GEODYNAMICAL IMPACTS ON THE WATER LEVEL VARIATIONS IN BOREHOLES

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It is known that variations of water level represents itself an integrated response of aquifer to different periodic as well as non periodic influences, including earthquake related strain generation in the earth crust. Quantitative analysis of impacts of separate components in observed integral dynamics remains one of the main geophysical problems. It is especially important for non periodic processes related to the earthquake generation, taking into account their possible prognostic value.

In the present study the dynamical complexity of water level variations has been analyzed. Dependence of dynamics on the presence of periodic components in considered data records (time series) was investigated. Modern tools of time series analysis have been used.

We present results of the analysis of the data of observations by a special program. The results illustrate that correlative dependence between tidal variations and water level changes is breached several days before the earthquake, both in the amplitude and the frequency spectrum.

Keywords: Geodynamical impact, periodic components

1. Introduction

Multi-parametrical monitoring (water level and micro-temperature, atmosphere pressure and air temperature) has been carried out on 10 deep boreholes of Georgia. Special monitoring equipment is installed at boreholes which record all deformations between 10^{-7}-10^{-9} which are caused by endogenous and exogenous factors. The lower value of deformation limits the sensitivity ($>10^{-7}$) which is fixed during earthquake preparation processes.

In order to analyze data series, we developed a new method in the computer program MatLab. It enables to synthesize a theoretical signal and compare it with original data of a water level. The program allows studying the influence of exogenous and endogenous factors on the aquifer. The reaction of boreholes demonstrates that one of these factors can dominate. Furthermore, from all earthquakes we can select earthquakes, energy of which reaches territory of boreholes using Dobrovolsky's equation (Dobrovolsky et al., 1979). After processing, program is extracting the “geodynamical trend” and “residual” values of high frequency signal from the original data of the water level variation.

Program demonstrates time-dependence of coefficients in correlation equation: *a* depends on water level and tidal variation, *b* on water level and atmosphere pressure, c is a constant coefficient. After calculation of coefficients, the program allows carrying out statistical analysis between periods and amplitudes of coefficients with seismic event. The result demonstrates informatively that the water level is an indicator of tectonic activity.

2. Data analysis

For example, the article demonstrates variation of parameters during preparation “Racha” earthquakes of 12.08.2009 (M= 4) and in 9.09.2009 (M= 4.6) in the tree boreholes. First of them “Oni” is located in the epicentral areas, the second one, “Adjameti”, is 100 km far to South-West direction and finally “Lagodekhi” is 200 km far to East direction from the epicentre.

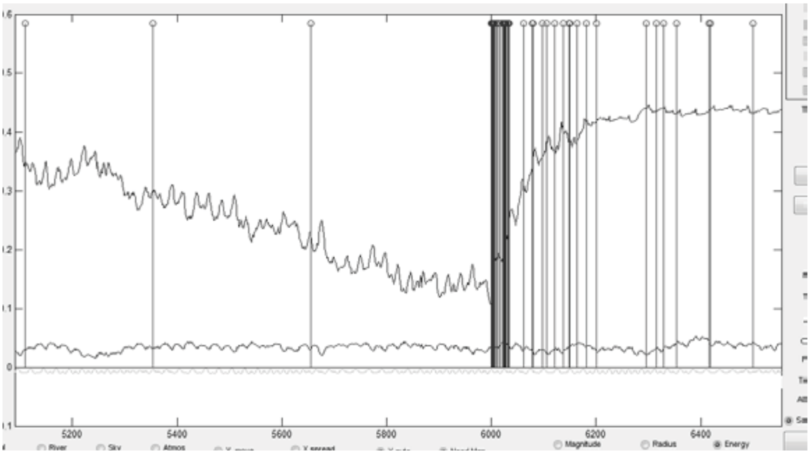

Fig. 1. Variation of water level (upper curve), atmosphere pressure (middle curve) and tidal variation (lower curve) at the "Oni" station. The vertical lines mark earthquakes.

