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POLITECHNIKA WARSZAWSKA  
INSTYTUT GEODEZJI WYŻSZEJ I ASTRONOMII GEODEZYJNEJ

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No. 4(12), 1994



SPECIAL ISSUE  
PROCEEDINGS OF THE 4th GEODETIC MEETING POLAND-ITALY  
WARSAW, POLAND  
12-13 SEPTEMBER 1994

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**REPORTS ON GEODESY**

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WARSAW UNIVERSITY OF TECHNOLOGY  
INSTITUTE OF GEODESY AND GEODETIC ASTRONOMY

**4th INTERNATIONAL GEODETIC MEETING  
POLAND-ITALY  
Warsaw, Poland  
12 September 1994**

**RECENT EXPERIENCE WHITHIN THE DEFINITION  
OF GEOID IN A SOUTH ITALIAN AREA**

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**Abstract**

The Calabria region has been characterised for a lot of geodynamic phenomena and a complex Geoid. This zone is a very interesting zone for geophysical and geodetic studies. In 1993 has been effectuated a GPS survey. This work shows the quality of the results and a comparison between GPS Geoid and the Italian Gravimetric Geoid performed by Politecnico di Milano.

**Introduction**

The Calabria region, seat of frequent seismic activity, has been characterised for the rising of the ground emerge also upper then 1000 m in the last 700'000 years (Ghisetti, 1980).

Differents models proposed to show the geological evolution of the Italian peninsula attribute to the Calabria segment a lateral translation very accentuate in EAST-Southeast direction, correlated with the opening of tyrrhenian sea. Movement survey and the earth crust deformation survey are aimed to explain the accumulation and release modality of the elastic energy which is at the base of the earthquake genesis. So geodetic measurements for geophysical purpose in this region have begun as far as 1970 (Arca et al. 1986; Caputo et al. 1982; Pingue e Guerra, 1989).The innovative technology has given to the research in this area a new impulse who has brought at the formulation of aimed project (Achilli et al. 1989). In this ambit we can see the GPS network in Calabria. The GPS technique is playing an important role in the study of geodinamical phenomena both at a local and regional scale by providing new opportunities for surveyors. The primary target shows the field deformations in big scale through the comparison of the measurements results along different years.

Because of tectonic complexity and uneven orography, the Geoid on the Calabrian region results complex. The result of the first set of GPS measurements in this country can give a contribution about the knowledge of the Geoid in this area, in so far as many vertexes have been chosen in correspondence of bench marks of national geometrical levelling network.

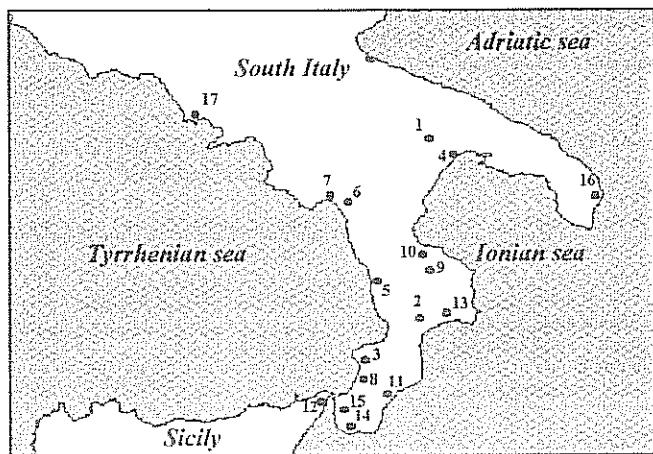


Fig.1 - Position of the GPS points used for this work: 1 Matera, 2 Comuni, 3 Poro, 4 Metaponto, 5 Paola, 6 Casa Timponi, 7 Villamare, 8 Gioia Tauro, 9 Rossano INA, 10 Rossano Staz., 11 Locri, 12 Messina, 13 Catanzaro, 14 Patteriti, 15 Reggio Calabria, 16 Otranto, 17 Napoli

#### General information about the measurements

The measurements was started the 3 May 1993 end stopped the 8 May 1993. The window time for each observation was eight hours (from 10.00 until 18.00 UTM) and the sampling time was 30 seconds. All receivers was double frequency. Three points has observed for 6 days (Matera, Poro, Comuni) and the other points has been observed just for two days (16 hours of measurements).

