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Development of Japan Tsunami Hazard Information Station -Database of Probabilistic Tsunami Hazard Assessment along the Nankai Trough-

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Abstract

In 2012, the National Research Institute for Earth Science and Disaster Resilience (NIED) undertook a project of nationwide Probabilistic Tsunami Hazard Assessment (PTHA) in Japan to contribute to effective preparedness for or measures against tsunamis. The project focused on inter-plate earthquake tsunamis along the Nankai Trough, Sagami Trough, Japan Trench, and Kuril Trench. In addition, for better usage application of tsunami hazard information based on PTHA, NIED set up the committee for Usage Application of Tsunami Hazard Information (2013-2016) and discussed the needs of people and organizations who use tsunami hazard information, the contents that would meet the needs, and the possibility of actually applying the information. The committee emphasized the importance of having a public system available with information on various tsunami hazards. In addition, NIED set up the committee for Advanced Usage of Tsunami Hazard and Risk Information (2017-). They focus on the specifications and the needs of people and organizations who use tsunami hazard information and risk at an advanced level to develop and improve the system. Regarding seismic hazard information, NIED developed an open web system for seismic hazard maps and started its operation in 2005 under the name Japan Seismic Hazard Information Station (J-SHIS).

Based on the above, we have been developing the Japan Tsunami Hazard Information Station (J-THIS) to build such a public system. In this paper, we introduce the contents of J-THIS. Some contents are equal to the PTHA for inter-plate earthquake tsunami along the Nankai Trough by the Headquarters for Earthquake Research Promotion (HERP) of Japanese Government (2020). Some contents are detail of or expansion of HERP (2020). This system is available on the web and can be classified into five main functions: displaying distributions of the exceedance probability of tsunami heights higher than 3m, 5m, and 10m within 30 years on Geospatial Information Authority of Japan (GSI) Maps, displaying tsunami hazard curves for 30 years for each site (every 50m mesh on the coastlines), displaying earthquake fault models used for tsunami simulation on GSI Maps and earthquake fault parameters, displaying distributions of tsunami heights for each earthquake fault model on GSI Maps, and displaying bathymetric charts on GSI Maps.

Keywords: Japan Tsunami Hazard Information Station (J-THIS), Probabilistic Tsunami Hazard Assessment, Nankai Trough

1. Introduction

Past tsunamis have taken away many lives and destroyed properties. It is an urgent issue that needs to be addressed. A framework and system have to be built to promote effective disaster countermeasures against possible tsunami disasters in the future.

In 2012, the National Research Institute for Earth Science and Disaster Resilience (NIED) undertook a project of nationwide Probabilistic Tsunami Hazard Assessment (PTHA) in Japan to contribute to effective preparedness for or measures against tsunamis. Based on not sufficient evaluation of the 2011 off the Pacific coast of Tohoku Earthquake Tsunami (the 2011 Tohoku tsunami), one of the aims of this project is to evaluate future tsunamis that can be generated by earthquakes, considering various types of earthquakes (i.e., considering not only past earthquakes but also earthquakes which have not occurred for as long as we know).

Based on probability concepts, some approaches toward tsunami hazard assessments have been proposed [1, 2, 3, 4]. In Japan, the PTHA method has been used in the tsunami risk assessment for nuclear power plants after the 2011 Tohoku Tsunami [5]. Most recently, the Headquarters for Earthquake Research Promotion (HERP) of the Japanese Government addressed PTHA along the Nankai Trough [6].

PTHA and its results have been provided to the national and regional disaster management and spatial planning institutions in some countries [6, 7, 8, 9, 10]. For example, in the US, the American Society of Civil Engineers (ASCE) Tsunami Loads and Effects Subcommittee developed a new chapter, Chapter 6 “Tsunami Loads and Effects” for the 2016 edition of the ASCE 7 standards which specifically address tsunami loads and effects on buildings. Used in conjunction with these designs, ASCE developed Tsunami Design Zone (TDZ) maps which provide information on 2,500-year probabilistic tsunami inundation for Alaska, Washington, Oregon, California, and Hawaii [10].

