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Research paper

Analytical Study of Static Observation According to IGS Products

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Abstract

There are many factors affecting the observation accuracy that adopt GNSS technique based on the International GNSS Service (IGS). This can be due to several factors occur in observing process, including satellites and stations clocks, atmospheric parameters, earth crust movement that causes annual changes in the earth's points locations including IGS stations, as well as Earth Polar Motion (EPM). This error ranges from a several centimeters to a few meters. To avoid these errors IGS gave many instructions to increase the observations accuracy in order to reach precise positioning measurements.
The objective of this study is to analyze the IGS products and then make a test by observing some points with (Leica Viva GNSS) device and send them to correction by adopt the instructions of this site, which are classified into four broad categories (Broad Cast, Ultra Rapid Predicted and Observed, Rapid, Final). All of these factors are affected by (observing period, Dilution of precision DOP, the timing of data transmission to the relevant site). The accuracy of the observed coordinates are related to these factors. A solution of this problem may be identifying by comparing the OPUS correction with the ideal IGS products to know the difference.
Finally, the results of the maximum observing period data (4 hours) and (4 week processing) were compared with the ideal values prepared by the IGS products then specifying the difference value. The results may be adopted as a guide for the surveyor to specify the optimum method of observing.

Keywords: *DOP , GNSS , GPS , IGS ,OPUS .*

1. Introduction:

IGS (International GNSS Services) products are used to compile and documenting the GNSS data in order to provide the required accuracy for users **(IGS 2018)** . The data are supported, analyzed and configured based on the tables shown in a special website. IGS products support many activities dealing with source errors for GNSS observations, these errors concentrated in satellite orbits, reference station clocks, CORS and other supporting stations, as well as earth rotation and polar motions that causing shift in the sites of reference stations as a result to natural movement of the earth's crust annually ... etc. **(Maciuk 2016)** .
These errors can be significantly reduced by reviewing the reference network data of the observed region and according to five different process types: Broadcast, Ultra-Rapid Predicted, Ultra-Rapid Observed, Rapid, Final. They depend on the response time of data processing and the strength of satellites network that cover the device and reference stations together as well as the Satellite Geometric distribution (DOP) above the observing region **(Hafedh 2017)**.
It should be noted that the errors were not fixed at the mentioned service site in longitudinal values (cm, mm) but were displayed as a time values (Micro Second, Nano Second, Pico Second) that caused by the variation of wave speed in the vacuum according to intensity of atmospheric layers as well as total electrons content **(table 1)** . In other cases; errors reported in the form of arc lengths angle (Arc Second) and this is due to the changes in radius of the earth from location to another according to the elliptical shape of the earth and others **(table 4)**.

In this paper, we will analyze all IGS tables and convert the error values to the longitudinal values, then observe several points with different periods. After that we will compare the error in the four cases with those processed from the IGS site to determine the accuracy of the observing. Then prepare a table that contains the errors ratio of each type of processing (Broad Cast, Ultra Rapid Predicted - Observed, Rapid, Final) to be a reference for the users of this system in the future.

2. Analysis of IGS Tables:

All (IGS) tables will review through which observing data is processed. These tables include all types of errors associated with the observing process. The details of the tables will be briefly summarized, they contain the (type) of correction and the point's accuracy after correction. and the optimal time of data transmission to be correct (Latency), as well as the updating times that are processed by the service site.
The error sources that reviewed by IGS are: **(IGS 2018)**

1- GPS Satellite Ephemerides\ Satellite & Station Clocks.
2- Atmospheric parameter.
3- Earth Rotation.
4- GLONASS Satellite Ephemerides.
5- Geocentric Coordinates of IGS Tracking Stations.

2.1 GPS Satellite Ephemerides / Satellite & Station Clocks.

The correction processes fall in a five types of processing, which vary between major and minor methods, all of which deals with timing of the satellites and the orbits as a base in the correction process **(Tang, Hu et al. 2016)**. Here, its likely to refer to the orbits re-setting process through satellite maneuvers with classical method in IGS for GPS satellites (one time/year/satellite). Inclusion of BeiDou, in 2013 and QZSS (Quasi-Zenith Satellite System) since 2014 helped to find the solution of repositioning detection. Each satellite is reconfigure of the orbits before and after the maneuvers with the satellites mentioned above to be extrapolated the results to the observing day. It represents the coordinates calculated by Broadcast method **(Prange, Orliac et al. 2016).**

The European Space Operations Centre (ESA) explain the maximum accuracy of the RTS (Real time service) orbits and clocks, 5 cm for GPS timing, 8 centimeters for GPS orbits and 13 cm for GLONASS timing and 24 cm for GLONASS orbits, as detailed in The attached table for GPS only **(Elsobeiey and Al-Harbi 2016)**.

The first method (Broadcast) involves the navigational observe process without transmitting data to the processing sites, the combined broadcast file is generated directly on an hourly basis from all hourly navigation files archived at the CDDIS **(NASA 2015)**. The coordinate accuracy of this method indicates an error in orbital data up to 100 cm and the error rate in the satellite timing reach to (5 Nano second). Noted; there is no correction of reference stations and there is no update to data, this indicates the computed coordinates is based on the satellites location only. Usually; this method is used if the work doesn't require high accuracy (1-5) m **(Jia, Li et al. 2014)**.

The second method (Ultra Rapid pred.) contains the same principles as the previous method, but the data is sent to the processing sites directly (Real time) where the correction is based on the data owned from preprocessing of satellite clock offsets in the case of satellite clock prediction **(Huang, Cui et al. 2018)**. Often these data are acceptable, where the error rate indicates to decreases in the orbits from (100 cm) to (5 cm), which is good indicator, but; in this case it is necessary to secure three reference stations - at least - of the (IGS) reference station groups to find the required point **(Wanninger 2000)** . The orbits error in this method up to (5 cm) and the error of the satellites timing reach to 3 Nano second. Data is updated every day at 3:00, 9:00, 15:00 and 21:00 UTC time, however the correction values in the four updates may be fixed because of non-availability of additional data after the first correction at 3:00 am, that's according to several tests of correction process. In the Ultra Rapid Obs., the timing of the data transmission is changed to 3-9 Hr. After the observing process, the updates in this period gives a realism of the observed coordinates. This evident from the accuracy of orbits reaching to (3 cm) and the satellite timings to 150 Pico second **(IGS 2018)**.

