UTM coordinates correction between WGS84 and Clarke1880 ellipsoid in Mosul by using GPS

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الخلاصة

تستخدم أنظمة تحديد المواقع العالمية (GPS) للحصول على بيانات متجهة عن المواقع الجغرافية وتخزينها في جداول قواعد بيانات يمكن تصديرها إلى برامجيات أنظمة المعلومات الجغرافية(GIS).

وتعتمد قياسات أنظمة تحديد المواقع العالمية على النظام الجيوديسي العالمي (WGS84) في تحديد الإحداثيات الجغرافية للمواقع ، بينما النظام المستخدم في العراق لتحديد الإحداثيات هو نظام كلارك 1880(Clarke1880) .

يقدم هذا البحث النتائج العملية لتحويل الإحداثيات الجغرافية و التربيعية(الشبكية) من نظام (WGS84) إلى نظام (Clarke1880) ضمن النطاق 38 شمالاً(Zone 38N) لبعض المواقع في مدينة الموصل باستخدام تقنية (GPS) وبرامجيات نظم المعلومات الجغرافية (ArcGIS software)

ويقدم البحث أيضاً المعادلات الخاصة بعملية التحويل للاستفادة منها من قبل المستخدم في تحويل الإحداثيات من الصيغة الجغرافية إلى الصيغة التربيعية لأي موقع ضمن مدينة الموصل.

أظهرت نتائج البحث أن هناك اختلاف نسبي بين النظامين في تحديد الإحداثيات الجغرافية للموقع، ويمكن إجراء التصحيح بين قراءات النظامين عن طريق إضافة قيم ثابتة لكلاً من الإحداثيات الجغرافية و التربيعية لغرض تحقيق مستوى مقبول للدقة نتائج التحويل.

ABSTRACT

Most GPS receivers calculate their locations by a geodetic coordinate referenced to the WGS84 ellipsoid, whereas the local reference applied in IRAQ (referred as Clarke1880 ellipsoid) have different geodetic coordinates.

This paper presents the results of particulars conversion between geographical and UTM grid coordinates system from WGS84 reference ellipsoid system to Clarke1880 reference ellipsoid system for a selective

locations in Mosul (Zone 38N). Conversion formulae and parameters are also given to facilitate users to convert the coordinates of any point in the study area between the two systems by using GPS receiver and ArcGIS software.

The result shows that the geographical and UTM grid systems of the two systems are slightly different, but additive constants are sufficient to attain the general accuracy.

INTRODUCTION

It has been noted earlier that it is frequently required to convert coordinates derived in geographic coordinate system to values expressed in another (ref.1, 2). For example, land and seismic surveys are nowadays most conveniently positioned by Global Positioning System (GPS) satellites in the World Geodetic System 1984 (WGS84) geographic coordinate system, whereas the local geodetic system in use for most country concerned will probably be a much earlier coordinate system. It may therefore necessary to convert the observed WGS84 data to the local geodetic system in order to avoid discrepancies.

This paper introduces the results of converting (WGS84) coordinate system to main reference map coordinate system currently used in Iraq (Clarke1880 ellipsoid) for selective positions in Mosul area by using GPS receiver, visualGPS software, and Geographic Information System (GIS) program (ArcGIS package). These results include UTM (Universal Transverse Mercator) coordinate transformation also.

The need for such coordinate transformation comes from the increasing use of GPS receivers for measuring the spatial position of physical features in the ground-based surveys (such as: the location of the road, rivers, building and elevation of the ground). Also the ability of the GPS to storage facilities which enable reading of remotely data for subsequent transfer to a GIS package for the purpose of coincidence between the coordinate system of the received data with the topographic map as required for the geometrical correction in remote sensing technology (ref.3). .

Analyzing GPS derived heights is a separate problem, which is beyond the scope of this study.

Global Position System (GPS)

GPS is an example of a single technology that profoundly changed contemporary navigation, surveying and mapping techniques. Its technology currently supports a variety of applications ranging from tracking remote sensing satellites at altitude below (3000km) to environmental and geographic information system (GIS) surveys.

