Case study
Accuracy assessment of SRTM 1,3 – arcsec by using topographic DEM over limited area of Egypt territory

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Abstract — Digital Elevation Model (DEM) is imperative to the creation of slope maps, the substructure planning, gravity field modeling and many other applications. Thus, there is a great need for accurate and low cost DEMs. In this case study, Shuttle Radar Topography Mission (SRTM) 30m, SRTM 90m have been used with Topographic DEM generated from ground topographic maps with scale 1:50,000 as a reference elevation to check the accuracy of those models by evaluation process at 625 CGPs. As known the Egyptian topographic maps with scale 1:50,000 has not been updated from long time ago. Unfortunately, most of the Northern desert does not cover with any type of topographic maps up to the writing of this paper. The aim of this study is approaching to a proper, accurate and economical scientific method for updating those topographic maps by evaluate of the vertical accuracy of such models over different terrain types compared with the accuracy of the DEM produced from topographic maps of scale 1: 50,000, over studying area lies between (31 to 31.5 E and 29.5 to 31.5 N), A number of (625) ground control points (GCPs) have been used in the evaluation process. From the statistical computations, it is obvious SRTM 30m has the most discrimination of its performance in terms of the Standard deviation by ±5.53m compared with ±5.88 for SRTM 90m. While By using the spot heights of a topographic map with scale 1:50,000 elevations as a reference elevation, the statistic indicated that the vertical accuracy of 625 GCPs elevation data is ±5.71m and ±6.23m, respectively. SRTM 30m elevation data featured a much greater absolute vertical accuracy than the value of ±16 m which published in the SRTM data specification. The analyses presented in this paper indicate that the absolute vertical accuracy of SRTM 1 arcsec data for our datasets proven to 2.94 times higher than the value of ±16 m presented in the original SRTM requirement specification by using GCPs as a reference.

Keywords— STRM, digital elevation models, DEM, enhancement DEMs, topographic DEMs, DTM, DSM.

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1. INTRODUCTION

SRTM1 arc second and SRTM3 arc second are two free available sources for digital elevation model DEM covering the most of the world. The creation of slope maps, the substructure planning, gravity field modeling, flood or drainage modeling, land-use studies, geological applications, and many other applications [1,4]. Thus, there is a great need for accurate and low cost DEMs. Several researchers have been checked the accuracy of SRTM 30 m and SRTM 90m in many places by using Ground Control Points (GCP) measured by differential GPS or by using elevations DEM from topographic maps (e.g., [2,7,8,10,11]).

1.1. Shuttle Radar Topography Mission (SRTM) 1, 3 Arc-Second Global

The Shuttle Radar Topography Mission (SRTM) was flown aboard the space shuttle *Endeavour* February 11-22, 2000. The National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA) participated in an international project to acquire radar data which were used to create the first near-global set of land elevations. The radars used during the SRTM mission were developed and flown on two *Endeavour* missions in 1994. The C-band Spaceborne Imaging Radar and the X-Band Synthetic Aperture Radar (X-SAR) hardware were used on board the space shuttle in April and October 1994 to gather data about Earth's environment.

Space shuttle orbited Earth 16 times each day during the 11-day mission, completing 176 orbits. SRTM successfully collected radar data over 80% of the Earth's land surface between 60° north and 56° south latitude with data points posted every 1 arc-second [6, 9 and 13] was a single pass, synthetic aperture radar interferometry (InSAR) campaign conducted in February 2000 for the first time a global high-quality DEM was achieved with a resolution of 1 arcsec (30 m) and 3 arc sec (free availability SRTM 90 m), which reported to be less than ±16 m [12] as global accuracy, were the errors in DEM are widely recognized to comprise mainly two components, the horizontal, often referred as the positional accuracy of X and Y components, and the vertical component or the accuracy of the attribute [3,5].

SRTM DEMs are referenced to the WGS84 ellipsoid [14]. SRTM DEMs were downloaded from their website (http://earthexplorer.usgs.gov) then Global Mapper program is used to subset the DEMs of the study area, also transformation from international ellipsoid (WGS84) to Helmert 1906 (adopted datum from Egyptian Surveying Authority, ESA) have been done, after that the system of coordinates is converted from geographical coordinates to Cartesian coordinates using ETM as the adopted projection from ESA.

