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VALIDATION OF THE PROBABILISTIC SEISMIC HAZARD MAPS FOR JAPAN

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Abstract

This paper discusses the validation of the probabilistic seismic hazard maps for Japan by comparing with the experienced seismic hazard maps developed from the earthquake catalog during the corresponding time period. The probabilistic seismic hazard maps were published by the Earthquake Research Committee, Headquarters for the Earthquake Research Promotion of the Japanese government, as part of National seismic hazard maps for Japan. These maps were significantly improved in 2014 based on the lessons from the 2011 off the Pacific Coast of Tohoku Earthquake.

First, Probabilistic and experienced seismic hazard maps for a time period of 30 years starting from 1890, 1920, 1950, 1980 and 2010 were evaluated. The seismic activity model and strong ground motion evaluation model of the probabilistic map were the same as the National seismic hazard maps for Japan in 2014. The experienced map showed the probability exceedance with a seismic intensity of equal or larger than 6 Lower and the seismic intensity with a probability exceedance 3% within 30 years, based on the hazard curve with the earthquake occurrence probability of 1.0 for an earthquake that occurred during the period from 1890 to 2009. As a result, the features of the probabilistic and experienced seismic hazard maps were described.

Next, we compared the expected number of meshes of about 250m square in Japan of JMA seismic intensity of equal or larger than 6 lower within 30 years for each starting year between probabilistic maps and experienced maps. For all seismic categories, the number of meshes of the experienced map is slightly larger for a time period of 30 years starting from 1890, but the number of meshes of the probabilistic map is slightly larger in other starting years. Although the results are for the 2011 off the Pacific Coast of Tohoku Earthquake alone, the number of meshes of probabilistic maps and experienced maps for a time period of 30 years starting from 2010 almost correspond. This suggests that the improved seismic activity modeling in 2014 was reasonable from the viewpoint of the number of meshes in Japan.

Keywords: Probabilistic Seismic Hazard Map, Experienced Seismic Hazard map, Validation, The 2011 off the Pacific Coast of Tohoku Earthquake

1. Introduction

After the 1995 Hyogo-ken Nanbu (Kobe) earthquake, preparation of the National Seismic Hazard Maps for Japan (NSHMJ) was initiated. The first version of the NSHMJ, consisting of probabilistic seismic hazard maps and scenario earthquake shaking maps, was published in 2005 by the Earthquake Research Committee, Headquarters for Earthquake Research Promotion of Japan (HERP), with annual updates through 2010, including a major revision in 2009 [1]. Furthermore, the seismic activity model for NSHMJ was significantly improved in 2014 [2] based on the lessons from the 2011 off the Pacific Coast of Tohoku Earthquake.

Validation of probabilistic seismic hazard maps published in 2010 had already been carried out by Ishikawa et al. [3]. The purpose of this paper is to validate of probabilistic seismic hazard maps for Japan significantly improved in 2014 based on the lessons from the 2011 off the Pacific Coast of Tohoku Earthquake.

2. Method of Validation

Validation of the probabilistic seismic hazard maps was performed in the same method as Ishikawa et al.(2011) [3]. First, we compared probabilistic seismic hazard maps at different starting time with experienced seismic hazard maps developed from the earthquake catalog during the corresponding time period. Next, the expected number of meshes of about 250m square above a seismic intensity calculated of probabilistic maps was compared the number of meshes experienced maps at Japan and three regions with different characteristics of seismic hazard. However, we should note that the characteristics of seismic hazard of the NSHMJ in 2014 did not always match the characteristics of seismic hazard of the NSHMJ in 2010 because the modeling of seismicity was different.

2.1 Probabilistic seismic hazard maps at different starting time

Probabilistic seismic hazard maps for a time period of 30 years starting from 1890, 1920, 1950, 1980 and 2010 were evaluated. The seismic activity model and ground motion prediction equations were based on the NSHMJ in 2014 [2].

