TOPOGRAPHIC MAP SCALE 1:100,000 MANIPULATED DIGITALLY BY GPS AND GIS ON ADINDAN (SUDAN) DATUM

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Abstract: *This paper describes a technique for evaluation the planimetric accuracy of 100,000 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 receivers and their corresponding values have been derived from maps based on the GIS Techniques. The area of the base maps (scale 1: 100,000), 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 (ESRL – 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, Map, SSD, Sudan, ESRI .*

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1. 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 around 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.

2. 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 [4]. 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].

3. 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 [3].

Mapmaking 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].

4. 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. 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 6).

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 1:100,000).

Each of the plotted sheets were scanned by the CALCOMP SCAN PLUS III 400T scanner, to produce grid maps in a raster from, 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. The maps at scale 1:100,000 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 6).

5. RESULT AND ANALYSIS

Table 1 gives the difference in Easting and Northing between observed GPS (WGS-84) coordinate values and the actual coordinates obtained from GIS map scale 1:100,000. The mean of the results (in Easting and Northing) of the GPS coordinates values and the actual GIS manipulated map scale (1:100,000) were approximately in the same range (± 40.54 m in Easting to ± 40.83 m in Northing, (a small and negligible difference because 40 meters on the ground represents 0.4 mm on the map scale 1: 100,000).

Table 2 gives the difference in Easting and Northing between the actual Adindan coordinate values obtained from SSD and GIS map scale 1:100,000. For the coordinates on Adindan datum, the difference in Easting and Northing between the actual coordinates and the GIS map (scale 1:100000) showed a small variation ranging from ± 46.58 m in Easting to ± 35.33 m in Northing, which are also a very small and negligible difference. Accordingly it was shown that the topographic maps at scale 1:100000 and smaller are suitable for GIS manipulation *w*ith a very small and negligible error.

Table 3 gives the shifts between the two datums using the actual coordinates. Table 4 gives the shifts values using coordinates obtained from 1:100000 scale map. the mean shift values in the three tables (tables 3,4) were summarized in table 5. However the shifts seem to have very small values, which were emphasized by the Molodensky-Badekas model.transformation parameter which are shown in Table 6 .

6. CONCLUSION AND FUTURE RECOMMENDATION

The project maps (1:100000) 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 ranged from ± 35.33 m to ± 40.83m (at scale 1:100000). The shifts parameters between the local and the GPS coordinates are approximately the same with negligible variations (Table 5).

Accordingly it was conclude and recommended that the topographical (digitized or scanned) maps which have to be transformed can 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, it is very important to put in mined the actual datum transformation parameters between Adindan and WGS-84, where the GPS coordinates system is in the form of 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 actual coordinates obtained from GIS map scale 1:100,000.

Note: EG and NG are the actual GPS Easting and Northing coordinates, EG1 and NG1 are the GPS Easting and Northing coordinates read from the GIS manipulated map scale 1:100,000 .

St.No.	EG m	NG m	EG1 m	NG1 m	EG1-EG	NG1-NG
2006	445725.830	1684470.960	445776.938	1684512.625	51.107	41.665
2010	451815.000	1766504.020	451852.438	1766528.625	37.438	24.605
2601	450577.170	1726007.350	450620.000	1726044.000	42.830	36.650
4100	446595.880	1705103.570	446637.781	1705154.375	41.901	50.805
8491	451233.020	1730391.360	451270.281	1730434.875	37.261	43.515
4102	445734.240	1716473.350	445783.125	1716518.875	48.885	45.525
2003	425689.550	1709069.080	425704.906	1709111.875	15.356	42.795
2007	447108.500	1740148.070	447158.031	1740189.125	49.531	41.055
The mean value					40.539	40.829

Table 2: The difference in Easting and Northing between the actual Adindan coordinate values obtained from SSD and GIS map scale 1:100,000.

Note: EA and NA are the actual Adindan (Sudan) Easting and Northing coordinates, EA1 and NA1 are the Adindan (Sudan) Easting and Northing coordinates read from the GIS manipulated map scale 1:100,000 .

St.No.	EA m	NA m	EA1 m	NA1 m	EA1-EA	NA1-NA
2006	445654.780	1684259.151	445715.031	1684295.875	60.251	36.724
2010	451743.950	1766291.963	451790.500	1766318.125	46.550	26.162
2601	450506.110	1725795.315	450545.687	1725821.000	39.578	25.685
4100	446524.816	1704891.608	446582.063	1704937.625	57.247	46.017
8491	451161.968	1730179.310	451202.156	1730212.000	40.188	32.690
4102	445663.192	1716261.385	445715.031	1716302.125	51.839	40.740
2003	425618.493	1708856.944	425630.594	1708895.125	12.101	38.181
2007	447037.433	1739935.951	447102.281	1739972.375	64.848	36.424
	The mean value				46.575	35.328

Table 3: The difference in Northing and Easting between the observed GPS (WGS-84) and Adindan coordinates from SSD. (Note: G for GPS and A for Adindan (Sudan)).

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 4: The difference in Northing and Easting between GPS (WGS-84) and Adindan coordinates obtained from GIS map scale 1:100,000.

St.No.	EG1 m	NG1 m	EA1 m	NA1 m	EG1-EA1	NG1-NA1
2006	445776.938	1684512.625	445715.031	1684295.875	61.906	216.750
2010	451852.438	1766528.625	451790.500	1766318.125	61.938	210.500
2601	450620.000	1726044.000	450545.687	1725821.000	74.313	223.000
4100	446637.781	1705154.375	446582.063	1704937.625	55.719	216.750
8491	451270.281	1730434.875	451202.156	1730212.000	68.125	222.875
4102	445783.125	1716518.875	445715.031	1716302.125	68.094	216.750
2003	425704.906	1709111.875	425630.594	1708895.125	74.313	216.750
2007	447158.031	1740189.125	447102.281	1739972.375	55.750	216.750
The mean value					65.020	217.516

Table 5: 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 1:100000	EG1- EA1 = 65.020	NG1 - NA1 = 217.516

Table 6: Transformation parameters between WGS-84 and Adindan (Sudan) datum using observed, GIS values obtained from maps to scale 1:100,000

Parameters	WGS- 84 to Adindan using observed values	WGS-84 to Adindan using GIS map scale 1:100,000
ΔX (m)	- 158.036 $\pm$ 0.013	- 156.007 $\pm$1.864
ΔY (m)	- 17.931 $\pm$ 0.013	- 23.813 $\pm$ 1.864
ΔZ (m)	209.911 $\pm$ 0.013	215.077 $\pm$ 1.864
ΔL (ppm)	1.502 $\pm$ 0.53	-76.51 $\pm$ 76.05
$RX \times 10^2$	- 0.32 $\pm$ 0.28	- 6.28 $\pm$ 1.14
$RY \times 10^2$	0.44 $\pm$ 0.19	- 5.71 $\pm$ 28.13
$RZ \times 10^2$	- 0.28 $\pm$ .06	-40.79 $\pm$ 91.10
σ^2_0	0.00135	27.810