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GPS signal accuracy and coverage analysis platform: Application to Trimble Juno SB receiver

A. El Abbous, O. Benarchid, N. Raissouni,
S. El Adib, A. Chahboun, A. Azyat, M. Lahraoua, N. Ben Achhab,

Innovation & Telecoms Engineering Research Group. Remote Sensing & Mobile GIS Unit.
University Abdelmalek Essaadi (www.UAE.ma). Mhannech II, B.P 2121 Tetuan, Morocco

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ABSTRACT

Nowadays, information and mobile information technologies are being considered by the scientific community as primordial support for many other emerging technologies. The present paper exposes the results of a study and the analysis of accuracy, coverage and continuity of Global Positioning System (GPS) signal, using the Trimble Juno SB receiver. This is frequently used today for data collection and integration within Geographic Information Systems (GISs). Location-based services quality is highly depending on the accuracy of the position of the user. Generally, for each GPS enabled receiver the user need to evaluate the radius of the confidence region which describes the accuracy of the GPS device. In order to describe the accuracy of GPS receivers; a statistical method using a mobile software acquisition tool developed within our research group has been used. Intensive field measurements (i.e., 1data/1min x 3days) were carried out in Tetuan city (Morocco) during days of 29-30-31 May 2012 using local storage database feature. Homogeneous observation conditions and settings were respected for GPS signal acquisition. Finally, after calibrating the equipment, the results indicate that the Trimble Juno SB GPS receiver is well suited for services where meter accuracy is required.

Corresponding Author:

Naoufal Raissouni, Ph.D.,
National School for Applied Sciences of Tetuan, Abdelmalek Essaadi University,
Innovation & Telecoms Engineering Research Group. Remote Sensing & Mobile GIS Unit,
Mhannech II, B.P 2121 Tetuan, Morocco.
Email: nraissouni@uae.ma

1. INTRODUCTION

The Global Positioning System (GPS) fields and solutions are seeing rapidly growing applications today, the idea that first was reveled in the early days in the Department of Defense (DoD) in ”the lonely Halls meeting in 1973”, became a very powerful technology which has, and will continue to provide the location data for attributes in many applications [1] . Nowadays, the use of GPS receivers has become widespread in all over the world, many areas of applications, and services benefit largely from the success story of GPS. The growth in innovation continue with hardware and device Manufacturers who have developed low cost consumption, user-friendly receivers and software which are capable of easily satisfying many users positioning requirements. Many studies have revealed the GPS signal acquisition challenges associated with using satellite navigation indoors and outdoors in where the satellite signals are blocked, weakened and reflected [2]. These challenges has been solved by providing aiding information from receivers at favorable sites to receivers in these difficult environments [3]. From the other hand, algorithms has been developed to increase the sensitivity of the GPS receivers to lower SNRs (Signal To Noise Ratio), ward of multipath and readily incorporate any aiding information that might be available [4].

The need of integration of Location Based Services in Remote Sensing and Geographic Information System (GIS) fields in Morocco towards decision making, urban and environmental planning pushes the areas of focusing into studying and enhancing the level of accuracy required from applications and services. It is important to recognize the measure scales of many GPS receivers, especially those dedicated to be used with mapping, surveying, and their ability to accurately map features with or without differential correction. In facts, each accuracy represents a service, the scale from centimeter to several meters, making it necessary to evaluate how accuracy and precision can affect individual applications. From the user experience side GPS becomes very attractive, since PDAs and mobile smart phones form factors that have an integrated GPS feature are on the market [8], with various kind of software and APIs end clients. Therefore the actual accuracy and precision of GPS devices has a strategic importance for the design of location-based services. Hence, we will be able to improve GPS accuracy and continuity and adapt the end client measures especially when collecting data for use with high-spatial resolution imagery. For example, Quickbird multispectral imagery, achieves a resolution of 2.4 meters per/pixel. To register corresponding ground sample locations within the correct pixel(s), an accurate GPS receiver is required, also To ensure that each field observation is registered with the correct pixel, a GPS receiver must achieve an accuracy <50 percent of the pixel size [5] .

The quality of location-based services highly depend on the accuracy of the presumed position of the user assuming the successful operation of GPS receivers and software, other measures are necessary to ensure the continuity, integrity, accuracy of positions . Many studies have been conducted in which GPS receiver accuracy has been investigated in comparing receivers under various conditions. An example, tested the capability of the Trimble GeoXT receiver in forested and clear areas and compare results in each study using internal and external receivers[6].

This paper addresses one very essential topic in evaluating GPS signal coverage, and accuracy towards a cognitive large vision in Tetuan City, Morocco, that will allows us to use a network of devices in services such as environmental and urban planning. As well, a mobile software tool has been developed for the acquisition of: single and many point positioning, accuracy, Satellites information and orbits function of time. Results based on this acquisition tool shows, a continuous three days (29-30-31 May 2012) measures (3days x 1data/min), single position, indoor, parameter that influences the signal to noise and that a metric level accuracy after calibrating the receiver may be achieved with Juno SB receiver. Also, a Satellite orbits diagram may be plotted.

2. METHODOLOGY

2.1. The vision behind this work

To understand the vision behind starting the study and the analysis with the single Juno SB receiver we presume in the future, to use a network of Mobile GIS Platforms (MGISP) [9] and GPS devices, to be connected with a High Resolution Web Mapping back end service towards urban planning, GPS tracking services. MGISP is a mobile GIS platform developed in our research group, for GIS data manipulation and geo-visualization with a mobile database feature. For each of the GPS receivers we need to evaluate the accuracy and best practice measures acquisition, Figure 1.

