Comparison of OPUS, CSRS-PPP and magicGNSS Online Post-processing Software of DGPS Observations for Geometric Geoid Modelling in FCT, Abuja

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Keywords: 3-D coordinates, Online post-processing Software, DGPS, ANOVA, F-test

SUMMARY

Global Positioning System (GPS) static measurements require post-processing to determine 3-D positions coordinates i.e. Eastings, Northings, and ellipsoidal height (E, N, h) of various points of interests. The adoption of differential GPS (DGPS) approach for data capture improves on the positional data. Use of dual frequency Hi- Target V30 Pro geodetic receivers also enhances the reliability and quality of GPS measurements through online processors. Online post-processing software (OPUS, CSRS-PPP, magicGNSS) were used to process the uploaded Receiver INdependent EXchange format (RINEX) data for the GPS position determination. ANOVA statistics was used to analyze the results. Computed F-test values compared against critical F-test table values and hypothesis testing was carried out. The results indicate that there is no significant difference between the three online post processing software. It is recommended that any of the online post-processing software can be used interchangeably to process DGPS observations.

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1. INTRODUCTION

Very many applications in physical planning development and scientific studies require geospatial data from processed field measurements. These field measurements will only become useful when processed into a usable data format by post processing and eventually transformed in information that meet the various needs in cadastral, engineering/environmental studies, mapping and in various other applications. Online post processing services are freely available and accessible for unlimited GPS position determination. We have two available systems namely: G1 system in which only GPS satellites are tracked/processed and G2 system for tracking of combined GPS +GLONASS satellites. GPS static observation is a procedure where a geodetic receiver is placed over known base control stations for a long period of observations e.g. 30 minutes, 1hour and for such periods up to 24 hours or more. FCT 276 P and FCT 260 P were both used as base reference stations for continuous data logging to generate highly accurate differential corrections for improved positioning.

The GPS observations are were converted into rinex data and uploaded via email/internet to the online post processing software. The Online software under investigation are: Online Processing User Service; Canadian Spatial Reference Service- PPP (CSRS-PPP) and magicGNSS. Post processing is not affected by satellite visibility, multipath and unreliable data transmission between base and rovers. Post processing uses IGS stations Network and the IGS product range and work globally according to Jha et al. (2016) to provide high quality and reliable coordinate using IGS stations network. Hamidi and Javadi (2017) stated that scientific software are prepared by universities and scientific centers and used by online services as opposed to commercial software developed by respective equipment manufacturer (e.g. HGO,CHC etc.). Geodesists, surveyors, engineers and other geospatial data users need to be assured that data resulting from field measurements and processing techniques are based on stable and software with reliable reference system. Bolbol et al. (2017) opined that the use of "GPS + GLONASS versus GPS only, improves both position and accuracy" and also provide position where GPS satellites are not visible.

2. BRIEFS ON ONLINE POST -PROCESSING SERVICES

These are services that are derived from submission of uploaded RINEX data to websites for position results referred to international reference frame (ITRF). For this study, OPUS, CSRS-PPP and magicGNSS online processing software are considered.

2.1 Online Processing User Service (OPUS)

OPUS gives access to highly accurate National Spatial Reference System (NSRS) coordinates globally using IGS stations around the world. It was developed by National Geodetic Survey

(NGS) and produces centimeter level positioning from static GPS observations. Enhanced results are given in ITRF coordinates. It tracks only GPS satellites. OPUS can be accessed through the website: http://geodesy.noaa.gov/OPUS/. Abd-Elazeem et al. (2011) observed that OPUS "does not process according to proximity of CORS site but compatibility between the users data and the CORS site".

2.2 Canadian Spatial Reference Service- PPP (CSRS-PPP)

This was developed by Geodetic Survey Division, Natural Resource Canada for post processing Static GPS measurements. It processes both GLONASS and GPS observations i.e. it is a G2 system. It can be accessed from http://www.geod.nrcan,gc.ca.

2.3 magicGNSS

magicGNSS was developed by the company GMV Aerospace and Defence and made available through the company web site for processing data in static and kinematic mode at two frequencies according to Austidillo et al. (2018). This online software processes both GLONASS and GPS observations. It supports only dual frequency observations.

An Online post processing software has the following advantages:

i) Type of computer is irrelevant

ii) Post processing can be done anywhere anytime provided internet/email service is available

iii) Customized software need not be installed and

iv) It is fast in sending results and reports back to sender.

