Impact of combining GPS-GLONASS data on base line solution

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ملخص البحث

يمكن قياس اداء نظم الاقمار العالمية الملاحية (GNSS) من خلال توافرها ودقتها و مدى الوثوق بها. تم تطوير المساحة و الملاحة على مدى العقدين الاخرين من قبل نظام تحديد المواقع العالمي(GPS). يلعب نظام(RTK) دور مهم فى تحسين المساحة و الملاحة وأصبح أداة أساسية لتحديد المواقع النسبية بدقة. ومع ذلك فأن الحصول على الغموض الموثوقة والصحيحة تعتمد على الملاحظة على عدد كبير من الأقمار الصناعية لتحديد المواقع. هذه التقنية من الصعب أن تطبق على المناطق التي يكون فيها عدد الاقمار المرئية محدودة. لذلك التكامل بين(GPS)و(GLONSS)يحدث دقة وموثوقية أكثر. نشر(GLONSS) بواسطة الروس يعمل على توفيرو مضاعفة عدد الاقمار الملاحية المتوفرة حاليا للمستخدمين. التعاون الكامل من جميع نظم الاقمار العالمية الملاحية(GNSS) سوف يتم التوصل معة لمستويات عالية من توافر الاقمار, ولذلك يمكن توقع التكامل. و من المهم استثماردرجة هذة التطورات.

Abstract

The execution of Global Navigation Satellite System (GNSS) can be measured by availability, accuracy and reliability. Surveying and navigation industries have been developed over the past two decades by the Global Positioning System (GPS). Real time kinematic GPS precise positioning has been playing an important role in both surveying and navigation, and has become an essential tool to precise relative positioning. However, reliable and correct ambiguity resolution depend on observation upon large number of GPS satellites. This technique is difficult to be applied on areas where the number of visible satellites are limited. With integration between GPS and GLONASS more and more accuracy and reliability happens. The deployment of GLONASS by Russian will provide double the number of navigation satellites currently available to users. With the complete co-operation of all of these Global Navigation Satellite Systems (GNSS) greater levels of availability will be reached. Therefore integrity can be expected. It is important to investigate the degree of these improvements.

Introduction

The Global Navigation Satellite Systems (GNSS) are expecting more satellite constellations to be developed, such as the Chinese Compass, European Galileo and Japanese QZSS, etc. Currently, however, only GPS and GLONASS have been widely used around the world, and the integration of these two satellite systems have greatly improved the number of available satellites, thus allowing more accurate and reliable positioning results. The demand of this integration is still high, and when the completed GLONASS satellite system is available, the expected number of satellites for the integration of GPS and GLONASS can reach 48, which makes fast static and kinematic positioning much more feasible than by either system alone. At present, the number of operating GLONASS satellites is 23.

This paper investigates the effect of combining GPS and GLONASS dual-frequency measurements on relative solution on different baselines with different processing strategies. Many data sets from IGS tracking stations(Drag) and (Nico) to improve the accuracy of the control points using the Trimple business Center (TBC) software package. It is shown that the addition of GLONASS constellation improves the number of visible satellites and geometry (PDOP).Statistical analysis of relative results shows that the performance of the combined GPS/GLONASS solution is superior to that of GPS-only solution. However, there are improvement in the accuracy of the baselines.

Data

The data was collected in different regions, in the form of geodetic networks. The first network area was in Giza (Grand Egyptian Museum). The study area was far away from Midan El Rmaia almost 1 km. . The baselines in this network were only 1 km . The second network was in Qenna (Isna Qenna). The third network was in 6th of October. The length of base lines starts from tens of meters till hundreds of kilo meters. At Giza, , which were monitored for a period of time starting from 30 minutes to 60 minutes, depending on the length of the base line. At Qenna (Isna Qenna), the base lines join between control points of the network with length ranged from 5 Km till more than 100 Km. They were observed in suitable conditions. As the length of the base line increases the period of observation increases. At 6th of October, the base lines exceed 6000 Km due to connecting the control points of this network with IGS station(DRAG) and (NICO) to solve the network. In this research, we used Trimble R8 GNSS which, delivers the latest advancements in R-Track™ technology, designed to deliver reliable, precise positioning performance In challenging areas for GNSS surveying, such as tree or limited sky view, Trimble R-Track provides unmatched tracking performance of GNSS satellite signals. The Trimble R8 GNSS supports a wide range of satellite signals, including GPS L2C and L5 and GLONASS L1/L2 signals.

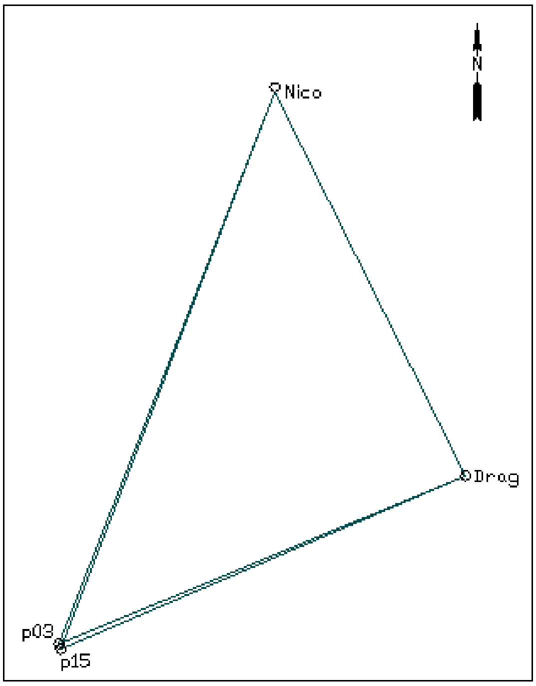


Figure (1) represents "6 October" Network

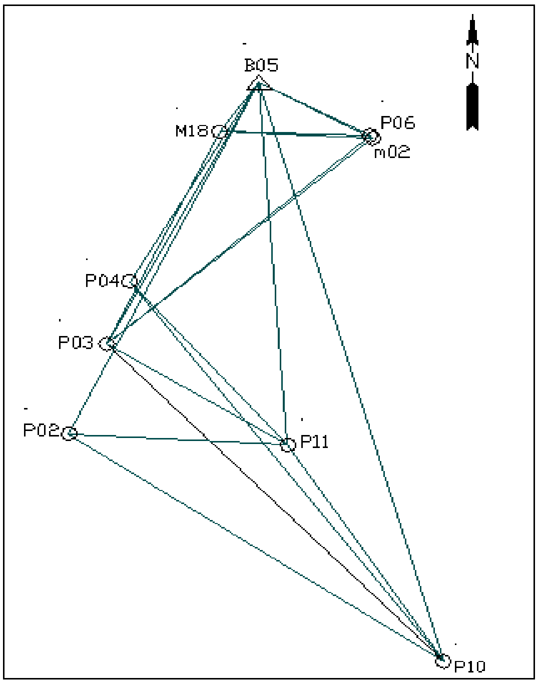


Figure (2) represents "Giza Network"

