MEaSUREs Greenland Ice Sheet Velocity Map from InSAR Data, Version 2

USER GUIDE

How to Cite These Data

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

Joughin, I., B. Smith, I. Howat, and T. Scambos. 2015, updated 2018. *MEaSUREs Greenland Ice Sheet Velocity Map from InSAR Data, Version 2.* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/OC7B04ZM9G6Q . [Date Accessed].

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FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/NSIDC-0478

National Snow and Ice Data Center

TABLE OF CONTENTS

1 DETAILED DATA DESCRIPTION

This data set contains eleven winter Greenland ice sheet-wide mosaicked velocity maps derived from SAR data. Depending on the year, different platforms and sensors were used to produce these data (see Table 3). For each winter, a shapefile is included to indicate the source satellite image pairs that were processed to produce the mosaic. Since speckle tracking may fail to produce results at some points within a SAR image pair, the swaths listed in the shapefile only indicate which data could have contributed to a particular point (i.e., some data from that swath were used in the mosaic, but at any particular point, there may not have been a valid result from that swath).

For maps of glacier outlet areas, some of which demonstrate profound velocity changes during the observation period, see the related data set MEaSUREs Greenland Ice Velocity: Selected Glacier Site Velocity Maps from InSAR.

1.1 Format

Data are available in GeoTIFF (.tif) format. Five GeoTIFF files are available for each winter product: a velocity magnitude map (vv), separate x- and y-component velocities (vx, vy), and separate x- and y-component error estimates (ex, ey). For the years 2014 to 2018, a shapefile (.shp) with the source satellite information as well as a browse (.jpg) image of the velocity magnitude with a color log scale saturating at 3000 m/year are provided.

1.2 File Naming Convention

The file naming convention used for this data set is:

greenland_vel_mosaic[RRR]_[yyyy_yyyy]_vv_v02.1.ext
greenland_vel_mosaic[RRR]_[yyyy_yyyy]_[vx OR vy]_v02.1.ext
greenland_vel_mosaic[RRR]_[yyyy_yyyy]_[ex OR ey]_v02.1.ext
greenland_vel_mosaic[RRR]_[yyyy_yyyy]_browse_v02.1.ext

Examples:

greenland_vel_mosaic500_2000_2001_vv_v02.1.tif
greenland_vel_mosaic500_2000_2001_vx_v02.1.tif
greenland_vel_mosaic500_2000_2001_vy_v02.1.tif
greenland_vel_mosaic500_2000_2001_ex_v02.1.tif
greenland_vel_mosaic500_2000_2001_ey_v02.1.tif
greenland_vel_mosaic500_2000-2001_browse_v02.1.jpg

greenland_vel_mosaic_2014_2015_v02.1.shp
greenland_vel_mosaic_2014_2015_v02.1.dbf
greenland_vel_mosaic_2014_2015_v02.1.shx
greenland_vel_mosaic_2014_2015_v02.1.prj

The following table describes the individual components used in the file names.

Table 1. File Naming Convention

Component	Description
`greenland_vel_mosaic`	Greenland velocity mosaic
`RRR`	Resolution: 500 m or 200 m
`yyyy_yyyy`	Winter season (e.g. 2014_2015)
`vx, vy, vv`	Velocity x-direction, velocity y-direction, velocity magnitude
`ex, ey`	Error x-direction, error y-direction
`browse`	Browse image
`v02.1`	Version 2.1
`.ext`	File extension: GeoTIFF (`.tif`) Shapefile (`.shp`, `.dbf`, `.shx`, `.prj`) JPEG (`.jpg`)

1.3 File Size

The total GeoTIFF volume is approximately 12 GB and the total JPG volume is approximately 418 MB. The total shapefile (.shp, .dbf, .shx, .prj) volume is approximately 3 MB.

The entire data volume is 13.3 GB.

1.4 Spatial Coverage

This data set covers Greenland.

