Accuracy Assessment of Global Bathymetry and Topography at 15 Arc Sec. (SRTM15+V2) Using Red Sea Floor Topography, Egypt

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***Abstract*:- Digital elevation model DEM is one of most used and simplest remote sensing elevation data. Global bathymetry and topography SRTM 15+ at 15 arc sec (~500 × 500 m pixel size at the equator) is the available Global model for Bathymetry and Elevation Data which provides ocean bathymetry background information. The sea floor information is based on a combination of satellite altimetry and echo sounder data compiled from various sources. This study presents a vertical accuracy assessment based on a single beam echo sounder survey data cover three study areas Abo zenima , El Ture and Ain El-Sokhna distributed on the Red Sea in Egypt .the vertical accuracy results referenced by RMS error for Abo zenima , El Ture and Ain El-Sokhna were ±3.45 m, ±1.10 m and ±2.05 m respectively. The validation study concluded that the SRTM 15+ V2 performance is best fit to the Red sea floor topography and suitable for geomorphological studies in Egypt.**

Keywords: SRTM 15+, Bathymetry, RMS, DEM, Egypt

1. INTRODUCTION

Seventy one percent of the earth’s surface is water cover. The water bed is still hasn’t enough chances of study. Sea floor topography is very important to understand its hydrological, geological, and geophysical processes behaviour. Water depth measurements are not as a vertical control land points known by benchmarks. This makes accuracy and precision of sea bed topography is in concern and, consequently, a key requirement for Sea floor study, exploitation, and delimitation (Lecours et. al., 2016).

Despite the apparent progress in data collection and processing, sea floor still face more problems especially how overcome the instrumental, human, and methodological for un-accepted results or inaccurate representation. Due to this lack of detailed and updated data, national scientific production decreases in comparison to surrounding the oceanic environment that are concerned with evaluating the other available data sources like SRTM15 + V2.0 (Foonde J.M., 2019).

In this paper a comparison between two bathymetric data sources were present in the Red Sea at Egypt country. The first data source is the updated version of global elevation bathymetry grid model at 15 arc sec spatial sampling interval. The used model is the global bathymetry and topography SRTM15+ version 2. This represents the updated iteration version of the SRTM15+ (DEM), constructed using our latest compilation of shipboard soundings and satellite-derived predicted depths. This follows from SRTM30_PLUS (Becker et al., 2009) and SRTM15_PLUS (Olson et al., 2016), where the additional symbol “+” represents the addition of the ocean bathymetry, SRTM15+ V2.0 is the updated 2019 of a package named by Global Terrain Models (GTM) that have gone through a series of enhancement and development from the date of start. This upgrade was in reflection to issues identified about its behaviours in shallow waters where features are unknown (Katsuto U., 2014).

2. DATA USED

The Global Bathymetric and Topographic Model SRTM15+V2.0

The recent released updated global bathymetric and topographic model SRTM15+V2.0 grid spacing 15 arc sec. This determine the upgraded version of the SRTM+ digital elevation model (DEM), constructed using a compilation of shipboard soundings and satellite-derived predicted depths. This released model is consider a new version follows from SRTM30_PLUS (Becker et al., 2009) and SRTM15_PLUS V1 (Olson et al., 2016). In this update the addition of the ocean bathymetry denoted by the “plus” represents in the SRTM 15+ is consider contribution to the previous one. The improvement in both accuracy and resolution in this version coming from the new data that has been acquired from last one in 2016, in addition to global shipboard sounding compilation (Tozer et.al, 2019).

There are three satellite altimeters data sources in non-repeat orbits as shown in Table (1); data from AltiKa, which operates using the Ka-band, are of particular importance due to its superior range precision (e.g., Smith, 2015; Zhang & Sandwell, 2017). In addition, the global shipboard sounding data set, at 15-arc sec resolution provided by the National Geospatial-Intelligence Agency. The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) was participated by some data and also there are three regional-scale high-resolution multi-beam surveys that together provide an additional ∼14.8 million soundings. Collectively, SRTM15+V2.0 incorporates >33.6 million new ship-constrained grid cells and greater than six cumulative years of altimetry measurements relative to SRTM15_PLUS (Olson et al., 2016).

Table (1): The Satellite Altimetry Data Sources (Sea Surface Slope) Used to build SRTM15+V2.0 (Tozer et.al, 2019).

