OPEN ACCESS

International
Journal
Of Modern Engineering Research (IJMER)

Geoid from Satlevel Collocation Model: A Case Study of Yanbu Industrial City, Saudi Arabia

K. F. Aleem

Department Of Surveying And Geoinformatics, Abubakar Tafawa Balewa University, Bauchi,Nigeria.

ABSTRACT:-*"Satlevel" Collocation is a method of geoid determination in which the ellipsoidal height from any satellite based system is combined with orthometric height from geodetic levelling to model the geoid. Geoid determination has been one of the problems of Geodesists. Several approaches has been adopted but the integration of geodetic levelling and Global Navigation Satellite System (GNSS), which enables the geoid to be determined in patches, is taken over from the empirical geoid determination. In this work, "Satlevel" Collocation model which has earlier been developed by the Author was used to generate geoidal coefficients in Yanbu Industrial city. The geoidal coefficients were used to predict the geoidal values using the user's interactive computer program "Orthometric Height on Fly". The program was used to compute the geoidal undulation of any geographical location within the area. Statistical analyses were carried out. The computed Satlevel Collocation's results compared favourably with sample results of the observed values. This method can be extended to other parts of Saudi Arabia and any other location.*

Keywords*:- Geoid, "Satlevel" Collocation Geodetic levelling and GNSS*

I. INTRODUCTION

The geoid is the surface which coincides with that surface to which the oceans would conform over the entire earth, if free to adjust to the combined effect of the earth's mass attraction (gravitation) and the centrifugal force of the Earth's rotation (Bomford, 1980). Specifically, it is an equipotential surface, meaning that it is a surface on which the gravitational potential energy has the same value everywhere with respect to gravity. The geoid surface is irregular, but considerably smoother than earth's physical surface. Sea level, if undisturbed by tides, currents and weather, would assume a surface equal to the geoid when the observation is carried out for a numbers of years.

Determination of the geoid has been one of major challenges of geodesists. Gravity data have been used in the past with stokes integration and other approaches. These methods are time consuming, expensive and laborious. GNSS provide WGS‟ 84 ellipsoidal heights and when compared with orthometric height, from geodetic levelling, allows for the computation of the geoid, or the geoid-ellipsoid separation in the region of the survey (Aleem, 1996; Olaleye et al, 2010; Aleem et al, 2011).

The development of the 'Satlevel' method has been facilitated by the improvement in technology. The Global Navigation Satellite System (GNSS) measurements are serving as important input in geodesy and providing new insights into geoid modelling. With GNSS, ellipsoidal height (height above the ellipsoid) can be computed directly, while the orthometric heights (height above the geoid) can be determined by geodetic levelling. The difference between them is called geoid height or geoidal undulation or geoid separation (N). These height differences were used to derive the geoidal models called "satlevel" collocation model (Aleem, 2013).

The geoid model will give geoidal undulation at every point of observation. This can be substituted with the ellipsoidal height from GNSS observation to get the orthometric height has given in Equation 1.1:

$$H = h - N \qquad (1.1)$$

Where:

H = Orthometric height
h = Ellipsoidal height
N = geoidal ubdulation

II. AIMS AND OBJECTIVES

The aim is to determine the geoid of the study area from data generated using Satlevel Collocation Model.
The objectives are:

1. To acquire data for ellipsoidal and orthometric height of the study

2. To compute geoidal coefficients of the “Satlevel” Collocation Model in the study area using Least squares adjustment.
3. To determine the geoid of the area using “satlevel” collocation model.

III. LIMITATION OF THE STUDY

The following are the limitation of this research:
1. The area of coverage is too small.
2. Automatic level was used to obtain orthometric height as against the use of Digital or Geodetic level.
3. The readings were taken to 3 places of decimal as against 5 places of decimal required by specification for geodetic levelling.
4. Outlier were not removed from the observation

The Study Area

The study was carried out in Yanbu Industrial City (popularly known as ‘Yanbu Al-Sina'iya’ in Arabic which literarily means Industrial Yanbu) in Madina Province of Saudi Arabia. The city was established around 1975, located on the Coast of Red Sea about 350km North of Jeddah. With Latitude 23^{0}59'57.840"N (23.9994) and longitude 38^{0}13'39.000"E (38.2275)

Figure 1: Map of Saudi Arabia showing the location of Yanbu Industrial city

Yanbu Industrial City has a section called the Royal Commission (RC). Its residents are mostly expatriates. RC Yanbu Existing Area: 185 km² and RC Yanbu Expansion Area: 420 km².

