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THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

Low-cost

Multiband GNSS receiver and their performance in accuracy

Analysis of geomagnetic storm effects on GNSS TEC during ascending phase of solar cycle 25

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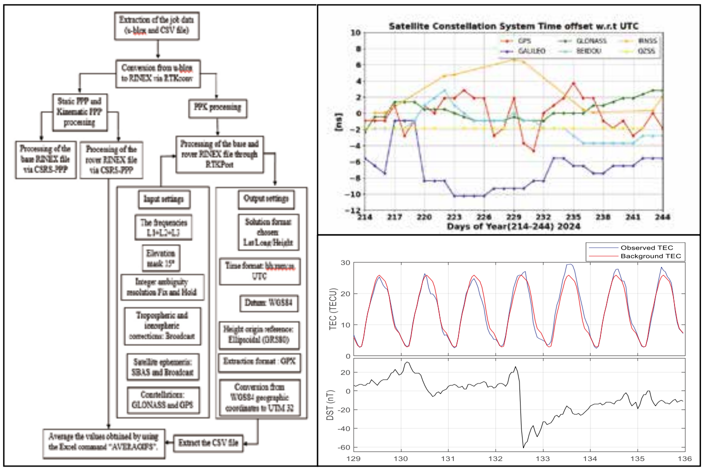

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The treaty provides a legal framework

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A landmark treaty.

Bal Krishna, Editor
bal@mycoordinates.org

Analysis of geomagnetic storm effects on GNSS TEC during ascending phase of solar cycle 25

A case study of (12 May, 17 April and 04 November 2021) geomagnetic storm at Abuja and Calabar Nigeria

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Abstract

This research was conducted in 2022, GNSS data were obtained in the Receiver Independent Exchange (RINEX) format. Retrieval analysis software developed by Gopi Seemela was utilized to extract vertical total electron content (vTEC) data, Disturbance Storm Time (DST) indices were employed for the purposes of storm detection and categorization. MATLAB was utilized to calculate the average TEC at hourly intervals. Additionally, the background diurnal TEC was determined by taking the median of the TEC values for 10-days period preceding and following the occurrence of storm events. By comparing the observed TEC to the background TEC, the response of TEC to the storm can be estimated. The results of this analysis show that during the May 12, 2021 geomagnetic storm event recorded in Abuja and Calabar stations. The maximum TEC recorded for Abuja station during the storm was 34 TECU, but the baseline TEC measurement was 28 TECU. Consequently, there was a 21.4% surge in TEC during the period; the peak value of the observed TEC during the storm was 29 TECU, while the corresponding background TEC value was 25 TECU, which gives a percentage increase of 20.8% during the time of the storm for Calabar station. Likewise, the storm event which occurred on November 04, 2021 recorded by Abuja station showed an increasing TEC value of 53 TECU, in contrast to the equivalent background value of 37 TECU. This suggests a percentage rise of approximately 43.2%. More also, the storm event which occurred on April 17, 2021 registered by Calabar station displayed a positive TEC response. The observed TEC was greater than the background TEC, especially after the storm peak time. In conclusion, the analysis of all the storm events recorded at Abuja and Calabar stations revealed significant TEC enhancement in comparison with the quiet days' condition in all the stations. The results of this work will provide useful data which may assist system operators or any application that relies on GNSS data for effective operation.

1. Introduction

"Geomagnetic storm" is one of the most frequent globally disruptions thus far. Regardless of the time of year, it happens anywhere on earth. A worldwide disruption of the earth's magnetic field is often referred to as a geomagnetic storm [1]. Solar radiation has a high density when it hits the atmosphere in the outer environment of the earth. The ionizing action of the sun's radiation on the earth's upper atmosphere produces free electrons, the number of which is sufficient above about 60 km to affect the propagation of electromagnetic waves. The distribution of high levels of radiation spans a spectrum that encompasses radio frequency, infrared radiation (IR), and X-ray. The plasma within the atmosphere's highly ionized zone, characterized by intense X-ray and UV radiation, consists of charged particles, namely electrons and ions. The number of free electrons along the ray path of one-meter-squared cross section that extends all the way up from the ground through the ionosphere is referred as total electron content (TEC) or the electron columnar number density. Its unit TECU, 1 TECU equals to1016 electrons per square meter. The earth's magnetic field experience perturbation due to the effects of geomagnetic storm which later cause changes in the ionospheric electron density and hence in ionospheric total electron content (TEC).

"Total electron content (TEC) is an important ionospheric parameter which can be used for many purposes, including the study of the ionosphere-plasmasphere system and Global Navigation Satellite Systems applications" [2]. "For example, one can get information about the ionization level of the ionosphere by measuring changes in the wave parameters when the signal transmitted by a satellite interacts with the ionospheric plasma" [3]. "On the other hand, it is known that TEC perturbations have a significant impact on satellite applications such as satellite navigation, communication, space weather forecasting, Global Positioning Systems (GPS) surveying, and remote sensing systems, which rely on an electromagnetic signal that interacts with ionospheric plasma when it passes through the ionosphere" [4,3,5].

"The strength of the geomagnetic storm is characterized by the minimum Disturbance storm-time (Dst) index and IMF-Bz" [6]. "Dst index is a quantitative measure of the energy injection into the ring current by the solar wind disturbance" [6]. "A typical geomagnetic storm usually consists of three major phases: storm sudden commencement (SSC) phase, which is characterized by an abrupt increment in Dst due to the compression of the magnetosphere by the shock wave hitting the Earth's environment; the s tor m m ain phase, which is characterized by the build-up of the intensified ring current by high energetic particle injection; storm recovery phase which normally takes a little longer than the main phase; the recovery phase, when Dst returns to its pre-storm values. Recovery phase can last for several days" [7].

Understanding how the Space Physics phenomenon known as Space Weather affects human technology has grown more and more important as mankind has become more and more reliant on it [8]. Because of the Sun's intense activity and the numerous unanticipated and unforeseen events that are occurring on its surface, we should be ready for the worst. The Sun's alterations have an impact on the Earth's surface, the atmosphere, and space. Most parts of space weather have some impact on us as our civilization becomes increasingly reliant on technology, and as space travel increases, so does the impact of space weather. The consequences it has on our daily lives on Earth are quite important. Dependence on technology has increased our vulnerability to bad space weather. In the past, only the most severe disruptions had an impact on technology; but, as our society now requires more advanced technology, this vulnerability may extend to less severe disturbances as well. Thus, there has been a lot of scientific interest in methods for forecasting space weather.

The interaction of the Earth's magnetic field with magnetized plasma ejected from the Sun, which happens when enormous amounts of energy are transferred to the magnetosphere, causes geomagnetic storms, which are widespread disturbances. Although geomagnetic storm effects vary depending on the characteristics of each event, some common effects to most storms include a dayside compression of the magnetosphere [9], enhancement of magnetospheric currents [9], depletion and enhancement of trapped particles in the radiation belts [10], increased precipitation in the auroral regions, global response and the rapid transfer of enormous amounts of energy to the Earth's magnetic field can also have significant effects on a variety of technological instruments, including damage and disruption to satellites and communication systems, jamming of radio signals, disruptions to the global positioning system, but they can also pose a threat to human exploration at high latitudes and high altitudes through increased radiation doses. "These events have the potential to cause technological disruptions, economic losses, and dangers to human life in the past and most likely in the future" [11]. The study of geomagnetic storm occurrence and their intensity over time is essential to improve our forecasting models and prevent or mitigate the risk associated with them.

Recent headlines such as "Space storms threaten technology", emphasizes how crucial it is to comprehend space weather phenomena.

Various researches on TEC response to geomagnetic activities has been carried out during the previous solar cycles, it will be necessary to also carry out a study analysis on geomagnetic storm effects on GNSS-TEC during this current solar cycle.

This research was carried out in 2022, which is a period at the ascending phase of solar cycle 25; it provides information on TEC response to geomagnetic activities over the selected locations.

1.1 The Study Area

Abuja currently serves as the political and administrative centre of Nigeria, functioning as the nation's capital city. The location of this area is situated inside the central region of Nigeria, specifically within the Federal Capital Territory (FCT). Abuja is situated at an elevation of 1,180 feet (360 metres) above sea level, encompassing an area of 2,824 square miles (7,315 square kilometres). Abuja is situated at a latitude of 9.0667ºN and a longitude of 7.4951ºE. Calabar serves as the administrative centre of Cross River State, which is located in Nigeria. The region encompasses a total area of 406 square kilometres. Calabar is situated at a geographical position defined by a latitude of 4.9757°N and a longitude of 8.3417°E.

2. Materials and methods

2.1 Materials

The materials employed in this investigation encompassed ground-based GNSS receivers situated inside the designated study area, a GNSS dataset, a DST dataset, version 3.0.3 of the Gopi programme, and the Matlab software.

2.2 Methods

The data collected from the TERONET was acquired in the Receiver Independent Exchange (RINEX) format. The RINEX specification encompasses three distinct file types, namely the Observation file, Navigation file, and meteorological data file. The contents of each file comprise of a header section that contains pertinent information regarding the station, receiver, and antenna, followed by a main body that contains the actual data.

The retrieval analysis software, namely version 3.03, developed by Gopi Seemala, was utilized to extract vertical total electron content (vTEC) data from the RINEX files. The software possesses the capability to perform batch processing on input files, such as rinex files. This includes the ability to process all files within a given month or year, as well as all files associated with various stations or located within a specified directory. The software retrieves ephemeris data from the International GNSS Service (IGS) navigation file. It possesses the capability to automatically download the navigation file when an internet connection is available, unless the file is already present in the same directory as the data. The Total Electron Content (TEC) can be determined by analyzing the observation data obtained from the Global Positioning System (GPS) Rinex. The algorithm detects and corrects cycle slips in phase data, retrieves satellite biases from the International GNSS Service (IGS) code files for Differential Code Bias (DCB), and if these biases are not readily accessible, it computes them. The receiver bias is computed, and the calculations are performed.

The presence of inter-channel biases among many satellites in the receiver is a noteworthy aspect to consider. The software visually displays the vertical Total Electron Content (TEC) values on the computer screen and generates ASCII output files (*.CMN and *.STD) in the directory where the data file is located.

The estimation of the Total Electron Content (TEC) is facilitated through the utilization of dual frequency GPS measurements. This parameter holds significant importance in the characterization of the ionosphere and serves as a crucial input for data assimilative models. The Slant Total Electron Content (STEC) refers to the quantification of the total quantity of unbound electrons along a vertical column of unit cross-sectional area along the trajectory of the electromagnetic wave connecting the satellite and the receiver. The quantity of unbound electrons is directly related to the discrepancy in ionospheric delay seen at the L1 frequency of 1575.42 MHz. The L2 (1227.60 MHz) signals were provided.

$$STEC = \int \frac{satelite}{receiver} Nds \qquad (2.1)$$

Where N is the electron density; 1 TECU Unit = 10^{16}electrons/m^2

The STEC is obtained from the dual frequency code measurements using the relation [12]:

$$STEC = \frac{1}{40.3} \times \{\frac{1}{l_1^2} - \frac{1}{l_2^2}\} \times (P1 - P2) + TEC_{cal} \qquad (2.2)$$

Where *P1* is the Pseudo range at *L1*; *P2* is the Pseudo range at *L2*, TECcal is the bias error correction. The measured STEC is corrected for the receiver differential delay TECCAL. The slant TEC is dependent on the ray path geometry through the ionosphere, an equivalent vertical value of TEC which is independent of the elevation of the ray path is calculated [12]. The Vertical TEC was obtained by taking the projection from the slant to vertical using the thin shell model assuming a height of 350 km, following the technique given by Klobuchar [13]:

$$VTEC = STEC \times \cos\left\{sin^{-1}\left(\frac{R_e cos}{R_e + h_{max}}\right)\right\} \qquad (2.3)$$

Where Re=6378 km, hmax=350 km, θ = elevation angle at the ground station

According to the findings of Rama Rao et al. [14], it was found that an Ionospheric Pierce Point (IPP) height of 350 km is applicable when the satellite elevation angle exceeds 50°. The data processing software utilized for the analysis of RINEX format data was developed by GOPI Krishna Samela, an esteemed researcher affiliated with the Institute for Scientific Research at Boston College in the United States [15,16].

Following the processing phase, the software generates data in various file forms. For the purpose of this study, the data was extracted in ' .std' file types. In order to mitigate problems commonly seen with low-elevation satellites, such as multipath and tropospheric errors, exclusively data from satellites with elevation angles exceeding 30 degrees was utilized.

MATLAB is a programming language and computational environment that is proprietary and encompasses multiple paradigms. It has been developed by MathWorks, a company specializing in numerical computing. The MATLAB software platform provides users with the ability to perform various operations on matrices, generate visual representations of functions and data, execute algorithms, develop user interfaces, and establish connections with programmes developed in different programming languages. In this study, the software MATLAB was utilized to calculate the average Total Electron Content

(TEC) at hourly intervals. Additionally, the background diurnal TEC was determined by taking the median of the TEC values for the 10-hour period preceding and following the occurrence of storm events. Finally, the graph depicting the background Total Electron Content (TEC) in conjunction with the observed TEC was generated using MATLAB. To examine the impact of individual geomagnetic storms on GNSS TEC, we analyzed data spanning a duration of 10 days prior to and 10 days following each storm. To assess the extent of the TEC's reactions to individual geomagnetic storms, the median values of the diurnal TEC profiles were calculated for the ten days preceding and following the storm. These medians were then considered as the background TEC for subsequent analysis. The background total electron content (TEC) is calculated to model the anticipated TEC pattern during the period of low solar activity surrounding the occurrence of the storm event. By comparing the observed total electron content (TEC) to the background TEC, one can estimate the response of TEC to the storm. Fig. 1 depicts the various stages and methodologies employed, together with the software utilized for data analysis in the present study.

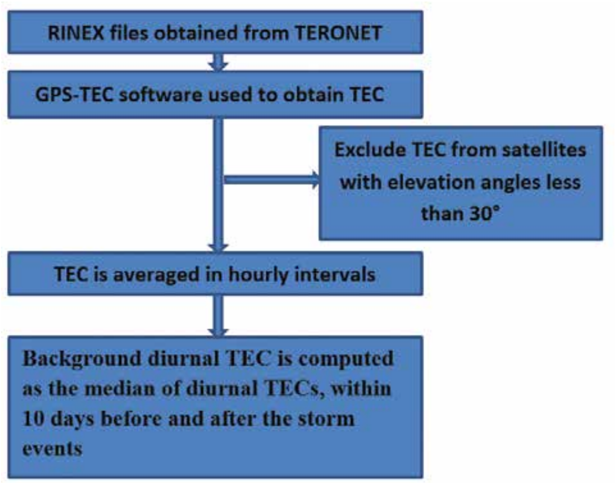

Fig. 1. Flow chart of data processing

3. Results and discussion

The results of the study are presented in Figs. 2- 5

The results presented are discussed below;

Fig. 2 depicts the temporal variation of the Total Electron Content (TEC) in response to the geomagnetic storm that occurred on May 12, 2021 (day 132 of the year) at the Abuja station. The visual representation includes plots depicting the measured Total Electron Content (TEC) in blue and the background TEC in red. These plots are accompanied by equivalent measurements of the Disturbance storm time (Dst) magnitudes, both during and in the vicinity of the storm period.

Fig. 2 displays the observed and background Total Electron Content (TEC) values during and in the vicinity of the geomagnetic storm occurrence on May 12, 2021 (Day number 132). The observed Total Electron Content (TEC) is represented by the blue line, while the background TEC is represented by the red line. The lower panel displays the relevant Dst indices.

