CryoSat-2 Level-4 Sea Ice Elevation, Freeboard, and Thickness, Version 1

USER GUIDE

How to Cite These Data

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

Kurtz, N. and J. Harbeck. 2017. *CryoSat-2 Level-4 Sea Ice Elevation, Freeboard, and Thickness, Version 1.* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/96JO0KIFDAS8. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/RDEFT4

National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

This data set, which contains estimates of Arctic sea ice freeboard, was developed using a new method to retrieve sea ice freeboard from CryoSat-2 data. The results are compared to a threshold-tracking method and to independent freeboard observations from airborne data (Kurtz et al., 2014).

NOTE: This data set has an associated Quick Look counterpart: CryoSat-2 Sea Ice Freeboard, Thickness, and Snow Depth Quick Look.

1.1 Format

The data files are in netCDF format (.nc). Each data file is paired with an associated XML file (.xml), which contains additional metadata. In addition, sea ice thickness plots in PNG (.png) format are provided for each data file.

1.2 File Naming Convention

Example file name:
RDEFT4_20170103.nc

Files are named according to the following convention, which is described in more detail in Table 1:
RDEFT4_YYYYMMDD.xxx

Table 1. File Naming Convention

Variable	Description
`RDEFT4`	Data set ID
`YYYYMMDD`	4-digit year, 2-digit month, and 2-digit day Note: each file contains a 30-day average. The file name date is the end date of that 30-day period.
`.xxx`	Indicates file type: netCDF (`.nc`) data file, XML (`.xml`) metadata file, or PNG (`.png`) image file

1.3 Spatial Coverage

The spatial coverage for this data set currently includes the Arctic Ocean, as noted by the spatial extents below:

Southernmost latitude: 55° N

Northernmost latitude: 90° N

Westernmost longitude: 180° W

Easternmost longitude: 180° E

1.3.1 Spatial Resolution

25 km by 25 km

1.3.2 Projection and Grid Description

Data are gridded to the Polar Stereographic SSM/I Grid and referenced to the WGS-84 ellipsoid, with each grid point center latitude and longitude provided with the data.

1.4 Temporal Coverage

20 September 2010 to ongoing (with a temporal lag of approximately 1.5 months between the most recent file and the present date). The data collection period spans the time frame from 20 September of one year to 15 May of the next year (e.g., 20 September 2011 to 15 May 2012). This period excludes the summer months when data are not reliable for measuring ice thickness due to retrieval issues caused by melt.

Beginning with the 2020–2021 sea ice season, the start and end dates for the full nominal 30-day time period of each file are available as separate global attributes.

Note: A gap in data exists from 08:20 on 16 December 2021 to 17:00 on 20 December 2021.

1.4.1 Temporal Resolution

The files are monthly (i.e., 30-day) averages, provided on a daily basis. For example, the file `RDEFT4_20170420.nc` contains data averaged between 21 March 2017 to 20 April 2017. Only files are provided that contain a minimum of 10 days of CryoSat-2 data.

Note: The data directory's date corresponds to the start date of the file contained within, whereas the file name contains the data end date. Thus, as each data file spans one month, the dated directory precedes the file name by one month.

1.5 Parameter or Variable

1.5.1 Parameter Description

The gridded data file contains fields as described in Table 2.

Table 2. Data Parameter Description

Parameter	Description	Units
sea_ice_thickness	Sea ice thickness	Meters
snow_depth	Snow depth	Meters
snow_density	Snow density	Kg/Meters^3
lat	Latitude of grid point center	Degrees
lon	Longitude of grid point center	Degrees
freeboard	Ice freeboard	Meters
roughness	Ice surface roughness	Meters
ice_con	Sea ice concentration	Percent

1.5.2 Sample Data Record

Figure 1 shows sea ice thickness values from the file RDEFT4_20170420.nc as displayed in HDFView.

