MEaSUREs Greenland Quarterly Ice Velocity Mosaics from SAR and Landsat, Version 3

USER GUIDE

How to Cite These Data

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

Joughin, I. 2018, updated 2021. *MEaSUREs Greenland Quarterly Ice Sheet Velocity Mosaics from SAR and Landsat*, *Version 3*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/7D8Z6UMS8AD4. [Date Accessed].

Literature Citation

As a condition of using these data, we request that you acknowledge the author(s) of this data set by referencing the following peer-reviewed publications.

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

Joughin, I., B. Smith, and I. Howat. 2018. Greenland Ice Mapping Project: ice flow velocity variation at sub-monthly to decadal timescales, *The Cryosphere*. 12. 2211-2227. https://doi.org/10.5194/tc-12-2211-2018

FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/NSIDC-0727

National Snow and Ice Data Center

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1 DATA DESCRIPTION

These data provide quarterly (three-month interval) surface velocity estimates for the Greenland Ice Sheet and periphery. To access annual or monthly velocities see related GIMP datasets: MEaSUREs Greenland Annual 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 section of this document for details about changes to the data set.

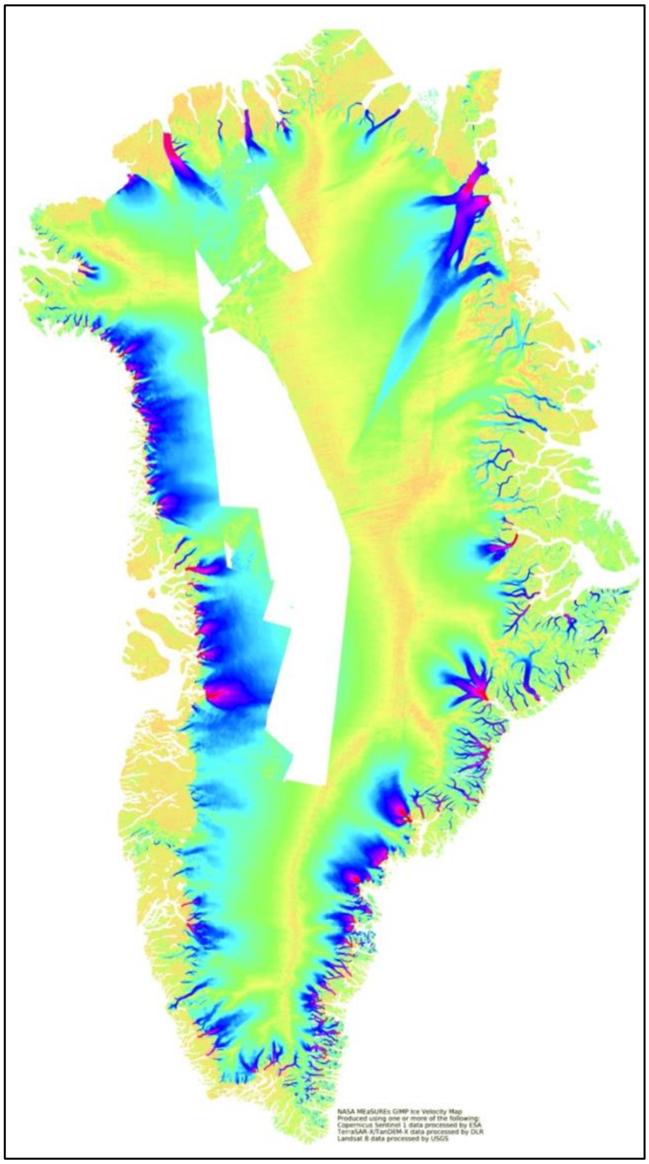

Figure 1. Sample browse.jpg file for the dates 01 September 2019 to 30 November 2019

1.1 Parameters

The parameter for this data set is ice velocity.

1.1.1 Ice Velocity Parameters

Figure 2. Sample vx.tif file for dates 01 September 2019 to 30 November 2019.

Figure 3. Sample vy.tif file for dates 01 September 2019 to 30 November 2019.

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

Figure 5. Sample dT.tif file for dates 01 September 2019 to 30 November 2019.

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

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

Velocities are reported in meters per year. 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 holes 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, “vv”, a scalar value, was calculated using the following formula: $\sqrt{vx^2 + vy^2}$

1.1.1.1 Temporal Offset

The dT metric is the difference between the date for each velocity estimate and the midpoint date. 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 quarter 01 March 2015 to 31 May 2015 the midpoint is 15 April. 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 quarterly measurement period. For example, if the mosaic covers the interval from 01 March 2015 to 31 May 2015, then the nominal midpoint date would be 15 April 2015, thus a value dT=5 for a point would indicate that 20 April 2015 better represents the date for that point.

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.

1.1.1.2 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.

1.1.1.3 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 (LS8) and the German Aerospace Center (DLR) and European Space Agency (ESA)-provided Synthetic Aperture Radar (SAR) data.

1.1.1.4 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.

