

Assessing Data from Permanent GNSS Stations in Algeria

Hassen ABDELLAOUI^a, Naima ZAOURAR^a et Mohamed Aïssa MESLEM^b

^aFSTGAT-USTHB, BP 32, El Alia Bab Ezzouar, Alger, Algérie,

abdhasen@hotmail.fr, naimaboulasba@gmail.com

^bINCT-BP 123, Rue de Tripoli, BP430, Hussein Dey, Alger, Algérie,

meslem_ma@hotmail.com

المخلص : تم الإشراف على مشروع وطني شامل منذ بضع سنوات لتحسين البنية التحتية الجيوديزية وذلك بإنجاز شبكة المحطات المرجعية المتواصلة العمل واسعة المدى في الوقت الحقيقي التابعة للنظم العالمية. ومن هذا المنظور، أجريت دراسة في سياق هذه المهمة بغرض إختيار مواقع البنية الأساسية المؤهلة لشبكة GNSS/CORS.

تستند معايير إختيار التقنية أساساً على تقييم المعطيات GNSS المتحصل عليها من خلال الشبكات في قيد الخدمة.

لقد تم إختيار محطتين لإجراء هذه الدراسة استناداً إلى تقييم تداخل الإشارات وتعدد المسارات وتحليل استقرار المعالم وذلك عن طريق المعالجة اللاحقة للبيانات الواردة من هذه المواقع التي تقع في شمال الجزائر العاصمة وفي جنوب ورقلة وهي OGLA و DZAL على التوالي.

الكلمات الأساسية : نظام الأقمار الصناعية، تعدد المسار، إجهات البيانات GNSS، المحطة الدائمة.

Résumé : Un projet d'envergure nationale est mené depuis quelques années dans le but d'améliorer l'infrastructure géodésique par la mise en place d'un vaste réseau de stations de référence opérant en continu (CORS) GNSS en temps réel. Dans cette perspective, une étude a été réalisée dans le cadre de cette étude dans but de sélectionner des sites éligibles de l'infrastructure de réseau GNSS/CORS. Les critères de sélection techniques étaient essentiellement basés sur l'évaluation des données GNSS reçues par les sites GNSS déjà opérationnels.

Deux stations ont été sélectionnées pour réaliser cette recherche fondée sur l'évaluation des interférences de signaux et de la propagation par trajets multiples et sur l'analyse de la stabilité du monument par le post-traitement des données GNSS fournies par ces sites GNSS, qui sont situés au nord d'Alger et au sud de Ouargla, à savoir DZAL et OGLA respectivement.

Mot clés : Système satellite, interférences, données GNSS, station permanente.

Abstract : A nationwide project is undertaken since a few years with the purpose to upgrade the geodetic infrastructure by setting up a wide real-time GNSS Continuously Operating Reference Stations (CORS) network. In this perspective a

study has been undertaken in the setting of this assignment with the purpose to select eligible sites of the GNSS/CORS network infrastructure. The technical selection criteria were based essentially on the assessment of GNSS data received by already operating GNSS sites.

Two stations have been selected to perform this investigation based on signal interference and multipath evaluation and monument stability analysis through the post-processing of GNSS data supplied by these GNSS sites, there are located in Algiers in the north and Ouargla in the south, namely DZAL and OGLA respectively.

Keywords : Satellite System, multipath, Interferences, GNSS data, Permanent Station.

1. Introduction

As part of the modernization of the national geodetic infrastructure, the implementation of a national GNSS network (Global Navigation Satellite System) is undertaken since few years. It is composed of a Control Center and a set of GNSS Continuously Operating Reference Stations (CORS).

In this point of view, a data assessment from GNSS permanent sites has been done with a purpose to experiment the quality of the received signals in order to select eligible sites of the GNSS/CORS infrastructure constituted by GNSS dual-frequency receivers and their related equipments. The technical selection were based essentially on the assessment of GNSS data received by these permanent sites through the evaluation of signal interference and multipath phenomena caused by nearby objects of antenna reception, corresponding to two already operating GNSS sites located in Algiers in the north and Ouargla in the south, as shown on the figure 1.

Furthermore, and in order to analyze the sites stability, a time series of coordinates have been generated and analyzed through a GNSS post-processing by the Precise Point Positioning (PPP) technique in the University of Luxembourg, using BERNESSE GNSS software 5.2, (University of Bern, Dach & al. 2015), this work has been performed by the PHD student Hassen Abdellaoui. The main results of this study are presented and discussed in the present paper.

