DEUTSCHE GEODÄTISCHE KOMMISSION

bei der Bayerischen Akademie der Wissenschaften

Reihe B Angewandte Geodäsie Heft Nr. 299

WOLFGANG TORGE, LUDGER TIMMEN,
RÜDIGER H. RÖDER, MANFRED SCHNÜLL

The IFE Absolute Gravity Program "South America" 1988 – 1991

München 1994

Verlag der Bayerischen Akademie der Wissenschaften
in Kommission bei der C. H. Beck'schen Verlagsbuchhandlung München

ISSN 0065-5317 ISBN 3 7696 8582 2

DEUTSCHE GEODÄTISCHE KOMMISSION

bei der Bayerischen Akademie der Wissenschaften

Reihe B | Angewandte Geodäsie | Heft Nr. 299

Wolfgang Torge, Ludger Timmen,
Rüdiger H. Röder, Manfred Schnüll

The IFE Absolute Gravity Program
"South America"
1988 – 1991

München 1994

Verlag der Bayerischen Akademie der Wissenschaften
in Kommission bei der C. H. Beck'schen Verlagsbuchhandlung München

ISSN 0065-5317

ISBN 3 7696 8582 2

Adresse der Deutschen Geodätischen Kommission:

Deutsche Geodätische Kommission

Marstallplatz 8 • D – 80 539 München

Telefon (089) 23 031 113 • Telefax (089) 23 031 – 100/ – 240

Telex 5 213 550 dgfi d • E-mail hornik@dgfi.badw-muenchen.de

Adressen der Autoren / *Addresses of the authors*:

Prof. Dr.-Ing. Wolfgang Torge • Dipl.-Ing. Ludger Timmen

Dipl.-Ing. Rüdiger H. Röder • Dipl.-Ing. Manfred Schnüll

Institut für Erdmessung

Universität Hannover

Nienburger Straße 6

D – 30167 Hannover

Fax: ++49 – 0511 – 762 4006

Tel.: ++49 – 0511 – 762 2794/95

ISSN 0065-5317

ISBN 3 7696 8582 2

Contents

Abstract / Zusammenfassung / Resumen 4

1. Introduction 5

2. The JILAG-3 absolute gravimeter system 5

3. The IFE Absolute Gravity Program in South America 6

3.1 Venezuela 6

3.2 Brazil 9

3.3 Uruguay 9

3.4 Argentina 10

4. Conclusions 10

Acknowledgements 11

References 11

Annex 1: Earth tides parameters for South America 13

Annex 2: Station results of absolute gravity measurements in South America 1988 to 1991 14

Annex 3: Time sequences and histograms of absolute gravity observations (examples) 22

Annex 4: Station descriptions of the absolute gravity stations 23

Annex 5: Station descriptions of eccenter gravity stations 44

Abstract

The Institut für Erdmessung (IFE), University of Hannover, Germany, performed a large-scale gravity control survey between 1988 and 1991 in South America, in cooperation with university institutes and state agencies of the countries involved and supported by "Deutsche Forschungsgemeinschaft (DFG)" and "Instituto Panamericano de Geografía e Historia (IPGH)". This control system covers a large part of South America by establishing 22 absolute gravity stations with additional local eccenters. After a first observation campaign in Venezuela in 1988 (6 stations), a project in Brazil (7 stations), Uruguay (2 stations) and Argentina (3 stations) has been performed in 1989. A final campaign in 1991 concentrated on Argentina (3 new stations) and Uruguay (1 new station, 1 reoccupied). Three gravity stations (Sta. Elena, Brasilia, Tandil) are part of the International Absolute Gravity Basestation Network (IAGBN,set A). In addition, the stations serve as absolute gravity control for geodynamic networks in the Central and Venezuelan Andes and they improve existing national gravity networks.

Zusammenfassung

Von 1988 bis 1991 führte das Institut für Erdmessung (IFE) der Universität Hannover mehrere gravimetrische Meßkampagnen in Südamerika durch, um ein großräumiges Absolutschwerekontrollsystem aufzubauen. In Kooperation mit nationalen Agenturen und Universitäten und mit Unterstützung durch die Deutsche Forschungsgemeinschaft (DFG) und das Instituto Panamericano de Geografía e Historia (IPGH) wurden 22 Absolutschwerestationen mit zusätzlichen Exzentren angelegt; damit ist ein großer Teil Südamerikas überdeckt. Die erste Meßkampagne fand 1988 in Venezuela statt (6 Absolutstationen), eine zweite folgte 1989 in Brasilien (7 Stationen), Uruguay (2 Stationen) und Argentinien (3 Stationen). Das letzte Meßprojekt 1991 konzentrierte sich auf Argentinien (3 Stationen) und Uruguay (1 neue Stat., 1 wiederbesetzt). Drei Punkte (Sta. Elena, Brasilia, Tandil) gehören zum International Absolute Gravity Basestation Network (IAGBN, set A). Die Absolutpunkte dienen ferner der Verbesserung (Schwereniveau und Maßstab) der nationalen Schwerenetze und zur Stützung regionaler geodynamischer Kontrollnetze in den zentralen und den venezuelanischen Anden.

Resumen

Entre 1988 y 1991, el Institut für Erdmessung (IFE), Universidad de Hannover, Alemania, ha establecido una red de control de gravedad absoluta, que cubre largas partes de Sudamérica. El programa fue efectuado en cooperación con universidades e instituciones nacionales de los respectivos países, y subvencionado por la "Deutsche Forschungsgemeinschaft" y el Instituto Panamericano de Geografía e Historia. La red incluye 22 estaciones y adicionales excentros locales. En la primera campaña (1988), IFE ha observado 6 puntos en Venezuela. En el año 1989, se han establecido 7 puntos en Brasil, 2 puntos en Uruguay, y 3 puntos en Argentina. La ultima campaña se concentró en Argentina (3 puntos) y Uruguay (un punto nuevo y un punto reocupado). Tres puntos (Sta. Elena, Brasilia, Tandil) son parte de la Red Básica Internacional de Gravedad Absoluta (IAGBN), propuesta por la Asociación Internacional de Geodesia. Los puntos absolutos también apoyan las redes gravimetricas nacionales, con respecto al nivel absoluto y la escala. Finalmente, los puntos sirven para mejorar las redes gravimétricas especiales, que existen en los Andes Venezolanos y los Andes Centrales, para investigar fenómenos geodinámicos recientes.

1. Introduction

Within its *Absolute Gravimetry Program in South America*, the Institut für Erdmessung (IFE), University of Hannover, Germany, realizou carried out three absolute gravity measurement campaigns between 1988 and 1991. The survey concentrated on Venezuela (1988), Brazil, Uruguay and Argentina (1989), and Argentina and Uruguay (1991). através Through the IFE Absolute Gravity Program an *absolute gravity control system* of continental dimensions was realized for the first time in South America, with the main objectives

- to establish and firstly survey the three *IAGBN* (International Absolute Gravity Basestation Network) *stations* (set A) in South America. The IAGBN has been proposed by the International Association of Geodesy (IAG), e deve fornecer um sistema absoluto de gravidade a nível mundial and shall provide a world-wide absolute gravity system, strengthening the International Gravity Standardization Net 1971 (IGSN71) (MORELLI et al. 1974), and ressaltando especially serving as a global control system for monitoring gravity changes with time (BOEDECKER and FRITZER 1986),

"dá um suporte e fortalecer"

- to support and strengthen the *national gravity networks* of the countries involved in the program (Argentina, Brazil, Uruguay, Venezuela) with respect to absolute gravity level, scale and eventual network distortions. In addition, the absolute stations provide a calibration system and calibration lines for relative gravimeters,

fornece

- to support and strengthen *regional geodynamic networks* in the area of the Andes, with respect to absolute gravity level and scale, cf. TORGE (1993). Networks of this type exist in the Venezuelan Andes (DREWES et al. 1993) and the Central Andes (BECKER et al. 1993), and serve for monitoring recent vertical mass shifts of tectonic origin.

The program was carried out in close cooperation with university institutes and state agencies of the countries involved:

- Escuela de Ingeniería Geodesia, La Universidad del Zulia, Maracaibo, Venezuela,
- Dirección de Cartografía Nacional, Caracas, Venezuela,
- Dirección de Geología, Ministerio de Energía y Minas, Caracas, Venezuela,
- Curso de Pós-Graduação em Ciências Geodésicas, Universidade Federál do Paraná (UFPR), Curitiba, Brazil.
- Servicio Geográfico Militar, Montevideo, Uruguay,
- Instituto de Geodesia, Facultad de Ingeniería, Universidad de Buenos Aires, Argentina,
- Instituto Geográfico Militar, Buenos Aires, Argentina.

For the Venezuelan part, the long-term cooperation with Deutsches Geodätisches Forschungsinstitut, Abteilung I, München, Germany, continued also in this project.

2. The JILAG-3 absolute gravimeter system

The JILAG-3 absolute gravimeter of IFE was employed at the South America Absolute Gravity Program in combination with relative-type LaCoste-Romberg gravimeters. The *JILAG-3 gravimeter* is a transportable free-fall apparatus , developed by Prof. J.E. FALLER and coworkers at the Joint Institute for Laboratory Astrophysics (JILA), Boulder, Col., U.S.A. (FALLER et al. 1983). It is operated by IFE since 1986, and has since been used for more than 130 absolute gravity determinations worldwide. As the instrument as well as the measurement and evaluation method employed at IFE is well documented (TORGE et al. 1987, TORGE 1991), we here only summarize the main features.

The instrument includes a Michelson interferometer with a frequency stabilized laser for positioning of the dropped object (one corner cube reflector of the interferometer), and an atomic frequency standard for timing. It is operated under high vacuum (10^{-4} Pa), and microseismic noise on the reference reflector is strongly absorbed by a "superspring", with an electronically generated Eigen-period of 30 to 40 sec. 200 evenly distributed time/distance measurements are carried out over the falling distance of 0.25 m, and adjusted on-line to a fitting parabola thus giving one g-value for the reference height (about 0.8 m). Generally, 1500 drops are performed per station, distributed over 1 to 2 days, and the drop number is increased at a higher noise level. From the analysis of the JILAG-3 results obtained during 6 years, the average *precision* (standard deviation of the mean value per station) has been found at the order of 0.01 μms^{-2} at "stable" stations. Long-term *accuracy* includes errors of laser calibration, residual microseisms and floor recoil effects, and "gravitational noise" from not sufficiently modelled effects of earth tides, air pressure changes and (on sediments) soil moisture and ground water variations, and is estimated to ± 0.07 μms^{-2} on the average (TORGE 1991).

Relative gravity measurements have to be included into the absolute gravimetry projects, in order to transfer the absolute value from the reference height to a ground marker, to connect the absolute station to existing gravity networks, and to establish local eccenter stations for relative control of the station stability with time. At IFE, two LaCoste-Romberg (LCR) gravimeters are used for the relative ties, both of them equipped with the SRW electronic feedback system (RÖDER et al. 1988). By repeated measurements (e.g. 10 times for the vertical transfer of gravity) gravity differences <100 μms^{-2} can be determined then with an accuracy of ± 0.02 to ± 0.03 μms^{-2}.

3. The IFE Absolute Gravity Program in South America

Through the IFE Absolute Gravity Program 1988-1991 an absolute gravity control system was established, consisting of 22 absolute gravity stations, and covering large parts of South America (Fig.1). The regional and local selection of the stations was handled by the counterparts in the respective country, following the criteria given by the IFE gravimetry group, and taking local aspects of logistics and microseisms into account. Within the program, the three IAGBN stations (set A) proposed for South America have been established: Sta. Elena (Venezuela), Brasilia (Brazil), and Tandil (Argentina). The IFE JILAG-3 absolute gravimeter system has been employed, together with the IFE LCR gravimeters G298 and G709, and additionally in Uruguay the LCR G13 and G703 (Servicio Geografico Militar). 1500 to 3000 drops have been performed per station according to local microseisms. The standard deviation for one drop varied between ± 0.3 and ± 1.7 μms^{-2} (except Buenos Aires 1991: ± 4.4 μms^{-2}), the standard deviation of the adjusted gravity values are between ± 0.01 and ± 0.05 μms^{-2}. For the gravimetric earth tide reduction an expanded series development was used, with a tidal amplitude factor of 1.164 and a zero phase shift (till 1989) for the long and short partial tides. For the time-constant M0S0 term the amplitude factor 1.000 and phase lead 0.000° was used according to IAG standards (RAPP 1983). Since 1990, IFE uses the CTE (CARTHWRIGHT-TAYLOR-EDDEN) series development (505 waves) (CARTWRIGHT and TAYLER 1971, CARTWRIGHT and EDDEN 1973) and the data base of the International Earth Tide Center (MELCHIOR et al. 1984), to apply a refined tidal model with observed parameters. The earth tide parameters used at the evaluation of the 1991 results, are given in Annex 1. The field work with JILAG-3 and LCR gravimeters was performed by cand. geod. D. BEENING (Uruguay/Argentina 1989), Cap. J. MELCONIAN (Uruguay 1989), Dipl.-Ing. R. H. RÖDER (Venezuela 1988, Brazil/Uruguay/Argentina 1989, Uruguay 1991), cand. geod. S. SANDER (Uruguay 1991), Dipl.-Ing. M. SCHNÜLL (Venezuela 1988, Brazil 1989, Argentina 1991), Cap. W. SUBIZA (Uruguay 1991) and Dipl.-Ing. L. TIMMEN (Argentina 1991).

3.1 Venezuela

Six absolute gravity stations have been established in Venezuela, in September/October 1988 (TORGE 1989, DREWES et al. 1991, 1993), see Fig. 2 and Tab. 1. The absolute stations were connected by two LCR gravimeters (2 resp. 4 gravity differences), in order to control the relative quality of the system. In addition, they have been tied to 13 local reference stations, 7 of them being identical with stations of the national gravity net. A common adjustment of absolute (s.d. a.priori ± 0.1 μms^{-2}) and relative (± 0.25 μms^{-2}) measurements resulted in standard deviations of ± 0.08 to ± 0.13 μms^{-2} for the adjusted gravity values. The national gravity basestation net of Venezuela (RGNV82, 29 stations) has been readjusted, including the six absolute stations. While the absolute gravity level as derived from IGSN71 was confirmed (agreement 0.02 μms^{-2}), a scale correction of about $+5\times10^{-4}$ has been derived. The improved RGNV82 result agrees with the IFE 1988 data set wihtin ± 0.06 μms^{-2} (r.m.s. discrepancy, cf. Tab. 2). The Venezuelan Andes Geodynamics Network (63 stations), established in 1978 and reobserved 1981/83/85/88/92 was tied to the absolute stations Caracas, Maracaibo and Merida. As the deficiencies of absolute gravity level and scale are completely removed now in the national and in the geodynamics gravity network, and as the internal accuracy of both networks is better than ± 0.1 μms^{-2} both systems can serve more efficiently at future regional and local investigations about long-term gravity changes as related among others to an uplift of the Andes and a subsidence of the Maracaibo basin (DREWES et al. 1993).

