MEaSUREs Greenland Annual Ice Sheet Velocity Mosaics from SAR and Landsat, Version 1

USER GUIDE

How to Cite These Data

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

Joughin, I. 2017, updated 2019. *MEaSUREs Greenland Annual Ice Sheet Velocity Mosaics from SAR and Landsat, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/OBXCG75U7540. [Date Accessed].

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National Snow and Ice Data Center

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1 DATA DESCRIPTION

These data provide annual surface velocity estimates for the Greenland Ice Sheet and periphery. To access quarterly or monthly velocities see related GIMP data sets: *MEaSUREs Greenland Quarterly IceSheet Velocity Mosaics from SAR and Landsat and MEaSUREs Greenland Monthly Ice Sheet Velocity Mosaics from SAR and Landsat.*

1.1 Parameters

The parameter for this data set is ice velocity.

Velocities are reported in meters per year (m/yr). The vx and vy files contain component velocities 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 gaps have been filled via interpolation in some areas. Interpolated values are identifiable as locations that have velocity data but no error estimates. Radar-derived velocities are determined using a combination of conventional Interferometric SAR (InSAR) and speckle tracking techniques (Joughin et. al., 2002).

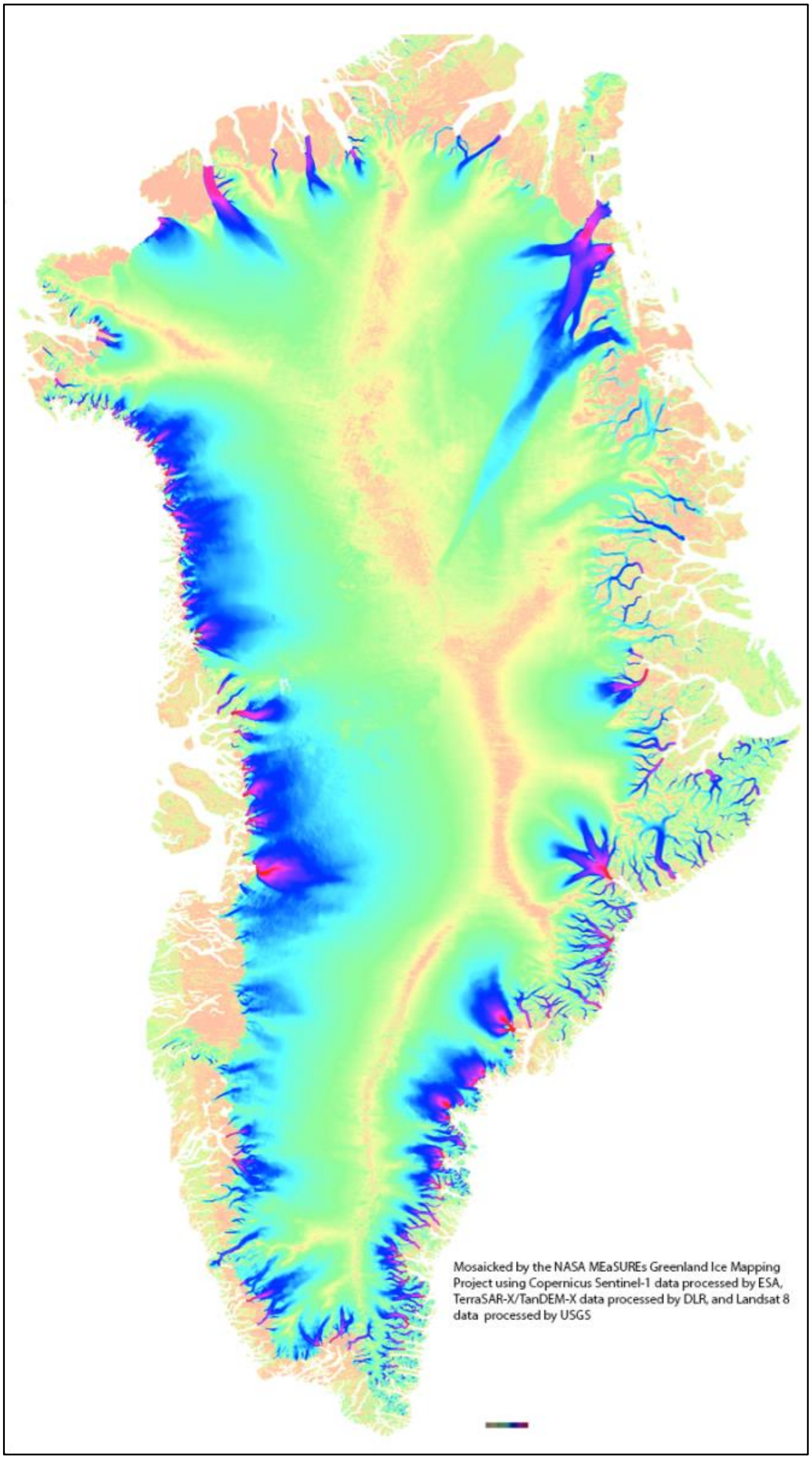

Figure 1. 2016 Greenland Annual Velocity Mosaic Browse Image produced by the MEaSUREs GIMP project. Refer to the Acknowledgements section for information on the instruments and data used.

1.2 File Information

1.2.1 Format

Data are provided at both 200 m and 500 m grid resolutions in GeoTIFF (`.tif`) format. Six data files are available for each data year and resolution: a velocity magnitude map (`vv`); separate x- and y-component velocities (`vx, vy`); separate x- and y-component error estimates (`ex, ey`); and a