MEaSUREs Greenland Ice Sheet Mosaics from SAR Data, Version 1

USER GUIDE

How to Cite These Data

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/NSIDC-0633

National Snow and Ice Data Center

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1 DATA DESCRIPTION

This data set consists of image mosaics, each covering the majority of the Greenland Ice Sheet, derived from the Canadian Space Agency's (CSA) RADARSAT-1 Synthetic Aperture Radar (SAR) and the Japan Aerospace Exploration Agency's (JAXA) ALOS Phased Array type L-band Synthetic Aperture Radar (PALSAR). The following mosaics are available:

- Calibrated and uncalibrated mosaics from RADARSAT-1 data for the winters of: 2000–2001, 2005–2006, 2006–2007, 2007–2008, 2008–2009, and 2012–2013. Refer to Table 9 for exact date ranges for each winter
- Calibrated and uncalibrated RADARSAT-1 multiyear composites spanning 2000–2009
- Uncalibrated mosaics from ALOS PALSAR data for the winter of 2009–2010

Uncalibrated mosaics are generated from the original source data, instrument parameters, and satellite orbital characteristics. The data have been mapped to grey scale values in the range of 0 — 255 (byte values) using a nonlinear stretch, to allow visual discrimination of topographical features within the images. As a result, the pixel values for each year are not directly comparable (calibrated image mosaics should be used for inter-annual comparison of backscatter values).

Calibrated sigma naught (σ_0) mosaics show spatial patterns in both the surface slope and the surface reflectance for C-band (5.3 GHz) radiation. σ_0 refers to calibration technique whereby the ratio between power incident on the surface and reflected power (backscatter) is normalized by a standard area on the ground. The imagery is thus calibrated with respect to instrument parameters and the range between the satellite and the target, while preserving information that gives visual clues to the shape of the surface topography. σ_0 values are stored in the calibrated mosaics as floating-point decibels (dB) rounded to the nearest one-sixteenth dB.

1.1 File Information

1.1.1 Format

The following formats are available:

- GeoTIFF
- Shapefile (`.dbf, .prj, .shp, .shx`)
- `.vrt` (GDAL Virtual Data Set)
- `.ovr` (image pyramids)
- `.png` (portable network graphics)

1.1.1.1 Format Descriptions

All mosaics are available in Geographic Tagged Image File Format (GeoTIFF) at two resolutions: a 100 m resolution mosaic provided as a single file; and a 20 m resolution mosaic consisting of a set of 25 tiles. In addition, the following ancillary files are available:

- Shapefiles that contain nominal outlines[1] for the images used in the mosaic along with date, sensor, track number, and orbit number. For details about the shapefile format, see the ESRI Shapefile Technical Description white paper (pdf, 124 KB);
- Geospatial Data Abstraction Library (GDAL) `.vrt` files, which allow the 20 m GeoTIFFs to be opened as a single file in geographical information system (GIS) programs such as ArcGIS and QGIS. The VRT format is discussed in detail on the GDAL Virtual Format Tutorial Web page;
- OVR files (`.ovr`) that contain image pyramids at several resolutions to facilitate rapid viewing of the 20 m mosaics. See the ArcGIS Resource Center's Raster Pyramids and OVR Pyramid Files help pages to learn more about raster data set downsampling.

[1]Because of feathering at the edges and the irregular boundaries of the images after terrain correction, images do not conform exactly to these boundaries.