The high level architecture of the future solution (Figures 2 and 3) contains three essential parts:

a) Back end Client or users: Generally it is a device used to store, manage GIS data or synchronize it via the network. The PDA or phones device can be tracked using the GPS signal; other equipment can be used like Data Loggers, Universal Serial Bus (USB) or Bracelets. Figure 3 shows different GPS equipments, each with specific accuracy and is dedicated to specific service.
b) Network: packet network like General packet radio service (GPRS), 3G, 4G. Each device can access to the medium once the specific Subscriber Identity Module (SIM) card is plugged in. Smart phones and Personal Digital Assistants (PDA) must implement client software allowing starting the service, editing, managing, sending and reading from the remote services.
c) Back End service:
   - Database: in a server side connected to the internet and store GIS data, state of the equipments, positions, users and administrators of the service.
   - Service Management user interface: a Graphical User Interface (GUI) that permit the administrator to manage data, edit properties and databases.
   - Web user interface: a page that can be accessed through the internet and which will display information, graphs reports about the user’s states.

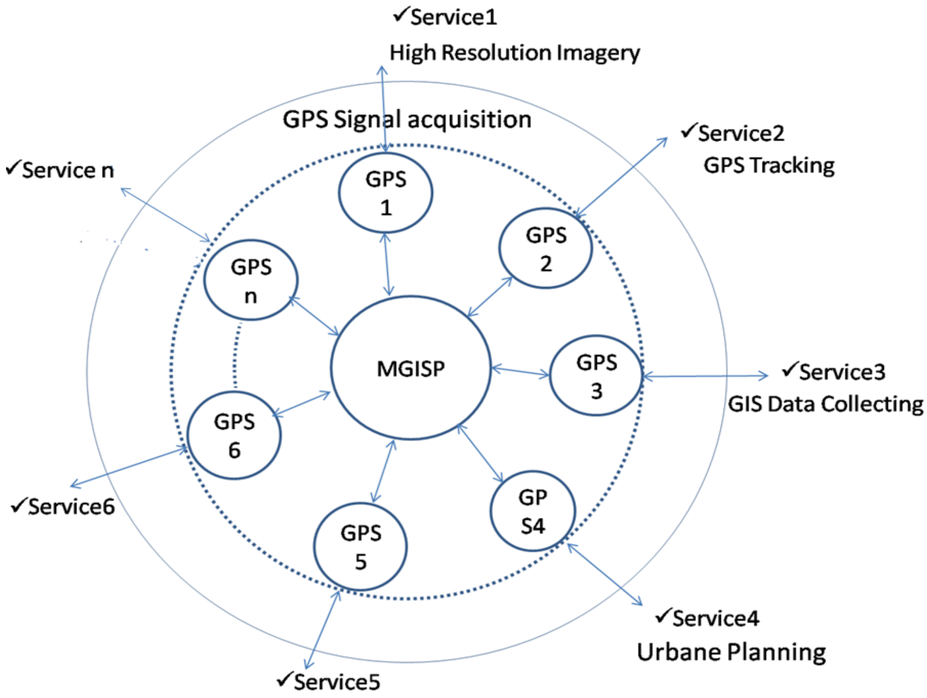


Figure 1.GPS Network with mobile GIS capabilities.

Figure 2.Architecture of the GIS Data Managing Solution

Figure 3.GPS equipments to be used and studied

2.2. The GPS acquisition tool : Application to Trimble Juno SB

Figure 4 presumes the technical specifications of the handled PDA Juno SB used in this paper: This equipment uses GPS acquisition software, such as Trimble's TerraSync or GPS Controller which has raised concern about data quality. Many such receivers collect data that cannot be differentially corrected, increasing the margin of positional errors in the data collected. Receivers are also unable to control the quality of DOP (Dilution of Precision) and so it doesn‘t prevent the user to acquire measure at a highest value of the DOP, which may highly causes several positional errors. Using that software as an acquisition tool is not suitable we presume develop a tool which will have the features described in Table 1.

- GPS type: GPS/SBAS, NMEA/SIRF compatible.
- High yield GPS receiver with 2 to 5 meter.
- Positioning accuracy in real time or 1 to 3 meter post processed.
- Durable, lightweight field computer that integrates an array of powerful features.
- Processor: 533 MHz Samsung S3C2443.
- Memory: 128 MB RAM and 128 MB internal Flash storage.
- Cellular Networks: GSM850, GSM900, GSM1800, GSM1900, UMTS900, UMTS1900, UMTS2100.
- Providing photo capture, cellular data transmission.

Figure 4.The GPS Trimble Juno SB used in the study

Table 1.The developed acquisition tool features

Features	acquisition frequency	Mobile Database	Remote Database	scalability	Other features
Trimble TerraSync	Fixed NMEA 1 sec	NO	NO	NO	----
Trimble GPS Controller)	Fixed NEMA 1 sec	NO	NO	NO	----
Our acquisition Tool	**adjustable**	**YES**	**YES**	**YES**	✓ Imaging ✓ Data collection ✓ GPS Tracking.

Herein, we focused on the Trimble Juno SB study. For data acquisition we had the choice to choose an existing application tool integrated with the device, or to develop our own acquisition tool, however the software that comes with this device do not offers scalable, flexible and extensible features. The Mobile GIS acquisition Tool Figure 5 developed on top of Windows Mobile 6.1 using the Microsoft .net CE, Sql Server CE [14], it key features are:

- A local and remote database access to store acquisition performance and GIS information in a user friendly interface.
- Configuration of measure frequency in sec.
- Acquisition position and satellites real time display.
- Excel importation Storage: The performance acquisition data after being stored in a SQL Server CE can be easily imported to a spread sheet in order to analyze it.
- Setting configuration for the points to be measured: latitude (Lat), longitude (Long), altitude (Alt) conditions, time, etc.

The study area is located in Tetuan city (Morocco); latitude: 35.58036, longitude: -5.400732458, Altitude: 93m, in indoor condition. Conditions of measures are:

- Three days: 29, 30, 31 May 2012, in which the sky remains clear approximately.
- 1 sample per minute which gives 1436 sample registered per day.
- The samples were compared to the latitude, longitude in decimal degree (DD) (WGS84) obtained from Google Earth (GE).
- Intensive field measurements for the satellites orbits information were also registered: 32046 sample, during the campaign, for each point collected we register the satellites SNR (Signal to Noise Ratio), elevation, and azimuth.

