ICESat-2 Derived Sea Ice Melt Pond Characteristics from the Density-Dimension Algorithm, Version 3

USER GUIDE

How to Cite These Data

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

Herzfeld, U. C., T. Trantow, M. Lawson, H. Han, E. Buckley, and S. L. Farrell (2024). *ICESat-2 Derived Sea Ice Melt Pond Characteristics from the Density-Dimension Algorithm, Version 3*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/LLRQ29WG4MZH [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/IS2MPDDA

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

This data set provides locations and depths of melt ponds in the Multi-Year Arctic Sea Ice Region, calculated from *ATLAS/ICESat-2 L2A Global Geolocated Photon Data, Version 5 (ATL03)* using an autoadaptive algorithm.

1.2 File Information

1.2.1 Format

The data are grouped into 178 multi-file granules, each corresponding to an ATL03 data file. Each granule includes the following files:

- Metadata (`seaice_ponds`)
- ATL03 photon point cloud data (`raw_photon_data`)

A granule may also include any of the following files:

- Weighted photons (`weighted_photons_pass0`)
- Photon signal sets associated with top and bottom surfaces (`ground_estimate_pass_top` and `ground_estimate_pass_bot`)
- Calculated pond characteristics (`pond_chars`)
- Browse file (`GlacierCoverage`)

Data are provided as ASCII (.txt) files, metadata are provided as .log files, and browse files are provided as .png images.

1.2.2 Naming Convention

Data files utilize the following naming convention, as described in Table 1:

`IS2MPDDA_yyyymmdd_tttt_gtxx_v3_[keywords].ext`

Table 1. File Naming Convention Variables and Descriptions

Variable	Description
`IS2MPDDA`	ICESat-2 Derived Sea Ice Melt Pond Characteristics from the Density-Dimension Algorithm data product
`yyyymmdd`	Year, month, and day of data acquisition for the given Reference Ground Track (RGT)

Variable	Description
tttt	Four-digit RGT number; the ICESat-2 mission has 1,387 RGTs, numbered from 0001 to 1387
gtxx	Left/right Ground Track pairs: gt1l, gt1r, gt2l, gt2r, gt3l, or gt3r
v3	Data set version number
keywords	Description of the file contents: raw_photon_data, weighted_photons_pass0, ground_estimate_pass_top, ground_estimate_pass_bot, pond_chars, GlacierCoverage, or seaice_ponds
.ext	File extension: .txt, .png, or .log

Examples:

IS2MPDDA_20200729_0517_gt3l_v3_raw_photon_data.txt

IS2MPDDA_20200729_0517_gt3l_v3_weighted_photons_pass0.txt

IS2MPDDA_20200729_0517_gt3l_v3_ground_estimate_pass_bot.txt

IS2MPDDA_20200729_0517_gt3l_v3_ground_estimate_pass_top.txt

IS2MPDDA_20200729_0517_gt3l_v3_pond_chars.txt

IS2MPDDA_20200729_0517_gt3l_v3_GlacierCoverage.png

IS2MPDDA_20200729_0517_gt3l_v3_seaice_ponds.log

1.2.3 File Contents

Parameters and corresponding details of the data files are listed in Tables 2–5.

Table 2. Parameter Description of **raw_photon_data**

Variable	Description
delta_time_(seconds)	The transmit time of a given photon measured in seconds from the ATLAS Standard Data Product Epoch[1]. Serves as a time stamp for each photon.
longitude_(degrees-east)	Longitude
latitude_(degrees-north)	Latitude
elevation_(meters)	Elevation
along_track_distance_(meters)	Distance along the ICESat-2 ground track with 0 corresponding to the start (first photon) of the granule

Table 3. Parameter Description of **weighted_photons_pass0**

Variable	Description
delta_time_(seconds)	The transmit time of a given photon measured in seconds from the ATLAS Standard Data Product Epoch[1]. Serves as a time stamp for each photon.