For subduction-zone earthquakes and active faults in non-steady seismic activity model that occurred during the period from 1890 to 2009, the timing of the latest event was re-evaluated from the occurred year. Table 1 shows occurrence probabilities of each earthquake within 30 years of the major occurred earthquakes between 1890 and 2009 for the each five starting year. For a subduction-zone earthquake with a short average recurrence interval, such as Nankai trough earthquake, the occurrence probability of the earthquake within 30 years becomes extremely small after the earthquake.

2.2 Experienced seismic hazard maps

The evaluation method of experienced seismic hazard maps was the same as Ishikawa et al.[3]. A hazard curve for each mesh was calculated with the earthquake occurrence probability of 1.0 for an earthquake that occurred during the period from 1890 to 2009. A exceedance probability of a seismic intensity or a seismic intensity for a exceedance probability for each mesh were calculated based on the hazard curve. Experienced seismic hazard maps showed the exceedance probability or the seismic intensity for each mesh on a map. At this time, the ground motion prediction equation and the model of the ground amplification factor were the same as those used in the probabilistic seismic hazard maps.

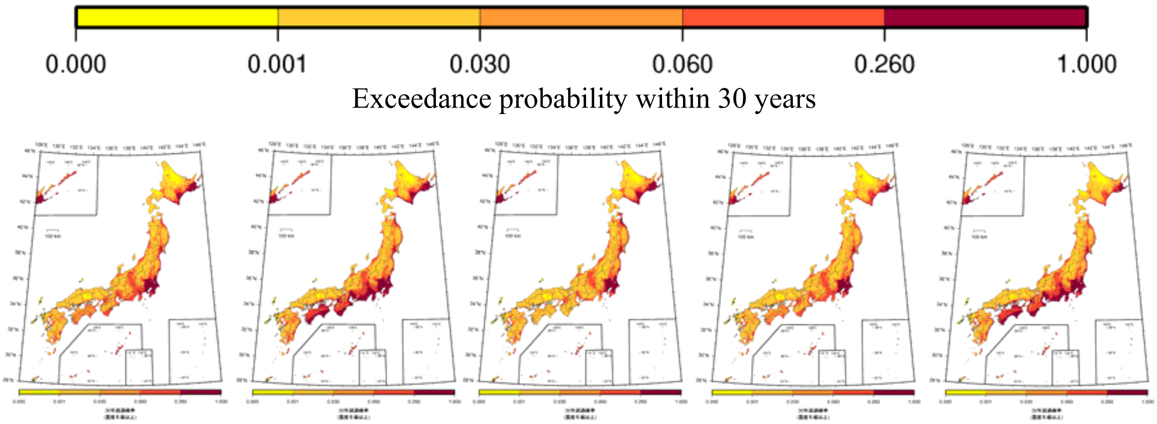
Table 1 – Occurrence probabilities within 30 years