Figure (1) shows the nominal GPS operational constellation that consists of (24) satellites which orbits earth at altitude of (~ 20.000km). The satellites approximately repeat the same track and configuration once a day, advancing by roughly (4 minutes) each day (ref.4).

The signal generated by a GPS satellite oscillator contains three primary components: pure sinusoidal waves or carrier (L1 an L2 with frequency of

(1575.42 MHz and 1227.6MHz, respectively), Pseudo –Random Noise (PRN) codes and the navigation message.

The GPS satellite position is parameterized in terms of predicted ephemeris, expressed in Earth-Centered –Earth-Fixed (ECEF) reference frame, known as World Geodetic System 1984 (WGS84) (ref.5). The clock parameters are provided in a form of polynomial coefficients, and together with the predicted ephemeris are broadcast to the users in the GPS navigation message (ref.6).

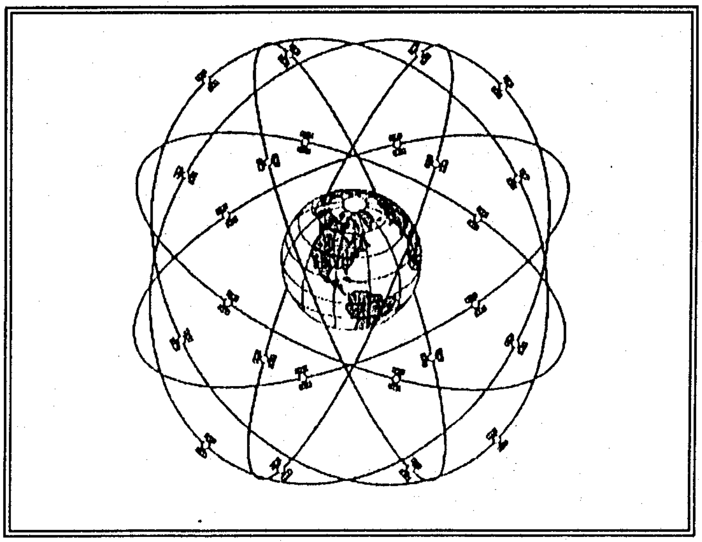

Figure (1): The GPS constellation

Coordinate Transformation Description

The conversion between geographical coordinate and projected or grid coordinates, and the conversion of geographical coordinate from one geodetic datum to another are both termed coordinate transformation although the forms of these transformations are totally dissimilar (ref.7).

Generally, a user would not be concerned with the mechanics of a coordinate transformation. These are defined and their parameters are included within the applied software. Because these are standard transformations, it is generally only required that the user know the names of coordinate systems to be used, but the appropriate set must be secured through the transformation process.

However, the (WGS84) reference frame constitutes a mean or standard earth rotating at a constant rate around a mean pole of rotation fixed in time, Its origin is at the earth's center of mass, and the axes are coincident with the conventional terrestrial system (ref.2).

Clarke1880 is a three-dimensional and the main reference ellipsoid in Iraq as indicated in the local topographic maps (ref.8). The main parameters of the two systems are listed in table (1).

Table (1): WGS84 and Clarke1880 ellipsoid parameters

ellipsoid	Semi-major axis (a)	Semi-minor axis (b)	Eccentricity e^2	Reciprocal flattening (1/f)
WGS84	6378137.000	6356752.314	0.00669437999	298.25722
Clarke1880	6378249.145	6356514.8696	0.00680351126	293.465

These parameters are very important for the conversion process between the two systems.

Universal Transverse Mercator calculations

UTM is not a coordinate system, but it is a set of coordinate transformations. When this is applied to a geographic coordinate system, it generates a projected coordinate system (ref.9).

It is necessary to apply a UTM transformation to geographic coordinate system to form a projected coordinate system of a very importance in the geographical correction part in the digital image processing of the remote sensing data set and in geographical geodetic survey (ref.3).

The UTM coordinate system has been used in Iraq, the system used Clarke1880 as a reference ellipsoid.

