UNIVERSITÀ DEGLI STUDI DI TRIESTE
ISTITUTO DI STRADE E TRASPORTI

PROCEEDINGS

III GEODETIC MEETING ITALY - POLAND ON

GPS - GLOBAL POSITIONING SYSTEM

IN CIVIL ENGINEERING

EDITED BY GIORGIO MANZONI

TRIESTE - 23-25/9/1992

GPS MEASUREMENTS
IN THE CENTRAL MEDITERRANEAN AREA

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Abstract

Among the different activities of the italian scientific community in the field of GPS measurements, interesting remarks about GPS application over distances exceeding 1000 km were made thanks to the institution of a network for the geodinamical control of the central Mediterranean area. This collaborative project among many Italian and foreign Istitutions (tab. I) allowed the use of many different receivers deployed on a very large area. This implies that the purpouse of the project can be considered beyond the geodynamical purpose. The choice of many vertices belonging to the National Geodetic Network as sites of the TYRGEONET will allow useful comparisons and the improvement of the computed terrestrial coordinates.

TYRGEONET PROJECT		
Institutions belonging to the project		
ASI	=	*Agenzia Spaziale Italiana*
DEF	=	*Gruppo Deformazioni SIFET*
DGC	=	*Direzione Generale del Catasto*
IGMI	=	*Istituto Geografico Militare Italiano*
IIV	=	*Istituto Internazionale di Vulcanologia*
ING	=	*Istituto Nazionale di Geofisica*
SSN	=	*Servizio Sismico Nazionale*
CNES	=	*Centre Spatial de Toulose*
IME	=	*Istitut de la Meteorologie, Tunisi*
IPG	=	*Istitut de Physique du Globe (Parigi)*
IPT	=	*Istitut Preparatoire Technique du Nabeul (Tunisia)*
UNICA	=	*Università di Cagliari*
UNIBO	=	*Università di Bologna*
UNIPG	=	*Università di Perugia*
UNIRC	=	*Università di Reggio Calabria*
UNICAL	=	*Università della Calabria*
UNIRM1	=	*Università di Roma "La Sapienza"*
UNIRM2	=	*Università di Roma "Tor Vergata"*
UNIUD	=	*Università di Udine*
UNILUB	=	*Università di Lubiana*
UNIZAG	=	*Università di Zagabria*
UNITES	=	*Università di Tessalonica*
POLIMI	=	*Politecnico di Milano*
POLITO	=	*Politecnico di Torino*
POLITI	=	*Politecnico di Tirana*

Table I. *Italian and foreign istitutions collaborating on the TYRGEONET project.*

The paper describes the network ; the results of preliminary data analysis are presented.

Introduction

Due to the rather complicated nature of the tectonic activity of the Mediterranean region mainly related to the broad scale collision between the African and Eurasian plates, a dense network of points is required to monitor this region properly with repeated geodetyc surveys (fig. 1).

TYRGEONET is made up of about 60 vertices (fig. 2) concentrated mainly in Italy but also deployed over a broad area exstending from Germany to Tunisia, France, Croazia, Albania and Greece.

The vertices sited in Wettzell, Cagliari, Grasse, Lampedusa and Matera are also SLR (Satellite Laser Ranging) stations. We should also keep in mind that Medicina, as well as Matera, Wettzell and Grasse are VLBI (Very Long Basiline Interferometry) stations: this will enable us to compare the results obtained from different measurement tecniques.

Some of TYRGEONET italian vertices belong to the National Geodetic Network (about 15), others belong to local networks already established and measured such as Calabrian Arc, Cassino, Aquilano, Colli Albani, Ancona, Lucera, Forlivese, Catanzaro and Messina Strait networks. The TYRGEONET network design provides connection among these local networks whitch are periodically surveyed by terrestrial or GPS tecniques, in order to monitor local deformation (fig. 2).

Local networks

The Calabrian Arc Network was established in 1986 and stretches from North-Eastearn Sicily to the Aeolian Islands and Southern Calabria. It is designed for to crustal deformation research by terrestrial and GPS

