

Empirical forecast of occurrence of mainshocks based on foreshock activities

- Applied to the specific five 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 reported that such defined foreshock activities are particularly effective for specific three regions in Japan: along the Japan trench, off the Izu peninsula region, and in the north-central Nagano prefecture. In this study we report the current status of prediction performance for these three regions basing on the latest data and also the results for newly investigated regions: the central part of Kyushu and the San-in districts. Besides, we also demonstrate the preliminary results of prediction performance for the inland area of Japan using the temporally applied parameters.

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 N_f with magnitude $\geq M_{f_0}$ occur in the segment of the size of $D \times D$ degree (latitude \times longitude) during the period of T_f days. 3) To set the alarm period of T_a days during which a mainshock is expected to occur after a foreshock candidate is found. 4) To search for the values of D , M_{f_0} , T_f , N_f and T_a which give high prediction performance for mainshocks with $M \geq M_{m_0}$ 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 foreshock-based model mentioned above, 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

We applied the above method to the earthquakes in three regions along the Japan trench, i.e., off Iwate, off Miyagi and off Ibaraki, cataloged by JMA. The prediction performance for the latest period from 1961 to 1/31/2017 is expressed as AR=27% (=13/48) and TR=22% (=17/77) for $M_{m_0}=6.0$ by applying the best parameters ($D=0.5$ degree, $M_{f_0}=5.0$, $T_f=10$ days, $N_f=3$, and $T_a=4$ days) obtained for the period of 1961-2010.

2) Off the Izu Peninsula

The prediction performance from 1977 to 1/31/2017 resulted in AR=68% (=44/65) and TR=22% (=44/197) for $M_{m_0}=5.0$ by applying the best parameters ($D=0.2$ degree, $M_{f_0}=3.0$, $T_f=3$ days, $N_f=3$, and $T_a=5$ days) obtained for the period of 1977-6/30/2013.

3) North-central Nagano Prefecture

The prediction performance from 1998 to 1/31/2017 resulted in AR=45% (=5/11) and TR=11% (=8/70) for $M_{m_0}=5.0$ by applying the best parameters ($D=0.1$ degree, $Mf_0=2.0$, $Tf=1$ day, $Nf=5$, and $Ta=5$ days) obtained for the period of 1998-2014.

4) Central Kyushu District

The prediction performance from 1970 to 1/31/2017 resulted in AR=31% (=4/13) and TR=6.5% (=3/46) for $M_{m_0}=5.0$ by applying the best parameters ($D=0.1$ degree, $Mf_0=3.0$, $Tf=10$ days, $Nf=3$, and $Ta=12$ days) obtained for the period of 1977-3/31/2016.

5) San-in District

The prediction performance from 1977 to 1/31/2017 resulted in AR=24% (=5/21) and TR=11% (=4/37) for $M_{m_0}=5.0$ by applying the best parameters ($D=0.1$ degree, $Mf_0=3.0$, $Tf=1$ day, $Nf=2$, and $Ta=24$ days) obtained for the period of 1977-12/31/2016.

6) Inland of Japan

The prediction performance from 1977 to 1/31/2017 resulted in AR=12% (=23/190) and TR=4.6% (=30/657) for $M_{m_0}=5.0$ by applying the same parameters for off the Izu peninsula region.

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