DETERMINATION OF THE FREE-AIR GRAVITY ANOMALIES OVER BRONG-AHAFO REGION OF GHANA

By

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ABSTRACT

Free-air gravity anomalies over Brong-Ahafo Region of Ghana on a regular 2.5×2.5 arc minute grid is determined from combined surface gravity and digital elevation model data using Simple Bouguer anomaly procedure and Gravity Reconstruction method of gridding. The Geodetic Reference System 1980 (GRS80) ellipsoid was used as the reference ellipsoid for computation of the normal gravities at the grid points.

The results of this study shows that the residual free-air gravity anomalies over Brong-Ahafo Region range from -63.07 to -3.56 mGal, with the negative values indicating places where the normal gravity values are higher than the corresponding free-air values and that the ellipsoid is below the geoid surface.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Ghana has a beautiful landmass with water bodies at various sections and bounded on the southern side by the sea. Within these abound a lot of resources (examples are minerals and oil). To improve the economy as well as living conditions there is the need to use scientific methods that will transform the resources to economic gains. To a large extent gravity prospecting plays a major role in the study and exploration for these resources.

Gravity prospecting evolved from the study of the Earth's gravity field, a subject of interest to geodesists for determining the shape of the Earth. The magnitude of gravity depends on five factors; latitude, elevation, topography of the surrounding terrain, earth tides and density variations in the subsurface. Gravity exploration is mainly concerned with anomalies due to density variations in the subsurface, and these anomalies generally are much smaller than the changes due to latitude and elevation, although larger than the anomalies due to tidal and topographic effect (Telford et al, 1994 p. 10). Gravity reduction due to elevation and topography of the surrounding mass are the results of the free-air and bouguer gravity respectively. This reduction procedure is major application to the gravity data in this research.

Anomalies in the Earth's gravity field play important roles in both geodesy and geophysics. In geodesy, gravity anomalies are used to define the figure of the Earth, notably the geoid (the equipotential surface of the Earth's gravity field that corresponds most closely with mean sea level). In geophysics, gravity anomalies are used to deduce variations in mass-density and hence subsurface geological structure for a wide variety of applications. To these ends, the geophysicist's aim is to remove gravity effects that mask the local anomalies that are of interest, whereas the geodesist is interested in using a gravity anomaly that preserves the mass of the Earth. In both disciplines, however, it appears that the definition and practical realization of a 'gravity anomaly' remains open to question, despite it being subject to ongoing investigation. Of some concern is that investigators in these disciplines seem to be unaware of the other's work, which is evidenced by even a cursory inspection of the literature cited research works. This is unsatisfactory since (often parallel) advances being made in each discipline are not being used, or even acknowledged, in the other.

A 'gravity anomaly' is essentially the difference between the gravity acceleration caused by the Earth's masses and gravity acceleration generated by some reference mass distribution. However, there are numerous subtleties to the definition and, moreover, to the practical realization of a 'gravity anomaly'.

A surface of constant potential energy that coincides with mean sea level over the oceans is the geoid. The object of gravity exploration is the lateral variation of density which causes variation between the geoid and its ellipsoid. The geoid surface is more irregular than the Earth, but considerably smoother than the earth's physical surface. The

irregular surface of the geoid is due to the local masses warping the geoid. Free-air gravity anomaly is considered the most important computation in the determination of the geoid.

Generally, large amounts of data are involved in the evaluation of the Earth's gravity field quantities, particularly in geoid determination and terrain reduction. This is due to the fact that, theoretically the geoid is determined using gravity data having a global coverage. However, a global gravity field model may represent data far beyond the area of interest. Thus, geoid modeling takes into account information regarding three parts of the gravity field, namely, the long-, intermediate- and short-wavelength parts.

For the interpretation of geophysical data, it is often convenient if the quantity to be analyzed is decomposed as a sum of components, a process known as spectral analysis. The Fast Fourier Transformation (FFT) technique (Brigham, 1988; Bracewell, 1986) has proven to be a very powerful for the efficient evaluation of gravity field convolution integrals (Tziavos, 1996; Zhang et al, 2000) and present a very attractive alternative to the classical, time consuming numerical methods.

However, the FFT approach normally requires that gridded gravity data are utilized (Li et al, 1995; Schwarz et al, 1990). Therefore, the irregularly spaced gravity observations must be resampled unto a grid over the area of interest. The conventional approach to such gravity gridding is to smoothen the gravity field using reductions- the remove stage, interpolate these smoothed quantities onto the desired grid, then add back the appropriate gravity reduction in the restore stage (Forsberg, 1984). In many instances, the Bouguer anomalies are used for data smoothing purposes prior to gravimetric geoid

computation (Bian and Zhang, 1991). However, if the reduced gravity data are not smooth, interpolation errors will result, which will then propagate into the gravimetric geoid (Hipkin, 1988).

1.2 RESEARCH PROBLEM

The earth scientist is challenged with an effective way of solving the various problems they encounter in their career. For some problems they need the free-air gravity anomalies to provide solutions. This research takes into consideration the problems some earth scientists are faced without determined free-air gravity anomalies. To mention but a few;

- The geodesist is challenged to determining the physical shape of the earth
- The geophysicist is to understand the subsurface mass distribution of the earth.
- The geologist wishes to be able to understand different geological formations

1.3 RESEARCH OBJECTIVE

The objective of this research is to determine a free-air anomaly. This includes;

- Generating a map of the observed gravity data provided.
- Generating a map of gridded orthometric heights.
- Producing bouguer gravity map over Brong-Ahafo Region.
- Producing free-air gravity map over Brong-Ahafo Region.
- Producing a free-air gravity anomalies map over Brong-Ahafo Region.

- Comparing the free-air gravities, normal gravities and the free-air gravity anomalies.

1.4 RESEARCH WORK

The computation of free-air gravity anomaly will follow the procedure below;

- Acquiring the raw data and identifying the appropriate method for free-air gravity anomaly.
- Applying the reduction methods required in the determination of the free-air gravity anomaly.
- Selecting and applying a gridding procedure to transform the irregular grid points into regular grid points.
- Selecting a reference ellipsoid and the equation for computing its normal gravity.
- Determining the free-air gravity anomaly.
- Analyzing the determined free-air gravity anomaly.

1.5 THESIS OUTLINE

The chapters of this write-up are basically described by the content. Chapter 1 (the current chapter) deals with the introduction and explanation of the general scope of the thesis. Chapter 2 contains the review of the theory and methodologies to derive free-air gravity anomalies using terrestrial gravity data. Also a description of additional procedures for the manipulation and reduction of the data such as downward

continuation is given. Two procedures for practical computation of free-air gravity anomalies are described. Chapter 3 describes the numerical methods and steps associated with computing free-air gravity anomaly data are presented. The data format as well as the location of the site of the research is presented. In chapter 4, the production of maps describing the various steps and procedure involved in the computation of the free-air gravity anomalies. Gravity readings provided by the Geological Survey of Ghana are processed to get the observed gravity data. The free-air gravity anomaly is computed by the use of the observed gravity data and topographic data. In the final chapter 5, observations, conclusions and recommendations after the derivation of the free-air gravity anomaly is presented.

CHAPTER 2

GRAVITY ANOMALIES

This chapter gives an overview of the theories and methods of free-air anomalies derivation. These include; the coordinates system for gravimetry, the normal gravity field and anomalous gravity field. The geoid surface on which the free-air gravity anomaly was derived serves as a boundary surface which requires the theory of the Geodetic Boundary Value Problem (GBVP). The most important consideration was the third GBVP.

An overview of two ways of determining free-air gravity anomaly was included in this chapter i.e. the simple bouguer and refined bouguer anomaly procedures. With some factors considered, the simple bouguer was chosen for this work.

With the data sets acquired, the theory of the gravity reduction and the method of gridding were reviewed. The procedure for analysis of terrestrial gravity data, topographic data and their combination in free-air gravity anomaly derivation were included in this chapter.

2.1 BASIC CONCEPTS OF THE EARTH'S GRAVITY FIELD

To simplify the mathematics, one decomposes the Earth's gravity field into the sum of the normal gravity field and anomalous gravity field.

2.1.1 Normal gravity field

The normal gravity fieId, a first approximation of the actual gravity field, is generated by an ellipsoid of revolution with its centre at the geocentre, called the reference ellipsoid. There are several reference ellipsoids. The most widely used reference ellipsoid is the WGS-84 ellipsoid, which is defined by the following parameters:

Semi major-axis, $a_e = 6378137$ m

Semi minor-axis, $b_e = 6356752$ m

Angular velocity $\omega = 7292115 \times 10^{-11} rads^{-1}$

Theoretical gravity Potential of the reference ellipsoid

$U_0 = 62636860.8497 m^2 s^{-2}$

Another important parameter is the first eccentricity *e* defined as

$$e = \left(1 - \frac{b_e^2}{a_e^2}\right)^{\frac{1}{2}} \qquad 2.1$$

With the four quantities a_e, b_e, ω, U_0, the normal gravity potential U and the normal gravity γ outside (or on) the reference ellipsoid can be evaluated uniquely from closed formulas (Heiskanen and Moritz 1967, Guan and Ning, 1981). U satisfies:

$$\Delta U = \begin{cases} 2\omega^2 & \text{Outside } S_e \\ -4\pi G\rho_N + 2\omega^2 & \text{Inside } S_e \end{cases} \qquad 2.2$$

where S_e, is the surface of the reference ellipsoid and ρ_N is the normal density, which cannot be determined uniquely by the four parameters.

Similar to the gravity potential W, the normal gravity potential U and its first order derivative γ are continuous in the space R^3 while the second-order derivatives of U are discontinuous on the surface S_e.

The surfaces U=Constant are called normal level surfaces and the direction of the normal gravity vector $\underline{\gamma}$ is called the direction of the normal vertical or the normal plumb line. The distance h of a point P to the reference ellipsoid is called *the geodetic height*.

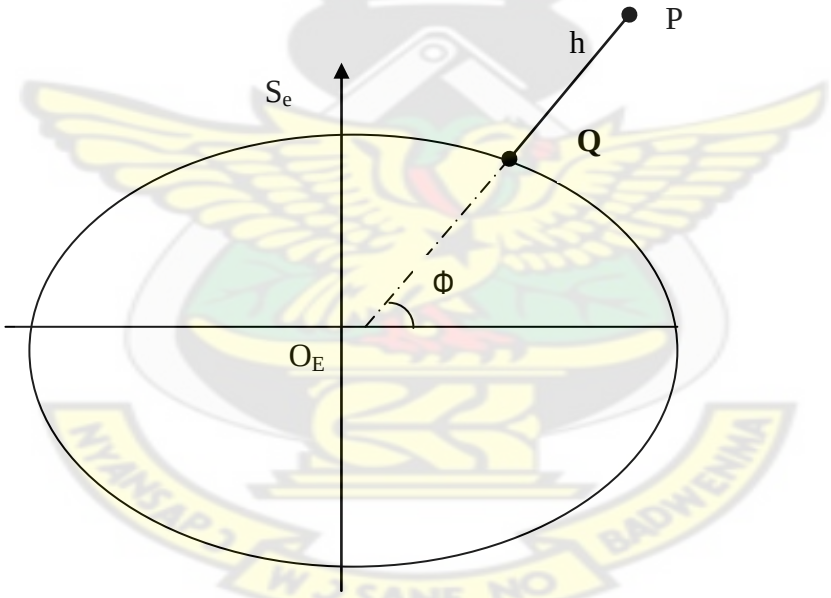


Figure 2.1 The reference ellipsodi S_e and the geodetic height h

The geodetic coordinates of a point is the triplet (ϕ, λ, h) where ϕ the geodetic latitude defined as the angle between $\underline{\gamma}$ and the equatorial plane, λ is the geodetic longitude, which equals to Λ.

The telluroid S_t, the first approximation of the topographic surface, is defined as a surface, the points *Q* of which are in one to one correspondence with the points P of the topographic surface satisfying either

$$(\Phi, \Lambda, W)_P = (\phi, \lambda, h)_Q \qquad 2.3$$

Or

$$(\Phi, \Lambda, \mathrm{H})_P = (\phi, \lambda, h)_Q \qquad 2.4$$

The distance of a point on *St* to S, along the normal plumb is the normal height H.

2.1.2 Anomalous gravity field

The disturbing potential is the difference between the gravity potential W and the normal gravity potential U

$$T = W - U, \qquad 2.5$$

It can be considered as being produced by a disturbing density $\delta\rho(\equiv \rho - \rho_N)$ as follows:

$$T_P = G\int_{\tau_E} \frac{\delta\rho(Q)}{l_{PQ}} dQ \qquad 2.6$$

It can be proved that T satisfies the following condition

$$\begin{cases} \Delta T_p = 0 & \text{P is the outside, } \Delta T_p \text{ is the Laplace function} \\ T_p = O(1/r_p) & r_P \to \infty, O(1/r_P) \text{ is the poisson function} \\ T & \text{and its first order derivatives are continuous outside and on } S_E \end{cases} \qquad 2.7$$

where the first condition (is called the **harmonic condition** of T, the second condition is called the **regularity condition** of T and the third condition is called **the continuation condition** of T.

The **deflection of the vertical** θ is the angle between the directions of the vertical and the normal vertical, which is very small.

The **disturbing gravity**, the difference between gravity and normal gravity, has two different definitions: One is the gravity disturbance δg defined as

$$\delta g(P) = g_P - \gamma_P, \qquad 2.8a$$

The other is the gravity anomaly Δg defined as

$$\Delta g(P) = g_P - \gamma_Q \qquad 2.8b$$

where P and Q satisfy

$$(\Phi, \Lambda, \mathrm{H})_P = (\phi, \lambda, h)_Q$$

The above relation shows that if P is on the geoid, Q is on the reference ellipsoid and if P is on the topographic surface, Q is on the telluroid. The difference between the geoid and the reference ellipsoid can be expressed by the geoidal height N, which is defined as the geodetic height of a point on the geoid.

2.2 GEODETIC BOUNDARY VALUE PROBLEMS

Geodetic boundary value problems deal with the determination of the gravity potential on and outside the Earth's surface from the ground gravity data. They can be defined mathematically as finding the disturbing potential T satisfying:

$$\begin{cases} T \in H[S] \\ BT_P = f_P \end{cases} \quad \text{P is on S} \qquad 2.9$$

Where the boundary surface S is the topographic surface S_E outside which the mass density is zero and on which the input data f_P are given and B, which corresponds to f_P, a zero or first order derivative operator or their combination. After a proper adjustment for the disturbing potential T, S can be the telluroid S_t, the geoid S_g, the reference ellipsoid S_e or the mean sphere S_M, where the **mean sphere** S_M is a sphere centered at the geocentre and with radius R.

According to the difference of the input data, there are various kinds of geodetic boundary value problems. They are: first, second and third geodetic boundary value problem. For this work the third geodetic boundary value problem will be of significance. This will be discussed under subsection 2.3.1.

2.2.1 The third geodetic boundary value problem

In this problem, the inputs are the gravity potential W (or the orthometric height H or the normal height H^*) and the gravity g on S_E , which can be obtained via gravimetry and leveling, the output data are the topographic surface S_E (or the geodetic height h or the geoidal height N) and the external gravity potential. Correspondingly, in (2.17), f_P is the gravity anomaly data Δg on S_E and B is a combination of the first and zero order derivative operators. The regularity condition of the third geodetic BVP is below

$$T_P = \frac{c}{r_P} + \mathrm{O}\left(\frac{1}{r_P^3}\right) \quad P \to \infty \qquad \text{(c is a constant)} \tag{2.10a}$$

This condition is satisfied when the centre of the reference ellipsoid coincides with the geocentre (Heiskanen and Moritz, 1967). Furthermore, if the mass of the reference ellipsoid equals to the mass of the Earth, the constant c in (2.10a) equals to zero (Heiskanen and Moritz, 1967). So the regularity condition becomes

$$T_P = \mathrm{O}\left(\frac{1}{r_P^3}\right) \quad P \to \infty \tag{2.10b}$$

In the following, supposing T in the third geodetic BVP satisfies the regularity condition (2.10b). The mathematical expression of the third geodetic BVP (Zhiling Fei 2000) is as follows

$$\begin{cases} T \in H\left[S_E\right] \\ T_P = \mathrm{O}\left(\dfrac{1}{r_P^3}\right) \qquad P \to \infty \\ \dfrac{\partial}{\partial h} T_P - \dfrac{1}{\gamma_P} \dfrac{\partial \gamma_P}{\partial h} T_P = -\Delta g(P) \end{cases} \tag{2.11}$$

where $\dfrac{\partial}{\partial h}$ means the derivative along the normal plumb line.

This equation (2.11) is called **Molodensky's problem.** Since the plumb line is not normal to S_E, Molodensky's problem is an oblique derivative problem. After transforming the disturbing potential T, the Molodensky's problem can be converted into the Stokes' problem, a normal derivative problem in which the boundary surface is the geoid.

2.3 NORMAL FREE-AIR GRADIENT

The gravity gradient is computed from (Heiskanen & Moritz, 1967)

$$\frac{\partial g}{\partial H} = -2gJ + 4\pi k\rho - 2\omega^2 \qquad 2.12$$

Where $\frac{\partial g}{\partial H}$ is the gravity gradient sought, g is the gravity value, J is the mean curvature of a level surface and is equal to $-\frac{W_{xx}+W_{yy}}{2g}$, with W_{ii} being the partial derivative of the gravity potential along the i-axis, ρ is the density of the underlying masses at the location where $\frac{\partial g}{\partial H}$ is evaluated, and ω is the rotation rate of the earth.

This equation cannot be easily computed and, instead, the normal gravity gradient is used as an approximation.

The normal gravity γ at altitude h can be expanded into a series of terms of h (Heiskanen & Moritz, 1967)

$$\gamma_h = \gamma + \frac{\partial \gamma}{\partial h} h + \frac{1}{2}\frac{\partial^2 \gamma}{\partial} h^2 + \ldots \qquad 2.13$$

In this series only terms up to second order are significant. The first term of the order is approximately equal to 0.3086 mGal m^{-1}. The second can reach approximately 1.4 mGal for heights of 4325 m and is evaluated as:

$$\frac{\partial^2 \gamma}{\partial h^2} = \frac{6\gamma}{a_e{}^2} \qquad 2.14$$

Where a_e is the semi-major axis of the ellipsoid and γ is the normal gravity.

2.4 GRAVITY ALIASING AND GRIDDING

Fast Fourier Transforms (FFT) and Terrain Correction (TC) computations require gridded points for gravity computations. When surface gravity observations are made for mapping or exploration purposes, the ideal situation is for them to be located so that they are spatially distributed to adequately sample the gravity field. This means that, in ideal circumstances, there will be a higher density of observations where the gravity field is rapidly changing and a lower density where it changes more smoothly. In reality, the areas where the gravity field is more variable (e.g., mountainous regions) are frequently the areas where gravity observations are sparsely located due to difficulties physically accessing the desired locations, terrain roughness and problems with gravimeter drift (Janák and Vaníček 2005). To overcome these limitations, Featherstone and Kirby (2000) proposed a gravity "reconstruction" technique to predict the gravity field using high-frequency topography information from an elevation data.

2.4.1 Gravity pseudo-aliasing

The Ghana gravity observations are not regularly spaced. The irregularly spatial distribution of surface gravity observations becomes a problem when they are interpolated. This is because the interpolated surface is not representative of the actual gravity field (Reilly 1972).

Featherstone and Kirby (2000) and Goos et al., (2003) explain that the effect of irregular sampling is similar to the phenomenon of aliasing in signal processing. This is because both involve sampling a continuous function at discrete intervals that cannot duplicate the desired function. In signal processing, the samples are usually made at regular

intervals, where information at frequencies higher than twice the sampling frequency (Nyquist frequency) is incorrectly represented. According to sampling theory, this high-frequency information becomes aliased into the lower frequencies, thus continuing the sampled function.

With gravity data acquisition, the sampling interval is usually irregular but the consequence is similar; the gravity signal is sampled such that higher-frequency information is omitted and may be aliased into the lower frequencies. Mean gravity will be required to numerically solve Stokes' integral (Heiskanen and Moritz, 1967)

2.4.2 Gravity reconstruction

Free-air gravity anomalies are highly correlated with the height of the observation points. This means that the "roughness" of the free-air anomalies is similar to that of the topography, thus in mountainous areas it is not sensible to directly interpolate and average the anomalies because of aliasing (e.g., Featherstone and Kirby, 2000). To minimize the error, a common method is to grid Bouguer (or refined Bouguer) anomalies which are by definition "smoother" than their free-air counterparts (Featherstone and Kirby 2000; Goos et al. 2003; Janák and Vaníček 2005). Because the same (limited) number of gravity observations is used, this approach will still give a surface that is aliased.

Featherstone and Kirby (2000) proposed a method to reduce the effects of both gravity aliasing and the irregularly spaced gravity observations where supplementary terrain information from digital elevation model (DEM) is used to compute additional

"reconstructed" anomalies at unobserved locations on the topography. Termed the "reconstruction" technique, the resulting Faye gravity anomaly grid is a better representation of the true integral mean over the topography than simple averaging of the original Faye anomalies. This method has been implemented in a number of other studies (Goos et al., 2003; Janák and Vaníček, 2005; Bajracharya and Sideris, 2005a, 2005b)

The reconstruction method initially reduces the individual gravity observations to their planar Bouguer anomaly equivalents using (alternatively the spherical approximation could be used):

$$\Delta g_B = g_S - \gamma(\phi) + \delta g_F(\phi, H) - \delta g_B(H) \qquad 2.15$$

where g_S is the observed gravity acceleration on the Earth's surface: γ is normal gravity at the reference ellipsoid, computed from the geocentric latitude ϕ of the observation using the Somigliana formula (Moritz, 1980a); $\delta g_F(\phi, H)$ is the second-order free-air gravity reduction given as:

$$\delta g_B(H) = 2\pi G\rho H \qquad 2.16$$

The above procedure was used by Goos et al. (2003) in Australia, and by Janák and Vaníček(2005) and Bajracharya and Sideris (2005a) in the Canadian Rocky Mountains. The general procedures followed were the same, however they reached different conclusions regarding what was the best type of Bouguer anomaly to use in gravity data

interpolation for subsequent geoid computation. Both of the Australian studies (albeit performed by the same team) found that the use of simple Bouguer anomalies gave better results while both Canadian studies favored the use of refined Bouguer anomalies. This difference was attributed to the more rugged terrain that is found in Canada (and similarly in New Zealand) versus that in Australia and the corresponding sparse gravity observations.

The topography of some part of Ghana (Brong Ahafo) can be described to some extent to that of rugged terrain although the gravity coverage in the areas of rough topography is not as dense. This suggests that the direct interpolation of refined Bouguer anomalies in Ghana will not produce un-aliased values.

2.5 GRAVITY REDUCTION

The solution of the Boundary Value Problems requires the function to be known on the geoid. The gravity field at the geoid is very important in the geoid determination. The surface gravity field g_{P_S} has to be reduced down to the geoid g_P, as visualized in the figure below

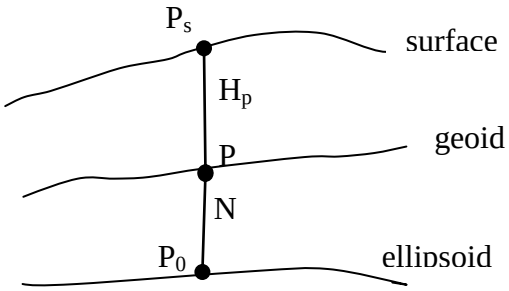


Figure 2.2: Reduction of gravity from surface point P_s down to the geoid point P. The ellipsoid is the set of approximate points P_0

Over most of the land masses, the geoid is inside the Earth. When performing gravity reductions assumptions are made about the internal density structure of the Earth, at least about its upper parts. Geophysical relevance is not a criterion, though. The main aim is to obtain a reduced gravity field that is smooth. From a geodetic standpoint this is a sensible requirement for geoid computation.

