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Case Study

Contribution of GPS-GNSS technology to the determination of altimetric measurements: Case of the Commune of Abomey-Calavi, Benin

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Abstract

The altimetric requirements for projects with a strong vertical component are numerous and urgent. These needs can not be properly realized without the control of both this vertical component and the instruments used for its determination. The present study proposes to answer the fundamental question of how to achieve a leveling of an acceptable precision in accordance with the aspirations of the specifications using conventional tools and a GPS receiver. The results obtained point out that the accuracy of the altimetric data depends on the type of apparatus used and this in a good state of operation. Similarly, the results show that it is the technical tolerance and accuracy of the altimetry meters that lead to the choice of equipment and procedure to respond promptly to the Terms of Reference (TOR) in the execution of an altimetric survey operation. Finally, the same results showed us that for a precision leveling, are highly recommended for the impressive quality of accuracy they present, the SL10 digital level, the GPS-CHC and the engineering level. As for the total station and the Trimble R7-R8 GPS they are recommended under the best conditions of their use for ordinary leveling. In the case of this study, a model test was determined by the geometric leveling and GPS positioning method, which consisted of directly exploiting the ripple of the study area.

Keywords: Vertical component, leveling of a precision, ordinary levelling, GPS receiver, TDR, geoid.

Introduction

In the early 1990s, precision positioning by GPS technology expanded steadily and accelerated in the 2000s[1]. The emergence of electronics then computer science has given rise to new techniques of surveying and data processing: total stations motorized and remote controlled, positioning by GPS satellites then GNSS, barcode levels, laser rangefinder, etc. In recent years, GPS positioning technology has spread because of the many advantages it offers in terms of position, accuracy, speed and versatility. Today, satellite positioning is the fastest and most effective way for topographic work. Although the results obtained by this technique in planimetry are completely satisfactory, shadow points still exist at the level of the altimetric determination. However, the altimetric requirements for projects with a high vertical component (irrigation, water supply, dam, roads, sanitation, water evacuation, etc.) are enormous and urgent. The fundamental question is how to achieve a leveling of a precision according to the aspirations of the specifications using conventional tools or GPS-GNSS receiver? The answer to this question will allow the topographers to choose the ideal instrument to carry out their work, according to the specificities of the project (nature, urgency, financial conditions etc.). It is with a view to contributing to a better determination of the instruments indicated for each altimetry data generation situation that the present study, entitled "Contribution of GPS-GNSS technology to the determination of altimetric measurements is conducted. The work is organized around three main parts: i. The first part deals with the theoretical and geographical framework of the study; ii. The second part presents the methodological approach adopted; iii. The third part presents the results and discussions.

Background and justification

The most widely used tracking system in the world today is the global and unique global positioning and satellite navigation system: the Global Navigation Satellite System (GNSS). It makes it possible to measure the earth in its entirety in a perennial, uniform, global and coherent way, offering the user the possibility of obtaining the three-dimensional coordinates X, Y and Z. The data quality especially in topometry is characterized by the fidelity and the accuracy of the instrument used for their collection. The accuracy of the measurement is therefore the result of the fidelity and accuracy of the instrument, coupled with the care taken by the operator to perform his task. Nevertheless, whatever the precautions taken by the operator, a measurement is always tainted with a certain error. This uncertainty comes from various factors: the method used, the instrument used, the experience of the operator, the measured quantity. Different concepts are used to qualify the quality of the measurement and various means exist to allocate the residuals of a measurement series[2]. In topometry, despite the multitude of instruments and their various operating principles, the expected results contribute to the production of geographic information in various forms (plans, listing of coordinates, maps, etc.). One of the major concerns of developers is to have coherent altitudes throughout the territory. Indeed, the installation of sanitation network, irrigation, drinking water must respect the slope of the land for a correct flow of water. These few examples show the usefulness of the control of altimetry for the planning of the territory. The accuracy is even more sensitive in altimetry because it often reaches the order of a millimeter.

To determine its position using a GNSS system, two calculation modes are possible: the absolute mode and the differential mode. These two modes of location are essentially distinguished by the type of measurements used, the treatments used and the level of precision offered[3]. Is a leveling operation carried out with an opto-mechanical instrument still less accurate than the same operation performed from an electronic instrument? While the performance and features of the devices such as the total station and GPS / GNSS receiver reassure all users. These devices designed to combine fast operations, accuracy and secure results inspire such confidence to technicians that they are unaware that certain conditions and environments are not suitable for their use. This confidence in the measurements obtained with the electronic devices, born from a certain ignorance of the operating principles of these modern instruments will only be credible with the studies that would lead to a better appropriation of the mode of the use of these instruments. The efficient use of these instruments, which have become very popular among professionals in geomatics and related sciences, depends on several factors that are often not integrated by the various users. Thus, "in order to determine the position of a user located in the vicinity of the Earth, satellite navigation systems use the principle of multilateration in which the geometric distance between a ground-based receiver and a transmitter on board a satellite is “by measuring the propagation time of a particular signal emitted by the satellite”[3]. The two main variables that influence costs for the same technique are the observation time required at each location and the cost of the required receivers[2]. The present study will be based on the principle of GNSS, show how to observe a point and get the desired accuracy in altimetry. It will show how to cross several types of data to achieve the same accuracy. In this perspective, it is then urgent to take into consideration this diversity of findings and to answer effectively a number of questions namely: i. Is the accuracy of the leveling guaranteed by the type of measuring instrument? ii. Are modern devices suitable for leveling everywhere and at all times? iii. Do the results from the collection of altimetric data comply with the standards and technical specifications applicable to topographic and cartographic work in the Republic of Benin?

These are some questions that motivate and justify the choice of this study.

The overall objective of this research is to study the conformity of the different devices in topography in terms of the accuracy of the altimetry data in the ideal conditions of use in the field.

It is specifically to: i. analyze the accuracy of altimetric data obtained as a function of the measuring instrument used; ii. identify the type of device to be used according to the specifications of the specifications; iii. compare the results with the regulatory requirements defined by the 2009 decree N° 068 / MUHRFLEC / DC / SGM / IGN / DGURF / SA setting the standards and technical specifications applicable to the topographic and cartographic works in the Republic of Benin.

