JAKU: Earth Sci., **Vol. 23,** No. 1, pp: 23-33 (2012 A.D. / 1433 A.H.)
DOI: 10.4197 / Ear. 23-1.2

Accuracy Assessment of Digital Elevation Model From ASTER Data Using Automatic Stereocorrelation Technique, East Luxor, Egypt

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Received: 29/12/2010 Accepted: 25/5/2011

Abstract. Digital Elevation Model (DEM) is a raster grid of elevation data that represents features on earth surface. It is useful for many applications such as mapping, contour derivation and watershed analyses. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), provides along-track stereo images at 15m spatial resolution with a base-height (B/H) ratio suitable for DEM extraction using automatic stereocorrelation technique. In the present study the automatic stereocorrelation technique is implemented to derive DEM using the ASTER stereo images (3N & 3B) for east Luxor area, Nile Valley, Upper Egypt, within ENVI v.4.5 environment. DEM extraction includes two main steps, defining tie points and calculation of epipolar geometry. 24 tie points collected from ASTER stereo images show a good correlation as indicated by y-parallax value (0.6331). 15 control points collected from reference topo-map covered the study area as well as the topo-DEM generated from their contours are utilized for accuracy assessment procedure. Results indicate that the RMSEz values reach 5.4 meters in wadis and low elevation hill (below 300m) whereas in the mountainous areas (above 300m) the RMSEz values scored 27.2 meters. The present study proved the usefulness of ASTER stereo images for DEM generation with accuracy in Z ranges between 5.4 to 27.2m using automatic stereocorrelation technique.

1. Introduction

The procedures that are used to extract ASTER digital elevation model (DEM) resemble the simple principles of geometry that are probably used routinely with stereo aerial photographs (American Society of Photogrammetry, 1952). Practical implementation of digital photogrammetry has been demonstrated with results using data from numerous satellite systems such as SPOT, IRS, MOMS & JERS. The capability of a computer-automated procedure of stereocorrelation from digital stereoscopic images is first described and evaluated since 30 years ago (Ackermann, 1984), and has been implemented by several commercial softwares such as ENVI (Trinder *et al.*, 1994). ENVI v.4.5 DEM extraction module is designed to extract DEM from satellite stereo images such as ASTER, IKONOS, KOMPSAT-2, QuickBird and SPOT. Along track stereo images (ASTER) are acquired on the same orbital pass by a satellite which usually has more than one sensor looking at the earth from different angles. A cross track stereo images are those taken by the same sensor on multiple orbits. A major advantage of the along-track mode of data acquisition (as compared to cross-track) is that the images forming the stereo-pairs are acquired a few seconds apart under uniform lighting conditions, which are suitable for DEM generation by automatic stereocorrelation techniques (Colvocoresses, 1982 and Fujisada, 1994). Digital elevation models (DEM) produced from SPOT series images (along-track) by automatic stereocorrelation technique are reported to have an accuracy in Z between ±5 and ±20 m depending on the base-to-height (B/H) ratio (Welch, 1990 and Al-Rousan *et al.*, 1997). ASTER data have the capability to produce DEM by automated stereocorrelation technique. ASTER images generated from the nadir (Band 3N) and aft telescopes (Band 3B) yield a B/H ratio of 0.6, which is close to ideal for generating DEM by automated techniques for a variety of terrain conditions. ASTER is a cooperative effort between NASA and Japanese Ministry of Economy Trade and Industry (METI), with the collaboration of scientific and industry organizations in both countries. ASTER captures high spatial resolution data in 14 bands from the visible to the thermal infrared wavelengths; and provides stereo viewing capability for digital elevation model creation. Table 1, shows the ASTER VNIR data characteristics modified after Fujisada (1994).

Table 1. ASTER VNIR data characteristics (modified after Fujisada (1994).

Characteristics	**VNIR**	
Spectral Range	Band 01	0.52–0.60 µm
	Band 02	0.63–0.69 µm
	Band 03N	0.78–0.86 µm
	Band03B	0.78–0.86 µm
Radiometric Resolution	8 bits	
Ground Resolution	15m	
Swath Width	60 km	

Stereocorrelation is a computational and statistical procedure utilized to derive a DEM automatically from a stereopair of registered images (Ackermann, 1984; Ehlers and Welch, 1987 and Lang and Welch, 1999, Hirano *et al*., 2003 and Cuartero *et al*., 2004). The DEM extraction process requires a stereo pairs of images containing rational polynomial coefficients (RPC) positioning from puchbroom sensors. RPCs are used to generate tie points and to calculate the stereo image pair relationship. The present study aims to: 1) Generate DEM using ASTER stereo images (bands 3N&3B) for east Luxor area, Nile Valley, Upper Egypt using automatic stereocorrelation technique, and 2) accuracy assessment for the generated ASTER DEM using 15 control points & topo-DEM derived from reference topographic map covering the study area**.**