2.5.1 Free-air reduction

The simplest assumption for gravity reductions is to neglect all the topographic masses between surface point P_S and its footprint on the geoid P. Gravity has to be downward continued along the plumbline between P_S and P over a distance H_P, the orthometric height of P_S. This type of reduction is known as free-air reduction. In linear approximation:

$$g_P^{FA} = g_{P_S} - \left.\frac{\partial g}{\partial h}\right|_P H_{P,} \qquad 2.17$$

FA stands for the free-air gradient. The gravity gradient depends on the location and on the actual gravity field. In order to have a uniform definition of free-air gravity, a fixed value is taken. In this case FA comes from the simplification:

$$g \approx \frac{GM}{r^2} : \frac{\partial g}{\partial r} = -2\frac{GM}{r^3} = -2\frac{g}{r}. \qquad 2.18$$

Inserting numbers gives:

$$g_P^{FA} = g_{P_S} + FA \cdot H_P$$
$$with \qquad 2.19$$
$$FA = 0.3086\, mGal/m$$

The gradient is expressed in $mGal/m$. Thus heights are expressed in m and gravity values in mGal. Note that FA is positive. Gravity increases towards the centre of the Earth.

Calculating the free-air gravity field, topography is neglected, particularly its gravitational attraction. This shows up in the reduced gravity field g^{FA} as a large correlation with the original topography. This is definitely unwanted for geoid computations. The topography must be considered in a different way.

2.5.2 Bouguer reduction

During the famous French arc measurement expedition to Peru, Bouguer noticed the correlation between gravity and topography of the Andes. The reduction of gravity for topography is named after him: *Bouguer reduction*.

Bouguer Plate is the simplest form to approximate the topography surrounding point P_S by an infinite plate of thickness H_P a Bouguer plate. This does not imply the model of a whole region by such a plate. On the contrary, at each terrain point a new plate is considered. The Bouguer plate can be considered a cylinder of height H_P and infinite radius.

g(Bouguer plate)= $2\pi G\rho H_P$

$$: BO = -\frac{\partial g(B \cdot p.)}{\partial h} = -2\pi G\rho = -0.1119\, mGal/m \qquad 2.20$$

The latter number was derived with the conventional crustal density $\rho = 2670\, kg/m^3$. The Bouguer gradient BO, which is also expressed in $mGal/m$, is negative because gravity becomes less if the plate is removed.

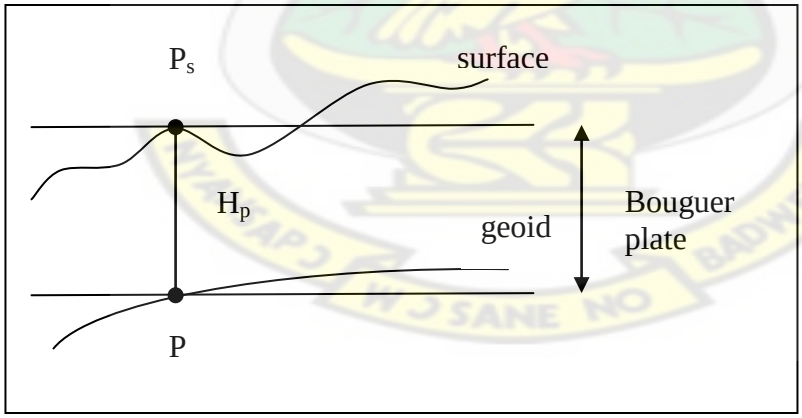


Figure 2.3: Bouguer plate: modeling the topography point-wise by an infinite slab of thickness H_P .

The procedure now consists of:

Surface gravity: g_{P_S}

Remove plate: $+BO \cdot H_P$

Go down to the geoid: $+FA \cdot H_P$

$$g_P^{BO} = g_{P_S} + (BO + FA)H_P$$
$$g_P^{BO} = g_{P_S} + 0.1967 H_P \qquad 2.21$$

These steps account for a large reduction in correlation between Bouguer gravity and original topography. Nevertheless they are still a rough approximation for two reasons: The real topography surrounding a given point P_S is approximated as a plate. A constant density was assumed. The latter point is interesting from a geophysical point of view. Variations in the Bouguer gravity field indicate variations in the underlying density structure.

For a free-air gravity anomaly, normal gravity γ_{Po} at the corresponding ellipsoid point is subtracted from the free-air gravity value at the corresponding point on the geoid:

$$\Delta g^{FA} = g_p^{FA} - \gamma_{Po} \qquad 2.22$$

Bouguer gravity anomalies, terrain corrected gravity anomalies and isostatically reduced gravity anomalies are defined in the same way.

2.6 METHODOLOGY FOR THE DETERMINATION OF THE FREE-AIR GRAVITY ANOMALIES

In the free-air gravity anomalies derivation, there are two methods available in the field of physical geodesy. Assuming gravity measurements (magnitude of the gravity vector) on the earth surface $g(r_t,\Omega)$ at horizontal locations $\Omega(\varphi,\lambda)$ and supposing these values have been corrected for time dependent effects, such as tides. From these values it is easy to compute the point values of free-air gravity anomalies at the same locations using the formula (Torge, 1989, Eq. (3.7a))

$$\Delta g^{FA}(r,\Omega) = g(r_t,\Omega) - \gamma_0(r_e,\Omega) + \delta g^{FA}(\Omega) \qquad 2.23$$

where $g(r_t,\Omega)$ is the measured gravity on the topography, $\gamma_0(r_e,\Omega)$ is the normal gravity on the reference ellipsoid. The term $\delta g^{FA}(\Omega)$ denotes the free-air reduction of normal gravity defined by the following expression (Janák and Petr Vaníček)

$$\delta g^{FA}(\Omega) \cong -\left[\frac{\partial\gamma_0(r_e,\Omega)}{\partial h}H_N(\Omega) + \frac{1}{2}\frac{\partial^2\gamma_0(r_e,\Omega)}{\partial h^2}H_N^2(\Omega) + \frac{1}{6}\frac{\partial^3\gamma_0(r_e.\Omega)}{\partial h^3}H_N^3(\Omega)\right], \qquad 2.24$$

where H_N stands for normal height. Because of the correlation of free-air anomalies with heights, the roughness of the free-air gravity anomalies is similar to the roughness of the terrain. Therefore, in the mountains it is not possible to interpolate and average these anomalies directly, unless there is really dense gravity mapping (e.g. 10 values per km^2) which is usually not the case. Thus in order to minimize the interpolation error there is the need to follow one of two possible ways showed in fig. 2.5.

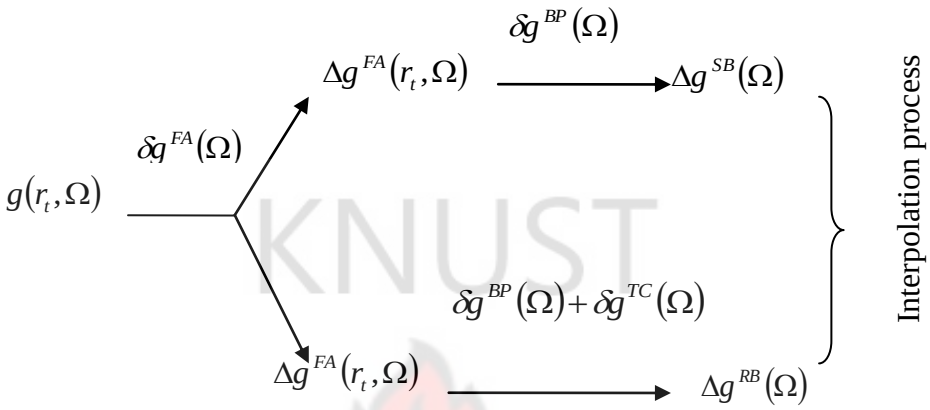


Fig. 2.4 Two ways of free-air anomaly determination.

The methods in figure 2.4 are classified as;

1) the simple Bouguer gravity anomalies Δg^{SB} determination, related to free-air anomalies by the following formula *(Heiskanen and Moritz, 1967, Eq. (3-18))*:

$$\Delta g^{SB}(\Omega) = \Delta g^{FA}(r,\Omega) + \delta g^{BP}(\Omega), \qquad 2.25$$

where $\delta g^{BP}(\Omega)$ denotes the Bouguer plate reduction

$$\delta g^{BP}(\Omega) = -2\pi G\rho H\,, \qquad 2.26$$

G stands for the Newton gravitation constant and ρ represents the volume density of topographical masses.

2) the refined Bouguer gravity anomalies Δg^{RB}, related to free-air anomalies by *(ibid., Eq. (3-21))*

$$\Delta g^{RB}(\Omega) = \Delta g^{FA}(r,\Omega) + \delta g^{BP}(\Omega) + \delta g^{TC}(\Omega), \qquad 2.27$$

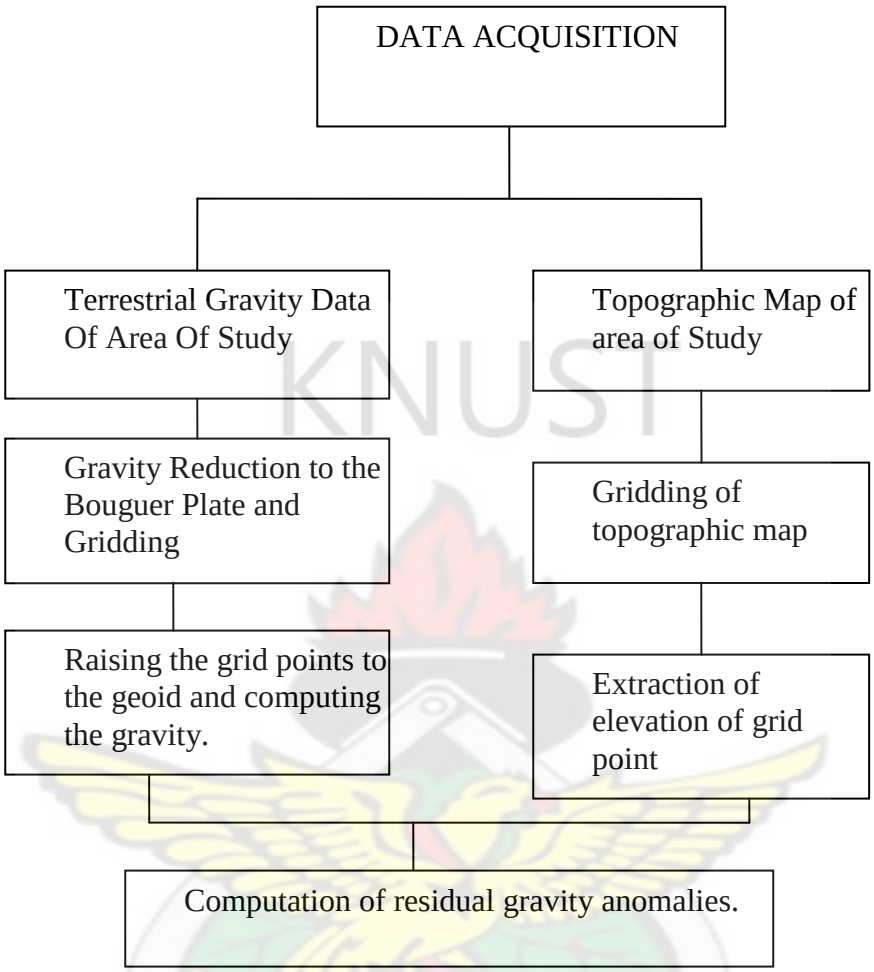
which differ from the simple bouguer anomalies by the point terrain correction $\delta g^{TC}(\Omega)$. Both, the simple and the refined bouguer gravity anomaly fields are smooth enough to perform an interpolation operation over the point values within a specific geographical cell.

The refined bouguer anomaly is more time consuming because it requires the evaluation of the terrain correction both at the observation points and after the interpolation on chosen regular grid in order to obtain terrain correction with sufficient accuracy.

The simple bouguer anomaly is implemented in gravity pseudo-aliasing technique (gravity "reconstruction" technique), proposed by Featherstone and Kirby (2000). This technique is explained in chapter three. Added to the terrestrial gravity data is the topographic gravity data.

The method for the research work is the simple bouguer anomaly process which is presented in the flowchart shown in fig. 2.6:

Fig. 2.5 Flow chart of the method for research work



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CHAPTER 3

COMPUTATIONAL PROCESSES

Chapter three considers the raw data format and procedures undertaken to process it. The practical derivation of the free-air anomaly considers an assumption which makes procedure workable. The region chosen for the research and the data structure was discussed.

Systematically, after the data acquisition, the ground gravity data was reduced to the bouguer plate. The topographic data acquired undergoes gridding by krigging method of interpolation. This was done, using the surfer 7.0 software, to derive the elevation values of the various grid points chosen. The values of gravity on the bouguer plate and the elevation for their corresponding grid points were used to derive the free-air gravity values. The normal gravity was deducted from the free-air gravity to arrive at the free-air anomaly.

3.1 DATA

The data for this research consist of a terrestrial gravity and elevation extracted from a Digital Elevation Model (DTM). The gravity data used for this work was taken from the Geological Survey Department of Ghana. The data covers the whole of Ghana. In all 260 data points were given for the work. Time constraints and access to the elevation data for the whole of Ghana restricted the coverage area of the work. In its entirety four grid areas of total dimension $1^{O} \times 1^{O}$ was used for the work. The raw gravity data consist

of latitudes, longitudes and terrestrial measurement of the gravity at mostly accessible points. The format of the data is shown in appendix A.

3.2 AREA OF WORK

The region chosen for the free-air gravity anomaly computation is bound by $7^{o}N \leq \phi \leq 8^{o}N$, and $2^{o}W \leq \lambda \leq 3^{o}W$, which covers the a major portion of the Brong Ahafo region and some portions of Ashanti region. The significant towns in the area of study are Sumaahenekuro, Dormaa-Ahenkro, Dormaa-Akwamu Wamfie, Duayaw-Nkwanta, Sunyani and Wenchi. The grid spacing chosen is 2.5′x 2.5′ which gives an array of 25 rows by 25 columns. In addition to the terrestrial gravity data, the corresponding topographic map covering the area of work was acquired from the Land Surveying Department of Ghana.

Fig.3.1 The map of Ghana at the scale 1:50000 (An extract from google maps)

The map of the area concerned is shown in fig.3.2.

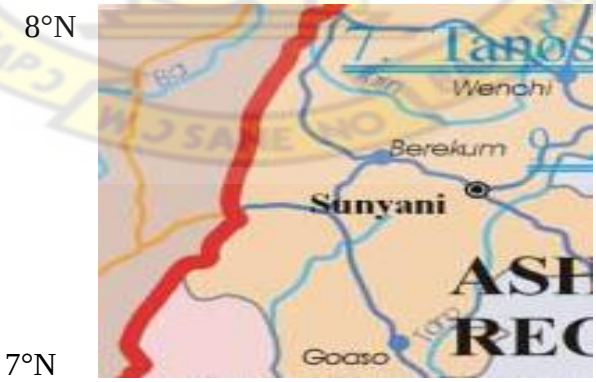

Fig.3.2 Extract of the area of work from Ghana map (scale of 1:50000)

3.3 TOPOGRAPHIC DATA GRIDDING

The topographic data contains coordinates extracted from a digitized topographic map of Ghana. This data was in the ArcGIS format and had to be converted into a SURFER 7.0 format. The data consist of latitude (φ), longitude (λ) and the elevations (h). The elevations of the grid points are derived from the data by kriging method of interpolation. This method of interpolation is of higher accuracy and mostly preferred in geospatial data analysis. The blocks extracted are superimposed on the gravity data given for the coordinate system of the gravity data and that of the topographic data to coincide. The elevation of the various grid points are achieved for use in the free-air gravity reduction process.

3.4 GRAVITY RECONSTRUCTION

To compute the free-air gravity anomaly at specified grid points, the following steps were adapted;

1. irregular free-air anomalies are computed for the gravity data.
2. the irregular free-air anomalies are reduced unto a bouguer plate by the bouguer reduction method to generate irregular bouguer anomalies.
3. the irregular bouguer anomalies are interpolated onto 2.5 arc-minute grid.
4. applying “reverse” bouguer plate correction using height at each DEM cell. This gives reconstructed free-air anomalies.

Therefore, the individual free-air anomalies are reduced to their planar Bouguer equivalents and then interpolated onto a relatively coarse grid. A high-resolution Digital

Elevation Model (DEM) is then used to reconstruct free-air anomalies at each higher resolution DEM element by the application of a "reverse" Bouguer correction. Bajracharya and Sideris (2005b) showed that the best results are achieved when a DEM with the highest resolution is utilized. The resulting high-resolution grid of free-air anomalies is then interpolated onto the coarse grid that can be used for geoid computation. The resulting grid of free-air anomalies should theoretically be more representative of the actual gravity field than the grid obtained by simply interpolating the original observations.

3.5 DETERMINATION OF THE FREE-AIR GRAVITY ANOMALY

The free-air gravity anomaly is computed by subtracting the normal gravity on a corresponding ellipsoid from the free-air gravity derived. That is:

$$\Delta g^{FA} = g_P^{FA} - \gamma_{p_0} \qquad 3.1$$

In the determination of the free-air gravity anomaly by the process of gravity reconstruction, the free-air gravity (eqn. 2.26) is used as well as the bouguer gravity (eqn. 2.27).

With an assume density ($\rho = 2670 kg/m$) the free-air reduction and the bouguer plate component of the bouguer reduction are as follows:

$FA.H_P = 0.3086 H_P mGal$: This equation is the free-air reduction.

$BO.H_P = -0.1119 H_P mGal$: This equation is the bouguer plate component of the bouguer reduction.

H_P is the orthometric height of the gravity station. This is also equal to the thickness of the infinite slab of the bouguer plate.

The use of the bouguer reduction is necessary in the gravity reconstruction process as after obtaining the grid points in the bouguer plate there is the need to reduce gravity to the geoid (free-air reduction). This is done by applying a reverse of the bouguer plate component. Hence free-air gravity is obtained for all the grid points.

The normal gravity γ_{P_O} of the grid points are computed using the GRS80/WGS84 ellipsoid parameters. The Somigliana-Pizzetti normal gravity formula:

$$\gamma(\phi) = \frac{a\gamma_a \cos^2\phi + b\gamma_b \sin^2\phi}{\sqrt{a^2\cos^2\phi + b^2\sin^2\phi}} \qquad 3.2$$

a=6378137 m semi-major axis

b=6356752.3141 m semi-minor axis

γ_a =978032.67715 mGal normal gravity at the equator

γ_b =983218.63685 mGal normal gravity at the poles

ϕ = the geodetic latitude.

Alternatively normal gravity formula can be written in the series form as:

$$\gamma(\phi) = 978032.7\left(1 - 0.0057024\sin^2\phi + 0.0000059\sin^4\phi\right) mGal$$

Table 3.1 the reduction performed on the observed gravity values.

Observed Gravity	Orthometric height	Bouguer Reduction	Reverse Bouguer Plate	Free-air reduction	Free-air gravity	Normal Gravity	Free-air gravity anomaly
g_{p_s}	H_P	$(FA+BO).H_P$	$-BO.H_P$	$FA.H_P$	g_P^{FA}	$\gamma(\phi)$	Δg^{FA}

CHAPTER 4

RESULTS AND ANALYSIS

This chapter gives the results of data manipulation and processing. The systematic procedure required to determine the free-air anomaly was undertaken to arrive at the results.

The first step in the work was the processing of the raw data given. This includes the reduction of the gravity data unto a bouguer plate and gridding to determine the gravity values of the required grid points. The topographic data underwent krigging interpolation process to extract the elevation of the grid points for the work. These elevations are used to compute the free-air reduction for the derivation of the free-air anomaly.

The step by step order of the work was arranged and the resultant maps plotted. The final procedure was analysis in 2D graphs of the free-air gravity, the normal gravity and free-air anomaly in connection with the surface topography.

4.1 MAP DEVELOPMENT

The processing of the data to arrive at a map of the free-air anomaly has been arranged in stages. These stages are in the following order of arrangement:

Stage 1

Figure 4.1 is a map of observed gravity data taken from the Geological Survey Department of Ghana. This data covers the whole of Ghana. The intention of producing this map is to determine the area with the most observed gravity values.

From the map (fig. 4.1) there are areas of high and uniform gravity most especially on the upper division. Some other regions of the map experience low gravity values. Points of higher gravity values experience strong gravitational field from the centre of the earth. Thus it is closer to the source of gravitational attraction.

The table used in the development of the map (fig 4.1) is extracted from appendix A

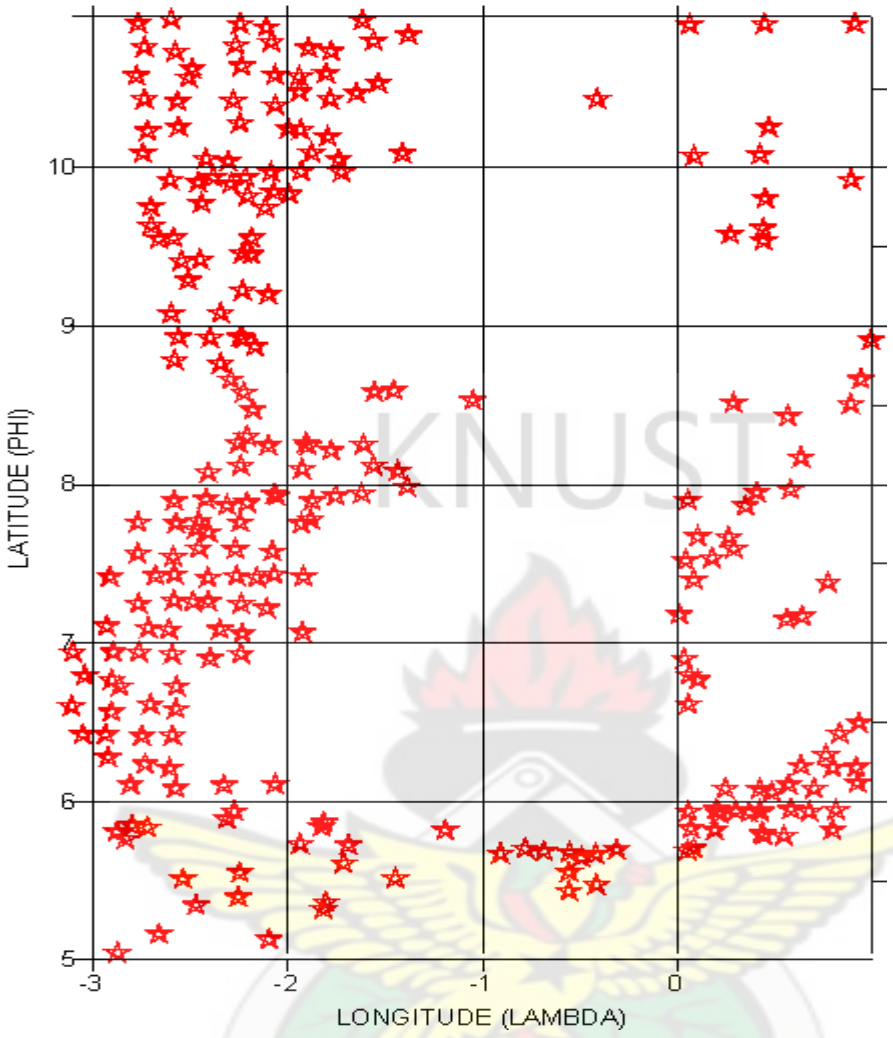

Fig 4.1a A map of observed gravity from irregular gravity data points covering the whole Ghana.