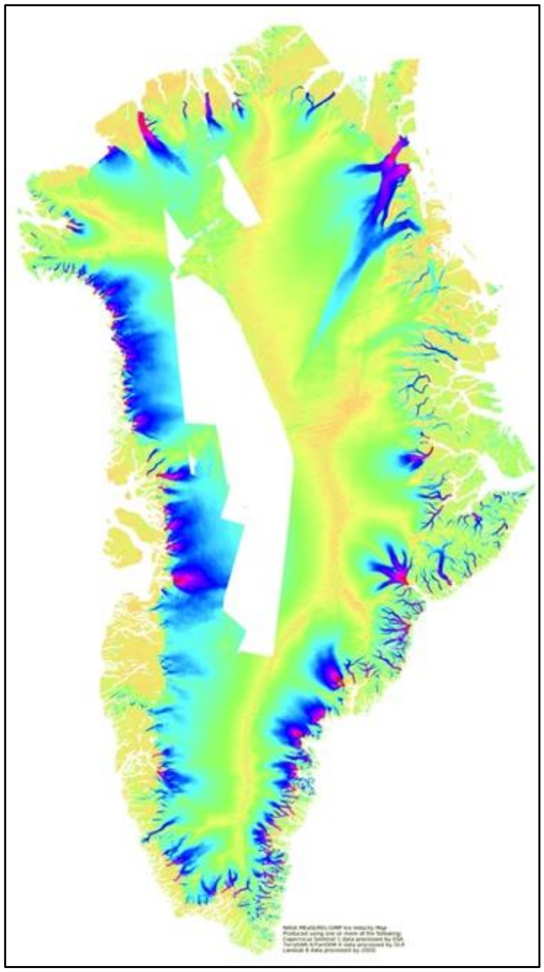

Figure 8. Sample browse.jpg Image for the period covering 01 September 2019 to 30 November 2019.

1.2 File Information

1.2.1 Format

Data are provided at 200 m resolution in cloud optimized GeoTIFF (.tif) format and at a 500 m resolution for the browse .jpg file. The GeoTIFFs were generated with GDAL 3.2.1 so the image statistics are written directly into the GeoTIFF file header. The statistical information for the 500 m .jpg browse files is stored in the accompanying .jpg.aux.xml files.

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).

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

This section explains the file naming convention used for this product with examples of the different file types. Refer to Table 1 for file name details. The general format for file names is as follows:

```
Product_startdate_enddate_parameter_version_filetype
```

Table 1. File Naming Conventions

File Name Component	GeoTIFF	JPEG	Shapefile
Product	GL_vel_mosaic_Quarterly: Greenland Ice Sheet Velocity Mosaic		
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
v0#.#	Version number		
.ext	File extension, cloud optimized GeoTIFF: .tif; (raster)	.jpg (raster) .jpg. aux.xml (auxiliary file containing GDAL generated image statistics)	Shapefiles consisting of four files with extensions: .dbf the database file

File Name Component	GeoTIFF	JPEG	Shapefile
			.prj (projection information) .shp (shapes) .shx (shape indices)

1.2.3 Example File Names

1.2.3.1 Velocity Files

```
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_dT_v03.0.tif
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_ex_v03.0.tif
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_ey_v03.0.tif
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_vv_v03.0.tif
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_vx_v03.0.tif
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_vy_v03.0.tif
```

1.2.3.2 Shapefiles

LS8

```
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_LS8_v03.0.dbf
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_LS8_v03.0.prj
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_LS8_v03.0.shp
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_LS8_v03.0.shx
```

SAR

```
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_SAR_v03.0.dbf
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_SAR_v03.0.prj
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_SAR_v03.0.shp
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_SAR_v03.0.shx
```

1.2.3.3 Browse Files

```
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_browse_v03.0.jpg
GL_vel_mosaic_Quarterly_01Sep19_30Nov19_browse_v03.0.jpg.aux.xml

GL_vel_mosaic_Quarterly_01Sep19_30Nov19_browse_v03.0.tif
```

1.3 Spatial Information

1.3.1 Coverage

This data set spans the entire Greenland Ice Sheet.

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 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 30 or more individual measurements. Although this enhances the final resolution beyond that of the individual source products, the amount is 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)

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	https://epsg.io/3413

Table 3. Geographic Coordinate System (4326)

Geographic Coordinate System	WGS 84
EPSG Code	4326
PROJ4 String	`+proj=longlat +datum=WGS84 +no_defs`
Reference	http://epsg.io/4326

1.4 Temporal Information

1.4.1 Coverage

This data set provides quarterly (approximately three-month) velocity mosaics for the time period from December 2014 to May 2021. Data is compiled quarterly. Quarterly periods are defined as:

December 1 to February 28 (or 29)
March 1 to May 31
June 1 to August 31
September 1 to November 30

1.4.2 Resolution

The temporal resolution equals three months.