The next two methods (Rapid & Final) have unified processing, it depends on the correction of orbits, satellites and stations timings, as well as the expected error are equal to (2.5 cm) for orbits and (75 Pico seconds) for satellites and reference stations timing, However; changing the time of data transmission to secure more information about the observing region to (IGS) appears in (SDev.), where it was in rapid about 25 Pico Second and final 20 Pico Second. It should be noted that adopt the timing of the reference stations in addition to the timing of satellites increased the accuracy of the observed coordinates **(IGS 2018)**.

2.1.1 Supplementary definitions and meanings:

- The main work of multi-GNSS global real-time augmentation positioning system is to obtain the real-time updates, namely real-time orbit and clock **(Chen, Zhao et al. 2018)**. The processing strategy and parameter model .

Based on the two real-time clock estimation methods, the Multi-GNSS global real-time positioning system is designed and the prototype system is constructed. The main processes of the include obtaining the real-time observation data of GNSS reference station, generating the real-time orbit and satellite timing messages and broadcasting multi-GNSS updates. In the prototype system, the GNSS system needs to be built to acquire the real-time observation data and send it to the data processing center through the Internet to acquire a rapid correction.

The real-time Precise Orbit Determination (POD) strategy is that once processing carries out every three hours using previous 48 h observations to obtain the real-time orbit (6 h predicted part). Based on the IGS CORS stations and MGEX stations, about 80 multi-GNSS stations and 40 of which can track BeiDou satellites signal and 60 can capture Galileo satellites signal **(Chen, Zhao et al. 2018).**

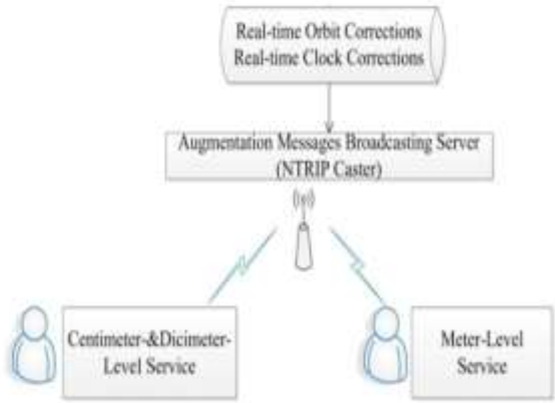

Fig. 1: The prototype frame of multi-GNSS global real-time augmentation positioning system.

It is also noticed that the errors in the satellites and reference stations timing were mentioned in a time format because of variant the wave speed according to nature of the vacuum and total electron content , but by adoption of the ideal wave speed in the vacuum can estimate the expected error that can be produced in the above four methods , if we assume that there is a (1 second) error between the Sat and Stn clocks, this will produce a 3x108 m error at the observed point location, depending on the ideal speed of the electromagnetic wave in the vacuum, as follows:

Wave speed (299,792,458 m/s) ~ 3x10^8 m/s

$$\text{Wave speed} = \frac{\text{Distance}}{\text{Time}} \rightarrow 3x10^8\ m/sec. = \frac{Dis.}{1\ sec.} \rightarrow D = 3x10^8\ m$$

1 Nano second = 1x10-9 second
1 Pico second = 1x10-12 second

It means every (1 ns) satellites or stations timing error will cause coordinates error as shown below :

$$\text{Wave speed} = \frac{Dist.}{Time} \rightarrow 3*10^8\ {}^{m}/_{s} = \frac{Dist.}{10^{-9}} = 0.3\ m$$

However every (1 ps) error in the satellites or stations timing will cause an error in a distance as shown below **(Elsobeiey and Al-Harbi 2016)**:

$$\text{Wave speed} = \frac{Dist.}{Time} \rightarrow 3*10^8\ {}^{m}/_{s} = \frac{Dist.}{10^{-12}} = 0.3\ mm$$

Table 1: GPS Satellite Ephemerides / Satellite & Station Clocks

Type of Observation Process	Accuracy Accuracy of Pointing		Latency	The timing of updating data
Broadcast Direct observing & receiving navigation data without send it to correcting web sites	**Orbits** Error	**~100 cm**	**real time** receiving navigation data from controller without process	**Not found**
	Sat. clocks Only Satellites Clocks Error	**~5 ns RMS** ~ 5 Nano Second Root Mean Square		
		~2.5 ns S.Dev ~ 2.5 Nano second Standard Deviation		
Ultra-Rapid correction (predicted) Based on previously statistics for our region within a specific period	**Orbits** Error	**~5 cm**	**real time** Direct send data after observing process	**at 03, 09, 15, 21 UTC** The timing of updating data at 3:00 , 9:00 , 15:00 , 21:00 Coordinated Universal Time
	Sat. clocks Only Satellites Clocks Error	**~3 ns RMS** ~ 3 Nano Second Root Mean Square		
		~1.5 ns SDev ~ 1.5 Nano second Standard Deviation		
Ultra-Rapid correction (observed) based on statistics of the Rapid method , begin after (3 Hr.) of observing time.	**Orbits** Error	**~3 cm**	**3 - 9 Hours**	**at 03, 09, 15, 21 UTC** The timing of updating data at 3:00 , 9:00 , 15:00 , 21:00 Coordinated Universal Time
	Sat. clocks Only Satellites Clocks Error	**~150 ps RMS** ~ 150 Pico second Root Mean Square		
		~50 ps S.Dev ~ 50 Pico second Standard Deviation		
Rapid Rapid Correction Taking account the timing errors of reference stations as well as timing errors of satellites	**Orbits**	~2.5 cm	**17 - 41hours**	**at 17 UTC daily** Every day at 17 Coordinated Universal Time (UTC)
	Sat. & Stn. Clocks Reference Stations & Satellites Clocks Error	**~75 ps RMS** ~ 75 Pico second Root Mean Square		
		~25 ps S.Dev ~ 25 Pico second Standard Deviation		
Final Final Correction Taking account the timing errors of reference stations as well as timing errors of satellites	**Orbits**	**~2.5 cm**	**12 - 18 days**	**every Thursday**
	Sat. & Stn. Clocks Reference Stations & Satellites Clocks Error	**~75 ps RMS** ~ 75 Pico second Root Mean Square		
		~20 ps S.Dev ~ 20 Pico second Standard Deviation		

- **LOD (Length of Day)** Earth liquid core contains different sets of magnetic waves with periods ranging from several days to many thousands of years. Interplay Archimedes and Coriolis magnetic forces for a periods of several decades is causing MAC waves are thought to be relevant to this Concept that called LOD fluctuations **(Buffett, Knezek et al. 2016)**.

