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RELATIONSHIP OF ETM AND UTM PROJECTION SCALE FACTORS IN EGYPT

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ABSTRACT

To convert the 3D coordinates' values (ϕ ,λ, h) to 2D coordinates on plane (E, N) such as a map, one expect to have different types of distortions on the projected coordinates. One of these distortions is the Scale Distortion. Scale factor has to be used to correct distances plotted or measured from maps. Many countries in the world have more than one coordinates system used for their maps such as in Egypt. In Egypt Universal Transverse Mercator (UTM) and Egyptian Transverse Mercator (ETM) are used for production of maps. To transfer data from one to the other system, the projection scale factors are different for the two systems and ignoring it in these transformations can led to large errors. In this paper we will study the effect of distortion caused by Scale Factor and trying to get the Scale Factor relationship between ETM and UTM systems in Egypt.

KEYWORDS: Projection Scale Factor, Map Distortion, ETM system, UTM system, Geodetic Datum, Geodetic Coordinates (Geographic Coordinates), Map Projection, Projected Coordinates, UTM and ETM Zones

INTRODUCTION

Identifying locations on the earth requires choosing the mathematical form whish expresses the shape and size for earth; it is called the **Reference Surface** such as the Plane, Sphere or Ellipsoid references.

Many attempts have been conducted by geodesist to determine the most appropriate horizontal ellipsoid reference expresses the best fitting shape of earth. Whenever gathered new geodetic measurements, new values for radiuses (a) and (b) were calculated to define the ellipsoid reference. Examples for the used ellipsoids are Airy 1830 (at British), Bassel 1841 (at Middle Europe), Clarcke 1866 (at North Amarica), Helmert 1906 (at Egypt), WGS72 and WGS84 (International).

A **Geodetic Datum** for any country is a modification of the International Ellipsoid Reference to express the best fit for that country and to increase the accuracy for its maps based on this reference. A Geodetic Datum can also called A **Local Datum** or Simply a **Datum**. Therefore, even if different countries are using the same International Ellipsoid Reference, each country can have its Geodetic Datum which means every country will have its different parameters. For example; although the Ellipsoid Reference at Egypt is Helmert 1906 but the Local Datum is Egypt 1907 **Datum** that expresses the best fit of Egypt.

Coordinates are the values to identify a specific location on the earth and/or map. There are many systems of coordinates based on the used **Reference Surface**. One of these systems is **Geodetic Coordinates** (Geographic Coordinates) which can be expressed by three values [Longitude (λ), Latitude (ϕ) and Ellipsoidal Height (h)]. The second system is **Cartesian Geodetic Coordinates** which can be expressed by three values (X, Y, Z). The third system is **Projected Coordinates** which can be expressed usually by two values [Easting (E), and Northing (N)], so it is used to express the coordinates for points on map. In order to convert the coordinates of points from **Geodetic Coordinates system** (ϕ, λ, h) to **Projected Coordinates** (E, N) must use one of **Map Projection methods**.

Map Projection is a mathematical process to convert the 3D coordinates' values on Earth (ϕ, λ, h) to 2D coordinate's values on plane (E, N) such as a map. By any way that isn't possible without distortion. Each method of map projection tries to maintain matching for one or more of the following characteristics: distances, areas, shapes, directions and/or angles between the real target and its picture on the map. Map projection methods can be classified to four main groups; cylindrical projections, Conical projections, Azimuth projections and others. The most famous models of map projection are Mercator projection, Transverse Mercator projection (TM), Universal Transverse Mercator projection (UTM), Sinusoidal Equal-Area projection, Lambert Conformal Conic projection, Lambert Azimuthal Equal-Area projection and Orthographic projection. Each model has its own known parameters which called **Projection parameters**. Usually the Projection parameters are concluded origin (central meridian and standard parallel), false Easting, false Northing and the scale factor at central meridian.

In Egypt Universal Transverse Mercator (UTM) and Egyptian Transverse Mercator (ETM) are used for production of maps. A Modified Egypt Transverse Mercator projection (METM) was suggested to replace (MTM), but is not used till now. So it is normally required to transfer data from one system to the other. Projection scale factors are different for the systems. Ignoring scale factors in these transformations can led to large errors.

In this paper we will study the effect of scale distortion and study the Scale Factor relationship between ETM and UTM systems in Egypt.

RELATED WORK

ETM Projection System

The ETM projection system divides Egypt to three main zones (belts) purple belt, red belt and Green belt. Each zone has a longitude width of 4° and has its origin of coordinate system as shown in figure (1). Also, properties of ETM system are given in table (1) [1,2].

