ICESat L4 Seasonal Gridded Sea Ice Thickness, Version 1

USER GUIDE

How to Cite These Data

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

Petty, A. and N. Kurtz. 2023. *ICESat L4 Seasonal Gridded Sea Ice Thickness, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/1S5M59IQ0OK3. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/ISSITGR4

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

This data set reports seasonal, gridded winter sea ice thickness across the Arctic Ocean. Sea ice thickness is estimated using ICESat/GLAS L3A Sea Ice Freeboard data and NASA Eulerian Snow On Sea Ice Model (NESOSIM) Version 1.1 snow loading.

1.2 File Information

1.2.1 Format

Data are provided as NetCDF-4 (V4.4.1) formatted files.

1.2.2 File Contents

All parameters and corresponding details of this data set are listed in **Error! Reference source not found.**.

Table 1. Parameter Details

Name	Long Name	Units
campaign_dates	campaign dates	N/A
crs	NSIDC Sea Ice Polar Stereographic North	N/A
ice_density	Bulk sea ice density	kg m^{-3}
ice_thickness	Mean ICESat/NESOSIM sea ice thickness	m
ice_thickness_int	Mean ICESat/NESOSIM sea ice thickness interpolated	m
ice_thickness_unc	Mean systematic sea ice thickness uncertainty	m
ice_type	Mean OSI SAF ice type[1]	Flag: 0 = first-year ice; 1 = multi-year ice
latitude	latitude	degrees N
longitude	longitude	degrees E
mean_day_of_campaign_period	Mean day of campaign period	day
num_shots	Number of shots	count
region_mask	NSIDC v2 Northern Hemisphere region mask	N/A
sea_ice_conc	Mean CDR ice concentration data	fraction

Name	Long Name	Units
snow_density	Mean snow density from NESOSIM	kg m^{-3}
snow_depth	Mean snow depth from redistributed NESOSIM data	m
snow_depth_int	Mean interpolated snow depth from redistributed NESOSIM data	m
total_freeboard	Mean total freeboard from ICESat	m
total_freeboard_int	Mean interpolated total freeboard from ICESat	m
x	center values of projection grid in x direction	m
y	center values of projection grid in y direction	m

[1] OSI SAF = Ocean and Sea Ice Satellite Application Facility

1.2.3 Naming Convention

Data files utilize the following naming convention:

```
ISSITGR4-[HH]_[FMxx]_[rrr].nc
```

The following table describes the file naming convention variables:

Table 2. File Naming Convention Variables and Descriptions

Variable	Description
ISSITGR4	ICESat L4 Seasonal Gridded Sea Ice Thickness data
HH	Hemisphere code. Northern Hemisphere = 01, Southern Hemisphere = 02 (not currently available)
FMxx	Campaign identifier. FM = February/March, ON = October/November, and MA = March/April campaign periods; xx = 2-digit year (e.g., 03 = 2003)
rrr	3-digit version number of this sea ice thickness data product

Example:

```
ISSITGR4-01_FM08_001.nc
```

1.2.4 Browse File

A `.png` browse file is provided for each granule containing map representations of sea ice thickness, thickness uncertainty, freeboard (ICESat/GLAS), snow depth (NESOSIM v1.1), snow density (NESOSIM v1.1), ice type (OSI SAF), mean day of month, number of segments, interpolated sea ice thickness, interpolated freeboard (ICESat/GLAS), interpolated snow depth

(NESOSIM v1.1), and CDR sea ice concentration. **Error! Reference source not found.** shows an example browse file.