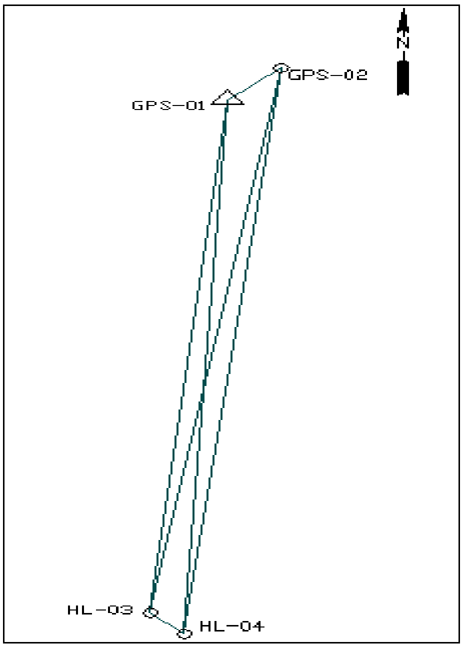


Figure (3) represents "Isna-Qena Network"

Brief overview of GPS and GLONASS

Today GPS and GLONASS are the main GNSS systems. They are similar in many respects, both systems are able to provide with the three-dimensional positioning, velocity and timing anywhere in the world or near-Earth space. Both navigation systems are based on determining the unknown user position by measuring the time of flight of signals broadcasted by satellites at known positions and epochs.

GPS: Consists of 28 satellites inclined at 55° to the equator, orbit the Earth every 11 hours and 58 minutes at a height of 20,180 km on 6 different orbital planes. Each one of these satellites has up to four atomic clocks on board. Atomic clocks are currently the most precise instruments known. In order to make them even more accurate, they are regularly adjusted or synchronised from various control points on earth. Each satellite transmits its exact position and its precise on board clock time to earth at frequency of 1575.42 MHz. These signals are transmitted at the speed of light (300,000 km/s) . Therefore, If you wish to establish your position on land(or at sea or in the air), all you require is an accurate clock. By comparing the arrival time of the satellite signal with the onboard clock time (the moment the signal was emitted). So it is possible to determine the transit time of that signal.

GLONAS, The International GLONASS Experiment (IGEX-98) is the first global GLONASS observation and analysis campaign for geodetic and geodynamics applications, conducted from October 19, 1998 to April 19, 1999 and organized jointly by the International GNSS Service (IGS), the International Association of Geodesy (IAG) and the International Earth Rotation Service (IERS). The main objectives of the experiment were to collect a globally-distributed GLONASS dataset by using dual frequency GLONASS receivers and determine the precise GLONASS satellite orbit. IGEX-98 has a global network consisting of 52 stations with 19 dual-frequency and 13 single-frequency receivers. GLONASS has been on the way to its modernization. In 2003, the first GLONASS-M satellite was launched, where “M” stands for Modified. On December 25, 2006, three GLONASS-M satellites (GLONASS 715, GLONASS 716 and GLONASS 717) were launched. The GLONASS-M is a modernized version of the GLONASS spacecraft which supports a number of new features, such as the satellite design-lifetime increased to 7 years, a second civil modulation on L2 signal, and improved clock stability. The third generation GLONASS satellite, GLONASS-K, was launched on 26 February 2011.

The new satellite has an operational lifetime of 10 years, three years longer than that of GLONASS-M and seven years longer than the lifetime of the original GLONASS satellite. GLONASS-K will transmit additional navigation signals to improve the system's accuracy.

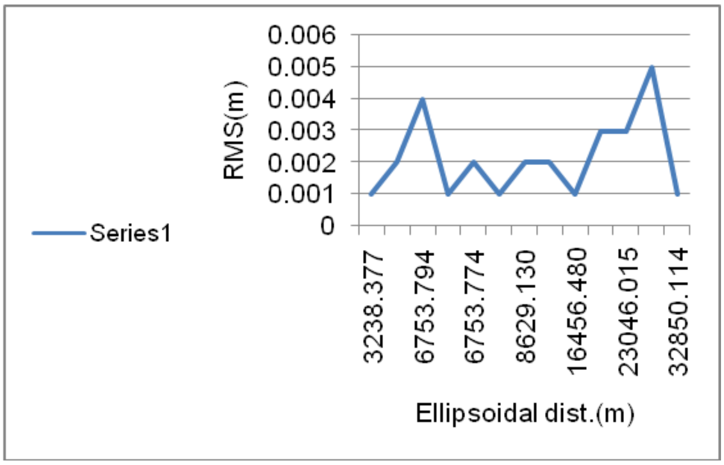
Numerical Results and Analysis

The observations from the four mentioned networks have been processed using the Trimple Business Center (TBC) software package. GPS-only and GPS/GLONASS observations are processed respectively using the same processing strategy. The results of the GPS-only baselines and GPS/GLONASS baselines have been compared. The research studies the effect of the integration between GPS and GLONASS on the accuracy of baseline on the four networks through the following different solutions: solving by GPS/GLONASS with broadcast ephemeris, precise ephemeris of GPS/GLONASS, precise ephemeris of GPS satellite, precise ephemeris of GLONASS, and solving by GPS only with broadcast ephemeris and precise ephemeris. The study results are shown in the following tables and figures:

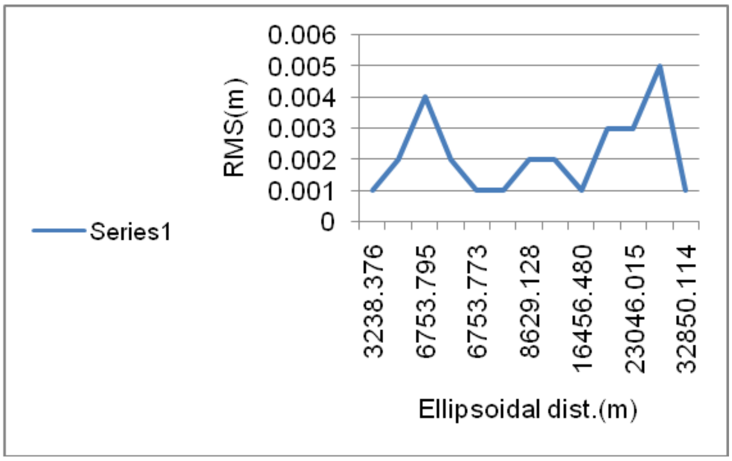
Table (1):Giza, this study was characterized by baseline with length less than1 Km.

