Додаток до журналу «Космічна наука і технологія», 1995, Т. 1, № 2.

GPS Observational Campaign in the Geodynamics Test Area "SIMEIZ-KATSIVELI": Data Processing and Results

S. Bolotin, I. Gaiovitch, O. Khoda, A. Samoilenko, Ya. Yatskiv

Main Astronomical Observatory, National Academy of Sciences of Ukraine

A network in the local scale geodynamics test area "SIMEIZ—KATSIVELI" was designed and GPS observational campaign was conducted. The preprocessing with the purpose to determine the precision, consistency, and cycle slips of GPS data was performed by the BERNESE version 3.5 GPS software (Astronomical Institute, University of Berne). In the final adjustment the geocentric coordinates of GPS points were estimated with a precision of 1—3 mm. Based on the eccenters from GPS markers to the reference points of two SLR stations and VLBI antenna, the geocentric coordinates derived by three different techniques — GPS, SLR, and VLBI — were compared. The possible error of equipment calibration of SLR stations in Simeiz (12337S003) and in Katsiveli (12337S006) is concluded.

1. INTRODUCTION

The geodynamics test area "SIMEIZ—KATSIVELI" is situated on the southern seaside of the Crimean peninsula to the west of Yalta. From the geological and geodynamics points of view this seismoactive site is very complicated and is worth being investigated by different methods. The main objective of our studies is to determine the positions and motions of some terrestrial points by different space geodesy techniques referred to the unique reference frame. The location of main points of geodynamics interest in this area is shown in Fig. 1. First of all it is necessary to mention two SLR stations (SIMEIZ — DOMES NUM. 12337S003, CDP NUM. 1873; KATSIVELI — DOMES NUM. 12337S006, CDP NUM. 1893) [1—2] which are involved in international observational programs. The geocentric coordinates of these stations are estimated by different analysis centers of the International Earth Rotation Service and are referred to ITRF [1—2]. Recently the MARK III system has been implemented on the radiotelescope RT-22 of the Crimean Astrophysical Observatory. This resulted in the participation of RT-22 in the international VLBI observational program and the determination of the position of this VLBI point. Moreover, a tide gauge is located in this area. The Black Sea level has been measured here for about 50 years. The point MARKERA (see Fig. 1) is a ground marker which was referred to a reference point of the SLR mobile system. This mobile laser system was supplied by Germany and was installed for some time in 1991 (DOMES NUM. 12337M001, CDP NUM. 7561). Supplementary ground markers around the MARKERA are denoted as SZE1 (eastern), SZE2 (south-eastern), SZE3 (south-western), SZE4 (western). The purpose of installation of other ground markers is threefold:

1) development of a local network for monitoring crustal movements by GPS as well as by conventional geodetic techniques;

2) determination of ties between ground markers and the VLBI and SLR stations by conventional geodetic techniques;

3) determination of the position of the tide gauge reference point in the geocentric reference system.

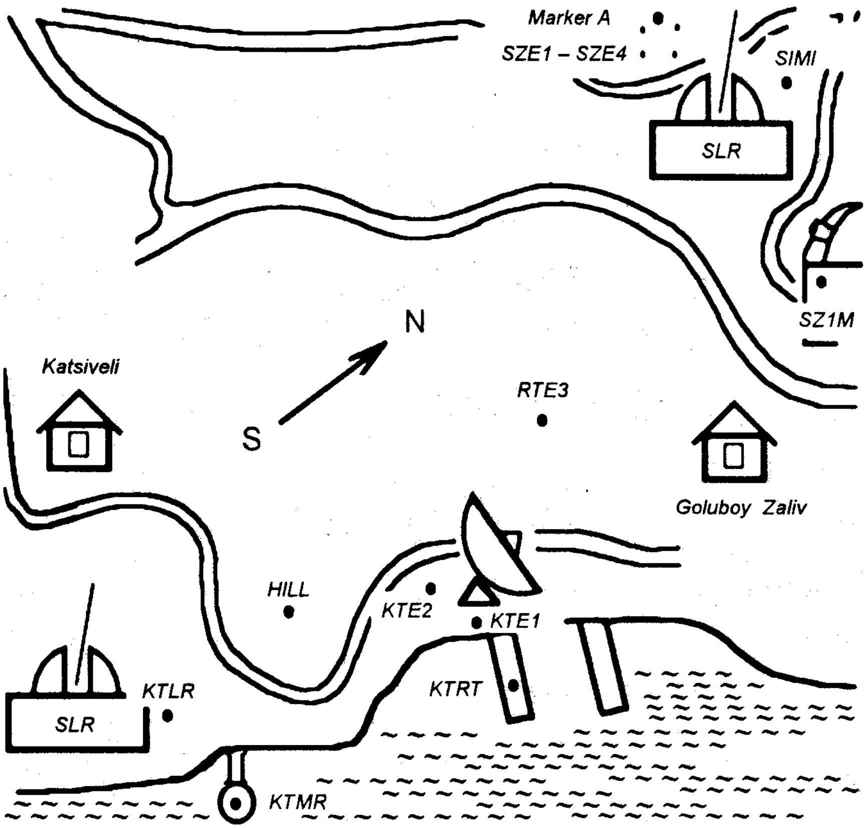

Fig. 1. Geodynamics test area "SIMEIZ—KATSIVELI"

