SnowEx20 Community Snow Depth Probe Measurements, Version 1

USER GUIDE

How to Cite These Data

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

Hiemstra, C. A., H. P. Marshall, C. M. Vuyovich, K. Elder, M. A. Mason, and M. Durand. 2020. *SnowEx20 Community Snow Depth Probe Measurements, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/9IA978JIACAR. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SNEX20_SD

NSIDC National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

The main parameter for this data set is snow depth, measured in centimeters (cm).

1.2 File Information

1.2.1 Format

Data files are provided in Comma-Separated Values (CSV) format.

Extensible Markup Language (.xml) files with associated metadata are also provided.

1.2.2 File Contents

The data file contains 13 columns, described in Table 1 and as shown in Figure 1.

Table 1. File Description

Column Title	Description
Measurement Tool	Name of the instrument used to take the snow depth measurement: • MP = Magnaprobe • M2 = Mesa 2 • PR = Pit Ruler
ID	Measurement ID: • 100000s = Magnaprobe measurements • 200000s = Mesa 2 measurements • 300000s = Pit Ruler measurements
Date	Date of measurement in yyyy-mm-dd format
Time	Time (local MST) of measurement in hh:mm format[1]
PitID	Name of the snow pit where measurements occurred (see Section 9. Appendix for more details)
Longitude	Longitude of measurement, measured in decimal degrees
Latitude	Latitude of measurement, measured in decimal degrees
Easting	Projected x-coordinate (UTM WGS84), in meters
Northing	Projected y-coordinate (UTM WGS84), in meters
Depth	Snow depth, measured in centimeters (cm)
Elevation	Elevation above sea level, measured in meters
Equipment	Magnaprobe or Mesa 2 instrument ID (“ruler” for pit ruler measurements)

Column Title	Description
Version Number	Data set version number
[1]All Magnaprobe (MP) times are approximate	

Measurement Tool	ID	Date	Time	PitID	Longitude	Latitude	Easting	Northing	Depth (cm)	elevation (m)	equipment	Version Number
MP	100000	20200128	11:48	8N58	-108.13515	39.03045	747987.62	4324061.71	94	3148.2	CRREL_B	1
MP	100001	20200128	11:48	8N58	-108.13516	39.03045	747986.75	4324061.68	74	3148.3	CRREL_B	1
MP	100002	20200128	11:48	8N58	-108.13517	39.03045	747985.89	4324061.65	90	3148.2	CRREL_B	1
MP	100003	20200128	11:48	8N58	-108.13519	39.03044	747984.19	4324060.49	87	3148.6	CRREL_B	1
MP	100004	20200128	11:48	8N58	-108.13519	39.03042	747984.26	4324058.27	90	3150.1	CRREL_B	1
MP	100005	20200128	11:48	8N58	-108.13521	39.03041	747982.56	4324057.1	93	3151.7	CRREL_B	1
MP	100006	20200128	11:48	8N58	-108.13523	39.03039	747980.9	4324054.83	84	3151.6	CRREL_B	1
MP	100007	20200128	11:48	8N58	-108.13524	39.03038	747980.07	4324053.69	81	3152.3	CRREL_B	1
MP	100008	20200128	11:48	8N58	-108.13523	39.03037	747980.97	4324052.61	71	3152.8	CRREL_B	1
MP	100009	20200128	11:48	8N58	-108.13522	39.03036	747981.87	4324051.53	65	3152.9	CRREL_B	1

Figure 1. Column headers and the first ten lines of data from SnowEx2020_SnowDepths_COGM_alldepths_v01_2j4uly2020.csv

1.2.3 Naming Convention

The data file is named: `SnowEx2020_SnowDepths_COGM_alldepths_v01_24july2020.csv`.

1.3 Spatial Information

1.3.1 Coverage

Northernmost latitude: 39.07° N

Southernmost latitude: 39.0° N

Easternmost longitude: 107.997° W

Westernmost longitude: 108.228° W

1.3.2 Resolution

This data set contains point data with a 1 cm vertical resolution.

