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Article

# Comprehensive Assessment of Satellite Visibility and Positioning Accuracy in Benghazi: A 24-Hour GNSS Evaluation in the Al-Salmani Al-Gharbi Region

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**Abstract:** Using the Trimble Online GNSS Planning Tool, a comprehensive analysis was conducted to evaluate the satellite visibility and positioning accuracy in the city of Benghazi, specifically in the Al-Salmani Al-Gharbi area. The study was structured around a 24-hour period, spanning from 12 AM to 11:59 PM Libyan time. This timeframe was selected to assess the satellite availability and the corresponding Dilution of Precision (DOP) values for both GPS and Galileo satellite systems, which are crucial for accurate navigation and positioning. Initially, the analysis focused on the GPS satellites. Upon selecting the geographical coordinates for the specified location, a total of 32 GPS satellites were identified as available within the observed timeframe. Each satellite exhibited varying visibility durations, influenced by its elevation angle, which is a critical parameter in GNSS applications. The elevation angle of satellites is pivotal since higher angles generally provide more reliable signals, leading to improved accuracy in positioning. During this evaluation, it was observed that the number of visible GPS satellites fluctuated between 6 and 11 at different times throughout the day. Following the assessment of GPS satellites, a similar process was executed for the Galileo satellite system. The analysis revealed that there were 29 Galileo satellites available within the same 24-hour period. The visibility of these satellites also varied, with the number of satellites observed ranging from 5 to 10. The monitoring of DOP values during this period was essential, as it provides insight into the potential accuracy of the positioning solutions derived from satellite signals. To gain a more comprehensive understanding of the satellite availability, both GPS and Galileo satellites were considered simultaneously. This combined analysis resulted in a total of 61 satellites being available. Notably, the monitoring revealed that the maximum number of satellites visible at any given time reached 18. This figure exceeds the satellite counts observed when each system was evaluated individually, showcasing the benefits of utilizing both satellite systems together. The increase in the number of simultaneously visible satellites is particularly advantageous for navigation and tracking applications. A higher satellite count typically leads to lower positioning errors, as it enhances the geometric configuration of the satellite signals. Consequently, the DOP values calculated during this analysis demonstrated lower readings when both GPS and Galileo satellites were combined, compared to the isolated evaluations of each system. This reduction in DOP values indicates a higher potential accuracy for navigation and location determination, thereby minimizing the error percentage associated with positioning solutions.

**Keywords:** GNSS, Satellite Visibility, GPS, Galileo, Dilution of Precision, Satellite Systems.

## 1.Introduction

Global Navigation Satellite Systems (GNSS) have become an indispensable tool for various applications, ranging from precise navigation and positioning to geospatial data collection and timing services [1,2,3]. With the proliferation of satellite constellations such as the Global Positioning System

(GPS) and Galileo, understanding satellite visibility and the resulting positioning accuracy is critical for ensuring optimal performance in urban environments [4,5]. This study focuses on the Al-Salmani Al-Gharbi area of Benghazi, Libya, to evaluate the visibility of GNSS satellites and assess the associated Dilution of Precision (DOP) values over a 24-hour period.

The urban landscape can significantly impact satellite visibility due to obstructions caused by buildings and topography, which can lead to increased multipath effects and reduced signal quality [6,7]. Urban environments pose unique challenges for GNSS performance, requiring a thorough analysis of satellite availability and positioning accuracy in such settings [8,9]. The selection of a 24-hour timeframe, from 12 AM to 11:59 PM local time, allows for a comprehensive evaluation of satellite geometry and visibility throughout the day, capturing variations due to factors such as atmospheric conditions and satellite orbits.

In addition to GPS, the integration of the Galileo system, which offers enhanced accuracy and reliability, is paramount for improving positioning capabilities in urban areas [10,11]. According to data from the European GNSS Agency (2020), Galileo provides improved DOP values compared to traditional GPS systems, making it crucial for applications requiring high precision [12]. This study employs the Trimble Online GNSS Planning Tool to analyze satellite availability and DOP values for both GPS and Galileo systems, thereby providing insights into the potential for high-accuracy applications in Benghazi. The findings of this analysis will contribute to the understanding of GNSS performance in urban settings and may inform future developments in navigation technologies and urban planning strategies.

