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Methodology of detection of distribution in geodynamic field of the Earth during preparation the earthquakes

Tamar Jimsheladze, George Melikadze, Genadi Kobzev, Aleksandre Tshankvetadze, Marina Devidze, Nino Kapanadze,

Iv. Javakhishvili Tbilisi State University, M. Nodia Institute of Geophysics

Abstract

This article discusses the processing techniques of hydrodynamic observations for the purpose to study the geodynamic processes during preparation of seismic events that includes in itself both the complex field observation and cameral data processing using specialized software package.

Introduction

The Regime network of hydrodynamic observations in Georgia currently is presented by 15 observation boreholes. They were selected among many boreholes as the sensitive to the geodynamic stress ones. The criterion of sensitivity was their ability to capture the Sun-lunar tidal and atmospheric pressure variations as well as their location characterizing the main geological units.

Field observation methodology

Field observations include a real-time monitoring of groundwater level and atmospheric pressure. To conduct qualitative observations the equipment which provides measurements with a predetermined frequency and data transmission upon request is used. We use the data logger XR-5 produced in USA, which has 8 analog and two pulse ports. There are selected the appropriate water level, atmospheric pressure and temperature sensors. The data are registered with a frequency of once per minute. Using GSM communication systems data is transferred from the data logger located at the observation point.

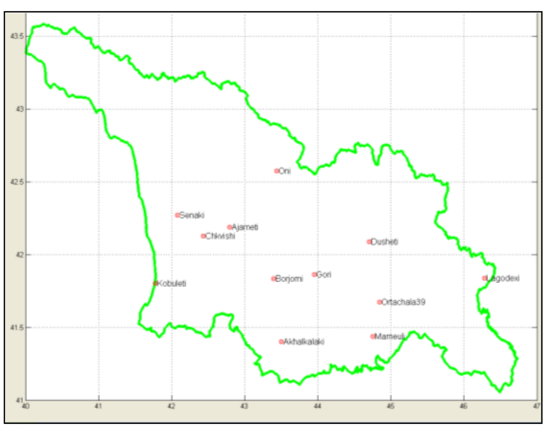

Figure 1. Location of hydrodynamic regime boreholes on the territory of Georgia

Data analyze

Water level variations as a multiple value includes both the influence of exogenous (tidal variations, atmospheric pressure and precipitation) and endogenous (earthquake, seismic movements) factors (1-6). Therefore, when analyzing the data of water level should be taken into account all influencing factors of Earth stress and accuracy of measuring devices and others.

In calculating the actual deformation quantities reaching borehole after the earthquake, the Dobrovolsky's (7) equation is used:

$$e=10^{1,3M-8,19}/R^3 \; ; \; R=\sqrt{(x^2+y^2+h^2)} \; , \qquad (1)$$

Where x and y – are earthquake coordinate, h and M – depth and magnitude respectively.

Let us assume that the water level variation in the borehole *water level* can be represented as a linear equation:

$$water\_level(x)=a*tidal(x)+b*atmosphere(x)+c. \qquad (2)$$

To find three unknown coefficients (a, b, c), included in the linear equation we must compose and solve a system with three equations (three or more equations). In order to compose one such equation is enough to have the measured values for *water level* and *atmosphere*. The Values of tidal variations are calculable- generated by a separate program. We can assume that these coefficients (a, b, c) are valid only for a limited period of time.

For the observation data processing by us was composed the computer program "StationsMany". The program is written in the medium of MatLab (authors of the program G. Kobzev and G. Melikadze). To generate the tidal variations is used program GRAV (8).

The program "StationsMany" is designed to study the behavior of water level in one or more boreholes, it is possible to analyze the reaction of water during earthquakes and to help with search for earthquake precursors. The program allows visualizing water level variations, atmospheric pressure, tidal-variation. It also allows finding unknown coefficients (a, b, c) of the equation (2) for any chosen time interval.

