ASSOCIATION INTERNATIONALE DE GEODESIE

BUREAU GRAVIMETRIQUE INTERNATIONAL

BULLETIN D'INFORMATION

N° 74

Juin 1994

18, Avenue Edouard Belin
31055 TOULOUSE CEDEX
FRANCE

INFORMATIONS FOR CONTRIBUTORS

Contributors should follow as closely as possible the rules below :

Manuscripts should be typed (double-spaced) in Prestige-Elite characters (IBM-type), on one side of plain paper 21 cm x 29,7 cm, with a 2 cm margin on the left and right hand sides as well as on the bottom, and with a 3 cm margin at the top (as indicated by the frame drawn on this page).

Title of paper. Titles should be carefully worded to include only key words.

Abstract. The abstract of a paper should be informative rather than descriptive. It is not a table of contents. The abstract should be suitable for separate publication and should include all words useful for indexing. Its length should be limited to one typescript page.

Table of contents. Long papers may include a table of contents following the abstract.

Footnotes. Because footnotes are distracting, they should be avoided as much as possible.

Mathematics. For papers with complicated notation, a list of symbols and their definitions should be provided as an appendix. All characters that are available on standard typewriters should be typed in equations as well as test. Symbols that must be handwritten should be identified by notes in the margin. Ample space (1.9 cm above and below) should be allowed around equations so that type can be marked for the printer. Where an accent or underscore has been used to designate a special type face (e.g., boldface for vectors, script for transforms, sans serif for tensors), the type should be specified by a note in a margin. Bars cannot be set over superscripts or extended over more than one character. Therefore angle brackets are preferable to accents over characters. Care should be taken to distinguish between the letter 0 and zero, the letter l and the number one, kappa and k, mu and the letter u, nu and v, eta and n, also subscripts and superscripts should be clearly noted and easily distinguished. Unusual symbols should be avoided.

Acknowledgements. Only significant contributions by professional colleagues, financial support, or institutional sponsorship should be included in acknowledgements.

References. A complete and accurate list of references is of major importance in review papers. All listed references should be cited in text. A complete reference to a periodical gives author (s), title of article, name of journal, volume number, initial and final page numbers (or statement "in press"), and year published. A reference to an article in a book, pages cited, publisher's location, and year published. When a paper presented at a meeting is referenced, the location, dates, and sponsor of the meeting should be given. References to foreign works should indicate whether the original or a translation is cited. Unpublished communications can be referred to in text but should not be listed. Page numbers should be included in reference citations following direct quotations in text. If the same information has been published in more than one place, give the most accessible reference ; e.g. a textbook is preferable to a journal, a journal is preferable to a technical report.

Tables. Tables are numbered serially with Arabic numerals, in the order of their citation in text. Each table should have a title, and each column, including the first, should have a heading. Column headings should be arranged to that their relation to the data is clear.

Footnotes for the tables should appear below the final double rule and should be indicated by a, b, c, etc. Each table should be arranged to that their relation to the data is clear.

Illustrations. Original drawings of sharply focused glossy prints should be supplied, with two clear Xerox copies of each for the reviewers. Maximum size for figure copy is (25.4 x 40.6 cm). After reduction to printed page size, the smallest lettering or symbol on a figure should not be less than 0.1 cm high ; the largest should not exceed 0.3 cm. All figures should be cited in text and numbered in the order of citation. Figure legends should be submitted together on one or more sheets, not separately with the figures.

Mailing. Typescripts should be packaged in stout padded or stiff containers ; figure copy should be protected with stiff cardboard.

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BUREAU GRAVIMETRIQUE
INTERNATIONAL

Toulouse

BULLETIN D'INFORMATION

Juin 1994

N° 74

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Bulletin d'Information n° 74

Announcement

Meeting of the INTERNATIONAL GRAVITY COMMISSION
and
the INTERNATIONAL COMMISSION FOR THE GEOID
PROGRAMS and CONVENORS
GRAZ, Austria, Sept. 11-17, 1994

Sept. 11	13.00 - 18.00	**BGI Directing Board Meeting**
Sept. 12	09.00 - 13.00	**IGC Technical Reports**
	15.00 - 18.00	**Progress in Gravity Instrumentation** Convenor : Prof. J. Faller JILA Univ. of Colorado Campus Box 440 Boulder, Co. 80309 - USA Fax : +1 3034925235
Sept. 13	09.00 - 13.00	**Intercomparison Campaigns** Convenor : Prof. I. Marson DINMA, Univ. Trieste Via Valerio 10 34127 Trieste - Italy Fax : +39 40 6763497 E-Mail : marson@univ.trieste.it
	15.00 - 18.00	**Standards, Networks, Data Bases and Software** Convenor : Dr. G. Boedecker Deutsches Geod. Forschungsinstitut Bayer Akademie der Wissenschaften DGFI, Abt. 1 - Marstallplatz 8 D-8000 München 22 - Germany Fax : +49 89 23031240
Sept. 14	09.00 - 13.00	**Space and Airborne Gravity and Gradiometry** Convenor : Prof. R. Rummel Technische Universität München Institut für Astronomische und Physikalische Geodäsie Arcistrasse 21 D-8000 München 22 - Germany Fax : +49 89 21053178
	15.00 - 18.00	**Geophysical Inversion of Gravity and Geoid** Convenor : Dr. P. Holota Res. Inst. of Geod. Topogr. and Cart. CS-250 66 Zdiby 98 Praha-Vychod - Czech Republic Fax : +42 2 686 7056
Sept. 15	09.00 - 13.00 15.00 - 18.00	**Sightseeing** **Altimetry** Convenor : Prof. F. Sanso Politecnico di Milano Ambientale e del Rilevamento Piazza L. da Vinci 32 20133 Milano - Italy Fax : +39 2 23996530
Sept. 16	09.00 - 13.00	**International Projects and Advanced Techniques** Convenor : Dr. M.G. Sideris University of Calgary Dept. of Geomatics Engineering 2500 University Drive N.W. Calgary, Alberta, Canada T2N 1N4 Fax : +1 403 2841980 E-mail : sideris@acs.ucalgary.ca
	15.00 - 18.00	**ICG Technical session**
Sept. 17	09.00 - 13.00	**The Geoid in Europe** Convenor : Dr. M. Vermeer Finnish Geodetic Institut Ilmalankatu 1A SF - 00240 Helsinki - Finland Fax : +358 0 414946 and National Survey and Cadastres Rentemstervej 8 DK-2400 Copenhagen N.V. Denmark Fax : +45 358 7500054
	15.00 - 18.00	**Poster Presentation**

FIRST CIRCULAR : CALL FOR CONTRIBUTIONS

IUGG / IAG

COMMISSION FOR GEODESY IN AFRICA

5th SYMPOSIUM ON GEODESY IN AFRICA

Harare - Zimbabwe 22-27 November 1994

With the sponsorship and support of:

Commission for Geodesy in Africa (CGA)
International Association of Geodesy (IAG)
Committee for Developing Countries of the IAG
Department of the Surveyor General, Harare
The Departments of Physics and Surveying, Universityof Zimbabwe, (UZ)

The 5th Symposium on Geodesy in Africa will be held at the University of Zimbabwe, Harare, Zimbabwe, with provisional dates of 22 - 27 November 1994.

The Symposium will consist of lectures, poster presentations and a technical/equipment exhibition. Please take this opportunity to inform other researchers who are concerned with the latest developments in the fields of **geodesy, gravity and surveying** and come to learn of the advances being made in African geodesy.

PLEASE COPY THIS CIRCULAR AND DISTRIBUTE TO YOUR COLLEAGUES

Accommodation is available at a range of excellent hotels in/near the city centre (10 km from the university) or in student rooms on campus.

Zimbabwe is a tourist paradise: please indicate below whether you (and any accompanying persons) are interested in receiving information on tours which are available. Late November is likely to be warm to hot, with the possibility of some rain.

Local Organising Committee: Dr F. Podmore (UZ) *(Chairman)*, Mr J. Davies (UZ)
Dr O. Gwavava (UZ), Mr M.T. Hawadi (Geol.Surv), Mr C. Masterton (UZ), Ms C. Webber (DSG)

CUT HERE -

5th SYMPOSIUM ON GEODESY IN AFRICA 22-27 November 1994

Name..
Organisation..................................
Address......................................
....
....
....
Fax...
Email..
No. of accompaning persons.............

☐ Please send the second circular
☐ I am interested in attending the symposium
☐ I wish to present a paper/poster *(delete one)* with the following title:.......................
....
....
☐ I wish to mount an exhibit at the symposium *(please attach a discription of your display)*
☐ Please send tourist information on 1 day/2 day/ 5 day tours. *(please indicate your interest)*

Please return this form as soon as possible to:

Dr F. Podmore, Department of Physics, University of Zimbabwe, P.O. Box MP167, HARARE, ZIMBABWE. Fax: 263-4-333407 Email: podmore@zimbix.uz.zw

PART I

INTERNAL MATTERS

GENERAL INFORMATIONS

1. HOW TO OBTAIN THE BULLETIN
2. HOW TO REQUEST DATA
3. USUAL SERVICES B.G.I. CAN PROVIDE
4. PROVIDING DATA TO B.G.I.

1. HOW TO OBTAIN THE BULLETIN

The Bulletin d'Information of the Bureau Gravimétrique International is issued twice a year, generally at the end of June and end of December.

The Bulletin contains general informations on the community, on the Bureau itself. It informs about the data available, about new data sets...

It also contains contributing papers in the field of gravimetry, which are of technical character. More scientifically oriented contributions should better be submitted to appropriate existing journals.

Communications presented at general meeting, workshops, symposia, dealing with gravimetry (e.g. IGC, S.S.G.'s,...) are published in the Bulletin when appropriate - at least by abstract.

Once every four years, a special issue contains the National Reports as presented at the International Gravity Commission meeting. Other special issues may also appear (once every two years) which contain the full catalogue of the holdings.

About three hundred individuals and institutions presently receive the Bulletin.

You may :

- either request a given bulletin, by its number (74 have been issued as June 30,1994 but numbers 2,16, 18,19 are out of print).

- or subscribe for regularly receiving the two bulletins per year plus the special issues.

Requests should be sent to:

Mrs. Nicole LESTIEU
CNES/BGI
18, Avenue Edouard Belin
31055 TOULOUSE CEDEX - FRANCE

Bulletins are sent on an exchange basis (free of charge) to individuals, institutions which currently provide informations, data to the Bureau. For other cases, the price of each issue is 70 FF.

2. HOW TO REQUEST DATA

2.1. Stations descriptions Diagrams for Reference, Base Stations (including IGSN 71's)

Request them by number, area, country, city name or any combination of these.

When we have no diagram for a given request, but have the knowledge that it exists in another center, we shall in most cases forward the request to this center or/and tell the inquiring person to contact the center.

Do not wait until the last moment (e.g. when you depart for a cruise) for asking us the information you need: station diagrams can only reach you by mail, in many cases.

2.2. G-Value at Base Stations

Treated as above.

2.3. Mean Anomalies, Mean Geoid Heights, Mean Values of Topography

The geographic area must be specified (polygon). According to the data set required, the request may be forwarded in some cases to the agency which computed the set.

2.4. Gravity Maps

Request them by number (from the catalogue), area, country, type (free-air, Bouguer...), scale, author, or any combination of these.

Whenever available in stock, copies will be sent without extra charges (with respect to usual cost - see § 3.3.2.). If not, two procedures can be used:

- we can make (poor quality) black and white (or ozalide-type) copies at low cost,

- color copies can be made (at high cost) if the user wishes so (after we obtain the authorization of the editor).

The cost will depend on the map, type of work, size, etc... In both cases, the user will also be asked to send his request to the editor of the map before we proceed to copying.

2.5. Gravity Measurements

BGI is now using the ORACLE Data Base Management System. One implication is that data are stored in only one format (though different for land and marine data), and that archive files do not exist anymore.

There are two distinct formats for land or sea gravity data, respectively EOL and EOS.

EOL
LAND DATA FORMAT
RECORD DESCRIPTION
126 characters

Col.			
	1-8	B.G.I. source number	(8 char.)
	9-16	Latitude (unit : 0.00001 degree)	(8 char.)
	17-25	Longitude (unit : 0.00001 degree)	(9 char.)
	26-27	Accuracy of position The site of the gravity measurements is defined in a circle of radius R 0 = no information 1 - R <= 5 Meters 2 = 5 < R <= 20 M (approximately 0'01) 3 = 20 < R <= 100 M 4 = 100 < R <= 200 M (approximately 0'1) 5 = 200 < R <= 500 M 6 = 500 < R <= 1000 M 7 = 1000 < R <= 2000 M (approximately 1') 8 = 2000 < R <= 5000 M 9 = 5000 M < R 10...	(2 char.)
	28-29	System of positioning 0 = no information 1 = topographical map 2 = trigonometric positioning 3 = satellite	(2 char.)
	30	Type of observation 1 = current observation of detail or other observations of a 3rd or 4th order network 2 = observation of a 2nd order national network 3 = observation of a 1st order national network 4 = observation being part of a nation calibration line 5 = coastal ordinary observation (Harbour, Bay, Sea-side...) 6 = harbour base station	(1 char.)
	31-38	Elevation of the station (unit : centimeter)	(8 char.)
	39-40	Elevation type 1 = Land 2 = Subsurface 3 = Lake surface (above sea level) 4 = Lake bottom (above sea level) 5 = Lake bottom (below sea level) 6 = Lake surface (above sea level with lake bottom below sea level) 7 = Lake surface (below sea level) 8 = Lake bottom (surface below sea level) 9 = Ice cap (bottom below sea level) 10 = Ice cap (bottom above sea level) 11 = Ice cap (no information about ice thickness)	(2 char.)
	41-42	Accuracy of elevation 0 = no information 1 = E <= 0.02 M 2 = .02 < E <= 0.1 M 3 = .1 < E <= 1 4 = 1 < E <= 2 5 = 2 < E <= 5 6 = 5 < E <= 10 7 = 10 < E <= 20 8 = 20 < E <= 50 9 = 50 < E <= 100 10 = E superior to 100 M	(2 char.)
	43-44	Determination of the elevation 0 = no information 1 = geometrical levelling (bench mark) 2 = barometrical levelling 3 = trigonometric levelling 4 = data obtained from topographical map 5 = data directly appreciated from the mean sea level 6 = data measured by the depression of the horizon 7 = satellite	(2 char.)
	45-52	Supplemental elevation (unit : centimeter)	(8 char.)
	53-61	**Observed gravity** (unit : microgal)	(9 char.)

62-67 **Free air anomaly** (0.01 mgal) (6 char.)

68-73 **Bouguer anomaly** (0.01 mgal) (6 char.)

Simple Bouguer anomaly with a mean density of 2.67. No terrain correction

74-76 Estimation standard deviation free-air anomaly (0.1 mgal) (3 char.)

77-79 Estimation standard deviation bouguer anomaly (0.1 mgal) (3 char.)

80-85 **Terrain correction** (0.01 mgal) (6 char.)

computed according to the next mentioned radius & density

86-87 Information about terrain correction (2 char.)

0 = no topographic correction
1 = tc computed for a radius of 5 km (zone H)
2 = tc computed for a radius of 30 km (zone L)
3 = tc computed for a radius of 100 km (zone N)
4 = tc computed for a radius of 167 km (zone 02)
11 = tc computed from 1 km to 167 km
12 = tc computed from 2.5 km to 167 km
13 = tc computed from 5.2 km to 167 km
14 =tc (unknown radius)
15 = tc computed to zone M (22 km)
16 = tc computed to zone G
17 = tc computed to zone K (18.8 km)
25 = tc computed to 48.6 km on a curved Earth
26 = tc computed to 64. km on a curved Earth

88-91 Density used for terrain correction (4 char.)

92-93 Accuracy of gravity (2 char.)

0 = no information
1 = E <= 0.01 mgal
2 = .01 < E <= 0.05 mgal
3 = .05 < E <= 0.1 mgal
4 = 0.1 < E <= 0.5 mgal
5 = 0.5 < E <= 1. mgal
6 = 1. < E <= 3. mgal
7 = 3. < E <= 5. mgal
8 = 5. < E <= 10 mgal
9 = 10. < E <= 15. mgal
10 = 15. < E <= 20. mgal
11 = 20. < E mgal

94-99 Correction of observed gravity (unit : microgal) (6 char.)

100-105 **Reference station** (6 char.)

This station is the base station (BGI number) to which the concerned station is referred

106-108	Apparatus used for the measurement of G	(3 char.)

0.. no information
1.. pendulum apparatus before 1960
2.. latest pendulum apparatus (after 1960)
3.. gravimeters for ground measurements in which the variations of G are equilibrated of detected using the following methods :
30 = torsion balance (Thyssen...)
31 = elastic rod
32 = bifilar system
34 = Boliden (Sweden)
4.. Metal spring gravimeters for ground measurements
41 = Frost
42 = Askania (GS-4-9-11-12), Graf
43 = Gulf, Hoyt (helical spring)
44 = North American
45 = Western
47 = Lacoste-Romberg
48 = Lacoste-Romberg, Model D (microgravimeter)
5.. Quartz spring gravimeter for ground measurements
51 = Norgaard
52 = GAE-3
53 = Worden ordinary
54 = Worden (additional thermostat
55 = Worden worldwide
56 = Cak
57 = Canadian gravity meter, sharpe
58 = GAG-2
59 = SCINTREX CG2
6.. Gravimeters for under water measurements (at the bottom of the sea or of a lake)
60 = Gulf
62 = Western
63 = North American
64 = Lacoste-Romberg

109-111 **Country code (BGI)** (3 char.)

112 **Confidentiality** (1 char.)
0 = without restriction
.....1 = with authorization
2 = classified

113 **Validity** (1 char.)
0 = no validation
1 = good
2 = doubtful
3 = lapsed

114-120 Numbering of the station (original) (7 char.)

121-126 Sequence number (6 char.)

EOS
SEA DATA FORMAT
RECORD DESCRIPTION
146 characters

Col. 1-8 **B.G.I.** source number (8 char.)

9-16 **Latitude** (unit : 0.00001 degree) (8 char.)

17-25 **Longitude** (unit : 0.00001 degree) (9 char.)

26-27 Accuracy of position (2 char.)

The site of the gravity measurements is defined in a circle of radius R

0 = no information
1 - R <= 5 Meters
2 = 5 < R <= 20 M (approximately 0'01)
3 = 20 < R <= 100 M
4 = 100 < R <= 200 M (approximately 0'1)
5 = 200 < R <= 500 M
6 = 500 < R <= 1000 M
7 = 1000 < R <= 2000 M (approximately 1')
8 = 2000 < R <= 5000 M
9 = 5000 M < R
10...

28-29 System of positioning (2 char.)

0 = no information
1 = Decca
2 = visual observation
3 = radar
4 = loran A
5 = loran C
6 = omega or VLF
7 = satellite
8 = solar/stellar (with sextant)

30 Type of observation (1 char.)

1 = individual observation at sea
2 = mean observation at sea obtained from a continuous recording

31-38 **Elevation of the station** (unit : centimeter) (8 char.)

39-40 Elevation type (2 char.)

1 = ocean surface
2 = ocean submerged
3 = ocean bottom

41-42 Accuracy of elevation (2 char.)

0 = no information
1 = E <= 0.02 Meter
2 = .02 < E <= 0.1 M
3 = .1 < E <= 1
4 = 1 < E <= 2
5 = 2 < E <= 5
6 = 5 < E <= 10
7 = 10 < E <= 20
8 = 20 < E <= 50
9 = 50 < E <= 100
10 = E superior to 100 Meters

43-44 Determination of the elevation (2 char.)

0 = no information
1 = depth obtained with a cable (meters)
2 = manometer depth
3 = corrected acoustic depth (corrected from Mathew's tables, 1939)
4 = acoustic depth without correction obtained with sound speed 1500 M/sec. (or 820 fathom/sec)
5 = acoustic depth obtained with sound speed 1463 M/sec (800 fathom/sec)
6 = depth interpolated on a magnetic record
7 = depth interpolated on a chart

45-52 Supplemental elevation (unit : centimeter) (8 char.)

53-61 **Observed gravity** (unit : microgal) (9 char.)

62-67 **Free air anomaly** (0.01 mgal) (6 char.)

68-73 **Bouguer anomaly** (0.01 mgal) (6 char.)

Simple Bouguer anomaly with a mean density of 2.67. No terrain correction

74-76 Estimation standard deviation free-air anomaly (0.1 mgal) (3 char.)

