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PREDICTIONS OF EARTHQUAKE OCCURRENCE BEHAVIORS FROM ACTIVE FAULT SYSTEMS ACROSS THE JAPANESE ARCHIPELAGO BY STATISTICAL SIMULATIONS

Michiyo Sugai[1], Tomohiko Hatori[2], and, Satoru Nishikawa[3]

SUMMARY

The main aim of the present paper is to predict the earthquake occurrence behaviors from major active fault systems across the Japanese archipelago, and following contents are reported.
First, probabilities for numbers of earthquakes occurring over set periods of time are estimated by statistical simulation. Second, it is estimated that more than 90% of the earthquakes occur when their 30-year probabilities exceed 0.01. Third, the probabilities are estimated for a number of active fault systems whose 30-year probabilities are particularly large. Fourth, it is estimated that activities in “agitated” periods are more than 3 times as high as in “tranquil” periods.

INTRODUCTION

The aim of the present paper is to predict frequencies of earthquake occurrences from the major active fault systems across the Japanese archipelago.
Simulated mean recurrence intervals and simulated times elapsed since the most recent earthquake occurrence in each active fault system are utilized for this purpose, as estimated in a previous paper by the same authors (Sugai et al., [4], [5]). The gist of that paper's findings can be summarized as follows:
Figure 1 shows the distribution of the major active fault systems in Japan, statistics of which are analyzed in the present paper. These are geomorphically recognized active fault systems in which earthquakes of $M_{JMA} \geq 6.5$ are likely to occur (Kumamoto [2]). M_{JMA} is the local scale magnitude of the Japan Meteorological Agency, each magnitude value being estimated by an empirical relation between fault length L and M_{JMA} as follows (Matsuda [3]):

$$\log L = 0.6M_{JMA} - 2.9 \quad (1).$$

The Subcommittee for Long-term Evaluation under the Earthquake Research Committee of the Headquarters for Earthquake Research Promotion [1] has determined the periodicity of earthquake

[1] Senior Researcher of Nagoya Industrial Science Research Institute and Visiting Researcher at Asian Disaster Reduction Center
[2] Senior Researcher of Asian Disaster Reduction Center
[3] Executive Director of Asian Disaster Reduction Center

occurrences for each active fault system. The authors have studied this periodicity and found that recurrence intervals ΔT (years) in each active fault system can be modeled in a probabilistic manner, as follows:

$$f_{\Delta T}(\Delta T) = \frac{1}{\sqrt{2\pi}\sigma_{\Delta T}\Delta T} \exp\left\{ -\frac{1}{2}\left(\frac{\ln \Delta T - \ln \mu'_{\Delta T}}{\sigma_{\Delta T}} \right)^2 \right\} \quad (2),$$

where the mean recurrence interval

$$\mu_{\Delta T} = \mu'_{\Delta T} \exp\left(\frac{1}{2}\sigma^2_{\Delta T} \right) \quad (3),$$

$$(\mu'_{\Delta T} = \text{geometric mean})$$

and the coefficient of variation

$$\delta_{\Delta T} = \sqrt{\exp \sigma^2_{\Delta T} - 1} = 0.298 \quad (4).$$

Here, the mean recurrence interval $\mu_{\Delta T}$ (years) is specific to each fault system.

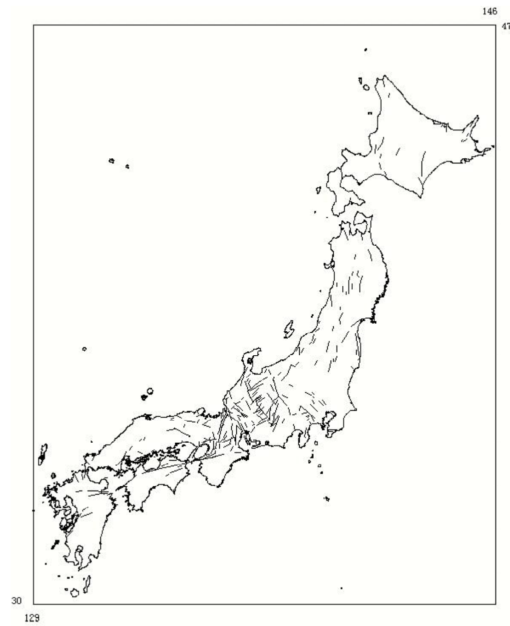

Figure 1 Distribution of major active fault systems with potential activity M_{JMA}≥6.5 in the Japanese archipelago

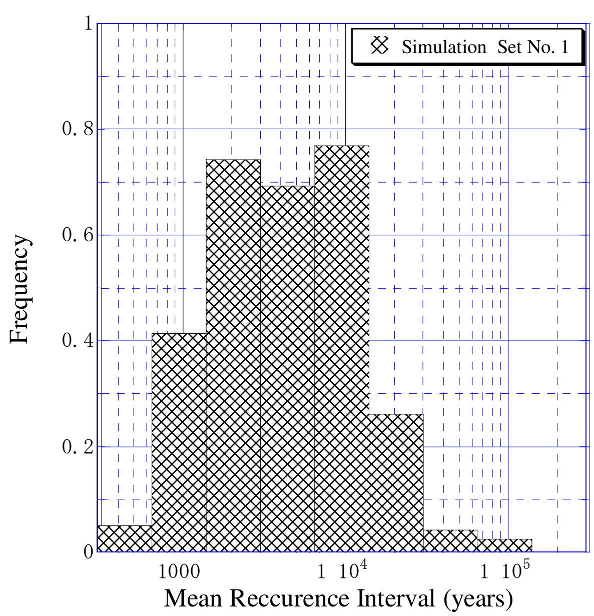

Figure 2 Frequency of Simulated Mean Recurrence Intervals $\mu_{\Delta T}$ (Simulation Set No. 1)