2. PLANNING AND CONDUCTING THE OBSERVATIONAL CAMPAIGN IN THE LOCAL SCALE GEODYNAMICS TEST AREA "SIMEIZ—KATSIVELI" IN THE PEKA-94 FRAME

It was desirable to conduct a GPS survey in the test area "SIMEIZ—KATSIVELI" simultaneously with the PEKA-94 GPS campaign (Crimea—Caucasus) which was conceived as a part of the WEGENER project. The PEKA-94 GPS campaign as well as the measurements in the test area "SIMEIZ—KATSIVELI" were conducted during a five day period from September 5 6:00 UT to September 10 6:00 UT, 1994, days of year (DOY) 248—252. It should be pointed out that some of the points in the test area "SIMEIZ—KATSIVELI" are the same as in the PEKA-93 GPS campaign (SIMI, KTLR, KTRT, HILL(1994)—KTHI(1993), and KTMR). The flow diagram of observation sessions is shown in Table 1.

According to the PEKA-94 GPS campaign plan the main interest for the PEKA-94 GPS campaign in the Crimea was to conduct continuous observations around the clock at the MARKERA of the mobile laser platform. Besides, it was important to occupy the points involved earlier into the PEKA-93 GPS campaign. Several two or three 4—10 hour sessions were planned for these points. The rest of the points (KTE1, KTE2, and RTE3) were included in the campaign project in order to provide additional checks of terrestrial measurements which were performed to tie GPS markers to the intersection point of orientation axes of the VLBI antenna.

As a matter of fact the eccentric points SZE1—SZE4 are secondary markers on the Mobile Laser Platform. They were used for local collocation of GPS receivers (see below). Finally, the eccentric point SZ1M is located on the western edge of the dome of the 1 meter telescope installed on the Mt. Koshka.

The number of GPS receivers is another essential factor for the planning of the GPS survey in the test area "SIMEIZ—KATSIVELI". Three GPS receivers of Trimble 4000 SSE type were available for measurements. One of them was provided by the IfAG, Frankfurt am Meine (FRG) for continuous observations on the MARKERA. Other two receivers were borrowed from the Ukrainian Mapping Agency of the Main

Table 1. PEKA-94. The Crimea. Test Area "SIMEIZ—KATSIVELI". Session—Station Schedule.

Station	StationID	PEKA-93 ID	Days of year														
			248			249			250			251			252		
SIMEIZ:																	
Mobile laser platform																	
MarkerA	M001	—	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
East. eccenter	SZE1	—		×													
S—E eccenter	SZE2	—			×	×											
S—W eccenter	SZE3	—		×	×												
West. eccenter	SZE4	—				×											
Fixed laser station	SIMI	SIMI	×												×	×	
Optical 1 meter telescope	SZ1M	—															×
KATSIVELI:																	
Radiotelescope	KTRT	KTRT	×	×			×										
eccenter 1	KTE1	—						×									
eccenter 2	KTE2	—									×						
eccenter 3	RTE3	—												×			
Mareograph	KTMR	KTMR										×	×				
Fixed laser station Phys. Inst. of the RAS	KTLR	KTLR							×	×		×	×		×	×	
Hill point	HILL	KTHI					×	×	×	×							

Administration of Geodesy, Cartography and Cadastre to the Cabinet of Ministers of Ukraine (MAGCC). These receivers had a restricted internal memory (2 MB). They can not be used for 24-hour observation sessions with a 15 sec data record interval. In general the plan of the GPS campaign in the test area "SIMEIZ—KATSIVELI" (Crimea) was implemented successfully. The technical details to be mentioned are as follows:

1) As it was planned the continuous observations were conducted on the mobile laser platform at the point MARKERA. It should be pointed out that the MarkerA has a certain defect, namely, there is no centering rod (with diameter about 3 mm) with a hole about 0.2 mm as in the eccentric markers SZE1—SZE4. The measurements of slant antenna height were performed to the inside edge of metallic plate of the MARKERA. The necessary radial correction for the determination of the vertical height from the slant one is about 4 mm (i.e. the diameter of the inside hole is about 8 mm — see Fig. 2).

2) The tripods were used for occupation of all points except RTE3 where an enforced centering was used. Therefore the antenna parameter is the slant antenna height. For the point RTE3 the vertical height is used. An optical plummet delivered from the IfAG could not be focused, therefore a correct centering of antenna was impossible for one of the tripods. So, only a plumb bob was used in this case for occupations of less important points.

3) Organizations and personnel. Three organizations were involved in the implementation of the campaign in Simeiz. They are

IfAG — Institute of Applied Geodesy (Institute für Angewandte Geodäsie), Frankfurt am Meine, Federal Republic of Germany.

MAO — Main Astronomical Observatory, National Academy of Sciences, Kyiv, Ukraine,

MAGCC — Main Administration of Geodesy, Cartography and Cadastre to the Cabinet of Ministers of Ukraine.

The information about participants and their affiliations is presented in Table 2.

4) Observables. It occurred during the campaign that the Anti-Spoofing was invoked on all NAVSTAR satellites as well as the Selective Availability except SVs 12, 15, 28. Therefore, Trimble SSE receivers were switched automatically to the cross-correlation mode at L2 locking and the observables were measurements of C/A-code at L1 frequency, code difference P1—P2, and full wavelength phases at L1 and L2.

