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Linear methods of studying the water level variation related with seismicity

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Abstract

The article describes the methods of hydrodynamic observations for monitoring tectonic processes in real time and seismic isolation component. The developed methods are used to extract the geodynamic component of observation data to examine patterns of its distribution in space and time over large areas in the process of preparation of strong earthquakes. For data processing, we have developed a new method on MATLAB (program RestDance) to synthesize the theoretical signal and compare it with the real data of the water level. The article also describes the method of speed and its values to visualize the anomalous behavior of water level during strong earthquakes.

Introduction

The correlation between the hydrodynamic anomalies of groundwater and seismic phenomena, caused by tectonic processes, long fixed. Physical meaning of this phenomenon: the lithosphere rocks contain cracks and pores that respond to mechanical stresses. As is known, the water is incompressible medium in the case of open system during compression changes the water extracts from the stress-strain medium and this makes it possible to observe the change of intensity. Identifying the mechanism of the relationship of deformation processes, the strong earthquake and hydrodynamics of groundwater helps to explain this variability hydrodynamic field.

Description of the methods of data processing

To monitor hydrogeodeformation field of the Earth, which allows to fix the rapid changes of deformation-stress state of the medium (1), due to the preparation of the earthquake, in

the 80s of the last century, work began on the creation specialized network of water wells. Regime wells were chosen so that they are all characterized by large geological units.
Well as bulk strain meters, sensitive to deformation of various kinds, both exogenous and endogenous (2-5). Accuracy of the observations reached 10^{-7}-10^{-9} values. Has accumulated a long series of observations throughout the Caucasus.

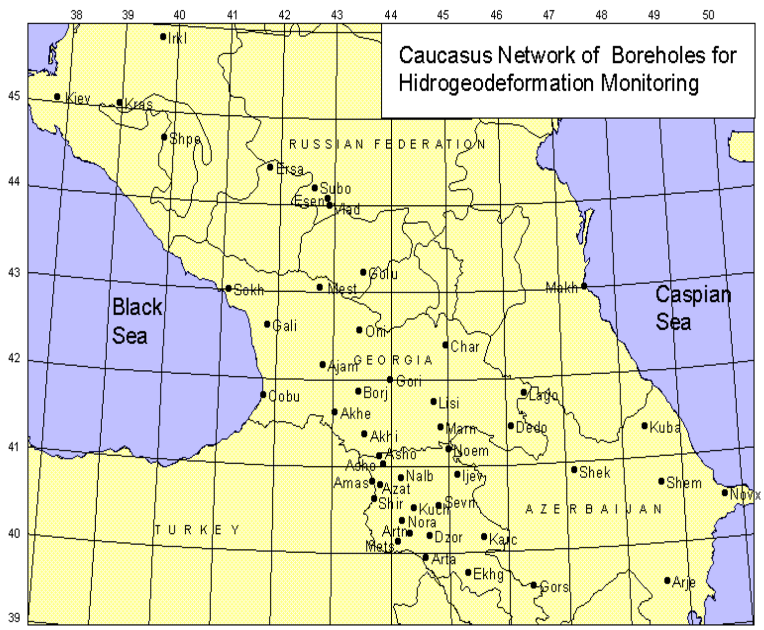

Figure1. Caucasian observation network of Hidrogeodeformathional field

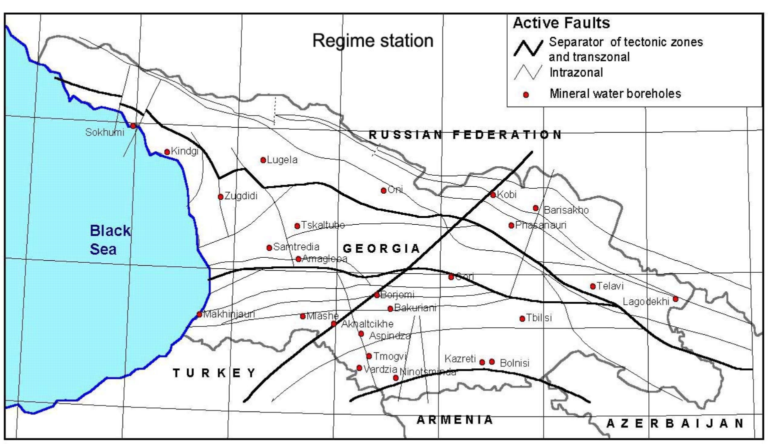

Figure2. Layout observed wells for geological units

Change in water level due to the following factors: atmospheric pressure (AP); precipitation (PR); tidal variation (TI); Tectonics-seismic stress (T/S) and the proportion of errors apparatus (e).

