MEAN SEA LEVEL HEIGHT AND ELLIPSOID HEIGHT AS THE THIRD DIMENSION OF THE CLARKE 1880 ELLIPSOID ON ADINDAN DATUM AND THEIR EFFECT ON THE DATUM TRANSFORMATION PARAMETERS

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Abstract: Through this paper the author is aiming to test the mean sea level height which is the third dimension of the Sudan national network coordinates, for the similetery datum transformation instead of the ellipsoid height of the Clarke 1880 ellipsoid. The optimal case is to use the ellipsoid height, but the Clarke 1880 ellipsoid of Adindan-Sudan datum coordinates are two dimensional, because the height which is the third dimension is related to the mean sea level. The surface of the mean sea level approximates the Geoid surface and the vertical height relative to the irregular geoid surface is different from the height related to the ellipsoid. Then accordingly an iterated ellipsoid heights were established by smoothing the geoid surface to approximate the shape of the surface of the ellipsoid. This paper is aiming to evaluate the Adindan (Sudan) mean sea level height by comparing it with the iterated new Clarke 1880 ellipsoid coordinates and with the parameters determined by the American National Imagery and Mapping Agency (NIMA). After the comparison took place it was concluded that the iterated ellipsoid height and the mean sea level height of Adindan Sudan datum had shown the same transformation parameters.

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1. INTRODUCTION

Geodesy begins with measurements from control points. Geometric geodesy measures heights and angles and distances on the earth. For the Global Positioning System (GPS), the control points are satellites and the accuracy is phenomenal. But even when the measurements are reliable, we make more than absolutely necessary. Mathematically the positioning problem, is over determined. There are errors in the measurements. The data are nearly consistent, but not exactly. An algorism must be chosen (very often it is least squares) to select the out put that best satisfies all the inconsistent and overdtermined and redundant (but still accurate) measurements [3]. In areas overlapping geodetic triangulation networks, each computed on a different datum, the coordinates of the points given with respect to one datum will differ from those given with respect to the other. The differences occur because of the different ellipsoids used and the different deflections of the vertical and geoid separations. The latitude and longitude components of the absolute deflection at the initial points result in a parallel shift between the systems. Such a shift is due to the fact that the minor axis of the various reference ellipsoids do not coincide with the rotation axis of the earth. In addition, deflection errors in azimuth cause a relative rotation between the systems. Finally, a difference in the scale of horizontal control may result in a stretch in the corresponding lines of the geodetic nets. Transformation between coordinate systems are routinely carried out in surveying. If the coordinates are given for a number of stations common to both coordinate systems, the transformation parameters can be estimated from a least squares solution. When measuring with GPS there is usually a need for a transformation because GPS measures coordinates on a different system to that used in any one particular country. Therefore the results obtained from GPS need to be transformed into the local coordinate system. So as to have a unified network connecting the survey control networks dedicated in Sudan to the Dams projects along and around the Nile river and its tributaries, a set of 10 reference sites regularly spread over the covered area (From Hlfa city at the Northern boarder of Sudan to Kosti city at the Southern Border) have been selected and implemented. This reference network was designed in agreement with the Sudan Dam Implementation Unit (DIU). To ensure a better reliability of the network in terms of durability, 2 safeguard points were set up for each reference site. Based on the GPS observations of these points processed with some International GPS service for geodynamics (IGS) permanent stations data, a new Reference Frame was defined related to the IGS05 reference frame. The coordinates were expressed at epoch 2005.0 using a conventional African plate rotation model. In order to have a transformation model between the new reference frame and the Adindan (Sudan local datum related to Clarke 1880 ellipsoid), thirteen trigonometric points with their local (Adindan –Clarke 1880 ellipsoid) coordinates were observed in static mode with geodetic GPS (WGS84) relative to reference points. Anew ellipsoid was established replacing the old two dimensional Clarke 1880 ellipsoid so as to have a new ellipsoid height instead of the mean sea level (trigonometric) height. The thirteen points with their common (local and WGS84) coordinates have been used for determination of the transformation parameters. The parameters determined were compared with National Imagery and Mapping Agency (NIMA) parameters [9]. Through this paper this paper the author is intending to evaluate the mean sea level height as the third dimension of the Clarke 1880 ellipsoid on Adindan (Sudan) datum relative to the parameters of the Clarke 1880 with the new ellipsoid height on Adindan (Sudan datum) which was evaluated relative to NIMA in a previous research paper [9].