77-79	Estimation standard deviation bouguer anomaly (0.1 mgal)	(3 char.)
80-85	**Terrain correction** (0.01 mgal) *computed according to the next mentioned radius & density*	(6 char.)
86-87	Information about terrain correction 0 = no topographic correction 1 = tc computed for a radius of 5 km (zone H) 2 = tc computed for a radius of 30 km (zone L) 3 = tc computed for a radius of 100 km (zone N) 4 = tc computed for a radius of 167 km (zone 02) 11 = tc computed from 1 km to 167 km 12 = tc computed from 2.5 km to 167 km 13 = tc computed from 5.2 km to 167 km 14 =tc (unknown radius) 15 = tc computed to zone M (22 km) 16 = tc computed to zone G 17 = tc computed to zone K (18.8 km) 25 = tc computed to 48.6 km on a curved Earth 26 = tc computed to 64. km on a curved Earth	(2 char.)
88-91	Density used for terrain correction	(4 char.)
92-93	Mathew's zone *when the depth is not corrected depth, this information is necessary. For example : zone 50 for the Eastern Mediterranean Sea*	(2 char.)
94-95	Accuracy of gravity 0 = no information 1 = E <= 0.01 mgal 2 = .01 < E <= 0.05 mgal 3 = .05 < E <= 0.1 mgal 4 = 0.1 < E <= 0.5 mgal 5 = 0.5 < E <= 1. mgal 6 = 1. < E <= 3. mgal 7 = 3. < E <= 5. mgal 8 = 5. < E <= 10. mgal 9 = 10. < E <= 15. mgal 10 = 15 < E <= 20. mgal 11 = 20. < E mgal	(2 char.)
96-101	Correction of observed gravity (unit : microgal)	(6 char.)
102-110	Date of observation *in Julian day - 2 400 000 (unit : 1/10 000 of day)*	(9 char.)
111-113	Velocity of the ship (0.1 knot)	(3 char.)
114-118	Eötvös correction (0.1 mgal)	(5 char.)
119-121	**Country code (BGI)**	(3 char.)
122	**Confidentiality** 0 = without restriction 1 = with authorization 2 = classified	(1 char.)
123	**Validity** 0 = no validation 1 = good 2 = doubtful 3 = lapsed	(1 char.)
124-130	Numbering of the station (original)	(7 char.)
131-136	**Sequence number**	(6 char.)
137-139	**Leg number**	(3 char.)
140-145	**Reference station**	(6 char.)

Whenever given, the theoretical gravity (γ_O), free-air anomaly (FA), Bouguer anomaly (BO) are computed in the 1967 geodetic reference system.

The approximation of the closed form of the 1967 gravity formula is used for theoretical gravity at sea level :

$$\gamma_O = 978031.85 \times [\, 1 + 0.005278895 * \sin^2(\phi) + 0.000023462 * \sin^4(\phi)\,] \text{, mgals}$$

where ϕ is the geographic latitude.

The formulas used in computing FA and BO are summarized below.

Formulas used in computing free-air and Bouguer anomalies

Symbols used :

g	*: observed value of gravity*
γ	*: theoretical value of gravity (on the ellipsoid)*
Γ	*: vertical gradient of gravity (approximated by 0.3086 mgal/meter)*
H	*: elevation of the physical surface of the land, lake or glacier (H = o at sea surface), positive upward*
D_1	*: depth of water, or ice, positive downward*
D_2	*: depth of a gravimeter measuring in a mine, in a lake, or in an ocean, counted from the surface , positive downward*
G	*: gravitational constant* ($667.2\ 10^{-13}\ m^3\ kg^{-1}\ s^{-2}) \Rightarrow k = 2\ \pi\ G$
ρ_c	*: mean density of the Earth's crust (taken as 2670 kg* m^{-3}*)*
ρ_w^f	*: density of fresh water (1000 kg* m^{-3}*)*
ρ_w^s	*: density of salted water (1027 kg* m^{-3}*)*
ρ_i	*: density of ice (917 kg* m^{-3}*)*
FA	*: free-air anomaly*
BO	*: Bouguer anomaly*

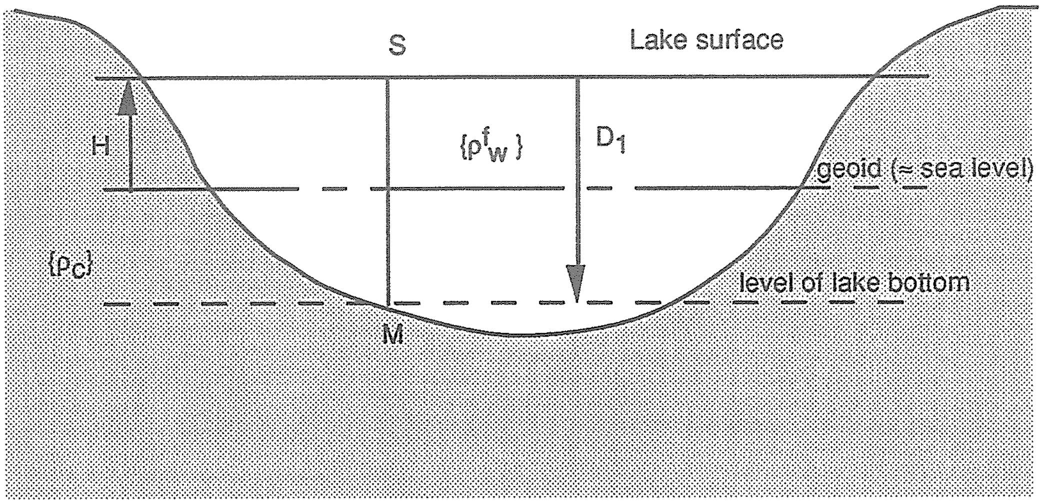
Formulas :

* *FA : The principle is to compare the gravity of the Earth at its surface with the normal gravity, which first requires in some cases to derive the surface value from the measured value. Then, and until now, FA is the difference between this Earth's gravity value reduced to the geoid and the normal gravity* γ_o *computed on the reference ellipsoid (classical concept). The more modern concept *, in which the gravity anomaly is the difference between the gravity at the surface point and the normal (ellipsoidal) gravity on the telluroid corresponding point may be adopted in the future depending on other major changes in the BGI data base and data management system.*

* *BO : The basic principle is to remove from the surface gravity the gravitational attraction of one (or several) infinite plate (s) with density depending on where the plate is with respect to the geoid. The conventional computation of BO assumes that parts below the geoid are to be filled with crustal material of density* ρ_c *and that the parts above the geoid have the density of the existing material (which is removed).*

* cf. "On the definition and numerical computation of free air gravity anomalies", by H.G. Wenzel. Bulletin d'Information, BGI, n° 64, pp. 23-40, June 1989.

For example, if a measurement g_M is taken at the bottom of a lake, with the bottom being below sea level, we have :



$$g_S = g_M + 2\,k\,\rho^f_w\,D_1 - \Gamma D_1$$
$$\Rightarrow FA = g_S + \Gamma H - \gamma_0$$

Removing the (actual or virtual) topographic masses as said above, we find :

$$\begin{aligned}\delta g_s &= g_s - k\,\rho^f_w\,D_1 + k\,\rho_c(D_1 - H)\\ &= g_s - k\,\rho^f_w\,[H + (D_1 - H)] + k\,\rho_c\,(D_1 - H)\\ &= g_s - k\,\rho^f_w\,H + k\,(\rho_c - \rho^f_w)(D_1 - H)\end{aligned}$$

$$\Rightarrow \quad BO = \delta g_s + \Gamma\,H - \gamma_o$$

The table below covers most frequent cases. It is an update of the list of formulas published before.

It may be noted that, although some formulas look different, they give the same results. For instance BO (C) and BO (D) are identical since :

$$\begin{aligned}-k\,\rho_i H + k(\rho_c - \rho_i)(D_1 - H) &\equiv -k\,\rho_i(H - D_1 + D_1) - k(\rho_c - \rho_i)(H - D_1)\\ &\equiv -k\,\rho_i\,D_1 - k\,\rho_c(H - D_1)\end{aligned}$$

Similarly, BO (6), BO (7) and BO (8) are identical.

Elev. Type	Situation	Formulas
1	Land Observation-surface	$FA = g + \Gamma H - \gamma_0$
		$BO = FA - k \rho_c H$
2	Land Observation-subsurface	$FA = g + 2k \rho_c D_2 + \Gamma (H - D_2) - \gamma_0$
		$BO = FA - k \rho_c H$
3	Ocean Surface	$FA = g - \gamma_0$
		$BO = FA + k(\rho_c - \rho_w^s) D_1$
4	Ocean submerged	$FA = g + (2k \rho_w^s - \Gamma) D_2 - \gamma_0$
		$BO = FA + k(\rho_c - \rho_w^s) D_1$
5	Ocean bottom	$FA = g + (2k \rho_w^s - \Gamma) D_1 - \gamma_0$
		$BO = FA + k(\rho_c - \rho_w^s) D_1$
6	Lake surface above sea level	$FA = g + \Gamma H - \gamma_0$
	with bottom above sea level	$BO = FA - k \rho_w^f D_1 - k \rho_c (H - D_1)$
7	Lake bottom, above sea level	$FA = g + 2k \rho_w^f D_1 + \Gamma (H - D_1) - \gamma_0$
		$BO = FA - k \rho_w^f D_1 - k \rho_c (H - D_1)$
8	Lake bottom, below sea level	$FA = g + 2k \rho_w^f D_1 + \Gamma (H - D_1) - \gamma_0$
		$BO = FA - k \rho_w^f H + k(\rho_c - \rho_w^f)(D_1 - H)$
9	Lake surface above sea level	$FA = g + \Gamma H - \gamma_0$
	with bottom below sea level	$BO = FA - k \rho_w^f H + k(\rho_c - \rho_w^f)(D_1 - H)$
A	Lake surface, below sea level (here $H < o$)	$FA = g + \Gamma H - \gamma_0$
		$BO = FA - k \rho_c H + k(\rho_c - \rho_w^f) D_1$
B	Lake bottom, with surface below sea level ($H < o$)	$FA = g + (2k \rho_w^f - \Gamma) D_1 + \Gamma H - \gamma_0$
		$BO = FA - k \rho_c H + k(\rho_c - \rho_w^f) D_1$
C	Ice cap surface, with bottom below sea level	$FA = g + \Gamma H - \gamma_0$
		$BO = FA - k \rho_i H + k(\rho_c - \rho_i)(D_1 - H)$
D	Ice cap surface, with bottom above sea level	$FA = g + \Gamma H - \gamma_0$
		$BO = FA - k \rho_i D_1 - k \rho_c (H - D_1)$

2.6 Satellite Altimetry Data

BGI has access to the Geos 3, Seasat and Geosat data bases which are managed by the Groupe de Recherches de Géodésie Spatiale (GRGS). These data are now in the public domain. ERS1 and TOPEX-POSEIDON data are not.

Since January 1, 1987, the following procedure has been applied :

(a) Requests for satellite altimetry derived geoid heights (N), that is : time (julian date), longitude, latitude, N, are processed by BGI. for small areas (smaller than 20° x 20°), and forwarded to GRGS for larger areas.

(b) Requests for the full altimeter measurements records are forwarded to GRGS, or NASA in the case of massive request.

In all cases, the geographical area (polygon) and beginning and end of epoch (if necessary) should be given.

All requests for data must be sent to :

Mr. Gilles BALMA
Bureau Gravimétrique International
18, Avenue E. Belin - 31055 Toulouse Cedex - France

In case of a request made by telephone, it should be followed by a confirmation letter, or telex. Except in particular case (massive data retrieval, holidays...) requests are satisfied within one month following the reception of the written confirmation, or information are given concerning the problems encountered.

If not specified, the data will be written, formatted (EBCDIC) on labeled 9-track tape (s) with a fixed block size, for large amounts of data, or on diskette in the case of small files. The exact physical format will be indicated in each case.

3. USUAL SERVICES BGI CAN PROVIDE

The list below is not restrictive and other services (massive retrieval, special evaluation and products...) may be provided upon request.

The costs of the services listed below are a revision of the charging policy established in 1981 (and revised in 1989) in view of the categories of users : (1) contributors of measurements and scientists, (2) other individuals and private companies.

The prices given below are in french francs. They have been effective on January 1, 1992 and may be revised periodically.

3.1. Charging Policy for Data Contributors and Scientists

For these users and until further notice, - and within the limitation of our in house budget, we shall only charge the incremental cost of the services provided. In all other cases, a different charging policy might be applied.

However, and at the discretion of the Director of B.G.I., some of the services listed below may be provided free of charge upon request, to major data contributors, individuals working in universities, especially students ...

3.1.1. Digital Data Retrieval

. on one of the following media :
** printout .... 2 F/100 lines*
** diskette....................... 25 F per diskette (minimum charge : 50 F-*
** magnetic tape .... 2 F per 100 records*
+ 100 F per tape - 1600 BPI
(if the tape is not to be returned)

. minimum charge : 100 F

. maximum number of points : 100 000 ; massive data retrieval (in one or several batches) will be processed and charged on a case by case basis.

3.1.2. Data Coverage Plots : in Black and White, with Detailed Indices

. 20°x20° blocks, as shown on the next pages (maps 1 and 2) : 400 F each set.

. For any specified area (rectangular configurations delimited by meridians and parallels) : 1. F per degree square : 100 F minimum charge (at any scales, within a maximum plot size of : 90 cm x 180 cm).

. For area inside polygon : same prices as above, counting the area of the minimum rectangle comprising the polygon.

3.1.3. Data Screening

(Selection of one point per specified unit area, in decimal degrees of latitude and longitude, i.e. selection of first data point encountered in each mesh area).

. 5F/100 points to be screened.

. 100 F minimum charge.

3.1.4. Gridding

(Interpolation at regular intervals Δ in longitude and Δ' in latitude - in decimal degrees) :

. 10 F/($\Delta\Delta'$) per degree square

. minimum charge : 150 F

. maximum area : 40° x 40°

3.1.5. Contour Maps of Bouguer or Free-Air Anomalies

At a specified contour interval Δ (1, 2, 5,... mgal), on a given projection :
10 F/Δ per degree square, plus the cost of gridding (see 3.4) after agreement on grid stepsizes. (at any scale, within a maximum map size for : 90 cm x 180 cm).

. 250 F minimum charge

. maximum area : 40° x 40°

3.1.6. Computation of Mean Gravity Anomalies

(Free-air, Bouguer, isostatic) over Δ xΔ' area : 10F/ΔΔ' per degree square.

. minimum charge : 150 F

. maximum area : 40°x40°

3.2. Charging Policy for Other Individuals or Private Companies

3.2.1. Digital Data Retrieval

..1 F per measurement

. minimum charge : 150 F

3.2.2. Data Coverage Plots, in Black and White, with Detailed Indices

. 2 F per degree square ; 100 F minimum charge. (maximum plot size = 90 cm x 180 cm)

. For area inside polygon : same price as above, counting the area of the smallest rectangle comprising ihe polygon.

3.2.3. Data Screening

. 1 F per screened point

. 250 F minimum charge

3.2.4. Gridding

Same as 31.4.

3.2.5. Contour Maps of Bouguer or Free-Air Anomalies

Same as 3.1.5.

3.2.6. Computation of Mean Gravity Anomalies

Same as 3.1.6.

3.3. Gravity Maps

The pricing policy is the same for all categories of users

3.3.1. Catalogue of all Gravity Maps

Printout : 200 F

Tape 100 F (+ tape price, if not to be returned)

3.2.2. Maps

. Gravity anomaly maps (excluding those listed below) : 100 F each

. Special maps :

Mean Altitude Maps

FRANCE	*(1: 600 000)*	*1948*	*6 sheets*	*65 FF the set*
WESTERN EUROPE	*(1:2 000 000)*	*1948*	*1 sheet*	*55 FF*
NORTH AFRICA	*(1:2 000 000)*	*1950*	*2 sheets*	*60 FF the set*
MADAGASCAR	*(1:1 000 000)*	*1955*	*3 sheets*	*55 FF the set*
MADAGASCAR	*(1:2 000 000)*	*1956*	*1 sheet*	*60 FF*

Maps of Gravity Anomalies

NORTHERN FRANCE	*Isostatic anomalies*	*(1:1 000 000)*	*1954*	*55 FF*
SOUTHERN FRANCE	*Isostatic anomalies Airy 50*	*(1:1 000 000)*	*1954*	*55 FF*
EUROPE-NORTH AFRICA	*Mean Free air anomalies*	*(1:1 000 000)*	*1973*	*90 FF*

World Maps of Anomalies (with text)

PARIS-AMSTERDAM	*Bouguer anomalies*	*(1:1 000 000)*	*1959-60*	*65 FF*
BERLIN-VIENNA	*Bouguer anomalies*	*(1:1 000 000)*	*1962-63*	*55 FF*
BUDAPEST-OSLO	*Bouguer anomalies*	*(1:1 000 000)*	*1964-65*	*65 FF*
LAGHOUAT-RABAT	*Bouguer anomalies*	*(1:1 000 000)*	*1970*	*65 FF*
EUROPE-AFRICA	*Bouguer Anomalies*	*(1:10 000 000)*	*1975*	*180 FF with text* *120 FF without text*
EUROPE-AFRICA	*Bouguer anomalies-Airy 30*	*(1:10 000 000)*	*1962*	*65 FF*

Charts of Recent Sea Gravity Tracks and Surveys (1:36 000 000)

CRUISES prior to	*1970*	*65 FF*
CRUISES	*1970-1975*	*65 FF*
CRUISES	*1975-1977*	*65 FF*

Miscellaneous

CATALOGUE OF ALL GRAVITY MAPS

listing	*200 FF*
tape	*300 FF*

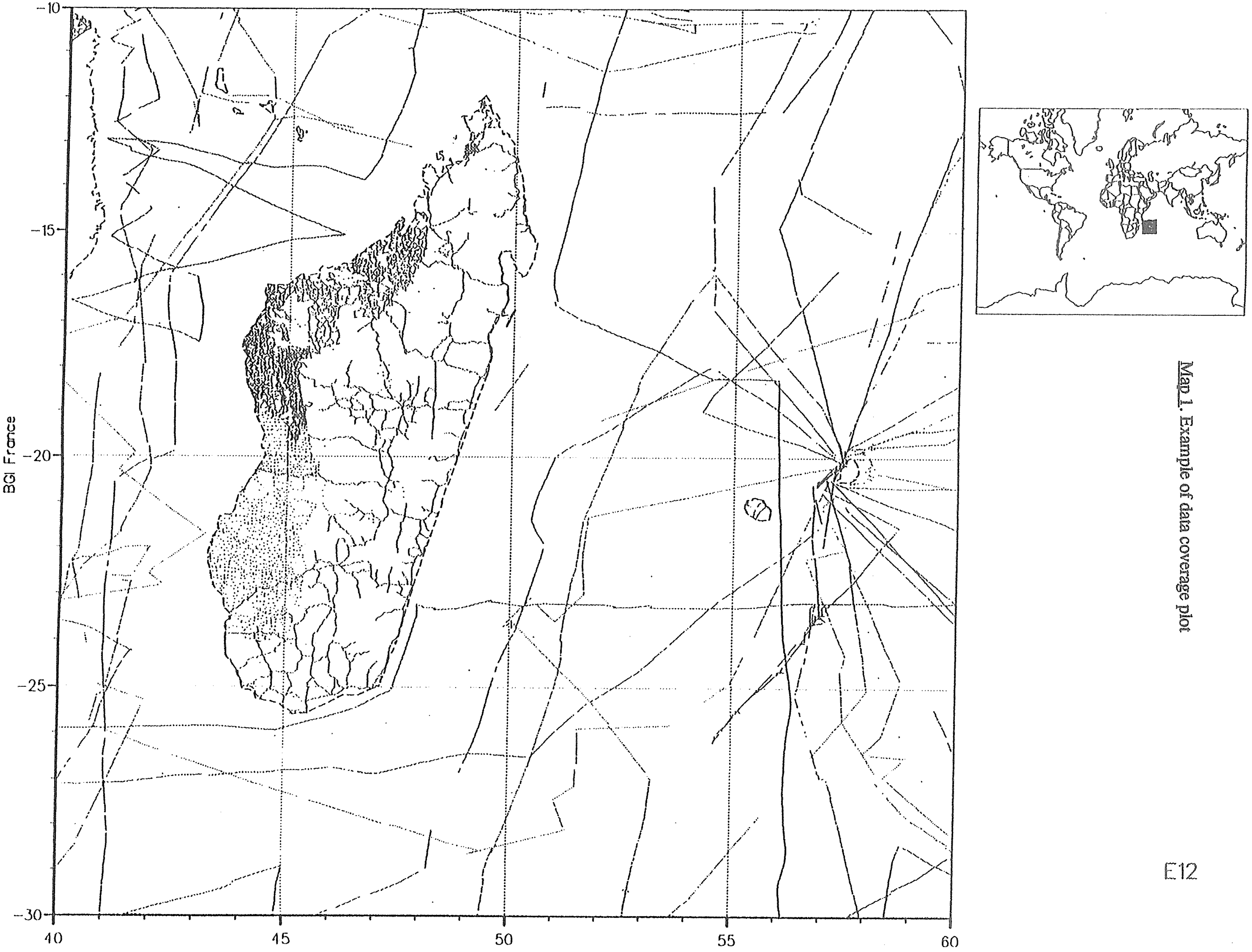
THE UNIFICATION OF THE GRAVITY NETS OF AFRICA

(Vol. 1 and 2) *1979* *150 FF*

. Black and white copy of maps : 150 F per copy

. Colour copy : price according to specifications of request.