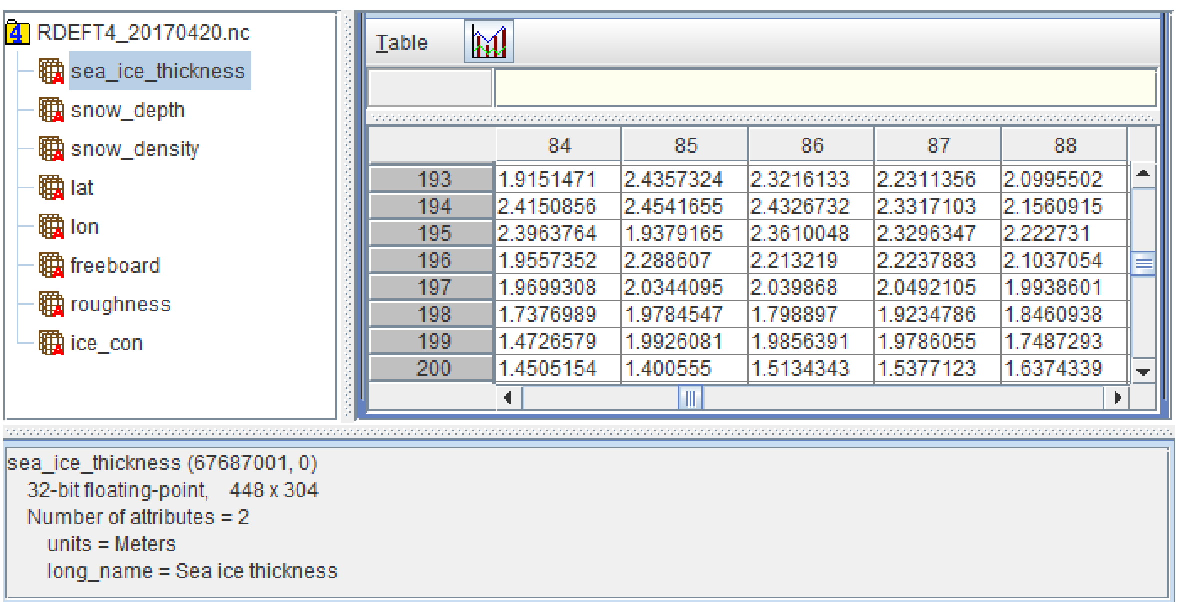

Figure 1. HDFView can be used to view the data files.

The sea ice thickness plot is illustrated in Figure 2.

