Delineation & Representation of Linear Megadunes from CSI-SRTM DEM

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1. Introduction

Desert environments are dominated by dunes that are accumulation of sediment blown by the wind into a mound or ridge. Dunes have gentle upwind slopes on the wind-facing side. The downwind portion of the dune is commonly a steep avalanche slope referred to as a slipface; dunes may have more than one slipface (Summerfield, 1996). The slipface stands at the angle of repose, which is the maximum angle at which loose material is stable (30° to 34° for sand). Dunes typical heights and wavelengths (spacing) are in the range of 5 to 30 m and and 50 to 300 m respectively. Megadunes, in the Western Desert (Egypt and Libya) and in Namib Sand Sea (Namibia) attain even greater dimensions with heights of up to 400 m and wavelegths up to 4 km, the most significant factors determining their morphology are wind regime and sand supply (Summerfield, 1996). Australian dunes (in Simpson Desert) are classified in between dunes and megadunes (Wasson and Hyde, 1983a).

Nowadays, broad-scale quantification of topography and SRTM digital elevation models (DEMs) represents the earth's relief at moderate scale (Farr and Kobrick, 2000). Since SRTM elevation data became widely available, many studies utilized them for applications in geomorphology, vegetation cover studies, and hydrologic studies (Wang et al., 2005; Kellndorfer et al., 2004). In its original release, SRTM data contained regions of no-data (named voids), specifically over water bodies (lakes and rivers), and in areas where insufficient textural detail was available in the original radar images to produce three-dimensional elevation data (Rabus, et al., 2003). The existence of voids in a DEM causes significant problems in using SRTM DEMs. The Consortium for Spatial Information (CSI) of the Consultative Group for International Agricultural Research (CGIAR) applied a hole-filling algorithm to SRTM DEM in order to provide continuous elevation surfaces at 3-arc second for the globe (Jarvis et al., 2006). The CSI-SRTM data is available in 5^{o} tiles, referenced to WGS-84 ellipsoid.

At the same time various digital image processing and G.I.S. techniques are being developed in order to automate the segmentation and the qualitative interpretation of geomorphologic features (Miliaresis and Kokkas, 2004). These methods allow the terrain segmentation to elementary geomorphic objects and subsequent parametrically representation of objects on the basis their spatial 3-dimensional arrangement (Miliaresis, 2006).

Megadunes must take hundreds of years to attain an equilibrium form (Wasson and Hyde, 1983b) and thus they are key landforms in the study of possible severe climatic change that will possibly be expressed by change in the direction and intensity of winds in desert regions. This paper is concerned with both the extraction (delineation) of megadunes and the study of limitations evident in megadunes representation in CSI-SRTM elevation dataset in the particular study area in SW Egypt.

2. Study area and Data

The study area is bounded by longitude 25.0101^o to 26.5588^o E and latitude 23.8566 ^{o} to 25.0073^o N (Fig. 1) in SW of Egypt. It belogs to the Western Desert that covers about 700,000 square kilometers and accounts for about two-thirds of Egypt's land area. This immense desert to the west of the Nile spans the area from the Mediterranean Sea south to the Sudanese border where no rivers or streams drain into or out of the area. The study area occupies the Jilf al Kabir Plateau that has an altitude of about 1,000 meters, an exception to the uninterrupted territory of basement rocks covered by layers of horizontally bedded sediments forming a massive plain or low plateau.

