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Original paper

Modern GPS geodynamics of Azerbaijan

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Abstract: The relevance. The article considers the monitoring of geodynamic deformations of the territory of Azerbaijan according to the data of GPS stations (Global Positioning System). The identification of changes in the velocities of tectonic blocks is the basis for the construction of geodynamic models that allow establishing a connection with the tectonic-geological structure of the region under study. **The aim** of the work was geodetic analysis and comparison of the results of GPS stations with the seismicity of the region under study, obtained for the period 2017-2021 on the territory of Azerbaijan. **Methods.** The article presents a method for calculating the velocity fields of modern horizontal displacements of the tectonic blocks of Azerbaijan, obtained from the results of observations at 24 GPS_RCSS stationary stations, a characteristic aspect of which is a noticeable horizontal displacement in the northeast direction at a rate of 4-12 mm/y. In the study, mainly two space-time modes were applied: calculation of the initial coordinates of the stations of the geodetic network and the calculation of the shear deformation compared to the original. In this article, the velocity field of tectonic blocks on the territory of Azerbaijan was studied based on the results of GPS measurements calculated using the GAMIT program. (Global Navigation Satellite System (GNSS) at the Massachusetts Institute of Technology). Based on the results calculated using the GAMIT (Global Navigation Satellite System (GNSS)) program, the velocities of individual tectonic structures within the study region were obtained. **Results.** To identify the gradient zones of velocity change, the azimuthal directions of the velocity vectors of the horizontal movements of the territories of Turkey and Iran, obtained on the UNAVCO website (a consortium of the NAVSTAR University), were also taken into account. Work results. Thus, it was obtained that along the central part and in the southwest of the country, in the Nakhchivan Autonomous Republic and the border regions of Iran, compression oriented to the NE prevails. The maximum value of the strain rate throughout the territory of Azerbaijan fluctuates within 17 mm/y. Analysis of the velocity field also showed low velocity values in the Greater Caucasus (4-6 mm/y). In addition, a correlation analysis of the value of velocities with the seismic activity of the region was carried out. It is concluded that there is a certain relationship between the change in velocity of horizontal displacement of blocksand the distribution of strong earthquakes in the field of the rate of deformation of the earth's crust. At GPS stations Nardaran (NRDG), Gobu, Gala (GALG) and Jiloy Island (JLVG), which enter the Absheron zone, are tracked almost the same as the values of horizontal displacements of 4.7 mm / 4.0 mm / 4.0 mm., 5 mm / year 4.9 mm / year respectively). In the direction of the Talysh region up to the Absheron Peninsula (in the direction of SW-NE) there is a noticeable decrease in the northern components change in the rate of displacements compared to the values of the (LKRG=14.9 mm/y, GLBG=19.8 mm/y, YRDG= 13.0 mm/y).

Keywords: GPS stations, geodynamics, horizontal displacement velocity fields, plate tectonics.

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ГЕОТЕКТОНИКА И ГЕОДИНАМИКА

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Оригинальная статья

Современная GPS-геодинамика Азербайджана

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Резюме: Актуальность работы. В статье рассмотрен мониторинг геодинамических деформаций территории Азербайджана по данным GPS-станций (Global Positioning System). Выявление изменения значений скоростей тектонических блоков является основой для построения геодинамических моделей, позволяющей устанавливать связь с тектоно-геологическим строением исследуемого региона. **Целью работы** был геодезический анализ и сравнение результатов станций GPS с сейсмичностью исследуемого региона, полученных за период 2017-2021 гг. на территории Азербайджана. **Методы исследования**. В статье представлена методика расчета полей скоростей современных горизонтальных смещений тектонических блоков Азербайджана, полученных по результатам наблюдений на 24 стационарных станциях GPS_RCSS, характерным аспектом которых является заметное горизонтальное смещение в северо-восточном направлении со скоростью 4-12 мм/год. В процессе изучения геодинамических процессов с помощью GPS-технологий в основном используются два пространственно-временных режима: однократное переопределение начальных координат точек геодезических сетей и смещение начальных значений деформаций. В данной статье изучено поле скоростей тектонических блоков на территории Азербайджана по результатам GPS измерений, рассчитанных по программе GAMIT (Global Navigation Satellite System (GNSS) в Массачусетском технологическом институте). По результатам вычисленных на программе GAMIT (GNSS) были получены значения скоростей отдельных тектонических структур в пределах исследуемого региона. Для выявления градиентных зон смены скоростей, также учитывались азимутальные направления векторов скоростей горизонтальных движений территорий Турции и Ирана, полученные на сайте UNAVCO (консорциум Университета NAVSTAR). **Результаты работы.** Таким образом, было получено, что вдоль центральной части и на ЮЗ-де страны, в Нахичеванской АР и приграничных районах Ирана преобладает сжатие, ориентированное на СВ. Максимальное значение скорости деформации на всей территории Азербайджана колеблется в пределах 17 мм/год. Анализ поля скоростей также показал низкие значения скоростей на Большом Кавказе (4-6 мм/год). Кроме того, был проведен корреляционный анализ значений скоростей с сейсмической активностью региона. Сделан вывод о наличии определенной связи между изменением значений скоростей горизонтальных движений и распределением сильных землетрясений поля скорости деформации земной коры. На GPS-станциях Нардаран (NRDG), Гобу, Гала (GALG) и острове Жилой (JLVG), входящих в Абшеронскую зону, отслеживаются практически одинаковые значения горизонтальных перемещений 4,7 мм/4,0 мм/4,0 мм, 5 мм/г., 4,9 мм/г. соответственно. В направлении Талышского района вплоть до Абшеронского полуострова (в направлении ЮЗ-СВ) наблюдается заметное уменьшение северной составляющей изменения скорости перемещений по сравнению со значениями (LKPG= 14,9 мм/год, GLBG=19,8 мм/год, YRDG= 13,0 мм/год).

Ключевые слова: GPS-станции, геодинамика, поля скоростей горизонтальных перемещений, тектоника плит.

