GNSS Permanent Networks in Kyrgyzstan

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***Abstract* - Geodetic applications of the Global Navigation Satellite Systems - GNSS technology in Kyrgyzstan are increasing. Use of full power of satellite based positioning can be achieved in case of employing local (national, regional) networks of GNSS permanent stations serving as control points as well as for satellite signal corrections. There are networks of such stations in Kyrgyzstan operated by international and local organizations, companies and institutions. Investigation and analysis of temporal and spatial parameters of operational GNSS networks can improve the further development and applications of the precise satellite positioning for various purposes. The research work focused on investigations of the operational permanent GNSS networks in order to maximize the benefit from combined use of sparsely located continuously operating stations.**

I. INTRODUCTION

The Global Navigation Satellite System (GNSS) has been actively used as a geodetic tool, which provides precise vector measurements over long and short distances. It is used for solving the wide range of positioning tasks in engineering survey, land cadaster and urban mapping, construction and transportation, geodynamic studies, military and other applications. The different methods of global satellite positioning and navigation allow achieving position accuracy down to the millimeter level. Applied use of these systems gives significant economic efficiency on geodetic works worldwide by reducing the required resources and time. The geodesy science and technologies have experiencing dramatic changes created by real time and long term precise measurements by using GNSS technologies [1]. The combination of satellite navigation, internet, wireless communication and geoinformation technology is perfect mix on contemporary technologies. Integration of these advanced technologies launched many new applications, which could not be imagined before.

Efficient and precise GNSS positioning available by using satellite or ground-based augmentation systems. Only few developed countries have own satellite based augmentation systems, which are technologically complex and expensive systems used in combination with ground based systems. Such systems significantly improves capacities of GNSS by enabling the satellite based geodetic positioning. The most popular ground-based augmentation systems are feasible and implemented in many countries including Kyrgyzstan.

The ground-based augmentation system consists of continuously operating GPS/GNSS receivers with antennas mounted on buildings or terrain peaks and connected with service centers by internet, telephone or computer network. These networks are expensive and require advanced technological and methodological solutions.

The traditional requirement to occupy physical geodetic monuments or control points in the field can be replaced by downloading the satellite tracking data available online from appropriate continuously operating reference stations (CORS) where their density is sufficient. These stations also known as active stations and their networks as Active GNSS Networks. They are frequently administered by governmental organizations, some are managed by public-private organizations and some are commercial ventures [2]. The service coverage areas of the Active GNSS Networks are limited with insufficient numbers of CORS and there are deficiencies on satellite differential correction services needed for geodetic observations in many countries. Other operational networks of passive GPS/GNSS permanent stations can be useful in areas without or with sparsely located active CORS for precise geodetic measurements by applying collected datasets in post-processing to remove all types of environmental and physical range biases.

II. ACTIVE GNSS NETWORK OF KYRGYSTAN

The Active GNSS Network in Kyrgystan with 18 continuously operating reference stations (CORS) started providing public service in 2010. The GNSS Reference Network Control Center "KyrPOS" is established by the Department of Cadaster and Registration of rights on immovable property, State Registry Service of the Kyrgyz Republic (DCR SRS KR) [3]. It is operating and managing the network by providing satellite differential corrections for users of GPS/GNSS field receivers on base of Trimble® Pivot Platform GPS NET software. At present time the Center controls 18 permanent stations, 6 of which cover Chui oblast (province), 8 cover Fergana valley, 1 in Naryn oblast and 3 installed in Issyk-Kul oblast (see Table 1). All stations have internet connection with central server and support the high accuracy cadastral and geodetic GPS/GNNS surveys in the most populated regions of country where main active property markets are concentrated (see Fig.1).

The current GNSS surveying technology requires permanent reference stations located in 25-50 km from each other for the precise and reliable satellite positioning. However, the ongoing modernization of GPS and the full operational capability of GLONASS, with the deployment of other GNSSs, are expected to support 2-cm level Real-Time Kinematic (RTK) and Real-Time

TABLE 1. GPS/GNSS PERMANENT NETWORKS IN KYRGYZSTAN [5, 6, 7, 8, 9]