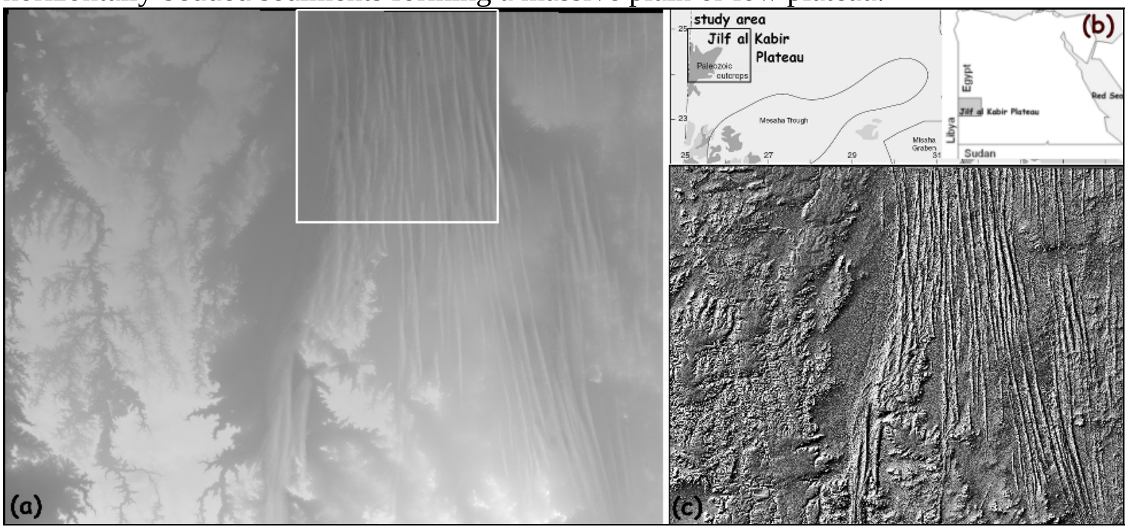

Figure 1. (a) DEM the greater the elevation, the brighter a DEM point. The white rectangular indicates the study area. (b) Location of the study area. (c) Shaded relief map of the study area (sun azimuth equals to 315^o while sun elevation equals to 45^o).

The CSI-SRTM DEM tile srtm_42_08.zip was used that bounds an area by longitude 25^o to 30^o E and latitude 20^o to 25^o N (Jarvis et. al., 2006). The shaded relief map of the study area (Fig 1c) indicates a set of a rectilinear landform pattern in the North and East portion. DEM was reprojected to UTM, zone 35 with both reference ellipsoid and datum the WGS84, resampled by nearest neighbor and a DEM with spacing 92m was derived. The white rectangular portion (Fig.1a) of the DEM used in this research is enclosed by the rectilinear co-ordinates with X in the range 367,052 to 417,284 and Y in the range 2,708,010 to 2,764,774 consisting of 546 columns and 617 rows (Fig. 1a) while elevation is within the range 454 to 728 m.

The Landsat-ETM satellite image (p179r043_7p19990927_z35), acquired on Sept. 27, 1999 (GLGC, 2006) was used for photointerpretation of the landforms and for evaluation of the segmentation results. During acquisition time sun azimuth was 136.5^o and sun elevation was 55.8^o.

The intepretation of satellite imagery (Figure 2) indicates as system of straight or slightly sinuous sand ridges typically much longer than they are wide, known as linear megadunes. The megadunes elevation is up to 250 m while wavelength is less than 2 km. The most researchers believe that they develop where there are two obliquely converging prevailing winds (Summerfield, 1996). There are two, more or less opposing slip faces while sand transport is parallel to the crest line. In the study area free dunes are observed since their form is primary function of wind characteristics and not impeded dunes whose morphology is influenced significaltly by the effects of vegetation or topographic bariers. Linear dunes generally form sets of parallel ridges separated by sand, gravel, or rocky interdune corridors. Some linear dunes merge to form Y-shaped compound dunes.

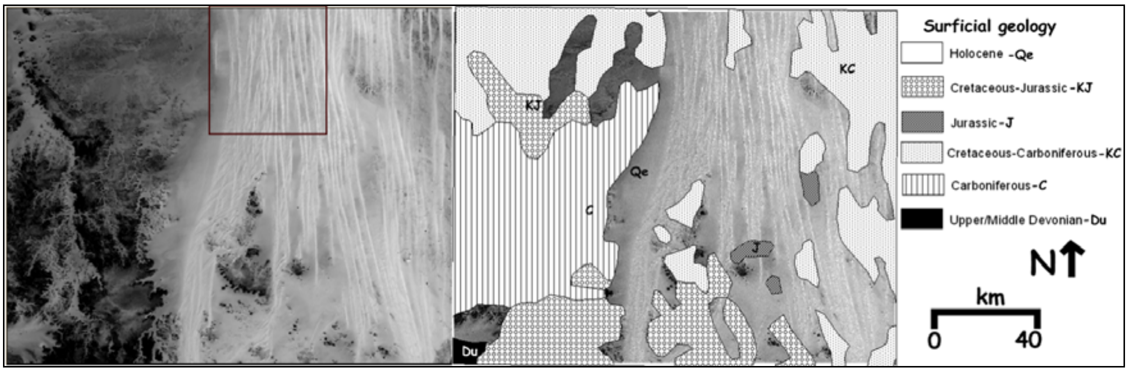

Figure 2. The panchromatic image (Landsat ETM, band 8) with pixel size equal to 14.25 m is shown in the left image. The geologic map of the study area in the right image (note the panchromatic band is shown through the Holocene).

