ISSN 2229-5518

# Validation of Algorithms for Datum Transformations and Map Projections

Dhiraj Sunehra

**Abstract**— The advent of GPS revolutionized position-fixing procedures in the fields of navigation and geodesy. Early existing maps and nautical charts used non-geocentric regional geodetic datums. Indian Geodetic Datum (IGD) based on Everest spheroid had been in use in India for many years. As distance requirements increased beyond national boundaries, new requirements arose from datums and a need was felt for defining a common geodetic reference system that can be adopted globally. This led to the development of global geocentric reference frames such as World Geodetic System, 1984 (WGS-84). When plotting position information on maps, it is advantageous to work with the local or national grid coordinates obtained on a particular map projection. In this paper, datum conversion algorithms for conversion from WGS-84 coordinates to IGD coordinates, WGS-84 to UTM, WGS-84 to Lambert, and vice versa are presented. The algorithms for the datum conversions are developed in 'C' language. GPS coordinates data at twenty sample stations within India are taken to validate the results.

**Index Terms**— Global Positioning System, Datum, World Geodetic System-1984, Indian Geodetic Datum, Everest spheroid, Map projection, Universal Transverse Mercator, Lambert conic projection

---

## 1 Introduction

As the physical surface of the Earth is not smooth, it is difficult to determine the user's position accurately. To surmount this problem, a hypothetical geometric reference surface is defined that approximates the irregular shape of the Earth. For high accuracy positioning using GPS, the best mathematical surface near to the shape of the Earth is the biaxial ellipsoid or reference ellipsoid. A properly positioned reference ellipsoid is known as geodetic datum. The parameters used to define a geodetic datum uniquely are: semimajor axis, eccentricity of the ellipsoid; position of the origin; and the orientation of three axes with respect to the Earth [1]. A number of geodetic datums are defined throughout the world.

Datum is classified into two types: (a) regional datum, and (b) global datum. A local or regional datum is non-geocentric. Each of the regional datum uses a different mathematical model that "best fits" or provides the best representations of the Earth's shape in that specific geographic region. Indian Geodetic Datum (IGD) based on the Everest spheroid best suits the Indian subcontinent and is an example of regional datum. Most of the map data existed in the form of Everest system. As distance requirements increased beyond national boundaries, new requirements arose from datums and a need was felt for defining a common geodetic reference system that can be adopted globally. This led to the development of global geocentric reference frames.

A global datum is geocentric, means that origin coincides with the center of the Earth. Examples of global datum include World Geodetic System, 1984 (WGS-84) and North American Datum, 1983 (NAD-83). These are based on the Geodetic Reference System (1980) or GRS-80 ellipsoid. WGS-84 is an earth-centered, earth-fixed (ECEF) coordinate system, being adopted universally for position fixing in disciplines such as geodynamics, geodesy and satellite operations. Global Positioning System (GPS) is the most widely used satellite based navigation system that can provide three-dimensional position (viz., longitude, latitude, and altitude), velocity and time continuously for users, in all weather conditions and anywhere on or above the surface of the Earth. GPS measurements are based on WGS-84 reference frame.

The geodetic coordinates of a point, based on local datum differ considerably (up to several hundreds of meters) as compared to the coordinates based on a global datum like WGS-84. This is a matter of concern for civil aviation applications especially during approach phase or landing, where higher accuracy and integrity requirements are to be met. With the increasing exchange of geographic information, both locally and globally, position information need to be available in terms of both a local and global datum. Hence there is a need for datum conversion [2].

The transformation of geodetic coordinates on the curved surface of the earth into rectangular grid coordinates onto a flat surface is called map projection. When plotting position information on maps, it is advantageous to work with the local or national grid coordinates obtained on a particular map projection.

