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Data analysis of the first epoch GPS Algerian regional network

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Summary. - With the aim to evaluate the present day crustal deformation of central western Mediterranean and northern Africa, a regional GPS network was planned and measured in the frame of the Tyrgeonet and Algeonet projects. We analyse GPS data collected at ten geodetic monuments located in Algeria, together with the Villafranca, Roquetes, Cagliari, Matera and Noto IGS permanent stations. This GPS network is deployed in a crucial area for the comprehension of the Western Mediterranean geodynamics, being located along the collision belt between the Eurasian and African plates. Moreover, some of the Algerian stations are located in the inner Algeria, along the Atlas deformed zone that released strong seismic events in the past, not yet studied by space based geodetic techniques. Other four stations are located in the tectonically stable of the Algerian erg. In this paper we describe the network and the data analysis of the first epoch surveys performed during June 1998.

ANALISI DEI DATI DELLA PRIMA RETE REGIONALE GPS ALGERINA.

Sommario. - Con lo scopo di valutare la deformazione crostale attuale del Mediterraneo centrale e occidentale e dell'Africa settentrionale, è stata progettata e misurata una rete GPS regionale, nell'ambito delle attività legate ai progetti Tyrgeonet e Algeonet. Si analizzano i dati GPS acquisiti in dieci stazioni geodetiche poste in Algeria, unitamente ai dati provenienti dalle stazioni permanenti afferenti alla rete IGS di Villafranca, Roquetes, Cagliari, Matera e Noto. La rete GPS è distribuita in un area cruciale per la comprensione della geodinamica del Mediterraneo occidentale, essendo posta attraverso la fascia di collisione tra le placche continentali Africana ed Europea. Inoltre alcune delle stazioni algerine sono poste all'interno di questa regione, lungo la zona deformata dell'Atlante che non è ancora indagata mediante tecniche geodetiche spaziali, che nel passato ha rilasciato forti eventi sismici. Quattro stazioni sono poste nell'erg algerino, tettonicamente stabile.

Viene descritta la rete GPS e mostrati i risultati della prima campagna di misura, effettuata nel 1998.

Keywords: Algeria, Central Mediterranean, geodynamics, GPS, plate tectonics.
Parole chiave: Algeria, geodinamica, GPS, Mediterraneo Centrale, tettonica delle placche.

1. - INTRODUCTION

In 1998 the Algerian Centre National des Technique Spatiales (Arzew) and the Institut National de Cartographie (Algiers), started the Algeonet project (Algerian Geodetic Network) for the evaluation of the present day crustal deformation of the Algerian region by means of a regional geodetic network, based on the Global Positioning System (GPS) technique (Kahlouche et al., 2001). The first epoch surveys of Algeonet were performed in June 1999, during the Tyrgeonet campaign carried out by the Istituto Nazionale di Geofisica and the University of Bologna (Anzidei et al., 1995), allowing the connection between the two networks. The use of five GPS permanent stations of the IGS network located in southern Europe, together with the other ten non permanent stations located in the inner Algeria, set up for the project, can provide a new opportunity to clarify the debated European-African kinematics, not yet been investigated in this area by regional geodetic networks devoted to geophysical research (De Mets et al., 1990; Albarello et al., 1995; Le Pichon et al., 1995; Mantovani et al., 1996, 1997).

The relative low velocity of plates, especially in the central and western Mediterranean area, as predicted by global geodynamic models (De Mets et al., 1990), or observed by recent GPS campaigns (Anzidei et al., 1999, 2001), needs observations over a long time span to resolve the kinematic pattern of this heterogeneous region. Thus is required the establishment of several geodetic monuments deployed in the critical areas, to be reoccupied during repeated campaigns, for a long enough time span to reveal the present day tectonic strain rate. This holds in particular for the Mediterranean region where a complex microplate mosaic is present and the different tectonic sub-domains must be discriminated. Nowaday GPS technique is success-fully used to detect crustal deformations at various scales, so that GPS networks are currently used for this purpose all over the world. In this paper we describe the general tectonic framework of the network and we analyse and discuss the data from the first epoch survey using different computing strategies to compute this regional network.

2. - GEODYNAMICS OF THE ALGERIA REGION

The geodynamic of the Algerian region is mainly affected by the deformation pattern occurring along the collisional belt between the African and the Eurasian plates, characterized by a complex space-time distribution of compressional and tensional events, with the opening of basins and the formation of mountain chains (fig. 1).