Presentation of the study area

The commune of Abomey-Calavi is located in the southern part of Benin and precisely in the department of the Atlantic. Located between 06°18'36" and 06°41'24" north latitude and between 02°12' and 02°18'12" east longitude, the city of Abomey-Calavi shares its limits to the north with the common Zè, in the east with the communes of Adjohoun, Sô-Ava and Cotonou, in the west with the communes of Zè, Tori-Bossito and Ouidah while its southern part is bathed by the Atlantic Ocean (Figure-1). With an area of 539 km², it is the second largest commune in the department after that of Zè and occupies 16.67% of its territory. Administratively, the municipality of Abomey Calavi has seventy (70) villages and city districts grouped in nine (09) districts: Calavi, Godomey, Akassato, Zinvié, Ouedo, Togba, Hêvié, Kpanroun and Golo-Djigbé.

Methodological approach

These include: i. to do documentary research; ii. to set up pegs sealed on the site of technical observations; iii. to check the stability of the support point (EPAC1); iv. to perform GPS / GNSS observation series in static and kinematic mode on sealed stakes; v. to perform leveling operation series on the pegs sealed with TC total station, digital level and engineer level; vi. to process the data from the observations; vii. to perform a comparative study of the results in relation to the altimetry survey requirements; viii. to present results.

This approach has made it possible to use programs, software and technical equipment that consist of: Trimble Business Center (TBC), ActiveSync, Trimble Data transfer, ArcGIS, PrepaComp, Excel, Trimble R7 dual-frequency GPS receiver, dual-frequency GPS CHC i80, TC BULDER 309 total station, Engineering or construction level with optical aiming, Léica SL10 digital level, two-meter invar,Toads, tripod and Tripod, Strips, Macaroons, Bolt.

Results and discussion

Results: These include altimetry observations at direct leveling of densified points, static and kinematic GPS observations of densified points and determination of local geoid ripples in the study area from points observed at the GPS and by leveling. i.

Precision leveling with SL10 electronic level: The observations of the points were made by way of return trip. ii. Leveling with the engineer level: same procedure as that of precision leveling. iii. Observations with the Total Station, iv. GPS-R7 observations in static mode: GPS observation Trimble dual frequency -R7 in static mode consisted of determining the pegs sealed with observation times of 30 minutes on each stake. The sealed stakes are calculated with the TBC processing software from the EPAC1 database initially observed for 4 hours and calculated from the permanent stations of Cotonou and Abomey used as pivots. v. GPS CHC observations in kinematic mode :the result of observations at the GPS CHC receiver in kinematic mode is obtained with an observation time of ten (10) seconds on each point. These points are related to EPAC1 previously determined in static mode and calculated from the permanent stations of Cotonou and Abomey.

Table-1: Summarizes the observed data for each device type.

Synthesis of Altitudes					
Pts	SL10	Level	CHC	R7	TC
EPAC1	14.7873	14.7873	14.7873	14.471	14.787
P1	14.6355	14.6263	14.6125	14.299	14.59604
P2	14.8725	14.8613	14.8604	14.562	14.7951
P3	14.068	14.0583	14.0996	13.717	13.95698
P4	13.5574	13.5441	13.578	13.22	13.41503
P5	13.4269	13.4171	13.4883	13.078	13.24907
P6	13.2376	13.2211	13.2232	12.897	13.01367
P7	12.9416	12.9161	12.9146	12.568	12.66816
P8	12.0131	11.9861	12.0164	11.707	11.58128
P9	11.0417	11.0001	11.0644	10.713	10.55872
P11	10.0727	10.0271	10.0891	9.736	9.41874
P12	12.0757	12.0401	12.0983	11,738	11.87432
P13	12.5986	12.5121	12.558	12.242	12.26913
P14	12.3361	12.3171	12.3174	11.996	12.06005
P15	11.9104	11.8911	11.9092	11.569	11.58614
P16	12.1756	12.1551	12.1675	11.835	11.80427
P17	12.1565	12.1241	12.1749	11.844	11.68099
P18	11.5656	11.5271	11.5322	11.216	11.04117
P19	11.282	11.2381	11.2932	10.943	10.71123
P20	10.9923	10.9481	11.0004	10.661	10.3787
P21	9.7706	9.7041	9.8934	(9 474)	9.11333
P23	11.6906	11.6621	11.6975	11,335	11.31443

Reading Table-1 reveals classes of deviation for each type of device. These are the difference classes of: i. 1mm to 12cm with CHC; ii. 9mm to 8cm with Engineer Level; iii. 4cm to 66cm with the total station and; iv. 29cm to 35cm with the Trimble R7 GPS.

In the light of the differences obtained for each type of device used, it is that observations at the GPS-CHC receiver and those at the Engineer Level are closer in terms of SL10 digital level altimetry accuracy than those at the GPS-Trimble R7 receiver and the total station. Figure-2 illustrates the comparison of data between the SL10 and the engineering level. Figure-3 shows the data comparison between SL10 and GPS-CHC. Figure-4 shows the data comparison between the SL10 and the Total Station. Figure-5 shows the comparison of data between the SL10 and GPS-R7.