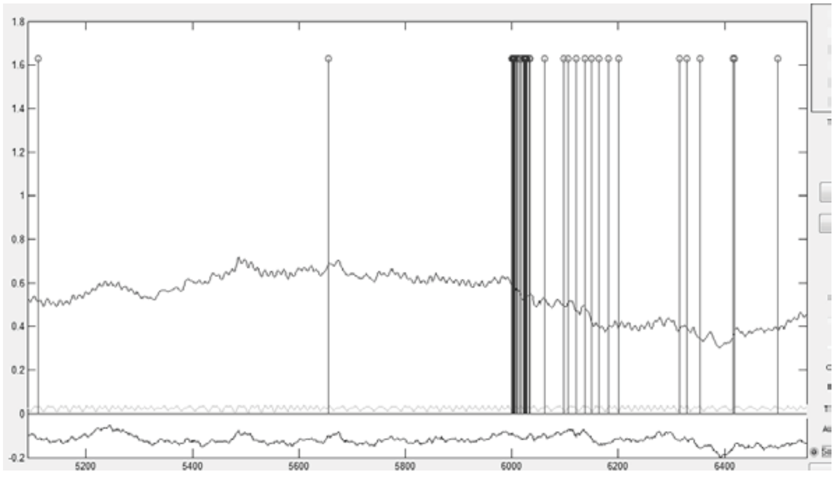

Fig. 2. Variation of water level (upper curve), atmosphere pressure (lower curve) and tidal variation (middle curve) on the "Ajameti" station. The vertical lines mark earthquakes.

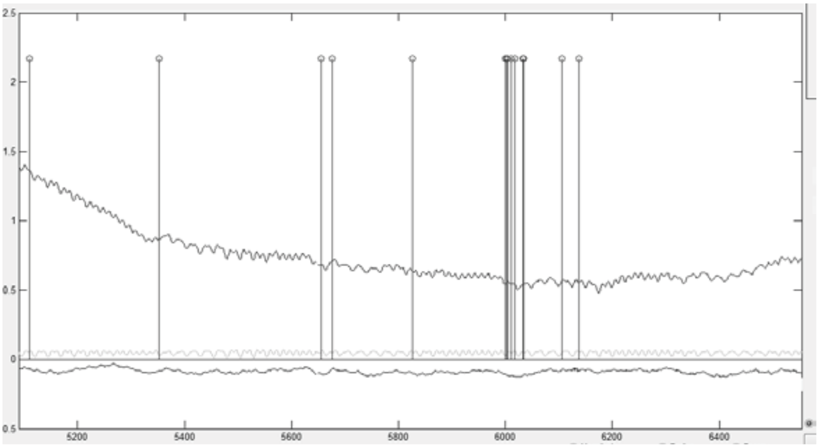

Fig. 3. Variation of water level (upper curve), atmosphere pressure (lower curve) and tidal variation (middle curve) on the “Lagodekhi” station. The vertical lines mark earthquake.

The pictures show the variation of different fields on the stations. Water level variation as a multi-signal value contains all exogenous (tidal variation, atmosphere pressure and precipitation) and endogenous (earthquakes) factors’ influence. In the seismically passive period the background of variation reflects only exogenous factors, but during earthquake preparation process the character of variation changed (Bella, Biagi P. et al., 1992, Hsieh et al., 1988). In this period are recorded disturbances in the water level variation before and after of earthquakes (Fig. 1-3).

In order to calculate the “geodynamical signal” special program extracts each exogenous factor from the multi-signal separately (Fig. 4-6).