## 2 World Geodetic System (1984)

The Conventional Terrestrial Reference System (CTRS) is a 3-D geocentric coordinate system which is rigidly tied to the Earth, i.e., it rotates with the Earth. For this reason, it is also known as the Earth-Centered, Earth-Fixed (ECEF) coordinate system [3]. WGS-84 is a realization of the CTRS developed by the National Imagery and Mapping Agency (NIMA), of the U.S Department of Defense (DoD). WGS-84 is the official geodetic system for all mapping, charting, navigation and geodet-

• *Dr. Dhiraj Sunehra is currently working as an Associate Professor of Electronics and Communication Engineering in Jawaharlal Nehru Technological University Hyderabad at JNTUH College of Engineering, Jagtial, Karimnagar, Andhra Pradesh, India, PH-+917893278314, E-mail: dhirajsunehra@yahoo.co.in*

ic products used through the DoD [4]. WGS-84 is an earth-fixed global reference frame, that includes an earth model. It provides a single, common, accessible 3-dimensional coordinate system, which is free of any significant distortions. The fundamental parameters of the WGS-84 reference ellipsoid are defined in Table 1.

TABLE 1
FUNDAMENTAL PARAMETERS OF WGS-84

| Parameter | Value |
|---|---|
| Semi-major axis (a) | 6378137.0 m |
| Inverse Flattening (1/f) | 298.257223563 |

## 3 Datum Conversion between WGS-84 and IGD

The Indian Geodetic Datum has been used as a reference datum in India and several adjacent countries in south-east Asia. Derived in 1830, the Everest spheroid is the oldest of the ellipsoids in use and is much localized.

### 3.1 Everest Spheroid

The Everest spheroid is a non-geocentric regional geodetic datum that best fits the Indian subcontinent. Its center is chosen at Kalianpur in Madhya Pradesh. All the maps and nautical charts prepared by Survey of India (SOI), India's premier mapping agency are based on the Everest datum. This datum is also called as Indian Geodetic Datum (IGD). The Everest spheroid parameters are defined in Table 2.



TABLE 2
EVEREST SPHEROID PARAMETERS

| Parameter | Value |
|---|---|
| Origin | Kalianpur |
| Latitude of origin | 24°07'11.26" |
| Longitude of origin | 77°39'17.57" |
| Semi-major axis (a) | 6377301.243 m |
| Inverse Flattening (1/f) | 300.8017 |

The geodetic coordinates based on Everest spheroid differ considerably (up to hundreds of meters) as compared to WGS-84 and other International ellipsoids.

### 3.2 Datum Transformation Parameters

The WGS-84 coordinates derived from GPS and local geodetic coordinates of points may be processed together using suitable transformation models. The outcome of the processing is a set of transformation parameters, which can be used for converting the coordinates from global datum to local datum and vice-versa. The three mathematical models, namely (1) Molodensky (2) Bursa-Wolf, and (3) Veis are widely used around the world for determining the datum transformation parameters. The transformation parameters for the Indian subcontinent are specified by NIMA. These parameters are obtained using Molodensky equations as dx=295m, dy=736m, dz=257m. dx, dy and dz represent the shifts between centers of Everest datum and WGS-84 datum. They can be used to transform WGS-84 coordinates to local geodetic system i.e. IGD coordinates, and vice-versa.

### 3.3 Datum Transformation from WGS-84 to IGD

A program is developed in 'C' language for converting WGS-84 geodetic coordinates to IGD coordinates. The following are the important steps of the algorithm:

1. The WGS 84 geodetic coordinates ($\Phi$, $\lambda$) are converted into WGS 84 - ECEF coordinates i.e. x, y and z. In this conversion semi major axis (a) and inverse flattening (1/f) correspond to WGS-84 ellipsoid (Table 1).
2. The transformation parameters dx, dy and dz are subtracted from x, y and z respectively obtained in step1, to give IGD related rectangular coordinates $x_1$, $y_1$ and $z_1$.
3. The IGD rectangular coordinates ($x_1$, $y_1$, $z_1$) are further converted into spherical coordinates ($\Phi_1$, $\lambda_1$). In this conversion, semi major axis (a) and inverse flattening (1/f) correspond to Everest spheroid (Table 2).