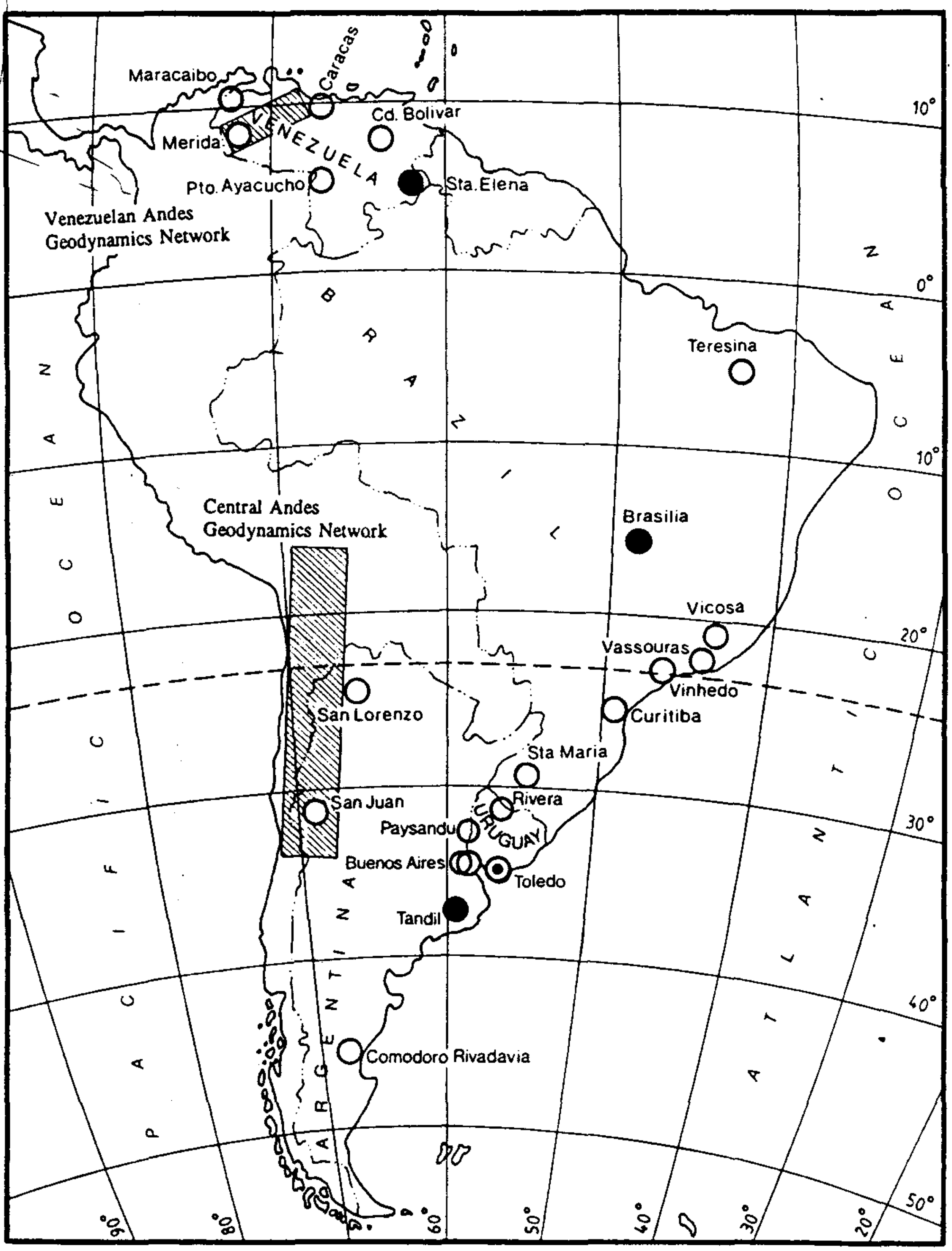


Fig. 1: JILAG-3 absolute gravity stations in South America: ● IAGBN, set A, station, ◯◯ two adjacent stations, ⊙ two independent determinations, ○ other JILAG-3 stations.

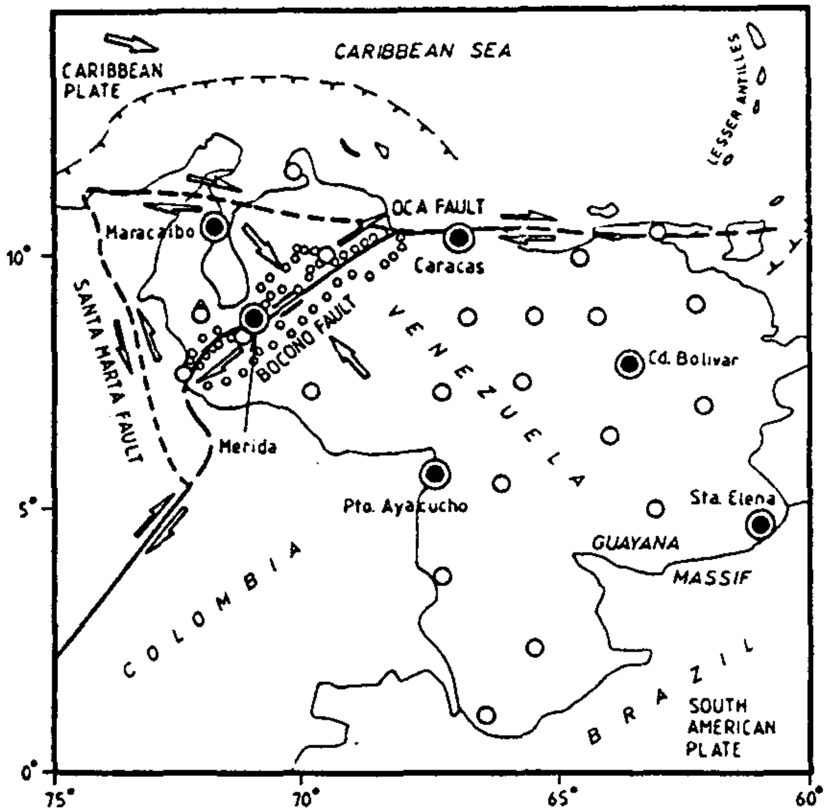


Fig. 2: Location of gravity stations in the Venezuelan research areas.
⊙ absolute gravity stations; O national gravity net basestations;
o Andes Geodynamics Network gravity stations.

Tab. 1: Results of absolute gravity measurements in Venezuela 1988

Station	IFE-No.	Epoch	ϕ [deg]	λ [deg]	H [m]	g_{floor} *) [μms^{-2}]
Caracas	10	9/88	10.51	293.07	1000	9780246.92
Maracaibo	20	9/88	10.67	288.37	20	9781856.31
Mérida CIDA	30	9/88	8.78	289.13	3600	9773522.10
Sta. Elena	40	9/88	4.67	298.92	93	9778220.84
Cd. Bolivar	50	10/88	8.08	296.50	46	9781153.49
Pto. Ayacucho	60	10/88	5.67	292.44	39	9780438.66

*) gravity values differ slightly (≤ 0.02 μms^{-2}) from publications TORGE 1989, DREWES et al. 1993, due to refined postprocessing.

Tab. 2: Results of gravity observations by IFE in 1988 (from absolute and relative measurements) and comparison with results of combined adjustment with RGNV82 (DREWES et al. 1991)

Station	IFE-No.	g_{IFE} [μms^{-2}]	g_{RGNV82} [μms^{-2}]	$\Delta g_{IFE-RGNV82}$ [μms^{-2}]
Caracas	10	9780246.96	... 6.95	+0.01
Caracas	11	9780510.37	... 0.43	−0.06
Maiquetía	12	9782309.03	... 9.10	−0.07
Caracas	13	9780612.91	... 2.93	−0.02
Maracaibo	21	9781602.02	... 1.95	+0.07
Cd. Bolivar	51	9781367.45	... 7.41	+0.04
Pto. Ayacucho	61	9780458.90	... 8.99	−0.09

3.2 Brazil

In Brazil, seven absolute gravity stations were established in February/March 1989 (GEMAEL et al. 1990), see Tab. 3. Nine eccenter stations were connected to the absolute stations, five of them being sites of national gravity networks. A common adjustment of absolute (±0.1 μms^{-2}) and relative (±0.05 to ±0.2 μms^{-2}, depending on transportation mode and use of feedback) data (including the data obtained in Uruguay and Argentina in 1989) gave standard deviations <0.12 μms^{-2} for the adjusted gravity values, which sufficiently controls the absolute data with respect to local disturbances. The comparison with the Brazilian gravity network, based on IGSN71, indicated an average shift of -0.3 μms^{-2} (JILAG-3 - IGSN71), and an internal accuracy of ±0.4 μms^{-2} (r.m.s.-discrepancy), cf. Tab. 4.

Tab. 3: Results of absolute gravity measurements in Brazil 1989

Station	IFE-No.	Epoch	ϕ [deg]	λ [deg]	H [m]	dg/dH [μms^{-2}/m]	g_{floor} *) [μms^{-2}]
Teresina	112	2/89	-5.06	317.20	70	-3.04	9780163.43
Brasilia	122	2/89	-15.66	312.10	1100	-2.48	9780487.98
Viçosa	132	2/89	-20.76	317.17	653	-2.87	9784602.30
Vassouras	142	2/89	-22.40	316.35	400	-3.06	9786375.81
Vinhedo	152	3/89	-23.00	313.03	850	-3.68	9785637.78
Curitiba	162	3/89	-25.45	310.76	910	-3.12	9787603.87
Sta. Maria	172	3/89	-29.72	306.28	85	-3.03	9792616.36

*) Gravity values differ slightly (≤0.12 μms^{-2}) from the results published in GEMAEL et al. 1990, due to refined post-processing

Tab. 4: Comparison between JILAG-3 eccenter points and local network points (Brazil)

Station	IFE-No.	g_{IFE} [μms^{-2}]	g_{net} [μms^{-2}]	$\Delta g_{IFE-net}$ [μms^{-2}]
Teresina B	113	9780173.75	... 4.16	−0.3
Brasilia C	123	9780883.54	... ~~4.2~~ 4.04	−0.7
Vassouras B	143	9786378.89	... 9.31	−0.4
Campinas C	153	9786023.96	... 3.96	±0.00
Sta. Maria	173	9792381.99	... 2.25	−0.26

3.3 Uruguay

The absolute stations Rivera and Toledo were established in March 1989. In December 1991, the station Paysandu was added, and Toledo was reoccupied, see Tab. 5. There is an excellent agreement (0.01 μms^{-2}) between the two determinations in Toledo. A connection to a LAGSN77 (Latin American Gravity Standardization Network 1977, MCCONNELL et al. 1979), based on IGSN71, point in Montevideo gave a discrepancy of -0.5 μms^{-2} (JILAG-3-LAGSN77, Tab. 6), which corresponds to the results obtained in Brazil. A readjustment of the national network, including the absolute gravity data, is under preparation.

Tab. 5: Results of absolute gravity measurements in Uruguay 1989/91

Station	IFE-No.	Epoch	ϕ [deg]	λ [deg]	H [m]	dg/dH [μms^{-2}/m]	g_{floor} [μms^{-2}]
Rivera	212	3/89	-30.90	304.46	213	-3.08	9793443.77
Toledo	222	3/89	-34.74	303.91	65	-3.07	9797158.55
Toledo	222	12/91	-34.74	303.91	65	-3.07	9797158.56
Paysandu	232	12/91	-32.38	301.97	61	-3.04	9795235.26

Tab. 6: Comparison between JILAG-3 eccenter point and LAGSN77 point (Uruguay)

Station	IFE-No.	$g_{IFE(89/91)}$ [μms^{-2}]	$g_{LAGSN77}$ [μms^{-2}]	$\Delta g_{IFE-LAGSN77}$ [μms^{-2}]
Montevideo (ecc.)	223	9797324.14	. . . 4.6	−0.5

3.4 Argentina

Six absolute gravity determinations were performed in Argentina, in April 1989 and in November 1991, with two adjacent stations (site change in 1991 because of groundwater problems) located in Buenos Aires, see Tab. 7. The two sites in Buenos Aires were connected by relative gravimetry, and agreed within 0.04 μms^{-2}. From a relative tie to an IGSN71 station in Buenos Aires, a shift (JILAG-3−IGSN71) of +0.4 μms^{-2} was found, cf. Tab. 8. The stations San Juan and San Lorenzo have been integrated into the Central Andes Geodynamics Network, which has been established in 1984 and reobserved several times with LCR gravimeters, in order to detect gravity variations with time at that active continental margin, triggered by the subduction of the Nazca plate (BECKER et al. 1989, BECKER et al. 1993).

Tab. 7: Results of absolute gravity measurements in Argentina 1989/91

Station	IFE-No.	Epoch	ϕ [deg]	λ [deg]	H [m]	dg/dH [$\mu ms^{-2}/m$]	g_{floor} [μms^{-2}]
Buenos Aires	311	4/89	-34.57	301.48	8	-	9796900.69
Buenos Aires	313	11/91	-34.57	301.48	13	-2.48	9796891.41
Tandil	322	4/89	-37.40	300.77	180	-2.98	9799043.60
San Lorenzo	332	4/89	-24.73	294.51	1500	-2.51	9784094.10
San Juan	342	11/91	-31.55	291.32	730	-1.92	9791416.49
Comodoro Rivadavia	352	11/91	-45.82	292.54	10	-2.56	9806637.57

Tab. 8: Comparison between JILAG-3 station and IGSN71 station (Argentina)

Station	IFE-No.	$g_{IFE(88/91)}$ [μms^{-2}]	g_{IGSN71} [μms^{-2}]	$\Delta g_{IFE-IGSN71}$ [μms^{-2}]
Buenos Aires*	311	9796900.71	. . . 0.3	0.4

*) gravity datum station IGSN71 "Buenos Aires A" in Migueletes

4. Conclusions

The IFE Absolute Gravity Program (1988–1991) in South America provided a large-scale gravity control for a large part of the subcontinent. 22 absolute gravity stations have been established, 6 of them located in Venezuela, 7 in Brazil, 3 in Uruguay, and 6 in Argentina. From repetitions and relative connections between the stations, we estimate the accuracy of the final gravity values to be ±0.1 μms^{-2} or better, which agrees with the results obtained at other surveys. This accuracy assessment is confirmed by absolute measurements performed by the US absolute gravimetry group (National Oceanic and Atmospheric Administration (NOAA), National Ocean Service) in 1992. The JILAG-4 and JILAG-3 results show an r.m.s. discrepancy of ±0.07 μms^{-2} (Tab. 9, KLOPPING 1994).

Tab. 9: Comparison between JILAG-4 and JILAG-3 gravity determinations in Brazil

xxxStation	IFE-No.	Height [m]	g(JILAG-4) [μms^{-2}]	g(JILAG-3) [μms^{-2}]	Δg [μms^{-2}]
Teresina	112	0.905	9780160.65	... 0.68	0.03
Brasilia	122	0.910	9780485.80	... 5.72	-0.08
Curitiba	162	0.908	9787600.94	... 1.03	0.09

Local connections to the existing national gravity networks indicated, that the absolute level of the IGSN71 based networks is correct within a few 0.1 μms^{-2}, but may be locally biased of up to 0.4 to 0.5 μms^{-2}. Scale errors of some 10^{-4} may occur, while the internal accuracy is ± a few 0.1 μms^{-2}. National networks have been (Venezuela) or can be readjusted now, thus providing a state-of-the-art gravity standard for the countries. Covering a total gravity range of 0.0265 ms^{-2}, a long-range gravimeter calibration line is available now, with subdivisions in the countries involved in the program. Concerning geodynamic aspects, the IFE program has established the three IAGBN stations in South America, which will serve for monitoring global gravity variations with time. Existing geodynamic networks in the Venezuelan and the Central Andes have been tied to absolute stations, thus providing gravity level and scale for these regional high precision control systems.

Acknowledgements

The authors thank all the institutions and persons, who cooperated in the projects and contributed to the success of the program. We are grateful to Prof. C. BADELL and Prof. M. HOYER (Universidad del Zulia, Maracaibo), Ing. D. BRAVO (Dirección de Geología, Caracas), Ing. O. CHOURIO (Dirección de Cartografía National, Caracas), Prof. C. GEMAEL, Ing. O.H.S. LEITE, F.A. ROSIER (Universidade Federál do Paraná, Curitiba), Cap. J. MELCONIAN and Cap. W. SUBIZA (Servicio Geografico Militar, Montevideo), Prof. A.A. CERRATO (Universidad de Buenos Aires), Agrim. RODRIGUEZ (Instituto Geografico Militar, Buenos Aires), Dr. H. DREWES (Deutsches Geodätisches Forschungsinstitut, Abt. I, München). The projects have been supported by Deutsche Forschungsgemeinschaft (German Research Society), through research grants To 46/29-1, To 46/30-1, To 46/30-2, Instituto Panamericano Geografía y Historia, and a number of institutions in Brazil: IBGE (Instituto Brasileiro de Geografia e Estatistica), Petrobrás (Petrobrás S/A), Varig (Viação Aérea Riograndense), the universities UFPR, UFPI, UNB, UFV, USP, UFSM and the Observatório Nacional.

References

BECKER M, ARANEDA M, GROTEN E, HIRSCH O, KNÖLL T, OSTRAU S (1989): *First results for gravity variations in the Central Andes*. Zbl. Geol. Paläont. Teil I, H. 5/6, 1151-1161.

BECKER M, GROTEN E, ARANEDA M, CERRATO A.A., STAROWINSKY M, CSAPO G, HIRSCH O, VOLPONI F. (1993): *Monitoring of gravity variations in the southern Central Andes*. In: TORGE W, GONZALEZ-FLETCHER A, tanner JG (eds.), Recent Geodetic and Gravimetric Research in Latin America. IAG Symp. No. 111, Vienna, Austria 1991, IAG Symp. Proceed., 184-191, Springer, Berlin etc.

BOEDECKER G, FRITZER TH (1986): *International Absolute Gravity Basestation Network*. I.A.G.-SSG 3.87 Status Report March 1986. Veröff. Bayer. Komm. für die Internat. Erdmessung der Bayer. Akad. d. Wissensch., Astron.-Geod. Arb., Heft Nr. 47.

CARTWRIGHT DE, EDDEN AC (1973): *Corrected tables of tidal harmonics*. Geophysical Journal of the Royal Astronomical Society, No. 33, 253-264, Oxford.

CARTWRIGHT DE, TAYLOR RJ (1971): *New computations of the tide generating potential*. Geophysical Journal of the Royal Astronomical Society, No. 23, 45-74, Oxford.

DREWES H, TORGE W, RÖDER RH, BADELL C, BRAVO D, CHOURIO O (1991): *Absolute and relative gravimetric surveys of national and geodynamic networks in Venezuela*. Journal of South American Earth Science, Vol. 4, No. 4, 273-286.

