Medium-Term Prediction of Sakhalin's Dangerous Seismic Events in the LURR and SRP Models

Medium-Term Prediction of Sakhalin's Dangerous Seismic Events in the LURR and SRP Models

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Abstract. This paper is devoted to the two methods of strong earthquakes prediction based on the analysis of seismic catalogues. The first method is well-known as LURR (*load-unload response ratio*) and involve the Coulomb-Mohr's criteria and basic laws of linear theory of elasticity. Inherently, it allows identify attainment of the deformation process of the phase when medium response to loading can be no longer linear (pre-destruction). The second method so called as SRP has relation to self-organized processes theory. The both methods have proved the effectiveness on the Sakhalin but have used separately. The research is based on Sakhalin seismic catalog ($M_w > 2$). We have considered retrospectively seismic event near the Cape Krillon in case of combination of two methods.

1. Introduction

Nowadays there are some achievements in long and short time earthquake prediction. We should mark some of them [1-8]. These approaches are mostly based on seismological data and predictions are made for 5-10 years (long-term) and 3-5 years (mid-term). The method of mid-term prediction, named LURR, was invented in 90-th years of previous century and in accordance with [9, 10] was successfully applied in different seismicity active regions. Besides, the methodology has been verified and accomplished in the laboratory tri-axial compression simulation together with numerical simulation [11]. This method is used in the Institute of Marine Geology and Geophysics of Russian Academy of Sciences since 2014 year. We have made special software [12] to perform main calculations and get important result for seismic hazard of Sakhalin Island [13-15].

To detect the final stages of preparation of strong earthquake and prediction of the time of its occurrence in the IMGiG FEB RAS successfully used the SRP method (a method of self-developing processes), developed by A. I. Malyshev (IGiG UB RAS) [16-18]. This technique allows construct adequate models of seismic process on the basis of the nonlinear differential equation of the second order called the equation of self-developing processes. At the same time, the forecast of earthquake occurrence time is days – the first months before the main shock. Good accuracy of the algorithm is achieved so far only retrospectively with the appropriate setting, which involves the selection of the boundaries of the zone and the calculation period. There is the presence of parameters that are obtained by direct selection, and it causes a reasonable share of criticism. However, the LURR method can help to make the approach of parameter selection in the SRP more specific. The boundaries of the earthquake preparation zone with a magnitude above 5 can be localized according to the seismotectonic model of the region on the nearest lineament within 50-100 km. In this paper,

retrospectively on the Krillon earthquake example (24.04.2017, Mw=5.2), the LURR and SRP methods will work together.

2. Methodology

The starting point of LURR method is equivalence of load-unload response rates during elastic state deformation $X_+ = X_-$(LURR = 1). Since damage of material becomes more serious and goes beyond the bounds of elastic limit (figure 1), the LURR-parameter starts to increase.

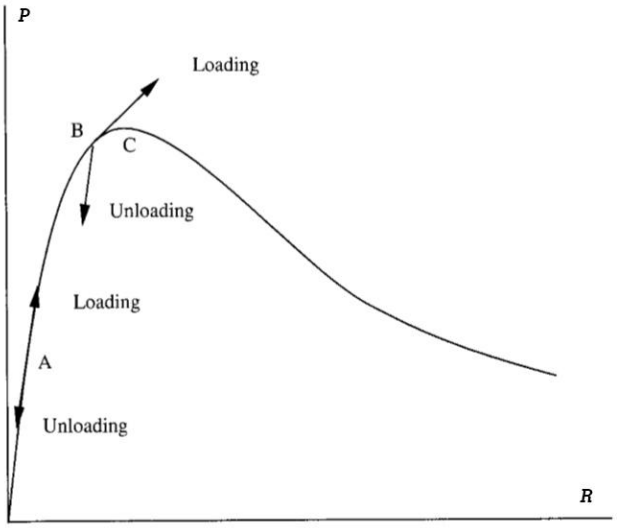

Figure 1. The constitutive curve of focal zone.

This relation grows as the rock is approaching to fast microcracking phase. We can consider that near critical behavior prior damage. The main concept and details of LURR method are expounded in the author's articles [10, 11, 19]. In our calculations we have used our own software the "Seis-ASZ" created in the Institute of Marine Geology & Geophysics of Russian Academy of Sciences [12]. The "Seis-ASZ" software uses the original algorithms of LURR method as well as analytic correlations for tidal perturbation [20, 21]. We have verified our "Seis-ASZ" tidal displacement simulation with [22] data of Berger's program and satisfactory convergence was found. Calculations using the SRP method were performed in the software package provided by the author of the method Malyshev A.I. "SeisDynamicsView".