All parts of the GNSS including (satellites, reference stations and user segment) based on UTC (Coordinated Universal Time), because of GMT adopt the daily time 24 hours, but real time per day is not exactly 24 hours There is a slightly difference as shown in the table (2).

Table 2: sample of the day length.

Today's Day Length* in Context		
	Day length	Date
Yesterday	24 hours +1.19 ms	Mon, 6 Nov 2017
Today	24 hours +1.07 ms	Tue, 7 Nov 2017
Tomorrow	24 hours +1.03 ms	Wed, 8 Nov 2017
Shortest 2017	24 hours +0.06 ms	Fri, 4 Aug 2017
Longest 2017	24 hours +2.20 ms	Tue, 25 Apr 2017
Last Year Average	24 hours +1.34 ms	Year 2016

* Yesterday's, today's and future day lengths are predictions.

Noting the sample in the table above, there is a constant change in the day length of the year, the process of calculating the differences in these times to update (UTC) accurately requires periodic follow-up of the control stations .

This means that every day will increased or decreased to the real time 1-2 milliseconds, i.e. (24 hours + 1-2 ms). If this difference is installed in the satellites but the timing of user segment (GMT), that will cause an error (1 ms) it will added to the electromagnetic wave time from the satellite to the user segment. This difference in time will displayed as a distance in the observed coordinates, 1 millisecond difference will cause an error 300 km in the coordinates of the observed point. So it must be; the timing of satellite, reference stations and user segments by (UTC) to find precise coordinates. The following website enables you to know the timing of any day of the year and current time in (UTC) **(Steffen 2018)**.

Note: in the sample date (6 Nov. 2017) it takes Earth to rotate 57.39 cm (22.60 in), as measured at the equator for the time (1.19 ms) **(UTC 2018)**.

- **Why the root mean square and standard deviation.**

a- Root Mean Square (RMS): It is a type of arithmetical averages, as shown in the following formula:

$$RMS = \sqrt{\frac{\sum_{i}^{n}{}_{1} x_i^2}{n}}$$

This (Mean) is a method to given negative values a proportional importance to its absolute value, considering that the values that give negative deviations from the real values in the observing sample must be taken account, for example, if the ideal (X) coordinate of a Suggested point (10 meters) and the observations 10.003, 10.007, 9.995, 9.992, etc.). Therefore, the value of the mean can't be used with negative signals (-5mm, -8mm) because the sum with the positive values (+3 mm, +7mm) will reduce the real value of the average Error, so; this Mean was adopted as a solution for this problem.

b- Standard Deviation (S. Dev): An amount that expresses the extent of data dispersion in the sample, or the maximum range of deviations of anomalous values from mean values (mean deviations). Thus, it expresses the maximum extent of the error in the abnormal observations of the real values in the instrument observations, the figure (2) illustrates the two concepts above.

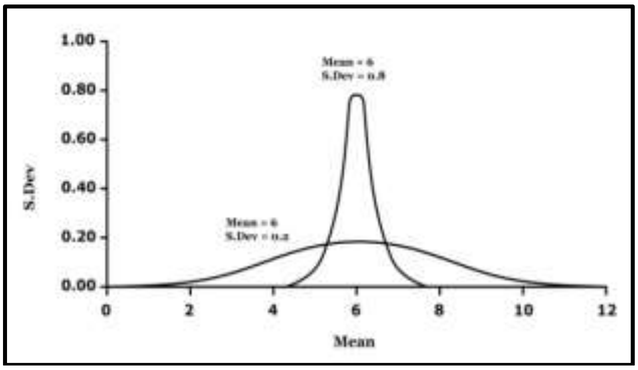

Figure 2: A sample of Standard Deviation and Mean.

The error values shown in the previous calculations for (Satellite Ephemerides / Satellite & Station Clocks) will be as showing in the table (3).

Table 3: total errors of GPS Satellite Ephemerides / Satellite & Station Clocks

Type	Accuracy		Error value	Total error
Broadcast	Orbits	~100 cm	100 cm	2.5 m RMS
	Sat. clocks	~5 ns RMS	5 x 0.3 m = 1.5 m	
		~2.5 ns SDev	2.5 x 0.3 m = 0.75 m	0.75 m S.Dev
Ultra-Rapid (predicted half)	Orbits	~5 cm	5 cm	0.95 m RMS
	Sat. clocks	~3ns RMS	3 x 0.3 m = 0.9 m	
		~1.5 ns SDev	1.5 x 0.3 m = 0.45 m	0.45 m S.Dev
Ultra-Rapid (observed half)	Orbits	~3 cm	3 cm	7.5 cm RMS
	Sat. clocks	~150 ps RMS	150 x 0.3 mm= 45 mm	
		~50 ps SDev	50 x 0.3 mm= 15 mm	1.5 cm S.Dev
Rapid	Orbits	~2.5 cm	2.5 cm	4.75 cm RMS
	Sat. & Stn. Clocks	~75 ps RMS	75 x 0.3 mm= 22.5 mm	
		~25 ps SDev	25 x 0.3 mm= 7.5 mm	0.75 cm S.Dev
Final	Orbits	~2.5 cm	2.5 cm	4.75 cm RMS
	Sat. & Stn. Clocks	~75 ps RMS	75 x 0.3 mm= 22.5 mm	
		~20 ps SDev	20 x 0.3 mm= 6 mm	0.6 cm S.Dev

The figure (2) explain the error values by Mean and Standard deviation of Satellite Ephemerides / Satellite & Station Clocks.

