PRINT ISSN 1119-8362
Electronic ISSN 1119-8362

Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 26 (5) 801-808 May 2022

Establishment and Validation of Continuously Operating Reference Stations Geosystems Network on Static and Real-Time Kinematic in Benin City, Nigeria

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ABSTRACT: An infrastructure highly treasured by Geomatics Engineers is the continuously operating reference stations (CORS). CORS technology is a complete paradigm shift from the previously known ground control system to a virtual control system. In this paper, we present the steps taken to install CORS Geosystems in Benin City and further test its efficacy by observing fifteen existing control points located far and near using two Tersus GNSS receivers (A&B) concurrently. We perform statistical adjustment using Trimble Business Center software. Successful adjustment took two (2) iterations with Chi square test at (95%) precision confidence level and degree of freedom being nine (9) showed that the result of the adjustment was reliable. Means of 0.007m, 0.003m 0.000m for Easting, Northings and Heights were obtained while the standard errors (σ) in E, N and H are 0.003m, 0.007m and 0.000m respectively. The achieved RMS errors obtained from the attempted validation confirmed further that the newly installed CORS is capable of providing reliable 3D geo-spatial data for prospective authorized users to proffer solutions to engineering, scientific, environmental and research driven challenges.

DOI: https://dx.doi.org/10.4314/jasem.v26i5.4

Impact factor: http://sjifactor.com/passport.php?id=21082

Google Analytics: https://www.ajol.info/stats/bdf07303d34706088ffffbc8a92c9c1491b12470

Dates: Received: 18 March 2022; Revised: 13 April 2022; Accepted: 11 May 2022

Keywords. Geosystems network; real-time kinematics; static-time kinematics; operating reference system

A complete paradigm shift from the previously known conventional ground surveying techniques employed many decades ago in the establishment of first order control networks is the innovation brought about as a result of the advent and utilization of GNSS. CORSs are basically referred to as ground-based or roof-based mounted infrastructure that can be used to store, process and archive geo-spatial data useful in several area of applications (Supinajaroen and Loenen, 2019). CORS is regarded as Reliable, Accurate, Robust and Economical (RARE) Positioning Service as noted by Jamal, (2011; Ayodele et. al 2017). Area of application includes but not limited to the following: real-time monitoring of high rising building, monitoring of dredging activities, real-time traffic flow monitoring, mining site elemental positioning system, local geoidal model integration and realization, flood and fire hazard monitoring, smart and precision farming, oil exploration and exploitation positioning, freight navigation and positioning, transport monitoring, surface and underground pipeline monitoring, disaster monitoring, logistic and delivery services, location-based services, water resources management, military and security management, surveying and mapping, construction management etc. (Nnamani and Ijaware, 2020; Peter and Oliver, 2017; Supinajaroen and Loenen, 2019; Canadian Geodetic Survey, 2017). According to Supinajaroen and Loenen, (2019) CORS network includes four main components viz: observation station, data transmission, central facility and data distribution. The Intra-Frame Velocity Model (IFVM) being conceived in North American to take effect from year 2022, as reported by Martin, (2020) may likely be built upon CORS data, geodynamic models and InSAR, therefore emphasis on establishing more CORSs are becoming increasingly advocated globally. Fixing local-based functional GNSS CORS point installation is (particularly important for providing useful information for tackling large-scale landslides, wide-area land subsidence, large-scale social

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infrastructures such as dams and bridges). Besides, disasters associated with global warming will increase the demand for spatial data around the world (Martin, 2020). The history of CORS in Nigeria dated back to 2008 when the Office of the Surveyor General of the Federation (OSGoF) established some CORS in selected areas across the country. The Agency is saddled with responsibility of mapping and other related matters, Jatau et. al., (2010). As at 2013, 11 CORS was reported by Iyiola et. al., (2013) in Nigeria while between the space of 2013 to 2020 (Ayodele et. al, 2020; Nwilo et. al., 2016) reported up to 16 CORS respectively. However, there are many other CORS that are not yet enlisted, like the one being reported in this paper. It is becoming more interesting and promising as people who can afford to set up a CORS infrastructure for the benefit of authorized end users are now enlightened to do so. In view of this, it is therefore advisable for the modern-day Surveyors, Geomatics engineers, Geologists, Geographers, Earth and Environmental Scientists to make the most advantageous use of such rare opportunity available to them for better positioning solutions capable of providing environmental sustainability and other areas of CORS applications.