#	Site ID	Network/Operator (Country)	Satellite system/ Observation data	Permanent station coordinates in WGS84		
				Latitude, °	Longitude, °	Height, m
1.	CHUM	IGS/IVTAN (KZ)	GPS	42.9985	74.7511	716.33
2.	POL2	IGS/ IVTAN	GPS	42.6798	74.6943	1714.20
3.	KAZA	UNAVCO/IVTAN	GPS	41.3849	73.9435	1409.45
4.	KMTR	UNAVCO/IVTAN	GPS	41.8678	78.1995	4169.00
5.	TALA	UNAVCO/IVTAN	GPS	42.4455	72.2104	1499.77
6.	BATK	KyrPOS	GPS, GLONASS	40.0609	70.8215	1043.29
7.	BEL_	KyrPOS	GPS, GLONASS	42.8261	74.0961	716.85
8.	BISH	KyrPOS	GPS	42.8745	74.6430	730.55
9.	CHPA	KyrPOS	GPS	42.6463	77.0785	1599.19
10.	JALA	KyrPOS	GPS, GLONASS	40.9318	72.9810	732.99
11.	KAN_	KyrPOS	GPS, GLONASS	42.8978	74.8431	703.35
12.	KAR1	KyrPOS	GPS	42.7983	73.8550	787.51
13.	KEMI	KyrPOS	GPS	42.7802	75.6890	1091.26
14.	NOOK	KyrPOS	GPS, GLONASS	40.2653	72.6156	1264.61
15.	OSH_	KyrPOS	GPS	40.5607	72.8054	918.59
16.	TOKM	KyrPOS	GPS	42.8250	75.2818	785.02
17.	UZGE	KyrPOS	GPS, GLONASS	40.7592	73.2806	933.30
18.	ALAB	KyrPOS	GPS, GLONASS	41.4047	71.4955	1227.27
19.	BAlY	KyrPOS	GPS, GLONASS	42.4627	76.1939	1612.90
20.	ISFA	KyrPOS	GPS, GLONASS	39.8378	69.5245	1266.11
21.	KOCH	KyrPOS	GPS, GLONASS	42.2129	75.7548	1777.34
22.	TASH	KyrPOS	GPS, GLONASS	41.3477	72.2229	569.45
23.	TON_	KyrPOS	GPS, GLONASS	42.1182	76.9945	1772.91
24.	ABRA	CAWa/CAIAG	GPS	39.6486	71.5858	4091.58
25.	ALAI	CAIAG	GPS	39.5265	72.1659	2600.97
26.	ARSL	CAIAG	GPS, GLONASS	41.2436	72.9814	963.67
27.	ASAI	CAIAG	GPS	40.9178	76.5210	3024.38
28.	BIS2	CAIAG	GPS	42.8541	74.5331	744.89
29.	KEKI	CAWa/CAIAG	GPS	41.8484	74.3344	1442.58
30.	KRBK	CAIAG	GPS, GLONASS	42.7756	78.3609	1648.90
31.	KRGT	CAIAG	GPS, GLONASS	42.4994	78.5804	1924.33
32.	TKUM	CAIAG	GPS, GLONASS	41.3587	72.2343	602.33

Network (RTN) surveys with larger inter-CORS distances of up to 140-180 km in the future [4]. The distribution of Kyrgyz Active GNSS network CORSs shows the lower number of active stations needed for the full coverage of the economically active regions at this time. There are about 100 GPS/GNSS observed temporary base stations with adjusted precise coordinates for differential GNSS observations and survey control.

GPS/GNSS measurement data from CORSs (see Fig.2) of the Kyrgyz Active GNSS network is transferred to KyrPOS where the data are stored, processed, differential corrections are determined and transferred to the users in real time (RTK/RTN). The communication with and transfer of differential corrections to the GNSS receivers of users are realized with GSM/GPRS services of mobile telecommunication providers. At present time the most of users of the Active GNSS network are regional branches of DCR SRS KR and the GNSS Reference Network Control Center is providing such differential correction services without payment.