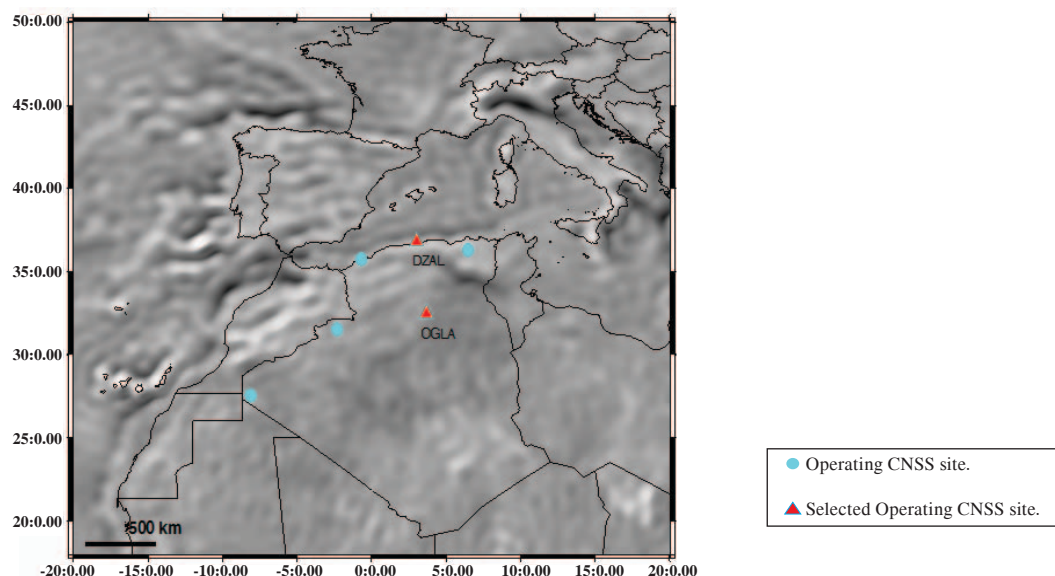


Fig. 1 Selected Operating Algerian Permanent GNSS Stations in red located in Algiers and Ouargla from the whole permanent network.

2. GNSS Installation and Equipments

The GPS/GNSS equipments related to the permanent stations of Algiers, Oran, Constantine, Ourgla, Tindouf and Bechar includes a dual-frequency geodetic receivers type: Ashtech UZ-12 and Leica GRX1200+GNSS and Choke-ring antenna types. The management software of the receivers used are Ashtech Micro Manager and GNSS Spider for Ashtec u-Z12 and Leica GRX1200 + receivers respectively.

These stations produce sessions of daily observations corresponding to 24 hours with a sampling interval ≥ 1 second. The raw data are downloaded regularly and are converted to the RINEX standard exchange (Receiver INdependent EXchange) and Hatanaka formats which are collected through a special network and stored in servers. The figure 2. shows the main equipment details of the GNSS stations selected to perform this study.



3. Data Quality Control and Site Assessment

This step of the study is planned especially to compute key GNSS data quality parameters which could affect the quality data product. The quality of data collected from the two selected sites from the six Algerian continuously operating GNSS sites is analyzed and corresponding to the Modified Julian Date (MJD) 56789. The resulting quality data indicators are presented below, such as code multi-paths (MP) on L1 and L2 carrier frequencies, signal to noise ratio (C/No) depending on each permanent station.

3.1 Multipaths inference

Multipath effects are a major residual error source in the double-differenced GPS observables, and they can have a significant impact on the positioning results. If we know the magnitude of multi-path effects, then it will be possible to carry the quality control of GPS observations.

The magnitude of multi-path effect is defined as the ranging error caused by the reflected carrier-phase GPS signal. The multi-path effects on the pseudo-range observables of L_1 and L_2 frequencies (MP_1 and MP_2 , respectively) can be written as linear combinations as follows.

$$MP_1 = P_1 - \Phi_1 + \frac{2}{1-\alpha} (\Phi_1 - \Phi_2) \quad (1)$$

$$MP_2 = P_2 - \Phi_2 + \frac{2\alpha}{1-\alpha} (\Phi_1 - \Phi_2) \quad (2)$$

Where P_1 and P_2 are L_1 and L_2 pseudo-range (m), Φ_1 and Φ_2 are L_1 and L_2 phase measurement (m), $\alpha = (f_1/f_2)$ and f_1 and f_2 are L_1 and L_2 phase frequencies (Hz), respectively [Minchan Kim & al. 2014].

Statistical summaries and graphical displays of multi-path effects for both carrier frequencies L_1 and L_2 data, are described in figures below for the stations under study and for PRN02 GPS satellite and R10 GLONASS satellite.