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Introduction

As you know, Azerbaijan is part of the Alpine-Himalayan mountain belt, formed in the Cenozoic on the southern margin of the East European platform as a result of a collision between the Eurasian and Scythian plates, which has experienced rapid uplift over the past five million years. The advance of the Scythian Plate to the north is partially offset by the displacement of the Anatolian block to the west. The tectonics of this vast region is mainly determined by the collision of the Arabian and African plates with the Eurasian plate [Milyukov et al., 2015; Reilinger et al., 2006; Robertson et al., 1996; Tapponnier et al., 2001]. Regionally, the region under study includes three tectonic blocks of the Alpine fold system: the Deshte-Lut block, located in the east of Iran, the Turan Plate, located on the eastern coast of the Middle Caspian, and the Bitlis-Zagros Thrust, located in southwestern Iran. These large geoblocks are surrounded by the main geostructural elements of Azerbaijan [McKenzie, 1972, 1978]. A huge meridional depression of the Caspian Sea adjoins Azerbaijan from the east. The northern part of the republic is covered by the eastern segment of the complex southern wing of the meganticlinoria of the Greater Caucasus [Mahmoud et al., 2005, 2006; Rogozhin et al., 2015, 2018; Shempelev et al., 2017; Stogny et al., 2022; Zaalishvili et al., 2016, 2018]. The meganticlinorium of the Lesser Caucasus and the Talysh region are located in the southern and southwestern parts of the republic. In the geodynamic aspect, the Taysh region is characterized by high seismic activity and high horizontal slip rates. The Lesser Caucasus region is also characterized by increased velocities at GPS stations, but in recent years the level of seismic activity has been moderate. The results of the global positioning system (GPS) allowed us to get a new perspective and the ability to monitor the movements of blocks and trace the deformations of the earth's crust.

Materials and Methods

All calculations were made using the GAMIT program, which is a universal package for analyzing GPS data. Although the software is currently maintained by three authors, many other people have also contributed to the development of this program. High-precision geodetic surveys using space satellites work on the basis of the phase of the carrier wave, which is the product of a single phase channel of the GPS receiver. These calculations include an analysis of the difference between the phase of the satellite signal and the phase at the station. To obtain reliable and accurate data, it is necessary to analyze data from both several stations and several satellites simultaneously [Jackson et al., 1984].

The GAMIT program includes separating algorithms that map the phase of the carrier wave into first and second phase differences. The calculation of one-way phases relative to the station clock is performed using the -autcln program. This program is used to estimate atmospheric and ionospheric errors [Herring et al., 2010].

The range measurements, together with the station and satellite coordinates, are used to determine the station clock offset within a microsecond, which is sufficient to ensure that the calculation error does not exceed 1 mm.

Using the least squares method for space satellites, reference orbits are created, according to which the errors between the observed and calculated values of the partial derivatives of the geometric model are revealed. It should be noted that in 2012, the installation of a new network of GPS stations began at the RSSC under ANAS. A total of 24 stations were installed. Geodetic coordinates are processed on the AUSPOS server (Australia) [Herring et al., 2003].

To estimate the speeds of the determined stations, 8 closely located reference stations of the IGS network were used: ARTU (Arti, Russia), CRAQ (Simeiz, Ukraine), DRAG (Metzoke, Israel), POLV (Poltava, Ukraine), MDVJ (Mendeleevo, Russia) ANKR (Ankara, Turkey) NICO (Nicosia, Cyprus), POL2 (Bishkek, Kyrgyzstan). The selected ref-

Table 1.

Parameters of the world reference stations of the IGS network (compiled by the authors)

Code	Region	Country	Lat ϕ°	Lon λ°	Receiver	Antenna	Register satellites
ANKR	Ankara	Turkey	39,88	32,75	LEICA GR30	LEIAR10 + NONE	GPS GLONASS Galileo BeiDou SBAS
ARTU	Arty	Russia	56,43	58,56	ASHTECH Z-XII3	ASH700936D_M + DOME	GPS
CRAO	Simeiz	Ukraine	44,41	33,99	ASHTECH UZ-12	ASH701945C_M + SCIS	GPS
DRAG	Metzoke, Israel	Israel	31,59	35,39	JAVAD TRE_3 DELTA	ASH700936D_M + SNOW	GPS GLONASS
MDVJ	Mendeleevo	Russia	56.02	37.21	TPS NETG3	JPSREGANT_DD_E1 + NONE	GPS GLONASS
NICO	Nicosia	Cyprus	35,14	33,4	LEICA GR25	LEIAR25. R4 + LEIT	GPS GLONASS Galileo BeiDou SBAS
POL2	Bishkek	Kyrgyzstan	42,68	74,69	ASHTECH UZ-12	TPSCR. G3 + NONE	GPS
POLV	Poltava	Ukraine	49,6	34,54	LEICA GR10	LEIAR10 + NONE	GPS GLONASS Galileo

erence stations with the indicated coding are included in the implementation of the international terrestrial reference frame ITRF2008 [Kazimova, Kazimov, 2020]. Table 1 shows the coordinates, international code, type of equipment and registered satellites of reference stations.

Seismicity of the territory of Azerbaijan in 2017-2021 yy.

Seismicity of the territory of Azerbaijan in 2017-2021, seismic analysis of the territory of Azerbaijan have been conducted on the basis of 40 digital data (Annual report on the results of scientific and production work of the seismology department of the Republican Seismic Survey Center of Azerbaijan National Academy of Sciences. Fund of Materials of ANAS. Baku. 2017). During the 2019 year, 13,818 earthquakes were recorded by RSSC. Of these, 5442 are local (Azerbaijani territory), 1825 regional and 2188 remote earthquakes. At the same time, 2948 weak shocks (recorded by a single station), 1405 explosions, 7 landslides and 3 volcanoes were recorded. The map of the earthquakes epicenters for 2017-2021 with ml>3.0 in Azerbaijani territory has been created (fig. 1).

