SRTM Topography

1.0 Introduction

The SRTM data sets result from a collaborative effort by the National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA - previously known as the National Imagery and Mapping Agency, or NIMA), as well as the participation of the German and Italian space agencies, to generate a near-global digital elevation model (DEM) of the Earth using radar interferometry. The SRTM instrument consisted of the Spaceborne Imaging Radar-C (SIR-C) hardware set modified with a Space Station-derived mast and additional antennae to form an interferometer with a 60 meter long baseline. A description of the SRTM mission can be found in Farr and Kobrick (2000).

Synthetic aperture radars are side-looking instruments and acquire data along continuous swaths. The SRTM swaths extended from about 30 degrees off-nadir to about 58 degrees off-nadir from an altitude of 233 km, and thus were about 225 km wide. During the data flight the instrument was operated at all times the orbiter was over land and about 1000 individual swaths were acquired over the ten days of mapping operations. Length of the acquired swaths range from a few hundred to several thousand km. Each individual data acquisition is referred to as a "data take."

SRTM was the primary (and pretty much only) payload on the STS-99 mission of the Space Shuttle Endeavour, which launched February 11, 2000 and flew for 11 days. Following several hours for instrument deployment, activation and checkout, systematic interferometric data were collected for 222.4 consecutive hours. The instrument operated almost flawlessly and imaged 99.96% of the targeted landmass at least one time, 94.59% at least twice and about 50% at least three or more times. The goal was to image each terrain segment at least twice from different angles (on ascending, or north-going, and descending orbit passes) to fill in areas shadowed from the radar beam by terrain.

This 'targeted landmass' consisted of all land between 56 degrees south and 60 degrees north latitude, which comprises almost exactly 80% of Earth's total landmass.

2.0 Data Set Characteristics

2.1 Processing steps and versioning

The SRTM data have undergone a sequence of processing steps resulting in several data versions having slightly different characteristics. In addition, the different naming conventions used by the NGA and NASA can lead to some confusion.

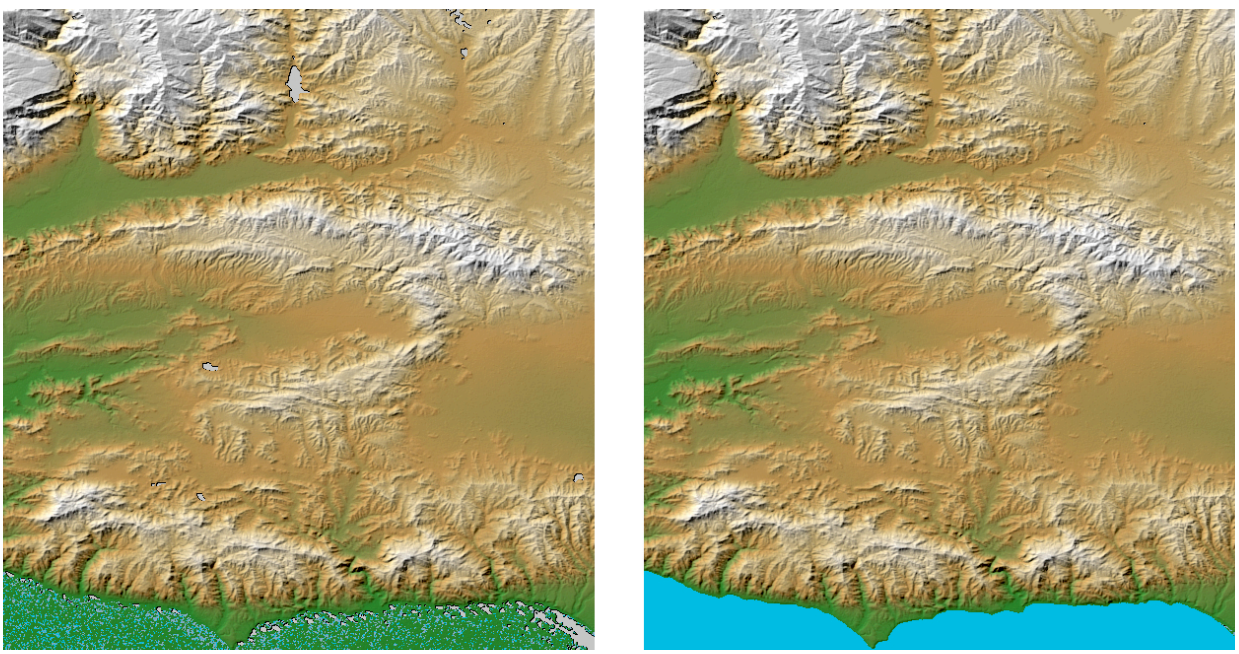
In the first step raw SRTM radar echo data were processed in a systematic fashion using the SRTM Ground Data Processing System (GDPS) supercomputer system at the Jet Propulsion Laboratory. This processor transformed the radar echoes into strips of digital elevation data, one strip for each of the 1000 or so data swaths. These strips were then mosaicked into just less than

