ARDHI UNIVERSITY

DETERMINATION OF GRAVITY DISTURBANCE DATABASE AND ITS VALIDATION USING REFERENCE AND ABSOLUTE GRAVITY DATA IN TANZANIA

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A Dissertation Submitted to the Department of Geospatial Sciences and Technology in Partially Fulfilment of the Requirements for the Award of Science in Geomatics (BSc. GM) of Ardhi University

CERTIFICATION

The undersigned certify that they have proof read and hereby recommend for acceptance of Ardhi University a dissertation titled "**DETERMINATION OF GRAVITY DISTURBANCE DATABASE AND ITS VALIDATION USING REFERENCE AND ABSOLUTE GRAVITY DATA IN TANZANIA**" in partial fulfillment of the requirements for the award of degree of Bachelor of Science in Geomatics at Ardhi University.

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Ms. Regina V.Peter

(Supervisor)

Date ………………………

DECLARATION AND COPYRIGHT

I Marandu, Flavian F hereby declare that, the contents of this dissertation are the results of my own findings through my study and investigation, and to the best of my knowledge they have not been presented anywhere else as a dissertation for diploma, degree or any similar academic award in any institution of higher learning.

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Marandu, Flavian F

22779/T.2019

(Candidate)

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First and foremost, we praise and thank the God for his showers of blessings throughout my study and dissertation work until its successful completion. I was so alive and healthy that I was able put this very professional book together in an optimal way.

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DEDICATION

I dedicate this dissertation to my beloved family; my parents Mr & Mrs Francis Marandu, and Gudilah Shirima, for their invaluable encouragement, prayers, unlimited love, patience, support and care throughout my studies. I really appreciate you for all you have done to me. I love you, God bless you all.

ABSTRACT

Gravity disturbance refers to any deviation from the expected gravitational field of an object or region. This can be caused by variety of factors, including the presence of other massive objects nearby, the distribution of mass within an object and the effect of rotation. The Earth's crust is made up of several tectonic plates that are in constant motion, and when these plates shift or collide, they can cause changes in the distribution of mass within the Earth, which can lead to gravity disturbances. Additionally, the gravitational pull of the Moon and Sun can cause the Earth's crust to bulge and stretch, leading to gravity disturbances.

The creation of gravity disturbance data from point gravity measurements and its subsequent validation using reference and absolute gravity data are essential steps in geophysical studies and earth science research. This abstract presents an overview of the methodology involved in creating gravity disturbance data through point gravity measurements and the subsequent validation process using reference and absolute gravity data. On which we started with data acquisition from Ardhi university and being able to have over 29899-point gravity after then we compute the Gravity disturbance by using different relations for computing the gravity disturbance and the program used in computation has been written by matlab programming language, after computation we also acquire the Reference gravity data for validation. The validation process involves statistical analyses and error assessments to ensure the accuracy and reliability of the computed gravity disturbances.

The final 1'×1' Gravity Disturbance were checked against 19 reference gravity stations over the area of interest and proved to be good for the various applications like gravimetric geoid determination, fluid transportation and mineral and gas exploration, there were no outliers detected at 99% confidence level. At 95% confidence level, 1 outlier detected was removed and remained17 stations which yielded STD value of 50.42, RMS value of 50.41 mGal, mean value of 9.596mGal, minimum value of 288.92 mGal and maximum value of 104.01 mGal

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ABBREVIATIONS

AOI	Area Of Interest
ARU	Ardhi University
BGI	Bureau Gravimetrique International
d.ddd	Decimal degree
DEM	Digital Elevation Model
DGST	Department of Geospatial Science and Technology
DMA	Defense Mapping Agency
DTU	Technical University of Denmark
GGA	Gravity and Geoid for Africa
GGM	Global Gravitational Model
GMT	Generic Mapping Tool
GNSS	Global Navigation Satellite System
GOCE	Gravity Field and steady state Ocean Circulation Explorer
GRACE	Gravity Recovery and Climate Experiment
IGSN71	International Gravity Standardization Network 1971
Matlab	Matrix Laboratory
PDF	Probability Distribution Function
RCR	Remove Compute Restore
RMS	Root Mean Square
RTE	Residual Terrain Effect

RTM	Residual Terrain Model
SRTM	Shuttle Radar Topography Mission
STD	Standard Deviation
TGDB	Tanzania Gravity Database

CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Gravity disturbance refers to any deviation from the expected gravitational field of an object or region. This can be caused by variety of factors, including the presence of other massive objects nearby, the distribution of mass within an object and the effect of rotation. One of the most well known examples of gravity disturbance is the effect of the earth's gravity on nearby objects, which can cause tides and other phenomena. In addition, gravity disturbance can also be caused by a number of other factors, such as the presence of other massive objects in space, changes in the earth's crust and even human-made structures (Guglielmetti, 2021).

Gravity disturbances on Earth are caused by a variety of factors, including changes in the distribution of mass within the Earth, the movement of tectonic plates, and the gravitational pull of the Moon and Sun. The Earth's crust is made up of several tectonic plates that are in constant motion, and when these plates shift or collide, they can cause changes in the distribution of mass within the Earth, which can lead to gravity disturbances. Additionally, the gravitational pull of the Moon and Sun can cause the Earth's crust to bulge and stretch, leading to gravity disturbances. These disturbances can also lead to the formation of earthquakes, volcanic eruptions, and other geological events (Smilde, 2009).

Gravity disturbance research deals with the study of variations in the Earth's gravitational field caused by various factors such as changes in the distribution of mass within the Earth, changes in the Earth's rotation, and the effects of the Sun and Moon on the Earth's gravitational field. This research can be used to improve our understanding of the Earth's interior structure and dynamics, as well as to improve the accuracy of satellite-based navigation and positioning systems. Techniques used in gravity disturbance research include satellite-based gravimetric, ground based gravimetric, and numerical modelling (Smilde, 2009).

Different studies on Gravity disturbance determination using GGMS have been done by many scholars. Among of them include; (Klemann, 2013) he did a research on computing the gravity disturbance by using one of the GGMS(DGM-1S) he calculate the mean value of the gravitational acceleration to obtain the normal gravity at the location the he subtract the normal gravity from each GGm value and he get the gravity disturbance in order for him to study the inner part of the earth, and proposed that Gravity disturbance can be computed by using the new GGMS because by the time of the research the current GGM was DGM-1S with degree of 250 with the data from GOCE and GRACE satellites. The author suggested this approach as an accurate method for estimating Gravity disturbance.

Also (Shuanggen, 2015) does a research on computation of gravity disturbance by using Topographic Gravity Field Models (RWI_TOPO_2015) with a degree of 2190, he does first the topographic correction caused by terrain by using topographic correction model (Bouguer correction) and then subtract the topographic correction from observed gravity data and he obtain the bouguer anomaly, the bouguer anomaly represents the gravity disturbance caused by subsurface density variations. and proposed that Gravity disturbance can be computed by using the new Topographic Gravity Field Models because by the time of the research the current Topographic Gravity Field Models was RWI_TOPO_2015 with degree of 2190. This information is crucial for precise surveying, mapping, and geodetic reference systems. The geoid is a hypothetical surface that represents the mean sea level of the Earth's oceans, extended continuously under the continents. It is a critical reference surface for measuring heights and elevations. Gravity disturbance data, along with other geodetic measurements like GPS and levelling, are used to determine the geoid's irregular shape and height variations across the globe.

