

ASSOCIATION INTERNATIONALE DE GÉODÉSIE

**BUREAU
GRAVIMETRIQUE
INTERNATIONAL**

BULLETIN D'INFORMATION

N° 91

Décembre 2002

**18, Avenue Édouard Belin
31401 TOULOUSE CEDEX 4
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, ru 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.

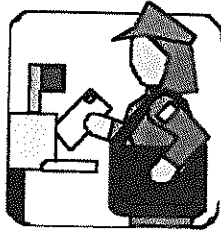
References. A complete and accurate list of references is of major importance in review papers. All listed references should be cited in text. A complete reference to a periodical gives author (s), title of article, name of journal, volume number, initial and final page numbers (or statement "in press"), 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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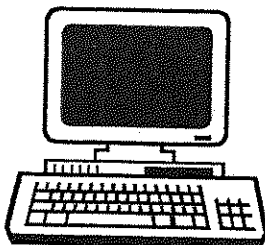
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**BUREAU GRAVIMÉTRIQUE
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BULLETIN D'INFORMATION

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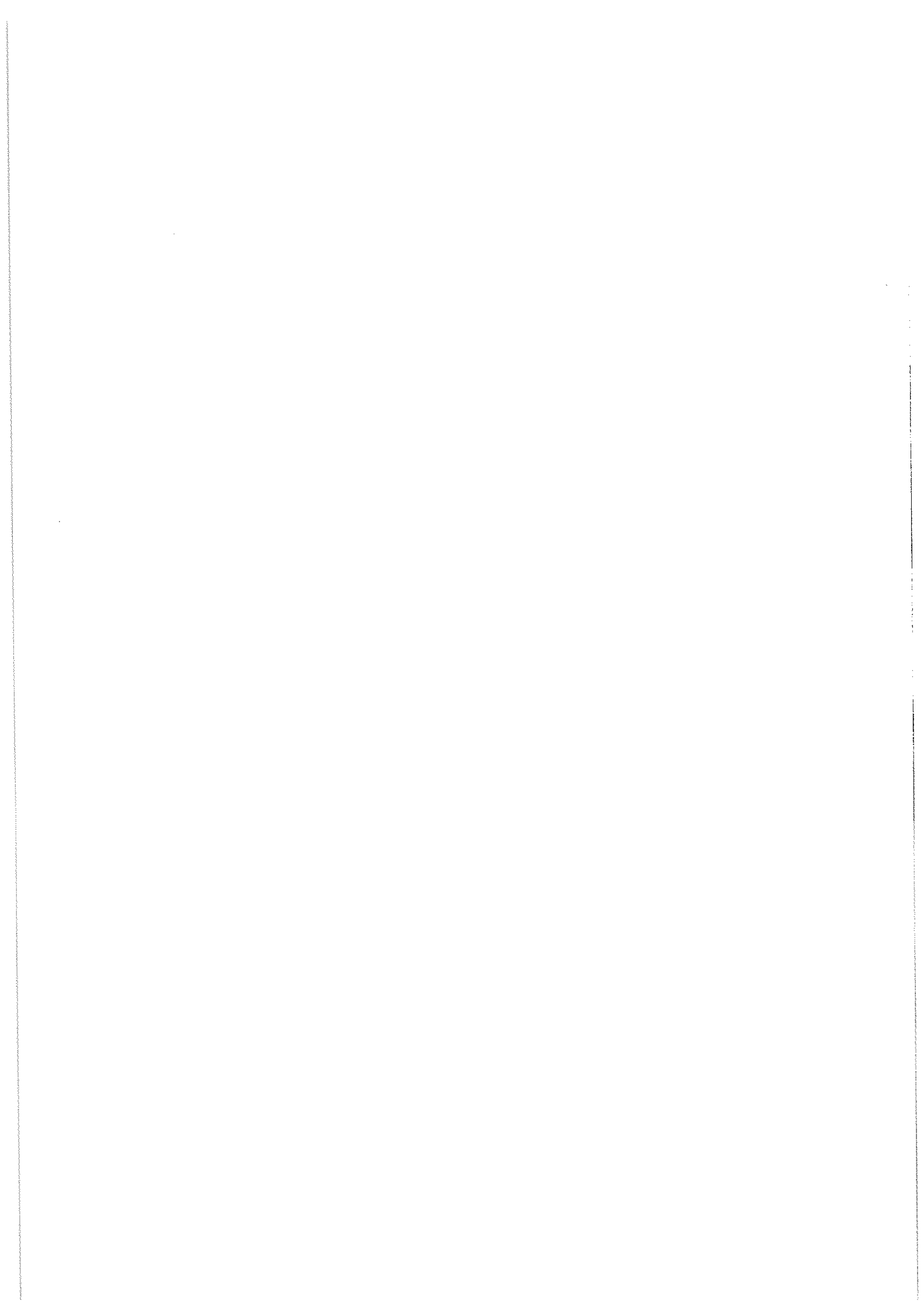


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PART I
INTERNAL MATTERS

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 (91 have been issued as of December 31, 2002 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.