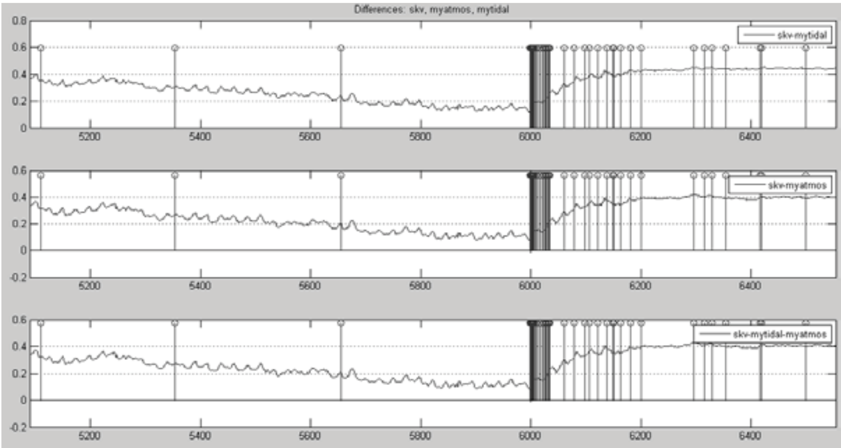

Fig. 4. Extraction of exogenous factor from the multi-signal of "Oni" station. Multi-signal without tidal variation (upper curve), without atmosphere pressure (middle curve) and without both parameters (lower curve). The vertical lines mark earthquake.

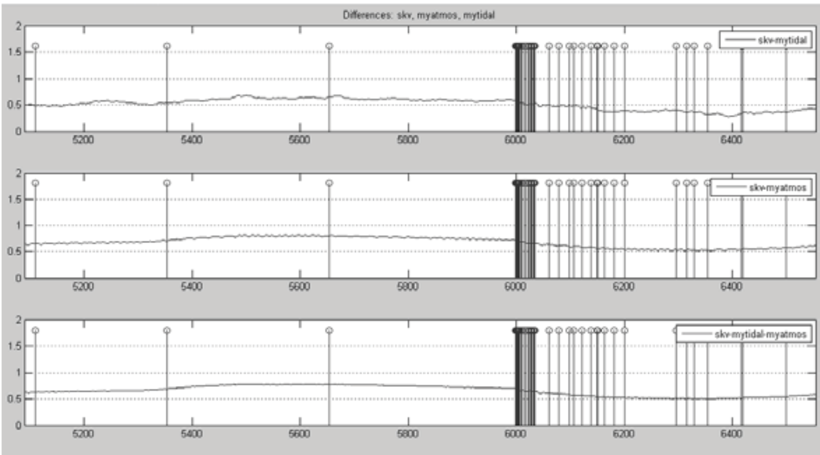

Fig. 5. Extraction of exogenous factor from the multi-signal of "Adjameti" station. Positions of curves are similar to Fig. 4.

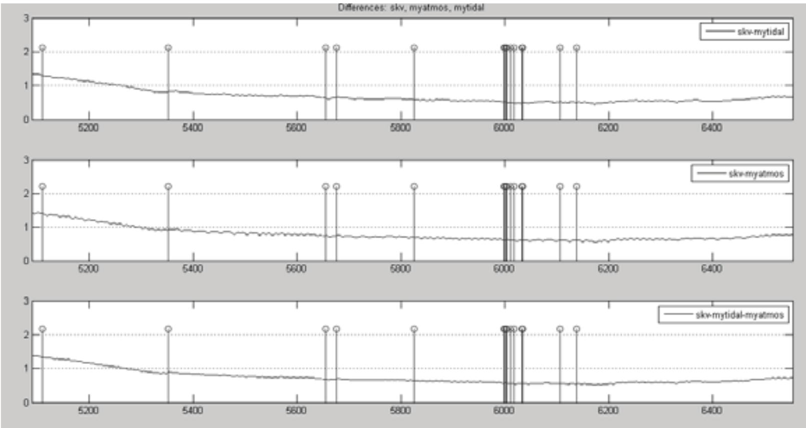

Fig. 6. Extraction of exogenous factor from the multi-signal of "Lagodekhi" station. Positions of curves are similar to Fig. 4.

Furthermore, the program calculates variation of "geodynamical" signal - difference between the water level's theoretical and observed values and "residual" values of high frequency signal in the water level variation. (Fig. 7-9).