Various countries e.g. Geneva in Switzerland (Perozzi, 2021) created a gravity disturbance database in order to monitor Earthquake and volcanos, Changes in gravity can be indicative of magma movement or other geological events. Before and after an earthquake or volcanic eruption, there are often significant changes in the Earth's crust due to stress accumulation and release. Gravity disturbance data can help measure these deformations by detecting shifts in the mass distribution of the subsurface they create Gravity disturbance from different Topographic surface.

Gravity data helps identify subsurface density variations, which can be indicative of potential mineral deposits or oil and gas reservoirs. It is used in mineral exploration and hydrocarbon prospecting. Different rock types have varying densities, and gravity disturbance data can help identify regions with significant density variations beneath the Earth's surface. Anomalies in the gravity field can indicate areas where denser materials, such as minerals or hydrocarbons, may be present.

So from those various factors it has been seen that in Tanzania we are lack of this Gravity Disturbance Database because there is no any research that have been conducted in creating the database and this research aims to fill the gap. Because they are new GGMs produced as well as different Topographic Gravity Field Models,

The goal of the research is to create a 1'×1' gravity disturbance database that can be used for a variety of applications, such as mineral exploration, oil and gas exploration, and geohazard assessment. The 1' x 1' resolution refers to the spatial resolution of the data, meaning that the database would have measurements taken every 1 foot by 1 foot. The optimal method for creating such a database would likely involve a combination of ground-based measurements, satellite-based measurements, and modelling techniques.

This research aims to create gravity disturbance database of Tanzania in 1'×1' from various gravity data sources.

1.2 Problem Statement

Despite the importance of a detailed and accurate gravity disturbance database in understanding the Earth's interior structure and dynamics, there is currently a lack of comprehensive and high resolution gravity disturbance data for many regions, including Tanzania. This research is being conducted in the aims that it improves the heights system by having good geoidal height which has been determined from hotine method and its known that the hotines method uses gravity disturbance data has the way to determine the geoidal height.

1.3 Objectives of the research

1.3.1 Main objectives

To Develop 1'×1' gravity disturbance database in Tanzania.

1.3.2 Specific objectives

i. Development of a 1'×1' gravity disturbance database that can be used for various applications such as mineral exploration, geotechnical engineering, and environmental monitoring.

ii. Validation of the Created Gravity disturbance database by using reference and absolute gravity data.

1.4 Output

The output of this study is a 1' x 1' gravity disturbance database.

1.5 Significance of the Dissertation

i. Improved mineral exploration: The database could be used to identify areas of potential mineral deposits, which could lead to increased exploration and mining activity in Tanzania, and ultimately, economic development.

ii. Better geotechnical engineering: The database could be used to identify areas of unstable ground, which could improve the safety and stability of infrastructure such as buildings, roads, and bridges.

iii. Enhanced environmental monitoring: The database could be used to identify areas of potential environmental impact, such as land subsidence, which could inform conservation and land-use planning decisions.

iv. Advancing research: The research could improve the understanding of the geology, geophysics and geochemistry of the area and could lead to new discoveries.

v. Improved data availability: The database could be used as a source of high-resolution, accurate data for various research, academic and industrial applications.

vi. Height Reference: The geoid provides a consistent and uniform reference surface for measuring elevations and heights on Earth. It serves as a baseline from which precise measurements of land and sea can be made, aiding in activities such as surveying, cartography, and construction.

vii. Sea Level Determination: The geoid is used to define mean sea level (MSL) accurately. By combining measurements of the geoid with local measurements of gravity and tidal data, scientists can determine precise sea level measurements at various locations. This information is crucial for studies related to oceanography, climate change, and coastal management.

1.6 Scope of limitations

The study area is limited within 4°N to 15°S latitude and 26°E to 44°E longitude on which Tanzania is within the boundaries, (1°N to 12S °latitude and 29°E to 41°E longitude). See Figure 1.1 below,

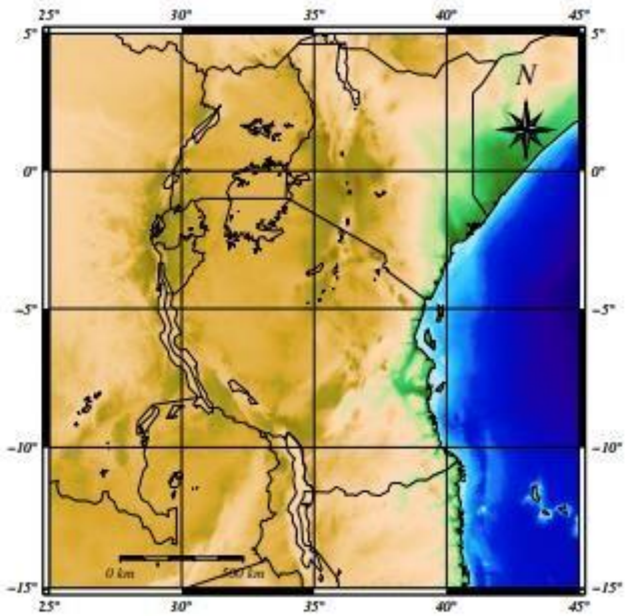

Figure 1.1 The study area

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Tanzania Gravity Database

Tanzania is among the few African countries that have almost all sources of gravity data. The Gravity data include terrestrial, satellite, aerial and altimetry marine gravity. However, there is no Specific public organization within Tanzania which archives and maintains information obtained From gravity surveys conducted within the country. There are several organizations in Tanzania that store gravity data and some of them have developed their own gravity database. The gravity Sources in Tanzania are categorized in two groups; those which are within the country and those from overseas. The following are sources of gravity data within Tanzania:

a) Ardhi University under the Department of Geospatial Sciences and Technology (DGST).

b) University of Dar es salaam (UDSM) Department of Geology.

c) Tanzania Petroleum Development Center (TPDC).

d) Ministry of Minerals and Energy.

e) Ministry of Lands, Housing and Human Settlements Development.

f) Eastern and Southern African Mineral Resources Development Centre.

The overseas sources of Tanzania gravity data are:

a) Bureau Gravimetrique International (BGI), which has a task of storing the gravity data

From all over the world.

b) Gravity and Geoid for Africa (GGA)

c) USA National Geospatial Agency (NGA)

d) Global Exploration Technology (GETECH), it provides the gravity data for Oil and mineral exploration and also for dissertation purposes.

e) Danish National Space Centre (DNSC) of the Technical University of Denmark (DTU) which provides the satellite altimetry marine gravity data.

Gravity observation in Tanzania started in the 1890's and reference was to different local datums Prior to arrival of the Potsdam datum in early 1950's (Ulotu, 2009). However, gravity information Should be unified by ensuring that gravity data are referred to a standard international datum and heights to unified known vertical datum. Gravity data collected after the declaration of the International Gravity Standardization Network 1971 (IGSN71), was invariably standardized to Potsdam and IGSN71.

Tanzania has a network of interconnected gravity bases which has been set up to provide a unified Datum for the whole country. A network consists of seven interconnected IGSN71 gravity station, and the 40 base which were established by Overseas Geological Surveys (OGS) in 1958-1961 as a part of the Eastern and Central Africa Gravity Net (ECAGN) (Ulotu, 2009).

