High Mountain Asia 8-meter DEMs Derived from Along-Track Optical Imagery, Version 1

High Mountain Asia 8-meter DEMs Derived from Cross-Track Optical Imagery, Version 1

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

Shean, D. 2017. *High Mountain Asia 8-meter DEMs Derived from Along-Track Optical Imagery, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi: https://doi.org/10.5067/GSACB044M4PK. [Date Accessed].

or

Shean, D. 2017. *High Mountain Asia 8-meter DEMs Derived from Cross-Track Optical Imagery, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi: https://doi.org/10.5067/0MCWJJH5ABYO. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT OR https://nsidc.org/data/HMA_DEM8m_AT OR https://nsidc.org/data/HMA_DEM8m_CT

National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

The Digital Elevation Models (DEMs) provided in these data sets were generated from very-high-resolution (VHR) along- and cross-track stereoscopic imagery from DigitalGlobe satellites.

The DEM strips have unique timestamps, allowing users to perform change detection analysis and compare observations of topographic data acquired in different seasons and/or years.

DEM strips range from approximately 13.1 km to 17.4 km wide by 111 km long. Figure 1 shows a sample shaded relief map.

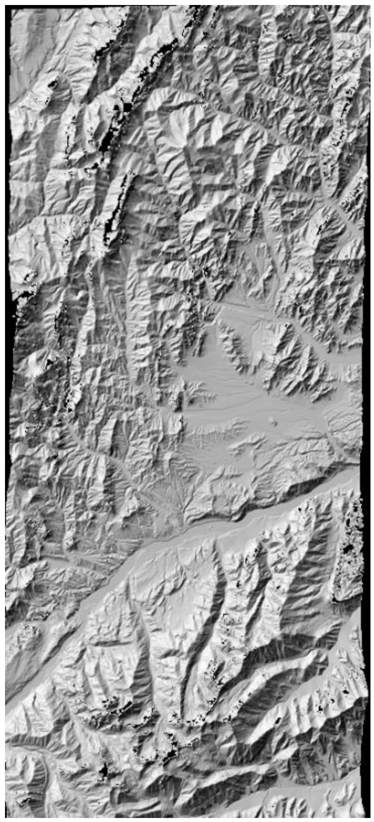

Figure 1. Sample Data Record. Sample 8 m DEM strip generated from along-track stereo imagery. Produced by D. Shean for the NASA High Mountain Asia project.

1.1 Parameter

These data sets report elevation in meters above the WGS84 ellipsoid. The fill value for pixels containing no data is -9999.

1.2 Format

DEMs are provided as LZW-compressed* GeoTIFFs (.tif) with elevations stored as single precision, floating point numbers (Float32).

Shaded relief browse images in PNG (.png) format accompany each DEM file. These images were created using a standard azimuth setting of 315 degrees and an elevation of 45 degrees.

An associated Extensible Markup Language (XML) metadata file is also provided for each data file.

*Refers to lossless Lempel–Ziv–Welch (LZW) compression.

1.3 File Naming Convention

File names vary slightly as shown in the following examples. Variables used in the file names are defined in Table 1.

1.3.1 Example File Names

- HMA_DEM8m_[AT/CT]_20141226_0534_1050410011D3AB00_1050410011D3AD00.tif
- HMA_DEM8m_[AT/CT]_20141226_0534_1050410011D3AB00_1050410011D3AD00_hs_az315.png

1.3.2 Naming Conventions

- HMA_DEM8m_[AT/CT]_[YYYYmmdd_HHMM]_[CATID1_CATID2].tif
- HMA_DEM8m_[AT/CT]_[YYYYmmdd_HHMM]_[CATID1_CATID2]_hs_az315.png