2. DATUMS

In geodesy two types of datums must be considered a horizontal datum which forms the basis for the computation of horizontal control surveys in which the curvature of the earth is considered, and a vertical datum to which elevations are referred. In other words, the co-ordinates for points in specific geodetic surveys and triangulation networks are computed from certain initial quantities (datums).

2.1 Horizontal geodetic datums

A horizontal datum consist of the longitude and latitude of an initial point (origin);an azimuth of a line (direction);the parameters (a and f) of the ellipsoid selected for the computations; and the geoid separation at the origin. a change in any of these quantities affect every point on the datum. For this reason, while positions with in a system are directly and accurately relatable, data such as distance and azimuth derived from computations involving geodetic positions on different datums will be in error in proportion to the difference in the initial quantities.

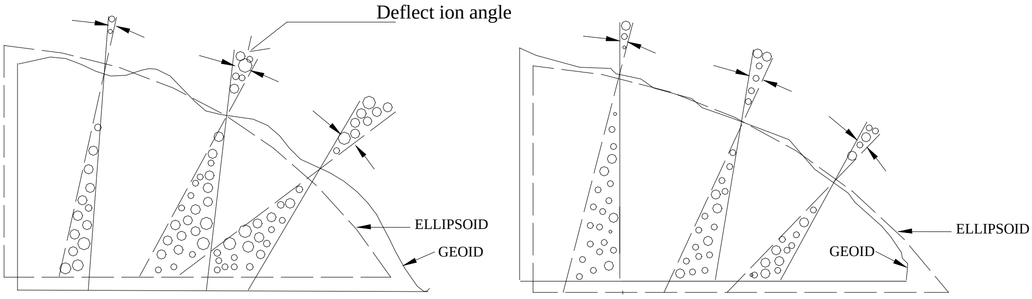
2.1.1 Orientation of ellipsoid to geoid

2.1.1.1 Single astronomic position datum orientation

Selection of the reference ellipsoid provides the radius and flattening factors. The simplest mean of obtaining the other three factors to establish the geodetic datum is to select a first order triangulation station, preferably one located near the centre of a triangulation net work, to serve as the datum origin. Then the astronomical co-ordinates of the station and the astronomical azimuth of a line from the station to another control station are observed. The observed astronomical co-ordinates and azimuth are adopted without any correction as the geodetic co-ordinates and azimuth of the datum origin on the reference ellipsoid [2]. Further, the geoid and ellipsoid are assumed to coincide at that point. . This means that the deflection of the vertical and the separation between the ellipsoid and geoid are defined as zero at the origin. By using this method of orientation, the normal to the ellipsoid is arbitrary made to coincide with the plumb line at the datum origin.Although the computed positions will be correct with respect to each other in this type of orientation, the entire net will be shifted with respect to the axis of the earth. This is not significant for local use of the positions but may introduce large systematic errors as the survey is expanded. It should be noted that although the deflection and undulation are defined as zero at the origin, deflections will occur at other positions with in the network. Therefore, when comparing the geodetic latitude and longitude of any other point in the net with the corresponding astronomical latitude and longitude of that point , discrepancies will appear between the two sets of values. A datum oriented by a single astronomical point may produce large systematic geoid separations [2] . The ellipsoid is not earth-centred and its rotation axis is not coincident with the axis of the earth. The inconvenience of such an orientation is that the positions derived from different astronomical oriented datums are not directly comparable to each other in any geodetic computation.

