Processing of GNSS data in Gamit/Globk: on the example of the reference stations of the Uzbekistan network

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Abstract. The article presents the results of processing, a preliminary assessment of the quality of measurements, and the accuracy of the coordinates of the points of the reference network of Uzbekistan (MAGK, FARG, JARQ, and URGA). Observation data of GNSS points were processed using the GAMIT/GLOBK v.10.71 software package by applying standard procedures for position and velocities estimation relating to the ITRF2014 global reference frame. The horizontal velocities of points were compared with the latest versions of global tectonic models such as ITRF 2014, GEODVEL 2010, and NNR - MORVEL 56. Analysis of the point time series confirmed the good quality of the measurements and the accuracy of the processed coordinates in the GAMIT/GLOBK program. The calculated solutions had horizontal coordinates, uncertainties uncertainty, and repeatability, at the level of 1-3.2 mm for horizontal coordinates and 3.2-6.5 mm for height. However, the analysis of the horizontal velocities of points and comparison of the results with global tectonic models confirmed the need for further compaction of the regional satellite network, especially in the western part of the territory, taking into account the new model of modern movements of the region.

1 Introduction

Nowadays, the study of mechanisms, and the quantitative assessment of global and regional geodynamic phenomena over short time intervals, which are indicators of modern processes occurring in the body of the Earth and on its surface, are the most important physical problems solved by the methods of space geodesy. From this point of view, the task of

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creating an earth reference system of coordinates and a network of reference points, relative to which destructive geodynamic processes will be studied at the millimetre level of accuracy, becomes actual, which is successfully solved in many countries [1-4]. Significant results have also been achieved in the Republic of Uzbekistan in creating a state geodetic Network (SGN), improving the methods of its construction, and improving the accuracy of coordinates through the introduction of new, measuring technologies, such as the Global Navigation Satellite System (GNSS) and combining with existing points of an international geodynamic network of the republic (Kitab, Tashkent, Maidanak, and Maidantal). The widespread use of satellite methods became the basis for the development of the National Geographic information system (NGIS) in the Republic of Uzbekistan for solving various problems in the country's economy [5]. About 200 points have been installed on the territory of the country now, 50 of these points have been transferred to the continuously operating reference (CORS) monitoring mode since 2018.

Increasing the efficiency of coordinate support should be ensured through the development of theoretical foundations for the further implementation of modern innovative satellite technologies and the transition to a high-precision kinematic positioning system ITRS (International Terrestrial Reference System). Currently, research is being carried out to develop methods for integrating the international ITRS system into the country's territory, taking into account the relief and tectonic features of the regions. In particular, research is being carried out in the following priority areas: building a mathematical model of coordinate transformation, including information about the quasi-geoid, studying the influence of processing methods and the load of the environment (atmospheric, hydrological, etc.) on changing the coordinates of points, creating a local digital model of heights using data of global models the Earth's gravitational field [6-7]. From the point of view of solving these tasks, the problem of high-precision determination of velocities, first of all, reference and permanent points, is actual. The purpose of this work is to process and study the accuracy of reference stations of the network of reference geodetic points (RGP) MAGK (Tashkent), FARG (Fergana), JARQ (Dzharkurgan), and URGA (Urgench), and compare the horizontal velocities of points with the latest versions of global tectonic models such as ITRF 2014, GEODVEL 2010 and NNR - MORVEL 56.

2 Materials and methods

In 2005, the National Center for Geodesy and Cadaster started the establishment of the state geodetic GNSS network (SGN). Basically, the site selection aimed to cover geographically all densely populated eastern parts of the country's territory. It is both the most tectonically active and the most studied from this point of view. Also, the chosen station places fulfilled the standard required criteria, such as a clear view of the horizon without any obstructions and accessibility. The Geodetic receivers which perform precise baseline measurements were Dual-frequency Trimble receivers 4000 SSI and 4000 SSE. The antenna at all sessions of measurements was centered above the marker, directed to the North, and fixed vertically on the benchmark. SGN includes about 200 stations of several subnetworks:

- Reference Geodetic Points (RGP),
- Satellite geodetic network 0-the class points (SGN-0), and
- Satellite geodetic network 1st class points (SGN-1).

The RGP network was installed in 2005-2006. The network includes 4 points: MAGK (Tashkent), FARG (Fergana), JARQ (Dzharkurgan), and URGA (Urgench). But, the processing of these measurements and the assessment of their accuracy have not yet been completed. Taking into account the need for stage-by-stage processing of all levels of networks and the current needs of cadastral organizations, in this work, only the measurements of the RGP for 2005-2006 have been analyzed. Observation period from September 9 to November 9, 2005, and from August 15 to September 27, 2006.

