A METHOD OF HYDROGEODYNAMICAL DATA ANALYSIS FOR REVEALING EARTHQUAKE PRECURSOR

GENADI KOBZEV, GEORGE MELIKADZE
Institute of Earth Sciences, Ilia State University

In order to analyze data series, different methods of mathematical statistics are applied generally. However, all of them have one weak point: after removal of the trend caused by exogenous factors (tidal variation and atmospheric pressure) the applied frequency filters distort the required endogenous signal.
We have developed a new method using computer program MatLab. It enables to synthesize a theoretical signal and compare it with original data of water level. The program enables to characterize each exogenous parameter separately. It allows studying the influence of each of them on the aquifer. It is determined that the aquifers are influenced by all kinds of exogenous factors. The reaction of boreholes demonstrates that one of them can dominate. After processing by suggested method almost identical figures describing the tectonic factor have been received.

Keywords: MatLab program, exogenous factors

1. Introduction

Revealing mechanism of interrelation between the deformation processes, strong earthquakes and hydrodynamics of underground waters would allow explaining precursory behaviour of hydrodynamic field and developing scientifically well grounded methods of earthquakes' forecast. At the analysis of materials, scientists individually selected methods of mathematical statistics, but all of them had one thing in common: after removal of the trend caused by exogenous factors (tidal variation and atmospheric pressure) they used frequency filters (P. A. Hsieh at al., 1987, 1988), that in our opinion distort the required endogenous signal. The residual values were analyzed for revealing correlation of water level variations with seismic events.

Our method, which uses the computer program MatLab, created exogenous theoretical signal and compare it with real signal. In comparison with the last, the method enables to characterize every exogenous parameter separately. That makes possible to study influence of each of them on the water aquifer.

2. Data analysis

The following factors influence the aquifer and changes in water level: tides, atmospheric pressure, precipitation, tectonic-seismic factors, the error from apparatus and so on. Let us represent the summary signal using linear equation:

$$Water\ level = a*tidal + b*atmos + c*precip + e;$$

with *a* - coefficient for tidal variation, *b*–atmosphere pressure, *c*–precipitation, and *e*–geodynamical signal.

Water level and atmospheric pressure are measured directly at boreholes. Theoretical data for tidal variations are generated by the program GRAV. To determine the, stress conditions in the aquifer after strong earthquake, Dobrovolsky's $e=10^{1, 3M-8, 19}/R^3$ equation has been applied. In the catalog, we select earthquakes, which are strong enough to affect boreholes' sites (Fig. 1).

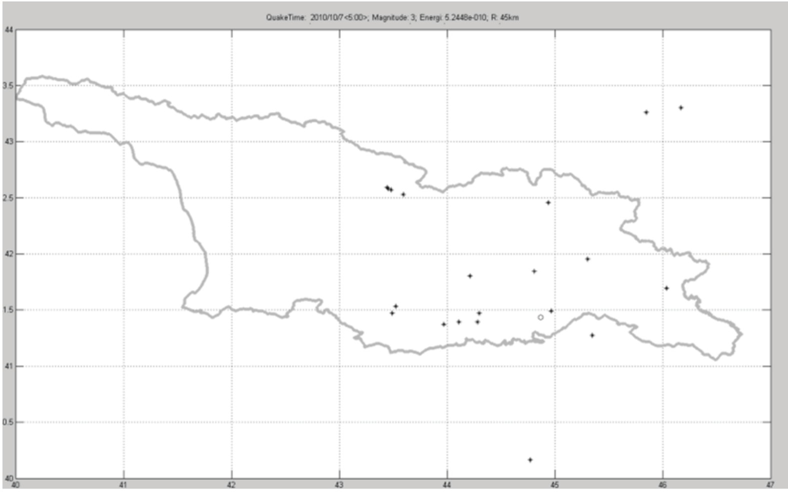

Fig. 1 Earthquakes, which were selected by energy, distance or magnitude

We can also select earthquakes by magnitude and distance from the borehole. So, for example, there is observed an evident correlation of underground water level changes with tidal variations for “Marneuli” borehole.

