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Research Article

PROCESSING AND ANALYSIS OF GPS DATA IN GAMIT-GLOBK SOFTWARE FOR THE FIRST TIME IN UZBEKISTAN

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ABSTRACT
The article presents the fundamentals of satellite navigation: the principle of determining the transit time of the waves and the principle of operation of GNSS receivers, main types according to the degree of GPS receivers in terms of accuracy, sources of errors that reduce the accuracy of coordinates obtained using GPS, a stepwise process for processing GPS data into the program GAMIT-GLOBK, the results of research work carried out for the first time in Uzbekistan. The results of processing and analysis of GNSS measurement data in the GAMIT-GLOBK environment are used for monitoring endogenous geological processes, rapid assessment of changes in sharply deformed rocks in seismically active zones, are important in protecting the population and territories from dangerous natural disasters, and to a certain extent serve to ensure the seismic safety of regions.

Keywords: *GNSS, GPS, Transit Waves, GAMIT-GLOBK, H and GLX files, Modern Movements of the Earth's Crust, Stress-Strain State*

INTRODUCTION

Protection of the population and territories from natural and man-made disasters, including ensuring seismic safety, protection from hazardous natural processes are in the world practice one of the most urgent tasks of today. In the developed countries of the world, the geographic information system (GIS) serves as an important tool for monitoring endogenous geological processes, processing and analyzing space geodesy data (GNSS), and creating their models. In this regard, studies to assess the state of the earth's interior using modern methods of monitoring endogenous geological processes serve in the socio-economic and sustainable development of the country.

Currently, a number of scientific studies are being carried out in the world to assess endogenous geological processes, determine the stress-strain state of the geological environment, and develop models of modern movements of the earth's crust in order to solve the problems of predicting earthquakes. In particular, in the USA, Germany, France, Japan, South Korea, China, and Russia, when modeling the deformation state of the earth's crust, special attention is paid to the use of continuous data on the movement of points of the international cosmo-geodetic measuring system. This scientific approach allows processing and analyzing GPS data based on modern GIS technologies and modernizing the earthquake forecasting methodology.

In our country, comprehensive measures are being taken to assess the seismic hazard of the population and the territory of Uzbekistan. In particular, vertical movements of the earth's crust have been identified in the territories where strategic objects are located. The "Action Strategy for the Further Development of the Republic of Uzbekistan" defines the tasks for «...ensuring the life of the population in an ecologically safe environment...». In this regard, Pritashkent and the surrounding areas are considered one of the most densely populated areas of the republic in demographic terms, and are considered to have an important role in conducting comprehensive geological, geophysical and geodetic surveys in order to assess the stress-strain state of the region, taking into account the peculiarities of its development. it is known that direct research work on the study of the stress-strain state of the earth's crust is carried out by identifying modern vertical and horizontal movements in the first place. the results of the conducted research will serve to a certain extent to fulfill the tasks of the above problems.

MATERIALS AND METHODS

GPS (GNSS) is a global navigation satellite system used to determine coordinates (longitude, latitude and altitude) and UTC time at any point on the earth's surface. The velocity and direction of movement are determined by these indicators.

GPS consists of three different segments (Figure 1): 1. Space Segment - satellites orbiting the Earth; 2. Control Segment - the stations needed to control satellites, located near the equator; 3. User Segment - that receive and use GPS waves [Brennan, 2018].

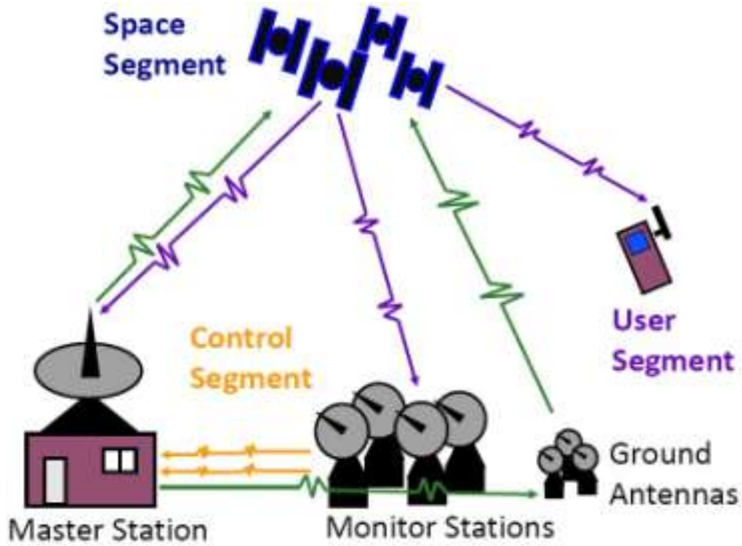

Figure 1: The three segments of the GPS [Brennan, 2018]

