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Accuracy Analysis of a Dual Frequency Gnss Smartphone in Yaounde

Yakum Paul Nuiping

Department of Land Surveying, National Advanced School of Public Works (NASPW) Yaoundé

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Abstract: Geodetic receivers are more demanding in cost and operation than low-cost devices, especially smartphone receivers. Low-cost devices usually have lower positioning accuracy and thus limited to Navigation and GIS applications. With the coming of dual frequency (L1/L5) GNSS smartphones, it is important to diagnose whether their accuracy could meet topographic expectations. Xiaomi 12t smartphone is chosen here with the main objective to measure its accuracy in absolute positioning. By so doing, two geodetic pillars were surveyed one after the other with the smartphone in question. The methodology entails 4h of GNSS observation in PPP static mode at both the control points CP1 and CP2 and the raw data logged by the phone was post-processed online at NRCan/CSRS PPP to obtain the phone's coordinates. The accuracies were evaluated as absolute discrepancies in phone's coordinates in planimetric dimension and also using the statistical model from CSRS in evaluating the 95% confidence interval. Apart from the east direction at CP1 that showed a severe discrepancy of 7.954m, the average planimetric accuracy observed in the north and up directions at the two control points using both models in error analysis were found to occur within 2m to 3m interval. The general conclusion was that Xiaomi 12t smartphone is not suitable for topometric and geodetic surveys but very suitable for navigation and GIS applications. The following recommendations were proposed; smartphone accuracy analysis in PPP static using a much longer observation time (at least 10h), determination of precise location of smartphone's Antenna Reference Point, update of Cameroon Geodetic Network to the ITRF20 realization, similar research with two or more smartphones placed in different directions with use of augmentation systems such as SBAS and NTRIP, similar research with post processing done with a software that enables the treatment of L1 and L5 carrier frequencies of the smartphone and also use of a smartphone that captures signals from both the L1 and L2 carrier wave.

Keywords: Android smartphone, Dual-frequency multi-GNSS, PPP post-processing.

I. General Introduction

In general terrestrial survey, point localization is fundamental and the type of surveying is usually determined by the accuracy of measured points. For instance, the accuracy ranges from 15m to 5m in standard navigation, 5m to 50cm in precise navigation (DGNSS), 50cm to 5mm in topometric surveying (PPP) and 5cm to 5mm in geodetic surveying involving RTK and static observation modes (Yap, 2022, p. 43). This accuracy is usually characterized by the type of GNSS receiver and observation method used, operation cost and procedure required. GNSS observations are normally executed by high-grade geodetic receivers and antennas. These geodetic receivers are usually costlier to purchase and to operate. Nowadays, technology is greatly advancing in low-cost systems so much so that in May 2018, the first smartphone with dual-frequency GNSS receiver, the Xiaomi mi8 was released in China (Lachlan, 2019, p. 2). Thereafter, some others were released in other places and by so-doing, several researches about accuracy investigation on low-cost receivers in general and smartphone positioning in particular have been conducted in recent past. After examining some of these past works, some smartphones had promising topometric capabilities regarding their positioning accuracies though others were still highly degraded. Also, the L5 carrier frequency is relatively new and thus, has not been adequately analysed with smartphones. Again, the smartphone's ARP is not clearly pointed out as examined from previous works and above all, smartphone positioning accuracy analysis has not yet been carried out in Cameroon before. By so doing, Xiaomi 12T dual frequency GNSS android smartphone released in November 2022 is used as a test device for this research generally aimed at evaluating the positional capabilities of low-cost devices. In that respect, the main objective is to measure the phone's accuracy in PPP static mode in Yaounde, Cameroon. To that effect, two geodetic pillars of the RGC located in Yaounde 7, labelled CP1 and CP2 were used as control points and three specific objectives were established as follows; 1) to obtain the absolute coordinates of the pillars using the Emlid Reach Rs2 geodetic receiver, 2) to obtain again the absolute coordinates of the pillars using the smartphone in question and 3) to use the true coordinates of the pillars to assess the extent to which Emlid Reach Rs2 geodetic receiver is valid. Chapter one outlines the relevant literature including the summary of three similar researches, chapter two presents the methods (positioning, processing and analysis) used in this research while chapter three talks about the results and discussion, including the conclusion drawn and some recommendations made.

II. Review of Related Literature

With the coming of GNSS chipsets on smartphones and their miniaturization to reduce both production cost and the costs of survey tasks and also the increasing need to make navigation easy to the general public, satellite positioning has become a common practice in spreading of location-based applications dedicated for low-cost receivers like; smartphones, tablets and other mobile navigation systems.

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When the first Android Nougat 7 was introduced in May 2016, GNSS observations could be processed by Android-dedicated applications and recorded into files. Since then, GNSS observation data like code pseudo range, carrier-phase data and doppler GNSS measurements obtained from mobile phones have been topical in the scientific community. Presently, common users can exploit signals from the four global navigation satellite systems and most low-cost systems easily function on PPP. PPP is becoming increasingly used than differential techniques because of its ease of use. With PPP, precise satellite orbit and clock corrections are calculated using numerous IGS permanent stations used as reference stations in the ITRS/ITRF. PPP performance is usually analyzed as a function of the receiver and antenna type, measurement utilized and observation considered. Generally, more than 20 satellites are above the visible horizon at any time for a receiver in open-sky conditions. This can empower positioning accuracy up to cm level in real time for low-cost equipment. However, it is very difficult to fix ambiguities to their correct integer values since PPP is not a differential technique and hence, cannot build double difference to eliminate phase biases originating from satellite and receiver hardware. Starting from the study of Wubbena et al, several researchers have found different ways to fix the un-differenced phase ambiguities to their correct integer values and calculate a fixed PPP solution introducing the PPP-RTK technique. PPP-RTK, also known as PPP with integer ambiguity resolution extends the PPP concept by providing to single-receiver user information about satellite phase and code biases and atmospheric delays in addition to orbit and clock correction data, thus, enabling single-receiver ambiguity resolution. The PPP-RTK methods differ in the models used, the corrections applied and the estimation strategies employed. Generally, three cases of smartphone positioning accuracy evaluation exploited in this research were summarized and presented as follows;

The work of Marcin Uradzinski and Mieczyslaw Bakula

The following work, titled "*Assessment of Static Positioning Accuracy using Low-cost smartphone GPS devices for geodetic survey points' determination and monitoring*" was carried out in 2020 where the performance of carrier phase ambiguity fixing and positioning accuracy of the latest Huawei P30 Pro smartphone equipped with a dual frequency GNSS receiver was investigated. By so doing, 3hours of raw static data was collected in separate observation sessions at a known location where the smartphone was mounted vertically for two sessions and horizontally for the third session. At the same time, a high-class geodetic receiver was used for L1 and L5 signals comparison purposes. The carrier phase measurements were processed using commercial post-processing software with reference to the closest base station observations located about 4km away. In order to also check the accuracy of the survey results in fast static mode, an additional 1hour static session divided into 10-, 15-, 20- and 30-minutes sub-session was executed. All the three 1hour static session results were at cm level of accuracy, ranging from 1cm to 4cm. For the fast static surveying mode, the best results were obtained for 20 to 30min sessions where average accuracy was also at the cm level. The main drawback was the antenna reference point, ARP of the smartphone which is not pointed out by the manufacturers. It was however suggested that it is located at the top of the smartphone above the line of the upper camera.

The work of Gerard Lachapelle and Paul Gratton

In this research, titled, "*GNSS Precise Point Positioning with Android Smartphones and Comparison with High Performance Receivers*", the smartphone used was Huawei Mate 20X and the geodetic receiver used was Leica GS16 which is a high-end multi-constellation and multi-frequency receiver. The measurements intercompared among them include; 1) Single frequency code, 2) Single frequency code and carrier-phase, 3) Dual frequency code, 4) Dual frequency code and carrier-phase. Huawei Mate 20X has the capability to capture and record code, carrier-phase, Dopler and C/No measurements every second on GPS L1/L5, GLONASS E1/E5a, BeiDou and QZSS L1/L5. The data logger used was the Geo++RINEX logger and the PPP post-processing was performed with the NRCan CSRS PPP 2.26.1 online software that can process GPS, GLONASS or GPS-GLONASS L1/L2 in either static or kinematic mode. However, the results were analyzed based on GPS and GLONASS L1. DGNSS performance evaluation was conducted using RTKLib, a well-known open-source software, producing high cm level accuracy and hence, their positions served as reference to evaluate the Mate 20X derived positions. In PPP static mode and under low multipath line of sight conditions, the phone delivered coordinate accuracy of the order of 1m using 30mins of data. A major drawback here was the fact that the mate 20X is equipped with a planner inverted F antenna like in many other smartphones and this is a well-known limitation for GNSS measurements that results in high code measurement noise and multipath. Secondly, raw data recorded on the L5 carrier waves were not analyzed by the post processing software used.

