Empirical forecast of mainshocks based on foreshock activities - Applied to the specific three regions and inland area of Japan -

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1. Introduction

Generally it is quite difficult to distinguish foreshocks from background seismicity before a mainshock occurs. However, it is known that some activities like swarms tend to be followed by large earthquakes. We have investigated statistical features of swarm-like activity and searched for the best parameters to define foreshocks. So far, we have found that such defined foreshock activities are particularly effective for specific three regions in Japan: regions along the Japan trench, off the Izu peninsula region, and in the north-central Nagano prefecture, and proposed best parameters for each regions to define foreshocks. In this study we report the current status of prediction performance for three regions basing on the latest data. Besides, we also demonstrate the preliminary results of prediction performance for the inland area of Japan using the same parameters estimated for the north-central Nagano prefecture.

2. Method

The method to search for parameters for foreshocks that present high prediction performance consists of four steps. 1) To eliminate small aftershocks from the original data. 2) To define foreshock candidates satisfying the condition that earthquakes of count Nf with magnitude >= Mf_0 occur in the segment of the size of D x D degree (latitude x longitude) during the period of Tf days. 3) To set the alarm period of Ta days during which a mainshock is expected to occur after a foreshock candidate is found. 4) To search for the values of D, Mf_0, Tf, Nf and Ta which give high prediction performance for mainshocks with M >= Mm_0 by the grid search method. The prediction performance is measured mainly by dAIC that is defined as the difference of AIC for a stationary Poisson model and a model based on a foreshock activity, and additionally by alarm rate (AR: the fraction of mainshocks alarmed), truth rate (TR: the fraction of foreshock candidates followed by a mainshock), and probability gain (PG: the ratio of mainshock occurrence rate in the predicted space-time to background occurrence rate).

3. Data and Results

1) Along the Japan Trench

By applying the above method to the earthquakes with M >= 4.0 and depth <= 100 km in three regions along the Japan trench, i.e., off Iwate, off Miyagi and off Ibaraki, cataloged by JMA during the period from 1961 through 2010, we obtained the best parameters for foreshocks as D=0.5 degree, Mf_0 =5.0, Tf=10 day, Nf=3, and Ta=4 days to predict mainshocks with M>=6.0. The prediction performance for the latest period from 1961 to 1/31/2016 is expressed as AR=27% (=13/48) and TR=22% (=17/77).

2) Off the Izu Peninsula

Using earthquakes with M >= 3.0 and depth <= 50 km off the Izu peninsula regions during the period from 1977 to 6/31/2013, we obtained the best parameters for foreshocks as D=0.2 degree, Mf_0=3.0, Tf=3 day, Nf=3, and Ta=5 days to predict mainshocks with M>=5.0. The prediction performance from 1977 to 1/31/2016 using the above parameters is expressed as AR=68% (=44/65) and TR=22% (=43/195).

3) In the North-central Nagano Prefecture

Using earthquakes with M >= 2.0 and depth <= 30 km in the north-central Nagano prefecture during the period from 1998 through 2014, we obtained the best parameters for foreshocks as D=0.1 degree, Mf_0=2.0, Tf=1 day, Nf=5, and Ta=5 days to predict mainshocks with M>=5.0. The prediction performance from 1998 to 1/31/2016 using the above parameters is expressed as AR=45% (=5/11) and

TR=12% (=8/69).
4) Inland of Japan
As a preliminary calculation, we apply the parameters obtained for the north-central Nagano prefecture, i.e., D=0.1 degree, Mf_0=2.0, Tf=1 day, Nf=5, and Ta=5 days for mainshocks with M>=5.0, to the inland area of Japan except for Izu. The prediction performance obtained for the period from 1977 to 1/31/2016 is expressed as AR=11% (=9/79) and TR=1.8% (=11/607).

Keywords: earthquake prediction, performance, foreshocks, statistics, empirical relation, Japanese inland area