The coordinates and velocities of the research stations were determined using the GAMIT/GLOBK software package version 10.7 developed at MIT (Massachusetts Institute of Technology), Harvard-Smithsonian Center of Astrophysics, and Scripps Institution of Oceanography [8-9]. GAMIT/GLOBK consists of various programs for processing GPS data, the startup sequence of which can be controlled using c-shell Unix utilities. The complex is mainly used to calculate daily solutions of coordinates, variance-covariance matrices, ambiguities, atmospheric delays, and orbit parameters. The basic stages of data processing in GAMIT/GLOBK are shown in Figure 1. To get a stable solution and accurately link regional measurements to the ITRF2014 international reference coordinate system [10], in addition to the KIT3, TASH points, 9 more stations of the international GNSS service for geodynamics, IGS (ARTU, BADG, CHUM, GUAO, HYDE, IISC, IRKT, MDVJ, POL2) were used. The height cutoff angle was taken as 15°. The initial stage includes the preliminary preparation of measurement files in RINEX (Receiver Independent Exchange Format) format and checking their quality in the TEQC program [11]. For all solutions, high-precision geocentric satellite orbits provided by the IGS were used.

Automatic iteration in the GAMIT block, using the least-squares method, is performed until the remaining values of the a-priori-specified and estimated coordinates are obtained down to the millimeter level. At the same time, in the autcln program, cyclic shifts are restored or removed using double or triple differences of observations. For each of the satellites, a broadband ambiguity of 95% was estimated using the combination of Melbourne-Wubben [12] and satellite delay code offset data. In addition, standard models were selected for analysis: the IERS-1992 gravitational field model [13], the nongravitational satellite acceleration model [14], the Saastamoinen (1972) model for estimating the dry and wet parts of atmospheric delays, the GPT2 global pressure and temperature model [15] for zenith delay correction and ocean tidal load model FES2004 [16].

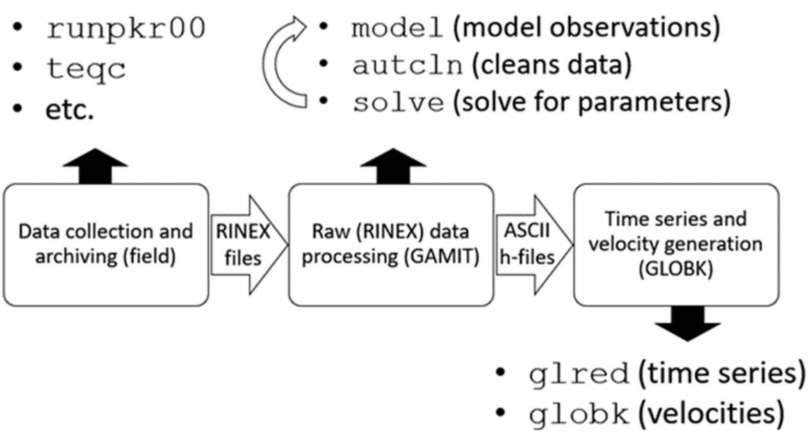
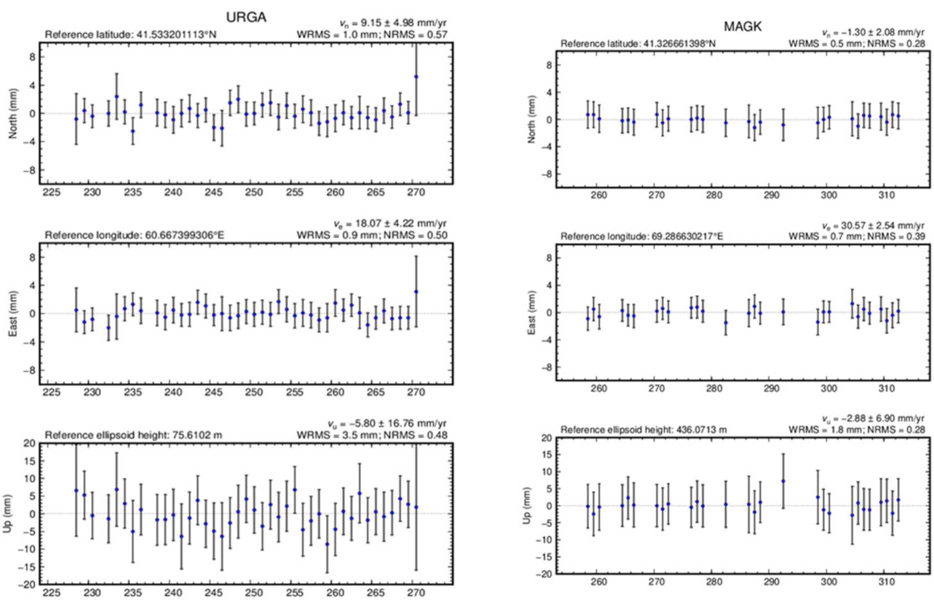