Today, the space segment consists of 32 satellites in motion, each orbital width of 4 to 6 satellites in 6 different orbits moving on a regular basis (Figure 2).

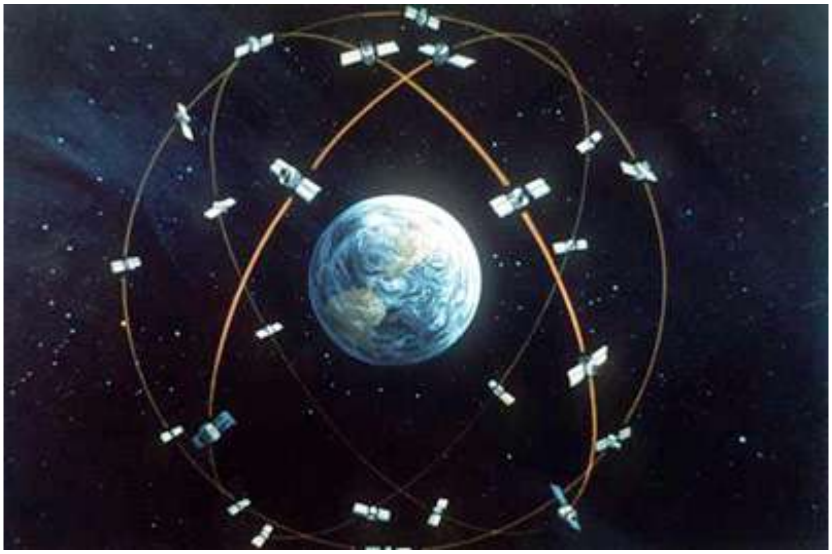

Figure 2: The Space Segments of GPS [Brennan, 2018]

The satellites are located at an average distance of 20000 km from the Earth's surface and 55^0 degrees from the equator. Each satellite completes a full circle in 12 hours. Due to the rotation of the Earth, the satellite returns to its original position in 23 hours 56 minutes. Each satellite carries a very high precision 4-atomic clock. The clock operates mainly at 10,23 MHz, which is used to transmit waves transmitted from satellites [Brennan, 2018].

The control segment consists of a main control station, 5 control stations and 4 terrestrial antennas, evenly distributed around the equator. The GPS satellites will be tracked through the control segment, their orbital position will be updated, and the atomic clock will be calibrated and synchronized. Satellite signals are received on stations in Ascension, Diego, Garcia, Kwajalein. The measurements are then sent to the main control station in Colorado Springs where they are processed for detection errors in the signal of each satellite, and automatically correct these errors [Brennan, 2018].

User segments are means of receiving GPS waves, for example, airplanes, buses, telephones, GPS devices, etc [Brennan, 2018].

GPS satellites are devices that transmission waves over time. To determine global positioning, at least four devices are needed that transmitter waves in time in three-dimensional space, based on the principle of determining the time of travel of a wave. Three-dimensional coordinates (longitude, latitude, altitude) are determined using waves transmitted over the entire measurement time of the four satellites. Consider this process in the following example. Distance can be determined relatively easily: distance = instant of lightning flash (start time) and instant of lightning sound appearance (end time), the difference is multiplied by the speed of sound (about 330 m/s). Based on this, the time of passage of the wave is determined [Brennan, 2018].