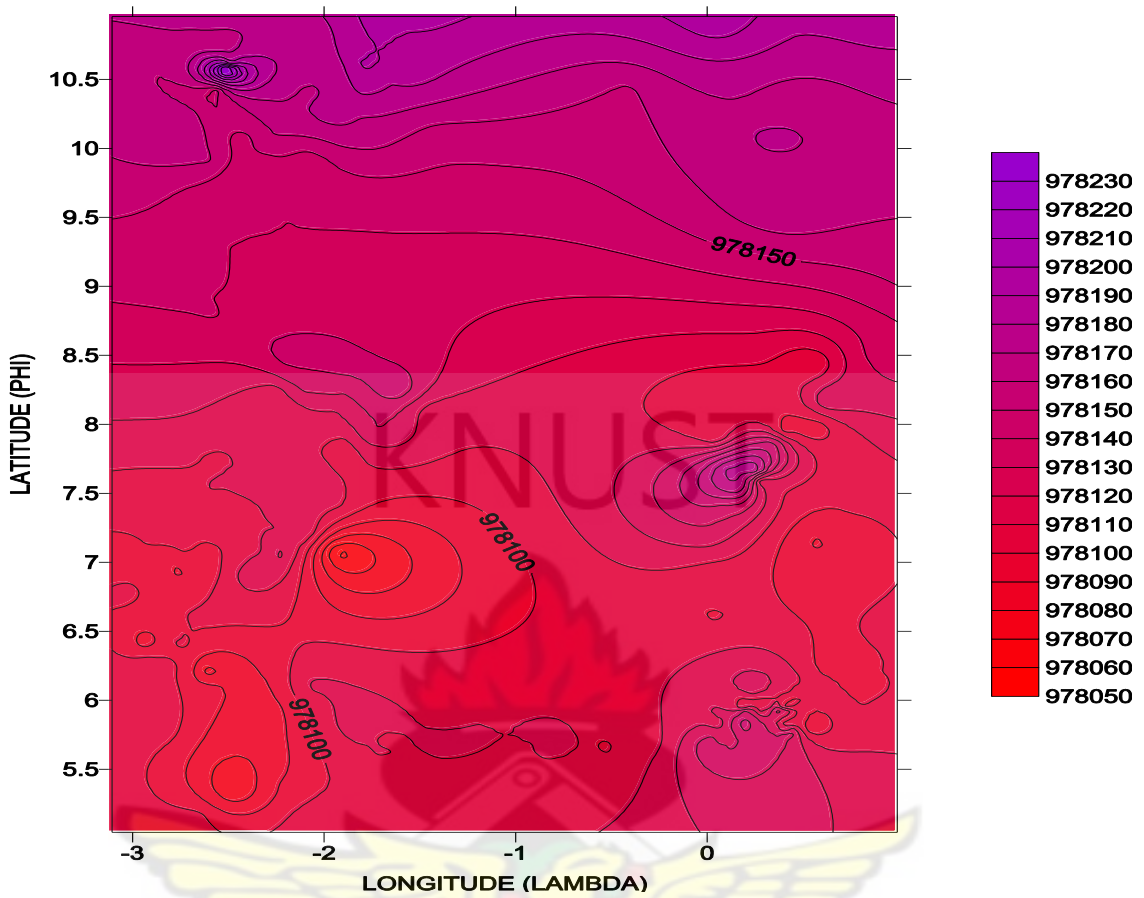

Fig 4.1b 2-D map of the irregular free-air gravity of Ghana

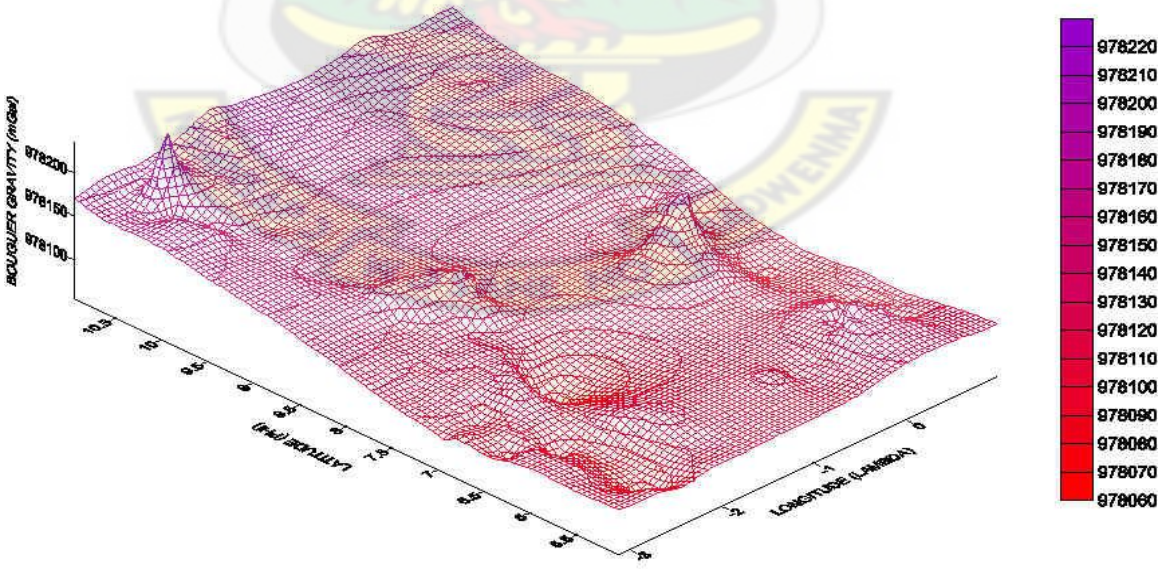

Fig 4.1c 3-D map of the irregular free-air gravity of Ghana

Stage 2

From the topographic map given by the Survey Department of Ghana which is in correspondence to the region chosen for the work in the terrestrial gravity data, the elevation of the various grid points are determined by krigging interpolation method. The bouguer gravity of the area of which topographic data is provided is also extracted from the gridded bouguer plate gravity values of the stage one. The resultant is used in the computation of the free-air gravity values on the geoid for the various points. The gridding process gives points with equal intervals. Figure 4.2a and 4.2b gives the irregular gravity points and the gridded points required for a regular gravity respectively. *See data in appendix B.*

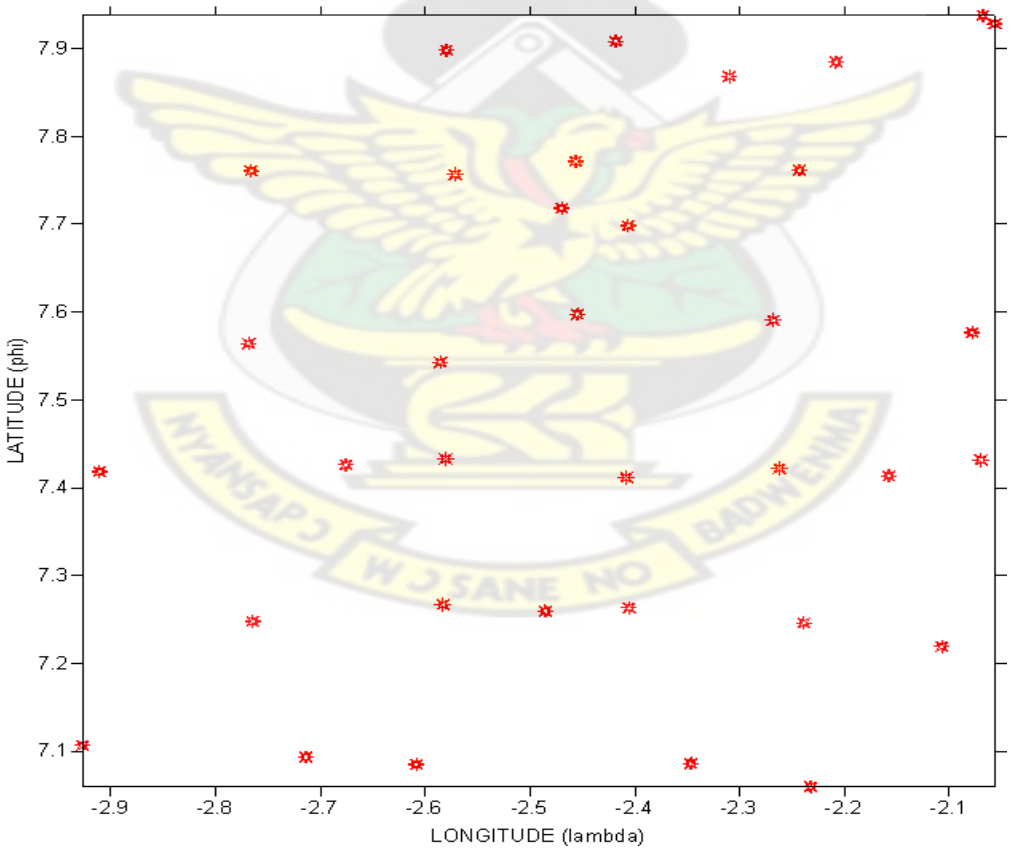

Fig 4.2a Gravity data of extracted area with irregular intervals.

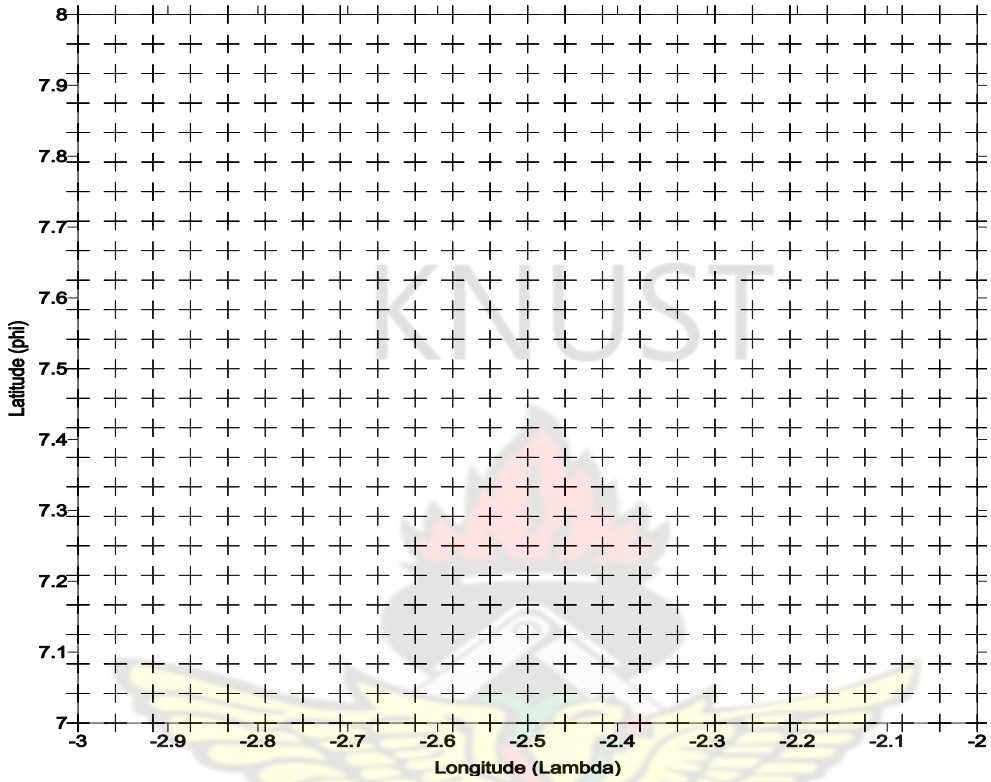

Fig 4.2b The extracted areas gridded into regular intervals.

Stage 3

This stage of the process is an extract of the portion of the region required from the whole Ghana data. The resultant bouguer gravity of the various grid points and the corresponding latitudes and longitudes are used in the development of these maps (fig 4.3a and fig 4.3b).

From the map (fig 4.3a and fig 4.3b), there is an indication of changes of gravity of low values at the ends moving along the longitudinal axis. From longitude 2.5˚W, there is a steady increase in the gravity values on the plate describing a dip in the topography

(terrain). The gravity values decreases steadily to longitude 2.03˚W (approximately). The essence of this process is for easy derivation of the free-air gravity of the grid-points. *See appendix B for table*.

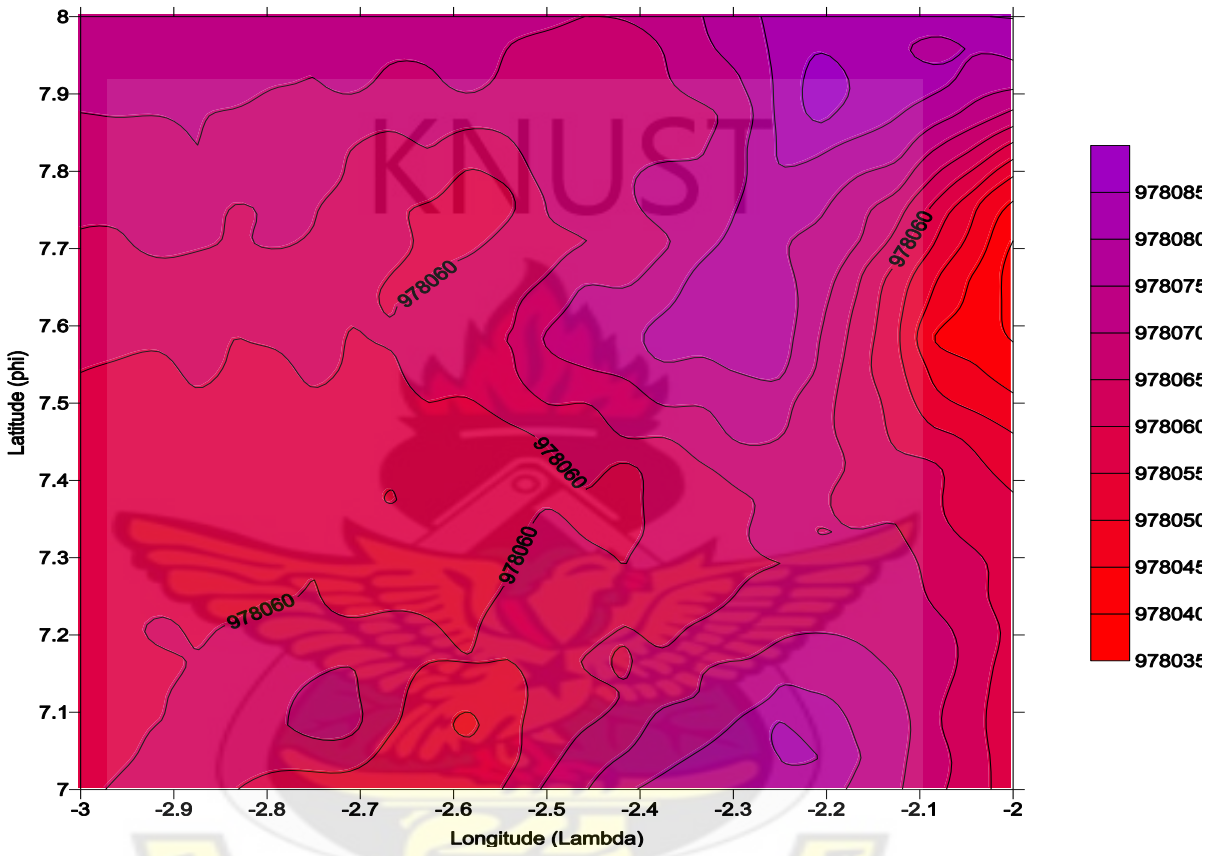

Fig 4.3a 2-D map of bouguer gravity

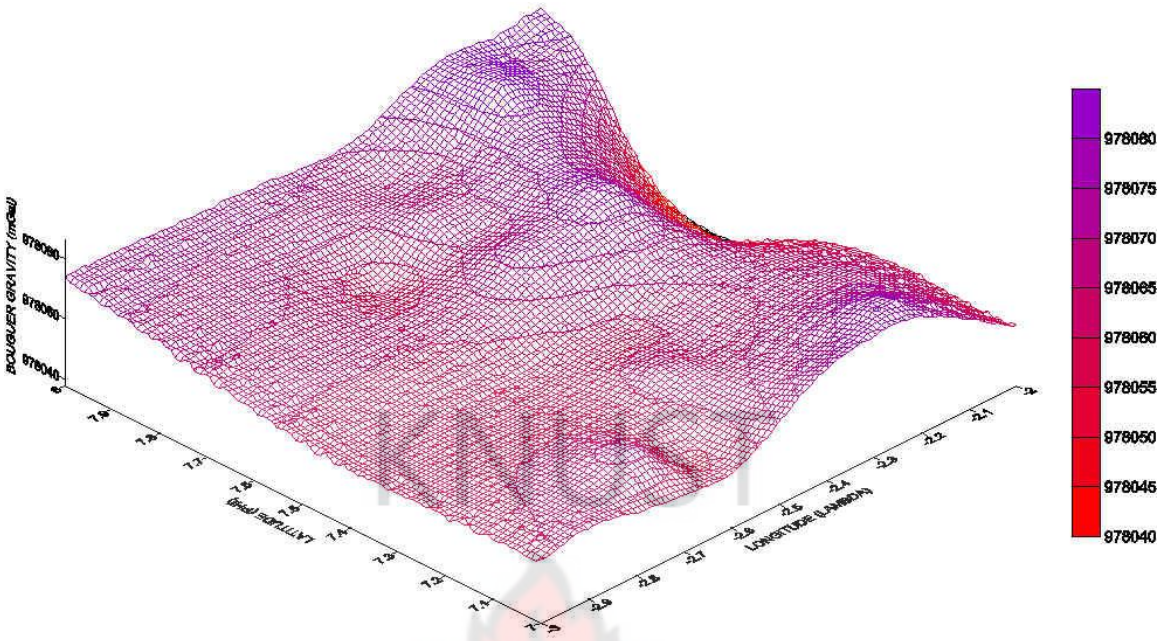

Fig 4.3b 3-D map of bouguer gravity

Stage 4

The gridded topographic data in stage two is used to construct a map in this stage. These elevations were achieved by the use of the surfer 7.0. The topographic data is loaded into the surfer programme worksheet and then processed by krigging interpolation method to produce the map (fig 4.4a and fig.4.4b). With the bouguer gravity values of the grid points, the corresponding elevations are also included in the computation of their free-air gravities by the addition of the reverse bouguer plate component.

In this map the elevation displays a group format of values. Descriptively, some sections have high elevation concentration with other areas with low elevation concentration. The range of elevation values is from 161.91 to 436.41 meters.

NB: The data of this map is an extract of appendix B.

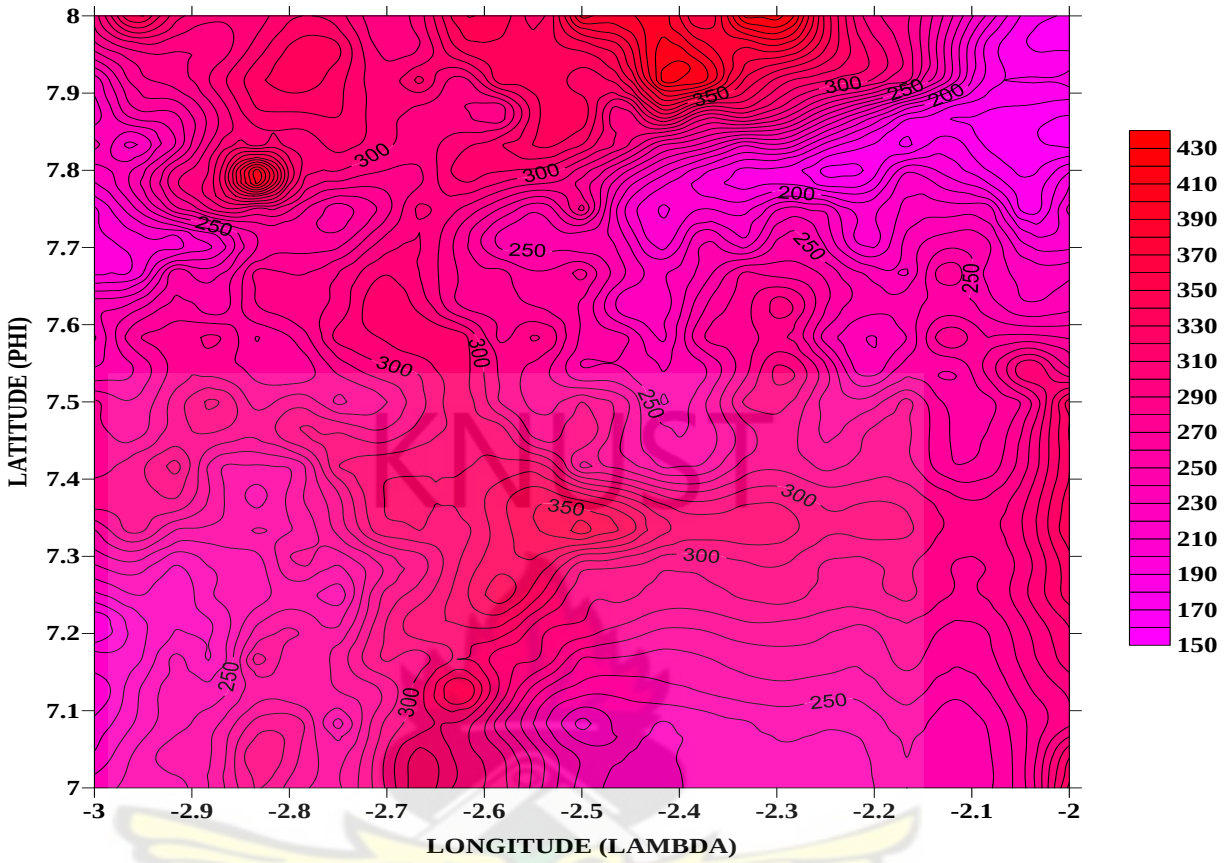

Fig 4.4a 2-D map of the orthometric heights of grid points generated from the DTM.

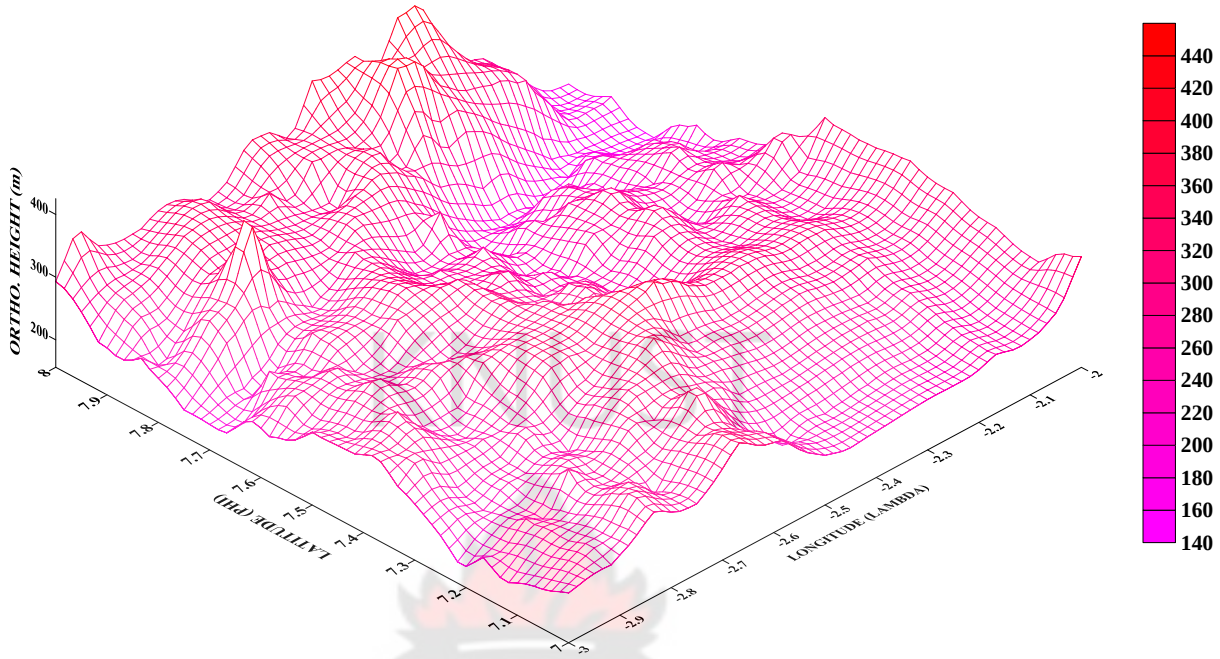

Fig 4.4b 3-D map of the orthometric heights of grid points generated from the DTM

Stage 5

The map in fig. 4.5a and fig.4.5b represent free-air gravity which signifies the gravity on the geoid. These maps are the resultant of the application of the "reverse" bouguer correction to the bouguer gravity data in stage three. The resultant gravity value here is a correction that neglects the existence of the masses above the geoid since the work process employs geodetic boundary value procedure. The description of the geoid can be deduced from the gravity values on these maps. This is because the free-air gravity values give a fair idea of the separation of the geoidal surface from the ellipsoidal surface with the normal gravity along the plumb line.