3. SCOPE OF THE STUDY

The scope is limited to DGPS field observations with relative technique adopting 2 hours duration. Hi-Target V30 Pro dual frequency GPS geodetic receivers on dual base reference station and on rover controls were used for the data acquisition phase.

4. STUDY AREA

Federal Republic of Nigeria consists of 36 states and Federal Capital, the FCT, Abuja. Nigeria is located between 4° and 14° latitude and 2° and 15° longitude occupying an area of 923768 km^2. Two major rivers in the country are Niger and Benue that meets at Lokoja. The FCT was created in 1976 as the Capital of Nigeria replacing Lagos. Mapping activities are going on continuously and require best software for various processing needs. Presently, FCT has six area councils with Federal Capital City (FCC) as the capital city with an area of 713km^2. The population by Nigerian Population Commission (2006) FCT is 1,405,201. The FCT lies between 8° 15'N to 9° 12'N latitude and 6° 27'E to 7° 23'E longitude. Fig. 1a and 1b are maps of Nigeria and Federal Capital Territory Area Councils respectively.

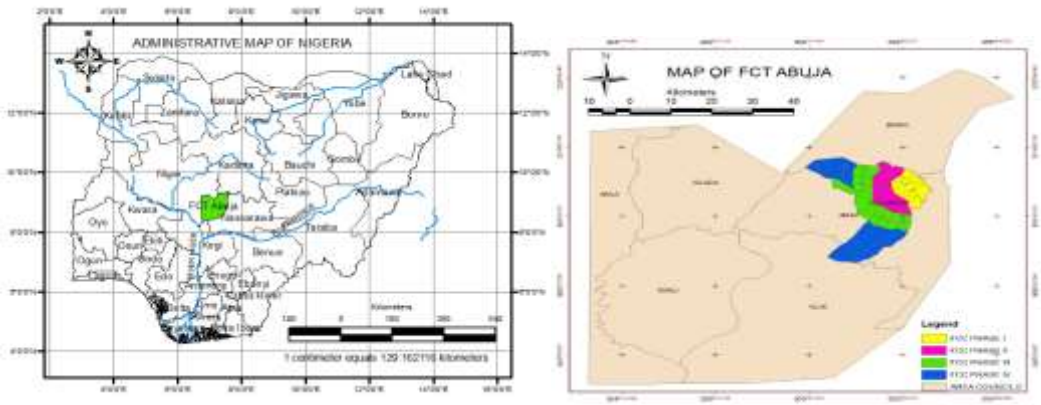

Fig. 1a: Nigeria map with thirty-six states and FCT. Fig. 1b: Map of FCT Area Councils

4.1 GPS Field Survey

There are various techniques available for GPS data acquisition in the field during data capture. They include static, PPP, relative observations. The mode of the GPS when in use may be Kinematic, RTK, Stop and Go and DGPS.

Ranges are obtained from measured phase differences based on comparison between received and generated receiver signals. The measurements are made up of time; phase and range which are stored in the receivers are called RINEX data, (Receiver Independent Exchange format) - data interchange format for raw satellite navigation system data.

4.2 Differential GPS/GNSS

Precision of the DGPS method determines the overall accuracy of the project observed Jha et al. (2017). Eissfeller et al. (2011) opined that "differential GNSS/GPS measurement is the only practical way to reach high accuracy with GNSS measurements" to achieve high accuracy, Eissfeller et al, (2011) stated that for centimeter level accuracy, resolving the "ambiguity of the ambiguous differential carrier phase measurements must be ensured.

Double differencing by differencing two single differencing can achieve this. Using double differencing observation equations, unknown combined receiver clock error is eliminated according to Eissfeller et al. (2011) with a conclusion that "one obtains a better result over double difference observation equations than by positioning with single differencing". See Fig. 2 for double differencing.