2.1.1.2 Astronomical- geodetic orientation

The deflections of the vertical at a number of Laplace stations can be used for a second type of datum orientation known as the astro-geodetic orientation. In an orientation of this type, a correction is made at the origin (initial point) which in effect reduces the sum of the squares of the astro-geodetic deflections at all the Laplace stations to a minimum (Fig. 1). One of the Laplace stations in the adjustment is arbitrarily selected as the origin [2]. The deflection of the vertical (the angle between the plumb line and the normal to the ellipsoid) is usually resolved into a north-south component which is equal to the different between astronomic and geodetic latitude; and east-west component proportional to the difference between astronomical and geodetic longitude. The Laplace equation provides a mean of reconciling the azimuth differences resulting from the use of two separate reference surfaces. Laplace stations are introduced into triangulation adjustments to control the azimuth and orient the ellipsoid. Therefore instead of a zero deflection at the origin as with a single astronomic position, there is a deflection of the vertical. Similarly, the geoid separation can be determined at the origin and the ellipsoid reoriented so that a best average fit is provided for the ellipsoid and the geoid in the area of the Laplace stations used. Consequently, astro-geodetically oriented datums are applicable over larger areas than those oriented by a single astronomic position. The astronomic-geodetic orientation has the disadvantage that the deflections of the vertical remain relative. If the ellipsoid is changed, the deflections of the vertical will also change. Secondly, it is necessary to assume a specific orientation of the reference ellipsoid with respect to the geoid before computing the astro-geodetic deflections (Fig.4.3). The orientation is fixed by the initial values of the datum origin from which the geodetic co-ordinates were computed,. Any change in these initial quantities will change the deflection of the vertical at each point . Consequently, the astro-geodetic deflection of the vertical depend upon a specific geodetic datum and the use of geodetic data developed by this method is limited to relatively small areas[2].



Note that: a change in ellipsoid orientation
has changed the astro-geodetic deflections.

Fig. 1: Astro-Geodetic deflections are relative.

2.1.1.3 Discrepancies between datums

In areas overlapping geodetic triangulation networks, each computed on a different datum, the co-ordinates of the points given with respect to one datum will differ from those given with respect to the other. The differences occur because of the different ellipsoids used and the different deflections of the vertical and geoid separations. The latitude and longitude components of the absolute deflection at the initial points result in a parallel shift between the systems. Such a shift is due to the fact that the minor axis of the various reference ellipsoids do not coincide with the rotation axis of the earth. In addition, deflection errors in azimuth cause a relative rotation between the systems. Finally, a difference in the scale of horizontal control may result in a stretch in the corresponding lines of the geodetic nets.

The discrepancies are generally larger between datums oriented by a single astronomical point than those with an astro-geodetic orientation [2].

In view of the initial point translation, the azimuth rotation, and the horizontal scale differences; the computation of geodetic information from one datum to another unconnected datum is quite impossible. Regardless of the accuracy of the individual datums for computation within themselves, there is no accurate way to perform distance and azimuth computations between unconnected geodetic systems.

With the development of both intermediate and long range weapons systems, geodetic problems have become more critical than ever before. To satisfy military requirements, it is necessary to provide detailed cartographic coverage of areas of strategic importance and to accomplish geodetic computations between theses areas and lunch sites which are often on unrelated datums. Both of these requirements necessitate unification of major geodetic datums by one or a combination of existing methods.

2.2 Vertical datums

Just as horizontal surveys are referred to specific datums, vertical surveys are also related to an initial quantities or datums. As already noted, elevations are referred to the geoid because the instruments used either for differential or trigonometric levelling are adjusted with the vertical axis coincident to the local vertical. As with horizontal datums, there are many discrepancies among vertical datums. There is never more than 2 metres variance between levelling nets based on different mean sea level datums; however, elevations in some areas are related to surfaces other than geoid.