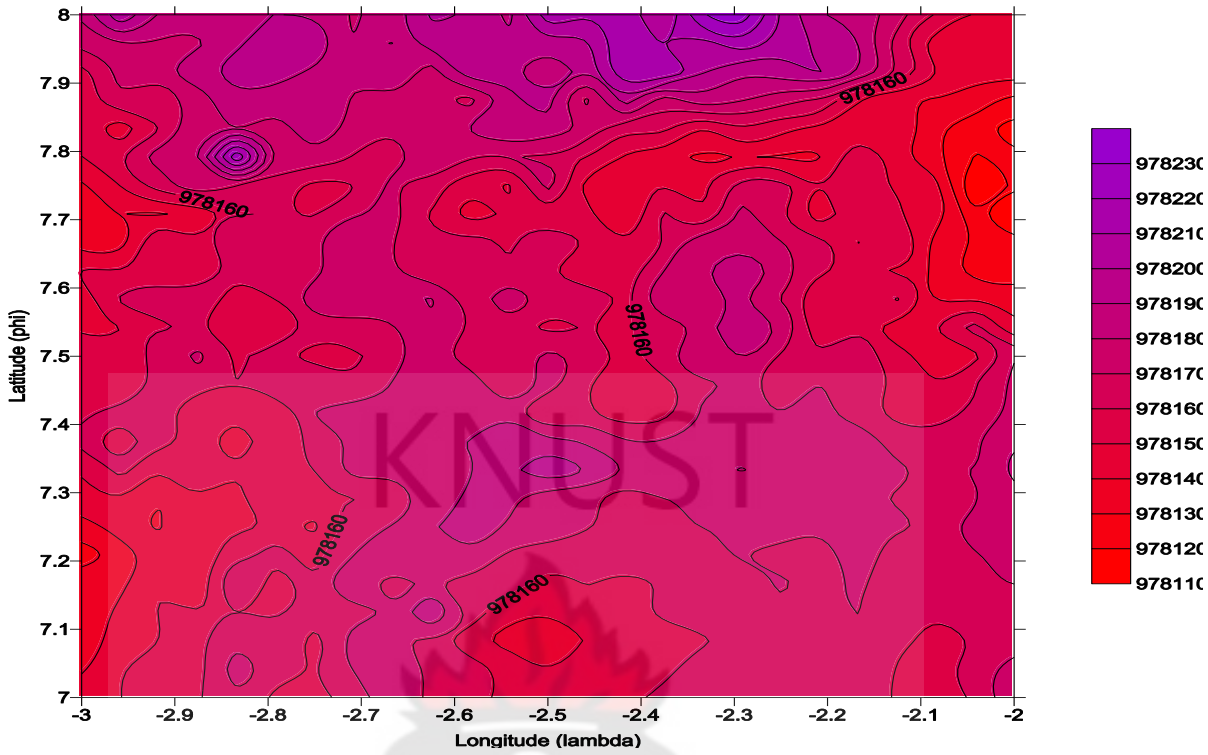

Fig 4.5a 2-D map of Free-air gravity

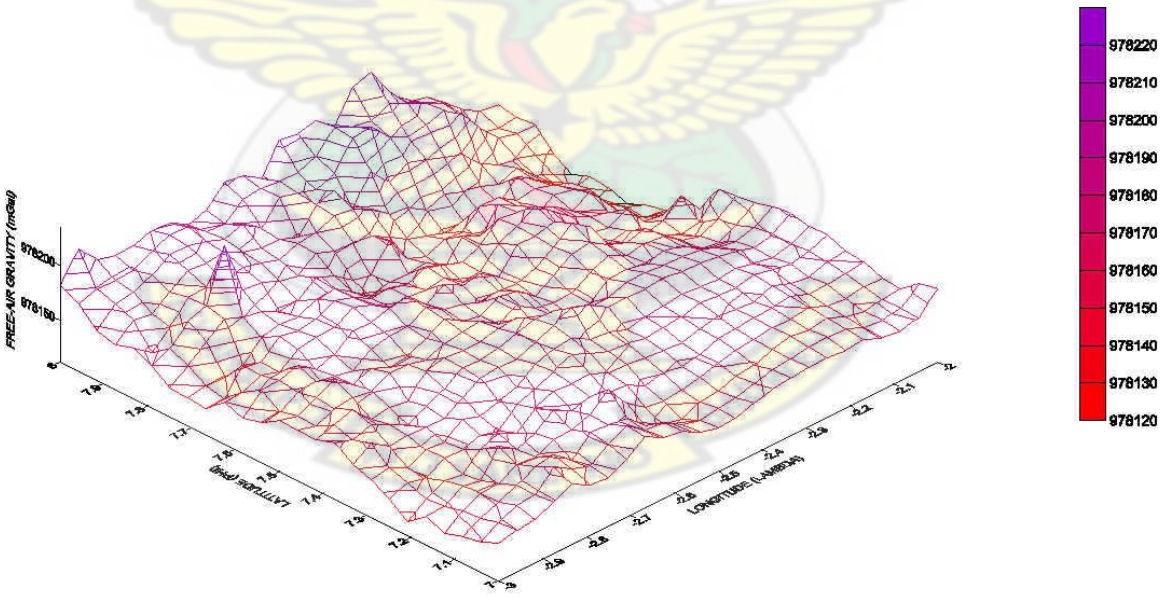

Fig 4.5b 3-D wireframe map of Free-air gravity

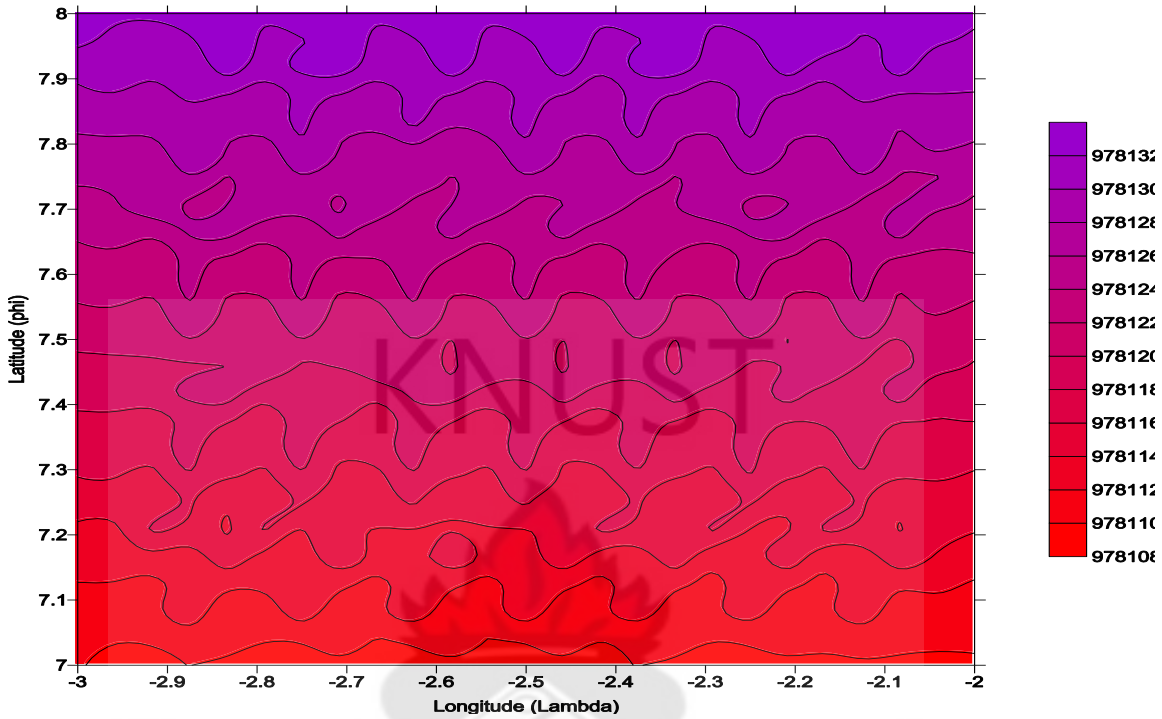

Fig 4.6a 2-D normal gravity map of grid-points

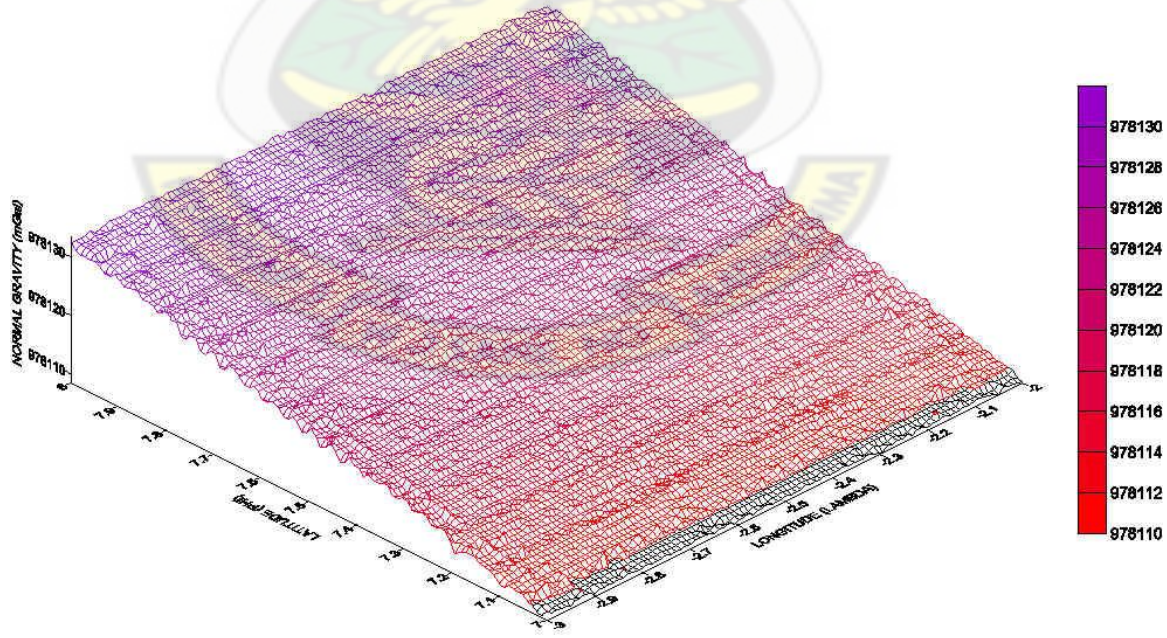

Fig 4.6b 3-D wireframe of normal gravity map of grid-points

The normal gravity required in order to compute the free-air gravity anomaly for the various grid-points is computed using Somigliana-Pizzetti formula. This formula requires the use of a chosen ellipsoid that describes the mathematical surface of the earth. Fig 4.6a and fig 4.6b are the maps generated for the normal gravity using the GRS80 ellipsoid parameters. They describe a uniform change of the gravity along the latitude axis. Fig. 4.6 is the resultant map of the computed normal gravity of the grid points.

Stage 6

This stage considers the difference between the free-air gravity and the normal gravity of the various grid points. The map gives residual gravity anomalies ranging from -20 to 100 mGal. The negative values indicate the normal gravity is greater than the free-air gravity. Majority of the area experiences small residual gravity values and some few sections have high residual gravity anomalies. The negative free-air anomaly values describes situation where the ellipsoid surface is above the geoid surface. Whilst the positive free-air anomaly values signifies the geoid surface is above the ellipsoidal surface.

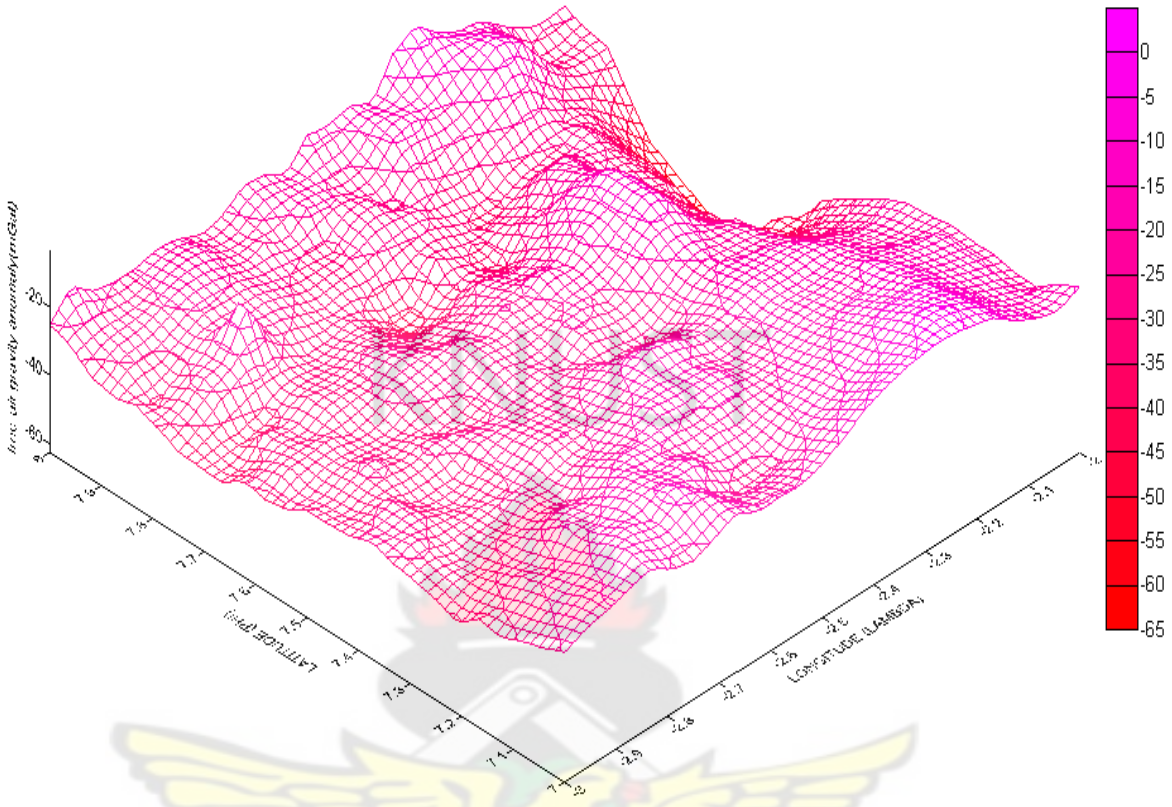

Fig 4.7a 2-D Free-air gravity anomaly map

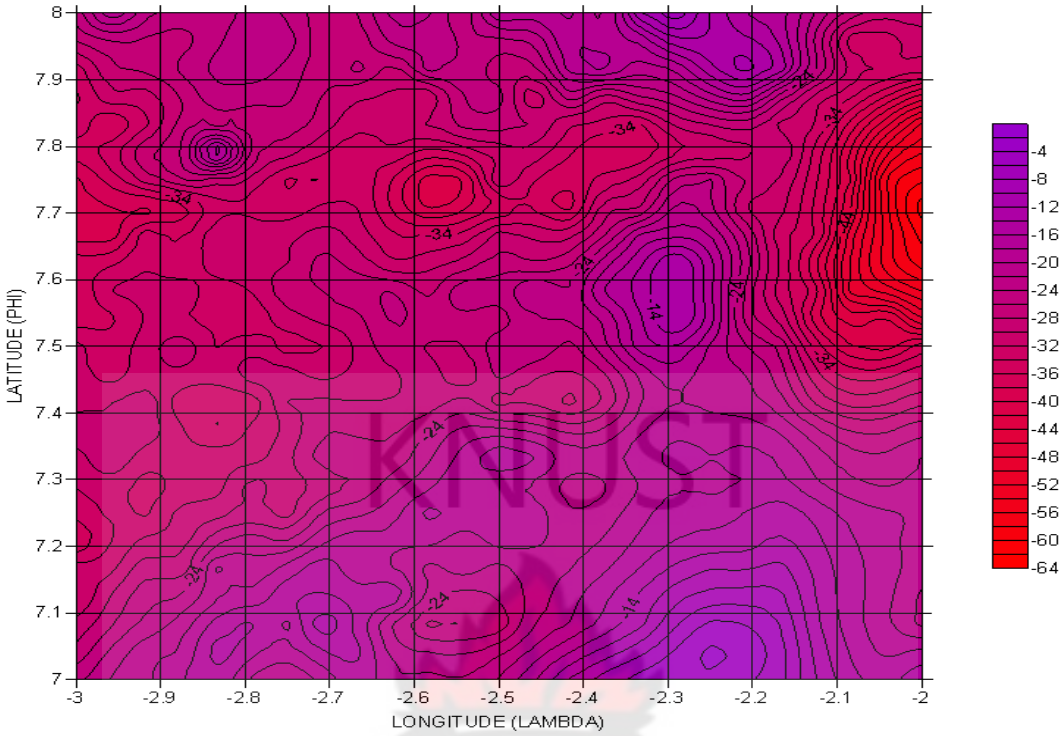

Fig 4.7b 3-D wireframe of free-air gravity anomaly

Fig. 4.8 gives a 3D wireframe of the free-air anomaly of which gravity exhibits a rough surface topography. With normal gravity having regular trend of change in its values, the rough behavior of this map signifies that the geoid has a rough and irregular surface. Relating the map to its key, the surface of high free-air anomaly has a high peak on the map and low free-air anomaly has a valley deep bottom on the map. *See appendix B for the table of values*

Further analysis of the free-air gravity, normal gravity and the free-air gravity anomaly is done adapting two methods of comparisons. These methods are discussed in the next sub-heading.

4.2 COMPARING THE GRAVITIES AND THE FREE-AIR ANOMALIES

The difference in the free-air gravity and the normal gravity values generates a trend of free-air anomaly values. Most importantly the changing values of free-air gravity at the various grid points. This variation provides an easy way of relating the free-air gravity anomalies and residual geoid undulation. The modes of gravity comparison for this work are:

1. Direct visual comparison of the profiles.
2. Statistics of the variations of gravity anomalies across different profiles.

Graphs of gravity (gravity at the geoid and normal gravity) against latitude of constant longitudes (profiles) 3.0ºW, 2.8333ºW, 2.66667ºW and 2.00ºW are constructed to analyze the residual gravity anomalies. The longitudes are represented as profile one, two, three and four respectively. Below are four graphs for assessment.

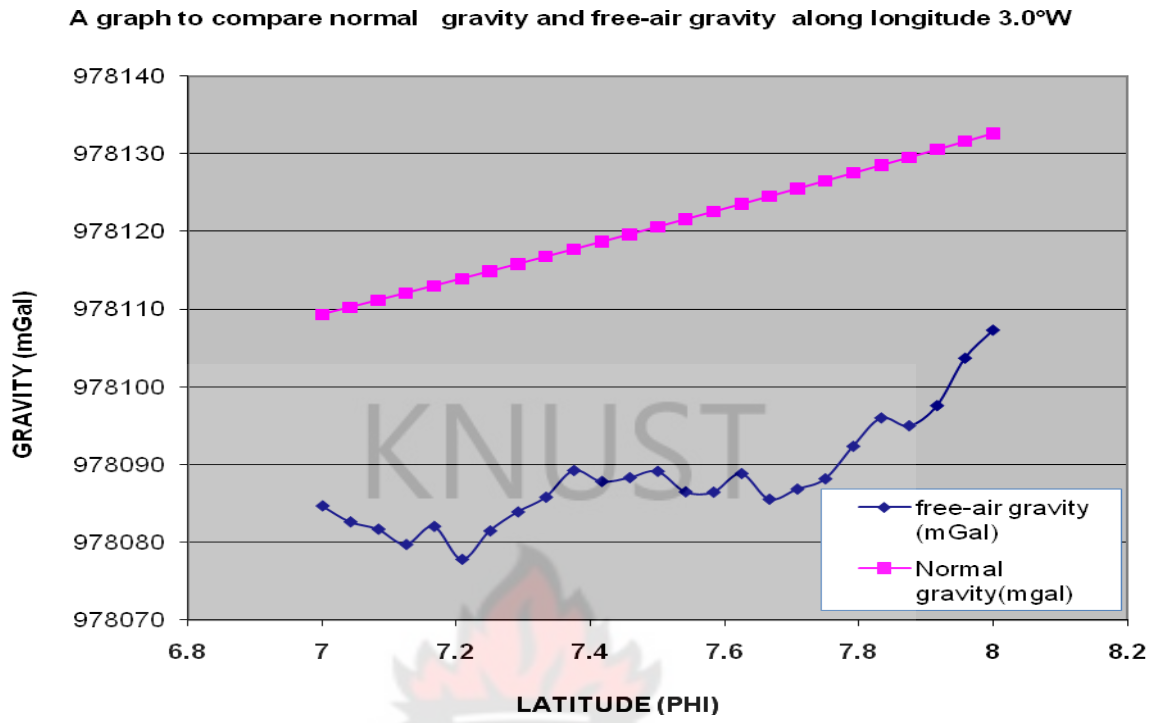

Fig 4.8a A graph of gravity against latitude for longitude 3.0°W.

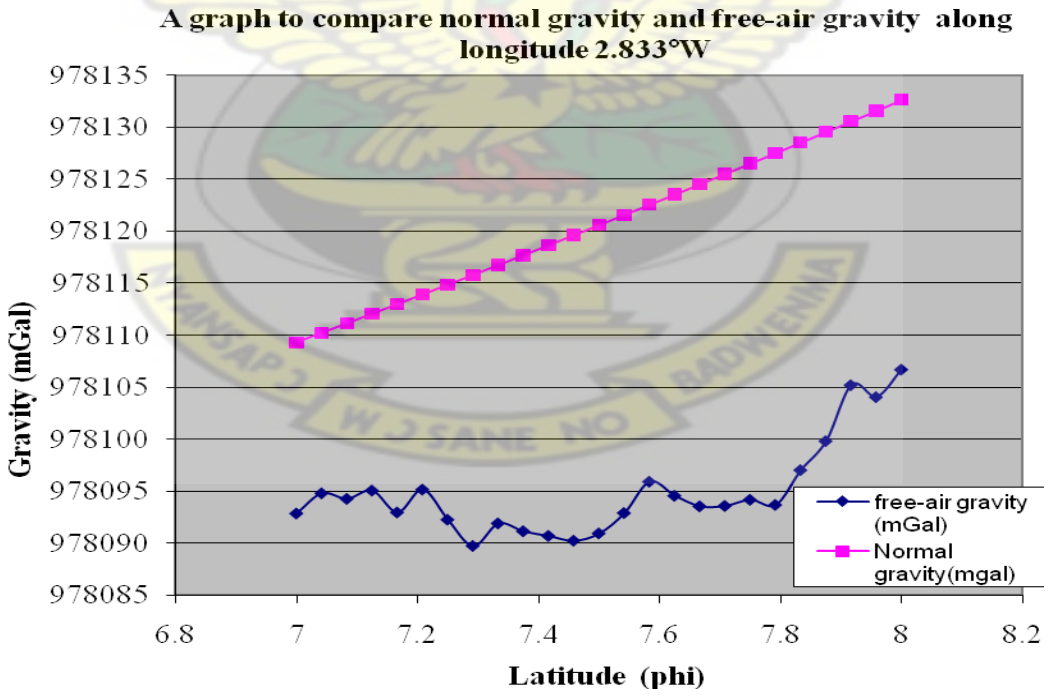

Fig 4.8b A graph of gravity against latitude for longitude 2.833°W.

