# SnowEx23 Laser Snow Microstructure Specific Surface Area Data, Version 1

## USER GUIDE

**How to Cite These Data**

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

Meloche, J., J. Lemmetyinen, K. Meyer, I. Alabi, C. Vuyovich, S. Stuefer, H.P. Marshall, M. Durand, and A. Langlois. 2023. *SnowEx23 Laser Snow Microstructure Specific Surface Area Data, Version 1.* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/BSEP59ADC6XN. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SNEX23_SSA

National Snow and Ice Data Center

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# 1 DATA DESCRIPTION

This data set reports vertical profiles of snow reflectance and specific surface area (SSA) from two study sites in Alaska, USA collected as part of the NASA SnowEx 2023 field campaign. The study sites include a boreal forest environment in the Fairbanks region of central Alaska and a coastal tundra environment in the North Slope region of the northern Alaska coastal plain. Reflectance was measured *in situ* using three different integrating sphere laser devices: an A2 Photonic Sensor IceCube (1310 nm), an InfraRed Integrating Sphere (IRIS) system (1310 nm), and an InfraSnow SSA sensor (945 nm). Measured reflectance values were converted to SSA during data processing. It is recommended that data users work with either the IceCube or IRIS data as the InfraSnow data were collected primarily for testing of the instrument's capabilities. Snow-off SSA data from these same study sites are available as SnowEx23 Laser Snow Microstructure Specific Surface Area Snow-off Data, Version 1.

## 1.1 Parameters

This data set characterizes snow microstructure, including sample signal in mV, reflectance in %, SSA in $m^2/kg$, and sample top height in cm. The data files also include a column for comments. InfraSnow data also include measured snow density ($kg/m^3$), derived from the adjacent snow pit measurement, and a recalculated SSA. See Section 2.2 of this user guide for additional details about the recalculated SSA values.

NOTES: 'Sample top height' is the vertical measure from ground surface to the snow top and is equivalent to the 'top depth' measure in the 2017 SSA data set (SNEX17_SSA). The name was changed in the 2020 data set (SNEX20_SSA) and also in this data set to better represent the physical measured property.

Previously published SSA data sets (SNEX17_SSA and SNEX20_SSA) include an additional parameter: 'spherical equivalent diameter (deg)' or 'optical equivalent diameter (DO)'. This data set does not include an equivalent diameter parameter. However, the data providers indicate this parameter can be easily calculated from the provided data.

## 1.2 File Information

### 1.2.1 Format

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

### 1.2.2 File Contents

All files begin with a 15-row header that specifies the date and time of acquisition, field campaign, pit ID, location (in UTM), instrument, operator, timing, notes, total snow depth, and calibration values. An example header is shown in Figure 1 below:

| | A | B | C | D |
|---|---|---|---|---|
| 1 | # Date (yyyy-mm-ddTHH:MM) | 2023-03-11T11:10 | | |
| 2 | #Name field campaign | SnowEx2023 | | |
| 3 | #Pit_ID | DA470 | | |
| 4 | #UTM_Zone | 6W | | |
| 5 | #Easting | 437847 | | |
| 6 | #Northing | 7176272 | | |
| 7 | #Instrument | IS3-SP-15-01US | | |
| 8 | #Profile_ID | DA470 | | |
| 9 | #Operator | K. Meyer | | |
| 10 | #Timing | 25 min | | |
| 11 | #Notes | | | |
| 12 | #Total_snow_depth(cm) | 30 | | |
| 13 | #Spectralon | 0,5.26,11.83,25.36,51.76,83.48,97.76 | | |
| 14 | #Calibration Values (mV) | -3.1,75.7,133.5,258.7,574.1,1151.5,1530 | | |
| 15 | # | | | |

Figure 1. Header example for SNEX23_SSA_BCEF_20230311_DA470_ICECUBE_v01.csv.

For IRIS and IceCube files, sample data begin on row 16 of the spreadsheet, with a header featuring 4 columns of data and 1 column of comments (see Figure 2):

| 16 | #Sample_signal(mV) | Reflectance(%) | SSA(m2 kg-1) | Sample_top_height(cm) | Comments |
|---|---|---|---|---|---|
| 17 | 560 | 50.68 | 50.2 | 30 | |
| 18 | 430 | 40.73 | 29.1 | 27 | |
| 19 | 435 | 41.14 | 29.8 | 24 | |
| 20 | 426 | 40.4 | 28.6 | 21 | |
| 21 | 420 | 39.91 | 27.9 | 18 | |
| 22 | 255 | 24.99 | 12.5 | 15 | |
| 23 | 244 | 23.89 | 11.7 | 12 | |
| 24 | 240 | 23.49 | 11.5 | 9 | |
| 25 | 220 | 21.45 | 10.2 | 6 | |

Figure 2. Example data for SNEX23_SSA_BCEF_20230311_DA470_ICECUBE_v01.csv.