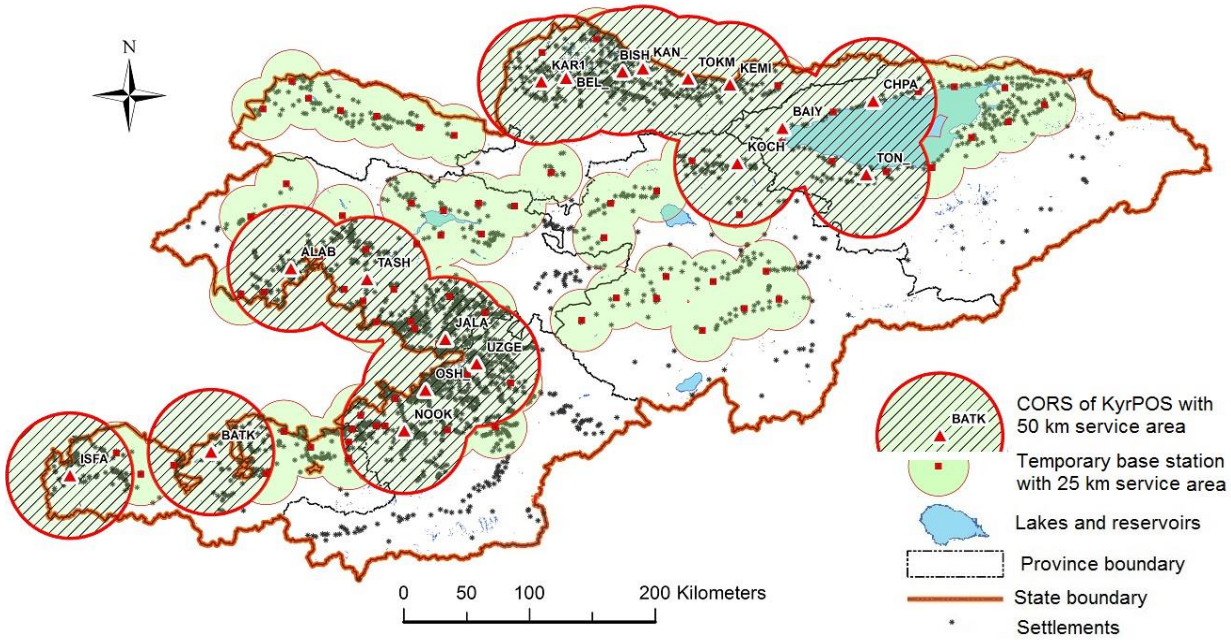

Figure 1. Active GNSS network in Kyrgyzstan [7]

III. OTHER GNSS PERMANENT NETWORKS

There are passive GPS/GNSS permanent stations of other networks operated by international and local organizations, companies and institutions in Kyrgyzstan and other Central Asian countries. These stations has been integrated into networks of stations providing satellite orbit and clock correction, precise point positioning, time synchronization and many other public-benefit applications. The Joint Institute for High Temperatures (IVTAN) of the Russian Academy of Sciences (RAS) is the long term GPS/GNSS service provider with 10 permanent GPS/GNSS sites located in Kazakhstan and Kyrgyzstan (Fig.3). Data acquisition and maintenance of these permanent sites (installation, setup, repair and replacement of equipment) is carried out by staff of the Research Station, RAS. Most of these sites are included in operational arrays of the International GNSS Service (IGS) and UNAVCO - Nonprofit university-governed consortium [7]. Many scientific and applied research activities are realized in the region by combined use of these networks benefiting their integrated capacities.

Figure 2. GNSS antenna of KyrPOS CORS [7]

IGS network

The International GNSS Service (IGS) has ensured open access, high-quality GNSS data products since 1994. The IGS, as a component of the Global Geodetic Observing System, operates a global network of GNSS ground stations, data centers, and data analysis centers to provide data and derived data products that are essential for Earth science research; multi-disciplinary positioning, navigation, and timing (PNT) applications; and education. The IGS Reference Frame Coordinator determines tracking site coordinates and velocities in the International Terrestrial Reference Frame (ITRF), and organizes the IGS contribution to ITRF [5].

The IGS network is a collection of heterogeneous stations operated by many different organizations pooling their resources under the IGS umbrella for the common good. There is a permanent station POL2 (Poligan IVTAN 2) in Kyrgyzstan included in the operational array of IGS since 1997. This station is installed in 30 km to the southeast from Bishkek city in 1995 and operated by IVTAN in shared responsibility with the Jet Propulsion Laboratory (JPL USA). Another IGS station included in this study is CHUM (Chumysh), which is located in Kazakhstan close to the border with Kyrgyzstan. This GPS site is in use for GNSS observations and geodynamic studies by benefiting its close distance to Kyrgyzstan, reliable and long-term service since 1997.

Through the Real-time Service (RTS), IGS extends its capability to support applications requiring real-time access to IGS products. RTS is a GNSS orbit and clock correction service that enables precise point positioning (PPP) and other related applications at worldwide scales. RTS is based on the IGS global infrastructure of network stations, data centers and analysis centers that provide