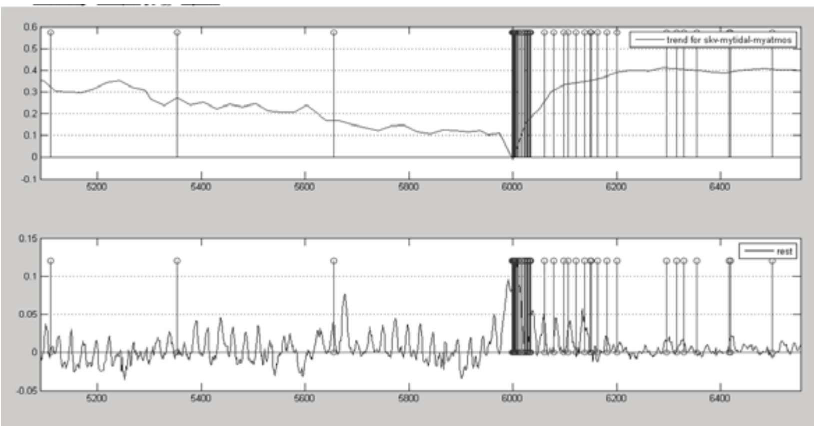

Fig. 7. Variation of "trend" value of geodynamical signal (upper curve) and "residual" (lower curve) at "Oni" station. The vertical lines mark earthquake.

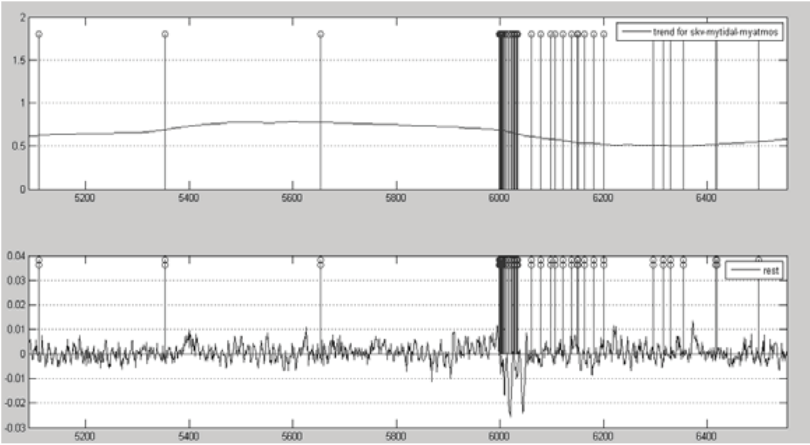

Fig. 8. Variation of “trend” value of geodynamical signal (upper curve) and “residual” (lower curve) at “Adjameti” station. The vertical lines mark earthquake.

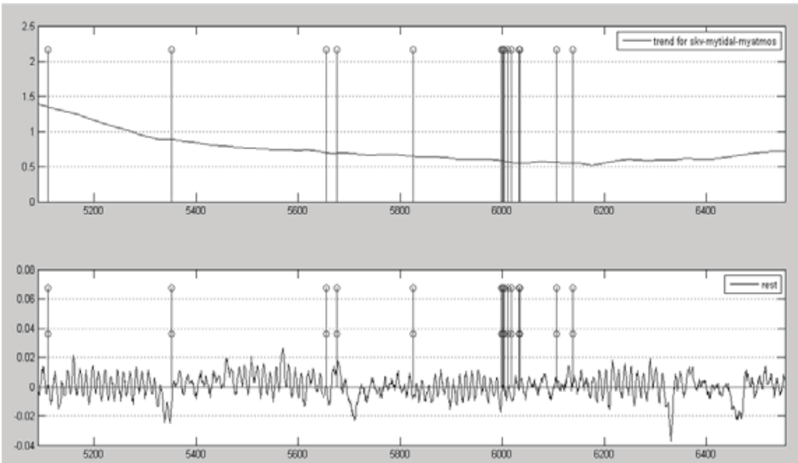

Fig. 9. Variation of “trend” value of geodynamical signal (upper curve) and “residual” (lower curve) at “Lagodekhi” station. The vertical lines mark earthquake.

The drawdown of water level in the “Oni” and “Lagodekhi” boreholes and increase of the “Adjameti” boreholes are fixed. The first effect is characterizing decompression and the second one - compression of aquifer system before Racha earthquakes. After considered events water level in the “Adjameti” borehole goes down, this characterizes decompression processes. “Oni” station kept compression processes.

In the “residual” lines, the high frequency signal shows changes of period values of variation before and after earthquake events.

In order to calculate statistic dependence between disturbances in coefficients *a, b*, *c* and other parameters and to relate it to energy reaching boreholes areas from the epicenter zone, a special statistical program has been written. “Background” values of coefficients *a*, *b*, *c* and summary signal before earthquakes events on both stations are shown in Figs. 10-15.

