ASSOCIATION INTERNATIONALE DE GEODESIE

BUREAU
GRAVIMETRIQUE
INTERNATIONAL

BULLETIN D'INFORMATION

N° 70

Juin 1992

18, Avenue Edouard Belin
31055 TOULOUSE CEDEX
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INFORMATIONS FOR CONTRIBUTORS

Contributors should follow as closely as possible the rules below :

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

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

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

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

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

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

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

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

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

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

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

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

BUREAU GRAVIMETRIQUE INTERNATIONAL

Toulouse

BULLETIN D'INFORMATION

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N° 70

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Part I

INTERNAL MATTER

GENERAL INFORMATIONS

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4. PROVIDING DATA TO B.G.I.

1. HOW TO OBTAIN THE BULLETIN

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

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

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

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

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

About three hundred individuals and institutions presently receive the Bulletin.

You may :

- *either request a given bulletin, by its number (70 have been issued as June 30, 1992, but numbers 2, 16, 18, 19 are out of print).*
- *or subscribe for regularly receiving the two bulletins per year plus the special issues.*

Requests should be sent to :

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

Bulletins are sent on an exchange basis (free of charge) for individuals, institutions which currently provide informations, data to the Bureau. For other cases, the price of each number is as follows :

- 65 French Francs without map,

- 75 French Francs with map.

2. HOW TO REQUEST DATA

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

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

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

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

2.2. G-Value at Base Stations

Treated as above.

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

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

2.4. Gravity Maps

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

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

- *we can make (poor quality) black and white (or ozalide-type) copies at low cost,*
- *color copies can be made (at high cost) if the user wishes so (after we obtain the authorization of the editor).*

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

2.5. Gravity Measurements

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

EOL
LAND DATA FORMAT
RECORD DESCRIPTION
126 characters

Col. 1-8	**B.G.I.** source number	X	(8 char.)
9-16	**Latitude** (unit : 0.00001 degree)		(8 char.)
17-25	**Longitude** (unit : 0.00001 degree)		(9 char.)
26-27	Accuracy of position		(2 char.)

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

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

	8 = 2000 < R <= 5000 M *9 = 5000 M < R* *10...*	
28-29	System of positioning *0 = no information* *1 = topographical map* *2 = trigonometric positioning* *3 = satellite*	(2 char.)
30	Type of observation *1 = current observation of detail or other observations of a 3rd or 4th order network* *2 = observation of a 2nd order national network* *3 = observation of a 1st order national network* *4 = observation being part of a nation calibration line* *5 = coastal ordinary observation (Harbour, Bay, Sea-side...)* *6 = harbour base station*	(1 char.)
31-38	**Elevation of the station** (unit : centimeter)	(8 char.)
39-40	Elevation type *1 = Land* *2 = Subsurface* *3 = Lake surface (above sea level)* *4 = Lake bottom (above sea level)* *5 = Lake bottom (below sea level)* *6 = Lake surface (above sea level with lake bottom below sea level)* *7 = Lake surface (below sea level)* *8 = Lake bottom (surface below sea level)* *9 = Ice cap (bottom below sea level)* *10 = Ice cap (bottom above sea level)* *11 = Ice cap (no information about ice thickness)*	(2 char.)
41-42	Accuracy of elevation *0 = no information* *1 = E <= 0.02 M* *2 = .02 < E <= 0.1 M* *3 = .1 < E <= 1* *4 = 1 < E <= 2* *5 = 2 < E <= 5* *6 = 5 < E <= 10* *7 = 10 < E <= 20* *8 = 20 < E <= 50* *9 = 50 < E <= 100* *10 = E superior to 100 M*	(2 char.)
43-44	Determination of the elevation *0 = no information* *1 = geometrical levelling (bench mark)* *2 = barometrical levelling* *3 = trigonometric levelling* *4 = data obtained from topographical map* *5 = data directly appreciated from the mean sea level* *6 = data measured by the depression of the horizon* *7 = satellite*	(2 char.)
45-52	Supplemental elevation (unit : centimeter)	(8 char.)
53-61	**Observed gravity** (unit : microgal)	(9 char.)
62-67	**Free air anomaly** (0.01 mgal)	(6 char.)
68-73	**Bouguer anomaly** (0.01 mgal) 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) *computed according to the next mentioned radius & density*	(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 02)
11 = tc computed from 1 km to 167 km
12 = tc computed from 2.5 km to 167 km
13 = tc computed from 5.2 km to 167 km
14 = tc (unknown radius)
15 = tc computed to zone M (22 km)
16 = tc computed to zone G
17 = tc computed to zone K (18.8 km)
25 = tc computed to 48.6 km on a curved Earth
26 = tc computed to 64. km on a curved Earth

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

92-93 Accuracy of gravity (2 char.)

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

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

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

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

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

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

	60 = Gulf *62 = Western* *63 = North American* *64 = Lacoste-Romberg*	
109-111	**Country code** (B.G.I.)	(3 char.)
112	**Confidentiality** *0 = without restriction* *1 = 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
145 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 (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 Brasses/sec)
5 = acoustic depth obtained with sound speed 800 Basses/sec (or 1463 M/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) (6 char.)
computed according to the next mentioned radius & density

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

0 = no topographic correction
1 = tc computed for a radius of 5 km (zone H)
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16 = tc computed to zone G
17 = tc computed to zone K (18.8 km)
25 = tc computed to 48.6 km on a curved Earth
26 = tc computed to 64. km on a curved Earth

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

92-93 Mathew's zone (2 char.)
when the dept is not corrected depth, this information is necessary. For example : zone 50 for the Eastern Mediterranean Sea

94-95 Accuracy of gravity (2 char.)

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

96-101 Correction of observed gravity (unit : microgal) (6 char.)

102-110 Date of observation (9 char.)
in Julian day - 2 400 000.

111-113 Velocity of the ship (0.1 knot) (3 char.)

114-118 Eötvös correction (0.1 mgal) (5 char.)

119-121 **Country code** (B.G.I.) (3 char.)

122	**Confidentiality** *0 = without restriction* *1 = with authorization* *2 = classified*	(1 char.)
123	**Validity** *0 = no validation* *1 = good* *2 = doubtful* *3 = lapsed*	(1 char.)
124-130	Numbering of the station (original)	(7 char.)
131-136	**Sequence number**	(6 char.)
137-139	**Leg number**	(3 char.)
140-145	**Reference station**	(6 char.)

Whenever given, the theoretical gravity (γ_o), free-air anomaly (FA), Bouguer anomaly (B0) are computed in the 1967 geodetic reference system.

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

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

where ϕ is the geographic latitude.

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

Formulas used in computing free-air and Bouguer anomalies

Symbols used :

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

Formulas :

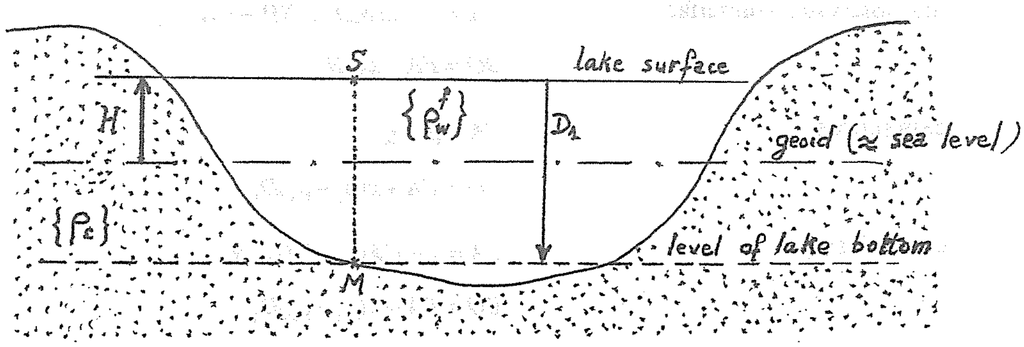
* *FA :* *The principle is to compare the gravity of the Earth at its surface with the normal gravity, which first requires in some cases to derive the surface value from the measured value. Then, and until now, FA is the difference between this Earth's gravity value reduced to the geoid and the normal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

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

---

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

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



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

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

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

$$\delta g_s = g_s - k\rho_w^f D_1 + k\rho_c(D_1 - H)$$

$$= g_s - k\rho_w^f[H + (D_1 - H)] + k\rho_c(D_1 - H)$$

$$= g_s - k\rho_w^f H + k(\rho_c - \rho_w^f)(D_1 - H)$$

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

The table below covers most frequent cases. It is an update of the list of formulas published so far, which had four typing errors (for cases 2, 4, 5, 8).

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 :

$$-k\rho_i H + k(\rho_c - \rho_i)(D_1 - H) \equiv -k\rho_i(H - D_1 + D_1) - k(\rho_c - \rho_i)(H - D_1)$$

$$\equiv -k\rho_i D_1 - k\rho_c(H - D_1)$$

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

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

2.6. Satellite Altimetry Data

BGI has access to the Geos 3 and Seasat data base which is managed by the Groupe de Recherches de Géodésie Spatiale (GRGS). These data are now in the public domain.

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

(a) *Requests for satellite altimetry derived geoid heights (N), that is : time (julian date), longitude, latitude, N, are processed by B.G.I.*

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

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

All requests for data must be sent to :

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

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

If not specified, the data will be written, formatted (EBCDIC) on unlabeled 9-track tape (s) with a fixed block size. The exact physical format will be indicated in each case.

3. USUAL SERVICES B.G.I. 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 January 1, 1991 and may be revised periodically.

3.1. Charging Policy for Data Contributors and Scientists

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

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

3.1.1. Digital Data Retrieval

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

. minimum charge : 100 F.

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

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

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

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

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

3.1.3. Data Screening

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

. 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/ΔΔ' 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 ΔxΔ' area : 10 F/ΔΔ' per degree square.

. minimum charge : 150 F

. maximum area : 40° x 40°

3.2. Charging Policy for Other Individuals or Private Companies

3.2.1. Digital Data Retrieval

. 1 F per measurement

. minimum charge : 150 F

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

- *2 F per degree square ; 100 F minimum charge. (maximum plot size = 90 cm x 180 cm)*
- *For area inside polygon : same price as above, counting the area of the smallest rectangle comprising in the polygon.*

3.2.3. Data Screening

. 1 F per screened point

. 250 F minimum charge

3.2.4. Gridding

Same as 2.1.4.

3.2.5. Contour Maps of Bouguer or Free-Air Anomalies

Same as 2.1.5.

3.2.6. Computation of Mean Gravity Anomalies

Same as 2.1.6.

3.3. Gravity Maps

The pricing policy is the same for all categories of users.

3.3.1. Catalogue of all Gravity Maps

printout : 200 F

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

3.3.2. 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*

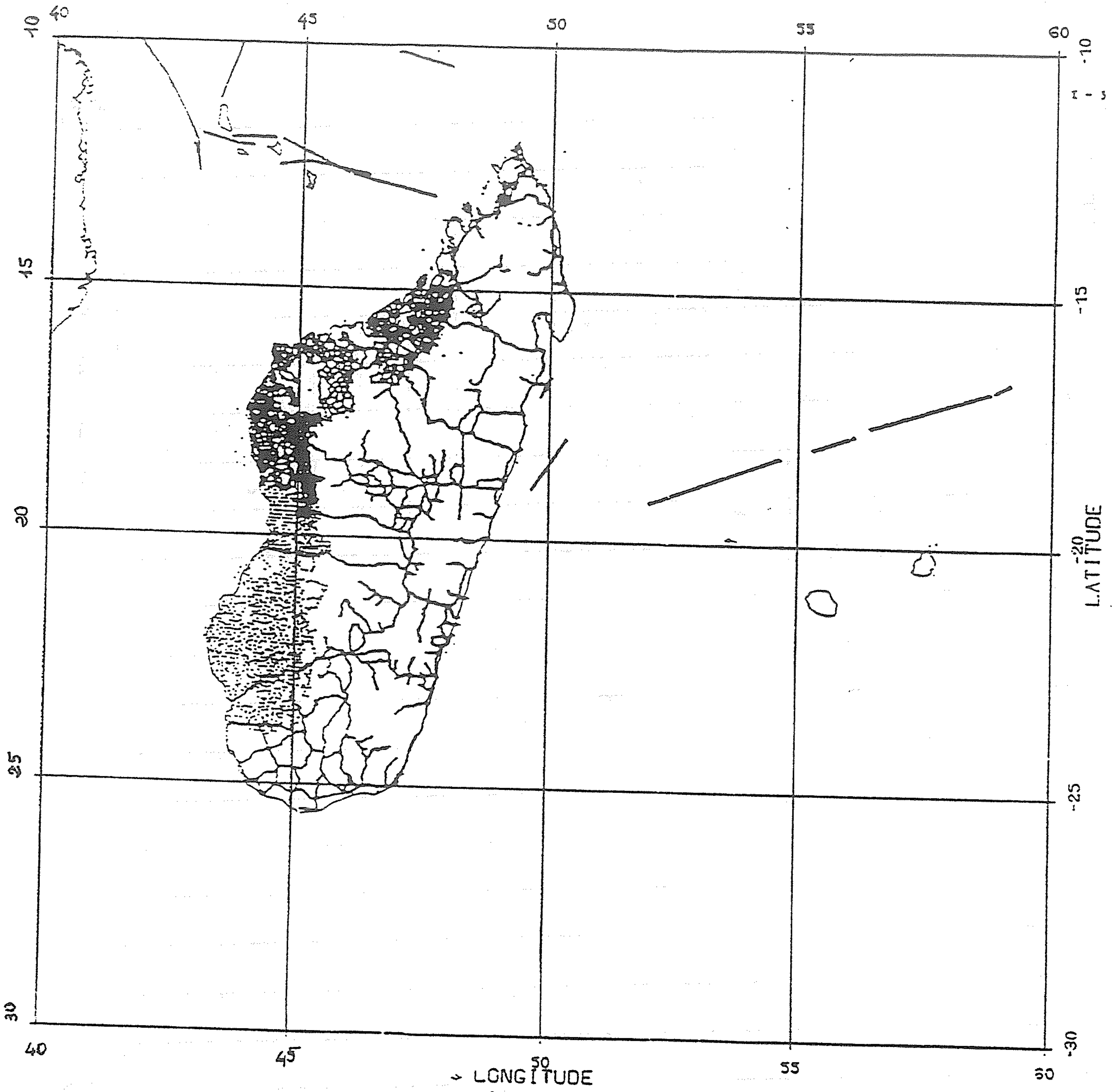
THE UNIFICATION OF THE GRAVITY NETS
OF AFRICA (Vol. 1 and 2) 1979 150 FF

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

. Colour copy : price according to specifications of request.

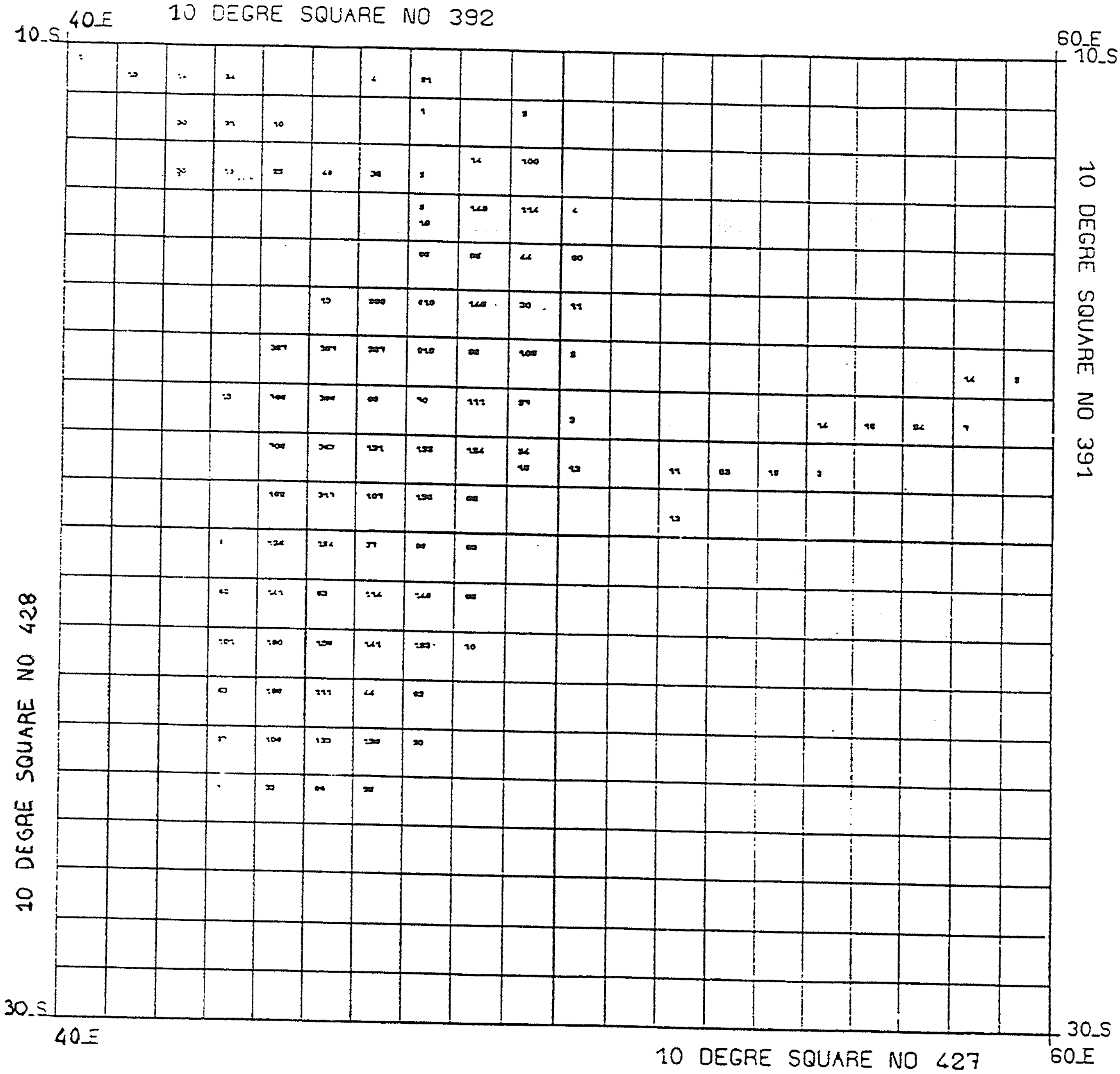
Mailing charges will be added for air-mail parcels when "Air-Mail" is requested)

Map 1. Example of data coverage plot



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

REPRESENTATION OF EARTH AND SEA GRAVIMETRIC STATIONS



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 instrumental 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.

. 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.

**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 wheter 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.

The contributor may use, 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 unlabeled tapes (if possible), with no password, and formated records of possibly fixed length and a fixed blocksize, too. Tapes are returned whenever specified, as soon as they are copied.

Part II

NATIONAL REPORTS

UNION GEODESIQUE ET GEOPHYSIQUE INTERNATIONALE

ASSOCIATION INTERNATIONALE DE GEODESIE

ASSEMBLEE GENERALE

VIENNE, AUTRICHE 1991

RAPPORT NATIONAL DE L'ALGERIE

Extraits : Introduction - Gravimétrie - Perspectives

établi par l'Institut National de Cartographie
123 rue de Tripoli 16040 HUSSEIN-DEY - ALGER

INTRODUCTION

Ce rapport est établi par l'Institut National de Cartographie (INC) qui, en Algérie a, entre autres missions, celle d'effectuer sur le territoire national, les travaux nécessaires à l'implantation de réseaux géodésique, gravimétrique et de nivellement de précision.

En matière de géodésie, en 1982, l'INC s'est fixé pour objectif à atteindre avant 1995 :

. le parachèvement des travaux de géodésie classique de premier ordre et de densification, jusqu'à ce que cette dernière couvre l'ensemble du territoire au Nord du piémont sud de l'Atlas Saharien

. l'implantation d'un réseau de "géodésie doppler" couvrant l'ensemble du territoire national ;

. l'homogénéisation du réseau national de géodésie en intégrant les observations effectuées pendant le programme, de nouvelles mesures de bases et astronomiques, données gravimétriques et de nivellement, ainsi que les observations faites dans le cadre de programmes internationaux tels que ADOS

. la densification du réseau de nivellement de précision au nord de l'Atlas Saharien ,

la réfection et l'implantation des mailles de nivellement de précision au Sud du pays suivant les grands axes de communication ;

. l'implantation d'un réseau gravimétrique national de premier ordre, et le début de sa densification.

Le rapport donnera un apperçu sur l'évolution des travaux entre 1987 et 1990 en matière de :

- Géodésie classique ;
- Géodésie par effet doppler
- Nivellement de précision :
- gravimétrie ;

et concluera sur les perspectives du quadriennal 1991-1994.

GRAVIMETRIE

Cette mission est réalisée en collaboration étroite avec le Centre de Recherche en Astronomie, Astrophysique et Géophysique (CRAAG).

Le CRAAG est chargé de réaliser et de maintenir le réseau fondamental, tandis que l'INC est chargé de la réalisation et du suivi du réseau de base qui sera constitué d'un réseau de premier ordre (une centaine de stations distantes d'environ 150 Km) et d'un réseau de second ordre (une station tous les 25 à 30 Km). Quant aux réseaux locaux pour les besoins de la prospection minière, l'hydrogéologie et autres, ils restent du ressort des opérateurs économiques.

Le programme d'observations gravimétriques a débuté en 1989. Cette première année a été consacrée à la formation du personnel, à l'observation de 50 points espacés de 1 à 2 Km dans la région de Chlef, dans le cadre de l'étude de la déformation du sol dans cette zone sismique, et parallèlement, au développement des logiciels de compensation, lesquels ont été calqués sur ceux du nivellement de précision.

En 1990, quatre bases ont été observées, ainsi que 4 points de premier ordre et 15 points de second ordre à l'aide de 2 gravimètres LACOSTE ROMBERG.

PERSPECTIVES

Parachèvement des réseaux de géodésie primordiale, de détail, et spatiale.

Parachèvement du réseau de nivellement de précision au Nord de l'Atlas Saharien, et accroissement des cadences de production (nivellement motorisé) pour avancer le Nivellement de précision au Sud.

Parachèvement du réseau gravimétrique de premier ordre, et début de densification.

Maintenance des réseaux de géodésie et de nivellement.

Détermination d'un réseau de points de LAPLACE.

Détermination d'un reseau de points GPS.

Participation aux projets régionaux.

Compensation globale (en un seul bloc d'extension longitudinale de plus de 10 degrés) de la géodésie primordiale (quelques 400 points), et de la géodésie de détail (quelques 3 000 points).

Après cette première compensation, le reseau géodésique sera valorisé par l'intégration des données disponibles, à savoir :

- les mesures de géodésie spatiale déterminées dans le systeme TRANSIT, ainsi que les points ADOS ;
- les mesures astro-géodésiques ;
- Les mesures gravimétriques et de nivellement ;

Pour aboutir avant la fin de la decennie à la définition :

1- d'un réseau national de géodésie homogène et unifié λ, ϕ.

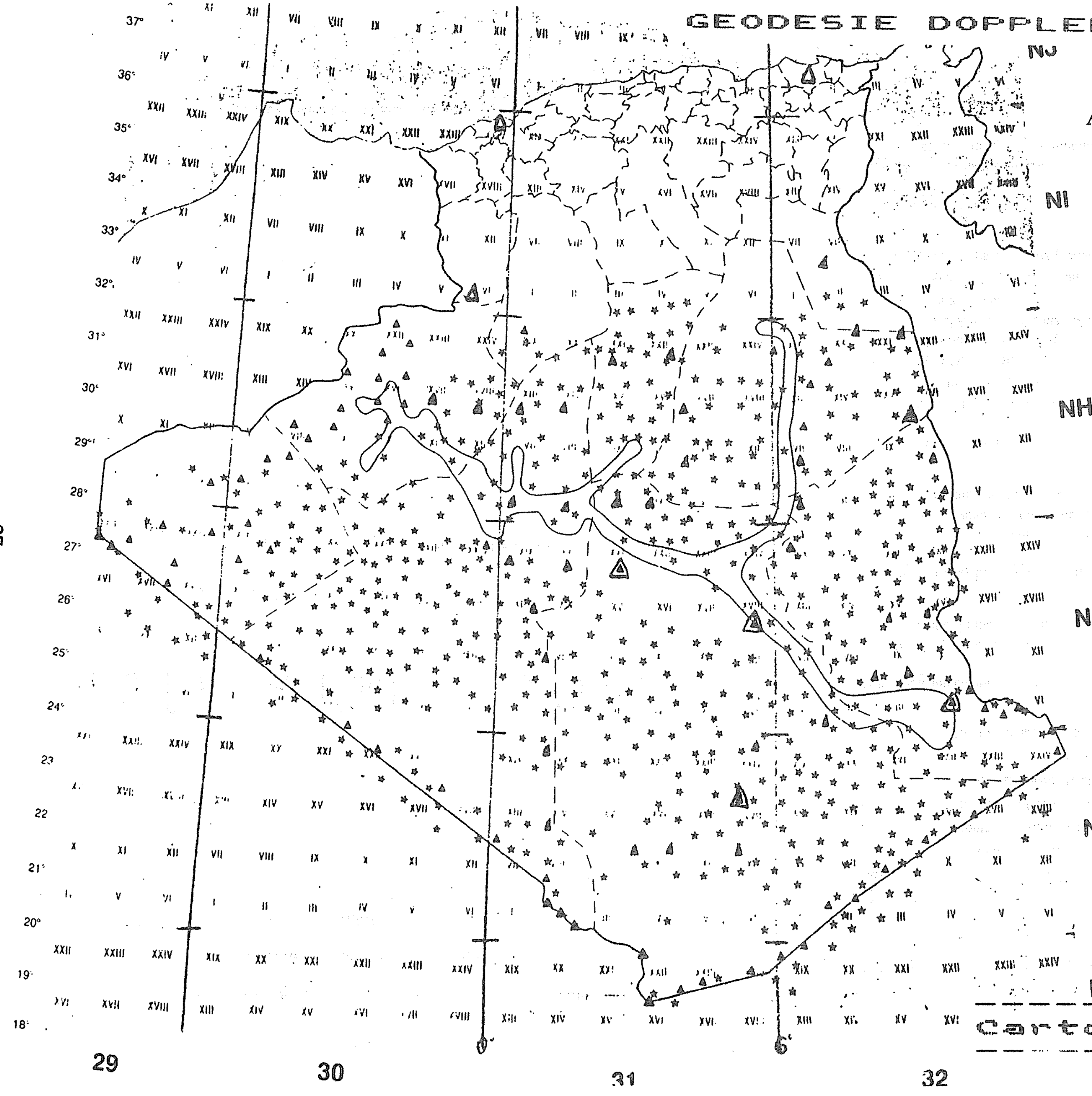
2- d'un réseau national de nivellement homogène et unifié, donnant HA.

3- d'un réseau national de gravimétrie homogène et unifié, donnant gA.

4- du géoïde en ALgérie en liaison avec avec les systèmes définis en 1, 2, et 3, qui donnera NA.

Ce réseau national moderne doit s'insérer dans un réseau plus vaste, continental. Ce sera un réseau de référence tridimentionnel.

GEODESIE DOPPLER (sud)



ALGERIE Régions Sud Géodésie

Situation au 1er Janvier 1991

- Chaine Geodesique 1er Ordre Ancien-Anterieur à 1954
- Point Astronomique
- Points de Base de Geodesie Doppler
- Point ADOS

Cartogramme N° 4

INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS

XX GENERAL ASSEMBLY - VIENNA, AUSTRIA

AUGUST 11-24, 1991

AUSTRIA - AUTRICHE - ÖSTERREICH

IAG - Report of the Austrian Geodetic Commission

Excerpt : Determination of the Gravity Field

Printed by: Bundesamt für Eich- und Vermessungswesen

SECTION III: DETERMINATION OF THE GRAVITY FIELD

Abreviations:

BEV . . . Bundesamt für Eich- und Vermessungswesen, Wien
(Federal Office for Metrology and Surveying)
ML . . . Montanistic University of Leoben, Inst. of Geophysics
UW . . . University of Vienna, Inst. of Meteorology and Geophysics
TG . . . Technical University of Graz
TW . . . Technical University of Vienna, Inst. of theor. Geodesy and Geophysics
ZA . . . Central Institute for Meteorology and Geodynamics, Vienna

1) Absolute measurements:

BEV, ML, UW, ZA: 23 stations in Austria, 2 stations in Germany with the JILAG-6 absolute gravity meter. Participation at the comparison in Sevres 1989.

2) Austrian Gravity Base Net (ÖSGN):

BEV: The ÖSGN includes now 637 stations (incl. absolute stations). Relative connection measurements were made to the adjucent network (I, CH, D, CS, H), control measurements within the internal part of the network, first adjustment.

3) Regional measurements:

BEV: Continuing the measurements along the levelling lines for calculation of geopotential units and orthometric heights.

ML: SE of Austria: 9000 stations / 18 000 km^2.
W of Austria (Vorarlberg): ca. 1000 stations.
NW of Austria (Bohemian Mass west): ca. 700 stations.
mining - gravity.

UW / ZA: N of Austria (Bohemian Mas).
Central Alps of Austria (continuing) 1 station/10 km^2.

4) Local measurements:

BEV,UW,ZA: Hochkar Calibration Line. Investigations on recent gravity changing with absolute and relative gravity measurements in Obergurgl in the Austrian Central Alps and in the Vienna Basin.

ML: Investigations for 8 projects of coal and groundwater prospecting and detection of cavities.

TW: Investigations for engineering projects.

5) Reductions and computations:

BEV: Interpolation of gravity values for levelling points and calculation of the average gravity value along the plumbline for orthometric heigths.

ML: Computations of a new Bouguer gravity map of the southeast of Austria.