Distance = time of passage wave • speed of sound

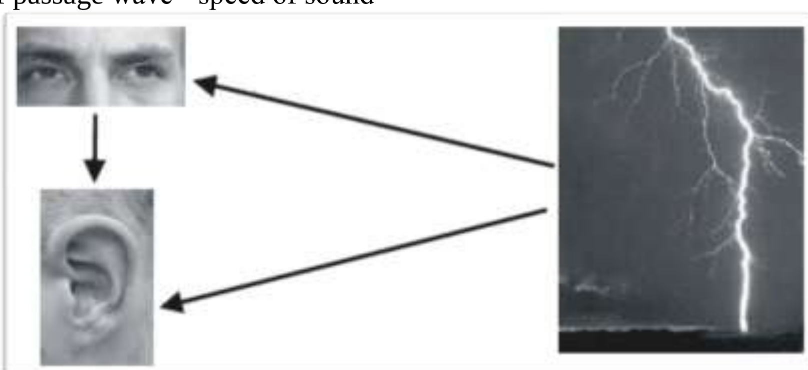

Figure 3: The principle of determining the transit wave time [Brennan, 2018]

The GPS system works in the same way. To calculate the exact position, we need to measure the transit wave time of an electromagnetic wave between four other satellites with a known point and location (Figure 4).

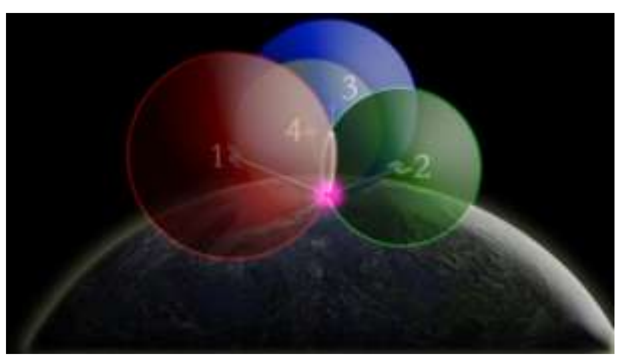

Figure 4: The principle of determining coordinates in three-dimensional space [Brennan, 2018]

There are different ways to determine coordinates using GNSS. The choice depends on the level of accuracy, customer requirements and the type of GPS receiver. In general, the methods can be divided into three main classes: autonomous navigation, coordinate accuracy 20-100 m; differentially corrected positioning, coordinate accuracy 0,5-5 m; differential phase position, coordinate accuracy 0,5-20 mm [Brennan, 2018].

The accuracy of GPS data is associated with several types of errors. Up until this point on practices, it has been assumed that the position derived from GPS is very accurate and free of error, but there are several sources of error that degrade the GPS position from a theoretical few meters to tens of meters. These error sources are: 1. Ionospheric and atmospheric delays; 2. Satellite and Receiver Clock Errors; 3. Multipath; 4. Dilution of Precision; 5. Selective Availability (S/A); 6. Anti Spoofing (A-S) [Brennan, 2018].

In field observations, GPS measurements are performed in real-time, that is, mobile stations must simultaneously register satellite waves. GPS devices must work in static mode for at least 8 hours, the accuracy of the results depends on the long-term operation of GPS stations. Since the GPS satellite takes 24 hours to orbit the Earth, turn around accuracy is achieved by continuous measurements over 1, 2, and 3 days. The accuracy of the results obtained from permanently operating GPS stations is high as measurements are taken every 30 seconds. Our GPS surveys were based on highly accurate differential phase positions.

The reason the GPS data has not yet been fully processed in Uzbekistan is that the above cases have not been excluded from processing. In our study, the sources of GPS errors that reduce the accuracy of the data were taken into account, and they were excluded during processing based on the GAMIT-GLOBK program.

POST PROCESSING GPS DATA

The GPS data processing was carried out on the basis of the GAMIT-GLOBK program, developed by scientists at the Massachusetts Institute of Technology in the United States, working in the Linux / Unix operating system [Herring *et al.*, 2006; Herring *et al.*, 2016]. The advantage of the program is that it works in a semi-automatic mode.

GPS data available on the Internet, GPS data from partner organizations, measured GPS data are collected in one place for processing in the form of the GPS data on the flow chart of the GAMIT-GLOBK below (Figure 5).