The first gravity database in Tanzania was established by Sowerbutts (1968), and it has been Improving with time ever since it was developed. In 1991 Dr. Marobhe I, from the University of Dar es Salaam and Mr. Parker M, from East and South Africa Mineral Resource Development Center (ESAMRDC) wrote a report called Review of Gravity Survey Tanzania which compiled all known gravity data made in Tanzania although some gravity surveys were missing on this report. This report was an attempt to create a Tanzania gravity database at that time however there is no clear information on whether the Database was created. The report contains gravity data of about 14000 points and stored by the University of Dar es salaam, ESARMDC and TPDC.

The first digital gravity database was developed by (Simon, 2001) and it was based on the gravity point collected by (Parker & Marobhe, 1991). This gravity database was heavily updated to TGD08 by Ulotu (2009). The TGDB08 was created from 39,677 statistically cleaned point gravity

Data at 99% confidence level covering (4°N to 15°S latitude and 26°E to 44°E longitude (Ulotu, 2016). Pure GGM ITG-GRACE03S, combined GGM EIGEN-CG03C and SRTM3.1 CGIARCSI DEM for RTE computation were used to densify the gravity at 1'×1' grid intervals.

The Tanzania gravity database (TGDB17) was created by Mrema (2017). TGDB17 includes The previous gravity data from the Tanzania Gravity Database (TGDB08), satellite altimetry Marine gravity data and the gravity point data which are not included in TGDB08 (Mrema, 2017). Therefore, TGDB17 lacks GGMs and DEMs data which are among the important Ingredients in geoid model computation.

2.1.1 Reference Gravity Data

In this research Reference gravity data will be used to validate the 1'×1' Gravity disturbance database. For the absolute gravity stations, only one has position coordinates and thus the only one useful for this work, this is the fundamental absolute gravity station of Tanzania TANZ. For the relative gravity stations, out of 57-relative gravity stations, only 56-relative gravity stations have all the required information, i.e. Geodetic coordinates, orthometric height and gravity value hence used in this research.

Figure 2.1 shows the spatial distribution of the gravity stations on the study area.

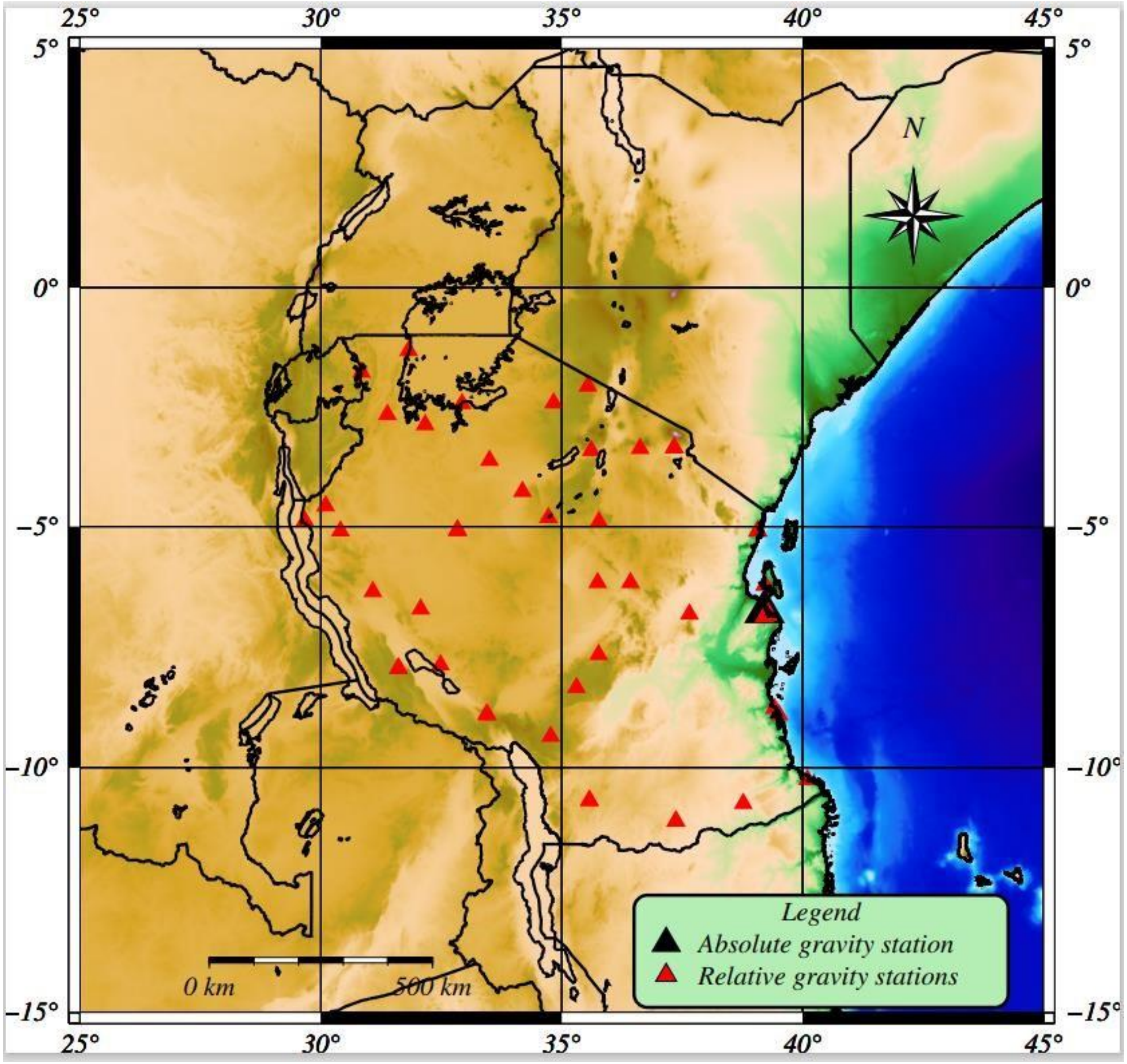

Figure 2.1 Image showing Reference Gravity Stations in Tanzania

2.2 Gravity Disturbance

Gravity disturbance refers to the deviation of the Earth's gravitational field from a standard or reference model. It represents the difference between the actual gravity field at a specific location on the Earth's surface and the expected or normal gravity field based on a theoretical model (Wolfgang, 2018).

The gravity disturbance is typically quantified by measuring the difference between the observed gravity and the theoretical gravity at a given location. This difference can arise from several factors, including variations in the mass distribution of the Earth, local geology, and the presence of topographic features.

Gravity disturbances play a crucial role in geodesy as they provide valuable information about the Earth's internal structure, mass distribution, and geophysical processes. By measuring and analyzing gravity disturbances, geodesists can gain insights into the subsurface composition, tectonic activities, and the density distribution within the Earth.

In practical terms, gravity disturbances are often expressed in terms of a quantity called the gravity anomaly, which is the difference between the observed gravity and the normal gravity at a specific location. Gravity anomalies are typically measured using sensitive instruments such as gravimeters and are represented as deviations in milligals (mGal) or microgals (μGal).

Geoid models determined from gravity disturbances are used by countries worldwide for various applications. Here are a few examples of how countries utilize geoid models:

1. United States: The National Geodetic Survey (NGS) of the United States utilizes geoid models to provide accurate height reference systems for the country. The NGS has developed the North American Vertical Datum of 1988 (NAVD 88) based on a geoid model, which serves as a reference for elevation measurements in the United States.

2. European countries: The European Vertical Reference System (EVRS) is based on a geoid model called European Gravimetric Quasigeoid (EGG), which is determined using gravity disturbance data. Many European countries use the EVRS as a common height reference system for applications such as surveying, mapping, and infrastructure development.