Figure 5.The developed mobile data acquisition tool

In the future works, the acquisition of signal performance for each study area or point will be observed with the following GPS receivers:

- Trimble Juno SB (subject of this paper).
- Trimble Juno SC.
- Trimble Ceo XM (Geo Explorer 2008).
- GPS USB DONGLE.
- Garmin GPS MAP 62.

It turns out that the acquisition tool developed works perfectly on Windows Mobile 6.1 which is the Operating System of Juno SC and Geo XM, which will allow us to make the same methodology we do herein for those two equipments. While starting, the GPS measures will be constantly logged onto the Juno SB mobile device in close to the exactly known positions to enable a comparison afterwards. Once terminating, we evaluate the registered data the following research questions should be answered

Performance Data to be analyzed are:

- The actual GPS error.
- Is there a correlation between the error estimates of the device and the real errors
- Which other factors determine the accuracy of GPS measure.
- Satellite constellation in the studied area.

3. RESULTS AND ANALYSIS

The results accuracy calculations for the JUNO SB GPS receiver are given in figures. There is a large difference in the magnitude of errors between the latitude and longitude coordinates. For the three days measures large error between the true positions, has been registered. Sum of squares was used to assess positional accuracy. To gain insight into the error of GPS localization the estimated coordinates provided by the GPS Juno SB receiver are compared to the reference point with well known position. To make the error analysis representative a dense network of points was constructed for.

3.1. Measures and error analysis

Table 2 shows the accuracy obtained during the measures. To assess the utility of the data received for the three days measures we use sum of squares of GPS differences divided by the number of points $P(xi, yi)$ samples N = 1436 (24h×60min) acquired in each day. A distinction should be made between accuracy and precision. Accuracy is the degree of closeness of a position frame the true one, the precision is the degree of closeness of observations to their means. Accuracy and precision are often used to describe the how good is the position acquired by GPS receiver estimate to its true [7]: The radius of the shaded area is given by the formula : $R = \frac{\sqrt{(x-xi)^2+(y-yi)^2}}{N}$

Table 2.Accuracy obtained for the latitude, longitude and altitude

Days	**29/05/2012**	**30/05/2012**	**31/05/2012**
R (m)	9.55	9.52	9.55
Latitude Error (DD)	-7.10382E-05	-5.98009E-05	-6.27492E-05
Longitude Error (DD)	-6.74542E-05	-3.32938E-05	-2.77782E-05
Altitude Error (m)	3.45	3.51	4.55

Figure 6 plots the distribution of SNR and the Elevation degree during the experience for one satellite during its apparition period. Two principles sources of large values of errors that were registered: The HDOP is very high, and the visibility of the viewed satellite in solution decreases at this time and so SNR is very low (less than 20dB-Hz). However, the data shows that the values of SNR which itself depend on the elevation degree of the satellites, at a good visibility elevation SNR can reach the 45 dB-Hz which is a good signal value in indoor condition. To determine the source of the largest error compared with the theoretical value shown in Figure 4 we have to analyze the Latitude and the longitude errors, Figure 8 presents the data registered. SNR function of elevation data shows important multipath signal distribution in our condition which will lead primarily to important errors.