Mailing charges will be added for air-mail parcels when "Air-Mail" is requested)



Map 1. Example of data coverage plot

E12

BGI France

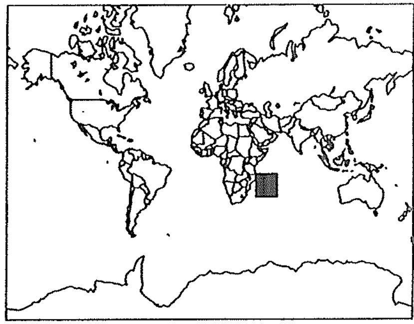
-10 -15 -20 -25 -30

214 23.3 10.1	102 -38.8 42.1	15 5.6 6.2	52 -25.9 12.0	8 -14.5 1.3	26 -18.3 4.3	29 -27.7 17.6	184 -22.5 26.3	53 -23.9 10.3	65 -27.9 26.7	26 -8.2 37.4	8 -7.2 24.0	116 -5.5 8.2	138 -13.1 11.1	51 -5.8 6.0	44 -3.8 12.2	52 -1.5 23.2	85 -9.2 9.1		66 -13.9 9.4
	118 -11.0 30.0	39 -14.1 12.6	53 66.2 89.8	37 -16.6 16.6	41 -26.4 3.9		85 -42.6 9.9		2 77.7 2.8	13 -45.1 4.8	82 -12.9 16.3	43 -7.7 8.4	29 -16.9 4.3	3 -7.8 1.2	25 -2.6 13.6	68 -14.2 10.5	40 -1.7 2.6		37 -21.3 5.9
21 -55.9 5.6	207 -41.0 15.9	51 -63.4 12.2	28 93.6 114.6	98 6.4 83.8	74 66.8 121.5	32 -47.1 3.7	99 -58.0 6.1	14 37.9 9.1	111 54.8 17.3	15 -32.7 1.7	101 -17.2 4.5	26 -12.3 6.0	26 -20.4 5.9	35 -23.8 3.1	58 -11.0 13.1	50 -8.6 10.1	6 -6.1 1.4		16 58.7 4.8
3 -47.8 1.8	334 -13.0 30.1	170 -40.3 11.7	204 -39.8 8.3	125 -52.1 4.7	84 -40.1 5.6	172 -38.4 8.0	35 -32.0 37.7	155 29.6 16.6	117 34.3 15.9	4 82.6 10.5	72 -5.9 3.5			23 -0.2 6.7	1 21.7 0.0	49 -4.5 5.5			62 12.4 54.4
	249 13.8 72.1	13 -37.0 3.0	88 -28.4 4.0	84 -36.3 7.6	97 -42.4 5.2		87 -13.1 12.8	101 1.2 32.6	44 12.3 16.4	60 47.6 20.2	71 -10.8 4.5			31 -8.6 4.7	11 11.9 4.2	62 3.7 7.3	41 -0.8 11.4	3 12.3 0.4	49 -39.7 10.8
1 -45.2 0.0	220 -40.7 42.1	548 -22.3 12.7	396 -63.3 8.2	151 -72.8 25.2	103 -63.1 33.0	329 -12.2 14.5	617 -18.2 10.5	146 -5.0 10.3	38 -36.5 6.8	47 13 28.1	35 -27.3 2.4			40 29.0 54.2	6 1.4 1.6	32 8.8 10.7	9 -7.4 3.3	68 -17.7 17.1	7 -33.3 3.0
102 -20.1 14.1	421 -51.3 40.2	158 -40.4 16.0	176 -25.6 10.6	348 12.6 19.8	416 -5.2 15.2	407 -26.0 8.9	244 -3.2 12.8	53 50.4 19.5	117 0.3 20.4	45 -15.8 12.2	51 -14.9 11.7		16 -18.2 3.6	60 -14.3 13.9	14 -10.6 16.2	73 4.9 9.3	6 -18.4 2.5	95 -0.0 19.4	31 57.7 50.5
22 -9.1 13.1	81 -47.6 36.5	98 -4.4 28.1	136 -18.1 12.5	782 6.1 24.4	399 8.0 17.8	83 -10.4 22.3	76 50.3 33.1	110 35.0 20.6	66 15.9 19.4	3 -43.9 2.1	27 -16.8 4.3	79 -2.1 6.9	106 -2.2 5.6	14 3.4 5.2	116 -7.4 10.8	64 -6.5 17.9	28 -19.8 10.5	98 -2.5 41.4	23 39.5 30.2
47 -38.9 7.4	23 -27.4 29.7	32 21.1 12.5		725 -7.6 11.8	387 -9.2 33.8	155 46.4 12.9	202 62.1 16.1	137 23.2 25.1	90 18.5 32.6	13 -47.8 3.0		47 -7.0 6.6	70 -8.0 6.1	167 -0.3 11.8	198 -5.1 14.1	81 -32.7 13.0	59 25.1 50.0	23 36.9 59.0	34 -0.3 25.8
37 -41.2 8.6	46 -45.8 15.1	38 16.8 19.8		178 -20.2 10.0	336 -23.4 19.7	115 40.8 20.0	171 67.2 18.7	91 31.8 26.5	2 56.6 2.1	2 -9.8 1.1	37 -13.3 3.7	73 -8.8 8.2		26 -13.0 5.3	96 -25.8 8.9	114 -59.0 24.2	241 74.2 105.9	105 -14.7 72.2	66 4.5 27.9
24 -22.6 7.4	96 -21.2 14.5	12 -29.8 16.2	6 4.3 2.3	151 5.1 28.1	144 -15.8 28.3	49 49.4 27.5	104 49.6 22.1	81 47.0 38.1		43 -21.3 7.3	12 -3.8 8.8	12 -1.7 15.2	23 -3.7 15.9	24 8.8 23.7	47 149.9 98.1	145 -24.2 33.3	356 8.8 71.3	71 -31.9 28.5	46 -0.8 17.0
25 -25.5 6.9	67 -10.5 8.9	29 -16.1 20.0	87 13.8 11.2	166 -2.7 14.8	82 -4.3 19.9	146 26.4 16.7	176 -5.8 33.8	99 46.9 39.3		52 -24.8 5.7	48 2.7 6.2	24 -5.5 1.2	8 -18.5 4.5	1 13.0 0.0	65 281.3 61.4	177 -4.5 53.0	212 -29.4 24.2	170 -2.4 16.1	44 16.5 9.0
110 6.4 27.8	81 3.3 11.5	30 -20.8 11.0	113 30.0 12.9	200 17.6 16.0	166 41.8 30.8	149 29.4 19.1	205 7.6 34.6	13 75.7 3.6		45 -14.0 1.7	50 -6.0 12.3		1 1.6 0.0	5 -2.8 1.0	46 -14.4 4.6	170 -8.7 11.9	100 -15.0 24.7	106 -0.8 14.4	108 9.4 14.1
122 -2.8 10.0	33 3.1 9.1		76 27.0 12.3	237 11.4 23.4	118 31.8 14.8	46 36.0 17.4	157 32.3 29.4	145 -7.5 6.2	116 -2.8 7.5	214 -25.0 13.6	157 7.3 10.6	105 21.2 16.0	76 5.2 3.5	97 11.1 7.2	79 5.2 32.8	294 9.0 9.6	166 -8.6 26.1	87 2.6 10.0	124 -8.0 14.1
28 -3.2 6.1	99 1.2 15.8		28 39.4 10.6	132 50.4 10.8	150 30.0 9.8	139 11.0 34.3	131 27.0 42.3		34 -7.5 4.0	17 -16.5 3.6	47 3.7 5.4	27 3.7 3.8	27 1.6 9.3	6 42.8 3.2	49 3.1 14.9	173 5.9 10.7	41 -21.1 25.3	29 -12.5 17.2	
109 -8.9 9.6	130 -1.5 10.3	58 3.7 7.0	58 1.2 14.4	104 19.5 32.7	161 11.4 28.4	123 41.3 41.0	31 66.7 19.1	1 -24.9 0.0	45 -12.2 6.2	24 -1.7 7.3	65 -4.4 7.6	50 4.0 7.5	13 13.9 3.2	42 0.5 23.3	70 -8.9 3.7	100 6.4 4.0	47 -3.7 18.7	26 -8.1 2.9	24 -6.5 9.6
37 -27.9 4.9	77 10.9 23.4	51 2.2 10.5	49 -14.7 21.6	34 -22.2 21.0	37 -7.4 6.9	30 -6.7 10.4	35 -7.5 5.9	48 -20.5 7.6	71 -16.2 4.7	68 -12.2 5.9	26 -7.1 3.7	21 -11.9 5.8	9 -9.7 1.1	15 -17.9 4.5		105 2.1 7.7	26 9.4 22.9	57 -7.7 10.1	13 -18.2 7.4
54 -12.2 13.3	74 -1.1 14.6	3 -5.7 0.5		18 10.3 21.1	20 42.4 10.4	30 59.4 22.8	7 36.5 10.5		3 2.4 1.1	21 -1.7 4.3	28 0.9 10.3		25 -11.6 4.2		4 -8.9 2.6	78 6.7 3.3	24 1.5 3.2	34 -29.5 21.5	27 -0.1 17.3
32 -23.9 8.2	34 -14.1 4.9			12 10.7 4.8	1 6.2 0.0		14 39.6 6.4	58 33.9 16.1	67 14.5 6.7	19 -3.2 3.9	10 -6.9 11.8	17 8.6 4.4	6 -3.2 1.9	16 -12.0 5.3	18 -0.8 3.1	115 -3.5 10.0	29 -3.6 19.9	29 1.2 15.2	108 12.4 20.6
	55 -13.2 8.3	31 3.9 3.9	33 -6.1 16.4	64 16.1 17.5	9 47.1 22.8	21 20.3 17.2	40 11.7 4.6	3 7.7 0.4	24 23.1 12.0			37 16.7 8.0	11 -6.2 4.8	23 -5.6 3.8		88 0.1 7.2	56 0.6 20.9	111 1.4 17.5	36 20.6 8.7

40 45 50 55 60

30314 GRAVITY measurements:

19050 marine data 11264 land data



BGI GRAVITY DATA

MEAN FREE AIR ANOMALY

1st field : number of points

2nd field : mean value (mgal)

3nd field : Std. Dev. (mgal)

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Map 2. Example of detailed index (Data coverage corresponding to Map 1)

4. PROVIDING DATA TO B.G.I.

4.1. Essential Quantities and Information for Gravity Data Submission

1. Position of the site :

- *latitude, longitude (to the best possible accuracy),*
- *elevation or depth :*
  . for land data : elevation of the site (on the physical surface of the Earth) *
  . for water stations : water depth.

2. Measured (observed) gravity, corrected to eliminate the periodic gravitational effects of the Sun and Moon, and the instrument drift **

3. Reference (base) station (s) used. For each reference station (a site occupied in the survey where a previously determined gravity value is available and used to help establish datum and scale for the survey), give name, reference station number (if known), brief description of location of site, and the reference gravity value used for that station. Give the datum of the reference value ; example : IGSN 71.

4.2. Optional Information

The information listed below would be useful, if available. However, none of this information is mandatory.

. Instrumental accuracy :

- *identify gravimeter (s) used in the survey. Give manufacturer, model, and serial number, calibration factor (s) used, and method of determining the calibration factor (s).*

- *give estimate of the accuracy of measured (observed) gravity. Explain how accuracy value was determined.*

. Positioning accuracy :

- *identify method used to determine the position of each gravity measurement site.*

- *estimate accuracy of gravity station positions. Explain how estimate was obtained.*

- *identify the method used to determine the elevation of each gravity measurement site.*

- *estimate accuracy of elevation. Explain how estimate was obtained. Provide supplementary information, for elevation with respect to the Earth's surface or for water depth, when appropriate.*

. Miscellaneous information :

- *general description of the survey.*
  date of survey : organization and/or party conducting survey.
- *if appropriate : name of ship, identification of cruise.*
- *if possible, Eötvös correction for marine data.*

. Terrain correction

Please provide brief description of method used, specify : radius of area included in computation, rock density factor used and whether or not Bullard's term (curvature correction) has been applied.

---

* Give supplementary elevation data for measurements made on towers, on upper floor of buildings, inside of mines or tunnels, atop glacial ice. When applicable, specify whether gravity value applied to actual measurement site or it has been reduced to the Earth's physical surface (surface topography or water surface)
Also give depth of actual measurement site below the water surface for underwater measurements.

** For marine gravity stations, gravity value should be corrected to eliminate effects of ship motion, or this effect should be provided and clearly explained.

. Isostatic gravity

Please specify type of isostatic anomaly computed.
Example : Airy-Heiskanen, T = 30 km.

. Description of geological setting of each site

4.3. Formats

Actually, any format is acceptable as soon as the essential quantities listed in 4.1. are present, and provided that the contributor gives satisfactory explanations in order to interpret his data properly.

The contributor may use the EOL and/or EOS formats as described above, or if he wishes so, the BGI Official Data Exchange Format established by BRGM in 1976 : "Progress Report for the Creation of a Worldwide Gravimetric Data Bank", published in BGI Bull. Info, n° 39, and recalled in Bulletin n° 50 (pages 112-113).

If magnetifc tapes are used, contributors are kindly asked to use 1600 bpi, unlabelled tapes (if possible), with no password, and formatted records of possibly fixed length and a fixed blocksize, too. Tapes are returned whenever specified, as soon as they are copied

PART II

CONTRIBUTING PAPERS

Absolute Gravity Measurements at the National Measurements Laboratory as a Co-operative Research between Japan and Australia

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John Williams[3], Kazuo Shibuya[4] and Katsutada Kaminuma[4]

[1]*National Astronomical Observatory, Mizusawa, Iwate 023, Japan*
[2] *Australian Surveying and Land Information Group, Bruce, ACT 2617, Australia*
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Abstract

We have measured absolute gravity values at the National Measurements Laboratory, CSIRO, Australia on the way back from the Syowa station, the Antarctic as a cooperative research between Japan and Australia. The arithmetic mean of 11 measurements made from March 24 to 26, 1993 was 9.79637480 ± $2.7\times10^{-7}ms^{-2}$ with a standard deviation of $8.9\times10^{-7}ms^{-2}$.

1. Introduction

There are a few stations selected or proposed for the International Absolute Gravity Basestation Network (IAGBN) subset A in Australia. They are Orroral, Alice springs, Yaragadee and Perth. There are satellite laser ranging stations at Orroral and Yaragadee, and an astronomical observatory at Perth. The IAGBN was established under the resolution of the 19th International Union of Geodesy and Geophysics (IUGG) General assembly held at Vancouver (Canada) in 1987. The IAGBN has the purposes of 1) monitoring secular gravity changes, 2) establishing bases for subordinate networks, and 3) offering up-to-date absolute gravity data useful for calibration and metrology (Boedecker, 1986). The IAGBN subset A consisting of 36 stations meets very high standards regarding geological stability, global distribution pattern, distance to seismologically active zones, facilities for other geodetic observations.

Though there are many important stations for gravity measurements in Australia, many absolute gravity measurements have not yet been made. The proposal for absolute gravity measurements at Perth and Sydney during the stopover of the icebreaker "Shirase" on the way to or from the Syowa Station in the Antarctic was first submitted by the Australian Surveying and Land Information Group (AUSLIG) on June 1991 under such a circumstance. The Mizusawa Astrogeodynamics Observatory, National Astronomical Observatory (NAOM), of which three scientists were to be the member of the 34th Japanese Antarctic Research Expedition (JARE), could partly accepted the proposal. The observations at Perth, however, was omitted for want of time. We have carried out high precision absolute gravity observations as a basis for an international cooperative scientific research project between the NAOM and the AUSLIG studying vertical crustal motion.

2. Measurements and Results

The instrument used for the measurements was the absolute gravimeter with a rotating vacuum pipe which was developed at the National Astronomical Observatory, Mizusawa (Hanada *et al.*, 1987). The dropping mechanism in the absolute gravimeter utilizes the balance between the centrifugal force and the gravity acting on a falling object. The falling object is composed of a corner cube prism and a cylindrical metallic can with a knob which covers the prism, and only one surface perpendicular to an axis is an incident surface for laser interferometry. When a incidence surface of the corner cube prism faces the interferometer, we rotate a vacuum pipe with an angular velocity high enough for keeping the falling object to the end of the pipe and stop the motion suddenly when it becomes vertical. Then the falling object inside the pipe begins to drop and three claws set at the other end of the pipe catch it. This drop is not used for measurement of g but used for preparation of the object for the next measurement since the object falls headlongs and a incidence surface of the corner cube prism does not face the interferometer. The acceleration of the object is measured during the next half cycle and it does not require the quick motion of the pipe since the falling object is hold by the claws controlled by piezoelectric ceramics. The falling object is at rest for a while after the vacuum pipe becomes vertical and it begins to drop when the claws open triggered by the zero crossing of a seismic signal. Fringe signals are produced during this drop and they are used for measurement of g. The fringe signals are stored in IC memories in the time span of 2μs at every 1 ms for 250 ms with a transient recorder (TR8828D, LeCroy). The burst sampling at every 1 ms consists of 1024 data of 2 ns time intervals. We determine the phase of the fringe signal at every 1 ms by the least square method and obtain the relation between falling distance and time in order to determine g (Murata, 1978; Tsubokawa, 1984).

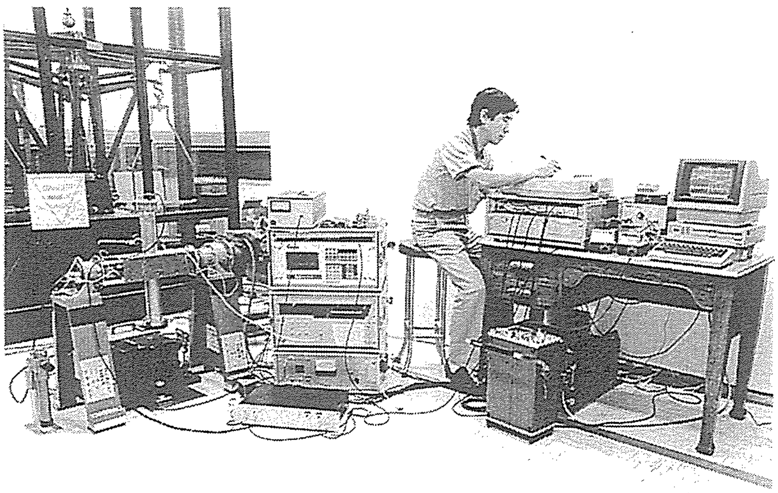

Fig.1. A photograph showing the absolute gravity measurements made at the room of 100kg balance, National Measurements Laboratory.

We took the absolute gravimeter out from the icebreaker Shirase on the way back from the Syowa station to Japan on March 21, 1993 and transported to the National Measurements of Laboratory (NML) by a two-ton truck on the same day. The instrument was set on the metal mark of about 0.3m square, which had been used for absolute gravity measurements, in the center of the room for 100 kg balance (room number 245). Figure 1 shows the absolute gravity measurements made there. Although it took about only one day to assemble the instrument, it needed another two days to start measurements since there was something wrong in the vacuum valve or in the ion pump attached to the absolute gravimeter. One reason why the vacuum system did not work well seems to be that we exposed the inside of the vacuum chamber to dusty air containing a lot of fine flakes of mica several times for repair or adjustment when we were at the Syowa Station in the Antarctica. The condition became better though not wholly satisfactory after we had replaced only the vacuum valve with a new one. It was also necessary to renew the ion pump since electric current flowing in the pump was not stable and the pump often generated electrical noises which affected the motor controller or other components. We, however, did not hold a new ion pump in reserve. We could barely start the measurement after the unexpected two-day repairment.