## 2. Simulation Results

Figure 1 illustrates the specific location from which the challenge was initiated, situated in the vibrant city of Benghazi, specifically within the Al-Salmani Al-Gharbi area. The geographical coordinates of this point are precisely N 32° 6' 58.3" and E 20° 5' 9.8", placing it in a notable position on the global map. The observation point is at an elevation of 58.5 meters above sea level, providing a vantage point that is conducive to a variety of observational and analytical activities. On April 28, 2025, the observations were conducted within the context of Libyan time, which is UTC+2. The viewing angle was set to 15 degrees and above, allowing for a focused examination of the surroundings, which likely facilitates a comprehensive understanding of the area's topography and other relevant features.

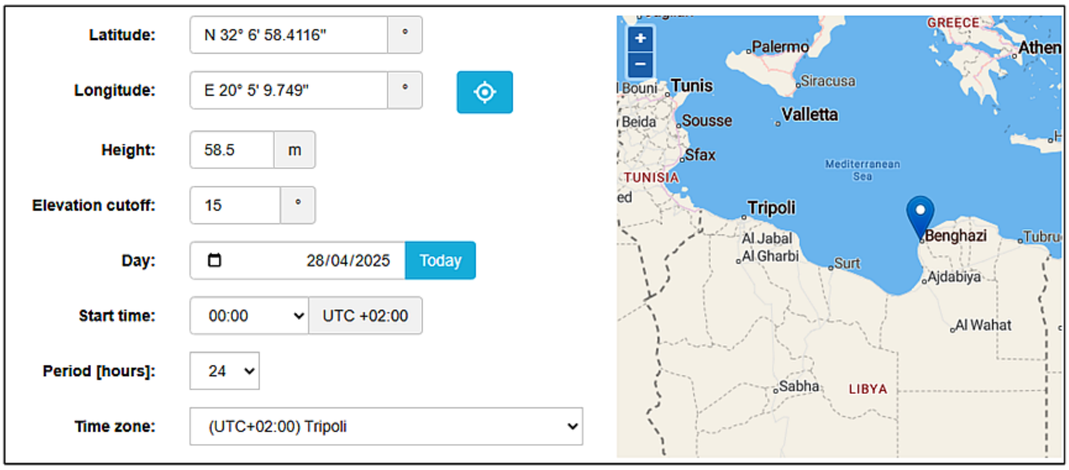


Figure 1: Trimble's GNSS planning Tool.

The choice of this particular date and time for the challenge is significant, as it may correspond to specific environmental or operational conditions that were deemed advantageous for the objectives of the challenge. Given the 24-hour duration of the observations, this setup allows for a thorough assessment of the area over different times of the day, capturing variations in light, visibility, and potentially other dynamic factors that could influence the results.

Figure 2 presents the Sky Plot of GPS satellites at 13:30, offering a visual representation of the satellite positions relative to the observation point. In this plot, the satellites' elevation angles are depicted, illustrating their ability to contribute to accurate geolocation. As satellites move closer to the center of the plot, they approach a 90° elevation angle, which significantly enhances their effectiveness in determining precise locations. This is crucial for achieving high accuracy in GPS measurements.
Among the satellites displayed, the G16 satellite stands out as it is positioned closest to the center of the plot, boasting an elevation angle of approximately 69°. This relatively high elevation angle indicates that G16 is well-placed to provide strong signals, thereby improving the potential for accurate positioning data. The closer a satellite is to the zenith (the point directly overhead), the less atmospheric interference its signals encounter, resulting in more reliable GPS readings.

In addition to G16, several other satellites are also contributing to the overall position fix. The G10, G26, and G23 satellites are situated at elevation angles around 55°. Although not as optimal as G16, these satellites are still positioned favorably, offering valuable signals that can enhance the accuracy of location determinations. The signals from these satellites can help triangulate the user's position, especially when combined with those from higher elevation satellites.