2. Study Area Description

The area of study lies to the east of Luxor city along the Nile Valley, Upper Egypt and extends to the east about 50 km (Fig.1). It covers an area about 60km X 60km with the highest point reaches about 800m a.s.l. The main wadis crossing the study area (Wadi Madamoud, Wadi Banat Biri and Wadi Khozam, Fig.2) have nearly NW-SE direction and drain to the Nile River.

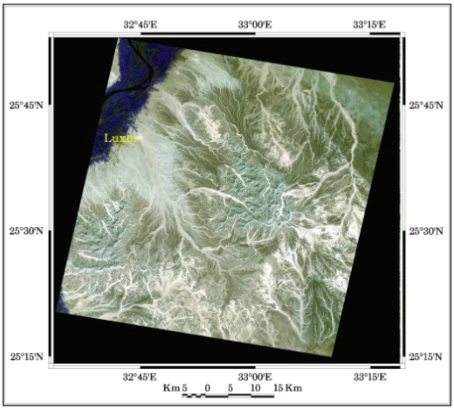

Fig. 1. False color composite ASTER image (bands1, 2& 3 in RGB), shows the location map of the study area.

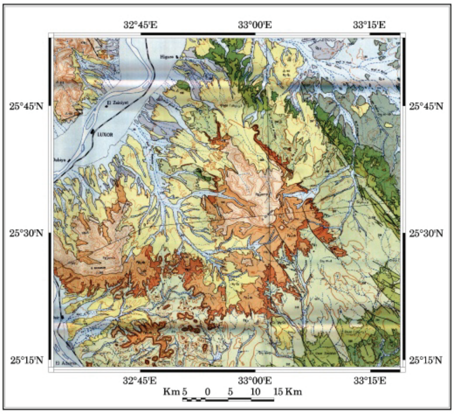

Fig. 2. Topographic map for the study area showing Gebels and Wadies.

3. Data Processing

Stereocorrelation is a very useful technique for estimating the 3D structure of highly textured images of continuous surfaces that are almost fronto-parallel and Lambertian (Dhond and Aggarwal, 1989, and Fua, 1991). The stereocorrelation algorithm requires three main steps: 1- The epipolar geometry is computed by using a sparse set of point matches (Hartly, 1995 and Lindeberg, 1998). 2- The fundamental matrix is used to rectify the images (Ayache and Hansen, 1988). 3- Finally, the correlation procedure is used to match each point of reference image to a corresponding point of displaced image. The actual stereocorrelation algorithm for discrete images is given by the following equation (Fujisada, 1998):

$$c\,(s, t, p) = \sum_{i=-1}^{1} \sum_{j=-N}^{N} \text{REF}\,(s + i, t + j)\ \text{DISP}\,(s + i, t + j + p)$$

where s and t are the pixel coordinates of the point being evaluated, p is the parallax, 2N + 1 is the dimension of the correlation window, c is the cross-correlation coefficient, and REF and DISP are brightness values from the reference and displaced images.

Two types of DEM (relative & absolute) can be generated using stereocorrelation technique: (1) Relative DEM where the elevations are not tied to a ground or map datum; no ground control points (GCPs) are required and are generated by using the satellite ephemeris data only with accuracy range between 10–30m, and (2) absolute DEM where the locations of the DEM position are fitted to a reference map coordinate system with an accuracy between ±7 and ±50 m, depending on the number of GCPs used. In the present study digital stereocorrelation technique is utilized to derive DEM from ASTER Level 1 stereo pair images (bands 3N&3B) within ENVI environment.

3.1. DEM Generation Using ENVI v.4.5 Software

ENVI v.4.5 DEM extraction module is a multi-step decision making module that consists of three main tools: DEM editing Tool, Stereo Pair 3D measurement Tool and Epipolar 3D Cursor Tool. Figure 3 shows the procedures that were carried throughout the present study to extract DEM form ASTER stereo images level 1A. It includes the following procedures: Input ASTER stereo image pairs (3N&3B) level 1A, defining tie points, specify objective projection parameters (UTM, WGS84, 36N zone) and finally DEM extraction & editing. The scanned reference topographic map covering the study area is geometrically corrected using image to map procedure under the following projection parameters (UTM, WGS84, 36N zone). On screen digitization for contours and control points extracted from the geo referenced topo-map is the next step for DEM generation. DEM are generated from ASTER L1A product without GCPs using VNIR normal (3N) and backward (3B) bands as right and left images, respectively.

