Error Estimates for WGS-84 and Everest (India-1956) Transformation (MAPASIA REF 037)

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Abstract

WGS-84 is an earth-fixed, earth-centred global reference frame including an earth model as defined by a set of primary and secondary parameters. WGS-84 system has come into existence only towards the end of 20th Century, and prior to that the local coordinate system (Everest or Indian System) had been in use in India for more than 150 years. Thus, most of the maps, records and data are available in the form of Everest system only. Till such time all the records are transformed to WGS-84 and new maps are printed, the local system is also likely to continue along with WGS-84.

Ready-made softwares like MADTRAN or DATUM, use the standard and average values of transformation parameters for conversion of coordinates of WGS-84 and Everest system. Therefore, some extent of errors gets introduced during such mathematical transformations, which is required to assessed. Similarly, it is also desirable to determine whether coordinates of one system could be used instead of other system without any transformation for non-precision activities in the field of aviation.

Accordingly a study was conducted to examine the above aspects of WGS–84 and Everest Coordinate Systems. During observations, it was found that there was a maximum error of about 1 arc-second between precise observations and mathematical transformation. Thus, it was concluded that it could be possible to use the software for non-precision activities in aviation field where maximum positioning error ranging upto 50 meters is acceptable.

It was also observed that if the local coordinates are used in place of WGS-84 coordinates or vice versa, there could be a maximum positioning error ranging upto 500 metres. Thus, for activities where an error tolerance of ½ km to 1 km is acceptable, there may not be any requirement of carrying out any transformation from one system to other and the coordinates of one system could be conveniently used in place of other.

In the field of aviation, the methodology could be safely applied for representing coordinates of En-route Navigational Aids, En-route Reporting Points, Control Zones, Control Areas, Terminal Control Areas (TMAs) and Flight Information Region (FIR) boundaries and to some extent even for Restricted Areas in WGS-84 System.

INTRODUCTION

WGS-84 coordinate System is being adopted universally as the standard form of Geographical Coordinates Representation System. This system has come into existence only towards the end of 20th Century, and prior to that the local coordinate system (Everest or Indian System) had been in use in India for more than 150 years. Thus, most of the maps, records and data are available in the form of Everest system only. Till such time all the records are transformed to WGS-84 and new maps are printed, the local system is also likely to continue along with WGS-84.

Thus, a need is felt to assess the extent of error involved in case of transforming the geographical coordinates from one system to other by using standard conversion softwares like MADTRAN, which uses the average values of transformation parameters. Similarly, it is also desirable to determine whether coordinates of one system could be used instead of other system without any transformation for non-precision activities in the field of aviation.

The paper deals about the study conducted to examine the above aspects of WGS–84 and Everest Coordinate Systems.

WGS-84 CO-ORDINATES SYSTEM [4]

The position of any place, object or point can be represented by means of its geographical co-ordinates expressed in three-dimensional form of Latitude, Longitude, and height. The Latitude and Longitude are measured from the intersection of lines of prime meridian (passing through Greenwich) and the Equator. Similarly the height (or elevation) is normally measured from the mean sea level and is generally referred as "Above Mean Sea Level" or AMSL (amsl).

However, it is a known fact that the surface of earth is not flat but it is approximately of spheroid (or ellipsoid) shape having an assumed centre of its own. Thus with a view to get the accurate results of the distance between two points say, Delhi and Mumbai, a spheroid (or ellipsoid) which best fits the shape of earth between Delhi and Mumbai should also be assumed.

In the similar manner, it can be further extended to represent all the areas of the country into a common spheroid, which best fits to the surface of earth existing in India. This spheroid can be defined in terms of its inherent characteristics such as the semi-major axis, semi-minor axis, eccentricity etc. on the basis of which it is possible to mathematically work out the distances and bearings of any two points by geometrically plotting these points on that spheroid. This spheroid provides the basis for mapping to that area.