1.1.2 Directory Structure

Data are available on the HTTPS site in `https://daacdata.apps.nsidc.org/pub/DATASETS/nsidc0633_MEASURES_greenland_sar_mosaics_v1/`. Within this directory, there are the following folders:

Table 1. Top-Level HTTPS Directory Structure

Folder Name	Description
2000_2001	Winter 2000–2001 mosaics
2005_2006	Winter 2005–2006 mosaics
2006_2007	Winter 2006–2007 mosaics
2007_2008	Winter 2007–2008 mosaics
2008_2009	Winter 2008–2009 mosaics
2009_2010	Winter 2009–2010 mosaics (ALOS PALSAR)
2012_2013	Winter 2012–2013 mosaics
multiyear_composite	Multiyear (2000-2009) composite mosaics

Each of the annual folders listed in Table 1 (above) contain that winter's shapefile (.dbf, .prj, .shp. .shx) plus the following four[1] subdirectories:

Table 2. Annual Folder Subdirectories and Files

Folder Name	Description	Files
100byte	100 m uncalibrated mosiac	1 GeoTIFF
100sig	100 m calibrated mosaic	1 GeoTIFF
20byte	20 m uncalibrated mosaic	25 GeoTIFFs, 1 .vrt, 1 .ovr file
20sig	20 m calibrated mosaic	25 GeoTIFFs, 1 .vrt, 1 .ovr file

[1]The `2009_2010` folder only contains two subdirectories, `100byte` and `20byte`. A calibrated mosaic was not constructed for 2009–2010. See Section 2.3.2.

1.1.3 Naming Convention

1.1.3.1 GeoTIFF (100 m)

This section explains the GeoTIFF file naming convention for the 100 m mosaics in this data set.

Example File Names:

100mCband0001_v01.1.tif
100mCband0001Sigma_v01.1.tif

Convention:

[RRR]m[B]band[YYYY][CCCCC]_v[XX.X].tif

Table 3. Naming Convention for 100 m Mosaic GeoTIFF Files

String	Description
RRR	Resolution (100 meters)
B	SAR band. Either C (RADARSAT-1) or L (ALOS PALSAR).
YYYY	Winter season expressed as two, two-digit years. For example, 0001 is the winter of 2000–2001 ("multiyear" denotes a multiyear mosaic file).
CCCCC	"Sigma" denotes a calibrated σ0 mosaic. This string is omitted for uncalibrated mosaics.
XX.X	Denotes the version number

1.1.3.2 GeoTIFF (20 m)

This section explains the GeoTIFF file naming convention for the 20 m mosaics in this data set.

Example File Names:

20mTile0_0Cband0001_v01.1.tif
20mTile0_0Cband0001Sigma_v01.1.tif

Convention:

[RR]mTile[C_R][B]band[YYYY][CCCCC]_v[XX.X].tif

Table 4. Naming Convention for 20 m Mosaic GeoTIFF Files

String	Description
RR	Resolution (20 meters)
C_R	Column and row of mosaic tile. Tile 0-0 is in the lower left corner, Tile 4-4 is in the upper right (see Figure 1).
B	SAR band. Either C (RADARSAT-1) or L (ALOS PALSAR).
YYYY	Winter season expressed as two, two-digit years (or "multiyear"). For example, 0001 is the winter of 2000–2001 ("multiyear" denotes a multiyear mosaic file).
CCCCC	"Sigma" denotes a calibrated σ0 mosaic. This string is omitted for uncalibrated mosaics.
XX.X	Denotes the version number

1.1.3.3 Shapefile

This section explains the shapefile file naming convention for this data set.

Example File Names:

20mCband0001_v01.1.dbf
20mCband0001_v01.1.prj
20mCband0001_v01.1.shp
20mCband0001_v01.1.shx

Convention:

20m[B]band[YYYY]_v[XX.X].[EXT]

Table 5. Naming Convention for Shapefiles

String	Description
B	SAR band. Either C (RADARSAT-1) or L (ALOS PALSAR).
YYYY	Winter season expressed as two, two-digit years. For example, 0001 is the winter of 2000–2001 ("multiyear" denotes a multiyear mosaic file).
XX.X	Denotes the version number
EXT	File extension. The shapefile format consists of four files: .dbf (database file); .prj (projection information); .shp (shapes); .shx (shape indices).

