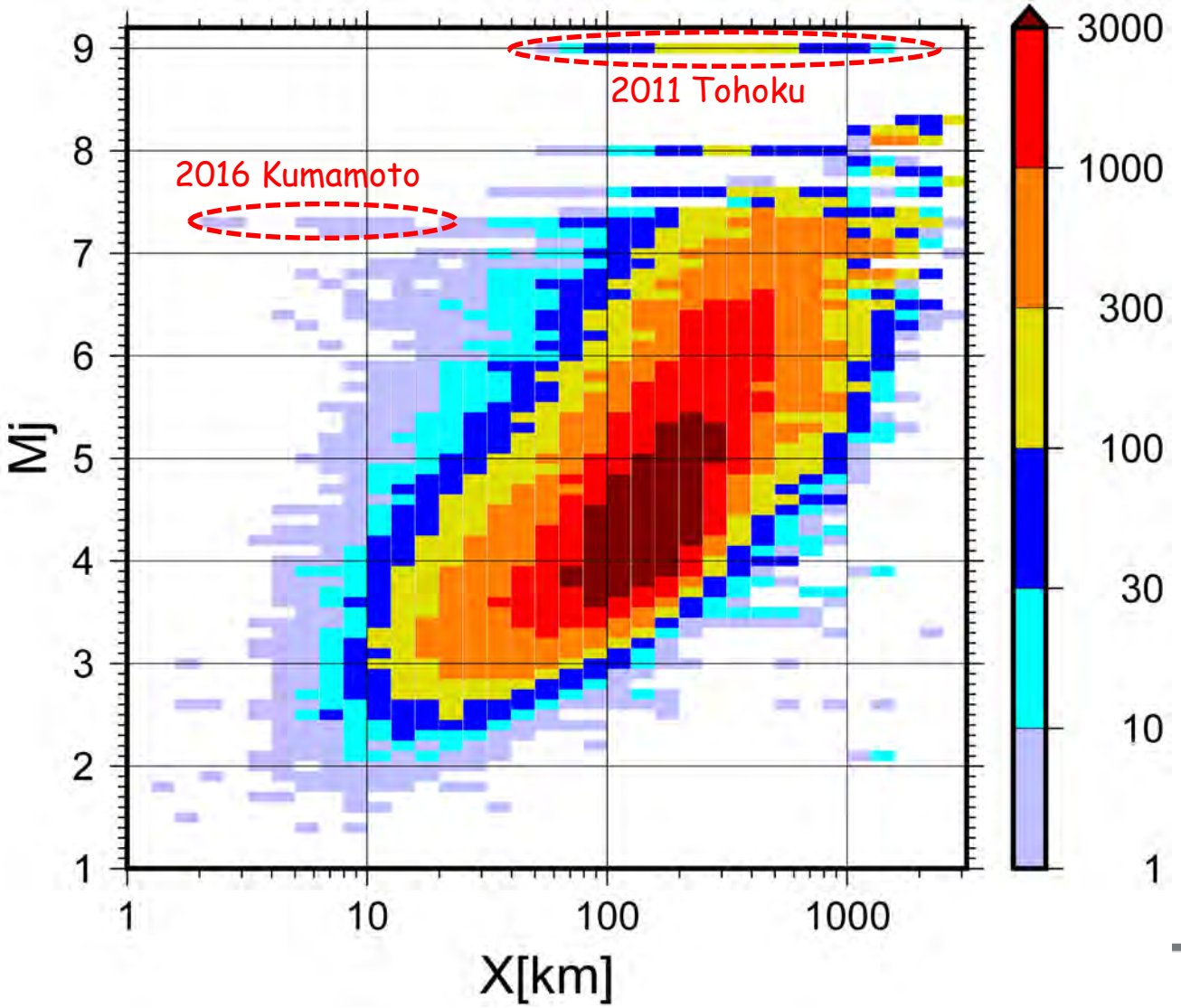
Modeling the unknown [Discussion]

The biggest challenge in predicting ground motion (and other natural phenomena) that we have never experienced or recorded in the history, is the management of various uncertainties in prediction.

