Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 7 Issue 5, May - 2020

Investigating The Performance Of Static-Ppp Using Ultra-Rapid, Rapid And Final Orbit/Clock Products For Higher Order Survey

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Abstract— ***The use of final IGS precise orbit and clock products for accurate Static-PPP proved its effectiveness in determining the positional information of points for higher order survey. However, the leading shortcoming of using the final products is that they are available after approximately 13days of data collection, which is bad for timely measures after an event. In this study, the use of ultra-rapid products, which are available after a few hours of data collection, and rapid products, which are available in less than 24 hrs, are investigated and their results are compared to the more precise final products. To evaluate the accuracy of PPP using ultra-rapid, rapid and final products for higher order surveying, their products were compared with DGNSS coordinates. The results showed that accurate Static-PPP solutions based on the three products can be used for precise positioning with good accuracy but for different categories of applications. There were slight differences between ultra-rapid, rapid and final products, where some of the tested control point's position indicated that the latter two product are more accurate and provide better results compared to the ultra-rapid product which is better suited for reconnaissance survey.***

Keywords: -PPP; Static-PPP; Control Points; GNSS; Reconnaissance Survey; IGS; precise satellite products.

I. INTRODUCTION

Precise Point Positioning (PPP) is a positioning technique that appeared in the past two decades; this new technique requires only one global navigation satellite system (GNSS) receiver, which makes it a cost effective method when compared with the differential positioning technique. In the PPP technique, the processing procedure does not use the clock and satellite ephemerides broadcasted in the navigation massage. Instead of this, precise ephemerides and clock data are used.

PPP has several serious disadvantages; the most significant shortage is the long convergence time that may exceed 20 min to solve the ambiguity resolution in order to ensure centimeter-level positioning accuracy for dual-frequency observations and exceeds 30 min to ensure half meter level for single-frequency observations. Because of this shortage, the use of PPP in real-time applications has been limited. In addition to the convergence time, ionospheric delay makes a severe difficulty in single-frequency receivers for decimeter-level accuracy (Rizos et al., 2012).

For dual-frequency observations, it has been demonstrated that millimeter-level accuracy can be obtained using PPP in static mode. In kinematic mode, the centimeter-level accuracy can potentially be achieved (Gao and Chen, 2004; Choy, 2009; Li et al., 2011; Rizos et al., 2012).

Providing accurate orbit ephemerides for the Global Navigation Satellite Systems (GNSS) has been a core objective of the International GNSS Service (IGS) since its founding in 1994 (e.g., Beutler et al. 1999). Different product series are published for diverse applications; see http://igscb.jpl.nasa.gov/components/prods.html. The Ultra-rapid GPS orbits span 48hrs and are released four times daily with an initial latency of 3hrs. The first half of each Ultra-rapid file is based on fits to observational data while the second half is predicted. These are intended for real-time and near real-time applications. The daily Rapid GPS orbits cover the 24h of the previous UTC day with an initial latency of 17h. They have near-definitive quality and robustness, and are intended for high-accuracy, rapid-turnaround uses. The Final GPS and GLONASS orbits are the definitive IGS orbital products and are released weekly as a bundle of seven daily files. Special care is taken to ensure the highest level of consistency with the associated IGS terrestrial reference frames, Earth rotation parameters, and receiver and satellite clocks. Consequently, the latency of the Final products is longer, about 13days or more. Each IGS orbit product is generated from a weighted linear combination (Beutleretal.1995) of solutions contributed by up to eight independent Analysis Centers (ACs); see http://igscb.jpl.nasa.gov/organization/centers.html for a list of the IGS ACs. The individual ACs mostly use distinct data reduction systems and procedures, drawing GPS observational data from the IGS global tracking network of more than 300 stations. The Standard Product #3 (SP3) format (Spofford and Remondi 1995) is used to exchange orbital information in the form of tabular ephemerides of satellite positions every 15min expressed in a terrestrial crust-fixed reference frame; see also http://igscb.jpl.nasa.gov/ igscb/data/format/sp3c.txt. Associated consistent estimates for the satellite clocks are also provided in the SP3 files at 15-min intervals. (Since November 2000 the satellite clocks are available in addition at 5-min intervals, and since January 2007 at 30-s intervals).