The birth of AFREF in 2005, with the objective of initiating a unified and modernized system of geodetic reference frame for the African continent has put forward their drive to various governments, people and national mapping agencies to expedite action on the creation of zero order geodetic networks using the present day available modern GNSS technologies including the establishments of CORS eco-system networks capable of providing variety of Real Time Networks (RTN) services including DGPS/RTK broadcast corrections and support for various applications including mapping, engineering, cadastral, weather, geodynamics, geotechnical, seismic, hydrodynamics etc. According to AFREF Report, (2016), when this common unified frame of reference is fully implemented, it will constitute a functional (RTNs) where raw data and RTK/DGNSS broadcast corrections would be made available for many applications. But limitations such as reduction in accuracy at distances greater than 20km from the CORS and the failure of connection to the CORS station due to limitation in network qualities from service provider can bring delay in data acquisition nonetheless we overcame this problem by taken such into consideration during reconnaissance and field planning. As at 25th August, 2021, we discovered 505 CORS stations in the International GNSS Service (IGS) networks (Nigeria inclusive) from which Global Navigation Satellite System (GNSS) observation datasets from a cooperatively operated global network of ground tracking stations from various contributing countries are archived. The archival data are then distributed freely to the end users on demand for different purposes (IGS, 2021). The objective of this paper is therefore to establish and validate the CORS Geosystems Network on static and real-time kinematic in Benin City, Nigeria.

MATERIALS AND METHODS

Study Area: The study area is within Benin the capital city of Edo State, Nigeria. It is in Zone 31 North of the UTM projection. The eastings and northings boundaries coordinates are: 5° 34'; 6° 27' and 5° 44'; 6° 14' as depicted in Figure 1. LGAs within the circumference of 70km will benefit from CORS Geosystems on RTK mode. Furthermore, distance more than 200km on Static mode is still within the circumference of the newly established CORS Geosystems.

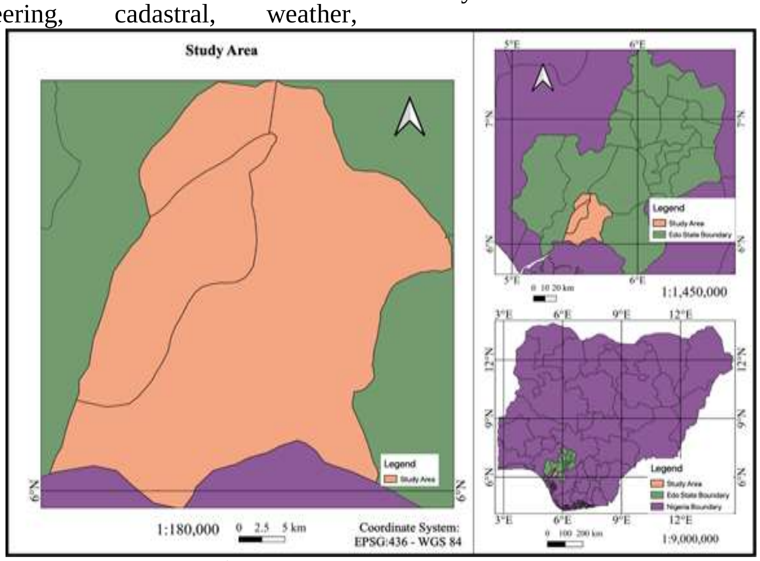

Fig 1: Map of Nigeria, Edo State and Benin City, the study area

Network Design: The planning of the implementation of the computer network infrastructure is presented in figure 2.

