ASSOCIATION INTERNATIONALE DE GÉODÉSIE

# BUREAU GRAVIMETRIQUE INTERNATIONAL

## N° 27

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# B U R E A U   G R A V I M E T R I Q U E

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# B U L L E T I N   D ' I N F O R M A T I O N

NOVEMBRE 1971

N° 27

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### XVth GENERAL ASSEMBLY of the IUGG
Moscow, 28 July - 14 August 1971

2ème Partie

## TABLES for CONDENSATION REDUCTION




Prof. P.TARDI
Dr. S. CORON

XVth GENERAL ASSEMBLY OF THE IUGG
(Moscow, 28 July - 14 August 1971)

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- I -

## NEW ORGANISATION OF THE INTERNATIONAL ASSOCIATION OF GEODESY (I.A.G.)

In the "Report of the General Secretary of the I.A.G." presented to the XVth General Assembly, M. LEVALLOIS give the results of the Cassinis Commission created in Luzern (IUGG 1967), particularly to study the structures of the I.A.G. and namely to define the numbers and the content of the Sections, the outlines of their areas of interest, the junctions with the Commissions, the structure of the Study Groups...

We are extracting the principal points, which can be of special interest to the participants of the section "Gravimetry" :

Sections of I.A.G.

It was unanimously acknowledged that the division of the Association into sections was an excellent organisational set up and should be retained. After lengthy discussions, the following proposal for organisational chart was adopted, 5 sections are retained arranged as follows :

I - Nets
Triangulation : trilateration; bases, precision surveying, astronomical positioning; refraction; nets at sea.

II - Aerospace techniques
Geometric and dynamic aerospace techniques including optical measurements of distances and Doppler measurements, stellar triangulation ; application of interferometric techniques by means of long bases and lunar distances measuring techniques.

III - Gravimetry
Absolute and relative determination of the gravitational force ; gravity nets gravimetry at sea and in space ; measurements of the variations of the gravitational force : determination of the gravitational force gradients ; reduction, interpolation and extrapolation of the force of gravity..

IV - Theory and Data Processing
Mathematical geodesy ; application of potential theory and astromechanics ; applied statistical and numerical analysis ; adjustement theories ; methods of least squares ; data processing.

V - Physical Interpretation
Shape of the Earth, geometrical and physical parameters ; reference systems;variation in time including pole movement, rotation, earth tides and movements of the crust ; mean sea levels ; geological and geophysical consequences stemming from the geodetic results.

Commissions

The Cassinis commission approves the existence of commissions, they shall no longer be called "permanent", and, at least, as far as the technical Commissions are concerned, they should be under a Section.

The Cassinis Commission puts forward the following proposal :

"On a proposal by the Sections Chairmen, the Executive Committee appoints and disbands the Commissions. These decisions are approved by the General Assembly. The Chairman of a Commission is elected by the Council and the choice approved by the General Assembly".

Special Study Groups

The Cassinis Commission approves the existence of Special Study Groups. Each Group in under a Section and is formed for a specific study work, in principle lasting one term, (interval between two General Assemblies) and reports to its Section, during the General Assembly, on the work accomplished. It is then decided if the Group must carry on its work or be disbanded, there is no automatic reconstitution.

The Cassinis Commission, proposes that :

"On a proposal by the Sections Chairmen, the Executive Committee appoints and disbands the Study Groups and also nominates the Chairman".

Duration of mandates

The Cassinis Commission proposes that from now on, the duration of the Mandates of Sections Chairmen and Secretaries be for one term (the interval between two Assemblies) that is 4 years. Il also proposes that in principle, Secretaries become Chairmen at the following election and this in order to ensure the continuity in the work of the Sections. It recommends that the Executive Committee be enlarged and made up of the Chairmen in Office and those of the previous term.

General Assembly

According to the new rules of the International Geodetic and Geophysical Union, Associations must during General Assemblies, hold joint meetings, common to at least two Associations. But furthermore, each Association will have the possibility of holding separate meetings during these General Assemblies and if it seems it necessary will hold a special General Assembly in between two General Assemblies of the Union. On this last point, the Cassinis Commission is unable to decide : some Geodesians staying away from Assemblies of the Union may be feared if special Assemblies are instigated.

## DECISIONS CONCERNING THE SECTION III "GRAVIMETRY" (old Section IV)

Section "Gravimetry" remained almost unchanged, only the number IV was changed to III. The elections for the I.A.G. left also the section officers nearly unchanged.

- Officers in Section III, Gravimetry 1971-1975

| | |
|---|---|
| President : | Professor C. MORELLI, Osservatorio Geofisico Sperimentale Viale R. Gessi 4, 34123 Trieste, Italy |
| Secretary : | Professor T. HONKASALO, Geodeettinen laitos Pasilankatu 43, 00240 Helsinki, Finland |

- International Gravimetric Commission

President : Professor C. MORELLI (see above)

- Special Study Group 3.05

Establishment of a worldwide net of first order gravity stations and connections of these stations to the stations with absolute measured gravity.

President : Professor C. MORELLI (see above)

- Special Study Group 3.18

Absolute measurements of gravity

President : Professor A.H. COOK, F.R.S., Department of Geophysics, University of Edinburgh, 6 South Oswald Road, Edinburgh, Great Britain.

- Special Study Group 3.20

Measurements of gravity at sea

President : Professor J.L. WORZEL, Lamont Doherty Geological Observatory, Columbia University, Palisades. New York 10964, USA

- Special Study Group 3.21

Special techniques of gravity measurements

President : Professor T. HONKASALO (see above)

## RESOLUTIONS AND RECOMMENDATIONS *

We give here after the resolutions proposed by the Section "Gravimetry" and some other resolutions or recommendations concerning gravity but proposed by other Sections than IV.

Resolution n° 11

The IUGG,

recognizing that the Potsdam datum adopted in London in 1909, has served its purpose in providing a reference for international gravity measurements,

considering

a) that for scientific purposes a more accurate system of gravity values is needed to provide both datum and scale,

b) that the IAG has adopted at the Lucerne General Assembly in 1967 a provisional correction of - 14 mgal to the Potsdam value (Resolution n° 22),

c) that the International Committee on Weights and Measures adopted in 1967 a resolution for a correction of - 14 mgal to the value of gravity in the Potsdam datum to be used for metrological purposes,

d) that recent absolute, pendulum and gravimeter observations have provided a firm basis for the determination of datum and scale to the required accuracy,

e) that the above mentioned measurements have been adjusted to provide a homogeneous International Gravity Standardization Net (IGSN 71) which defines the datum and scale and gives gravity values with the same order of accuracy throughout its range,

f) that the establishment of such a system represents a major international effort, and provision for maintenance and improvement must be made,

g) that the accuracy of the absolute determination of gravity is adequate for studies of variations in the distribution and displacements of masses, and variations of G,

recommends

(i) that the International Gravity Standardization Net 1971 (IGSN 71) be adopted and published in the Bulletin Géodésique,

(ii) that the Potsdam datum be corrected by the amount specified in the adjustment.

* Among the remarks of Professor HONKASALO, we notice : "quite confusing is, however, to give the name resolution for some of these and the name recommendation for some others, e.g. you have in the proof sheet resolution 12 and the recommendation 12. All must be resolutions and have final numbers ... I spoke with the Vice president of the IAG Professor KUKKAMAKI and he agreed with my opinion". (Letter Dec. 2, 1971).

Resolution n° 12

The I.A.G.,

recommends that a Permanent International Gravity Service, coordinated with the International Gravimetric Commission (IGC) and the International Gravimetric Bureau (IGB), be formed with the following functions :

1. to provide for expansion of the IGSN 71 to include areas where no stations now exist or values are not available,
2. the maintenance and re-observation of stations, and the replacement of any which may be destroyed,
3. to maintain the files in a computer-processable format and to incorporate new measurements into the existing files (one complete set of the values and descriptions to be deposited at the IGB),
4. to promote improvements in instrumentation, including the development of transportable absolute gravity meters, and their applicability to the standardization problem,
5. to establish in cooperation with the appropriate scientific institutions a net of permanent stations at which the absolute measurement of gravity, periodically repeated with an accuracy of the order of a few microgals, could be used as a geodetic reference and, in conjunction with other advanced geodetic methods, to monitor slowly varying parameters of the Earth,
6. to carry out computations necessary for incorporating new stations into the system,
7. to maintain contact with agencies active in the field of gravity measurements or using gravity data, to ensure that the IGSN 71 satisfies currents needs,
8. to provide advice, when requested, to agencies using the IGSN 71 in local standardization problems.

Resolution n° 13

The I.A.G.,

considering

- that an improved apparatus for the absolute measurement of g has been set up by the International Bureau of Weights and Measures,
- that the International Bureau apparatus offers the possibility to monitor the small variations of g arising from a variety of causes including secular effects of which tendency has been detected for the first time by means of absolute measurements,
- that this station (Sèvres, point A) has already been used as one starting point of gravimetric networks,

recommends
- that the installation at the International Bureau be maintained, and if possible improved, and that absolute measurements of g be performed as required in order to satisfy the needs mentioned above,

...

- that the International Bureau be requested to provide access to Sèvres not only to gravimeters but also other absolute gravity apparatuses to permit comparison of their results obtained at Sèvres point A against the value obtained with the International Bureau apparatus.

Resolution n° 14

The I.A.G.,

recognizing that Antarctica and the surrounding oceans are almost devoid of gravity observations and that gravimetric research is conducted by many groups from different nations,

recommends,

a) the connection of all major Antarctic base stations to IGSN 71 as quickly as possible and with comparable precision,
b) the establishment of a base net in the interior of Antarctica with stations located at appropriate intervals,
c) the formation of a working group to plan and coordinate Antarctic gravity research and data exchange so that a precise and homogeneous coverage is obtained. Particular care should be given to the precision of geodetic coordinates associated with these stations.

Resolution n° 15

The I.A.G.,

recognizing that geodetic satellite and terrestrial data are of a great importance for studies of the Earth, its interior and various geophysical phenomena,

recommends that geodesists should actively participate in the Geodynamics project and similar programmes for investigating the structure and dynamics of the Earth's interior and their variation with time.

Resolution n° 16

The I.A.G.,

considering

a) that it is necessary to improve the comparison between the elastic parameters of the earth found by measurements, and those of theoretical models,
b) that the precision now obtained in the absolute measurement of g is in the order of one microgal,
c) that experimental measurements of g, in order to be comparable, must be corrected for the effect of earth tides as well as for the indirect effect due to the ocean tides,

...

recommends

a) that earth tides should be measured in those regions where measurements have not previously been made, with the aim of determining with precision the local constants, particularly in the southern hemisphere and eastern Asia,

b) that continental profiles, already begun in the U.S.A. and Europe, should be extended as fully as possible in every region of the earth; these measurements must be carried out with instruments of the highest precision,

c) to continue research on the disturbances due to the oceanic tides.

Recommendation n° 4

The I.A.G.,

recognizing the increasing importance of statistical methods for determining the terrestrial gravity field,

recommends research into the application of these methods to data of different kinds, and to their combination.

Recommendation n° 5

The I.A.G.,

recognizing the new problems raised by the processing of the contemporary highly accurate measurements of gravitational field elements by space and terrestrial techniques,

recommends that all relevant geophysical effects be investigated.

Recommendation n° 6

The I.A.G.,

recognizing the importance of astro-geodetic, gravimetric and other three-dimensional terrestrial methods for determining the figure and gravitational field of the Earth in detail and their variation with time, and

noting recent theoretical and practical work in the use of astro-geodetic and gravimetric methods for determining the geoid and geocentric positions,

recommends that the application of such methods and their combination with methods using satellite data be actively pursued.

Recommendation n° 7

The I.A.G.,

considering the great number of theoretical earth models currently used, and the accuracy obtained in experimental results during recent years,

recommends Section V of the I.A.G. to contact the I.A.S.P.E.I. in order to set up study group whose task should be to propose a single earth model to be used as a "Standard of comparison" for all results.

## VOEUX (texte français)

Voeu n° 11

L'U.G.G.I.

reconnaissant que la valeur fondamentale de Potsdam adoptée à Londres (1909) a rempli son rôle en fournissant une valeur de référence pour les mesures internationales de pesanteur,

considérant

a) que les besoins scientifiques nécessitent un système plus précis de valeurs de la pesanteur qui fournisse à la fois la valeur et l'échelle,

b) que l'Association Internationale de Géodésie a adopté à l'Assemblée de Lucerne en 1967 une correction provisoire de - 14 mgal à la valeur de Potsdam (Voeu n° 22),

c) que le Comité International des Poids et Mesures a adopté en 1967 une résolution apportant une correction de - 14 mgal aux valeurs de la pesanteur dans le système de Potsdam, pour les usages métrologiques,

d) que des mesures absolues, au pendule et au gravimètre, ont fourni récemment une base solide pour la détermination des valeurs et de l'échelle avec l'exactitude nécessaire,

e) que les mesures mentionnées ci-dessus ont été compensées en vue de fournir un réseau gravimétrique international homogène d'étalonnage (appelé Réseau Gravimétrique International Unifié 1971) qui définisse les valeurs et l'échelle et qui donne des valeurs de la pesanteur avec le même degré d'exactitude dans toute son étendue,

f) que l'établissement d'un tel système est le résultat d'efforts internationaux considérables, et qu'on doit prendre des décisions en vue de son maintien et de son amélioration.

g) que l'exactitude de la détermination absolue de la pesanteur est adéquate pour l'étude des variations dans la répartition des masses et de leurs déplacements, ainsi que des variations de la constante de gravitation universelle G.

...

recommande

(i) que le Réseau Gravimétrique International Unifié 1971 soit adopté et publié dans le Bulletin Géodésique.

(ii) que la valeur de Potsdam soit corrigée de la quantité définie dans la compensation.

Voeu n° 12

L' A.I.G.

recommande que l'on constitue un Service International Permanent, travaillant en liaison avec la Commission Gravimétrique Internationale et le Bureau Gravimétrique International, chargé des tâches suivantes :

1. étendre le Réseau Gravimétrique International Unifié 1971 aux régions où il n'existe actuellement aucune station ou aucune valeur,
2. surveiller les stations, les moderniser et remplacer celles qui seraient détruites,
3. incorporer de nouvelles mesures dans les listes existantes et entretenir ces listes sous une forme compatible avec l'ordinateur (le Bureau Gravimétrique International centralisant valeurs et fiches),
4. provoquer le progrès de l'instrumentation et de son application aux problèmes d'étalonnage, en particulier par la mise au point de gravimètres absolus transportables.
5. établir, en coopération avec les institutions scientifiques adéquates, un réseau de stations permanentes dont les mesures absolues de pesanteur, répétées périodiquement avec une précision de quelques microgals, pourraient être utilisées comme référence géodésique et, associées à d'autres méthodes géodésiques récentes, pour surveiller les paramètres lentement variables de la Terre,
6. effectuer les calculs nécessaires pour l'incorporation de nouvelles stations dans le système,
7. rester en contact avec les Institutions travaillant dans le domaine des mesures de pesanteur, ou utilisant des données gravimétriques afin de garantir que le Réseau Gravimétrique International Unifié 1971 donne satisfaction aux besoins courants.
8. fournir des conseils, sur demande, aux Institutions utilisant le Réseau Gravimétrique International Unifié 1971 dans leurs problèmes de standardisation locale.

Voeu n° 13

L'A.I.G

considérant

- qu'un appareil perfectionné pour la mesure absolue de g a été construit par le Bureau International des Poids et Mesures.
- que cet appareil offre la possibilité de déceler les petites variations de g provenant de diverses causes, y compris les effets séculaires dont la tendance a été détectée pour la première fois par des mesures absolues,

...

- que cette station (Sèvres, point A) a déjà été utilisée comme point de départ de réseaux gravimétriques,

recommande

- que l'appareillage du Bureau International des Poids et Mesures soit maintenu et, si possible, amélioré et qu'on exécute les mesures absolues qui sont nécessaires pour satisfaire les besoins mentionnés ci-dessus,

- qu'on demande au Bureau International des Poids et Mesures de recevoir à Sèvres non seulement des gravimètres mais aussi des appareils de mesure absolue de la pesanteur afin que les résultats qu'ils fournissent à Sèvres, point A, puissent être comparés à la valeur obtenue avec l'appareil du Bureau International des Poids et Mesures.

Voeu n° 14

L'A.I.G.,

reconnaissant que l'Antarctique et les océans qui l'entourent sont presque dépourvus d'observations de pesanteur et que les recherches gravimétriques sont faites par plusieurs groupes de différentes nations,

recommande

a) qu'on relie les principales stations de référence de l'Antarctique au Réseau Gravimétrique International Unifié 1971 aussi rapidement que possible et avec une précision comparable à celle du Réseau International.

b) qu'on établisse un réseau de base à l'intérieur de l'Antarctique avec des stations convenablement espacées,

c) que l'on crée un "Groupe de Travail sur la pesanteur en Antarctique" pour établir les programmes de recherche et d'échange de données, et pour coordonner les travaux afin d'obtenir un réseau précis et homogène. Une attention particulière devra être donnée à la précision des coordonnées géodésiques des stations de ce réseau.

Voeu n° 15

L'A.I.G.,

reconnaissant l'importance des données géodésiques terrestres et de celles fournies par les satellites pour l'étude du globe, de l'intérieur de la Terre et de divers phénomènes géophysiques,

recommande que les géodésiens participent activement au projet géodynamique et à des programmes analogues comportant des recherches relatives à la structure et à la dynamique de l'intérieur de la Terre et à leur variation dans le temps.

Voeu n° 16

L'A.I.G.

considérant

a) qu'il est nécessaire d'améliorer les comparaisons entre les paramètres d'élasticité terrestres obtenus par des mesures et les modèles théoriques,

...

b) que la précision obtenue actuellement dans la mesure absolue de g est de l'ordre du microgal;

c) que les mesures expérimentales de g, pour être comparables, doivent être corrigées des effets des marées terrestres aussi bien que des effets indirects dus aux marées océaniques;

recommande

a) que des mesures de marées terrestres soient entreprises dans les régions où aucune mesure n'a encore été tentée, afin d'en connaître avec précision les constantes locales, particulièrement dans l'hémisphère Sud et la partie Est du continent asiatique;

b) que les profils continentaux actuellement en cours aux Etats-Unis d'Amérique et en Europe soient étendus aussi largement que possible à toutes les régions du globe terrestre et que ces mesures soient effectuées avec des instruments de la plus haute précision ;

c) que les recherches sur les perturbations dues aux marées océaniques soient poursuivies.

## Recommandation n° 4

L'A.I.G.,

reconnaissant l'importance croissante des méthodes statistiques pour la détermination du champ de la pesanteur terrestre,

recommande d'effectuer des recherches relatives à l'application de ces méthodes aux données de diverses natures et à leur combinaison.

## Recommandation n° 5

L'A.I.G.,

tenant compte des problèmes nouveaux posés par le traitement des mesures de haute précision des éléments du champ de la pesanteur obtenues à la fois par des techniques spatiales et des techniques terrestres,

recommande l'étude de tout effet géophysique en relation avec ces mesures.

## Recommandation n° 6

L'A.I.G.,

reconnaissant l'importance de la détermination de la figure de la Terre, de son champ détaillé de pesanteur et de ses variations dans le temps au moyen des méthodes astro-géodésiques, gravimétriques et d'autres méthodes terrestres tridimensionnelles, et

...

*notant* les récents travaux, théoriques et pratiques, relatifs à l'emploi de méthodes astro-géodésiques et gravimétriques pour déterminer le géoïde et des positions géocentriques,

*recommande* de poursuivre activement l'application de ces méthodes et de leur combinaison avec celles basées sur l'emploi des satellites.

Recommandation n° 7

L'A.I.G.,

*considérant* les nombreux modèles théoriques en usage actuellement et la précision des résultats expérimentaux de ces dernières années,

*recommande* à la section compétente de l'A.I.G de prendre contact avec l'A.I.S.P.I.T. afin de constituer une commission d'étude chargée de proposer un modèle terrestre unique qui serait utilisé comme "étalon de comparaison" de tous les résultats.

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PROCEEDINGS OF THE MEETINGS OF SECTION IV OF THE I.A.G. "GRAVIMETRY"

(Text of Professor HONKASALO completed with some abstracts).

Section IV held six meetings during the General Assembly at Moscow University. The chairman of all the meetings was Professor C. MORELLI and the secretary Professor T. HONKASALO. The agenda was as follows :

Meeting I. Tuesday, August 3rd at 11.30-13.00

1. Opening address by the president of Section IV, Professor MORELLI
2. Activité du Bureau Gravimétrique International, by Dr. S. CORON
3. Report of the SSG 4.05 "Establishment of a worldwide net of first order gravity stations and connection of these stations to the stations with absolute measured gravity", by the president of the SSG, Professor C. MORELLI.

   Professor MORELLI gave a history of the work 1954-1971 * with particular reference to the last four years, during which the final adjustments to the International Gravity Standardization Net 1971 were performed. The account of the work was continued by the observers and members of the SSG.

4. Absolute gravity measurements in the IGSN 1971, by Professor J.FALLER.

   Discussion on the possibilities of constructing a really portable absolute gravity meter weighing 100-150 kg (MORITZ, SAKUMA, FALLER, MORELLI).

Meeting II. Wednesday, August 4th at 15.00-16.30

Continuation of the SSG 4.05 report.

1. International cooperation, by Professor C. MORELLI
2. Pendulum observations and computings, by Professor T. HONKASALO.
3. Gravimeter observations, by Professor C. MORELLI
4. Adjustments and studies at the 1st Geodetic Survey Squadron, by C.T. WHALEN.
5. Computations at the Earth Physics Branch, by Dr. J. TANNER.

   Discussion of the work of the SSG. Professor MORELLI drew special attention to the fact that the results of three independant adjustment computations, performed by C.T. WHALEN at the 1st Geodetic Survey Squadron, Professor U.UOTILA at Ohio State University and R.K. MCCONNELL and C. GANTAR at the Earth Physics Branch, differed only slightly.

* See : Introduction of the Report of the SSG 4.05, page 1 - 29.

Following discussion and studies of all systematic and individual differences in Ottawa, May 1971, the net now described is a new combined adjustment of 25 000 observations with grav., pend.apparatus and absolute devices. The new set of 1997 g-values obtained is no longer tied to a single reference point ans is therefore assumed to possess almost the same degree of accuracy all over the world.

On the question of standard errors (TORGE), Mr. WHALEN referred to UOTILA's adjustment, which shows that all standard errors of gravity differences are smaller than $\pm$ 0.11 mGal.

On the question of value at Potsdam (ELSTNER) Professor MORELLI mentioned that the new value is more than 13.8 mGal smaller than the old one ; the new determination in Potsdam gives $\Delta g = -13.9 \pm 0.3$ mGal and agrees closely within the limits of its standard error .

Meeting III. Thursday, August 5th at 11.30-13.00

1. Further discussion about IGSN 71.

   Professor BOULANGER proposed the publication of the work of SSG 4.05 in a complete form as soon as possible, and suggested that new independent accurate tying measurements be made between Potsdam and the most important gravity sites (England, Canada, USA, Australia) so that after careful new studies the proposal be submitted to the next General Assembly of the IAG.

   The chairman postponed the decision to the next meeting of Section IV to have time to consider the arguments of both proposals, the adoption of IGSN 71 or postponement of it to the next General Assembly.

2. Une tendance de la variation de la pesanteur observée au Bureau International des Poids et Mesures, by Dr. A. SAKUMA *

   Discussion (BOULANGER, FALLER, TERRIEN) on the accuracy of temperature and tidal corrections and the stability of the whole instrumentation.

3. Sur la nécessité d'un Service International de la Mesure absolue de la Pesanteur, by J. LEVALLOIS (x)

   A permanent international service was proposed for studying the elements of the earth slowly varying with time (center of mass, seasonal variations of the radius, convection, variations of G).

   The chairman supported the proposal but wanted to extend the scope of the permanent service, i.e. to take in the duties presented in the SSG 4.05 report. For absolute gravity studies he proposed a working group of experts (SAKUMA, FALLER, BELL, COOK).

* See : Annexe B, page I - 34

(x) See : Bul.Inf. n° 24, page I-42-43 "Quelques conséquences géophysiques des nouvelles méthodes de haute précision de mesures absolues de G."

4. Report of SSG 4.20, Measurements of gravity at sea, by M. TALWANI
Short report mostly of measurements and results in the Indian Ocean.

5. Vibration string sea gravity meter by Dr. C. BOWIN

The Woods Hole Oceanographic Institution has utilized the MIT vibrating string (VSA) sea gravity meter for the past four years. Experience gained and instrument improvements are summarized. An automatic data acquisition system incorporating a small digital computer (Hewlett-Packard 2114A) has been developed to record gravity, ship's velocity, magnetic bathymetric and date and time information. The W.H.O.I. system consists of the VSA gravity sensor mounted upon a Sperry Mark 19 Gyrocompass which in addition to acting as a stabilized platform provides velocity north and east components of ship's motion. The entire system is installed in a portable enclosure to enable easy transfer from one ship to another. The excellent quality of the data obtained has improved the ability to resolve the gravity field at sea and allowed the development of improved navigation processing schemes.

Meeting IV - Monday August 9th at 15.00-16.30

I. The chairman reported that he and some members of the SSG had consulted with Professor BOULANGER about his proposal to postpone the adoption of the IGSN 71 and said that after checking the accuracy of the proposed net, Professor BOULANGER withdrew his proposal to postpone the decision.