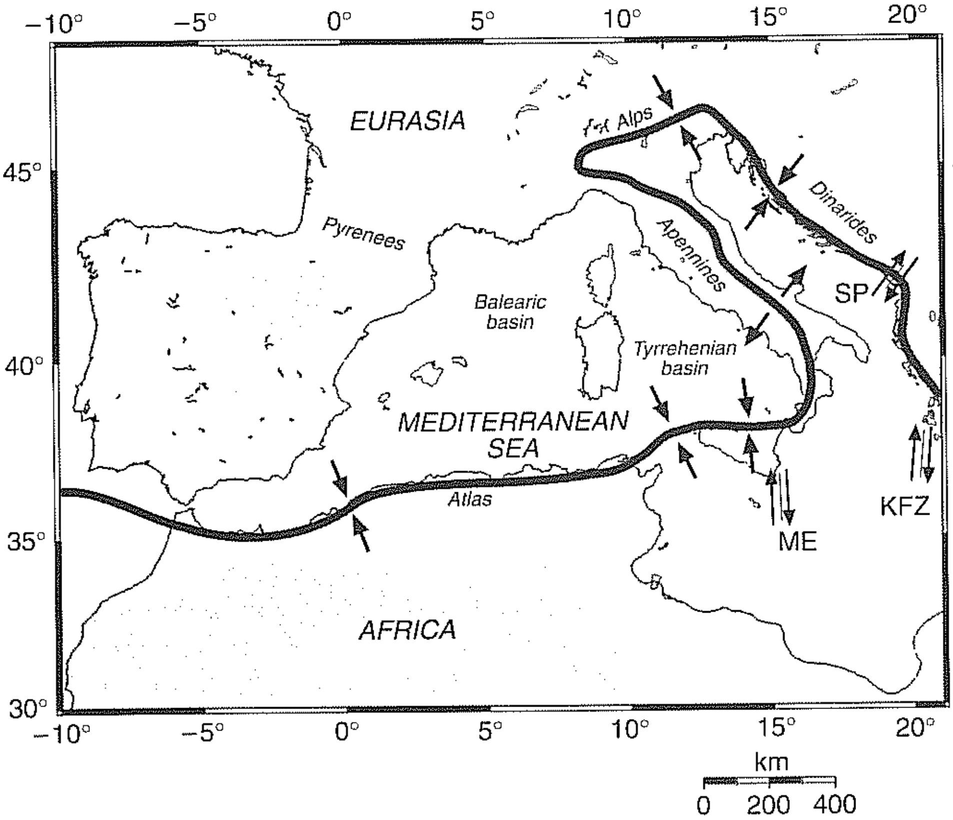

Fig. 1 - Tectonic setting of the central and Western Mediterranean region. The continuous line represents the Africa - Eurasia boundary where seismicity is still active. Black arrows show the general trend of plate deformation (modified from Pondrelli, 1999). White arrows: SP = Skutari-Pec fault; KFZ = Kephalonia fault zone; ME = Malta Escarpment.

This area experienced significant quaternary tectonic movements, mostly associated with compressional folds, strike-slip faults and thrusts; moreover evidences of E-W to ENE-WSW extension was also observed (Ouyed et al., 1981; Philip and Meghroui, 1983). Neotectonic studies have shown that this collision, mostly induced compressive tectonics with related strike-slip and thrust faults. The direction of shortening is mainly N-S and NNW-SSE, in agreement with the Europe-Africa convergence. Moreover Recurrent seismicity is mainly located along the belt extending from the triple junction of the Azores islands to Middle East, running through Italy and Greece (Udias et al., 1982, Pondrelli et al., 1992). In the southern Iberia, Alboran Sea and northern Algeria is active a predominant regional stress computed from earthquake focal mechanisms, N-S or NW-SE oriented (Buforn et al., 1995). Seismicity of the entire region is mainly clustered in the Maghreb area of the Tell Atlas chain, where the crust is deformed at the border with the oceanic litospehere of the Algerian-Provence basin.

