



# MEaSURES Greenland Annual Ice Sheet Velocity Mosaics from SAR and Landsat, Version 2

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## USER GUIDE

### How to Cite These Data

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

Joughin, I. 2017, updated 2020. *MEaSURES Greenland Annual Ice Sheet Velocity Mosaics from SAR and Landsat, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. <https://doi.org/10.5067/10.5067/TZZDYD94IMJB>. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT [NSIDC@NSIDC.ORG](mailto:NSIDC@NSIDC.ORG)

FOR CURRENT INFORMATION, VISIT <https://nsidc.org/data/NSIDC-0725>



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 Ice Sheet Velocity Mosaics from SAR and Landsat* and *MEaSURES Greenland Monthly Ice Sheet Velocity Mosaics from SAR and Landsat*. Refer to the Version History table for details about changes to the data set.

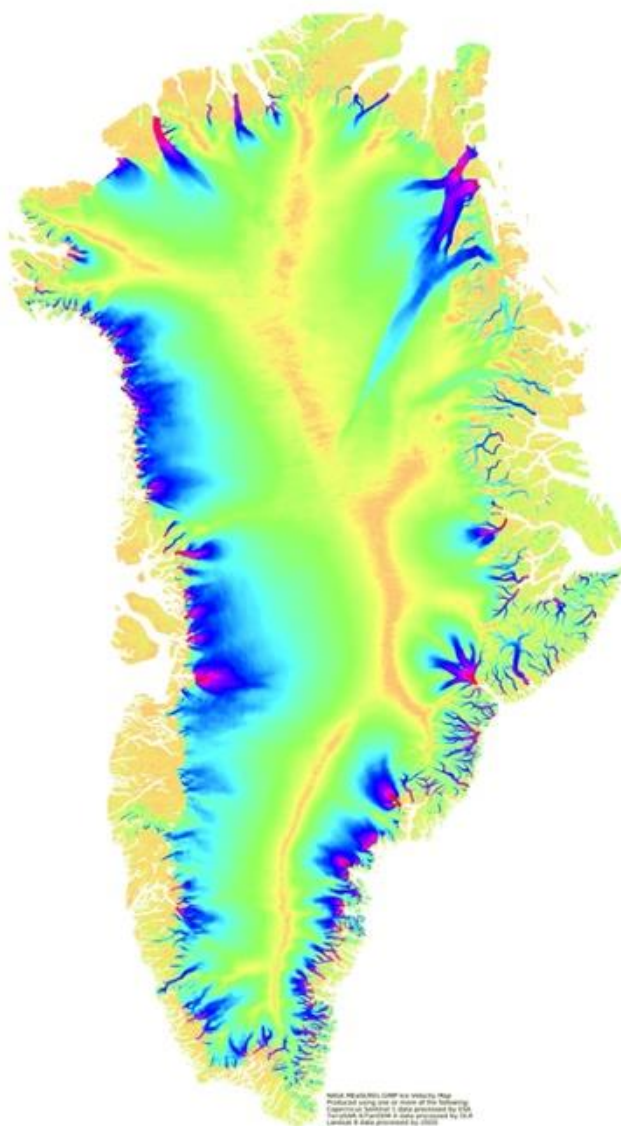


Figure 1. Sample browse.jpg file for the dates 01 December 18 to 30 November 2019

## 1.1 Parameters

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The overall parameter for this data set is ice velocity.

### 1.1.1 Ice Velocity Parameters



Figure 2. Sample vx.tif file for the dates 01 December 18 to 30 November 2019

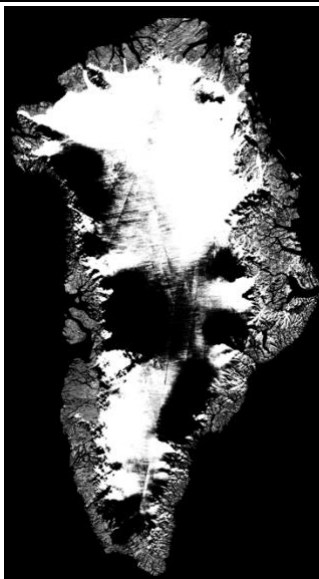


Figure 3. Sample vy.tif file for the dates 01 December 18 to 30 November 2019.



