MEaSUREs Greenland 6 and 12 Day Ice Sheet Velocity Mosaics from SAR, Version 2

USER GUIDE

How to Cite These Data

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

Joughin, I. 2022. *MEaSUREs Greenland 6 and 12 Day Ice Sheet Velocity Mosaics from SAR, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/1AMEDB6VJ1NZ. [Date Accessed].

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National Snow and Ice Data Center

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1 DATA DESCRIPTION

This data set contains 6 and 12 day surface velocity estimates for the Greenland Ice Sheet and periphery derived from images acquired by the European Space Agency (ESA) Copernicus Sentinel-1A and Sentinel-1B satellites.

To access similarly derived annual, quarterly, and monthly velocity mosaics, see the following Greenland Ice sheet Mapping Project (GrIMP) data sets:

- MEaSUREs Greenland Annual Ice Sheet Velocity Mosaics from SAR and Landsat
- MEaSUREs Greenland Quarterly Ice Sheet Velocity Mosaics from SAR and Landsat
- MEaSUREs Greenland Monthly Ice Sheet Velocity Mosaics from SAR and Landsat

1.1 Parameters

Velocities are reported in meters per year and provided as velocity magnitude (vv), x and y component velocities (vx, vy), and x and y component velocity error estimates (ex, ey).

In addition, a temporal offset parameter (dT) is included that reports the difference in days between the date of each velocity estimate and the midpoint date of the corresponding measurement period.

1.2 File Information

1.2.1 Format

Data are provided as cloud optimized GeoTIFFs (.tif) and shapefiles. TIFF and JPEG browse files are also available.

1.2.2 File Contents

Each of the parameters listed in the "Parameters" section above is provided as a separate 6- or 12-day GeoTIFF file. Corresponding shapefiles are also available that indicate the source of the image pairs used to produce the mosaics.

1.2.3 Naming Convention

1.2.3.1 GeoTIFF

Naming Convention

GL_vel_mosaic_s1cycle_[start date]_[end date]_[parameter]_[version].[ext]

Example

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_vv_v02.0.tif

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_vx_v02.0.tif

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_vy_v02.0.tif

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_ex_v02.0.tif

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_ey_v02.0.tif

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_dT_v02.0.tif

The following table describes the variables in the GeoTIFF file naming convention:

Table 1. GeoTIFF File Naming Convention Variables

Variable Name	**Description**
GL_vel_mosaic_s1cycle	Greenland 6 and 12 Day Ice Sheet Velocity Mosaics from SAR, Version 2 product
start date_end date	Specifies the 6 or 12 day date range (DDMMMYY)
parameter	One of the following: vv (velocity magnitude) vx, vy (component velocity) ex, ey (component velocity error) dT (temporal offset) browse*
version	Two digit version, plus release number (when applicable). E.g., V02.0 = Version 2 (initial release).
ext	File extension (.tif)

*Browse images are available in both GeoTIFF and JPEG formats. The file with the ".browse.jpg.aux.xml" file name contains file metadata for the corresponding JPEG browse image.

1.2.3.2 Shapefile

A shapefile is a vector data storage format that contains multiple files. Each shapefile in this data set contains the following four file types:

- .dbf – dBASE table with attribute information
- .prj – coordinate system information
- .shp – feature geometry
- .shx – spatial index of the features

Naming Convention

GL_vel_mosaic_s1cycle_[start date]_[end date]_SAR_[version].[ext]

Example:

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_SAR_v02.0.dbf

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_SAR_v02.0.prj

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_SAR_v02.0.shp

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_SAR_v02.0.shx

Just like the GeoTIFF naming convention described above, the “start_date” and “end_date” variables specify the 6 or 12 day date range and “version” indicates the data set version and release number.

1.2.3.3 Browse Image

Browse images follow the GeoTIFF naming convention (absent “SAR”), but include the word “browse” in the file name. Browse images are available as both GeoTIFFs (.tif) and JPEGs (.jpg).

Example

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_browse_v02.0.jpg

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_browse_v02.0.tif

1.3 Spatial Information

1.3.1 Coverage

This data set spans the entire Greenland Ice Sheet:

Northernmost Latitude: 83° N
Southernmost Latitude: 58.5° N
Easternmost Longitude: 8.32° E
Westernmost Longitude: 90.9° W

1.3.2 Resolution

Data are posted at a 200 m spacing. JPEG browse files are at 500 m resolution.

Note that this resolution does not reflect the true "on the ground" resolution. The velocities are derived from source data with spatially varying averages that range from a few hundred meters to 1.5 km, making it difficult to specify the resolution at any point.

For example, some estimates are derived as the average of tens of individual measurements. While this enhances the final resolution to some degree relative to the individual source products, the amount of the enhancement is not well quantified.

