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Digital Topographic Mapping With Two Different Scales Using GPS And GIS On Adindan (Sudan) Datum

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ABSTRACT: The geodetic data used in the production of the topographical base map for any area in Sudan were observed and computed by the classical system related to the local datum (Adindan) of Clarke 1880 ellipsoid. At this time there are satellite receivers used in geodetic observations, where the data produced by the satellite systems are referenced to the geocentric datum (The World Geodetic System (WGS)). Now a days The Global Positioning System was replacing the classical local system which was based on Adindan (Sudan) datum. This paper describes a technique for evaluation the planimetric accuracy of 100,000 and 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 receivers 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: 100,000, and 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 (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.

INTRODUCTION:

It is essential for Geographical Information System (GIS) and spatial analysis that all data are referenced to the same coordinate system. When working within a single country one usually adopts the coordinate conventions without question, but when building multinational data sets it is very important to ensure cross-border equivalence of ellipsoid, projection, and bas level. As a first step, all spatially related data and object data have to be collected. Traditional maps are in many cases not sufficient. Here GPS provides an economic and efficient tool for an automatic data flow into the GIS. Vice versa, all objects that are selected in a GIS can be immediately identified in the field [2]. Integrated GIS - GPS concepts are offered by many manufacturers. The market is rapidly growing. Application examples are inventories for pipelines, power lines, fresh and waste water, streets, traffic signs, railway tracks, trees, contaminated locations, and so on. The problem of defining and recording the location of a data point has been eased through the development of Global Positioning System (GPS) which are being used increasingly in many types of data collections exercise, often in tandem with data loggers. These instruments are able to define the geographical location and altitude, to varying degrees of accuracy, anywhere on the earth's surface using triangulation geometry based on signals emitted by the NAVSTAR GPS satellites. A hand-held ground receiver must be able to receive signals from at least three of these satellites that provide details of their orbits and an atomic clock correction. The distances from each satellite to the receiver are a function of the number of whole wavelengths and the phase shift and this information, combined with the positional information, is sufficient to compute the location of the receiver in latitude/longitude or grid reference, and altitude. These results are displayed the GPS handset and may be downloaded into a computer system. GPS is an important source of locational information particularly in areas where map coverage is limited. The main limitations are the accuracy with which the geographical position can be derived because the precise time code is dithered by the US Department of Defense, the number of satellites in view, and the quality of the GPS reciver. By using a local base station on a well-located object such as a block of flats or a lighthouse, differential GPS measurements can improve spatial resolutions to within 1 m accuracy.

2. THE GLOBAL POSITIONING SYSTEM (GPS)

GPS was designed primarily as a navigation system, to satisfy both military and civilian needs for real-time positioning. This positioning is accomplished through the use of coded information, essentially clever timing signals, transmitted by the satellites. Each GPS satellite transmits a unique signal on two L-band frequencies: L1 at 1575.42 MHz and L2 at 1227.60 MHz (equivalent to two wavelengths of approximately 19 and 24 cm, respectively). The satellite signals consist of L band carrier waves modulated with a "Standard" or S code (formerly called the C/A code), a "Precise" or P code and a Navigation message containing, amongst other things, the coordinates of the satellite as a function of time the "Broadcast Ephemerides". The S code which is intended mainly for civilian use, yields a range measurement precision of about 10 m. The navigation service provided by this code is referred to as the Standard Positioning Service (PSP). The P code is intended for military and selected civilian use only and yields a measurement precision of about 1 m. The navigation services provided by the P code is therefore referred to as the Precise Positioning Service (PPS). Although both codes can be used for surveying, a more accurate method is to measure the phase of the carrier signal [6]. The following factor influence the final positioning accuracy obtainable with GPS:

(a) The precision of the measurement and the receiver satellite geometry.

(b) The measurement processing technique adopted.

(c) The accuracy with which atmospheric and ionosphere effects can be modeled.

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(d) The accuracy of the satellite ephemerides.

The GPS work done in geodetic and land surveying relies on post processed relative positioning. There are several very different techniques available to GPS surveyors, and each method makes unique demands on the receivers used to support it. One of these methods is the static method. The static method was the first method of GPS surveying used in the field and it continues to be the primary technique today. Relative static positioning involves several stationary receivers simultaneously collecting data from at least four satellites during observation sessions that usually last from 30 minutes to two hours. Atypical application of this method would be the determination of vectors, or baselines, are they are called, between several static receivers to accuracies from 1 ppm to 0.1 ppm over tens of kilometers [7]

3. GEOGRAPHICAL INFORMATION SYSTEM (GIS)

The tool-base of definition of a GIS is a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes. The geographical (or special) data represent phenomena from the real world in terms of (a) their position with respect to a known coordinate system, (b) their attributes that are unrelated to position (such as color, cost), (c) their spatial interrelation with each other which describe how they are linked together (this is known as topography and describes space and spatial properties such as connectivity which are unaffected by continuous distortions). 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 [4.5]. 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 [3].

