BOREHOLES WATER LEVEL AND EARTHQUAKE'S PREDICTION (2011-2013)

A.Sborshchikovi [1,2] , G.Kobzev [1,2] , S.Cht.Mavrodiev [2] , G.Melikadze [1]

[1] M.Nodia Institute of Geophysics, Georgia , [2] Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences ,

rossoneri08@yandex.ru

Abstract

Studies of precursors and events that occur before an earthquake is one of the most important problem that arose in todays' seismology. Earthquake prediction has become the issue that needs to be solved, it will help us to forecast destructive earthquake. In this article we will discuss water level daily monitoring in several boreholes located in different parts of Georgia.
Keywords: water level, precursors, earthquake prediction, geoelectromagnetism

Introduction

The main reason of this research was to find the answer to the question is the change of water level in the boreholes the same effect on the incoming earthquake appearance as the variations of magnetic fields or not.

The hypothesis for possible correlations between the earthquakes and the variations of magnetic fields, Earth's horizontal and vertical currents in the atmosphere, was born when in the when the historical data on the Black Sea was systemized. The achievement in the Earth surface tidal potential modeling, with the ocean and atmosphere tidal influences being included, makes an essential part of the research. In this sense, the comparison of the Earth tides analysis codes [1] was very useful. The possible tidal triggering of earthquakes has been investigated for a long period of time [2].

The earthquake-related part of the models has to be infinitely repeated in the "theory–experiment–theory" process, using nonlinear inverse problem methods in looking for correlations between the different fields in dynamically changing space and time scales. Each approximate model supported by some experimental evidence should be included in the analysis. The adequate physical understanding of the correlations among electromagnetic precursors, tidal extremes and a impendant earthquake is related to the progress of an adequate Earth magnetism theory and electrical currents distribution, as well as to the quantum mechanical understanding of the processes in the earthquake source volume before and during the earthquake.

Simultaneous analysis of more accurate space and time measuring sets for the Earth crust condition parameters, including the monitoring data of the electromagnetic field under and over the Earth surface, as well as the temperature distribution and other possible geophysical precursors, would be the basis of nonlinear inverse problem methods. It could be promising for studying and solving the "when, where and how" earthquake prediction problem.

The discovery of geomagnetic quake as reliable precursor for increasing of regional seismicity

In December 1989, a continuous measurement of a projection of the Earth's magnetic field (*F*) with a magnetometer (know-how of JINR, Dubna, Boris Vasiliev) with absolute precision less than one nano-Tesla at a sampling rate of 2.5 samples per second was started. The minute's mean value of *F*, its error mean value, the minute's standard deviation *SDF*, and its error were calculated, i.e., every 24 hours, 1440 quartets of data were recorded.
Minute standard deviation of *F* is defined as:

$$SDF_m = \left(\left(\frac{1}{N} \right) \sum_{i=1}^{N_m} \left(1 - F_{mean} / F_i\right)^2 \right)^{\frac{1}{2}} \quad (1)$$

where *m* is the chosen time interval and *n* is the number of simples during the period,

$$F_{mean} = \left(\frac{1}{N} \right) \sum_{i=1}^{N_m} F_i \quad (2)$$

and N_m is the number of samples per minute.

The connection between variations of local geomagnetic field and the Earth currents was established in INRNE, BAS, Sofia, 2001 seminar [3]. The statistic of earthquakes that occurred in the region (1989-2001), confirmed the Tamrazyan notes [4,5], that the extremes of tides are the earthquake's trigger. The Venedikov's code [6,7] for calculating the regional tide force was used [8].

The signal for imminent increasing regional seismic activity (incoming earthquakes) is the "geomagnetic quake" (Gq), which is defined as a jump (positive derivative) of daily averaged SDF_{mean}, devoted to half sum of middle geomagnetic field indices. Such approach permits to compare by numbers the daily behavior of the geomagnetic field with those in other days.