Southernmost latitude: 60° N
Northernmost latitude: 83° N
Westernmost longitude: 75° W
Easternmost longitude: 14° W

1.4.1 Spatial Resolution

500 m or 200 m

Note: Prior to 2014, the data are provided only at 500 m resolution.

1.4.2 Projection

Data are provided in a WGS 84 polar stereographic grid with a standard latitude of 70° N and rotation angle of -45° E (sometimes specified as a longitude of 45° W). With this convention, the y-axis extends south from the North Pole along the 45° W meridian.

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° E
Latitude of true origin	70° N
Scale factor at longitude of true origin	1
Datum	WGS 84
Ellipsoid/spheroid	WGS 84
Units	meters
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

1.5 Temporal Coverage

This data set provides velocity data for the winters listed in Table 3. The data sources and their agencies are:

- RADARSAT-1: Canadian Space Agency (CSA)
- ALOS: Japan Aerospace Exploration Agency (JAXA)
- TSX and TDX: German Aerospace Center (DLR)
- S-1A and S-1B: European Space Agency (ESA)

Table 3. Velocity Maps listed by Source Data and Temporal Coverage

Temporal Coverage	SAR Data Source
2000/2001	RADARSAT-1
2005/2006	RADARSAT-1
2006/2007	RADARSAT-1, ALOS
2007/2008	RADARSAT-1, ALOS
2008/2009	RADARSAT-1, ALOS, TSX
2009/2010	ALOS, TSX
2012/2013(*)	RADARSAT-1, TSX, TDX
2014/2015	S-1A, TDX, TSX
2015/2016	S-1A, TDX, TSX
2016/2017	S-1A, S-1B, TDX, TSX
2017/2018	S-1A, S-1B, TDX, TSX

(*)**Note:** For the 2012/2013 winter, the first track starts on 03 March 2012. There is a temporal gap between that date and the rest of the data, which continue on 10 November 2012. The later date was chosen as the directory name for that winter (i.e., /2012.11.10/).

1.6 Parameter or Variable

Velocities are reported in meters per year. The velocity magnitude is reported in the vv files. The vx and vy files contain the velocity components in the x- and y-directions, defined by the polar stereographic grid. These velocities are true values and not subject to the distance distortions present in a polar stereographic grid. Small spatial gaps were filled via interpolation in some areas. Interpolated values are identifiable as locations with velocity data but no error estimates. Radar-derived velocities are determined using a combination of conventional InSAR and speckle tracking techniques (Joughin et al., 2002).

Error estimates are provided for all non-interpolated, radar-derived velocity vectors in separate GeoTIFF files appended with _ex.tif and _ey.tif. These estimates include the statistical uncertainty associated with the phase and speckle tracking error. Formal errors agree reasonably well with errors determined by comparison with GPS data (Joughin et al., 2002). The values, however, underestimate the true uncertainty in several ways, and should be used as an indication of relative quality rather than absolute error. Refer to the Error Sources section for more details.

The missing data value for the velocity magnitude (vv) files is -1 and is set as the attribute in all files. The missing data value for the velocity component (vx, vy) and error estimate (ex, ey) files is -2e+9.

2 SOFTWARE AND TOOLS

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

3 DATA ACQUISITION AND PROCESSING

3.1 Theory of Measurements

The velocity maps in this data set were created by mosaicking multiple strips of InSAR-derived data. The methods include a combination of speckle tracking and conventional interferometry. Individual images were selected based on two criteria: images should be taken from the same winter; and the time span between images from any given winter should be as short as possible. For more detail, refer to Joughin et al. (2002).

3.2 Derivation Techniques and Algorithms

Annual mosaics were created using data collected during each Greenland winter. Spatial gaps exist either because no data were available or because interferometric correlation was insufficient to produce an estimate in those regions. The latter is most often the case in regions with high snow accumulation. In regions with sufficient data, the averages are based on up to three measurements. Typically, more data are available in regions of swath overlap, especially at higher latitudes.