3. Australia: Geoscience Australia maintains a geoid model called AUSGeoid, which is determined using gravity disturbance data and serves as a reference for height

measurements across the country. AUSGeoid is used in various fields, including surveying, navigation, and geodesy.

4. Canada: The Canadian Geodetic Vertical Datum (CGVD) is based on a geoid model determined from gravity disturbance data. CGVD provides a consistent height reference system for Canada and is used in applications such as mapping, engineering, and environmental studies.

These are just a few examples, and many other countries around the world utilize geoid models determined from gravity disturbances for their specific geodetic and height reference systems. The use of geoid models helps ensure accurate and consistent measurements of elevation and supports various applications in surveying, mapping, navigation, and other geospatial fields.

Geoid determination using gravity disturbances involves analysing gravity anomaly data to derive a model that represents the Earth's geoid surface. Here is a high-level overview of the process:

1. Gravity anomaly data collection: Precise gravity measurements are collected across the Earth's surface using instruments such as gravimeters or satellite missions. These measurements capture deviations from the expected or average gravity values due to variations in the distribution of mass within the Earth.

2. Gravity anomaly computation: The collected gravity measurements are processed to calculate gravity anomalies. Gravity anomalies represent the differences between the measured gravity and a reference gravity field, such as a theoretical normal gravity field or a global mean gravity model.

3. Filtering and data processing: The gravity anomaly data may undergo various filtering techniques to remove unwanted noise and systematic errors. Corrections are applied to account for instrumental and environmental factors that can influence the gravity measurements.

4. Geoid modeling: The processed gravity anomaly data is used to derive a geoid model. Mathematical and computational techniques, such as spherical harmonic analysis or least squares fitting, are employed to fit the gravity anomaly data to a theoretical geoid representation. This involves determining coefficients that represent the geoid's shape and harmonics.

5. Validation and adjustment: The derived geoid model is validated against independent data sources, such as precise leveling measurements or satellite altimetry data, to assess its accuracy. Adjustments may be made to the model based on the validation results to improve its fit to the observed data.

6. Geoid dissemination: The final geoid model, along with associated data and documentation, is made available for use by various applications and stakeholders. It serves as a reference surface for accurate height determination, surveying, mapping, and other geospatial activities.

The specific details and methodologies used for geoid determination can vary depending on the organization, research institution, or national geodetic agency conducting the work. Different approaches may be employed to account for regional or local variations in the gravity field and to achieve higher accuracy in specific areas of interest.

Gravity disturbances can have several effects on geodesy, impacting various geodetic measurements and calculations. Here are some of the key effects:

- ✓ Vertical Deflection: Gravity disturbances cause deviations in the vertical direction, leading to variations in the direction of the plumb line. This can affect the measurement of vertical angles and the determination of heights and elevations.

- ✓ Geoid Determination: The geoid represents the equipotential surface of the Earth's gravity field, which approximates mean sea level. Gravity disturbances affect the shape of the geoid, resulting in local variations. Accurate determination of the geoid is crucial for geodetic measurements, such as precise positioning and mapping.

- ✓ Coordinate Systems: Gravity disturbances introduce anomalies in the Earth's gravitational field, which can affect the definition and realization of coordinate systems. Coordinate systems used in geodesy, such as geodetic datum’s, need to account for these anomalies to ensure accurate and consistent measurements.

- ✓ Gravity Anomalies: Gravity disturbances are often expressed as gravity anomalies, which are deviations from the normal gravity field. These anomalies provide information about subsurface mass distributions, such as variations in density and geological structures.

Geodesy utilizes gravity anomalies to study the Earth's interior, geological processes, and geophysical exploration.

- ✓ Satellite Orbit Determination: Gravity disturbances affect the orbits of satellites, particularly in regions with significant mass anomalies. Precise orbit determination is crucial for satellite-based geodetic techniques like Global Navigation Satellite Systems (GNSS) and satellite altimetry.
- ✓ Geodetic Survey Planning: Gravity disturbances influence the planning and execution of geodetic surveys. Prior knowledge of gravity anomalies helps in selecting appropriate survey locations and designing survey networks to minimize the effects of disturbances on measurements.

Understanding and accounting for the effects of gravity disturbances is essential for accurate geodetic measurements, geoid determination, coordinate system realization, and geophysical studies. Geodesists employ sophisticated mathematical models, such as geopotential models and geoid models, to incorporate gravity disturbances into their calculations and ensure the highest level of precision and reliability in geodetic applications.

CHAPTER THREE

METHODOLOGY

The creation of gravity disturbance database in geodesy involves a combination of various data sources, mathematical modeling, and computational techniques. Here is an overview of the methodology typically used to create gravity disturbance Database:

3.1 Creation of 1'×1' Gravity disturbance database

3.1.1 Data Acquisition

Gravity measurements are obtained using precise instruments called gravimeters. These measurements capture the local gravitational field at different locations on the Earth's surface. Gravity surveys are conducted over a wide area to obtain a dense and representative dataset. And in Tanzania we have some areas where we can get the Gravity data as they have been listed in chapter 2 which it is in Ardhi University under the Department of Geospatial Sciences and Technology (DGST).

Over 29899 point and 57 reference gravity data were obtained from the Department of Geospatial Sciences and Technology (DGST) of Ardhi University (ARU). As it is shown on Figure 3.1 below, gravity coverage in many places of Tanzania is sparse. There is denser concentration of point gravity measurements where deposits/minerals have been found in abundance, for example coastal strip.