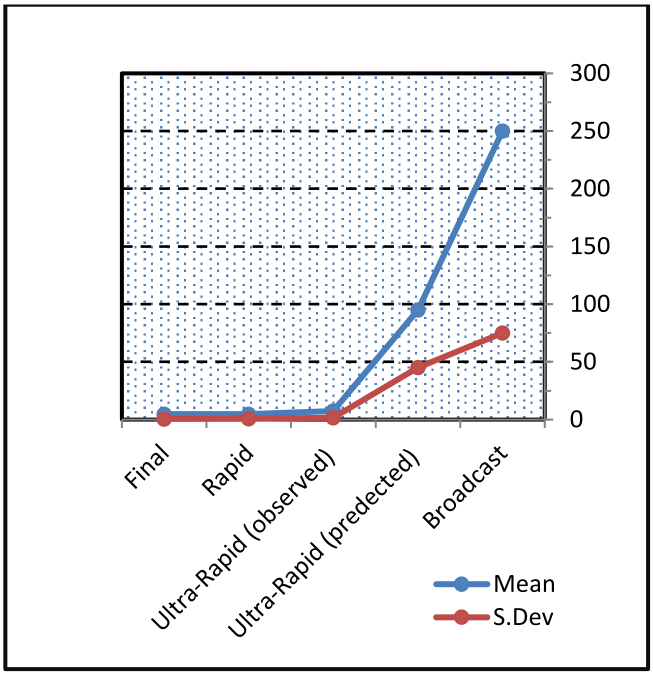

Figure 2: The Mean and Standard Deviation in Satellite & Station Clocks & Ephemerides) by Centimeter

2.2 Atmospheric parameters :

Second type is the Troposphere & Ionosphere correction. The two layers of the atmosphere are directly affected by the electromagnetic wave speed traveling between the satellite and the user segment. The latency of final tropospheric zenith path delay (ZPD) is (11 day), (4 Week) for Ionosphere if the correction (Final), and (24 Hr.) for Ionosphere if the correction (Rapid), as shown in Table (4).

Table 4: Atmospheric parameters correction details

Type	Accuracy	Latency	Updates
Final tropospheric zenith path delay with N, E gradients	4 mm (ZPD) zenith path delay 4 mm	< 4 weeks	Daily
Final ionospheric TEC grid total electron content	2-8 TECU	~11 days	Weekly
Rapid ionospheric TEC grid	2-9 TECU	<24 hours	Daily

The figure bellow shows the atmosphere around the earth with the Troposphere & Ionosphere.

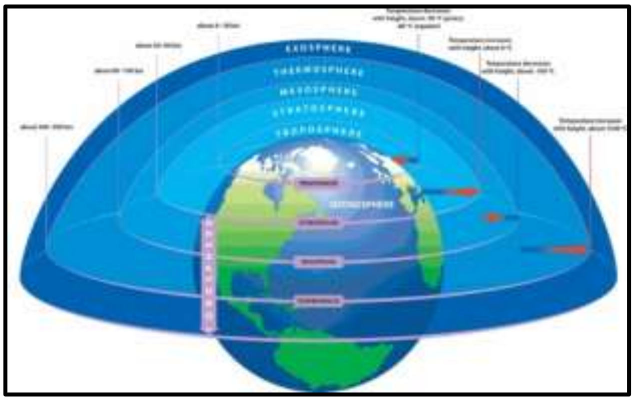
Figure 3: Atmospheric layers, troposphere and Ionosphere Layers are clearly defined.

One of the principal notes adopted from GNSS (Global Navigation Satellite Systems) ionospheric total electron content (TEC), which measures the free electrons in ionosphere plasma along the signal path **(Breitsch 2017)**. Total electron content is generally computed from the difference of dual-frequency signals of the GNSS satellite. However, it is very difficult to specify the difference between the ionosphere and other effects, such as satellite antenna phase effects and multipath. At the present time triple-frequency GNSS signals allow computation of geometry-ionosphere-free combinations (GIFC) **(Li 2018).**

2.3 Earth Rotation:

The below table (5) includes two types of errors associated with ground rotate around itself:

Table 5: Earth rotation error details

Type	Accuracy		Latency	Updates
Ultra-Rapid (predicted half)	PM Polar Motion	~200 µas Micro Arc Second	real time	at 03, 09, 15, 21 UTC Coordinated Universal Time
	PM rate Polar Motion Rate	~300 µas/day Micro Arc Second/Day		
	LOD Length of Day	~50 µs Micro Second		
Ultra-Rapid (observed half)	PM	~50 µas	3 - 9 Hours	at 03, 09, 15, 21 UTC
	PM rate	~250 µas/day		
	LOD	~10 µs		
Rapid	PM	~40 µas	17 - 41 hours	at 17 UTC daily
	PM rate	~200 µas/day		
	LOD	~10 µs		
Final	PM	~30 µas	11 - 17 days	every Wednesday
	PM rate	~150 µas/day		
	LOD	~10 µs		

2.3.1 Polar Motion (PM):

The spiral motion at the north & south poles as a result to deflect the geographic axis and spin axis, The Earth rotation axis moves continuously relative to a crust reference frame. PM is control by this relative motions the angular momentum conservation of the of the earth as a result of merge the fluid layers (atmosphere, oceans, and surface hydrology etc.) with the solid part of the earth so; it provides an exquisitely precise system to monitor the Earth and assess its parts, and it's one of the global scales to study the variable state of the earth, PM is uniquely well observed since the mid-1990s with accuracy 1 mm of surface movement or an angle of ~30 mas of the planet's circumference **(Ray, Rebischung et al. 2017)**.
It should be noted that the value of micro arc-second (µas) represents the following:

1 µas = 1.0×10^{-6} arc sec & to convert it to Degree

$$\frac{10^{-6}}{3600} = 2.7777777777778 * 10^{-10}$$

1 µas = $2.7777777777778 \times 10^{-10\,\circ}$

To find the value of the earth's periphery arc that corresponding the angle (1 µas).

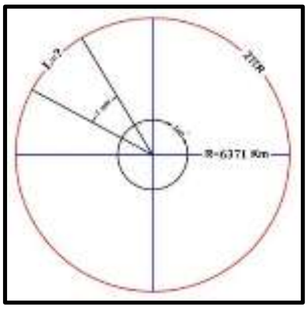

Fig. 4: length of the arc opposite to (1 µas) with average radius of the earth (6371 km)

From the above figure, the value (L) can be extracted as shown:

$$\frac{2.7777778 * 10^{-10}}{L} = \frac{360^\circ}{2\pi R} \rightarrow L = \frac{2.77777778 * 10^{-10} * 2 * \pi * 6371 * 10^6}{360^\circ} = 0.0309\ mm$$

This means that the amount of arc corresponding to (1 µas) = 0.031 mm on earth surface, i.e. that each (100 µas) = 3.1 mm. In other words, the circular polar motion resulting of a central angle of 250 µas will causing an error 7.75 mm.