The work of Lachlan L. Ng

This work was carried out on "*The Performance Evaluation of a Dual-frequency Multi-constellation GNSS smartphone*". It was aimed at evaluating the positioning performance of L1 and L5 dual-frequency GNSS observations from three Xiaomi Mi8 smartphones. Here, a ground control point was established using a high-grade GNSS equipment, Leica Viva GS16 and analyzing post-processed smartphone observations relative to the ground control point. Raw data logging was by using the Android app Geo++RINEX Logger through an external antenna fixed to the smartphone firmly held horizontally over the control point. The first experiment was conducted on three control points (CP1, CP2 and CP3) in an open environment with baseline of approximately 20m and 1.450km from the reference station. The second experiment investigates the performance of the smartphone GNSS observations post-processed relative to other smartphone observations in short baseline of approximately 5m, logging with Geo++ for 6h. The smartphone observations were post-processed in ITRF2014, using RTKLib 2.4.2 which computes static relative positioning in double-difference mode to eliminate satellite and receiver clock biases and mitigate ionospheric and tropospheric errors. The smartphone accuracy was measured as the differences between each Cartesian dimension of the post-processed coordinates and the

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corresponding dimension from the ground truth coordinates. The experiment demonstrated that cm level accuracy static relative positioning solutions are achievable using dual-frequency multi-constellation smartphone observations. This is because it was found that smartphone GNSS network positioning solutions are accurate to 1 – 50 cm in the horizontal and vertical domain. For the geodetic receiver used for the establishment of the control point, it was accurate to 1-5cm in the horizontal and vertical domains respectively. The major drawback encountered in this thesis was the fact that the smartphone ARP was not clearly identified due to poor mastery of the PCO vector and the PCV vector or the unstable nature of the phase center of the antenna in smartphone or the smartphone antenna reference.

III. Methodology

This chapter generally includes the methods, equipment and software used in data collection and processing. It is presented in six parts- namely; presentation of the control points, the set up used in data collection, the required data captured during observation, software involved, the procedure used and general GNSS observation modes with accuracy ranges required.

The ground control points

The two ground control points were B501-51 (CP1) and the B501 (CP2) geodetic terminals of MEEC and Nkolbisson respectively from RGC as established in 2011 by Fugro Geoid (Jean-Louis, 2011, p. 41).

Table 2. 1. Coordinates of ground Control Points

	Meec			Nkolbisson		
Geog.	$\lambda/^0$	$\varphi/^0$	h/m	$\lambda/^0$	$\varphi/^0$	h/m
	11.48516236	3.86957883	733.16	11.45917183	3.869118972	744.326
Cartesian	X/m	Y/m	Z/m	X/m	Y/m	Z/m
	6236989.15	1267247.85	427499.55	6237577.649	1264421.392	427449.38
Rect.	E/m	N/m	H/m	E/m	N/m	H/m
	775996.47	428115.38	718.62	773108.385	428056.092	729.73

Data Collection Setup

The setup used at the control points for data collection, involves a horizontal wooden platform incorporated on a tripod such that the two devices can be simultaneously mounted at the same altitude under the same conditions where the phone is 25cm in the north from the geodetic receiver. Instrument heights were 1.375m and 1.565m at CP1 and CP2 respectively.

Figure 2. 1. The data collection general set up

Data

The observation data required were code and carrier phase data in RINEX format captured by the devices while navigation data were the precise ephemeris information (satellite orbit and clock products) obtained by the software from IGS network stations during post processing. The Emlid Reach RS2 geodetic receiver logged raw data in RINEX 3.02 on L1 and L2 CF while the smartphone logged raw data in RINEX (.23o) format on L1 and L5 CF.

Equipment and Software

Equipment

The main equipment/tools involved were the two devices; Xiaomi 12T smartphone and the Emlid Reach Rs2 geodetic receiver and its accessories; - the tripod, wooden platform and a measuring tape.

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Fig. 2.2 Emlid REACH Rs2

Fig. 2.3 Xiaomi 12T

Software

The main software includes; GNSSLogger used to log GNSS raw data with the smartphone in question at the control points, the emlid flow app used to log GNSS raw data during collection by the Emlid Reach RS2 geodetic receiver at the control points and the NRcan used in data post-processing at CSRS all the way from Canada.

Fig. 2.4 GNSS Logger

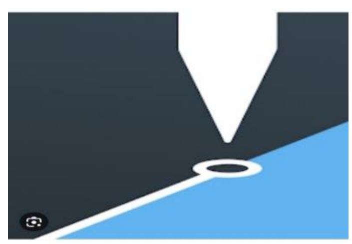

Fig. 2.5 Emlid Flow

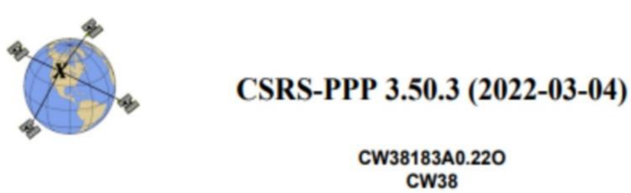

Fig. 2.6 NRcan Logo

Procedure

First specific objective: Measuring the absolute coordinates of the control points with the Emlid Reach Rs2 geodetic receiver.

At each control point, the observation of the Rs2 geodetic receiver in PPP static is monitored in the Emlid flow app on another smartphone connected to Rs2 through Wi-Fi. At the end of the session (ie, after 4h), raw data was downloaded and stored on the smartphone for online post processing at NRcan/CSRS using the ITRF20 reference system and the standard GRS80 ellipsoid of

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revolution where the return coordinates were expected in Geographic, Cartesian and Rectangular forms in the WGS84, UTM32N projection system which is the one suitable for Cameroon.

Second specific objective: Measuring the absolute coordinates of the control points with the Xiaomi 12t smartphone.

Similarly, at each control point, the smartphone also observed in PPP static mode while Wi-Fi and Bluetooth were turned off and the phone was put in **developer** mode to turn on **force full** GNSS measurements. At each point, observation took place under the same conditions at the same time on the same setup as the geodetic receiver for a duration of 4h and the raw GNSS data was acquired in RINEX format on L1 and L5 and stored in the phone. Duty cycle was disabled so as to enable continuous recording of carrier phase data. For post processing, the RINEX data was uploaded to the CSRS PPP online service and the coordinates were also expected equally in Cartesian, Geographic and Rectangular forms using the GRS80 horizontal datum in the same references and projected systems as for the geodetic receiver.

Third specific objective: Verifying the validity of the Emlid Reach Rs2 geodetic receiver.

This was done by evaluating the absolute discrepancies (errors) in coordinates of the control points obtained with the geodetic receiver and the true values provided by RGC from the geodetic data sheet as obtained in 2011 by Fugro Geoid. Acceptable error margin for absolute positioning in phase observation is 50cm – 5mm (Yap, 2022, p. 43). This was otherwise done by the statistical evaluation model from CSRS.

The main objective of the research: Positioning accuracy of Xiaomi 12t smartphone in PPP static mode.

Similarly, the positioning accuracy of the smartphone was evaluated as the absolute discrepancies or deviations of the smartphone measurements from those of the geodetic receiver. This is because if the receiver is justifiably accurate, then, its measurements are more reliable to be used as a reference since the measurements of the pillars in 2011 might have been affected by continental drift and other environmental factors.

In summary, methodology used included: Positioning, Processing and Analysis. Positioning method was 4h PPP static at both the control points to acquire the required data, Processing method was CSRS PPP online post processing service to achieve the required coordinates and Analysis method was absolute discrepancies in coordinates from those taken as reference to attain the set objectives and also the statistical evaluation model used by NRcan/PPP.

(See annex for the scatter plots of carrier phase data and pseudo-distance with the convergence profiles of the coordinates in the different directions obtained during observation at the control points by both receivers).

General Gnss Observation Modes and Accuracy Ranges

There are four basic modes of observation in global positioning, regarding code and phase measurements generally categorized as absolute or relative positioning. They can be summarized in the tree diagram below with their respective accuracy ranges.

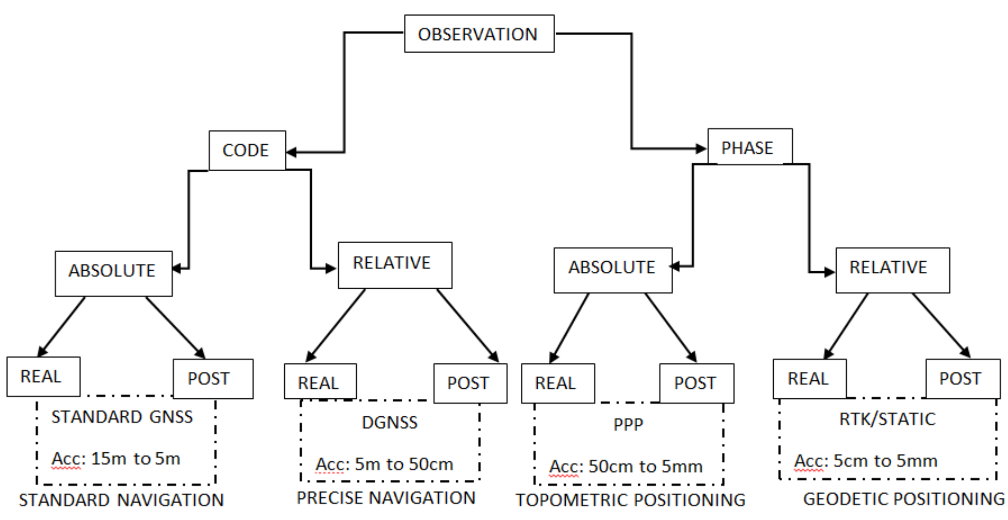

Figure 2. 7. GNSS observation modes and their accuracy ranges (Yap, 2022, p. 43).

IV. Results and Discussion

This chapter includes data processing procedure, analysis and presentation of results. In general, post processing of raw data logged with both receives was executed independently at the same site (NRCan/CSRS PPP) one after the other using the same parameters (GPS and GLONASS satellites, NRCan rapid orbit and clock products, ITRF20 reference system, GRS80 horizontal datum) and the following results were achieved:

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First Specific Objective: Emlid Reach Rs2 geodetic receiver's coordinates measured at the control points.