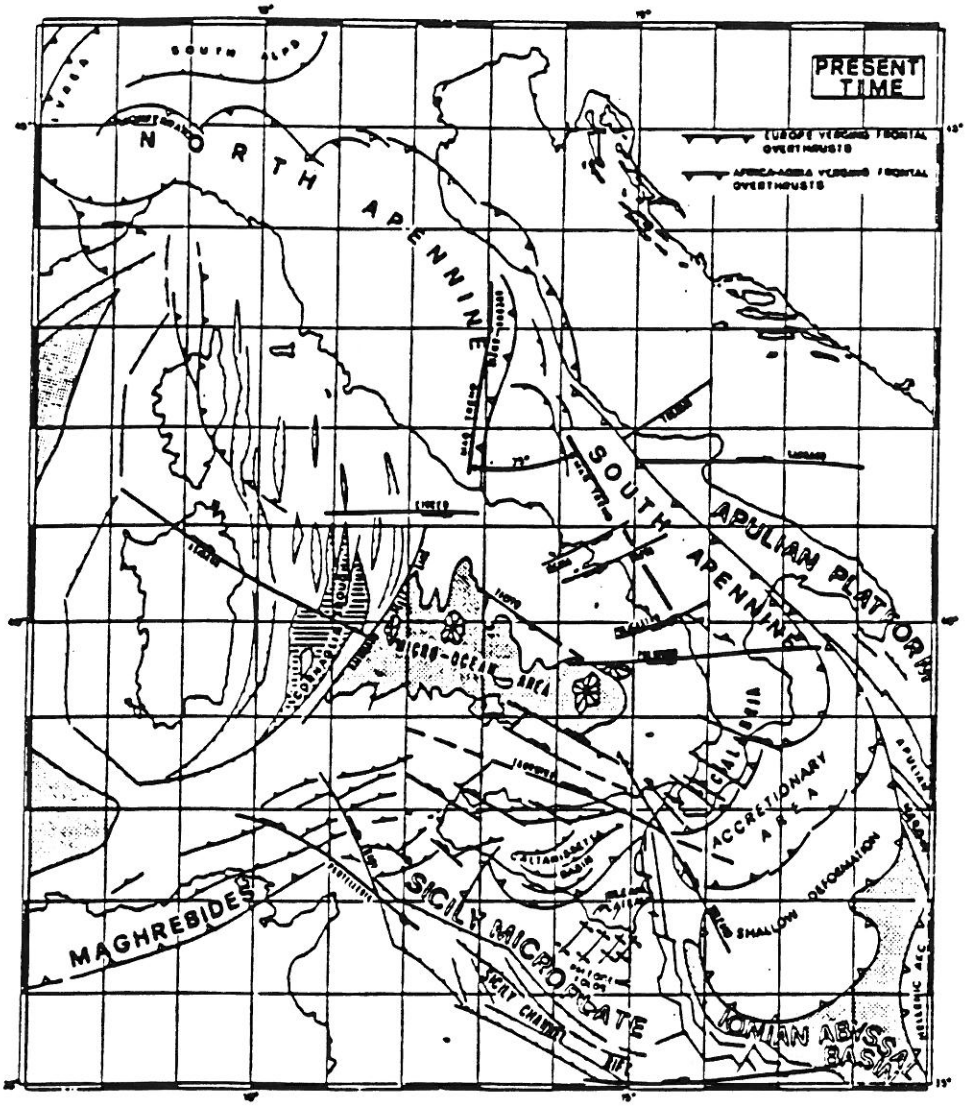

Figure 1 . *Present model of the Tyrrhenian basin.*

surveys in the Southern Tyrrenian sea (Achilli *et al.*, 1987; Baldi *et al.*, 1988).