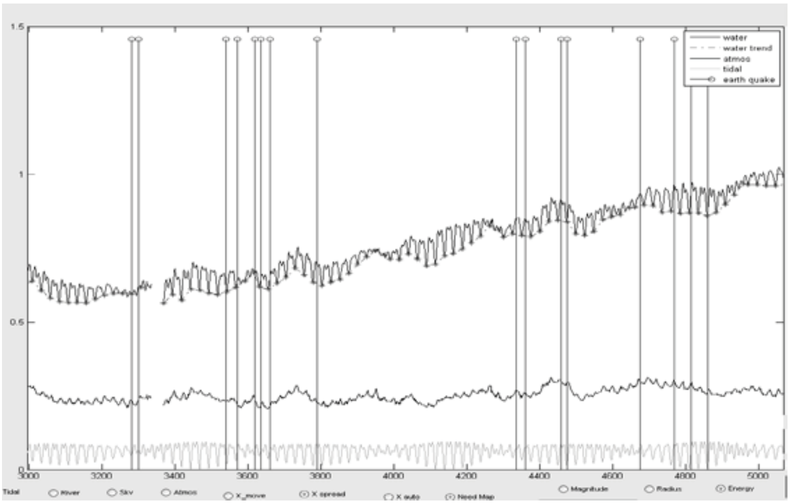

Fig. 2. Water level, tidal variation, atmosphere pressure and earthquakes at Marneuli station Upper line is water level, lower line is tidal variation, middle line is atmospheric pressure. Vertical lines indicate earthquakes.

Program finds minimum time-points of tidal variation and compare it with water level variation value's point at the same time. By connection of these points we receive some "trends" of both parameters. After extracting this "trend" from the original data, we receive "residual" values of water level variation.

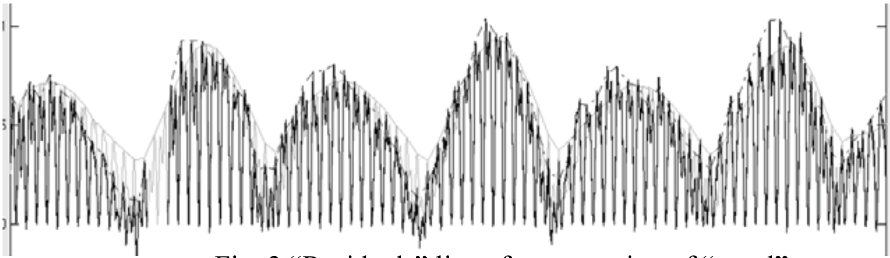

Fig. 3 "Residuals" line after extraction of "trend"

Program calculated such type of "residual" values for atmosphere pressure, too. Program allows extracting different influence of tidal-variation, atmosphere pressure and both totally.

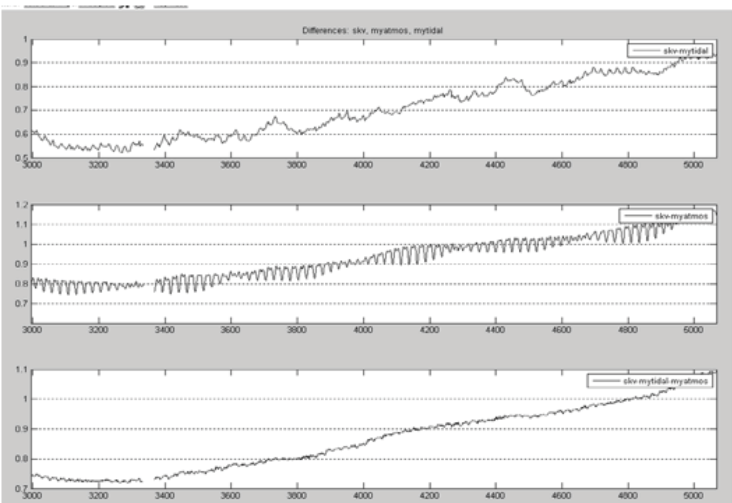

Fig. 4. Water level variation after extraction of tidal variation (upper line), atmosphere pressure (middle line) and of both parameters (lower line).

This program allows also calculating time shift between extremes of tidal-variation and water level, which tells us about how the aquifer is stressed.

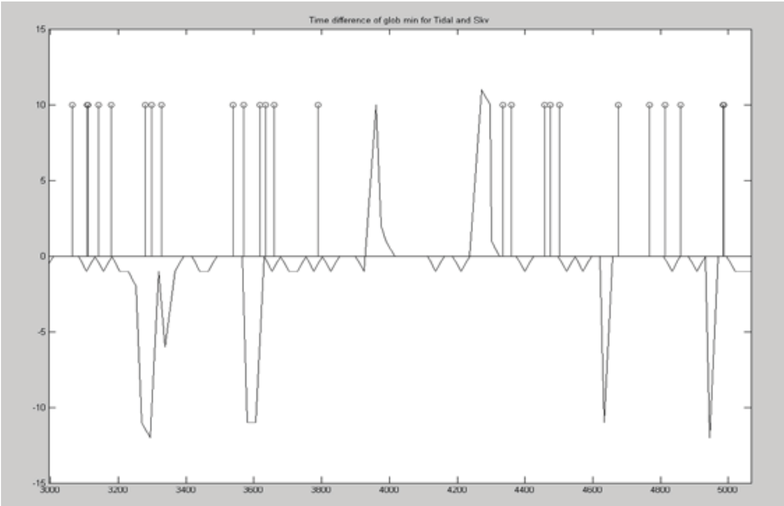

Fig. 5. Time-shift difference between extremes of water level and tidal variation (broken line). Vertical strait lines indicate earthquakes.