Altimeter	New in SRTM15+ V2	measurements (20 Hz; 10^6)	precision (mm)	Latitude Range (◦)
Geosat	0	517	57	±72
ERS1	0	442	61.8	±81
Envisat	0	128	51	±81
Jason-1/2*	14	746	43	±66
CryoSat-2*	48	3.011	43.7	±88
AltiKa*	12	847	20.5	±81

The used data was freely download from officially web site of the National Geospatial-Intelligence Agency (https://topex.ucsd.edu/cgi-bin/get_srtm15.cgi) in ASCII XYZ and Geo tiff format. The global data was divided in to strips, each strip cover 40 degrees in longitude and 50 degrees in latitude. Egypt was loaded in the file Strip e020 n40 as shown in Figure (1). Where e020 means that this file contain data starts from 20°East to 60° East and n40 means that this file contain data starts from 10° South up to 40° North.

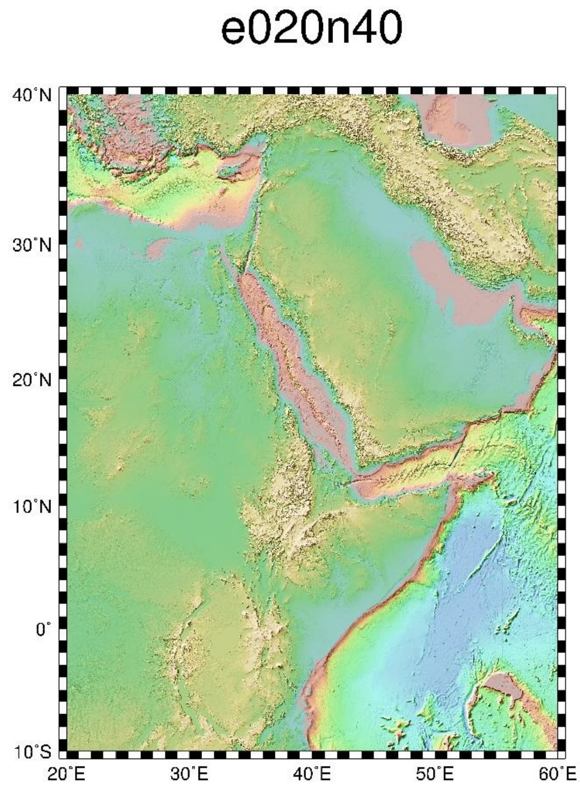

Figure (1) shows the file strip e020n40, Egypt.

3. STUDY AREA

Three study areas were selected for validation the vertical accuracy assessment of SRTM15+ V2. Three projects were achieved in order to survey water depths and investigate the suitability of construction a new port on the boundaries of the project. The GNSS GPS was used to survey each single beam location referenced to WGS84. The mean sea level is the vertical datum for the two sites Abo Zenima and Ain-Sokhna however, the EGM2008 Geoid model is the datum of the third project in El Turr study area. The site Abo Zenima has an area 352397 m^2 i.e., approximately 84 acres located at Suez Gulf at 29° 59′ 25″ N and 33° 10′ 45″ E. The total number of surveyed point were 6589 spot. Ain Sokhna site has the area 778019 m^2 i.e., approximately 185 acres located at West of Suez Gulf at 29° 36′ 36″ N and 32° 21′ 25″ E. The total number of surveyed points were 3252 spots. The third site is El-Turr where the site area is 201840 m^2 i.e., approximately 48 acres located at the south east of El Suez Gulf in south of Sini at 28° 14′ 55″ N and 33° 35′ 30″ E. The total number of surveyed point were 1549 spot. Figure (2) shows the location of the three sites and how them distributes over the SRTM 15+ V2 model.