2. BACKGROUND

Fig. 1. Shows the numbering techniques for the EGYPTIAN topographic maps as following:

The map 1:1000,000 was divided into 16 sub maps 1:250,000 which numbering by the Romanian capitals letter from A: P which added to the map million as NH36-M

The map 1:250,000 was divided into 4 sub maps 1:100,000 which numbering by, regular numbers from 1:6, which added to 1:250, 000 map no. as NH36-E1

The map 1:100,000 was divided into 4 sub maps 1:50,000 which numbering by the Romanian small letter from a: d, which added to 1:250, 000 map no. as
NH36-E1c

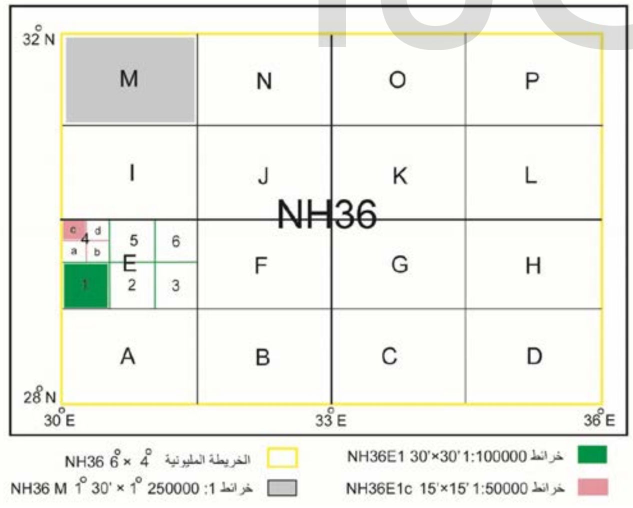

Fig. 1. The Egyptian topographic map index as Egyptian Surveying Authority "ESA"

Each map converges an area of 15′ in latitude and longitude where the total no. of the all maps are 1531 maps for the whole territory of Egypt, while the produced by ESA are 445 for Northing and southing parts in addition to the northern desert of Egyptian territory.

We can notice from the previous maps the western desert has not any topographic maps as mentioned in ESA documentations, so it will be valuable participation for the country if we able use the global elevation model DEM to be as the first approximation instead of the Aerial photography or traditional land surveying where they time consuming and high cost for producing those maps.

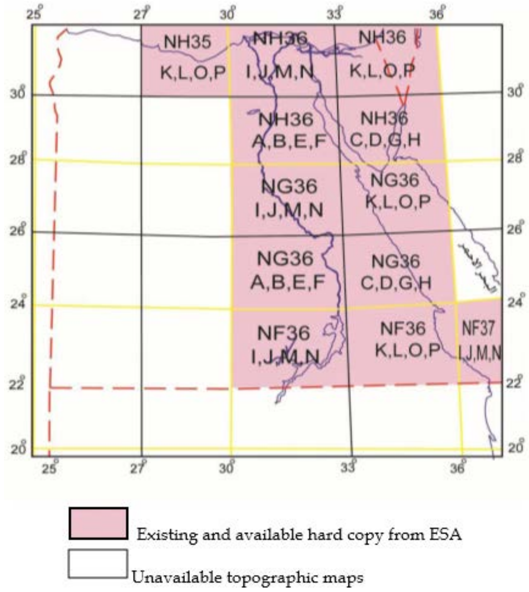

Fig. 2. Topographic map coverage all over Egypt territory

3. METHODOLOGY

The methodology consists the following steps:

1. Generate Ground DEM from the topographic maps of scale 1: 50,000 through the scanning and digitizing process for the spot elevation points and contour lines.
2. SRTM 1 arc second and SRTM 3 arc second were downloaded from their website then Global Mapper program is used to subset the DEMs for the study area.
3. Transforming and projection of the proper window of SRTM 1 arc second and SRTM 3 arc second from international ellipsoid (WGS84) to Helmert 1906 have been done
4. Comparison and maps visualization are performing with ARCGIS package.
5. The traditional method of standard deviation for accuracy check have been used in all DEM evaluations

4. AVAILABLE DATA

Fig. (1) Illustrates the study area which extended from (30° to 31.5° E) and from (29.5° to 31.5° N), approximately it is located in the northern Nile Valley. This area contains irregular features between hills, valleys, plane, and slopes it is suitable for this case study.

The data is varied and dense were SRTM 1 arcsec has 30 m resolution while, SRTM3 arcsec has 90 m spatial resolution as shown in fig. 5, 6. Finally, local TOPO DEM produced from the topographic maps of scale 1:50,000 through the process of digitizing of the contour and the spot elevation, these maps were obtained from the military survey authority (MSA), a number of (625) GCPs as shown in fig. (4) were used as a reference data for the purpose of the evaluation process of the DEMs accuracy, these GCPs were collected from a number of projects. The DEM from topographic maps of scale 1:50,000 expected a vertical RMSE reaches half of the contour interval which is 5 m for flat terrain and 10 m for steep terrain.