Water level: = f (AP)+ f (PR)+ f (TI)+ f(T/S)+ e;

To isolate the tectonic components necessary filtering and selection of primary materials netektonicheskih components. As a good example of the decomposition analysis can point to the analysis of the level of water wells Gaybara (Japan). Akaike et al, 1985 and Tamuta, et al, 1991 developed a special program BAYTAP-G (Bayesian Tidal Analysis Program in a Grouping Method) to filter rainfall and tidal variations. Influence of precipitation on water level by means of regression analysis was evaluated Matsumoto (1992), Matsumoto and Takahashi (1993). It should be noted that Kitagava and Matsumoto (1996) used the Kalman filter to select all netektonicheskih components of the water level data. They identified tectonic component after subtracted influence of atmospheric pressure, tidal variations and precipitation. (Matsumoto et al, 2003).

Another example of a consistent approach to the problem is to analyze the data of the water level in the well Lisi, Georgia (Gavrilenko, Melikadze et al, 2000), where the decomposition of the water level was applied a special method. On the basis of real data on the tidal variations, atmospheric pressure and precipitation for the period 1988 - 1992 years. Was promoted synthesis of theoretical reaction variations of the water level in the well Lisi, which was compared with the actual variations in the water level. With this same time period, two strong earthquakes in the Caucasus region - Spitak (7.12.1988, M = 6,8, Δ = 110 km) and Raczynski (29.04.1991, M = 6.9, Δ = 125 km), here M - is magnitude, and Δ - epicentral distance. Before the earthquakes observed anomaly of water level throughout the region.

For data processing, we have developed a new method on MATLAB (program RestDance) to synthesize the theoretical signal and compare it with the real data of the water level. The program enables counts each exogenous parameter separately and examine their impact on the aquifer.

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 three 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.

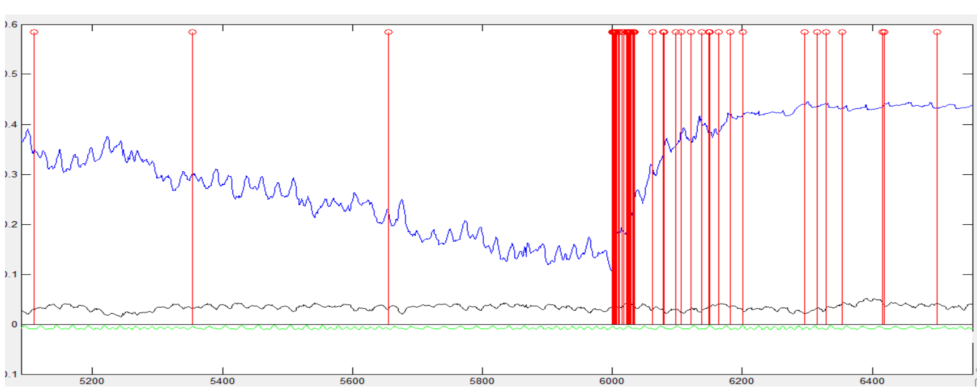

Figure 3. Variation of water level (upper curve), atmosphere pressure (middle curve) and tidal variation (lower curve) at the "Oni" station. The vertical lines mark earthquakes.

The figure shows the violations that occurred at the station Oni at the time of the earthquake in Racha.

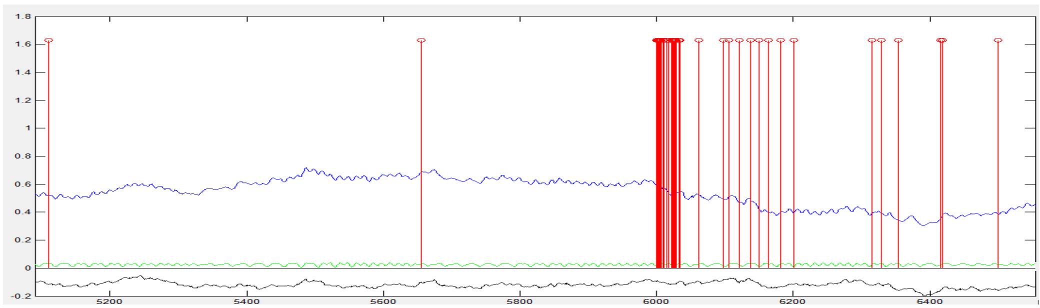

Figure 4. Variation of water level (upper curve), atmosphere pressure (lower curve) and tidal variation (middle curve) on the “Ajameti” station. The vertical lines mark earthquakes.