Table 1. File Name Variables and Definitions

Variable	Definitions
HMA_DEM8m_[AT/CT]	Data set IDs [abbreviations for High Mountain Asia (HMA) DEM 8 m Along-track or Cross-track Product]
YYYYmmdd_HHMM	Stereo-pair center acquisition date/time [4-digit year, 2-digit month, 2-digit day, 2-digit hour, 2-digit minute), Coordinated Universal Time (UTC); indicates mean of the two image timestamps]
[CATID1_CATID2]	Catalog IDs of first and second DigitalGlobe images in the stereo pair; the first 3 digits indicate the DigitalGlobe sensor, including: 101: QuickBird-2 (QB02) 102: WorldView-1 (WV01) 103: WorldView-2 (WV02) 104: WorldView-3 (WV03) 105: GeoEye-1 (GE01)

Variable	Definitions
hs_az315	Shaded relief/hillshade (hs) browse image generated at 315 azimuth (az)

1.4 Spatial Coverage

Northernmost Latitude: 46° N
Southernmost Latitude: 26° N
Easternmost Longitude: 103° E
Westernmost Longitude: 67° E

Coverage extends to portions of the following eleven countries:

- Afghanistan
- Bhutan
- China
- India
- Kazakhstan
- Kyrgyzstan
- Myanmar
- Nepal
- Pakistan
- Tajikistan
- Uzbekistan

To view the coverage of a particular DEM, refer to the Knowledge Base FAQ: *What is the spatial extent of individual HMA DEMs?*

Note: Initial archive request and processing was limited to images that intersected one or more of the Randolph Glacier Inventory (RGI) glacier polygons. Future releases will include expanded HMA coverage.

1.4.1 Spatial Resolution

The DEMs have 8 m posting (output grid pixel size).

1.4.1.1 Projection and Grid

The along- and cross-track DEMs are provided in Universal Transverse Mercator (UTM) projection with a standard parallel of 0° N and central longitudes ranging from 69° N to 105° N. The output UTM zone is automatically determined based on the longitude of the stereo intersection geometry. Projected coordinates are meters, with the origin at 0° N. Elevation values are in meters above the WGS84 ellipsoid. Refer to Tables 2 and 3 for details.

Table 2. Projection and Grid Details

Projection	Transverse Mercator, UTM Zones 12N-48N (details vary by zone; see Table 3)
Grid Spacing	8 m
Latitudes of True Scale (Standard Parallels)	0° N
Datum	WGS84
Ellipsoid	WGS84
Units	Meters

Table 3. Projection Details by UTM Zone

UTM Zone	Central Longitude (Meridan)	EPSG Code	PROJ4 String
42N	69° E	32642	+proj=utm +zone=42 +ellps=WGS84 +datum=WGS84 +units=m +no_defs
43N	75° E	32643	+proj=utm +zone=43 +ellps=WGS84 +datum=WGS84 +units=m +no_defs
44N	81° E	32644	+proj=utm +zone=44 +ellps=WGS84 +datum=WGS84 +units=m +no_defs
45N	87° E	32645	+proj=utm +zone=45 +ellps=WGS84 +datum=WGS84 +units=m +no_defs
46N	93° E	32646	+proj=utm +zone=46 +ellps=WGS84 +datum=WGS84 +units=m +no_defs
47N	99° E	32647	+proj=utm +zone=47 +ellps=WGS84 +datum=WGS84 +units=m +no_defs
48N	105° E	32648	+proj=utm +zone=48 +ellps=WGS84 +datum=WGS84 +units=m +no_defs

1.5 Temporal Coverage

The optical images used for the DEMs were obtained between 2002 and 2017, with the majority of coverage from 2013 to 2016. For HMA stereo:

- The WorldView-1 (WV-1) record began in late 2008.
- The WorldView-2 (WV-2) record began in mid 2010.
- The WorldView-3 (WV-3) record began in late 2014.
- The GeoEye-1 (GE-1) record began in late 2009.
- The QuickBird-2 (QB-2) record began in 2002.

1.5.1 Temporal Resolution

The temporal resolution for this data set varies. Time intervals between overlapping DEM strips can be hours to decades, depending on the location, with typical values of approximately one to three years.

Figure 2 shows a histogram of the annual DEM count.

