SnowEx20 Grand Mesa Snow Depth from Snow Pole Time-Lapse Imagery, Version 1

USER GUIDE

How to Cite These Data

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

Breen, C., C. Hiemstra, C. Vuyovich, and M. Mason. 2022. *SnowEx20 Grand Mesa Snow Depth from Snow Pole Time-Lapse Imagery, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/14EU7OLF051V. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SNEX20_SD_TLI

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

This data set contains snow depth measurements extracted from time-lapse images capturing a snow pole in each picture frame (SnowEx20 Grand Mesa Time-Lapse Imagery) collected by cameras placed around Grand Mesa, CO at 29 sites coincident with other SnowEx 2020 measurements.

1.2 File Information

1.2.1 Format

Data is available in two comma separated value files (.csv). An additional browse file (.png) is available displaying all snow depth data over the course of the SnowEx 2020 measurement campaign.

1.2.2 File Contents

The clean data file contains one main data tab with 7 columns described in the first 7 entries of Table 1. The raw .csv file contains one main data tab with 9 columns described in Table 1.

Table 1. Data Parameters

Parameter short name	Description	Unit
Camera	3-digit camera name. See section 2.1 for details on naming convention.	N/A
Date&Time	Date of data acquisition using the following format: (D)D/(M)M/YY where the digits in parenthesis are only used when the value is 10 or larger.	N/A
Longitude	Camera location longitude.	°
Latitude	Camera location latitude.	°
UTM WGS84 Northing (meters)	Camera location northing.	m
UTM WGS84 Easting (meters)	Camera location easting.	m
Snow Depth (cm)	Image extracted snow depth	cm
Pole Length (pixels)*	Image pole length	px
errorcodes*	Error code options and descriptions are listed in Table 8	N/A

Parameter short name	Description	Unit
* only available in the raw data file.		

1.2.3 Naming Convention

The two data files are named:

- `SNEX20_SD_TLI_raw.csv`
- `SNEX20_SD_TLI_clean.csv`

The browse file is named:

- `SNEX20_SD_TLI_clean_br.png`

1.3 Spatial Information

1.3.1 Coverage

This data set has the following spatial bounds:

Northernmost Latitude: 39.067° N
Southernmost Latitude: 39.000° N
Easternmost Longitude: 107.997° W
Westernmost Longitude: 108.228° W

Table 2 below lists the individual location coordinates for each camera and pole pair.

Table 2. Camera and pole names and location.

Camera Name	Latitude [°]	Longitude [°]	Northing [m]	Easting [m]
E3A CAM	39.108011	-107.881267	4333394.94	769672.96
E3A POLE	39.107937	-107.881191	4333386.95	769679.82
E6A CAM	39.097489	-107.862526	4332282.79	771334.19
E6A POLE	39.097464	-107.862476	4332280.17	771338.61
E6B CAM	39.048970	-107.913070	4326746.99	767145.25
E6B POLE	39.048982	-107.913198	4326747.94	767134.13
E8A CAM	39.097379	-107.887580	4332195.97	769167.45
E8A POLE	39.097329	-107.887477	4332190.72	769176.55
E9A CAM	39.103473	-107.880787	4332892.61	769731.79
E9A POLE	39.103561	-107.880742	4332902.52	769735.35

