Probability of earthquake growth to a large one in an earthquake early warning system: Re-estimation for the Nankai trough region

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In an earthquake early warning system (EEWS), it is important to estimate the focal parameters (location, magnitude) of an earthquake quickly. However, there is difficulty in estimating quickly the magnitude for a large earthquake. If we use only the first few seconds of the wave data, the estimation of the magnitude is done before the rupture terminates; there is a possibility that the magnitude estimated quickly is smaller than the final magnitude (i.e., the estimated magnitude after the rupture termination). Considering this difficulty, Iwata et al. [2005] (hereafter referred to as IW2005) suggested a method to estimate the growth probability (i.e., probability of earthquake growth to a large one) immediately after observing its initiation, and applied the method to the Nankai trough region, located along the southwest coast of Japan. A part of the results of IW2005 is improper for a practical EEWS use; in this study we modify the method and re-estimated the growth probability in the Nankai trough region.

To examine the growth probability, we first need to estimate $p(M)$, the probability density function of the final magnitude in the focused region. In IW2005, $p(M)$ was derived from the historical earthquake data occurred in the Nankai trough. In the estimation of the $p(M)$, two models were considered: in one model (hereafter referred to as model A), the existence of the characteristic earthquakes is not assumed; in the other model (hereafter referred to as model B), the existence is assumed. The growth probabilities, which is defined as the probability that the final magnitude exceeds 7.5 if the observed earthquake magnitude reaches 6.5, is 25% and 41% for model A and B, respectively. Incidentally, since degree of the goodness-of-fit between the two models is close, we cannot find which model is the significantly better; we only conclude that the true growth probability between 25% and 41%. However, for incorporating our idea to the EEWS, a specified value of the growth probability must be given.

In case when we have plural competitive models, the quasi-Bayesian method [Akaike, 1979, 1980] is useful. In this method, model parameters are derived from the mixture of the competitive models, and mixing proportion of the models are determined by AIC (Akaike's Information Criterion) or ABIC (Akaike's Bayesian Information Criterion) of the models. Using the quasi-Bayesian method, we do not need to specify one model as the best one among the competitive models; in our case, we can estimate a value of the growth probability without specification of the models.

In IW2005, a Bayesian approach is used in the estimation of the model parameters. In model B, g, a parameter that indicates the ratio of the number of earthquakes having the characteristic behavior to that of the whole earthquakes, is introduced. As a prior distribution of g, the uniform distribution on an interval (0, 0.5] was used in IW2005. This is because the number of characteristic earthquakes is assumed to be smaller than that of earthquakes following the Gutenberg-Richter law. However, the number of characteristic earthquakes would be much smaller than a half of the whole number of the earthquakes; the upper limit of the uniform distribution as a prior distribution of g must be set to a value much smaller than 0.5. However, it is difficult to determine this value a priori. We regard the upper limit as a hyperparameter and determine this using the ABIC minimization procedure.

As a result of the modification, the growth probability is re-estimated as 31%. Using this probability, we could incorporate our method in EEWS.

References
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