Development of Geoid Model for Chhattisgarh State using Geophysical Methods and GPS Technology

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***Abstract*--**This paper presents computation of Geoid undulations of Chhattisgarh region from terrestrial gravity and elevation data. Statistical analysis of comparison suggests that the computed gravimetric Geoid model has a good match with the Geoid determined from observed (GPS-leveling) data. The difference of N values between observed (GPS-levelling) locations with EGM2008 at majority of stations fall in the range of *0-2* metres. The gravimetric Geoid is calculated from the available data using combined (Hybrid) method i.e. gravimetric method (Rapp1997) followed by geometric method. The accuracy of the model was investigated by comparing the respective Geoidal heights with respect to Geoidal heights of 15 permanent benchmarks as check points distributed in Chhattisgarh that showed a closer proximity of various 'N' values.

***Keywords*--**Gravimetric Geoid; EGM2008; GPS.

I. Introduction

RECENT gravity models, e.g., EGM2008, provide a global variation of Geoid undulations though with less accuracy. Determination of Geoid undulations over Chhattisgarh region is of specific importance because it is central part of India and the large spatial gradient of Geoid undulation is observed in this region. In IndiaGeoid height decreases from central region to south region; reaching up tominimum value of 106.00 m located in the Indian Ocean.

Numerous global geopotential coefficient models are available, which primarily present the long wavelength information about the Geoid and the geopotential. There are hybrid models as well for example, EGM2008, that uses long wavelength data from satellite and short wavelength data from available terrestrial gravity. The regions which have large Geoidal anomalies and enough terrestrial data are not included (i.e., from India) in the development models; it is necessary to compare these models with computed Geoid from the local gravity data.

II. Study Site

Chhattisgarh is a state in central India. It is the 10th largest state in India, with an area of 135,190 km2 (52,200 sq. miles).With a population of 25.5 million, Chhattisgarh is the 16th most-populated state of the nation.It's having about 80-84.5 degree Longitude and about 18-24 degree Latitude.The northern and southern parts of the state are hilly, while the central part is a fertile plain.

A.Data

GPS measurements in campaign mode were carried out at 190 first order levelling Bench Marks (BM) to determine the ellipsoidal height. All the observation points are connected by a closed GPS traverse circuit starting from the known station and closed at the other known station to check the consistency and accuracy of observation points. GPS observations in static mode are recorded for about 3 hours at each location using Trimble 5700 dual frequency GPS receivers. Double tertiaryleveling network in the area is determined with respect to the mean sea-level datum of India with an accuracy of few millimeters as per survey done for Geodetic Datum Trans-formations (GDT). Difference of ellipsoidal height determined from GPS measurements and orthometric height from precise leveling provides the Geoidal undulation N-observed. Free-air anomaly values of the area are taken from Gravity Anomaly Map of India.

III. Methodology

Determination of Geoid undulation is not an easy task at a time when we do not have sufficient data, but there are some methods for the Geoid determination as per the condition and data availability. Following are three methods used in Geoid determination:

- Geometric method
- Gravimetric method
- Combined(Hybrid) method

First method is used when gravity value is not in Geoid determination. This method is used for very small area with less variation in different features of our concern. Second method is widely used throughout the world for the Geoid determination because it is most precise method in which almost every feature is considered. There are different gravimetric approaches, here namely (Rapp3, 1997) approach is discussed. Third method is combination of the first two. In this method Geoidalundulation is calculated using gravimetric approach and then combined it with the data available as done in geometric approach.

IV. Result And Comparison

After developing the model the orthometric height derived from the model are compared against the observed values and from the EGM-2008. Table below shows the comparison of model edorthometric heights, observed heights and from EGM-

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2008. From the differences in orthometric heights RMSE value is found to be observed with respect to observed heights and whereas it is 1.01 with respect to EGM-2008. Therefore the geodes model generated could be used precisely at some check points in the study area. Comparing their actual orthometric height with our model generated orthometric height.