**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 - $R \leq 5$ 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...	(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 = $E \leq 0.02$ 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	(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) 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 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	(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) 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	(3 char.)
109-111	Country code (BGI)	(3 char.)
112	Confidentiality 0 = without restriction1 = with authorization 2 = classified	(1 char.)
113	Validity 0 = no validation 1 = good 2 = doubtful 3 = lapsed	(1 char.)
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 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 = Decca 2 = visual observation 3 = radar 4 = loran A 5 = loran C 6 = omega or VLF 7 = satellite 8 = solar/stellar (with sextant)	(2 char.)
	30	Type of observation 1 = individual observation at sea 2 = mean observation at sea obtained from a continuous recording	(1 char.)
	31-38	Elevation of the station (unit : centimeter)	(8 char.)
	39-40	Elevation type 1 = ocean surface 2 = ocean submerged 3 = ocean bottom	(2 char.)
	41-42	Accuracy of elevation 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	(2 char.)
	43-44	Determination of the elevation 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	(2 char.)
	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) 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	(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 : 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

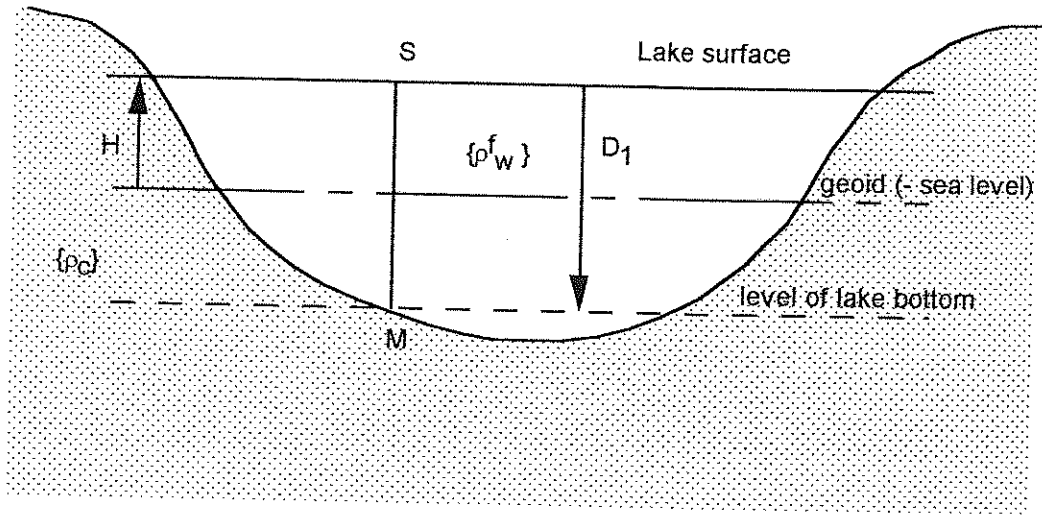
Formulas :

* 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 :



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

$$\Rightarrow FA = g_s + \Gamma H - \gamma_0$$

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

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

$$\Rightarrow BO = \delta g_s + \Gamma H - \gamma_0$$

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
EOL land data format		
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	Lake surface above sea level with bottom above sea level	$FA = g + \Gamma H - \gamma_0$ $BO = FA - k \rho_w^f D_1 - k \rho_c (H - D_1)$
4	Lake bottom, above sea level	$FA = g + 2 k \rho_w^f D_1 + \Gamma (H - D_1) - \gamma_0$ $BO = FA - k \rho_w^f D_1 - k \rho_c (H - D_1)$
5	Lake bottom, below sea level	$FA = g + 2 k \rho_w^f D_1 + \Gamma (H - D_1) - \gamma_0$ $BO = FA - k \rho_w^f H + k (\rho_c - \rho_w^f) (D_1 - H)$
6	Lake surface above sea level with bottom below sea level	$FA = g + \Gamma H - \gamma_0$ $BO = FA - k \rho_w^f H + k (\rho_c - \rho_w^f) (D_1 - H)$
7	Lake surface, below sea level (here $H < 0$)	$FA = g + \Gamma H - \gamma_0$ $BO = FA - k \rho_c H + k (\rho_c - \rho_w^f) D_1$
8	Lake bottom, with surface below sea level ($H < 0$)	$FA = g + (2 k \rho_w^f - \Gamma) D_1 + \Gamma H - \gamma_0$ $BO = FA - k \rho_c H + k (\rho_c - \rho_w^f) D_1$
9	Ice cap surface, with bottom below sea level	$FA = g + \Gamma H - \gamma_0$ $BO = FA - k \rho_i H + k (\rho_c - \rho_i) (D_1 - H)$
10	Ice cap surface, with bottom above sea level	$FA = g + \Gamma H - \gamma_0$ $BO = FA - k \rho_i D_1 - k \rho_c (H - D_1)$
EOS Sea Data Format		
1	Ocean Surface	$FA = g - \gamma_0$ $BO = FA + k (\rho_c - \rho_w^s) D_1$
2	Ocean submerged	$FA = g + (2 k \rho_w^s - \Gamma) D_2 - \gamma_0$ $BO = FA + k (\rho_c - \rho_w^s) D_1$
3	Ocean bottom	$FA = g + (2 k \rho_w^s - \Gamma) D_1 - \gamma_0$ $BO = FA + k (\rho_c - \rho_w^s) D_1$

All requests for data must be sent to :

*Mr. Bernard LANGELLIER
Bureau Gravimétrique International
18, Avenue E. Belin - 31401 Toulouse Cedex 4 - France
E-mail : Bernard.Langellier@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 Δ x Δ' 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

