The Current Status of Global Navigation Satellite Systems GNSS. Case Study: Comparative study of getting positions in Gaza City based on operating GNSS Systems

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1 author:

M. A. El-Hallaq
Islamic University of Gaza

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The Current Status of Global Navigation Satellite Systems GNSS. Case Study: Comparative study of getting positions in Gaza City based on operating GNSS Systems.

Maher A. El-Hallaq
Assistant Professor of Surveying and Geodesy, Civil Eng. Department, The Islamic University of Gaza, Palestine, Email: mhallaq@iugaza.edu.ps

Abstract: GNSS applications in all fields play a key role, moving its use from navigation domain to multimodal use outdoors and indoors. Although, some GNSS systems like United States' GPS and Russian GLONASS are fully operated, modernization of these systems is still on-going. The European Unions' Galileo and the Chinese COMPASS GNSS systems are expected to be in full service in global navigation modes by 2020. Some other regional navigation systems such as the Japanese QZSS and the Indian IRNSS are being under development and expected to be completed and implemented through the coming few years. This study aims to investigate and report the current status of GNSS systems and to focus on its applications and use in the Gaza Strip. A comparative analytical case study of getting positions in Gaza City and based on GPS, GLONASSS and GPS + GLONASS multifrequency data is performed. It shows that about 56 % improvements in the positioning accuracy is obtained when considering GPS + GLONASS data instead of GPS data alone and 69 % compared with that of using GLONASS data alone.

Keywords: GNSS systems, positioning accuracy, Gaza City

ملخص: تلعب تطبيقات أنظمة الملاحة العالمية GNSS دورا أساسيا في جميع المجالات إنتقالا من مجال الملاحة إلى مجالات أخرى متعددة داخلية و خارجية.على الرغم بأن بعض هذه الأنظمة مثل GPS الأمريكي و الروسي GLONASS تعمل كاملة التشغيل، إلا أن عمليات التحديث لها ما زالت مستمرة. يتوقع لنظام الإتحاد الأوروبي GALILEO و النظام الصيني COMPASS أن يكتملا كنظامين عالميين للملاحة في العام 2020. بعض الدول ما زالت في مرحلة تطوير أنظمة ملاحة إقليمية مثل النظام الياباني QZSS والهندي IRNSS و يتوقع أن يبدءا التشغيل الكامل خلال السنوات القليلة القادمة. تهدف هذه الدراسة إلى معرفة و تقرير الوضع الحالي لأنظمة الملاحة العالمية مع التركيز على تطبيقاتها و استخداماتها في قطاع غزة. و قد تم إجراء دراسة تحليلية لمقارنة الحصول على إحداثيات عدد من النقاط في مدينة غزة إعتمادا على بيانات متعددة التردد باستخدام النظام الأمريكى GPS مرة والنظام الروسي GLONASS مرة وبيانات مشتركة للنظامين معا GPS+GLONASS. وقد أوضحت الدراسة أن تحسنا في الدقة المكانية بلغ 56% عند مقارنة نتائج النظامين معا مقارنة بنتائج نظام GPS و 69% مقارنة بنتائج GLONASS.

1. Background

Satellite based positioning is the determination of positions of observing targets on land , at sea and in space by means of artificial satellites. Operational satellites primarily provide the user with the capability of determining his position expressed, for example, by latitude, longitude and height. These systems also provide precise timing information anywhere on the Earth with high reliability and low cost. The systems can be operated day or night, rain or shine, and do not require cleared lines of sight between survey stations. This represents a revolutionary departure from conventional surveying procedures, which rely on observed angles and distances for determining point positions. This task is accomplished by the simple resection process using ranges measured to satellites. A historical review on the development of satellite based positioning can be found in (Guier and Weiffenbach, 1997).

The entire scope of satellite systems used in positioning is now referred to as Global Navigation Satellite Systems (GNSS). During the last 25 years, there are many important events in the field of GNSS such as: (a) the full operational of American GPS in 1993, when 24 GPS satellites were operating in their assigned orbits, available for navigation use and providing Standard Positioning Services (SPS), (b) the new European satellite system GALILEO, (c) the modernized of US satellite system GPS, and (d) the reconstruction of Russian satellite system GLONASS.

