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# Analysis of Methods of Rational and Complex Use of Gold Ore Deposits

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***Abstract****— In this article deals with optical and radiometric methods of observing celestial bodies to determine the coordinates of points and their change. Observations of stars are analyzed astronomical to determine the non-polar change in the axis of rotation of the Earth. A technique for determining the zero point of the reference coordinate system based on positional observations of extragalactic objects is described. The use of geodynamic polygons in geological-tectonic regions is noted in this work. Special attention is paid to GPS measurements according to the international program "CATS". In order to study deformation processes, it is proposed to carry out systematic GNSS measurements at the Tashkent geodynamic polygon. For metrological support of navigation measurements, it is proposed to create a Central Asian GNSS polygon.*

**Keywords—** plate tectonics, deformations, geodynamic polygon, pole movement, coordinates, GNSS, CATS.

## 1. INTRODUCTION

At the end of the 19th century, it was proved that astronomical observations of stars can reveal changes in the coordinates of points associated with the unevenness of the Earth's axis of rotation and the movement of masses within the planet. Long-term meridian observations of geodesic stars led to a hypothesis about the variability of latitude and longitude, caused not only by precession-nutation movements, but also by internal processes [1]. Thanks to the use of quartz and then atomic clocks, the values of tidal deformations were calculated, which affect the direction of the acceleration of gravity and the parameters of the Earth's rotation. Such deformation processes, of course, directly lead to changes in the coordinates of the points of the geodetic network. The need to improve the accuracy of the coordinates of points and the determination of geodetic constants are associated with new complexes created on the basis of GNSS and satellite altimetry. Reliable results of changes in coordinates can be obtained at geodynamic polygons located in different geological and tectonic regions (Fig. 1). This makes it possible to compare not only internal deformations, but also other geomorphological changes [2].

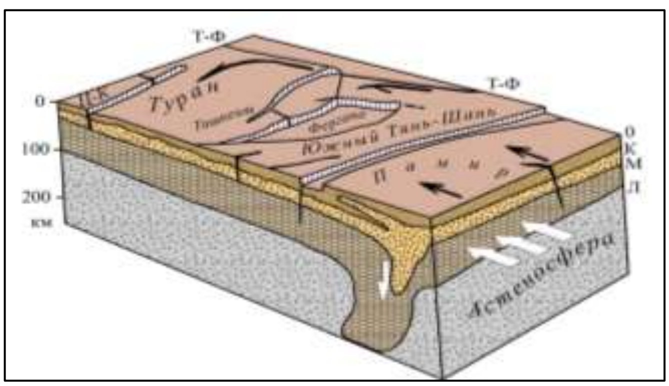


**Figure 1.** Schematic of tectonic faults.

For example, high-precision triangulation measurements are used to study horizontal displacements; based on the results of the adjustment, you can confidently determine the displacement of the center of the sign and the reference. Multiple repeated leveling of I and II classes at the Tashkent geodynamic test site led to the fact that there is a correlation between changes in the rates of vertical movements and deformations of the earth's crust [3]. Usually, measurements are carried out with classical instruments and devices, which require a considerable amount of time and a large amount of computers to process. In this regard, the search for ways to optimize observations and solutions of the system of differential equations for corrections to the coordinates of geodynamic networks was started.

With the progress of modern technology, such as laser ranging from satellites, Doppler observations of satellites, radio interferometric observations of extragalactic radio sources, GNSS measurements, the accuracy of positioning has increased, which made it possible to interpret not only the geoid model, but also to record minor changes in tectonic plates [4]. Since part of the territory of Central Asia is located at the junction of three global and two local plates (Fig. 2), the problem arises of determining the magnitude of the displacements of these areas.