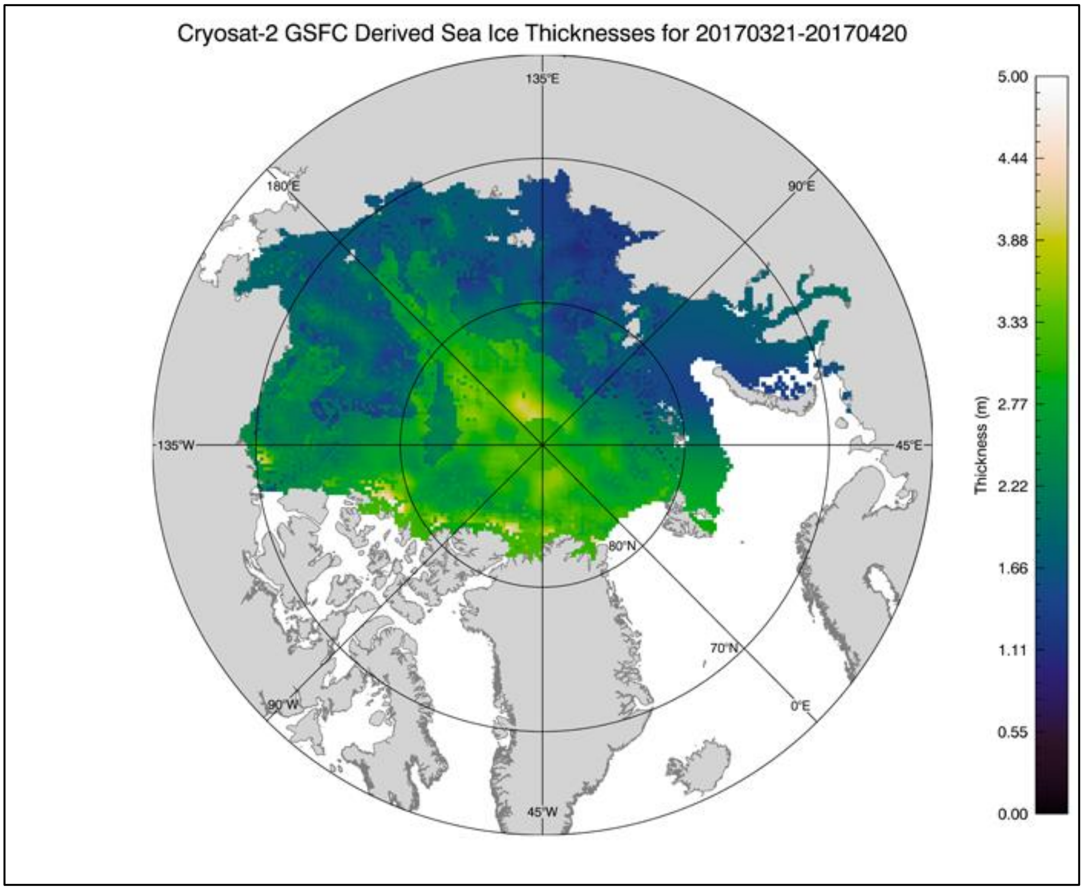

Figure 2. Sea Ice Thickness Plot RDEFT4_20170420_thickness_plot.png

2 SOFTWARE AND TOOLS

The data files can be opened by software that supports the netCDF format, such as HDFView and Panoply.

3 QUALITY ASSESSMENT

Quality assessment was done through comparison with NASA's Operation IceBridge data.

4 DATA ACQUISITION AND PROCESSING

4.1 Data Acquisition Methods

Primary data sources are ESA's CryoSat-2 Level-1B SAR and SARIn data.

Geophysical corrections for the wet and dry tropospheric delay time, ionospheric delay, oscillator drift, inverse barometer effect, ocean equilibrium tide, long period ocean tide, load tide, solid earth tide, and pole tide have been applied from the ESA CryoSat-2 L1B data products.

Gridded CryoSat-2 data is generated from the processed along-track waveform product CryoSat-2 Level-1B Waveforms, Sea Ice Elevation, and Surface Roughness.

Sea ice concentration is determined from the NSIDC Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations product.

Sea ice type is determined from the OSI-403-b: Sea Ice Type Maps on 10 km Polar Stereographic Grid product.

4.2 Derivation Techniques and Algorithms

Sea ice elevation is determined from CryoSat-2 using a physical model to determine the best fit to each CryoSat-2 waveform. The fitted waveform is used to determine the retracking correction for surface elevation retrieval as well as the surface roughness within the footprint. Sea ice freeboard is then determined by subtracting the gridded sea surface elevation from the gridded sea ice floe elevation and applying the radar propagation speed correction where snow depth data is available.

Snow depth is constructed from a modified Warren et al. (1999) climatology of snow depth on sea ice with a value of half the climatology applied to first year ice.

Snow density is likewise based on the Warren et al. (1999) climatology.

Sea ice thickness is retrieved assuming hydrostatic balance and nominal densities of snow, ice, and water. Retrievals are only done when the sea ice concentration is at least 70%.

Sea ice concentration is from the near real time DMSP SSMI_S daily polar gridded data set with the pole hole set to a constant value of 100%.

Ice surface roughness is derived using the physical model to fit the CryoSat-2 waveform. The surface roughness is the standard deviation of the ice surface elevation with an assumed Gaussian height distribution.

4.2.1 Processing Steps

Sea ice freeboard is determined from CryoSat-2 using a physical model to determine the best fit to each CryoSat-2 waveform.

The fitted waveform is used to determine the retracking correction and also allows determination of the surface roughness within the footprint.

For sea ice floes, the dominant backscattering layer is taken to be from the sea ice surface and thus sea ice freeboard is here defined as the height of the ice layer above the local sea surface.

The DTU10 Ocean wide Mean Sea Surface (DTU10 MSS) is subtracted from each elevation measurement and the elevations from leads and sea ice floes are placed onto a 25 km polar stereographic grid.

Sea ice freeboard is then determined by subtracting the gridded sea surface elevation from the gridded sea ice floe elevation and applying the radar propagation speed correction where snow depth data are available.

Sea ice freeboard is then determined by subtracting the gridded sea surface elevation from the gridded sea ice floe elevation and applying a freeboard correction for the lower radar propagation speed in snow, following the method of Kurtz et al. (2014) (Equations 16 and 17). The freeboard correction is only applied where snow depth data are available. It is set to 0 when snow depth data are not available, i.e., outside of the central Arctic region.