GNSS applications in all fields play a key role, moving its use from the transportation domain to multimodal use, outdoors and indoors. The concept of reference system for navigation is essential since all the applications of GNSS are related to the coordinate system used. The main application of GNSS is focused on the potential to determine the position in the Global reference system anywhere any time on the Globe in a simple, fast and cost-effective manner. The integration between GNSS and other related technologies such as the Geographic Information Systems (GIS), telecommunications (GSM, GPRS, and UMTS) and Inertial Navigation System (INS), has created numerous applications that needs more time to be discussed in details. Many research efforts have been exerted in order to find each new application to promote the quality of our life using the GNSS benefits (Lohnert et al., 2001; Al-Bayari and Sadoun, 2005).

2. Aim and Objectives

The aim of this research is to investigate and report the current status of GNSS applications in the Gaza Strip. To confirm this aim, the following objectives will be achieved:

- Determining the current significant components of GNSS positioning systems and making a comparison between these components.
- Performing a comparative analytical study of getting positions in Gaza City based on operational GNSS components; GPS and GLONASS.

3. GNSS Components

GNSS consists of constellations satellites that provide continuously optimized location and time information, transmitting a variety of signals on multiple frequencies available at all locations on planet Earth. The GNSS are the Global Positioning System (GPS) of the United States, the Global Navigation Satellite System (GLONASS) of the Russian Federation, Galileo of the European Union, and the Compass/BeiDou of China. India and Japan have developed regional GNSS capability by launching a number of satellites into space that augment the capabilities that are already supplied by the global systems to provide additional regional coverage. When GPS, GLONASS, GALILEO, and COMPASS will be fully operational and interoperable, four times more satellites may be available for navigation, positioning, and timing, providing more types of signals broadcasted on more frequencies (United Nations office for outer space affairs, 2011).

Each of them consists mainly of three segments: (a) space segment, (b) control segment and (c) user segment. These segments are almost similar in the three satellite technologies, which are all together make up the GNSS. As of today, the famous satellite technology is the GPS technology and most of the existing worldwide applications related to the GPS technology.

3.1. Operational GNSS

As of October 2011, only the United States NAVSTAR Global Positioning System (GPS) and the Russian GLONASS are fully globally operational GNSSs. The United States' Global Positioning System (GPS) consists of up to 32 medium Earth orbit satellites in six different orbital planes, with the exact number of satellites varying as older satellites are retired and replaced. Operational since 1978 and globally available since 1994, GPS is currently the world's most utilized satellite navigation system.

The formerly Soviet, and now Russian, ***Glo**bal'naya* ***Na**vigatsionnaya* ***S**putnikovaya* ***S**istema* (Global Navigation Satellite System), or GLONASS, was a fully functional navigation constellation in 1995. After the collapse of the Soviet Union, it fell into disrepair, leading to gaps in coverage and only partial availability. It was recovered and restored in 2011 (Wikipedia, 2013).

3.2 In Development GNSS

The European Union's Galileo positioning system is a GNSS in initial deployment phase, scheduled to be fully operational by 2020 at the earliest. The European Union and European Space Agency agreed in March 2002 to introduce their own alternative to GPS, called the Galileo positioning system. At an estimated cost of EUR 3.0 billion, the system of 30 Medium Earth Orbit (MEO) satellites was originally scheduled to be operational in 2010. The estimated year to become operational is 2014. The first experimental satellite was launched on 28 December 2005. Galileo is expected to be compatible with the modernized GPS system. The receivers will be able to combine the signals from both Galileo and GPS satellites to greatly increase the accuracy. Galileo is now not expected to be in full service until 2020 at the earliest and at a substantially higher cost (Wikipedia, 2013).