**Figure 2.** Scheme of the location of the territory of Central Asia

Naturally, taking into account the parameters of tectonic shifts significantly affects the accuracy of calculating geocentric coordinates, which are expressed by the formula:

$$\vec{R}(t_0) = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} (N+H)\cos B \cos L \\ (N+H)\cos B \sin L \\ [N(1-e^2)+H]\sin B \end{bmatrix} \quad (1)$$

where a, e - semi-major axis and eccentricity (a = 6378137.000 m, $e^2$ = 0.00669438), B, L - latitude and longitude, H - orthometric or normal height, N - radius of curvature of the ellipsoid in the first vertical, which has the form:

$$N = \frac{a}{\sqrt{1-e^2 \sin^2 \varphi}} \quad . \quad (2)$$

Consequently, changes in coordinates can be represented by partial derivatives of the vector radius with respect to the variables B, L, H, where the differentials to the projections of the X, Y, Z axes are the difference between the two epochs [5]

$$d\vec{R} = \frac{\partial \vec{R}}{\partial B} dB + \frac{\partial \vec{R}}{\partial L} dH + \frac{\partial \vec{R}}{\partial H} dH. \quad (3)$$

When performing scientific and practical tasks, it is inconvenient to operate with instantaneous coordinates (X, Y, Z), changing in time, because the reasons for changes in the coordinates of these points have not been studied. They need to be reduced to a certain epoch and ellipsoid, and they must be used until it becomes necessary to move to the coordinates of another epoch. The current geocentric radius vector of the point can be represented by the expression [6]:

$$\vec{R}(t) = \vec{R}_0 + \dot{\vec{R}}_0 (t - t_0) + \sum_i \Delta_i \vec{R}(t), \quad (4)$$

where $\vec{R}_0$- position in the era $t_0, \dot{\vec{R}}_0$ - speed in the era $t_0$, $\Delta_i \vec{R}(t)$ - displacement parameters calculated by the formulas of the theory of tides. Other parameters associated with the Earth, including the expansion coefficients of the geopotential in a series in spherical harmonics, are tied to the Earth's reference coordinate system. If for some station the speed $\dot{\vec{R}}_0$ in ITRF has not yet been determined from observations, then it should be determined as the sum of the velocities:

$$\dot{\vec{R}}_0 = \dot{\vec{R}}_{plate} + \dot{\vec{R}}_r \quad (5)$$

where $\dot{\vec{R}}_{plate}$- horizontal velocity calculated from the tectonic plate movement model NNRNUVEL1A, a$\dot{\vec{R}}_r$ - residual speed.

## 2. RESEARCH METHODS

The first work on determining the geographic latitude of a point and its changes was carried out by the staff of the Tashkent Astronomical Observatory (TAO) based on calculations of zenith distances near the pole stars in 1890-1900. (1897) obtained the differences between the astronomical and geodetic coordinates for the territory of the Fergana Valley, according to the results of which the geoid figure of the indicated area was developed. Later, in 1948, the idea of registering continental drift based on longitudinal determinations was proposed, but this idea remained at the theoretical level due to the low accuracy of the transit and meridian instruments [7-9].

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One of the authors of this article made an attempt to determine the rate of change of the instantaneous pole based on the results of 5 international latitudinal stations. The general equation of the difference between instantaneous and mean latitude has the form

$$\varphi - \varphi_0 = x cos\lambda + y sin\lambda + z, \qquad (6)$$

where $\varphi$, $\varphi_0$ – instantaneous and calculated latitude; x, y are the coordinates of the celestial ephemeris pole, determined using the theory of precession and nutation, λ is the longitude of the station, z is the z-term.

By interpolation or extrapolation, it is possible to achieve a point such that the average observation epoch is the same for all five MRDP stations. The equation for calculating the coordinates of the pole can be written as follows:

$$x = -0.4359\Delta\varphi_M + 0.1227\Delta\varphi_K + 0.4483\Delta\varphi_C + 0.1232\Delta\varphi_G - 0.2583\Delta\varphi_U,$$
$$y = -0.2636\Delta\varphi_M - 0.3133\Delta\varphi_K - 0.0172\Delta\varphi_C + 0.3382\Delta\varphi_G + 0.2559\Delta\varphi_U, \qquad (7)$$
$$z = +0.2305\Delta\varphi_M + 0.2007\Delta\varphi_K - 0.1755\Delta\varphi_C + 0.1850\Delta\varphi_G - 0.2082\Delta\varphi_U,$$

where the indices M, K, C, G, U denote the names of the stations.