Figure 4. Sample vv.tif file for the dates 01 December 18 to 30 November 2019; gray scale version of color log scale velocity saturating at 3000 m/year.



Figure 5. Sample dT.tif file for the dates 01 December 18 to 30 November 2019

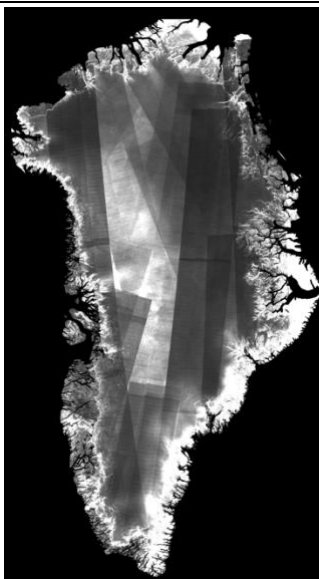


Figure 6. Sample ex.tif file for the dates 01 December 18 to 30 November 2019

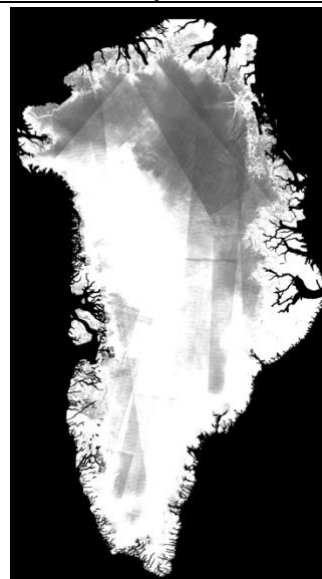


Figure 7. Sample ey.tif file for the dates 01 December 18 to 30 November 2019

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, EPSG 3413. 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). The velocity magnitude, “ $v$ ”, a scalar value, was calculated using the following formula:  $\sqrt{vx^2 + vy^2}$

### 1.1.2 Temporal Offset

The  $dT$  metric is the difference between the date for each velocity estimate and the midpoint date of the period measured. This metric can be used to measure temporal skew in the data.

The nominal time stamp for each mosaic is the midpoint date over the sampling period. So, in the case of the annual mosaics the midpoint is either May 31st or June 1st in a leap year. Due to the way the data are combined the time stamp is nominal rather than exact.

The  $dT$  for each point represents the number of days between the date for the velocity estimate for that point and the midpoint date of the annual measurement period. For example, if the mosaic covers the interval from 01 December 2014 to 30 November 2015, then the nominal midpoint date would be 31 May 2015, thus a value  $dT=5$  for a point would indicate that 05 June better represents the midpoint for the data.

Although the averaged  $dT$  value provides some idea of the deviation from nominal date, **users should be cautious when using  $dT$  to correct date**. For more information regarding this topic, including how  $dT$  is calculated and its usage, refer to the Processing section.

### 1.1.3 Error Estimates

Error estimates represent the average behavior of the data and 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. For more on error estimates, please refer to the section on Quality, Errors, and Limitations

### 1.1.4 Landsat 8 and Synthetic Aperture Radar Shapefiles

Shapefile ancillary files are provided for each data year to indicate the source image pairs that were processed to produce the mosaics. These are provided for the US Geological Survey (USGS)-provided Landsat 8 (L8s) and the German Aerospace Center (DLR) and European Space Agency (ESA)-provided Synthetic Aperture Radar (SAR) data.

## 1.1.5 Browse Files

JPG and GeoTIFF browse files provide an overview of the data. The files come in two resolutions, 200 m for TIFF and 500 m for the JPG files. In addition, there is an auxiliary file, .jpg.aux.xml, which provides projection information.