The purpose of this research is to investigate the performance PPP using ultra-rapid, rapid and final IGS orbits and clock products for higher order survey. The solution gotten from the first two products were compared with that of the later to determine the correlation. The solutions gotten from those three products were later compared to that gotten from relative GNSS positioning in order to determine their suitability for higher order survey.

II. PRECISE POINT POSITIONING VS RELATIVE POSTIONING

PPP method uses only one receiver without relating to reference station. It means common GNSS errors do not cancel in PPP, errors such as orbital error, tropospheric delay, ionospheric delay, multipath, satellite clock error and receiver clock error. In PPP method, utilizing precise product from IGS can eliminate the observational error. Moreover, the duration of observation can affect the result. In this contribution we assume that the observations are multipath free. Ionospheric delay can be eliminated by utilizing the ionospheric-free linear combination, while tropospheric delay can be eliminated by using troposphere model like saastamoinen. Utilizing precise clock product from IGS can eliminate the satellite and receiver clock errors, and using precise orbit from IGS can reduce the orbital error.

On the other side, the relative positioning method uses two or more receivers. This method requires simultaneous observations at both receivers to determine the coordinates of an unknown point with respect to a known point. Assuming such simultaneous observation at the two points A and B to satellites j and k, linear combination can be formed leading to single difference, double difference, and triple difference.

By using the double difference technique, common errors can be eliminated. However, quality of the result of relative method depends on the distance between receivers. Relative method can be performed with a maximum distance of 20 km length (short baseline) between receivers, with the absence of the tropospheric and ionospheric influences.

III. FIELD DATA

The observation was carried out on five control points (URF1-URF5) located within the premises of Federal School of Surveying, Oyo. Static observation of not less than one hour was carried out on each of these control pillars using Trimble R4-3 Dual Frequency GNSS Recievers with a 30s recording interval and 10^{o} cut-off elevation angle with a receiver with a receiver station on an existing first order control point (XSN07). The individual static-PPP data was sent to GAPS website (GNSS ANALYSIS AND POSITIONING SOFTWARE) for processing using ultra-rapid, rapid and final IGS products to obtain PPP solution for each of the control points. In order to validate the PPP results, a differential solution was being implemented. The coordinates of the base point were derived from processing a static observation using the CSRS online service (CSRS-PPP, 2019). After obtaining the coordinates of the base station, differential processing was done using Trimble Business Centre Processing (TBC) Software in other to get a DGNSS solution for each of the control points.

IV. RESULTS AND DISCUSSION

Section A:FINAL VS RAPID AND FINAL VS ULTRA-RAPID

Tables 1 present Static-PPP precision variation per station using different IGS products (Final, Rapid and Ultra-Rapid) resulting from this research. Table 2 present the coordinates difference between the solution gotten using final orbit and those gotten using rapid orbit and ultra-rapid orbit.

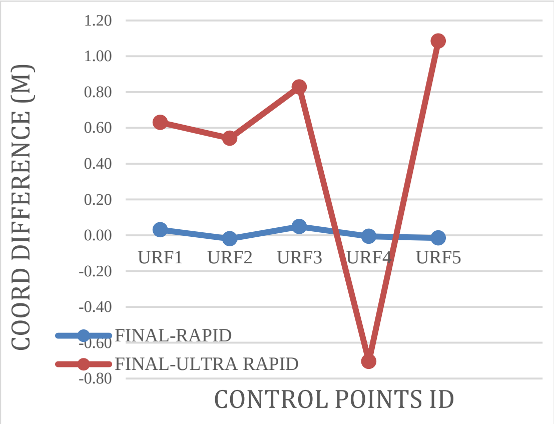

Fig 1: Eastings btw Final vs Rapid&Ultra Rapid

Table 1: Final, Rapid and Ultra-Rapid Orbit/Clock PPP Solution Sigma for each control points

STN	FINAL			RAPID			ULTRA-RAPID		
	X(m)	Y(m)	Z(m)	X(m)	Y(m)	Z(m)	X(m)	Y(m)	Z(m)
URF1	0.0275	0.0231	0.0085	0.0275	0.0231	0.0085	3.5646	1.7410	1.3903
URF2	0.0342	0.0268	0.0112	0.0342	0.0268	0.0112	3.9102	1.5951	1.3429
URF3	0.0149	0.0090	0.0030	0.0149	0.0090	0.0030	2.4798	1.3331	1.0442
URF4	0.0396	0.0149	0.0111	0.0396	0.0149	0.0111	4.3806	1.6778	1.6151
URF5	0.0222	0.0170	0.0048	0.0222	0.0170	0.0048	2.3672	1.2269	1.2527