In the mentioned program is given the possibility to upload earthquake data, to conduct a selection among them by the number of parameters: the magnitude, the distance from the borehole, the energy which came from the earthquake to the borehole. It is also possible to choose an earthquake area.

The program creates an exogenous theoretical signal and compares it with the actual signal. Comparison allows you to characterize each exogenous (atmospheric pressure, tidal variation) parameters separately. This allows studying the effect of each on the level of water in the aquifer.

Water level variations that are caused by changes in atmospheric pressure and tides of the earth's crust are considered as "background" values. They change their form during earthquake preparation.

We have also developed the second method of studying the behavior of water level - with the help of "velocity". The proposed concept of "velocity" removes the seasonal trend of water level, which is usually presented when measuring the water level variations in boreholes and create a number of problems in the processing of data. The "velocity" of groundwater level change is determined by the equation for the difference of water levels in two points of time:

$$Speed(\mathrm{m+i})=(water(\mathrm{m+i})-water(\mathrm{i}))/\mathrm{m}, \quad \mathrm{i}=1,2,3,\ldots \qquad (3)$$

Where m - fixed number of minutes, for example, m = 180 minutes.

And finally, the third technique displayed in the program is «RestDance», which allows fixating violations in the geodynamic regime calculating the difference in amplitudes of the variations in water level and tidal variations, as well as the time shift between extremums of these variations.

In the study of the groundwater regime in observation wells we have been focused on the period of preparation for earthquakes, as well as post-seismic stress.

Results

To demonstrate the technique of data analysis, we consider the change of parameters during earthquake preparation period.

In seismically quiet period the water level variations are caused only by the external factors, but in the earthquake preparation process we observe the changes in the nature of variations. During this period, there are irregularities in the changing of "background running" water level before and after the earthquake.

We studied the earthquake, which occurred on the territory of Azerbaijan May 26, 2015, 1:20, magnitude 4.6, and its impact on the borehole Ajameti located at a distance of 360 km from the epicenter of the earthquake, and also the earthquake in Georgia July 27, 2015, 6:58, magnitude 4.1, and its impact on the borehole Marneuli located at a distance of 75 km from the epicenter of an earthquake.

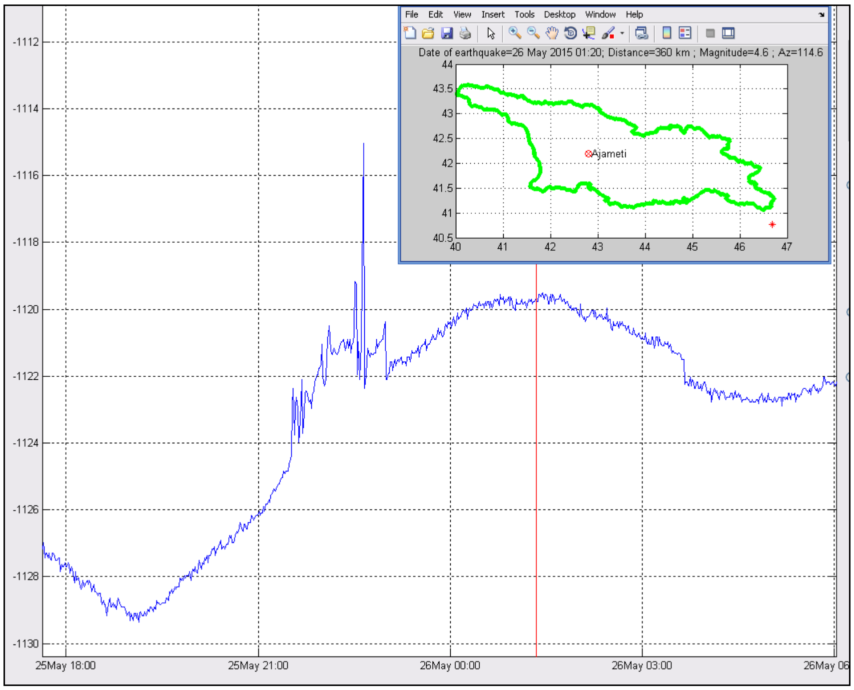

Fig. 2. Water level variation in the borehole “Ajameti”. The vertical line indicates the time of the earthquake: 26 May 2015, 1:20, 4.6 magnitude, 360 km away. On the abscissa - the date in hours.