Among the earthquakes occurred on the territory under consideration in certain time period, the "predicted" one is the earthquake with magnitude *M* and distance between epicenter and monitoring point *Dist,* which is identified by the maximum value of the function:

$$S_{ChtM} = 10^{1.5M+4.8} / \left(D + Depth + Dist\right)^2 \left[J / km^2\right] \quad (3)$$

where *D* = 40 km is a fit parameter. Probably, its sence is connected with the mean of Earth crust thickness.

The physical meaning of the function S_{ChtM} is a surface density of earthquake's energy in the point of measurement. It is important to stress out that the first consideration of the earthquake magnitude *M* and epicenter distance dependence was obtained using nonlinear inverse problem methods. Obviously, the close distance strong earthquake (with relatively high value of S_{ChtM}) will bear more local Earth currents variations, which will generate more power geomagnetic quake.

It is very important to note that in the time scale of one minute, the correlation between the time period of increasing regional seismic activity (incoming earthquake), and tide extrema, recognized of predicted earthquake was established using the Alexandrov's code REGN for solving the over - determined nonlinear systems [8,9]. The very big worthiness of Alexandrov's theory and its code is possibility to choose between two functions, which describe the experimental data with the same *hi*-squared, the better one.

Day-Difference analysis

The role of the electromagnetic variations as earthquake's precursor can be explained in general by the hypothesis: the strain accumulation in the Earth Crust during the earthquake preparation causes medium's density change, within which a chemical phase ("dehydration") shift and a corresponding electrical charges shift appears. The Earth tides extreme as earthquake's trigger could be based on the hypothesis of "convergence of tidal surface waves" in the region (territory with prominent tectonic activity as consequences of chemical phase shift) of impending seismic activity.

For every occurred earthquake was calculated “day-difference”; the smaller absolute time difference between the hypocenter time and the daily times of pre and post tide’s extreme time at that site on the Earth surface (the earthquake epicenter). This procedure was provided on all reported earthquakes in ISC catalogue (http://www.isc.ac.uk/) for the time period 1981-2011 and $M \geq 3.5$. The program for calculating of daily averaged module of vector movement *Tmean* is based on Dennis Milbert TIDE program (solid.for), by which Tide data could be calculated only for the time period after 1981. The DailyTide time of the Tide extremes *Tmean* were calculated by analogy of center mass calculation.

The statistic of day-differences for the earthquakes that occurred worldwide (1981-2011) and the Gaussian fitted curve (Fig.4), confirmed the Tamrazyan notes [5,6] from 1960-th, that the extrems of tides play a role of earthquake’s trigger.

Data and stations

The main reason of this research was to find the answer to the question was is the change of water level in the boreholes has the same effect for earthquake appearance as the variations of magnetic fields or not.

The hypothesis for possible correlations between the earthquakes, the variations of magnetic fields, Earth’s horizontal and vertical currents in the atmosphere, was born when in early 1988, the historical data on the Black Sea was systemized. The achievement in the Earth surface tidal potential modeling, with the ocean and atmosphere tidal influences being included, makes an essential part of the research. In this sense, the comparison of the Earth tides analysis codes [6] is very useful. The possible tidal triggering of earthquakes has been investigated for a long period of time [7].

After studying this fact a hypothesis was born may be we can forecast earthquake using the same methodology.

Before discussing our methodology let stop our attention on the boreholes, which are located in different parts of Georgia.We have Ajameti borehole (depth 1300 m); Axalkalaki (1400 m); Borjomi-70 (1300 m); Kobuleti (2000 m); Lagodehi (800m) and Marneuli (3500m).

The location of these boreholes is shown in Fig.1a.