1.1.3.4 GDAL Virtual Format (.vrt), Image Pyramids (.ovr)

This section explains the GDAL Virtual Format (.vrt) and image pyramid (.ovr) file naming convention for this data set.

Example File Names:

20mCband0001_v01.1.vrt
20mCband0001_v01.1.vrt.ovr

Convention:

20m[B]band[YYYY]_v[XX.X].[EXT]

Table 6. Naming Convention for .vrt and .ovr Files

String	Description
B	SAR band. Either C (RADARSAT-1) or L (ALOS PALSAR).
YYYY	Winter season expressed as two, two-digit years. For example, 0001 is the winter of 2000–2001 ("multiyear" denotes a multiyear mosaic file).
XX.X	Denotes the version number
EXT	File extension. Either .vrt (GDAL Virtual Format) or .vrt.ovr (image pyramids).

1.1.4 File Size

File sizes vary widely. Shapefiles and .vrt files are less than 25 KB, while .ovr files are between 3.5 GB and 4.0 GB. As shown in Table 7, mosaic sizes depend on the resolution, number of GeoTIFFs, and whether the images are uncalibrated (byte) or calibrated (float):

Table 7. GeoTIFF File Sizes

Resolution	Byte/Float	# of GeoTIFFs	Mosaic Size
100 m	Byte	1	236 MB — 274 MB
100 m	Float	1	419 MB — 477 MB
20 m	Byte	25	8.5 GB — 9.4 GB
20 m	Float	25	13 GB — 15 GB

Notes:

1. All GeoTIFF files are LZW compressed. LZW compression is a lossless format supported by GIS programs such as ArcGIS and QGIS;
2. Pyramids for each 100 m mosaic are embedded in the GeoTIFF.
3. To keep the .ovr files from exceeding 4GB, the first pyramid level (half resolution) is embedded in each 20 m GeoTIFF.

1.2 Spatial Information

1.2.1 Coverage

Southernmost Latitude: 60° N
Northernmost Latitude: 83° N
Westernmost Longitude: 75° W
Easternmost Longitude: 14° W

1.2.2 Resolution

The nominal ground resolution for the mosaics is as follows:

- 100 m RADARSAT: 89 m by 99 m
- 100 m ALOS PALSAR: 88 m x 76 m
- 20 m RADARSAT: 22 m x 22 m
- 20 m ALOS PALSAR: 22 m x 19 m

1.2.3 Projection and Grid Description

1.2.3.1 Projection

Data are provided in the polar stereographic projection with a standard latitude of 70° N and a rotation angle of -45° (sometimes referred to as a longitude of 45° W). With this convention, the x-axis extends south from the North Pole along the 45° W meridian.

1.2.3.2 Grid

The 20 m mosaics are provided as a set of 25 tiles, numbered from 0-0 in the lower left corner to 4-4 in the upper right (see Figure 1). Each mosaic has a corresponding shapefile that contains the nominal outline for the images used in the mosaic along with the acquistion date, sensor, track number, and orbit number. However, because of the irregular boundaries of the images after terrain correction and feathering at the edges, images do not conform exactly to these boundaries.

