MA Heqing and YANG Mingzhi, 2018. Discussions on Several Problems about the Seismic Activity Field. *Acta Geologica Sinica* (English Edition), 92(supp.2):93-95.

Discussions on Several Problems about the Seismic Activity Field

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1 Introduction

In order to solve the problem of earthquake forecasting, above all, it is necessary to find the element variable that can represent the essence of seismic activity. Secondly it is necessary to find the method that can analyze the anomalies of this element variable. The authors have taken the random variables such as energy released by small earthquakes and seismic activity frequency as the seismic activity element field. And through the method of natural orthogonal expansion on the random field, its temporal changes could be analyzed to discover the abnormal changes before large earthquakes (Yang and Ma, 2016).

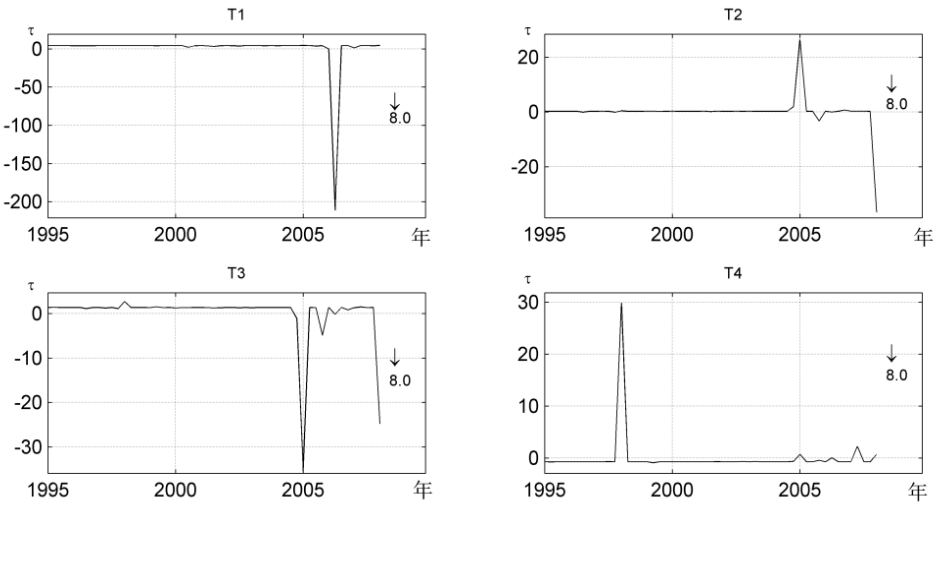

Fig. 1 The first four typical time factor curves of May 12, 2008 Sichuan Wenchuan 8.0 earthquake

The first three typical field time factors remain near the base value for a long time and changes are little. It shows that the main part of regional seismicity is in a relatively stable active state. The time factor of the fourth typical field was basically stable except for a sudden rise in 1998. But three years before the Wenchuan M8.0 earthquake, the stationary state became changed. The point value of the first typical field time factor T_1 in April-June 2006 showed obvious negative abrupt decrease abnormal change. The other three typical field time factors change as follows: T_2 and T_3 showed mid-term abnormal changes in 2005, respectively and the point values from January to March 2008 showed short and imminent sudden drop before the earthquake. And the point value of the fourth typical field T_4 increased by a small margin 15 months before the earthquake, i.e., from April to June 2007.

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The natural orthogonal expansion method on the random field is briefly described as below, taking the seismic activity energy field as the example. To make the narrative simple, we have omitted the formula and please refer to the reference for details (Yang and Zhao, 2004).

Taking energy released by earthquakes in an area within a certain time period and within grids divided by longitude and latitude to be calculated, the results are given in matrix form $\boldsymbol{E}$. Having excluded large earthquakes and aftershocks, the seismic energy distribution gotten shown in energy matrix have been called seismic background field, or taking its annual average to get the mean field of annual seismic activity. Just giving the m-degree observations of n spatial meshes in matrix form, an energy matrix $\boldsymbol{F}$ related to space and time has been gotten. It represents a seismic energy element field with space-time coordinates as variables. In order to analyze the relative variation of the field, the moment equality of energy is generally taken as the observed value, that is, the matrix $\boldsymbol{F}$ formed by subtracting the background field from the energy field,

the moment equality of energy is generally taken as the observed value, that is, the matrix $\boldsymbol{F}$ formed by subtracting the background field from the energy field observed at each time period. The expansion of natural orthogonal function is to decompose $\boldsymbol{F}$ into the sum of orthogonal space function and orthogonal time function. Note that the space functions and time and functions are orthogonal and normalized.