1.3.3 Geolocation

The following tables provide information for geolocating this data set.

Table 2. Geolocation Details

Geographic coordinate system	WGS 84
Projected coordinate system	WGS 84/ UTM zone 12N
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	Degree
False easting	500000
False northing	0
EPSG code	32612
PROJ4 string	+proj=utm +zone=12 +datum=WGS84 +units=m +no_defs
Reference	http://epsg.io/32612

1.4 Temporal Information

1.4.1 Coverage

Data were obtained between 28 January and 12 February 2020.

1.4.2 Resolution

Data points are unique; sites were not revisited multiple times.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

These snow depth observations are one of the core SnowEx 2020 Intensive Observation Period (IOP) data sets. During the IOP in Grand Mesa, Colorado, 4 to 18 snow pits were visited each day by one to five ground observation teams. This snow depth data set contains observations from all 150 Grand Mesa IOP snow pits (Figure 2), as well as from spiral transects walked around the snow pits. Snow depths from nearby time series and terrestrial laser scanner (TLS) sites (which are not part of the 150 Grand Mesa IOP snow pits) are also included.

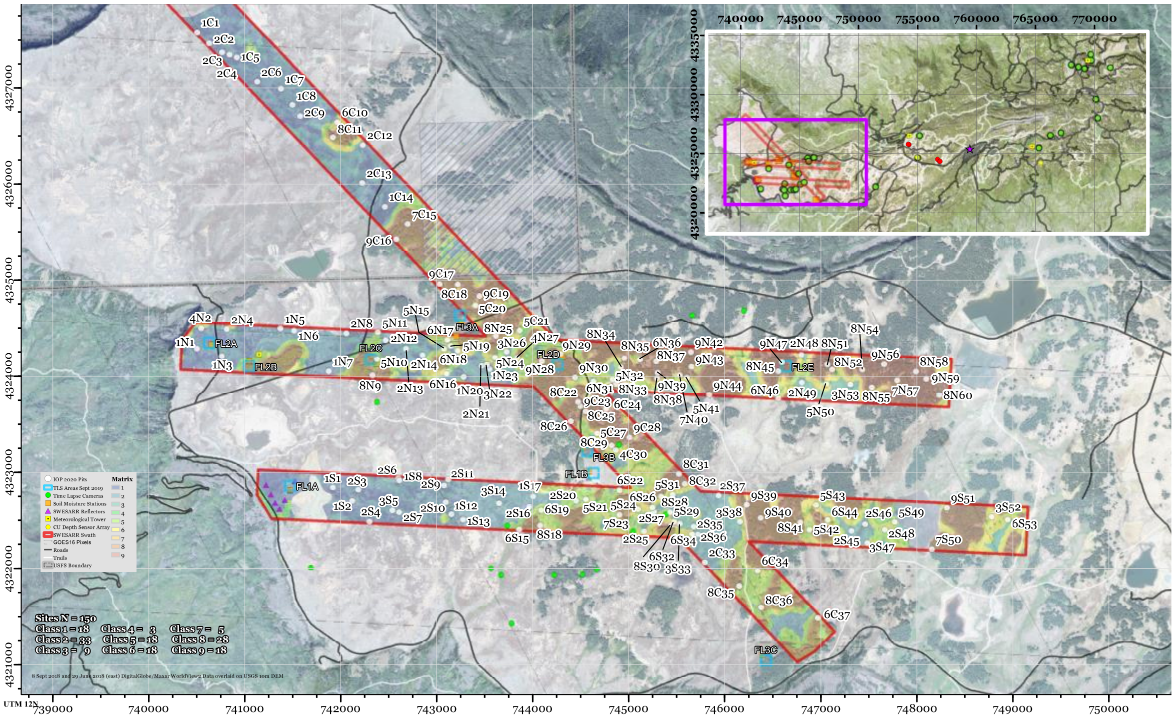

Figure 2. Location of the 2020 Grand Mesa IOP snow pits. Snow pits were randomly spaced along the North (upper horizontal line), South (lower horizontal line), and Cross (diagonal line) flight lines, along which airborne measurements and various ground observations were collected. See Section 9. Appendix for more details on how snow pit locations and names were chosen.