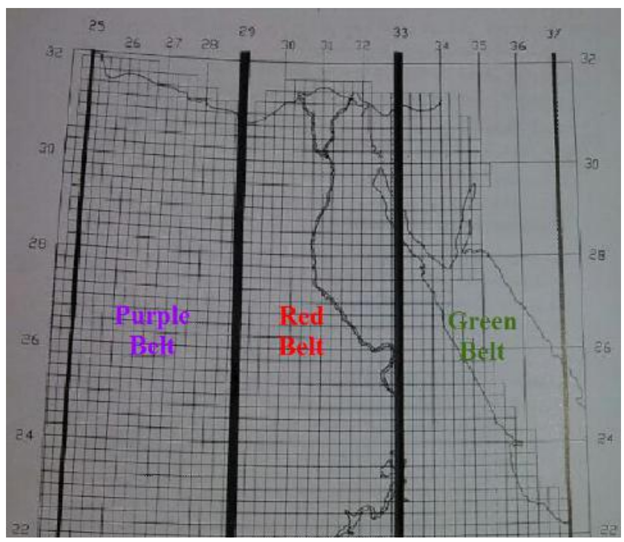

Figure 1: Zones of ETM Projection System in Egypt [10].

METM Projection System

In the last few years; Egyptian Survey Authority (ESA) has made study to modernized Egypt datum and projection system. The study proposed the following;

- To adopt using International Ellipsoid Reference (WGS84) datum instead of Old Egyptian datum.
- To use Modified Egypt Transverse Mercator (METM) Projection.

ETM is also TM projection type, conforming to the main concept of the world wide used UTM system. It divides Egypt to five main zones, the width of zone is 3° as shown in figure (2) and all properties of METM system are given in table (1) [3].

UTM Projection System

The UTM projection system is based basically on the Transverse Mercator projection. Egypt is covered by two zones. Each zone has a longitude width 6° as shown in figure (3) and all properties of UTM system are given in table (1) [4,5].

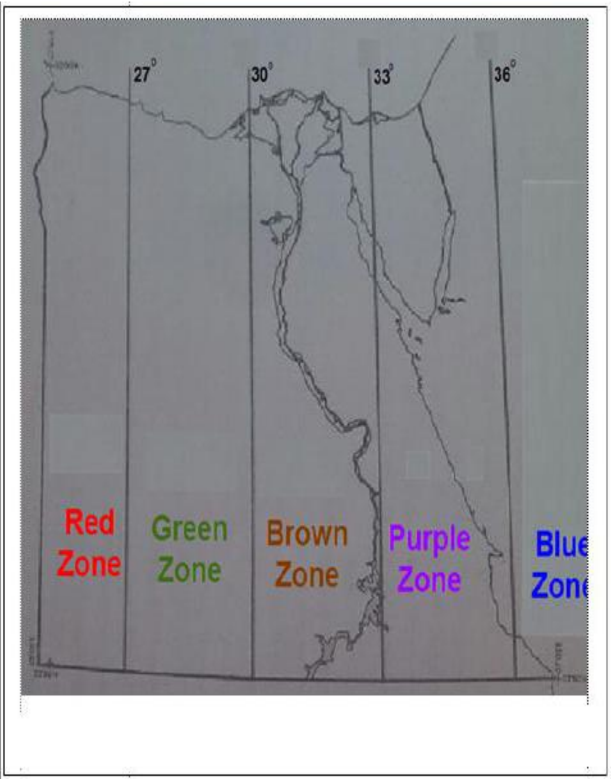

Figure 2: Zones of METM Projection System in Egypt [10].

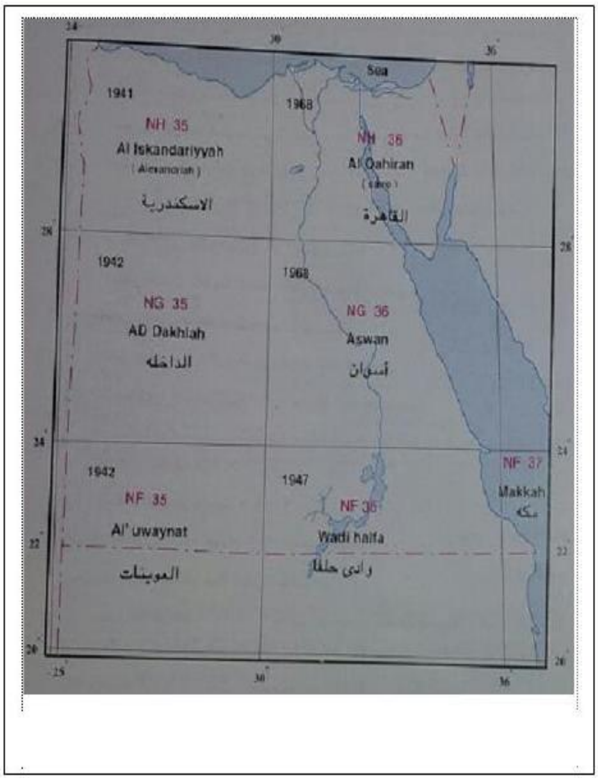

Figure 3: Zones of UTM Projection System in Egypt [10].

Table 1: The Main Characteristics for Projection Systems used in Egypt [6,7].