Thus it is evident that the geographical position of a place or object when expressed in terms of X, Y, Z co-ordinates (known as Latitude, Longitude and Height of the place) are always based on a particular reference datum. These co-ordinates are called `ground derived co-ordinates' or `local co-ordinates' and the reference datum on which measurements are made is known as local datum.

In other words a geographical datum is a mathematical model representing the shape of the earth that is used as a reference or starting point for the determination or calculation of Latitude, Longitude and height.

Accordingly a mathematical spheroid roughly representing the shape of Indian sub-continent has been assumed by the Survey of India and all measurements are related to this spheroid. The reference datum fixed by "Survey of India" is located near Kalianpur in Madhya Pradesh. This is known as `Everest-1830' (Everest is the name of first Surveyor General of India `(Late) Sir George Everest' [5] and the term `1830' represents the year in which the spheroid was defined). This datum is also sometimes called as `Indian datum'. The Indian spheroid has been marginally modified on a number of occasions so that the parameters assumed for the spheroid have been refined slightly from time to time. For example, such changes were made in the year 1930, 1956 and so on. Thus sometimes the Everest spheroid or (Indian spheroid) is also referred as Indian-1880, Everest-1930 or Indian-1956 etc. (Even now some changes to the original definition are under consideration by Survey of India).

Obviously, the centre of the Everest spheroid does not coincide with the centre of the earth. However, this is the best fitting spheroid that works fairly well for our country. All the maps prepared by Survey of India and other agencies use `Everest-1830 datum' for expressing geographical co-ordinates of places in India. Based on this, a number of sub-datums have also been established in India and all measurements are taken from the main datum and sub-datums. [Aerodrome Reference Points (or ARPs) established at various airports in India, which for all practical purposes, are assumed, as the centre of the airport, are also one of the sub-datums].

It is, however also true that the spheroid defined for India does not hold good for other countries such as England or USA or Australia, which have defined their own spheroids in the similar manner, and thus, have brought out a set of co-ordinates best fitting to their countries and best representing the shape of earth in the particular geographical region. Thus, each country has its own datum for measurement of ground derived geographical co-ordinate and height. The mathematical parameters of these datums differ with each other and normally their datum centres would not coincide with the centre of earth, unless and until their co-ordinates have been re-adjusted to a geo-centric spheroid, (Such as North American datum NAD-83, which is an earth centred datum) and may be in few more countries.

Due to that reason, a need was felt for defining a new set of co-ordinates having a common origin and a common spheroid. This has now been done and is known as World Geodetic System of 1984 or WGS-84. This particular datum is a geocentric geodetic datum, established through space geodetic observations, which is earth-centred, earth-fixed (ECEF). Global Positioning System (GPS) and other similar modern aids needed for Global Navigation Satellite System (GNSS) are using the new co-ordinates system i.e. WGS-84 System, which does not change from place to place or from country to country.

DEFINITION OF WGS-84 CO-ORDINATES SYSTEM

The WGS-84 (World Geodetic System-1984) is a Conventional Terrestrial System (CTS), realised by modifying the Navy Navigation Satellite System (NNSS), or TRANSIT, Doppler Reference Frame in origin and scale, and rotating it to bring its reference meridian into coincidence with the Bureau International de l`Heure (BIH)-defined Zero meridian.

The origin of WGS-84 System is the centre of mass of the earth. Its Z-axis lies along the direction of Conventional Terrestrial Pole (CTP) for polar motion and the X-axis lies along inter-section of the WGS-84 Reference Meridian Plane and the Plane of the CTP's Equator. The Y-axis of this system completes a right-handed, Earth-Centred, Earth-Fixed (ECEF) orthogonal co-ordinates system, measured in the plane of CTP Equator 900 East of X-axis.

The origin and orientation of co-ordinates axis in WGS-84 have been defined by the X, Y, Z co-ordinates established under the control of the 5 GPS monitoring stations located at Hawaii, Colorado Springs, Ascension, Diego Garcia and Kwajalein.

