Algerian permanent GPS network : first results

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ملخّص : تبيّن الإهتزازات الأرضية التي تضرب شمال الجزائر والمقاييس الخاصّة بقياسات الأرض المحليّة بأن تشوه حركات القشرة الأرضية ما زال نشيطا. هذا التشوه يُترجمُ عموماً بتقارب أوروبا-آسيا-إفريقيا. يسمح إستعمال تقنيات الأقمار الصناعية تحددُ من التخلص من الصعوبات الكلاسكية و تقدم إضافةً إلى الفوائد التقنية مكسب في الوقت ، في الدقّة وفي الكلفة. من بين درع لأجهزة التحديد الفضائي تبقى أجهزة تحديد المواقع الحالية GPS الأداة الأكثر ملائمة للحاجات الحركية الأرضية والمراقبة الزلزالية ، كما تقدم حقل كبير منْ التطبيقات الخاصّة بقياسات الأرض والأداءات المهمة أكثر بكثير منْ الأجهزة الأخرى.
يتمثل الهدف من هذه الدراسة من جهة في التقدير الدقيق للإحداثيات محطات GPS الثلاثة الجزائرية الدائمة الجديدة بإدماج معطيات ومُنتَجات IGS وذلك بإستعمال البرنامج العلمي بيرنيس 5.0 ، ومن جهة أخرى في متابعة تغير السرعة التي تسببها الحركات الأرضية .

الكلمات الأساسية: شبكة GPS الجزائرية الدائمة، AFREF ، بيرنيس 5.0 ، إحداثيات ، الحركية الأرضية ، IGS ، حركات القشرة الأرضية ، سلسلة زمنية ، السرعة .

Résumé : La sismicité qui touche le nord de l'Algérie et les mesures géodésiques locales montre que la déformation tectonique est encore active. Cette déformation est interprétée généralement par la convergence de Afrique-Eurepe-Asie. L'usage des techniques de positionnement satellitaire permettrait à se liberer de contraints classique et présente. en plus les avantages techniques. un gain dans le temps. dans la précision et dans le coût. Parmi la panoplie des systèmes de positionnement spatiaux actuels. le GPS reste l'outil le plus approprié pour les besoins géodynamiques et la surveillance sismique. comme il presente un grand champ d'applications géodésiques et des performances beaucoup plus intéressantes que les autres systèmes.
L'objectif de cette étude consiste d'une part en l'estimation précise des coordonnées des trois nouvelles stations GPS permanentes Algérienes en intégrant les données et les produits IGS en utilisant le logiciel scientifique Bernese 5.0. et d'autre part reconduire le déplacement des vélocités causé par les mouvements géodynamiques.

Mots-clés : Réseau GPS Permanent Algérien. AFREF. Bernese 5.0. coordonnées. Géodynamique. IGS. tectonique, série du temps. vitesse.

Abstract : seismicity which marks out Northern Algeria and local geodetic measures shows that the tectonic deformation is still active. This deformation is generally interpreted as the result of Eurasia-Africa convergence. The use of satellites positioning techniques would allow to get free from classical constraints and offer. besides the technical advantages. a gain in time. in precision and in cost. Among the panoply of existing spatial positioning systems. the GPS remains the most appropriate tool for the geodynamic needs and the seismic surveillance. as it offers a large field of geodetic applications and much more interesting performances than the other systems.
The objective of this study consists of on one hand in the precise estimation of the coordinates of the three new permanent Algerian GPS stations while integrating the IGS data and products and that by using the Bernese 5.0 scientific software. and on the other hand in showing out the velocities displacement caused by geodynamic movements.

Keywords : Algerian permanent GPS network. AFREF. Bernese 5.0. coordinates. Geodynamic. IGS. tectonic. repeatability. time series. velocities.

1. Introduction

Northern Algeria. a limit of the European and the African tectonic plates. is the place of intense tectonic deformation marked by the occurrence of catastrophic strong earthquakes (Algiers 1365. Algiers 1716. Oran 1790. Mascara 1810. Jijel 1856. Gouraya 1891. Tenes 1922. El Asnam 1954 et 1980. Constantine 1985. Tipasa 1989. Mascara 1994. Ain Temouchent 1999. Beni Ouartilane 2000. Zemmouri 2003). One of the surveying techniques of these phenomena consists in the setting of geodetic precise networks into national scale (geodynamic) or local scale (seismic surveillance). so as to quantify the deformations. The access to this cinematic knowledge goes through, in particular. the direct measure of the displacements and crustal deformations by geodesy The permanent GPS technique allows the obtention of continuous temporal series of stations positions. which allows to detect the geophysics effects. particularly those of tectonic origin. which can affect the position of stations in course of time.