The chairman put forward two resolutions in Section IV. These were unanimously adopted.

2. Report of SSG 4.21 "Special Techniques of Gravity Measurements" by Professor TH. HONKASALO *.

3. Problems of measuring small gravity differences by Professor E.GROTEN :

The results were found in connection with experiments done mainly with LaCoste-Romberg gravimeters by recording gravity; problems specific for any instrument type will not be dealt with (like, e.g temperature and pressure control, read out errors) because they can be overcome by specific devices. Calibration is a main problem. Nonlinearities are produced by (1) read-out and output system, (2) elastic system even though $f=dg/dz$ = const. for zero length spring where z = output; when accuracy $< 10^{-3}$ is considered such effects are to be taken into account. Digitising is used for avoiding low accuracy of recorders ($\pm$ $2.10^{-3}$). In the absence of

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* See : Annexe C, page 1-36

noise, precise calibration (inbuilt device for repeated calibration) is an alternative of linearity but filtering is, of course problematic in case of time dependent (tidal) observations. Since beam deflections and corresponding diameter variations of spring are so small feedback meters seem to be necessary mainly because of hysteresis for time dependent measurements.
Vibrational perturbations (like microseisms, M) and order of magnitudes of corresponding CC-effects are discussed.
After-effects and hysteresis of nonfeedback, meters may not simply depend on gravity changes with time but seem to be affected by vibrations too. Since microseisms usually varies with seasons this fact could influence long time (tidal) observations.

Discussion of accuracy (HONKASALO), air pressure influence (BONATZ).

4. Results of high-precision gravity measurements, by. Dr. Cl. ELSTNER:

A special profile consisting of several gravity stations was chosen in order to detect an upper limit of the accuracy for the measurements with gravimeters and in view of the possible influence of slow variances in the distribution of masses inside the upper layers of the earth crust and in the surrounding of the observation points. For geological reasons the profile was erected in the middle part of the GDR. There an approximate homogeneous sedimentary situation is to be found. The avoid calibration errors the six observation points include a small gravity range of 16 mGal. The length of the line amounts about 250 km.
The construction of the points and first measurements of gravity are briefly discribed. An evaluation of their accuracy is given. Repeated gravity observations during the next years should give a first information on the amounts of the different disturbing effects in the microgal-range and on the detection of possible mass deviations in the ground. The work was performed in cooperation with other institutions in the German Democratic Republic.

5. Gravity variations in time, by. Dr. V.V. FEDYNSKY.
Translated paper of V.V. FEDYNSKY, A. Sh. FAITELSON, K.E. VESELOV, E.A. ASARKINA, B.A. KRASNOV.

Discussion oc accuracy (TORGE). No single closure exceeds 0.1 mGal.

6. Investigations of secular gravity variations in Iceland, by Professor W. TORGE.

In 1938, 1965 and 1970 gravity measurements across the young volcanic zone of northen Iceland have been carried out along a west-east profile of about 100 km length, including also the zone of the western adjoining tertiary plateau basalts. On aim of the survey was to detect whether there exist any variations of gravity with time or not in the mobile zone of recent volcanism and open fissures.

About 30 stations have been established in 1938 by using one Thyssen-Schleusener gravity meter with accuracy of a few 0,1 mgal. These stations have been reconstructed and completed by about 60 stations in 1965, when the points were monumented too. The observations in 1965 and 1970 were performed with LaCoste and Romberg gravity meters, the standard deviation being less than 0,02 mgal.
The comparison of the gravity values obtained in the different periods indicates, that the gravity in the young volcanic zone might have more increased with time than in the tertiary basalts, the time rate over the total profile being about 0,01 mgal per year. Because of the strong correlation of the 1938 gravity values, the change between 1938 and 1965 is not significant, whereas between 1965 and 1970 a significant change is indicated.

Meeting V  Tuesday, August 10 th at 16.30-18.00

1. Some problems of gravity measurements by means of gravimeters, by Dr. I. NAKAGAWA.
Report of the working group for gravity survey and precise levelling in Japan.

Formerly gravity measurements were independently made by the respective institution in Japan. From an urgent fundamental necessity of cooperative measurements of gravity with many gravimeters, a Working Group for Gravity Survey and Precise Levelling was organized under the Geodetic Society of Japan in 1969.
The Working Group had the symposium once a year and made precise gravity measurements over the areas of South Kanto, Tokai and Kii. An anomalous crustal activity has been observed in the areas of South Kanto and Tokai, and therefore simultaneous gravity measurements using 6 LaCoste gravimeters were carried out for investigating the second purpose described above. Simultaneous gravity measurements using 6 LaCoste and 2 Worden gravimeters were also carried out in the Kii Peninsula for investigating the first purpose.
A summary of conclusions obtained hitherto through the measurements and symposiums is as follow :

(1) An extreme care must always be taken to the gravimeters.
(2) Fundamental experiments about the gravimeters should systematically be made. Especially, effects of temperature, pressure and various shocks to the gravimeters should thoroughly be investigated for the gravimeters to be used.
(3) Effect of mechanical, thermal and other shocks to the gravimeters is the most important in field measurements. Fluctuation amounting to 0.02 mgal was observable even by taking in and out the gravimeters to and from the carrying case.

(4) Drift of the gravimeters is not linear even for a short duration of measuring time.
(5) It is rather difficult to keep a measuring accuracy always within 0.01 mgal even by careful measurements in quiet stations.
(6) An opportunity to detect the gravity change is expected for great earthquakes with magnitude larger than 7.5. For this purpose, gravity measurementshould simultaneously be made with precise levelling.
(7) An improvement of the gravimeters is necessary in order to increase the measuring accuracy.

2. Pendulum apparatus with a constant amplitude pendulums, by Dr. V.A. ROMANJUK :

(1) The most important feature of the apparatus is an electro-magnetic pusher with a reverse coupling for providing a constant amplitude for a long time. Experiments do not reveal the fact of the electro-magnetic pusher affecting the pendulum period within the accuracy the periods are measured with ($1 \times 10^{-9}$ sec).
(2) The pendulum elements are interconnected by means of springs. A brass glass rigidly fixed to the pendulum ensures temperature componsation.
(3) The pendulum swinging periods are registered photoelectrically. Physical periods of 2 actual and 1 fictitious pendulum are measured by the method of "typing" the pendulum pulses to quartz clock "minute" pulses.
(4) The amplitudes of 2 actual pendulums are equalized within $\pm$ 4". The amplitude is measured by means of the auto-collimation method with the error $\pm$ 0".5.
(5) Experimental forming of the cylindrical surface resting on the knife-edge of about 10 radius ensures the speed of the "drift" period equal to $3 + 8 \times 10^{-10}$ sec/hour compared to $50 \times 10^{-10}$ sec/hour drift period of the non-formed knife edge.
(6) In 1969 the first experimental measurement of $\Delta$ g 800 mgl with the error $\pm$ 0.02 mgl for actual pendulum was carried out.

Discussion on accuracy and technical details

3. Measurements of the vertical gradient of gravity in mountains, by Dr. M. PICK :

In the Czechoslovakian mountain test-area in the High Tatras, the investigation of the vertical gradient of gravity has been started. An area of 250 km2 was covered by about 60 points, at which the vertical gradient of gravity was determined correctly from gravity measurements on two levels by means

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of gravimeter Sharpe Canadian CG2. The procedure of measurements was arranged in such a way for the measurement errors to be less than 20 E. The influence of the gravity topographic corrections was reduced by a suitable procedure as well.
At the same time the value of the vertical gradient of gravity was computed from the map of gravity anomalies. The accuracy of computed values dg/dz is lower than that of the measured values, and may amount to about 100 E.

4. Submarine vertical gradient of gravity, by Professor J. LAGRULA :

The vertical gradient of g in the oceanic masses, is a slowly decreasing function of the depth. A bathyscaph allow to determine it. Its anomalies are more quiet than in continental areas and can therefore be used for geodetic purposes.

5. Reduction of vertical gradients of gravity, by Dr. H. MÄLZER :

The observed vertical gradients of gravity are dependent in a high degree on the topographic masses. Compared with the theoretical value differences of ± 30% and more are existing.
Above all the topography of the immediate vicinity must be known for the reduction very exactly. Questions of the accuracies for heights and density and for the dimensions of the compartments are discussed. The influence of masses far from the observation point are investigated theoretically. The highest disturbances exist when the angle between the horizontal and the direction to the disturbling mass has 35°3. This result already found by N. KUMAGAI, E. ABE, and Y. YOSHIMURA (1962) is established in the computed table of reduction values.
The reduction of observed vertical gradients of gravity is illustrated by examples. The measurements are carried out with several LaCoste-Romberg gravitymeters.

6. Experiment of the determination of the Cavendish gravity constant, mass and average density of the earth, by Dr. M.U. SAGITOV :

The exact expression for the momentum of the attractive forces of the trial masses is derived, and the unlinear theory of an experiment on the determination of the gravity constant is improved. Differents effects are considered, which should be taken into account in an exact experiment.
It is described a laboratory installation for this experiment, which was completed recently. Preliminary results of determination of the Cavendish gravity constant, mass and average density of the Earth are presented and considered.
The preliminary results promise an accuracy of $10^{-5}$, theoretically $10^{-6}$ is possible.

Discussion : Why use cylinder masses, not balls ? Accurate cylinders are more easily prepared but the theory is more difficult

The chairman read the proposal of Professor BOULANGER and Dr. SAGITOV for a resulution :

> " The International Association of Geodesy draws your attention to the necessity of improving the value of the constant of gravitation in the metric system of mass, length and time units as well as of the value of the Earth's mean density.
> To distinguish this new constant of gravitation from other ones, such as the Gaussian, Einsteinian, geocentric and selenocentric, it is suggested to call it the Cavendishian constant of gravitation or merely the Cavendishian constant".

Düring the discussion (TERRIEN, FALLER , MORELLI) attention was drawn to the fact that the question of nominating a new constant in the metric system belongs to the International Committee of Weights and Mesures and Several Scientific Unions, not only the IAG. Thus this resulution was not adopted by Section IV.

Meeting VI Wednesday, August 11th at 16.30-18.00

1. Some problems of tidal gravity correction, by Professor P. MELCHIOR.
   A plan made by the Commission of Earth Tides to measure the tidal gravity constant with standardized gravimeters at several stations along two lines in Europe, one from Liverpool to Padova and the other from Lisbon to Helsinki was presented.

   Discussion of local effects.

2. Les grandes anomalies de la carte gravimétrique de l'Afrique Occidentale et Centrale, by Doctor P. LOUIS.

   (1) L'Office de la Recherche Scientifique et Technique Outre Mer a établi, durant ces quinze dernières années, une carte gravimétrique de reconnaissance qui couvre une grande partie de l'Ouest africain y compris le bassin du Tchad (Sénégal, presque toute la Mauritanie, le Mali, la Côte d'Ivoire, le Togo, le Dahomey, le Niger, la Haute Volta, le Tchad, le Cameroun et la République Centrafricaine). La densité des stations est d'environ une pour 70 km2. Les résultats des levés ont été publiés à l'échelle de 1/1.000.000. Des cartes de synthèse (anomalies de Bouguer et anomalies isostatiques) ont été établies.

   (2) La carte isostatique permet de constater que si globalement la compensation est réalisée à l'échelle de mille ou deux mille kilomètres, il n'en est plus de

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même à l'échelle de quelques centaines de kilomètres. On constate, en effet, l'existence de grandes anomalies régionales. Ce sont les principales d'entre elles qui sont examinées et pour lesquelles des explications sont proposées dans cette communication...

3. About the preparation of a gravity map of the Western Section of Cuba at a 1:100 000, by G. OLIVA :

    This paper aescribes, in some of its aspects, a recollection of gravity data concerning an area of approximately 40000 square kilometers in Western Section of Cuba, land and sea shelf being herein included. The paper has taken into account gravity surveys performed from 1929 to the present day, as well as the various recollections of data made during that period.
    Sources used comprise documentation obtained from the Cuban Ministry of Mines, Fuel and Metallurgy, from the Cuban Institute of Geodesy and Cartography, and from a number of foreign companies, mainly American, that have performed geophysical surveys in Cuba before 1959.
    Some 20000 gravity stations, taken from those diverse sources, have been checked for the area under study. That processing of the points selectedguarantees compliance to all the conditions required in the preparation of gravity maps to a 1:100000 scale with a contour interval of 2 mgal.
    The methodology followed for the preparation of the map is here given in two variants ; Free-Air Anomalies and Bouguer Anomalies...

4. Airborne gravity, by O. WILLIAMS, :

    Description of research in gravity measurements in the aeroplane and the helicopter.

5. Proposed International System Unit of Gravitational Acceleration.

    The chairman reported on the content of Dr. W.I. REILLY's paper, in which he proposed a nex name for unit $m/s^2$ = Galileo with the symbol Gl.
    In the discussion no reason wa found for the new naming. Futhermore the symbol was found to be confusing, since it has already the meaning of Gigalitre (TERRIEN).

6. Gravity field, structure of the under-ice relief and the earth's crust in Antarctica, by Dr. N.P. GRUSHINSKY :

    The survey of the bulk of gravimetrical data on the antarctic and that of the fundamental gravity connections are given. The general plan of the future study of gravity field of the Antarctica is suggested, which secures the maximal information for the geodetic and geophysical study of the continent.

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The fundamental connection between the gravity anomalies and the structures of the under-ice relief and Earth crust are discussed.
The conclusion on the high degree of the isostatic compensation of the Antarctica is done.

The discussion showed international cooperation to be necessary and a resolution on it was proposed.(Resolution n° 14).

Meeting of the SSG N° 4.21

Special techniques of gravity measurement.

Wednesday, August 11th at 9.30, Chairman Professor T. HONKASALO.

1. The most important task of this study group was stated to be high precision field measurements.
2. It was considered necessary for the SSG to have a large number of members to get information of high precision techniques all over the world. An active working group is necessary if joint test measurements are planned.
3. International cooperation was planned to remeasure the Fennoscandian land uplift line. This would provide an opportunity to test the influence of the improvements of new reading devices and thus separate the drift and reading uncertainties.

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SOME PAPERS READ OR DISTRIBUTED AT THE GENERAL ASSEMBLY
of interest for gravimetrists

- K.H. AFSHAR , H. ZOMORRODIAN : The measurements and the adjustments of the First Order Gravity Network in Iran.
- A.I.G. : Liste des stations de déviation de la verticale rattachées au Réseau Européen; liste n° 4, 1971.
- A.I.G. : Geodetic Reference System 1967, Bul. Géod.
- P. BANKWITZ, E. BANKWITZ : Conceptions about Motions along Oceanic Fracture Zones.
- G. BARTA : Interpretation of the Geoid Shape.
- G. BARTA : On the hypothesis of the secular variations of gravity field.
- G. BARTA : Uber die Massenverteilung der Erde auf Grund der Geoidform.
- E. BAYER : Die Berücksichtigung des lunisolaren Effektes in der geodätischen Beobachtungen in Ungarn,
- Arne BJERHAMMAR : Prediction And Filtering of Non-Stationary Stochastic Processes in Geodesy.
- Arne BJERHAMMAR : Linear Unbiased Estimation Theory.
- M. BONATZ, P. MELCHIOR, B. DUCARME : Station : Longyearbyen (Spitsbergen) Mesures faites dans les trois composantes avec six pendules horizontaux VM et trois gravimètres Askania.
- L. BRAGARD : Potentiel de déformation superficielle produit par un bourrelet de marée. Relations entre les nombres de Love $h_n$ et $k_n$.
- R. BREIN : An instrument for precise measurements of small differences of the gravity.
  Report of the Institut für Angewandte Geodäsie. Abteilung II des Deutschen Geodätischen Forschungsinstituts for the XVth General Assembly of the IUGG - IAG 1-14th August 1971 in Moscow.
- Milan BURSA : Fundamental Geodetic Parameters of the Earth's Figure and the Structure of the Earth's Gravity Field Derived from Satellite Data.
- Milan BURSA : Determination of parameters of a selenocentric Reference System and Deflections of the vertical at the Lunar Surface.
- J. BYL : Results of tilt observations at Potsdam.

- T. CHOJNICKI : Problèmes des moyens d'élaboration des observations de marée en tenant compte des techniques contemporaines d'observation et de calcul.
- B.H. CHOVITZ : Generalized Three-Dimensional Transformations.
- G. DESVIGNES : Geoïde sur l'Europe et l'Atlantique Nord-Est.
- H.M. DUFOUR : La représentation du potentiel terrestre par des fonctions regionalisées.
- Cl. ELSTNER : Results of high precision gravity measurements.
- V.V. FEDYNSKY, A.Sh. FAITELSON, K.E. VESELOV, E.A. ASARKINA, B.A. KRASNOV - Gravity variations in time.
- F. FELDBACHER : Anwendungen einer numerischen Integrationsmethode bei der Lösung der Hauptaufgabe über grosse Entfernungen.
- I. FISCHER : Recent Geoïd Studies (Secretary's Report, Section V, 1967-1971.
- D. FLACH, O. ROSENBACH, H. WILHELM : Comparative harmonic analysis of records of 2 Askania borehole tiltmeters.
- D. FLACH, G. JENTZSCH, O. ROSENBACH, H. WILHELM : Ball-calibration of Askania borehole tiltmeters.
- J. FLICK, P. MELCHIOR, J-M van GILS : Le laboratoire souterrain de Geodynamique de Walterdange-Luxembourg.
- E.M. GAPOSCHKIN ym. : Geodetic Studies at the Smithsonian Astrophysical Observatory
- E. GROTEN : New determination of the gravitational constant.
- E. GROTEN : Problems in measuring small gravity differences.
- Rolland L. HARDY : Geodetic Applications of Multiquadric Analysis.
- T. HONKASALO : Report on IAG Special Study Group No.4.21 of Special Techniques of Gravity Measurements.
- T. HONKASALO : Geophysical Interpretation of Gravity Anomalies 1963-1970.
- Vladimir HRISTOV :Proposal by the Bulgarian National Committee on Geodesy and Geophysics for a Specification of the Geodetic Reference System 1967.
- Vladimir HRISTOV : Paramètres initiaux antérieurs et actuels en géodésie.
- K. HUBENY ; Die exzentrische Anomalie als Parameter des Rotationsellipsoids.
- Lubomir KUBACEK : Some mathematical aspects in the designing of geodetic nets.
- J. LAGRULA : Equal-area blocks.

- J. LAGRULA : Sur les corrections topographiques, géologiques et isostatiques.
C.R. Acad. Sc. Paris, t.272, p. 816-820 , 1971.

- J. LAGRULA. S. CORON : Submarine vertical gradient of the gravity.

- J.J. LEVALLOIS : Sur la nécessité d'un Service International de la Mesure absolue de la Pesanteur.

- J.J. LEVALLOIS : Calcul du géoide gravimétrique sur le territoire de la France.

- J.J. LEVALLOIS : Sur le prolongement analytique du développement en harmoniques sphériques du potentiel terrestre.

- J.J. LEVALLOIS : Le système de Référence 1967.

- M. MAJEWSKA : The calibration of sharp gravimeter No. 228 G by means of tilting method in relation to temperature, atmospheric pressure and time.

- H. MALZER : Reduction of vertical gradients of gravity.

- R.S. MATHER B.C. BARLOW, J.G. FRYER : A Study of the Earth's Gravitational Field in the Australian Region.

- R.S. MATHER : Practical Techniques for the Establishment of a World Geodetic System from Gravity Data.

- P. MELCHIOR : Intercation between Ocean an Earth Tides.

- P. MELCHIOR : Rapport sur les Marées Terrestres 1967-1971.

- V. MITROVIC, M. GRASIC : Gravimetrical calibration measurements in 1967 and 1969 (Yugoslavia).

- C. MORELLI, C. GANTAR, TN HONKASALO, R.K. McCONNEL, B. SZABO, J.G.TANNER, U. UOTILA, C.T. WHALEN : The International Gravity Standardization Net 1971 (IGSN 71).

- Helmut MORITZ : Series Solutions of Molodensky's Problem (Dtsche Geod. Komm. A:70).

- Foster MORRISON : The Manipulation of Density Layer Models for the Geopotential.

- Abdulah MUNINAGIC : Investigation of Real Geoid in Yugoslavia.

- I. NAKAGAWA : Some remarks on gravity measurements by means of gravimeters.

- G. OLIVIA : About the preparation ofa gravity map of the Western Section of Cuba at a 1:100 000 scale.

- O.M. OSTACH : Solution of Stokes' Problem for a Boundary Ellipsoidal Surface by Means of Green Functions.

- L.P. PELLINEN, O.M. OSTACH, E.M. ORLOVA : Some Results of Astro-Gravimetric Leveling in the USSR.

- M. PICK : On the computation of the gravity terrain correction in Czechoslovakia.

- M. PICK : Measurements of the vertical gradient of gravity in mountains.

-M. PICK, J. PICHA : The Mean Density of the Earth.

- O.J. RAICES VIDAL : A Unified Procedure for the Solution of the Least Squares Problem and for Estimating the Precision of the Adjusted Variables.

- R.H. RAPP : Preliminary Report of the Equal Area Block Working Group.

- W.I. REILLY : Proposed international system unit of gravitational acceleration.
Geophys. J.R. astr.Soc. (1971) 22

- K. RINNER : Berich über die Erdgezeitenstation im Grazer Schlossberg.

- A. SAKUMA : Une tendance de la variation de la Pesanteur observée au Bureau International des Poids et Mesures, Sèvres, France.

- A.Z. SAZONOV : Astro-Geodetic Network of the USSR. Lay-out and Adjustment Principales, Actual Accuracy.

- M. SCHÄDLICH : The Accuracy of Schematic Extended Astrogeodetic Networks.

- M. SCHÄDLICH :Modeltheory and the Technique of Geodetic Measurements - A General Conception of the Theory of Measurements.

- A. SCHLEUSENER, W. TORGE : Investigations of secular gravity variations in Iceland.

- M.M. SCHNEIDER : Measurements of the Earth's Tides at Vòstok station in Central Antarctica.

-R. SCHULER, G. HARNISCH, H. FISCHER, R. FREY : Absolute Schweremessungen mit Reversionspendeln in Potsdam 1968-1969. Veröff. d. Zentralinstituts Physik der Erde No.10.

- D. SIMON : First results of earth tidal observations in airtight measuring boxes.

- Z. SIMON, L. TRÄGER : Polygons for studying the secular variations of the acceleration of gravity on the territory of Czechoslovakia.

- J.G. TANNER, R.A. Gibb: Gravity measurements in Canada January 1,1967 to December 31, 1970.

- P. TARDI, S. CORON : Activité du Bureau Gravimétrique International,**Paris**.

- **TEHRAN UNIVERSITY** : Report on the Tidal Measurements of the Crust and Their Harmonic Analysis in Tehran.

- Erik TENGSTROM : Studies of different methods of Physical Geodesy for determining the figure of the Earth, and its external gravitational potential.

- Urho A. UOTILA : Interpolation and Extrapolation of Surface Gravity Values.

- A.P. VENEDIKOV, P. VARGA : Facteurs moyens des marées terrestres.

- H.W. WIRTH : Isostasy and Deformations of the Equipotential Surfaces in the Earth's Interior.

- G. WITTLINGER, R. LECOLAZET : Sur les observations de marée clinométrique dans un long tunnel.

- V.F. YEREMEEV, M.I. YOURKINA : L'expression des altitudes du Quasi-Geoïde et des deviations de la verticale pour le champ de Reference de l'Ellipsoïde de niveau.

- H. ZOMORRODIAN : The measurements and the adjustments of the second order gravity network in Iran.

- H. ZOMORRODIAN : A summarizing report on the establishment of the Iran National Gravity Calibration Line (I.N.G.C.L.) and the computation of the scale factors of the 4 applied LaCoste-Romberg gravimeter.

ANNEXE A

# THE INTERNATIONAL GRAVITY STANDARDIZATION NET 1971
(IGSN 71)

## INTRODUCTION

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### 1.2. Evolution of world gravity standards

Early development

The first internationally accepted gravity reference system was known as the Vienna Gravity System. It was adopted in 1900 at the XIIIth Conference of the International Association of Geodesy held in Paris and had as estimated relative accuracy of ± 10 mGal.

The Potsdam Gravity System was introduced soon after (Borass, 1911) and internationally accepted at the 1909 meeting of the IAG in London, The relative accuracy of this system was estimated at ± 3 mGal and it corrected the Vienna System by - 16 mGal. Absolute gravity measurements in the past few decades indicated an error of + 12 to + 16 mGal in the absolute Potsdam value (Dryden, 1942; Morelli, 1946b; Berroth, 1949; Preston Thomas et al., 1960; Cook, 1965a).

By the end of World War II it was evident that not only more absolute measurements but also an interconnecting net of relative gravity ties were required to define a new gravity system.

The publication of two independent adjustments (Morelli, 1946a); Hirvonen. 1948) demonstrated the insufficient distribution and accuracy of the existing gravity measurements and induced G.P. Woollard to undertake his pioneer work of promoting the geodetic use of new instruments (Worden and LaCoste Romberg gravimeters. Gulf pendulums) to provide new and more accurate relative gravity measurements all over the world (Woollard and Rose, 1963).

By the early 1950's many agencies had become involved in long range gravimeter and pendulum measurements. Inhomogeneity in the distribution of stations, in observational criteria and techniques and in data reduction methods necessitated the coordination of these activities. Accordingly action was taken through the IGC of the IAG and in 1954 Special Study Group 4.05 was formed with responsabilities in the following fields.