On the Fig. 2 at the upper right corner is shown the location of the borehole “Ajameti” (circle) and the epicenter of the earthquake (the star, the lower right corner).

On The graph of the water level can be seen significant violations that took place in the borehole before the earthquake. They had being continued on May 25 from 21:30 to 23:00 on the amplitude of up to 3 cm. The earthquake occurred on May 26, 2015, 1:20. Anomaly appeared 3 hours 50 minutes before the earthquake, and lasted for 1 hour 30 minutes). Next May 26 at 3:40 there was a drop in water level about 1 cm. After was observed the normalization of the behavior of the water level.

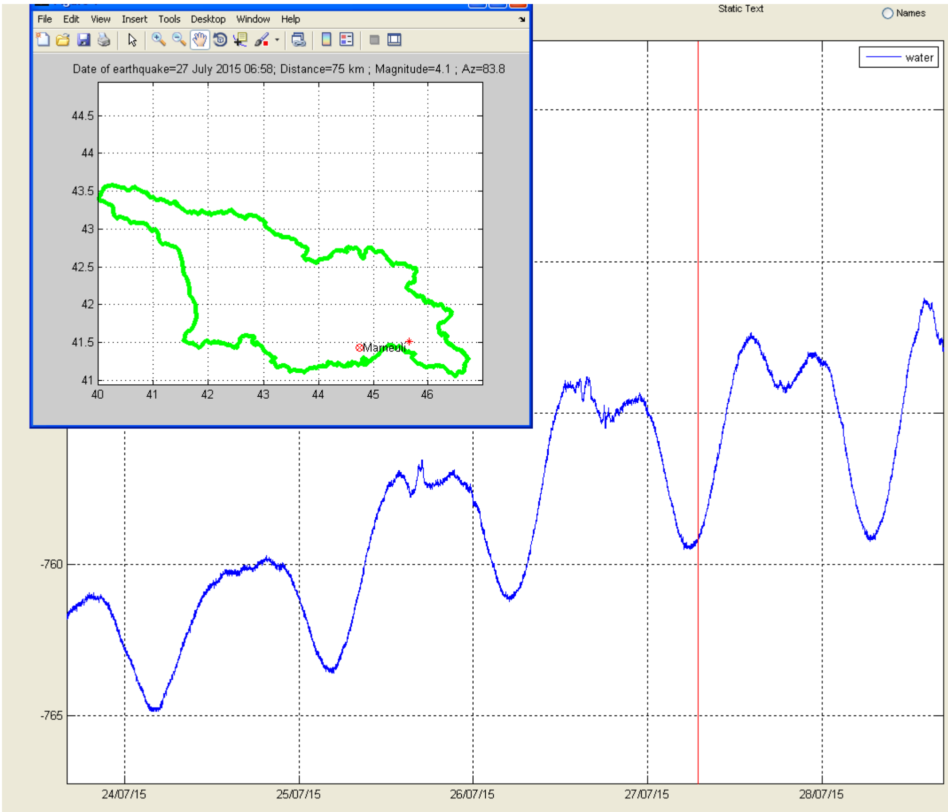

Fig. 3 Water level variations in the station "Marneuli" (in cm). The vertical line marks earthquake July 27, 2015, 6:58, 4.1 magnitude, 75 km away.

Fig. 3 shows the location of the borehole "Marneuli" (circle) and the epicenter (star to the East). Now let us have a look at the changes in water level, using the method of velocity, ie, comparing the velocity of change of water and tidal-variations.