The objective of this paper consists in the precise estimation of the coordinates and the velocities of the three new permanent Algerian GPS stations (DZOR, DZAL, DZCO). The GPS data are processed with the Bernese v5.0 software, together with eight IGS stations (CAGL, GRAS, MAS1, MATE, NOT1, SFER, VILL and ZIMM) that serve as ties with the IGS05. By the term of the good accuracy obtained on the position of the whole of the stations: 1-4 mm for the planimetry components and 1-8 mm for the vertical component, the Algerian permanent GPS network constitute no doubt a basic geodetic infrastructure for the GPS works of the different Algerian institutions. The geophysical interpretation of the velocities components estimated at 2.4 cm/year towards the North East for the Oran station and at 2.6 cm towards the North East for both Algiers and Constantine stations, although they are marginally significant, will allow to complete information related to the geodynamic and seismologic bahaviour Algeria.

2. Geodynamical context of the Western Mediterranean

The Mediterranean basin is characterized by an active global tectonic. Folds, faults and high orogenic accidents characterize the area such as the Rif, the Atlas, the Betic Cordillera, the Alps, the Apennines and the Pyrenees. With these important deformation zones, alternate continental blocks with small deformations: the High Plateau (Algeria), the Corsica – Sardinia block, the Sicily and the Iberian Meseta. These major deformations are the result of the continental collision of the North - European and African platforms which converge with a globally North - South direction since seventy millions years, with a rising extension East-West with approximately a half-centimeter rate per year in Algiers to reach the average of a centimeter in the Sicily meridian.

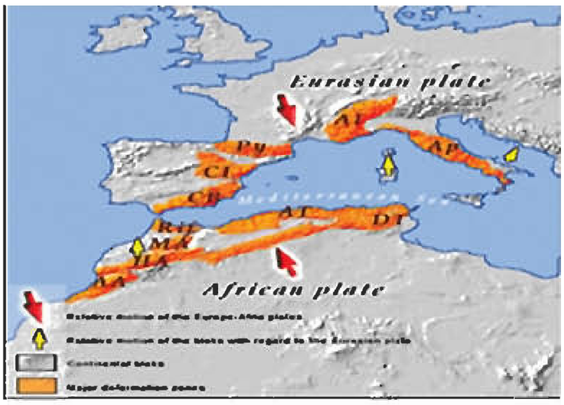

Fig. 1 Great tectonic structures in western Mediterranean.

AA: Anti-Atlas, **Al:** *Alps,* ***Ap:*** *Appenins,* **AS:** *Saharian Atlas,* ***AT:*** *Tellian Atlas,* ***CB:*** *Betic Cordelira,* ***CI:*** *Iberic Chain,* ***DT:*** *Tunisian Dorsal,* ***HA:*** *High Atlas,* ***Py:*** *Pyrenees,* ***MA:*** *Medium Atlas.*

This relative displacement is accompanied by a rotation of the two plates which rotation axis is situated near Rabat: there is then a quasi non-existent movement. Figure (1) shows the great tectonic structures in the western Mediterranean (Rebaï, 1996).

3. Algerian permanent GPS network

The Algerian permanent GPS network was initiated in 2006 by the National Institute of Cartography and Remote Sensing in the framework of the AFREF project (AFrican REference Frame). Actually, three stations are already operational: DZAL (Algiers), DZOR (Oran) and DZCO (Constantine). The time period of GPS observations from these three stations covers two weeks in 2007: 1420 and 1421 (084 GPS day to 097 GPS day) and two other weeks in 2008: 1447 and 1475 (097 GPS day to 110 GPS day).
The GPS data from the Algerian network are processed, together with eight IGS stations (CAGL, GRAS, MAS1, MATE, NOT1, SFER, VILL and ZIMM) that serve as ties with the IGS05. Figure (2) illustrates the Algerian Permanent GPS and IGS stations used in our data processing.

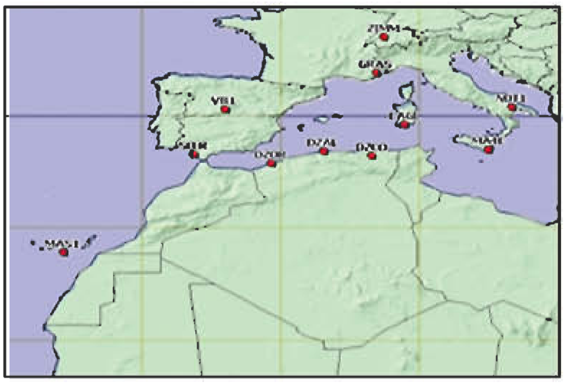

Fig. 2 Algerian Permanent GPS and IGS stations used.