China has indicated that they intend to expand their regional navigation system, called BeiDou or *Big Dipper*, into a global navigation system by 2020, a program that has been called *Compass* in China's official news agency Xinhua. The Compass system is proposed to utilize 30 medium Earth orbit satellites and five geostationary satellites. A 12-satellite regional version (covering Asia and Pacific area) is completed in 2012.

The Quasi-Zenith Satellite System (QZSS) is a proposed three-satellite regional time transfer system and Satellite Based Augmentation System for the Global Positioning System that would be receivable within Japan. The first satellite 'Michibiki' was launched on 11 September 2010. Full operational status is expected by 2013. Authorized by the Japanese government in 2002, work on a concept for a Quasi-Zenith Satellite System (QZSS), began development by the Advanced Space Business Corporation (ASBC) team, including Mitsubishi Electric, Hitachi, and GNSS Technologies Inc. However, ASBC collapsed in 2007. The work was taken over by the Satellite Positioning Research and Application Center. SPAC is owned by four departments of the Japanese government: the Ministry of Education, Culture, Sports, Science and Technology, the Ministry of Internal Affairs and Communications, the Ministry of Economy, Trade and Industry, and the Ministry of Land, Infrastructure and Transport.

QZSS is targeted at mobile applications, to provide communications-based services (video, audio, and data) and positioning information. With regards to its positioning service, QZSS can only provide limited accuracy on its own and is not currently required in its specifications to work in a stand-alone mode. As such, it is viewed as a GNSS Augmentation service. Its positioning service could also collaborate with the geostationary satellites in Japan's Multi-Functional Transport Satellite (MTSAT), currently under development, which itself is a Satellite Based Augmentation System similar to the U.S. Federal Aviation Administration's Wide Area Augmentation System (WAAS).

The Indian Regional Navigational Satellite System (IRNSS) is an autonomous regional satellite navigation system being developed by Indian Space Research Organization (ISRO) which would be under the total control of Indian government. The government approved the project in May 2006, with the intention of the system to be completed and implemented by 2014. It will consist of a constellation of 7 navigational satellites. All the 7 satellites will be placed in the Geostationary orbit (GEO) to have a larger signal footprint and lower number of satellites to map the region. It is intended to provide an all-weather absolute position accuracy of better than 7.6 meters throughout India and within a region extending approximately 1,500 km around it. A goal of complete Indian control has been stated, with the space segment, ground segment and user receivers all being built in India.

In addition to, Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS) is a French precision navigation system (Wikipedia, 2013).

4. Comparison of GNSS Components

Table 1 takes into considerations some key parameters for GPS, GLONASS, GALILEO, COMPASS and QZSS as navigation satellite systems (Inside GNSS, 2013).

Table 1: Basic Comparison faces related to essential GNSS systems

Constellation	GPS	GLONASS	GALILEO	COMPASS	QZSS
Political entity	United States	Russia	European Union	China	Japan
Total Satellites	24 + 3	24 (4 Orb)	27 + 3	5 geostationary 30 medium Earth orbit	3
Full Operational Capacity	1995	GLONASS: 1995 GLONASS-M: 2010	2020	2020	2013
Orbital Period	12 Hours	11 Hours, 15 Min	14 Hours, 22 Min	12.63 hours (12 h 38 m in)	
Orbital Planes	6	3	3	6	3
Orbital Height	20,200 km	19,100 km	23,616 km	21,150 km	36,000 km
Satellite in Each Plane	4	8	10	5	1
Inclination	55°	64.8°	56°	55.5°	45°
Plane Separation	60°	120°	120°		
Frequency	1575.42 M Hz 1227.6 M Hz	1246-1257 M Hz 1602-1616 M Hz	1164 - 1300 M Hz 1559 - 1591 M Hz	1.561098 GHz 1.589742 GHz 1.20714 GHz 1.26852 GHz	L1: 1575.42 MHz L2: 1227.60 MHz L5: 1176.45 MHz LEX: 1278.75 MHz
Modulation	CDMA	FDMA	CDMA	CDMA	CDMA