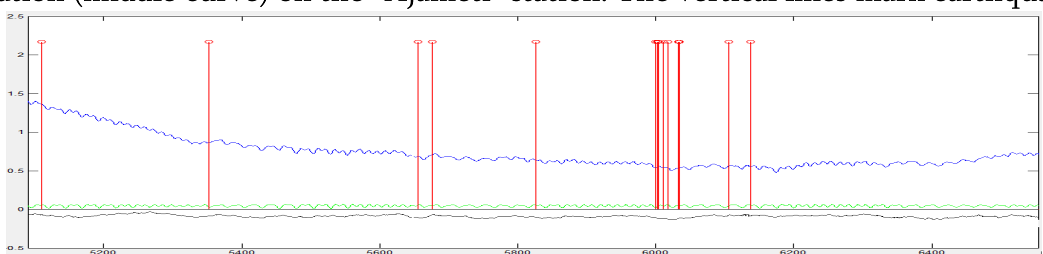

Figure 5. Variation of water level (upper curve), atmosphere pressure (lower curve) and tidal variation (middle curve) on the “Lagodekhi” station. The vertical lines mark earthquake.

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. 3-5).

In order to calculate the relationship between changes in the parameters and earthquakes were introduced correlation coefficients with the tidal water level variations - a, with atmospheric pressure changes - b, and the constant- c. To identify the statistical dependence of the change of energy reaching the area well away from the epicenter zone, was written by a special program that allows you to identify "variation" of the coefficients ***a***, ***b***, ***c*** and the signal "balance" between earthquakes on the three stations are shown in Fig. (6-11).

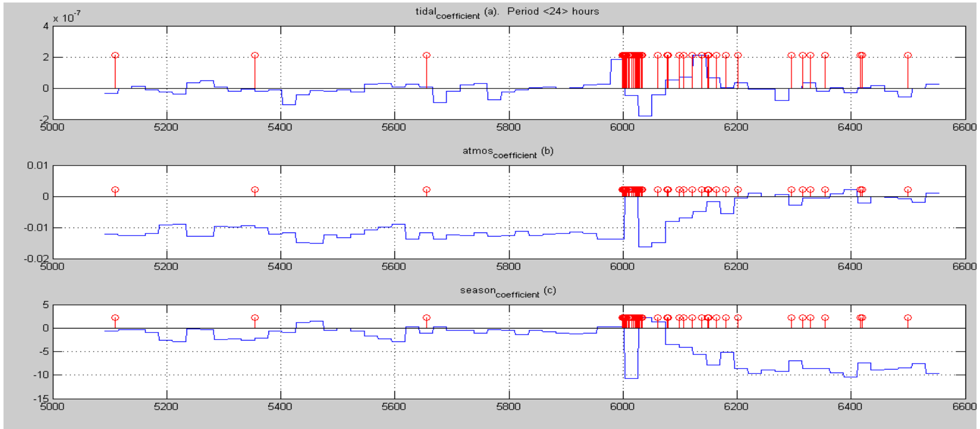

Figure 6. Variation of a, b and c coefficients at the "Oni" station.

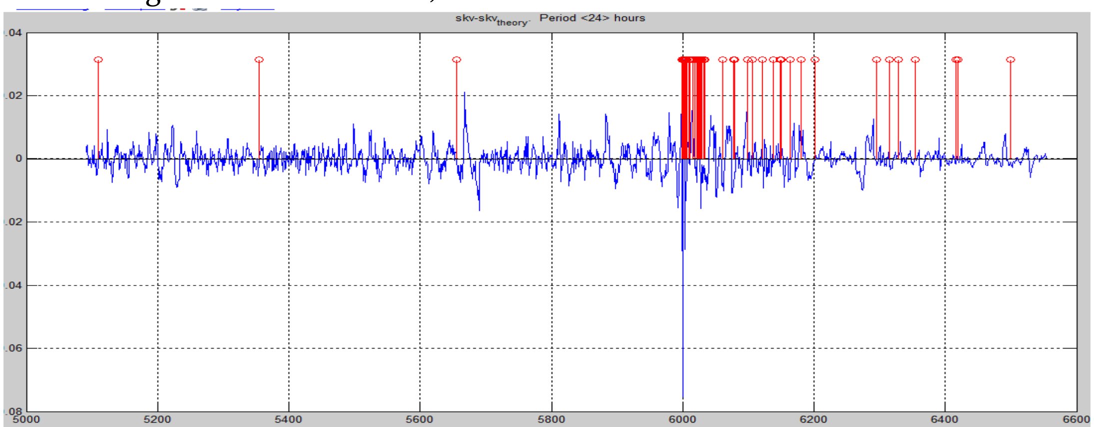

Figure 7. Variation of "residual" signal at the "Oni" station.