UW: Computation of an isostatic residual gravity map of Austria.

BEV, ML, UW, TW, TG: Investigations in reduction problems of gravity in high mountainous areas using a topographic model with variable densities.

6) Earth tide investigations:

UW: Regional studies of tidal parameter distribution in the Eastern Alps and Pannonian Basin, investigation of calibration problems.

Publications:

Becker, M., Bernard, B., Boulanger, Y., Corrado, G., Faller, J., Fried, J., Groten, E., Hanada, H., Lindner, K., Meurers, B., Peter, G., Röder, R., Ruess, D., Timmen, L., Toro, B., Tsuruta, S., Zürn, W.: Relative Gravity Measurements at the 3rd International Comparison of Absolute Gravimeters. Bureau Gravimetrique International, Bulletin d'Information No. 67, Toulouse Dec. 1990.

Figdor, H., Roch, K.H, Scheidegger, A. E.: Anwendung kombinierter geophysikalischer Methoden für Baugrunduntersuchungen. Arcus, Zeitschr. f. Architektur u. Naturwiss., Wien 1986/4.

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Figdor, H., Koren, G., Roch, K.H.: Geophysikalische Erkundung eines überdeckten Deponiekörpers. ÖIAZ, 134. Jg, Heft 9, 450-456, Wien 1989.

Figdor, H., Roch, K.H, Scheidegger, A.E.: Geophysikalische und geodätische Untersuchungen an einer Hangrutschung im Flysch. ÖZ f. Verm. u. Photogr., Wien 1990.

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Granser, H., Steinhauser, P., Ruess, D., Meurers, B.: Beiträge zur Erkundung der Untergrundstrukturen der Neusiedlersee - Region mit gravimetrischen und magnetischen Methoden. In press, Wien 1990.

Kraiger, G., Kühtreiber, N.: Freiluftanomalien, Bougueranomalien und isostatische Anomalien im Bereich der Ostalpen und ihr statistisches Verhalten. Tagungsber. 5. Int. Alpengravimetrie - Kolloquium Graz 1989, Österr. Beitr. zu Meteorol. u. Geophysik, 2, 73-94, Wien 1989.

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Lichtenegger, H., Colic, K.: Ergebnisse von Erdgezeiten - Registrierungen in der Station Zagreb. Tagungsber. 5. Int. Alpengravimetrie -Kolloquium Graz 1989, Österr. Beitr. zu Meteorol. u. Geophysik, 2, 153-160, Wien 1989.

Lichtenegger, H., Klostius, W.: Programmsystem zur Berechnung des Schwerefeldes von Massen in Isolinien - Darstellung. Tagungsber. 5. Int. Alpengravimetrie - Kolloquium Graz 1989, Österr. Beitr. zu Meteorol. u. Geophysik, 2, 239-248, Wien 1989.

Meurers, B.: Comparison of earth tidal observations in Vienna. B.I.M., 100, 6942-6953, 1987.

Meurers, B., Ruess, D., Steinhauser, P.: The Gravimetric Alpine Traverse. Geodynamics of the Eastern Alps, Flügel H. and Faupl P. Editors, Deuticke, 99-109, Vienna 1987.

Meurers, B., Steinhauser, P., Zych, D.: Berechnung von Bougueranomalien mit variablem Dichteansatz. Tagungsber. 5. Int. Alpengravimetrie - Kolloquium Graz 1989, Österr. Beitr. zu Meteorol. u. Geophysik, 2, 213-228, Wien 1989.

Meurers, B., Steinhauser, P., Zych, D.: Berechnung der Bougueranomalie im Hochgebirge unter Anwendung eines geologischen Dichtemodelles. JB. Geol. BA. ISSN 0016-7800, Bd. 133, Heft 1, 99-109, Wien, März 1990.

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Meurers, B., Varga, P., Mitnyik, J.: Results from an instrumental comparison in Budapest - an attempt to study the reliability of regional variations of tidal parameters. B.I.M., 107, 7575-7586, 1990.

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Posch, E., Walach, G.: Schwerekarte des ÖK-Blattes 186, St. Veit / Glan mit Nachbargebieten. Tagungsband d. Arbeitstagung 1989 d. GBA, 132-136, Wien 1989.

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Ruess, D.: Stand des Österr. Schweregrundnetzes und des digitalen Geländemodelles. Tagungsber. 4. Int. Alpengravimetrie - Kolloquium, Wien 1986. Berichte über den Tiefbau der Ostalpen, 159-164, Wien 1988.

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Steinhauser, P., Höggerl, N.: On the Correlation between Recent Crustal Movements and Gravity Anomalies in Austria. Bureau Gravimetrique International, Bulletin d'Information No 62, Toulouse 1988.

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Steinhauser, P., Meurers, B., Ruess, D.: Gravity investigations in mountainous areas. Exploration Geophysics, in press, 1990.

Wagini, A., Steinhauser, P., Meurers, B.: Isostatic Residual Gravity Map of Austria. ZA f. Met. u. Geodyn., Wien, Publ. Nr. 324, 1988.

Walach, G.: Gravimetrische Untertagemessungen in den Ostalpen. Oppolzer - Gedächtnissymposium 1986, Geodät. Arbeiten Österr. f. d. Int. Erdmessung, Bd. 5, Wien 1987.

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Walach, G.: The Gravity Field in Southern Austria. Proceedings 1. Int. Symp. Gravity Field Determination and GPS-Positioning in the Alps - Adria Area. Dubrovnik and Hvar, Oct. 1989. Mitt. d. geodät. Inst. d. TU Graz, Graz 1990.

Walach G.: The Gravity Field in Southern Austria. Mitt. geodät. Inst. TU Graz, 67, 135-140, Graz 1990.

Institute of Theoretical Geodesy and Geophysics (TUW)

Section Theoretical Geodesy

Activities:

Studies on the possibility of the existance of a fifth natural force. Investigation of figures of hydrostatic equilibrium.

Publications:

Bretterbauer, K.: Bedarf das Newton'sche Gravitationsgesetz einer Revision? Österreichische Zeitschrift für Vermessungswesen und Photogrammetrie, Vol. 77, No. 2, Vienna, 1989.

Hoffmann, W.: Gleichgewichtsmodelle für Jupiter und Saturn. Thesis, Technical University Vienna.

Institute of Applied Geodesy and Photogrammetry (TUG)

Section of Surveying and Landinformation Systems

Hofmann-Wellenhof, B.: A touch of United States of Europe: common data management for the geoid determination. Bollettino di geodesia e scienze affini, 46, No. 2, pp. 169-177, 1987.

National Report on Gravimetry in Belgium 1987-1990

prepared for
the International Gravity Commission
IAG-meeting, XXth IUGG General Assembly
Vienna, August 11-24, 1991

by

C. Poitevin

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BELGIUM

1 Regional gravimetry (gravity mapping)

Three separate local gravity networks have been established in Belgium with a total of 1619 stations.

The first one in N-W of Belgium:	696 km^2 (0,85 station/km^2) 593 st. MSE = 10 μgl.
Second: N-E of Belgium:	604 km^2 (0,97 station/km^2) 587 st. MSE = 8 μgl.
third: N of Belgium:	504 km^2 (0,87 station/km^2). 439 st. MSE = 11 μgl.

This work was performed by the "Centre de Géophysique Interne" of the Royal Observatory of Belgium with the assistance of the National Geographical Institute for the Geological Survey of Belgium.

Reports not available.

2 Microgravimetry

A feed-back system for LaCoste-Romberg model D gravimeter has been adapted and tested for field measurements (Thimus & al, 1988a & 1988b) in view of the localization of cavities and mineral deposits. Five microgravimetric campaigns, with a total of 957 stations were performed by the Laboratory of Civil Engineering of the University of Louvain-la-Neuve (Thimus & al., 1989 - Thimus 1989a & 1989b).

Reports not available.

3 Gravity reference networks

A first step to re-actualize the gravity network of the "Grand Duché de Luxembourg (1948)" (96 stations) has been done by linking this network to the absolute station of Uccle-Observatory (Brussels-Belgium) and IGSN71 (Poitevin & al., 1990). The next step is to level the stations by better height determinations than these acquired by barometric levelling in 1948.

In the frame of activities of the IGC-WG V: "Monitoring of non tidal Gravity Variations" repeated absolute gravity measurements have been performed at the site of the superconducting gravimeter of the Royal Observatory (Uccle):

June 1987	JILAG-3
April 1989	JILAG-5
December 1989	JILAG-5
December 1989	JILAG-3
September 1990	JILAG-5

A less-noisy site, Membach, located on the bedrock has been choosen for the implantation of another superconducting gravimeter. Absolute gravity measurements have been performed at this site by the JILAG-5 in September 1990 (Poitevin, 1990a).

4 Gravity data base activities

The belgian gravity data base established and maintained by the "Centre de Géophysique Interne" of the Royal Observatory of Belgium cover the area comprised between $2° - 7°$ longitude and $49° - 52°$ latitude.
Around 30.000 point gravity values are stored in the data base and are under the process of validation (Poitevin, 1990 b) and homogeneization in a coherent datum.
This gravity data base will be restructured with the DBMS software now available on the new computer of the Royal Observatory.

5 Instrumental developments and investigation

A study of the screw error and electrostatic effects on three LCR gravimeters with feedback system was published in (Zhou Kungen & al., 1986).
A calibration system for gravimeters, based on the principle on a vertical moving platform, has been developped at the Royal Observatory. The motion is sinusoidal with an amplitude of 1cm and periods bewteen 200 to 1000 sec. (Van Ruymbeke, 1989 a & b).
Feedback systems for gravimeters with possible grounding of the beam, infinite gain, large range (100 milligals) and digital direct counting possibilities were developped too (Van Ruymbeke, 1989 c). Preliminary results have been presented at the IGC meeting in Toulouse 1990 in (Van Ruymbeke, 1990) and (Ducarme & d'Oreye, 1990).

6 Other studies in gravimetry

6.1 Interpretation and analysis

A gravimetric exploration has been realized in the area of Mol and Turnhout (province of Antwerp, Belgium) to localize steep dipping faults in the Paleozoic bedrock and the meso-to-cenozoic overburden. The interpretation is based upon comparison with theoretical anomalies computed for various density contrasts and depths. The results confirm the presence of several faults already detected by other methods and enable a more accurate positioning (Dassargues & al., 1990).

Two perturbing effects on gravity have been calculated: the effect of the atmospheric pressure variations and the effect of the water-level variations (Delcourt-Honorez, 1988, 1990a, b). The barometric effect is calculated by using the Multi Input Single Output method (De Meyer, 1982) to deduce the transfer function, e.g. on Alice Springs (Australia), Strasbourg (France) and Lanzhou (China) gravimetric records, cf. (Delcourt-Honorez, 1988). The effect of the water-level variations including the land surface displacement, the gravitational, the barometric and the Earth tidal effect, has been estimated on the superconducting gravimeter records installed at the Royal Observatory of Belgium (Delcourt-Honorez, 1988, 1990a, b).

6.2 Theoretical studies

Some considerations about what we can expect as gravity changes due to tectonic features in Belgium are reviewed in (Poitevin, 1990 c).

7 Software development

The software package for the reduction (including tidal correction, etc ...) of gravity measurements, least-squares adjustment and statistical analysis of gravity networks have been adapted to run on a PC computer.

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CHINA NATIONAL REPORT

(1987—1990)

ON

GEODESY

for the XXth General Assembly of IUGG
Vienna, Austria, 1991

Excerpts : Gravimetry - Geodetic Database - Marine Geodesy

Chinese National Committee for the International
Union of Geodesy and Geophysics
Beijing, China

I. CLASSICAL GEODESY

Gravimetry

On the ground of the Basic Gravity Net established in China in 1985 (CGBN 85), a national first–order gravity network has been developed to meet the requirements in the field of surveying and mapping, geology, petroleum, astronautics and oceanology. The national first–order gravity points are disposed along main communication lines at intervals around 300 km. The observations were carried out with gravimeters LCR–G and LCR–D since 1983 and accomplished in 1989. There are altogether 195 first–order gravity points in our whole territory within the continent, among which 20 are exir points and 12 coincide with the points of the Gravity Net 1957. The lines are either closed or in form of loops. The number of segments in both lines is not superior to 5. The connection measurement RMSE of the segment gravity difference is not beyond $\pm 25 \times 10^{-8}ms^{-2}$and the RMSE of the gravity value is within $\pm 60 \times 10^{-5}ms^{-2}$. An adjustment project of the whole net is currently being developed.

To determine the scale value and the periodic error of gravimeters, 8 gravity calibration base lines have been set up at Beijing, Xi'an, Lushan, Chengdu, Fuzhou, Kunming, Lanzhou and Urumqi.

During the period of May–June 1990, Chinese experts and the Finnish Geodetic Institute, using the Finnish absolute gravimeter JILAG–5, worked together to determine 8 absolute gravity points in China, among which Beijing and Nanning are two international absolute gravity points; Harbin and Lhasa are two national gravity datum points of max. and min. value respectively; the rest four points, Kunming, Guangzhou, Shanghai and Xi'an, are basic gravity points measured with Italian absolute gravimeter under the cooperation of China and Italy in 1981. The standard error of this gravity measurement is $\pm 2.3 \times 10^{-8}ms^{-2}$at the least and $\pm 21 \times 10^{-8}ms^{-2}$at the most. It provides new absolute gravity values for the optimization of the net CGBN 85.

To facilitate the reduction of gravity values, while carrying out the absolute gravity measurement at the 8 points mentioned above, vertical gradient measurements and relative gravity connection measurements were made with 2 gravimeters of type LCR–G.Comparisons were made between the observed values at coincident points (or the calculated values at non–coincident points) of absolute gravimeter JILAG–5 and that of IMGC from Italy. The range of variation of the difference is -82 to $+91 \times 10^{-8}ms^{-2}$(exclusive of Kunming). Besides, comparisons were also made with the adjusted value (at coincident points) or the calculated value (at non–coincident points) of Net 85, the range of difference being -67 to $+38 \times 10^{-8}ms^{-2}$(exclusive of Harbin).

Nearly at the same time as the Sino–Finnish absolute gravity measurement, in cooperation with University of Hannover, FRG, 10 absolute gravity points at Beijing, Wuhan, Kunming and in the west region of Yunnan province were determined in order to study the tectonic movement in the service of seismological prediction. The instrument employed was the absolute gravimeter JILAG-3. Together with the absolute gravity measurement, relative gravity measurements were carried out, using 3 relative gravimeters. Beside the gravity gradient measurements, relative gravity connection measurements between adjacent points were made. The comparison between the absolute and relative determinations shows, with exception of very few points, the difference lies within $20\times10^{-8}ms^{-2}$.

New progress has been made in absolute gravity instrumentation in recent years. Instrument of type NIM 2 makes the distance measurement more stable thanks to the use of iodic laser. The calibration precision in 1988 was $14\times10^{-8}ms^{-2}$. Comparison measurement was carried out between the points A1 and A3 in Sevres, Paris in 1989. The mean error of the gravity difference between two points was $3\times10^{-8}ms^{-2}$.During this time, the portableabsolute gravimeter of type NIM 3 also came out. It is more portable than the NIM 2. The preliminary comparison with the measurement of JILAG-5 reveals, the difference amounts only 10 odd μgal.

Setting up ofnational geodetic databank

In the last forth years, a wealth of geodetic measurement information has been accumulated. Plenty of compatation results have been formed. Along with the development of modern science and technology, geodetic data will increase rapidly and the data handling will become even more complicated. The application sphere of the data will become more and more widespread. Thus the traditional way of administration, handling and providing must be modified. The general objective of setting up the national geodetic databank consists of:

automatization of datacollection;

setting up an integrate system of databank, including horizontal and vertical control surveying, astronomical surveying, gravimetric surveying and space geodesy;

fitting up with abundant data processing software, realization of data-processing automatization;

possibility of becoming a geodetic data source for the needs of other relevant databank systems;

supply of multiuser shairing of min. superfluity and higher independent character of program and data, ensuring safty and integrity.

At present, the first phase of the geodetic databank project has been deployed. The first term project of horizontal network databank retrieval has been already completed. The gravity databank is being established.

Marine geodesy

Marine geodesy in china has been developed into an epoch of multi-desciplinary and extensive application. It keeps on extending toward the mid-sea and far-sea. Notable achievements have been obtained in researches in different spheres such as the establishment and connection measurement of marine geodetic network, development and application of water sonic positioning system, application of GPS in marine survey, marine gravimetry, mean sea level, sea level topography and oceanic geoid.

The marine geodetic network consists of sea shore and island networks as well as off-shore sea-floor network. Besides the traditional triangulation method, GPS has also been used for the sea shore and island network. By using the carrier phase for the relative positioning, the precision comes up to 1~5 ppm. The precision of single point positioning is ± 20—100m. In sea-floor network, underwater sonar targets (responders) of water sonic positioning system are used as fixed points. Connection measurments were carried out by means of water sonic positioning system, radio positioning system and GPS.

In 1988, the geodetic connection was carried out between part of the islands and reefs in Xisha and Nansha archipedagos on the one side and national triangulation points Yulin and Zhangjiang on the other side. Mean error of the connection is around ! 1m. In the years 1988-1990, tens of GPS points were established at Nansha archipelago and other islands far away from continent. Along the South-China sea shore and in the Bohai sea region, local sea-floor networks were set up to meet the needs of oceanic oil project.

China-developed water sonic positioning system consists of types of long baseline, short baseline and infra short baseline. They have been used in marine survey undertaking. For example, during June to October 1989, by laying out oil pipe in mid Bohai, China-made long baseline water sonic positioning system was employed. After repeated checkings, the positioning error is about 0.4—3.3m.

In the sphere of marine gravimetry, apart from the basically completed surface measurement in mid distant and off shore sea region, cross-section surveys were repeatedly carried out in West and South Atlantic. In the current reporting period, around 500 thousand km of marine gravimetry line have been completed. The position precision runs ± 3—$-4\times10^{-5}ms^{-2}$. The marine gravimetry data were processed with electronic computer. The list of gravimetry points and the diagrams of freeair anomaly and Bougue anomaly were given automatically. Many research units are under way of establishing gravimetric databank.

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CZECHOSLOVAK COMMITTEE FOR GEODESY AND GEOPHYSICS

CZECHOSLOVAK REPORT ON GEODESY

1987 – 1991

Excerpt : Determination of the Gravity Field

PRESENTED AT THE XXth GENERAL ASSEMBLY OF THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS IN VIENNA

1991

Section III

Determination of the Gravity Field

The state gravimetric network (ca 700 points) is being updated with the use of Sharp and Worden gravimeters (Träger, 1990). The field measurements should be finished in 1992. The network is connected to seven absolute gravimetric stations, two of them are on the territory of Czechoslovakia (Pecný, Žilina). In the measurements of the basic network (9 points, airplain connections) also a group with a La-Coste gravimeter took part. A group of two Sharpe and two Worden gravimeters is being used in the first order network (ca 200 points) and a group of one Sharpe and one Worden gravimeter in the second order one (ca 500 points). These networks will be connected to the networks of all neighbouring countries. The national calibration base line Hřensko-Dolní Dvořiště (30 points) has a gravity difference of 316×10^{-5}m s^{-2} and a relative accuracy of about 1×10^{-4}.

A great attention is paid to the calibration of instruments used (Diviš and Kostelecký, 1990) and to the elimination of air pressure (Diviš *et al.*, 1988, 1989), temperature, ground vibration and magnetic field influences. In the adjustment of the state network the Helmert blocking method is used. The unknowns are: relative gravity values, parameters of the gravimeters drift and scale coefficients of individual gravimeters. The mean square errors of the adjusted gravity values are less then 0.1μm s^{-2} in the first order network and less then 0.15μm s^{-2} in the second order network in most cases.

At the fundamental gravimetric station Pecný three absolute gravity measurements were done up to now (1978, 1983 and 1986). The time changes of the results are 480nm s^{-2} and cannot be explained by the errors of the measurements.

A gravimetric mapping of density 4 – 6 points per km^2 was completed on ca 80% of the territory of the country in the scale 1:25000. The data bank contains information of about 600000 points. A digital model of the Bouguer gravity anomalies with topographic reductions is being constructed from these data in a 500 × 500m grid. Moreover, detailed gravimetric measurements are done in connection with studies of recent dynamics in regions of great open coal mines and great energetic works (Tresl, 1988).

Problems of some reductions of gravimetric measurements were solved: a more precise normal gravity formula (Pick, 1990), vertical gradient reductions (Olejník, 1988), the topographic reduction (Pick, 1987, 1988a) and precise tidal corrections (Šimon and Zeman, 1987) and (Zeman, 1989a,b,c). A new definition of the normal gravity field, which contains the constant direct tidal effect of the Moon and the Sun was proposed in (Zeman, 1987). In this way the influence of external masses on the disturbing potential may be eliminated. Consequences for definition of heights are discussed in (Zeman, 1991).

The structure of the lithosphere and upper mantle inhomogeneities were studied on the basis of a complex geophysical data interpretation (Bielik *et al.*, 1987), (Beránek *et al.*, 1988a,b), and (Burda, *et al.*, 1988). Some theoretical questions of the direct and indirect gravimetric problems were solved in (Sitárová and Boldižárová, 1989), (Moskovčiaková and Boldižárová, 1989, 1991) and (Moskovčiaková, 1991).

A hypothesis on the gravitation absorption was proved on the basis of results of tidal measurements done by means of a superconducting gravimeter at the station Brussels (Šimon *et al.*, 1988).

The detailed quasigeoid on the territory of Czechoslovakia was investigated using both a combined processing of heterogeneous data, i.e. vertical deflections, gravity anomalies, harmonic coefficients and directly determined (doppler) quasigeoid heights, by means of a least squares adjustment and a direct combination of terrestrial gravity anomalies entering the Stokes integral formula and (quasi)geoid heights computed from harmonic coefficients.

In the latter case mean Bouguer gravity anomalies with terrain corrections and mean heights for the elements $5' \times 7.5'$ compiled from different sources for a substantial part of the European territory were used together with point gravity anomalies of density ca 1 point per 3km^2 and sets of harmonic coefficients for geopotential model GEM 10C, GRIM 3B, OSU 81 and GRIM 4 MIT for $n, m = 32, 32$ or $52, 52$. The cap radius for the integration of terrestrial anomalies was 5°.63 and 3°.46. Atmospheric corrections were taken into account in the integration. Molodensky's Q coefficients were considered for the estimation of the truncation error.

Quasigeoid heights were computed for about 4000 points of the regular grid $5' \times 7.5'$ covering the territory limited by meridians 12°, 22°.5 and parallels 47° and 51°. Eight different variants were computed combining the two mentioned radii of the integration area and four geopotential models. An example is given in Fig. 3.1.

A local quasigeoid was determined on the territory of 10 × 10km in the city of Bratislava (Mojzeš, 1988). A set of mean Bouguer anomalies and mean heights for $5' \times 7.5'$ elements on the territory of Europe was elaborated. The components of vertical deflections and the geoid heights were computed for this territory by means of an integration up to a 300 km distance.

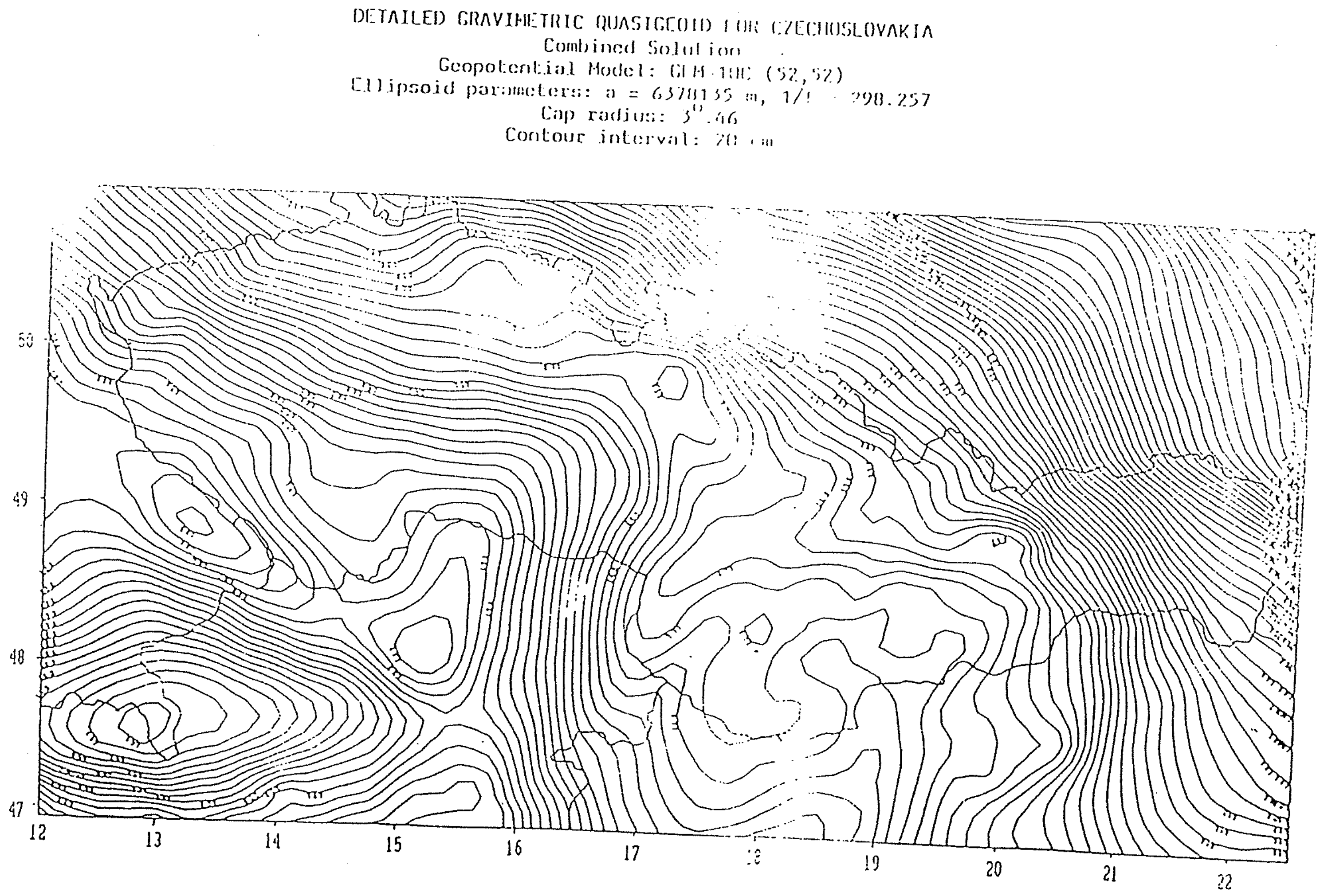

Fig. 3.1. Detailed gravimetric quasigeoid for Czechoslovakia.

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Excerpt : GRAVIMETRY

The Danish National Report of Geodetic Activities 1987-1991

by

Ole Bedsted Andersen

Introduction

The last four years have been formed under dynamic circumstances for Danish geodesy. Geodetic Institute has been merged with the Land Registry and the Hydrographic Office in september 1987 and the chair of professor in geodesy at Copenhagen University has been reoccupied in december 1988.

Already now it can be stated that both events have been successful from a geodetic point of view and give hopeful prospects for the future.

The amalgamation of the three institutions in one new organization Kort- og Matrikelstyrelsen, KMS (National Survey and Cadastre, Denmark) is in good progress.

The geodetic and surveying activities have been placed in a Geodetic-Seismic division in the new organization structure. The Geodetic-Seismic division is subdivided in five branches of which two are dealing with applied geodesy and surveying including calculations and registration of geodata, two others are dealing with development of geodetic theory and technique including edp-innovations, and one branch deals with seismic service and development.

It shall be mentioned here that KMS in the Danish research system is adopted as a Governmental Research Laboratory for geodesy and seismology.

It is most satisfying to see that the new organization of geodesy and surveying works with good progress and to welcome the active cooperation with the new professor of geodesy.

Greenland

The geodetic work in Greenland has been continued during 1987 and 1988 in order to fulfil the requirements for geodetic information in East Greenland. The area in question was in 1987 from latitude 62 degrees North to 65 degrees North, and in 1988 between 72 degrees North and 75 degrees North.

The basic observations were performed by means of Doppler satellite receivers but GPS observations were used on an experimental basis. Gravity observations were performed with an overall spacing of 25 kms.

Geodetic information has now been introduced in all ice-free areas of East Greenland according to the standards used in the North Greenland project from 1978-1980. North American Datum 1983 (WGS84) was introduced in North Greenland in 1980 shortly after the completion of the geodetic field work. NAD 83 or WGS84 will in the near future be introduced in the remaining part of Greenland in connection with a new adjustment of the existing networks.

Aerial triangulation has been continued in selected areas of East Greenland. A special aerial triangulation has been performed to support the determination of the border line between East Greenland and Jan Mayen.

Geophysical methods and collocation

This field has been developed in a fruitful cooperation between KMS and Geophysical Institute at the University of Copenhagen. The main activity here has been related to the Nordic geoid. An intense data collection effort has been made. A large amount of commercial gravity data have been received from the Geological Survey of Denmark, from GECO A/S (Norway) and Amarok A/S (Norway). GEOSAT altimeter data have been acquired from NOAA and GPS and levelling data from TU Hannover. These data are stored in the data base of KMS, and have been used for the geoid determination or its evaluation.

The problem of merging regional geoids has been studied and the achivable precision for a geoid in the strait of Gibraltar and in the Great belt has been investigated.

Impelled by the great demand for computer capacity associated with the collocation method a geoid edp-computer programme has been developed in the frequency domain by Fast Fourier Tranformations. This project has taken great advantage of the Finnish-Danish cooperation on development of the Burried Mass method. The calculation of the Nordic geoid has been performed by this method as well as by collocation.