Observation	H.Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)	RMS	RMS**6
B05 --M18(B22)	0.001	0.002	213°35'33"	83.033	2.486	0	0
B05 --- P06 (B10)	0.001	0.003	119°35'36"	148.192	-5.674	0	0
B05 --- P06 (B8)	0.057	0.032	119°38'29"	148.342	-5.718	0	0
B05 --- m02(B12)	0.001	0.003	120°24'34"	153.018	-6.853	0	0
M18 --- P06(B20)	0.001	0.003	91°18'59"	174.847	-8.159	0	0
M18 --- P06(B21)	0.034	0.022	91°22'42"	174.922	-8.202	0	0
M18-- m02 (B19)	0.001	0.003	92°40'02"	178.101	-9.337	0	0
P03 --- P11 (B16)	0.003	0.005	122°42'04"	251.038	-8.868	0	0
P11 --- p02 (B18)	0.001	0.002	273°23'39"	254.473	7.138	0	0
P11 --- P04 (B17)	0.002	0.003	320°05'52"	287.45	7.124	0	0
B05 --- P04 (B2)	0.002	0.003	208°57'46"	310.152	32.491	0	0
P03 --- M18(B23)	0.001	0.002	24°32'35"	315.605	-31.755	0	0
P11 --- P10 (B14)	0.001	0.002	148°18'13"	344.812	6.862	0	0
B05 --- P03 (B1)	0.001	0.002	206°25'30"	397.819	34.242	0	0
P03 --- m02 (B13)	0.002	0.004	47°56'28"	416.19	-41.09	0	0
P03 --- P06 (B11)	0.002	0.003	47°13'08"	416.778	-39.913	0	0
B05 --- P11 (B15)	0.001	0.002	176°01'19"	493.067	25.373	0	0
B05 --- p02 (B3)	0.001	0.002	204°45'01"	525.043	32.516	0	0
P10 --- p02 (B7)	0.002	0.003	305°19'41"	533.42	0.276	0	0
P03 --- P10 (B5)	0.003	0.004	137°32'58"	581.412	-2.009	0	0
P10 --- P04 (B6)	0.002	0.004	324°34'29"	630.655	0.261	0	0
B05 --- P10 (B4)	0.001	0.002	164°39'44"	814.26	32.234	0	0

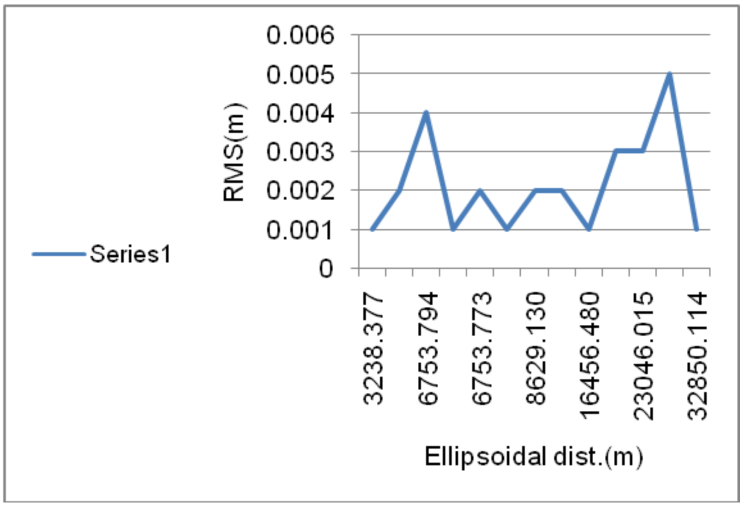
Qenna (Qenna El Gedida), this study was characterized by presence of baselines with lengths between 10Km till more than 30Km and the study is done according to the six cases and the results were as follow:



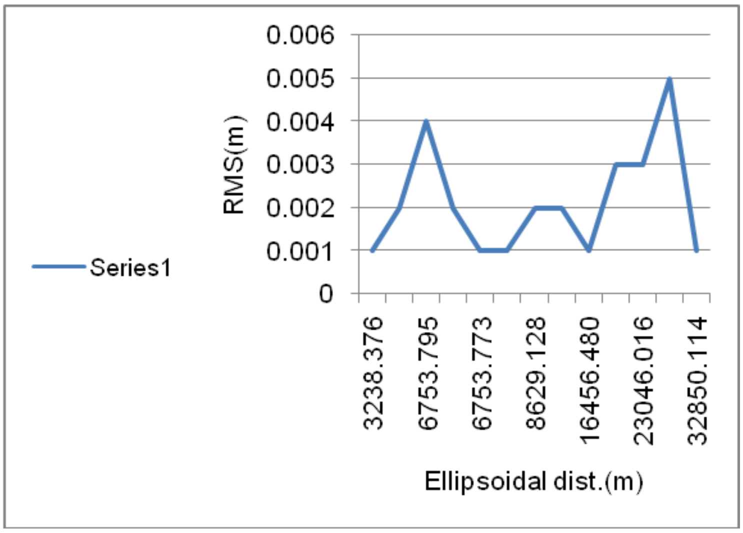
Figure(4): RMSs of the Baselines In case of solving by GPS/GLONASS with broadcast ephemeris in Qenna (Qenna El Gedida)



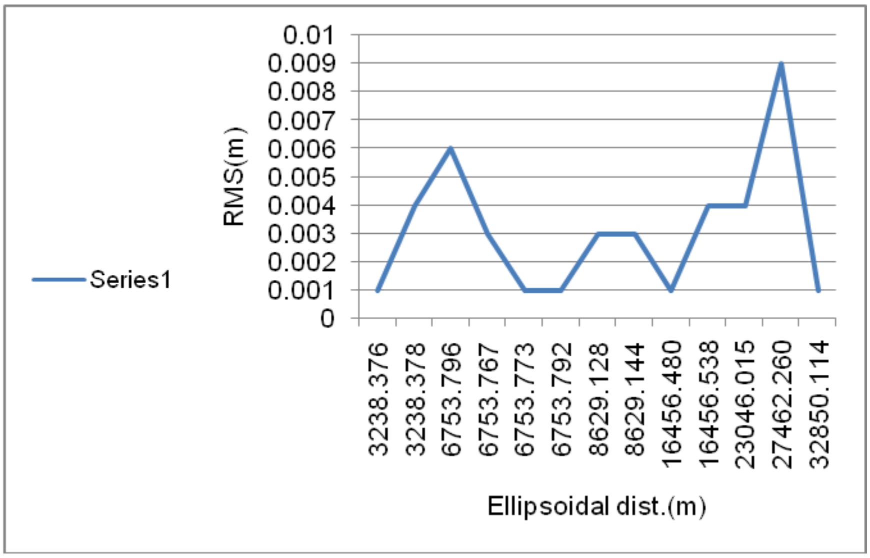
Figure(5): RMSs of the Baselines In case of solving by GPS/GLONASS with precise ephemeris of GPS/GLONASS satellite in Qenna (Qenna El Gedida)