DREWES H, TORGE W, RÖDER R, BADELL C, BRAVO D, CHOURIO O (1993): *Geodynamic research by absolute and relative gravimetry in Venezuela*. In: TORGE W, GONZALEZ-FLETCHER A, TANNER JG (eds.), Recent Geodetic and Gravimetric Research in Latin America. IAG Symp. No. 111, Vienna, Austria 1991, IAG Symp. Proceed., 202-214, Springer, Berlin etc.

FALLER JF, GUO YG, GSCHWIND J, NIEBAUER TM, RINKER RL, XUE J (1983): *The JILA portable absolute gravity apparatus.* Bur. Grav. Int., Bull. d'Inf., No. 53, 87-97.

GEMAEL C, LEITE OHS, ROSIER FA, TORGE W, RÖDER RH, SCHNÜLL M (1990): *Large-scale absolute gravity control in Brazil.* In: RUMMEL R, HIPKIN RG (eds.): IAG Symp. No.103, Edinburg, Scotland, IAG Symp. Proceed., 49-55, Springer, New York etc.

KLOPPING F (1994): *Personal communication.*

MCCONNELL RK, WINTER PJ, GELLER RF (1979): *Latin American Gravity Standardization Network 1977 (LAGSN 77).* Earth Physics Branch, Ottawa, Canada.

MELCHIOR P, DUCARME B, VAN RUYMBEKE M, POITEVIN C (1984): *Trans world tidal gravity profiles.* Obs. Royal de Belgique, Bull. d'Observ.: Marées Terrestres, Vol. V, Fasc. 1,Section Geodynamique, 1-102.

MORELLI C, GANTAR C, HONKASALO T, MCCONNELL K, TANNER JG, SZABO B, UOTILA U, WHALEN T (1974): *The International Gravity Standardization Net 1971 (IGSN71).* I.U.G.G.-I.A.G.-Spec. Publ., No. 4.

RAPP RH (1983): *Tidal gravity computations based of recommendations of the Standard Earth Tide Commitee.* Bulletin d'Informations Marées Terrestres, No. 89, 5814-5819, Bruxelles.

RÖDER RH, SCHNÜLL M, WENZEL H-G (1988): *SRW-feedback for LaCoste-Romberg gravimeters with extended range.* Bur. Grav. Int., Bull. d'Inf., No. 62, 46-50.

TORGE W (1989): *Observaciones gravimetricas absolutas en Venezuela; pro medio del gravimetro JILAG-3 (IFE).* Memorias II. Congreso Venezolano de Geodesia, Maracaibo. Bol. Cartogr. y Geodesia, Ed. esp., 206-210.

TORGE W (1991): *The present state of absolute gravimetry.* Conseil de l'Europe, Cahiers du Centre Européen de Géodynamique et de Séismologie, Vol. 3, 9-22.

TORGE W (1993): *Gravimetry and tectonics.* In: KAKKURI J (ed): Geodesy and Geophysics, Publ. Finn. Geod. Inst., No. 115, 131-172, Helsinki.

TORGE W, RÖDER RH, SCHNÜLL M, WENZEL H-G, FALLER JE (1987): *First results with the transportable absolute gravity meter JILAG-3.* Bull. Géod., No.61, 161-176.

Annex

Annex 1: Earth tides parameters for South America

Annex 2: Station results of absolute gravity measurements in South America 1988 to 1991

Annex 3: Time sequences and histograms of absolute gravity observations (examples)

Annex 4: Station descriptions of the absolute gravity stations

Annex 5: Station descriptions of eccenter gravity stations

Annex 1

Earth tides parameters for South America (used at the data processing of the 1991 results)

Local earth tide parameters for Buenos Aires (Argentina)

wave group	wave number		amplitude factor	phase
	from	to	[ ]	[°]
M0S0	1	1	1.000	0.00
Mf	2	128	1.164	0.00
O1	129	241	1.184	-0.36
K1	242	333	1.152	-0.29
N2	334	398	1.182	0.97
M2	399	441	1.177	0.44
S2	442	488	1.161	0.36
M3	489	505	1.110	3.60

Local earth tide parameters for San Juan (Argentina)

wave group	wave number		amplitude factor	phase
	from	to	[ ]	[°]
M0S0	1	1	1.000	0.00
Mf	2	128	1.164	0.00
O1	129	241	1.171	0.96
K1	242	333	1.156	0.63
N2	334	398	1.175	-0.61
M2	399	441	1.148	-0.46
S2	442	488	1.137	0.11
M3	489	505	0.940	-1.10

Local earth tide parameters for Comodoro Rivadavia (Argentina)

wave group	wave number		amplitude factor	phase
	from	to	[ ]	[°]
M0S0	1	1	1.000	0.00
Mf	2	128	1.164	0.00
O1	129	241	1.247	0.26
K1	242	333	1.195	0.30
N2	334	398	1.127	5.12
M2	399	441	1.211	6.28
S2	442	488	1.232	0.05
M3	489	505	1.100	0.00

Annex 1 (cont'd)

Local earth tide parameters for Paysandu and Toledo (Uruguay)

wave group	wave number from	wave number to	amplitude factor [ ]	phase [°]
M0S0	1	1	1.000	0.00
Mf	2	128	1.164	0.00
O1	129	241	1.182	-0.29
K1	242	333	1.149	-0.04
N2	334	398	1.163	0.26
M2	399	441	1.172	0.59
S2	442	488	1.144	0.08
M3	489	505	1.100	0.00

Annex 2

Station results of absolute gravity measurements in South America 1988 to 1991

Venezuela

Caracas (IFE-No. 10)

Run	Date	Drops	$g_{h=0.801}$ *) [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	880913	289	9780242.72	1.02	9780246.84
2	880913	288	9780242.83	0.68	9780246.95
3	880913	230	9780242.90	0.55	9780247.02
4	880914	578	9780242.76	0.24	9780246.88**)
5	880914	578	9780242.82	0.24	9780246.94**)
		1963	9780242.80		9780246.92 s= ±0.073 s_{mean}= ±0.028

Maracaibo (IFE-No. 20)

Run	Date	Drops	$g_{h=0.801}$ *) [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	880917	290	9781853.74	0.34	9781856.31
2	880917	289	9781853.72	0.51	9781856.29
3	880917	290	9781853.72	0.68	9781856.29
4	880918	287	9781853.77	0.33	9781856.34
		1156	9781853.74		9781856.31 s= ±0.024 s_{mean}= ±0.012

Annex 2 (cont'd)

Mérida CIDA (IFE-No. 30)

Run	Date	Drops	$g_{h=0.802}$ *) [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	880921	291	9773519.74	0.69	9773522.18
2	880921	580	9773519.69	0.72	9773522.13**)
3	880922	581	9773519.63	0.24	9773522.07**)
4	880922	291	9773519.66	0.34	9773522.10
5	880922	290	9773519.58	0.68	9773522.02
		2033	9773519.66		9773522.10 s= ±0.064 s_{mean}= ±0.024

Sta. Elena (IFE-No. 40)

Run	Date	Drops	$g_{h=0.803}$ [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	880928	284	9778218.37	0.40	9778220.76
2	880928	282	9778218.44	0.40	9778220.82
3	880928	287	9778218.47	0.30	9778220.86
4	880929	289	9778218.56	0.40	9778220.95
5	880929	290	9778218.49	0.40	9778220.88
6	880929	289	9778218.42	0.34	9778220.80
		1721	9778218.46 dg/dh = -2.97 μms^{-2}/m		9778220.84 s= ±0.067 s_{mean}= ±0.027

Ciudad Bolivar (IFE-No. 50)

Run	Date	Drops	$g_{h=0.808}$ *) [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	881003	576	9781150.89	2.16	9781153.47
2	881003	578	9781150.96	1.44	9781153.54
3	881003	573	9781150.93	1.43	9781153.51
4	881004	569	9781150.89	1.19	9781153.47
5	881004	574	9781150.88	0.96	9781153.46
		2870	9781150.91		9781153.49 s= ±0.034 s_{mean}= ±0.015

Annex 2 (cont'd)

Puerto Ayacucho (IFE-No. 60)

Run	Date	Drops	$g_{h=0.807}$ *) [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	881008	287	9780435.50	0.51	9780438.68
2	881008	286	9780435.58	0.50	9780438.76
3	881008	283	9780435.52	0.34	9780438.70
4	881009	581	9780435.38	0.48	9780438.56**)
5	881009	285	9780435.49	0.67	9780438.67
		1722	9780435.48		9780438.66 s= ±0.089 s_{mean}= ±0.036

Brazil

Teresina (IFE-No. 112)

Run	Date	Drops	$g_{h=0.812}$ [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	890214	284	9780160.86	0.51	9780163.33
2	890214	282	9780160.98	0.67	9780163.45
3	890214	287	9780161.03	0.34	9780163.50
4	890214	283	9780160.84	0.84	9780163.31
5	890214	172	9780161.01	0.63	9780163.48
6	890215	566	9780160.99	0.48	9780163.46**)
		1874	9780160.96 dg/dh = -3.04 μms^{-2}/m		9780163.43 s= ±0.082 s_{mean}= ±0.031

Brasilia (IFE-No. 122)

Run	Date	Drops	$g_{h=0.808}$ [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	890217	287	9780485.98	0.31	9780487.98
2	890217	289	9780485.97	0.30	9780487.97
3	890218	284	9780485.96	0.34	9780487.96
4	890218	290	9780485.97	0.31	9780487.97
5	890218	291	9780485.99	0.28	9780487.99
		1441	9780485.97 dg/dh = -2.48 μms^{-2}/m		9780487.98 s= ±0.011 s_{mean}= ±0.005

Annex 2 (cont'd)

Viçosa (IFE-No. 132)

Run	Date	Drops	$g_{h=0.806}$ [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	890222	285	9784600.16	1.01	9784602.47
2	890222	286	9784600.06	1.18	9784602.37
3	890222	290	9784600.01	0.51	9784602.32
4	890223	573	9784599.90	0.96	9784602.21**)
5	890223	577	9784599.90	0.72	9784602.21**)
6	890223	570	9784600.02	1.19	9784602.33**)
7	890223	275	9784600.05	0.65	9784602.36
		2856	9784599.99		9784602.30
			dg/dh = -2.87 $\mu ms^{-2}/m$		s= ±0.110
					s_{mean}= ±0.035

Vassouras (IFE-No. 142)

Run	Date	Drops	$g_{h=0.813}$ [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	890227	289	9786373.41	1.02	9786375.90
2	890228	551	9786373.35	0.75	9786375.84**)
3	890228	574	9786373.32	0.72	9786375.81**)
4	890228	550	9786373.29	0.79	9786375.78**)
5	890228	291	9786373.32	0.51	9786375.81
6	890228	290	9786373.25	0.85	9786375.74
		2545	9786373.32		9786375.81
			dg/dh = -3.06 $\mu ms^{-2}/m$		s= ±0.058
					s_{mean}= ±0.019

Vinhedo (IFE-No. 152)

Run	Date	Drops	$g_{h=0.803}$ [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	890302	288	9785634.77	0.51	9785637.72**)
2	890302	146	9785635.00	0.37	9785637.96
3	890302	270	9785634.92	0.33	9785637.88**)
4	890302	288	9785634.75	0.51	9785637.70**)
5	890302	280	9785634.76	0.67	9785637.72**)
6	890302	279	9785634.81	0.67	9785637.76**)
7	890303	283	9785634.83	0.50	9785637.78**)
		1834	9785634.82		9785637.78
			dg/dh = -3.68 $\mu ms^{-2}/m$		s= ±0.116
					s_{mean}= ±0.032

Annex 2 (cont'd)

Curitiba (IFE-No. 162)

Run	Date	Drops	$g_{h=0.811}$ [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	890309	290	9787601.43	0.85	9787603.96
2	890309	580	9787601.37	1.20	9787603.90**)
3	890309	291	9787601.35	0.68	9787603.88
4	890309	255	9787601.35	0.64	9787603.88
5	890309	561	9787601.33	0.95	9787603.86**)
6	890310	572	9787601.25	0.96	9787603.78**)
7	890310	226	9787601.36	1.05	9787603.89
		2775	9787601.34		9787603.87
			dg/dh = -3.12 μms^{-2}/m		s= ±0.067
					s_{mean}= ±0.021

Sta. Maria (IFE-No. 172)

Run	Date	Drops	$g_{h=0.807}$ [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	890314	286	9792613.87	1.01	9792616.32
2	890314	577	9792613.87	0.96	9792616.32**)
3	890315	572	9792613.96	1.91	9792616.40**)
4	890315	289	9792613.98	1.02	9792616.42
5	890315	290	9792613.87	0.85	9792616.32
		2014	9792613.91		9792616.36
			dg/dh = -3.03 μms^{-2}/m		s= ±0.057
					s_{mean}= ±0.022

Uruguay

Rivera (IFE-No. 212)

Run	Date	Drops	$g_{h=0.805}$ [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	890318	266	9793441.27	0.52	9793443.75
2	890319	276	9793441.26	0.52	9793443.74
3	890319	273	9793441.32	0.47	9793443.80
4	890319	280	9793441.32	0.40	9793443.80
5	890319	275	9793441.26	0.50	9793443.74
		1370	9793441.29		9793443.77
			dg/dh = -3.08 μms^{-2}/m		s= ±0.031
					s_{mean}= ±0.014

Annex 2 (cont'd)

Toledo (IFE-No. 222)

Run	Date	Drops	$g_{h=0.812}$ [µms^{-2}]	s_{drop} [µms^{-2}]	g_{floor} [µms^{-2}]
1	890323	289	9797156.11	0.47	9797158.60
2	890323	289	9797156.17	0.53	9797158.66
3	890324	289	9797156.13	0.47	9797158.62
4	890324	288	9797156.08	0.50	9797158.57
5	890324	290	9797155.92	0.62	9797158.41
6	890324	289	9797155.94	0.50	9797158.43
		1734	9797156.06		9797158.55
					s= ±0.104
			dg/dh = -3.07 µms^{-2}/m		s_{mean}= ±0.042

Toledo (IFE-No. 222)

Run	Date	Drops	$g_{h=0.916}$ [µms^{-2}]	s_{drop} [µms^{-2}]	g_{floor} [µms^{-2}]
1	911217	294	9797155.79	2.43	9797158.60
2	911217	276	9797155.67	1.38	9797158.48
3	911217	291	9797155.83	1.07	9797158.64
4	911217	296	9797155.72	0.86	9797158.53
5	911217	267	9797155.76	1.68	9797158.57
		1424	9797155.75		9797158.56
					s= ±0.062
			dg/dh = -3.07 µms^{-2}/m		s_{mean}= ±0.028

Paysandu (IFE-No. 232)

Run	Date	Drops	$g_{h=0.916}$ [µms^{-2}]	s_{drop} [µms^{-2}]	g_{floor} [µms^{-2}]
1	911213	110	9795232.66	0.74	9795235.44
2	911213	135	9795232.05	0.65	9795234.83
3	911213	192	9795232.34	0.77	9795235.12
4	911214	203	9795232.49	0.61	9795235.27
5	911214	189	9795232.47	0.81	9795235.25
6	911214	224	9795232.46	1.33	9795235.24
7	911214	251	9795232.54	0.75	9795235.32
8	911214	239	9795232.60	0.65	9795235.38
9	911214	236	9795232.68	1.25	9795235.46
10	911214	254	9795232.60	1.06	9795235.38
		2033	9795232.48		9795235.26
					s= ±0.185
			dg/dh = -3.04 µms^{-2}/m		s_{mean}= ±0.059

Annex 2 (cont'd)

Argentina

Buenos Aires (IFE-No. 311)

Run	Date	Drops	$g_{h=0.799}$*) [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	890404	247	9796898.85	0.79	9796900.51
2	890404	264	9796899.00	0.49	9796900.66
3	890405	266	9796898.98	0.98	9796900.64
4	890405	279	9796899.08	1.67	9796900.74
5	890405	285	9796899.05	1.01	9796900.71
6	890405	278	9796899.05	1.50	9796900.71
7	890405	258	9796899.20	3.85	9796900.86
		1877	9796899.03		9796900.69
					s= ±0.106
					s_{mean}= ±0.040

Buenos Aires (IFE-No. 313)

Run	Date	Drops	$g_{h=1.917}$ [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	911105	300	9796889.05	1.84	9796891.33
2	911105	299	9796889.13	1.26	9796891.41
3	911105	300	9796889.05	0.81	9796891.33
4	911105	300	9796888.99	1.54	9796891.27
5	911106	300	9796889.39	1.30	9796891.67
6	911106	300	9796889.07	2.10	9796891.35
7	911106	150	9796889.28	1.16	9796891.56
8	911106	299	9796889.09	1.56	9796891.37
		2148	9796889.13		9796891.41
			dg/dh = -2.48 μms^{-2}/m		s= ±0.135
					s_{mean}= ±0.048

Tandil (IFE-No. 322)

