MEaSUREs Greenland Ice Velocity: Selected Glacier Site Velocity Maps from Optical Images, Version 2

USER GUIDE

How to Cite These Data

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

Howat, I. 2017, updated 2019. *MEaSUREs Greenland Ice Velocity: Selected Glacier Site Velocity Maps from Optical Images, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/VM5DZ20MYF5C. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/nsidc-0646

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

1.1.1 Parameter Description

This data set reports the following parameters:

- Ice velocities (x- and y-components)
- Error estimates (x- and y-components)

Corresponding ASCII text metadata files (`.meta`) are also provided and contain geographical information plus dates and codes that reveal the sensor combinations of the images used to create the monthly mean. The sensor combination key is provided in Table 1.

Table 1. Sensor Key for Metadata Files

Sensor	Code
Landsat 8 OLI	LC08
Landsat 7 ETM+	LE07
Landsat 5 TM	LT05
Landsat 4 TM	LT04
ASTER	ASTR

The following sensor combinations are possible: LT04/LT04, LT04/LT05, LT05/LT05, LT05/LE07, LT05/ASTR, LE07/LE07, LC08/LC08, LE07/LC08, ASTR/ASTR, LE07/ASTR, LC08/ASTR.

1.2 File Information

1.2.1 Format

This data set is organized into 74 study sites. Study sites in this data set correspond to geographical sub-regions of Greenland. The name of each sub-region reflects its center latitude. Table 3 of this document lists the name (center latitude) of each sub-region, the latitude and longitude of its lower left corner, and the geographical features it contains.

The following files are provided for each site:

- Velocity browse image (PNG)
- Component velocity in the x-direction (GeoTIFF)
- Component velocity in the y-direction (GeoTIFF)

- Error estimates in the x-direction (GeoTIFF)
- Error estimates in the y-direction (GeoTIFF)
- Metadata file (ASCII text)

1.2.2 File Size

Each data file ranges in size from 0.3 MB to 5.1 MB.

The total data volume is approximately 41.3 GB.

1.2.3 Directory Structure

Data are available via HTTPS in the following directory:

`https://daacdata.apps.nsidc.org/pub/DATASETS/nsidc0646_MEASURES_greenland_vel_optical_v2`

In this directory, there are 74 folders corresponding to the 74 study sites. Within each of these folders, there are subfolders for each date of acquisition. Each subfolder contains six data files.

1.2.4 Naming Convention

This section describes the naming convention for this product with an example. Refer to Table 2 for descriptions of the values in the file naming convention.

File Naming Convention:

`OPT_[sub-region]_[date]_[datum]_[v02.1].[ext]`

Example File Names:

- OPT_E61.10N_1999-09_v02.1.png
- OPT_E61.10N_1999-09_vx_v02.1.tif
- OPT_E61.10N_1999-09_vy_v02.1.tif
- OPT_E61.10N_1999-09_ex_v02.1.tif
- OPT_E61.10N_1999-09_ey_v02.1.tif
- OPT_E61.10N_1999-09_v02.1.meta

Table 2. File Name Variables and Descriptions

Variable	Description
OPT	Velocities derived from optical image pairs acquired by Landsat 8 OLI, Landsat 7 ETM+, Landsat 4 TM, Landsat 5 TM, ASTER or a combination.

Variable	Description
Sub-region	Sub-region names are defined as follows: • E, W, or S: East, West, or South Coast • Center latitude in degrees, minutes
Date	Date of acquisition (YYYY-MM)
Datum	Component velocity or component error estimate: • vx: x-component of velocity • vy: y-component of velocity • ex: x-component of error • ey: y-component of error
V02.1	Version number
Ext	File extension: • `.png`: Portable Network Graphic file • `.tif`: GeoTIFF-formatted file • `.meta`: ASCII text file. Contains image dates, production date, sensor combinations, and geographical information.

1.3 Spatial Information

1.3.1 Coverage

This data set contains velocity maps for most of the outlet glaciers on the Greenland Ice Sheet. The study area lies within the following bounding box:

- Southernmost Latitude: 60° N
- Northernmost Latitude: 82° N
- Easternmost Longitude: 20° W
- Westernmost Longitude: 70° W

1.3.2 Resolution

100 m

1.3.3 Geolocation

GeoTIFFs 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).