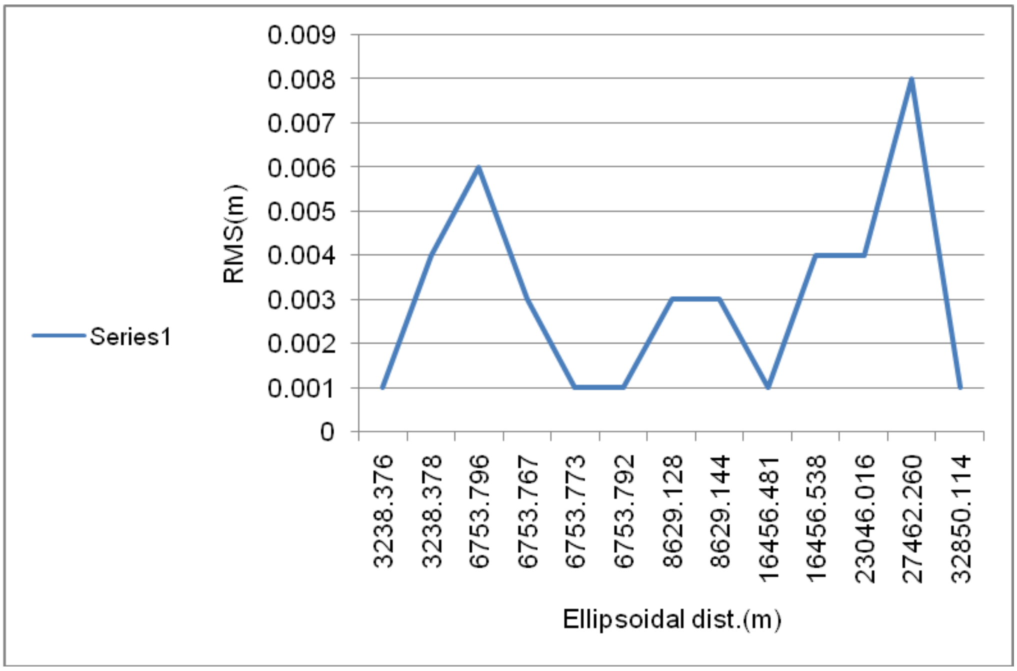
Figure(6): RMSs of the Baselines In case of solving by GPS/GLONASS with precise ephemeris of GPS satellite in Qenna (Qenna El Gedida)



Figure(7): RMSs of the Baselines In case of solving by GS/GLONASS with precise ephemeris of GLONASS satellite in Qenna (Qenna El Gedida)



Figure(8): RMSs of the Baselines In case of solving by GPS with precise ephemeris of GPS satellite in Qenna (Qenna El Gedida)

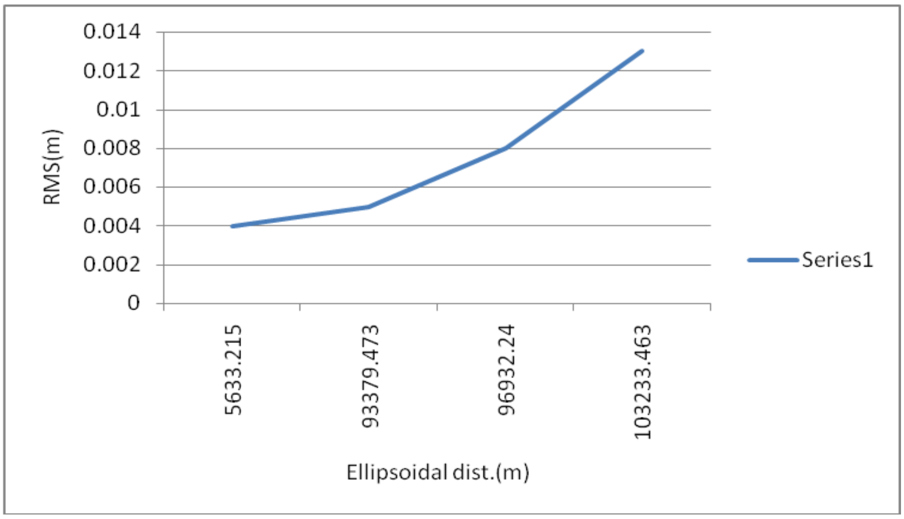


Figure(9): RMSs of the Baselines In case of solving by GPS with broad cast ephemeris of GPS satellite in Qenna (Qenna El Gedida)

Qenna (Isna-Qenna), this study was characterized by presence of baselines with lengths between 5Km till more than 100Km. They were observed in suitable conditions. the length of baseline is directly proportional to the epoch.

Table (2): In case of solving by GPS/GLONASS with broadcast ephemeris in Qenna(Isna-Qenna)

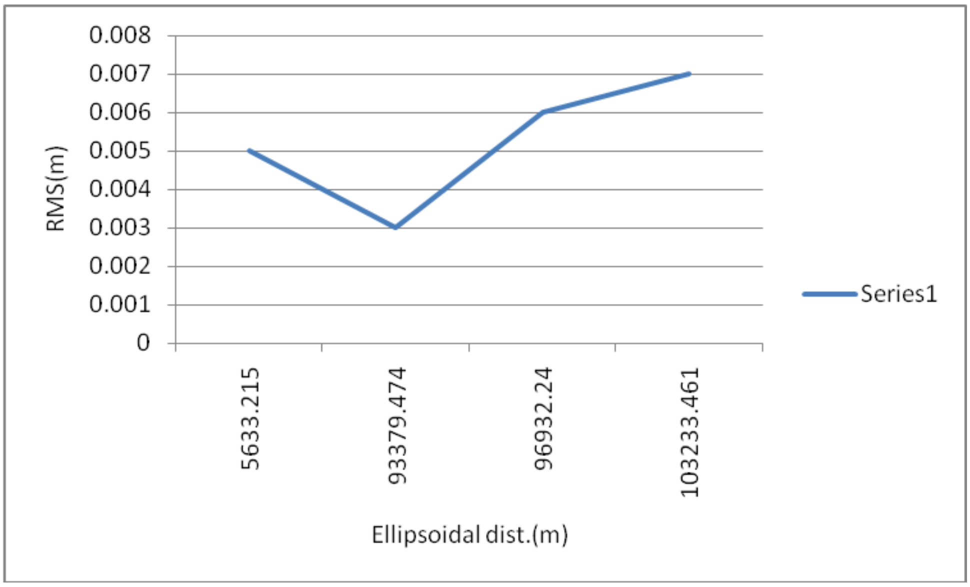
Observation	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)	RMS	RMS*10**6	Duration
HL-04 --- HL-03 (B4)	0.004	0.019	313°21'52"	5633.215	-0.004	0.004	4000	03:56:35
GPS-01 --- HL-03 (B5)	0.008	0.025	185°36'54"	93379.473	-29.158	0.005	5000	04:07:25
GPS-01 --- HL-04 (B2)	0.010	0.033	182°58'55"	96932.240	-29.125	0.008	8000	04:13:15
GPS-02 --- HL-04 (B3)	0.011	0.037	186°23'13"	103233.463	-17.652	0.013	13000	04:13:15



Figure(10): RMSs of the Baselines In case of solving by GPS/GLONASS with broadcast ephemeris in Kenna(Isna-Kenna)

Table (3): In case of solving by GPS/GLONASS with precise ephemeris of GPS/GLONASS satellite in Kenna(Isna-Kenna).