WGS-84 is an earth-fixed global reference frame, including an earth model and is defined by a set of primary and secondary parameters. The primary parameters are as follows;[1]

Semi-major axis (a)	**6378137 m**
Flattening (f)	**1/298.257223563**
Angular velocity (w)	**7.292115 X $10^{(-5)}$ (Radian per second)**
Geocentric gravitational Constant (GM) (Mass of the earth's atmosphere included)	**398600.5 $Km^3 s^{-2}$**
Normalized 2nd degree zonal harmonic coefficient of the gravitational potential	**-484.16685 X 10^{-6}**

CONVERSION SOFTWARES [4]

For conversion of geographical coordinates from one datum to other, 7 transformation parameters are required to be taken into account. They are three translation parameters (i.e. ?x, ?y, ?z), three rotational parameters (i.e. e_X, e_Y, e_Z) and one scalar factor ?. In addition, change in ellipsoid semi-major axis ?a and flattening ?f are also necessary.

Accordingly, mathematical relationships have been developed to transform the co-ordinates from one datum to other (say from Everest-1830 to WGS-84 or vice versa).

However, in order to achieve results of conversion by avoiding lengthy manual calculations, help of computer programs is normally taken. For this purpose a number of Softwares have been developed by different organisations for converting the co-ordinates of the local system to WGS-84 system.

Among the above, the "DATUM" Software developed by EUROCONTROL and the "MADTRAN" software developed by National Imagery and Mapping Agency (NIMA), (earlier known as Defense Mapping Agency, DMA), USA are most popular. It is also mentioned that although, NIMA has brought the latest version of Transformation Software in Feb. 2003, known as GEOTRANS (Geographic Translator Vers 2.2.3), replacing MADTRAN, however, during this study, only MADTRAN has been used for transformation.

In fact, the transformation parameters between WGS-84 and the local co-ordinates system (such as Everest Co-ordinates System) vary from place to place and therefore, for each particular location a different set of formulae (transformation parameters) are required to be used.

On the other hand, a ready-made software such as MADTRAN and DATUM mentioned above uses the standard and average values of these parameters. For example, MADTRAN uses the following transformation parameters for conversion of local co-ordinates to WGS-84.

Reference Ellipsoid Names and Constants used for Datum Transformation Pertaining to Certain Asian Countries. [1]

Reference Ellipsoid	**Code**	**a (meters)**	**1/f**
Bessel 1841			
Indonesia, Japan and Korea	BR	6377397.155	299.1528128
Everest			
Brunei & E. Malaysia (Sabah and Sarawak)	EB	6377298.556	300.8017
India 1830	EA	6377276.345	300.8017
India-1956**	**EC**	**6377301.243**	**300.8017**
Pakistan**	EF	6377309.613	300.8017
W. Malaysia and Singapore 1948	EE	6377304.063	300.8017
W. Malaysia 1969**	ED	6377295.664	300.8017
Indonesian 1974	ID	6378160	298.247
WGS 1972	WD	6378135	298.260
WGS 1984	WE	6378137	298.257223563

*****Through adoption of a new yard to meter conversion factor in the referenced country.***

In this above table, NIMA has also provided the transformation parameters of Reference Ellipsoid Everest-1830 (or India-1830) (EA) and India-1956 (EC), which is a modified form of Everest-1830 for refining the parameters of Everest ellipsoid from time to time. Accordingly MADTRAN Software designed and developed by NIMA (Earlier US Defense Mapping Agency, DMA) uses the same for conversion of Everest system (Indian datum) to WGS-84.

Reference Ellipsoid [2]	**India-1956** ***(Used for Transformation)***
ID Code	**EC**
Semi-major Axis (a)	**6377301.243 m**
?x	**295 m**
?y	**736 m**
?z	**257 m**
Inverse Flattening (1/f) [Where f = (a-b)/a]	**300.8017**

It may be mentioned that the difference of transformation parameters between WGS-84 and Local co-ordinates systems is quite small and it does not make any significant difference for non-precision activities and in respect of small-scale maps prepared in two systems. However, for best precise results, actual survey of the site by using GPS equipment and also by other sophisticated survey equipment is always recommended, so that the actual values of the transformation parameters are available.