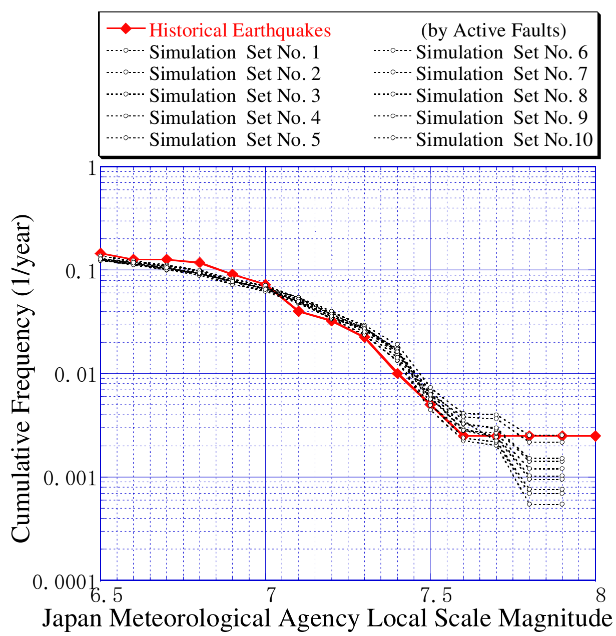

Figure 3 Simulated cumulative frequencies of earthquakes by JMA local scale magnitude

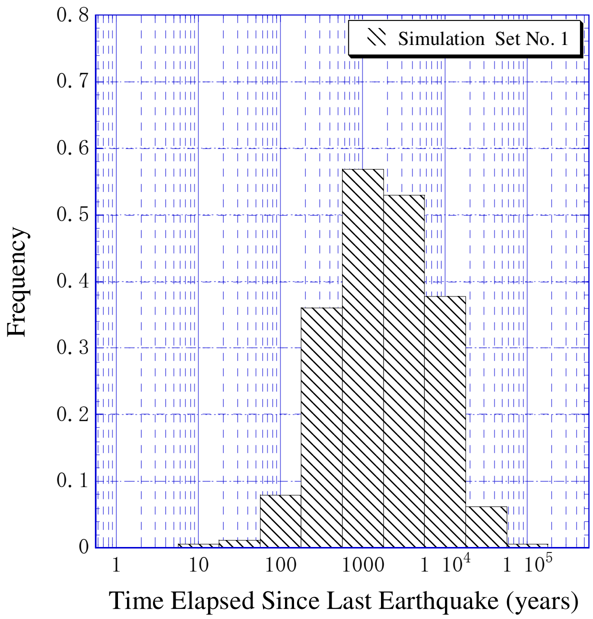

Figure 4. Frequency of time elapsed (Simulation Set No. 1).

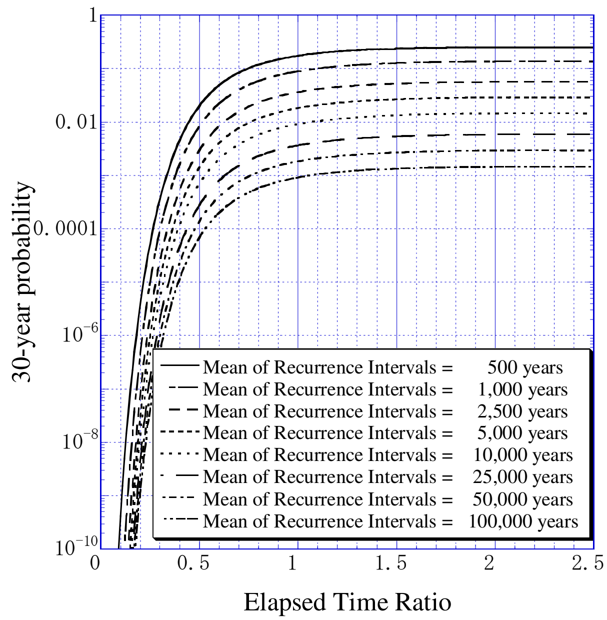

Figure 5 30-year probability versus elapsed time ratio (Time elapsed since last occurrence/Mean recurrence interval)

The mean recurrence interval $\mu_{\Delta T}$ and elapsed time Δt since the most recent earthquake occurrence are needed to predict the next earthquake in each fault system. These have not yet, however, been investigated in the field for most of the fault systems shown in Figure 1. This is to say, trenching or similar types of investigation have not yet, been performed in these systems.

As a first step, then, the authors statistically simulated $\mu_{\Delta T}$ for these active fault systems using the known geomorphologically-derived data for slip rates and active fault lengths. Figure 2 shows the frequency distribution of simulated mean recurrence intervals $\mu_{\Delta T}$. As is clear from the figure, the mean recurrence intervals lie mainly in a distribution between thousands and tens of thousands of years. This is in accord with the findings of trenching research in the field. In this way, the frequency of earthquake occurrences from each active fault system can be calculated as the inverse value of $\mu_{\Delta T}$. Figure 3 shows the cumulative frequencies for each M_{JMA} obtained from the simulations compared with those from historical data provided by Usami [7]. Ten sets of simulations were made and, as the figure shows, the cumulative frequencies they give are in good accord with the historical record. It is also clear from the figure that the variation between simulation sets is slight, except in a small range where the M_{JMA} are particularly large (the number of fault systems concerned is small).

In a second step, the authors simulated Δt on the assumption that each active fault system generates earthquakes independently. Figure 4 shows the frequency distribution. As is clear from the figure, the results lie mainly between one hundred and ten thousand years.

Then the authors calculated the 30-year probability P_{30} for each active fault system from the simulated $\mu_{\Delta T}$ and Δt values according to eq.(2) as follows:

$$P_{30}\left(\Delta t \middle| \mu_{\Delta T}, \delta_{\Delta T}\right) = \frac{\int_{\Delta t}^{\Delta t+30} f_{\Delta T}(\Delta T)\, d\Delta T}{\int_{\Delta t}^{\infty} f_{\Delta T}(\Delta T)\, d\Delta T} \qquad (5).$$

Naturally a 50-year probability P_{50}, or any other desired probability can be calculated in the same manner.