Run	Date	Drops	$g_{h=0.810}$ [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	890408	214	9799041.14	0.54	9799043.55
2	890408	274	9799041.29	0.43	9799043.70
3	890408	287	9799041.13	0.44	9799043.54
4	890408	285	9799041.09	0.42	9799043.50
5	890409	283	9799041.20	0.40	9799043.61
6	890409	284	9799041.28	0.42	9799043.69
		1627	9799041.19		9799043.60
			dg/dh = -2.98 μms^{-2}/m		s= ±0.083
					s_{mean}= ±0.034

Annex 2 (cont'd)

San Lorenzo (IFE-No. 332)

Run	Date	Drops	$g_{h=0.801}$ [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	890414	282	9784092.18	0.33	9784094.20
2	890414	290	9784091.99	0.34	9784094.00
3	890414	285	9784092.05	0.51	9784094.06
4	890414	256	9784092.08	0.48	9784094.09
5	890414	271	9784092.14	0.33	9784094.15
6	890414	265	9784092.10	0.49	9784094.11
		1649	9784092.09		9784094.10
			dg/dh = -2.51 $\mu ms^{-2}/m$		s= ±0.070
					s_{mean}= ±0.028

San Juan (IFE-No. 342)

Run	Date	Drops	$g_{h=0.910}$ [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	911109	299	9791414.74	0.41	9791416.49
2	911109	298	9791414.75	0.21	9791416.50
3	911110	300	9791414.77	0.10	9791416.52
4	911110	298	9791414.75	0.16	9791416.49
5	911110	298	9791414.76	0.28	9791416.50
6	911110	300	9791414.71	0.14	9791416.46
		1793	9791414.75		9791416.49
			dg/dh = -1.92 $\mu ms^{-2}/m$		s= ±0.020
					s_{mean}= ±0.008

Comodoro Rivadavia (IFE-No. 352)

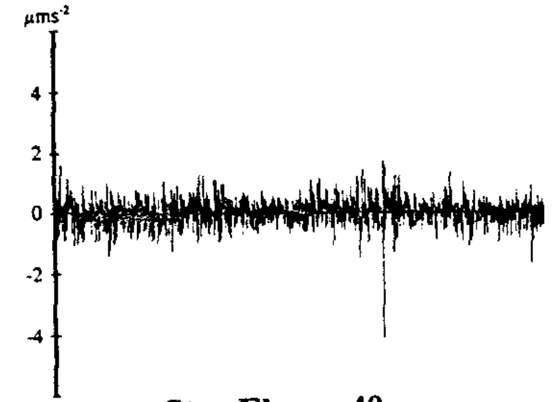
Run	Date	Drops	$g_{h=0.915}$ [μms^{-2}]	s_{drop} [μms^{-2}]	g_{floor} [μms^{-2}]
1	911115	287	9806635.30	0.97	9806637.65
2	911115	286	9806635.23	0.57	9806637.57
3	911115	298	9806635.14	0.95	9806637.48
4	911115	299	9806635.25	0.80	9806637.59
		870	9806635.23		9806637.57
			dg/dh = -2.56 $\mu ms^{-2}/m$		s= ±0.070
					s_{mean}= ±0.035

*) measured at eccenter station

**) double weight for calculation of mean result

Annex 3

Time sequences and histograms of absolute gravity observations (examples)

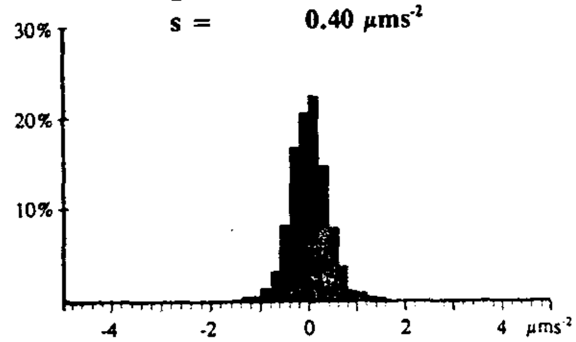


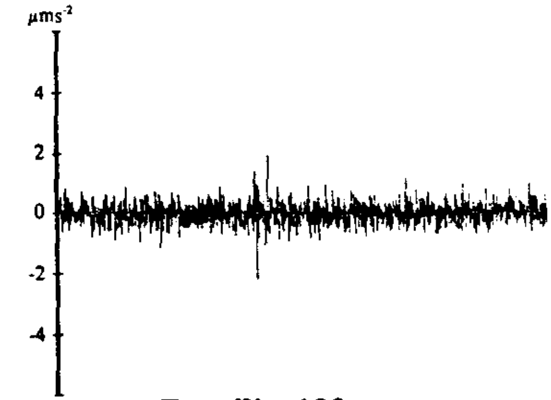
Sta. Elena 40

No. of drops: 1721

g = 9778220.84 μms^{-2}

s = 0.40 μms^{-2}



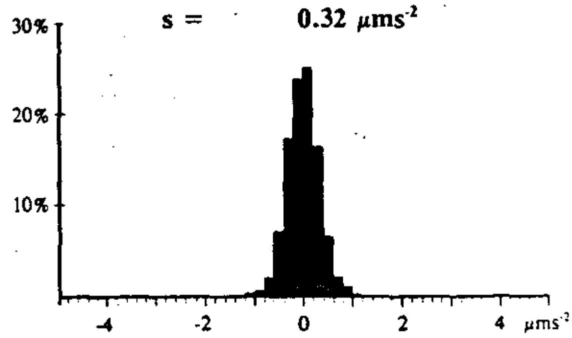


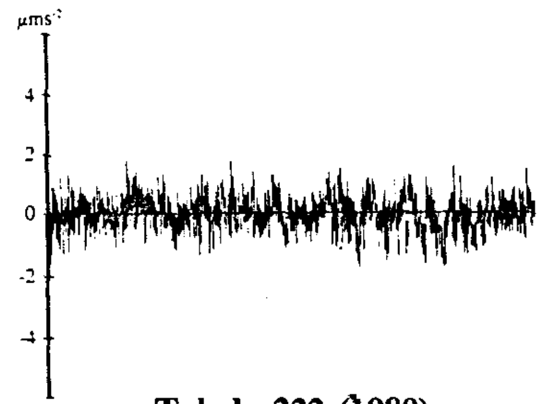
Brasilia 122

No. of drops: 1441

g = 9780487.98 μms^{-2}

s = 0.32 μms^{-2}



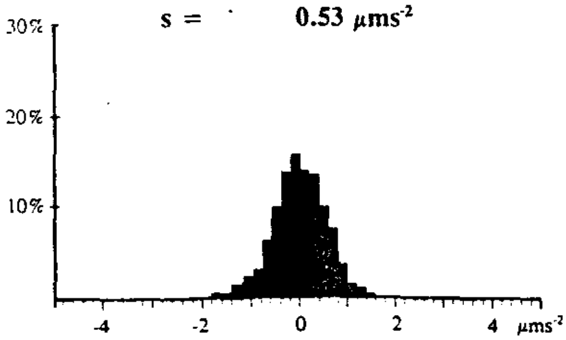


Toledo 222 (1989)

No. of drops: 1734

g = 9797158.55 μms^{-2}

s = 0.53 μms^{-2}

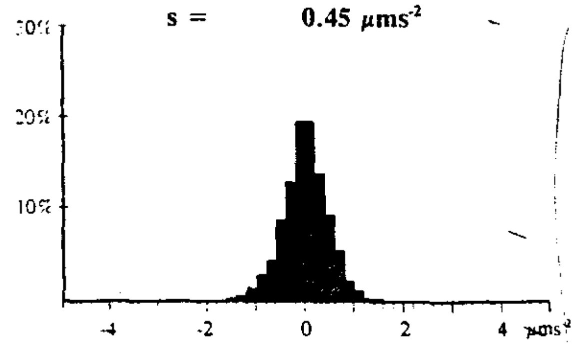


Tandil 322

No. of drops: 1627

g = 9799043.60 μms^{-2}

s = 0.45 μms^{-2}



Annex 4
Station descriptions of the absolute gravity stations

Absolute Gravity Station

Station Location: Caracas | Country: Venezuela

φ= 10.51°N | λ= 293.07°E | H= 1000 m | g= 9. 780 247 ms^{-2}

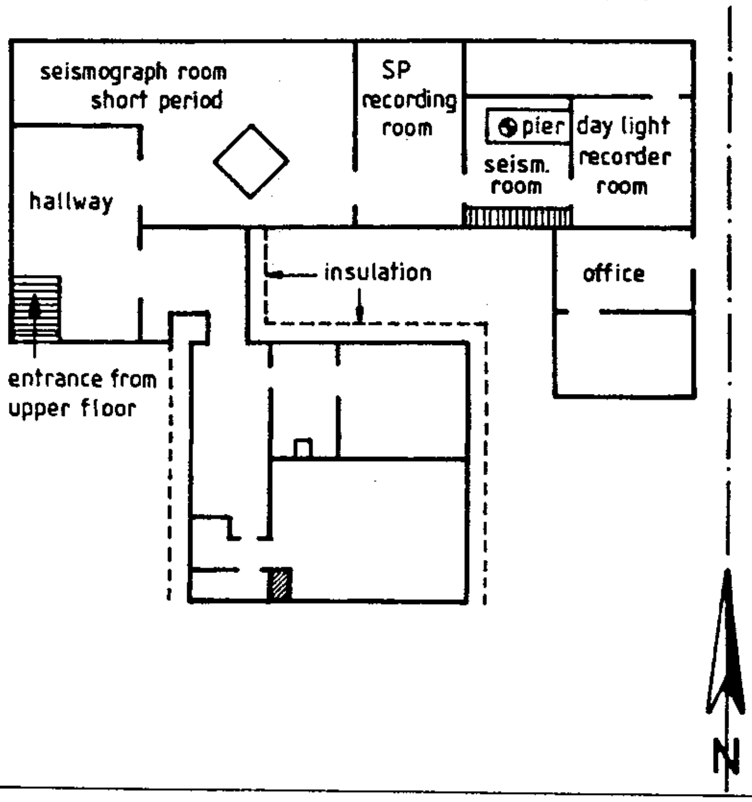
Overview / Access / Outside View / Topo Map

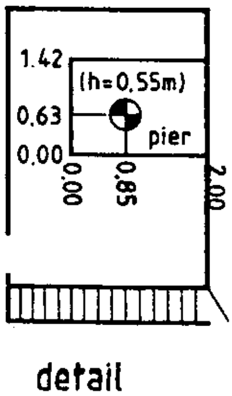
Remarks / Station Identity / Contact

The station is located in a building of the Observatorio Astronomico, Seismologico, y Geomagnetico Cajigal in Caracas. For additional station informations contact one of the following organizations:

Escuela de Ingenieria Geodesia, La Universidad del Zulia, Maracaibo;
Dirección de Cartografía Nacional, Caracas;
Dirección de Geología, Ministerio de Energía y Minas, Caracas.

Detailed Sketch (North? Station Marker?) / Photograph





Date / Author | December 1993, L. Timmen

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

Annex 4 (cont'd)

Absolute Gravity Station

Station Location: Maracaibo		Country: Venezuela	
$\varphi =$ 10.67°N	$\lambda =$ 288.37°E	H= 20 m	g= 9. 781 856 ms^{-2}

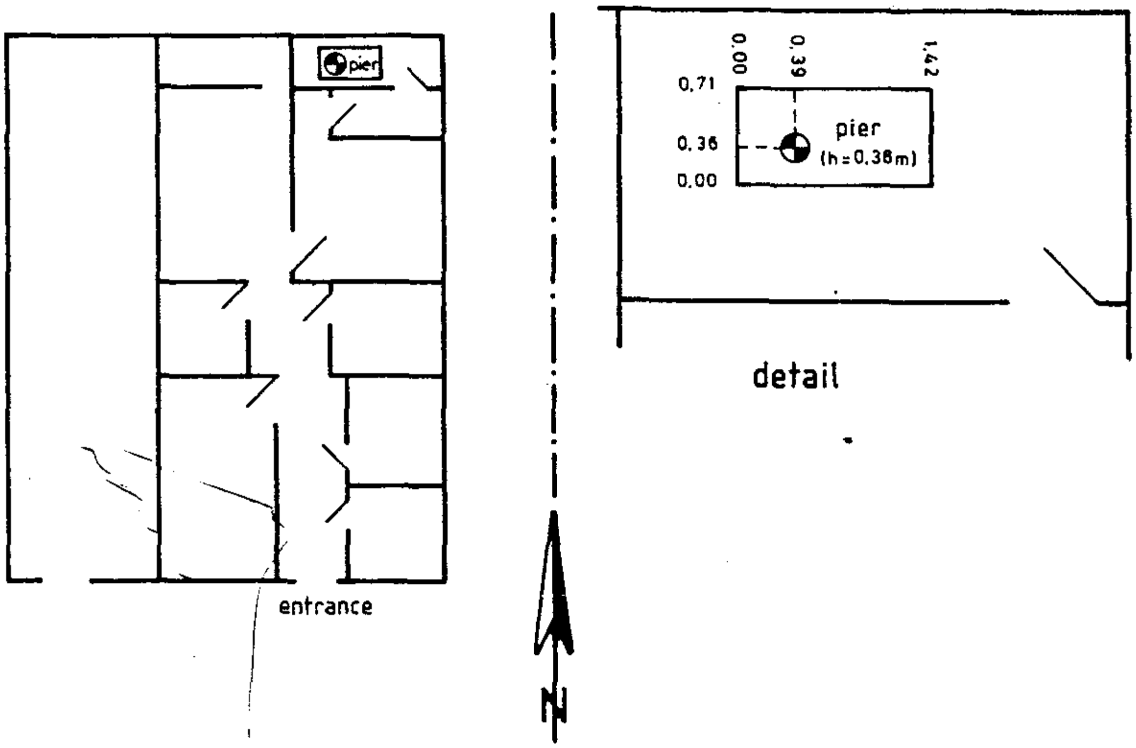
Overview / Access / Outside View / Topo Map

Remarks / Station Identity / Contact

The station is located in a building of the Escuela de Ingenieria Geodesia. For additional station informations contact one of the following organizations:

Escuela de Ingenieriy Geodesia, La Universidad del Zulia, Maracaibo;
Dirección de Cartografía Nacional, Caracas;
Dirección de Geología, Ministerio de Energía y Minas, Caracas.

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author December 1993, L. Timmen

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

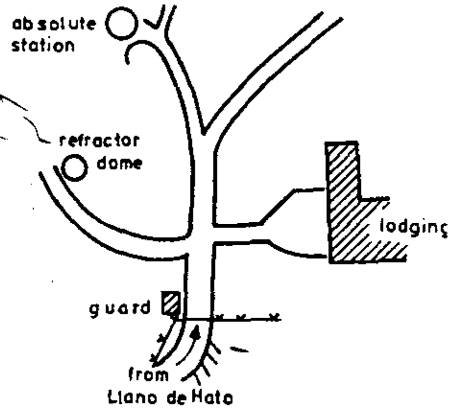
Annex 4 (cont'd)

Absolute Gravity Station

Station Location: Mérida CIDA — Country: Venezuela

φ= 8.78°N — λ= 289.13°E — H= 3600 m — g= 9. 773 522 ms^{-2}

Overview / Access / Outside View / Topo Map

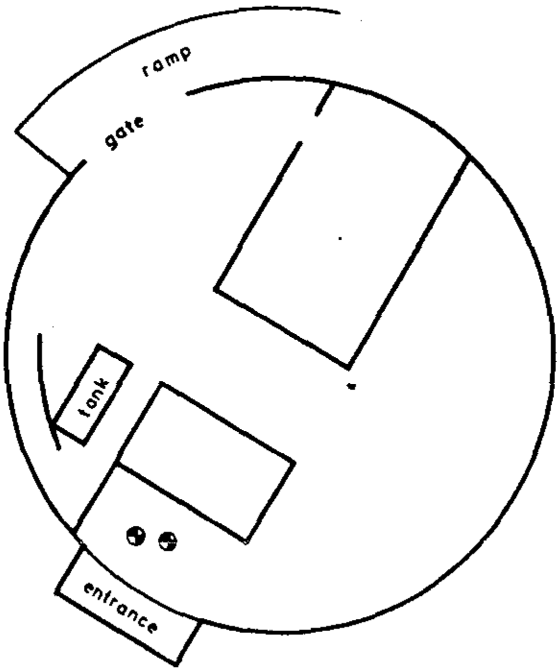


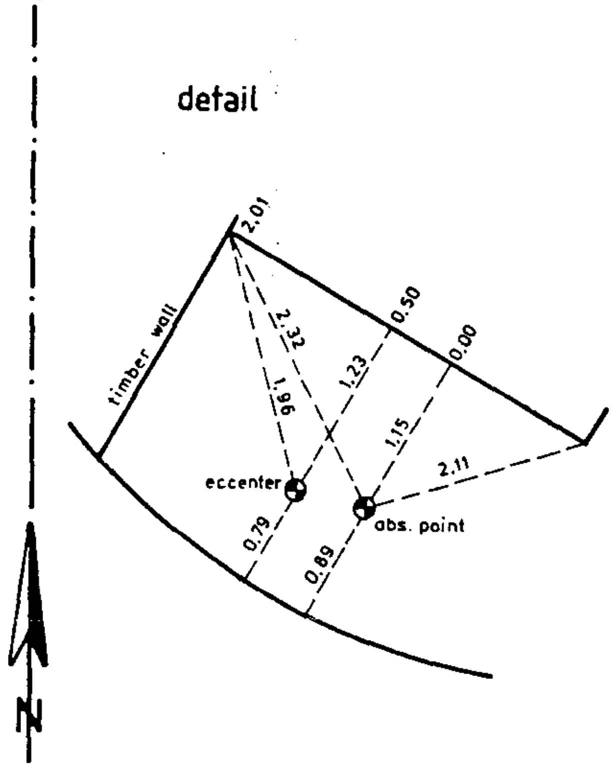
Remarks / Station Identity / Contact

The station is located in a dom of the Observatorio CIDA which is in the vicinity of Apartaderos, about 60 km north west from Mérida. For additional station informations contact one of the following organizations:

Escuela de Ingenieria Geodesia, La Universidad del Zulia, Maracaibo;
Dirección de Cartografía Nacional, Caracas;
Dirección de Geología, Ministerio de Energía y Minas, Caracas.