Table 1. Measured gravity values at the National Measurements Laboratory

No.	Date	Time	Raw Value	Vib.[1)]	Tide[2)]	A.P.[3)]	Corrected[4)]
1	Mar. 24	14:05	979636.6918	0.4222	0.0323	-0.0039	979637.1341
2	Mar. 24	14:51	979637.6881	-0.4306	0.0031	-0.0039	979637.2484
3	Mar. 24	17:11	979637.4729	-0.2867	-0.0785	-0.0039	979637.0955
4	Mar. 25	07:09	979637.2881	0.0786	-0.0815	-0.0040	979637.2730
5	Mar. 25	16:41	979637.2778	-0.0946	-0.0579	-0.0041	979637.1129
6	Mar. 25	17:51	979637.3311	-0.0126	-0.0837	-0.0041	979637.2225
7	Mar. 25	21:25	979637.1222	0.2208	0.0041	-0.0041	979637.3347
8	Mar. 26	07:44	979637.2548	0.1321	-0.0734	-0.0041	979637.3012
9	Mar. 26	08:36	979637.3443	-0.0939	-0.0657	-0.0041	979637.1722
10	Mar. 26	09:00	979637.1608	0.2641	-0.0580	-0.0041	979637.3545
11	Mar. 26	09:43	979637.7394	-0.4388	-0.0396	-0.0041	979637.2485

1) Vib. means the vibration correction.
2) Tide means the Earth tide correction.
3) A.P. means the atmospheric pressure correction.
4) Corrected means the corrected gravity values including the correction for the laser wavelength of -0.0123 mGal (-1.23×10^{-7}ms^{-2}) and the polar motion correction of 0.0040 mGal (4.0×10^{-8}ms^{-2}) which are almost constant through the period of the experiments.
5) All the gravity and the correction values are in the unit of mGal (10^{-5}ms^{-2}).

The absolute gravity measurements at the NML have been repeated from March 24 to 26, 1993 and only eleven measurements have been succeeded in the end. The other measurements were affected either by uncontrollable motion of the motor or by mistrigger in the transient recorder. Arithmetic mean of the eleven measured gravity values corrected for Earth tides, ground vibration, air pressure, laser wavelength and polar motion is $9.79637480 \pm 2.7\times10^{-7}$ ms^{-2} (979637.480 ± 0.027 mGal) with a standard deviation of 8.9×10^{-7} ms^{-2} (89 μGal). This is the gravity value at the floor level converted from that at the effective height of the instrument of 0.85 m by using the vertical gradient of gravity of 0.321 mGal/m. Respective measured gravity values are listed in Table 1. This value is about 1.0×10^{-6}ms^{-2} (100μGal) lower than that obtained by the Russian instrument in 1979 (Arnautov *et al.*, 1979). It is necessary to repeat measurements of absolute gravity by various absolute gravimeters in the future in order to strengthen the IAGBN and to monitor gravity changes.

Acknowledgment

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REFERRING THE OLD GRAVITY NETWORK OF THE NATIONAL OBSERVATORY TO THE IGSN 71/ABSOLUTE DATUM. PART I: THE LC & R 61 DATA SET.

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Abstract

The first stage of an ongoing project of referring all gravity measurements undertaken in the period 1955-1975 by the Department of Geophysics of the National Observatory to the IGSN 71 and to the Absolute Gravity *Datum* has been completed. In total 1,484 gravity stations established with the LC & R 61 gravimeter were reprocessed using a three-step procedure: (i) internal compensation of the network through application of condition equations, (ii) iterative parametrization of the node stations and (iii) simple linear parametrization of the internode stations. Eleven IGSN 71 gravity stations were taken as *datum* and scale reference. Most of the stations are leveling bench marks with very good altimetric control and the output file produced (with station identification, geographical coordinates, g values and Faye/Bouguer anomalies) is available under the IBM-PC format.

1. Introduction

The National Observatory in Rio de Janeiro (Brazil) started systematic land gravity surveys in 1955 employing a Worden gravimeter (W 178) and this apparatus was used up to 1968. From this date up to 1975 one LaCoste & Romberg gravimeter (G 61) replaced the W 178 and from 1971 onwards another LC & R gravimeter (G 257) joined the G 61 in the surveys. All gravity measurements made in the period 1955-1975 were referred to the Potsdam *datum* via the First Order Reference Station in Rio de Janeiro with the absolute value of 978,805.00 mGal.

Most measurements were made on leveling bench marks along tractorable roads, with mean distance of 3 km between them, or in towns and villages, forming large polygons over several tectonic provinces of the Brazilian territory. In total 7,328 gravity measurements were undertaken with the W 178 on 923 stations and for the LC & R gravimeters there were 4,090 measurements over 1,484 stations.

The original reduction of the gravity measurements in the late 60's, early 70's, was mostly hand-made and no digital files were left available that could be reprocessed. In fact, except for the internal reports published by the National Observatory (Gama & Gualda, 1968; Gama, 1971, 1972, 1973), the only other written records found of this activities that lasted for twenty years were the original field data logs. Given the interest of the National Observatory to have these gravity measurements referred to the

IGSN 71, the whole data set is now being reprocessed and this paper deals with the reprocessing work performed for the LC & R 61 measurements. The geographical distribution of gravity stations established with the LC & R 61 is shown in Figure 1 and eleven of them were found to be coincident with stations belonging to the International Gravity Standardization Net 1971 (Morelli, 1972). After compiling all field records for all campaigns from 1955 to 1975, they were separated by gravimeter type, coded, fed into a microcomputer and sorted chronologically. A digital file holding the gravity station identification codes and the geographical coordinates has been assembled and, for the bench marks, the errors in heights are ±0.01 meter and less than 100 meter horizontally. Those stations that are not bench marks had their coordinates taken from topographic maps with scales 1:100,000; 1:250,000 or 1:1,000,000 with estimated maximum height errors of ±50 meters and 5,000 meters horizontally. This file holds 1,484 records and has been distributed to the Brazilian Institute of Geography and History (IBGE) for the Brazilian Gravity Data Base in a format close to what is recommended by the *Bureau Gravimétrique International.*

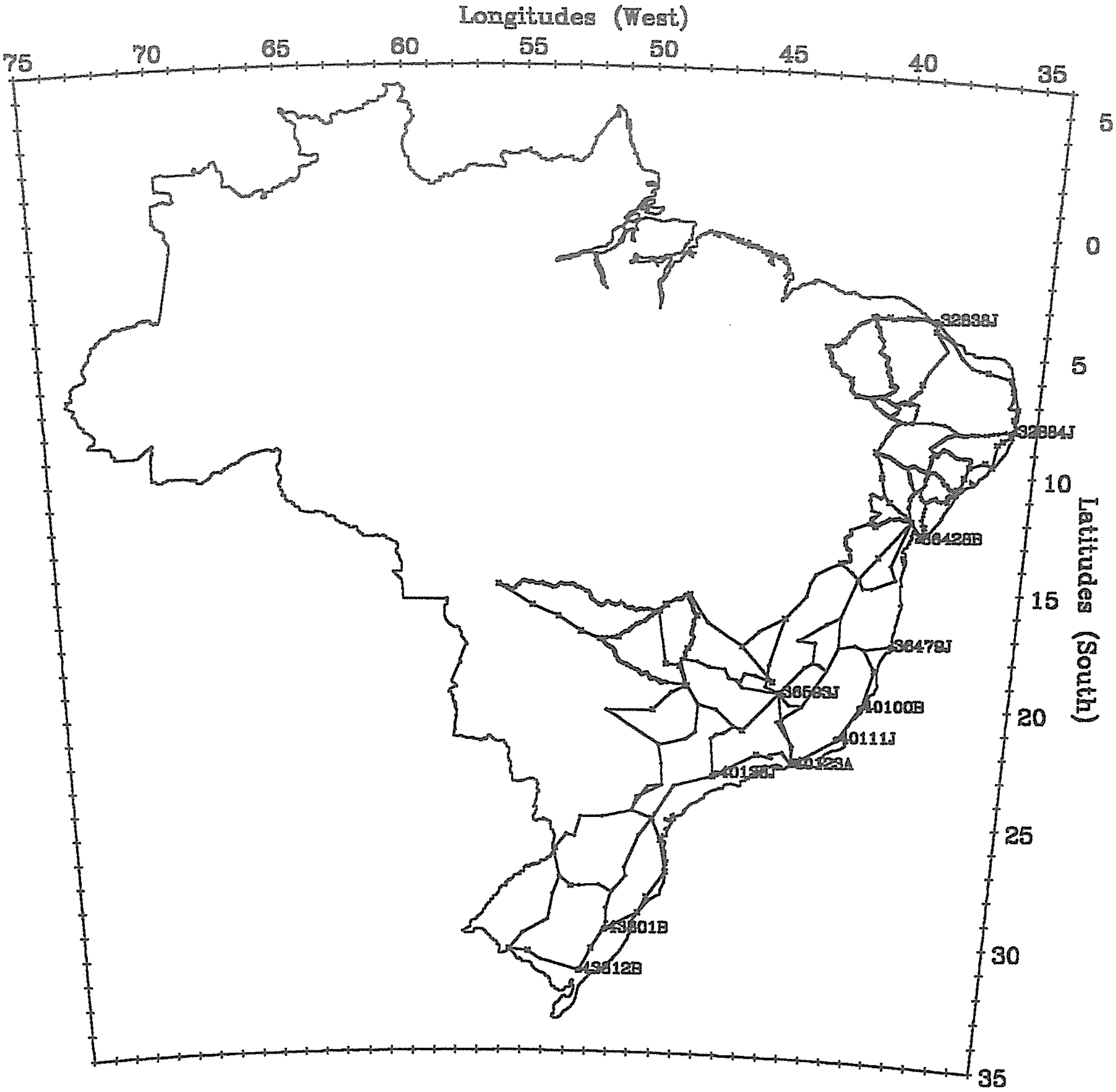
Another digital file holding the dates and times of measurements, gravimeter identification codes, observer's identification codes and gravity readings had to be assembled, with 4,090 records in it. Field data records were initially reduced by converting the instrumental readings into mGal values according to the LaCoste & Romberg Table, then correcting for earth tides (Longman, 1959) and for instrumental drift (either *static* and *dynamic drifts*). Mean gravity intervals between subsequent stations were computed as well as their standard deviations and the number of determinations for each interval.

2. Mathematical models for gravimetric adjustment

The algorithms used for gravity network adjustment are usually based on the least-squares method (the L_2 norm) where an *economized* (Uotila, 1976) mathematical structure is sought to compute the maximum likelihood estimators of physical observables. The mathematical structure relates measured quantities and functions of some parameters either explicitly or implicitly. For a given set of n measured quantities the number of u mutually independent parameters is kept fixed and the structure is said to be economized when u is kept as small as possible. An adjustment is necessary when $n > u$ and the difference $n - u = r$ is the number of mutually independent conditions. Strictly speaking, the gravity readings are actually the available observed (measured) independent quantities while the gravity intervals are formed by their differences. Although the gravity intervals are not strictly independent they are usually considered to be the appropriate input data for gravity adjustment with a diagonal variance- covariance matrix.

The following matrix notation is used in adjustment theory:
$X_0 = (x_{0_i})$, approximate values (computed or estimated) for the parameters, which are numerical values selected before the adjustment;
$X_a = (x_{a_i})$, values obtained as results of the adjustment;
$L_b = (l_{b_i})$, observed values of quantities;
$L_0 = (l_{0_i})$, numerical values of observed quantities computed through the mathematical structure as a function of X_0; and
$L_a = (l_{a_i})$, adjusted values of observed quantities.

Figure 1 - The LC & R 61 gravity network (32 polygons). Stations coincident with the IGSN 71 are identified.



Using the notation above the following differences can be established:
$X = X_a - X_0$ or $X_a = X_0 + X$, vector X: the corrections vector;
$L = L_b - L_0$, the discrepancy before the adjustment; and
$V = L_a - L_b$, the vector of residuals.

A mathematical model can be expressed as (Uotila, 1976; Lugnani, 1983):

$$F(X_a, L_a) = 0, \tag{1}$$

where $F = (f_i)$, $i = 1, 2, ..., m$ is a vector of functions associating the adjusted parameters $X_a = (x_{a_i})$, $i = 1, 2, ..., u$ to the adjusted values for the observables $L_a = (l_{a_i})$, $i = 1, 2, ..., n$. The mathematical model can be linear or non-linear whereas it has to be linearized in order to find its solution.

Considering the linear case when the vector of approximate parameters $X_0 = (x_{0_i})$, $i = 1, 2, ..., u$ and the vector of observed quantities $L_b = (l_{b_i})$, $i = 1, 2, ..., n$, are sufficiently close to X_a and L_a, respectively, the model described by (1) can be approximated by a Taylor series development around X_0, L_b and truncated in the linear term,

$$F(X_a, L_a) = F(X_0, L_b) + X\left(\frac{\partial F}{\partial X_a}\right)_{X_a=X_0, L_a=L_b} + V\left(\frac{\partial F}{\partial L_a}\right)_{X_a=X_0, L_a=L_b}$$

or

$$AX + BV + W = 0, \tag{2}$$

where

$$A = \left(\frac{\partial F}{\partial X_a}\right)_{X_a=X_0, L_a=L_b},$$

$$B = \left(\frac{\partial F}{\partial L_a}\right)_{X_a=X_0, L_a=L_b}$$

and

$$W = F(X_0, L_b).$$

Being m the number of equations in the system, u the number of parameters and n the number of observations, equation (2) can be written as

$${}_mA_{uu}X_1 +_m B_{nn}V_1 +_m W_1 = 0$$

which is a consistent system of linear equations with $n + u$ unknowns and $m < n + u$ equations to be solved for X and V.

If it is assumed that $A = 0$ in equation (2) we get the so called method of *condition equations* or *correlates* for the adjustment of observations only, with no parameters involved. It is desired to find out the best estimates for the observed (measured) quantities. In the specific case of a gravity network these observables are the gravity intervals measured between stations and it is imposed the condition that the circulation of the gravity field along any closed path is zero. Condition equations are usually applied as a preliminary adjustment since they deal only with actually measured quantities, not being affected by sources of errors external to the gravity network. This allows having a pure estimate of the quality of observations avoiding error propagation from other sources. On the other hand, at least one known absolute gravity value is needed to assign g values to all other gravity stations.

The corresponding mathematical model for the condition equations is (*e.g.* Uotila, 1976):

$$F(L_a) = 0,$$

and its linearized form can be written as

$$BV + W = 0,$$

where

$$B = \left(\frac{\partial F}{\partial L_a}\right)_{L_a = L_b}$$

and $W = F(L_b)$. The vector of residuals V, assumed small, should be added to the vector L_b of observed values to get the vector of adjusted observations L_a. Then, given an appropriate weight matrix P for the observations L_b

$$L_a = L_b + V,$$

with

$$\begin{aligned} V &= P^{-1}B^T K, \\ K &= -M^{-1}W, \quad \text{and} \\ M &= BP^{-1}B^T. \end{aligned}$$

The variance-covariance matrix Σ_{L_a} for the adjusted observations is

$$\Sigma_{L_a} = \sigma_0^2 P^{-1}(I - B^T M^{-1} B P^{-1})$$

where $\sigma_0^2 = V^T PV/m = -K^T W/m$ is the variance of unit weight and m is the number of condition equations. The rank of the coefficient matrix M is given by the number of polygons in the network. It is much smaller than the number of unknown gravity stations, what greatly reduces the computing effort when compared either to the implicit or to the parametric model.

When $A \neq 0$ and $B = -I$ we get the *parametric* or *observation equations* method with the corresponding mathematical structure, (*e.g.* Lugnani, 1983),

$$L_a = F(X_a),$$

where F is generically a non-linear functional.

The problem is usually linearized by performing a Taylor series expansion around the approximate values X_0,

$$AX = L + V$$

with

$$A = \left(\frac{\partial F}{\partial X_a} \right)_{X_a = X_0}.$$

Since $F(X_a) = L_b + V, F(X_0) = L_0$ and $L = L_b - L_0$, the solution can be found by minimizing the function $\Phi = V^T PV$ in the L_2 sense. The corrections vector X and the residuals are then given by

$$X = (A^T PA)^{-1} A^T PL,$$
$$V = AX - L.$$

Given the generic non-linear nature of F and the linear approximation taken, the final solution is found iteratively by establishing,

$$X_a = X_0 + X \longrightarrow X_0'$$

$$X_a' = X_0' + X'$$

until convergence is eventually reached. After the final set of adjusted values for the parameters is obtained its dispersion can be estimated through

$$\sigma_0^2 = \frac{V^T PV}{n - u}$$

with the variance-covariance matrix given by

$$\Sigma_X = \sigma_0^2 (A^T PA)^{-1}. \tag{3}$$

3. Adjustment of the LC & R 61 gravity network to the IGSN 71

The gravity intervals measured with the LC & R 61 were provisionally adjusted using the condition equations method applied to the 32 polygons defined by the network in Figure 1. There are 88 gravity intervals defining the polygons and 6 additional intervals tying the network to IGSN stations. Table 1 shows the misclosures for each circuit before the adjustment. The polygons were defined by node stations which were considered as those gravity stations with at least three ties to neighboring stations. This helps diminishing the size of the matrices involved in the problem.

Table 1. Polygon misclosures (in mGal)

#	Misc.	#	Misc.	#	Misc.	#	Misc.
1	.027	9	-.083	17	-.119	25	-.428
2	.056	10	.109	18	-.018	26	.471
3	.057	11	.191	19	-.096	27	.065
4	.268	12	-.187	20	.178	28	.115
5	-.108	13	.076	21	-.076	29	.142
6	.211	14	.205	22	.292	30	.097
7	-.065	15	-.010	23	.098	31	-.450
8	-.061	16	.015	24	-.218	32	.206

Since the observer was always the same for all measurements and most gravity intervals of the network had the same number of determinations (were usually measured twice), the precision might be considered as the same for all intervals, *i.e.* the weight matrix could be set to the Identity matrix. However, the number of subintervals between two node stations is quite different, imposing a different precision to the total gravity interval. As a first approximation the weight matrix was set to I and an initial variance of unit weight σ_0^2 as well the residuals could be estimated. After that, a diagonal weight matrix was iteratively fitted as

$$P = \sigma_0^2 \Sigma_{L_b}^{-1} = \sigma_0^2 \begin{pmatrix} \frac{1}{\sigma_1^2} & 0 & \dots & 0 \\ 0 & \frac{1}{\sigma_2^2} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \frac{1}{\sigma_{88}^2} \end{pmatrix}$$

with elements σ_i^2, $i = 0,\ 1,\ \dots,\ 88$ being recomputed at each step.

The application of the method of correlates produced a variance of unit weight σ_0^2 = 0.00170916 mGal^2 which can be considered as an estimate for the variances of all conditionally adjusted intervals with an adequate weight matrix. The standard deviation was found to be 0.041 mGal and this is an estimate of the quality of the LC & R 61 measurements.

After correcting for misclosures the parametric method was iteratively applied to the node stations, taking the gravity values for the IGSN 71 stations as fixed. The IGSN 71 has been used as the source of *datum* and scale in the present work and Table 2 lists the eleven IGSN 71 stations tied to the LC & R 61 network. A dependence on latitude of the difference between the IGSN g values and the previously published (Gama, *op. cit.)* g values is clearly seen in this table.

Table 2. IGSN 71 stations tied to the LC & R 61 network.

Gravity Station	Latitude (^{0} South)	g_{IGSN} (mGal)	g_{Gama} (mGal)	$g_{Gama} - g_{IGSN}$ (mGal)
32838J Fortaleza	-3.73	978067.81	978083.12	15.31
32884J Recife	-8.09	978151.25	978166.58	15.33
36428B Salvador	-12.98	978311.31	978326.57	15.26
36479J Caravelas	-17.63	978511.46	978526.69	15.23
36593J Belo Horizonte	-19.91	978385.50	Not available	Not computed
40100B Vitória	-20.31	978641.83	978657.04	15.21
40111J Campos	-21.70	978717.49	978732.58	15.09
40123A Rio de Janeiro	-22.90	978789.90	978805.00	15.10
40136J São Paulo	-23.56	978627.29	Not available	Not computed
43801B Porto Alegre	-30.04	979305.00	979320.06	15.06
43812B Pelotas	-31.76	979466.63	979481.65	15.02

The functional chosen was

$$F : \kappa \delta g_{ij} = g_i - g_j,$$

where κ is the appropriate linear scale coefficient for the LC & R 61 gravimeter, δg_{ij} is the adjusted gravity interval and g_i, g_j are the adjusted absolute gravity values.

Square and cubic scale coefficients were not included in the mathematical model due to their possible absence of statistical significance, given the fact that occasional non-linearities in the apparatus are already considered in the Calibration Table for the gravimeter (the LaCoste & Romberg Table). Also, according to McConnell *et al.* (1972), these non-linearities are undetected unless gravity intervals larger than 2,000 mGal are measured. Since the largest gravity interval in the network is 1,398.82 mGal between the IGSN stations of Fortaleza (32838 J) and Pelotas (43812 B) the use of scale coefficients other than the linear term was thought to be unnecessary.

Rewriting F as $\delta g_{ij} = (g_i - g_j)/\kappa$ and considering that the adjusted values are not available, the following approximate values were taken: δg^0_{ij} given by the output of the condition equations; g^0_i, g^0_j obtained by transporting the absolute value of the IGSN station 40123 A (Rio de Janeiro) to all node stations and 1.0 for the linear scale coefficient.