Figure 5 shows the relationships between these probabilities and the elapsed time ratios *r* calculated from eq.(5). These ratios are of the time elapsed since the last earthquake to the mean recurrence interval for each active fault system. The probabilities are calculated for a number of representative mean recurrence intervals as indicated in the legend. As is clear from the figure, the probabilities rapidly increase with the length of time elapsed for all mean recurrence intervals where elapsed time ratios *r* are small. However, they do not increase nearly so much for any mean recurrence interval where elapsed time ratios *r* are larger than 0.7. Specifically, the figure shows that the possibility of the next earthquake occurring in an active fault system is small immediately after the most recent event, and that the next event is liable to occur at any time after the elapsed time ratio *r* is greater than about 0.7. The number of fault systems with *r* in the larger ranges here would not be very large, however. As also shown in Figure 5, the probabilities decrease as the mean recurrence intervals increase, for any elapsed time. This is because the ratio of 30 years to the mean recurrence interval decreases as this interval increases. In particular, it becomes more difficult to predict in which 30 year-interval the next earthquake will occur when the mean recurrence interval is long and when the elapsed time ratio *r* is over 0.7. As is clear from Figure 5, the maximum probability is about 0.25 for fault systems with short mean recurrence intervals, and about 0.1% for those with long intervals.

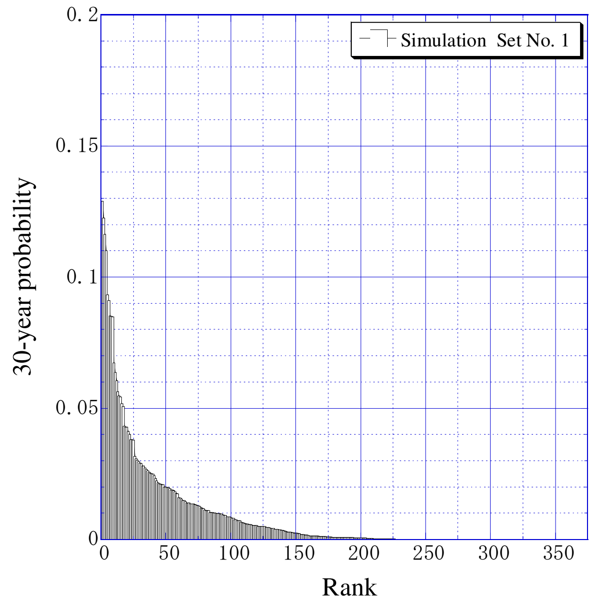

Figure 6. 30-year probabilities (Simulation Set No. 1)

Figure 6 shows the distribution for one of the ten sets of 30-year probabilities. The probabilities are arranged in order of increasing size, with larger probabilities in the smaller rank. As is clear from the figure, 30-year probabilities decrease at an exponential rate as ranks increase. That is to say, there are significant differences between these 30-year probabilities. As the figure shows only one of the simulation results, the probability cannot be excluded that the largest and smallest probabilities will be different in every simulation, and trenching investigations have to be performed to estimate the actual $\mu_{\Delta T}$, Δt, and P_{30}. However, the shapes of the distributions are almost identical in all ten sets. Therefore, the following can be inferred.

1. The 30-year probabilities of one-third of all active fault systems are smaller than 10^{-8}(0.000001%).
2. The 30-year probabilities of one-half of all active fault systems are larger than 10^{-3}(0.1%).
3. The 30-year probabilities of one-third of all active fault systems are larger than 10^{-2} (1%).
4. The 30-year probabilities of about 10% of all active fault systems are larger than $3 \cdot 10^{-2}$ (3%).
5. The 30-year probabilities of very few active fault systems are larger than 0.10 (10%).

PREDICTION OF FUTURE EARTHQUAKE OCCURENCES IN THE MAJOR ACTIVE FAULT SYSTEMS ACROSS THE JAPANESE ARCHIPELAGO

Probabilities of number of earthquake occurrences

In the next stage of their study, the authors simulated likely times of earthquake occurrences in the long-term future for each active fault system, by utilizing the results in section 1, in the following steps:

1 Based on eqs.(2)-(4) and the simulated Δt, the time of the next earthquake occurrence is simulated.
2 Based on eqs.(2)-(4) and the simulated time of the next earthquake occurrence, the time of the following second occurrence is simulated.
3 By repeating the procedure of 2, the times of all subsequent occurrences are simulated for each active fault system, over a sufficiently long-term future $\Delta term\_T$.
4 Repeating the procedure of 1-3, the times of earthquake occurrences are simulated for every active fault system, over a sufficiently long-term future $\Delta term\_T$.

Next, one identical $\Delta term\_T$ is determined for every active fault system, so that the number of earthquake occurrences from one active fault system come to differ from one fault system to another according to the difference in mean recurrence. Using the simulation, the authors then calculated the frequency of earthquake occurrences over a certain time period, as follows:

1 Choose a certain time period $\Delta term\_t$ in which to calculate the frequency of earthquake occurrences (e.g. 30, 50 or 100 years).
2 Calculate the total number m_{total} of periods $\Delta term\_t$ in the above long span of time $\Delta term\_T$, by dividing $\Delta term\_T$ by $\Delta term\_t$.
3 Count the number of earthquake occurrences in each successive $\Delta term\_t$ period.
4 In the long-term $\Delta term\_T$, count the number m_n of $\Delta term\_t$ periods in which any given number $n_{\Delta term\_t}$. (0, 1, 2, …) of occurrences is simulated to take place.
5 Calculate the frequency $P_{\Delta term\_t}(n|\Delta term\_t)$ for each given number $n_{\Delta term\_t}$ of occurrences in the long-term $\Delta term\_T$, by dividing m_n by m_{total}.

Here the frequency $P_{\Delta term\_t}(n|\Delta term\_t)$ represents the probability of a given number n of earthquake events