5) Local collocation of receivers. To check independently a local collocation of receivers on the Mobile Laser Platform site the distances between the points MarkerA, SZE1, SZE2, SZE3, and SZE4 were measured by a common method (steel tape) with an accuracy of about 0.5—1 mm (the platform surface is not flat). The results

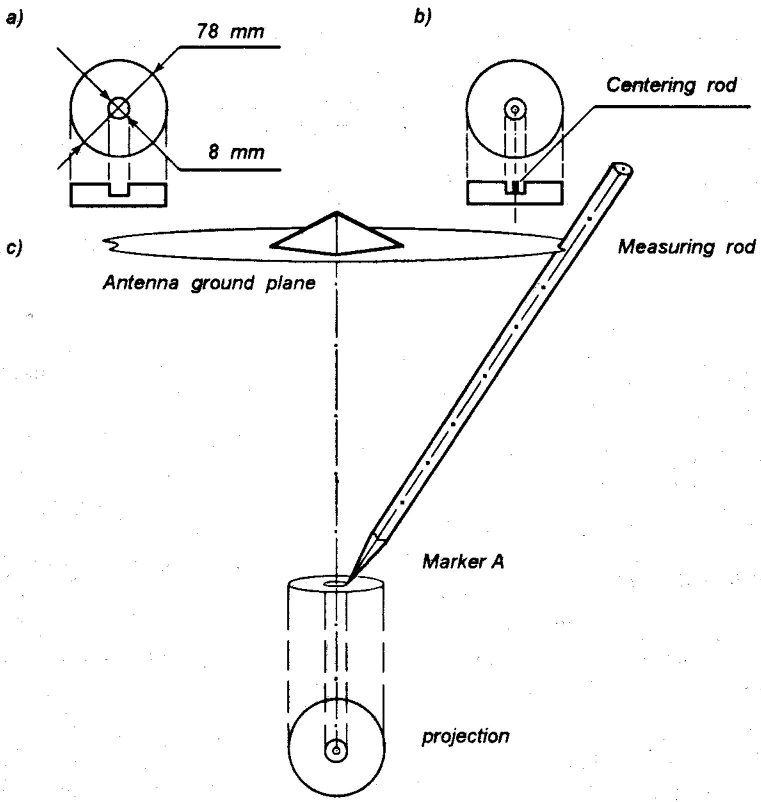

Fig. 2. PEKA-94. Mobile Laser Platform Site.
Markers: *a)* — Marker A, *b)* — Markers SZE1—SZE4, *c)* — Antenna slant height measurement to the Marker A.

Table 2. List of Obserservers.

Surname	Name	Affiliation	Remarks
Faltchuk	Sergey	MAGCC	observer
Gaiovitch	Igor	MAO	local person of responsibility and observer
Ihde	Johannes	IfAG	observer
Kharuta	Boris	MAGCC	observer
Khoda	Oleg	MAO	observer
Senyuk	Ernest	traffic company	driver
Rudenko	Sergey	MAGCC	observer
Zagoruiko	Vladimir	MAGCC	observer
Zayets	Ivan	MAGCC	observer

of these measurements form an upper triangular matrix (see Table 3).

6) Data storage. All raw data files are stored in computers at the IfAG, MAO and MAGCC. Observation sheets are copied for every participating organization (3) as well as for the Institute of Applied Astronomy (St.-Petersburg, Russia) which carried out the Caucasus part of the PEKA-94 GPS campaign.

3. SHORT DESCRIPTION OF THE BERNESE VERSION 3.5 GPS SOFTWARE PROGRAM

The GPS data processing software BERNESE version 3.5 was developed at the Astronomical Institute of the University of Berne (Switzerland) for processing both code and phase GPS observations for the purpose of precise positioning, determination of orbit parameters, satellite and receiver clock corrections, tropospheric

Table 3. Distances Between Points on the Mobile Laser Platform Site in Simeiz (in Meters)*

	MARKERA	SZE1	SZE2	SZE3	SZE4
MARKERA	0.0	2.363 2.364	4.359 4.359	4.290 4.291	2.837 2.837
SZE1		0.0	2.853 2.853	4.265 4.265	3.944 3.944
SZE2			0.0	2.701 2.700	3.893 3.893
SZE3				0.0	2.091 2.091
SZE4					0.0

* — the distance to the MARKERA was measured to the point which is approximately equidistant from the inside edges of the marker's metallic plate (i.e. no corrections are necessary — see Fig. 2).

parameters etc. The program provides the possibility to eliminate the ionospheric effect by iono-free combination of two-frequency observables as well as enables the computation of the ionosphere model which can be used for ambiguity resolution.

The float diagram of the BERNESE program for coordinate estimation includes the following steps:

1) Generation of the campaign project with definition of the points, receiver types, session schedule;
2) Input of the orbit information (either broadcast or precise from the International GPS Geodynamics Service), generation of the orbit file in the internal format of the BERNESE program;
3) Transformation of the data stored in the receiver specific format to the RINEX format;
4) Generation of data files in the internal format of the BERNESE program;
5) Checking code observations on smoothing (CODCHK subroutine);
6) Single point positioning and receiver clock correction determination from code observations (CODSPP);
7) Generation of files of single-differences (between points) of simultaneous phase observations;
8) Relative positioning from triple-difference observations and cycle slip detection;
9) Relative positioning in a baseline mode from double differences and float ambiguity estimation;
10) Ambiguity fixing;
11) Relative positioning from the adjustment of GPS network with the fixed ambiguity introduced as known quantities;
12) Covariance matrix estimation and quality analysis of the solution in comparison with baseline and float ambiguity solutions.

