Digitally Manipulated Topographic Map Scale 1:25000 using Global Positioning System and Geographical Information System on Adindan (Sudan) Datum

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Abstract– **This paper describes a technique for evaluation the planimetric accuracy of 1:25,000 scale maps produced by Sudan Survey Department (SSD). The techniques are based on direct observation of ground control points using Trimble 5700 GPS receiver and arithmetic transformation algorithms. A set of 8 Ground Control Points (GCPs) has been selected inside the study area. The coordinates of all points have been observed by the GPS receiver and their corresponding values have been derived from maps based on the GIS Techniques. The area of the base-maps (scale 1: 25,000), bounded by jebelawlia to Elsheikh Eltieb (South – North) and Jebel Madaha to the University of Khartoum (West – East), was plotted by the analytical plotter BC-2 and scanned by the Scan Plus III 4000T and manipulated by ARC/ INFO (ESRI-GIS software) to check the coordinate values of 8-points using both Adindan (Sudan) and WGS-84 datums. Statistical analysis shows that both GIS transformation and GPS processing produce the same planimetric accuracy.**

Keywords– **GPS, GIS, Datum, SSD, ESRI and Transformation**

I. INTRODUCTION

Two of the most exciting and effective technical developments to emerge in the last decade are the global positioning systems and the phenomenon of the Geographical Information System (GIS). GIS is an extremely broad and complex field, concerned with the use of computers to input, store, retrieve, analyze, and display geographic information. While GPS is also an extremely complex system, it allows you to know where you are by consulting a radio receiver. The accuracies range from as good as a few millimeters to somewhere a round 100 meters, depending on equipment and procedures applied to the process of data collection. More advanced GPS receivers can also record location data transfer to computer memory, so GPS can not only tells you where you are, but also tells you where you were. Thus, GPS can serves as a mean of data input of GISs. Traditionally, GISs got their data from maps and aerial photos. These were either scanned by some automated means or, more usually, digitized manually using a hand-held "puck" to trace map features, the map being placed on an electronic drafting board. The GPS receiver becomes the puck. This approach inverts the entire traditional process of GIS data collection: spatial data come directly from the environment and the map becomes a document of output rather than input.

II. THE GLOBAL POSITIONING SYSTEM (GPS)

The Global Positioning System (GPS) is funded and controlled by the U.S Department of Defense (DOD). While there are many thousands of civil users of GPS worldwide, the system was designed for and is operates by the U.S. military. GPS provides specially coded satellite signals that can be processed in a GPS receiver, enabling the receiver to compute position, velocity and time. Four GPS satellite signals that can be processed in three dimensions and the time offset in the receiver clock. GPS has revolutioned the science of positioning and earth measurement. One part of that revolution is accuracy another part is speed and implicitly, a third part is cost. All of these improvements are contributing to the growth of major applications [6]. The inheritent accuracy of a GPS receiver can be enhanced by careful processing, it is designed by accepting (instead of trying to eliminate) significant sources of error. The GPS measurement yield distance and not angles. Thus it concerns with trilateration rather than triangulation. GPS can be compared to trilateration. Both techniques rely exclusively on the measurement of distances to fix position. One of the differences between them, however, is that the distances, called range in GPS, are not measured to control points on the surface of the earth. Instead they are measured satellites orbiting more than 20,000 km above the earth [1].

III. GEOGRAPHICAL INFORMATION SYSTEM (GIS)

GIS is a computer-based tool for mapping and analyzing things that exist and events that happen on earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes and planning strategies [4].

Map making and geographic analysis are not new, but a GIS performs these tasks better and faster than do the old manual methods. GIS is truly a general-purpose tool. GIS can perform all these operations because it uses geography, or space, as the common key between the data sets. Information is linked only if it relates to the same geographic area. Geographic information contains either an explicit geographic reference, such as a latitude and longitude or national grid coordinate, or an implicit reference such as an address, postal code, census tract name, forest stand identifier, or road name. An automated process called geocoding is used to create explicit geographic references (multiple locations) from implicit references (descriptions such as addresses). These geographic references allow you to locate features, such as a business or forest stand and events such as an earthquake, on the earth's surface for analysis [2].

IV. PROCEDURES

The 8 control points were carefully selected and distributed all over the Khartoum State map sheet with common values in both local (Adindan) and GPS (WGS-84) datum [5]. The Moldensky-Baekas model was used to determine the transformation parameters between GPS (WGS-84) and local (Adindan) datum using the 8 GPS points (Table 7).