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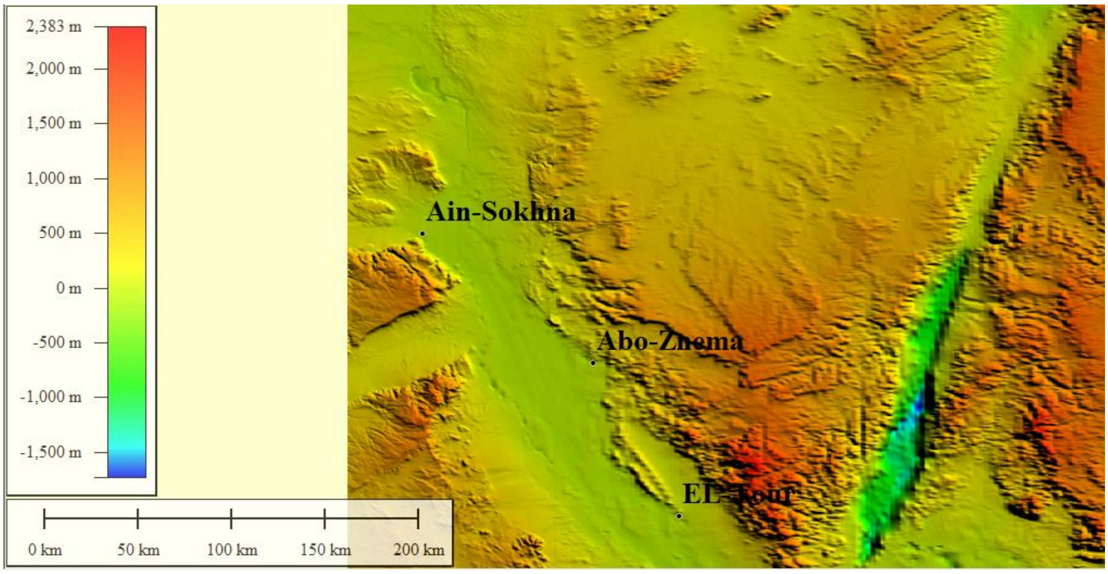

Figure (2) shows the location of the three sites over the SRTM 15+ V2 Tiff image.

4. METHODOLOGY

The applied methodology for accuracy assessment of SRTM 15+ using single-beam echo sounder survey is summarized in the following main steps:

- Data preparation
- Georeferencing and datum unification.
- Exporting SRTM 15+ V2 elevations in the same resolution as echo data.
- Vertical accuracy validation based on RMS.
- Results analysis.

The SRTM15+V2 global elevation model was available on ASCII XYZ-format at a spatial resolution approximately 500m × 500m pixel size (Tozer et.al, 2019). The data were available in geographic longitude and latitude horizontal coordinate system referenced to WGS 84. The single beam echo sounder data were available in Universal Transverse Mercator (UTM) referenced to WGS84. The validation accuracy assessment for the Sea floor onshore elevation needs to unify the two data sources format. A georeferenced unification for the coordinated systems was done for the SRTM data source to unify the reference vertical datum for the two data sources. SRTM15+ V2 available in geographic projection. So, the model data was projected again using a Transverse Mercator projection on world geodetic datum WGS 84. The default transformation parameters tools in the software Global Mapper (GM) were used in geo-referencing process to transform the geographic coordinate system to the UTM one using the available world parameters in global mapper for the Egypt northern hemisphere zone (36). The nearest neighbor technique (3x3) was used in extrapolation process to produce the computed SRTM 15+ V2 elevations in the same echo sounder point's location. Now the two data sources are available in the same reference datum with the same projection and the same resolution. So, validation process for elevation accuracy was done. The differences between the elevations for each individual point are called residuals. The Root-Mean-Squared Error (RMSE) (also called the root mean square deviation, RMSD) was used to measure the vertical accuracy between the site data and SRTM 15+ V2 one.

$$RMS = \sqrt{\sum_i^n (\Delta Z)^2 / (n-1)} \qquad (1)$$

$$\Delta Z_i = Z_{iC} - Z_{iS} \qquad (2)$$

Where:

Z_{iC} the reference site elevation at the i^{th} point
Z_{iS} The SRTM elevation at the i^{th} point
ΔZ_i The DEM height error at the i^{th} point
n Number of data set points

Statistical Analysis and Results

Statistical and geostatistical analysis were done for the variance between the site and model elevation to determine the accuracy of SRTM 15+ V2 at a spatial resolution 15 arc sec. approximately 500m × 500m pixel size and how fit the Red Sea floor topography in Egypt. The statistical analysis results are summarized in table (2). Three sites' data sets were tested, the first one is at Abu Zenima. The total number of tested points was 6589 points. The second site is El- Turr with number of points1548 echo sounder points. The last site is Ain Sokhna site with 3252 tested points. The results show that the absolute vertical accuracy of SRTM 15+ V2 represented by RMS is ±3.45m for Abu Zenima site and ±2.05m for Ain Sokhna site however the RMS was ±7.04m for El-Turr site which reveal that there is a big shift between the two data sources.

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Table (2): statistical Results of vertical accuracy of SRTM 15+ V2 at a spatial resolution 15 arc sec. approximately 500m × 500m pixel size referenced to Echo sounder data set for three areas at Red sea in Egypt.