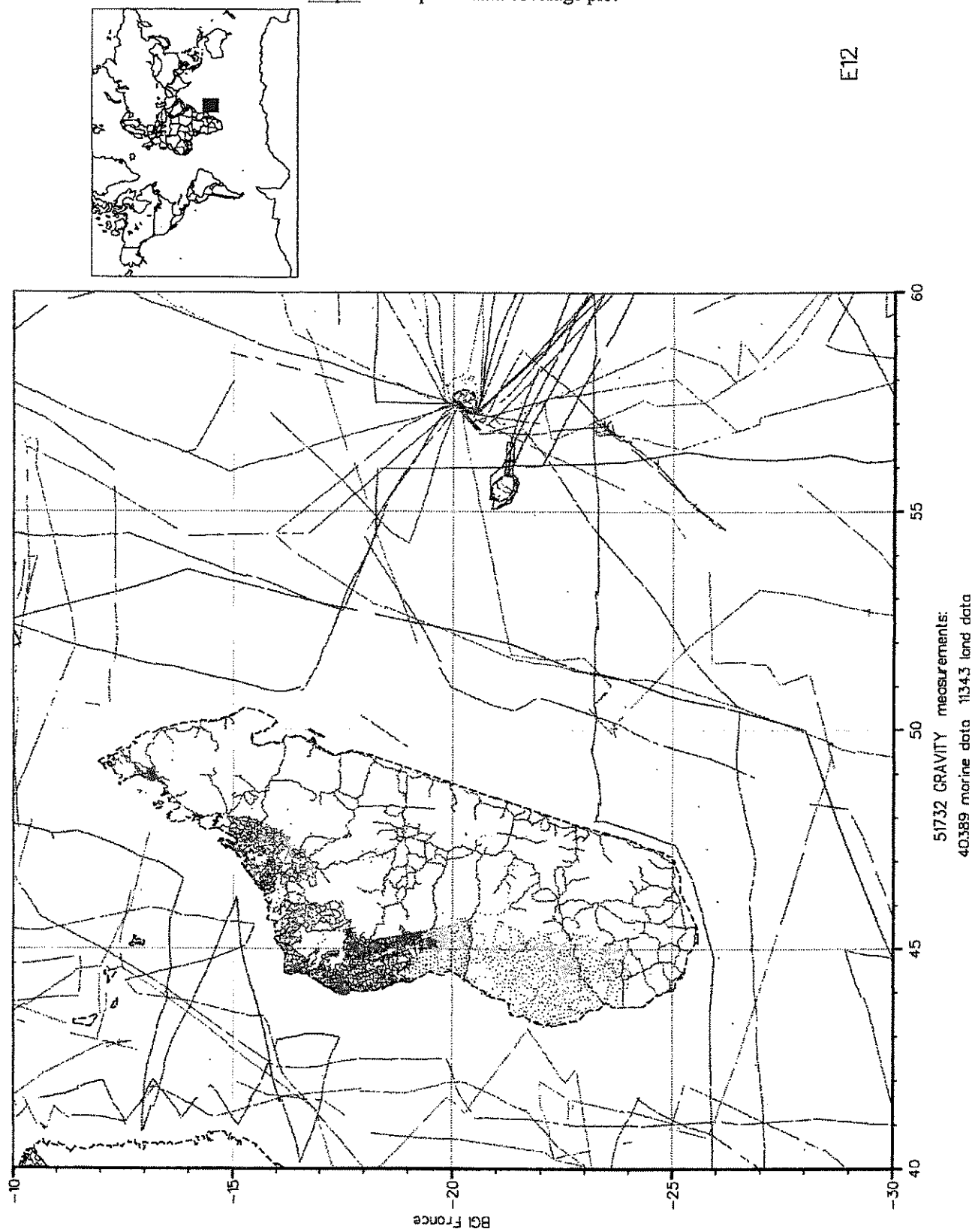
(Vol. 1 and 2) 1979 150 FF

. 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



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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

PART II
CONTRIBUTING PAPERS

GRAVITY DATA VALIDATION AND OUTLIER DETECTION USING L₁-NORM

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1/Introduction

The Bureau Gravimétrique International is managing a worldwide gravity database. These data have different origins and must be controlled to detect and eliminate outliers. Up to now, we used a prediction technique based on the L₂-norm (collocation) method. We have developed a new method, using the L₁-norm. We present here shortly the outlines of this method, and compare it for different test cases with the L₂-method.

2/ Theory of the L₁ prediction method

Self-validation is the detection of outliers in a survey from the cross-comparison of all the values of the survey.

Let \underline{g} the N -vector of the set of observed gravity values over a survey: $\underline{g} = \begin{bmatrix} g_1 \\ g_2 \\ \vdots \\ g_N \end{bmatrix}$

The N -vector $\hat{\underline{g}}$ of the "true" (unknown) values is related to the N -vector \underline{g} of observed values by $I_N \hat{\underline{g}} = \underline{g} + \underline{\varepsilon}$ (1), where I_N is the identity matrix of order N and $\underline{\varepsilon}$ is the N -vector of errors. In a perfect world, $\underline{\varepsilon} = \underline{0}$ and then $\hat{\underline{g}} = \underline{g}$. In an imperfect (our) world, $\underline{\varepsilon} \neq \underline{0}$. We have then to solve Eq. (1) contaminated by errors.

- **L₂-norm solution:**

$\underline{\varepsilon}$ and $\hat{\underline{g}}$ are considered as random variables with *a priori* $\underline{0}$ means and respectively

$\sigma_\varepsilon^2 I_N$ and $Cov(\hat{\underline{g}})$ covariances. The L₂ *a posteriori* estimate of $\hat{\underline{g}}$ as then

$$\hat{\underline{g}}^* = Cov(\hat{\underline{g}}) \left[Cov(\hat{\underline{g}}) + \sigma_\varepsilon^2 I_N \right]^{-1} \underline{g} \text{ mean}$$

$$\text{and} \left[\sigma_\varepsilon^{-2} I_N + \left(Cov(\hat{\underline{g}}) \right)^{-1} \right]^{-1} \text{ covariance.}$$

This is the usual least-squares collocation solution.