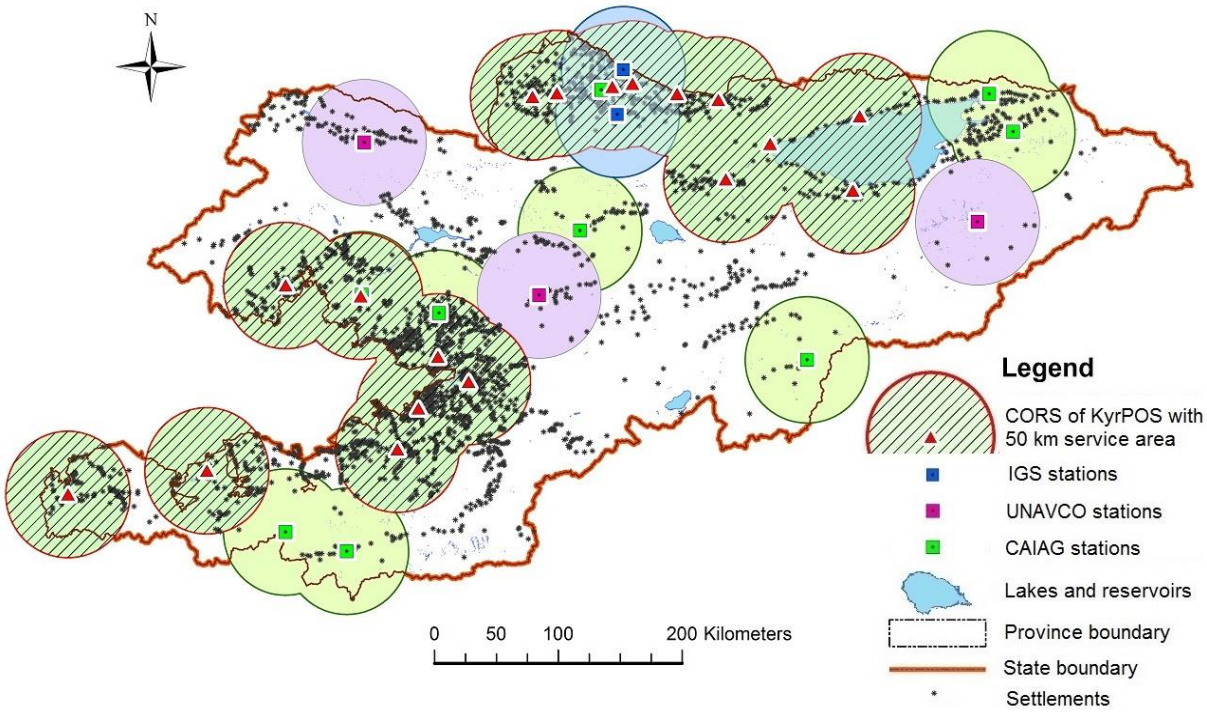

Figure 3. GNSS Permanent Networks in Kyrgyzstan

world standard high-precision GNSS data products. IGS stations are included and downloadable from the UNAVCO data archive.

UNAVCO network

UNAVCO promotes research by providing access to data that community of geodetic scientists uses for quantifying the motions of rock, ice and water that are monitored by a variety of sensor types at or near the Earth's surface. After processing, these data enable millimeter-scale surface motion detection and monitoring at discrete points and high-resolution strain imagery over areas of tens of square meters to hundreds of square kilometers. The data types include GPS/GNSS, imaging data such as from SAR and TLS, strain and seismic borehole data, and meteorological data. Most of these data can be accessed via web services [7].

The interactive GPS/GNSS Data Access Methods help users visualize the data types that are available and to explore the variety of tools and methods of access. In addition to direct ftp access, several Application Programming Interfaces (APIs) and web based graphical user interfaces are available, along with map-based visualization tools.

There are two GPS stations (TALA-Talas, KAZA-Kazarman) in Kyrgyzstan and a GPS site PODG (Podgornoe) in Kazakhstan operated by IVTAN, which are included in the UNAVCO global network and considered in this study. KMTR (Kumtor-2) is the most eastern and highest GPS permanent station installed in Issyk-Kul region of the country and operated by IVTAN since 2000. The permanent station PODG, which is located in Kazakhstan, can be useful in precise satellite positioning in the most eastern part of Kyrgyzstan.

Data from UNAVCO/IVTAN permanent stations is collected normally every day and then is transferred or delivered to RS RAS and UNAVCO. Permanent sites are aimed mainly at geodynamic monitoring and spatial coupling between GPS/GNSS sites of the network during campaign measurements [9]. Availability of GPS/GNSS data processing, archiving and access services of high-precision satellite observation data by UNAVCO enables this network in geodetic and geophysical applications.

CAIAG network

The Central Asian Institute of Applied Geosciences (CAIAG) is focused on studying those processes in the Earth system, which have the highest impact on the developing society in the Central Asian region as earthquake and landslide hazards and risks, glaciology, climate and water. CAIAG has operation and long-term maintenance of networks for the monitoring of processes, which includes seismic, geodetic, geo-electric and hydro-meteorological sensor networks all over Central Asia.