For InfraSnow files, sample data also begin on row 16 of the spreadsheet but with a header featuring 6 data columns and 1 column for comments (see Figure 3). The column 'SSA($mm^{-1}$)' is the initial SSA calculated with a default density of 200 $kg/m^3$. The column 'recalculated SSA($m^2/kg$)' is an additional SSA measurement derived from the actual snow density values measured in the snow pit. These measured density values are shown in the column 'snow pit density ($kg/m^3$)'. Additional discussion of recalculated SSA values can be found in Section 2.2 of this user guide.

| 16 | #Sample_signal(mV) | Reflectance(%) | SSA(mm-1) | snow pit density(kgm-3) | recalculated SSA(m2 kg-1) | Sample_top_height(cm) | Comments |
|---|---|---|---|---|---|---|---|
| 17 | 712 | 76 | 33.4 | 70 | 94.8 | 54 | |
| 18 | 661 | 69.1 | 25.7 | 100 | 55.4 | 50 | |
| 19 | 648 | 67.2 | 24 | 240 | 24.7 | 45 | crust |
| 20 | 514 | 44.7 | 10.8 | 210 | 11.9 | 40 | |
| 21 | 491 | 40.3 | 9.1 | 230 | 9.2 | 35 | |
| 22 | 454 | 32.8 | 6.8 | 210 | 7.4 | 30 | MFCr |
| 23 | 492 | 40.4 | 9.2 | 350 | 6.5 | 25 | |
| 24 | 494 | 40.8 | 9.3 | 290 | 7.9 | 20 | |
| 25 | 516 | 45 | 10.9 | 400 | 7.1 | 15 | refrozen crust |
| 26 | 522 | 46.2 | 11.4 | 230 | 11.6 | 10 | |
| 27 | 565 | 53.9 | 15 | 230 | 15.5 | 5 | previous density used no measurement |

Figure 3. Datasheet example for 'SNEX23_SSA_UKT_20230311_N729_INFRASNOW_v01.csv'.

### 1.2.3 File Naming Convention

Data files utilize the following naming convention which is described in Table 1:

`SNEX23_SSA_[site]_[yyyymmdd]_[pitID]_[instrument]_v[nn].csv`

Table 1. File Naming Convention

| Variable | Description |
|---|---|
| SNEX23_SSA | SnowEx 2023 field campaign specific surface area (SSA) measurements |
| site | General measurement area. Fairbanks sites include: `BCEF` (Bonanza Creek Experimental Forest), `CPCW` (Caribou Poker Creek Watershed) and `FLCF` (Farmers Loop/Creamer's Field). North Slope sites include: `ACP` (Arctic Coastal Plain) and `UKT` (Upper Kuparuk Toolik) |
| yyyymmdd | 4-digit year, 2-digit month, and 2-digit day of data acquisition |
| pitID | Pit ID for the SnowEx23 Alaska campaign |
| instrument | Instrument code: `ICECUBE`, `IRIS`, or `INFRASNOW` |
| nn | Version number |

Example file names:

`SNEX23_SSA_BCEF_20230311_DB468_INFRASNOW_v01.csv`

`SNEX23_SSA_ACP_20230312_N501_IRIS_v01.csv`

NOTE: A few file names (see below) contain the additional variable: "`practice1`". These files contain data from a test pit located adjacent to the training location for SnowEX 2023 field participants. This location is not a named SnowEx 2023 snow pit, but these data were used to perform quality control (see Section 2.3 of this user guide) and are therefore included in this data set.

`SNEX23_SSA_Fairbanks_20230306_practice1_IRIS2_v01.csv`
`SNEX23_SSA_Fairbanks_20230306_practice1_INFRASNOW_v01.csv`
`SNEX23_SSA_Fairbanks_20230306_practice1_ICECUBE-BSU_v01.csv`
`SNEX23_SSA_Fairbanks_20230306_practice1_ICECUBE-FMI_v01.csv`
`SNEX23_SSA_Fairbanks_20230306_practice1_ICECUBE-OSU_v01.csv`

## 1.3 Spatial Information

### 1.3.1 Coverage

Northernmost Latitude: 70.0840º N
Southernmost Latitude: 68.5284º N
Easternmost Longitude: 148.6127° W
Westernmost Longitude: 149.5964° W

Northernmost Latitude: 65.1546º N
Southernmost Latitude: 64.7010º N
Easternmost Longitude: 147.4906° W
Westernmost Longitude: 148.2902° W

### 1.3.2 Resolution

Vertical profiles were obtained at 78 locations across the Fairbanks and Arctic coastal region. The vertical distance between measurements within a single snow pit is either 3 cm, 5 cm, or 10 cm depending on the thickness of the snowpack. Most measurements were taken at 5 cm intervals, but measurements taken from areas with thicker snowpack (i.e., deeper snow pits) were taken at 10 cm intervals in the interest of time. A very small number of measurements were taken at 3 cm intervals.