4. PROCEDURES:

The 8 control points were carefully selected and distributed all over the Khartoum State (Sudan) 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-Sudan) datum using the 8 GPS points (table 10) [1]. 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, and 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 for m, 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 map at scale 1:100,000 and 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 10).

5. RESULT AND ANALYSIS

Table 1 gives The difference in Easting and Northing between observed GPS (WGS-84) coordinate values and the coordinates obtained from GIS map scale 1:100,000. Table 3 gives corresponding values for the 1:25,000 scale map. Tables 2 and 4 give the same corresponding values on Adindan datum. 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, which is corresponding to ± 0.4 mm on the ground, very small and negligible error). For the coordinates on Adindan datum, the difference in Easting and Northing between the actual coordinates and the GIS map (scale 1:100,000) showed a small variation ranging from ± 46.58 m to ± 35.33 m. Which is also a very small and negligible. Accordingly it was concluded that the topographic maps at scale 1:100,000 and smaller are suitable for GIS manipulation with a very small and negligible error. Referring to Table 3 and 4, the mean difference in Easting and Northing coordinates between the actual and GIS manipulated map at scale 1:25000 (GPS and Adindan) was 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 Tables 3 and 4, the Easting coordinates are more affected by the projection process. Table 6 gives the shifts between the two datums using the actual coordinates. Table 7 gives the shifts values using coordinates obtained from 1:100000 scale map, while table 8 gives the shifts using coordinates at scale 1:25,000. the mean shift values in the three tables (tables 6,7,8) were summarized in table

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9. However the shifts seem to have very small values, which were emphasized by the Molodensky–Badekas model. Transformation parameters are shown in Table 10.

6. CONCLUSION AND FUTURE RECOMMENDATION

The project maps (1:100,000 and 1:25,000) 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 at scale 1:25000 and from ± 35.33 m to ± 40.83m (at scale 1:100000). 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 9). Accordingly it was concluded that the topographical (digitized or scanned) maps have to be transformed and manipulated by any GIS software, using a checked transformation model. The affine transformation model used by ESRI (ARC/INFO) software showed good results. Moreover when 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 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 1:100,000. (**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

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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 Easting and Northing between observed GPS (WGS-84) coordinate values and the coordinates obtained from GIS map scale 1:25,000. (**Note**: EG and NG are the actual GPS Easting and Northing coordinates, EG2 and NG2 are the GPS Easting and Northing coordinates read from the GIS manipulated map scale 1:25,000)

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 4: The difference in Easting and Northing between the actual Adindan coordinate values obtained from SSD and GIS map scale 1:25,000. (Note: EA and NA are the actual Adindan (Sudan) Easting and Northing coordinates, EA2 and NA2 are the Adindan (Sudan) Easting and Northing coordinates read from the GIS manipulated map scale 1:25,000)

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

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Table 5: The mean values of the difference in Easting and Northing using observed coordinates and coordinates obtained by GIS

Classification of the value Presented	The mean value of difference in Easting and Northing	
	∆E (m)	∆N (m)
observed values –obtained from GIS map 1:100000	EG1 – EG = 40.539 EA1 – EA = 46.575	NG1 – NG = 40.829 NA1 – NA = 35.328
observed values –obtained from GIS map 1: 25000	EG2 – EG = 3.533 EA2 – EA = 7.029	NG2 – NG = 41.202 NA2 – NA = 41.466
GIS values scale 100000 – GIS values scale 1:25000	EG1 – EG2 = 35.191 EA1 – EA2 = 39.547	NG1 – NG2 = -3.000 NA1 – NA2 = -6.141

Table 6: 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 7: 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

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Table 8: The difference in Northing and Easting between GPS (WGS-84) and Adindan coordinates obtained from GIS map scale1: 25,000.

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 9: 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
GIS(GPS-Adindan) map scale 1: 25000	EG2- EA2 = 69.375	NG2 - NA2 = 211.750

Table 10: Transformation parameters between WGS-84 and Adindan datum using observed, GIS values obtained from maps to scale 1:100,000 and 1:25,000.

Parameters	WGS- 84 to Adindan using observed values	WGS-84 to Adindan using GIS map scale 1:100,000	WGS- 84 to Adindan using GIS map scale 1:25,000
ΔX (m)	- 158.036 ± 0.013	- 156.007 ±1.864	- 157.259 ± 0.751
ΔY (m)	- 17.931 ± 0.013	- 23.813 ± 1.864	- 19.279 ± 0.751
ΔZ (m)	209.911 ± 0.013	215.077 ± 1.864	210.114 ± 0.751
ΔL (ppm)	1.502 ± 0.53	-76.51 ± 76.05	-24.22 ± 30.61
$RX \times 10^2$	- 0.32 ± 0.28	- 6.28 ± 1.14	- 5.02 ± 4.55
$RY \times 10^2$	0.44 ± 0.19	- 5.71 ± 28.13	- 1.77 ± 11.32
$RZ \times 10^2$	- 0.28 ± .06	-40.79 ± 91.10	-4.49 ± 36.72
σ^2_0	0.00135	27.810	4.507