As a result of the analysis of a large array of latitudinal data, the speed of the pole movement was 2.5 cm per year.

The most detailed studies of the variability of the parameters of the Earth's orientation were carried out by the Astronomical Observatory of Bratislava (Slovakia) on the basis of all classical latitudinal observations from 1899 to 1973 [10]. The results obtained by various observatories, including the results of the Kitab Latitude Station (Uzbekistan) in the interval from 1930 to 1978, were used for the final calculation of the point velocity. Despite the laborious work, the obtained results of the International Pole Motion Service and the International Time Bureau represent a unique data bank for further studies of the Earth's figure (Fig. 3).

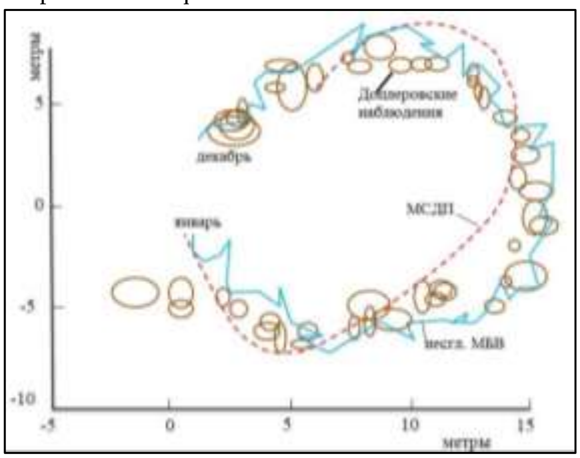


**Figure 3.** Pole movement by different methods

The advent of high-precision laser range finders has reduced the processing time of measurements, and also provided a basis for the refinement of the geometrical and physical parameters of the Earth's ellipsoid.

From 1979 to 2003, at the measuring complex Maidanak (Uzbekistan), continuous observations of geodetic and geophysical satellites LAGEOS, TOPEX / Poseidon, ERS1,2 were carried out using a range measurement system. The main difficulty of laser measurements is setting the exact position of the satellite in azimuth and altitude on the sighting sensor, which depends not only on the scale division of the limbs, but also on the ephemeris positions of the object. As a result, there are systematic errors due to the incorrectness of the method of observations of the satellite. To determine systematic errors, 2GPS and 2GLONASS laser observations were carried out, on which corner reflectors were installed [11]. Regular measurements of distances to space objects made it possible to estimate the influence of the Earth's and atmospheric attraction on the satellite's trajectory using Earth models, which are normalized coefficients $C_{nm}$, $S_{nm}$ of the expansion of the geopotential in spherical functions. The height of the geoid ζ at a point with spherical coordinates r, φ, λ can be calculated by the formula

$$\zeta = \frac{GM}{r\gamma}\left[1 + \sum_{n=2}^{n_{max}} \sum_{m=0}^{n} \left(\frac{a}{r}\right)^n \bar{P}_{nm}(\sin\varphi)\,(\bar{C}_{nm} com\, m\lambda + \bar{S}_{nm}\sin m\lambda)\right], \qquad (8)$$

where $a$ is the semi-major axis, $\bar{C}_{nm}$, $\bar{S}_{nm}$– normalized harmonic coefficients, λ, φ - longitude and latitude, GM - gravitational parameter of the Earth, $\bar{P}_{nm}(\sin\varphi) -$ normalized attached Legendre functions.

Of the optical methods, only laser measurements are used in the study of geodynamic processes and in the determination of the parameters of the general terrestrial ellipsoid. But ground geodetic measurements at the points of the geodetic network have not lost their significance, since the development of high-precision geodetic instruments, electronic total stations, laser scanners led to the need to investigate the coordinates of points for stability. Although classical methods provide grounds for studying the deformation of the earth's crust, their weak point is the impossibility of having continuous data on the course of the process. They are considered a reliable way of recognizing secular surface shifts, and it is so difficult to make frequent repeated geodetic measurements that in fact it is possible to find out only an average picture of events that have occurred over a long period of observation.

