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SOME REQUIREMENTS FOR THE CREATION OF A NATIONAL REFERENCE SYSTEM OF COORDINATES OF UZBEKISTAN

Annotation: *The article provides some requirements for the national reference coordinate system. The change in the coordinates of the classical geodetic network due to global and local displacements of microplates is described in this article. The role of modern satellite navigation systems in improving the accuracy of geodetic network coordinates is noted. The relevance of the introduction of the national reference coordinate system of Uzbekistan and its application in the cadastre, registration of real estate, topography and cartography is described in detail in this paper. The possibility of transitioning from a single coordinate system to a global coordinate system by applying transition parameters is analyzed here. It is proposed to upgrade the existing geodetic network using GNSS receivers and reduce it to the international ITRF coordinate system.*

Keywords: *reference system CK -42, State Geodetic Network SGN, SatelliteGN, GNSS, ITRF.*

Introduction. The State Geodetic Network (SGN) on the territory of Uzbekistan was created in accordance with the main provisions of 1954-1961 y. in the SK42 coordinate system [2]. It was intended for mapping the territory of the republic, carrying out topographic and geodetic surveys during the construction of buildings and structures, land surveying. Recent studies of the SGN have shown that it is so inhomogeneous that it actually captures different, albeit close, coordinate systems. This manifests itself in very large values of errors in the conversion parameters between CK-42 and WGS-84 [3]. In addition, SK42 is outdated and closed for public use, does not meet the requirements of international standards and does not allow numerous categories of users to freely access it.

Goal and tasks. The aim of the work is to analyze the current state of the basic geodetic network of Uzbekistan, consider the ways of its modernization in order to create a single high-precision state satellite geodetic network (SSGN) with an open international reference coordinate system (RCS) throughout the territory. The solution of this problem allows to ensure a uniform density of network points, and their easy accessibility, increases the accuracy and reliability of cadastral survey materials, topographic and geodetic surveys and cartographic materials.

Main part. The creation of an open reference coordinate system (RCS) and its use in the cadastre, topography, cartography and for obtaining other geospatial data is a key criterion for using an integrated information system for cadastre and registration of real estate.

The practical implementation of the open RCS is carried out as part of the improvement and modernization of the current geodetic infrastructure. The upgraded infrastructure is planned to include about 400-500 points, including about 200 GGS points, currently operating points of the satellite geodetic network, the coordinates of which are determined with high accuracy from GPS measurements in the SK42 coordinate system and GNSS stations, forming a network of high-precision satellite positioning UZPOS (Fig. 1). The final number of points is determined after a thorough field survey.

The modernization of the current geodetic infrastructure and the transition from the state coordinate system to the 1984 open world geodetic coordinate system (WGS) and the international geocentric coordinate system - ITRS will require the establishment of precise parameters for the transition between them and the choice of a new map projection.

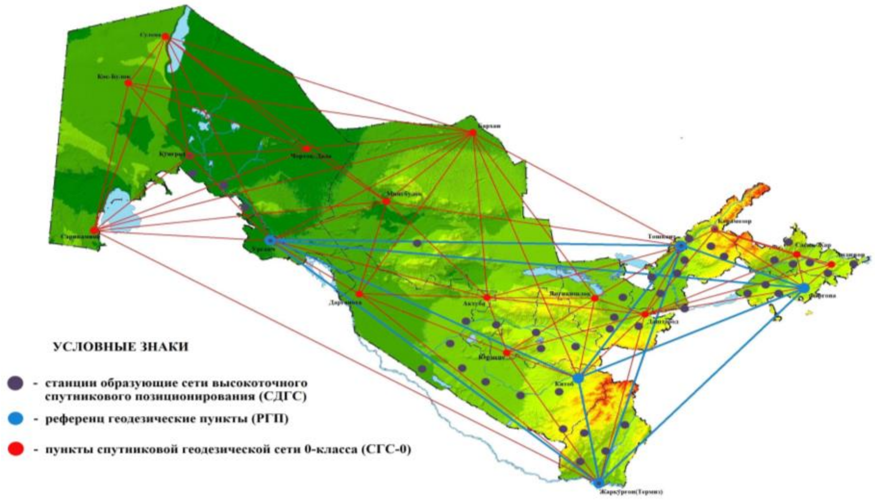


Figure 1. Scheme of the satellite geodetic network of Uzbekistan

With the progress of modern technology, such as laser ranging of satellites, Doppler observations of satellites (DORIS), radio interferometric observations of extragalactic radio sources, global navigation satellite systems (GNSS), the accuracy of determining the positions of points has reached 1-3 mm. At this level of accuracy, it is possible to interpret the geoid model of Uzbekistan and identify plate displacements that led to deformation of the coordinate grid of topographic maps (Fig. 2). If we consider geodetic and gravimetric measurements, then taking into account shifts affects the geocentric and reference coordinate systems (RCS)[1].