At the current time the regional network of GPS/GNSS sites and other monitoring stations installed jointly and operated by CAIAG consists of 23 permanent stations in Kyrgyzstan (Fig.3), Tajikistan and Uzbekistan. Most of monitoring stations have GNSS receivers in addition to the seismo, meteo, hydro, and other sensors [8].

One of stations with the most stable and quality data service is a GNSS station BIS2 (Bishkek-2). It is mounted on CAIAG's building and provides online communication with institute's and international data centers.

GPS/GNSS stations investigated in this study include KRGT (Kerege-Tash) on northern slope of the range Terskey-Alatoo mountains and KRBK (Kara-Batkak) in southern foothills of the range Kungey-Alatoo mountains. Other two stations ARSL (Arslanbob) и TKUM (Tash-Kumyr) are located to southwest from Fergana range near Togtogul hydro power station. Other stations of CAIAG

network, included in this study, are ABRA (Abramov) at Abramov glacier, ASAI (Aksai) at eastern end of Aksai valley, ALAI (Alai) in the western part of the Alai valley and KEKI (Kokomeren) at the Kokomeren river [8].

The Central Asian Institute of Applied Geosciences (CAIAG) has advanced hardware, software and information systems, geodatabase portals as well as data transfer systems and facilities. The archive of collected GPS/GNSS data is available for scientific and applied use upon request from CAIAG administration.

IV. SPATIAL AND TEMPORAL CAPACITIES OF GNSS PERMANENT NETWORKS

GPS/GNSS observation data received from permanent network stations in Kyrgyzstan, operated by IGS, UNAVCO, KyrPOS and CAIAG, are selected for further processing and analysis in the research. These networks have different functional purposes, number of GPS/GNSS sites and areal coverage, data collection, communication networks and data access policies. The temporal and spatial parameters of available datasets of these networks have being the main objectives to investigate.

The Receiver Independent Exchange Format (RINEX) files of 24-hour GPS/GNSS observations from the selected permanent network stations are collected and integrated in the study. Leica Geo Office software was used in data processing and analysis. Satellite observation datasets were downloaded from IGS and UNAVCO websites and received from GNSS permanent network operators - KyrPOS and CAIAG.

The operational six IGS and UNAVCO stations are providing the most reliable and continuous datasets through web based open data access platforms [5, 7]. These stations have been used in the post-processing of data and precise point positioning as additional reference points (Fig.3).

18 continuously operating reference stations of the Active GNSS Network in Kyrgystan, managed by KyrPOS, are providing satellite observation and differential correction services to users. The investigation has identified 12 of total 18 CORS with the most reliable and quality services based on expert evaluation of observation periods, data communication and processing parameters. Other 6 stations have been used on temporary base according to the demand from users, limited operation and maintenance of hardware, disruptions of power and communication.

The passive GNSS network of the Central Asian Institute of Applied Geosciences (CAIAG) can be applied in geodetic surveying benefited with sophisticated infrastructure and professional staff. CAIAG is developing the Central Asian Geodatabase promoting spatial data sharing policy and regional research cooperation. The institute has provided needed datasets, excellent research collaboration in this study and selected GPS/GNSS permanent stations of CAIAG were included in the combined network calculations.

The spatial and statistical analyses show that 44% of the most densely populated and economically active areas (cities, aiyl okmot-local municipalities) are covered with RTK/RTN service by KyrPOS with assumed 50 km radius service area (Fig.3). High mountainous territories of Kyrgyzstan do not have ongoing engineering, agricultural and other economic activities, which impede further extension of the Active GNSS network in these areas. The full coverage of the economic active areas with RTK/RTN services will be available by increasing the needed number of CORS up to 30 by applying the latest and more efficient network technology solutions.

V. CONCLUSION

Geodetic applications of GNSS in Kyrgyzstan are tremendously increasing and changing the engineering survey, mapping and land management technologies. The spatial and temporal capacities of the operational GNSS permanent networks Kyrgyzstan, investigated and analyzed in the study, show their potential in improving of the satellite based precise positioning.

Four different networks of GPS/GNSS permanent stations are operated by the international consortiums and local institutions. The GNSS Reference Network Control Center "KyrPOS" – a national level service provider on satellite differential corrections for GNSS users, is operating the Active GNSS Network in Kyrgyzstan. Other passive networks of GNSS permanent stations, operated by IGS, UNAVCO and CAIAG, have strong potential in satellite based positioning by increasing the capacity of the Active GNSS Network.

The spatial resolution and accuracy of engineering and land surveying should be assessed and analyzed in order to provide stable and efficient RTK/RTN services over the country. The passive GNSS networks can improve the quality of surveying supported by the Active GNSS Network in the areas with sparsely located CORS.

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