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# Geoid Models for Indian Territory

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## ABSTRACT

Geoid modelling for India is a complex, exhaustive and continuous task because of its large area and tremendous varieties of surface. This paper reviews available geoid models for Indian Territory developed through geometric, gravimetric and hybrid methods for Northern, Eastern, Southern, and Western regions and presents a summary of further scope for the geoid development in India.

**Keywords:** Geoid, Geometric, Gravimetric, Hybrid

## I. INTRODUCTION

The shape of earth was always the matter of suspense and discussion from the origin of human society. The Markandeya Puran describes that the earth is flat at the poles and bulging at the equator not spherical but closer to its actual shape later philosophers such as Pythagoras (6th BC), Aristotle (4th BC) and Hipparchus (2nd century BC) from different parts of globe concluded that earth is spherical in shape. However Eartosthenes (3rd BC) is considered to be one of the founders of geodesy because he was the first to describe and apply a scientific measuring technique for determining the size of earth [1].

Several definitions of geoid have been prearranged in last 150 years where the first of them was given by C.F.Gauss in 1828 as “Mathematical figure of earth”, next 1849: G.G. Stokes derives the formula for computing the "surface of the Earth's original fluidity" from surface gravity measurements. This later became immortalized as "Stokes's integral", 1873: J.F. Listing coins the term "geoid" to describe this mathematical surface, 1880: F.R. Helmert presents the first full treatise on "Physical geodesy", including the problem of computing the shape of the geoid [2].

Geoid is the equipotential surface of gravity which is fairly accurate to the mean sea level that is the state of gravitational equilibrium. Geoid anomalies are the deviations between the geoid and the reference ellipsoid, also known as geoid undulations. The ellipsoidal heights are perpendicular to the ellipsoid determined by Global Positioning System (GPS) measurements while the mean sea level or geoidal heights are perpendicular to the geoid determined by geophysical methods. Determination of geoid is required to find the exact position on the earth and develop correct maps for different purposes.

India is a vast South Asian country with diverse terrain where it is spread in north to south from Himalayan peaks to Indian Ocean coastline and in east to west from Arunachal Pradesh to Gujarat. The latitude is of 22º 00’ N and longitude of 77º 00’ E denote geographical coordinates of India. Geoid development for India is a silent thought because of the lack of awareness and resources. New geoid model is required to redefine and accurate the maps to survive and interact with the current scenario of high technology and redefined scales where GPS technology is one of the most powerful and effective techniques. Approaches of geoid development for the Indian regions are discussed here with the techniques involved in development.

## II. METHODS AND MATERIAL

### A. Survey Of India

Survey of India, under the Department of Science & Technology is responsible for exploration and mapping of country’s domain suitably to provide base maps for prompt and integrated development and make certain that all resources contribute their full measure to the progress, prosperity and security of our country now and for generations to come. A network of well distributed precise control points is essential for carrying out mapping or location based research activities.

This department started participation in Indian Antarctica Research Program from 10th expedition, 1990-91 and started providing a network of Ground Control Points, mapping for scientific studies in Schirmacher Oasis, Antarctica. Geodetic and Geophysical observation were made using theodolites, EDM instruments, GPS and other Surveying equipments for providing a network of Ground Control Points. 18 plan metric control points in WGS84 datum were established in Schirmacher Oasis and surrounding area using Ashtech dual frequency GPS Receiver. Heights of the stations were provided in two different ways: (i) Connecting to instantaneous Mean Sea Level. (ii) Computing ellipsoidal height from GPS and then subtracting the Geoidal Undulation from OSU86D. Gravity measurements were also made on all control points established through GPS Techniques. Gravimetric and geomagnetic control network contains 56 standard gravity stations in the country and used for densification, measurements of height above vertical datum, geodynamic studies and development of Geoid Model for India. High resolution gravimetric geoid model has been developed for Delhi area and is under testing and under development for the other areas [3].