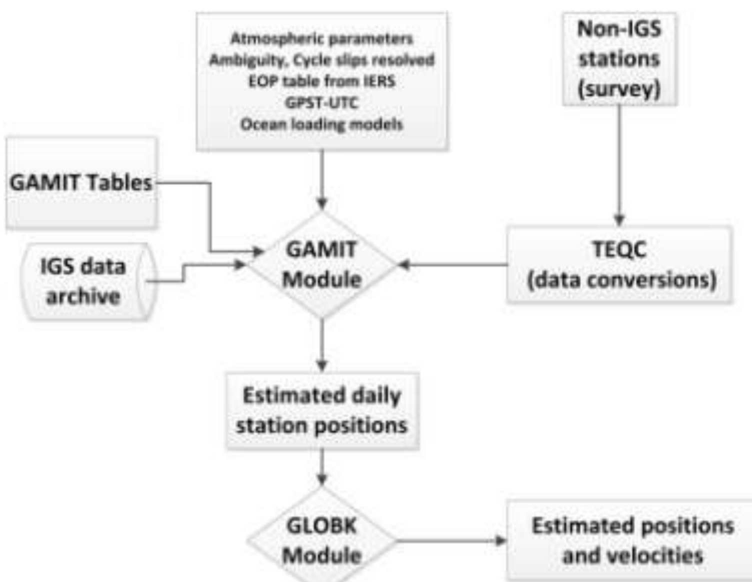

Figure 5: Simple flow chart of the GAMIT-GLOBK [Munghemezulu *et al.*, 2014]

At the first stage of the process of processing in the GAMIT program, the measured GPS data in partner organizations and field conditions are brought into a system with the data of the world GPS networks. That is, almost all the characteristics of GPS devices are will bring uniformity. For the reason that the processing process has passed in the semi-automatic state, it is necessary to put in place all the incoming data in the processing process.

In field work, measured "raw" data is copied to the computer. GPS data is transferred to the RINEX format through the TEQC special program. Below is an example of the processing process for the Fergana GPS stations together with the data of 2011 on 190, 191, 192, 193, 194 days, data of 2012, 2013 in the same days of the year. The internal appearance of the RINEX format can be seen in Figure 6 below [Shukurov, 2020].

```
fgna1900.11o | fgna1910.11o | fgna1920.11o | fgna1930.11o | fgna1940.11o

     2.11           OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
teqc  2018Jun8                          20180703 09:34:42UTCPGM / RUN BY / DATE
Linux 2.6.32-573.12.1.x86_64|x86_64|gcc -static|Linux 64|=+ COMMENT
BIT 2 OF LLI FLAGS DATA COLLECTED UNDER A/S CONDITION       COMMENT
FGNA                                                        MARKER NAME
ZAHA                ISUZ                                    OBSERVER / AGENCY
356725              LEICA GRX1200GGPRO  8.00/3.019          REC # / TYPE / VERS
                    LEIAT504GG NONE                         ANT # / TYPE
  1521195.7291  4622420.5851  4110096.3681                  APPROX POSITION XYZ
        0.3000        0.0000        0.0000                  ANTENNA: DELTA H/E/N
     1     1                                                WAVELENGTH FACT L1/2
     6    L1    L2    C1    P2    S1    S2                  # / TYPES OF OBSERV
    10.0000                                                 INTERVAL
                                                            COMMENT
Project creator:                                            COMMENT
 SNR is mapped to RINEX snr flag value [0-9]                COMMENT
  L1 & L2: min(max(int(snr_dBHz/6), 0), 9)                  COMMENT
  2011     7     9     0     0    0.0000000     GPS         TIME OF FIRST OBS
    15                                                      LEAP SECONDS
                                                            END OF HEADER
 11  7  9  0  0  0.0000000  0 14G24G19G14G22G11G18G31G09R17R12R01R02
                                R18R11
 126166108.444 6  98311262.26245  24008612.780    24008612.420          41.500
        34.750
 124836029.583 7  97274815.75846  23755507.120    23755503.420          46.000
        40.500
```

Figure 6: The RINEX format of Fergana GPS station

As noted above, the errors, which reduces the accuracy of the coordinates, is extracted from the values of the primary X, Y, Z coordinates in the RINEX file through the GAMIT program, and as a result, the H-file is created. When the process of processing in the GAMIT program comes to half a stage, the graphs that reflect the accuracy of the H-files of the GPS station are obtained. From these graphs, the accuracy of H-files is checked. If we are satisfied with the accuracy of the H-files, we will proceed to the next stages, otherwise, we will return to the first stage and check that everything is in place and correct, after which the process will continue again [Shukurov, 2020].