Earthquke	Average recurrence interval (year)	Aperiodicity parameters α	Occurrence probabilities within 30 years from starting year (%)				
			1890	1920	1950	1980	2010
Nankai trough	88.2	0.22	10	64*	0	9	62
Great Tohoku	600	0.24	7	9	11	13	15*
Northern Sanriku	97.0	0.18	1	45	86*	0	5
Off Tokachi	72.2	0.28	61	83	89*	25*	1
Off Nemuro	72.2	0.28	80*	21	72*	1	43
Off Shikotan Island	72.2	0.28	80*	23	72*	2	51
Off Etorofu Island	72.2	0.28	56*	0	32*	7	60
Sagami trough	315	0.45	12	14*	0	0	1
Off west of Hokkaido	2,650	0.21	2.8	2.8*	0.6	0.6	0.6
Hokkaido southwest offshore	950	0.21	6.2	6.2	7.2	7.7*	1.6
Aomori prefecture west offshore	950	0.21	6.4	6.9	7.4	7.9*	1.6
Offshore northern Niigata	1,000	0.21	6.4	6.9	7.3*	1.5	1.5
Nukumi fault NW	2,300	0.24	5.9*	0.0	0.0	0.0	0.0
Neodani fault	2,850	0.24	1.9*	0.0	0.0	0.0	0.0
Umehara fault	14,500	0.24	1.4*	0.0	0.0	0.0	0.0
Shonaiheiya toen fault zone	1,250	0.24	8.6*	0.0	0.0	0.0	0.0
Gomura fault zone	12,500	0.24	0.04	0.04*	0.0	0.0	0.0
Kita-Izu fault zone	1,450	0.24	0.6	0.7*	0.0	0.0	0.0
Fukuiheiya toen fault zone W	26,200	(Poisson)	0.1	0.1*	0.0	0.0	0.0
Awaji fault W	2,150	0.24	3.1	3.2	3.3	3.4*	0.0
Kego fault zone NW	7,900	(Poisson)	0.4	0.4	0.4	0.4*	0.0
Muikamachi fault zone N	3,600	0.24	1.1	1.1	1.2	1.2*	0.0
Mahirunosanchi toen fault zone N	18,650	0.24	0.6*	0.0	0.0	0.0	0.0
Yokote bonchi toen fault zone S	3,400	0.24	3.3*	0.0	0.0	0.0	0.0
Iwatsubo fault	34,400	(Poisson)	0.09	0.09*	0.00	0.00	0.00
Fukouzu fault	3,500	(Poisson)	0.85	0.85*	0.00	0.00	0.00
Irozaki fault	2,200	(Poisson)	1.35	1.35*	1.35*	0.00	0.00
Noto Peninsula earthquake fault	56,300	(Poisson)	0.05	0.05	0.05	0.05*	0.00

* : Earthquake occurred within 30 years from start year

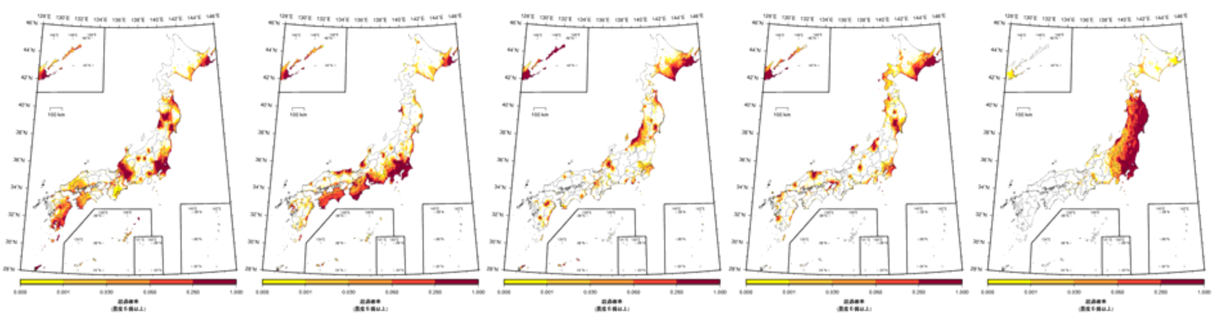
3. Results

Fig. 1 shows probabilistic seismic hazard maps at different starting time, and Fig. 2 shows experienced seismic hazard maps during the corresponding time period. Both maps are distributions of the exceedance probability with JMA seismic intensity of equal or larger than 6 lower within 30 years. However, the experienced seismic hazard map starting from 2010 is the distribution when only the 2011 off the Pacific Coast of Tohoku Earthquake occurred. Fig. 3 and Fig. 4 show probabilistic seismic hazard maps and experienced seismic hazard maps for JMA seismic intensity with a probability exceedance 3% within 30 years. The features of the probabilistic seismic hazard maps are as following. The Pacific region from southern Kanto to Shikoku is affected by the non-steady seismic activity models of the Kanto and Nankai Trough earthquakes. On the Pacific coast from Hokkaido to the Tohoku region, the effect of the difference in the starting period is not so large. On the other hand, the experienced seismic hazard maps is that the distribution is significantly different depending on the starting period. Miyagi, Kushiro, and Nemuro regions have experienced high seismic hazards at all starting periods. The Pacific regions of southern Kanto and western Japan have experienced high earthquake hazards only at certain starting period. On the Sea of Japan side and inland areas, areas that have experienced high seismic hazards are scattered in different areas depending on the starting year.