Fig.1a Map of boreholes in Georgia

Here is the detail description of the boreholes:

Borehole	Depth, meters	Filter interval, meters	Lithology	Geological intervals, meters	Water level, meters
Ajameti	1330	520-740	Litostone	520-740	-6
Ahalkalaki	1400	1000	Tuff, andezit, basalt, dolomite	580-1000	-0.2
Borjomi-70	1330	1260-1300	Clay	0-12	-22
Kobuleti	2000	187-640	Tuff, andezit, bazalt	0-150 150-2000	-0.5
Lagodehi	800	255-367	Sand+gravel	0-24	-15.8
Marneuli	3500	1235-1600	Gravel	0-50	-5

Methodology of analysis

We have selected earthquakes with magnitude $M \geq 3.5$ at distance $D \leq 500$km from boreholes for 2011, 2012 and 2013 years. After format conversion of water level data we calculate the daily standard deviation (daily level signal). When we have the jump of today and yesterday signals we say that we have a precursor for incoming regional seismicity. After this we analyze the day difference between occurred earthquakes and next extreme of the tide, calculated using Dennis Milbert FORTRAN code for local tidal behavior, http://home.comcast.net/~dmilbert/softs/solid.htm.

For precursors calculation we used one hour water level data. The statistic evidence that water level precursors can be used for estimation of incoming regional seismic situation is illustrated in the figures 2,3 and 4,5.