The use of satellite altimetry for geodetical and geophysical purposes has been intensively studied in part as a contribution to a project sponcored by Norsk Hydro A/S and in part as preparation for the ESA ERS-1 satellite.

Studies of the use of satellite altimetry over the Greenland Ice Cap are in progress. Applications for topographic mapping and climatic studies are foreseen, and a PRARE ground station has been ordered with the purpose of improving the tracking of ERS-1 over Greenland.

In an interesting project an attempt has been made to combine geodetic, geophysical, and geological data i.e. gravity anomalies, seismic velocities, and density logs. The project aims at producing a better model of the Earth potential field but may also be used to predict specific density in the Earths crust which may be used in the search for natural resources. The project looks promissing and negotiations are going on to extent the project to 1993.

Another interesting project also dealing with natural resources concerns gravity measurements in Southern Jutland which may reveal deep ground water reservoirs when studied in combination with shallow-seismic data produced by the Geophysical Institute at the University of Arhus.

Finally the second order derivatives of the gravity potential have been studied in cooperation with the Geophysical Institute at the University of Copenhagen in an investigation made for ESA in order to assess the quality of gravity field recovery from satellite gravity gradiometry. Results obtained in this project may be used if the ARISTOTELES mission is launched by ESA, or if airborne gradiometry becomes feasible.

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NATIONAL REPORT ON GRAVIMETRY IN FINLAND, 1987 - 1990.

The XX General Assembly of the IUGG

Vienna 11 - 24 August 1991.

by

Aimo Kiviniemi

Finnish Geodetic Institute

1. Regional gravimetry.

1.1. Densification of the national net

After completion of the national net at a spacing of 5x5 km^2, the densification of the net started in 1980 at an average spacing of two stations per square kilometer.

The number of new stations measured in southern Finland, 61.5°N and 22°E, from 1987 to 1990 was as follows:

Year	1987	1988	1989	1990
Number	448	425	319	345

LaCoste-Romberg G and Worden Master gravimeters were used. If the elevations of the stations were not known, they were determined for the most part with a 3-d numerical photogrammetric method with an accuracy of $\pm$0.3 m and, if this method was not possible, Thommen altimeters were used.

1.2. Measurements on the ice of the Bothnian Sea

Gravity measurements at a density of one station per 5x5 km^2 on the ice of the Bothnian Sea were continued. Because of unfavorable ice conditions, the measurements could only be made in 1987. The equipment was a LaCosteRomberg G-gravimeter using full damping. The observation method was described by the author at the 12th Meeting of the IGC in 1986. 322 stations were measured between latitudes 61-62°N. The project is being carried out in cooperation with the National Survey of Sweden and the Geological Survey of Sweden. The measurements will be continued as soon as ice conditions permit.

1.3. Measurements in the Antarctic

The Finnish Antarctic station ABOA was built in 1988-89, in Western Queen Maud Land, 73°03' S, 13°25' W. 100 gravity stations were measured from ABOA between December 26, 1989 and February 9, 1990. The gravity measurements were made using a Worden Master gravimeter. Positioning was done with two Astech L-XII GPS receivers. One of these was always located in the same place at the ABOA station, and the other moved with the expedition. Thus positioning was determined in relation to the ABOA station. The elevations of the stations were also measured using three Thommen 3B4 altimeter-barometers. As only very few stations of known elevation were available, and as the difference between the geoid and the reference ellipsoid was not known in detail, the elevations of the gravity stations remained a problem. Furthermore, as the thickness of the ice was unknown, making the reductions was unsafe. The two geodesists on the expedition travelled by two snow scooters along marked trails. Movement outside the trails was highly dangerous. Consequently, the measurements formed lines with an average distance of 5 kilometers between successive stations. The absolute gravity value was not available. The scale of the Worden gravimeter was too small to measure the gravity difference from Montevideo. The absolute measurement is planned for 1991. (OLLIKAINEN, ROUHIAINEN 1990)

2. Microgravimetry.

2.1. Measurements on the land uplift gravity lines

High precision gravity measurements on the Fennoscandian land uplift gravity line running at approximately latitude 63° N were carried out as follows:

Section	Year	Gravimeters	Single measurements
Joensuu-Vaasa	1987	2,(1)	9,(7)
Vaasa-Kopperå	1987	2,(1)	6,(4)
Kopperå-Vågstranda	1987	2,(1)	4,(4)
Vaasa-Joensuu	1988	2	8
Vaasa- Joensuu	1989	2	9

The campaign in 1987 was carried out jointly with the University of Madrid. The number of Spanish gravimeters and measurements are in given parenthesis.(EKMAN, MÄKINEN 1990)

2.2 Studying the variation in gravity at fault lines

It is believed that active fault lines can cause variation in gravity. One way in which fault lines can be detected is by aerial photographs. A test field was established at a suspected fault line in the region of Pasmajärvi, Finnish Lapland, 67.2°N, 24.4°E. A station was built on bed rock right on the suspected fault line, and a similar reference station 14 km away. Precise measurements were carried out in 1987 and 1989 using two LCR G-gravimeters. Significant results are expected after some decades. Any variation in gravity found will indicate activity in the fault line.

3. Gravity reference networks.

3.1.Absolute measurements

Absolute gravity measurements were conducted on the IAGBN stations:

Sodankylä	1988
Madrid	1989
Beijing	1990
Nanning	1990

and on the followiong stations of various national and/or international reference networks:

Vaasa (Finland)	1987,1988
Clausthal (FRG)	1989 (twice), 1990
Brussels (Belgium)	1989 (twice), 1990

Sevres (France) 1989

Harbin, Lhasa, Kunming, Guangzhou, Shanghai, Xi'an (PRC) 1990

Absolute gravimeter JILA-5 was used for the measurements above.

4. Instrument developments and investigations.

4.1. Absolute gravimeter JILA-5

Recoil effects in the absolute gravimeter were investigated in cooperation with JILA (Joint Institute of Laboratory Astrophysics, Boulder, Colorado). The influence of ambient temperature variations on its laser was determined in cooperation with the University of Helsinki.

5. Other studies in gravimetry.

5.1. Observations during the solar eclipse on July 22, 1990

The gravitational shielding effect during the solar eclipse was investigated using four equipments: an absolute gravimeter, a recording ET gravimeter, a bore hole tilt meter and two water tubes. The absolute measurements were carried out in Ilomantsi, 62.7°N, 30.9°E, and the other measurements close to Helsinki at the Metsähovi Space Geodetic Station and in the underground laboratory, Lohja 2. The data are being analysed and the results will be published in the near future by J. KAKKURI, J. KÄÄRIÄINEN and J. MÄKINEN.

5.2. Subsurface water and gravity

The effect of the variation in the ground water level and soil moisture on the gravity has been studied since 1984. Observations were continued at two test fiels in southern Finland. The attraction of snow and gradient effects were measured. (J. MÄKINEN, S. TATTARI 1987, 1989,1990)

5.3. Gravimetric work at the Geological Survey of Finland

The activities of the Geological Survey of Finland will be reported in the publication "Geodetic Operations in Finland 1987-1990".

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GERMAN NATIONAL REPORT ON GRAVIMETRIC ACTIVITIES IN THE PERIOD 1986 - 1990, SUBMITTED TO THE INTERNATIONAL GRAVIMETRIC COMMISSION OF IAG

List of some principal abbreviations

AdV	- Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland
BEK	- Bayer. Kommission für die Intern. Erdmessung
BGR	- Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover
DGFI	- Deutsches Geodätisches Forschungsinstitut
DHN	- Deutsches Hauptdreiecksnetz
DHSN 82	- Deutsches Hauptschwerenetz
DSGN	- Deutsches Schweregrundnetz
GDR	- former German Democratic Republic
HLVA	- Hessisches Landesvermessungsamt, Wiesbaden
IAGBN	- Intern. Absolute Gravity Basestation Network
IfAG	- Institut für Angewandte Geodäsie, Frankfurt
IfE	- Institut für Erdmessung, University of Hannover
IoS	- Institute of Seismology, SSB, China
IPG	- Institut für Physikalische Geodäsie, TH Darmstadt
JILAG	- JILA-Absolute Gravimeter, designed by Prof. J. Faller
LCR	- LaCoste and Romberg Gravimeter
NLfB	- Niedersächsisches Landesamt für Bodenforschung, Hannover
SFP	- Schwerefestpunkt
SSB	- State Seismological Bureau, China
UGN	- Unified Gravimetric Net (in Eastern Europe)
ZIPE	- Zentralinstitut Physik der Erde, Potsdam

0. General activities

A reference and text book about gravimetry was presented by Torge (1989a). Present state and problems of gravimetry were summarized in (Torge, 1989b).

1. Absolute Gravimetry

1.1 Measurements in the International Absolute Gravity Basestation Network (IAGBN)

The Institut für Erdmessung (IfE) of the University of Hannover contributed to the establishment of the IAGBN (Boedecker and Fritzer, 1986) by performing absolute gravity observations with the JILAG-3 absolute gravity meter at six stations, within the frame of different campaigns. This includes one IAGBN station in Godthab/Greenland (1988), three stations in South America (Tandil/Argentina 1989, Brasilia/Brazil 1989, Sta. Elena/Venezuela 1988), (Gemael et al., 1990) and (Drewes, 1990), and one station in Beijing/China (1990), Torge et al., 1990a). In Germany, a gravity determination was carried out at the fundamental satellite observation station Wettzell (1989).

Global Gravity Networks:
For the 'International Absolute Gravity Basestation Network'(IAGBN), initiated by the BEK of the Bavarian Acad. Sci. (Boedecker, 1988a, 1988b) and accepted by IGC and IAG through resolutions, 17 out of 33 proposed stations were established and observed, several of these by the 'Institut für Erdmessung'(Prof. Torge), Hannover; c.f. his report. Reconnaissance was done for four australian IAGBN-stations in 1989. Standards for establishing absolute observation stations and also for the processing of observation data and their archiving were created in the framework of WG2 of BGI (Bureau Gravimetric International).
In fulfilment of a request of IGC, the IGSN71-stations in the Federal Republic of Germany were reviewed in cooperation with the DGFI (I) and reported to BGI. Out of originally 115 stations, predominantly along the European (gravity meter) Calibration Line (ECL), 79 could be used in 1976/77, 68 in 1990/91. However, in many cases the height identification is very bad because of roadworks and lost height reference. Because of superior quality of the national networks DSGN76 and DHS82 compared to IGSN71, this review probably has been the last one.

1.2 Absolute gravity measurements at Potsdam

At the Central Institute for Physics of the Earth at Potsdam (ZIPE) in January 1988 and January 1990 measurements of the absolute value of gravity were performed by the University of Hannover, IfE using the JILAG-3 gravimeter. The results agree with the tendency shown by the soviet absolute gravity data determined at this place in the period 1976 - 1986 and presenting a sinusoidal variation (Arnautov et al., 1990; Elstner, 1987, 1990; Torge et al., 1990c).

1.3 Measurements in the national gravity net and regional surveys

In spring 1987, absolute gravity determinations at 15 stations in northern Germany were performed. The comparison of JILAG-3 results with the German Gravity Base Net DSGN 76 yielded a r.m.s. discrepancy of $\pm 0.07\ \mu ms^{-2}$ (Torge, 1990a).

2. Instrumental developments and investigations

In a joint research program with the Institute of Seismology/State Seismological Bureau (IoS/SSB), Wuhan/China, IfE has strengthened and extended the Wuhan Calibration System (Torge et al., 1990a). Long wave calibrations terms of relative gravimeters can be controlled at an accuracy level of $\pm 10^{-5}$. Two absolute measurements with JILAG-3 have been carried out on sites of the Hornisgrinde Black Forest Gravimeter Calibration Line (northern Black Forest, Germany) in 1988. The calibration line Hornisgrinde is described in (Lindner et al., 1990).

For instrumental investigations of superconducting gravimeters, JILAG-3 performed two absolute measurements close to the site of the superconducting gravimeter in Brussels (1987 and 1989). The observation at the IAGBN station Wettzell (1989) also serves for that purpose.

To improve repeatability and accuracy of JILAG-3 measurements, special technical investigations have been performed. The laser frequency variation due to temperature changes is taken into account now by an appropriate reduction function. Floor recoil effects, produced by tilting of the interferometer base triggered by the dropping procedure (Peter et al., 1990), require improvements of the hardware and the evaluation software which are under way now. Comparisons of JILAG-3 results with independent gravity data showed a long term accuracy of

±0.07...0.1 μms^{-3} (Torge, 1990b).

In September 1989 the 3rd International Comparison of Absolute Gravimeters took place in Sèvres with the participation of JILAG-3 of IfE and more than 10 institutions taking part in the relative measurements, see 4.1.

3. Precise Geodynamic Investigations

3.1 Precise gravity observations and time dependent gravity changes

G. Boedecker (BEK, Bavarian Acad. Sci.) established 13 stations between Munich and Verona (Italy) for the study of the alpine uplift and observed over 8 years. The evaluation of the observations with LaCoste-Romberg gravity meters showed that after this time span that a significant gravity change in the Alps could not be concluded yet.

IFE has employed the JILAG-3 gravity meter in several geodynamics research projects. These gravity control systems are established for monitoring vertical movements of the earth surface and/or subsurface mass shifts and are generally combined with geodetic geometric networks (levelling, GPS).

Some regional gravity networks were densified and strengthened by LCR relative gravity measurements between absolute stations, as well as to national and international gravity net points, if possible, cf. (Torge, 1990a). The four LCR gravimeters of IFE are now equipped with electronic feedback systems, constructed at IFE. Gravimetric repetition surveys are generally planned after five years. In addition to geodynamic purposes, improvements of the national fundamental networks, and contributions to the IAGBN have been major objectives of these projects.

In 1987/88 gravity observations have been carried out on the Faeroer Islands (one absolute station) and in Iceland (five absolute stations for geodynamics). In 1988 three absolute points were established in Greenland (fundamental network, IAGBN), in cooperation with the Danish Geodetic Institute. In a cooperative project with Geodätisches Institut, Universität Karlsruhe, JILAG-3 was employed in six gravity determination in South-West Germany (Hohenzollerngraben, geodynamics). In 1988 a gravity campaign was performed in Venezuela (six abs. stations, geodynamics, fundamental network), cf. (Drewes et al., 1991). In 1989 seven absolute measurements were carried out in Brazil, two in Uruguay, and three in Argentina (fundamental network, IAGBN, geodynamics), in cooperation with several institutions (Instituto Panamericano de Geografia e Historia; Comision de Cartografia, Comite de Geodesia, Buenos Aires; Instituto de Geodesia, Univ. de Buenos Aires; Univ. Federal do Parana, Curitiba; Servicio Geografico Militar, Montevideo). In a joint project with the Institute of Seismology (IoS), Wuhan, a gravity control system has been established in the Yunnan earthquake region in China 1990 (six absolute stations, 37 gravity points, geodynamics), (Torge et al., 1990a).

By repeated absolute and relative gravity measurements in Hannover and Potsdam (1988-1990), an absolute gravity baseline was established, which can be used as a reference for future geodynamic investigations in the German coastal regions (Torge et al., 1990b).

Yearly measurements at the W-E-profile in eastern Germany were continued by ZIPE using 6 to 8 astatised quartzgravimeters. In 1990 five LaCoste Romberg-gravimeters additionally could be used for these measurements by the support of Geodetic Institutes from Berlin, Technical University, and Darmstadt. The accuracies reached for a single gravity difference amounted to 5 to 8 microgals. The results of all the measurements underline the temporal stability of the relative gravity field in the region of the profile at the microgal level. Therefore gravity variations according to the results of absolute measurements at Potsdam may be assumed as representative along the profile (Gendt, G., and R. Dietrich, 1987; Gendt, G., 1987; Knothe, Chr., et al., 1988; Lindner, H. and M. Militzer, 1988; Lindner H., et. al., 1988; Roesler, R. and H. Lindner, 1986).

Further gravimetric investigations by ZIPE are concerned with the determination of geodynamic parameters by the observation of satellites, the gravity effects of ground water table movements in surface mining areas, the structure of the lithosphere and the direct and inverse gravimetric problem.

In October 1990, the Institute for Applied Geodesy (IfAG), Frankfurt received the prototype of a transportable superconducting gravimeter. In cooperation with the manufacturer GWR, San Diego California, it is planned to investigate the possibility of using such a technique in gravimetric field work. In principle, the delivered superconducting gravimeter SG-101 is equivalent to the full size instruments but downscaled by the factor of two. The weight of the new instrument with a Dewar size of 40 cm in diameter and 60 cm in height amounts to approx. 40 kg (Schlüter, W., et al., 1990).

The Institute of Physical Geodesy of the University of Darmstadt has continued the works on the ABC-profiles in Argentina, Bolivia and Chile. The first re-observation documented gravity differences of up to 0.40 μms^{-2}, with an r.m.s. of 0.20 μms^{-2} (Becker et al., 1989; Groten and Becker, 1989). The third major campaign was conducted in 1990. Results will be published at the IUGG 1991 General Assembly.

The gravimetric works within the interdisciplinary Turkish-German project on Earthquake prediction continued with extensions and re-observations of the networks across the North Anatolian fault zones. Whereas the small local profile did not reveal gravity changes, see (Aksoy et al., 1988), significant gravity decreases are observed in the western part of the network, whereby in the center and the eastern part mostly periodic, insignificant gravity variations are found (Akin et al., 1991; Demirel and Gerstenecker, 1990).

3.2 Some Tidal Results

The analysis of the tidal residuals of long period gravity recordings at Potsdam, Bad Homburg and Brussels showed the influence of third degree tidal constituents in N2 and L2 wave groups and resulted to the detection of the S3 gravity variation caused by 8-hourly variations of meteorological parameters. SAVIN's Narrow Band Spectrum Analysis was successfully used for the presentation of higher degree tidal constituents and for the M2 air pressure variation in long period air pressure series (Elstner, C., and W. Schwahn, 1989; Dittfeld, H.-J., 1989; Savin et al., 1989; Schwahn, W., et al., 1989, 1989a, 1989b).

4. Relative gravity measurements

4.1 High Precision Gravimetry, Instruments and Modelling

The actual version of the feedback system model SRW-E, constructed at IfE for precise relative measurements with LaCoste-Romberg (LCR) gravimeters, was tested in a six months registration experiment in 1990, in cooperation with the Geodetic Institute, University of Karlsruhe. The data processing is still under way.

For data handling and adjustment some new modules were developed at IPG. A data logging system for relative gravity field measurements was developed at IPG and HLVA and tested in the field. The system allows data collection of different gravimeter types and meteorological sensors, the exact reduction and control of the readings, editing and least square adjustment of the data (Czuczor et al., 1989). The integration of the data logging system in a data bank system is described in (Czuczor et Gerstenecker, 1990). Becker (1990) presented an adjustment model using Robust-M-Estimation with the data of different types of gravity networks. Among these was the Blasjö artificial reservoir gravity survey, where the effects of loading are studied by repeated gravity observations and levelling (Becker et al., 1988). This project is being carried out by Statens Kartverk, Hönefoss in cooperation with IPG.

At the 3rd International Comparison of Absolute Gravimeters a network was observed for the interconnection of absolute sites and vertical gradient determination. Accuracies obtained using 12 LaCoste instruments are better than 0.01 μms^{-2} (Becker et al., 1990).

4.2 Gravimetric Networks and Maps

Regional Gravity Networks:
A Unified European Gravity Network (UEGN) comprising 400 stations is being adjusted using 16 000 observations in cooperation with I. Marson (Trieste), C. Poitevin (Bruxelles) and G. Strang van Hees (Delft). This work conformes to the IGC-policy, which favours regional gravity base networks instead of readjustments of the IGSN71 because of advanced absolute observation technics. A first solution will be presented 1991.

For the installation of an Unified Gravimetric Net (UGN) inside the territories of the Estern European countries five measuring points, Potsdam included, were prepared at the territory of the former German Democratic Republic (GDR). These points are situated in massive buildings and consist of concrete pillars steadily fixed to the ground and are suitable also for absolute determinations of gravity. In the nearest surroundings out of the buildings twin points were arranged. The gravity differences between all these points and to some of the first order gravity net were determined by the aid of different gravimeters.

A complex revision of the points of the first and second order gravity nets of the former GDR was accomplished to ensure geodetic or geophysical utilizations in the future. After the completion of UGN a common recalculation of these three gravity nets is provided.

Special investigations were made for the precise determination of geoid or quasigeoid respectively. The existing density of measuring points of 1 point per 1.5 km was found to be sufficient for the determination of a gravimetric geoid with cm-accuracy.

A detailed documentation by AdV on the Fundamental Gravity Base Net (1982) of Germany (DHSN 82) has been published which contains the unified First Order Gravity Network of State Survey Offices (Arbeitsgemeinschaft der Vermessungsverwaltungen, AdV, 1989, Augath et al., 1988). In Baden-Württemberg, Bavaria, Hessen, Lower-Saxony, Rheinland-Pfalz and Saarland also the establishment of the Second Order Networks was accomplished. As far as station density is concerned there is 1 gravity station (SFP) per 100 km^2. Now 2200 stations are incorporated having accuracies of 10 to 15 microgal. For the measurements double differences were observed using two gravimeters on each. In Lower-Saxony a particular network of Second Order for determining temporal changes of gravity was established; it consists of 18 stations, few of them being absolute sites. In the Third Order Gravity Network stations were established along the First Order Leveling lines. Along the coast in Schleswig-Holstein and Hamburg observations were replaced by gravity data taken from existing maps. Based on the aforementioned data geopotential units were derived in the German First Order Leveling Network (DHN) for the repeated leveling lines from 1980-1985. In order to be able to derive soon geopotential units for all official leveling stations is most part of Germany gravity measurements were carried out along the lower order leveling lines. Also gravity stations all over the area with station density of 1 station per 5 km^2 are being installed. At the end of 1990 more than 14 000 such Third Order Gravity Stations had been observed and monumented.

In Rheinland-Pfalz a computer program for the computation of Bouguer anomalies based on topographic reductions using digital terrain models was developed whereas in Nordrhein-Westfalen a computer program was installed for areal gravity interpolation was installed on which the evaluation of geopotential units can be based.

NLfB completed the regional gravity survey of the Fed. Rep. of Germany. Additional measurements were carried out in various regions, preferably along the border to several neighbouring countries (Austria, Luxembourg, Belgium) in order to improve the isoline fitting of German gravity maps to those of adjacent areas.

After the German re-unification first connections to gravity base stations on the territory of the former German Democratic Republic have been accomplished.

As in the past again a lot of local surveys has been performed all over the Republic, supporting the work of the different Geological Surveys. It would go to far to count up all of them. But two special investigations may be mentioned being related to two great research programs : A survey near Eupen/Belgium for the German Continental Reflection Seismic Program (DEKORP) and a detailed local survey around the drilling site of the German Continental Deep Drilling Program (KTB). Also for KTB a gravity map of NE Bavaria and CSFR has been compiled by Plaumann (1988).

A Bouguer anomaly map 1:1 500 000 of the Fed. Rep. of Germany has been published (Plaumann, 1987); the center sheet of the Bouguer anomaly map 1 : 500 000 is being printed.

FFT-Technique/Terrain Corrections:
On the bases of series developments for the gravitational potential and its derivatives of the topography, FFT technique Boedecker (1990) applied to a test area comprising 1000 x 1000 stations with a grid spacing of 50 meters in the alpine foreland.

Relative Gravimetry Projects of DGFI : The relative gravimetric network along the Caribbean - South American plate boundary in the Venezuelan Andes was reobserved in spring 1985 and autumn 1988. About 60 stations in an extension of about 600 km provide precise information on point gravity variations with time. In comparison with the earlier observation campaigns in 1978 and 1981, seasonal gravity changes up to 1 nms^{-2} are clearly detected, which are correlated with tropic rainfalls. The secular variations are small (less than 0.05 nms^{-2}/yr) and in most cases not significant. They indicate, however, a decrease of gravity in the Andes, which would correspond to a slight uplift.

The Alfred-Wegener-Institute for Polar and Marine Research carries out gravity measurements in polar regions. These studies are of regional extent and are usually studies accompanying seismic research. In the marine environment measurements are carried out with a sea gravity meter KSS 31 installed on RV "Polarstern", for land based work LaCoste-Romberg gravity meters are used.

H.K. Ilk, Inst. f. Astron. und Physik. Geodäsie, TU München, contributed to the establishment of the gravity network of Indonesia :

BAKOSURTANAL (National Coordination Agency for Surveys and Mapping of the Republic of Indonesia) started the establishment of a precise levelling network for Indonesia in the year 1980. To perform the levelling network adjustment in terms of geopotential differences and to derive meaningful heights a plan has been set up to establish also hierarchically organized gravity networks.

The papers (Ilk, 1988a; Ilk, 1987a; Ilk, 1987b; Ilk, 1989a) are related to the design of the networks in Sumatera and Jawa as well as to the measurement procedure. The gravity measurements themselves are documented in the papers (Ilk, 1988a; Ilk, 1990a; Ilk, 1990b). The adjustment procedure is described in the papers (Ilk, 1987c; Ilk, 1989b; Ilk 1990a). The use of gravity data for gravity field approximation and computation of geopotential differences is discussed in (Ilk, 1988b; Ilk and Priyanto, 1989a and Ilk and Priyanto, 1989b) ("Aust. J. Geod., Photogramm. and Surv.").

4.2 Gravimetry at Sea and in the Air

BGR performed gravity measurements at sea with USS 31 on research cruises as follows :

- SO-49 in April/May 1987, about 3 000 km surveyed in the Sulu Sea and South China Sea;
- GANOVEX V/1 in December 1988/Janury 1989, about 1 000 km surveyed in the Ross Sea;
- PROSPEKTA 89 in August/September 1989, about 3 500 km surveyed in the NE-Atlantic;
- ANT 8/6 in March/April 1990, about 6 500 km surveyed off East Antarctica between 0° and 40° E;
- M14/3 in November/December 1990; about 7 000 km surveyed in the Southern Atlantic.

Airborne experiments were carried out at the Institut für Astronomische u. Physikalische Geodäsie of Universität d. Bundeswehr, München :

With the possibility of determining threedimensional positions of sensors in flying aircrafts by kinematic satellite observations to the Global Positioning System (GPS) with centimeter accuracy (and corresponding velocities in the range of millimeter per second), it seems that the airborne gravimetry becomes feasible (again) with considerable improvement in accuracy. Flight experiments carried out in summer 1989 and 1990 by the Institute of Astronomical and Physical Geodesy (IAPG), University-FAF Munich, and the Bundesanstalt für Geowissenschaften und Rohstoffe, Hannnover, analyzed by special GPS and gravity filter software, indicate that the disturbing accelerations can be determined by GPS with an accuracy of 1-2 mGal over wavelengths of 1-2 km. This progress (by factor 10 approximately) may lead to a replacement of shipborne gravimetry as well as may consider airborne gravimetry as a powerful method over land in near future (Hehl et al., 1990; Hein et al., 1990, Hein, 1990).

5. Non-Newtonian gravitation

In 1988 an experiment searching for eventual deviations from Newton's gravitational law took place in the Hornberg pumped-storage reservoir in the southern Black Forest, South-west Germany. Besides the IFE, Institut für Meteorologie und Geophysik, University of Frankfurt, Observatorium Schiltach, Wolfach, and Geodätisches Institut, Universität Karlsruhe were involved. Water-level changes and earth tides produced signals which were recorded with six LCR gravimeters. The accuracy of the registration was limited by calibration uncertainties in the order of $\pm 2...4 * 10^{-3}$. Non-significant deviation from Newton's law was detected (Müller et al., 1990).

Significant contributions to Yukawa-term determination were based on gravimetric approaches where repeated high-precision gravimetry has been used. The results can be summarized in stating that significant deviation from Newton's law of attraction could not be found (Müller, G., et al., 1989, Müller, G., et al., 1990).; associated problems inherent in such experiments were discussed in (Groten, 1988).

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INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS
(I.U.G.G.)

India

National Report on the Geodetic and Gravimetric Work done in India by Various Organisations and Institutions during the period 1987-90 with Emphasis on Geophysical Investigations and Scientific Studies under International Programmes

COMPILED BY

V. K. Nagar, Surveyor General of India and Brig. C. B. Jhaldiyal, Additional Surveyor General, Geodetic and Research Branch, Survey of India on behalf of the Indian National Committee for the International Union of Geodesy and Geophysics

PRESENTED AT THE TWENTIETH GENERAL ASSEMBLY OF THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS HELD AT VIENNA (AUSTRIA) BETWEEN 11TH AND 24TH AUGUST, 1991.

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Excerpt : GRAVIMETRY

15-km National Gravity Net.- Under the National Gravity Programme of establishing a 15-km mesh of gravity stations, Survey of India established 948 gravimetric stations thus bringing the total number of stations observed so far to 11952. This covers nearly 58% area of the country.

Gravity observations along selected profiles.- 620 stations in connection with 5 to 8 km mesh were established in Daccan Trap area during the period under report. The total numbers of stations observed so far along selected profile and for other dense control provided at an interval of 1 to 8 km is about 11626.

No. of standard gravity stations (Air Port Stations) in the country has remained fixed at 56.

Reduction of Gravity Anomalies in terms of IGSN-71 System and GRS 1967 by Survey of India.- Free-air Anomaly, Bouguer Anomaly for and Isostatic anomaly for about 2500 stations have been computed, which brings the total number of stations for which these three types of Anomaly are known to 16710, 12907 and 12907 respectively.

Geological Survey of India carried out gravimetric surveys in different parts of the country for study of tectonic model of the crust and for exploration of minerals such as coal, lignite, chromite, diamond, gold, potash, basemetal etc. Gravity surveys were also carried out in Damodar Valley and Raniganj Coal fields to study the morpho-tectonics of east Gondwana basins.