Satellite Life Time	GPS IIR: 10 Yrs	GLONASS: 3 Yrs GLONASS-M: 7Yrs	> 12 Years		12 Years
Satellite Mass	GPS IIR: 2000 kg	1415 kg	700 kg	2200 kg	1,800kg
Intersatellite Links	Yes	GLONASS: No GLONASS-M: Yes	No		No
Commercial Service	No	No	Yes	Yes	Yes
Usage	Dual	Dual	Civilian	Dual	Civilian
Funding	Public	Public	Public/Private	Public	Public

Figure 1 shows the GNSS satellite availability at different locations of the world (Casa and Barza, 2006). It can be seen that when GPS, GLONASS and GALILEO will be fully operational and interoperable, more satellites may be available for navigation, positioning, and timing, providing more types of signals broadcasted on more frequencies, thus providing the potential for improved positioning. Average number of available satellites is ranged between 4 and less than 12 based on GPS but it becomes to about 20 for GPS + GLONASS or GPS + Galileo. Satellite availability increases to 32 satellites for receivers that can track GPS + GLONASS + Galileo

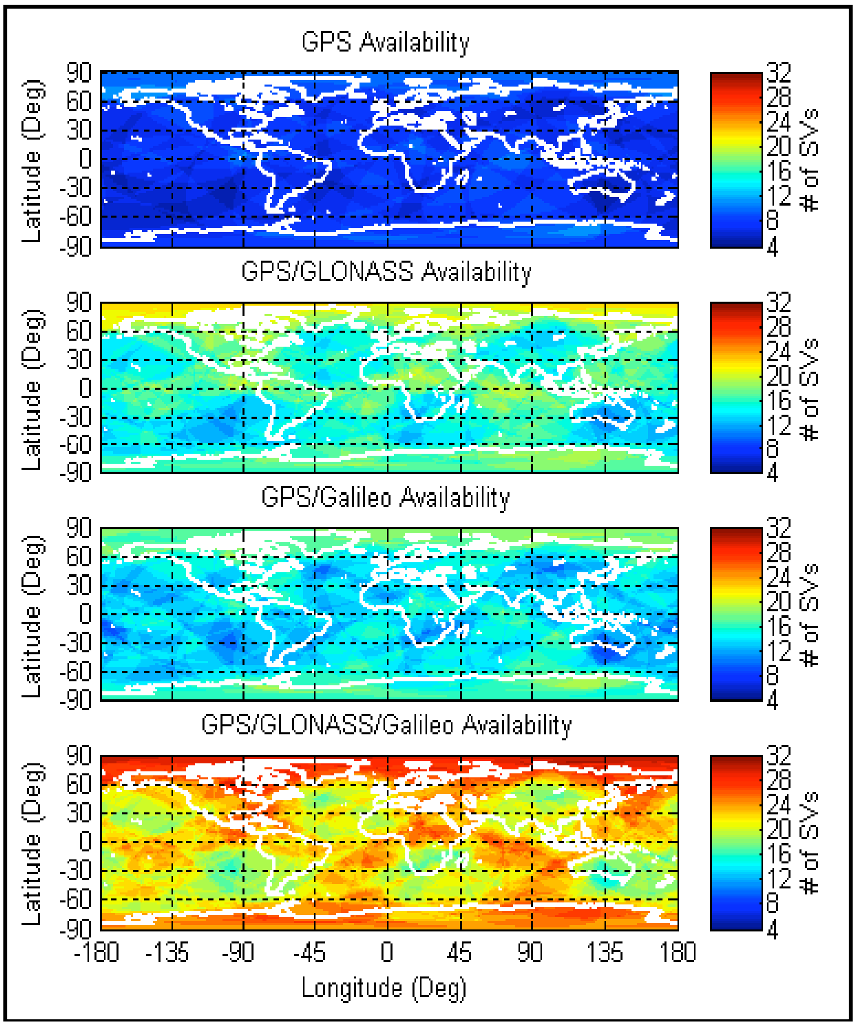

Figure 1: Systems' combinations of satellite vehicles (SV) availability.