Survey of India has taken new initiatives in the field of Geodesy and Geodynamics by Setting up of Ground Control Points (GCP) library for Realization of Horizontal Reference system, Redefinition of Indian Vertical Datum, Augmentation and expansion of Indian Tide Gauge Network and Real Time GPS Network. Expansion of GPS permanent Station network and setting up new CORS GPS Permanent station at IISM campus are some of the few initiatives which has been taken by the department. Under the Modernization of Indian Tide Gauge/GPS Network, Survey of India has already installed a network of Tide Gauge stations collocated with GPS receivers and real time data transmission facilities through VSAT which has been a major input for Indian Tsunami Warning System. The GCP Project for redefinition of Horizontal Datum consists of Primary control points at spacing of approximately 250 to 300 km. In all, 292 such precise control points have been established, observed and computations completed during the period under report. These first order control points have been installed and protected with fencing. In the Redefinition of Indian Vertical Datum project, High Precision Levelling forming a framework covering 5,775 linear km in Fore and Back direction has already been completed along with Gravity observations on the established bench marks along levelling lines by SOI [4].

The present data is summarized as follows [5]:

| | |
|---|---|
| Horizontal Datum | Indian |
| Ellipsoid | Everest<br>Semi major axis (a) = 6377301.243m<br>Flattening ($^1/_f$ ) = 300.80 |
| Vertical Datum | Mean sea level at nine tide gauges |
| Geoid | Geoidal undulations are determined through gravity and astronomical observation. |
| Permanent Geodetic Facilities | |
| Tectonic Movement Problems | Yes. Particularly in Himalayan region. |
| Forward Program | Plan to establish permanent GPS stations and improve geodetic control network. |

## B. International Geoid Commission National Report for India

Geoid determination in India is very old work. Astrogeodetic geoid studies have been carried out since 1922 and charts have been published in annual Geodetic Reports of Survey of India, from time to time. In 1924 International spheroid accepted as a reference spheroid in India that defines its geodetic datum in more of less in arbitrary manner, on local considerations only. The geoid computation till 1967 was based on the limited amount of surface gravity data available within the Indian sub-continent but later on the same was computed by utilizing the sufficient amount of gravity data generated by Survey of India. Geoid studies in Survey of India are still continued to achieve an accuracy of few centimetres in geoid determination in near future. Sources of data for geoid computation are:

i. Data observed by Survey of India has been utilized for geodetic Geoid studies in India from time to time.

ii. 5º X 5º and 1º X 1º mean free-air anomalies supplied by B.G. I. in 1974 for the areas of outside the Indian sub-continent.

iii. 1º X 1º mean free-air anomalies of the Indian Ocean, published by Kahle and Tawani in 1973.

iv. 1º X 1º mean free-air anomalies published by DMA in 1973 available in GRS 1967.

v. Average free-air anomalies near Kalianpur of 5'X5' blocks computed from Survey of India data using International Gravity Formula.

vi. 1º X 1º means free-air anomalies on GRS of India Data. S 1967, computed from Survey on India data [6].

## C. Local Gravimetric Geoid

Precise knowledge of geoid undulation is mandatory for the determination of orthometric height using GPS and understanding the subsurface mass distribution of the earth. Global gravity models are available to calculate geoidal undulations but are restricted by the spatial declarations. Local area geoid heights are determined by GPS-leveling observations or calculated from terrestrial gravity values. Gravimetric geoid using spherical FFT is computed in two regions of India; one over south India region, where a large geoidal depression exists and other in northern Indian region [7].

A spectral analysis of the Indian Ocean Geoid has been done and provides that the tectonic and residual geoid anomalies of the Indian continent and adjoining regions suggest that the geoid highs of Kachchh and the Shillong plateau along the North-West and the North-East corners of India are connected to the geoid highs of the plate boundaries through several lineaments and faults that also show geoid highs and trends of seismic activity leading to plate boundaries. Geoid highs indicating high density mafic rocks suggest their connections/extensions to plate boundaries indicating them to be plausibly part of diffused plate boundaries [8].

A gravimetric geoid model for part of National Capital Region (NCR) of Delhi is developed using the analytical solution of Stokes' integral to validate the Airborne Laser Terrain Mapping (ALTM) survey results of the area. A fairly dense free air gravity anomaly data consist of about 160 uniformly distributed points covering a block of 1°x 1° have been used in the geoid modeling process. The study made use of EGM96 model to provide the reference surface for the local geoid and long wavelength part of gravity anomaly data. A comparison of geoidal undulation with GPS/leveling differences has shown a good agreement and achieved an accuracy of ±15 cm which is sufficient enough for most of the large scale mapping applications in order to provide contour information up to 1m vertical interval [9].