More effort is needed to reduce the uncertainties in the prediction model by constraining the conditions based on scientific knowledge. Alternative is to make up the data by simulation.



Strong-motion database for K-NET and KiK-net (1996-2021)
~15000 event
~1.33M records

Biased dataset lacking near-fault and large-magnitude data

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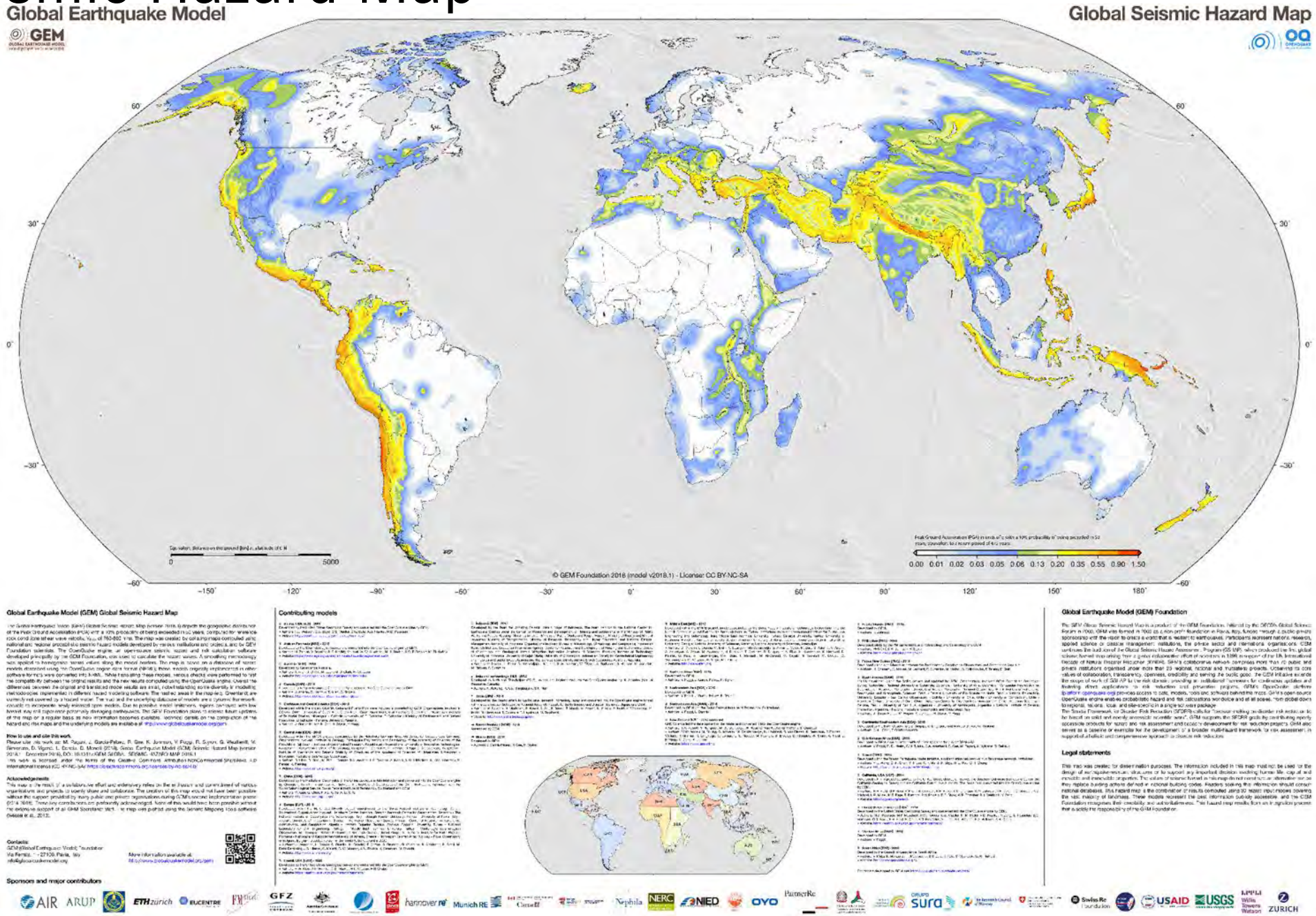
Global Seismic Hazard Map