(a) Absolute measurements of gravity
(b) Network connections
(c) International Gravity Formula.

A network of 34 stations to be known as the First Order World Gravity Net, were chosen at the 1956 meeting of the IGC in Paris and plans were made to concentrate on gravity connections between them. These stations were :

| | | |
|---|---|---|
| Algiers | Khartoum | Oslo |
| Azores | Kyoto | Ottawa |
| Bad Harzburg | Leopoldville | Panama |
| Beirut | Lisbon | Paris |
| Buenos Aires | Madison | Potsdam |
| Capetown | Madrid | Quito |
| Christchurch | M'Bour-Dakar | Reykjavik |
| Fairbanks | Melbourne | Rio de Janeiro |
| Helsinki | Mexico City | Singapore |
| Honolulu | Milan | Teddington |
| Johannesburg | New-Delhi | Vancouver |
| | | Washington |

During the next 8 or 9 years, relative gravity measurements were carried out on a world-wide basis by many observers. For logistic and technical reasons it was often impractical to carry out direct interconnection of the FOWGN stations and a large number of inhomogeneous subnets came into existence. Apart from partial solutions such as the basic world-wide work of Woollard and Rose (1963) and the European Calibration System (Kneissl , Marzahn, 1963b) the evolution of a nex world gravity system proceeded slowly. Some significant improvements in instrumentation occurred during this period, e.g. development of the LCR gravimeter, but some disturbing aspects of the performance of pendulum apparatuses came to light. The state of the art was summarized (Morelli, 1963a) as follows :

" a) Modern pendulum results, previously considered fairly reliable, have revealed (Woollard and Rose, 1963) tares and creep: that is, the same weak points as the gravity-meters; pendulums should therefore always be used in connection with properly chosen and studied gravity-meters;

b) Results with modern, geodetic gravity-meters have shown that it may also be possible to measure large differences in gravity, provided that :

(1) they are operated in groups to control tares and creep;
(2) they are properly checked in the laboratory and on the calibration lines to detect and evaluate pseudo-periodic errors and nonlinearity;
(3) They are calibrated (on sufficiently accurate and extended calibration lines) to determine their scale-factor function.

It is well known that normally (3) can be done only by comparison with pendulum measurements.

It would seem that a solution would be impossible : we need the gravity-meters to be sure of the pendulums, and the pendulums to calibrate the gravity-meters.

Without proper consideration of this point, it is clear that confusion and uncertainty have been and will continue to be created. This is the reason that we do not yet have a "World Standardization System", although we have many "Calibration Systems" : referred to different pendulum apparatus, or to different pendulum results, or to a different evaluation of the same pendulum measurements".

The above situation led the SSG 4.05 during the XIII IUGG General Assembly (Berkeley, 1963) to propose, and the IAG to accept, a new philosophy as follow :

I. The establishment of three International Calibration Lines, with large gravity intervals.

They were : the ACL from Ushuaia to Point Barrow;
the EACL from Capetown to Hammerfest;
the WPCL from Christchurch to Sapporo.

II. The selection of a few stations on each International Calibration Line to be occupied by the best available pendulum apparatuses using the same operational criteria.

The chosen apparatuses were :

The Gulf pendulums;
The Cambridge " ;
The CGI " ;
The GSI " .

III. Groups of LaCoste and Romberg gravimeters would be observed on the Lines, for checking and calibration purposes.

IV. Interconnection would be established between the Lines for strenghtening the structure and establishing the skeleton of the world net.

In the next few years,most of the measurements required for a new reference system were carried out. Important contributions were made by 1381$^{st}$ GSS with the first systematic global LaCoste and Romberg gravimeter measurements and by AFCRL who supported many projects, especially pendulum and absolute measurements.

The further coordinate the collection and reduction of data for the preparation of a final adjustment, the SSG 4.05 formed a sub-group of specialists devoted to the solution of specific problems. The representatives of the institutions most actively partdcipating met for the first time in 1965 in Torino, Italy, and formed a permanent Working Sub-Group.

In the next few years the work of collecting and editing the nex observations was carried out and many partial adjustments performed by members of the Working Sub-Group or others (TORGE, 1966). The increased relative accuracy of the best pendulum apparatuses (± 0.2 mGal and gravimeters (± 0.05 mGal) made possible the attainment of a world network of high relative accuracy. The problem of obtaining high absolute accuracy as well was solved with the development of Cook's semi-transportable apparatus (± 0.1 mGal) *

The amount of new data and the dangers inherent in continuous disseminations of new values led the International Gravity Commission at its last meeting (Paris, 1970) to request that only one final adjustment should be published and internationally adopted. The present report describes the adjustments and analyses which led to the final adjustment and the resulting International Gravity Standardization Net 1971. This proposed system is estimated to have an absolute accuracy of ± 0.2 mGal or better over the gravity range of the earth.

### 1.3 Summary of the work of SSG 4.05

Reports pf the SSG 4.05 have been presented and discussed at the following meetings :

| | | |
|---|---|---|
| 1954, in Rome | - X IUGG General Assembly | (unp.) |
| 1956, in Paris | - IGC Meeting | (unp.) |
| 1957, in Toronto | - XI IUGG General Assembly | (see Morelli, 1959) |
| 1959, in Paris | - IGC Meeting | (unp.) |
| 1960, in Helsinki | - XII IUGG General Assembly | (unp.) |
| 1962, in Paris | - IGC Meeting | (unp.) |
| 1963, in Berkeley | - XIII IUGG General Assembly | (unp.) |
| 1965, in Paris | - IGC Meeting | (unp.) |
| 1967, in Lucerne | - XIV IUGG General Assembly | (unp.) |
| 1970, in Paris | - IGC Meeting | (unp.) |

Meetings of the Working Sub-Group have been held in :

- Torino, April 1965;
- Paris, September 1965;
- Bedford, April 1967;
- Paris, September 1970;
- Ottawa, Mai 1971.

Some information concerning the Group's activity and discussions at the IGC and IUGG Meetings are printed in the "Bulletin d'Information" of the IGB.

The members of the Sub-Group participating in the final adjustment and the presentation of this report are :

| | | | |
|---|---|---|---|
| AFCRL | : B. SZABO | 1st GSS | : C.T. WHALEN |
| EPB | : R.K. McCONNELL, J.G TANNER | OGST | : C.GANTAR, C.MORELLI |
| GL | : T HONKASALO | OSU | : U. UOTILA |

* Faller's transportable apparatus (± 0.05 mGal) and Sakuma's stationary apparatus (± 0.03 mGal-systematic errors included).

Professor WOOLLARD contributed to the efforts of this Working Sub-Group, but could not participate in the final adjustment or in the presentation of this report. Professor WOLF acted from time to time as a consultant to the Sub-Group.

The IGSN 71 has been achieved within the framework of SSG 4.05 and through the cooperation of a great many agencies throughout the world.

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ANNEXE B

## UNE TENDANCE DE LA VARIATION DE LA PESANTEUR OBSERVEE AU BUREAU INTERNATIONAL DES POIDS ET MESURES, SEVRES, FRANCE

PAR A. SAKUMA

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Depuis Août 1967, les mesures de g ont été poursuivies périodiquement au B.I.P.M. par un gravimètre absolu de haute sensibilité (1) (2) et nous avons déjà signalé (3) que les valeurs moyennes de g observées pendant les trois premières années (Août 1967 - Août 1970) restaient constantes à environ $\pm 1 \times 10^{-8}$ ($\pm$ 10 μGal) près. Avec l'augmentation de la précision de nos mesures, les variations observées, qui atteignent par exemple $2 \times 10^{-8}$ entre Août 1970 et Juillet 1971 doivent être considérées comme significatives. Nous ignorons les causes de ces variations et malgré nos efforts, aucun défaut instrumental de cet ordre n'a été décelé jusqu'à présent dans notre appareil.

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(1) Bull. Géod. N° 69, 249/260, 1963.
(2) Bull. Information de l'I.G.N., Paris, N° 11, 8/19, 1970.
(3) Bull.Géod., N° 100, 159/163, 1971.

Les valeurs moyennes de g au point de mesure A2 après correction théorique de l'effet luni-solaire (établie grâce à la collaboration du Professeur LECOLAZET de Strasbourg) et les écarts types d'une mesure sont pour la quatrième année :

| | | | | |
|---|---|---|---|---|
| | (980 925 657,4 ± 2,0) | µGal | (Août | 1970) |
| | ( 45,3 ± 2,2) | " | (Octobre | 1970) |
| | ( 86,3 ± 9,4) | " | (fin Décembre | 1970) |
| | ( 79,6 ± 6,0) | " | (Janvier | 1971) |
| $g_{A2}$ = | ( 74,7 ± 9,7) | " | (Février | 1971) |
| | ( 71,0 ± 8,7) | " | (Mai | 1971) |
| | ( 80,1 ± 6,2) | " | (Juin | 1971) |
| | ( 76,7 ± 5,5)* | " | (Juillet | 1971) |

La fig. 1 présente également tous les résultats de même nature obtenus depuis quatre ans.

Ce prototype de gravimètre absolu est composé actuellement par une centaine d'appareils. Les manipulations et l'entretien de ces appareils sont assez complexes. Néanmoins, les améliorations apportées jusqu'à présent permettent de mesurer g, par un seul opérateur, après une heure de préparation, à la cadence d'une mesure de g toutes les 10 à 15 minutes, sauf pendant les tremblements de terre.

Ce gravimètre pourra être utilisé, dans l'avenir, pour plusieurs études géophysiques; vérification de la marée gravimétrique théorique, l'effet de l'affaiblissement du sol sous la surcharge atmosphérique, corrélations entre les dérives de g et les mouvements du pôle, etc.

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* Résultat provisoire.

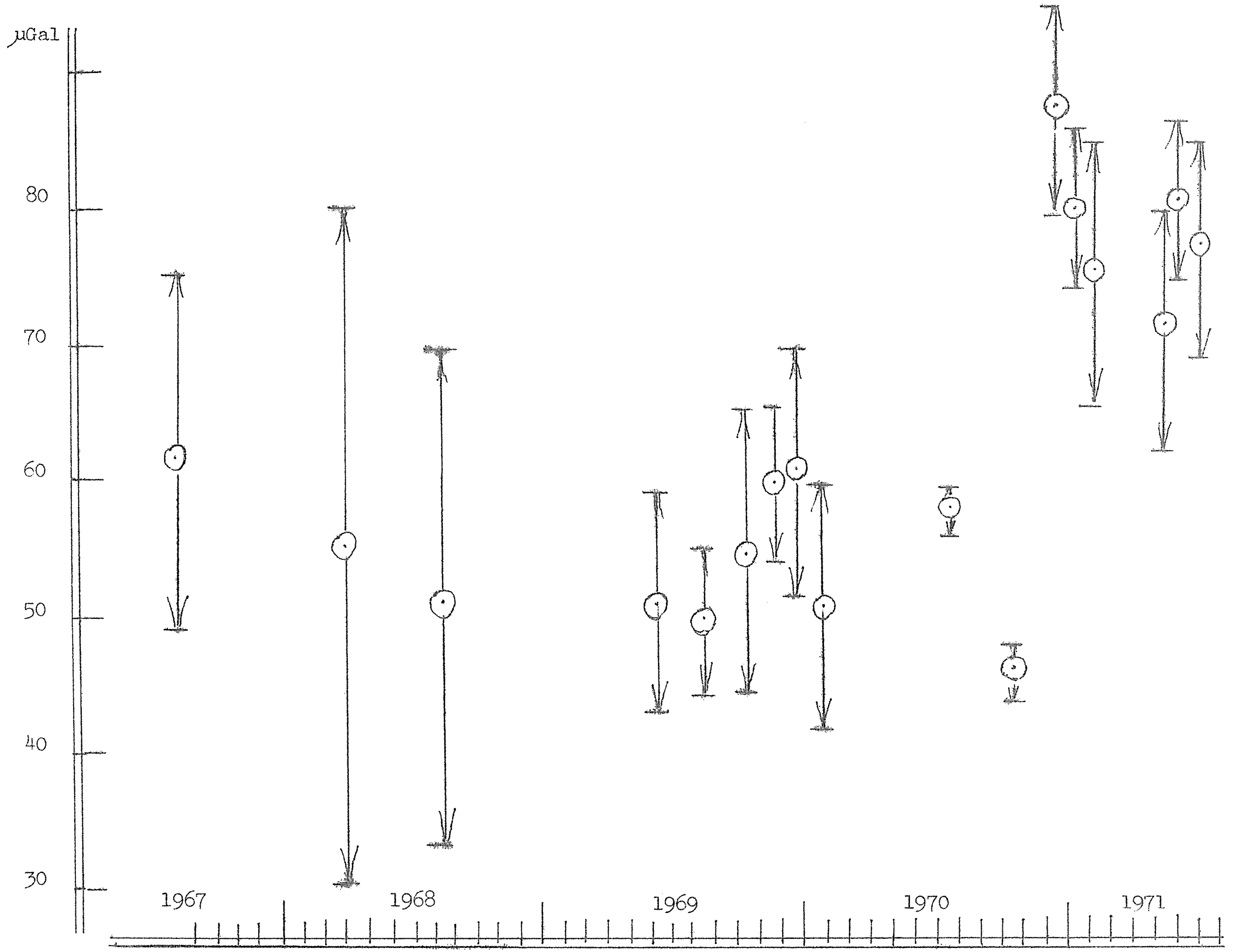

Fig. 1 - Valeurs moyennes de g avec les écarts types d'une mesure à SEVRES Point A2 ; $g_{A2}$ = 980 925 600 µGal + les valeurs en ordonnées

ANNEXE C

# REPORT OF IAG SPECIAL STUDY GROUP N° 4.21 ON "SPECIAL TECHNIQUES OF GRAVITY MEASUREMENTS"

T. HONKASALO

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A provisional Report was presented to the IGC (Paris, September 1970) and published in Bulletin Information N° 24 (I-52).

As the Report presented to the General Assembly in Moscow (August 1971) was only partly changed, we give hereafter some complementary information extracted of the last Report.

## 1 - INTRODUCTION

To study the secular variation of gravity, to predict earthquakes, and for some other purposes, gravity measurements of high precision are necessary. To collect experiences and initiate new methods, a new special study group was established at the General Assembly of the IAG in Lucerne.

The SSG prepared a preliminary report on special gravity measurements based on 13 answers received to a circular sent ou by the president of the SSG. This preliminary report was supplemented by 9 new pieces of information on a new circular sent out in February 1971.

...............

## 3 - THE WORKING OF THE SSG

The special Study groups of the IAG usually do nothing else but collect experiences and ideas from the specific field appointed for the SSG, and circulate its report. Other functions would be possible only if sponsored by the IAG or some other institutions. So far this SSG has only reported on the studies made by various institutes. Most of the members have considered that "there is no basis for continuing unless it undertakes to co-ordinate a specific project".

The following reports on special accurate gravity measurements in various countries and some new instrumental or measuring technique ideas.

## 4 - SPECIAL ACCURATE GRAVITY MEASUREMENTS

..............

### General remarks

The following sources of disturbances in gravity measurements have been commonly given.

...

1. Vibration during transport or ground vibration can cause serious inaccuracies in the precise measurements (A.C. HAMILTON, B.C BARLOW, W. BULLERWELL, M. BONATZ, T. MURPHY, E. GROTEN, etc.).

2. Rapid or slow temperature changes have an effect on reading and scale (A. KIVINIEMI, Cl. ELSTNER, R. SIGL, E. GROTEN).

3. Mechanical shocks, also clamping the instrument, cause changes in readings (J.G. TANNER, R. BREIN).

4. In addition to air pressure influence on the gravimeter, the mass of air above the station and the deformation of the earth's crust caused by pressure changes must be taken into consideration in high precision accuracy measurements (A. KIVINIEMI, R. BREIN, R. LECOLAZET).

5. The variation of ground water level can cause larger changes than is generally appreciated (G. BARTA, W. BULLERWELL).

6. The selection of sites for high precision measurements is very important. The gravity differences to be measured should be as small as possible.

## 5 - NEW CONSTRUCTIONS

In the Institut für Angewandte Geodäsie in Frankfurt a new gravimeter for accurate measurement of small gravity differences has been constructed and a testing instrument built (4). This consists of a vertical spring balance. The reading device is a capacitance bridge, the reading accuracy of which corresponds to ±1 uGal. An electromagnetic spring is situated below the capacitor. The current in the electric coil is changed until the indication of the capacitor bridge is zero. The electric current in the coil is the measure of gravity difference. The elimination of seismic perturbations is carried out by air damping of the capacitor device and by electronic integration.

A continuously recording, drift-free cryogenic gravimeter with very high sensitivity is under development at Stanislaws State College, in California, for AFCRL (12). A niobium hollow sphere floats freely in a properly adjusted magnetic field and field gradient produced with niobium zirconium coils in super-conduction state at 4°2 K. The motion of the ball induces magnetic flux changes, which are recorded. The theoretical accuracy of this instrument is $10^{-8}$ Gal. This instrument is suitable for studying :

1. The secular variation of gravity

2. The variation of station positions with respect to the centre of mass or the variation of the Newtonian constant "G".

3. The correlation between short and long period variations and the angular velocity of the Earth's rotation.

4. The dynamic processes occurring inside the Earth.

A dynamic gravity gradient gradiometer has been developed by Dr. R. FORWARD of the Hughes Research Laboratories (U.S.A.)(13).

The basic principle of the rotating gradient sensor is as follows: If a system of proof masses is rotated in the static gravitational field of an object, the gravitational force gradient of this field will induce dynamic forces on the proof masses with an frequency which is twice the rotation frequency of the system; at the same time, inertial effects, caused by accelerations of the proof mass mounting, will induce forces with a frequency at the rotational frequency. The gravitational gradient can therefore be determined independently of inertial forces, also if the proof mass system is in free fall.

The Laboratory prototype has reached an accuracy of $\pm 1$ E.U. at an integration time of 10 sec.

The instrument will have applications in airborne, marine and satellite gravimetry and navigation.

Dr. M. BONATZ, at the Institut für Theoretische Geodesie der Universität Bonn, has constructed an astatized lever arm balance to measure small vertical differences in gravity (1). The instrument has been tested on the vertical calibration base of the University of Bonn and an accuracy of $\pm 0.01$ mGal with one measurement has been achieved.

Prof. GROTEN of the Technische Hochschule, Darmstadt, has used a LaCoste-Romberg gravimeter with a capacitance-read-out-system with a strip chart recorder to study vertical gradient. µGal accuracy has been obtained. Prof. GROTEN also proposes to remeasure the Gravitational Constant using gravimeters and heavy masses which he has used for calibration of gravimeter (6).

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# TABLES FOR CONDENSATION REDUCTION

J.C. BHATTACHARJI

Survey of India, Dehra Dun

Summary

By making use of the rigorous formula as already developed by the author (BHATTACHARJI 1969) for the determination of condensation reduction on the basis of spherical hypothesis for the mathematical form of the earth, suitable reduction tables are worked out in the form of fundamental and special tables easily adaptable for general use at condensation surfaces of any elevations including those of the Earth model and the geoid.

## INTRODUCTION

One of the most important geodetic applications of gravity anomalies is the determination of the shape of the geoid. By making use of Green's theorem, one can ultimately obtain the form of the surface parallel to the geoid (Ellipsoid) on having known its gravity anomaly field provided all terrestrial masses external to the surface are imagined as being transferred either to infinity or to within the surface (Heiskanen and Vening Meinesz 1958). But from practical point of view it becomes essential that the intended mass-transfers should cause as little change in the shape of the surface as possible. Hence Stokes and later Helmert introduced the condensation reduction for the purpose. In this reduction all terrestrial masses external to the geoidal surface are condensed into a surface layer of infinitesimal thickness lying on the geoid itself. The ideal geoid after condensation is found to differ from the actual geoid by only 3 metres in extreme cases and perhaps 1 metre on the average (Lambert 1930). But in the case of the Earth model surface, the entire mass-transfers involved being very limited, the corresponding intermediate surface or the co-geop similar to the ideal geoid in the case of the geoid, does not appreciably differ from the Earth model surface we seek to study. Now as a result of condensation into a surface layer either on the geoid or the Earth model or any other condensation surface, the value of gravity observed at a station on the physical surface of the earth is bound to undergo change by an amount equal to the gravity effect E at a point on the condensation surface vertically below or above the station of observation, due to the condensed topographic mass minus the gravity effect T at the station of observation, due to the same amount of the actual topographic mass lying above the condensation surface considered. This is taken as appro-wimately equal to the "Gelandereduktion" or "Topographiche Korrektion" of Borrass's reports on gravity (Lambert 1930), but is significantly in error in the oceanic region as well as in regions or rugged topography, especially when the station of observation is at a lower elevation, as will be quite clear from the examples cited at the end. The procedure followed by Cassinis in his Fundamental Tables, is also quite approximate, as he seems to have avoided the rigorous treatment of the problem thinking it to be too much complicated for a pratical solution (Cassinis and Dore 1937).

An attempt has therefore been made to make use of the rigorous formula as already developed by the author (Bhattacharji 1969) and reproduced here for reference, for a precise solution on the basis of spherical hypothesis for the mathematical form of the earth and then design suitable reduction tables easily adaptable for general use. The gravity effect T of the actual topographic mass requires to be computed by the usual methods (Bullard 1936, Cassinis and Dore 1937, and Bhattacharji 1963 & 1965) ; while the effect E of the condensed topography evaluated with the help of the fundamental or special tables for condensation reduction given in this publication.

## DERIVATION OF CONDENSATION REDUCTION FORMULA

In Fig. 2, let be $H_s$ the elevation of the station S, and H (positive upwards above the geoid) be the elevation of the zone on the Hayford system, having uniform density of unity throughout and bounded by the angular distances $\theta_1$ and $\theta_2$ so that

$$h = H - H_s$$

$$r = R + H_s$$

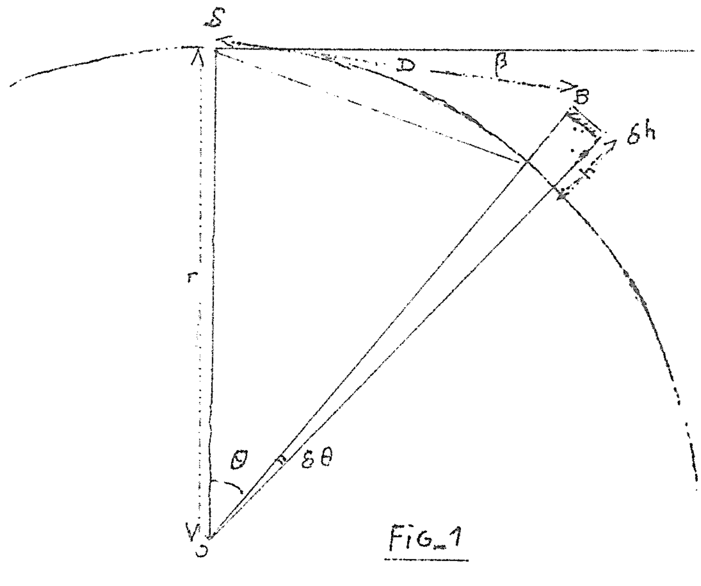


FIG_1

where the mean radius R of the International Ellipsoid is equal to 6371.2 km.

Let an elementary mass dm at B (Fig. I ) be at an angular distance $\theta$ and direct distance D from S.