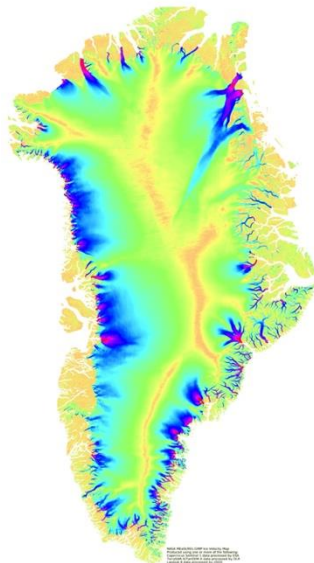


Figure 8. Sample browse.jpg file for the dates 01 December 18 to 30 November 2019

## 1.2 File Information

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### 1.2.1 Format

Data are provided at 200 m resolution in cloud optimized GeoTIFF (.tif) format and 500 m resolution for the browse .jpg file. Also available are tif.aux.xml GeoTIFFs with GDAL-generated image statistics, used by many GIS programs for image scaling. Auxiliary files may contain information regarding color, statistics, and geographic coordinates or projections

Velocity data files available for each data year and resolution include:

- velocity magnitude map (vv),
- separate x- and y-component velocities (vx, vy),
- separate x- and y-component error estimates (ex, ey),
- (dT) temporal offset; and
- 500 m resolution browse file in .tif format, and a browse file (with color log scale velocity saturating at 3000 m/year).

Statistical information for a raster (image) data sets are stored as jpg.aux.xml or .tif.aux.xml files. The LS8 and SAR data contain shapefiles used by most GIS software to geographically represent

data. Shapefiles consist of a folder within which are several files all of the same name but with different extensions: .dbf, prj, .shp, and .shx.

## 1.2.2 Naming Convention

All files follow the same file naming convention. The only components of the name which change per the product or parameter and the file type.

Table 1. File Naming Conventions

File Name Component	GeoTiff	JPEG	Shapefile
GL_vel_mosaic_Annual	Greenland Annual Ice Sheet Velocity Mosaics from SAR and Landsat		
Start date	Date of first image used in mosaic period (DDMonYY)		
End date	Date of last image used in mosaic period (DDMonYY)		
Parameter	Velocity Parameters dT: Temporal offset ex: x-axis error ey: y-axis error vv: velocity vx: x-axis velocity vy: y-axis velocity browse: vv browse image	browse: vv browse image	LS8: Landsat 8 SAR: Synthetic Aperture Radar
vxx.x	Version number		
.ext	File extension, cloud optimized GeoTIFF: .tif (raster) .tif.aux.xml (auxiliary file containing GDAL generated image statistics)	.jpg (raster) .jpg.aux.xml (auxiliary file containing GDAL generated image statistics)	Shapefiles consisting of four files with extensions: .dbf the database file .prj (projection information) .shp (shapes) .shx (shape indices)

## 1.2.3 Example File Names

### 1.2.3.1 Velocity Files

GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_dT\_v02.0.tif  
 GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_dT\_v02.0.tif.aux.xml  
 GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_ex\_v02.0



GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_ex\_v02.0.tif.aux.xml  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_ey\_v02.0  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_ey\_v02.0.tif.aux.xml  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_vv\_v02.0  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_vv\_v02.0.tif.aux.xml  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_vx\_v02.0.tif  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_vx\_v02.0.tif.aux.xml  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_vy\_v02.0.tif  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_vy\_v02.0.tif.aux.xml

### 1.2.3.2 Shapefiles

#### LS8

GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_LS8\_v02.0.dbf  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_LS8\_v02.0.shp  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_LS8\_v02.0.shx  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_LS8\_v02.0.txt

#### SAR

GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_SAR\_v02.0.dbf  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_SAR\_v02.0.shp  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_SAR\_v02.0.shx  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_SAR\_v02.0.txt

### 1.2.3.3 Browse Files

GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_browse\_v02.0.jpg  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_browse\_v02.0.jpg.aux.xml  
  
GL\_vel\_mosaic\_Annual\_01Dec18\_30Nov19\_browse\_v02.0.tif

## 1.3 Spatial Information

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### 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 a 200 m grid resolution, 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 if 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

Velocity parameters 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). The SAR and LS8 shapefiles are in EPSG 4326.