The Cassino and Aquilano Networks were established in 1984 in high

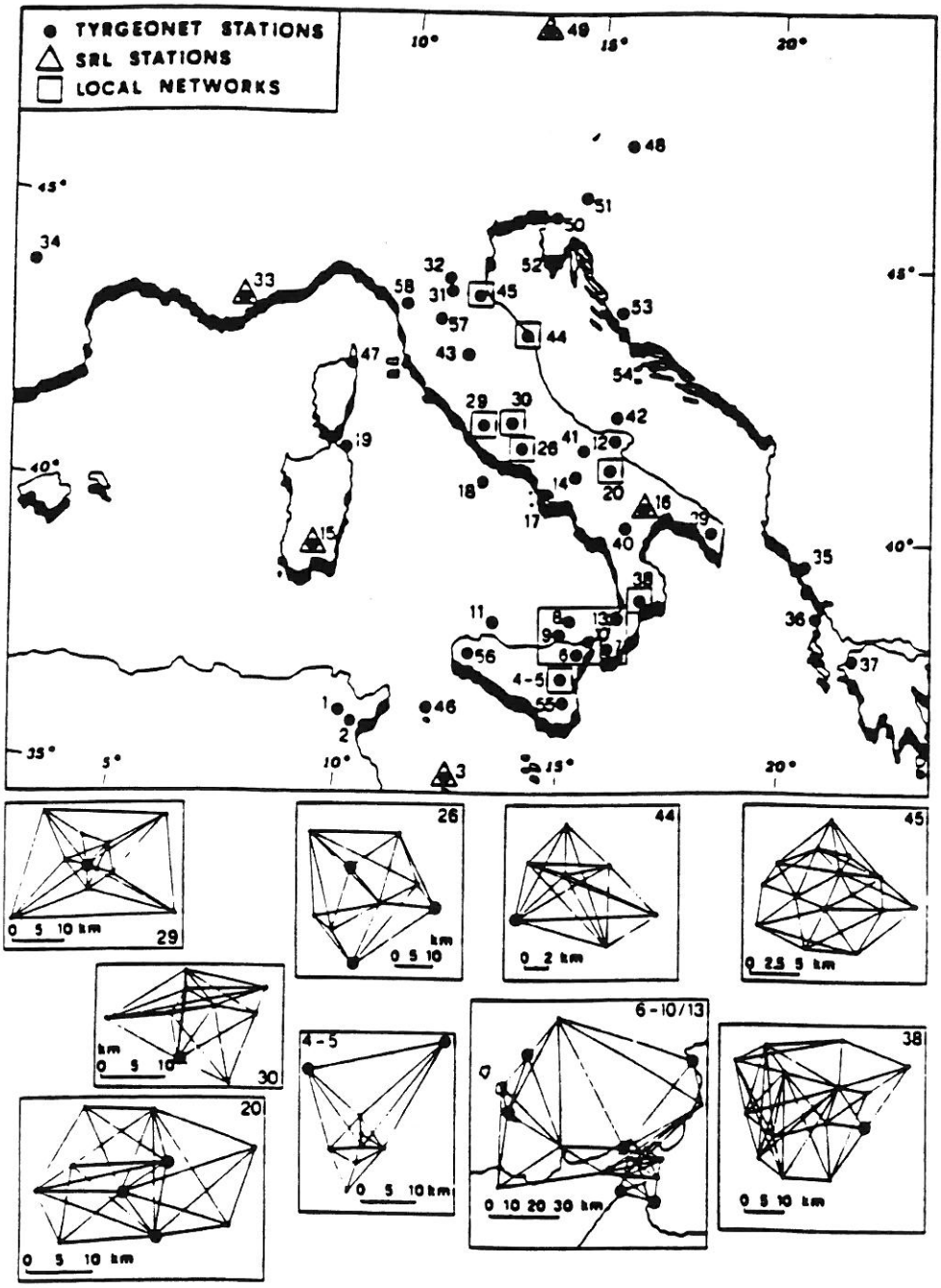

Figure 2. *TYRGEONET and local networks are reported in the figure. Local networks: 29) Colli Albani, 30) Aquilano, 20) Lucera, 26) Cassino, 4-5) Stretto di Messina, 44) Ancona, 6-13) Arco Calabro, 45) Forlivese, 38) Catanzaro.*

seismic risk areas (Achilli *et al.*, 1986).

The Colli Albani Network has been measured since 1990 in order to detect deformation in a volcanic area (Achilli *et al.*, 1991; Anzidei *et al.*, 1991).

The Ancona Network was established in 1975 and monitored by terrestrial and GPS surveys (Baldi and Marson, 1981; Achilli *et al.*, 1982).

The Lucera Network is an experimental polygon for GPS application in the field of aerophotogrammetry (Achilli *et al.*, 1992).

The Messina Strait Network was established 1971 in the most seismic area of the Italian Peninsula (Achilli *et al.*, 1988).

The Forlivese and Calabrian Networks have been recently instituted in the frame of a global study of two seismic areas (Achilli *et al.*, 1990; Achilli *et al.*, 1992).

Campaigns

1990 *campaign* (fig. 3)

The first GPS TYRGEONET campaign was held from June 25 to June 30, 1990 using 12 WM-102 and 5 WM-101 Wild Magnavox, 2 ASHTECH dual frequency, 2 TRIMBLE dual frequency, 4 TRIMBLE single frequency receivers employed over 33 stations. The measurements were executed for six sucessive days, for 6-8 hours per day.