Apart from Gravity observations taken to understand tectonic features, effort was also made to tap Ground Water and Geo-thermal resources.

National Geophysical Research Institute has published Bouguer Gravity Anomaly Map of Cuddapah Basin in four sheets with Brochure. The Residual Gravity Anomaly Map of South India, South of Lat 16°N was also brought out.

Apart from carrying out Regional Gravity Studies of Tosham mineral prospects for exploration of mineralisation of Tin, Evaluation of N-S Gravimetric Calibration Line, Examination of Gravity data in Central India for exploration of mineralisation vis-a-vis study of earthquake occurrences. due to activities along faults, the marine Gravity Activities were also initiated.

The Marine Gravity studies were concentrated along western continental margin along 400 km profile, Afanasy-Nikitin Sea Mount and Chagos-Laccadive Ridge. These studies helped in finding crustal thickness, under deep sea regions. mechanism of ocean floor volcanism etc.

The seismic data was also utilised with Gravity data for study of Gravity features in Mahanadi basin, Cuddapah basin, Cambay basin etc.

Oil and Natural Gas Commission, Dehra Dun carried out Gravimetric observations in various basins of India to study Basement configuration and stratigraphic traps.

The Indian School of Mines Dhanbad carried out gravity surveys in Raniganj coalfield area and near Singhbhum etc. including interpretation of gravity for Andaman Sea and Bengal Fan etc.

Osmania University, Hyderabad, apart from teaching Geodesy and Gravity Prospecting carried out gravity observations in Andhra Pradesh and Goa for study of lithocomposition of granites and for coal mineral exploration.

Wadia Institute of Himalayan Geology (WIHG) Dehra Dun carried out Microgravity surveys in the foot hills of Himalayas and along Chhota Shigri Glacier and around Kunjumla to study neotectonic activity, subsurface features and faults.

The centre for Earth Science studies, Trivandrum

carried out gravity surveys in Palghat gap along north and south directions. Detailed gravity surveys were also undertaken along selected profiles for study of basement configuration.

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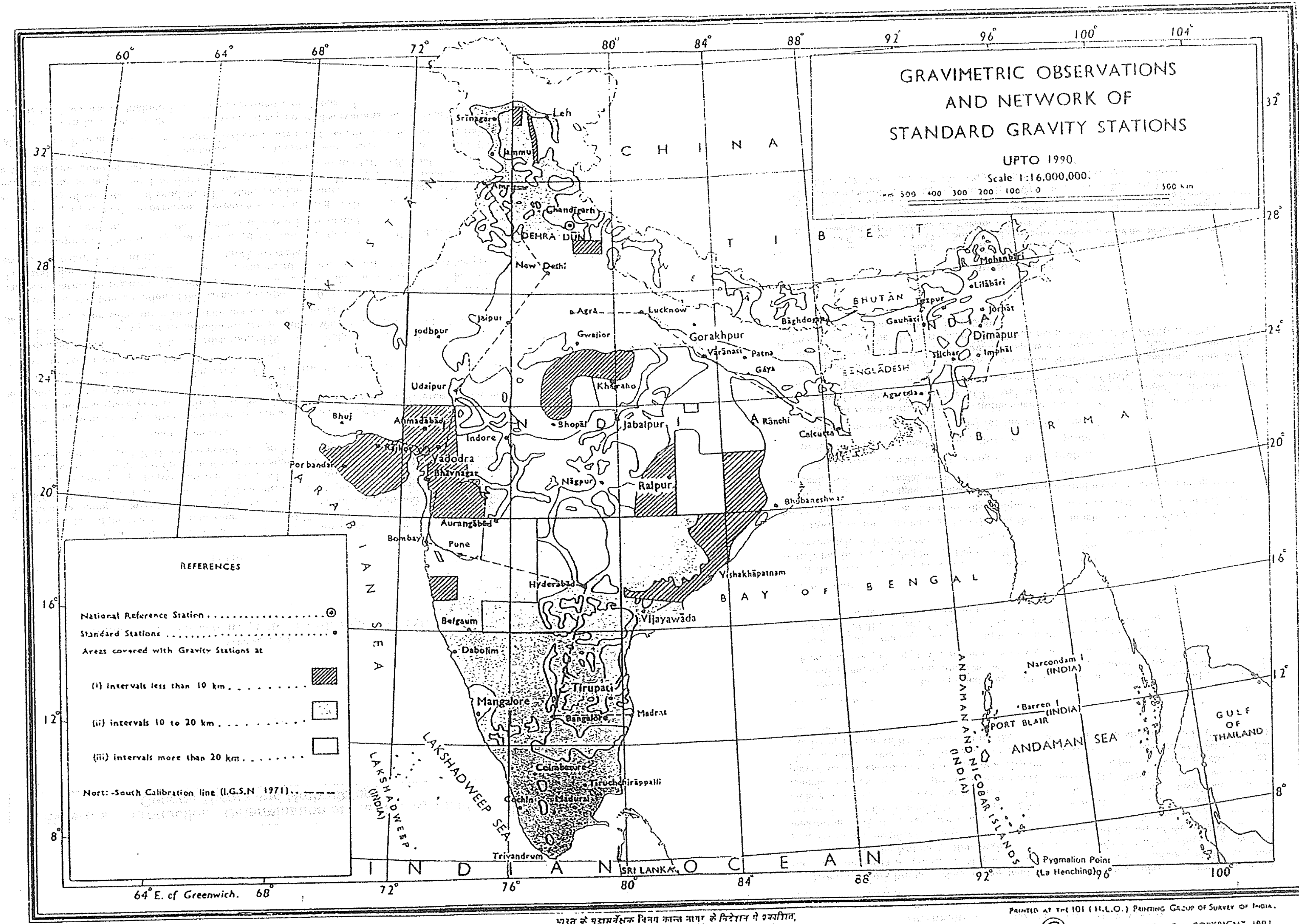
Chart I



भारत के महासर्वेक्षक विनय कान्त नागर के निदेशन से प्रकाशित,
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The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line

Excerpts : Introduction - Determination of the Gravity Field - General Theory and Methodology

C. MORELLI

GEODESY
Italian research activity (1987-1990) report to IAG

INTRODUCTION

During the 70's and 80's Geodesy in Italy suffered greatly from two major losses: the suppression by law of the Italian Geodetic Commission (1977), and prof. Marussi's death (1984). The first was compensated by the institution (1978) by CNR of the National Group of Solid Earth Geophysics, which very soon included Geodesy as a sub-group; Marussi's work has been continued in part by his pupils and scientific geodetic research in Italy has reached a good level in University Institutes: theoretical research mainly in Milano and Napoli, space geodesy in Milano, Bologna and Bari; experimental research in many other Universities.

Theoretical research mainly concerned:

- development of a rigorous closed form numerical formula for the Pizzetti Somigliana theory for the normal space gravity of the Earth based on the 1979 Geodetic Reference System to replace the approximate series expansions available;

- definition and analysis of the hierarchy of gravimetric boundary value problems (Molodensky, in vector and scalar from, fixed boundary);

- definition and analysis of the Overdetermined Boundary Value Problems: these problems, when linear, can be analyzed by introducing the so-called Wiener integral by which we can describe stochastic solutions with a white noise at the boundary;

- study of the determination of the harmonic coefficients from boundary and non-boundary data with particular regard to: the effects of unevenness in the data distribution (e.g. holes in the data), the aliasing produced by non-uniform distributions, in particular, by regular geographic distributions, and the effect of a block averaging;

- development of the theory and the related software for the interpretation of gravity and magnetic anomalies in terms of the thickness of a two layer model.

The major part of the *experimental research* was dedicated to GPS. The main activity was in the theory of operations of geodetic GPS, static and kinematic, with applications to the problems of tectonic movement detection in many areas of Italy and Mediterranean countries, and to the determination of the geoidal undulations with respect to the GPS ellipsoid.

Tectonic movements are to be monitored in the Western and Eastern Alps, across the Po valley, in the Pisa area, in the Southern Tyrrhenian area and, locally, in other parts of Italy.

Results can be expected after several years of repeated observations; the network design and the GPS accuracy obtained have been presented and discussed.

DETERMINATION OF THE GRAVITY FIELD

Absolute gravimetry

Extensive work has been done in this field by the *Istituto di Miniere e Geofisica Applicata (IMGA)*, Università di Trieste, I. Marson. It was initiated with the updating of the Absolute gravity meter of the *Istituto di Metrologia* G. Colonnetti *(IMGC)*, Torino, which consisted essentially in the modification of the launching mechanism and the use of the multiple stations measuring method. It was then continued with the design and realisation of a new absolute gravity meter at the *Istituto di Miniere e Geofisica Applicata* (Univ. Trieste). This new transportable gravimeter is based on the free-rise-and-fall method and on a new design for both the launching mechanism and the Michelson interferometer. The *IMGC* gravity meter was employed for the establishment of nine new absolute sites for studies on volcanic activity, a calibration line for relative gravimeters, and space geodesy. Finally it was transferred to the Italian base, Terranova Bay (Antartica) for the establishment of an absolute site in the 1990/91 Antarctic Campaign.

Microgravimetry

Several activities can be reported from *IMGA* in this area, mainly devoted to the study of time-dependent gravity variations associated with the exploration of geothermal fields (both of high and low enthalpy), the monitoring of volcanism, and archeology.

In this field, a microgravity survey in the archeological zone of Selinunte (Sicily) was done by the *Dept. of Mater. Sc., University of Lecce* in collaboration with workers from other Universities; the data are being interpreted.

Gravity maps

A data base of all the measurements taken over the last twenty years at Gravity Stations in Italy has been compiled by the *Dept. of Mat. Sc., University of Lecce*. The data base covers approximately 270,000 stations: the majority of them were supplied by AGIP.

Drawing on this data base and on that for the mean heights, a map of Bouguer Anomalies for the whole of Italy was automatically compiled: it is now in print at a scale of 1:500,000.

By interpreting Bouguer Anomalies with bi-dimensional methods and assuming as bounds the geological data, crustal models have been constructed:

A) Ivrea Zone (crustal models along the CROP profile);

B) Sardinia (crustal models along three east-west profiles).

A three-dimensional crustal model for the Sicilian area has also been constructed.

The major result in this field is the publication of the new Bouguer Map of Italy (land data only) at the 1:1,000,000 scale (by *AGIP* and *Servizio Geologico Nazionale*). Another map, at the scale 1:500,000, together with the structural model of Italy, is presently in press.

Based on OGS data for the western and central Mediterranean, Cambridge data for the eastern Mediterranean, a Bouguer anomaly map as overprint to the UNESCO's Internat. Bathymetric Chart of the Mediterranean (IBCM) has been published by IOC-UNESCO at a 1 M scale (10 sheets, isoanomals at 10 mGal).

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GENERAL THEORY AND METHODOLOGY

The main topics developed at the *Istituto di Topografia Fotogrammetria e Geofisica, Politecnico di Milano* are:

- computation of the highly precise Italian geoid (Italgeo 90) according to the procedure of reducing gravity data with a global model, correcting them for the residual topographic effect, interpolating by collocation and restoring the factors which were subtracted from gravity in the geoid: according to initial tests, this geoid should be accurate to better than 10 cm, depending on the geological structure of the area:

- formulation of an International Project for the computation of the most accurate geoid in the Mediterranean Sea (Geomed) by analyzing gravity and satellite altimetry data (partecipation to the ERS 1 project):

- development of a general purpose package for gravity manipulation in the frequency domain (upward and downward continuation, Stokes, Molodensky, T.C. etc.):

- improvement of the collocation software with a new Fast Collocation algorithm for gridded data;

- definition and analysis of the hierarchy of gravimetric boundary value problems (Molodensky, in vector and scalar form, fixed boundary);

- definition and analysis of the Overdetermined Boundary Value Problems; these problems, when linear, can be analyzed by introducing the so-called Wiener integral by which we can describe stochastic solutions with white noise at the boundary;

- study of the determination of the harmonic coefficients from boundary and non-boundary data with particular regard to: the effects of unevenness in the data distribution (e.g. holes in the data); the aliasing produced by non-uniform distributions, in particular, by regular geographic distributions; the effect of a block averaging; the use of data from non-selfadjoint boundary operators exploiting suitable bi-orthogonal sequences;

- development of the theory and of the related software for the interpretation of gravity and magnetic anomalies in terms of the thickness of a two layer model.

In the field of Space Geodesy the *Politecnico of Milan* proceeded in:

study of the optimal preprocessing of laser ranging measurements and identification of a non-reduced signal of intensity between 5 and 10 cm; proof that the signal is time, but not regionally, correlated;

definition of the integrated approach to satellite geodesy;

analysis of data from radaraltimeters in view of the forthcoming missions ERS1 - Topex Poseidon; solution of the rank deficiency problem in cross-over adjustment;

partecipation in the studies for the definition of the Aristoteles mission (Gradiometry); proposal and study of the gravity field retrieval in terms of an overdetermined BVP.

Caputo (*University of Rome*) has produced the rigorous closed form numerical formula of the Pizzetti Somigliana theory for the normal space gravity of the Earth based on the 1979 Geodetic Reference System to replace the approximate series expansions available.

Caputo and Cerlesi have found the fractal dimension of the topography of the Apennines to be nearly unitary.

From the Fourier analysis of the topography of the Apennines, Caputo has also found that the amplitude of the Fourier components are quasi-proportional to the wavelength, and has related this empirical law to the seismogenesis and to the rheology of the crust and upper mantle.

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International Association of Geodesy

Japan

National Report on the Gravimetry during the Period from January 1987 to December 1990

a) Regional Gravimetry (gravity mapping)

Gravity surveys (mapping) were intensively achieved during the period concerned by using LaCoste & Romberg gravimeters as shown in Table 1 .

Table 1.

Institute	Area	Epoch	Method/Bibliography
GSI	at bench marks and triangulation points	1987-1990	
	Odawara area and Boso Peninsula	1989	high dense gravity survey
GSJ	Kanto Mountains Abukuma Mountains Kitakami Mountains	1985-1987 1987-1989 until 1990	
	Izu Islands	1989	combined with GPS
NEDO	volcanoes and geothermal areas	1987-1989	
Hokkaido Univ.	Hokkaido District	since 1986	Yamamoto et al.(1989)
Hirosaki Univ.	Tsugaru Peninsula Tsugaru Plain		Matsuhashi et al.(1989), Kosuga et al.(1990)
Akita Univ.	Median Tectonic Line Hidaka area,Hokkaido	1987 1986-1988	Sato et al.(1988)
Tohoku Univ.	Iwate and Fukushima Prefectures		
MRI	Hadano Basin	1988	

Table 1. (continued)

Institute	Area	Epoch	Method/Bibliography
ERI	Kanto District		Hagiwara et al. (1987a,1988a,1988b)
	Itoigawa-Shizuoka Geodetic Line		Hagiwara et al.(1987b), Okubo et al.(1990)
Shizuoka Univ.	Fossa Magna		Satomura(1989)
Shizuoka and Kyoto Univ.s	Tokusa Basin, Yamaguchi Prefecture		Satomura et al.(1990)
Kanazawa Univ.	Hokkaido, Kanto, Chugoku Districts etc.		Kono and Furuse (1989,1990)
Nagoya Univ.	Southwest Japan	since 1978	
Hokkaido and Nagoya Univ.s	Fossa Magna	1989	
Speleological Institute	Ryusendo Cave, Iwate Prefecture		Kikuchi(1990a,b c)
Kyoto Univ.	Gojo City	1989	
	Arima-Takatsuki Tectonic Line		Ito et al.(1989)
	Beppu Bay	1989-1990	Faculty of Science, Kyoto Univ.(1990)
Kyoto Univ. conducted	Shikano, Iwai and Beppu Hot Springs		
Kyoto and Tottori Univ.s	Daisen Volcanoes		
Ehime Univ.	Shikoku District and Seto Inland Sea	since 1979	Ohno et al.(1989)
Kochi Univ.	Shikoku District	1989	
NIPR and Tohoku Univ.	Ross Island, West Antarctica	1886-1987	Miura et al.(1987), Miura et al.(1988)
GSJ conducted	Izu-Ogasawara and Mariana Arcs	1986-1989	Ishihara(1987)

Table 1. (continued)

Institute	Area	Epoch	Method/Bibliography
HDJ conducted	seas around Japan	1987-1990	Kasuga et al.(1987), Kato et al.(1988), Oshima et al.(1988)

Abbreviations
NIPR; National Institute of Polar Research, GSI; Geographical Survey Institute, GSJ; Geological Survey of Japan, NEDO; New Energy Developing Organization, MRI; Meteorological Research Institute, ERI; Earthquake Research Institute, Univ. of Tokyo, HDJ; Hydrographic Department of Japan

A high density gravity survey was started by the Geographical Survey Institute (GSI) to investigate a precise crustal structure in seismically active regions. Geological Survey of Japan (GSJ) conducted gravity surveys in the Kanto, Abukuma and Kitakami Mountains at about 3000 points during the period concerned.

The northern part of Itoigawa-Shizuoka Geotectonic Line was surveyed by the Earthquake Research Institute, the University of Tokyo (ERI), where Eurasian Plate might be subducting under North-American Plate, and a thrust fault system was detected along the eastern margin of Matsumoto Basin (Hagiwara et al., 1987b ; Okubo et al. 1990). By a joint work between Nagoya and Hokkaido Universities, a steep change of gravity anomaly was found just along the aftershock area of the Western Nagoya Prefecture Earthquake of 1984 at the southern foot of the volcano Mt. Ontake which suggests the existence of an unknown fault (Shichi et al., 1988). In the vicinity of the Arima-Takatsuki Tectonic Line, Kinki District, it was shown that micro-seismicities are concentrated in the high gravity anomaly zone (Ito et al., 1989).

A gravity survey conducted by Nagoya University and Technical Institute of Tokyo along four routes across Peruvian Andes showed that the crust is thicker in Western Cordillera than in Eastern Cordillera (Fukao et al., 1989 ; Kono et al., 1989a, b).

Marine gravity surveys were conducted by GSJ using a survey vessel " Hakurei-maru" during the period from 1986 to 1989 (Ishihara, 1987). Dense sea gravity surveys were conducted by the Hydrographic Department of Japan (HDJ) using two survey vessels " Shoyo" (1,842 gross tons) and " Takuyo" (2,600 gross tons). The survey vessels are equipped with Bodenseewerk sea gravimeters (KSS-30) (Hydrographic Department, 1989 and 1990, 1986-1990a, 1986-1990b).

A dense gravity survey revealed that the Hidaka Mountain, Central Hokkaido, is characterized by a high Bouguer anomaly accounting to more than 130 milligals (Yamamoto and Moriya, 1989). A sharp gravity anomaly change along the Tsugaru Fault was found and its relation to the tectonics was investigated in that area (Matsuhashi et al, 1989).

b) Microgravimetry

The tidal observations of gravity were achieved at some institutes to investigate both the core dynamics and regional variations of tidal factors (δ-factor) as shown in Table 2.

Four sets of super-conducting gravimeters (GWR, model TT-70) were installed in Japan for continuous observations of gravity changes. They are two at Kyoto (Kyoto University), one at Esashi (National Astronomical Observatory, Mizusawa (NAOM)) and one at Kakioka (University of Tokyo).

Table 2.

Institute	Area	Gravimeters	Bibliog.
Kyoto Univ.	Shizuoka and Omaezaki Kyoto ('88-'90)	L-R D,G two SCGs	Doi et al.(1988)
GSI	Omaezaki Kanozan ('85-'90)	L-R G L-R D	
MRI	Izu-Oshima Island ('85-'89)	L-R ET	

Table 2. (continued)

Institute	Area	Gravimeters	Bibliog.
ERI	Fukushima and Kanazawa		Okubo et al.(1987)
NAOM	Esashi Earth Tides Station('88-'90)	SCG	
Tohoku Univ.	Honjo etc.	L-R ET, Gf,Df	
NIPR	Syowa and Asuka Stations,Antarctica ('86-'88)	L-R Gf	Shibuya and Sakai (1989), Ogawa et al. (1990)

Abbreviations L-R ; LaCoste & Romberg gravimeter, Gf and Df ; type G and D reformed to an electrostatic feed back, SCG ; superconducting gravity meter

The tidal gravity data obtained at Fukushima and Kanazawa were analyzed and no anomalies lager than 1 percent in δ-factor were found out after correcting effects of ocean tides (Okubo et al., 1987).

Precise gravity surveys were carried out in various areas to detect gravity changes associated with crustal activities and volcanic eruptions as shown in Table 3.

Table 3.

Institute	Area	Epoch	Method/Bibliog.
GSI	around Mt.Fuji and in Izu Peninsula		
MRI and Shizuoka Univ.	northern coast of Suruga Bay	five times in '85-'88	
MRI conducted	Izu-Oshima Island		to investigate volcanic activity
ERI	Izu Peninsula	repeated in each year	
Kyoto Univ.	Tokai region and Kyoto	every four months	repeated connection
	Muroto Peninsula	March '90	along levelling route

Table 3. (continued)

Institute	Area	Epoch	Method/Bibliog.
Kyoto Univ.	Kii Peninsula and Lake Biwa	since 1971	biannually
Nagoya, Kyoto and Shizuoka Univ.s, NAOM	Tokai region	since 1981	repeated connection Shichi et al.(1987a) etc.
Nagoya Univ.	Ontake Volcano	since 1978	repeated connect.
Shizuoka Univ.	Suruga Trough (2000 m depth)		Satomura et al. (1987)
Tohoku Univ.	from Nezugaseki to Fukaura		along levelling route
	Bandai Volcano	1987,1988	Faculty of Science Tohoku Univ.(1989)
Tohoku and Kyushu Univ.s	Unzendake Volcano	1987	at 38 points
A cooperative team of institutes and universities	around Kuji Underground Fluid Oil Storage	since 1988	
Akita Univ.	Akita-Komagatake Volcano	1988	at bench marks, Kitsunezaki et al. (1989)
Kyoto Univ. etc.	Sakurajima Volcano	since 1965	at levelling points, Nishimura et al. (1988,1989)
		every two or three years since 1975	Ishihara et al.(1988,1989)

The 28th Japanese Antarctic Research Expedition made combined observations at Bried Bay, Antarctica, to determine the geoid height at the marginal ice zone (Shibuya et al., 1989).

Gravity data obtained in the Tokai region, were jointly analyzed by correcting periodic errors of LaCoste & Romberg (Shichi et al., 1987a ; Faculty of Science, Kyoto

University et al. (1990)). The gravity at the Cape Omaezaki referred to Kakegawa was estimated to increase with a constant rate of 1 microgal/yr during the period from 1981 to 1990.

Significant gravity changes were investigated at several volcanoes : gravity changes around Oshima Volcano (Koizumi et al., 1988) ; increase of several tens microgals around Izu-Oshima Volcano a month after the 1986 eruption (Okubo et al., 1988, Okubo and Watanabe 1989) ; a gravity increase on Medake of Akita-Komagatake Volcano which erupted in 1970 (Kitsunezaki et al., 1989) ; increase of about 5 microgals/yr near the coast of Sakurajima Volcano and more than 10 microgals/yr at points of 3 km to the summit crater (Nishimura et al., 1989).

c) Gravity reference networks

At the Syowa base, one of 36 stations in Subset A of the International Absolute Gravity Basestation Network, the National Institute of Polar Research (NIPR) has been constucting a gravity station with two pires, one for an absolute gravimeter and another for a superconducting gravimeter.

In Japan, absolute gravimeters have been independently developed at two institutes; NAOM and GSI. NAOM has four sets of absolute gravimeters. One of them is the Sakuma's original station type apparatus. The other three sets are transportable and the first model of them has been used since 1978. NAOM carried out absolute gravity measurements at 9 stations in Tohoku District since 1984 with it. The second model was completed in 1989 and took part in the third International Comparison of Absolute Gravimeters at BIPM in 1989. The result obtained there was in good agreement with the mean value of the other nine participants. The third model is of a rotation vacuum-pipe type, which has several advantages for consecutive measurements (Hanada et al, 1987; Tsubokawa, 1987).

GSI has performed absolute gravity measurements at 11 reference stations in Japan since 1982. The main purpose of the measurements is to update and revise the Japan Gravity Standardization Net 1975 (JGSN 75). The fundamental part of the GSI apparatus is a commercial version of the Sakuma's transportable type. However a number of improvements especially for the data acquisition system have been made. Direct comparisons of this apparatus with the NAOM gravimeter were made at four stations. Discrepancies between both apparatuses were found to be much larger than the measurement errors (Tsubokawa et al., 1988). The error sources of such discrepancies are still being investigated.

As for gravity reference networks, activities in international and domestic gravity connections are given in Table 4.

Table 4.

Institute	Region	Epoch	Method/Bibliography
GSI conducted	Japan-Malaysia	1989	
	Japan-Republic of Korea	1990	
	improvement of JGSN 75	1987-1990	three L-R
	Kyushu Island	1990	along levelling route, second order gravity net.
	scale test lines	1989	calibration of L-R
NAOM, Tohoku Univ. and ERI	scale test lines in Tohoku District	1988,1989	calibration of L-R
NAOM	Esashi,Kyoto, Sendai,Hirosaki	Since 1986	Abs.G.
	Kashima	1988	Abs.G., in collocation with VLBI,Hanada et al. (1988)
GSI	ten sites (Tsukuba, Kyoto,Esashi,etc.)	1987-1990	Abs. G., Murakami et al. (1987),Murakami(1989)
NAOM and GSI	Esashi	1987	comparison of Abs.G.s, Tsubokawa et al.(1988)

Table 4. (continued)

Institute	Region	Epoch	Method/Bibliography
NAOM	Sèvres, France	1989	joined to Third Intern. Comparison of Abs. G.

Abbreviation Abs. G.; Absolute gravimeter

Data obtained from an international gravimetric connection between Japan and China during the period from October 1985 to February 1986, were analyzed and examined in detail (Nakagawa et al., 1987a, 1987b, 1989).

GSI repeatedly carried out the first order gravity survey with three LaCoste& Romberg gravimeters. In order to investigate the relationship between changes in gravity and those in height, both levelling and gravity surveys have been conducted in the same years for the same areas.

d) Gravity data base activities

A half million gravity data were collected by Kanazawa University during the past 15 years from various institutions and literatures. Using the data set, 1:1million scale gravity anomaly map in and around the Japanese Islands was published (Kono and Furuse, 1989). A free-air gravity anomaly map covering all over the world was compiled and published by the Ocean Research Institute, the University of Tokyo (ORI), using altimetry data of GEOS-3 and SEASAT-1 (Segawa and Matsumoto,1987). Anomalies around the Japanese Antarctic station were evaluated using both land and sea gravity data as well as GEOS-3 and SEASAT-1 altimetry data (Fukuda et al., 1988a). Geoidal undulation and free-air gravity anomaly maps for the sea around Antarctica using GEOSAT altimetry data were compiled by ORI (Fukuda and Segawa, 1989). The reliability of geoid and gravity anomaly obtained by the satellite altimetry was discussed by Fukuda (1989a). A Bouguer anomaly map of whole Hokkaido District was prepared by GSI in 1988. A detailed complete Bouguer anomaly map of Aomori and Akita Districts was constructed by GSJ in 1:200,000 scale (Geological Survey of Japan, 1989, 1990 ; Hiroshima, 1990). A Bouguer anomaly map of Japan on a scale of 1:1,000,000 was published in 1987 by the New Energy Development Organization (NEDO) (New Energy Development Organization, 1987).

A method for precise data processing including the terrain correction was established by GSJ (GSJ Gravity Survey Group, 1989 ; Komazawa, 1988, 1989).

A new system of data processor was developed by Akita University for calculating terrain corrections and for the reduction of field gravity data (Nishitani et al., 1988 ; Kikuchi and Nishitani, 1990).

e) Instrumental development and investigations

ORI in cooperation with NIPR has been developing a marine gravity measuring system for Antarctic research mainly by use of icebreaker " Shirase". The sea gravimeter system NIPR-ORI (model-2) was installed on board " Shirase" by improving the vertical gyro and the data processing system of the previous model (Segawa et al., 1988). A new method for Eotvos correction for improving marine gravity measurements was proposed (Fukuda, 1989b). NAOM developed a method of coinciding the optical center with the center of gravity of a falling body of corner cube, in order to reduce errors in absolute gravimetry (Hanada, 1988a). A new method to simultaneously determine both the gravitational acceleration and ground vibrations was presented in free fall experiments (Hanada, 1990). A LaCoste & Romberg gravimeter was reformed at Shizuoka University for continuous observations of tidal gravity by a method to attach an automatically controlled stepping motor on the measuring screw (Iwahashi et al., 1989).

f) Other studies in gravimetry

1) Interpretation and analysis

Geoidal undulation and gravity anomaly around Japanese Antarctica stations were estimated by combining satellite altimeter data and surface data (Fukuda et al., 1990).

A method for editing and processing of GEOSAT exact Repeat Mission Altimeter Data was developed (Fukuda et al., 1988b). In this study, the GEOSAT data were compared with SEASAT data, and it was confirmed that the former is more accurate than the latter, because of improved orbit prediction. Detectable sea bottom topographies were investigated by using satellite altimetry data in the northwestern Pacific region (Ganeko and Tsukahara, 1986).

The " Residual Bouguer Anomaly", which means the Bouguer anomaly corrected the gravitational effect of subducting Pacific Plate, was calculated in and around the Northern Japanese Island Arc by Tohoku University.

Long wave-length gravity anomalies across the Pacific Ocean were discussed by applying a correction for the bottom topography etc. (Tomoda and Fujimoto, 1987 ; Fujimoto and Tomoda, 1988).

