Seismoprogn. Observ. Territ. Azerb. V.12, №1, 2015 pp.27-34

OBSERVATION OF THE TIDAL VARIATIONS IN GRAVITY ON THE TERRITORY OF AZERBAIJAN

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ABSTRACT. The work is devoted to research of the direction in Physics of the Earth intensively developing nowadays: the dynamics of the Earth-Moon system, deformations of the Earth caused by tidal forces. The article presents the primary results of the tidal registering network of stations. Results are given for the main diurnal and semidiurnal tidal waves.

Introduction

The study of the tidal variations in gravity is one of the perspective methods of geodynamic studies. Tidal variations in gravity are caused by the influence on the earth of variable in space and time the lunar-solar exposure. Experimental data is important in the development of models of tidal deformation, for the calculation of tidal corrections in high-precision measurements of gravity, in high-precision geophysical measurements that reflect the variations of strain and stress in the Earth's crust, to determine the displacements of the earth's surface in the geocentric coordinate system (on the methods of space geodesy GPS). [14, 4, 20].

Currently, the Earth's tidal observations are widely implemented in many countries, but the number of stations of earth tidal observations is far from enough. In addition, the existing network of these stations is not evenly distributed. This creates difficulties of interpretation of the geodesic results. Therefore, increase in the reliability and the quality of the experimental data, as well as the geographical expansion of the observations is highly relevant. Azerbaijan is located along the northern part of the collision zone of the Arabian and Eurasian plates [8, 9, 10, 12] and here there are frequent earthquakes with a maximum magnitude M≥6.3. In this regard, gravimetric observations of tidal perturbations in such seismically active region as Azerbaijan are of great scientific interest [11].

This research presents an analysis of gravimetric observations at Sheki station of Republican Seismic Survey Center with coordinates (41.210, 47.200), Lankaran (coordinates 38,710, 48.780) and Gazakh (coordinates 41,060, 45.370).

The factual material and research methods

The theoretical basis for solving the problem is the theory of tidal deformations of the Earth and the physical models of environmental deformation with linear rheology. For the experimental study of tidal and slow team of the Republican Seismic Survey Center (RSSC) of the Azerbaijan National Academy of Sciences (ANAS) conducted long-term high-precision measurements using gravimeter Scintrex AutoGrav CG-5 (2013-2015) and gathered unique data on the results of three gravimetric stations Sheki, Gazakh and Lankaran. Similar series of experimental data for the region are characterized by high accuracy.

Gravimetric data was obtained in the period of 2013-2015 years. Apparatus complex used in the studies included instruments belonging to RSSC of ANAS. Analysis of tidal data was performed using the materials databank of International Center for Earth Tides (ICET).

Basic research methods: tidal analysis, experiment and tidal parameters. Methods of processing of tidal measurements' materials comply with the requirements of the International tidal center. Were used PC programs, designed by Venedik (Bulgaria), Wenzel (Germany) and Ducarme (Belgium).

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We used a set of experimental methods: for the first time for gravimeters were used the reconciliation and the method of calibration using gravimeter Scintrex AutoGrav CG-5 at the basic tidal Observatory of Mox (Germany), of the global network ICET. Use of a complex calibration methods ensured the accuracy of gravimeters, corresponding to the fourth sign in the tidal parameter.

For all kinds of measurements was conducted the assessment of seasonal effects (thermal and baric effects) and their contribution to the results of observations.

Tidal stations of RSSC of ANAS and their geological and geophysical characteristics

The observations of tidal variations in gravity were conducted in accordance with the plan of RSSC of ANAS and were part of a program aimed at the study of earth's crustal deformation in Azerbaijan.

The observations were carried out on the territory of Sheki seismic station of RSSC ANAS, seismic station Gazakh (RSS) and Lankaran seismic station (RSS) (Fig.1).

Figure 1. Schematic map of the location of tidal stations Sheki, Gazakh and Lankaran RSSC ANAS.