3. Results

The seismic catalogue for the calculations includes earthquakes with a magnitude of 2 in the period from 2010 till the 12-th of April of 2017, this is the last entry before main shock. The parameters for the calculation of LURR function are standard for all our work: window – 360 days, shift 60 days, the range of magnitudes 3.3-5. Areas for the calculation were initially selected in the size of 1 degree latitude and longitude in the semi-axis of the ellipse. Ellipses were selected with an overlap of 1 degree (total 9 zones). The study area is the South Sakhalin and North Hokkaido (Figure 2). These dimensions satisfy the original work and our experience [9, 15]. In zones 4 and 5, signs of a significant excess of the threshold were found in April-May 2015 (an example of the result for zone 5 in Figure 2b). Also, a slight increase was recorded in 2013 did not exceed 3σ. By sorting out the smaller rectangular zones, the position of the zone where the precursor of 2015 is maximally reflected was established (figure 2c). The LURR parameter returned to the background values only at the beginning of 2016. In fact, within 2 years after the appearance of the precursor, an earthquake with a magnitude higher than 5 occurred in this zone and it agrees with LURR technique. The results of calculations in areas of smaller size, including the zone of the West Sakhalin fault (WSF) showed that a precursor

was formed in the zone of responsibility of the WSF. This information is used in basic settings for SeisDynamicsView. In this area, according to the SRP method, we used a catalogue of earthquakes in the magnitude range from 2 to 3 for the period from 2003 to April 2017. The graph of the accumulation of events during the investigated period on the figure 3a is shown. This chart reflects the periods of preparation of the seismic regime to SRP. However, as can be seen from the curve and catalog data – not always SRP leads to a strong earthquake. So, such case reflects the earthquake occurred in the period from 06.2012 to 08.2012, but is not associated with a strong event. Opposite case is earthquake near the Gornozavodsk (17.08.2006, Mw=5.6) and its aftershock process. Important information in this graph are the points of transition from the period of deceleration to the stationary process, and then to the mode with acceleration. The starting point for the new process (after 2006 and 2012) is 10.04.2013.

