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ANALYSIS OF THE INFLUENCE OF EXTERNAL FACTORS ON GNSS MEASUREMENTS AT GEODETIC POINTS

Abstract: *This article is devoted to the use of high-precision GNSS observations for the construction of satellite geodetic networks and the study of the effects of external and internal factors on the results obtained. In this article, the influence of external factors on GNSS measurements and their accuracy, such as solar radiation, ionosphere, troposphere, geophysical, technogenic, etc., is considered in detail.*

Keywords: *satellite, GNSS, influence of solar radiation, ionospheric effect, tropospheric effect, geophysical effect, man-made effect.*

Introduction. The methods of describing the shape of the Earth and determining its parameters using satellite observations have undergone significant changes, which has led to a revision of coordinate systems. Today, global satellite measurements are used to solve problems in geodesy, cartography, and space navigation. Different countries have adopted different ellipsoids, and their parameters do not coincide. Many countries have begun to develop methods for determining reference ellipsoids or use the WGS 84 universal coordinate system [4, 9].

In Uzbekistan, this problem is being paid great attention not only by industry enterprises, but also by the government itself. It actively develops relations with other countries of the world, creates all the conditions for the construction of facilities and large industrial enterprises. Considering that the intensity of the development of industrial facilities determines the scale and level of modernization of the country, the problem of the development of this sector is of particular importance. On the basis of the laws and resolutions issued in our republic, large-scale work is being carried out on the introduction and use of satellite navigation systems in topographic and geodetic works, as well as the creation of a single state system of geodetic coordinates [2, 13].

Taking into account the above, the theoretical foundations of the methodology, methods and factors affecting the accuracy of measurements of satellite observations have not yet been created in our republic. Therefore, in this article we aim to consider the influence of external factors on GNSS measurements.

Currently, GNSS measurements and their accuracy can be affected by external factors such as solar radiation, ionosphere, troposphere, geophysical, and technogenic.

Solar radiation effects. The effect of solar eclipses on GNSS measurements, solar activity leads to changes in the environment and signal propagation. It is appropriate to analyze how solar eclipses affect GNSS measurements. To assess the effect of the sun on GNSS measurements, we can use navigation observations obtained during the solar eclipse period on several GNSS receivers. A number of works devoted to the study of solar eclipses and related processes usually study changes in the ionosphere, where a decrease in electron concentration during a solar eclipse, a decrease in critical frequencies, and the formation of F1 and F2 layers characteristic of the nocturnal ionosphere are noted. During a solar eclipse, the surface layer cools and air pressure decreases, and an acoustic-gravity wave (AGW) is formed in the atmosphere, which leads to interaction with the troposphere [1, 2].

Ionosphere effect. The ionosphere, which extends from about 50 km to 1000 km above the Earth, is a layer of ionized gases (free electrons and ions). Ionization occurs due to solar radiation, and the state of the ionosphere is determined primarily by the intensity of solar activity.

The propagation speed of radio signals in the ionosphere is determined by the value of the total electron concentration TEC (Total Electron Content). This is the number of electrons in a 1 m^2 cross-sectional area extending from the receiver to the satellite:

$$TEC = \int_S^R n_e(s)\,ds,$$

where: $n_e(s)$ is the electron density and integration along the signal path; S is the distance from the satellite to the receiver; R is the transmission path. The path length through the ionosphere is shortest in the zenith direction and therefore the TEC in the vertical direction is the smallest (Vertical TEC, TECV) TEC value is set to 1016 electrons/m^2.

The length of the signal path varies with the satellite's position in the sky: the lower the satellite is, the longer the path and the greater the TEC. Assuming no lateral electron gradients, a simple and compact characteristic of the TEC along the signal path can be obtained by using the vertical TEC (TECV) and multiplying it by the length of the transmission path. This factor is called the OF slope factor (also called the ionospheric display function). To indicate the position of the satellite S relative to the satellite R, we take into account the zenith distance ζ. The ionospheric effect is not the same everywhere on Earth, but varies from place to place. This can be seen in Figure 1 below [5, 12].

Let us note several important facts, evident in Fig. 1. First, the tropospheric delay is similar to the ionospheric delay at high-angle altitudes and at middle latitudes for the conditional minimum of solar activity. Consequently, changes in the delay from the zenith to the minimum altitude of 5 occur by an increase of 3 times for the ionosphere, but by 10 times for the troposphere. This explains that the troposphere rises from the earth's surface, by the time the ionospheric peak reaches an altitude of about 250-300 km. In my example, the increase in thickness of the tropospheric layer occurs quickly, and the ionosphere, which is more elevated.