TABLE I
DIFFERENCE OF HEIGHTS AT CHECK POINTS

S. No.	Longitude	Latitude	H_{model}	H_{obs}	H_{egm}
1	82.7569	23.209	542.991	544.15	544.39
2	82.7528	23.210	542.999	544.20	544.39
3	82.7946	23.084	513.020	513.46	514.50
4	82.8048	23.197	545.892	546.21	547.36
5	82.8143	23.122	546.941	547.31	548.43
6	82.8463	23.187	559.808	560.28	561.32
7	82.8359	23.069	514.939	515.51	516.47
8	82.8969	23.172	539.703	539.99	541.25
9	82.8734	23.156	611.778	612.21	613.31
10	82.8864	23.059	550.835	551.44	552.38
11	82.9424	23.086	538.678	539.18	540.24
12	82.9554	23.014	557.717	558.75	559.25
13	83.0330	23.135	553.444	553.75	555.01
14	82.9829	23.074	556.596	557.18	558.15
15	82.9968	23.002	571.632	572.51	573.15
16	83.0648	23.114	567.366	567.677	568.90

Table continue

S. No.	$H_{observed}$-H_{model} = (δ_1)	H_{obs}- H_{egm} = (δ_2)	$(\delta_1)^2$	$(\delta_2)^2$
1	1.159	-0.239	1.345	0.057121
2	1.204	-0.187	1.451	0.034969
3	0.439	-1.046	0.192	1.094116
4	0.326	-1.144	0.106	1.308736
5	0.369	-1.128	0.136	1.272384
6	0.475	-1.04	0.226	1.0816
7	0.572	-0.958	0.327	0.917764
8	0.290	-1.265	0.084	1.600225
9	0.433	-1.104	0.188	1.218816
10	0.611	-0.939	0.374	0.881721
11	0.501	-1.065	0.251	1.134225
12	1.034	-0.502	1.070	0.252004
13	0.307	-1.262	0.094	1.592644
14	0.589	-0.971	0.347	0.942841
15	0.885	-0.632	0.784	0.399424
16	0.310	-1.231	0.096	1.515361
			7.077	15.30395
	RMS values	$\sqrt{\frac{\delta^2}{15}}$	0.686	1.01008

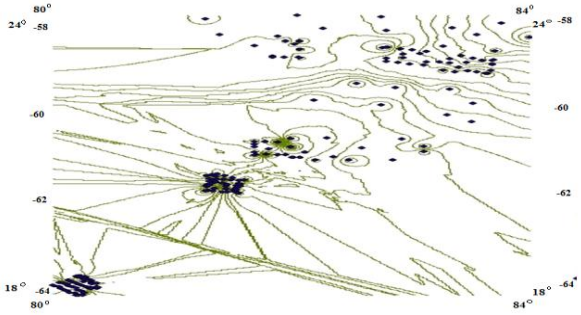

Fig. 1Contour of Geoid undulation from model

A. *Comparison of Model and EGM-2008*

At different check points the model is compared against with existing earth gravitational models. Using MS EXCEL, Figure 2 show the plots of series of N values from model, N values from EGM2008 and actual N values are plotted at different observed reference points. Figure 4 shows change in Geoid undulation with respect to the latitude. In both the figures, it can be seen that our model generated N values are matching with the observed N values and also EGM-2008. From Figure 3, showing variation of N values with respect to latitude, it can be seen that N values shows uniform and similar nature by which our model could be interpreted as correct and reliable in the study area.

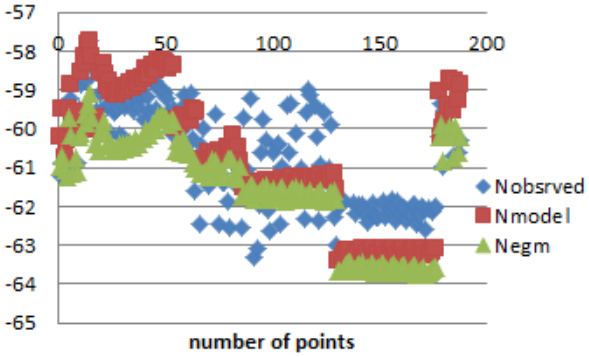

Fig.2 Comparison of Geoid Undulation

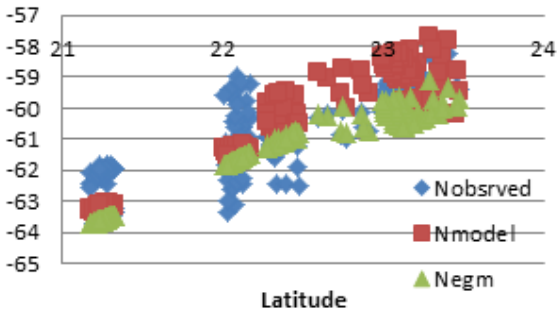

Fig. 3 Comparison of Geoid Models with respect to latitude

B. *Comparison of Nobserved, NEMG-2008 And Nmodel*

The histogram showing frequency of variation of $N_{observed}$and N_{EGM}-2008 at different locations is plotted in figure 4. Similarly the variation of $N_{observed}$and $N_{model}$are plotted in figure 5. It is quite evident from figure 6 that variation of values is high (50%) in figure 4 whereas the variation is low (40%) in figure 5. Thus it can be interpreted

that the model generated could be used to derive precise results.