Results have shown changes in stress–sensitivity and deterioration of reaction of aquifer to tidal variations before and during the period of seismic event that demonstrates the value of water level variation as an indicator of tectonic activity.

For automatic finding of disturbances of environment's equilibrium condition in relation to the exogenous factors, caused by imposing an additional endogenous component (Melikadze G. at al., 1989, 2002), special program had been developed, allowing finding components of this equation.

$$water\ level(x)=a*tidal(x)+b*atmosphere(x)+c.$$

During monitoring, we measure water level, tidal variation and atmospheric pressure. In order to find coefficients *a*, *b*, c it is necessary to write a system of 3 (or more) equations. MatLab allows working with over-determined systems and the whole time interval will be split on many intervals (for example on 24 hour's intervals). For every interval the program finds a set of coefficients. During calculations the following equation are solved, where *W*(x) is water level variation, *T(x)* is tidal variation; *A(x)* is atmospheric pressure, *c* is constant. Program use measured values of *W*, *A*, *T* at the moment x_i for system of equations

$$\begin{cases} W(x_1)=a*T(x_1)+b*A(x_1)+c \\ W(x_2)=a*T(x_2)+b*A(x_2)+c \\ W(x_3)=a*T(x_3)+b*A(x_3)+c \end{cases}$$

or in the matrix form *W=M*X*, where

$$W = \begin{Bmatrix} W(x_1) \\ W(x_2) \\ W(x_3) \\ \ldots \end{Bmatrix} \qquad M = \begin{Bmatrix} T(x_1) & A(x_1) & 1 \\ T(x_2) & A(x_2) & 1 \\ T(x_3) & A(x_3) & 1 \end{Bmatrix} \qquad X= \begin{Bmatrix} a \\ b \end{Bmatrix}$$

After calculation, program demonstrates time-dependence of coefficient *a,* which depends on water level and tidal variation, *b*, which depends on water level and atmosphere pressure and distribution of constant coefficient *c* (Fig. 6).

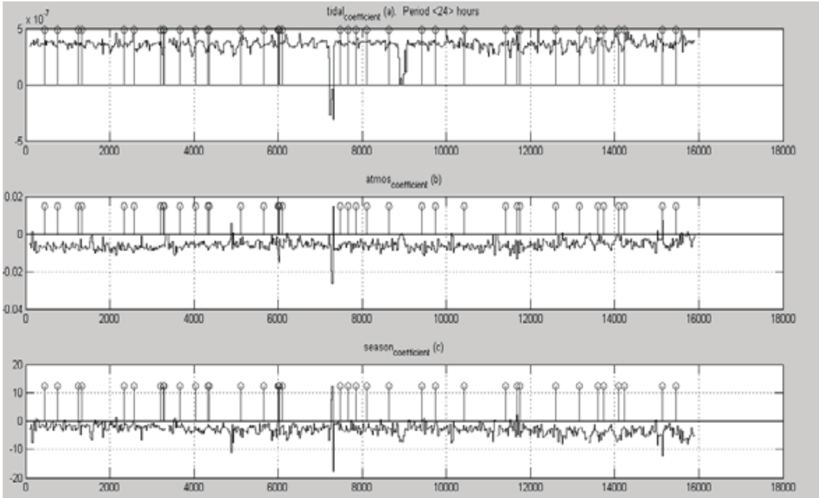

Fig. 6. Variation of coefficients (broken line). Vertical strait lines indicate earthquakes.

Furthermore, c of all coefficients is done (Fig. 7).