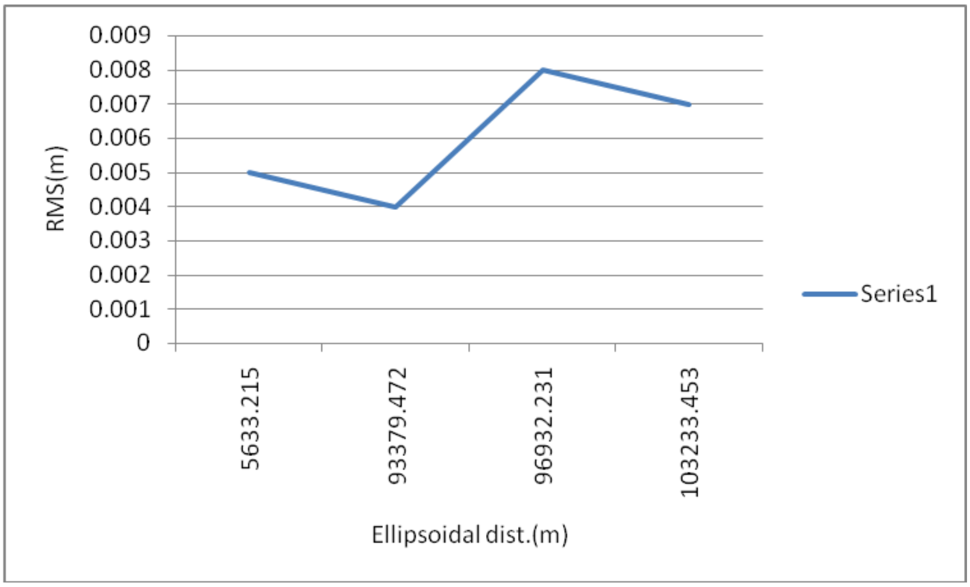
Observations	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)	RMS	RMS*10**6	Duration
HL-04 --- HL-03 (B4)	0.005	0.020	313°21'53"	5633.215	0.000	0.005	5000	03:56:35
GPS-01 --- HL-03 (B5)	0.007	0.023	185°36'54"	93379.474	-29.159	0.003	3000	04:07:25
GPS-01 --- HL-04 (B2)	0.010	0.037	182°58'55"	96932.240	-29.135	0.006	6000	04:13:15
GPS-02 --- HL-04 (B3)	0.010	0.030	186°23'13"	103233.461	-17.642	0.007	7000	04:13:15



Figure(11): RMSs of the Baselines In case of solving by GPS/GLONASS with precise ephemeris of GPS/GLONASS satellite in Kenna(Isna-Kenna)

Table 4: In case of solving by GPS/GLONASS with precise ephemeris of GPS satellite in Kenna(Isna-Kenna)

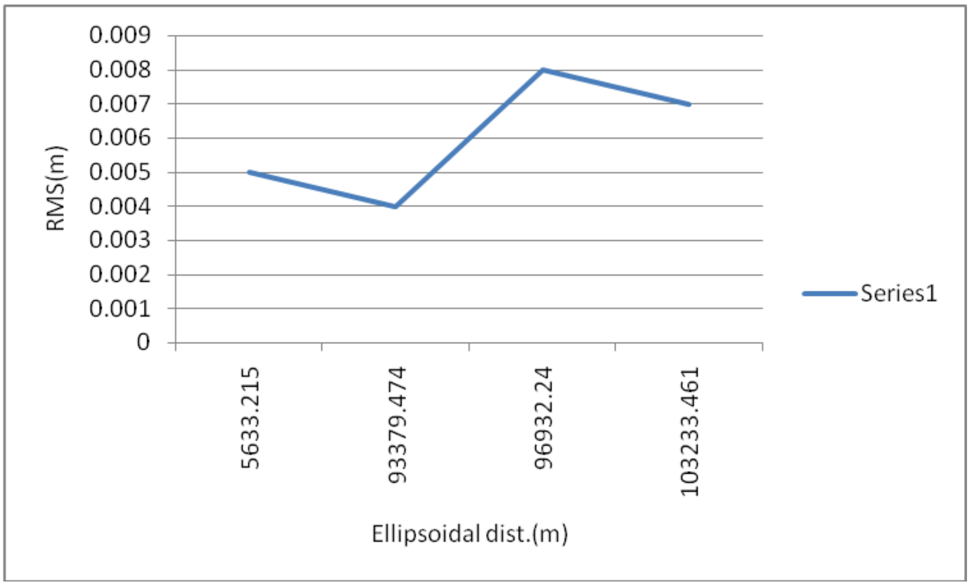
Observation	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)	RMS	RMS*10**6	Duration
HL-04 --- HL-03 (B4)	0.005	0.020	313°21'52"	5633.215	-0.002	0.005	5000	03:56:35
GPS-01 --- HL-03 (B5)	0.003	0.011	185°36'54"	93379.472	-29.163	0.004	4000	04:07:25
GPS-01 --- HL-04 (B2)	0.004	0.014	182°58'55"	96932.231	-29.156	0.008	8000	04:13:15
GPS-02 --- HL-04 (B3)	0.004	0.015	186°23'13"	103233.453	-17.657	0.007	7000	04:13:15



Figure(12): RMSs of the Baselines In case of solving by GPS/GLONASS with precise ephemeris of GPS satellite in Kenna(Isna-Kenna)

Table(5): In case of solving by GS/GLONASS with precise ephemeris of GLONASS satellite in Kenna(Isna-Kenna)

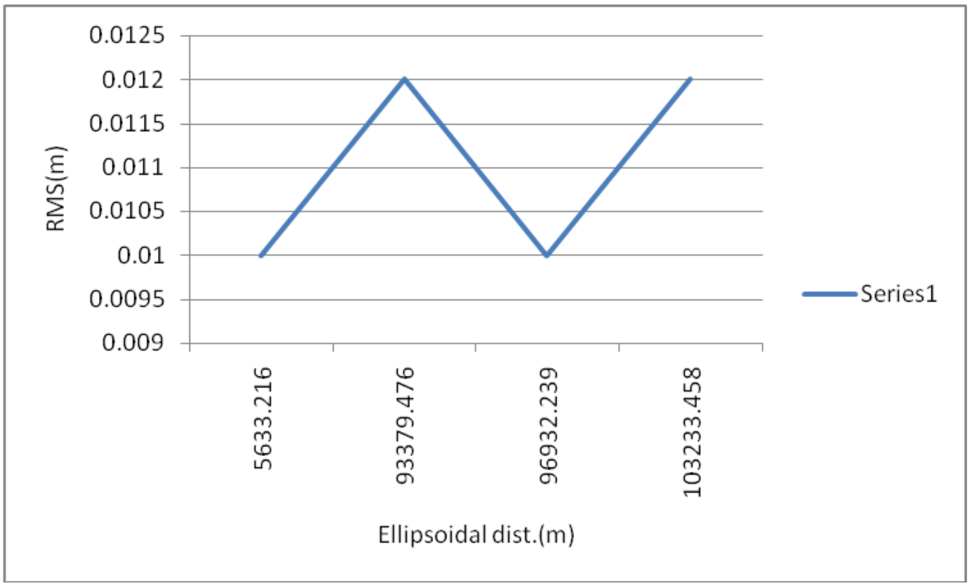
Observation	H.Prec. (Meter)	V. rec. (Meter)	Geodetic Az.	Ellipsoid Dist.(Meter)	ΔHeight (Meter)	RMS	RMS*10**6	Duration
HL-04 --- HL-03 (B4)	0.005	0.020	313°21'53"	5633.215	0.000	0.005	5000	03:56:35
GPS-01 --- HL-03 (B5)	0.007	0.023	185°36'54"	93379.474	-29.159	0.004	4000	04:13:15
GPS-01 --- HL-04 (B2)	0.010	0.037	182°58'55"	96932.240	-29.135	0.008	8000	04:07:25
GPS-02 --- HL-04 (B3)	0.010	0.030	186°23'13"	103233.461	-17.642	0.007	7000	04:07:25



