Detection of Earthquake Precursors in GIS GeoTime

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INTRODUCTION

In this article we consider the theoretical foundation of GeoTime technology which developed to conduct earthquake forecast research and earthquake precursors detection and analysis. Experimental testing was performed for Suusamyr earthquake precursors analysis.

Identification of earthquake precursors based on the assumption that the geological environment is inhomogeneous in space but has stationary dynamics in normal state, which is violated during the preparation of a geological disaster. It is considered that analyzed sequences are stationary, but their statistical characteristics are changed in the process of preparing earthquake.

DETECTION ALGORITHM

The basic idea of GeoTime is to complement the traditional analysis of individual geo-monitoring time series with analysis of the grid dynamic fields. Dynamic fields are calculated by the earthquake catalogs and the time series of geophysical, hydrogeological, geochemical and geodetic measurements. Presenting data as a spatial-temporal raster allows to see more complete the preparation of the earthquake dynamics than the submission in the form of time series to observe the processes evolving in time and space. It is obvious that cartographical and statistical analysis of initial and transformed dynamic fields to supplement the analysis of time series that will provide an opportunity to explore more fully the process of earthquake preparation and to find new precursors of earthquakes or other geological disasters.

In this article, the method of constructing a 3D raster based on density of earthquakes estimation is used: given the cylinder of radius R in the (space) and the length of T in time, value in the grid point is the ratio of the number of events, caught in this cylinder, to its volume.

To detect anomalies the temporal sequence of values of each element of the spatial raster is analyzed. The current interval of time series values in the raster elements is divided into two consecutive subintervals with duration set by the user, depending on the context of the problem being solved. Thus the problem reduces to a comparison of two random samples belonging to the subintervals. Each sample is stationary and homogeneous in a probabilistic sense, and then we can consider the *t*-statistics, which is the normalized difference between two averages of the first and second sample. If this statistic exceeds a certain threshold we can say that the anomaly is observed.

To automate the anomaly search using the following scheme. For each moment of time (cut in 3 dimensional raster) is determined by the method of optimized brute force approximating Gaussian (i.e., its coordinates and magnitude), the size of anomaly and the degree of confidence determine this anomaly. Then the dependence of these parameters on time is displayed and you can choose the anomalies with a good degree of confidence.

DETECTION OF SUUSAMYR EARTHQUAKE PRECURSORS

Suusamyr earthquake occurred on 19.08.1992. For the analysis we used the catalogue that had been cleaned of aftershocks. Preprocessing of the catalogue had been fulfilled in IES RAS by G.A. Sobolev. The catalogue covers the polygon from 40.4°N to 44°N and from 71°E to 81°E and corresponds to the period 1980 – 2001. In the catalogue there are 16329 events of energy class K from 7 to 17. For research of the Suusamyr earthquake precursors we used the subcatalogue up to the day before the earthquake occurred.

Because of insufficient volume of seismostatistics in relation to spatio-temporal extent of the anomaly previous Suusamyr earthquake, we used density of epicenters of earthquakes. At estimation following parameters of a window were used: radius of window R=100 km, time interval T=10 of days. The 3D grid-based field of density of epicenters is constructed in a grid with step on longitude $\Delta\lambda=0.3°$, on width $\Delta\varphi=0.2°$ and on time $\Delta T=10$ of days. For each knot of a spatial grid the statistics for model with independent Gaussian sequences with parameters is calculated: duration of a back window $T_1=1440$ days, duration of a forward window $T_2=30$ days.

On the following step estimation of time rows, parameters 3D a grid-based layer of anomalies is made: degrees of confidence that on an appropriate time cut there is one anomaly which is well enough approximated by Gaussian, centre co-ordinates, decrement of fading, amplitude and size.

On fig. 1 results of the analysis of anomalies in three projections are shown: XY, TY and XT where the axis X corresponds to a longitude, axis Y – width and axis T – time. By red dots in all projections epicenters of the strongest earthquakes with $M \geq 5.5$ are shown. By white circles co-ordinates of Gaussians for which approximate negative anomalies values degree of confidence detection of anomaly are exceeded by level 0.5 are shown. From picture it is possible to see that the anomalies corresponding to these conditions, since 1981, are allocated only before Suusamyr earthquake. Also we can see that in investigated spatio-temporal area significant anomalies are found out only before investigated earthquake. The anomaly centre will shift on 50-100 km to the east from earthquake epicenter. The found parameters can be used for construction of a formal rule of the forecast.

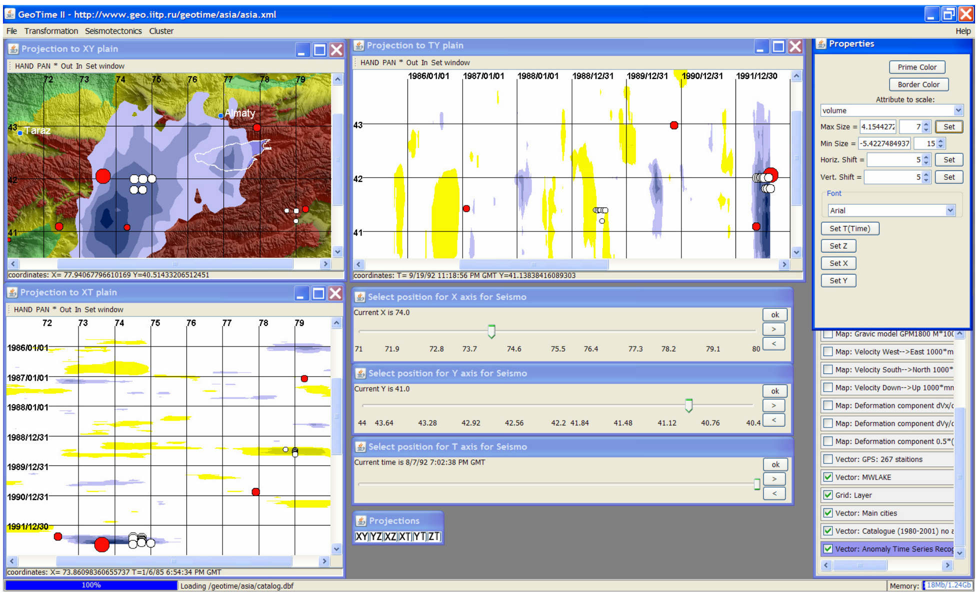

Figure 1: A pattern of Susamyrsky earthquake precursor.

CONCLUSIONS

The basic idea of geo-information analysis in GeoTime technology is to complement the traditional time series analysis and temporal sequences of events, obtained by geomonitoring, with complex spatial-temporal analysis of multidisciplinary dynamic fields, calculated from these data. The problem of detection of earthquake precursors and estimation of their significance is reduced to the problem of detecting space-time anomalies on one or more 3D meshes. The algorithm analysis of earthquake catalogs and estimating the parameters of seismicity based on the statistical model the flow of seismic events. On the example of Susamyr earthquake it's shown that, using GIS GeoTime II, spatial and temporal anomalies associated with the preparation of the earthquake can be reliably detected with high confidence.

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