

Is it possible to be early magnitude estimation of the 2011 Tohoku earthquake from tau_c by increased time window?

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Introduction

The tau_c method has been proposed as one of the algorithms for Earthquake Early Warning system for rapid estimation of eventual M (e.g., Wu and Kanamori, 2005). This method is based on the scaling law that large earthquakes are expected to be relatively richer in low-frequency than small earthquakes. The tau_c, average frequency of the seismic waveform, is calculated from the initial 3 s of the seismic waveform at the stations close to the epicenter, which is used to estimate the eventual M from the empirical tau_c-M relation. Applying the tau_c method to the 2011 Tohoku earthquake (Mw9.0), it would be difficult to estimate that the Mw9.0 event would be larger than the Mw7.3 event (Hoshiba and Iwakiri, 2011).

Is it possible to estimate appropriately M of the huge earthquake from tau_c if we use long time windows or the stations far from the epicenter? Even if as long as 30 s is used for window, or the stations far from the epicenter are analyzed, it would be available in terms of rapidity of the tsunami forecast. Zollo et al., (2011) showed that the M of the 2011 Tohoku earthquake was estimated to be more than 8.5 from tau_c method by using initial 30 s of the P-wave portion at the stations far from the epicenter. This suggests that the tau_c method has possibility of rapid estimate of M of the huge earthquake, even though its inherent rapidity of M estimation would be lost.

In this study, we investigate the possibility of rapid M estimation of the 2011 Tohoku earthquake from tau_c method by increasing time window length and/or by using the stations far from the epicenter.

Data and analysis

The earthquakes used in this analysis were 22 events occurred from January 2000 to December 2011 in and around Japan, in which we analyzed events of $M_j \geq 6.8$ and focal-depth ≤ 20 km for inland area and $M_j \geq 7.0$ and focal-depth ≤ 80 km for offshore area. We used the vertical-component accelerograms of the earthquakes recorded at the K-NET and KiK-net (surface). The tau_c is obtained from the ratio of square sum of displacement amplitude to square sum of velocity amplitude in time domain. The accelerogram was integrated and passed through a high-pass filter of 0.075 Hz to obtain the displacement and the velocity waveform. The time windows were used initial 3, 6, 9, 12, 15, 18, 21, 24 and 30 s of P-wave portion. The tau_c of event was the geometric average of more than five stations in the range of 50 km interval of epicentral distance.

Result and Discussion

First, we investigated the dependences of tau_c on time window length and distance. The tau_c tends to increase with increasing time window length, and also with increasing distance. It suggests that tau_c-M relation varies according to time window length and distance. Estimation of tau_c is scattered among the same M.

Based on the tau_c-M relation obtained from 3 s window and stations close to epicenter in previous study, tau_c of the 2011 Tohoku earthquake corresponds to about M8.5 in case that we use 30 s window and stations of the range from 300 km to 350 km. This might be consistent with the result of Zollo et al. (2011) mentioned above in Introduction.

However, when the dependences of tau_c on the time window length and the distance is taken into account, M of the earthquake from tau_c is estimated to be no more than M8, which is against the result of Zollo et al. (2011). The same tendency is obtained when 0.03 Hz or 0.02 Hz high-pass filter and 180 s window are used. This suggests that it would be difficult to recognize obviously that the 2011 Tohoku earthquake would be larger than the M8 event using tau_c, even if the long time window length and the stations far from the epicenter are used. Because the waveforms of the 2011 Tohoku earthquake contained strong high-frequency contents, especially for more than 10 Hz (Iwakiri and Hoshiba, 2011), which deviated considerably from the empirical tau_c-M relation, the M of the 2011 Tohoku earthquake was underestimated in tau_c method.

Keywords: tau_c, the 2011 off the Pacific coast of Tohoku Earthquake