Tidal registering station Sheki is located within the Alpine mountain-folded structure of the Greater Caucasus, which covers the northern part of the Caucasus isthmus and stretches from Taman peninsula to Absheron to a distance of 1,300 km with a maximum width of 150 km. Modern understanding of the tectonics of the region is based on the materials of long-term observations by Russian, Georgian and Azerbaijani geologists, the results of deep geological mapping by geophysical methods, and the implementation of paleotectonic reconstruction, and refers to Vandam zone. Thus emerges the disharmonious-layers structure of the earth's crust, which is divided into a number of differentially offset plates, i.e., in the present structure of the Greater Caucasus it is represented in the form of a complex fold-thrust structures formed as a result of later alpine tectonic movements of three main Mesozoic structures - the North Caucasus and South Caucasus (Transcaucasian) continental micro plates and extensive marginal-sea basin of the Tethys, separating them. The boundaries between these macrostructures meet through deep faults or structural joints, the Greater Caucasus in the north and Krasnopolyan-Zangi in the south, which in the modern structure of the consolidated crust and of the alpine mantle are mapped as deep thrusts of large amplitude directed on the south. Branching of the latest in ascending order leads to the separation of multiscale tectonic scales, complicating the internal construction of these macrostructures. Along the strike the structure of the Greater Caucasus is not monolithic and breaks down into four separate transverse tectonic segments separated by Pshehsko-Adler, Mineralovod and Agdash-Darband (Samur) flexure-fault zones in the geological literature is referred to as the North-West, Central, East and South Eastern Caucasus (Azerbaijan Geology, Volume IV, 2005, pages 43-47).

Tidal registering station Gazakh refers to Gazakh-Agburun subzone of Lesser Caucasian mountain-fold system, which covers the southern part of the Caucasian isthmus and is characterized by a heterogeneous internal structure due to the convergence within it of two branches of the Alpine-Himalayan Mobile Belt: the Iberian-Elbrus in the north and Dinara- Sunda in the south. The northern branch in the Caucasus region is represented by the South Caucasus microplate, to the south wing of which is related the main part of the Lesser Caucasus - Artvin-Garabag mega zone responsible for elevation, continuing in the east the system of Eastern Pontides of North Anatolia. In the south-east along the fault of the lower flow of Araz river is the border of the Lesser Caucasus region with fold-cover construction of Elbrus Mountain.

Tidal registering station Lankaran tectonically belongs to the Talysh folded mega zone, which is located on the northern edge of Lesser Caucasus-Elbrus fold system, separated from the structures of the Lesser Caucasus by cross Lower Araz deflection. Within the Republic of Azerbaijan mega zone is represented by its north-eastern wing and the south-western part is a part of the Garadagh area of northern Iran, where volcanic-sedimentary formations overlap Paleogene Miocene-Pliocene volcanic complexes of Savalan volcano. (Geology of Azerbaijan, volume IV, 2005, page 41, 360)

Hardware complex

In measurements of tidal gravity variations on the gravimetric stations were used high-precision gravimeters Scintrex (Scintrex CG5 AutoGraf) (Fig. 2) with metal springs as the most stable by the metrological parameters of the mobile gravimeters. It is one of the most common instruments for studying the Earth's tides.

When measuring with gravimeters, the modern methods of calibration were used.

Figure 2. Gravimeter CG-5 AutoGrav.

<u>Gravimeter GG-5 AutoGrav:</u>

The high precision automatic gravimeter Scintrex CG-5 AutoGrav is an automatic microprocessor gravimeter without the need to reinstall (its measuring range exceeding 8,000 mGal) and resolution is up to 0,001 mGal. Sensitive gravimeter system is a spring balance of fused quartz and is not astatizing (Fig. 3). The gravitational force exerted on the tested weight is balanced by a spring, and its variations in time are compensated by the electrostatic force. Since the sensor is made of a nonmagnetic fused quartz. AutoGrav system is not affected by the changes of magnetic field (if they do not exceed the magnitude of the Earth's magnetic field in ten times).

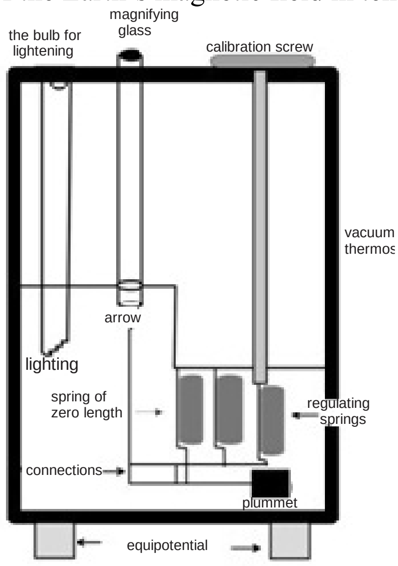

Figure 3. Scheme of gravimeter Scintrex CG-5 AutoGrav.