Detailed Sketch (North? Station Marker?) / Photograph





Date / Author — December 1993, L. Timmen

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

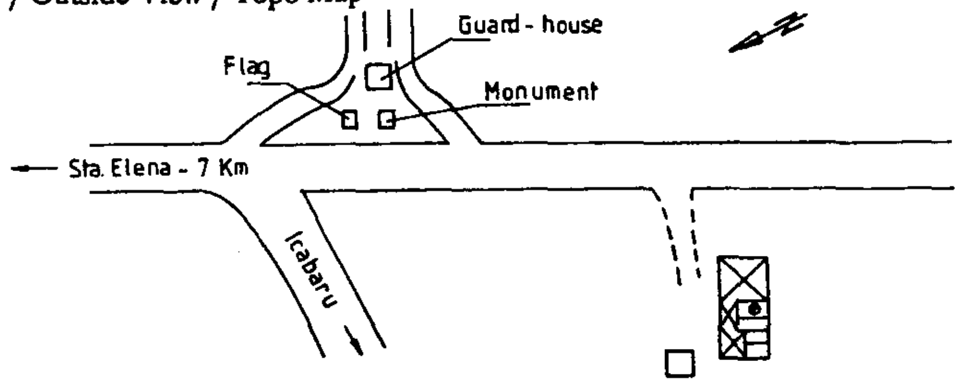
Annex 4 (cont'd)

International Absolute Gravity Basestation Network (IAGBN)

Station Location: Sta. Elena Uairen **Country:** Venezuela

φ = 4.67°N **λ =** 61.07°W **H =** 870 m **g =** 977 822 085 µgal

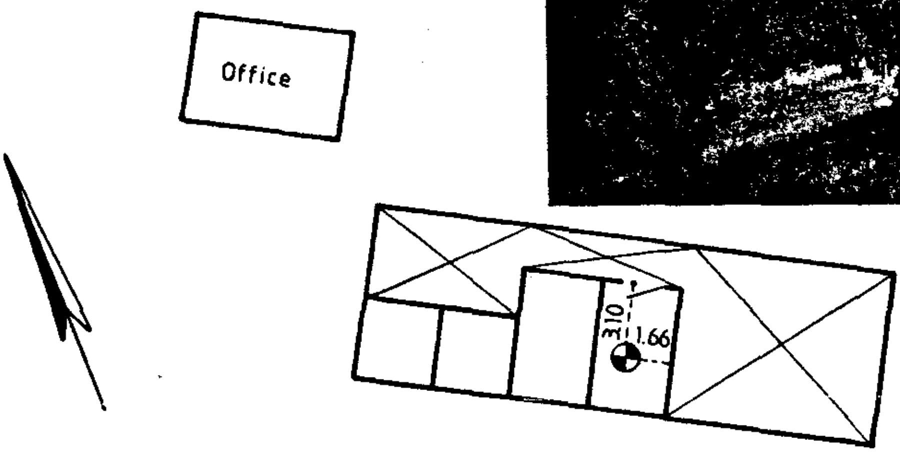
Overview / Access / Outside View / Topo Map



Remarks / Station Identity / Contact

Mearuments performed in a building of Ministerio del Ambiente y de los Recources Naturales Renovables (M.A.R.N.R.) near Sta. Elena Uairen on a pillar (same level as floor). Contact: Direccion de Cartografia Nacional
Edificio Camejo / Esq. Camejo
Centro Simon Bolivar
Caracas

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author July 1989 Rüdiger Röder

Annex 4 (cont'd)

Absolute Gravity Station

Station Location: Cd. Bolivar		Country: Venezuela	
φ= 8.08°N	λ= 296.50°E	H= 46 m	g= 9. 781 153 ms^{-2}

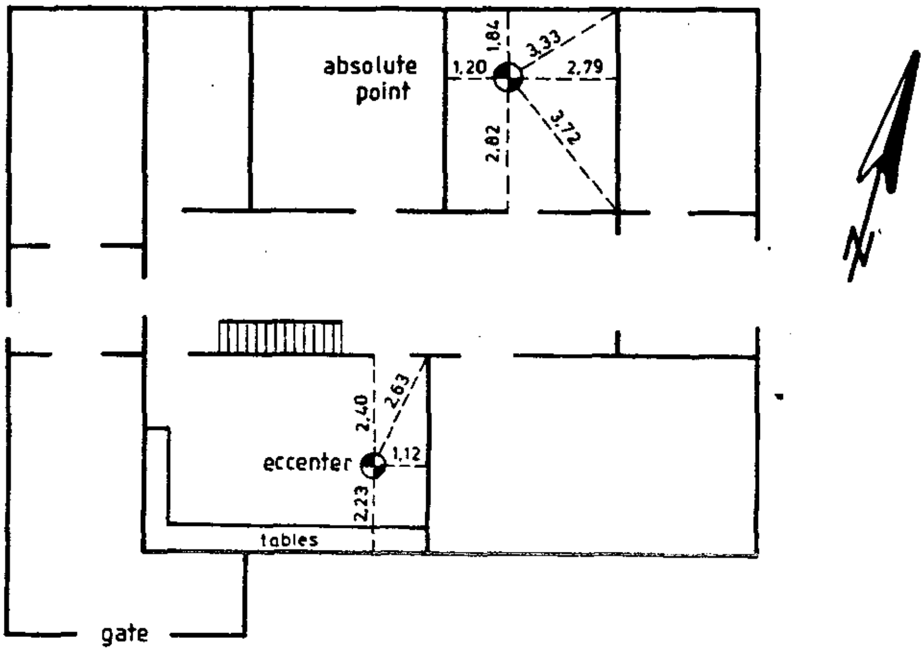
Overview / Access / Outside View / Topo Map

Remarks / Station Identity / Contact

The station is located in a building of the Ministerio de Energía y Minas (MEM). For additional station informations contact one of the following organizations:

Escuela de Ingenieriy Geodesia, La Universidad del Zulia, Maracaibo;
Dirección de Cartografía Nacional, Caracas;
Dirección de Geología, Ministerio de Energía y Minas, Caracas.

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author December 1993, L. Timmen

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

Annex 4 (cont'd)

Absolute Gravity Station

Station Location: Teresina | Country: Brazil

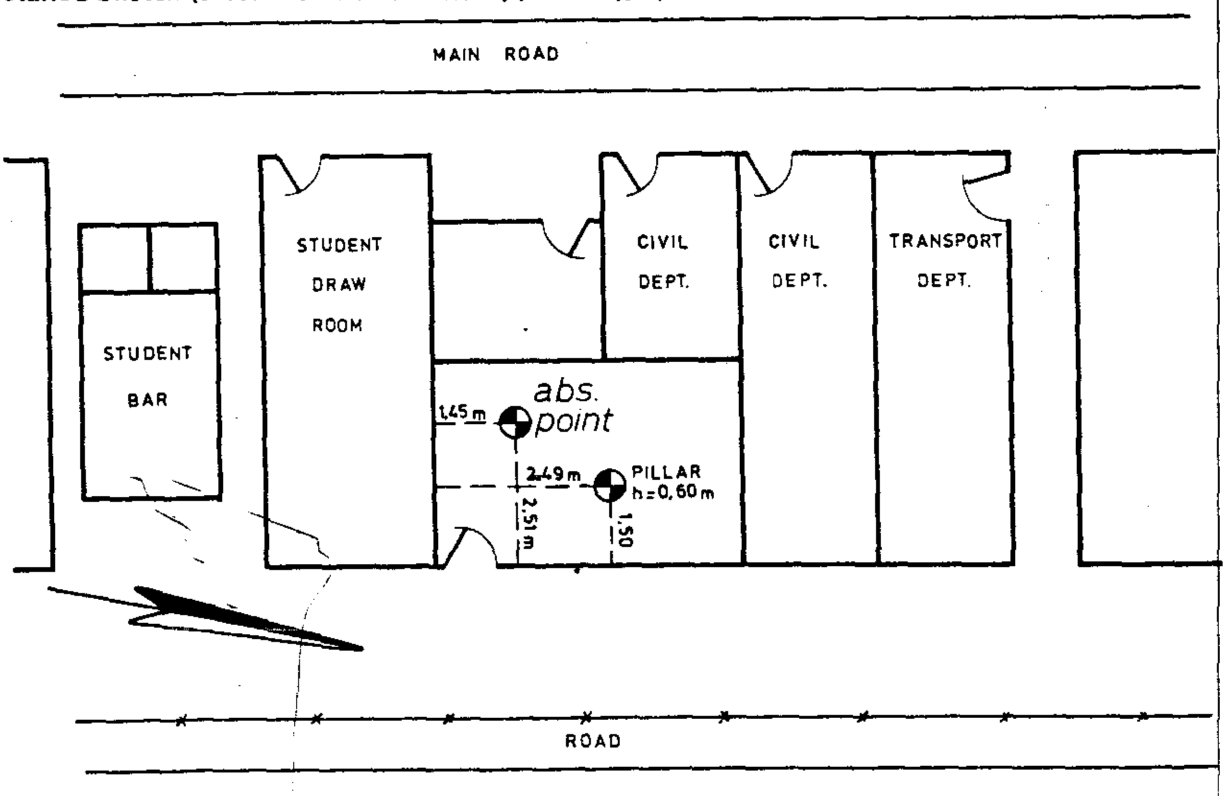
$\varphi =$ 5.06°S | $\lambda =$ 42.80°W | H = 70 m | g = 9.780 163 ms^{-2}

Overview / Access / Outside View / Topo Map

Remarks / Station Identity / Contact

The station is located in a university building in Teresina.

Detailed Sketch (North? Station Marker?) / Photograph



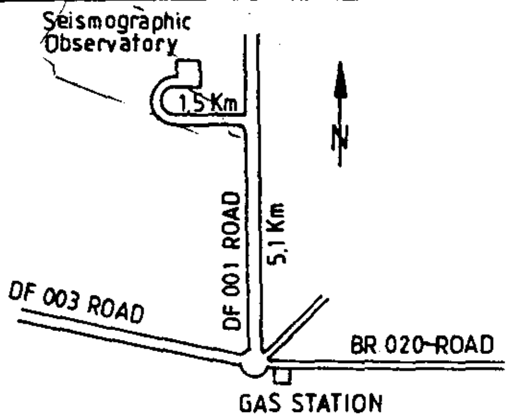
Date / Author — December 1990, R.H. Röder

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

Annex 4 (cont'd)

International Absolute Gravity Basestation Network (IAGBN)			
Station Location:	Brasilia	Country:	Brazil
$\varphi =$ 15.66°S	$\lambda =$ 312.10°E	H= 1100 m	g= 9. 780 488 ms^{-2}

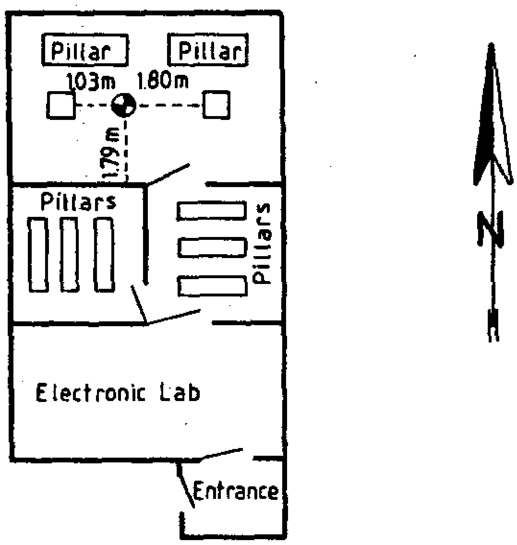
Overview / Access / Outside View / Topo Map



Remarks / Station Identity / Contact

Station is located in the observatory of Universidade Nacional de Brasilia, Departamento de Geociencias, Brasilia
The observatory is in a natural park 15 km north of the city.
Floor is concrete (35 cm thickness).

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author July 1989 Rüdiger Röder

Annex 4 (cont'd)

Absolute Gravity Station

Station Location: Pto. Ayacucho — Country: Venezuela

φ = 5.67°N — λ = 292.44°E — H = 39 m — g = 9. 780 439 ms^{-2}

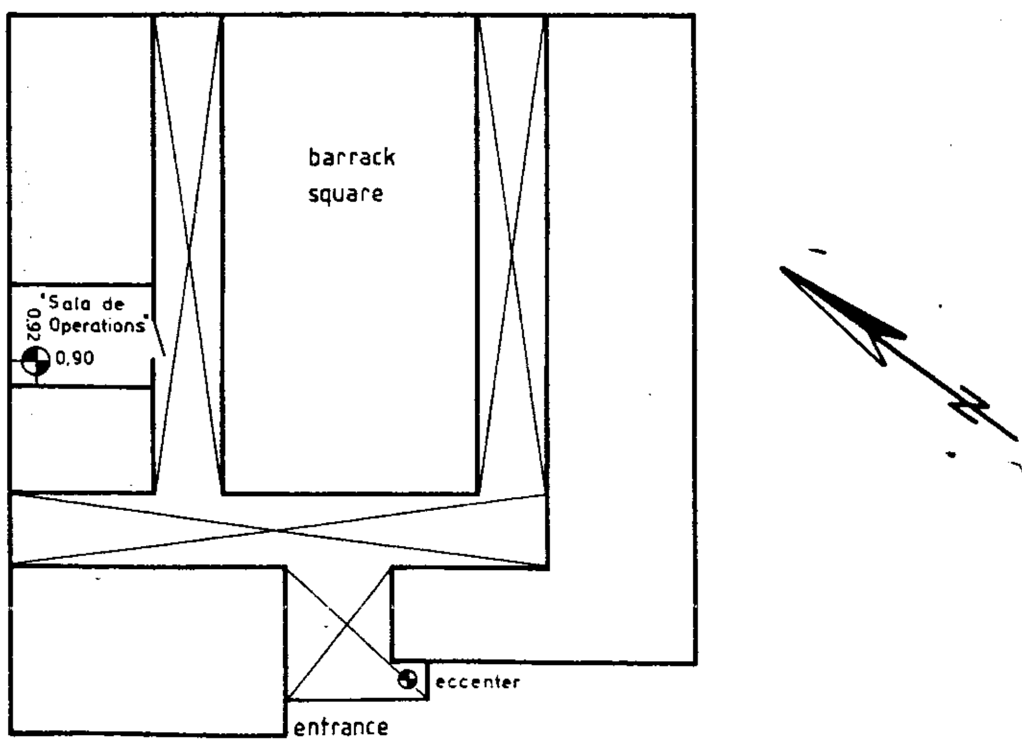
Overview / Access / Outside View / Topo Map

Remarks / Station Identity / Contact

The station is located in a building of the Guardia National. For additional station informations contact one of the following organizations:

Escuela de Ingenieriy Geodesia, La Universidad del Zulia, Maracaibo;
Dirección de Cartografía Nacional, Caracas;
Dirección de Geología, Ministerio de Energía y Minas, Caracas.