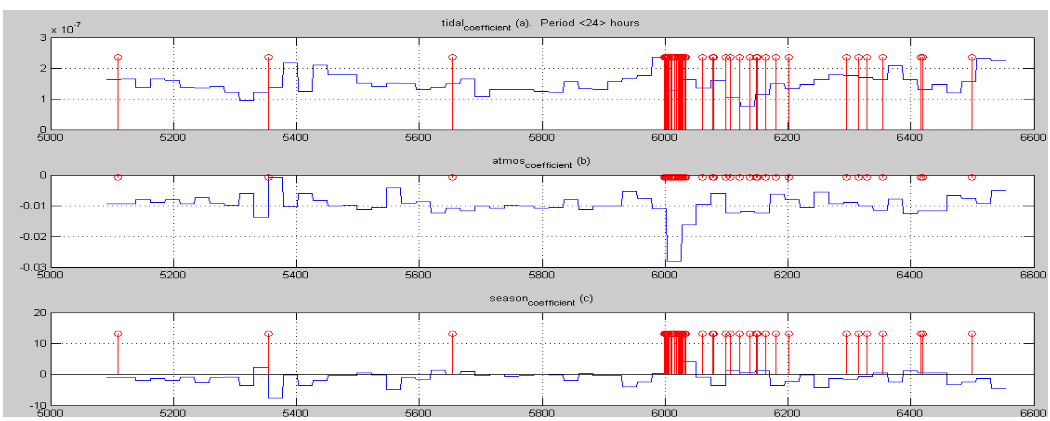

Figure 8. Variation of a, b and c coefficients at the "Adjameti" station.

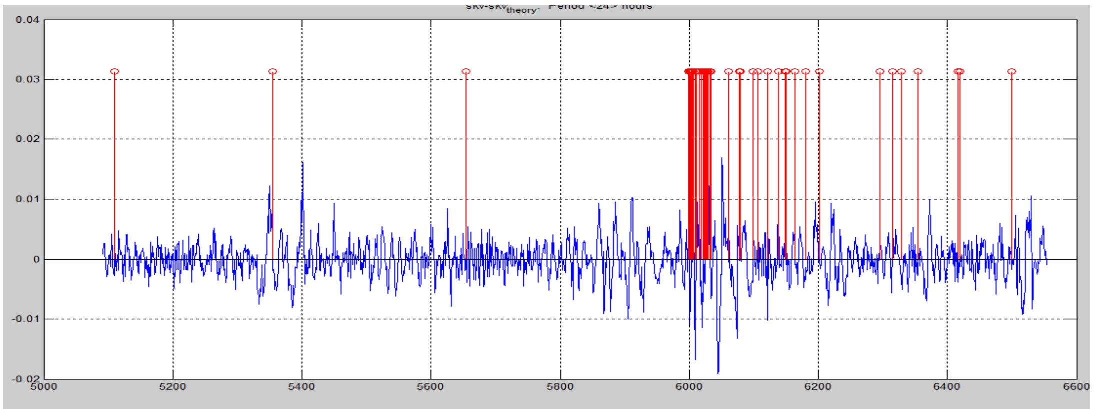

Figure 9. Variation of "summary" coefficients at the "Adjameti" station.

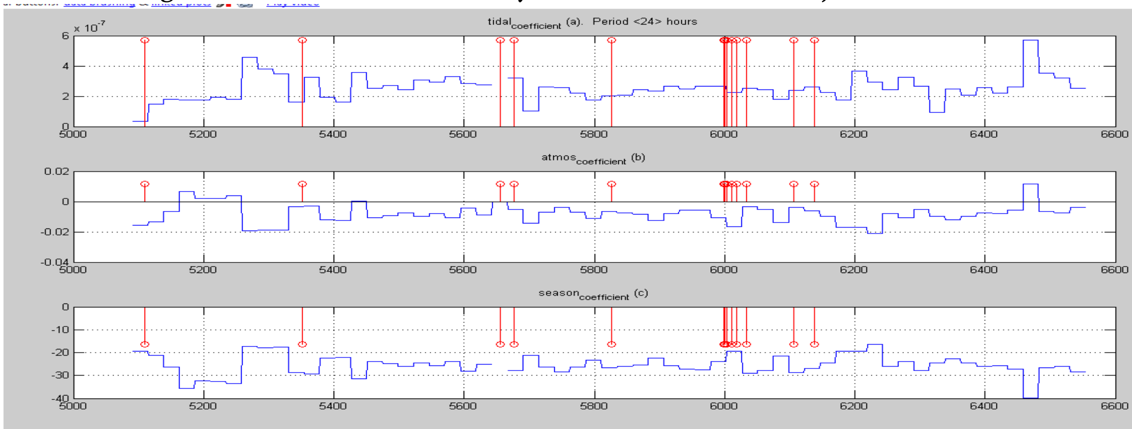

Figure 10. Variation of a, b and c coefficients at the "Lagodekhi" station.

