Crustal Deformations in the Central Mediterranean Derived from the WHAT A CAT GPS Project

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Abstract

The West Hellenic Arc Tectonis and Calabrian Arc Tectonics (WHAT A CAT) project aimes at monitoring crustal deformations in the Central Mediterranean by repeated GPS campaigns. The data set acquired so far is rather heterogeneous in terms of availability of GPS satellites, performance of the involved receiver systems and quality of the satellites' orbits. The paper presents the velocity estimates achieved using a modified version of the Bernese GPS software. Main characteristic of the solution strategy is the definition of station velocity parameters already on the observation equation level.

Introduction

Projects aiming at determining crustal deformations along the West Hellenic and the Calabrian Arcs in the Central Mediterranean from repeated GPS observations were established in 1989 and 1987 respectively. Originally initiated independently, both efforts were joined to the West Hellenic Arc Tectonics and Calabrian Arc Tectonics (WHAT A CAT) project in 1992. A first common adjustment of the entire network including several GPS campaigns up to 1994 has been performed in 1995 and established first estimates of site velocities.

This paper describes very briefly the processing characteristics and the results of the latest solution comprising all available data sets from 1988 to 1996. A more extensive analysis including a review of the geophysical background, a detailed discussion of the adjustment approach and an interpretation of the derived velocities will soon be published elsewhere.

Data Set

The GPS campaigns included in this solution are listed in table 1. As can be seen the data set is extremely heterogeneous with regard to the involved receiver systems:

The first campaigns up to 1992, mainly in the Calabrian Arc area, were observed with the old Texas Instruments 4100 and the Wild Magnavox 102 receivers; in particular the WM 102 experienced many data losses on the L2 frequency.

Even the later campaigns included different receiver types, however with a majority of Leica 200 systems.

Some colocations of different receiver types were performed in order to combine receiver specific subnetworks or baselines with each other. Even then the reliability of the applied antenna phase center models is of great importance. In addition, the number of occupation days per site and epoch varies considerably, and the session length was on the average limited to about eight hours. Moreover, different markers were occupied at a number of sites in the course of the project; consequently, at some sites the results strongly depend on the quality of the observed local ties.

Table 1 GPS campaigns included in the network adjustment

Epoch	West Hellenic Arc		Calabrian Arc	
	Stat.	Receiver Types	Stat.	Receiver Types
1988, Sept.			7	TI 4100
1989, June			4	TI 4100
1990, June			20	TI 4100 + WM 102
1991, Sept.			6	WM 102
1992, Sept.	16	Leica 200 + WM 102	20	Leica 200 + WM 102
1993, Sept.	20	Leica 200	7	Leica 200
1994, Sept.	15	Leica 200	25	Leica 200
1995, Dec.			2	Leica 200
1996, Sept.	9	Leica 200 + Trimble SST / SSE	24	Leica 200 / 300, Trimble SSE, Ashtech ZXII + Turbo Rogue

Processing

The data processing was performed using the Bernese GPS software versions 3.4 and 4.0 respectively (*Rothacher* et al. 1993, *Rothacher* and *Mervart* 1996) . The subnetwork adjustments generating and saving normal equations for a subsequent combined solution used a modified version of the Bernese program GPSEST. The modifications implemented at DGFI relate mainly to the tropospheric delay modeling and the approach for estimating velocities. The characteristics of the WHAT A CAT solution can be summarized as follows:

Ionosphere free double difference linear phase combination L3, minimum elevation angle 15°, ambiguities partly resolved; day by day variation of network design (baseline definition).

Satellite orbits during 1988 - 1990 based on broadcast ephemerides and a constrained improvement by the regional network itself; precise orbits estimated by the University of California and the University of Berne respectively were available for the campaigns 1991 - 1993; from1994 on the combined orbits operationally generated by the International GPS Service (IGS) were used.

The tropospheric path delay was predicted using the *Saastamoinen* (1973) model and the mapping functions by *Davis* et al. (1985) or *Niell* (1996); residual zenith delays were estimated for two to three hours intervals using a crude mapping function; the troposphere estimated at antenna colocations were constrained to identity.

Antenna phase center offsets and elevation dependent variations modeled by applying the values recommended by IGS (1996).

The site velocities are not derived by transformation of position parameters using the Bernese program ADDNEQ; instead, the positions at the selected reference epoch 1993.0 and linear annual velocities are already defined on the observation equation level.

Accumulation and solution of normal equations with DGFI's programm ACCSOL (ACCumulate and SOLve) applying the following condition equations:

Velocities of sites occupied only once 0,
Velocities of stations tied by eccentricity vectors identity.