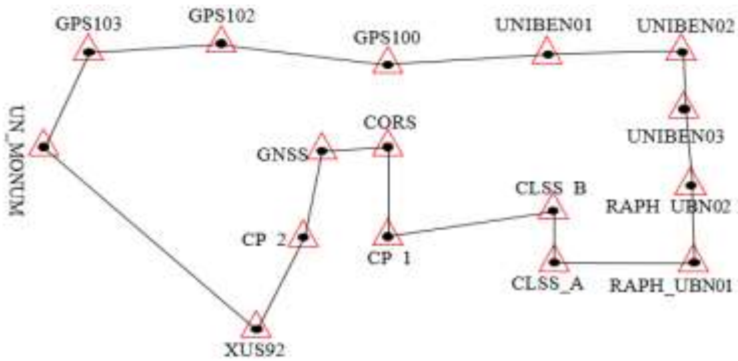

Fig 2: Network Design, not drawn to scale

Network Key: *CORS = continuously operating reference station virtual control point; GNSS = Global navigation satellite system control point located close to the CORS; RAPH_UBN01, RAPH_UBN02 = University of Benin control points abbreviated with a name prefix located inside Uniben. Two in this series; CLASS_A and CLASS_B = Two control points established inside Uniben by PG student groups as abbreviated; CP_1 and CP_2 = Two control points located along second east circular road Benin city abbreviated; GPS 100 GPS 102, GPS 103 = Global positioning system tagged controls located inside Uniben. Three in that categories; UNIBEN 01 and UNIBEN 02, UNIBEN 03 =Three control points inside University of Benin controls abbreviated, three in that series; XUS92 = Surveyor Council of Nigeria (SURCON) control located at Edo College Benin City; UN-MONUM = University monumented control located in front of Uniben main gate*

Considerations for the Installation of CORS Geosystems: The procedure followed in terms of choice of site before installing the CORS Geosystems relied on thorough literature search and the understanding of the varied as well as similar information provided in (NGS, 2021, CGS, 2017; University NAVSTAR Consortium, 2017a; NOAA, 2006; NOAA, 2013; UNAVCO, 2017b; Schmidt, et. al., 2000) such as: (i) Possibility of maximizing the GNSS antenna stability at the reference point in 3D since we chose "roof mount" option at 10 degrees above the horizon to minimize signal due to obstruction tendencies in this work. (ii) Avoidance of area susceptible to interference with other frequency dependent stations like: Television station, Microwave, FM radio stations, Cellular telephones, Telecommunication mast, VHF and UHF repeaters, RADAR, High voltage power line, etc. The listed examples, if not avoided, could introduce unwanted noise that may contribute much to intermittent or partial loss of lock or at worst make a CORS useless/inoperable (CGS, 2017). (iii) Centrality to the heart of Benin City which makes the coverage more adequate for the end users. Having met the minimum acceptable criteria we proceeded with the installation process which was successful.

Static Data Acquisition and Post-Processing with CORS Geosystems: After a successful installation of the geodesy parameters (Datum: WGS 1984; Zone: 31North; Geoid: EGM 2008 global model 2.5') and proper determination of the receiver's antenna height, we took observations to verify the station is working properly. We perform statistical adjustment using Trimble Business Center software. Number of iterations for Successful Adjustment was two (2). The adjustment passed the Chi square test at (95%) precision confidence level with degree of freedom being nine (9). Post-processed vector statistics reference factor was 1.01, number of redundancy was 9.00 and a-priori scalar was obtained as 0.59.