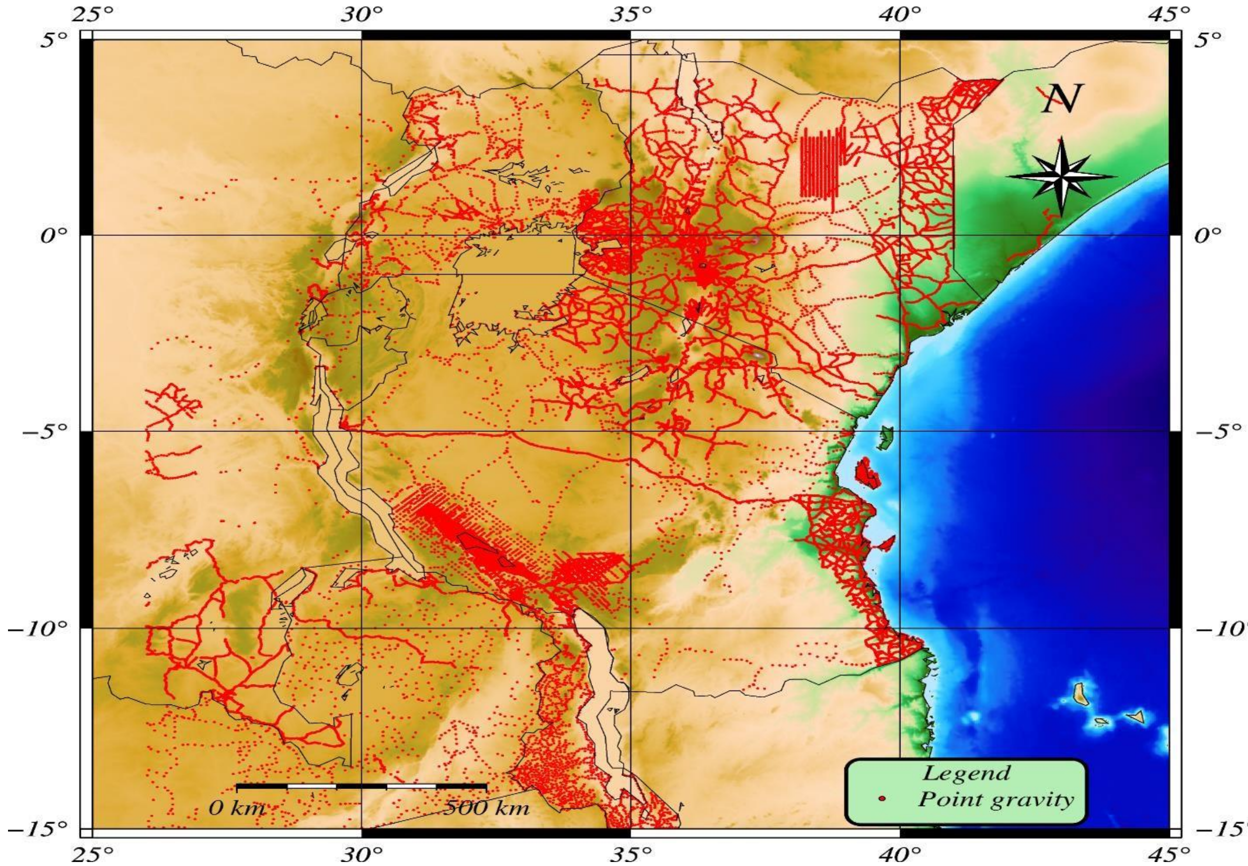

Figure 3.1 Image showing distribution of point gravity data

3.1.2 Gravity Disturbance Computation

After having the point gravity data then mathematical models for computation of Gravity disturbance should be well understood because the point gravity data comprises with gravity data the latitudes and the longitudes as well as ellipsoidal elevation so for normal gravity the latitudes and ellipsoidal elevation was used.

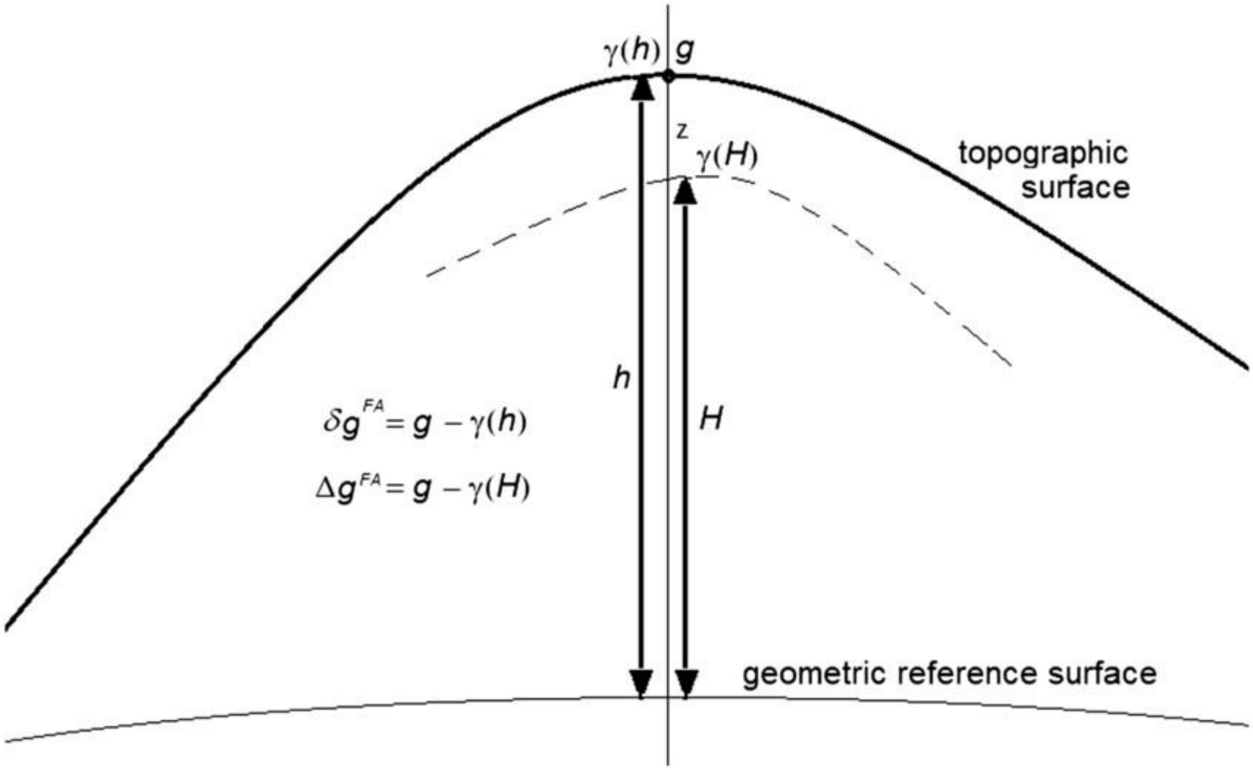

Figure 3.2 Geometry of Gravity disturbance

By definition Gravity disturbance is given as follows:

$$\delta g = g_P - \gamma_P, \tag{3.1}$$

Where: g_P is point gravity at point P on earth's surface and γ_P is a normal gravity at point P on earth's surface. $\gamma_P = [\gamma_o - (0.3087691 - 0.0004398\sin 2\varphi)\, h + 7.2125\times10^{-8} h^2]$ mGal (3.2)

Where φ – Latitude h – Height from reference ellipsoid to surface But $\gamma_o = 978032.7(1 + 0.0053024\sin 2\varphi - 0.000058\sin^2 2\varphi)$ mGal (3.3)

The programs used in computations have been written by Matlab programming language. These programs include program for computations of Gravity disturbance derived from Point Gravity.

All written Matlab programs are attached as the appendices 1

3.1.3 Validation

The created gravity disturbance of the database is validated against Reference and Absolute gravity data, including data not used in the model creation process. Iterative adjustments may be performed to refine the model and improve its accuracy. The validation step ensures the reliability and consistency of the model.

It's important to note that the methodology for creating gravity disturbance models may vary depending on the specific requirements, available data, and advancements in modeling techniques. Researchers and institutions involved in geodesy continuously work on improving the methodologies to enhance the accuracy and resolution of gravity disturbance models.

3.2 Required Data

The data to be used in this research are:

a. Pure satellite only GOCE GGMs

b. Topographic-Isostatic Gravity Field Models

c. Terrestrial Gravity Data for assessment of results

3.2.1 Global Geopotential Models (GGMs)

One GGM are used in this research as explained in Section 2.3; see Table 3.1

Table 3.1: Selected GOCE GGMs

S/N	Model	Year	Max. Degree
1	GO CONS GCF 2 DIR R6	2019	300

3.2.2 Topographic Gravity Field Models

One topographic gravity field model is used in this research because the rest of the available models at the time of conducting this research, June, 2023, do not account for isostasy, hence of the 4-models in Section 2.5.1 only one qualifies; see Table 3.2.

Table 3.2: Selected topographic gravity field models

S/N	Model	Year	Max. Degree
1	RWI_TOIS_2012_plusGRS80	2012	1800

3.2.3 Terrestrial Gravity Data

In this research terrestrial gravity data will be used to validate $1' \times 1'$ Gravity disturbance database. For the absolute gravity stations, only one has position 40 coordinates and thus the only one useful for this work, this is the fundamental absolute gravity station of Tanzania TANZ. For the relative gravity stations, out of 57-relative gravity stations, only 56-relative gravity stations have all the required information, i.e. geodetic coordinates, orthometric height and gravity value hence used in this research. Figure 3.2 shows the spatial distribution of the gravity stations on the study area.