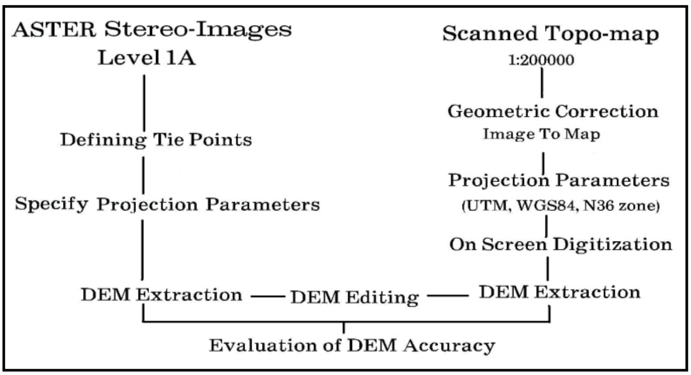

Fig. 3. The procedures for DEM generation from ASTER stereo images level 1A and reference topo-map.

Figure 4 shows the tie points collected based terrain features within the stereo images. 24 conjugate tie points collected from ASTER stereo images are used for DEM extraction and as a result, image matching was performed with y parallax value of 0.6331. The Y parallax value indicates that the tie points show a good correlation and matching. The next step is to calculate epipolar geometry and epipolar images that are used to extract DEM. DEM output projection parameters are UTM projection, Zone 36, Datum WGS84 with 15 meters spatial resolution. Figure 5 shows the DEM generated throughout the present study whereas Fig. 6 shows the 3D perspective view of ASTER DEM draped over the false color composite (FCC) ASTER image for the study area.

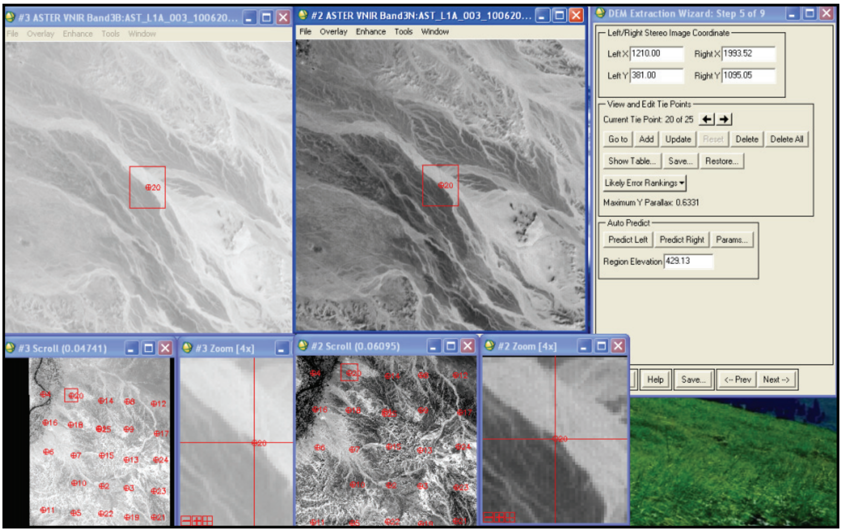

Fig. 4. ASTER stereo pair images with 24 tie points covering the study area.

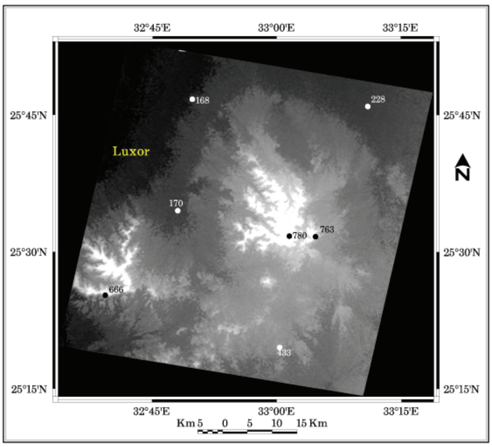

Fig. 5. DEM for the study area shows some elevation points in meters.