According to the data presented in Fig. 2, the primary phase of the geomagnetic storm event took place at approximately 15:00 UT. During this phase, there was a significant decline in the Dst index value from approximately 25 nT to -61 nT. Subsequently, the storm entered a gradual recovery phase, characterized by several hours of increasing Dst index values, eventually reaching -10 nT, as illustrated in the Dst curve. The presence of a positive total electron content (TEC) response may be shown in Fig. 2 for this particular storm. The measured total electron content (TEC) exhibits an increase compared to the baseline TEC, commencing several hours subsequent to the culmination of the storm on the 133rd day of the calendar year. The impact of the storm on the Total Electron Content (TEC) was notably favorable, as evidenced by a substantial disparity between the recorded TEC

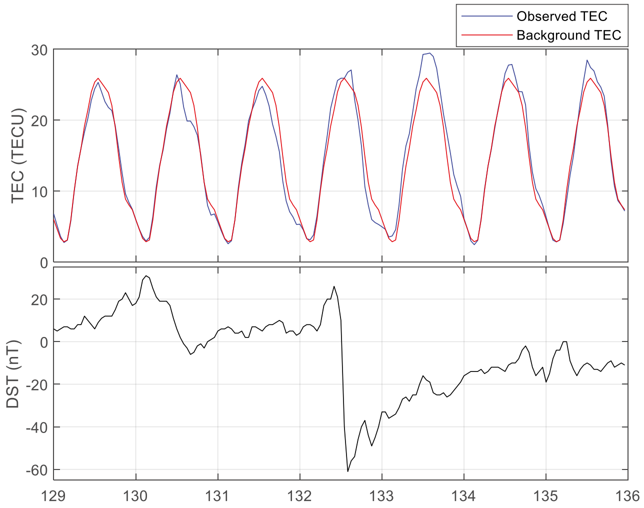

Fig. 2. Observation for Abuja May 12, 2021 geomagnetic storm event

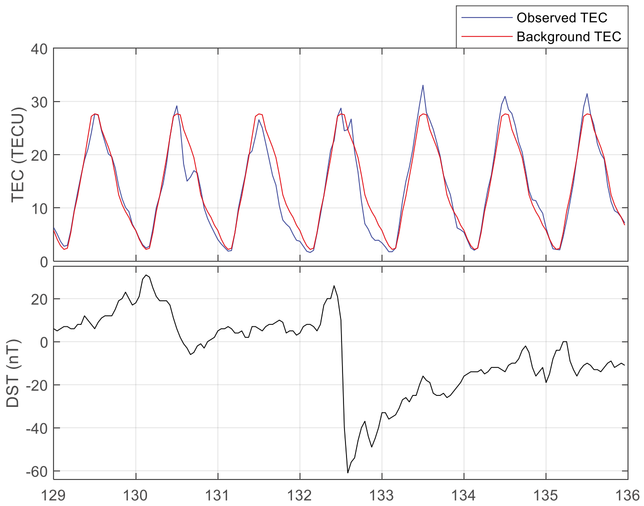

Fig. 3. Observation for Calabar May 12, 2021 geomagnetic storm event

and the background TEC, particularly during the mid-day period following the peak of the storm. The maximum measured Total Electron Content (TEC) during the storm is 29 TECU, but the accompanying baseline TEC value is 25 TECU, resulting in a percentage increase of 20.8% during this period. According to a research conducted by Daniel and Samuel (2013) to study Total Electron Content (TEC) variation over Abuja using GNSS data obtained from the NIGNET (Nigeria GNSS Reference Network) for the OSGF (Office of the Surveyor General of the Federation) station located in Abuja (Geographic: 7.49 °E, 9.03 °N, altitude 533.60 m; Geomagnetic: 79.49 °E, 1.60 °S), in the months of May-July the peak TEC value are the range of 40-55 TECU, while the minima are in the range of 2.1-3.0 TECU. It can be seen in Fig. 2, the daytime measured Total Electron Content (TEC) levels were comparable to the equivalent background values before the occurrence of the storm event. However, commencing from the day subsequent to the culmination of the storm (during the phase of recuperation from the storm), the values measured during daylight hours surpass the comparable background levels.

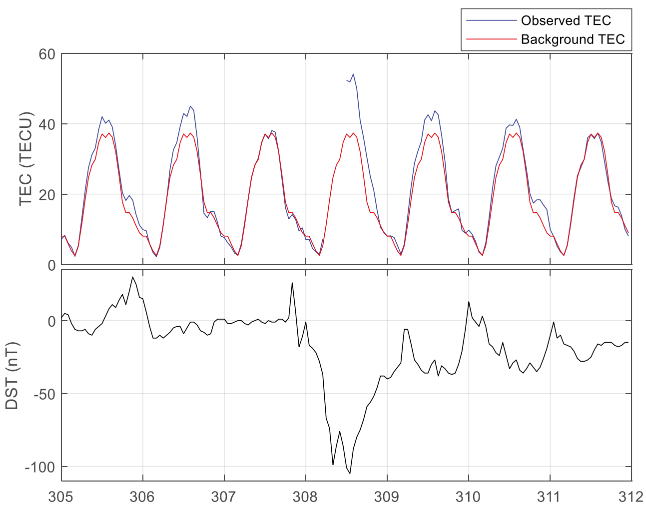

Fig. 4. Observation for Abuja November 04, 2021 geomagnetic storm event

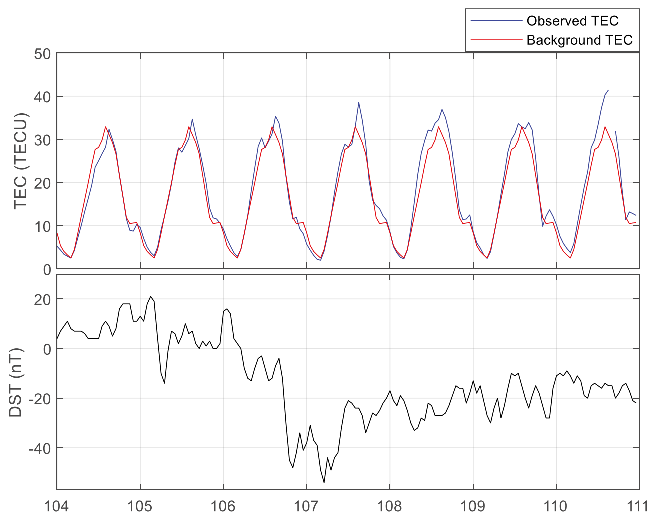

Fig. 5. Observation for Calabar April 17, 2021 geomagnetic storm event

There is a noticeable decrease in the disparity between the diurnal observed values and their matching background values subsequent to day 133.

Fig. 3 depicts the TEC response to the geomagnetic storm that occurred on May 12, 2021 (day 132 of 2021), specifically at the Calabar station, in a manner akin to the presentation in Fig. 2.

Fig. 3 The top panel displays the observed and background Total Electron Content (TEC) values during and in the vicinity of the geomagnetic storm occurrence on May 12, 2021 (Day 132). The observed total electron content (TEC) is represented by the blue line, while the background TEC is represented by the red line. The lower panel displays the relevant Dst indices.

In a manner similar to the Abuja station, as depicted in Fig. 2, the Calabar station, illustrated in Fig. 3, reveals a favorable Total Electron Content (TEC) reaction to the aforementioned storm. The data shown in Figs. 2 and 3 indicate that comparable storm patterns are detected at both sites. The measured total electron content (TEC) exhibits an increase relative to the baseline TEC, commencing a few hours subsequent to the culmination of the storm on the 133rd day of the calendar year. The impact of the storm on the Total Electron Content (TEC) was found to be notably favorable, as evidenced by a substantial disparity between the recorded TEC and the background TEC, particularly during the mid-day period following the peak of the storm. The maximum Total Electron Content (TEC) recorded during the storm is 34 TECU, but the baseline TEC measurement stands at 28 TECU. Consequently, there is a 21.4% surge in TEC during this period. In a study conducted by Akinyemi *et al*., 2011 to determine the response of the Equatorial Ionesphere to a geomagnetic storm that occurred on 25 October, 2011, the storm caused enhancements in the TEC (positive storm effect) in comparison with the quiet condition's TEC across Calabar station during both main and the recovery phases. During the storm of October 25, recorded peak enhancement in TEC was 14.8 %. Ikani and Oladipo 2018 conducted a research to estimate TEC gradient over Nigeria using GPS data for the year 2014 from seven out of fourteen operational NIGNET stations in Nigeria found between geomagnetic latitudes -4.33 and 0.72ºN, the results obtained show diurnal variation in TEC gradient values with the minimum values of TEC gradient recorded between 05:00 and 07:00 UT (~0.11-0.012 TECU) while the maximum values were observed between 14:00 and 16:00 UT (~0.54-0.55 TECU). According to Fig. 3, the daytime measured Total Electron Content (TEC) levels were comparable to the equivalent background values before the occurrence of the storm event. However, commencing from the day subsequent to the culmination of the storm (during the phase of recuperation following the storm), the values seen during daylight hours surpass the comparable values in the background. After day number 133, there is a decrease in the disparity between the measured values during the day and the matching background values.

Fig. 4 depicts the temporal variation of Total Electron Content (TEC) in reaction to the geomagnetic storm that occurred on

November 4, 2021, which corresponds to day 308 of the year 2021. The provided data includes graphical representations of the observed Total Electron Content (TEC), denoted by the color blue, as well as the remaining plot.

The background of the TEC (Total Electron Content) parameter, represented in red, is presented in conjunction with the relevant Dst (Disturbance storm time) magnitudes observed during and in the vicinity of the storm period.

Fig. 4 The top panel displays the observed and background Total Electron Content (TEC) values during and in the vicinity of the geomagnetic storm occurrence on November 04, 2021. The observed TEC is represented by the blue line, while the red line represents the background TEC. The lower panel displays the relevant Dst indices.

According to the data presented in Fig. 4 the primary phase of the geomagnetic storm event took place at approximately 14:00 UT. During this period, there was a significant decline in the Dst index value, dropping from approximately 0 to just below -100 nT. Consequently, the storm is categorized as a robust geomagnetic storm occurrence. The storm underwent a protracted recovery period, characterized by multiple hours during which the disturbance storm time (Dst) index returned to approximately 0 nanoteslas (nT), as indicated by the Dst curve. As illustrated in Fig. 4, a predominantly positive total electron content (TEC) response is observed for this particular storm. Fig. 4 illustrates a temporal interval of approximately 10 hours in the Global Navigation Satellite System (GNSS) data at the onset of the geomagnetic storm. The cause of this data gap remains uncertain; nevertheless, it is plausible that it may be associated with the occurrence of GNSS signal disruptions caused by ionospheric irregularities created by the storm. Upon the resumption of GNSS data recording, the observations reveal a substantial increase in Total Electron Content (TEC) during midday, particularly in close proximity to the peak time of the storm. This increase is quite notable, reaching a value of 53 TECU, in contrast to the equivalent background value of 37 TECU. This suggests a percentage rise of approximately 43.2%. According to a research conducted by Daniel and Samuel (2013) to study Total Electron Content (TEC) variation over Abuja using GNSS data obtained from the NIGNET (Nigeria GNSS Reference Network) for the OSGF (Office of the Surveyor General of the Federation) station located in Abuja (Geographic: 7.49 °E, 9.03 °N, altitude 533.60 m; Geomagnetic: 79.49 °E, 1.60 °S), in the months of November and December the peak TEC value are the range of 56-58 TECU while the minima are the range of 2.5-3.5 TECU. It is observed from the results of Daniel and Samuel research that the VTEC values are relatively higher during the equinox’s months (March, April, August, September and October). This is expected since the sun (primary source of ionospheric ionization) is overhead the equatorial region (where the OSGF station used in their work is located) at this season.

Fig. 5 depicts the temporal variation of Total Electron Content (TEC) in reaction to the geomagnetic storm that occurred on April 17, 2021, which corresponds to the 107th day of the year 2021. The visual representation includes plots depicting the observed Total Electron Content (TEC) in blue and the background TEC in red, accompanied by the corresponding magnitudes of the Disturbance storm time (Dst) during and in the vicinity of the storm phase.

Fig. 5 The top panel displays the observed and background Total Electron Content (TEC) values during and in the vicinity of the geomagnetic storm occurrence on April 17, 2021. In this representation, the observed TEC is depicted by the blue line, while the red line represents the background TEC. The lower panel displays the relevant Dst indices.

According to the data presented in Fig. 5, the primary phase of the geomagnetic storm event took place at around 06:00 UT. During this period, there was a significant decline in the Dst index value, dropping from approximately -5 nT to -57 nT. This decline was followed by a steady recovery phase that extended over several hours, as depicted in the Dst curve. Additionally, it is worth mentioning that a positive Total Electron Content (TEC) reaction has been observed in relation to this storm. The measured total electron content (TEC) exhibits a higher value compared to the baseline TEC, particularly during the culmination of the storm event. A comparative study of Nigeria GNSS reference Network’s-Global Positioning System (NIGNET’s- GPS) vertical Total Electron Content (vTEC) measurements with the International Reference Ionosphere-Total Electron Content (IRI-TEC) predictions over Calabar Nigeria was carried out by Joseph et al., 2018,the results obtained show high hourly and diurnal correlation of about 0.9 with the IRI-TEC predictions for the days examined; thus supporting the viability of the receiver as a vTEC measuring device.

4. Conclusion

This paper has used storm that occurred on same day (12 May, 2021) at two stations (Abuja and Calabar) and also two storms (04 November, 2021 and 17 April, 2021) at two stations (Abuja and Calabar) as a case study to investigate and analyze geomagnetic storm effects on GNSS TEC during the ascending phase of solar cycle 25 across two stations in Nigeria. The storm event analysis revealed significant TEC enhancement in comparison with the quiet days’ condition in all the stations. The results of this work will provide useful data which may assist system operators.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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Competing Interests

Authors have declared that no competing interests exist.

References

1. Alberti T, Faranda D, Consolini G, De Michelis P, Donner RV, Carbone V. Concurrent effects between geomagnetic storms and Magnetospheric Substorms. Universe. 2022;8(4):226-230.

2. Stankov S, Stegen K, Warnant R. Seasonal variations of storm-time TEC at European middle latitudes, Adv. Space Res. 2010;46(10):1318–1325.

3. Jakowski N, Borries C, Wilken V, Introducing a disturbance ionosphere index (DIX),Radio Sci. 2012. DOI: 10.1029/2011RS004939

4. Habarulema JB, McKinnell L-A, Opperman BD. Towards a GPS-based TECprediction model for Southern Africa with feed forward networks, Adv. Space Res. 2009;44(1):82–92.

5. Borries C, Berdermann J, Jakowski N, Wilken V. Ionospheric storms—A challenge for empirical forecast of the total electron content, J. Geophys. Res. Space Physics. 2015;120:3175–3186.DOI: 10.1002/2015JA020988

6. Gonzalez W, Joselyn J, Kamide Y, Kroehl H, Rostoker G, Tsurutani B, Vasyliunas V. What is a geomagnetic storm? J. Geophys. Res. 1994;99:5771–5792. Abailable:https://doi.org/10.1029/93JA02867

7. Tsurutani BT, The interplanetary causes of magnetic storms, substorms andgeomagnetic quiet, in Space Storms and Space Weather Hazards, Daglis, I.A., Ed., Dordrecht: Kluwer. 2001;103–130.

8. Aragaw M, Gebiregiorgis A, Tsegaye K. Solar activity and geomagnetic storm effects on GPS ionospheric TEC over Ethiopia. Momona Ethiopian Journal of Science. 2019;11(2):276-300.

9. Reyes PI, Pinto VA, Moya PS. Geomagnetic storm occurrence and their relation with solar cycle phases. Space Weather. 2021;19(9):741-749.

10. Pandya M, Bhaskara V, Ebihara Y, Kanekal SG, Baker DN. Variation of radiation belt electron flux during CME-and CIR-driven geomagnetic storms: Van Allen Probes observations. Journal of Geophysical Research: Space Physics. 2019;124(8):6524-6540.

11. Worman S, Taylor S, Onsager T, Adkins J, Baker DN, Forbes KF. The social and economic impacts of moderate and severe space weather. In Extreme Events in Geospace. 2018;13(8):701-710.
Abioye A, Atanda PO, Majolagbe SB, Isadare DA, Abioye OP, Akinluwade KJ, Adetunji AR. Material selection for gas turbine blade coating using GRANTA material selector. Advances in Research. 2015;5(1):1-9. Abailable:https://doi.org/10.9734/AIR/2015/15769
Onwuzuruike B, Jessica A, Maruf A. Aminu. Experimental determination of panel generation factor for apo area of federal capital territory in Nigeria. Journal of Scientific Research and Reports. 2019;24(3):1-5. Abailable:https://doi.org/10.9734/jsrr/2019/v24i330157

12. Bagiya MS, Joshi HP, Lyer KN, Aggarwal M, Ravindran S, Pathan BM. TEC variations during low solar activity period (2005-2007) near the equatorial ionospheric anomaly crest region in India. In Annales Geophysicae. 2009;27(3):1047-1057. Copernicus GmbH

13. Klobuchar JA. Design and characteristics of the GPS ionospheric time delay algorithm for single frequency users. In PLANS'86–Position Location and Navigation Symposium. 1986;1:280-286

14. Rama Rao, Niranja, K., Gopi Krishna, S., and Uma, G. On the validity of ionospheric pierce point (IPP) altitude of 350km in the indian equatorial and low-latitude sector. In Annales Geophysicae. 2006, September ;24(8):2159-2168.

