ICESat-2 Cal/Val 2022 L2 CHIR Green Wavelength Lidar Arctic Sea Ice Heights and Bathymetry, Version 1

USER GUIDE

How to Cite These Data

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

Saylam, K., Averett, A., Andrews, J., Kurtz, N. T., & Tilling, R. L. (2026). ICESat-2 Cal/Val 2022 L2 CHIR Green Wavelength Lidar Arctic Sea Ice Heights and Bathymetry (IS2CV22L2HB, Version 1). [Data set]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/1HQSJWJGKWDL [Date Accessed].

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

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Summary

This data set provides Arctic summer sea ice heights and bathymetry with the primary purpose to evaluate the positional accuracies of NASA's ICESat-2 ATLAS measurements. The bathymetric lidar data (green wavelength, 515 nm) were acquired during a July 2022 calibration/validation airborne campaign using a Leica Chiroptera 4X (CHIR) airborne lidar system. Simultaneous topographic lidar data are also available (ICESat-2 Cal/Val 2022 L2 CHIR NIR Lidar Arctic Sea Ice Heights, IS2CV22L2H).

1.2 File Information

1.2.1 Format

The bathymetric lidar data are formatted as compressed lidar point data records, version 1.2 (`.laz`).

NOTE: The `.laz` files must be converted to `.las` to display in ArcGIS Pro.

1.2.2 File Contents

The files contain the attributes described in Table 1.

Table 1. File Attributes

Attribute	Description
`X`	x position (m)
`Y`	y position (m)
`Z`	z position (m)
`Intensity`	The return strength of the laser pulse that generated the lidar point
`ReturnNumber`	An emitted laser pulse can have up to five returns
`NumberOfReturns`	The total number of returns for a given pulse
`ScanDirectionFlag`	The direction the laser scanning mirror was traveling at the time of the output laser pulse. A value of 1 is a positive scan direction, and a value of 0 is a negative scan direction.
`Classification`	Green wavelength lidar classification (0–19). See Appendix A for class definitions.

Attribute	Description
`ScanAngleRank`	Scanning was performed in an elliptic pattern (17 degrees forward and backward, and 20 degrees left and right). At 0 degrees, the laser pulse is directly below the aircraft at nadir. At -20 degrees, the laser pulse is to the left side of the aircraft, while at +20, the laser pulse is to the right side of the aircraft in the direction of flight.
`PointSourceId`	The flight line from which the point was collected.
`GpsTime`	The GPS time stamp at which the laser point was emitted from the aircraft.

1.2.3 Naming Convention

1.2.3.1 Lidar

The files utilize the following naming convention:

`IS2CV22L2HB_HD_[UTM##]_[RGT###]_[code]_[FL#]_[SSS]_[YYYYMMDD]_01.laz`

Examples:

`IS2CV22L2HB_HD_UTM23_RGT453_LB000_FL0_SA_20220721_01.laz`

Table 2. File Naming Convention Variables and Descriptions

Variable	Description
`IS2CV22L2HB`	ICESat-2 Cal/Val 2022 L2 CHIR Green Wavelength Lidar Arctic Sea Ice Heights and Bathymetry
`HD`	Bathymetric lidar (indicates green wavelength data)
`UTM##`	Projection (UTM Zone 16N, UTM Zone 19N, or UTM Zone 23N)
`RGT###`	ICESat-2 reference ground track
`code`	“Cal” = calibration, “IS” = ice sheet; “LB” and “QD” refer to nodes (kml files)
`FL#`	Flight line number (e.g., FL1)
`SSS`	Section number (SA, SA1, SA2, SB, SB1, SB2, SC, SD, SE, SF, SG, or SH)
`YYYYMMDD`	Year, month, and day of data acquisition
`01`	Data set version 1

1.3 Spatial Information

1.3.1 Coverage

Lidar data were collected over the Arctic Ocean around northeastern Canada and northwestern Greenland:

Westernmost longitude: 81.9° W

Easternmost longitude: 41.9° W

Northernmost latitude: 86.1° N

Southernmost latitude: 83.4° N

1.3.2 Resolution

Varies with lidar scanner configuration, aircraft speed, and altitude. Approximately 0.5 pts/m^2.

1.3.3 Geolocation

NAD83 / UTM Zone 16N (EPSG 26916)

NAD83 / UTM Zone 19N (EPSG 26919)

NAD83 / UTM Zone 23N (EPSG 26923)

1.4 Temporal Information

1.4.1 Coverage

The campaign consists of three flight days for data collection:

21 July 2022, 23 July 2022, and 26 July 2022.

1.4.2 Resolution

Varies

2 DATA ACQUISITION AND PROCESSING

2.1 Background

Measuring ocean surface elevations, sea ice topography, and freeboard, as well as characterizing summer sea ice melt ponds with variable depths, has remained challenging using laser altimeters that operate solely in the near-infrared (NIR) wavelength domain. The CHIR system employs a dual-scanner configuration that combines NIR laser (1,064 nm) for topographic measurements and green-wavelength laser (515 nm) for bathymetric applications. Both wavelengths are transmitted simultaneously to enable concurrent surface and subsurface measurements. The scanning mechanisms distribute the laser pulses in an elliptic scan pattern, allowing for efficient spatial sampling of the observed surface and subsurface features.