As can be seen from this map, the vast majority of tangible earthquake sources are located at the junction zone of the Kura Plain and the southern slope of the Greater Caucasus. In 2019, 81 earthquakes with a magnitude of ml≥3.0 were recorded in the territory of Azerbaijan and 25 of them are tangible earthquakes. Compared to 2018, the number of earthquakes in 2019 has increased and the amount of released seismic energy has decreased (Annual report of RSSC ANAS, 2018); Yetirmishli et al., 2019]. Thus, the num-

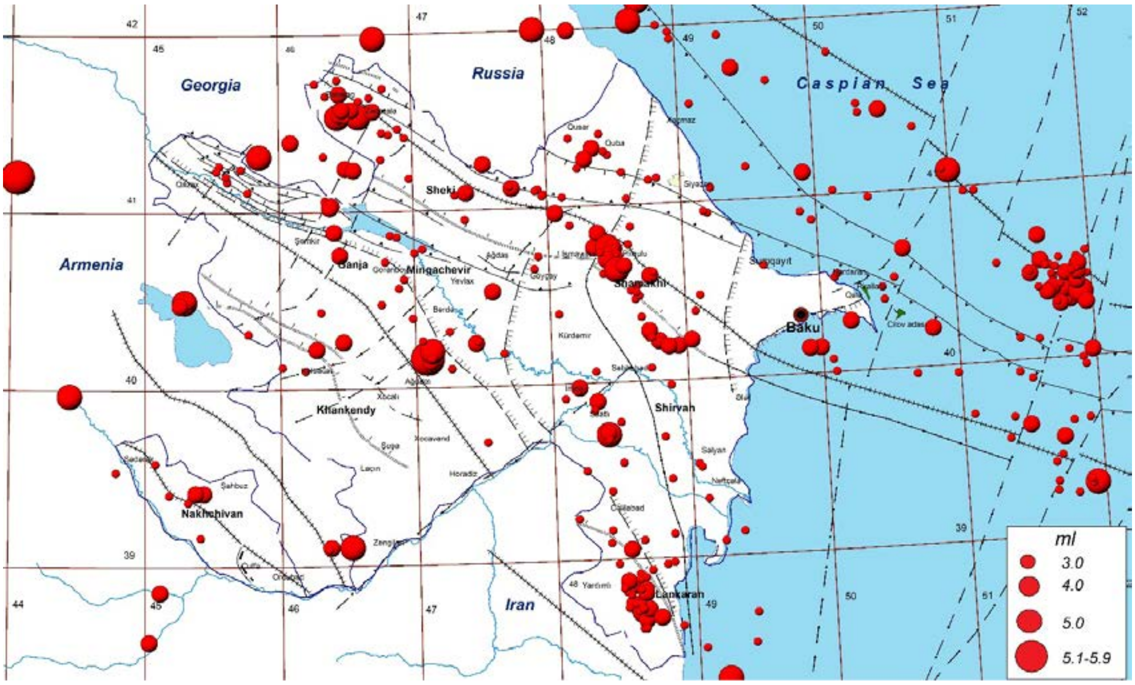

Fig. 1. Map of earthquake epicenters in Azerbaijan and adjacent regions for 2017-2021 (Compiled by the authors)

ber of earthquakes was 4081 in the territory of Azerbaijan in 2018, the amount of released seismic energy $\sum E= 42.7 \cdot 10^{11}$, the maximum magnitude 5.5, the number of earthquakes was 5442 in 2019, the amount of released seismic energy $\sum E=31.9 \cdot 10^{11}$J, the maximum magnitude 5.2. Compared to 2019, the number of earthquakes and the amount of seismic energy released in 2020 decreased (Annual report of RSSC ANAS, 2019).

Analysis of the number of earthquakes in Azerbaijan and adjacent areas and the distribution of seismic energy by months shows that in 2020, seismic energy was higher in February, April and June. This is due to earthquakes of magnitude 5.9 on the Turkish-Iranian border. Lets` noted that, ml=6.4 earthquake was registered on February 23, 110 km south-west of Nakhchivan station on the Turkish-Iranian border. In February and March 2020, the number of earthquakes was higher than in other months. This is due to the aftershocks of an earthquake with a magnitude of ml=5.9. During 2021, 15,599 earthquakes were registered (Annual report of RSSC ANAS, 2020). Of them, 4173 are local (Azerbaijani territory), 4059 regional and 3346 remote earthquakes. In addition, 5 volcanoes, weak 2599 tremors (recorded by a single station), 1417 eruptions were recorded. 63 and 17 tremors with a magnitude of 3 were recorded in Azerbaijan. The number of earthquakes and the distribution of seismic energy within the countryin 2010-2021, the number of earthquakes within the considered region in 2020 is 4030, the amount of seismic energy is $\sum E = 13.1 \cdot 10^{11}$J, the maximum magnitude is ml = 4.9. In 2021, the number of earthquakes was 4173, the amount of seismic energy released was $\sum E = 14.3 \cdot 10^{11}$J, and the maximum magnitude was ml = 5.1 (Annual report of RSSC ANAS, 2020). Seismicity monitoring over the past 15 years has revealed an increase in activity from year to year, reaching its maximum in 2012, when a number of strong earthquakes (ml=5.0-5.7) were registered in the northern part of the republic. This is due to the strong (ml=4.0÷5.7) earthquakes in the country. In 2012, the amount of seismic energyreleased increased 25 times compared to 2011. The amount of seismic energy released in 2013 decreased by about 28 times compared to 2012. It should be noted that the sharp increase in the number of earthquakes in 2010 compared to previous years is associated with an increase in the number of seismic stations in the region. As noted earlier, high activity was also observed in 2014, 2016, 2017 and 2019, associated with strong earthquakes in the Hajigabul, Aghdam, Saatli and Ismayilli regions (Annual report of RSSC ANAS, 2021).

Analysis of the number of earthquakes in Azerbaijan and adjacent areas and the distribution of seismic energy by months shows that in 2021, seismic energy was higher in February and November. The high energy level in November was due to an earthquake of magnitude 5.1 in Shamakhi. In February 2021, the high level of seismic energy is due to earthquakes of ≤5.5 ml in Armenia (Annual report of RSSC ANAS, 2021).

Geodynamics of the territory of Azerbaijan in 2017-2021 on the basis of GPS data

Based on the foregoing, the directions of the velocities of horizontal movements for 2017-2021 were studied. Analysis of the data showed that in the Greater and Lesser Caucasus in 2017, the deformation of the northwestern displacement prevailed with a speed of 1.0-2 mm higher compared to the previous year. The central part of the region was characterized by an increase in strain values by 1.5-2.5 mm. The station located in the Caspian Sea on Zhiloy Island is characterized by low average annual values (2-3 mm) (Fig. 2). The analysis of station data showed that the values of deformations increased by 1-2 mm/year compared to the previous year.