### 3.4 Datum Transformation from IGD to WGS-84

A program is developed in 'C' language for converting IGD geodetic coordinates to WGS-84 coordinates. The following are the important steps of the algorithm:

1. The IGD geodetic coordinates ($\Phi_1$, $\lambda_1$) are converted into corresponding rectangular coordinates ($x_1$, $y_1$, $z_1$). In this conversion, semi major axis (a) and inverse flattening (1/f) correspond to Everest spheroid (Table 2).
2. The transformation parameters dx, dy and dz are added to ($x_1$, $y_1$, $z_1$) obtained in step1, to give WGS 84 – ECEF coordinates, x, y, and z.
3. The WGS 84 - ECEF coordinates (x, y, z) are further converted into WGS-84 geodetic coordinates ($\Phi$, $\lambda$). In this conversion, semi major axis (a), and inverse flattening (1/f) correspond to the WGS-84 ellipsoid (Table 1).

### 3.5 Results - Transformation between WGS-84 and IGD

The developed 'C' programs are checked for twenty sample readings around the Indian subcontinent. The program results are validated with two executable software available in public domain, namely TatukGIS calculator and Map and Chart Datum Transformation (MADTRAN) software developed by NIMA of the U.S DoD.

In forward datum conversion, i.e. WGS-84 to IGD, maximum error in longitude is 0.07 s and maximum error in latitude is 0.08 s, when compared with that obtained using TatukGIS calculator and MADTRAN software. The results comparison with MADTRAN software for six samples is given in Table 3. The latitude and longitude are expressed in units of degrees, minutes, seconds.

In reverse datum conversion, i.e. IGD to WGS 84, maximum error in longitude is 0.06 s and maximum error in latitude is 0.1 s, when compared with that obtained using Tatuk GIS calculator and MADTRAN software. The results comparison with MADTRAN software for six samples is given in Table 4. The maximum error obtained with TatukGIS calculator and MADTRAN software are almost identical and the error obtained is negligibly small.

TABLE 3
WGS-84 TO IGD RESULTS COMPARISON WITH MADTRAN SOFTWARE

| S.No. | Input: WGS-84 coordinates | | | | | | Output: IGD coordinates 'C' program | | | | | | Output: IGD coordinates MADTRAN software | | | | | | Error in seconds | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Longitude | | | Latitude | | | Longitude | | | Latitude | | | Longitude | | | Latitude | | | Long | Lat |
| 1 | 69 | 30 | 48 | 22 | 47 | 30 | 69 | 30 | 48.67 | 22 | 47 | 28.06 | 69 | 30 | 48.6 | 22 | 47 | 28 | 0.07 | 0.06 |
| 2 | 78 | 12 | 30 | 24 | 30 | 48 | 78 | 12 | 34.93 | 24 | 30 | 46.48 | 78 | 12 | 34.9 | 24 | 30 | 46.4 | 0.03 | 0.08 |
| 3 | 83 | 18 | 18 | 19 | 5 | 5 | 83 | 18 | 25.09 | 19 | 5 | 1.59 | 83 | 18 | 25.1 | 19 | 5 | 1.6 | -0.01 | -0.01 |
| 4 | 70 | 18 | 19 | 26 | 0 | 0 | 70 | 18 | 20.06 | 25 | 59 | 59.13 | 70 | 18 | 20.1 | 25 | 59 | 59.1 | -0.04 | 0.03 |
| 5 | 87 | 0 | 0 | 27 | 0 | 0 | 87 | 0 | 9.29 | 26 | 59 | 58.86 | 87 | 0 | 9.3 | 26 | 59 | 58.8 | -0.01 | 0.06 |
| 6 | 92 | 0 | 0 | 26 | 0 | 0 | 92 | 0 | 11.53 | 25 | 59 | 58.17 | 92 | 0 | 11.5 | 25 | 59 | 58.1 | 0.03 | 0.07 |