The geologic map of the study area (Persits et al., 2002) indicates that the dunes are developed mainly on Holocone and partially on Cretaceus-Carboniferous layers (Fig. 2).

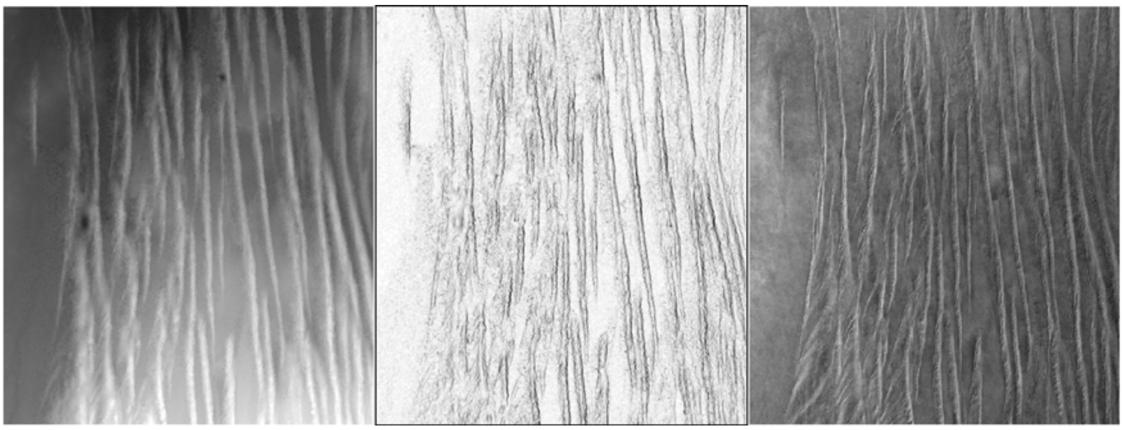

Figure 3. DEM (left), slope image (middle), thermal infrared Landsat ETM (band 6) in the right.

3. Delineation of Linear Megadunes

Region growing segmentation was applied (Miliaresis 2006). The initial set of seed points was defined by thresholding the upslope runoff image, while region growing criteria were based both to the slope image and to the valley network (region growing stopping borders). Iterative image morphology operators allowed the elimination of the small islands of points within the valley corridors and the merging of megadune tops (failed to be segmented by the region growing) to the megadune sides.

4. SRTM Representaion of Megadunes

The evaulation of the results by the aid of Landsat-ETM imagery indicated that megadunes were failed to be segmented in areas were voids existed in the initial SRTM dataset.

More than that the slope values in SRTM DEM are generalised (possibly due to DEM resolution) and thus region growing criteria was slope greater than 5^{o} degrees (slope values up to 30° to 34° might be observed in the field).

The overall form of megadunes is similar in cross section to that of dunes but in detail is often more complicated by the presence of superimposed dunes. The interpretation of satellite imagery (spacing 14.25 m) indicated a complex surface (ripples in a E to W direciton) that were not evident in SRTM DEM. This is expected due to the 92 m resolution of SRTM DEM.