For the present problem the number of parameters was 53 (52 node stations and 1 scale coefficient) and the number of gravity intervals was 94. Since the gravity intervals were already properly weighted in the conditional adjustment, the weight matrix for this step was simply taken as a diagonal matrix with elements $p_{ii} = \sigma_0^{-2}$, $i = 1, 2, \ldots, 88$ with σ_0^{-2} as given by the correlates. In this second step the *a posteriori* variance of unit weight should be close to 1.0. The value actually found was 0.9326, which can be considered as an indication that the weight matrices considered were appropriate.

Since the g values for the IGSN 71 stations were kept fixed throughout the adjustment process, the variance-covariance matrix, as given by the parametric method, underestimated the dispersions involved. More realistic estimates were obtained by considering the intrinsic errors in the IGSN 71 stations. The total standard deviation for the node stations was computed by the expression

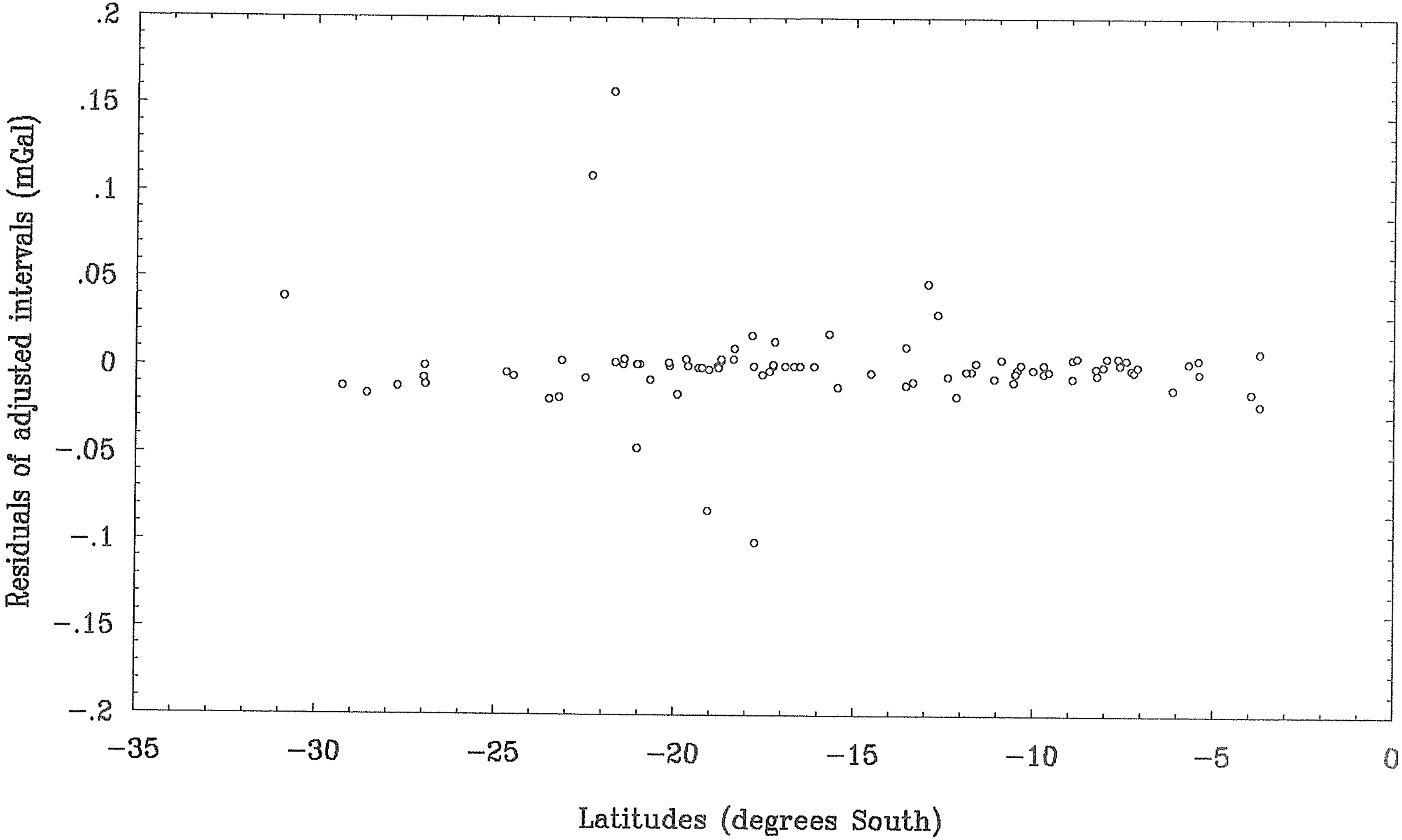
$$\sigma_{total_i} = (\sigma_i^2 + \overline{\sigma_{IGSN}}^2)^{1/2}, \tag{4}$$

where σ_i is the standard deviation given by the ith element of the main diagonal of the variance-covariance matrix Σ_X, as defined by (3), and $\overline{\sigma_{IGSN}}$ is the average standard deviation for the eleven IGSN stations tied to the net.

Figure 2 shows that the residuals found for the adjusted gravity intervals are smaller than 0.16 mGal with no systematic dependencies on latitudes. The apparent larger dispersion towards the south is due to the much smaller number of polygons measured with the LC & R 61 in that region (the W 178 was used instead) as compared to the southeast and east regions. Unfortunately, the LC & R 61 is not available anymore for remeasuring those gravity intervals with poorer results.

The final step in the adjustment procedure was the computation of absolute gravity values for the internode stations. The parametric method was again applied but no *a priori* approximate values were used, with no iterations involved. Each time the algorithm was employed only one side of a polygon was adjusted with the linear scale coefficient already known. The gravity values for the node stations were kept fixed and the functional F, as defined before, was used with known κ. The number of parameters varied according

Figure 2 — Distribution of adjusted residual against geographical latitudes.



to the number of gravity stations between the nodes with a maximum of 148. Again, a more realistic estimate of the standard deviation of the gravity values for the internode stations was found by applying an equation similar to (4) with the mean deviation for the two node stations defining the side of the polygon being considered and σ_i given by the appropriate diagonal element of the matrix Σ_X. After all the gravity values and the scale coefficient for the LC & R 61 were computed a digital file was created holding all gravity station identification codes, plani-altimetric coordinates, g values, standard deviations and gravity anomalies. This file is available upon request on a floppy disk under the IBM-PC format at the Department of Geophysics of the National Observatory.

4. Discussion

The procedures presented above allowed the computation of absolute gravity values of 1,580 stations distributed over Brazil. These measurements have now been referred to the IGSN 71 and the techniques developed are currently being applied to the LC & R 257 and W 178 data sets. The linear scale coefficient for the LC & R 61 compared to the IGSN 71 was found to be 1.000761 $\pm$ 0.000052. The accuracy of the whole LC & R 61 gravity network was found to be of the order of $\pm$0.1 mGal.

Although the matrices involved in the calculations are sparse no instabilities were found in the Gauss-Jordan inverting algorithm (Subroutine GAUSSJ, Press *et al.*, 1987).

It is also possible to approach the problem of adjusting gravity observations using the *implicit* or *combined model* applying equation (1) directly with a functional F generically non-linear. However, since three different meters were used in forming the old gravity network, with a few differences in field methodology, the three-step procedure was rather taken as the best way to compare differences in data sets.

A quick transformation rule can also be used to convert the old g_{Gama} values into IGSN-compatible ones, taking into account the latitude dependence shown in Table 3. Figure 3 clearly shows this dependence and a best fit (in the L_2 sense) regression line was also drawn. The equation for the straight line is

$$dg = -15.396 - 0.012\phi,$$

where dg is the correction in mGal to be added to the listed g_{Gama} values and ϕ is the latitude in degrees of the gravity station. This is in close agreement to the transformation rule proposed by Sá & Blitzkow (1986) for converting the Woolard Gravity Network in Brazil to the IGSN 71. The WGN also conforms to the Potsdam *datum* and a mean correction of -15.0 mGal seems to make it consistent with the IGSN 71. The estimated maximum error for this simple transformation rule is $\pm$0.1 mGal and the correlation coefficient found was 0.946.

Recently (Gemael *et al.*, 1990), absolute gravity measurements at seven different sites allowed establishing a Absolute Gravity Calibration Network in Brazil (RECEGA). These stations have been tied to the Brazilian Gravity Reference Network (RGFB) and the latter has been readjusted taking the absolute gravity stations as source of *datum* (Escobar & Santos, 1993).

Figure 3 – Best-fit regression line for the dependence of the differences Gama – IGSN 71 on latitude.

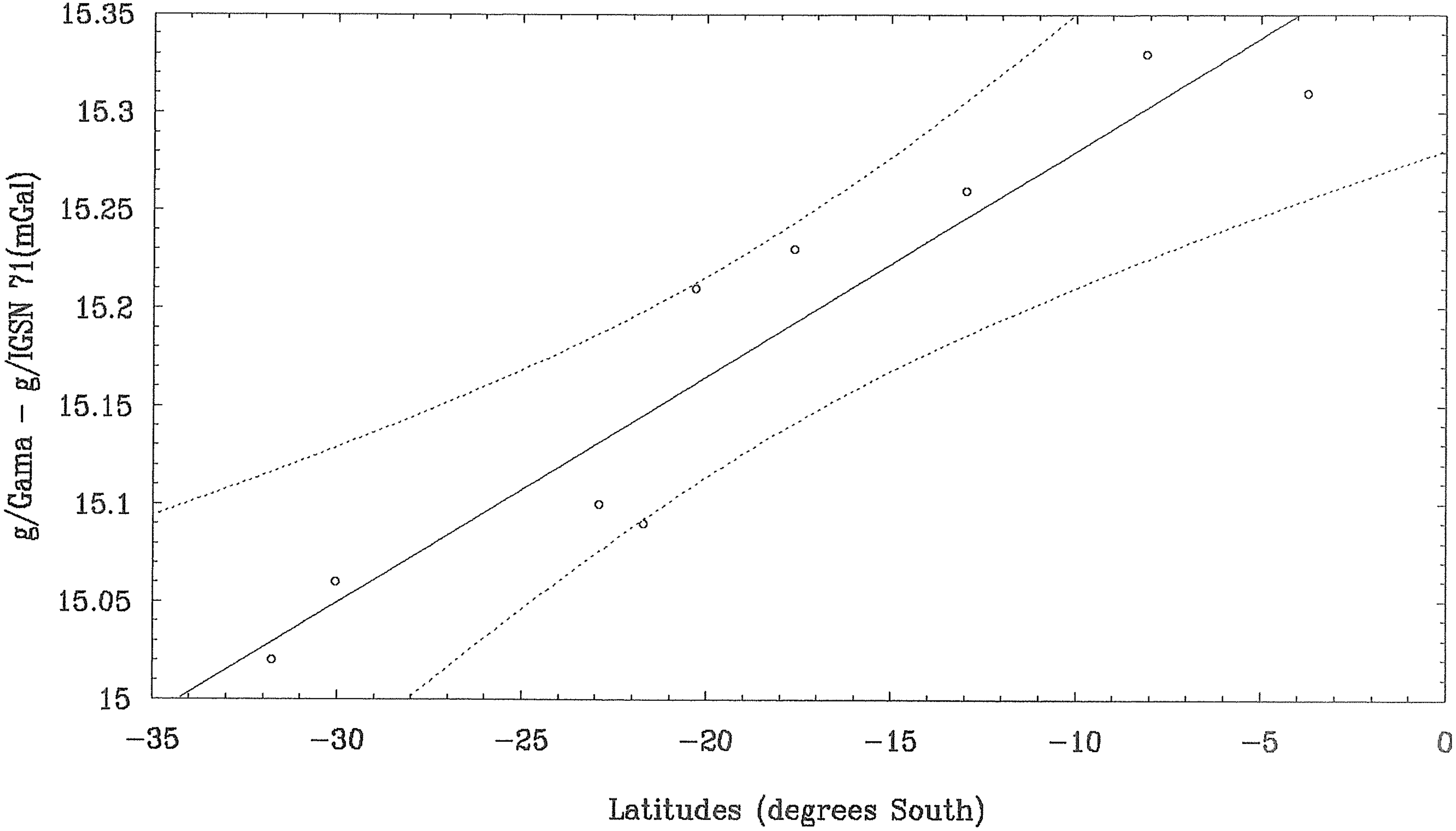
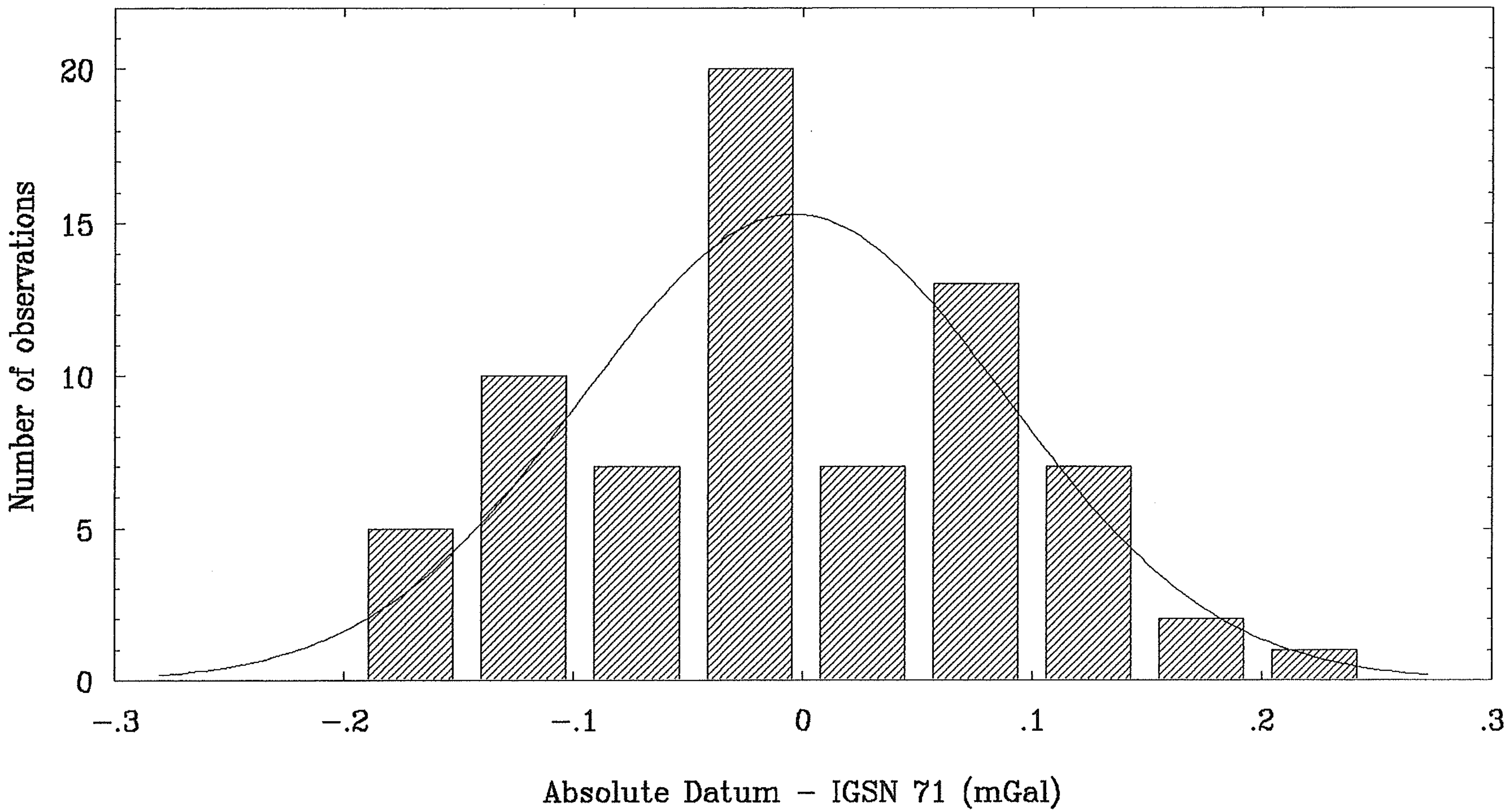


Figure 4 – Histogram of gravity differences between the Absolute Datum and the IGSN 71
(72 cases, mean = 0.0 mGal, st. dev = 0.1 mGal)



Considering that 72 gravity stations of the RGFB are coincident with the LC & R 61 network, a comparison between their gravity values obtained in the present work and those adjusted to the absolute *datum* could be made. A histogram of the differences found is shown in Figure 4 with mean difference of 0.0 mGal and a standard deviation of 0.1 mGal. Since the accuracy of the LC & R 61 network is also of ±0.1 mGal it is seen that the gravity values computed are consistent with the absolute *datum* at this level of accuracy.

Ebong (1981, 1985), working with the leveling network of Nigeria, concluded for the apparent superiority of the application of the adjustment methods based on the minimization of the sum of absolute residuals (the L_1 norm) instead of their least squares. The absence of a constraint that the observables follow a normal distribution would be an advantage with the more intense computational effort producing more realistic results. That would be particularly true for sets of measurements involving several apparatuses and observers, different field methodologies and spanning for several years; a situation similar to the measurements composing the old gravity network of the National Observatory. Claerbout & Muir (1973), Barrodale & Young (1966) and, more specifically, Fuchs (1983), analyzing the problem of adjusting large geodesic networks, proposed an algorithm for minimizing the function $\Phi = V^T PV$ in the L_1 sense by turning the problem equivalent to a linear programming optimization process solved by the SIMPLEX method. The viability of using robust statistic techniques to the adjustment of gravity networks is now being investigated.

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The connection of the 1st order Gravity Network of Albania to the IGSN71 in Athens Greece

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Summary

The tying up of the Albania gravity network with those of the neighbouring countries was imperative.

The station at East Air Terminal of Athens Airport in Greece was chosen for this purpose since IGSN71 include this station which is tied up with the stations in Rome and Britain (Hipkin et all 1987).

The gravity measurements resulted in a diference of 130.68+0,10 mGal between the two reference points (Athens-Jercucati).

1. Introduction

The International Gravity standardisation Net 1971 (Morelli et al., 1974) was established from weighted adjustment of relative observations with gravity meters and pendula, in combination with some stations, where absolute gravity measurements were made. The IGSN71 includes no reference sites in Albania. The existed gravity networks in this country developed with respect to a reference point at Tirana, where a zero gravity value was assigned.

However, the necessity for tying up the Albanian Gravity net with those of the neighbouring countries was imperative. One of the main reasons was the compilation and the continuation of the gravity anomaly maps of Albania (scale 1:500.000 & 1:200.000) with those of adjacent countries for the interpretation of the gravity field, in terms of crustal structure studies.

Gravity measurements between stations in Albania and Greece was chosen to be made, specificaly with the gravity station at East Air Terminal of Athens Airport, which is tied up with IGSN71 stations in Rome and Britain (Hipkin et al., 1987), using Lacoste & Romberg gravity meters.

2. The Gravity Observations

The gravity measurements were performed with two gravity meters (No 468 and 470) of 25M III type, having a sensitivity of 0.01 mGal. Their 4000 mGal range provides the possibility of making gravity ties between points, which have large difference in values of geographic latitude.

Prior to the beginning of the gravity measurements, the gravity meters were subjected to various test controls as in the following:

i) Level Checking Control

An initial test of the longitudinal and transverse levels was made. The optimum sensitivity controlled by the tilt of each instrument was cousidered.This procedure is performed by first keeping fixed the longitudinal level and subsequently changing the indication at the transversal level at the two opposite directions and taking readings at prefi fixed intervals. The peak of the obtained tuns curve should then coincide with the perpendicular axis of the diagram shown in figure 1. The same procedure is repeated for the transversal level. The curves (Fig.1) obtained in this manner are usually not symmetric and should therefore be properly adjusted.

ii) Beam Sensitivity Control

The beam sensitivity of each instrument was properly controlled by the fine dial counter by moving the light bean first to the right and secondly to the left from the center of the full optical scale a step of one scale unit.

The magnitude of the difference,"d", between readings on the right and on the left side of the scale should be within the interval 1.0 to 1.2.In our measurement procedure,the difference "d"was within this limit and therefore,no further adjustment was required.

iii) Calibration Control

Measurements along the Elbasan calibration line with the above mentioned gravity meters were made. This calibration line was established in 1960, using various gravity meters, such as Askania Werke, Gak, ZS-2/66 and CG-2. The gravity observations were made in a sequence from the stations PM-3 to PM-5 ,of 76.484 mGal difference, along this calibration line at time intervals not greater than 2 hours.