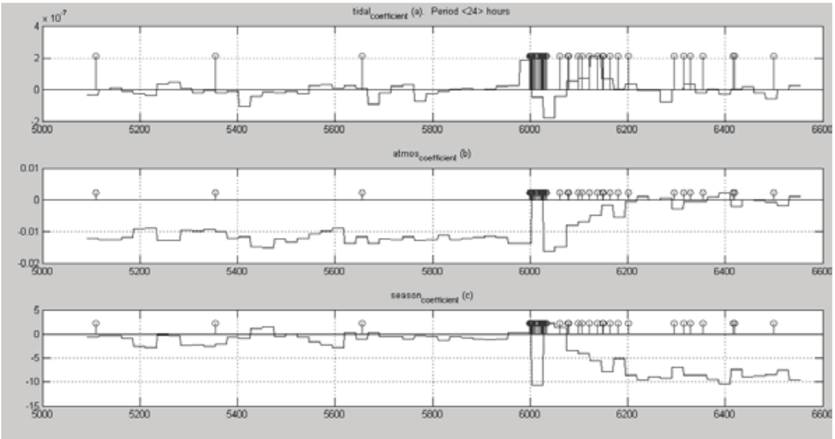

Fig. 10. Variation of a, b and c coefficients at the “Oni” station. The vertical lines mark earthquake.

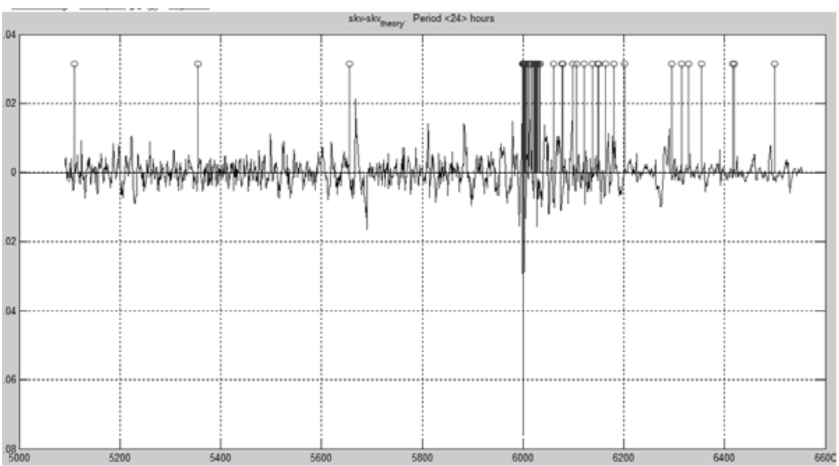

Fig. 11. Variation of “join” signal at the “Oni” station. The vertical lines mark earthquake. The vertical lines mark earthquake.

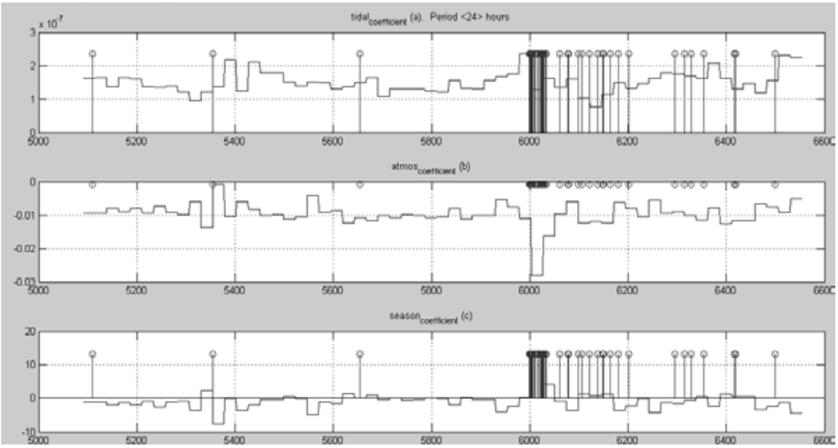

Fig. 12. Variation of a, b and c coefficients at the “Adjameti” station. The vertical lines mark earthquake. The vertical lines mark earthquake.

