

ASSOCIATION INTERNATIONALE DE GÉODÉSIE

BUREAU
GRAVIMÉTRIQUE
INTERNATIONAL

BULLETIN D'INFORMATION

N° 84

Juin 1999

**18, Avenue Edouard Belin
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FRANCE**

INFORMATIONS for CONTRIBUTORS

Contributors should follow as closely as possible the rules below :

Manuscripts should be typed (single spaced), 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).

NOTA : *The publisher welcomes the manuscripts which have been prepared using WORD 6 for Macintosh and also accepts ASCII files on diskettes 3"5.*

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.

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. 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 O 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 have 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.

Table. 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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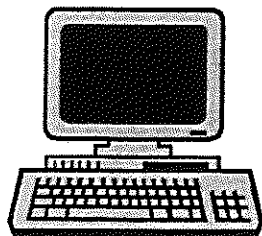
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**BUREAU GRAVIMÉTRIQUE
INTERNATIONAL**

Toulouse

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PART I
INTERNAL MATTERS

GENERAL INFORMATION

- 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 information 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, an issue contains the National Reports as presented at the International Gravity Commission meeting. 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 (83 have been issued as of December 31, 1998 but numbers 2,16, 18,19 are out of print).

- or subscribe for regularly receiving the two bulletins per year (the special issues are obtained at additional cost).

Requests should be sent to:

*Mrs. Nicole LESTIEU
CNES/BGI
18, Avenue Edouard Belin
31401 TOULOUSE CEDEX 4 - 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 75 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

2.5.1. CD-Roms

The non confidential data, which have been validated by various procedures are available on two CD-ROMs.

The price of these is :

- 800 (Eight hundred) French francs for individual scientists, universities and research laboratories or groups working in geodesy or geophysics.*
- 3000 (Three thousand) French francs for all other users.*

Most essential quantities are given, in a compressed format. The package includes a user's guide and software to retrieve data according to the area, the source code, the country.

2.5.2. Data stored in the general data base

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.

<p style="text-align: center;">EOL LAND DATA FORMAT RECORD DESCRIPTION 126 characters</p>
--

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 - $R \leq 5$ Meters	
		2 = $5 < R \leq 20$ M (approximately 0'01)	
		3 = $20 < R \leq 100$ M	
		4 = $100 < R \leq 200$ M (approximately 0'1)	
		5 = $200 < R \leq 500$ M	
		6 = $500 < R \leq 1000$ M	
		7 = $1000 < R \leq 2000$ M (approximately 1')	
		8 = $2000 < R \leq 5000$ M	
		9 = $5000 \text{ M} < R$	
		10...	
	28-29	System of positioning	(2 char.)
		0 = no information	
		1 = topographical map	
		2 = trigonometric positioning	
		3 = satellite	
	30	Type of observation	(1 char.)
		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	
	31-38	Elevation of the station (unit : centimeter)	(8 char.)
	39-40	Elevation type	(2 char.)
		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)	
	41-42	Accuracy of elevation	(2 char.)
		0 = no information	
		1 = $E \leq 0.02$ M	
		2 = $.02 < E \leq 0.1$ M	
		3 = $.1 < E \leq 1$	
		4 = $1 < E \leq 2$	
		5 = $2 < E \leq 5$	
		6 = $5 < E \leq 10$	
		7 = $10 < E \leq 20$	
		8 = $20 < E \leq 50$	
		9 = $50 < E \leq 100$	
		10 = E superior to 100 M	
	43-44	Determination of the elevation	(2 char.)
		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	
	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) Simple Bouguer anomaly with a mean density of 2.67. No terrain correction	(6 char.)
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) <i>computed according to the next mentioned radius & density</i>	(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 2.3 km to 167 km 13 = tc computed from 5.2 km to 167 km 14 = tc (unknown radius) 15 = tc computed to zone M (58.8 km) 16 = tc computed to zone G (3.5 km) 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	Accuracy of gravity 0 = no information 1 = $E \leq 0.01$ mgal 2 = $.01 < E \leq 0.05$ mgal 3 = $.05 < E \leq 0.1$ mgal 4 = $0.1 < E \leq 0.5$ mgal 5 = $0.5 < E \leq 1.$ mgal 6 = $1. < E \leq 3.$ mgal 7 = $3. < E \leq 5.$ mgal 8 = $5. < E \leq 10$ mgal 9 = $10. < E \leq 15.$ mgal 10 = $15. < E \leq 20.$ mgal 11 = $20. < E$ mgal	(2 char.)
94-99	Correction of observed gravity (unit : microgal)	(6 char.)
100-105	Reference station <i>This station is the base station (BGI number) to which the concerned station is referred</i>	(6 char.)
106-108	Apparatus used for the measurement of G 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)	(3 char.)

	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.)

<p style="text-align: center;">EOS SEA DATA FORMAT RECORD DESCRIPTION 146 characters</p>
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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 - $R \leq 5$ Meters	
		2 = $5 < R \leq 20$ M (approximately 0'01)	
		3 = $20 < R \leq 100$ M	
		4 = $100 < R \leq 200$ M (approximately 0'1)	
		5 = $200 < R \leq 500$ M	
		6 = $500 < R \leq 1000$ M	
		7 = $1000 < R \leq 2000$ M (approximately 1')	
		8 = $2000 < R \leq 5000$ M	
		9 = $5000 \text{ M} < R$	
		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 = $E \leq 0.02$ Meter	
		2 = $.02 < E \leq 0.1$ M	
		3 = $.1 < E \leq 1$	
		4 = $1 < E \leq 2$	
		5 = $2 < E \leq 5$	
		6 = $5 < E \leq 10$	
		7 = $10 < E \leq 20$	
		8 = $20 < E \leq 50$	
		9 = $50 < E \leq 100$	
		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	(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) <i>computed according to the next mentioned radius & density</i>	(6 char.)
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 O2)	
	11 = tc computed from 1 km to 167 km	
	12 = tc computed from 2.3 km to 167 km	
	13 = tc computed from 5.2 km to 167 km	
	14 = tc (unknown radius)	
	15 = tc computed to zone M (58.8 km)	
	16 = tc computed to zone G (3.5 km)	
	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	Mathew's zone <i>when the depth is not corrected depth, this information is necessary. For example :</i> <i>zone 50</i> <i>for the Eastern Mediterranean Sea</i>	(2 char.)
94-95	Accuracy of gravity	(2 char.)
	0 = no information	
	1 = $E \leq 0.01$ mgal	
	2 = $.01 < E \leq 0.05$ mgal	
	3 = $.05 < E \leq 0.1$ mgal	
	4 = $0.1 < E \leq 0.5$ mgal	
	5 = $0.5 < E \leq 1.$ mgal	
	6 = $1. < E \leq 3.$ mgal	
	7 = $3. < E \leq 5.$ mgal	
	8 = $5. < E \leq 10.$ mgal	
	9 = $10. < E \leq 15.$ mgal	
	10 = $15 < E \leq 20.$ mgal	
	11 = $20. < E$ mgal	
96-101	Correction of observed gravity (unit : microgal)	(6 char.)
102-110	Date of observation <i>in Julian day - 2 400 000 (unit : 1/10 000 of day)</i>	(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	(1 char.)
	0 = without restriction	
	1 = with authorization	
	2 = classified	
123	Validity	(1 char.)
	0 = no validation	
	1 = good	
	2 = doubtful	
	3 = lapsed	
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_0), 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 :

$$\gamma_0 = 978031.85 * [1 + 0.005278895 * \sin^2 (\phi) + 0.000023462 * \sin^4 (\phi)] , \text{ mgals}$$

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 ($H = 0$ 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 ($667.2 \cdot 10^{-13} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$) $\Rightarrow k = 2 \pi G$
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

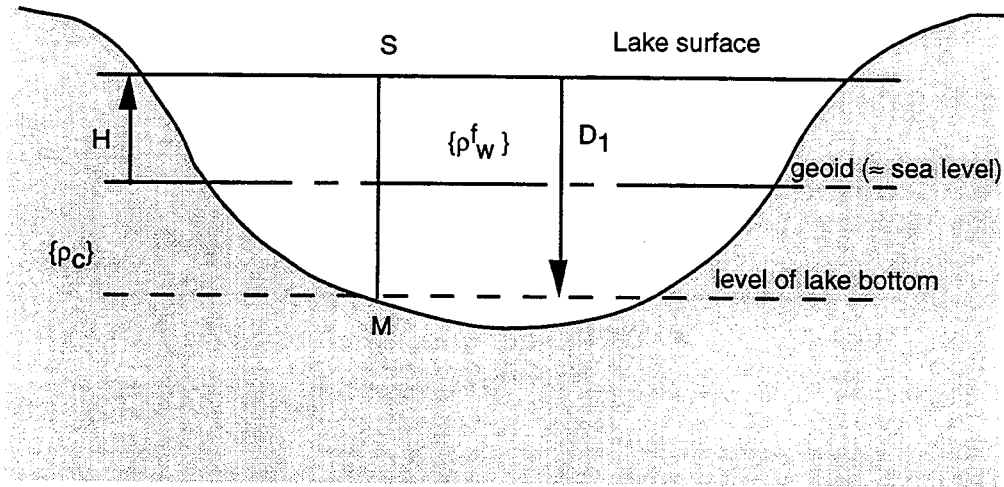
Formulas :