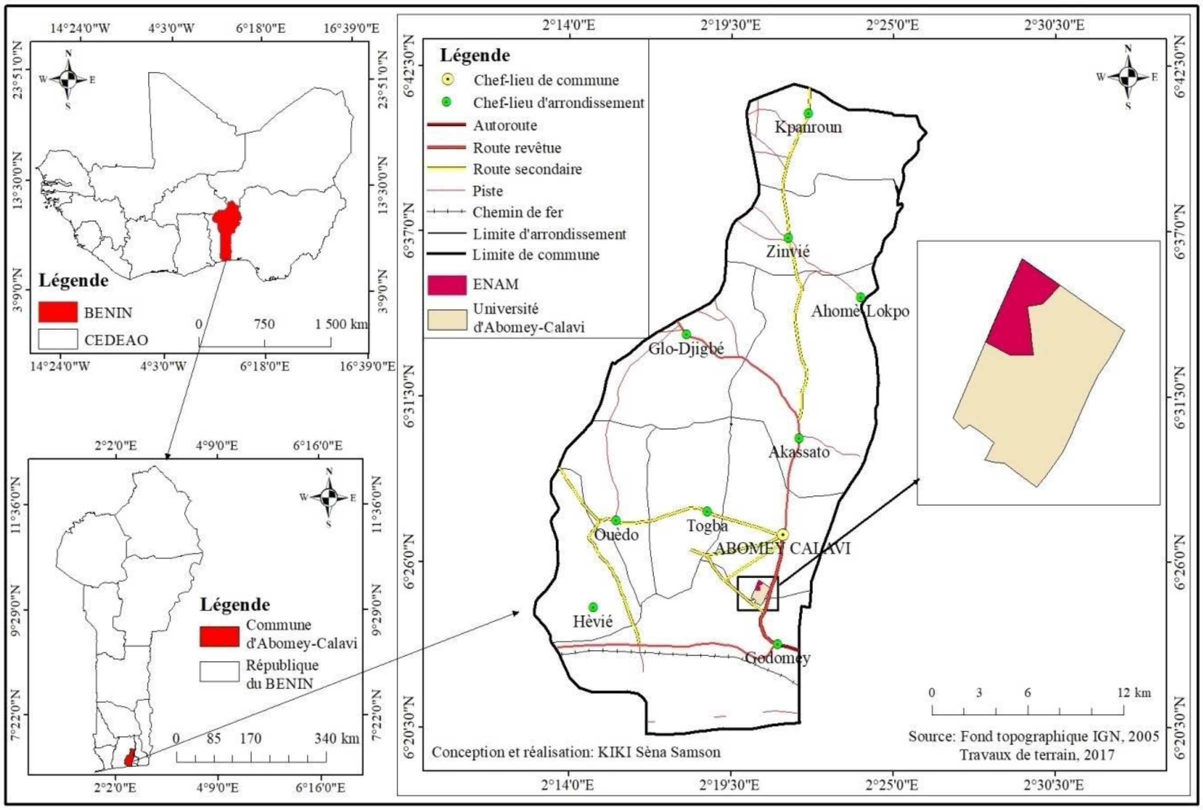

Figure-1: Geographic location of the municipality of Abomey-Calavi.

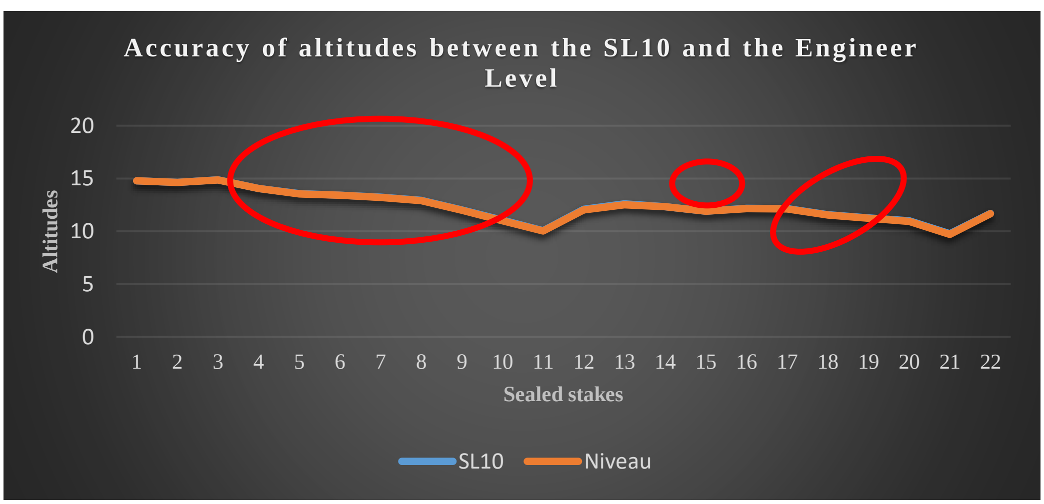

Figure-2: Comparison of data between the SL10 and the Engineer Level.

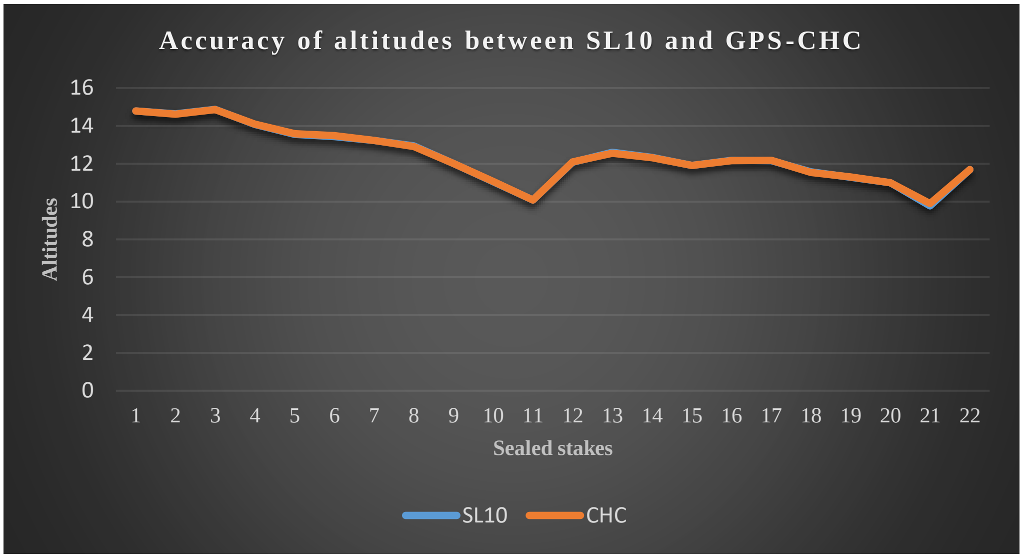

Figure-3: Comparison of data between SL10 and GPS-CHC.

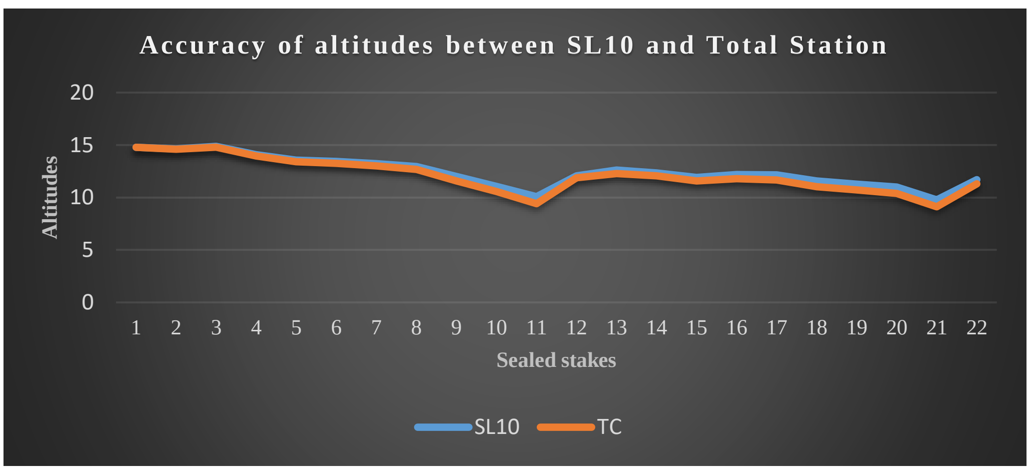

Figure-4: Comparison of data between the SL10 and the Total Station.