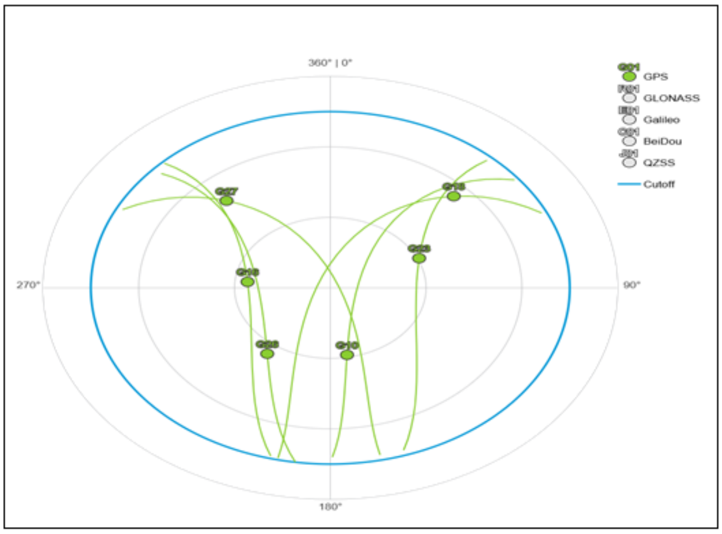


**Figure 2:** Sky plot of GPS Satellites.

While these satellites can still provide useful data, their lower elevation angles mean that their signals may be subjected to greater atmospheric distortion and multipath effects. As a result, their contributions to the overall positioning accuracy may be less significant compared to the satellites positioned at higher angles.
Figure 3 presents a comprehensive overview of the GPS system, showcasing the visibility of 32 satellites over a 24-hour period. This depiction is essential for understanding how satellite positioning and elevation angles affect the accuracy of GPS readings. In the context of GPS technology, the visibility of satellites is a critical factor influencing the quality of positional data that can be obtained. Each satellite's elevation angle, measured from the observer's location, plays a significant role in determining how effectively it can provide accurate positioning information. The closer the elevation angle of a satellite is to 90 degrees, the more optimal its position becomes for signal reception. This high elevation angle minimizes the effects of atmospheric interference and multipath errors, which occur when signals reflect off surfaces before reaching the receiver [13].

A satellite positioned at or near 90 degrees is located almost directly overhead, resulting in a stronger, clearer signal that travels a shorter distance through the Earth's atmosphere. This spatial arrangement ensures that the signal is less distorted by atmospheric conditions, improving the overall precision of the GPS readings.

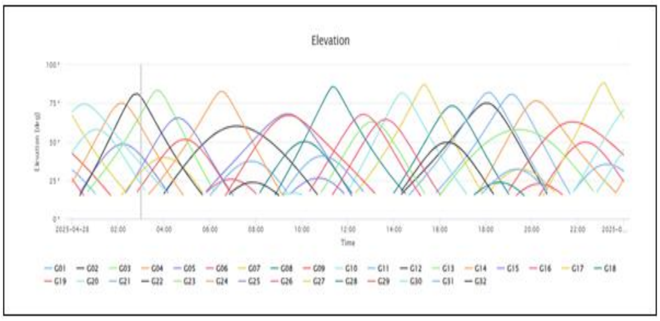


**Figure 3:** The elevation angle of 32 GPS Satellites.

Conversely, satellites at lower elevation angles, particularly those below 30 degrees, may be hindered by various factors, including increased atmospheric attenuation and potential obstructions from buildings or natural terrain [14]. The 24-hour visibility chart in Figure 3 allows users to assess how the position of each satellite changes throughout the day. This dynamic view illustrates the continuous movement of satellites in their respective orbits as the Earth rotates, showcasing periods when certain satellites are more or less visible from the observation point. Users can identify optimal times for GPS observations, maximizing the number of satellites available at elevated angles to enhance the accuracy of their position fixes [15].

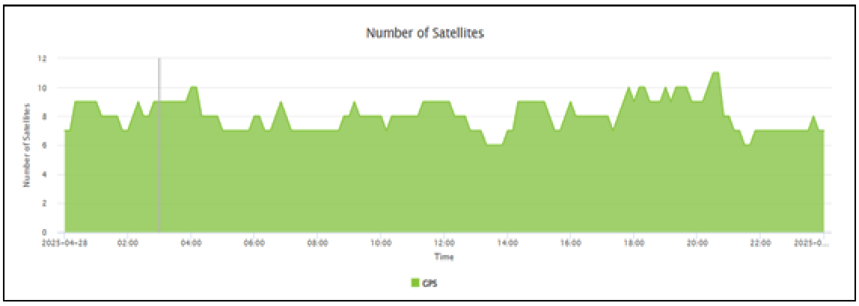


**Figure 4:** Number of GPS satellites in view during a 24-hour cycle.

Figure 4 illustrates the availability of GPS satellites over the course of a 24-hour period, offering valuable insights into how satellite visibility fluctuates throughout the day. The graph highlights that the number of available satellites ranged from 6 to 11 at any given time, and this variability significantly impacts the accuracy and reliability of location determinations. In GPS technology, the effectiveness of positioning is closely linked to the number of satellites that a receiver can access. A greater number of visible satellites enhances the ability to triangulate a precise location, as the system can leverage signals from multiple sources to compute position more accurately. Generally, the more satellites in view, the better the results, as this increases the redundancy of the data and reduces the potential for errors [16].