Then the vertical component of the attractive effect dT at S of the elementary mass dm at B, acting upon a unit mass of one gramme at S, becomes :

$$dT = \frac{K\,dm}{D^2} \sin\beta$$

where $K = 6.67 \times 10^{-8}$ c.g.s., the constant of gravitation

$$dm = 2\pi(r+h)^2 \sin\theta .\ d\theta .\ dh$$

and $\beta$ = the angle of depression / elevation of the straight distance from S to B, below / above the horizon at S. (Fig.I )

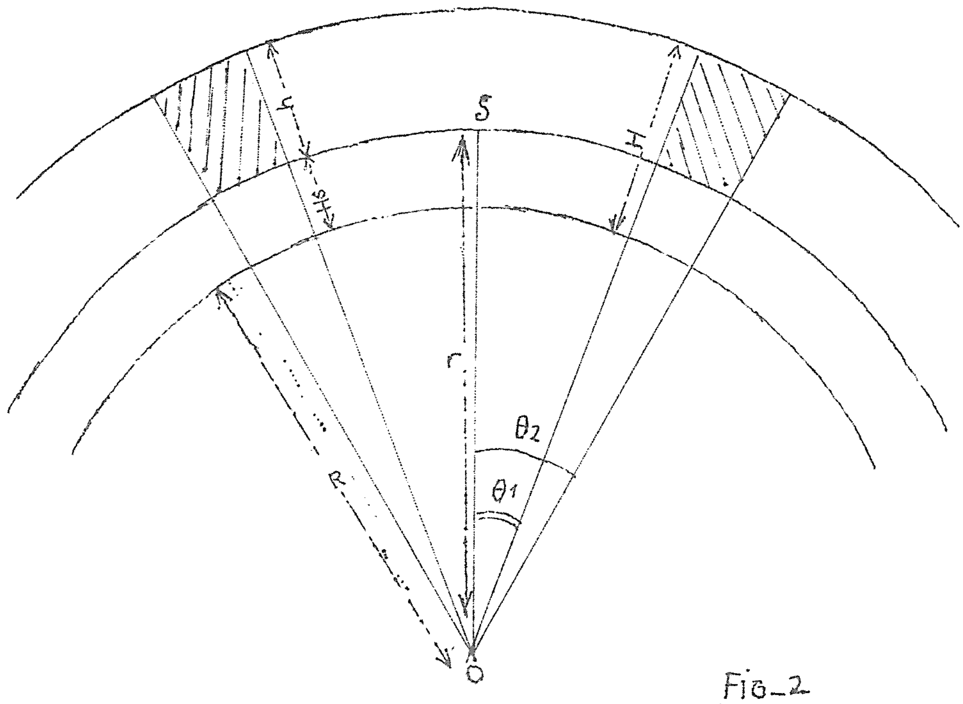


FIG-2

Now from Fig. I , we have,

$$\sin\beta = \frac{r - (r+h)\cos\theta}{D} = \frac{2\,(r+h)\sin^2\theta/2}{D} - \frac{h}{D}$$

$$dT = \frac{2\pi K\,(r+h)^2 \sin\theta d\theta .\ dh}{D^3}\left\{2\,(r+h)\,\sin^2\frac{\theta}{2} - h\right\}$$

$$= 2\pi K\,(1+y)^2\left\{2\,(1+y)\,x^2 - y\right\}\frac{\sin\theta . d\theta .\ dh}{F^{3/2}}$$

where $x = \sin\frac{\theta}{2}$ , $y = \frac{h}{r}$

$$F = \frac{D^2}{r^2} = \frac{1}{r^2}\left[ r^2 + (r+h)^2 - 2r\,(r+h)\cos\theta \right] = 4\,x^2\,(1+y)+y^2$$

$$dh = r dy \quad ; \qquad \text{and } 1 - x^2 = \cos^2 \frac{\theta}{2}$$

$$\sin\theta \, d\,\theta = 2\,d(x^2)$$

thus

$$dT = \frac{4\pi K\,(1+y)^2\,\left[2\,x^2\,(1+y) - y\right]\;d(x^2).\,dh}{\left[4\,x^2\,(1+y) + y^2\right]^{3/2}} \qquad (\text{ I })$$

Now on integrating the above, and remembering that the gravity effect E of the actual topography condensed into a surface layer of thickness of 1 metre and of superficial density $\tau$ on the condensation surface $\bar{H}$ is equivalent to $\tau\left(\frac{dT}{dh}\right)_{h = \bar{H} - H_s}$ where $\bar{H}$ is the elevation of the condensation surface, we have :

$$E = \tau\, dT = \left\{ 4\pi\, K\, \tau\, (1+y)^2 \int \frac{\left[2x^2\,(1+y) - y\right]}{\left[4x^2\,(1+y) + y^2\right]^{3/2}} \cdot (x^2) \right\} \text{ X 100 gal} \quad h = \bar{H} - H_s$$

or

$$E = 200\,\pi\, k\, \tau \left[ \frac{(1+y)^2\,(y+2x^2)}{\left\{4x^2\,(1+y) + y^2\right\}^{1/2}} \right]_{x_1}^{x_2} , \; h = \bar{H} - H_s \qquad (\text{ 2 })$$

where $x_1$ and $x_2$ denote the sines of half the angular distances of the inner and outer radii of the considered zone and superficial density $\tau$ of the condensed layer as given by Cassinis is

$$- \qquad \delta_1 (H_1 - \bar{H}) \left( 1 + \frac{H_1 - \bar{H}}{R} - \frac{20}{3}\,\frac{\bar{H}^2}{R^2} + \ldots \right)$$

in the case of the continental zone of density $\delta_1$ and elevation $H_1$ (in metres)

$$- \text{ and } \; \delta_1 (H_2 - \bar{H}) \left(1 + \frac{H_2 - \bar{H}}{R} - \frac{20}{3}\,\frac{\bar{H}^2}{R^2} + \ldots\right) - \delta_2\; H_2 \left(1 + \frac{H_2 - 2\bar{H}}{R} - 5\,\frac{\bar{H}^2}{R^2} + \ldots\right)$$

in the case of the oceanic zone of density $\delta_2$ and depth $H_2$

$$\text{or} \qquad \delta_1\,(H_1 - \bar{H}) \left(1 + \frac{H_1 - \bar{H}}{R}\right)$$

in the case of the condensation surface at the Earth model surface

$$- \text{ and simply } \; \delta_1 \; H_1 \left(1 + \frac{H_1}{R}\right) \qquad \ldots$$

in the case of the condensation surface at the geoid, the depth of the oceanic zone being completely ignored, in the first case due to all depths of the oceanic zone being converted into negative heights by the relation : $H_1 = -0.615\ H_2$ while smoothening the Earth model surface, and in the second case due to the complete absence of any terrestrial masses lying above the geoid.

## FUNDAMENTAL TABLES FOR REDUCING CONDENSATION EFFECTS AT CONDENSATION SURFACE OF ANY ELEVATION

The expression for condensation effect E as given in relation (2) has been evaluated zone by zone, first by assuming y to be equal to $\frac{h}{R}$ instead of $\frac{h}{R+H_s}$, for different values of h or $\bar{H} - H_s$ from − 9000 m to + 9000 m as given in the fundamental tables, and then by providing appropriate corrections known as corrections for station elevation due to y being assumed to be $\frac{h}{R}$ instead of $\frac{h}{R+H_s}$, for different values of $H_s$, and h from − 9000 m to + 9000 m, in the auxiliary tables given at the end of those fundamental tables where the corrections are considered appreciable. The tabular values have been given correct to $0.5 \times 10^{-8}$ gal (*) in the case of the fundamental tables to $0.5\ H_s \times 10^{-12}$ gal (*) in the case of the auxiliary tables, so that for all normal values of $H_1 - \bar{H}$ or $H_2 - \bar{H}$ and $\bar{H}-H_s$, and of densities $\delta_1$ and $\delta_2$ of the order of 3 and 1 respectively, the final results of the computed effect E of the condensed masses in any one zone may be of the precision of 0.1 mgal.

Example 1.

To find the condensation effect E of the continental zone F of elevation $H_1 = 9500$ and density $\delta_1 = 2.67$, at the station $H_s$, the elevation $H_s$ and that of the condensation surface $\bar{H}$ being 700 m and 500 m respectively.

We have

$$H_1 - \bar{H} = +9000 \text{ m}$$

$$\tau = 2.67 \times 9000 \left(1 + \frac{9000}{6371000} + \ldots.\right) = +24064$$

$$h = \bar{H} - H_s = -200 \text{ m}$$

and from the fundamental tables, ...

---

(*) Tabular values $45\bar{7}$ stands for 456.5, $39\bar{5}$ for 394.5, $0.000\bar{1}\ H_s$ for $0.00005\ H_s$ etc....

$$dT = +28\bar{3} \times 10^{-8} \text{ gal} \qquad (*)$$

Hence the required condensation effect E

$$E = +28\bar{3} \times 24064 \times 10^{-8} \text{ gal} = +68.0 \text{ mgal}$$

N.B. The same according to Cassinis' method = + 68.8 mgal

Example 2.

To find the condensation effect E of the continental zone G of elevation $H_1$ = 8500 m and density $\delta_1$ = 2.67, at the station $H_s$; the elevation $H_s$ and that of the condensation surface $\bar{H}$ being 0 m and − 500 m respectively.

We have,

$$H_1 - \bar{H} = +9000 \text{ m}$$

$$\tau = 2.67 \times 9000 \left(1 + \frac{9000}{6371000} + \ldots\right) = +24064$$

$$h = \bar{H} - H_s = -500 \text{ m}$$

and from the fundamental tables,

$$dT = +305 \times 10^{-8} \text{ gal} \qquad (*)$$

Hence the required condensation effect E

$$= +305 \times 24064 \times 10^{-8} \text{ gal} = +73.4 \text{ mgal}$$

N.B. The same according to Cassinis' method = +72.2 mgal

Example 3.

To find the condensation effect E of the oceanic zone N of depth $H_2$ = − 2000 m and density $\delta_2$ = 1.027, the elevation of the station $I_s$ and that of the condensation surface $\bar{H}$ being 500 m and − 7000 m respectively.

We have,

$$H_2 - \bar{H} = +5000 \text{ m}$$

$$\tau = 2.67 \times 5000 \left(1 + \frac{5000}{6371000} + \ldots\right) + 1.027 \times 2000 \left(1 + \frac{12000}{6371000} + \ldots\right)$$

$$= +15418$$

$$h = \bar{H} - H_s = -7500 \text{ m}$$

and from the fundamental tables,

$$dT = +22\bar{7} \times 10^{-8} \text{ gal} \qquad (*)$$

Hence the required condensation effect E

$$= +22\bar{7} \times 15418 \times 10^{-8} \text{ gal} = +34.9 \text{ mgal}$$

N.B. The same according to Cassinis' method = + 35.5 mgal

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* Correction to dT = 0

## SPECIAL TABLES FOR REDUCING CONDENSATION EFFECTS AT EARTH MODEL AND GEOIDAL SURFACES

Use has been made of the fundamental tables to design 3 special tables for the computation of condensation effects of terrestrial masses at the level of the Earth model surface as well as of the geoid.

Table 1 has been designed for the purpose of obtaining the condensation effect E for the station elevation differences $h_s - H_s$ and the earth's topography $h-H>0$ (topographic masses of heights for negative values of $h - H$ lying below the condensation surface H, negative values of $h - H$ to be taken as zero) condensed at the elevation H of the Earth model surface fo zones H to 12, that for zones A to G and 11 to 1 being negligible.

Table 2 has been designed for the purpose of obtaining the condensation effect E for the terrain of the earth's topography $h-h_s$ (topographic masses of heights for negative values of h lying below the condensation surface at the geoid, negative values of h to be taken as zero ⁎) condensed at the condensation surface at the geoid upto zone $O_2$.

Table 3 has been designed for the purpose of reduciug the topographic-conde sation effects E-T for the terrain of the earth's topography $h-h_s$ (negative values of h to be taken as zero as before ⁎) condensed at the condensation surface on the geoid for zones 18 to 12, that for zones 11 to 1 being negligible as in the case of Table 1. As far as the topographic condensation effects E-T for the earth's plateaux of thickness $h_s$ and density 2.67, considered from zone A to $O_2$ and also between zones 18 and 12 in the case of the condensation surface at the geoid are concerned, these are comparatively small in magnitude and therefore their combined effects have been given at the end of Tables 2 and 3, as corrections for station elevation for zones A to $O_2$ and 18 to 12 respectively, the corresponding corrections for zones 11 to 1 being negligible.

Apart from that, the gravity effect T due to the earth's entire topography lying above the Earth model surface in the case of the condensation surface considered at the Earth model, works out as $T_1 - \underline{O} - (\overline{O} - \Omega)$ (Bhattacharji 1965),

where

$T_1 = (A + 5.6 \times 10^{-3})(h_s - H_s)$ or $0.1174\,(h_s - H_s)$,

which is easily computable by simple multiplications only.

$\underline{O}$ = Terrain effect of the earth's topography $h-h_s$ for zones A to $O_2$, which can be easily read off from the table given by the author in his previous paper (Bhattacharji, 1963, pp. 26-27), and

....

⁎ In this case, the terrain effect $\underline{O}$ or $\overline{O}$ for elevations h is also to be substracted from the computed res lts.

$(\bar{O} - \bar{\Omega})$ = Terrain effect $\bar{O}$ of the earth's topography $h - h_s$ for zonez 18 to 12 <u>minus</u> terrain effect of the topography of the Earth model $H - H_s$ for zones 18 to 12, which can be easily read off from the table given by the author in his previous paper (Bhattacharji 1965, pp. 24-25).

Thus the topographic effects as obtained above, when substracted from the corresponding condensation effects E as read off from Table 1 and Tables 2 & 3 respectively, will furnish the topographic condensation effects E-T for the entire earth in the case of the Earth model surface and the geoidal surface separately.

The tabular values have been given correct to $0.5 \times 10^{-5}$ gal in the case of the main tables and to $1.0 \times 10^{-4}$ gal in the case of the corrections for station elevations, so that the final results of the computed effects may be of the precision of about 0.1 mgal.

Example 1.

To find the condensation effect E of the continental zone K of elevation h = 6000 m and density 2.67, the elevation of the station $H_s$ and that of the condensation surface H at the Earth model being 4000 m and 3000 m respectively.

We have :

$$h - H = + 3000 \text{ m}$$

$$H - H_s = - 1000 \text{ m}$$

and from Table 1,

$$E = + 0.4\bar{7} \times 20 = + 9.3 \text{ mgal}$$

N.B. The same according to Cassinis' method = + 9.6 mgal. (x)

Example 2.

To find the condensation effect E of the <u>oceanic zone K</u> of depth d = - 4000 m and density 1.027, the elevation of the station $H_s$ and that of the condensation surface H at the Earth model being - 4000 m and - 5000 m respectively.

We have :

$$h = -0.615 \times 4000 \text{ m} = -2460 \text{ m}$$

$$h - H = -2460 \text{ m} + 5000 \text{ m} = +2540$$

$$H - H_s = -1000 \text{ m}$$

....

(x) See p. T - II the results obtained by Cassinis' method and Lambert's formula.

and from Table 1,

$$E = +0.4\overline{0} \times 20 = +7.9 \text{ mgal} \qquad (*)$$

Example 3.

To find the topographic-condensation effect E-T of the continental zones A to $O_2$ of elevations h = 1000 m for zones A to K and 5000 m for zones L to $O_2$, and density 2.67, at the geoidal surface, the elevation of the station $h_s$ being 1000 m.

we have

$$h - H_s = 0 \text{ for zones A to K and } +4000 \text{ m for zones L to } O_2.$$

From Table 2,

$$E = +0.015 \times 24 + 0.075 \times 14 + 0.09 \times 16 + 0.04 \times 28 + 0.04 \times 28$$

$$= + 5.1 \text{ mgal.}$$

Correction for station elevation = +0.4 mgal and from the table of terrain effect $\underline{O}$ (Bhattacharji 1963, pp. 26-27),

$$\underline{O} = -36.5 \text{ mgal}$$

Hence the required topographic-condensation effect E-T

$$= +5.1 + 0.4 + 36.5 = +42.0 \text{ mgal.} \qquad (*)$$

Example 4.

Same as Example 3 except that the elevations of the station $h_s$ and of the zones A to K = 6000 m instead of 1000 m.

We have :

$$h - h_s = 0 \text{ for zones A to K, and } -1000 \text{ m for zones L to } O_2.$$

From Table 2 :

$$E = -0.005 \times 24 - 0.02 \times 14 - 0.02 \times 16 - 0.01 \times 28 - 0.01 \times 28$$

$$= -1.3 \text{ mgal.}$$

Correction for station elevation = +12.7 mgal and from the table of terrain effect $\underline{O}$ (Bhattacharji 1963, pp. 26-27).

$$\underline{O} = -3.9 \text{ mgal}$$

Hence the required topographic-condensation effect E-T

$$= -1.3 + 12.7 + 3.9 = + 15.3 \text{ mgal.} \qquad (*)$$

(*) See remark p. T - 8

Example 5.

To find the topographic-condensation effect E–T of zones A to $O_2$ of elevations h = 1500 m for zones A to M, and d = 2000 m for zones N to $O_2$, and densities $\delta_1$ = 2.67 and $\delta_2$ = 1.027, at the geoidal surface, the elevation of the station $h_s$ being 1500 m.

We have :

$$h - h_s = 0 \text{ for zones A to M, and } -1500 \text{ m for zones N to } O_2 ,$$
h being negative

From Table 2,

$$E = -0.035 \times 16 - 0.015 \times 28 - 0.015 \times 28$$

$$= -1.4 \text{ mgal}$$

Correction for station elevation = +0.8 mgal and from the table of terrain effect O (Bhattacharji 1963, pp. 26–27)

$$O = -5.0 \text{ mgal}$$

Hence the required topographic-condensation effect E–T

$$= -1.4 + 0.8 + 5.0 = +4.4 \text{ mgal} \qquad (\text{x})$$

Example 6.

To find the topographic-condensation effect E–T of the continental zones 18 to 12 of elevations h = 4000 m and density 2.67 at the geoidal surface, the elevation of the station $h_s$ being 1000 m.

We have, :

$$h - h_s = +3000 \text{ m}$$

From Table 3,

$$E-T = +0.035 \times 10 + 0.03 \times 10 + 0.03 \times 10 + 0.03 \times 10 + 0.03 \times 10$$
$$+ 0.025 \times 16 + 0.025 \times 10$$
$$= +2.2 \text{ mgal}$$

Correction for station elevation = –0.3 mgal.

Hence the required topographic-condensation effect E–T

$$= +2.2 - 0.3 = +1.9 \text{ mgal.} \qquad (\text{x})$$

(x) See remark p. T - 8

Example 7.

Same as Example 6 except that the elevation of the station $h_s$ = 7000 m instead of 1000 m.

We have :

$$h - h_s = -3000 \text{ m}$$

From Table 3,

$$E-T = +0.035 \times 10 + 0.03 \times 10 + 0.03 \times 10 + 0.03 \times 10$$
$$+0.03 \times 10 + 0.025 \times 16 + 0.025 \times 10$$
$$= +2.2 \text{ mgal.}$$

Correction for station elevation = − 12.1 mgal.

Hence the required topographic-condensation effect E-T

$$= +2.2 - 12.1 = -9.9 \text{ mgal} \qquad (\text{x})$$

Abstract of Results

| Examples | Results obtained by | | | Discrepancy | |
|---|---|---|---|---|---|
| | Suggested method (1) | Cassinis' method (2) | Lambert's method (3) | (1)-(2) | (1)-(3) |
| | mgal | mgal | mgal | mgal | mgal |
| 1 p.T-6 | + 68.0 | + 69.8 | − | − 1.8 | − |
| 2 p.T-6 | + 73.4 | + 72.2 | − | + 1.2 | − |
| 3 p.T-6 | + 34.9 | + 35.5 | − | − 0.6 | − |
| 1 p.T-8 | + 9.3 | + 9.6 | − | − 0.3 | − |
| 2 p.T-9 | + 7.9 | + 8.1 | − | − 0.2 | − |
| 3 p.T-9 | + 42.0 | + 42.9 | + 36.5 | − 0.9 | + 5.5 |
| 4 p.T-9 | + 15.3 | + 19.2 | + 3.9 | − 3.9 | + 11.4 |
| 5 p.T-10 | + 4.4 | + 5.7 | + 7.1 | − 1.3 | − 2.7 |
| 6 p.T-10 | + 1.9 | + 2.0 | 0 | − 0.1 | + 1.9 |
| 7 p.T-11 | − 9.9 | − 9.9 | 0 | 0.0 | − 9.9 |

(x) See remark p. T − 8

## CONCLUSION

From the abstract of results obtained by various methods as illustrated above, it becomes immediately clear that the reduction tables incorporated in this publication are not only more easily adaptable for general use than any of the existing methods, but also most essential for the precise determination of the condensation reductions carried out on different hypotheses having condensation surfaces of any elevations including those of the geoid and the Earth model, and as such, will prove useful in solving various delicate problems relating to reductions of condensation correction involved in physical geodesy.

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# F U N D A M E N T A L   T A B L E S

in units of $10^{-8}$ Gal

## Z O N E A

0 -- 2m

| $h_m$ | $dT x 10^8$ | $h_m$ | $dT x 10^8$ | $h_m$ | $dT x 10^8$ | $h_m$ | $dT x 10^8$ |
|---|---|---|---|---|---|---|---|
| ∓ 0 | ± 4181 | ∓ 18 | ± 2$\bar{6}$ | ∓ 36 | ± $\bar{7}$ | ∓ 70 | ± $\bar{2}$ |
| 1 | 2317 | 19 | 23 | 37 | 6 | 75 | $\bar{2}$ |
| 2 | 1228 | 20 | 21 | 38 | 6 | 80 | $\bar{2}$ |
| 3 | 704 | 21 | 19 | 39 | $\bar{6}$ | 85 | 1 |
| 4 | 44$\bar{3}$ | 22 | 17 | 40 | 5 | 90 | 1 |
| 5 | 300 | 23 | 16 | 41 | 5 | 95 | 1 |
| 6 | 215 | 24 | 1$\bar{5}$ | 42 | $\bar{5}$ | 100 | 1 |
| 7 | 16$\bar{2}$ | 25 | 1$\bar{4}$ | 43 | $\bar{5}$ | 105 | 1 |
| 8 | 125 | 26 | 1$\bar{3}$ | 44 | $\bar{5}$ | 110 | $\bar{1}$ |
| 9 | 100 | 27 | 1$\bar{2}$ | 45 | 4 | 115 | $\bar{1}$ |
| 10 | 8$\bar{2}$ | 28 | 1$\bar{1}$ | 46 | 4 | 120 | $\bar{1}$ |
| 11 | 6$\bar{8}$ | 29 | 10 | 47 | 4 | 125 | $\bar{1}$ |
| 12 | 57 | 30 | 1$\bar{0}$ | 48 | $\bar{4}$ | 130 | $\bar{1}$ |
| 13 | 49 | 31 | $\bar{9}$ | 49 | $\bar{4}$ | 135 | $\bar{1}$ |
| 14 | 42 | 32 | 8 | 50 | $\bar{4}$ | 140 | $\bar{1}$ |
| 15 | 37 | 33 | $\bar{8}$ | 55 | 3 | 145 | $\bar{1}$ |
| 16 | 3$\bar{3}$ | 34 | 7 | 60 | $\bar{3}$ | 150 | $\bar{1}$ |
| 17 | 2$\bar{9}$ | 35 | 7 | 65 | 2 | 200 | 0 |
| ∓ 18 | ± 2$\bar{6}$ | ∓ 36 | ± 7 | ∓ 70 | ± $\bar{2}$ | ∓ 9000 | ± 0 |

ZONE B

2m - 68m

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| $\mp$ 0 | $\pm$ 0 | $\mp$ 120 | $\pm$ 544 | $\mp$ 240 | $\pm$ $15\bar{9}$ | $\mp$ 600 | $\pm$ $2\bar{7}$ |
| 5 | $368\bar{4}$ | 125 | 509 | 245 | $15\bar{3}$ | 650 | $2\bar{3}$ |
| 10 | $350\bar{0}$ | 130 | 477 | 250 | 147 | 700 | $2\bar{0}$ |
| 15 | $325\bar{2}$ | 135 | $44\bar{8}$ | 255 | $14\bar{2}$ | 750 | 17 |
| 20 | $298\bar{8}$ | 140 | $42\bar{1}$ | 260 | $13\bar{7}$ | 800 | 15 |
| 25 | $273\bar{2}$ | 145 | 396 | 265 | $13\bar{2}$ | 850 | $1\bar{4}$ |
| 30 | 2490 | 150 | $37\bar{4}$ | 270 | 127 | 900 | 12 |
| 35 | 2266 | 155 | $35\bar{3}$ | 275 | $12\bar{3}$ | 950 | $1\bar{1}$ |
| 40 | 2061 | 160 | $33\bar{4}$ | 280 | $11\bar{9}$ | 1000 | $1\bar{0}$ |
| 45 | 1874 | 165 | 316 | 285 | $11\bar{5}$ | 1200 | $\bar{7}$ |
| 50 | 1705 | 170 | $30\bar{0}$ | 290 | $11\bar{1}$ | 1400 | 5 |
| 55 | $155\bar{3}$ | 175 | $28\bar{5}$ | 295 | 107 | 1600 | 4 |
| 60 | 1416 | 180 | 270 | 300 | $10\bar{4}$ | 1800 | 3 |
| 65 | 1293 | 185 | 257 | 320 | $9\bar{2}$ | 2000 | $\bar{3}$ |
| 70 | 1183 | 190 | 245 | 340 | $8\bar{2}$ | 2200 | 2 |
| 75 | $108\bar{5}$ | 195 | $23\bar{4}$ | 360 | 73 | 2400 | $\bar{2}$ |
| 80 | $99\bar{7}$ | 200 | 223 | 380 | $6\bar{6}$ | 2600 | $\bar{2}$ |
| 85 | 917 | 205 | 213 | 400 | 59 | 2800 | 1 |
| 90 | 846 | 210 | $20\bar{4}$ | 420 | 54 | 3000 | 1 |
| 95 | 782 | 215 | 195 | 440 | 49 | 3500 | 1 |
| 100 | $72\bar{5}$ | 220 | $18\bar{7}$ | 460 | 45 | 4000 | $\bar{1}$ |
| 105 | $67\bar{3}$ | 225 | 179 | 480 | $4\bar{2}$ | 5000 | $\bar{1}$ |
| 110 | $62\bar{6}$ | 230 | 172 | 500 | 38 | 6000 | $\bar{1}$ |
| 115 | 583 | 235 | 165 | 550 | $3\bar{2}$ | 7000 | 0 |
| $\mp$ 120 | $\pm$ 544 | $\mp$ 240 | $\pm$ 159 | $\mp$ 600 | $\pm$ 27 | $\mp$ 9000 | $\pm$ 0 |