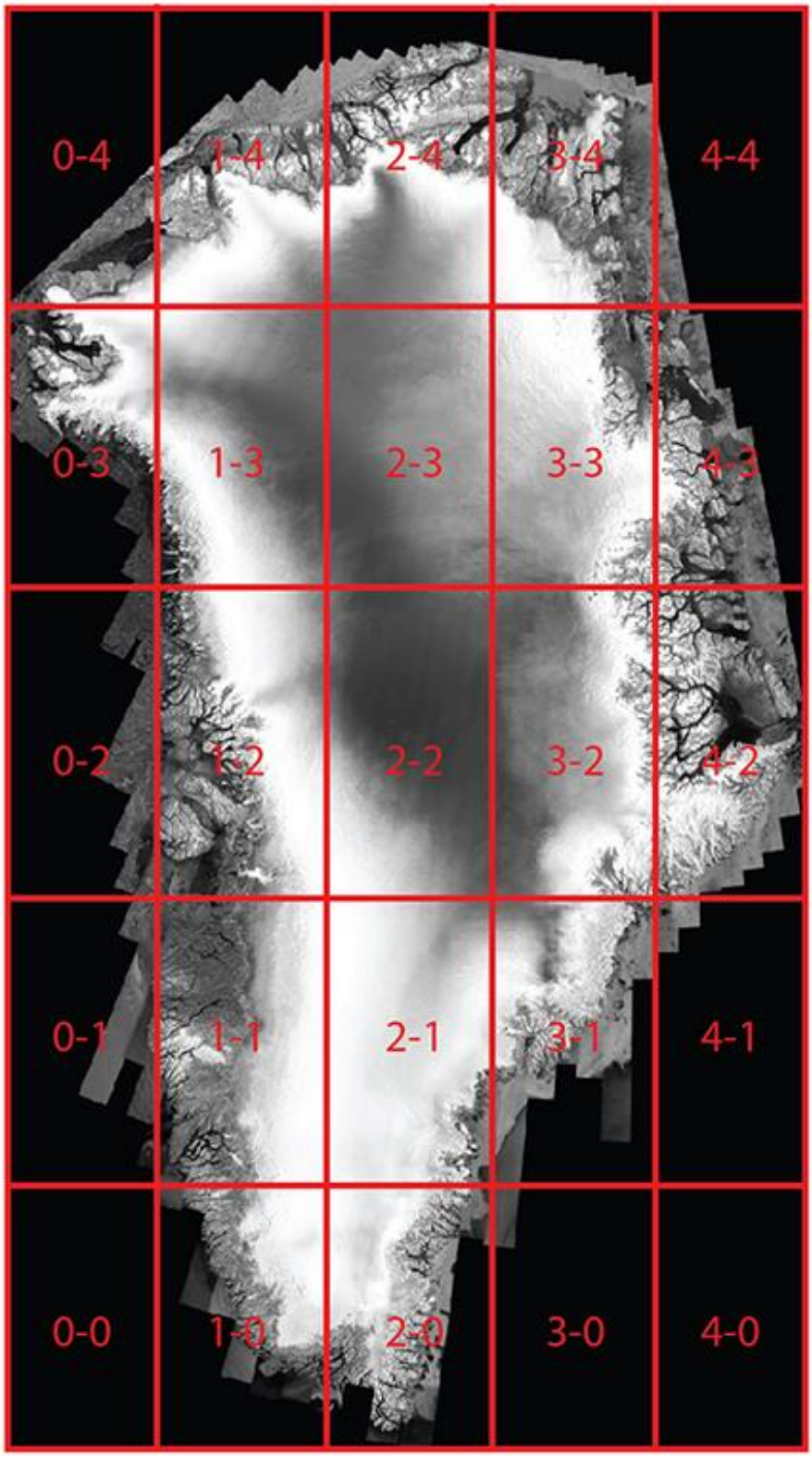

Figure 1. Approximate tile grid locations for the 20 m resolution mosaics.

1.3 Temporal Information

1.3.1 Coverage

Data are available for the following winters. For exact date ranges for each winter season, see Table 8 under Data Acquisition and Processing.

RADARSAT-1

- 2000–2001
- 2005–2006
- 2006–2007
- 2007–2008
- 2008–2009
- 2012–2013

ALOS PALSAR

- 2009–2010

1.3.2 Resolution

Annual

1.4 Parameter or Variable

1.4.1 Parameter Description

The mosaics in this data set consist of either uncalibrated radar backscatter or sigma naught (σ_0) calibrated backscatter. In SAR applications, backscatter is the ratio between the power of a radar pulse transmitted to the target and the power scattered back towards the antenna. σ_0 refers to a calibration technique whereby backscatter is normalized by a standard area on the ground.