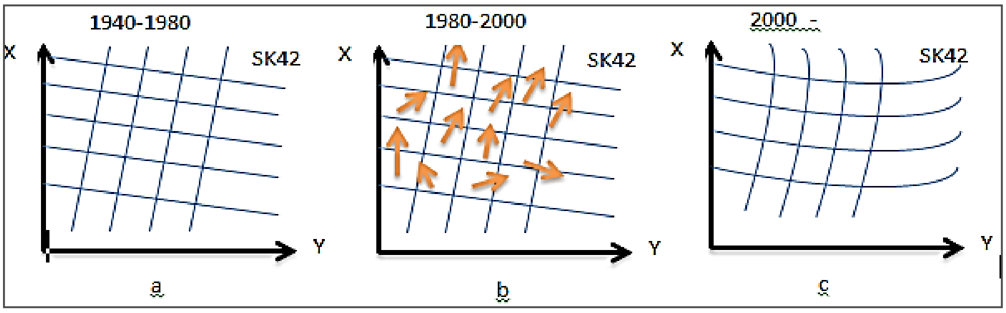


Figure 2. Deformation of the coordinate grid of the topographic map:
a- stable system; b- influence of plate tectonics; c- deformed coordinate grid.

The position of points in plan and height changes due to tidal deformations of the earth's crust, modern movements of the earth's surface, as well as due to the movement of large masses in the body of the Earth, etc [4]. Therefore, taking into account minor changes will require the development of exact differential equations for the relationship between spatial rectangular and geodetic coordinates, which should be represented as:

$$dX = \frac{\partial X}{\partial B}dB + \frac{\partial X}{\partial L}dL + \frac{\partial X}{\partial H}dH + \frac{\partial X}{\partial m}dm,$$

$$dY = \frac{\partial Y}{\partial B}dB + \frac{\partial Y}{\partial L}dL + \frac{\partial Y}{\partial H}dH + \frac{\partial Y}{\partial m}dm,$$

$$dZ = \frac{\partial Z}{\partial B}dB + \frac{\partial Z}{\partial L}dL + \frac{\partial Z}{\partial H}dH + \frac{\partial Z}{\partial m}dm,$$

where $\frac{\partial X}{\partial m}dm$ – partial derivatives, taking into account local changes to be developed, respectively for Y and Z.

It should be noted that when solving practical problems, it is inconvenient to operate with instantaneous coordinates that change in time. They must be reduced to a certain epoch and ellipsoid, and used until it becomes necessary to move to the coordinates of another epoch due to the accumulation of their unacceptably large changes. Thanks to the creation of a satellite geodetic network (SGN) and the performance of repeated measurements in it according to a special program, it will be possible to build a system of control points, the coordinates of which will be known at each moment of time. Taking the elements of the SGN as a basis, and combining with the State Geodetic Network (SGN) points, it will be possible to periodically improve the geodetic network and maintain it at the proper level for a long time.

Work on further development and modernization should continue almost continuously [5, 6]. This is due to the fact that the density of points is still insufficient for the territory of Uzbekistan. Over time, the geodetic network gradually “ages”, losing its original accuracy, and the requirements are constantly increasing. In this regard, it is advisable not only to revive the lost points and constantly take care of the development and safety of the network, but also to continuously work to refine its parameters.

The SGN built using GNSS differs from the traditional one not only in accuracy, but also in the architecture of the relationship between points. It is equally important to ensure the optimal location of ground points and GNSS configuration.

The basis for drafting a modernized network is the patterns of error actions in such a network. This refers to the composition of measurements, the geometric characteristics of the network, the distribution of starting points, the choice of the optimal variant of building the network under certain limiting conditions. The results of the SGN design can be expressed by a number of numerical characteristics:

- errors of SGN elements such as bases (m_D);
- errors in the position of SGN points (m_X, m_Y, m_Z);
- average distance between points or density of points;
- the nature of the distribution of satellites in the visibility zone of the point;
- location of bases and starting points;
- the number of measured values to determine one point;
- the number of starting points and bases;
- the frequency of the passage of satellites in the zone of visibility of points;
- duration of observation sessions.

One of the immediate tasks is to determine the required number of points in the network using GNSS so that the lengths of the sides of the triangles in it are about 5–10 km with centimeter or higher accuracy [7]. Each point should become a stationary fundamental geodetic station, at which, according to a specific program, the most accurate measurements of various types should be made. In the vicinity of each point, it is expedient to carry out systematic measurements of changes in the level of soils that cause corresponding changes in the height of the point. All points should be interconnected by leveling lines, repeated at regular intervals.