1.3.3 Geolocation

The following tables provides information for geolocating this data set:

Table 2. NSIDC Sea Ice Polar Stereographic North (EPSG:3413)

Geographic coordinate system	WGS 84
Projected coordinate system	WGS 84 / NSIDC Sea Ice Polar Stereographic North
Longitude of true origin	-45°
Latitude of true origin	70°
Scale factor at longitude of true origin	1
Datum	WGS 1984
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 +k=1 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs
Reference	http://epsg.io/3413

Table 3. World Geodetic System 1984 (EPSG:4326)

Geographic Coordinate System	WGS 84
Projected Coordinate System	N/A
Longitude of True Origin	0°
Latitude of True Origin	N/A
Scale factor at longitude of true origin	N/A
Datum	World Geodetic System 1984
Ellipsoid/spheroid	WGS 84
Units	degree
False Easting	N/A
False Northing	N/A
EPSG Code	4326
PROJ4 String	+proj=longlat +datum=WGS84 +no_defs
Reference	http://epsg.io/4326

1.4 Temporal Information

1.4.1 Coverage

1 January 2015 – 19 March 2024[1]

1.4.2 Resolution

12 days (through 27 September 2016)

6 days (from 28 September 2016 to current end date)

2 DATA ACQUISITION AND PROCESSING

2.1 Acquisition

The maps in this data set were created from Sentinel-1A and -1B source data using a nearly identical approach as the following annual, quarterly, and monthly velocity mosaics:

- MEaSUREs Greenland Annual Ice Sheet Velocity Mosaics from SAR and Landsat
- MEaSUREs Greenland Quarterly Ice Sheet Velocity Mosaics from SAR and Landsat

[1]This data set undergoes periodic temporal coverage updates as new Sentinel-1 data are collected and processed.

- MEaSUREs Greenland Monthly Ice Sheet Velocity Mosaics from SAR and Landsat

However, unlike the data sets above they were generated from Sentinel-1A and -1B source data *only* (i.e., no TerraSAR-X or Landsat-8 data).

2.1.1 Annual Variation in Data Acquisition

The following sections provide details about changes during the course of the Copernicus Sentinel mission that have impacted data acquisition:

1 Dec 2014 – 30 Nov 2015
Sentinel-1A data acquisitions began in 2015, but the acquisition rates were not as regular as in later years. As a result, these data tend to be somewhat noisier than data acquired from 2016 onward, particularly in the middle of the ice sheet.

Dec 1, 2015 – Nov 30, 2016
The six Sentinel-1A tracks that image the majority of the Greenland coast were collected for almost every 12 day satellite repeat cycle during this time range. Beginning in October 2016, Sentinel-1B started acquiring data over Greenland in an orbit that lags Sentinel-1A by six days, providing better coverage and more opportunities to refine the output data.

Dec 1, 2016 – Nov 30, 2017
This represents the first year that regular 6 day coverage occurred throughout the entire year, which can improve results for fast moving glaciers. In addition, the mission improved coverage for the southern part of Greenland in mid-2017. As such, data should be improved for areas south of 67.5° N.

2.2 Processing

2.2.1 Aggregation

Velocities are computed as averages, by aggregating all available data and combining them in an error-weighted method to achieve an optimal estimate with respect to error reduction (Joughin, 2002). Note, however, that unlike the annual, quarterly, and monthly velocity mosaics, for most regions the 6 or 12 day velocity estimate was generated from a single, source image pair.

In order to maximize coverage, data have been included in which the sampling interval of the input data did not fully lie within the output interval. In these cases, the data are weighted by the amount they overlap the output interval (e.g., if the first 6 days of a 12 day image pair lies within the output interval, a weight of 0.5 would be applied).

In addition, Sentinel-1A and -1B provide crossing ascending and descending orbit data over much of the ice sheet. In areas where crossing-orbit data were available, an error-weighted range-offset-only solution was used for the velocity product, which eliminates azimuth offsets and reduces the error from ionospheric streaking in the azimuth offsets.

2.2.2 Baseline Fits

Each image pair used in the mosaic must be calibrated to determine parameters related to the relative positions of the satellites when the images in a pair were collected (e.g., baseline). In the previous version of this data set, linear regressions were used to fit control points with known velocity and elevation and thus capture the along-track variation in the parameters. However, this approach can propagate any biases present in the control points.

With Sentinel-1 greater reliance can be placed on the knowledge of the parameters derived from the orbital state vectors. As a result, the data in Version 2 have been re-calibrated relative to previous versions by using the fitting process to determine a constant for each parameter rather than a quadratic function, with the along-track dependence determined directly from the state vectors.

For periods where data are not well controlled (sparse ground control points), control points from other periods with adequate controls are used. This greatly improves consistency of the data. While this could mask some true change, the errors without this procedure are far larger than any change likely to occur.

Note that while the annual, quarterly, and monthly products are manually edited to remove obvious errors, this approach is infeasible for this data set due to the large data volume, and an automated process has been used to cull outliers.

2.2.3 Submergence/Emergence Velocity

In previous versions, velocities were computed using a surface-parallel flow assumption to estimate and remove the vertical velocity contribution to the line-of-sight displacement so that the horizontal velocities can be resolved (Joughin et al., 1998). This assumption, however, neglects the submergence/emergence velocity (i.e., the vertical motion of the ice surface).