Camera Name	Latitude [°]	Longitude [°]	Northing [m]	Easting [m]
E9B CAM	39.100560	-107.900539	4332510.72	768034.45
E9B POLE	39.100639	-107.900614	4332519.27	768027.66
E9C CAM	39.098843	-107.893792	4332340.07	768624.56
E9C POLE	39.098962	-107.893702	4332353.55	768631.89
E9D CAM	39.073889	-107.877764	4329617.58	770106.20
E9D POLE	39.074028	-107.877689	4329629.90	770109.70
E9E CAM	39.059785	-107.876640	4328055.29	770257.30
E9E POLE	39.059881	-107.876662	4328065.88	770255.03
E9F CAM	39.047249	-107.923515	4326525.28	766247.62
E9F POLE	39.047323	-107.923406	4326533.40	766256.40
E9G CAM	39.038187	-107.935015	4325485.71	765286.11
E9G POLE	39.038270	-107.935097	4325494.69	765278.70
TLSK20 CAM	39.033764	-108.054196	4324653.57	754984.52
TLSK20 POLE	39.033806	-108.053996	4324658.79	755001.67
W1A CAM	39.017118	-108.184854	4322447.43	743730.22
W1A POLE	39.017236	-108.184880	4322460.46	743727.57
W1B CAM	39.007931	-108.184663	4321428.19	743778.33
W1B POLE	39.008078	-108.184794	4321444.16	743766.48
W2A CAM	39.013720	-108.208580	4322006.92	741687.30
W2A POLE	39.013823	-108.208536	4322018.47	741690.76
W2B CAM	39.029056	-108.200016	4323732.00	742376.50
W2B POLE	39.029174	-108.199952	4323745.27	742381.64
W3A CAM	39.013114	-108.186933	4321997.42	743563.94
W3A POLE	39.013208	-108.186994	4322007.69	743558.34
W5A CAM	39.017686	-108.165745	4322561.88	745382.96
W5A POLE	39.017744	-108.165836	4322568.07	745374.88
W6A CAM	39.012471	-108.185758	4321929.19	743667.90
W6A POLE	39.012546	-108.185686	4321937.71	743673.88
W6B CAM	39.016241	-108.169723	4322390.40	745043.70
W6B POLE	39.016342	-108.169688	4322402.06	745046.17
W6C CAM	39.012711	-108.174204	4321986.86	744667.64
W6C POLE	39.012837	-108.174167	4322001.00	744670.00
W8A CAM	39.050536	-108.051602	4326522.59	755148.70
W8A POLE	39.050599	-108.051624	4326529.52	755146.57
W8B CAM	39.012307	-108.179372	4321928.12	744221.49

Camera Name	Latitude [°]	Longitude [°]	Northing [m]	Easting [m]
W8B POLE	39.012356	-108.179477	4321933.28	744212.23
W8C CAM	39.012731	-108.095955	4322202.55	751443.85
W8C POLE	39.012585	-108.095973	4322186.29	751442.80
W9A CAM	39.036252	-108.161794	4324633.37	745660.75
W9A POLE	39.036208	-108.161851	4324628.34	745655.97
W9B CAM	39.012294	-108.175999	4321935.74	744513.63
W9B POLE	39.012393	-108.176150	4321946.32	744500.21
W9C CAM	39.024344	-108.171138	4323286.37	744892.98
W9C POLE	39.024416	-108.171069	4323294.54	744898.70
W9D CAM	39.036556	-108.155603	4324683.87	746195.65
W9D POLE	39.036476	-108.155686	4324674.77	746188.74
W9E CAM	39.033624	-108.160760	4324344.46	745759.38
W9E POLE	39.033751	-108.160689	4324358.00	745766.00
W9G CAM	39.031286	-108.180180	4324032.61	744086.18
W9G POLE	39.031366	-108.180167	4324041.52	744087.03

1.3.2 Resolution

Point locations with 1 cm vertical resolution for snow depth measurements.

1.3.3 Geolocation

Geolocation information in this data set is available in WGS84 (decimal degrees) and WGS84 UTM Zone 12N (meters). The following tables provide details for geolocating this data set.

Table 3. Geolocation Details

Geographic coordinate system	WGS 84
Projected coordinate system	UTM zone 12N
Longitude of true origin	-111
Latitude of true origin	0
Scale factor at longitude of true origin	0.9996
Datum	WGS 84
Ellipsoid/spheroid	WGS 84
Units	Meters
False easting	500000
False northing	0

EPSG code	32612
PROJ4 string	+proj=utm +zone=12 +datum=WGS84 +units=m +no_defs
Reference	https://epsg.io/32612

Table 4. Geolocation Details

Geographic coordinate system	WGS 84
EPSG code	4326
PROJ4 string	+proj=longlat +datum=WGS84 +no_defs
Reference	https://epsg.io/4326

1.4 Temporal Information

1.4.1 Coverage and Resolution

The temporal coverage for this data set is 29 September 2019 through 10 June 2020.