Mapping System	Zone Width	Coverage Longitudes	Central Meridian		E_0 , N_0 (m)	True Origin Location
			Longitude	S.F. at Central Meridian $(S.F)_0$		
ETM	4°	Purple Belt : 25° - 29°	27°	1.0	700000 , 200000	The intersection of the parallel of latitude 30° and the central meridian
		Red Belt : 29° - 33°	31°		615000 , 810000	
		Green Belt : 33° - 37°	35°		300000 , 110000	
METM	3°	Red Zone : 24° - 27°	25° 30"	0.9999	300000 , 0	The intersection of the equator and the central meridian
		Green Zone : 27° - 30°	28° 30"			
		Brown Zone : 30° - 33°	31° 30"			
		Purple Zone : 33° - 36°	34° 30"			
		Blue Zone : 36° - 39°	37° 30"			
UTM	6°	Zone 35 : 24° - 30°	27°	0.9996	500000 , 0	The intersection of the equator and the central meridian
		Zone 36 : 30° - 36°	33°			

3 METHODOLOGY

The Transverse Mercator Projection is the ordinary Mercator projection turned 90° angle related to the equator and the cylinder is tangent to the central meridian, therefore the scale is true only along the central meridian. The central meridian represents by straight lines, other meridians are concave curves toward the central meridian and parallels toward the Pole. Transverse Mercator projection is used usually for zones of greater north-south than east-west extent. Transverse Mercator projection formulas are as follows; [8,9].

$$N = \frac{a}{\sqrt{1-\varepsilon^2 \sin^2 \phi}} \tag{1}$$

$$\frac{X}{N} = \lambda' \cos\phi + \frac{\lambda'^3 \cos^3\phi}{6}(1 - t^2 + \eta^2) + \frac{\lambda'^5 \cos^5\phi}{120}\left(5 - 18t^2 + t^4 + 14\eta^2 - 58t^2\eta^2 + 13\eta^4\right) + \cdots \tag{2}$$

$$\frac{Y}{N} = \frac{S_\phi}{N} + \frac{\lambda'^2}{2}\sin\phi\cos\phi + \frac{\lambda'^4}{24}\sin\phi\cos^3\phi\,(5 - t^2 + 9\eta^2 + 4\eta^4) + \frac{\lambda'^6}{720}\sin\phi\cos^5\phi\left(61 - 58t^2 + t^4 + 720\eta^2 - 330t^2\eta^2 + 445\eta^4\right) + \cdots \tag{3}$$

Where;

- ✓ $t = \tan\phi$
- ✓ $\eta^2 = \varepsilon'^2 \cos^2\phi = \frac{\varepsilon^2 \cos^2\phi}{1-\varepsilon^2} = \frac{(a^2-b^2)\cos^2\phi}{b}$
- ✓ ε is the eccentricity, and $\varepsilon^2 = \frac{(a^2-b^2)}{a^2}$
- ✓ a is the semi-major axis of the earth ellipsoid.
- ✓ b is the semi-minor axis of the earth ellipsoid.

- ✓ $\lambda' = \lambda - \lambda_0$= longitude difference from central meridian λ_0, in radians.
- ✓ S_ϕ is the length of the meridian arc from the equator to latitude $\phi$and is given by.

$$S_\phi = \int_0^\phi \frac{a(1-e^2)}{(1-e^2\sin^2\phi)^{3/2}}d\phi \quad \text{or} \quad S_\phi = a(A_0\phi - A_1\sin 2\phi + A_2\sin 4\phi - A_3\sin 6\phi + \cdots) \tag{4}$$

Where;

- $A_0 = 1 - \frac{1}{4}\varepsilon^2 - \frac{3}{64}\varepsilon^4 - \frac{5}{256}\varepsilon^6 - \cdots$
- $A_1 = \frac{3}{8}\varepsilon^2 + \frac{3}{32}\varepsilon^4 + \frac{45}{1024}\varepsilon^6 + \cdots$
- $A_2 = \frac{15}{256}\varepsilon^4 + \frac{45}{1024}\varepsilon^6 + \cdots$
- $A_3 = \frac{35}{3072}\varepsilon^6 + \cdots$

The scale factor (S.F) can be calculated from either (ϕ, λ) or from (E, N) coordinates as shown in equations 5 and 6 respectively [9].

$$\mathrm{S.F} = 1 + \frac{(\lambda')^2\cos^2\phi}{2}(1+\eta^2) + \frac{(\lambda')^4\cos^4\phi}{24}\left(5 - 4t^2 + 14\eta^2 + 13\eta^4 - 28t^2\eta^2 + 4\eta^6 - 48t^2\eta^4 - 24t^2\eta^6\right) + \frac{(\lambda')^6\cos^6\phi}{720}(61 - 148t^2 + 16t^4) \tag{5}$$

$$\mathrm{S.F} = (\mathrm{S.F})_0 + \frac{1}{2}\left(\frac{\Delta\mathrm{E}}{\mathrm{N}}\right)^2(1+\eta^2) + \frac{1}{24}\left(\frac{\Delta\mathrm{E}}{\mathrm{N}}\right)^4(1+6\eta^2) \tag{6}$$

Where;

- ✓ $(\mathrm{S.F})_0$ is the scale factor value at the central meridian of the zone, see table (1).
- ✓ $\Delta\mathrm{E} = E_i - E_0 \Rightarrow$ For (E_0) value, see table (1).
- ✓ E_0 and E_i are the East of coordinates at the central meridian and Point (*i*) respectively.

