Complete SRTM digital elevation data for the Arabian Peninsula

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Abstract

Digital Elevation Models (DEM) are an important data source in studies of land surface processes, and a central component of Spatial Data Infrastructures (SDI). Medium resolution DEMs have many applications, including continental-scale land characterisation, regional hydrologic studies, and geometric correction of medium and high resolution satellite imagery. During the Shuttle Radar Topography Mission (SRTM), Interferometric Synthetic Aperture Radar (InSAR) was applied to scan land surfaces between 60° north and 58° south latitude. From the reflected C-band radar signals a DEM of 3-arc seconds horizontal grid spacing was derived. However, SRTM C-band data has voids in areas of poor signal reflection (steep mountain slopes, water, ice, or dry desert areas). Voids cause significant problems in data use, e.g. in hydrological models which require continuous flow surfaces. The Consultative Group for International Agricultural Research - Consortium for Spatial Information (CGIAR-CSI) has now published a version of the SRTM C-band DEM with data voids filled. Resulting continuous elevation data for the Arabian Peninsula are presented in this paper and possible applications are discussed.

Keywords

Digital elevation data, Shuttle Radar Topography Mission (SRTM), Arabian Peninsula, hydrological applications

Introduction

Digital Elevation Models (DEM) are used in many applications including hydrologic modelling (surface runoff calculations), the generation of ortho-images from air photos and high-resolution satellite imagery, the modelling of solar radiation, cut-and-fill analyses in construction (e.g. of roads, rail tracks, etc.), or the modelling of radio signal propagation (antenna network optimisation). During the Shuttle Radar Topography Mission (SRTM), Interferometric Synthetic Aperture Radar (InSAR) was applied to scan land surfaces between 60° north and 58° south latitude. From the reflected C-band radar signals a DEM of three arc seconds horizontal grid spacing (equivalent to 90 m at the equator) was derived. Carried out from 11 to 23 Feb. 2000 onboard Space Shuttle 'Endeavor', the SRT-Mission was the most complex mission to map the Earth's surface. Two InSAR Systems, one in the X-Band and one in the C-Band, were used in a stereoscopic arrangement of antennas on board the Space Shuttle and on a 60-m extension mast. Elevation data was derived during post-processing of signal runtime differences. Table 1 describes technical specifications of the SRT-Mission; Fig. 1 shows the area covered by SRTM (C-band), from 60° north to 58° south latitude, covering 95% of the land areas populated by humans.

Tab. 1: Technical specifications of SRT-Mission radar systems.

Radar System	**C-Band**	**X-Band**
Manufacturer	JPL – Jet Propulsion Laboratory	Dornier Satellite Systems GmbH
On-board antennas	12 m x 80 cm	12 m x 40 cm
Off-board antennas	8 m x 80 cm	6 m x 40 cm
Wave length	5,6 cm	3,1 cm
Frequency	5,3 GHz	9,6 GHz
Ground swath width	225 km	50 km
Mapped area (% of regions covered by flight)	100%	40%
Data rate	180 Mbit/s	90 Mbit/s
Data amount	8,6 Terabyte	3,7 Terabyte

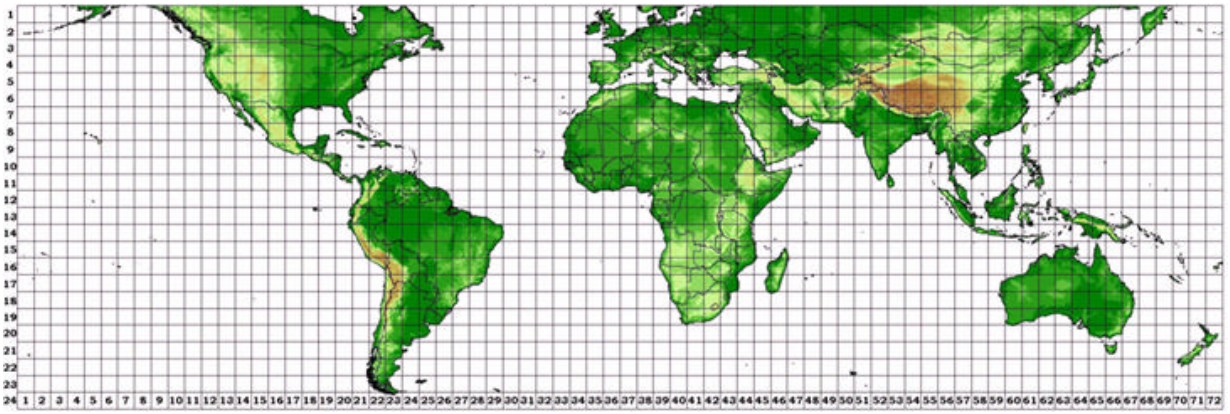

Fig. 1: SRTM C-band coverage (image source: http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp)

Because of its narrower ground swath width (Tab. 1), SRTM X-band data covers the regions depicted in Fig. 1 only partly. Therefore, only SRTM C-band elevation data are discussed in the following. SRTM C-band elevation data are in the public domain, and are available in several versions from various organisations for free download from the Internet, e.g. the US Geological Survey (USGS, http://edcsgs9.cr.usgs.gov/pub/data/srtm/), or the University of Maryland (http://glcf.umiacs.umd.edu/data/srtm/).