There are marked two lines on the figure: the line of the water level variation velocity and the line of tidal-variations velocity. It is noticeable that the graph of velocity of tidal-variation has a "smooth" look as tidal variations are theoretically -generated by program GRAV.

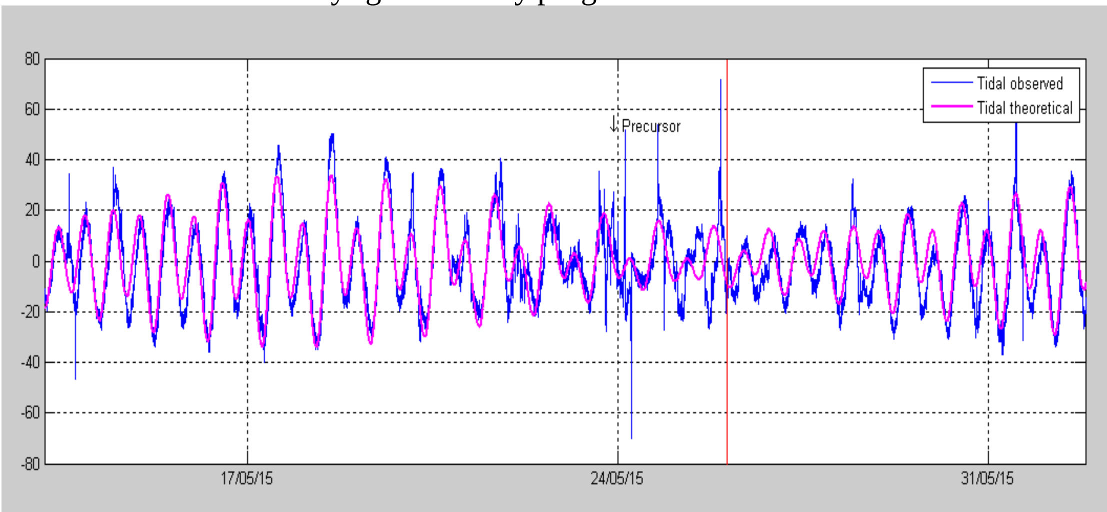

Fig. 4 The velocity of change in water level and tidal (tidal, smooth line). According to the data of borehole Ajameti

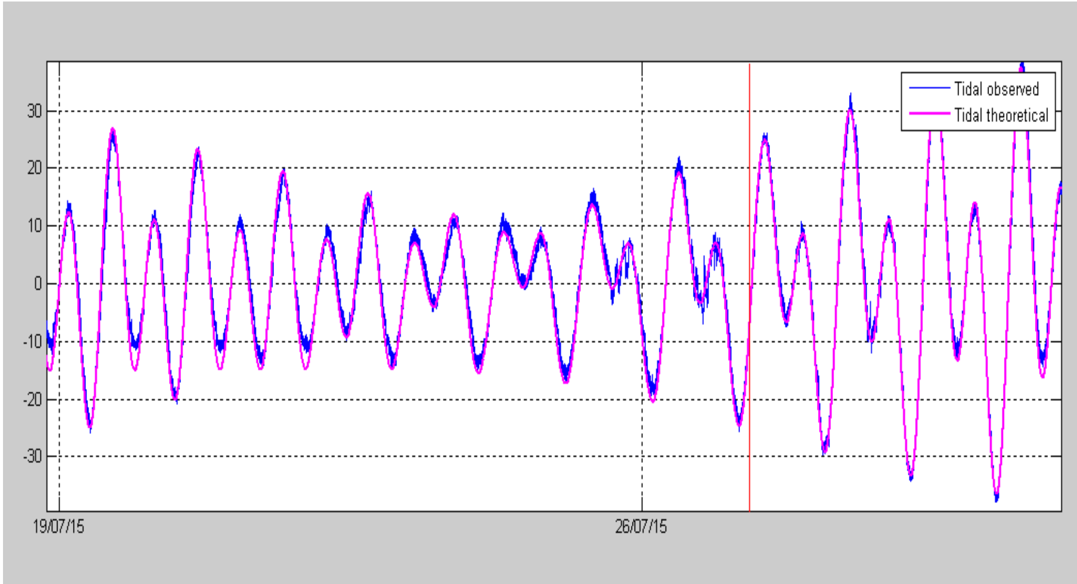

Fig. 5 Velocity of changes in water level and tidal (tidal, smooth line).
According to the data from borehole Marneuli