CORS Geosystems Validation Using Two Receivers (A&B) in RTK: The second stage was the validation of CORS Geosystems by concurrent deployment of receivers (A and B) on fifteen controls in RTK mode. We acquired data setting the two rovers in turn for one minute on the different controls spread within Benin City at various distances apart. This development enabled us to compare two observed datasets to verify the ability of the CORS to deliver accurate, dependable and reliable positional data because that is the service the CORS will provide eventually when receivers from different authorised users will be permitted to hooked-up to it. With the IGS introduction of the so-called Receiver INdependent EXchange (RINEX) and bespoke software interoperability, data captured by receivers from different manufacturer of GNSS equipment easily go through processing phase when converted to RINEX file format. Equation 1 explains better what takes place with using two receivers and how errors are controlled (Cheng et. al., 2021).

$$\phi = \rho - I + Tr + C(b_{Rx} - b_{Sat}) + N\lambda + \varepsilon_{\phi} \quad (1)$$

Where: *I*, is the signal path delay due to the ionosphere; *Tr*, is the signal path delay due to the troposphere b_{Rx}, is the receiver clock offset from the reference (GNSS) time; b_{Sat}, is the satellite clock offset from the reference (GNSS) time; *C*, is the vacuum speed of light; λ, is the carrier nominal wavelength; *N*, is the ambiguity of the carrier-phase (integer number); ε_{ϕ}, are the measurement noise components, including multipath and other effects; ρ, is the geometrical range between the satellite and the receiver, computed as a function of the satellite $(x_{Sat}, y_{Sat}, z_{Sat})$ and receiver (x_{Rx}, y_{Rx}, z_{Rx}) coordinates. Equation 2 is the pseudo range (Cheng et. al., 2021).

$$\rho = \sqrt{(x_{Sat} - x_{Rx})^2 + (y_{Sat} - y_{Rx})^2 + (z_{Sat} - z_{Rx})^2} \quad (2)$$

For two receivers *a* and *b* making simultaneous measurements at the same nominal time to satellites *1* and *2*, the double difference observable is:

$$\phi_a^{12} - \phi_b^{12} = \rho_a^{12} - \rho_b^{12} - I_a^{12} + I_b^{12} + Tr_a^{12} - Tr_b^{12} + \lambda(N_a^{12} - N_b^{12}) + \varepsilon_a^{12} - \varepsilon_b^{12} \quad (3)$$

In the equation 3 receiver and satellite clock offsets and hardware biases canceled out. The single difference ambiguities difference $N_a^{12} - N_b^{12}$ is commonly parameterized as a new ambiguity parameter. N_{ab}^{12}. The advantage of double differencing is that the new ambiguity parameter N_{ab}^{12} is treated as an integer because the non-integer terms in the GNSS carrier phase observation, due to clock and hardware delays in the transmitter and receiver are eliminated.

Ellipsoidal and Orthometric Heights Challenge: While GNSS gives ellipsoidal height, levelling provides the orthometric height. The difference between the two is referred to as geoidal undulation. Ellipsoidal height will not provide sufficient information to model the direction of flow critically needed in engineering. This challenge was overcame as the Tersus GNSS NUWA software used was enhanced with EGM2008 (Geoidal model). It convert from Ellipsoidal height to Nigeria Lagos orthometric height datum. Equation 4 provides the solution for the determination of the separation between these values.

$$N = H_e - H_o \quad (4)$$

Where: N, is the geoidal undulation; He is the ellipsoidal height and Ho is the orthometric (geoid) height