However, SRTM C-band data have voids in areas of poor signal reflection, such as steep mountain slopes, water, ice, or dry desert areas. Voids cause significant problems in data use, e.g. in hydrological models which require continuous flow surfaces. The Consultative Group for International Agricultural Research - Consortium for Spatial Information (CGIAR-CSI) has recently published a version of the SRTM C-band DEM with data voids filled (see http://srtm.csi.cgiar.org/). The purpose of these version 2 SRTM-elevation data is to generate a homogeneous, void-free elevation dataset, and to reset off-shore elevation values (‘noise‘) to zero.

The following data-processing methodology was used for gap-filling to produce SRTM version 2 data:

- Calculation of elevation contours from SRTM v1 with ?z = 10 m.
- Raster interpolation using the Arc/Info TOPOGRID command. TOPOGRID interpolates through the no-data holes, producing a smooth elevational surface where no data was originally found.

- The interpolated DEM for the no-data regions is merged with the original DEM to provide continuous elevational surfaces without no-data regions.
- The resultant seamless dataset is clipped along shorelines using the GSHHS - a Global Self-consistent, Hierarchical, High-resolution Shoreline Database (http://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html).
- The result is a smooth elevational surface of no-data regions.

Objectives

The objective of this study is to mosaic SRTM version 2 data tiles in order to generate a complete, homogeneous DEM for the Arabian Peninsula. Further objectives are to test possibilities of SRTM elevation data applications, in particular for general hydrological purposes, such as the determination of slope steepness, slope aspect, or runoff direction.

Materials & Data

SRTM C-band DEM v2 tiles covering the Arabian Peninsula were downloaded from the Internet site http://srtm.csi.cgiar.org/.

SRTM C-band v2 DEM statistics for the Arabian Peninsula:

25 data tiles	30,000 x 30,000 cells
Extent:	10° to 35° N, 35° to 60° E
Spatial reference:	GCS WGS 1984
Data range:	lowest point: -528 m (Dead Sea), highest point: 4517 m (Africa)

Methodology

SRTM C-band DEM v2 tiles covering the Arabian Peninsula are mosaicked using ERDAS Imagine 8.7 software, and are stored in uncompressed ESRI GRID format (file size: 1,68 GB). Slope steepness (in deg), slope aspect (compass directions in deg from 0° to 360°), surface water flow directions, and contours are calculated using ArcGIS 9.0 (Spatial Analyst Module). SRTM C-band DEM v2 data are compared to the older GTOPO30 elevation data (avaiable from http://edc.usgs.gov/products/elevation/gtopo30/gtopo30.html).

Results & Discussion

A perspective view of mosaicked SRTM data for the Arabian Peninsula from South-Eastern direction is shown in Fig. 2. The image was prepared using ArcScene software (by ESRI). Results of slope steepness and slope aspect calculations will be presented during the conference. Further results of standard hydrological surface model calculations (analyses of flow direction, flow accumulation, flow length, stream lines, stream order, and watershed boundaries) are presently carried out by Phoenics GmbH using the Spatial Analyst Module of ArcGIS.

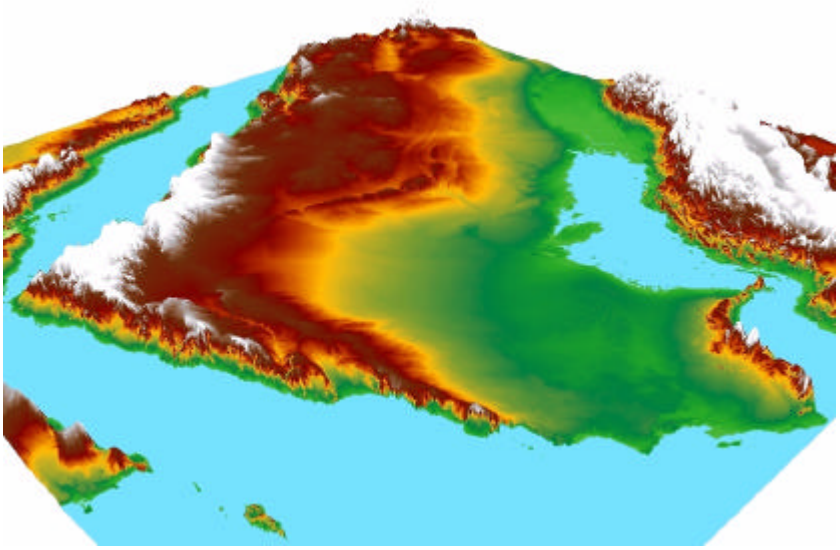

Fig. 2: SRTM C-band DEM v2, covering the Arabian Peninsula.
Perspective view from South-Eastern direction (prepared by Phoenics).