Table 3. 1. CP1 (MEEC) coordinates measured by geodetic receiver

	Rs2		
Geog.	$\lambda/^0$	$\varphi/^0$	h/m
	11.4851645	3.86958089	733.128
Cartesian	X/m	Y/m	Z/m
	6236985.524	1267247.356	427606.898
Rect.	E/m	N/m	H/m
	775996.702	428115.611	/

Table 3. 2. CP2 (Nkolbisson) coordinates measured by geodetic receiver

	Rs2		
Geog.	$\lambda/^0$	$\varphi/^0$	h/m
	11.45917416	3.86912098	744.343
Cartesian	X/m	Y/m	Z/m
	6237574.058	1264420.928	427556.908
Rect.	E/m	N/m	H/m
	773108.643	428056.313	/

Second Specific Objective: Smartphone's coordinates measured at the control points.

After adjusting the smartphone's coordinates using the planimetric displacement in the north direction (25cm) and the instrument heights of 1.375m and 1.565m at CP1 and CP2 respectively, the following results were obtained:

Table 3. 3. CP1 (MEEC) coordinates measured by smartphone

	Smartphone		
Geog.	$\lambda/^0$	$\varphi/^0$	h/m
	11.48523608	3.86958184	731.894
Cartesian	X/m	Y/m	Z/m
	6236984.072	1267255.174	427607.012
Rect.	E/m	N/m	H/m
	776004.656	428115.490	/

Table 3. 4. CP2 (Nkolbisson) coordinates measured by smartphone

	Smartphone		
Geog.	$\lambda/^0$	$\varphi/^0$	h/m
	11.45920091	3.8691013	742.989
Cartesian	X/m	Y/m	Z/m
	6237573.818	1264423.911	427554.751
Rect.	E/m	N/m	H/m
	773111.622	428053.895	/

Analysis of Results

Result analysis and presentation was done in two folds- that is, it was first of all obtained from absolute deviation of measured values from given ones and then from the 95% confidence interval on the ellipse of error given by the CSRS-PPP post processing.

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Third Specific Objective: Comparing geodetic receiver's coordinates obtained at the control points with those of Fugro Geoid.

Since the general objective of the research will be based on the performance of the geodetic receiver, it was necessary to ascertain that the measurements it provided are reliable. This was done by comparing those values it gave at the control points with the true coordinates on the geodetic data sheet so as to verify whether they fall within the expected accuracy range.

Table 3. 5. Discrepancies of Rs2 measured values from true values at the control points

CP1: $\|\text{mesured} - \text{true}\|$	Geo/^{0}	$\delta_\lambda = 0.00000214$	$\delta_\varphi = 0.00000206$	$\delta_h = 0.032$
	Cart/m	$\delta_X = 3.626$	$\delta_Y = 0.494$	$\delta_Z = 107.348$
	Rect/m	$\delta_E = 0.232$	$\delta_N = 0.231$	/
CP2: $\|\text{mesured} - \text{true}\|$	Geo/^{0}	$\delta_\lambda = 0.00000233$	$\delta_\varphi = 0.000002008$	$\delta_h = 0.017$
	Cart/m	$\delta_X = 3.591$	$\delta_Y = 0.464$	$\delta_Z = 107.528$
	Rect/m	$\delta_E = 0.258$	$\delta_N = 0.221$	/

Third Specific Objective: Error estimation given by CSRS-PPP from 95% confidence interval

Here, the error was calculated as the average radius of the ellipse of error at 95% confidence interval.

Table 3. 6. Average radius of ellipse of error measured by Rs2 at 95% confidence interval

Control point	Error in cm
CP1	1.2
CP2	1.1

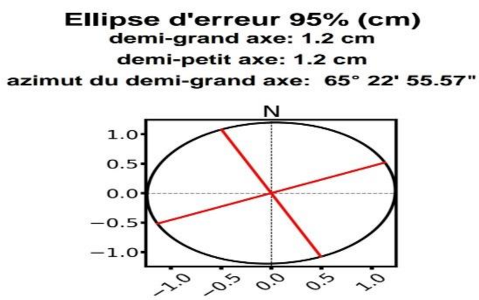

Fig. 3.1 CSRS ellipse error of Rs2 at CP1

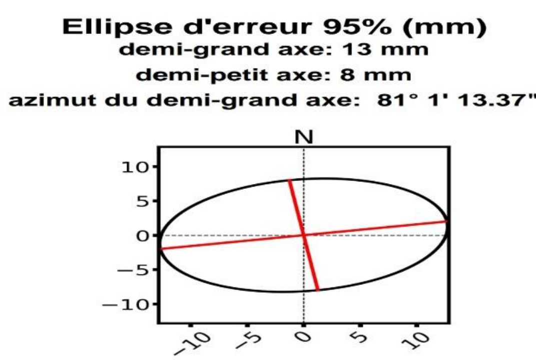

Fig. 3.2 CSRS ellipse error of Rs2 at CP2

Based on planimetric coordinates, Rs2 is found reliable because all discrepancies lie within 50cm – 5mm which is PPP accuracy range used for Topometric positioning. As seen on table 2.5 above, the maximum planimetric error was 25.8cm. CSRS measured errors show that Rs2 receiver is even more reliable as the maximum error obtained was 1.2cm which falls within RTK/Static accuracy range and used for geodetic positioning. Therefore, third specific objective was achieved.

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The Main Objective: Accuracy of Xiaomi 12t android smartphone in PPP static mode both in planimetry and altimetry.

Having achieved the third specific objective, the accuracy of the smartphone was equally established from two perspectives as specified above with Rs2 measured values used as reference. That is, it was first of all obtained by evaluating the absolute discrepancies in its coordinates from those of Rs2 and the following results were achieved and then, by the evaluating errors given by CSRS.

Table 3. 7. Discrepancies in phone's coordinates from those of the Rs2

CP1: $\lvert Phone - Rs2 \rvert$	Geo/^{0}	$\delta_\lambda = 0.00007158$	$\delta_\varphi = 0.00000095$	$\delta_h = 1.234$
	Cart/m	$\delta_X = 1.452$	$\delta_Y = 7.818$	$\delta_Z = 0.114$
	Rect/m	$\delta_E = 7.954$	$\delta_N = 0.121$	$\delta_H = 1.234$
CP2: $\lvert Phone - Rs2 \rvert$	Geo/^{0}	$\delta_\lambda = 0.00002675$	$\delta_\varphi = 0.00001968$	$\delta_h = 1.354$
	Cart/m	$\delta_X = 0.24$	$\delta_Y = 2.983$	$\delta_Z = 2.157$
	Rect/m	$\delta_E = 2.979$	$\delta_N = 2.418$	$\delta_H = 1.354$

Table 3. 8. Average radius of ellipse of error measured by smartphone at 95% confidence interval

Control point	Error in m
CP1	2.83
CP2	2.57

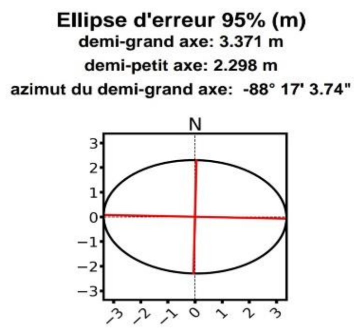

Fig. 3.3 CSRS ellipse error of smartphone at CP1

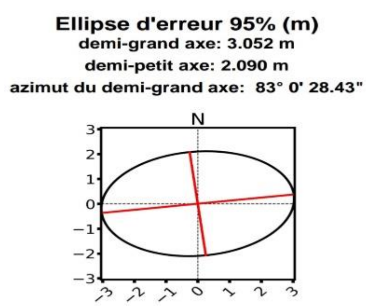

Fig. 3.4 CSRS ellipse error of smartphone at CP2

All planimetric discrepancies in table 2.7 and measured errors by CSRS in table 2.8 are less than 3m except for the east coordinates at CP1 where an error of 7.95m was observed. A possible reason to this severe discrepancy could be due to smartphone positioning since it was placed 25cm in the north direction from the Rs2 receiver because another bigger error of 2.98m also came from the same direction at CP2. This could have also been that in the east direction especially at CP1, signal strength was weak during observation or signal obstruction was severe in that direction at the first control point. Therefore, it is very likely that if the direction of the smartphone is altered in another attempt maybe 25cm in the west, a consistent trend could be achieved in the error measurement. Hence, considering both estimation models used, the smartphone measurement error could generally be considered to range within 2m to 3m which falls within the accuracy range of DGNSS used in precise navigation.

V. Discussion

With respect to map coordinates, the results show a consistency in accuracy degrading trend which gets better in the north and up directions but worst in the east and this trend is similar as seen at the two control points. With the exception of the north direction at CP1, the phone's accuracy was generally ranging from 2m to 3m on the other directions which agrees with DGNSS accuracy range applied in precise navigation.

The smartphone experienced some challenges including the fact that NRCan/CSRS PPP post processing considered only the L1 and L2 CF whereas the phone didn't measure the L2 CF. Though dual frequency data (L1 and L5) was recorded by the phone, only the L1 measurements were finally processed by the software used meanwhile for the Rs2 geodetic receiver, both frequencies were processed since it captured the L1 and L2.

More so, the L5 CF is relatively new and still pre-operational and so, not all visible satellites provide dual frequency measurements to the smartphone and therefore this can limit positioning capability significantly (Guenther et al., 2022, p. 3).