Z O N E  C  $(C_1+C_2)$

68m - 230m

| $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + 1 | − 1100 | + $8\overline{1}$ | − 500 | + 345 | − 280 | + 834 |
| 7000 | 2 | 1050 | $8\overline{9}$ | 490 | $35\overline{8}$ | 275 | $85\overline{4}$ |
| 6000 | 3 | 1000 | 97 | 480 | 370 | 270 | $87\overline{4}$ |
| 5000 | 4 | 950 | 107 | 470 | $38\overline{4}$ | 265 | $89\overline{5}$ |
| 4000 | $\overline{7}$ | 900 | $11\overline{9}$ | 460 | $39\overline{8}$ | 260 | $91\overline{6}$ |
| 3800 | 7 | 880 | $12\overline{4}$ | 450 | 412 | 255 | $93\overline{8}$ |
| 3600 | 8 | 860 | 129 | 440 | $42\overline{8}$ | 250 | $96\overline{0}$ |
| 3400 | $\overline{9}$ | 840 | 135 | 430 | 444 | 245 | $98\overline{3}$ |
| 3200 | 10 | 820 | $14\overline{2}$ | 420 | 461 | 240 | $100\overline{7}$ |
| 3000 | 11 | 800 | 148 | 410 | $48\overline{0}$ | 235 | $103\overline{1}$ |
| 2800 | 13 | 780 | 155 | 400 | 499 | 230 | $105\overline{6}$ |
| 2600 | 15 | 760 | 163 | 390 | $51\overline{9}$ | 225 | 1081 |
| 2400 | $1\overline{8}$ | 740 | 171 | 380 | 540 | 220 | 1107 |
| 2200 | $2\overline{1}$ | 720 | 180 | 370 | $56\overline{3}$ | 215 | 1134 |
| 2000 | 25 | 700 | $19\overline{0}$ | 360 | $58\overline{7}$ | 210 | 1161 |
| 1900 | $2\overline{8}$ | 680 | 200 | 350 | $61\overline{2}$ | 205 | 1189 |
| 1800 | 31 | 660 | $21\overline{2}$ | 340 | 638 | 200 | 1218 |
| 1700 | $3\overline{5}$ | 640 | $22\overline{4}$ | 330 | $66\overline{7}$ | 195 | 1247 |
| 1600 | 39 | 620 | $23\overline{7}$ | 320 | 696 | 190 | $127\overline{7}$ |
| 1500 | 44 | 600 | 251 | 310 | 728 | 185 | 1307 |
| 1400 | $5\overline{1}$ | 580 | $26\overline{7}$ | 300 | 761 | 180 | $133\overline{8}$ |
| 1300 | $5\overline{9}$ | 560 | $28\overline{4}$ | 295 | $77\overline{9}$ | 175 | $136\overline{9}$ |
| 1200 | 68 | 540 | $30\overline{3}$ | 290 | $79\overline{7}$ | 170 | 1400 |
| 1150 | 74 | 520 | $32\overline{3}$ | 285 | 815 | 165 | 1432 |
| − 1100 | + $8\overline{1}$ | − 500 | + 345 | − 280 | + 834 | − 160 | + $146\overline{4}$ |

Z O N E   C

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| − 160 | + $146\overline{4}$ | − 40 | + 1407 | + 80 | − $181\overline{7}$ | + 200 | − 1218 |
| 155 | $149\overline{6}$ | 35 | $128\overline{8}$ | 85 | 1820 | 205 | $119\overline{0}$ |
| 150 | $152\overline{8}$ | 30 | $115\overline{0}$ | 90 | $181\overline{7}$ | 210 | $116\overline{2}$ |
| 145 | $156\overline{0}$ | 25 | $99\overline{4}$ | 95 | 1808 | 215 | 1134 |
| 140 | $159\overline{1}$ | 20 | $82\overline{0}$ | 100 | $179\overline{5}$ | 220 | 1107 |
| 135 | $162\overline{2}$ | 15 | 630 | 105 | 1777 | 225 | 1081 |
| 130 | $165\overline{2}$ | 10 | 428 | 110 | $175\overline{7}$ | 230 | $105\overline{6}$ |
| 125 | 1680 | − 5 | + $21\overline{7}$ | 115 | 1733 | 235 | $103\overline{1}$ |
| 120 | $170\overline{8}$ | 0 | 0 | 120 | $170\overline{8}$ | 240 | $100\overline{7}$ |
| 115 | 1733 | + 5 | − $21\overline{6}$ | 125 | $168\overline{0}$ | 245 | 983 |
| 110 | $175\overline{7}$ | 10 | $42\overline{8}$ | 130 | $165\overline{2}$ | 250 | 960 |
| 105 | 1777 | 15 | 630 | 135 | $162\overline{2}$ | 255 | $93\overline{8}$ |
| 100 | $179\overline{5}$ | 20 | $82\overline{0}$ | 140 | $159\overline{1}$ | 260 | $91\overline{6}$ |
| 95 | $180\overline{8}$ | 25 | 993 | 145 | $156\overline{0}$ | 265 | $89\overline{5}$ |
| 90 | $181\overline{7}$ | 30 | $115\overline{0}$ | 150 | $152\overline{8}$ | 270 | 874 |
| 85 | 1820 | 35 | $128\overline{8}$ | 155 | $149\overline{6}$ | 275 | $85\overline{4}$ |
| 80 | $181\overline{7}$ | 40 | 1407 | 160 | 1464 | 280 | 834 |
| 75 | $180\overline{6}$ | 45 | 1508 | 165 | 1432 | 285 | 815 |
| 70 | 1786 | 50 | $159\overline{3}$ | 170 | 1400 | 290 | $79\overline{7}$ |
| 65 | 1756 | 55 | 1661 | 175 | $136\overline{9}$ | 295 | 779 |
| 60 | 1715 | 60 | 1715 | 180 | $133\overline{8}$ | 300 | $76\overline{2}$ |
| 55 | 1661 | 65 | 1756 | 185 | 1307 | 310 | 728 |
| 50 | $159\overline{3}$ | 70 | 1786 | 190 | $127\overline{7}$ | 320 | $69\overline{7}$ |
| 45 | 1508 | 75 | $180\overline{6}$ | 195 | 1247 | 330 | $66\overline{7}$ |
| − 40 | + 1407 | + 80 | − $181\overline{7}$ | + 200 | − 1218 | + 340 | − $63\overline{9}$ |

## Z O N E  C

| $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ |
|---|---|---|---|---|---|---|---|
| + 340 | $- 63\bar{9}$ | + 500 | $- 34\bar{6}$ | + 820 | $- 14\bar{2}$ | + 1800 | − 31 |
| 350 | $61\bar{2}$ | 520 | 323 | 840 | 135 | 1900 | $2\bar{8}$ |
| 360 | $58\bar{7}$ | 540 | $30\bar{3}$ | 860 | $13\bar{0}$ | 2000 | 25 |
| 370 | $56\bar{3}$ | 560 | $28\bar{4}$ | 880 | 124 | 2200 | $2\bar{1}$ |
| 380 | 540 | 580 | 267 | 900 | $11\bar{9}$ | 2400 | $1\bar{8}$ |
| 390 | 519 | 600 | 251 | 950 | 107 | 2600 | 15 |
| 400 | $49\bar{9}$ | 620 | $23\bar{7}$ | 1000 | 97 | 2800 | 13 |
| 410 | $48\bar{0}$ | 640 | $22\bar{4}$ | 1050 | $8\bar{9}$ | 3000 | 11 |
| 420 | $46\bar{2}$ | 660 | $21\bar{2}$ | 1100 | 81 | 3200 | 10 |
| 430 | 444 | 680 | 200 | 1150 | 74 | 3400 | $\bar{9}$ |
| 440 | $42\bar{8}$ | 700 | 190 | 1200 | 68 | 3600 | 8 |
| 450 | 412 | 720 | 180 | 1300 | $5\bar{9}$ | 3800 | 7 |
| 460 | $39\bar{8}$ | 740 | $17\bar{2}$ | 1400 | $5\bar{1}$ | 4000 | $\bar{7}$ |
| 470 | $38\bar{4}$ | 760 | 163 | 1500 | 44 | 5000 | 4 |
| 480 | 370 | 780 | $15\bar{6}$ | 1600 | 39 | 6000 | 3 |
| 490 | $35\bar{8}$ | 800 | 148 | 1700 | $3\bar{5}$ | 7000 | 2 |
| + 500 | $- 34\bar{6}$ | + 820 | $- 14\bar{2}$ | + 1800 | − 31 | + 9000 | $- \bar{2}$ |

| h | $\pm$ 1000 |
|---|---|
| Corrections to $dT \times 10^8$ | $\mp 0.000\bar{1}\ H_S$ |

Z O N E  D  ($D_1$+$D_2$)
230m - 590m

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| - 9000 | + $\bar{8}$ | - 2000 | + $14\bar{4}$ | - 1040 | + $44\bar{7}$ | - 500 | + 1098 |
| 8000 | $1\bar{0}$ | 1950 | $15\bar{1}$ | 1020 | $46\bar{1}$ | 480 | $113\bar{5}$ |
| 7500 | 11 | 1800 | 158 | 1000 | $47\bar{5}$ | 460 | $117\bar{2}$ |
| 7000 | $1\bar{3}$ | 1850 | 166 | 980 | $49\bar{0}$ | 440 | $120\bar{9}$ |
| 6500 | $1\bar{5}$ | 1800 | $17\bar{5}$ | 960 | 505 | 420 | $124\bar{6}$ |
| 6000 | 17 | 1750 | 184 | 940 | 521 | 400 | $128\bar{2}$ |
| 5500 | 20 | 1700 | $19\bar{4}$ | 920 | 538 | 390 | 1299 |
| 5000 | $2\bar{5}$ | 1650 | $20\bar{5}$ | $90\bar{0}$ | $55\bar{5}$ | 380 | 1316 |
| 4800 | $2\bar{7}$ | 1600 | 216 | 880 | $57\bar{4}$ | 370 | $133\bar{3}$ |
| 4600 | 29 | 1550 | $22\bar{9}$ | 860 | $59\bar{3}$ | 360 | $134\bar{9}$ |
| 4400 | $3\bar{2}$ | 1500 | $24\bar{3}$ | 840 | $61\bar{3}$ | 350 | 1364 |
| 4200 | $3\bar{5}$ | 1450 | 257 | 820 | 633 | 340 | $137\bar{9}$ |
| 4000 | 38 | 1400 | $27\bar{4}$ | 800 | 655 | 330 | $139\bar{3}$ |
| 3800 | 42 | 1350 | 291 | 780 | 677 | 320 | 1405 |
| 3600 | $4\bar{7}$ | 1300 | $31\bar{1}$ | 760 | $70\bar{1}$ | 310 | $141\bar{7}$ |
| 3400 | 52 | 1280 | $31\bar{9}$ | 740 | 725 | 300 | $142\bar{7}$ |
| 3200 | $5\bar{9}$ | 1260 | 327 | 720 | $75\bar{1}$ | 290 | 1435 |
| 3000 | $6\bar{7}$ | 1240 | 336 | 700 | 777 | 280 | $144\bar{2}$ |
| 2900 | 71 | 1220 | $34\bar{6}$ | 680 | $80\bar{5}$ | 270 | $144\bar{7}$ |
| 2800 | 76 | 1200 | 355 | 660 | 833 | 260 | 1449 |
| 2700 | $8\bar{2}$ | 1180 | 365 | 640 | $86\bar{3}$ | 250 | 1449 |
| 2600 | $8\bar{8}$ | 1160 | $37\bar{6}$ | 620 | 893 | 240 | $144\bar{7}$ |
| 2500 | $9\bar{5}$ | 1140 | 386 | 600 | 925 | 235 | $144\bar{5}$ |
| 2400 | + 102 | 1120 | 397 | 580 | $95\bar{8}$ | 230 | $144\bar{2}$ |
| 2300 | $11\bar{1}$ | 1100 | 409 | 560 | $99\bar{2}$ | 225 | $143\bar{8}$ |
| 2200 | 120 | 1080 | 421 | 540 | 1026 | 220 | $143\bar{3}$ |
| 2100 | 131 | 1060 | $43\bar{4}$ | 520 | $106\bar{2}$ | 215 | 1427 |
| - 2000 | $14\bar{4}$ | - 1040 | + $44\bar{7}$ | - 500 | + 1098 | - 210 | $142\bar{1}$ |

ZONE D

| $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ |
|---|---|---|---|---|---|---|---|
| − 210 | + $142\bar{7}$ | − 75 | + 771 | + 60 | − 634 | + 195 | − 1395 |
| 205 | 1413 | 70 | $72\bar{7}$ | 65 | $68\bar{1}$ | 200 | $140\bar{5}$ |
| 200 | $140\bar{5}$ | 65 | 681 | 70 | $72\bar{7}$ | 205 | 1413 |
| 195 | 1395 | 60 | 634 | 75 | $77\bar{1}$ | 210 | $142\bar{1}$ |
| 190 | $138\bar{5}$ | 55 | 586 | 80 | $81\bar{4}$ | 215 | 1427 |
| 185 | 1373 | 50 | $53\bar{7}$ | 85 | 855 | 220 | $143\bar{3}$ |
| 180 | 1360 | 45 | 486 | 90 | 895 | 225 | $143\bar{8}$ |
| 175 | 1346 | 40 | $43\bar{5}$ | 95 | $93\bar{4}$ | 230 | 1441 |
| 170 | $133\bar{1}$ | 35 | $38\bar{3}$ | 100 | $97\bar{1}$ | 235 | 1445 |
| 165 | 1314 | 30 | $33\bar{0}$ | 105 | 1006 | 240 | $144\bar{7}$ |
| 160 | $129\bar{7}$ | 25 | $27\bar{6}$ | 110 | 1040 | 250 | 1449 |
| 155 | $127\bar{8}$ | 20 | 221 | 115 | $107\bar{3}$ | 260 | 1449 |
| 150 | 1257 | 15 | $16\bar{7}$ | 120 | 1103 | 270 | $144\bar{7}$ |
| 145 | 1235 | 10 | 111 | 125 | $113\bar{3}$ | 280 | $144\bar{2}$ |
| 140 | $121\bar{2}$ | 5 | + $5\bar{6}$ | 130 | $116\bar{1}$ | 290 | 1435 |
| 135 | $118\bar{7}$ | 0 | 0 | 135 | $118\bar{7}$ | 300 | $142\bar{7}$ |
| 130 | $116\bar{1}$ | + 5 | − $5\bar{6}$ | 140 | $121\bar{2}$ | 310 | $141\bar{7}$ |
| 125 | $113\bar{3}$ | 10 | 111 | 145 | $123\bar{5}$ | 320 | 1405 |
| 120 | $110\bar{4}$ | 15 | 166 | 150 | $125\bar{7}$ | 330 | $139\bar{3}$ |
| 115 | $107\bar{3}$ | 20 | 221 | 155 | 1277 | 340 | 1379 |
| 110 | 1040 | 25 | $27\bar{6}$ | 160 | $129\bar{7}$ | 350 | 1364 |
| 105 | 1006 | 30 | 329 | 165 | 1314 | 360 | 1349 |
| 100 | 971 | 35 | 382 | 170 | $133\bar{1}$ | 370 | $133\bar{3}$ |
| 95 | 934 | 40 | $43\bar{5}$ | 175 | 1346 | 380 | 1316 |
| 90 | $89\bar{6}$ | 45 | 486 | 180 | 1360 | 390 | 1299 |
| 85 | $85\bar{6}$ | 50 | $53\bar{7}$ | 185 | $137\bar{3}$ | 400 | $128\bar{2}$ |
| 80 | 814 | 55 | $58\bar{6}$ | 190 | $138\bar{5}$ | 420 | $124\bar{6}$ |
| − 75 | + 771 | + 60 | − 634 | + 195 | − 1395 | + 440 | − $120\bar{9}$ |

## Z O N E  D

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| + 440 | − 120$\bar{9}$ | + 880 | − 574 | + 1350 | − 29$\bar{2}$ | + 2900 | − 71 |
| 460 | 117$\bar{2}$ | 900 | 55$\bar{6}$ | 1400 | 27$\bar{4}$ | 3000 | 6$\bar{7}$ |
| 480 | 113$\bar{5}$ | 920 | 538 | 1450 | 25$\bar{8}$ | 3200 | 5$\bar{9}$ |
| 500 | 1098 | 940 | 52$\bar{2}$ | 1500 | 24$\bar{3}$ | 3400 | 52 |
| 520 | 1062 | 960 | 505 | 1550 | 229 | 3600 | 4$\bar{7}$ |
| 540 | 102$\bar{7}$ | 980 | 49$\bar{0}$ | 1600 | 21$\bar{7}$ | 3800 | 42 |
| 560 | 99$\bar{2}$ | 1000 | 475 | 1650 | 20$\bar{5}$ | 4000 | 38 |
| 580 | 958 | 1020 | 46$\bar{1}$ | 1700 | 194 | 4200 | 3$\bar{5}$ |
| 600 | 925 | 1040 | 447 | 1750 | 184 | 4400 | 3$\bar{2}$ |
| 620 | 89$\bar{4}$ | 1060 | 434 | 1800 | 175 | 4600 | 29 |
| 640 | 86$\bar{3}$ | 1080 | 421 | 1850 | 166 | 4800 | 2$\bar{7}$ |
| 660 | 833 | 1100 | 409 | 1900 | 158 | 5000 | 2$\bar{5}$ |
| 680 | 80$\bar{5}$ | 1120 | 39$\bar{8}$ | 1950 | 151 | 5500 | 2$\bar{1}$ |
| 700 | 77$\bar{7}$ | 1140 | 38$\bar{7}$ | 2000 | 144 | 6000 | 17 |
| 720 | 75$\bar{1}$ | 1160 | 37$\bar{6}$ | 2100 | 13$\bar{2}$ | 6500 | 1$\bar{5}$ |
| 740 | 72$\bar{6}$ | 1180 | 365 | 2200 | 12$\bar{1}$ | 7000 | 1$\bar{3}$ |
| 760 | 701 | 1200 | 355 | 2300 | 11$\bar{1}$ | 7500 | 11 |
| 780 | 67$\bar{8}$ | 1220 | 34$\bar{6}$ | 2400 | 102 | 8000 | 1$\bar{0}$ |
| 800 | 655 | 1240 | 33$\bar{7}$ | 2500 | 9$\bar{5}$ | + 9000 | − $\bar{8}$ |
| 820 | 63$\bar{4}$ | 1260 | 32$\bar{8}$ | 2600 | 8$\bar{8}$ | | |
| 840 | 613 | 1280 | 319 | 2700 | 8$\bar{2}$ | | |
| 860 | 593 | 1300 | 31$\bar{1}$ | 2800 | 76 | | |
| + 880 | − 574 | + 1350 | − 29$\bar{2}$ | + 2900 | − 71 | | |

| h | ± 1000 | ± 2000 |
|---|---|---|
| Corrections to $dTx10^8$ | ∓ 0.0001 $H_s$ | ∓ 0.000$\bar{1}$ $H_s$ |

ZONE E ($E_1+E_2$)

590m - 1280m

| $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ |
|---|---|---|---|---|---|---|---|
| - 9000 | + $3\bar{3}$ | - 3000 | + 257 | - 1450 | + 740 | - 540 | + $120\bar{1}$ |
| 8500 | $3\bar{7}$ | 2900 | $27\bar{3}$ | 1400 | $76\bar{9}$ | 520 | $119\bar{4}$ |
| 8000 | 41 | 2800 | 289 | 1350 | $79\bar{9}$ | 500 | $118\bar{5}$ |
| 7500 | $4\bar{7}$ | 2700 | 307 | 1300 | 830 | 490 | $118\bar{0}$ |
| 7000 | $5\bar{4}$ | 2600 | 327 | 1250 | $86\bar{2}$ | 480 | $117\bar{4}$ |
| 6500 | $6\bar{2}$ | 2500 | 348 | 1200 | $89\bar{5}$ | 470 | 1167 |
| 6000 | 72 | 2450 | $36\bar{0}$ | 1150 | $92\bar{8}$ | 460 | $116\bar{0}$ |
| 5800 | 77 | 2400 | $37\bar{2}$ | 1100 | $96\bar{2}$ | 450 | $115\bar{2}$ |
| 5600 | 82 | 2350 | 384 | 1050 | $99\bar{6}$ | 440 | 1143 |
| 5400 | 88 | 2300 | 397 | 1000 | 1029 | 430 | 1134 |
| 5200 | $9\bar{5}$ | 2250 | 411 | 950 | $106\bar{3}$ | 420 | 1124 |
| 5000 | 102 | 2200 | 425 | 900 | $109\bar{5}$ | 410 | $111\bar{4}$ |
| 4800 | 110 | 2150 | 440 | 850 | $112\bar{5}$ | 400 | 1102 |
| 4600 | 119 | 2100 | 456 | 800 | $115\bar{2}$ | 390 | $109\bar{0}$ |
| 4400 | $13\bar{0}$ | 2050 | $47\bar{3}$ | 780 | $116\bar{2}$ | 380 | $107\bar{7}$ |
| 4200 | 141 | 2000 | $49\bar{0}$ | 760 | 1171 | 370 | 1063 |
| 4000 | $15\bar{5}$ | 1950 | $50\bar{8}$ | 740 | 1179 | 360 | $104\bar{9}$ |
| 3900 | $16\bar{2}$ | 1900 | $52\bar{7}$ | 720 | 1187 | 350 | 1033 |
| 3800 | $17\bar{0}$ | 1850 | 546 | 700 | $119\bar{4}$ | 340 | 1017 |
| 3700 | 178 | 1800 | 567 | 680 | $120\bar{0}$ | 330 | $100\bar{0}$ |
| 3600 | 187 | 1750 | $58\bar{9}$ | 660 | 1204 | 320 | 982 |
| 3500 | $19\bar{7}$ | 1700 | 611 | 640 | 1207 | 310 | 963 |
| 3400 | 207 | 1650 | $63\bar{5}$ | 620 | 1209 | 300 | $94\bar{4}$ |
| 3300 | 218 | 1600 | $66\bar{0}$ | 600 | $121\bar{0}$ | 290 | 923 |
| 3200 | 230 | 1550 | 685 | 580 | $120\bar{9}$ | 280 | $90\bar{2}$ |
| 3100 | 243 | 1500 | 712 | 560 | $120\bar{6}$ | 270 | 879 |
| - 3000 | + 257 | - 1450 | + 740 | - 540 | + $120\bar{1}$ | - 260 | + 856 |

ZONE E

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| − 260 | + 856 | − 10 | + $3\overline{9}$ | + 240 | − $80\overline{7}$ | + 490 | − 1179 |
| 250 | 832 | 0 | 0 | 250 | $83\overline{2}$ | 500 | $118\overline{5}$ |
| 240 | 807 | + 10 | − 38 | 260 | $85\overline{6}$ | 520 | $119\overline{4}$ |
| 230 | 781 | 20 | $7\overline{7}$ | 270 | 879 | 540 | $120\overline{1}$ |
| 220 | $75\overline{5}$ | 30 | $11\overline{5}$ | 280 | 901 | 560 | $120\overline{6}$ |
| 210 | 727 | 40 | $15\overline{3}$ | 290 | $92\overline{3}$ | 580 | 1208 |
| 200 | $69\overline{9}$ | 50 | 190 | 300 | 943 | 600 | $121\overline{0}$ |
| 190 | $67\overline{0}$ | 60 | $22\overline{8}$ | 310 | $96\overline{3}$ | 620 | 1209 |
| 180 | $64\overline{0}$ | 70 | $26\overline{5}$ | 320 | $98\overline{2}$ | 640 | 1207 |
| 170 | 609 | 80 | $30\overline{2}$ | 330 | $100\overline{0}$ | 660 | 1204 |
| 160 | $57\overline{8}$ | 90 | 338 | 340 | $101\overline{7}$ | 680 | $120\overline{0}$ |
| 150 | 545 | 100 | $37\overline{4}$ | 350 | $103\overline{3}$ | 700 | $119\overline{4}$ |
| 140 | 512 | 110 | 409 | 360 | 1048 | 720 | 1187 |
| 130 | $47\overline{9}$ | 120 | 444 | 370 | $106\overline{3}$ | 740 | $118\overline{0}$ |
| 120 | $44\overline{5}$ | 130 | 478 | 380 | $107\overline{7}$ | 760 | 1171 |
| 110 | $41\overline{0}$ | 140 | $51\overline{2}$ | 390 | $109\overline{0}$ | 780 | $116\overline{2}$ |
| 100 | 374 | 150 | $54\overline{5}$ | 400 | $110\overline{2}$ | 800 | $115\overline{2}$ |
| 90 | $33\overline{9}$ | 160 | 577 | 410 | 1113 | 850 | $112\overline{5}$ |
| 80 | 302 | 170 | $60\overline{9}$ | 420 | $112\overline{4}$ | 900 | $109\overline{5}$ |
| 70 | 265 | 180 | 639 | 430 | $113\overline{4}$ | 950 | $106\overline{3}$ |
| 60 | 228 | 190 | 669 | 440 | 1143 | 1000 | $103\overline{0}$ |
| 50 | $19\overline{1}$ | 200 | $69\overline{9}$ | 450 | $115\overline{2}$ | 1050 | 996 |
| 40 | 153 | 210 | $72\overline{7}$ | 460 | $116\overline{0}$ | 1100 | 962 |
| 30 | 115 | 220 | 754 | 470 | $116\overline{7}$ | 1150 | 928 |
| 20 | $7\overline{7}$ | 230 | 781 | 480 | 1173 | 1200 | 895 |
| − 10 | + $3\overline{9}$ | + 240 | − $80\overline{7}$ | + 490 | − 1179 | + 1250 | − 862 |