Order $\boldsymbol{R} = \boldsymbol{F'F}$, so the problem is transformed into finding eigenvalues and eigenvectors of matrix $\boldsymbol{R}$. Having solved n eigenroots of matrix $\boldsymbol{R}$, thus the corresponding eigenvector can be obtained. Because of the symmetry of matrix $\boldsymbol{R}$, all eigenvalues are positive real numbers. If they are arranged in order of magnitude, the corresponding n eigenvectors are the n typical fields of the energy field.After finding the coefficient matrix of eigenvectors, the main typical fields represented by the first k eigenvalues can be expanded on $\boldsymbol{E}$. Generally speaking, the number of typical fields is OK when the expansion accuracy is over 90%.

2 Significances to introduce the concept of the random field of seismic activity

2.1 About the method

Taking the seismic activity element variable as the function of time and space, passing through the natural orthogonal function expansion, n typical fields independent of each other could have been resolved. Each typical field is a pattern or type of the spatial distribution of seismic activity energy. The typical field, together with its time factor, have described a state of seismic activity. Thus, a mathematical method for describing seismic activity is found .

2.2 Significances

And more significantly, that random functions have been expanded into the sum of natural orthogonal components can select the linear combination which has the maximum variability(variance). That is, this linear combination is the time factor of typical field T_1 which the maximum eigenvalue corresponding to. Then linear combinations T_k not corresponding to T_1 can be analyzed. And the linear combination T_2 which has the maximum variability can be selected. After selecting a few linear combinations that are not large in number, the variability of all the remaining linear combinations is small. Thus, if we want to describe the main variation characteristics of the field, we don't have to use all the expanded items. It is sufficient to use the combinations which the largest of these eigenvalues corresponding to. These n typical fields, which are naturally orthogonal expanded, are not equally important. The typical field with large eigenvalue occupies a large proportion in the total field. In the case of energy field, because the convergence of natural orthogonal function expansion is very fast, more than 95% accuracy can be reached as long as only the first 3 ~ 4 typical fields are superimposed in most cases. They represent the main part of the field and this would be tantamount to concentrating the main information of the original field in the first three to four major typical fields. So concentrating on these major typical fields, main variation characteristics of earthquake energy release can be understand and the problem can be simpler and clearer. The main typical fields of seismic activity field and time factors of main typical fields are the macroscopic statistical parameters which reflect abnormal changes with focus. By analyzing them, finding out the typical field with abnormal variation, excluding typical fields that do not change or are less associated with large earthquakes, it would probably be an effective way of searching for anomalies of seismic activity before large earthquakes and doing further exploration of earthquake forecasting (Yang and Ma, 2013).

2.3 Focus

If the earthquake occurrence is regarded as a kind of nonlinear process, it is not the end result of system evolution but the system performance before mutation that we are interested in from the angle of earthquake forecasting. That is, from analyzing abnormal activities before mutation, then judgement about stability of dynamic evolution of seismicity could be gotten.

3 Conclusion and discussion

The seismic activity fields have described the radom characteristics of seismic activity. The seismic activity contains rich information about deep stress state and dielectric property. The temporal and spatial variation of regional seismic activity can show the spatial variation of the field and can show the tendency of actual stress accumulation and concentration related to the preparation of large earthquakes. It might be different that the degree of anomaly indicated by different grades of earthquakes. Because larger magnitude earthquake activity is more likely to highlight abnormal changes, so it is more significant for precursor from the angle of earthquake forecasting.

By analyzing the examples of multiple earthquakes with $M \geqslant 7$ and $M6$ that occurred after 1980, it is showed that random field method can identify seismicity anomalies. And different seismic element fields and various methods can be used to show anomalies. Abnormal appearances are clear and have the characteristics of abnormal index quantification. In the process of time, middle, short, and temporary features have been showed (Yang and Ma, 2011; Yang and Ma, 2012; Ma and Yang, 2012; Yang et al., 2013; Ma and Yang, 2018). It is very advantageous to analyze the anomaly of seismic activity. The May 12, 2018 Wenchuan 8.0 earthquake is taken as an example, see Fig. 1.

4 The problems existed

Earthquake examples of current analysis have been done in the case of having known earthquake parameters. It is still very difficult to forecast unknown large earthquakes, and it is necessary to make unremitting exploration.

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