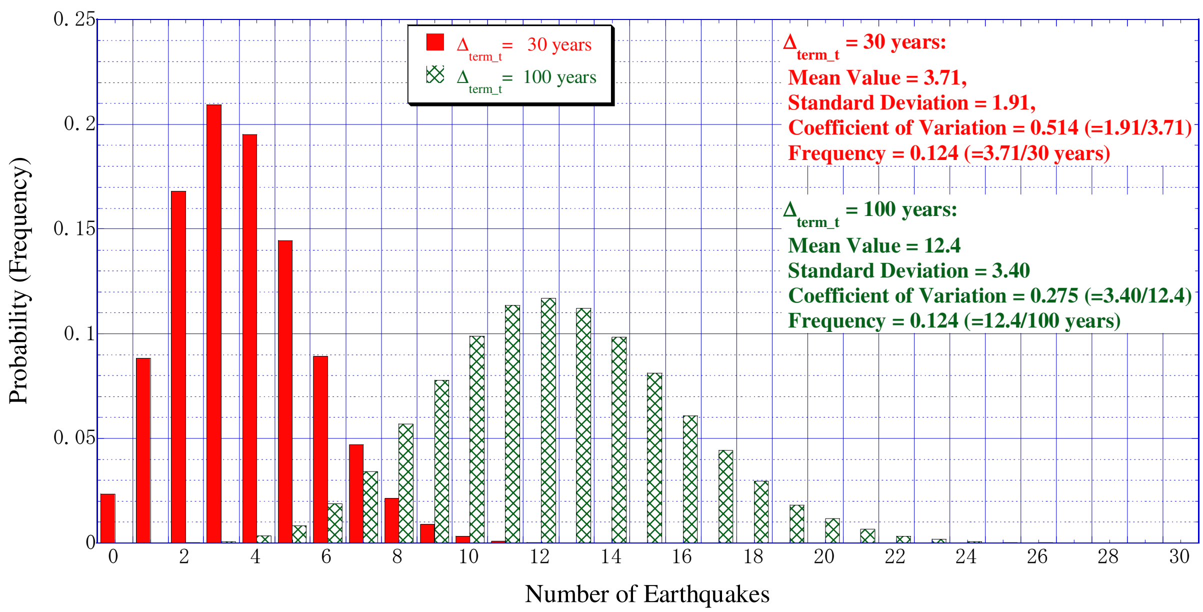

Figure 7 Probabilities of numbers of earthquake occurrences of $M_{JMA} \geq 6.5$ in given periods of 30 and 100 years in the Japanese major active fault systems

occurring in some period $\Delta term\_t$, when $\Delta term\_T$ is sufficiently long. Note that in principle all such probabilities $P_{\Delta term\_t}(n|\Delta term\_t)$ can be calculated by using the probability distribution for all the major active fault systems as shown in Figure 6. However, in practice, it takes too much computation time to calculate them directly from such probability distributions, especially when the number n is large.

Figure 7 shows the probabilities obtained for respective numbers of occurrences (occ.) in $\Delta term\_t$ periods of 30 years ($=P_{\Delta term\_t}(n|30)$) and 100 years ($=P_{\Delta term\_t}(n|100)$). Summarizing the results, the estimated probabilities are: $P_{\Delta term\_t}(n|30)$: 0 occ. 2.35%, 1 occ. 8.84%, 2 occ. 16.8%, 3 occ. 20.9% etc. $P_{\Delta term\_t}(n|100)$: 0 occ. 0.00%, 1 occ. 0.00%, 2 occ. 0.02%, 3 occ. 0.09% etc.

The mean value of the numbers of earthquake occurrences in $\Delta term\_t$ is calculated as follows:

$$E(\Delta term\_t) = \sum_n n \times P_{\Delta term\_t}(n \mid \Delta term\_t) \quad (6).$$

Standard deviation:

$$S(\Delta term\_t) = \sqrt{\sum_n P_{\Delta term\_t}(n \mid \Delta term\_t) \times (n - E(\Delta term\_t))^2} \quad (7).$$

Coefficient of variation:

$$C(\Delta term\_t) = \frac{S(\Delta term\_t)}{E(\Delta term\_t)} \quad (8).$$

Average frequency:

$$freq(\Delta term\_t) = \frac{E(\Delta term\_t)}{\Delta term\_t} \quad (9).$$

For the periods of 30 and 100 years respectively, the numerical values are: 30 years: $E(30)=3.71$,

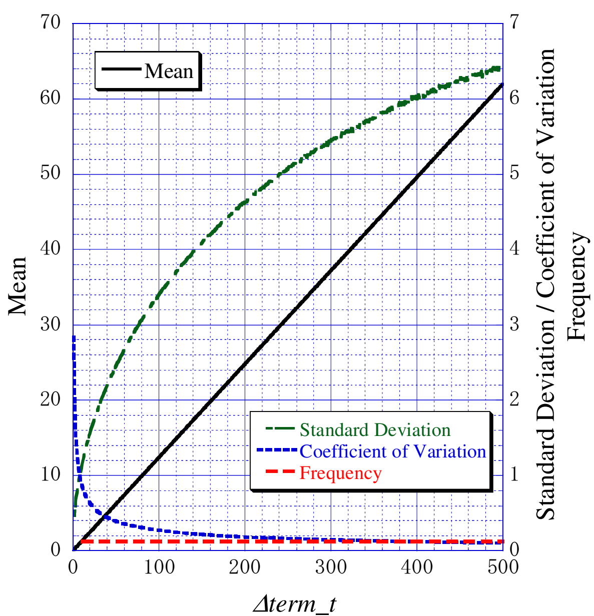

Figure 8. Mean, standard deviation, coefficient of variation of number of occurrences and frequency in relation assigned estimation term

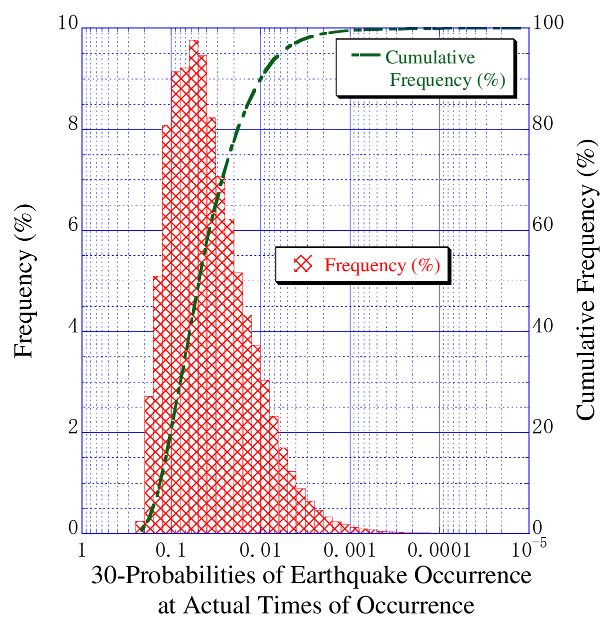

Figure 9. Frequency distribution and cumulative distribution of 30-year probabilities at actual time of each event