longitude_(degrees-east)	Longitude
latitude_(degrees-north)	Latitude
elevation_(meters)	Elevation
along_track_distance_(meters)	Distance along the ICESat-2 ground track with 0 corresponding to the start (first photon) of the granule
density_(non-dimensional)	Density of signal photons

Table 4. Parameter Description of **ground_estimate_pass_top** and **ground_estimate_pass_bot**

Variable	Description
longitude_(degrees-east)	Longitude
latitude_(degrees-north)	Latitude
elevation_(meters)	Elevation
along_track_distance_(meters)	Distance along the ICESat-2 ground track with 0 corresponding to the start (first photon) of the granule
delta_time_(seconds)	The transmit time of a given photon measured in seconds from the ATLAS Standard Data Product Epoch[1]. Serves as a time stamp for each photon.
elevation_standard_deviation_(meters)	Standard deviation of the elevation of the signal photons (post-quantile)
density_mean_(non-dimensional)	Mean density of signal photons (post-quantile)
density_weighted_elevation_standard_deviation_(meters)	Standard deviation of the elevation of the signal photons (post-quantile) weighted by density

Table 5. Parameter Description of **pond_chars**

Variable	Description
start_along_track_distance_(meters)	Along-track distance of the leading edge of the pond
end_along_track_distance_(meters)	Along-track distance of the trailing edge of the pond
pond_width_(meters)	Width of pond. Equivalent to `end along-track distance` minus `start along-track distance`
mean_pond_depth_(meters)	Mean depth of pond
maximum_pond_depth_(meters)	Maximum depth of pond
mean_saturation_(non-dimensional)	Mean saturation value of the pond derived from the `full_sat_fract` variable of ATL03, defined as "the fraction of pulses within the segment determined to be fully saturated".

[1]A description of the time stamps is available in the ATL03 Data Dictionary and User Guide on the ATL03 data set landing page under Documentation.

1.2.4 Browse Files

Some files have .png browse images ("`GlacierCoverage`") that plot the subsetted granule coverage (Figure 1).

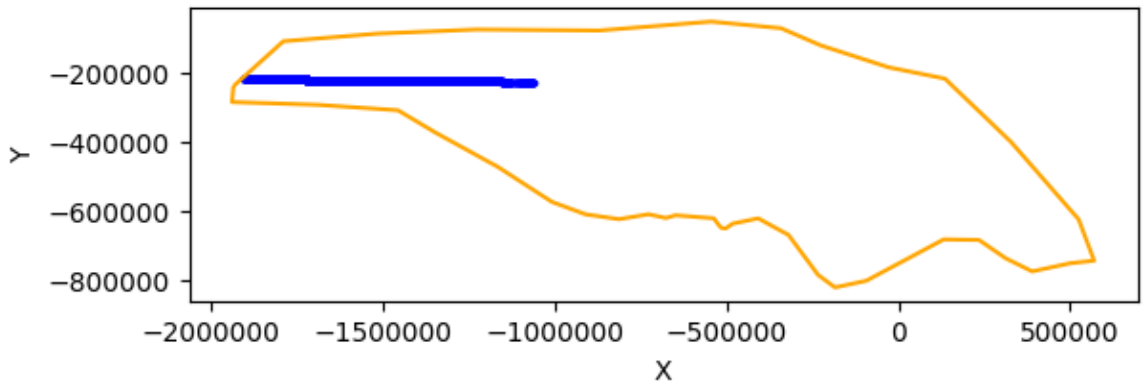

Figure 1. Example browse image showing the subsetted granule coverage.

1.3 Spatial Information

1.3.1 Coverage

The data are located within the Multi-Year Arctic Sea Ice Region:

Northernmost Latitude: 90° N
Southernmost Latitude: 75° N
Easternmost Longitude: 0° E
Westernmost Longitude: 150° W

1.3.2 Resolution

Varies

1.3.3 Geolocation

The following table provides information for geolocating this data set.