In 1980-2003, the aerogeodetic enterprise of Uzbekistan carried out linear-angular measurements of geodetic points of the Tashkent geodynamic test site [12]. Based on the results of repeated leveling, the velocities of the points were determined within 3.24 cm / year. To determine the movement of the microplate, you must have data for at least three cycles of altitude measurements, where the difference between the two cycles will correspond to the general trend of movement. However, this method of leveling allows only the vertical component to be investigated, and triangulation and trilateration methods should be used for horizontal displacements.

The development of high-precision electronic total stations has become universal and mobile; it is possible to automatically measure in circles and simultaneously measure the distance to the point where the reflector is installed (Fig. 4).

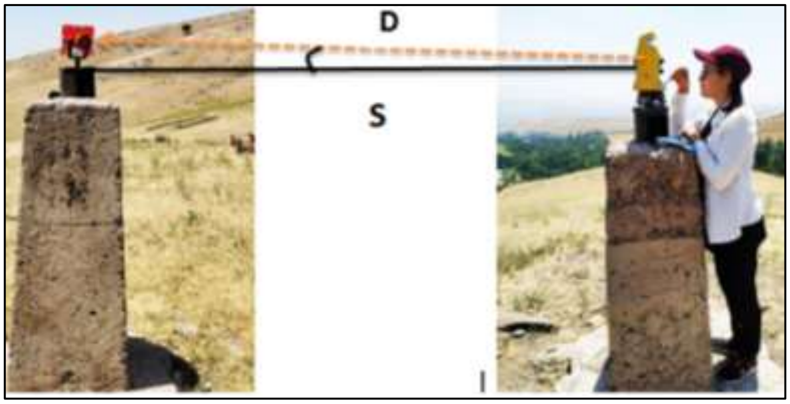


**Figure 4.** Measuring the distances between points

This principle makes it possible to determine the coordinates, slope distance and elevation by the method of trigonometric leveling. If we consider the displacement of the geodetic network, then here we will have to take into account the entire procedure for reducing the distance, angles and coordinates to an ellipsoid according to the Legendre principle. To study the kinematic parameters, the most optimal is to estimate the accuracy of the independent parameters of the geodetic network. Usually, according to geophysical and geological measurements, zones are found that are most sensitive to deformations and tectonic actions, where geodetic constructions are organized in the form of a quadrangle [13]. High-precision linear angular measurements are made in these local areas. Moreover, the two sides of this figure should be located on different blocks or vertices, approximately parallel to the direction of the fault. For example, for the Tavaksay geodynamic polygon, you can use several quadrangles, the points of which are located on the tops of the hills where the Karzhatau fault passes (Fig. 5).

Thus, the geodetic method for determining the deformation of plates is the most effective and economical in comparison with other methods. But the most difficult and laborious in this method is the geometric leveling of the relief of hilly terrain.

In 1995, the international program "Geodynamics" was created, which united the radio telescopes of the Eurasian part of the Earth into a single radio interometric network in order to determine the movement of lithospheric plates. Quasars and active galactic nuclei were used as reference points, with the help of which it is possible to track the location of the telescope with high accuracy. In order to process modern data, it is necessary to use several relativistic frames of reference. For example, in 1998, the International Celestial Reference Frame (ICRF) was implemented based on the high-precision equatorial coordinates of 608 extragalactic radio sources, and the accuracy of the inertial reference frame was estimated as a result of regular observations of these objects.

**Figure 5.** Scheme of a geodesic quadrangle

The Astronomical Institute of the Academy of Sciences of the Republic of Uzbekistan also participated in the observations of radio-optical astronomical sources using the Zeiss double astrograph in Kitab (Fig. 6).

**Figure 6.** DAC in Kitab

Several images were obtained with images of radio sources using the ROAS program organized by the Main Astronomical Observatory (Pulkovo, Russia). One of the authors of this article took an active part in observing these objects and calculating the equatorial coordinates relative to the fundamental catalog of stars AGK3 [14]. The obtained images of radio sources on astro plates with a size of 30x30 cm are stored in the glass library of the AI Academy of Sciences of the Republic of Uzbekistan. and can be processed based on high-precision stellar catalogs. In addition, the Astronomical Institute participated in the refinement of the zero-point of the fundamental star catalog and coordinate support of the astrometric satellite “Hipparcos”. Based on the results of positional measurements, the oscillation of the zero point of the fundamental star catalog FK-5, PPM was revealed (Fig. 7).