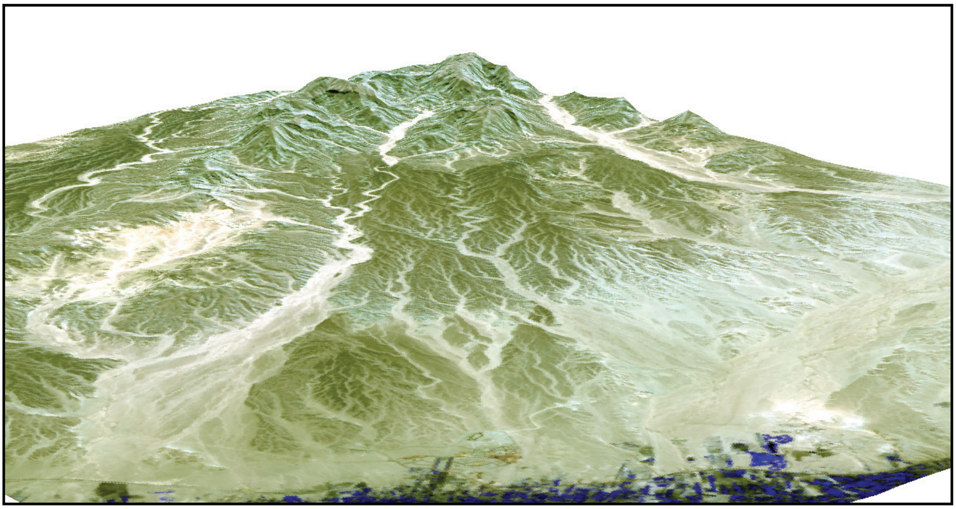

Fig. 6. 3D perspective view of ASTER FCC image (bands 1, 2 & 3; RGB) draped over ASTER digital elevation model generated during the present study for Luxor area.

3.2. ASTER DEM Accuracy Assessment

15 control points (Table 2) as well as topo-DEM derived from reference topographic map are prepared for accuracy assessment procedures. Two transect lines (Fig. 7a & 8a) are drawn for comparison between ASTER and topo-DEMs. Figure 7b shows ASTER DEM plotted against Topo-DEM for wadis and low elevated hills (below 300m). The maximum elevation differences recorded are 9 & 7 meters (Table 2) with an average root mean square error (RMSEz) equal 5.4m. Control point No.3 is excluded from the calculations. Figure 8b shows ASTER DEM plotted against Topo-DEM for mountainous area (above 300m). The maximum elevation differences recorded are 59 & 52 meters (Table 2) with an average RMSEz equal 27.2m.

Table 2. Elevation values & positions of the control points collected from ASTER & topo-map.

Control Points	Latitude	Longitude	Map(T.P.) Elevation (m)	ASTER Elevation (m)	Difference in Elevation (m)
1	25d39'55.8262"N	32d45'21.7144"E	111	106	5
2	25d42'14.0261"N	32d43'48.2004"E	85	81	4
3	25d46'45.6643"N	32d49'46.5369"E	168	145	23
4	32d53'41.0053"E	25d48'32.0723"N	157	159	2
5	25d33'24.7252"N	32d55'41.5262"E	346	346	0
6	25d27'40.4660"N	33d01'38.8475"E	375	361	14
7	25d27'55.4262"N	33d09'54.2228"E	381	371	10

Control Points	Latitude	Longitude	Map(T.P.) Elevation (m)	ASTER Elevation (m)	Difference in Elevation (m)
8	25d27'23.2842"N	32d50'39.5776"E	367	317	50
9	25d29'48.3757"N	32d38'12.1555"E	593	534	59
10	25d27'12.8335"N	32d50'46.6798"E	367	324	43
11	25d34'43.0757"N	32d47'18.5469"E	170	161	9
12	25d40'57.6339"N	32d55'39.4798"E	429	377	52
13	25d34'43.0770"N	32d47'19.4339"E	170	163	7
14	25d27'13.6361"N	32d50'44.9066"E	367	320	47
15	25d30'35.0371"N	32d58'23.8569"E	600	550	50

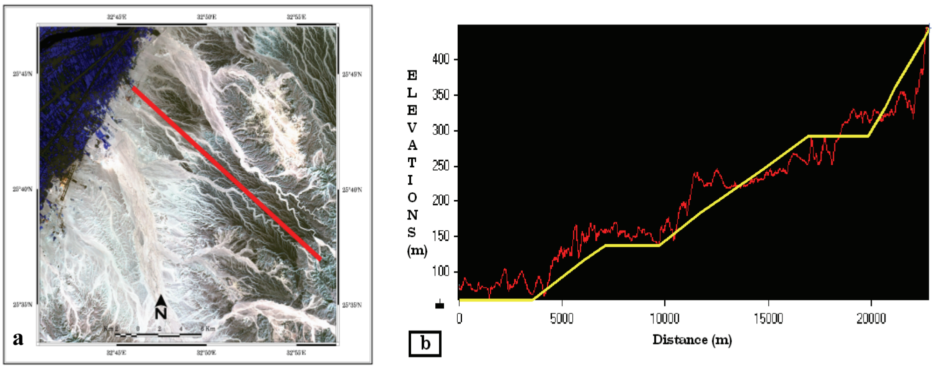

Fig. 7. a) Transect line drawn in low elevated hills and wadis. b) Profiles of ASTER & topo-DEMs in red and yellow colors, respectively.