Figure(13): RMSs of the Baselines In case of solving by GS/GLONASS with precise ephemeris of GLONASS satellite in Kenna(Isna-Kenna)

Table (6): In case of solving by GPS with precise ephemeris of GPS satellite in Kenna(Isna-Kenna)

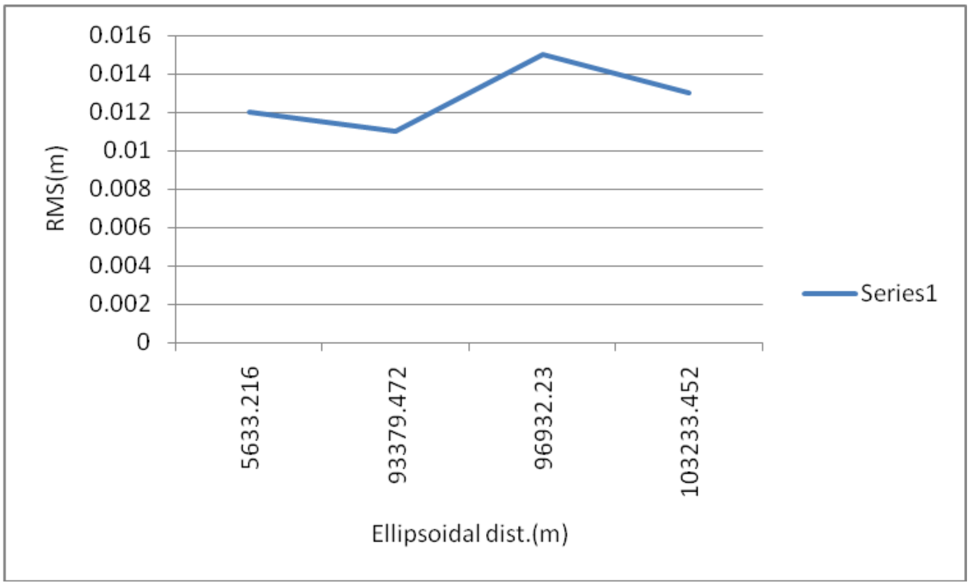
Observation	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist.(Meter)	ΔHeight (Meter)	RMS	RMS*10**6	Duration
HL-04 --- HL-03 (B4)	0.006	0.029	313°21'53"	5633.216	0.019	0.01	10000	03:56:35
GPS-01 --- HL-03 (B5)	0.010	0.028	185°36'54"	93379.476	-29.163	0.012	12000	04:13:15
GPS-01 --- HL-04 (B2)	0.014	0.046	182°58'55"	96932.239	-29.129	0.01	10000	04:07:25
GPS-02 --- HL-04 (B3)	0.012	0.044	186°23'13"	103233.458	-17.645	0.012	12000	04:07:25



Figure(14): RMSs of the Baselines In case of solving by GPS with precise ephemeris of GPS satellite in Kenna(Isna-Kenna)

Table (7): In case of solving by GPS with broad cast ephemeris of GPS satellite in Kenna(Isna-Kenna)

Observation	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)	RMS	RMS*10**6	Duration
HL-04 --- HL-03 (B4)	0.007	0.030	313°21'53"	5633.216	0.022	0.012	12000	03:56:35
GPS-01 --- HL-03 (B5)	0.003	0.011	185°36'54"	93379.472	-29.164	0.011	11000	04:07:25
GPS-01 --- HL-04 (B2)	0.005	0.018	182°58'55"	96932.230	-29.154	0.015	15000	08:00:40
GPS-02 --- HL-04 (B3)	0.005	0.018	186°23'13"	103233.452	-17.654	0.013	13000	04:13:15

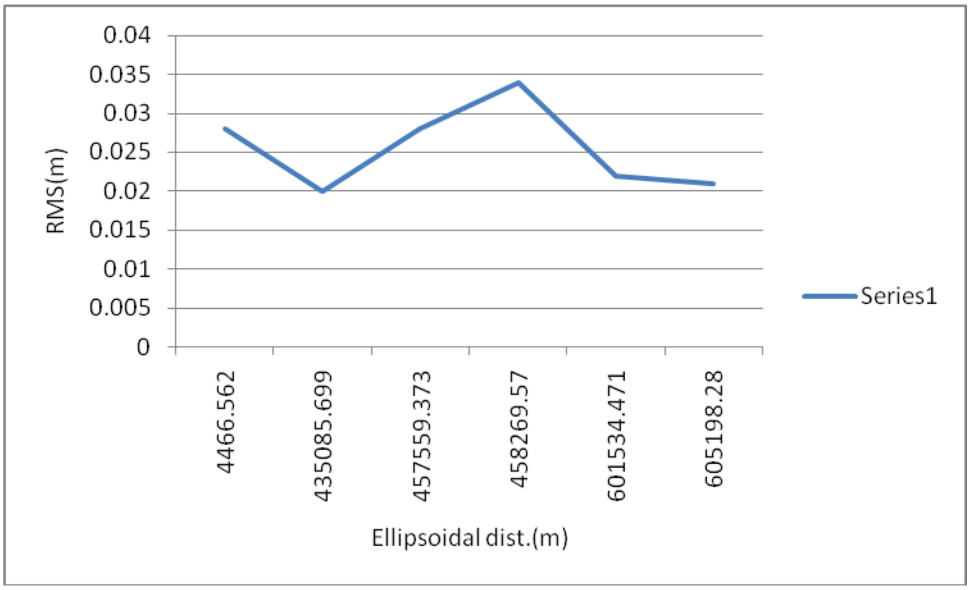


Figure(15): RMSs of the Baselines In case of solving by GPS with broad cast ephemeris of GPS satellite in Kenna(Isna-Kenna)

6th of October, this study was characterized by presence of baselines with length exceed 6000 Km due to the usage of IGS in solving the network.