The coordinates derived are referred to the reference system as defined by the known coordinates of fixed points and orbital parameters. A detailed description of the terminology and processing algorithms can be found in [3—4]. Today due to the accuracy of models and algorithms used the BERNESE GPS software became the worldwide standard for GPS data processing in networks of local, regional, or global scales.

4. INPUT COORDINATES, PREPROCESSING AND ANALYSIS OF GPS DATA

The GPS data collected during the campaign in the "SIMEIZ—KATSIVELI" test area and additional GPS data from IGS stations MATERA (Italy) and WETTZELL (FRG) were processed using BERNESE version 3.5 GPS software.

The precise satellite orbits of the Center of Orbit Determination CODE7651—CODE7656 were used. They have an internal accuracy of 10—20 cm. These orbital data are refered to ITRF92 on epoch 1994.7.

The points listed in Table 4 were used as fixed (known).

The transformation of coordinates into the ITRF92 and on the epoch $T = 1994.7$ was performed in the following way:

a) for coordinates of the points S003 and S006 referred to ITRF92 by means of the formula (units: coordinates — in meters, velocities — in meter/year, time — in years)

Table 4. Initial Coordinates of Fixed Points.

Station	Reference system, Epoch	Coordinates, m	RMS, m	Velocity in the system ITRF92 [2], m/year	RMS, m/year
MATERA [1]	ITRF93	X: 4641949.788	0.004	−0.0217	0.0013
GPS (MATE)	1993.0	Y: 1393045.203	0.004	0.0171	0.0011
		Z: 4133287.273	0.004	0.0119	0.0014
WETTZELL [1]	ITRF93	X: 4075578.643	0.003	−0.0169	0.0009
GPS (WETT)	1993.0	Y: 931852.624	0.003	0.0161	0.0009
		Z: 4801569.995	0.002	0.0092	0.0012
12337M001 [1]	ITRF93	X: 3783746.561	0.039	−0.0204	0.0070
SIMEIZ, Mobile	1993.0	Y: 2551362.612	0.031	0.0162	0.0053
Laser Platfrom		Z: 4441445.098	0.048	0.0059	0.0079
RT-22 [5]	ITRF93	X: 3785231.1346	0.039	−0.0204	0.0070
SIMEIZ	1993.0	Y: 2551207.3625	0.031	0.0162	0.0053
radiotelescope		Z: 4439796.3420	0.048	0.0059	0.0079
12337S003 [2]	ITRF92	X: 3783902.746	0.046	−0.0204	0.0070
SIMEIZ	1988.0	Y: 2551405.925	0.040	0.0162	0.0053
		Z: 4441257.589	0.028	0.0059	0.0079
12337S006 [2]	ITRF92	X: 3783944.913	0.052	−0.0204	0.0070
KATSIVELI	1988.0	Y: 2550780.525	0.040	0.0162	0.0053
		Z: 4439461.512	0.029	0.0059	0.0079

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_T = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{T_0} + \begin{pmatrix} V_X \\ V_Y \\ V_Z \end{pmatrix}_{T_0} \cdot 6.7$$

where T = 1994.7, T_0 = 1988.0 — is an epoch of coordinates in catalogue.

b) for coordinates of other fixed points referred to ITRF93;

Using the tranformation parameters from ITRF92 to ITRF93 on epoch 1993.0 (see [1, pp. 79—82]):

	T1	T2	T3	D	R1	R2	R3
Units:	cm	cm	cm	$\times 10^{-8}$		×0.001 arcsec	
	1.65	0.9	0.3	−0.0012	0.94	0.1	0.71

and coordinates $(X, Y, Z)_{93}^T$ referred to ITRF93 we derive the coordinates $(X, Y, Z)_{92}^T$ referred to ITRF92 on the epoch 1993.0 by means of the formula

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{92} = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{93} + \begin{pmatrix} T1 \\ T2 \\ T3 \end{pmatrix} + \begin{pmatrix} D & -R3 & R2 \\ R3 & D & -R1 \\ -R2 & R1 & D \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{93}$$

Finally we transform the coordinates (X,Y,Z) referred to ITRF92 from epoch T_0 = 1993.0 to the epoch T = 1994.7

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_T = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{T_0} + \begin{pmatrix} V_X \\ V_Y \\ V_Z \end{pmatrix}_{T_0} \cdot (T - T_0)$$

where $T - T_0$ = 1.7 year.

The final coordinates of the fixed points referred to ITRF92 on epoch 1994.7 are given in Table 5.

The GPS-data preprocessing includes the following steps:

1) generation of orbit file on the basis of the input CODE orbits;

2) for all data files: check code data smoothing — by the program CODCHK;

single point positioning and time tag determination — by the program CODSPP;

3) for all phase data files:

Table 5. The Coordinates of Fixed Points Referred to ITRF92 on Epoch 1994.7.