On the contrary, in the south of this area, Algeria is almost aseismic and geologically stable (Benouar, 1994). Only during recent years Algeria is object of geophysical research for seismicity and seismotectonic potential estimation and for seismic risk assessment. From historical and instrumental seismological data can be identified three main seismic areas, around Oran (Western Algeria), Algiers (central Algeria) and El Asnam (Central Atlas) (Benouar, 1994a; 1994b; 1994c). The latter, on October 10, 1980 was struck by the largest known seismic event in this region of M = 7.3, with the occurrence of extensive vertical and horizontal ground deformations were reported with maximum vertical amplitudes of ~ 6 m (Ouyed et al., 1981; Ruegg et al., 1982). This earthquake is the first known earthquake which produced large surface ruptures in the western Mediterranean area and reveals the magnitude of compressional tectonics that characterize the present day north Africa geodynamics. After 1980, only moderate seismicity is reported in the area (Pondrelli et al., 1992).

Due to the tectonic complexity of this region it is mandatory to plan a regional geodetic network, establishing several observation points in the inner African plate with the aim to evaluate its deformation field and the geodetic strain rate also for seismic risk assessment in a region where earthquake hazard constitutes a severe risk which caused economic losses and disruption.

3. - THE GPS NETWORK

The Algeonet network consists of ten monuments located in the whole Algerian region (fig. 2). All the sites belong to the African plate, and part of them are located along the Tell Atlas range (ALGE, ARZE, BISK, LAGH, MECH and SOAH) while others (OUAR, TIND, INSA and HAMA) in the not deformed Erg region. All the monuments consist of concrete pillars built on the ground with the exception of ARZE, HAMA and ALGE which are located on the roof of stable buildings. These last points are independently controlled by local networks in order to evaluate local instabilities.

Two vertices of the network (ALGE and ARZE) have been included since 1995 in the field activities of Tyrgeonet Project, which integrates the European IGS permanent network by means of repeated measurements at a large number of observation points distributed in Italy and surrounding regions (Anzidei et al., 1995). The results of four annual campaigns did not show significant deformation of the Algerian monuments with respect to the IGS and Tyrgeonet stations located in the stable Europe (Anzidei et al., 2001). We underline that the Algerian stations of DEBD and TAMA were established but not included in this computation.

The first GPS measurements were performed in June 1998. Ten stations were occupied for at least two survey sessions spanning from 10 to 24 hours of observations (table 1), using Trimble 4000SSE and Ashtech Z-XII dual frequency receivers, at 30 s sampling rate.