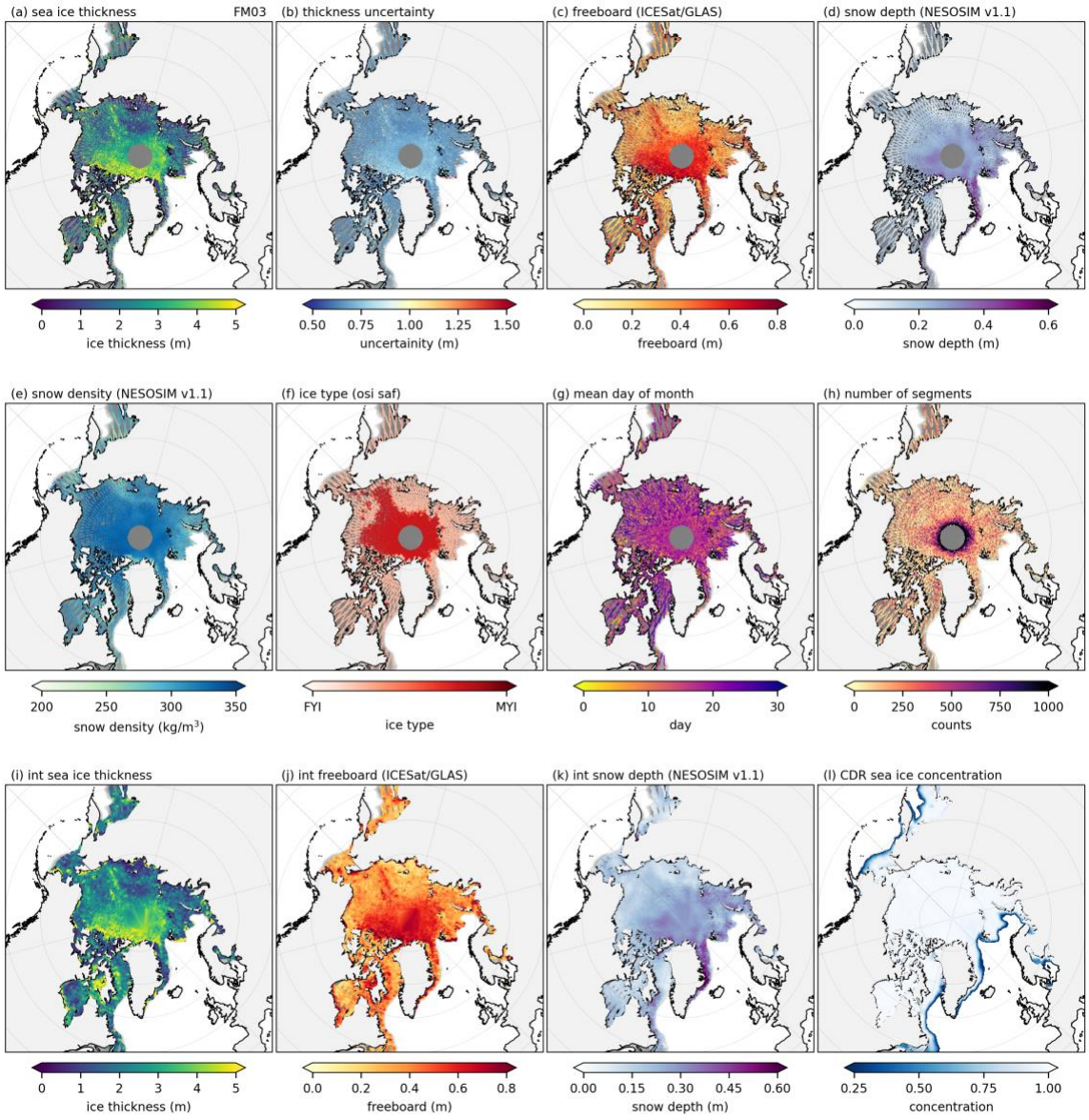

Figure 1. Example browse file.

1.3 Spatial Information

1.3.1 Coverage

Data span the Arctic Ocean and its peripheral seas south of 86° N (northern limit of ICESat data collection).

1.3.2 Resolution

Nominally 25 km x 25 km but varies across the grid due to polar stereographic projection.

1.3.3 Geolocation

The following table provides information for geolocating this data set:

Table 3. Geolocation Details

Geographic coordinate system	Unspecified datum based upon the Hughes 1980 ellipsoid
Projected coordinate system	NSIDC Sea Ice Polar Stereographic North
Central meridian	-45°
Latitude of origin	70°
Scale factor at longitude of true origin	1
Datum	Not specified (based on Hughes 1980 ellipsoid)
Ellipsoid/spheroid	Hughes 1980
Units	meter
False easting	0
False northing	0
EPSG code	3411
PROJ4 string	+proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +x_0=0 +y_0=0 +a=6378273 +b=6356889.449 +units=m +no_defs +type=crs
Reference	http://epsg.io/3411

1.4 Temporal Information

1.4.1 Coverage

The ICESat mission spanned February 2003 to October 2009. Due to instrument degradation issues, data collection was limited to sporadic campaign periods. This product provides data for the following campaigns:

February/March (FM)

- 20 February to 29 March 2003 (FM03)
- 17 February to 21 March 2004 (FM04)
- 17 February to 24 March 2005 (FM05)
- 22 February to 27 March 2006 (FM06)

- 17 February to 21 March 2008 (FM08)

October/November (ON)

- 1 October to 18 November 2003 (ON03)
- 3 October to 8 November 2004 (ON04)
- 21 October to 24 November (ON05)
- 25 October to 27 November 2006 (ON06)
- 2 October to 5 November 2007 (ON07)

March/April (MA)

- 12 March to 14 April 2007 (MA07)

1.4.2 Resolution

Seasonal (campaign-period) averages

2 DATA ACQUISITION AND PROCESSING

2.1 Background

Reliable estimates of sea ice thickness are needed to understand ongoing changes to the polar climate. This data set reports seasonal gridded sea ice thickness across the Arctic Ocean using ICESat/GLAS L3A Sea Ice Freeboard data and NASA Eulerian Snow On Sea Ice Model (NESOSIM) Version 1.1 snow loading.