VI. General Conclusion

Based on the main problem (achieving high accuracy with low-cost devices), based on the main objective (estimating the positioning accuracy of Xiaomi 12t smartphone), based on the methods used (Positioning: 4h PPP static, Processing: NRCan/CSRS online and Analysis: absolute discrepancies in coordinates and the statistical model from CSRS), it can be concluded that Xiaomi 12T smartphone is not suitable for geodetic and topometric surveys but very suitable for standard and precise navigations including GIS applications.

Recommendations

Knowing that the phone's accuracy could improve in better conditions, the following research areas are proposed to future researchers;

- Investigation of the precise position of the smartphone's ARP, Antenna Reference Point.
- Smartphone PPP accuracy evaluation with a much longer observation time (at least 10h) in a more isolated environment.
- Update of the Cameroon Geodetic Network (RGC) to the ITRF20 reference system.
- Similar research using two or more smartphones placed in different directions and incorporated with use of augmentation systems such as SBAS and NTRIP.
- Similar research with the use of a software that can post process both the L1 and L5 signals from the smartphone.
- Use of a smartphone that can capture the L1 and L2 carrier waves.

Declaration

- This piece of work was done in November 2023. Some data were collected using the equipment specified in chapter 2 and the rest came from archives and other publications with their links included in the references. The processing report from NRcan/CSRS and the main source work are attached to the following online data repository:

Data Availability Statement (DAS): Nuiping Yakum, P. (2024). Positioning Accuracy Analysis of Low-cost GNSS for Dual-frequency Android Smartphone in Yaounde 7 [Zenodo]. https://doi.org/10.5281/zenodo.10575020

Author's contribution

This is an article with a single author and everything from beginning to end was done by the same person, the author. This includes; conception, data collection, data analysis, data processing, calculations, graphics and tables etc.

Acknowledgement

Special credit goes to Pr. YAP LOUDI, a senior lecturer in geodesy at NASPW Yaounde and a senior research fellow at NIC Yaounde through whom the author acquired great inspiration as he supervised him for master thesis.

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Finally, the author is heavily indebted to the International Journal of Latest Technology in Engineering, Management and Applied Sciences (IJLTEMAS) for the great in-depth evaluation and correction of this paper prior to its publication that was done by their Editorial Office.

Author's information

The author is a Certified Land Surveyor from the National Advanced School of Public Works, Yaounde Cameroon for the September 2022 graduation session in master of engineering.

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He is equally a member of the National Order of Cameroon Surveyors (N.O.C.S.) with the rank of Géomètre-topographe.

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Preface:

Nowadays, low cost GNSS positioning and navigation, especially in smartphones is largely becoming a possible alternative to geodetic receivers in GNSS observations. This article is a brief summary of a master dissertation defended by the author in the National Advanced School of Public Works (NASPW) Yaounde, Cameroon, estimating the accuracy of Xiaomi 12T smartphone in absolute positioning (PPP mode), which was the first low-cost GNSS positioning accuracy investigation to be conducted in Cameroon.

Data Availability Statement (DAS): Nuiping Yakum, P. (2024). Positioning Accuracy Analysis of Low-cost GNSS for Dual-frequency Android Smartphone in Yaounde 7 [Zenodo]. https://doi.org/10.5281/zenodo.10575020

List of Abreviations

ARP: Antenna Reference Point

CF: Carrier Frequency

CP: Control Point

CSRS: Canadian Spatial Reference System

GIS: Geographic Information System

GNSS: Global Navigation Satellite System

GLONASS: "GLObal'naya NAvigationnaya Sputnikovaya Sistema"

GRS80: Geodetic Reference System 1980

IGS: International GNSS Service

ITRF: International Terrestrial Reference Frame

NTRIP: Network Transport of RTCM via Internet Protocol

NRCan: Natural Resource Canada

PCO: Phase Centre Offset

PCV: Phase Centre Variation

PPP: Precise Point Positioning

RGC : "Réseau Géodésiques du Cameroun" (Cameroon Geodetic Network)

RTCM: Radio Technical Commission for Maritime Services

RINEX: Receiver Independent Exchange

UTM: Universal Transverse Mercator

WGS84: World Geodetic System 1984

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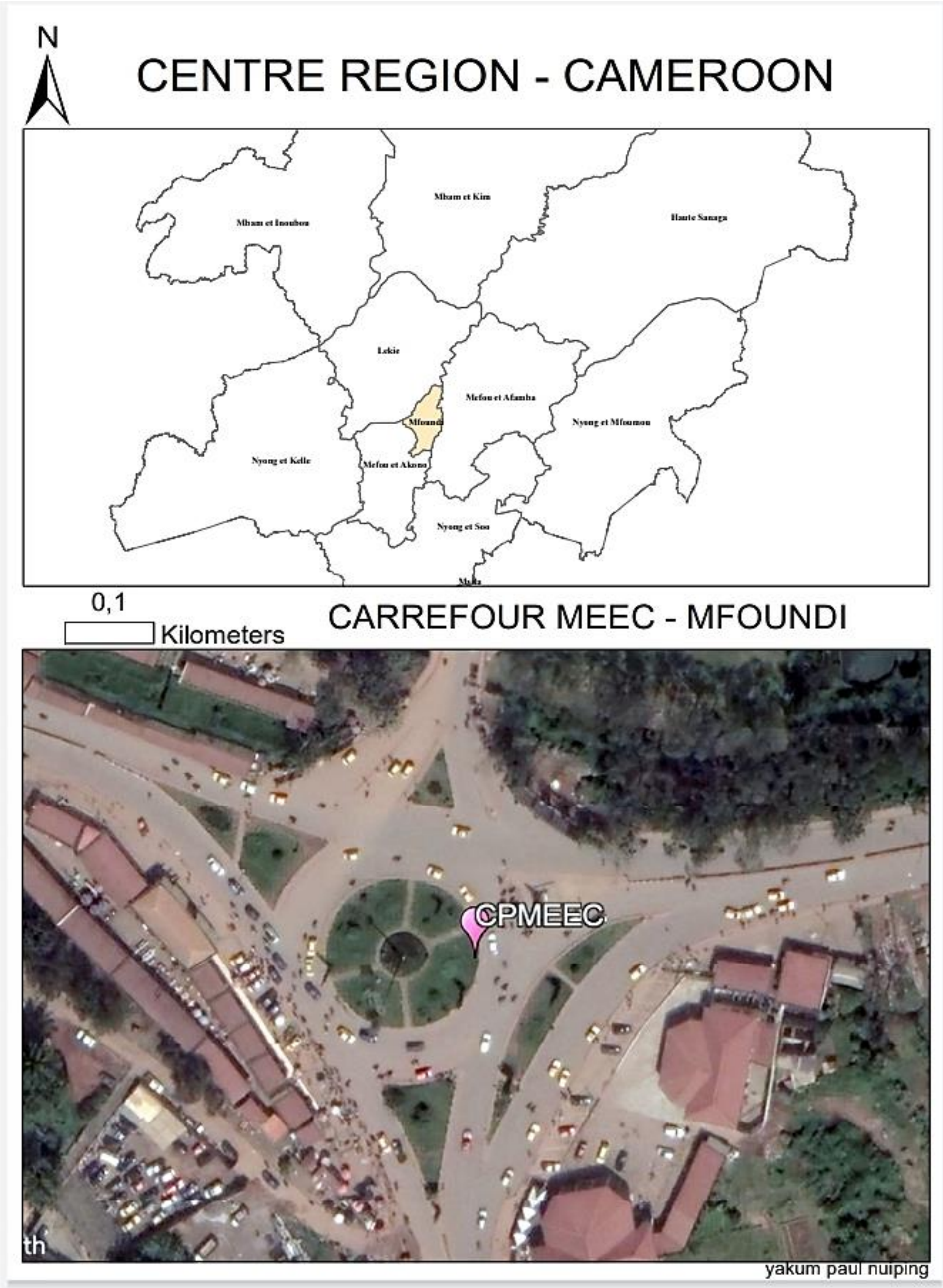
List of Annexes