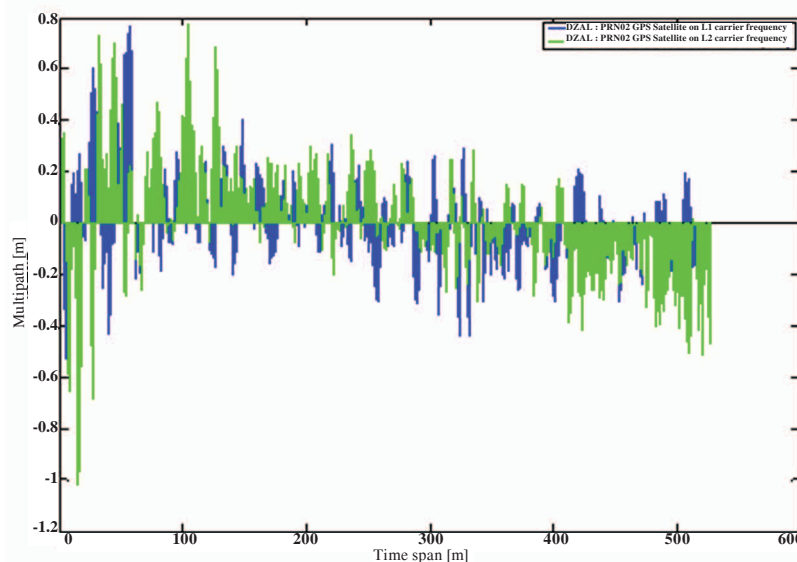
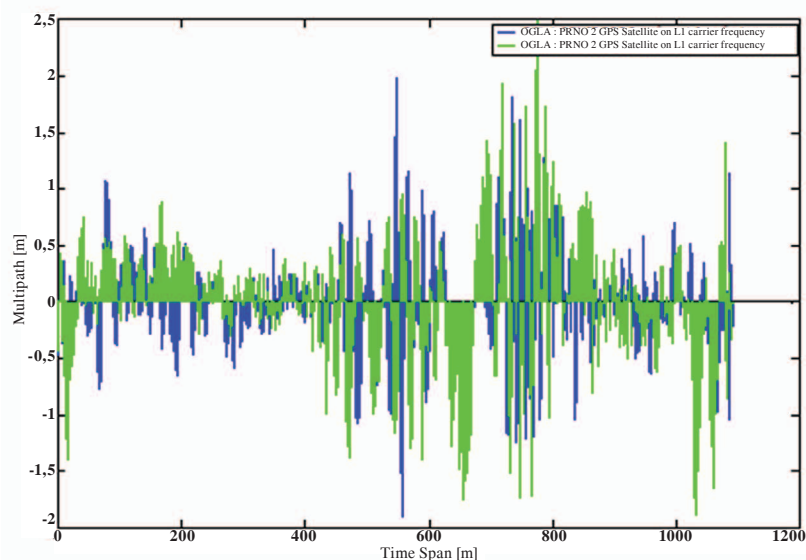


Fig. 3 Multipath (m) for both stations DZAL and OGLA: GPS system (PRN02): L1&L2.



The figures above revealed signal multipath on the southern site OGLA for GPS system, rather more important comparing to signal emitted from satellites over the

northern one DZAL on the same carrier frequencies. These trends are caused by interference on satellite signals, due essentially to the surroundings around the site.

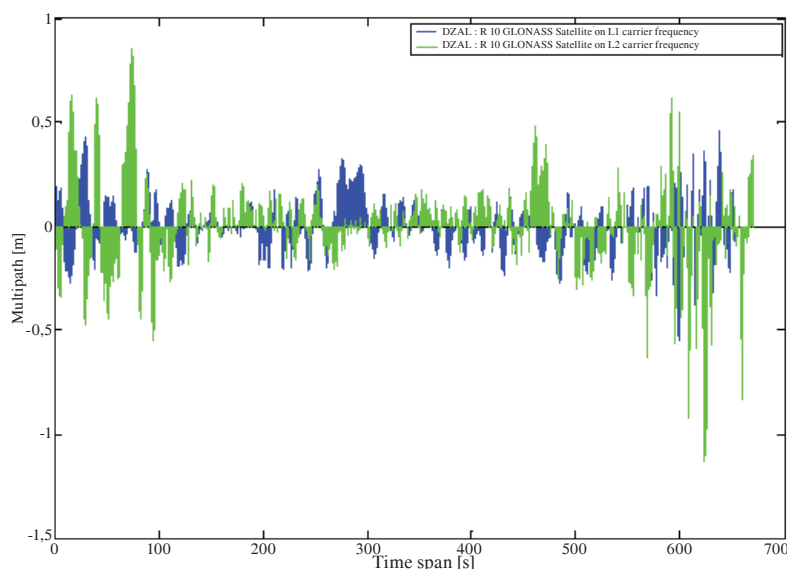
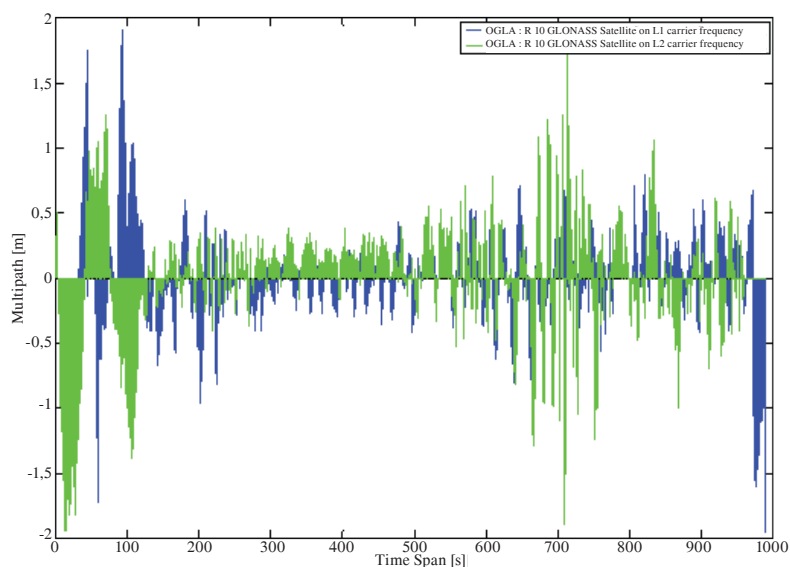


Fig. 4 Multipath (m) vs Sat Elev (°) for both stations DZAL and OGLA : GLONASS system (R10) : L1 & L2.