The data are gridded at 0.5 km resolution, but the true resolution varies between 0.5 and 1 km. Many small glaciers are resolved outside the main ice sheet; however, for glaciers that are narrower than 1 km, the velocity represents an average of both moving ice and stationary rock. So, while a narrow glacier may be visible on the map, its speed is likely underestimated. Furthermore, interpolation produces artifacts where the interpolated value is derived from nearby rock, causing apparent stationary regions in the middle of otherwise active flow. In such instances, the data should be interpreted with care.

3.3 Processing Steps

The following sections briefly describe how the mosaics were generated for each winter.

3.3.1 2000/2001

In late 2000 and early 2001, during the RADARSAT-1 Modified Antarctic Mapping Mission, CSA acquired nearly complete coverage of Greenland with multiple passes suitable for InSAR (03 September 2000 to 24 January 2001). All of the available data for Greenland were used to produce the 2000/2001 mosaic. In cases where the data quality was too poor, some products were discarded. All source data were obtained from the Alaska Satellite Facility (ASF).

3.3.2 2005/2006

In 2005 and 2006, RADARSAT-1 imaged most of Greenland on four consecutive missions, producing three InSAR pairs. Once all of the data were processed, poor coherence passes were screened out and the remaining data were used to assemble the 2005/2006 mosaic.

3.3.3 2006/2007

The 2006/2007 mosaic was produced with RADARSAT-1 fine-beam data. Coverage is substantially improved by including ascending JAXA ALOS quad-pol data, including coverage in the southeast of Greenland. The ionospheric errors are often large (>20 m/year) in the ALOS data; therefore, points were manually removed where errors were excessive. This approach was chosen in order to balance maximal coverage with minimal error. Nevertheless, these data should be interpreted with care, particularly in the southeast region.

3.3.4 2007/2008

The 2007/2008 mosaic was produced with RADARSAT-1 fine-beam data in the same manner as the 2006/2007 mosaic, including the use of a substantial volume of ALOS fine-beam data, largely along the northwest coast.

3.3.5 2008/2009

The 2008/2009 mosaic utilizes data from CSA's RADARSAT-1, the DLR's TSX, and JAXA's ALOS satellites.

3.3.6 2009/2010

The 2009/2010 mosaic consists almost entirely of ALOS SAR data collected in Fine-Beam, Single-Polarization (FBS) mode. Because L-band is more subject to ionospheric distortion of speckle-tracked azimuth offsets, streak errors for some areas are large (>10 m/year), often exceeding the magnitude of the accompanying error estimates. In other areas, these errors are barely perceptible. Some of the worst streaks were edited out. However, a number of lesser streaks were left in place to preserve coverage and illustrate the magnitude of these errors with obvious examples. Despite being more susceptible to ionospheric distortion, L-band data correlate well in areas with high accumulation. As a result, this map has better coverage in the southeast than many of the maps from other winters.

Twenty coastal sites in this mosaic utilize 30 km x 50 km TSX scenes. These X-band data greatly improve the results for many of the fast-moving outlet glaciers.

3.3.7 2012/2013

The data for the 2012/2013 mosaic were collected from January 2013 to March 2013, which corresponds to the last months during which RADARSAT-1 was active. These data were combined with TSX winter data from November 2012 to March 2013.

3.3.8 General Information for 2014 to 2018

The 2014 to 2017 mosaics were produced mostly with ESA's Copernicus Sentinel-1A/1B data and supplemented by DLR's TSX/TDX data for coastal outlets. The data for the 2014 to 2017 mosaics were acquired in either 12-day (through 16 September) or 6-day repeat cycles (16 October forward). In cases of missing acquisitions, the repeat periods may be longer (i.e., integer multiples of 6 or 12 days) for some of the image pairs.

Unlike earlier SAR acquisitions, Sentinel-1A/1B provides crossing ascending and descending orbit data over much of the ice sheet. In areas where data from crossing orbits were available, an error-weight range-offset-only solution was included in the velocity product, eliminating azimuth offsets and reducing the error from ionospheric streaking in the azimuth offsets.