* 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_0 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 :



$$g_s = g_M + 2 k \rho_w^f D_1 - \Gamma D_1$$

$$\Rightarrow FA = g_s + \Gamma H - \gamma_o$$

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

$$\begin{aligned} \delta g_s &= g_s - k \rho_w^f D_1 + k \rho_c (D_1 - H) \\ &= g_s - k \rho_w^f [H + (D_1 - H)] + k \rho_c (D_1 - H) \\ &= g_s - k \rho_w^f H + k (\rho_c - \rho_w^f) (D_1 - H) \\ \Rightarrow BO &= \delta g_s + \Gamma H - \gamma_o \end{aligned}$$

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	$FA = g + 2 k \rho_c D_2 + \Gamma (H - D_2) - \gamma_0$ $BO = FA - k \rho_c H$
3	Ocean Surface	$FA = g - \gamma_0$ $BO = FA + k (\rho_c - \rho_w^s) D_1$
4	Ocean submerged	$FA = g + (2 k \rho_w^s - \Gamma) D_2 - \gamma_0$ $BO = FA + k (\rho_c - \rho_w^s) D_1$
5	Ocean bottom	$FA = g + (2 k \rho_w^s - \Gamma) D_1 - \gamma_0$ $BO = FA + k (\rho_c - \rho_w^s) D_1$
6	Lake surface above sea level with bottom above sea level	$FA = g + \Gamma H - \gamma_0$ $BO = FA - k \rho_w^f D_1 - k \rho_c (H - D_1)$
7	Lake bottom, above sea level	$FA = g + 2 k \rho_w^f D_1 + \Gamma (H - D_1) - \gamma_0$ $BO = FA - k \rho_w^f D_1 - k \rho_c (H - D_1)$
8	Lake bottom, below sea level	$FA = g + 2 k \rho_w^f D_1 + \Gamma (H - D_1) - \gamma_0$ $BO = FA - k \rho_w^f H + k (\rho_c - \rho_w^f) (D_1 - H)$
9	Lake surface above sea level with bottom below sea level	$FA = g + \Gamma H - \gamma_0$ $BO = FA - k \rho_w^f H + k (\rho_c - \rho_w^f) (D_1 - H)$
A	Lake surface, below sea level (here $H < 0$)	$FA = g + \Gamma H - \gamma_0$ $BO = FA - k \rho_c H + k (\rho_c - \rho_w^f) D_1$
B	Lake bottom, with surface below sea level ($H < 0$)	$FA = g + (2 k \rho_w^f - \Gamma) D_1 + \Gamma H - \gamma_0$ $BO = FA - k \rho_c H + k (\rho_c - \rho_w^f) D_1$
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	$FA = g + \Gamma H - \gamma_0$ $BO = FA - k \rho_i D_1 - k \rho_c (H - D_1)$

All requests for data must be sent to :

*Mr. Gilles BALMA
Bureau Gravimétrique International
18, Avenue E. Belin - 31401 Toulouse Cedex 4 - France
E-mail : Gilles.Balma@cnes.fr*

*In case of a request made by telephone, it should be followed by a confirmation letter, or fax.
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 as tarfiles on DAT cartridge (4 mm). for large amounts of data, or on
diskette in the case of small files. The exact physical format will be indicated in each case. Also a FTP anonymous
service is available on our computer center.*

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 CD-Roms : see 2.5.1.*
- . 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 DAT cartridge*
 - (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 scale, 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).

- . 5 F/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 $\Delta x \Delta'$ area : 10F/ $\Delta \Delta'$ 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

. on CD-Roms : see 2.5.1.

. 1 F per measurement for non commercial use (guaranteed by signed agreement), 5 F per measurement in other cases (direct or indirect commercial use - e.g. in case of use for gridding and/or maps to be sold or distributed by the buyer in any project with commercial application). Minimum charge : 500 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 the polygon.

3.2.3. Data Screening

. 1 F per screened point for non commercial use (guaranteed by signed agreement), 5 F per screened point in other cases (cf. 3.2.1.).

. 500 F minimum charge

3.2.4. Gridding

Same as 3.1.4.

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

DAT cartridge (4 mm) 100 F

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

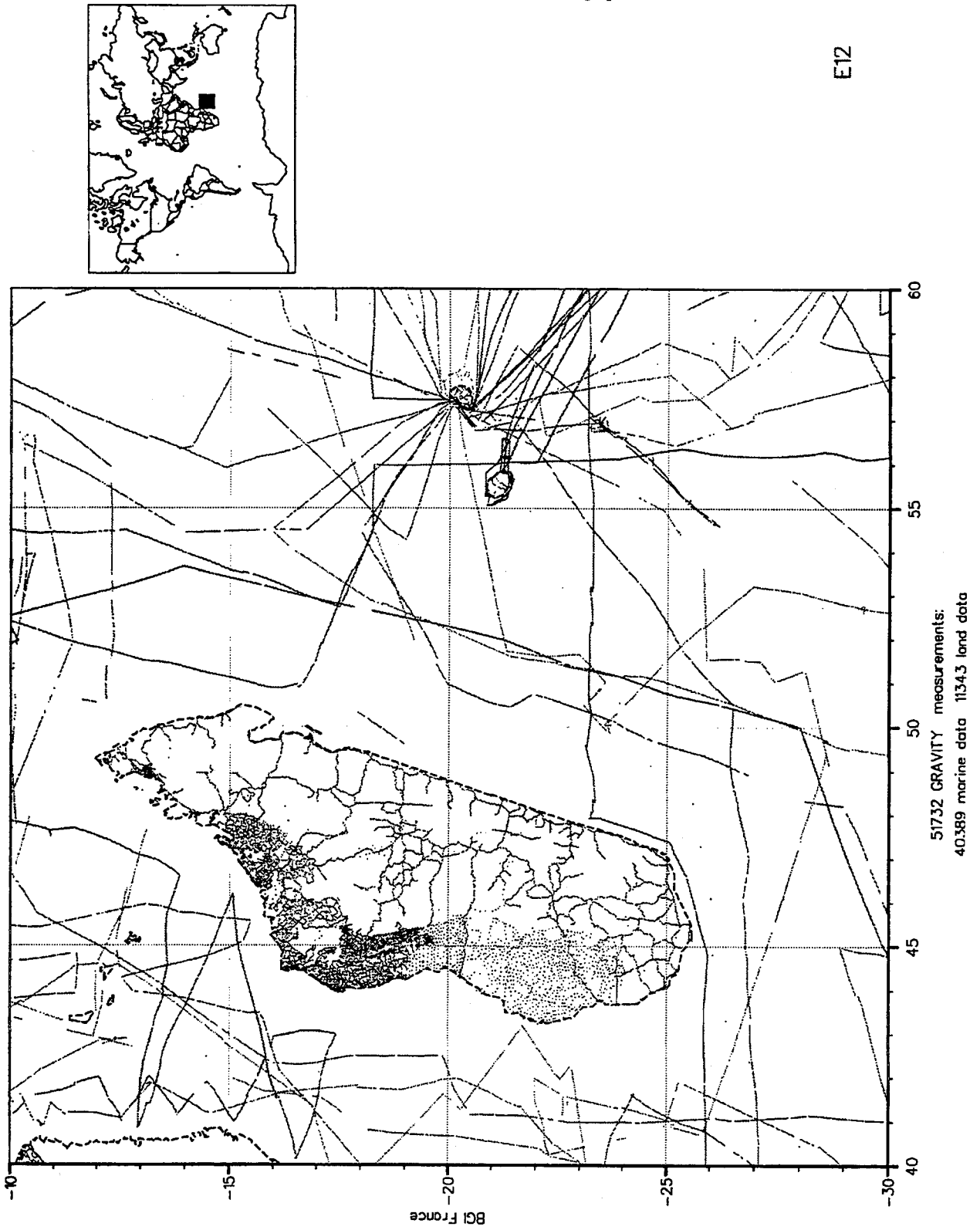
(Vol. 1 and 2)	1979	150 FF
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. Black and white copy of maps : 150 F per copy

. Colour copy : price according to specifications of request.