TABLE 4
IGD TO WGS-84 RESULTS COMPARISON WITH MADTRAN SOFTWARE

| S.No. | Input: IGD coordinates | | | | | | Output: WGS-84 coordinates 'C' program | | | | | | Output: WGS-84 coordinates MADTRAN software | | | | | | Error in seconds | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Longitude | | | Latitude | | | Longitude | | | Latitude | | | Longitude | | | Latitude | | | Long | Lat |
| 1 | 69 | 30 | 49 | 22 | 47 | 28 | 69 | 30 | 48.34 | 22 | 47 | 29.93 | 69 | 30 | 48.4 | 22 | 47 | 30 | -0.06 | -0.07 |
| 2 | 78 | 12 | 35 | 24 | 30 | 46 | 78 | 12 | 30.09 | 24 | 30 | 47.53 | 78 | 12 | 30.1 | 24 | 30 | 47.6 | -0.01 | -0.07 |
| 3 | 83 | 18 | 25 | 19 | 5 | 2 | 83 | 18 | 17.92 | 19 | 5 | 5.41 | 83 | 18 | 17.9 | 19 | 5 | 5.4 | 0.02 | 0.01 |
| 4 | 78 | 0 | 5 | 31 | 0 | 1 | 77 | 59 | 59.89 | 31 | 0 | 0.30 | 77 | 59 | 59.9 | 31 | 0 | 0.4 | -0.01 | -0.10 |
| 5 | 87 | 0 | 9 | 26 | 59 | 59 | 86 | 59 | 59.72 | 27 | 0 | 0.14 | 86 | 59 | 59.7 | 27 | 0 | 0.2 | 0.02 | -0.06 |
| 6 | 92 | 0 | 12 | 25 | 59 | 58 | 92 | 0 | 0.48 | 25 | 59 | 59.83 | 92 | 0 | 0.5 | 25 | 59 | 59.9 | -0.02 | -0.07 |



## 4 MAP PROJECTIONS

Many of the GPS receivers provide position information in terms of latitude, longitude and height and typically in a range of selectable geodetic datum. However, when plotting position information on maps, it can be advantageous to work with local or National grid coordinates on a particular map projection.

In a map projection, no change of datum is involved. As the ellipsoidal shape of the Earth and flat projection surface differ, the projected features suffer from distortion. Distortions can be in area, shape (angle) and scale (distance). A number of projection types have been defined to minimize map distortions. A projection with accurate representation of area is known as cylindrical projection, such as Universal Transverse Mercator (UTM). A projection that preserves angle (shape) on the ellipsoidal surface is called conformal projection, for example Lambert conformal conic projection [3].

### 4.1 Universal Transverse Mercator

Universal Transverse Mercator (UTM) is one of the most widely used map projection and grid system. UTM was established in 1936 by International Union of Geodesy and Geophysics. It gives two-dimensional projection of any point defined on the globe. The UTM projection is depicted in Fig. 1 [5]. In UTM, the globe is divided into 60 zones, each 6° of longitude wide. These zones are numbered from one to sixty beginning at 180°W longitude. This system is used only from latitude 84°N to 80°S as distortion at the poles is too great. Universal Polar Stereographic (UPS) projection is used for polar areas. The meridian in the middle of two boundary meridians for each zone is known as the central meridian. The origin is chosen at the intersection of the equator and the zone's central meridian.