15,000 one degree by one degree cells and formatted according to the Digital Terrain Elevation Data (DTED) specification for delivery to NGA, who are using it to update and extend their DTED products. The DTED specification can be found in MIL-PDF-89020b.pdf on this server. The data were processed on a continent-by-continent basis beginning with North America and proceeding through South America, Eurasia, Africa, Australia and Islands, with data from each continent undergoing a “block adjustment” to reduce residual errors.

These data were also reformatted into the SRTM format, detailed in Section 3 below, and placed on this server as Version 1.0.

In the next step NGA applied several post-processing procedures to these data including editing, spike and well removal, water body leveling and coastline definition as described in the document SRTM_Edit_Rules.doc on this server. Following these "finishing" steps data were returned to NASA for distribution to the scientific and civil user communities as well as the public. These data were also reformatted into the SRTM format and are referred to as Version 2. The figure below shows a portion of cell N34W119.hgt, demonstrating the difference between the edited and unedited data.

N34W119.hgt

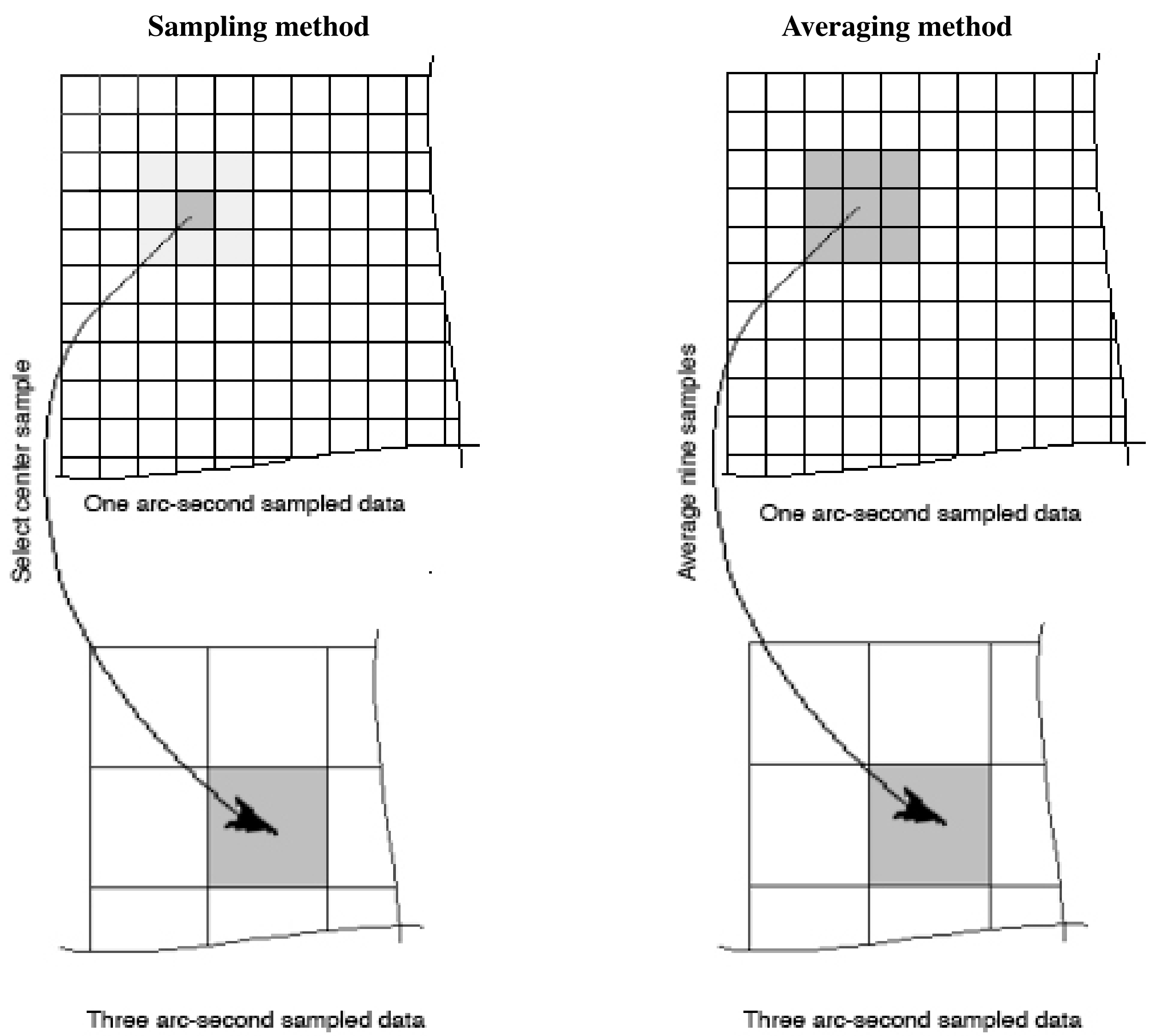


unedited   edited

During the summer of 2009 the three arc-second sampled Version 2 data were replaced by Version 2.1, reflecting an improvement in the generation method. The editing for Version 2 had been applied by masking in the edited samples from the lower-resolution data publicly released by the NGA. This resulted in occasional artifacts, and in particular a very slight vertical “banding” in data beyond 50° latitude. For Version 2.1 the entire set was regenerated by averaging the full-resolution edited data which eliminated these artifacts, although most users will not notice the difference.