Finally, let us pay attention to the approximate value of the errors in determining delays 1 (in Fig. 1 they are marked with a bar). The increase in the ionospheric delay under the average conditions of the moon and the flow of the sun all the time, independent of the solar and geomagnetic activity levels, is about 25%. For the troposphere, there is an increase of less than 5%.

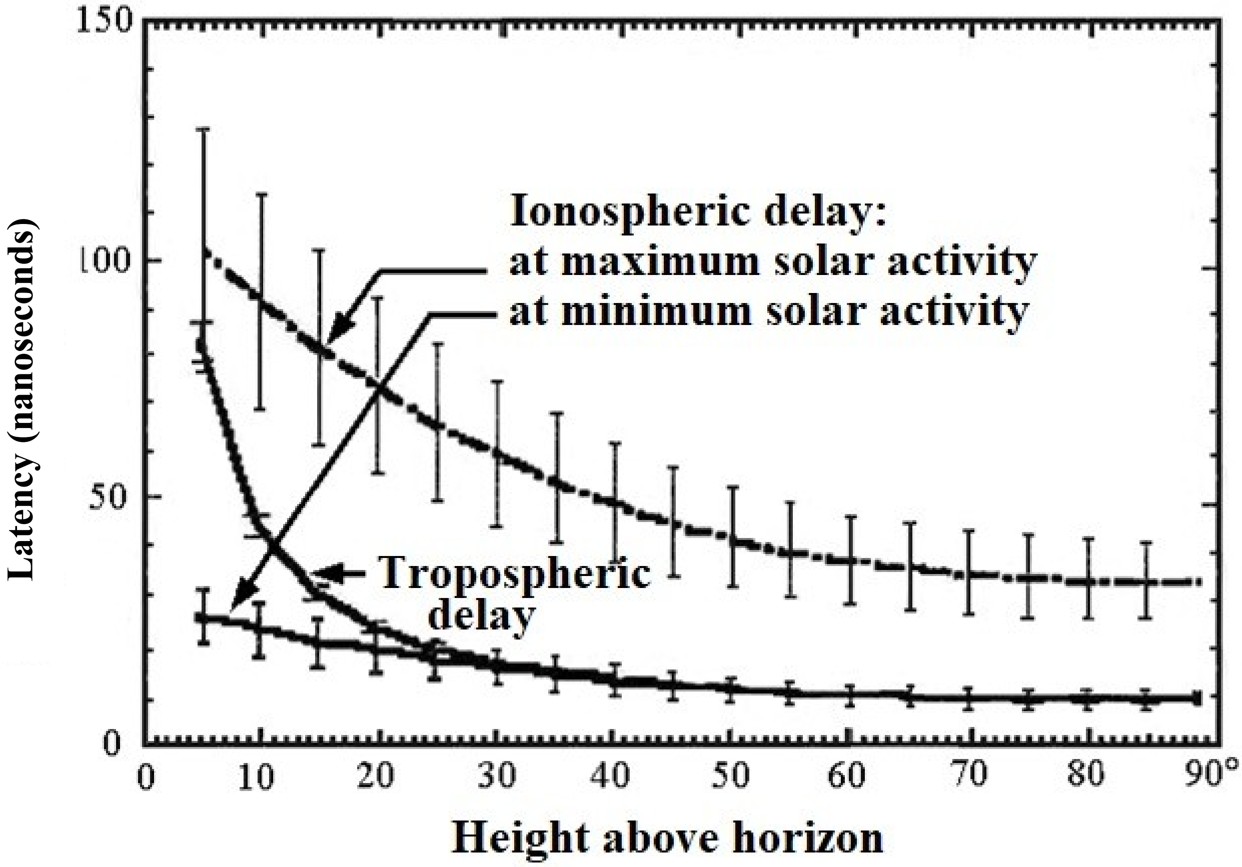

Fig. 1. Comparison of ionospheric and tropospheric storage and their funds for average conditions and average conditions at different altitudes

Disturbances in the Earth's ionosphere often cause short-term signal decays that seriously affect the tracking ability of a GPS receiver. This is the area extending ± 30° on either side of the geomagnetic equator and the polar ice caps. The attenuation can be so severe that the signal level drops completely below the receiver's reception threshold. When this happens, data is lost until the receiver can reacquire the signals.

The path from the satellite to the GPS receiver encounters certain obstacles, which reduces the accuracy of the position of the point. The source of the errors can be seen in Figure 2 below.

