

Resolution for Estimating Occurrence Time of the 1707 Hiei Earthquake from Historical Documents

Kentaro Imai^{1*}, Akihito Nishiyama², Takuto Maeda¹, Takeo Ishibe², Kenji Satake², Takashi Furumura¹

¹CIDIR/ERI Univ. of Tokyo, ²ERI Univ. of Tokyo

Many Japanese historical documents record not only earthquake and tsunami damages, but also time of ground shaking. Usami (2003) and Iida (1985) compiled arrival times of the 1707 Hiei earthquake, and respectively concluded that the Tokai, Tonankai and Nankai segments ruptured simultaneously or sequentially within 2 hours. Tsunami can be amplified due to the superposition principle by a delayed rupture up to a few hours along the Nankai trough (Kawata, Suzuki and Takahashi, 2003; Imai, Satake and Furumura, 2010). Therefore, it is important to accurately estimate the earthquake occurrence time(s) for tsunami disaster mitigation from large interplate earthquakes along the Nankai trough. Furthermore, additional historical documents describing the Hiei earthquake were collected after the studies of Iida (1985) and Usami (2003). In this study, we selected reliable documents, statistically estimated the occurrence time of the Hiei earthquake, and discussed its resolution.

We selected reliable documents that were written within 30 years of the 1707 Hiei earthquake from Kyushu to Tohoku region. The recorded times of the Hiei earthquake at each location were compiled from these documents. The recorded times were spatially averaged because these arrival times can be regarded as the origin time of the Hiei earthquake. In 1700's Japan, time is counted by dividing day (between sunrise and sunset) and night into 6 units respectively, hence each time unit is about 2 hours. However, in some documents, a third of time unit was used to describe the earthquake, hence the temporal resolution can be assumed as short as about 40 minutes in such descriptions. Occurrence times described in historical documents are not directly comparable because sunrise and sunset times vary from one location to another. Therefore, we applied corrections for longitudinal differences.

The maximum likelihood estimate yields the occurrence time of the Hiei earthquake as 13:47 p.m. with the standard deviation of 1.02 hours. In addition, we investigated whether the Hiei earthquake had simultaneously ruptured all the segments or separately ruptured. For this purpose, we looked for the most suitable point that separates the recorded arrival times from two segments with different occurrence time, by using the Akaike's Information Criterion (AIC). The result indicates that statistically significant differences in the origin times are recognized; the rupture started on the Tonankai and Nankai segments followed by the rupture on the Tokai segment about 18 min later. We have shown that a delayed rupture of Tokai segment by 20 minutes would amplify tsunami heights about 1.2 times along the coast of Sagami Bay (Imai et al, 2010). Therefore delayed rupture scenario for future Nankai earthquakes is important for tsunami disasters.

Acknowledgments. This study was supported by Research Project of the "Improvements of strong ground motion and tsunami simulation accuracy for application of realistic disaster prevention of the Nankai-Trough mega-thrust earthquake" of the Ministry of Education, Culture and Sports,

Science and Technology.

Keywords: the 1707 Hiei earthquake, historical document, occurrence time, statistical analysis