browse file (with color log scale velocity saturating at 3000 m/year). In addition, ancillary files are provided for each data year to indicate the source image pairs that were processed to produce the mosaics. These are provided in two separate shapefiles (.shp) for the US Geological Survey (USGS)-provided Landsat 8 (L8) and the German Aerospace Center (DLR) and European Space Agency (ESA)-provided Synthetic Aperture Radar (SAR) data.

1.2.2 Naming Convention

This section describes the naming convention for this product with an example. Refer to Table 1 for descriptions of the values in the file naming convention.

Naming Convention:

greenland_vel_mosaic[RRR]_[yyyy]_[vv OR vx OR vy]_v[VV.V].ext
greenland_vel_mosaic[RRR]_[yyyy]_[ex OR ey]_v[VV.V].ext
greenland_vel_mosaic[RRR]_[yyyy]_browse_v[VV.V].ext
greenland_vel_mosaic_[yyyy]_[SS]_v[VV.V].ext

Example File Names:

greenland_vel_mosaic500_2015_vv_v01.0.tif
greenland_vel_mosaic500_2015_vx_v01.0.tif
greenland_vel_mosaic500_2015_vy_v01.0.tif
greenland_vel_mosaic500_2015_ex_v01.0.tif
greenland_vel_mosaic500_2015_ey_v01.0.tif
greenland_vel_mosaic500_2015_browse_v01.0.tif

greenland_vel_mosaic_2015_L8_v01.0.shp
greenland_vel_mosaic_2015_L8_v01.0.dbf
greenland_vel_mosaic_2015_L8_v01.0.shx
greenland_vel_mosaic_2015_L8_v01.0.prj

greenland_vel_mosaic_2015_SAR_v01.0.shp
greenland_vel_mosaic_2015_SAR_v01.0.dbf
greenland_vel_mosaic_2015_SAR_v01.0.shx
greenland_vel_mosaic_2015_SAR_v01.0.prj

Table 1. File Naming Convention

Variable	Description
greenland_vel_mosaic	Greenland velocity mosaic
RRR	Resolution: 500 m or 200 m
yyyy	Data year
vv OR vx OR vy	Velocity magnitude OR velocity x-direction OR velocity y-direction
ex OR ey	Error x-direction, error y-direction
browse	Browse image
SS	Source sensor and satellite information: `SAR` (TerraSAR-X/TanDEM-X, Sentinel-1A and -1B) `L8` (Landsat-8)
VV.V	Version number (currently 01.0)
.ext	GeoTIFF (`.tif`) Shapefile (`.shp, .dbf, .shx, .prj`)