2.2 Acquisition

Pit teams were assigned to dig three to five snow pits each day, which they located using a Garmin GPSMAP 64ST. At each snow pit location, the pit team dug a snow pit and recorded its depth using the pit ruler. An additional one or two snow depth observers snowshoed or skied in an indefinite spiral out and away from the snow pit. The target spacing was ~10 m between the spiral's lines, with snow depth measurements taken every 3-5 m along the spiral track. Snow depth observers walked the spiral until the snow pit team completed all pit measurements. Final spirals averaged between 50 and 100 m in diameter.

The majority of snow depths were collected using Magnaprobe instruments. In order to record a measurement, the Magnaprobe operator must insert a probe into the snow until it reaches the ground and then press a button to record the depth, GPS location, elevation, date, and time of the measurement. Any other observations about the measurement (e.g. proximity to vegetation) were recorded in a field notebook. For depths deeper than 120 cm (the Magnaprobe's maximum depth), an avalanche probe was used to manually measure snow depth. Avalanche probe observations were recorded in a field notebook and later used to overwrite raw Magnaprobe data.

For areas where the majority of depths were expected to be greater 120 cm and/or in areas of dense tree canopy, the Mesa 2 system was deployed. Using the Mesa 2 system, snow depths were manually read from a 1-3 m probe and recorded on the Mesa 2 computer. The GPS location for each measurement was also recorded by the Mesa 2 computer.

Pit rulers were used exclusively at snow pit walls and recorded in the pit sheets.

2.3 Processing

2.3.1 Magnaprobe Data

1. Downloaded raw data from the Magnaprobe.
2. Calculated latitude and longitude.
3. Eliminated calibration measurements, false measurements or misfires, zero values, and other recorded data errors from the raw instrument output.
4. Changed the raw snow depth measurements for areas deeper than 120 cm (the Magnaprobe's maximum depth), where snow depth was manually collected using an avalanche probe.
5. Removed global outliers. Global outliers included any values outside expected ranges (i.e. snow depths less than 30 cm). Expected ranges were based on the researchers' experiences in the field and the values of adjacent measurements. Less than 30 data points were removed using this method.
6. Removed local outliers. Using ArcGIS 10.7, performed a "Cluster and Outlier Analysis" with a 10 m radius. This identified potential outliers in the data or areas where some depths were mistakenly recorded. Only two data points were eliminated using this method.
7. Calculated and appended UTM coordinates in ArcGIS 10.7.
8. Exported the cleaned data from ArcGIS 10.7 to the .csv file.

2.3.2 Mesa 2 Data

1. Downloaded raw data from the Mesa 2 computers.
2. Deleted any data points with a latitude and longitude of 0°.
3. Removed global outliers. Global outliers included any values outside expected ranges (e.g. snow depths less than 30 cm). Expected ranges were based on the researchers' experiences in the field.
4. Removed local outliers. Using ArcGIS 10.7, performed a "Cluster and Outlier Analysis" with a 10 m radius. This identified potential outliers in the data or areas where some depths were mistakenly recorded. Only one data point was eliminated using this method.
5. Calculated and appended UTM coordinates in ArcGIS 10.7.
6. Exported the cleaned data from ArcGIS 10.7 to the .csv file.

2.3.3 Pit Ruler Data

1. Extracted pit depths and locations from pit book sheets.
2. In ArcGIS 10,7, plotted recorded pit locations against their original identified locations to look for positional or transcription errors. Any identified location errors were corrected using field notes, team GPS tracks, and plotted snow depths.
3. Calculated and appended decimal degree coordinates to the data fields in ArcGIS 10.7.
4. Exported the cleaned data from ArcGIS 10.7 to the .csv file.