2 DATA ACQUISITION AND PROCESSING

2.1 Theory of Measurements

The interactions between radar signals and the ground depend upon many factors, such as the density and dielectric properties of surface materials, vegetation cover, surface roughness at the scale of the signal's wavelength, topographic variations, and the instrument's look angle and signal

polarization. The image resolution is particularly affected by signal strength, chirp pulse length and bandwidth, return signal integration time, and the time between pulse transmissions.

For a detailed discussion of SAR theory, see SAR Theory/Interpreting Images. For general information about the mathematical derivations and theories behind SAR processing algorithms, see Scientific SAR User's Guide.

2.2 Acquisition

CSA's RADARSAT-1 data were collected using the FN1 (Fine-1) beam, which has a single-look resolution of around 4.6 m in the range direction and 5.6 m in the azimuth direction, at incidence angles between 33° and 35°. All JAXA ALOS PALSAR images were collected from ascending orbits with the instrument in Fine-Beam Single-Polarization (FBS) mode, which yields a ground resolution of about 10 m.

Table 9 lists the exact date ranges for each winter's images. These dates are also stored in each mosaic's shapefile.

Table 8. Data Acquisition Dates

Winter	Date Range	Notes
2000–2001	21-Sep-2000 to 23-Jan-2001	—
2005–2006	24-Dec-2005 to 04-Apr-2006	—
2006–2007	30-Dec-2006 to 04-Feb-2007	—
2007–2008	22-Nov-2007 to 30-Mar-2008	—
2008–2009	04-Jan-2009 to 05-Feb-2009	No 2008 data available.
2009–2010	04-Nov-2009 to 08-Mar-2010	Includes an image from 25 October, 2008, used to fill a spatial coverage gap. See shapefile for details.
2012–2013	15-Jan-2013 to 26-Mar-2013	No 2012 data available.
Multi-Year	10-Nov-2000 to 13-Jan-2009	—

2.3 Derivation Techniques and Algorithms

2.3.1 CSA RADARSAT-1 SAR Processing Steps

Mosaics were created from data collected by the Canadian Space Agency. All source data were provided by the Alaska Satellite Facility as Level-0 data, which includes digitized voltage values, instrument calibration constants, and satellite timing, attitude, and position information. Together, this constitutes all the information necessary to generate uncalibrated SAR images of ground targets. The Level-0 data were processed into SLC (Single-Look Complex) images using the GAMMA software MSP package, assuming a flat, constant 0-dB antenna-sensitivity pattern. This determines the scaling between recorded DN (digital numbers, the output of the RADARSAT-1 digitizer) and power returned from the ground, as a function of antenna angle.

For the 20 m mosaics, data were multi-looked by incoherently averaging three looks in range by four looks in azimuth. This degree of averaging translates into a nominal ground resolution of 22 m by 22 m. For the 100 m mosaics, the data were multi-looked using 12 pixels in range and 18 pixels in azimuth, which yields a nominal ground resolution of 89 m x 99 m.

2.3.1.1 Uncalibrated Mosaics

Data were mapped to grey scale values in the range of 0 — 255 using a nonlinear stretch, to allow visual discrimination of features within the images. The stretched data were also thresholded to discard extreme values. As result, the pixel values for each year are not directly comparable. For inter-annual comparison of backscatter values, the calibrated image mosaics should be used.

2.3.1.2 Calibrated Mosaics

Because the GAMMA software does not provide calibrated outputs, it was necessary to derive radiometric calibration coefficients. This derivation is described in detail in the Algorithm Theoretical Basis Document (ATBD) for this data set (see Page 2: Calibrated SAR mosaics from RADARSAT C-band SAR Data).