Figure 4 and 5 can distinguish three plots. At the first station, there is a good match between these velocity lines. In the second section, there is a marked discrepancy between these lines, which becomes significant before the earthquake. After a few days again, there is a good match between the lines.

We also observe the violations on the plots of apmlitude differences and quotients:
We can compare the water level and tidal amplitude variations using program «RestDance». Under the amplitude variation we will assume the following: On the graph of tidal variation we find the point t_0, in which the daily absolute maximum and minimum is reached.

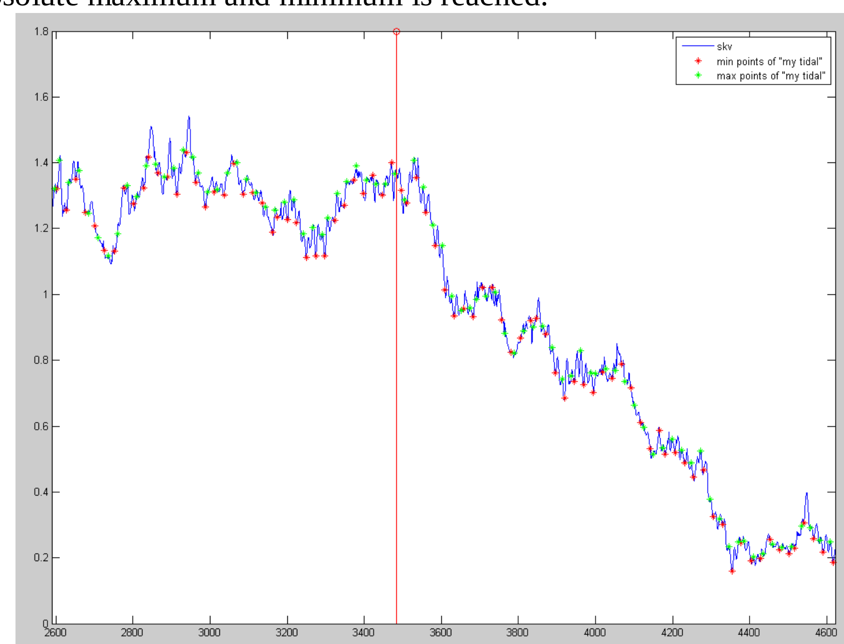

Fig. 6 . Graph of the water level with marked points where were reached the minimum and the maximum of tidal according to the data in borehole "Ajameti"