Local vectors and/or ellipsoidal height differences and/or distances between eccentric markers were introduced as individually weighted observation equations.

The reference frame was defined by introducing the ITRF 96 positions at epoch 1993.0 and the annual velocities as observation equations applying individual weights according to the ITRF standard deviations propagated to 1993.0 (table 2). It is evident from the table that the accuracy of the four Greek stations in ITRF 96 (*Sillard* et al. 1998) is by far to bad as to contribute at all to the reference frame realization.

Table 2 ITRF 96 fiducials: standard deviations of positions at reference epoch 1993.0 [mm] and of annual velocities [mm/y]

Site	x	y	z	vx	vy	vz
Matera	4.9	4.8	4.9	0.3	0.4	0.3
Cagliari	3.4	2.7	3.4	0.2	0.1	0.2
Noto	3.6	3.4	3.7	0.4	0.5	0.4
Medicina	2.9	2.8	3.3	0.2	0.3	0.3
Dyonysos	31.2	34.8	25.3	4.0	4.4	3.4
Xrisokellaria	40.4	36.8	36.9	5.7	5.2	5.1
Karitsa	49.9	35.4	48.9	6.7	5.2	7.0
Roumeli	99.8	83.6	98.8	10.5	9.3	10.3

Results

The results of the WHAT A CAT network adjustment following the outlined strategy are given in figures 1 to 4. The absolute horizontal velocities in the ITRF 96 are displayed in figures 1 and 2. Figures 3 and 4 present the velocities remaining after reducing the absolute velocities to the motion of the Eurasian plate as predicted by the NUVEL 1A NNR plate model (*Argus* and *Gordon* 1991). The precision of the estimated horizontal velocity components ranges between 0.1 mm and 0.3 mm per year mainly depending on the number of occupations. It should be noted that these numbers are precision but not at all accuracy estimates.

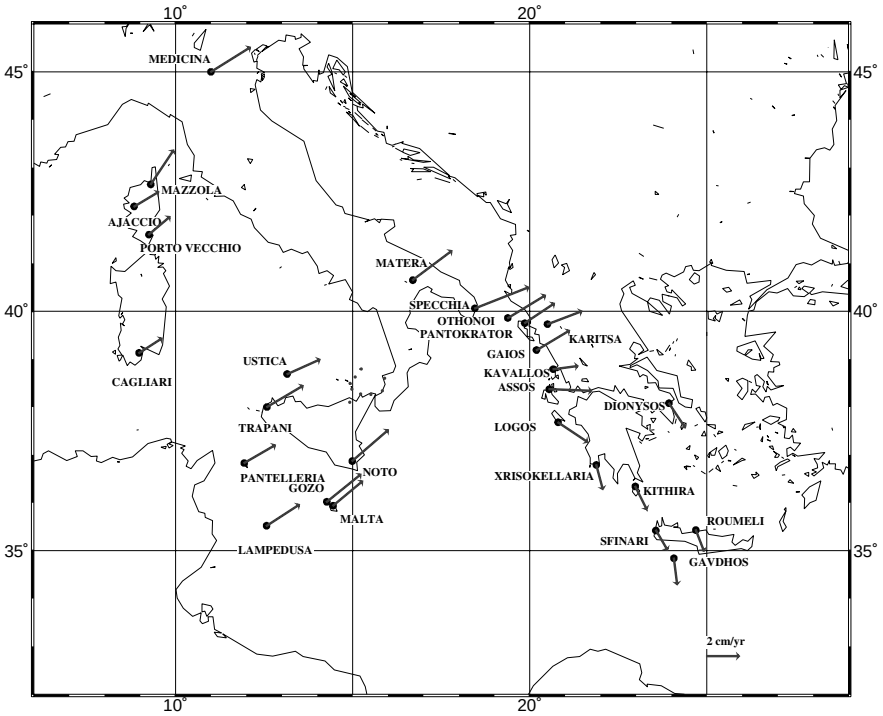

Fig. 1 Horizontal velocities in the ITRF 96 reference frame

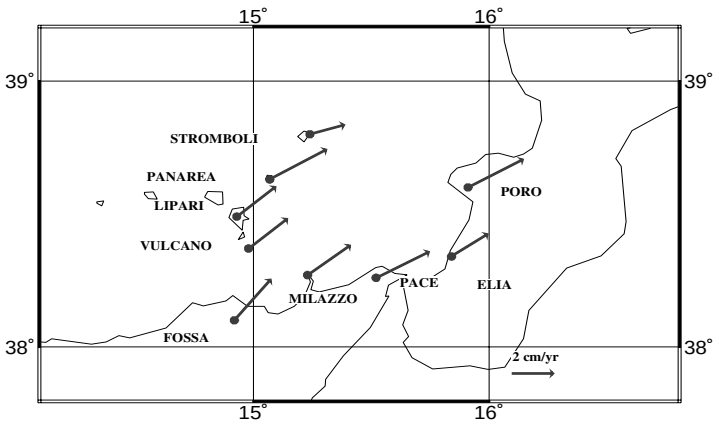

Fig. 2 Horizontal velocities in the ITRF 96 reference frame (detail)