1991 *campaign* (fig. 4)

The second campaign was held from June 19 to 28, 1991 and the network was extended to Greece and Croazia. A densification of the network in the central Appennines was provided for a better survey of this seismic area. The measurements were executed for ten consecutive days using

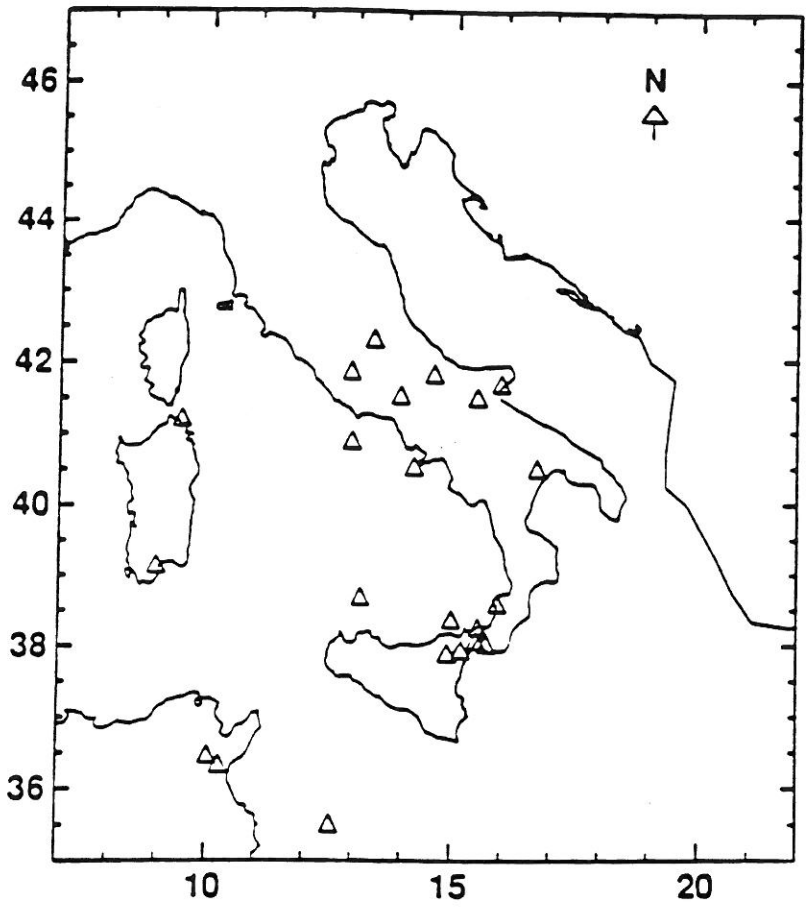

Figure 3. *Vertices of the 1990 campaign.*

dual frequency receivers. The period of a single session was about 6-8 hours.

1992 *campaign* (fig. 5)

In the third campaign 31 vertices were occupied. The observation schedule consisted of up to 15 dual frequency receivers recording 8 hours per day over a 10-day-period (in June). 20 stations were observed.

Three vertices of the National Albanian Network were utilized during this campaign (Scutari [A], Durazzo [B], Valona [C], fig. 6), in order to achieve better knowledge of the geodynamics of the Adriatic plate.

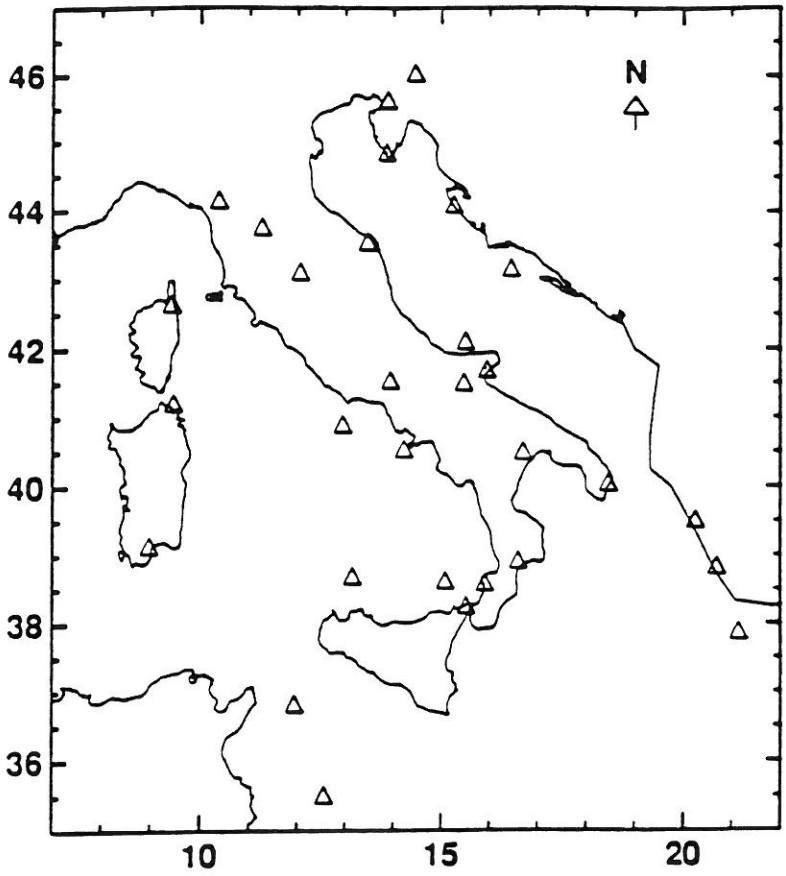

Figure 4. *Vertices of the 1991 campaign*

In september 1992, a second campaign was performed, in conjunction with the SAGET GPS campaign. In the framework of these activities, Forlivese network was remeasured and connected with many vertices of the TYRGEONET network.

