MEaSUREs Greenland 6 and 12 Day Ice Sheet Velocity Mosaics from SAR, Version 1

USER GUIDE

How to Cite These Data

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

Joughin, I. 2021. *MEaSUREs Greenland 6 and 12 Day Ice Sheet Velocity Mosaics from SAR,* Version 1. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/6JKYGMOZQFYJ. [Date Accessed].

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FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/NSIDC-0766

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 between 2015–2021 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 (GIMP) datasets:

- 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

The main parameters of interest in this data set are ice velocity magnitude (m/year), component velocities, and component velocity error estimates. Ancillary data include shapefiles that specify the Synthetic Aperture Radar (SAR) source images used to derive the velocities and date corrections to compute time stamps for each date interval.

1.2 File Information

1.2.1 Format

Velocity data, error estimates, and date corrections are provided as GeoTIFFs. Ancillary data are provided as Esri shapefiles. Browse images are also available in GeoTIFF and JPEG formats.

1.2.2 Sample Data Image

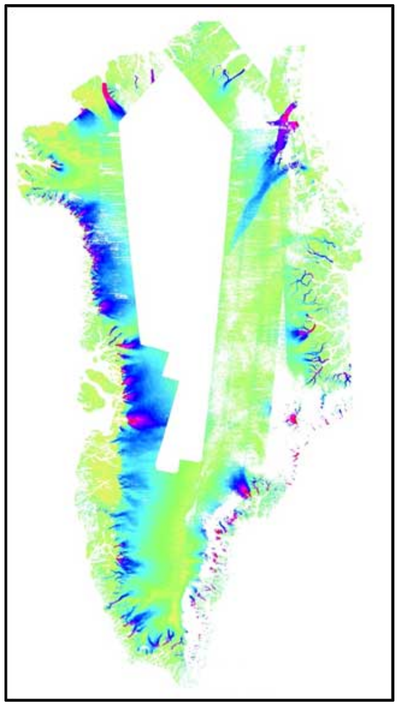

Figure 1. Browse image for
29 January – 03 February 2021.

1.2.3 Directory Structure (Direct Download)

Data are available from NASA's Earthdata Search or via direct download using HTTPS. When using the direct download option, the top-level directory contains a subfolder for each date interval whose name reflects the interval start date. Each subfolder contains all the GeoTIFFs and shapefile files stored in a flat directory structure.

1.2.4 Naming Convention

1.2.4.1 GeoTIFF

GeoTIFFs utilize the following naming convention:

Example

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_vv_v01.0.tif

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_vx_v01.0.tif

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_vy_v01.0.tif

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_ex_v01.0.tif

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_ey_v01.0.tif

GL_vel_mosaic_s1cycle_01Jan15_12Jan15_dT_v01.0.tif

Naming Convention

GL_vel_mosaic_s1cycle_[start date]_[end date]_[identifier]_v01.0.tif

See the following table for the key to variables in the GeoTIFF naming convention:

Table 1. File Identifiers

Variable Name	Description
GL_vel_mosaic_s1cycle	Greenland 6 and 12 Day Ice Sheet Velocity Mosaics from SAR, Version 1 product
start_date_end_date	Specifies the 6 or 12 day date range (DDMMMYY)
identifier	vv – velocity magnitude (m/yr)
	vx, vy – velocity in the x-, y-direction (m/yr)
	ex, ey – velocity error estimates in the x-, y-direction (m/yr)
	dT – date corrections (days)
	browse – browse image

Note: Browse images are available in both GeoTIFF and JPEG formats.
The “GL_vel_mosaic_s1cycle_[start date]_[end date].browse.jpg.aux.xml” file contains file metadata for the JPEG browse images.

1.2.5 Shapefile

A shapefile is a vector data storage format that contains multiple files. The shapefiles in this data set include:

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

Shapefiles utilize the following naming convention:

Example:
GL_vel_mosaic_s1cycle_01Jan15_12Jan15_SAR_v01.0.dbf
GL_vel_mosaic_s1cycle_01Jan15_12Jan15_SAR_v01.0.prj
GL_vel_mosaic_s1cycle_01Jan15_12Jan15_SAR_v01.0.shp
GL_vel_mosaic_s1cycle_01Jan15_12Jan15_SAR_v01.0.shx

Naming Convention
GL_vel_mosaic_s1cycle_[start date]_[end date]_SAR_v01.0.[ext]

Just like the GeoTIFF files, the “start_date” and “end_date” variables specify the 6 or 12 day date range. Within the shapefile, each file will have one of the four file extensions described above.

1.3 Spatial Information

1.3.1 Coverage

This data set spans the entire Greenland Ice Sheet, specifically:

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

1.3.2 Resolution

Data are posted at a 200 m spacing, but this should not be confused with the actual resolution. These products are derived as spatially varying averages from source data with resolutions that range from 500 m 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. Although this enhances the final resolution beyond that of the source data, the amount is not well quantified.

1.3.3 Geolocation

The following table provides information for geolocating this data set:

Table 2. Geolocation Details

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

1.4 Temporal Information

1.4.1 Coverage

1 January 2015 — 3 February 2021

1.4.2 Resolution

12 days (through 28 November 2016)

6 days (after 28 November 2016)

The nominal temporal resolution is 6 or 12 days as indicated by the sampling interval (e.g., the 6 day products are formed almost entirely from 6 day pairs). In a few cases, missed acquisitions could degrade the temporal resolution. For example, if an image was missed so that no 6 day pair was available, a 12 day pair might have been used instead. The results from any such 12 day pair will be assigned to whichever 6 day interval contains the center date for the 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, the accompanying shapefile does show the dates of all of the pairs that potentially contributed to a given pixel.