HDJ had conducted sea gravity survey of Tokyo Bay in 1985 using a survey vessel Shoyo and compiled gravity anomaly maps. The negative Bouguer anomaly of Tokyo Bay was ascribed to pre-Neogene basement structure and the slope of Moho boundary (Ueda et al., 1987). A gravity anomaly map of two-seamounts near Marcus Island was compiled and a new analysis method of magnetic anomalies in correlation with gravity ones was developed (Ueda, 1888, 1990).

The gravity field of Kanto District was investigated and it was suggested that the depth of the basement exceeds 3 km in the center of the Kanto Plain and two graben structures run through the basin in NNE-SSW direction and NW-SE direction (Komazawa and Murata, 1988). The basement structure beneath the Kanto Plain was clarified by gravity and seismic surveys (Hasegawa et al., 1990).

A low gravity anomary in Kinki-Tokai Districts was examined and it was suggested that the negative anomary is ascribed to the shallow ocean crust which contacts with the continental crust under the Lake Biwa (Yamamoto, 1989). Gravity data in Bandai area were investigated and it was found that a high density layer is upheaved under the Bandai-san (Komazawa et al., 1988). The Sengan and the Kurikoma geothermal areas in Northeast Japan were investigated quantitatively and it was found that some steep gradient structures are connected with the geothermal activities (Komazawa and Hasegawa, 1988 ; Komazawa et al., 1987).

Positioning by GPS was shown to be so useful for precise gravity measurements (Komazawa et al., 1990). A new method was developed by GSJ for automatic and simultaneous estimation of Bouguer density and Bouguer anomalies, using a Bayesian procedure with ABIC (Akaike Bayesian Information Criterion).

2) Theoretical studies

The deformation of the earth and the gravity change were estimated in the case of polar drift, and it was confirmed that the viscous flow in the mantle can not compensate the mass distribution caused by polar drift if the mantle viscosity is higher than 10^{22} poises (Hanada, 1988b).

A theoretical formula of gravity change caused by fault motion was presented on a finite rectangular plane buried in a homogeneous halfspace (Okubo, 1989).

Hagiwara (1989a, 1989b) proposed an upward continuation theory of non-Newtonian gravity field and estimated its contribution to the geoid height. The non-Newtonian gravitational attraction formulas of simple-shaped bodies are introduced (Hagiwara, 1990).

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GEODETIC WORK
IN
THE NETHERLANDS
1987-1990

Excerpt : GRAVIMETRY

Report prepared for the General Assembly of the International
Association of Geodesy, XXth General Assembly
of the International Union of Geodesy and Geophysics.
Vienna, 1991

NETHERLANDS GEODETIC COMMISSION

3. GRAVIMETRY

3.1 Land gravimetry

In 1988 the Survey Department of Rijkswaterstaat, in cooperation with the Delft University of Technology, completed the first measurement of the new primary gravity network. The measurements were carried out using gravimeters that were kindly provided by the Munich University of Technology and the Stuttgart University of Technology. The primary network consists of 22 points in the Netherlands, and is connected to the neighbouring countries by means of 6 points (3 in Germany, 3 in Belgium). The points in the Netherlands consist of first order underground benchmarks. These benchmarks are founded in the upper reaches of the Pleistocene layers, and therefore satisfy the high requirements of modern precise gravimetry.
In 1990 a second measurement of the primary network was started; this will be completed in 1991. The decision whether the frequency of measurement will be adjusted in the coming years, will be based on the comparison between the results of the two campaigns.
Also in 1990, the measurement of a second order gravity network was started by the Survey Department of Rijkswaterstaat. In cooperation with the Delft University of Technology a network with a density of 1 point per 5 km^2 was constructed. This density seems to be sufficient right now, but it may be changed during the project. The measurement of the network is expected to be completed in 1993.
The new LaCoste Romberg gravimeter (type G) of the Survey Department of Rijkswaterstaat, which was obtained in 1990, and the gravimeter of Delft University of Technology will be used for the measurement.
Preparations have been made for a first absolute gravity measurement in Dutch history. This will be carried out in September 1991 on three fundamental stations: Kootwijk, Westerbork and Delft. Apart from the application as constraints for the Dutch gravity networks, the absolute gravity measurements are also expected to improve discrimination between land subsidence and sealevel rise, matters of major concern for the Netherlands.
Tidal registrations have been made in Delft and at the satellite observatory in Kootwijk. The difference between the registrations and the theoretical computed tides shows a mean standard deviation of about 6 microgal.

3.2 Geoid determination

The previously mentioned second order gravity network will be used to calculate the (relative) geoidal height in the Netherlands with an expected 1-cm precision. Theoretical research on this topic is being carried out at Delft University of Technology. Taking into account the expected year of completion for the measurement of the second order network, this high-precision geoid will not be available until 1994.

3.3 Publications

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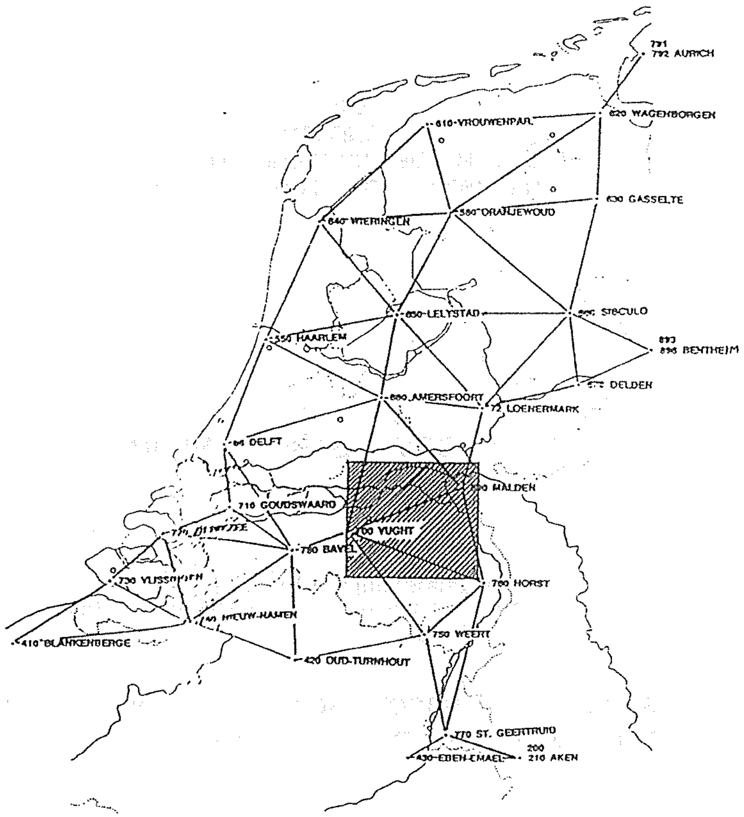

Fig. 1 Primary gravity network of the Netherlands (1990). Shaded: measurement of a second order gravity network in 1990.

NEW ZEALAND
GEODETIC OPERATIONS 1987-90

REPORT FOR THE GENERAL ASSEMBLY OF THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS

Excerpts : Introduction - Determination of the Gravity Field - Geophysical Interpretation

VIENNA, AUSTRIA, AUGUST 1991

NEW ZEALAND NATIONAL COMMITTEE
FOR GEODESY AND GEOPHYSICS
WELLINGTON
1991

Report for the General Assembly of the
International Union of Geodesy and Geophysics
Vienna, Austria, August 1991

INTRODUCTION

Since the publication of the last report for the August 1987 General Assembly there have been considerable changes in the organisation and structure of Government departments and in funding arrangements.

The national survey mapping and land information functions formerly carried out by the Department of Lands and Survey have, since March 1987, become the responsibility of the new Department of Survey and Land Information (DOSLI).

The NZ Geological Survey and Geophysics Divisions of the Department of Scientific and Industrial Research (DSIR) have been combined into one Division, entitled Geology and Geophysics Division. A separate Ministry of Research, Science and Technology (with responsibility for policy advice) and a Foundation for Research, Science and Technology (with responsibility for allocation of science funding) have been established. Government is currently considering proposals to reconstitute DSIR and other government science agencies (Forestry, Agriculture and Fisheries, Meteorology) into a number of Crown Research Institutes, one of which it is expected will probably continue the existing Geology and Geophysics Division functions.

The Ministry of Works and Development has been substantially restructured as a State Owned Enterprise known as Works Development Corporation Ltd.

Government agencies are now expected to operate in an increasingly commercial manner and in many cases to charge for the full cost of scientific and operational activities.

SECTION 3:
DETERMINATION OF THE GRAVITY FIELD

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH, GEOLOGY AND GEOPHYSICS

The precise gravity network has been extended, with measurements along benchmark lines between Napier and Whakātane via East Cape, and Gisborne and Opotiki. The section of the network through Edgecumbe was repeated immediately following the 2 March 1987 Edgecumbe earthquake, the network was extended locally and its density increased, and reobserved again in 1988. Large changes were observed around Edgecumbe, closely correlated with observed level changes. Most of the line Dunedin to Haast (first occupied between 1980 and 1984) was reobserved in 1989.

Changes of gravity with time, combined with level change data, have been used to test several 3-dimensional, numerical reservoir simulation models for the response of the Broadlands (Ohaaki) geothermal field to pre-production mass withdrawal. The test enabled serious deficiencies in the models to be identified.

Changes in gravity with time, combined with level change data, have been used to map the flow paths of reinjected fluid at Wairakei geothermal field during a 13-month long test.

A baseline precise gravity survey has been made on benchmarks in and around the Kawerau geothermal field to monitor changes associated with continuing exploitation of the field.

Offshore acquisition of gravity data has continued, using a LaCoste and Romberg marine gravimeter on HMNZS Monowai, north of East Cape and around the Auckland Islands. Gravity data has been collected using the DSIR vessel R.V. Rapuhia from the Chatham Rise - Hikurangi Plateau area east of the North Island, and from the Challenger Plateau and New Caledonia Basin.

The following offshore gravity maps have been published: Coastal Gravity maps at 1:250,000 scale of Motueka, Napier, and Grassmere; Island Series Gravity maps of Chatham and Bounty Islands; and Ross Sea (Antarctica) Gravity map at 1:1,500,000 scale.

HYDROGRAPHER, ROYAL NEW ZEALAND NAVY

Underway LaCoste and Romberg gravimeter observations have been undertaken in Monowai for DSIR Geology and Geophysics, north of East Cape and around the Auckland Islands.

GEOPHYSICAL INTERPRETATION

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH, GEOLOGY AND GEOPHYSICS

A very small scale precise gravity survey (5000sq m area) was carried out over a limestone formation in an evaluation of methods for locating subsurface cavities.

Bouguer and Residual gravity anomaly data in and around the Rotokawa geothermal field have been interpreted to map the sub-surface distribution of rhyolite intrusions.

Gravity anomalies have been interpreted in terms of basement topography over several sedimentary basins in the New Zealand land and offshore area (Canterbury Plains, Hanmer Depression, Chatham Islands), and in terms of crustal structure under the west and central Ross Sea, Antarctica.

The long wavelength pattern of the isostatic gravity anomaly field over the North Island has been interpreted in terms of an abrupt change in crustal and upper mantle structure (i.e. a gravity "edge effect").

Gravity anomalies have been used to model the structure of the crust and upper mantle at the boundary between East and West Antarctica. The model is constrained by a flexural analysis.

Two profiles of gravity anomaly across the North Island have been used in the interpretation of structures formed at the plate boundary.

A borehole tiltmeter was operated on Mt Ruapehu (Tongariro National Park) until 1988. Its ability to detect tilt of volcanic origin was limited by rainfall related tilts (5-10 microradians) which were too irregular to enable accurate removal from the tilt record.

A Westphal bubble tiltmeter was operated at Wairakei geothermal field for five months during 1987. The data were contaminated by a large diurnal variation related to air temperature changes, but the secular variation (tilt rate) was well determined, and in reasonable agreement with estimates derived by other means.

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POLISH NATIONAL COMMITTEE
FOR
INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS

NATIONAL REPORT
1987 - 1990
FOR THE XX GENERAL ASSEMBLY
OF THE INTERNATIONAL UNION
OF GEODESY AND GEOPHYSICS

VIENNA, AUGUST 11 - 24, 1991

INTERNATIONAL ASSOCIATION OF GEODESY

Excerpt : GRAVIMETRY

COMPILED BY THE COMMITTEE OF GEODESY
OF THE POLISH ACADEMY OF SCIENCES
BOGDAN NEY - PRESIDENT
ANDRZEJ SAS-UHRYNOWSKI - SCIENTIFIC SECRETARY

INSTITUTE OF GEODESY AND CARTOGRAPHY, WARSAW

GRAVIMETRY (M. Barlik)

The widest experience as regards the construction and calibration on of gravity-meters as well as executing large gravimetrical projects has the staff of the Institute of Higher Geodesy and Geodetical Astronomy of the Warsaw Technical University. Theoretical studies in the field of gravity and searching the harmonical fuctions have been performed by the staff of Space Research Centre of the Polish Academy of Sciences. In the Institute of Geodesy and Cartography some works concerning the management of gravimetric network are performed. During last four years the following gravimetrical projects have been caried out:

- observations of gravity differences on the 1-st order gravimetric network;
- observations on the spanes connecting Poland and Czechoslovakia, as well as late DDR (East Germany) territory;
- measurements of the JSG (uniform gravimetric network of the East-European countries) by pendulum apparatus on the territory of Poland;
- establishment, measurements and processing of results of the measurements of the gravimetric vertical base line in Warsaw;
- calibrations of the all gravity-meters used in geophysical probing by tilt method using the examinator specially constructed in the Warsaw Technical University;
- gravimetrical measurements along over 300 km of the SAGET traverses as well as gravimetric observations of geodynamic networks PIENINY (Carpathians) and GRYBÓW (near Cracow). Periodical gravimetric measurements were also carried out along meridian bases at the astronomical observatories Józefosław and Borowiec;
- gravimetric measurements on the glaciers in Horsund on Spitzbergen by the first Polish student expedition from Warsaw Technical University;
- the construction of an original Polish absolute balistic gravity-meters has already reached the final stage;
- working out the analytical estimations of the covariance functions and cross-covariance functions of the Earth's gravity characteristics on the territory of Poland.

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PORTUGAL

SECÇÃO PORTUGUESA DAS UNIÕES INTERNACIONAIS
ASTRONÓMICA E GEODÉSICA E GEOFÍSICA

NATIONAL REPORT ON GEODETIC WORKS

EXECUTED FROM 1987 TO 1990

PRESENTED TO THE XX GENERAL ASSEMBLY
OF THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS
HOLD AT VIENNA, AUGUST, 1991

Excerpt : Determination of the Gravity Field

LISBOA
MCMXCI

Section III - Determination of the gravity field.

1 - Gravimetry

The gravimetric observations continued, with the main purpose of covering all the levelling bench marks an establishing a first order gravimetric network to support the densification project that will take place in the next years (see 3.2).

In the period 1987-1990 two LaCoste and Romberg gravitymeters were used to establish 1266 new points.

2 - Geoid

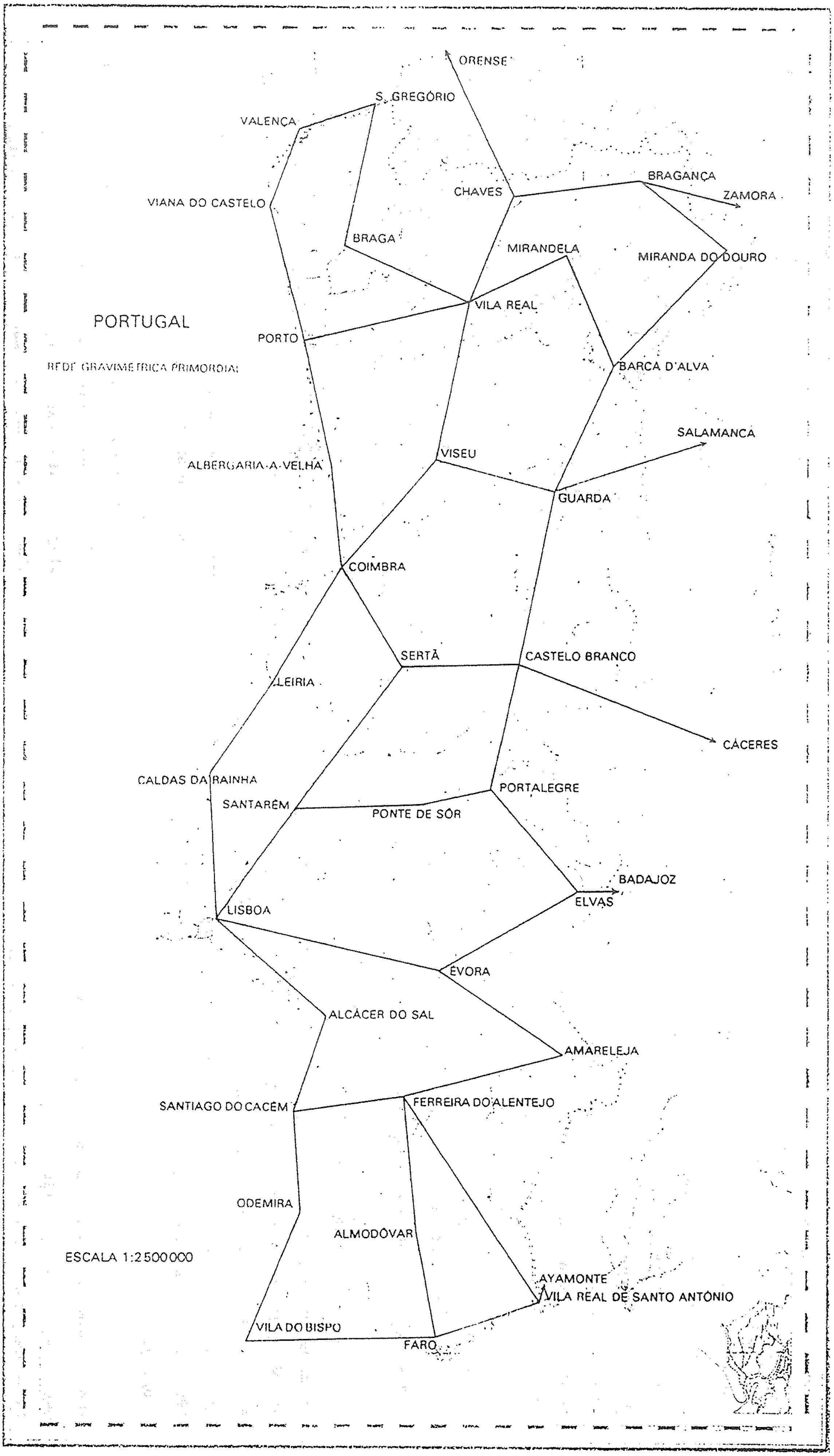
In 1990 the "Instituto de Astronomia y Geodesia" (IAG) of the Madrid University and the IGC began the co-operation for the computation of the Iberian Peninsula geoid using gravimetric observations.

The Portuguese available data were already sent to the IAG.

In the next years is intended to start the gravimetric observations in order to achieve a density of 1 point/25 km2.

Publication

Torres, J. Agria, Nuñez, A., Sevilla, M. J. - "Dèterminacion del Geoide en Portugal y su influencia en la rèd geodesica de primer orden". Revista nº 9 do IGC, Lisboa, 1989.


PORTUGAL
REDE GRAVIMETRICA PRIMORDIAL
ORENSE
S. GREGÓRIO
VALENÇA
VIANA DO CASTELO
BRAGA
CHAVES
BRAGANÇA
ZAMORA
MIRANDELA
MIRANDA DO DOURO
VILA REAL
PORTO
BARCA D'ALVA
SALAMANCA
VISEU
ALBERGARIA-A-VELHA
GUARDA
COIMBRA
SERTÃ
CASTELO BRANCO
LEIRIA
CÁCERES
CALDAS DA RAINHA
SANTARÉM
PONTE DE SÔR
PORTALEGRE
BADAJOZ
ELVAS
LISBOA
ÉVORA
ALCÁCER DO SAL
AMARELEJA
SANTIAGO DO CACÉM
FERREIRA DO ALENTEJO
ODEMIRA
ALMODÔVAR
ESCALA 1:2 500 000
AYAMONTE
VILA REAL DE SANTO ANTÓNIO
VILA DO BISPO
FARO

National report on Gravimetry in Sweden 1987 - 1990

Lars Åke Haller
National Land Survey
S-801 82 Gävle
Sweden

a) Regional gravimetry (gravity mapping)

NATIONAL LAND SURVEY OF SWEDEN

Gravity measurements on the ice of the Bothnian Sea

In cooperation with the Geodetic Institute in Finland and the Geological Survey of Sweden, gravity measurements have been made on the ice of the Bothnian Sea (320 stations 1987; no measurements 1988 - 1990 because of lack of ice).

Second Order Gravity Net

Because of low priority only about 400 points have been measured in the ordinary second order net (5x5 km net).

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THE GEOLOGICAL SURVEY OF SWEDEN

Measurements for geological mapping

The Geological Survey has done regional gravity mapping in central Sweden, Siljan area and Skellefte orefield area. Some 8500 observations were taken during 1987-1990. This work is done for the purpose of geological mapping.

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THE DEPARTMENT OF GEOPHYSICS, UNIVERSITY OF UPPSALA

Measurements in Antarctica

In January 1989, about 115 km of gravity profiles were measured across the ice of Dronning Mauds Land in Eastern Antarctica. This project, which is a part of the Swedish Antarctic Research Programme, is a combined geophysical-geological study of the tectonic structures in the area.

b) Microgravimetry

NATIONAL LAND SURVEY OF SWEDEN

THE DEPARTMENT OF GEOPHYSICS, UNIVERSITY OF UPPSALA

The Fennoscandian Land Uplift Gravity Lines

Measurements have been carried out on one of the four Land Uplift Gravity Lines which have been established for studying secular variations in gravity. Observing institutes have been National Land Survey of Sweden with LCR G-54 and G-290 and Institute of Geophysics, Uppsala University, with LCR G-786 and D-56.

Year	Line	End stations
1987	63^{o}	Vågstranda - Joensuu

The results from this measurements have been published in Ekman & Mäkinen 1990.

c) Gravity reference networks

NATIONAL LAND SURVEY OF SWEDEN

IGSN-71 stations

In 1988, IGC (International Gravity Commission) decided to update the BGI (Bureau Gravimétrique International) catalogue of the IGSN-71 stations. A review of the Swedish stations has been made. Of the 20 Swedish stations in the catalogue, four are destroyed, one is cancelled because of no description and one because it is situated in Denmark (!). For the remaining 14 stations, corrected descriptions have been sent to BGI.

The Swedish Zero Order Net

During this period, the measurements of the Zero Order Net are adjusted and the result is published (Haller et al.). The net consists of 24 outdoor stations (each of them with one reserve station) plus the absolute station Mårtsbo. The net is connected with the absolute stations Göteborg, Copenhagen and Sodankylä and with three IGSN-71 stations in Sweden and four in Norway.

d) Gravity data base activities

NATIONAL LAND SURVEY OF SWEDEN

Bureau Gravimétrique International

In 1988 about 7200 measurements from the southern part of Sweden were delivered to BGI in Toulouse.

f) Other studies in gravimetry

i) interpretation and analysis

THE DEPARTMENT OF GEOPHYSICS, UNIVERSITY OF UPPSALA

Combined surface and borehole gravity data

In the area of the Siljan Ring impact structure in central Sweden gravity data have been interpreted in order to study the subsurface density structure (Dyrelius 1988). In September 1987, borehole gravity data down to 5.1 km depth were acquired in the deep well, located at the centre of the major negative (-15 mgal) Bouguer anomaly in the area. A density inversion of the combined surface and borehole gravity data (Dyrelius 1990), demonstrated that the observed surface Bouguer anomaly can be readily explained by lithological differences, possibly in combination with a smaller contribution due to the observed 1-2% increase of porosity, that is believed to be associated with impact fracturing.

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DEP.OF GEODESY,ROYAL INSTITUTE OF TECHNOLOGY, STOCKHOLM

Gravity field interpret. over the Main Ethiopian Rift

In 1970-1989 1500 gravity data where taken in the Main Ethiopian Rift and its shoulders. These data and 2000 old reprocessed older measurements were compiled to a new database with more than 2000 gravity values (including Bouguer anomalies). A first analysis of these data has shown that the long wave length negative Bouguer anomaly, which is characteristic of the region in East Africa, is disturbed by a positive anomaly (100 km width, 50 mGal amplitude) under the entire width of the Main Ethiopian Rift. Crustal models that produce the observed gravity anomalies and matching the geological and tectonic data are presented in Alemu (1989) and Alemu and Sjöberg (1990).

An iterative MINQUE-technique

Jansson and Norin (1990) gives a summary of the planning and realization of an observation campaign in the second order gravity network of Sweden. A study on variance components is also carried out in the thesis. This is performed by an iterative MINQUE-technique on a set of measurements in the Swedish zero order network.

This technique yielded significant changes from earlier network results.

h) Bibliography (reference list)

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Switzerland
Swiss Geodetic Commission
and Federal Office of Topography

Suisse
Commission Géodésique Suisse
et Office Fédérale de Topographie

Report on the GEODETIC ACTIVITIES in the years 1987 to 1991

Presented to the XX General Assembly
of the International Union of Geodesy and Geophysics
in Vienna, August 1991

Rapport sur les TRAVAUX GÉODÉSIQUES exécutés de 1987 à 1991

Présenté à la vingtième Assemblée générale
de l'Union Géodésique et Géophysique Internationale
tenue à Vienne, août 1991

Excerpt : Determination of the Gravity Field

Zurich 1991

3 Determination of the Gravity Field

Gravity reference networks

Gravity Measurements along re-measured first order levelling lines
by E. Klingelé

In the last years gravity values have been determined simultaneously with the re-levelling of the Swiss National Levelling Network in order to correctly reduce the levelling measurements (see also chapter on height systems). In the period extending from 1987 to the end of 1990, gravity measurements using LaCoste and Romberg gravity meters have been carried out on the following levelling lines (see also Map 6).

1987:	Fribourg - Yverdon - Vuiteboeuf	(Line A)
	Bellinzona - Brissago	(Line B)
	Visp - Zermatt	(Line C)
1988:	Vuiteboeuf - St. Imier - Biel	(Line D)
1989:	La Cibourg - Basle	(Line E)
1990:	Nyon - St. Cergnes - Vuiteboeuf	(Line F)

Gravity values have been computed on the basis of the absolute gravity value in Zürich and also linked to the Swiss National Gravity Network. The measured stations are fully documented and will be included in the new national levelling documentation.

Swiss Absolute Gravity Network
by E. Klingelé, I. Marson, H.-G. Kahle

In June 1987 and May 1988 the station Bäzberg of the Swiss Absolute Gravity Network in the St. Gotthard road tunnel was re-measured by means of the improved absolute gravity meter of the Istituto di Metrologia "G. Colonnetti", Torino. A new absolute gravity campaign is planned for 1992.

Microgravimetry and gravimetric tests of the Newtonian Law
by E. Klingelé and H.-G. Kahle

Since 1989 the IGP of the ETH Zurich is conducting microgravimetric measurements in a dam of an electrical power plant at two stations separated by 90m height. The measurements are performed mostly during spring when the variations of the water level are maximum. A good knowledge of the artificial lake enable the computation of the theoretical value of the vertical component of the attraction on both stations.
The comparison between computed and measured gravity enables the computation of the value of the universal gravity constant. This experience will continue until a sufficiently large set of data will be available for statistical tests.

Regional gravimetry (gravity mapping)
by E. Klingelé

In a frame of a systematic gravity mapping of Switzerland at a scale of 1/100'000, the geophysical Institute of the University of Lausanne, on behalf of the Swiss Geophysical Commission (SGPK) has measured around 1'900 new gravity points (see Map 6). These stations, mostly located in the Jura mountains, will enable the SGPK to publish in 1992 the first seven 1/100'000 maps of the eighteen which compose the full coverage of Switzerland.

Apart from this systematic gravity mapping, two very detailed surveys were carried out by the geophysical institute of the ETH Zurich for hydrological purposes. The number of stations measured for these two surveys is approximately 950.
The geodetic institute of the ETH Zürich received, in 1987, from the European Science Foundation, the duty of compiling the gravity data along the European Geotraverse. This compilation consisted of the collection, validation and re-computation in a homogeneous system (1975) of more than 250'000 data coming from up to 11 different countries. The results of this compilation is in the form of two Bouguer Gravity Anomaly coulour maps at a scale of 1/250'000 and covering a strip of 250 km width and appoximately 4'500 km length.

Interpretation and analysis

Application of the admittance technique to gravity data in Central Europe
by S. Ott, E. Klingelé

The earth's Isostatic Response function has been calculated for an area of 740 x 740 km in Central Europe. This zone is delimited by the meridians 6.5°W and 17.166°E and by the parallels 47°N and 53.4°N. The gravity data were provided by the Geodetic Institute of the University of Hannover (Germany). The computed transfer function shows an interesting similarity with the one computed for North America by Dorman and Lewis (1970).

Evaluation of gravity measurements in the Gotthard Tunnel
by R. Glaus, B. Wirth

The gravity data measured in the Gotthard road tunnel have been used to predict the deviations of the vertical, the gravity anomalies and the geoid undulations by means of the collocation method. The bulk density of the surrounding mountains were also computed and yielded a value of 2.74 g/cm^3 which fits quite well with the values obtained by the classical sampling method.