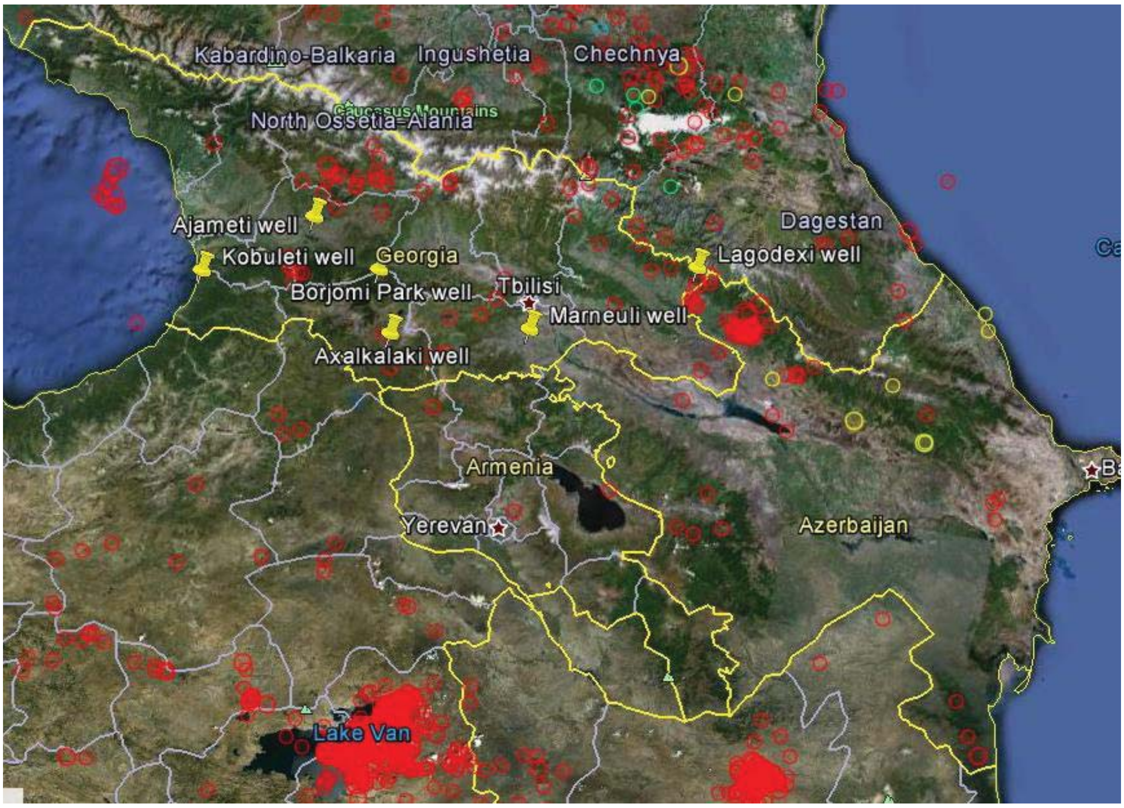

Fig.1b The map of earthquakes during 2011-2012

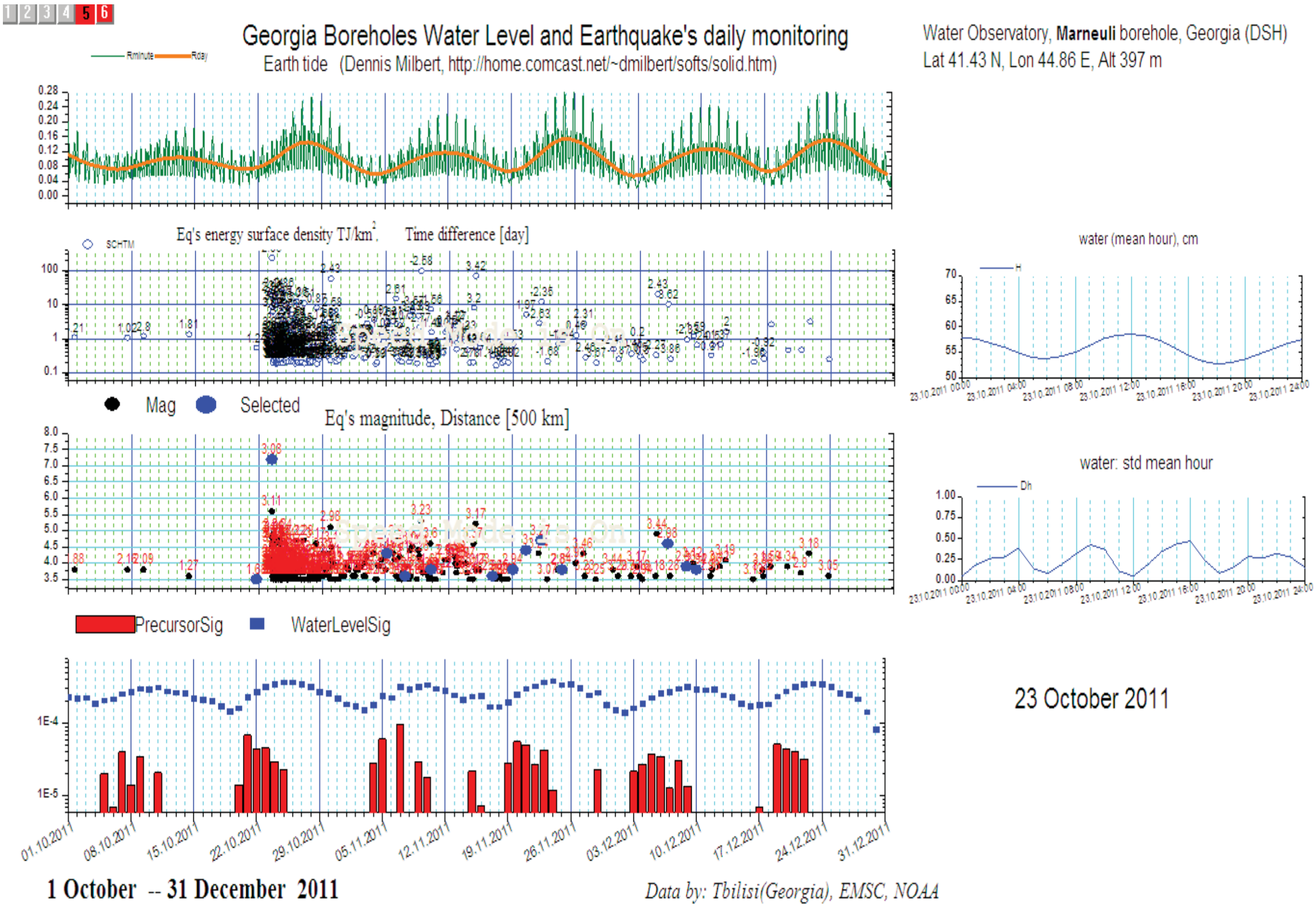

Fig.2 Marneuli borehole daily monitoring including period of great earthquake in Turkey (2011)