The general quality of the SRTM elevation data is assessed by comparing it with the older GTOPO30 global elevation model. GTOPO30 data (originally in 30 arc seconds spatial resolution) is resampled to the cell size of the SRTM data. In a second step, the SRTM elevation model is subtracted from the GTOPO30 data. Results for the Arabian Peninsula are shown in Fig. 3 in perspective view. It becomes apparent that the two elevation datasets are quite similar in flat areas (yellow), but are quite different in mountainous regions (red and green areas). Some areas of high discrepancy between GTOPO30 and SRTM elevations also exist in flat areas. It is assumed that these are areas of bad InSAR C-band signal reflection (dry desert areas), i.e. data voids in the original SRTM v1 dataset. However, the absolute accuracy of neither of the DEMs (i.e., local derivation of SRTM or GTOPO30 from true terrain elevation) could be assessed during the present study.

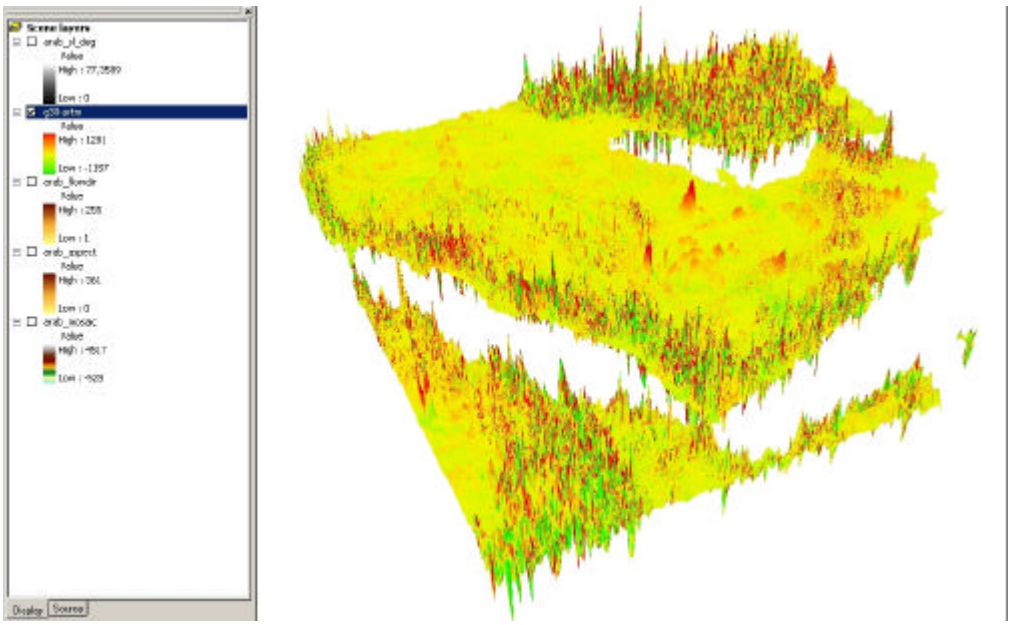

Fig. 3: Differences between GTOPO30 and SRTM C-band (v2) DEMs.
Perspective view from South-Western direction (prepared by Phoenics).

The histogram of GTOPO30 minus SRTM elevation data is shown in Fig. 4, together with some basic statistics.

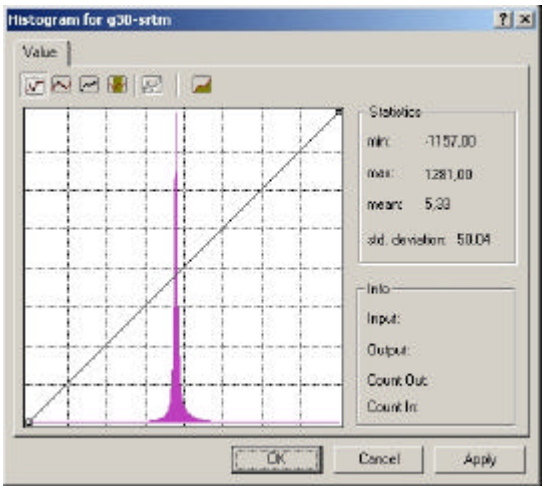

Fig. 4: Histogram of GTOPO30 minus SRTM C-band (v2) DEMs.

Conclusions

With the results of SRT-Mission, a complete and homogeneous DEM can be derived for most land areas of the Earth, including the Arabian Peninsula. The spatial resolution of the freely availabe data (three arc seconds) is approximately equivalent to that of a map at scale 1: 100,000. The general quality of SRTM C-band elevations appears sufficient to carry out standard hydrologic surface analyses, or to ortho-rectify medium or high-resolution satellite imagery. Care must be taken when the data shall be used in applications such as infrastructure planning. To assess the true accuracy of SRTM data, comparison with elevation information derived from independent sources, such as maps of scale 1: 100,000, will be required.

All data used in this study are freely available from the sources mentioned in the text (see also references). However, because of large file sizes data processing is somewhat time-consuming. Mosaicked SRTM elevation data for the Arabian Peninsula, together with test results and results of hydrological surface analyses, are available through Phoenics GmbH upon request (www.phoenics.de, dhermsmeyer@phoenics.de).

References

http://srtm.csi.cgiar.org/

http://edcsgs9.cr.usgs.gov/pub/data/srtm/

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