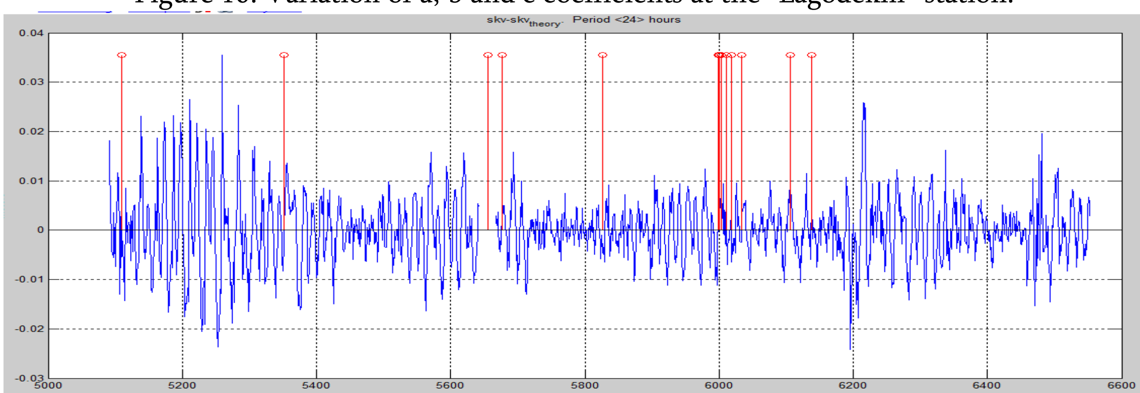

Figure 11. Variation of "summary" coefficients at the "Lagodekhi" station.

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.,).

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. 12-14).

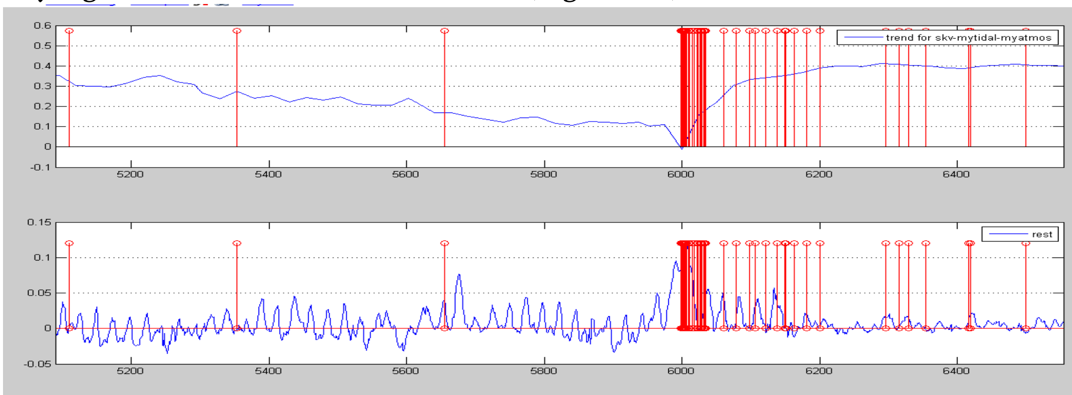

Figure 12. Variation of "trend" value of geodynamical signal (upper curve) and "residual" (lower curve) at "Oni" station.

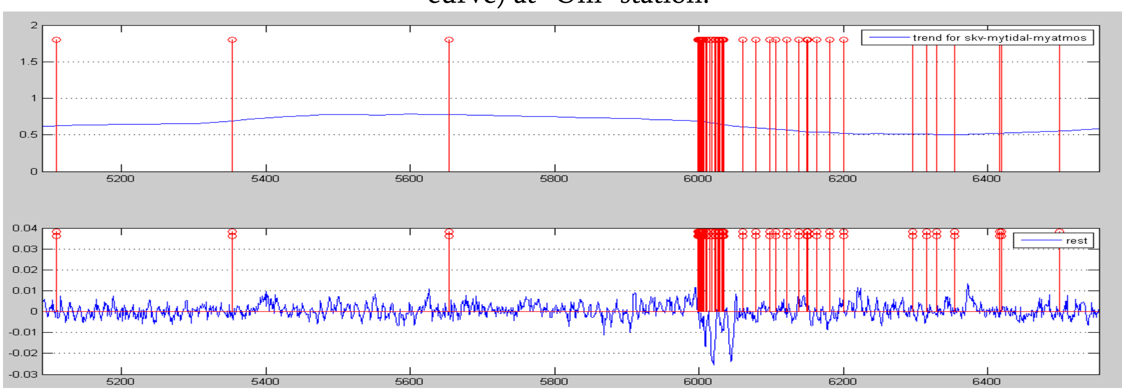

Figure 13. Variation of "trend" value of geodynamical signal (upper curve) and "residual" (lower curve) at "Adjameti" station.