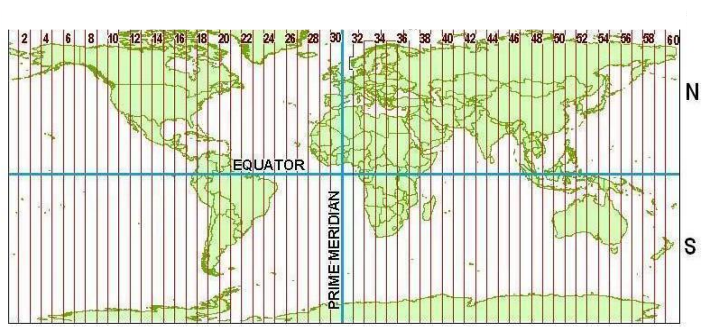


Fig. 1 UTM Zone System

A scale factor of 0.9996 is applied to the central meridian. The reason for this factor is to avoid fairly large distortions in the outer area of the zone. The system coordinates are expressed in terms of Easting and Northing. The units of the coordinates are in meters. Easting coordinates are referenced to the central meridian and the northing coordinates are measured relative the equator and varies depending on the hemisphere.

### 4.2 Lambert Conformal Conic Projection

Lambert conical projection is developed by Johann Hienrich Lambert in 1772. It is a conformal map projection. It portrays shape more accurately than area. In this method, points on the ellipsoidal surface are projected mathematically onto an imaginary cone. The imaginary cone touches the ellipsoid along one of the parallels, which would be called a tangent, or intersect the ellipsoid along two parallels called secants as depicted in Fig. 2 [6]. These parallels are often referred to as standard parallels. The flat map is produced after cutting and unfolding the imaginary cone. Every feature along the standard parallels is mapped without any distortion and as we progress away from the standard parallels, distortion increases. Hence, this projection is appropriate for areas that stretch in the east-west direction. The choice of two standard parallels will be made according to the latitudinal coverage of the area, which is to be mapped.

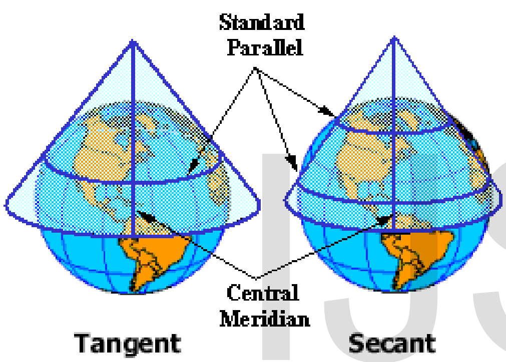


Fig. 2 Lambert conic projection depicting one and two standard parallels

## 5 Transformation of WGS-84 to UTM Coordinates

The various transformation equations for converting WGS-84 to UTM coordinates are given below.

**Constants**

Semi major axis (a) = 6378137. 0m
Eccentricity (e) = 0.081696831
Square of second eccentricity ($e^{1\,2}$) = 0.06719218
False Easting (FE) = 5,00,000 m
False Northing (FN) = 0m (for northern hemisphere),
=10,000,000m (for southern hemisphere)
Origin of longitude ($\lambda o$)

**Inputs**

Latitude ($\Phi$)
Longitude ($\lambda$)

Note: $\Phi$, $\lambda$, $\lambda_o$ are in radians

**Outputs**

Easting (E) and Northing (N) in meters

$$E = FE + 0.9996n[\{A + \frac{A^3}{6}(1 - T + C)\} + \frac{A^5}{120}\{5 - 18T + T^2 + 72C - 58e^{1^2}\}] \quad (1)$$

$$N = FN + 0.9996[M + n\tan\phi\{\frac{A^2}{2} + \frac{A^4}{24}(5 - T + 9C + 4C^2) + \frac{A^5}{720}(61 - 58T + T^2 + 600C - 330e^{1^2})\}] \quad (2)$$

The intermediate equations and reverse transformation equations are given in [7].

## 6 Transformation of WGS-84 to Lambert Grid Coordinates

The various transformation equations for converting WGS-84 to Lambert grid coordinates are given below.

