



شبكة المعلومات الجامعية

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ





شبكة المعلومات الجامعية



شبكة المعلومات الجامعية

التوثيق الالكتروني والميكرو فيلم

جامعة عين شمس

التوثيق الالكتروني والميكرو فيلم

قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
علي هذه الأفلام قد اعدت دون أية تغيرات



يجب أن

تحفظ هذه الأفلام بعيداً عن الغبار

في درجة حرارة من 15 – 20 مئوية ورطوبة نسبية من 20-40 %

To be kept away from dust in dry cool place of
15 – 25c and relative humidity 20-40 %



شبكة المعلومات الجامعية



بعض الوثائق الأصلية تالفة



شبكة المعلومات الجامعية



بالرسالة صفحات
لم ترد بالأصل

**CIVIL ENGINEERING DEPARTMENT
FACULTY OF ENGINEERING
MINIA UNIVERSITY**



**COMPARISON OF DIFFERENT GRAVITY REDUCTION
TECHNIQUES FOR GEODETIC
APPLICATIONS IN EGYPT**

*A THESIS
SUBMITTED TO
FACULTY OF ENGINEERING
MINIA UNIVERSITY
FOR
THE DEGREE OF MASTER OF SCIENCE*

*BY
ATEF ABD- ELHAKEEM MAKHLOOF
B.Sc. CIVIL ENGINEERING*

SUPERVISORS

Prof. Dr. Mohammed Mohammed Nassar
Public Works Department
Faculty of Engineering
Ain Shams University

Prof. Dr. Omar Tawfeek Ibraheem
Civil Engineering Department
Faculty of Engineering
Minia University

Assoc. Prof. Dr. Hussein Abou-Elsoaad Hussein Abd-Elmotaal
Civil Engineering Department
Faculty of Engineering
Minia University

B
919C

MINIA 1997

EXAMINERS

Name	Occupation
Prof. Dr. Ahmed Abd-Elstar Shaker	Professor of Surveying and Geodesy Civil Engineering Department Faculty of Engineering Shoubra - Zagazig University
Prof. Dr. Osman Mahmoud Abou-Beih	Professor of Surveying and Geodesy Public Works Department Faculty of Engineering Ain Shams University
Prof. Dr. Mohammed Mohammed Nassar	Professor of Surveying and Geodesy Public Works Department Faculty of Engineering Ain Shams University

ACKNOWLEDGMENTS

I wish to express my deepest gratitude to my supervisor Prof. Dr. **Mohammed Mohammed Nassar**, Professor of Surveying and Geodesy, Public works Department, Faculty of Engineering, Ain Shams University, for his help and encouragement throughout this work, as well as his constructive discussions.

I would like to acknowledge Prof. Dr. **Omar Tawfeek Ibraheem**, Civil Engineering Department, Faculty of Engineering, Minia University, for his help during this research.

I would like to express my deepest thanks, great appreciation and sincere gratitude to my supervisor Assoc. Prof. Dr. techn. **Hussein Abou-Elsoaad Hussein Abd-Elmotaal**, Associate Professor of Surveying and Geodesy, Civil Engineering Department, Faculty of Engineering, Minia University, for suggesting the topic of the research, continuously cross-checking the results, for his lengthy and valuable discussions, and for supplying me with the necessary data and many computer programs. I wish also to thank him for allowing me to have an unlimited access to his own geodetic library.

Special thanks go to also Dr. **Rabia Ali Sadeek**, Civil Engineering Department, Faculty of Engineering, Minia University for his assistance and encouragement.

ABSTRACT

It's known that, in principle, all gravity reductions are equivalent and should yield the same geoid if the indirect effect has been taken into account. However, there are some requirements which should be taken into consideration when deciding to use a certain gravity reduction technique to determine the geoid. Mainly, the reduction should yield gravity anomalies that are small and smooth, and it must correspond to a geophysical meaningful model. Also, the indirect effect should be as small as possible.

The main aim of this study is the comparison among all gravity reduction methods that are used to reduce the gravity from the earth's surface to the geoid, and using the reduced gravity for determining the geoid in Egypt, which is considered the most important geodetic application. These methods are: free-air reduction, Bouguer reduction, isostatic reduction (Pratt-Hayford, Airy-Heiskanen), the Rudzki reduction and Helmert reduction. For doing this study, a computer programs were used for calculating the gravity anomalies for all gravity reduction techniques, and also for calculating the geoid for Egypt. Data used are gravity observations, digital terrain model for Egypt and constant density of 2.67 g/cm^3 .

