Underestimate of the size of microearthquakes by the JMA magnitude scale and its influence to earthquake statistics

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Earthquake statistics needs parameterized information on earthquakes. One of such parameters is the magnitude. The local magnitude scales, such as the JMA magnitude (Mj), based on amplitudes of seismograms are easy to estimate and therefore usually included in earthquake catalogs. The moment magnitude (Mw) is based on the physical source parameter, seismic moment, however needs much effort for the estimation especially for microearthquakes. Though the consistency between Mj and Mw is guaranteed for the medium earthquakes, we need to check that for microearthquakes.

As for use of earthquake catalogs, we should know the completeness magnitude above which catalog is complete. A type of it is Mc defined as a magnitude where magnitude-frequency distribution starts deviating from the Gutenberg-Richter’s (GR) law. Another one is based on earthquake detectability. Schorlemmer and Woessner [2008] proposed Mp based on the detectability inferred from the pick information. They showed the Californian case that Mp is smaller than Mc, which indicates the breakdown of the GR law. It is important to confirm if the breakdown really occurs. Our study investigates if the discrepancies are also seen in case of Mw.

Mw Estimation for Microearthquakes

We stably estimate seismic moment of microearthquakes based on moment ratios to nearby small earthquakes whose seismic moments are available in the NIED MT catalog, by a multiple spectral ratio analysis [Uchide and Imanishi, under review]. Applying this method to earthquakes in Fukushima Hamadori and northern Ibaraki prefecture areas, eventually we obtained the seismic moments of a total of 19140 earthquakes (Mj 0.4 - 3.8). The striking result of this study is that the change in slopes of the Mj-Mw curve: 1 and 0.5 at higher and lower magnitudes, respectively (see Figure). The discrepancies between Mj and Mw are significant for microearthquakes, suggesting that Mj underestimates the sizes of microearthquakes.

Completeness Magnitudes and b-values

The result above must affect earthquake statistics. Here we study Mc and b-value of the GR law. Following Ogata and Katsura [1993], we assume the earthquake detectability as the cumulative normal distribution with a mean, μ, and a standard deviation, σ, and estimate the GR parameters (a and b) together with μ and σ. We define Mj = μ + 2.33σ where the detection rate is 99 %. Applying this method to the monthly seismicity data in the study area, we found that the Mc for Mw is lower than that for Mj converted into Mw, however still larger than Mp converted into Mw. This may be due to the breakdown of the GR law for microearthquakes, though another possibility is that the incompleteness of earthquake catalog overestimates the detectability, resulting the underestimate of Mw.

b-values for Mw (bw) are systematically larger than those for Mj (bj). The temporal trends for bw and bj are similar to each other. When bj increases, bw also increases. This does not affect discussions inferred from the qualitative temporal change in b-values [e.g., Nanjo et al., 2012]. bw is often larger than 1.5, indicating that the moment release is dominantly done by smaller earthquakes.

Acknowledgement

We used the JMA Unified Earthquake Catalog, seismograms from NIED Hi-net and the NIED moment tensor catalog.
Keywords: Earthquake statistics, JMA magnitude, Moment magnitude, Spectral analysis, Completeness magnitude, b-value