It is highly accurate (1 mGal) and is the easiest of the automatic gravimeters providing automatic leveling of the device and automatic diagnosis after powering. Personal observer's errors in the measurements are completely excluded, as the device is fully automated.

In the AutoGrav system angle gravimeter sensors that allow you to enter data for the automatic adjustment of the inclination of the device are implemented. The system of automatic adjustment of data also introduces a correction for lunisolar attraction, and, in addition, has a progressive function of rejection the noisy indicators and seismic noise filter FIR. Protection from changes of external temperature and atmospheric pressure is achieved by sealing the sensor element of the AutoGrav system in the vacuum chamber with temperature stabilization. Small displacement of the zero point allows conducting the accurate long-term assessment of the displacement sensor. (Scintrex Limited CG-5 Manual 2006).

The implementation of measurements by tidal devices requires a preliminary assessment of systematic instrumental characteristics. The measurements are usually conducted by means of linear sensors or in the linearity of the measuring system. When measuring the displacement of sensor element were used different types of sensors: differential photocells, capacitive displacement sensors with the feedback system, laser movement sensor, inductive displacement sensors. In fact, most of the received information was obtained without the use of schemes to enhance the signal, i.e., sensor - galvanometer.

In the spring gravimeters are widely used various feedback systems for increasing the sensitivity. This technology was used when working with gravimeter Scintrex on the tidal stations of Gazakh (Gazakh seismic station), Lankaran (Lankaran seismic station), Shaki (Shaki seismic station). Special attention is paid to the account of the instrumental delay of registration systems. The importance of an accurate determination of the phase delay in the tidal variations derives from the existing tidal models of tidal Earth's deformation, ocean tides, and the effects of tidal dissipation in the theory of evolution of the Earth [1, 3, 14, 15 ,17, 18, 19, 21].

The observed results and discussion

In 2013, RSSC of ANAS set a task on the organization of monitoring of the tidal changes in gravity at three seismic stations of Azerbaijan. For this purpose it was decided to use the available Scintrex gravity meters with a recording device.

Starting from 2013 gravimeters, respectively, have been installed at seismic stations of Sheki, Gazakh (since 2014) and Lankaran (Fig. 4, 5, 6).

Figure 4. Gazakh station**.**

Figure 5. Shaki station.

Figure 6. Lankaran station.

Within two years was gathered the first unique data on the tidal parameters in variations of the gravitational field in different parts of Azerbaijan.

Observations on tidal registering stations of Azerbaijan continue today.

Data on analysis

The observation results were processed using a combination of software Pre Analysis (Gebauer, 2005) and ETERNA [22].

Data recording: to record data on long-term observations of the Earth's tides, we used the "continuous monitoring" function. This function allows measuring the gravity continuously, as required for the observations of earth tides and variations in gravity.

Frequency measurement (taking samples) was performed with an interval of 3 to 4 minutes. Date and time were corrected by GPS antenna gravimeter. During the initial data processing, we have interpolated some gaps in measurements. 3 and 4 minute measurements were interpolated to 1 minute by PreAnalyse program and were filtered to 5 minute and 1-hour date. (Fig. 7 and 8)

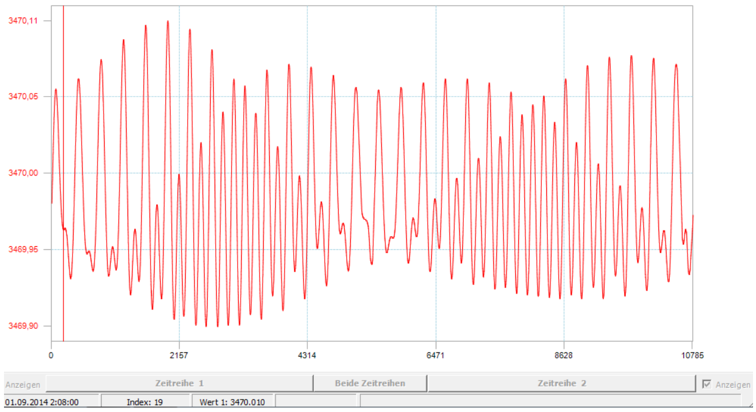

Figure 7. Fragment of recording on Gazakh stations over a period of 1 month.