The same trends have been observed for GLONASS system, The figures have shown as well signal multipath, on the southern site OGLA ; more significant comparing

to signal emitted from satellite R10 over the northern one DZAL on the same carrier frequencies.

Tab 1. Multipath rms values (m) for DZAL and OGLA GNSS sites.

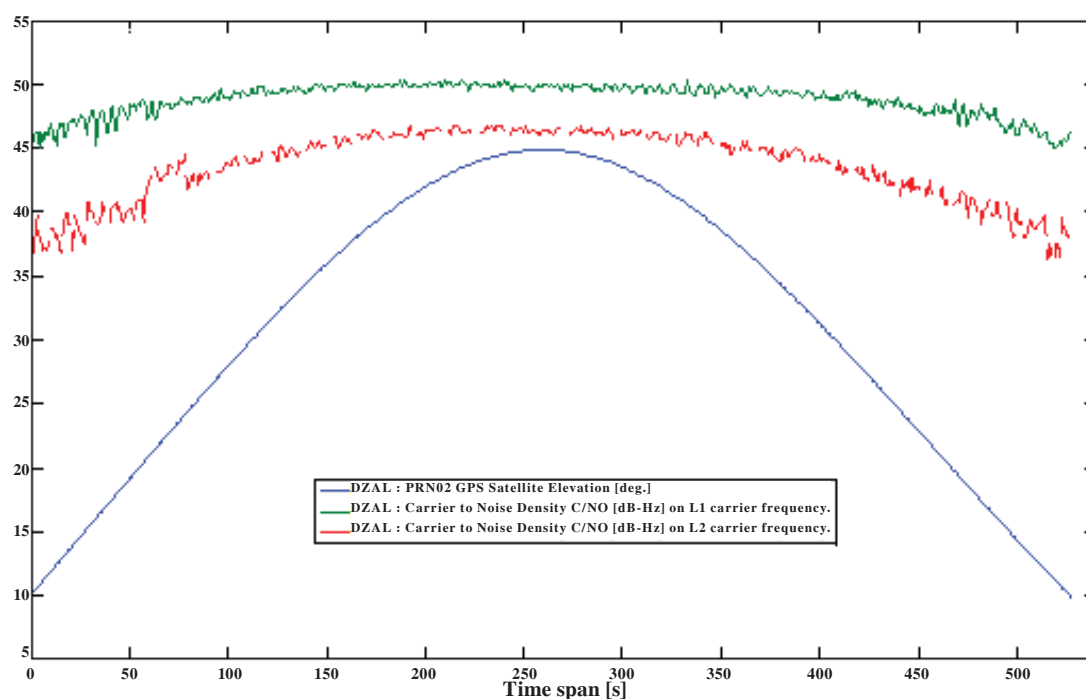
#	Multipath rms (m)			
System/Satellite	GPS/PRN02		GLONASS/R10	
Frequencies	L_1	L_2	L_1	L_2
DZAL	0.2061	0.2681	0.1407	0.2187
OGLA	0.4652	0.5756	0.3751	0.5157

3.2 Signal strengths in permanent station receivers

The GPS/GNSS receivers have a method for indicating the signal strength of the different satellites they are tracking. Some receivers display the signal strength in the form of vertical bars, some in terms of normalized signal strength, and others in terms of carrier-to-noise density (C/No) or signal-to-noise ratio (SNR).

The carrier-to-noise density (C/No) is defined as the carrier power divided by the noise power spectral density. It is

expressed in decibel-Hertz (dB-Hz) and refers to the ratio of the carrier power and the noise power per unit bandwidth. The (C/No) value provides an indication of the signal quality that is independent of the acquisition and tracking algorithms used by a GNSS receiver. It is also independent of the receiver's front-end bandwidth and can be readily used to indicate the quality of the site under assessment.