The geographical coordinates of the 8 GCPs in each system were transformed into the UTM Cartesian coordinates. This process of transformation (from geographical to UTM) was done, because the analytical plotter BC-2 (precise WILD plotter used in map production from aerial photographs) did not accept the coordinates in geographical form. The UTM values of the 8-points in the two systems (GPS and local) were plotted on the BC-2 sheets produced by (scale 1:25,000). Each of the plotted sheets were scanned by the CALCOMP SCAN PLUS III 400T scanner, to produce grid maps in a raster form, where they could be converted into a vector form. The raster data was converted into a vector form so that it could be handled and manipulated in a GIS environment. The vector map with the 8-points with their corner points stated in geographical coordinates were imported to the ARC/INFO software. Based on the affine transformation algorithm but in ARC/INFO all points (GCPSs) have been transformed into UTM coordinates system [3]. The maps at scale 1:25000 were transformed to the corresponding geographical coordinates and then to their corresponding geocentric coordinates. The transformation for each point was determined using Molodensky-Badekas model, (Table 7).

V. RESULT AND ANALYSIS

Table 1 gives the difference in easting and northing between the actual and the transformation coordinates of the 1:25,000 scale map. Table 2 gives the same values on Adindan datum.

Referring to Table 3, the mean differences in Easting and Northing coordinates between the actual and GIS manipulated map at scale 1:25000 (GPS and Adindan) were very small in Easting (ranging from ± 3.53 m (GPS) to ± 7.03 m (Adindan) and approximately the same in Northing (ranging from ± 41.20m (GPS) to ± 41.47m (Adindan). Referring to same table (Table 3), the easting coordinates are more affected by the projection process.

Table 4 gives the shifts between the two datums using the actual coordinates. Table 5 gives the shifts values using coordinates obtained from 1:25000 scale map. The mean shift values in the three tables (tables 4,5) were summarized in table 6. However the shifts seem to have very small values, which were emphasized by the Molodensky – Badekas model. Transformation parameters are shown in Table 7.

VI. CONCLUSION AND FUTURE RECOMMENDATION

The project maps scale 1:25000 have an allowable error (ranging from ± 35.33 to ± 46.58) compared to the actual observed values. The error in the North direction is approximately the same in both systems (Local and GPS) which is ranging from ± 41.20 m to 41.47 . The error in the Easting is decreased (ranging from ± 3.53 m to 7.03 m). this indicates that the distortion in projected maps is small in Easting of the large scale maps. The shifts parameters between the local and the GPS coordinates are approximately the same with negligible variations (Table 6).

Accordingly it was concluded that the topographical (digitized or scanned) maps have to be transformed to be manipulated by any GIS software, using a checked transformation model. The affine transformation model used by ESRI (ARC/INFO) software showed good results. Moreover using coordinates observed by GPS (WGS – 84 ellipsoid) with a map transformed to a local coordinates, is very important putting in mined the actual datum transformation parameters between Adindan and WGS-84, where the GPS coordinates system is WGS-84, coordinates values.

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Table 1: The difference in Easting and Northing between observed GPS (WGS-84) coordinate values and the coordinates obtained from GIS map scale 1:25000

St.No	EG m	NG m	EG2 m	NG2 m	EG2-GE	NG2-NG
2006	445725.830	1684470.960	445738.281	1684511.000	12.451	40.040
2010	451815.000	1766504.020	451824.875	1766542.625	9.875	38.605
2601	450577.170	1726007.350	450588.438	1726046.750	11.268	39.400
4100	446595.880	1705103.570	446594.594	1705147.125	1.286	43.555
8491	451233.020	1730391.360	451241.563	1730433.125	-8.542	41.765
4102	445734.240	1716473.350	445733.875	1716515.500	-0.365	42.150
2003	425689.550	1709069.080	425689.625	1709109.375	0.075	40.295
2007	447108.500	1740148.070	447110.719	1740191.875	2.219	43.805
The mean value					3.533	41.202

Table 2: The difference in Easting and Northing between the actual Adindan coordinate values obtained fro**m SSD and GIS map scale 1:25000**