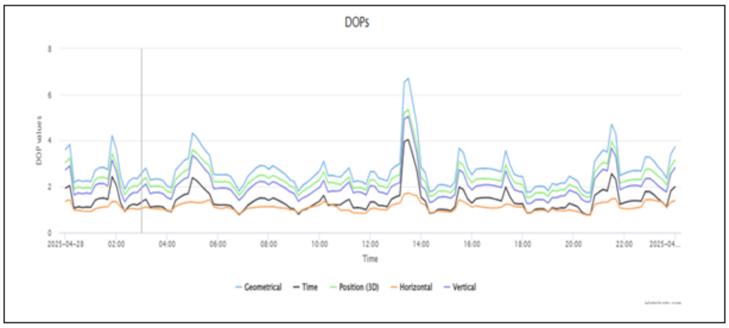


**Figure 5:** DOPs values during 24-hour for GPS Satellites.

Figure 5 provides a detailed illustration of the Dilution of Precision (DOP) values calculated over a 24-hour period, serving as a key indicator of the geometric strength of satellite configurations in relation to the GPS receiver's positional accuracy [9]. The DOP values are derived based on the relative positions of the satellites within the receiver's field of view, and their variation directly impacts the reliability and precision of the GPS positioning. When satellites are arranged in a way that offers a well-distributed geometric configuration, meaning they are spread out across the sky, the DOP values tend to be low, signifying high positional accuracy and reliability. Conversely, when satellite geometry is poor, with satellites clustered in a small part of the sky or at unfavorable angles, the DOP increases, indicating a higher potential for positional errors [17].

An interesting observation from the figure is the notable spike in DOP values around 1:30 PM. At this particular time, the DOP was considerably elevated, which corresponds to a moment of diminished positional precision. This spike is attributable to the observed satellite configuration at that time, which was characterized by a relatively low number of satellites in view, only 6 satellites were observed during this period, representing the lowest count throughout the entire 24-hour window. Moreover, the elevation angles of these satellites ranged from 35 to 68 degrees. While these angles are generally acceptable, a lower number of satellites combined with less optimal geometric distribution can significantly compromise position accuracy.

In comparison, early in the morning at 9:10 AM, the DOP values were observed to be very low, indicating highly reliable GPS positioning during this time period. During this morning window, the number of satellites in view was higher, 9 satellites were detected, which typically enhances positional accuracy. The elevation angles at this time ranged from 15 to 67 degrees, demonstrating a broader distribution of satellite positions across the sky, which is beneficial for precise navigation solutions. The combination of more satellites and favorable geometric arrangement resulted in minimal positional error, underscoring the importance of satellite geometry and quantity in achieving optimal GPS performance.

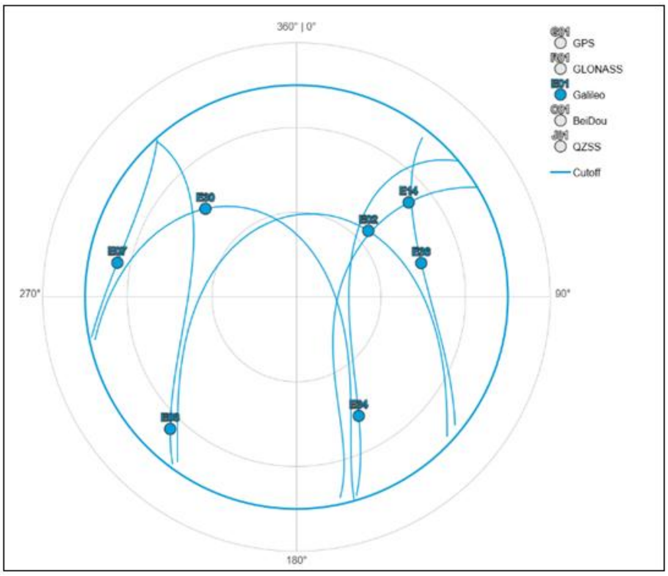


**Figure 6:** Sky plot of Galileo Satellites.

Figure 6 presents a detailed depiction of the Galileo satellites at 8:30 AM. Upon examining the image, it is evident that there is a total of seven satellites visible at this specific moment. As the satellites move closer to the center of the diagram, their corresponding angles tend to converge towards 90 degrees, which is a crucial aspect of satellite positioning.