- **L₁-norm solution:**

From a L₁-norm point of view, we select the particular $\hat{\underline{g}}^{(i)}$, which realizes

$$\min_i \sum_{j=1}^M \sum_{l=1}^N \left| \hat{g}_l^{(i)} - g_l \right|$$
 over a set of M realizations of the N -vectors \underline{g} and $\underline{\varepsilon}$, with $\hat{g}^{(i)} = \underline{g}^{(i)} + \underline{\varepsilon}^{(i)}$. Of course, in the real world, we have to cope with a unique realization of \underline{g} and $\underline{\varepsilon}$ (and we know only their sum $\hat{\underline{g}}$), so we

2-1/ select from $\hat{\underline{g}}$ observed M subvectors $\underline{\gamma}^{(i)}$ ($i=1, \dots, M$) of dimension K ,

2-2/ complete through a given interpolation-extrapolation procedure the missing $N-K$ values in order to get M vectors $\hat{\underline{\Gamma}}^{(i)}$ of dimension N ,

2-3/ select the best estimate $\hat{\underline{\Gamma}}$ of \underline{g} as the one which realizes $\min_i \sum_{l=1}^N \left| \hat{\Gamma}_l^{(i)} - \hat{g}_l \right|$.

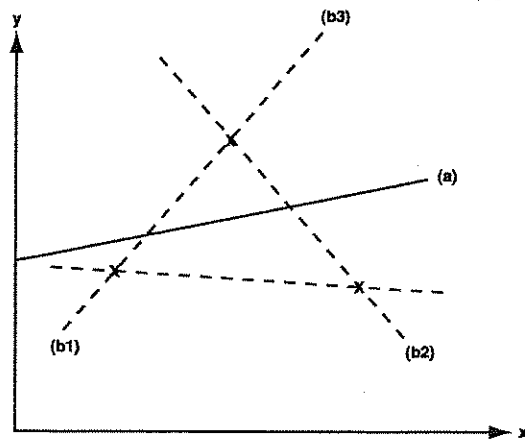


Fig. 1: Fitting a line through 3 data points. The L_2 solution (a) goes through the 3 data points (x_i, y_i) by realizing $\min_{a,b} \sum_i (y_i - (ax_i + b))^2$. For the L_1 solution, the solution fulfills $\min_{a,b} \sum_i |y_i - (ax_i + b)|$, and corresponds to one of the lines (b1, b2, b3) that joins the 3 two points subsets.

For L_1 norm, there is no equivalent of covariance matrices, so if we want to have some indication about the robustness of the solution, we can only construct Monte-Carlo estimates of the errors by adding to the observed $\hat{\underline{g}}$ values a random vector $\underline{\zeta}$ of 0 mean and known σ_{ζ}^2 variance and infer from this

perturbation the corresponding mean and variance of $\hat{\underline{\Gamma}}^{(i)}$.

3/ L_1 prediction method algorithm

For a given gravity station where we have to predict the gravity value:

3-1: search of all the neighbouring points, up to a given radius;

3-2: determination of the "best" plane (Fig. 2) or paraboloid (Fig. 3) approximation of the local gravity around the station, by using the gravity values of a subset of selected neighbours, in the sense of the L_1 norm. The gravity value at the predicted point is excluded. As we consider only a limited number of neighbouring points, we study all the subsets of neighbours (subsets of 3 points for the "best" plane, subsets of 6 points for the "best" paraboloid), instead of considering the simplex method;

3-3: computation of the difference between observed and predicted anomaly, interpolated from the "best" L_1 -surface, at the location of the predicted value;

3-4: comparison with a given threshold;

3-5: rejection or validation of the gravity value.

4/ Pros and cons of the L_1 norm method

- 4-1 Pro: no "contamination" of the neighbouring points by "bad" points (i.e. a "good" point can be flagged as false, if compared to erroneous ("bad") neighbouring points);
- 4-2 Pro: no need to use residual anomalies;
- 4-3 Con: systematic rejection of extrema;
- 4-4 Con: rejection of points near the edges of the map (only with paraboloid prediction);
- 4-5 Con: rejection only based on a threshold on the difference between observed and predicted anomaly;
- 4-6 Con: no error estimate of the predicted anomaly.

5/ Pros and cons of the L_2 norm method

- 5-1 Pro: rejection based on thresholds for the difference between observed and predicted anomaly and for the standard deviation error of the predicted anomaly;
- 5-2 Con: robustless solution: a "good" point can be flagged as "false", if compared to "bad" neighbouring points (see 4-1);
- 5-3 Con: need of computing residual anomalies before prediction;
- 5-4 Con: rejection of extrema.

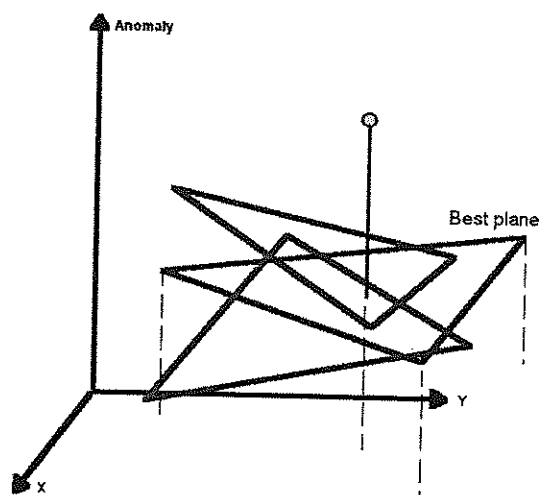


Fig. 2: Dark triangle: « best » approximating plane going through the neighbouring gravity values. Black bar: difference between the observed and the predicted anomaly on the selected point (dot).