Nowadays, several software’s have capability to convert the coordinates of points from (ϕ, λ) system to (E, N) projected coordinates and vise verse. Then the S.F can be calculated for any location using the East value of projected coordinates (E) as equation (6).

4 TESTS AND RESULTS

The test in this investigation has been carried out as follows;

i. Two latitudes ϕ = 23° N and ϕ = 30° N on South and North sections of Egypt have been chosen.
ii. (E, N) coordinates in UTM and ETM systems were calculated for 25 points using ϕ = 23° and longitudes (λ) starts from 29° to 33° with 10` interval.
iii. Step (ii) above was repeated using ϕ = 30° instead of ϕ = 23°.
iv. Table 2 shows the calculated ETM and UTM coordinates for the 50 points.
v. Using Equation (6) the Scale Factor were calculated for 25 points when ϕ = 23° and 25 points when ϕ = 30°. Table 3 shows the calculated Scale Factors for the 50 points.

Table 2: The Calculated Projected Coordinates at Different Locations and Zones in Egypt.

Geodetic Coordinates		Projected Coordinates					
		ETM (Red Belt)		UTM (Zone No. 36)		UTM (Zone No. 35)	
ϕ (°)	λ (° `)	E (m)	N (m)	E (m)	N (m)	E (m)	N (m)
23° N	29° 00`	409923.79	35814.909	------	------	705151.225	2544933.949
	29 10	427017.74	35591.392	------	------	722239.557	2545176.84
	29 20	444110.57	35387.338	------	------	739329.204	2545439.201
	29 30	461202.4	35202.74	------	------	756420.268	2545721.044
	29 40	478293.32	35037.589	------	------	773512.849	2546022.375
	29 50	495383.42	34891.882	------	------	790607.047	2546343.208
	30 00	512472.82	34765.613	192617.741	2546676.985	807555.640	2546676.985
	30 10	529561.61	34658.778	209713.619	2546336.643	------	------
	30 20	546649.89	34571.372	226807.776	2546015.812	------	------
	30 30	563737.77	34503.392	243900.315	2545714.481	------	------
	30 40	580825.35	34454.838	260991.336	2545432.641	------	------
	30 50	597912.73	34425.705	278080.942	2545170.28	------	------
	31 00	615000	34415.995	295169.233	2544927.391	------	------
	31 10	632087.27	34425.705	312256.311	2544703.963	------	------
	31 20	649174.65	34454.838	329342.275	2544499.991	------	------
	31 30	666262.23	34503.392	346427.229	2544315.465	------	------
	31 40	683350.11	34571.372	363511.272	2544150.381	------	------
	31 50	700438.39	34658.778	380594.506	2544004.732	------	------
	32 00	717527.18	34765.613	397677.033	2543878.513	------	------
	32 10	734616.58	34891.882	414758.953	2543771.72	------	------
	32 20	751706.69	35037.589	431840.367	2543684.348	------	------
	32 30	768797.6	35202.74	448921.377	2543616.397	------	------
	32 40	785889.43	35387.338	466002.085	2543567.861	------	------
	32 50	802982.26	35591.392	483082.589	2543538.74	------	------
	33 00	820076.21	35814.91	500000	2543519.76	------	------
30° N	29 00	422005.82	811684.62	------	------	693073.952	3320493.461
	29 10	438091.55	811415.47	------	------	709154.078	3320785.938
	29 20	454176.54	811169.75	------	------	725235.096	3321101.855
	29 30	470260.84	810947.45	------	------	741317.072	3321441.22
	29 40	486344.52	810748.57	------	------	757400.075	3321804.045
	29 50	502427.66	810573.1	------	------	773484.176	3322190.338
	30 00	518510.31	810421.04	210751.181	3322591.712	789422.070	3322591.712
	30 10	534592.55	810292.38	226836.409	3322181.939	------	------
	30 20	550674.45	810187.12	242920.472	3321795.647	------	------
	30 30	566756.08	810105.25	259003.44	3321432.824	------	------
	30 40	582837.5	810046.78	275085.378	3321093.46	------	------
	30 50	598918.79	810011.7	291166.359	3320777.545	------	------
	31 00	615000	810000	307246.449	3320485.069	------	------
	31 10	631081.22	810011.7	323325.717	3320216.023	------	------
	31 20	647162.5	810046.78	339404.231	3319970.399	------	------
	31 30	663243.92	810105.25	355482.06	3319748.191	------	------
	31 40	679325.55	810187.12	371559.273	3319549.39	------	------
	31 50	695407.45	810292.38	387635.936	3319373.992	------	------
	32 00	711489.69	810421.04	403712.121	3319221.99	------	------
	32 10	727572.34	810573.1	419787.894	3319093.381	------	------
	32 20	743655.48	810748.57	435863.326	3318988.162	------	------
	32 30	759739.16	810947.45	451938.482	3318906.326	------	------
	32 40	775823.46	811169.75	468013.433	3318847.876	------	------
	32 50	791908.45	811415.47	484088.247	3318812.805	------	------
	33 00	807994.19	811684.62	500000	3318785.35	------	------