RESULTS AND DISCUSSIONS

The following Tables are presented to show the results of various analysis carried out from the adjustment of field observations. Discussion of each Tables is made at the end of presentation of all Tables. Tables 1 to 3, are basically obtained from the post-processing analysis of the static observation during CORS Geosystems installation. From Table 1, we fixed the existing first order triangulation control XUS92 established by (OSGoF) for the adjustment of the CORS station, Geosy control, and Uniben control respectively. After obtaining the adjusted 3D coordinates of the stations, errors recorded in the Eastings and Northings (horizontal) are in the order of 0.003m, 0.001m, 0.002m for the unfixed stations while for the Height (vertical), the error order are: 0.003 for CORS, 0.006m for Geosy, and 0.008m for Uniben stations respectively. Table 2: showed the error ellipse components for the semi major and semi minor axes with the values 0.002m and 0.002m and azimuth 90° for CORS and Uniben stations. Similarly 0.003m and 0.003m at 38°.was the values at Geosy station. Table 3, represented the covariance terms of the GNSS adjusted observations. The observation progressions of the station (From) and the station (To) were recorded. It can be seen that station distances from the CORS has significant impacts on the Horizontal Precision Ratio (HPR) and the 3D Precision Ratio (3DPR) such that the greater the ellipsoidal distances the greater the HPR and 3DPR respectively. Again, the time in (sec) taken for a-posteriori error adjustment increases as ellipsoidal distances decreases. Table 4 to 7 are derived from the RTK observations with receivers (A&B) used for validation exercise of the CORS Geosystems. The various analysis carried out are hereby presented. Table 4 represents receiver (A) post-processing data analysis results. In the Table are the following: Control_ID, N coordinates in (m), E coordinates in (m), Height in (m) position dilution of precision (PDOP), horizontal dilution of precision (HDOP), vertical dilution of precision (VDOP), horizontal root mean squared error (HRMS), vertical root mean squared error (VRMS), northings standard deviation (NSTD), and eastings standard deviation (ESTD) respectively. UN_MONUMT has the highest elevation of 129.977m while CP_2 has the least elevation of 100.853m. PDOP varied between 0.9m to 1.1m. Also, HDOP varied between 0.4m and 0.6m and VDOP varied between 0.8m and 1.0m which are really good. The least and the highest horizontal RMS errors recorded was 0.0039 at CP_2 station and 0.0088m at RAPH_UBN01 station while the least and the highest vertical RMS errors recorded was 0.0072m at CP_2 station and 0.0142m at RAPH_UBN01 station respectively.

Table 1: Adjusted Grid Coordinates

Point_ID	E (m)	E/Error (m)	N (m)	N/Error (m)	Elev. (m)	Elev./ Error (m)	Constraint
CORS	791897.989	0.001	700539.954	0.001	83.291	0.003	
Geosy STN	791905.737	0.002	700556.117	0.002	83.171	0.006	
UniBen STN	789802.914	0.002	708408.330	0.002	102.605	0.008	
XUS92	792922.225	-	700767.778	-	85.798	-	LLh

Table 2: Components of the Error Ellipse

Point ID	Semi-major axis (m)	Semi-minor axis (m)	Azimuth
CORS	0.002	0.002	90°
Geosy STN	0.003	0.003	38°
UniBen STN	0.002	0.002	90°

Table 3: Covariance Terms of Adjusted Observations

From Point	To Point		Components	A-posteriori Error	Horiz. Precision (Ratio)	3D Precision (Ratio)
Geosy STN	CORS	Az.	205°54'10"	23.685 sec	1 : 6822	1 : 6859
		ΔHt.	0.120 m	0.006 m		
		ΔElev.	0.120 m	0.006 m		
		Ellip Dist.	17.912 m	0.003 m		
Geosy STN	UniBen STN	Az.	345°18'03"	0.063 sec	1 : 3508535	1 : 3495060
		ΔHt.	19.841 m	0.010 m		
		ΔElev.	19.434 m	0.010 m		
		Ellip Dist.	8123.649 m	0.002 m		
Geosy STN	XUS92	Az.	78°31'43"	0.460 sec	1 : 427663	1 : 427366
		ΔHt.	2.631 m	0.006 m		
		ΔElev.	2.627 m	0.006 m		
		Ellip Dist.	1037.608 m	0.002 m		
UniBen STN	CORS	Az.	165°22'51"	0.043 sec	1 : 5352329	1 : 5350306
		ΔHt.	-19.721 m	0.008 m		
		ΔElev.	-19.314 m	0.008 m		
		Ellip Dist.	8137.257 m	0.002 m		
XUS92	CORS	Az.	257°45'07"	0.259 sec	1 : 729045	1 : 728876
		ΔHt.	-2.511 m	0.003 m		
		ΔElev.	-2.507 m	0.003 m		
		Ellip Dist.	1048.577 m	0.001 m		
XUS92	UniBen STN	Az.	338°05'09"	0.042 sec	1 : 5377006	1 : 5377470
		ΔHt.	17.210 m	0.008 m		
		ΔElev.	16.807 m	0.008 m		
		Ellip Dist.	8247.398 m	0.002 m		