4. Data processing

The Bernese GPS Software v5.0 (Dach et al., 2007 & 2004) was used to process the data. The standard method was based on the script file RNX2SNX. The RNX2SNX.PCF is intended for a double-difference based analysis of RINEX GNSS observation data from a regional network. Station coordinates and troposphere parameters are estimated and stored in Bernese and SINEX format to facilitate further processing and combination. For each session, the corresponding normal equation information is saved for a subsequent multi-session solution (allowing the estimation of station velocities).The basic options of the used processing strategy are:

- The consideration of "absolute" GNSS receiver and satellite antenna phase center offset (105).

- Observation files with significant gaps or unexpectedly big residuals will automatically be removed from the processing to ensure a robust processing and a reasonable network solution.

- Phase ambiguity fixing is attempted for baselines up to 2000 km length based on the Quasi-Ionosphere-Free (QIF) resolution strategy.

- The final network solution is a minimum constraint solution, realized by three no-net-translation conditions imposed on a set of IGS05) reference coordinates. The coordinates of all involved fiducial stations are subsequently verified by means of a 3-parameter Helmert transformation. In case of discrepancies, the network solution is recomputed based on a reduced set of fiducial stations.

Besides some standard files (orbit and pole information, satellite clocks information, GOT00.2 ocean loading parameters, etc.), some other files are specifically required to execute this RNX2SNX PCF: coordinate file (IGS 05.CRD), velocity file (IGS05.VEL), and list of reference sites in the coordinate file (IGS05.FIX).

To obtain a set of station coordinates and NNR-NUVEL-1A velocities for the three new Algerian stations, necessary as a priori information for the double-difference analysis done by RNX2SNX.PCF, we used the precise point positioning approach

5. Results

5.1 Repeatability coordinates rms values

To appreciate the quality of results, we are interested to the weekly coordinate repeatability. A bad repeatability indicates possible environmental, station, or processing problems. It also may be caused by geophysical phenomena (e.g., Earthquake).

The obtained weekly coordinate repeatability, the daily reduced normal equation files (NEQs) results are combined by week using the ADDNEQ2 program. The geodetic datum of the network is defined based on minimum constraint solution. The tables (1), (2), (3) and (4) represent respectively the weekly 1420, 1421, 1474 and 1475 repeatability coordinates rms (Root Mean Square) values:

Table 1. Repeatability coordinates rms values, week 1420.

	Repeatability (mm)		
Station	N	E	U
CAGL 12725M003	0.38	0.73	1.61
DZAL	0.48	0.80	1.33
DZCO	0.51	0.75	2.49
DZOR	1.04	0.63	3.19
GRAS 10002M006	0.70	0.58	.35
MAS1 31303M002	0.91	0.64	1.57
MATE 12734M008	0.91	0.39	2.60
NOT1 12717M004	0.56	1.23	2.01
SFER 13402M004	0.32	0.33	2.02
VILL 13406M001	0.55	0.43	1.63
ZIMM 14001M004	0.44	0.69	1.33

Table 2. Repeatability coordinates rms values, week 1421.

	Repeatability (mm)		
Station	N	E	U
CAGL 12725M003	1.83	2.32	4.15
DZAL	0.79	1.80	3.57
DZCO	1.32	1.96	2.01
DZOR	1.08	1.66	3.04
GRAS 10002M006	2.00	4.18	7.57
MAS1 31303M002	2.92	1.88	2.07
MATE 12734M008	2.90	2.59	3.98
NOT1 12717M004	3.03	3.25	3.22
SFER 13402M004	1.16	1.14	1.89
VILL 13406M001	1.32	2.24	3.30
ZIMM 14001M004	4.11	17.58	7.19

Table 3. Repeatability coordinates rms values, week 1474.

	Repeatability (mm)		
Station	N	E	U
CAGL 12725M003	1.28	1.77	5.20
DZAL	0.88	1.12	1.99
DZCO	0.73	1.13	3.54
DZOR	0.64	1.46	2.82
GRAS 10002M006	0.74	0.52	3.05
MAS1 31303M002	0.26	0.96	2.99
MATE 12734M008	0.82	0.39	1.78
NOT1 12717M004	0.60	1.62	2.81
SFER 13402M004	0.73	0.71	4.14
VILL 13406M001	0.82	0.73	3.72
ZIMM 14001M004	1.28	0.69	2.39

Table 4. Repeatability coordinates rms values, week 1475.