15. Labitzke K. On the solar cycle–QBO relationship: A summary. Journal of Atmospheric and Solar-Terrestrial Physics. 2005 Jan 1;67(1-2):45-54.

16. Hathaway DH. The solar cycle. Living reviews in solar physics. 2015 Dec;12(1):4.

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GNSS Constellation Specific Monthly Analysis Summary: August 2024

The analysis performed in this report is solely his work and own opinion. State Program: U.S.A (G); EU (E); China (C) "Only MEO- SECM satellites"; Russia (R); Japan (J); India (I)

Narayan Dhital
Actively involved to support international collaboration in GNSS-related activities. He has regularly supported and contributed to different workshops of the International Committee on GNSS (ICG), and the United Nations Office for Outer Space Affairs (UNOOSA). As a professional employee, the author is working as GNSS expert at the Galileo Control Center, DLR GfR mbH, Germany.

Introduction

The article is a continuation of monthly performance analysis of the GNSS constellation. Please refer to previous issues for past analysis. The two new Galileo satellites (GSAT0225-PRN E29) and GSAT0227-PRN E06) which are declared operational and usable from 05 September, 2024 will be analyzed in the coming issues.

Analyzed Parameters for August, 2024

(Dhital et. al, 2024) provides a brief overview of the necessity and applicability of monitoring the satellite clock and orbit parameters.

a. Satellite Broadcast Accuracy, measured in terms of **Signal-In-Space Range Error (SISRE) (Montenbruck et. al, 2010).**

b. SISRE-Orbit (only orbit impact on the range error), SISRE (both orbit and clock impact), and **SISRE-PPP** (as seen by the users of carrier phase signals, where the ambiguities absorb the unmodelled biases related to satellite clock and orbit estimations. Satellite specific clock bias is removed) **(Hauschlid et.al, 2020)**

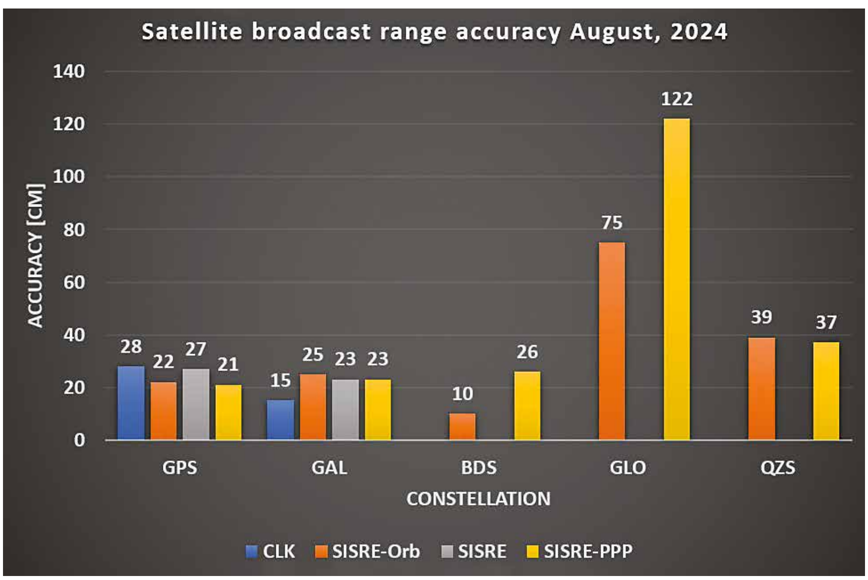
c. Clock Discontinuity: The jump in the satellite clock offset between two consecutive batches of data uploads from the ground mission segment. It is indicative of the quality of the satellite atomic clock and associated clock model.

d. URA: User Range Accuracy as an indicator of the confidence on the accuracy of satellite ephemeris. It is mostly used in the integrity computation of RAIM.

e. GNSS-UTC offset: It shows stability of the timekeeping of each constellation w.r.t the UTC

Note:- for India's IRNSS there are no precise satellite clocks and orbits as they broadcast only 1 frequency which does not allow the dual frequency combination required in precise clock and orbit estimation; as such, only URA and Clock Discontinuity is analyzed.

(a), (b) Satellite Clock and Orbit Accuracy (monthly RMS values)



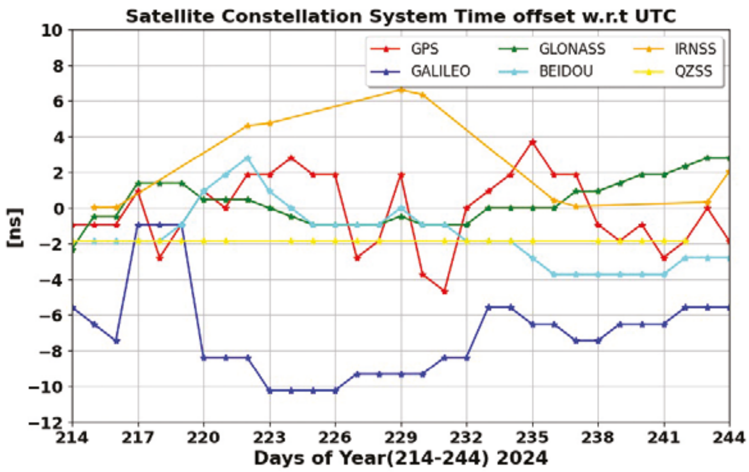
(c) Satellite Clock Jump per Mission Segment Upload

Const	Mean [ns]	Max [ns]	95_Percentile [ns]	99_Percentile [ns]	Remark (Best and Worst 95 %)
IRNSS	5.38	624.68	7.64	41.35	Best I02 (4.47 ns) Worst I06 (25.02 ns) I03 is not there in BRDC
GPS	0.39	32.28	0.86	2.09	Best G04 (0.46 ns) Worst G03 (2.34 ns) No large jumps
GAL	0.08	5.30	0.17	0.42	Best E02 (0.15 ns) Worst E26 (0.21 ns) Note: E14 and E18 are excluded

(d) User Range Accuracy (Number of Occurrences in Broadcast Data 01-31 August)

IRNSS-SAT	2 [m]	2.8 [m]	4.0 [m]	5.7 [m]	8 [m]	8192 [m]	9999.9	Remark Other URA values (frequency)
I02	5935	73	5	-	2	7	-	11.3 (1)
I03	-	-	-	-	-	-	-	-
I06	1357	8	2	-	7	-	4	32 (1) 11.3 (1)
I09	1190	8	2	1	2	-	-	16 (1)
I10	1134	6	3	-	3	3	-	-

(e) GNSS-UTC Offset



Monthly Performance Remarks:

1. Satellite Clock and Orbit Accuracy:
   - For GPS and Galileo, the performance looked similar to the past months.
   - For GLONASS, the overall performance seems to have improved in terms of orbits and clocks.
   - For BDS and QZSS, the performance looks very much the same as in the past.
   - For IRNSS, the notable difference in this month's performance is the omission of I03 satellite. There is no broadcast record for I03. It is also noticeable that the number of broadcast messages for other satellites have increased significantly.

2. UTC Prediction (GNSS-UTC):
   - Galileo shows higher uncertainty in comparison to previous months

References

Alonso M, Sanz J, Juan J, Garcia, A, Casado G (2020) Galileo Broadcast Ephemeris and Clock Errors Analysis: 1 January 2017 to 31 July 2020, MDPI

Alonso M (2022) Galileo Broadcast Ephemeris and Clock Errors, and Observed Fault Probabilities for ARAIM, Ph.D Thesis, UPC

Cao X, Zhang S, Kuang K, Liu T (2018) The impact of eclipsing GNSS satellites on the precise point positioning, Remote Sensing 10(1):94

Dhital N (2024) GNSS constellation specific monthly analysis summary, Coordinates, Vol XX, Issue 1, 2, 3, 4

Hauschlid A, Montenbruck O (2020) Precise real-time navigation of LEO satellites using GNSS broadcast ephemerides, ION

Guo F, Zhang X, Wang J (2015) Timing group delay and differential code bias corrections for BeiDou positioning, J Geod,

IERS C04 (2024) https://hpiers.obspm.fr/iers/eop/eopc04/eopc04.1962-now

IGS (2021) RINEX Version 4.00 https://files.igs.org/pub/data/format/rinex_4.00.pdf

Li M, Wang Y, Li W (2023) performance evaluation of real-time orbit determination for LUTAN-01B satellite using broadcast earth orientation parameters and multi-GNSS combination, GPS Solutions, Vol 28, article number 52

Li W, Chen G (2023) Evaluation of GPS and BDS-3 broadcast earth rotation parameters: a contribution to the ephemeris rotation error Montenbruck O, Steigenberger P, Hauschlid A (2014) Broadcast versus precise ephemerides: a multi-GNSS perspective, GPS Solutions

Liu T, Chen H, Jiang Weiping (2022) Assessing the exchanging satellite attitude quaternions from CNES/CLS and their application in the deep eclipse season, GPS Solutions 26(1)

Montenbruck O, Steigenberger P, Hauschlid A (2014) Broadcast versus precise ephemerides: a multi-GNSS perspective, GPS Solutions

Montenbruck O, Hauschlid A (2014 a) Differential Code Bias Estimation using Multi-GNSS Observations and Global Ionosphere Maps, ION

Steigenberger P, Montenbruck O, Bradke M, Ramatschi M (2022) Evaluation of earth rotation parameters from modernized GNSS navigation messages, GPS Solutions 26(2)

Sylvain L, Banville S, Geng J, Strasser S (2021) Exchanging satellite attitude quaternions for improved GNSS data processing consistency, Vol 68, Issue 6, pages 2441-2452

Walter T, Blanch J, Gunning K (2019) Standards for ARAIM ISM Data Analysis, ION

Wang N, Li Z, Montenbruck O, Tang C (2019) Quality assessment of GPS, Galileo and BeiDou-2/3 satellite broadcast group delays, Advances in Space Research

Note: References in this list might also include references provided to previous issues.

Data sources:

https://cddis.nasa.gov (Daily BRDC); http://ftp.aiub.unibe.ch/CODE_MGEX/CODE/ (Precise Products); BKG “SSRC00BKG” stream; IERS C04 ERP files

(The monitoring is based on following signals- GPS: LNAV, GAL: FNAV, BDS: CNAV-1, QZSS:LNAV IRNSS:LNAV GLO:LNAV (FDMA))

Galileo is prepared for the upcoming operational declaration of OSNMA

The European Union Agency for the Space Programme (EUSPA) has successfully completed testing of the Galileo Open Service Navigation Message Authentication (OSNMA) and is preparing for its operational launch.

Galileo, like other Global Navigation Satellite Systems (GNSS), plays a crucial role in various sectors, including transportation, finance, telecommunications, etc. However, the increase in spoofing attacks that can disrupt these services has led to the development of OSNMA. Implemented by EUSPA in collaboration with the European Commission (EC) and the European Space Agency (ESA), it aims to enhance the security of GNSS signals.

The OSNMA Public Observation phase began in November 2021, marked by the release of the Signal in Space Interface Control Document (SIS ICD) and Receiver Guidelines, which enabled early testing of OSNMA receivers globally. Since then, users have reported high stability and performance of the OSNMA signal transmitted by Galileo satellites.

In December 2022, EUSPA and the EC published the OSNMA SIS ICD and Receiver Guidelines for the service phase, with further updates provided between October 2023 and January 2024. Additionally, the OSNMA Internet Data Distribution (IDD) ICD was released in July 2023 and updated in January 2024, alongside the operational cryptographic material. The OSNMA signal has been transmitted in accordance with these specifications since August 2023.

EUSPA reports that testing by industry and public entities has confirmed the service’s readiness, with the latest cryptographic material published in January 2024. This material and the necessary certificates are accessible through the EUSPA and GSC websites for the Initial Service provision phase.

Testing activities wrapped up in early June 2024, which included the execution of cryptographic keychain renewal and revocation processes. The program is now poised to declare the OSNMA Initial Service, which will involve an EC communication, the release of the OSNMA Service Definition Document (SDD), and the transition of the OSNMA Status Flag from “test” to “operational.” This process mirrors the approach used for the Galileo High Accuracy Service (HAS) Declaration in 2023. *www.euspa.europa.eu*

Beidou navigation service platform begins trial operations

China’s national Beidou high-precision navigation and positioning service platform has entered trial operation, marking a significant advancement in the country’s satellite navigation capabilities. This initiative brings together over 3,300 base stations into a unified network, enabling centralized management of resources. The network provides seamless, high-precision positioning services nationwide, delivering real-time, accurate, and reliable navigation for various sectors. The service operates both online and offline. regional.*chinadaily.com.cn*

New Galileo satellites operational

The two new Galileo satellites launched in April have entered service, completing the second of three constellation planes. Three months after their launch from Cape Canaveral, Galileo satellites 29 and 30 have reached their target positions at an altitude of 23 222 km, where they have been fully tested and declared operational.

Both satellites have been deployed on the same orbital plane, one of the three that make up the Galileo constellation. Now two of the three Galileo orbital planes are fully populated, bringing the constellation one launch away from completion. The two new satellites are active and providing navigation signals to users. Their addition to the constellation slightly increases the accuracy of the system and further guarantees the availability and robustness of Galileo signals. *www.esa.int*

Low-cost multiband GNSS receiver and their performance in accuracy

This study aim is to investigate the possibility to used low cost GNSS receiver in the place of those costly one, by appreciating the time of processing data and the coordinates

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Abstract

The high cost of modern GNSS (Global Navigation Satellite System) receiver and their post processing software present an obstacle in the surveyed laboratories for poor countries. This study aim is to investigate the possibility to used low cost GNSS receiver in the place of those costly one, by appreciating the time of processing data and the coordinates to converge under 50 seconds, then model the errors between those two instruments before evaluating their accuracy. The materials used were the one of reading, and observation of data, the order for the processing of data. The method consisted to carry out data by the static PPP (Precise Point Positioning) and the dynamic method (Kinematic PPP) and PPK (Post Processed Kinematic) of 10 benchmarks SEPRET (Société d'Etude des Projets et de Réalisations des Travaux) pilars through two multiband GNSS receivers Emlid Reach RS2.

The results shows that the differences between the readings data in static PPP, PPK and kinematic PPP mode is small and they are respectively within the ranges [20.3cm-24cm], [7.5cm-30.4cm] and [-9.3cm-22.8cm] along the X-axis, [17.8cm-22cm], [14.8cm-25.2cm] and [11.4cm-29cm] along the Y-axis and [5.3cm-6.1cm], [-16.5cm-0.8cm] and [-55.2cm-9.6cm] along the Z-axis which are around the centimetre. Then the error model per axis is $\boldsymbol{\beta 1x6 + \beta 2x5 + \beta 3x4 + \beta 4x3 + \beta 5x2 + \beta 6x + \beta 1}$ and the accuracy model is a linear function W(x) = Ax+B showing the very closeness coordinates values between the two types of instruments.

1. Introduction

The Global Navigation Satellite System (GNSS) has been widely used for many years because it provides precise positioning (Omer F. et al., 2021). Also has been used for various navigation (air, water, road transport, earth observation, weather forecasting timing and national coordinate systems) and monitoring engineering structures, naturals hazards, surveying and others purposes (Tsakiri, M., et al., 2017; Lipatnikov, L., et al., 2019; Leick, A., et al., 2015; Teunissen, P.J.G., et al 2017; Guo, L., et al., 2017; Biagi, L., et al., 2016; Wang, S., et al., 2022).

Traditionally, they were obtaining positioning with GNSS using at least two receivers. The collected data were processed for highly accurate positioning by using the GNSS data processing software (Muchammad M., 2020). Those GNSS use Differential methods for high accuracy through with high cost. Nowadays, Precise Point Positioning (PPP) is an enhanced single GNSS receiver user with a point positioning technique for code or phase measurements using precise orbits and clocks to adjust ionospheric effects in dual frequency Measurements by an ionosphere free combination (Ashraf F., 2018). But because of its low cost and large number of users, PPP takes the spotlight (Amr H. et al., 2017; Semler, Q., et al., 2019; Krietemeyer, A., et al., 2020; Hamza, V., et al., 2021; Romero-Andrade, R., et al., 2021; Hamza, V., 2020; Hamza, V., et al., 2021; Broekman, A., et al., 2021; Tunini, L., et al., 2020; Samboko, H. T., et al., 2022; Janos, D., et al., 2021; Läpädat, A.M., et al., 2021).