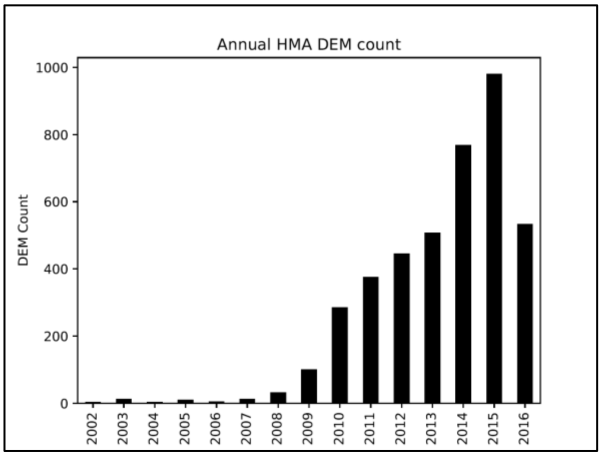

Figure 2. Histogram showing annual DEM count from 2002 through 2016.

2 SOFTWARE AND TOOLS

GeoTIFF files with embedded geospatial metadata can be accessed using GIS software such as QGIS and ArcGIS, or command-line tools such as the GDAL (Geospatial Data Abstraction Library) utilities and API.

3 DATA ACQUISITION AND PROCESSING

3.1 Sensors

For detailed information on the various satellites and sensors used to produce this data set, refer to the DigitalGlobe, Inc. Web site. Satellite and sensor details are also provided in Shean et al. (2016).

3.2 Data Sources

The DEM strips were generated from Level-1B (L1B) panchromatic (450-800 nm) imagery acquired by the following DigitalGlobe satellites:

- GeoEye-1
- WorldView-1, WorldView-2, and WorldView-3
- QuickBird-2

The pushbroom swath imagery was collected in strips, ranging from approximately 13.1 km to 17.4 km wide and up to 111 km long.

All DigitalGlobe imagery was made available through the National Geospatial-Intelligence Agency's NextView License. The original L1B imagery used to generate the DEMs is archived and distributed by the Polar Geospatial Center at the University of Minnesota.

3.3 Derivation Techniques and Algorithms

All DEMs were generated using the NASA Ames Stereo Pipeline (ASP) (v2.5.3 Build ID: 0be5052 to v2.6.0 Build ID: 4521300) and methodology described in Shean et al. (2016).. The data were processed using the NASA High-Performance Computing (HPC) resources, primarily the NASA Pleiades Supercomputer at the NASA Ames Research Center.

The DEMs in these data sets were created from two sets of images. One set was generated from along-track (also referred to as in-track) stereoscopic imagery in which both images were collected minutes apart along the same orbital pass. The other set was generated from cross-track imagery collected at different times on different orbits, and potentially from different spacecraft.

All subscenes for each 11-bit panchromatic image were mosaicked, and new rational polynomial coefficients (RPCs) were derived for each image strip. The mosaicked images were orthorectified using the 1-arcsec (30 m) SRTM-GL1, the void-filled Global Shuttle Radar Topography Mission (SRTM) DEM. Orthorectification using a low-resolution DEM removes most of the feature offsets due to terrain and viewing geometry, providing a significant performance improvement during stereo correlation.

The ASP stereo utility was run for the input orthoimages with the following parameters:

Integer correlation kernel size of 21x21 pixels

Parabolic sub-pixel refinement (using the ASP sub-pixel-mode 1 utility) with kernel size 11x11 pixels

Conservative filtering to remove isolated "islands" up to 1024 pixels

The ASP point2dem utility was used to produce gridded DEMs from the triangulated point cloud.

Along-track Stereo Strips

These are generated from in-track/along-track stereo pairs, involving images acquired on the same orbit, typically 60-90 seconds apart.

Cross-track Stereo Strips

Cross-track (also referred to as coincident mono) DEMs were generated from pairs of independent monoscopic images with geometry suitable for stereo reconstruction. Candidate pairs in the DigitalGlobe image archive were identified based on the criteria in Table 4. Some of these cross-track pairs were acquired on the same orbit, while others were acquired on different orbits or by different spacecraft (e.g., WorldView-1 and WorldView-2).