Snow depth was extracted at the images collection rate. Images were taken two or three times a day at 11AM and 12PM or at 11AM, 12PM and 1PM. Table 5 lists the number of pictures taken per day for each camera.

The following table lists the start and end dates of snow depth data for all cameras as well as the daily sampling.

Table 5. Start and End Dates and Daily Readings per Camera

Camera Name	Start Date	End Date	Readings per Day
E3A	29 September 2019	10 June 2020	3
E6A	29 September 2019	5 June 2020	3
E6B	29 September 2019	5 June 2020	3
E8A	29 September 2019	5 June 2020	3
E9A	29 September 2019	10 June 2020	3
E9B	29 September 2019	5 June 2020	3
E9C	29 September 2019	5 June 2020	3
E9D	29 September 2019	5 June 2020	3
E9E	29 September 2019	5 June 2020	3
E9F	29 September 2019	30 November 2019	3
E9G	29 September 2019	5 June 2020	2

Camera Name	Start Date	End Date	Readings per Day
W1A	29 September 2019	10 June 2020	2
W1B	29 September 2019	5 June 2020	2
W2A	29 September 2019	10 June 2020	2
W2B	29 September 2019	5 June 2020	2
W3A	29 September 2019	5 June 2020	2
W5A	29 September 2019	10 June 2020	2
W6A	29 September 2019	28 November 2019	2
W6B	29 September 2019	10 June 2020	2
W6C	29 September 2019	10 June 2020	2
TLSK20	29 September 2019	5 June 2020	2
W8A	29 September 2019	10 June 2020	2
W8C	29 September 2019	24 February 2020	2
W9A	29 September 2019	10 June 2020	2
W9B	29 September 2019	5 June 2020	2
W9C	5 October 2019	5 June 2020	2
W9D	29 September 2019	10 June 2020	2
W9E	29 September 2019	10 June 2020	2
W9G	29 September 2019	10 June 2020	2

2 DATA ACQUISITION AND PROCESSING

2.1 Background

The SnowEx 2020 Grand Mesa study area was classified into nine matrix classes by combining snow depth data from the SnowEx 2017 airborne lidar and optical imagery (Figure 1 top-left) with a tree density map (Figure 1 bottom-left). Specifically, the Airborne Snow Observatory's 8 February 2017 lidar-derived snow depths (ASO L4 Lidar Snow Depth 3m UTM Grid, Version 1) were binned into three classes: shallow (<90 cm), intermediate (90-122 cm), and deep (>122 cm). Similarly, the tree density map created from November 2010 WorldView-2 imagery was binned into three classes based on the percentage of tree-class pixels within a 50 m radius: treeless (0%), sparse (1-30%), and dense (31-100%). The two factors were combined to form a nine-point snow and tree matrix (Figure 1 right). Within this matrix, values 1-3, 4-6, and 7-9 represent treeless, sparse, and dense tree areas, respectively. These three ranges can be further subdivided into three classes of snow depth: shallow (lowest number in a range, e.g. 1), intermediate, and deep (highest number in a range, e.g. 3). Treeless areas include those characterized as shrub and meadow types. Water bodies and areas where lidar data is missing remain unclassified (grey areas in Figure 1).