Station		Repeatability (mm) N	E	U
CAGL	12725M003	0.99	1.25	1.58
DZAL		0.68	0.81	3.21
DZCO		0.59	0.34	2.69
DZOR		1.29	1.90	1.12
GRAS	10002M006	0.80	1.05	2.06
MAS1	31303M002	0.52	0.79	1.67
MATE	12734M008	0.71	0.41	1.05
NOT1	12717M004	1.11	0.87	3.92
SFER	13402M004	0.69	1.21	1.41
VILL	13406M001	0.67	0.38	2.03
ZIMM	14001M004	0.85	1.09	2.24

We get for the whole of the stations repeatabilities going from 1-4 mm for the planimetric components (except the ZIMM station, week 1421: 17.6 mm) and of 1-8 mm for the vertical component. These results clearly show the accuracy of obtained results is very satisfactory in relation with the requirements in the subject.

5.2 Final coordinates

The Bernese GPS Software allows to estimate final site coordinates in a network analysis. The normal equation systems from different sessions are combined in a multi-session solution with ADDNEQ2. All coordinate parameters belonging to the same station are combined to one single set of coordinates. The resulting coordinates then refer to the middle epoch (October 07, 2007).

A seven-parameter Helmert transformation is applied to compare each individual solution with the combined solution. The geodetic datum of the network is defined based on minimum constraint solution. The table (5) represents the repeatability coordinates rms values of the combined solution:

Table 5. Repeatability coordinates rms values of the combined solution (weeks: 1420, 1421, 1474 and 1475).

Station		Repeatability (mm) N	E	U
CAGL	12725M003	1.32	1.76	3.76
DZAL		1.04	1.60	2.54
DZCO		1.52	1.35	3.36
DZOR		1.39	1.54	3.37
GRAS	10002M006	1.02	2.05	3.79
MAS1	31303M002	1.85	1.28	4.31
MATE	12734M008	1.55	1.40	3.09
NOT1	12717M004	1.79	1.95	2.85
SFER	13402M004	0.90	1.27	3.18
VILL	13406M001	1.08	1.89	3.87
ZIMM	14001M004	2.52	8.87	4.54

5.3 Velocities

Using ADDNEQ2 program, the normal equation systems from different sessions are recombined again in a multi-session solution with ADDNEQ2. The velocity estimation is activated by the option "Set up station velocities" in panel "ADDNEQ2 3.1. The geodetic datum of the network is defined based on minimum constraint solution. The table (6) represents the estimated velocities

Table 6. Estimated velocities.

Site		A priori value	Estimated value	RMS error
CAGL	VU	0.0003	-0.0010	0.000
	VN	0.0161	0.0158	0.000.
	VE	0.0215	0.0199	0.0001
DZAL	VU	0.0001	0.0010	0.0004
	VN	0.0200	0.0180	0.0001
	VE	0.0174	0.0191	0.0001
DZCO	VU	0.0001	0.0050	0.0004
	VN	0.0203	0.0174	0.0001
	VE	0.0182	0.0194	0.0001
DZOR	VU	0.0001	0.0033	0.0004
	VN	0.0196	0.0170	0.0001
	VE	0.0169	0.0176	0.0001
GRAS	VU	-0.0003	0.0011	0.0004
	VN	0.0164	0.0155	0.0001
	VE	0.0201	0.0207	0.0001
MAS1	VU	0.0009	-0.0107	0.0006
	VN	0.0179	0.0184	0.0001
	VE	0.0165	0.0166	0.0001
MATE	VU	0.0012	0.0021	0.0005
	VN	0.0194	0.0194	0.0001
	VE	0.0232	0.0233	0.0001
NOT1	VU	-0.0007	0.0038	0.0005
	VN	0.0199	0.0184	0.0001
	VE	0.0211	0.0209	0.0001
SFER	VU	0.0029	0.0054	0.0004
	VN	0.0170	0.0171	0.0001
	VE	0.0133	0.0153	0.0001
VILL	VU	-0.0018	0.0027	0.0005
	VN	0.0168	0.0171	0.0001
	VE	0.0196	0.0168	0.0001
ZIMM	VU	0.0023	0.0007	0.0004
	VN	0.0161	0.0163	0.0001
	VE	0.0196	0.0178	0.0001

The Oran station (DZOR) shows a 2.4 cm/year displacement to the North East. Both stations of Algiers (DZAL) and Constantine (DZCO) show as concerns them a 2.6 cm/year displacement to the North East. This result is in accordance with the seismotectonic results which show a generalized radial extension affecting the north of Algeria.