ERROR ESTIMATES

With a view to work out the extent of error observed while transforming WGS-84 into India-1956 System (Everest) or vice-versa, an attempt was made to use a software which uses the average values of the parameters of Everest System Ellipsoid for mathematical conversion of India-1956 (Everest) to WGS-84 or vice-versa. For this purpose MADTRAN developed by the National Imagery and Mapping Agency (NIMA) of USA was selected for mathematically converting the coordinates from Everest to WGS –84 of certain selected points located inside the airport premises in India. Further;

1. Actual GPS observations were made to get the precisely measured coordinates of those points in WGS-84 system and a comparison was made to determine the extent of error between these two observations.

2. Direct comparison of the values of WGS-84 and Everest Coordinates of various points without conversion was also done to determine the maximum extent of error between these two systems of coordinates.

3. These observations (and comparison) were done for Latitudes and Longitudes only.

For this purpose eleven airports geographically located towards the Northern, Southern, Eastern and Western parts of India viz., Delhi, Kolkata (earlier known as Calcutta), Mumbai (earlier known as Bombay), Ahmedabad, Coimbatore, Tiruchirrappalli (Trichy), Chennai (earlier known as Madras), Calicut, Trivandrum, Hyderabad and Bangalore were selected. Prolonged and continuous GPS observations were made at the Aerodrome Reference Points (ARPs) inside those Airports and precise WGS-84 coordinates were measured. The geo-coordinates of the above mentioned airports were also transformed from Everest to WGS-84 by using MADTRAN software. The observation results are summarised and presented in Table 1.

It may be mentioned that the Aerodrome Reference Point (ARP) is taken as the centre of the airport and it is physically located at a suitable place as close to the middle of the airport as possible. The ARP is treated as the standard benchmark and the geographical coordinates (latitude, longitude and elevation) of the ARP is precisely determined in Everest Coordinate System by some expert agency like Survey of India. The remaining areas of the airport are then surveyed by the survey team of Airports Authority of India (AAI) by taking the ARP as the starting point, and the coordinates and elevations of other important points of the airport are connected to the ARP. In view of the above, it was decided to take the GPS observation at the ARPs of the above mentioned 11 airports.

Additionally, few more airports were selected for mathematically transforming geo-coordinates of an arbitrarily assumed point each inside those airports from Everest System to WGS-84 by using MADTRAN software. These airports were Tezu, Dibrugarh, Along, Port Blair, Car Nicobar, Tuticorin, Cochin, Agatti, Porbandar, Jaisalmer, Srinagar, Kargil, and Leh. The differences between WGS-84 and Everest coordinates at the above mentioned airports were also examined; however, no GPS observation was made for these airports. The observation results for these airports are summarized and presented in Table 2.

Table 1
Latitudes and Longitudes of Airports where Actual GPS Observations were made at the ARPs, to Show the Everest Coordinates, WGS-84 Actually Observed and WGS-84 Mathematically Converted (Transformed) Coordinates.

