Empirical forecast of the occurrence of mainshocks based on foreshock activities

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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 (the truth rate is more than 10%) for specific three regions in Japan: three areas along the Japan trench, off the Izu peninsula region, and the north-central Nagano prefecture region. We have also reported the prediction performance for two regions; the central part of Kyushu and the San-in districts. Besides, we have demonstrated the preliminary results of prediction performance for the inland area of Japan using the temporally applied parameters. In this study we report the current situation of the prediction performance for these regions (Fig.1).

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 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 (Table 1)

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 Mm_0=6.0 by applying the best parameters (D=0.5 degree, Mf_0=5.0, Tf=10 days, Nf=3, and Ta=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 Mm_0=5.0 by applying the best parameters (D=0.2 degree, Mf_0=3.0, Tf=3 days, Nf=3, and Ta=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 Mm_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 Mm_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 Mm_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 Mm_0=5.0 by applying the same parameters for off the Izu peninsula region.

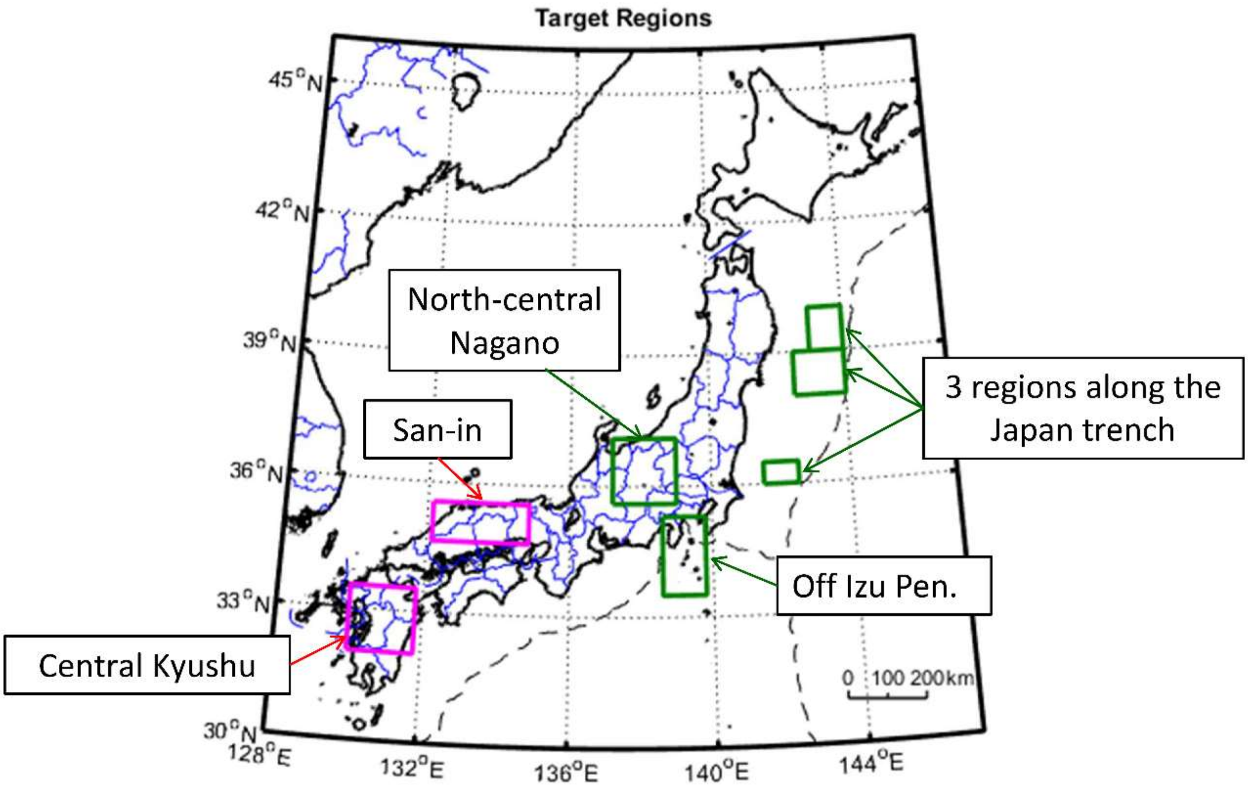

Figure 1. Target regions to be applied the prediction method based on foreshock activities.

Table 1. Summary of the prediction parameters and performance for each region.

Target Regions	Target Periods	Best Parameters D,Mf_0,Tf,Nf,Ta for Mm_0 (optimized period)	Alarm Rates	Truth Rates	Probability Gains (For optimized periods)
3 regions along the Japan trench	1961～ 2017/1/31	0.5, 5.0, 10, 3, 4, 6.0 (1961－2010)	13/48 = 27(%)	17/77 = 22(%)	380
Off the Izu pen.	1977～ 2017/1/31	0.2, 3.0, 3, 3, 5, 5.0 (1977－2013/6)	44/65 = 68(%)	44/197 = 22(%)	225
N.C. of Nagano	1998～ 2017/1/31	0.1, 2.0, 1, 5, 5, 5.0 (1998－2014)	5/11 = 45(%)	8/70 = 11(%)	333
Central Kyusyu	1970～ 2017/1/31	0.1, 3.0, 10, 3, 12, 5.0 (1970－2016/5)	4/13 = 31(%)	3/46 = 6.5(%)	365
San-in	1977～ 2017/1/31	0.1, 2.0, 5, 2, 12, 5.0 (1977－2016)	9/21 = 43(%)	11/492 = 2.2 (%)	89
		0.1, 3.0, 1, 2, 24, 5.0 (under TR≧5%)	5/21 = 24(%)	4/37 = 11 (%)	120
Inland of Japan (temporary)	1998～ 2017/1/31	0.1, 2.0, 1, 5, 5, 5.0 (from Nagano case)	8/84 = 9.5(%)	10/496 = 2.0(%)	—
	1977～ 2017/1/31	0.2, 3.0, 3, 3, 5, 5.0 (from Izu case)	23/190 = 12(%)	30/657 = 4.6(%)	—