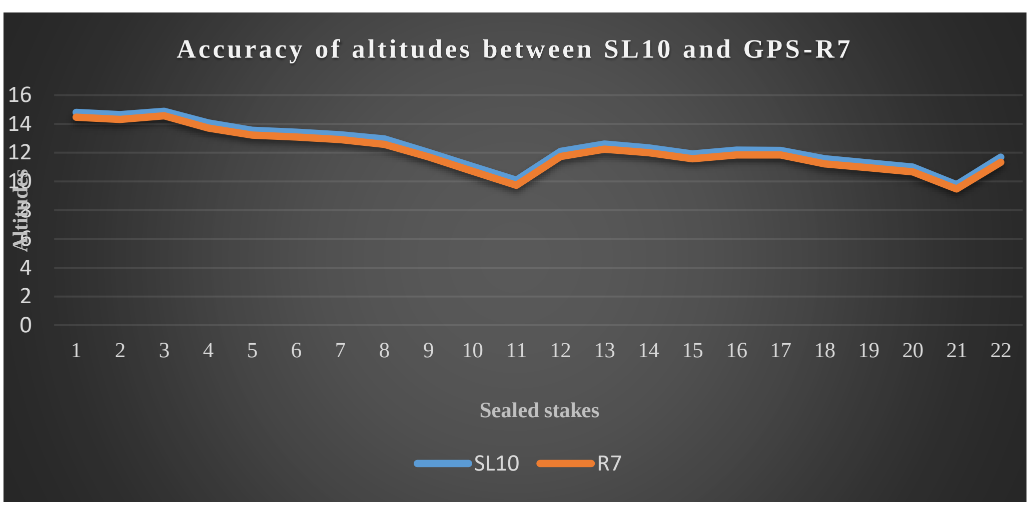

Figure-5: Comparison of data between the SL10 and the GPS-Trimble R7.

A comparative analysis of Figures-2, 3, 4 and 5 shows that the GPS-CHC elevation data is more accurate than the Engineering Level. The results with the engineer level are respectfully more accurate than those with the Trimble R7 GPS receiver and electronic tachometer.

Table-2: Standard deviations of the different altimetric measuring instruments.

ECART_TYPES	
SL10	0
GPS-CHC	0.035822492
TC	0.395772194
TRIMBLE R7	0.344173784
LEVEL	0.036246005

From the reading of the Table-2, we note that compared to the reference instrument that is the digital level SL10, the instruments providing the most accurate altimetric data in the good conditions of their use are respectfully: the GPS-CHC receiver, the engineer level, the GPS-Trimble R7 receiver and the total station.

Determination of geoid ripples in the study area

It required the use of altimetry data calculated on 22 points distributed throughout the study area. Table-9 summarizes the ripple values obtained with respect to each point considered.

Reading Table-3 reveals that the minimum of the ripples the geoid is obtained in point 7 and the maximum in point 21. The average of the corrugations calculated in this way generally gives a ripple of the study area which is equivalent to: N = 23.24. Figure 6presents the geoid map of Benin.

Table-3: Values of the corrugations obtained.

The point id	Ellipsoidal height (h)	Altitude RNGB (H)	Geoid undulation
	(Metric)	(Metric)	N = h – H
EPAC2	36.673	13.4225	23.2505
P1	37.851	14.636	23.2155
P2	38.116	14.873	23.2435
P3	37.277	14.068	23.209
P4	36.784	13.557	23.2266
P5	36.643	13.427	23.2161
P6	36.465	13,238	23.2274
P7	36.141	12.942	23.1994
P8	35.287	12.013	23.2739
P9	34.297	11.042	23.2553
P11	33.325	10.073	23.2523
P12	35.311	12,076	23.2353
P13	35 815	12.599	23.2164
P14	35,567	12.336	23.2309
P15	35.144	11.91	23.2336
P16	35.413	12.176	23.2374
P17	35.43	12.157	23.2735
P18	34.808	11.566	23.2424
P19	34.54	11.282	23.258
P20	34.258	10.992	23.2657
P21	33.063	9.7706	23.2924
P23	34.916	11.691	23.2254

The projection of the study environment in the Benin geoid made it possible to elaborate the EGM96 geoid of the Abomey-Calavi commune, as shown in Figure-7.

The results from the comparative analysis of calculated and interpolated corrugations are illustrated in Figure-8.