Parameters	Abu Zenima	EL-Turr	Ain Sokhna
No. of used points	6589	1549	3252
Site Area (m^2)	352397	201840	778019
MEAN(m)	2.09	-6.95	-0.47
Min. Residuals (m)	-1.98	-9.16	-3.05
Max. Residuals (m)	10.18	-4.05	4.34
Standard Deviation	2.75	1.10	2.00
RMSE(m)	±3.45	±7.04	±2.05

Abu Zenima and Ain Sokhna data sets RMS demonstrate that the SRTM 15+ V2 gives high vertical accuracy and the model data fit the actual sea bed topography. The standard deviations for the two data sets are 2.75m and 2m respectively which ensure the RMS results. Also the minimum, maximum and mean variance for the two data sets demonstrate the good fit of the SRTM15+ V2 over Red Sea in Egypt. The results of El-Turr make a doubt in the results which push in more investigation in our results and study the surface profiles in these sites. Using the Civil 3D software, the section profiles were prepared. Each section was selected East-West direction over study areas. The section station was set every 100m to study any change in surface. The surfaces was created by linear triangulation interpolation technique. Each surface has the same latitude and longitude to avoid horizontal errors. The following cross sections shows the relation between the bathymetric Model SRTM 15+ V2 and the Echo data after referenced to mean sea level. The elevation of each station every 100m was recorded on profile band. The profiles sections were studied over the three sites Abu-Zenima, Ain Sokhna and El-Turr.

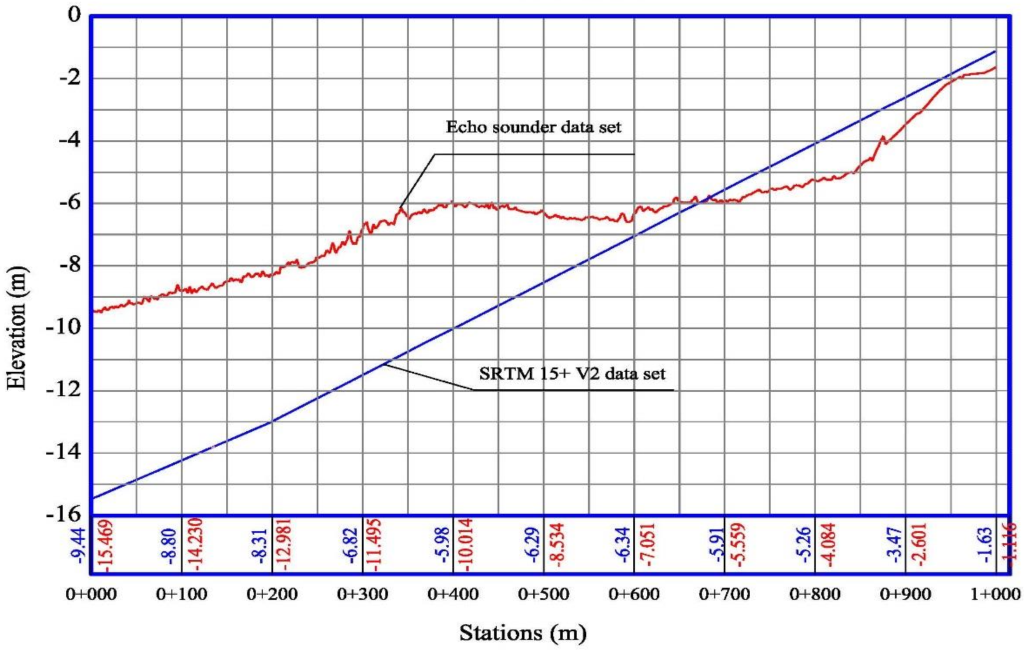

Figure (3): A relation profile of SRTM 15+ V2 surface against Sea floor topography at Abu Zenima –Red Sea Egypt.