Station	Reference system, Epoch	Coordinates, m	RMS, m
MATERA GPS (MATE)	ITRF92 1994.7	X: 4641949.7511 Y: 1393045.2341 Z: 4133287.2992	0.0045 0.0045 0.0045
WETTZELL GPS (WETT)	ITRF92 1994.7	X: 4075578.6243 Y: 931852.6434 Z: 4801570.0126	0.0035 0.0035 0.0025
12337M001 SIMEIZ, Mobile Laser Platform	ITRF92 1994.7	X: 3783746.5273 Y: 2551362.6315 Z: 4441445.1230	0.0450 0.0350 0.0500
RT-22 KATSIVELI radiotelescope	ITRF92 1994.7	X: 3785231.1003 Y: 2551207.3815 Z: 4439796.3670	0.0140 0.0100 0.0150
12337S003 SIMEIZ SLR	ITRF92 1994.7	X: 3783902.6083 Y: 2551405.0344 Z: 4441257.6285	0.0520 0.0370 0.0560
12337S006 KATSIVELI SLR	ITRF92 1994.7	X: 3783944.7763 Y: 2550780.6335 Z: 4439461.5515	0.0550 0.0370 0.0360

generation of single-difference files by the program SNGDIF; detection of the data with large gaps, low elevation (< 15 deg.), and cycle slips and its repair — by the program MAUPRP; ambiguity fixing — by the program GPSEST;

4) quality test for baseline data;

a) for baselines under 10 km in length (local scale test area "SIMEIZ—KATSIVELI"): The detailed analysis of data quality is presented in Appendix (Tables A1.1—A1.5). The analysis uses several criteria for testing: L1—L2 differences for float and fixed ambiguity solutions, number of ambiguities which were fixed with high level of confidence, etc. The results of baseline repeatability test are presented in Table 6.

Based on the above data quality checks the conclusion is the following: the best baselines are

DOY 248 — SIMI-M001, KTRT-M001;
DOY 249 — HILL-M001, KTE1-M001, KTRT-HILL;
DOY 250 — KTE2(L2)-M001; KTLR-M001; KTLR-HILL;
DOY 251 — RTE3-M001; KTLR-M001; KTMR-M001;
DOY 252 — KTLR-M001; SIMI-M001; SZ1M-SIMI.

Table 6. Baseline Repeatability Test (Differences Between the Solutions from Different Sessions).

Baseline	Frequency	Session 1	Session 2	Coordinates, cm	RMS, cm	Baseline, cm
M001-KTRT	L2	2481 2482	249	H 0.32 B −0.03 L 0.33	0.15 0.02 0.02	0.16
M001-KTHI	L1&L2	249	250	H 0.67 B 0.21 L −0.11	0.13 0.02 0.02	0.22
M001-KTLR	L1&L2	250	251	H −0.36 B −0.42 L −0.05	0.08 0.01 0.01	0.35
M001-KTLR	L1&L2	251	252	H 0.44 B −0.38 L 0.14	0.09 0.01 0.01	0.19
M001-SIMI	L1&L2	248	252	H 0.01 B 0.08 L 0.03	0.06 0.01 0.01	0.09

b) for baselines over 100 km

Taking into account long (~20 hours) sessions the ambiguities have not been fixed. The baselines MATE-M001, M001-WETT, WETT-MATE were of the major interest. Only data for DOY 248 were available for stations MATE and WETT.

The results of the triangle loop misclosure test are the following:

M001 ⟶ MATE ⟶ WETT ⟶ M001

Coordinates, cm	RMS, cm	Baseline, cm
H 2.50	0.06	
B −0.30	0.01	0.05
L −0.20	0.01	

Afterwards the coordinates listed in Table 5 are referenced as catalogue coordinates (e.g. X(Cat)). The coordinates obtained from the GPS solution are denoted as GPS-coordinates (e.g. X(GPS)).

If the position of the MATE point is assumed to be known, the following differences between GPS and catalogue coordinates are obtained for the WETT point:

Coordinate differences, cm	Coordinate differences, cm	Baseline difference, cm
X 0.40	H 1.26	
Y −1.70	B 0.63	0.77
Z 1.36	L −0.25	

The same type of comparison yields for the baseline M001-MATE:

Coordinate differences, cm	Coordinate differences, cm	Baseline difference, cm
X −3.20	H −4.70	
Y −1.60	B 0.32	0.05
Z −3.10	L 0.44	

One could see that

— the GPS technique provides acceptable accuracy for long regional scale baselines;

— there is a good agreement between the coordinates of the point on the mobile laser platform determined by means of SLR and GPS techniques.

5. FINAL SOLUTION OF GPS DATA

a) The positions of MATERA and WETTZELL stations given in Table 5 having been fixed, a common adjustment was performed by means of the CORRECT mode.

This solution provides the following M001 point coordinates saved in M001WEMA.CRD file.

The differences "GPS-Cat" are within the limits of possible errors (Table 7). Therefore, the GPS position of the point 12337M001 (M001) can be fixed in addition to MATERA and WETTZELL points.

b) Given the GPS position of M001 from the M001WEMA.CRD file and the parameters of the eccenter from GPS markers to the reference points of SLR and VLBI stations (Table 8) determined by means of conventional triangulation-trilateration technique, it is possible to determine the GPS positions of these reference points and to make a comparison with catalogue coordinates (see Tables 9 and 10).

