CryoSat-2 Level-1B Waveforms, Sea Ice Elevation, and Surface Roughness, 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. 2018. *CryoSat-2 Level-1B Waveforms, Sea Ice Elevation, and Surface Roughness, Version 1.* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/5SZA7GSQI0YT. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/RDWES1B

National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

This data set contains surface elevations from retracked CryoSat-2 waveforms, geophysical corrections, as well as model fitting parameters used to retrack the surface elevation. Retracking is the process of selecting the point on the return radar waveform that corresponds to the mean scattering surface. Primary data sources are ESA's CryoSat-2 Level-1B Synthetic Aperture Radar (SAR) and SAR Interferometric (SARIn) data.

This data set provides information on Arctic sea ice thickness which is a key parameter for understanding changes in the climate. The data are needed for a variety of purposes ranging from model validation and initialization, data assimilation efforts, seasonal sea ice forecasting, and development of new retrieval methods.

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.

1.2 File Naming Convention

This section explains the file naming convention used for this product with an example.

Example File Names:

RDWES1B_CS_LTA__SIR_SIN_1B_20111120T235738_20111120T235905_C001.nc
RDWES1B_CS_OFFL_SIR_SAR_1B_20180102T235343_20180102T235802_C001.nc
RDWES1B_MM_CCCC_TTTTTTTTTT_yyyymmddThhmmss_YYYYMMDDTHHMMSS_Cvvv.nc

Refer to Table 1 for the valid values for the file name variables listed above.

Table 1. File Naming Convention

Variable	Description
RDWES1B	Data set ID
MM	The mission identifier. CS = CryoSat (ESA-introduced variable)
CCCC	File class, e.g.: OFFL = Off-line Systematic Processing (ESA-introduced variable) LTA_ = Long Term Archive
TTTTTTTTTT	File type, e.g.: SIR_SAR_1B: SIRAL SAR mode Level-1B SIR_SIN_1B: SIRAL SIN mode Level-1B

Variable	Description
`yyyymmddThhmmss`	Start time window as extracted from job order (ESA-introduced variable)
`YYYYMMDDTHHMMSS`	Stop time window as extracted from job order (ESA-introduced variable)
`Cvvv`	Data reprocessing release C, followed by version number (ESA-introduced variable)
`.xxx`	File format: netCDF data file (`.nc`) XML metadata file (`.xml`)

1.3 Spatial Coverage

Spatial coverage for the NASA GSFC CryoSat-2 sea ice product currently corresponds to the sea ice-covered areas of the Arctic Ocean.

Southernmost Latitude: 55° N
Northernmost Latitude: 90° N
Westernmost Longitude: 180° W
Easternmost Longitude: 180° E

1.3.1 Spatial Resolution

Satellite along-track swath; footprint size: 380 m along-track by 1650 m cross-track

1.3.2 Projection and Grid Description

Geographic coordinates (latitude and longitude)

1.4 Temporal Coverage

15 September 2010 to ongoing (with a temporal lag of approximately one month between the most recent file and the present date). The data collection period spans the time frame from 15 September of one year to 15 May of the next year (e.g., 15 September 2010 to 15 May 2011). 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, Cryosat-2 files that span midnight are broken up and placed into their respective days.

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

Multiple footprints every second, with each file a portion of a satellite swath.

There are between 1 and 130 files per day. Each data file covers a range of time from 1 second to greater than 2300 seconds, with an average length of ~175 seconds.

1.5 Parameter or Variable

Scientific variables included in this data set are listed in Table 2 with the Parameter Origin NASA Kurtz or ESA.

1.5.1 Parameter Description

The data file contains fields as described in Table 2.

