

# M6 repeating earthquakes near Tokyo

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## 1. Introduction

On October 7, 2021, a magnitude 5.9 earthquake occurred in the northwestern part of Chiba Prefecture, with a maximum seismic intensity of 5 Upper on the JMA scale. This earthquake is considered to have occurred at the boundary of the Pacific Plate and the Philippine Sea Plate. It has been pointed out that the waveforms of this earthquake and the following M6 class earthquakes that occurred in the vicinity in the past (Figure 1) are similar (Earthquake Research Committee, 2021), and there is a possibility that they are repeating earthquakes.

2021/10/07 22:41 Depth 75km Mj5.9 Maximum seismic intensity 5 Upper  
2005/07/23 16:34 Depth 73km Mj6.0 Maximum seismic intensity 5 Upper  
1980/09/25 02:54 Depth 80km Mj6.0 Maximum seismic intensity 4  
1956/09/30 08:20 Depth 81km Mj6.3 Maximum seismic intensity 4  
1928/05/21 01:29 Depth 75km Mj6.2 Maximum seismic intensity 5

We digitized the seismic waveforms of the 1980 and 1956 earthquakes that were left as images on microfilm, and calculated the correlation coefficients (CC) between the earthquakes in the above list, including the 2005 and 2021 earthquakes for which digital seismic waveforms were available, to confirm whether they were repeating earthquakes.

## 2. Analysis method

Seismic waveform images of the east-west component of the Type 52 1x strong-motion seismograph at the Tokyo observation point of earthquakes in 1956 and 1980 were used for analysis. The seismic waveforms were picked manually by using GSYS2.4 graph reading system (Fig. 2). In addition, arc correction was applied by using the method of Kikuchi et al. (1999), and got 0.01second sampling data by using linear interpolation. For the 2005 and 2021 earthquakes, the data from seismic intensity meter at Otemachi, Chiyoda-ku, Tokyo, was filtered to match the characteristics of the Type 52 seismograph. CC were calculated by moving the time window of 40 seconds added to the S-P time by 0.01 seconds between 1 second before and 1 second after the arrival time of the P wave of each earthquake, and the maximum value was taken as the CC of the pair.

## 3. Analysis results

Figure 3 shows examples of the superposition of the waveforms of the 2005 earthquake and each earthquake. The full results of CC are shown in Table 1.

## 4. Discussion

The CC of the pair of 2021 and 2005 earthquakes is 0.93 and this high CC suggests that they are repeating earthquakes. 1980 and 1956 earthquakes have CCs that do not reach 0.9. However, considering the fact that these are manually picked data and the pen tip of the seismometer is too thick to read detail of the tremors, the CC seems to be high enough. The similarity in the superimposition of the waveforms suggests that these earthquakes are also repeating earthquakes that destroy almost the same

asperities.

Figure 4 shows cumulative slip of earthquakes calculated by using the equations of Hanks and Kanamori (1979) and Nadeau and Johnson (1998). 1928 earthquake is included tentatively. This graph chart shows that this seismic activity fits to both of slip predictable model (blue) and time predictable model (green). Since the slopes of both lines are almost the same, we can assume that earthquakes with almost the same amount of slip are occurring with almost regular time intervals. According to the time predictable model, the next earthquake of the 2005 earthquake is predicted to occur in mid-2028, but it actually occurred in October 2021, 16.2 years after the previous earthquake. This would be due to the faster subduction of the Pacific plate caused by the 2011 Tohoku earthquake.

Keywords: repeating earthquake, northeastern part of Chiba prefecture, Tokyo, digitize, Tohoku Earthquake, Pacific plate

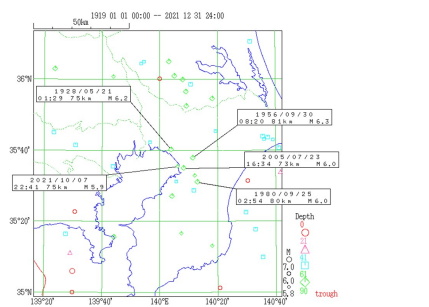


Fig. 1. Candidate earthquakes for M6 class repeating earthquakes in the northwestern part of Chiba prefecture.

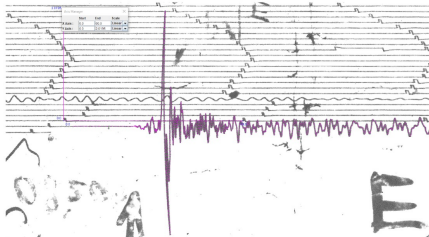


Fig. 2. View of GSYS2.4 graph reading system while reading seismic waveform data from an image of the 1956 earthquake manually. This is a seismogram of EW component.

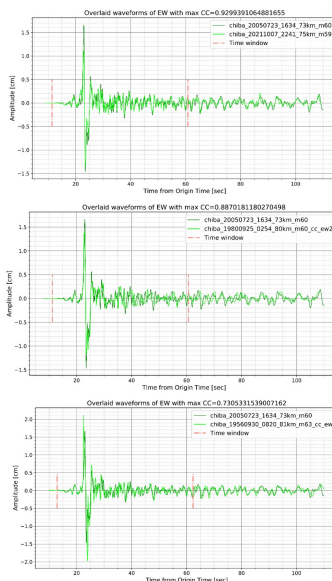


Fig. 3. Superposition of the waveforms of the 2005 earthquake (dark green) and earthquakes occurred in 2011, 1980 and 1956 (light green). Time windows for calculations of CCs are shown by pink dash-dot-dash lines.

Table 1. Correlation coefficients of EW components calculated in this study.

CC of EW comp.	2005/07/23 Mj6.0	1980/09/25 Mj6.0	1956/09/30 Mj6.3
2021/10/7 Mj5.9	0.93	0.82	0.69
2005/07/23 Mj6.0		0.89	0.73
1980/09/25 Mj6.0			0.76
1956/09/30 Mj6.3			

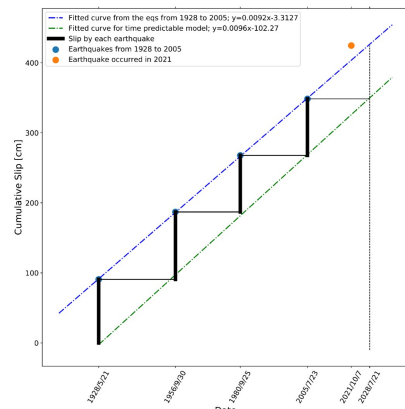


Fig. 4. Cumulative slip by earthquakes occurred in 1928, 1956, 1980 and 2005. This seismic activity fits both slip (blue line) and time (green line) predictable models. The latest earthquake occurred in 2021 (orange circle), earlier than prediction.