Sl. No.	Name of Airport	Everest [3] Co-ordinates	Precise WGS-84 Co-ord. (GPS Observation)	WGS-84 Co-ordinates (Mathe. Transformed)	Difference between WGS-84 (Transformed) and Everest	Difference between WGS-84 (Converted) and WGS-84 (Precise)
		Latitude (N) Longitude (E)	Latitude (N) Longitude (E)	Latitude (N) Longitude (E)	Seconds	Seconds
1	DELHI	28^0-34'-07. 3"	28^0-34-7.42185"	28^0-34-7.5"	(+) 0.2	(+) 0.07815
		77^0-06"-47.9"	77^0-06-43.69343"	77^0-06-43.4"	(-) 4.5	(-) 0.29343
2	AHEMEDABAD	23^0-04'-14. 4"	23^0-04'-16. 28032"	23^0-04'-16. 3"	(+) 1.9	(+) 0.01968
		72^0-37'-37. 3"	72^0-37'-35. 15308"	72^0-37'-35. 1"	(-) 2.20	(-) 0.05308
3	KOLKATA	22^0-39"-11.03"	22^0-39'-14. 24691"	22^0-39'-13. 6"	(+) 2.57	(-) 0.64691
		88^0-26'-57. 25"	88^0-26'-48. 18029"	88^0-26'-47. 7"	(-) 9.55	(-) 0.48029
4	MUMBAI	19^0-05'-26. 88"	19^0-05'-29. 54342"	19^0-05'-30. 1"	(+) 3.22	(+) 0.55658
		72^0-52'-00. 01"	72^0-51'-57. 53373"	72^0-51'-57. 8"	(-) 2.21	(+) 0.26627
5	HYDERABAD	17^0-27'-08. 6"	17^0-27'-12. 0076"	17^0-27'-12.4"	(+) 3.80	(+) 0.3924
		78^0-27'-49. 5"	78^0-27'-44. 8952"	78^0-27'-44. 7"	(-) 4.80	(-) 0.1952
6	CHENNAI	12^0-59'-36. 6"	12^0-59'-41. 26623"	12^0-59'-41. 7"	(+) 5.10	(+) 0.43377
		80^0-10'-37. 3"	80^0-10'-32. 22512"	80^0-10'-31. 8"	(-) 5.50	(-) 0.42512
7	BANGALORE	12^0-57'-03. 39"	12^0-57'-07. 85655"	12^0-57'-08. 4"	(+) 5.01	(+) 0.54345
		77^0-39'-56. 58"	77^0-39'-52. 58417"	77^0-39'-52. 2"	(-) 4.38	(-) 0.38417
8	CALICUT	11^0-08'-11. 47"	11^0-08'-16. 31058"	11^0-08'-17. 0"	(+) 5.53	(+) 0.68942
		75^0-57'-05. 05"	75^0-57'-02. 03711"	75^0-57'-01. 5"	(-) 3.55	(-) 0.53711
9	COIMBATORE	11^0-01'-44. 3"	11^0-01'-49. 17249"	11^0-01'-49. 9"	(+) 5.60	(+) 0.72751
		77^0-02'-34. 9"	77^0-02'-31. 24667"	77^0-02'-30. 8"	(-) 4.10	(-) 0.44667
10	TRICHY	10^0-45'-51"	10^0-45'-56. 18154"	10^0-45'-56. 7"	(+) 5.70	(+) 0.51846
		78^0-42'-58"	78^0-42'-53. 93941"	78^0-42'-53. 2"	(-) 4.80	(-) 0.73941
11	TRIVANDRUM	08^0-28'-40"	08^0-28'-46. 12243"	08^0-28'-47. 1"	(+) 7.10	(+) 0.97757
		76^0-55'-15"	76^0-55'-12. 01753"	76^0-55'-11. 3"	(-) 3.70	(-) 0.71753

Table 2

Latitudes and Longitudes of Airports to show the Everest Coordinates and WGS-84 mathematically converted (Transformed) Coordinates, by using MADTRAN Software.