#### Data Elaboration

Data processing by using BERNSE Ver.3.4 software was performed. Only dual frequency observations were used; code pseudoranges in the first step of the elaboration to calibrate the receiver clock with respect to GPS time were adopted. Precise ephemerides obtained from data bank of University of Bern for the computation were included. To account for tropospheric refraction, we adopted an extrapolated model (Saastamoinen, 1972), starting from a standard atmosphere, and assuming the information on heights not being critical for our purpose. Furthermore in order to reduce the atmospheric noise all the observations with an elevation angle lower than 20° has been discarded. We derived a local ionospheric model for each session by adopting a single layer model with constant electron density, computed as function of latitude and hour angle of the sun by using the  $L_4$  observable (Wild et al., 1989). For the computation of the network we defined for each session a number of linearly independent baseline, assuming, in a first time, as reference the station of Matera (SLR station), and in a second time the station of Comuni (Catanzaro TYRGEONET), of which was well-know a priori precise coordinate. The reason of this computing strategy was due to verify the agreement between the first solution (good knowledge of Matera coordinates) and the second one (good position of Comuni in the network). The data screening was performed simultaneously for  $L_1$  and  $L_2$  data on triple and double

difference levels (Achilli et al., 1994). After we tried to resolve the integer ambiguity with a standard procedure.

The Bernese layout software provides many informations, particularly about baselines with RMS, cartesian coordinate and geographics coordinate are available.

The result of GPS data elaboration are summarised in the following tables (Tab.1,2,3,4,5,6).

<i>Baseline</i>	<i>Length (m)</i>	<i>RMS(m)</i>
MATERA-COMUNI	190770.9417	0.0003
MATERA-PORO	237078.324	0.0027
MATERA-METAPONTO	30235.527	0.0009
MATERA-PAOLA	149400.3993	0.0011
MATERA-CASATIMPONE	110481.9547	0.0004
MATERA-VILLAMMARE	113989.9123	0.0005
MATERA-GIOIATAURO	251801.3565	0.0006
MATERA-ROSSANOINA	116816.7735	0.0005
MATERA-ROSSANOSTAZ	116278.2402	0.0004
MATERA-LOCRI	270675.1007	0.0009
MATERA-MESSINA	284930.1357	0.0005
MATERA-CATANZARO	199849.9734	0.0016
MATERA-PATERITI	303435.5313	0.0005
MATERA-REGGIO CALABRIA	295007.6198	0.0005

Tab.1 -Results of data elaboration: Length and Root Mean Square in meters relative at the first network scheme with Matera fixed station.

<i>Baseline</i>	<i>Length (m)</i>	<i>RMS(m)</i>
COMUNI-MATERA	190770.9417	0.0003
COMUNI-PORO	70413.5454	0.0004
COMUNI-METAPONTO	162172.3335	0.0006
COMUNI-PAOLA	72438.5605	0.0057
COMUNI-CASATIMPONE	150399.7575	0.0007
COMUNI-VILLAMMARE	153680.0514	0.0009
COMUNI-GIOIATAURO	78217.2083	0.0005
COMUNI-ROSSANOINA	73954.5408	0.0006
COMUNI-ROSSANOSTAZ	74493.3389	0.0006
COMUNI-LOCRI	82878.6661	0.0006
COMUNI-MESSINA	118307.037	0.0006
COMUNI-CATANZARO	10613.3013	0.0009
COMUNI-PATERITI	127699.2662	0.0007
COMUNI-REGGIO CALABRIA	122627.0463	0.0005

Tab.2 -Results of data elaboration: Length and Root Mean Square in meters relative at the first network scheme with Comuni fixed station.

<i>Site</i>	<i>X(m)</i>	<i>Y(m)</i>	<i>Z(m)</i>
MATERA	4641949.803	1393045.179	4133287.329
COMUNI	4761340.177	1419704.941	3986901.625
PORO	4800242.902	1368324.147	3958535.137
METAPONTO	4657555.335	1405826.829	4110740.117
PAOLA	4742993.635	1362609.028	4027531.558
CASATIMPONE	4706854.25	1318509.044	4083910.73
VILLAMMARE	4707565.435	1313722.385	4084336.413
GIOATAURO	4808671.954	1373059.098	3945648.746
ROSSANOINA	4715193.255	1409409.591	4043767.625
ROSSANOSTAZ	4714891.709	1409173.504	4044180.647
LOCRI	4815585.277	1405008.649	3925988.885
MESSINA	4832055.724	1346885.701	3926129.754
CATANZARO	4765009.807	1426194.5	3979347.738
PATERITI	4843126.707	1360901.637	3908414.458
REGGIO	4837935.056	1355282.439	3916047.16
OTRANTO	4629996.024	1548924.383	4090517.542
NAPOLI	4683078.592	1191030.016	4149151.128

Tab.3 -Geocentric coordinate obtained from the elaboration with the first network scheme (Matera fixed).