Table 2: Coordinate Difference between PPP data using Final - Rapid and Final -Ultra-Rapid Orbit/Clock corrections for each control point

Stations	FINAL - RAPID			FINAL – ULTRA RAPID		
	ΔX(m)	ΔY(m)	ΔZ(m)	ΔX(m)	ΔY(m)	ΔZ(m)
URF1	0.0310	0.0460	-0.0718	0.6300	0.7050	1.3172
URF2	-0.0190	-0.0180	-0.1185	0.5420	0.0900	-3.4005
URF3	0.0490	-0.0030	0.0512	0.8280	0.7550	0.6538
URF4	-0.0060	-0.0180	0.0877	-0.7050	0.4040	0.3920
URF5	-0.0150	-0.0190	0.0522	1.0850	-0.0250	-1.3968

Fig 1, 2, and 3 present the coordinates difference between the solution gotten using final orbit and those gotten using rapid orbit and ultra-rapid orbit

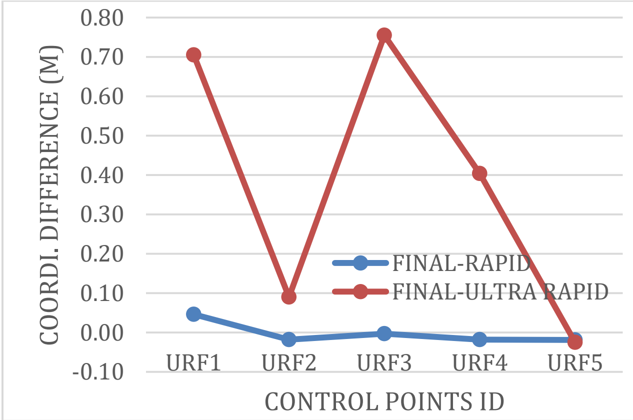

Fig 2: Northings btw Final vs Rapid&Ultra Rapid

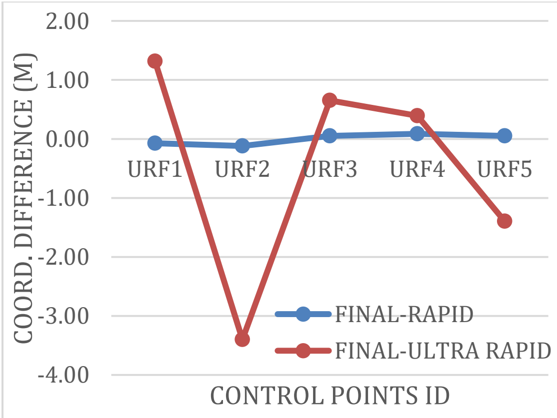

Fig 3: Height btw Final vs Rapid&Ultra Rapid

Table 3 presents the Pearson Correlation Coefficient values between coordinates gotten between Final – Rapid Orbit/Clock products and Final – Ultra Rapid Orbit/Clock products. Table 4 shows the Root Mean Square Error analysis of coordinates gotten between Final – Rapid Orbit/Clock products and Final – Ultra Rapid Orbit/Clock products

Table 3: Pearson's Correlation coefficient values between 'Final-Rapid' and 'Final-Ultra Rapid'

PEARSON CORRELATION COEFFICIENT VALUES			
VARIABLES	X	Y	Z
FINAL - RAPID	0.999999	0.999999	0.999325
FINAL - ULTRA-RAPID	0.999901	0.999979	0.835641

Table 4: Root Mean Square Error Analysis between 'Final-Rapid' and 'Final-Ultra Rapid'

ROOT MEAN SQUARE ERRORS			
VARIABLES	E	N	H
FINAL - RAPID	0.028	0.025	0.080
FINAL - ULTRA-RAPID	0.781	0.498	1.779

The standard deviations of points URF1-URF5 estimated by using different orbital products for north (x), east (y), up (z) directions and the coordinate differences are listed in Tables 6 and 7 and illustrated in Figures 1, 2 and 3, respectively. The solutions estimated through GAPS online services using final orbits was compared with that estimated using rapid and ultra-rapid products and there exist a maximum difference of 49mm and 12cm horizontally and vertically respectively between coordinates gotten with respect to Final and Rapid Orbit while a maximum difference of 1m and 3.4m horizontally and vertically respectively between coordinates gotten with respect to Final and Ultra-Rapid Orbit. Regarding the standard deviation, solutions gotten through rapid orbits provide the same accuracy to that gotten through the final orbit unlike the ultra-rapid orbit whose standard deviation is too big, signaling a poor solution precision.