Figure 2: The Existing and land use Map of Yanbu Industrial City. Source: RCJY (2012)

The presence of industries such as the three oil refineries, plastics facilities and several other petrochemical plants in the existing and expansion of Yanbu Industrial City will require detailed map and updating of the existing map of which geoid determination have a prominent role to play.

IV. MATERIALS AND DATA

The equipment needed for the exercise are:

GNSS receiver and its accessories to acquire data for ellipsoidal height Level and its accessories to acquire data for orthometric height Computer and its accessories for computation and analysis Surfer software for plotting the contour Any software or program that can implement least square adjustment to the solution vector. In this exercise Microsoft Office excel was used for all calculations, However Aleem, (2013) has developed computer program for all the procedures “Orthometric Height on Fly” which was used to validate the results.

V. METHODOLOGY

4.1 Data Acquisition:

Levelling operation was carried out to obtain data for orthometric height.

GNSS observation was carried out to acquire data for geodetic coordinates which includes the geodetic latitude, geodetic longitude and ellipsoidal height.

Other relevant data such constant for the referenced ellipsoid were collected from various literature and INTERNET websites for data analysis and processing.

4.2 Data Processing:

Levelling reduction was carried out, the reduced level were the orthometric height of each of the points reduced.

GNSS observation was processed to get the three dimensional coordinates. These are the geodetic latitude (ϕ), geodetic longitude (λ) and ellipsoidal height (h), which were used in “satevel” collocation model.

4.3 “Satlevel” Collocation Model:

“Satlevel” Collocation model was developed by Aleem, (2013), who gave the detailed of the derivation. The model is of the form:

$$\begin{aligned} N_i = N_L &+ A_1\left(\cos^3\phi_i\cos\lambda_i + \sin^2\phi_i\cos\phi_i\cos\lambda_i + \cos^3\lambda_i\cos\phi_i + \sin^2\lambda_i\cos\phi_i\cos\lambda\right) + \\ &A_2\left(\cos^3\phi_i\sin\lambda_i + \sin^2\phi_i\cos\phi_i\sin\lambda_i + \cos^2\lambda_i\cos\phi_i\sin\lambda_i + \sin^3\lambda_i\cos\phi_i\right) + \\ &A_3\left(\cos^2\phi_i\sin\phi_i + \sin^3\phi_i + \cos^2\lambda_i\sin\phi_i + \sin^2\lambda_i\sin\phi_i\right) + r_i \end{aligned} \tag{4.1}$$

Where:

N_L is the long wavelength part of the geoid undulation in the area.

A_1, A_2 and A_3 are the geoidal coefficients which are unknown coefficients to be determined.

ϕ and λ are the WGS ‘84 geodetic coordinates (Latitudes and Longitudes)

ri is residue at an observation point.

The “satlevel” collocation model geoidal coefficients of the area were computed using least square adjustment observation equation method.

The “satlevel” collocation model geoidal coefficients were used to compute the geoidal undulation of each point in the area, which were connected to get the geoidal surface.

A user interactive program called “Orthometric height on Fly” was designed using FORTRAN Powerstation. The flowchart (Figure. 3) for the program gives detailed procedure of its usage. Orthometric height on the fly was designed using Microsoft FORTRAN PowerStation.

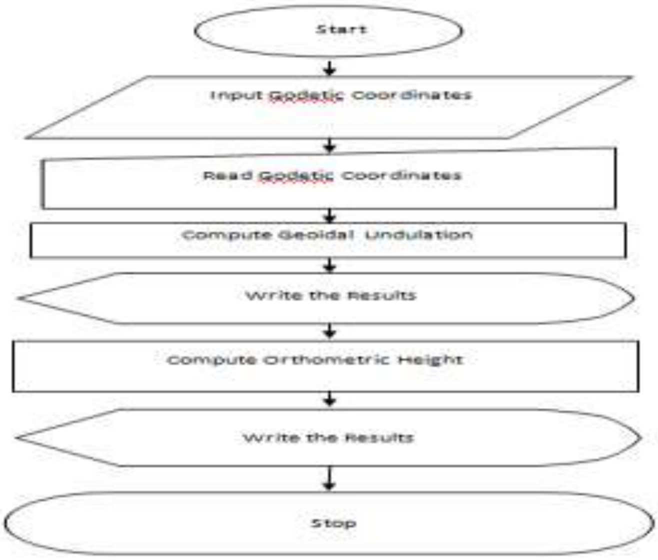

Figure 3: Flowchart for “Orthometric Height on the Fly” Programs (Source: Aleem, 2013a):