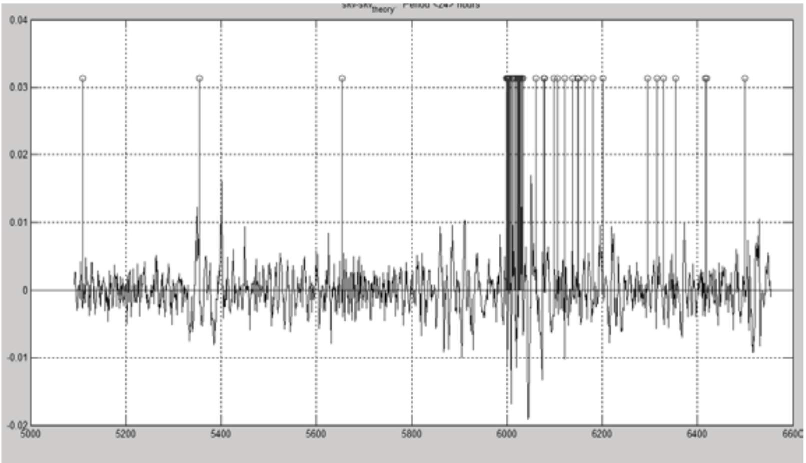

Fig. 13. Variation of ”summary” coefficients at the “Adjameti” station. The vertical lines mark earthquake.

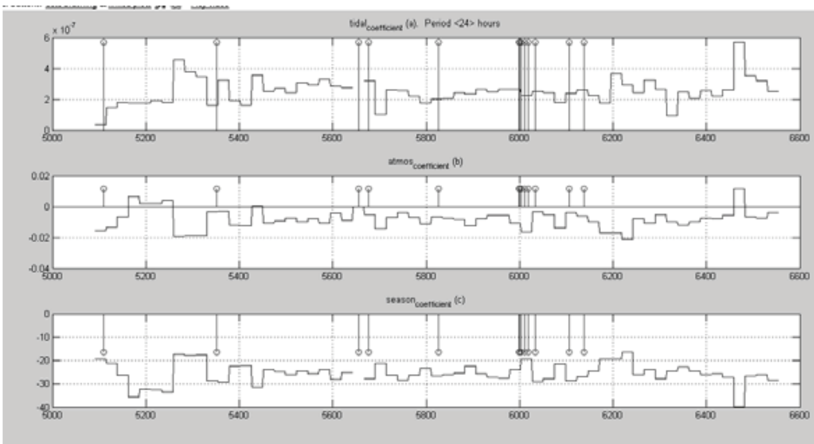

Fig. 14. Variation of a, b and c coefficients at the “Lagodekhi” station. The vertical lines mark earthquake.

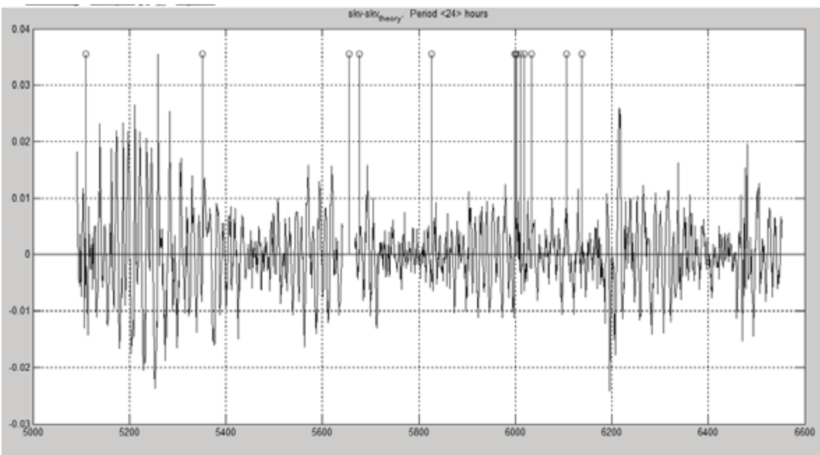

Fig. 15. Variation of "summary" coefficients at the "Lagodekhi" station. The vertical lines mark earthquake.