The Canadian Spatial Reference System (CSRS) Precise Point Positioning (PPP) service provides post-processed position estimates over the Internet from GPS observation files submitted by the user. Precise position estimates are referred to the CSRS standard North American Datum of 1983 (NAD83) or the International Terrestrial Reference Frame (ITRF). Single station position estimates are computed for users operating in static or kinematic modes using precise GPS orbits and clocks. The online PPP positioning service is designed to minimize user interaction while providing the best possible solution for the given observation availability. Currently, users need only to specify the mode of processing (static or kinematic) and the reference frame for position output (NAD83 (CSRS) or ITRF). The observations processes are selected from the submitted RINEX (Receiver Independent Exchange) file in the following order:

- L1 and L2 pseudo-range and carrier phase observations
- L1 pseudo-range observation An L1 pseudo-range only solution will be performed in case of failure of the L1 and L2 pseudo-range and carrier phase solution (Ashraf Farah, 2013).

RTKLib (Real Time Kinematic library) is an open-source program package for multi-GNSS positioning software developed by Tomoji Takasu from the Tokyo University of Marine Science and Technology in Japan. RTKLIB can process collected data with standard and precise positioning techniques by using different satellite constellations, GPS, GLONASS, Galileo, QZSS, BeiDou and SBAS. It supports many positioning modes including DGPS/DGNSS, Kinematic, Static, Moving-Baseline, PPP-Kinematic, PPP-Static and PPP-Fixed modes (Ibrahim M., 2018).

The online service that will be used in the case of this study is CSRS-PPP because of its low-cost and it is the most precise free online service. The CSRS-PPP is taking into consideration only the GPS and GLONASS constellations due to the fact that the others constellations are not yet considered to be very stable.

RTKLIB software will equally be used in this study to convert our raw logs to RINEX format as it provides good and acceptable results and is equally free software.

At the societal level, this work will help the Ministry of State Property, Surveys and Land Tenure, the Ministry of Housing and Urban Development, and the Ministry of Public Works to take better decision in the georeferentiations of the parcels of lands in the process of obtaining land certificates and equally in the georeferentiation of public work projects. This work will equally facilitate developing countries in the process of equipping their research laboratories since they don't have sufficient finance to buy high-cost equipment. Also, the work elaborates on the resolution that can be obtained in the realization of the digital elevation model useful during the hydrologic and hydraulic modelling in the Tongo Bassa watershed.

From a scientific view, this work will give idea on the influence of accuracy and the duration of observations on the convergence behaviour using a multiband GNSS receiver with three common positioning techniques: static PPP, PPK mode and kinematic PPP in the equatorial zone of the earth globe. It will also:

Determine the required duration of readings to reach the convergence by employing the three different techniques and also give the relationship that exists between them in the equatorial zone using a low cost multiband GNSS receiver.

Draw the diagram of uncertainties (sigma 95%) in function of the observation lengths over the latitude, the longitude and the ellipsoidal height in static PPP;
Study the average, the minimum, the maximum and the standard deviation of the uncertainties in static PPP over the three axes;
Study the coordinates' behaviour of the PPK and the Kinematic PPP techniques in function of the observation duration;
Study the difference between the three observation technique coordinates and the benchmarks coordinates over the three axes;
Draw the prediction curves existing between the three observation modes and the benchmarks.

During the project of densification of the geodetic network system in Cameroon, many benchmarks' points of the first order, second order and third order have been coordinated using sophisticated and high-cost equipment. The high cost of these modern equipment is an obstacle in the survey laboratories of developing countries. The comparison study between the accuracy of low-cost and high-cost equipment where carried (Margaria, M., 2020; Nguyen, N.V., et al., 2021; Gabl, M and Heller, A, 2021), and also the relationship between the accuracy and the recording interval using single and dual frequency receivers (Ashraf, F, 2013; Odolinski, R., et al., 2020; Garrido-et M. S. et al., 2019) but not through a convergence behaviour.

The main objective of this research is to study the performance through accuracy of a low cost multiband GNSS receiver. More specifically, the study seeks to study the influence of the recording interval on the convergence behaviour, then model theirs errors and accuracy with benchmark SERPRET pillars. This will be realized by assessing the evolution of time interval during the reading.

To study the influence of the accuracy of the coordinates on the convergence behaviour. This will be realized by evaluating the difference between the reading value of the low-cost receiver and the benchmark.

2. Methodology

The present study has been done in the Tongo Bassa watershed following four steps which took place from March to September 2021 such as the collection of data, the reading and observation, the data processing, the evolution of the convergence of accuracy and the difference between the readings. Figure 1 gives all the steps of the methodology used to carry out this research study.

2.1. Data

With a surface area of about 42 km², the area of study, the Tongo Bassa watershed is located in the Littoral Region of Cameroon which is in the Equatorial zone falling within the

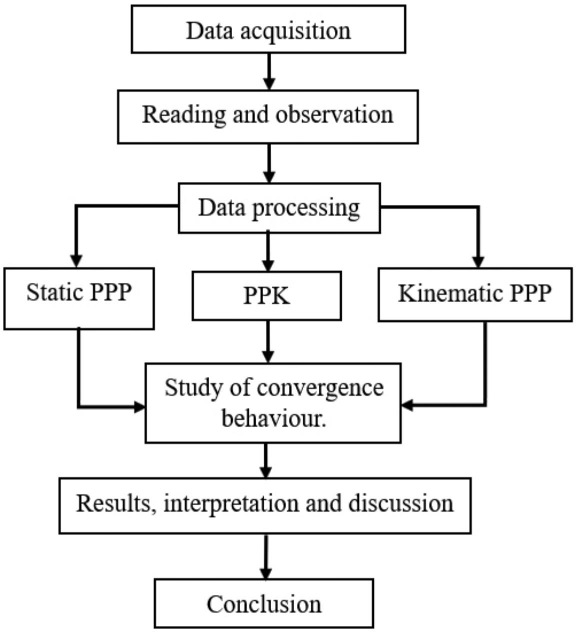

Figure 1. Methodology chart

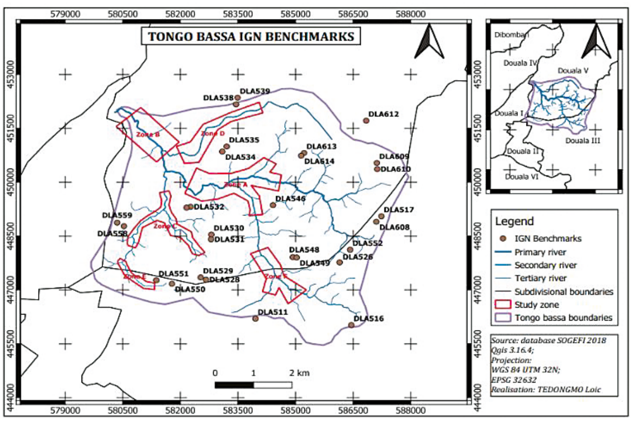

Figure 2: distribution of the Tongo Bassa SEPRET benchmarks

Table 1: Classification of the Tongo Bassa SEPRET benchmarks reading measurement system

Observation mode	Group1	Group2	Group3
Static	DLA535, DLA 612.	DLA558, DLA538, DLA608, RGCB0350.	DLA529, DLA552, DLA613, DLA 526.
Dynamic	DLA535, DLA 612, DLA539, DLA532, DLA 530, DLA531.	DLA528, DLA538, DLA558, DLA608, RGCB0350, DLA609, DLA548, DLA550, DLA551.	DLA529, DLA534, DLA552, DLA613, DLA610, DLA 526.

Source: Field work (2021)

Douala municipality. It is the biggest watershed of the Douala municipality and is located between 4°2'0'' and 4°5'30' North latitude and between 9°43'0'' and 9°47'20'' East longitude. The Tongo Bassa watershed has among the 148 benchmarks in the Wouri division, 25 Benchmarks of the third order made up by the SEPRET Company. Due to the inaccessibility of some of the benchmarks, 21 have been surveyed in the case of this study.

2.2. Reading and observation materials

During the observations, we used:
Two multiband GNSS receivers Emlid Reach RS2 (the base and the rover).
A tripod BOCH BT 170 HD to keep our base stable;
A meter of 5m length to measure the pole height of our base station;
A smartphone Samsung Galaxy S8 having the android app ReachView installed in its system;
A field notebook well prepared to avoid the oblivion of any important information on the site.

Data processing materials:
The processing of the data is based for the majority on the software such as:
The online software CSRS-PPP;
The software package RTKLIB that has 3 main sections: RTKCONV, RTKPOST and RTKPLOT.

2.3. Methods

Classification of the benchmarks
The benchmarks are classified in 3 groups according to the crowding of the environment where the benchmarks are located following the order given below:
Group1, for the most crowed environment with the presence of buildings or trees of more than 10m height at a distance of less than 50m around the beacon.
Group2, for the environment with the presence of buildings or trees comprised between 5 to 10m in height at a distance of less than 50m around the beacon.
Group3, for the environment without buildings or trees in a radius of 50m around the beacons, or with the presence of buildings or trees comprised between 0 to 5m in height at a distance of less than 50m around the beacon.

The table 1 classified the 21 benchmarks in function of the observation modes and the crowding of the environment in which they belong.

2.4. Data collection methods

During this step, the ReachView app connected to the base and the rover to create the daily job before starting the collection was used. The base and the rover were set to save data each 01 second with and elevation mask of 15°. The instrumental height was measured with our 5m length meter and set in the base and was equally noted on the field notebook.

PPP and PPK solutions were estimated using a multiband frequency L1/L2/L5 observations. And each static PPP-solution contains different lengths of observation duration (10 min., 20 min., 30 min, 45 min., 1 hr., 1.5 hrs., 2 hrs., 2.5 hrs., and 3 hrs.). Kinematic PPP and PPK solutions contain a length of observation of 50 seconds. Management of observations files was done using the software RTKLIB. The different sets of observations were processed and the PPP solutions were estimated through Canadian Spatial Reference System (CSRS) Precise Point Positioning (PPP) service (CSRS-PPP, 2013) and PPK solutions were estimated through RTKLIB since the coordinates of the base was already known. The chosen total length of observations was about 3 hrs. for the static PPP mode.

Figure 3: Pillar of the second order RCGN (Republic of Cameroon Geodetic Network) (Carmel, 2012)

Figure 4: pillar Observe with the rover in dynamic modes (Carmel, 2012)

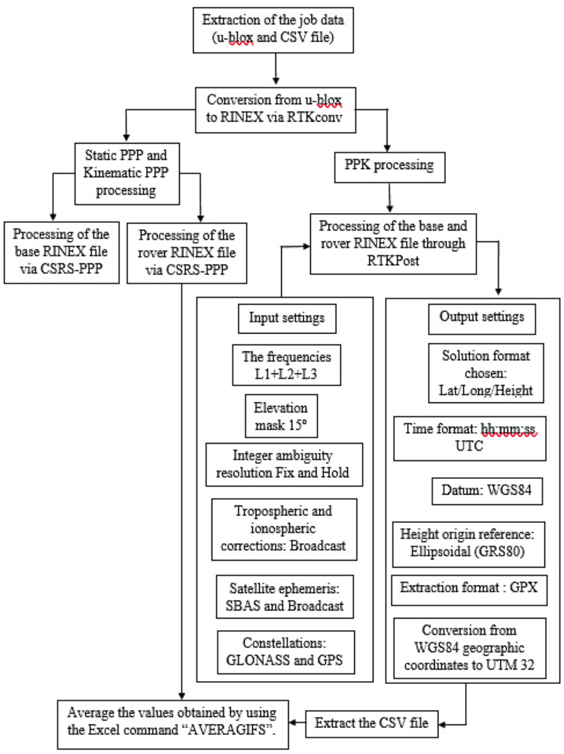

Figure 5: Data processing chart.

2.5. Data processing method

The data processing method is summarized in the figure 5.

3. Results and discussions

3.1. Convergence Accuracy Value Tendance According to the Recording Interval

Sigma 95% in function of the observation lengths in static PPP. Figures 6, 7, 8 and 9 present respectively the convergence behaviour of sigma 95% in function of the observation lengths in static PPP mode over the latitude, the longitude, the ellipsoidal height and over the three-dimensional axes.

We can observe on the above figures that after 10 minutes of observation in static PPP, the value of sigma 95% is ranged within 130cm and 285cm. After 3 hours of observations, the values of sigma 95% for the 10 points surveyed become constants with an average value of 55mm. We can therefore conclude that static PPP over the latitude, the longitude, the ellipsoidal height and the three-dimensional axes converges respectively towards the values 10mm, 25mm, 45mm and 55mm after about 3 hours of observations with a low-cost GNSS multiband receiver in the equatorial zone.

Table 2 gives for each of the points surveyed in static PPP the

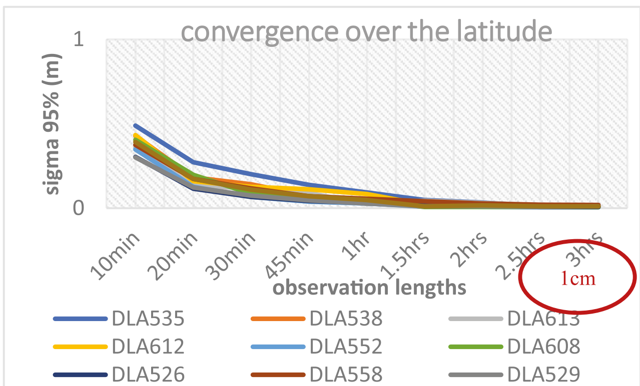

Figure 6: convergence behaviour in static PPP over the latitude.

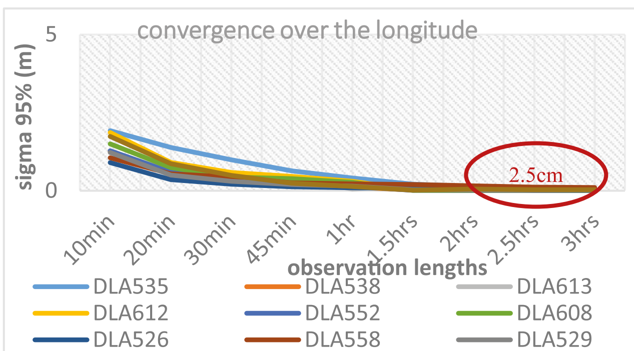

Figure 7: convergence behaviour in static PPP over the longitude.

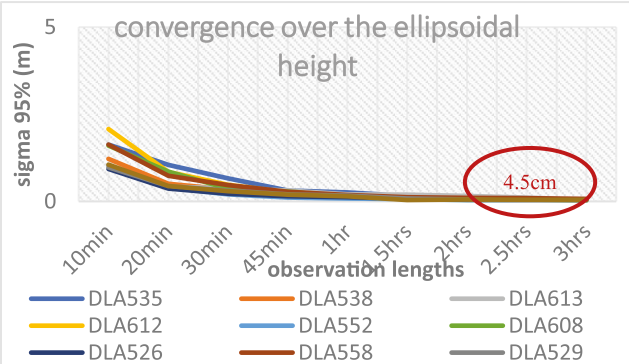

Figure 8: convergence behaviour in static PPP over the ellipsoidal height.

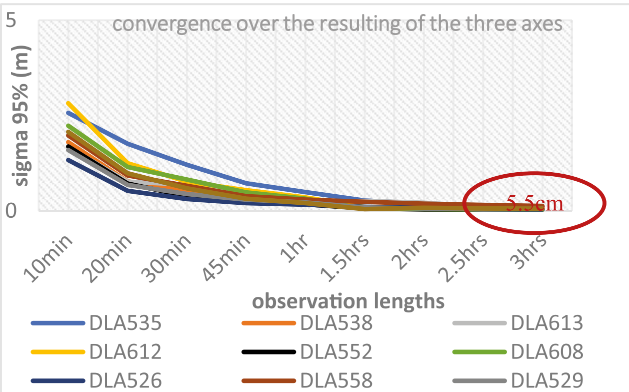

Figure 9: convergence behaviour in static PPP over the resulting 3- D axis.