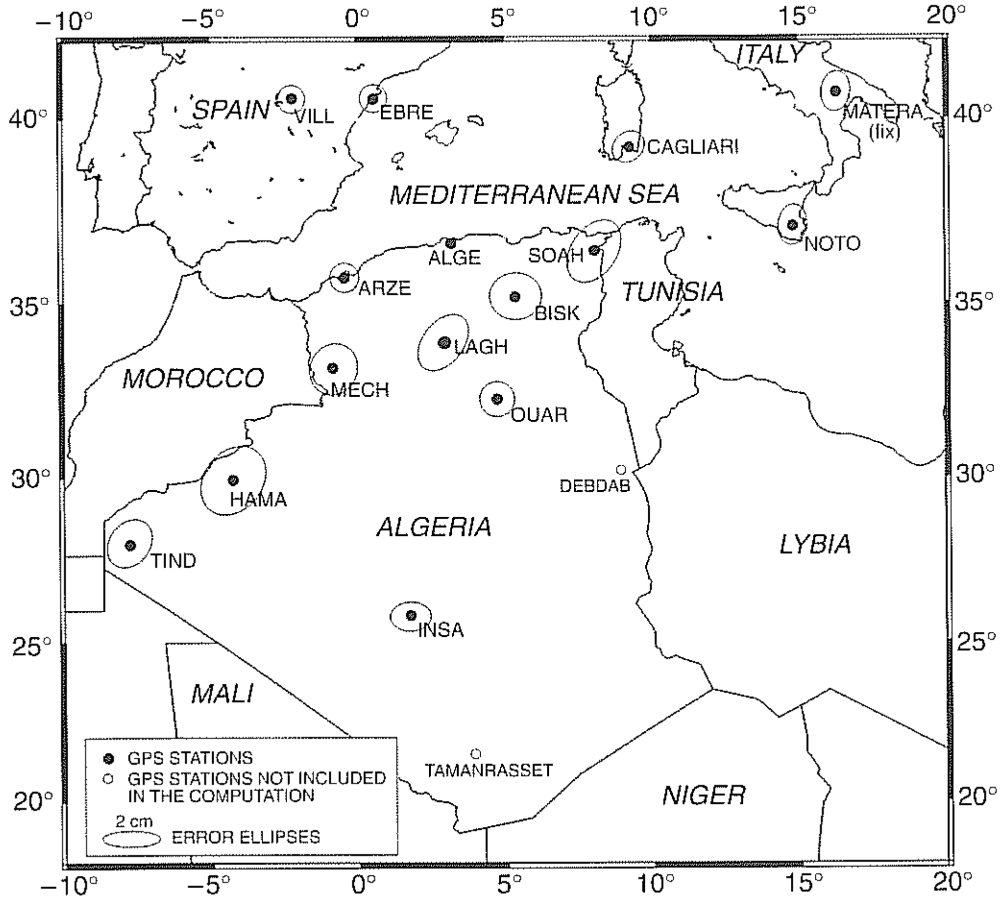

Fig. 2 - The ALGEONET (Algerian GEOdetic NETwork) and error ellipses (99% confidence level) from the first epoch survey (June 1998).

The IGS permanent stations of Villafranca, Roquetes, Matera, Cagliari and Noto, located in the European region were also included in the data analysis.

Table 1 – general features of first epoch survey (June 1998) ALGEONET campaign and data analysis

ALGEONET General features		
Date	June 1998	
Station	15	10 Local 5 IGS (regional)
Monuments	Concrete pillars	
Receivers	8	2 Trimble 4000SSE 6 Ashtech Z-XII
Sampling rate	30 s	
Occupations	2-7 each station	
Time window	10-24 hours	
Data reduction softwares	Bernese vers. 4.0; Netgps	
Ephemerides	CODE	

4. – DATA ANALYSIS

GPS data were processed by the Bernese GPS software v. 4.0 according to well tested procedures for regional campaigns (Rothacher et al., 1996). Precise ephemerides, satellite clock corrections, antenna height phase center variations and some other general files provided by CODE (Center of Orbit Determination in Europe) of the Bern University were included into the computation. Absolute tropospheric delay parameters every four hours were estimated for each station, starting from the Saastamoinen standard model. Each observing session was processed separately to obtain one network solution per session. Each network solution, consisting of the parameter estimations (coordinates, ambiguities, tropospheric delays and the covariance matrix), obtained strongly constraining the coordinates of one different site.

Network adjustment was performed by the program Netgps (Crespi, 1996), that assumes as observations the cartesian component of independent baselines for each session and by Addneq, a program element of the Bernese software, used to combine normal equations previously determined for each session starting from single difference equations where not only coordinate but also other parameters, such as troposphere are considered.

Table 2 shows a comparison between the coordinates obtained by these two different adjustment procedures, after an Helmert transformation of coordinate solutions: the minimal values of residuals point out their consistence.

Table 2 – Results of the Helmert transformation between the two adjusted coordinate set (North, East and Height components)

Nr.	Station	ΔN [mm]	ΔE [mm]	ΔH [mm]
1	CAGL	0.4	0.2	0.3
7	MATE	−0.6	−0.2	−1.3
9	NOTO	0.1	−0.1	−0.6
400	VILL	0.1	−0.5	0.2
401	EBRE	0.5	0	0.9
21	ALGE	0.1	−0.1	2
22	ARZE	−0.2	−0.2	−1
71	OUAR	0	0.2	−1.1
72	BISK	−0.3	0.2	2.4
73	MECH	−0.6	−0.7	4.3
74	INSA	−0.7	−0.1	2.6
75	TIND	0.4	0.6	−1.4
76	LAGH	0.1	0	0.3
77	HAMA	0.7	0.8	−4.9
78	SOAH	0	−0.3	−2.6

Table 3 shows sessions repeatability of station coordinates of Addneq solution and unweighted RMS of individual coordinate residuals.