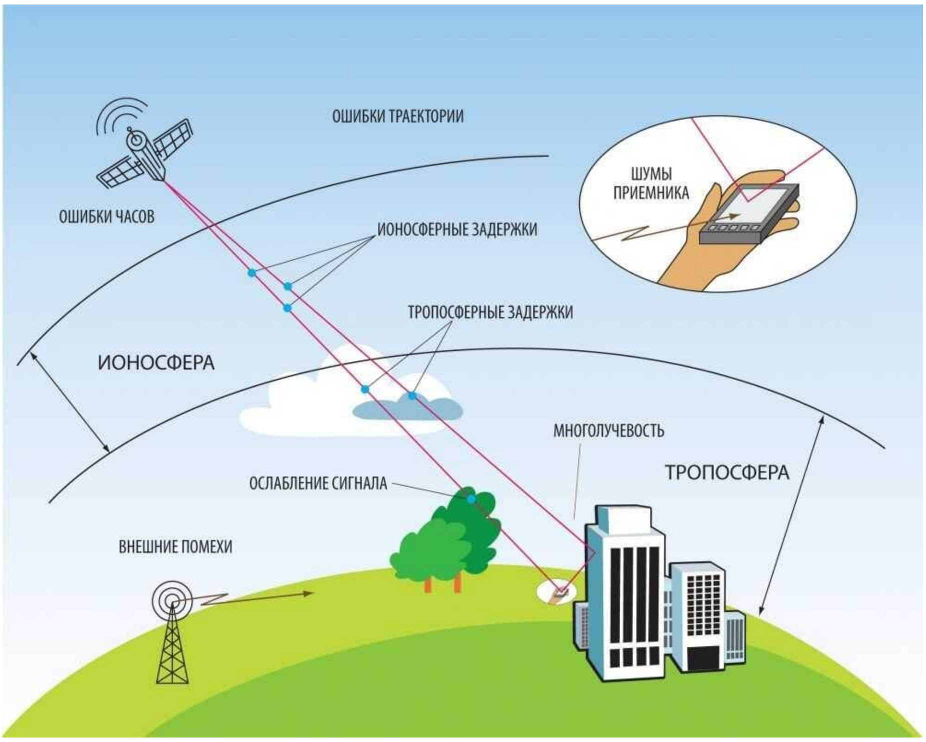

Figure 2. Factors affecting the GNSS signal

Magnetic storms (and related ionospheric storms) are caused by the arrival of high-energy charged particles from explosions or coronal holes to Earth, causing disturbances in the Earth's magnetic field. The charged particles interact with the Earth's neutral atmosphere, producing ions and additional electrons. The resulting strong electric fields cause significant changes in the morphology of the ionosphere [6].

Troposphere effect. The troposphere is the part of the atmosphere closest to the Earth. It extends from the surface to about 9 km at the poles and to about 16 km at the equator. Although the troposphere is no more cooperative than the ionosphere in terms of coherence, the troposphere and ionosphere are never the same in their effects on satellite signals. The troposphere is refractile, which causes the frequency of the GPS satellite signal to be refracted. Refraction is equivalent to a delay in the arrival of the GPS satellite signal [7, 8].

The elaborated set of methods accounts for the tropospheric delay, which can be divided into two groups (Fig. 3). In the first of these, the delay is calculated using some external information and is entered into measurements in accordance with a certain model (Hopfield, Saastamoynena and others, see section 6.3). This method is usually realized in commercial programming. The second group of methods for studying the influence of tropospheric radiation uses SRNS signals as a means of distance sensing, and their tropospheric parameters are determined from GPS/GLONASS measurement processing.