3. LOCAL COORDINATE SYSTEM

When the term “local co-ordinate system” is used it usually means a co-ordinate system used by a particular country or part of a particular country. Such co-ordinate system usually give co-ordinates in term of Eastings (x -axis), Northing (z -axis) and heights above sea level (orthometric heights) with reference to a map projection. Local or Grid co-ordinate systems are normally based on a plane grid. However, the earth may be more accurately described as an ellipsoid and therefore, the curvature of the ellipsoid must be taken into account. For this reason, local grid co-ordinate systems always have some defining parameters that allows them to be directly related to this imaginary ellipsoidal surface that approximates to the shape of the earth. Local ellipsoids are so called because they normally only apply to a certain specific area of the earth's surface. This is due to the fact that most were defined many years ago before the advent of modern space measuring techniques and whilst adequately approximating to the country or continent in which they were defined, they do not adequately approximate to the earth's shape as a whole. Thus the local ellipsoid used for a particular country or group of countries on the earth's surface. Ellipsoids that better approximate the earth's surface have only been defined in recent years since the advent of modern space techniques. GPS measurements will be made with reference to World Geodetic System 1984 (WGS84) ellipsoid. There is therefore a requirement for the results produced by geodetic GPS software to be transformed from the WGS 84 ellipsoidal system to the local ellipsoidal system. Points defined on an ellipsoidal system (local or WGS84) are not given coordinates in the same way as the same points defined on Local Grid system. There are two methods for defining points on an ellipsoidal system . The first and most commonly used is by latitude, longitude, and height. The second (and more useful in terms of transforming coordinates), is by X,Y and Z coordinates from the origin of the ellipsoid. This is known as Cartesian system and is the system used during datum transformation.

Table 1: Clarke 1880 ellipsoid parameters.

Paramètre	**Symbole**	**Value**
Equatorial radius of the Earth	A	6378249.145 m
Semi minor axis (polar radius)	B	6356514.8695 m
first excentricity	e^2	0. 006803511283
Flattening	F	1 : 293.465

3. 1 Adindan Datum Definition

Adindan datum is the historical local datum of Sudan that all triangulation and traverse network observations in Sudan has subsequently been reduced to it. Adindan base terminal ZY was chosen as the origin of 22º 10' 7.1098" latitude (North) and 31º 29' 21.6079" longitude (East), with azimuth of 58º 14' 28.45" from the north to YY.ZY is now about 10 meters below the surface of Lake Nasser at the Northern boarder of Sudan. On the other hand, Clarke 1880 is that ellipsoid of a semi major axis of 6378249.145m, and 293.465 reciprocal of the flattening (1/f) (see table 3).

4. SATELLITE DATUMS

Satellite datums, on the other hand, are global in nature and defined by:

(a) Physical (or dynamic) models such as the adopted gravity field model of the earth, models for the other satellite perturbing forces [7]), and fundamental constants such as GM (gravitational constant times the earth's mass), rotation rate of the earth, velocity of light, etc.

(b) Geometric models such as the adopted co-ordinates of the satellite tracking stations used in the orbit determination procedure and the models of precision, nutation, polar motion, etc.

In essence, the satellite datum is defined by the above mentioned models and maintained by the satellite ephemerides (the coordinates of the orbiting " trig stations ") expressed in an earth-fixed reference system.

4.1 GPS datum

During the initial deployment and testing phase of GPS, the Broadcast ephemerides and post-processed ephemerides computed by the U.S. Department of Defence have been given nominally in the WGS72 system (King, 1985). Beginning in October 1985, both sets of ephemerides are computed in the new World Geodetic System 1984 (WGS84). The new system incorporates an improved gravity field model, an origin much closer the geocenter, and an improved set of station co-ordinates. WGS-84 define a global reference system the accuracy and consistency of which is more than adequate for most surveying applications [7]. However, the precise transformation relationship between WGS-84 and a particular local geodetic datum will need to be established.

Table 2: Geodetic Reference System 1980 (GRS80) parameters.

Paramètres	**Symbole**	**Value**
Equatorial radius of the Earth	A	6378137.0 m
Geocentric gravitational constant (including the atmosphere)	**GM**	$3986005 \cdot 10^{8}$ $m^{3}s^{-2}$
dynamical form factor (excluding permanent tides)	J_2	$108263 \cdot 10^{-8}$
Angular velocity of the Earth	**W**	$7292115 \cdot 10^{-11}$ rad s^{-1}
seminor axis (polar radius)	**B**	6356752.3141 m
first excentricity	e^2	0.00669438002290
Flattening	F	1 : 298.257222101

Table 3: Primary parameters of WGS-84.

