



# Converging Geodetic transformations in Geophysical applications: - A case study for customized E2E solution in Cambay Basin

Authors: \*Guha Randeep, Garg R.K, Pandey U.S.D GS, ONGC, Vadodara  
 E-mail\*: randeep.guha@gmail.com

## Abstract

The upstream E & P organisations are now days equipped with the state-of-art hardware & software technology in surveying through advanced GPS instruments to capture point data with great precision in an integrated approach. In-line with the induction of technology in acquisition, a very pertinent and important concern is the choice of datum and subsequently the projection systems used in seismic surveys and the most importantly suitability as per the area of operation.

Though, there are many advantages in adopting to WGS(World Geodetic System) datum and widely acceptable UTM projection system(Universal Transverse Mercator), the obvious challenge to the geoscientists would be to transform the data already acquired in Everest Datum to WGS Datum along with projection change, as it would encounter positional shifts and further transforming the projection system from Lambert Conformal Conical to UTM cylindrical would distort the positional data in shape & size as depicted in Fig 4 & 5

This paper is an endeavour to customise an end-to-end in-house solution wherein, all the legacy data recorded in Everest Datum and either Lambert IIA / IIIA projection systems is to be seamlessly converted to WGS and UTM Zone 42/43 system and vice versa for end-users in seismic data used in applications with minimum allowable distortions both for Post-stack & Pre-stack mode. The area under discussion/study is for Western onshore i.e. Cambay Basin in particular of Indian subcontinent and is applicable to other study areas also. The generic approach is to derive the grid parameters from post-stack stack data, convert the data with preserved old coordinate's w.r.t boundary points and try to best fit the grid in pre-stack data

## Introduction

To measure the Earth, geodesists build simple mathematical models of the Earth which capture the largest, most obvious features. Geodesists have adopted the **ellipsoid** as the most basic model of the Earth.

Because the ellipsoid is based on a very simple mathematical model, it can be completely smooth and does not include any mountains or valleys. When additional detail of the Earth is needed, geodesists use the **geoid** as depicted in Fig 1 & 2. A geoid has a shape very similar to global mean sea level, but this exists over the whole globe, not just over the oceans.

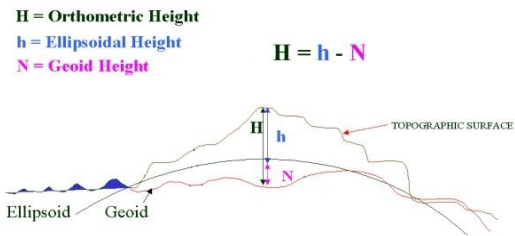


Fig 1 Depicting Equipotential surfaces as vertical datum

To overcome this problem of convergence, WGS ellipsoid /datum which is used as default in all GPS systems is chosen as the default datum. Now-a-days it is most commonly used by Survey of India (SOI) and other cartographic agencies for publishing maps and surveying methods.

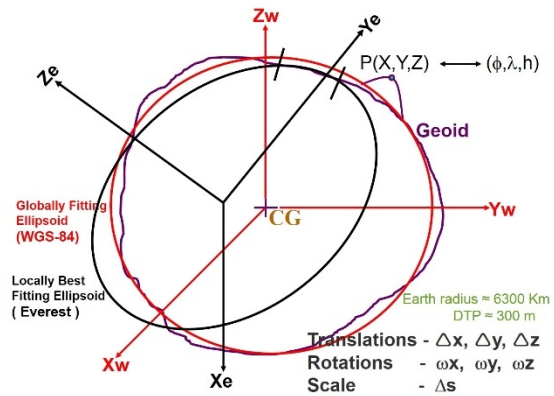


Fig 2 Geocentric & Locally Best Fitting Ellipsoids

The advantages of choosing WGS ellipsoid/datum are as follows:

- ✓ Ease in surveying layout
- ✓ Seamless interface of data for all systems in exploration
- ✓ Ease to retain uniform CRS (Coordinate Reference system) , thus avoiding different Datum transformation Parameters(DTP) as detailed in Fig5
- ✓ Seamless merging of on-land and off-shore data
- ✓ Ease of using satellite imageries
- ✓ Flexibility of using Survey of India(SOI)and other 3<sup>rd</sup> party published map, data or tools directly

- ✓ No distortion of acquired positional data involved in exploration activities.