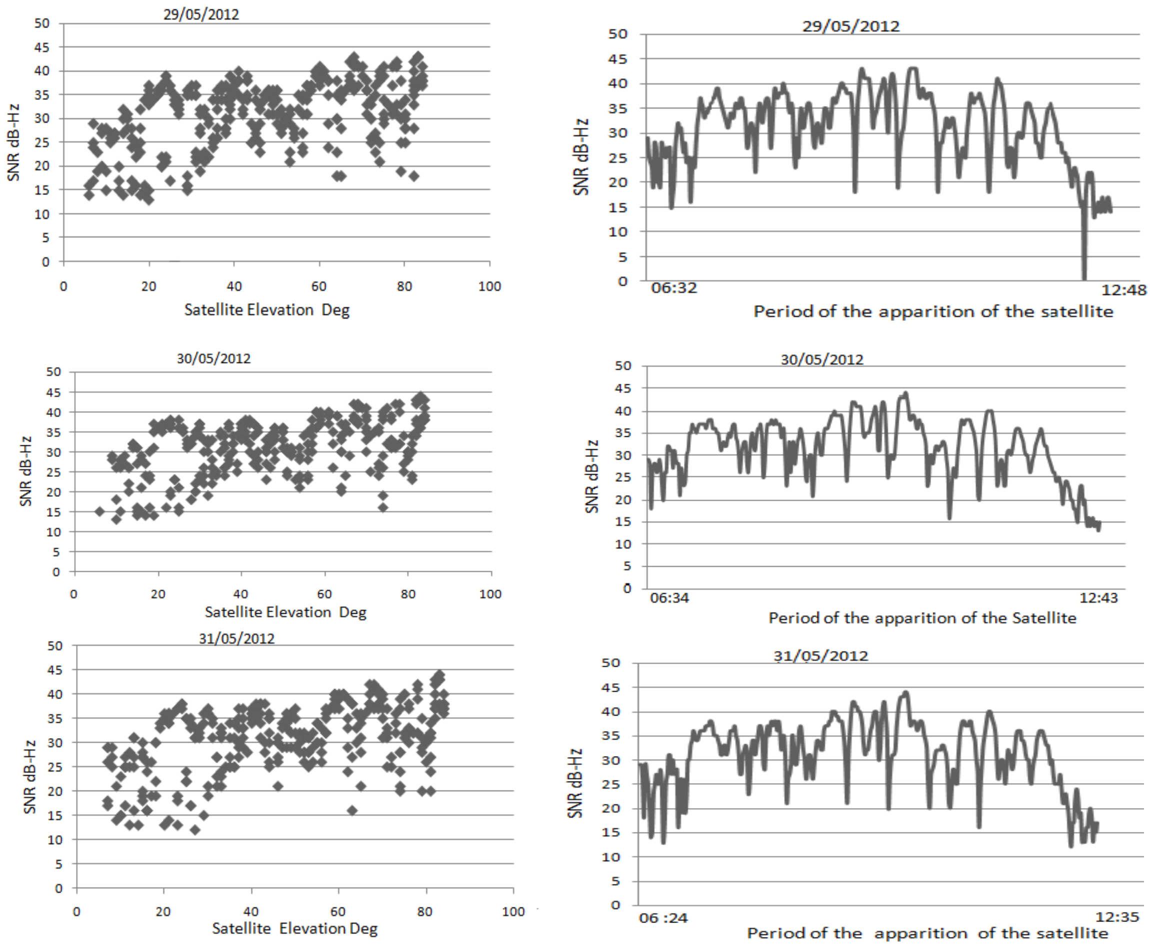
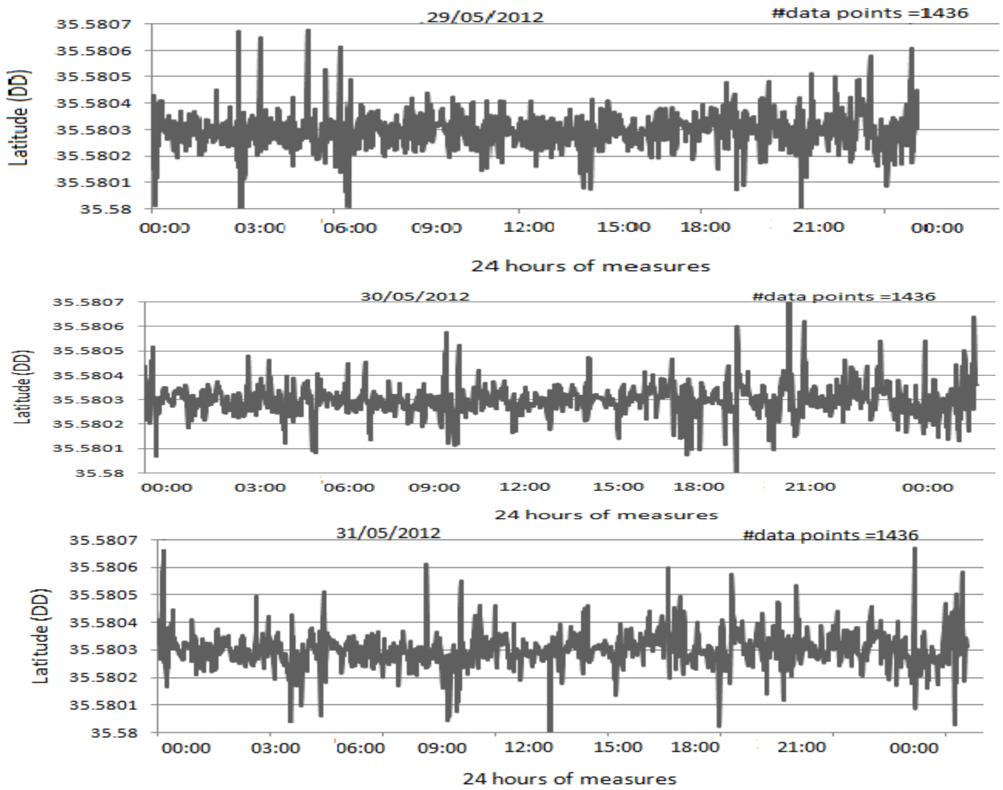


Figure 6.SNR (dB-Hz) for Satellite PRN 5 during days 29-30-31 May 2012.

Figure 7, shows the Latitude and Longitude in decimal degree (DD) data collected during the measurements campaign dates (i.e., 29-30-31 May 2012).

a) Latitude :



b) Longitude :