2.3.2 Length of Day (LOD) :

The rotational motion around the Earth axis which produces a retrograde movement resulting from the mismatch the apparent Greenwich with Greenwich, that leads to the time argument (UT1). Here we need to determine the difference between UT1 and UTC to determine exact atomic time, this difference called LOD **(Nothnagel, Fischer et al. 2006)**.
So we should know the difference in the central angle between the apparent Greenwich with Greenwich. Depending on the results above, the deflection (1 µas) between the apparent Greenwich with Greenwich will be 0.031 mm. Therefore; the error shown in the previous table will be:

50 µs = 0.031 mm x 50 = 1.55 mm

10 µs = 0.031 mm x 10 = 0.31 mm

Based on the previous concepts, the errors resulting from Earth Rotation will be as shown in the following table (6):

Table 6: Total errors of Earth rotation by (mm)

Type	Accuracy		Total error	Error value
Ultra-Rapid (predicted half)	PM Polar Motion	~200 µas Micro Arc Second	6.2 mm	7.75 mm
	PM rate Polar Motion Rate	~300 µas/day	---	
	LOD Length of Day	~50 µs	1.55 mm	
Ultra-Rapid (observed half)	PM	~50 µas	1.55 mm	1.58 mm
	PM rate	~250 µas/day Micro Arc Second/Day	---	
	LOD	~10 µs Micro Second	0.031 mm	
Rapid	PM	~40 µas	1.24 mm	1.27 mm
	PM rate	~200 µas/day	---	
	LOD	~10 µs	0.031 mm	
Final	PM	~30 µas	0.93 mm	0.96 mm
	PM rate	~150 µas/day	---	
	LOD	~10 µs	0.031 mm	

2.4 GLONASS Satellite Ephemerides

The total error in GLONASS satellites is limited to 3 cm. The ideal data transmission time is between 12-18 days. The data update time is every Thursday. The details of the satellite system are not shown in the table above. However, its compatible with the (GPS) satellites as mentioned previously **(Seppänen, Ala-Luhtala et al. 2012)**, but we didn't find repositioning for the Galileo and BeiDou satellites **(Prange, Orliac et al. 2016)**.

Table 7: Total errors of GLONASS Satellite Ephemerides

Type	Accuracy	Latency	Updates
Final	3 cm	12-18 days	Every Thursday

2.5 Geocentric Coordinates of IGS Tracking Stations

It refers to the location of IGS reference stations, which are adopted as base points. The coordinates of these stations are recorrected and updated weekly. This simple motion of reference stations is a result to the natural movement of the earth crust which cause annually movement of any location on the surface of the earth, including sites of these stations.

Table 8: Total errors of Geocentric Coordinates of IGS Tracking Stations

Type	Accuracy		Latency	Updates
Final positions	Horizontal accuracy	3 mm	11 - 17 days	every Wednesday
	Vertical accuracy	6 mm		
Final velocities of IGS reference stations	Horizontal	2 mm/yr	11 - 17 days	every Wednesday
	Vertical	3 mm/yr		

3. Results of previous tables:

From the previous tables, we find that there are a number of causes of errors that can be summarized as follows:

1- Errors of (GPS Satellites): GPS Satellite Ephemerides\ Satellite & Station Clocks.
2- Errors of (GLONASS Satellites): GLONASS Satellite Ephemerides.
3- Errors of (IGS Stations): All IGS references stations.
4- Errors of (Earth Rotation): (Polar Motion &and Length of Day).
5- Errors of (Atmospheric Parameter): (Troposphere & Ionosphere).

These errors can be processed by five methods:
[Broadcast , Ultra-Rapid (predicted) , Ultra-Rapid (observed) , Rapid , Final]. And we would like to point out that these acts are directly affected by the following factors **(Hafedh 2017)** :

1- Time of data transmission (giving IGS Sufficient time to study the observing area).
2- Increased observing period.
3- Use the appropriate Dilution of Precision (DOP) at the observing time.

The results error for all observing methods and their processing are as shown in Table (9).

Table 9: Total errors that showing in IGS web site

No.	Type	Method	Error	S. Dev.
1	GPS Satellite Ephemerides / Satellite & Station Clocks	Broadcast	2.5 m	0.75 m
		Ultra-Rapid (predicted)	0.95 m	0.45 m
		Ultra-Rapid (observed)	7.5 cm	1.5 cm
		Rapid	4.75 cm	0.75 cm
		Final	4.75 cm	0.6 cm
2	GLONASS Satellite Ephemerides	Final	3 cm	---
3	Geocentric Coordinates of IGS Tracking Stations	Final	3 mm	---
4	Earth Rotation	Ultra-Rapid (predicted)	7.75 mm	---
		Ultra-Rapid (observed)	1.58 mm	---
		Rapid	1.27 mm	---
		Final	0.96 mm	---
5	Atmospheric parameters	Final tropospheric	4 mm	---
		Rapid ionospheric	---	---
		Final ionospheric	---	---
SUM.		1- Broadcast	2.5 m	0.75 m
		2- Ultra-Rapid (predicted)	0.997 m	0.45 m
		3- Ultra-Rapid (observed)	11.36 cm	---
		4- Rapid	8.58 cm	---
		5- Final	8.45 cm	---

Ultra-Rapid & Rapid correction values were computed through adding the final error values from GLONASS satellites, reference stations and atmospheric parameters to the normal error, because this correction is comprehensive for all previous errors.
It should be noted that the amount of error in each of the five types may not correspond others , may be the direction error of a point not in the same direction of other error , in other words may be the error in the (X) coordinates of the Earth rotation is positive and the direction of Atmospheric parameters is negative for the same, in this case the X-direction will reduce the amount of error for this point, while the assumption that we followed is in the five errors are taken in the same direction to put the worst cases.

4. Research Observations :

Several observations have been made that have yielded very close results, and because of big processing data that the research does not accommodate it, we was selected the most important two points that achieve the objective of this research. This observations of a specific point on the building of Department of Surveying Techniques at the Institute of Technology – Baghdad , the first with a period of two hours beginning at 10:30 am to 12:45 pm in 29/11/2017 and the other was 4 hours from 11:00 am to 3:00 pm in12/3/2018. In both observations the (DOP) was adopted by Follow up the satellite tracking site (https://www.n2yo.com) as shown in Figure (5).