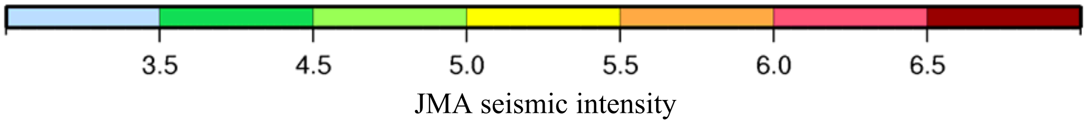
(a) 1890 (b) 1920 (c) 1950 (d) 1980 (e) 2010

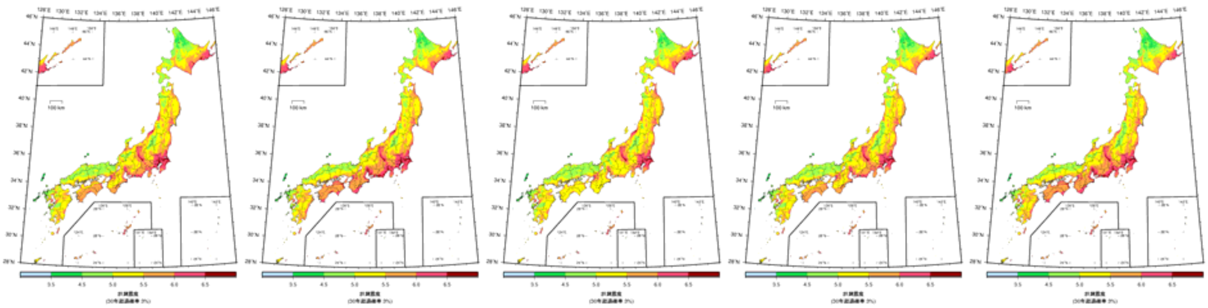
Fig. 1 – Probabilistic seismic hazard maps (distributions of the exceedance probability with JMA seismic intensity of equal or larger than 6 lower within 30 years)



(a) 1890 (b) 1920 (c) 1950 (d) 1980 (e) 2010

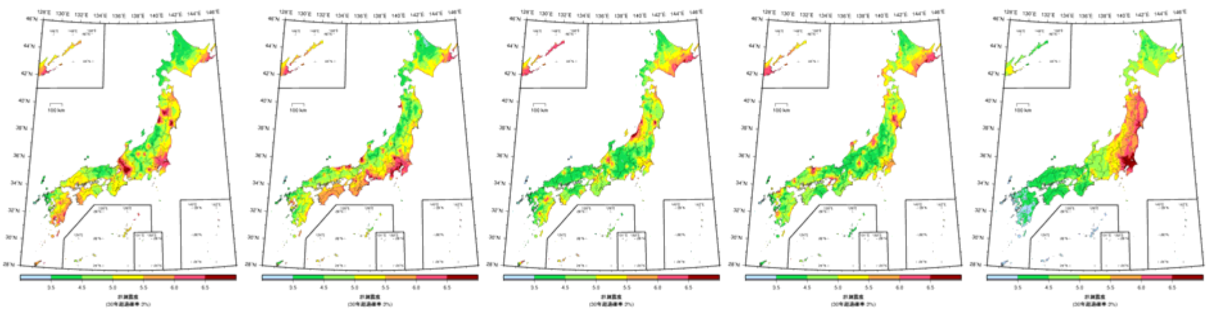
Fig. 2 – Experienced seismic hazard maps (distributions of the exceedance probability with JMA seismic intensity of equal or larger than 6 lower within 30 years)