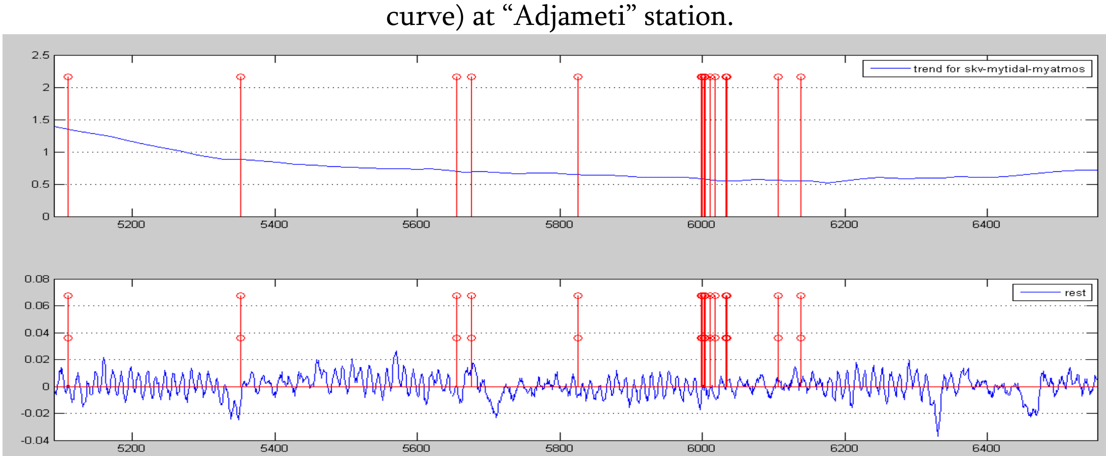

Figure 14. Variation of "trend" value of geodynamical signal (upper curve) and "residual" (lower curve) at "Lagodekhi" station.

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.

Another way to study the anomalous behavior of water level – is the speed method. Seasonal trend, which is usually present in the water level of wells, take a number of problems in monitoring.

Consider the concept of velocity (speed) for the water level.

Definition:

$$Speed\ (m + i) = (water\ (m + i) - water\ (i)) / m,\ i = 1,2,3, \ldots$$

Where *m* is some fixed number of minutes.

In the examples below (Figure 15) the speeds are multiplied on coefficients for visual comparison. We point out that in the speed graph disappears seasonal component.

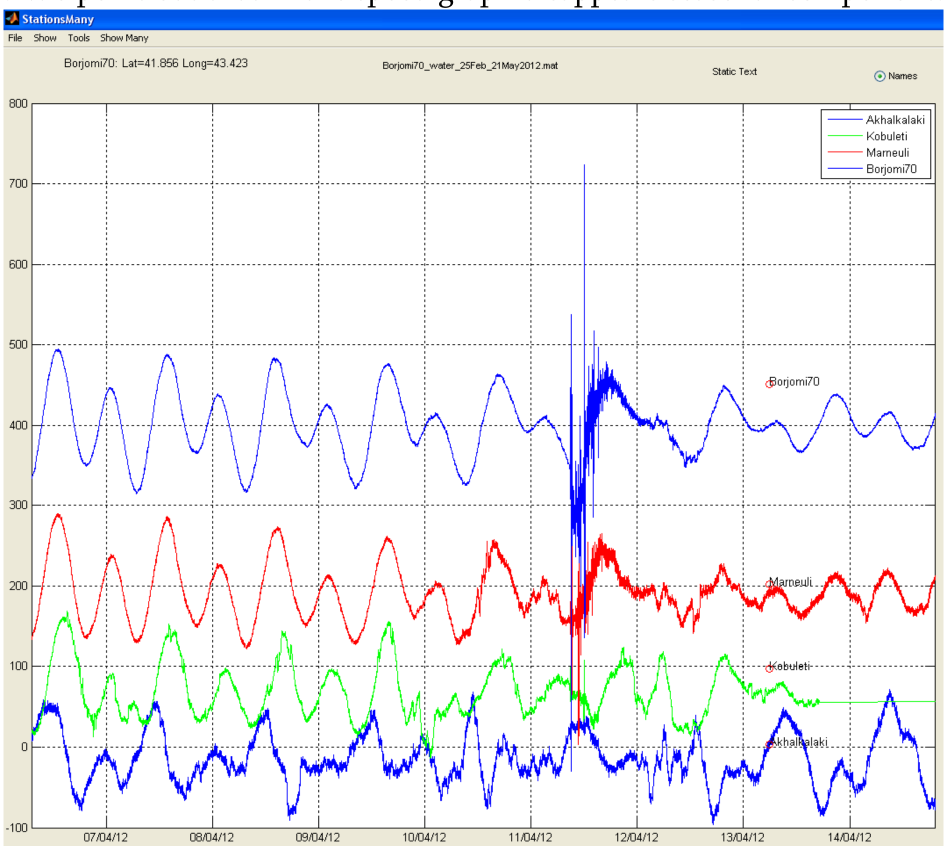

Figure15. Speeds. The reaction to the earthquake in Indonesia (Sumatra)
From top to bottom: Borjomi70 (top), Marneuli, Kobuleti, Akhalkalaki
m=180 minutes

The figure shows the velocity violations during an earthquake in Indonesia (Sumatra).