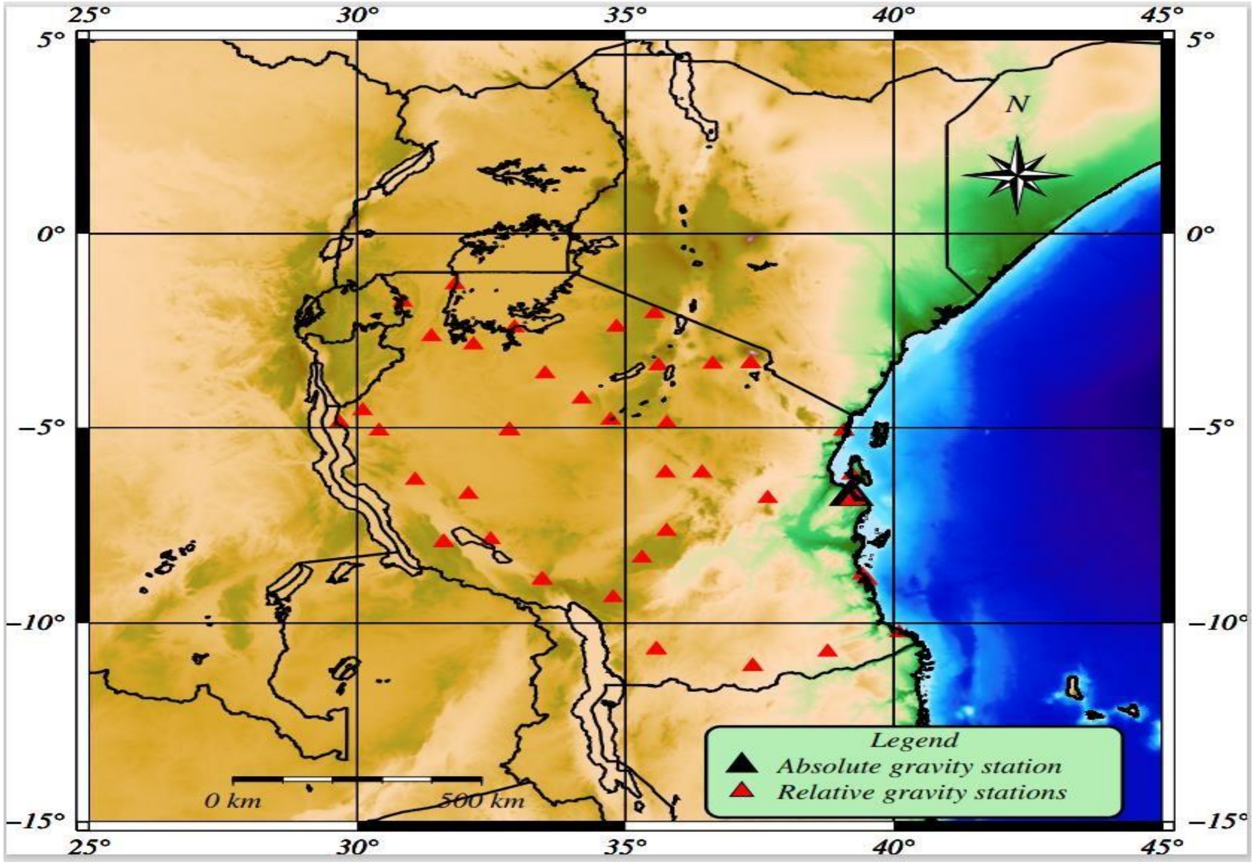

Figure 3.2; 1-Absolute and 56-Relative gravity stations in Tanzania

3.3 Software

In this research several softwares related to earth sciences were used. These are; GrafLab, Global Mapper, Golden Surfer and Generic Mapping Tools (GMT). Table 3.3 shows the purpose of each software in this research.

Table 3.3: Software used for data processing

S/N	Software	Version	Purpose in this Research
1	GrafLab	2.1.4	Computing Gravity disturbance from GGMs and topographic gravity field models
2	Global Mapper	15.0	Merging and conversion of grid formats
3	Golden surfer	15.4.354	Gridding, contouring and statistics computation
4	Generic Mapping Tool	6.1.0	Displaying grids

CHAPTER FOUR
RESULTS AND DISCUSSION OF RESULTS

This chapter presents discussion and analysis of the result. This involves processing and refinements of the point gravity data and obtaining the gravity disturbance data from point gravity as well as from reference gravity data that were used for validation.

4.1 $1' \times 1'$ Gravity Disturbance from Point Gravity

The Gravity Disturbance from Point Gravity were computed using Eq. 3.3 within the study area at a resolution of $1' \times 1'$. The results are displayed as grids with a Color Palette Table (CPT) used to show the variations of Gravity disturbance.

Table 4.1 Sample of Gravity Disturbance from point gravity

Phi (d.ddd)	Lambda (d.ddd)	δg
-14.9969	34.8189	-20.124
-14.9958	25.4622	10.56
-14.9958	28.1458	12.385
-14.9939	34.6172	58.765
-14.9917	35.1739	-34.601
-14.9883	35.2186	-41.608
-14.9864	35.4478	-29.869
-14.9853	34.9575	-19.256