In this situation, for better usage application of tsunami hazard information based on PTHA of the above, NIED set up the committee for Usage Application of Tsunami Hazard Information (2013-2016) and discussed the needs of people and organizations who use tsunami hazard information, the contents that meet the needs, and potential of usage application [11]. The committee emphasized the importance of a public system available for usage application of various tsunami hazard information. In addition, NIED set up the committee for Advanced Usage of Tsunami Hazard and Risk Information (2017-) and has been discussing the specifications and the needs of people and organizations who use tsunami hazard information at an advanced level and risk to develop and improve the system. Regarding seismic hazard information, NIED developed an open web system for seismic hazard maps, and started its operation in 2005 under the name Japan Seismic Hazard Information Station (J-SHIS) [12].

Based on the above, we have been developing the Japan Tsunami Hazard Information Station (J-THIS) which is a public system. The system is available for usage application of information on various tsunami hazards. In this paper, we introduce the contents of J-THIS. Some contents are equal to the PTHA along the Nankai Trough, issued by HERP (2020) [6]. Some contents are detail of or expansion of HERP (2020) [6]. In the following chapters, we describe the outline of PTHA along the Nankai Trough by HERP (2020) [6] (chapter 2), development of J-THIS (chapter 3), and summary of this paper (chapter 4).

2. Outline of PTHA along the Nankai Trough

Some contents of J-THIS introduced in this paper are equal to the PTHA along the Nankai Trough issued by HERP (2020) [6]. Some are detail of or an expansion of HERP (2020) [6]. Therefore, in this chapter, we describe the outline of the PTHA along the Nankai Trough by HERP (2020) [6], in the order shown in Fig. 1: evaluating earthquake occurrence probability, constructing earthquake fault models, constructing offshore bathymetry and onshore topography models, simulating tsunami propagation and run up, and finally, calculating tsunami hazard curves and distributions of the exceedance probability of tsunami heights within 30 years.

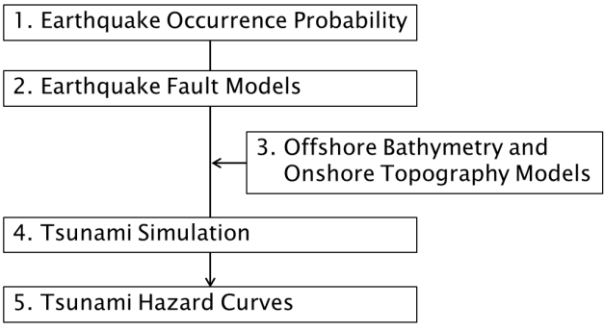

Fig. 1 Outline of PTHA

2.1 Earthquake occurrence probability

PTHA by HERP (2020) [6] was based on the long-term evaluation of seismic activities at the Nankai Trough by HERP (2013) [13]; namely, the recurrence interval could be assumed to follow the Brownian Passage Time (BPT) distribution. Using the recurrence interval is assumed to follow the BPT distribution where the mean recurrence interval=88.2 years, the time of the latest event=74.0 years ago (the 1946 Showa-Nankai earthquake), and variance α=0.22 [14]; the earthquake occurrence probability within 30 years could be calculated as 74.3 years as of January 1, 2020. HERP (2020) [6] used this value as the occurrence probability of large earthquakes along the Nankai Trough within 30 years.

2.2 Earthquake fault models

Considering a variety of future earthquakes that may occur along the Nankai Trough, HERP (2020) [6] constructed 2,720 simplified earthquake fault models (Characterized Earthquake Fault Models: CEFMs) (Mw 7.6-9.0), except for the maximum possible earthquake composed of a combination of segments that HERP (2013) [13] divided the evaluation area of the Nankai Trough into 18 segments. Considering that tsunami height could be influenced greatly by spatially heterogeneous slip distribution, HERP (2020) [6] set the large slip area in CEFM.

2.3 Offshore bathymetry and onshore topography models

Regarding the areas along the Nankai Trough and the coastal areas where large tsunami may hit in the future, HERP (2020) [6] used offshore bathymetry and onshore topography models composed of 1350m, 450m, 150m, and 50m mesh (Fig. 2) for tsunami simulation, using a nesting method.