Duration	indicators	sigma 95% latitude (m)	sigma 95% longitude (m)	sigma 95% Ellipsoidal Height (m)
10 minutes	AVERAGE	0.384	1.399	1.320
	STD DEV	0.056	0.327	0.367
	MAX	0.489	1.923	2.074
	MIN	0.301	0.901	0.931
20 minutes	AVERAGE	0.166	0.712	0.596
	STD DEV	0.047	0.308	0.235
	MAX	0.273	1.383	1.051
	MIN	0.116	0.352	0.366
30 minutes	AVERAGE	0.111	0.471	0.371
	STD DEV	0.039	0.207	0.128
	MAX	0.202	0.991	0.658
	MIN	0.068	0.206	0.203
45 minutes	AVERAGE	0.075	0.314	0.232
	STD DEV	0.030	0.149	0.066
	MAX	0.138	0.632	0.313
	MIN	0.039	0.128	0.112
1 hour	AVERAGE	0.049	0.190	0.161
	STD DEV	0.022	0.104	0.044
	MAX	0.094	0.409	0.255
	MIN	0.025	0.052	0.084
1.5 hour	AVERAGE	0.023	0.078	0.092
	STD DEV	0.015	0.079	0.046
	MAX	0.049	0.213	0.191
	MIN	0.008	0.013	0.040
2 hours	AVERAGE	0.017	0.063	0.074
	STD DEV	0.009	0.057	0.036
	MAX	0.033	0.156	0.154
	MIN	0.007	0.009	0.041
2.5 hours	AVERAGE	0.011	0.027	0.055
	STD DEV	0.005	0.032	0.025
	MAX	0.021	0.119	0.107
	MIN	0.006	0.009	0.033
full-time	AVERAGE	0.010	0.025	0.046
	STD DEV	0.003	0.027	0.011
	MAX	0.019	0.103	0.072

Table 2: Sigma 95% over Latitude, Longitude and Ellipsoidal Height

average of the uncertainties, the standard deviation, the maximum and the minimum of sigma 95% in function of the observation lengths over the latitude, the longitude and the Ellipsoidal Height.

It shows that in static PPP, we reach centimetre level accuracy after about 3 hours of observations on the latitude, longitude and ellipsoidal height. This study is in perfect accordance with the results of Ashraf Farah on the study of convergence behaviour of static PPP (ASHRAF F., 2013), our observations

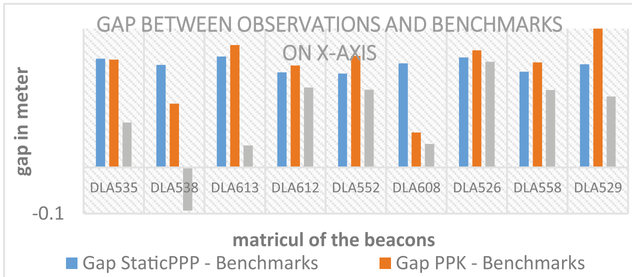

Figure 10: Difference between the 03 observation modes and the benchmarks on the X axis.

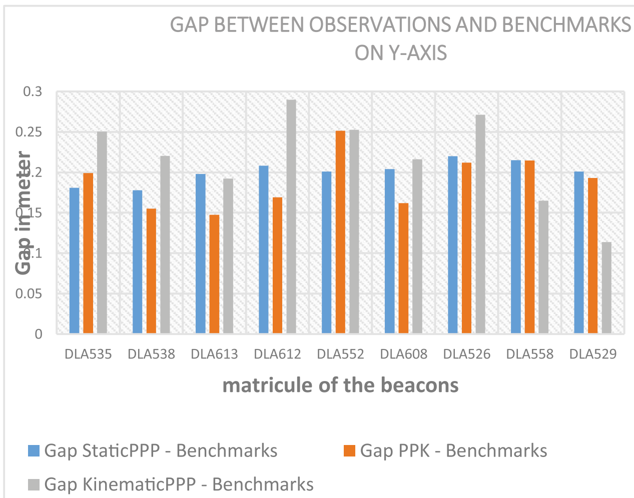

Figure 11: Difference between the 03 observation modes and the benchmarks on the Y – axis.

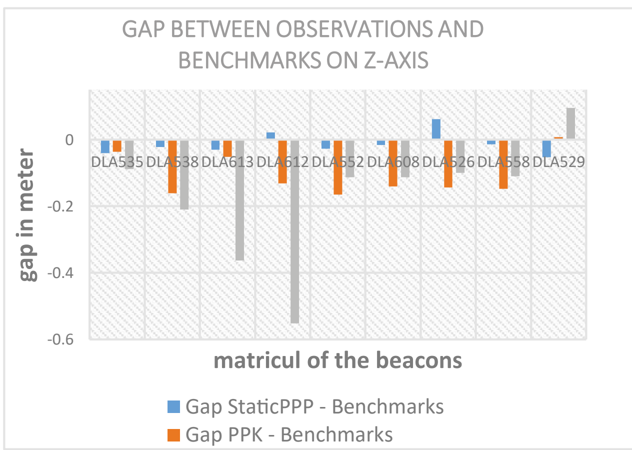

Figure 12: Difference between the 03 observation modes and the benchmarks on the Z-axis.

with the receiver Emlid reach RS2 which is a three-frequency receiver converge faster than those of TOPCON GR3. They are equally in accordance with the results of Margaria Marie who found out that the receiver Emlid reach gives more accurate results than the receiver Trimble R8 (Margaria M., 2020). This might be due to the fact that the receivers Trimble R8 and Topcon GR3 are dual frequency receivers.

Behaviour of coordinates as a function of recording time in PPK and kinematic PPP

Figures 10, 11 and 12 present the behaviour of point DLA535 respectively over x, y and z axis in PPK mode and figures 13, 14 and 15 present also the behaviour of point DLA535 in kinematic PPP after 50 seconds of observations. The coordinates over X, Y and Z axes varied respectively within the ranges of 2.5cm length, 3cm length and 3cm in PPK; and 12cm length, 13cm length and 7cm length in kinematic PPP. The observations in PPK converge faster and are less mode disperse than those in kinematic PPP.

This is due to the fact the observations in kinematic PPP does not take into consideration the corrections of the base of the receiver and also there is no fix receiver used by CSRS-PPP around our area of survey to minimize the errors of the observations.

3.2. Errors Values Difference between the Benchmark and the Reading Coordinates

Difference between the 03 observation modes and the benchmarks. The figures 10, 11 and 19 present the differences of the reading between the static PPP and the benchmarks, the PPK and the benchmarks, and the Kinematic PPP and the benchmarks respectively on the X-axis, Y-axis and Z-axis.

3.3. Modeling of the Variation of Reading Values According to the Benchmark Coordinates of Beacons

The static PPP solutions are more related to the benchmarks than the PPK and the kinematic PPP solutions with a relative maximum difference of 5cm in the X, Y and Z-axis.

The kinematic PPP coordinates of the points DLA538 and DLA612 respectively along the x and z axes are systematically closer to the corresponding benchmarks for DLA538 and farer for DLA612 than the other points due to the static PPP solutions are more related to the benchmarks than the PPK and the kinematic PPP solutions with a relative maximum difference of 5cm in the X, Y and Z-axis.

The kinematic PPP coordinates of the points DLA538 and DLA612 respectively along the x and z axes are systematically closer to the corresponding benchmarks for DLA538 and farer for DLA612 than the other points due to the fact that the beacons DLA538 and DLA612 belong to group1. Meaning there are building or trees of more than 10m height at a distance of less than 50m around the beacon. We can therefore understand that the accuracy of observations with a low-cost multiband GNSS receiver depends of the sky visibility which is in accordance with the results obtained by AYHAN Ceylan, et al. in 2015 evaluating the Performance of Kinematic PPP and Differential Kinematic Methods in Rural and Urban Areas (AYHAN Ceylan, et al., 2015).

Relationship between the reading measurements and the benchmarks. The figures 13, illustrate respectively the relationships between ΔX (the difference between the coordinates of the observations in static PPP mode and the benchmarks over the axes X, and the benchmarks over X, -axis. The (1) equations of the trend lines of ΔX in function of the benchmarks over X. The values of R-squared are respectively equal to 0.9007, 0.858 and 0.5578 over X, Y and Z. this simply means that the relationship between the differences delta and the corresponding benchmarks is polynomial of 6th other and are more linked over the X-axis than over the Y-axis, and also more linked over the Y-axis than over the Z-axis.

$$y = 2 \times 10^{-22}x^6 - 8 \times 10^{-16}x^5 + 109x^4 - 0.0009x^3 + 401.78x^2 - 9 \times 10^7x + 9$$

The figures 14, shows the relationships between ΔX, (the difference between the coordinates of the observations in PPK

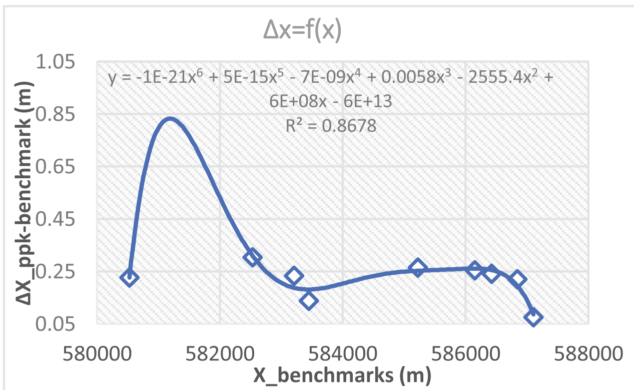

Figure 13: Model of Δx errors in Static PPP according to the benchmark along the X-axis.

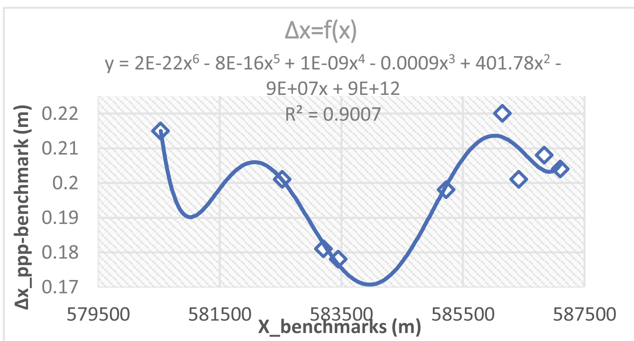

Figure 14: Model of Δx errors in PPK according to the benchmark along the X-axis.

mode and the benchmarks over the axes X, and the benchmarks over X-axis. The (2), equations of the trendlines of ΔX, in function of the benchmarks over X. The values of R-squared are respectively equal to 0.8678, 0.6764 and 0.9798 over X, Y and Z. this simply means that the relationship between the differences delta and the corresponding benchmarks are nearer over the Z-axis than over the X-axis, and also nearer over the X-axis.

$$y = -10^{-21}x^6 + 5 \times 10^{-15}x^5 - 7 \times 10^{-9}x^4 + 0.0058x^3 - 2555.4x^2 + 6 \times 10^8 x - 6 \times 10^{13} \quad (2)$$

The figures 15 illustrate respectively the relationships between ΔX, (the difference between the coordinates of the observations in Kinematic PPP mode and the benchmarks over the axes X,), and the benchmarks over X,-axis. (3), is an equations of the trendlines of ΔX, in function of the benchmarks over X. The values of R-squared are respectively equal to 0.8374, 0.8915 and 0.9929 over X, Y and Z. this simply means that the relationship between the differences delta and the corresponding benchmarks are nearer over the Z-axis than over the Y-axis, and also nearer over the Y-axis than over the X-axis.

$$y = 2 \times 10^{-21}x^6 - 8 \times 10^{-15}x^5 + 10^{-8}x^4 - 0.0088x^3 + 3861.5x^2 - 9 \times 10^8 x + 9 \times 10^{13} \quad (3)$$

Modelling of the different delta errors according to the predicted errors. The figures 16, below illustrate respectively the relationships between ΔX, (the difference between the coordinates of the observations in static PPP mode and the benchmarks over the axes X,), and εpx, εpy, and εpz (representing respectively the predicted error over X,). The (3), is an equations of the trendlines of ΔX, in function of the predicted error over X,. The values of R-squared are respectively equal to 0.9792, 1 and 1 over X, Y and Z. this simply means that the relationship between the difference deltas and the corresponding predicted errors are nearer over the Y-axis than over the Z-axis, and also nearer over the Z-axis than over the X-axis.

$$y = -6 \times 10^7 \times 10^{12} \quad (4)$$

Figures 17 illustrates the relationships between ΔX, (the difference between the coordinates of the observations in PPK mode and the benchmarks over the axes X), and εpx, εpy, and εpz (representing respectively the predicted error over X, Y and Z) respectively. The (4) is an equation of the trendlines of ΔX in function of the benchmarks over X,. The values of R-squared are respectively equal to 0.9994, 1 and 1 over X, Y and Z. this simply means that the relationship between the difference deltas and the corresponding predicted errors are nearer over the Y-axis than over the Z-axis, and also nearer over the Z-axis than over the X-axis.

$$y = 6 \times 10^8 x - 6 \times 10^{13} \quad (5)$$

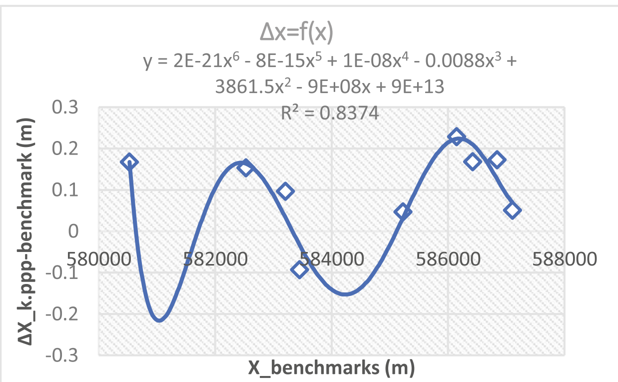

Figure 15: Model of Δx errors in K.PPP according to the benchmark along the X-axis.

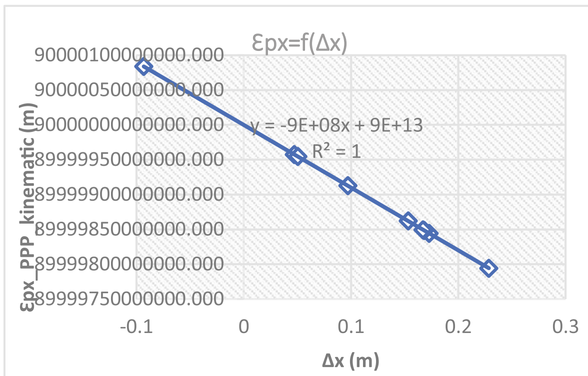

Figure 17: Model of Δx errors in Kinematic-PPP according to the predicted error along the X-axis.

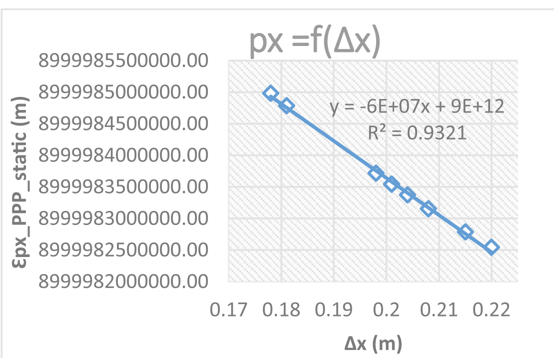

Figure 16: Model of Δy errors in static – PPP according to the predicted error along the Y-axis.

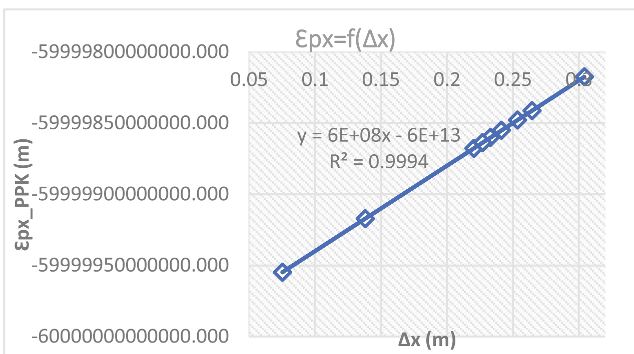

Figure 18: Model of Δx errors in PPK according to the predicted error along the X-axis.