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author — December 1993, L. Timmen

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

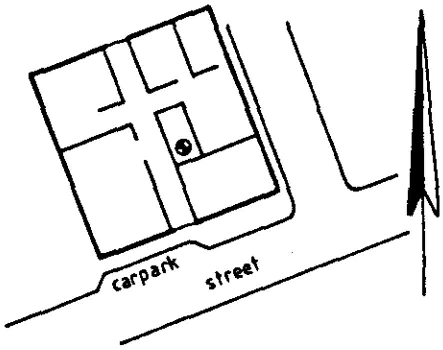
Annex 4 (cont'd)

Absolute Gravity Station

Station Location: Viçosa | Country: Brazil

φ= 20.76°S | λ= 317.17°E | H= 653 m | g= 9. 784 602 ms^{-2}

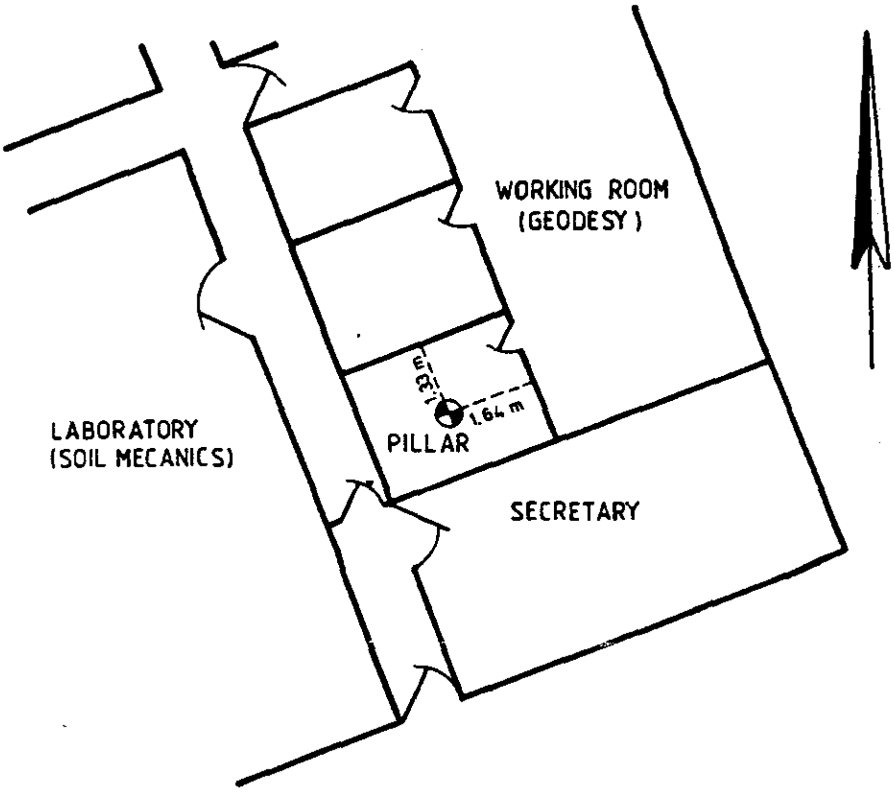
Overview / Access / Outside View / Topo Map



Remarks / Station Identity / Contact

The station is located in a laboratory of the Federal University of Viçosa

Detailed Sketch



Date / Author December 1993, L. Timmen

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

Annex 4 (cont'd)

Absolute Gravity Station

Station Location: Vassouras/Rio de Janeiro   Country: Brazil

φ = 22.40°S λ = 316.35°E   H = 400 m   g = 9. 786 376 ms^{-2}

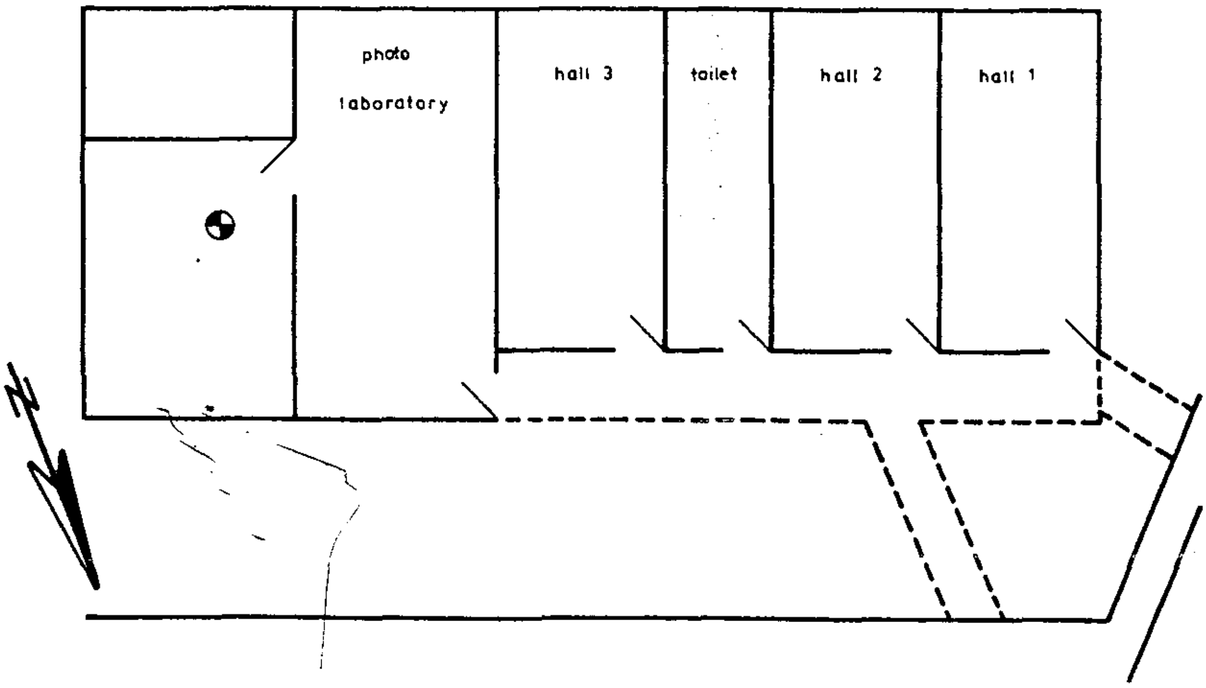
Overview / Access / Outside View / Topo Map

Remarks / Station Identity / Contact

The station is located in the Observatório Magnético de Vassouras of the Universidade Federál do Paraná (UFPR). For additional station informations contact the following organization:

Curso de Pós-Graduação em Ciências Geodésicas, Universidade Federál do Paraná.

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author   December 1993, L. Timmen

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

Annex 4 (cont'd)

Absolute Gravity Station

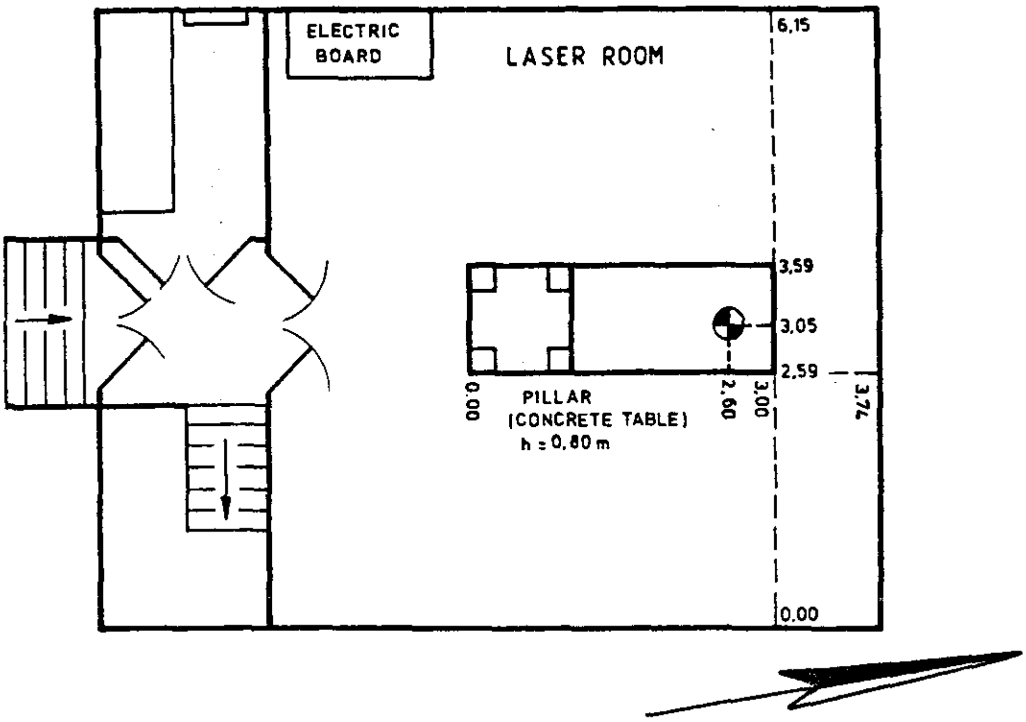
Station Location: Vinhedo/São Paulo		Country: Brazil	
$\varphi =$ 23.00°S	$\lambda =$ 46.97°W	H = 850 m	g = 9.785 638 ms^{-2}

Overview / Access / Outside View / Topo Map

Remarks / Station Identity / Contact

The station is located in the "Abraão de Morais" Observatory, Astronomical and Geophysical Institute, São Paulo University, Vahlinos.

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author December 1990, R.H. Röder

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

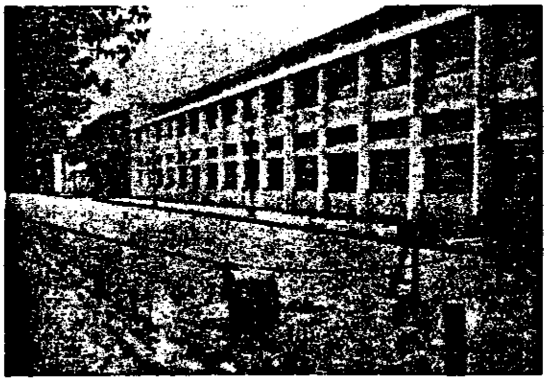
Annex 4 (cont'd)

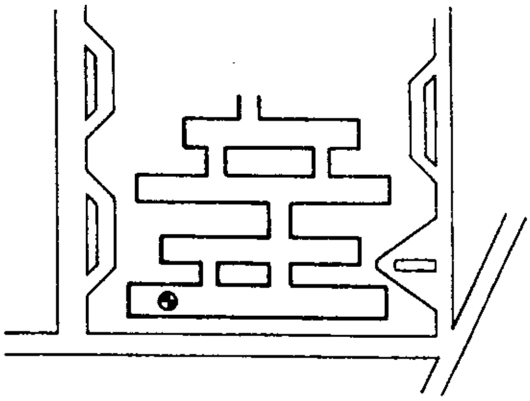
Absolute Gravity Station

Station Location: Curitiba — Country: Brazil

$\varphi =$ 25.45°S — $\lambda =$ 49.24°W — H = 910 m — g = 9.787 604 ms^{-2}

Overview / Access / Outside View / Topo Map

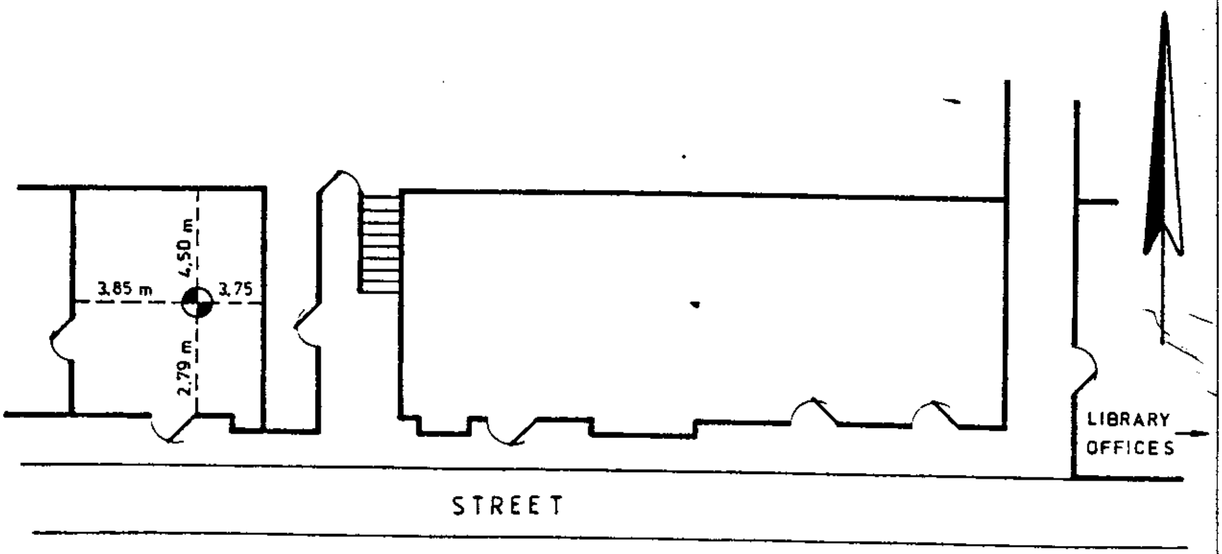




Remarks / Station Identity / Contact

The station is located in the Interferometry Laboratory of the Federal University of Paraná and belongs to the Polytechnic Center, Technology Sector, Geosciences Department.

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author — December 1990, R.H. Röder

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

Annex 4 (cont'd)

Absolute Gravity Station

Station Location: Santa Maria | Country: Brazil

φ = 29.72°S | λ = 53.72°W | H = 85 m | g = 9.792 616 ms^{-2}

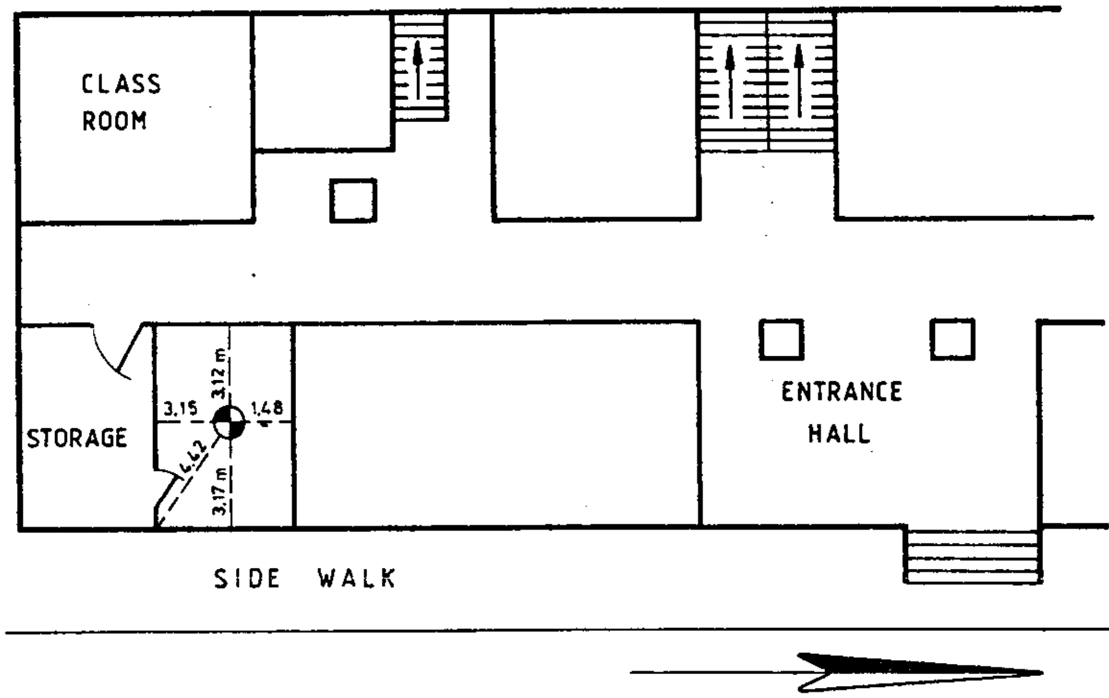
Overview / Access / Outside View / Topo Map

Remarks / Station Identity / Contact

The station is located at the campus of the Federal University of Santa Maria and belongs to the Rural Sciences Center, Department of Rural Engineering, Sector of Topography.