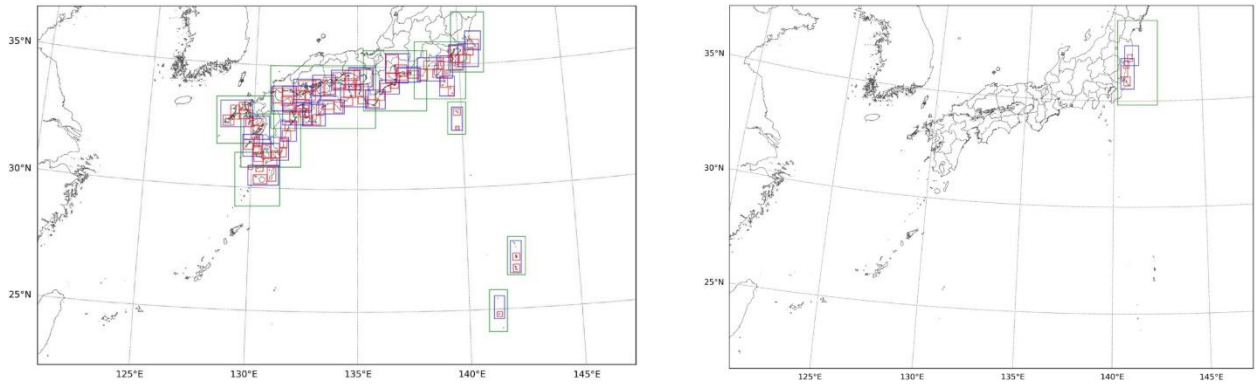

Fig. 2 Calculation regions for tsunami simulation by HERP (2020) [6]. Left figure shows UTM zone 53N and right figure shows UTM zone 54N. (Black: 1350m mesh, green: 450m mesh, blue: 150m mesh, red: 50m mesh)

2.4 Tsunami simulation

Based on Tsunami Recipe (HERP, 2017) [15], HERP (2020) [6] simulated tsunami propagation and run up for each earthquake fault model (2,720 CEFMs) on the calculation conditions shown in Table 1.

Table 1 Calculation conditions for tsunami simulation by HERP (2020) [6]

Governing equation	Non-linear long wave theory
Numerical solution	Finite-difference method (FDM) with a leapfrog scheme on a staggered grid
Mesh resolutions	1350 m, 450 m, 150m, 50m (Fig. 2)
Boundary condition	Land side: run up, Offshore side: open
Structures	Not considered
Calculation time	3-12 hours
Initial water level	Sea bed movement calculated by Okada (1992) [16]. Considering the effect of horizontal deformation by Tanioka and Satake (1996) [17].
Censored water depth	10^{-2} m
Roughness coefficient	0.025

2.5 Tsunami hazard curves

A tsunami hazard curve indicates the relation between a tsunami height and the probability of exceeding it within a specific period. Based on the tsunami hazard curves for 30 years calculated independently for each site (every 50m mesh on the coastlines), HERP (2020) [6] issued distributions of the exceedance probability of tsunami heights higher than 3m, 5m, and 10m within 30 years (Fig. 3).