In general, Iraq is in zone 37, 38, and 39 of the UTM with a specific central meridian. This grid system can be found in all scale maps of (1/100000).

To distinguish positions in different UTM zones, each position is prefixed with its unique zone name.

The following formulae are used in this research to carried out the conversion process between the geographical coordinate to UTM coordinate for the selected points in the zone (38) for both reference ellipsoid WGS84 and Clarke1880.

From figure (2), let (P) be the point to be converted.

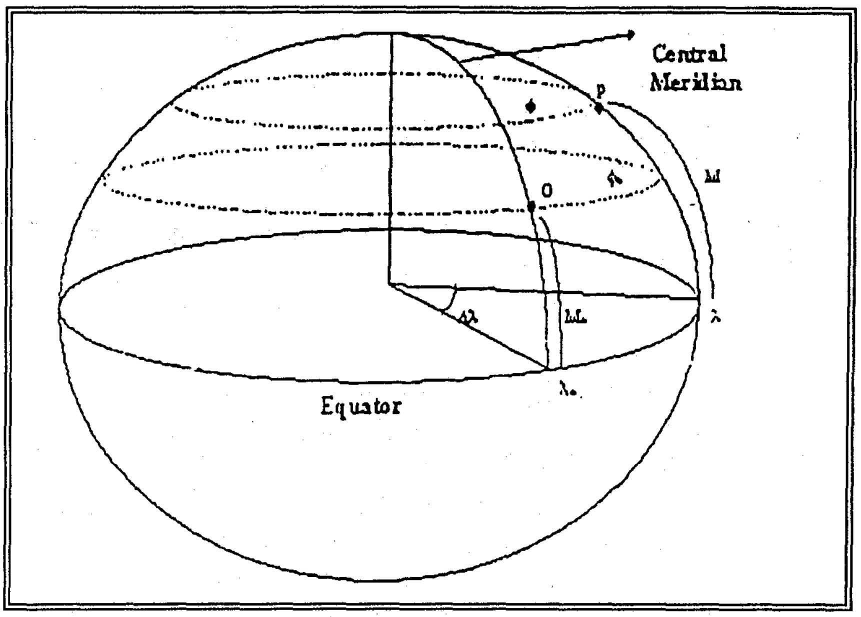

Figure (2): ellipsoidal surface of the earth (ref.10)

The main equations of conversion from geographical to UTM (or Grid) coordinates given by (ref.10):

$$N = N_o + m_o[(M - M_o) + \nu_s \sin\phi \frac{\Delta\lambda^2}{2} \cos\phi] \quad ....1$$

$$E = E_o + m_o[\nu_s \Delta\lambda \cos\phi + \nu_s \frac{\Delta\lambda^3}{6} \cos\phi(\psi_s - t^2)] \quad ....2$$

where;

N, E = Northing, Easting of point (P)

N_o, E_o = Northing, Easting of projection origin (O)

ϕ, λ = Latitude, Longitude of point (P) in radian

m_o = scale factor on the central meridian

$\Delta\lambda$ = Longitude of (P) measured from central meridian in radian (i.e.: $\lambda - \lambda_o$)

t = $tan\phi$

M = meridian distance measured from the Equator to (P)

M_o = meridian distance measured from the Equator to origin projection

ν_s = radius of curvature in prime vertical $= a/(1 - e^2 \sin^2\phi)^{1/2}$

ρ_s = radius of curvature in the meridian $= a/(1 - e^2)/(1 - e^2 \sin^2 \nu_s)^{3/2}$

ψ_s = isometric latitude = ν_s / ρ_s

a = semi-major axis of the reference ellipsoid

Meridian Distance, M, are given by:

$$M = a[A_o\phi - A_2 \sin\nu(2\phi) + A_4 \sin\nu(4\phi)] \quad ....3$$

where;

$$A_0 = 1 - \frac{e^2}{4} - \frac{3e^4}{64}$$

$$A_2 = \frac{3}{8}(e^2 + \frac{e^4}{4})$$

$$A_4 = \frac{15e^2}{256}$$

Here, e^2, is the first eccentricity of the reference ellipsoid = $2f\text{-}f^2$

f, is the flattening of the reference ellipsoid (table (1))

Note: M_0 is computed using (eq.3) by butting $\phi = \phi_o$ (latitude of the origin).