Table 1. shows the values of water level changes that have been committed during the earthquake in Sumatra (Indonesia).

Table1. Earthquake in Sumatra (Indonesia), 11 April 2012, Mag=8.4, distance =6508 km

Borehole	Jump of water (cm)

Kobuleti	4
Marneuli	8
Borjomi70	70

Figure 16. also seen some irregularities that occurred 2-3 days before the earthquake in Turkey (Vani), which occurred October 23, 2011 (Magnitude = 7.2).

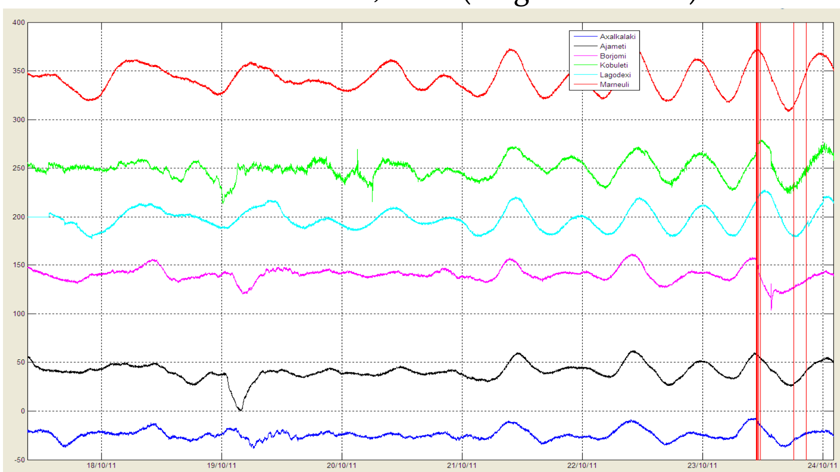

Figure 16. Speeds: *m*=180 minutes interval for boreholes of Georgia, 18-24 October and Turkey (Vani) earthquakes 23 October 2011, Mag=7.2 From top: Marneuli, Kobuleti, Lagodekhi, Borjomi, Ajameti, Akhalkalaki.

Within 2 days, from October 18 to 21, before the earthquake, see the violation, and then there was a leveling off. During an earthquake on October 23 following changes were observed.

- The well Kobuleti, which is located at a distance from the epicenter 369km, there was a drop in water level at 0.5 cm; The well Borjomi, which is located at 339km from the epicenter, there was an increase in water level at 3.5 cm;

- The well Akhalkalaki, which is located at 291km from the epicenter, there was a drop in water level at 0.5 cm.

- Minor violations can be seen at the station Marneuli, which is located at 317km from the epicenter. With help of speed method were also studied water levels for wells of Bulgaria (Irechek, Belgun, Chelopechene and Vaklino) for 2008-2014 years. In the vicinity of these wells are almost no rivers, as developed karst and surface runoff is absent.

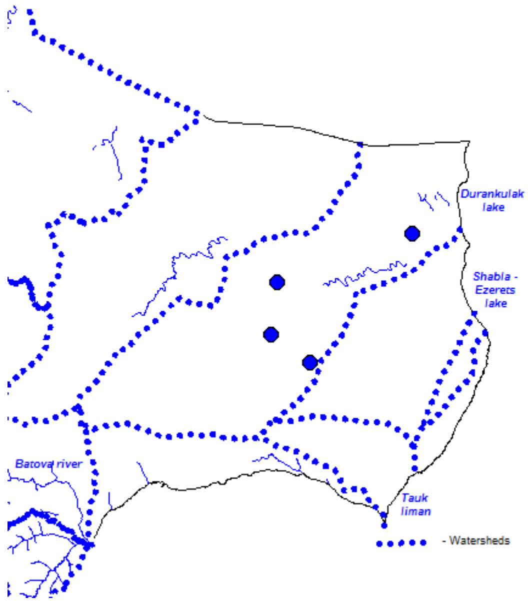

Figure 17. Wells of Bulgaria: Irechek, Belgun, Chelopechene and Vaklino.