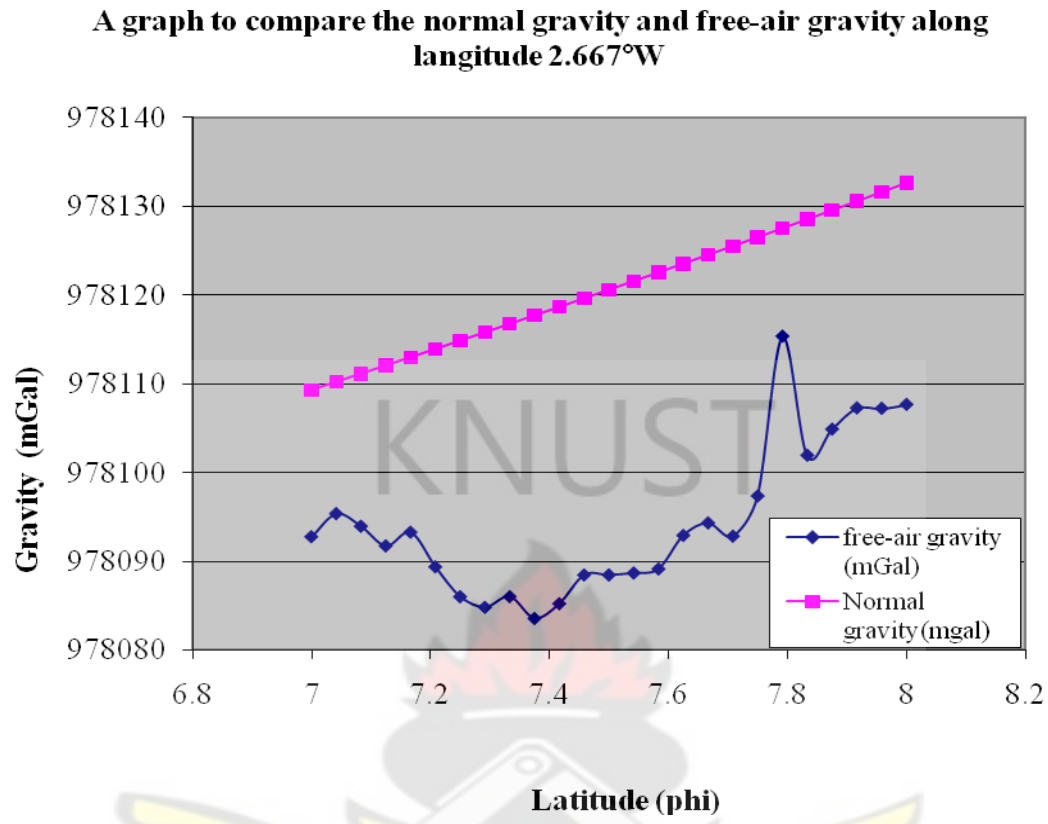

Fig 4.8c A graph of gravity against latitude for longitude 2.667°W

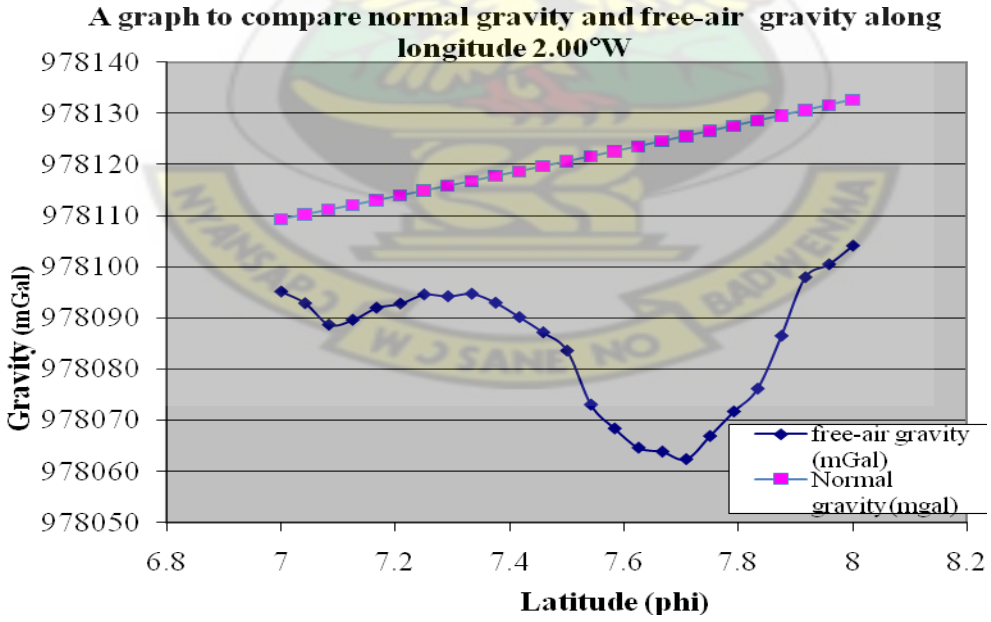

Fig 4.8d A graph of gravity against latitude for longitude 2.00°W.

4.2.1 Direct visual comparison

The above graphs (fig.4.9a to4.9d) generally have the free-air gravity's rough descriptive nature signifying a rough topography of the surface of the earth. The normal gravity values display a linear relationship with the latitudes. There is a uniform change in the gravity values along the latitude and a constant value of normal gravity along the longitudinal direction.

The graphs display high normal gravity values compared to free-air gravity. The difference between the gravities at a point along a plumb line is the free-air gravity anomaly. The change in the free-air gravity and normal gravity vary along the latitude axis.

All the areas with the free-air gravity describing a valley indicates the existence of high land area with reference to the ellipsoid. This generates a higher free-air gravity anomaly. Analytically the higher the gravity value of a point the closer the point to the geocenter of the earth. Relating the gravity anomaly to the residual geoid and with reference to the geocenter of the earth, a positive free-air anomaly gives an equal but negative contribution to the geoid undulation computation.

The gravity (g) behavior in the graphs is the direct inverse of the elevation (H) from the surface of the earth:

$$g \propto \frac{1}{H} \qquad 4.1$$

The free-air gravity on the graphs above display a uniform inclination and declination along the axis of latitude. There is some form of harmonic relation of the free-air gravity values. This describes the non uniform nature of the earth. The normal gravity displays a linear relation along the latitude describing a mathematical representation of the earth.

The description of the residual gravity is dependent on the structural surface of the geoid. The higher gravity at a point signifies how close the point is to the geocenter of the earth.

4.2.2 Statistics

The second indication of the relative roughness of the free-air can be seen by simply comparing the statistical properties of each chosen profile.

Table 4.1a The statistical property of gravity (free-air and normal) and the free-air anomaly of profile 1 (units in mGal).

Profile 1	Max	Min	Mean	STD	RMS
Free-air gravity	978107.308	978077.838	978088.365	7.08808	978088.365
Normal gravity	978132.631	978109.306	978120.726	7.15417	978120.726
Free-air anomaly	-24.59126	-38.95136	-32.36034	3.86309	32.58095

Table 4.1b The statistical property of gravity (free-air and normal) and the free-air anomaly of profile 2 (units in mGal).

Profile 2	Max	Min	Mean	STD	RMS
Free-air gravity	978115.319	978083.577	978094.344	8.47222	978094.344
Normal gravity	978132.631	978109.306	978120.726	7.15417	978120.726
Free-air anomaly	-12.20256	-34.11913	-26.38197	6.45724	27.13000

Table 4.1c. The statistical property of gravity (free-air and normal) and the free-air anomaly of profile 3 (units in mGal).

Profile 3	Max	Min	Mean	STD	RMS
Free-air gravity	978106.721	978089.762	978094.954	4.51130	978094.954
Normal gravity	978132.631	978109.306	978120.726	7.15417	978120.726
Free-air anomaly	-15.39439	-33.80874	-25.77212	5.48238	26.32597

Table 4.1d. The statistical property of gravity (free-air and normal) and the free-air anomaly of profile 4 (units in mGal).

Profile 4	Max	Min	Mean	STD	RMS
Free-air gravity	978104.125	978062.442	978085.020	12.61688	978085.020
Normal gravity	978132.631	978109.306	978120.726	7.15417	978120.726
Free-air anomaly	-14.13837	-63.07214	-35.70547	16.06207	39.01989

The statistical data in the tables above give an indication of the free-air gravity and free-air anomalies almost describing the similar representation of the behavior of the earth's surface topography. The values of the standard deviations of both free-air gravity and anomaly are high indications that their values of gravity deviate from the average and thus give rough characteristics. This implies that the application of a constant topographical density model cannot effectively remove the irregularities (errors) of the gravity field of the topography in the Brong Ahafo and Ghana as a whole. The rough topography under geophysics indicates a complicated geological structure. The free-air anomalies show prevalence of negative values in the northeastern portion of the map.

For the normal gravity there is an almost equal value of the standard deviation indicating similar behavior which is linear in the 2D graphs produced along the latitude direction.

This makes the earth have a mathematically defined shape and represents the gravity trend of the chosen ellipsoid.

The statistical computation can be seen in appendices c and d.

NB: In the tables 4.1a to 4.1d, the free-air gravity anomaly values are not plotted in the graphs but are extracted from the difference in the free-air gravity and normal gravity points in the graphs.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

After the data manipulation, computation and results analysis, some conclusions and recommendations were made.

5.1 CONCLUSIONS

In conclusion the free-air gravity anomalies over Brong-Ahafo region have been determined. Additionally:

- Free-air anomalies over Brong-Ahafo Region range from -63.07 to -3.56 mGal.
- The negative values of free-air gravity anomalies indicate that the normal gravity values are greater than their corresponding free-air gravity values and that the reference (GRS80) ellipsoid is below the geoid surface.
- The variation in the free-air gravity values largely influences that of the free-air gravity anomalies.

5.2 RECOMMENDATIONS

In recommendation, the determined free-air gravity anomalies should be used:

- To generate a geoid surface for leveling and derivation of astronomical coordinates.

- For the study of ocean circulation, current and tides, geodynamics of the earth, geophysical prospecting.
- To generate a nautical chart for water transportation system.
- To predict the direction of water flow along the earth surface.

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Appendix A

Application of Reductions to Raw Data

Latitude		Longitude		Elevation (m)	Obs. Gravity (mgals)	Free-Air (mgal)	Bouguer Plate (mgal)	Free-Air gravity (mgall)	Bouguer Reduction (mgal)	Complete Bouguer gravity
10.9016666667	N	0.0583333333	E	234.70	978150.61	7.242842	-26.26293	978157.8528	46.16549	978196.7755
10.9050000000	N	0.4416666667	E	207.30	978141.11	6.397278	-23.19687	978147.5073	40.77591	978181.8859
10.9066666667	N	0.9050000000	E	201.20	978145.95	6.209032	-22.51428	978152.159	39.57604	978185.526
10.8381666667	N	-1.3821666667	W	245.40	978140.84	7.573044	-27.46026	978148.413	48.27018	978189.1102
10.9290000000	N	-1.6170000000	W	271.30	978146.13	8.372318	-30.35847	978154.5023	53.36471	978199.4947
10.8858333333	N	-2.1091666667	W	317.00	978112.98	9.78262	-35.4723	978122.7626	62.3539	978175.3339
10.9055000000	N	-2.2428333333	W	303.30	978117.74	9.359838	-33.93927	978127.0998	59.65911	978177.3991
10.9553333333	N	-2.3980000000	W	310.90	978112.55	9.594374	-34.78971	978122.1444	61.15403	978173.704
10.9370000000	N	-2.5971666667	W	292.60	978120.49	9.029636	-32.74194	978129.5196	57.55442	978178.0444
10.9111666667	N	-2.7653333333	W	272.80	978122.9	8.418608	-30.52632	978131.3186	53.65976	978176.5598
10.7995000000	N	-1.5596666667	W	259.10	978136.15	7.995826	-28.99329	978144.1458	50.96497	978187.115
10.7350000000	N	-1.7778333333	W	289.60	978131.59	8.937056	-32.40624	978140.5271	56.96432	978188.5543
10.7548333333	N	-1.8931666667	W	303.30	978124.05	9.359838	-33.93927	978133.4098	59.65911	978183.7091
10.7928333333	N	-2.0846666667	W	304.80	978113.16	9.406128	-34.10712	978122.5661	59.95416	978173.1142
10.7728333333	N	-2.2656666667	W	294.10	978118.02	9.075926	-32.90979	978127.0959	57.84947	978175.8695
10.7310000000	N	-2.5750000000	W	272.80	978111.25	8.418608	-30.52632	978119.6686	53.65976	978164.9098
10.7596666667	N	-2.7326666667	W	281.90	978106.22	8.699434	-31.54461	978114.9194	55.44973	978161.6697
10.5333333333	N	-1.5366666667	W	167.60	978151.86	5.172136	-18.75444	978157.0321	32.96692	978184.8269
10.5950000000	N	-1.8033333333	W	286.50	978134.23	8.84139	-32.05935	978143.0714	56.35455	978190.5846
10.5750000000	N	-1.9416666667	W	310.90	978112.18	9.594374	-34.78971	978121.7744	61.15403	978173.334
10.5850000000	N	-2.0650000000	W	271.30	978119.01	8.372318	-30.35847	978127.3823	53.36471	978172.3747

10.6413333333	N	-2.2358333333	W	280.40	978124.65	8.653144	-31.37676	978133.3031	55.15468	978179.8047
10.5688333333	N	-2.5073333333	W	310.90	978198.24	9.594374	-34.78971	978207.8344	61.15403	978259.394
10.6245000000	N	-2.4900000000	W	304.80	978116.07	9.406128	-34.10712	978125.4761	59.95416	978176.0242
10.5801666667	N	-2.7745000000	W	259.10	978110.88	7.995826	-28.99329	978118.8758	50.96497	978161.845
10.4316666667	N	-0.4150000000	W	219.50	978115.86	6.77377	-24.56205	978122.6338	43.17565	978159.0357
10.4700000000	N	-1.6466666667	W	295.70	978120.84	9.125302	-33.08883	978129.9653	58.16419	978179.0042
10.4316666667	N	-1.7833333333	W	269.70	978129.24	8.322942	-30.17943	978137.5629	53.04999	978182.29
10.4783333333	N	-1.9400000000	W	286.50	978116.86	8.84139	-32.05935	978125.7014	56.35455	978173.2146
10.3933333333	N	-2.0633333333	W	208.80	978127.84	6.443568	-23.36472	978134.2836	41.07096	978168.911
10.4216666667	N	-2.2783333333	W	277.40	978119.37	8.560564	-31.04106	978127.9306	54.56458	978173.9346
10.4183333333	N	-2.5633333333	W	310.90	978085.53	9.594374	-34.78971	978095.1244	61.15403	978146.684
10.4316666667	N	-2.7333333333	W	237.70	978111.51	7.335422	-26.59863	978118.8454	46.75559	978158.2656
10.2566666667	N	0.4633333333	E	140.20	978132.68	4.326572	-15.68838	978137.0066	27.57734	978160.2573
10.1950000000	N	-1.7950000000	W	246.90	978118.71	7.619334	-27.62811	978126.3293	48.56523	978167.2752
10.2383333333	N	-1.9333333333	W	198.10	978134.94	6.113366	-22.16739	978141.0534	38.96627	978173.9063
10.2466666667	N	-1.9966666667	W	193.50	978134.6	5.97141	-21.65265	978140.5714	38.06145	978172.6615
10.2800000000	N	-2.2450000000	W	256.00	978118.51	7.90016	-28.6464	978126.4102	50.3552	978168.8652
10.2566666667	N	-2.5583333333	W	307.80	978087.89	9.498708	-34.44282	978097.3887	60.54426	978148.4343
10.2316666667	N	-2.7166666667	W	242.30	978118.58	7.477378	-27.11337	978126.0574	47.66041	978166.2404
10.0733333333	N	0.0816666667	E	161.50	978135.16	4.98389	-18.07185	978140.1439	31.76705	978166.9271
10.0816666667	N	0.4183333333	E	140.20	978146.59	4.326572	-15.68838	978150.9166	27.57734	978174.1673
10.0883333333	N	-1.4116666667	W	170.70	978119.09	5.267802	-19.10133	978124.3578	33.57669	978152.6667
10.0516666667	N	-1.7383333333	W	175.30	978127.89	5.409758	-19.61607	978133.2998	34.48151	978162.3715
10.0933333333	N	-1.8766666667	W	217.00	978122.01	6.69662	-24.2823	978128.7066	42.6839	978164.6939
10.0416666667	N	-2.3050000000	W	281.90	978102.79	8.699434	-31.54461	978111.4894	55.44973	978158.2397
10.0533333333	N	-2.4183333333	W	327.70	978079.46	10.112822	-36.66963	978089.5728	64.45859	978143.9186
10.0916666667	N	-2.7416666667	W	237.70	978121.81	7.335422	-26.59863	978129.1454	46.75559	978168.5656
9.9230000000	N	0.8850000000	E	149.40	978135.06	4.610484	-16.71786	978139.6705	29.38698	978164.447
9.9716666667	N	-1.7233333333	W	182.90	978121.06	5.644294	-20.46651	978126.7043	35.97643	978157.0364
9.9766666667	N	-1.9316666667	W	205.70	978114.82	6.347902	-23.01783	978121.1679	40.46119	978155.2812
9.8316666667	N	-1.9916666667	W	320.00	978082.45	9.8752	-35.808	978092.3252	62.944	978145.394

9.9700000000	N	-2.0850000000	W	268.80	978095.93	8.295168	-30.07872	978104.2252	52.87296	978148.803
9.8466666667	N	-2.0716666667	W	338.30	978072.34	10.439938	-37.85577	978082.7799	66.54361	978138.8836
9.8983333333	N	-2.2900000000	W	318.50	978083.28	9.82891	-35.64015	978093.1089	62.64895	978145.929
9.9366666667	N	-2.2166666667	W	327.70	978086.37	10.112822	-36.66963	978096.4828	64.45859	978150.8286
9.9383333333	N	-2.3816666667	W	303.30	978087.45	9.359838	-33.93927	978096.8098	59.65911	978147.1091
9.9081666667	N	-2.4586666667	W	313.90	978085.61	9.686954	-35.12541	978095.297	61.74413	978147.3541
9.9216666667	N	-2.6028333333	W	251.50	978111.07	7.76129	-28.14285	978118.8313	49.47005	978160.5401
9.8053333333	N	0.4456666667	E	137.20	978135.93	4.233992	-15.35268	978140.164	26.98724	978162.9172
9.7450000000	N	-2.1150000000	W	221.00	978099.82	6.82006	-24.7299	978106.6401	43.4707	978143.2907
9.8200000000	N	-2.2050000000	W	295.70	978083.9	9.125302	-33.08883	978093.0253	58.16419	978142.0642
9.7753333333	N	-2.4406666667	W	320.00	978080.26	9.8752	-35.808	978090.1352	62.944	978143.204
9.7530000000	N	-2.7003333333	W	289.60	978095.1	8.937056	-32.40624	978104.0371	56.96432	978152.0643
9.5801666667	N	0.2665000000	E	219.50	978123.42	6.77377	-24.56205	978130.1938	43.17565	978166.5957
9.5390000000	N	0.4370000000	E	172.20	978134.6	5.314092	-19.26918	978139.9141	33.87174	978168.4717
9.6176666667	N	0.4351666667	E	198.10	978129.36	6.113366	-22.16739	978135.4734	38.96627	978168.3263
9.5550000000	N	-2.1850000000	W	271.30	978097.25	8.372318	-30.35847	978105.6223	53.36471	978150.6147
9.5566666667	N	-2.5833333333	W	289.60	978086.19	8.937056	-32.40624	978095.1271	56.96432	978143.1543
9.5500000000	N	-2.6583333333	W	259.10	978095.34	7.995826	-28.99329	978103.3358	50.96497	978146.305
9.6326666667	N	-2.6988333333	W	249.00	978097.79	7.68414	-27.8631	978105.4741	48.9783	978146.7683
9.4533333333	N	-2.1866666667	W	271.30	978087.89	8.372318	-30.35847	978096.2623	53.36471	978141.2547
9.4583333333	N	-2.2300000000	W	326.10	978079.19	10.063446	-36.49059	978089.2534	64.14387	978143.3339
9.4183333333	N	-2.4483333333	W	272.80	978088.14	8.418608	-30.52632	978096.5586	53.65976	978141.7998
9.4100000000	N	-2.5433333333	W	259.10	978093.75	7.995826	-28.99329	978101.7458	50.96497	978144.715
9.2888333333	N	-2.5090000000	W	281.90	978084.83	8.699434	-31.54461	978093.5294	55.44973	978140.2797
9.2005000000	N	-2.0983333333	W	291.10	978078.02	8.983346	-32.57409	978087.0033	57.25937	978135.2794
9.0818333333	N	-2.3428333333	W	320.00	978071.19	9.8752	-35.808	978081.0652	62.944	978134.134
9.2235000000	N	-2.2303333333	W	272.80	978085.17	8.418608	-30.52632	978093.5886	53.65976	978138.8298
9.0783333333	N	-2.5961666667	W	243.80	978095.95	7.523668	-27.28122	978103.4737	47.95546	978143.9055
8.9116666667	N	0.9881666667	E	106.70	978125.18	3.292762	-11.93973	978128.4728	20.98789	978146.1679
8.9698333333	N	0.9918333333	E	135.60	978123.35	4.184616	-15.17364	978127.5346	26.67252	978150.0225
8.8716666667	N	-2.1683333333	W	229.00	978084.96	7.06694	-25.6251	978092.0269	45.0443	978130.0043