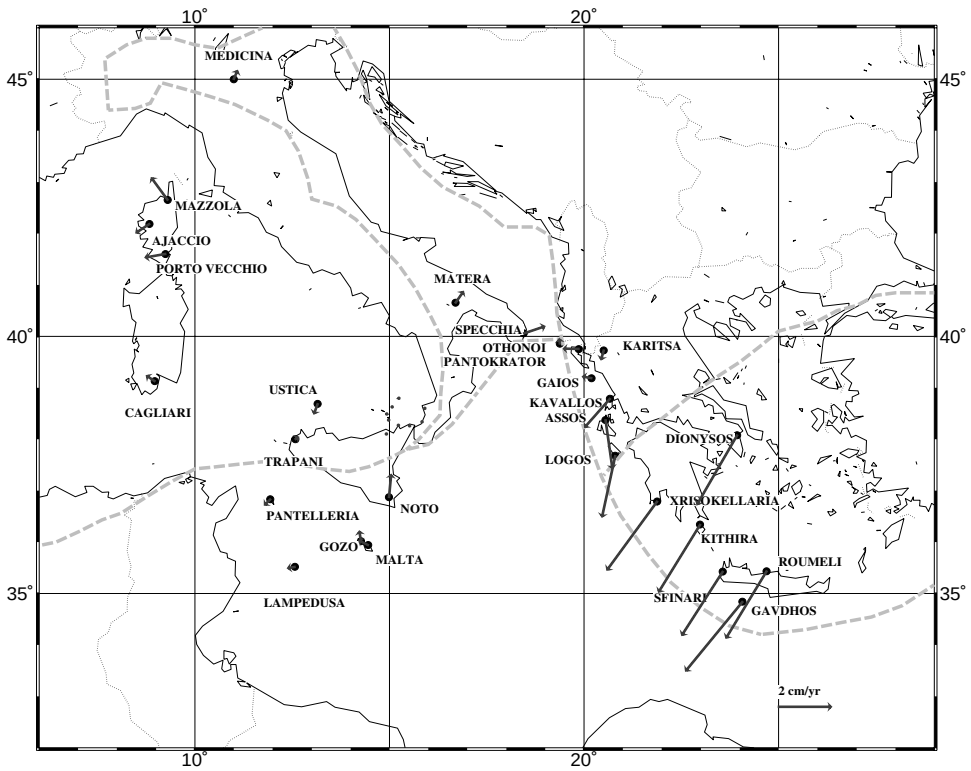

Fig. 3 Horizontal velocities relative to the NUVEL 1A NNR plate motion model

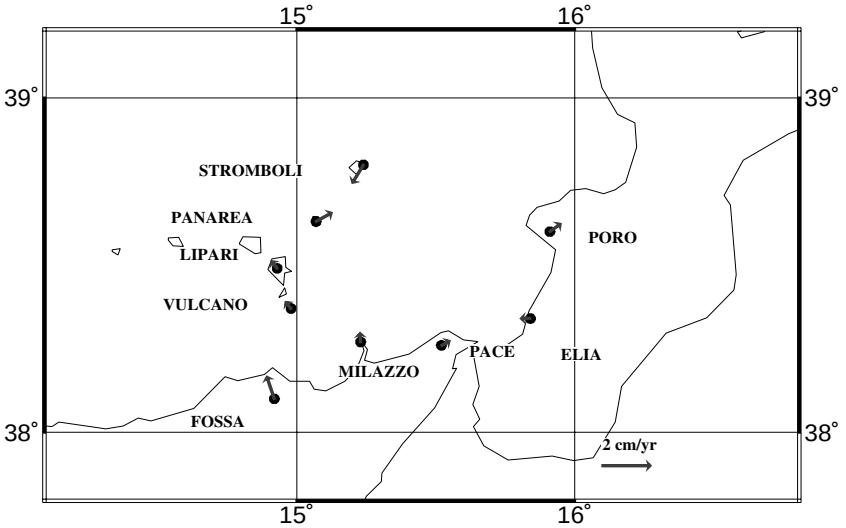

Fig. 4 Horizontal velocities relative to the NUVEL 1A NNR plate motion model (detail)

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