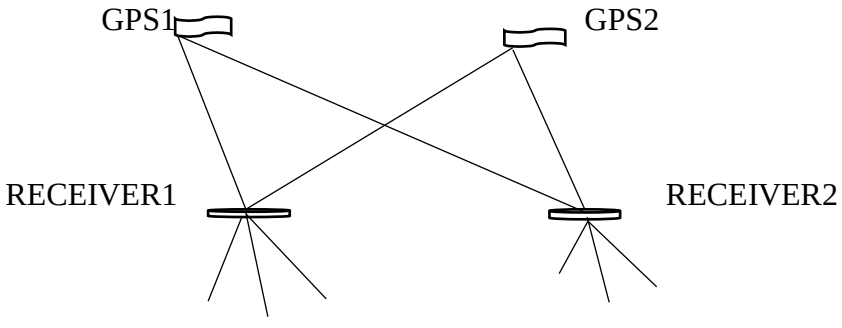

Figure 2: Double differencing; Source: Eissfeller et al. (2011)

5. STATIC MODE OBSERVATIONS

Static GPS surveying is a relative method that uses two or more stationary receivers simultaneously tracking same satellites. Two receivers were set up on known coordinated monuments/controls called base reference stations while the other controls are called rover i.e. placed on points under consideration within the study area.

Data were acquired using Hi-Target V30 Pro DGPS model to obtain highly accurate 3-D coordinates (N, E, h) of various points of interest within the study area. The geodetic GPS receivers were mounted on tripods set up directly over the base reference stations and rover observation stations. All settings were done including control point identifier, mask angles, height of instrument, etc. The rover control positions were chosen to reflect the various points in the study area of FCT.

6. POST-PROCESSING

Static observations are generally post-processed using post processing software that usually accompany GPS equipment. The Hi-Target V30 Pro GPS model can be post processed by Hi-Target Geomatic Office (HGO). HGO has to be installed on a computer system for raw data processing to obtain 3-D coordinates of points of interest. DGPS accuracy is also improved by post-processing GPS observations. Offline or free online post-processing software are available to adopt depending on requirements of study. This study adopted the online post-processing software. The Hi-Target Geomatic Office (HGO) software will be used to post-process the observations to produce the 3-D coordinates of the points. The Online post processing software (OPUS, CSRS-PPP and magicGNSS) was each used for processing and coordinate determination.

7. RESULTS

The results of the post processing by the online software are shown in Table 1 for ellipsoidal height of twenty-four points.

Table 1: Ellipsoidal heights from the three online post processing software

	OPUS	**CSRS-PPP**	**MagicGNSS**
CONTROL POINTS	**HEIGHT, h (m)**	**HEIGHT, h(m)**	**HEIGHT, h(m)**
FCC11S	509.413	509.410	509.365
FCT260P	224.737	224.753	224.731
FCT103P	556.836	556.851	556.821
FCT12P	760.201	760.185	760.189
FCT19P	659.837	659.817	659.817
FCT2168S	455.252	455.290	455.28
FCT24P	477.973	478.013	477.974
FCT276P	649.841	649.851	649.851
FCT4154S	501.178	501.247	501.27
FCT4159S	476.589	476.442	476.627
FCT66P	321.096	321.126	321.122
FCT9P	521.648	521.720	521.712

FCT35P	451.315	451.276	451.306
FCT57P	347.771	347.845	347.768
FCT4028S	473.905	473.994	473.926
FCT53P	375.938	375.991	375.936
FCT4652S	487.076	486.992	487.27
FCT162P	215.006	215.073	215.193
FCT130P	719.357	719.411	719.381
FCT2327S	207.433	207.446	207.561
FCT2652S	163.774	163.774	163.674
FCT2656S	229.230	229.244	229.212
FCT83P	592.759	592.876	592.822
XP382	298.410	298.432	298.329

Thirty points were uploaded for post processing and the results from the three online software are presented in percentages in Table 2.

Table 2. Statistics of online post-processing software

Online Software type	No processed out of 30	No not processed	Success rate in%
magicGNSS	30	0	100 accepted
CSRS-PPP	30	0	100 accepted
OPUS	28	2	93.3 accepted

8. ANALYSIS OF OBSERVATIONS/DATA

From Table 2, it looked as if both magicGNSS and CSRS-PPP scientific software are on the same page and also have better processing ability than OPUS since they both use GPS and GLONASS satellites for measurements i.e. more satellites than OPUS that works with only GPS. But let statics assist us in making confident pronouncements, reliable and quality decision. In order to compare samples on the basis of their means, ANOVA statistics was applied as we have three samples to compare. That is to say if three or more groups are significantly different from each other e.g. to ascertain if all the three online software of OPUS, CSRS-PPP and magicGNSS are equally reliable or not. For two samples, t-test and ANOVA gave the same results. For more than two samples, t-test will be unreliable. If multiple t-tests are conducted in a situation of more than two sample, it is said that the error rate compounded effect on the result according to www.analyticsvidhya.com.