## D. Application of Gravimetric Geoid in Mapping Through Advance Surveying Techniques: A Case Study of Delhi Area

The present nationwide geoid for India was computed a long time back based on astro geodetic observations with respect to Everest spheroid. In the current scenario it has no significance for the GPS solutions for the orthometric height because of various limitations. A pilot project to validate the results of orthometric heights derivation for large scale mapping of a part of Delhi through Airborne Laser Terrain Mapping (ALTM) Technique was completed. A Fairly dense gravity anomaly data consisting of about 160 uniformly distributed points covering a block of 1º X 1º including National Capital Region (NCR) of Delhi was used in the geoidal modelling process.

A remove-compute-restore technique that calculates corrected gravity anomalies $\Delta g_{cor}$, reduced anomalies $\Delta g_m$, terrain corrections $\Delta g_t$, gridding of the residual gravity anomalies $\Delta g_{res}$, and applies stokes' formula on the residual gravity anomalies to produce residual geoid heights $N_{res}$, and restores the effect of the global model and the terrain to the residual geoid heights $N = N_{res} + N_m + N_t$.

**Stokes' Integration:** Stokes integral is one of the fundamental and most important formulas in physical geodesy. It was derived by G.G. Stokes in 1849 to compute geoid undulations from terrestrial gravity anomalies.

$$N=\frac{R}{4\pi r}\iint_{\sigma} \Delta g S(\varphi) d\sigma \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where

R Mean Earth radius

γ Mean normal gravity for the Earth

σ The sphere of Integration

S (ψ) Stokes function

Δg Gravity Anomalies

dσ Element of surface area on the sphere

Ψ Surface spherical radius (ψ) between two points on the sphere and is given by

$$\cos\varphi = \sin\varphi \sin\varphi' + \cos\varphi \cos\varphi' \cos(\lambda' - \lambda)$$

The stokes function in closed form is given by

$$S\ (\psi) = \frac{1}{\sin\frac{\varphi}{2}} - 6\ \sin\frac{\varphi}{2} + 1 - 5\cos\varphi - 3\ \cos\varphi\ \ln\left(\sin\frac{\varphi}{2} + \sin^2\frac{\varphi}{2}\right) \ldots\ldots\ldots (2)$$

The Stokes formula in its original form suppresses the harmonic terms of degrees one and zero in N and it holds only for a reference ellipsoid that:

(1) Has the same potential $v_0$ - $\omega_0$ as the geoid
(2) Encloses a mass that is numerically equal to Earth's mass
(3) Has its centre at the centre of gravity of the Earth

**Residual Gravity Anomalies:** The methodology for geoid computation is based on remove-compute-restore technique. The anomalous gravity potential T is split into three parts

$$T = T_{EGM96} + T_{RTM} + T_{RES} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3)$$

Where

$T_{EGM96}$ – is the anomalous gravity potential of the EGM96 global field

$T_{RTM}$ – is the anomalous gravity potential generated by Residual Terrain Model (RTM) is the high frequency part of the topography.

$T_{RES}$ – is the residual anomalous gravity potential residual i.e. the potential corresponding to the un modeled part of the residual gravity field. From equation (1) geoidal heights can also be split into three parts

$$N = N_{EGN96} + N_{RTM} + N_{RES} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

The computation of geoid is straight forward.

$$N_{EGN96} = \frac{GM}{Rr}\sum_{n=2}^{n=Nmax}\left(\frac{R}{r}\right)^n x \sum_{m=0}^{m=n}\left(\bar{C}_{nm}\cos(m\lambda) + \bar{S}_{nm}\sin(m\lambda)\right)\bar{P}_{nm}(\sin\phi)\ldots\ldots\ldots\ldots\ldots(5)$$

We have used the complete expansion to degree 360 of EGM96 global geopotential model to define the reference spheroid as per the generalized Stokes' scheme

$$N = N_M + \frac{R}{4\pi r}\int_\sigma S^{m+1}(\varphi)\,\Delta g^{m+1}\,d\sigma \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

The residual gravity anomalies ($\Delta g^{m+1}$) were obtained by subtracting the contribution of EGM96 from the terrestrial gravity anomalies ($\Delta g$) according to the following equation:

$$\Delta g^{m+1} = \frac{GM}{R^2}\sum_{n=2}^{n=N}(n-1)\left(\frac{R}{r}\right)^n x \sum_{m=0}^{m=n}\left(\bar{C}_{nm}\cos(m\lambda) + \bar{S}_{nm}\sin(m\lambda)\right)\bar{P}_{nm}(\sin\phi)\ldots\ldots\ldots\ldots\ldots(7)$$

The reference anomalies computed from EGM96 potential coefficient must use the same degree of expansion M (=360) as for the reference spheroid (eq. 6).