Tab. 3 – repeability of station coordinates: comparison with respect to the combined solution (addneq) and unweighted RMS of the individual coordinates

Repeatability of station coordinates [mm]											
Nr.	Station	Sess.	1	2	3	4	5	6	7	8	RMS for station
1	CAGL	N	-6.5	-4.8	-2.2	1.5	-2.0	-5.8	10.2	5.3	5.9
		E	-2.3	3.6	3.1	-1.4	-12.1	0.7	0.8	3.9	5.2
		U	-2.6	24.3	8.8	2.0	-7.9	2.4	-13.7	-3.6	11.7
7	MATE	N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		U	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	NOTO	N	-4.7	-4.4	-1.8	1.5	2.9	-1.4	2.6	7.3	4.1
		E	-1.9	4.3	2.8	-0.4	-4.7	0.2	-3.6	3.7	3.4
		U	-9.8	23.3	12.6	-2.1	-16.2	9.9	5.0	-11.6	13.8
400	VILL	N	-2.9	-9.7	-3.7	1.8	-0.4	1.8	4.9	7.0	5.3
		E	-1.0	9.5	11.3	3.7	-7.4	4.9	-9.6	-4.7	7.8
		U	-11.2	23.5	42.5	4.8	-0.4	-3.0	-2.5	-35.2	23.2
401	EBRE	N	-5.9	-6.2	-5.9	1.8	-8.3	1.9	9.2	10.1	7.3
		E	-3.7	8.4	8.4	1.6	-11.8	2.1	-5.5	4.0	7.1
		U	-1.8	13.8	10.1	-7.2	12.2	-6.2	15.8	-24.6	14.1
21	ALGE	N		-1.2	1.9	2.5	-1.6	-4.8	5.9	0.0	3.4
		E		10.7	7.2	-1.9	-11.0	1.0	-1.9	0.9	7.0
		U		4.8	11.5	-0.8	-14.4	20.4	16.4	-6.9	13.5
22	ARZE	N	-7.1	-1.4	0.7	1.2	-1.6	3.2	3.8	0.7	3.4
		E	-3.8	10.9	7.2	-2.9	0.5	1.3	-6.1	-1.6	5.8
		U	-22.8	16.8	30.1	-8.9	14.2	2.2	-4.7	-11.4	17.5
71	OUAR	N	-7.7	3.3	-2.0	2.6	-2.5	-1.1	5.5	-0.9	4.1
		E	14.2	9.8	7.1	6.8	-11.8	1.1	-16.0	7.8	11.0
		U	-55.7	59.2	15.5	4.2	42.1	21.9	-50.4	-10.8	41.0
72	BISK	N							6.0	0.5	6.0
		E							-5.5	2.7	6.2
		U							-9.2	-13.2	16.0
73	MECH	N							5.4	0.3	5.4
		E							-4.6	-1.9	4.9
		U							-17.0	-5.5	17.9
74	INSA	N		6.5	5.5	3.1	-2.2	2.8	0.9	-4.6	4.4
		E		11.2	9.6	0.9	-10.9	1.3	-3.7	-0.4	7.7
		U		29.6	26.0	5.6	-0.2	-0.4	-8.1	-23.4	19.1
75	TIND	N		4.3	4.3	4.8	-5.6	0.0			4.8
		E		17.4	10.0	2.6	-18.2	3.3			13.7
		U		31.5	25.7	-13.8	24.1	3.2			24.7
76	LAGH	N		-0.3	0.3	2.8					2.0
		E		9.9	5.6	0.8					8.1
		U		11.3	20.9	8.0					17.7
77	HAMA	N		2.5	2.2						3.3
		E		12.3	8.7						15.1
		U		12.7	39.3						41.3
78	SOAH	N		-3.7	0.0	2.1					3.0
		E		1.7	7.3	1.8					5.4
		U		26.7	30.0	19.5					31.6

In table 4 the RMS North, East and Height component of the adjusted coordinates are listed. The formal errors of Addneq are improved with respect to the

Table 4 – Formal and realistic RMS on North, East and Height components of adjusted coordinates