Pearson's Correlation Coefficient was later used to establish the degree of relationship that exist between these results and a strong positive relationship was observed to have existed in the horizontal coordinates between final orbit and rapid/ultra-rapid orbits but a weak relationship exists between the final orbit solution and that of the ultra-rapid solution.

Root mean square error analysis was also conducted with the final-rapid orbit products giving 0.028,0.025and 0.080 coordinate errors respectively in the X, Y, Z axis while the Final-Ultra rapid products gave 0.781,0.498,1.779 coordinate errors respectively in the X, Y, Z axis. The implication is that the PPP coordinates gotten using rapid orbits is almost same as that obtained using final orbital data and is suitable for higher order survey unlike the coordinates obtained with the ultra-rapid orbital data which seems to be good only for survey of less accuracy like reconnaissance survey.

Section B: -DGNSS vs PPP

Table 5 shows the coordinates difference between the solution gotten through DGNSS and PPP using final, rapid and ultra-rapid orbit/clock products. Fig 4, 5, and 6 present the graphical presentation of the coordinates difference between the solution gotten through DGNSS and PPP using final, rapid and ultra-rapid orbit/clock products. Finally, Table 6 presents the Pearson Correlation Coefficient values between coordinates gotten through DGNSS and PPP using Final, Rapid and Ultra-Rapid Orbit/Clock products. Table 4 shows the Root Mean Square Error analysis of coordinates gotten through DGNSS and PPP using Final, Rapid and Ultra-Rapid Orbit/Clock products.

STN	DGNSS – FINAL ORBIT			DGNSS – RAPID ORBITS			DGNSS - ULTRA-RAPID		
	X(m)	Y(m)	Z(m)	X(m)	Y(m)	Z(m)	X(m)	Y(m)	Z(m)
URF1	-0.084	0.044	-0.0727	-0.053	0.09	-0.1445	0.546	0.749	1.2445
URF2	-0.096	0.004	-0.1998	-0.115	-0.014	-0.3183	0.446	0.094	-3.6003
URF3	-0.074	0.027	0.0699	-0.025	0.024	0.1211	0.754	0.782	0.7237
URF4	0.11	-0.111	0.851	0.104	-0.129	0.9387	-0.595	0.293	1.243
URF5	-0.17	0.02	1.3588	-0.185	0.001	1.411	0.915	-0.005	-0.038

Table 5:Coordinate Difference between DGNSS and PPP data using Final, Rapid and Ultra-Rapid Orbit/Clock corrections for each control point.