Integral gravity field determination in the Ivrea-Zone and its geophysical interpretation
by B. Bürki

The main task of this work was to apply modern zenith camera systems and gravimeters in determining of gravity and astrogeodetic data simultaneously. A total of 117 astronomic stations was observed in northern Italy and southern Switzerland where the prominent zone of Ivrea-Verbano causes very significant disturbances of the gravity field. For the determination of ellipsoidal coordinates, two Doppler satellite receivers MX1502 were used in the translocation mode.
The astro-geodetic and gravity measurements were used to interpret the deep-seated mass disturbance caused by the Ivrea body in terms of location, size and density contrast. The entire structure was assembled by a series of elementary bodies which may be oriented arbitrarily in space and from which the gravitational attraction can be computed using rigorous formulae. For the geophysical interpretation, the effects of all known mass inhomogeneities were removed from the observed values.
The applied reductions include digital mass models for the following effects: topography, Moho discontinuity, sediments of the Po Plain and of the main valleys, lakes as well as geological reductions for near-surface structures. Furthermore, an appropriate mathematical model was used to perform a least-squares adjustment for estimating the following parameters: Density contrast of a single or a group of elementary structures with respect to the mean density value, changes in the geometry of every single element (either rectangular or triangular prisms); changes in the position of the spatial orientation of every element. As a result of these investigations, a new astro-gravimetric model for the Ivrea body is presented showing some new aspects with respect to the structural composition and extension of the Ivrea body.

A 2-D gravity model of the seismic refraction profile of the EGT Southern Segment
by E. Klingelé, G. Schwarz

A two-dimensional gravity algorithm was applied to a model constructed from the interpretation of the seismic refraction data as presented at the end of the follow-up meeting (in Zurich, June 1988) to the Third Earth Science Study Centre, which focussed on the Southern Segment of the European Geotraverse (EGT). A trial-and-error procedure optimized the density distribution versus depth with the seismic interfaces kept as fixed as possible. Then the physical consistency of the proposed seismic model in terms of mass distribution was tested. Algorithms for an automatic constrained optimization of the density distribution were also applied. The results of the gravity modelling show good agreement between the observed and computed Bouguer anomalies on a regional scale, with the exception of the part of the profile between the Southern Alps and the Po Plain where the gravity model shows a distinct mass deficit.

Theoretical Studies

Theoretical study of the gravity field in the Alpine area: Gravimetric Geoid of Switzerland
by A. Geiger

This work is divided in two parts which are not completely separated. In the first part, a few mathematical foundations of the functional gravity field approximation are presented.
One of the most important problems of physical geodesy, the solution of Laplace's equation has systematically been reviewed by means of the Stäkel-Separation in cartesian, spherical and ellipsoidal coordinates. Special emphasis has been put on the demonstration of the relations between the different solutions in different coordinate frames. The relation between sperical harmonics and the cartesian solution is made by means of homogeneous polynomials. The relation between Fourier transforms and the cartesian solution is shown as well.
A possibility to develop some orthogonal series approximation by the least-square method even for unevenly spaced data samples is shown. The Operator-calculus is introduced and specialized for self-adjoint operators like the Laplace-operator. By treating a few eigenvalue problems, the solution will appear in terms of reproducing kernels. The error propagation is briefly discussed.
The boundary value problem is treated using all the previously established and reviewed formalisms. The Stockes' solution is consequently elaborated by this functional approach. The Stockes' function is derived only by the use of operators solving for the Greens' functions. In view of future numerical developments, the boundary value problem has been formulated as a variational problem which can be solved by numerical methods such as finite elements or finite differences. A brief overview of spectral and approximation methods is given.
The last chapter of part I concentrates on real calculations in the framework of the gravity field. The operational approach is briefly rewied on the basis of functional theory. A small outlook in differential geometry is given. Especially the analogies of the gravity field, the lightwave propagation and the conformal mapping is pointed out.
Some examples of applying Gauss' formula to describe physical properties of the gravity field are carried out. The rigorous application of the Fourier transformation leads to a new formula for calculating the gravity vector and the potential from known density destributions. 'Parker's' formula will appear as a special case for the z-component. The multipole development might have some interest for calculating global topographic effects or for gravity field determination inside mass distributions.
In the second part, the practical evaluation of Stokes' formula is carried out. Several formulas developed in the previous chapters of part I will be applied. Some distributing effects such as time dependent gravity changes etc. are discussed. Most of them are negligible for our purposes. In a newly formulated least squares model, trend- and Moho parameters with horizontally variing crustal densities are estimated.
A simple algorithm for correcting Stokes' formula in the near zone of integration is developed. The correction of height anomalies or orthometric height corrections are derived from Bouguer anomalies.
For the calculation of the geoid GEM10C in the GRS80 has been used as a reference. The 6'x10' free air "Wenzel" anomalies as well as our own data of Switzerland have been processed. By the calculation in

the GRS80, it was possible to calibrate the existing astro-geodetic geoid with respect to this system. The a priori variances of the gravimetric geoid showed values from 12 cm to 30 cm. The comparison with the astro-geodetic solution reveals a mean deviation of 26 cm rms. Here it is to say that the regions of the Molasse basin and the Alpine forelands showed a much lower discrepancy of the order of 16 cm rms. The major contribution to the residuals are located in the Ivrea-zone and in the southern part of the canton of Valais. To examine this problem the pure 'Stokes' principle of free air anomalies has been left. Some suspect free air anomalies have been calculated by interpolation of Bouguer anomalies and by adding the corresponding topographic effect. The residuals remained in the same regions, but on a lower level. An overall precision turned out to be of the order of 30 cm.

Automatic interpretation of gravity gradiometric data
by E. Klingelé, I. Marson, H.-G. Kahle

The magnetic and gravity field produced by a given homogeneous source are related through Poisson's equation. Starting from this consideration, it is shown that some 2D interpretation tools, widely applied in the analysis of aeromagnetic data, can also be used for the interpretation of gravity gradiometric data (vertical gradient). This paper deals specifically with the Werner deconvolution, analytic signal and Euler's equation methods. After a short outline of the mathematical development, synthesized examples have been used to discuss the efficiency and limits of these interpretation methods. These tools could be applied directly to airborne gravity gradiometric data as well as ground gravity surveys after transformation of the Bouguer anomalies into vertical gradient anomalies. An example is given of the application of the Werner deconvolution and Euler's equation methods to a microgravity survey.

Regularization by digital topography and by estimating crustal parameters from gravity field data: Example of Switzerland
by A. Geiger, B. Wirth, U. Marti

In this paper emphasis is put on the determination of crustal parameters by gravity anomalies. The determined parameters may also be used for the gravity field interpolation. The crustal parameters will be restricted in our case to densities and reference depth of the Mohorovicic discontinuity in the Swiss Alpine area. A procedure similar to the well known 'Nettleton'-profiling for determination of the homogeneous density of a small scale, the topographic structure will be generalized to two-dimensional data sets and varying density. The method will still be limited to small areas. Elsewhere similar approaches are used for gravity prediction, where in some way the correlation of height and anomaly is also used. The estimation of the parameters, which may also include density and trend parameters, is done by least-squares adjustment or by least-squares collocation. In this approach different components of all the methods can be identified. The basic idea consists of reducing the gravity field anomalies by physically meaningful parameters, which have to be estimated to a more or less stochastic remainder. The applied model consists of horizontally varying crustal density, mantle density, reference depth of the Moho discontinuity and known disturbing mass distributions like the 'Ivrea' body in the southern part of Switzerland. Similar calculations are carried out to treat the deflections of the vertical. The regularization of the deflections by topographic masses is clearly demonstrated, especially in rugged topography.

Astronomical geodesy

The connection of space related observations such as satellite measurements using GPS techniques, satellite laser ranging (SLR) and Very Long Baseline Interferometry (VLBI) with terrestrial data measured in the earth's gravity field requires the knowledge of the equipotential surface at sea level represented by the geoid. The determination of its parameters in terms of deflections of the vertical and azimuths is one of the major objectives of the astronomical geodesy.

Zenith camera and Determination of Deflections of the Vertical
by B. Bürki

The upgraded transportable zenith camera measuring- and evaluation system of the Institute of Geodesy and Photogrammetry (ETH Zurich) has been used to carry out numerous new measurements serving different purposes. In order to improve the geoid determinations, deflections of the vertical are of utmost interest. Beside the geoid determination the astro-geodetic observations may be used for geophysical interpretation purposes as well.
The zenith camera system has been used within the following projects:

In Switzerland (see also Map 7):
- 30 stations in the framework of practical field courses for students in connection with several research projects
- 30 stations for the Swiss National Research Project NFP20: Exploration of the Deep Geological Structure of Switzerland.
- 26 stations for the densification of deflections of the vertical in Switzerland

In other countries:
- 20 stations in Greece for the geoid determination in the Ionian Sea area.
- 5 stations in the vicinity of Venice. The purpose of these measurements was the determination of the local geoid in the frame of ESA's ERS 1 altimeter task and furthermore height determinations.

Computer-Supported On-Line Astronomical Positioning
by B. Bürki, U. Marti and B. Wirth

The objective is to investigate new observation methods including software and hardware developments such as especially designed digital clocks and electronic theodolites in connection with Laptop computers. A comprehensive software package has been developed which enables on-line observations using different methods and modern electronic theodolites. In this system, the astro-geodetic observation procedure including digital data transfers as well as the evaluation is supported and controlled by the software running on a Laptop PC. The software makes use of rigorous evaluation algorithms based on the new star catalogue FK5 and the actual astronomical procedures and constants as defined by the IAU.
In collaboration with the Istituto Geografico Militare Italiano and the University of Padova, a total of about 30 stations has been observed in several field campaigns in Switzerland, Italy and in the Central Karakorum mountain chain in Pakistan.

Geoid Determinations

Gravimetric Geoid in Switzerland
by A. Geiger
(see under Theoretical Studies, this section)

Geoid determination in Switzerland using GPS (ALGESTAR)
by U. Marti

The objective of the project ALGESTAR (Alpine Geoid by Satellite Timing and Ranging) was to test the suitability of GPS measurements for height determinations in a rugged topography and furthermore to calculate a satellite-based geoid for Switzerland. A set of 40 stations of the Swiss triangulation network which are connected to the national levelling lines was selected in order to get accurate orthometric heights. The measurements took place in collaboration with different Swiss and German institutes in the end of August 1989. The 40 stations were measured by using 16 WM-102 double-frequency-receivers in only 4 days. The GPS solution were evaluated with the 'Bernese GPS-Software'-package. Comparisons between the solutions of every single day revealed an accuracy of the ellipsoidal heights better than 10 cm over the whole area (200 to 300 km).

The geoidal undulations at the observed stations were obtained by subtraction of the orthometric heights and the ellipsoidal heights calculated from the GPS measurements.

In the Alpine region the geoid can't be interpolated with sufficient accuracy without reducing the observed undulations by the influence of known mass models (topography, MOHO discontinuity, Ivrea body). The resulting co-geoid shows a smooth surface and can therefore easily be interpolated (e.g. by collocation methods). The geoid itself is obtained by applying Bruns' theorem. Following the 'remove-restore' technique, the gravity potential of the reduced mass models has to be added to the interpolated co-geoid.

The resulting geoid reveals an accuracy of about 10 to 15 cm over the whole of Switzerland. In most parts of the country, the differences to the astro-geodetic geoid are less than 20 cm.

Astrogeodetic Geoid-Determination in the Zone of Ivrea

by U. Marti

In the framework of a dedicated study of the gravity field in the vicinity of the Ivrea zone in southern Switzerland and northern Italy, 117 astrogeodetic stations were measured with the transportable zenith camera system of the Institute of Geodesy and Photogrammetry at the ETH Zurich. These astro-geodetic measurements were completed by some 110 additional gravity measurements.

One first principal aim of these investigations was to increase the knowledge of the location, size, shape and density of the prominent zone of Ivrea. B. Bürki has determined a detailed 3D-model of this zone (see "Integral gravity field determination in the Ivrea-Zone and its geophysical interpretation", in this section).

Based on these results, a second goal was to calculate a new geoid in this complicated region. Because of the irregular distribution of the measured deflections of the vertical (mainly caused by topography), the effects of known mass models (topography, crust mantle boundary (MOHO discontinuity), Ivrea body, sedimentations of the Po Plain and of the major Alpine valleys as well as the masses of lakes and glaciers) have been subtracted. The reduced deflections of the vertical show a smooth form and can easily be interpolated.

Presuming that all mass disturbances near the surface have been reduced, integration leads to the co-geoid of the residuals. This integration has been performed by means of collocation methods based on multivariate predictions of geoid heights, deflections of the vertical and gravity anomalies. We used the 3rd order Markov model presented in 1972 by S.K. Jordan which was already applied by W. Gurtner in his determination of the astro-geodetic geoid of Switzerland in 1978.

Since the number of measured gravity anomalies is too small to increase the accuracy of the geoid, only astro-geodetic data were used in this case. From the co-geoid of the residuals the geoid itself is then obtained by applying Bruns' theorem.

The main features of the geoid are caused by the topography. It generates differences in the undulations of 12 to 13 meters in the Alpine region. The other important mass models (Ivrea body, MOHO discontinuity and sedimentations of the Po Plain) are associated with undulation of 5 to 7 meters.

In Map 9 the geoid is shown referred to the Swiss Bessel-Ellipsoid. It has a relative accuracy of better than 3 cm over the whole region. It represents the base for future combinations of levelled heights and elevations obtained by satellite methods (GPS). The final goal is to determine a 'cm-Geoid', which is in accordance with resolutions obtained by the International Union of Geodesy and Geophysics (IUGG) 1987 in Vancouver.

High Precise Local Geoid Determination in Turtmann

by B. Wirth

In the GPS test net Turtmann (see also section 1 and report 1987), the Institute of Geodesy and Photogrammetry of the ETH Zurich (IGP) and the Federal office of Topography (L+T) have determined 10 astronomical stations with the transportable zenit camera system of the IGP. In the same area of 5 x 6 km² with up to 900 m height differences, the IGP measured 202 gravity stations. All these measurements were reduced for the effects of topography, the Moho discontinuity and an Ivrea model. The reduced data were used for a combined astrogeodetic gravimetric geoid determination. The two-dimensional Markov undulation model of third order was taken to predict co-geoid undulations. The characteristic distance was set to 2000 m, the standard deviations for the noise to 0.5" for ξ, 0.7" for η and 0.5 mgal for δg. The potential effects of the models were calculated in all interesting stations on mean sea level and transformed to geoidal heights by Bruns' theorem and added to the co-geoid heights. The relative accuracy of the geoid to the GPS station Turtmann in the center of the area was computed and has its maximum in the GPS station Agarn with ± 1 mm. In this example, we succeeded in computing a local geoid with subcentimeter accuracy.

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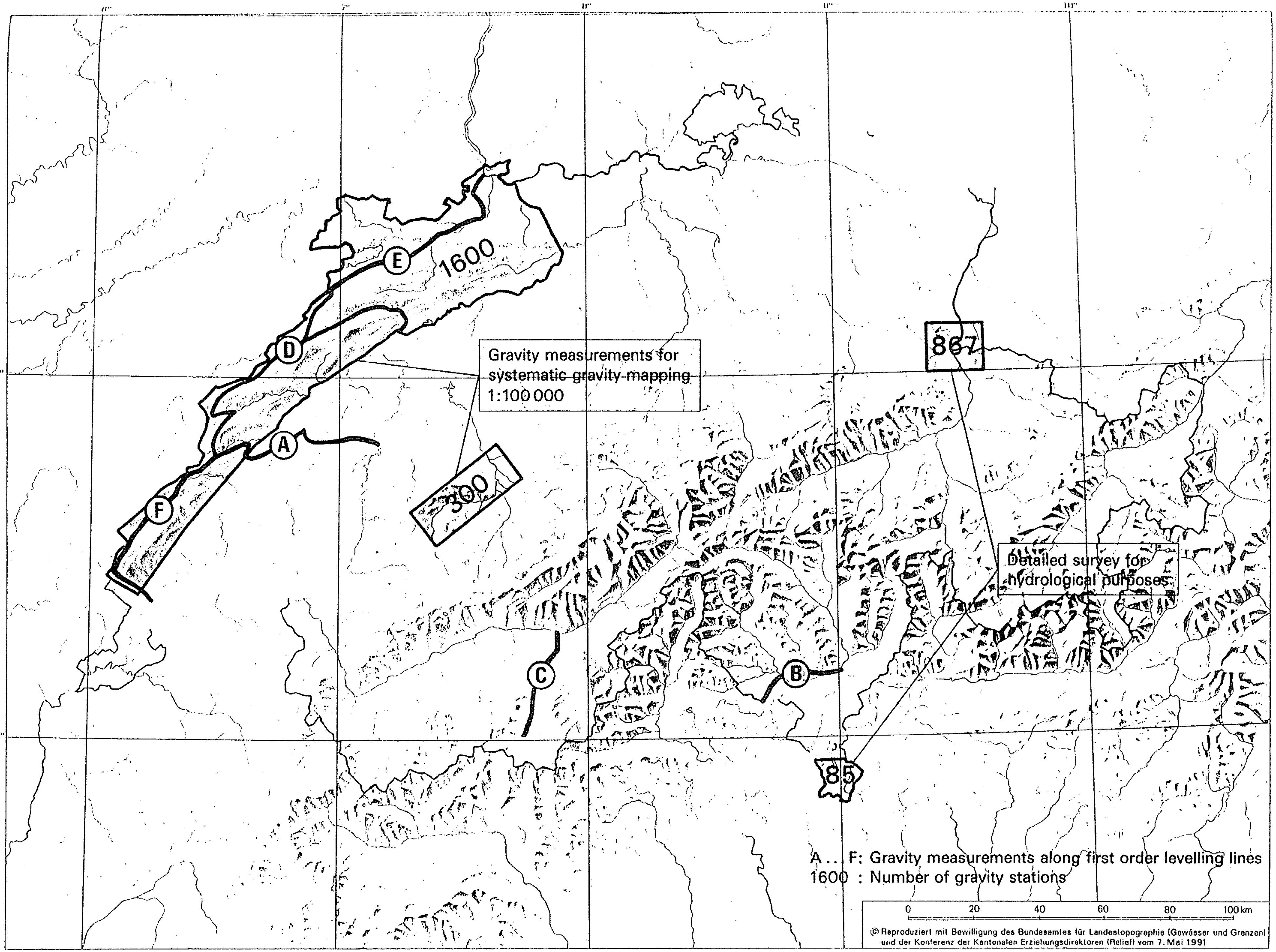
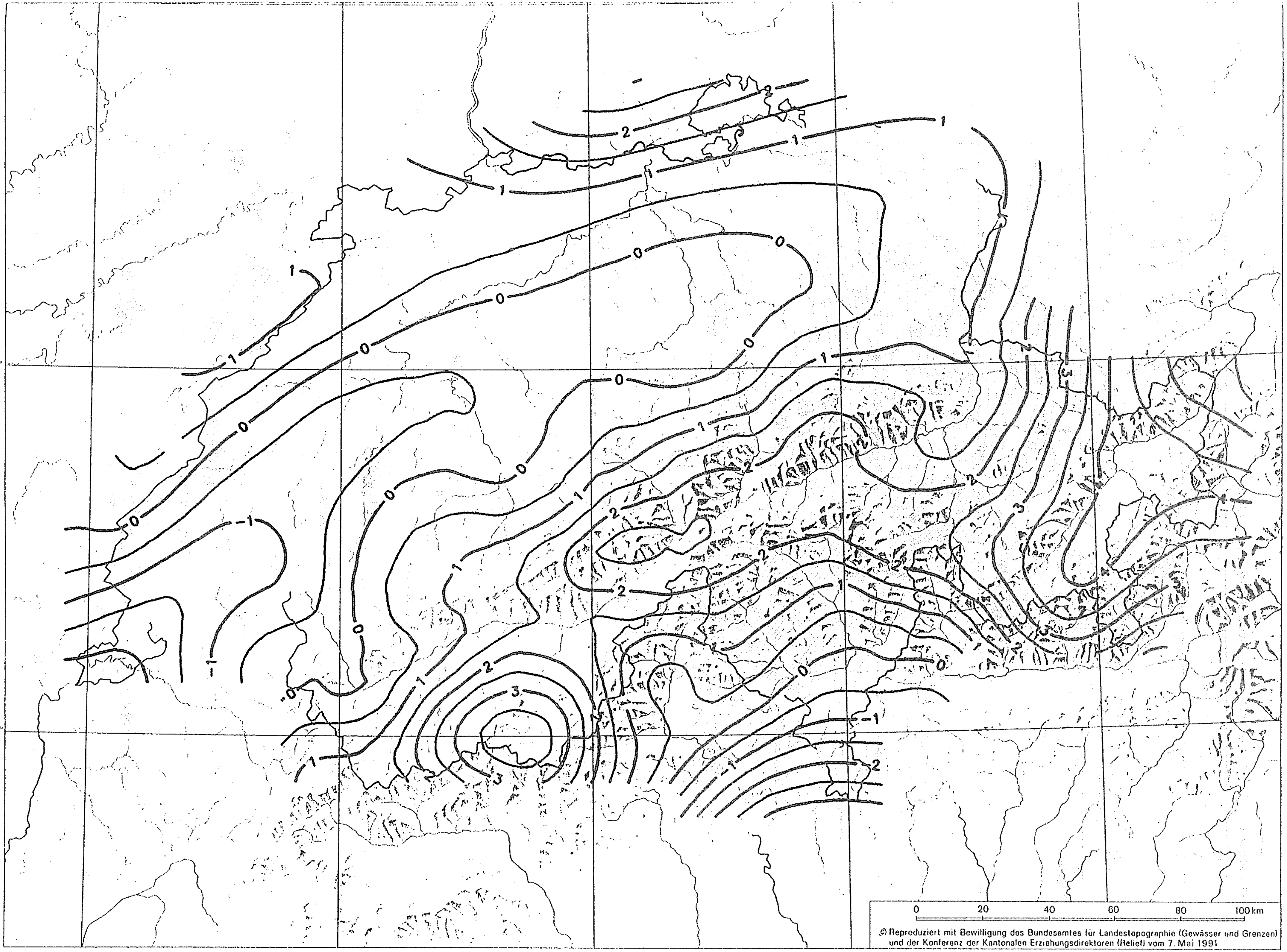


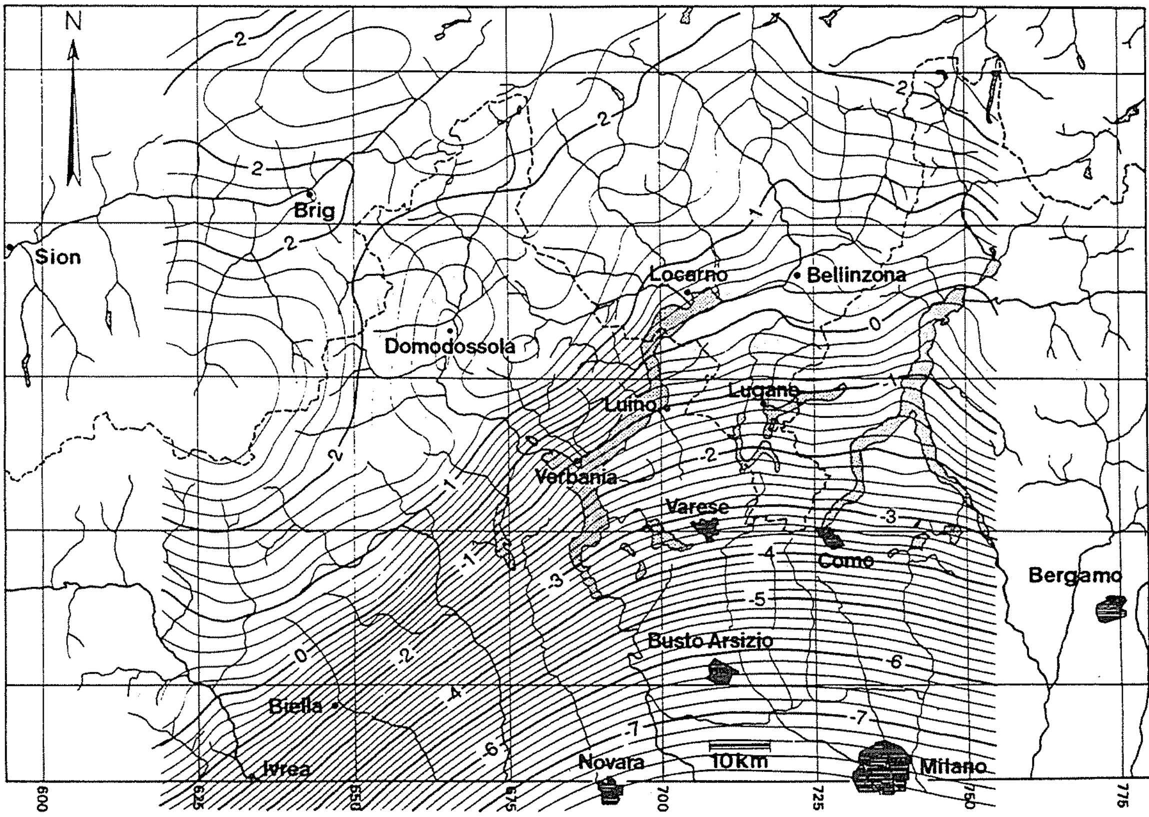
Map 6 Gravity Measurements in Switzerland 1987–1991



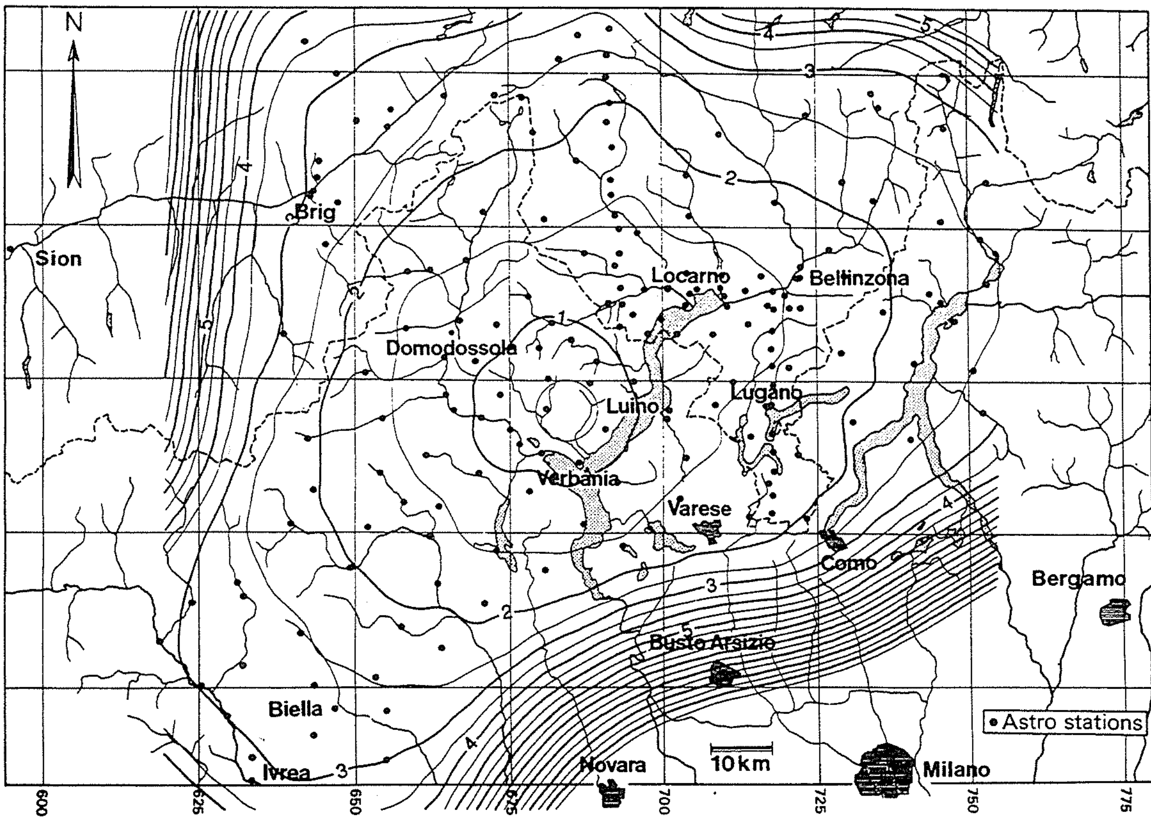
Map 8 Gravimetric Geoid in Switzerland (Swiss datum) [m]

Printed by Federal Office of Topography 1991

Astrogeodetic Geoid referring to the Swiss Bessel Ellipsoid [m]



Mean Relative Errors of the Geoid [cm]



Map 9 Local Astrogeodetic Geoid in the Ivrea Zone

Printed by Federal Office of Topography 1991

INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS

XX General Assembly

Vienna, Austria

11 - 24 August 1991

Report on the Geodetic Activities of

the Thai National Committee on Geodesy and Geophysics

Period

1987 - 1990

Paper Submitted by Thailand

Excerpts : Gravimetry - Geoid

Land Gravity Survey

During the reporting period, The gravimetric observation has been carried out in the southern, central, and northeastern parts of the country and the total number of 520 stations were established.