(a) 1890 (b) 1920 (c) 1950 (d) 1980 (e) 2010

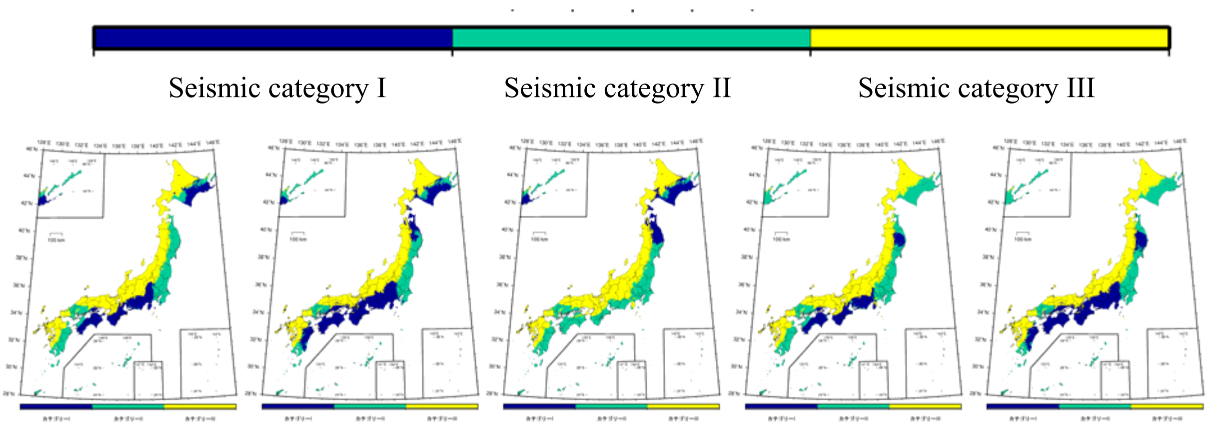
Fig. 3 – Probabilistic seismic hazard maps (distributions of JMA seismic intensity with a probability exceedance 3% within 30 years)



(a) 1890 (b) 1920 (c) 1950 (d) 1980 (e) 2010

Fig. 4 – Experienced seismic hazard maps (distributions of JMA seismic intensity with a probability exceedance 3% within 30 years)

Fig. 5 shows the distribution map of the seismic category with the highest exceedance probability with JMA seismic intensity of equal or larger than 6 lower within 30 years for probabilistic maps among the three seismic categories: subduction-zone large earthquakes (seismic category I), subduction-zone non-large earthquakes (seismic category II), earthquakes occurring in shallow inland (seismic category III). Fig. 6 shows the expected number of meshes in Japan for the seismic category with the highest exceedance probability within 30 years for each starting year. The number of meshes for seismic category III is the largest at all starting period, and the number of meshes for seismic category II and seismic category I differs depending on the starting year.



(a) 1890 (b) 1920 (c) 1950 (d) 1980 (e) 2010

Fig. 5 – Distribution of the seismic category with the highest exceedance probability with JMA seismic intensity of equal or larger than 6 lower within 30 years for probabilistic maps among the three seismic categories (seismic category I : subduction-zone large earthquakes, seismic category II : subduction-zone non-large earthquakes, seismic category III : earthquakes occurring in shallow inland)