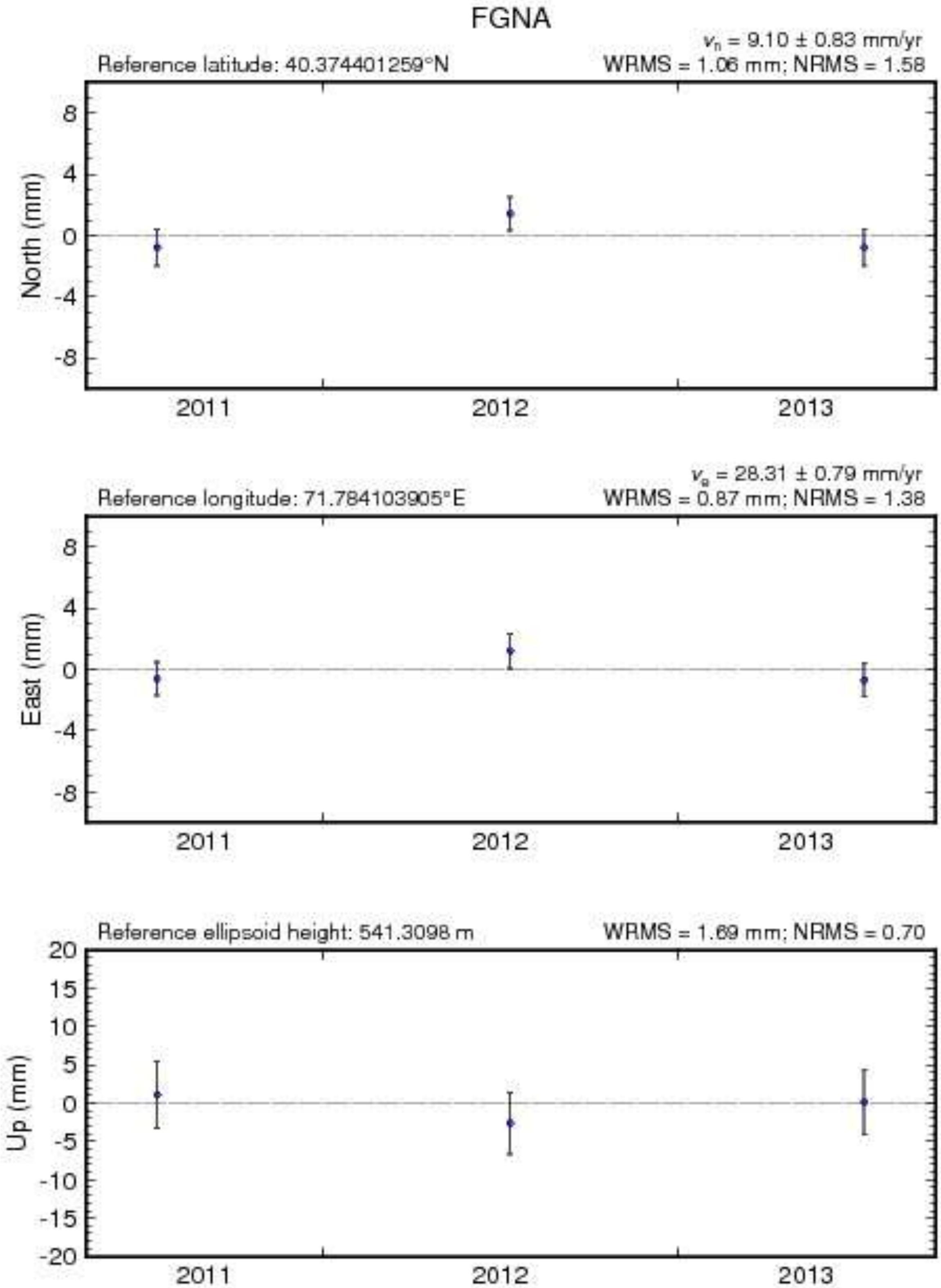

Figure 7: Checking the accuracy H-file of Fergana GPS station

In the final stage of processing in the GAMIT program, the time series of the coordinates of the points, the table of the velocity of the rappers - the velocity table of the annual average horizontal and vertical movements of the GPS stations rappers is obtained. As an example, Figure 7 below shows the accuracy of the Fergana GPS station H-file [Shukurov, 2020].
Once the accuracy of the H-Files is checked, they are added, that is, the GLX-files are created and brought to a holistic overall state. The GLX-files that are listed in the general condition are processed through the GLOBK program (Figure 8).