1.3 Spatial Information

1.3.1 Coverage

This data set spans the entire Greenland Ice Sheet, as noted by the coverage below:

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

1.3.2 Resolution

The data are posted at both 500 m and 200 m grid resolutions, which should not be confused with the true "on the ground" resolution. These products are derived as spatially varying averages from source data with resolutions ranging from a few hundred m to 1.5 km, making it difficult to specify the resolution at any point. As some estimates are derived as the average of 30 or more individual measurements, there is some degree of resolution enhancement such that the final resolution is better than that of the individual source products, but not well quantified.

For work requiring finer resolution, it may be preferable to use the individual DLR TerraSAR-X (TSX)/TanDEM-X (TDX) and USGS Landsat data where available (*MEaSUREs Greenland Ice Velocity: Selected Glacier Site Velocity Maps from InSAR; MEaSUREs Greenland Ice Velocity: Selected Glacier Site Velocity Maps from Optical Images*).

1.3.3 Geolocation

Data are provided in a WGS 84 polar stereographic grid with a standard latitude of 70° N and rotation angle of -45° (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 (EPSG:3413).

1.4 Temporal Information

1.4.1 Coverage

This data set provides annual velocity mosaics for 2015 to 2018. The actual year is broadly defined as 01 December of one year to 30 November of the next year. For example, the year 2015 is defined as 01 December 2014 to 30 November 2015.

1.4.2 Resolution

The temporal resolution is one year.

2 DATA ACQUISITION AND PROCESSING

2.1 Acquisition

The image mosaics were produced mostly from Copernicus Sentinel-1A and Sentinel-1B data from the European Space Agency (ESA) and supplemented by TSX/TDX data from DLR for coastal outlets. The data were acquired in either 12-day (through Sept 2016) or 6-day repeat cycles (October 2016 forward). In cases of missing acquisitions, the repeat periods may be longer (integer multiples of 6 or 12 days) for some of the image pairs. In addition to the SAR data, during periods when there was sufficient daylight, USGS's Landsat 8 velocities were merged with the SAR data.

Although the mosaics represent a full calendar year, they are computed as averages of all available data at each point and weighted by their respective errors (Joughin, 2002), so these products do not represent true annual averages. For example, in some places mid-summer may be weighted more heavily than mid-winter due to the seasonal availability of Landsat 8 data. In some regions, clouds or large snow accumulation events may also affect the seasonal distribution of the data. As a result, comparison of adjacent years at any location might produce differences that represent some degree of seasonal variation. Such differences should be small, particularly when examining trends over multiple years.

Unlike earlier SAR acquisitions, 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 included in the velocity product, which eliminated azimuth offsets and reduced the error from ionospheric streaking in the azimuth offsets.

2.1.1 Annual mosaic for 2015 (01 December 2014 - 30 November 2015)

Sentinel-1A data acquisitions began in 2015, but the acquisition rates were not as regular as later years. As a result, these data tend to be somewhat noisier than the 2016 data, particularly in the middle of the ice sheet. In addition, the sampling of coastal regions is more irregular (there are gaps in the temporal coverage where TSX/TDX data was not acquired by the satellite for a month or more), which reduces the averaging of seasonal variation.

2.1.2 Annual mosaic for 2016 (01 December 2015 - 30 November 2016)

For this year, the six Sentinel-1A tracks that image the majority of the Greenland coast were collected for almost every 12-day satellite repeat cycle. 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 thus more correlations in the data. As a result, the accuracy for this mosaic is considerably better than the mosaic for 2015 for most regions.

2.1.3 Annual mosaic for 2017 (01 December 2016 - 30 November 2017)

This product is similar to the earlier 2015 and 2016 products. The major difference is that this is the first year during which a regular 6-day coverage occurred throughout the year, which should improve performance on fast-moving glaciers. In addition, the Copernicus Sentinel mission improved coverage for the southern part of Greenland in mid-2017, improving the results for areas south of 67.5 degrees N.