Fig. 1. The basic stages of data processing in GAMIT/GLOBK [8].

Horizontal velocities of the reference stations were compared with three recent global plate models (ITRF2014, GEODVEL 2010, and NNR- MORVEL56). ITRF2014 (International Terrestrial Reference System) is based on all available historical observations of four space geodetic methods (very long baseline interferometry (VLBI), satellite laser ranging (SLR), global navigation satellite systems (GNSS), and Doppler orbitography and radio positioning integrated satellite (DORIS)). For the model, for the first time, enhanced modeling of non-linear station movements was performed, including seasonal (annual and semi-annual) station position signals and post-seismic deformations for areas subjected to strong earthquakes [10]. GEODVEL 2010 (for GEODesy VELocity) is a plate model obtained by combining individual solutions of the analytical centers of four space-borne geodetic methods: DORIS, GNSS, SLR, and VLBI. Each technique solution was determined by one analysis center [17]. Model NNR-MORVEL56 is a geological plate model. For 20 of the 25 plates that comprise MORVEL, their relative motions are estimated using geological observations [18]. Horizontal velocities of RGP stations were estimated through the UNAVCO plate motion calculator website [19].

3 Results and discussion

At the first stage of processing raw RINEX files in the GAMIT module, an assessment of the quality of the measurements was made by using the standard deviation (RMS) values for the satellites and the stations. The error range for the best network's points is from 4 mm to 5 mm, and for the worst points is from 8 mm to 10 mm. The baseline uncertainty values indicate the adequacy of the initial data for obtaining a reliable solution. Ambiguities were resolved with 90 % for the wide lane and 80 % for the narrow lane, which confirms the noise-free pseudo-range. The normalized RMS is about 0.19 mm for all sessions. The generated time series (glred's step) for RGP stations are presented in Figure 2.



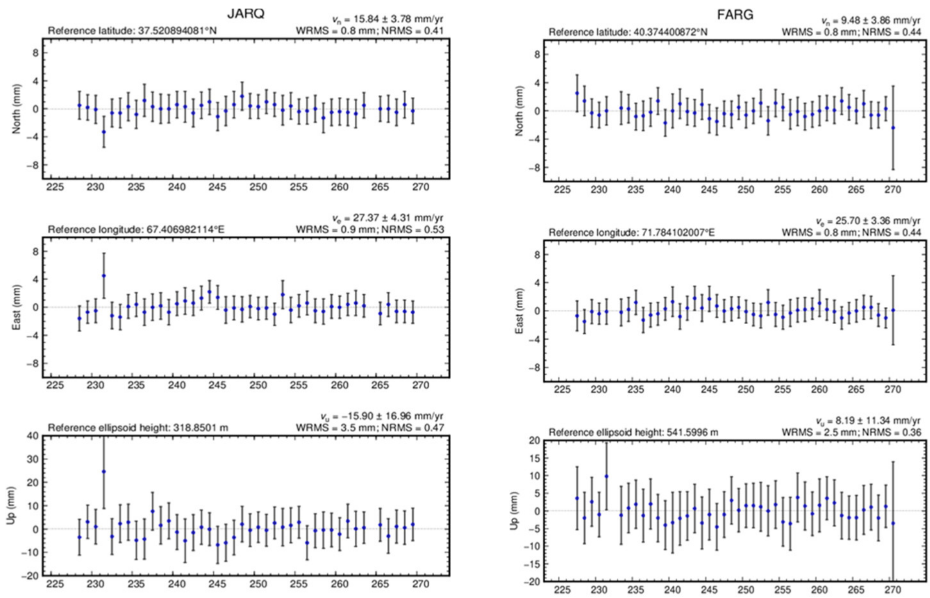


Fig. 2. The time series for RGP stations.