A map projection is a mathematical expression that is used to represent the round, 3D surface of the earth on a flat, 2D map. A cartographical **map projection** is a formal process which converts (mathematically speaking, **maps**) features between a spherical or ellipsoidal surface and a **projection surface**, often flat. Although many projections have been designed, just a few are currently in widespread use. Some were once historically important but were superseded by better options, several are useful only in very specialized contexts, while others are little more than fanciful curiosities.

While choosing a projection, the first thing to consider is the purpose of our map. For general reference and atlas maps, we usually want to balance shape and area distortion. If the map has a specific purpose, we may need to preserve a certain spatial property—most commonly shape or area—to achieve that purpose. Maps that preserve shape on a conformal projection, all local angles measured from a point are correct and all local shapes are true. We should use a conformal projection when the map's main purpose involves measuring angles, showing accurate local directions, or representing the shapes of features or contour lines.

The need of an ellipsoid is

- To transform between geocentric, geodetic, and mapping coordinates as detailed in Fig 3
- To establish Datum and cartographic coordinate systems upon which to perform trigonometric computations to calculate the coordinates as explained in Fig 4

Given ellipsoid1 semi-major axis (*a*) and flattening (*f*), and latitude (*φ*), longitude (*λ*), and height (*h*)

$$b = a - a \cdot f \quad e^2 = (a^2 - b^2) / a^2 \quad v = \frac{a}{(1 - e^2 \sin^2 \phi)^{1/2}}$$

$$X = (v + h) \cos \phi \cos \lambda$$

$$Y = (v + h) \cos \phi \sin \lambda$$

Given ellipsoid2 *a* and *f*, and *X*, *Y* and *Z* Cartesians

$$b = a - a \cdot f \quad e^2 = (a^2 - b^2) / a^2 \quad e^2 = (a^2 - b^2) / b^2$$

$$v = \frac{a}{(1 - e^2 \sin^2 \phi)^{1/2}} \quad p = (X^2 + Y^2)^{1/2} \quad \theta = \tan^{-1} \left( \frac{Z \cdot a}{p \cdot b} \right)$$

$$\phi = \tan^{-1} \frac{Z + e^2 b \sin^3 \theta}{p - e^2 a \cos^3 \theta}$$

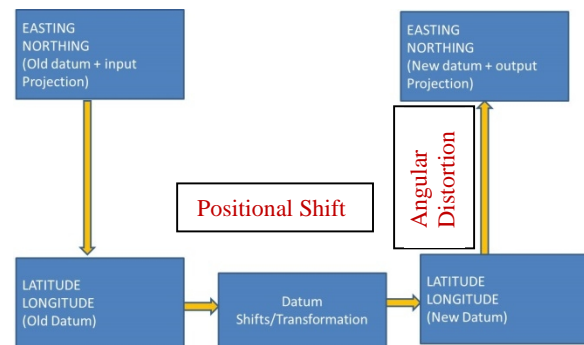
$$\lambda = \tan^{-1} \left( \frac{Y}{X} \right)$$

$$h = (p / \cos \phi) - v$$

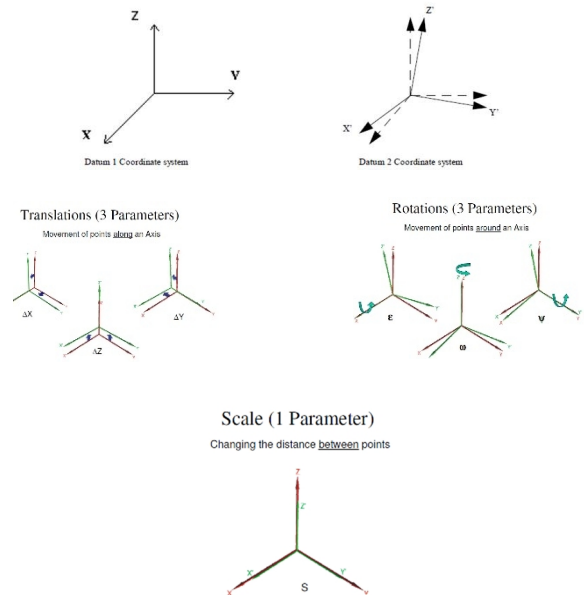
**Fig 3** Formula for Geographical to Cartesians and vice-versa