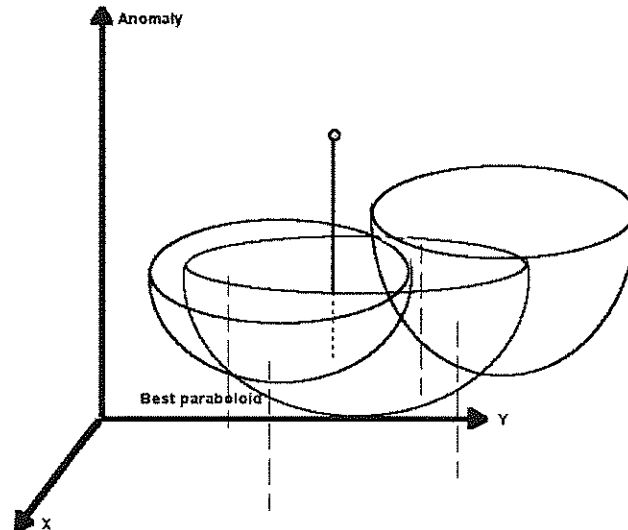


Fig. 3: Light grey: « best » approximating paraboloid going through the neighbouring gravity values. Black bar: difference between the observed and the predicted anomaly on the selected point (dot).

6/ Future improvements of the L_1 method

- 6-1: estimating of the error on the predicted anomaly by Monte-Carlo method (see point 2);
- 6-2: Replacing planar or paraboloidal approximation by collocation prediction, to take into account the covariance function of the anomalies. This will realize a "mix" between L_1 and L_2 methods.

7/ Example of data validation

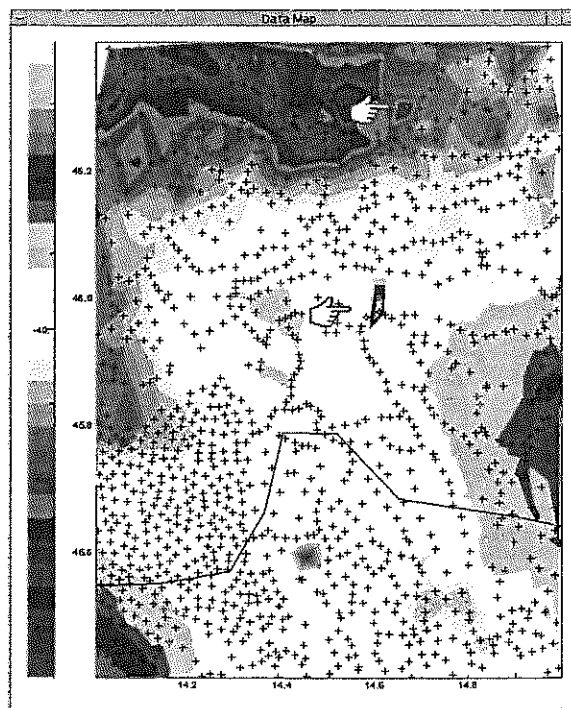


Fig. 4: Bouguer anomaly map: good points (cross marker), doubtful points (circle marker) are identified by prediction using a collocation technique, taking into account the local covariance function.

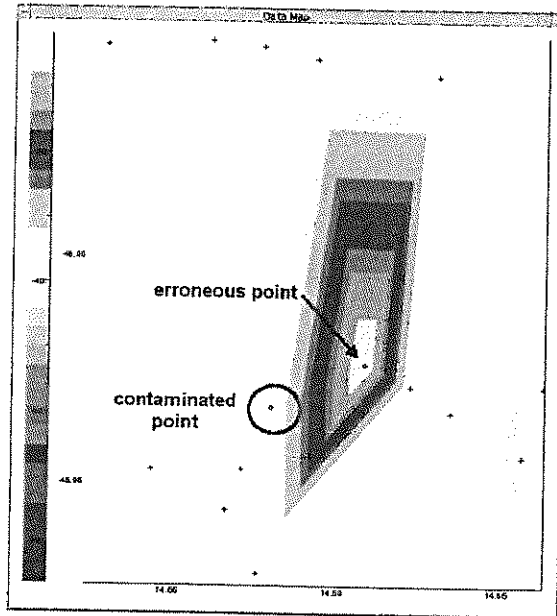


Fig. 5: With the collocation technique, "bad" points can "contaminate" neighbouring points. Such points must be repredicted, after flagging of the erroneous ("bad") points with the largest differences between observed and predicted anomaly (see points 4-1 and 5-2).

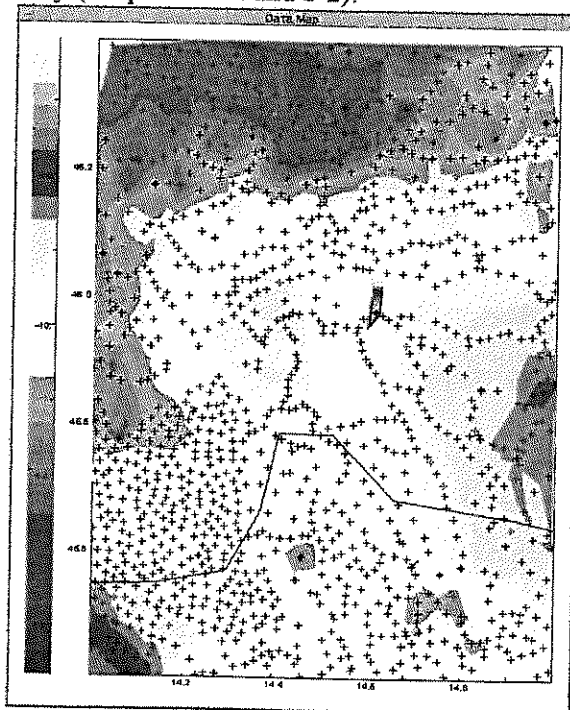


Fig. 6: Prediction using L_1 norm and plane approximation (Fig. 2). Seven neighbouring points are selected per predicted point. The points predicted are considered doubtful if the difference between the observed anomaly and the predicted one is larger than 7 mGals.