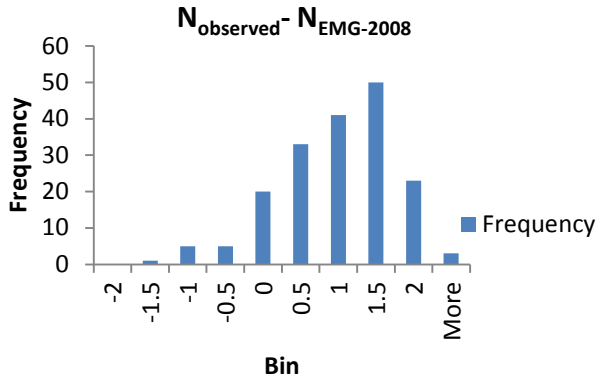

Fig.4 Histogram of the differences of $N_{observed}$and $N_{EGM-2008}$

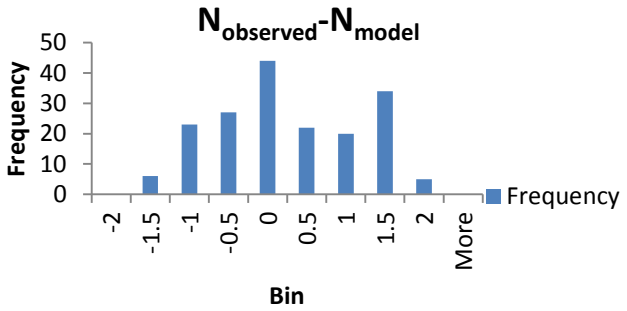

Fig.5 Histogram of the differences of $N_{observed}$and N_{model}

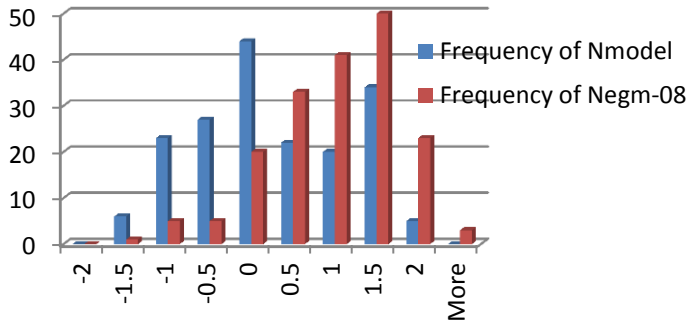

Fig.6 Histogram for$N_{observed}$, N_{model} and $N_{EGM-2008}$

For region,the accuracy of the computed gravimetric Geoid is estimated using GPS measurements at BMs by simple difference. Diference of gravimetric Geoid and the GPS-levelingGeoid height at the same observation point has the RMS value of 0.7metres. The accuracy standard of derived model is comparatively better as compared to the RMS of differences EGM model which has 1.05metres. From careful examination, it appears Nmodelare close to Nobserved as compared to Negm-2008

V. Conclusions

The model designed has used "Hybrid approach" combining properties of geometric and gravimetric method taking a single gravity value for state of Chhattisgarh.Generation of model is based on height and positioned data of 190 reference points spread across Chhattisgarh.RMSE of 0.686 is obtained. The model is calculator of Geoid undulation at a point with known /observed latitude, longitude and ellipsoidal height (WGS84). Computing program is designed in VB environment with inputs of latitude, longitude and ellipsoidal height orthometric height and Geoidal undulation will be displayed as output.

Comparison of result with known orthometric height shows a variation of 1.20 metres for sample check points. The RMSE obtained with respect to EGM-2008 model and observed points have come to 1.01 whereas present model yielded RMSE of 0.686.The results has asserted the fact that the regional model thus created for Chhattisgarh is viable for orthometric height determination in comparison to globally available latest gravity model EGM-2008.

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