Once all Magnaprobe, Mesa 2, and pit ruler data were exported to the .csv file, the entire dataset was sorted based on date and equipment ID.

2.4 Quality, Errors, and Limitations

This data set has undergone multiple levels of QA/QC. The few remaining, potential sources of error are described below.

2.4.1 Depth Errors

Snow depth measurements may not be exact if the probe was inserted into unfrozen soil (snow depth estimates would be too deep) or atop vegetation (snow depth estimates would be too shallow). The effect and prevalence of this error is expected to be minor. We estimate that this error occurs <10% of the time and with a magnitude of <10 cm. In February 2020, the soil at the snow-soil interface was consistently frozen and offered a firm resistance.

2.4.2 Location Errors

Geolocation errors may impact measurements near tree canopies since trees can impact GPS signals and accuracy. This error is smallest for the Mesa 2 measurements (<1 m) and largest (~3-15 m) for the Magnaprobe and pit ruler measurements.

2.4.3 Transcription Errors

Since Mesa 2 and pit ruler data were manually recorded, transcription errors may exist, but none were identified in pit-data QA/QC. Transcription errors might also affect Magnaprobe depth measurements above 120 cm since those were also manually recorded.

2.5 Instrumentation

2.5.1 Magnaprobe Description

The Magnaprobe (Strum and Holmgren, 2018) is a snow probe attached to a data logger and GPS unit. The snow probe includes a basket that remains on top of the snow when the probe is inserted into the snowpack.

Four Magnaprobes were deployed during the campaign – Boise-State, CRREL-A, CRREL-B, and CRREL-C. The Boise-State Magnaprobe had a maximum snow depth of 170 cm. Unfortunately, the Boise-State Magnaprobe failed on the first day and was only able to collect measurements from one snow pit site before being retired. The remaining three CRREL (-A, -B, and -C) Magnaprobes had a maximum snow depth of 120 cm. To measure depths deeper than 120 cm, an avalanche probe was included with each CRREL Magnaprobe kit.

2.5.2 Mesa 2 Description

Two Mesa 2 systems (Mesa2-1 and Mesa2-2) were deployed over the campaign. Each Mesa 2 system includes a snow depth or avalanche probe from which snow depths could be manually read; Juniper System Inc's Geode, a high-accuracy Global Navigation Satellite System (GNSS) GPS antenna; and Juniper System Inc.'s Mesa 2, a field computer. The Mesa 2 connected to the GPS antenna via Bluetooth.

2.5.3 Pit Ruler Description

The folding ruler was part of the standard SnowEx 2020 pit kit and was used to measure snow depth on the pit wall. Pit ruler measurements were geolocated using a Garmin GPSMAP 64ST handheld unit.

3 VERSION HISTORY

Initial release.

4 RELATED DATA SETS

Other SnowEx Data at NSIDC

5 RELATED WEBSITES

SnowEx at NASA

6 CONTACTS AND ACKNOWLEDGMENTS

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7 REFERENCES

Sturm, Matthew, and Jon Holmgren. 2018. “An Automatic Snow Depth Probe for Field Validation Campaigns.” Water Resources Research 54 (11): 9695–9701. doi:10.1029/2018WR023559.

8 DOCUMENT INFORMATION

8.1 Publication Date

August 2020

8.2 Date Last Updated

August 2020

9 APPENDIX – ABOUT THE SNOWEX 2020 GRAND MESA IOP SNOW PITS

The SnowEx Grand Mesa Intensive Observation Period (IOP) 2020 snow pits were used to validate snow remote sensing on Grand Mesa. 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.

Potential Grand Mesa snow conditions were evaluated based on SnowEx 2017 airborne lidar and optical imagery (Figure A1). 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). A tree density map created from November 2010 WorldView-2 imagery was also 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 A1). 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 categories of shallow (lowest number in a range, e.g. 1), intermediate, and deep (highest number in a range, e.g. 3) snow depth classifications. Treeless areas were not split into shrub or meadow cover types. Water bodies and missing lidar data remain unclassified (grey areas in Figure A1).