Table 2. Data Parameter Description

Parameter	Description	Units	Parameter Origin
lat	Latitude	Degrees	ESA
lon	Longitude	Degrees	ESA
elev	Elevation at center of range window	Meters	ESA
retrack_elev	Elevation retracking correction	Meters	NASA Kurtz
roughness	Surface roughness	Meters	NASA Kurtz
alpha	Angular backscattering efficiency	Dimensionless	NASA Kurtz
norm_res	Error of fit	Dimensionless	NASA Kurtz
peakiness	Pulse Peakiness	Dimensionless	NASA Kurtz
stack_sd	Stack standard deviation	Dimensionless	ESA
geophys_corr	Sum of geophysical corrections	Meters	ESA
sat_alt	Satellite Altitude	Meters	ESA
pitch	Pitch	Microradians	ESA
roll	Roll	Microradians	ESA
day	Days since January 1st, 2000	Day	ESA
sec	Seconds since start of day	Seconds	ESA
i	Row index within Cryosat file	Index	ESA
j	Column index within Cryosat file	Index	ESA
amp_fit	Amplitude fit parameter	Dimensionless	NASA Kurtz
time_shift	Time shift	Nanoseconds	NASA Kurtz
wf_start_bin	Beginning index of waveform subset	Index	NASA Kurtz
wf_end_bin	Final index of waveform subset	Index	NASA Kurtz

Parameter	Description	Units	Parameter Origin
`phase`	Phase	Microradians	ESA

Elevation (elev)

Elevation at the center of range window with the geophysical corrections field and oscillator drift delay added in. This parameter is referenced to the WGS-84 ellipsoid. Note that a correction for the lower propagation speed in snow is not applied to these data.

Elevation retracking correction (retrack_elev)

Waveform-fitting method-based retracking correction for the elevation field. This field must be added to the elev field to calculate the final retracked elevation (sea ice elevation).

Surface roughness (roughness)

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.

Sum of geophysical corrections (geophys_corr)

Geophysical corrections for the wet and dry tropospheric delay time, ionospheric delay, dynamic atmospheric correction, 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.

Retracking model fitting parameters (roughness, alpha, amp_fit, time_shift)

These parameters include the following variables to recreate the model waveform fit: roughness, alpha, amp_fit, and time_shift. The model which uses these parameters is described in Kurtz et al. (2014).

Error of fit (norm_res)

Defined as the sum of the squared difference of the normalized Cryosat-2 waveform and the model waveform fit.

1.5.2 Sample Data Record

Figure 1 shows elevation (elev) from the file RDWES1B_CS_LTA__SIR_SAR_1B_20100915T003553_20100915T004134_C001.nc:

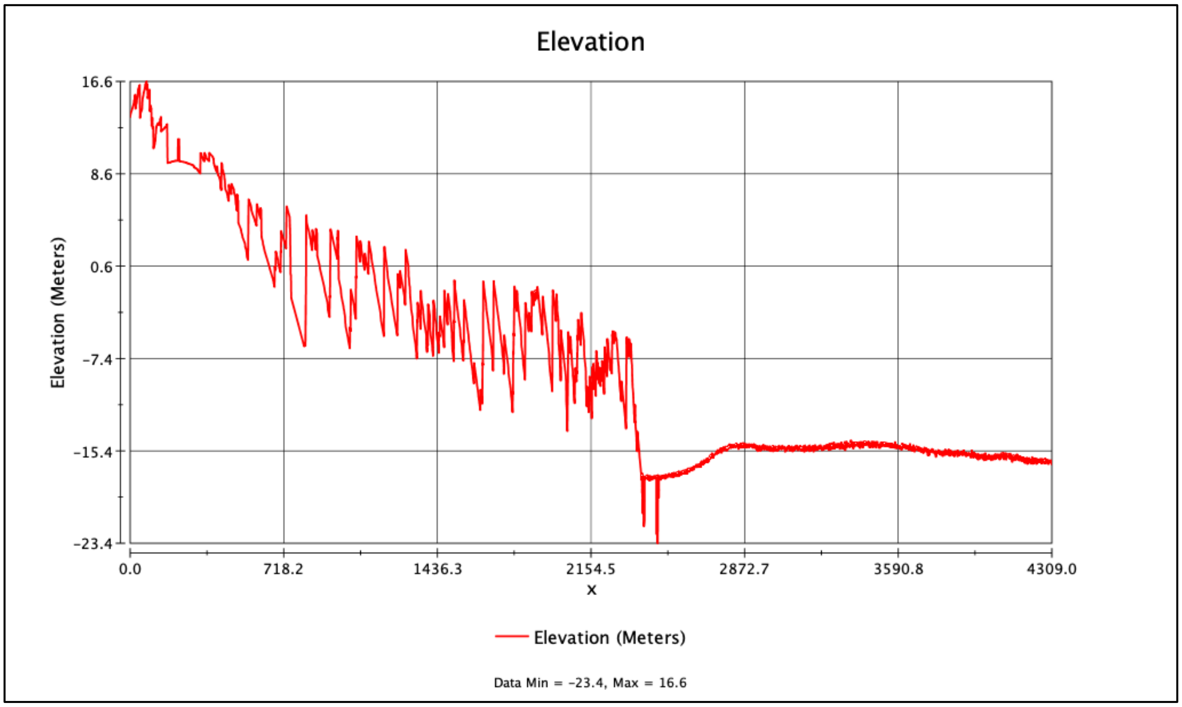

Figure 1. Sample elevation from the file RDWES1B_CS_LTA__SIR_SAR_1B_20100915T003553_20100915T004134_C001.nc

2 SOFTWARE AND TOOLS

The data files can be opened by software that supports the HDF5 and netCDF formats, such as HDFView and Panoply.

3 QUALITY ASSESSMENT

Comparison of retrieved freeboards from CryoSat-2 with ATM airborne laser scanner data from Operation IceBridge suggest an uncertainty of 4-9 cm (Kurtz et al., 2014). A retracked elevation bias of ~20 cm has also been found in comparison to airborne laser scanner data from Operation IceBridge. This is anticipated to be corrected in a future version and does not affect the retrieval of sea ice freeboard, which is a relative measurement.

The norm_res parameter provides one measure of the elevation retrieval quality. This parameter is the sum of the squared difference between the normalized CryoSat-2 waveform and the modeled waveform fit. A lower norm_res indicates a better goodness of fit, and values higher than 0.5 are not used in the retrieval of freeboard in the *CryoSat-2 Level-4 Sea Ice Elevation, Freeboard, and Thickness* product.

4 DATA ACQUISITION AND PROCESSING

4.1 Derivation Techniques and Algorithms

4.1.1 Processing Steps

Surface elevation and roughness are retrieved from individual CryoSat-2 waveforms by fitting a model waveform to the data. First, a look-up table for the CryoSat-2 impulse response convolved with the transmit pulse is produced as described in Kurtz et al. (2014) and placed on a regular grid. Each CryoSat-2 waveform is then sub-sampled to 128 range bins around the expected location of the surface return, with the start and end points of the waveform location provided in the wf_start_bin and wf_end_bin fields, and the waveform power is normalized to have a maximum value equal to 1. The waveforms are separated into expected lead returns and floe returns using the pulse peakiness and stack standard deviation parameters. Initial guesses for the model fit parameters and bounds are produced. The specification for the initial guesses and bounds are described in Kurtz et al. (2014), who used a 50% threshold tracker. However, the initial guess for the echo time shift of sea ice leads is now derived using a 70% threshold tracker. Once initial guesses and bounds are specified, the waveform fitting procedure is applied using the MATLAB lsqcurvefit function. If the waveform fit has an initial poor fit (defined as a norm_res value greater than 0.3), then an iteration on the fitting is done using a range of values for the initial guess and bounds of the alpha parameter. If a lower value of norm_res is found in the iteration, then it is used in the retrieval process. The waveform fitting process produces the roughness, alpha, amp_fit, and time_shift parameters. The time_shift parameter is then converted into a range bin value and elevation retracking correction by finding the difference with the center of the range window.

4.1.2 Error Sources

The primary error source in the data comes from unmodeled physical parameters including backscatter from the snow surface and volume and surface roughness-induced backscatter variations within the footprint. For sea ice leads the dominant errors are due to the finite range resolution of the instrument and off-nadir lead returns.

4.2 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 receiver bandwidth of 320 MHz. The SAR processing of CryoSat-2 utilizes an unfocused aperture synthesis technique which uses Doppler beam formation to reduce the footprint size in comparison with a beam-limited altimeter. The effective footprint size after post-processing 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 256 range bins in SAR mode and 1024 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

5.1 Related Data Collections

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

5.2 Related Websites

IceBridge product website at NSIDC

IceBridge website at NASA

NASA Cryosphere Science Research Portal

6 CONTACTS AND ACKNOWLEDGMENTS

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7 DOCUMENT INFORMATION

7.1 Publication Date

04 April 2018

7.2 Date Last Updated

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