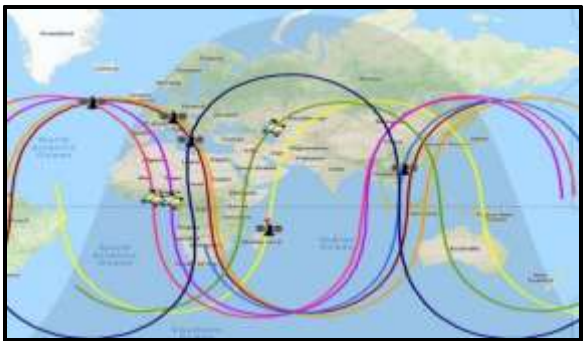

Fig. 5: satellite tracking site and its paths

Based on the data prepared by the IGS web site, the timing of the data transmission was adopted according to the time allotted of each them. The CORS reference stations surrounding the observation site were also adopted at close range (ISBA ~ 10~Km, ISKU ~ 200 Km, ISNA ~ 200 Km) .
As we explained previously that the coordinate's accuracy correlated with the distance between the stations **(Hafedh 2017)**. From about 100 Pico second for a 500 km baseline, it grows up to about 300 Pico second for the inter-continental baselines **(Defraigne 2015)**.

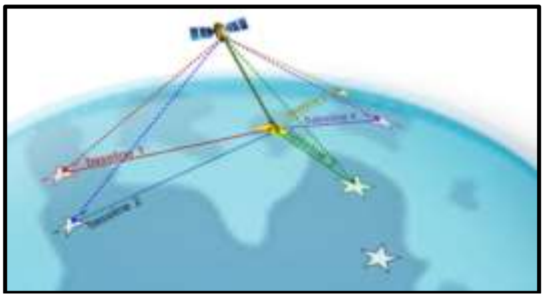

Fig. 6: Base lines for observing point with reference stations

5. Results of the tables (10-19):

Considering that the best values those of 4 hours observing period and 4 weeks of data transmission (E = 452597.368, N = 3680276.112), which contains an error of (8.45 cm) included in this table based that noted in IGS Products.
Where the amounts of errors (deviations) were determined from the value assumed to be the value closest to the right, as shown in the table (20):

Table 20: The error value of each correction method added to it the assumed actual error (8.45 cm)

Type	IGS Products Error	2 Hours Observation Error	4 Hours Observation Error
Broadcast	2.5 m	2.577 m	2.25 m
Ultra-Rapid (predicted)	0.997 m	---	8.45 cm + 0.753 m
Ultra-Rapid (observed)	11.36 cm	8.45 cm + 1 cm	8.45 cm + 2 cm
Rapid	8.58 cm	8.45 cm + 1.6 cm	8.45 cm + 0.7 cm
Final	8.45 cm	8.45 cm + 1.2 cm	8.45 cm + 0 cm

It is noted in the above data that the errors have a harmonic gradient, where the error value of the observe (2 hours) to these opposite it (4 hours) in all five cases, except the observe (4 hours) in the (ultra-Rapid (observed)) and it explains the deflection values that mentioned in S. Dev.

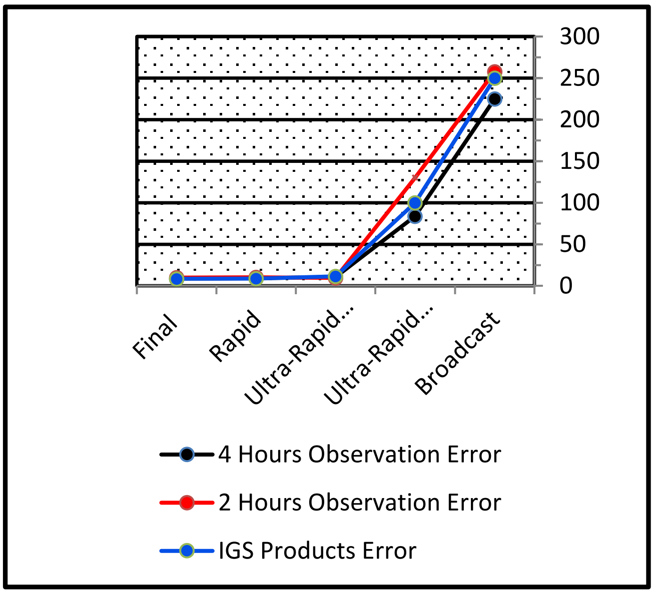

Fig. 7: the resulted errors of 2 – 4 Hours of all correction methods

From what previously mentioned, we deduced that errors increase with less observing time and less data transmission time to processing web site. We also conclude that the errors (if we exclude the first two cases) range from 8.5 to 10.5 cm, and with the exception of the error shown in IGS tables, the errors are reduced to 2 cm.

6. Conclusions:

To specify a precise point, we need to three main factors (observing time, data transmission time or latency, DOP), and these factors are the key factors in optimal observation. In some cases, we find that the observer sends the data directly to the processing site, and this is one of the reasons of increasing the error values, which may reach to (1 m)

In other cases, the observing period may be longer. But, the shortest observing period may give more accuracy, that's according to the time of data transmission to the processing site, because IGS will have sufficient data for the observing area.
Depending on the standard deviations, it is assumed that the observing is repeated for the same point in order to avoid abnormal values, especially when the work requires Real-time data, so first data should be sent to the processing site within the required time, then resend it later according to IGS products to check the previous coordinate.
It is preferable to locate reference stations closest to the observing site, there is a positive relationship between base line and the error value.
The errors described in this research are systematic errors, but there are human errors such as (Multi-Path), or fixation a point on a soft ground that would later be shifted as a result to natural or human affects, so the human errors should avoid before making observation and corrections with systematic errors.

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References :