The gradual implementation of the modernization of the geodetic infrastructure with its subsequent improvement at the initial stage requires the following:

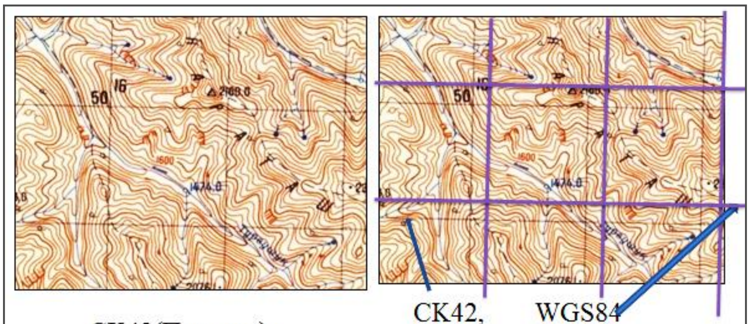
- reconnaissance of geodetic points,
- restoration, renewal of lost geodetic points,
- preliminary calculation of the accuracy of SGN points,
- geodetic measurements at SGN points,

- reduction of the State Geodetic Network (SGN) to the points of the Central Asian geodynamic network (CATS).

This is especially important when developing digital terrain models for large objects and structures being built along coastal zones and in densely populated areas [8]. For the effective fulfillment of the tasks set, a number of activities related to the field survey and preliminary measurement at the points should be carried out. First of all, this is reconnaissance and restoration of existing signals and pyramids. Secondly, this is the development of a project for a fundamental geodetic network, where all classical, geodynamic and GPS data should be used. Thirdly, the development of a software package for processing measurements with the involvement of modern geoinformation technologies.

The main problem is to determine the parameters of the transition from SK-42 to the national RSC, as well as to convert the Gauss-Kruger projection into a modified map projection (Fig. 3).

The mathematical model of transformation should provide spatial transformation without changing the geometry and scale of the network. In addition, the state high-rise base (SHB) and the gravimetric network, which was built in 1930-1950 y. are subject to revision, employees of the Tashkent Astronomical Observatory and officers of the Topographic Service of the Turkestan Military District.



$y_{wgs84} - y_{sk42} = 64m.$, $L_{wgs84} - L_{sk42} = 2.90$ arcsec
$x_{wgs84} - x_{sk42} = 9m.$, $B_{wgs84} - B_{sk42} = 0.23$ arcsec

$B_0 = \varphi_0 - \xi_0$
$L_0 = \lambda_0 - \eta_0 \sec B_0$
$A_0 = \alpha_0 - \eta_0 \mathrm{tg} B_0$

Scale	$\Delta X_{wgs84-sk42}$	$\Delta Y_{wgs84-sk42}$	
1:100 000	0.09mm	0.64mm	
1:50 000	0.18mm	1.28mm	
1:25 000	0.30mm	2.56mm	
1:10 000	0.9mm	6.40mm	
1:5 000	1.8mm	12.8mm	

Figure 3. Topographic map with additional grid [9].

The points of the State Geodetic Network (SGN) and SHB for the field survey should be selected according to predetermined criteria. Carrying out field work on the survey of selected points of the State Geodetic Network (SGN) and carrying out high-precision GNSS measurements on them require a lot of labor and time. To speed up the work, it would be possible to attract specialized organizations with experienced specialists and high-precision geodetic satellite receivers. The Department of Geodesy and Geoinformatics of the NUUz is ready to participate in these works, having qualified specialists from among the teachers and having modern GNSS receivers [10].

For the correct implementation of the ITRF coordinate system in topographic and geodetic works and publication of digital cadastral maps based on WGS-84, it is necessary to have initial data on classical and satellite measurements [11]. First of all, these are data from the fundamental astronomical and geodetic network (FAGN), high-precision geodetic network (HGN) and satellite geodetic network (SGN -1). As the FAGN, HGN and SGN-1 networks develop, the GGS adjustment should be performed and the parameters of the relative orientation of the geocentric coordinate system and SK-42 should be refined. The main points of FAGN are stations of laser location of satellites, points of service of the Earth rotation, and other points of satellite observations, planned and high-altitude (normal heights) positions, as well as the absolute values of the accelerations of gravity of which must be determined. HGN and FAGN serve as the basis for the development of geodetic constructions of subsequent classes, and are also used to create high-precision quasi-geoid height maps together with gravimetric information and leveling data. Normal heights should be determined from high-accuracy geometric leveling or from satellite leveling as the difference between geodetic and quasi-geoid heights. The accuracy of the relative position of satellite network points is approximately an order of magnitude higher than the corresponding accuracy of the existing State Geodetic Network (SGN).

Conclusions. The points of the planned and high-altitude State Geodetic Network (SGN) do not form a single three-dimensional spatial coordinate system, since they are created in different physical reference systems, while the SSGN forms a three-dimensional spatial system with coordinates approximately equal in accuracy.

When combining the State Geodetic Network (SGN) and State satellite geodetic network (SSGN), combining the results of traditional and satellite measurements in a limited area, the system of communication equations is ill-conditioned.

Processing of archival and new GNSS measurements with adjustment of the common network is performed by modern versions of commercial software products.

It is necessary to ensure a reliable connection of the new open high-precision RSC with the previous SK42, which will allow you to quickly and efficiently solve the problems of the cadastre, topographic and geodetic surveys, cartography, etc.

To improve the accuracy of the coordinate transformation parameters, it is necessary to use all ground and satellite measurements made evenly over the entire territory of the study area.

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