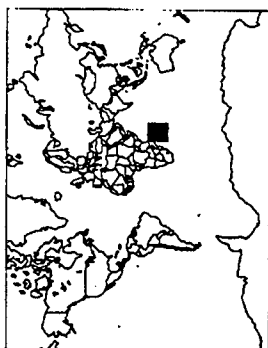
Mailing charges will be added for air-mail parcels when "Air-Mail" is requested)
--

Map 1. Example of data coverage plot



E12

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



BGI GRAVITY DATA
MEAN FREE AIR ANOMALY

1st field : number of points
2nd field : mean value (mgal)
3rd field : Std. Dev. (mgal)

E12

24	102	15	52	8	26	29	184	53	65	26	8	116	136	51	44	52	85	66
23.3	-38.8	5.6	-25.9	-14.5	-18.3	-27.7	-22.5	-23.9	-27.9	-8.2	-7.2	-5.5	-13.1	-5.8	-3.8	-1.5	-9.2	-13.9
10.1	42.1	6.2	12.0	1.3	4.3	17.6	26.3	10.3	26.7	37.4	24.0	8.2	11.1	6.0	12.2	23.2	9.1	9.4
118	39	53	37	41	37	85	85	2	2	37.4	82	43	29	3	25	68	40	37
-11.0	-14.1	66.2	-16.6	-16.6	-26.4		-42.6		77.7	-45.1	-12.9	-7.7	-16.9	-7.8	-2.6	-14.2	-1.7	-21.3
30.0	12.6	80.8	6.6	3.9	3.9	32	99	14	2.8	4.8	16.3	8.4	4.3	12	13.6	10.5	2.6	5.9
21	207	51	28	68	74	471	-98.0	37.9	54.8	15	101	26	26	35	58	50	6	16
-55.9	-41.0	-63.4	93.6	6.4	68.8	-47.1	-98.0	37.9	54.8	-32.7	-17.2	-12.3	-20.4	-23.8	-11.0	-8.6	-6.1	58.7
5.6	15.9	12.2	114.8	83.8	121.5	3.7	6.1	9.1	17.3	1.7	4.5	6.0	5.9	2.3	1.3	1.1	1.4	4.8
3	334	170	204	125	84	172	35	355	117	4	72				13.1	10.1	1.4	62
-47.8	-13.0	-40.3	-38.8	-52.1	-40.1	-38.4	-32.0	36.6	34.3	82.6	-5.9			-0.2	2.7	-4.5		12.4
18	30.1	117	8.3	4.7	5.6	8.0	37.7	36.6	15.9	10.5	3.5			6.7	0.0	5.5		54.4
249	13	88	84	97	87	101	12	42.3	47.6	-0.8	70.1			3.1	62	41	3	
13.8	-37.0	-28.4	-36.3	-42.4	-13.1	12	12	12.3	47.6	-0.8	70.1			-8.6	11.9	37	-0.8	12.3
72.1	3.0	4.0	7.6	5.2	5.2	62.8	32.6	18.4	20.2	4.5				4.7	4.2	7.3	11.4	0.4
1	220	54.9	396	15	103	32.9	617	38	47	35				40	6	32	9	68
-45.2	-40.7	-22.3	-63.3	-72.8	-63.1	-12.2	-18.2	-15.0	-36.5	1.3	-27.3			29.0	14	8.8	-7.4	-17.7
0.0	42.1	12.7	8.2	25.2	33.0	14.5	10.5	10.3	6.8	28.1	2.4			54.2	16	10.7	3.3	17.1
802	421	158	176	348	416	407	244	53	117	45	51			60	60	14	7.3	6
-20.1	-51.3	-40.4	-25.6	12.6	-5.2	-26.0	-3.2	50.4	0.3	-15.8	-14.9			-18.2	-14.3	-10.6	4.9	-18.4
14.1	40.2	18.0	10.6	19.8	15.2	8.9	12.8	93.5	20.4	12.2	11.7			3.6	13.9	16.2	9.3	2.5
22	81	96	136	782	369	83	76	10	66	3	27			79	106	14	16	64
-9.1	-47.6	-4.4	-18.1	6.1	8.0	-22.4	50.3	35.0	15.9	-43.9	-1.1			-2.2	3.4	-7.4	-16.8	-2.5
47	23	32	12.5	24.4	17.8	22.3	33.1	20.6	18.4	21.9	4.3			6.9	5.6	5.2	10.8	17.9
38.9	-27.4	21.1	7.5	-7.5	-8.2	46.4	62.1	23.2	89.5	-47.8				4.7	70	67	19.8	81
7.4	29.7	12.5	11.8	33.8	12.9	16.1	25.1	37.6	30.0	3.0				6.6	6.1	11.8	14.1	13.0
37	46	38	178	336	115	171	91	2	2	2	37	73	8.8	5.2	15.9	23.7	98.1	33.3
-41.2	-45.8	16.8	-20.2	-23.4	40.8	67.2	31.8	56.6	21	-0.8	-13.3	-8.8		-13.0	-25.8	-59.0	74.2	-14.7
8.6	15.1	19.8	10.0	18.7	20.0	18.7	26.5	21	11	13	12	8.2		8.9	24.2	105.9	72.2	27.0
24	96	12	6	151	144	49	104	81	43	43	37	8.2	23	24	47	366	71	46
-22.6	-21.2	-29.8	4.3	51	-15.8	49.4	48.6	47.0	-21.3	-3.8	-1.7	-3.7	8.8	14.9	-24.2	8.8	-31.9	-0.8
7.4	14.5	6.2	23	28.1	28.3	27.5	22.1	36.1	7.3	8.8	5.2	15.9	23.7	98.1	33.3	71.3	28.5	17.0
25	67	29	87	168	82	146	176	89	52	48	24	8		6.5	177	212	170	44
-25.5	-10.5	-16.1	13.8	-17.8	-4.3	26.4	-5.8	46.9	-24.8	2.7	-5.5	-18.5	13.0	281.3	-4.5	-28.4	-2.4	16.5
6.9	8.9	20.0	11.2	14.8	18.9	16.7	33.8	39.3	5.7	6.2	12	4.5	0	61.4	53.0	24.2	16.1	9.0
10	81	30	113	200	66	149	205	13	45	30			1	5	46	170	100	106
6.4	3.3	-20.8	30.0	17.6	41.8	29.4	74.6	3.6	-14.0	-6.0			1.6	-2.8	-4.4	-8.7	-15.0	-0.8
27.8	11.5	11.0	12.9	65.0	30.8	19.1	34.6	3.6	17	12.3			0.0	10	46	11.9	24.7	14.4
122	33	110	76	237	118	46	157	145	116	21.4	15.7	105	76	97	79	29.4	166	87
-2.8	31	27.0	11.4	31.8	36.0	32.3	-7.5	-2.8	-25.0	7.3	21.2	5.2	11	5.2	9.0	-8.6	2.6	-8.0
10.0	91	12.3	23.4	14.8	17.4	29.4	6.2	7.5	13.6	10.6	16.0	3.5	7.2	32.8	9.6	26.1	10.0	14.1
-28	99	26	132	150	159	131	34	17	47	47	27	27	6	49	173	41	29	
-3.2	12	39.4	50.4	30.0	10.0	27.0	-7.5	-7.5	-16.5	3.7	3.7	1.6	42.8	3.1	5.9	-21.1	-12.5	
6.1	15.8	10.6	10.8	9.8	14.3	42.3	31	4.0	3.6	5.4	3.8	9.3	3.2	14.8	10.7	25.3	17.2	
109	130	58	58	104	161	123	3	1	45	24	6.5	80	13	42	70	100	47	26
-8.9	-1.5	17	12	19.5	11.4	41.3	66.7	-24.9	-12.2	-1.7	-4.4	4.0	13.9	0.5	-8.9	6.4	-3.7	-8.1
9.6	10.3	7.0	14.4	32.7	28.4	41.0	19.1	0.0	6.2	7.3	7.6	7.5	3.2	23.3	3.7	10.7	2.9	9.6
37	77	51	49	34	37	30	35	48	71	88	26	21	9	15	105	26	57	13
-27.9	10.9	22	-14.7	-22.2	-7.4	-6.7	-7.5	-20.5	-16.2	-12.2	-7.1	-11.9	-8.7	-17.9	2.1	9.4	-7.7	-18.2
4.9	23.4	10.5	21.6	21.0	6.9	10.4	5.9	7.6	4.7	5.9	3.7	5.8	11	4.5	7.7	22.9	10.1	7.4
5.4	7.4	3	8	20	30	7	3	3	21	28	25	25	25	4	78	24	34	27
-12.2	-1.1	-5.7	10.3	42.4	59.4	36.5	10.5	1.1	4.3	10.3				-8.9	6.7	1.5	-26.5	-0.1
13.3	14.6	0.5	211	10.4	22.8	14	58	67	19	10	17	6	5	18	15	29	29	10.8
32	34	12	12	1	39.6	33.9	14.5	-3.2	-6.9	8.6	-3.2	-2.0	-3.8	-0.1	-3.5	-3.6	12	12.4
-23.9	-14.1		107	6.2	6.4	16.1	6.7	3.9	11.8	4.4	1.9	5.3	3.1	10.0	19.9	15.2	20.6	
8.2	4.9	31	33	64	9	21	40	3	24	37	11	23	11	88	56	11	20.6	
55	31	33	64	9	21	40	3	24	37	11	23	11	23	11	88	56	11	20.6
-13.2	3.9	-6.1	16.1	47.1	20.3	11.7	7.7	23.1	16.7	-6.2	-5.6	0.1	0.6	14	20.6			
8.3	3.9	16.4	17.5	22.8	17.2	4.6	0.4	12.0	8.0	4.8	3.8	7.2	20.9	17.5	8.7			