1.4.2.1 Date Corrections

Nominal dates have been selected as the center date of the interval. For example, the nominal date for the 2015-01-01 to 2015-01-12 is 2015-01-07 (00:00:00). At any given pixel, however, the true date is the weighted central date of the pairs used to produce the estimate. For areas created by using data from a single image pair, the date can be corrected exactly by adding the date correction value (in days) to the nominal center date.

By way of example, if the date interval has the range 2015-01-01 to 2015-01-12, and the date correction file indicates a value of -3.5 at a particular point, then the corrected date for that point is:

2015-01-07 (00:00:00) + (-3.5 days) = 2015-01-03 (12:00:00)

However, at points where more than one Sentinel-1A, -1B pair was used to produce an estimate, the dT correction is approximate, as it was computed as an average based on the weights used to average the velocity data.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

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
- 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).

2.2 Acquisition

The source data used to generate the velocity maps were acquired in either 12 day (through 28 November 2016) or 6 day repeat cycles (after 28 November 2016). However, due to missing acquisitions some image pairs have longer repeat periods (integer multiples of 6 or 12 days).

2.3 Processing

2.3.1 Data 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). Given uniformly sampled data (e.g., every 12 days) and uniformly weighted data, this procedure would be equivalent to a linear interpolation of the time series.

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.

Each image pair used in the mosaic requires a four- to six-parameter fit for the baseline parameters. The data are fit to a common set of ground control points as described by Joughin et al. (2010). 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.

2.3.2 Date Correction

Due to the data aggregation process described above, the true date represented by the data may differ from the nominal center date of an interval. As a measure of temporal skew, a mean deviation from the nominal date (dT in days) was computed based on the dates of the source image pairs for each point. This metric is calculated as an offset in days to each point's nominal date by applying the same methods used to weight the source data's contribution to the output velocity. However, because different weights are used for the vx and vy velocity components, an intermediate weight is used for individual dTs.

For areas created using data from only a single image pair, the date can be corrected exactly using the dT value.

2.4 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.

The automated process to remove obvious outliers results in more numerous gaps, as for most regions the 6 or 12 day velocity estimate was generated from a single source image pair. 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 against stationary bedrock points and slow-moving interior ice indicates that RMS errors for this data set averages 6 m/yr for the x-component and 14 m/yr for the y-component. This asymmetry reflects the underlying SAR images, which have a resolution in the along-track (azimuth) direction that is nearly 4 times poorer than in the across-track (range) direction. As a result, velocity errors in the y-component are larger because the y-direction aligns most closely with the along-track direction.

Although the nominal temporal resolution is 6 or 12 days as indicated by the sampling interval (e.g., the 6 day products are formed almost entirely from 6 day pairs), 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). Although no separate layer is provided to indicate temporal resolution on a pixel-by-pixel basis, users can consult the accompanying shapefile to determine the dates of all of the pairs that may have contributed to any given pixel.

If data from more than one Sentinel-1A, -1B pair has been used at a particular point, the dT correction is approximate, computed as an average date based on the weights used to average the corresponding velocity data. As such, corrected dates for points created from more than one image pair can potentially correspond to a date on which no measurement occurred. In these cases, the date correction is best used to flag potential time-skew issues.

The following sections provide additional 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 the 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.

2.5 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

Version 1 (November 2021)

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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6.2 Acknowledgements

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

7 REFERENCES

Joughin, I. (1995). Estimation of ice-sheet topography and motion using interferometric synthetic aperture radar. *PhD Dissertation*, University of Washington.

Joughin, I. (2002). Ice-sheet velocity mapping: a combined interferometric and speckle-tracking approach. *Annals of Glaciology*, 34, 195–201. https://doi.org/10.3189/172756402781817978

Joughin, I., Tulaczyk, S., Bindschadler, R., & Price, S. F. (2002). Changes in west Antarctic ice stream velocities: Observation and analysis. *Journal of Geophysical Research: Solid Earth, 107*(B11), EPM 3-1-EPM 3-22. https://doi.org/10.1029/2001jb001029

Joughin, I., Abdalati, W., & Fahnestock, M. (2004). Large fluctuations in speed on Greenland's Jakobshavn Isbræ glacier. Nature, 432(7017), 608–610. https://doi.org/10.1038/nature03130

Joughin, I., Smith, B. E., Howat, I. M., Scambos, T., & Moon, T. (2010). Greenland flow variability from ice-sheet-wide velocity mapping. *Journal of Glaciology*, 56(197), 415–430. https://doi.org/10.3189/002214310792447734

Joughin, I., Smith, B. E., & Howat, I. M. (2017). A complete map of Greenland ice velocity derived from satellite data collected over 20 years. Journal of Glaciology, 64(243), 1-11. https://doi.org/10.1017/jog.2017.73

Moon, T., & Joughin, I. (2008). Changes in ice front position on Greenland's outlet glaciers from 1992 to 2007. *Journal of Geophysical Research*, 113(F2). https://doi.org/10.1029/2007jf000927

Phillips, T., Rajaram, H., Colgan, W., Steffen, K., & Abdalati, W. (2013). Evaluation of cryo-hydrologic warming as an explanation for increased ice velocities in the wet snow zone, Sermeq Avannarleq, West Greenland. *Journal of Geophysical Research*: Earth Surface, 118(3), 1241–1256. https://doi.org/10.1002/jgrf.20079

Rignot, E. (2006). Changes in the Velocity Structure of the Greenland Ice Sheet. *Science*, 311(5763), 986–990. https://doi.org/10.1126/science.1121381

8 DOCUMENT INFORMATION

8.1 Publication Date

November 2021

8.2 Date Last Updated

November 2021