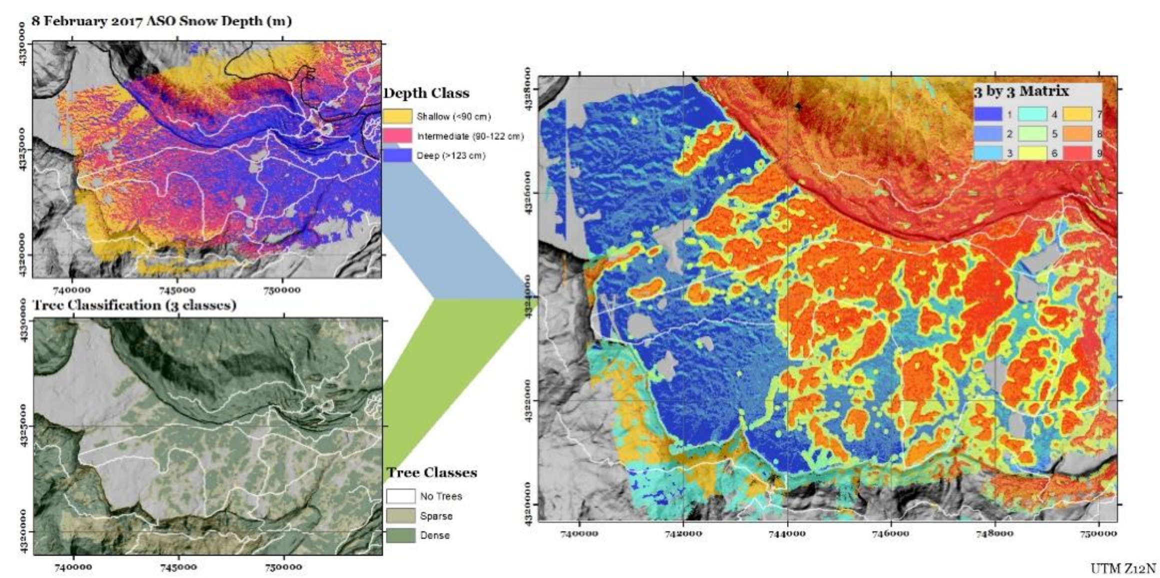

Figure A1. Separate vegetation and snow depth classifications for the Grand Mesa IOP study site are shown (left). These classifications were combined to form the final tree density and snow depth matrix used to describe snow pit locations (right). In all images, gray areas represent undefined regions (e.g. water bodies).

Finally, the Grand Mesa IOP study site was clipped into three flight lines (north, N; south, S; and cross, C) (Figure A2). These flight lines correspond to the scheduled IOP airborne observations. Within the flight lines, 150 snow pit locations (approximately three weeks of work) were proportionally divided by the nine matrix classes' areal extents, then randomly distributed amongst the three flight lines for each matrix class (Figure A2). Matrix classes were not evenly represented and varied in frequency from 3 (Class 4) to 33 (Class 2). Snow pit names use the following convention, as described in Table A1:

```
<matrix>[FlightLine]##
```

Table A1. Snow Pit Naming Convention Description

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

Variable	Description
	• S = South • C = Crossline
##	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.

For example, Pit "9S40" denotes matrix class 9 (deep snow and dense trees), South flight line, and the 40th total pit on the South line from west to east. Similarly, Pit "1C14" denotes matrix class 1 (shallow snow and no trees), Cross line, and the 14th pit along the Cross line from Northwest to Southeast.