The results show that, isostatic gravity reduction (Pratt-Hayford, Airy-Heiskanen) is the best method for reduction where it gives gravity anomalies that are small, smooth and slightly osculating around zero, but the indirect effect in Pratt-Hayford isostatic reduction on gravimetric quantities is slightly large. Bouguer reduction gives systematically negative gravity anomalies increased under mountains, but they are smooth. Also, gravity anomalies calculated from free-air gravity reduction are approximately equal to the same values from Helmert method, but the latter are smoother. Moreover, the gravity anomalies calculated from Rudzki reduction are big and do not have a geophysical meaning. In addition, the geoid calculated from isostatic gravity anomalies is not completely equivalent to the geoid calculated from free-air gravity anomalies. Finally, it has been demonstrated that, refining the digital terrain model for Egypt and determining the density field from geological observations are expected to increase the accuracy of isostatic gravity reduction, and hence, the reliability of produced gravimetric geoid for Egypt.

TABLE OF CONTENTS

	Page
ABSTRACT	i
ACKNOWLEDGMENTS	iii
LIST OF FIGURES	ix
LIST OF TABLES	xiii
1 INTRODUCTION	1
2 THE EARTH AND ITS GRAVITY FIELD	10
2.1 Attraction and Potential	11
2.2 Potential of Solid Body	14
2.3 Potential of Surface Layer	15
2.4 The Earth's Gravity Field	18
2.5 The Potential of the Earth in Terms of Spherical Harmonics	20
2.6 Geoid and Reference Ellipsoid	23
2.7 The Anomalous Gravity Field, Geoid Undulation, Deflection of the Vertical	25
2.8 Other Mathematical Figures of the Earth	28

CONTINUE

page

3 GRAVITY REDUCTION TECHNIQUES	31
3.1 Free-Air Gravity Reduction	32
3.2 Bouguer Reduction	36
3.2.1 Incomplete or Simple Bouguer Reduction	37
3.2.2 Complete Bouguer Gravity Reduction	38
3.2.3 Spherical Bouguer Plate	40
3.3 Isostatic Reduction	40
3.3.1 Airy-Heiskanen Isostatic Model	40
3.3.2 Pratt-Hayford Isostatic Model	43
3.3.3 Vening Meinesz Isostatic Reduction	45
3.4 Residual Terrain Model (RTM)	46
3.5 Inversion Reduction of Rudzki	48
3.6 Helmert's Second Method of Condensation Reduction	51
3.7 Closing Discussion	54
 4 GRAVITY REDUCTION: FORMULAS AND COMPUTER PROGRAMS	 56
4.1 Terrain Reduction Formula Using Rectangular Prism	57
4.2 Original TC-Program	60
4.3 Modification Introduced by Kühtreiber et al. (1989)	66

CONTINUE	Page
4.4 Modified TC-Program	66
4.4.1 Calculation of Pratt- Hayford Reduction	66
4.4.2 Calculation of Helmert Condensation	68
4.4.3 Calculation of Rudzki Reduction	69
5 PRACTICAL GRAVITY REDUCTIONS FOR EGYPT	71
5.1 Used Data	72
5.1.1 Digital Terrain Model	72
5.1.2 Gravity and Height Data	75
5.1.3 Density Data	77
5.2 Computation of Gravity Anomalies	77
5.2.1 Free-Air Gravity Anomalies	77
5.2.2 Bouguer Gravity Anomalies	78
5.2.3 Airy-Heiskanen Isostatic Gravity Anomalies	78
5.2.4 Pratt-Hayford Isostatic Gravity Anomalies	83
5.2.6 Rudzki Gravity Anomalies	83
5.2.5 Gravity Anomalies According to Helmert's Second Method of Condensation	86
5.3 Comparison Among the Different method of gravity Reductions in Egypt	88

CONTINUE	Page
5.3.1 Statistical Characteristics of Different Gravity Anomalies	89
5.3.2 Empirical Covariance Functions for Different Types of Gravity Anomalies	92
5.3.3 Indirect Effect on Geoid Computation	99
5.3.4 Closing Remarks	102
6 GEOID DETERMINATION FOR EGYPT	104
6.1 Geoid Determination Techniques	106
6.1.1 Gravimetric Method	106
6.1.2 Astrogeodetic Method	112
6.1.3 Global Positioning System(GPS)	115
6.1.4 Satellite Altimetry	116
6.1.5 Least-Squares Collocation	118
6.2 Removing the Reference Gravity Field	120
6.2.1 Reference Potential Coefficients	124
6.2.2 Calculation of Geocentric Latitude and Geocentric Radius	125
6.2.3 Normal Gravity	127

CONTINUE	Page
6.2.4 Recursion Formula for Calculating $\cos m\lambda$, $\sin m\lambda$	128
6.2.5 Fully Normalized Associated Legendre Function	128
6.3 Computational Procedure for the Geoid Determination	130
6.4 Geoid Solutions for Egypt and Their Comparisons	132
7 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS	158
REFERENCES	165
ARABIC SUMMARY	170