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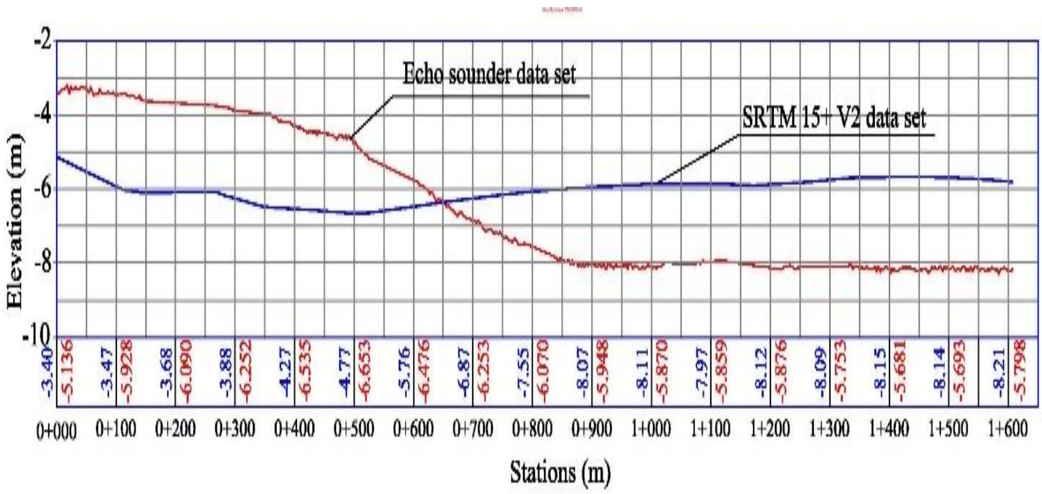

Figure (4): A relation profile of SRTM 15+ V2 surface against Sea floor topography at Ain Sokhna –Red Sea Egypt.

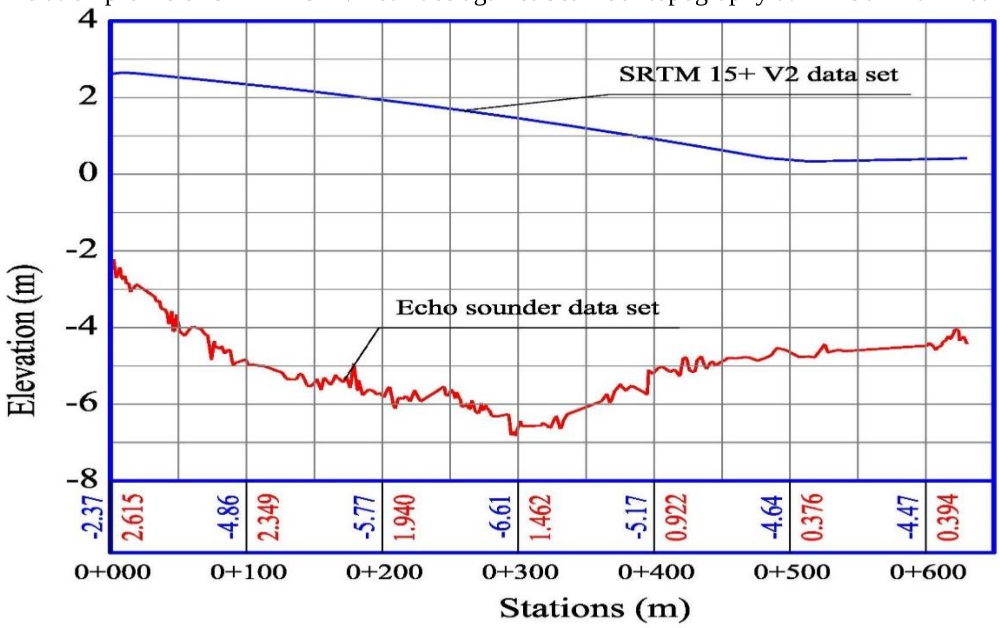

Figure (5): A relation profile of SRTM 15+ V2 surface against Sea floor topography at El Turr –Red Sea Egypt.

From the surfaces profiles as showed in figures (3, 4, and 5) it is clear that the two sites data sets Abu Zenima and Ain Sokhna figure (3 and 4) were confirm the statistics and RMS results. It was clear the two surfaces are closer and very near to each other's which confirm the results. The behavior of the surfaces shown in figure (5) for El Turr site confirm that there is a systematic shift clear between the two surfaces. Logically the site data should be trusted and the doubt forward only to the model data however, the two sites prove the inverse. Follow the concept of there is a shift in site data may come from bench mark or other mistake during survey so, let us check this test. To recognize the systematic shift it was clear from the mean value. From table (1) the mean value for El Turr data set was 9.95 m however the standard deviation is 1.10 m. the value of mean variance 6.95 m will removed from each point in the site data set and recalculate the statistical again and see the profile. Table (3) shows the standard deviation and RMS error for the variance after removing the mean shift from the data set of el Turr site.

Table (3): statistical Results of vertical accuracy of SRTM 15+ V2 at a spatial resolution 15 arc sec. approximately 500m × 500m pixel size referenced to Echo sounder data set for three areas at Red sea in Egypt after removing systematic shift from El Turr data set.