Table 3: The Calculated Scale Factors for Different Locations in Egypt.

λ (° `)	The Calculated Scale Factors (S.F.)					
	ETM (Red Belt)		UTM (Zone No. 36)		UTM (Zone No. 35)	
	ϕ					
	23° N	30° N	23° N	30° N	23° N	30° N
29° 00`	1.0005169	1.0004578	------	------	1.0001173	1.0000582
29 10	1.0004343	1.0003847	------	------	1.0002070	1.0001377
29 20	1.0003589	1.0003179	------	------	1.0003040	1.0002235
29 30	1.0002907	1.0002575	------	------	1.0004081	1.0003157
29 40	1.0002297	1.0002034	------	------	1.0005195	1.0004143
29 50	1.0001759	1.0001558	------	------	1.0006380	1.0005193
30 00	1.0001292	1.0001144	1.0007613	1.0006283	1.0007613	1.0006283
30 10	1.0000897	1.0000795	1.0006357	1.0005171	------	------
30 20	1.0000574	1.0000509	1.0005173	1.0004123	------	------
30 30	1.0000323	1.0000286	1.0004061	1.0003138	------	------
30 40	1.0000144	1.0000127	1.0003021	1.0002217	------	------
30 50	1.0000036	1.0000032	1.0002053	1.0001360	------	------
31 00	1.0000000	1.0000000	1.0001157	1.0000566	------	------
31 10	1.0000036	1.0000032	1.0000332	0.9999836	------	------
31 20	1.0000144	1.0000127	0.9999580	0.9999170	------	------
31 30	1.0000323	1.0000286	0.9998899	0.9998567	------	------
31 40	1.0000574	1.0000509	0.9998290	0.9998028	------	------
31 50	1.0000897	1.0000795	0.9997752	0.9997552	------	------
32 00	1.0001292	1.0001144	0.9997287	0.9997140	------	------
32 10	1.0001759	1.0001558	0.9996893	0.9996791	------	------
32 20	1.0002297	1.0002034	0.9996571	0.9996506	------	------
32 30	1.0002907	1.0002575	0.9996321	0.9996284	------	------
32 40	1.0003589	1.0003179	0.9996142	0.9996126	------	------
32 50	1.0004343	1.0003847	0.9996035	0.9996031	------	------
33 00	1.0005169	1.0004578	0.9996000	0.9996000	------	------

Figure 4 and 5 show the S.F relationship in Egypt between ETM (Red Belt) and UTM (Zone No. 35) Projection Systems at $\phi = 23°$ and $\phi = 30°$ respectively.

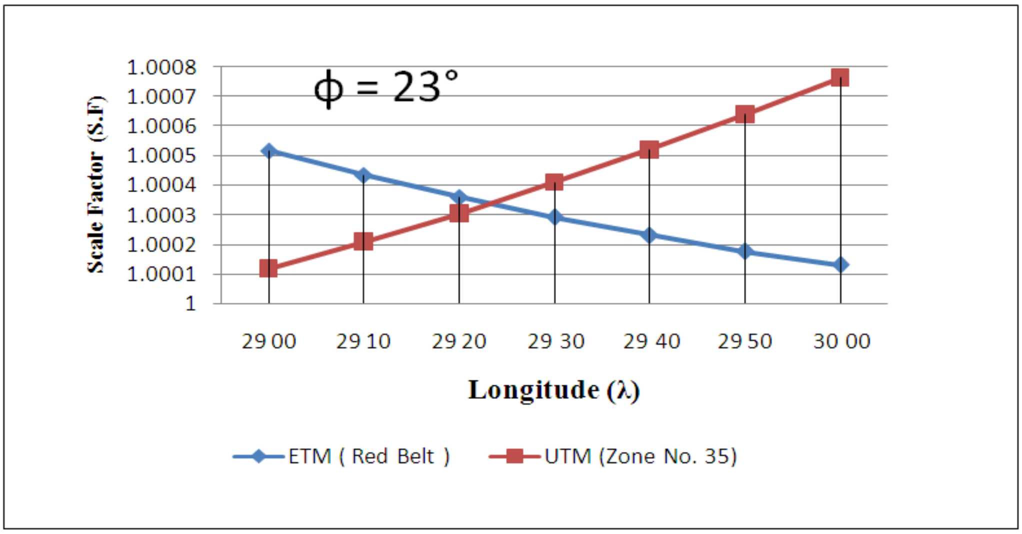

Figure 4: Scale Factors Relation between ETM (Red Belt) and UTM (Zone No. 35) [ϕ = 23°].