Contact: Distrito de Camobi, 97100 Santa Maria
Estado do Rio Grande do Sul, Brasil

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author December 1990, R.H. Röder

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

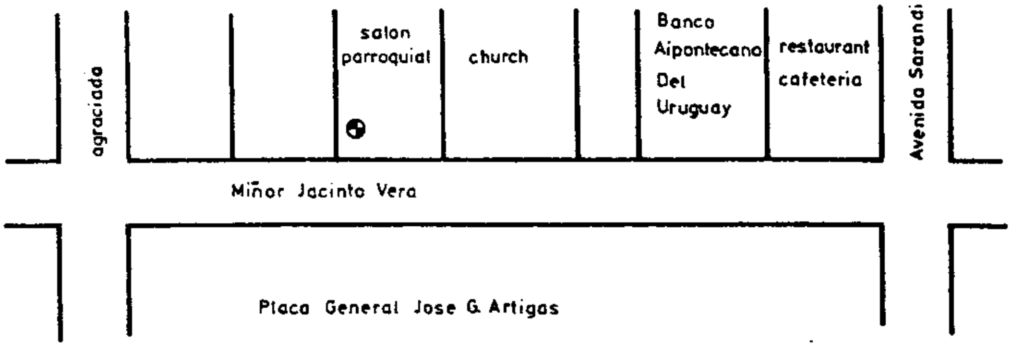
Annex 4 (cont'd)

Absolute Gravity Station

Station Location: Rivera	Country: Uruguay

φ= 30.90°S	λ= 304.46°E	H= 213 m	g= 9. 793 444 ms^{-2}

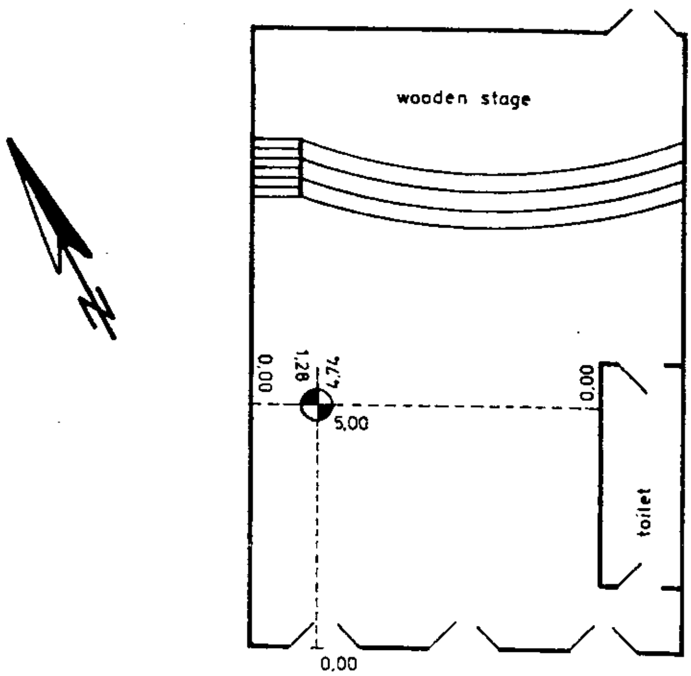
Overview / Access / Outside View / Topo Map



Remarks / Station Identity / Contact

For station informations contact the following organization:
Servicio Geografico Militar, Montevideo.

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author	December 1993, L. Timmen

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

Annex 4 (cont'd)

Absolute Gravity Station

Station Location: Toledo | Country: Uruguay

φ = 34.74°S | λ = 303.91°E | H = 65 m | g = 9. 797 159 ms^{-2}

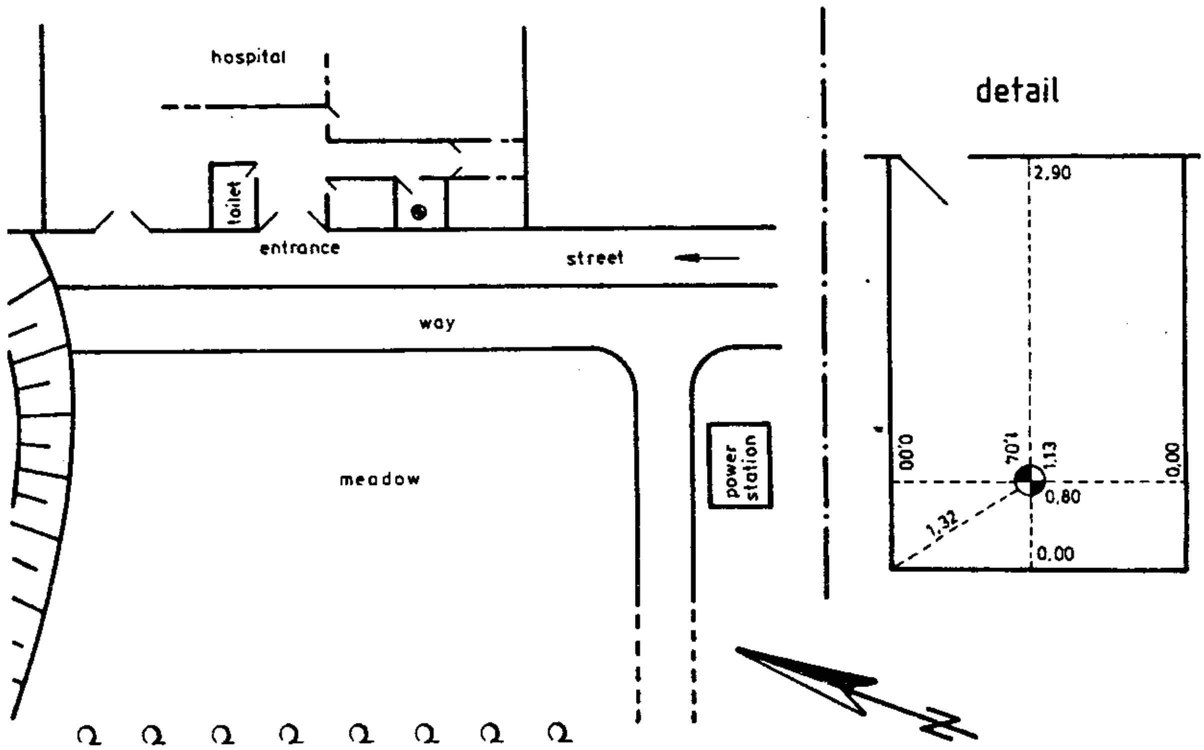
Overview / Access / Outside View / Topo Map

Remarks / Station Identity / Contact

The station is located in a building of the Escuela Militar de Toledo. For additional station informations contact of the following organization:

Servicio Geografico Militar, Montevideo.

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author | December 1993, L. Timmen

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

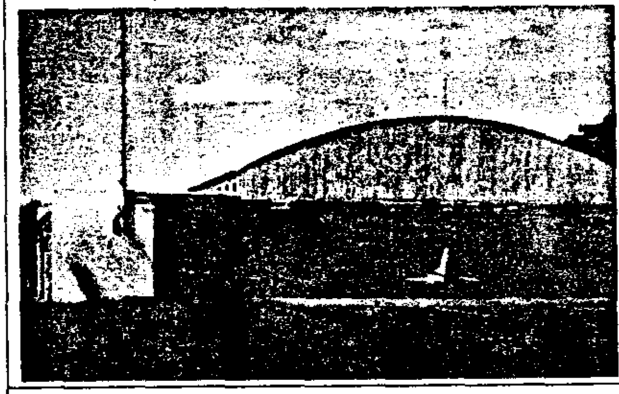
Annex 4 (cont'd)

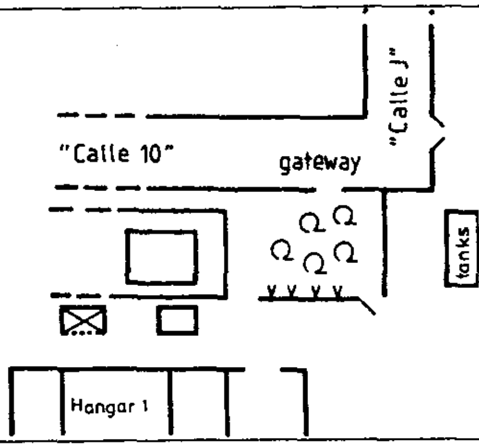
Absolute Gravity Station

Station Location: Paysandu   Country: Uruguay

φ = 32.38°S λ = 301.97°E   H = 61 m   g = 9. 795 235 ms^{-2}

Overview / Access / Outside View / Topo Map



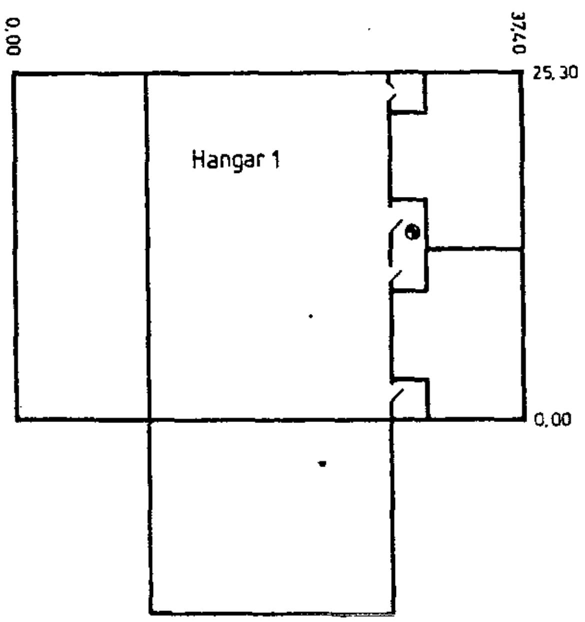


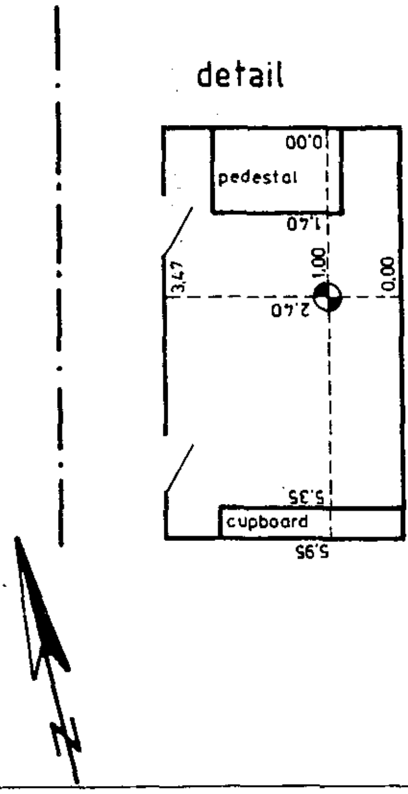
Remarks / Station Identity / Contact

The station is located on the airport of Paysandy. For additional informations contact of the following organization:

Servicio Geografico Militar, Montevideo.

Detailed Sketch (North? Station Marker?) / Photograph





Date / Author   December 1993, L. Timmen

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

Annex 4 (cont'd)

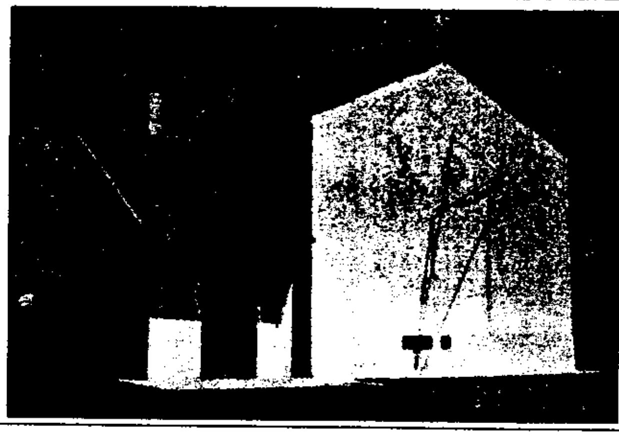
Absolute Gravity Station

Station Location: Buenos Aires — Country: Argentina

φ = 34.57°S — λ = 301.48°E — H = 8 m — g = 9. 796 901 ms^{-2}

Overview / Access / Outside View / Topo Map

entrance to the station established in 1991:
ϕ=34.57°S, λ=301.48°E, H=13 m,
g=9. 796 891 ms^{-2}

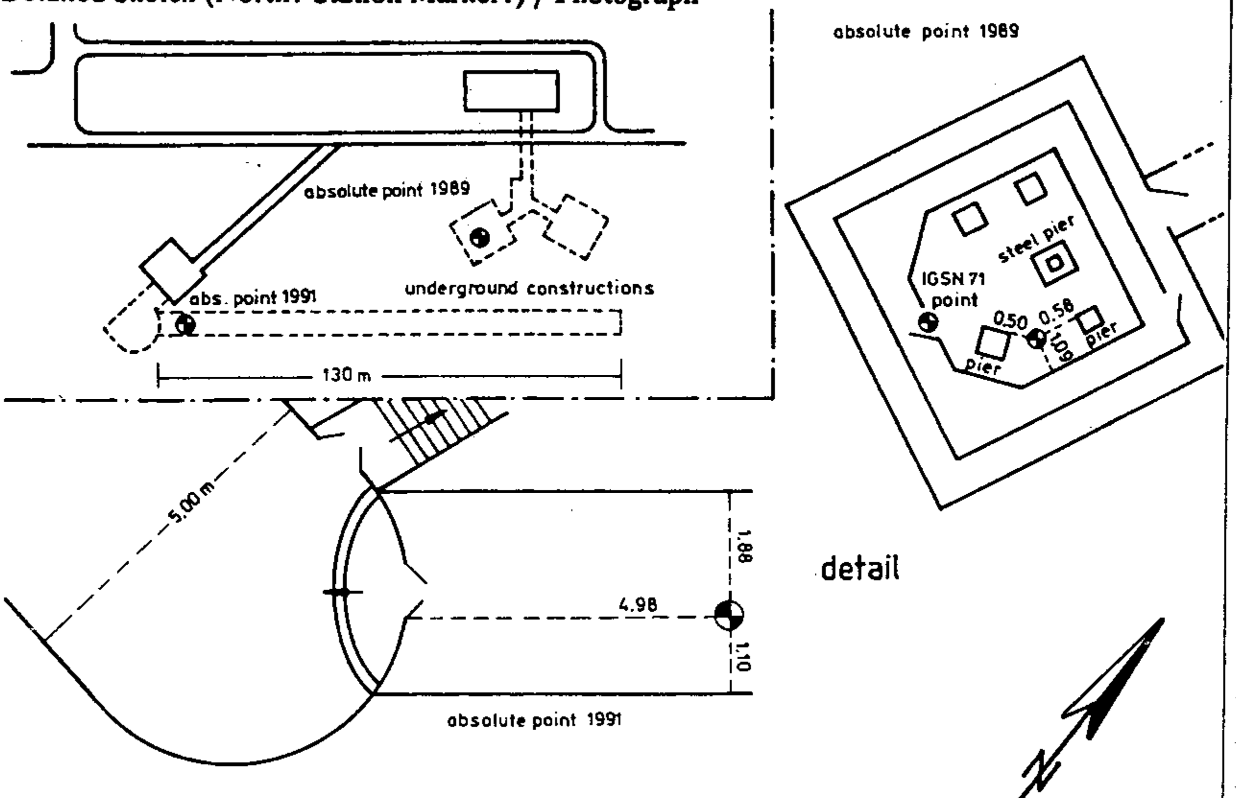


Remarks / Station Identity / Contact

The two absolute gravity points are located in buildings of the *Instituo Geografico Militar* in Migueletes, Buenos Aires. The absolute point 1989 is situated in the "Sotano de Gravedad", more than 8 m below surface level. Due to severe ground water problems a new absolute point was established in 1991. The distance between the stations is about 200 m.

Contact: Carlos Augustos Kurtz, Servicio International de la Hora, Calle 38 (Gral. Savio) No. 865, C.P.1650 Villa Meipú, San Martin. Pcia. de Buenos Aires.