Everest ellipsoid has evolved in India from measurement of great Meridional arc from Kanyakumari to Mussoorie. Arc closely passes through 78° E Meridian and it has got variants which have been adopted from time to time depending upon suitability. Most commonly used/adopted datum for seismic acquisition & processing is **Everest 1856 or Everest 1830-Modified Modified** with semi-major axis(*a*) as **6377301.243** and Flattening(*f*) as **1/300.8017**

WGS84 was designed to be a practical standard global, geocentric horizontal datum for Mapping, Charting, Geodesy and Navigation with semi-major axis(*a*) as **6378137.00** and Flattening(*f*) as **1/298.257223563** and used as a standard in all GPS measurements.



**Fig 4** Coordinate transformation cycle from WGS84 reference datum to local reference datum i.e. Everest & LIIA/LIHA to UTM

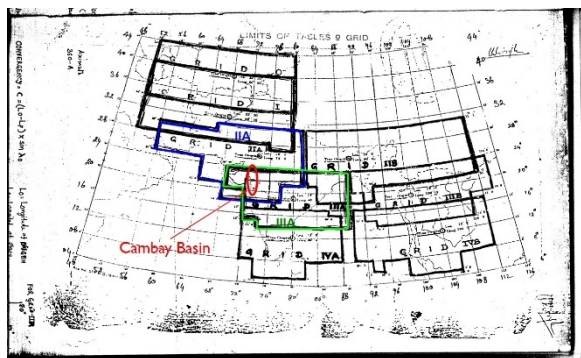


**Fig 5** Most suitable Transformation parameters for the area under study (7 parameters Bursa-Wolf *Dx, Dy, Dz, Rx, Ry, Rz, Scale*)

As the positional data are already acquired in WGS datum through GPS measurements, it would be unnecessary to transform using DTP and projecting at the surface.

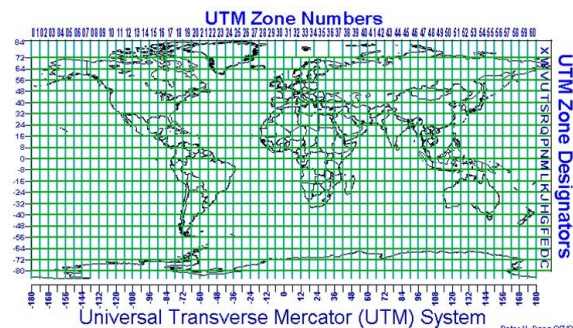
Advantages perceived in Datum Transformations in case of legacy data in Everest with parameters as depicted in Fig 5 followed by transformation in projection from Lambert (Conical) to UTM (cylindrical) are as follows

- ▶ In future only WGS-84 reference stations will be available
- ▶ Since the whole world is adopting WGS-84 & UTM and Big Giant like Survey of India is also switching over from Everest to WGS-84
- ▶ All new campaigns of on-land API activities may be switched over to WGS and UTM like the present offshore practice.



**Fig 6 Classification of Lambert Survey Grid/Zones**

- ▶ This will bring standardization of on-land API activities, in line with the recommendations of International Association of Oil and Gas Producers (OGP) best global practices.
- ▶ As entire Cambay Basin (area under study) falls in Zone 43 of UTM Grid as depicted in Fig 7, there is no need to maintain different survey zones in Lambert i.e. IIA & IIIA zones as depicted in Fig 6.
- ▶ Scale factor distribution of UTM projection is much better (closer to 1) than Lambert IIA and IIIA projections in Cambay basin (area under study), which means adopting UTM projection will give more accurate results than using different Lambert projection.
- ▶ This will also solve many positioning related problems of merging data as depicted in Fig 8 in both acquisition and processing thus avoiding different Lambert grids