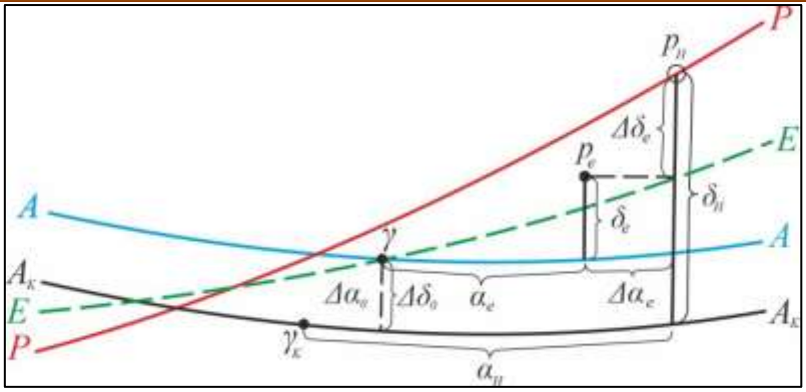

Figure 7. Corrections of the zero point of the inertial coordinate system

Since the measurements are made from the Earth in the ITRF system, the calculated positions of the observer and the object must be transferred to the BRF system. The change in the point of intersection of the equator and the ecliptic can be expressed through the corrections of the elements of the orbits of a celestial body:

$$\begin{aligned}(\Delta\alpha_e)_p &= \frac{\partial\alpha}{\partial\Omega}\Delta\Omega + \frac{\partial\alpha}{\partial i}\Delta i + \frac{\partial\alpha}{\partial a}\Delta a + \frac{\partial\alpha}{\partial e}\Delta e + \frac{\partial\alpha}{\partial\omega}\Delta\omega + \frac{\partial\alpha}{\partial M_0}\Delta M_0, \\ (\Delta\delta_e)_p &= \frac{\partial\delta}{\partial\Omega}\Delta\Omega + \frac{\partial\delta}{\partial i}\Delta i + \frac{\partial\delta}{\partial a}\Delta a + \frac{\partial\delta}{\partial e}\Delta e + \frac{\partial\delta}{\partial\omega}\Delta\omega + \frac{\partial\delta}{\partial M_0}\Delta M_0,\end{aligned} \tag{9}$$

The use of observations of various space objects will give the most probable value of the correction to the catalog of stars [15].

The launch of navigation satellites of the "Navstar" system led to a more efficient way of determining the coordinates of points. It became possible to more accurately and quickly determine the speed of displacement not only of points, but also of entire regions, which prompted international organizations to organize various missions to study the gravitational field and plate tectonics. One of such missions was the CATS program for the study of deformation of the Central Asian region, organized by the Center for Geosciences in Potsdam, Germany [16]. The aim of the program was to determine the values of vertical and horizontal displacements of CA micro-plates in the interval from 1992 to 1998 (Table 1).

**Table 1.** Deviation of coordinates of CATS network points between cycles

| Station | $\Delta X_{(1994\text{-}92)}$ | $\Delta Y_{(1994\text{-}92)}$ | $\Delta Z_{(1994\text{-}92)}$ | $\Delta R_{(1994\text{-}92)}$ |
|---|---|---|---|---|
| djan | -0.0257 | 0.0345 | 0.0346 | 0.098 |
| kitb | -0.0692 | -0.0213 | -0.0056 | 0.076 |
| okto | -0.0595 | -0.0054 | -0.0024 | 0.061 |
| dena | -0.0455 | 0.0184 | 0.0143 | 0.046 |
| sanz | -0.0769 | -0.0419 | -0.0435 | 0.098 |
| circ | -0.0519 | -0.0263 | -0.0173 | 0.061 |
| alma | -0.0512 | 0.0041 | 0.0033 | 0.051 |
| sary | -0.0462 | -0.0176 | 0.0026 | 0.049 |
| mada | -0.0589 | 0.0195 | 0.0050 | 0.063 |

Table 1 shows that in such a short time interval as 2 years, the rate reaches 4 cm per year. The scalar value of the resulting vector is calculated under the assumption that the trend is linear, i.e. the kinematic nature of the movement was used. Based on the coordinate differences between the cycles, a histogram was built, where the legend of the points is shown along the horizontal axis, and the value of the calculated speed is shown along the vertical axis (Fig. 8).