### 1.3.3 Geolocation

The following table provides information for geolocating this data set.

Table 2. Geolocation Details

| | |
|---|---|
| **Geographic coordinate system** | WGS 84 |
| **Datum** | WGS 1984 |
| **Ellipsoid/spheroid** | WGS 84 |
| **Units** | meters |
| **EPSG code** | 4326 |
| **PROJ4 string** | +proj=longlat +datum=WGS84 +no_defs +type=crs |
| **Reference** | https://epsg.io/4326 |

## 1.4 Temporal Information

### 1.4.1 Coverage

6 March 2023 to 16 March 2023

### 1.4.2 Resolution

Each snow pit was analyzed either once or twice (if also measured with the InfraSnow) during the campaign period. Sampling duration spanned a period of 10–60 minutes per snow pit, depending on the depth of the snow pit.

# 2 DATA ACQUISITION AND PROCESSING

## 2.1 Background

Vertical profiles of reflectance to either a 1310 nm or 945 nm laser were recorded in the field using one of three integrating sphere systems: IRIS or IceCube (both 1310 nm instruments) or InfraSnow (a 945 nm instrument). These devices utilize the same underlying principle—the relationship between the hemispherical infrared reflectance of snow and SSA. IRIS and IceCube differ only in their respective sphere sizes, while InfraSnow utilizes a different overall design. One of each instrument was deployed to the North Slope, while two IceCubes and one InfraSnow were deployed to the Fairbanks sites. The instrument used is denoted in data file names ("IRIS", "IceCube", or "InfraSnow") and the specific instrument is identified in the header of each data file as "#Instrument". An effort was made to collect all measurements at 5 cm sampling intervals in order to have a uniform resolution across sites. For deeper snow pits, this sampling interval was increased to 10 cm. A very small number of measurements were taken at 3 cm intervals.

Past SnowEx field campaigns have used both IRIS and IceCube to collect SSA data. The InfraSnow device is a relatively new instrument, and its use during this campaign was primarily a test of its capability in measuring SSA compared to the other instruments. All snow pits analyzed using InfraSnow were also analyzed using either IRIS or IceCube as well, and the data producers strongly suggest using the IRIS or IceCube data.

## 2.2 Acquisition and Processing

In the field, a snow sample is illuminated with the instrument's laser. An InGaAs photodiode (IRIS and IceCube) or VIS photodiode (InfraSnow) converts the reflected light to current, and the

voltages are converted to reflectance using certified standards. SSA is calculated from reflectance, using custom calibration algorithms for each instrument.

InfraSnow uses snow density in the SSA calculation, and a density of 200 kg/m$^3$ was used as a default value during the initial measurements. The original SSA calculated using this default value is presented in the data set in units of 1/m, which are the original units given by the InfraSnow instrument. SSA values were then recalculated using the actual snow density measured adjacent to each sampling site within each snow pit. On occasion, a measured density was unavailable for a specific layer, in which case the closest available measurement was used.

## 2.3 Quality, Errors, and Limitations

Quality control was performed by visually inspecting graphs of each reflectance, SSA, and equivalent diameter profile. To assess the consistency of SSA observations among instruments, a comparison of all instruments was done at the beginning of the campaign (Figure 4). IRIS and IceCube instruments produce excellent data consistency, with most of the differences in the ±10% range. The largest differences are ±25% and occur when measuring fresh snow near the snow-air interface, which can be difficult to sample. As IRIS was used on tundra snow where fresh snow is minimal, snow-air interface issues should not impact this data set. The differences between the three IceCube instruments were also minimal (< 10%).