Nr.	Station	Add_f_N [m]	Add_f_E [m]	Add_f_H [m]	Net_N [m]	Net_E [m]	Net_H [m]	AddC_N [m]	AddC_E [m]	AddC_H [m]
1	CAGL	0.0001	0.0001	0.0007	0.002	0.002	0.01	0.001	0.001	0.007
7	MATE	0	0	0	0	0	0	0	0	0
9	NOTO	0.0001	0.0001	0.0007	0.002	0.001	0.01	0.001	0.001	0.007
400	VILL	0.0001	0.0002	0.0007	0.002	0.002	0.01	0.001	0.002	0.007
401	EBRE	0.0001	0.0002	0.0007	0.002	0.002	0.009	0.001	0.002	0.007
21	ALGE	0.0001	0.0002	0.0008	0.002	0.002	0.011	0.001	0.002	0.008
22	ARZE	0.0001	0.0002	0.0007	0.002	0.002	0.01	0.001	0.002	0.007
71	OUAR	0.0002	0.0001	0.0008	0.002	0.002	0.011	0.002	0.001	0.008
72	BISK	0.0002	0.0002	0.0012	0.003	0.003	0.017	0.002	0.002	0.012
73	MECH	0.0002	0.0002	0.0011	0.003	0.003	0.017	0.002	0.002	0.011
74	INSA	0.0002	0.0002	0.0008	0.002	0.002	0.011	0.002	0.002	0.008
75	TIND	0.0002	0.0002	0.0008	0.002	0.003	0.012	0.002	0.002	0.008
76	LAGH	0.0002	0.0002	0.0008	0.003	0.003	0.013	0.002	0.002	0.008
77	HAMA	0.0002	0.0002	0.0012	0.003	0.003	0.016	0.002	0.002	0.012
78	SOAH	0.0002	0.0002	0.001	0.003	0.003	0.014	0.002	0.002	0.010
		Formal RMS (Addnet)			RMS (Netgps)			Scaled RMS (Addnet)		

repeatability shown in table 3. The values derived by baseline adjustment (Netgps) are consistent with those obtained by the formal RMS, scaled by a factor determined as relationship between a group RMS from weighted coordinates repeatability and the sigma of single difference observations (BrocKmann, 1996).

Finally, Addneq network solution was related to the ITRF 1997.0 reference frame, determining rotations to transform IGS station coordinates on their ITRF values at the epoch of the campaign measurements. In table 5, the geographic Addneq adjustment coordinates transformed on the ITRF system are listed together with error ellipses at 99% level of confidence.

Table 5 – error ellipses at 99% confidence level

Nr.	Station	Smax [m]	Smin [m]	Azim. [°]
1	CAGL	0.003	0.003	140.7
7	MATE	0	0	0
9	NOTO	0.003	0.003	116.3
400	VILL	0.006	0.003	170.9
401	EBRE	0.006	0.003	172.6
21	ALGE	0.006	0.003	149.3
22	ARZE	0.006	0.003	151.3
71	OUAR	0.006	0.003	128.6
72	BISK	0.006	0.006	129.4
73	MECH	0.006	0.006	141.2
74	INSA	0.006	0.003	126.5
75	TIND	0.009	0.003	140.7
76	LAGH	0.006	0.003	137.6
77	HAMA	0.009	0.006	137.9
78	SOAH	0.006	0.003	131.9

5. – CONCLUSION

Field surveys and data analysis from the first epoch GPS surveys provided a reliable geodetic data set for 15 monuments located in the inner Algeria and across the central-western Mediterranean area, where the Eurasian and African plates collides. The low values of the error ellipses semiaxes of the planar coordinates, computed at 99% confidence level, confirm the good quality of the GPS observations used in the analysis. Future repetition campaigns are planned after five years for the full appreciation of our efforts. The GPS data will provided an estimation of the present day kinematics and deformation field of this complex area, characterized by a broad scale crustal deformation and destructive seismicity.

We want to underline that:

– The extension of geodetic observations in northern and inner Africa will achieve a better resolution of the spatial pattern of deformation styles of this area, to evaluate the present day kinematics of the main tectonic structures and of the minor tectonic lineaments, which may play a major role in controlling the present day strain field;

– combining the geodetic observations of Algeonet network with those collected in the central Mediterranean (using GPS data from permanent, non permanent, local and regional networks) in the frame of the Tyrgeonet and GeoModAp projects (Anzidei et al., 1995 and 2001) stable Europe, Apennines and Tyrrhenian sea/Calabrian Arc tectonic system, will be obtained a new independent constraint on the kinematic pattern of this region and an accurate estimate of the ongoing deformation between the European and African plates.

– The future comparison of geodetic data from repeated GPS campaigns with seismicity data collected in the area during the time span of the geodetic surveys, will provide new insights into the balance between seismic and aseismic deformations and will contribute to the seismic hazard reduction in this seismogenetic area that suffered destructive earthquakes in the recent past.

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