VI. RESULTS AND DISCUSSIONS

5.1 Results:

The GNSS data acquired from the field were processed and the ellipsoidal heights were extracted from the processed result. Similarly, the results of levelling operation that was done were reduced and adjusted to give the Orthometric Heights

Point Number	Latitude	Longitude	Ellipsoidal Heights	Orthometric Height (H)	Observed Geoidal Undulation
	24.0139679	38.23162	20.47	12.271	8.199
	23.9986702	38.25177	21.035	12.879	8.156
	23.9889997	38.29309	19.642	11.521	8.121
	23.9786575	38.30171	15.432	7.328	8.104
	23.9647993	38.32007	9.732	1.651	8.081
	24.0247153	38.20963	16.838	8.61	8.228
	24.0069791	38.21283	14.077	5.878	8.199
	23.9199488	38.38525	7.846	-0.179	8.025
	23.9262857	38.39142	8.719	0.686	8.033
	23.9343396	38.40011	10.972	2.93	8.042
	23.8990198	38.43258	17.625	9.601	8.024
	23.9021175	38.48912	30.976	22.942	8.034
	23.8965039	38.48059	29.479	21.45	8.029
	24.0029661	38.22813	23.281	15.083	8.198

(Source: Aleem, 2013b):

The data used for this research acquired in Yanbu Industrial City were used to plot chart (Figure 4):

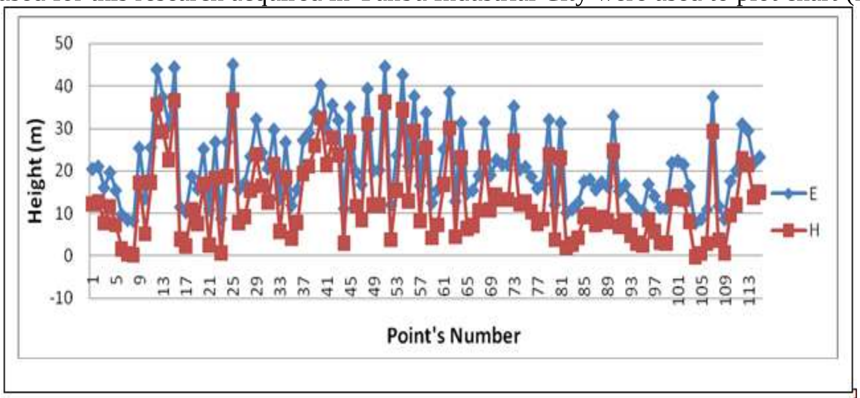

Figure 4: Orthometric and Ellipsoidal Heights of part of Yanbu Industrial City

The geoidal coefficients of Yanbu Industrial City were computed using least square adjustment observation equation as:

N_L=7.85995128

A_1=0.36447485

A_2=-0.5309024

A_3=0.15167311

(Aleem, 2013b)

The results of the "satlevel" collocation geoidal undulations were plotted into chart (Figure 5):

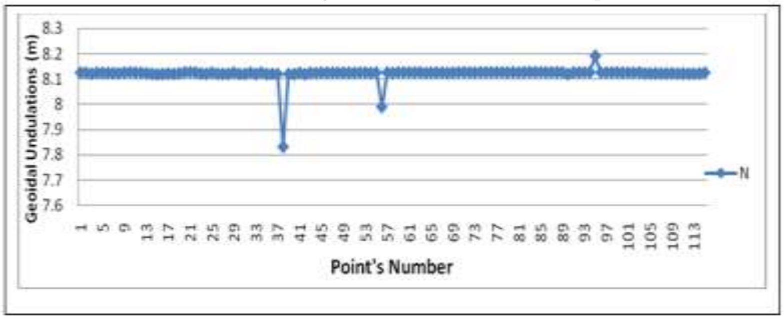

Figure 5: Geoidal Surface of parts of Yanbu Industrial City

The result of the "satlevel" collocation orthometric height were plotted into chart (Figure 5):

5.2 Discussion

Over Six hundred geodetic coordinates and orthometric heights data were acquired. One hund red and fifteen of these data were randomly selected and used to determine the geoidal coefficients of the Yanbu Industrial City.

The ellipsoidal and orthometric heights data were used to draw the chart shown in Figure 4. In this chart, ellipsoidal and orthometric height follows the same pattern shows an indication that the two are true representation of the same terrain. Olaleye et al (2010) also supported this claim.