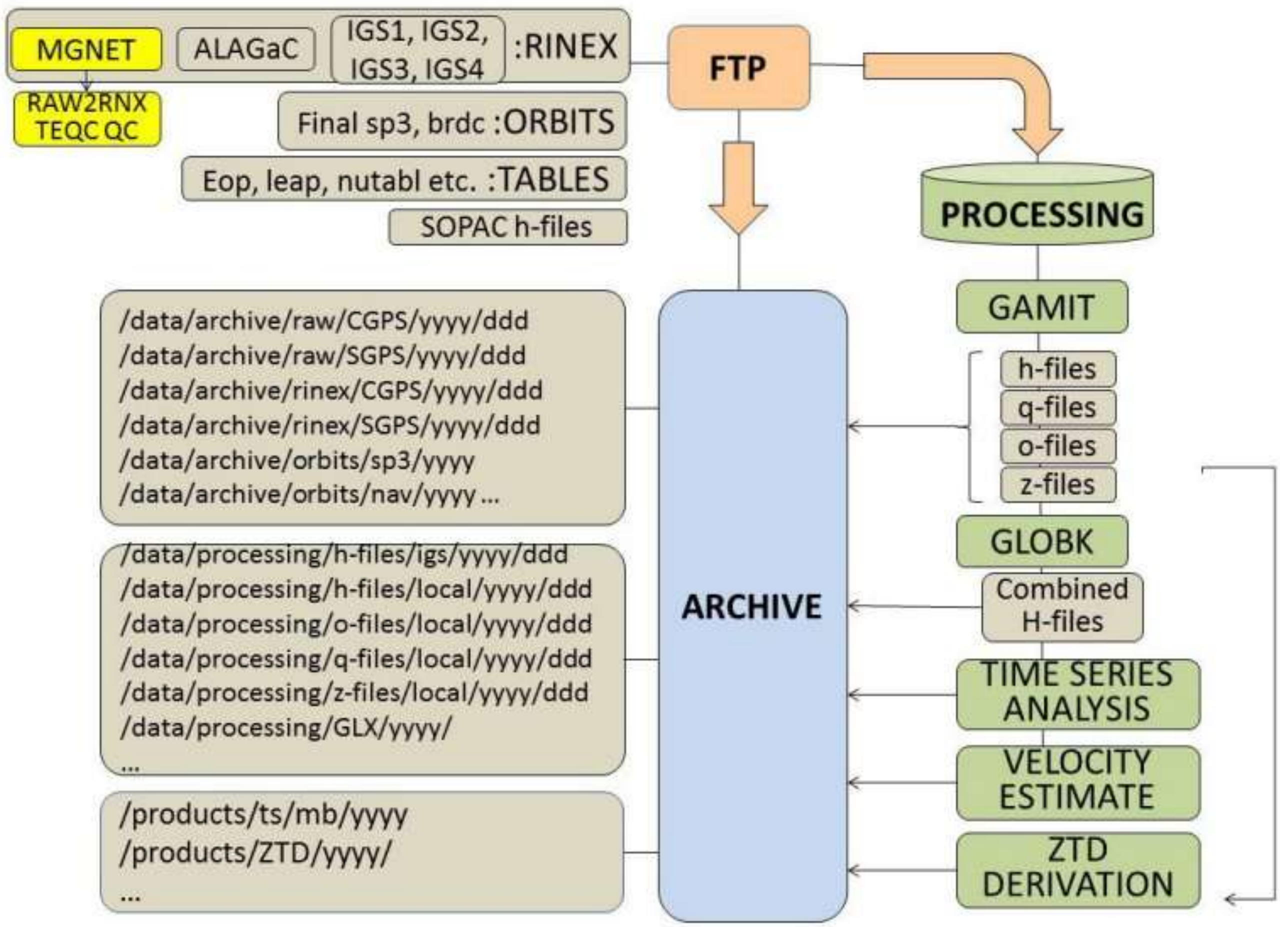

Figure 8: GPS data processing block diagram [Amarjargal *et al.*, 2016]