5. GNSS in the Gaza Strip

GNSS was introduced in the Gaza Strip in 1999 when the British Consulate-General in Jerusalem had provided funding for a program to design and implement a GPS-based National Geodetic Network in Palestine. The main deliverable of this program was a new zero order geodetic infrastructure of coordinated points and had thus been completed with the establishment of 24 publicly accessible ground control points; 15 stations in West Bank and 9 in the Gaza Strip.

During this program, an informal training session in the use of Leica GPS was carried out to several surveyors from the Palestinian Survey Department as well as to all interested surveyors from the private sector. Most of the surveyors involved were experienced in traditional surveying and had developed a similar level of competence in field use of the GPS equipment.

Although the extensive progress and use of GNSS applications worldwide, it is still limited in the Gaza Strip. Table 2 shows the important places that have GNSS receivers units in the Gaza Strip and the degree of use. Nowadays, many other groups start to use handheld GPS receivers for absolute positioning or navigation.

Table 2: The GNSS applications and use in the Gaza Strip

ID	Group	Group Type	GNSS Kind	Year of Establishment	Field of Use
1	Survey Department	Government	GPS	1999	Positioning
2	Al-Mashharawy Company	Private	GPS	2000	Positioning
3	Gaza Municipality	Government	GPS GLONASS	2010	Positioning
4	Mohamed El-Banna Company	Private	GPS GLONASS	2012	Positioning Mapping

6. Case Study

In order to perform an analytical study of getting positions in Gaza City based on operational GNSS components, 27 control survey points are selected for this purpose. The selected points cover 1 km buffer around each one and the total buffers around the points cover all the city area. Figure 2 shows the geographic distribution of these points.

Survey point's positions are measured using the differential global positioning method (DGPS) considering the base station of Gaza Municipality that located at the city center, with a 25 minute period at least for each rover survey point. All rover points are within a maximum distance of 8 km apart from the base station. In order to carry out the investigation, a GNSS data processing is developed to process a different combinations of GNSS data including dual frequency GPS data, GLONASS data and GPS + GLONASS multiple frequency data.

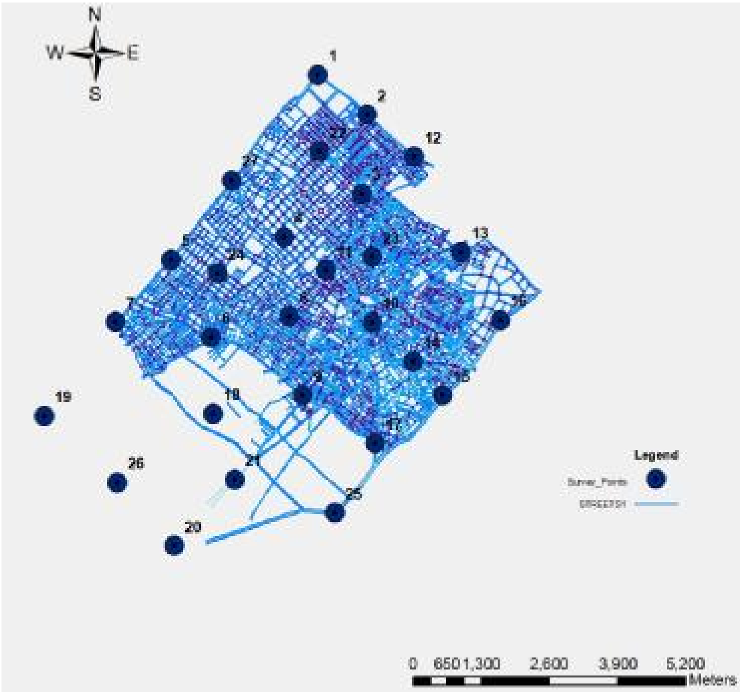

Figure 2: The geographic distribution of the selected control survey points.