Table 6. Geolocation Details

Geographic coordinate system	WGS 84
Projected coordinate system	NSIDC Sea Ice Polar Stereographic North
Longitude of true origin	-45º
Latitude of true origin	70º
Scale factor at longitude of true origin	1
Datum	World Geodetic System 1984 ensemble
Ellipsoid/spheroid	WGS 84
Units	meter
False easting	0
False northing	0
EPSG code	3413
PROJ4 string	+proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs +type=crs
Reference	https://epsg.io/3413

1.4 Temporal Information

1.4.1 Coverage

4 June 2020 to 28 August 2020

1.4.2 Resolution

Varies according to the temporal resolution of the ATL03 data

2 DATA ACQUISITION AND PROCESSING

2.1 Background

Melt ponds and thinning sea ice are important indicators of climate change in the Arctic. This data set applies the Density-Dimension Algorithm (DDA) for bifurcating sea ice reflectors to automatically detect melt ponds in the Multi-Year Arctic Sea Ice Region and measure their depth (uncorrected for the speed of light in water).

2.2 Acquisition and Processing

The algorithm uses geolocated photon point clouds of ATL03 as input data to retrieve two surface heights (pond surface and bottom), as well as estimate melt pond depth and width. The following processing steps are performed:

1. Separate signal and noise at large spatial scales, where the surface of sea ice, sea water, or pond water coincides with the height range of the strongest reflectors.
2. Use radial basis function to calculate density field for noise and signal ranges.
3. Operate autoadaptive threshold function to separate noise and signal photons, thus providing candidates for melt-pond surface or bottom photons.
4. Detect melt ponds using bifurcation algorithm by calculating a vertical histogram of the signal photons, applying a binomial filter to the histogram, finding peaks in the filtered vertical histogram of signal photons, and creating a set of bifurcation and rejoining points.
5. Apply pond-specific surface follower to the surface signal sets to create sets of piecewise linearly interpolated surface and bottom heights.
6. If ponds are detected, apply correction to melt-pond surface heights and calculate pond statistics (pond width, maximal pond depth, average pond depth).

For a complete description of data acquisition and processing, see Herzfeld et al. (2023).

2.3 Quality, Errors, and Limitations

The smallest width of ponds tracked with the ground follower is 15 m for rough surfaces and 30 m for smooth surfaces. The minimal pond depth is 0.5 m due to the pulse width of the ATLAS sensor. Signal saturation, in which more photons are received by the sensor than can be counted, is partly avoided but can lead to false positives, especially in near-nadir central beams (Herzfeld et al., 2023).

2.4 Instrumentation

The ATLAS instrument on the ICESat-2 satellite utilizes a photon-counting lidar and ancillary systems (GPS and star cameras) to measure the round-trip time of photon pulses from ATLAS to Earth and back again and to determine the geodetic latitude and longitude of these signal photon pulses on the Earth's surface. See the NASA ICESat-2 website for more information on the mission and instrumentation.

3 VERSION HISTORY

Table 7. Version History Summary

Version	Release Date	Description of Changes
3	April 2024	Initial release; V3 is based on ATL03 V5

4 RELATED DATA SETS

ATLAS/ICESat-2 L2A Global Geolocated Photon Data (ATL03)

5 ACKNOWLEDGMENTS

Adam Hayes, as well as ICESat-2 SIPS for generating ATL03

6 REFERENCES

Herzfeld, U. C., Trantow, T. M., Han, H., Buckley, E., Farrell, S. L., and Lawson, M. (2023). Automated Detection and Depth Determination of Melt Ponds on Sea Ice in ICESat-2 ATLAS Data—The Density-Dimension Algorithm for Bifurcating Sea-Ice Reflectors (DDA-Bifurcate-Seaice). *IEEE Transactions on Geoscience and Remote Sensing*, 61. https://doi.org/10.1109/TGRS.2023.3268073

7 DOCUMENT INFORMATION

7.1 Publication Date

April 2024

7.2 Date Last Updated

April 2024