At this time, we can observe that the elevation angle for satellite E02 is approximately 55 degrees, indicating a relatively favorable position for receiving signals. In contrast, satellite E07 is positioned at a much lower elevation angle of around 25 degrees. The difference in these angles is significant, as it can impact the overall accuracy of the positioning data being transmitted.

Additionally, it is important to note that the accuracy of the positioning system is often reflected in the DOP (Dilution of Precision) readings. At this specific time, the DOP values were notably high, suggesting that the positioning accuracy may not be optimal. High DOP values typically indicate that the satellites are not well-distributed in the sky relative to the receiver, which can lead to less accurate positioning results.

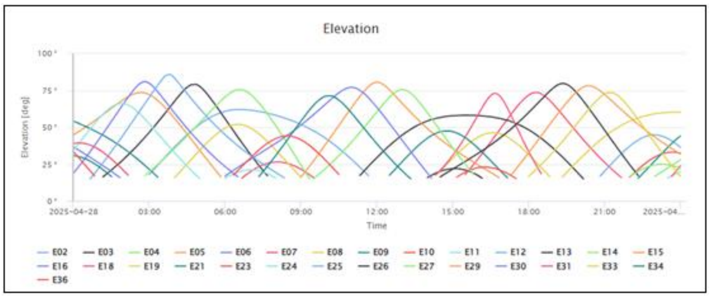


**Figure 7:** The elevation angle of 29 Galileo Satellites.

Figure 7 provides a comprehensive visualization of the Galileo 29 satellites and their visibility patterns throughout a 24-hour period. The diagram tracks the position and orientation of each satellite relative to a fixed observation point, illustrating how their visibility fluctuates over time.

One key aspect highlighted in the figure is the viewing angle, which is measured from the observer's perspective. Specifically, the angles are marked from E02 to E36, representing different points or time intervals during the day. It is important to note that the accuracy of the readings obtained from these satellites is significantly influenced by the viewing angle. When the viewing angle approaches 90 degrees that is, when the satellite appears nearly perpendicular to the observer's line of sight the measurements tend to be more precise and reliable. This is because at such angles, the signals are less affected by atmospheric interference and positional distortions, resulting in higher data fidelity.

Conversely, when the viewing angles deviate significantly from 90 degrees, either being more acute or more obtuse, the accuracy of the satellite readings may diminish. Understanding these angle-dependent variations is crucial for optimizing satellite tracking and data collection strategies, ensuring that measurements are taken at the most favorable angles for maximum accuracy. Overall, the figure emphasizes the dynamic nature of satellite visibility and the importance of angle considerations in geospatial and navigation applications.

Figure 8 presents an analysis of the availability of Galileo satellites over a 24-hour period. Throughout this timeframe, the number of accessible satellites fluctuates between 5 and 10. Generally, a higher number of satellites contributes to more accurate positioning results. Several specific intervals highlight the variability in satellite availability. For instance, from 10:40 to 11:40, 11:50 to 12:20, 13:30 to 13:50, 19:00 to 19:10, and 20:20 to 20:40, we see notable changes in the number of satellites accessible. A particularly low point occurs at 21:50, when only 5 satellites are available, the lowest count recorded during this period.

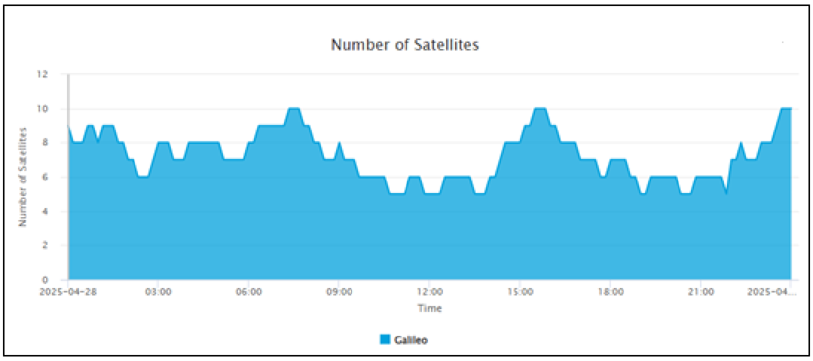


**Figure 8:** Number of Galileo satellites in view during a 24-hour cycle.

On the other hand, there are moments of peak satellite availability as well. Notably, from 7:20 to 7:40, 15:30 to 15:50, and 23:40 to 00:00, the system reports a maximum of 10 accessible satellites. This variation in satellite availability underscores the importance of timing for achieving optimal positioning accuracy.

