SnowEx20 Grand Mesa Reference GIS Data Sets, Version 1

USER GUIDE

How to Cite These Data

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

Hiemstra, C. A., C. M. Vuyovich and H.-P. Marshall. 2021. *SnowEx20 Grand Mesa Reference GIS Data Sets, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/YDZXY4Q79VIJ. [Date Accessed].

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

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

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

This data set contains geolocation information of the infrastructure locations for the SnowEx20 Intensive Observation Period (IOP) and Time Series (TS) campaigns. Available scientific infrastructure locations in this data set are tower and sensor locations, aircraft flight lines, planned and actual snow pit locations, and time-lapse camera locations. Additionally, this data set contains areal snow depth and tree density classification matrix over the Grand Mesa, CO study area.

1.2 File Information

1.2.1 Format

Data are provided in ESRI shapefiles (.shp, .shx, .dbf, .prj, .sbn, .sbx, .cpg) and in GeoTIFF (.tif, .tfw, .tif.ovr, .tif.vat.cpg, .tif.vat.dbf) files.

1.2.2 File Contents

1.2.2.1 Grand Mesa Sensor Infrastructure File Contents

The Grand Mesa sensor infrastructure consisted of

- Four metrological tower locations (SNEX20_GIS_REF_GM_met_towers.shp). The parameters in this file are: Tower (tower short name), Latitude (°), Longitude (°), Northing (m), Easting (m), Elevation (m).
- Ten USDA soil moisture measurement stations (SNEX20_GIS_REF_GM_usda_soil_moisture_stations.shp). The parameters in this file are: SM_station (3-digit soil moisture station number), Latitude (°), Longitude (°), Northing (m), Easting (m), TLS_area (4-digit terrestrial laser scanners study area names).
- Two Judd sensor array sites (SNEX20_GIS_REF_GM_CU_judd_sensor_arrays.shp). The parameters in this file are: Latitude (°), Longitude (°), Northing (m), Easting (m), Site (SnowEx 2017 TLS Site Letters).

1.2.2.2 Grand Mesa IOP Data File Contents

The Grand Mesa IOP data contains

- Three SnowEx20 SWESARR flight lines (SNEX20_GIS_REF_GM_SWESARR_flightlines.shp). The single parameter in this file is Flightline. The three options as N (north), S (south) and C (cross).
- One SnowEx20 SWESARR flight area (SNEX20_GIS_REF_GM_SWESARR_flightarea.shp)

- Nine terrestrial laser scanner (TLS) site areas (SNEX20_GIS_REF_GM_TLS_areas.shp). The single parameter in this file is TLS_area referring to the 4-digit name of each site.
- 150 original study design snow pit locations intended for measurements (SNEX20_GIS_REF_GM_original_150_pit_locations.shp). The parameters in this file are Line (referring to the flight line on which the pit location falls, options are N (north), S (south) and C (cross)), matrixclas (Options are 1-9, see section 2.1 for details on the matrix classes.), SnowPitID0 (3- or 4-digit snow pit name. See section 2.1 for details on snow pit naming conventions.), Easting (m), Northing (m), Longitude (°), Latitude (°).
- 155 actual IOP pit locations used for measurements (SNEX20_GIS_REF_GM_IOP2020_pit_locations.shp). The parameters in this file are: ID_num (6-digit snow pit ID number), SnowPitID (3- or 4-digit snow pit name, refer to section 2.1 for details on snow pit naming conventions.), YYYY (4-digit year of snow pit measurement), mm (2-digit month of snow pit measurement), dd (2-digit day of snow pit measurement), HH_MM (1- or 2-digit hour followed by 2-digit minute of snow pit measurement in MST), Easting (m), Northing (m), Longitude (°), Latitude (°).
- 19 Delta monitoring stake and board locations where throughout the SnowEx 2020 campaign the snow depth change was monitored. (SNEX20_GIS_REF_GM_IOP_Delta_sites.shp). The parameters in this file are: Delta_Site (2-digit site name containing one number followed by one letter.), Easting (m), Northing (m), Longitude (°), Latitude (°), Elevation (m).