2.3.2 JAXA ALOS PALSAR Processing Steps

Uncalibrated JAXA ALOS PALSAR L-band image mosaics were created using a similar set of processing steps to those described for RADARSAT-1. The 20 m mosaics were produced from images multi-looked 3 pixels in range by 6 pixels in azimuth, which yields a nominal ground resolution of 22 m by 19 m. The 100 m mosaics were produced from images multi-looked 12 pixels in range by 24 pixels in azimuth, which yields a nominal ground resolution of 88 m x 76 m.

No calibrated mosaics were produced for ALOS PALSAR.

2.4 Quality, Errors, and Limitations

2.4.1 Error Sources

2.4.1.1 Geometric Calibration – CSA RADARSAT-1

Errors in the onboard satellite time produce along track errors of up to several tens of meters. For the 2000–2001 mosaics, adjacent overlapping tracks were cross-correlated to compute the relative timing offset. A mean offset was then calculated and subtracted to determine an offset for each track. Comparison with other geolocated imagery indicates no substantial absolute offsets. For subsequent years, the timing offsets were determined by cross-correlating with the original 2000–2001 mosaic. A range correction of 60 m to 70 m was applied to the data from each year (a single value in this range was used for each year). As a result, the mosaics are internally consistent with relative displacement errors between mosaics that generally are less than one pixel (20 m), in locations where the topography is fixed (see next paragraph).

2.4.1.2 Geometric Calibration – ALOS

Applying a constant 0.062 second along track timing offset to all images yielded locations consistent with other geolocated data. No range correction was applied.

2.4.1.3 Terrain Correction

The mosaics have all been terrain corrected using the Greenland Ice Mapping Project Digital Elevation Model (GIMP DEM). Any errors in the elevation used at a given point translate to a horizontal displacement error in the across-track (range) direction of approximately dz/tan(38.5°). In areas of unchanging topography, this yields a common location error at each pixel that depends on the elevation error. Where glaciers are thinning rapidly, there is a time varying error that depends on the change in elevation relative to the GIMP DEM used for terrain correction. For example, the location of a point on a glacier that has thinned by 100 meters relative to the GIMP DEM will have a horizontal location error of about 125 meters.

2.5 Instrumentation

2.5.1 Description

For additional information about the SAR systems used to construct this data set, see NSIDC's RADARSAT-1 Standard Beam SAR Images Web page and About ALOS - PALSAR at the Japan Aerospace Exploration Agency (JAXA).

3 SOFTWARE AND TOOLS

These data can be readily accessed using GIS software such as ArcGIS and QGIS.

4 VERSION HISTORY

Version 1.1 was released in February 2020. Refer to Table 9 for the data set version history:

Table 9. Version History

Version	Description
V1 (Aug. 2015)	Initial release
V1.1 (Feb. 2020)	.vrt files were rebuilt with correct .tif file names. For multiyear_composite/20byte/ files: • 'mosaic' at beginning of filename was removed. • 'Completegeo' at end was replaced with 'multiyear'. All files were appended with '_v01.1' before the extension.

5 RELATED DATA SETS

Digital SAR Mosaic and Elevation Map of the Greenland Ice Sheet
RAMP AMM-1 SAR Image Mosaic of Antarctica
MEaSUREs Greenland Ice Sheet Velocity Map from InSAR Data
MEaSUREs Greenland Ice Velocity: Selected Glacier Site Velocity Maps from InSAR
MEaSUREs InSAR-Based Antarctica Ice Velocity Map
MEaSUREs InSAR-Based Ice Velocity Maps of Central Antarctica: 1997 and 2009
MEaSUREs InSAR-Based Ice Velocity of the Amundsen Sea Embayment, Antarctica

6 RELATED WEBSITES

MEaSUREs Data | Overview
Alaska Satellite Facility
Canadian Space Agency
Japan Aerospace Exploration Agency
Greenland Ice Sheet Mapping Project (GIMP)

7 CONTACTS AND ACKNOWLEDGMENTS

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8 DOCUMENT INFORMATION

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