The "background" values of water level variation was changing before and after events (Melikadze et al., 1989). Character of variation of coefficients for each borehole depends on the energy value, which reached boreholes area. "Lagodekhi" borehole is sensitive for local earthquakes then for "Racha" earthquake. At the same time the amplitude of variation before "Racha" earthquake is stronger in the "Adjameti" station. This can be explained by larger strain-sensitivity of "Adjameti" station (Melikadze et al., 2002).

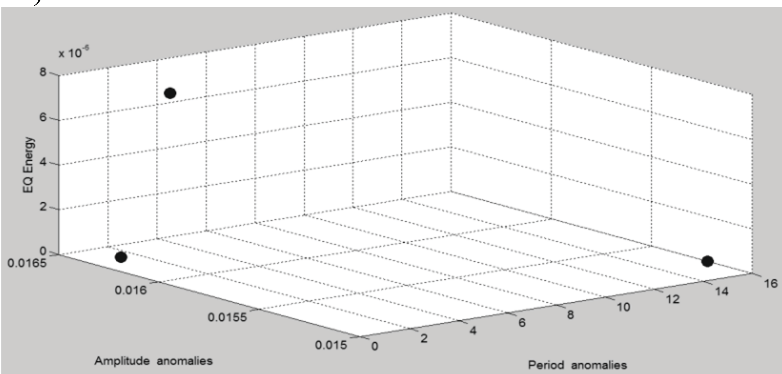

Fig. 16. Dependence between amplitudes and periods of anomalies and earthquakes energy in the "Oni" station

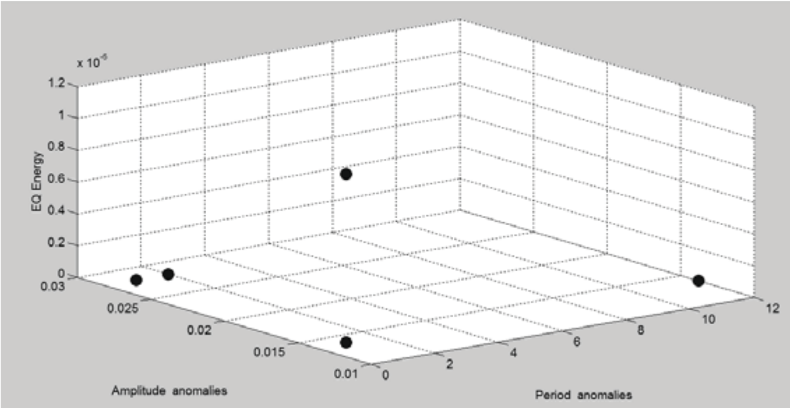

Fig. 17. Dependence amplitudes and periods of anomalies and earthquakes energy in the "Adjameti" station

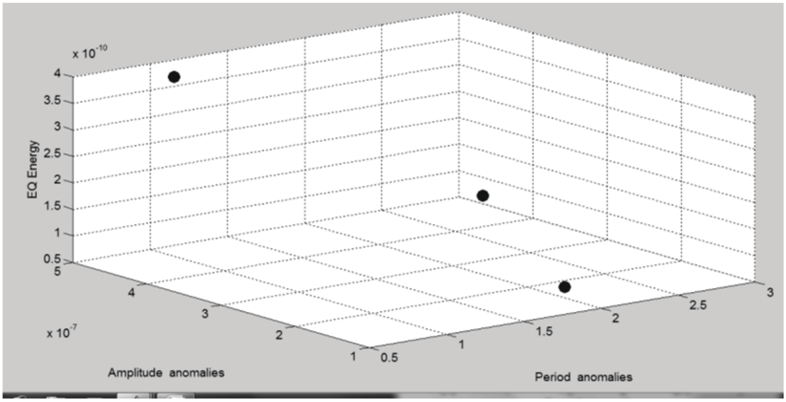

Fig. 18. Dependence between amplitudes and periods of anomalies and earthquakes energy in the "Adjameti" station

A special program is calculating the dependence between earthquakes energy and characteristic of anomalies (amplitudes and periods of anomalies (Figs. 16-18).