Level temporary rivers near Irechek, Belgun and Chelopechene about 80-100 meters, and near Vaklino - about 15 -20 meters. Two wells are not deep and open the first karst of unconfined aquifer in sarmath (neogen) limestone - Belgun and Vaklino. Wells do not cross the entire thickness of the aquifer. The upper part of the casing strings isolated. Water-bearing intervals Belgun- from 51 to 106 m, and in Vaklino - from 40 to 68 m. Upper limits depend on supply.

The remaining two wells are deep and reach the head waters in the Upper Jurassic-Lower Cretaceous sediments.

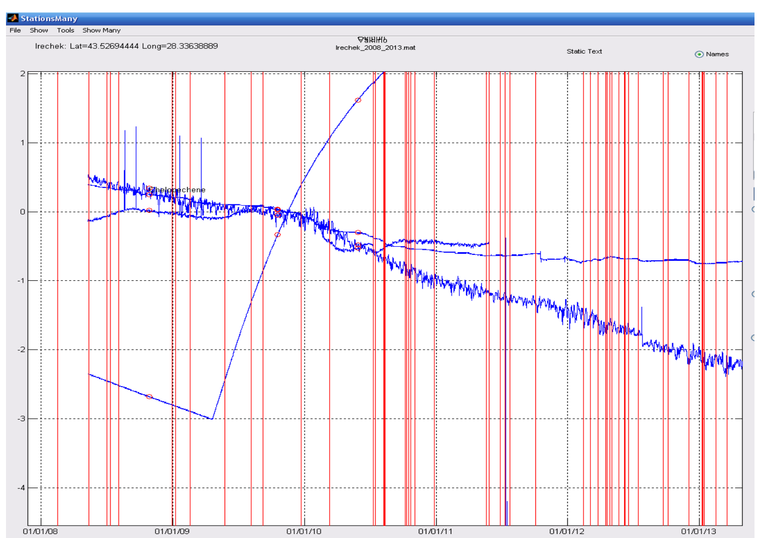

Figure18. Changes in water level in wells located on the territory of Bulgaria. 2008-2014yy.

According to the result of the processed data was recorded by the influence of external factors (tidal variations, atmospheric influence, seasonal fluctuations), this they have low information to fix the possible geodynamic factors

Conclusion

The results of data analysis showed deterioration reaction coefficients **a**, ***b***, ***c*** before and during a seismic event. Periods recorded anomalies coincide with periods of strong earthquakes occurrence. Characteristic anomalies (amplitude, period coefficients ***a***, ***b***, ***c***) are correlated with the strength of an earthquake. Speed method showed its suitability for imaging of the anomalous behaviour of water level during strong earthquakes.

Acknowledgments:

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Линейные методы изучения вариации уровня воды в связаных с сейсмичностью

Тамар Джимшеладзе, Георгий Меликадзе, Генадий Кобзев

Резюме

В статье рассмотрены методы гидродинамических наблюдений для мониторинга тектонических процессов в режиме реального времени и выделения сейсмического компонента. Разработанные методы используются для выделения геодинамической составляющей из данных наблюдений с целью изучения закономерности ее распределения в пространстве и времени на больших площадях в процессе подготовки сильных землетрясений. Для обработки данных был разработан новый метод в среде

MATLAB (программа RestDance), позволяющий синтезировать теоретический сигнал и сравнивать его с реальными данными уровня воды. В статье также рассмотрен метод скоростей и его значения для визуализации аномального поведения уровня воды во время сильных землетрясений.

მიწისძვრებთან დაკავშირებული წყლის დონის ვარიაციების შესწავლა წრფივი მეთოდებით

ჯიმშელაძე თამარი, მელიქაძე გიორგი, კობზევი გენადი

რეზიუმე

სტატიაში განხილულია ჰიდროდინამიური დაკვირვების სპეციალური მეთოდები,რომლებიც გამოიყენება რეალურ დროში, ტექტონიკური პროცესების მონიტორინგისა და სეისმური მდგენელების გამოყოფის მიზნით. შემუშავებული მეთოდიკა გამოიყენება დიდ ფართობზე ძლიერი მიწისძვრის მომზადების პროცესში ,დაკვირვების მონაცემებიდან გეოდინამიკური მდგენელის გამოყოფისა და მისი დროსა და სივრცეში განაწილების კანონზომიერების დადგენის მიზნით. მონაცემტა დამუშავებისათვის შეიქმნა პროგრამა MAთLAB-ის გარემოში (პროგრამა ღესტDანცე), რომელიც იძლევა საშუალებას მოვახდინოთ თეორიული სიგნალის სინთეზი და შევადაროთ იგი წყლის დონის რეალურ მნიშვნელობას.

სტატიაში ასევე განხილულია “სიჩქარეები”-ს მეთოდი და მისი მნიშვნელობა წყლის დონის ანომალური ცვლილების ილუსტრირებისათვის ძლიერი მიწისძვრების დროს.