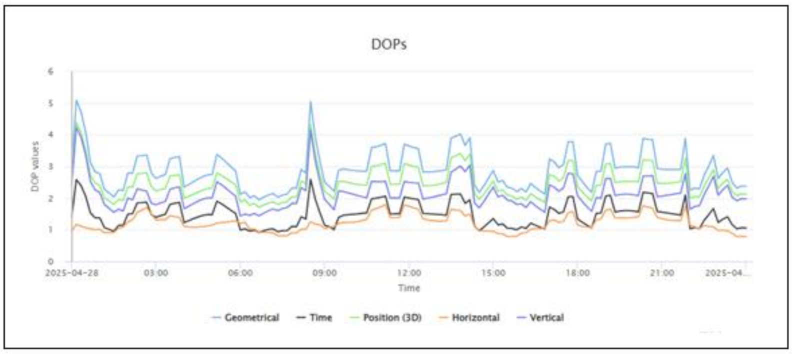


**Figure 9:** DOPs values during 24-hour for Galileo Satellites.

Figure 9 presents the Dilution of Precision (DOP) values recorded over a 24-hour period, illustrating the relationship between satellite configuration and positioning accuracy in GPS receivers. DOP is a critical metric that indicates the precision of a GPS solution; lower DOP values correspond to better positioning accuracy, while higher values suggest greater potential for error [18].

Throughout the observed period, it is evident that DOP values fluctuate significantly based on the satellites within the receiver's field of view. Optimal satellite configurations, characterized by a wide angular distribution, yield low DOP values and consequently enhance the reliability of GPS positioning. Conversely, suboptimal configurations lead to elevated DOP values, which can introduce substantial positioning errors.

Notably, during the times of 00:10 and 08:30, the DOP readings were particularly high, indicating significant positioning errors. At these intervals, the number of satellites in view was 8 and 7, respectively, with the highest elevation angles recorded at 53 and 55 degrees. Despite a sufficient number of satellites, the suboptimal geometry resulted in elevated DOP values, highlighting the importance of satellite positioning over mere quantity. Similarly, at 01:30 and 16:50, the DOP values remained high, with readings of 64 and 71, respectively. During these times, the number of satellites observed was 9 and 8. The high DOP values recorded at these times again suggest that, despite having a relatively high number of satellites, the geometric configuration was not conducive to accurate positioning.

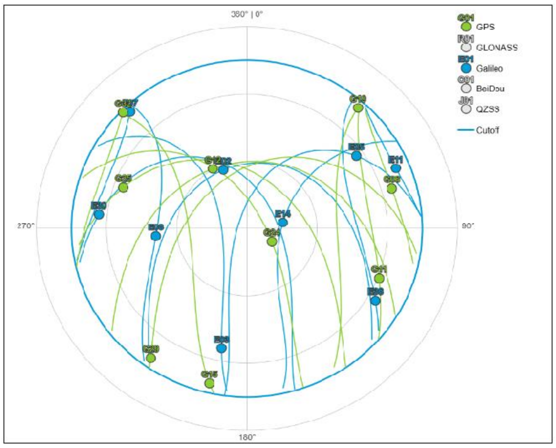


**Figure 10:** Sky plot of GPS and Galileo Satellites.

Figure 10 depicts the simultaneous visibility of GPS and Galileo satellite constellations at epoch 06:50:00 UTC. In this visualization, green markers denote the positions of eight visible GPS satellites, while blue markers represent eight visible Galileo satellites. This combined constellation count of 16 satellites represents the maximum co-visible availability achievable during the analyzed 24-hour observation period.

The geometric configuration of these satellites yields favorable Dilution of Precision (DOP) parameters. This optimized spatial distribution directly contributes to enhanced positioning solution accuracy and reduced measurement uncertainty compared to suboptimal satellite geometries.