To take advantage of the year-round Sentinel coastal coverage, data are collected during Greenland winter periods with little or no melt. This definition might produce small seasonal differences compared to mosaics from other years in which narrower acquisition periods were used. However, such differences are generally small relative to inter-annual variability and to the noise reduction accomplished by averaging a greater volume of data acquired over a longer time period.

Due to the reduction in the resolution of Sentinel-1A/1B SAR data, some systematic differences between the mosaics produced by RADARSAT, ALOS, and TSX/TDX data may exist, especially in regions with sharp gradients or strong curvatures. Smoothing earlier velocity results to approximately 1.5 km resolution (i.e., to roughly the resolution of Sentinel-1) should improve agreement among data sets. In producing the mosaics, higher resolution TSX/TDX data are given more weight, hence the loss in resolution should be smaller in these areas. These mosaics are posted at both 0.2 km and 0.5 km spacing. For work requiring a finer resolution, see Version 1 of the MEaSUREs Greenland Ice Velocity: Selected Glacier Site Velocity Maps from InSAR data set.

As a result of the large volume of data used, the overall quality of the data is good. Compared to earlier products, the coverage in the southeast is generally improved, particularly for 2016/17; however, high accumulation in the southeast reduces image-to-image correlation, resulting in higher noise. Additionally, there may be coherent displacement signals in these regions that are not associated with horizontal ice motion. If such displacement occurs with characteristics other than those assumed in the solution (e.g., predominantly vertical instead of horizontal displacement), then the result will be incorrectly mapped to horizontal motion, contributing to the overall level of noise.

3.3.9 2014/2015

The 2014/2015 mosaic was largely produced from TSX data, with the addition of Sentinel-1A data. As Sentinel-1 data acquisition began during this winter period, there are almost no Sentinel-1 data prior to January 2015, with the exception of the region around the Jakobshavn glacier. As a result of the limited satellite coverage, the 2014/2015 mosaic contains more noise and less spatial coverage than the 2015/2016 and 2016/2017 mosaics.

3.3.10 2015/2016

The 2015/2016 mosaic was largely produced from Sentinel-1A data. The six tracks that covered nearly the entire coast were collected at almost every 12-day interval. In the interior, typically four images (i.e., three pairs) were collected with better coverage and fewer errors than the 2014/2015 mosaic.

3.3.11 2016/2017

The 2016/2017 mosaic was largely produced from Sentinel-1A/1B data. In October 2016, Sentinel-1B started acquiring data over Greenland in an orbit that lags behind Sentinel-1A by six days. As a result, Sentinel-1A/1B pairs are often separated by only six days, providing better correlation and coverage, particularly in the southeast of Greenland. Thus, the mosaic for this winter provides almost complete spatial coverage relative to all prior winter velocity products.

3.3.12 2017/2018

The 2017/2018 mosaic was largely produced from 6-day repeat cycles from Sentinel-1A/1B. In general, more data were collected in the ice sheet interior during this winter mapping campaign. As a result, this mosaic should have a lower level of noise in the data relative to prior winter velocity products. The 6-day sampling also provides better coverage because the image-to-image correlation is improved with shorter time intervals.

3.4 Error Sources

3.4.1 Baseline Fits

Each image pair used in the mosaics requires a 4-to-6 parameter fit for the baseline parameters (in other words, the separation between satellite tracks). For Version 1, the baseline was fitted to a sparse common set of ground control points as described by Joughin et al. (2010). This led to errors exceeding 10 m/year being misinterpreted as actual change (Phillips et al., 2013). In Version 2, for a year where the data were not well controlled, control points from other years with adequate controls were used. This greatly improves consistency of the data from year to year. While this could mask some true change, the errors without this procedure were far larger than any change likely to occur.