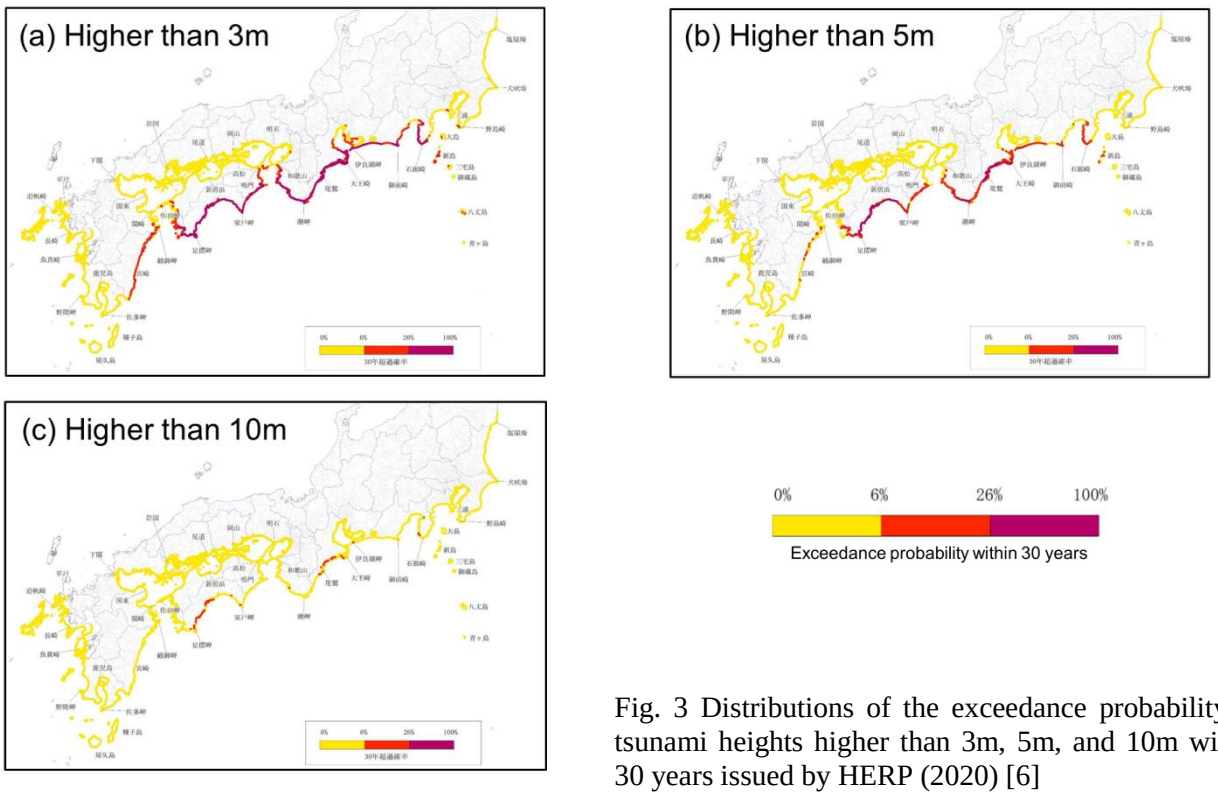

Fig. 3 Distributions of the exceedance probability of tsunami heights higher than 3m, 5m, and 10m within 30 years issued by HERP (2020) [6]

3. Development of J-THIS

3.1 Concept of J-THIS

J-THIS has been developed as a public portal available for usage application on a broad spectrum of tsunami hazards. We have been developing and improving the system based on discussion and proposals from the committee for Usage Application of Tsunami Hazard Information (2013-2016) and the committee for Advanced Usage of Tsunami Hazard and Risk Information (2017-) which NIED had set up. J-THIS provides a broad spectrum of information on tsunami hazards based on the PTHA and displays on the Geospatial Information Authority of Japan (GSI) Maps.

3.2 Outline of the functions of J-THIS

Fig. 4 shows the top page of J-THIS. Users can access the page for PTHA along the Nankai Trough displayed on the map (main contents), the outline page of PTHA along the Nankai Trough, the operational description page, the description page of terms, the user policy page, the FAQ page, and the downloads page (left side of Fig. 4). The following sections describe the display functions in J-THIS.

Fig. 4 Top page of J-THIS

3.3 Display function of exceedance probability

J-THIS displays distributions of the exceedance probability of tsunami heights higher than 3m, 5m, and 10m within 30 years for each site (every 50m mesh on the coastlines) on GSI Maps. Fig. 5 (a)(b) shows distributions of the exceedance probability of tsunami heights higher than 5m within 30 years. Users can enlarge a map and identify the exceedance probability for each site (Fig. 5 (b)).

3.4 Display function of tsunami hazard curves

J-THIS displays tsunami hazard curves over the next 30 years calculated independently for each site (every 50m mesh on the coastlines). Users can select the site (Fig. 5 (b)) and can identify the tsunami hazard curves for 30 years at a selected site (Fig. 5 (c)). In addition, J-THIS displays the tsunami height and exceedance probability for 30 years at the mouse cursor position on the tsunami hazard curve. Fig. 5 (c) shows that the tsunami height is 5m and exceedance probability is 30.11% at the mouse cursor position on the tsunami hazard curve.