**Constants**

Semi major axis (a) = 6378137. 0m
Eccentricity (e) = 0.081696831
Square of second eccentricity ($e^{1\,2}$) = 0.06719218
False Easting (FE)
False Northing (FN)
First Standard Parallel ($\Phi_1$)
Second Standard Parallel ($\Phi_2$)
Latitude of False Origin ($\Phi_F$)
Longitude of False Origin ($\lambda_F$)

The above constants FE, FN, $\Phi_1$, $\Phi_2$, $\Phi_F$, and $\lambda_F$ are specified by mapping authorities based on the area to be mapped.

**Inputs**

Latitude ($\Phi$)
Longitude ($\lambda$)

Note: $\Phi$, $\lambda$, $\Phi_1$, $\Phi_2$, $\Phi_F$, $\lambda_F$ are in radians.

**Outputs**

Easting (E) and Northing (N) in meters

$$E = FE + r\sin\theta \quad (3)$$

$$N = FN + r_F - r\cos\theta \quad (4)$$

The intermediate equations and reverse transformation equations are given in [7].

## 7 Results - Transformation of WGS-84 Coordinates to Grid Coordinates

### 7.1 Results- Transformation between WGS-84 and UTM

The developed 'C' programs are checked for twenty sample readings around the Indian subcontinent. The program results are validated with two executable software, namely MADTRAN software and TatukGIS calculator.

In forward conversion, i.e. WGS-84 to UTM, maximum error in easting (for the cases studied) is less than 1.12m and maximum error in northing is less than 0.49m, when compared with that obtained using MADTRAN software and

ISSN 2229-5518

TatukGIS calculator. The results comparison with TatukGIS calculator for six samples is given in Table 5.

In reverse conversion, i.e. UTM to WGS-84, maximum error in longitude is 0.01s and maximum error in latitude is 0.0 s, when compared with that obtained using MADTRAN software and Tatuk GIS calculator. The results comparison with TatukGIS calculator for six samples is given in Table 6. The value of FE and FN are chosen arbitrarily large to avoid negative coordinates.

### 7.2 Results- Transformation between WGS-84 and Lambert

The developed programs are checked for twenty sample readings around the Indian subcontinent. The program results are validated with Tatuk GIS calculator, which is a executable software available in public domain. In addition to the input coordinates, the other parameters to be entered by the user are chosen as follows:

Latitude of Origin: 22°15′00″
Longitude of Origin: 77°00′00″
False Easting: 50,00,000 m
False Northing: 50,00,000 m

It is observed that in forward conversion, i.e. WGS-84 to Lambert, maximum error in easting is 0.34 m and maximum error in northing is 0.15 m when compared with that obtained using TatukGIS calculator, as given in Table 7.

In reverse datum conversion, i.e. Lambert to WGS-84, maximum error in longitude as well as latitude is 0.03 s, when compared with that obtained using TatukGIS calculator, as given in Table 8. The value of first and second standard parallel are chosen as 8°N and 37°N respectively, so that the mapped area covers the Indian subcontinent.

## 8 Conclusions

In order to specify the position of a point accurately, we first have to define a coordinate frame precisely. For GPS, the framework for specifying a position is provided by WGS-84. This paper has presented datum transformation procedures for converting WGS-84 coordinates to UTM, Lambert and IGD coordinates. The conversion programs are very easy to handle and written in ‘C’ language. Survey of India (SOI), India’s premier mapping agency has begun to realize digital maps based on WGS-84 datum using UTM projection for civil users. Another series of maps based on Everest spheroid datum using Lambert conic projection shall be utilized for defence purposes only [8]. These conversions have several applications, especially in the fields of defence, civil aviation and geodesy, mapping and survey applications.