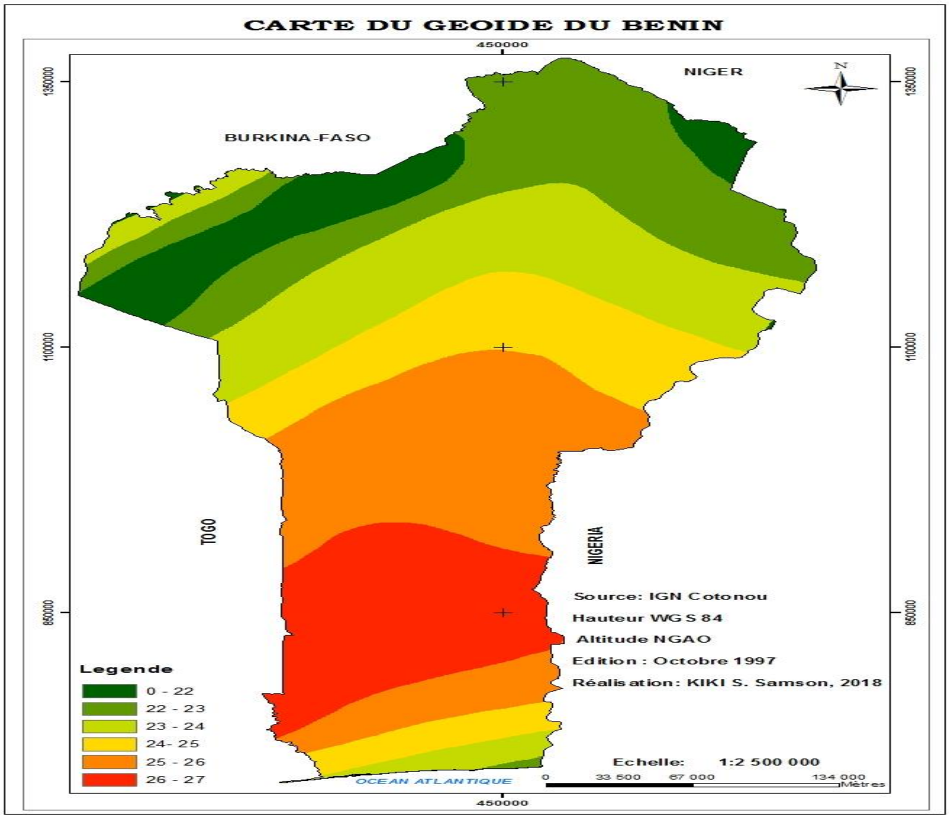

Figure-6: Geoid map of Benin.

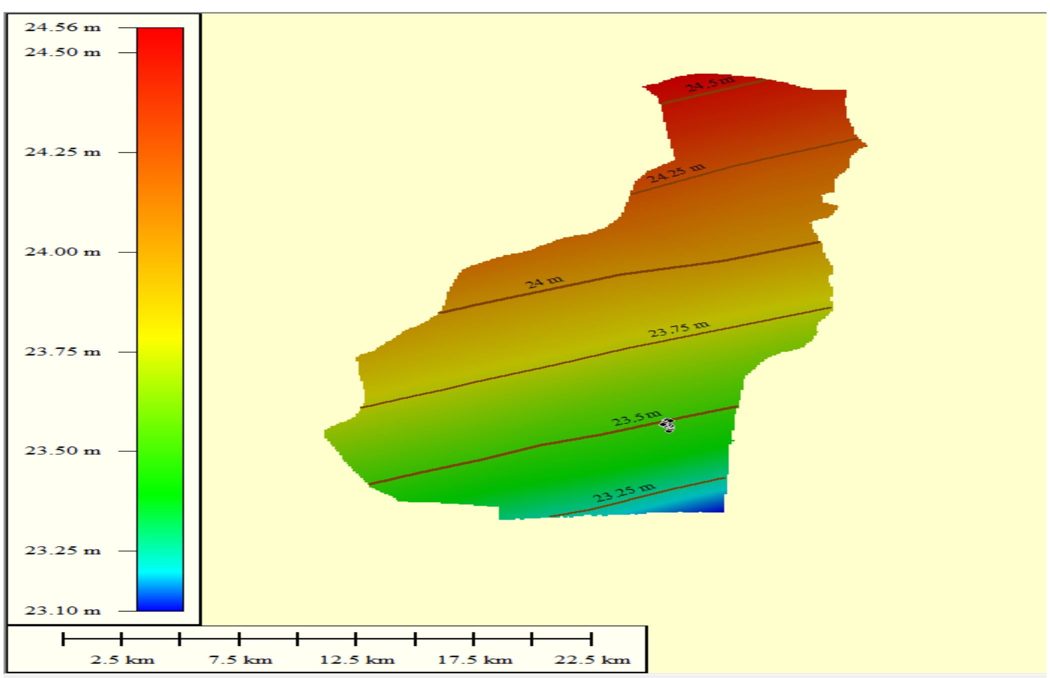

Figure-7: Geoid EGM96 of the municipality of Abomey-Calavi.

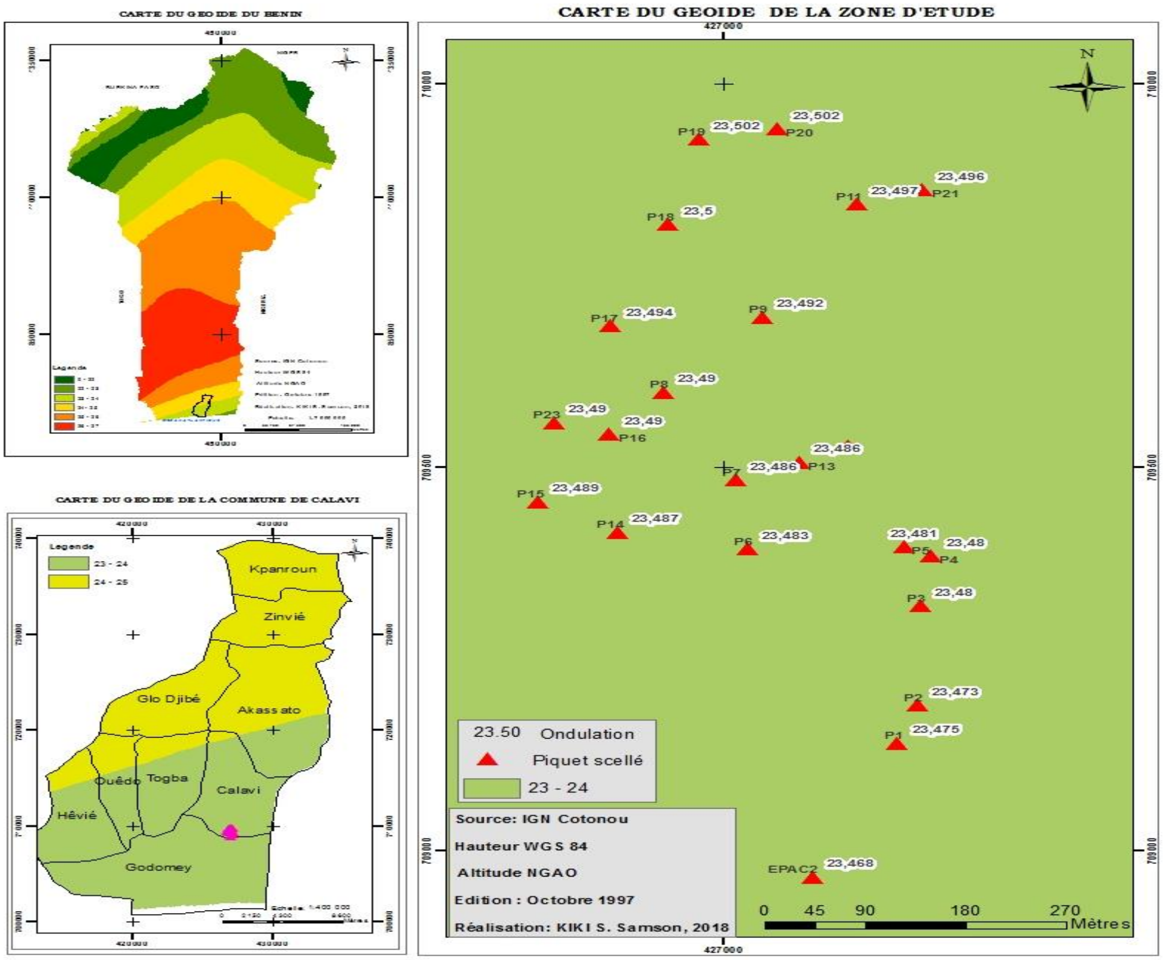

Figure-8: Determination of corrugations by interpolation.