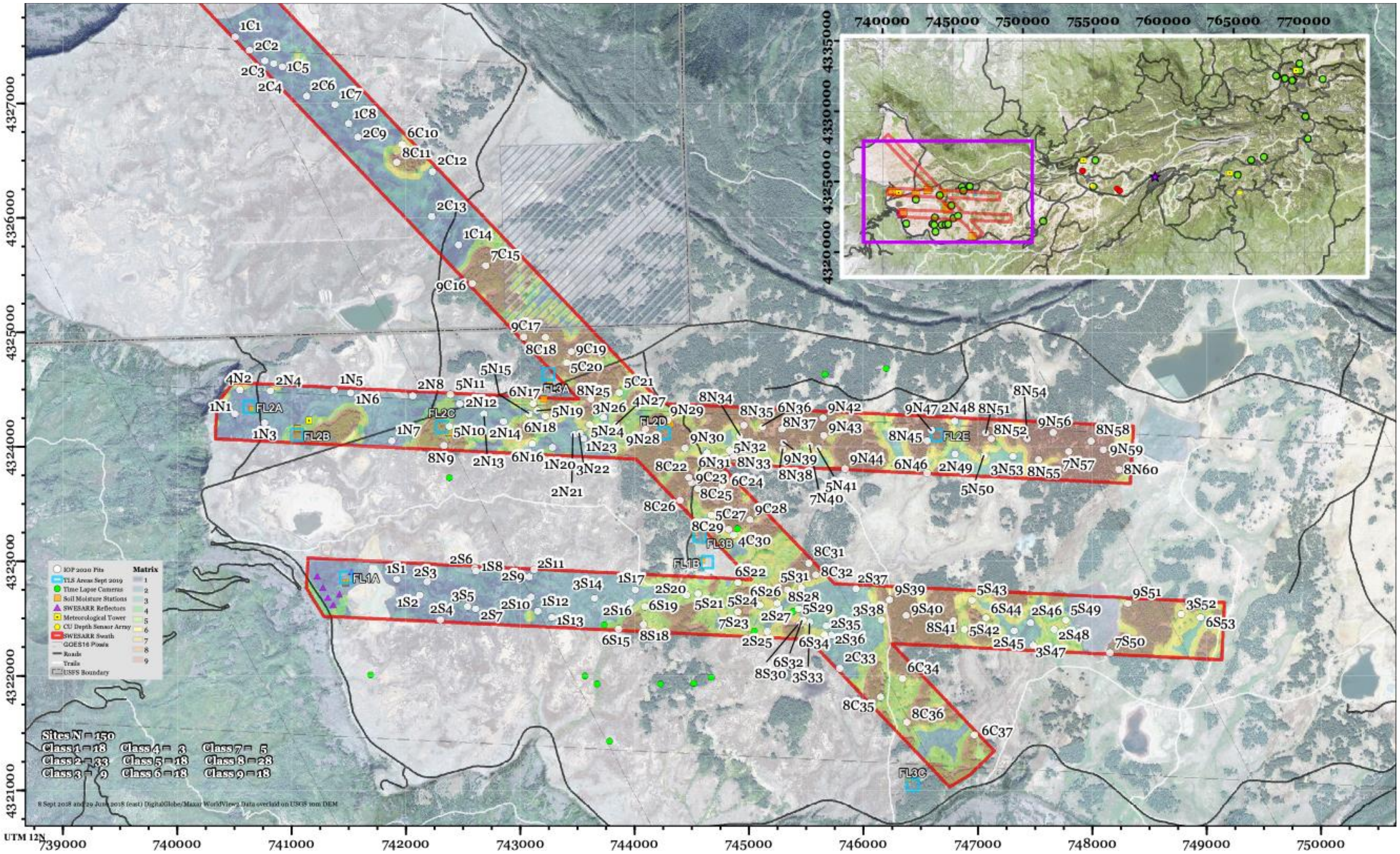

Figure A2. Location of the 150 Grand Mesa IOP snow pits. Snow pits were randomly spaced along the North (upper horizontal line), South (lower horizontal line), and Cross (diagonal line) flight lines, along which airborne measurements were collected. Snow pit naming conventions are described in Table A1. 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.