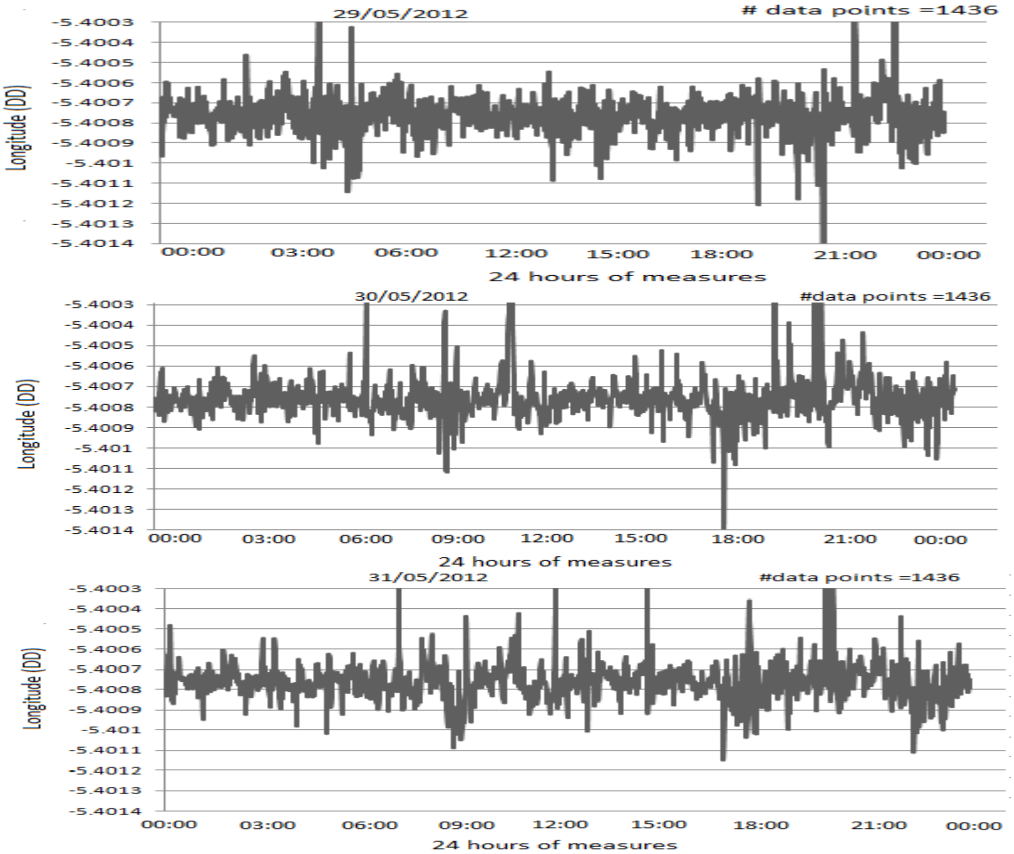


Figure 7.Latitude and longitude set of data collected during campaign dates: a) 29 May 2012, b) 30 May 2012 and c) 31 May 2012.

The Plots shows an error underneath the real value in longitude and latitude to be calibrated. In longitude we evaluate an error of: -6.45294E-05, and in latitude: -4.28421E-05. The altitude results show that 90 % of the points are registered with an error less than 3m which is acceptable. The error results highly depend on the DOP and Satellites Elevation (see Figure 8).

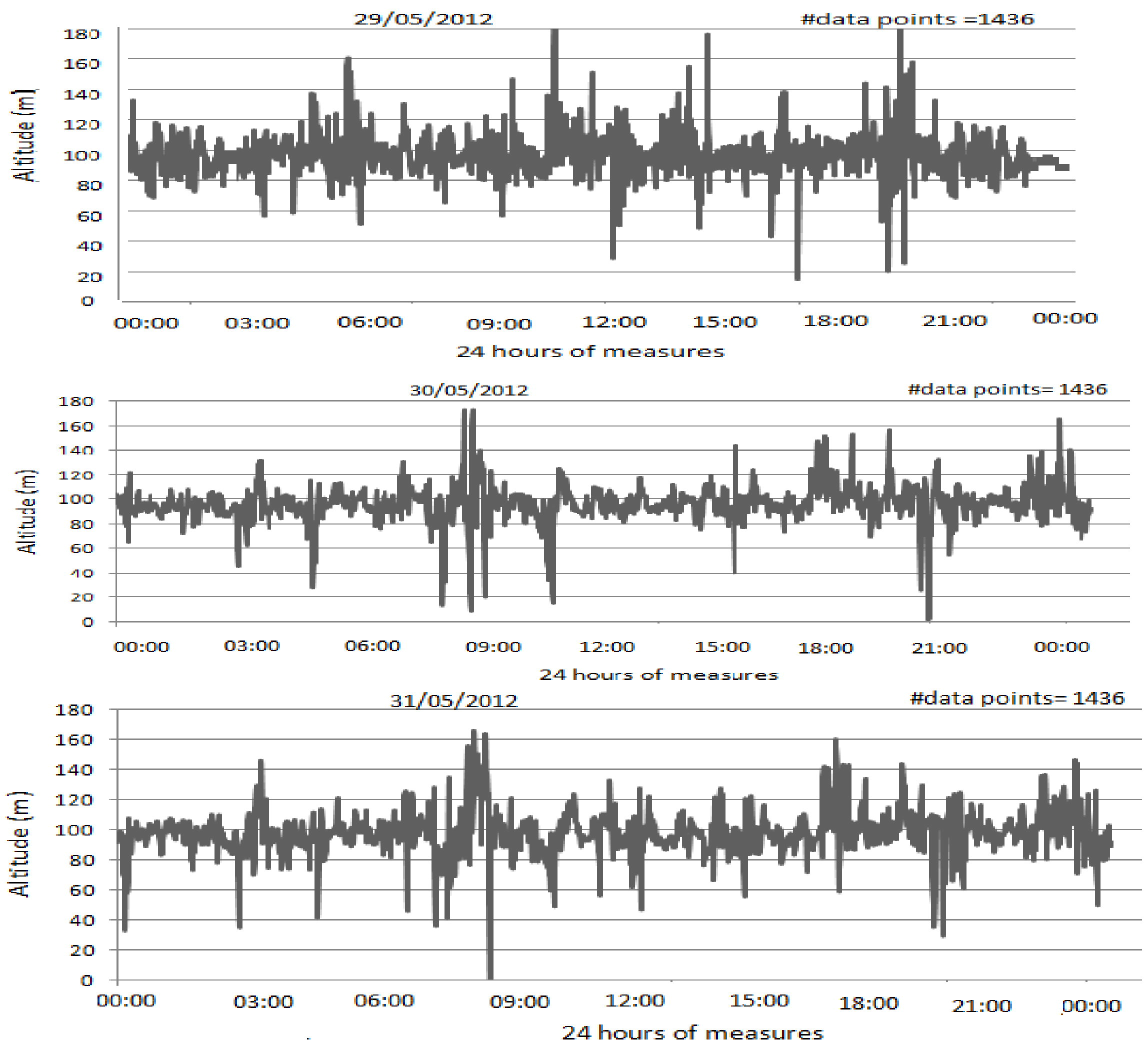


Figure 8.Error in altitude (m) during days 29-30-31 May 2012.

The software tool will be reconfigured so each point registered by the Juno SB will be added an offset of -6.45294E-05 in Latitude, and -4.28421E-05 in longitude. Through that, we can achieve accuracy less than 3m at 95 % probability.

3.2. Satellites orbits constellation

The PRN from 1 to 31 were tracked during three days of measurements, except PRN 24. Figure 9 shows the Elevation and SNR for three of the satellites. The SNR increases with the elevation angle; it degrades when the signal from the satellite has followed multiple paths to the receiver. This leads to oscillations in SNR, multipath phase error, and multipath pseudo-range error.