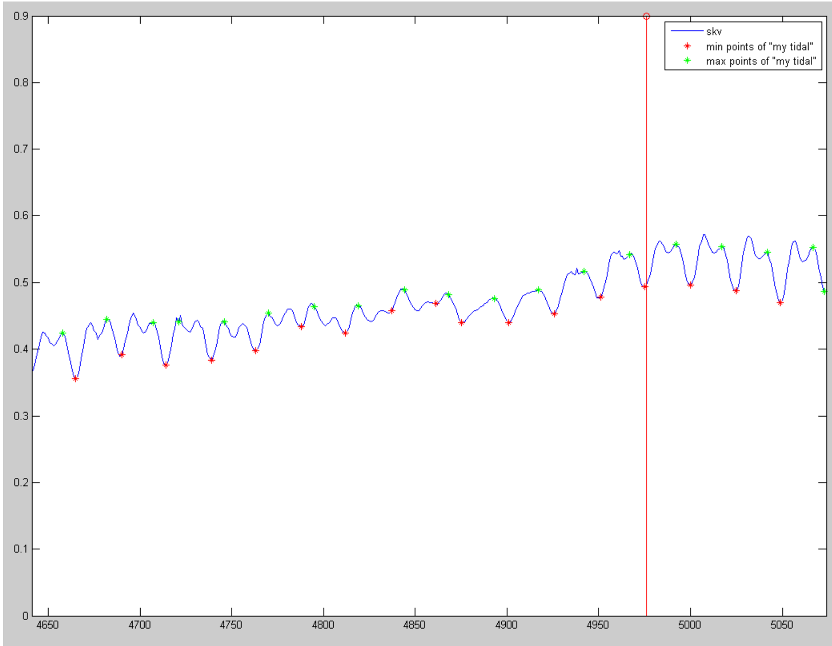

Fig. 7. Graph of the water level (hourly data) with points where were reached the minimum and the maximum of tidal data for borehole Marneuli.

Next, we find the first point (time)) $t_1>t_0$, when the tidal reaches the greatest value. Tidal amplitude at t_0 is AT=tidal(t_1)- tidal(t_0). For water level amplitude will be AW=water(t_1)- water(t_0). The figure above shows the results of dividing the amplitudes of water AW / AT. The figure below shows the results of subtracting the amplitude AW-AT.

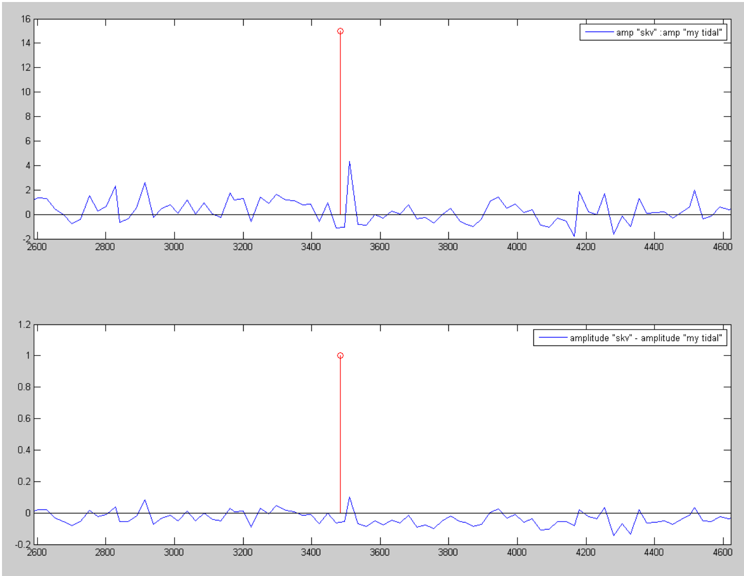

Fig. 8 Upper Graph AW / AT: amplitude of water divided by the amplitude of the tidal.

The lower figure Graph AW-AT: the amplitude of water minus the amplitude of tidal according to the data from "Ajameti" well