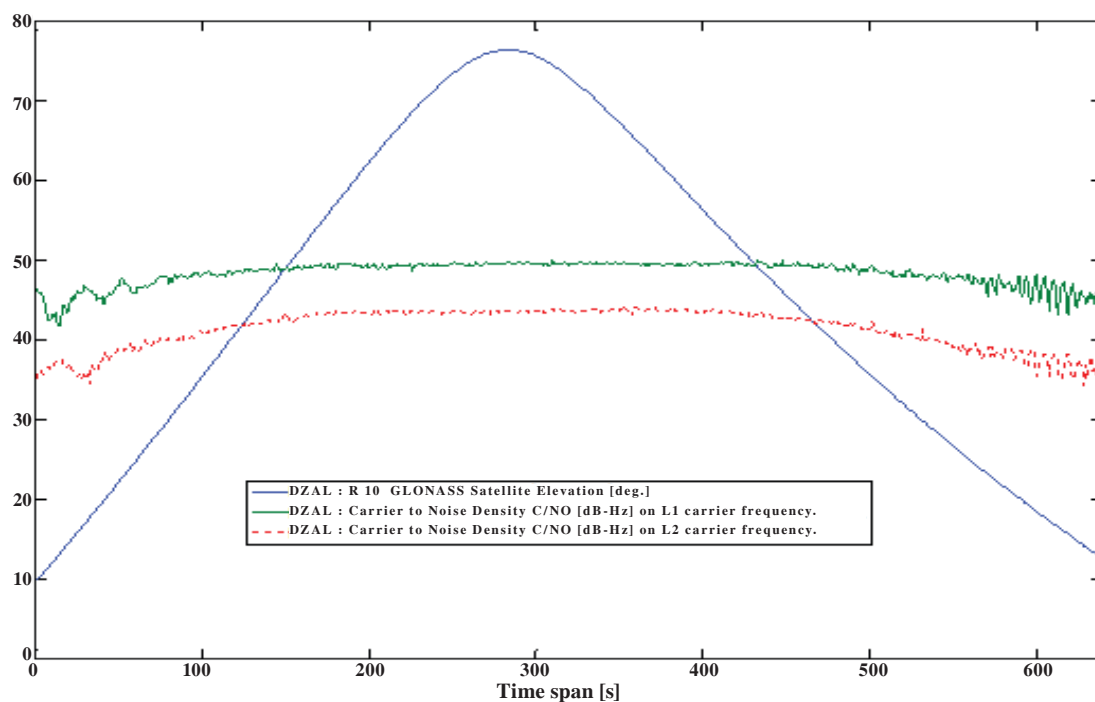
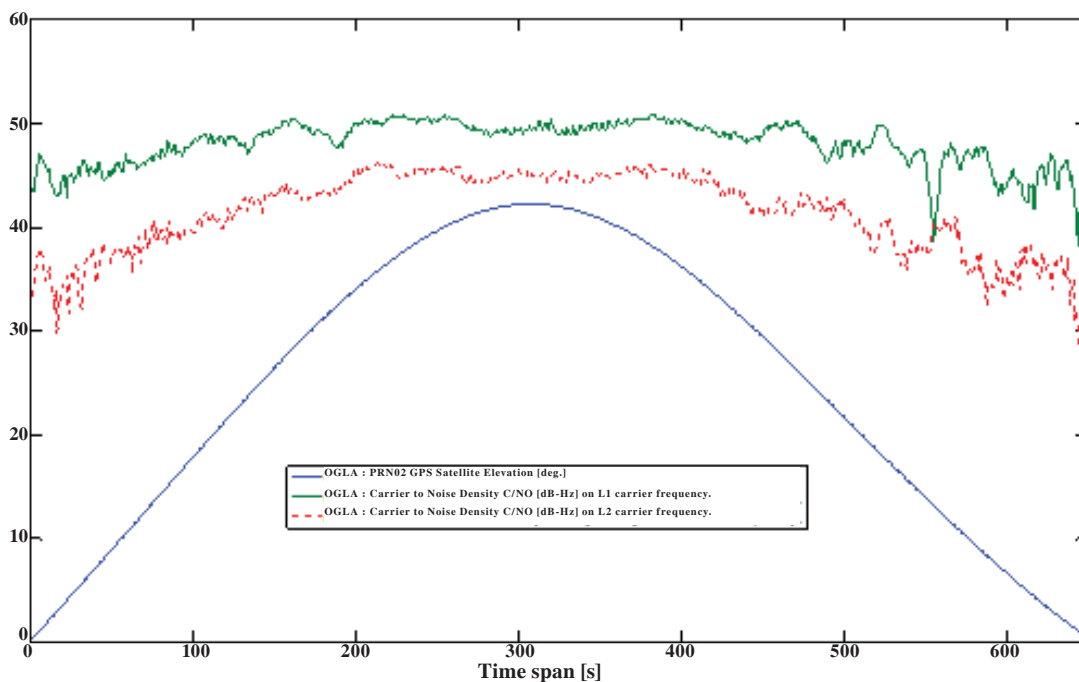


Fig. 5 Carrier-to-Noise-Density C/N₀ (dB-Hz) vs Sat Elev (°) for both stations DZAL and OGLA: GPS system (PRN02) : L1 & L2.

The figures above related to signal to noise ratio for GPS system (satellite PRN02) revealed signal interference, on the southern site OGLA; larger than the signal emitted

from satellite over the northern one DZAL on the same carrier frequencies.