Table 2. Northern Hemisphere Projection Based on WGS 1984 (EPSG: 3413)

<b>Geographic Coordinate System</b>	WGS 84
<b>Projected Coordinate System</b>	WGS 84 / NSIDC Sea Ice Polar Stereographic North
<b>Longitude of True Origin</b>	-45
<b>Latitude of True Origin</b>	70
<b>Scale factor at longitude of true origin</b>	1
<b>Datum</b>	WGS 1984
<b>Ellipsoid/spheroid</b>	WGS 84
<b>Units</b>	meter
<b>False Easting</b>	0
<b>False Northing</b>	0
<b>PROJ4 String</b>	+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
<b>Reference</b>	<a href="http://epsg.io/3413">http://epsg.io/3413</a>

Table 3. Geographic Coordinate System

<b>Geographic Coordinate System</b>	WGS 84
<b>EPSG code</b>	4326
<b>PROJ4 string</b>	+proj=longlat +datum=WGS84 +no_defs
<b>Reference</b>	<a href="http://epsg.io/4326">http://epsg.io/4326</a>

## 1.4 Temporal Information

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### 1.4.1 Coverage

This data set provides annual velocity mosaics for 2015 to 2019. 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 equals one year.

## 2 DATA ACQUISITION AND PROCESSING

### 2.1 Acquisition

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These image mosaics were produced mostly from Copernicus, Sentinel-1A, Sentinel-1B data from the European Space Agency (ESA), 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, USGS's Landsat 8 velocities were merged with SAR data during periods when there was sufficient daylight.

#### 2.1.1 Annual Variations in Data Acquisition

This section details variations in data acquisition for the given time frames.

- 2015 (Dec 1, 2014 – Nov 30, 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 were not acquired by the satellite for a month or more), which reduces the averaging of seasonal variation.
- 2016 (Dec 1, 2015 – Nov 30, 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 these mosaics is considerably better than the mosaics for 2015 for most regions.

- 2017 (Dec 1, 2016 – Nov 30, 2017): These products are similar to the earlier 2015 and 2016 products. The major difference is that this is the first year that 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, so the results should be improved for areas south of 67.5 degrees.
- 2018 (Dec 1, 2017 – Nov 30, 2018): These products follow the same specifications as the previous year's release, with the following minor differences: some data using a few scenes from the COntellation of small Satellites for the Mediterranean basin Observation (COSMOSSkyMed) were included; some of the glaciers which were monitored by TSX in past years are covered by other instruments during this year.
- 2019 (Dec 1, 2018 – Nov 30, 2019): See specifications for previous releases.

## 2.2 Processing

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These annual mosaics were computed as averages of all available data at each point and weighted by their respective errors (Joughin, 2002). As such, they 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. Where these data are included, the error are generally substantially lower than solutions with azimuth offsets, which can be subject to large errors due to ionospheric streaking. By virtue of the error weighting, the range-offset-only solutions tend to dominate the aggregate solution, to yield more accurate results. In the latest product, the mosaics are all processed with a variation of the GIMP DEM (NSIDC-0715), of lower resolution (270 m), and geoidal heights are used for the ocean. Data have more robust error checking. Each estimate is compared against the statistics from the entire time series. Data are discarded if they exceed a threshold (e.g., 3sigma). The final products are also manually edited to remove obvious artifacts.

### 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 Aggregation and Weighting

For each year, all available data are aggregated and combined in an error-weighted method to achieve an optimal estimate with respect to error reduction. Due to limited coverage or lack of unsuccessful matches, there are data gaps such that the full annual period may not be sampled uniformly.

## 2.2.3 Temporal Offset Calculation

It is recommended that the  $dT$  parameter is used to flag potential time-skew issues, and that it is not used for date correction. As a result of the data aggregation process, the true date represented by the data may differ from the nominal midpoint date of the mosaic period.