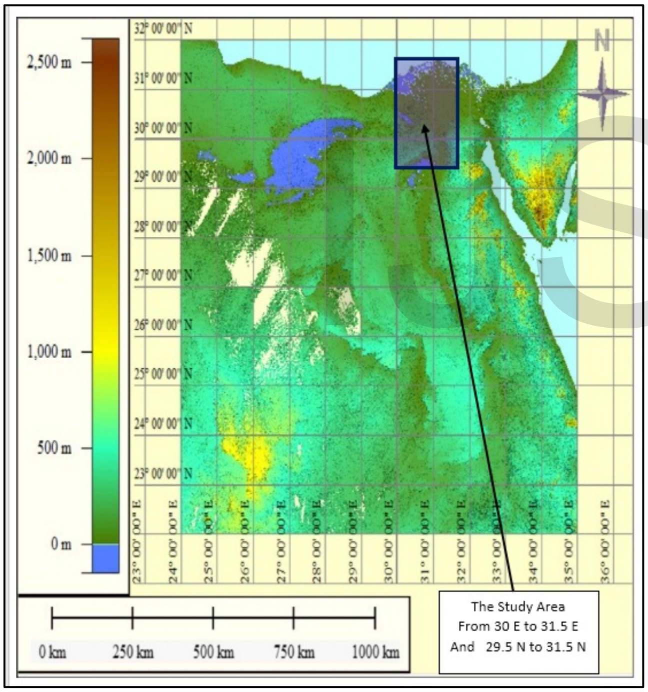

Fig. 3. The study area located at Northern Nile valley

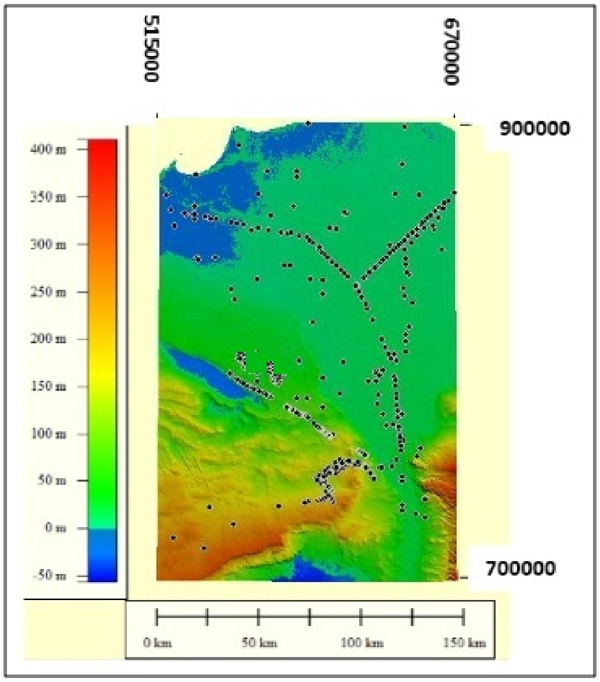

Fig. 4. The ground control point of the interested case study area

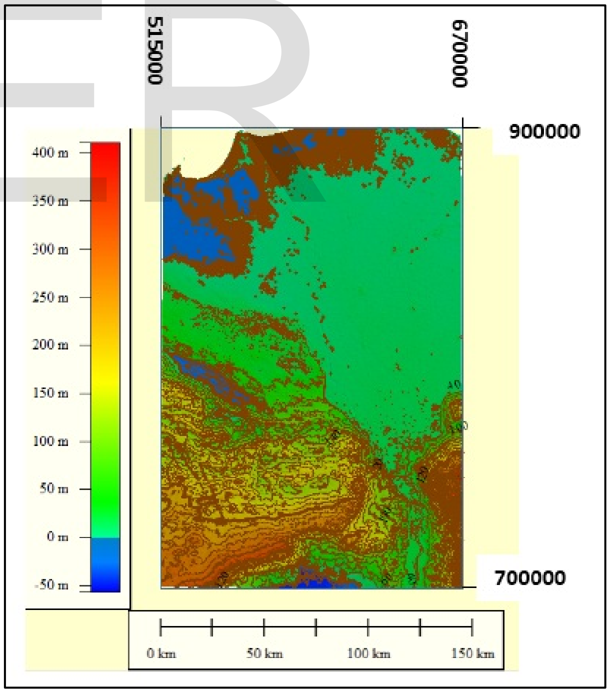

Fig.5. Contour map with 20 m contour interval for SRTM3 arcsec DEM.
of the interested case study area