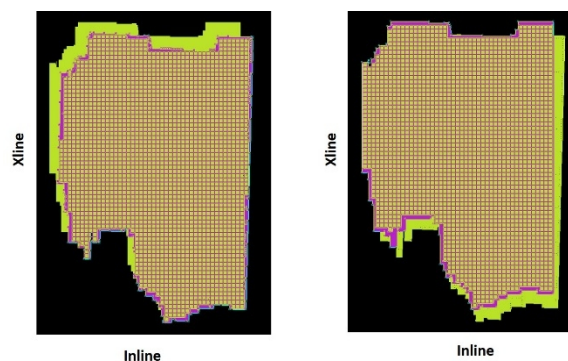
**Fig 7 Classification of UTM Survey Grid/Zones**

### Methodology

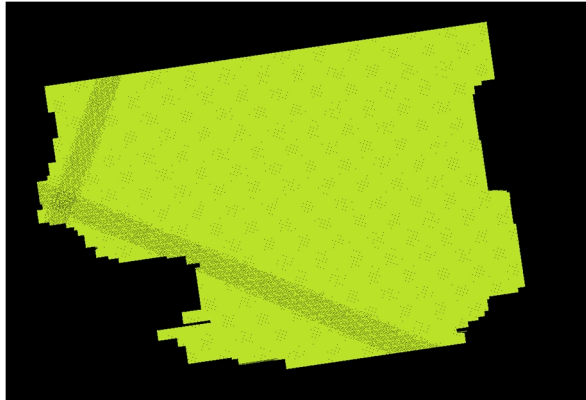
The advantages in adopting to WGS datum and UTM projection system to surface is widely acceptable, the obvious challenge to the geoscientists would be to transform the data already acquired in Everest Datum to WGS Datum along with projection change, as it would encounter positional shifts and further transforming the projection system from Lambert Conformal Conical to UTM cylindrical would distort the positional data in shape & size as depicted in Fig4

Although point-to-point conversion/transformation utilities would convert/transform one X,Y in one datum/projection to another X,Y in another datum/projection which is true for point coordinates like Wells, Navigation data, Map boundaries etc. But the main area of concern is for subsurface imaging where binning is done over a substantial area. The **potential problems** faced are as follows:

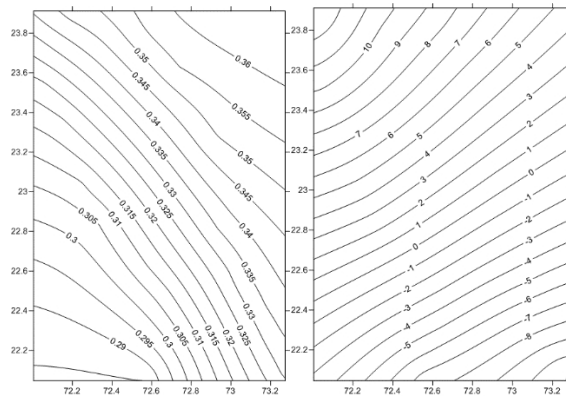
- Substantial distortion in distance and angle is envisaged in Point-to-Point Approach for Geodetic Conversion from Everest-LIIA/LIHA to WGS-UTM Zone 42/43 as depicted in Fig 8 & 9 (To an order of 20' in case of LIIA & ~1.8<sup>0</sup> on case on LIHA) as detailed in Fig 11 & 12



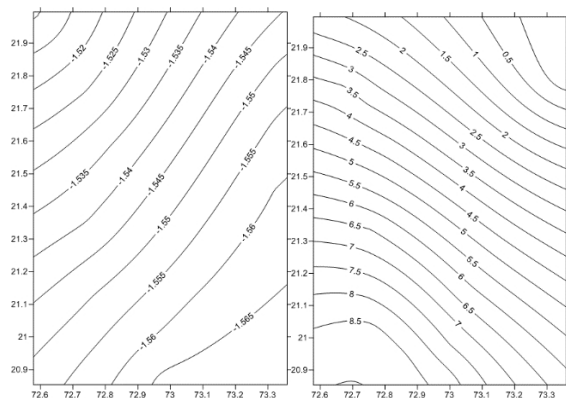
**Fig 8 Mismatch in superposition of Lambert & UTM surveys and vice-versa**