The examination of Figure-8 shows that the average of the corrugations calculated confirms that indicated on the geoid EGM96 of the Abomey-Calavi commune.

Discussion: The quality of data in topometry is characterized by the accuracy, fidelity and accuracy of the instrument used to collect it. Nevertheless, whatever the precautions taken by the operator, a measurement is always tainted with a certain error. This uncertainty comes from various factors: the method used, the instrument used, the experience of the operator, the measured quantity. The accuracy of the altimetry operations raises, among other issues, that of the quality of the instruments and methods used on the one hand and that of the environment in which the observations were made without forgetting the use that the technician intends to make measurements carried out, on the other hand. With regard to the information obtained on the data collected with the engineering level and the numerical level SL10, it can be concluded that the tolerances set by *Order 068 / MUHRFLEC / DC / SGM / IGN / DGURF / SA, setting the standards and technical specifications applicable to topographic and cartographic work in the Republic of Benin*[4] are respected whether in ordinary leveling T $=4\sqrt{36L+L^2}$ either 34 mm or in precision leveling T $=4\sqrt{9L+L^2}$ 18 mm, with T= tolerance in millimeters and The= length expressed in kilometers of the path closed on itself. It should therefore be pointed out that for precision leveling (on civil engineering sites), only the numerical level, the engineer level (opticomechanical) and the GPS CHC receiver are a priori indicated while the Total Station and the Trimble R7 GPS receiver are recommended for ordinary leveling (on sites of rough assessment of the behavior of a topographic surface). To confirm or refute this first conclusion, a second method of analysis was used. It is governed by *the French Decree of September 2003 concerning the class of clarifications applicable to the categories of topographic works carried out by the State and the local authorities and their public establishments or carried out on their behalf*[5]. This method does not take into account either the working method or the instrument used, but only the results obtained.

Thus, for a precision leveling of an acceptable tolerance of 18 mm, Tables 4, 5, 6 and 7 show the accuracy qualities of the points determined respectively with the GPS-CHC, the engineer level, the Trimble GPS receiver. R7 and the total station.

Table-4: Quality of the points determined with the GPS-CHC receiver.

Détermination de la qualité des points			
Nombre [N] d'objets de l'échantillon	**22**	valeur de k	**3,23**
Classe de précision [xx] demandée (cm)	**2**	L'écart moyen en position doit être inférieur à	**2,0**
Coefficient de sécurité [C]	**2**	Premier seuil [T1] cm	**6,5**
Nombre [n] de coordonnées des objets	**1**	Deuxième seuil [T2] cm	**9,8**
		Nombre maximum autorisé [N'] d'écarts dépassant le premier seuil	**2**
		Nombre maximum autorisé d'écarts dépassant le deuxième seuil	**0**

Liste des points retenus pour le contrôle			**Ecarts de position**		**Ecart Moyen de**	**Tolerance**	**Comparaison de Epos aux valeurs des Seuils**	**Nbre d'écarts dépassant le 1er Seuil**	**Nbre d'écarts dépassant le 2ème seuil**	**Observations**
N° Points	**Altitude des points SL10** **Zr**	**Altitude des points CHC** **Za**	**Zi=Zr-Za (m)**	**Zi(cm)**	**Emoy Pos (cm)**					
1	14,7873	14,7873	0	0,0	-0,761	oui	Conforme	0	1	
2	14,6355	14,6125	0,023	2,3			Conforme			
3	14,8725	14,8604	0,0121	1,2			Conforme			
4	14,068	14,0996	-0,0316	-3,2			Conforme			
5	13,5574	13,578	-0,0206	-2,1			Conforme			
6	13,4269	13,4883	-0,0614	-6,1			Conforme			
7	13,2376	13,2232	0,0144	1,4			Conforme			
8	12,9416	12,9146	0,027	2,7			Conforme			
9	12,0131	12,0164	-0,0033	-0,3			Conforme			
10	11,0417	11,0644	-0,0227	-2,3			Conforme			
11	10,0727	10,0891	-0,0164	-1,6			Conforme			
12	12,0757	12,0983	-0,0226	-2,3			Conforme			
13	12,5986	12,558	0,0406	4,1			Conforme			
14	12,3361	12,3174	0,0187	1,9			Conforme			
15	11,9104	11,9092	0,0012	0,1			Conforme			
16	12,1756	12,1675	0,0081	0,8			Conforme			
17	12,1565	12,1749	-0,0184	-1,8			Conforme			
18	11,5656	11,5322	0,0334	3,3			Conforme			
19	11,282	11,2932	-0,0112	-1,1			Conforme			
20	10,9923	11,0004	-0,0081	-0,8			Conforme			
21	9,7706	9,8934	-0,1228	-12,3			1er et 2è Seuil			
22	11,6906	11,6975	-0,0069	-0,7			Conforme			

Reference: Decree of September 2003 on the class of precisions in France[5].

Table-5: Quality of points with the level of engineer.