The final design of TYRGEONET is shown in fig. 6.

The three successive campaigns had numerous station in commmon (fig. 7)

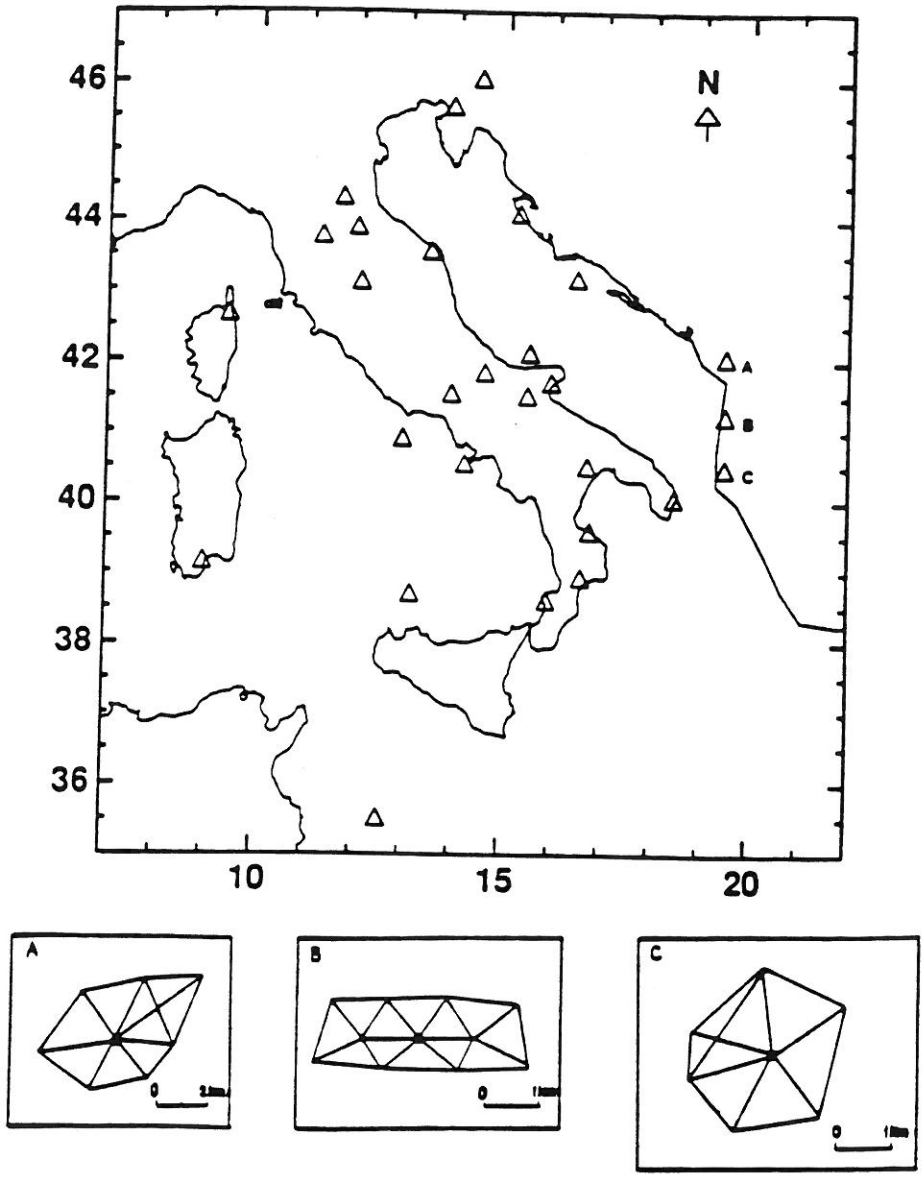

Figure 5. *Vertices of the 1992 campaign. A, B, C, National Albanian Network (Scutari [A], Durazzo [B], Valona [C]).*

Data analysis

Data processing was performed by using Bernese software (Rothacher *et al.*, 1988). Precise ephemerides were included for the computation. A