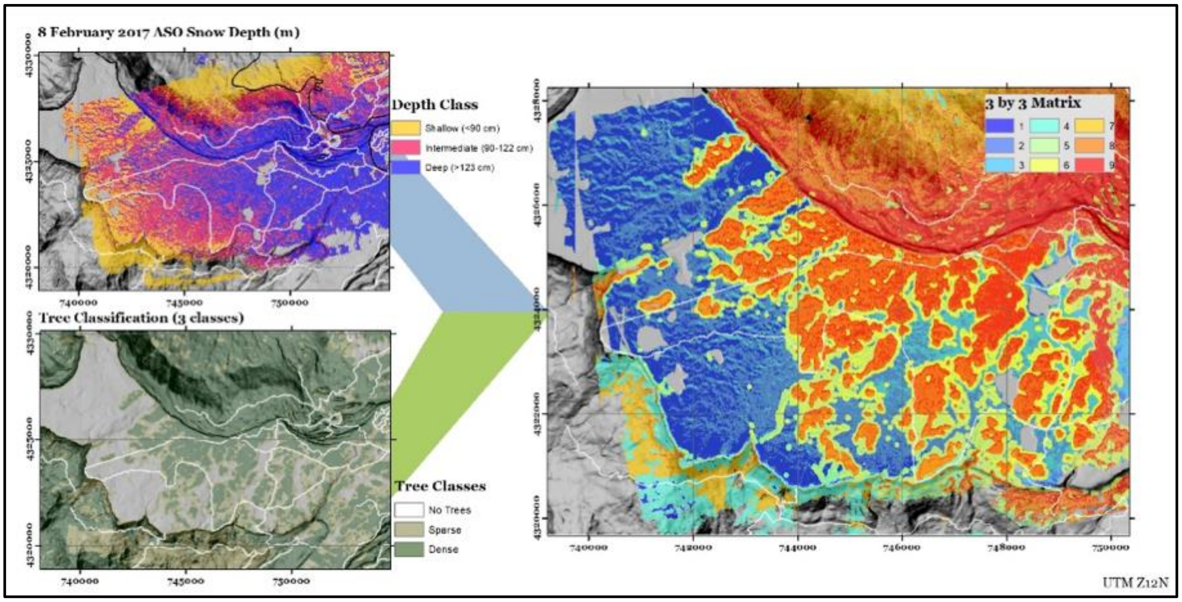

Figure 1. Separate vegetation and snow depth classifications for the Grand Mesa IOP study site are shown (left). These classifications were combined to form the final tree density and snow depth matrix used to describe snow pit and camera locations (right). In all images, gray areas represent undefined regions (e.g., water bodies).

The camera and pole pairs were split into 20 cameras on the western area and 10 cameras in the eastern area of the Grand Mesa study site (Figure 2). Within those two areas, cameras were distributed proportionally among the matrix classes based on matrix class area (Table 6). All sites were randomly located with the exception of the Terrestrial Laser Scanner (TLS) site. One camera went missing after deployment leading to a total of 29 camera locations.

Table 6. Matrix classes with in parenthesis numbers of cameras in that class.

Matrix class (number of cameras per class)	Shallow snow (<90 cm)	Intermediate snow (90-122 cm)	Dense snow (>122 cm)
Treeless	1 (n=2)	2 (n=2)	3 (n=2)
Sparse forest	4 (n=0)	5 (n=1)	6 (n=6)
Dense forest	7 (n=0)	8 (n=4)	9 (n=13)

With the exception of the TLS site (named TLSK20), camera names use the following 3-digit naming convention: [XMR], where:

X = East(E) or West (W) area on the Grand Mesa study site (Figure 2)
M = Matrix class value for vegetation and snow (See Table 6)
R = Replicate of the combination of X and M. (Options A-G)