Table 5 represents receiver (B) post-processing data analysis results with the same headings as Table 4. As shown in the Table, UN_MONUMT has the highest elevation of 131.599m while CP_2 has the least elevation of 102.316m. PDOP varied between 0.9m to 1.2m, also, HDOP varied between 0.4m and 0.6m and VDOP varied between 0.8m and 1.0m which are really good. the least and the highest horizontal RMS errors recorded was 0.0041m at station CP_2 and 0.0102m at GNSS station while that of the least and highest vertical RMS error was 0.0073m at station CP_2 and 0.0162m at station GNSS respectively. These value are within the range of allowable error, as such we accepted the result of the observations. From Table 6, we compare the differences in N, E, H, PDOP, HDOP, VDOP, VRMS, HRMS, NSTD and ESTD between the observed values of receivers A and B. For PDOP, HDOP, VDOP. Ten stations showed no significant difference with outright zeros while five stations showed little variations between zeros and ones. On the other hand, five stations showed outright zeros with no significant difference while ten stations showed some minimal variations in VRMS, HRMS, NSTD and ESTD respectively. The implication of using two receiver is to test the reliability of the results, which has been achieved. The result represented in Table 7 shows the mean and the standard deviation of the E, N and H coordinates obtained from data acquired by Receiver (A&B). When comparing the performance of both receivers, the following inferences were deduced: The mean of the difference in eastings is more than doubled that of the northings and their corresponding values are 0.007m and 0.003, while the difference in heights showed no significant difference with the value of 0.000m obtained. A reverse case was observed in standard deviation where the difference in northings is more than doubled the eastings with their corresponding values showed as 0.003m and 0.007m while that of the difference in means for heights showed no significant difference with value of 0.000m indicated. Figure 3 represents the graph of difference in heights obtained using equation 4. Figure 3, is the differences obtained in orthometric and ellipsoidal heights on the fifteen controls using equation 4.

Table 4: Receiver (A) data analysis

Control_ID	N (m)	E (m)	H (m)	PDOP	HDOP	VDOP	HRMS	VRMS	NSTD	ESTD
GNSS	700442.281	791987.484	102.908	1.1	0.5	1.0	0.0056	0.0078	0.0043	0.0035
CP_1	700452.517	791952.809	102.803	1.1	0.5	1.0	0.0042	0.0074	0.0025	0.0034
CP_2	700417.558	791947.050	102.316	1.1	0.5	1.0	0.0039	0.0072	0.0026	0.0029
XUS92	700653.888	793003.963	105.471	1.1	0.5	1.0	0.0043	0.0079	0.0028	0.0032
UN_MOUMT	707940.000	788745.662	131.599	1.1	0.6	1.0	0.0086	0.0132	0.0067	0.0055
RAPH_UBN01	708198.878	789854.418	122.597	1.0	0.5	0.9	0.0088	0.0142	0.0064	0.0060
RAPH_UBN02	708294.391	789884.579	122.174	1.0	0.5	0.8	0.0077	0.0123	0.0055	0.0053
UNIBEN03	708420.873	789924.536	121.661	1.0	0.5	0.8	0.0082	0.0121	0.0054	0.0062
UNIBEN02	708540.639	789955.850	120.665	0.9	0.5	0.8	0.0081	0.0120	0.0054	0.0061
UNIBEN1	708507.097	789713.292	125.531	0.9	0.5	0.8	0.0081	0.0110	0.0055	0.0059
GPS100	708471.489	789478.171	128.845	1.0	0.5	0.8	0.0084	0.0119	0.0056	0.0062
GPS101	708462.617	789292.532	129.601	1.0	0.5	0.8	0.0086	0.0121	0.0061	0.0060
GPS102	708424.075	789041.536	130.058	1.0	0.5	0.9	0.0079	0.0112	0.0054	0.0058
CLASS A	708044.231	789399.407	128.762	1.1	0.6	1.0	0.0080	0.0137	0.0052	0.0060
CLASS B	708022.219	789463.022	128.917	1.2	0.6	1.0	0.0081	0.0117	0.0056	0.0058