Visual basic language has been used in programming the above equations to facility the transformation process.

MATERIALS AND METHODS

Materials

Topographic map of Mosul at a scale of (1:100000) were provided for the study. The selected and surveyed points of the study have been chosen to be located in a part of the map, shown in figure (3). The geographical coordinates of the study map are provided in table (2).

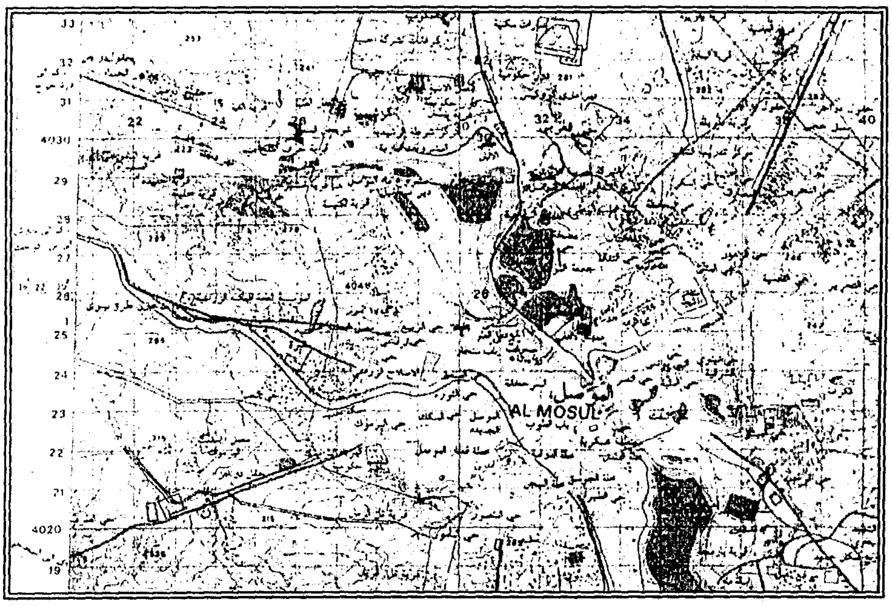

Figure (3): Part of Mosul Map selected for the study (Scale of 1:100000)

Table (2): geographical position for the study area (inside Mosul)

Corner positions	Latitude (degrees:minutes:seconds)	Longitude (degrees:minutest:seconds)
Upper left	36:25:31.0	43:00:11.20
Upper right	36:44:00.0	43:12:54.0
Lower left	36:17:57.10	43:00:23.10
Lower right	36:18:09.0	43:18:09.0

The computer facilities included a serial port (RS-232) which compatible with the operating GPS (PCM-3291) which in turn must be in active with visualGPS software.

The main software used in this research were:

1-VisualGPS: This software has a mode of operation that can be communicates with GPS receiver, the GPS receiver must have ability to send NIMA data sentence (ref.11).

2- ArcGIS: It is a comprehensive program of geographical information produced by (ESRI), it focuses on data, maps, and tools by desktop applications, which are (ref.12);

- ArcCataloge: Create, Manage, and View data documentation (Metadata).
- ArcMap: Perform map-based tasks include Mapping, Editing, Querying, Analyzing, Charting, and Reporting.
- Arctool Box: deals with Geographic Processing Functions as well as tools and wizards.

3- Coordinate calculator: It is a geodetic coordinate calculator (ref.13). It can be calculate Latitude/Longitude coordinates to/from coordinates in different projection, datum (264 datum) and on different spheroids (33 spheroids). It is a 32-bit application and can be run under windows 95/98/NT/2K/XP.