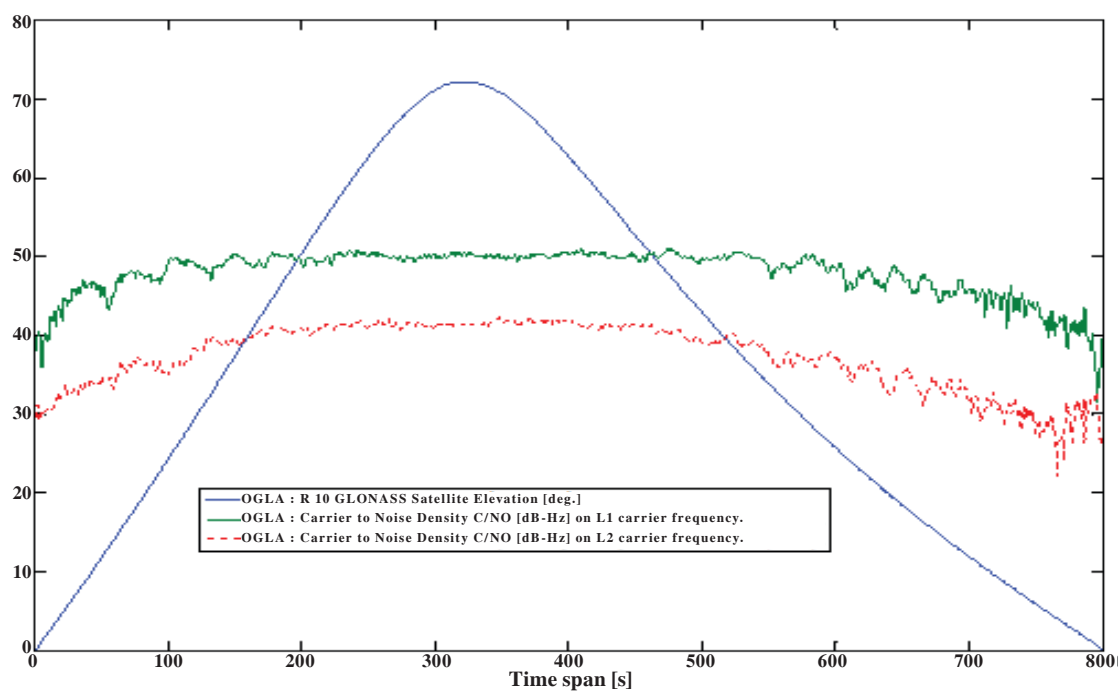


Fig. 6 Carrier-to-Noise-Density C/N₀ (dB-Hz) vs Sat Elev (°) for both stations DZAL and OGLA : GLONASS system (R10) : L1 & L2.

The same inference has been done through the figures above related to signal to noise ratio for GLONASS system (satellite R10) ; the signal interference on the southern

site OGLA is larger than the signal emitted from this satellite over the northern one DZAL on the same carrier frequencies.

Tab 2. Carrier to Noise Density rms values (dB-Hz) for DZAL and OGLA GNSS sites.

#	C/N ₀ rms (dB-Hz)			
System/Satellite	GPS/PRN02		GLONASS/R10	
Frequencies	L_1	L_2	L_1	L_2
DZAL	1.4477	2.8360	1.8174	3.0306
OGLA	2.7303	3.9466	3.1206	4.4310

4. Post-processing data analysis

4.1 Position estimates Precise Point Positioning PPP Technique

In order to ensure the data reliability and completeness and site stability analysis, GNSS post-processing was performed by the Precise Point Positioning (PPP) technique where a daily position estimates were computed from 2008 until 2015 for the northern station DZAL and from 2012 until 2015 for southern one OGLA.

This fast and efficient technique [S. D. Desai & al. JPL] allow determining the exact coordinates of a single point using code or phase measurements with precise clocks, orbit information and Earth orientation parameters provided from IGS (International GNSS Service). The use of dual frequency measurements eliminates the ionosphere effects. The main mathematical model

underlying dual frequency PPP is defined by the desired ionosphere free combination of code pseudo-range [Dach, R., et al. BSW5.2].

$$\frac{P_1 f_1^2}{f_1^2 - f_2^2} - \frac{P_2 f_2^2}{f_1^2 - f_2^2} = \rho + c\delta_r + \Delta_{irp} \quad (3)$$

And carrier phases

$$\frac{\lambda_1 \Phi_1 f_1^2}{f_1^2 - f_2^2} - \frac{\lambda_2 \Phi_2 f_2^2}{f_1^2 - f_2^2} = \rho + c\delta_r + \Delta_{irp} + \frac{\lambda_1 N_1 f_1^2}{f_1^2 - f_2^2} - \frac{\lambda_2 N_2 f_2^2}{f_1^2 - f_2^2} \quad (4)$$

The figure 6 below shows the de-trended time series (i.e. after removal of trend and periodic terms) of the estimated daily positions from to Algerian GNSS stations and statistics for the three components, North, East and Up.