30314 GRAVITY measurements:
19050 marine data 11264 land data

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 magnetic 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

Gravmaster: a processing tool for gravity measurements

Michel SARRAILH

BGI, Toulouse, France

Obtaining gravity anomalies, to be used for geophysical or geodetic purposes, requires a complex but well-known processing: meter reading to gravity conversion, instrument, tidal and drift corrections, reference tying, terrain correction for Bouguer anomaly determination. Geotools Corporation¹ has developed and is marketing a new software for gravimetrists : Gravmaster, offering all these functions. BGI has tested the version 1.1 of this product.

Installing Gravmaster:

Running on PC platform, with Windows 95, 98, NT operating system, this package on CD-Rom is easy to install. Three installation options are proposed. With the typical one, you need 10 Mbytes on your hard disk, with the custom option the size requirements increases to up 45 Mbytes to install basemaps.

Gravmaster training:

Three data sets (two of them correspond to real surveys, the third one to a synthetic case designed for a didactic use) allow the user to discover the main functions and to become more familiar with the package. The online help is limited to a copy of the user's manual, which can only be accessed from the table of contents, there is no contextual sensitive help nor index table.

¹ Geotools Corporation, 5808 Balcones Drive, Suite 202

Austin, Texas 7831 USA

Phone : (512) 454-0679 Fax : (512) 454-9309 e-mail : geotools@geotools.com W3 : www.geotools.com

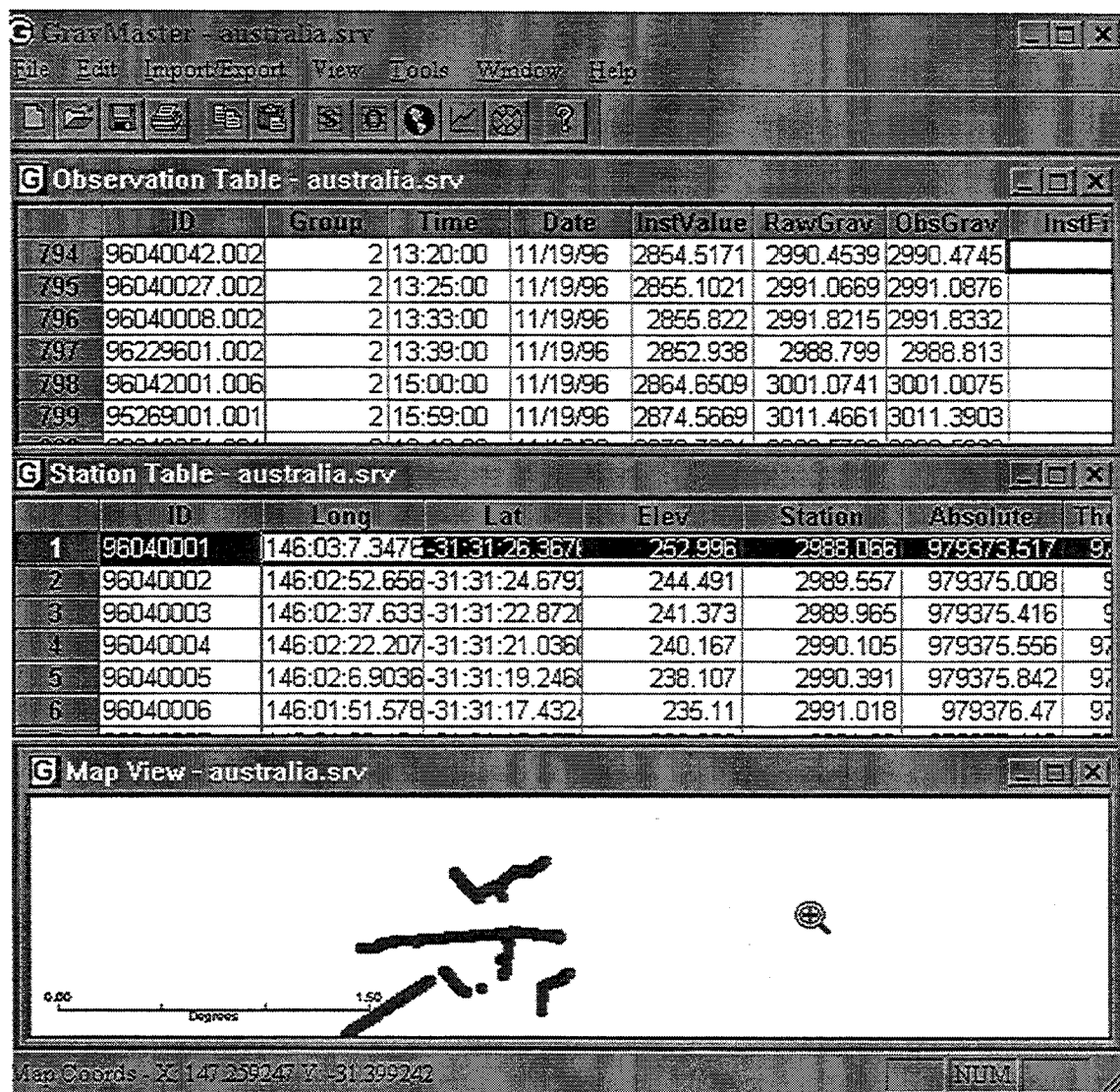


Fig.1: The GravMaster main menu

How to import or edit data?

You need first to define a new survey: you have to specify the map projection (UTM, TM or Lambert) and the associated spheroid. You can then:

- 1) either enter data by keyboard, using dedicated forms for stations and observations (Fig. 2);

Station			
ID	Longitude	Latitude	Elevation
B263	45.3267	12.7843	256.8

Observation						
ID	Date	Time	Reading	Height	Error	Calibration File
B263-00	06/23/99	10:17:00	2956.3754	0	0	grav1

Fig 2: The Station and Observation form

- 2) or import data from files: GravMaster offers a wizard to help it. You can import text files, formatted or with delimiters, or Excel95 files (*.xls). The package takes into account the regional settings for time and date.

GravMaster creates two tables, the stations and the observations ones.

Process Observations

Process: ☒ All Observations ☐ Only Observations in Group (Group zero never gets processed) [0]

Set Raw Gravity:

- ☒ Use InstValue, Convert to Raw Grav using Meter Calibration File (*.fac)
- ☐ Use InstValue, Convert to Raw Grav, Multiply by [] then add []
- ☐ Use Raw Grav from Observations Table

Correct Raw Gravity to get Observation Gravity:

- ☒ Correct for Meter Height
- ☒ Correct for Tides
- ☐ Correction for Meter Drift by Tying Repeat Observations
 - ☐ Tie using nearest loop
 - ☐ Tie to specified base station []
 - ☐ User specified drift rate [0] (mGal / Day)
- ☐ No drift correction - Just average observations

Average Observation Gravities to get Station Gravity:

- ☒ Average Observed Gravities to get Station Gravity
- ☒ Use Reference Station to get Absolute Gravity from Station Gravity

Reference Station: [A] Gravity: [981960] ☐ Int. Gravity Standard Net - IGSN ☐ Potsdam Datum 1909

OK Cancel

Fig 3: The observations process

The figures 2 & 3 illustrate the whole processing which can be applied to each of these tables.