Figures 18 illustrates the relationships between ΔX, (the difference between the coordinates of the observations in kinematic PPP mode and the benchmarks over the axes X), and εpx, εpy, and εpz (representing respectively the predicted error over X-axis) respectively. The (5) is an equations of the trendlines of ΔX in function of the benchmarks over X. The values of R-squared are respectively equal to 1, 1 and 0.9999 over X, Y and Z. this simply means that the relationship between the difference deltas and the corresponding predicted errors are nearer over the X-axis than over the Y-axis, and also nearer over the Y-axis than over the Z-axis.

$$y = -9 \times 10^8 x + 9 \times 10^{13} \qquad (6)$$

Looking at the value of the leading coefficients of (4), ((5), (6),we can conclude that the static PPP coordinates are relatively nearer to the benchmark's coordinates than the PPK and the kinematic PPP coordinates over the X, Y and Z axis. The value of R-squared is very small for all the equations, which means the equations that link the observation modes and the benchmarks cannot be used in a high precision work.

4. Conclusion

The work aimed at studying the influence of the accuracy and the duration on the convergence behaviour using low cost multiband GNSS receiver. We started by studying the influence of the recording interval on the convergence behaviour using a low-cost receiver and then the impact of accuracy on the convergence using a low-cost GNSS receiver. We did 172 readings in kinematic mode (kinematic PPP and PPK) and 10 readings in static mode using the multiband GNSS receiver Emlid Reach RS2. The PPK readings gives better accuracy than kinematic PPP readings and the difference between the PPK coordinates and the benchmarks is ranged within [7.5cm – 30.4cm], [14.8cm – 25.2cm] and [-16.5cm – 0.8cm] respectively over the X, Y and Z-axis. PPK survey can be used in many surveying applications such as: cadastral survey, road construction survey, realization of DEM for hydrologic and hydraulic modelling. While the difference between the Kinematic PPP coordinates and the benchmarks is ranged between [-9.3cm – 22.8cm], [11.4cm – 29cm] and [-55.2cm – 9.6cm] respectively over the X, Y and Z-axis. Kinematic PPP survey can show itself important in the applications such as agriculture, forestry works, mining exploitations, and so on.

The study of the convergence behaviour in static PPP shows that we obtain centimetre or millimetre level accuracy after observing for about 3 hours on the latitude, longitude and Ellipsoidal height. The difference between the Static PPP coordinates and the benchmarks is ranged within [20.3cm – 24cm], [17.8cm – 22cm] and [-5.3cm – 6.1cm] respectively over the X, Y and Z-axis. Static PPP can therefore be used in high precision surveyed work.

The assessment of differences between the 03 reading methods and the benchmarks shows that the static PPP positioning with the receiver Emlid Reach RS2 gives better accuracy than kinematic PPP and PPK and can be used to control the stability or to create new benchmarks.

All the tests were performed in the open sky and in an area with small baseline of less than 10km that was in the favour of the low–cost antennas, which are more sensitive to multi-path. To fully evaluate the performance of the low–cost receivers, more tests will be realized in the future over long baselines and real environmental conditions where different factors, such as multi-path, weather conditions, and others, can influence the results.

The difference between the Static PPP coordinates and the Benchmarks is considerable in the case of high precision survey works. Referring to previous studies, this difference is due to either the quality of the antenna used or certain environmental factors.

5. References

Amr H. Ali. (2017). Performance Evaluation of Precise Point Positioning (PPP) Using CSRS-PPP online service. Surveying. American journal of geographic information system, 6(4):156-167.

Ashraf Farah (2013). Effect analysis of GPS observation type and duration on convergence behavior of static PPP. The journal of geomatics, Vol 7 N°2.

Ashraf Farah (2017). GPS static-PPP positioning accuracy variation with observation recording interval for hydrographic applications. Twentieth international water technology IWTC 20 Hurghada, 18-20

Ashraf Farah (2017). Accuracy Assessment Study for Kinematic PPP using Low-Cost GPS Receiver. Al Azhar.14th International conference on engineering, architecture, technology.

Ayhan CEYLAN (2015). Evaluating the Performance of Kinematic PPP and Differential Kinematic Methods in Rural and Urban Areas. FIG working week, sofia Bulgary, 17-21

CSRS-PPP (2021). Canadian Spatial Reference System (CSRS) Precise Point Positioning (PPP) service .http://www.geod.nrcan.gc.ca/productsproduits/ppp_e.php. Accessed 26/05/2021)

Biagi, L.; Grec, F.; Negretti, M. (2016). Low-Cost GNSS Receivers for Local Monitoring: Experimental Simulation, and Analysis of Displacements. Sensors, 16, 2140.

Broekman, A.; Gräbe, P.J. A (2021). Low-Cost, Mobile Real-Time Kinematic Geolocation Service for Engineering and Research Applications. HardwareX, 10, e00203. 1.

Gabl, M.; Heller, A. (2021). SmartRTK: Präzise Positionsdaten und Mobile Geodatenerfassung mit Low-Cost-GNSS—Eine Prototypenentwicklung für Hochalpine Einsätze; Wichmann Verlag: Berlin/Offenbach, Germany.

Garrido-Carretero, M.S.; de Lacy-Pérez de los Cobos, M.C.; Borque-

Arancón, M.J.; Ruiz-Armenteros, A.M.; Moreno-Guerrero, R.; Gil-Cruz, A.J. (2019). Low-Cost GNSS Receiver in RTK Positioning under the Standard ISO-17123-8: A Feasible Option in Geomatics. Measurement, 137, 168–178.

Guo, L.; Jin, C.; Liu, G. (2017). Evaluation on Measurement Performance of Low-Cost GNSS Receivers. In Proceedings of the 2017 3rd IEEE International Conference on Computer and Communications (ICCC), Chengdu, China, 13–16.

Hamza, V.; Stopar, B.; Ambrožič, T.; Turk, G.; Sterle, O. (2020). Testing Multi-Frequency Low-Cost GNSS Receivers for Geodetic Monitoring Purposes. Sensors, 20, 4375. Hamza, V.; Stopar, B.; Sterle, O. (2021) Testing the Performance of Multi-Frequency Low-Cost GNSS Receivers and Antennas. Sensors 21, 2029.

Hamza, V.; Stopar, B.; Ambrožič, T.; Sterle, O. (2018). Performance Evaluation of Low-Cost Multi-Frequency GNSS Receivers and Antennas for Displacement Detection. Appl. Sci. 2021, 11, 6666

Ibrahim Murat Ozulu. (2018). Kinematic PPP Positioning using different processing platforms .FIG congress, Istanul, Turkey, may 6-11

Jean-Louis Carme (2012). Le nouveau réseau géodesique du Cameroun, Revue XYZ N°131 2é trimestre

Janos, D.; Kuras, P. (2021). Evaluation of Low-Cost GNSS Receiver under Demanding Conditions in RTK Network Mode. Sensors, 21, 5552.

Krietemeyer, A.; van der Marel, H.; van de Giesen, N.; ten Veldhuis, M.-C. (2020). High Quality Zenith Tropospheric Delay Estimation Using a Low-Cost Dual-Frequency Receiver and Relative Antenna Calibration. Remote Sens, 12, 1393.

Lăpădat, A.M.; Tiberius, C.C.J.M.; Teunissen, P.J.G. (2021). Experimental Evaluation of Smartphone Accelerometer and Low-Cost Dual Frequency GNSS Sensors for Deformation Monitoring. Sensors, 21, 7946.

Leick, A.; Rapoport, L.; Tatarnikov, D. (2015). GPS Satellite Surveying, 4th ed.; Wiley: Hoboken, NJ, USA; ISBN 978-1-118-67557-1

Lipatnikov, L.; Shevchuk, S. (2019). Cost Effective Precise Positioning with GNSS; International Federation of Surveyors: Copenhagen, Denmark; p. 82

Margaria Marie, (2020) Évaluation des performances des drones et DGPS à faible coût pour la recherche en géomorphologie côtière. Université via dmitia, Perpignan, France

Muchammad Masykur (2020). Analysis of accuracy the InaCORS BIG online post-processing service. Applied geomatics, https://doi.org /10.1007/s12518-020-00343-2

Omer F. et al. (2021). Investigation of the Kinematic PPP-AR Positioning Performance with Online CSRS-PPP Service. FIG e-working Week, 2021, conference paper, 21-25

Nguyen, N.V.; Cho, W.; Hayashi, K. (2021). Performance Evaluation of a Typical Low-Cost Multi-Frequency Multi-GNSS Device for Positioning and Navigation in Agriculture—Part 1: Static Testing. Smart Agric. Technol, 1, 100004.

Odolinski, R.; Teunissen, P.J.G. (2020). Best Integer Equivariant Estimation: Performance Analysis Using Real Data Collected by Low-Cost, Single- and Dual-Frequency, Multi-GNSS Receivers for Short- to Long-Baseline RTK Positioning. J. Geod, 94, 91.

Romero-Andrade, R.; Trejo-Soto, M.E.; Vázquez-Ontiveros, J.R.; Hernández-Andrade, D.; Cabanillas-Zavala, J.L. (2021). Sampling Rate Impact on Precise Point Positioning with a Low-Cost GNSS Receiver. Appl. Sci. 11, 7669.

Samboko, H.T.; Schurer, S.; Savenije, H.H.G.; Makurira, H.; Banda, K.; Winsemius, H. (2022). Evaluating Low-Cost Topographic Surveys for Computations of Conveyance. Geosci. Instrum. Method. Data Syst. 11, 1–23

Semler, Q.; Mangin, L.; Moussaoui, A.; Semin, E. (2019). Development of a Low-Cost Centimetric GNSS Solution for Android Applications. In Proceedings of the ISPRS TC II 6th International Workshop LowCost 3D—Sensors, Algorithms, Applications, Strasbourg, France, 2–3 December 2019; Volume XLII-2/W17, pp. 309–314

Teunissen, P.J.G.; Montenbruck, O. (2017). (Eds.) Springer Handbook of Global Navigation Satellite Systems; Springer International Publishing: Cham, Switzerland; ISBN 978-3-319-42926-7.

Tsakiri, M.; Sioulis, A.; Piniotis, G. (2017). Compliance of Low-Cost, Single-Frequency GNSS Receivers to Standards Consistent with ISO for Control Surveying. Int. J. Metrol. Qual. Eng., 8, 11.

Tunini, L.; Zuliani, D.; Magrin, A. (2022). Applicability of Cost-Effective GNSS Sensors for Crustal Deformation Studies. Sensors, 22, 350.

Wang, S.; Dong, X.; Liu, G.; Gao, M.; Zhao, W.; Lv, D.; Cao, S. (2022). Low-Cost Single-Frequency DGNSS/DBA Combined Positioning Research and Performance Evaluation. Remote Sens. 14, 586 .

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In Coordinates

10 years before...

mycoordinates.org/vol-X-issue-8-August-2014

So you think you are safe

Prof Dr ir E Theunissen
Netherlands Defence Academy, Den Helder, The Netherlands

Jamming and spoofing threats may have seemed unwarranted, impossible, unlikely, too difficult to realize or technically infeasible in 1999. Given that nowadays anyone can buy a GPS jammer for about 30$ through a webstore, such optimism is neither justifiable nor affordable.

When two do the same thing

Deák Peter
Head of department, GIS and development projects, Research Institute of Geodesy and Cartography in Bratislava, Slovak Republic

Anyone who provides data and services for INSPIRE, read and follow the same documents. Nevertheless, the results of individual solutions across Europe are different. Here an old familiar saying holds true- "If two do the same thing, this is not always the same." We believe that the paper will contribute to increasing the knowledge of INSPIRE issues and stir up debate to avoid problems which the future may bring and contribute to their solutions.

EDAS: EGNOS data over the internet for added value services

Elisabet Lacarra, Pedro Gómez, Juan Vázquez and Miguel Ángel Sánchez
ESSP SAS, Madrid, Spain

EDAS is the access point to the data collected and generated by the EGNOS ground infrastructure through the EGNOS stations network in real time and off line in form of an FTP archive. This EDAS Service has been officially available for GNSS community since July 2012, with a commitment of minimum availability of 98.5% for the main data services and of 98% for the rest of the EDAS Services.

Detecting Changes in Coastline in United States and Malaysia

Lawal Abdul Qayoom Tunji, Kamaruzaman Wan Yusof and Ahmad Mustafa Hashim
Civil Engineering Department, Universiti Teknologi PETRONAS, Malaysia

The use of LIDAR has achieved some level of accuracy as compared to the medium resolution images of 30 m spatial resolution. Conclusively the accuracy of the LIDAR data could be put at 0.6 m vertical accuracy which makes a valuable data for remote sensing. Past research have also reported the accuracy of using Landsat 5 images and the accuracy is mostly put at ±30 m, but with the method described in this paper it is believed the accuracy has been tremendously improved.

Expanding horizons: Key achievements in ISRO's 2023-24 annual report

The recently published ISRO annual report 2023-24 highlights significant advancements in during last year. Here are some of the achievement especially in the field Earth Observation and Navigation system.

The report highlights significant advancements in satellite data reception, processing, and applications by the Indian Space Research Organisation (ISRO) in the context of the Indian Space Policy 2023. The primary aim is to enhance remote sensing capabilities and accessibility to support various user communities, including agriculture, water resources, and disaster management.

Satellite data reception

ISRO's satellite data reception systems focus on archiving and processing payload data from both Indian and foreign remote sensing satellites to ensure comprehensive coverage. In 2023, ISRO supported 15 Indian missions and 9 foreign missions, successfully receiving approximately 10,494 satellite passes with an impressive efficiency rate exceeding 99.8%.

ISRO has made notable strides in technology development for satellite data reception:

- **Tri-band Antenna Systems:** New in-house designed tri-band antennas (S/X/Ka) enhance data reception across multiple frequency bands.
- **Servo Control Loops:** Implementation of advanced control systems on antenna drives has improved tracking accuracy to within 100 milli-degrees.
- **Machine Learning Models:** These models have been developed to improve the pointing accuracy of the 7.5-meter antenna systems, achieving targeted precision levels.

The report emphasizes the importance of data processing and dissemination, particularly through the Bhoonidhi portal, which was enhanced to provide free and open access to remote sensing data as per the Indian Space Policy 2023. This portal facilitates user engagement by allowing downloads of extensive datasets, including those collected since 1988.

In 2023, ISRO processed over 640,150 satellite data sets, generating approximately 268,558 products available for open access. Significant upgrades to the Bhoonidhi portal have improved the user experience, including new features for data searchability and visualization.

Remote sensing applications

ISRO's remote sensing capabilities are being effectively utilized across various sectors:

- **Agriculture:** Satellite data has been pivotal for yield estimation and drought impact assessments, providing critical information to state governments. Specific projects have been implemented to enhance agricultural productivity and monitor crop health.
- **Water Resources:** The development of a national hydrology modeling framework utilizes geospatial and hydro-meteorological datasets to compute water balance components. This framework aids in flood management and drought monitoring.
- **Forestry and Ecology:** Satellite data is being employed for estimating forest biomass and detecting long-duration fire events, demonstrating its versatility in environmental monitoring.

Disaster Management Support

ISRO's commitment to disaster management is underscored by its real-time monitoring of natural disasters. The organization has utilized multi-sensor and multi-temporal satellite datasets to map and monitor significant flood events across 14 states, providing valuable insights to disaster response organizations.

Moreover, ISRO has generated comprehensive atlases, such as the Flood Affected Area Atlas and the Landslide Atlas, which compile historical data on flood and landslide occurrences to support risk assessment and management efforts. These resources are made available on national disaster management portals.

ISRO actively participates in international initiatives to support disaster response efforts worldwide. Under the International Charter on Space and Major Disasters, ISRO provided assistance for 29 events across 24 countries in 2023, delivering a total of 170 products. Similarly, cooperation through Sentinel Asia resulted in servicing 31 requests, further showcasing ISRO's commitment to global collaboration in emergency management.

Navigation Systems

India's Navigation with Indian Constellation (NavIC) is an independent regional navigation satellite system designed to provide accurate positioning services over India and an area extending 1,500 km beyond its borders. ISRO has developed both the space and ground infrastructure necessary for this system, continuously promoting its utilization in civilian sectors such as land transportation, aviation, maritime operations, mapping, surveying, geodesy, telecommunications, and more. Additionally, the GPS Aided Geo Augmented Navigation (GAGAN) system, which ISRO established for civil aviation, is supported by ground infrastructure provided by the Airports Authority of India (AAI).