1.2.2.3 Grand Mesa Time Series Data File Contents

- Four time series pit locations (SNEX20_GIS_REF_GM_time_series_pit_locations.shp). The parameters in this file are: TSPitID (3-digit pit ID), TSPitName (Pit ID long name), Easting (m), Northing (m), Longitude (°), Latitude (°).
- 30 time-lapse camera and 30 snow depth pole locations (SNEX20_GIS_REF_GM_timelapsecams_poles.shp). The parameters in this file are: ID_num (Number of data set entry from 1 to 60.), cam_site (3-digit or 6-digit site number), site_item (Options are pole or camera), Easting (m), Northing (m), Longitude (°), Latitude (°).

1.2.2.4 Raster Data File Contents

- A 9-class snow depth and tree density raster file (SNEX20_GIS_REF_GM_9matrix.tif) mapping the GM study area into matrix classes. 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 categories of snow depth classification: shallow (lowest number in a range, e.g. 1), intermediate (2), and deep (highest number in a range, 3). See section 2.1 for more information on matrix classifications.

1.2.3 Naming Convention

All file names start with `SNEX20_GIS_GM` referring to the SnowEx20 Grand Mesa References GIS Data Sets and are followed by the individual sensor/infrastructure name. All files and their contents are individually described in section 1.2.2.

1.3 Spatial Information

1.3.1 Coverage

Northernmost Latitude: 39.125º N

Southernmost Latitude: 38.993º N

Easternmost Longitude: 107.863º W

Westernmost Longitude: 108.225º W

1.3.2 Resolution

N/A

1.3.3 Geolocation

The following table provides information for geolocating this data set

Table 1. Geolocation Details

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

Additionally, to WGS 84 (EPSG:4326), geolocation information is also provided in WGS UTM 12N (EPSG:32612):

Table 2. Geolocation Details

Geographic coordinate system	WGS 84
Projected coordinate system	WGS 84 / UTM Zone 12 North
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	32612

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

1.4 Temporal Information

1.4.1 Coverage

21 September 2019 – 14 February 2020

1.4.2 Resolution

N/A

2 DATA ACQUISITION AND PROCESSING

2.1 Background

The SnowEx 2020 Grand Mesa study area was classified into nine matrix classes. Snow depth data from the SnowEx 2017 airborne lidar and optical imagery (Figure 1 top-left) were combined 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 categories of snow depth classification: shallow (lowest number in a range, e.g. 1), intermediate, and deep (highest number in a range, e.g. 3). Treeless areas were not split into shrub or meadow cover types. Water bodies and missing lidar data areas remain unclassified (grey areas in Figure 1)