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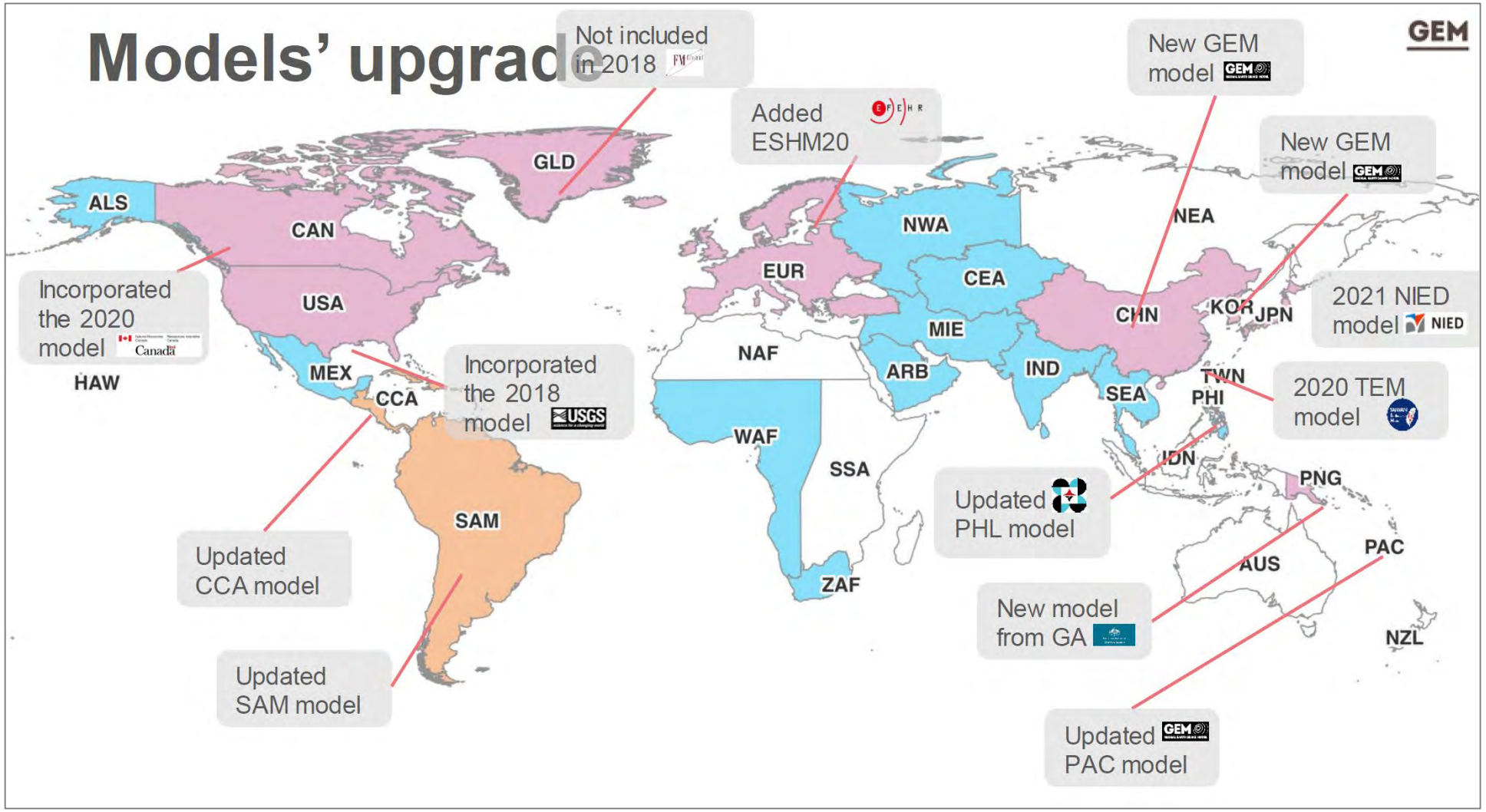

https://www.globalquakemodel.org/gem-conference-2023