As we see in figure 2 the first graph in the left corner is the picture of tidal behavior [m], the next shows the energy (J/km ^{2}), the next – magnitude, and the last describes precursors (red columns) and water level signals (blue points). The blue points has been count using normal standard deviation and the red columns so called precursors were obtain by subtraction of the daily standard deviation of today and the previous day [10,11]. The first graph in the right corner is water mean during 23 October the period of great Turkey earthquake and the next describes standard deviation of water level [12].

The same emplacement is shown for another period in the figure 3.

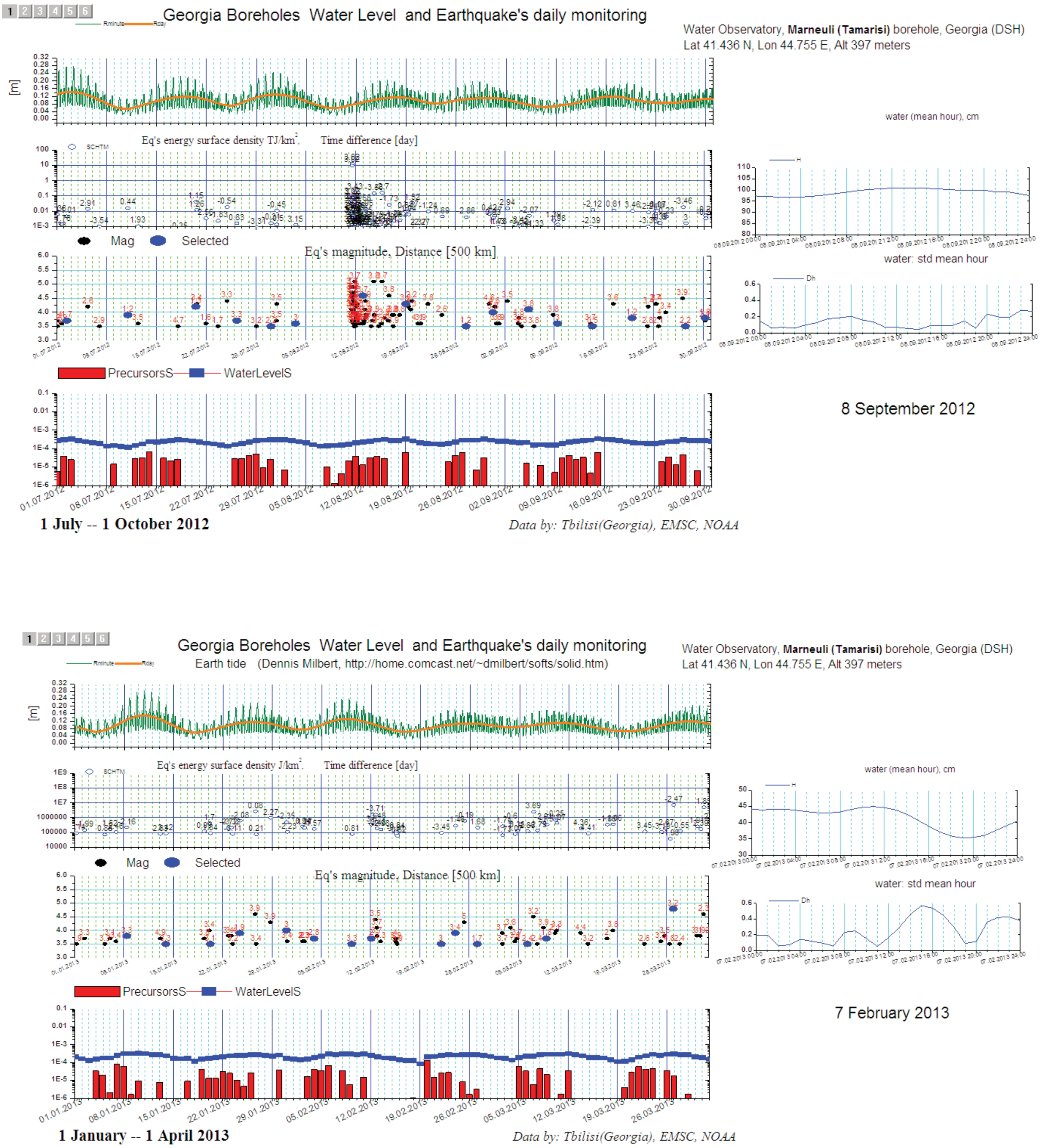

Fig.3 Marneuli borehole daily monitoring (2012,2013)

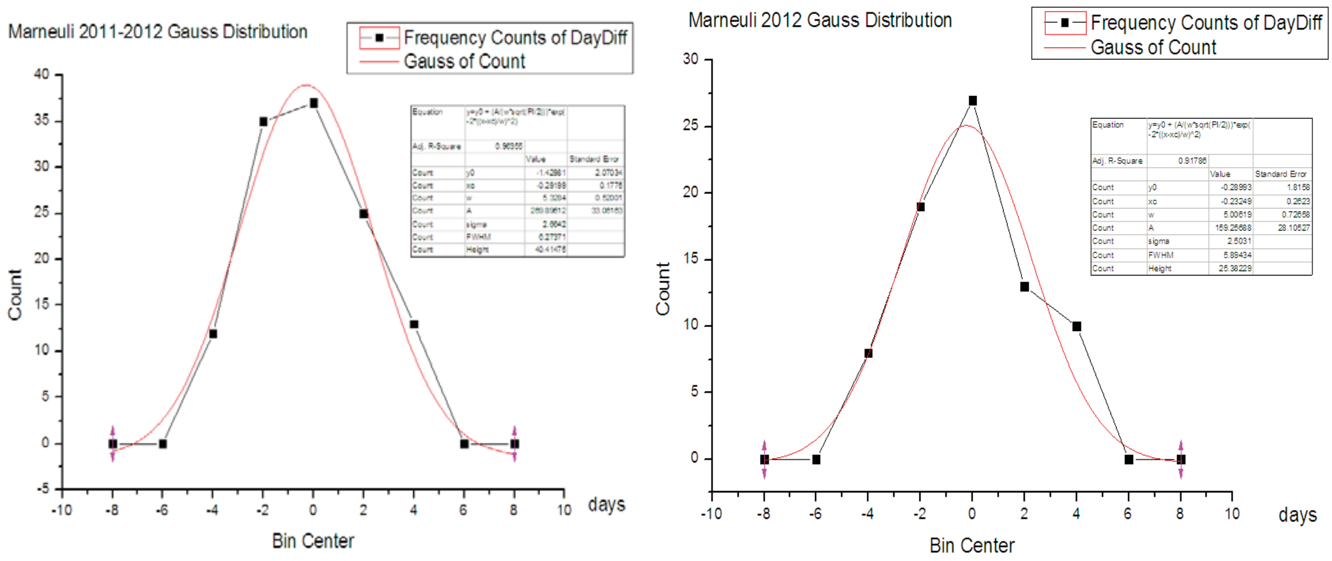

Fig.4 Marneuli borehole Gauss Distribution for day difference (2011-2012,2012)