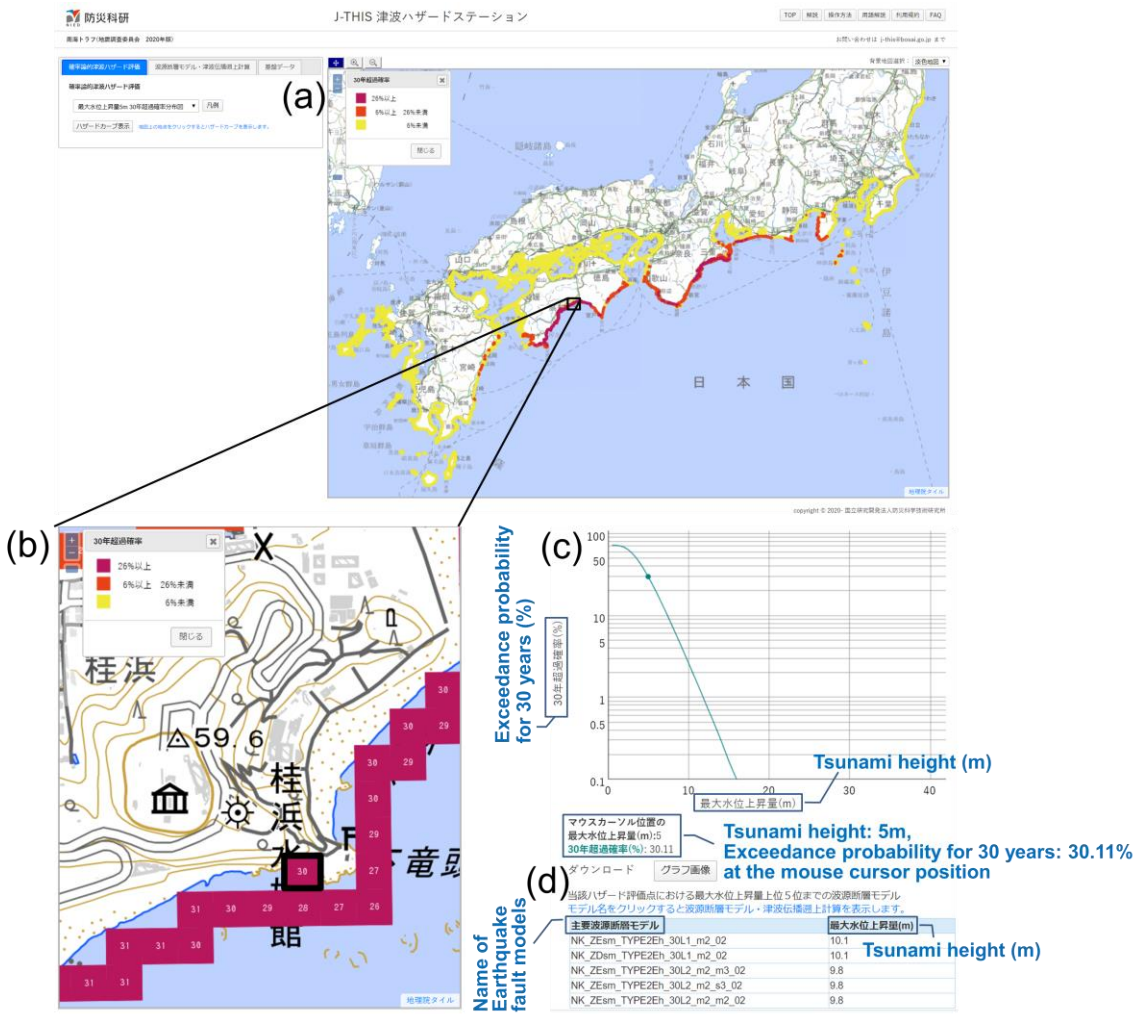

Fig. 5 Display function of exceedance probability and tsunami hazard curve in J-THIS. (a, b) Distribution of the exceedance probability of tsunami heights higher than 5m within 30 years. (c) Tsunami hazard curves for 30 years at selected site. (d) Top five tsunami heights of tsunami simulation results using 2,720 earthquake fault models at selected site.

3.5 Display function of earthquake fault models

J-THIS displays each earthquake fault model (2,720 CEFMs) on GSI Maps and earthquake fault parameters of the model by setting the location of both the earthquake fault and the large slip area (Fig. 6).