8.9316666667	N	-2.2433333333	W	251.00	978081.15	7.74586	-28.0869	978088.8959	49.3717	978130.5217
8.9200000000	N	-2.2300000000	W	281.00	978075.24	8.67166	-31.4439	978083.9117	55.2727	978130.5127
8.9251666667	N	-2.3976666667	W	291.10	978079.81	8.983346	-32.57409	978088.7933	57.25937	978137.0694
8.9300000000	N	-2.5583333333	W	267.00	978087.66	8.23962	-29.8773	978095.8996	52.5189	978140.1789
8.7616666667	N	-2.3433333333	W	259.10	978084.2	7.995826	-28.99329	978092.1958	50.96497	978135.165
8.7850000000	N	-2.5783333333	W	198.10	978102.14	6.113366	-22.16739	978108.2534	38.96627	978141.1063
8.5150000000	N	0.2833333333	E	171.00	978080.77	5.27706	-19.1349	978086.0471	33.6357	978114.4057
8.5066666667	N	0.8833333333	E	83.80	978117.78	2.586068	-9.37722	978120.3661	16.48346	978134.2635
8.6635000000	N	0.9351666667	E	85.30	978120.3	2.632358	-9.54507	978122.9324	16.77851	978137.0785
8.5316666667	N	-1.0516666667	W	127.10	978097.19	3.922306	-14.22249	978101.1123	25.00057	978122.1906
8.5933333333	N	-1.4566666667	W	118.90	978107.39	3.669254	-13.30491	978111.0593	23.38763	978130.7776
8.5866666667	N	-1.5550000000	W	106.70	978110.23	3.292762	-11.93973	978113.5228	20.98789	978131.2179
8.5791666667	N	-2.2255000000	W	228.60	978098.01	7.054596	-25.58034	978105.0646	44.96562	978142.9756
8.6633333333	N	-2.2916666667	W	253.00	978080.59	7.80758	-28.3107	978088.3976	49.7651	978130.3551
8.4300000000	N	0.5616666667	E	241.00	978051.78	7.43726	-26.9679	978059.2173	47.4047	978099.1847
8.3033333333	N	-2.2083333333	W	176.80	978094.38	5.456048	-19.78392	978099.836	34.77656	978129.1566
8.2516666667	N	-1.6116666667	W	143.30	978119.44	4.422238	-16.03527	978123.8622	28.18711	978147.6271
8.2151666667	N	-1.7775000000	W	100.60	978117.72	3.104516	-11.25714	978120.8245	19.78802	978137.508
8.2445000000	N	-1.8958333333	W	106.70	978111.39	3.292762	-11.93973	978114.6828	20.98789	978132.3779
8.2616666667	N	-1.9066666667	W	100.60	978117.64	3.104516	-11.25714	978120.7445	19.78802	978137.428
8.2466666667	N	-2.0990000000	W	228.60	978087.5	7.054596	-25.58034	978094.5546	44.96562	978132.4656
8.2595000000	N	-2.2508333333	W	152.40	978087.74	4.703064	-17.05356	978092.4431	29.97708	978117.7171
8.4716666667	N	-2.1783333333	W	164.60	978110.71	5.079556	-18.41874	978115.7896	32.37682	978143.0868
8.1700000000	N	0.6283333333	E	99.10	978108.42	3.058226	-11.08929	978111.4782	19.49297	978127.913
8.0850000000	N	-1.4361666667	W	237.70	978065.95	7.335422	-26.59863	978073.2854	46.75559	978112.7056
8.1178333333	N	-1.5596666667	W	253.00	978078.85	7.80758	-28.3107	978086.6576	49.7651	978128.6151
8.0966666667	N	-1.9266666667	W	137.20	978095.6	4.233992	-15.35268	978099.834	26.98724	978122.5872
8.1183333333	N	-2.2400000000	W	155.40	978083.34	4.795644	-17.38926	978088.1356	30.56718	978113.9072
8.0750000000	N	-2.4066666667	W	243.80	978067.75	7.523668	-27.28122	978075.2737	47.95546	978115.7055
7.9516666667	N	0.4016666667	E	195.00	978058.1	6.0177	-21.8205	978064.1177	38.3565	978096.4565
7.8650000000	N	0.3450000000	E	129.50	978117.15	3.99637	-14.49105	978121.1464	25.47265	978142.6227

7.9868333333	N	-1.3885000000	W	265.20	978061.43	8.184072	-29.67588	978069.6141	52.16484	978113.5948
7.9416666667	N	-1.6216666667	W	317.00	978065	9.78262	-35.4723	978074.7826	62.3539	978127.3539
7.9283333333	N	-1.7550000000	W	428.20	978046.36	13.214252	-47.91558	978059.5743	84.22694	978130.5869
7.8966666667	N	-1.8750000000	W	304.80	978050.6	9.406128	-34.10712	978060.0061	59.95416	978110.5542
7.9283333333	N	-2.0566666667	W	168.00	978082.67	5.18448	-18.7992	978087.8545	33.0456	978115.7156
7.8850000000	N	-2.2083333333	W	166.00	978082.3	5.12276	-18.5754	978087.4228	32.6522	978114.9522
7.8683333333	N	-2.3100000000	W	274.00	978059.89	8.45564	-30.6606	978068.3456	53.8958	978113.7858
7.9083333333	N	-2.4183333333	W	283.00	978055.62	8.73338	-31.6677	978064.3534	55.6661	978111.2861
7.8983333333	N	-2.5800000000	W	282.00	978060.79	8.70252	-31.5558	978069.4925	55.4694	978116.2594
7.7533333333	N	-1.9300000000	W	491.00	978011.8	15.15226	-54.9429	978026.9523	96.5797	978108.3797
7.7783333333	N	-1.8816666667	W	485.00	978008.8	14.9671	-54.2715	978023.7671	95.3995	978104.1995
7.7616666667	N	-2.2433333333	W	201.00	978071.23	6.20286	-22.4919	978077.4329	39.5367	978110.7667
7.6983333333	N	-2.4066666667	W	306.00	978055.7	9.44316	-34.2414	978065.1432	60.1902	978115.8902
7.7716666667	N	-2.4566666667	W	242.00	978063.93	7.46812	-27.0798	978071.3981	47.6014	978111.5314
7.7183333333	N	-2.4700000000	W	274.00	978055.65	8.45564	-30.6606	978064.1056	53.8958	978109.5458
7.7566666667	N	-2.5716666667	W	317.00	978045.1	9.78262	-35.4723	978054.8826	62.3539	978107.4539
7.7608333333	N	-2.7665000000	W	285.00	978058.24	8.7951	-31.8915	978067.0351	56.0595	978114.2995
7.5933333333	N	0.2850000000	E	79.00	978095.7	2.43794	-8.8401	978098.1379	15.5393	978111.2393
7.6716666667	N	0.1000000000	E	79.20	978155.78	2.444112	-8.86248	978158.2241	15.57864	978171.3586
7.6666666667	N	0.2583333333	E	79.20	978164.56	2.444112	-8.86248	978167.0041	15.57864	978180.1386
7.5766666667	N	-2.0783333333	W	415.00	978031.12	12.8069	-46.4385	978043.9269	81.6305	978112.7505
7.5908333333	N	-2.2681666667	W	198.10	978074.76	6.113366	-22.16739	978080.8734	38.96627	978113.7263
7.5975000000	N	-2.4548333333	W	225.60	978066.69	6.962016	-25.24464	978073.652	44.37552	978111.0655
7.5428333333	N	-2.5856666667	W	289.60	978053.46	8.937056	-32.40624	978062.3971	56.96432	978110.4243
7.5641666667	N	-2.7685000000	W	262.10	978052.07	8.088406	-29.32899	978060.1584	51.55507	978103.6251
7.3983333333	N	0.0800000000	E	79.20	978121.06	2.444112	-8.86248	978123.5041	15.57864	978136.6386
7.5200000000	N	0.0383333333	E	79.20	978141.38	2.444112	-8.86248	978143.8241	15.57864	978156.9586
7.5350000000	N	0.1733333333	E	79.20	978152.87	2.444112	-8.86248	978155.3141	15.57864	978168.4486
7.4183333333	N	-1.9200000000	W	354.00	978040.78	10.92444	-39.6126	978051.7044	69.6318	978110.4118
7.4133333333	N	-2.1580000000	W	298.70	978054.05	9.217882	-33.42453	978063.2679	58.75429	978112.8043
7.4316666667	N	-2.0700000000	W	337.00	978046.77	10.39982	-37.7103	978057.1698	66.2879	978113.0579

7.4220000000	N	-2.2623333333	W	259.10	978059.43	7.995826	-28.99329	978067.4258	50.96497	978110.395
7.4116666667	N	-2.4083333333	W	297.20	978049.09	9.171592	-33.25668	978058.2616	58.45924	978107.5492
7.4328333333	N	-2.5808333333	W	304.80	978044.77	9.406128	-34.10712	978054.1761	59.95416	978104.7242
7.4261666667	N	-2.6758333333	W	315.50	978044.72	9.73633	-35.30445	978054.4563	62.05885	978106.7789
7.4183333333	N	-2.9110000000	W	274.30	978047.64	8.464898	-30.69417	978056.1049	53.95481	978101.5948
7.1800000000	N	0.0066666667	E	79.20	978109.34	2.444112	-8.86248	978111.7841	15.57864	978124.9186
7.1500000000	N	0.5550000000	E	149.40	978058.74	4.610484	-16.71786	978063.3505	29.38698	978088.127
7.1683333333	N	0.6350000000	E	140.20	978062.96	4.326572	-15.68838	978067.2866	27.57734	978090.5373
7.3816666667	N	0.7666666667	E	125.00	978074.87	3.8575	-13.9875	978078.7275	24.5875	978099.4575
7.2191666667	N	-2.1073333333	W	312.40	978058.54	9.640664	-34.95756	978068.1807	61.44908	978119.9891
7.2460000000	N	-2.2390000000	W	259.10	978058.18	7.995826	-28.99329	978066.1758	50.96497	978109.145
7.2633333333	N	-2.4056666667	W	303.30	978049.35	9.359838	-33.93927	978058.7098	59.65911	978109.0091
7.2670000000	N	-2.5833333333	W	304.80	978046.94	9.406128	-34.10712	978056.3461	59.95416	978106.8942
7.2593333333	N	-2.4856666667	W	262.10	978055.58	8.088406	-29.32899	978063.6684	51.55507	978107.1351
7.2478333333	N	-2.7646666667	W	268.20	978050.41	8.276652	-30.01158	978058.6867	52.75494	978103.1649
7.9683333333	N	0.5750000000	E	143.30	978063.93	4.422238	-16.03527	978068.3522	28.18711	978092.1171
7.0671666667	N	-1.9236666667	W	32.50	978046.63	1.00295	-3.63675	978047.633	6.39275	978053.0228
6.1070000000	N	-2.0641666667	W	259.10	978061.17	7.995826	-28.99329	978069.1658	50.96497	978112.135
7.0596666667	N	-2.2323333333	W	243.80	978074.37	7.523668	-27.28122	978081.8937	47.95546	978122.3255
7.0858333333	N	-2.3466666667	W	227.10	978063.12	7.008306	-25.41249	978070.1283	44.67057	978107.7906
7.0850000000	N	-2.6085000000	W	272.80	978042.74	8.418608	-30.52632	978051.1586	53.65976	978096.3998
7.0933333333	N	-2.7141666667	W	211.80	978061.17	6.536148	-23.70042	978067.7061	41.66106	978102.8311
7.1065000000	N	-2.9271666667	W	243.80	978052.21	7.523668	-27.28122	978059.7337	47.95546	978100.1655
7.9000000000	N	0.0500000000	E	91.40	978084.75	2.820604	-10.22766	978087.5706	17.97838	978102.7284
7.9380000000	N	-2.0681666667	W	266.70	978065.14	8.230362	-29.84373	978073.3704	52.45989	978117.5999
6.9313333333	N	-2.2391666667	W	237.70	978067.96	7.335422	-26.59863	978075.2954	46.75559	978114.7156
6.9023333333	N	-2.3975000000	W	182.90	978079.98	5.644294	-20.46651	978085.6243	35.97643	978115.9564
6.9275000000	N	-2.5915000000	W	240.80	978048.61	7.431088	-26.94552	978056.0411	47.36536	978095.9754
6.9415000000	N	-2.7620000000	W	230.10	978043.59	7.100886	-25.74819	978050.6909	45.26067	978088.8507
6.9433333333	N	-2.8933333333	W	198.10	978057.73	6.113366	-22.16739	978063.8434	38.96627	978096.6963
6.9416666667	N	-3.1000000000	W	240.80	978045.43	7.431088	-26.94552	978052.8611	47.36536	978092.7954

6.7966666667	N	0.0566666667	E	79.20	978086.53	2.444112	-8.86248	978088.9741	15.57864	978102.1086
6.8983333333	N	0.0300000000	E	100.60	978083.32	3.104516	-11.25714	978086.4245	19.78802	978103.108
6.7683333333	N	0.1000000000	E	79.20	978090.68	2.444112	-8.86248	978093.1241	15.57864	978106.2586
6.7256666667	N	-2.5696666667	W	196.60	978063.77	6.067076	-21.99954	978069.8371	38.67122	978102.4412
6.7266666667	N	-2.8600000000	W	164.60	978065.14	5.079556	-18.41874	978070.2196	32.37682	978097.5168
6.7650000000	N	-2.9016666667	W	213.40	978054.99	6.585524	-23.87946	978061.5755	41.97578	978096.9658
6.7933333333	N	-3.0400000000	W	228.60	978058.61	7.054596	-25.58034	978065.6646	44.96562	978103.5756
6.6133333333	N	0.0516666667	E	79.20	978082.99	2.444112	-8.86248	978085.4341	15.57864	978098.5686
6.5833333333	N	-2.5716666667	W	216.40	978060.42	6.678104	-24.21516	978067.0981	42.56588	978102.9859
6.6116666667	N	-2.7033333333	W	243.80	978052.86	7.523668	-27.28122	978060.3837	47.95546	978100.8155
6.5650000000	N	-2.9033333333	W	144.80	978064.33	4.468528	-16.20312	978068.7985	28.48216	978092.8122
6.6000000000	N	-3.1066666667	W	204.20	978057.6	6.301612	-22.84998	978063.9016	40.16614	978097.7661
6.4966666667	N	0.9250000000	E	207.30	978062.94	6.397278	-23.19687	978069.3373	40.77591	978103.7159
6.4150000000	N	-2.5900000000	W	239.30	978048.53	7.384798	-26.77767	978055.9148	47.07031	978095.6003
6.4133333333	N	-2.7466666667	W	192.00	978063.04	5.92512	-21.4848	978068.9651	37.7664	978100.8064
6.4233333333	N	-2.9316666667	W	171.00	978048.83	5.27706	-19.1349	978054.1071	33.6357	978082.4657
6.4233333333	N	-3.0500000000	W	200.00	978055.94	6.172	-22.38	978062.112	39.34	978095.28
6.2921666667	N	0.7563333333	E	160.00	978064.57	4.9376	-17.904	978069.5076	31.472	978096.042
6.4283333333	N	0.8266666667	E	207.30	978059.37	6.397278	-23.19687	978065.7673	40.77591	978100.1459
6.2100000000	N	-2.6050000000	W	167.60	978043.45	5.172136	-18.75444	978048.6221	32.96692	978076.4169
6.2366666667	N	-2.7300000000	W	195.10	978059.73	6.020786	-21.83169	978065.7508	38.37617	978098.1062
6.2783333333	N	-2.9200000000	W	146.30	978073.82	4.514818	-16.37097	978078.3348	28.77721	978102.5972
6.2248333333	N	0.6278333333	E	221.00	978052.22	6.82006	-24.7299	978059.0401	43.4707	978095.6907
6.2136666667	N	0.7918333333	E	152.40	978066.43	4.703064	-17.05356	978071.1331	29.97708	978096.4071
6.2160000000	N	0.9110000000	E	182.90	978064.76	5.644294	-20.46651	978070.4043	35.97643	978100.7364
6.0800000000	N	0.2416666667	E	16.80	978126.01	0.518448	-1.87992	978126.5284	3.30456	978129.3146
6.0763333333	N	0.4173333333	E	13.70	978111.83	0.422782	-1.53303	978112.2528	2.69479	978114.5248
6.1033333333	N	-2.3266666667	W	152.40	978057.51	4.703064	-17.05356	978062.2131	29.97708	978087.4871
6.0833333333	N	-2.5750000000	W	152.40	978063.59	4.703064	-17.05356	978068.2931	29.97708	978093.5671
6.1066666667	N	-2.8050000000	W	176.80	978068.03	5.456048	-19.78392	978073.486	34.77656	978102.8066
6.0583333333	N	0.4800000000	E	243.80	978053.52	7.523668	-27.28122	978061.0437	47.95546	978101.4755

6.0803333333	N	0.6960000000	E	208.80	978059.98	6.443568	-23.36472	978066.4236	41.07096	978101.051
6.1066666667	N	0.5650000000	E	320.00	978050.36	9.8752	-35.808	978060.2352	62.944	978113.304
6.1171666667	N	0.9186666667	E	152.40	978069.77	4.703064	-17.05356	978074.4731	29.97708	978099.7471
5.9373333333	N	-2.2731666667	W	155.40	978055.34	4.795644	-17.38926	978060.1356	30.56718	978085.9072
5.8340000000	N	-2.7176666667	W	80.80	978082.26	2.493488	-9.04152	978084.7535	15.89336	978098.1534
5.8466666667	N	-2.7966666667	W	88.40	978087.41	2.728024	-9.89196	978090.138	17.38828	978104.7983
5.0433333333	N	-2.8716666667	W	173.70	978070.3	5.360382	-19.43703	978075.6604	34.16679	978104.4668
5.9368333333	N	0.0521666667	E	56.40	978110.99	1.740504	-6.31116	978112.7305	11.09388	978122.0839
5.9228333333	N	0.2091666667	E	39.60	978126.8	1.222056	-4.43124	978128.0221	7.78932	978134.5893
5.9291666667	N	0.3640000000	E	45.70	978124.1	1.410302	-5.11383	978125.5103	8.98919	978133.0892
5.9333333333	N	0.4200000000	E	30.50	978123.04	0.94123	-3.41295	978123.9812	5.99935	978129.0394
5.9511666667	N	0.1938333333	E	189.00	978064.75	5.83254	-21.1491	978070.5825	37.1763	978101.9263
5.9405000000	N	0.2975000000	E	74.70	978080.21	2.305242	-8.35893	978082.5152	14.69349	978094.9035
5.9466666667	N	0.4183333333	E	83.80	978073.02	2.586068	-9.37722	978075.6061	16.48346	978089.5035
5.9483333333	N	0.5766666667	E	146.30	978071.26	4.514818	-16.37097	978075.7748	28.77721	978100.0372
5.9350000000	N	0.6716666667	E	213.40	978061.17	6.585524	-23.87946	978067.7555	41.97578	978103.1458
5.9450000000	N	0.8083333333	E	143.30	978071.96	4.422238	-16.03527	978076.3822	28.18711	978100.1471
5.8183333333	N	-1.1933333333	W	146.30	978079.6	4.514818	-16.37097	978084.1148	28.77721	978108.3772
5.8400000000	N	-1.8266666667	W	213.40	978074.75	6.585524	-23.87946	978081.3355	41.97578	978116.7258
5.8666666667	N	-1.8150000000	W	195.10	978075.03	6.020786	-21.83169	978081.0508	38.37617	978113.4062
5.8890000000	N	-2.3120000000	W	137.20	978055.71	4.233992	-15.35268	978059.944	26.98724	978082.6972
5.8200000000	N	0.1883333333	E	21.30	978142.27	0.657318	-2.38347	978142.9273	4.18971	978146.4597
5.7866666667	N	0.4366666667	E	3.00	978136.14	0.09258	-0.3357	978136.2326	0.5901	978136.7301
5.8200000000	N	0.7900000000	E	6.10	978106.16	0.188246	-0.68259	978106.3482	1.19987	978107.3599
5.8278333333	N	0.0656666667	E	45.70	978106.89	1.410302	-5.11383	978108.3003	8.98919	978115.8792
5.8033333333	N	0.4300000000	E	73.20	978078.23	2.258952	-8.19108	978080.489	14.39844	978092.6284
5.7833333333	N	0.5416666667	E	76.20	978078.67	2.351532	-8.52678	978081.0215	14.98854	978093.6585
5.7250000000	N	-1.6900000000	W	112.80	978086.35	3.481008	-12.62232	978089.831	22.18776	978108.5378
5.7300000000	N	-1.9366666667	W	76.20	978093.24	2.351532	-8.52678	978095.5915	14.98854	978108.2285
5.7616666667	N	-2.8306666667	W	118.90	978080.99	3.669254	-13.30491	978084.6593	23.38763	978104.3776
5.8088333333	N	-2.8750000000	W	108.20	978082.78	3.339052	-12.10758	978086.1191	21.28294	978104.0629

5.6883333333	N	0.0500000000	E	9.10	978140.22	0.280826	-1.01829	978140.5008	1.78997	978142.01
5.7038333333	N	0.0793333333	E	36.60	978112.25	1.129476	-4.09554	978113.3795	7.19922	978119.4492
5.6966666667	N	-0.3150000000	E	45.70	978093.1	1.410302	-5.11383	978094.5103	8.98919	978102.0892
5.6450000000	N	-0.4966666667	E	94.50	978081.02	2.91627	-10.57455	978083.9363	18.58815	978099.6082
5.6768333333	N	-0.5558333333	E	91.40	978080.51	2.820604	-10.22766	978083.3306	17.97838	978098.4884
5.6850000000	N	-0.6883333333	E	128.00	978086.81	3.95008	-14.3232	978090.7601	25.1776	978111.9876
5.7016666667	N	-0.7833333333	E	118.90	978090.92	3.669254	-13.30491	978094.5893	23.38763	978114.3076
5.6700000000	N	-0.9100000000	E	106.70	978088.34	3.292762	-11.93973	978091.6328	20.98789	978109.3279
5.6100000000	N	-1.7133333333	W	109.70	978088.38	3.385342	-12.27543	978091.7653	21.57799	978109.958
5.6660000000	N	-0.4233333333	E	24.40	978099.39	0.752984	-2.73036	978100.143	4.79948	978104.1895
5.5538333333	N	-0.5595000000	E	83.80	978085.83	2.586068	-9.37722	978088.4161	16.48346	978102.3135
5.5133333333	N	-1.4483333333	W	100.60	978087.76	3.104516	-11.25714	978090.8645	19.78802	978107.548
5.3956666667	N	-2.2533333333	W	44.20	978081.59	1.364012	-4.94598	978082.954	8.69414	978090.2841
5.5510000000	N	-2.2445000000	W	61.00	978075.74	1.88246	-6.8259	978077.6225	11.9987	978087.7387
5.5116666667	N	-2.5366666667	W	121.90	978055.25	3.761834	-13.64061	978059.0118	23.97773	978079.2277
5.4728333333	N	-0.4195000000	E	10.70	978102.61	0.330202	-1.19733	978102.9402	2.10469	978104.7147
5.4348333333	N	-0.5606666667	E	45.70	978092.41	1.410302	-5.11383	978093.8203	8.98919	978101.3992
5.3631666667	N	-1.8053333333	W	74.70	978086.76	2.305242	-8.35893	978089.0652	14.69349	978101.4535
5.3200000000	N	-1.8166666667	W	64.00	978090.08	1.97504	-7.1616	978092.055	12.5888	978102.6688
5.3450000000	N	-2.4700000000	W	137.20	978044.43	4.233992	-15.35268	978048.664	26.98724	978071.4172
5.1300000000	N	-2.0950000000	W	64.00	978093.17	1.97504	-7.1616	978095.145	12.5888	978105.7588
5.1633333333	N	-2.6600000000	W	29.00	978098.22	0.89494	-3.2451	978099.1149	5.7043	978103.9243