# Z O N E   E

| $h_m$ | $dT x 10^8$ | $h_m$ | $dT x 10^8$ | $h_m$ | $dT x 10^8$ | $h_m$ | $dT x 10^8$ |
|---|---|---|---|---|---|---|---|
| + 1250 | − 862 | + 1950 | −508 | + 2800 | − 29$\bar{0}$ | + 4400 | − 130 |
| 1300 | 830 | 2000 | 490 | 2900 | 273 | 4600 | 12$\bar{0}$ |
| 1350 | 799 | 2050 | 473 | 3000 | 25$\bar{8}$ | 4800 | 11$\bar{1}$ |
| 1400 | 769 | 2100 | 45$\bar{7}$ | 3100 | 24$\bar{4}$ | 5000 | 102 |
| 1450 | 740 | 2150 | 44$\bar{1}$ | 3200 | 23$\bar{1}$ | 5200 | 95 |
| 1500 | 71$\bar{3}$ | 2200 | 42$\bar{6}$ | 3300 | 21$\bar{9}$ | 5400 | 8$\bar{9}$ |
| 1550 | 68$\bar{6}$ | 2250 | 41$\bar{2}$ | 3400 | 207 | 5600 | 8$\bar{3}$ |
| 1600 | 660 | 2300 | 39$\bar{8}$ | 3500 | 197 | 5800 | 77 |
| 1650 | 635 | 2350 | 38$\bar{5}$ | 3600 | 187 | 6000 | 72 |
| 1700 | 61$\bar{2}$ | 2400 | 372 | 3700 | 178 | 6500 | 62 |
| 1750 | 589 | 2450 | 360 | 3800 | 170 | 7000 | 5$\bar{4}$ |
| 1800 | 56$\bar{8}$ | 2500 | 34$\bar{9}$ | 3900 | 162 | 7500 | 47 |
| 1850 | 54$\bar{7}$ | 2600 | 32$\bar{8}$ | 4000 | 15$\bar{5}$ | 8000 | 4$\bar{2}$ |
| 1900 | 527 | 2700 | 30$\bar{8}$ | 4200 | 14$\bar{2}$ | 8500 | 37 |
| + 1950 | − 508 | + 2800 | − 29$\bar{0}$ | + 4400 | − 130 | + 9000 | − 33 |

| h | $\pm$ 1000 ... $\pm$ 2000 | $\pm$ 3000 ... $\pm$ 5000 |
|---|---|---|
| Corrections to $dT x 10^8$ | $\mp$ 0.0001 $H_s$ | $\mp$ 0.000$\bar{1}$ $H_s$ |

ZONE F ($F_1+F_2$)

1280m–2290m

| $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + 88 | − 5100 | + 242 | − 2700 | + 591 | − 1060 | + 913 |
| 8800 | 91 | 5000 | 250 | 2600 | 615 | 1040 | 910 |
| 8600 | 95 | 4900 | 258 | 2500 | 640 | 1020 | 907 |
| 8400 | 100 | 4800 | 267 | 2400 | 666 | 1000 | 903 |
| 8200 | 104 | 4700 | 276 | 2300 | 692 | 980 | 899 |
| 8000 | 109 | 4600 | 286 | 2200 | 719 | 960 | 895 |
| 7800 | 114 | 4500 | 296 | 2100 | 746 | 940 | 890 |
| 7600 | 120 | 4400 | 306 | 2000 | 773 | 920 | 884 |
| 7400 | 126 | 4300 | 318 | 1900 | 800 | 900 | 878 |
| 7200 | 132 | 4200 | 329 | 1800 | 826 | 880 | 871 |
| 7000 | 139 | 4100 | 341 | 1700 | 850 | 860 | 864 |
| 6800 | 147 | 4000 | 354 | 1650 | 862 | 840 | 857 |
| 6600 | 155 | 3900 | 368 | 1600 | 872 | 820 | 848 |
| 6400 | 164 | 3800 | 382 | 1550 | 882 | 800 | 839 |
| 6200 | 173 | 3700 | 397 | 1500 | 892 | 780 | 830 |
| 6000 | 183 | 3600 | 413 | 1450 | 900 | 760 | 820 |
| 5900 | 189 | 3500 | 429 | 1400 | 907 | 740 | 809 |
| 5800 | 194 | 3400 | 446 | 1350 | 913 | 720 | 798 |
| 5700 | 200 | 3300 | 464 | 1300 | 918 | 700 | 786 |
| 5600 | 206 | 3200 | 483 | 1250 | 920 | 680 | 774 |
| 5500 | 213 | 3100 | 503 | 1200 | 921 | 660 | 760 |
| 5400 | 220 | 3000 | 523 | 1150 | 920 | 640 | 747 |
| 5300 | 227 | 2900 | 545 | 1100 | 917 | 620 | 732 |
| 5200 | 234 | 2800 | 567 | 1080 | 915 | 600 | 717 |
| − 5100 | + 242 | − 2700 | + 591 | − 1060 | + 913 | − 580 | + 701 |

# Z O N E   F

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| − 580 | + 701 | − 100 | + 144 | + 380 | − $50\bar{7}$ | + 860 | − $86\bar{4}$ |
| 560 | $68\bar{5}$ | 80 | $11\bar{6}$ | 400 | $52\bar{9}$ | 880 | 871 |
| 540 | $66\bar{8}$ | 60 | 87 | 420 | $55\bar{1}$ | 900 | $87\bar{8}$ |
| 520 | $65\bar{0}$ | 40 | 58 | 440 | $57\bar{2}$ | 920 | $88\bar{4}$ |
| 500 | 631 | − 20 | 29 | 460 | $59\bar{2}$ | 940 | 889 |
| 480 | $61\bar{2}$ | 0 | + 1 | 480 | $61\bar{2}$ | 960 | 894 |
| 460 | $59\bar{3}$ | + 20 | − $2\bar{9}$ | 500 | $63\bar{1}$ | 980 | $89\bar{9}$ |
| 440 | 572 | 40 | $5\bar{8}$ | 520 | 649 | 1000 | 903 |
| 420 | 551 | 60 | 86 | 540 | 667 | 1020 | $90\bar{7}$ |
| 400 | 529 | 80 | 115 | 560 | 684 | 1040 | $91\bar{0}$ |
| 380 | 507 | 100 | $14\bar{4}$ | 580 | $70\bar{1}$ | 1060 | $91\bar{3}$ |
| 360 | 484 | 120 | $17\bar{2}$ | 600 | $71\bar{7}$ | 1080 | 915 |
| 340 | $46\bar{1}$ | 140 | $20\bar{0}$ | 620 | $73\bar{2}$ | 1100 | 917 |
| 320 | 437 | 160 | $22\bar{8}$ | 640 | 746 | 1120 | $91\bar{9}$ |
| 300 | $41\bar{3}$ | 180 | 255 | 660 | 760 | 1140 | $92\bar{0}$ |
| 280 | $38\bar{8}$ | 200 | 282 | 680 | 773 | 1160 | $92\bar{1}$ |
| 260 | 362 | 220 | 309 | 700 | $78\bar{6}$ | 1180 | 921 |
| 240 | 336 | 240 | 335 | 720 | $79\bar{8}$ | 1200 | 921 |
| 220 | $31\bar{0}$ | 260 | 361 | 740 | $80\bar{9}$ | 1250 | 920 |
| 200 | $28\bar{3}$ | 280 | $38\bar{7}$ | 760 | $82\bar{0}$ | 1300 | $91\bar{8}$ |
| 180 | $25\bar{6}$ | 300 | $41\bar{2}$ | 780 | $83\bar{0}$ | 1350 | 913 |
| 160 | 228 | 320 | 436 | 800 | 839 | 1400 | 907 |
| 140 | $20\bar{1}$ | 340 | 460 | 820 | $84\bar{8}$ | 1450 | 900 |
| 120 | 172 | 360 | $48\bar{4}$ | 840 | 856 | 1500 | $89\bar{2}$ |
| − 100 | + 144 | + 380 | − $50\bar{7}$ | + 860 | − $86\bar{4}$ | + 1550 | − $88\bar{3}$ |

Z O N E   F

| $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ |
|---|---|---|---|---|---|---|---|
| + 1550 | − $88\overline{3}$ | + 2700 | − 591 | + 4300 | − 318 | + 5900 | − 189 |
| 1600 | $87\overline{3}$ | 2800 | 568 | 4400 | 307 | 6000 | $18\overline{4}$ |
| 1650 | $86\overline{2}$ | 2900 | $54\overline{6}$ | 4500 | $29\overline{7}$ | 6200 | $17\overline{4}$ |
| 1700 | 850 | 3000 | 524 | 4600 | 286 | 6400 | 164 |
| 1750 | 838 | 3100 | 503 | 4700 | $27\overline{7}$ | 6600 | 155 |
| 1800 | $82\overline{6}$ | 3200 | $48\overline{4}$ | 4800 | $26\overline{8}$ | 6800 | 147 |
| 1850 | 813 | 3300 | $46\overline{5}$ | 4900 | $25\overline{9}$ | 7000 | $14\overline{0}$ |
| 1900 | 800 | 3400 | $44\overline{7}$ | 5000 | 250 | 7200 | $13\overline{3}$ |
| 1950 | $78\overline{7}$ | 3500 | $43\overline{0}$ | 5100 | 242 | 7400 | $12\overline{7}$ |
| 2000 | $77\overline{4}$ | 3600 | 413 | 5200 | $23\overline{5}$ | 7600 | $12\overline{1}$ |
| 2100 | $74\overline{7}$ | 3700 | $39\overline{8}$ | 5300 | 227 | 7800 | $11\overline{5}$ |
| 2200 | 719 | 3800 | $38\overline{3}$ | 5400 | 220 | 8000 | $11\overline{0}$ |
| 2300 | $69\overline{3}$ | 3900 | $36\overline{9}$ | 5500 | 213 | 8200 | $10\overline{5}$ |
| 2400 | 666 | 4000 | 355 | 5600 | 207 | 8400 | 100 |
| 2500 | $64\overline{1}$ | 4100 | 342 | 5700 | $20\overline{1}$ | 8600 | $9\overline{6}$ |
| 2600 | $61\overline{6}$ | 4200 | $33\overline{0}$ | 5800 | $19\overline{5}$ | 8800 | $9\overline{2}$ |
| + 2700 | − 591 | + 4300 | − 318 | + 5900 | − 189 | + 9000 | − 88 |

| h | $\pm$ 1000 | $\pm$ 2000 ... 4000 | $\pm$ 5000 ... $\pm$ 9000 |
|---|---|---|---|
| Corrections to $dT\times10^8$ | $\pm\ 0.000\overline{1}\ H_s$ | $\mp\ 0.0001\ H_s$ | $\mp\ 0.000\overline{1}\ H_s$ |

## Z O N E   G

2290m–3520m

| $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + 158 | − 5600 | + $33\overline{7}$ | − 3200 | + $58\overline{9}$ | − 1300 | + $61\overline{8}$ |
| 8800 | $16\overline{5}$ | 5500 | $33\overline{9}$ | 3100 | 601 | 1250 | $60\overline{6}$ |
| 8600 | 171 | 5400 | 347 | 3000 | $61\overline{3}$ | 1200 | 593 |
| 8400 | $17\overline{8}$ | 5300 | $35\overline{6}$ | 2900 | 624 | 1150 | $58\overline{0}$ |
| 8200 | 185 | 5200 | $36\overline{5}$ | 2800 | 635 | 1100 | 565 |
| 8000 | $19\overline{3}$ | 5100 | $37\overline{4}$ | 2700 | $64\overline{6}$ | 1050 | 549 |
| 7800 | 201 | 5000 | 383 | 2600 | 655 | 1000 | 532 |
| 7600 | $21\overline{0}$ | 4900 | $39\overline{3}$ | 2500 | $66\overline{4}$ | 900 | 495 |
| 7400 | $21\overline{9}$ | 4800 | $40\overline{3}$ | 2400 | 671 | 800 | $45\overline{4}$ |
| 7200 | $22\overline{9}$ | 4700 | $41\overline{3}$ | 2300 | $67\overline{8}$ | 700 | 408 |
| 7000 | $23\overline{9}$ | 4600 | 423 | 2200 | 682 | 600 | $35\overline{9}$ |
| 6900 | 244 | 4500 | $43\overline{4}$ | 2100 | $68\overline{6}$ | 500 | 305 |
| 6800 | $25\overline{0}$ | 4400 | $44\overline{5}$ | 2000 | $68\overline{7}$ | 400 | $24\overline{9}$ |
| 6700 | 255 | 4300 | $45\overline{6}$ | 1900 | $68\overline{6}$ | 300 | 189 |
| 6600 | 261 | 4200 | 467 | 1800 | 682 | 200 | $12\overline{8}$ |
| 6500 | 267 | 4100 | $47\overline{9}$ | 1750 | 679 | − 100 | 64 |
| 6400 | $27\overline{4}$ | 4000 | $49\overline{1}$ | 1700 | $67\overline{6}$ | 0 | + $\overline{1}$ |
| 6300 | $28\overline{0}$ | 3900 | $50\overline{3}$ | 1650 | $67\overline{2}$ | + 100 | − $6\overline{4}$ |
| 6200 | $28\overline{7}$ | 3800 | $51\overline{5}$ | 1600 | 666 | 200 | $12\overline{7}$ |
| 6100 | 293 | 3700 | 527 | 1550 | $66\overline{1}$ | 300 | 188 |
| 6000 | 300 | 3600 | $54\overline{0}$ | 1500 | $65\overline{4}$ | 400 | $24\overline{8}$ |
| 5900 | $30\overline{8}$ | 3500 | $55\overline{2}$ | 1450 | 646 | 500 | 304 |
| 5800 | 315 | 3400 | 564 | 1400 | $63\overline{8}$ | 600 | $35\overline{8}$ |
| 5700 | $32\overline{3}$ | 3300 | $57\overline{7}$ | 1350 | 628 | 700 | $40\overline{8}$ |
| − 5600 | + $33\overline{7}$ | − 3200 | + $58\overline{9}$ | − 1300 | + $61\overline{8}$ | + 800 | − 453 |

## Z O N E   G

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| + 800 | − 453 | + 2600 | − 655 | + 4400 | − 44$\bar{6}$ | + 6200 | − 28$\bar{8}$ |
| 900 | 49$\bar{5}$ | 2700 | 64$\bar{6}$ | 4500 | 43$\bar{5}$ | 6300 | 28$\bar{1}$ |
| 1000 | 53$\bar{2}$ | 2800 | 63$\bar{6}$ | 4600 | 424 | 6400 | 274 |
| 1100 | 56$\bar{5}$ | 2900 | 62$\bar{5}$ | 4700 | 41$\bar{4}$ | 6500 | 268 |
| 1200 | 59$\bar{3}$ | 3000 | 613 | 4800 | 40$\bar{4}$ | 6600 | 262 |
| 1300 | 617 | 3100 | 60$\bar{2}$ | 4900 | 39$\bar{4}$ | 6700 | 256 |
| 1400 | 637 | 3200 | 59$\bar{0}$ | 5000 | 384 | 6800 | 25$\bar{1}$ |
| 1500 | 65$\bar{4}$ | 3300 | 577 | 5100 | 37$\bar{5}$ | 6900 | 245 |
| 1600 | 666 | 3400 | 56$\bar{5}$ | 5200 | 36$\bar{6}$ | 7000 | 24$\bar{0}$ |
| 1700 | 67$\bar{6}$ | 3500 | 55$\bar{3}$ | 5300 | 35$\bar{7}$ | 7200 | 229 |
| 1800 | 68$\bar{2}$ | 3600 | 540 | 5400 | 348 | 7400 | 22$\bar{0}$ |
| 1900 | 68$\bar{6}$ | 3700 | 52$\bar{8}$ | 5500 | 34$\bar{0}$ | 7600 | 21$\bar{1}$ |
| 2000 | 68$\bar{7}$ | 3800 | 51$\bar{6}$ | 5600 | 33$\bar{2}$ | 7800 | 20$\bar{2}$ |
| 2100 | 68$\bar{6}$ | 3900 | 503 | 5700 | 32$\bar{4}$ | 8000 | 19$\bar{4}$ |
| 2200 | 68$\bar{3}$ | 4000 | 491 | 5800 | 316 | 8200 | 186 |
| 2300 | 67$\bar{8}$ | 4100 | 48$\bar{0}$ | 5900 | 30$\bar{9}$ | 8400 | 17$\bar{9}$ |
| 2400 | 67$\bar{2}$ | 4200 | 468 | 6000 | 301 | 8600 | 17$\bar{2}$ |
| 2500 | 664 | 4300 | 45$\bar{7}$ | 6100 | 294 | 8800 | 165 |
| + 2600 | − 655 | + 4400 | − 44$\bar{6}$ | + 6200 | − 28$\bar{8}$ | + 9000 | − 159 |

| h | ± 1000 | ± 2000 | ± 3000 ... ± 9000 |
|---|---|---|---|
| Corrections to $dTx10^8$ | ± 0.000$\bar{1}$ $H_s$ | 0 | ∓ 0.000$\bar{1}$ $H_s$ |

Z O N E   H

3520m–5240m

| $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + $28\bar{1}$ | − 5600 | + $48\bar{8}$ | − 3200 | + 635 | − 800 | + 297 |
| 8800 | $29\bar{0}$ | 5500 | 495 | 3100 | 636 | 700 | 263 |
| 8600 | 299 | 5400 | 503 | 3000 | 636 | 600 | 228 |
| 8400 | 309 | 5300 | $51\bar{1}$ | 2900 | $63\bar{6}$ | 500 | 192 |
| 8200 | 319 | 5200 | 518 | 2800 | 634 | 400 | 155 |
| 8000 | $33\bar{0}$ | 5100 | $52\bar{6}$ | 2700 | 631 | 300 | 117 |
| 7800 | $34\bar{1}$ | 5000 | $53\bar{4}$ | 2600 | $62\bar{8}$ | 200 | $7\bar{9}$ |
| 7600 | 352 | 4900 | 541 | 2500 | $62\bar{3}$ | − 100 | $4\bar{0}$ |
| 7400 | $36\bar{4}$ | 4800 | $54\bar{9}$ | 2400 | 616 | 0 | + $\bar{1}$ |
| 7200 | 376 | 4700 | 556 | 2300 | 608 | + 100 | − $3\bar{9}$ |
| 7000 | $38\bar{9}$ | 4600 | 563 | 2200 | 599 | 200 | $7\bar{8}$ |
| 6900 | 395 | 4500 | 570 | 2100 | $58\bar{9}$ | 300 | 116 |
| 6800 | $40\bar{2}$ | 4400 | $57\bar{8}$ | 2000 | 576 | 400 | $15\bar{4}$ |
| 6700 | $40\bar{9}$ | 4300 | 584 | 1900 | $56\bar{3}$ | 500 | $19\bar{1}$ |
| 6600 | 415 | 4200 | $59\bar{1}$ | 1800 | 547 | 600 | 227 |
| 6500 | 422 | 4100 | 597 | 1700 | $53\bar{0}$ | 700 | 262 |
| 6400 | 429 | 4000 | 603 | 1600 | $51\bar{1}$ | 800 | 296 |
| 6300 | 436 | 3900 | $60\bar{9}$ | 1500 | 490 | 900 | 328 |
| 6200 | 443 | 3800 | 614 | 1400 | $46\bar{8}$ | 1000 | 359 |
| 6100 | $45\bar{1}$ | 3700 | 619 | 1300 | 443 | 1100 | $38\bar{9}$ |
| 6000 | $45\bar{8}$ | 3600 | 623 | 1200 | 417 | 1200 | $41\bar{7}$ |
| 5900 | 465 | 3500 | 627 | 1100 | $39\bar{0}$ | 1300 | $44\bar{3}$ |
| 5800 | $47\bar{3}$ | 3400 | $63\bar{1}$ | 1000 | 360 | 1400 | $46\bar{7}$ |
| 5700 | 480 | 3300 | 633 | 900 | 329 | 1500 | 489 |
| − 5600 | + $48\bar{8}$ | − 3200 | + 635 | − 800 | + 297 | + 1600 | − 510 |

ZONE H

| $h_m$ | $dT x 10^8$ | $h_m$ | $dT x 10^8$ | $h_m$ | $dT x 10^8$ | $h_m$ | $dT x 10^8$ |
|---|---|---|---|---|---|---|---|
| + 1600 | − 510 | + 3200 | − 635 | + 4800 | − 549 | + 6400 | − 430 |
| 1700 | 529 | 3300 | 633 | 4900 | $54\bar{2}$ | 6500 | 423 |
| 1800 | 546 | 3400 | $63\bar{1}$ | 5000 | 534 | 6600 | 416 |
| 1900 | 562 | 3500 | $62\bar{8}$ | 5100 | $52\bar{7}$ | 6700 | $41\bar{0}$ |
| 2000 | $57\bar{6}$ | 3600 | $62\bar{4}$ | 5200 | 519 | 6800 | 403 |
| 2100 | 588 | 3700 | 619 | 5300 | $51\bar{2}$ | 6900 | 396 |
| 2200 | $59\bar{9}$ | 3800 | $61\bar{5}$ | 5400 | $50\bar{4}$ | 7000 | $39\bar{0}$ |
| 2300 | 608 | 3900 | 609 | 5500 | 496 | 7200 | 377 |
| 2400 | $61\bar{6}$ | 4000 | $60\bar{4}$ | 5600 | $48\bar{9}$ | 7400 | 365 |
| 2500 | 622 | 4100 | $59\bar{8}$ | 5700 | 481 | 7600 | 353 |
| 2600 | 627 | 4200 | 591 | 5800 | $47\bar{4}$ | 7800 | 342 |
| 2700 | 631 | 4300 | $58\bar{5}$ | 5900 | 466 | 8000 | 331 |
| 2800 | $63\bar{4}$ | 4400 | 578 | 6000 | $45\bar{9}$ | 8200 | $32\bar{1}$ |
| 2900 | $63\bar{6}$ | 4500 | 571 | 6100 | $45\bar{2}$ | 8400 | 310 |
| 3000 | 636 | 4600 | 564 | 6200 | 444 | 8600 | $30\bar{1}$ |
| 3100 | 636 | 4700 | $55\bar{7}$ | 6300 | 437 | 8800 | 291 |
| + 3200 | − 635 | + 4800 | − 549 | + 6400 | − 430 | + 9000 | − 282 |

| h | ± 1000 | ± 2000 | ± 3000 | ± 4000 ... ± 9000 |
|---|---|---|---|---|
| Corrections to $dT x 10^8$ | $\pm 0.000\bar{1}\ H_s$ | $\mp 0.000\bar{1}\ H_s$ | 0 | $\mp 0.000\bar{1}\ H_s$ |

## ZONE I

5240m–8440m

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + 564 | − 6600 | + 700 | − 3200 | + 699 | − 800 | + 238 |
| 8900 | $57\bar{0}$ | 6500 | 705 | 3100 | $69\bar{0}$ | 700 | $21\bar{0}$ |
| 8800 | $57\bar{6}$ | 6400 | 710 | 3000 | 679 | 600 | $18\bar{1}$ |
| 8700 | 581 | 6300 | $71\bar{5}$ | 2900 | 668 | 500 | $15\bar{2}$ |
| 8600 | 587 | 6200 | $72\bar{0}$ | 2800 | 656 | 400 | $12\bar{2}$ |
| 8500 | $59\bar{3}$ | 6100 | $72\bar{4}$ | 2700 | $64\bar{4}$ | 300 | $9\bar{2}$ |
| 8400 | $59\bar{9}$ | 6000 | 728 | 2600 | $63\bar{0}$ | 200 | $6\bar{2}$ |
| 8300 | $60\bar{5}$ | 5800 | 736 | 2500 | 615 | − 100 | $3\bar{2}$ |
| 8200 | 610 | 5600 | 743 | 2400 | $60\bar{0}$ | 0 | + 1 |
| 8100 | 616 | 5400 | 749 | 2300 | $58\bar{4}$ | + 100 | − $3\bar{0}$ |
| 8000 | 622 | 5200 | $75\bar{4}$ | 2200 | 566 | 200 | $6\bar{0}$ |
| 7900 | 628 | 5000 | 757 | 2100 | 548 | 300 | $9\bar{0}$ |
| 7800 | $63\bar{4}$ | 4800 | 759 | 2000 | 529 | 400 | $12\bar{0}$ |
| 7700 | $64\bar{0}$ | 4600 | $76\bar{0}$ | 1900 | 509 | 500 | 149 |
| 7600 | 645 | 4400 | $75\bar{8}$ | 1800 | $48\bar{9}$ | 600 | $17\bar{9}$ |
| 7500 | 651 | 4200 | 754 | 1700 | $46\bar{7}$ | 700 | $20\bar{8}$ |
| 7400 | $65\bar{7}$ | 4000 | $74\bar{9}$ | 1600 | 444 | 800 | 236 |
| 7300 | $66\bar{3}$ | 3900 | $74\bar{5}$ | 1500 | 421 | 900 | 264 |
| 7200 | 668 | 3800 | 740 | 1400 | 397 | 1000 | $29\bar{2}$ |
| 7100 | $67\bar{4}$ | 3700 | 735 | 1300 | 372 | 1100 | $31\bar{9}$ |
| 7000 | 679 | 3600 | $73\bar{0}$ | 1200 | $34\bar{7}$ | 1200 | $34\bar{5}$ |
| 6900 | $68\bar{5}$ | 3500 | 723 | 1100 | $32\bar{1}$ | 1300 | 370 |
| 6800 | $69\bar{0}$ | 3400 | $71\bar{6}$ | 1000 | $29\bar{4}$ | 1400 | 395 |
| 6700 | 695 | 3300 | $70\bar{8}$ | 900 | 266 | 1500 | 419 |
| − 6600 | + 700 | − 3200 | + 699 | − 800 | + 238 | + 1600 | − $44\bar{3}$ |