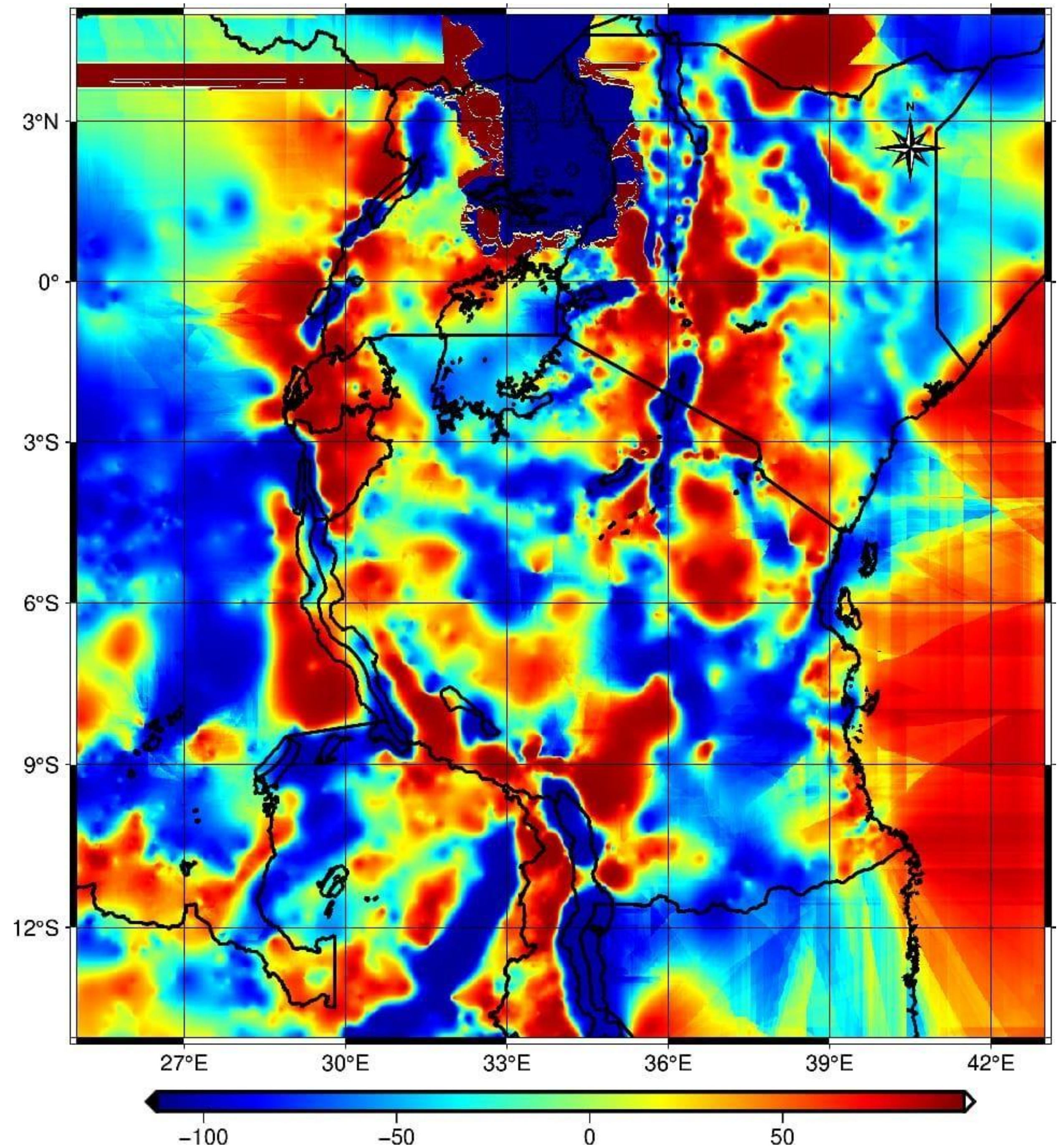

Figure 4.1 Relief map for 1'×1' Gravity Disturbance on the study area computed from the Point Gravity

Table 4.2 below shows statistics of Gravity Disturbance generated by surfer 13 software for the AOI

Table 4.2 Statistics of 1'×1' Gravity Disturbance from point gravity in mGal in the AOI

Population	SUM	Minimum	Maximum	Mean	STD	RMS
27892	-47022.18	-153.60	321.82	-1.68	35.53	35.54

4.2 1'×1' Gravity Disturbance from GGM

The surface gravity anomalies from the GGM (Table 3.1) were computed within the study area at a resolution of *1'×1'*. The results are displayed as grids with a Color Palette Table (CPT) used to show the variatioins of Gravity disturbance.

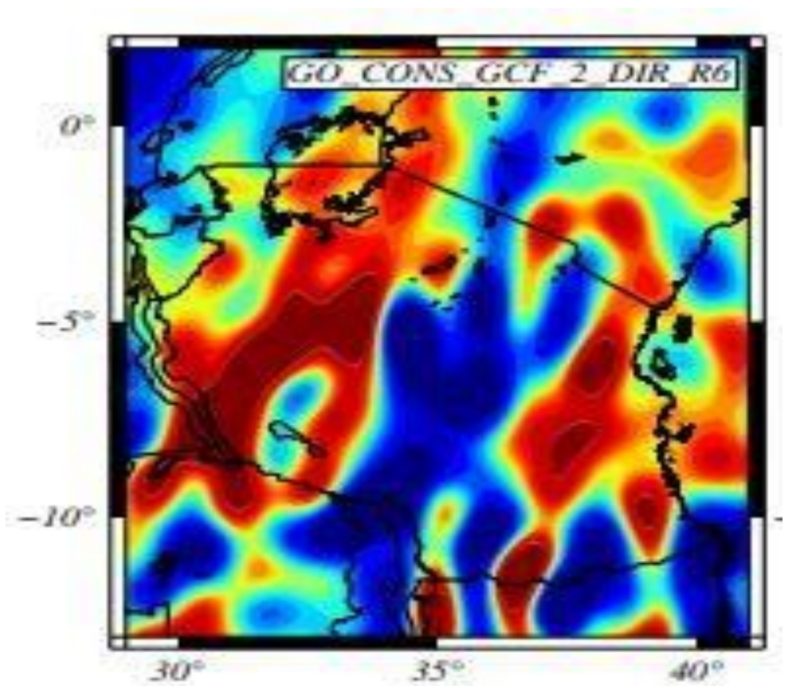

Figure 4.2 Relief map for 1'×1' Gravity Disturbance on the study area computed from the GGM

Table 4.3 below shows statistics of Gravity Disturbance that were generated by surfer 13 software for the AOI

Table 4.3 Statistics of 1'×1' Gravity Disturbance from GGM in mGal in the AOI

S/N	Model	Minimum	Maximum	Mean	STD	RMS
1	DIR R6	-111.3672	138.3152	14.7423	50.40	50.41

4.3 $1' \times 1'$ Gravity Disturbance from Topographic Models

The surface gravity anomalies from the selected topographical model (table 3.2) were computed within the study area at a resolution of $1' \times 1'$.