[1] Breitsch, B. (2017). LINEAR COMBINATIONS OF GNSS PHASE OBSERVABLES TO IMPROVE AND ASSESS TEC ESTIMATION PRECISION. Electrical and Computer Engineering. Colorado, Colorado State University. Published Master Thesis.
[2] Buffett, B., et al. (2016). "Evidence for MAC waves at the top of Earth's core and implications for variations in length of day." Geophysical Journal International 204(3): 1789–1800.
[3] Chen, L., et al. (2018). "GNSS global real-time augmentation positioning: Real-time precise satellite clock estimation, prototype system construction and performance analysis." Advances in Space Research 61(1): 367-384.
[4] Defraigne, P. (2015). "Monitoring of UTC(k)'s using PPP and IGS real-time products." GPS Solutions 10(1): 165–172.
[5] Elsobeiey, M. and S. Al-Harbi (2016). "Performance of real-time Precise Point Positioning using IGS real-time service." GPS Solutions 20(3): 565–571.
[6] Hafedh, H. (2017). Accuracy Assessment of Different GNSS Processing Software. Surveying Engineering Engineering Technical College – Baghdad Middle Technical University. Master: 76.
[7] Huang, G., et al. (2018). "An Improved Predicted Model for BDS Ultra-Rapid Satellite Clock Offsets." Remote Sensing 10(1).
[8] IGS (2018). "INTERNATIONAL GNSS SERVICE . http://www.igs.org/products".
[9] Jia, R. X., et al. (2014). "Broadcast Ephemeris Accuracy Analysis for GPS Based on Precise Ephemeris." Applied Mechanics and Materials 602: 3667-3670.
[10] Li, B. (2018). "Review of triple-frequency GNSS: ambiguity resolution, benefits and challenges." The Journal of Global Positioning Systems 16(1).
[11] Maciuk, K. (2016). "THE STUDY OF SEASONAL CHANGES OF PERMANENT STATIONS COORDINATES BASED ON WEEKLY EPN SOLUTIONS." The Journal of Space Research Centre of Polish Academy of Sciences 51(1): 1–18.
[12] NASA (2015" .(Daily GPS Broadcast Ephemeris Files, https://cddis.nasa.gov/Data_and_Derived_Products/GNSS/broadcast_ephemeris_data.html".
[13] Nothnagel, A., et al. (2006). Observation of the Earth System from Space. Institut für Astonomische Physikalische GeodäsieTU München München Germany, Earth and Environmental Science.
[14] Prange, L., et al. (2016). "CODE's five-system orbit and clock solution—the challenges of multi-GNSS data analysis." Journal of Geodesy 91(4): 345–360.
[15] Ray, J., et al. (2017). "IGS polar motion measurement accuracy." Geodesy and Geodynamics 8(6): 413-420.
[16] Seppänen, M., et al. (2012). "Autonomous Prediction of GPS and GLONASS Satellite Orbits." Journal of the Institute of Navigation 59(2): 119-134.

[17] Steffen (2018). "A Day Is Not Exactly 24 Hours https://www.timeanddate.com/time/earth-rotation.html".
[18] Tang, C., et al. (2016). "Improvement of orbit determination accuracy for Beidou Navigation Satellite System with Two-way Satellite Time Frequency Transfer." Advances in Space Research 58(7): 1390.1400-
[19] UTC (2018). "A Day Is Not Exactly 24 Hours . https://www.timeanddate.com/time/earth-rotation.html".
[20] Wanninger, L. (2000). "The Performance of Virtual Reference Stations in Active Geodetic GPS-networks under Solar Maximum Conditions." Proceedings of ION GPS 99: 1419 - 1428.

.Observed data End at 12:45 PM (BGW) – 9:45 AM (UTC) >>>>> Obtained 1:00
Observing Time Period : 2:15
Date : Wed 29/11/2017
With : VDOP , GDOP , HDOP , PDOP

Table 10: GPS Satellite Ephemerides / Satellite & Station Clocks

Method	Latency	Updates (UTC)	Updates (BGW)		Latency Time (BGW)	Data Sent according Updates (BGW)	Coordinates	
							Easting	Northing
Broadcast	Real Time	---	---		---	Without Sending (Direct)	452594.791	3680277.368
Ultra Rapid Predicted	Real Time	3:00	6:00 AM	29/11	1:00 PM 29/11 To 4:00 PM 29/11 (After 4:00 PM → Observed)	1:00-4:00 PM Not Accepted, last update 6:00 AM	---	---
		9:00	12:00 PM	29/11		1:00-4:00 PM Not Accepted, last update 12:00 PM	---	---
		15:00	6:00 PM	29/11		(After 4:00 PM → Observed)	---	---
		21:00	12:00 AM	30/11		(After 4:00 PM → Observed)	---	---
Ultra Rapid Observed	3-9 Hr.	3:00	6:00 AM	29/11	6:00 PM 29/11 To 3:00 AM 30/11	1:00-4:00 PM Not Accepted, last update 6:00 AM	---	---
		9:00	12:00 PM	29/11		1:00-4:00 PM Not Accepted, last update 12:00 PM	---	---
		15:00	6:00 PM	29/11		6:00 PM 29/11 - 12:00 AM 30/11	452597.379	3680276.128
		21:00	12:00 AM	30/11		12:00-3:00 AM 30/11	452597.378	3680276.127
Rapid	17-41 Hr.	at 17 Daily	at 8:00 PM Daily		6:00 AM 30/11 To 6:00 AM 1/12	8:00 PM 30/11 – 6:00 AM 1/12	452597.376	3680276.127
Final	12-18 day	Every Thursday	Every Thursday		11/12 Mon. – 17/12 San.	14/12 Thurs. – 17/12 San.	452597.362	3680276.121

Table 11: GLONASS Satellite Ephemerides

Method	Latency	Updates (UTC)	Updates (BGW)	Latency Time (BGW)	Data Sent according Updates (BGW)	Coordinates	
						Easting	Northing
Final	12-18 day	Every Thursday	Every Thursday	11/12 Mon. – 17/12 San.	14/12 Thurs. – 17/12 San.	452597.362	3680276.121

Table 12:. Geocentric Coordinates of IGS Tracking Stations

Method	Latency	Updates (UTC)	Updates (BGW)	Latency Date (DGW)	Data Sent according Updates (BGW)	Coordinates	
						Easting	Northing
Final	11-17 day	Every Wednesday	Every Wednesday	10/12 San. – 16/12 Sat.	13/12 Wed. – 16/12 Sat.	452597.361	3680276.122

Table 13: Earth Rotation

Method	Latency	Updates (UTC)	Updates (BGW)		Latency Time (BGW)	Data Sent according Updates (BGW)	Coordinates	
							Easting	Northing
Ultra Rapid Predicted	Real Time	3:00	6:00 AM	29/11	1:00 PM 29/11 To 3:00 AM 30/11	1:00-4:00 PM Not Accepted, last update 6:00 AM	---	---
		9:00	12:00 PM	29/11		1:00-4:00 PM Not Accepted, last update 12:00 PM	---	---
		15:00	6:00 PM	29/11		(After 4:00 PM → Observed)	---	---
		21:00	12:00 AM	30/11		(After 4:00 PM → Observed)	---	---
Ultra Rapid Observed	3-9 Hr.	3:00	6:00 AM	29/11	6:00 PM 29/11 To 3:00 AM 30/11	Not Accepted	---	---
		9:00	12:00 PM	29/11		Not Accepted	---	---
		15:00	6:00 PM	29/11		6:00 PM 29/11 - 12:00 AM 30/11	452597.379	3680276.129
		21:00	12:00 AM	30/11		12:00-3:00 AM 30/11	452597.378	3680276.131
Rapid	17-41 Hr.	at 17 Daily	at 8:00 PM Daily		6:00 AM 30/11 To 6:00 AM 1/12	8:00 PM 30/11 – 6:00 AM 1/12	452597.376	3680276.127
Final	11-17 day	Every Wednesday	Every Wednesday		10/12 San. – 16/12 Sat.	13/12 Wed. – 16/12 Sat.	452597.361	3680276.122

