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Prediction performance of empirically defined foreshocks in the Izu region

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1. Introduction

Foreshocks have been thought one of the most promising phenomena to predict large earthquakes. However, as the physical mechanism of foreshocks is not clarified yet, it is very difficult to distinguish them deterministically from background seismicity before a mainshock occurs. Therefore, empirical approach is one of the realistic ways to use foreshock activity as a precursor of a mainshock. We investigate probabilistic features of empirically defined foreshocks and search for the best parameters to define foreshocks which present relatively high performance to predict large earthquakes. Maeda (1996) and Maeda and Hirose (2012) proposed a foreshock definition which gives relatively high performance to predict large earthquakes along the Japan trench. In this study we basically apply the same method to the seismicity in the Izu region where swarm activities related with magma movements are frequently observed, and estimate the prediction performance based on empirically defined foreshock activities.

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 as the activities that have number of Nf earthquakes with magnitude >= Mf during the period of Tf days in the segment of the size of D x D degree (latitude x longitude). 3) To set the alarm period of Ta days after a foreshock candidate during which a mainshock is expected to occur. 4) To search for the values of Tf, Mf, D, Nf, and Ta which give high prediction performance by the grid search method. The prediction performance is measured mainly by dAIC, which 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 for predicted space-time to background occurrence rate).

3. Data and Results

By applying the above method to the earthquakes cataloged by JMA for the period of 1977 - 2013/06 in the Izu region (33.5N, 138.6E - 35.3N, 139.8E), we obtained the best parameters for foreshocks as Tf=3 days, Mf=3.0 D=0.2 degree, Nf=3, and Ta=5 days for the prediction of mainshocks with M>=5.0. The prediction performance is expressed as dAIC=473, AR=68% (=44/65), TR=23% (=46/196), and PG=225. We also confirmed that the distribution of interval time between foreshocks and mainshocks is better approximated by a power law like the modified Omori's aftershock distribution rather than an exponential distribution. The 26%(=20/77) of mainshocks that occurred within 5 days after the foreshocks have occurred within 4.8 hours after the foreshock. The distance distribution between foreshocks and mainshocks is also found to be better expressed by a power law. If we focus on the specific region of Off Ito (34.8N, 139.0E - 35.1N, 139.3E) where is one of the most active foreshock region, the prediction performance of the same foreshock definition measured by AR and TR, becomes as better as AR= 100% (=18/18) and TR= 37% (=15/41) with dAIC= 166, and PG= 105. As for the Off Ito region, the JMA have been operating an algorithm for predicting the swarm activity basing on the rate increase of volumetric strain observed near the region. When we compare the timing of issuing the prediction information about the swarm activity by the JMA with that of the occurrence of the foreshock defined above, we find that there is not much difference between them. This means that the foreshock activity in this region is strongly related to the crustal deformation before the mainshock.

Keywords: foreshocks, probabilistic prediction, prediction performance, alarm rate, truth rate, Izu region