Major Developments in 2023

1. **NavIC Base Layer Constellation:** The NVS-01 satellite, launched on May 29, 2023, marked a significant addition to the NavIC constellation. It introduces advanced features, including an optimized long code, a

civilian L1 signal, and an indigenous atomic clock (iRAFS). Following successful in-orbit tests in June 2023, the satellite was cleared for navigation operations in July. With the inclusion of NVS-01, the base layer now comprises five operational satellites (IRNSS-1B, 1C, 1F, 1I, and NVS-01).

2. **Aadhaar Enrolment Devices:** The Unique Identification Authority of India (UIDAI) is procuring NavIC-enabled receivers for use in Aadhaar enrolment centers. A technical committee, including ISRO experts, is finalizing the technology and encryption algorithms for these receivers.
3. **National Disaster Warning System:** The National Disaster Management Agency (NDMA) has implemented a Common Alert Protocol (CAP) for various natural disasters. NavIC messaging has been integrated into this system, and the service is accessible to the public through the Sachet mobile app.
4. **Consumer Devices:** Over 50 mobile handsets in India are now equipped with NavIC capabilities. This includes devices from well-known manufacturers as well as domestically produced handsets. Consumer-grade devices such as wearables and trackers are increasingly using small, low-power GNSS chips, with future NavIC satellites providing civilian signals in the L1 band alongside existing signals in L5 and S-bands.
5. **Indigenous Multi-GNSS Chip:** Under a MeitY contract, Indian company Accord has developed a multi-GNSS SPS chip based on NavIC. The chip has passed technical evaluations and is now cleared for production.
6. **Indigenous Reference Receiver:** A tri-band reference receiver (L1, L5, and S-band) has been developed and integrated into the NavIC ground segment, enhancing operational capabilities.
7. **Industry Standards:**
   - Maritime Equipment: The International Electrotechnical Commission (IEC) has released the IEC 61108-6 standard for NavIC-based maritime receiver equipment, with ISRO contributing to its formulation. A related standard for augmentation systems, including GAGAN, is under review.
   - Unmanned Aerial Vehicles: The Bureau of Indian Standards (BIS) has established the national standard IS 18381:2023 for general-purpose drones, which incorporates NavIC specifications for navigation systems. ISRO has actively participated in developing this standard.

Space science exploration and research in India

The Indian space program emphasizes space science exploration, research, and capacity building across several key areas. These activities are organized into distinct verticals: Heliosphere, Astronomy & Astrophysics; Solar System Bodies; Space Weather; and Atmospheric Science. ISRO and its affiliated laboratories conduct various activities such as modeling, simulation, observations (both space and ground-based), and laboratory analyses of meteoroids. International collaboration is vital for advancing India's space exploration goals. Some of the highlights of 2023-24 are:

Chandrayaan-3 Mission: After its successful soft landing on August 23, 2023, the Chandrayaan-3 lander-rover module began deploying its science payloads as per ISRO's science plan. Preliminary findings include measurements of the lunar plasma environment, temperature gradients in the lunar regolith, and the detection of elemental compositions, showcasing significant advances in lunar science.

Aditya-L1 Mission: Launched on September 2, 2023, Aditya-L1 is India's first solar mission aimed at studying solar activities. It was successfully placed in a halo orbit around the Sun-Earth L1 point, collecting valuable data on energetic particle environments.

Chandrayaan-2: The orbiter, operational for over four years, has released around 20 TB of data, aiding in significant discoveries like lunar hydration and mapping noble gas dynamics.

AstroSat Mission: Ongoing projects under AstroSat have yielded nearly 70 publications in 2023, showcasing its substantial contributions to astrophysics research.

XPoSat Mission: Following successful reviews, XPoSat is scheduled for launch on January 1, 2024, to further enhance observational capabilities.

ISRO is also working on future missions such as:

- Venus Mission: Discussions are underway to focus on the science surrounding Venus, aiming to build capacity and interlink payloads for a proposed orbiter mission.
- DISHA Mission: This proposed aeronomy mission aims to improve understanding of ionospheric dynamics and enhance GNSS services.
- LuPEX Mission: Collaboration with JAXA continues as plans for a lunar polar exploration mission develop, with configurations being finalized.
- Mars Lander Mission: A task force has been established to identify potential landing sites on Mars and address scientific observation requirements.

International Cooperation in Space

India's space agency, ISRO, has significantly expanded its international partnerships, notably through the signing of various agreements. A pivotal agreement between ISRO and NASA aims to establish a strategic framework for human spaceflight cooperation, enhanced by India's recent signing of the Artemis Accords on June 21, 2023. This collaboration explores opportunities in critical and emerging technologies, including quantum communication and low Earth orbit (LEO) satellite constellations.

India's partnership with Russia focuses on human spaceflight and the development of advanced launch vehicle engines, with ongoing discussions about enhancing payload capacities for future missions. Collaboration with France has also progressed, with agreements for the TRISHNA mission and maritime awareness initiatives. Additionally, ISRO's engagement with the French space agency, CNES, has facilitated support for the Aditya-L1 mission and discussions about joint engine development.

Engagements with other nations are equally dynamic. Cooperation with Japan includes receiving signals from JAXA's Venus mission and exploring a joint lunar mission. Discussions with Australia have centered on establishing an ISRO ground station and support for recovery operations related to the Gaganyaan mission.

ISRO is also fostering relationships with countries like Bhutan, where it has launched a satellite and conducted training on satellite data usage, and Mauritius, with a joint satellite initiative. The agency has launched a geospatial data portal for Pacific Island countries and actively participates in international forums to discuss and promote the global space economy.

Furthermore, ISRO's commitment to capacity building is evident through its training programs, benefiting over 3,500 participants from 109 countries. Through these initiatives and collaborations, ISRO is solidifying its role as a key player in the global space community.

IN-SPACe: Authorization, Promotion, and Enablement

IN-SPACe, the Indian National Space Promotion and Authorization Center, operates in three key areas: Authorization of Space Activities, Promotion, and Enablement of Non-Governmental Entities (NGEs). Here's an overview of recent initiatives and activities.

Authorization of Space Activities As of October 15, 2023, IN-SPACe received 402 applications from over 250 NGEs, including ISRO, MSMEs, start-ups, and academic institutions. Of these, 219 proposals have been processed, with 52 specifically for launch authorizations; 22 have already been granted. Applications that need inter-ministerial consultations are reviewed by a Standing Committee chaired by the IN-SPACe Chairman, ensuring comprehensive oversight.

In a bid to streamline operations, IN-SPACe has drafted detailed guidelines in alignment with the Indian Space Policy – 2023. Additionally, 45 Memoranda of Understanding (MoUs) and 25 Joint Project Initiatives (JPIs) have been established to support various space activities, with 18 JPIs already completed.

Initiatives to Enable NGEs IN-SPACe is actively fostering a conducive environment for NGEs through several initiatives. Notably, a framework MoU was signed with the Gujarat government to establish a manufacturing park for space systems. IN-SPACe is also facilitating technology transfers from ISRO, with 10 technologies already transferred to 8 NGEs.

To enhance NGEs' capabilities, a state-of-the-art Design Lab has been set up in Ahmedabad, providing access to advanced simulation tools. Furthermore, IN-SPACe has released a "Catalogue of Indian Standards for Space Industry" and is collaborating with the Bureau of Indian Standards to establish additional standards.

To support startups, IN-SPACe introduced a Seed Fund scheme, offering financial assistance up to INR 1 crore. Recent initiatives also include a new "Space Technology" course developed in collaboration with IIT Bombay and IIT Madras, aimed at equipping future engineers with essential skills for the space sector.

These efforts position IN-SPACe as a pivotal player in transforming India's space landscape, driving innovation and collaboration in the industry.

The complete report can be accessed at https://www.isro.gov.in/media_isro/pdf/AnnualReport/Annual_Report_2023_24_English.pdf

Bayanat and Yahsat launch UAE's first SAR satellite

Bayanat and Al Yah Satellite Communications Company PJSC, UAE announced the successful launch of their first Low Earth Orbit (LEO) Synthetic Aperture Radar (SAR) satellite into orbit on August 16, 2024, in partnership with ICEYE, a pioneer in SAR satellite operations for earth observation. It was launched via integrator Exolaunch and successfully lifted off aboard SpaceX's Transporter 11 rideshare from Vandenberg Space Force Base in California, USA. The satellite has established communication, and early routine operations are underway.

Launching the UAE's first SAR satellite is a significant milestone for the companies and the region to bolster Earth Observation capabilities. The satellite will use SAR technology, an active sensing system that illuminates the Earth's surface and measures the reflected signal to generate high-resolution images. Unlike traditional optical imaging satellites, SAR can capture images day and night, regardless of weather conditions or solar illumination. *www.yahsat.com*

USPACE Technology Group and EgSA form joint venture

USPACE Technology Group Limited has signed a strategic partnership agreement with the Egyptian Space Agency ("EgSA"), in relation to satellite manufacturing and testing, satellite launch, education and training. Both also intend to set up a joint venture in Cairo, Egypt, which will be one of the first commercialised aerospace companies in Egypt, marking a significant milestone in the Group's aerospace business development in the Africa region. The collaboration of companies encompasses a wide range of initiatives, including the establishment of centers for satellite manufacturing, payload design and manufacturing, and component and precision manufacturing at the Egyptian Space City in Cairo Egypt. They will also establish an integrated satellite constellation for remote sensing and communication across the African continent and a globally oriented space laboratory in Cairo. *www.uspace.com*

Amendment to Malaysia's Licensed Land Surveyors opposed by various associations

Malaysia's Institution of Geospatial and Remote Sensing Malaysia (IGRSM) is among a dozen organisations calling for a reconsideration of an amendment to the country's Licensed Land Surveyors Act (1958).

The Legislative Bill D.R. 2/2024 to amend the Licensed Land Surveyors Act (1958) (Akta Juruukur Tanah Berlesen 1958) was approved by the Dewan Rakyat on 25 March 2024 and the Dewan Negara on 4 April 2024. The legislative amendment prevents non-licensed land surveyors (LLS) from conducting geomatic surveys, meaning anyone who is not registered as a LLS with the Land Surveyors Board (LJT) can no longer participate in geomatics surveys.

In addition to IGRSM, the organisations calling for reconsideration of the amendment include the National Hydrographic Association (Malaysia); Malaysian Society of Soil Science: Institute of Electrical and Electronics Engineers; Geoscience and Remote Sensing Society (Malaysia Chapter); Malaysian Society of Agricultural and Food Engineers; Institute of Geology Malaysia; Agricultural Institute of Malaysia; Institute of Foresters Malaysia; International Institute of Plantation Management; Malaysian Society for Engineering and Technology; Malaysian Institute of Planners; and Institute of Landscape Architects Malaysia.

The organisation understands that the Ministry of Natural Resources and Environmental Sustainability conducted engagement sessions on the legislative amendment in 2020 with a few professional boards and government departments. In addition, a survey was conducted through the Malaysian Productivity Corporation's (MPC) web portal from December 18, 2020, to January 15, 2021. The organisations conducted discussion sessions with 41 relevant stakeholders in June and July 2024. Of these stakeholders, 38 stated that their organisations were unaware of the legislative amendment. They were neither informed nor invited to the engagement sessions conducted by the LJT in 2020, even though it significantly impacts their industries. The organisations say the absence of these stakeholders in the engagement sessions raises serious concerns about how the government considered industry requirements and views during the amendment process.

The other three organisations, namely the Board of Engineers Malaysia (BEM), Board of Architects Malaysia (BAM) and Board of Town Planners Malaysia (LPBM), stated that they were involved in the engagement sessions with LJT, but they did not express support for the amendment of the act as approved.

In addition, all 41 stakeholders stated that they did not receive any notice regarding the survey in the MPC portal. This raises questions about the effectiveness of information dissemination and the openness of this process to all parties involved. The legislative amendment stipulates a six-month transitional period for non-LLS geomatics professionals to register with LJT. However, from the organisation's observations, professionals seeking registration must also meet the requirements for LLS registration, which is almost impossible to fulfil. *https://aseantechsec.com*

Institution of Geospatial and Remote Sensing Malaysia raises concerns about amendment to the licensed land surveyors act 1958 and corresponding draft regulations

IGRSM expresses concerns regarding the Amendment to the Licensed Land Surveyors Act 1958 and Corresponding Draft Regulations

Following the Town Hall session held on 9 September 2024 by the Ministry of Natural Resources and Environmental Sustainability, Land Surveyors Board (LJT) and Department of Survey and Mapping Malaysia (JUPEM), we are compelled to express our deep concerns regarding the amendment to the Licensed Land Surveyors Act 1958 (Akta Jurukur Tanah Berlesen 1958) and the accompanying draft regulations (Peraturan-Peraturan Juruukur Tanah Berlesen (Pindaan) 2024). The following points highlight the critical issues arising from the session:

1) Denial of Access to Draft Regulations

Stakeholders were denied and not provided with the draft regulations prior to the session despite our repeated requests, thus preventing us from thoroughly studying and evaluating its impact, as well as proposing suitable amendments. The partial regulations were only briefly presented during the session, followed by a limited Q&A period, leaving insufficient time for stakeholders to engage in a meaningful discussion. Such minimal engagement is unacceptable and inappropriate given the gravity of the regulations particularly to all the stakeholders from various sectors.

2) Ambiguity in the Definition of Geomatics Survey

The definition of geomatics survey in the legislative amendment is given as:

"geomatics survey" means any survey undertaken for the purposes of production of or in connection with, maps, geomatics survey plans or information using survey-accurate techniques

This definition appears to be quite ambiguous, which may lead to confusion among readers, professionals and laypersons. It is concerning that a definition which lacks clarity and transparency carries such significant penalties, including a potential prison sentence of up to three years and / or a fine of up to RM 250,000. We believe with the emphasis of the Madani culture on language and terminology, the definition should be further clarified and articulated in a manner that is both explicit and easily understood.

3) Overly Broad Definition of "Survey-Accurate Technique"

The definition of "survey-accurate technique given as follows is highly inappropriate and unnecessary:

survey-accurate technique means the act or process of determining -

(a) the form, contour, position, area, height, depth or any other particulars of -
- **(i) the earth's surface, whether of land or water; or**
- **(ii) any natural or artificial features on, below or above any part of the earth's surface; or**

(b) the position or the boundary of any part of the earth's surface, or of any natural or artificial features on, below or above any part of the earth's surface, and includes the act or process of making or obtaining any plan therefrom using standards and specifications as determined by the Director General of Survey and Mapping.

The definition gives neither accuracy nor technique, hence its name itself is misleading. It seeks to encompass virtually all geomatic surveys, whether conducted on land, water, natural and artificial features, and above, on and below the Earth's surface. By casting such a wide net, the definition risks unduly restricting non-Licensed Land Surveyors (non-LLS) geomatics professionals who have long provided accurate and reliable geomatics services in areas such as town & country planning, hydrography, agriculture, forestry, geology, landscape architecture and other fields. Such a broad interpretation could stifle innovation and progress in sectors that depend on geomatics expertise beyond the scope of land surveying conducted by LLS.

4) Restrictions on Geomatic Surveys

During the briefing, it was made clear that non-LLS geomatic professionals would no longer be permitted to conduct a wide range of geomatic surveys, including Airborne Survey and Mapping, Hydrographic Survey and Mapping, Survey and Mapping for Building Information Model (BIM), Survey and Mapping for Geospatial Information System (GIS), Terrestrial Survey and Mapping, and Topographic Survey and Mapping. This restriction applies to geomatics surveys for:

- the purpose of any submission to any government authority;
- public purposes; or
- any other purposes as required by any government agency, statutory body, government link company, or company appointed by government

This broad exclusion risks sidelining many experienced geomatic professionals, to the detriment of the development of industries reliant on these services. The regulations appear to reserve all geomatics survey projects by government departments and government linked companies (GLCs) exclusively for LLS. We express our concern on the competitiveness and value for money for government procurement of services.

5) No Pathway for Automatic LLS Registration for Non-LLS Professionals

Despite years of experience in the field and running their own practices, it was truly shocking to observe that no regulations were introduced to absorb non-LLS geomatics professionals to continue working uninterrupted after the legislative amendment is gazetted. Once the amendment is enforced, these professionals will not be able to fulfil the new requirements of procuring projects and tenders, which unfairly wipes out these experts who were providing thus far excellent service to their clientele. Their businesses will suffer, and a number of employees and graduates could be jobless. Ultimately this will impact the Madini Government.