TABLE 5
WGS-84 to UTM Results comparison with TatukGIS calculator

| S.No | Input: WGS-84 coordinates | | | | | | Output: UTM coordinates ‘C’ program | | | Output: UTM coordinates TatukGIS calculator | | | Error | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Longitude | | | Latitude | | | Zone | Easting(m) | Northing(m) | Zone | Easting(m) | Northing(m) | Zone | Easting(m) | Northing(m) |
| 1 | 78 | 12 | 30 | 24 | 30 | 48 | 44 | 217120.60 | 2713922.48 | 44 | 217120.05 | 2713922.43 | 0 | 0.55 | 0.05 |
| 2 | 74 | 16 | 18 | 18 | 18 | 18 | 43 | 423028.77 | 2024083.78 | 43 | 423028.38 | 2024083.75 | 0 | 0.39 | 0.03 |
| 3 | 77 | 18 | 60 | 17 | 30 | 59 | 43 | 745963.36 | 1938179.13 | 43 | 745963.16 | 1938179.22 | 0 | 0.20 | -0.09 |
| 4 | 83 | 18 | 18 | 19 | 5 | 5 | 44 | 742529.77 | 2111797.56 | 44 | 742529.44 | 2111797.51 | 0 | 0.33 | 0.05 |
| 5 | 70 | 18 | 19 | 26 | 0 | 0 | 42 | 630635.88 | 2876336.22 | 42 | 630635.87 | 2876336.22 | 0 | 0.01 | 0.00 |
| 6 | 78 | 0 | 0 | 37 | 0 | 0 | 44 | 233037.87 | 4099080.66 | 44 | 233037.62 | 4099080.70 | 0 | 0.25 | -0.04 |

TABLE 6
UTM to WGS-84 Results comparison with TatukGIS calculator

| S.No. | UTM coordinates | | | Output: WGS-84 coordinates ‘C’ program | | | | | | Output: WGS 84 coordinates Tatuk GIS calculator | | | | | | Error in seconds | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Zone | Easting(m) | Northing(m) | Longitude | | | Latitude | | | Longitude | | | Latitude | | | Long | Lat |
| 1 | 44 | 217120.60 | 2713922.48 | 78 | 12 | 30.01 | 24 | 30 | 48.00 | 78 | 12 | 30.0 | 24 | 30 | 48.0 | 0.01 | 0.00 |
| 2 | 43 | 423028.77 | 2024083.78 | 74 | 16 | 18.00 | 18 | 18 | 18.00 | 74 | 16 | 18.0 | 18 | 18 | 18.0 | 0.00 | 0.00 |
| 3 | 43 | 745963.36 | 1938179.13 | 77 | 19 | 0.00 | 17 | 30 | 59.00 | 77 | 19 | 0.0 | 17 | 30 | 59.0 | 0.00 | 0.00 |
| 4 | 44 | 742529.77 | 2111797.56 | 83 | 18 | 18.00 | 19 | 5 | 5.00 | 83 | 18 | 18.0 | 19 | 5 | 5.0 | 0.00 | 0.00 |
| 5 | 42 | 630635.88 | 2876336.22 | 70 | 18 | 19.00 | 26 | 0 | 0.00 | 70 | 18 | 19.0 | 26 | 0 | 0.0 | 0.00 | 0.00 |
| 6 | 44 | 233037.87 | 4099080.66 | 78 | 0 | 0.00 | 37 | 0 | 0.00 | 78 | 0 | 0.0 | 37 | 0 | 0.0 | 0.00 | 0.00 |