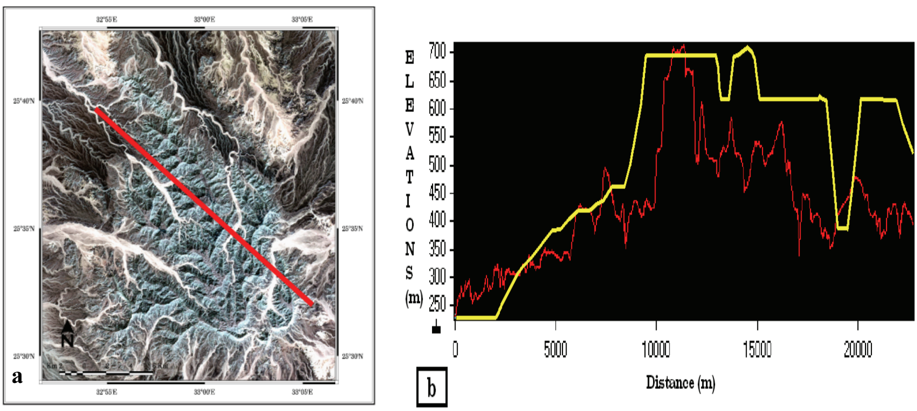

Fig. 8. a) Transect line drawn in mountainous area. b) Profiles of ASTER& topo- DEMs in red and yellow colors, respectively.

4. Conclusion

Along-track ASTER stereo images covers east Luxor area, Nile Valley, Upper Egypt are utilized to generate DEM using automatic stereocorrelation technique. The procedures for DEM extraction form ASTER stereo images level 1A within ENVI v.4.5 environment includes defining tie points, specify objective parameters and DEM extraction. 15 control points collected from reference topo-map covered the study area as well as the topo-DEM generated from their contours are utilized for accuracy assessment procedure. The output ASTER DEM has 15 m spatial resolution. Results indicate that in wadis and low elevated hills (below 300m) the RMSEz values reach 5.4 m whereas in the mountainous areas (above 300m) the RMSEz values reach 27.2 m. The present study proved the usefulness of ASTER stereo images for DEM generation with accuracy in Z ranges between 5.4 to 27.2 m using automatic stereocorrelation technique.

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تعيين دقة نموذج ارتفاع رقمي ثلاثي الأبعاد والمنتج من بيانات أستر بواسطة تقنية مضاهاة الاستريو

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المستخلص. تهدف هذه الدراسة إلى تعيين دقة نموذج ارتفاع رقمي ثلاثي الأبعاد منتج باستخدام مرئيات أستر بواسطة تقنية مضاهاة الاستريو لمنطقة شرق مدينة الاقصر – وادى النيل– مصر. وقد تم إنتاج هذا النموذج باستخدام مرئيات أستر 3B & 3N بداخل بيئة برنامج ENVI v.4.5 على مرحلتين أساسيتين هما: ١) تجميع ٢٤ نقطة ارتباط من المرئيتين، ٢) حساب مايسمى ب epipolar geometry وكذلك إنتاج صور epipolar وتخليق نموذج الارتفاع الرقمي ثلاثي الأبعاد. ولتعيين دقة النموذج الرقمي ثلاثي الأبعاد تم استخدام خريطة طوبوغرافية بمقياس رسم ١:٢٠٠٠٠٠ لإنتاج نموذج ارتفاع رقمي مجسم واستخلاص عدد من نقاط الارتفاع المرجعية (١٥ نقطة). ولقد أكدت النتائج أن نموذج الارتفاع الرقمي المنتج بواسطة مرئيات أستر باستخدام تقنية مضاهاة الاستريو تختلف دقته باختلاف الارتفاعات. حيث تبلغ هذة الدقة حوالي ٥,٤ مترًا في الأودية والتلال قليلة الارتفاعات (أقل من ٣٠٠ متر) أما في الجبال والمناطق المرتفعة (أعلى من ٣٠٠ متر) فإن دقة النموذج الرقمي المنتج تبلغ حوالي ٢٧,٢ مترًا.