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Rapid magnitude estimation of great earthquakes for tsunami warning

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One of major problems in the tsunami warning for the 2011 off the Pacific coast of Tohoku Earthquake (Mw 9.0) was a lack of awareness of underestimation of the earthquake magnitude at the time soon after the occurrence. Displacement magnitude, which is usually used for the first tsunami warning a few minutes after the earthquake occurrence, could not evaluate such large magnitude due to short cutoff period (six seconds) compared to the rupture duration (about three minutes). Seismic moment could not be determined from the regional seismological network data due to over range of broadband sensor outputs, and it took longer time to estimate it from global data. To overcome these difficulties in earthquake magnitude estimation, we are developing servral methods to estimate proper magnitude roughly and to understand possible magnitude underestimation soon after such large earthquakes.

Large earthquakes cause strong shaking in a wide area. Length of strong-shaking area is related to earthquake magnitude. Seismic intensity distribution in Japan can be known in a few minutes after earthquake occurrence owing to a dense on-line network of seismic intensity meter in Japan. The area of seismic intensity greater or equal to 5-upper (the Japan Meteorological Agency seismic intensity scale) reached about 700 kilometers in length. It is possible to estimate earthquake magnitude and source area roughly from the span of strong shaking.

Strong motion is observed at sites close to the source region. Maximum distance between the observation site and source area can be estimated from observed seismic intensity. If source area is assumed on the plate boundary, the fault plate could be estimated. However, the far edge of the fault is not able to be obtained from seismic intensity distribution.

The duration of the strong motion becomes also longer for larger earthquakes. Good correlation is seen between strong-motion duration and earthquake magnitude. The duration of the earthquake in March, 2011 exceeded eighty seconds, which is the largest among those of large earthquakes in and around Japan.

It takes a long time to complete a rupture of a large earthquake. Excitation of long-period seismic wave is one of features of large earthquakes. The cutoff period for the displacement magnitude was too short for the earthquake. Usage of long period components of seismic wave would help to estimate earthquake magnitude properly. A method of watching growth of magnitude from long-period seismic wave was developed. The magnitude from long-period seismic wave was estimated to reach the final value within three minutes for the earthquake in March, 2011.

Combination of these methods is expected to help us to issue a proper tsunami warning for the next great earthquake.

Keywords: magnitude determination, great earthquakes, area of strong motion, strong-motion duration