Appendix B

Extracted Grid Point Gravity Data at the Bouguer Plate and Computations

Lat.	Lon.	bouguer plate gravity (mgal)	Elev (m)	Reverse Boug (mGal)	Free-air gravity (mGal)	Normal gravity (mgal)	Free-air gravity anomaly (mgal)
7	-3	978058.3315	235.77277	26.38297286	978084.7145	978109.3058	-24.59126261
7.04	-3	978058.0139	220.21974	24.64258876	978082.6565	978110.2169	-27.56039598
7.08	-3	978057.8368	213.36259	23.87527432	978081.712	978111.1333	-29.42126318
7.13	-3	978057.7062	196.98048	22.042116	978079.7483	978112.055	-32.30667012
7.17	-3	978057.5609	219.05978	24.51278893	978082.0737	978112.982	-30.90836192
7.21	-3	978057.3742	182.88222	20.46452085	978077.8388	978113.9143	-36.07558758
7.25	-3	978057.1601	217.40132	24.32720736	978081.4873	978114.8519	-33.36464471
7.29	-3	978056.9599	241.05616	26.97418421	978083.9341	978115.7948	-31.86076569
7.33	-3	978056.8326	259.08315	28.99140454	978085.824	978116.743	-30.91896686
7.38	-3	978056.8598	289.56352	32.40215801	978089.2619	978117.6965	-28.4345315
7.42	-3	978057.15	274.32334	30.69678127	978087.8468	978118.6552	-30.80840666
7.46	-3	978057.7721	273.2094	30.57213186	978088.3442	978119.6192	-31.27504509
7.5	-3	978058.667	272.47394	30.48983379	978089.1569	978120.5885	-31.43165116
7.54	-3	978059.7316	239.42134	26.79124831	978086.5229	978121.5631	-35.04023682
7.58	-3	978060.8969	228.60278	25.58065106	978086.4775	978122.543	-36.06543938
7.63	-3	978062.1255	239.00173	26.74429393	978088.8698	978123.5281	-34.65827957
7.67	-3	978063.3972	198.12241	22.16989759	978085.5671	978124.5185	-38.95136255
7.71	-3	978064.6999	198.12241	22.16989759	978086.8697	978125.5142	-38.64442629
7.75	-3	978066.0255	198.12241	22.16989759	978088.1954	978126.5151	-38.31974863
7.79	-3	978067.3704	223.42051	25.00075503	978092.3712	978127.5213	-35.15011736
7.83	-3	978068.7362	243.84297	27.2860278	978096.0222	978128.5328	-32.51056085

7.88	-3	978070.1279	222.45215	24.89239576	978095.0203	978129.5495	-34.52916555
7.92	-3	978071.5517	232.81278	26.05175052	978097.6034	978130.5715	-32.96805362
7.96	-3	978073.0115	274.32334	30.69678127	978103.7083	978131.5987	-27.89044397
8	-3	978074.5086	293.1137	32.79942318	978107.308	978132.6312	-25.32319615
7	-2.96	978060.2792	243.84297	27.2860278	978087.5652	978109.3058	-21.74054853
7.04	-2.96	978059.5714	242.75565	27.16435684	978086.7357	978110.2169	-23.48112763
7.08	-2.96	978059.0873	230.41356	25.78327685	978084.8705	978111.1333	-26.26275785
7.13	-2.96	978058.7196	228.60278	25.58065106	978084.3002	978112.055	-27.754778
7.17	-2.96	978058.3595	214.2914	23.97920813	978082.3387	978112.982	-30.64328115
7.21	-2.96	978057.9422	214.35126	23.98590585	978081.9281	978113.9143	-31.98619327
7.25	-2.96	978057.4868	232.1684	25.97964351	978083.4664	978114.8519	-31.38548814
7.29	-2.96	978057.0442	249.01287	27.86454061	978084.9088	978115.7948	-30.88603816
7.33	-2.96	978056.6738	287.05419	32.12136332	978088.7952	978116.743	-27.94778567
7.38	-2.96	978056.4534	276.15613	30.90187103	978087.3553	978117.6965	-30.34115011
7.42	-2.96	978056.5639	286.55438	32.06543533	978088.6293	978118.6552	-30.0258711
7.46	-2.96	978057.2212	262.16137	29.33585757	978086.5571	978119.6192	-33.06215832
7.5	-2.96	978058.2206	260.08654	29.10368369	978087.3242	978120.5885	-33.26429218
7.54	-2.96	978059.3638	246.32415	27.56367198	978086.9275	978121.5631	-34.63563987
7.58	-2.96	978060.581	271.97556	30.43406543	978091.0151	978122.543	-31.52788199
7.63	-2.96	978061.8435	243.83951	27.28564128	978089.1291	978123.5281	-34.3989548
7.67	-2.96	978063.1385	198.08957	22.16622274	978085.3047	978124.5185	-39.21375629
7.71	-2.96	978064.458	206.20888	23.07477395	978087.5328	978125.5142	-37.98136741
7.75	-2.96	978065.794	229.27708	25.65610493	978091.4501	978126.5151	-35.06501502
7.79	-2.96	978067.1418	246.47969	27.58107696	978094.7229	978127.5213	-32.79840867
7.83	-2.96	978068.5057	210.01259	23.50040918	978092.0061	978128.5328	-36.52670774
7.88	-2.96	978069.8964	264.0664	29.54902987	978099.4455	978129.5495	-30.10403131
7.92	-2.96	978071.325	277.37426	31.03817967	978102.3632	978130.5715	-28.20827079
7.96	-2.96	978072.7974	289.26664	32.36893671	978105.1664	978131.5987	-26.43236863
8	-2.96	978074.3145	361.41216	40.44202047	978114.7565	978132.6312	-17.87470042

7	-2.92	978061.6362	243.84297	27.2860278	978088.9222	978109.3058	-20.38354883
7.04	-2.92	978060.7525	259.07163	28.99011579	978089.7426	978110.2169	-20.47423678
7.08	-2.92	978060.2184	245.68357	27.49199099	978087.7103	978111.1333	-23.42295093
7.13	-2.92	978059.7691	248.17359	27.77062418	978087.5397	978112.055	-24.51531781
7.17	-2.92	978059.252	244.10405	27.31524353	978086.5672	978112.982	-26.41481294
7.21	-2.92	978058.6065	230.54188	25.79763617	978084.4041	978113.9143	-29.51019806
7.25	-2.92	978057.8997	220.79799	24.70729527	978082.607	978114.8519	-32.24492313
7.29	-2.92	978057.2149	227.42763	25.4491517	978082.6641	978115.7948	-33.13076566
7.33	-2.92	978056.6178	259.23114	29.00796448	978085.6258	978116.743	-31.11720331
7.38	-2.92	978056.1509	293.18405	32.80729526	978088.9582	978117.6965	-28.73828408
7.42	-2.92	978055.8831	304.80371	34.10753475	978089.9906	978118.6552	-28.66459844
7.46	-2.92	978056.7828	284.93428	31.88414597	978088.6669	978119.6192	-30.95232688
7.5	-2.92	978057.9003	285.1507	31.90836316	978089.8087	978120.5885	-30.77985127
7.54	-2.92	978059.101	274.32334	30.69678127	978089.7978	978121.5631	-31.76533472
7.58	-2.92	978060.3473	274.32334	30.69678127	978091.0441	978122.543	-31.49888593
7.63	-2.92	978061.6214	265.43443	29.70211233	978091.3235	978123.5281	-32.2046363
7.67	-2.92	978062.9226	259.66439	29.05644483	978091.979	978124.5185	-32.53949246
7.71	-2.92	978064.2493	198.12241	22.16989759	978086.4192	978125.5142	-39.09493114
7.75	-2.92	978065.5886	267.88299	29.97610673	978095.5647	978126.5151	-30.9503959
7.79	-2.92	978066.9284	293.26097	32.81590267	978099.7443	978127.5213	-27.77701183
7.83	-2.92	978068.2765	250.35332	28.01453681	978096.2911	978128.5328	-32.24170734
7.88	-2.92	978069.6557	258.0585	28.8767463	978098.5324	978129.5495	-31.01711067
7.92	-2.92	978071.0841	285.39691	31.93591468	978103.02	978130.5715	-27.5514549
7.96	-2.92	978072.5685	289.56352	32.40215801	978104.9706	978131.5987	-26.62810866
8	-2.92	978074.1069	313.5505	35.08630115	978109.1932	978132.6312	-23.43806639
7	-2.88	978061.6038	263.81377	29.5207606	978091.1246	978109.3058	-18.18120442
7.04	-2.88	978061.2903	258.55434	28.93223088	978090.2225	978110.2169	-19.99436104
7.08	-2.88	978061.1838	257.37778	28.80057389	978089.9844	978111.1333	-21.14889067
7.13	-2.88	978060.8729	242.45458	27.13066704	978088.0035	978112.055	-24.05147786

7.17	-2.88	978060.2273	226.431	25.33762849	978085.5649	978112.982	-27.41710079
7.21	-2.88	978059.3324	227.16142	25.41936294	978084.7517	978113.9143	-29.16259149
7.25	-2.88	978058.3573	243.84297	27.2860278	978085.6433	978114.8519	-29.20862926
7.29	-2.88	978057.4462	243.5889	27.25759784	978084.7038	978115.7948	-31.09101285
7.33	-2.88	978056.6925	257.91782	28.86100431	978085.5536	978116.743	-31.18944544
7.38	-2.88	978056.1736	265.22701	29.67890296	978085.8525	978117.6965	-31.84393404
7.42	-2.88	978056.0819	259.08315	28.99140454	978085.0733	978118.6552	-33.58189007
7.46	-2.88	978056.7263	289.79515	32.42807754	978089.1544	978119.6192	-30.46483098
7.5	-2.88	978057.7776	306.69417	34.31907728	978092.0967	978120.5885	-28.49188137
7.54	-2.88	978058.9723	272.55779	30.49921707	978089.4715	978121.5631	-32.09158069
7.58	-2.88	978060.2069	286.07105	32.01135051	978092.2182	978122.543	-30.32475889
7.63	-2.88	978061.4524	246.81724	27.61884907	978089.0712	978123.5281	-34.45685243
7.67	-2.88	978062.7315	246.23963	27.55421493	978090.2857	978124.5185	-34.23279323
7.71	-2.88	978064.0573	213.57321	23.89884169	978087.9562	978125.5142	-37.55802335
7.75	-2.88	978065.3996	298.93308	33.45061162	978098.8502	978126.5151	-27.66486936
7.79	-2.88	978066.7182	303.29317	33.93850544	978100.6567	978127.5213	-26.86462259
7.83	-2.88	978068.0297	297.89962	33.33496802	978101.3646	978128.5328	-27.16814743
7.88	-2.88	978069.3856	288.51993	32.28538055	978101.671	978129.5495	-27.87855182
7.92	-2.88	978070.8139	305.85022	34.22463976	978105.0386	978130.5715	-25.53293567
7.96	-2.88	978072.3154	289.63597	32.41026506	978104.7256	978131.5987	-26.87311431
8	-2.88	978073.8805	302.14951	33.8105301	978107.691	978132.6312	-24.94023102
7	-2.83	978060.1496	291.52419	32.62155639	978092.7712	978109.3058	-16.53459502
7.04	-2.83	978061.3047	304.39507	34.06180795	978095.3665	978110.2169	-14.85034829
7.08	-2.83	978062.1095	284.51542	31.83727571	978093.9468	978111.1333	-17.18647744
7.13	-2.83	978062.0902	264.96401	29.64947285	978091.7397	978112.055	-20.31536486
7.17	-2.83	978061.2799	285.98601	32.00183412	978093.2817	978112.982	-19.70028862
7.21	-2.83	978060.0562	262.05346	29.32378167	978089.38	978113.9143	-24.53435551
7.25	-2.83	978058.7758	243.46643	27.2438938	978086.0197	978114.8519	-28.83224131
7.29	-2.83	978057.6554	242.87979	27.17824894	978084.8336	978115.7948	-30.96120669

7.33	-2.83	978056.7971	261.2307	29.23171509	978086.0288	978116.743	-30.71422208
7.38	-2.83	978056.2913	243.84297	27.2860278	978083.5773	978117.6965	-34.11912729
7.42	-2.83	978056.2702	258.85602	28.96598911	978085.2362	978118.6552	-33.41902825
7.46	-2.83	978056.8114	282.87106	31.65327184	978088.4647	978119.6192	-31.1545685
7.5	-2.83	978057.7842	274.23458	30.68684931	978088.471	978120.5885	-32.11752579
7.54	-2.83	978058.9653	265.64031	29.72515048	978088.6905	978121.5631	-32.87265337
7.58	-2.83	978060.1542	259.08315	28.99140454	978089.1456	978122.543	-33.39740575
7.63	-2.83	978061.3048	282.51754	31.61371286	978092.9185	978123.5281	-30.60960134
7.67	-2.83	978062.5139	284.23222	31.80558517	978094.3195	978124.5185	-30.19898702
7.71	-2.83	978063.8362	259.08315	28.99140454	978092.8276	978125.5142	-32.68653551
7.75	-2.83	978065.2076	287.291	32.14786269	978097.3555	978126.5151	-29.15965688
7.79	-2.83	978066.4844	436.41053	48.83433869	978115.3188	978127.5213	-12.20255825
7.83	-2.83	978067.7223	305.68114	34.20571986	978101.928	978128.5328	-26.60476619
7.88	-2.83	978069.0513	320.04389	35.81291148	978104.8642	978129.5495	-24.6852623
7.92	-2.83	978070.4951	328.47398	36.75623887	978107.2513	978130.5715	-23.32019322
7.96	-2.83	978072.0301	314.36692	35.17765807	978107.2077	978131.5987	-24.39101514
8	-2.83	978073.6327	303.99502	34.01704254	978107.6497	978132.6312	-24.98149611
7	-2.79	978058.3429	271.53939	30.38525792	978088.7282	978109.3058	-20.57757243
7.04	-2.79	978061.346	280.1531	31.349132	978092.6952	978110.2169	-17.52171686
7.08	-2.79	978063.3853	288.61434	32.29594452	978095.6812	978111.1333	-15.45206716
7.13	-2.79	978063.5883	259.06755	28.98965897	978092.578	978112.055	-19.47703642
7.17	-2.79	978062.3471	257.37275	28.80001087	978091.1471	978112.982	-21.83493545
7.21	-2.79	978060.6447	274.13302	30.67548483	978091.3202	978113.9143	-22.59412356
7.25	-2.79	978059.0219	254.40763	28.46821384	978087.4901	978114.8519	-27.3618167
7.29	-2.79	978057.735	279.04263	31.2248703	978088.9598	978115.7948	-26.83499843
7.33	-2.79	978056.7939	259.10935	28.99433572	978085.7882	978116.743	-30.95476825
7.38	-2.79	978056.2641	268.70934	30.0685754	978086.3326	978117.6965	-31.36382295
7.42	-2.79	978056.2488	259.10777	28.99415973	978085.243	978118.6552	-33.41223178
7.46	-2.79	978056.7905	304.85841	34.11365569	978090.9042	978119.6192	-28.71503595

7.5	-2.79	978057.7884	289.59532	32.40571638	978090.1942	978120.5885	-30.39436841
7.54	-2.79	978059.0421	258.33875	28.9081063	978087.9502	978121.5631	-33.61294484
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7.67	-2.79	978062.1663	278.82393	31.2003975	978093.3667	978124.5185	-31.1517627
7.71	-2.79	978063.4603	264.83275	29.63478446	978093.0951	978125.5142	-32.41905041
7.75	-2.79	978064.9711	274.32799	30.69730236	978095.6684	978126.5151	-30.84671981
7.79	-2.79	978066.138	304.80371	34.10753475	978100.2455	978127.5213	-27.27579515
7.83	-2.79	978067.2554	300.01459	33.57163264	978100.827	978128.5328	-27.70574349
7.88	-2.79	978068.602	319.64203	35.76794279	978104.37	978129.5495	-25.1795373
7.92	-2.79	978070.112	335.28408	37.51828822	978107.6303	978130.5715	-22.94121136
7.96	-2.79	978071.7128	335.28408	37.51828822	978109.231	978131.5987	-22.3676886
8	-2.79	978073.3672	320.04389	35.81291149	978109.1802	978132.6312	-23.45107844
7	-2.75	978057.2891	267.95418	29.98407288	978087.2732	978109.3058	-22.03256503
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7.13	-2.75	978065.3011	271.93286	30.42928751	978095.7304	978112.055	-16.3245893
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7.29	-2.75	978057.6388	259.20402	29.00492942	978086.6438	978115.7948	-29.15106062
7.33	-2.75	978056.6279	282.77314	31.6423139	978088.2702	978116.743	-28.47283102
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7.42	-2.75	978055.9949	309.85787	34.67309543	978090.668	978118.6552	-27.98719302
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7.63	-2.75	978060.7736	289.32075	32.37499156	978093.1486	978123.5281	-30.37952199

7.67	-2.75	978061.5728	289.83289	32.43230089	978094.0051	978124.5185	-30.51343494
7.71	-2.75	978062.6454	263.40219	29.474705	978092.1201	978125.5142	-33.39403307
7.75	-2.75	978064.1013	252.47627	28.25209515	978092.3534	978126.5151	-34.16174201
7.79	-2.75	978065.2435	297.57407	33.29853858	978098.542	978127.5213	-28.97927888
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8	-2.75	978073.0975	314.24898	35.16446113	978108.2619	978132.6312	-24.36930431
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7.17	-2.5	978061.4188	259.08315	28.99140454	978090.4102	978112.982	-22.57184128
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7.58	-2.25	978077.6805	244.50059	27.35961548	978105.0401	978122.543	-17.50290189
7.63	-2.25	978076.9692	260.86677	29.19099205	978106.1602	978123.5281	-17.3679345
7.67	-2.25	978075.5214	258.03646	28.87428037	978104.3957	978124.5185	-20.12282766
7.71	-2.25	978075.5128	237.00284	26.52061773	978102.0335	978125.5142	-23.4807161
7.75	-2.25	978076.9614	229.1112	25.63754297	978102.5989	978126.5151	-23.91616719
7.79	-2.25	978077.5793	162.12634	18.14193723	978095.7213	978127.5213	-31.80004521
7.83	-2.25	978078.5212	197.3703	22.08573711	978100.607	978128.5328	-27.92583008
7.88	-2.25	978080.3622	253.42613	28.35838404	978108.7206	978129.5495	-20.82895696
7.92	-2.25	978081.0193	311.39328	34.84490802	978115.8642	978130.5715	-14.70727315
7.96	-2.25	978080.9802	340.39019	38.08966197	978119.0699	978131.5987	-12.52882974
8	-2.25	978081.6512	346.16599	38.7359744	978120.3872	978132.6312	-12.24401298
7	-2.21	978077.0254	237.40514	26.56563565	978103.591	978109.3058	-5.714747117
7.04	-2.21	978078.945	238.22992	26.65792783	978105.6029	978110.2169	-4.613965877
7.08	-2.21	978077.9045	242.65585	27.15318972	978105.0577	978111.1333	-6.075623938
7.13	-2.21	978074.5739	253.56208	28.37359643	978102.9475	978112.055	-9.107471734
7.17	-2.21	978071.522	261.2967	29.23910062	978100.7611	978112.982	-12.22096846
7.21	-2.21	978068.8894	266.60232	29.83280009	978098.7222	978113.9143	-15.19217566
7.25	-2.21	978066.8034	287.80592	32.20548285	978099.0089	978114.8519	-15.84306388
7.29	-2.21	978065.6869	286.06272	32.01041787	978097.6974	978115.7948	-18.09746468
7.33	-2.21	978065.2081	305.08876	34.13943235	978099.3475	978116.743	-17.39547585
7.38	-2.21	978065.2509	299.36656	33.49911832	978098.7501	978117.6965	-18.94639808

7.42	-2.21	978065.6606	283.25357	31.696075	978097.3567	978118.6552	-21.29853535
7.46	-2.21	978066.2362	282.34058	31.59391058	978097.8302	978119.6192	-21.78906801
7.5	-2.21	978067.2376	262.90958	29.41958147	978096.6572	978120.5885	-23.93131949
7.54	-2.21	978068.8546	228.25502	25.54173672	978094.3963	978121.5631	-27.16677782
7.58	-2.21	978070.5247	227.24391	25.42859327	978095.9533	978122.543	-26.58969103
7.63	-2.21	978071.1892	245.62545	27.48548749	978098.6747	978123.5281	-24.85341802
7.67	-2.21	978071.6051	240.39775	26.90050806	978098.5056	978124.5185	-26.01293985
7.71	-2.21	978072.9263	196.69846	22.01055734	978094.9369	978125.5142	-30.57729848
7.75	-2.21	978075.2765	207.25931	23.1923173	978098.4688	978126.5151	-28.046267
7.79	-2.21	978077.8273	167.64204	18.75914411	978096.5865	978127.5213	-30.93486187
7.83	-2.21	978081.174	181.75515	20.33840139	978101.5124	978128.5328	-27.02041295
7.88	-2.21	978086.3314	222.56662	24.90520518	978111.2366	978129.5495	-18.31295102
7.92	-2.21	978085.2312	307.04299	34.35811104	978119.5893	978130.5715	-10.98221788
7.96	-2.21	978083.5332	308.05613	34.47148058	978118.0047	978131.5987	-13.5940666
8	-2.21	978083.5674	292.42919	32.72282593	978116.2902	978132.6312	-16.3410287
7	-2.17	978074.0006	250.08013	27.98396658	978101.9846	978109.3058	-7.321160038
7.04	-2.17	978074.8673	251.56297	28.14989688	978103.0172	978110.2169	-7.199703799
7.08	-2.17	978074.3758	255.98692	28.6449358	978103.0207	978111.1333	-8.112588534
7.13	-2.17	978072.6951	266.98947	29.8761218	978102.5712	978112.055	-9.483831515
7.17	-2.17	978070.8082	274.91294	30.76275778	978101.571	978112.982	-11.41103887
7.21	-2.17	978069.0326	279.30276	31.25397902	978100.2865	978113.9143	-13.62779614
7.25	-2.17	978067.2479	293.57326	32.85084782	978100.0988	978114.8519	-14.75317276
7.29	-2.17	978065.7259	292.08009	32.68376167	978098.4097	978115.7948	-17.38514539
7.33	-2.17	978064.6878	302.48085	33.84760669	978098.5354	978116.743	-18.20761351
7.38	-2.17	978064.0497	297.62392	33.30411687	978097.3538	978117.6965	-20.3426428
7.42	-2.17	978063.5832	284.17189	31.79883471	978095.382	978118.6552	-23.27318282
7.46	-2.17	978062.9098	283.43019	31.71583876	978094.6256	978119.6192	-24.99360956
7.5	-2.17	978062.349	284.03492	31.783507	978094.1325	978120.5885	-26.45601545
7.54	-2.17	978062.1632	258.5601	28.93287484	978091.0961	978121.5631	-30.46704507

7.58	-2.17	978062.6151	240.1464	26.87238177	978089.4875	978122.543	-33.05545632
7.63	-2.17	978063.7457	245.3701	27.4569146	978091.2026	978123.5281	-32.32546509
7.67	-2.17	978065.485	228.71902	25.59365853	978091.0786	978124.5185	-33.43988333
7.71	-2.17	978067.9647	234.91557	26.28705219	978094.2517	978125.5142	-31.26243737
7.75	-2.17	978071.2267	223.82769	25.04631867	978096.273	978126.5151	-30.24210031
7.79	-2.17	978075.0984	221.55043	24.79149323	978099.8899	978127.5213	-27.63146278
7.83	-2.17	978079.4379	166.62173	18.64497156	978098.0829	978128.5328	-30.44988889
7.88	-2.17	978083.2261	186.23992	20.84024741	978104.0663	978129.5495	-25.48319235
7.92	-2.17	978083.8422	284.18002	31.79974387	978115.6419	978130.5715	-14.92959271
7.96	-2.17	978083.2257	285.45188	31.94206495	978115.1677	978131.5987	-16.43099043
8	-2.17	978083.8408	282.43993	31.60502856	978115.4458	978132.6312	-17.18543378
7	-2.13	978070.2798	240.71039	26.93549228	978097.2153	978109.3058	-12.09049664
7.04	-2.13	978070.5935	240.85334	26.95148903	978097.545	978110.2169	-12.67188699
7.08	-2.13	978070.3715	243.03251	27.19533745	978097.5669	978111.1333	-13.56644677
7.13	-2.13	978069.6978	251.39762	28.13139366	978097.8292	978112.055	-14.22584045
7.17	-2.13	978068.9792	262.16009	29.33571463	978098.315	978112.982	-14.66707147
7.21	-2.13	978068.4206	267.30246	29.91114517	978098.3318	978113.9143	-15.58256065
7.25	-2.13	978066.7645	280.55523	31.39413	978098.1586	978114.8519	-16.69333855
7.29	-2.13	978064.8918	279.24934	31.24800145	978096.1398	978115.7948	-19.65503731
7.33	-2.13	978063.438	288.39453	32.27134759	978095.7093	978116.743	-21.03365933
7.38	-2.13	978062.2332	284.43606	31.82839521	978094.0616	978117.6965	-23.63488933
7.42	-2.13	978060.9397	259.96352	29.08991826	978090.0296	978118.6552	-28.62557618
7.46	-2.13	978059.1383	259.13209	28.99688127	978088.1352	978119.6192	-31.48400763
7.5	-2.13	978056.9379	256.91058	28.74829412	978085.6862	978120.5885	-34.9023216
7.54	-2.13	978054.7907	242.74914	27.16362917	978081.9543	978121.5631	-39.60881136
7.58	-2.13	978053.9729	285.01725	31.89343079	978085.8663	978122.543	-36.67666592
7.63	-2.13	978055.5642	251.15289	28.10400829	978083.6682	978123.5281	-39.85991024
7.67	-2.13	978058.263	273.29861	30.58211474	978088.8451	978124.5185	-35.67341575
7.71	-2.13	978061.596	243.84297	27.2860278	978088.882	978125.5142	-36.63216876