Based on the block scheme presented in Figure 8, the algorithms are conditionally divided into actions that were carried out before the launch of the globk and glred modules and were associated with the launch of globk and glred. Prior to the launch to the launch of globk and glred modules, the activity was related to the GAMIT program, while activities related to the launch of globk and glred were related to the GLOBK program. In the above block-scheme, almost all the actions of GAMIT-GLOBK are harmonized. Based on this block-scheme, through computer technology, it is possible to create a new program that processes GPS data by creating algorithms that embody ammals.

RESULTS AND DISCUSSION

In GLOBK, the data processing is semi-automatic, with two types of results:

1. Time series of coordinates of rappers (Herring *et al.,* 2006).
2. Table of velocity of rappers (Herring *et al.,* 2006).

The result to be determined in our research work is obtained, that is, a table of velocities of rappers. This table reflects the results of GPS data measured in 2011-2013 years. Below is the table, the average annual rate of movement of the Earth's crust obtained through the GLOBK program for 3 years.

Table 1: The velocities of movement of the earth's crust of stations of the GNSS network in Uzbekistan and adjacent regions in recent years (relative to the center of the Earth)

Coordinates		Horizontal velocity, $mm \cdot year^{-1}$		Height, $mm \cdot year^{-1}$	Station Code
Longitude	Latitude	Eastern components	Northern components		
115,89249	39,60860	31,32	-11,56	-0,31	BJFS*
107,05233	47,86507	28,22	-8,56	0,80	ULAB
104,31624	52,21902	24,55	-7,17	1,03	IRKM*
96,83397	-12,18834	45,05	64,71	5,94	COCO
91,10403	29,65733	44,74	17,76	1,00	LHAZ*
87,60067	43,80795	31,82	6,88	1,49	URUM
82,90949	55,03050	24,67	0,21	-3,53	NOVM*
77,57038	13,02117	45,88	38,79	0,89	IISC*
74,75110	42,99850	27,06	2,51	-4,64	CHUM*
74,69427	42,67977	27,81	4,96	-1,36	POL2*
72,77750	40,52993	27,46	9,09	-1,28	OSHK
71,78410	40,37440	27,99	9,43	-0,35	FGNA
69,29557	41,32805	24,02	3,27	-2,97	TASH*
66,88545	39,13477	28,73	4,72	0,27	KIT3
58,56046	56,42982	25,85	5,81	4,30	ARTU*
33,39645	35,14099	19,58	16,57	-1,63	NICO*

As a result of the research work carried out, for the first time in the conditions of Uzbekistan on the basis of the GAMIT-GLOBK program, the horizontal and vertical velocities of the modern movement of the Earth's crust in eastern Uzbekistan and the surrounding regions have been researched. As well as, Tashkent, Fergana, Kitab, and additional 13 more GPS points modern movements determined (table).

Based on the above table, the results of the average annual velocities of movement of GPS stations in the East and North directions were processed and analyzed on the basis of the GLOBK program. This East component is the distance from the 0° Meridian to the GPS station, while the North component is the distance from the Earth's equatorial line to the GPS station. Based on the horizontal movements of these two components of the East and North in 2011-2013, a vector map of the average annual rates of horizontal movement of the earth's crust relative to the center of the Earth was compiled (Figure 9).