**Terrain Correction:** Computation of $N_{RTM}$ is done relative to the mean elevation surface. The mean elevation surface was determined from the DEM data by applying the moving average method. The RTM gravity terrain effect in the planner approximation given by a volume integral:

$$\Delta g_{RTM} = G\rho\int_{-\infty}^{\infty}\int_{z=href(x,y)}^{z=h(x,y)}\int\frac{(z-h_p)\,dx\,dy\,dz}{\left[(x-x_p)^2+(y-y_p)^2+(z-h_p)^2\right]^{3/2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Where h is the height of topography, G is the gravitational constant and ρ is the mass density taken as 2.67 gm/cm$^3$ in the computation. The computations of $\Delta g_{RTM}$ were done in space domain prism integration by Fast Fourier Transform (FFT) method using the dense height data.

**Geoid Model:** Subtraction of the long wavelength effects of EGM96 model and terrain effects $\Delta g_{RTM}$ the residual gravity data was obtained according to the following equation:

$$\Delta g_{RES} = \Delta g - \Delta g_{EGM96} - \Delta g_{RTM}$$

The residual geoidal heights $N_{RES}$ were derived from $\Delta g_{RES}$ using the Stokes' integration. To optimize the modeling of $\Delta g_{RES}$ the Stokes' kernel, S (Ψ) was modified as follows:

$$S^{M+1}(\Psi) = S(\Psi) - \sum_{n=i}^{M}\frac{2n-1}{n-1}P_n(\cos\Psi)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(9)$$

As per the technique the spheroid Stokes' kernel $S_{M+1}(\Psi)$ in equation (6), which is implicit to the generalized Stokes' scheme, can be computed simply by removing the appropriated degree Legendre polynomials [$P_n$ ($\cos\Psi$)] from the closed from of the spherical Stokes' kernel where S (Ψ) is the spherical Stokes' kernel and Ψ is the spherical distance between the computation point and the remote points in eq. (6). The degree of kernel modification in eq. (9) was chosen to be m=360, which is same as the degree of reference spheroid used in the generalized Stokes' scheme eqn. (6)

when applied over a limited spherical cap $\sigma_0$ of radios size $\psi_0$ about each geoid computation point leads to the following approximation of geoid height:

$$N \approx N_M + \frac{R}{4\pi r} \int_{\sigma_0} S^{M+1} (\psi,\psi_0) \Delta g^{M+1} \delta \sigma ...........(10)$$

The final geoid was constructed and the gravity data was arranged in a grid using the Least Squares Collocation (LSC) technique. The geoid heights were computed by applying the generalized Stokes' scheme using spherical cap of radius 0.5°. $N_{RTM}$ was computed by planar approximation implemented using FFT technique on the 5 Km basic resolution grid. Final geoid is obtained by adding $N_{EGM96}$ to $N_{RES}$ and $N_{RTM}$. Computation of gravimetric geoid model in Indian context has been studied and the use of generalized Stokes' integral with modified Stokes' kernel in remove-compute-restore technique has been successfully implemented [9].

## E. GEOID Undulation Modelling and Interpretation at LADAK, NW HIMALYAS Using GPS and Levelling Data

Geoid undulations modeled by measuring orthometric heights of a few GPS stations through differential leveling techniques, that enables GPS to be used for orthometric height determination in a much faster and more economical way then terrestrial methods. Fast and accurate relative positioning for baseline less than 20km in length is possible using dual-frequency Global Positioning System (GPS) receivers. Tectonic structure study, GPS leveling and gravity measurements were carried out along a 200 km long highly undulating profile, at an average elevation of 4000 m, in the ladak region of NW Himalaya, India with the use of geoid undulation. The geoid undulation and gravity anomaly were measured at 28 common GPS-leveling and 67 GPS-gravity stations. A regional geoid low of nearly -4 m coincident with a steep negative gravity gradient is compatible with very recent findings from other geophysical studies of a low-velocity layer 20-30 km thick to the north of the India-Tibet plate boundary, within the Tibetan plate [10].