A map of the epicenters of strong (ml>4.0) earthquakes that occurred in 2017 was constructed in order to reveal the relationship of horizontal movements with the geodynamic conditions of prices. GPS stations and the directions of the faults built by Shikhalibeyli are added to this map.

In addition, it was found that in 2017 in the Gusar, Saatli, Shirvan and Talysh regions, the rate of deformation was maximum. In addition, comparing the data of the GPS stations with the seismic activity of that year, it can be seen that these regions were characterized by activity. An analysis of the source mechanisms also showed here the predominance of left-lateral strike slips in the NE direction, at medium depths, corresponding mainly to the granite layer. In 2017, at 03:25, an earthquake with a magnitude of 5.4 was recorded in the Lower Kura depression at a depth of 48 km. Note that in 2017, the velocity at Saatly station increased to 14.7 mm/yr. Note that this station was installed on an ultra-deep well. In 2018, the strain rate at this station dropped to 9.6 mm/year (Fig. 3).

In 2018, activation was observed in the Zakatala and Lerik regions. The earthquake that occurred in the northwest starny in the Zakatala region at the epicenter was felt up to

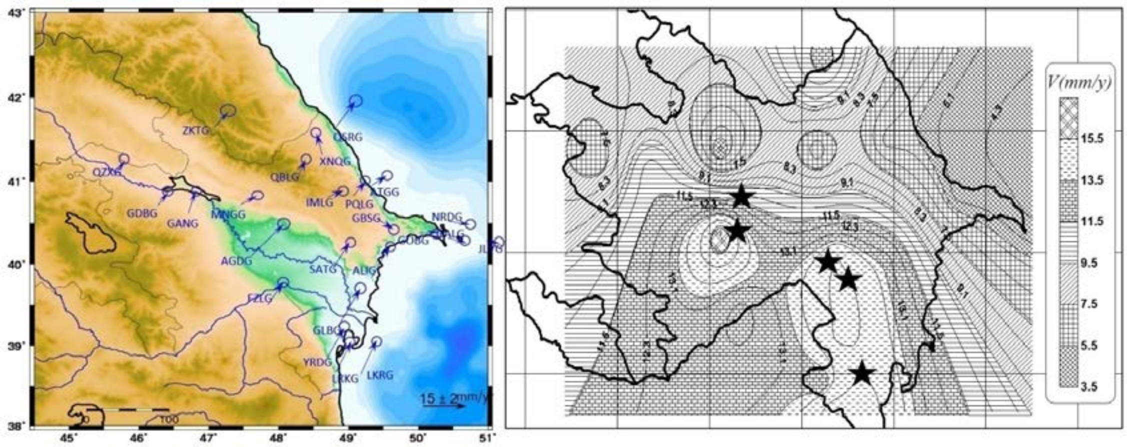

Fig. 2. Map of horizontal velocities obtained in the GAMIT program for GPS stations for 2017 (Compiled by the authors)

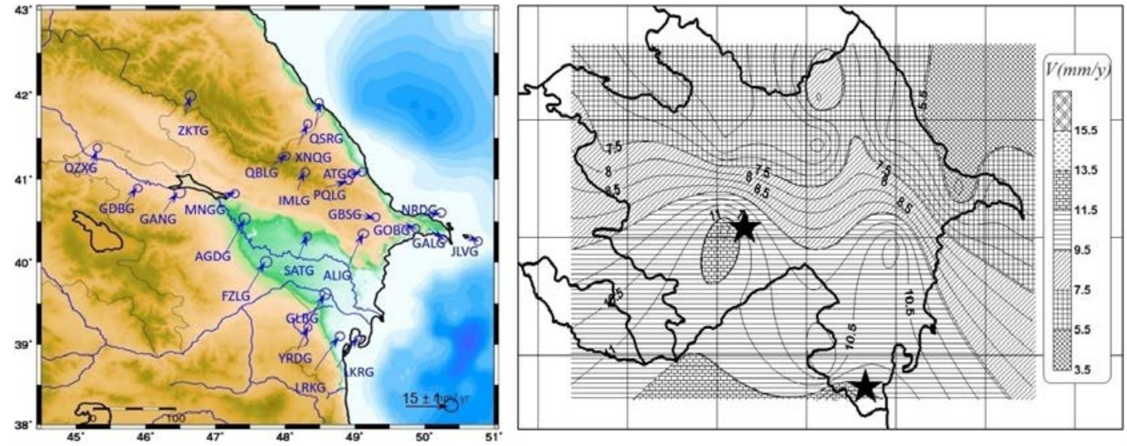

Fig. 3. Map of horizontal velocities obtained in the GAMIT program for GPS stations for 2018 (Compiled by the authors)

6 points (with magnitude ml = 5.5). It should be noted that the focus of this earthquake coincided with the focus of the strong Zagatala earthquake, which occurred in May 2012 [Yetirmishli et al., 2018]. The earthquake that occurred in the Talysh region (Lyankaran) was felt in the focus up to 5 points. Note that in 2018, the velocity values at the Lerik GPS station increased to 13.2 mm/year.

In 2019, the average value of the strain rate in the Greater Caucasus was characterized by values equal to 3.1-9.6 mm/year, in the central part of the region, in the area of depression 6.9-16.5 mm/year, in the south of the country 10.2-14.8 mm/year, and for stations located on the Caspian coast, the values varied within 3.6-4.8 mm/year. It can be noted that in 2019, for the territory of Azerbaijan, the average value of deformations was 8.4 mm/g in the direction of NE. The analysis of seismicity in 2019 showed a strong earthquake that occurred in the Agsu region with a magnitude of ml=5.2. The earthquake was so palpable that landslide processes and the eruption of a mud volcano located 10 km SE from the source were subsequently observed. In addition, it can be noted that throughout all these years, the Caspian Sea region was also characterized by high activity.