2 DATA ACQUISITION AND PROCESSING

2.1 Acquisition

These image mosaics were produced from data acquired by European Space Agency (ESA) Copernicus Sentinel-1A and Sentinel-1B satellites and supplemented with DLR TSX/TDX data 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 COnstellation 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

Quarterly mosaics represent three-month periods. They 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 three-month averages. For example, in some places the first half of a quarterly period may be weighted more heavily than the latter half 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, comparing adjacent years at any location might reveal 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 errors 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. This product uses a variation of the GIMP DEM (NSIDC-0715). The variation has a lower resolution of 270 m and geoidal heights are used for the ocean. The DEM used in this Version (v03) also contains a correction to a 15m horizontal shift that was identified in the DEM used in the previous version of this product. See the blue box below for further details on the implications of this correction for users. 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.

Note to Users: For version 3 of this product, an additional correction was made to the DEM to address a horizontal shift of 15 m identified in version 2 data, resulting in some changes to the data between version 2 and version 3. While in general the differences are minor (~< 1m/yr), very large differences (> 1000 m/yr) may occur at isolated pixels near steep calving fronts or other steep slopes. Points in these regions should always be treated with some degree of caution. Even with these extreme outliers, the root-mean-square differences are < 2 m/yr for the entire map.

2.3 Baseline Fits

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). For periods where data are not well controlled (sparse ground control points), control points from other periods with adequate controls were used. This greatly improves consistency of the data between each quarterly product. 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 interannual 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 1,000 m to 2,000 m); in other words, areas where the observed changes seem to follow a satellite swath boundary should be avoided. Refer to Figure 5 in Phillips et al. (2013) for an example.

2.3.1 Aggregation and Weighting

For each three-month period, 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 three-month period may not be sampled uniformly. In order to maximize coverage, data were included where the sampling interval of the input data did not fully lie within the output interval. In these cases, these 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). If uniformly sampled data (e.g., every 12-days) and uniformly weighted data were combined, this procedure would be equivalent to a linear interpolation of the time series. Finally, to reduce error and improve coverage, data were also included where the input estimate spanned an interval longer than the output interval (e.g., up to a 5-month pair for the three-month output). This inclusion slightly degrades the temporal resolution, but improves coverage and helps reduce errors. For these data, weights are applied to deemphasize the contribution of data spanning more than three months (i.e., they are only a factor where coverage from other data is poor). As a result, the nominal three-month resolution is applicable to most of the data set, but could be less in some regions.

2.3.2 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 center interval date.

As a measure of temporal skew, the mean deviation, dT, was calculated from the center interval 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 center interval date, and then weighted using the same methods as the velocity data. In estimating velocity, different weights are used for the vx and vy 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 were discarded. As a result, the time stamp error for the three-month product is less than or equal to approximately 45 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 vx and vy components.
4. dT = weighted average central date – midpoint.

Although the averaged dT value provides some idea of the deviation from the nominal date, users should be cautious when using dT to correct dates. For example, for a quarterly mosaic that covers the period 01 March – 31 May, the nominal center date is 15 April. If dT=10, then 25 April would better represent the midpoint date for the parameters in this interval. However, there are convoluted cases that could also result in a dT=10:

- The mosaic could have been produced using images collected from March 13 to March 24 and May 5 to May 18, which would result in a dT=10 even though there were no measurements for April 25,
- Alternatively, the mosaic could have been produced using a single pair from April 20 to April 30 which would have sampled April 25, and also produced a dT=10.

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.

2.3.3 Potential Artifacts

The data are posted to a 200 m grid, but the true resolution varies between 500 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.

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

2.3.5 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.

2.3.6 Geometric Terrain Correction

The mosaics in this data set were geometrically terrain-corrected with 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 and has a resolution of 270 m. Additionally, a correction was made to the modified DEM to address a 15 m horizontal shift identified in the previous, version 2, data set. See section 2.2, note to users for additional information.

2.3.7 GDAL-Generated Cloud Optimized GeoTIFFs

The GeoTIFFs were generated using Geospatial Data Abstraction Library (GDAL) 3.2.1 to make them compatible with the latest cloud optimized GeoTIFF format. GDAL generates previews for Cloud Optimized GeoTIFFs and the default is to use cubic interpolation, but this results in minor artifacts around the lower resolution previews. Therefore, averaging is used instead to avoid this issue and aliasing. Also, this version of GDAL writes the image statistics directly to the file header.

2.4 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 noise level.

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 when 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.

2.5 Instrumentation

2.5.1 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 Geologic Survey (USGS): Landsat 8

3 SOFTWARE AND TOOLS

GeoTIFF files, virtual raster 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
3.0	June 2021	This version update includes: • Use of GDAL 3.2.1 to create cloud optimized GeoTIFFs • Update of temporal coverage • Data reprocessed utilizing a corrected DEM. See user note in section 2.2
2.0	December 2020	This version update includes: • New file naming convention • Data set temporal range increased by one year from: 01 December 2014 to 30 November 2019. • Application of a new DEM, NSIDC-0715; prior versions relied on NSIDC-0646 • 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 • 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. • 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. • Newly available are cloud-optimized GeoTIFFs along with tif.aux.xml, and jpg.aux.xml files.

1.1	October 2019	This version update includes: • Updated the .tif file names within the .vrt files to match the actual .tif file names
1.0	February 2018	Initial release

5 RELATED DATA SETS

- MEaSUREs Greenland Annual 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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Contains modified Copernicus Sentinel data (2014-2019), 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

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