The meters Range was also checked in two stations of Known "G" by carrying measurements in closed loops at different time intervals within the year.These measuring cycles were obtained when earth Tides behave linearly.
Based on the average values of these cycles we obtained:

$$C_{468} = \frac{\Sigma C_n}{n} \doteq 0.10312 \text{ mGal/scale} \quad \text{for } n=8$$

$$\& \quad C_{470} = \frac{\Sigma C_n}{n} = 0.09914 \text{ mGal/scale} \quad \text{for } n=6$$

3. Tying up of the the two 1st order nets

The tying up to the two reference points of the respective 1st order nets was performed with the simultaneus use of the above mentioned gravity meters along the itinerary Athens-Kakavia-Tirana according to the scheme A-B-C-C-B-A-A-A-C.

The readings of the meters were corrected for the drift from the "0" of the instrument.

Since the used instruments behave linearly and measurements are planned at time intervals of linear behavioure of the Earth tides there is no need for applying the later.

The Earth tides for the hole 1991 at 10'interval were calculated and the time intervals of constant slope were choosed appropriate for field operations. The correction for the drift applied though was linear according to the slope coeficient obtained from the average of the repetitive observations at the same station.

The polygon sides of the connection network Fig.2 were estimated from the average of the repetitive measurements of each measuring sycle Table 1.

Discrepancies of the order of +0.10 mGal were accepted between the used sides of the polygon if else new measurement cycles were performed to obtain the desired accuracy.

Control measuring cycles were also made to ensure the quality of the measurements which resulted in less than +0.05mGal accuracy.

Following the above tying procedures and calculations to the "0" station of the Albania 1st order Network in Tirana was assigned the value of 980173.285+0.10mGal.

DISCUSSION

The implementation of the above task is considered invaluable since will allow the unification of the Gravity data of Albania to its neighboures.The interpretation of the gravity data will be also expanded for areas where previously was impossible such those close to the borders.

Acknowledgments

We wish to thank the Geological Survey of Albania for having approved this work,West-East European Gravity Project (at 1991) for the Financial help.It is to be Remembered with respect Miss Suzan Coron for the help given for the knowledge of the International Gravity Network and her encouragement to promote this work. We are indebted to Dr. Fairhead D. for his useful discussions.

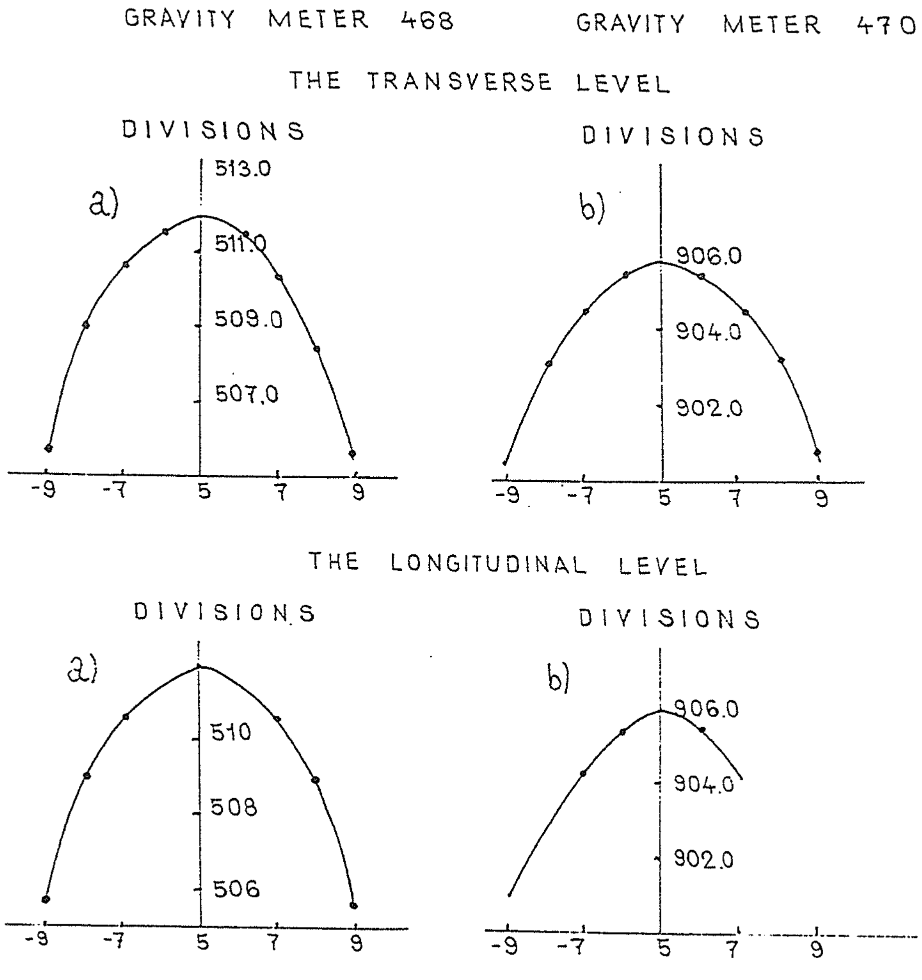

Fig 1 CHECKING THE LEVEL SENSITIVITY

Fig. 2. 1st order Gravity Net of Greece and the Stations used to Connect Argirokastra to Athens.

Table 1

Station	Location Name	Average value of sides for every instrument (mGal) G - 468	G - 470	Mean value of the sides of polygon (mGal)	Absolute Gravity value (mGal)
1	ATHENS *				980042.605±010
		2.06	2.09	2 . 07	
2	Megara				
		-59.18	-59.17	-59 . 17	
3	Likoporia				
		-60.84	-60.84	-60 . 84	
4	Dolcini				
		-21.41	-21.42	-21 . 41	
5	Antirio				
		27.30	27.38	27 . 34	
6	Lisimakeia				
		36.58	36.42	36 . 50	
7	Amfilochia				
		-23.92	-23.92	-23 . 92	
8	Hani Terovon				
		-22.59	-22.59	-22 . 59	
9	IOANINA airport				
		-43.24	-43.20	43 . 22	
10	Kakavia				
		68.91	68.91	68 . 91	
11	Jergucat				
		23.11	23.10	23 . 10	
PM - 6	Gjirokastra				980055.805±010

* By R.G.Hipkin et all., (1987).

THE RESIDUAL GRAVITY ANOMALY FIELD FOR SOUTH-EASTERN NIGERIA FROM TERRESTRIAL GRAVITY DATA

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ABSTRACT

A programme to cover Nigeria with gravity observations of the density required for geodetic application is currently being executed by the University of Lagos. Results obtained so far cover the South-Eastern portion of the country and they are based on the International Gravity Standardisation Network 71 (IGSN 71) station located within the premises of the former United State Embassy in Lagos. Bouguer gravity anomalies have been computed from the observed field data and the residual gravity anomalies also obtained for this region : latitude 4°.5 N to 6°.0 N and longitude 6°.5 E to 9°E.

1. INTRODUCTION :

The Surveying Department of the University of Lagos, Nigeria, initiated a programme in 1978 to systematically cover the whole country (Nigeria) with terrestrial gravity data. As things stand, only the states, presently designated Akwa Ibom, Abia, Imo, Cross Rivers and Rivers States have been covered with gravity Surveys of a densification appropriate for geodetic work [4, 15]. This detailed gravity survey, taken along established routes, extends from latitude 4°.0 to 6°.0 N and longitude 6°.5 to 8°.8 E, as shown in figure 1.

The residual anomaly field for the project area was determined as follows :

(1) Observed gravity data, g , was reduced to Bouguer gravity anomalies Δg_b.

(2) The region was subdivided into geographical grid squares of size 25 min x 25 min.

(3) The Bouguer gravity anomalies were transformed in space to predicted gravity anomalies Δg_p at the nodes (the intersections) of the grids.

(4) The regional gravity anomaly field $\Delta \overline{g}$ is then computed.

(5) Residual gravity anomalies Δg_r are computed through

$$\Delta g_r = \Delta g_b - \Delta \overline{g} \quad (1)$$

Equation 1 forms the basis of the gravimetric method for geophysical prospecting, based on some model of the underlying [5, 6].

2. TERRESTRIAL GRAVITY

Available evidence indicates that oil prospecting companies obtained some gravity data in the 1960's for the coastal towns where most of the oil prospecting industries are located. Notable among these works are those of Cratchley (1960), Cratchley and Jones (1965), Hospers (1965), Hedberg (1968) [4].

The 1970's witnessed an increase in geodetic activities in Nigeria. Gravity surveys were now required not only for geophysical prospecting but also for the numerous geodetic applications.

This interest in the geodetic applications of gravity data led to the surveys by Ajakaiye (1970 - Present), Olajiga (1972), Ojo (1974), Adighije (1976), Offrey (1976 - 1978), Orupabo (1978), Balogun (1981). Apart from the works of Orupabo (1978) and Balogun (1976), who used IGSN 71 (International Gravity Standardisation Network) stations as bases for their observations, most of the other works quoted above established independent base stations for their various works [4, 14].

Thus, even if their data are made available, the problem of standardising the gravity observations made on different bases will be expected to yield inconsistent results in geodetic applications.

A La Coste and Romberg gravimeter was used for the gravity observations carried out by the University of Lagos and based on the IGSN station located within the premises of the United States Information Service Building (formerly the U.S. Embassy). Other details of this IGSN station include :

IGSN Nos.	03663B
Latitude	6°27'
Longitude	3°24'
Height	6.10 m
Gravity value	978.12163 gals.

The 73 stations observed in all were reduced to Bouguer gravity anomalies based on the 1967 ellipsoid of reference [15]. These gravity anomalies Δg_{67} have now been reduced to the equivalent value on 1980 ellipsoid of reference Δg_{80} by the conversion [2, 4, 8].

$$\Delta g_{80} = \Delta g_{67} + k_1 + k_2 \tag{2}$$

k_1 is an expression that converts Δg_{67} to Δg_{80}

$$k_1 = -\left(0.8316 + 0.0782\ Sin^2\phi - 0.0007\ Sin^4\phi\right) mgal \tag{3}$$

while k_2 is the latitude (ϕ) dependent Honkasalo correction :

$$k_2 = 0.037\left(1 - 3\ Sin^2\phi\right) mgal \tag{4}$$

For a description of the physical location of these stations, refer to [14, 15]. We shall subsequently refer to these Δg_{80} values simply as Δg.

3. REGULARISATION OF THE OBSERVED FIELD ANOMALY

For simplicity of analyses, it is usually desirable to transform the randomly distributed observed anomaly field to a more spatially regular field based on some geometrical pattern.

The vector of the observed field Δg_b is thus converted to a vector of the pseudo-observed field $[\Delta g_P]$ at the intersection or nodes of geographically defined square grids. Least squares prediction methods were used for this transformation :

$$\left[\Delta g'_P\right] = \left[C_{P_{ij}}\right]\ \left[C_{i,k} + E_{i,k}\right]^{-1}\ \left[\Delta g_b\ \right] \tag{5}$$

$\left[C_{P_{ij}}\right]$ and $\left[C_{i,k}\ \right]$ are respectively the cross covariance and autocovariance matrices of the prediction. $\left[E_{i,k}\right]$ is the error covariance matrix (diagonal). The covariance function $C(s)$ which characterises the statistical field distribution may be derived from [9, 10].

$$C(s)\ \frac{C(O)}{\left(1 + (s/d)^2\right)^m} \tag{6}$$

where s is the spherical distance between the gravity points while d and m are parameters for the locality of interest, derived from a knowledge of the observed field anomalies. The values of d and m for the use in this work were obtained by a mathematical experimentation technique. Starting with a value of 757 for $C(O)$ in [13], for this locality, a pattern search optimisation procedure yielded the following optimum values for the parameters of equation 6 :

$$\begin{aligned} C(O) &= 751 \\ m &= 0.5 \\ d &= 50 \text{ km} \end{aligned} \qquad (7)$$

Figure 2 shows a manual contour plot of these pseudo observations.

4. THE REGIONAL AND RESIDUAL ANOMALY FIELDS

The regional is computed by passing a plane surface through a conceptualised mean anomaly field for the locality of interest. A non-orthogonal polynomial may be used to represent this surface, Z.

In the X and Y coordinate axes, Z can be represented by a polynomial of the first order thus :

$$Z = aX + bY + c \qquad (8)$$

This type of polynomial has been found very suitable for computing regional anomalies [1]. A least squares fit yields the following values of a, b and c :

$$\begin{aligned} a &= 0.3666 \\ b &= 3.2729 \\ c &= 17.5629 \end{aligned} \qquad (9)$$

The residual field Δg_r described in equation 1 can now be computed as :

$$\Delta g_r = \Delta g_b - Z \qquad (10)$$

where Z now represents $\Delta\bar{g}$ defined in equation 1.

5. CONCLUSIONS

Figure 3 shows a contour plot of the residuals, Δg_r, at 5 mgal intervals. These residuals which range between - 40 mgals and + 45 mgals show a reflection of the general geology of the south-eastern part of Nigeria. Three areas of local positive anomalies sandwich the two northwest-southeast trending arms of negative anomalies. The positive anomaly, + 45 mgal, between longitude 7°.0 E and 7°.5 E and latitude 4°.5 and 4°.7 N could be attributed to either a shallow basin underlain by intermediate rocks or basic igneous intrusives occurring predominantly in the basement. The steep gradient in the North of this positive anomaly may imply that the anomalous body causing it lies at shallow depth. The prevalence of oil exploration activities in this area is worthy of note. At present, the gravity survey project of the University of Lagos is concentrated at the Western part of the country. It is hoped that at the conclusion of the entire project, a terrestrial residual gravity anomaly field for the country will be produced for application in geodetic computations and geophysical prospecting.

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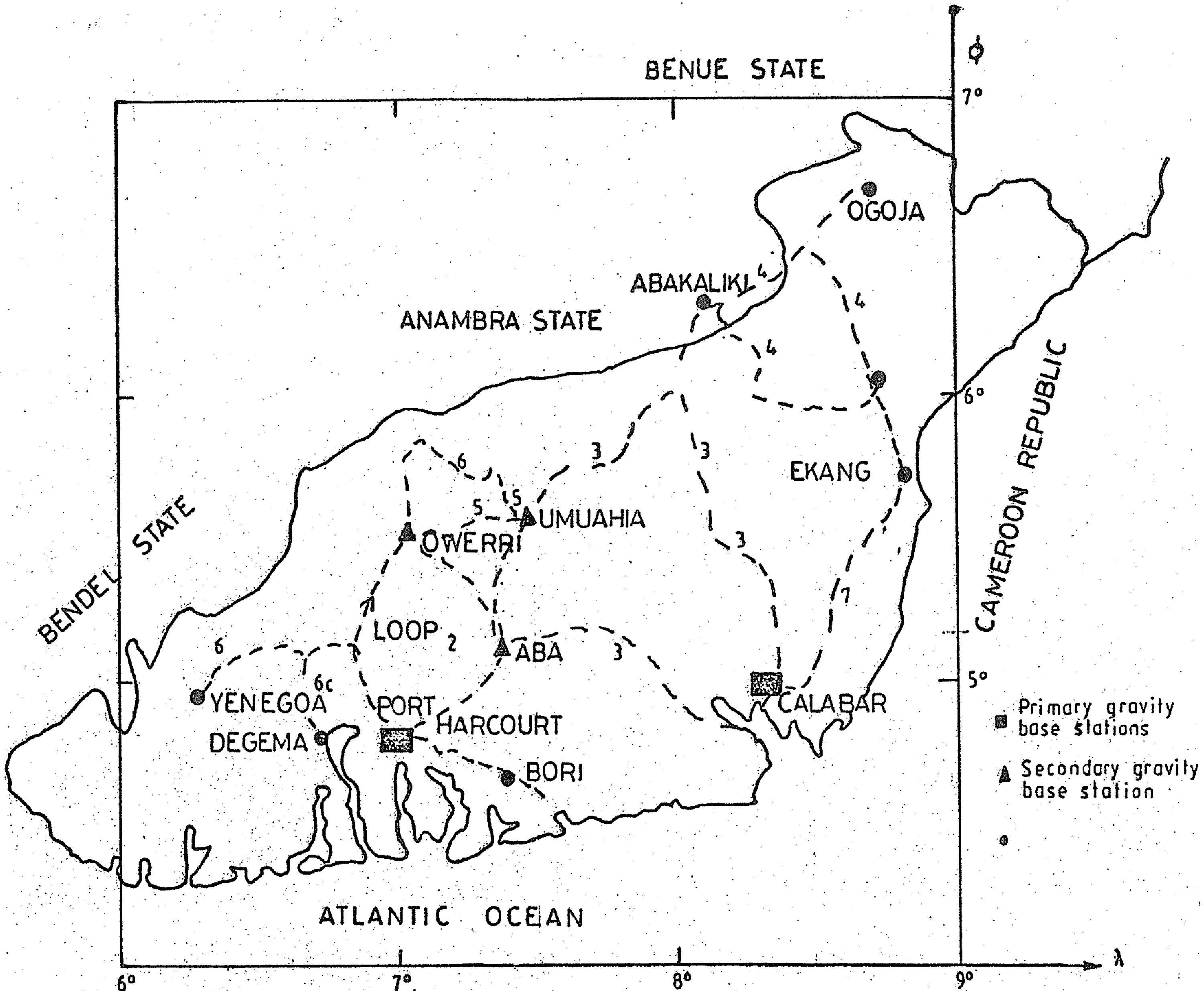