Version 2 has been corrected using an ice-equivalent submergence/emergence velocity based on a 30-year estimate of surface mass balance (net accumulation after ablation for 1991-2020) derived from MAR (v3.11) regional climate model (Fettweis et al., 2017).

2.2.4 Temporal Offset Calculation

As a measure of temporal skew, a mean temporal offset (dT) was calculated from the midpoint date in days for each point. This metric is calculated by applying the same weighting to the difference between the date for each velocity estimate and the midpoint date and then weighted using the same methods as the velocity data.

In estimating velocity, different weights are used for the v_x and v_y components, so an intermediate weight is used for the individual dTs. In the final mosaicking step, any data with dT greater than one-half the output interval was discarded.

In more detail, the process for calculating dT follows these steps:

1. Using a Day of the Year (DOY) calendar, determine the midpoint for the measurement period.
2. For each pixel, identify the image pairs used as input for velocity and calculate the central date in terms of the DOY.
3. Calculate a weighted average central date for that pixel using an intermediate weight based on the weights used for the v_x and v_y components.
4. dT = weighted average central date – midpoint.

For regions in which the 6 or 12 day velocity estimate was generated from a single image pair (i.e., most regions), the date can be corrected exactly using the dT value.

However, for a velocity estimated from more than one image pair, dT value was computed as an average based on the weights used to average the velocity data, and thus the corrected date should be considered approximate (e.g., the corrected date may correspond to a date on which no measurement occurred). In these few cases, the date correction is best used to flag potential time-skew issues.

2.2.5 GDAL-Generated Cloud Optimized GeoTIFFs

The GeoTIFFs were generated using Geospatial Data Abstraction Library (GDAL), to make them compatible with the latest cloud optimized GeoTIFF format. GDAL generates previews for Cloud Optimized GeoTIFFs; however, the software uses cubic interpolation that results in minor artifacts around the lower resolution previews. Averaging is used to avoid this issue.

ⓘ When GDAL creates cloud optimized GeoTIFFs, it writes image statistics directly to the file header.

2.3 Quality, Errors, and Limitations

In general, the formal error estimates represent the average behavior of the data and likely underestimate true uncertainty. They should be used more as an indication of relative quality rather than absolute error and care should be taken if assigning statistical significance based on the errors.

Because for most regions the velocity estimate was generated from a single, source image pair, the automated process to remove obvious outliers results in more numerous gaps. While gaps are undesirable, the decision was made to sacrifice coverage rather than provide data with excessive noise. Users for whom gaps represent a problem are advised to use the annual, quarterly, or monthly products instead.

The data are posted to 200 m grid; however, the true resolution varies between a few hundred meters to 1.5 km. While many small glaciers are resolved outside the main ice sheet, for narrow (<1 km) glaciers the velocity may represent an average of both moving ice and stationary rock, and the actual speed may be underestimated.

Because fewer points are averaged, errors are larger than the annual, quarterly, and monthly products. Comparisons with stationary bedrock points and slow-moving interior ice indicate that RMS errors for this data set average 6 m/yr for the x component and 14 m/yr for the y component. This asymmetry reflects the underlying SAR images — the resolution in the along-track (azimuth) direction, which aligns more closely with y component, is nearly 4x lower than in the across-track (range) direction.

Although the nominal temporal resolution is 6 or 12 days as indicated by the sampling interval, in a few cases missed acquisitions can degrade the true temporal resolution. For example, if an image was missed such that no 6 day pair exists, a 12 day pair might have been used instead by assigning the results from the 12 day pair to whichever 6 day interval contains the center date with the missing pair (the other 6 day interval will have no data). No separate layer is provided to indicate temporal resolution on a pixel-by-pixel basis. However, users can consult the accompanying shapefile to determine the dates of all of the pairs that may have contributed to any given pixel.

2.4 Instrumentation

For details about Sentinel-1A and -1B, the European Space Agency maintains a library of technical information at Sentinel Online | Sentinel-1.

3 SOFTWARE AND TOOLS

GeoTIFF files and shapefiles can be viewed with a variety of Geographical Information System (GIS) software packages including QGIS and ArcGIS.

4 VERSION HISTORY

Table 4. Version History

Version	Date	Description of Changes
2.0	Sep. 2022	• Temporal coverage extended • Data recalibrated relative to previous versions to reduce biases imposed by quadratic fits to control points • Correction added for the submergence/emergence velocity
1.0	Nov. 2021	Initial release

5 RELATED DATA SETS

- MEaSUREs Greenland Annual Ice Sheet Velocity Mosaics from SAR and Landsat
- MEaSUREs Greenland Quarterly Ice Sheet Velocity Mosaics from SAR and Landsat
- MEaSUREs Greenland Monthly Ice Sheet Velocity Mosaics from SAR and Landsat

6 CONTACTS AND ACKNOWLEDGMENTS

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These data sets contain modified Copernicus Sentinel data (2014-2016), acquired by the ESA, distributed through the Alaska Satellite Facility, processed by Joughin, I.

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8 DOCUMENT INFORMATION

8.1 Publication Date

September 2022

8.2 Date Last Updated

May 2024