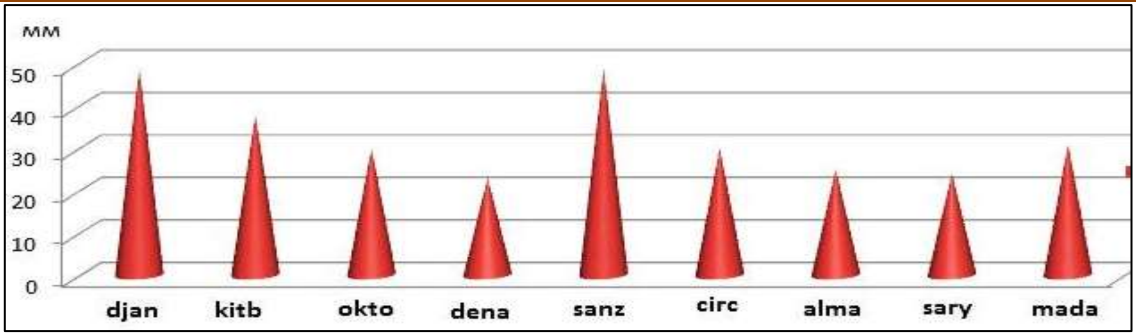


**Figure 8.** Annual shift of coordinates of CATS network points

Figure 8 shows that the coordinates of all stations in the CATS network are subject to change over time, which indicates tectonic shifts between plates and local deformation processes. Since more than 20 years have passed since the installation of CATS points, the issues of safety and sustainability of these points are timely. Of the 80 points of this network installed in Central Asia, 11 are installed in the territory of Uzbekistan. Reconnaissance of some points using a mobile navigator showed that the given coordinates correspond to the WGS84 coordinate system [17].

Modern geodetic instruments and receivers of the global navigation satellite system are implemented in all areas of production. The lack of a metrological service in Uzbekistan leads to certain difficulties in equalizing geodetic networks of vast territories, as well as in carrying out the necessary regular field calibration of geodetic instruments. [18] proposed a quadrangular GNSS polygon in Central Asia, which will be the main place for metrological support of modern geodetic instruments. But, for the study of local displacement, the most optimal and reliable way is to create geodynamic polygons in the vicinity of faults or to build special points in a seismically active zone. Taking this into account, it is advisable to organize a global geodynamic testing ground for Central Asia for testing modern satellite receivers. The existing GPS networks are local and not interconnected, and the state geodetic network has not been specified or corrected for 20-30 years. The problem arises of increasing the accuracy of coordinates of points of geodetic networks and modifying the GNSS network. The most efficient way is to create a polygon consisting of a quadrangle, the vertices of which can be the international IGS stations of Kitab and Bishkek, as well as the CATS points of Kizilsu and Koktol (Fig. 9).


**Figure 9.** Scheme of the GNSS of the CA test site

Uzbekistan has three permanent satellite stations (IGS, IDS, CHAMP), one laser ranging station (SLR) on the Maidanak mountain and 50 GNSS stations operating in real time. On the territory of Kyrgyzstan, one international IGS station has also been installed in Bishkek. In addition, high-precision GPS points have been built in Central Asia under the international CATS program. Despite the powerful leap forward in GNSS, optical methods have not lost their importance, but preference is given to radio measurements of cosmic bodies due to their all-weather and efficiency. Therefore, in 2018, attention was again drawn to the Suffa ground-based radio engineering complex located in the Zaamin district of the Jizzakh region (Uzbekistan), where design and installation work is currently underway. Not far from the Maidanak observatory on the Sanglok mountain, located in Tajikistan, work is underway to monitor space bodies on-line (Fig. 10). The same measuring system "Saryshagen" was built near Lake Balkhash, Kazakhstan [19-56].