Finally, we present the comparison between the GPS solutions based on L1 and L2 observations for the points of the local test area. Taking into account that both GPS solutions are in fact realizations of a certain reference frame, we make such comparison by the Helmert transformation (see Table 11).

The Helmert transformation parameters are small. This means that there is no significant difference between the L1 and L2 realisations of terrestrial reference frame.

Table 7. The GPS Position of the 12337M001 Point Resulted from the Solution of MATE-WETT-M001 Triangle, and the Difference with the SLR Position from the IERS Catalogue.

Point	Technique				
	GPS	Catalogue	Coord. dif. GPS-Cat, cm	Coord. dif. GPS-Cat, cm	Baseline dif., cm
12337M001	X: 3783746.5279 Y: 2551362.6286 Z: 4441445.1132	3783746.5273 2551362.6315 4441445.1230	X 0.06 Y −0.29 Z −0.98	H −0.77 B −0.62 L −0.27	0.08 (WETT) 0.46 (MATE)

Table 8. Eccentricities of SLR and VLBI Stations in the Geodynamics Test Area "SIMEIZ—KATSIVELI".

INPUT ECCENTRICITIES OF SLR AND VLBI STATIONS

GEODETIC DATUM: ITRF-92 — SYSTEM: GEOCENTRIC CENTER ⟶ STATION

Num	Station name	Center name	ΔX, m	ΔY, m	ΔZ, m
1	M001	12337M001	0.0000	0.0000	0.0000
2	SIMI	12337S003	−14.9030	−1.4760	9.3490
8	KTRT	RT-22	−70.1248	54.7323	−6.6146
13	KTLR	12337S006	−20.6030	1.1530	10.2440

Table 9. Final Solution for Coordinates of Points in the Test Area "SIMEIZ—KATSIVELI" Based on L2 Frequency Observations.

GEODETIC DATUM: ITRF-92

Station	X, m	RMS, m	Y, m	RMS, m	Z, m	RMS, m
M001	3783746.5279	0.0012	2551362.6286	0.0011	4441445.1132	0.0013
SIMI	3783887.5936	0.0005	2551403.4230	0.0003	4441266.7876	0.0006
SZ1M	3783947.7700	0.0015	2551467.6908	0.0012	4441195.0122	0.0016
KTRT	3785160.9947	0.0005	2551262.1306	0.0003	4439789.7554	0.0006
KTE1	3785206.3452	0.0010	2551216.2382	0.0007	4439790.9113	0.0012
KTE2	3785234.7852	0.0013	2551188.8789	0.0007	4439783.8021	0.0013
RTE3	3785220.1018	0.0010	2551078.8799	0.0007	4439987.6586	0.0011
KTMR	3785620.3852	0.0008	2551166.2233	0.0005	4439462.1095	0.0009
KTLR	3785924.0104	0.0004	2550781.6759	0.0003	4439471.5464	0.0005
HILL	3785378.7479	0.0004	2551165.2342	0.0003	4439717.3483	0.0005
SZE1	3783746.2945	0.0002	2551364.7487	0.0001	4441444.0955	0.0002
SZE2	3783748.2805	0.0002	2551365.2649	0.0002	4441442.1151	0.0002
SZE3	3783749.6829	0.0003	2551362.9644	0.0002	4441442.2289	0.0002
SZE4	3783748.8080	0.0002	2551361.7382	0.0002	4441443.6781	0.0002

Table 10. Coordinate and Baseline Differences "(GPS + ECCEN) − CAT".

		GPS + Eccen, m	Catalogue, m	Coord. difference, cm	Coord. difference, cm	Baseline difference, cm
RT-22	X	3785231.1195	3785231.1003	X 1.92	H 2.25	
	Y	2551207.3983	2551207.3815	Y 1.68	B −1.56	0.94
	Z	4439796.3700	4439796.3670	Z 0.30	L 0.32	
M003	X	3783902.4962	3783902.6083	X −11.2	H −25.51	
SIMEIZ	Y	2551405.8980	2551405.0344	Y −13.6	B −1.87	5.14
SLR	Z	4441257.4367	4441257.6285	Z −19.2	L −5.02	
M006	X	3783944.6140	3783944.7763	X −16.2	H −31.40	
KATSIVELI	Y	2550780.5231	2550780.6335	Y −11.0	B −4.04	6.6
SLR	Z	4439461.3028	4439461.5515	Z −24.9	L −0.09	

Table 11. Helmert Transformation Parameters Between the GPS Solutions on L1 and L2 for the Local Test Area "SIMEIZ—KATSIVELI".

HELMERT TRANSFORMATION
FILE 1: FIXED SOL L2 ALLECC
FILE 2: FIXED SOL L1 ALLECC
GEODETIC DATUM: ITRF-92
RESIDUALS IN REFERENCE SYSTEM (NORTH, EAST, UP)

Num	Name	FLG	Residuals, mm		
1	M001	F F	0.7	−2.0	−1.8
2	SIMI	E E	1.2	−1.7	−1.3
7	SZ1M	P P	−1.5	4.0	3.7
8	KTRT	E E	0.4	−0.7	−1.3
9	KTE1	P P	−1.3	−0.6	7.9
11	RTE3	P P	−1.2	−0.2	−3.9
12	KTMR	P P	1.8	0.5	−3.4
13	KTLR	E E	−1.0	−0.4	3.1
14	HILL	P P	1.0	1.1	−3.0