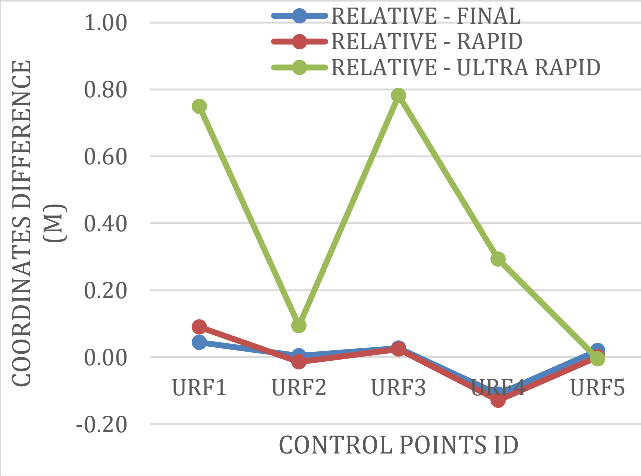

Fig 4: Eastings diff. btw. DGNSS vs PPP

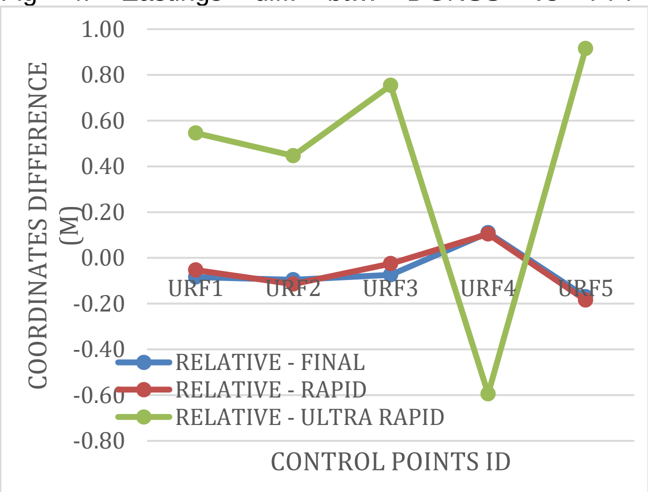

Fig 5: Northings diff. btw. DGNSS vs PPP

Table 6: Pearson's Correlation coefficient values between 'Final-Rapid' and 'Final-Ultra Rapid'

PEARSON CORRELATION COEFFICIENT VALUES			
VARIABLES	E	N	H
RELATIVE - FINAL	0.999997	0.999999	0.971275
RELATIVE - RAPID	0.999996	0.999999	0.964765
RELATIVE - ULTRA RAPID	0.999931	0.999980	0.791030

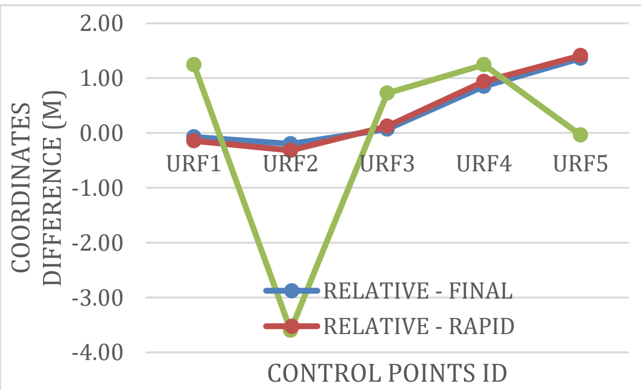

Fig 6: Height diff. btw. DGNSS vs PPP

Table 7: Root Mean Square Error Analysis between 'Final-Rapid' and 'Final-Ultra Rapid'

ROOT MEAN SQUARE ERRORS			
VARIABLES	E	N	H
RELATIVE - FINAL	0.112	0.056	0.724
RELATIVE - RAPID	0.111	0.071	0.776
RELATIVE - ULTRA RAPID	0.672	0.503	1.8213

It is widely known that DGNSS observation gives better positional values when compared to PPP results but things change and PPP have evolved over the years to be considered a viable alternative to DGNSS observation involving the use of two receivers simultaneously. The research involves the investigation of the performance of static-PPP solutions using varying IGS orbital products and determination of the degree of closeness of these results to the DGNSS results. The Pearson's Correlation Coefficient result obtained for the relationship between PPP coordinates gotten with the use of the final, rapid and ultra-rapid products are positively strong both horizontally and vertically as their value is approximately '1' except for that gotten with ultra-rapid product which is weak vertically. The maximum Root mean square errors obtained for the relationship between DGNSS coordinates and PPP coordinates using either final or Rapid products is 11cm horizontally and 8cm vertically and it's a result good enough for most third order survey, someone only need to be careful with the usage of the height data. The maximum RMSE values obtained for the relationship between DGNSS coordinates and PPP coordinates using ultra-rapid product is 7cm horizontally and 1.8m vertically and is seen to be far from being accurate as it can only be used for surveys requiring less accuracy.

V. CONCLUSION

In this study the performance of static-PPP using ultra-rapid, rapid and final IGS products was investigated by making dual frequency observation on five sets of control points within the premises of Federal School of Surveying, Oyo. The analyses of the outcome show a significant improvement in the solutions obtained using Rapid orbital/clock product as it shows great correlation to that obtained using final orbital/clock product both horizontally and vertically. This implies that the Rapid orbital/clock product can be used for all forms of survey requiring the use of the final precise orbital/clock product, consequently, there may be no need to wait for almost two weeks to get positional information as is the case if final product is to be used. The result involving the use of ultra-rapid orbital/clock product on the other hand shows minimal correlation to the PPP result gotten with the use of final orbital/clock product as well as DGNSS result. This means that the PPP coordinates obtained with the use of ultra-rapid products cannot be used for higher order survey requiring much accuracy but for surveys of less accuracy and precision.

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