7.75	-2.13	978065.67	223.63748	25.02503428	978090.6951	978126.5151	-35.82005096
7.79	-2.13	978070.4567	198.12241	22.16989759	978092.6266	978127.5213	-34.89474824
7.83	-2.13	978075.4914	190.3037	21.29498384	978096.7864	978128.5328	-31.74642673
7.88	-2.13	978079.4259	168.00878	18.80018273	978098.2261	978129.5495	-31.32343127
7.92	-2.13	978080.5145	236.1654	26.42690871	978106.9414	978130.5715	-23.63006026
7.96	-2.13	978080.7495	233.79683	26.16186536	978106.9114	978131.5987	-24.68737127
8	-2.13	978082.9767	246.23177	27.5533346	978110.53	978132.6312	-22.10122853
7	-2.08	978066.2447	247.92534	27.7428455	978093.9876	978109.3058	-15.31817785
7.04	-2.08	978066.1721	248.69339	27.82879056	978094.0009	978110.2169	-16.21599441
7.08	-2.08	978066.0441	250.7601	28.06005475	978094.1041	978111.1333	-17.02916476
7.13	-2.08	978065.9143	259.50118	29.0381821	978094.9525	978112.055	-17.10249422
7.17	-2.08	978065.8858	266.7743	29.85204407	978095.7378	978112.982	-17.24418983
7.21	-2.08	978065.8591	270.03702	30.21714234	978096.0763	978113.9143	-17.83805053
7.25	-2.08	978064.7012	281.27667	31.47485944	978096.176	978114.8519	-18.67590489
7.29	-2.08	978063.0558	279.41232	31.26623807	978094.322	978115.7948	-21.47281112
7.33	-2.08	978061.5408	286.28126	32.03487281	978093.5757	978116.743	-23.1673315
7.38	-2.08	978060.0489	281.16801	31.4627003	978091.5116	978117.6965	-26.18486358
7.42	-2.08	978058.3369	263.02548	29.43255121	978087.7694	978118.6552	-30.88579501
7.46	-2.08	978055.615	260.8195	29.18570157	978084.8007	978119.6192	-34.81854851
7.5	-2.08	978052.0476	256.35524	28.68615081	978080.7338	978120.5885	-39.85476956
7.54	-2.08	978048.0086	273.42004	30.5957023	978078.6043	978121.5631	-42.95881819
7.58	-2.08	978044.8907	259.97022	29.09066804	978073.9813	978122.543	-48.56162366
7.63	-2.08	978047.8438	243.84297	27.2860278	978075.1299	978123.5281	-48.39823166
7.67	-2.08	978050.9372	235.37819	26.33881932	978077.276	978124.5185	-47.2425119
7.71	-2.08	978054.5219	243.84297	27.2860278	978081.8079	978125.5142	-43.70622676
7.75	-2.08	978059.0355	226.69748	25.36744811	978084.4029	978126.5151	-42.11218313
7.79	-2.08	978064.6485	183.80582	20.56787119	978085.2163	978127.5213	-42.30497782
7.83	-2.08	978071.0249	167.64204	18.75914411	978089.784	978128.5328	-38.74873678
7.88	-2.08	978077.105	168.05588	18.80545314	978095.9104	978129.5495	-33.63908365

7.92	-2.08	978079.2603	184.98267	20.6995611	978099.9598	978130.5715	-30.61164754
7.96	-2.08	978077.6243	182.88222	20.46452085	978098.0888	978131.5987	-33.50993295
8	-2.08	978082.5555	207.81486	23.25448252	978105.81	978132.6312	-26.82120976
7	-2.04	978062.0769	269.13417	30.11611317	978092.1931	978109.3058	-17.11269557
7.04	-2.04	978061.5116	270.50846	30.26989685	978091.7815	978110.2169	-18.43534032
7.08	-2.04	978061.2913	271.1475	30.3414056	978091.6327	978111.1333	-19.50062248
7.13	-2.04	978061.4755	279.31551	31.25540575	978092.7309	978112.055	-19.3241592
7.17	-2.04	978061.8264	286.45999	32.05487299	978093.8813	978112.982	-19.10077805
7.21	-2.04	978062.051	290.28797	32.48322398	978094.5342	978113.9143	-19.38014955
7.25	-2.04	978061.4672	301.12647	33.69605234	978095.1633	978114.8519	-19.68865711
7.29	-2.04	978060.3967	295.57709	33.07507591	978093.4717	978115.7948	-22.32308418
7.33	-2.04	978059.1857	303.4393	33.95485816	978093.1405	978116.743	-23.6024731
7.38	-2.04	978057.7488	299.8475	33.55293566	978091.3017	978117.6965	-26.39474418
7.42	-2.04	978055.8139	289.42201	32.38632266	978088.2002	978118.6552	-30.45498735
7.46	-2.04	978052.8469	286.96645	32.11154575	978084.9584	978119.6192	-34.6608051
7.5	-2.04	978049.0947	270.71865	30.29341729	978079.3881	978120.5885	-41.20044116
7.54	-2.04	978045.1371	320.27608	35.83889372	978080.976	978121.5631	-40.58707199
7.58	-2.04	978042.1662	263.03992	29.43416716	978071.6003	978122.543	-50.94262391
7.63	-2.04	978043.0403	228.37513	25.55517661	978068.5955	978123.5281	-54.93263283
7.67	-2.04	978044.6322	227.46805	25.45367442	978070.0859	978124.5185	-54.43264048
7.71	-2.04	978047.0948	204.09386	22.83810285	978069.9329	978125.5142	-55.58126157
7.75	-2.04	978051.0755	167.69721	18.76531734	978069.8409	978126.5151	-56.67426256
7.79	-2.04	978057.1504	167.64204	18.75914411	978075.9096	978127.5213	-51.61174176
7.83	-2.04	978064.8721	161.90729	18.11742612	978082.9895	978128.5328	-45.54325973
7.88	-2.04	978072.9129	166.76876	18.66142419	978091.5743	978129.5495	-37.97517146
7.92	-2.04	978078.247	182.88222	20.46452085	978098.7115	978130.5715	-31.85998532
7.96	-2.04	978079.6714	167.88528	18.7863625	978098.4578	978131.5987	-33.14098237
8	-2.04	978083.8944	174.56656	19.53399809	978103.4284	978132.6312	-29.20280055
7	-2	978057.9092	332.96	37.25822399	978095.1674	978109.3058	-14.13837346

7.04	-2	978056.8512	322.13366	36.04675682	978092.8979	978110.2169	-17.31893668
7.08	-2	978056.5385	287.46819	32.16769011	978088.7062	978111.1333	-22.4271459
7.13	-2	978057.0366	291.47482	32.61603272	978089.6526	978112.055	-22.40241873
7.17	-2	978057.767	306.06931	34.24915561	978092.0161	978112.982	-20.965913
7.21	-2	978058.2428	309.08335	34.58642714	978092.8292	978113.9143	-21.08513327
7.25	-2	978058.2333	325.09277	36.37788084	978094.6112	978114.8519	-20.2407677
7.29	-2	978057.7376	326.34773	36.51831147	978094.2559	978115.7948	-21.53895963
7.33	-2	978056.8305	338.86809	37.91933957	978094.7499	978116.743	-21.99311933
7.38	-2	978055.4487	335.52022	37.54471283	978092.9934	978117.6965	-24.70307925
7.42	-2	978053.2909	329.65335	36.88821003	978090.1791	978118.6552	-28.47606957
7.46	-2	978050.0788	331.84106	37.13301451	978087.2118	978119.6192	-32.40744128
7.5	-2	978046.1417	335.05941	37.49314834	978083.6349	978120.5885	-36.95364349
7.54	-2	978042.2657	275.52943	30.83174281	978073.0974	978121.5631	-48.46566735
7.58	-2	978039.4417	259.08315	28.99140454	978068.4331	978122.543	-54.10988194
7.63	-2	978038.2367	236.25019	26.43639581	978064.6731	978123.5281	-58.85496161
7.67	-2	978038.3272	228.60278	25.58065106	978063.9079	978124.5185	-60.61064874
7.71	-2	978039.6677	203.52395	22.77432964	978062.442	978125.5142	-63.07214125
7.75	-2	978043.1156	213.05613	23.84098053	978066.9566	978126.5151	-59.55854689
7.79	-2	978049.6524	197.47926	22.09792874	978071.7503	978127.5213	-55.77099439
7.83	-2	978058.7193	156.32356	17.49260593	978076.2119	978128.5328	-52.32088225
7.88	-2	978068.7209	159.10947	17.80434949	978086.5252	978129.5495	-43.02430766
7.92	-2	978077.2337	185.32986	20.73841106	978097.9721	978130.5715	-32.59938499
7.96	-2	978081.7185	167.90052	18.78806787	978100.5066	978131.5987	-31.09216357
8	-2	978085.2333	168.82722	18.89176628	978104.1251	978132.6312	-28.50613418

Appendix C

Computation of Gravity and Gravity Anomaly

PROFILE ONE

Latitude	Free-Air Gravity (Mgal)	Normal Gravity (Mgal)	Free-Air Gravity Anomaly (Mgal)		Sqr Of Grav. At Geoid	Sqr Of Norm. Grav.	Sqr Of Grav. Anom.
7	978084.7145	978109.3058	-24.59126261		9.5665E+11	9.56698E+11	604.7301967
7.041667	978082.6565	978110.2169	-27.56039598		9.56646E+11	9.567E+11	759.5754265
7.083333	978081.712	978111.1333	-29.42126318		9.56644E+11	9.56701E+11	865.6107271
7.125	978079.7483	978112.055	-32.30667012		9.5664E+11	9.56703E+11	1043.720934
7.166667	978082.0737	978112.982	-30.90836192		9.56645E+11	9.56705E+11	955.3268368
7.208333	978077.8388	978113.9143	-36.07558758		9.56636E+11	9.56707E+11	1301.448019
7.25	978081.4873	978114.8519	-33.36464471		9.56643E+11	9.56709E+11	1113.199517
7.291667	978083.9341	978115.7948	-31.86076569		9.56648E+11	9.56711E+11	1015.108391
7.333333	978085.824	978116.743	-30.91896686		9.56652E+11	9.56712E+11	955.9825119
7.375	978089.2619	978117.6965	-28.4345315		9.56659E+11	9.56714E+11	808.5225816
7.416667	978087.8468	978118.6552	-30.80840666		9.56656E+11	9.56716E+11	949.1579209
7.458333	978088.3442	978119.6192	-31.27504509		9.56657E+11	9.56718E+11	978.1284456
7.5	978089.1569	978120.5885	-31.43165116		9.56658E+11	9.5672E+11	987.9486945
7.541667	978086.5229	978121.5631	-35.04023682		9.56653E+11	9.56722E+11	1227.818196

7.583333	978086.4775	978122.543	-36.06543938		9.56653E+11	9.56724E+11	1300.715917
7.625	978088.8698	978123.5281	-34.65827957		9.56658E+11	9.56726E+11	1201.196343
7.666667	978085.5671	978124.5185	-38.95136255		9.56651E+11	9.56728E+11	1517.208644
7.708333	978086.8697	978125.5142	-38.64442629		9.56654E+11	9.5673E+11	1493.391683
7.75	978088.1954	978126.5151	-38.31974863		9.56657E+11	9.56731E+11	1468.403135
7.791667	978092.3712	978127.5213	-35.15011736		9.56665E+11	9.56733E+11	1235.53075
7.833333	978096.0222	978128.5328	-32.51056085		9.56672E+11	9.56735E+11	1056.936567
7.875	978095.0203	978129.5495	-34.52916555		9.5667E+11	9.56737E+11	1192.263273
7.916667	978097.6034	978130.5715	-32.96805362		9.56675E+11	9.56739E+11	1086.89256
7.958333	978103.7083	978131.5987	-27.89044397		9.56687E+11	9.56741E+11	777.8768649
8	978107.308	978132.6312	-25.32319615		9.56694E+11	9.56743E+11	641.2642634
MAXIMUM	978107.308	978132.6312	-24.59126261	SUM	2.39164E+13	2.3918E+13	26537.9584
MINIMUM	978077.8388	978109.3058	-38.95136255	AVE.	9.56657E+11	9.5672E+11	1061.518336
MEAN	978088.3654	978120.7257	-32.36034335	RMS	978088.3654	978120.7258	32.58095051
STDEV	7.088081448	7.154169802	3.863088429				

PROFILE TWO

Latitude	Free-Air Gravity (Mgal)	Normal Gravity	Gravity Anomaly(Mgal)		Sqr Of Grav. At Geoid	Sqr Of Norm. Grav.	Sqr Of Grav. Anom.
7	978092.7712	978109.3058	-16.53459502		9.56665E+11	9.56698E+11	273.3928324
7.041667	978095.3665	978110.2169	-14.85034829		9.56671E+11	9.567E+11	220.5328444
7.083333	978093.9468	978111.1333	-17.18647744		9.56668E+11	9.56701E+11	295.3750067
7.125	978091.7397	978112.055	-20.31536486		9.56663E+11	9.56703E+11	412.7140493
7.166667	978093.2817	978112.982	-19.70028862		9.56666E+11	9.56705E+11	388.1013717
7.208333	978089.38	978113.9143	-24.53435551		9.56659E+11	9.56707E+11	601.9346004
7.25	978086.0197	978114.8519	-28.83224131		9.56652E+11	9.56709E+11	831.2981392
7.291667	978084.8336	978115.7948	-30.96120669		9.5665E+11	9.56711E+11	958.5963196
7.333333	978086.0288	978116.743	-30.71422208		9.56652E+11	9.56712E+11	943.3634377
7.375	978083.5773	978117.6965	-34.11912729		9.56647E+11	9.56714E+11	1164.114847
7.416667	978085.2362	978118.6552	-33.41902825		9.56651E+11	9.56716E+11	1116.831449
7.458333	978088.4647	978119.6192	-31.1545685		9.56657E+11	9.56718E+11	970.6071384
7.5	978088.471	978120.5885	-32.11752579		9.56657E+11	9.5672E+11	1031.535463
7.541667	978088.6905	978121.5631	-32.87265337		9.56657E+11	9.56722E+11	1080.61134

7.583333	978089.1456	978122.543	-33.39740575		9.56658E+11	9.56724E+11	1115.386711
7.625	978092.9185	978123.5281	-30.60960134		9.56666E+11	9.56726E+11	936.9476942
7.666667	978094.3195	978124.5185	-30.19898702		9.56668E+11	9.56728E+11	911.9788172
7.708333	978092.8276	978125.5142	-32.68653551		9.56666E+11	9.5673E+11	1068.409603
7.75	978097.3555	978126.5151	-29.15965688		9.56674E+11	9.56731E+11	850.2855896
7.791667	978115.3188	978127.5213	-12.20255825		9.5671E+11	9.56733E+11	148.9024279
7.833333	978101.928	978128.5328	-26.60476619		9.56683E+11	9.56735E+11	707.813584
7.875	978104.8642	978129.5495	-24.6852623		9.56689E+11	9.56737E+11	609.3621749
7.916667	978107.2513	978130.5715	-23.32019322		9.56694E+11	9.56739E+11	543.831412
7.958333	978107.2077	978131.5987	-24.39101514		9.56694E+11	9.56741E+11	594.9216194
8	978107.6497	978132.6312	-24.98149611		9.56695E+11	9.56743E+11	624.075148
MAXIMUM	978115.3188	978132.6312	-12.20255825	SUM	2.39167E+13	2.3918E+13	18400.92362
MINIMUM	978083.5773	978109.3058	-34.11912729	AVE.	9.56669E+11	9.5672E+11	736.0369448
MEAN	978094.3438	978120.7257	-26.38197923	RMS	978094.3438	978120.7258	27.13000083
STDEV	8.472217055	7.154169802	6.457240505				

PROFILE THREE

Latitude	Free-Air Gravity (Mgal)	Normal Gravity	Gravity Anomaly (Mgal)		Sqr Of Grav. At Geoid	Sqr Of Norm. Grav.	Sqr Of Grav. Anom.
7	978092.8825	978109.3058	-16.42322901		9.56666E+11	9.56698E+11	269.7224512
7.041667	978094.8225	978110.2169	-15.39439271		9.56669E+11	9.567E+11	236.987327
7.083333	978094.29	978111.1333	-16.84329067		9.56668E+11	9.56701E+11	283.6964406
7.125	978095.0879	978112.055	-16.96715636		9.5667E+11	9.56703E+11	287.884395
7.166667	978092.983	978112.982	-19.99905486		9.56666E+11	9.56705E+11	399.9621955
7.208333	978095.1843	978113.9143	-18.73000336		9.5667E+11	9.56707E+11	350.8130259
7.25	978092.288	978114.8519	-22.56396374		9.56665E+11	9.56709E+11	509.1324598
7.291667	978089.7619	978115.7948	-26.03291109		9.5666E+11	9.56711E+11	677.7124598
7.333333	978091.9279	978116.743	-24.81514838		9.56664E+11	9.56712E+11	615.7915894
7.375	978091.1729	978117.6965	-26.52351015		9.56662E+11	9.56714E+11	703.4965905
7.416667	978090.7296	978118.6552	-27.92563903		9.56661E+11	9.56716E+11	779.8413151
7.458333	978090.267	978119.6192	-29.35219137		9.56661E+11	9.56718E+11	861.5511383
7.5	978090.967	978120.5885	-29.62153446		9.56662E+11	9.5672E+11	877.4353038
7.541667	978092.9273	978121.5631	-28.63584765		9.56666E+11	9.56722E+11	820.0117707

7.583333	978095.9461	978122.543	-26.59687754		9.56672E+11	9.56724E+11	707.3938951
7.625	978094.5865	978123.5281	-28.94164215		9.56669E+11	9.56726E+11	837.6186501
7.666667	978093.5727	978124.5185	-30.94579812		9.56667E+11	9.56728E+11	957.6424212
7.708333	978093.6123	978125.5142	-31.90191875		9.56667E+11	9.5673E+11	1017.73242
7.75	978094.2007	978126.5151	-32.31440091		9.56668E+11	9.56731E+11	1044.220506
7.791667	978093.7126	978127.5213	-33.80874115		9.56667E+11	9.56733E+11	1143.030978
7.833333	978097.0551	978128.5328	-31.47764824		9.56674E+11	9.56735E+11	990.8423385
7.875	978099.8404	978129.5495	-29.70906874		9.56679E+11	9.56737E+11	882.6287654
7.916667	978105.2246	978130.5715	-25.34690525		9.5669E+11	9.56739E+11	642.4656057
7.958333	978104.0766	978131.5987	-27.52217567		9.56688E+11	9.56741E+11	757.4701539
8	978106.7213	978132.6312	-25.90997459		9.56693E+11	9.56743E+11	671.3267835
MAXIMUM	978106.7213	978132.6312	-15.39439271	SUM	2.39167E+13	2.3918E+13	17326.41098
MINIMUM	978089.7619	978109.3058	-33.80874115	AVE.	9.5667E+11	9.5672E+11	693.0564392
MEAN	978094.9536	978120.7257	-25.77212096	RMS	978094.9536	978120.7258	26.32596511
STDEV	4.511302826	7.154169802	5.482379017				

PROFILE FOUR

Latitude	Free-Air Gravity (Mgal)	Normal Gravity	Gravity Anomaly (Mgal)		Sqr Of Grav. At Geoid	Sqr Of Norm. Grav.	Sqr Of Grav. Anom.
7	978095.1674	978109.3058	-14.13837346		9.5667E+11	9.56698E+11	199.8936042
7.041667	978092.8979	978110.2169	-17.31893668		9.56666E+11	9.567E+11	299.9455679
7.083333	978088.7062	978111.1333	-22.4271459		9.56658E+11	9.56701E+11	502.9768734
7.125	978089.6526	978112.055	-22.40241873		9.56659E+11	9.56703E+11	501.8683648
7.166667	978092.0161	978112.982	-20.965913		9.56664E+11	9.56705E+11	439.5695078
7.208333	978092.8292	978113.9143	-21.08513327		9.56666E+11	9.56707E+11	444.582845
7.25	978094.6112	978114.8519	-20.2407677		9.56669E+11	9.56709E+11	409.688677
7.291667	978094.2559	978115.7948	-21.53895963		9.56668E+11	9.56711E+11	463.9267819
7.333333	978094.7499	978116.743	-21.99311933		9.56669E+11	9.56712E+11	483.6972979
7.375	978092.9934	978117.6965	-24.70307925		9.56666E+11	9.56714E+11	610.2421246
7.416667	978090.1791	978118.6552	-28.47606957		9.5666E+11	9.56716E+11	810.886538
7.458333	978087.2118	978119.6192	-32.40744128		9.56655E+11	9.56718E+11	1050.24225
7.5	978083.6349	978120.5885	-36.95364349		9.56648E+11	9.5672E+11	1365.571767
7.541667	978073.0974	978121.5631	-48.46566735		9.56627E+11	9.56722E+11	2348.920912

7.583333	978068.4331	978122.543	-54.10988194		9.56618E+11	9.56724E+11	2927.879324
7.625	978064.6731	978123.5281	-58.85496161		9.56611E+11	9.56726E+11	3463.906506
7.666667	978063.9079	978124.5185	-60.61064874		9.56609E+11	9.56728E+11	3673.650741
7.708333	978062.442	978125.5142	-63.07214125		9.56606E+11	9.5673E+11	3978.095002
7.75	978066.9566	978126.5151	-59.55854689		9.56615E+11	9.56731E+11	3547.220508
7.791667	978071.7503	978127.5213	-55.77099439		9.56624E+11	9.56733E+11	3110.403815
7.833333	978076.2119	978128.5328	-52.32088225		9.56633E+11	9.56735E+11	2737.474719
7.875	978086.5252	978129.5495	-43.02430766		9.56653E+11	9.56737E+11	1851.09105
7.916667	978097.9721	978130.5715	-32.59938499		9.56676E+11	9.56739E+11	1062.719902
7.958333	978100.5066	978131.5987	-31.09216357		9.56681E+11	9.56741E+11	966.7226355
8	978104.1251	978132.6312	-28.50613418		9.56688E+11	9.56743E+11	812.599686
MAXIMUM	978104.1251	978132.6312	-14.13837346	SUM	2.39163E+13	2.3918E+13	38063.777
MINIMUM	978062.442	978109.3058	-63.07214125	AVE.	9.5665E+11	9.5672E+11	1522.55108
MEAN	978085.0203	978120.7257	-35.70546864	RMS	978085.0204	978120.7258	39.01988057
STDEV	12.61688078	7.154169802	16.06207324				