2.1.4 Annual mosaic for 2018 (01 December 2017 - 30 November 2018)

This product is similar to the earlier 2015-2017 products.

2.2 Processing

The data are posted to 200 m and 500 m grids, but the true resolution varies between a few hundred m to 1.5 km. Many small glaciers are resolved outside the main ice sheet, but for narrow (<1 km) glaciers, the velocity represents an average of both moving ice and stationary rock. As a result, while the glacier may be visible in the map, the actual speed may be underestimated. For smaller glaciers, interpolation produces artifacts where the interpolated value is derived from nearby rock, causing apparent stationary regions in the middle of otherwise active flow. The data have been screened to remove most of these artifacts, but should be used with caution.

Areas with no data correspond either to regions where no data were acquired or where the interferometric or optical correlation was insufficient to produce an estimate, most often in areas with high snow accumulation. The “no data” value for magnitude (vv) files is -0.1. The "no data" value is -2e+9 for the vx, vy, ex, and ey files.

2.2.1 Baseline Fits

Each image pair used in the mosaic requires a 4- to 6-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). For years where data is not well controlled (sparse ground control points), control points from other years with adequate controls are used. This greatly improves consistency of the data from year to year. While this could mask some true change, the errors without this procedure are far larger than any change likely to occur.

These data should not be used to determine inter-annual change for interior regions of the ice sheet (roughly defined as areas above 2,000 m). In outlet glaciers close to the coast where the baselines are well constrained by bedrock, the velocity mosaics 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), i.e. avoid areas where the observed changes seem to follow a satellite swath boundary. Refer to Figure 5 in Phillips et al. (2013) for an example.

2.2.2 Interpolated Points

Small gaps 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.

2.3 Quality, Errors, and Limitations

Due to the large volume of averaged source data, the overall quality of the data set is quite good. While the spatial coverage is generally improved in the southeast relative to earlier Greenland Ice Mapping Project (GIMP) MEaSUREs products, the results are considerably noisy relative to other regions of the ice sheet. High snow accumulation in the southeast greatly reduces image-to-image correlation, resulting in higher noise. Additionally, in these regions there may be coherent displacement signals (e.g., vertical displacement associated with compacting snow) that are not associated with horizontal ice motion. If such displacement occurs with characteristics other than that assumed in the solution (e.g., predominantly vertical instead of horizontal displacement), then the results will be incorrectly mapped to horizontal motion, thereby contributing to the overall level of noise.

Error estimates are provided for all non-interpolated, radar-derived velocity vectors in separate GeoTIFF files appended with `_ex.tif` and `_ey.tif`. Formal errors agree reasonably well with errors determined by comparison with GPS data (Joughin et al., 2002; Joughin et al., 2017). The values, however, underestimate true uncertainty in several ways, and as such should be used more as an indication of relative quality rather than absolute error.

In general, the error estimates represent the average behavior of the data. This means that errors may be much lower than reported in some areas and much greater in others; care should be taken if assigning statistical significance based on the errors, especially given that the errors can be been 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 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.

2.4 Instrumentation

2.4.1 Description

Descriptions of the instruments used to construct the mosaics from which this data set is derived are at the mission sites:

- European Space Agency (ESA): Copernicus Sentinel-1
- German Aerospace Center (DLR): TerraSAR-X (TSX) and TanDEM-X (TDX)
- US Geological Survey (USGS): Landsat 8

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

This data set was first published in October 2017, with annual updates thereafter. In April 2020 the data access location was changed, leading to renaming of all data files to conform to the version-numbering standard.

5 RELATED DATA SETS

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

6 RELATED WEBSITES

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

7 CONTACTS AND ACKNOWLEDGMENTS

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Contains modified Copernicus Sentinel data (2014-2016), acquired by the ESA, distributed through the Alaska Satellite Facility, processed by Joughin, I. and from the TanDEM-X and TerraSAR-X missions processed by DLR, as well as results derived from optical images collected by Landsat-8 processed by USGS.

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9 DOCUMENT INFORMATION

9.1 Publication Date

20 March 2020

9.2 Date Last Updated

16 April 2020