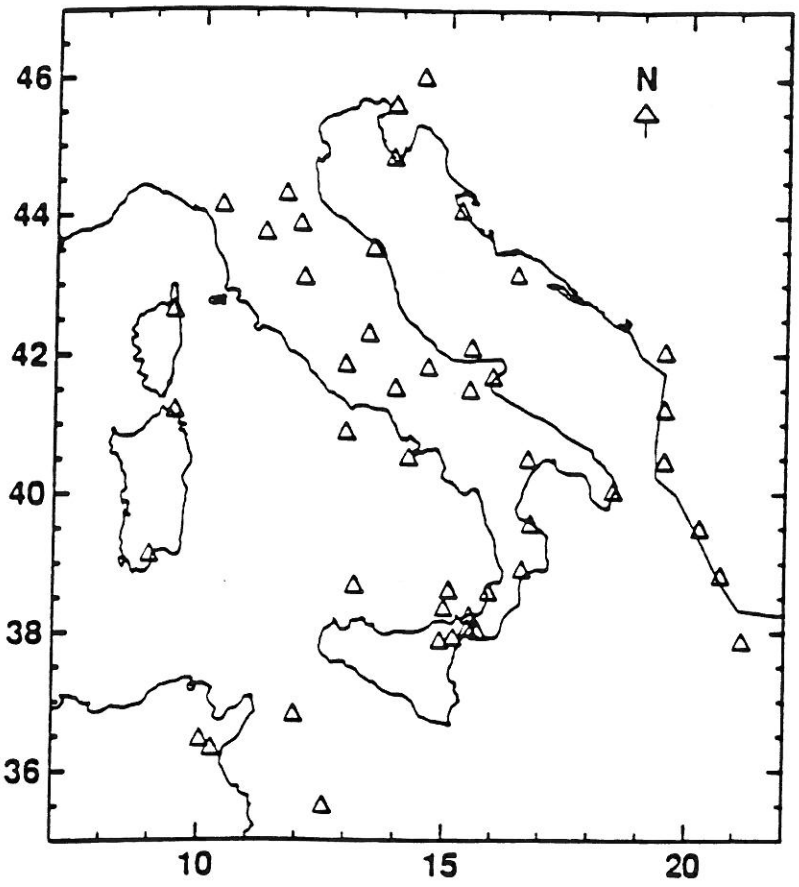

Figure 6. *Total TYRGEONET vertices.*

dayly solution of the baselines and a check of repeatibility in a ionosphere-free linear combination was performed to detect unexplained systematic errors not found by previous data screening. Generally we obtain a repeatibility of the order of 0.1 ppm (tab. II, fig. 8).

A comparison between the solutions of the 1990 and 1991 campaigns relative to 7 vertices, obtained by means of multisession solutions, confirm these results; infact the coordinates agree at a few-centimeter-level, in spite of the different satellite configuration, observation period, ionospheric and tropospheric conditions, ... (tab. III).