Form Figure 4, When latitude ϕ = 23° and longitudes (λ) starts from 29° to 30°, it can be seen that;

- **a)** For ETM (Red Belt) projection System, when (λ) increasing going to center meridian (λ = 31°) the S.F is decreasing. The maximum value of the S.F = 1.0005169 and the minimum value of the S.F = 1.0001292.
- **b)** For UTM (Zone 35) projection System, when (λ) increasing going away from center meridian (λ = 27°) the S.F is increasing. The maximum value of the S.F = 1.0007613 and the minimum value of the S.F = 1.0001173.
- **c)** When λ = 29° at the West border of Red Belt, the ETM S.F is large compared with UTM S.F. The difference between the two factors = 0.000400 which is correspond to 4/10000 accuracy.
- **d)** When λ = 30° at the East border of UTM (Zone 35), the UTM S.F is large compared with ETM S.F. The difference = 0.00063 which is correspond to 6.3/10000 accuracy.
- **e)** The two scale factors are equal at geodetic coordinates (ϕ = 23° and λ = 29° 23`) which is near of Shark Al-Owainat Region as shown in Figure 8.

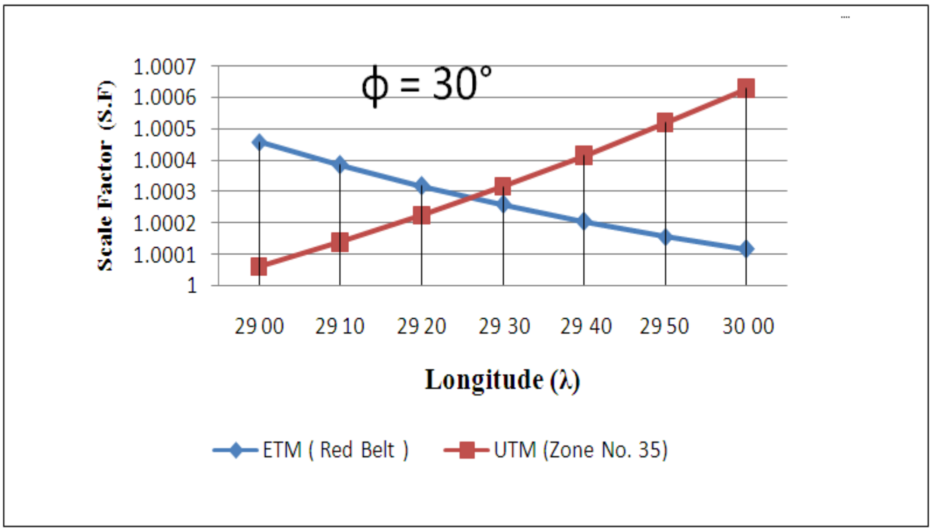

Figure 5: Scale Factors Relation between ETM (Red Belt) and UTM (Zone No. 35) [ϕ = 30°].

Form Figure 5, When latitude ϕ = 30° and longitudes (λ) starts from 29° to 30°, it can be seen that;

- **A)** The relation between the two scale factor has same trend as when ϕ = 23°
- **B)** For ETM the maximum and the minimum values of the S.F is 1.0004578 and 1.0001144 respectively.
- **C)** For UTM (Zone 35), the the maximum and the minimum values of the S.F is 1.0006283 and 1.0000582 respectively.
- **D)** When λ = 29° at the West border of Red Belt, the ETM S.F is larger compared with UTM S.F. the difference = 0.000400 which is correspond to 4/10000 accuracy.
- **E)** When λ = 30° at the East border of UTM (Zone 35), the ETM S.F is smaller compared to UTM S.F. The difference = 0.00051 which is correspond to 5.1/10000 accuracy.

F) The two factors are equal at geodetic coordinates (ϕ = 30°, λ = 29° 27`) which located in the north of Western Desert as shown in Figure 8.