Parameters	Abu Zenima	EL-Turr	Ain Sokhna
No. of used points	6589	1549	3252
Site Area (m^2)	352397	201840	778019
Min. Residuals (m)	-1.98	-2.20	-3.05
Max. Residuals (m)	10.18	2.90	4.34
MEAN(m)	2.09	zero	-0.47
Standard Deviation	2.75	1.10	2.00
RMSE(m)	±3.45	±1.10	±2.05

From the results it was clear that the behavior of the SRTM 15+ V2 over el Turr site has been changed to high accurate and fit good than before removing the systematic shift from the site data set.

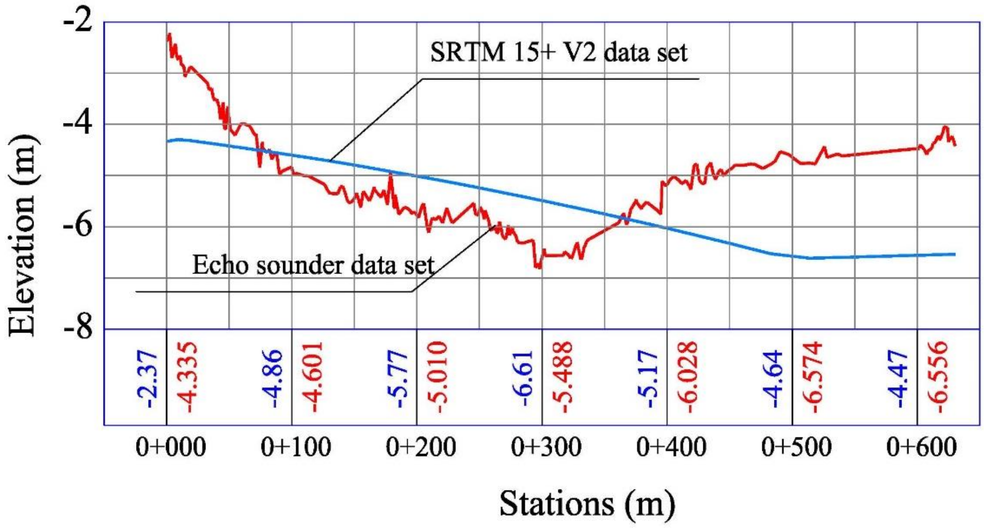

Figure (6): A relation profile of SRTM 15+ V2 surface against Sea floor topography at El Turr –Red Sea Egypt. SRTM after systematic shift removal.

The RMS for the analyzed data sets demonstrate that the bathymetry model SRTM 15+ V2 was high vertical accuracy and best fit in Red Sea floor Bed topography in Egypt. Although the SRTM model has grid 500 m x 500 m approximately which doesn't give exact results for the topography however, the topography details that required under water not in the same priority as off shore areas due to more activities were done on land than on shore. So, the available grid 500 m x 500 m give us topographic details that needed for sea floor activities.

5. CONCLUSION

Accuracy assessment was scrutinized to the newest released bathymetric and topographic model SRTM 15+ V2 over three sites under water of Red Sea in Egypt. The investigation analysis was done using echo sounder reference data sets for each site. The spot elevation was measured by single beam echo sounded survey where, in Abu Zenima study area has 6589 spots over 84 acres, in El-Turr has 1549 spots over 48 acres and in el-Ain Sokhna has 3225 spots distributed over 185 acres. This mean that there is approximately about 1 spot every 100 m^2 where is more densified then SRTM 15 V2 model. The data was projected in to the same coordinate system and extrapolated in same position to avoid any horizontal shift error. The vertical accuracy RMS in comparison with the single beam echo sounder data in three sites were ±3.45m for Abu Zenima, ±7.04m for El-Turr and ±2.05m for Ain Sokhna study area. A systematic shift study was done for the reference data of El-Turr site. The RMS after this study was found ± 1.10m. The RMS results indicate that the good fit and best performance for SRTM 15+ V2 for Red Sea under water topography in Egypt. The visual study using the relation between the two surfaces studied by longitudinal East West profile section for each study area confirmed the best performance of SRTM 15+ V2 on Egypt Red Sea. For the underwater applications the SRTM 15+ V2 at a spatial resolution 15 arc sec. approximately 500m × 500m pixel size is better and trusted in Egypt Red Sea. However it's recommended to increase the covering study area and select another areas in Red Sea, Mediterranean Sea and over the river Nile. Also, it's recommended to compare another Model source based on different techniques with the new one SRTM 15+ V2.

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