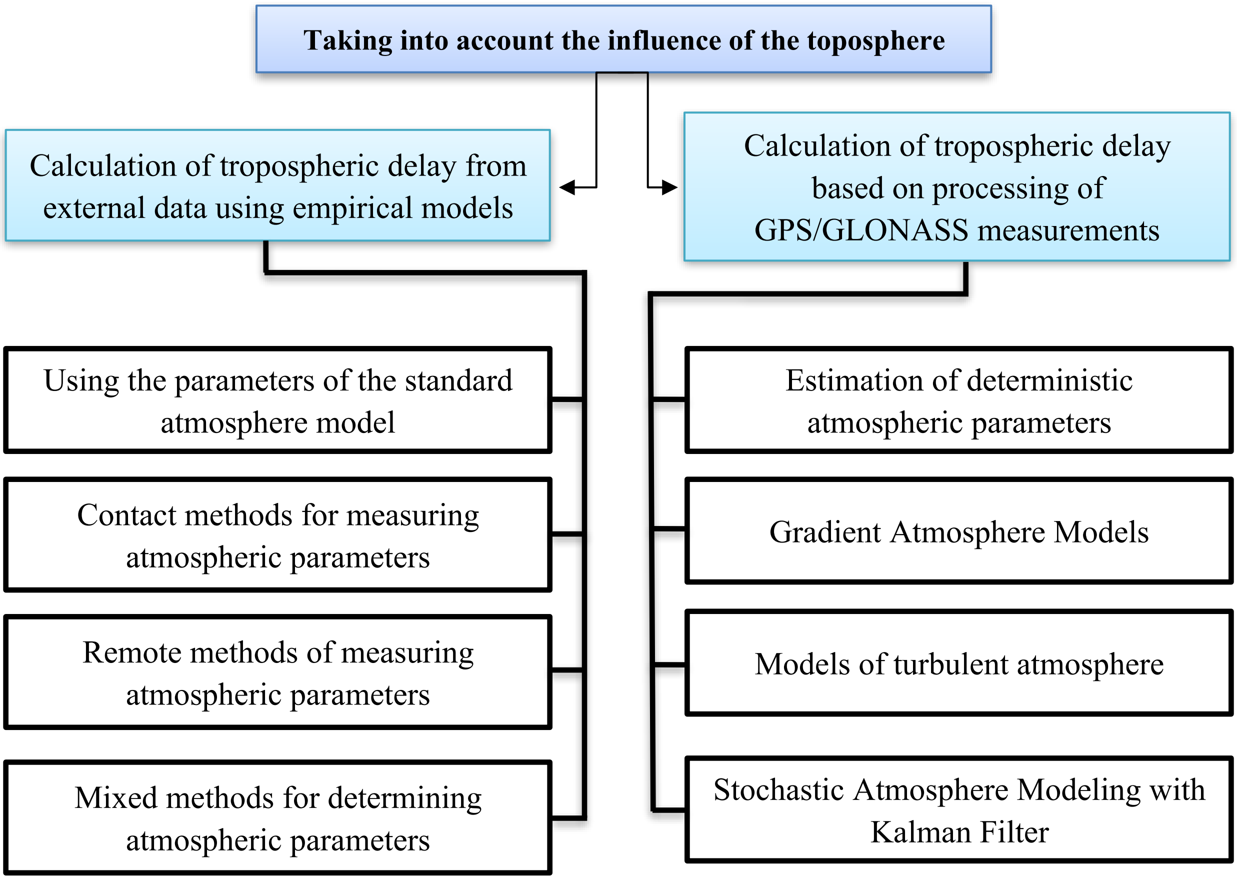

Fig. 3. Methods for accounting for tropospheric delay

The troposphere is part of the electrically neutral layer of the Earth's atmosphere, meaning it is not ionized. The troposphere is also opaque for frequencies below 30 GHz. This means that the distance between the receiver and the satellite is longer than it actually is. However, as in the ionosphere, density affects the delay of the GPS signal as it travels through the troposphere. For example, as the satellite approaches the horizon, the delay of the signal caused by the troposphere is maximized. At the zenith, the tropospheric delay of the signal from the satellite directly above the receiver is minimized (Figure 4).

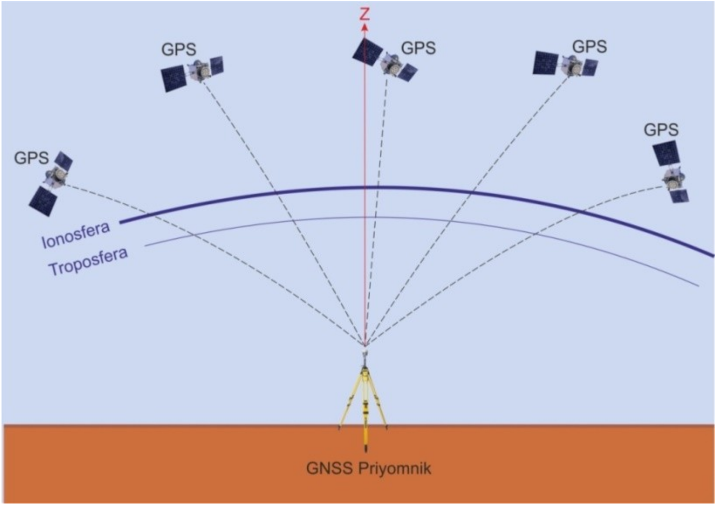

Figure 4. The influence of the atmosphere on the GNSS signal

Geophysical effects. The characteristics of satellite signals are significantly affected by climatic factors (air temperature, precipitation, atmospheric pressure) and space weather conditions (solar and magnetic activity levels).