PARAMETER	NAME	WGS-84
Semi-major axis	A	6378137 m
Flattening	F	1/298.257223563
Angular velocity	ω	7292115 x10 $^{-5}$ rad s $^{-1}$
Geocentric gravitational constant (Mass of earth's atmosphere included)	GM	398600.5 km ^{3} s^{-2}
Normalized 2nd degree zonal harmonic Coefficient of the gravitational potential	$\bar{C}_{20}$	-484.16685 x 10 $^{-6}$

5. PREVIOUS INVESTIGATIONS [9]

5. 1 Data involved through the previous study

5.1.1 Adindan (Sudan) input coordinates

Thirteen trigonometric points were observed in order to calculate a 3-dimensional transformation between Adindan and the Sudanese new reference points coordinates expressed in IGS05 in Sudan. They are 13 first order pillars. Their Adindan coordinates were collected as coordinates of table 5. The third dimension of table 5 (height) is a mean sea level height which is approximately equal to the geoid height. But the intended height for the establishment of the transformation parameters is the ellipsoid height and the Adindan datum of the Clarke 1880 ellipsoid has no ellipsoid height. For this reason there were a new ellipsoid heights have been determined by iterating and smoothing the Clarke 1880 ellipsoid coordinates with their mean sea level height. In other words the "Height" coordinate is an altitude for most of the points. Since the Adindan system is a bi dimensional one, and since we used a 3 Dimensional Helmert transformation model to estimate transformation parameters, we used an iterative process to have computed Adindan ellipsoid heights. The horizontal coordinates and their ellipsoid height were shown in table 6. The geodetic ellipsoid of the Adindan reference system is Clarke 1880 (English) whose features are as in table 3.

Table 4: The Adindan (Sudan) triangulation coordinates (on Clarke 1880 ellipsoid) selected for the transformation parameters computation (the heights are mean sea level height not ellipsoid height).

	North latitude (degrees minutes seconds)	East longitude (degrees minutes seconds)	Height (m)
G002	21 52 20.510	31 21 56.991	327.50
G018	19 26 34.591	30 21 31.043	298.30
G021	19 02 29.974	30 16 25.315	373.50
G036	17 50 25.970	31 19 55.063	355.50
G214	16 10 30.625	32 35 55.768	479.80
G216	16 14 52.314	32 40 38.867	549.30
G217	16 14 31.862	32 40 51.838	407.32
G218	16 09 49.097	32 45 20.063	434.04
G247	14 37 41.997	35 44 03.440	523.37
G249	14 23 18.194	35 56 53.216	578.20
G652	13 14 33.620	33 05 57.000	501.90
G901	12 34 46.251	34 05 56.010	450.06
G905	12 49 01.230	33 58 56.099	441.22

5.2 ITERATIVE COMPUTATION OF ADINDAN (CLARKE 1880 ELLIPSOID) HEIGHT

The process used was as follows:

First, pseudo Cartesian Adindan coordinates using he = H (altitude) was processed. From this set and from Sudan new geodetic reference set the three translation parameters were calculated. Using this temporary 3 translation parameters to transform Sudan new geodetic reference Points into Adindan + he , then Adindan new ellipsoid heights. The obtained new ellipsoid heights can be seen in table 6. From these computed heights and their original Adindan plane coordinats the final Cartesien Adindan coordinates were obtained and used to compté the final three translation parameters between the Sudan knew WGS84 datum network and the Adindan reference frame (table 7).

5.3 ADINDAN OUTPUT COORDINATES

So as to decide which set of parameters we keep to realise an Adindan (with new ellipsoid height) reference frame, we performed some coordinates comparisons between the use of the four computed parameters (three translations and one scale factor), the three computed ones (three translations) and the three translations ones published by the NIMA.

Table 5: The Adindan (Sudan) triangulation coordinates (on Clarke 1880 ellipsoid) selected for the transformation parameters computation (the height is new Clarke 1880 ellipsoid height).