In addition, there is a difference between the data distributed via ftp from the Land Processes Distributed Active Archive Center (LP DAAC - from which you likely downloaded this file), and those available on DVD from the EROS Data Center (EDC) or through its Seamless Data Distribution System (SDDS, aka 'Seamless Server'.)

Three arc-second sampled data from the EDC have been generated from the one arc-second data by the same method the NGA uses to generate DTED level 1 data, namely by "subsampling". In this method each three arc-second data point is generated by selecting the center sample of the 3x3 array of one arc-second points surrounding the post location. For the LP-DAAC three arc-second data each point is the average of the nine one arc-second samples surrounding the post, as illustrated in the figure below.



It is felt by most analysts that the averaging method produces a superior product by decreasing the high frequency 'noise' that is characteristic of radar-derived elevation data. This is similar to the conventional technique of 'taking looks', or averaging pixels in radar images to decrease the effects of speckle and increase radiometric accuracy, although at the cost of horizontal resolution.

The tables below summarize the naming conventions used to differentiate the SRTM products available here and NGS's DTED products, and the differences between the SRTM versions as well as their availability.

SRTM data naming conventions

posting (sample spacing)	**SRTM name**	**DTED equivalent**	**other data sets**
1 arc-second	SRTM1	DTED2 (indicating 'level 2')	
3 arc-seconds	SRTM3	DTED1	
30 arc-seconds	SRTM30	DTED0	GTOP30

