SRTM30

1.0 Introduction

SRTM30 is a near-global digital elevation model (DEM) comprising a combination of data from the Shuttle Radar Topography Mission, flown in February, 2000 and the U.S. Geological Survey's GTOPO30 data set. It can be considered to be either an SRTM data set enhanced with GTOPO30, or as an upgrade to GTOPO30.

It is formatted and organized in a fashion that mimics the GTOPO30 convention so software and GIS systems that work with GTOPO30 should also work with SRTM30. GTOPO30 is described in the file 'GTOPO30 Documentation' included here, and this SRTM document stresses the differences and additional files contained in SRTM30. The GTOPO30 data set can be downloaded from http://edcdaac.usgs.gov/gtopo30/gtopo30.html.

The SRTM data resulted from a collaborative effort by the National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA, formerly 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 virtually 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 the total landmass.

1.1 Generation of SRTM30

SRTM radar echo data were processed into elevation information in a systematic fashion using the SRTM Ground Data Processing System (GDPS) supercomputer system at the Jet Propulsion Laboratory. Elevation data were mosaiced into more than 14,000 one degree by one degree cells and formatted according to the Digital Terrain Elevation Data (DTED) specification for delivery to NGA, who is using it to update and extend their DTED products.

Sample spacing for the fundamental SRTM data set is 1 arc-second in latitude and longitude (approximately 30 meters at the equator), consistent with NGA's existing DTED Level 2 product. By agreement between NGA and NASA this product is under control of NGA and is subject to limited distribution, using procedures similar to those for the existing DTED products.

A second product with sample spacing of 3 arc-seconds was generated by a 3x3 averaging of the 1 arc-second data, and is publicly available through the U.S. Geological Survey's EROS Data Center. Data can be downloaded or ordered via the 'seamless server' at http://seamless.usgs.gov/, and ordered in NGA's DTED format at http://edc.usgs.gov/products/elevation/srtmdted.html. In addition, individual cells can be downloaded via anonymous ftp from ftp://e0srp01u.ecs.nasa.gov. These 3 arc-second data were then further averaged 10x10 to produce 30 arc-second data commensurate with GTOPO30.

The SRTM elevation data delivered to NGA were unedited, and they contain occasional voids, or gaps, where the terrain lay in the radar beam's shadow or in areas of extremely low radar backscatter where an elevation solution could not be found. Globally these voids amount to no more than 0.15% of the SRTM data, but in some regions such as the Himalayas or northern Africa they are extensive enough to be evident even after the 10x10 averaging.

To construct SRTM30, mosaics were assembled at 30 arc-second spacing in tiles that matched the GTOPO30 tiles. Then the results were combined with GTOPO30 such that each sample contains an SRTM data point where SRTM data were valid, or GTOPO30 data where the SRTM data were void. Since the SRTM mission was only able to map up to approximately 60.25 degrees north latitude values above this point are completely from GTOPO30.

The geodetic reference for SRTM data is the WGS84 EGM96 geoid as documented at http://earth-info.nga.mil/GandG/wgs84/gravitymod/index.htm, and no attempt was made to adjust the vertical reference of either data set during the combination.

1.2 Updates for version 2.0

SRTM30 ver 1.1 was generated using unedited SRTM 3 arc-second sampled data, known as SRTM3 ver. 1.1 These data were exactly as produced by the GDPS, and in addition to some voids over land surfaces contained very noisy or void data for ocean and lake surfaces caused by the very low radar reflectivity of undisturbed water. For this reason the water mask contained in GTOPO30 was also used for SRTM30 ver. 1.1.

Part of the data editing task undertaken by the NGA was a very careful delineation of coastlines based on radar and optical imagery and other sources, as well as editing to assure that lake and ocean surfaces were at constant elevation and that rivers decreased in elevation in the downstream direction. This resulted in a considerably improved water body definition, and this editing was incorporated in SRTM3 ver. 2.0.

These were also the data used to generate SRTM30 ver. 2.0, and these improved coastline definitions were maintained. That means that instead of the -9999 flag for oceans used by GTOPO30, SRTM30 ver. 2.0 shows the oceans at zero elevation and other water bodies at the elevations determined during the editing.

2.0 Data Format

SRTM30 has been divided into the same tiles as GTOPO30, except that since the data do not extend below 60 degrees south latitude the corresponding tiles, as well as the Antarctica file in GTOPO30, have not been generated.

The following table lists the name, latitude and longitude extent, and elevation statistics for each SRTM30 tile.