The reflection of the signal received from the satellite with a velocity= C, to the device at several times leads to offsets in position accuracy: the delay in the timing increases the error probability: $C = \frac{d}{t}$ Where d is the distance evaluated by the satellite using the triangulation method, t is the delay.

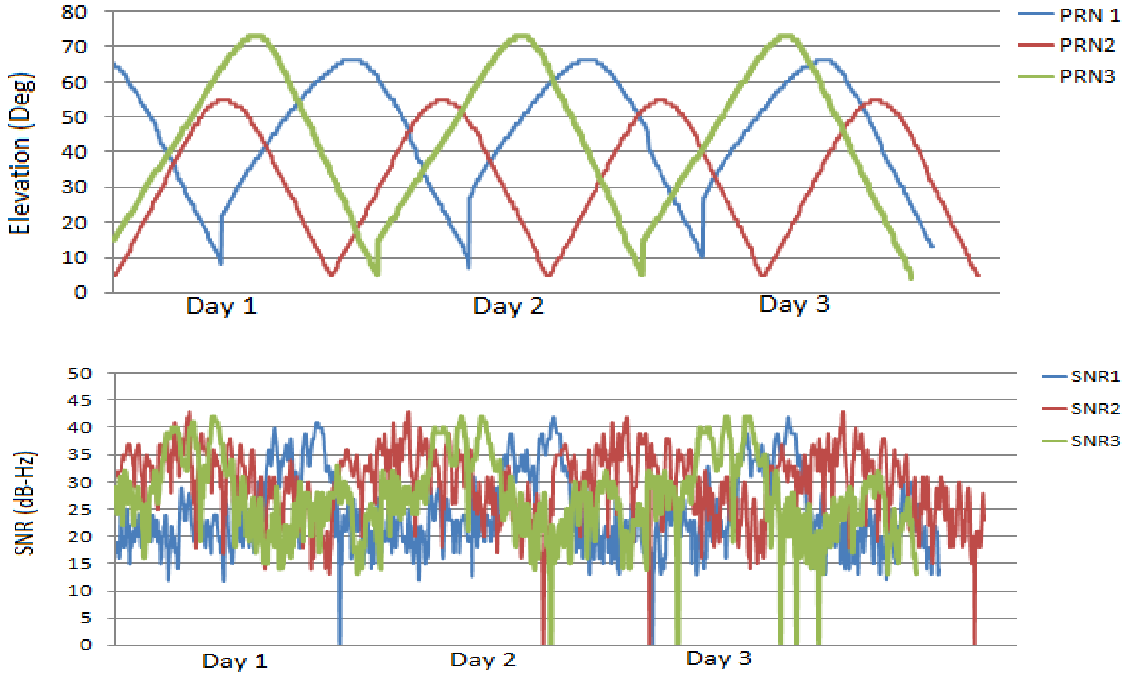


Figure 9: Elevation and SNR data for PRN 1, 2, 3 during days 29-30-31 May 2012

Results shows that the maximum number of satellites that can be viewed at the point of the experience is: 9 but in limited times (05:30, 14:00, 23:00) which lead to better accuracy, Figure 10:

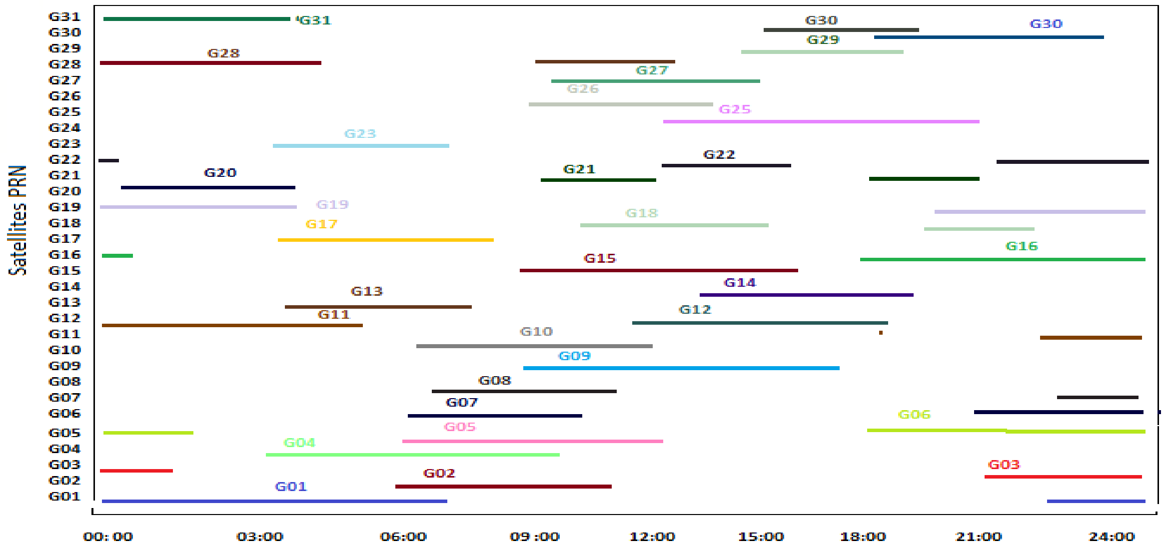


Figure 10: Satellites distribution and visibility in 24 hours for the studied region

3.3. Indoor error calibration

Results in indoor conditions shows that the Juno SB receiver must be calibrated, 95 % of the points has an offset of 9 m from the true position; figure 11 presents the error distribution in 24 hours during the campaign measures.

a) Before calibration :