Precipitation in the form of rain and snow affects radio navigation signals. When studying the effect of space weather conditions on radio navigation signals, we select days with the same climatic conditions (temperature, humidity, pressure, precipitation), as well as days with the same time interval, the same satellite azimuth and elevation angle. The effect of precipitation on GNSS measurements at different geophysical levels is given in Table 1.

Table 1

Density	District	Rain	Snow
Weak	<0,1 mm/hour	<2,5 mm/hour	<1,0 mm/hour
Average	0,1 and <0,5 mm/hour	2,5 and <10 mm / soat	1,0 and < 5 mm/hour
Strong	0,5 mm/hour	10 mm/hour	5 mm/hour

It is known that signals in a certain frequency range are attenuated when they propagate through the Earth's atmosphere due to the loss of part of the electromagnetic energy, which reduces the S/N ratio. A comparison of the results of changes in radio navigation signals for GPS and GLONASS systems with temperature changes in winter and autumn is shown in Table 2.

Table 2

Satellite №	Frequency	temperature, °C	Improve signal quality, dB	
			Winter	Autumn

21 (GPS)	L1	5	0.29	0.05
		10	0.38	0.12
		15	0.53	0.15
	L2	5	0.4	0.07
		10	0.47	0.15
		15	0.7	0.3
45 (ГЛОНАСС)	L1	5	0.16	0.13
		10	0.33	0.17
		15	0.39	0.2
	L2	5	0.06	0.21
		10	0.31	0.3
		15	0.34	0.5

Technogenic influence. One of the factors affecting the accuracy of the coordinates and height of a geodetic point in GNSS measurements is technogenic influence. In open areas, the influence of this factor is small, since the signals reaching the GNSS receiver reach the phase part of the antenna directly. In cities, difficulties arise when establishing geodetic points using a GNSS receiver. In this case, the signal reflected from the nearby reflecting surfaces at the location of the receiver reaches the phase part of the antenna, and the measured distance is determined incorrectly and the location of the point is found incorrectly. GPS signals cannot penetrate solid objects such as buildings, thick trees, cars, ships and bridges, and the signals reach the receiver via several paths [10, 11].

The path difference between the indirect and direct signal lengths of the wave Δ is the distance from the satellite antenna to the receiving antenna, which is shown in Figure 4.

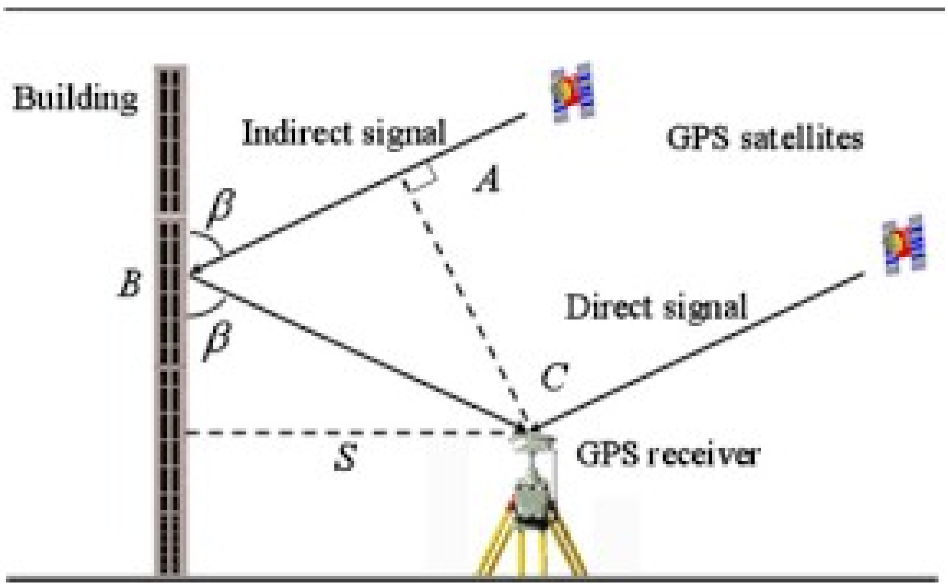

Figure 4. Geometry of the signal receiver

The time delay between the reflected signal and the direct incoming signal can be expressed as follows.