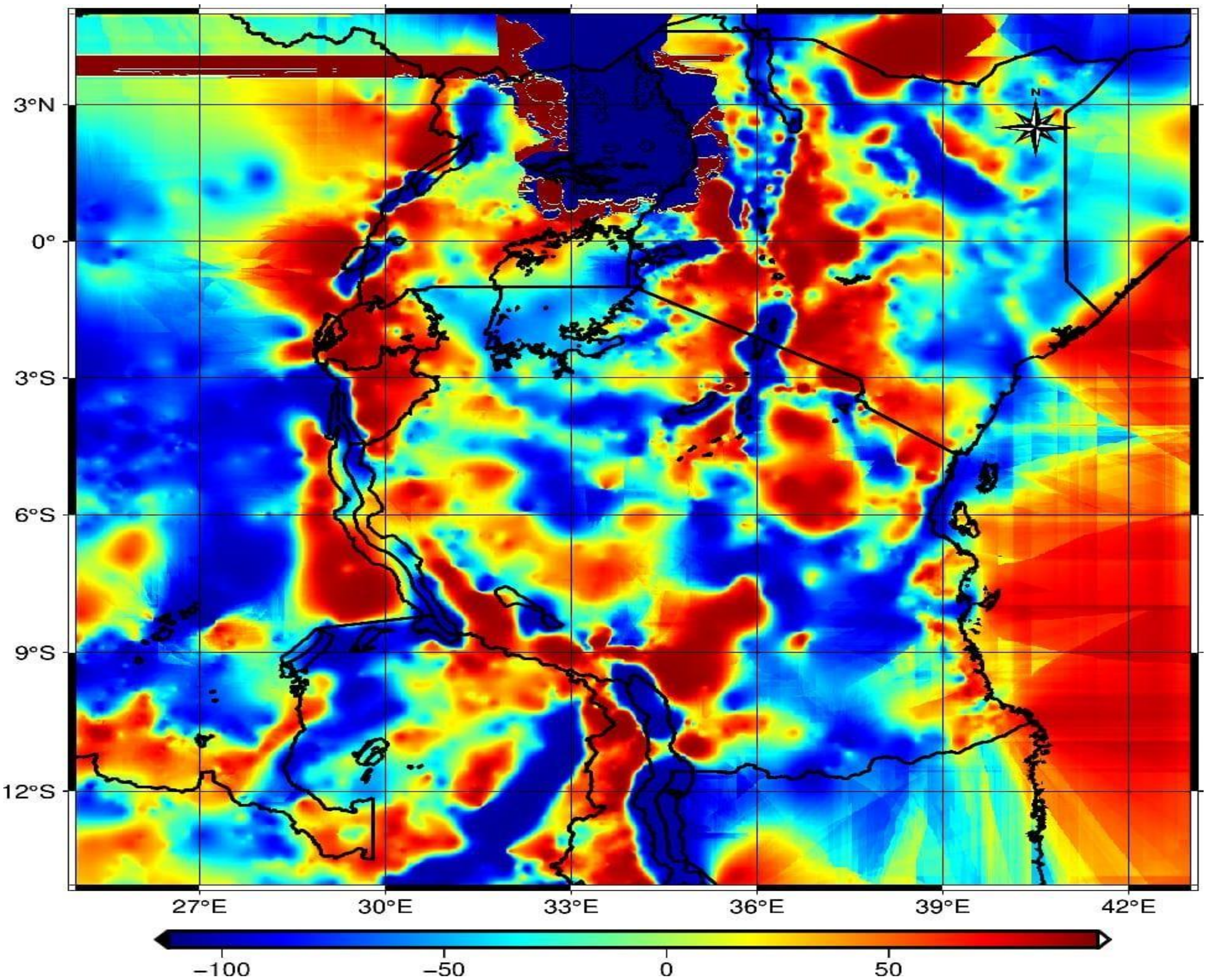

Figure 4.3 Relief map for 1'×1' Gravity Disturbance on the study area computed RWI TOIS 2012 plusGRS80 Topographic model

Table 4.4: Statistics of the computed Gravity Disturbance from the topographic gravity field model RWI TOIS 2012 plusGRS80 (mGal)

S/N	Model	Minimum	Maximum	Mean	STD	RMS
1	RWI TOIS 2012 plusGRS80	-88.6828	-88.6828	0.0092	50.47	50.47

4.4 1′ × 1′ Gravity Disturbance from Reference Gravity Data

After computing the Gravity disturbance from point gravity, we then have to validate by using the Reference gravity data and doing the statistical analysis such as mean, standard deviation to assess the similarity and difference between the reference and computed gravity disturbance Table 4.3 Sample of Gravity Disturbance from Reference gravity Data

Phi (d.ddd)	Lambda (d.ddd)	δg
-3.36867	36.625	-3.004
-2.41667	34.82917	12.744
-2.65833	31.3805	17.262
-1.32083	31.8195	-15.732
-6.825	39.28883	0.23
-6.835	39.26667	4.181
-6.82167	39.29633	0.722
-6.87633	39.20417	10.3
-6.87633	39.20333	3.298
-6.81917	39.28583	-0.891
-6.82167	39.29633	0.832
-6.855	39.28	4.102
-6.8	39.28333	-0.802
-6.82083	39.2875	-0.976

Table 4.4 below shows statistics of Gravity Disturbance that were generated by surfer 13 software for the AOI

Table 4.4 Statistics of 1'×1' Gravity Disturbance from Reference Data in mGal in the AOI

Population	SUM	Minimum	Maximum	Mean	STD	RMS
57	-121.89	-288.92	104.01	-2.13	50.42	50.41

4.5 Discussion of Results

The final 1'×1' Gravity Disturbance computed from the selected GGM and also from topographic models and for point gravity were checked against 19 reference gravity stations over the area of interest and proved to be good for the various applications like gravimetric geoid determination, fluid transportation and mineral and gas exploration, there were no outliers detected at 99% confidence level. At 95% confidence level, 1 outlier detected was removed and remained17 stations which yielded STD value of 50.42, RMS value of 50.41 mGal, mean value of 9.596mGal, minimum value of 288.92 mGal and maximum value of 104.01 mGal. There are no statistical comparisons done between this Gravity Disturbance database and any previous one due to unavailability of the database of the same coverage.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Our main objective has been fulfilled as the 1'×1' Gravity Disturbance database has been created from sparse point gravity data, GGM, Topographic Models.

The validation of the gravity disturbance data through comparison with high-quality reference and absolute gravity data is essential to ensure the accuracy and reliability of the results. Through statistical analyses and error assessments, we can assess the level of agreement between the computed gravity disturbances and the reference data. This validation process not only provides confidence in the reliability of the derived gravity disturbance database but also helps identify potential biases and uncertainties.

According to the validation performed on final surface gravity anomaly database against 57 reference gravity stations which yielded RMS value of 50.41 mGal, mean value of -2.13mGal, minimum and maximum values of -288.92mGal and 104.012mGal respectively, therefore this database can now be used for its intended purpose which is Geoid Number computation. Also, it can be used for the other geodetic, Geomatics and geological purposes. We have written Matlab program see appendix 1 for conversion of surface gravity anomalies to point gravity.

The spectral analysis of the gravity disturbance data further enhances our understanding of the geophysical characteristics of the Earth's subsurface. By examining the distribution of gravitational signals across different frequencies, we can discern various geological features and tectonic structures at different scales, ranging from large regional features to small local anomalies.

The integration of point gravity data, creation of gravity disturbance databases, and validation using reference and absolute gravity data contribute significantly to advancing our understanding of the Earth's subsurface and improving the accuracy of geophysical interpretations and models. This knowledge is essential for a wide range of applications, including natural resource exploration, geohazard assessments, and scientific research about the dynamics and structure of the Earth.

5.2 Recommendations

1. Dedicated initiatives should be taken by the government to observe more ground gravity in Tanzania Is less,

2. There are many geodesy programs or packages that are suitable for gravity database creation but most of them are in FORTRAN. It is suggested here that dedicated efforts should be directed towards developing similar packages using Matlab language as started in this dissertation.

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Appendices

APPENDIX 1: Matlab script to compute Gravity Disturbance from point gravity

```
 % Loading file to MATLAB workspace
load infile.txt ;   mat =
infile;
phi = mat (: ,1) ; %
latitude   lambda = mat (:
,2) ; % longitude
h = mat (: ,3) ; %
Ellipsoidal height height
g = mat (: ,4) ; % Point
gravity ( mGal )
  % ------- ------- -------- ------- -------- -------
-------- ------- -
% Computation of normal gravity ( gamma_grs )
referred to GRS80
% Units in mgal
% ------- ------- -------- ------- -------- -------
  -------- ------- - gamma_GRS80 =
  978032.67715*(1+0.0052790414*( sind ( phi ) .^2)
  +...
0.0000232718*( sind ( phi ) .^4) ...
+ 0.0000001262*( sind ( phi ) .^6) +0.0000000007*(
sind ( phi ) .^8) ) ;
% ------- ------- -------- ------- -------- -------
-------- ------- -
% ------- ------- -------- ------- -------- -------
-------- ------- -
 % Normal gravity on earth surface ( gamma_surf )
% Units in mgal
 % ------- ------- -------- ------- -------- ------
- -------- ------- -
gamma_surf = gamma_GRS80 -(0.3087691 -0.0004398*(
sind ( phi ) ) .^2) .* ...
h+ 7.2125*10^ -8* h.^2;
 % ------- ------- -------- ------- -------- ------
- -------- ------- -
```

```
% Computation of surface gravity anomalies ( delta_g_surf )
% Units in mgal
% ------- ------- -------- ------- -------- ------- -------- ------- -
delta_g_surf = g - gamma_surf ;

% ------- ------- -------- ------- -------- ------- -------- ------- -
data=table( phi, lambda, h,delta_g_surf,gamma_GRS80,'variableNames',{'lat','long','h','delta_g_surf','gamma_GRS80'});
filename='output_flavi.csv';
```