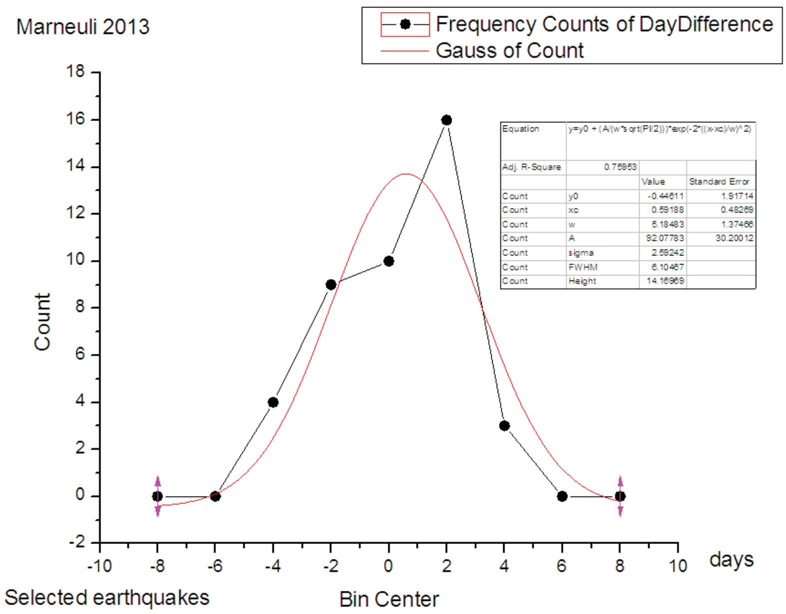

Fig.5 Marneuli borehole Gauss Distribution for day difference (2013)

From the figures 4 and 5 we see that the day difference distribution from 2011 until 2013 are described well by Gaussian curve with the R-square not less than 0.90.

The figure 6 presents frequency count for the distance of the selected by precursors earthquakes with maximal energy density in monitoring point with increment 10 km.

The highest number of the earthquakes is at the distance 300-350 km (Turkey earthquakes), the earthquake at distance 350-450 km are Iran earthquakes and the other one that are at distance less than 300 km are regional local earthquakes.