Such being the case, we earnestly urge the Government to resolve this extremely serious issue before it balloons into a larger and uncontrollable problem. **Please consider a moratorium on the amendment to resolve the problems of loss of livelihood of existing professionals.**

Based on the briefing given at the Town Hall session, non-LLS geomatics professionals have not been offered direct absorption to be licensed and continue their work. The procedure listed is actually for new entrants to the field as they would need to go through a lengthy process to be registered as LLS, which would involve training in fields that they may not even be working on. This includes a period of two years as Articled Pupil, including for non-LLS surveyors with degrees in geomatics and surveying. For non-LLS geomatics professionals, they would need to undergo bridging exams to qualify to become Articled Pupil.

During this time, whether these professionals can continue practicing remains solely at the discretion of LJT, a situation that could undoubtedly disrupt current practices and lead to significant delays in project execution.

Furthermore, the briefing did not clearly specify the qualifications recognised by LJT for registration as LLS via the bridging method, leading to further uncertainty.

6) Limitations on Government Surveyors

The requirement for all government departments to have their staff authorised by the Director General of Survey and Mapping to conduct geomatics surveys may have repercussions if these departments do not get sufficient staff authorised. Have the government departments, GLCs and local authorities been consulted prior on these amendments which has serious ramifications?

From our understanding of the briefing given at the session, the authorisation of public officers to undertake geomatic surveys will be limited to specific posts, which are Surveyor (*Juruukur*), Geospatialist (*Jurugeospatial*), and Assistant Surveyor (*Penolong Juruukur*). This poses a serious challenge for public departments that do not have these positions within their organisational structures. These departments may either have to create new posts or hire LLS for their geomatics surveys, adding to costs and administrative burdens to their operations.

7) Ensuring Protections and Preventing Misuse

For geomatics professionals who have been working legally and diligently, it is crucial to ensure that their rights and livelihoods are not unduly compromised by these changes. In order to prevent potential misuse of licenses and ensure ethical practices, the Government should consider implementing stringent deterrents and penalties for any unethical subcontracting practices. The Valuers, Appraisers, Estate Agents and Property Managers Act 1981, particularly Sections 24 and 30, could serve as a useful reference for creating such safeguards. Additionally, including whistleblower protections to safeguard individuals who report such abuses is highly recommended.

Conclusion

The changes proposed by the Ministry of Natural Resources and Environmental Sustainability, LJT and JUPEM are poised to significantly disrupt current practices in various sectors, including town & country planning, hydrography, agriculture, forestry, geology, landscape architecture and many others. We urge the Ministry to reconsider these amendments and engage in a more inclusive and transparent dialogue with all affected stakeholders. The current approach not only risks stifling industry innovation but also undermines the contributions of many geomatics professionals.

It is essential that significant legislations affecting specific groups undergo a thorough consultation process, with stakeholder feedback being properly incorporated. Unfortunately, we were neither consulted nor provided with the draft regulations in advance, receiving only a short and insufficient briefing. This lack of engagement is deeply disappointing and undermines transparent decision-making.

We call for the immediate dissemination of the draft regulations and an extension of the consultation period to ensure that all stakeholders can provide informed feedback. It is essential that any legislative changes reflect the full spectrum of professional practices in the geomatics industry and avoid the risk of monopolising critical sectors.

This press release was issued on 12 Sepetember 2024 by the Institution of Geospatial and Remote Sensing Malaysia (IGRSM).

A2Z Drone Delivery launches portfolio of drone docks

A2Z Drone Delivery has launched a portfolio of autonomous drone docks and a companion UAV adapted for the system's automatic charging capability. It offers the unique ability for UAVs to move from dock-to-dock to automatically top off batteries and pick up or deliver packages, infinitely expanding the drone's service area. It is offering multiple variants of its portable single-drone docks and permanent multi-drone docks. *www.a2zdronedelivery.com*

UAVOS tested drone navigation with advanced computer vision

UAVOS partnered with its client to test UAVOS' autopilot system using computer vision. Its Engineering Service supported this testing with its advanced avionics system integrated into its unmanned helicopter. The use of computer vision in drone navigation systems is an advanced approach that aims to set up new standards for autonomous drone navigation and safety. The UAVOS autopilot system leveraged advanced computer vision and AI to navigate the UAV in GNSS-denied. The onboard computer vision-based alternative navigation module with deep learning algorithms provided the UAVOS avionics system with the geospatial coordinates. *www.uavos.com*

YellowScan, Nokia partner for 5G lidar mapping

YellowScan and Nokia have announced a strategic partnership with integration of the YellowScan Surveyor Ultra Lidar scanner into the Nokia Drone Networks solution.

It focuses on automation of 5G based LiDAR scanning on drones for telecommunications tower and utilities inspections, mining use cases, where precision, efficiency, and safety are paramount. The joint development plans of both companies bear the potential to reduce the operational cost of industrial inspections in the selected verticals by more than 60%. *www.yellowscan.com*

WingtraCLOUD

Wingtra has enhanced its WingtraCLOUD software platform with new map processing features, aimed at simplifying the integration of aerial data into sectors like construction, mining, and urban planning. These upgrades are designed to facilitate a smoother transition for engineering firms and users from UAV data to actionable insights. By consolidating all stages of aerial data management—from mission planning to insight sharing—into one platform, WingtraCLOUD reduces the need for multiple complex tools, streamlining workflows. *wingtra.com*

uAvionix Achieves FAA TSO Certification

uAvionix has announced that the ping200XR Mode S ADS-B transponder with integral aviation GPS, has received Technical Standard Order (TSO) certification from the Federal Aviation Administration (FAA). This milestone is the latest major TSO certification for uAvionix and offers the lowest certified Size, Weight, and Power (SWaP) solution for worldwide airspace compliance.

The ping200XR TSO has received TSO-C112e and TSO-C166b for transponder and ADS-B functionality, TSO-C88b for its internal pressure altimeter, and TSO-C145e for the integral aviation GPS. *uavionix.com*

Skyfront releases UAV magnetometer

Skyfront MagniPhy is a UAV magnetometer designed for applications such as surveying, mineral prospecting, locating orphaned wellheads, and detecting landmines and unexploded ordnance (UXO). It boasts a new enclosure and a universal attachment mechanism, making it compatible with various third-party magnetometer sensors and UAV models, including DJI, ArduPilot, and PX4-based drones. Developed in partnership with Geometrics, creators of the MagArrow II UAS-enabled magnetometer, the MagniPhy is available for current MagArrow users through retrofit services, as well as for new users seeking seamless integration. *skyfront.com*

Telespazio secures contract for Italy's satellite navigation centre

Telespazio has been awarded, as the first contractor of a team composed of Italian universities, research centres and industrial companies, the call by the Italian Space Agency (ASI) for the creation of the "National GNSS Competence Centre".

The Centre, housed in the Telespazio headquarters in Rome, will aim to create a laboratory that will use resources distributed throughout the national territory, at the offices of the various team members, for the development of new capabilities, solutions and technologies to face current and future challenges in the field of satellite navigation.

The team includes the National Institute of Metrology Research (INRiM), the Italian Aerospace Research Centre (CIRA), Qascom and the National Inter-University Consortium for Telecommunications (CNIT) with the Research Units of the University of Pisa, the Polytechnic of Turin, the University of Padua and the University of Roma Tre.

The "National GNSS Competence Centre" will allow scientific and technological skills to be shared, while providing third parties with management skills for complex projects in the field of satellite navigation. The Centre will also develop new software for monitoring the performance of GNSS services, as well as testing new receivers. A specific collaborative cloud platform will provide the development software capabilities to be used by all the entities participating in the project and by future users of the laboratory.

The distributed form of the Centre, in fact, aims over time to involve other academic realities, research centres and other industrial realities, with the aim of sharing skills and knowledge to develop new innovative technologies and promote their transfer to the market.

In the area of training, the Centre aims to become a national landmark for the dissemination of satellite navigation expertise, organising specific workshops and courses intended for both university students in STEM disciplines and professionals in the field. *www.telespazio.com*

Digital MEMS accelerometer by TDK Corporation

TDK Corporation has introduced the AXO314, the latest addition to its Tronics AXO300 accelerometer series. It is engineered for industrial applications exposed to shock and vibration, featuring a ±14 g input range. It employs a closed-loop architecture to ensure linearity and high vibration rejection, providing a low-size, weight, and power (SWaP) digital alternative to tactical-grade quartz accelerometers. It has a one-year composite bias repeatability of 1 mg and bias instability of 4 µg. *www.tdk-electronics.tdk.com*

Propeller and GEODNET partnership

Propeller has announced a partnership with GEODNET to elevate its survey-grade mapping solutions. By integrating GEODNET stations into the Propeller Corrections Network, it can now deliver even more precise data to its customers. Propeller has developed a fully integrated PPK mapping workflow that works across a wide range of commercial drones. *www.propelleraero.com*

TrustPoint is awarded SpaceWERX contracts

TrustPoint has been selected by SpaceWERX for two Direct-to-Phase II contracts, in the amount of $3.8M total, focused on demonstrating the company's GPS-independent ground control segment and an advanced PNT security application. The Air Force Research Laboratory and SpaceWERX, the innovation arm of the U.S. Space Force and a unique division within AFWERX, have partnered to streamline the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) process by accelerating the small business experience through faster proposal to award timelines, changing the pool of potential applicants by expanding opportunities to small business and eliminating bureaucratic overhead by continually implementing process improvement changes in contract execution. *trustpointgps.com*

Aerial reconnaissance and elimination system

Skylark Labs has unveiled the Aerial Reconnaissance and Elimination System (ARIES), aimed at improving situational awareness and addressing emerging threats. It leverages artificial intelligence (AI) to detect, classify, and respond to threats in real-time, continuously adapting to new challenges across various domains without needing manual updates. This enhances situational awareness and speeds up decision-making for military personnel.

The system can detect and track UAVs beyond visual line of sight (BVLOS), boosting the range and effectiveness of counter-unmanned aerial system (C-UAS) operations while providing early warnings for swift threat responses. ARIES integrates seamlessly with existing defense infrastructure, reducing the need for frequent manual updates and enhancing mission success rates. *skylarklabs.ai*

Packaged PNT solution by OneWeb Technologies

Astra™ solution by OneWeb Technologies is designed to ensure seamless LEO SATCOM connectivity and operational performance when GPS/global navigation satellite signals (GNSS) are unavailable or compromised. It is the first packaged solution consisting of a software-defined outdoor receiver with access to A-PNT broadcast service to enhance connectivity resilience available in the market. The Astra receiver processes PNT signals from GNSS and other alternate sources and frequency bands. This advanced capability enables continuous connectivity and situational awareness even in very harsh spectrum-contested campaigns by adversaries. In fitting with the military's Primary, Alternate, Contingency, Emergency (PACE) communications plan considerations, Astra establishes options for resilient communications capabilities and ensures the continuity and success of critical missions. *onewebtechnologies.net*

Topcon releases upgraded surveying software

Topcon has released a new version of its computer-aided design (CAD) software suite, formerly known as MAGNET. Version 9 is also renamed under the Topcon software suite as the business retires the MAGNET brand.

The software is designed for professionals such as surveyors, engineers, modelers etc. It can be used as standalone, office-based CAD software or as a cloud-connected solution that integrates field and office operations with Topcon or Sokkia survey instruments. The platform offers user-friendly and versatile configurations suitable for various applications. *www.topconpositioning.com*

Hanwha Defence Australia, Hanwha Aerospace, and Advanced Navigation sign MoU

Advanced Navigation, Hanwha Aerospace and Hanwha Defence Australia (HDA have signed a Memorandum of Understanding (MoU) to co-develop strategic-grade APNT solutions. The agreement will see the three companies collaborate on the development of high-performance inertial navigation systems (INS) for autonomous, airborne and crewed systems. This will be used for precision targeting and vehicle navigation in global navigation satellite system (GNSS)-contested environments across land and air domains. *www.advancednavigation.com*

GMV for SIRTAP UAS navigation system development

GMV has been selected by Airbus to develop the navigation system of the tactical UAS SIRTAP (High Performance Remotely Operated System). The contract covers both the equipment on board the aircraft and the ground augmentation station to improve navigation accuracy during takeoff and landing.

The SIRTAP remotely piloted aircraft is designed for advanced intelligence, surveillance, and reconnaissance (ISR) missions (day and night), both on land and at sea.

The High Performance Remotely Piloted System (SIRTAP) will provide a performance leap in the high-end tactical unmanned aircraft segment. Its dual applications, both in support of civilian and military operations, will offer a wide range of missions tailored to the operational needs of institutional and government clients. *www.gmv.com*

EGNOS safety of life service for aviation SDD v3.6

The new EGNOS SoL Service for Aviation SDD introduces several updates designed to improve the precision, reliability, and safety of satellite navigation services in aviation.

One of the standout features in SDD v3.6 is the introduction of updated commitment maps. These maps visually represent the regions where EGNOS commits to delivering a specific level of service performance. The new maps bring significant improvements in service availability, particularly across the North, East, and West, offering aviation users a clearer understanding of where they can expect the highest levels of accuracy and reliability.

The document also highlights updates to the EGNOS architecture, covering both space and ground segments. The space segment update provides the latest information on the GEO satellites delivering EGNOS services. On the ground, the expansion of the RIMS network, including a new site in Kuusamo, Finland, strengthens the system's robustness, particularly in remote and challenging environments.

Another significant update in this version is the detailed analysis of ionospheric activity's impact under Solar Cycle 25, which began in December 2019 and

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MARK YOUR CALENDAR

October 2024

4th International Conference on Environmental Management (ICEM 2024)
4-7 October
Hyderabad India
https://icem2024jntuh.orgm

Vexcel Open Day India
7-9 October, 2024
Bengaluru, India
www.vexcel-imaging.com

Romanian Surveying Week
23 - 26 October 2024
Bucharest, Romania
https://sgr.ugr.ro

November 2024

K-GEO Festa 2024
6-8 November
Seoul, South Korea
https://kgeofesta.kr/fairDash.do?hl=ENG

IAG Workshop on Asia Pacific Gravity, Geoid, and Vertical Datums
06-08 November 2024
Philippines - Manila
https://iagworkshop2024.dge

Trimble Dimensions
11-13, November 2024
Las Vegas, USA
www.trimble.com

45th Asian Conference on Remote Sensing
17-21 November 2024
Colombo, Sri Lanka
www.survey.gov.lk

UN/Spain Workshop on GNSS and Related Space Technologies
18 - 22 November 2024
MÃ LAGA, SPAIN
www.unoosa.org

2024 Pacific Islands GIS & Remote Sensing User Conference
25 - 29 November
Suva, Fiji
https://pgrsc.org

GeoWorld
26-28 November 2024
Dubai, UAE
www.geoworldevent.com

December 2024

K-GEO Festa 2024
6-8 November
Seoul, South Korea
https://kgeofesta.kr/fairDash.do?hl=ENG

Workshop on GNSS
10-13 December 2024
https://soict.hust.edu.vn/navis

February 2025

GEO WEEK
10-12 February 2025
Colorado, USA
www.geo-week.com

is expected to peak around 2025. This extreme solar activity poses challenges to satellite navigation. The document offers insights into how EGNOS continues to maintain reliable performance, even under adverse ionospheric conditions. *www.euspa.europa.eu*

UK to build new £20m anti-jamming test facility

The UK Ministry of Defence will build a new anti-jamming test facility at Boscombe Down in Wiltshire, England, aimed at protecting military equipment from GPS jamming threats. The £20 million ($26 million) contract has been awarded to the defense technology company QinetiQ, which will develop one of Europe's largest anechoic chambers, scheduled to be operational by 2026.

This facility, known as a "silent hangar," will be capable of accommodating large military assets, including Protector UAVs, Chinook helicopters, and F-35 fighter jets, allowing for thorough testing against electronic warfare threats. Maria Eagle, the Minister for Defence Procurement and Industry, stated that the facility will address vulnerabilities in military systems, thereby enhancing national security and better safeguarding the armed forces during global deployments.

Engineered to minimize radio-frequency wave leakage, the hangar will ensure that testing does not disrupt local emergency services or air traffic control. Additionally, the UK Ministry of Defence anticipates that the project will create 20 new jobs in the Boscombe Down area and offer benefits beyond defense, supporting various government and industry sectors. *ukdefencejournal.org.uk*

UP42 and Planet partnership

UP42, announced a partnership with Planet Labs PBC. This collaboration significantly expands UP42's optical data portfolio with the integration of Planet SkySat, the world's largest constellation of high resolution Earth observation satellites. *up42.com*