Table (8): In case of solving by GPS/GLONASS with broadcast ephemeris in 6th of October

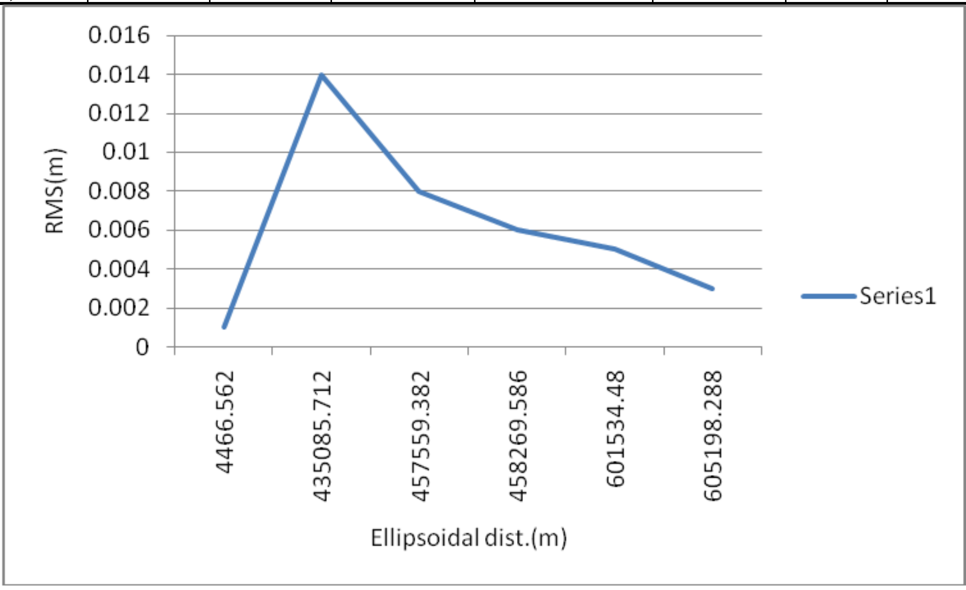
Observation	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)	RMS	RMS*10**6
P03 --- P15 (B1)	0.002	0.006	167°06'38"	4466.562	-8.095	0.028	28000
DRAG dragot --- NICO (B4)	0.013	0.028	335°16'36"	435085.699	158.171	0.02	20000
DRAG dragot --- P03 (B3)	0.022	0.037	250°32'09"	457559.373	142.575	0.028	28000
DRAG dragot --- P15 (B2)	0.021	0.039	249°59'00"	458269.570	134.454	0.034	34000
NICO --- P03 (B6)	0.027	0.038	203°27'38"	601534.471	-15.624	0.022	22000
NICO --- P15 (B5)	0.028	0.039	203°13'03"	605198.280	-23.732	0.021	21000



Figure(16): RMSs of the Baselines In case of solving by GPS/GLONASS with broadcast ephemeris in 6th of October

Table(9): In case of solving by GPS/GLONASS with precise ephemeris for GPS/GLONASS satellites in 6th of October.

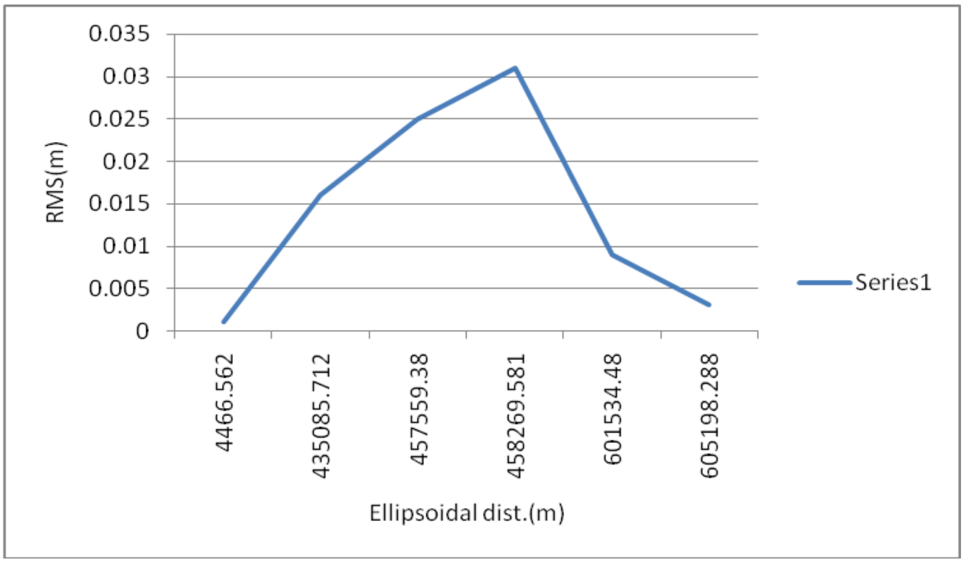
Observation	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)	RMS	RMS*10**6
P03 --- P15 (B1)	0.002	0.006	167°06'38"	4466.562	-8.095	0.001	1000
DRAG dragot --- NICO (B4)	0.002	0.005	335°16'36"	435085.712	158.174	0.014	14000
DRAG dragot --- P03 (B3)	0.003	0.008	250°32'09"	457559.382	142.596	0.008	8000
DRAG dragot --- P15 (B2)	0.003	0.008	249°59'00"	458269.586	134.474	0.006	6000
NICO --- P03 (B6)	0.003	0.008	203°27'38"	601534.480	-15.575	0.005	5000
NICO --- P15 (B5)	0.003	0.008	203°13'03"	605198.288	-23.691	0.003	3000



Figure(17): RMSs of the Baselines In case of solving by GPS/GLONASS with precise ephemeris of GPS/GLONASS satellite in 6th of October

Table (10): In case of solving by GPS/GLONASS with precise ephemeris of GPS satellite in 6th of October

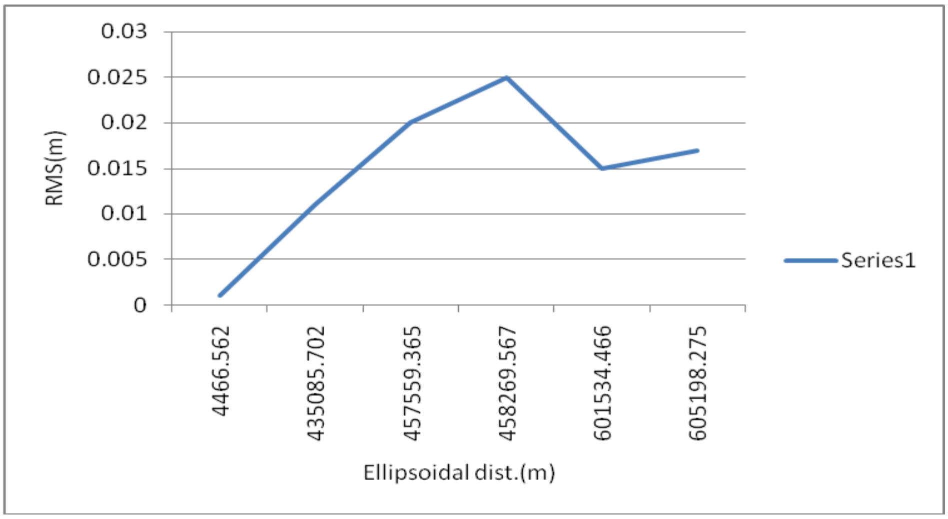
Observation	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)	RMS	RMS*10**6
P03 --- P15 (B1)	0.002	0.006	167°06'38"	4466.562	-8.095	0.001	1000
DRAG dragot --- NICO (B4)	0.002	0.005	335°16'36"	435085.712	158.173	0.016	16000
DRAG dragot --- P03 (B3)	0.004	0.008	250°32'09"	457559.380	142.607	0.025	25000
DRAG dragot --- P15 (B2)	0.004	0.009	249°59'00"	458269.581	134.479	0.031	31000
NICO --- P03 (B6)	0.003	0.008	203°27'38"	601534.480	-15.575	0.009	9000
NICO --- P15 (B5)	0.003	0.008	203°13'03"	605198.288	-23.690	0.003	3000