3.6 Display function of tsunami heights for each earthquake fault model

J-THIS displays the distribution of tsunami heights for each site (every 50m mesh on the coastlines) on GSI Maps by setting the location of both the earthquake fault and the large slip area (Fig. 7). Users can enlarge a map and identify the tsunami height, for selected earthquake fault models, for each site. In addition, in the same procedure of displaying the tsunami hazard curve, J-THIS displays the top five tsunami heights of tsunami simulation results using all earthquake fault models (2,720 CEFMs) at selected site (Fig. 5 (d)).

3.7 Display function of bathymetric charts

J-THIS displays bathymetric charts of 1350m, 450m, 150m, and 50m mesh (Fig.8). J-THIS can display distributions of the exceedance probability, earthquake fault models, and tsunami heights for each earthquake fault model over bathymetric charts. Users can directly compare and discuss them.

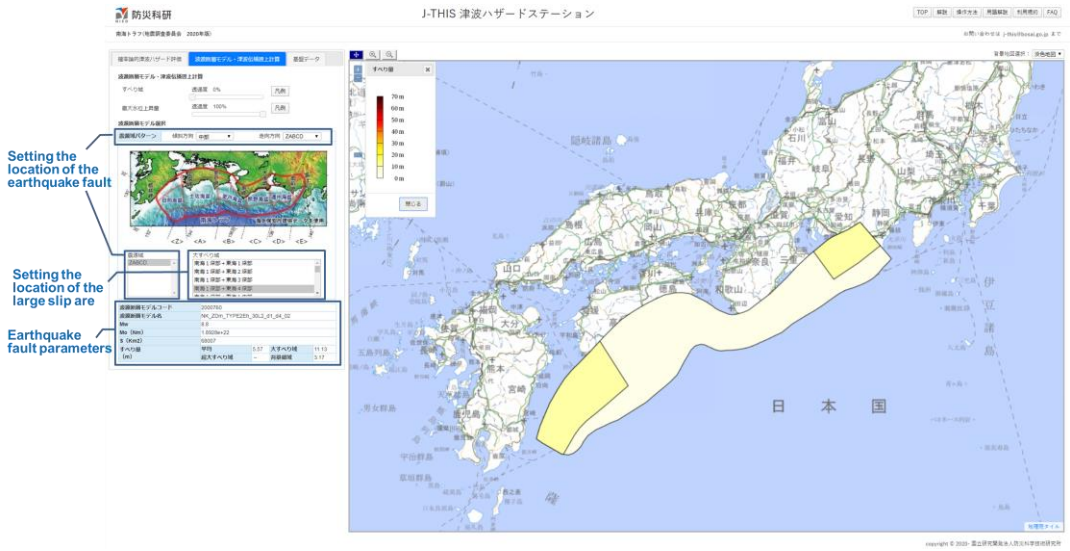

Fig. 6 Display function of Earthquake fault models in J-THIS

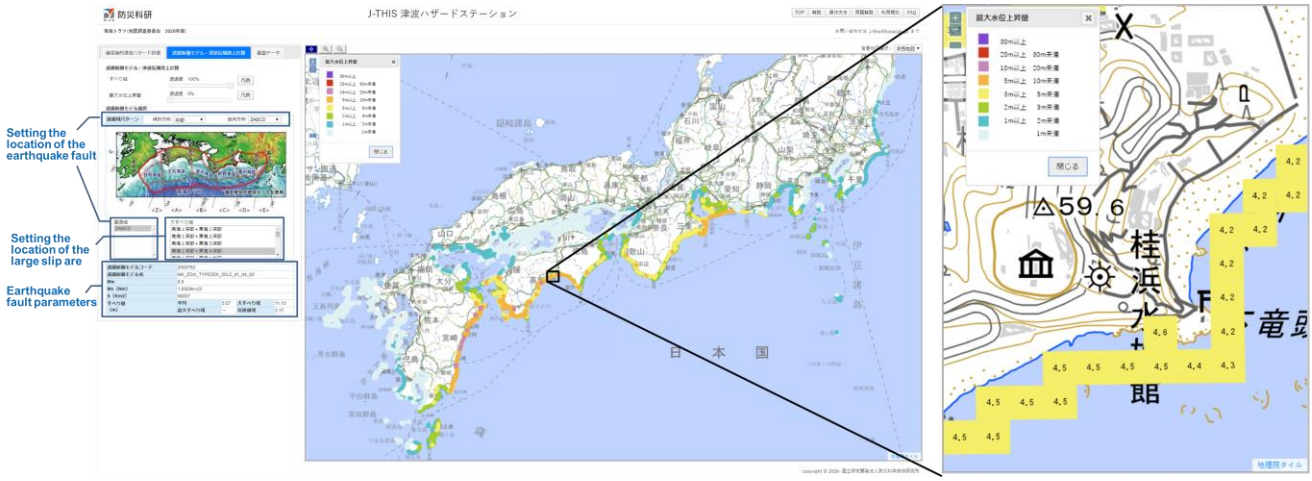

Fig. 7 Display function of tsunami heights for each earthquake fault model in J-THIS

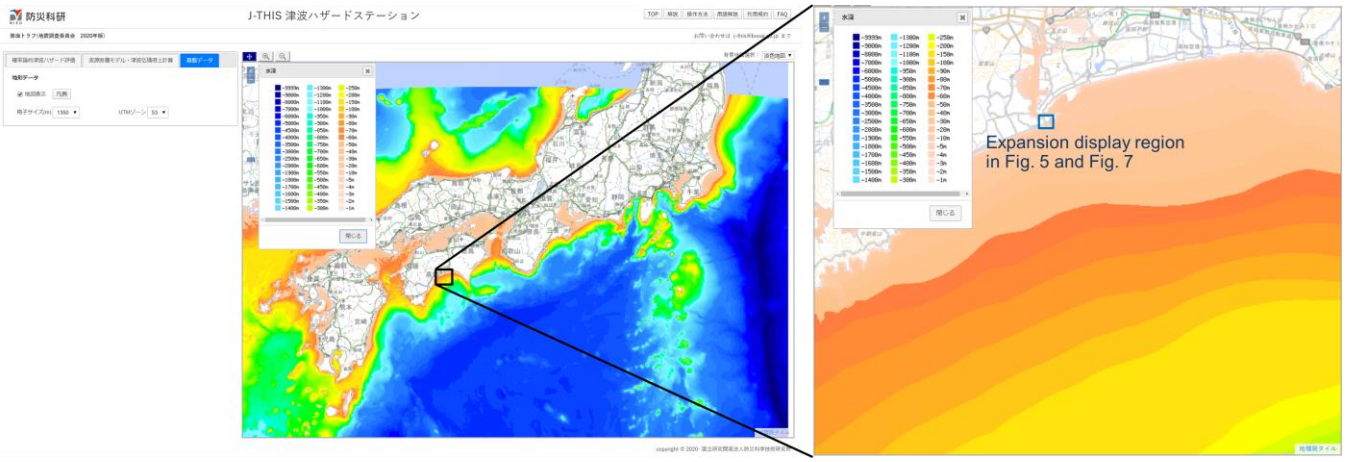

Fig. 8 Display function of bathymetric charts in J-THIS. Left figure shows bathymetric charts of 1,350m mesh and right figure shows bathymetric charts of 50m mesh.

4. Summary

NIED has been developing the J-THIS which is a public system available for usage application on a broad spectrum of tsunami hazards information. Tsunami hazard information in J-THIS was calculated based on PTHA. In this paper, we introduced the contents of J-THIS. Some contents are equal to the PTHA along the Nankai Trough issued by HERP (2020) [6]. Some contents are detail of or expansion of HERP (2020) [6]. J-THIS has display functions of (1) distributions of the exceedance probability of tsunami heights higher than 3m, 5m, and 10m within 30 years on GSI Maps, (2) tsunami hazard curves for 30 years for each site (every 50m mesh on the coastlines), (3) earthquake fault models used for tsunami simulation on GSI Maps and earthquake fault parameters, (4) distributions of tsunami heights for each earthquake fault model on GSI Maps, and (5) bathymetric charts on GSI Maps. We continue developing and improving the system which can meet the needs and contribute to effective preparedness for or measures against tsunamis.