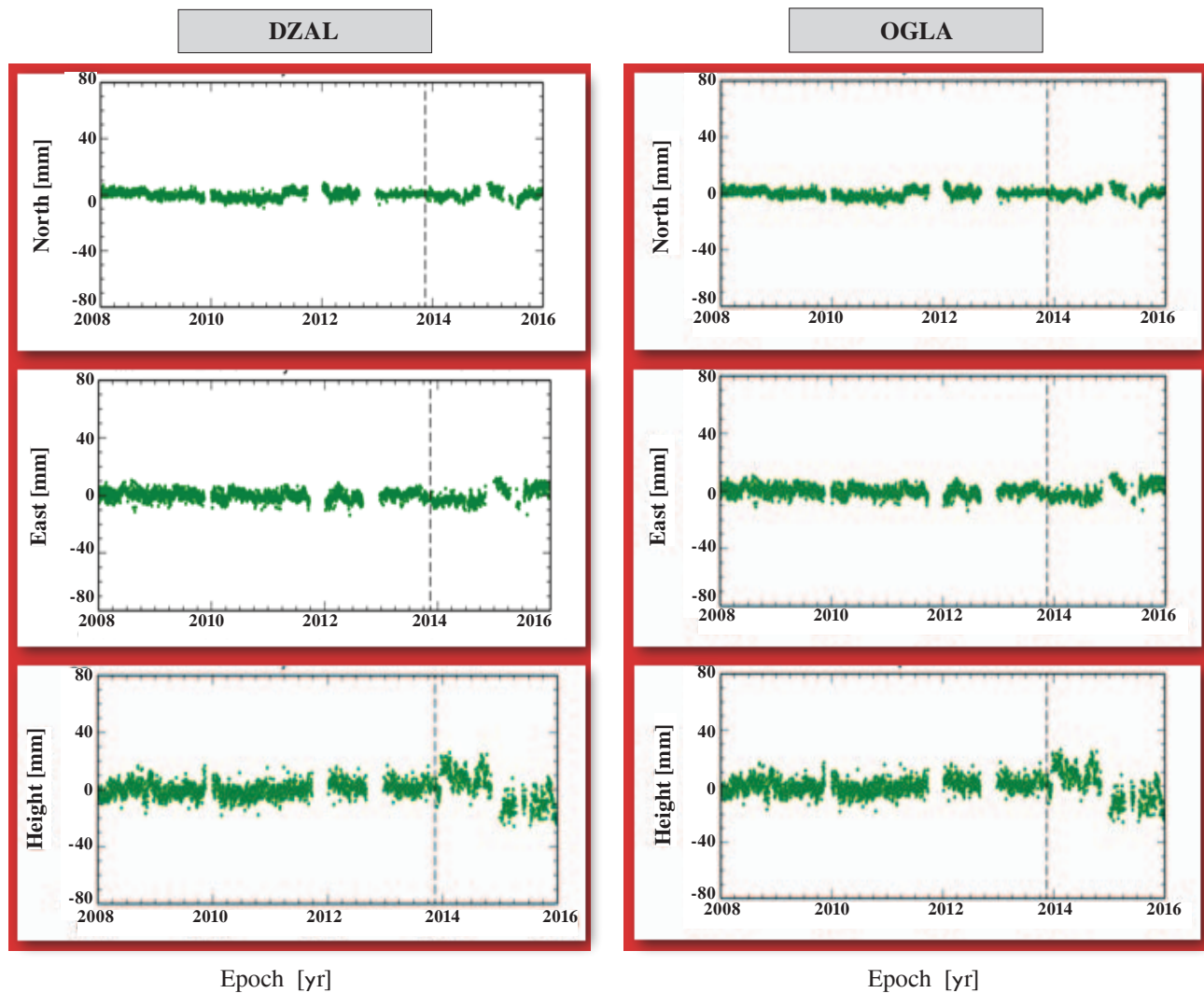


Fig. 6 Position time series for DZAL and OGLA from PPP post-processing.

Tab 3. Velocities (mm/yr) and their wrms(mm) values for the northern and southern Algerian GNSS Stations DZAL and OGLA respectively, for the three components, North, East and Up correspondent to their time series of coordinates.

	DZAL	wrms(mm)	OGLA	wrms(mm)
V_N (mm/yr)	19.3 ± 0.2	2.5559	19.2 ± 0.5	2.3756
V_E (mm/yr)	21.2 ± 0.3	3.5623	20.6 ± 0.8	3.6791
V_U (mm/yr)	-1.0 ± 0.7	5.8903	-5.8 ± 1.5	6.6382

4.2 Site stability analysis

The stochastic properties of the post-processed continuous position time series for the two mentioned permanent stations under study have been analyzed for noise content using maximum likelihood estimation (MLE) [Langbein and Johnson 1997] to evaluate the time series for linear combinations of white ($k = 0$) and colored noise sequences with integer spectral indices ($k = 1, k = 2$) [Mandelbrot and Van Ness, 1968] in order to study their monumentations stabilities.

It is important to understand the noise content of GNSS position data so that realistic uncertainties can be assigned to some relevant parameters estimated from them, so an important part of deducing site motion models from GNSS data is to categorize and measure the noise components.

The lengths of the time series under study were from 2008 until 2015 for the northern station DZAL and from 2012 until 2015 for the southern one. In this evaluation the noise was assumed to be white noise only, and with a combination of white noise plus flicker noise. The solutions have shown that the noise can be best described by a combination of white noise plus flicker noise [Williams, 2003a].

Two possible stochastic models have been evaluated: white noise (WN), and a combination of white noise and flicker noise (WN + FN).

Each individual noise process is represented by a single standard deviation of normally distributed random variables. The magnitudes of white noise and flicker noise have units of distance (millimeters).