Based on the data obtained in 2021, north-eastern movements are observed for the territory of Azerbaijan on average up to 5.4 mm/y per year. It was determined that in 2021, the average value in the Greater Caucasus will be 3.49 mm/y, in the Lesser Caucasus 4.80 mm/y, in the Middle and Lower Kura Basin 6.95 mm/y, in Talysh 10.58 mm/y, in the Apsheron Peninsula 2.80 mm/y velocities are set. Also, the values of displacement at the station located on Gilov Island in the Caspian Sea were set at 1.6 mm. In 2021, the highest speeds were observed at Yardimli (12 mm/y), Lankaran (11.90 mm/y) and Saatli (12.0 mm/y) stations. It should be noted that in general, compared to the data of 2020, in 2021 the prices of speeds decreased. Mainly at Aghdam, Ganja, Lerik and Gazakh stations (Fig. 4).

Results

Using the data of the GPS stations of the RSSC of ANAS, UNAVCO, Turkey and Iran [Kadirov et al., 2015], a map of the vectors of azimuthal motions and a diagram of the velocities of the horizontal motions of the blocks of the study region were constructed (Fig. 5,6). It should be noted that since 2013, a new monitoring system has been installed on the territory of Azerbaijan within the framework of the RSSC, consisting of 24 GPS stations from Trimble (USA).

An analysis of the velocity field of GPS stations showed the heterogeneity of deformation processes in the region of the Eastern Mediterranean and the Caucasus. The

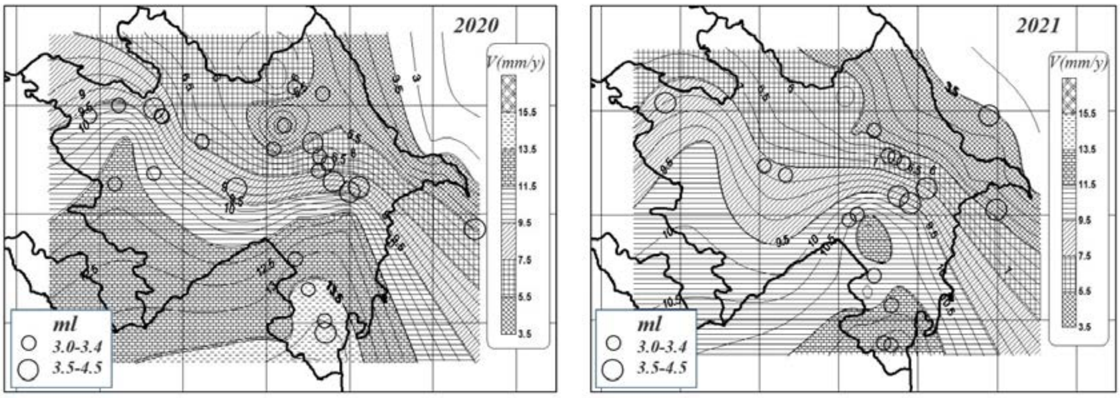

Fig. 4. Comparative maps of horizontal velocities obtained in the GAMIT program for GPS stations for 2020-2021 (Compiled by the authors)

considered results show the movement of the Scythian plate relative to the Eurasian one. Considering the speeds of movement of the Anatolian and Eurasian plates, and the Scythian and Anatolian plates, it was found that the shear rate along the North Anatolian fault turned out to be 20 mm/g, along the East Anatolian – 14 mm/year. This testifies to the convergence of the Anatolian and Eurasian plates through the system of right-hand strike-slip faults in eastern Turkey and the Thrust system in the Caucasus. The total reduction in the distance between the Lesser and Greater Caucasus is 10 mm/yr.

According to modern data of GPS measurements, Western Zagros at a rate of ~10 ± 2 mm/y in the direction of 12-8 ±2 mm/y in the direction 7±5° north – northeast. The difference in crushing rates is most likely due to a significant amount of shear deformation

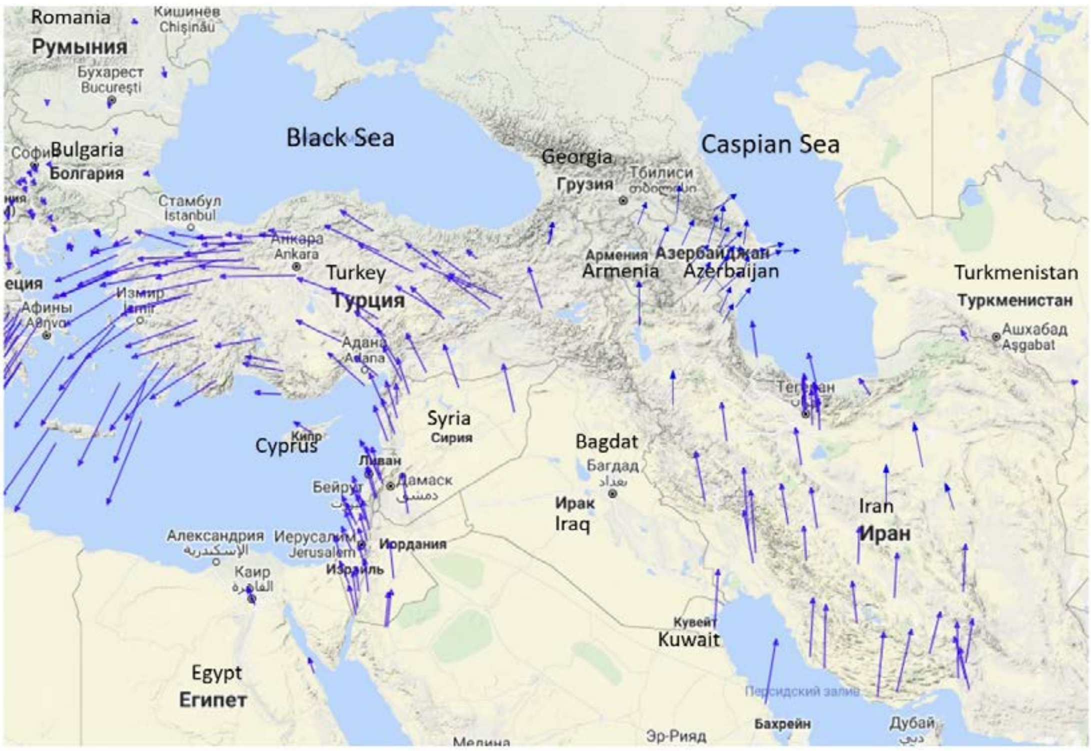

Fig. 5. Azimuth map of GPS station vectors in the Mediterranean region according to the RSSC data at ANAS, UNAVCO, Turkey and Iran (Compiled by the authors)

