SnowEx Colorado 3M Snow Depth Time Series and DEMs from High-Resolution Satellite Image Pairs, Version 1

USER GUIDE

How to Cite These Data

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

Hu, J.M., D. E. Shean and S. Bhushan. 2023. *SnowEx Colorado 3M Snow Depth Time Series and DEMs from High-Resolution Satellite Image Pairs, Version 1.* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/ 10.5067/7QCNCHVQMCI8. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/ SNEX_HRSI_SD_DEM_CO

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

This data set contains a time series of snow depth maps and related intermediary snow-on and snow-off DEMs for Grand Mesa, Colorado derived from very-high-resolution (VHR) satellite stereo images and lidar point cloud data. The VHR stereo images were acquired each year between 2016 and 2022 during the approximate timing of peak snow depth by the Maxar WorldView-2, WorldView-3, and CNES/Airbus Pléiades-HR 1A and 1B satellites, while lidar data was sourced from the USGS 3D Elevation Program.

1.1 File Information

1.1.1 Format

Data are provided as GeoTIFF files.

1.1.2 File Organization and Naming Convention

This data set is available as 11 granules. Eight of the granules contain two files: the primary snow depth map and the intermediary snow-on DEM. These eight granules conform to the following naming convention:

`SNEX_HSRI_SD_DEM_CO_GM_[SATELLITE]_[YYYYMMDD]`

The primary snow depth maps and intermediary snow-on DEMs conform to the following naming convention:

`SNEX_HRSI_SD_DEM_CO_GM_[SATELLITE]_[YYYYMMDD]_[SD/DEM]_3m_V01.1.tif`

Table 1. File Naming Variable Descriptions

Variable	Description
`SNEX_HRSI_SD_DEM_CO`	NSIDC data set ID • `SNEX`: SnowEx • `HRSI`: high resolution satellite imagery • `SD`: snow depth • `DEM`: digital elevation model • `CO`: Colorado

Variable	Description
GM	Study location: Grand Mesa (GM)
SATELLITE	Satellite used for stereo image acquisition: ● PHR1A: Pléiades-HR 1A ● PHR2B: Pléiades-HR 1B ● WV02: WorldView-2 ● WV03: WorldView-3
YYYYMMDD	Date of stereo image acquisition formatted as four-digit year, two-digit month and 2-digit day
SD/DEM	Data type contained in file: ● SD – snow depth ● DEM – intermediary snow-on DEM (DSM)
3m	Raster product resolution: 3 meters
V01.1	Data set version
.tif	File type: GeoTIFF

The three remaining granules each contain a single .tif file. The contents of these three granules are available in Table 2 below:

Table 2. Single file granule descriptions

Granule Name	Description
SNEX_HRSI_SD_DEM_CO_GM_2017_2022_SDmed_3m_V01.1	Composite map of median snow depths
SNEX_HRSI_SD_DEM_CO_GM_DSM_1m_V01.1	Snow-off digital surface model (DSM)
SNEX_HRSI_SD_DEM_CO_GM_DTM_1m_V01.1	Snow-off digital terrain model (DTM)

1.2 Spatial Information

1.2.1 Coverage

Northernmost Latitude: 39.216156 N
Southernmost Latitude: 38.785954 N
Westernmost Latitude: 108.382269 W
Easternmost Latitude: 107.747336 W

1.2.2 Resolution

Stereo snow depth products and snow-on DEMs have a resolution of 3 meters. Snow-off reference DSM and DTM files have a resolution of 1 meter.

1.2.3 Geolocation

The following table provide information for geolocating this data set.

Table 3. Geolocation Details

Geographic coordinate system	WGS 84
Projected coordinate system	WGS 84 / UTM zone 12 N
Longitude of true origin	-111
Latitude of true origin	0
Scale factor at longitude of true origin	0.9996
Datum	WGS 1984
Ellipsoid/spheroid	WGS 84
Units	Meters
False easting	500000
False northing	0
EPSG code	32610
PROJ4 string	+proj=utm +zone=12 +datum=WGS84 +units=m +no_defs +type=crs
Reference	https://epsg.io/32612

1.3 Temporal Information

1.3.1 Coverage

19 February 2016 to 2 March 2022

1.3.2 Resolution

Data collection occurred once yearly, with the exception of 2017, during which data was collected three times, each spaced approximately one month apart.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

This data set presents a time series of eight VHR satellite stereo imagery derived snow depth maps, collected over a six-year span between 2017 and 2022. Two of the snow depth maps coincide temporally with the 2017 NASA SnowEx Grand Mesa field campaign, providing a comparison between the satellite derived snow depth and in-situ snow depth measurements. Primary snow-on input data used to create the snow depth maps include Level-1B panchromatic VHR stereo image pairs sourced from the Maxar WorldView-2 and WorldView-3 satellites and the CNES/Airbus Pléiades-HR 1A and 1B satellites. Snow-off data was sourced from the USGS 3DEP) airborne lidar point cloud data archive. Also available are intermediary data products used to prepare the snow depth maps, including eight snow-on digital elevation models, two reference DEMs: a snow-off digital surface model (DSM) and snow-off digital terrain model (DTM), and a composite map showing median snow depth values between 2017 and 2022. A full discussion of this data set, study methodology, and significance can be found in Hu et al. 2023.