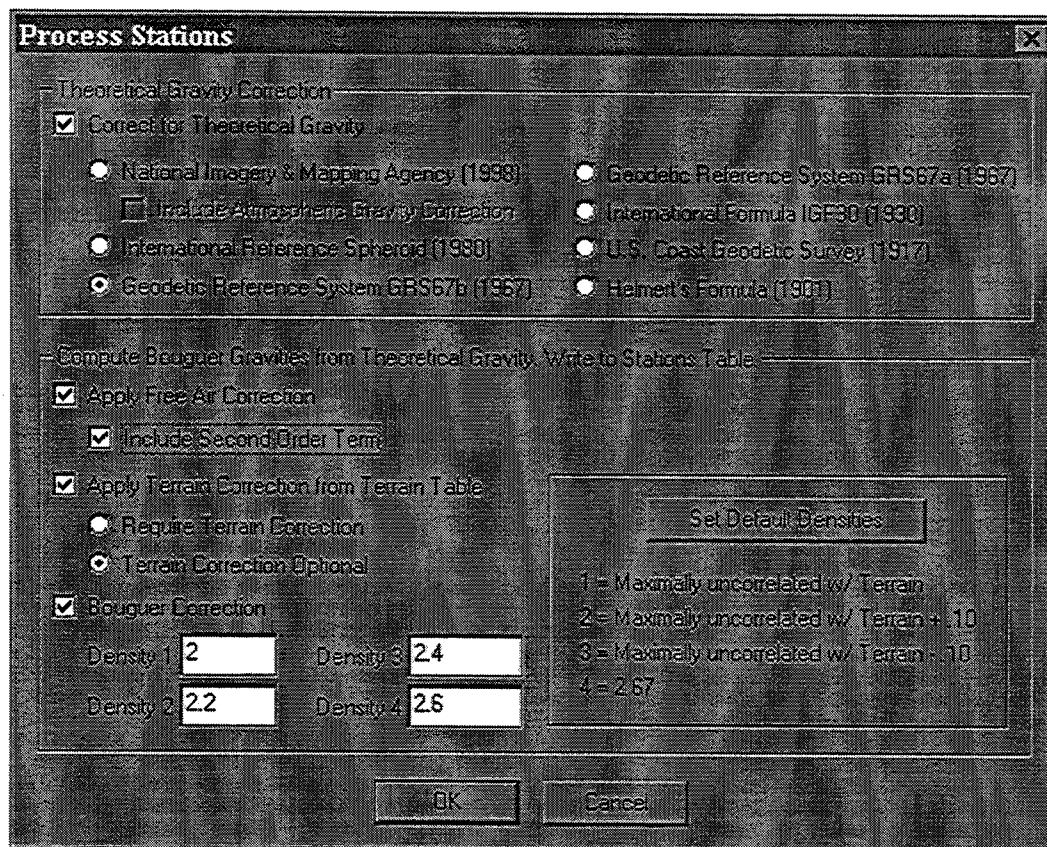


Fig 4 : The stations process

Convert meter reading to raw gravity

You have to define a meter calibration file to convert the readings to gravity observations. You can use several meters during a survey, the « Meter File » column being used as an identifier for the meter, allowing the drift determination of each meter separately. You can also process the observations for each meter separately by assigning them to different groups or you can process all of them together and the program will sort them out automatically.

Drift correction :

The gravity meters are very sensitive instruments, not only to small variations of the gravity field but also to the external environment. Temperature, pressure or shock or vibration effects are minimized by instrument manufacturers but cannot be totally eliminated. Such effects can lead to a drift of the instrument (Fig. 5).

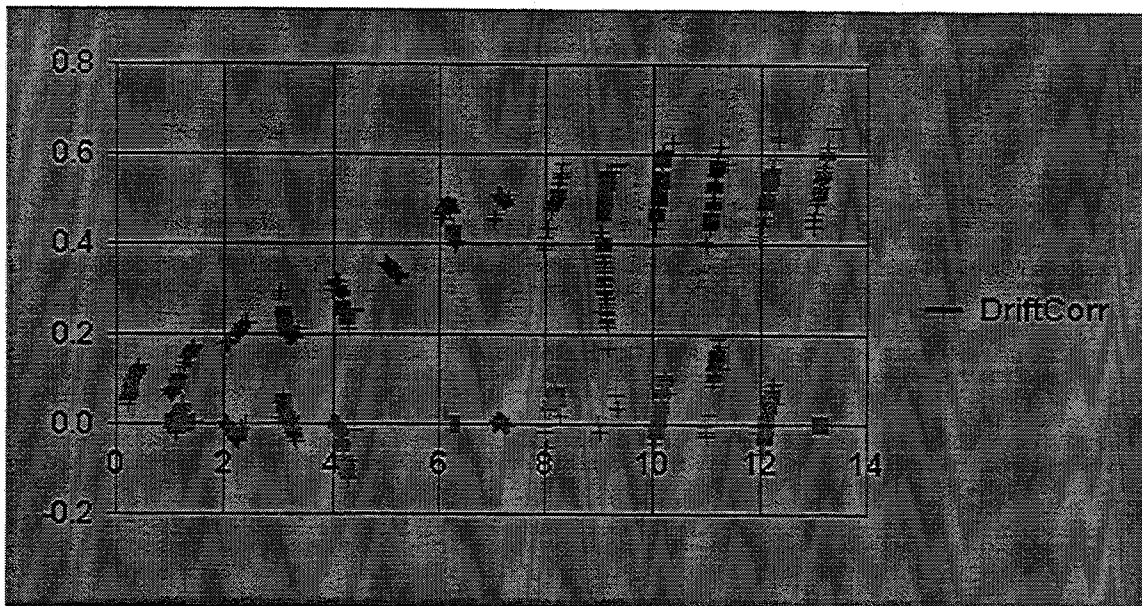


Fig 5: The meter drift correction

The drift correction method depends on the acquisition procedure:

- 1) if ties have been done in a strictly nested manner, Gravmaster will be able to determine the drift in a piece-wise linear manner
- 2) if ties are not strictly nested, the user has to specify a regularly visited station considered as the reference. The resulting drift is based on the observations done at this station
- 3) if no loop tie is available, the user can apply an a priori drift rate.

Averaging observations

Once corrections caused by meter height, tides and drift have been applied to each observation, all the observations for a particular station are then averaged and the result written in the station gravity column of the station table.

Tide correction:

The variations of the load factor (up to 20% of the total effect) is not considered. Even if a part of its variation can be absorbed by the drift correction, the user should be able to choose its value (Fig. 6). Geotools would implement it in a future version.

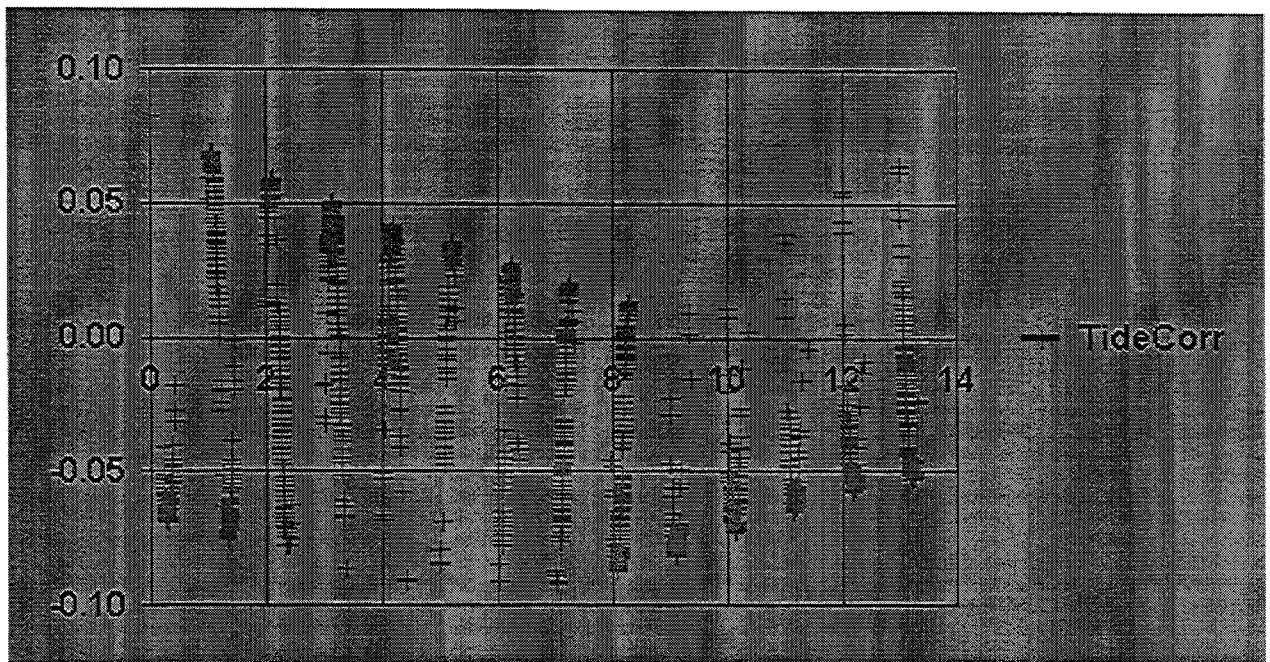


Fig 6: The tides correction

Terrain correction determination:

This function allows either the classical acquisition (Fig. 7) using the Hammer abacus (but in such a case you need to enter 150 height values for each gravity station to cover the zones A to M (22 km) !) and/or digital terrain modelling. This approach is very flexible: any file containing elevation data points (latitude, longitude, elevation) can be used, it can contain values issued from a topographic grid or from more or less randomly spaced points in the vicinity of the stations – using for example reflector or reflectorless laser ranging. You have to be cautious when merging different topographic dataset – you cannot have duplicate points.