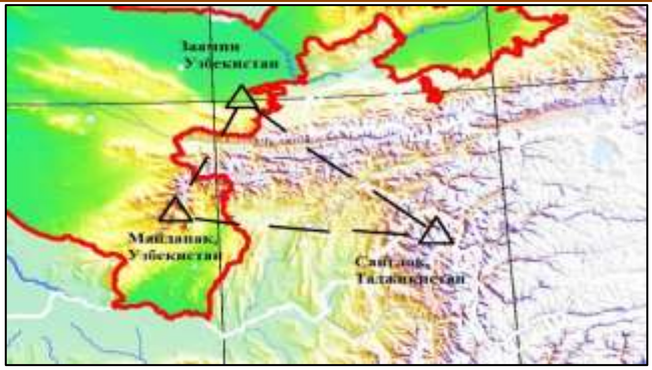

**Figure 10.** Centers for observing space bodies in Central Asia

The geometrical configuration of the CA measuring systems will make it possible to more accurately relate geodetic measurements made by topographic and geodetic organizations. The interrelation of GNSS points, laser ranging stations and the Suffa radio-technical observatory creates the prerequisites for the development of a unified coordinate system, which will have scientific and practical significance, covering all sectors of the national economy up to inter-republican projects. At the initial design stage, a preliminary calculation of the accuracy of the coordinates of the vertices and inner corners of the polygon should be made using the geographical coordinates of the indicated observatories (Table 2).

**Table 2.** Coordinates of observation points for space objects

| Names | L | B | H(м) | Republic |
|---|---|---|---|---|
| Maidanak | 66°56'35.76" | 38°41'08.24" | 2731 | Uzbekistan |
| Suffa | 68°26'50.70" | 39°37'25.87" | 2338 | Uzbekistan |
| Sanglok | 69°13'26.14" | 38°17'06.88" | 2079 | Tajikistan |
| Saryshagen | 73°31'05.00" | 45°50'33.10" | 358 | Kazakhstan |

To implement the above proposals, it is necessary to attract foreign specialists to the international project and equip the CA GNSS test site with modern computer technologies and software. The first step in this implementation was an agreement on scientific and technical cooperation between the National University of Uzbekistan and the laboratory for geodetic analysis of the Earth and outer space (Covilha, Portugal).

## 3. Conclusion

The use of optical and radiotechnical measurements will make a significant contribution to the study of the spatial motions of microplates at short and long time intervals. Establishing a connection between modern vertical movements of the earth's crust and tectonic movements of past geological periods will reveal the patterns of changes in the earth's crust. Thanks to the use of navigation receivers, it became possible to make adjustments to the coordinate system (Fig. 11). Such refinements are rather rare, since the coordinate system must be rather rigid.

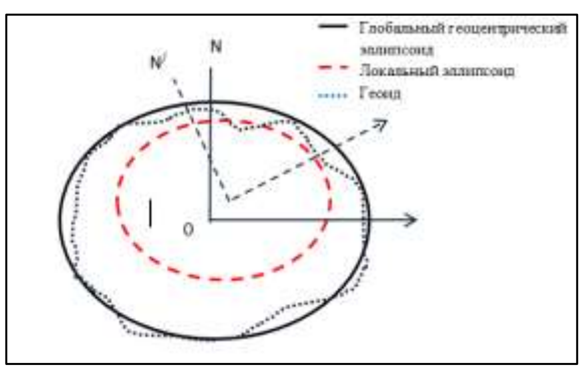


**Figure 11.** Scheme of ellipsoids

From the above, it can be concluded that the use of astronomical, geodetic, geophysical and GNSS measurements will lead to an accurate analysis of the geodynamic movements of individual areas, although for many years in Uzbekistan there have been centers, departments and faculties for the study of geodynamic processes that solve industry problems by virtue of their technical capabilities. Geodetic methods have not lost their importance and, in the future, can be used as the main method for analyzing local displacements in the vicinity of hydraulic structures and open pits under construction. In the future, a regional system for tracking geodynamic phenomena should be developed using high-precision geodetic and astronomical observations.

## 4. Acknowledgment

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