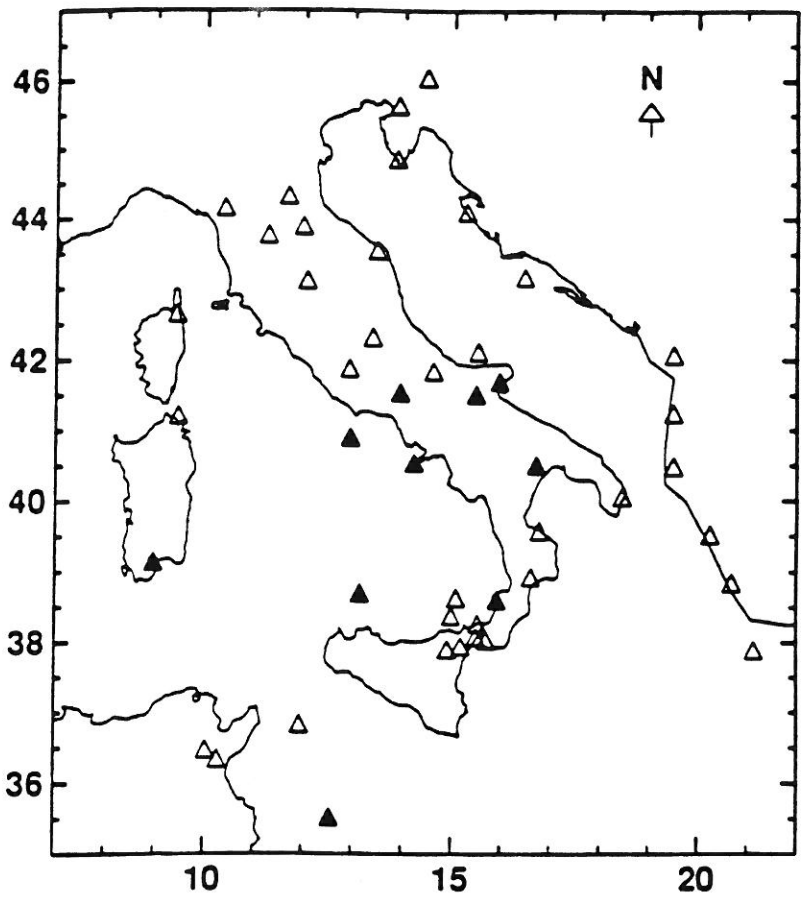

Figure 7. *Common TYRGEONET vertices of the 1990, 1991, 1992 campaigns.*

Conclusions

The cooperation among many Italian and foreign institutions led to the implementation of the TYRGEONET Project, whose aim is to provide a basic reference for future geodynamical research and cartographic applications.

The results of data processing confirm the possibility of obtaining accuracy at a centimeter level on baselines of several hundreds of km, by means of field measurement performed periodically for periods of few days.

DOY	MATERA LUCERA 141447 (m)	MATERA S. CRISTI 162532 (m)	MATERA PACE 283436 (m)	MATERA GRASSE 877296 (m)
June 25 1990	.803	-	-	.455
June 26 1990	.823	-	.075	.340
June 27 1990	.808	-	.065	.413
June 28 1990	.818	-	.058	.446
June 29 1990	.820	-	.058	.393
June 30 1990	.870	-	.094	-
June 19 1991	.777	.880	.074	.603
June 20 1991	.784	.863	.085	.584
June 21 1991	.792	.835	?	.500
June 22 1991	.860	.860	.062	.656
June 23 1991	.780	.856	.146	.579
June 24 1991	?	.870	.085	.594
June 25 1991	?	.880	.101	.559
June 26 1991	?	.861	.101	.512
June 27 1991	?	.835	.116	.532
June 28 1991	.691	.883	.092	.690

Table II. *Daily repeatability between some of the TYRGEO-NET sites (1990-1991 campaigns). [? Few data, or presence of unexplained systematic errors].*

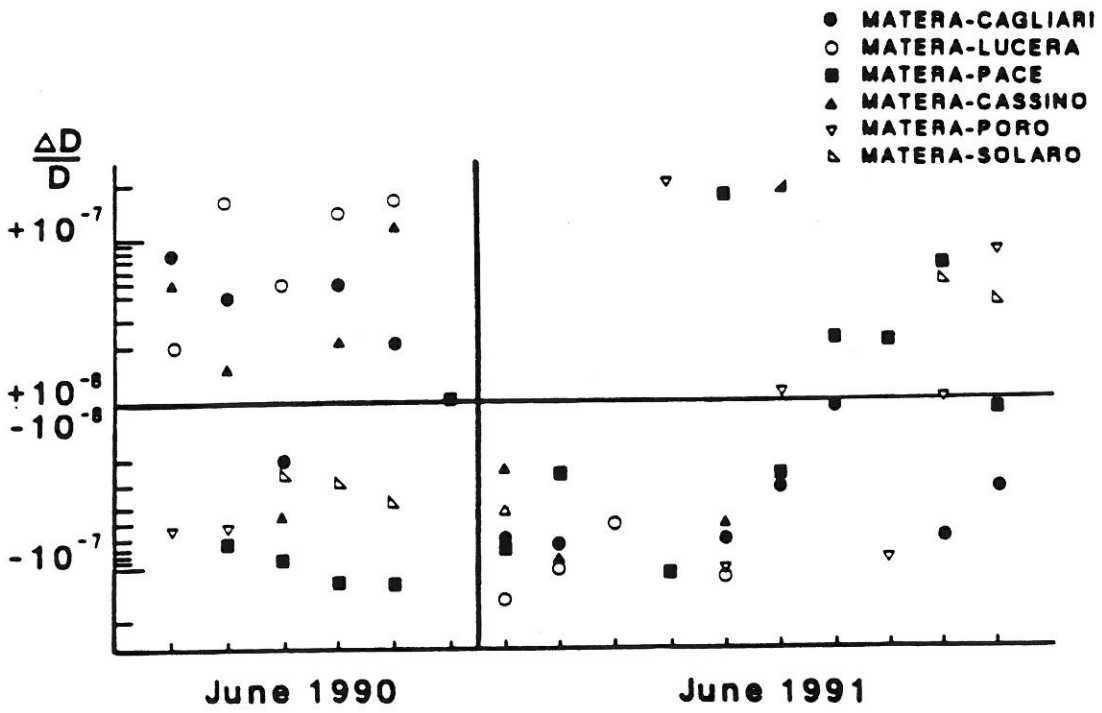

Figure 8. *Relative differences of some baseline lengths referred to the mean value of all the solutions (1990-1991 campaigns), (Baldi et al., 1992).*