S(30)=1.91, C(30)=0.514, and *freq*(30)=0.124. 100 years: E(100)=12.4, S(100)=3.40, C(100)=0.275, and *freq*(100)=0.124. The frequency 0.124 is the same for $\Delta term\_t$ periods of both 30 and 100 years, and this value is in good accord with that of the historical record shown in Figure 3 (for $M_{JMA} \geq 6.5$). As for the coefficient of variation, it is found to be smaller for $\Delta term\_t$ 100 years than for $\Delta term\_t$ 30 years. As larger values are taken for $\Delta term\_t$, the coefficient of variation becomes smaller. The variations in values $E(\Delta term\_t)$, $S(\Delta term\_t)$, $C(\Delta term\_t)$, and $freq(\Delta term\_t)$ are resumed in Figure 8 for increasing lengths of $\Delta term\_t$. As is clear from the figure, $E(\Delta term\_t)$ increases linearly with $\Delta term\_t$, indicating that $freq(\Delta term\_t)$ is constant. $S(\Delta term\_t)$, however, does not increase together with $\Delta term\_t$, and hence $C(\Delta term\_t)$ decreases as $\Delta term\_t$ increases. From this, it can be inferred that it is difficult to predict the numbers of earthquake occurrences accurately from the active fault systems in period of under 100 years, and easier to predict those in longer periods.

30-year probabilities of earthquake occurrence at actual times of occurrence

As well as simulating the times of earthquake occurrences from various active fault systems, the authors also calculated the 30-year probabilities of earthquake occurrence at the actual times of occurrence.
Figure 9 shows the frequency distribution and cumulative distribution of the 30-year probabilities at the time of occurrence in a sufficiently long-term $\Delta term\_T$. As earthquakes more frequently occur in active fault systems with shorter mean recurrence intervals, these fault systems are better reflected in this figure.
As clear from the figure, very few earthquakes occur when their 30-year probabilities are more than 0.2 (20%), while 90% of earthquakes occur when their 30-year probabilities are more than 10^{-2} (1%), and most occur when their 30-year probabilities are more than 10^{-3} (0.1%). The same is readily apparent from the distribution of the mean recurrence intervals $\mu_{\Delta T}$ in Figure 2. Namely, mean recurrence intervals for the active fault systems mainly lie between thousands and tens of thousands of years, and hence the 30-year probabilities mainly lie between 0.01(30-year/thousands of years) and 0.001(30-year/tens of thousands of years) at the times when the earthquakes occur. It should be noted that the 30-year

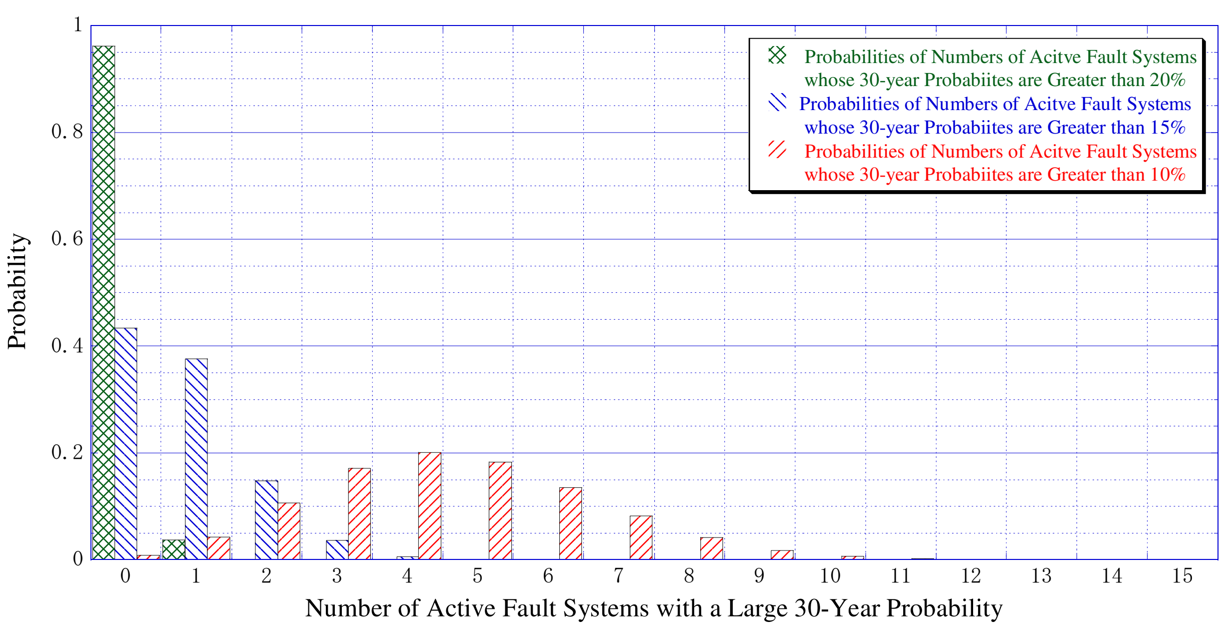

Figure 10 Probabilities of numbers of active fault systems whose 30-year probabilities are greater than selected values of 20%, 15%, and, 10%.

probability for one-third of all active fault systems is larger than 10^{-2}, and that for half of the active fault systems it is larger than 10^{-3}, as shown in Figure 6.

Probabilities of numbers of active fault systems whose 30-year probabilities are large

The authors also calculated the probabilities of numbers of active fault systems whose 30-year probabilities are noticeably large.

Figure 10 shows the probabilities of numbers of active fault systems whose 30-year probabilities are greater than 20%, 15%, and, 10%. For example, the probability of there being no active fault system whose 30-year probability is greater than 0.2 will be 96.2%, while the probability for one active fault system will be 3.76%, and the probability for two will be 0.05%. Similarly, the probability for no active fault system whose 30-year probability is greater than 0.15 will be 43.4%, while probability for one will be 37.6%. Or again, the probability for no active fault system whose 30-year probability is greater than 0.10 will be 0.78%, while that one such fault system will be 4.286%. As can be inferred from the figure, there is no good possibility of even the most hazardous of active fault system having a probability of 20% or more of an earthquake occurring within 30 years. On the other hand, there will be some active fault systems whose 30-year probabilities are more than 10%. There will be more or less one active fault system whose 30-year probabilities lie above 15%.

Sustainable countermeasure against earthquake disasters can be better planned utilizing these results in Figures 9 and 10. The number of hazardous active fault systems will be limited, while the 30-year probabilities will lie between 20% and 0.1%.