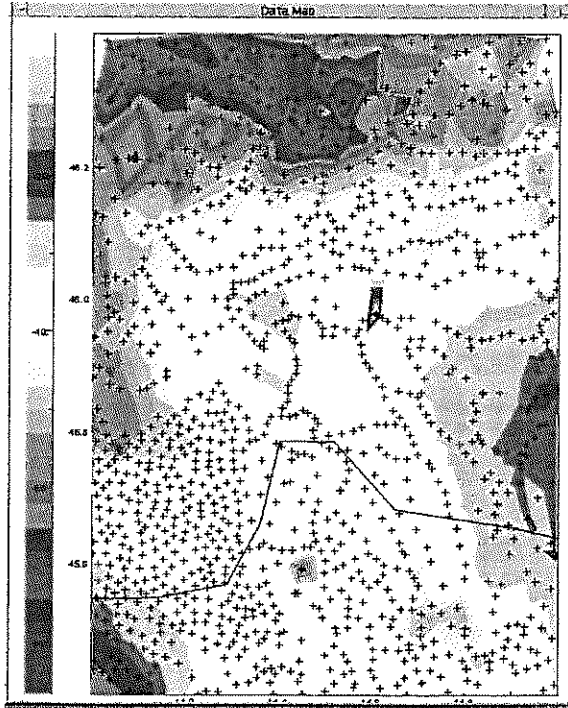


Fig. 7: Prediction using L_1 norm and paraboloid approximation (Fig. 3). Ten neighbouring points are selected per predicted point. The points predicted are considered doubtful if the difference between the observed anomaly and the predicted one is larger than 7 mGals.

ESTABLISHMENT AND MAINTENANCE OF A GRAVITY NETWORK IN THE CARIBBEAN

by Ludwik Sliwa (*Polytecnic University of Puerto Rico, sliwa@pupr.edu*) and Jean-Pierre Barriot
(*Bureau Gravimétrique International, bgi@cnes.fr*)

Poster presented at 3RD meeting of the International Gravity and Geoid Commission
Thessaloniki, Greece, August 26-30, 2002

PROJECT SUMMARY:

We propose the establishment and maintenance of a gravity network in the Caribbean. The project will consist of the following phases:

1. validation of existing gravity data and digital terrain models (DTM's) in this region;
2. establishment of the main (primary) gravity network in the following countries (islands): Jamaica, Cuba, Haiti, Dominican Republic, Puerto Rico, US and British Virgin Islands, French' and Holland's Antilles, Aruba, Bonaire and Curacao ("ABC" islands under Dutch administration), Trinidad and Tobago, Northern Venezuela and Northern Colombia, Panama, Costa Rica, Nicaragua, El Salvador, Guatemala, Belize, Honduras and Mexico. In the main gravity network the absolute gravity values shall be determined with FG5 or equivalent instrument;
3. densification of the primary gravity network, thus establishing a secondary gravity network;
4. network adjustment; dissemination of gravity data;
5. network maintenance.

Some of the reasons to justify this project are listed below:

- to fill-up the gap in gravity data between the North and the South Americas;
- to model the geoid (particularly geoid slopes) in this region;
- to validate the gravity data from the satellite missions: CHAMP, GRACE, GOCE;
- to verify (i.e. confirm) the existence of the following microplates: Gonave, Hispaniola, Puerto Rico and Northern Virgin Islands, Colombian, Venezuelan and Panamian within the Caribbean Plate and their behaviour as suggested by recent GPS surveys;
- to merge gravity data with other types of data, such as: satellite altimetry, seismic, magnetic and electrical to investigate the dynamics and (micro/intra) plate deformation;
- to validate the use of the gravimeters as the tool for natural hazard mitigation in this tectonically active region (i.e. swelling of the cones of the volcanoes before the eruption, or earthquake prediction);
- to check (control) the DTM's in this region;
- to test and model the behaviour of the gravimeters, and in particular:
 - drift;
 - sudden changes in atmospheric pressure (tropical storms);
 - tidal loading (Atlantic Ocean, Pacific and Caribbean Sea);
 - precipitation (dry versus wet seasons) and related changes in ground water levels;
 - humidity.