Table 4. Criteria for Identifying Stereo Pairs

Parameter	Minimum Value	Maximum Value
Convergence angle (degrees)	15	70
Pair time offset (days)	-	7
Intersection area (km2)	40	-
Intersection width (km)	6	-
Intersection height (km)	6	-
Cloud cover (%)	0	75

The cross-track DEMs potentially have increased error due to residual horizontal displacement errors (i.e., errors due to ice flow between image acquisitions), non-ideal stereo geometry (e.g., smaller convergence angles) and the fact that some errors in ephemeris data for the two images are independent (as opposed to highly correlated errors for along-track pairs). In practice, these issues can result in increased DEM vertical/horizontal bias and increased relative error (e.g., DEM “tilt”). Despite potentially increased error, we include these cross-track DEMs to fill critical gaps in along-track stereo coverage.

3.3.1 Processing Steps

In summary, two images are collected for the same ground extent from different angles. Cross-correlation is used to measure offsets between features in the images, which are related to the different viewing geometry and topography. These offsets are combined with spacecraft attitude/ephemeris data to identify precise sensor locations, and stereo triangulation is used to determine the three-dimensional coordinates of matched features. The resulting point cloud is interpolated to create the high-resolution DEM.

See Shean et al. (2016) for details of the full processing workflow. For information regarding ASP, refer to the official documentation (PDF, 21 MB).

3.4 Error Sources

The absolute geolocation accuracy of the DEMs depends on the sensor. In general, the WorldView and GeoEye along-track pairs will have horizontal/vertical accuracy of <5 m CE90/LE90. Quickbird-2 pairs have reduced horizontal (CE90 23 m) and vertical accuracy.

Relative error within an individual DEM strip depends on stereo-pair geometry and surface slope, but generally should be <1-2 m. Individual DEMs can contain "blunders" or local elevation errors due to image correlation errors that are not removed by subsequent filters.

Data voids can occur due to clouds, occlusions (surface not visible from both images), saturated images (e.g., overexposure for surfaces with fresh snow on illuminated slopes), errors in the low-resolution DEM used for initial orthorectification, and/or correlation failures. The investigators elected to preserve only valid DEM pixels, and do not perform any additional interpolation or filling to remove voids. Future releases will include void-filled products.

For more information on errors and limitations, refer to Shean et al. (2016).

Before comparing two DEMs, the user must remove horizontal and vertical offsets over control surfaces via co-registration (e.g., Berthier et al., 2007; Nuth and Kääb, 2011; Shean et al., 2016). This can be accomplished with the ASP pc_align utility (see the demcoreg tools https://github.com/dshean/demcoreg). Future data releases will include DEM products co-registered to satellite laser altimetry data for improved absolute accuracy.

4 REFERENCES AND RELATED PUBLICATIONS

Shean, D. E., O. Alexandrov, Z. Moratto, B. E. Smith, I. R. Joughin, C. C. Porter, and P. J. Morin. 2016. An automated, open-source pipeline for mass production of digital elevation models (DEMs) from very high-resolution commercial stereo satellite imagery, ISPRS J. Photogramm. Remote Sens, 116:101-117. https://doi.org/10.1016/j.isprsjprs.2016.03.012.

Berthier, E., Y. Arnaud, R. Kumar, S. Ahmad, P. Wagnon, and P. Chevallier. 2007. Remote sensing estimates of glacier mass balances in the Himachal Pradesh (Western Himalaya, India). Remote Sensing of Environment, 108(3):327–338. https://doi.org/10.1016/j.rse.2006.11.017.

Nuth, C. and A. Kääb. 2011. Co-registration and bias corrections of satellite elevation data sets for quantifying glacier thickness change. The Cryosphere, 5(1):271–290. https://doi.org/10.5194/tc-5-271-2011.

4.1 Related Data Collections

- High Mountain Asia Data
- Polar Geospatial Center Data

4.2 Related Websites

- Contribution to High Asia Runoff from Ice & Snow (CHARIS) Project
- Global Land Ice Measurements from Space (GLIMS) Project
- DigitalGlobe, Inc.
- NSIDC Scientific Data Search

5 CONTACTS

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7 DOCUMENT INFORMATION

7.1 Publication Date

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