	North latitude	East longitude	Height
	(degrees minutes seconds)		(m)
G002	21 52 20.510	31 21 56.991	333.552
G018	19 26 34.591	30 21 31.043	304.083
G021	19 02 29.974	30 16 25.315	380.073
G036	17 50 25.970	31 19 55.063	358.491
G214	16 10 30.625	32 35 55.768	480.614
G216	16 14 52.314	32 40 38.867	549.834
G217	16 14 31.862	32 40 51.838	407.737
G218	16 09 49.097	32 45 20.063	434.357
G247	14 37 41.997	35 44 03.440	517.333
G249	14 23 18.194	35 56 53.216	567.736
G652	13 14 33.620	33 05 57.000	500.504
G901	12 34 46.251	34 05 56.010	447.070
G905	12 49 01.230	33 58 56.099	438.107

Table 6: Adindan new ellipsoid Cartesian coordinates.

	X (m)	Y (m)	Z (m)
G002	5056757.910	3082520.434	2361227.297
G018	5192006.595	3041094.212	2109566.633
G021	5209212.927	3040811.309	2067654.260
G036	5188066.299	3158359.100	1941533.117
G214	5162483.107	3301396.446	1765331.968
G216	5156112.687	3307302.221	1773075.546
G217	5155937.897	3307647.757	1772432.219
G218	5153693.500	3315675.787	1764093.062
G247	5011106.410	3605394.598	1600331.833

G249	5003040.086	3628003.915	1574642.485
G652	5202482.046	3391347.557	1451536.300
G901	5156050.122	3490762.917	1380015.242
G905	5158349.719	3477026.187	1405643.756

Table 7: The GPS Geographic Coordinates (observed relative to Sudan IGS network epoch 2005.0)

	latitude (degrees minutes seconds)	longitude (degrees minutes seconds)	Ellips. Height (m)
G002	N 21 52 20.547455	E 31 21 59.451795	337.4061
G018	N 19 26 35.336135	E 30 21 33.371423	306.2209
G021	N 19 2 30.829160	E 30 16 27.620929	381.9369
G036	N 17 50 27.136189	E 31 19 57.459552	360.9299
G214	N 16 10 32.295922	E 32 35 58.276118	483.3360
G216	N 16 14 53.963890	E 32 40 41.382692	552.7296
G217	N 16 14 33.513467	E 32 40 54.354368	410.6173
G218	N 16 9 50.770628	E 32 45 22.585886	437.2637
G247	N 14 37 44.108464	E 35 44 6.241140	522.6840
G249	N 14 23 20.350000	E 35 56 56.054621	573.1138
G652	N 13 14 36.126770	E 33 5 59.593503	500.6076
G901	N 12 34 48.880116	E 34 5 58.653640	447.5745
G905	N 12 49 3.751063	E 33 58 58.721626	438.7897

Table 8: The GPS Cartesian Coordinates (observed relative to Sudan IGS network epoch 2005.0)

	X (m)	Y (m)	Z (m)
G002	5056596.5900	3082504.8393	2361429.8197
G018	5191844.7290	3041078.1182	2109770.8792
G021	5209051.1856	3040794.9725	2067858.5289
G036	5187904.4037	3158343.1591	1941737.2272
G214	5162320.4785	3301380.8894	1765537.4975
G216	5155950.0611	3307286.6654	1773281.1038
G217	5155775.2540	3307632.2034	1772637.7713
G218	5153530.8379	3315660.2623	1764298.6274
G247	5010942.8006	3605380.1620	1600538.0991
G249	5002876.2239	3627990.1446	1574848.0210
G652	5202318.3388	3391334.0501	1451741.1175
G901	5155887.2204	3490749.0003	1380217.9958
G905	5158187.2645	3477012.0684	1405845.4032

5.4 HELMERT TRANSFORMATION

Helmert transformations parameters were calculated between the GPS Cartesian Coordinates (observed relative to Sudan IGS network epoch 2005.0) set (see table 9) and the Adindan new ellipsoid Cartesian coordinates (table 8), using the GPS Bernese Software. Processed results were estimated three different sets of parameters: -3 translations -3 translations and one scale factor -3 translations, one scale factor and 3 rotations. The complete outputs are given in the tables 10, 11 and 12. The residuals are at the few meter level. This is accurate enough to enable the localization of points in the existing maps of Sudan.

