

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, \cdots) **Nankai trough earthquakes** have repeatedly occurred with $10^1 \sim 10^2$ 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

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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)

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Ocean-bottom seismic observation



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".

 \rightarrow Observation networks have been drastically enhanced after the 1995 earthquake.



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



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

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Long-term evaluation by HERP

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

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Classification for the occurrence probabilities for major earthquake sources

National Seismic Hazard Maps

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

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

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Probabilistic seismic hazard map

139.5"

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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.

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
- ightarrow Revision of the ground-motion prediction model for large-scale fault
- ightarrow 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 <u>uncertainty</u> 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.

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Global Seismic Hazard Map



Global Earthquake Model (GEM) Global Seismic Hazard Map

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Global Seismic Hazard Map





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