Annex 1. CP1: MEEC



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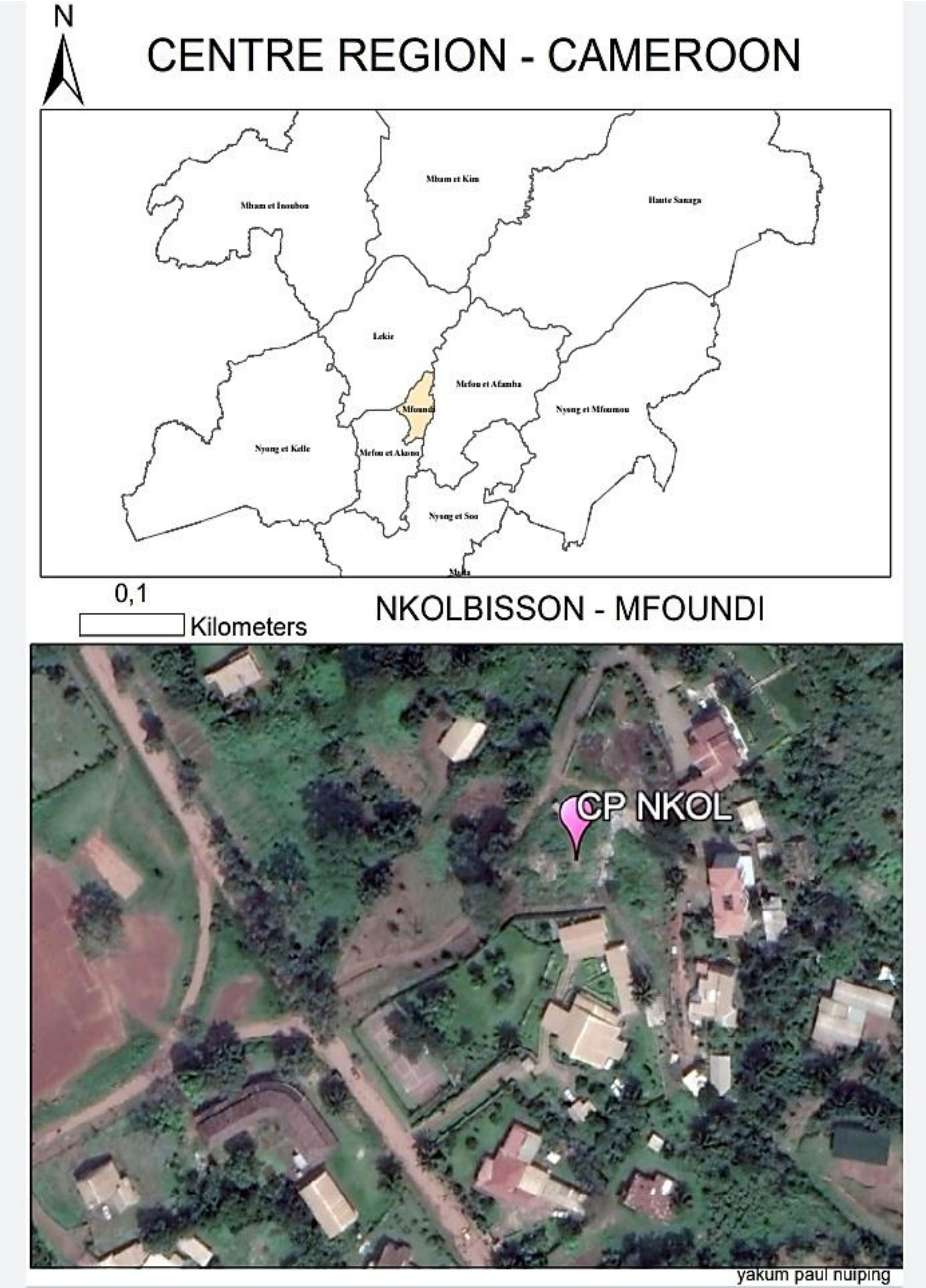
Annex 2. CP2: Nkolbisson



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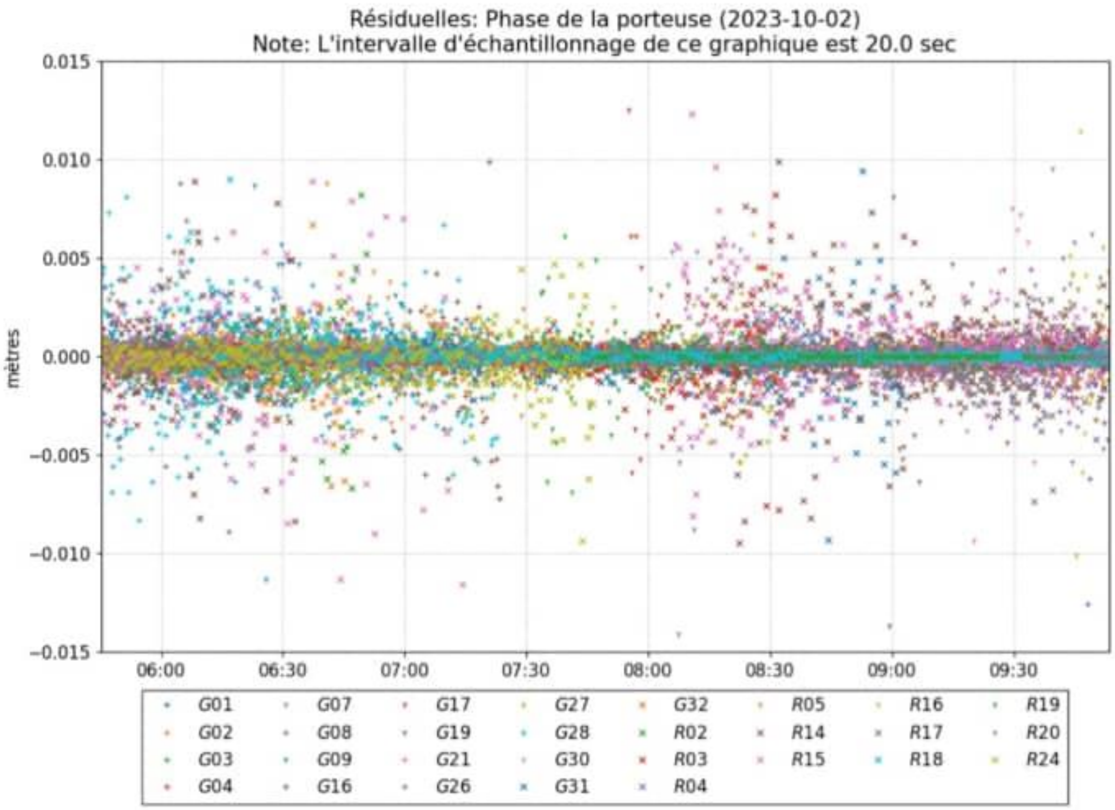
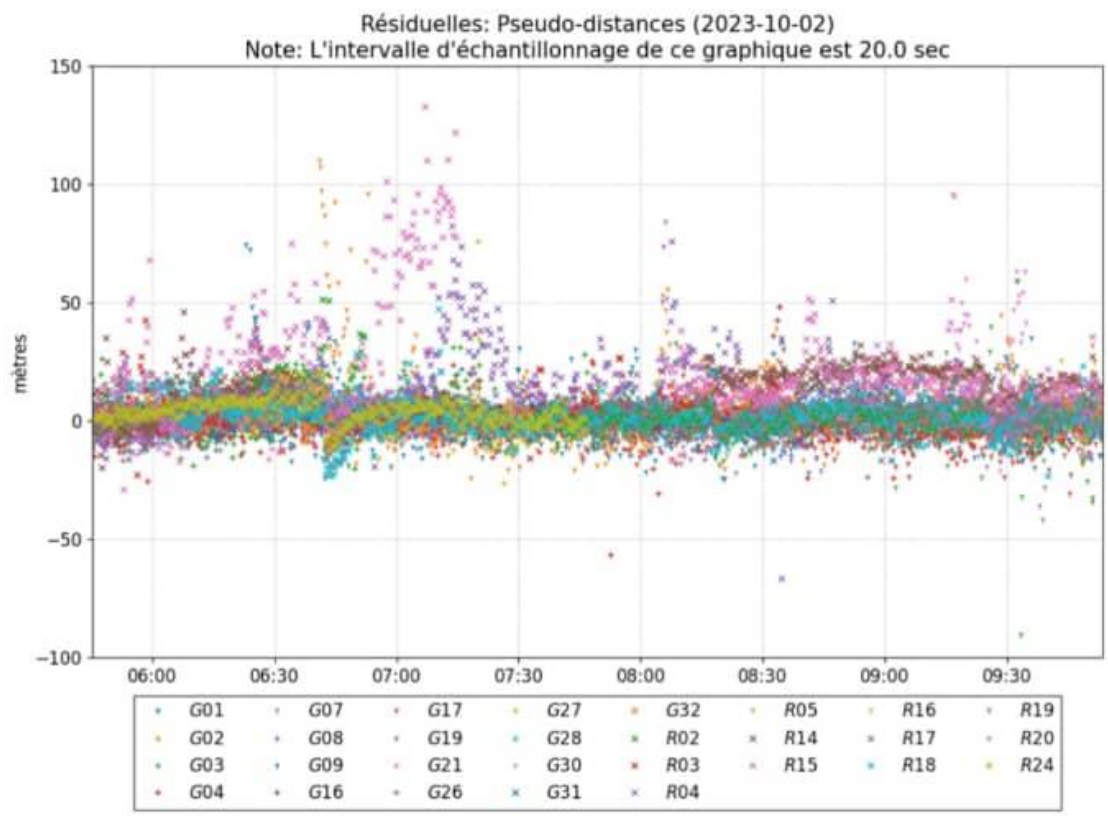
Annex 3. Scatter Plots of the smartphone at CP1 from NRcan/CSRS