Figure(18): RMSs of the Baselines In case of solving by GPS/GLONASS with precise ephemeris of GPS satellite in 6th of October

Table (11): In case of solving by GS/GLONASS with precise ephemeris of GLONASS satellite in 6th of October

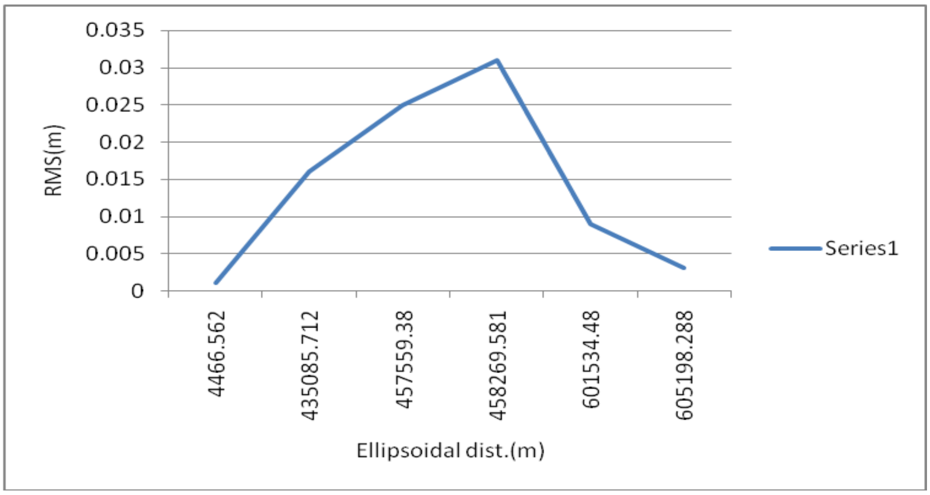
Observation	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)	RMS	RMS*10**6
P03 --- P15 (B1)	0.002	0.006	167°06'38"	4466.562	-8.095	0.001	1000
DRAG dragot --- NICO (B4)	0.012	0.022	335°16'36"	435085.702	158.175	0.011	11000
DRAG dragot --- P03 (B3)	0.013	0.027	250°32'09"	457559.365	142.581	0.02	20000
DRAG dragot --- P15 (B2)	0.018	0.039	249°59'00"	458269.567	134.464	0.025	25000
NICO --- P03 (B6)	0.013	0.027	203°27'38"	601534.466	-15.610	0.015	15000
NICO --- P15 (B5)	0.036	0.035	203°13'03"	605198.275	-23.723	0.017	17000



Figure(19): RMSs of the Baselines In case of solving by GPS/GLONASS with precise ephemeris of GLONASS satellite in 6th of October

Table (12): In case of solving by GPS with precise ephemeris of GPS in 6th of October satellite

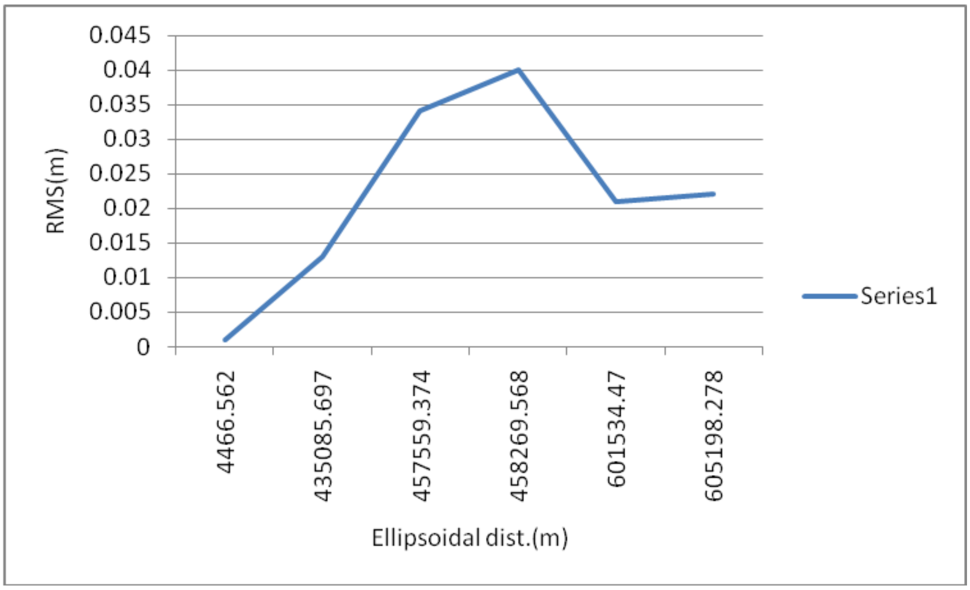
Observation	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)	RMS	RMS*10**6
P03 --- P15 (B1)	0.002	0.006	167°06'38"	4466.562	-8.095	0.001	1000
DRAG dragot --- NICO (B4)	0.002	0.005	335°16'36"	435085.712	158.173	0.016	16000
DRAG dragot --- P03 (B3)	0.004	0.008	250°32'09"	457559.380	142.607	0.025	25000
DRAG dragot --- P15 (B2)	0.004	0.009	249°59'00"	458269.581	134.479	0.031	31000
NICO --- P03 (B6)	0.003	0.008	203°27'38"	601534.480	-15.575	0.009	9000
NICO --- P15 (B5)	0.003	0.008	203°13'03"	605198.288	-23.690	0.003	3000



Figure(20): RMSs of the Baselines In case of solving by GPS with precise ephemeris of GPS satellite in 6th of October

Table (13): In case of solving by GPS with broad cast ephemeris of GPS satellite in 6th of October

Observation	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)	RMS	RMS*10**6
P03 --- P15 (B1)	0.002	0.006	167°06'38"	4466.562	-8.095	0.001	1000
DRAG dragot --- NICO (B4)	0.022	0.033	335°16'36"	435085.697	158.174	0.013	13000
DRAG dragot --- P03 (B3)	0.030	0.042	250°32'09"	457559.374	142.553	0.034	34000
DRAG dragot --- P15 (B2)	0.028	0.044	249°59'00"	458269.568	134.437	0.04	40000
NICO --- P03 (B6)	0.031	0.040	203°27'38"	601534.470	-15.631	0.021	21000
NICO --- P15 (B5)	0.033	0.042	203°13'03"	605198.278	-23.742	0.022	22000



Figure(21): RMSs of the Baselines In case of solving by GPS with broad cast ephemeris of GPS satellite in 6th of October

Conclusion

The RMS of the baselines stays at the same level in both GPS only solutions and GPS/GLONASS solutions in small baselines as shown in the first network (Giza) which is characterized by presence of baselines less than 1 Km. From the results generated from the four networks, it can be seen that the accuracy of long baseline can be improved by introducing GLONASS observations, especially in case of solving with GPS/GLONASS precise ephemeris for GPS/GLONASS satellites. Based on these results, inclusion of GLONASS observations does offer some significant advantages over GPS-only integrated systems for long baselines. In the future, by including data from other GNSS as well (e.g., Galileo) to GPS/GLONASS, better results would also be expected.

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