<i>Site</i>	<i>LAT(<math>^{\circ}</math> ' '')</i>	<i>LON(<math>^{\circ}</math> ' '')</i>	<i>H(m)</i>
MATERA	40 38 56.865008	16 42 16.040801	535.6290
COMUNI	38 55 58.12988	16 36 11.449403	610.8035
PORO	38 36 14.707120	15 54 37.317754	753.0827
METAPONTO	40 23 08.895249	16 47 44.900193	47.654
PAOLA	39 24 28.628037	16 01 43.559535	187.283
CASATIMPONE	40 04 04.411082	15 38 56.055972	238.1207
VILLAMMARE	40 04 27.577895	15 35 33.436220	49.9552
GIOATAURO	38 27 37.825886	15 56 09.827260	82.2949
ROSSANOINA	39 35 53.591954	16 38 30.598248	87.0904
ROSSANOSTAZ	39 36 11.279254	16 38 24.736797	75.6589
LOCRI	38 14 05.851725	16 15 55.010992	42.7848
MESSINA	38 14 11.535489	15 34 30.949314	47.9779
CATANZARO	38 50 58.073935	16 39 45.865347	50.6825
PATERITI	38 01 50.467940	15 41 42.637101	465.9913
REGGIO	38 07 15.668514	15 38 58.204258	43.2885
OTRANTO	40 08 49.904921	18 29 49.959093	39.1111
NAPOLI	40 50 29.235325	14 16 09.487796	48.8933

Tab.4 -Geographic coordinate obtained from the elaboration with the first network scheme (Matera fixed).

<i>Difference between geocentric coordinate of different network schemes</i>			
<i>Site</i>	$\Delta x$ (m)	$\Delta y$ (m)	$\Delta z$ (m)
COMUNI	0.032	-0.035	0.005
PORO	0.077	-0.015	0.059
METAPONTO	0.038	-0.027	0.018
PAOLA	0.073	0.117	0.056
CASATIMPONE	0.002	-0.055	-0.006
VILLAMMARE	0.033	-0.04	0.024
GIOIATAURO	0.016	-0.045	-0.003
ROSSANOINA	0.011	-0.044	-0.01
ROSSANOSTAZ	0.006	-0.038	-0.015
LOCRI	0.036	-0.038	0.005
MESSINA	-0.083	-0.026	-0.01
CATANZARO	-0.01	-0.049	-0.001
PATERITI	0.025	-0.032	0.009
REGGIO	0.029	-0.02	0.01

Tab.5 -Difference between the geocentric coordinate obtained with Matera fixed station and geocentric coordinate obtained with the second network (Comuni fixed).

<i>Difference between geocentric coordinate of different network schemes</i>			
<i>Site</i>	$\Delta \text{lat}$ (sec)	$\Delta \text{long}$ (sec)	$\Delta h$ (m)
COMUNI	0	0	0
PORO	0.000091	-0.001443	0.09
METAPONTO	-0.000143	-0.001541	0.033
PAOLA	-0.000704	0.003873	0.11
CASATIMPONE	0.000123	-0.002249	-0.014
VILLAMMARE	0.000175	-0.002002	0.03
GIOIATAURO	-0.000143	-0.001971	0.01
ROSSANOINA	-0.0002	-0.001853	-0.01
ROSSANOSTAZ	-0.000257	-0.001618	-0.01
LOCRI	-0.00035	-0.001923	0.02
MESSINA	-0.000051	-0.00101	-0.01
CATANZARO	0.000461	-0.001818	-0.02
PATERITI	-0.000008	-0.001521	0.02
REGGIO	-0.000203	-0.00112	0.02

Tab.6 -Difference between the geographic coordinate obtained with Matera fixed station and geographic coordinate obtained with the second network (Comuni fixed).

#### Comparison between GPS Geoid and Italian Gravimetric Geoid

The high repeatability of baseline length coupled with little root mean square and the good quality of vertex coordinate show in Tab. 1.6 permitted the use of these data in Geodetic studies.

