Journal scientific and applied research, vol. 18, 2020
International Journal

Original Contribution

ISSN 1314-6289

METHOD FOR CONDUCT HIGH-PRECISION GEODESIC MEASUREMENTS USING GNSS SYSTEMS

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ABSTRACT: *The subject of the research is the conduct of geodetic measurements and mathematical processing of the results of these measurements, together with mathematical models and data from measurements of geodynamic processes in order to eliminate the known influence of observed global and regional geodynamic processes on geodetic measurements and networks and to take into account the influence of local geodynamic processes on them.*

KEYWORDS: *GNSS system, ITRF2008, ITRS.*

1. Introduction

One of the generally accepted methods for processing primary phase measurements in the presence of several measured stations is the use of different algorithms, the work of which consists in compiling double differences from the initial phase measurements to derive information about the relative location of the measured points and detection and elimination of cyclic errors related to interruptions in the signal received by the satellite.

The next step is to apply to the obtained double differences an algorithm based on the least squares method for solving the phase uncertainty, calculation of the preliminary coordinates of the points, corrections to the parameters of the satellite orbits and corrections to the parameters of the theoretical models describing the influence of different factors. consequence of geodynamic processes on the measurements.

In the last step for obtaining high-precision daily decisions, it is necessary to set a reference frame in which to then obtain the coordinates of the points.

The setting of a reference frame is is carried out by applying the general constraints to the global network solutions obtained in the previous step by minimization the corrections to the a priori coordinates of the indicated reference stations of the ITRF terrestrial coordinate system [1, 2], whose coordinates are known at all times and with high accuracy. The reference stations in this case determine some realization of ITRF, and the transition from this to other realizations is possible through Helmert's transformation.
In this case, the choice of implementation of a reference frame is based on considerations of convenience in subsequent analyzes of the obtained coordinates. When setting the reference frame, it is necessary to take into account the movement of the ITRF center relative to the center of rotation of the lithosphere plates, which cause deformations in the earth's surface.

2. Related work

For high-precision determination of the coordinates of the points on the earth's surface with the help of the phase method of measurement and determination of the influence of the local geodynamic processes on the geodetic measurements and networks it is necessary:

- **Construction of fixed observation points provided with forced centering devices.**

The points from which the geodetic measurements will be carried out shall be construct on a solid, protected terrain with provided visibility in all directions at 15° from the horizon and visibility to at least two other points. There should be no water pools, walls, roofs and other metal structures with a significantly reflective surface near the points. There should be no transmitting antennas, radio magnetic, interference and other radiation in the area, which may cause interference or blocking of the signals of the satellites. The points should be fixed with massive concrete pillars on a concrete foundation. All concrete columns must be provided with forced centering devices. Carrying out high-precision measurements from these points should be performed at least one year after their construction;

- **High-class dual-frequency geodetic equipment for receiving GNSS signals.**

Carrying out high-precision measurements from these points should be performed at least one year after their construction. To measure all points (or for

a certain part of them used as starting points for angular and linear measurements) to use dual-frequency GNSS receivers, for which the manufacturers provide data on absolute models of variations of the antenna phase centers [3];

- **Carrying out cyclic (minimum 3 cycles) or continuous geodetic measurements.**

Take into account seasonal or rotational movements. The total sum of the periods between the different measurement cycles should not be less than one year in order to correctly distinguish the tectonic movements from the natural stress-strain state of the earth's surface;

- **Continuous (minimum 6 hours) simultaneous observations of 5 or more satellites, from 2 or more stations**

To check the data for detection of time intervals in which there are no cyclic errors with high reliability. The data from these intervals should be used in post-processing;

- **High-precision orbital parameters and satellite clock corrections distributed by IGS global centers.**

Use data containing the precise orbits of the satellites determined by laser location of the satellites, files containing information about the technical condition of the satellites and clock files with information about the corrections in the satellite clocks;

- **High-precision models of the various geodynamic processes required to determine corrections:**

To use data containing ionospheric models propagated by the global centers of IGS, homogeneous with the orbits of the pole coordinates from the Center for Orbiting in Bern (CODE) and to derive a tropospheric model for estimating the tropospheric gradient;

- **ITRS World Coordinate System based on the last realization of ITRF2008 (IGb08):**

The processing should include observations from permanent stations used for the realization of ITRF2008 of ITRS. The coordinates of the stations involved in the solutions and the pole model should be given in the

measurement era. The coordinates obtained from the combination of the daily decisions of the points should be given from the middle epoch of the campaigns in the epoch of realization (reference frame) ITRF2008 of the initial coordinate system.

➢ **Specialized software for post-processing of primary phase measurements**

To use software products allowing the introduction of the created different models of geodynamic processes and to use different strategies for solving and fixing the uncertainties;

➢ **Removal of the influence of the tectonic movements of the lithosphere plates:**

For all measured points to be derived annual values of tectonic velocities from the model NUVEL-1A, thus modeling the movement of points due to tectonic movements, tides in the hard crust and ocean tides;

➢ **To determine the influence of local geodynamic processes on geodetic measurements and networks to calculate the actual position of points relative to each other in time and space:**

$$\begin{aligned} X_{t_i} &= X_{t_0} + V_{X_{mek}}.(t_i - t_0) + \Delta X_{(t_i - t_0)} \\ Y_{t_i} &= Y_{t_0} + V_{Y_{mek}}.(t_i - t_0) + \Delta Y_{(t_i - t_0)} \\ Z_{t_i} &= Z_{t_0} + V_{Z_{mek}}.(t_i - t_0) + \Delta Z_{(t_i - t_0)} \end{aligned} \quad (1)$$

where:

$X_{t_i}, Y_{t_i}, Z_{t_i}$ – coordinates of the point at the moment t_i;

$X_{t_0}, Y_{t_0}, Z_{t_0}$ – coordinates of the point at the initial moment t_0;

$V_{X_{mek}}, V_{Y_{mek}}, V_{Z_{mek}}$ – annual tectonic velocities of the point;

$\Delta X_{(t_i - t_0)}, \Delta Y_{(t_i - t_0)}, \Delta Z_{(t_i - t_0)}$ – coordinate differences of the point in the epoch of realization of the coordinate system;

$(t_i - t_0)$ – a period of time between the first measurement *(0)* and the re-measurement *(i)*.

- **Creating an adequate model for visualization of displacements and deformations registered in the study area:**

To build graphs and histograms that clearly distinguish between horizontal and vertical movements, as well as those that reflect immediate information about the deformations and rotational nature of the movement of the earth's surface over time [3].

3. Conclusion

The use of the created models of global geodynamics and realization of ITRF in the processing of primary geodetic measurements allows to eliminate the influence of global geodynamic processes on geodetic measurements and networks and to create a basis for building a geodetic model of ground surface movements caused by local geodynamic processes. Such an approach allows to take into account the stochastic displacements of the points caused by seismic and post-seismic processes as well as the movements caused by the normal stress-strain state of the earth's crust.

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