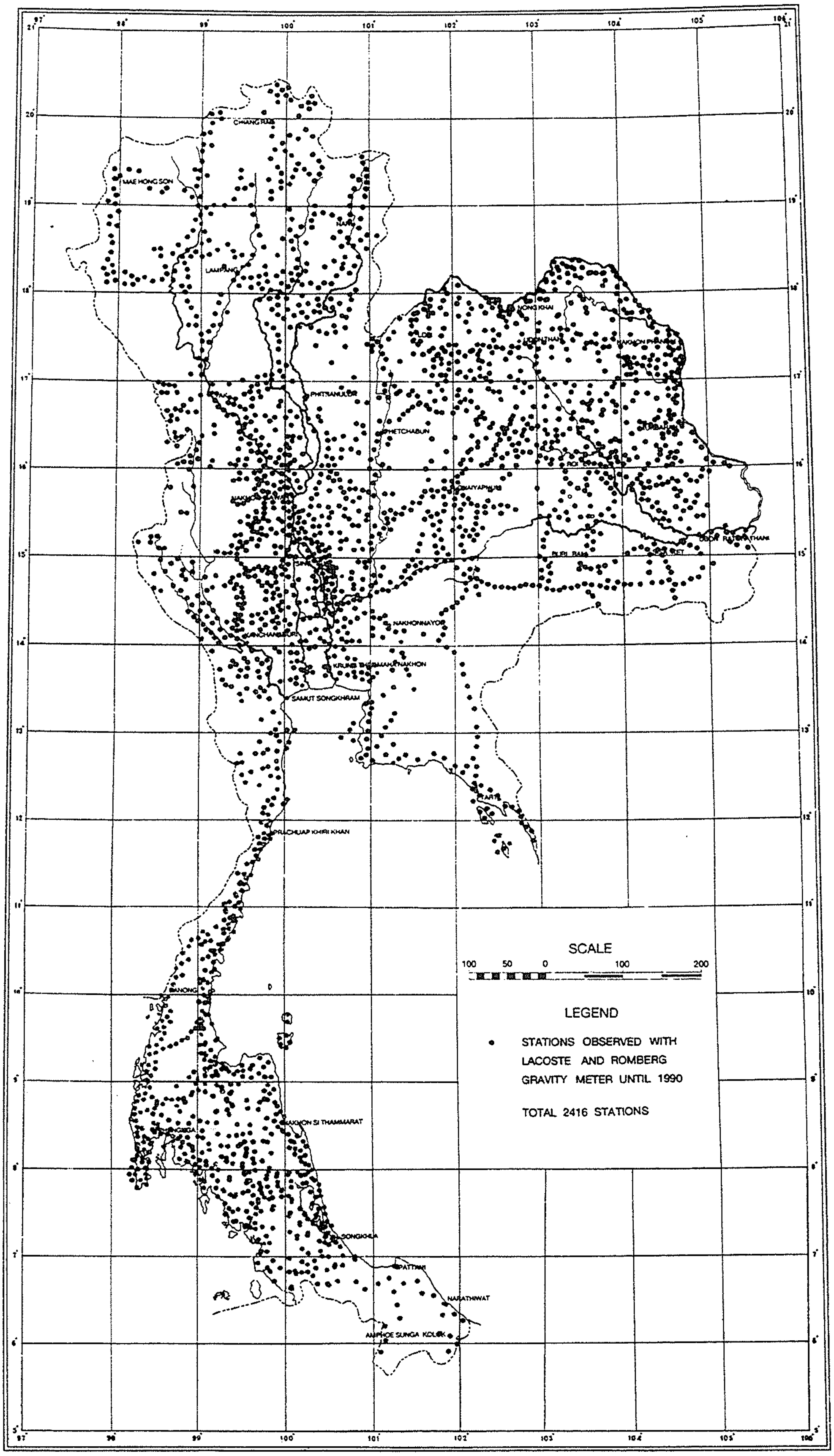
Geoid

Activities on geoid determination in Thailand are very low. In the past there was no attempt to precisely determine geoid over the part of Thailand for the reason that no real needs were visible. Nowadays, GPS satellite surveying are playing the major role in control surveying. The geoid as the connection between the classical methods and the satellite one is now needed. A plan for geoid determination is briefly described.

Two projects will be conducted by the Royal Thai Survey Department in order to study a geoid over Thailand. One uses a gravimetric method and the other uses a satellite technique and the principle of an astro-geodetic method.

Royal Thai Survey Department has continuously observed gravities along its levelling lines for many years. Gravity stations were established at approximately 10 km. apart. The observed values were adjusted to make a closed loop and then used in the levelling network. In the past these data were kept on paper sheets. RTSD now tries to put everything on the diskettes in order to ease the use of computer processing. The total number of gravity stations around the country is 2416. The locations of these stations are shown in Figure 1.

Based on the above data available, a lot of work must be done for a geoid computation. This includes gravity reduction, rearranging gravity data in an appropriate format etc.


SCALE
100 50 0 100 200
LEGEND
STATIONS OBSERVED WITH
LACOSTE AND ROMBERG
GRAVITY METER UNTIL 1990
TOTAL 2416 STATIONS
MAE HONG SON
PHITSANULOK
PHETCHABUN
NAKHONNAYOK
SAMUT SONGKHRAM
PRACHUAP KHIRI KHAN
NARATHIWAT
AMPHOE SUNGA KOLOK

1948

TNUGG

TURKISH
NATIONAL
UNION
OF
GEODESY
AND
GEOPHYSICS

NATIONAL REPORT OF GEODETIC COMMISSION OF TURKEY

Excerpt : Introduction - Gravity Network

GENERAL COMMAND OF MAPPING

ANKARA
1991

GEODETIC WORKS COMPLETED AND PLANNED IN TURKEY

ABSTRACT

Together with the developing technology, the updating and recovery activities of the present basic networks in Turkey have been kept on. In this respect relevant to the horizontal control network, classical observation such as EDM,direction and astronomical observations and doppler observations also were carried out upon the completion of this network. Works relevant to the vertical control network consist of re-levelling some of the routes, and along with this, gravity measurements. Geopotential number differences necessary for the adjustment of levelling net were calculated by means of the gravity values. Within the context of the works relevant to gravity, approximately 70000 points were established spacing 3-5 km.

Geoid determination which constitutes the foundation of basic geodetic works was completed and Turkish Gravimetric Geoid-1991 was determined.

In frame of the Wegener-Medlas and other National and International projects which aim at monitoring the plate and intraplate deformations using satellite techniques, SLR and GPS measurements have been carried out for geodynamic and geophysical purposes on many points spread over Turkey. Additionally GPS measurements were conducted for the geodetic purposes.

GRAVITY NETWORK

Gravity works in Turkey can be reviewed in the following three periods;

a. 1947-1951

In this period, gravity works are started, Turkish first order gravity network is designed and put into practice. First, an absolute gravity point in Istanbul was tied to postdam and then points in Ankara, İzmir, İskenderun, Konya, Sivas and Erzurum all tied to İstanbul were set up by using STERNECK four pendules absolute gravimeter.

b. 1956-1960

Gravity network studies began in 1956 by establishing first order gravity network. 24 points located at airports and 52 relative gravity observations in various combinations between the points were adjusted in 1958. The gravimeters used in these works are NORGARD TNK 325 and TNK 468. During this term, Ankara-Erzurum and later Ankara-İstanbul-Konya calibration baselines were established. This network was tied to Postdam with gravity observations along two seperate routes in 1960. The forward backward procedure is applied in measurements by using 2 NORGARD TNK 325 and TNK 468 gravimeters.

c. 1961-1990

In this period, 3718 second order gravity points were established along the highways with 5-10 km intervals and tied to first order gravity net. Gravity differences were observed by forward-backward procedure using worden and Lacoste and Romberg gravimeters. Third order gravity network linked to the first and second order gravity points was also established along the highways with 5-10 km intervals by using the above mentioned gravimeters and procedure. The fourth order gravity network in which one point falls in an area of 5x5 km was established. It is considered to hold 6-10 points of all 1:25000 scaled maps. Until now, 5400 third and fourth degree points have been established. Fifth degree gravity network consists of levelling points usually along levelling routes. At present, gravity measurements are still being continued at levelling points as enroute gravity measurements. These gravity works are summarized in App.-5.

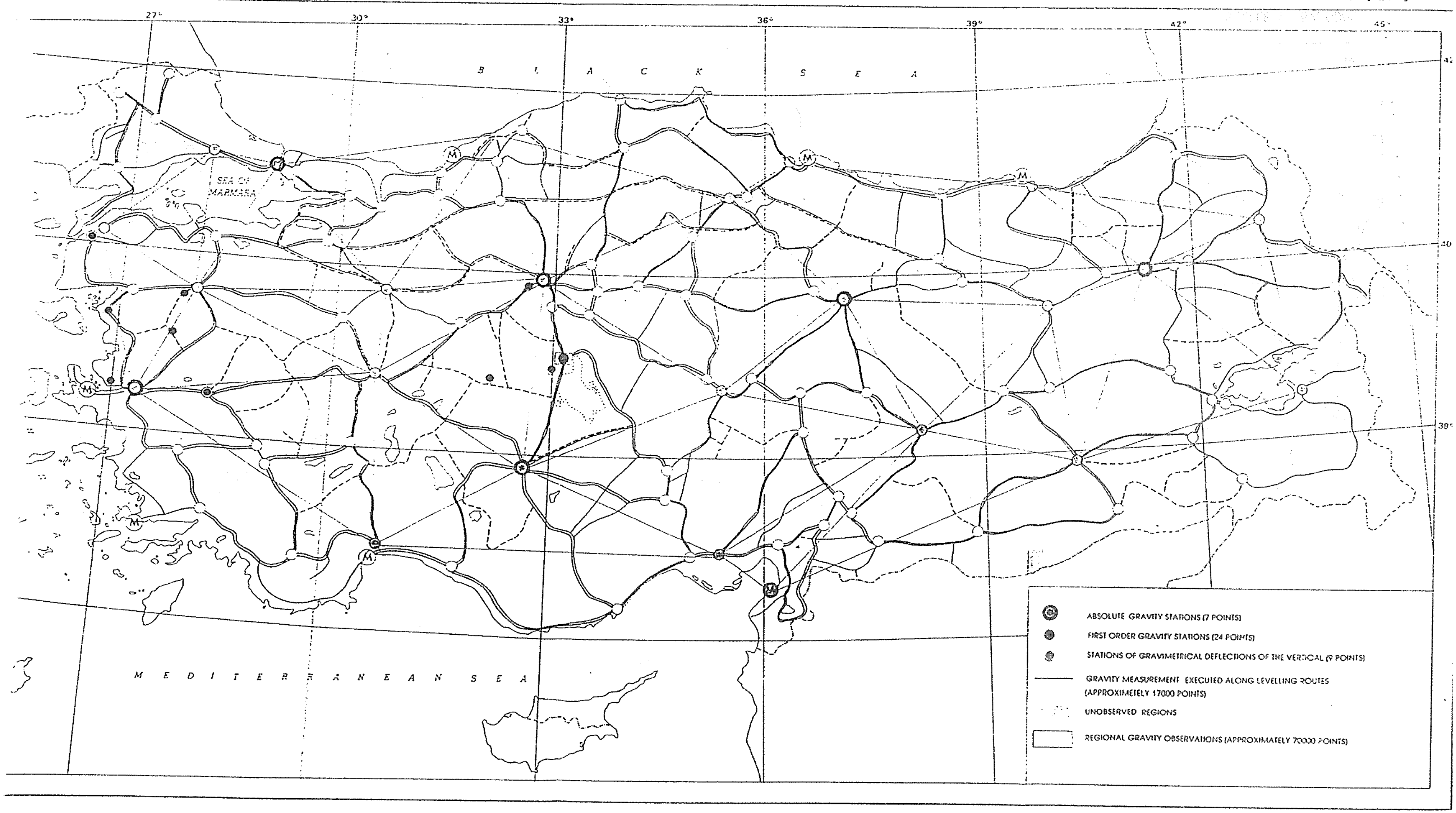
Up to now, 70000 gravity points were established with a densification of 3-5 km spread out whole Turkey. Readjustment of the gravity network including all gravimetric data available has been continued. The computed quantities from this adjustment will be used for;

- Prediction of deflections of vertical
- Geoid determination

REFERENCE

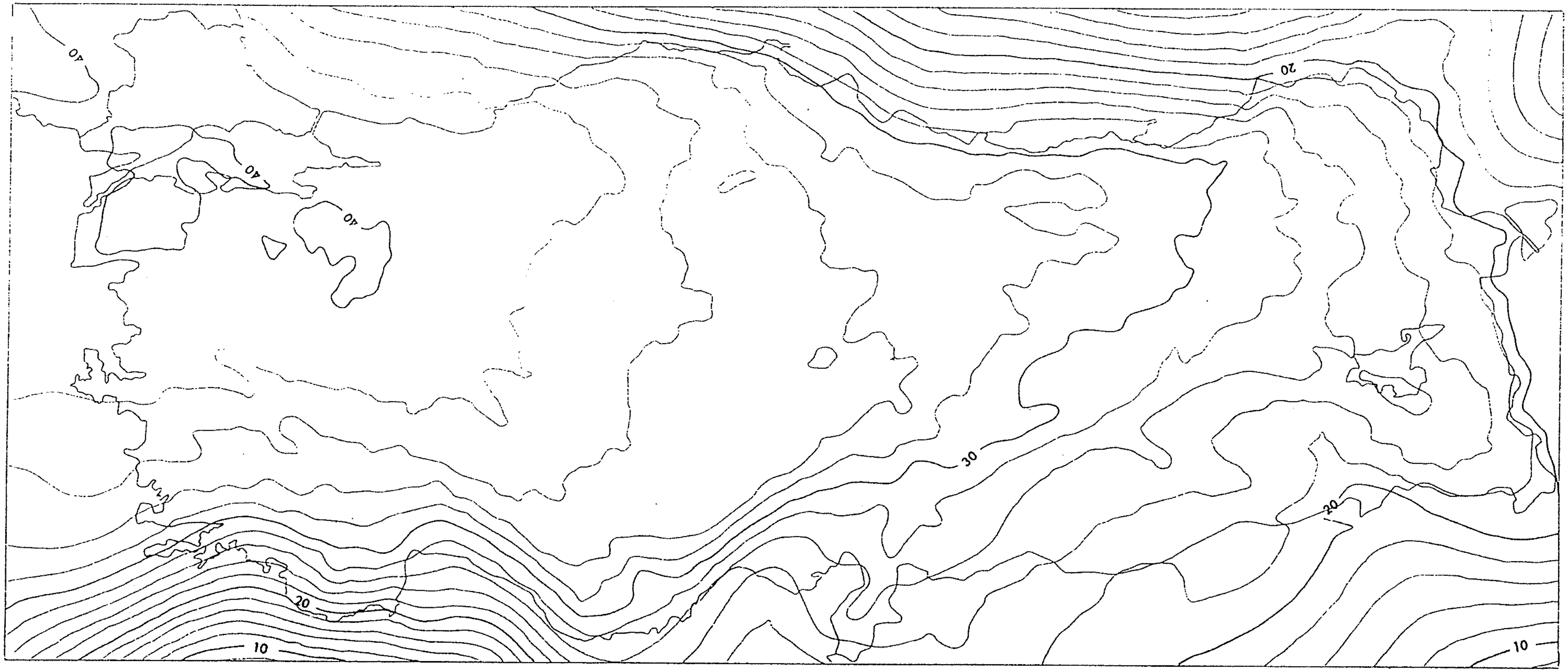
AYHAN Emin : Determination of local geoid by least squares collocation.(1991)

GRAVITY NETWORK



TURKISH GEOID - 1991 (In meters) GRS - 80 ELLIPSOID

APPENDIX : 3



SCALE 1 : 6750000

UNITED KINGDOM RESEARCH ON GEODESY 1987-1990

A REPORT

Excerpts : Forward - Gravity Surveys - Geoid Determination

Prepared on behalf of
The Royal Society's International Relations Committee
and the Geodesy Group of the Joint Association for Geophysics

Submitted to
The International Association of Geodesy
at the XX General Assembly of IUGG
(Vienna, August 1991)

Published on behalf of
The Royal Society
by
The Department of Surveying
The University
Newcastle Upon Tyne NE1 7RU

ISBN 0 9518129 0 4

FORWARD

This report outlines United Kingdom activities in geodesy for the period January 1987 to December 1990. It has been prepared for submission to the International Association of Geodesy (IAG) at its General Assembly in Vienna, Austria, during the XX General Assembly of the International Union of Geodesy and Geophysics (IUGG) in August 1991. It is issued on behalf of the Royal Society.

Since the last report there have been some important structural changes in the way that IUGG/IAG matters are administered within the United Kingdom. The Royal Society's British National Committee for Geodesy and Geophysics, and its Geodesy Subcommittee, have been disbanded and all formal IUGG/IAG matters are now dealt with via the Royal Society's new International Relations Committee (IRC). The IRC, which has one member with specific responsibility for IUGG matters, takes advice on geodesy from the UK National Correspondent to the IAG (appointed by the Royal Society through the IRC itself) and the Geodesy Group of the Joint Association for Geophysics (JAG), JAG being a scientific organisation of individual geophysicists and geodesists who are members of either the Royal Astonomical Society or of the Geological Society. Currently the National Correspondent to the IAG is also the Chairman of the Geodesy Group and it is planned that in the future, and as far as possible, these two positions will continue to be occupied by the same person.

These changes have, perhaps inevitably, caused some disruption to UK geodesy over the last year but it is anticipated that eventually they will lead to a closer liaison between, on the one hand individual geodesists and their scientific organisations and on the other the IUGG/IAG. One result is that this report has had to be prepared rather more rapidly than in the past and it may consequently be less complete. The editor apologises to those geodesists whose work may have been omitted for this reason.

Another important, and extremely successful, geodetic event that took place during the quadrennium to which this report refers was the holding of an IAG General Meeting in Edinburgh from 3-12 August 1989. This meeting was held to commemorate the 125 Anniversary of the *First International Geodetic Conference* held in Berlin in 1864. The meeting attracted 360 scientific delegates from 44 countries and a total of 90 oral and 160 poster presentations were made. The proceedings have subsequently been published by Springer-Verlag in a five volume set.

In the past the national report has been divided into sections corresponding to the five sections of the IAG, namely

- Positioning
- Advanced Space Technology
- Determination of the Gravity field
- Theory and Methodology
- Geodynamics

In a departure from tradition this report is presented in an undivided form. The objective is to emphasise the linkage between the various disciplines in geodesy and to avoid past difficulties in assigning particular activities to particular sections.

PAUL A CROSS
Editor and UK National Correspondent to the IAG

July 1991

GRAVITY SURVEYS

British Antarctic Survey

The British Antarctic Survey acquired marine gravity data from the Scotia and Weddell Sea region during cruises of RRS Discovery in 1987-88 (22, 500 km) and RRS Charles Darwin in 1988-89 (23,700 km), using Lacoste-Romberg air-sea gravimeters S84 and S40 respectively.

British Geological Survey

Over 3000 regional gravity stations have been measured in North-East England, the Peak district, the North Midlands and the Midland Valley of Scotland. These stations improve the national coverage by infilling outstanding gaps in the data and improving the quality of some early data. Most of these stations have been obtained using Land-Rover or foot transport. Funds for this work were provided by the Department of Education and Science, approved by the BGS Programme Board.

Detailed surveys have been carried out on in the Lake District, North-East England, South-West England, East Anglia, Central Wales and Central Scotland. These projects have been carried out for geothermal energy, mineral reconnaissance and in support of the geological mapping programme of British Geological Survey. Funds have been provided by the departments of Trade and Industry, Energy, and Education and Science. Detailed gravity surveys were also made in Co. Antrim for the Department of Economic Development of the Northern Ireland Government.

In 1986 a local gravity survey was carried out in Wollo, Ethiopia, during a water exploration project in connection with OXFAM. In 1990 a gravity base station network was established in Hong Kong tied to IGSN71. A gravity survey of the colony on behalf of the Geological Survey of Hong Kong, with funds from the Hong Kong Government.

Gravity data were also acquired offshore on two cruises of the RRS Charles Darwin in 1990: in the Celtic Sea, English Channel and its Western Approaches during cruise 48, and in the Irish Sea during cruise 54. Funds for this work were provided by Department of Energy.

University of Bristol

The Department of Geology at the University of Bristol have made 50 gravity measurements in the Bath area forming a detailed survey designed to locate ancient mines for Bath Stone. They have also made 130 gravity measurements in SW France and NW Spain along a profile across the Aquitaine basin, western Pyrenees and Ebro basin as part of an investigation of the deep geological structure of the Pyrenean region. Elevation control was provided using barometric levelling from geodetic benchmarks.

University of Cambridge

The Marine Geophysics group at the University of Cambridge has carried out several gravity surveys at sea using a LaCoste-Romberg gravity meter on a stabilised platform. The gravity data was acquired simultaneously with other underway data and has generally been interpreted jointly with other (usually wide-angle seismic) information. Surveys have been completed as follows:

(a) across the Blake-Spur Fracture Zone and adjacent oceanic crust in the western North Atlantic as part of a two-ship multichannel seismic experiment to study the internal structure of oceanic crust undertaken jointly with the universities of Columbia and Rhode Island (RRS Discovery and RV Conrad). Chief Scientist Prof. R.S. White, November-December 1987;

(b) in the Lau back-arc basin as part of a seismic study of the active spreading centre aboard RRS Charles Darwin. Chief Scientist Dr. M.C. Sinha, July-August 1988;

(c) on the Madeira-Tores Rise, north Atlantic as part of an Ocean Bottom Seismometer, heat flow and reflection survey of the plate boundary from RRS Discovery. Chief Scientist Dr. P.J. Barton, November-December 1988;

(d) on the East Pacific Rise at 13^{o} 15' N as part of an active source electromagnetic sounding survey of the spreading centre, joint with Scripps Institution of Oceanography. Chief Scientist Dr. M.C. Sinha aboard RRS Charles Darwin in May-June 1989; and

(e) as a detailed site survey for deep reflection profiling over Mesozoic oceanic crust north of the Cape Verde Rise in the eastern North Atlantic. Chief Scientist Mr.T. Henstock aboard RRS Charles Darwin, December 1990.

University of Durham

The Department of Geological Sciences at the University of Durham used Cruise EW9008 of RV Maurice Ewing to collect gravity continuously on the Reykjanes Ridge SW of Iceland during October 1990. The most useful data are in a detailed grid centred on 58 N, 32.5 W. These are currently being analysed and a publication will be prepared shortly.

Hydrographic Office (Royal Navy)

The Hydrographic Office continues to enhance the accuracy of the Eddystone Gravity Range, the purpose of which is to enable geophysical survey ships to prove the operating status of their onboard gravimeters prior to survey deployment.

This range covers the whole of Plymouth Bay and is approximately 20 miles in latitude extent by 65 miles in longitude extent. Gravity data, collected at sea from Bell BGM3 gravimeters, have been contoured to produce a 1 mgal interval contour representation of the gravity free air anomalies.

Currently, 103 lines of gravity data have been collected which yield 689 crossover misties. Statistical analysis suggests that the contoured gravity free air anomalies possess a 2-sigma accuracy of 0.18 mGal.

Institute of Oceanographic Sciences (Deacon Laboratory)

Marine gravity data was collected on the following cruises in the period 1 Jan 87 to 31 Dec 90. The Farnella data is the property of the U.S. Geological Survey but is held on file at IOSDL. It was collected as part of the Institute's GLORIA survey of the U.S. Exclusive Economic Zone.

1.	R.V. Farnella	2 Feb 87	-	28 May 87	E coast U.S.A.
2.	R.V. Farnella	26 Jun 87	-	25 Sep 87	off Alaska
3.	R.V. Farnella	9 Mar 88	-	1 Sep 88	Hawaiian islands/Alaska
4.	R.V. Farnella	13 Sep 88	-	7 Oct 88	Hawaiian islands
5.	R.V. Farnella	12 May 89	-	14 Jul 89	off Alaska
6.	R.V. Farnella	3 Nov 89	-	26 Feb 90	Hawaiian island chain
7.	R.V. Farnella	5 Dec 90	-	21 Dec 90	Hawaiian Island chain
8.	R.R.S. Ch Darwin	25 Aug 90	-	13 Sep 90	SW Rockall plateau plus outward/return tracks over the Irish shelf (cr.52)
9.	R.V. Maurice Ewing	26 Sep 90	-	21 Oct 90	Reykjanes Ridge

Also the RRS Charles Darwin cruise 37, October-November 1988, collected gravity data continuously on passage from Tahiti to the Easter Microplate (25 S, 115 W), and from there to Valparaiso, Chile. It also collected some 5000 miles of data in a grid survey of the microplate itself. These data are currently being processed at the Department of Geological Sciences at the University of Durham.

University of Leeds

Under the auspices of the University of Leeds Industrial Services Ltd (ULIS), staff in the Department of Earth Sciences undertook a major gravity compilation study entitled African Gravity Project (AGP) which commenced in 1986 and finished in 1988. The project was sponsored by 16 international oil companies and involved reprocessing and mapping many millions of previously archived land and marine gravity data collected in part by the oil industry over the last 50 years. The project 5' x 5' digital gridded data base has been used by Rapp to improve the African Geoid and the results have been published in JGR. Although point by point gravity data remain confidential the 5' x 5' grids of Bouguer Free air and Topography will be released to the public domain in 1998. Commercial sale of the project products and academic related studies on the gridded data base are ongoing.

In 1988, following AGP, 14 international oil companies funded the South American Gravity Project (SAGP) which finishes in mid 1991. This project has generated a 3' x 3' grid of topography values for S America and has linked with the majority of national oil companies to retrieve and reprocess archived point by point gravity data onto a 5' x 5' grid. Geoid studies of S America are underway by Prof D Blitzkow (University of Sao Paulo) using this gridded data base.

Two new continental/marine data basing projects commence in 1991 and include:

(i) West-East European Gravity Project (WEEGP) which covers the area 25°W to 60°E and 35°N to 85°N.

(ii) South East Asia Gravity Project (SEAGP) which covers area 60°E to 180°E and 50°S to 50°N. These projects represent international collaboration involving International Gravity Bureau (Toulouse, France) and other relevant groups.

The WEEGP results will be used to improve the European Geoid and links have already been made with the commission.

During the period 1987-1990, two surveys have been carried out, both as student mapping projects: on the Ross of Mull and Iona (about 150 stations); and in the Cardiff-Bridgend area (about 450 stations; in collaboration with industrial sponsors). In addition, a small-scale survey of the Llyd Idwal area, Snowdonia was completed in winter 1990, during a GPS/navigation training exercise. All three datasets have been lodged with the BGS Regional Geophysics Unit.

As part of their work on international gravity ties The University of Leeds undertook a connection from London to Mogadishu, Somali in December 1987. It confirmed previous findings that Leeds LaCoste-Romberg gravity meter G471 has its manufacturer's calibration in error by 0.66 mGal/Gal.

University of Leicester

The Department of Geology at the University of Leicester have carried out some detailed gravity surveys to investigate graben structures in mineralised areas within the Pellow Lavas in the northern part of the Troodos igneous complex. About 400 stations have been surveyed.

Military Survey

During 1987 gravity base transfers from Teddington, and between Dakar, Freetown and Monrovia were observed by Military Survey. In 1989 base transfers between Sri Lanka and the Maldives and between USA and the Antilles were carried out. Gravity detail surveys in West Africa were carried out in 1987, 1988 and 1989. Military Survey arranged for a US team with a JILA absolute gravity meter to carry out a determination in Edinburgh, Scotland during 1990.

Open University

Gravity surveys have been carried out by the Open University in a wide variety of volcanic settings. The signature associated with silicic calderas is usually a large amplitude negative anomaly reflecting low density caldera infill (uncompacted ash-flows for example) or a shallow silicic magma chamber. However, their work in Iceland has shown that the picture is much more complex than this. Their models of volcanic structure in Iceland, New Mexico and Central America aim to contribute to the debate over the influence of tectonic stresses and lithosphere rheological conditions in caldera evolution processes.

The Open University are also active in the field of microgravity monitoring surveys. The physical processes characterising magmatic plumbing systems beneath active volcano summit regions are best understood by monitoring the system dynamics (Rymer, 1989, Rymer and Brown, 1989; Brown et al., 1989). This project has produced new empirical models for predicting gravity change over deforming volcanoes so that sub-surface magma/gas/water movements may be better quantified and has extended high precision gravity, deformation and thermal output monitoring networks to several potentially hazardous volcanic targets. At present, they maintain monitoring networks at Poas, Rincon, Irazu, Miravalles, (Costa Rica), Askja and Krafla (Iceland), Chillan (Chile), Etna (Sicily) and Collima (Mexico).

THEORETICAL, EARTH TIDES AND MISCELLANEOUS GRAVIMETRIC STUDIES

British Geological Survey

The National Gravity Data Bank is the definitive collection of regional gravity data for the United Kingdom and is maintained by British Geological Survey. New data are incorporated as they become available and the existing data are maintained in clean condition.

Gravity data for many overseas countries are held by BGS on behalf of the government of those countries. Many of these datasets have been converted to computer readable form in period under review, with funds from the Overseas Development Agency of the British Foreign Office.

Work on 3-dimensional display and interactive modelling of gravity, together with other geoscientific data has been done using modern 3-D graphics computer workstations. Using these techniques for multi-disciplinary projects is potentially a most valuable contribution to earth sciences. A fast interactive 2.5-D gravity modelling program has been developed for use on personal computers, workstations and mainframe computers.

Bouguer gravity anomaly maps in the British Geological Survey 1:250 000 scale series have been published for Ostend (51N 2E), Lewis (58N 8W), Little Minch (57N 8W), Tiree (56N 8W), Judd (60N 6W), Flett (61N 4W) and Miller (61N 2W) sheets.

Proudman Oceanographic Laboratory

The Proudman Oceanographic Laboratory (POL) has made tidal gravity measurements at Chur, Switzerland (1987), Wuhan, China (1987-8) and Curitiba, Brasil (1987-8) for the purpose of earth tides and ocean tide loading studies. The measurements at Chur completed a programme of European tidal gravity and papers were written on the comparison of the European observations with model calculations (Baker, Edge and Jeffries 1989). The LaCoste-Romberg Earth Tide gravimeters ET13 and ET15 were used and altogether observations were made at 5 European stations: Brussels (Belgium), Bad Homburg (Germany), Zurich and Chur (Switzerland) and Valle de los Caidos (Spain). The LaCoste ET gravimeters have electrostatic feedback and were calibrated on the Hannover, FRG, vertical calibration line. The European results show a factor of 5-10 improvement in the agreement between observations and model calculations compared to that obtained previously from European and worldwide measurements. The observations at Brussels show that the 'standard' calibration of the International Center for Earth Tides, used for worldwide tidal gravity profiles, is 1.2% too high. Due to the small diurnal tidal loading in Europe, the POL tidal gravity observations can be used to test Earth body tide models. It was shown that the Wahr-Dehant anelastic body tide model gravimetric factor is accurate to 0.2%. This is the first valid test of this model. For the semi-diurnal tides, the POL observations in central Europe clearly show the errors in the Schwiderski ocean tide model due to the non-conservation of mass.