Table 9: Three Translations parameters

3 Translations parameters		
RMS OF TRANSFORMATION :		**1.0906 M**
PARAMETERS:		
TRANSLATION IN X	**:**	**-162.6090 +- 0.3025 M**
TRANSLATION IN Y	**:**	**-15.0696 +- 0.3025 M**
TRANSLATION IN Z	**:**	**204.4903 +- 0.3025 M**

Table 10: Three Translation parameters and one scale factor

3 Translations parameters and One scale factor		
RMS OF TRANSFORMATION :		**1.0745 M**
PARAMETERS:		
TRANSLATION IN X	**:**	**-168.9711 +- 4.4197 M**
TRANSLATION IN Y	**:**	**-19.1788 +- 2.8637 M**
TRANSLATION IN Z	**:**	**202.3027 +- 1.5452 M**
SCALE FACTOR	**:**	**1.2381 +- 0.8581 MM/KM**

Table 11: Three Translations parameters, one scale factor and 3 rotations

3 Translations parameters, one scale factor and 3 rotations

RMS OF TRANSFORMATION : 0.9241 M

PARAMETERS:

TRANSLATION IN X : -169.6582 +- 9.8029 M
TRANSLATION IN Y : -18.7252 +-10.8578 M
TRANSLATION IN Z : 203.4487 +- 8.2775 M
ROTATION AROUND X-AXIS: - 0 0 0.46570 +- 0.15653 "
ROTATION AROUND Y-AXIS: - 0 0 0.34679 +- 0.29870 "
ROTATION AROUND Z-AXIS: - 0 0 0.14192 +- 0.42728 "
SCALE FACTOR : 1.2381 +- 0.7380 MM/KM

6. THE (PREVIOUS RESEARCH) ACCURACY [9]

The accuracy of the points was taken from the final combination of the standard deviation. For the tied points (Adindan triangulation points with the new ellipsoid heights) it can be considered as a relative accuracy to the Sudan knew WGS84 datum network reference points. Since the observations sessions are quite homogeneous (4 hours for the points observation) and the processing strategy is the same, the accuracies are almost the same in each group of points. The accuracy of Adindan triangulation Points with the new ellipsoid heights are given in table 13 .

Table 12 : The accuracy of Adindan triangulation Points with the new ellipsoid heights .

Point	sX (mm)	sY (mm)	SZ (mm)
G002	4.3	3.5	2.6
G018	3.8	2.6	1.9
G021	3.9	2.4	1.9
G036	4.2	3.0	1.9
G214	4.2	3.0	1.7
G216	4.2	3.0	1.8
G217	3.5	2.7	1.6
G218	5.1	3.3	2.1

G247	4.1	3.4	1.7
G249	4.1	3.4	1.7
G652	4.3	3.1	1.6
G901	4.3	3.5	1.5
G905	4.7	3.7	2.1

7. THE (PREVIOUS RESEARCH) RESULTS AND ANALYSIS [9]

So as to decide which set of parameters we keep to realise an Adindan reference frame, we performed some coordinates comparisons between the use of the 4 computed parameters (3 translations and one scale factor), the 3 computed ones (3 translations) and the 3 translations ones published by the NIMA. NIMA translation parameters (shown in table 14) compared to the three translation parameters (table 10 and 15) and the three translation parameters plus one scale factor (table 11) .

Table 13: NIMA translation parameters

From	To	Tx (m)	Ty (m)	Tz (m)
"WGS84"	Adindan	**161**	**14**	**-205**

Table 14: WGS to Adindan- Sudan (with new ellipsoid height) translation parameters

From	To	Tx (m)	Ty (m)	Tz (m)
"WGS84"	Adindan	**162.6**	**15.1**	**-204.5**

Coordinates comparison between NIMA (WGS84 to Adindan) three translations parameters model and (WGS84 to new Adindan ellipsoid) three translations computed model of (table 16 column 2 and 3), and between NIMA (WGS84 to Adindan) three translations parameters model and (WGS84 to new Adindan ellipsoid) three translations and one scale factor computed model (table 16 column 4 and 5).

Table 15; Comparison between NIMA (WGS84 to Adindan (Sudan)) translation parameters coordinates and (WGS84 to Adindan (Sudan) new ellipsoid) translation coordinates.