Annex 4. Scatter Plots of the geodetic receiver at CP1 from NRcan/CSRS

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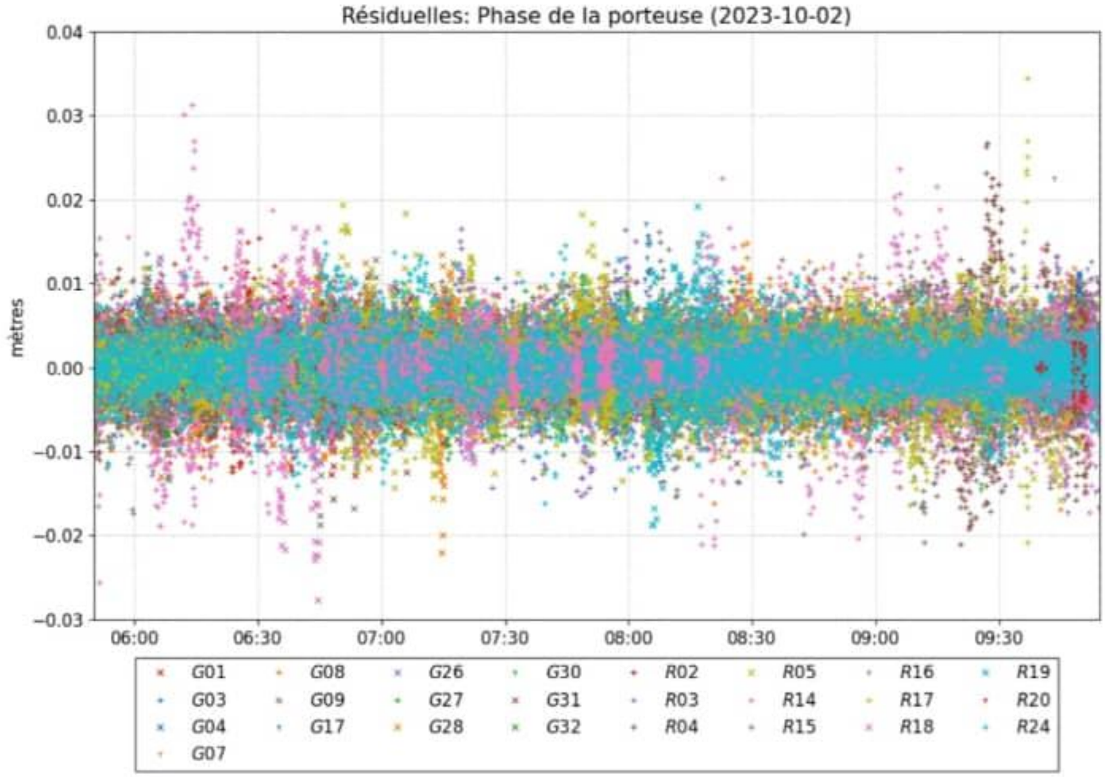

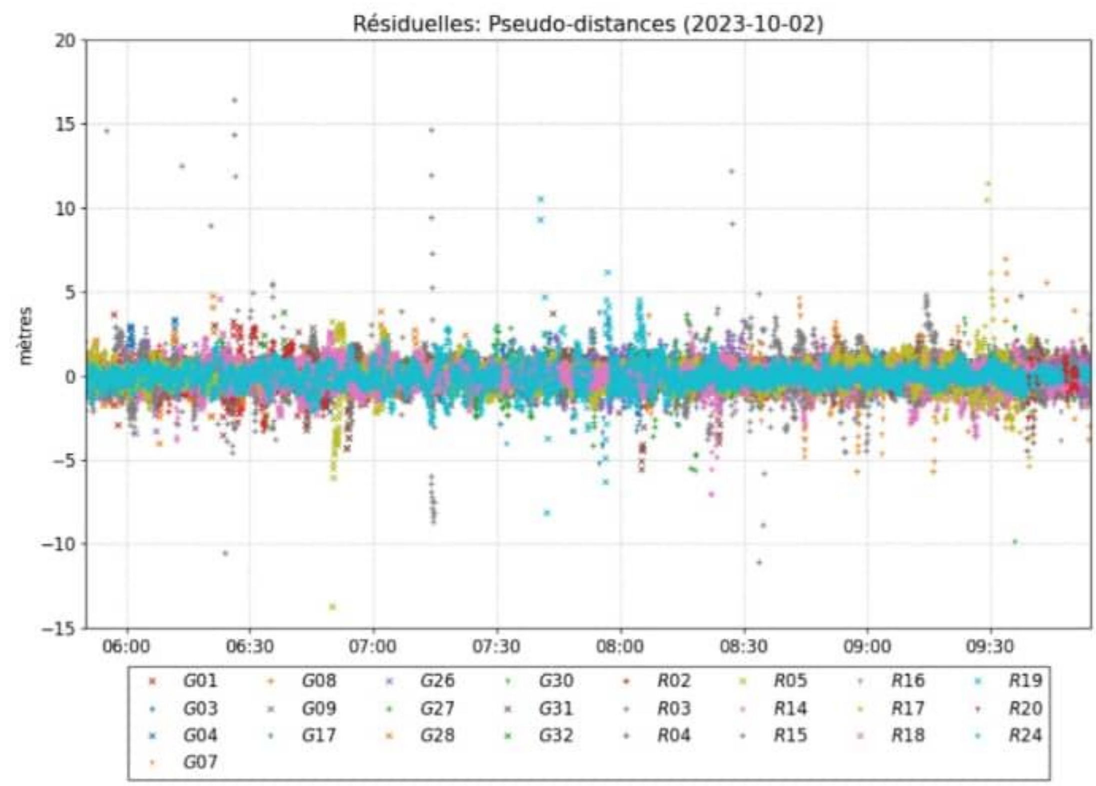

Annex 5. Convergence profiles of the smartphone at CP1 from NRcan/CSRS

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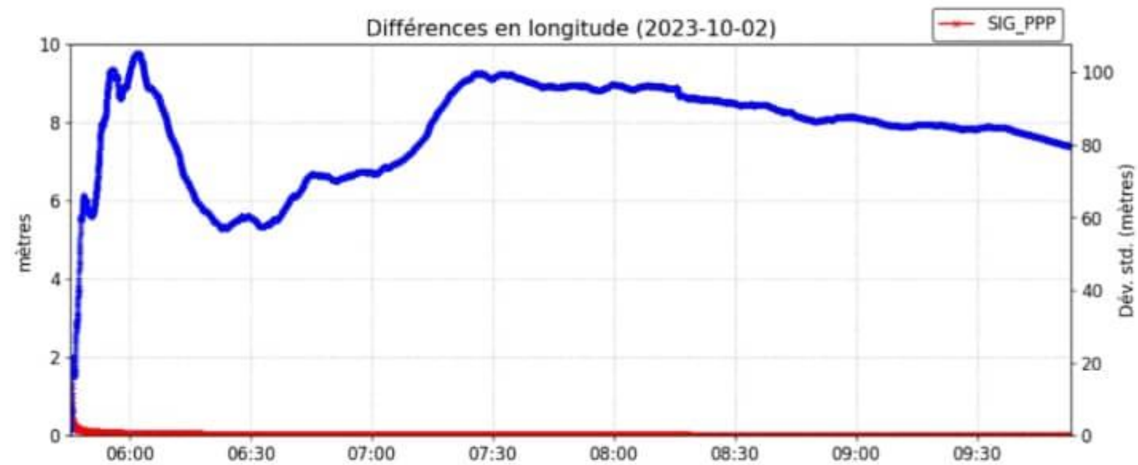

Annex 6. Convergence profiles of the geodetic receiver at CP1 from NRcan/CSRS

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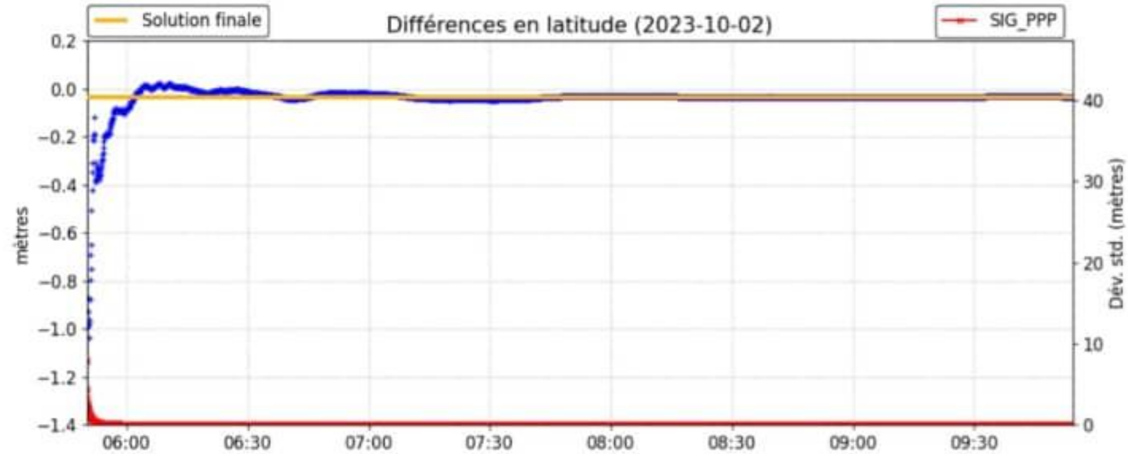