## Z O N E   I

| $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ |
|---|---|---|---|---|---|---|---|
| + 1600 | − $44\bar{3}$ | + 3200 | − 698 | + 5600 | − $74\bar{4}$ | + 7400 | − 658 |
| 1700 | 465 | 3300 | $70\bar{7}$ | 5800 | $73\bar{7}$ | 7500 | $65\bar{3}$ |
| 1800 | $48\bar{7}$ | 3400 | $71\bar{5}$ | 6000 | $72\bar{9}$ | 7600 | $64\bar{7}$ |
| 1900 | $50\bar{8}$ | 3500 | 722 | 6100 | $72\bar{5}$ | 7700 | 641 |
| 2000 | $52\bar{8}$ | 3600 | $72\bar{9}$ | 6200 | 720 | 7800 | 635 |
| 2100 | $54\bar{7}$ | 3700 | $73\bar{5}$ | 6300 | $71\bar{6}$ | 7900 | $63\bar{0}$ |
| 2200 | $56\bar{5}$ | 3800 | $74\bar{0}$ | 6400 | 711 | 8000 | $62\bar{4}$ |
| 2300 | 582 | 3900 | 744 | 6500 | 706 | 8100 | $61\bar{8}$ |
| 2400 | 598 | 4000 | 748 | 6600 | 701 | 8200 | 612 |
| 2500 | $61\bar{4}$ | 4200 | 754 | 6700 | 696 | 8300 | 606 |
| 2600 | $62\bar{9}$ | 4400 | $75\bar{8}$ | 6800 | 691 | 8400 | $60\bar{1}$ |
| 2700 | 642 | 4600 | 759 | 6900 | $68\bar{6}$ | 8500 | $59\bar{5}$ |
| 2800 | 655 | 4800 | 759 | 7000 | 680 | 8600 | $58\bar{9}$ |
| 2900 | 667 | 5000 | 757 | 7100 | $67\bar{5}$ | 8700 | 583 |
| 3000 | 678 | 5200 | 754 | 7200 | 669 | 8800 | 577 |
| 3100 | $68\bar{9}$ | 5400 | 749 | 7300 | $66\bar{4}$ | 8900 | $57\bar{2}$ |
| + 3200 | − 698 | + 5600 | − $74\bar{4}$ | + 7400 | − 658 | + 9000 | − $56\bar{6}$ |

| h | ± 1000 ... ± 3000 | ± 4000 ... ± 5000 | ± 6000 ... ± 9000 |
|---|---|---|---|
| Corrections to $dT \times 10^8$ | $\pm 0.000\bar{1}\, H_s$ | 0 | $\pm 0.000\bar{1}\, H_s$ |

## Z O N E   J

8440m–12440m

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + 595 | − 4800 | + $56\overline{0}$ | + 0 | + $\overline{2}$ | + 4800 | − $55\overline{9}$ |
| 8800 | 599 | 4600 | $54\overline{9}$ | 400 | − 62 | 5000 | 568 |
| 8600 | $60\overline{3}$ | 4400 | $53\overline{7}$ | 800 | $12\overline{5}$ | 5200 | 577 |
| 8400 | $60\overline{6}$ | 4200 | $52\overline{4}$ | 1200 | 285 | 5400 | 585 |
| 8200 | $60\overline{9}$ | 4000 | 509 | 1400 | $21\overline{5}$ | 5600 | $59\overline{2}$ |
| 8000 | 611 | 3800 | $49\overline{4}$ | 1600 | 243 | 5800 | $59\overline{8}$ |
| 7800 | 613 | 3600 | $47\overline{7}$ | 1800 | 271 | 6000 | $60\overline{3}$ |
| 7600 | $61\overline{5}$ | 3400 | $45\overline{9}$ | 2000 | 298 | 6200 | $60\overline{7}$ |
| 7400 | 615 | 3200 | $44\overline{0}$ | 2200 | 324 | 6400 | 610 |
| 7200 | $61\overline{6}$ | 3000 | 419 | 2400 | 349 | 6600 | $61\overline{3}$ |
| 7000 | $61\overline{6}$ | 2800 | $39\overline{8}$ | 2600 | $37\overline{3}$ | 6800 | 614 |
| 6800 | $61\overline{5}$ | 2600 | 375 | 2800 | $39\overline{6}$ | 7000 | 615 |
| 6600 | $61\overline{3}$ | 2400 | 351 | 3000 | 417 | 7200 | $61\overline{6}$ |
| 6400 | $61\overline{1}$ | 2200 | 326 | 3200 | $43\overline{8}$ | 7400 | $61\overline{6}$ |
| 6200 | 607 | 2000 | 300 | 3400 | 457 | 7600 | $61\overline{5}$ |
| 6000 | 603 | 1800 | $27\overline{4}$ | 3600 | 475 | 7800 | 613 |
| 5800 | $59\overline{9}$ | 1600 | $24\overline{6}$ | 3800 | $49\overline{2}$ | 8000 | 611 |
| 5600 | $59\overline{3}$ | 1400 | 217 | 4000 | $50\overline{8}$ | 8200 | 609 |
| 5400 | 586 | 1200 | $18\overline{8}$ | 4200 | 522 | 8400 | 606 |
| 5200 | 578 | 800 | 127 | 4400 | 535 | 8600 | 603 |
| 5000 | $57\overline{0}$ | 400 | $6\overline{5}$ | 4600 | $54\overline{8}$ | 8800 | $60\overline{0}$ |
| − 4800 | + $56\overline{0}$ | − 0 | + $\overline{2}$ | + 4800 | − $55\overline{9}$ | + 9000 | $59\overline{6}$ |

| h | ± 1000 | ± 2000 ... ± 5000 | ± 6000 ... ± 8000 | ± 9000 |
|---|---|---|---|---|
| Corrections to $dTx10^8$ | 0 | ± $0.000\overline{1}\ H_s$ | 0 | ± $0.000\overline{1}\ H_s$ |

# Z O N E   K

12440m–12800m

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + $65\overline{3}$ | − 5000 | + $49\overline{2}$ | + 0 | + 2 | + 5000 | − $48\overline{9}$ |
| 8800 | $65\overline{0}$ | 4800 | $47\overline{8}$ | 400 | − 44 | 5200 | 502 |
| 8600 | $64\overline{6}$ | 4600 | 463 | 800 | $9\overline{0}$ | 5400 | 515 |
| 8400 | $64\overline{2}$ | 4400 | 448 | 1200 | $13\overline{5}$ | 5600 | 527 |
| 8200 | 637 | 4200 | $43\overline{3}$ | 1600 | 179 | 5800 | 539 |
| 8000 | 632 | 4000 | 416 | 2000 | 222 | 6000 | 550 |
| 7800 | $62\overline{7}$ | 3800 | $40\overline{0}$ | 2200 | 243 | 6200 | $56\overline{1}$ |
| 7600 | 620 | 3600 | 382 | 2400 | $26\overline{4}$ | 6400 | $57\overline{1}$ |
| 7400 | $61\overline{4}$ | 3400 | 364 | 2600 | 284 | 6600 | $58\overline{0}$ |
| 7200 | $60\overline{7}$ | 3200 | 346 | 2800 | 304 | 6800 | $58\overline{9}$ |
| 7000 | 599 | 3000 | 327 | 3000 | 323 | 7000 | 597 |
| 6800 | 591 | 2800 | $30\overline{8}$ | 3200 | 342 | 7200 | $60\overline{5}$ |
| 6600 | 582 | 2600 | 288 | 3400 | $36\overline{1}$ | 7400 | $61\overline{2}$ |
| 6400 | 573 | 2400 | $26\overline{8}$ | 3600 | $37\overline{9}$ | 7600 | $61\overline{9}$ |
| 6200 | 563 | 2200 | 247 | 3800 | 396 | 7800 | $62\overline{5}$ |
| 6000 | $55\overline{3}$ | 2000 | 226 | 4000 | $41\overline{3}$ | 8000 | 630 |
| 5800 | $54\overline{2}$ | 1600 | 183 | 4200 | 429 | 8200 | $63\overline{6}$ |
| 5600 | 530 | 1200 | 139 | 4400 | 445 | 8400 | 640 |
| 5400 | 518 | 800 | $9\overline{4}$ | 4600 | 460 | 8600 | $64\overline{5}$ |
| 5200 | 505 | 400 | 48 | 4800 | $47\overline{5}$ | 8800 | 648 |
| − 5000 | + $49\overline{2}$ | − 0 | + 2 | + 5000 | − 489 | + 9000 | − $65\overline{2}$ |

| h | ± 1000 | ± 2000 ... ± 8000 |
|---|---|---|
| Corrections to $dTx10^8$ | 0 | ± $0.000\overline{1}\ H_s$ |

## Z O N E   L

18800m–38800m

| $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + $56\bar{2}$ | − 4500 | + $33\bar{2}$ | + 0 | + $\bar{4}$ | + 4500 | − $32\bar{6}$ |
| 8500 | $54\bar{3}$ | 4000 | $29\bar{9}$ | 500 | − $3\bar{6}$ | 5000 | $35\bar{8}$ |
| 8000 | $52\bar{2}$ | 3500 | $26\bar{5}$ | 1000 | 74 | 5500 | 388 |
| 7500 | 499 | 3000 | $23\bar{0}$ | 1500 | 112 | 6000 | $41\bar{7}$ |
| 7000 | 475 | 2500 | 193 | 2000 | 150 | 6500 | 444 |
| 6500 | $45\bar{0}$ | 2000 | 156 | 2500 | 187 | 7000 | 470 |
| 6000 | 422 | 1500 | $11\bar{9}$ | 3000 | 223 | 7500 | $49\bar{5}$ |
| 5500 | $39\bar{4}$ | 1000 | $8\bar{1}$ | 3500 | $25\bar{9}$ | 8000 | 517 |
| 5000 | 363 | 500 | 42 | 4000 | $29\bar{3}$ | 8500 | 538 |
| − 4500 | + $33\bar{2}$ | − 0 | + $\bar{4}$ | + 4500 | − $32\bar{6}$ | + 9000 | − $55\bar{8}$ |

| h | ± 1000 ... ± 2000 | ± 3000 ... ± 9000 |
|---|---|---|
| Corrections to $dT \times 10^8$ | 0 | $\pm 0.000\bar{1}\, H_s$ |

## ZONE M

28800m–58800m

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + $62\bar{5}$ | − 4500 | + $33\bar{7}$ | + 0 | + 10 | + 4500 | − $31\bar{8}$ |
| 8500 | $59\bar{6}$ | 4000 | $30\bar{2}$ | 500 | − 27 | 5000 | $35\bar{3}$ |
| 8000 | $56\bar{6}$ | 3500 | $26\bar{7}$ | 1000 | $6\bar{5}$ | 5500 | $38\bar{7}$ |
| 7500 | 535 | 3000 | $23\bar{1}$ | 1500 | $10\bar{2}$ | 6000 | 420 |
| 7000 | $50\bar{4}$ | 2500 | 194 | 2000 | 138 | 6500 | 453 |
| 6500 | $47\bar{2}$ | 2000 | $15\bar{8}$ | 2500 | $17\bar{5}$ | 7000 | 485 |
| 6000 | $43\bar{9}$ | 1500 | 121 | 3000 | 211 | 7500 | 517 |
| 5500 | 405 | 1000 | 84 | 3500 | 247 | 8000 | $54\bar{8}$ |
| 5000 | $37\bar{2}$ | 500 | 47 | 4000 | $28\bar{3}$ | 8500 | 578 |
| − 4500 | + $33\bar{7}$ | − 0 | + 10 | + 4500 | − $31\bar{8}$ | + 9000 | − 607 |

## ZONE N

58800m–99000m

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + $26\bar{8}$ | − 4000 | + $12\bar{9}$ | + 0 | + 13 | + 4000 | − 102 |
| 8000 | $24\bar{1}$ | 3000 | 100 | 500 | − 1 | 5000 | $13\bar{1}$ |
| 7000 | $21\bar{3}$ | 2000 | 71 | 1000 | $1\bar{6}$ | 6000 | 159 |
| 6000 | 185 | 1000 | 42 | 2000 | $4\bar{5}$ | 7000 | 187 |
| 5000 | 157 | 500 | $2\bar{8}$ | 3000 | $7\bar{4}$ | 8000 | $21\bar{5}$ |
| − 4000 | + $12\bar{9}$ | − 0 | + 13 | + 4000 | − 102 | + 9000 | − 242 |

| h | | ± 1000 ... ± 2000 | ± 3000 ... ± 6000 | ± 7000 ... ± 9000 |
|---|---|---|---|---|
| Corrections to $dTx10^8$ | Z.M | 0 | $\pm 0.000\bar{1}\ H_s$ | $\pm 0.0001\ H_s$ |
| | Z.N | 0 | 0 | $\pm 0.000\bar{1}\ H_s$ |

## ZONE 01

99000m–132850m

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| – 9000 | + 107 | – 4000 | + 54 | + 0 | + 11 | + 4000 | – 32 |
| 8000 | $9\bar{7}$ | 3000 | $4\bar{4}$ | 500 | $\bar{6}$ | 5000 | $4\bar{3}$ |
| 7000 | 86 | 2000 | $3\bar{3}$ | 1000 | + $\bar{1}$ | 6000 | $5\bar{4}$ |
| 6000 | $7\bar{6}$ | 1000 | 22 | 2000 | – $1\bar{1}$ | 7000 | 64 |
| 5000 | 65 | 500 | $1\bar{7}$ | 3000 | 21 | 8000 | $7\bar{5}$ |
| – 4000 | + 54 | – 0 | + 11 | + 4000 | – 32 | + 9000 | – 85 |

## ZONE 02

132850m–166735m

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| – 9000 | + $6\bar{9}$ | – 4000 | + $3\bar{7}$ | + 0 | + 11 | + 4000 | – $1\bar{5}$ |
| 8000 | 62 | 3000 | $3\bar{1}$ | 500 | 8 | 5000 | 21 |
| 7000 | 56 | 2000 | 24 | 1000 | $\bar{5}$ | 6000 | $2\bar{8}$ |
| 6000 | $5\bar{0}$ | 1000 | $1\bar{8}$ | 2000 | – $\bar{2}$ | 7000 | $3\bar{4}$ |
| 5000 | 43 | 500 | $1\bar{5}$ | 3000 | 8 | 8000 | 40 |
| – 4000 | + 37 | – 0 | + 11 | + 4000 | – $1\bar{5}$ | + 9000 | – $4\bar{7}$ |

| $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $sT \times 10^8$ | $h_m$ | $dT \times 10^8$ |
|---|---|---|---|---|---|---|---|

## Z O N E 18

| $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $sT \times 10^8$ | $h_m$ | $dT \times 10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + 32 | − 4000 | + 18 | + 0 | + 7 | + 4000 | − $\overline{5}$ |
| 7000 | $2\overline{7}$ | 3000 | 15 | 1000 | 4 | 5000 | 7 |
| 6000 | $2\overline{4}$ | 2000 | $1\overline{3}$ | 2000 | + $\overline{2}$ | 6000 | 10 |
| 5000 | 21 | 1000 | $1\overline{0}$ | 3000 | − $\overline{2}$ | 7000 | $1\overline{3}$ |
| − 4000 | + 18 | − 0 | + 7 | + 4000 | − $\overline{5}$ | + 9000 | − 18 |

## Z O N E 17

| $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $sT \times 10^8$ | $h_m$ | $dT \times 10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + 32 | − 4000 | + 19 | + 0 | + $\overline{9}$ | + 4000 | − $\overline{3}$ |
| 7000 | 27 | 3000 | $1\overline{7}$ | 1000 | $\overline{6}$ | 5000 | 5 |
| 6000 | 24 | 2000 | $1\overline{4}$ | 2000 | 3 | 6000 | $\overline{8}$ |
| 5000 | $2\overline{2}$ | 1000 | 11 | 3000 | + $\overline{1}$ | 7000 | 10 |
| − 4000 | + 19 | − 0 | + $\overline{9}$ | + 4000 | − $\overline{3}$ | + 9000 | − $1\overline{6}$ |

## Z O N E 16

| $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $sT \times 10^8$ | $h_m$ | $dT \times 10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + 33 | − 4000 | + $2\overline{1}$ | + 0 | + $1\overline{1}$ | + 4000 | − 0 |
| 7000 | 28 | 3000 | 18 | 1000 | 8 | 5000 | $\overline{3}$ |
| 6000 | $2\overline{6}$ | 2000 | $1\overline{6}$ | 2000 | $\overline{6}$ | 6000 | 5 |
| 5000 | 23 | 1000 | 13 | 3000 | 3 | 7000 | $\overline{8}$ |
| − 4000 | + $2\overline{1}$ | − 0 | + $1\overline{1}$ | + 4000 | + 0 | + 9000 | − $1\overline{3}$ |

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| | | | **ZONE 15** | | | | |
| − 9000 | + 35 | − 4000 | + 23 | + 0 | + 1$\bar{4}$ | + 4000 | + $\bar{4}$ |
| 7000 | 3$\bar{1}$ | 3000 | 2$\bar{1}$ | 1000 | 11 | 5000 | 1 |
| 6000 | 28 | 2000 | 18 | 2000 | $\bar{9}$ | 6000 | − $\bar{2}$ |
| 5000 | 2$\bar{6}$ | 1000 | 16 | 3000 | 6 | 7000 | $\bar{4}$ |
| − 4000 | + 23 | − 0 | + 1$\bar{4}$ | + 4000 | + $\bar{4}$ | + 9000 | − $\bar{9}$ |
| | | | **ZONE 14** | | | | |
| − 9000 | + 39 | − 4000 | + 2$\bar{8}$ | + 0 | + 18 | + 4000 | + $\bar{9}$ |
| 7000 | 3$\bar{5}$ | 3000 | 25 | 1000 | 1$\bar{6}$ | 5000 | 6 |
| 6000 | 32 | 2000 | 2$\bar{3}$ | 2000 | − 13 | 6000 | 4 |
| 5000 | 3$\bar{0}$ | 1000 | 20 | 3000 | 11 | 7000 | + $\bar{2}$ |
| − 4000 | + 2$\bar{8}$ | − 0 | + 18 | + 4000 | + $\bar{9}$ | + 9000 | − $\bar{4}$ |
| | | | **ZONE 13** | | | | |
| − 9000 | + 79 | − 4000 | + 61 | + 0 | + 4$\bar{7}$ | + 4000 | + 32 |
| 7000 | 7$\bar{2}$ | 3000 | 57 | 1000 | 43 | 5000 | 2$\bar{9}$ |
| 6000 | 68 | 2000 | 5$\bar{4}$ | 2000 | 39 | 6000 | 2$\bar{5}$ |
| 5000 | 6$\bar{5}$ | 1000 | 50 | 3000 | 3$\bar{6}$ | 7000 | 21 |
| − 4000 | + 61 | − 0 | + 4$\bar{7}$ | + 4000 | + 32 | + 9000 | + 14 |

| $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ |
|---|---|---|---|---|---|---|---|

## ZONE 12

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| − 9000 | + 73 | − 4000 | + 62 | + 0 | + 53 | + 4000 | + $4\bar{5}$ |
| 7000 | $6\bar{9}$ | 3000 | $6\bar{0}$ | 1000 | 51 | 5000 | $4\bar{3}$ |
| 6000 | $6\bar{7}$ | 2000 | $5\bar{8}$ | 2000 | 49 | 6000 | 40 |
| 5000 | 64 | 1000 | $5\bar{6}$ | 3000 | $4\bar{7}$ | 7000 | 38 |
| − 4000 | + 62 | − 0 | + 53 | + 4000 | + $4\bar{5}$ | + 9000 | + $3\bar{4}$ |

## ZONE 11

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| − 9000 | + $9\bar{2}$ | − 4000 | + 83 | + 0 | + 76 | + 4000 | +69 |
| 7000 | 88 | 3000 | 81 | 1000 | $7\bar{5}$ | 5000 | $6\bar{8}$ |
| 6000 | $8\bar{7}$ | 2000 | $8\bar{0}$ | 2000 | $7\bar{3}$ | 6000 | $6\bar{6}$ |
| 5000 | $8\bar{5}$ | 1000 | $7\bar{8}$ | 3000 | 71 | 7000 | 64 |
| − 4000 | + 83 | − 0 | + 76 | + 4000 | + 69 | + 9000 | + $6\bar{1}$ |

## ZONE 10

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| − 9000 | + 116 | − 4000 | + 110 | + 0 | + 105 | + 4000 | + 100 |
| 7000 | $11\bar{4}$ | 3000 | $10\bar{9}$ | 1000 | $10\bar{4}$ | 5000 | $9\bar{9}$ |
| 6000 | $11\bar{3}$ | 2000 | $10\bar{8}$ | 2000 | $10\bar{3}$ | 6000 | 97 |
| 5000 | 111 | 1000 | 106 | 3000 | 101 | 7000 | 96 |
| − 4000 | + 110 | − 0 | + 105 | + 4000 | + 100 | + 9000 | + $9\bar{4}$ |

## Z O N E 9

| $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + $13\overline{2}$ | − 4000 | + $12\overline{8}$ | + 0 | + 124 | + 4000 | + 121 |
| 7000 | 130 | 3000 | $12\overline{7}$ | 1000 | $12\overline{4}$ | 5000 | 120 |
| 6000 | 129 | 2000 | 126 | 2000 | $12\overline{3}$ | 6000 | $12\overline{0}$ |
| 5000 | $12\overline{9}$ | 1000 | 125 | 3000 | 122 | 7000 | $11\overline{9}$ |
| − 4000 | + $12\overline{8}$ | − 0 | + 124 | + 4000 | + 121 | + 9000 | + 117 |

## Z O N E 8

| $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + 243 | − 4000 | + $24\overline{0}$ | + 0 | + 236 | + 4000 | + 233 |
| 7000 | $24\overline{2}$ | 3000 | $23\overline{9}$ | 1000 | $23\overline{6}$ | 5000 | 232 |
| 6000 | 241 | 2000 | $23\overline{8}$ | 2000 | $23\overline{5}$ | 6000 | $23\overline{2}$ |
| 5000 | 240 | 1000 | 237 | 3000 | 234 | 7000 | $23\overline{1}$ |
| − 4000 | + $24\overline{0}$ | − 0 | + 236 | + 4000 | + 233 | + 9000 | + 229 |

## Z O N E 7

| $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ | $h_m$ | $dT \times 10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + 218 | − 4000 | + 216 | + 0 | + $21\overline{5}$ | + 4000 | + $21\overline{4}$ |
| 7000 | 217 | 3000 | 216 | 1000 | $21\overline{5}$ | 5000 | 213 |
| 6000 | 217 | 2000 | $21\overline{6}$ | 2000 | 214 | 6000 | $21\overline{3}$ |
| 5000 | $21\overline{7}$ | 1000 | 215 | 3000 | $21\overline{4}$ | 7000 | 212 |
| − 4000 | + 216 | − 0 | + $21\overline{5}$ | + 4000 | + $21\overline{4}$ | + 9000 | + $21\overline{2}$ |

| $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ | $h_m$ | $dTx10^8$ |
|---|---|---|---|---|---|---|---|
| **ZONE 6** | | | | | | | |
| − 9000 | + $33\overline{0}$ | − 4000 | + 328 | + 0 | + 327 | + 4000 | + $32\overline{6}$ |
| 7000 | 329 | 3000 | $32\overline{8}$ | 1000 | $32\overline{7}$ | 5000 | $32\overline{6}$ |
| 6000 | $32\overline{9}$ | 2000 | $32\overline{8}$ | 2000 | $32\overline{7}$ | 6000 | 325 |
| 5000 | 328 | 1000 | 327 | 3000 | 326 | 7000 | 325 |
| − 4000 | + 328 | − 0 | + 327 | + 4000 | + $32\overline{6}$ | + 9000 | + $32\overline{5}$ |
| **ZONE 5** | | | | | | | |
| − 9000 | + 514 | − 4000 | + $51\overline{4}$ | + 0 | + $51\overline{3}$ | + 4000 | + 512 |
| 7000 | 514 | 3000 | 513 | 1000 | $51\overline{3}$ | 5000 | $51\overline{2}$ |
| 6000 | $51\overline{4}$ | 2000 | 513 | 2000 | 512 | 6000 | $51\overline{2}$ |
| 5000 | $51\overline{4}$ | 1000 | $51\overline{3}$ | 3000 | 512 | 7000 | $51\overline{2}$ |
| − 4000 | + $51\overline{4}$ | − 0 | + $51\overline{3}$ | + 4000 | + 512 | + 9000 | + 511 |
| **ZONE 4** | | | | | | | |
| − 9000 | + 664 | − 4000 | + $66\overline{4}$ | + 0 | + $66\overline{4}$ | + 4000 | + 663 |
| 7000 | $66\overline{4}$ | 3000 | $66\overline{4}$ | 1000 | $66\overline{4}$ | 5000 | 663 |
| 6000 | $66\overline{4}$ | 2000 | $66\overline{4}$ | 2000 | 663 | 6000 | 663 |
| 5000 | $66\overline{4}$ | 1000 | $66\overline{4}$ | 3000 | 663 | 7000 | 663 |
| − 4000 | + $66\overline{4}$ | − 0 | + $66\overline{4}$ | + 4000 | + 663 | + 9000 | + 663 |

| $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ |
|---|---|---|---|---|---|---|---|

## Z O N E 3

| $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + $87\bar{3}$ | − 4000 | + $87\bar{3}$ | + 0 | + 873 | + 4000 | + 873 |
| 7000 | $87\bar{3}$ | 3000 | $87\bar{3}$ | 1000 | 873 | 5000 | 873 |
| 6000 | $87\bar{3}$ | 2000 | $87\bar{3}$ | 2000 | 873 | 6000 | 873 |
| 5000 | $87\bar{3}$ | 1000 | 873 | 3000 | 873 | 7000 | $87\bar{4}$ |
| − 4000 | + $87\bar{3}$ | − 0 | + 873 | + 4000 | + 873 | + 9000 | + 874 |

## Z O N E 2

| $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + $71\bar{4}$ | − 4000 | + 714 | + 0 | + 714 | + 4000 | + $71\bar{5}$ |
| 7000 | $71\bar{4}$ | 3000 | 714 | 1000 | $71\bar{5}$ | 5000 | $71\bar{5}$ |
| 6000 | $71\bar{4}$ | 2000 | 714 | 2000 | $71\bar{5}$ | 6000 | 715 |
| 5000 | $71\bar{4}$ | 1000 | 714 | 3000 | $71\bar{5}$ | 7000 | 715 |
| − 4000 | + 714 | − 0 | + 714 | + 4000 | + $71\bar{5}$ | + 9000 | + 715 |

## Z O N E 1

| $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ | $h_m$ | $dT\times10^8$ |
|---|---|---|---|---|---|---|---|
| − 9000 | + 134 | − 4000 | + 134 | + 0 | + 134 | + 4000 | + 134 |
| 7000 | 134 | 3000 | 134 | 1000 | 134 | 5000 | 134 |
| 6000 | 134 | 2000 | 134 | 2000 | 134 | 6000 | 134 |
| 5000 | 134 | 1000 | 134 | 3000 | 134 | 7000 | 134 |
| − 4000 | + 134 | − 0 | + 134 | + 4000 | + 134 | + 9000 | + $13\bar{5}$ |

# SPECIAL TABLES

1 - 2 - 3

TABLE 1 (See p. T - 7)

EFFECT E for EARTH'S TOPOGRAPHY h-H
condensed at EARTH MODEL
COMPARTMENT[a] of ZONES A to 1[c]

Unit = 0.01 mgal ; density : 2,67[b]

(a) The number of compartments n is given for each zone.