Proudman Oceanographic Laboratory and University of Newcastle upon Tyne

The Proudman Oceanographic Laboratory (POL), in collaboration with the Physics Department of the University of Newcastle upon Tyne investigated the possible existence of a 'fifth' force which would lead to a distance dependence for the Universal Gravitational constant G. A preliminary experiment at Dinorwic, N. Wales, where a LaCoste-Romberg ET gravimeter was used to measure the effect of large moving masses of water in a pumped-storage reservoir on the local value of 'g', indicated that the method was feasible.

A second experiment was carried out at Ffestiniog, N. Wales where observations of the change of 'g' were made as the water level changed at the upper reservoir of this pumped-storage powerstation. In the experiment two LaCoste-Romberg ET gravimeters were used simultaneously at sites above and below the reservoir. The accuracy of the gravimeters is known to about 0.2%. A comparison of the observations with the signal expected from modelling the water level changes according to Newtonian theory showed agreement was better than 0.3% at an effective distance of about 50m.

GEOID DETERMINATION

Mr J A Weightman

A new approach to modelling earth and atmospheric geoids was proposed in an invited paper for the German Geodetic Commission in 1988; later developments will be reported in a paper to XX IUGG Congress in Vienna. This method, known as the aggregated geoids method, separates the geoid as we know it into a concentric system of 'geoids', each of which represents one element of the total geoid, which is itself the sum or 'aggregate' of the component parts. The novelty of the concept lies in making each component a full geoid in its own right, so that these may be displaced relative to each other, and it is only a change of shape which requires additional modelling.

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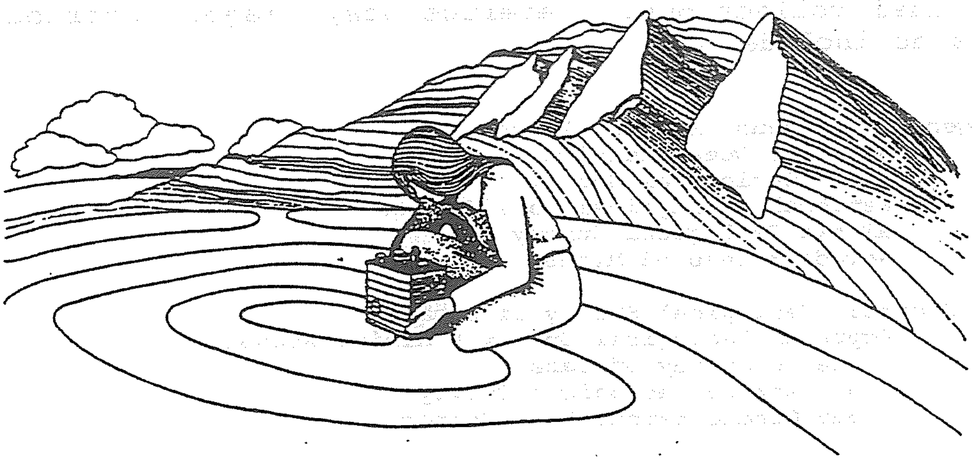
Part III

CONTRIBUTING PAPERS

Gravity

Earth System Data



UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE
National Geophysical Data Center
Boulder, Colorado 80303 USA

The Gravity Compact Disc

The National Geophysical Data Center (NGDC) of NOAA, in cooperation with the National Geodetic Survey of NOAA, have recently published a Gravity CD-ROM containing observed and derived gravity measurements. Contributions to this data compilation include many national and international organizations, in both academia and government.

The compact disc contains almost 560 Mbytes of data, partitioned into 970 files. Approximately 25 percent of the data are observed values -- regional station data collections (separated primarily by contributors) and absolute gravity measurements. Grids and other derived summary data sets represent another 20 percent of the data. The remaining 55 percent of the disc contains geopolitical base map reference data and software.

Contributors to the Data Compilation

It is impossible to cite all contributors, because often those who provide data to us have many contributors included within their individual collections. Nevertheless, major contributing institutions do include:

U. S. Agencies: Defense Mapping Agency
National Ocean Service
U. S. Geological Survey
National Geophysical Data Center
Alaska Geological Survey
Nevada Bureau of Mines

Foreign Groups: Geological Survey of Canada
Egyptian Geological Survey & Mining Authority
Geodetic Survey of Canada
South Africa Geological Survey
Japan Oceanographic Data Center

Organizations: Society of Exploration Geophysicists
Geological Society of America
AridTech, Inc.

Academia: Cooperative Institute for Geoscience Data Management
Scripps Institution of Oceanography
Ohio State University
University of New Brunswick
University of Texas (at Dallas)
Purdue University
Portland State University
Louisiana State University
University of Wisconsin
Northern Illinois University
Freie Universitat (Berlin)
Assiut University (Egypt)

DIRECTORY STRUCTURE OF THE GRAVITY CD-ROM

The directory structure of the compact disc is outlined in a summary manner as follows. Please note that all of the files within the "USGS_DLG" directory were obtained directly from the Digital Line Graph (DLG) CD-ROM of the U. S. Geological Survey.

1. ABSOLUTE

1.1 NGSAGRAV.DAT	Absolute gravity data from NGS

2. BOUNDARY

2.1 BOUNDS.DAT	Boundary data from WDBII
2.2 COASTS.DAT	Coastline data from WDBII
2.3 RIVERS.DAT	River data from WDBII
2.4 WVS1.DAT	World Vector Shoreline (1:1M Scale)
2.5 WVS12.DAT	World Vector Shoreline (1:12M Scale)
2.6 WVS250.DAT	World Vector Shoreline (1:250K Scale)
2.7 WVS3.DAT	World Vector Shoreline (1:3M Scale)
2.8 WVS43.DAT	World Vector Shoreline (1:43M Scale)
2.9 WVSFULL.DAT	World Vector Shoreline (1:200K Scale)

3. GRIDS

3.1 LISTS	Distribution info on gravity grids
3.2 CANADA10.xxx	Canadian graviy geoid (10 min)
3.3 DGRAV.xxx	2.5-min gravity grid of N. America
3.4 DNAGGRAV.xxx	6-km gravity grid of N. America
3.5 ISOREG.xxx	8-km isostatic gravity grid of U.S.
3.6 ISORES.xxx	4-km isostatic residual grid of U.S.
3.7 ISOTOP.xxx	8-km isostatic topo grid of U.S.
3.8 ISOSTAT.xxx	2.5-min isostatic gravity grid of U.S.
3.9 SEGGRAV.xxx	4-km gravity grid of U.S.
3.10 RAPP1DEG.xxx	1-deg global grid
3.11 RAPP30M.xxx	30-min global grid
3.12 SOGRAV.xxx	Southern Ocean (60-72 S. Lat) grid

4. REGIONAL

4.1 90NGSNET	NGS Gravity Monument Network (1990) for U.S.
4.2 AFRICA.xxx	Southern Africa data
4.3 ANDES.xxx	Argentina, Bolivia, and Chile data
4.4 ANTARC.xxx	Antarctica data
4.5 ANWR.xxx	ANWR and Alaska peninsula data
4.6 CADIZ.xxx	Cadiz, California, data
4.7 CALIF.xxx	California and southern Nevada data
4.8 DMA.xxx	DMA Station Database (1991 version) for U.S.
4.9 91DMAUTH.DAT	DMA Author Index File (1991 version)
4.10 DMANET.xxx	DMA Global Network Base Stations
4.11 EGYPT.xxx	National Base Net for Egypt
4.12 HOLITNA1.xxx	Holitna, Alaska, data
4.13 HOLITNA2.xxx	Holitna, Alaska, data
4.14 INDIANA.xxx	Indiana data
4.15 JODC.xxx	Japan data
4.16 NEVADA.xxx	Nevada data

4.17	NEWMEX.xxx	New Mexico data
4.18	NGS.xxx	NGS Station Database (1990 version) for U.S.
4.19	MONUMENT.xxx	NGS Monument Index File
4.20	NPRA.xxx	NPRA, Alaska, data
4.21	PORTLAND.xxx	Oregon data
4.22	SAMERICA.xxx	South American data
4.23	STATDESC	NGS Vertical Control Stations Descriptions
4.24	VERNAL.xxx	Vernal Quadrangle (Colorado/Utah) data
4.25	WISC1.xxx	Wisconsin data (Ashland area)
4.26	WISC2A.xxx	Wisconsin data (Rhinelander area)
4.27	WISC2B.xxx	Wisconsin data (Prentice area)

5. SAT

5.1 GEOS3	
GEOSnn.BIN	16 regional files of GEOS3/SEASAT data
5.2 GEOSAT	
GEO44ASC.BIN	GEOSAT data, 44 repeat cycles (ascending)
GEO44DES.BIN	GEOSAT data, 44 repeat cycles (descending)
GEO44.xxx	Format descriptions (for ASCII and binary)
GEOSAT.DOC	Documentation File
SEEHEAD.C	C program to decode internal headers

6. USGS_DLG — Digital Line Graph Data (USGS)

6.1 CREDIT	
USGS_DLG.DOC	Credits to U. S. Geological Survey
6.2 DEMO	Demo directory
6.3 DOC	Documentation directory
6.4 OPTNL	DLG Optional Format Data
SECTnn	21 regional files of DLG data
README.FIL	
6.5 ROOT	Data and info from DLG root directory
README.1ST	
6.6 SOFTWARE	Software utilities from DLG CD-ROM

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NOTE: CD-ROM contains 970 files and 557,901,062 bytes.

Towards an Improved Research Quality Data Base

In the hope of improving the research quality of the gravity data base at the National Geophysical Data Center, several unique concepts were implemented:

1. Station Data

- Instead of following the traditional approach of making all data set formats fit into a fixed common format, we developed a standard format description -- preserving fields unique to a specific data collection and making it possible to access the data without concern for formats.

- Common data compression techniques were employed to represent all data in a binary structure; decompression access utilities let end-user reconstruct the data in an ASCII (or binary) representation of their choice.

- Terminology has been standardized within a data dictionary, facilitating comparison of different data sets.

- Histograms have been prepared for each field within each data set format to support end-user validation of the data.

2. Gridded Data

- Grids developed by numerous scientific organizations and individual investigators have been incorporated.

- To help with comparison of these grids, NGDC has regridded some of the compilations into latitude-longitude projections. The original grids are also preserved in separate files.

3. Geopolitical Data

- To support the posting of data and information onto maps, geopolitical boundary data have been included. These data are from multiple sources, such as: DOD's World Vector Shoreline, CIA's World Data Bank II, and U. S. Geological Survey's Digital Line Graph data.

Data Preparation Techniques

Most of the gravity data on the **Gravity CD-ROM** were processed and documented through FREEFORM -- a format specification system developed by NGDC's Ted Habermann. FREEFORM was used for many functions (primarily within the "Regional" and "Grid" directories) on this compact disc: compression to binary representations, documentation of ASCII and binary formats (used in access software for flexible retrieval), sorting, indexing, and distribution statistics on every data field in every format processed.

Software Release Plans

There are three software releases that are envisioned during 1992:

Alpha Release - will operate on a PC-compatible machine and provide basic data retrieval and browse functionality.

Beta Release - will operate in either a Microsoft Windows or Macintosh Windows environment. Improved browse functionality is planned and EGA or VGA is required.

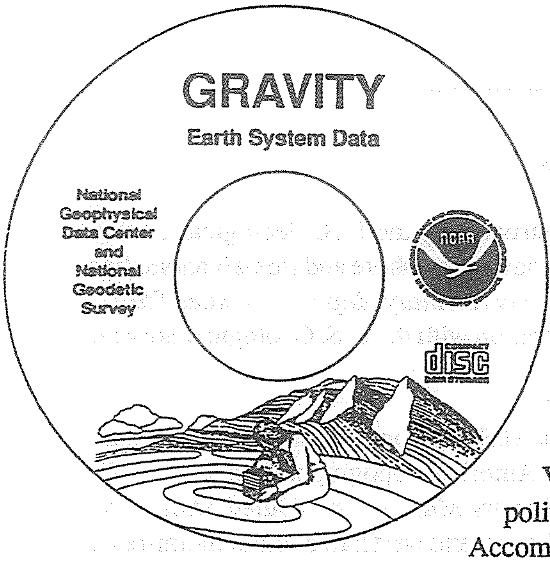
Full Release (1.0)- will expand platform compatibility to include UNIX (Sun with "Open Look" X-windows) and have a sophisticated browse and visualization capability.

Future Updates

As new data are provided to the National Geophysical Data Center, newer compilations similar to this are expected.

Gravity specialists can help us! Specifically, do you have additional data that you would like added to our next CD-ROM release? Do you have any additional documentation that can improve this collection? What other access capabilities should we develop? Are we going in the right direction?

We at NGDC view this as a "prototype" product. As such, your input is very much needed.



The land gravity data base at the National Geophysical Data Center (NGDC) has been significantly enhanced and improved by several important contributions. We are pleased to offer this extensive collection in various output media, including magnetic tape, diskette, and now, CD-ROM.

The Gravity CD-ROM

NGDC has produced a prototype Gravity CD-ROM, which contains all the digital gravity data listed in this flier. Boundary data include World Vector Shoreline (DMA), World Data Bank II (coastlines, rivers, and political boundaries), and Digital Line Graph Data (U.S. Geological Survey). Accompanying the CD-ROM is access software which allows you to extract the data from the disc. (Product number **1018-A27-001.**)

Gravity Station Data

The largest and most active gravity files maintained by NGDC are the digital files prepared by the Defense Mapping Agency (DMA) and NOAA's National Geodetic Survey (NGS). The two national data sets contain much of the same data; they differ primarily in quality control techniques and data reduction procedures. Both DMA and NGS data bases include an Author Source Index File—a bibliographic listing of data contributors. Each data source or compilation is given a numeric code which is included in a field at the data record level.

The **DMA gravity data base** (product number **116-F07-001**) consists of more than 910,000 non-terrain corrected observations for the conterminous United States and Alaska, and was compiled by the DMA in 1991. The file includes observed gravity, free-air and Bouguer anomalies, latitude and longitude, and elevation.

The **NGS gravity data base** for the U.S., compiled by the NGS in 1990, consists of nearly 1.5 million observations (**417-F07-001**). The file contains most of the data in the DMA gravity file, plus data from additional sources. In addition, NGS has included terrain corrections for all point gravity values where substantial variations in local topography exist.

Gravity Networks

The **DMA global reference base station file (896-J07-001)** was contributed by the DMA Aerospace Center. It contains nearly 16,000 records for 8,970 reference base stations worldwide, sorted by country code.

There are two NGS gravity network files—the **NGS gravity monument network (417-E07-001)** and the **vertical control station descriptions (417-E07-002)**. The monument network data records were extracted from the NGS gravity station file. This data set contains 7,298 records. The vertical control stations descriptions file describes 224 U.S. gravity stations of the NGS gravity benchmark network. The base stations, located in 54 U.S. cities are connected by more than 2,700 high quality gravity difference observations. In addition, NGS has provided NGDC with the latest version of the **absolute gravity network file**, which contains gravity values for 46 U.S. stations occupied since 1987. These data are available on magnetic tape (**417-D07-001**) or diskette (**417-D25-001**).

National Geophysical Data Center

Gravity Anomaly Grids

NGDC has data grids in several resolutions, compiled for various programs.

U.S. Bouguer and free-air anomalies (4 km). A 4-km data base was constructed by the U.S. Geological Survey primarily from the DMA land gravity data. The data consist of Bouguer anomalies onshore and free-air anomalies offshore **(894-A07-001)**. This data base was contoured to produce the *Gravity Anomaly Map of the United States*, which was published by the Society of Exporation Geophysicists in cooperation with the U.S. Geological Survey, DMA, and NOAA.

U.S. isostatic gravity (4 km). These data **(894-A07-001)** were derived by the U.S. Geological Survey from the data set used to prepare the map mentioned above and from the 5-minute North American topographic and SYNBAPS bathymetric data sets obtained from NGDC. The *Isostatic Residual Gravity Map for the United States* was produced from the data. The map set consists of a clear plastic overlay for the east and west half of the conterminous U.S. **(897-A01-R01)**. The gravity contours are presented at the same scale (1:250,000) and projection (Albers Equal Area) as the *Geological Map of the United States*, published by the U.S. Geological Survey.

North America Bouguer and free-air anomalies (6 km). The most recently compiled gridded gravity anomaly data (1987) are for North America at a resolution of 6-km **(980-B07-001)**. These data were compiled for the Geological Society of America's Decade of North American Geology (DNAG) project by the Committee for the *Gravity Anomaly Map of North America*. The gridded data set is based on a Transverse Mercator projection, and contains more than 2 million values. The data include Bouguer anomalies on land, and free-air anomalies offshore.

North America Bouguer and free-air anomalies (2.5 min). The 6-km DNAG gravity data were regridded at 2.5 minute resolution **(975-B07-001)** for NGDC's *Geophysics of North America* CD-ROM project.

U.S. isostatic gravity (2.5 min). Residual isostatic gravity data in a 2.5 minute grid **(975-B07-002)** were developed by the Cooperative Institute for Geoscience Data Management for the same *Geophysics of North America* CD-ROM project using the U.S. Geological Survey 4-km isostatic gravity grid.

Terrestrial free-air (30 min) and global free-air (1 deg). These data sets were provided by Ohio State University **(896-G07-001** and **896-H07-001)**.

Canada gravity geoid (10 min). A gravimetric geoid for Canada was provided by the University of New Brunswick, Canada **(896-F07-001)**. The data were compiled under contract with the Geodetic Survey of Canada; research was sponsored in part by the Natural Sciences and Engineering Research Council of Canada.

SOGRAV: Gridded gravity anomalies for the southern ocean. Data from the Geodetic (high resolution) Mission of GEOSAT were recently declassified for the area south of 60° South latitude. The Geosciences Laboratory, Ocean and Earth Sciences (NOAA) has produced a grid file of these data. Spaced at 0.1 degrees in longitude and 0.05 degrees in latitude, covering 60° to 72° South latitude, the data provide an exciting view of the physiography of the southern ocean. **(981-C07-001)**

Regional Surveys

Alaska: Arctic National Wildlife Range (ANWR) and Alaska Peninsula. These data are terrain-corrected for ANWR (northeastern Alaska), and non-terrain-corrected for the Alaska Peninsula. The data set was compiled in 1984 by the U.S. Geological Survey. **(895-C07-001)**

Alaska: Holitna/Minchumina area. This gravity data set is for southwestern Alaska. It was compiled in 1986 by the Alaska Geological Survey and the U.S. Geological Survey, and contains about 1300 records. **(895-F07-001)**

Alaska: National Petroleum Reserve (NPRA). The NPRA is located in the central portion of the North Slope, Alaska. The NPRA gravity data set, compiled in 1980 by the U.S. Geological Survey, contains more than 53,000 records of free-air and Bouguer gravity data. **(895-A07-NPR)**

California and southern Nevada. There are 64,000 records in the data set. The records were compiled in 1983 by the U.S. Geological Survey. **(895-D07-001)**

California: Cadiz. This data set consists of thirty-two newly metered gravity stations in central San Bernardino County. Measurements were provided by AridTech, Inc. **(895-I25-001)**

Colorado/Utah: Vernal quadrangle. Data records are for the 1° x 2° Vernal quadrangle area, located in northwestern Colorado and northeastern Utah. Data were compiled by the University of Texas. **(895-H07-001)**

Indiana. The file contains 10,600 gravity records; much of Indiana is represented. The data were contributed by Purdue University. **(895-J07-001)**

Oregon. Data include 1,500 gravity records for northwestern Oregon collected by Portland State University. **(895-K07-001)**

Nevada. These gravity data were assembled by the U.S. Geological Survey for a state gravity map to be published by the Nevada Bureau of Mines. The data were compiled from the DMA data base with additional data from the U.S. Geological Survey. **(895-L07-001)**

New Mexico. These data for New Mexico were compiled in 1984 by the University of Texas and the U.S. Geological Survey. The data set includes approximately 21,000 points **(895-E07-001)**. A clear plastic overlay map, *Bouguer Gravity Anomaly Map of New Mexico,* is also available. The scale of the map is 1:500,000. The map depicts computer-contoured data at a 2-mgal contour interval and shows locations used for control. **(895-E01-R01)**

Wisconsin. Gravity data for portions of Wisconsin were contributed by Louisiana State University (1985), and by the University of Wisconsin and Northern Illinois University (1987). The data consist of about 1500 records. **(895-G07-003)**

Africa. The data set for portions of southern Africa contains about 13,000 stations. It was compiled in 1986 by the South Africa Geological Survey. **(896-C07-001)**

Antarctica. The coverage for Antarctica is south of 50° South latitude. The data consists of two files on one magnetic tape **(896-A07-003)**. The first file was compiled in 1984 by DMA, and contains about 57,000 stations. The second file was compiled by the U.S.S.R. (1985), and contains about 11,000 stations. (Numerous positional errors are contained in this file. It was excluded from the CD-ROM.)

Argentina/Bolivia/Chile. The data coverage is for a study area located between 19° and 27° South latitude and 62° to 72° West longitude. The data were processed by Freie Universitaet, Berlin. **(896-I07-001)**

Egypt. Free-air and Bouguer anomalies were calculated for 71 stations representing the National Standardization Base Net for Egypt. The data were contributed by Assiut University, Egypt. **(896-E07-001)**

Japan. Data contains 4,400 records of land gravity data for Japan, contributed by the Japan Oceanographic Data Center. **(896-B07-001)**

South America. Approximately 139,000 records in this data set were compiled from numerous public sources by Carlos Aiken, University of Texas at Dallas. Selected offshore data, all containing bathymetric soundings of ocean depths, are included in the data set. **(896-K07-001)**

Satellite Measurements

GEOS-3 and SEASAT altimetry data have been successfully used for gravitational studies; both are available from NGDC. Altimetry data from the unclassified portion of the Navy's GEOSAT mission are also available. Call 303-497-6128 for more information. In addition, two specially derived data sets are available—**GEOS3/SEASAT (164-B07-001)**, and **GEOSAT44 (981-B07-001)**.

The GEOS3/SEASAT compilation includes detailed gravity anomalies and sea surface heights derived from a combined GEOS-3/SEASAT data set. It was contributed by Richard Rapp of Ohio State University. The GEOSAT44 data set contains precise geoid and gravity anomaly profiles which were constructed from the average of 44 repeat cycles (2 years) of GEOSAT altimetry. The data were compiled and contributed by David Sandwell of Scripps Institution of Oceanography.

Custom Data Services: Area Selections, Gridding, and Mapping Services

NGDC can provide customized data products in the form of area selections, digital grids, posting plots, and contour plots. Digital grids can be generated from randomly-spaced gravity data selected from any of the data sets held by the Data Center. These grids are computed using the "Brigg's minimum curvature algorithm" (Briggs, 1974, *Geophysics*, v. 39, no. 1). The customer specifies the area and the grid spacing, as well as the grid projection. A complete list of supported projections is available upon request but includes latitude-longitude, Mercator, UTM, Albers equal area, polyconic, Van der Grinten, and Polar azimuthal equal area. Contoured maps produced by a pen plotter at scales specified by the customer can also be obtained. Similar maps at specified scale and projection can be ordered which show station positions, state and county boundaries, or rivers. Prices for these customized products are available on request.

The Geophysics of North America CD-ROM

The **Geophysics of North America CD-ROM** is a collection of land and marine geophysical data for North America. Much of the data was collected under the auspices of the Geological Society of America's Decade of North American Geology—including gravity, magnetics, earthquake seismology, thermal aspect, and stress data. Satellite imagery data, topography, and additional grids of magnetics and gravity are also included in this compilation. The gravity data included in this compilation are the Bouguer and isostatic anomalies (4- and 6-km resolutions) discussed in this flier. The compact disc product also includes documentation, and access software which allows you to view the data, complete with geographical references and data contour overlays. Almost 600 megabytes of data and information are presented on the **Geophysics of North America CD-ROM. (975-B27-001)**

Ordering Information

The most recent price list for these data has been included with this brochure. If you do not find a price list, please call and we will be happy to send one to you. All data listed in this flier are available from:

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

Phone: 303-497-6120
Fax: 303-497-6513
Internet: info@ngdc1.colorado.edu
Telex: 592811 NOAA MASC BDR

Data contributors and academic researchers should call for information about obtaining data by special arrangement.

Mention of a commercial company or product does not imply endorsement by NOAA or the United States Department of Commerce.

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Gravity Data Base Price List

March 1992

Data contributors and academic researchers should call 303-497-6120 for information about obtaining data by special arrangement.

Magnetic tapes will be provided at 6250 bpi in ASCII format unless otherwise noted. All diskettes are IBM-PC compatible, high density, 5 1/4". Other output formats may be requested; call 303-497-6120 for more information.

	Product Number	Price	Description
CD-ROM Data Compilations	975-B27-001	$590	*Geophysics of North America* CD-ROM. Includes compact disc, access and display software, tutorial, and User's Manual.
	1018-A27-001	$277	*Gravity* CD-ROM. Prototype version of this new CD-ROM. Includes compact disc (with all gravity data listed below), preliminary software, draft documentation. Be sure to indicate end-user name when ordering.
Gravity Station Data	116-F07-001	$438	**DMA gravity data base.** Entire 1991 edition of data base on two magnetic tapes.
	417-F07-001	$438	**NGS gravity data base.** Entire 1990 edition of data base on two magnetic tapes.

For information on 1600 bpi tapes, or custom searches, call 303-497-6120.

	Product Number	Price	Description
Gravity Networks	896-J07-001	$164	**DMA global reference base station file** on one magnetic tape.
	417-E07-001	$164	**NGS gravity monument network file** on one magnetic tape.
	417-E07-002	$164	**NGS vertical control station descriptions** on one magnetic tape
	417-D07-001	$104	**NGS absolute gravity file** on one magnetic tape.
	417-D25-001	$30	**NGS absolute gravity file** on one diskette.
Gravity Anomaly Grids	894-A07-001	$164	**Bouguer and free-air anomalies (4 km)**; one magnetic tape.
	894-A07-001	$164	**Isostatic gravity (4 km)**; one magnetic tape.
	897-A01-R01	$35	***Isostatic Residual Gravity Map for the United States;*** clear plastic overlay map set.
	980-B07-001	$344	**Bouguer and free-air anomalies (6 km)**; one magnetic tape.
	975-B07-001	$164	**Bouguer and free-air anomalies (2.5 min)**; one magnetic tape.
	975-B07-002	$164	**Isostatic gravity (2.5 km)**; one magnetic tape.
	896-G07-001	$164	**Terrestrial free air (30 min)**; one magnetic tape.
	896-H07-001	$164	**Global free-air (1 deg)**; one magnetic tape.
	896-F07-001	$164	**Canada gravity geoid (10 min)**; one magnetic tape.
	981-C07-001	$258	**SOGRAV: Gridded gravity anomalies for the southern ocean**; two magnetic tapes

Regional Surveys

895-C07-001	$164	**Alaska: ANWR and Alaska Peninsula**; one magnetic tape.
895-F07-001	$164	**Alaska: Holitna/Minchumina area**; one magnetic tape.
895-A07-NPR	$164	**Alaska: NPRA**; one magnetic tape.
895-D07-001	$164	**California and southern Nevada**; one magnetic tape.
895-I25-001	$90	**California: Cadiz**; one diskette.
895-H07-001	$164	**Colorado/Utah: Vernal quadrangle**; one magnetic tape.
895-J07-001	$164	**Indiana**; one magnetic tape.
895-K07-001	$164	**Oregon**: Portland; one magnetic tape.
895-L07-001	$164	**Nevada**; one magnetic tape.
895-E07-001	$164	**New Mexico**; one magnetic tape.
895-E01-R01	$20	**New Mexico:** ***Bouguer Gravity Anomaly Map***; one clear plastic overlay.
895-G07-003	$164	**Wisconsin**; one magnetic tape.
896-C07-001	$164	**Africa**; one magnetic tape.
896-A07-003	$164	**Antarctica**; one magnetic tape.
896-I07-001	$164	**Argentina/Bolivia/Chile**; one magnetic tape.
896-E07-001	$164	**Egypt**; one magnetic tape.
896-B07-001	$164	**Japan**; one magnetic tape.
896-K07-001	$164	**South America**; one magnetic tape

Satellite Measurements

164-B07-001	$164	**GEOS3/SEASAT**; one magnetic tape.
978-H01-001	$15	***Gravity Fields of the World's Oceans.*** Rolled paper map.
981-B07-001	$164	**GEOSAT44**; one magnetic tape.

Ordering Instructions

U.S. Department of Commerce regulations require **prepayment on all orders**, with the exception of those from U.S. Federal agencies. Also, due to recent legislation, prices are subject to change without notice. Please call for price verification.

Make checks and money orders payable to COMMERCE/NOAA/NGDC. Do not send cash. All foreign orders must be in U.S. Dollars drawn on a U.S.A. bank. **A ten-dollar ($10) handling fee is required for delivery outside the U.S.A.**

Orders may be charged to American Express, MasterCard, or VISA by telephone, letter, fax, or Order Form. Please include a credit card account number, expiration date, telephone number, and your signature with order.

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Inquiries, orders, and payment should be addressed to:

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NOAA, E/GC1, Dept. 883
325 Broadway
Boulder, Colorado 80303-3328 U.S.A.

Telephone Numbers

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