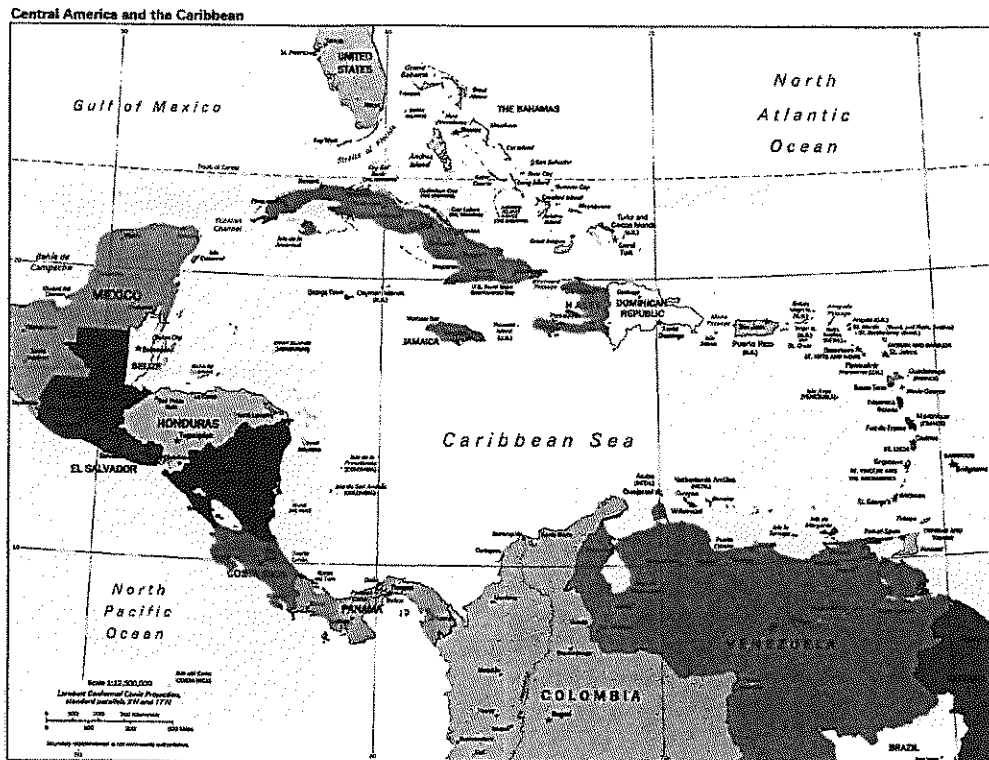


Fig. 1: Caribbean zone

INTRODUCTION

The Caribbean (formerly known as the West Indies) is the region spanned between the North and South Americas. In this vast area, the Central America and the numerous islands, which are predominantly formed in the shape of arcs, constitute one of the nature's unique laboratory to study geodynamic phenomena. This region is not only diversified politically, but geologically and geophysically as well. Caribbean plate is surrounded by NORTH AMERICAN (NOAM), SOUTH AMERICAN (SOAM), Nazca, Cocos, and Pacific plates with some triple junctions (i.e. Nazca, Cocos, Caribbean, or NOAM, SOAM, Caribbean), with the 2nd deepest (Puerto Rican) trench in the world (bis 8 000 m depth), numerous active volcanos (Montserrat, Popocatepetl, Irazu, Poas to mention a few), underwater active volcano (near the north coast of Grenada), hot springs (in the islands of Nevis and Saba) and diverse topography (ranging from sea level bis over 3000 m in Dominican Republic, and over 5 000 m in Mexico) which in some instances is interesting (such as mogotes in Cuba and Puerto Rico) and unique (such as for example the 30 km long cave system with underground river and lakes in Camuy, Puerto Rico and in Mexico). Tropical climate with clear distinction between the dry and wet seasons (and consequently distinct changes in ground water level fluctuations and the air humidity) and diversity in tidal loading from Atlantic Ocean, Caribbean Sea and Pacific makes this region interesting and unique to study.

BRIEF REVIEW OF GEOLOGIC HISTORY, STRUCTURE, AND ACTIVE TECTONICS

The origin and the history of the Caribbean plate is much debated in the recent years (Mann, 1999a,b; Dengo, 1969). One of the main themes is the relation of the Caribbean Plate to the surrounding NOAM and SOAM plates (Driscoll & Diebold, 1999). The "Pacific versus in situ" is the main controversy related to the origin of the Caribbean Plate. The "mobilist" model assumes, that Caribbean Plate was formed in the Eastern Pacific (near the Galapagos hot spot) and migrated over the time in predominantly eastward direction to its present location. The "fixist" model assumes, that the Caribbean Plate was formed "in situ" during break-up of the Pangea, and experienced (in Cenozoic) only minor motions with respect to North and South Americas. There was the "squeezed pumpkin theory" or "eastward escape"

of the Caribbean Plate, favoured by Mann et al. (1999a, 1999b), which recently was questioned by Mueller et al. (1999). According to Mueller (ibid.), the "eastward escape" of the Caribbean Plate is the result of the convergence of NOAM and SOAM tectonic plates.

The plate is composed of continental crust, oceanic crust, and mixture of both. Adjacent to, and within the Caribbean Plate, there are several crustal blocks, such as Yucatan Block, Bahama Platform, Maya Block, Cortis Block and Beata Ridge. They had an impact on migration and shape of the Caribbean Plate. And so, Bahama Platform which belongs to NOAM plate, stopped further eastward advancement of the Caribbean Plate and is presently subducting under Hispaniola and along the northern part of the Caribbean Plate. The Yucatan block in pre-rift phase was a homogeneous part of the Mexico; during the syn-rift phase (~210-160 Ma) it migrated along the eastern Mexico Transform Zone and was next (~160-155 Ma) bis 11 degrees anticlockwise rotated; during rifting phase (~160-140 Ma) was further (bis 42 degrees) rotated and when the thinning of the ocean floor stopped, reached its present position. (The reconstruction of the tectonic in the Gulf of Mexico and Caribbean can be found - among other - in : Pindel and Dewey, 1982; Anderson and Schmidt, 1983; Klitgord et al., 1984; Pindell and Barret, 1990; Marton and Buffler, 1994; Mann, 1999a, 1999b).

Maya Block which lies in northern part of Central America, covers the territory of Belize, northern part of Guatemala and the Yucatan Peninsula (Dengo, 1969). It is generally accepted, that Maya Block originated in the Gulf of Mexico (Donnelly et al., 1990). (More information relevant to Maya Block can be found for example in: Ave Lallemand and Gordon, 1999; Donnelly et al., 1990; Weyl, 1966, 1980; Steiner and Walker, 1966; Burkart, 1994).