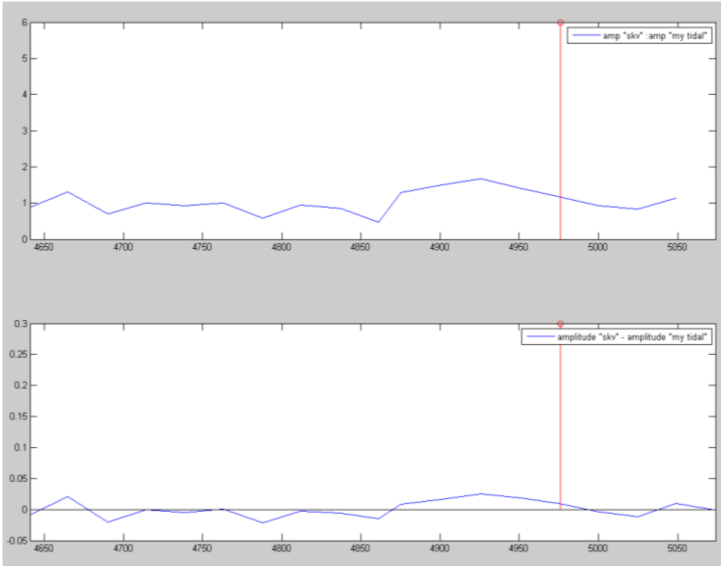

Fig. 9 Upper Graph AW / AT: amplitude of water divided by the amplitude of the tidal. The lower figure Graph AW-AT: the amplitude of water minus the amplitude of tidal according to the data from “Marneuli” borehole

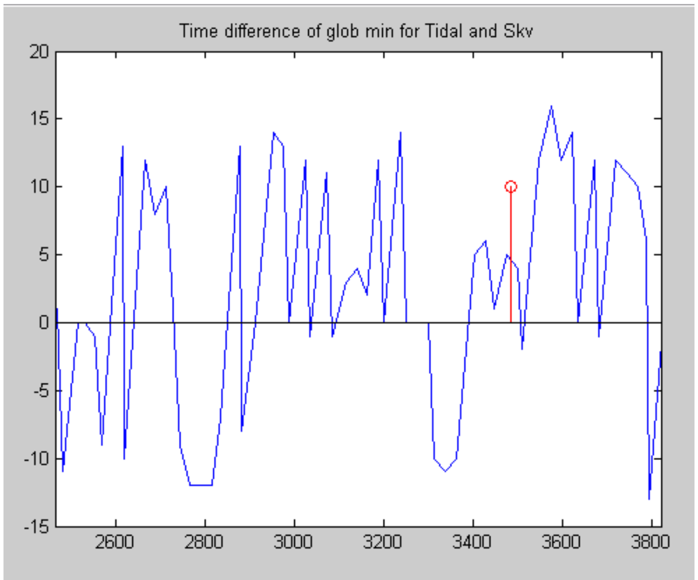

Fig. 10 The response to the earthquake of May 26, 2015, Mag. 4.6 (Azerbaijan); “Ajameti” borehole

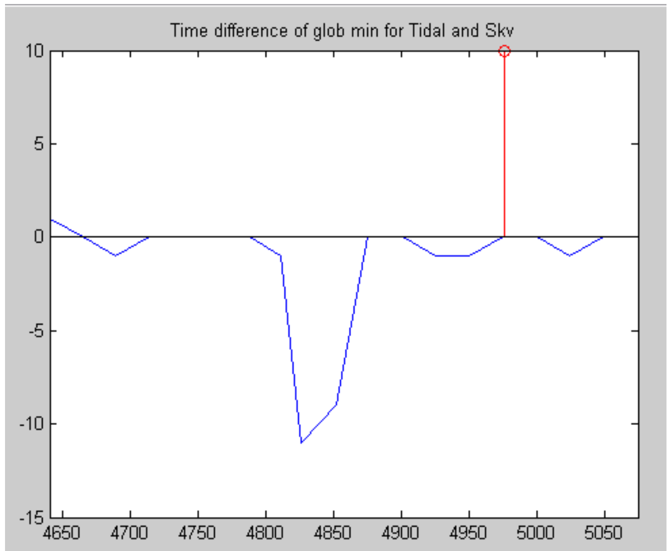

Fig. 11 The response to the earthquake of July 27, 2015, Mag. 4.1 (Georgia); “Marneuli” borehole

Conclusion

Has been developed the methods of detection of underground water geodynamic anomalies related to the seismic activity. For the same period of time all three methods detected abnormal changes which proves the suitability and the credibility of the methods.

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გიორგი მელიქაძე, თამარ ჯიმშელაძე, გენადი კობზევი, ალექსანდრე ჩანკვეტაძე, მარინა დევიძე, ნინო კაპანაძე

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აბსტრაქტი

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