Figs. 16-18 show that the main amplitudes of anomaly in the "Oni" station are located between 0.016- 0.0165 and fixed during 4 days. For "Adjameti" station the main amplitudes of anomaly are located between 0.025- 0.03 and generally fixed during 2 days. For "Lagodekhi" station the main amplitudes of anomaly are located between 2-4 and generally fixed during 3 days. In the "Lagodekhi" and "Adjameti" stations the period of anomaly is less than in the "Oni" station, because they are located far from the epicenter.

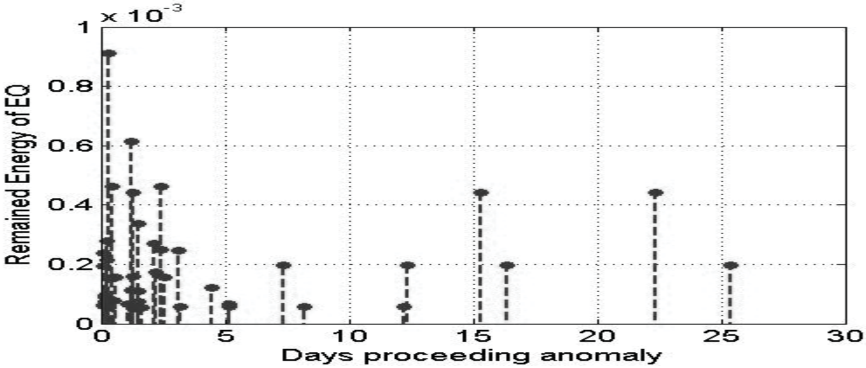

Fig.19. Dependence between the duration of anomaly (in days) and energy of earthquakes in the "Adjameti" station

On Fig. 19 is shown the dependence between the duration of anomaly (in days) and energy of earthquakes at the "Adjameti" station. High energy is registered in the first 5 days' period of anomaly.

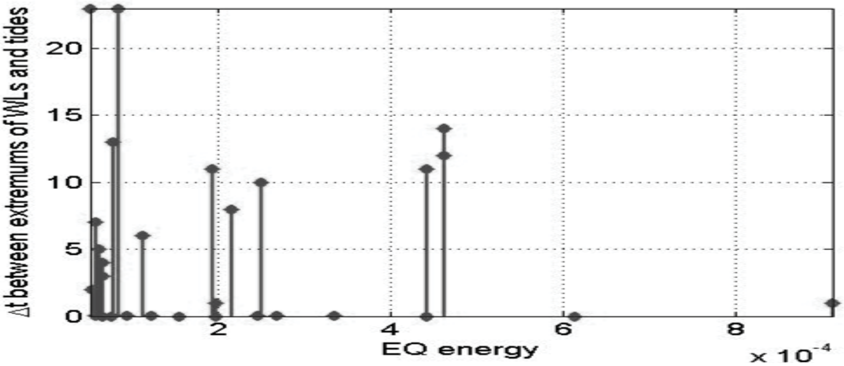

Fig. 20. Dependence of time-shift between extrema of water levels and tides on the energy of earthquakes at the "Adjameti" station.

Fig. 20 shows the correlation between time-shift (the lag) between extrema of water levels and tides on earthquakes energy. Generally, time-shift period increase accordingly of energy.

Conclusions

The information content of hydrodynamic boreholes from the earthquake prognostics point of view was ascertained. The recorded anomalies coincide with the preparation period for strong earthquakes. Characteristics of anomalies (amplitude, period, etc) are correlated with earthquake strength. However, in certain cases, high levels of anomalies are recorded in boreholes located relatively far from the epicentre. In order to explain this, the strain-sensitivity of each borehole should be studied, as well as distribution of strain field on the area and its geological characteristics.

References

Dobrovolsky, I. P., Zubkov, S. I., and Myachkin, V. I., Estimation of the size of earthquake preparation zones, Modeling of earthquake preparation. – Moscow. Nauka, 1979

Bella F., Biagi P., Melikadze G. et al. - Anomalies in geophysical and geochemical parameters revealed on the occasion of the Paravani (M=5.6) and Spitak (M=6.9) earthquakes (Caucasus). Amsterdam, Tectonophysics 202 Elsevier Science Publishers B. V.,1992, p.p. 23-41

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