NUMBER OF PARAMETERS: 7, NUMBER OF COORDINATES: 27, RMS OF TRANSFORMATION: 2.9 mm
PARAMETERS:

TRANSLATION IN X:	1.3±1.0 mm
TRANSLATION IN Y:	0.6±1.0 mm
TRANSLATION IN Z:	0.4±1.0 mm
ROTATION AROUND X-AXIS:	0°0′1.7314″±1.1968″
ROTATION AROUND Y-AXIS:	−0°0′0.6695″±0.7330″
ROTATION AROUND Z-AXIS:	0°0′0.2109″±0.2578″
SCALE FACTOR:	−1.358±0.870 mm/km

6. SUMMARY

1. The positions of the points in the geodynamics test area "SIMEIZ—KATSIVELI" have been determined by the GPS technique with an accuracy of 1—3 mm.
2. Based on the regional scale solution the coordinates of the marker MARKERA at the Platform 12337M001 of mobile laser system are estimated. These coordinates are in good agreement with catalogue (SLR) coordinates of this point.
3. Large discrepancies between the positions determined from the SLR observations and those obtained from the GPS observations are detected. In our opinion the bias of height components of positions are due to an erroneous calibration of the fixed SLR stations in Simeiz and Katsiveli.

ACKNOWLEDGEMENTS

The work was carried out within the framework of the WEGENER project. The research described in this publication was made possible in part by Grant No UCA000 from the International Science Foundation, and by Grant UCA200 from the Joint Fund of the Government of Ukraine and International Science Foundation. The authors are grateful to Dr. M. Becker from IfAG (FRG) for GPS data from the IGS stations MATERA and WETTZELL.

REFERENCES

1. C. Boucher, Z. Altamini, L. Duhem (October, 1994) Results and analysis of ITRF93, IERS Technical Note 18, Central Bureau of IERS, PARIS, FRANCE, p. 68—69.
2. C. Boucher, Z. Altamini, L. Duhem (October, 1993) ITRF92 and associated velocity fields, IERS Technical Note 15, Central Bureau of IERS, PARIS, FRANCE, p. 85—89.

3. B. Hofmann-Wellenhof, H. Lichtenegger, and J. Collins (1994) Global Positioning System: Theory and Practice. Third, revised edition. Springer-Verlag. Wien, New York.
4. M. Rothacher (1992) Orbits of Satellite Systems in Space Geodesy. Ph. D. Thesis.
5. The data are obtained from S. Bolotin's results of processing the VLBI campaign (CRIMEA—DSS65—MATERA—MEDICINA — ONSALA60—WETTZELL) by the original secondary VLBI data processing program STEEL BREEZE ver. 1.01.

APPENDIX

QUALITY TEST FOR BASELINE DATA FOR BASELINES UNDER 10 KM IN LENGTH (LOCAL SCALE TEST AREA "SIMEIZ—KATSIVELI"):

Table A1.1. DOY 248 (September 5, 1994).

Baseline, Session	L1-L2, cm (FLOAT)		Unfixed (float) ambiguities	L1-L2, cm (FIXED)		Note(s)
	Coordinates	Baseline		Coordinates	Baseline	
SIMI-M001 2481	H 1.0 B −0.4 L 1.0	—	NO	H 0.3 B −0.1 L 0.5	0.1	
SIMI-M001 2482	— — —	—	NO	— — —	—	
KTRT-M001 2481	— — —	—	NO	H −0.82 B 0.17 L 0.03	0.0	
KTRT-M001 2482	— — —	—	NO	H 0.9 B 0.1 L 0.1	0.7	
SIMI-KTRT 2481	H −2.3 B 1.6 L −2.2	—	NO	H −1.05 B 1.12 L −0.4	0.7	"BAD" baseline
SIMI-KTRT 2482	H −3.0 B −2.0 L −2.3	—	1 of 15	H 34.70 B −5.50 L 8.8	4.8	"BAD" baseline
SIMI-KTRT 2483	H −1.1 B 0.1 L −0.22	0.2	NO	H −0.80 B 0.08 L 0.02	0.06	

Triangle loop misclosure test (DOY 248 — September 5, 1994):

1) M001 ⟶ SIMI ⟶ KTRT ⟶ M001

Coordinates, cm	RMS, cm	Baseline, cm
H 0.19 B 0.15 L 0.1	0.09 0.01 0.01	0.14

Table A1.2 DOY 249 (September 6, 1994).

Baseline Session	L1–L2, cm (FLOAT)		Unfixed (float) ambiguities	L1–L2, cm (FIXED)		Note(s)
	Coordinates	Baseline		Coordinates	Baseline	
HILL–M001 2491	H −0.11 B 0.1 L 0.23	–	NO	H 0.17 B 0.47 L 0.12	0.33	
KTRT–M001 2491	– – –	–	NO	H −0.81 B −0.08 L 0.02	0.27	
KTRT–HILL 2491	– – –	–	NO	H 0.02 B 0.01 L −0.02	0.01	
KTE1–HILL 2491	H 1.8 B −0.8 L −0.9	–	1 of 21	H −0.35 B −0.25 L −0.02	0.12	
KTE1–M001 2491	H −0.58 B 0.47 L −0.05	0.5	NO	H 0.06 B 0.12 L −0.06	0.10	

Triangle loop misclosure test (DOY 249 – September 6, 1994):

1) M001 ⟶ HILL ⟶ KTE1 ⟶ M001

Coordinates, cm	RMS, cm	Baseline, cm
H −3.90 B 0.10 L −0.40	0.15 0.02 0.02	0.40

Table A1.3. DOY 250 (September 7, 1994).