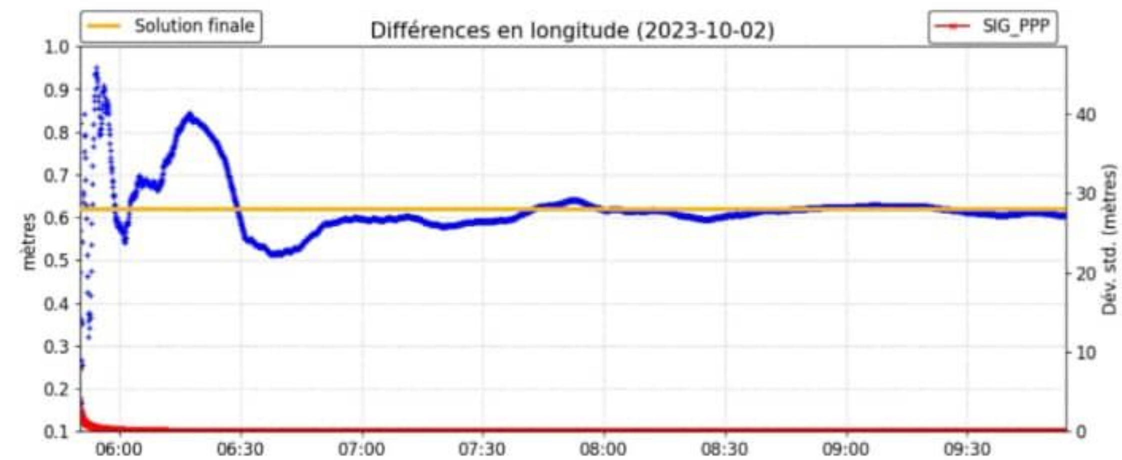

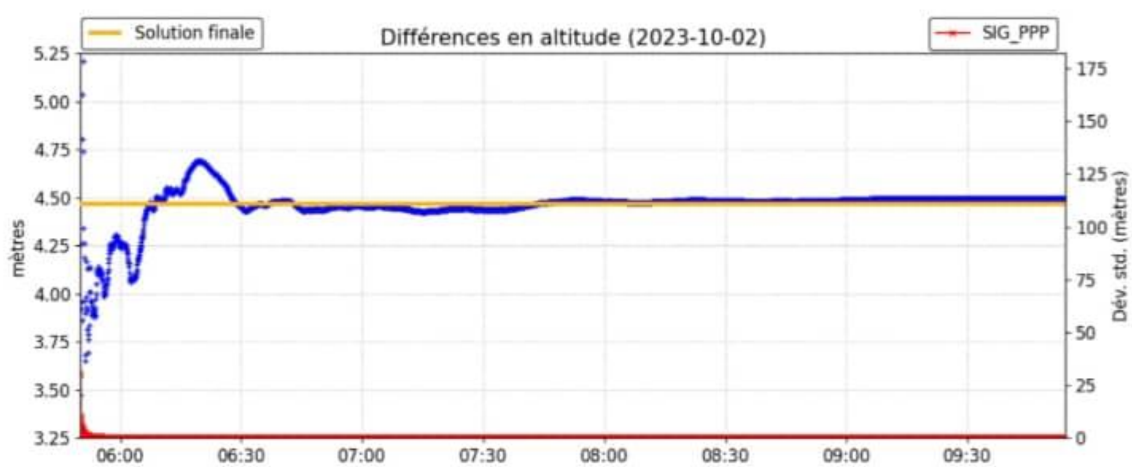

Annex 7. Scatter Plots of the smartphone at CP2 from NRcan/CSRS

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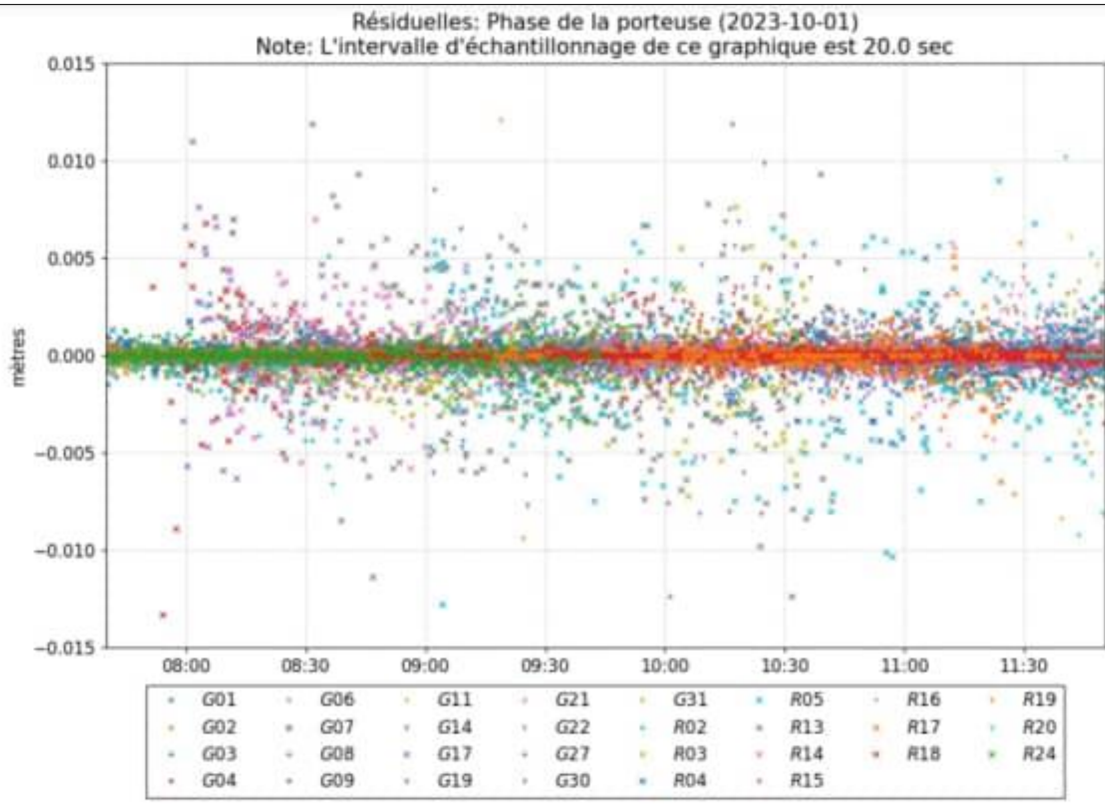

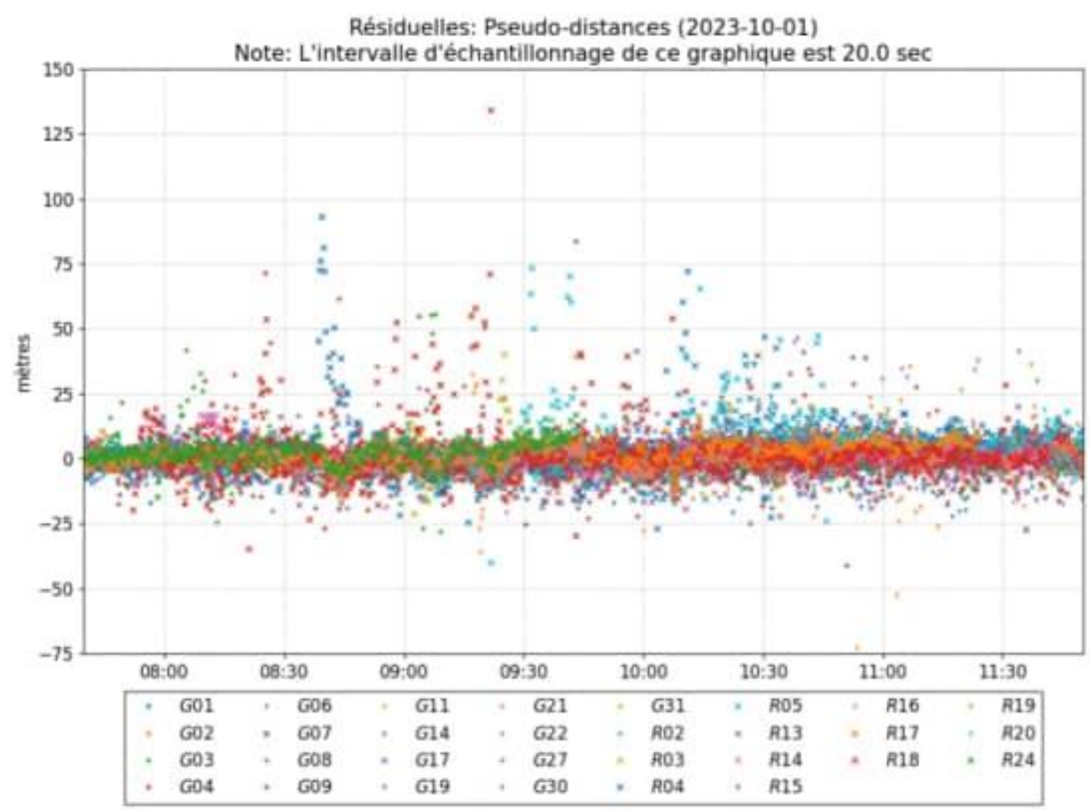

Annex 8. Scatter Plots of the geodetic receiver at CP2 from NRcan/CSRS

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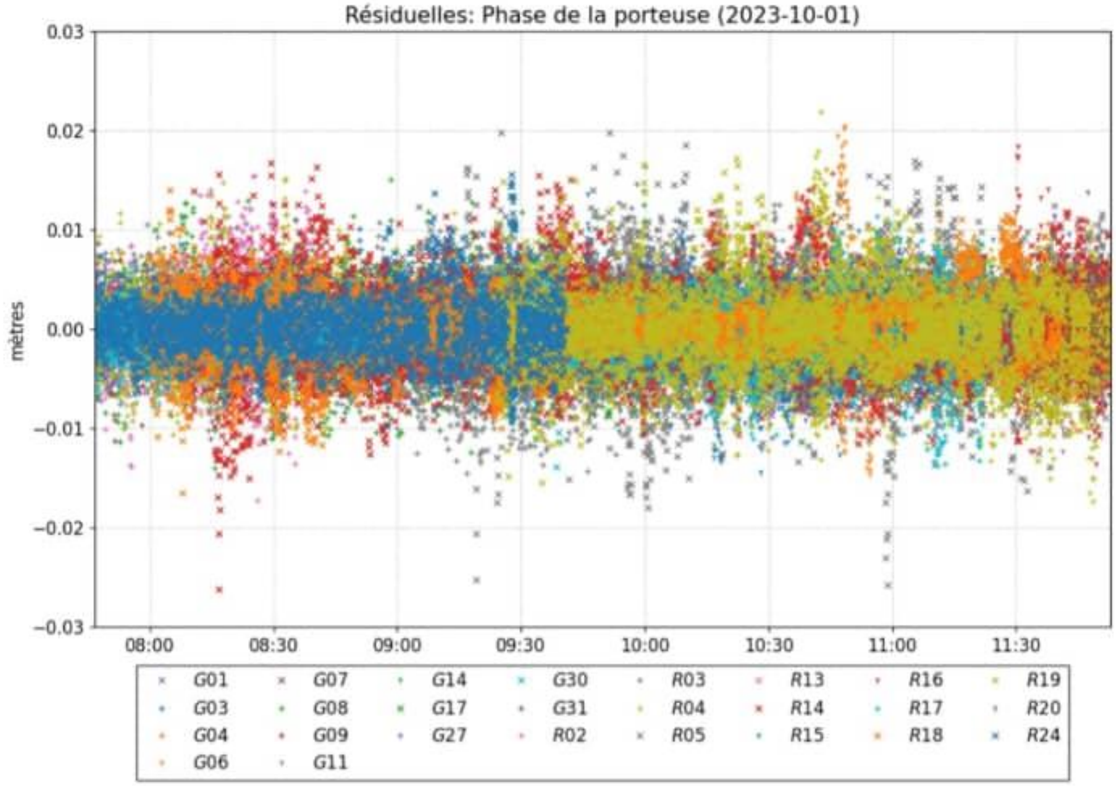