2.2 Acquisition

Level-1B VHR satellite stereo images were obtained from four commercial sources: the Maxar WorldView-2 and WorldView-3 satellites, and the CNES/Airbus Pléiades-HR 1A and Pléiades-HR 1B satellites. The WorldView images included in-track stereo pairs collected during 2017, 2018, 2019, and 2022. Image acquisition coincided with typical peak snow depth conditions in the Northern Hemisphere (within two weeks of April 1st), with the exception of images collected on 1 February and 26 February 2017. Images collected on these dates overlapped with the 2017 NASA SnowEx field campaign at Grand Mesa, Colorado. Stereo pairs sourced from Pléiades-HR 1A and Pléiades-HR 1B were acquired on 31 March 2020 and 31 March 2021, respectively. Detailed metadata for each VHR stereo image pair can be found in the Supporting Information section of Hu et al. 2023.

Airborne lidar data was obtained from the U.S. Geological Survey 3D Elevation Program (3DEP). Data acquisition occurred between 13-14 July 2016, 19 February 2016, and 31 October 2016.

2.3 Processing

A multi-step process was used to create the snow depth maps. Snow-on DEMs were derived from the stereo satellite image pairs using the NASA Ames Stereo Pipeline (ASP; Beyer et al., 2018; Shean et al., 2016). Snow-free reference DEMs, including both digital terrain models (DTM) and digital surface models (DSM) were derived from the airborne lidar point cloud data using the Point Data Abstraction Library (PDAL contributors, 2022). The snow-on DEMs were aligned with the snow-free reference DTM using an iterative co-registration approach (Nuth and Kääb, 2011; Shean et al., 2021). After alignment, the corresponding snow-free DTMs were subtracted from the snow-on DEMs to produce elevation difference maps. The difference maps were filtered and smoothed to create the final snow depth map products. A detailed discussion of the processing steps can be found in Hu et al. 2023.

2.4 Quality, Errors, and Limitations

Evaluation of data quality was conducted by examining the median of each stereo snow depth product from a subset of the Grand Mesa study site with the daily SNOTEL snow depth observations for the same dates. Additional data quality evaluation was performed by comparing the two February 2017 snow depth maps with airborne lidar snow depth measurements collected by the Airborne Snow Observatory and the in-situ snow depth measurements collected during the NASA SnowEx field campaigns. A full description of the data quality evaluation methods and the resulting error calculations can be found in Section 5.2 of Hu et al. 2023.

3 VERSION HISTORY

Table 4. Version History Summary

Version	Release Date	Description of Changes
1	February 2024	Initial release

4 RELATED DATA SETS

SnowEx at NSIDC | Data Sets

5 RELATED WEBSITES

Snow Ex at NSIDC | Overview

Snow Ex at NASA

6 ACKNOWLEDGMENTS

This research was funded by NASA awards 80NSSC18K1405 and 80NSSC22K0682 to the University of Washington. Resources supporting this work were provided by the NASA High-End Computing (HEC) Program through the NASA Advanced Supercomputing (NAS) Division at Ames Research Center. Public release of the DEMs and derived snow depth products was approved by the National Reconnaissance Office (NRO) Electro-Optical Commercial Layer (EOCL) Program Management Office.

7 REFERENCES

Beyer, R. A., Alexandrov, O., & McMichael, S. 2018. The Ames stereo pipeline: NASA's open source software for deriving and processing terrain data. Earth and Space Science, 5(9), 537–548. https://doi.org/10.1029/2018EA000409

Hu, J. M., Shean, D, and Bhushan, S. 2024. Six consecutive seasons of high-resolution mountain snow depth maps from satellite stereo imagery. Geophysical Research Letters, https://doi.org/10.1029/2023GL104871

Nuth, C., & Kääb, A. 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

PDAL contributors. 2022. PDAL point data abstraction library [Software]. Zenodo. https://zenodo.org/records/10359701

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

Shean, D., Bhushan, S., Lilien, D., Knuth, F., Schwat, E., Meyer, J., et al. 2021. dshean/demcoreg: v1.1.0. Zenodo. https://zenodo.org/records/5733347

8 DOCUMENT INFORMATION

8.1 Publication Date

February 2024

8.2 Date Last Updated

February 2024