Gravmaster builds a Delaunay triangulation and the relevant convex hull. The average elevation in a given compartment is determined querying for elevations at multiple sample locations and averaging.

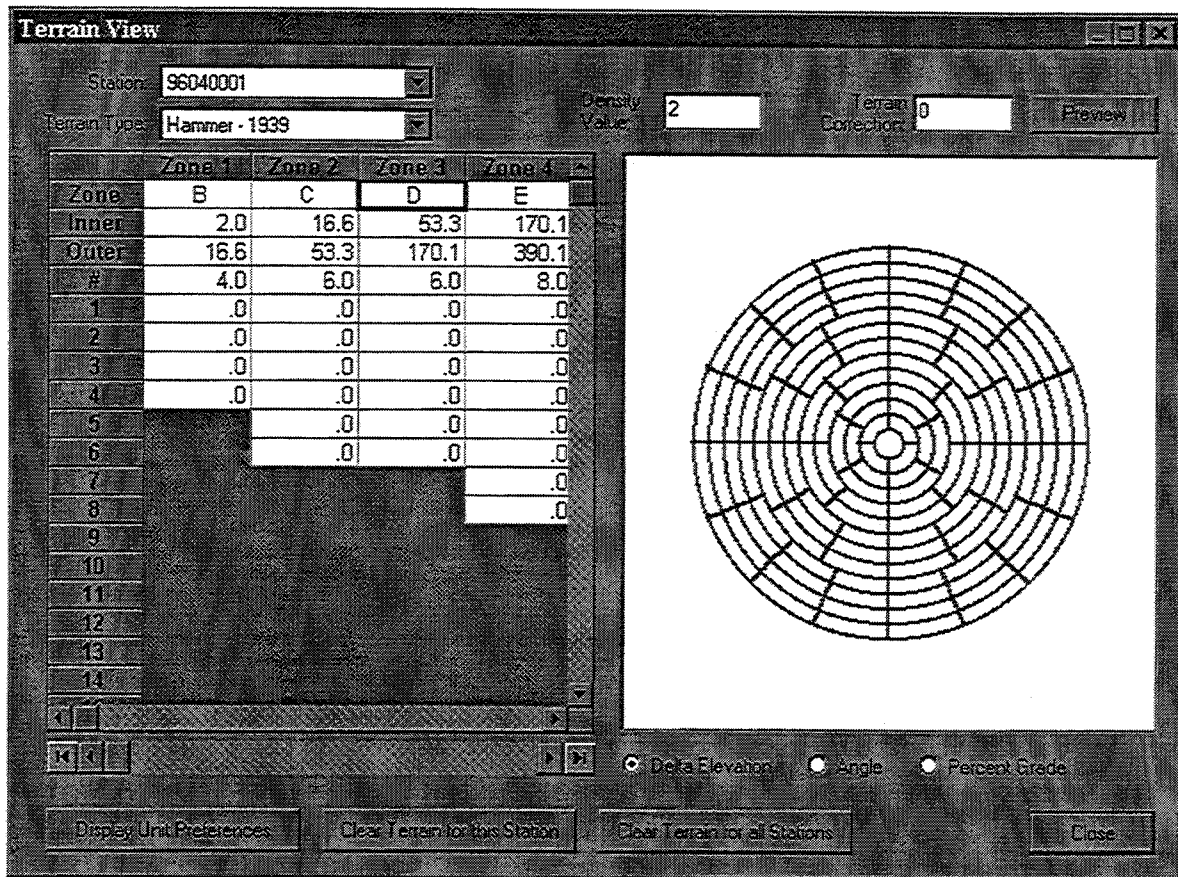


Fig 7: The terrain correction form

This approach has a limit, for example you cannot to extend the determination to 167 km. There is no way to use several topographic grids with different steps. Geotools has chosen to make the program simple to the user, limiting the choices on terrain tables, but the internal implementation is very flexible; it could support other geometries or allow the user to define his own.

The CD-Rom includes the GTOPO30 (30'' grid) and the ETOPO5 (5' grid) digital terrain models. The accuracy and the spatial resolution are variable and in the GTOPO30 model the grid sampling is finer than the source data, particularly in Africa, South America, Southeast Asia and Antarctica.

Plots and maps:

The observations can be graphically controlled: any observation field can be plotted as a function of time. A coverage map can be produced to control the location, with a symbol at each station color coded according to a selected field (Fig. 8).

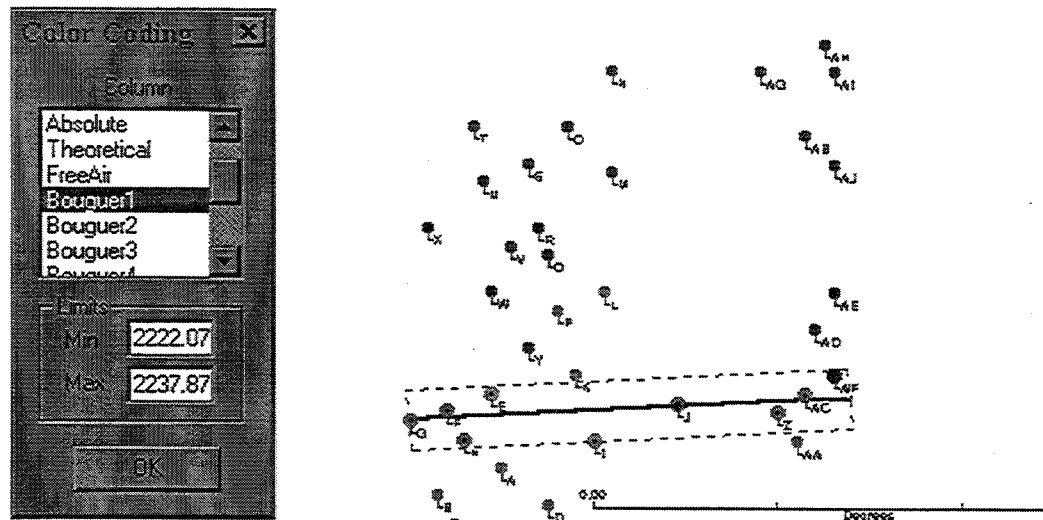


Fig.8: The coverage map, with color coding function of the Bouguer anomaly value

The coverage map can include overlays for roads, river, etc...from any basemap information available in Shape File Format, introduced by ESRI, a leading company in the GIS field with its product ArcView, which is a de-facto standard. Geotools includes with GravMaster public domain basemaps (DCW, Digital Chart of the World). You can find the Shape File description at www.geocities.com/~vmushinskiy. Utilities are available on the net to convert existing data into this format.

On such maps, the user can define profiles and plot for example the Bouguer anomaly versus the distance along the profile; this can be done for different densities, allowing a visual implementation of Nettleton technique to determine the topographic density.

These profiles can be exported for 2D interpretation, with GravModeler for example.

The results can also be exported to Geosoft and Surfer and other softwares for improved display and modelling.

Conclusion

GravMaster is a well-integrated tool, allowing to go quickly from the meter readings to final results with minimal operator intervention. It can be used in the field and it is a mean to validate observations practically in real time. It can also be used as a teaching tool.

GravModeler, gravity modeling software

GravModeler, also developed by Geotools, can be used for direct modelling, limited to 2D structures (with infinite extension perpendicularly to the section). You define polygonal structures, assign them a density and GravModeler determines the total resulting anomaly. You can modify the structures shape, move the structures with the mouse and follow the changes in the anomaly.

The anomaly can be calculated either at Earth Surface or at a constant elevation.

Bodies can be extended to infinity, for example in the case of faults. Superficial structures can also match the terrain (Fig. 9).

Some limitations:

- the background model, used to determine the density contrast, includes only one layer,
- 2.5D modelling is not implemented, so the structures are supposed to be elongated (5 or 6 times their section),
- there is no management of structures superposition.