FIG. 1 South-Eastern Nigeria showing loops for gravity survey

Scale: 1:2,000,000

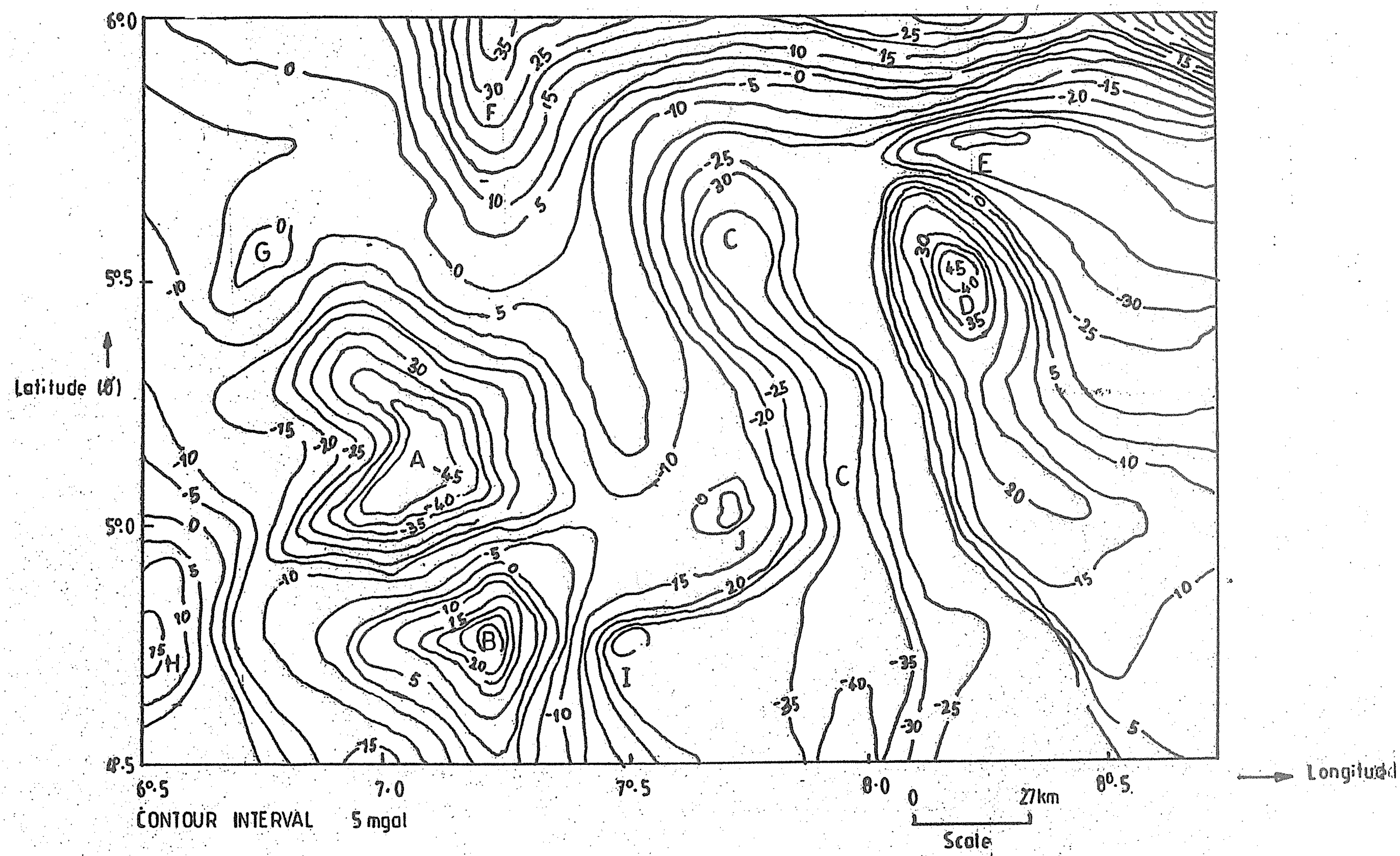

FIG. 2. CONTOUR OF ORIGINAL BOUGUER GRAVITY ANOMALIES

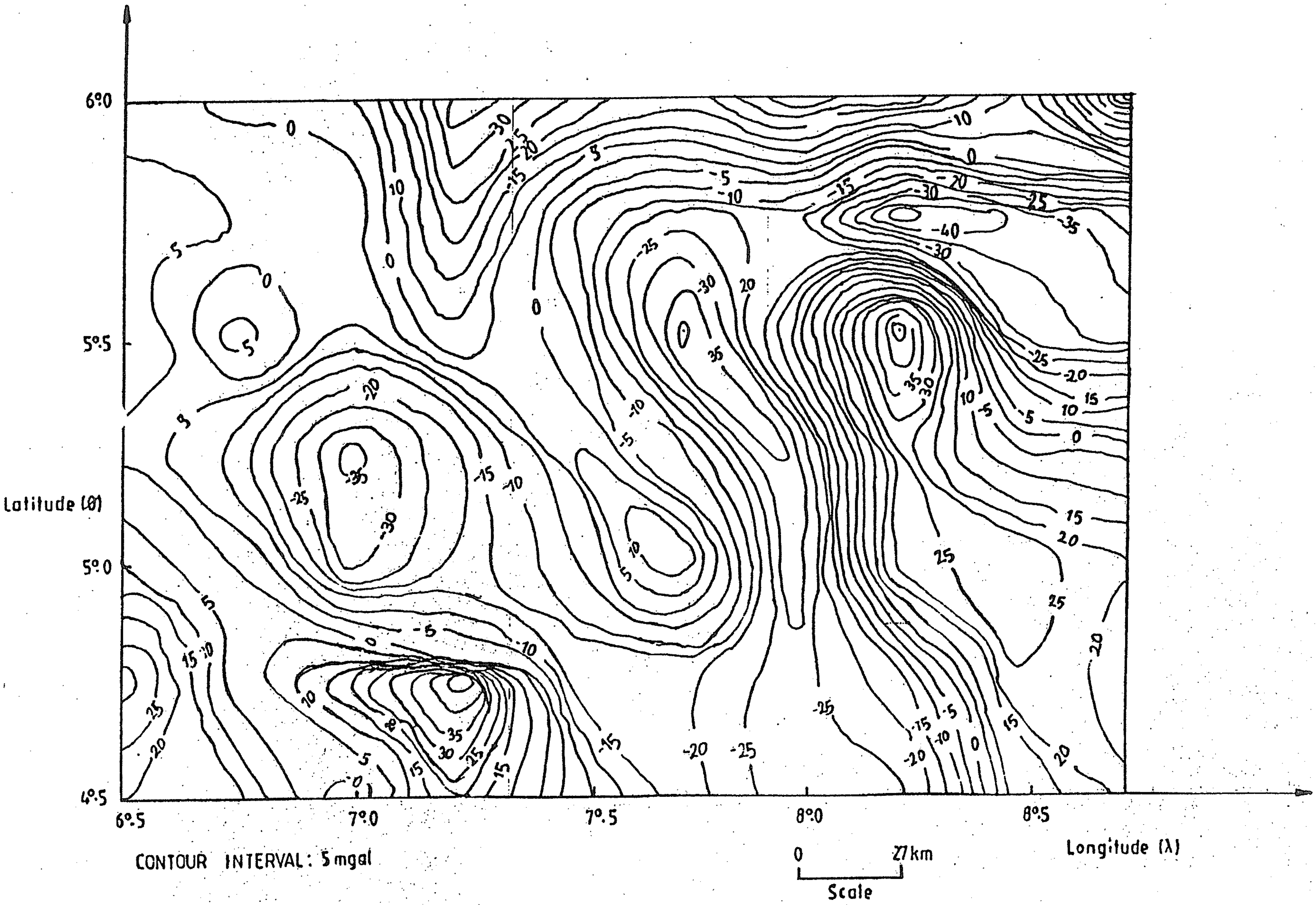

FIG. 3 CONTOUR OF RESIDUAL GRAVITY ANOMALIES

The National Geophysical Data Center's Gravity CD-ROM Project

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Introduction

The National Geophysical Data Center's (NGDC) Gravity Program represents an ongoing activity of the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA). In addition to its national role, NGDC operates on behalf of the International Council of Scientific Unions (ICSU) the World Data Center - A for Solid Earth Geophysics and Marine Geology and Geophysics. This *Gravity CD-ROM* project supports our role to collect and distribute data associated with the Earth's potential field, including: gravity, magnetics, and topography for use by scientists internationally.

The Gravity Program at NGDC is divided into two component projects: "land and satellite-derived data" and "shipborne oceanographic data." These projects are managed by the Solid Earth Geophysics (SEG) Division and the Marine Geology and Geophysics (MGG) Division, respectively. The focus of this project is the diverse activities of SEG. Readers should also be aware of the marine shipborne data, containing integrated bathymetry, gravity and magnetic measurements, and the availability of these data on CD-ROMs.

Type of Project

The project's focus is on *data management* associated with diverse categories of gravity data, such as: station records, absolute measurements, representations of the Earth's field in grid formats, and geoid determination. The entire effort is directly supported by the United States of America's federal government.

The data management philosophy of the *Gravity CD-ROM* project is somewhat innovative in stressing data documentation and lineage. Instead of employing the standard approach of restructuring the contributor's data to a standard format -- often losing information such as quality control fields or multiple anomaly computations -- all information is maintained and documented using a standard data description procedure and flexible data dictionary. This approach maintains a higher fidelity of the data.

Input

NGDC functions as an intermediary between data producers and data users. Data come from numerous national and international sources, including government agencies, academic institutions and commercial sources. NGDC assimilates these data by performing standard quality control, documentation, and archival procedures.

Several members of NGDC's staff hold advanced degrees in geophysics and have decades of experience in the collection and processing of gravity data. They, and others, have high levels of expertise with respect to computer technologies. Computers at the Data Center are fully networked and include IBM-compatibles, UNIX machines (i.e., Sun), and Macintoshes. Rarely do data contributors provide data in a format that we cannot process.

In addition to most standard software capabilities, NGDC has developed some specialized software to validate, document, inventory, and access data. These software products are in the public domain and available over Internet (either on-line or by special arrangement). Of special interest is a library of programs called FREEFORM which has: (1) platform-independent format description language which facilitates input and output of data (such as translations of data to and from ASCII to binary), (2) utilities that compute histograms of each field within a data file, (3) utilities that convert multiple representations of latitude-longitude to standard notations, and (4) conversion functions to generate standard formats (such as HDF).

Data contributed to the NGDC Gravity Program include: station observations, anomalies (Bouguer, free-air, and isostatic), satellite altimetry, sets of coefficients, deflections of the vertical, and geoid models. Data are typically digital and represented as tabular data sets (i.e., point data) or regional and global grids. Data are most frequently transmitted via magnetic tape or Internet. Data occasionally are contributed as maps; however, these are kept primarily as library items and not digitized. Almost 100 data sets are available, representing approximately 600 Megabytes of information in binary format.

Ancillary data include geomagnetic data and digital elevation models.

Output

NGDC has many modern computer devices and provides data in almost any format specified by a data customer. For convenience and cost savings considerations, we have compiled all of the data onto CD-ROM (with access software), and this has become the most popular media requested. Nevertheless, a user can request subsets of any data set on forms such as diskettes, magnetic tapes, printouts, or customized maps (a considerably more expensive option). In the last 80 requests for gravity data, 75 requested the CD-ROM, 4 requested magnetic tape and 1 requested diskette.

The staff of NGDC has extensive discipline and data management expertise. Standard and customized services can be provided. For example, data can be re-gridded and sent to the user as a write-once CD-ROM.

Data contained on the *Gravity CD-ROM* include: station observations, Bouguer and Free-air anomalies, satellite altimetry, sets of coefficients, deflections of the vertical, and geoid models. Data are represented as tabular data sets (i.e., point data), regional and global grids, and summarized as images (in GIF and PCX formats). Data access software is available to help browse, extract, and reformat the data; this data access is currently supporting DOS and MS-Windows (with UNIX and Macintosh software in development).

The *Gravity CD-ROM* is intended for potential field researchers -- perhaps engaged in exploration or planetary studies. It is available to all countries for which the U.S. has diplomatic ties. Those who contribute data to the Data Center are entitled to complimentary copies as part of our normal data exchange agreements, others can acquire it at a nominal cost (about $300).

Data Links and Information Flow

U.S. government agencies are the primary contributors to the National Geophysical Data Center. They include the Defense Mapping Agency, NOAA's National Ocean Service, and the U.S. Geological Survey. Several dozen other contributors exist in government, academia, and commercial organizations (nationally and internationally).

Data costs are nominal and provide negligible limitations, especially since contributors are entitled to data free in exchange. The only limitations (due to political constraints) are those associated with countries for which the United States does not have diplomatic relationships; even in these situations, accommodations could be negotiated, if requests are addressed to the World Data Center.

Future

The National Geophysical Data Center plans on producing updated CD-ROMs every year-or-so, depending on the acquisition of new and improved data sets.

Some popular and reasonably-small data sets may also be made available over Internet.

By late 1994 and early 1995, we hope to expand our software access support to include windows environments within UNIX and Macintosh.

The World Data Center-A hopes to expand its role to support international programs as an archive and data facilitator.

National Geophysical Data Center's GEODAS CD-ROM Project

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Dan Metzger

Marine Geology and Geophysics Division
National Geophysical Data Center
Boulder, CO 80303

Introduction

The National Geophysical Data Center's(NGDC) GEOphysical Data System (GEODAS) CD-ROM project represents the Marine Geology and Geophysics (MGG) Division's continuing efforts to collect, archive, index, catalog, and distribute trackline marine geophysical data, including bathymetry, magnetics and gravity. These GEODAS CD-ROMs contain the bulk of the world's marine trackline geophysical digital data apart from such high-density or multi-valued data as seismic reflection or multibeam bathymetry. In those cases, GEODAS contains index information regarding the existence and location of such data and pointers to external sources of these data.

Type of Project

This project is one of continuing *data management,* as NGDC is the national repository for marine geophysical data. Co-located with the MGG Division within NGDC are the International Hydrographic Organization's(IHO) Data Center for Digital Bathymetry and the International Council of Scientific Union's (ICSU) World Data Center A for Marine Geology and Geophysics. The focus of the GEODAS CD-ROM project is to make all available digital MGG trackline data readily accessible the world's scientific investigators. NGDC is one of three national data centers operated by the National Environmental Satellite Data and Information Service(NESDIS) of the National Oceanic and Atmospheric Administration(NOAA) within the Department of Commerce of the United States federal government. The project is supported by the United States federal government.

Input

NGDC serves as the national repository for all geophysical data collected at public expense and thus as an interface between those who collect data and those who wish to use data. The GEODAS CD-ROM project is one of continuing evolution, a data management system migrated to CD-ROM in the last four years. The project management personnel have been stable for over the last decade and acquired experience and expertise has been reinvested to produce continued improvement and advancement in storage, indexing, retrieval and delivery of the data. Many of the MGG division staff hold advanced degrees and hold decades of experience in marine data collection and management.

Two fundamental philosophies guide the management and delivery of marine geophysical data: self-documentation of data and abundant and intimately linked metadata. Both of these are presently accomplished through the use of the MGD77 data exchange format (Hittelman, et al., 1989) which begins with an ASCII "header record" describing the data and its format in a structured, though easily interpretable text description.

The importance of self-description or self-documentation is to permit ready access by those not necessarily familiar with the data, it's structure and format. This "first encounter" description of both the data, its quality and characteristics, and format in which it is structured provides any user with a clear and concise description by which they may access and use the data.

The importance of metadata is ever growing as the cost of collecting primary data grows ever larger. Abundant metadata is the key to applications of the data to purposes which may not have been conceived at the time of collection and which may prevent the necessity of re-collecting a parallel or duplicate set of data because of the absence of appropriate metadata. By intimately linking the metadata to the primary data, the probability of chance separation of the two and subsequent loss is greatly reduced. The MGD77 data exchange format has served as an early and robust model for these twin principles of data management.

Data management at NGDC begins with receipt, from institutions and agencies, of incoming data on 9-track magnetic tape, by direct file transfer using various networks, on floppy diskettes, or on special, agreed-upon, transfer media. Contributors are responsible for providing adequate metadata, a standard for which is the "header information" of the MGD77 format. Data provided in other formats are accepted when accompanied by sufficient metadata and documentation of format.

Upon arrival, the data are copied for archival security, scanned to confirm the format, and transferred to a high-end PC, where it is quality controlled via specialized programs, predominantly in FORTRAN and C, which have evolved over the life of the project for the specific applications required. These programs reformat the data into complete MGD77 format and check for obvious problems in the data set, such as data values outside expected ranges and improbable navigational patterns. In addition, plots of the navigation are reviewed and questionable data are further reviewed by staff personnel. If deemed necessary, contributors are consulted since the operational philosophy regarding quality assurance of data is: the prime responsibility for quality of data rests with the collector or custodian of the raw data. Most often it is the collector, alone, who has the only reliable information by which adjustments can be made.

Following quality assurance checks, the data are inventoried, using software developed in-house, to create an abstract (inventory) of the data which becomes the basis for providing users information about data spatial distribution. This inventory file includes just enough data to define the trackline of the original cruise and the locations where data were collected. This usually amounts about 2% of the original number of navigational points. The inventory trackline is displayed on a computer screen, where it is once again reviewed for obvious errors.

The time-history of marine gravity data collection and entry into the GEODAS system, in terms of cumulative surveys(cruises) and cumulative records (individual data) is shown in Figure 2.

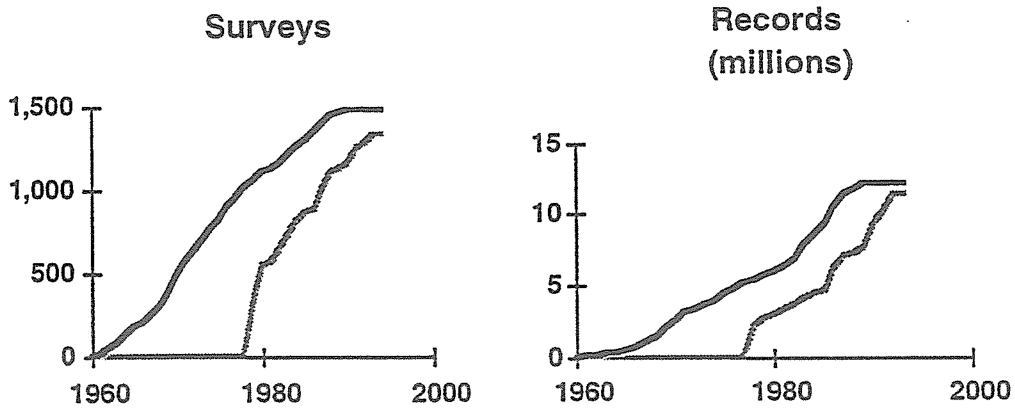


Figure 1. Cumulative time-histories of marine gravity data collection (dark) and entry into the GEODAS system (light).

The rise in accumulated, digital, marine gravity data is relatively linear over the 30 years, beginning with digital collection around 1960. The flattening of the curve in the last 3 years is probably an artifact of proprietary hold periods placed on data, although it may reflect the effective competition of remotely sensed marine gravity from satellite altimetry data.

Output

Once the data are assimilated into the GEODAS system, they may be queried on the basis of many of the characteristics contained in the metadata, including location, source institution or platform, date collected or date entered into the system. Locational trackplots are readily displayed or plotted on hard copy and the data are likewise readily downloaded to local storage from the stored, compacted form on CD-ROM. This output system is presently PC-based, so designed to address the broadest user community with the present CD-ROM technology.

Existing GEODAS software permits searches, summary plots and downloading of data to memory or disk from the CD-ROMs. Summary plots may be saved in PostScript files. These functions are identical to those provided from the Center in previous years with software on "mainframe" hardware. Advances in both machines and algorithms have now made this type of computational power available on the desktop.

Data Links and Information Flow

The source of most of these data are United States federal and federally funded academic marine geophysical cruises, thus fulfilling the requirement that data collected at public expense be made available in return to the public. Some marine gravity data in the GEODAS system has come from international and commercial sources, where those sources have seen fit to put their data in the public domain. Much of these data are acquired through formal and informal data exchange agreements, whereby the Center's acquisition of data from a source entitles that source to no-cost access to equivalent amounts of data from the Center.

On the other hand, the users of the GEODAS CD-ROMs are distributed world-wide. Sister data centers, both in academia and internationally are on the standard distribution list for these products. With the modest cost of the GEODAS CD-ROM, these data are available to virtually anyone with an interest in marine geophysical data, thus individual investigators may access the accumulated, public domain, marine geophysical, trackline data and is no longer dependent on centralized computer and data management facilities.

Continuing and Future Developments

The major revision to the GEODAS system in the last few years has been to put the entire trackline geophysical data base on two CD-ROM's and distribute it to users with access software for IBM compatible PC's at a very modest cost. Thus not only the gravity data, but bathymetry and magnetics as well are available to individual investigator with no more sophisticated computer equipment than a PC and a cost that would have been charged for only a few surveys delivered on magnetic tape a few years ago. While initial design of access software is for DOS-based IBM-compatible computers to accommodate the largest population of users, continued development of software for similar access by Windows, Macintosh, Sun UNIX, and other users is underway. Also systems for access to the GEODAS inventory over the internet via Mosiac is being developed.

Reference

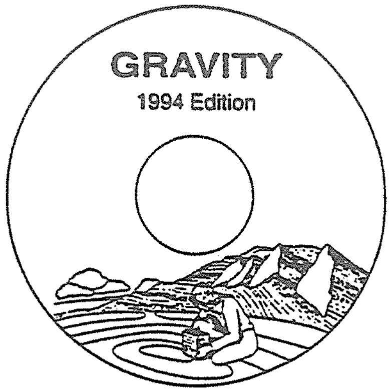
Hittelman, A.L., R.C. Groman, R.T. Haworth, T.L. Holcombe, G. McHendrie, and S.M. Smith, "The Marine Geophysical Data Exchange Format - 'MGD77' (Bathymetry, Magnetics, and Gravity)," Key to Geophysical Records Documentation No. 10 , February, 1989 (Revised), National Geophysical Data Center, Boulder, Colorado.

Gravity CD-ROM (1994 Edition)
Now Available . . .

The land gravity data base at the National Geophysical Data Center (NGDC) has been significantly enhanced and improved by several new and important contributions. The entire collection, jointly developed with the National Ocean Service, is now available on the 1994 edition of the Gravity CD-ROM.

New Data, New Resources . . .

The compilation contains approximately 100 data sets, including:



- U.S. station data
- absolute measurements
- gridded data—34 regional and 9 global data sets
- regional surveys—32 U.S. and 7 international data sets
- correlative data—geoids (U.S., Canada, and global) and global topography (5-min. grid)

The compact disc contains 634 megabytes of data partitioned into 1,490 files. Approximately 25 percent of the data are observed values—regional station data collections (separated primarily by contributors) and absolute gravity measurements. Grids and other derived summary data sets represent another 65 percent of the data. The remaining 10 percent of the disc contains geopolitical base map reference data. Accompanying the CD-ROM is access software (for DOS and MS-Windows) which allows you to extract the data from the disc.

Improved Research Quality . . .

Station Data:

- Instead of following the traditional approach of making all data sets fit into a fixed common format, NGDC has developed a standard format description, preserving fields unique to a specific data collection and allowing access the data without concern for formats.
- Common data conversion techniques were employed to represent all data as binary values; reformatting utilities let the end-user reconstruct the data in an ASCII (or binary) representation of their choice.
- Terminology has been standardized within a data dictionary facilitating comparison of different data sets.
- To support end-user validation of the data minimum and maximum values and histograms distributions have been prepared for each parameter within each data set format. In addition, point distribution plots have been prepared for each data set (and are included as .PCX and .GIF images).

National Geophysical Data Center

Gridded Data:

- Grids developed by numerous scientific organizations and individual investigators have been incorporated.
- To help with comparison of these grids, NGDC has regridded some of the compilations into latitude-longitude projections. The original grids are also preserved in separate files.
- To help summarize the data, the grids are graphically displayed in .PCX and .GIF images.

Geopolitical Data:

- To support the posting of data and information onto maps, geopolitical boundary data have been included. These data are from multiple sources such as the Department of Defense's World Vector Shoreline and Central Intelligence Agency's World Data Bank II (WDBII) data, and include coastlines, rivers, and political boundaries.