S - TRANFORMATION $\Delta X = 2.3 \pm 0.4$ $\Delta Y = 1.8 \pm 0.4$ $\Delta Z = -2.4 \pm 0.5$ $Scale = (-9 \pm 5)10^{-8}$ $\alpha = 0.005 \pm 0.001$ $\beta = -0.11. \pm 0.02$ $\gamma = -0.03 \pm 0.01$			
STATIONS	ΔX (cm)	ΔY (cm)	ΔZ (cm)
MATERA	+1.0	+1.0	+4.2
CAGLIARI	+2.4	+3.3	-1.6
CASSINO	-2.1	+0.4	+2.6
LUCERA	-1.2	+3.6	+1.0
PACE	+3.6	-3.3	-0.1
PORO	-1.2	-2.8	-2.4
SOLARO	-2.6	-2.2	-3.7

Table III. *Parameters of the S-tranformation between 1990 and 1991 solutions and residuals.*

References

ACHILLI V., BALDI P., POSTPISCHL D., UNGUENDOLI M., 1982. La rete geodetica di Ancona. *Consiglio Nazionale delle Ricerche, Progetto Finalizzato Geodinamica*, **500**, 1-41.

ACHILLI V., BALDI P., CAGNETTI V., DE MARCO R., GAZZIANO S.A., MARCUCCI S., MARSAN P., MILANA G., SCREPANTI A., UNGUENDOLI M., 1986. La Rete Geodimetrica ENEA nel Lazio Meridionale. *Atti del 4° Convegno del Gruppo Nazionale di Geofisica della Terra Solida,* Roma 29-31 Ottobre 1985, E.S.A., **II**, 1093-1101.

ACHILLI V., ARCA S., BALDI P., BROCCIO F., CAGNETTI V., DE MARCO R., MARSAN P., ZERBINI S., 1987. Misure geodetiche nell'area dell'Arco Calabro. *Atti del 5° Convegno del Gruppo Nazionale di Geofisica della Terra Solida*, Roma 17-19 Novembre 1986, E.S.A., **II**, 851-863.

ACHILLI V., BALDI P., ZERBINI S., BROCCIO F., CAGNETTI V., MARSAN P., GUBELLINI A., UNGUENDOLI M., 1988. Comparison between GPS and ground based distance measurements in the Messina Straits Area. *Bollettino di Geofisica Teorica ed Applicata*, **119-120**, vol. XXX, 361-369.

ACHILLI V., ARCA S., BALDI P., CHIGGIO R., LANDUZZI A., MARABINI S., MULARGIA F., TINTI S., VAI G. B., 1990. Studio sismotettonico dell'Appennino Forlivese: il progetto GEOSIS. *Bollettino di Geodesia e Scienze Affini*, **4**, 319-361.

ACHILLI V., ANZIDEI M., BALDI P., RIGUZZI F., 1991. Misure di deformazioni crostali nell'area dei Colli Albani. *Atti del Convegno "Determinazione dei punti di riferimento geodetici e topografici mediante il sistema G.P.S."*, Camera di commercio di Treviso, **16**, 91-104.

ACHILLI V., ANZIDEI M., ARTESE G., BARATIN L., BONINI C., CAMPOLO F., CAPONE G., GILORMO A., GUERRA I., MARSAN P., POGGI M., STROLLO R.M., VESPE F., 1992. La rete GPS della Calabria. *Rivista SIFET - Sezione di Reggio Calabria.* In corso di stampa.

ACHILLI V., CRESPI M., DI FILIPPO S., VETTORE A., 1992. Misure GPS sul poligono di Lucera: campagne 1989 e 1990. *Rivista del Catasto e Servizi Tecnici Erariali*, **1**.

ANZIDEI M., MARCHETTI M., RIGUZZI F., ACHILLI V., BALDI P., 1991. GPS and Tilt Surveys in the Albani Hills Area. *Cahiers du Centre Européen de Géodynamique et de Séismologie*, **4**, 87-96.

BALDI P., MARSON I., 1981. Gravity and geodetic network for the study of crustal deformations in seismic area (Ancona). *Boll. di Geodesia e Sci. aff.*, 3.

BALDI P., DREWES H., REIGBER Ch., ACHILLI V., ZERBINI S., 1988. Combined terrestrial and space techniques in the Calabrian Arc project. *CSTG Bulletin*, **10**, 115-124, Munchen, Fed. Rep. of Germany.

ROTACHER M., BEUTLER G., GUNTER W., SCHILDKNECHT B., ..., 1988. Documentation for the Bernese software version 3.0. University Berne.