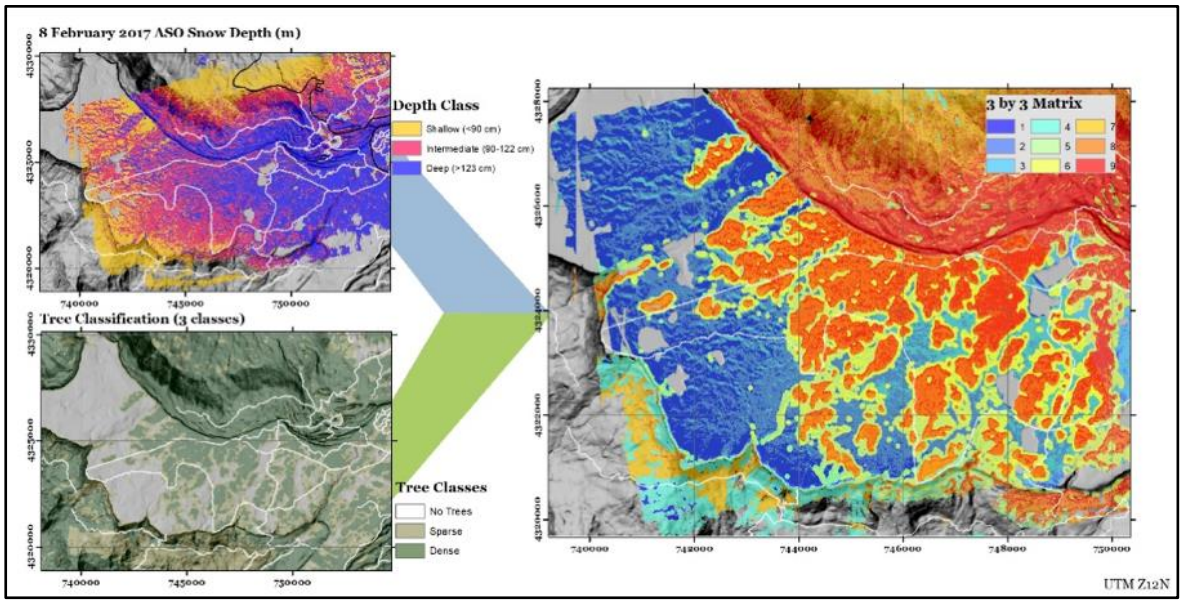

Figure 1. Separate vegetation and snow depth classifications for the Grand Mesa IOP study site are shown (left). These classifications were combined to form the final tree density and snow depth matrix used to describe snow pit locations (right). In all images, gray areas represent undefined regions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

Next, the Grand Mesa study site was clipped into three flight lines (north, N; south, S; and cross, C) (Figure 2). These flight lines correspond to the scheduled IOP airborne observations. Snow pits were selected to cover the full range of conditions found on Grand Mesa, from meadows to dense forests and from shallow snow depths to deep snowpack. The 150 snow pit locations were proportionally allocated to the nine matrix classes within the flight area and then randomly distributed over the flight area. Matrix classes were not evenly represented and varied in frequency; for example, there are 3 Class 4 snow pits and 33 Class 2 snow pits as 2% and 22% of the flight area falls into Class 4 and Class 2 respectively. Snow pit names use the convention described in Table 3.

Pit names start with the matrix class followed by the flight line and a pit number. For example, Pit “9S40” denotes matrix class 9, South flight line, and the 40th total pit on that line from west to east. Similarly, Pit “1C14” is matrix class 1, Cross line, and 14th pit along the line.