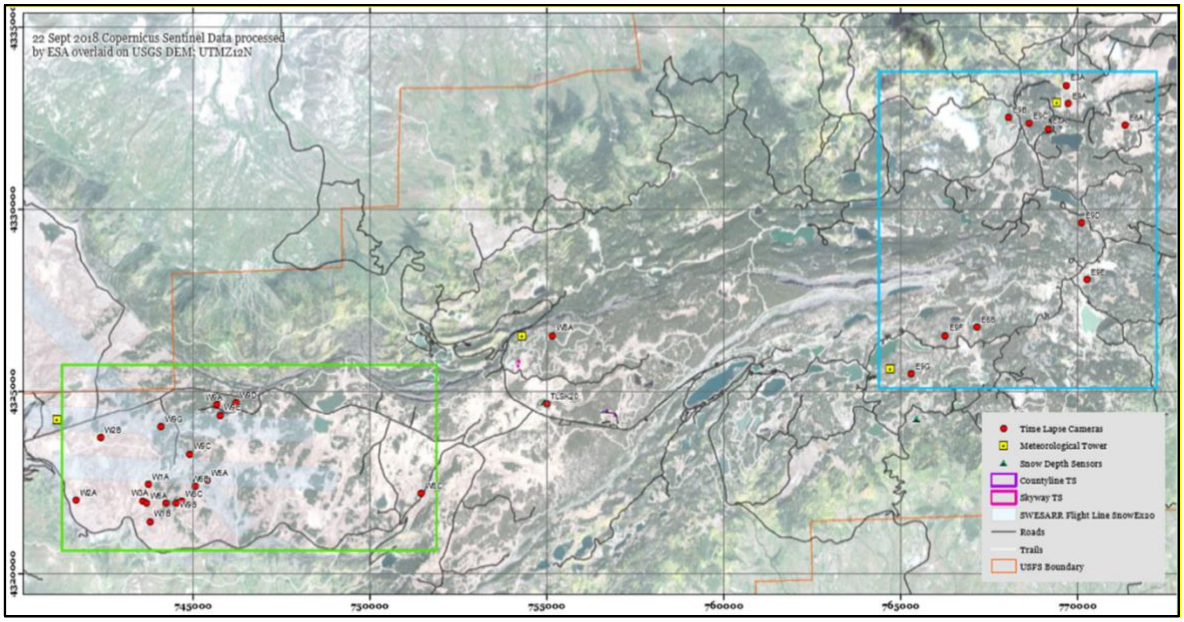

Figure 2. Camera Locations along with Weather Stations, Snow Depth Sensors and Land Boundaries during the SnowEx2020 Campaign on Grand Mesa, CO.

Snow depth data were derived from the SnowEx20 Grand Mesa Time-Lapse Imagery data set published separately at NSIDC. More details on camera locations as well as all individual images can be found there.

Time-lapse cameras have also been used to extract other information about snow properties such as snow-covered area and snow presence/absence in the forest canopy (Lumbrazo et al. 2021; Dickerson-Lange et al. 2015; Raleigh et al. 2013).

2.2 Instrumentation

The time-lapse camera network was composed of Wingscapes brand trail/game cameras. The deployed model was WCT-00126 TimeLapseCam Pro. The focal length of this camera is 3 mm and image dimensions are 6080 x 3402 pixels. Most cameras were mounted on t-posts approximately 2 m above the ground. The field view of all cameras included a 3.049 m, (10 ft) vertical pole that was painted red with a yellow top to serve as a reference for quantifying snow depth.

2.3 Acquisition

Camera and poles were placed around Grand Mesa, CO at 29 sites coincident with other SnowEx 2020 measurements. The cameras were installed 8-20 m from the poles. The poles, PVC pipes, were painted red/orange and had a yellow duct-tape band around the top 10 cm. The poles were attached to t-posts and installed in the ground using a t-post driver, clearing vegetation as necessary.

The cameras were installed in late September 2019 or early October 2019. Cameras were removed between June and August of 2020. Cameras E9F and W6A stopped functioning in November 2019 and camera W8C stopped functioning in February 2020.

Once installed, cameras took a test image and then either three images daily (11AM, 12 PM, 1PM) or twice daily (11AM and 12PM). See details on camera operation and image frequency in Table 5.