As a measure of temporal skew, the mean deviation,  $dT$ , 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  $dT$ s. In the final mosaicking step, any data with  $dT$  greater than one-half the output interval was discarded. As a result, for the annual product, the time stamp error is less than or equal to approximately 183 days.

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 i.e., quarterly, monthly or annual.
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.  $dT = \text{weighted average central date} - \text{midpoint}$ .

Although the averaged  $dT$  value provides some idea of the deviation from nominal date, users should be cautious when using  $dT$  to correct dates. For example, if the mosaic covers the period from 01 December 2014 to 30 November 2015, the nominal midpoint would be 31 May 2015, thus

a value  $dT=5$  would indicate that 05 June better represents the midpoint. However, there are convoluted cases that could also result in a  $dT=5$ . For examples of complex or convoluted cases, please refer to section 2.2.3 of the User Guide for [NSIDC-0727](#), MEaSURES Greenland Quarterly Ice Velocity Mosaics from SAR and Landsat, Version 2.

The use of  $dT$  to flag potential time skew issues is recommended, rather than for date correction. If a large temporal skew is identified, the use of other GIMP products with finer temporal sampling is recommended to analyze the temporally varying behavior.

## 2.2.4 Potential Artifacts

The data are posted to 200 m grid; however, the true resolution varies between a few hundred m to 1.5 km. Posting represents the spacing between samples and should not be confused with the resolution at which the data were collected. 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.

## 2.2.5 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.

## 2.2.6 Areas with No Data

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. This occurs most often in areas with high snow accumulation. The no data value for  $vv$ ,  $ex$ , and  $ey$  files is -1. The no data value for  $vx$ ,  $vy$  and  $dT$  is  $-2e9$ .

## 2.2.7 Geometric Terrain Correction

The mosaics in this data set were geometrically terrain-corrected with a 270 m slightly modified version of *MEaSURES Greenland Ice Mapping Project (GIMP) Digital Elevation Model from GeoEye and WorldView Imagery, Version 1*. The modified version of the DEM differed from the published one in that it used geoidal heights for the ocean.

## 2.3 Quality, Errors, and Limitations

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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 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

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### 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

Table 4. Version History Summary

Version	Release Date	Description of Changes
1.0	October 2017	Initial release
		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.



Version	Release Date	Description of Changes
2.0		<p>The following list summarizes changes:</p> <ul style="list-style-type: none"> <li>• New file naming convention.</li> <li>• Data set temporal range increased by one year from: 01 December 2014 to 30 November 2019.</li> <li>• Application of a modified version of the latest DEM, NSIDC-0715; prior versions relied on NSIDC-0645</li> <li>• Addition of dT GeoTIFFs, a temporal offset parameter.</li> <li>• All files have a 200 m resolution with the exception of the browse.jpg which is at 500 m; 500 m resolution velocity files no longer available</li> <li>• A more rigorous culling of the data removed bad data and added previously overlooked data. As a result, mosaics show more areas with no data, the min/max ex and ey values are lower, and SAR/LS8 feature counts differ from Version 1.</li> <li>• The no data value for vv changed from -0.1 to -1; the no data value for ex and ey changed from -2e9 to -1.</li> <li>• Newly available are cloud-optimized GeoTIFFs along with tif.aux.xml, and jpg.aux.xml files.</li> </ul>

## 5 RELATED DATA SETS

- [MEaSURES Greenland Quarterly Ice Sheet Velocity Mosaics from SAR and Landsat](#)
- [MEaSURES Greenland Monthly Ice Sheet Velocity Mosaics from SAR and Landsat](#)
- [MEaSURES Greenland Ice Velocity: Selected Glacier Site Velocity Maps from InSAR](#)
- [MEaSURES Greenland Ice Sheet Velocity Map from InSAR Data](#)

## 6 RELATED WEBSITES

- [MEaSURES Data | Overview](#)
- [Alaska Satellite Facility](#)
- [Greenland Ice Mapping Project \(GIMP\)](#)

## 7 CONTACTS AND ACKNOWLEDGMENTS

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### Acknowledgements

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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

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### 9.2 Date Last Updated

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