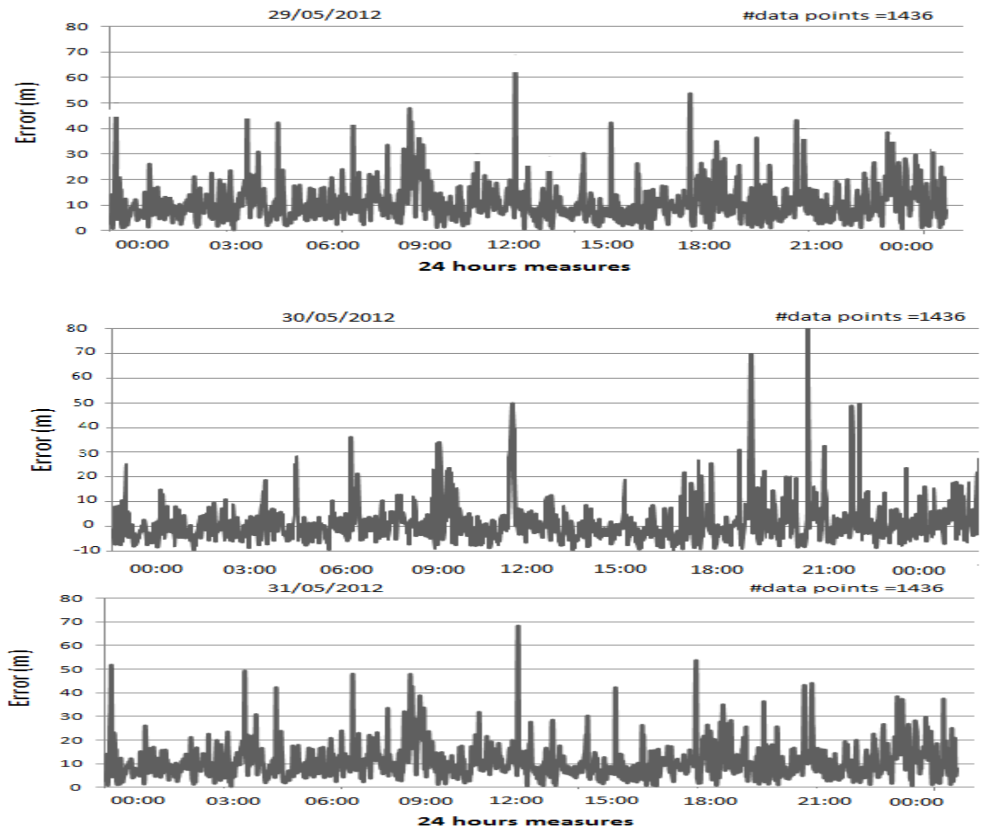


Figure11.Error (m) during days 29-30-31 May 2012

b) After calibration :

Figure 12 shows that at least 95% of the points are registered in a radius of 3m, which is close to the theoretical accuracy indicated by the constructor.

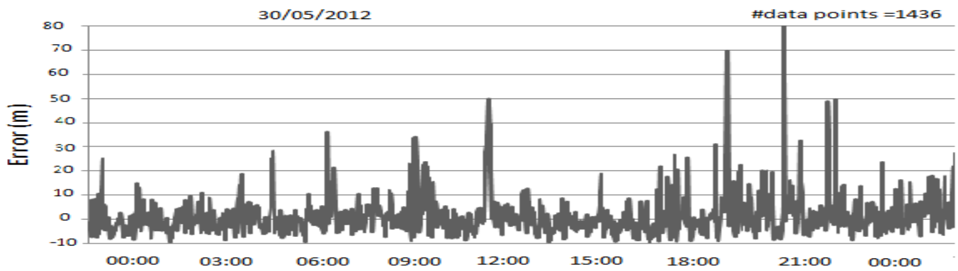


Figure 12: Error (m) distribution in 24 hours after calibration during days 29-30-31 May 2012

The Error is highly dependent on the DOP as it shown in figure 11 and 12. Since the point is static Vertical dilution of precision (VDOP) has no effect on accuracy. Results in Figure 13 shows that several times during the day when the Horizontal dilution of precision (HDOP) is low, we can achieve a lower uncertainty in our positional error. And there are also three high values of the DOP around 13:00, 17:00, 19:00 PM, so if we want to minimize potential position errors, we could avoid making a measurement at that time. Thus, it is highly recommended to collect data measures at the lowest DOP value.