Hazardousness of the Gofukuji active fault system

Here the hazardousness of one particular active fault system is evaluated based on the above analyses. The Gofukuji active fault system now has 30-year probability, which is estimated to be between 19% and 7% by the subcommittee for Long-term Evaluation under the Earthquake Research Committee of the Japanese government's Headquarters for Earthquake Research Promotion. The mean value of 19% and 7% is 13%. The probability of there being one active fault system whose 30-year probability is greater than 19% will be 0.0934, while the probability for two such systems will be 0.00349, the probability for three will be 0.00004, and so on. From this, the probability that the Gofukuji system is the most hazardous in Japan, assuming that its 30-year probability is greater than 19%, can be calculated as follows:

$$\begin{aligned} \mathrm{Pr}\,ob &= \mathrm{Pr}\,ob(\text{Gofukuji} = \text{most hazadous active fault system} \mid \text{its 30 - year probability} \geq 19\%) \\ &= \frac{0.0934 \times 1/1 + 0.00349 \times 1/2 + \cdots}{0.0934 + 0.00349 + \cdots} = 0.990 \end{aligned} \qquad (10).$$

Similarly the probabilities of there being one active fault system whose 30-year probability is greater than 13% will be 0.326, the probability for two will be 0.273, and so on. Accordingly,

$$\begin{aligned} \mathrm{Pr}\,ob &= \mathrm{Pr}\,ob(\text{Gofukuji} = \text{most hazadous active fault system} \mid \text{its 30 - year probability} \geq 13\%) \\ &= \frac{0.326 \times 1/1 + 0.273\, 1/2 + \cdots}{0.326 + 0.173 + \cdots} = 0.785 \end{aligned} \qquad (11)$$

Again the probabilities of there being one active fault system whose 30-year probability is greater than 7% will be 0.0011, and the probability for two will be 0.00054, and so on. Accordingly,

$$\Pr ob = \Pr ob(\text{Gofukuji} = \text{most hazadous active fault system} \mid \text{its 30 - year probability} \geq 7\%)$$
$$= \frac{0.00011 \times \frac{1}{1} + 0.00054 \times \frac{1}{2} + \cdots}{0.00011 + 0.00054 + \cdots} = 0.116 \qquad (12)$$

As a result, the probability of Gofukuji being the most hazardous active fault system in Japan can be estimated as lying between 99% and 11.6%, with a mean probability of 78.5%. The Gofukuji active fault system is, therefore, very likely to be the most hazardous in Japan at the current time.

INTERACTIONS OF INTRAPLATE AND INTERPLATE EARTHQUAKES

The interactions

The authors further analyzed the interactions between interplate and intraplate earthquakes across the Japanese archipelago, not from the viewpoint of mechanics, but of statistics.

There are major plate boundaries in the Pacific Ocean along the Japanese coast, and great earthquakes of around M_{JMA} 8.0 or above are occurring at these boundaries about every 100-150 years. These major interplate occurrences are called "Nankai Great Earthquakes", "To-Nankai Great Earthquakes" or "Tokai Great Earthquakes", depending on the region in which they occur. They have generally occurred at almost the same time in each region, or within a few years of one other. There is a possibility that these periods of great activity at the plate boundaries may influence activities in the major active fault systems. Some researchers are pursuing the hypothesis that there may be "agitated" and "tranquil" periods for earthquake occurrences in the active fault systems.

Records of historical earthquakes in Japan (e.g. Usami 1987) suggest the possibility of such "agitated" and "tranquil" periods resulting from the activities of the very large interplate earthquakes. Figure 11 shows great earthquake occurrences in Japan in the past 400 years. Only interplate and intraplate earthquake events of M_{JMA} >7.0 are shown in the figure, because smaller earthquake events, especially in the older periods, might not all have been recorded. As can be seen in the figure, huge interplate

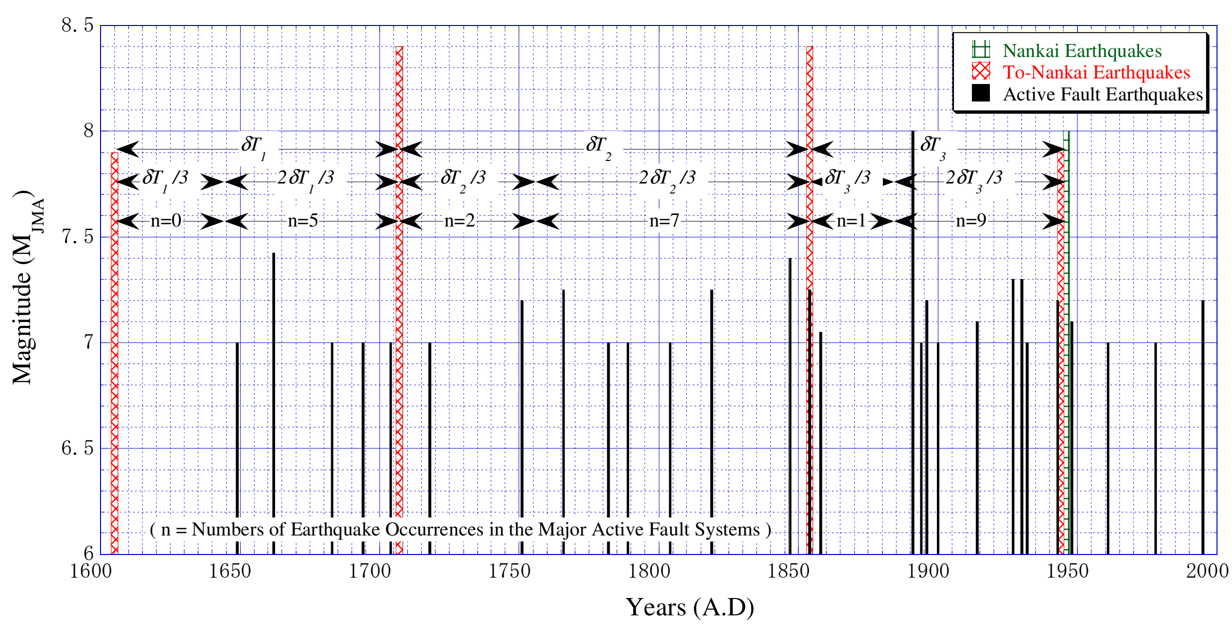

Figure 11 Recorded great earthquake occurrences in Japan in the past 400 years

earthquakes have occurred 4 times in the past 400 years, and hence 3 recurrence intervals δT_i $_{(i=1\text{-}3)}$ can be observed. It appears in the figure that very few intraplate earthquakes occurred in the active fault systems in the first third of each recurrence interval δT_i, while there were many occurrences in the later two thirds of each δT_i.