Sl. No	Name of Airport	Everest Co-ordinates	WGS-84 Co-ordinates (Transformed)	WGS-84 Coord. (Transformed) - Everest Coord.
		Latitude (N) Longitude (E)	Latitude (N) Longitude (E)	*Difference in arc-Seconds*
North- East & East				
1	*TEZU*	*27⁰-54' N 96⁰-04'E*	*27⁰-54'-1. 7" N 96⁰-03'-46. 4 E*	*(+) 1.7 (-) 13.6*
2	*DIBRUGARH*	*27⁰-28'-50"N 95⁰-01'-18"E*	*27⁰-28'-51. 7 "N 95⁰-01'-4. 9"E*	*(+) 1.7 (-) 13.1*
3	*ALONG*	*28⁰-11" N 94⁰-48' E*	*28⁰-11'-1. 4"N 94⁰-47'-47"*	*(+) 1.4 (-) 13.0*
4	*PORT BLAIR*	*11⁰-38'-45"N 92⁰-48'-06"E*	*11⁰-38'-50. 8"N 92⁰-47'-55. 1"E*	*(+) 5.8 (-) 10.9*
5	*CAR NICOBAR*	*09⁰-09' N 92⁰-49'E*	*09⁰-09'-6. 4"N 92⁰-48'-49. 2"E*	*(+) 7.6 (-) 10.8*
South & South- West				
6	*TUTICORIN*	*08⁰-43'-00"N 78⁰-02'-00"E*	*08⁰-43'-6. 2"N 78⁰-01'-55. 5"E*	*(+) 6.2 (-) 4.5*
7	*COCHIN*	*09⁰-57' N 76⁰-16' E*	*09⁰-57'-5. 9"N 76⁰-15'-56. 3"E*	*(+) 5.9 (-) 3.7*
8	*AGATTI*	*10⁰-49'-26"N 72⁰-10'-37"E*	*10⁰-49'-31. 6"N 72⁰-10'-35. 2"E*	*(+) 5.6 (-) 1.8*
West				
9	*PORBANDAR*	*21⁰-38'-59. 1"N 69⁰-39'-31. 7"E*	*21⁰-39'-1. 4"N 69⁰-39'-31"E*	*(+) 2.3 (-) 0.7*
10	*JAISALMER*	*26⁰-53' N 70⁰-52'E*	*26⁰-53'-0. 6"N 70⁰-51'-58. 7"E*	*(+) 0.6 (-) 1.7*
North				
11	*SRINAGAR*	*33⁰-59'N 74⁰-47'E*	*33⁰-58'-58. 1"N 74⁰-46'-56. 4"E*	*(-) 0.9 (-) 13.6*
12	*KARGIL*	*34⁰-31' N 76⁰-10'E*	*34⁰-30'-58"N 76⁰-09'-55. 7"E*	*(-) 2 (-) 4.3*
13	*LEH*	*34⁰-08' N 77⁰-33'E*	*34⁰-07'-58. 2"N 77⁰-32'-55"E*	*(-) 0.2 (-) 5.0*

OBSERVATION RESULTS:

Difference between WGS84^{Transformed} and WGS84^{Precise}

Based on information contained in Table '1', it was observed that;

1. the difference of Latitudes between WGS84^{Transformed} and WGS84^{Precise} was found oscillating from (-) 0.65 arc second [In respect of Kolkata, Lat. 23^0 N] to (+) 1.0 arc second [In respect of Trivandrum, Lat 08.5^0 N]. However, there were no predictable or defined trends for its variation.

2. difference of Longitudes between WGS84 ^{Transformed} and the WGS84 ^{Precise} was found oscillating from (+) 0.27 arc second [In respect of Mumbai, Long 72.9^0 E] to (-) 0.7 arc second [In respect of Trivandrum, Long 76.9^0 E & Trichy Long 78.7^0 E]. However, there were no predictable or defined trends for its variation.

Difference between WGS84 ^{Transformed} and Everest

Based on information contained in Table '1' & '2', it was observed that;

1. the difference of Latitude between WGS84^{Transformed} and the Everest System was found decreasing from (+) 7.6 arc seconds [In respect of Car Nicobar, Lat. 9^0 N] to (-) 0.9 arc seconds [In respect of Srinagar, Lat. 34^0 N] as one moves from South to North.

2. the difference of Longitude between WGS84^{Transformed} and the Everest System was always negative and the difference was decreasing from (–) 0.7 arc second [In respect of Porbandar, Long. 69.6^0 E] to (-) 13.6 arc second [In respect of Tezu, Long. 96^0 N] as one moves from West to East.