	Latitude		Longitude		Elevation			
Tile	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Mean	Std.Dev.
w180n90	40	90	-180	-140	-6	6098	67	246
w140n90	40	90	-140	-100	-71	4635	378	563
w100n90	40	90	-100	-60	-18	2416	185	267
w060n90	40	90	-60	-20	-14	3940	520	924
w020n90	40	90	-20	20	-179	4536	93	266
e020n90	40	90	20	60	-188	5472	116	254
e060n90	40	90	60	100	-156	7169	340	618
e100n90	40	90	100	140	-110	3901	391	464
e140n90	40	90	140	180	-26	4578	415	401
w180n40	-10	40	-180	-140	-2	4120	1	34
w140n40	-10	40	-140	-100	-83	4228	198	554
w100n40	-10	40	-100	-60	-42	6543	139	414
w060n40	-10	40	-60	-20	-10	2503	29	94
w020n40	-10	40	-20	20	-139	3958	256	314

e020n40	-10	40	20	60	-415	5778	516	573
e060n40	-10	40	60	100	-46	8685	784	1534
e100n40	-10	40	100	140	-71	7213	236	625
e140n40	-10	40	140	180	-6	4650	14	144
w180s10	-60	-10	-180	-140	0	1784	0	7
w140s10	-60	-10	-140	-100	0	910	0	1
w100s10	-60	-10	-100	-60	-206	6813	262	814
w060s10	-60	-10	-60	-20	-61	2823	83	211
w020s10	-60	-10	-20	20	-12	2498	73	291
e020s10	-60	-10	20	60	-1	3408	186	417
e060s10	-60	-10	60	100	-4	2555	0	8
e100s10	-60	-10	100	140	-20	1360	64	145
e140s10	-60	-10	140	180	-43	3119	40	140

The 8 files included for each tile in GTOPO30 are also present in SRTM30, using the following extensions:

Extension	Contents
DEM	digital elevation model data
HDR	header file for DEM
DMW	world file
STX	statistics file
PRJ	projection information file
GIF	shaded relief image
SRC	source map
SCH	header file for source map

In addition several additional files are included using these extensions:

Extension	Contents
DIF	difference between SRTM30 and GTOPO30
JPG	color coded shaded relief image
NUM	number of valid point included in the 10x10 average
STD	standard deviation of the elevations used in the average

Further information on the contents and format of the files is provided below.

2.1 DEM File (.DEM) - Same as GTOPO30

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

2.2 Header File (.HDR) - Same as GTOPO30

The DEM header file is an ASCII text file containing size and coordinate information for the DEM. The following keywords are used in the header file:

BYTEORDER	byte order in which image pixel values are stored M = Motorola byte order (most significant byte first)
LAYOUT	organization of the bands in the file BIL = band interleaved by line (note: the DEM is a single band image)
NROWS	number of rows in the image
NCOLS	number of columns in the image
NBANDS	number of spectral bands in the image (1 for a DEM)
NBITS	number of bits per pixel (16 for a DEM)
BANDROWBYTES	number of bytes per band per row (twice the number of columns for a 16-bit DEM)
TOTALROWBYTES	total number of bytes of data per row (twice the number of columns for a single band 16-bit DEM)
BANDGAPBYTES	the number of bytes between bands in a BSQ format image (0 for a DEM)
NODATA	value used for masking purposes
ULXMAP	longitude of the center of the upper-left pixel (decimal degrees)
ULYMAP	latitude of the center of the upper-left pixel (decimal degrees)
XDIM	x dimension of a pixel in geographic units (decimal degrees)
YDIM	y dimension of a pixel in geographic units (decimal degrees)

Example header file (W100N40.HDR):

```
BYTEORDER      M
LAYOUT         BIL
NROWS          6000
NCOLS          4800
NBANDS         1
NBITS          16
BANDROWBYTES   9600
TOTALROWBYTES  9600
BANDGAPBYTES   0
NODATA         -9999
ULXMAP         -99.99583333333334
ULYMAP         39.99583333333333
XDIM           0.00833333333333
YDIM           0.00833333333333
```

2.3 World File (.DMW) - Same as GTOPO30

The world file is an ASCII text file containing coordinate information. It is used by some packages for georeferencing of image data. The following is an example world file (W100N40.DMW) with a description of each record:

0.00833333333333	x dimension of a pixel (decimal degrees)
0.00000000000000	rotation term (will always be zero)
0.00000000000000	rotation term (will always be zero)
-0.00833333333333	negative y dimension of a pixel (decimal degrees)
-99.99583333333334	longitude of the center of the upper-left pixel
39.99583333333333	latitude of the center of the upper-left pixel

2.4 Statistics File (.STX) - Same as GTOPO30

The statistics file is an ASCII text file which lists the band number, minimum value, maximum value, mean value, and standard deviation of the values in the DEM data file.