Notably, satellites GPS E14 and Galileo G24 occupy positions near zenith (elevation ≈ 90°). Signals received from satellites at such high elevations experience significantly reduced tropospheric delay and minimal multipath interference effects. Consequently, measurements from E14 and G24 exhibit higher signal integrity and are consequently assigned greater weight in positioning solutions, making them particularly valuable contributors to solution reliability.

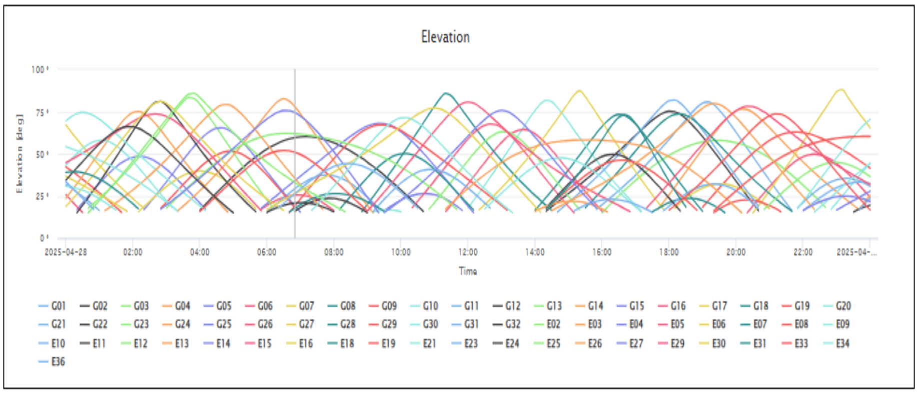


**Figure 11:** The elevation angle of 32 GPS and 29 Galileo Satellites.

Figure 11 depicts the elevation angles of a total of 61 satellites monitored over a 24-hour period, comprising 32 GPS satellites and 31 Galileo satellites. The data indicates that satellites with elevation angles closer to 90 degrees generally yield more accurate positioning results and are associated with lower error margins. Specifically, at 15:20, the G27 satellite reaches an elevation of 87 degrees; at 3:50, the A25 satellite attains an elevation of 86 degrees; and at 11:20, the G18 satellite is observed at an elevation of 86 degrees. These observations underscore the importance of satellite elevation in influencing the precision of positioning measurements.

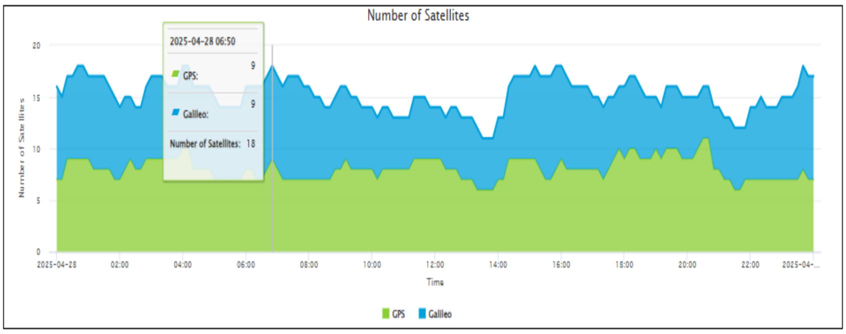


**Figure 12:** Number of GPS and Galileo satellites in view during a 24-hour cycle.

Figure 12 provides a comprehensive illustration of the number of available GPS and Galileo satellites, visually represented with distinct color coding, green for GPS satellites and blue for Galileo satellites, across a 24-hour observation period. This graphical representation is crucial for understanding the dynamics of satellite availability, which directly impacts navigation and positioning accuracy. To delve deeper into the data presented in this figure, it is noteworthy that at 6:50, the total count of available satellites peaks at an impressive 18. This figure comprises an equal distribution of 9 GPS satellites and 9 Galileo satellites. Such a balanced availability of satellites is significant, as it enhances the robustness of the positioning solutions provided to users. The presence of multiple satellites from different constellations allows for better triangulation, reducing the potential for error in positioning data.

The importance of satellite availability cannot be overstated; a higher number of visible satellites correlates directly with improved accuracy in readings. With more satellites in view, the system can utilize signals from various angles, which is essential for mitigating the effects of atmospheric disturbances and other factors that can introduce errors into positioning calculations. This redundancy is a vital feature of modern navigation systems, enabling them to maintain high levels of performance even in challenging environments [19-21]. Furthermore, the data illustrated in Figure 13 highlights the operational advantages of utilizing both GPS and Galileo systems. By leveraging the strengths of both satellite networks, users can experience enhanced reliability and accuracy in their navigational solutions. The convergence of signals from these two systems allows for a more comprehensive coverage, ensuring that users are less likely to encounter situations where satellite signals are weak or unavailable.