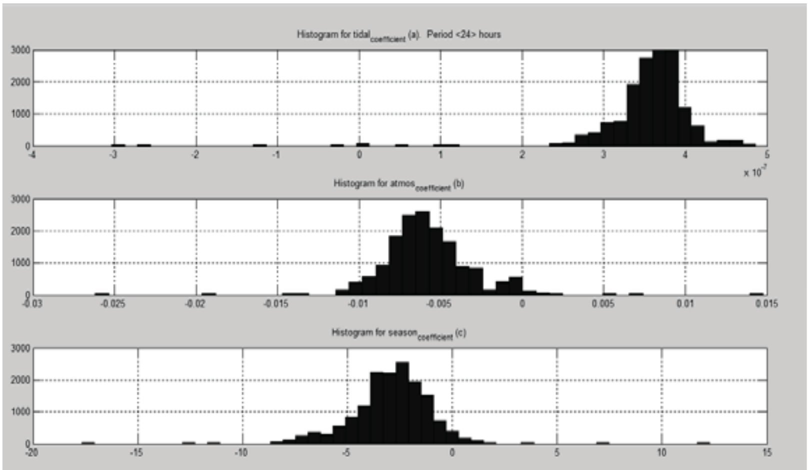

Fig. 7. Spectral graphics of a, b, c coefficient.

Program calculates "summary" signal (Fig. 8), which demonstrate reliability and relation of anomalies for all coefficients.

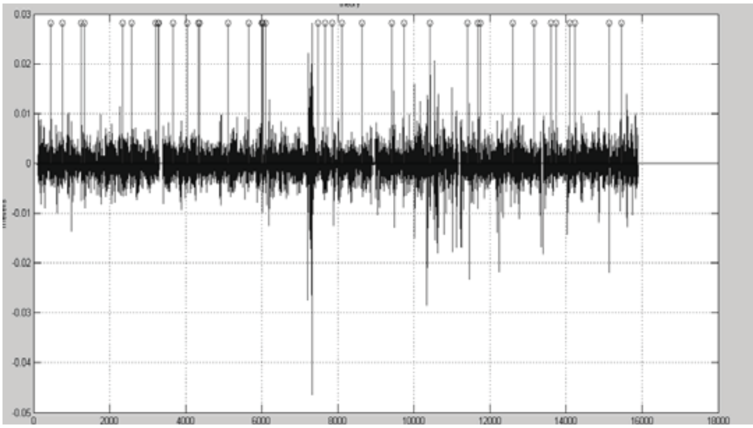

Fig. 8. Variation of “summery” signal (broken line). Vertical strait lines indicate earthquakes.

After extraction of high the frecency signal, program derives the trend signal from the water level value.

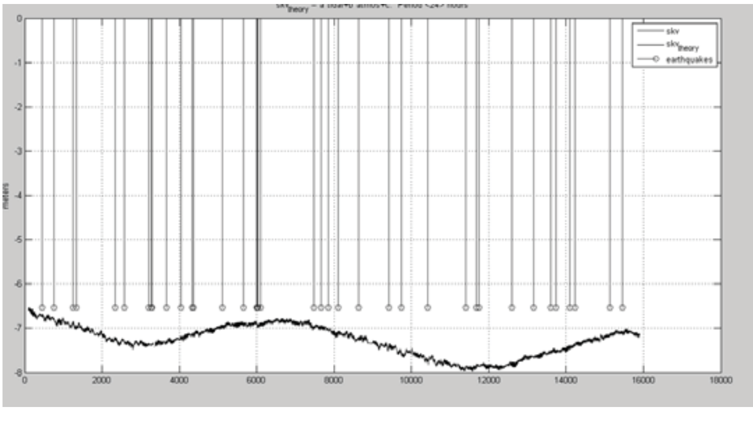

Fig. 9. Variation of trend signal in the Marneuli borehole. Vertical strait lines indicate earthquakes.

Results of data analysis have shown deterioration of reaction of coefficients *a, b, c* before and during seismic event that demonstrates the value of water level variation as an indicator of tectonic activity.

Conclusion

Water level variation basically is caused by the atmospheric pressure and earth crust tidal variations, as well as the "background" values, which change during earthquake preparation period. Amplitude and period of *a, b, c* coefficients changed by energy of earthquakes.

References

Hsieh, P. A., I. D. Bredehoeft, I. M. Farr. Determination of Aquifer Transmissivity from Earth Tide Analysis. Water resources research, vol. 23, 10, 1987, 1824-1832.

Hsieh, P. A., I. D. Bredehoeft, S. A. Rojstaczer. Response of Well-Aquifer Systems to Earth Ties: Problems Revisited. Water resources research vol. 24, No. 3, 1988, 468-472.

Melikadze, G., Popov, E. A technique of Hydro-geological supervision with the purposes of the forecast earthquake on territory of Georgia. A series geology «Gruziinti» N7, 1989.

Melikadze, G., Matcharashvili, T., Chelidze, T., Ghlonti, E. Earthquake related disturbance in stationarity of water level variation. Bulletin of the Academy of Sciences of Georgia, 165 № 1, 2002