Table 14: Atmospheric Parameters

Method	Latency	Updates (UTC)	Updates (BGW)	Latency Time (BGW)	Data Sent according Updates (BGW)	Coordinates Easting	Northing
Final Tropospheric	< 4 Week	Daily	Daily	27/12	27/12	452597.364	3680276.119
Final Ionospheric	~11 Days	Weekly	Weekly	10/12	10/12	452597.362	3680276.124
Rapid Ionospheric	< 24 Hr.	Daily	Daily	1:00 PM 30/12	1:00 PM 30/12	452597.379	3680276.128

Observed data End at 3:00 PM (BGW) – 12:00 PM (UTC) >>>>> Obtained 3:00 (BWG)
Observing Time Period: 4:00 Hours
Date: Mon 12/3/2018
With: VDOP, GDOP, HDOP, PDOP

Table 15: GPS Satellite Ephemerides / Satellite & Station Clocks

Method	Latency	Updates (UTC)	Updates (BGW)		Latency Time (BGW)	Data Sent according Updates (BGW)	Coordinates	
							Easting	Northing
Broadcast	Real Time	---	---		---	Without Sending (Direct)	452595.416	3680274.862
Ultra Rapid Predicted	Real Time	3:00	6:00 AM	12/03	3:00 PM 12/3 To 6:00 PM 12/3 (After 6:00 → Observed)	3:00-6:00 PM Not Accepted, After 6:00 AM	---	---
		9:00	12:00 PM	12/03		3:00-6:00 PM Not Accepted, After 12:00 PM	---	---
		15:00	6:00 PM	12/03		6:00 PM 12/3	452598.121	3680276.679
		21:00	12:00 AM	13/03		(After 6:00 → Observed)	---	---
Ultra Rapid Observed	3-9 Hr.	3:00	6:00 AM	12/03	6:00 PM 12/3 To 3:00 AM 13/3	Not Accepted	---	---
		9:00	12:00 PM	12/03		Not Accepted	---	---
		15:00	6:00 PM	12/03		6:00 PM 29/11 - 12:00 AM 30/11	452597.374	3680276.132
		21:00	12:00 AM	13/03		12:00-3:00 AM 30/11	452597.378	3680276.131
Rapid	17-41 Hr.	at 17 Daily	at 8:00 PM Daily		8:00 AM 13/3 To 8:00 AM 14/3	8:00 PM 13/3 – 8:00 AM 14/3	452597.375	3680276.1140
Final	12-18 day	Every Thurs-day	Every Thursday		24/3 Sat. – 30/3 Fri.	29/3 Thurs. – 30/3 Fri .	452597.365	3680276.121

Table 16: GLONASS Satellite Ephemerides

Method	Latency	Updates (UTC)	Updates (BGW)	Latency Time (DWG)	Data Sent accord-ing Updates (BGW)	Coordinates	
						Easting	Northing
Final	12-18 day	Every Thursday	Every Thursday	24/3 Sat. – 30/3 Fri.	29/3 Thurs. – 30/3 Fri .	452597.365	3680276.121

Table 17: Geocentric Coordinates of IGS Tracking Stations

Method	Latency	Updates (UTC)	Updates (BGW)	Latency Date (BGW)	Data Sent (BGW)	Coordinates	
						Easting	Northing
Final Posi-tions	11-17 day	Every Wednesday	Every Wednes-day	23/3 Fri . – 29/3 Thu.	28/3 Wed. – 30/3 29/3 Thu.	452597.365	3680276.121

Table 18: Earth Rotation

Method	Latency	Updates (UTC)	Updates (BGW)		Latency Time (BGW)	Data Sent according Updates (BGW)	Coordinates	
							Easting	Northing
Ultra Rapid Predicted	Real Time	3:00	6:00 AM	12/03	3:00 PM 12/3 To 6:00 PM 12/3 (After 6:00 → Observed)	3:00-6:00 PM Not Accepted, After 6:00 AM	---	---
		9:00	12:00 PM	12/03		3:00-6:00 PM Not Accepted, After 12:00 PM	---	---
		15:00	6:00 PM	12/03		6:00 PM 12/3	452598.121	3680276.679
		21:00	12:00 AM	13/03		(After 6:00 → Observed)	---	---
Ultra Rapid Observed	3-9 Hr.	3:00	6:00 AM	12/03	6:00 PM 12/3 To 3:00 AM 13/3	Not Acceptable	---	---
		9:00	12:00 PM	12/03		Not Acceptable	---	---
		15:00	6:00 PM	12/03		6:00 PM 29/11 - 12:00 AM 30/11	452597.374	3680276.132
		21:00	12:00 AM	13/03		12:00-3:00 AM 30/11	452597.378	3680276.131
Rapid	17-41 Hr.	at 17 Daily	at 8:00 PM Daily		8:00 AM 13/3 To 8:00 AM 14/3	8:00 PM 13/3 – 8:00 AM 14/3	452597.375	3680276.114

Final	11-17 day	Every Wednesday	Every Wednesday	23/3 Fri . – 29/3 Thu.	28/3 Wed. – 30/3 29/3 Thu.	452597.365	3680276.121

Table 19: Atmospheric Parameters

Method	Latency	Updates (UTC)	Updates (BGW)	Latency Time (BGW)	Data Sent according Updates (BGW)	Coordinates	
						Easting	Northing
Final Tropospheric	< 4 Week	Daily	Daily	27/12	27/12	452597.368	3680276.112
Final Ionospheric	~11 Days	Weekly	Weekly	10/12	10/12	452597.364	3680276.120
Rapid Ionospheric	< 24 Hr.	Daily	Daily	1:00 PM 30/12	1:00 PM 30/12	452597.373	3680276.118