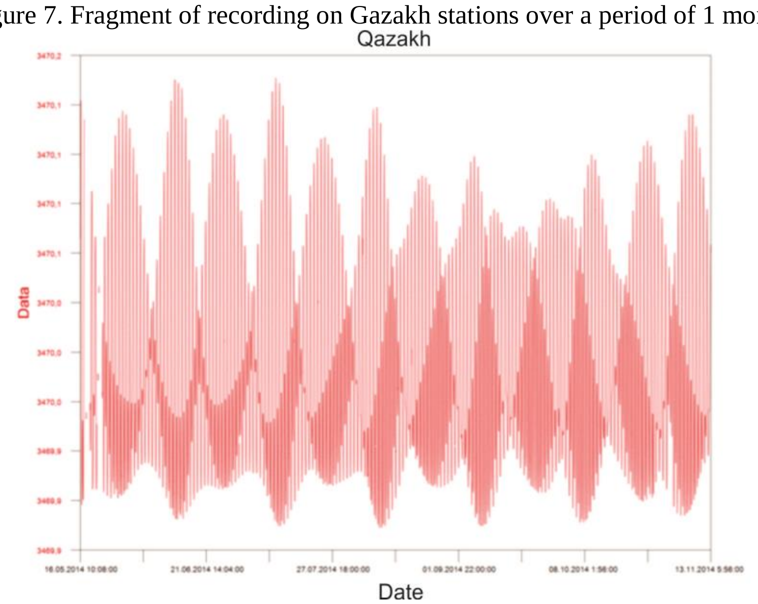

Figure 8. Fragment of recording on Gazakh stations for the year 2014.

The graphs show the stable recording of the amplitude that point to the good work of gravimeter. Breaks in the time series are not significant.

Time series were analyzed using program of tidal analysis ETERNA 3.4 [22].

Results

Analyzing the tides, an average of 14 to 20 basic diurnal and semidiurnal tidal waves was used (table 1). The standard deviation of 2.1 nm/s^2 shows the expected tidal parameters of the elastic Earth with tide approximately of 1.16 and a low phase from zero to a few degrees. Specifically, the main tidal components O1, K1, M2 and S2 show small standard deviations of the parameter and smaller tidal phases lead to less than 2°. Only tidal waves with very small amplitude as PSI1, J1, OO1 and M4 show the big mistakes or phase advance.

Good quality of the tidal analysis also confirms the tidal remains.

wave	**amp.fac.**	**stdv.**	**ph. Lead [deg]**	**stdv.[deg]**
Q1	1.15701	0.01300	-1.1056	0.6430
O1	1.15004	0.00247	0.0564	0.1227
M1	1.15106	0.02475	-0.0024	1.2335
P1	1.17278	0.00639	0.1383	0.3120

S1	2.94461	0.40712	23.1128	7.9131
K1	1.12644	0.00202	0.0386	0.1029
PSI1	2.71957	0.27759	-63.8957	5.8598
PHI1	2.23210	0.14630	-0.2523	3.7468
J1	1.03295	0.03295	4.0132	1.8267
OO1	1.15430	0.04641	4.2860	2.3005
2N2	1.21233	0.07792	-0.4752	3.6800
N2	1.18519	0.01470	-0.6918	0.7109
M2	1.16864	0.00277	-0.3369	0.1357
L2	1.06749	0.12653	0.2552	6.7904
S2	1.16833	0.00600	-1.8217	0.2943
K2	1.18932	0.02098	0.5638	1.0106
M3	1.04852	0.0491	1.2240	2.6833
M4	1.53400	2.34224	61.6109	87.4848

Table 1: Adjusted tidal parameters, based on the results of the tidal analysis (ETERNA34)

Conclusion

As a result, a stable network of three tidal registering stations was established by RSSC of ANAS for measuring tidal variations in gravity.

The parameters for the main lunisolar tidal waves were identified. Was demonstrated stable operation of gravimeter Scintrex GG-5 AutoGrav during the researches of tidal variations in gravity.

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