Maya and Cortis Blocks are separated by Motagua Suture, which is tectonically active zone and is assumed to be an extension of the Cayman Trench (Taber, 1922; Hess and Maxwell, 1953; Burke et al., 1984; Wadge and Burke, 1983)

Mauffret and Leroy (2001) interpret the Beata Ridge as a compressional plate boundary, resulting from overthrusting of the Colombian microplate onto the Venezuelan microplate. They have shown (ibid.), that Beata Ridge is a Crataceous plateau, bounded to the east by compressive structures reactivated by right-lateral strike-slip, and by normal faults to the west. Uplift of the ridge increases from the south to the north, and is estimated to have started in Early Miocene (~23 Ma), resulting in total shortening between 170-240 km as a function of latitude. Mann and Burke (1984) suggest, that Beata Ridge may be the consequence of the northward motion of the Maracaibo block, which is a tectonic block of the SOAM plate.

Cayman Trough with its elongated rhomboidal shape of 1200 km x 90-110 km (length x width) and depths reaching bis 6 800 m (Bartlett Depth) is one of the active zones which significantly contributed to understanding of the origin, formation and migration of Caribbean Plate. Spreading of the ocean floor is still the ongoing process and the source of many inspirations and interpretations (Perfit and Heezen, 1978; Mann, 1999a,b; Leroy et al, 2000).

From the times of Vening Meinesz, who have chosen Puerto Rican trench as the location for some of his experiments with the gravity surveys at sea and possibilities of measuring the gravity at the bottom of the ocean, much attention has been paid to investigation and interpretation of the gravity anomalies there since (to mention Maurice Ewing). At present the concern around Puerto Rican trench seem to be focused at the possibility of an underwater land slide of sediments accumulated on the slope of the trench (triggered by an earthquake), which could generate tsunamis there.

Caribbean is well suited nature's lab for testing some of the Active Tectonic hypotheses there. At present the concept of the mosaic of microplates (i.e. Panama, Gonave, Hispaniola, Puerto Rico and Northern Virgin Island, Colombian and Venezuelan) of which the Caribbean plate is (supposedly) composed seem to prevail (Mann, 1999a,b; Mauffret and Leroy, 1999; Mattioli and Jansma, 2002). However, there are also the representatives of one (rigid) plate theory (eventually, - with the possibility of intra-plate deformation). From North, South and West NOAM, SOAM, and Cocos plates are subducting (respectively) under the Caribbean plate, which is overriding the Atlantic plate (from the east).

Subduction of the Northern part of Venezuelan microplate along Muertos Trough (south of Puerto Rico) seems to be equally puzzling and interesting ongoing process; as is the over 700 km long Moron-El Pilar

collision zone between the Southern part of the Caribbean plate and Northern part of SOAM plate, stretching from Trinidad to Gulf of Cariaco with Bocono fault, Maracaibo, Santa Marta and Romeral (among other tectonically interesting zones).

SOME BASIC QUESTIONS:

The well known fact is, that the Caribbean Plate does not quite "fit" i.e. confirm the predicted general motion of the tectonic plates (Jordan, 1975; Sykes et al., 1982; Ward, 1990; DeMets et al., 1990; Dixon et al., 1991; Deng & Sykes, 1995; Larson et al., 1997; Jansma et al., 1999, 2000; DeMets et al., 2000).

The structural complexity onshore as well as the offshore, the limited quantity and lack of high quality of marine data (seismic, drilling and magnetic data) are some of the reasons which might explain, why the internally consistent model for the development of the Caribbean plate is still missing.

Equally puzzling is the thickness of the crust varying from 4 km (in the Venezuelan Basin) to 12 km (across the Beata Ridge).

The distinction between the active and the passive margins along the Caribbean Plate and the widths of the deformation zones calls for the refinement of the boundaries which should be more clearly outlined, i.e. defined. The rate of accretion of the crust (from the Caribbean Plate to the NOAM Plate) taking place in the Northern part of the Caribbean Plate might be compared against the rate of expulsion of the crustal blocks taking place in the Southern part of the Caribbean Plate (from the Northern part of the SOAM Plate to the Southern part of the Caribbean Plate).

The gravity data might eventually help to resolve the ambiguities related to the rate of convergence of the surrounding tectonic plates, rates of their subduction, internal plate deformation, translation and rotation of the crustal blocks within the Caribbean Plate (i.e. Maya, Cortis, Beata Ridge), thickness of the crust, or the rate of convergence between the microplates (i.e. overthrusting of the Colombian over Venezuelan microplate).

They may also help to answer the questions related to tectonic uplift rate in the Caribbean, the role of Motagua Valley (as an extension of the Cayman Trough) or help in interpretation of tectonic puzzle in Barbados. The trend of the major tectonic structures in Barbados is East-Northeast rather than North (the prevailing trend in island arc)

Sufficient spatial and temporal coverage with gravity data might eventually help to clarify the (co)relation between the variations in the ground water pressure and microearthquakes; i.e. help in hydrological modelling of the relation between changes in the ground water pressure, depth, inhomogeneity, lateral variations in geological layers and the triggering mechanisms of microearthquakes. This in turn might help to refine the models of the geometry of faults and the dynamics of ruptures.

In some parts of Caribbean extensive gravity data collection took place in the past. When these data are available (and comparable), their comparison with the proposed gravity survey would help to determine the temporal variation of the gravity field in this region.

They might also be used as the tool to verify the stages of the seismic deformation cycle (i.e. pre-inter- and post seismic deformation) in Hispaniola, Northern South America, or Western Central America (the tectonically active zones).

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