**Fig 9 Mismatch (distortions) in Geodetic Transformation from Everest-LIIIA to WGS-UTM with same Bin Size & Azimuth of Everest-LIIIA**



**Fig 10 Error estimates (Angular) in Deg.(Left) & Distance (in 10KM) (Right) from Everest1830-Modified-LIIIA to WGS-UTM**



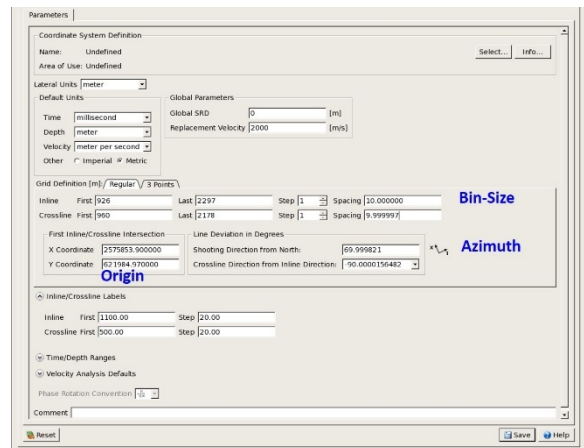
**Fig 11 Error estimates (Angular) in Deg.(Left) & Distance (in 10KM) (Right) from Everest1830-Modified-LIIIA to WGS-UTM**

- As the converted coordinates to WGS-UTM is non-parallel in nature, azimuth is not holding good in all the swaths( varies from location to location) with the above approach as
- No generic approach for determination of GRID which suits both Pre-Stack & Post-Stack data

- Design of Pre-stack grid for merging newly acquired projects with vintage data (especially important/applicable for processing centers)
- Up-dation of coordinates in SEG Y i.e. conversion in true sense for delivery/archiving to various Archival/preservation agencies etc.

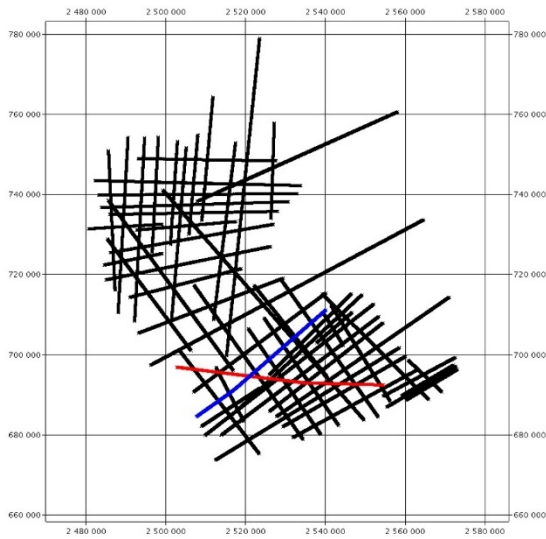
The **solution worked out to meet the challenges** and customised implementations of such transformations/conversions is highlighted as follows:

- ❖ 3 points based approach followed in most interpretation S/W like Landmark, Petrel, GeoFrame etc has been followed to interpolate 3D X & Y coordinates, wherein best fit bin-size and azimuth is recommended to fit the full survey or partial survey, if required as depicted in Fig 12



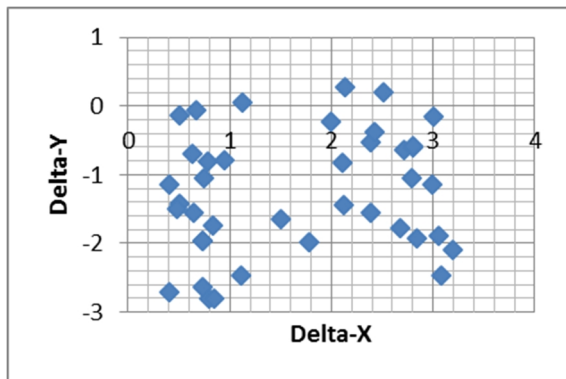
**Fig 12 Description of 3 points approach in fixing azimuth & bin size.**