In the last years one of the most important problem of the Geodesy is the correct definition of the Geoid surface. In this contest we performed the altimetric survey with GPS survey. With these data is possible to compare and eventually correct the Geoid in the southern part of the Italian peninsula. We can find the reason of this kind of analysis in the presence of high gradients in this area. In fact the presence of high gradient need the position knowledge of many points in the area.

As well know from theory we found out a high discrepancy between the altimetric survey results produced by GPS data elaboration and the ones obtained from geometric levelling. The difference between orthometric and GPS heights provided the so called Geoidal undulation. In fact heights obtained from GPS are referenced to an ellipsoid. For this reason we have linked, by mean of geometrical levelling, vertices of the GPS network with the benchmarks of the I.G.M. levelling network.

At the present we have compared the Geoidal heights, derived by levelling relative at the I.G.M. benchmarks and GPS ellipsoidal heights (WGS84) obtaining the relative Geoidal undulations.

The results are shown in the following table.

Comparison between GPS and IGM heights			
Site	GPS heights (m)	I.G.M. heights (m)	Difference (m)
<i>Metaponto</i>	47.637	5.149	42.487
<i>Catanzaro</i>	50.692	11.476	39.215
<i>Locri</i>	42.774	4.660	38.114
<i>Villammare</i>	49.939	3.874	46.065
<i>Rossanostaz</i>	75.666	36.085	39.581
<i>Rossanoina</i>	87.095	47.414	39.6803
<i>Messina</i>	47.985	5.603	42.381
<i>Casa Timpone</i>	238.128	192.006	46.121
<i>Gioiatauro</i>	82.295	40.224	42.071
<i>Reggio Calabria</i>	43.277	2.097	41.179
<i>Otranto</i>	39.11	4.55	37.56
<i>Napoli</i>	48.89	1.875	47.02

Tab.7 -comparison between GPS and IGM heights

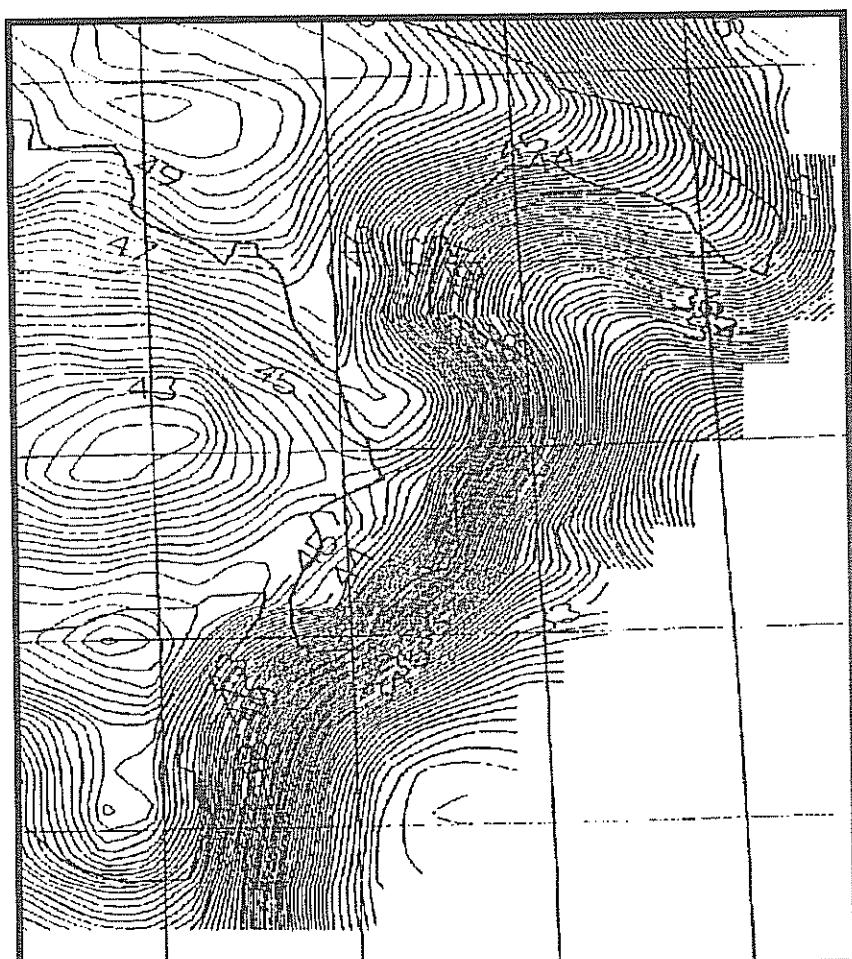


Fig. 2 - Italian Gravimetric Geoid in the South Italy (Crespi et al., 1993)

The last step consist of a comparison between our results and the results of the Gravimetric Geoid computation performed by Politecnico of Milan (Sguerso D., 1992). For this work is necessary to reduce all data at the same ellipsoid.