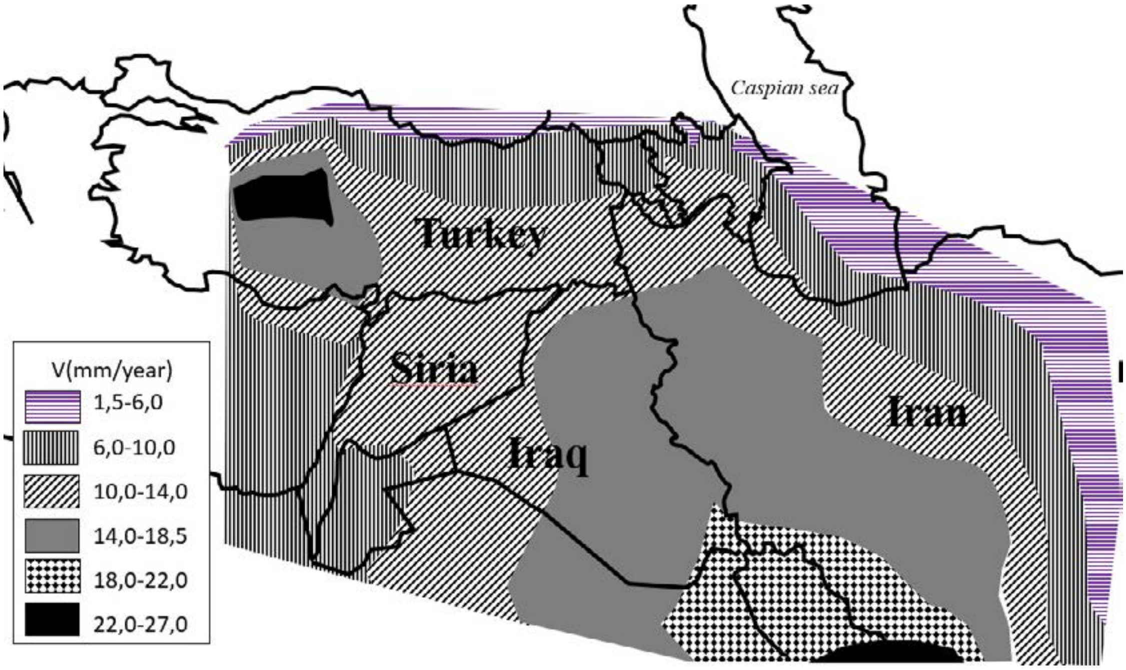

Fig. 6. Distribution of velocities of horizontal movements of the Mediterranean region according to GPS station data for the period 2006-2020 (Compiled by the authors)

along the Main Modern Fault MRF in the Northwestern Zagros [Conrad, Lithgow-Bertelloni, 2004]. The velocity field of GPS observations within the Caucasus region clearly illustrates the movement of the earth's crust in the N-NE direction on the territory of Azerbaijan and adjacent regions of the Lesser Caucasus relative to Eurasia [Kadirov et al., 2015].

On the graph of changes in speed values over the years, for each GPS station, the regions where they are located were identified. As seen in fig. 7 the minimum values are noted on the Apsheron peninsula. The maximum values are identified in the Lesser Caucasus and in the territory of Talysh. From this we can conclude that under the pressure of the Arabian Plate and the Iranian block, the Lesser Caucasus is moving towards the Kura depression at an average speed of 12 mm/y, thereby causing a compression zone. Taking into account the fact that the zone of the Greater Caucasus moves to the NE at an

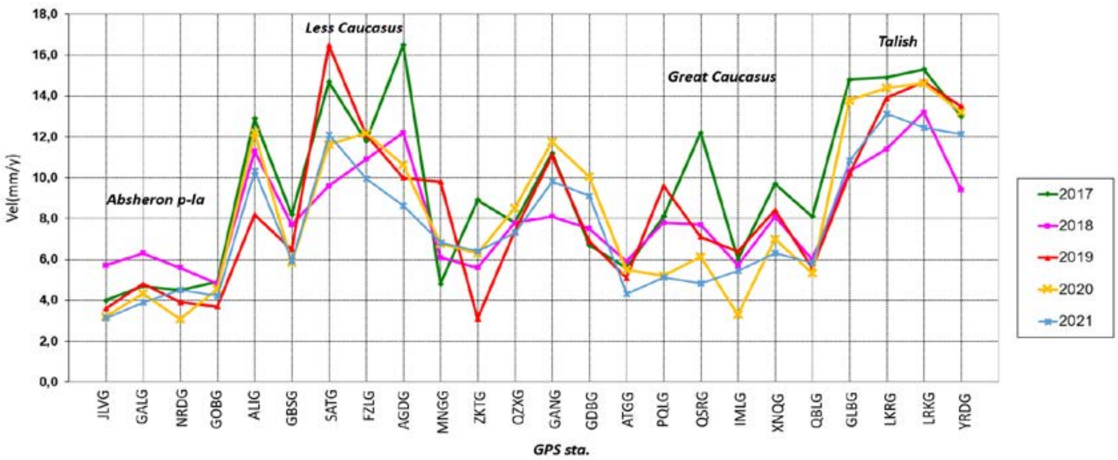

Fig. 7. Graph of changes in speed values over the years for each GPS station (Compiled by the authors)