2.4 Processing

- Image download
- Run Matlab script (available at this Github link) prompting the selection of the top and bottom of the pole to record the x and y coordinates of the pole ends in each image.
- Mark images where snow poles could not be identified e.g., during a storm or when the poles were fully covered in snow. (Error code 1)
- Export time series of snow pole pixel length for each camera
- Eliminate all images that are not taken at 11AM, 12PM, or 1PM.
- Remove dates that are outside the 29 September 2019 – 10 June 2020 time frame.
- Calibrate each camera's length per pixel using a snow and vegetation free snow pole pixel length divided by the actual snow pole length of 304.8 cm.
- Convert all other pixel lengths to snow depth using the following conversion:

$$Snow\ Depth = 304.8 - (Pixel\ length * Length\ per\ Pixel)$$

- Calculate and append latitude, longitude, northing and easting to each cameras snow depth values.
- Visually inspect snow depth time series for outliers and evaluate images for errors.

Table 7. Length per pixel and snow depth error estimate for each camera.

Camera ID	Length Per Pixel	Error Estimate (+/- cm)
E3A	0.13457	5
E6A	0.1096	7
E6B	0.1259	11
E8A	0.11251	8
E9A	0.12206	9
E9B	0.19303	10
E9C	0.11301	4
E9D	0.1365	4
E9E	0.13724	2
E9F	0.13552	4
E9G	0.14466	7
TLSK20	0.18665	6
W1A	0.15052	5
W1B	0.25004	7

Camera ID	Length Per Pixel	Error Estimate (+/- cm)
W2A	0.13873	4
W2B	0.1767	16
W3A	0.1312	3
W5A	0.12866	4
W6A	0.14183	10
W6B	0.15671	6
W6C	0.18574	7
W8A	0.16449	3
W8C	0.20977	4
W9A	0.11629	3
W9B	0.13293	3
W9C	0.13848	3
W9D	0.12758	4
W9E	0.1319	3
W9G	0.13223	3

2.5 Quality, Errors, and Limitations

This data set has been quality controlled visually. Error estimates listed in Table 7 are camera and snow pole pair dependent e.g., due to environmental differences in surrounding vegetation and snow pole distances to the camera. The error for each camera/pole pair was estimated by snow depth deviations from zero at snow free conditions. For example, the snow depth estimates for camera W1B, on September 29, 2019 at 12:00PM, is -4.5 cm. As the image is snow free, this negative value indicates an error of +/- 5 cm for all snow depth measurements from this camera. Error details and quality control measures are further described here:

- Camera calibration: Camera calibration was accounted for using Matlab's calibration package from the computer vision toolbox. Camera calibration parameters are included in the matlab code provided on this Github link.
- Image tilt: MATLAB's built-in function ginput.m calculates the distance formula between the top and bottom of the snow pole, therefore images do not need to be rotated. However, snow poles at an angle would overestimate the length of the snow pole. This error is assumed to be small as no more than 1 or 2 degrees of rotation were found using a MATLAB code realigning the images (imrotate.m).
- Resolution: The snow depth error is higher when the snow pole is farther away from the camera as the spatial resolution (pixels per centimeter) is lower.
- Quality error: Other quality errors include
    - Ground vegetation blocking the bottom view of the snow pole.
    - Snow pole occlusion due to a storm or deep snow blocking the lens.
    - Snow pole truncated in the image due to the camera or pole tilting.

- Blurry image due air or camera lens quality.

Table 8 lists the various error codes. The final data file includes only snow depths with error code 0.

Table 8. Error Codes for Snow Depth Image Processing

error codes	description
0	no error
1	storm
3	stake tilt
5	vegetation
6	stake top cropped off
8	camera tilt
9	insufficient data/camera malfunction

3 SOFTWARE AND TOOLS

The SnowEx Hackweek 2021 included a tutorial for accessing time-lapse camera data and describes possible data applications.

4 VERSION HISTORY

Table 9. Version History Summary

Version	Release Date	Description of Changes
001	17 March 2022	Initial release

5 RELATED DATA SETS

SnowEx at NSIDC | Data Sets
SnowEx20 Grand Mesa Time-Lapse Imagery

6 RELATED WEBSITES

SnowEx at NSIDC | Overview
NASA SnowEx

7 CONTACTS AND ACKNOWLEDGMENTS

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8 REFERENCES

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9 DOCUMENT INFORMATION

9.1 Publication Date

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9.2 Date Last Updated

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