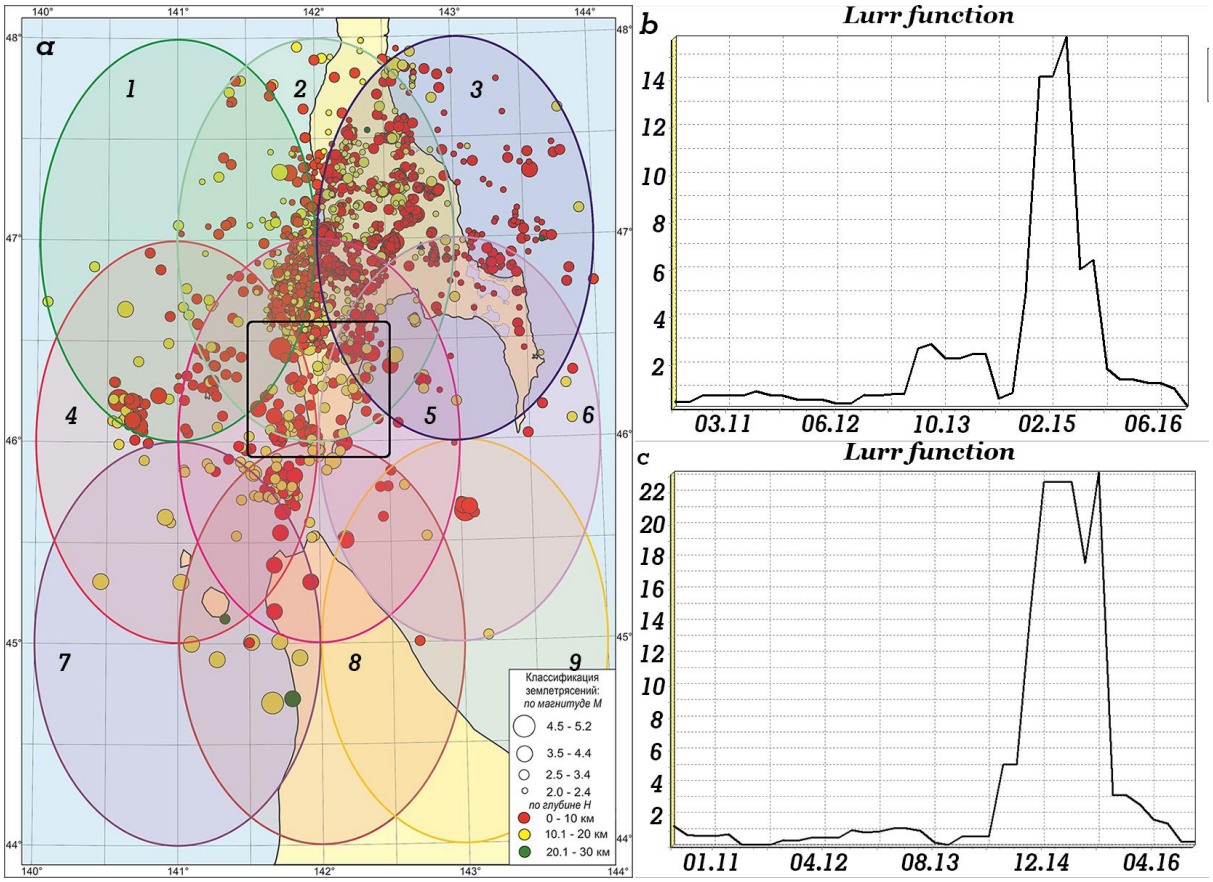

Figure 2. a) Calculation zones, b) The result for zone №5, c) The result for refine zone (black rectangle on the figure 2a).

The graph of the SRP based on full catalog until 12.04.2017 (the last event before the earthquake) on the figure 3b. The program calculates the time dependence of the asymptote 10.06.2017. The shift of the end point of calculation period one step ago showed that the parameter Ta (forecast time) changing, this uncertainty is present throughout the accelerated mode interval. We were able to determine the last point in the stationary mode (figure 3 c) and the first point in the accelerated mode (figure 3d), it is 02.06.2016 and 14.07.2016 respectively. The forecast in first point of acceleration mode is Ta = 25.11.2016 15:45:55. As data accumulates from July 2016 to April 2017, the forecast is regularly adjusted, with a waiting time of several days to three weeks. It makes no sense to react to such forecasts, and, apparently, in the mode with acceleration it will not be possible to improve the forecast any more.

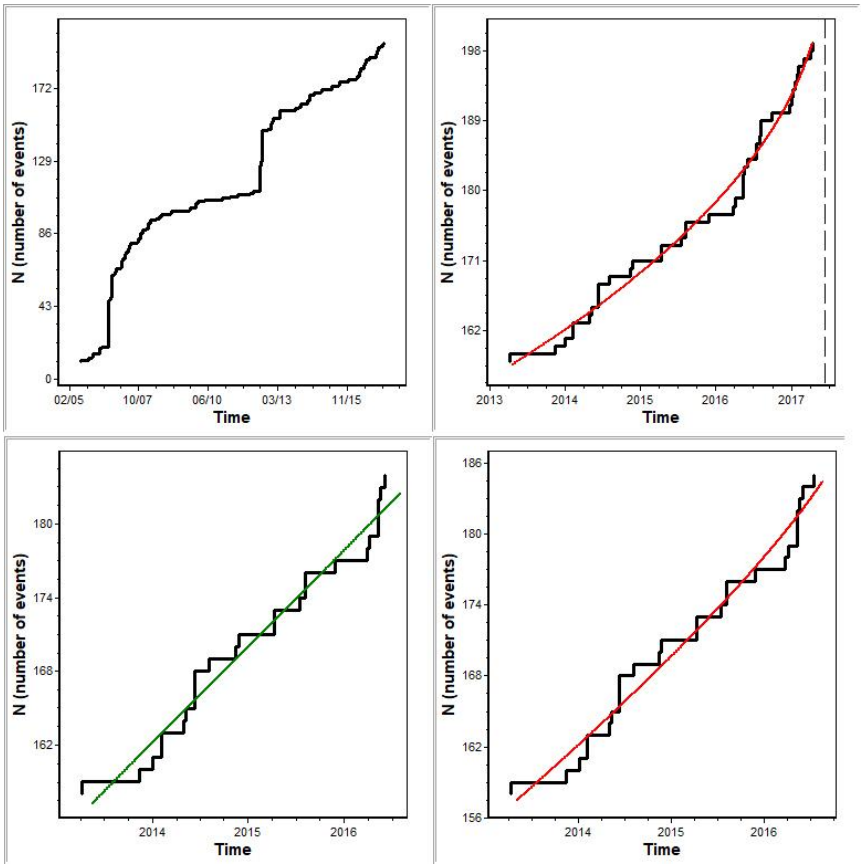

Figure 3. The SRP calculations for detailed LURR zone: full period, increase mode (all points), stationary mode, increase mode (first point).

4. Conclusions

LURR could also be an indicator measuring the proximity to the SOC state and the tectonic stress level for a specified region. The LURR theory is still young therefore it has a broad room to develop. Besides seismic energy that we have used in our calculations, many other geophysical parameters concerning the seismogenic process such as Coda Q, ratio of velocity, level of groundwater, radon activity could also be the R (response) to define LURR. Based on the results of this work, the LURR forecast was adjusted by the SRP method by the date with a time gain of more than one year (by the LURR method, slightly less than two years) to nine months. If you take into account what to expect on the result of SRP (point of exit to the mode with acceleration) earthquake could not earlier than 25.11.2016, the waiting time is less than five months.

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