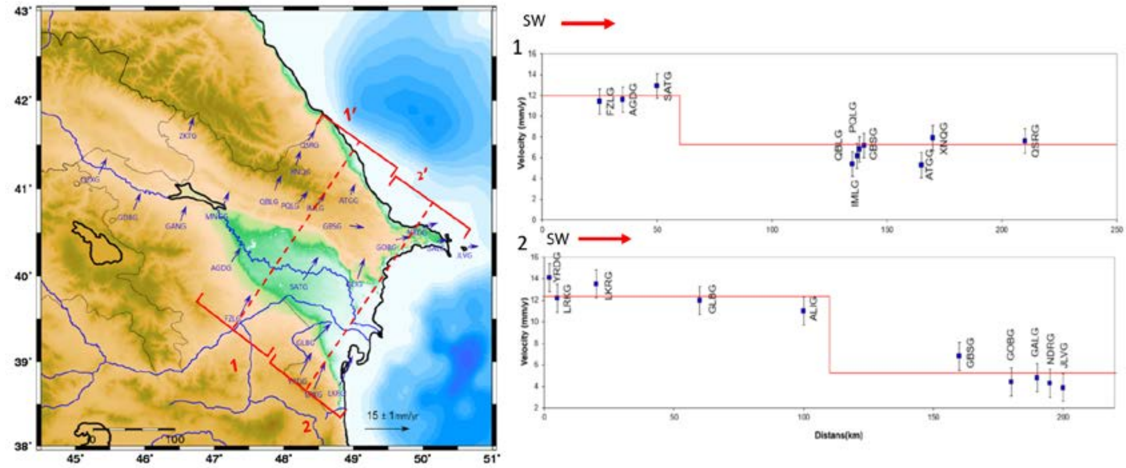

Fig. 8. Maps and profiles of average values of horizontal velocities obtained in the GAMIT program for GPS stations for 2017-2021 yy. (Compiled by the authors)

average speed of 4 mm/y, the Kura depression, in turn, moves at an average speed of 8 mm/y under the Greater Caucasus, thereby forming a thrust zone or a subduction zone [Aktug et al., 2009, 2013].

In order to monitor the change of velocities depending on the different regions, two profiles were constructed, 1-1 and 2-2 in the direction of SW-NE (Fig. 8).

Profile 1-1 is built on 7 stations. As can be seen from the profile, the values of velocities in the Lesser Caucasus are 12.0 and 10.2, while in the Greater Caucasus they are 6-8 mm/y. An interesting picture is observed when considering the profile 2-2, oriented to the NE, in cross strikes, through the Talysh region to the Caspian Sea (Fig. 8). It can be seen from the figure that if the values of velocities located at the Absheron in comparison with the Talysh stations decrease by two or even three times, the values of azimuth angles increase by three times.

That is, there is a shift of horizontal deformations on the Absheron Peninsula from NE to NE. An important role here is played by orthogonal faults separating Talysh from Absheron and, of course, the influence of the Arabian plate and the Iranian micro block. Under the pressure of these tectonic structures, a kind of clockwise turn towards the Caspian Sea is observed. It can be assumed that the Talysh region, being a single plate, is moving to the NE, and Absheron, being part of another plate, is moving to the east.

Thus, based on the data obtained in 2017-2021, up to 8.4 mm/y in the north-northeast direction was observed for the territory of Azerbaijan. As the analysis shows the distribution of velocity, the mean values of the horizontal displacement points in the north and east are not constant, nor are the processes of shortening the surface of the earth's crust in the region of study.

It was determined that on the territory of the Kura lowland in the direction from the Middle-Kura depression to the Low-Kura depression (i. e. from NE to SW) there is a gradual increase in the rates of horizontal movements from 7.3 to 11.3 mm/y, which in turn creates a stretching condition. It can be noted that in the last few years the territory of the Middle and Lower Kura depressions has increased significantly. Several earthquakes with M>5 were observed along the Kura, West Caspian and Palmir-Absheron tectonic faults.

Conclusion

Thus, summarizing the results of the study, it may be argued that a drop in the values of the velocities of horizontal movements by almost a factor of two is observed in the cross of the strike of the Greater and Lesser Caucasus, which indicates the thrusting of the Lesser Caucasus onto the Kura depression at a rate of 10-12 mm/y and the gradual underthrusting of the Kura depression under the Greater Caucasus.

At GPS stations Nardaran (NRDG), Gobu, Gala (GALG) and Jiloy Island (JLVG), which enter the Absheron zone, are tracked almost the same as the values of horizontal displacements of 4.7 mm/y 4.0 mm/y 4.0 mm/y, 5 mm/y 4.9 mm/yrespectively. In the direction of the Talysh region up to the Absheron Peninsula (in the direction of SW-NE) there is a noticeable decrease in the northern components change in the rate of displacements compared to the values of the (LKRG= 14.9 mm/y, GLBG=19.8 mm/y, YRDG= 13.0 mm/y). It can be argued that in 2018 in the Talysh region there was a strong tremor with a magnitude of 5.3. In addition, there is a noticeable increase in the azimuthal angles of the Absheron stations, indicating the movement of the clockwise direction in the direction of east-south-east to 140º.

Summing up the research, it can be concluded that methods of satellite geodesy for observations of the process of movement of the Earth's surface allows us to conduct research at a higher level. The results obtained can be used in studying the movement of lithospheric plates; and clarification of the boundaries of individual blocks. By correlating the received data with seismic data, one can also determine the expected depth of a particular block. Relying on the results of seismic analysis in the territory of Azerbaijan, the Shamakhi-Ismailli, Saatli, Gazakh, Caspian and Zagatala seismogenic zones are identified, which are confined to the gradient zones of the deformation rate field of the Earth's crust.

Referenses

1. Aktug B., Parmaksız E., Kurt M., Lenk O., Kılıchoglu A., Gurdal M.A., Ozdemir S. Deformation of Central Anatolia: GPS implications. J. Geodyn, 2013. Vol. 67. pp. 78-96.

2. Aktug B., Nocquet J.M., Cingöz A., Parsons B., Erkan Y., England P., Lenk O., Gürdal M.A., Kilicoglu A., Akdeniz H., Tekgül A. DeformationofwesternTurkey from a combination of permanent and campaign GPS data: limits to block-like behavior. J. Geophys. Res. Solid Earth., 2009. Vol. 114. B10404.

3. Conrad C.P., Lithgow-Bertelloni C. The temporal evolution of plate driving forces: Importance of "slab suction" versus "slab pull" during the Cenozoic. J. Geophys. Res. 2004. Vol. 109. Is. B10407.

4. Herring T.A. GLOBK: Global Kalman filter VLBI and GPS analysis program Version 10.1 Internal Memorandum, Massachusetts Institute of Technology, Cambridge, 2003. Vol. 20.