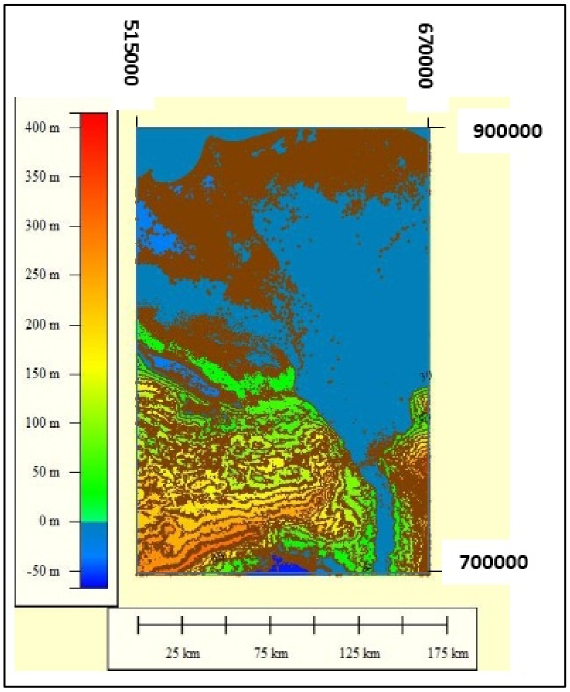

Fig.6. Contour map with 20 m contour interval for SRTM1 arcsec DEM.
of the interested case study area

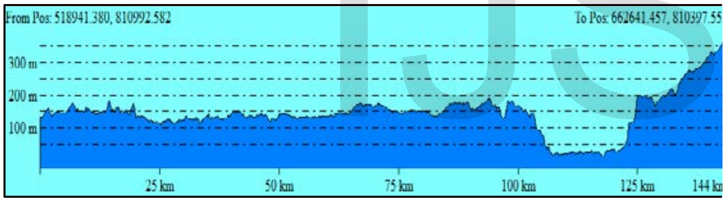

Fig.7. Profile at latitude 30 N for SRTM3 arcsec DEM. at the interested case study area

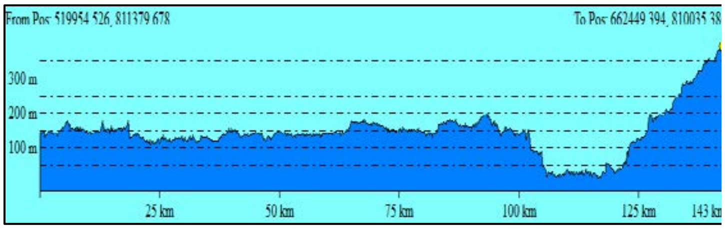

Fig.8. Profile at latitude 30 N for SRTM1 arcsec DEM. at the interested case study area

Profiles at latitude 30N are drawn above as in fig. 7, 8 for SRTM 1-arcsec and SRTM 3-arcsec to illustrated the elevations differences of study area related to SRTM 1-arcsec and SRTM 3-arcsec, respectively.

5. STATISTICAL COMPUTATION AND RESULTS

Standard Deviation (Std. Dev.) is the most widely used statistics as a measure, it measures the dispersion of the frequency distribution of deviations between the original value and the mean value and used to measures the dispersion of the residuals from mean residual. Std. Dev. for the deviations between the original and the mean elevations can be given as:

$$\text{Std. Div.} = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}} \qquad (1)$$

Where:

x_i = reference elevation at the point i, n

$\bar{x}$= The mean value of the sample points

n = the number of ground check points.