Methodology

In situ instantaneous measurements of the geodetic (latitude, longitude, and altitude) positions for a selected locations inside Mosul area were recorded by using GPS receiver in compact with the visualGPS software. Table (3) listed the geographical coordinates of the locations based on WGS84 system.

Coordinate calculator have been used for the geographical coordinates transformation process from the measured coordinates (based on WGS84 ellipsoid) listed in table (3) to geographical coordinates (based on the Clarke1880 ellipsoid) illustrated in table (4).

Table (3): WGS84 reference (geodetic) coordinates as measured by GPS for the selected points

Point no.	Latitude (degrees:minutes:seconds)	Longitude (degrees:minutes:seconds)	Altitude(m)
1	36:20:10.7	43:09:56.1	277.3
2	36:19:0.5	43:07:19.2	256.4
3	36:21:18.7	43:08:45.9	230.7
4	36:22:13.5	43:08:12.1	278.5
5	36:20:58.6	43:12:11.1	271.2
6	36:22:8.4	43:10:30.0	259.8
7	36:22:31.5	43:08:36.2	270.9
8	36:23:54.6	43:08:26.0	309.3

Table (4): The calculated geographical coordinates based on Clarke1880 for the selected points

Point no.	**Latitude (degrees:minutes:seconds)**	**Longitude (degrees:minutes:seconds)**	**Altitude(m)**
1	36:20:3.5	43:09:55.5	253.54
2	36:18:53.6	43:07:18.2	232.7
3	36:21:11.9	43:08:45.6	206.87
4	36:22:6.9	43:08:11.4	254.6
5	36:20:51.0	43:12:10.8	247.3
6	36:22:1.9	43:10:29.7	235.9
7	36:22:24.6	43:08:35.2	246.5
8	36:23:47.4	43:08:25.1	285.3

Through the measurements of the coordinates explained in table (3), the signal to noise ratio (dB) of the corresponding activated satellites that responded by the GPS receiver have been maintained in a relatively high level of accuracy as shown in figure (4).

The study map shown in figure (3) have been rectified and geographically projected to WGS84 reference ellipsoid by using georeferncing option in the arcGIS software. This process is important for the coinciding with the actual coordinates of the viewed topographic map. Figure (5) illustrates the geographical projected (based on WGS84) map as well as a layer of the measured locations by GPS, as shown ArcGIS/ArcMAP windows.

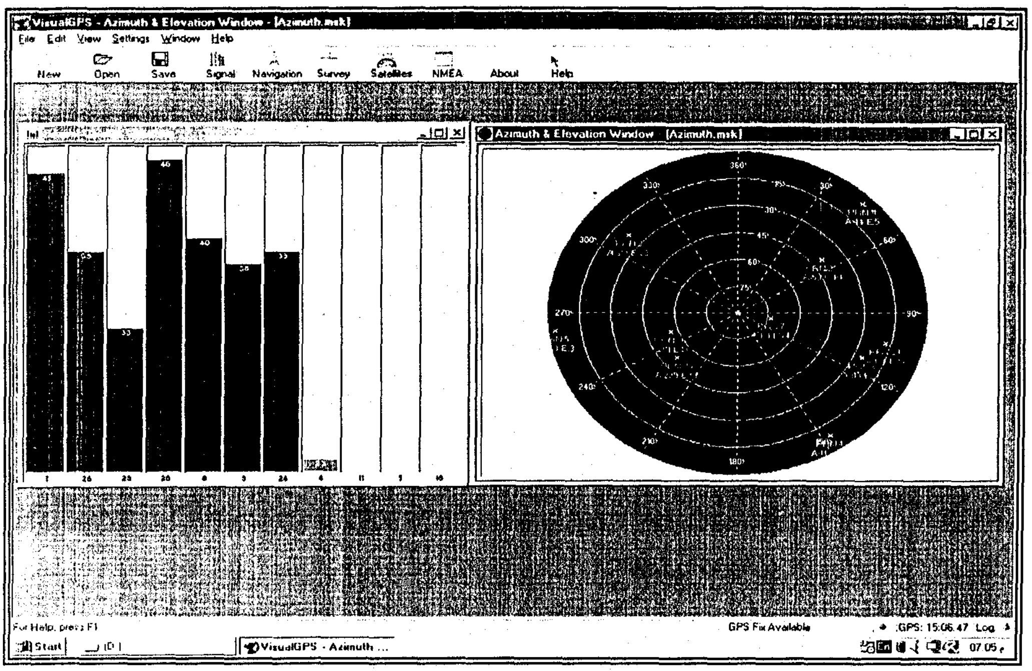

Figure (4): signal to noise ratio (left) and the corresponding satellites (right) responded by the operating GPS in this study