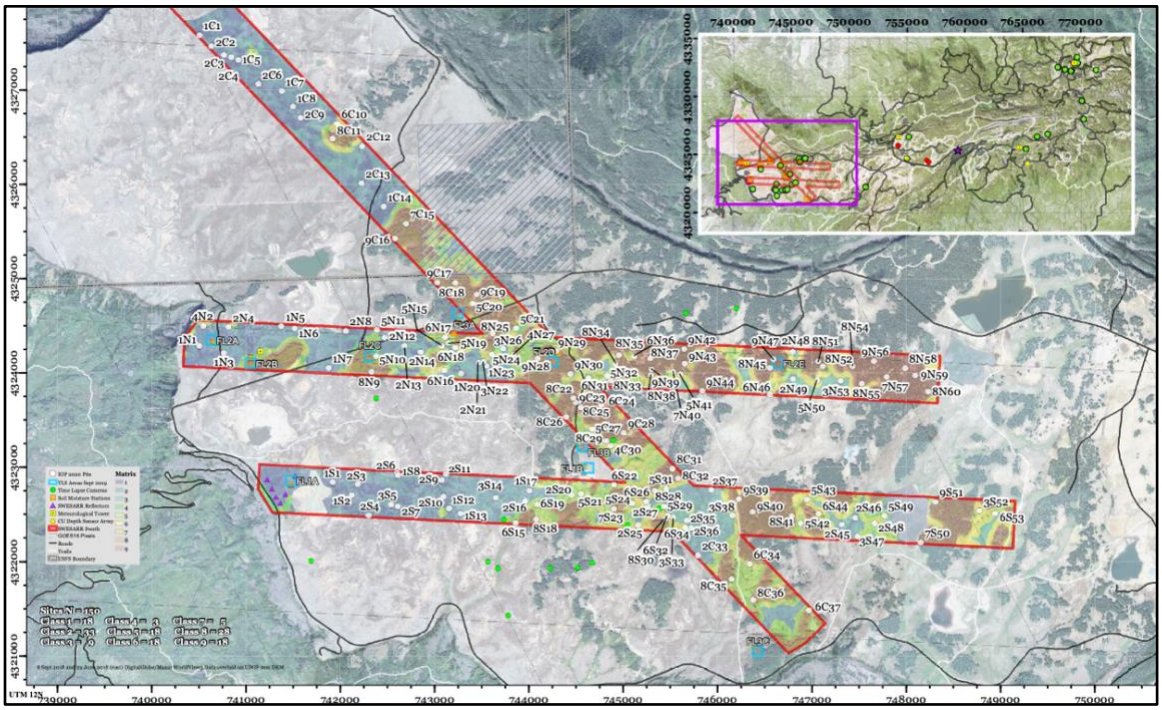

Figure 2. Location of the 150 planned Grand Mesa IOP snow pits. Snow pits were randomly spaced along the North (upper horizontal line), South (lower horizontal line), and Cross (diagonal line) flight lines, along which airborne measurements were collected. Snow pit naming conventions are described in Table 3. The inset in the top right shows the location of the IOP snow pits and flight lines relative to the rest of Grand Mesa and other SnowEx 2020 locations. Green dots show the location of time lapse cameras, red dots show the location of time series snow pits, yellow squares with black circles show the location of meteorological towers, and yellow circles show the location of snow depth sensors.

Table 3. Snow Pit Naming Convention

Variable	Description
Matrix	Number describing the measurement site conditions. Each number contains information about the amount of vegetation around the snow pit: • 1/2/3 = treeless (0% tree cover) • 4/5/6 = sparse (1-30% tree cover) • 7/8/9 = dense (31-100% tree cover) and the relative, expected snow pit depth: • 1/4/7= shallow snowpack • 2/5/8= medium snowpack • 3/6/9= deep snowpack
[FlightLine]	Indicates on which flight line the snow pit resided: • N = North • S = South • C = Cross

Variable	Description
##	Pit ID number. Numbers are lowest in the West and North and increase incrementally by whole numbers as you move further East or South along a particular flight line.

2.2 Acquisition

All point data in the ESRI shapefiles, such as tower locations, snow pit locations, time-lapse camera locations, etc., were collected with Garmin GPSMAP 64ST handheld units.

The SWESARR flight lines were created from coordinates in ArcGIS given landscape location and expected flight transits. A 250 m buffer was drawn around the flight lines to create the polygon flight box areas.

The terrestrial laser scanner (TLS) areas were created from a land cover map and SWESARR flight lines, assuming a roughly 1 ha TLS area.

2.3 Processing

2.3.1 Grand Mesa Sensor Infrastructure

- The meteorological tower locations were recorded upon installation in October 2016
- The USDA soil moisture measurement station locations were recorded upon installation in September 2017
- The two Judd sensor array site locations were recorded upon installation in October 2016

2.3.2 Grand Mesa IOP Data

- The SWESARR flight lines for SnowEx 2020 were determined based on flight paths and estimating flight times, winds, desired variable land covers and snow depths.
- The SWESARR flight area for SnowEx 2020 was created by adding a 250 m buffer around each flight line assuming that snow pit measurement locations need to fall within that box to be useful for validation.
- The TLS scan site areas were delineated for scanning in September 2019.
- The planned snow pit locations intended for measurements were selected randomly and details on snow pit naming can be found in section 2.1.
- The actual snow pit locations used for measurements were extracted from the snow pit data sheets.
- The Delta monitoring stakes and board locations were recorded in January 2020.

2.3.3 Grand Mesa Time Series Data

- The time series pit locations were recorded in December 2019

- The time lapse camera and snow depth pole locations were recorded upon installation in September and October 2019

2.3.4 Raster Data

The snow depth and tree density class matrix classifications are described in section 2.1.

2.4 Quality, Errors, and Limitations

A number of our locations were under tree canopy, which could be thick at times. Trees impact GPS signals and accuracy and GPS systems deployed as part of this work were no exception. In clear sky conditions, this error decreases markedly. Errors of 3 m were common in non-forest; errors of 15 m were common under canopies.

3 SOFTWARE AND TOOLS

ESRI Shapefiles and GeoTIFF files can be opened using GIS software, such as QGIS and ArcMap.

4 VERSION HISTORY

Table 4. Version History Summary

Version	Release Date	Description of Changes
1	26 October 2021	Initial release

5 RELATED DATA SETS

SnowEx at NSIDC | Data Sets

6 RELATED WEBSITES

SnowEx at NSIDC | Overview

SnowEx at NASA

NASA SnowEx 2020 Experimental Plan

7 CONTACTS AND ACKNOWLEDGMENTS

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8 DOCUMENT INFORMATION

8.1 Publication Date

26 October 2021

8.2 Date Last Updated

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