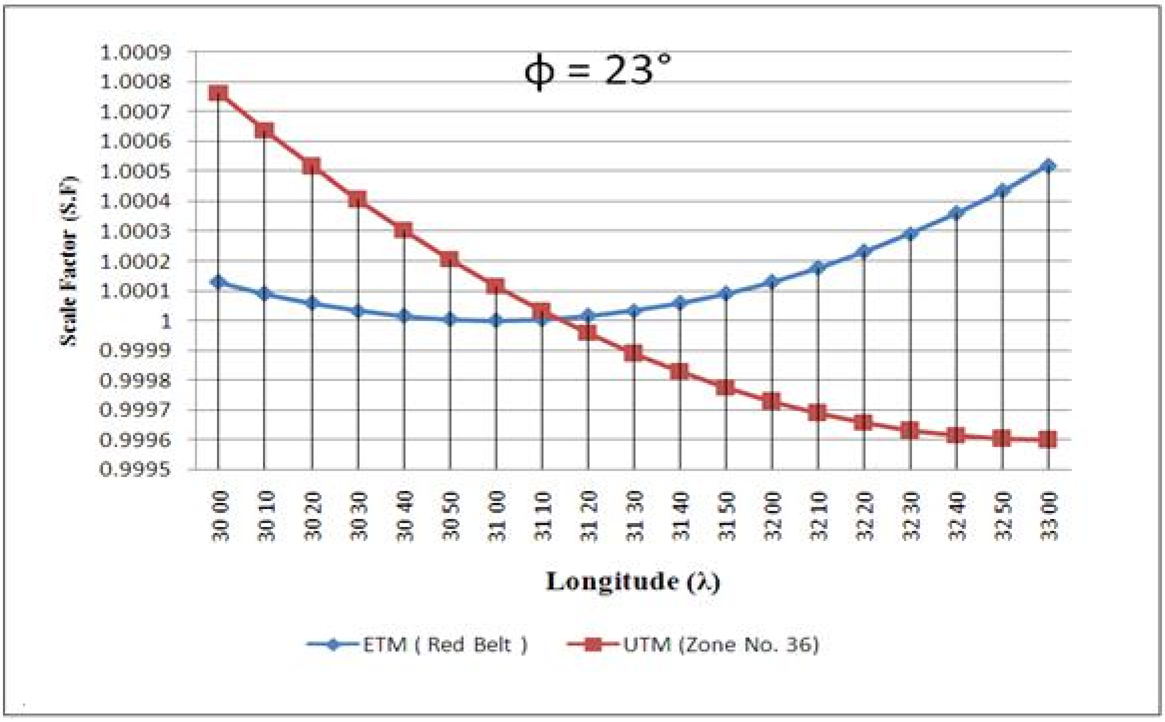

Figure 6: Scale Factors Relation between ETM (Red Belt) and UTM (Zone No. 36) [ϕ = 23°].

Form Figure 6, When latitude ϕ = 23° and longitudes (λ) starts from 30° to 33°, it can be seen that;

a. For UTM (Zone 36), the maximum value of the S.F = 1.0007613 at the West edge of the zone (λ = 30°) and the minimum value of the S.F = 0.9996000 at central meridian (λ = 33°).

b. The relations between longitudes (λ) and S.F for ETM (Red Belt) projection System can be divided to two sections:

- **The first section:** (λ) starts from 30° to 31° (the central meridian of the zone), the maximum value of the S.F = 1.0001292 and the minimum value of the S.F = 1.0000000.
- **The second section:** (λ) starts from 31° to 33° (the East edge of the zone), the maximum value of the S.F = 1.0005169 and the minimum value of the S.F = 1.0000000.

c. When λ = 30° at the West border of UTM (Zone 36), the ETM S.F is smaller compared with UTM S.F. the difference = 0.00063 which is correspond to 6.3/10000 accuracy.

d. When λ = 33° at the East border of ETM (Red Belt), the UTM S.F is small compared with ETM S.F. the difference = 0.00092 which is correspond to 9.2/10000 accuracy.

e. The two scale factors (S.F.) are equal at (ϕ = 23°, λ = 31° 14`) which close approximately to Toshka Lakes as shown in Figure 8.