4.2.2 Error Sources

Errors in the retrieval of sea ice thickness can be written as follows:

$$\sigma_{h_i}^2 = \sigma_{fb}^2\left(\frac{\partial h_i}{\partial fb}\right)^2 + \sigma_{h_s}^2\left(\frac{\partial h_i}{\partial h_s}\right)^2 + \sigma_{\rho_s}^2\left(\frac{\partial h_i}{\partial \rho_s}\right)^2 + \sigma_{\rho_i}^2\left(\frac{\partial h_i}{\partial \rho_i}\right)^2 \sigma_{\rho_w}^2\left(\frac{\partial h_i}{\partial \rho_w}\right)^2$$

and

$$h_i = \frac{\rho_w}{\rho_w - \rho_i}\left(fb + h_s\left(1 - \frac{c_{snow}}{c}\right)\right) + \frac{\rho_s}{\rho_w - \rho_i}h_s$$

Where h_i is the ice thickness, f_b the freeboard of the sea ice, ρ_w, ρ_i, and ρ_s the densities of water, ice, and snow, c the speed of light in vacuum, and c_{snow} the speed of light in snow (which is a function of snow density).

The error sources are thus as follows:

- Freeboard error from the associated surface elevation retrieval error, an estimate through comparison with IceBridge, is 0.065 m for a 25 km grid cell.
- Snow depth error is estimated to be between 0.04 to 0.06 m from the interannual variability of snow depth as reported in Table 1 of Warren et al. (1999).

- Density errors for snow, ice, and water: density errors for water are negligible and estimated from previous studies to be 100 kg/m3 for snow and 10 kg/m3 for ice.
- Interpolation errors occur due to filling of gaps where no observations are available. These vary depending on the distance used to interpolate between points.

4.3 Sensor or Instrument Description

The ESA SIRAL instrument, the primary instrument on board CryoSat-2, is a radar altimeter which measures the surface elevation through knowledge of the spacecraft position and the time delay between the emission of the radar pulse and subsequent reflection from the surface.

The SIRAL instrument operates at a center frequency of 13.575 GHz and has a receive bandwidth of 320 MHz. The SAR processing of CryoSat-2 utilizes an unfocused aperture synthesis technique which utilizes Doppler beam formation to reduce the footprint size in comparison with a beam-limited altimeter. The effective footprint size after postprocessing is pulse-limited at 1650 m in the across-track direction and pulse-Doppler-limited to be 380 m in the along-track direction. The power-detected echoes contain 128 range bins in SAR mode and 512 range bins in SARIn mode (Kurtz et al., 2014). The SAR mode is typically operated over sea-ice areas as well as ocean basins and coastal zones, whereas the SARIn mode is usually employed for the steep slopes of ice sheet margins, over small ice caps, and over mountain glacier regions.

5 REFERENCES AND RELATED PUBLICATIONS

Kurtz, N. T., Galin, N., & Studinger, M. (2014). An improved CryoSat-2 sea ice freeboard retrieval algorithm through the use of waveform fitting. The Cryosphere, 8(4), 1217–1237. https://doi.org/10.5194/tc-8-1217-2014

Warren, S. G., Rigor, I. G., Untersteiner, N., Radionov, V. F., Bryazgin, N. N., Aleksandrov, Y. I., & Colony, R. (1999). Snow Depth on Arctic Sea Ice. Journal of Climate, 12(6), 1814–1829. https://doi.org/10.1175/1520-0442(1999)012<1814:sdoasi>2.0.co;2

5.1 Related Data Collections

Ocean and Sea Ice SAF Ice Types

5.2 Related Websites

IceBridge product web page at NSIDC

IceBridge web page at NASA

NASA Cryosphere Science Research Portal

6 CONTACTS AND ACKNOWLEDGMENTS

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Acknowledgments:

The data providers acknowledge support from NASA's Cryospheric Sciences program from grant NNH12ZDA001N and also thank the European Space Agency for processing and providing CryoSat-2 data.

7 DOCUMENT INFORMATION

7.1 Publication Date

21 August 2017

7.2 Date Last Updated

17 November 2022