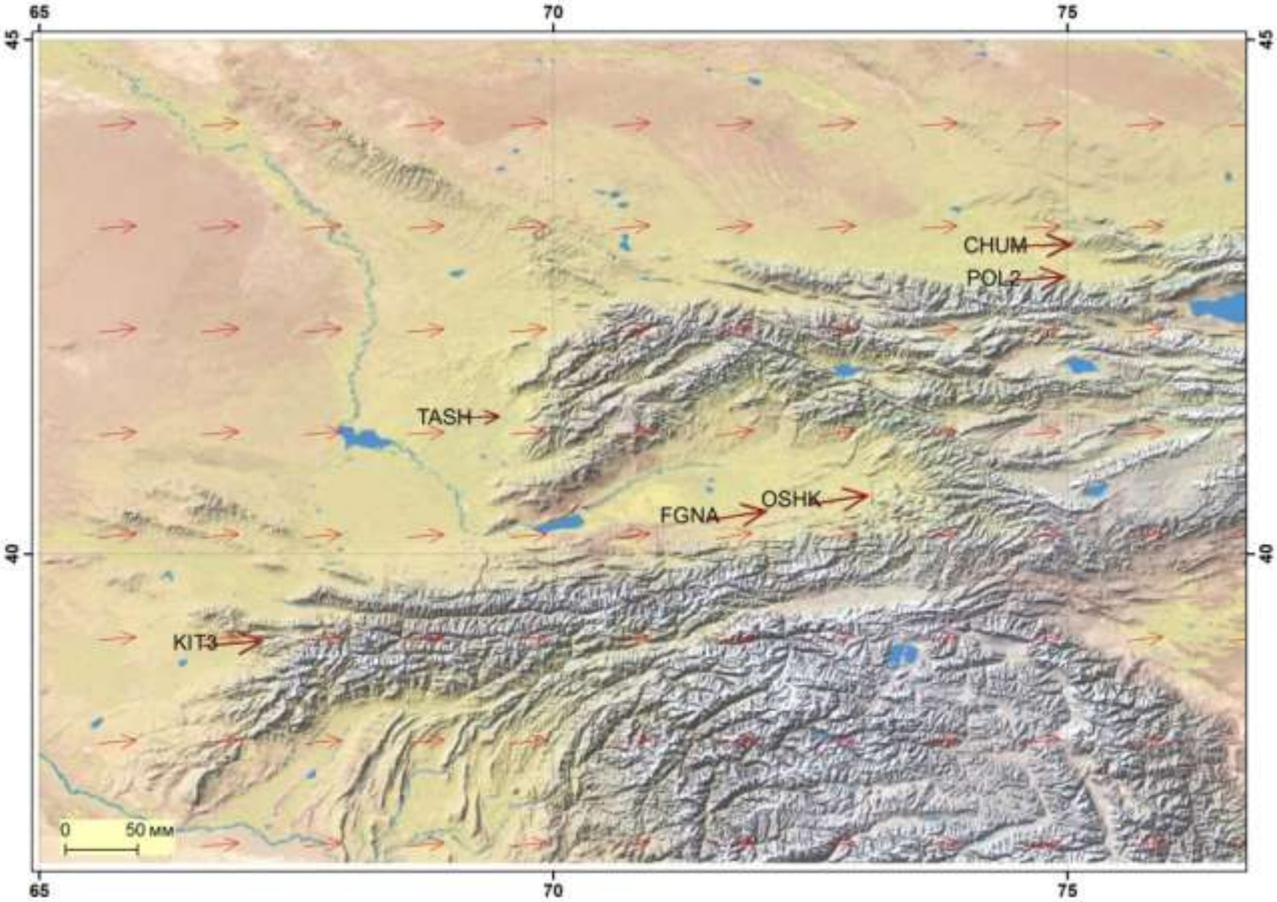

Figure 9: The Globk model of the annual average horizontal velocities of the Earth's crust in the regions of eastern Uzbekistan and the surrounding region, in comparison with the Earth's Center

CONCLUSION

For the first time in the conditions of Uzbekistan on the basis of the GAMIT-GLOBK program, the results of the latest period measurement of the Eastern Uzbekistan and the surrounding regions were brought into a single territorial system and provided for processing. The results of Tashkent, Fergana, Kitab and more 13 GPS stations provide an opportunity to identify modern horizontal and vertical movements of the Earth's crust, systematically monitor and analyze modern movements of the Earth's crust. Processing and analysis of GPS measurement data in the GAMIT-GLOBK environment using cosmogeodetic methods made will possible to analyze the variability of vertical and horizontal movements formed in the influence of geological and tectonic processes in the Earth's crust in eastern Uzbekistan and the surrounding regions, as well as assessment of Geodynamic processes in recent years.

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