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author — December 1993, L. Timmen

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

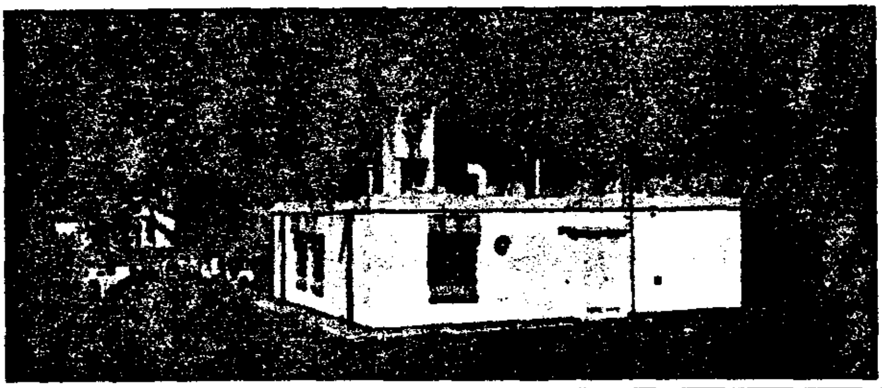
Annex 4 (cont'd)

Absolute Gravity Station

Station Location: San Lorenzo | Country: Argentina

φ = 24.73°S | λ = 294.51°E | H = 1500 m | g = 9. 784 094 ms^{-2}

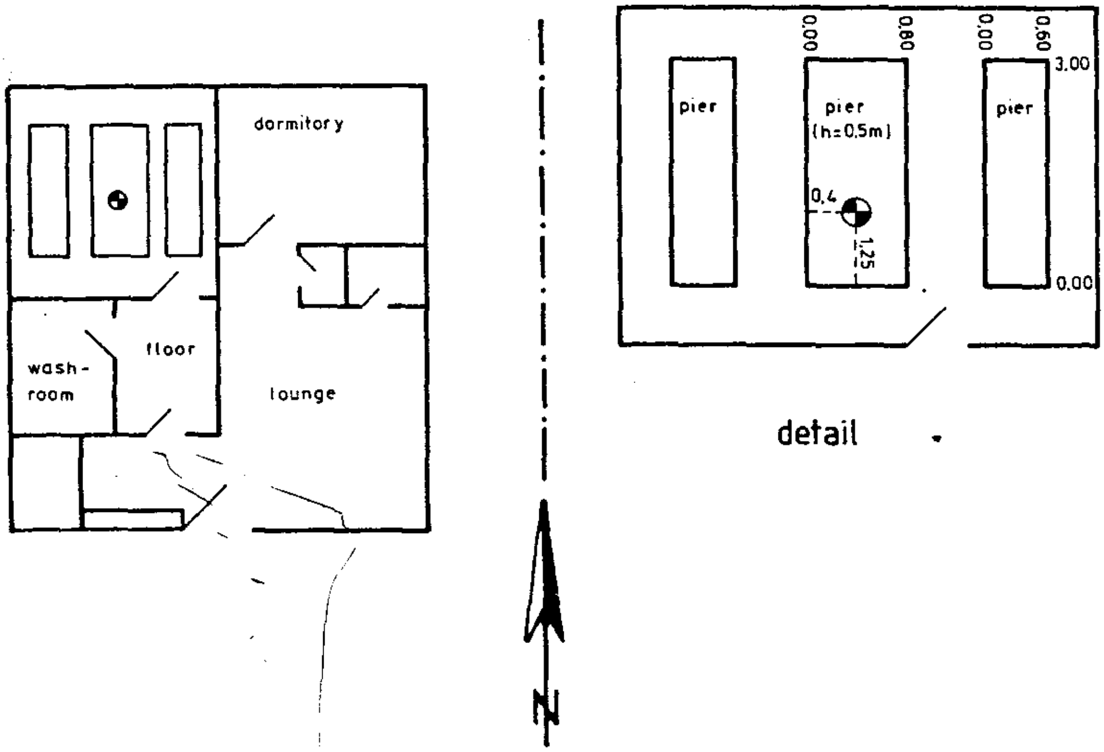
Overview / Access / Outside View / Topo Map



Remarks / Station Identity / Contact

The station is located in the *Instituo Nacional de Prevencion Sismica, San Lorenzo, Estation SLA (Salta).*

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author | December 1993, L. Timmen

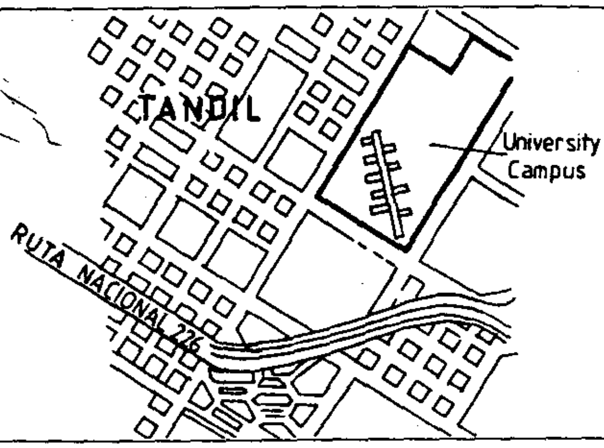
Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

Annex 4 (cont'd)

International Absolute Gravity Basestation Network (IAGBN)

Station Location:	Tandil	Country:	Argentina
$\varphi =$ 37.40°S	$\lambda =$ 59.23°W	H = 180 m	g = 979 904 345 ugal

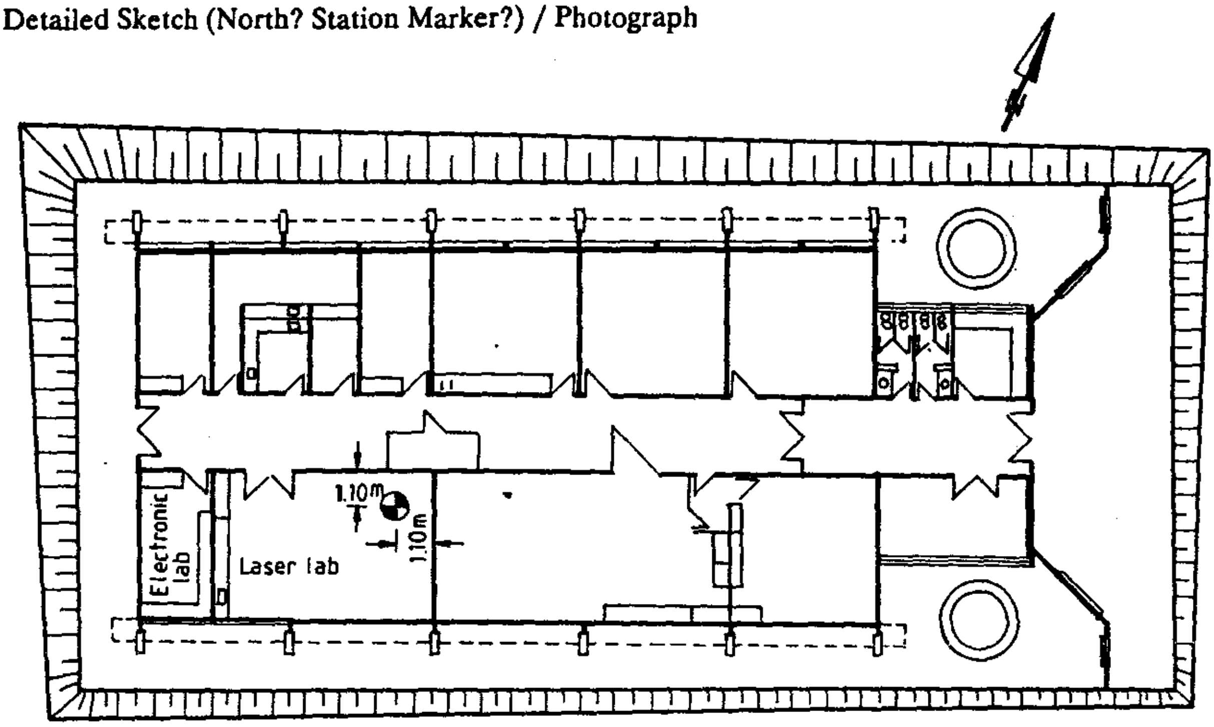
Overview / Access / Outside View / Topo Map



Remarks / Station Identity / Contact

Station is in the laser laboratory of Universidad Nacional del Centro de la Provincia de Buenos Aires, Fisica Experimental, Tandil (building No. 13)

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author July 1989 Rüdiger Röder

Annex 4 (cont'd)

Absolute Gravity Station

Station Location:	**Zonda / San Juan**	Country:	**Argentine**
φ = **31.546°S**	λ = **68.679°W**	H = **730 m**	g = **9 791 416.5 μms^{-2}**

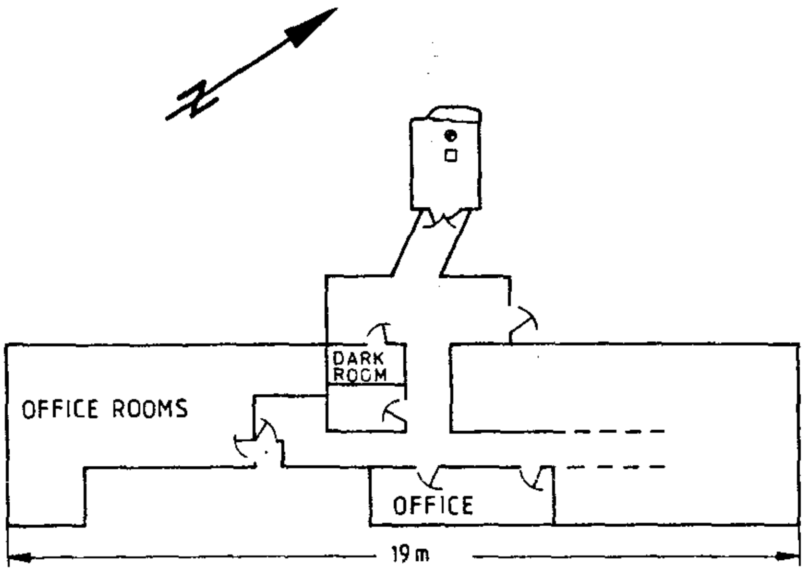
Overview / Access / Outside View / Topo Map

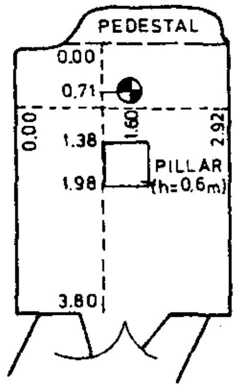
Remarks / Station Identity / Contact

The station is located in the west of San Juan, in the *Instituto Sismologico "Zonda", Universidad National De San Juan*. The room is built in a hill (limestone). The absolute point is established closed to the pillar which serves for relative gravity measurements and earth tide registrations.

Contact: Ingeniero D. Fernando Volponi, Calle La Pampa 2269/71, Oeste (5400) San Juan, phone: 064/230626

Detailed Sketch (North? Station Marker?) / Photograph





Date / Author **March 1992, L. Timmen**

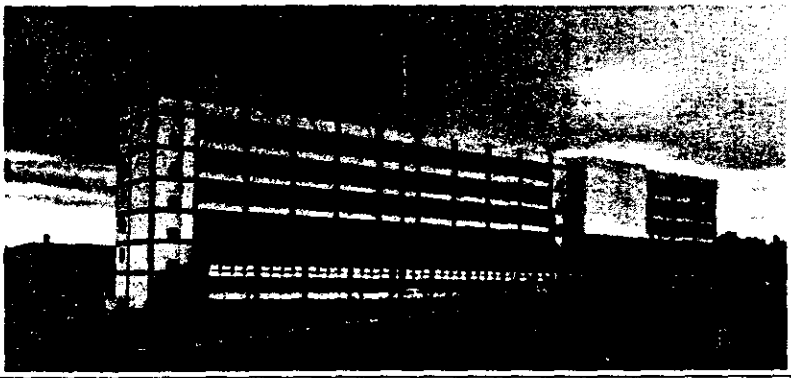
Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

Annex 4 (cont'd)

Absolute Gravity Station

Station Location: Comodoro Rivadavia		Country: Argentina	
φ = 45.82°S	λ = 292.54°E	H = 10 m	g = 9. 806 638 ms^{-2}

Overview / Access / Outside View / Topo Map

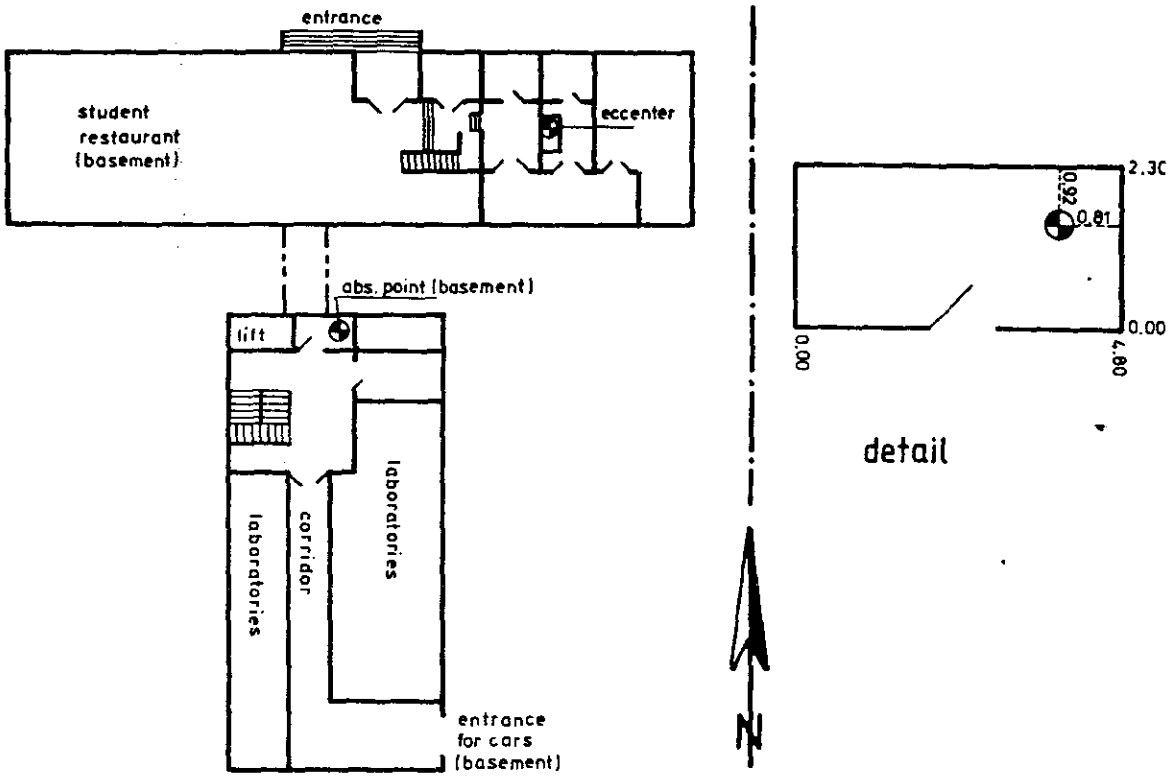


Remarks / Station Identity / Contact

The station is located in the south wing of the *University Nacional de la Patagonia "San Juan Bosco"*. The room belongs to the *Facultad de Ciencias Naturales*. The distance to the coast-line is about 300 m.

Contact: Geol. Mario Grizinik, Dpto. Geologia, Univ. Nac. Patagonia,
9000-Comodoro Rivadavia, Argentina.

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author: December 1993, L. Timmen

Institut für Erdmessung, Universität Hannover, Nienburger Str. 6, D-30167 Hannover, Germany

Annex 5

Station descriptions of eccenter gravity stations

IFE-No.	Location	φ [deg]	λ [deg]	H [m]	g [μms⁻²]	Description
Venezuela						
11	Caracas	10.51	293.08	914	9780510.37	Sta. Iners, RGNV82
12	Caracas	10.60	293.02	46	9782309.03	Maiquetia airport, inside the old terminal, RGN-V82
13	Caracas	10.50	293.07	1000	9780612.91	La Carlota airport, hangar, RGNV82
21	Maracaibo	10.57	288.30	8	9781602.02	La Chinita airport, airstrip, RGNV82
31	Mérida	8.78	289.13	3600	9773513.47	Observ. CIDA, on pillar of 2nd dome, former earth tide station
41	Sta. Elena	4.67	298.92	93	9778218.66	levelling station at road near stat. 40, above water pipe, close to military guard-house
51	Cd. Bolivar	8.12	296.46	40	9781367.45	airport, right corner of the entrance, RGNV82
61	Pto. Ayacucho	5.67	292.44	39	9780458.90	airport, RGNV82
Brazil						
111	Teresina	-5.06	317.20	70	9780161.77	pillar close to abs. point
113	Teresina	-5.06	317.20	70	9780173.75	church, BFGN, (Teresina B)
123	Brasilia	-15.66	312.10	1100	9780883.54	university, BFGN, (Brasilia C)
133	Viçosa	-20.76	317.17	653	9784594.75	old train station
143	Vassouras	-22.40	316.35	400	9786378.89	bench mark at main building of magn. observ., BFGN. (Vassouras B)
145	Vassouras	-22.40	316.35	400	9786378.34	small pillar in garden of magn. obs.
153	Campinas	-22.91	312.94	700	9786023.96	church, State of São Paulo gravity net. (Campinas C)
163	Curitiba	-25.45	310.76	910	9787610.72	earth tide station
173	Sta. Maria	-29.69	306.19	150	9792381.99	church, States of Sta. Catarina and Rio Grande do Sul gravity net
Uruguay						
213	Rivera	-30.90	304.46	213	9793444.78	under benchmark at building with absolute station
217	Tucuarembo	-31.67	304.07	185	9794122.54	earth tide station
223	Montevideo	-34.83	303.98	12	9797324.14	Int. Airp. Carrasco, LAGSN77
233	Paysandu	-32.38	301.97	60	9795272.74	church
Argentina						
315	Buenos Aires	-34.57	301.48	13	9796882.39	BA Airöparque
316	Buenos Aires	-34.57	301.48	13	9797166.91	Ezeiza airport
323	Tandil	-37.40	300.77	180	9799043.68	university campus, right of the entrance of building No. 13 with absolute station
333	Salta	-24.72	294.57	1190	9785213.34	church, Iglesia San Francisco
343	San Juan	-31.55	291.32	730	9791416.34	pillar close to absolute point, former earth tide station
353	Com. Rivadavia	-45.82	292.54	10	9806633.45	university, main building, former earth tide station

RGNV82: National Gravity Basestation Network of Venezuela
BFGN: Brazilian Fundamental Gravity Network, constrained by 16 ISGN71 stations
State of São Paulo gravity net: constrained by 1 IGSN71 and 5 BFGN stations
States of Santa Catarina and Rio Grande do Sul gravity net: constrained by 2 IGSN71 stations
LAGSN77: Latin American Gravity Standardization Network 1977