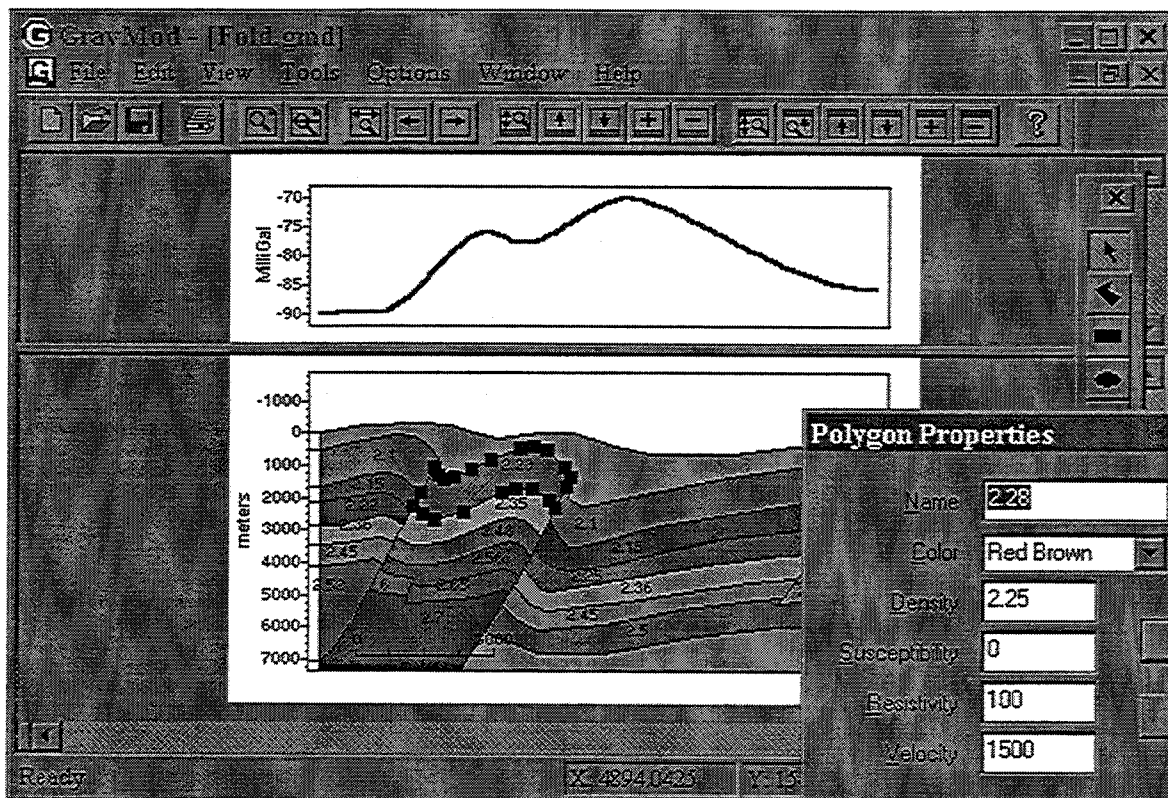


Fig.9: Gravity anomaly due to folding (the brown structure is selected)

Conclusion:

This product is mainly dedicated to educational purposes, but complex models can also be tested. It can also be used for survey design and quick analysis of data in the field.

Price List

Geotools is offering GravMaster/GravModeler Bundle at a special price of \$1,295 for the BGI Bulletin readers until October 31 1999, the regular prices being \$1,395 for GravMaster, \$495 for GravModeler and \$1,695 for the bundle. You can try these products at no risk, if they fail to meet your needs, you can return them within 30 days for a full refund (less shipping and handling). A free assistance by email is provided during the first 90 days after purchase. Discounts are available for educational institutions (cf. www.geotools.com).

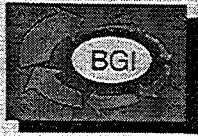
REFERENCE STATIONS UPDATE

In order to help BGI update its files of reference stations, we would be grateful to all of those who organised, or participated in recent gravity campaigns, and who used or encountered reference gravity stations, to fill in one of the forms which follow :

- either for each existing reference station they used (or searched)*
- or/and for newly created reference station.*

Would you please also do so in the future in the course of all new gravity surveys.

Thank you.



Bureau Gravimétrique International

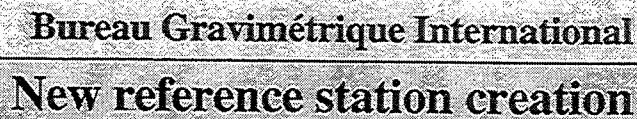
Existing reference stations inventory

Form to be filled in by the mission leader and to be sent back to the Bureau Gravimétrique International for updating of the reference station database.

date:	BGI station number : <input type="text"/>	other references: <input type="text"/>
country <input type="text"/>		latitude: <input type="text"/>
city <input type="text"/>		longitude: <input type="text"/>
		height: <input type="text"/>
station name <input type="text"/>		
Were you able to re-occupy the station ? <input type="checkbox"/> yes <input type="checkbox"/> no		
If not, can we consider it as definitively lost ? <input type="checkbox"/> yes <input type="checkbox"/> no		
Is an access permit necessary ? <input type="checkbox"/> yes <input type="checkbox"/> no		
If yes, from whom ?		
If you believe that in spite of the environmental changes, the station is still in good order, please draw the location scheme again or amend it.		
LOCATION DIAGRAM OR PICTURE(S)		

Bureau Gravimétrique International
<http://bgi.cnes.fr:8110>

14 avenue Edouard Belin 31400 TOULOUSE
tél: 05 61 33 28 90 fax: 05 61 25 30 98
Email : bgi.fags@cnes.fr



date: _____	Your station number : _____	other references: _____
country _____		latitude : _____
city _____		longitude : _____
station name _____		height : _____

G value: absolute measurements: ☐ yes
☐ no

If relative measurements, linked reference station name:

and its used g value:

Station description:

You can also send us an Email with gif or jpeg attached image files describing the location.

14 avenue Edouard Belin 31400 TOULOUSE
tél: 05 61 33 28 90 fax: 05 61 25 30 98
Email : bgi.fags@cnes.fr

PART II
CONTRIBUTING PAPER

Intercomparison between the FG5#202 and FGG#206 at the site of the superconducting gravimeter C021 in Membach (Belgium)

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Introduction

In January 1997, the Strasbourg absolute gravimeter FG5#206 was collocated in Membach with the Royal Observatory of Belgium's (ROB) FG5#202. The ROB's superconducting gravimeter (SG-C021) has been running at this station since August 1995 (Francis et al., 1997). Repeated absolute gravity measurements were made.

The first absolute gravity measurements were performed here by J. Mäkinen with the JILAG-5 meter in 1990 (Francis et al., 1994). Since January 1996, the ROB has performed more frequent measurements with their FG5#202 in order to calibrate the SG-C021 as well as to monitor its drift (if any).

We report here two kinds of comparisons. First, the data from both absolute gravity meters are compared. Then, we compare the absolute gravity data to the SG data. The SG calibration factor is estimated using both sets of absolute gravity measurements.

1. Comparison between the FG5#202 and FG5#206

The two FG5s were setup in the same room separated by about 4 meters. The simultaneous observations started on January 21 at 14:30 and ended on January 24 at 12:15. A data sampling rate of 1 observation/10 second was chosen to be synchronized with the SG data. The set duration is 15 minutes every 30 minutes giving us an interval of 15 minutes between sets. We collected 141 sets covering almost 3 days. Data corrupted by earthquakes were discarded. The remaining 128 sets, containing 11,648 drops (or measurements), were analyzed.

The FG5 results from the two instruments are summarized in Table 1. Although the drop-to-drop mean standard deviation of the FG5#206 is lower, the set standard deviations are very similar.

The difference between the set gravity mean at the reference point of the floor is about 23.9 microGal. This difference has been confirmed by measurements of the ROB team using a Scintrex spring gravimeter. In this case, the gravity mean difference is 23.8 with a standard deviation of 1.0 microGal. We conclude that the measurements of the two FG5 are consistent to within 1 microGal.

Table 1. Summary of the absolute gravity measurements with the FG5#202 and #206 at two different piers in Membach.

Parameter	FG5#202 / Pier 1	FG5#206 / Pier 2
Set Gravity Mean @ 0 cm (μ Gal)	981 046 709.2	981 046 685.3
Set Standard Deviation (μ Gal)	1.3	1.4
Mean Standard Deviation (μ Gal)	11.7	8.6
Difference (μ Gal)	23.9	
Difference measured with a Scintrex (μ Gal)	23.8 ± 1.0	

2. Calibration of the SG C021 with two FG5 absolute gravimeters

The times series of the absolute gravimeters were compared to data collected by the superconducting gravity meter. By adjusting the relative gravity measurements for the SG-C021 to the absolute gravity time series (Figure 1), we obtain the calibration factor for the SG meter. This kind of calibration procedure is generally performed with one absolute gravimeter. In the present experiment, we have two FG5s running at the same time.

