気象庁マグニチュードによる微小地震の大きさの過小評価と地震統計への影響
Underestimate of the size of microearthquakes by the JMA magnitude scale and its infuence 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 (M_j), based on amplitudes of seismograms are easy to estimate and therefore usually included in earthquake catalogs. The moment magnitude (M_w) is based on the physical source parameter, seismic moment, however needs much effort for the estimation especially for microearthquakes. Though the consistency between M_j and M_w 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 M_c 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 M_p based on the detectability inferred from the pick information. They showed the Californian case that M_p is smaller than M_c, 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 M_w.

M_w 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 (M_j 0.4 - 3.8). The striking result of this study is that the change in slopes of the M_j-M_w curve: 1 and 0.5 at higher and lower magnitudes, respectively (see Figure). The discrepancies between M_j and M_w are significant for microearthquakes, suggesting that M_j underestimates the sizes of microearthquakes.

Completeness Magnitudes and b-values

The result above must affect earthquake statistics. Here we study M_c 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 μand σ. We define M_c = μ+ 2.33 σwhere the detection rate is 99 %. Applying this method to the monthly seismicity data in the study area, we found that the M_c for M_w is lower than that for M_j converted into M_w, however still larger than M_p converted into M_w. 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 M_p.
b-values for M_w (b_w) are systematically larger than those for M_j (b_j). The temporal trends for b_w and b_j are similar to each other. When b_j increases, b_w also increases. This does not affect discussions inferred from the qualitative temporal change in b-values [e.g., Nanjo et al., 2012]. b_w is often larger than 1.5, indicating that the moment release is dominantly done by smaller earthquakes.

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Figure: Comparison between M_j and M_w inferred from the multiple spectral ratio analyses (color image for the distribution and circles for the median M_w) and the NIED MT solutions.

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