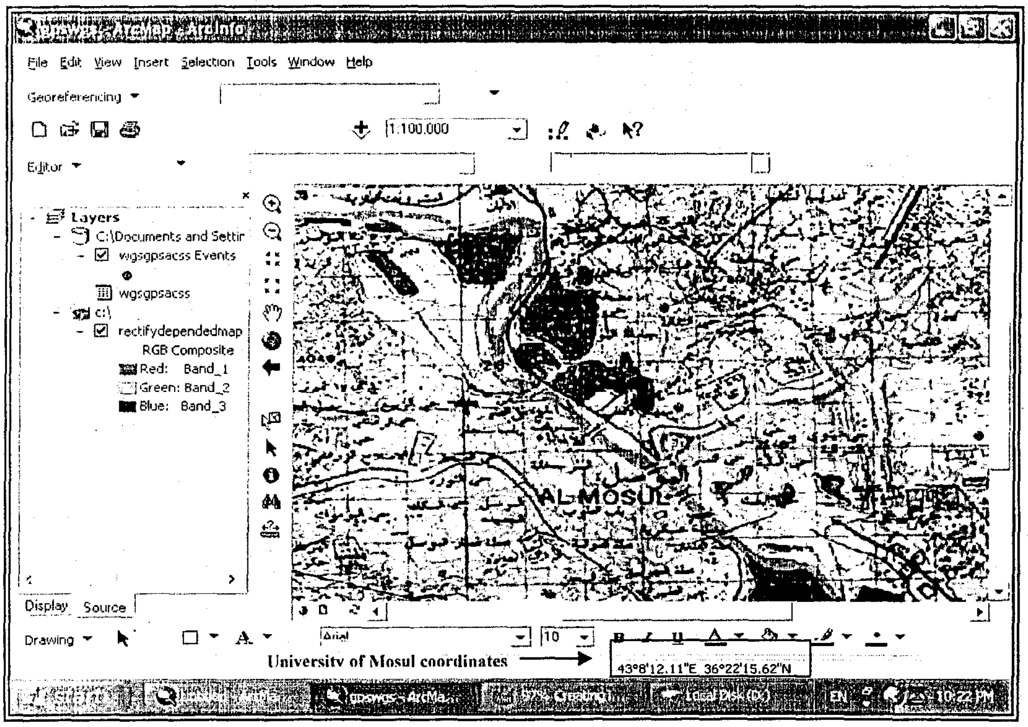

Figure (5): geographical projected (based on WGS84) coordinates of the study area and the selected recorded points.

RESULTS AND DISCUSSION

The conversion from the latitude and longitude to UTM grid coordinates on either Clarke1880 or WGS84 ellipsoid have been performed by using the projection formulae (1 through 3) and the appropriate parameters (ref.12) related to Zone (38) given in table (5).

Table (5): Parameters for UTM grid (Zone 38)

Parameters	**WGS84 & Clarke1880 (ϕ,λ to UTM)**
False_Easting	500000mE
False_Northing	0mN
Central Meridian	45 degree
Latitude of origin	0 degree
Scale factor	0.9996

Figure (6) shows the map of the surveyed locations in two layers, one related to the UTM (based on WGS84) coordinates and another related to the UTM (based on Clarke1880) coordinates system.

Due to the change of reference ellipsoid, the UTM coordinates as shown from figure (6) are slightly different.