TABLE 7
WGS-84 TO LAMBERT RESULTS COMPARISON WITH TATUKGIS CALCULATOR

| S.No. | Input: WGS-84 coordinates | | | | | | Output: Lambert coordinates 'C' program | | Output: Lambert coordinates TatukGIS calculator | | Error in metres | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Longitude | | | Latitude | | | Easting (m) | Northing (m) | Easting (m) | Northing (m) | Easting | Northing |
| 1 | 69 | 30 | 48 | 22 | 47 | 30 | 4243381.12 | 5077882.91 | 4243380.95 | 5077882.91 | 0.17 | 0.00 |
| 2 | 78 | 12 | 30 | 24 | 30 | 48 | 5120658.51 | 5247349.25 | 5120658.18 | 5247349.19 | 0.32 | 0.05 |
| 3 | 83 | 18 | 18 | 19 | 5 | 5 | 5654205.68 | 4668457.64 | 5654205.33 | 4668457.69 | 0.33 | -0.05 |
| 4 | 78 | 0 | 0 | 31 | 0 | 0 | 5095129.47 | 5958521.01 | 5095129.27 | 5958521.16 | 0.20 | -0.15 |
| 5 | 84 | 31 | 0 | 31 | 30 | 0 | 5712004.45 | 6031245.78 | 5712004.59 | 6031245.88 | -0.14 | -0.1 |
| 6 | 85 | 0 | 0 | 28 | 0 | 0 | 5778215.35 | 5648849.08 | 5778215.68 | 5648849.08 | -0.33 | 0.00 |

TABLE 8
LAMBERT TO WGS-84 RESULTS COMPARISON WITH TATUKGIS CALCULATOR

| S.No. | Input: Lambert coordinates | | Output: WGS 84 coordinates 'C' program | | | | | | Output: WGS 84 coordinates Tatuk GIS calculator | | | | | | Error in seconds | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Easting (m) | Northing (m) | Longitude | | | Latitude | | | Longitude | | | Latitude | | | Long | Lat |
| 1 | 4243381 | 5077883 | 69 | 30 | 47.99 | 22 | 47 | 30.00 | 69 | 30 | 48.0 | 22 | 47 | 30.0 | -0.01 | 0.00 |
| 2 | 5120659 | 5247349 | 78 | 12 | 30.02 | 24 | 30 | 47.99 | 78 | 12 | 30.0 | 24 | 30 | 48.0 | 0.02 | -0.01 |
| 3 | 5654206 | 4668458 | 83 | 18 | 18.02 | 19 | 5 | 5.01 | 83 | 18 | 18.0 | 19 | 5 | 5.0 | 0.02 | 0.01 |
| 4 | 5095129 | 5958521 | 77 | 59 | 59.99 | 31 | 0 | 0.00 | 78 | 0 | 0.0 | 31 | 0 | 0.0 | -0.01 | 0.00 |
| 5 | 5712004 | 6031246 | 84 | 30 | 59.98 | 31 | 30 | 0.00 | 84 | 31 | 0.0 | 31 | 30 | 0.0 | -0.02 | 0.00 |
| 6 | 5778215 | 5648849 | 84 | 59 | 59.97 | 28 | 0 | 0.00 | 85 | 0 | 0.0 | 28 | 0 | 0.0 | -0.03 | 0.00 |



## REFERENCES

[1] P. Misra and Per Enge, *Global Positioning System - Signals, Measurements and Performance*, Massachusetts: Ganga-Jamuna Press, 2001.

[2] S.K. Singh, "Coordinate transformation between Everest and WGS-84 datums - A parametric approach", *Proc. of Asian GPS*, 2002.

[3] Ahmed El-Rabbany, *Introduction to GPS*, Norwood: Artech House, 2002.

[4] European Organization for the Safety of Air Navigation (EUROCONTROL) Brussels, Belgium, and Institute of Geodesy and Navigation, University FAF Munich, Germany, "WGS-84 implementation manual", Version 2.4, 1998.

[5] Website 1: http://earth-info.nga.mil/GandG/coordsys/grids/utm.html, May 2011.

[6] Austin Troy, "Introduction to Projections and Coordinate Systems", University of Vermont, Burlington, VT, 2005.

[7] European Petroleum Survey Group (EPSG), Sunbury on Thames, U.K., and Petrotechnical Open Software Consortium, Inc. (POSC), Houston, "Coordinate Conversions and Transformations", Guidance Note Number 7, 2002.

[8] P. Ramachandran, "A Defence Roadblock", Frontline, Vol. 22, Issue 17, August 13-26, 2005 available at http://www.frontlineonnet.com/fl2217/stories/20050826002209400.htm2005.