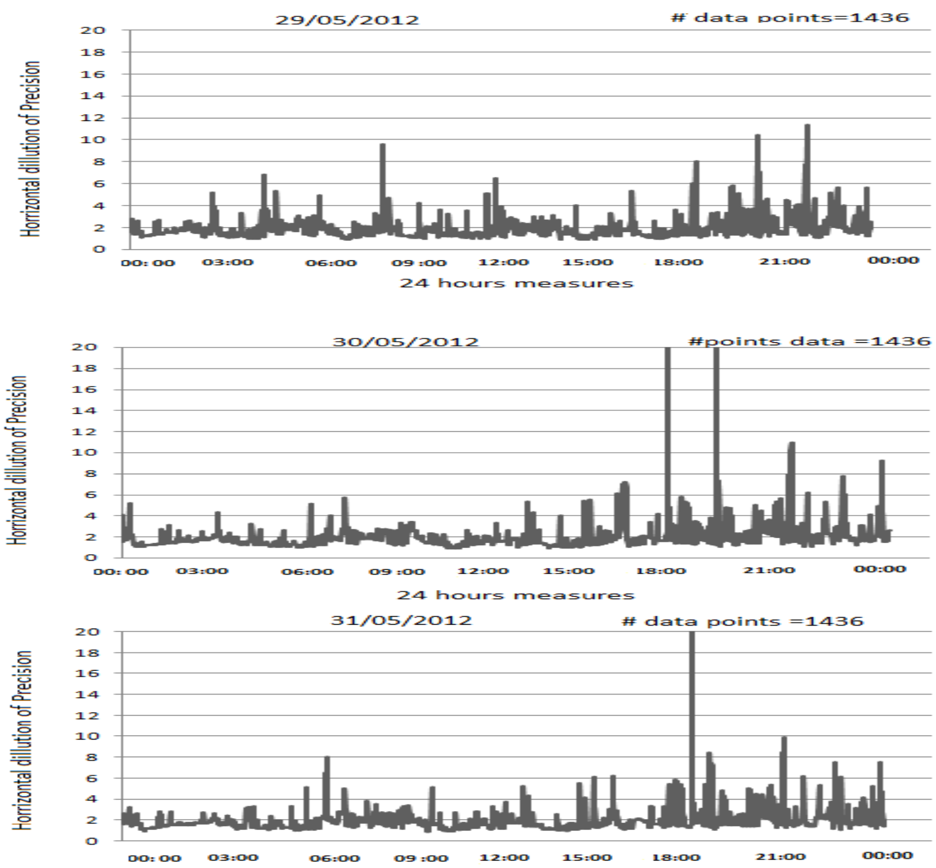


Figure 13: Horizontal dilution of precision during days 29-30-31 May 2012.

CONCLUSION

This study assessed the Trimble Juno SB GPS receiver and determined the accuracy at a high level probability. While describing the receiver accuracy, using the developed software acquisition tool, data received parameters has given us a vision of the GPS signal challenges of the area studied, as well, the satellites coverage and signal continuity. Overall, the results indicate that the Juno SB is well suited for services where meter accuracy is required.

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BIBLIOGRAPHY OF AUTHORS

Abdellah El Abbous obtained his engineer degree in Telecommunications from the National Institute of Posts and Telecommunications (INPT) in 2010, Rabat, Morocco. Currently, he is a member of the Remote-Sensing & Mobile-GIS Unit/Telecoms Innovation & Engineering Research group at the University Abdelmalek Essaadi. His current areas of research are GPS tracking, Mobile GIS, Networking, Remote Sensing, and Data High availability techniques. Email : abdellah.abbous@gmail.com

Omar Benarchid received the engineer degree in telecommunications and networks engineering from the National School of Applied Sciences, University of Abdelmalek Essaadi, Tetuan, Morocco, in 2011. He is currently working toward the Ph.D. He has been with the Remote Sensing & Mobile GIS Research Unit at National School of Applied Sciences, Abdelmalek Essaadi. His main research activities are in the fields of remote sensing, image processing, urban planning and environmental planning. In particular, his interests include buildings extraction, classification, and change detection.

Naoufal Raissouni received the M.S., and Ph.D. degrees in physics from the University of Valencia, Spain, in 1997, and 1999, respectively. He has been a Professor of physics and remote sensing at the National Engineering School for Applied Sciences of the University Abdelmalek Essaadi (UAE) of Tetuan, since 2003. He is also heading the Innovation & Telecoms Engineering research group at the UAE, responsible of the Remote Sensing & Mobile GIS unit. His research interests include atmospheric correction in visible and infrared domains, the retrieval of emissivity and surface temperature from satellite image, huge remote sensing computations, Mobile GIS, Adhoc networks and the development of remote sensing methods for land cover dynamic monitoring.

Samir El Adib received the M.S. in Informatics, Electronics, Electrotechnics, and Automatics (IEEA) and M.S. degree in automatic and data processing from University Abdelmalek Essaadi (UAE), Tetuan, Morocco, in 2004 and 2006 respectively. Currently, he is a member of Remote-Sensing & Mobile-GIS Unit/Telecoms Innovation & Engineering Research group. His main research interests are FPGAs in custom-computing applications, and more concretely, applications of reconfigurable hardware to cryptography.

Asaad Chahboun obtained his M.S. from Central School of Arts and Businesses in Brussels Belgium, M.S. in Telecommunication Systems from University Abdelmalek Essaadi in 2006. He was Maintenance responsible engineer of radiology and medical imaging materials, at FREELANCE SERVICE enterprise Rabat-Morocco, from 1995 to 2003. Currently, he is a member of Remote-Sensing & Mobile-GIS Unit/Telecoms Innovation & Engineering Research group. His current areas of research are Wireless Sensor Networks, Routing in Ad hoc Network, Network Security, remote sensing, the development of remote sensing methods for land cove dynamic monitoring and Grid computing.

Abdelilah Azyat received the M.S. in Informatics, Electronics, Electrotechnics, and Automatics (IEEA) and M.S. degree in Bioinformatics from University Abdelmalek Essaadi (UAE), Tetuan, Morocco, in 1995 and 2004 respectively. Currently, he is a member of Remote-Sensing & Mobile-GIS Unit/Telecoms Innovation & Engineering Research group. His research interests include remote sensing, spatiotemporal studies of thermal infrared satellite imagery of the earth's surface and the development of remote sensing methods for land cove dynamic monitoring, GIS and Mobile GIS.

Mohammed Lahraoua received the M.S. in Chemistry and M.S. degree in Bioinformatics from University Abdelmalek Essaadi (UAE), Tetuan, Morocco, in 1992 and 2004 respectively. Currently, he is a member of Remote-Sensing & Mobile-GIS Unit/Telecoms Innovation & Engineering Research group. His present investigations include remote sensing algorithms, thermal infrared satellite imagery of the earth's surface and the development of remote sensing methods for land cove dynamic monitoring and Grid computing.

Nizar Ben Achhab received the M.S. in Informatics, Electronics, Electrotechnics, and Automatics (IEEA) and M.S. degree in Bioinformatics from University Abdelmalek Essaadi (UAE), Tetuan, Morocco, in 1995 and 2004 respectively. Currently, he is a member of Remote-Sensing & Mobile-GIS Unit/Telecoms Innovation & Engineering Research group. His present research include remote sensing multitemporal and spatiotemporal studies of thermal infrared satellite imagery of the earth's surface, the insitu LST measurements and the development of remote sensing methods for land cove dynamic monitoring. It includes also, Grid computing, Multithreading, GPGPU, hardware and software methods for time computing optimizations.