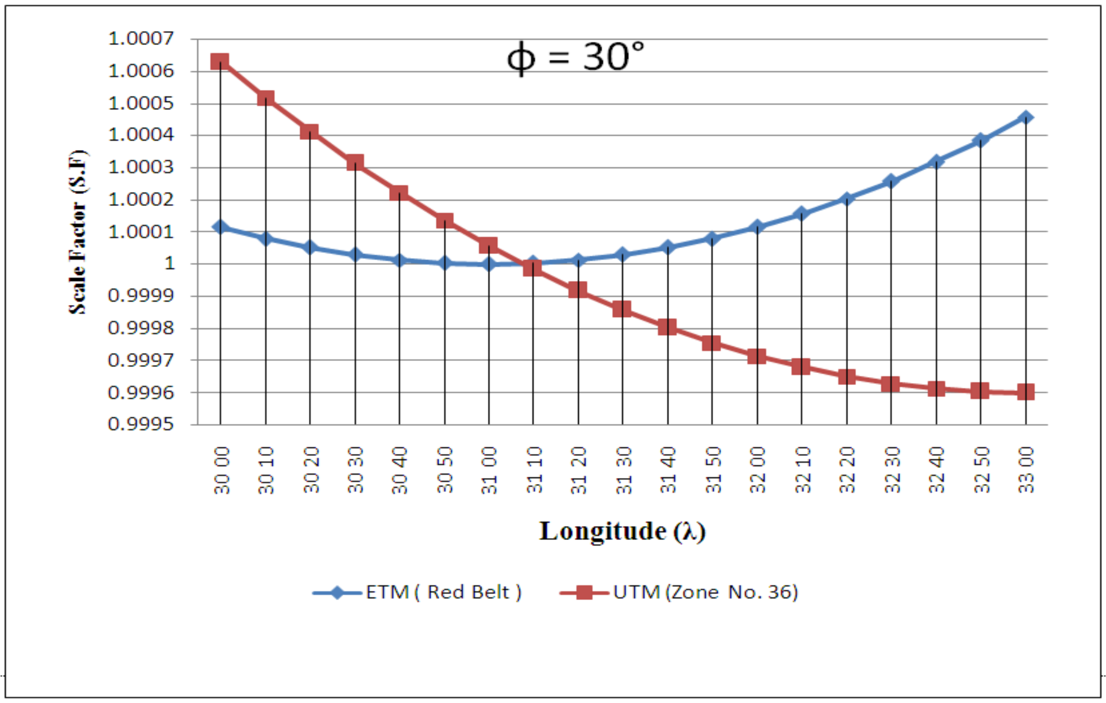

Figure 7: Scale Factors Relation between ETM (Red Belt) and UTM (Zone No. 36) [ϕ = 30°].

Form Figure 7, When latitude ϕ = 30° and longitudes (λ) starts from 30° to 33°, it can be seen that;

A. For UTM (Zone 36), the maximum value of the S.F = 1.0006283 at the West edge of the zone (λ = 30°) and the minimum value of the S.F = 0.9996000 at central meridian (λ = 33°).

B. The relations between longitudes (λ) and S.F for ETM (Red Belt) projection System can be divided to two sections:

- **The first section:** (λ) starts from 30° to 31° (the central meridian), the maximum value of the S.F = 1.0001144 and the minimum value of the S.F = 1.0000000.
- **The second section:** (λ) starts from 31° to 33° (the East edge of the zone), the maximum value of the S.F = 1.0004578 and the minimum value of the S.F = 1.0000000.

C. When λ = 30° at the West border of UTM (Zone 36), the ETM S.F is smaller compared with UTM S.F. the difference = 0.00051 which is correspond to 5.1/10000 accuracy.

D. When λ = 33° at the East border of ETM (Red Belt), the UTM S.F is small compared with ETM S.F. the difference = 0.00086 which is correspond to 8.6/10000 accuracy.

E. The two scale factors (S.F.) are equal at (ϕ = 30°, λ = 31° 08`) which close approximately of Giza Governorate as shown in Figure 8.

The geodetic coordinates for the equalizers points, signed to the Egypt's map by Google Earth software, are demonstrated in Figure 8.

Figure 8: Locations when ETM and UTM Scale Factors are equal for Red Belt Zone in Egypt.

5 CONCLUSIONS

This paper presents the Scale Factors (S.F.) at two different map projections systems, Egyptian Transverse Mercator (ETM) and Universal Transverse Mercator (UTM). The projected coordinates (E, N) in ETM (Red Belt) and UTM (Zone 35 and Zone 36) systems were calculated for 25 points using $\phi = 23°$ and 25 points using $\phi = 30°$ and longitudes (λ) starts from 29° to 33° (Red Belt) with 0°10` interval. The Scale Factors (S.F), for each of ETM and UTM systems, were calculated and presented for the 50 points in Egypt.

In red belt zone the ETM S.F range from 1.0000 to 1.000519. in the same region the UTM S.F range from 0.9996 to 1.00076 these scale factors must be consider when dealing with maps or projection coordinates (E, N), otherwise errors reach 7.6/10000 can occurred.

For the same points scale factors are different for the two projections systems used in Egypt (ETM) and (UTM). Ignoring this fact when converting coordinates from one system to the other can led to large errors. The relation between the two scale factors calculated for Red Belt zone at two latitudes $\phi = 23°$ N and $\phi = 30°$ N have been studied. The main conclusions for this study can be summarized as follows;

I) <u>In the range (λ) from 29° to 30°:</u>

i. When $\lambda = 29°$ at the West border of Red Belt, the ETM S.F is larger than UTM S.F by 0.000400 at both of $\phi = 23°$ and 30°.

ii. When $\lambda = 30°$ at the East border of UTM (Zone 35), the ETM S.F is smaller than UTM S.F by 0.00063 and 0.00051 when $\phi = 23°$ and 30° respectively.

II) <u>In the range (λ) from 30° to 33°:</u>

i. When $\lambda = 30°$ at the West border of UTM (Zone 36), the ETM S.F is smaller than UTM S.F. by 0.00063 and 0.00051 when $\phi = 23°$ and 30° respectively.

ii. When $\lambda = 33°$ at the East border of Red Belt, the ETM S.F is larger than UTM S.F. by 0.00092 and 0.00086 when $\phi = 23°$ and 30° respectively.

Finally, the results of this paper have potential since the users can find directly the effect of S.F. distortion of ETM and UTM systems in Egypt when needs to convert the coordinates between both systems.

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