Table 3 illustrates the results of the positioning survey of each GNSS type. The coordinates obtained are referenced to the local Palestine Grid coordinate system. Values of GDOP, Geometric Dilution of Precision, are considered as shown in Table 3. GDOP refers to the general geometric effect of satellite vector measurement errors together with receiver clock errors. GDOP values of 7 or below are usually considered suitable for positioning but values of 5 or lower are ideal (Barry, 2003). GDOP value directly affects the positional accuracy of the survey point.

Figure 3 shows the relationship between GDOP values and the positional accuracy. It is obvious that whenever GDOP value is large, the shift error seems to be high. Moreover, in general, the shift error values at GPS + GLONASS data (Blue Color) are less than that of the GPS data (Green Color). The shift error values at GPS data is also less than that of GLONASS data.

Table 3: Results of the GNSS positioning survey.

ID	GDOP	1		2		3	
		GPS + GLONASS		GPS		GLONASS	
		X	Y	X	Y	X	Y
1	2.50	98315.1899	106241.8083	98315.1896	106241.808	98315.1885	106241.8091
2	2.20	99247.8651	105479.088	99247.8649	105479.0878	99247.8519	105479.0914
3	2.70	99146.3304	103966.5551	99146.33	103966.5547	99146.3417	103966.5642
4	4.00	97664.7868	103137.715	97664.7807	103137.792	97664.6673	103137.834
5	2.30	95501.2405	102712.3447	95501.2403	102712.3445	95501.2511	102712.3439
6	1.38	96264.4939	101232.3384	96264.494	101232.3379	96264.4944	101232.3367
ID	GDOP	1		2		3	
		GPS + GLONASS		GPS		GLONASS	
		X	Y	X	Y	X	Y
7	1.33	94453.4901	101522.5915	94453.4902	101522.5916	94453.4921	101522.5917
8	1.39	97770.9456	101621.3027	97770.9455	101621.3029	97770.9471	101621.3101
9	1.80	98031.0712	100128.9276	98031.0714	100128.9277	98031.0729	100128.9201

10	2.30	99356.3716	101512.4636	99356.3714	101512.4635	99356.3804	101512.4717
11	3.60	98470.1523	102500.7474	98470.1531	102500.7482	98470.2413	102500.7501
12	3.00	100145.667	104667.3925	100145.6665	104667.392	100145.6975	104667.4213
13	2.60	101040.3386	102853.7756	101040.3383	102853.7753	101040.338	102853.7751
14	2.90	100130.2243	100767.3378	100130.2238	100767.3372	100130.2109	100767.4005
15	2.10	100691.3422	100128.6214	100691.3432	100128.6309	100691.3397	100128.6294
16	2.30	101787.3614	101555.5491	101787.364	101555.5498	101787.3572	101555.5364
17	2.60	99407.8023	99216.1703	99407.802	99216.17	99407.8307	99216.1502
18	2.90	96298.5775	99777.7117	96298.577	99777.7112	96298.4905	99777.7815
19	1.90	93079.685	99733.3994	93079.679	99733.3992	93079.6891	99733.4002
20	2.00	95557.1633	97264.533	95557.1592	97264.5301	95557.1674	97264.552
21	2.40	96712.4186	98520.7766	96712.4198	98520.7746	96712.4209	98520.7698
ID	**GDOP**	**1**		**2**		**3**	
		GPS + GLONASS		**GPS**		**GLONASS**	
		X	**Y**	**X**	**Y**	**X**	**Y**
22	4.20	98345.0619	104771.3308	98345.0637	104771.3382	98345.2247	104771.2104
23	2.00	99345.5254	102762.2529	99345.5314	102762.2531	99345.5272	102762.2583
24	3.20	96389.2605	102444.8025	96389.2614	102444.8034	96389.2068	102444.8732
25	2.60	98637.1176	97893.2373	98637.1174	97893.237	98637.1352	97893.2491
26	2.60	94478.8934	98468.215	94478.8932	98468.2148	94478.8821	98468.2291
27	2.50	96656.0161	104221.9381	96656.0163	104221.9384	96656.0166	104221.9394