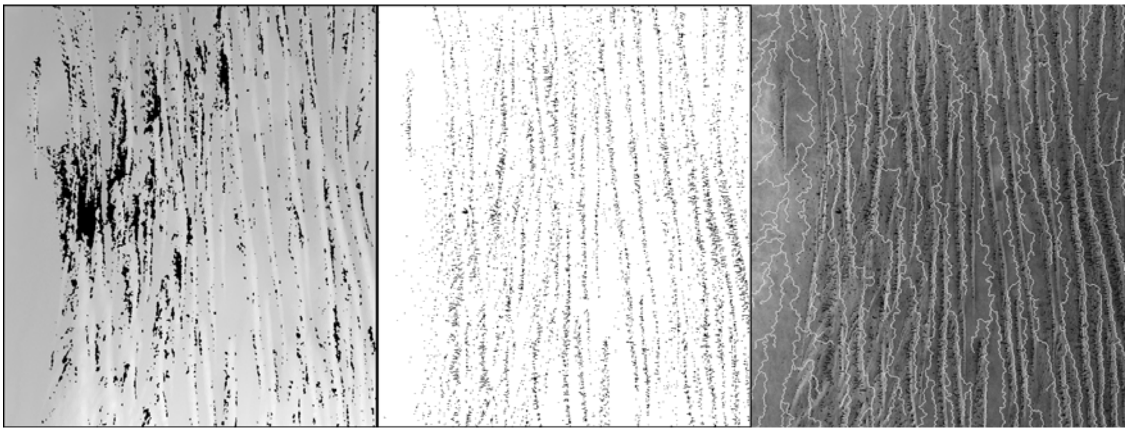

Figure 4. Voids (black pixels) superimposed over the interpolated CSI-SRTM DEM (left), seed points (in the middle image), and valley network superimposed over the thermal infrared image (right image).

5. Conclusion

The voids although that are not evident in CSI-SRTM DEM due to the post-processing applied, they do create problems in megadune extraction/delineation.

The geomorphometric representation of megadunes in SRTM DEM is generalised due to spacing (92 m) that underestimates the slope and certainly the curvature.

SRTM DEMs seems to be suitable in delinating linear megadunes if the surface extent of voids is few DEM points but it is doubtful if slope and elevation estimates are suitable for detecting a change of megadune geomorphometry due to a possible climatic change.

More accurate (in both horizontal and vertical) as well as denser DEMs are required in order to study megadunes geomorphometry.

6. References

Farr T, Kobrick M, 2000, Shuttle radar topography mission produces a wealth of data. *Amer. Geophys. Union Eos*, 81, 583-585.

GLFC, 2006, *Global Landcover Facilcity*. University of Maryland, http://glcf.umiacs.umd.edu/index.shtml

Jarvis A, Reuter H, Nelson A, Guevara E., 2006, Hole-filled seamless SRTM data V3, *International Centre for Tropical Agriculture (CIAT)*, available from http://srtm.csi.cgiar.org.

Kellndorfer J, Walker W, Pierce L, Dobson C, Fites J, Hunsaker C, Vona J, Clutter M, 2004, Vegetation height estimation from Shuttle Radar Topography Mission and National Elevation Datasets. *Remote Sensing of Environment*, 93, 339-358.

Miliaresis G, 2006, Geomorphometric mapping of Asia Minor from Globe digital elevation model. *Geografiska Annaler*, 88 A(3), 209-221

Miliaresis G, Kokkas N, 2004, Segmentation and terrain modeling of extra-terrestrial chasmata. *Journal of Spatial Sciences*, 49, 89-99.

Persits F, Ahlbrandt T, Tuttle M, Charpentier R, Brownfield M, Takahash K, 2002, Map showing geology, oil and gas fields and geologic provinces of africa. *Open File Report 97-470A, ver. 2.0.* US Geological survey. http://pubs.usgs.gov/of/1997/ofr-97-470/OF97-470A/

Rabus B, Eineder M, Roth A, Bamler R, 2003, The shuttle radar topography mission- a new class of digital elevation models acquired by spaceborne radar. *Photogrammetric Engineering & Remote Sensing*, 57, 241-262.

Summerfield M, 1996, *Global Geomorphology*. Longman Group, Essex, U.K.

Wang Y, Liao M, Sun G, Gong J, 2005. Analysis of the water volume, length, total area and inundated area of the Three Gorges Reservoir, China using the SRTM DEM data. *International Journal of Remote Sensing*, 26, 4001-4012.

Wasson R, Hyde R, 1983a, Factors determining desert dune type. *Nature*, 304, 337-339.

Wasson R, Hyde R, 1983b, A test of granulometric control of desert dune geometry. *Earth Surface Processes and Landforms*, 8, 301-312.