Most of the gravity data on the Gravity CD-ROM were processed and documented using FREEFORM, a format specification system developed by Ray E. Habermann of NGDC. FREEFORM was used for many functions (primarily within the regional and grid directories) on this compact disc. This included conversion to binary representations, documentation of ASCII and binary formats, and sorting, indexing, and creating distribution statistics on every data field in every format processed.

Improved Data Descriptions . . .

In the access software:

- Help files typically identify the source of data, the size and structure of the file and list processing specifics and references.
- Histograms of field-value distribution accompany each tabular data set. These are often useful in identifying data outliers, missing value strings, and general distribution characteristics.
- Dictionary definitions accompany each field within each data set defining terminology, units of measure, values of coded fields, and data off-sets (if applicable).

In documentation files:

A separate documentation file containing Postscript, WordPerfect (5.1), and ASCII files has been prepared with a detailed directory tree of the Gravity CD-ROM and extensive documentation on each data set including:

- source information
- text summary of data set
- file name and size (in both binary and ASCII)
- data formats (in both binary and ASCII)
- printout of first 10 records
- maximum and minimum values of each field.

Those without printer support can request a paper copy of this documentation for a small, additional cost.

Using FREEFORM:

Additional documentation and reformatting facilities are available with FREEFORM. These utilities are included on the CD. Of specific interest are the FREEFORM applications:

- CHECKVAR—computes histograms of field values
- NEWFORM—reformats data to user specifications

Generalized Summary of the Gravity CD-ROM

U.S. INTERPRETED STATION DATA
- Defense Mapping Agency (DMA) U.S. Station Data Base (1993 version)
- DMA Author Index File (1993 version)
- National Geodetic Survey (NGS) U.S. Station Data Base

ABSOLUTE
- Absolute gravity data from NGS
- The tabular structure of original NGS data
- Access software developed by NGS

BOUNDARY
- Boundary data from WDBII
- Coastline data from WDBII
- River data from WDBII
- World Vector Shoreline (1:1M scale)
- World Vector Shoreline (1:12M scale)
- World Vector Shoreline (1:250K scale)
- World Vector Shoreline (1:3M scale)
- World Vector Shoreline (1:43M scale)
- World Vector Shoreline (1:200K scale)
- Access software developed by the Department of Defense

GLOBAL
- 5-min global topography grid
- GEOSAT data—44 repeat cycles
  - Ascending
  - Descending
  - C program to decode internal GEOSAT headers
- 5-min marine gravity (72°N–72°S) grid derived from SEASAT
- RAPP
  - Geoidal coefficient data (complete to 360°)
  - 7.5-min gravity free-air anomaly grid
  - 30-min grids of gravity and geoid anomalies
  - 1-degree grids of gravity and geoid anomalies
  - Access software for 7.5- and 30-minute grids
  - 7.5-min grid of sea height elevations
- 3.0-min x 2.4-min southern ocean (30°–72°S) grid derived from GEOSAT
- Irregular world-wide gravity (72°N–72°S) grid derived from GEOSAT

GRIDS
- 1-km Bolivian gravity grid
- 10-min Canadian gravity geoid
- 2.5-min gravity grid of N. America
- 6-km gravity grid of N. America
- EROS grids from USGS's EROS Data Center
  - 2.5-km Bouguer grid for Idaho
  - 2-km Bouguer isostatic and density grids for Idaho batholith
  - 2-km Bouguer grid for Maine
  - 2-km Bouguer and isostatic grid for Nevada
  - 2-km Bouguer grid for Ohio
  - 2.5-km Bouguer grid for Utah
- GEOID93 (3-min grids of free-air deflections and height)
  - Hawaiian regional grids
  - Puerto Rico and Virgin Island regional grids
  - United States regional grids
- DOC & IMG files of all grids in IDRISI format
- 8-km isostatic gravity grid of U.S.
- 4-km isostatic residual grid of U.S.
- 2.5-min isostatic gravity grid of U.S.
- 8-km isostatic topo grid of U.S.
- 1.5-km Bouguer grid for Minnesota
- 2-km depth-to-basement grid for Nevada
- 2-km gravity (at basement) grid for Nevada
- 4-km Bouguer gravity grid of U.S.
- 1-deg gravity grid for the former Soviet Union

REGIONAL
- NGS Gravity Monument Network (1990) for U.S.
- Southern Africa data
- Alaska data isostatic based upon 25-km crust
- Alaska data isostatic based upon 30-km crust
- Argentina, Bolivia and Chile data
- Antarctica data
- Arctic National Wildlife Refuge and Alaska peninsula data
- Bolivian Bouguer data
- Cadiz California data
- California and southern Nevada data
- DMA Global Network Base Stations (1993 version)
- National Base Net for Egypt
- Regional Surveys from USGS's EROS Data Center
  - Idaho data
  - Idaho Batholith Study
  - Maine offshore data
  - Maine onshore data
  - Ohio data
  - Utah data
- Holitna, Alaska, data
- Indiana data
- Japan data
- Minnesota data
- Nevada data
- New Mexico data
- National Petroleum Reserve in Alaska data
- Ohio data
- Oklahoma data
- Oregon data
- NGS Vertical Control Stations Descriptions
- South America data
- Vernal Quadrangle (Colorado/Utah) data
- Wisconsin data

SUPPLEMENTAL
- FREEFORM software and tutorial
- Data set descriptions
- Dictionary of terms

Ordering Information

An order form for the Gravity CD-ROM is included with this brochure. In addition to the Gravity CD-ROM product, NGDC can provide select groupings of data and sub-data collections from the gravity data archive in a variety of media formats, including one-off CDs and floppy disks. Electronic delivery of data via Internet is also possible.

If you have questions about our products or services, please contact us and we will be happy to help you. Data contributors and academic researchers should call for information about obtaining data by special arrangement.

National Geophysical Data Center
NOAA, Code E/GC1
Department 936
325 Broadway
Boulder, CO 80303 U.S.A.

Phone: 303-497-6120
Fax: 303-497-6513
TDD: 303-497-6958
Internet: info@luna.ngdc.noaa.gov
Telex: 592811 NOAA MASC BDR

Related Data Collections

U.S. Gravity Station Data:

The **DMA gravity data base** consists of more than 925,000 non-terrain corrected observations for the conterminous United States and Alaska, and was compiled by the Defense Mapping Agency in 1993. The file includes observed gravity, free-air and Bouguer anomalies, latitude and longitude, and elevation. The **NGS gravity data base** for the U.S., compiled by the NOAA's National Geodetic Survey in 1993, consists of nearly 1.4 million observations. The file contains most of the data in the DMA gravity file, plus data from additional sources. In addition, NGS has included terrain corrections for all point gravity values where substantial variations in local topography exist. Both of these data bases include an **Author Source Index File**—a bibliographic listing of data contributors. Each data source or compilation is given a numeric code which is included in a field at the data record level. The two national data sets contain much of the same data; they differ primarily in quality control techniques and data reduction procedures. *Both of these data sets are on the Gravity CD-ROM, but may be purchased as a separate product.* Contact NGDC for pricing or for more information.

The Geophysics of North America CD-ROM:

This compilation (581.5 megabytes) is a collection of land and marine geophysical data for North America. Much of the data was collected under the auspices of the Geological Society of America's Decade of North American Geology, including gravity, magnetics, earthquake seismology, thermal aspect, and stress data. Satellite imagery data, topography, and additional grids of magnetics and gravity are also included. *The gravity data on this CD—Bouguer and isostatic anomalies (4- and 6-km resolutions)—are also on the Gravity CD-ROM.* The Geophysics of North America CD-ROM includes documentation, and access software which allows you to view the data, complete with geographical references and data contour overlays. Contact NGDC for pricing or for more information.

SE-0703
2/94

Gravity CD-ROM Order Form

National Geophysical Data Center, 325 Broadway, E/GC4,
Dept. 936, Boulder, Colorado 80303-3328 U.S.A. [FAX: 303-497-6513]

FROM	
NAME	
COMPANY OR INSTITUTION	
DEPARTMENT OR DIVISION	
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NAME	
COMPANY OR INSTITUTION	
DEPARTMENT OR DIVISION	
ADDRESS	
CITY STATE ZIP COUNTRY	
TELEPHONE, FAX, AND/OR E-MAIL NUMBER	

PRODUCT #	DESCRIPTION	UNIT PRICE	QUAN.	TOTAL
1018-A27-001	Gravity CD-ROM (1994 Edition) (includes CD, access software, and documentation)	$278		
	PLEASE PREPAY ALL ORDERS			
			SUBTOTAL	
			$10.00 Non-U.S.A. Handling	
			TOTAL	

Express delivery is available at an additional cost. Please call (303-497-6128) or fax (303-497-6513) for more information.

☐ Enclosed is a check or money order payable to **COMMERCE/NOAA/NGDC**

☐ MasterCard ☐ American Express ☐ VISA

Charge card number: ______________________ Expiration date: __________

Authorized signature: ______________________

Please print name on card: ______________________

The National Geophysical Data Center (NGDC) continually updates its mail lists for announcing new data services and products. Please mark your areas of interest (below) and you will receive future mailings. If you are already on NGDC's mail list but wish to receive information for additional disciplines, please check off the disciplines you want added. If no changes are needed, disregard this form. You will continue to receive data announcements for your areas of interest.

MARINE GEOLOGY AND GEOPHYSICS

___ Bathymetry
___ Deep-Penetration Seismic Reflection Profiles
___ Shallow, High Resolution Seismic Reflection Profiles
___ Marine Magnetics
___ Marine Gravity
___ Deep Sea Drilling Data
___ Well Logs
___ Marine Sediment/Rock Descriptions, Analyses
___ Engineering and Physical Properties of Sediments
___ Marine Minerals Data
___ Geographic Boundaries
___ Geochemistry
___ Paleomagnetism

SOLID EARTH GEOPHYSICS

___ Aeromagnetics
___ Earthquake Data Base - Epicenters
___ Earthquake Strong Motion
___ Geomagnetic Declination
___ Geomagnetic Models
___ Geothermics
___ Gravity
___ Satellite Remote Sensing
___ Seismic Refraction
___ Topography
___ Tsunami
___ Volcanology
___ Well Logs
___ Geochemistry
___ Paleomagnetism and Archeomagnetism
___ Satellite Solid Earth Geophysics
___ Global Change

SOLAR-TERRESTRIAL PHYSICS

___ Aurora (satellite or ground images)
___ Cosmic Rays
___ Geomagnetic Variations
___ Geostationary Satellite Space Environment
___ Indices
___ Ionospheric Phenomena
___ Low Altitude Satellite Space Environment
___ Satellite Anomalies
___ Solar Flares
___ Sunspots
___ Solar Indices Bulletin
___ Solar-Geophysical Data Monthly Publication Series
___ UAG Reports
___ Geomagnetic Indices Bulletin
___ Magnetosphere
___ Numerical Models

GLACIOLOGY

___ General
___ Sea Ice (digital)
___ DMSP Satellite Imagery
___ Snow Cover (digital)
___ Great Lakes Ice (freshwater ice)
___ Glacier Photos
___ Passive Microwave Data
___ Glaciers
___ Ice Cores
___ Ice Sheets

PALEOCLIMATOLOGY

___ Corals
___ Historical Records
___ Ice Cores
___ Lake and Bog Sediments
___ Marine Sediments
___ Tree Rings

Final Meeting of the West-East Europe Gravity Project (WEEGP)

April 6 - 8, 1994 - Leeds (UK)

WEEGP has been a collaborative project between the Bureau Gravimétrique International (Toulouse, France), the Geophysical Exploration Technology (GETECH) of the Department of Earth Sciences (University of Leeds, UK), the Institute of Physics of the Earth, IPE, and the International Scientific Environmental Center, ISEC (Moscow, Russia). It involved all European Countries, and those of Eastern and Central Europe were the most eager to participate.

The project brought together all public and privately owned gravity data for onshore and offshore Europe to generate a unified digital database so that a regular grid (5 to 10 km in size) can be constructed of Bouguer, free air and topography. This digital grid will provide an important new hydrocarbon exploration tool to help evaluate the spatial relationship and crustal tectonic settings of sedimentary basins thoughout Western and Eastern Europe. It will also contribute greatly to the new European Geoid project by filling some data gaps.

The project followed the highly successful African and South American gravity projects, completed in 1988 and 1991 respectively, which were sponsored by several oil companies. The project unified the extensive national databases in Western Europe and adjacent marine areas with the data sets of Eastern Europe (and Western Russia).

The Bureau Gravimétrique International, as one of the major gravity data bases of the world, could not but participate, which had been agreed by the BGI Directing Board.

WEEGP started at the beginning of 1992 and terminated at the end of July 1994. The project products are available in totality to the sponsors. Contributing countries and associate members receive some of them for their area of interest. BGI is archiving the products but has to honour the confidentiality attached to them. These products are :

a) Digital grids of interpolated Bouguer, free air and topography data

b) Digital locations of all gravity stations used in the study

c) Digital technical database providing technical details of all surveys used, owners and confidentiality

d) Technical report displaying the digital database on a country by country basis

e) Colour map atlas at scales of 1:2 million and 1:5 million Bouguer/free air anomaly maps interlinked with satellite altimetry derived data beyond the continental margins.

l

The main contribution of BGI to the project consisted in : data collection, and data validation, computation of free air gravity from satellite altimetry derived geoid heights, and advices on matters of geodetical nature.

The final meeting was held in a friendly atmosphere in Weetwood Hall, a University owned congress hotel, and gathered about fifty participants from twenty-four countries. It was organised as a workshop and consisted in :

- a business meeting
- a technical meeting
- a scientific meeting

The programs and time-tables of these meetings are given hereafter, followed by the abstracts of the scientific presentations and poster displays.

(I) Business Meeting

6 April, 1994
14.00 - 16.00

Weetwood Hall, Otley Road
Bramley Room

1• Chairman's Communications

2• Overview of Project and Status of Data Acquisition

3• Timetable for Dispatch of Products to Sponsors

4• Higher Resolution Grids

5• Associate Member's Regional Map

6• Financial Matters

7• Optional Extras

8• East European Magnetic Study / European Geoid Study

9• Any other business

(II) Technical Meeting

7 April, 1994

Weetwood Hall
Lawnswood Suite

09.00 - 09.30	Derek Fairhead	Introduction
09.30 - 09.40	Steven Spink	Overview of processing sequence
09.40 - 09.50	Chris Green	First stage processing
09.50 - 10.05	Dave Manton	Databasing
10.05 - 10.15	Simon Campbell	Land Processing
10.15 - 11.00	Coffee Break	
11.00 - 11.20	Dave Manton	Marine processing
11.20 - 11.40	Rob Daniels	Terrain data
11.40 - 12.10	Chris Green	Satellite data processing
12.10 - 12.20	Steve Neil	Mapping
12.30 - 13.30	Lunch in the Weetwood Hall restaurant	
13.30	Coach to GETECH	

14.00 - 16.30 Demonstrations of WEEGP software and techniques :

A. Digitisation of maps using a digitising tablet (GETECH)

B. On-screen digitisation of scanned maps (GETECH)

C. Automatic map digitisation by character recognition (ISEC)

D. Interactive validation of land gravity data using 3D visualisation (GETECH)

E. Validation of land gravity data using statistical and visualisation techniques (BGI)

F. Along track validation of marine gravity data and cross-over error analysis (GETECH)

G. Validation of repeat satellite altimetry data and analysis of cross-over errors (BGI)

H. Database viewing and extraction and automatic report generation (GETECH)

I. Map production software and techniques (GETECH)

16.30 - 17.00 Discussion of the talks and demonstrations

17.00 Coach to Weetwood and Bodington

18.45 - 22.30 Coach from Bodington and Weetwood to Conference Dinner at the Garden Restaurant, Harlow Car Gardens Harrogate

(III) Scientific Meeting

8 April, 1994

Weetwood Hall
Lawnswood Suite

Morning Session (chairman : A.B. Watts)

09.00 - 09.25	M.G. Kogan, J.D. Fairhead & G. Balmino	High Resolution Gravity Data in the Former USSR : Implications for Lithospheric Fabric and Strength
09.25 - 09.50	L. Torres, J. Castelo Branco & J. Carvalho	Gravity Data Modelling and Integrated Structural Interpretation of part of the Sado Basin
09.50 - 10.15	J.D. Fairhead	Application of Semi-automated Methods of Gravity and Magnetic Interpretation to Modelling Basin Structure in Central Western Siberia
10.15 - 10.50	Coffee Break	
10.50 - 11.15	H. Denker, W. Torge	Present status of European Geoid
11.15 - 11.40	A. Olgiati, M. Sarrailh D. Green & G. Balmino	Satellite Altimetry Data Products Methodology and Results
11.40 - 12.05	M. Everaerts, Ch. Poitevin, W. De Vos & M. Sterpin	Geophysical Modelling in the Brabant Massif
12.05 - 12.30	A. Casas, V. Pinto & Ll. Rivero	Actual Status of Gravity Measurements in Spain and Strategies to improve the Regional Coverage
12.30 - 14.00	Lunch in Weetwood Hall Restaurant	

Afternoon Session (chairman : G. Balmino)

14.00 - 14.25	A.B. Watts	The Free Air Gravity "Edge Effect" Anomaly and Flexure of the Lithosphere at Atlantic-type Continental Margins
14.25 - 14.50	M. Wilson	Magmatism and Basin Dynamics - Europe East and West of the Tornquist Line
14.50 - 17.30	Poster display. Each contributor gave a five minute overview of their poster	

S. Bushati, A. Kodra & A. Zajmi	Some aspects about the Relationships of Ophiolitic Albanides with Surrounding Rocks based on the Results of the Geophysical Studies
F.A.M. Santos, M. Moreira, A.R.A. Alfonso & L.A. Mendes-Victor	Modelling of the Chaves Graben (Portugal) by combined Geophysical Data
P.J. Sousa	Gravity Map of the Portuguese Section of the Iberian Pyrite Belt
T. Basic, M. Brkic, K. Colic, D. Medak & B. Pribicevic	Geodetic - Gravimetric Method for better Modelling of Geological Structures in the Test Area of Croatia *(cancelled)*
S. Bushati, E. Lagios, V. Veizaj & A. Angelopoulos	The Connection of the first Order Gravity Network of Albania to the IGSN71 in Athens, Greece
J.W.F. Edwards, J.R. Evans & A.J. Gibberd (presented by G.S. Kimbell)	Images of the Gravity Field West of Shetland
A. Olgiati, M. Sarrailh, G. Balmino	From Satellite altimetry to free-air gravity anomalies. Different methods
J.D. Fairhead	Overview of GETECH activities

PRESS RELEASE

Dr. Georges Balmino (left), Secretary General of the IUGG and Head of BGI, is seen presenting Prof. J. Derek Fairhead (right), Managing Director of Geophysical Exploration Technology Ltd (GETECH : a University of Leeds company), with the International Gravity Bureau medal for "outstanding works on the Earth's gravity".

The award was presented at the final meeting of the West-East Europe Gravity Project (WEEGP) held in Leeds (UK) in early April to which 60 gravity specialists from more than 23 European countries attended.

The meeting was a unique occasion in that it was the first time the east and west European scientists had worked together to enable all the available gravity data for the region 25°W (Greenland) to 60°E (Urals) and from the Mediterranean to 80°N to be compiled into a single unified data set.

The gravity data included satellite altimeter derived data from Topex-Poseidon, ERS1 and GEOSAT missions integrated and inverted to marine free air gravity values using new, novel techniques not previously used. These data have been integrated with the terrestrial marine surface, ice surface and sea bed gravity measurements and linked to a near complete coverage of land based gravity measurements allowing accurate 8 km x 8 km grids of Bouguer, free air and topography to be derived for the whole land mass of Europe. Only the southern half of Former Yugoslavia and Turkey still remain data gaps.

WEEGP has taken over three years to complete during which time GETECH has worked closely with East Europeans and the then Soviet scientists and politicians to declassify their gravity data so that they could be incorporated into WEEGP. The project has been a major collaborative effort between GETECH, the now Russian Academy of Sciences and BGI, and funded by nine oil companies : BP, Conoco, Exxon, JNOC, Marathon, Phillips, Shell, Texaco and Unocal. Since the project does not officially end until June 1994 both the amount of data and number of sponsors could still increase.

Sponsors are clearly eager to start their analysis of the WEEGP data set, particularly in the part covered by the former USSR (approx. 50 % of the project area). This interest also extends east of the Urals into West Siberian basins and beyond, now the focus of GETECH's latest collaborative project "North Central Asia Gravity Project (NCAGP)" which is mapping the rest of the Former USSR at a similar 8 km grid resolution.

The release of WEEGP products and the initial release of NCAGP products in May 1994 means that many oil companies will be buried deep in gravity data never previously released due to their classified nature.

GETECH will be presenting a paper on this study at EAPG Vienna, June 1994.

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J.D. Fairhead, head of GETECH, receives a medal
in recognition for his exceptional work and entrepreneurial
activities in WEEGP.