St.No.	EA m	NA m	EA2 m	NA2 m	EA2-EA	NA2-NA
006	445654.780	1684259.151	445669.281	1684300.875	14.501	41.724
2010	451743.950	1766291.963	451756.219	1766335.125	12.269	43.162
2601	450506.110	1725795.315	450517.375	1725835.750	11.265	40.435
4100	446524.816	1704891.608	446522.031	1704933.375	-2.785	41.767
8491	451161.968	1730179.310	451174.750	1730218.875	12.782	39.565
4102	445663.192	1716261.385	445665.375	1716302.875	2.183	41.490
2003	425618.493	1708856.944	425619.094	1708895.625	0.601	38.681
2007	447037.433	1739935.951	447042.844	1739980.875	5.411	44.924
The mean value					7.029	41.466

Table 3: The mean of the residual values in Easting and Northing using observed coordinates and coordinates obtained by GIS

Classification of the value Presented	The mean values of difference in Easting and Northing	
	ΔE (m)	ΔN (m)
Observed values obtained from GIS map 1:25,000	EG2 - EG = 3.533 EA2 - EA = 7.029	NG2 - NG = 41.202 NA2 - NA = 41.466
GIS value scales 1: 25,000	EA1 - EA2 = 39.547	NA1 - NA2 = -6.141

Table 4: The difference in Northing and Easting between the actual observed GPS (WGS-84) and Adindan coordinates from SSD

St.No	EG m	NG m	EA m	NA m	EG-EA	NG-NA
2006	445725.830	1684470.960	445654.780	1684259.151	71.050	211.809
2010	451815.000	1766504.020	451743.950	1766291.963	71.050	212.057
2601	450577.170	1726007.350	450506.110	1725795.315	71.060	212.035
4100	446595.880	1705103.570	446524.816	1704891.608	71.064	211.962
8491	451233.020	1730391.360	451161.968	1730179.310	71.052	212.050
4102	445734.240	1716473.350	445663.192	1716261.385	71.048	211.965
2003	425689.550	1709069.080	425618.493	1708856.944	71.057	212.136
2007	447108.500	1740148.070	447037.433	1739935.951	71.067	212.119
The mean value					71.056	212.017

Table 5: The difference in Northing and Easting between GPS (WGS-84) and Adindan coordinates obtained from GIS map scale1: 25000

St.No	EG2 m	NG2 m	EA2 m	NA2 m	EG2-EA2	NG2-NA2
2006	445738.281	1684511.000	445669.281	1684300.875	69.000	210.125
2010	451824.875	1766542.625	451756.219	1766335.125	68.656	207.500
2601	450588.438	1726046.750	450517.375	1725835.750	71.062	211.000
4100	446594.594	1705147.125	446522.031	1704933.375	72.562	213.750
8491	451241.563	1730433.125	451174.750	1730218.875	66.813	214.250
4102	445733.875	1716515.500	445665.375	1716302.875	68.500	212.625
2003	425689.625	1709109.375	425619.094	1708895.625	70.531	213.750
2007	447110.719	1740191.875	447042.844	1739980.875	67.875	211.000
The mean value					69.375	211.750

Table 6: The mean values of the difference in Easting and Northing between GPS(WGS-84) and Adindan datum using observed coordinates and coordinates obtained by GIS

Classification of the value Presented	The mean value of difference in Easting and Northing	
	ΔE (m)	ΔN (m)
Observed(GPS-Adindan)	EG - EA = 71.056	NG - NA = 212.017
GIS(GPS-Adindan) map scale 1: 25000	EG2- EA2 = 69.375	NG2 - NA2 = 211.750

Table 7: Transformation parameters between WGS-84 and Aindan datum using observed, GIS values obtained from maps to scale 1:100000 and 1:25000

Parameters	WGS- 84 to Adindan using observed values	WGS- 84 to Adindan using GIS map scale 1:25000
ΔX (m)	- 158.036 ±□□□□□□	- 157.259 ± 0.751
ΔY (m)	- 17.931 ± 0.013	- 19.279 ± 0.751
ΔZ (m)	209.911 ± 0.013	210.114 ± 0.751
ΔL (ppm)	1.502 ± 0.53	-24.22 ± 30.61
$RX \times 10^2$	- 0.32 ± 0.28	- 5.02 ± 4.55
$RY \times 10^2$	0.44 ± 0.19	- 1.77 ± 11.32
$RZ \times 10^2$	- 0.28 ± .06	-4.49 ± 36.72
σ^2_0	0.00135	4.507