Détermination de la qualité des points			
Nombre [N] d'objets de l'échantillon	22	valeur de k	3,23
Classe de précision [xx] demandée (cm)	2	L'écart moyen en position doit être inférieur à	2,0
Coefficient de sécurité [C]	2	Premier seuil [T1] cm	6,5
Nombre [n] de coordonnées des objets	1	Deuxième seuil [T2] cm	9,8
		Nombre maximum autorisé [N'] d'écarts dépassant le premier seuil	2
		Nombre maximum autorisé d'écarts dépassant le deuxième seuil	0

Liste des points retenus pour l'échantillon de contrôle			Ecarts de position		Ecart Moyen de Position		Comparaison de Epos aux valeurs des Seuils (Epos est)	Nbre d'écarts dépassant le 1er Seuil	Nombre d'écart dépassant le 2ème seuil	Observations
N° Points	Altitude des points du SL10 Zr	Niveau Za	Zi=Zr-Za (m)	Zi(cm)	Emoy Pos (cm)	Tolerance				
1	14,7873	14,7873	0	0,0	2,929	non	Conforme	2	0	
2	14,6355	14,6263	0,0092	0,9			Conforme			
3	14,8725	14,8613	0,0112	1,1			Conforme			
4	14,068	14,0583	0,0097	1,0			Conforme			
5	13,5574	13,5441	0,0133	1,3			Conforme			
6	13,4269	13,4171	0,0098	1,0			Conforme			
7	13,2376	13,2211	0,0165	1,7			Conforme			
8	12,9416	12,9161	0,0255	2,5			Conforme			
9	12,0131	11,9861	0,027	2,7			Conforme			
10	11,0417	11,0001	0,0416	4,2			Conforme			
11	10,0727	10,0271	0,0456	4,6			Conforme			
12	12,0757	12,0401	0,0356	3,6			Conforme			
13	12,5986	12,5121	0,0865	8,6			1er seuil			
14	12,3361	12,3171	0,019	1,9			Conforme			
15	11,9104	11,8911	0,0193	1,9			Conforme			
16	12,1756	12,1551	0,0205	2,1			Conforme			
17	12,1565	12,1241	0,0324	3,2			Conforme			
18	11,5656	11,5271	0,0385	3,8			Conforme			
19	11,282	11,2381	0,0439	4,4			Conforme			
20	10,9923	10,9481	0,0442	4,4			Conforme			
21	9,7706	9,7041	0,0665	6,6			1er seuil			
22	11,6906	11,6621	0,0285	2,8			Conforme			

Reference: Decree of September 2003 on the class of precisions in France[5].

Table-6: Point quality with the Trimble-R7 GPS.

Détermination de la qualité des points			
Nombre [N] d'objets de l'échantillon	22	valeur de k	3,23
Classe de précision [xx] demandée (cm)	2	L'écart moyen en position doit être inférieur à	2,0
Coefficient de sécurité [C]	2	Premier seuil [T1] cm	6,5
Nombre [n] de coordonnées des objets	1	Deuxième seuil [T2] cm	9,8
		Nombre maximum autorisé [N'] d'écarts dépassant le premier seuil	2
		Nombre maximum autorisé d'écarts dépassant le deuxième seuil	0

Liste des points retenus pour l'échantillon de contrôle			Ecarts de position		Ecart Moyen de Position		Comparaison de Epos aux valeurs des Seuils (Epos est)	Nbre d'écarts dépassant le 1er Seuil	Nombre d'écart dépassant le 2ème seuil	Observations
N° Points	Altitude des points du SL10	R7	Zi=Zr-Za (m)	Zi(cm)	Emoy Pos (cm)	Tolérance				
	Zr	Za								
1	14,7873	14,471	0,3163	31,6	33,579	non	1er et 2è A18:N2è Seuil	0	21	
2	14,6355	14,299	0,3365	33,7			1er et 2è Seuil			
3	14,8725	14,562	0,3105	31,1			1er et 2è Seuil			
4	14,068	13,717	0,351	35,1			1er et 2è Seuil			
5	13,5574	13,220	0,3374	33,7			1er et 2è Seuil			
6	13,4269	13,078	0,3489	34,9			1er et 2è Seuil			
7	13,2376	12,897	0,3406	34,1			1er et 2è Seuil			
8	12,9416	12,568	0,3736	37,4			1er et 2è Seuil			
9	12,0131	11,707	0,3061	30,6			1er et 2è Seuil			
10	11,0417	10,713	0,3287	32,9			1er et 2è Seuil			
11	10,0727	9,736	0,3367	33,7			1er et 2è Seuil			
12	12,0757	11,738	0,3377	33,8			1er et 2è Seuil			
13	12,5986	12,242	0,3566	35,7			1er et 2è Seuil			
14	12,3361	11,996	0,3401	34,0			1er et 2è Seuil			
15	11,9104	11,569	0,3414	34,1			1er et 2è Seuil			
16	12,1756	11,835	0,3406	34,1			1er et 2è Seuil			
17	12,1565	11,844	0,3125	31,3			1er et 2è Seuil			
18	11,5656	11,216	0,3496	35,0			1er et 2è Seuil			
19	11,282	10,943	0,339	33,9			1er et 2è Seuil			
20	10,9923	10,661	0,3313	33,1			1er et 2è Seuil			
21	9,7706	9,474	0,2966	29,7			1er et 2è Seuil			
22	11,6906	11,335	0,3556	35,6			1er et 2è Seuil			

Reference: Decree of September 2003 on the class of precisions in France[5].

Table-7: Quality of the points with the total station.

Détermination de la qualité des points			
Nombre [N] d'objets de l'échantillon	22	valeur de k	3,23
Classe de précision [xx] demandée (cm)	2	L'écart moyen en position doit être inférieur à	2,0
Coefficient de sécurité [C]	2	Premier seuil [T1] cm	6,5
Nombre [n] de coordonnées des objets	1	Deuxième seuil [T2] cm	9,8
		Nombre maximum autorisé [N'] d'écarts dépassant le premier seuil	2
		Nombre maximum autorisé d'écarts dépassant le deuxième seuil	0