These activities can be assessed statistically by utilizing the probability estimates introduced in section 2, as follows. First, it is noticeable that no earthquake occurred in the first one-third term $\delta T_1/3$ (34 years) of the first recurrence interval δT_1, although Figure 10 indicates that the average number of earthquakes of $M_{JMA} \geq 7.0$ that can be expected in a 34 period is statistically 2.21. Similarly only two earthquakes occurred in the first third $T_2/3$ (49 years) of the second recurrence interval δT_2, although the statistical average for 49 years would be 3.18. Again, only one earthquake occurred in the first $\delta T_3/3$ (31 years) of the third recurrence interval δT_3, whereas the average would be 2.01. On the other hand, five earthquakes occurred in the later two-thirds $\delta T_1 \cdot 2/3$ (68 years) of δT_1, for which 4.42 would be the average number. Similarly, there were seven earthquakes in the later two-thirds $\delta T_2 \cdot 2/3$ (98 years) of δT_2, compared with the statistical average of 6.36 occurrences, and nine in the later two-thirds $\delta T_3 \cdot 2/3$ (61 years) of δT_3, where 3.96 is the average statistical number.

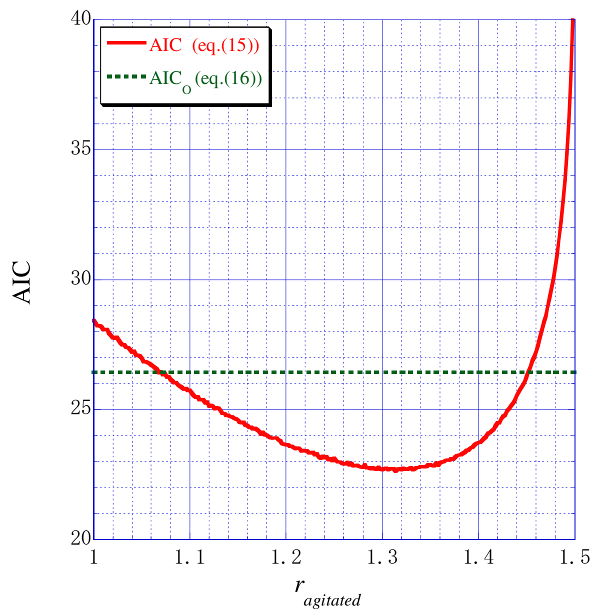

Figure 12 Result of the AIC assessment in terms of $r_{agitated}$ based on eqs.(15) and (16).

From this, the authors made a simple statistical assessment based on AIC with the following very rough assumptions: 1) In the later "agitated" two-thirds of each recurrence interval δT_i, the number of earthquakes occurring is expressed by the term $r_{agitated}$ (≥ 1) · 2/3 δT_i. 2) In the first "tranquil" third of each recurrence interval δT_i, the number of earthquakes is expressed in a similar way as $r_{tranquil}$ (≤ 1) · 1/3 δT_i. The relationship between $r_{agitated}$ and $r_{tranquil}$ can the be expressed as follows:

$$\delta T_i = r_{tranquil} \times \frac{1}{3} \cdot \delta T_i + r_{agitated} \times \frac{2}{3} \cdot \delta T_i \qquad (13).$$

Expressing $r_{tranquil}$ in terms of $r_{agitated}$ gives:

$$r_{tranquil} = 3 - 2 \times r_{agitated} \qquad (14).$$

Here $r_{agitated}$ is greater than 1.0 and smaller than 1.5. The AIC value can be calculated as follows:

$$\mathrm{AIC} = -2 \times \sum_{i=1,3} \ln(P_{term\_t}(n_{tranquil\_i} \mid \frac{1}{3}\delta T_i \times r_{tranquil})) - 2 \times \sum_{i=1,3} \ln(P_{term\_t}(n_{agitated\_i} \mid \frac{2}{3}\delta T_i \times r_{agitated})) + 2 \qquad (15).$$

Here $n_{tranquil\text{-}i}$ is the number of earthquakes occurring in the first third of the i^{th} recurrence interval, and $n_{agitated\text{-}i}$ is the number occurring in the later two-thirds of the same interval. The constant value in eq.(12) is 2 as the number of independent parameters is 1($r_{tranquil}$ or $r_{agitated}$). The AIC value of eq.(12) can be compared with that obtained without the assumption of a parameter $r_{tranquil}$ or $r_{agitated}$, which would be calculated as follows:

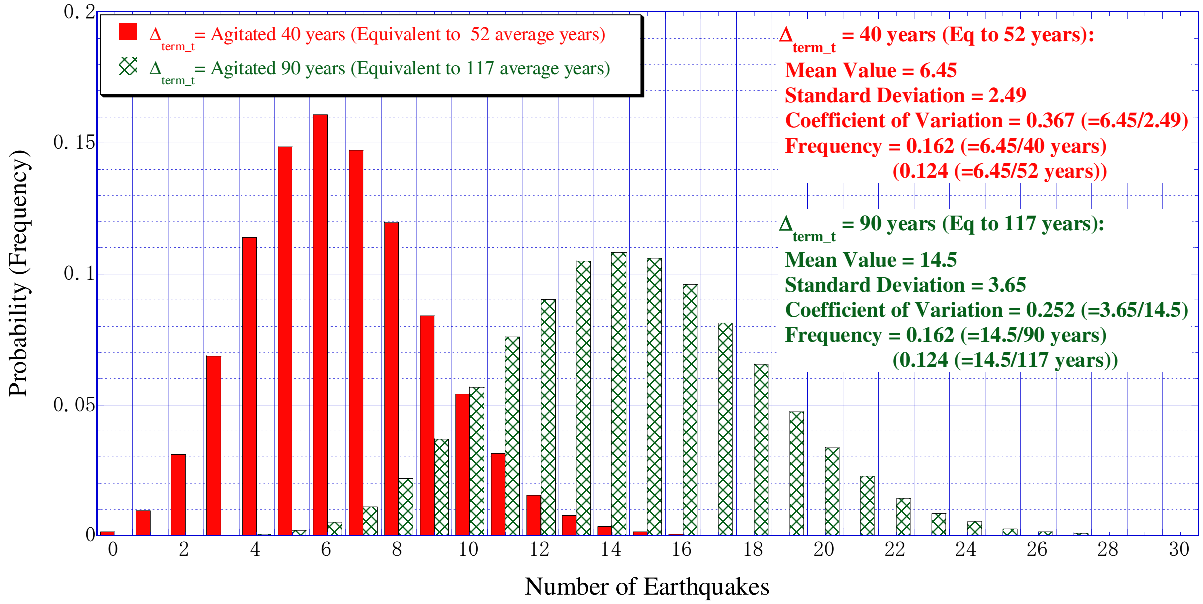

Figure 13 Probabilities of numbers of earthquake occurrences of $M_{JMA}\geq 6.5$ in the next "agitated" period of 40, or 90 years in the Japanese major active fault systems

$$\mathrm{AIC_O} = -2\times\sum_{i=1,3}\ln(P_{term\_t}(n_{tranquil\_i} \mid \frac{1}{3}\delta T_i)) - 2\times\sum_{i=1,3}\ln(P_{term\_t}(n_{agitated\_i} \mid \frac{2}{3}\delta T_i)) \quad (16).$$

Figure 12 shows the result of the AIC assessment of eqs.(15) and (16). As clear from the figure, the AIC values change remarkably under the influence of $r_{agitated}$. The AIC value is about 28.4 when $r_{agitated}$ is 1.0, and about 43.1 when it is 1.5. The AIC value reaches its minimum of 22.7 when $r_{agitated}$ is about 1.3. $\mathrm{AIC_O}$ maintains a constant value of 26.4. The difference between the AIC minimum and $\mathrm{AIC_O}$ is 3.7 (>1.0). Thus it can be roughly inferred from a statistical viewpoint that intraplate seismic activities in the "agitated" periods are 1.3 times as high as average, whereas those in the "tranquil" periods are only 0.4 times the average level. In other words, the activities in the "agitated" periods are more than 3 times (=1.3/0.4≥3.0) as high as those in the "tranquil" periods.

Probabilities of numbers of earthquake occurrences in the next "agitated" period

According to the above assumption and analyses, it can be predicted that the intraplate earthquakes are currently highly active across the Japanese archipelago. As shown in Figure 10, the great interplate earthquakes occur about every 100-150 years, and the latest ones occurred in 1944 and 1946. From this, the next earthquakes of this type can be roughly predicted to occur around 2045-2095. If the initial "tranquil" period is estimated as lasting one-third of the recurrence interval, this will amount to 33-50 years, and these years have already passed since 1944 or 1946. Now it can be inferred that the active fault systems are in an "agitated" period.

In the case of the next great interplate earthquakes occurring around 2045 (about 100 years after the latest ones), the current "agitated" period will continue around 40 years into the future. If they occur in 2095, it will continue about 90 years. For an "agitated" 40 years, the intraplate seismic activities in the active fault systems will be equivalent to those for 52 average years (1.3 times 40). For an "agitated" 90 years, they will be equivalent to those for 117 average years (1.3 times 90).

Figure 13 shows the probabilities for numbers of earthquake occurrences in "agitated" 40-year and 90-year periods (equivalent to those for average periods of 52 years and of 117 years). As shown by the 40-year curve, the mean number of earthquake occurrences is 6.45, the standard deviation 2.49, the coefficient of variation 0.367, and the frequency 0.162. As shown by the 90- year curve, the mean is 14.5, the standard deviation 3.65, the coefficient of variation 0.252, and the frequency 0.162. As can be seen from the figure, some ten or more earthquakes of M_{JMA}≥6.5 are expected to occur in the major active fault systems before the next very large interplate earthquake takes place.

RESULT

The present paper evaluated the frequencies of earthquake occurrences in the major active fault systems across the Japanese archipelago. The following points became clear from the results reported.

1 Probabilities can be predicted for the numbers of earthquake occurrences in given periods. For example, the probability of no earthquake occurring in 30 years is estimated as 2.35%, the probability of one earthquake is 8.84%, that of two earthquakes 16.8%, and so on.
2 It will be difficult to accurately predict the numbers of earthquake occurrences from the active fault systems in short periods of less than 100 years, but easier to predict those in longer periods.
3 It is estimated that very few earthquakes occur when their 30-year probabilities increase to more than 0.2, while more than 90% occur when their 30-year probabilities exceed 0.01, and more than 99.9% when their 30-year probabilities exceed 0.001. It should be noted that the 30-year probability for one-third of the active fault systems is estimated to be larger than 0.01, and that for half of the active fault systems is estimated to be larger than 0.001.
4 Probabilities are estimated for numbers of active fault systems whose 30-year probabilities are conspicuously large. For example, the probability of there being no active fault system whose 30-year probability is greater than 0.2 will be 96.2%, and the probability of there being one active fault system will be 3.76%. Similarly, the probability of there being no active fault system whose 30-year probability is greater than 0.15 will be 43.4%, the probability of there being one will be 37.6%, and so on.
5 The probability of Gofukuji being the most hazardous active fault system in Japan lies between 99.0% and 11.6%, and the mean probability is 78.5%.
6 It seems from statistics that intraplate seismic activities in the active fault systems in Japan might be influenced by the very large interplate earthquake occurrences at the plate boundaries off the Pacific coast, and that there might be so called "agitated" and "tranquil" periods.
7 Based on AIC analyses with one of the simplest models of seismic activities, it is estimated that activities in the "agitated" periods are about 1.3 times as high as average, and activities in the "tranquil" periods only about 0.4 times the average. That is to say, the activities in the "agitated" periods are more than 3 times (=1.3/0.4≥3.0) as high as in the "tranquil" periods.
8 On average, some ten or more earthquakes of M_{JMA}≥6.5 are expected to occur in the major active fault systems before the next very large interplate earthquake takes place.

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