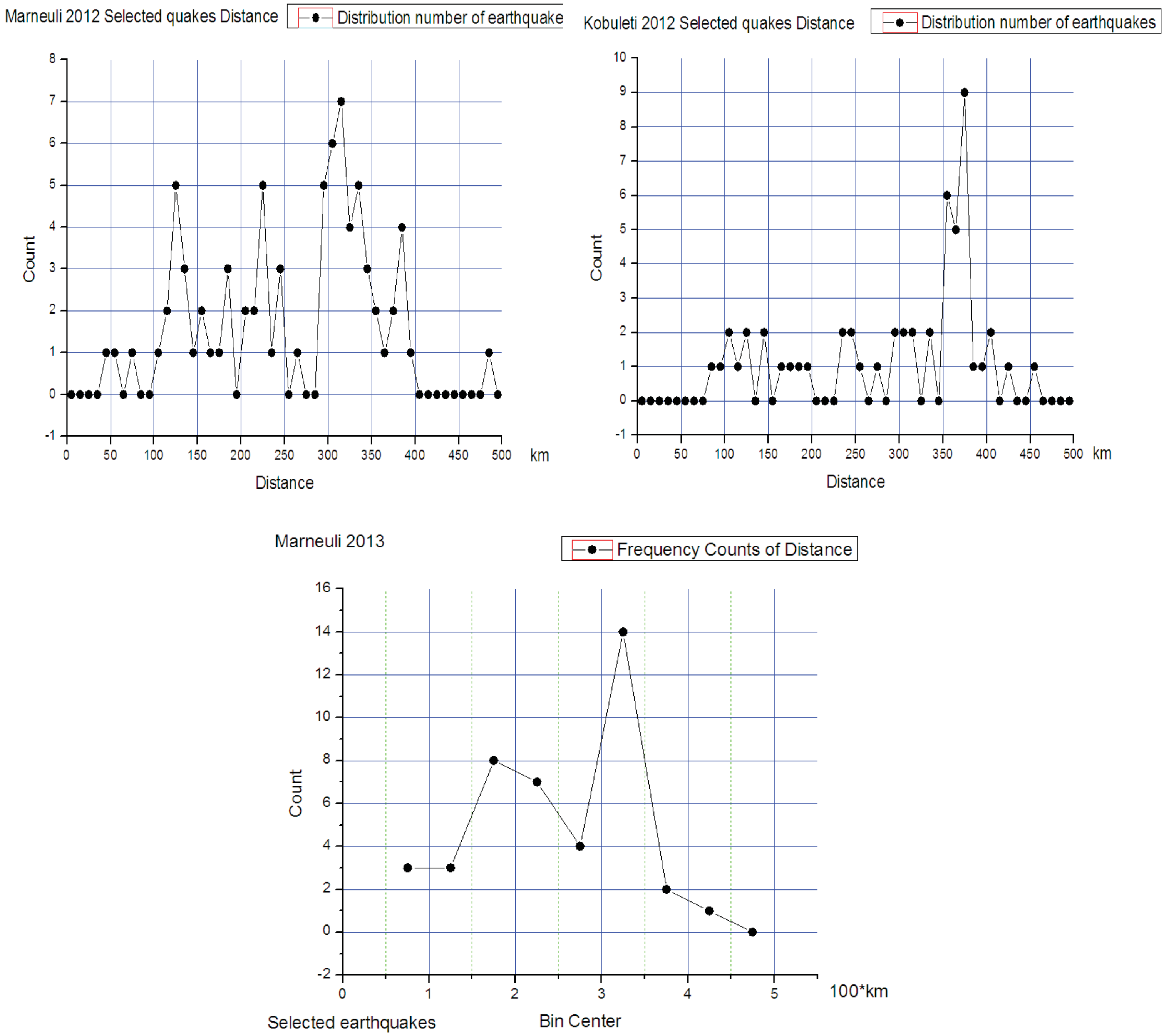

Fig.6 Two boreholes frequency counts for distance of selected by precursors quakes
And frequency count of distance on Marneuli borehole 2013

Conclusion

As conclusion we can say that the using in analogy of geomagnetic quake approach of daily boreholes water data level analyzes can serve as precursor of increasing regional seismic activity.

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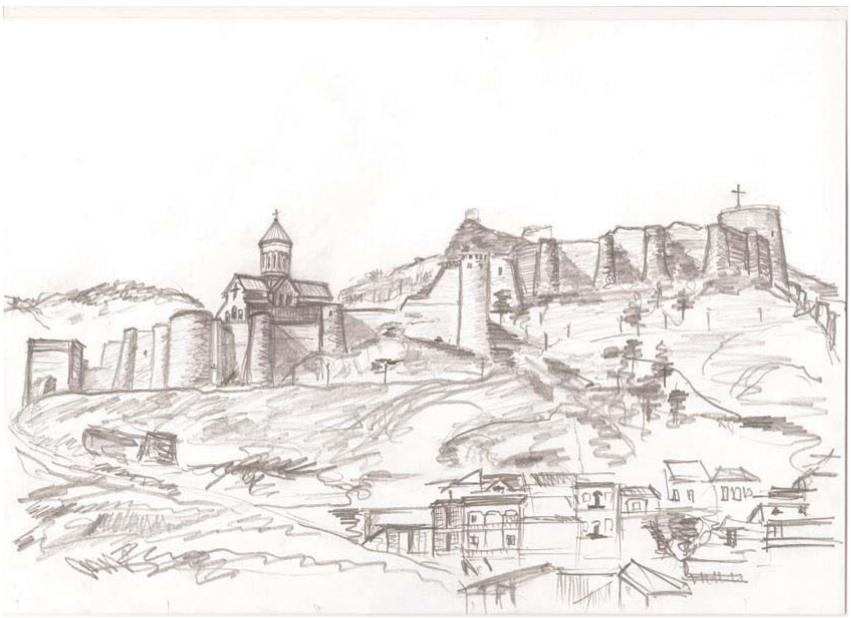

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