5. Acknowledgements

We have been developing J-THIS as a part of the research project on “Research on Evaluation of Hazard and Risk” of NIED. Some contents in J-THIS are equal to the PTHA along the Nankai Trough issued by HERP (2020) [6].

6. References

[1] Geist, E. and Parsons, T. (2006): Probabilistic analysis of tsunami hazards, *Natural Hazards*, **37**, 277-314.

[2] Annaka, T., Satake, K., Sakakiyama, T., Yanagisawa, K., and Shuto, N. (2007): Logic-tree approach for probabilistic tsunami hazard analysis and its applications to the Japanese coasts, *Pure and Applied Geophysics*, **164**, 577-592.

[3] Sugino, H., Korenaga, M., Sakagami, M., and Ebisawa, K. (2011): Probabilistic Tsunami Hazard Assessment Considering Time-Lag of Seismic Event on Nankai Trough, *Journal of JSCE, B2, Coastal Engineering*, **67** (2), I_351-I_355 (in Japanese with English abstract).

[4] The Nuclear Civil Engineering Committee, Japan Society of Civil Engineers (2011): The methodology of Probabilistic Tsunami Hazard Analysis (in Japanese).

[5] Iwabuchi, Y., Sugino, H., and Ebisawa, K. (2014): Guidelines for Developing Design Basis Tsunami based on Probabilistic Approach, Japan Nuclear Energy Safety Organization, JNES-RE-2013-2041 (in Japanese with English abstract).

[6] Earthquake Research Committee, Headquarters for Earthquake Research Promotion (2020): Probabilistic Hazard Assessment of Tsunami due to Large Earthquakes along the Nankai Trough (in Japanese).

[7] Strunz, G., Post, J., Zosseder, K., Wegscheider, S., Mück, M., Riedlinger, T., Mehl, H., Dech, S., Birkmann, J., Gebert, N., Harjono, H., Anwar, H. Z., Sumaryono, Khomarudin, R. M., and Muhari, A. (2011): Tsunami risk assessment in Indonesia, *Natural Hazards and Earth System Sciences*, **11**, 67–82, https://doi.org/10.5194/nhess-11-67-2011 (Accessed January 19, 2020).

[8] Berryman, K. (2006): Review of Tsunami Hazard in New Zealand, https://www.civildefence.govt.nz/assets/Uploads/publications/GNS-CR2005-104-review-of-tsunami-hazard.pdf (Accessed January 19, 2020).

[9] Davies, G. and Griffin, J. (2018): The 2018 Australian Probabilistic Tsunami Hazard Assessment: Hazard from Earthquake Generated Tsunamis, Geoscience Australia, http://dx.doi.org/10.11636/Record.2018.041 (Accessed January 19, 2020).

[10] American Society of Civil Engineers (2017): ASCE Tsunami Design Geodatabase Version 2016-1.0, https://www.asce7tsunami.online/ (Accessed December 15, 2019).

[11] Committee for Usage Application of Tsunami Hazard Information (2016): Report on Usage Application of Tsunami Hazard Information, Technical Note of the National Research Institute for Earth Science and Disaster Resilience, **406** (in Japanese).

[12] National Research Institute for Earth Science and Disaster Resilience (NIED): Japan Seismic Hazard Information Station (J-SHIS), http://www.j-shis.bosai.go.jp/en/ (Accessed January 25, 2020).

[13] Earthquake Research Committee, Headquarters for Earthquake Research Promotion (2013): Long-term evaluation of seismic activities at the Nankai Trough (2nd Edition) (in Japanese).

[14] Earthquake Research Committee, Headquarters for Earthquake Research Promotion (2014): Hazard map of prediction of ground motion of 2014 year edition - Overview of ground motion hazard in Japan (in Japanese).

[15] Earthquake Research Committee, Headquarters for Earthquake Research Promotion (2017): Tsunami prediction method for earthquakes with specified source faults (Tsunami Recipe) (in Japanese).

[16] Okada, Y. (1992): Internal deformation due to shear and tensile faults in a half-space, *Bulletin of the Seismological Society of America*. **82**, 1018-1040.

[17] Tanioka, Y. and Satake, K. (1996): Tsunami generation by horizontal displacement of ocean bottom, *Geophysical Research Letters*, **23** (8), 861-864.