SRTM data availability

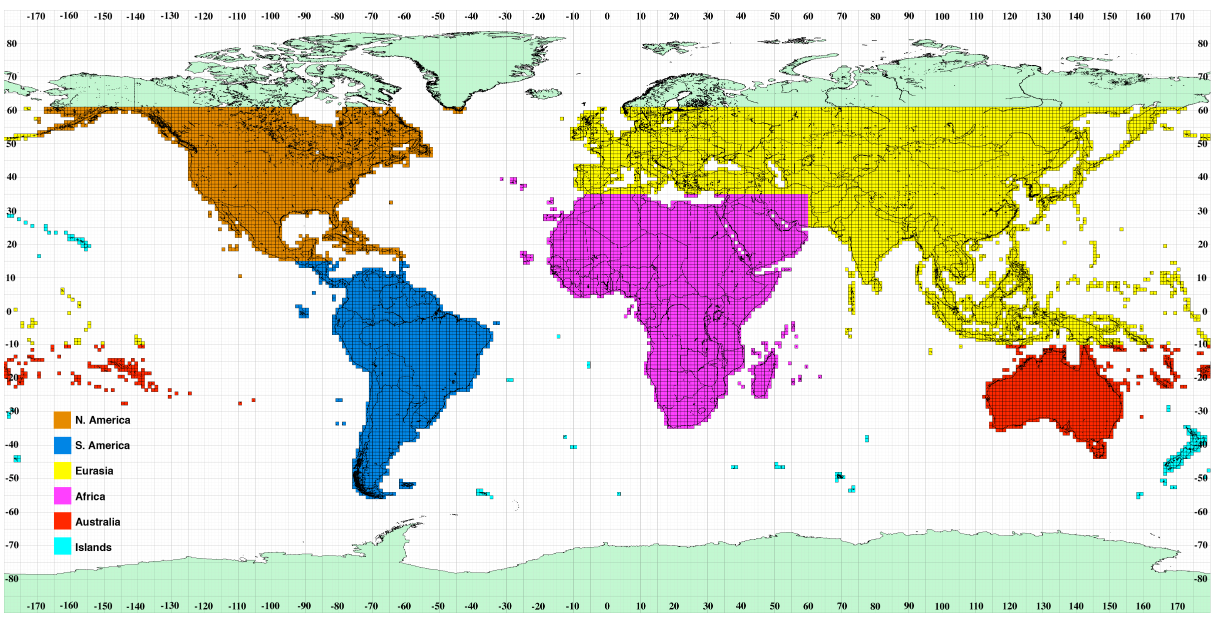
	SDDS **'Seamless server'** http://seamless.usgs.gov/	**Mail order**	**LP DAAC** ftp://e0srp01u.ecs.nasa.gov/ srtm/
Version 1	-	-	1" U.S. 3" world - averaged 30" world - averaged *Format: SRTM*
Version 2	1" U.S. 3" world - subsampled *Formats: ArcGrid, Bil, TIFF, GridFloat*	1" U.S. 3" world - subsampled *Formats: DTED, SRTM*	1" U.S. 3" world - averaged 30" world - averaged *Format: SRTM*

Notes: 1. Version 2 data are also known as *finished*, or *edited*
2. Averaged data are also known as *research data*
3. Subsampled data are also known as *thinned*, or *sampled*
4. 30" Version 2 data are not yet available

2.2 Organization

SRTM data are organized into individual rasterized cells, or tiles, each covering one degree by one degree in latitude and longitude. Sample spacing for individual data points is either 1 arc-second, 3 arc-seconds, or 30 arc-seconds, referred to as SRTM1, SRTM3 and SRTM30, respectively. Since one arc-second at the equator corresponds to roughly 30 meters in horizontal extent, the SRTM1 and SRTM3 are sometimes referred to as "30 meter" or "90 meter" data.

SRTM data were processed and delivered continent-by-continent and data for each continent are located in a separate directory on this server. The definitions of the continents are displayed in the figure below and at higher resolution in the file Continent_def.gif. Edited SRTM1 data for the United States and its territories and possessions are also being released and can be found in the directory /United_States_1arcsec./ Cells that straddle the border with neighboring countries have been masked with quarter degree quantization such that data outside the U.S. have the void value.



2.3 Elevation mosaics

Each SRTM data tile contains a mosaic of elevations generated by averaging all data takes that fall within that tile. Since the primary error source in synthetic aperture radar data is speckle, which has the characteristics of random noise, combining data through averaging reduces the error by the square root of the number of data takes used. In the case of SRTM the number of data takes could range from a minimum of one (in a very few cases) up to as many as ten or more.

3.0 Data Formats

The names of individual data tiles refer to the longitude and latitude of the lower-left (southwest) corner of the tile (this follows the DTED convention as opposed to the GTOPO30 standard). For example, the coordinates of the lower-left corner of tile N40W118 are 40 degrees north latitude and 118 degrees west longitude. To be more exact, these coordinates refer to the geometric center of the lower left sample, which in the case of SRTM3 data will be about 90 meters in extent.