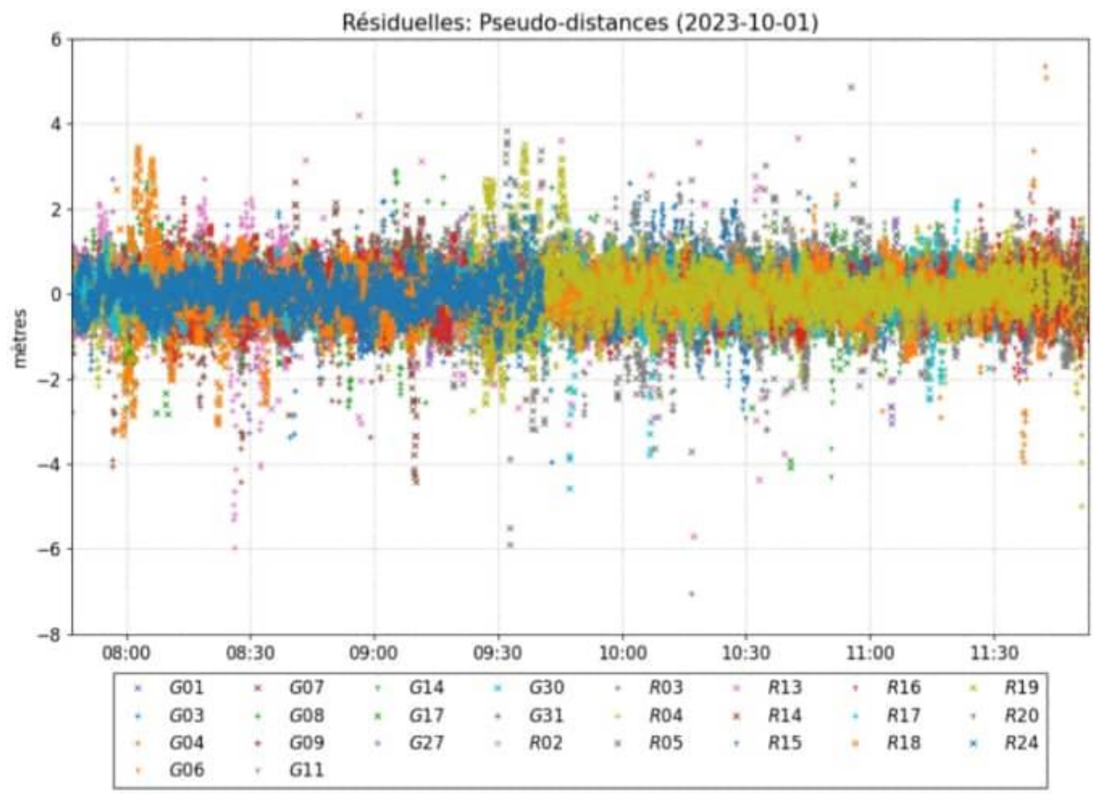

Annex 9. Convergence profiles of the smartphone at CP2 from NRcan/CSRS

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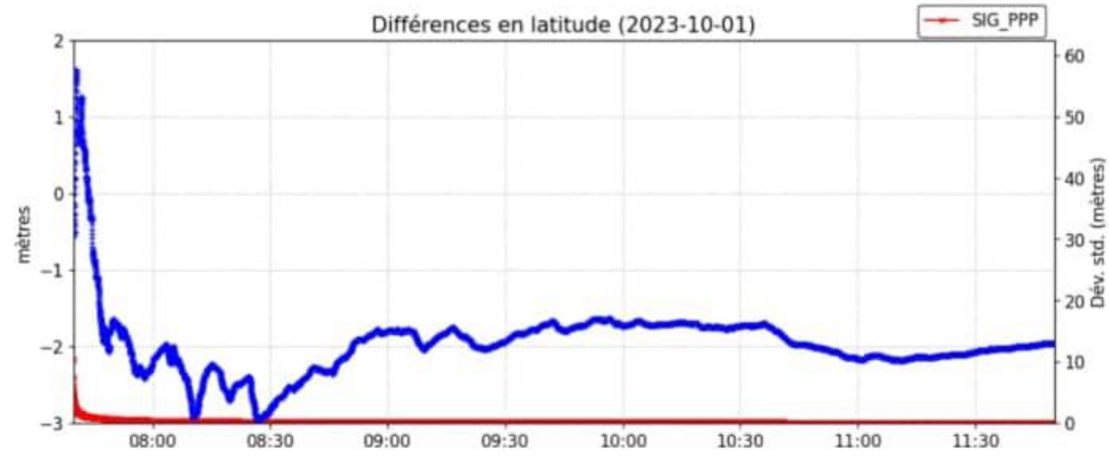

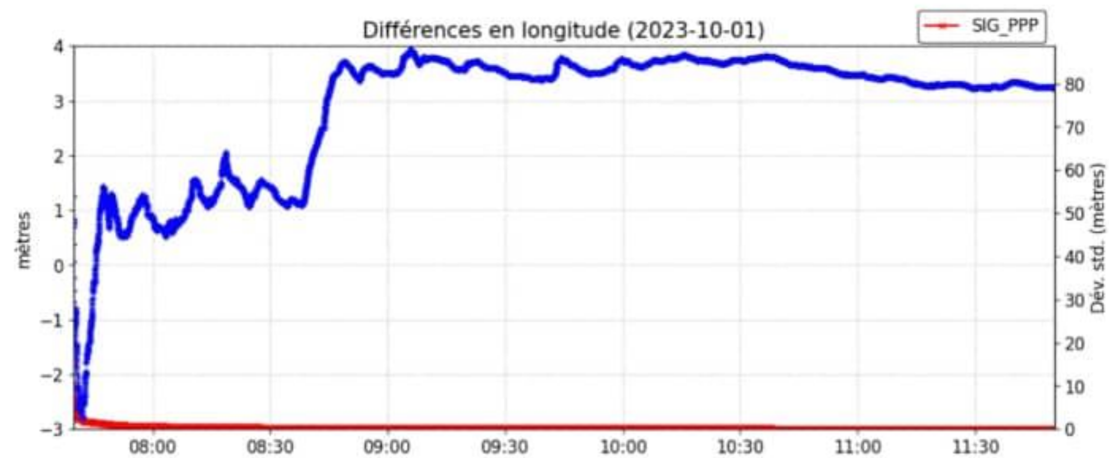

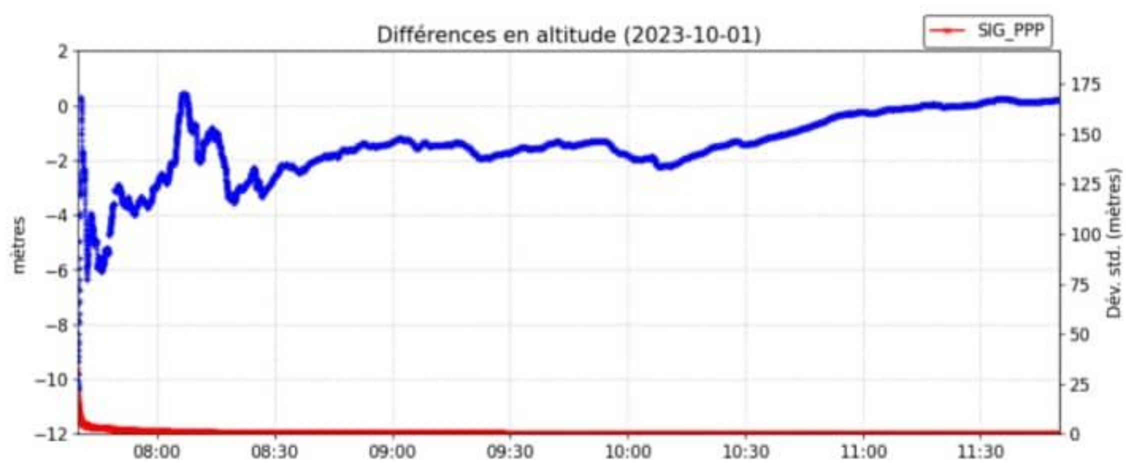

Annex 10. Convergence profiles of the geodetic receiver at CP2 from NRcan/CSRS

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