Liste des points retenus pour l'échantillon de contrôle			Ecarts de position		Ecart Moyen de Position	Tolerance	Comparaison de Epos aux valeurs des Seuils (Epos est)	Nbre d'écarts dépassant le 1er Seuil	Nombre d'écart dépassant le 2ème seuil	Observations
N° Points	Altitude des points du SL10	TC	Zi=Zr-Za (m)	Zi(cm)	Emoy Pos (cm)					
	Zr	Za								
1	14,7873	14,787	0,0003	0,0	33,34	non	Conforme	1	19	
2	14,6355	14,59604	0,03946	3,9			Conforme			
3	14,8725	14,7951	0,0774	7,7			1er seuil			
4	14,068	13,95698	0,11102	11,1			1er et 2è Seuil			
5	13,5574	13,41503	0,14237	14,2			1er et 2è Seuil			
6	13,4269	13,24907	0,17783	17,8			1er et 2è Seuil			
7	13,2376	13,01367	0,22393	22,4			1er et 2è Seuil			
8	12,9416	12,66816	0,27344	27,3			1er et 2è Seuil			
9	12,0131	11,58128	0,43182	43,2			1er et 2è Seuil			
10	11,0417	10,55872	0,48298	48,3			1er et 2è Seuil			
11	10,0727	9,41874	0,65396	65,4			1er et 2è Seuil			
12	12,0757	11,87432	0,20138	20,1			1er et 2è Seuil			
13	12,5986	12,26913	0,32947	32,9			1er et 2è Seuil			
14	12,3361	12,06005	0,27605	27,6			1er et 2è Seuil			
15	11,9104	11,58614	0,32426	32,4			1er et 2è Seuil			
16	12,1756	11,80427	0,37133	37,1			1er et 2è Seuil			
17	12,1565	11,68099	0,47551	47,6			1er et 2è Seuil			
18	11,5656	11,04117	0,52443	52,4			1er et 2è Seuil			
19	11,282	10,71123	0,57077	57,1			1er et 2è Seuil			
20	10,9923	10,3787	0,6136	61,4			1er et 2è Seuil			
21	9,7706	9,11333	0,65727	65,7			1er et 2è Seuil			
22	11,6906	11,31443	0,37617	37,6			1er et 2è Seuil			

Reference: Decree of September 2003 on the class of precisions in France[5].

Table-8: Point quality with the Trimble-R7 GPS.

Détermination de la qualité des points			
Nombre [N] d'objets de l'échantillon	22	valeur de k	3,23
Classe de précision [xx] demandée (cm)	34	L'écart moyen en position doit être inférieur à	37,8
Coefficient de sécurité [C]	2	Premier seuil [T1] cm	122,1
Nombre [n] de coordonnées des objets	1	Deuxième seuil [T2] cm	183,1
		Nombre maximum autorisé [N'] d'écarts dépassant le premier seuil	2
		Nombre maximum autorisé d'écarts dépassant le deuxième seuil	0

Liste des points retenus pour l'échantillon de contrôle			Ecarts de position		Ecart Moyen de Position	Tolerance	Comparaison de Epos aux valeurs des Seuils (Epos est)	Nbre d'écarts dépassant le 1er Seuil	Nombre d'écart dépassant le 2ème seuil	Observations
N° Points	Altitude des points du SL10 Zr	GPS_R7 Za	Zi=Zr-Za (m)	Zi(cm)	Emoy Pos (cm)					
1	14,7873	14,471	0,3163	31,6	33,579	oui	Conforme	0	0	
2	14,6355	14,299	0,3365	33,7			Conforme			
3	14,8725	14,562	0,3105	31,1			Conforme			
4	14,068	13,717	0,351	35,1			Conforme			
5	13,5574	13,220	0,3374	33,7			Conforme			
6	13,4269	13,078	0,3489	34,9			Conforme			
7	13,2376	12,897	0,3406	34,1			Conforme			
8	12,9416	12,568	0,3736	37,4			Conforme			
9	12,0131	11,707	0,3061	30,6			Conforme			
10	11,0417	10,713	0,3287	32,9			Conforme			
11	10,0727	9,736	0,3367	33,7			Conforme			
12	12,0757	11,738	0,3377	33,8			Conforme			
13	12,5986	12,242	0,3566	35,7			Conforme			
14	12,3361	11,996	0,3401	34,0			Conforme			
15	11,9104	11,569	0,3414	34,1			Conforme			
16	12,1756	11,835	0,3406	34,1			Conforme			
17	12,1565	11,844	0,3125	31,3			Conforme			
18	11,5656	11,216	0,3496	35,0			Conforme			
19	11,282	10,943	0,339	33,9			Conforme			
20	10,9923	10,661	0,3313	33,1			Conforme			
21	9,7706	9,474	0,2966	29,7			Conforme			
22	11,6906	11,335	0,3556	35,6			Conforme			

Reference: Decree of September 2003 on the class of precisions in France[5].

It is therefore retained that the SL10 digital level, the GPS-CHC receiver and the engineer level are recommended for precision leveling whereas the Total Station and the Trimble-R7 GPS receiver in this order are not recommended.

For standard leveling with a tolerance of 33.6mm, Table-14 shows the result of the quality of the points obtained with the Trimble-R7 GPS receiver used for ordinary leveling with a tolerance of 33.6mm.

The analysis in Table-8 notes that the result is within the required tolerance and that no points are out of the 1st and 2th thresholds. And so through this observation, all other devices used are recommended for ordinary leveling.

In summary, it is noted that: i. the SL10 digital level, the GPS-CHC receiver and the engineer level are acceptable for precision leveling while the Total Station and Trimble-R7 GPS receiver are not recommended; ii. the SL10 digital level, the GPS-CHC receiver, the engineer level, the Total Station and the Trimble-R7 GPS receiver are acceptable for ordinary leveling; iii. the SL10 digital level, the GPS-CHC receiver, the engineer level, the Total Station and the Trimble-R7 GPS receiver in this order are more accurate one after the other.

Conclusion

The study of the results of the altimetric measurements made it possible to report through the analyzes carried out and the observations made, that a leveling operation performed with an opto-mechanical instrument is less accurate than the same operation performed from a digital instrument. This is all the more remarkable as on a round trip of approximately 2km length, the closure in millimeter obtained is 0.16mm with a permissible technical tolerance of 3.86mm. This closure is 10 mm with an optico-mechanical instrument with a tolerance of 18 mm defined in the norms and specifications applicable to cartographic and topographical work in the Republic of Benin by decree 068. The accuracy of the altimeter data therefore depends on the type of device used and this in a good working condition. As for the GNSS technique, it provides information relating to the vertical component that is not directly usable by the user. The passage of this information (height above the ellipsoid) towards "an altitude above average sea level" which is the one usable by the professionals of the land, requires the use of a model called "model of geoid "that it is important to know precisely to determine the altitude. During this study, a non modeled geometric model was determined which is only a step towards the effective determination of the geoid model of the study area. This approximate model is determined by the combination of a global GRS80 ellipsoid model (EGM1996) and leveled GPS points attached to the RNGB. A second version can be significantly improved by using a network of GPS points leveled much denser and good quality on a much larger perimeter that can take into account the topographic surface in all its meanders on the extent of the municipality. Abomey.

Finally, it is important to note that for more credible results, such a study is done on a larger area and a longer path length. This will evaluate the accuracy of RTK altimetry observations with the length of the baseline.

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