A measured station coordinate component can be modeled by an initial value of the component x_0 (abscissa intercept) and velocity v (assuming a linear accumulation of deformation) such that

$$x(t_i) = x_0 + vt_i + \varepsilon_x(t) \quad (5)$$

Or in the matrix form

$$y(t) = Ax(t) + \varepsilon(t) \quad (6)$$

With

$$A = \begin{bmatrix} 1 & t_1 \\ \vdots & \vdots \\ 1 & t_N \end{bmatrix}; y = \begin{bmatrix} x_1 \\ \vdots \\ x_N \end{bmatrix}; x = \begin{bmatrix} x_0 \\ v \end{bmatrix} \quad (7)$$

We assume that the error term is a linear combination of a sequence of uncorrelated unit-variance random variables α and a colored noise sequence β such that

$$\varepsilon(t) = a\alpha(t) + b_k\beta(t) \quad (8)$$

Coefficients a and b_k are the magnitude of white noise and colored noise, respectively. The covariance matrix of $x(t)$ is given by

$$C_x(t) = E\{\varepsilon^T(t) \varepsilon(t)\} = a^2 I + b_k^2 J_k(t) \quad (9)$$

Where I is the identity matrix and J_k is the colored noise covariance matrix. Matrices I and J_k have dimension N , the number of points in the time series [Simon D. P. Williams, 2004]. The subscript k denotes the spectral index of the colored noise (i.e, $k = 1$ for flicker noise).

By the use of the MLE algorithm, we estimate coefficients a and b_k such that

$$C_x(t) = \hat{a}^2 I + \hat{b}_k^2 J_k(t) \quad (10)$$

The maximum likelihood estimates of the coefficients (a and b_k) for the two permanent stations DZAL and OGLA time series are presented in Table 4 for WN and WN+FN stochastic models.

Tab 4. Rate (mm/yr) and abscissa intercepts (mm) with their uncertainties values for DZAL and OGLA respectively, for the three components, North, East and Up correspondent to their time series of coordinates.

Site	N/ E/ U	WN		WN+FN		Ratio
		Rate	Intercept	Rate	Intercept	
DZAL	N	19.2575 +/-0.0358	-53.8271 +/-0.1148	19.2575 +/- 0.244	-53.8271 +/- 0.1148	6.8
	E	21.2254 +/-0.0525	-70.5626 +/- 0.1685	21.2254 +/-0.3387	-70.5626 +/- 0.1685	6.5
	U	-0.9603 +/- 0.0998	-18.6591 +/- 0.3203	-0.9603 +/- 0.6849	-18.6591 +/- 0.3203	6.9
OGLA	N	19.1920 +/-0.0663	-43.7834 +/- 0.1643	19.7032 +/-0.5764	-31.9192 +/- 0.2129	5.0
	E	20.6384 +/-0.1055	-45.4380 +/-0.2615	19.1406 +/-0.5954	-41.5505 +/- 0.2433	4.5
	U	-5.7668 +/- 0.1946	6.8432 +/- 0.4825	-3.4341 +/- 1.2802	12.3537 +/- 0.5042	4.7

Tab 5. Noise amplitude estimates (mm) for white and colored noises for DZAL and OGLA, for the three components, North, East and Vertical.

Components	White noise, (mm)			Flicker noise, (mm / yr ^{1/d})		
	North	East	Vertical	North	East	Vertical
DZAL	0.0013	0.0022	0.0036	0.0062	0.0086	0.0174
OGLA	0.0010	0.0016	0.0030	0.0064	0.0066	0.0142

5. Conclusion

Despite the characteristics of the choke-ring GNSS antennas that are conceived to mitigate the multipath signals, the figures related to signal to noise ration and multipath revealed signal interferences, on the southern site OGLA for both GPS and GLONASS; somewhat more important comparing to signal emitted from satellites over the northern one DZAL on the same carrier frequencies. These trends have probably latitude dependence and at the same time are caused by interference of the direct and reflected satellite signals and due essentially to the environment around the site, probably telecommunication antennas interference, new buildings and neighboring sharp structure effects.

This effect depends as well on the Earth's atmospheric conditions, absorption and re-radiation of the GNSS signals. The southern site seems to be more subject to this phenomena opposing to the northern one. One of the reasons also of this fact is that the southern station OGLA

is located close to the northern crest of the Equatorial Ionization Anomaly (EIA) and an impact of the multipaths and high ionospheres' gradients is predominantly significant at low elevation satellites as avowed in the figures below of 28° of satellite elevations PRN02 (GPS) and R10 (GLONASS). It is worth pointing out others environmental factors such as temperature, humidity, salt, which can affect the performance of a GNSS antenna. These space losses change also with a varying distance between satellites and receiver, as shown in the figures describing signal strength versus satellites elevation.

Besides, the estimated parameters from the daily position time series of the permanent sites under study have revealed a fairly stability of monumentations. However, both noise type components (WN and FN) have shown latitude dependence in their amplitudes [Calais, 1999] higher at northern site as shown in table 5.

A comparison of the noise amplitudes to the different monument types suggests that the deep drill braced monument is preferred for maximum stability in the Northern site.

The methodology as described in this work, providing key indicators computation with post-processing, will be applied on the whole planned sites, in order to select the best GNSS sites for highest standard and for maximum stability.

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