The geoidal coefficients of Yanbu Industrial City obatained in this research can be used to compute the geoid undulation with satlevel collocation model for place around Yanbu Industrial City/

Figure 5 shows the geoidal surface of Yanbu Industrial City. In this chart, the geoidal Undulation of 3 of the points was outrageous, which is an indication that, there was presence of outliers in the observations. These observations should have been removed because they are more than 3 standard deviations (Heliani et al, 2004). Physically, those bump exists on ground as a result of excavations around the areas. This a;s6 sh6es that the data is a true representation of the area.

VII. CONCLUSION AND RECOMMENDATION

In this study, levelled heights were established along with GPS observation in some parts of Yanbu Industrial city to model the geoid in the study area. We have coordinated some of the points collocated with both GNSS and levelling in the area. 'Satlevel" Collocation Model was used to obtain the geoidal coefficients. With these geoidal coefficients, it is possible to obtain the geioidal undulation of any other point in the area using the geodetic coordinates obtained with Global Navigation Satellite receiver.

VIII. RECOMMENDATIONS

The area of coverage needs to be extended and more data should be acquired to improve the results**.**
A local geoid of Saudi Arabia is required.

REFERENCES

[1]. Aleem, K. F. (1996): “GPS and Remote Sensing of Environment”. The Graduate Surveyors. Journal of NISS University of Nigeria, Enugu Campus. 12(1) 24 – 29

[2]. Aleem, K. F. (2013a): “Adaptation of a Global Orthometric to a Local Height Datum Using “Satlevel” Collocation Model”. A Ph.D Thesis. Deaprtment of Surveying and Geoinformatics, University of Lagos, Nigeria. **UNPUBLISHED**

[3]. Aleem, K. F. (2013b) Satlevel Collocation Model for Adapting GEM 2008 to Geoid in Yanbu Industrial City. Proceeding of 2013 Scientific Assembly International Association of Geodesy, Potsdam Germany, 1-6th September2013.Available online http://www.iag2013.org/IAG_2013/Welcome_files/abstracts_iag_2013_2808.pdf

[4]. Aleem, K. F., J. B. Olaleye, O. T. Badejo and J. O. Olusina (2011). A Combination of Ellipsoidal Height from Satellite Method and Orthometric Height for Geoid Modelling. publication of the International Global Navigation SatellitesSocietyIGNSSwebsite http://ignss.org/Conferences/PastPapers/2011ConferencePastPapers/2011PeerReviewedPapers/tabid/108/Default.aspx

[5]. Aleem K. F. AlGhamdi, H. and Khayyat M. M. (2013). Conventional and Satlevel Collocation Model for Production of Contour Map: A case study of Yanbu Industrial City. Coordinates Magazine. Vol. IX, Issue 10, October 2013. Available online: http://mycoordinates.org/conventional-and-%e2%80%98satlevel%e2%80%99-collocation-model-for-production-of-contour-map/

[6]. Bomford, G. (1980) Geodesy. 4th Edition. London: Clerendon press. Deakin R. E. (1996). The Geoid, What’s it got to do with me?. The Australian Surveyor, 41(4): 294 – 303. http://user.gs.rmit.edu.au/rod/files/publications/The_Geoid.pdf

[7]. Heliani, L. S., Y. Fukuda, and S. Takemoto (2004). Simulation of the Indonesian Land Gravity Data Using a Digital Terrain Model Data. Earth Planets Space, 56(1): 15–24

[8]. Olaleye, J. B., K. F. Aleem, J. O. Olusina and O. E. Abiodun (2010). Establishment of an Empirical Geoid Model for a Small Geographic Area: A Case Study of Port Harcourt, Nigeria. Surveying and Land Information Science. 70(1): 39-48(10) http://www.ingentaconnect.com/content/nsps/salis/2010/ 00000070/00000001/art00006

[9]. Royal Commission for Jubail and Yanbu, Royal Commission at Yanbu (2012). Annual Report of the Strategic Planning & Investment Development Division Economic Planning Department. https://eservices.rcyanbu.gov.sa/Doc/YanbuIndustrialCityEconomicReview.pdf

[10]. Zaletnyik, P., L. Völgyesi, and B. Paláncz b, (2006). Approach of the Hungarian Geoid Surface with Sequence of Neural Networks. Research supported by the Hungarian National Research Fund (OTKA), Contract No. T-046718.