## F. Geoid Generation and Subsurface Structure Delineation Under the Bayo Bengal, India Using Satellite Altimeter Data

Geosat Exact Repeat Mission (ERM) and ERS-1 altimeter data over the Bay of Bengal have been processed for deriving marine geoid and gravity. Processing of altimeter data involves corrections for various atmospheric and oceanographic effects, stacking and averaging of repeat passes, crossover correction, removal of deeper structures and bathymetric effects, spectral analysis and conversion of geoid into free - air gravity anomaly. The final processed results are available in the form of residual/ prospecting geoid and gravity anomaly maps. The highs and lows observed in those maps have been interpreted in terms of a number of prominent mega structures, e.g. gravity linear, 85°E and 90°E ridges, the Andaman trench complex, etc. Satellite - derived gravity contour patterns match well with the available ship - borne results. Also, continental margin as well as 85°E and 90°E ridges could be demarcated well along latitudinal profiles. In addition, subsurface modelling over 85°E ridge shows that the crustal root has become shallower as one moves from north to south (14°N to 10°N). Progressive shifting of Continent Ocean crustal Boundary (COB) along the eastern passive continental margin has been observed both in satellite - derived and ship - borne gravity data [11].

## G. Gravity and Geoid Estimate in South India and Their Comparison With EGM08

The geopotential model EGM2008 has been tested in the southern part of India by fitting gravity data. These data have been collected by the National Geophysical Research Institute of India and have been also used to estimate the geoid in this region. For the comparisons a total of 16013 gravity values have been considered. Previous global geopotential models have been also computed on these gravity points to analyze their performance as related to EGM2008. Furthermore, this new model has been compared with the local geoid estimate that is available in this region. The results prove that, in terms of gravity anomaly, in the southern India region, EGM2008 is better than any other existing model. As for the geoid undulation, the differences between the local South India geoid and EGM2008 are less than 2 m (in absolute value) and are partially correlated with the topography [12].

## H. Gravimetric Geoid of A Part of South India and Its Comparison With Global Geopotential Models and GPS-LEVELING Data

A computation of geoid undulations over a part of southern Indian region from terrestrial gravity and elevation data using remove–restore technique that involves spherical Fast Fourier Transform (FFT) to compute 'Stokes' coefficients is performed. Computed geoid undulations are compared with geoid obtained from global geopotential models such as EGM2008 and EIGEN-GRACE02S and measured GPS-leveling records at 67 locations. Statistical analysis of comparison suggests that the computed gravimetric geoid model has a good match with the geoid determined from GPS-leveling with rms of 0.1 m whereas EGM2008 has 0.46 m. The differences of GPS-leveling with EGM2008 at majority of stations fall in the range of ±0.5 m, which indicates that EGM2008 may be used for orthometric height determination with an accuracy of < 0.5 m in the south Indian region and offers a reasonably good transformation platform from ellipsoid to local datum[13].

## I. High-Resolution Residual Geoid And Gravity Anomaly Data Of The Northern Indian Ocean

An improved version of high resolution (1'×1') geoid anomaly map of the northern Indian Ocean generated from the altimeter data obtained from Geodetic Missions of GEOSAT and ERS-1 along with ERS-2, TOPEX/POSIDEON and JASON satellites. The geoid map of the Indian Ocean is dominated by a significant low of -106 m south of Sri Lanka, named as the Indian Ocean Geoid Low (IOGL), whose origin is not clearly known yet. The residual geoid data are retrieved from the geoid data by removing the long-wavelength core-mantle density effects using recent spherical harmonic coefficients of Earth Gravity Model 2008 (EGM 2008) up to degree and order 50 from the observed geoid data. The coefficients are smoothly rolled off between degrees 30-70 in order to avoid artifacts related to the sharp truncation at degree 50. Geoid anomalies are converted to free-air gravity anomalies and validated with cross-over corrected ship-borne gravity data of the Arabian Sea and Bay of Bengal. The present satellite derived gravity data matches well with the ship-borne data with Root Mean Square Error (RMSE) of 5.1-7.8 mGal. The new residual geoid anomaly map shows excellent correlation with regional tectonic features such as Sunda subduction zone, volcanic traces (Chagos-Laccadive, Ninetyeast and 85°E ridges, etc.) and mid-ocean ridge systems (Central Indian and Carlsberg ridges) [14].