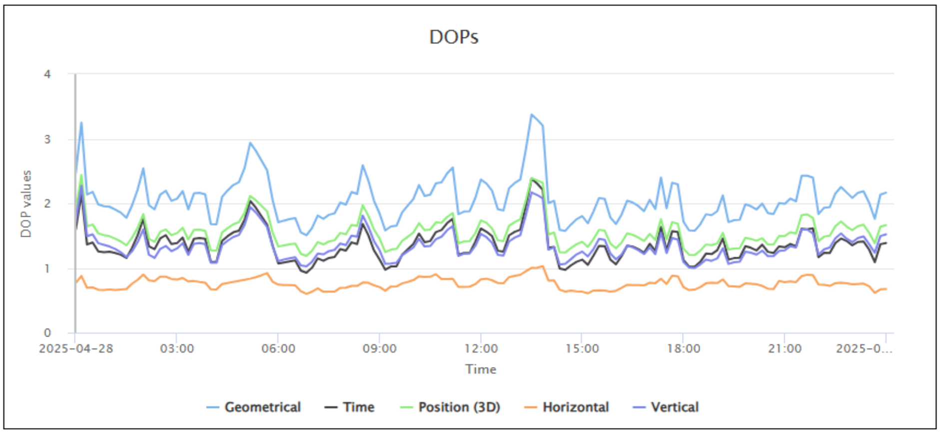


**Figure 13:** DOPs values during 24-hour for GPS and Galileo Satellites.

In Figure 13, a detailed examination reveals critical insights into the relationship between the Dilution of Precision (DOP) values and the availability of satellites from both the Global Positioning System (GPS) and the Galileo system during specific time intervals. The DOP is a measure that indicates the potential accuracy of the positioning data derived from satellite signals; lower values signify better accuracy, while higher values suggest greater potential for error.

The analysis highlights that high DOP values were recorded at distinct times: 00:10, 5:10, and 13:30. During these intervals, the number of available satellites was noted to be 15, 14, and 11, respectively. These figures represent a scenario where the satellite geometry is less favorable, which in turn results in elevated DOP values. The implications of this are significant, as the diminished number of satellites can lead to a less reliable positioning fix, thereby increasing the potential for errors in location determination.

Conversely, at other critical time points, specifically 6:50, 9:10, 14:20, and 18:20, the DOP values were observed to be low. Corresponding to these intervals, the number of satellites available from both GPS and Galileo systems was notably higher, with counts of 18, 16, 17, and 17 satellites, respectively. This abundance of satellites contributes to a more favorable geometric configuration, which is crucial for achieving accurate positioning. The low DOP values during these times suggest that the satellite signals are well-distributed, thus minimizing the potential for error in location readings.

## 3. Conclusion

The comprehensive analysis conducted in the Al-Salmani Al-Gharbi area of Benghazi using the Trimble Online GNSS Planning Tool highlights the critical importance of satellite visibility and positioning accuracy in urban environments. Over the 24-hour period assessed, both GPS and Galileo satellite systems demonstrated varying degrees of availability and visibility, with GPS satellites ranging from 6 to 11 in number and Galileo satellites from 5 to 10 at different times throughout the day.

The findings underscore the significance of elevation angles in determining the reliability of satellite signals, which directly impacts positioning accuracy. The analysis revealed that a total of 61 satellites from both systems could be utilized simultaneously, with a maximum of 18 satellites visible at any given time. This enhancement in satellite availability is particularly beneficial for navigation and tracking applications, as it improves the geometric configuration of the satellite signals, leading to reduced positioning errors.

Moreover, the combined analysis of GPS and Galileo satellites yielded considerably lower Dilution of Precision (DOP) values, indicative of enhanced accuracy for positioning solutions. This reduction in DOP values reinforces the advantages of integrating multiple GNSS systems to achieve higher precision in navigation and location determination. The results of this study not only provide valuable insights into GNSS performance in urban settings like Benghazi but also highlight the potential for improved accuracy through the strategic utilization of both GPS and Galileo satellite systems. Future work should continue to explore the implications of these findings in practical applications, particularly in urban planning and the development of advanced navigational technologies.

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