Table 5: Receiver (B) data analysis

Control_ID	N (m)	E (m)	H (m)	PDOP	HDOP	VDOP	HRMS	VRMS	NSTD	ESTD
GNSS	700442.300	791987.500	102.907	1.1	0.5	1.0	0.0102	0.0162	0.0077	0.0067
CP_1	700452.500	791952.800	102.803	1.1	0.5	1.0	0.0044	0.0076	0.0026	0.0035
CP_2	700417.600	791947.000	102.316	1.0	0.4	0.9	0.0041	0.0073	0.0027	0.0031
XUS92	700653.900	793004.000	105.471	1.1	0.5	1.0	0.0042	0.0079	0.0027	0.0032
UN_MOUMT	707940.000	788745.700	131.599	1.1	0.5	1.0	0.0066	0.0119	0.0048	0.0046
RAPH_UBN01	708198.900	789854.400	122.597	1.0	0.5	0.8	0.0061	0.0093	0.0045	0.0041
RAPH_UBN02	708294.400	789884.600	122.174	0.9	0.5	0.8	0.0062	0.0085	0.0040	0.0047
UNIBEN03	708420.900	789924.500	121.661	0.9	0.5	0.8	0.0063	0.0084	0.0041	0.0047
UNIBEN02	708540.600	789955.800	120.665	0.9	0.5	0.8	0.0067	0.0086	0.0044	0.0051
UNIBEN1	708507.100	789713.300	125.531	0.9	0.5	0.8	0.0073	0.0097	0.0048	0.0056
GPS100	708471.500	789478.200	128.845	1.0	0.5	0.8	0.0084	0.0119	0.0056	0.0062
GPS101	708462.600	789292.500	129.601	1.0	0.5	0.8	0.0086	0.0121	0.0061	0.0060
GPS102	708424.100	789041.500	130.058	1.0	0.5	0.9	0.0079	0.0112	0.0054	0.0058
CLASS A	708044.200	789399.400	128.762	1.1	0.6	1.0	0.0080	0.0137	0.0052	0.0060
CLASS B	708022.200	789463.000	128.917	1.2	0.6	1.0	0.0081	0.0117	0.0056	0.0058

Table 6: Differences in station information of receivers (A&B)