## J. High Resolution Satellite Geoids/Gravity Over The Western Indian Offshore For Tectonics And Hydrocarbon Exploration

Satellite altimetry is an efficient alternative for expensive ship-borne gravity survey and powerful reconnaissance tool for exploration of offshore region and development of high-resolution gravity database of spatial resolution ~3.33 km. The averaged sea surface height over the Indian offshore (-10 to 108m) as obtained from satellite altimeter is a good approximation to the classical geoid. Various satellite geoid/gravity maps of the western Indian offshore region correlated with known tectonic features such as Bombay high. Chagos-Lacca dive ridge complex, Laxmi ridge have been studied and the satellite-derived gravity maps have been compared with those of ship-borne gravity for validation purpose. The interpreted results indicate a positive correlation between the known geological elements and gravity field [15].

## K. Computation Of Geoid And Its Interpretation In Saurashtra, Western India Using Gravity Data

By applying the Least-square collocation technique (LSC), geoid undulations have been determined by combining a geopotential model, Free-air gravity anomalies and height data in Saurashtra region, Western India. A detail terrain model (DTM) has been used for removing the residual terrain effect and the terrain effect. A positive geoidal undulation of 1-2 m has been observed after removing a regional trend from the gravimetric geoid over the Saurashtra Plateau. The effects of crustal structure have also been studies by applying Airy and Pratt-type isostatic models and compared with observed gravimetric geoidal anomalies. The geoidal undulations suggest that the main source of geoidal high lies within the crust/upper mantle [16].

## L. Geometric Method

Simple geometric methods can be used to determine geoid for small area. This method considers some reference points within the study area and as the number of points increases the accuracy of geoid increases. By taking readings of ellipsoidal height and orthometric height at different points, $N_{local}$ can be calculated at those points. EGMs is used to calculate geoid undulations and denoted as $N_{EGM}$. The interpolated geoidal heights $N_{EGM}$ were algebraically subtracted from all the co-located points via the following equation

$$\mathbf{h - H - N_{EGM} = 0}$$

$$\mathbf{h - H = N_{EGM}}$$

Also the difference between the ellipsoidal and orthometric height were obtained as follows,

$$\mathbf{N_{local} = h - H}$$

The differences (residuals) between the EGM96 geoid heights and the geometrically derived local geoid heights at each benchmark was obtained as

$$\mathbf{N_{residual} = N_{EGM} - N_{local}}$$

Different approaches are there for combining $N_{EGM}$ and $N_{local}$ in order to optimally obtain orthometric height from GPS observations. In first approach the difference between the geoidal undulations of the earth model and the local geoid is approximated by a flat surface which is usually sufficient over quite small areas (typically of few square kilometers) and can be modeled as a plane.

$$\mathbf{H = h - N_{EGM} + \Delta N}$$

where, $N = ((\Sigma N_{residual}) \div n)$ and n = No. of height points. Second method considers the use of second order polynomial to model the residual between the two geoid models. Third method employs the use of a polynomial of the second degree and order. An alternative approach is to use a correcting term to be determined for an area or a project site with common stations with ellipsoidal and orthometric height (co-located points) using the mean of the difference between the global earth model and GPS/leveling geoid heights. This technique is not useful for larger area.

## M. Hybrid Method

Hybrid method is combination of geometric method and gravimetric method. In this method height anomaly ($\xi$) is calculated and anomaly correction is added to compute geoidal undulation (N).

## III. CONCLUSION AND FUTURE SCOPE

Geoid determination for India is divided into small regions and as a whole a complete geoid model for it is absent. North, East, South and West four dimensions are touched slightly for geoid determination of specific small area. As a complete, we could see that India is lacking somewhere a standard geoid model for the nation and the central part is still untouched in this matter and the scope of further research and development is widely open.

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