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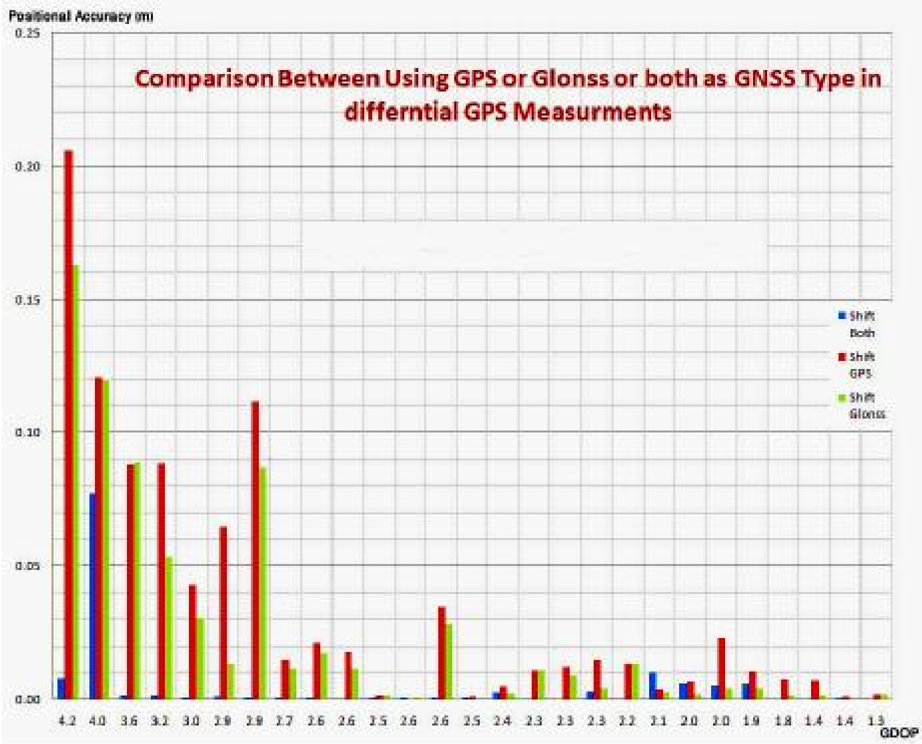

Figure 3: Position variations and Geometric Dilution of Precision (GDOP) relationship.

The statistical results of positioning errors in centimeters using different GNSS multiple frequency survey data are shown in Table 4. From the statistical results in Table 4, positioning accuracy of using GPS data shows about 29 % better than that of using GLONASS data. Positioning accuracy of using GPS + GLONASS data shows about 56 % improvements when compared with that of using GPS data alone and about 69 % compared with the use of GLONASS alone. This enhancement refers to more satellites can be available for navigation, positioning, and timing, providing more types of signals broadcasted on more frequencies, thus providing the potential for improved positioning.

Table 4: Statistical results of positioning errors of each GNSS data.

GNSS Type	Mean Error			Standard Deviation		
	dX	**dY**	**2D error**	**dX**	**dY**	**SD**
GPS	0.2811	0.6848	***0.7402***	4.0433	3.024	***5.0490***
GLONASS	0.2619	1.0096	***1.043***	4.1481	3.4548	***5.3984***
GPS+GLONASS	0.0193	0.3248	***0.3253***	0.1922	1.4766	***1.489***

7. Conclusion

The current status of operating and in development GNSS components is briefly discussed and a basic comparison faces related to these essential GNSS components is shown. In addition to, this study shows limited applications and use of GNSS systems in the Gaza Strip even the extensive progress of GNSS applications worldwide. An analytical case study of 27 survey stations distributed in Gaza City and based on operating GPS, GLONASS and GPS + GLONASS multifrequency data is performed. It shows about 56 % improvements in the positional accuracy when comparing GPS + GLONASS data with that of using GPS data alone and 69 % when using GLONASS data alone.

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