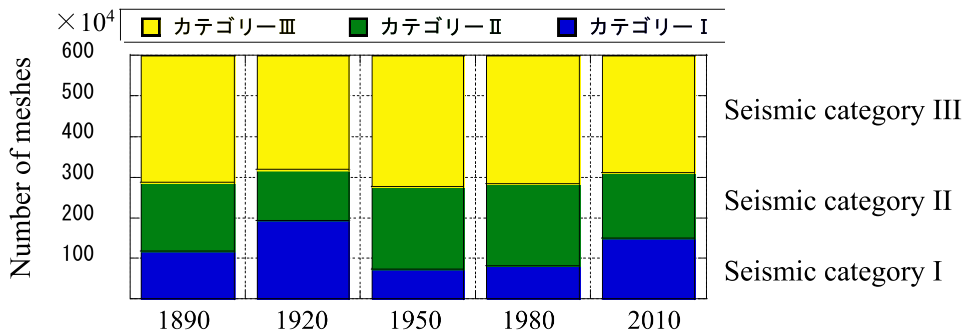
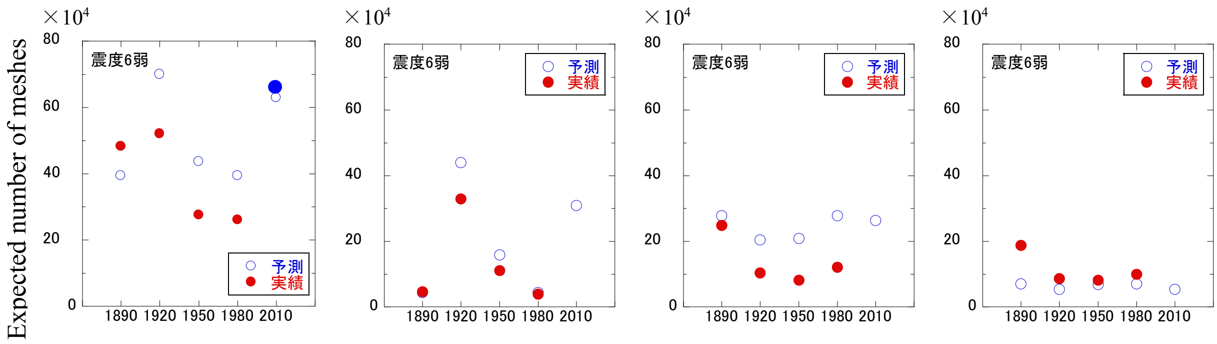


Fig. 6 – Expected number of meshes in Japan for the seismic category with the highest exceedance probability within 30 years
(seismic category I (■) : subduction-zone large earthquakes, seismic category II (■) : subduction-zone non-large earthquakes, seismic category III (■) : earthquakes occurring in shallow inland)

Fig. 7 shows the comparison of the expected number of meshes in Japan of JMA seismic intensity of equal or larger than 6 lower within 30 years for each starting year between probabilistic maps and experienced maps. However, the expected number of meshes of the experienced map for a time period of 30 years starting from 2010 indicates the number of meshes when only the 2011 off the Pacific Coast of Tohoku Earthquake occurred. For the probabilistic map, the difference in the number of meshes according to the starting year is large in seismic category I, which models non-steady seismic activity, and small in seismic categories II and III, where seismic activity is near steady. For the experienced map, the number of meshes for a time period of 30 years starting from 1920 is the largest compared to other starting years. The results of comparing the number of meshes between the probabilistic map and the experienced map is as follows. For all seismic categories, the number of meshes of the experienced map is slightly larger for a time period of 30 years starting from 1890, but the number of meshes of the probabilistic map is slightly larger in other starting years. Although the results are for the 2011 off the Pacific Coast of Tohoku Earthquake alone, the number of meshes of probabilistic maps and experienced maps for a time period of 30 years starting from 2010 almost correspond. This suggests that the improved seismic activity modeling in 2014 was reasonable from the viewpoint of the number of meshes in Japan.



(a) All categories (b) Category I (c) Category II (d) Category III

Fig. 7 – Expected number of meshes in Japan of JMA seismic intensity of equal or larger than 6 lower within 30 years (○ : probabilistic maps, ● : experienced maps, ● : experienced maps when only the 2011 off the Pacific Coast of Tohoku Earthquake occurred)

4. Conclusions

This paper discussed the validation of the probabilistic seismic hazard maps for Japan significantly improved in 2014 based on the lessons from the 2011 off the Pacific Coast of Tohoku Earthquake by comparing with the experienced seismic hazard maps developed from the earthquake catalog during the corresponding time period. First, we compared probabilistic seismic hazard maps at different starting time with experienced seismic hazard maps developed from the earthquake catalog during the corresponding time period. Next, the expected number of meshes of about 250m square above a seismic intensity calculated of probabilistic maps was compared the number of meshes experienced maps at Japan and three regions with different characteristics of seismic hazard. As the result, it was suggested that the improved seismic activity modeling in 2014 was reasonable from the viewpoint of the number of meshes in Japan.

5. References

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