For this computation has been necessary made an interpolation between nearest points of the grids of the Italian Geoid. The computation of the interpolation is a weighted average where we use like a weight the inverse of the distance from know points (Crespi et al., 1993).

To define the quality of this method is important know the technical data about the Italian Geoid. The grating costant is  $0.125^\circ$  both in latitude and in longitude.

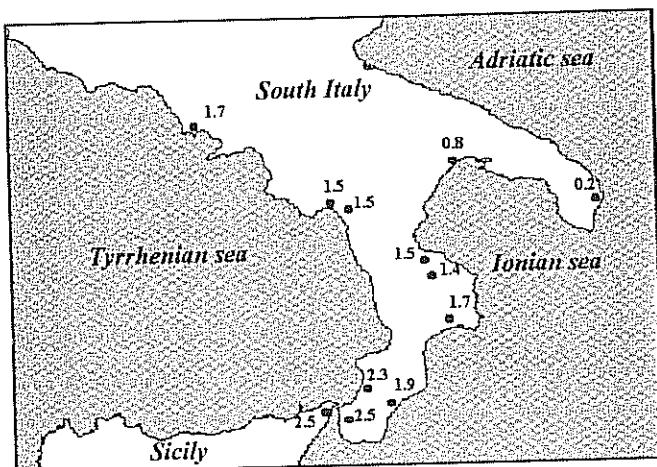


Fig. 3 - Position of the points used for the definition of the Geoid. The numbers shown in the picture are the difference between the GPS Geoid and the Italian Gravimetric Geoid (m).

Comparison between heights of GPS Geoid and Italian Geoid			
Site	GPS Geoid (m)	Italian Geoid (m)	difference (m)
Metaponto	42.487	43.258	0.770
Catanzaro	39.215	40.886	1.670
Locrì	38.114	40.022	1.907
Villammare	46.065	47.535	1.469
Rossanostaz	39.581	41.092	1.511
Rossanoina	39.680	41.128	1.447
Messina	42.381	44.856	2.474
Casa Timpone	46.121	47.616	1.494
Gioiatauro	42.071	44.398	2.326
Reggio C.	41.179	43.712	2.532
Otranto	37.56	37.743	0.183
Napoli	47.02	48.746	1.726

Tab.8 - Comparison between heights of GPS Geoid and Italian Geoid

The difference between the GPS and the Italian Gravimetric Geoid and their position (Fig. 3), show a numerical decrement from Messina straits to North. Taking our set of data as fixed, it has been made a rototranslation with the same planimetric coordinates and the Italian Gravimetric Geoid heights. The result are shown in table 9.

<i>New comparison between heights of GPS Geoid and Italian Geoid rototraslated</i>			
<i>Site</i>	<i>GPS Geoid (m)</i>	<i>new height of Italian Geoide (m)</i>	<i>Difference (m)</i>
<i>Metaponto</i>	42.487	42.408	-0.082
<i>Catanzaro</i>	39.215	39.219	0.001
<i>Loci</i>	38.114	37.867	-0.250
<i>Villammare</i>	46.065	45.988	-0.080
<i>Rossanostaz</i>	39.581	39.786	0.202
<i>Rossanoina</i>	39.680	39.820	0.137
<i>Messina</i>	42.381	42.382	-0.002
<i>Casa Timpone</i>	46.121	46.091	-0.033
<i>Gioiatauro</i>	42.071	42.203	0.129
<i>Reggio C.</i>	41.179	41.215	0.033
<i>Otranto</i>	37.56	37.554	-0.048
<i>Napoli</i>	47.02	46.998	-0.004

Tab.9 - *New comparison between heights of GPS Geoid and Italian Geoid rototraslated*

Observing Tab.9 we can see a good correlation between GPS Geoid and Italian Gravimetric Geoid. Results confirm the good work performed by Politecnico di Milano for the definition of Italian Gravimetric Geoid and, in the other side, the high potentiality of GPS measurements coupled with geometrical levelling to define the Geoid surface.

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