(b) In calculating average heights, depths D (or d) are to be converted into heights H (or h) by the relation H = -0,615 D.

(c) Effect for zone A is $A\,(h_c - H_c)$ in which A = 11.18/m
Effect for zones B to G and zones 11 to 1 is negligibile.

| Difference of elevation h - H in metres | ZONE H (n = 16) H - $H_s$ in metres | | | ZONE I (n = 20) H - $H_s$ in metres | | |
|---|---|---|---|---|---|---|
| | + 100 | 0 | - 100 | + 200 | 0 | - 200 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 100 | $-\overline{1}$ | 0 | $+\overline{1}$ | $-1$ | 0 | $+1$ |
| 200 | $-\overline{2}$ | 0 | $+\overline{2}$ | $-\overline{2}$ | 0 | $+\overline{2}$ |
| 300 | $-2$ | 0 | $+2$ | $-\overline{3}$ | 0 | $+\overline{3}$ |
| 400 | $-\overline{3}$ | 0 | $+\overline{3}$ | $-3$ | 0 | $+\overline{4}$ |
| 500 | $-3$ | 0 | $+\overline{4}$ | $-4$ | 0 | $+4$ |
| 600 | $-4$ | 0 | $+4$ | $-5$ | 0 | $+5$ |
| 700 | $-\overline{5}$ | 0 | $+\overline{5}$ | $-\overline{6}$ | 0 | $+6$ |
| 800 | $-5$ | 0 | $+\overline{6}$ | $-\overline{7}$ | 0 | $+\overline{7}$ |
| 900 | $-6$ | 0 | $+6$ | $-7$ | 0 | $+\overline{8}$ |
| 1000 | $-\overline{7}$ | 0 | $+\overline{7}$ | $-8$ | 0 | $+8$ |
| 1200 | $-\overline{8}$ | 0 | $+8$ | $-1\overline{0}$ | 0 | $+10$ |
| 1400 | $-9$ | 0 | $+1\overline{0}$ | $-11$ | 0 | $+1\overline{2}$ |
| 1600 | $-1\overline{1}$ | 0 | $+1\overline{1}$ | $-1\overline{3}$ | 0 | $+13$ |
| 1800 | $-1\overline{2}$ | 0 | $+12$ | $-1\overline{5}$ | $+\overline{1}$ | $+15$ |
| 2000 | $-13$ | 0 | $+13$ | $-16$ | $+\overline{1}$ | $+17$ |

| Difference of elevation h − H in metres | ZONE J (n = 16) | | | ZONE K (n = 20) | | |
|---|---|---|---|---|---|---|
| | $H - H_s$ in metres | | | $H - H_s$ in metres | | |
| | + 500 | 0 | − 500 | + 1000 | 0 | − 1000 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 100 | $-\overline{2}$ | 0 | $+\overline{2}$ | $-\overline{2}$ | 0 | $+\overline{2}$ |
| 200 | $-\overline{3}$ | 0 | $+\overline{3}$ | − 3 | 0 | + 3 |
| 300 | − 4 | 0 | + 4 | $-\overline{5}$ | 0 | $+\overline{5}$ |
| 400 | − 5 | 0 | $+\overline{6}$ | − 6 | 0 | + 6 |
| 500 | $-\overline{7}$ | 0 | $+\overline{7}$ | $-\overline{8}$ | 0 | + 8 |
| 600 | − 8 | 0 | + 8 | − 9 | 0 | $+\overline{10}$ |
| 700 | − 9 | 0 | $+1\overline{0}$ | $-1\overline{1}$ | 0 | +11 |
| 800 | $-1\overline{1}$ | 0 | $+1\overline{1}$ | −12 | 0 | $+1\overline{3}$ |
| 900 | $-1\overline{2}$ | 0 | +12 | $-1\overline{4}$ | $+\overline{1}$ | +14 |
| 1000 | −13 | 0 | $+1\overline{4}$ | −15 | $+\overline{1}$ | $+1\overline{6}$ |
| 1200 | $-1\overline{6}$ | $+\overline{1}$ | +16 | −18 | $+\overline{1}$ | $+1\overline{9}$ |
| 1400 | −18 | $+\overline{1}$ | +1[illegible] | −21 | $+\overline{1}$ | $+2\overline{2}$ |
| 1600 | $-2\overline{1}$ | $+\overline{1}$ | $+2\overline{2}$ | −24 | $+\overline{1}$ | +25 |
| 1800 | $-2\overline{4}$ | $+\overline{1}$ | +24 | −27 | $+\overline{1}$ | +28 |
| 2000 | −26 | $+\overline{1}$ | +27 | −30 | $+\overline{1}$ | +31 |
| 2200 | $-2\overline{9}$ | $+\overline{1}$ | $+3\overline{0}$ | −33 | $+\overline{1}$ | +34 |
| 2400 | −31 | $+\overline{1}$ | +32 | −36 | $+\overline{1}$ | $+3\overline{8}$ |
| 2600 | $-3\overline{4}$ | $+\overline{1}$ | +35 | −39 | $+\overline{1}$ | $+4\overline{1}$ |
| 2800 | $-3\overline{7}$ | $+\overline{1}$ | $+3\overline{8}$ | −42 | + 1 | $+4\overline{4}$ |
| 3000 | −39 | $+\overline{1}$ | +40 | −45 | + 1 | $+4\overline{7}$ |

| Difference of elevation $h - H$ in metres | ZONE L $(n = 24)$ | | | ZONE M $(n = 14)$ | | |
|---|---|---|---|---|---|---|
| | $H - H_s$ in metres | | | $H - H_s$ in metres | | |
| | + 1000 | 0 | − 1000 | + 1000 | 0 | − 1000 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 100 | − 1 | 0 | + 1 | − 1 | 0 | + $\bar{2}$ |
| 200 | − $\bar{2}$ | 0 | + 2 | − $\bar{3}$ | + $\bar{1}$ | + 3 |
| 300 | − $\bar{3}$ | 0 | + $\bar{3}$ | − $\bar{4}$ | + $\bar{1}$ | + 5 |
| 400 | − $\bar{4}$ | 0 | + $\bar{4}$ | − 5 | + 1 | + $\bar{7}$ |
| 500 | − 4 | 0 | + $\bar{5}$ | − 6 | + 1 | + 8 |
| 600 | − 5 | 0 | + $\bar{6}$ | − $\bar{8}$ | + 1 | +1$\bar{0}$ |
| 700 | − 6 | + $\bar{1}$ | + $\bar{7}$ | − $\bar{9}$ | + $\bar{2}$ | +11 |
| 800 | − $\bar{7}$ | + $\bar{1}$ | + 7 | −10 | + $\bar{2}$ | +13 |
| 900 | − $\bar{8}$ | + $\bar{1}$ | + 8 | −11 | + $\bar{2}$ | +1$\bar{5}$ |
| 1000 | − 8 | + $\bar{1}$ | + 9 | −1$\bar{3}$ | + 2 | +16 |
| 1200 | −10 | + $\bar{1}$ | +1$\bar{1}$ | −1$\bar{5}$ | + $\bar{3}$ | +19 |
| 1400 | −1$\bar{2}$ | + $\bar{1}$ | +1$\bar{3}$ | −17 | + $\bar{3}$ | +2$\bar{3}$ |
| 1600 | −13 | + $\bar{1}$ | +1$\bar{5}$ | −2$\bar{0}$ | + 3 | +2$\bar{6}$ |
| 1800 | −15 | + $\bar{1}$ | +16 | −22 | + $\bar{4}$ | +29 |
| 2000 | −1$\bar{7}$ | + $\bar{1}$ | +18 | −2$\bar{5}$ | + 4 | +32 |
| 2200 | −18 | + 1 | +2$\bar{0}$ | −27 | + 4 | +3$\bar{6}$ |
| 2400 | −2$\bar{0}$ | + 1 | +2$\bar{2}$ | −3$\bar{0}$ | + $\bar{5}$ | +3$\bar{9}$ |
| 2600 | −2$\bar{2}$ | + 1 | +2$\bar{4}$ | −32 | + 5 | +4$\bar{2}$ |
| 2800 | −23 | + 1 | +25 | −3$\bar{5}$ | + $\bar{6}$ | +45 |
| 3000 | −2$\bar{5}$ | + 1 | +27 | −37 | + $\bar{6}$ | +48 |

| Difference of elevation h − H in metres | ZONE N (n = 16) | | | ZONE $O_1$ (n = 28) | | |
|---|---|---|---|---|---|---|
| | $H - H_s$ in metres | | | $H - H_s$ in metres | | |
| | + 1000 | 0 | − 1000 | + 2000 | 0 | − 2000 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 500 | $-\overline{2}$ | + 1 | $+\overline{4}$ | $-\overline{1}$ | $+\overline{1}$ | $+\overline{2}$ |
| 1000 | $-\overline{3}$ | 2 | + 7 | − 1 | + 1 | + 3 |
| 1500 | − 4 | $+\overline{4}$ | $+1\overline{1}$ | $-\overline{2}$ | $+\overline{2}$ | $+\overline{5}$ |
| 2000 | − 5 | $+\overline{5}$ | +14 | − 2 | + 2 | + 6 |
| 2500 | $-\overline{7}$ | $+\overline{6}$ | $+1\overline{8}$ | $-\overline{3}$ | $+\overline{3}$ | + 8 |
| 3000 | − 8 | $+\overline{7}$ | +21 | − 3 | + 3 | $+1\overline{0}$ |

| Difference of elevation h − H in metres | ZONE $O_2$ (n = 28) | | |
|---|---|---|---|
| | $H - H_s$ in metres | | |
| | + 2000 | 0 | − 2000 |
| 0 | 0 | 0 | 0 |
| 500 | 0 | $+\overline{1}$ | + 1 |
| 1000 | 0 | + 1 | $+\overline{3}$ |
| 1500 | 0 | $+\overline{2}$ | $+\overline{4}$ |
| 2000 | $-\overline{1}$ | + 2 | $+\overline{5}$ |
| 2500 | $-\overline{1}$ | $+\overline{3}$ | $+\overline{6}$ |
| 3000 | $-\overline{1}$ | + 3 | + 7 |

| Difference of elevation h − H in metres | ZONE 18 (n = 10) | | | ZONE 17 (n = 10) | | |
|---|---|---|---|---|---|---|
| | $H - H_s$ in metres | | | $H - H_s$ in metres | | |
| | + 5000 | 0 | − 5000 | + 4000 | 0 | − 4000 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 200 | $-\overline{1}$ | $+\overline{1}$ | + 1 | 0 | $+\overline{1}$ | + 1 |
| 400 | − 1 | + 1 | + 2 | 0 | + 1 | + 2 |
| 600 | − 1 | $+\overline{2}$ | $+\overline{4}$ | $-\overline{1}$ | $+\overline{2}$ | + 3 |
| 800 | $-\overline{2}$ | $+\overline{2}$ | $+\overline{5}$ | $-\overline{1}$ | + 2 | + 4 |
| 1000 | − 2 | + 2 | $+\overline{6}$ | $-\overline{1}$ | + 2 | + 5 |
| 1200 | $-\overline{3}$ | $+\overline{3}$ | $+\overline{7}$ | $-\overline{1}$ | $+\overline{3}$ | + 6 |
| 1400 | $-\overline{3}$ | $+\overline{3}$ | + 8 | − 1 | + 3 | + 7 |
| 1600 | − 3 | + 3 | + 9 | − 1 | $+\overline{4}$ | + 8 |
| 1800 | $-\overline{4}$ | $+\overline{4}$ | +10 | − 1 | + 4 | + 9 |
| 2000 | − 4 | + 4 | +11 | − 1 | $+\overline{5}$ | +10 |

| Difference of elevation h − H in metres | ZONE 16 (n = 10) | | | ZONE 15 (n = 10) | | |
|---|---|---|---|---|---|---|
| | $H - H_s$ in metres | | | $H - H_s$ in metres | | |
| | + 5000 | 0 | − 5000 | + 5000 | 0 | − 5000 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 200 | 0 | $+\overline{1}$ | + 1 | 0 | $+\overline{1}$ | $+\overline{2}$ |
| 400 | 0 | + 1 | $+\overline{3}$ | 0 | $+\overline{2}$ | $+\overline{3}$ |
| 600 | $-\overline{1}$ | $+\overline{2}$ | $+\overline{4}$ | 0 | + 2 | + 4 |
| 800 | $-\overline{1}$ | + 2 | + 5 | 0 | + 3 | $+\overline{6}$ |
| 1000 | $-\overline{1}$ | + 3 | + 6 | $+\overline{1}$ | $+\overline{4}$ | + 7 |
| 1200 | $-\overline{1}$ | $+\overline{4}$ | $+\overline{8}$ | $+\overline{1}$ | $+\overline{5}$ | + 8 |
| 1400 | − 1 | + 4 | $+\overline{9}$ | $+\overline{1}$ | + 5 | $+1\overline{0}$ |
| 1600 | − 1 | $+\overline{5}$ | +10 | $+\overline{1}$ | $+\overline{6}$ | +11 |
| 1800 | − 1 | + 5 | +11 | $+\overline{1}$ | $+\overline{7}$ | $+1\overline{3}$ |
| 2000 | − 1 | $+\overline{6}$ | $+1\overline{3}$ | $+\overline{1}$ | + 7 | $+1\overline{4}$ |

| Difference of elevation h – H in metres | ZONE 14 (n = 10) | | | ZONE 13 (n = 16) | | |
|---|---|---|---|---|---|---|
| | H – $H_s$ in metres | | | H – $H_s$ in metres | | |
| | + 5000 | 0 | – 5000 | + 5000 | 0 | – 5000 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 200 | $+\overline{1}$ | + 1 | $+\overline{2}$ | + 1 | $+\overline{2}$ | + 2 |
| 400 | $+\overline{1}$ | + 2 | + 3 | + 2 | + 3 | $+\overline{5}$ |
| 600 | + 1 | + 3 | $+\overline{5}$ | + 3 | $+\overline{5}$ | $+\overline{7}$ |
| 800 | $+\overline{2}$ | + 4 | $+\overline{7}$ | + 4 | + 6 | $+\overline{9}$ |
| 1000 | $+\overline{2}$ | + 5 | + 8 | $+\overline{5}$ | $+\overline{8}$ | +11 |
| 1200 | + 2 | $+\overline{6}$ | $+1\overline{0}$ | $+\overline{6}$ | $+1\overline{0}$ | +13 |
| 1400 | $+\overline{3}$ | $+\overline{7}$ | +11 | $+\overline{7}$ | +11 | +15 |
| 1600 | $+\overline{3}$ | $+\overline{8}$ | $+1\overline{3}$ | $+\overline{8}$ | $+1\overline{3}$ | +17 |
| 1800 | + 3 | $+\overline{9}$ | +14 | $+\overline{9}$ | +14 | $+2\overline{0}$ |
| 2000 | $+\overline{4}$ | $+1\overline{0}$ | +16 | $+1\overline{0}$ | $+1\overline{6}$ | $+2\overline{2}$ |

| Difference of elevation h – H in metres | ZONE 12 (n = 10) | | |
|---|---|---|---|
| | H – $H_s$ in metres | | |
| | + 5000 | 0 | – 5000 |
| 0 | 0 | 0 | 0 |
| 200 | $+\overline{3}$ | + 3 | $+\overline{4}$ |
| 400 | $+\overline{5}$ | $+\overline{6}$ | + 7 |
| 600 | + 7 | $+\overline{9}$ | $+1\overline{1}$ |
| 800 | + 9 | $+1\overline{2}$ | $+1\overline{4}$ |
| 1000 | $+1\overline{2}$ | +14 | +17 |
| 1200 | $+1\overline{4}$ | +17 | $+2\overline{1}$ |
| 1400 | +16 | +20 | +24 |
| 1600 | +18 | $+2\overline{3}$ | $+2\overline{8}$ |
| 1800 | $+2\overline{1}$ | $+2\overline{6}$ | +31 |
| 2000 | $+2\overline{3}$ | $+2\overline{9}$ | +34 |

T A B L E 2 (See p. T - 7)

EFFECT E for EARTH'S TOPOGRAPHY $h-h_s$
condensed at GEOID
COMPARTMENT (a) of ZONES A to $O_2$

Sign same as for $h-h_s$ (b)

Unit : 0,01 mGal; density : 2,67

(a) For numbers of compartments in each zone, refer to the table 1
(b) h when negative is to be taken as zero

| Differences of elevation $\|h - h_s\|$ in metres | Compartment of zones | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A-H | I | J | K | L | M | N | $O_1$ | $O_2$ |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 500 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | $\bar{1}$ | $\bar{1}$ |
| 1000 | 0 | 0 | 0 | $\bar{1}$ | $\bar{1}$ | 2 | 2 | 1 | 1 |
| 1500 | 0 | 0 | $\bar{1}$ | $\bar{1}$ | $\bar{1}$ | 3 | $\bar{4}$ | $\bar{2}$ | $\bar{2}$ |
| 2000 | 0 | $\bar{1}$ | $\bar{1}$ | $\bar{1}$ | $\bar{1}$ | 4 | $\bar{5}$ | 2 | 2 |
| 2500 | | $\bar{1}$ | $\bar{1}$ | $\bar{1}$ | 1 | $\bar{5}$ | $\bar{6}$ | $\bar{3}$ | $\bar{3}$ |
| 3000 | | | $\bar{1}$ | 1 | 1 | $\bar{6}$ | $\bar{7}$ | 3 | 3 |
| 3500 | | | | | $\bar{2}$ | $\bar{7}$ | $\bar{8}$ | $\bar{4}$ | $\bar{4}$ |
| 4000 | | | | | $\bar{2}$ | $\bar{8}$ | 9 | 4 | 4 |
| 4500 | | | | | | | 10 | 5 | 5 |
| 5000 | | | | | | | 11 | $\bar{6}$ | $\bar{6}$ |
| 5500 | | | | | | | | 6 | 6 |
| 6000 | | | | | | | | $\bar{7}$ | $\bar{7}$ |

A= Elevation of station $h_s$ in kilometers

B= Correction for station elevation - Zones A to $O_2$
Unit: 0.1 mGal

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0,5 | 1 | 1,5 | 2 | 2,5 | 3 | 3,5 | 4 | 4,5 | 5 | 5,5 | 6 | 6,5 | 7 | 7,5 | 8 | 8,5 | 9km |
| B | 2 | 4 | 8 | 15 | 22 | 32 | 44 | 57 | 72 | 89 | 107 | 127 | 149 | 173 | 199 | 225 | 255 | 286mGal |

## T A B L E 3 (See p. T - 7)

### EFFECT E-T for EARTH'S TOPOGRAPHY $h - h_s$ with condensation at GEOID COMPARTMENT (a) OF ZONES 18 to 1 (b)

Unit : 0.01 mGal : density : 2,67

(a) For number of compartments in each zone refer to the Table 1
(b) Effect E-T for zones 11 to 1 is negligible
(c) h when negative is to be taken as zero

P = Station above compartment Q = Station below compartment.

| Differences of elevations $\lvert h - h_s \rvert$ (c) in metres | COMPARTMENT OF ZONES | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 18 | | 17 | | 16 | | 15 | | 14 | | 13 | | 12 | |
| | P | Q | P | Q | P | Q | P | Q | P | Q | P | Q | P | Q |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1000 | $\bar{1}$ | $\bar{1}$ | $\bar{1}$ | $\bar{1}$ | $\bar{1}$ | $\bar{1}$ | $\bar{1}$ | $\bar{1}$ | $\bar{1}$ | 0 | $\bar{1}$ | $\bar{1}$ | 0 | $\bar{1}$ |
| 1500 | $\bar{1}$ | 1 | $\bar{1}$ | 1 | $\bar{1}$ | $\bar{1}$ | 1 | 1 | $\bar{1}$ | $\bar{1}$ | $\bar{1}$ | $\bar{1}$ | $\bar{1}$ | $\bar{1}$ |
| 2000 | $\bar{2}$ | $\bar{2}$ | $\bar{2}$ | $\bar{2}$ | $\bar{2}$ | $\bar{2}$ | $\bar{2}$ | 1 | 1 | $\bar{2}$ | 1 | 1 | 1 | 1 |
| 2500 | $\bar{3}$ | $\bar{3}$ | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 3000 | $\bar{4}$ | $\bar{4}$ | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | $\bar{3}$ | $\bar{3}$ | $\bar{3}$ | $\bar{3}$ |
| 3500 | $\bar{5}$ | $\bar{5}$ | $\bar{5}$ | $\bar{5}$ | 4 | 4 | 4 | 4 | 4 | 4 | $\bar{4}$ | $\bar{4}$ | $\bar{4}$ | $\bar{4}$ |
| 4000 | 6 | 6 | $\bar{6}$ | $\bar{6}$ | $\bar{6}$ | $\bar{6}$ | $\bar{6}$ | 5 | 5 | 5 | $\bar{5}$ | 5 | $\bar{5}$ | 5 |
| 4500 | $\bar{8}$ | $\bar{8}$ | 7 | 7 | $\bar{7}$ | 7 | $\bar{7}$ | $\bar{7}$ | $\bar{7}$ | $\bar{7}$ | 6 | 6 | 6 | 6 |
| 5000 | 9 | $1\bar{0}$ | 9 | 9 | $\bar{9}$ | $\bar{9}$ | 8 | 8 | 8 | 8 | $\bar{8}$ | $\bar{8}$ | 7 | 7 |
| 5500 | 11 | $1\bar{2}$ | 11 | $1\bar{1}$ | 10 | 10 | 10 | 10 | $1\bar{0}$ | $1\bar{0}$ | 9 | 9 | 9 | 9 |
| 6000 | 13 | $1\bar{4}$ | 13 | 13 | 12 | 12 | 12 | $1\bar{2}$ | 11 | $1\bar{2}$ | 11 | 11 | $1\bar{1}$ | $1\bar{1}$ |

A = Elevation of station $h_s$ in kilometers

B = Correction for station elevation - Zones 18 to 12
Unit : 0.1 mGal

| A | 0,5 | 1 | 1,5 | 2 | 2,5 | 3 | 3,5 | 4 | 4,5 | 5 | 5,5 | 6 | 6,5 | 7 | 7,5 | 8 | 8,5 | 9km |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B | -1 | -2 | -5 | -10 | -16 | -22 | -31 | -39 | -50 | -62 | -75 | -89 | -105 | -121 | -139 | -158 | -179 | -200 mGal |

## TABLE D

## BULLARD'S B CORRECTIONS

Unit : 0.1 mGal

| Station elevation in metres | Correction |
|---|---|
| 0 | 0 |
| 500 | 7 |
| 1000 | 11 |
| 1500 | 14 |
| 2000 | 16 |
| 2500 | 16 |
| 3000 | 14 |
| 3500 | 10 |
| 4000 | 5 |
| 4500 | − 2 |
| 5000 | − 11 |
| 5500 | − 21 |
| 6000 | − 33 |
| 6500 | − 47 |
| 7000 | − 62 |
| 7500 | − 79 |
| 8000 | − 98 |
| 8500 | −118 |
| 9000 | −140 |