Baseline Session	L1–L2, cm (FLOAT)		Unfixed (float) ambiguities	L1–L2, cm (FIXED)		Note(s)
	Coordinates	Baseline		Coordinates	Baseline	
HILL–M001 2501	H −0.41 B 0.26 L −0.21	0.09	3 of 24	H −0.08 B 0.24 L 0.04	0.31	In |B| FLT better than FIX
KTLR–M001 2501	H −0.32 B 0.18 L 0.35	0.31	2 of 36	H −0.16 B −0.27 L 0.06	0.24	
KTLR–HILL 2501	H 0.15 B 0.07 L 0.22	0.23	NO	H 0.15 B 0.09 L 0.13	0.15	
KTE2–M001 2501	– – –	–	1 of 8	H 0.42 B −0.24 L 0.76	0.18	L1 malfunctioning ⇒ only FIX–FLT at L2
KTE2–KTLR 2501	– – –	–	NO	H −0.12 B 0.30 L 0.16	0.34	L1 malfunctioning ⇒ only FIX–FLT at L2

Triangle loop misclosure test (DOY 250 – September 7, 1994):

1) M001 ⟶ HILL ⟶ KTLR ⟶ M001

Coordinates, cm	RMS, cm	Baseline, cm
H –0.57 B 0.17 L 0.03	0.07 0.01 0.01	0.01

2) M001 ⟶ KTE2 ⟶ KTLR ⟶ M001

Coordinates, cm	RMS, cm	Baseline, cm
H 1.22 B 0.17 L 0.44	0.14 0.02 0.02	0.02

Table A1.4. DOY 251 (September 8, 1994).

Baseline, Session	L1–L2, cm (FLOAT)		Unfixed (float) ambiguities	L1–L2, cm (FIXED)		Note(s)
	Coordinates	Baseline		Coordinates	Baseline	
KTLR–M001 2511	H 0.08 B 0.14 L 0.55	0.44	NO	H –0.26 B 0.18 L 0.22	0.24	
KTMR–M001 2511	H –0.44 B 0.36 L 0.06	0.29	NO	H –0.56 B –0.37 L 0.05	0.22	
RTE3–M001 2511	H –0.56 B –0.28 L 0.33	0.13	2 of 20	H –0.48 B 0.07 L 0.00	0.00	
KTMR–KTLR 2511	H 0.20 B 0.38 L –0.93	0.90	NO	H –0.23 B 0.21 L 0.20	0.17	
RTE3–KTMR 2511	H –2.97 B 1.00 L 2.44	1.09	2 of 52	H 1.35 B –0.08 L 0.08	0.13	"BAD" baseline

Triangle loop misclosure test (DOY 251 – September 8, 1994):

1) M001 ⟶ KTLR ⟶ KTMR ⟶ M001

Coordinates, cm	RMS, cm	Baseline, cm
H –0.22 B 0.04 L 0.04	0.07 0.01 0.01	0.02

2) M001 ⟶ KTMR ⟶ RTE3 ⟶ M001

Coordinates, cm	RMS, cm	Baseline, cm
H –1.34 B –0.38 L 0.09	0.15 0.03 0.04	0.58

Table A1.5. DOY 252 (September 9, 1994).

Baseline, Session	L1–L2, cm (FLOAT) Coordinates	L1–L2, cm (FLOAT) Baseline	Unfixed (float) ambiguities	L1–L2, cm (FIXED) Coordinates	L1–L2, cm (FIXED) Baseline	Note(s)
KTLR–M001 2521	H –0.48 B –0.01 L –0.33	0.25	NO	H –0.19 B 0.03 L –0.05	0.03	
SIMI–M001 2521	H –0.43 B 0.03 L –0.21	0.06	NO	H –0.31 B 0.04 L –0.12	0.02	
SIMI–M001 2522	H 0.21 B –0.61 L 0.04	0.56	2 of 14	H –0.09 B –0.10 L –0.15	0.14	
SZ1M–M001 2522	H 3.19 B 0.41 L 0.50	0.24	1 of 20	H 0.35 B 0.50 L –0.29	0.49	"BAD" in |B|
KTLR–SIMI 2521	H 0.83 B 0.04 L 0.03	0.13	NO	H 0.48 B 0.03 L 0.15	0.05	"BAD" in H
SZ1M–SIMI 2521	H –0.01 B –0.53 L –0.28	0.46	NO	H 0.57 B –0.23 L –0.50	0.19	"BAD" in X, Y, Z

Triangle loop misclosure test (DOY 252 – September 9, 1994):

1) M001 ⟶ KTLR ⟶ SIMI ⟶ M001

Coordinates, cm	RMS, cm	Baseline, cm
H 0.76 B –0.07 L 0.20	0.06 0.01 0.01	0.05

2) M001 ⟶ SZ1M ⟶ SIMI ⟶ M001

Coordinates, cm	RMS, cm	Baseline, cm
H –5.92 B 0.51 L 1.43	0.21 0.04 0.04	0.37