	3 translations		3 translations One scale factor	
Point number	DE (m)	DN (m)	DE (m)	DN (m)
G002	0.103	-0.259	0.265	-1.031
G018	0.138	-0.175	0.435	-0.616
G021	0.141	-0.161	0.45	-0.547
G036	0.107	-0.119	0.279	-0.338
G214	0.064	-0.061	0.07	-0.051
G216	0.062	-0.063	0.058	-0.063
G217	0.061	-0.062	0.057	-0.062
G218	0.059	-0.06	0.045	-0.049
G247	-0.042	-0.007	-0.454	0.213
G249	-0.049	0.002	-0.49	0.255
G652	0.048	0.042	-0.013	0.454
G901	0.014	0.065	-0.181	0.568
G905	0.018	0.057	-0.161	0.527

Taking into account that in the three different sets of parameters the residuals are similar (about 1-2 meters), it is proposed to keep the three Translations parameters model for the following reasons :

a) there is no enough information to estimate rotations parameters
b) it keeps the consistency of the WGS84 network
c) there have no information to have reliable ellipsoid height
d) the network doesn't cover all Sudan
e) they are close to those computed by the NIMA

8. CONCLUSIONS (OF THE PREVIOUS RESEARCH) [9]

8.1 SMALL SCALE MAPS:

The project distance (measured directly on maps) between one point near Wadi Halfa (Town at the Northern boarder of Sudan (400 000, 2 400 000, UTM Adindan) and one point near Roseries (Town at the South- West of Sudan 600 00, 1 300 000 UTM Adindan) is 1147562.634 m in UTM Adindan and 1147562.069 m in UTM Sudan new geodetic reference. This difference of 57 cm for a distance longer than 1000 km can not be seen on any map.

8.2 LARGE SCAL MAPS

The project distance (measured directly on maps) between one point near Wadi Halfa (Town at the Northern boarder of Sudan (400 000, 2 400 000, UTM Adindan) and 450 000, 2 400 000 UTM Adindan) is 500.000 m in UTM Adindan and 499.999 m in UTM Sudan new geodetic reference. This difference of 1 mm for a distance of 500 m can not be seen on any map even very large scale map.

9. RESULTS AND ANALYSIS OF THE RUNNING RESEARCH

Using the Adindan datum coordinates of Clarke 1880ellipsoid with mean sea level height in table 4 and the WGS84 coordinates in table 7 the author determined the transformation (between Wgs84 and Adindan – Clarke 1880 with mean sea level height) parameters. The three translation parameters and the scale factor were shown in table 16 where table 17 shows the three translation, rotation around x-axis and the scale factor. Results shows that the parameters (specially the three translations) is very nearly the same as the parameters established using the new ellipsoid height of the Clarke 1880 ellipsoid which was determined previously.

10. COCLUSIONS AND RECOMMONDATIONS OF THE RUNNING RESEARCH

Through the previous research the author determined by iteration the new ellipsoid height for the purpose of the parameters transformation between WGS84 and Adindan Sudan (Clarke 1880 ellipsoid) datum but according to the results above which were showed that the two heights (the new ellipsoid and the mean sea level) are the same three translation parameters, so it is recommended to use the mean sea level height as the third dimension of the Clarke 1880 ellipsoid and their is no need to get and to use the new ellipsoid height.

Table 16 :Parameters using the mean sea level trigonometric height

Parameters	
Translation in X-Axis	-162.612 **+-** .38859 m
Translation in Y-Axis	-15.228 **+-** .38859 m
Translation in Z-Axis	204.646 **+-** .38859 m
Scale factor	-.00002 **+-** .0000019
THE APS VAR	1.9631

Table 17: Parameters using the mean sea level trigonometric height

Parameters	
Translation in X-Axis	-162.612 **+-** .38859 m
Translation in Y-Axis	-15.228 **+-** .38859 m
Translation in Z-Axis	204.646 **+-** .38859 m
Rotation around x	.000001 **+-** .0000011"
Scale factor	-.00002 **+-** .0000019
THE APS VAR	1.9631

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