5. Herring T.A., King R.W., McClusky S.C. Introduction to GAMIT/GLOBK. Department of Earth, Atmospheric, and Planetary Sciences Massachusetts Institute of Technology, 2010. 48 p.

6. Jackson J., McKenzie D. Active tectonics of the Alpine – Himalayan Belt between western Turkey and Pakistan. Geophys. J.Roy. Astron. Soc., 1984. Vol. 77. pp. 185-264.

7. Kadirov F.K., Floyd M., Rueinger R., Alizadeh Ak.A., Guliyev I., Mammadov S.G., Safarov R.T. Active geodynamics of the Caucasus region: implications for earthquake hazards in Azerbaijan. Proceedings of Azerbaijan National Academy of Sciences. The Sciences of Earth, 2015. Vol. 3. pp. 3-17.

8. Kadyrov F.A., Mamedov S.K., Safarov R.T. The study of the current geodynamic situation and the danger of earthquakes deformation of the earth's crust in Azerbaijan using 5-year GPS data. Modern methods of processing and interpretation of seismological data. Obninsk, GS RAS, 2015. pp. 156-162. (In Russ.)

9. Kazimova S.E., Kazimov I.E. Geodynamics of the Talish region according to earthquake source mechanisms and GPS stations. Geology and Geophysics of the South of Russia, 2020. Vol. 10 (3). pp. 40-56. DOI: 10.46698/VNC.2020.35.39.003

10. Mahmoud S., Reilinger R., McClusky S., Vernant P., Tealeb A. GPS evidence for northward motion of the Sinai Block: implications for E. Mediterranean tectonics. Earth Planet. Sci. Lett. 2005. Vol. 238. pp. 217-224.

11. Mahmoud S., Sakr K., ArRajehi A., Paradissis D., AlAydrus A., Prilepin M., Guseva T., Evren E., Dmitrotsa A., Filikov S. V., Gomez F., AlGhazzi R., Gebran Karam. GPS constraints on continental deformation in the Africa Arabia Eurasia continental collision zone and implications for the dynamics of plate interactions. J. Geophys. Res., 2006. Vol. 111. Is. B05411. DOI: 10.1029/2005JB004051.

12. McKenzie D. Active tectonics of the Alpine-Himalayan belt: the Aegean Sea and surrounding regions. Geophys. J. Int., 1978. Vol. 55. pp. 217-254.

13. McKenzie D. Active tectonics of the Mediterranean region. Geophys. J. Int., 1972. Vol. 30. pp. 109-185.

14. Milyukov V.K., Mironov A.P., Rogozhin E.A. Steblov G.M. Velocities of Recent Movements of the Northern Caucasus Estimated from GPS Observations. Geotectonics, 2015. No. 3. pp. 56-65.

15. Reilinger R., McClusky S., Vernant P., Lawrence., Ergintav S., Cakmak R., Ozener H., Kadirov F., Guliev I., Stepanyan R., Nadariya M., Hahubia G. GPS constraints on continental deformation in the Africa-Arabia-Eurasia continental collision zone and implications for the dynamics of plate interactions. J. Geophys. Res. Solid. Earth. 2006. DOI: 10.1029/2005JB004051

16. Robertson A., Mountrakis D. Tectonic Development of the Eastern Mediterranean Region. Geol. Soci. London Spec. Publ., 1996. Vol. 260. pp. 1-9.

17. Rogozhin E.A., Milukov V.K., Mironov A.P., Ovsyuchenko A.N., Gorbatikov A.V. Characteristics of modern horizontal movements in the central sector of the greater Caucasus according to GPS observations data and their relationship with the newest tectonics and deep structure of the crust. Geology and Geophysics of Russian South. 2018. – No. 4. pp. 141-148. (In Russ.)

18. Rogozhin E.A., Gorbatikov A.V., Zaalishvili V.B., Stepanova M.Y., Andreeva N.V., Kharazova, Y.V. New data on the deep structure, tectonics, and geodynamics of the Greater Caucasus. Doklady Earth Sciences. 2015. Vol. 462 (1). pp. 543-545. DOI: 10.1134/S1028334X15050244

19. Shempelev A.G., Zaalishvili V.B., Kukhmazov S.U. Deep structure of the western part of the Central Caucasus from geophysical data. Geotectonics. 2017. Vol. 51 (5). pp. 479-488. DOI: 10.1134/S0016852117050053

20. Stogny V.V., Zaalishvili V.B., Ponomareva N.L. Modern geodynamics and seismicity of the North Caucasus: problems of monitoring. Geology and Geophysics of Russian South. 2022. Vol. 12 (2). pp. 35-52. DOI: 10.46698/VNC.2022.25.32.003 (In Russ.)

21. Tapponnier P., Zhiqin X., Roger F., Meyer B., Arnaud N., Wittlinger G., Jingsui Y. Oblique stepwise rise and growth of the Tibet Plateau. Science, 2001. Vol. 294. Is. 5547. pp. 1671-1677. DOI: 10.1126/science. 105978

22. Yetirmishli G.J., Ismayilova S.S., Kazimova S.E. Seismicity of the territory of Azerbaijan in 2019. Seismoprognosis observations in the territory of Azerbaijan, 2021. Vol. 19. No. 1. pp. 3-18.

23. Yetirmishli G.J., Rzaev A.G., Kazimov I.E., Kazimova S.E. Modeling of the geodynamic situation of the Kura depression based on the latest seismological, geodetic and magnetometric data. Bulletin of the Orenburg Scientific Center of the Russian Academy of Sciences. No.. pp. 1-11. DOI: 10.24411/2304-9081-2018-12008

24. Zaalishvili V.B., Melkov D.A., Dzeranov B.V., Morozov F.S., Tuaev G.E. Integrated instrumental monitoring of hazardous geological processes under the Kazbek volcanic center. International Journal of GEOMATE. 2018. Vol. 15 (47). pp. 158-163. DOI: 10.21660/2018.47.20218

25. Zaalishvili V.B., Melkov D.A., Kanukov A.S., Dzeranov B.V., Shepelev V.D. Application of microseismic and calculational techniques in engineering-geological zonation. International Journal of GEOMATE. 2016. Vol. 10 (1). pp. 1670-1674.