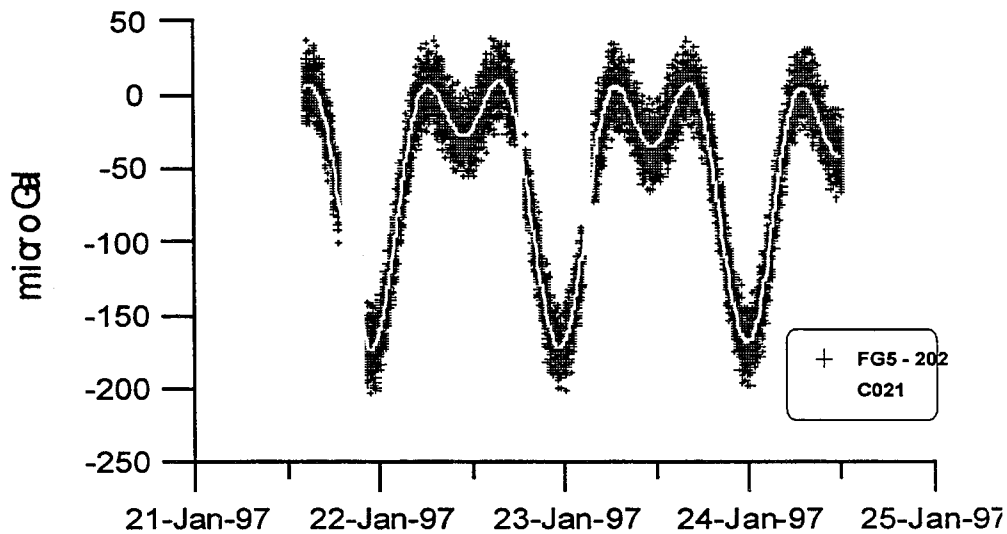


Figure 1. Parallel registration of the superconducting gravimeter C021 (white line) and the FG5#206 absolute gravity meter (crosses) in Membach (Belgium).

The results for the calibration factor using data from the FG5#202 and #206 are given in Table 2. The number of data used is slightly different because more data were rejected in the FG5#202/SG comparison because the FG5#202 time series is more noisy. Error bars on the offset and on calibration factor estimates, as well as the RMS value are highest when using data of the FG5#202. However, the correlation coefficient is smaller. The two scale factor estimates differ by 0.3 microGal/Volt or by 0.4 %. Moreover, the 2-sigma error bars are consistent. Results from other calibration experiments (Francis, 1996 and Francis et al., 1997b) show that to reach a precision of 0.1 % on the calibration factor parallel registration should continue for 4 to 6 days. This result was obtained at Membach and Boulder, two quiet stations, with different instruments. With two days of data (as in this present experiment), one may expect a precision of 0.4 %. Our present results are in fairly good agreement with the results of previous experiments. At this stage, the difference in the results cannot be attributed to instrumental problems as a better agreement is expected if 4-6 days of data were available.

Table 2. Results of the linear regression between data of the SG-C021 superconducting gravimeter and of two FG5 absolute gravimeters: $y = a + b x$ where a is the offset and b the calibration factor.

Parameter	FG5#202	FG5#206
Number of data	11,492	11,470
a (μGal)	347.46 ± 0.53	319.19 ± 0.29
b ($\mu\text{Gal/Volt}$)	77.76 ± 0.02	78.06 ± 0.01
Correlation Coefficient	0.982	0.990
R.M.S. (μGal)	11.67	8.66

The mean value of the calibration factors estimated from both FG5 corresponds exactly to the calibration factor of the SG deduced previously (Francis, 1997). It means that the new estimated calibration factors differs by 0.2% with respect to the reference value.

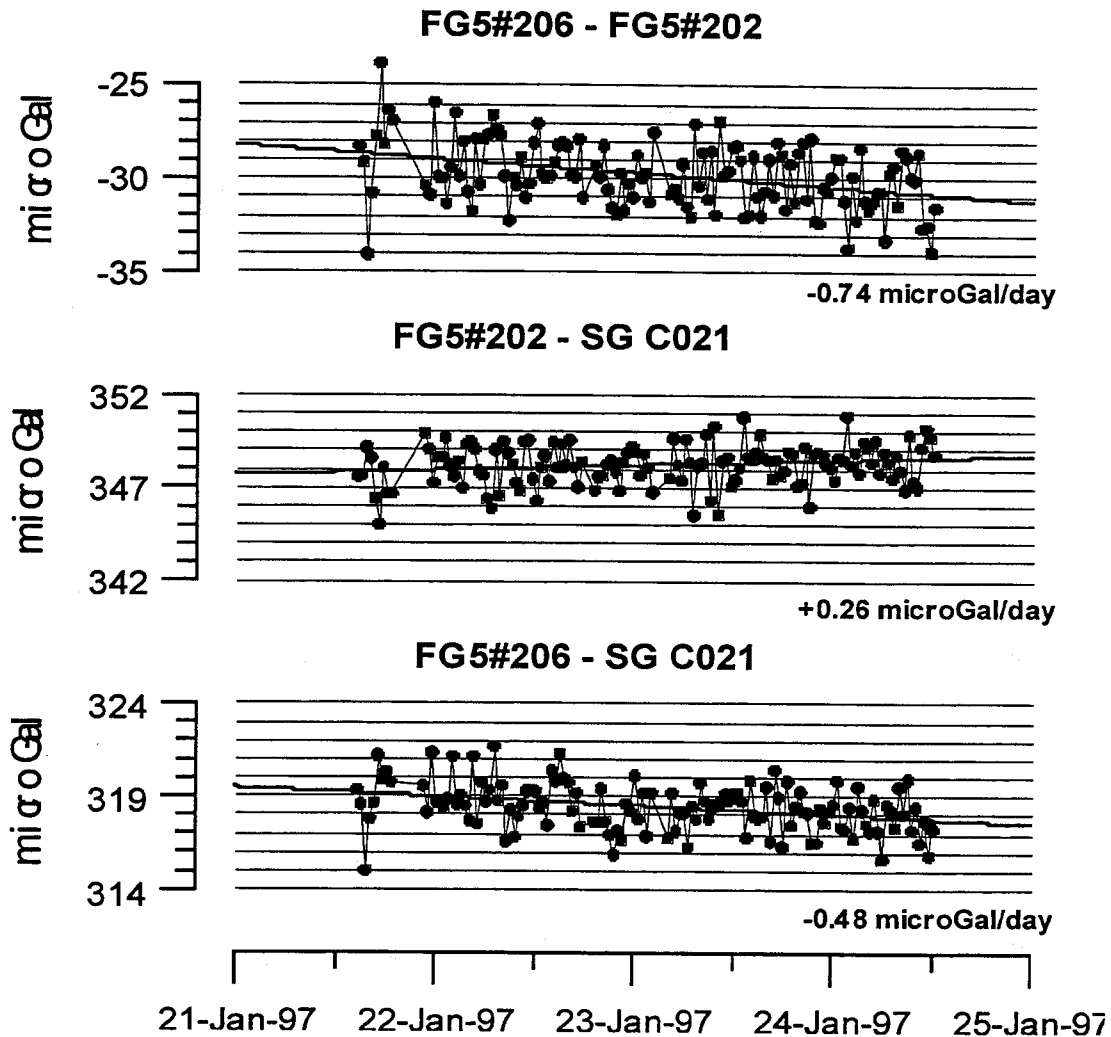
3. Discussion

As a final test, we have differenced the mean set values of the FG5s observations (Figure 2a). The standard deviation on the difference is 1.77 microgal with minimum and maximum deviations of -5.96 and +4.3, respectively. There is an obvious trend of -0.74 microGal/day. It seems that the absolute gravity measurements of one or of both absolute meters have a drift.

In order to investigate this result further, we have also computed the differences between the FG5s data and the calibrated SG data averaged over the time of the sets. The results are displayed in Figures 2b and c.

Comparisons of FG5 data with the SG time series reveal a drift of +0.26 microgal/day with the FG5#202 and of -0.48 microgal/day with the FG5#206. Since the sum of the drifts of the FG5s with

respect to the SG is comparable to the drift of the FG5s with respect to one another, we can conclude that the SG has no drift.



Figures 2. Differences, (a) between the mean set values of the FG5#206 and #202, (b) between the FG5#202 and the SG-C021 data averaged over the time of the sets, and (c) between the FG5#206 and the SG-C021 data averaged over the time of the sets.

Conclusion

The intercomparison between the FG5#202 and #206 shows an agreement within 1 microGal at the Membach station. Only 2 days of data were available so that the determinations of the calibration factor of the SG-C021 are not precise. Nevertheless, we found that both FG5s data show a drift of the order or less than 0.5 microGal/day. Over these 2 days, the SG-C021 does not exhibit any drift.

Acknowledgments

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