Example statistics file (W100N40.STX):

```
1   -42 6543   138.7  414.3
```

2.5 Projection File (.PRJ) - Same as GTOPO30

The projection information file is an ASCII text file which describes the projection of the DEM and source map image.

Example projection file (W100N40.PRJ):

```
Projection  GEOGRAPHIC
Datum       WGS84
Zunits      METERS
Units       DD
Spheroid    WGS84
Xshift      0.0000000000
Yshift      0.0000000000
Parameters
```

2.6 Shaded Relief Image (.GIF)

Same as for GTOPO30, except that brightness is also modulated by the elevation. This is a actually a greyscale version of the .JPG file noted below.

2.7 Source Map (.SRC)

Same as for GTOPO30, except a new source code has been added for SRTM data. The codes are now:

Value	Source
0	Ocean
1	Digital Terrain Elevation Data
2	Digital Chart of the World
3	USGS 1-degree DEM's
4	Army Map Service 1:1,000,000-scale maps
5	International Map of the World 1:1,000,000-scale maps
6	Peru 1:1,000,000-scale map
7	New Zealand DEM
8	Antarctic Digital Database
9	SRTM data

2.8 Source Map Header File (.SCH) - <u>Same as GTOPO30</u>

The source map header file is an ASCII text file containing size and coordinate information, similar to the DEM header file. The following keywords are used in the source map header file:

BYTEORDER	byte order in which image pixel values are stored M = Motorola byte order (most significant byte first)
LAYOUT	organization of the bands in the file BIL = band interleaved by line (note: the source map is a single band image)
NROWS	number of rows in the image
NCOLS	number of columns in the image
NBANDS	number of spectral bands in the image (1 for the source map)
NBITS	number of bits per pixel (8 for the source map)
BANDROWBYTES	number of bytes per band per row (the number of columns for an 8-bit source map)
TOTALROWBYTES	total number of bytes of data per row (the number of columns for a single band 8-bit source map)
BANDGAPBYTES	the number of bytes between bands in a BSQ format image (0 for the source map)
NODATA	value used for masking purposes
ULXMAP	longitude of the center of the upper-left pixel (decimal degrees)
ULYMAP	latitude of the center of the upper-left pixel (decimal degrees)

XDIM	x dimension of a pixel in geographic units (decimal degrees)
YDIM	y dimension of a pixel in geographic units (decimal degrees)

Example source map header file (W100N40.SCH):

BYTEORDER	M
LAYOUT	BIL
NROWS	6000
NCOLS	4800
NBANDS	1
NBITS	8
BANDROWBYTES	4800
TOTALROWBYTES	4800
BANDGAPBYTES	0
NODATA	-9999
ULXMAP	-99.99583333333334
ULYMAP	39.99583333333333
XDIM	0.00833333333333
YDIM	0.00833333333333

2.9 Difference file (.DIF)

16 bit signed integers indicating the difference between the SRTM30 DEMs and the corresponding GTOPO30 tiles. Calculated as difference = SRTM30 value - GTOPO30 value.

2.10 Color Shaded Relief Image (.JPG)

Color coded shaded relief image of the data in each file. Colors were assigned by elevation, then manipulated to produce a pleasing image - thus they cannot be related directly to elevation.

2.11 Number of Points in Average (.NUM)

8 bit integers indicating the number of valid data points that were included in the 10x10 averaging process.

2.12 Standard Deviation (.STD)

16 bit integers indicating the standard deviation of the data points used in the averaging. This is thus an indication of topographic roughness useful in some applications.

3.0 References

Farr, T.G., M. Kobrick, 2000, Shuttle Radar Topography Mission produces a wealth of data, Amer. Geophys. Union Eos, v. 81, p. 583-585.

Rosen, P.A., S. Hensley, I.R. Joughin, F.K. Li, S.N. Madsen, E. Rodriguez, R.M. Goldstein, 2000, Synthetic aperture radar interferometry, Proc. IEEE, v. 88, p. 333-382.

DMATR 8350.2, Dept. of Defense World Geodetic System 1984, Its Definition and Relationship with Local Geodetic Systems, Third Edition, 4 July 1997. http://earth-info.nga.mil/GandG/wgs84/gravitymod/index.htm

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/portal/site/nga01/

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/

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