SRTM1 data are sampled at one arc-second of latitude and longitude and each file contains 3601 lines and 3601 samples. The rows at the north and south edges as well as the columns at the east and west edges of each cell overlap and are identical to the edge rows and columns in the adjacent cell.

SRTM3 data are sampled at three arc-seconds and contain 1201 lines and 1201 samples with similar overlapping rows and columns. This organization also follows the DTED convention. Unlike DTED, however, 3 arc-second data are generated in each case by 3x3 averaging of the 1 arc-second data - thus 9 samples are combined in each 3 arc-second data point. Since the primary error source in the elevation data has the characteristics of random noise this reduces that error by roughly a factor of three.

This sampling scheme is sometimes called a "geographic projection", but of course it is not actually a projection in the mapping sense. It does not possess any of the characteristics usually present in true map projections, for example it is not conformal, so that if it is displayed as an image geographic features will be distorted. However it is quite easy to handle mathematically, can be easily imported into most image processing and GIS software packages, and multiple cells can be assembled easily into a larger mosaic (unlike the pesky UTM projection, for example.)

3.1 DEM File (.HGT)

The DEM is provided as 16-bit signed integer data in a simple binary raster. There are no header or trailer bytes embedded in the file. The data are stored in row major order (all the data for row 1, followed by all the data for row 2, etc.).

All elevations are in meters referenced to the WGS84/EGM96 geoid as documented at http://www.NGA.mil/GandG/wgsegm/.

Byte order is Motorola ("big-endian") standard with the most significant byte first. Since they are signed integers elevations can range from -32767 to 32767 meters, encompassing the range of elevation to be found on the Earth.

These data also contain occassional voids from a number of causes such as shadowing, phase unwrapping anomalies, or other radar-specific causes. Voids are flagged with the value -32768.

4.0 Notes and Hints for SRTM Data Users

4.1 Data Encoding

Because the DEM data are stored in a 16-bit binary format, users must be aware of how the bytes are addressed on their computers. The DEM data are provided in Motorola or IEEE byte order, which stores the most significant byte first ("big endian"). Systems such as Sun SPARC, Silicon Graphics workstations and PowerPC Macintosh computers use the Motorola byte order. The Intel byte order, which stores the least significant byte first ("little endian"), is used on DEC Alpha systems, most PCs and MAcintosh computers built after 2006. Users with systems that address bytes in the Intel byte order may have to "swap bytes" of the DEM data unless their application software performs the conversion during ingest.

4.3 SRTM Caveats

As with all digital geospatial data sets, users of SRTM must be aware of certain characteristics of the data set (resolution, accuracy, method of production and any resulting artifacts, etc.) in order to better judge its suitability for a specific application. A characteristic of SRTM that renders it unsuitable for one application may have no relevance as a limiting factor for its use in a different application.

5.0 References

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Kobrick, M., 2002, Engineering and Science, v. LXV, Number 1, p. 23-31.

Farr, t., Rosen, P., Caro, E., Crippen, R., Duren, R., Hensley, S., Kobrick, M., Paller, M., Rodriguez, E., Roth, L., Seal, D., Shaffer, S., Shimada, J., Umland, J., Werner, M., Oskin, M., Burbank, D., Alsdorf, D., 2008, Rev. Geophys., 45, RG2004.

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Lemoine, F.G. et al, NASA/TP-1998-206861, The Development of the Joint NASA GSFC and NIMA Geopotential Model EGM96, NASA Goddard Space Flight Center, Greenbelt, MD 20771, U.S.A., July 1998.

Other Web sites of interest:

NASA/JPL SRTM: http://www.jpl.nasa.gov/srtm/

NGA: http://www.nga.mil/

STS-99 Press Kit: http://www.shuttlepresskit.com/STS-99/index.htm

Johnson Space Center STS-99: http://spaceflight.nasa.gov/shuttle/archives/sts-99/index.html

German Space Agency: http://www.dlr.de/srtm

Italian Space Agency: http://srtm.det.unifi.it/index.htm

U.S. Geological Survey, EROS Data Center: http://edc.usgs.gov/

Note: DTED is a trademark of the National Imagery and Mapping Agency