B=AB+BC =BC·cos(180°-2β) Ssinβ=2S·sinβ–S sinβ + S sinβ = 2S sinβ where β is the angle of incidence of the point from the satellite signal and S is the horizontal distance.

In conclusion, it can be said that when using satellite navigation receivers, it is necessary to take into account the influence of various external and internal factors.

List of used literature

1. Антонович К.М. Исползование спутниковых радионавигационных систем в геодезии. Том 2. – Москва: ФГУП "Картгеоцентр", 2006. – 311 с.
2. Мирмахмудов Э.Р., Юсупжонов О.Ғ., Тошонов Б.Ш., Хасанбаева Д.О. Предварительний анализ геодезической сети Алмалыкской промишленной зоны. Научно-технический журнал. Наука и образование сегодни. – Москва, 2020. – №5(52). – С. 106-109.
3. Юсупжонов О.Ғ. СК-42 ва WGS-84 координата тизимлари орасидаги ўтиш параметрларни ҳисоблаш. ЎзМУ хабарлари. 3/2 Табиий фанлар. – Тошкент, 2022. – Б. 348-351.
4. Azizjon Ruziev, Otabek Yusupjonov, Lóránt Földváry, Ziyo Okhunov, Sherzod Rakhimov, Sherzod Rakhmonov, Gayrat Yakubov. Development stages of the geodetic network in Tashkent city. E3S Web of Conferences Volume 590 (2024). 6th Annual International Scientific Conference on Geoinformatics - GI 2024: "Sustainable Geospatial Solutions for a Changing World". Published online: 13 November 2024.
5. Bekanov, K. K. (2021). Development of economic-mathematical models for optimizing the agricultural land use through GIS technologies (on the example of Chimbay district of the Republic of Karakalpakstan). Ekonomika i Sotsium, (9-1), 36-46.
6. Bekanov, K., Safarov, E., Prenov, S., Yusupov, B., & Uvraimov, S. (2020). Creating Land Use / Land Cover Map Using Methods GIS and Remote Sensing (On the Example the Chimbay District of the Karakalpakstan Republic). International Journal of Pharmaceutical Research, 12(3).
7. Bekanov, K. K., Safarov, E., Prenov, Sh., & Yusupov, B. (2022). Optimization of Agricultural Land Use in Chimbay District of the Republic of Karakalpakstan Using GIS Technologies. International Journal of Geoinformatics, 18(1), 27–36.
8. Gulyamova L., Rakhmanov D., Abdurahmanov A., Yusupjonov O., Anvarov SH. Analytical tool for retriving geospatial information from open source data in Uzbekistan.
9. Muborakov Kh, Yusupjonov O.G'., Ruziev A.S. Some requirements for the creation of a national reference system of coordinates of Uzbekistan. Электронное научно-практическое периодическое издание. "Экономика и социум" ISSN 2225-1545. Выпуск №11 (102) част 2, 2022. – С. 160-166.
10. Ruziev A.S. Yusupjonov O.G'., Matmusayev M.SH. About improving the method of producing large-scale topographic surveying in cities. Электронный сборник материалов Международной научно-технической конференции «Актуальные проблемы геодезии,

картографии, кадастра, геоинформационных технологий, рационального земле и природопользования». Беларусь. – Новополоцк, 2022. – С. 83-87.

11. Ruziev A.S., Yusupjonov O.G‘. Experimental research of the accuracy of the engineering and topographic survey plan performed with a total station. Электронное научно-практическое периодическое издание. “Экономика и социум” ISSN 2225-1545. №5 (108) част 1, 2023. – С. 650-658

12. Sattarbergan Avezov, Dilnoza Yunusova, Otabek Yusupjonov, Mukhabbat Kazakbaeva, Roza Gulmurzaeva, Umidjon Saksonov and Oykhumor Ruzikulova, Salomat Djumabaeva. Quantifying Water Bodies with Sentinel-2 Imagery and NDWI: A Remote Sensing Approach. E3S Web of Conferences Volume 590 (2024). 6th Annual International Scientific Conference on Geoinformatics - GI 2024: “Sustainable Geospatial Solutions for a Changing World”. Published online: 13 November 2024.

13. Yusupjonov O., Abdukarimov M., Ibragimov J. Davlat tayanch tarmoqlarini barpo qilishda yo‘ldoshli GNSS kuzatishlarni qo‘llashni nazariy masalalari. O‘zMU xabarlari. 3/1 Tabiiy fanlar. – Toshkent, 2024.