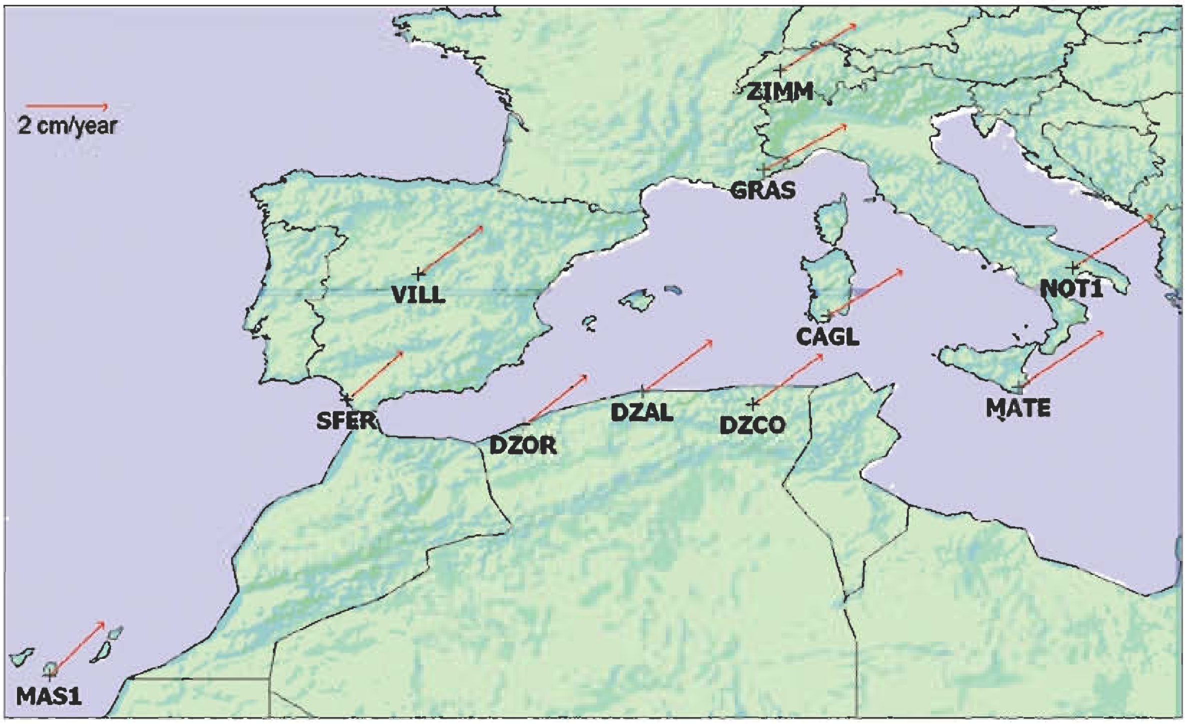

Fig. 3 Estimated velocities.

6. Conclusion

The main objective of the present study refers in general to the mastery of positioning technology by GPS satellites and its application to concrete needs.
Concerning the data processing of the whole of the stations, the weekly repeatability coordinates rms values obtained by combination of daily reduced normal equation files (NEQs) are 1-4 mm for planimetrc components (exception of the station ZIMM, week 1421 : 17.6 mm), 1-8 mm for vertical components. We conclude that the quality of processing results is acceptable regarding to the international criteria in permanent GPS.
Concerning the obtained results on components velocities, although they are still that marginally significant becoming one year time interval between the measures, show a 2.4 cm/year displacement to the North East for Oran station and 2.6 cm/year displacement to the North East for the two Algiers and Oran stations. Moreover, these results have the advantage of being independent from the cinematic model NNR-NUVEL-1A and of being based only on GPS measures.

In perspective, the Algerian permanent GPS network densification represents a capital stake for the modernization of the national geodetic infrastructure and for a better knowledge of the deformations of geodynamic origin, especially in northern Algeria were the seismic activity is strong. Finally, we will keep in mind the increasing importance represented by the spatial geodesy for the studies of the earth crust deformations. The tectonic applications represent a capital stake for the future of the geodesy. Indeed, that exist today to search for more accuracy if not those of the geophysicians.

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