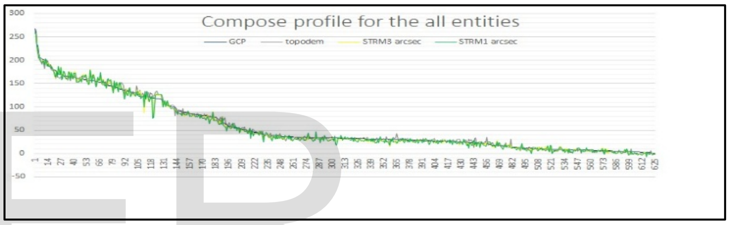

Fig.9. composed profiles among SRTM 30m, SRTM 90m, TOPO DEM and GCPs

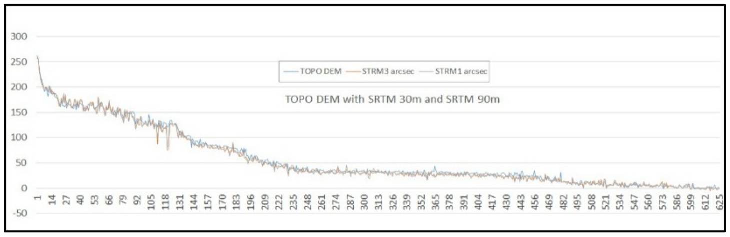

Fig.10. composed profiles among TOPO DEM, SRTM 30m and SRTM 90m

Fig.9,10, shown the trend relationship of elevation differences of the study area among GCP, TOPO DEM, SRTM 1-arcsec and SRTM 3-arcsec, its clear SRTM 3-arcsec has some bias from the other entities.

TABLE (1) STATISTICS COMPUTATIONS OF ORTHOMETERIC HEIGHT DATA SETS FROM THE DISCRETE GROUND CONTROL POINTS G.C.P WITH DEMS (UNIT: METER)

	Digital Elevation Model -DEM	No. of GCPs	Min m	Max m	Mean m	Rang m	Std. Dev. m
H	GCPs	625	-0.28	266.667	57.232	266.947	55.987
	Topo. DEM.		-1.235	262.46	57.438	263.695	56.629
	SRTM 1 Arcsec		-6.279	258.615	55.385	264.894	56.568
	SRTM 3 Arcsec		-5.969	256.127	55.524	262.096	56.612

TABLE (2) STATISTICS COMPUTATIONS RESIDUALS OF ORTHOMETRIC HEIGHT DATA SETS FROM THE DISCRETE GROUND CONTROL POINTS G.C.P WITH DEMS (UNIT: METER)

	Digital Elevation Model -DEM	No. of GCPs	Min m	Max m	Mean m	Rang m	Std. Dev. m
δH	Topo. DEM.	625	-16.627	19.153	-0.206	35.780	4.797
	SRTM 3 Arcsec		-23.521	44.254	1.848	67.775	5.878
	SRTM 1 Arcsec		-24.574	38.095	1.709	62.669	5.351

TABLE (3) STATISTICS COMPUTATIONS THE RESIDUALS OF ORTHOMETRIC HEIGHT DATA SETS FROM THE DISCRETE SPOT ELEVATIONS FROM TOPO DEM WITH SRTM1,3 ARCSEC (UNIT: METER)

	Digital Elevation Model -DEM	No. of GCPs	Min m	Max m	Mean m	Rang m	Std. Dev. m
δH	GCPs-Topo. DEM.	625	-16.627	19.153	-0.206	35.78	4.797
	TOPO DEM - SRTM 3 Arcsec		-23.652	45.812	2.053	69.464	6.230
	SRTM 1 Arcsec		-21.927	39.653	1.914	61.58	5.709

6. CONCLUSIONS

In this study, two free global DEMs; SRTM 30m and SRTM 90m were evaluated for two reference elevation data GCPs and TOPO DEM. The statistical computation for the absolute vertical accuracy of SRTM 30m and SRTM 90m elevation data for the study area gave the values of ±5.35m and ±5.88m, respectively. By using the spot heights of a topographic map with scale 1:50,000 elevation as a reference elevation, the statistic indicated that the vertical accuracy of 625 GCPs elevations data is ±5.71m and ±6.23m, respectively. The 30 m SRTM elevation data featured a much greater absolute vertical accuracy than the value of ±16 m which published in the SRTM data specification. The analyses presented in this paper indicate that the absolute vertical accuracy of SRTM 1 arcsec data for our datasets proven to 2.94 times higher than the value of ±16 m presented in the original SRTM requirement specification by using GPS elevation as a reference. The vertical accuracy obtained from both used DEMs has indicated that they can be used to develop or produce a topographic map with scale 1:50,000.

7. RECOMMENDATIONS

Based on the computation results of this case study, we recommend the following:

1- Check the accuracy of the advanced digital terrain model (DTM) and digital surface model (DSM) features like road rivers railways as X, Y and fuse all utilities with the evaluated SRTM1- arcsec to produce a good model can utilize for producing the topographic map as X, Y, Z features.
2- Fuse the New elevation models which produced by the new observation technique LIDAR, with SRTM 1-aersec and check the new output models with GCPs and TOPO DEM.
3- Instead of spending time and money for constructions a new topographic map for northern desert, construct a new and accurate control points for evaluation SRTM1-arcsec to remove its systematic bias and then use it as a reference elevation model for topographic maps.

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