2.2 Acquisition

An airborne lidar data acquisition campaign was conducted in July 2022 based out of Pituffik Space Base (formerly Thule Air Base), Greenland, through the collaborative effort of NASA, The University of Texas at Austin, and researchers from additional academic and federal institutions. The CHIR system was mounted aboard a Gulfstream V aircraft equipped with two glass viewports, and it was operated concurrently with NASA's Land, Vegetation, and Ice Sensor (LVIS).

The calibration and validation campaign acquired airborne lidar and high-resolution four-band aerial imagery to support evaluating retrievals of Arctic summer sea ice elevations and melt pond characteristics derived from ICESat-2’s ATLAS sensor. Although adverse environmental and operational conditions prevented the completion of all planned survey missions, three survey flights were successfully completed for which CHIR and LVIS data were simultaneously acquired.

During these coincident acquisitions, the dual-wavelength configuration of the CHIR system enabled simultaneous characterization of both surface topography and shallow subsurface features. Discrete NIR laser pulses reflect primarily from solid surfaces and water surfaces, providing precise surface elevation measurements; in contrast, continuous green-wavelength laser penetrates the water column to measure shallow bathymetry. Depths are determined by computing the temporal separation between waveform peaks corresponding to reflections from the water surface and bottom boundary. Each lidar return is georeferenced and recorded with seven fundamental parameters: acquisition time, latitude, longitude, ellipsoidal height, and aircraft orientation parameters (roll, pitch, and yaw).

2.3 Processing

The CHIR swath can be adjusted to account for temporal offsets to enable optimal comparisons with ICESat-2 ATLAS measurements. The *LidarShift* algorithm facilitates spatial alignment between the CHIR and ATLAS beam locations by estimating and correcting for time-dependent displacement, thereby adjusting each lidar point position to compensate for sea ice drift during acquisition. The *LidarShift* algorithm is publicly available at https://github.com/ut-beg/ICESat2LidarShift.

Additional details on the alignment methodology, drift compensation parameters, and preliminary quality comparisons to ATLAS data products can be found in Saylam et al. (2025).

2.4 Quality, Errors, and Limitations

CHIR system calibration was verified using high-precision, multi-channel Global Navigation Satellite System (GNSS) survey measurements established on the runway at Pituffik Space Base. The absolute mean vertical difference for both scanning channels was computed at less than 1 cm. A preliminary comparison against ATL03 strong beam photon elevations over the same calibration surface indicated a similarly small absolute mean vertical difference of < 1 cm.

Concurrent CHIR and LVIS instrument observations produced consistent sea ice heights measurements, further confirming the cross-sensor calibration fidelity. The intercomparison generated a strong goodness-of-fit ($R^2 > 0.98$) and Root Mean Square Error of 0.045 m. Further details on the calibration framework, evaluation procedures, and full validation results are provided in Saylam et al. (2025).

An assessment by Buckley et al. (2026) found that ICESat-2 and CHIR surface heights show strong agreement ($R \geq 0.9$), and freeboard differences are minimal (-0.05 ± 0.12 m to 0.01 ± 0.10 m). Trantow et al. (2026) evaluated melt-pond depth quantile using Chiroptera data to show that the uniform value used in *ATLAS/ICESat-2 L3A Sea Ice Height, Version 7* (ATL07) is near-optimal.

3 VERSION HISTORY

Table 3. Version History Summary

Version	Date	Description of Changes
1.0	Sep 2026	Initial release

4 ACKNOWLEDGMENTS

The authors acknowledge Tom Neumann, Lori Magruder, Michelle Hofton, David Rabine, Marco Bagnardi, Sinead Farrell, Helen Cornejo, and all other sea-ice community researchers involved in the 2022 summer campaign for their science support and contributions. CHIR was leased and provided by Leica Geosystems (Switzerland). Flight operations and associated services were provided through Ellington Field (Houston, Texas) in coordination with NASA, which also supplied mission-critical information supporting the campaign. We also acknowledge Pituffik Space Base staff for their hospitality and NSIDC experts for their careful and sustained efforts in data archiving and distribution.

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5 REFERENCES

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6 DOCUMENT INFORMATION

6.1 Publication Date

September 2026

6.2 Date Last Updated

September 2026

APPENDIX A – DATA CLASSIFICATION

Table A - 1. Green Wavelength Lidar Data Classification*

Class #	Label	Description
0	Water surface 1	NIR + green returns
2	High noise	Returns rejected due to thresholds and deleted
3	Unclassified	Returns rejected due to thresholds and not deleted
5	Water surface 2	Green only returns
6	Shallow	Returns detected at shallow and intermediate surfaces
7	Water bottom	Last return in water column
8	Low noise	Returns neglected due to peak anomaly
9	Ground	First and only return originating from hard surfaces
10	TWE1	Turbid Water Enhancement; deeper returns; high peak
13	Low	Feature detection; last of multiple returns
14	Mid	Feature detection; intermediate layer
15	High	Feature detection; first of multiple returns
17	Submerged	Intermediate returns reflected off sub surface
19	TWE2	Turbid Water Enhancement; deeper returns; low peak

*Note: The classification for this data set is **not** based on ASPRS. Users must manually reclassify to ASPRS, which is used in QGIS and ArcGIS displays.