- ❖ In-house Automation in generation of interpolated coordinates in 2D & 3D mode and simultaneous up-dation of SEG Y headers while preserving OLD X, Y values
- ❖ Coordinate transformation for Point-to-Point Data like SPS, Navigation etc.
- ❖ The program is independent of any CRS and is purely based on coordinates fed by the user, if required and hence applicable to all survey areas
- ❖ The program gives an option to user for running the 2D/3D interpolation in entire or partial survey (restricted by inline & xline or by coordinates) to minimize the distortions as deemed fit for the area.
- ❖ Additionally generates an equivalent GRID by adjusting the ORIGIN automatically to facilitate Pre-stack merging of data belonging to different geodesies.
- ❖ The program has the flexibility for user defined input header words for Geodetic conversion/interpolation
- ❖ The program is independent of any Application Licensed Software and takes cares of distance and angular distortion and distributes it uniformly
- ❖ The program is applicable in both 3D & 2D surveys (including crooked lines) to generate interpolated X & Y coordinates as depicted in Fig13

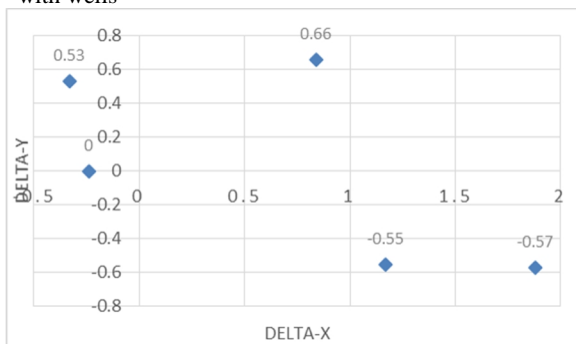


**Fig 13 Conversion of Multiple 2D lines including crooked lines in one go**

- ❖ Thorough validation has been done w.r.t. wells in most of areas covering almost full LIIA & LIIIA coverage as depicted in Fig 14 & 15



**Fig 14 Delta-X/Delta-Y after Geodetic conversion from Everest1830-Modified-LIIA to WGS-UTM calibrated with wells**



**Fig 15 Delta-X/Delta-Y after Geodetic conversion from Everest1830-Modified-LIIA to WGS-UTM calibrated with wells**

- ❖ The program is portable/deployable in other concerned centres handling exploration data for bulk conversion of Seismic SEG Y data(2D/3D) for Geodetic conversion

## Conclusions

As we derive a lot of benefits in acquiring /retaining the survey in WGS ellipsoid as cited above and can also minimize projection related issues by adopting to UTM projection system, hence switching over from **Everest-LIIA/IIIA** geodesy to **WGS-UTM Zone 42/43 Geodesy** for the area under discussion would be ideal from surveying /mapping perspective in exploration activities.

The vintage data /point maintained in the conventional **Everest-LIIA/IIIA** would suffer from permissible distortions.

As the distortions are more prominent and discernable in Pre-stack Mode as it has bin attributes like fold, offset & azimuth distribution, it is recommended to continue with the same geodesy as planned in acquisition of data.

The geodetic transformation of the seismic data say from Everest-LIIA/IIIA geodesy to WGS-UTM Zone 42/43 Geodesy is mostly desirable in post-stack phase, as it would encounter less distortion and errors are distributed in whole of the survey.

The software developed allows point-to-point conversion but advocates the bulk conversion of seismic exploration data with 3 points approach as the errors are distributed.

It also facilitates by generating a best fit grid for pre-stack surveys considering the post-stack data for merging of seismic from different vintages.

Moreover, the approach would allow reduction in turnaround time for geodetic transformations as and when required allowing minimum distortions ensuring minimization of human intervention & customer satisfaction.

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*The views expressed in the paper are solely of the authors and do not necessarily reflect the views of the organization which they belong to.*

## References

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