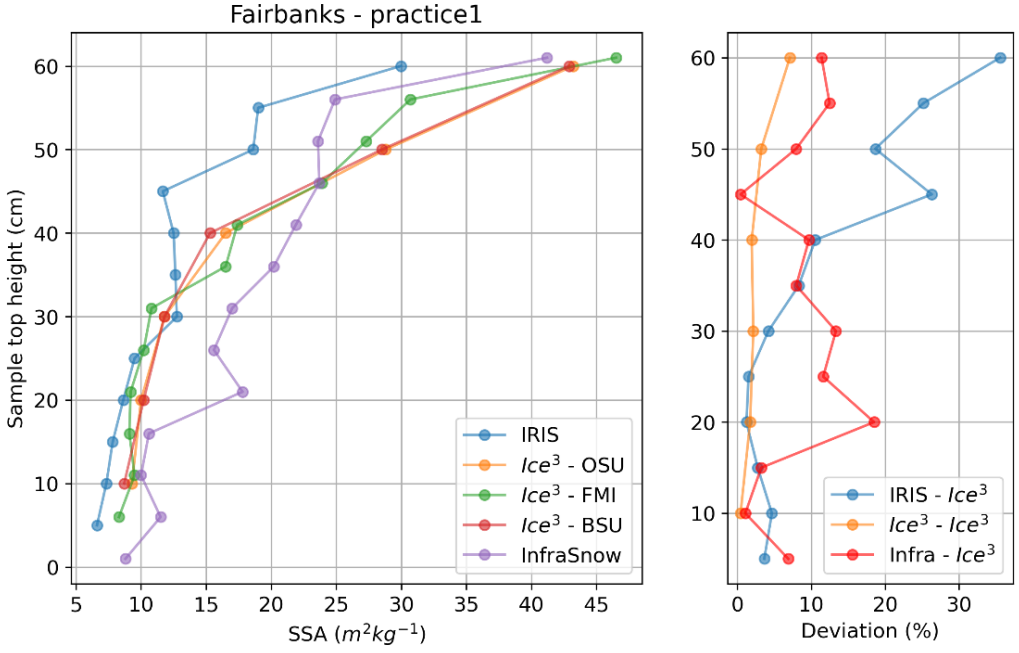


Figure 4. Instrument comparison for the site Practice 1

The measured SSA from the InfraSnow instrument was also compared with the measured SSA from IceCube over multiple pits (n = 8). Figure 5 shows $R^2$ and RMSE values for both the original SSA data (calculated using the default density) and the recalculated SSA data (calculated using measured density).

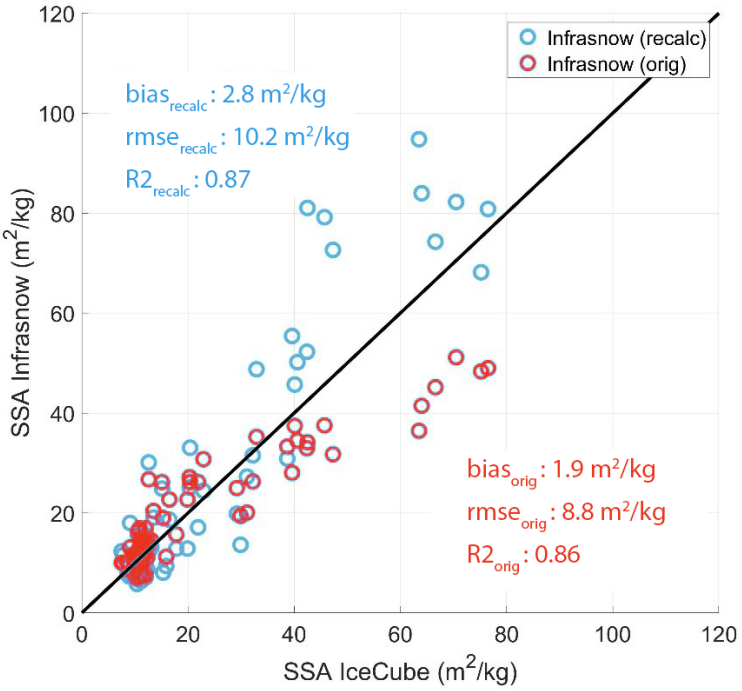


Figure 5. SSA comparison between InfraSnow and IceCube measurements over multiple snow pits.

# 3 VERSION HISTORY

Initial release

# 4 RELATED DATA SETS

SnowEx at NSIDC | Data Sets

SnowEx 2017 Specific Surface Area

SnowEx 2020 Specific Surface Area

# 5 RELATED WEBSITES

SnowEx at NSIDC | Overview

SnowEx at NASA

# 6 ACKNOWLEDGMENTS

The authors acknowledge the contribution of Megan Mason, NASA/Goddard Space Flight Center.

# 7 REFERENCES

Gallet, J.C., F. Domine, C. S. Zender, and G. Picard. 2009. Measurement of the specific surface area of snow using infrared reflectance in an integrating sphere at 1310 and 1550 nm, *The Cryosphere* 3:167-182. https://doi.org/10.5194/tc-3-167-2009

# 8 DOCUMENT INFORMATION

## 8.1 Publication Date

July 2023

## 8.2 Date Last Updated

July 2023