The average correction of these conversion (for the selective locations in Mosul) according to the parameters mentioned in table (5) should be:

UTM Northing (Clarke1880) = UTM Easting (WGS84) -252 m

Zone 38N

UTM Easting (Clarke1880) = UTM Easting (WGS84) - 41 m

Similarly the latitude and longitude are also slightly different, but an additive constants for the given geographic coordinates shown below are sufficient to attain the relatively general accuracy:

Longitude (Clarke1880)= Longitude (WGS84) – 4.3″ (corrected to nearest 0.1″)

Latitude (Clarke1880) = Latitude (WGS84) – 6.9″ (corrected to nearest 0.1″)

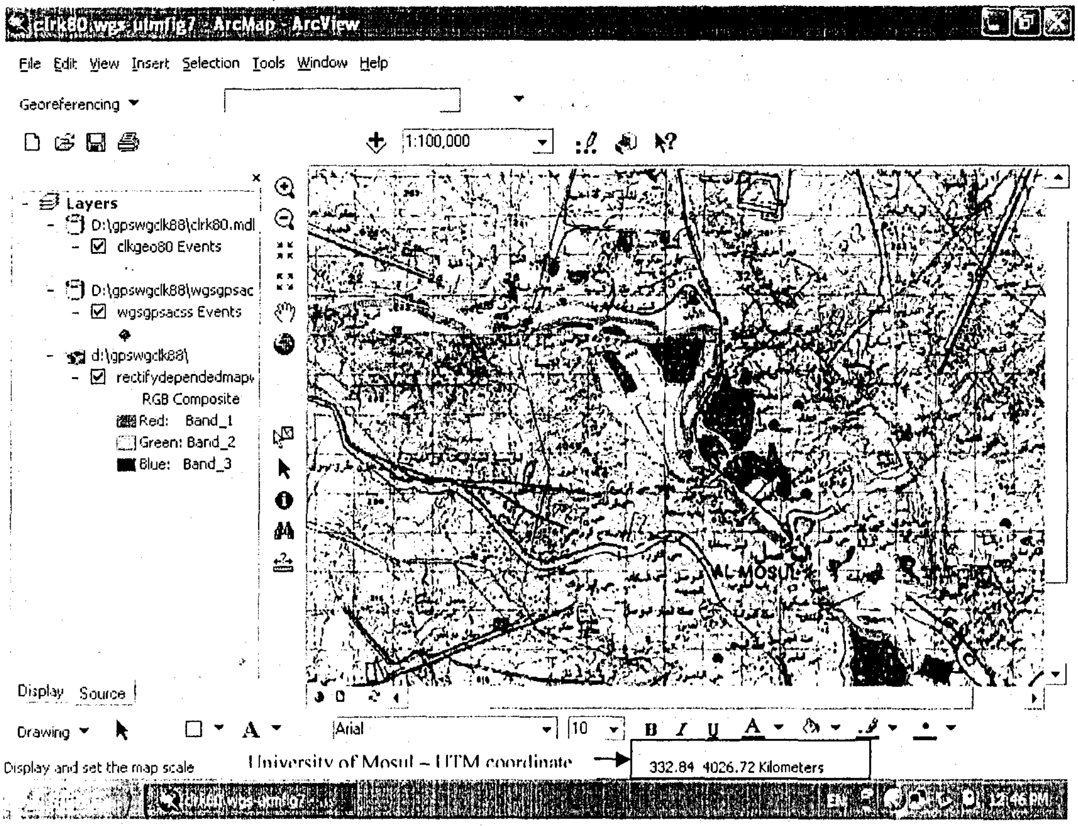

Figure (6): UTM coordinates difference between WGS84 and Clarke1880 reference ellipsoid

CONCLUSIONS

For many navigation applications, a very simple approach to convert WGS84 latitude and longitude as well as UTM coordinates system to Clarke1880 is to determined an offset to apply to the geographical and UTM coordinates. One method of calculating the offset is by using GPS techniques and ArcGIS software together.

Users should be a ware to apply appropriate parameters for different ellipsoid according to the applied zone.

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