As a result, these data should not be used to determine inter-annual change for interior regions of the ice sheet (roughly defined as areas above 2000 meters). In outlet glaciers close to the coast where the baselines are well constrained by bedrock, the velocity maps are well suited to this task. However, care should be exercised in interpreting any change observed in intermediate regions (roughly 1000 m to 2000 m), especially areas where the observed changes seem to follow swath boundaries. Refer to Figure 5 in Phillips et al. (2013) for more information. Note that baseline errors are not included in the formal error estimates and thus actual errors can always be substantially larger than stated. In particular, where they are derived mostly from phase, the reported errors are extremely low (<0.5 m/year). With baseline errors included, the actual error is probably in the 1 to 3 m/year range in most cases.

3.4.2 Error Estimates

In general, the error maps represent the average behavior of the data. As a result, errors could be much lower than reported in some areas and much greater in others; care should be taken when assigning statistical significance based on the errors, especially given that the errors can be correlated over large areas. For example, even if the errors are correct in a global sense, one might compare two mosaics and find a large difference of over 5% of the ice sheet. However, because errors can be spatially correlated over broad areas, one should not assume significance at the 95% confidence level; this might be precisely the 5% that statistically should exceed the errors because the errors are not uniformly distributed. By contrast, if the errors were completely uncorrelated, one could average over neighborhoods to reduce the error.

3.4.3 Phase Data

Phase data (as opposed to speckle tracked) have been used for the x- and y-component of motion in the across-track direction, improving the accuracy in areas with slow-moving ice. In addition, some mosaics have more crossing orbit data (ascending and descending). This substantially improves the accuracy of both components in some areas by minimizing the use of noisy azimuth offsets.

3.4.4 Interpolated Points

Small holes in the final maps have been filled via interpolation. These points can be identified as those that have valid velocity data but no corresponding error estimate.

See Joughin et al. (2002) for more detail on errors and how they were computed.

3.5 Version History

Refer to Table 4 for a complete version history.

Table 4. Version History

Version	Description	Effective Date
V1	Initial version	September 2010
V1.1	Discontinued binary data file format; data available in GeoTIFF only	August 2015
V2	Added new map for 2009/2010 Added ALOS fine-beam data to improve coverage in 2006/2007, 2007/2008, and 2008/2009 Corrected a substantial error on Rink glacier where the time interval was off by a factor of 2 Improved baseline fits for consistency in the interior Updated error estimates to better represent the average behavior of the data Performed additional quality control screening to remove erroneous data points	December 2015
V2	Published 2012/2013 data	January 2017
V2	Published 2014/2015, 2015/2016, and 2016/2017 data Added shapefiles of satellite tracks for those winters Added browse files for those winters Changed the velocity magnitude file name from greenland_vel_mosaic[RRR]_[yyyy_yyyy]_v2.ext to greenland_vel_mosaic[RRR]_[yyyy_yyyy]_vel_v2.ext	August 2017
V2.1	Published 2017/2018 data Updated/replaced shapefiles for winter products from 2014 to 2018 (i.e., corrected the shapefile dates) Changed the velocity magnitude file name from greenland_vel_mosaic[RRR]_[yyyy_yyyy]_vel_v2.ext to greenland_vel_mosaic[RRR]_[yyyy_yyyy]_vv_v02.1.ext Changed the missing data value for the velocity magnitude (vv) files to -1 and set it as the attribute in all files.	September 2018

4 REFERENCES AND RELATED PUBLICATIONS

4.1 References

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

4.2 Related Data Collections

- MEaSUREs Greenland Ice Velocity: Selected Glacier Site Velocity Maps from InSAR
- Antarctic Ice Velocity Data (VELMAP)

4.3 Related Websites

- MEaSUREs Data | Overview
- Alaska Satellite Facility
- Greenland Ice Mapping Project (GIMP)

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6 DOCUMENT INFORMATION

6.1 Publication Date

December 2015

6.2 Date Last Updated

29 December 2020