The calculated solutions had a horizontal coordinate, uncertainty, and repeatability, at the level of 0.5-1 mm for horizontal coordinates and 1.8-3.5 mm for height. As can be seen from the time series graphs, the normalized root mean square (NRMS) error is also close to 1. Therefore, we can conclude that all the necessary criteria for assessing the accuracy of both the measurements themselves and their processing performed in the GAMIT/GLOBK program are met and meet the requirements of the program developers [8].

The results of calculating the horizontal velocities of the RGP points in the GLOBK program and their comparison with the global tectonic models (ITRF2014, GEODVEL 2010, and NNR-MORVEL56) are shown in Table 1 and Figure 3. It is obvious that only the results for the points of the international Kitab network (KIT3) and Tashkent (TASH) are in better agreement with the results of the ITRF 2014 model. At the same time, the KIT3 point, unlike TASH, also has the same direction of the velocity vector that has been used as the reference point in the implementation of global models. For the rest of the points, the value and direction of the speed are certainly affected by both the relief features of the territory (MAGK, FARG, JARQ) and insufficient network density (URGA) when creating global models.

Table 1. The horizontal velocities of points according to GNSS measurements and global models.

Points	GNSS		ITRF 2014		GEODVEL 2010		NNR-MORVEL56	
	v_E, mm/y	v_N, mm/y	v_E, mm/y	v_N, mm/y	v_E, mm/y	v_N, mm/y	v_E, mm/y	v_N, mm/y
FARG	24.95	12.63	28.76	2.65	27.74	1.63	24.78	0.49
URGA	26.46	11.5	28.15	5.76	27.27	4.66	24.52	3.62
MAGK	25.94	6.73	28.62	3.36	27.64	2.32	24.76	1.2
JARQ	21.11	13.71	28.72	3.89	27.74	2.84	24.68	1.73
KIT3	31.61	2.05	28.64	4.04	27.67	2.98	24.71	1.88
TASH	25.94	6.73	28.62	3.36	27.64	2.32	24.76	1.2

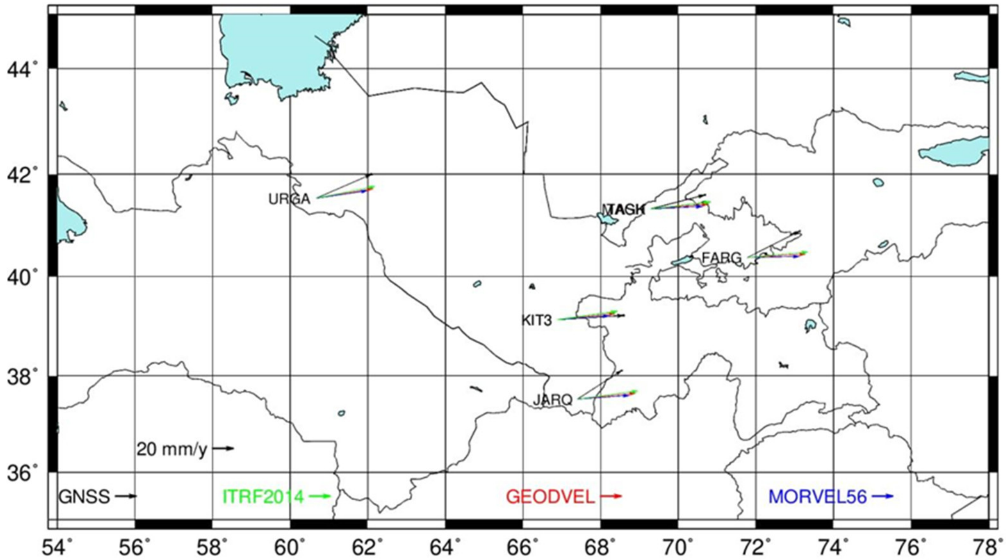


Fig. 3. The horizontal velocities of RGP points.

4 Conclusions

In this work, processing and preliminary assessment of the quality of measurements and the accuracy of the coordinates of the points of the reference network of Uzbekistan (MAGK, FARG, JARQ, and URGA) were carried out. Analysis of the time series of points showed the good quality of the measurements and the accuracy of the processed coordinates in the GAMIT/GLOBK program. While the calculated solutions had a horizontal coordinates uncertainty and repeatability, at the level of 0.5-1 mm for horizontal coordinates and 1.8-3.5 mm for height. However, the analysis of horizontal point velocities and comparison of the results with global tectonic models confirmed the need for further development of the regional geocentric network, taking into account the new model of modern movements in the region.

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