FOR OTHER ASIAN COUNTRIES

In the similar manner, when the MADTRAN software is used to convert the local co-ordinates of the "Airport Reference Points" of some of the airports located in South East Asia to WGS-84 co-ordinates, the following results are obtained,

AIRPORT	***NAME OF DATUM***	***DIFF. IN LAT****	***DIFF.IN LONG****
BANGKOK	*INDIAN 1975*	*+6.0" (183 m)*	*-11.9" (362 m)*
DELHI	*INDIAN 1956*	*+0.2" (6 m)*	*-4.5" (137 m)*
DENVER, USA	*NAD 1983*	*0.0" (0 m)*	*0.0" (0 m)*
HONG KONG	*HONG KONG 1963*	*-5.5" (168 m)*	*+8.9" (271 m)*
MANILA	*LUZON*	*-5.4" (164 m)*	*+5.1" (155 m)*
MUMBAI	*INDIAN 1956*	*+3.2" (98 m)*	*-2.2" (67 m)*
SEOUL	*TOKYO-KOREA*	*+10.0"(304 m)*	*-7.6" (232 m)*
SINGAPORE	*KERTAU 1948*	*-0.2" (6 m)*	*-6.3" (192 m)*
SYDNEY	*AUST GEODETIC84*	*-5.7" (174 m)*	*+4.1" (125 m)*
TOKYO	*TOKYO*	*+11.8"(360 m)*	*-11.6"(354 m)*

**NOTE-- The positive values of difference in Latitude/ Longitude shown above indicate that the WGS-84 co-ordinates are higher than the local coordinates and vice-versa.*

The purpose of showing the above table is to get an idea of the changes in the values of the co-ordinates between local and geo-centric datums.

FINDINGS:

It is, therefore, observed that in certain cases, if a conversion software like MADTRAN, which takes into account the average values of the parameters of reference Ellipsoid, is used for mathematical conversion of India-1956 to WGS –84 or vice-versa the maximum deviation in respect of the transformed values and precise observation in WGS-84 Coordinates could be of the order of 0.01 to 1 second in terms of Latitude which corresponds to about a maximum of 30 metres and (+) 0.27 seconds to (-) 0.7 seconds in terms of Longitude corresponding to about 22 mtrs. Thus the maximum positioning error of within 50 mtrs could be expected in such cases.

Further, even if WGS-84 coordinates are replaced with Everest Co-ordinates without applying any transformation, the maximum deviation within the boundary of India may vary from about (+) 7.6 arc seconds to (-) 0.9 arc seconds in terms of Latitude which corresponds to a maximum deviation of 250 metres from Southern part to Northern part of India, and from 0 to 14 arc seconds (roughly corresponding to 425 metres) in terms of Longitude from Western part to Eastern part of India.

In other words, if no transformation is done from WGS-84 to Everest System or vice-versa, the maximum positioning error could be expected within 500 mtrs.

CONCLUSION

It is observed that the cases where the requirement of accuracy is not much (say of the order of ½ kilometre to 1 kilometre), there may not be any necessity to do any transformation from Everest to WGS-84 system or vice versa and the co-ordinates of one system could be substituted by the coordinates of the other system for rough values.

In aviation this can be safely applied for en-route navigational aids, en-route reporting points, control zones, control areas, Terminal Areas (TMAs) and Flight Information Region (FIR) boundaries and to some extent even for restricted areas. Similarly, in other fields also, like estimating the location of fast speed distant vehicles, distance between two cities, small-scale maps with scale smaller than 1:1 million (for school children), etc., WGS-84 & India-1956 coordinates could be easily substituted with each other.

If the conversion is done by using a conversion software for mathematical relationship with average values of transformation parameters, the results will get further modified making it as accurate as upto 50 metres and so.

CAUTION: The above methodology should not be used for applications where precise results are needed.

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