9. Sample mean and Grand mean

Sample means (μ_1, μ_2, μ_3) imply arithmetic average of a range of values or data. Grand mean (μ) is the mean of sample means or mean of all observations combined. Sample and grand mean are the two types of means used in ANOVA computations stated in www.analyticsvidhya.com. This was adopted in the analysis of this study.

9.1 Hypothesis

A hypothesis is generally assumed to be an educated guess about a phenomenon in the world that can be tested by experiment or observations. ANOVA also uses a Null hypothesis (H_0) and an Alternate hypothesis (H_1). The null hypothesis is valid when all the sample means are equal, or they don't have any significant difference. The alternate hypothesis is valid when at least one of the sample means is different from the rest of the sample means. Mathematically, we write:

$H_0 : \mu_1 = \mu_{2=} \mu_3 \ldots = \mu_i$ Null hypothesis (1)

$H_1 : \mu_i \neq \mu_m$ Alternate hypothesis (2)

where μ_i and μ_m belong to any two sample means out of all the samples considered for the test.

H_0 Implies all the sample means are equal

H_1 Implies at least one of the sample means is different from another.

9.1.1 Between the group variability

This refers to the variations between the distributions of individual groups as the values with each group are different. Variability of each sample is the difference between sample mean ($\bar{y}$) and grand mean ($\bar{y}_G$). Mathematically,

Variability = $\bar{y} - \bar{y}_G$ (3)

9.1.2 Sum of squares between group variability (ss_{btw})

This is given by

$$SS_{btw} = n_1(\bar{y}_1 - \bar{y}_G)^2 + n_2(\bar{y}_2 - \bar{y}_G)^2 + n_3(\bar{y}_3 - \bar{y}_G)^2 + \ldots + n_k(\bar{y}_k - \bar{y}_G)^2 \quad \textbf{(4)}$$

$$MS_{btw} = (n_1(\bar{y}_1 - \bar{y}_G)^2 + n_2(\bar{y}_2 - \bar{y}_G)^2 + n_3(\bar{y}_3 - \bar{y}_G)^2 + \ldots + n_k(\bar{y}_k - \bar{y}_G)^2)/\text{K-1} \quad \textbf{(5)}$$

$$MS_{within} = \sum(y_{ij} - \bar{y}_j)^2 / \text{(N-K)} \quad \textbf{(6)}$$

y_{ij} is the i^{th} value from the sample j and so on

$\bar{y}_G$ is grand mean

Where N is sum of sample sizes which is 24 *3 = 72

K is the number of sample which is 3 in this study

By computation, MS_{within} = 28231.01

$MS_{between}$ = 0.003984

F calculated = $\frac{MS_{between}}{MS_{within}}$ (7)

= 0.003984/28231.01

= 1.411e-7 = 0

F from F –Distribution Table at α = 0.05 critical/confidence level (www.socr.ucla.edu accessed on 25/10/2018), $F_{.05,2,69}$ =2.39325

10. ANALYSIS OF RESULTS AND DISCUSSIONS

The decision rule is if F calculated > F critical for α = 0.05, then rejectH_0. We have F calculated = 0 and it is less than F critical = 2.39325, then H_0 is accepted. The implication of this is that the means processed from the three online software are identically the same i.e. $H_0 : \mu_1 = \mu_2 = \mu_3$.

We conclude that the values from each online software can be used in place of the arithmetic mean. While the CSRS-PPP and magicGNSS online software process both GLONASS and GPS satellite measurements, the OPUS processes only GPS measurements. This implies that if geodetic receiver is a G1 system, acceptability can still be obtained i.e. a G2 system is not compulsory for measurements.

If statistically, there is no difference in the means computed, it can therefore imply that all the critical factors necessary for processing data are present in each of the software. This may be the reason they are termed scientific software as different from commercial software that is manufacturer dependent.

11. CONCLUSIONS

This study has revealed that for processing ellipsoidal height for geoid modelling and other applications, the values from any of the three online software can be used instead of using the arithmetic mean. Processed results from two or three online software serve as a check on the results and any significant abnormality reported to processing agency for investigation and possible mitigation.

Generally, any software for online processing services will have similar architecture and processing algorithm for producing GPS position of high accuracy and stability. The ANOVA statistical method of comparing three datasets was applied in analyzing the OPUS, CSRS-PPP and magicGNSS online software. The null hypothesis indicated that there is no difference in the three online software and hence any of the three can be used interchangeably in ellipsoidal height determination for geoid modelling.

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