These data are a historical complement to the ICESat-2 L4 Monthly Gridded Sea Ice Thickness data set, which is derived from ATLAS/ICESat-2 L3A Sea Ice Freeboard data available since 2018.

2.2 Instrumentation

The Geoscience Laser Altimeter System (GLAS) instrument on the Ice, Cloud, and land Elevation Satellite (ICESat) combines a precise surface lidar with a dual wavelength cloud and aerosol lidar. The laser light pulse measurements provide global data on polar ice sheet elevation, land topography, vegetation cover, sea ice thickness, and the vertical distributions of clouds and aerosols.

GLAS has a 1064 nm laser channel for measuring the altimetry and echo pulse shape of thick clouds. A 532 nm channel measures the vertical extents of thin clouds and the planetary boundary layer. These data have a footprint of ~70 m, an along-track spacing of 170 m, and coverage up to 86° N.

Please refer to the official ICESat/GLAS website at NASA GSFC for details of the ICESat platform and GLAS instrument.

2.3 Processing

The underlying ICESat/GLAS Sea Ice Freeboard data are from the work by Kurtz et al. (2011), following the methodology of Kwok et al. (2007). The freeboard data were converted into sea ice thickness using NESOSIM v1.1 snow loading and a piecewise redistribution scheme, as in the ICESat-2 L4 Along-Track Sea Ice Thickness (IS2SITDAT4) data product (Petty et al., 2020; Petty et al., 2023). The main processing steps are as follows:

- Read in ICESat freeboard data for a given day and set all negative values to zero (as in ATL10)
- Read in coincident NESOSIM v1.1 snow loading data for the given day
- Redistribute coarse (100 km) NESOSIM snow depth input to higher resolution ICESat freeboard measurements using piecewise relationship obtained from Operation IceBridge data
- Calculate sea ice thickness assuming hydrostatic equilibrium
- Calculate random and systematic uncertainties (see Section 2.4)
- Bin seasonal sea ice thickness to 25 km x 25 km NSIDC polar stereographic grid for all data within a given campaign period
- Record additional information, such as the campaign period day

2.4 Quality, Errors, and Limitations

For details on the ICESat freeboard data acquisition, processing, quality, errors, limitations, and instrumentation, see Kwok et al. (2007) and Kurtz et al. (2011). For details on the thickness data processing and uncertainty estimates, see Petty et al. (2020).

The present data set has some key differences from the ICESat thickness data presented in Petty et al. (2020):

1. The estimated systematic freeboard uncertainty is calculated as the greater of 4 cm or the measured ICESat freeboard.
2. The estimated systematic snow depth uncertainty is calculated as the greater of 8 cm or the snow depth in cases where it is less than the measured ICESat freeboard.
3. The systematic snow density uncertainty is set to 30 kg m^{-3}, and the systematic ice density uncertainty is set to 10 kg m^{-3}.

3 RELATED DATA SETS

ICESat-2 L4 Monthly Gridded Sea Ice Thickness (IS2SITMOGR4)

ICESat-2 L4 Along-Track Sea Ice Thickness (IS2SITDAT4)

ATLAS/ICESat-2 L3A Sea Ice Freeboard (ATL10)

4 RELATED WEBSITES

Polar Stereographic Data | NSIDC Polar Stereographic Grid Definitions

ICESat/GLAS at NASA

5 REFERENCES

Kurtz, N. T., Markus, T., Farrell, S. L., Worthen, D. L., and Boisvert, L. N. (2011). Observations of recent Arctic sea ice volume loss and its impact on ocean-atmosphere energy exchange and ice production. *Journal of Geophysical Research*, *116*, C04015. https://doi.org/10.1029/2010JC006235

Kwok, R., Cunningham, G. F., Zwally, H. J., & Yi, D. (2007). Ice, Cloud, and land Elevation Satellite (ICESat) over Arctic sea ice: Retrieval of freeboard. *Journal of Geophysical Research*, *112*, C12013. https://doi.org/10.1029/2006JC003978

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Petty, A. A., Kurtz, N. T., Kwok, R., Markus, T., & Neumann, T. A. (2020). Winter Arctic sea ice thickness from ICESat-2 freeboards. *Journal of Geophysical Research: Oceans*, *125*, e2019JC015764. https://dx.doi.org/10.1029/2019JC015764

6 DOCUMENT INFORMATION

6.1 Publication Date

May 2023

6.2 Date Last Updated

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