Control_ID	ΔN (m)	ΔE (m)	ΔH (m)	ΔPDOP	ΔHDOP	ΔVDOP	ΔVRMS	ΔHRMS	ΔNSTD	ΔESTD
GNSS	-0.019	-0.016	0.022	0.0	0.0	0.0	-0.0046	-0.008	-0.0034	-0.0032
CP_1	0.017	0.009	-0.002	0.0	0.0	0.0	-0.0002	0.000	-0.0001	-0.0001
CP_2	-0.042	0.050	-0.001	0.1	0.1	0.1	-0.0002	0.000	-0.0001	-0.0002
XUS92	-0.012	-0.037	-0.011	0.0	0.0	0.0	0.0001	0.000	0.0001	0.0000
UN_MOUMT	0.000	-0.038	-0.061	0.0	0.1	0.0	0.0020	0.001	0.0019	0.0009
RAPH_UBN01	-0.022	0.018	0.013	0.0	0.0	0.1	0.0027	0.005	0.0019	0.0019
RAPH_UBN02	-0.009	-0.021	-0.019	0.1	0.0	0.0	0.0015	0.004	0.0015	0.0006
UNIBEN03	-0.027	0.036	0.000	0.1	0.0	0.0	0.0019	0.004	0.0013	0.0015
UNIBEN02	0.039	0.050	0.018	0.0	0.0	0.0	0.0014	0.003	0.0010	0.0010
UNIBEN1	-0.003	-0.008	-0.019	0.0	0.0	0.0	0.0008	0.001	0.0007	0.0003
GPS100	-0.011	-0.029	0.017	0.0	0.0	0.0	0.0000	0.000	0.0000	0.0000
GPS101	0.017	0.032	0.029	0.0	0.0	0.0	0.0000	0.000	0.0000	0.0000
GPS102	-0.025	0.036	0.005	0.0	0.0	0.0	0.0000	0.000	0.0000	0.0000
CLASS A	0.031	0.007	-0.006	0.0	0.0	0.0	0.0000	0.000	0.0000	0.0000
CLASS B	0.019	0.022	0.001	0.0	0.0	0.0	0.0000	0.000	0.0000	0.0000

Table 7: Mean and standard deviation of the coordinates obtained with receivers (A&B)

GNSS Receiver	Mean (m)			Standard Deviation (m)		
	E	N	H	E	N	H
A	790242.954	706219.517	120.260	1257.808	3458.956	10.703
B	790242.947	706219.520	120.260	1257.811	3458.949	10.703
(+ve) Diff.	0.007	0.003	0.000	0.003	0.007	0.000

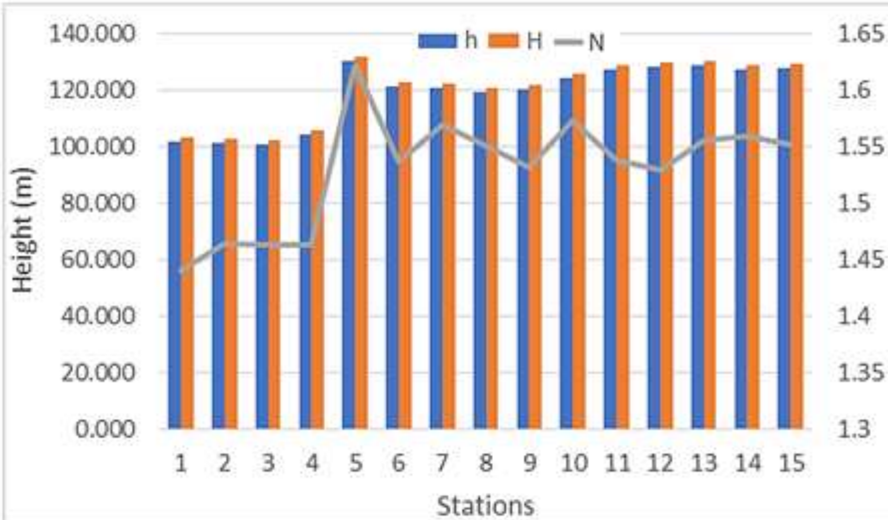

Fig 3: Geoidal separation with respect to height of controls

The highest separation of 1.622m was realised at UN_MOUMT station while GNSS station has the least recorded separation of 1.441m.

Conclusion: The delivery of geospatial data acquired using the two receivers from the same make on different controls at the same campaign time with respect to the newly installed CORS Geosystems has been successfully carried out. The results obtained showed that the CORS is reliable and we concluded that interested and prospective authorized users with at least one receiver component can adequately save cost by hooking-up to this virtual control. The CORS service, can provide coverage for user within 70km on RTK and more than 200km on Static.

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