Table 3. Sub-Region Names, Locations, and Geographical Features

Sub-Region Name • **Latitude, Longitude (lower left corner)**	**Geographical Features in Grid**
E61.10N • 60.8004, -43.9589	• Unnamed glacier near Danell Fjord • Danells • Kanderdluluk Fjord • Cape Herluf Trolle • Cape Tordenskjold
E61.70N • 61.3903, -43.7671	• Anorituup Kangerlua Fjord • Napasorsuaq Fjord
E62.10N • 61.801, -43.2149	• Puisortoq Glacier (north) • Puisortoq Fjord (south)
E62.55N • 62.2422, -43.6371	• Mogens Heinesen Fjord • Timmiarmiut Fjord
E63.00N • 62.7212, -43.5332	• Heimdal Glacier
E63.35N • 63.0911, -42.5656	• Thrym Glacier • Sehested Fjord • Skinfaxe Glacier
E63.85N • 63.5620, -42.4419	• Bernstorffs Fjord
E64.35N • 64.0768, -42.2688	• Gyldenlove Fjord
E64.65N • 64.3291, -41.7539	• Fridtjof Nansens Peninsula
E65.10N • 64.7987, -41.8569	• Koge Bay
E65.55N • 65.2242, -40.5156	• Ikertivaq Sound • Pamiatig
E66.00N • 65.9492, -38.6334	• Bruckner • Heim
E66.50N • 66.1973, -39.1116	• Fenris Glacier • Helheim Glacier
E66.60N • 66.3305, -37.4428	• Midgard Glacier • Midgard North
E66.90N • 66.5045, -36.2923	• Kruuse Fjord • Steenstrup Glacier • Tasiilaq Fjord

Sub-Region Name • **Latitude, Longitude (lower left corner)**	**Geographical Features in Grid**
E67.55N • 67.2762, -34.9643	• Norde Parallel Glacier • Nordre
E68.05N • 67.9148, -33.9170	• Hutchinson Glacier
E68.50N • 68.3044, -31.1040	• Courtauld Glacier • Frederiksborg Glacier • Christian IV Glacier • Sorgenfri Glacier
E68.52N • 68.3044, -31.1040	• Schjelderup Glacier • Sorgenfri Glacier
E68.75N • 68.5151, -30.1133	• Rosenborg • Kronborg • Borggraven
E68.80N • 68.4663, -34.3672	• Kangerdlussuaq Glacier • Nordfjord Glacier
E68.95N • 68.7516, -27.7071	• Sortebrae
E69.30N • 69.1760, -26.1549	• Barclay Bay • unnamed glacier
E69.80N • 69.6752, -25.0537	• Steno • Bartholin
E69.90N • 69.8224, -29.5537	• unnamed glaciers
E70.10N • 70.0023, -26.7390	• Syd Glacier
E70.40N • 70.0488, -30.6613	• Rolige Glacier
E71.05N • 70.9090, -30.0003	• Harefjord • Rypefjord • unnamed glacier
E71.75N • 71.4887, -30.9758	• Daugaard-Jensen Glacier
E71.95N • 71.7410, -29.9742	• Daugard-Jensen Glacier
E74.05N • 73.9482, -26.4408	• Waltershausen
E75.15N • 75.1665, -23.2614	• Heinkel

Sub-Region Name • **Latitude, Longitude (lower left corner)**	**Geographical Features in Grid**
E75.70N • 75.6225, -23.3212	• Ejnar Mikkelsen • Storm Stejl
E76.55N • 76.2080, -24.5210	• Bistrup • Brede • Storstrommen
E77.55N • 77.51625, -22.7208	• Kofoed-Hansen
E78.95N • 78.7851, -22.2120	• Gammel Hellerup Glacier
E79.40N • 79.190, -24.0779	• Fjorden
W61.30N • 61.2671, -47.8697	• unnamed
W61.70N • 61.4746, -48.4912	• Sermiligarssuk Fjord
W62.10N • 61.8077, -49.0172	• Nigerdlikasik Glacier • Avangnardleq Glacier • Ukassorssuaq
W63.05N • 62.9804, -49.7627	• Nakaissorssuaq
W64.25N • 63.9263, -49.8721	• Kangiata Nunata Sermia Glacier • Quamanarssup Glacier
W64.75N • 64.4610, -50.1732	• Ujarassuit Paauat Fjord • Narsap Sermia Glacier
W67.95N • 67.9133, -50.3921	• Usulluup
W69.10N • 68.7418, -50.4126	• Alangordliup Sermia Glacier • Jakobshavn Isbræ Glacier • Torsukattak Glacier
W69.95N • 69.6356, -50.6122	• Kangilerngata Sermia Glacier • Kujatdleq Glacier • Torsukattak Fjord
W70.55N • 70.2285, -50.9177	• Lille Glacier • Sermilik Glacier • Kangilleq Glacier • Store Glacier
W70.90N • 70.7542, -50.9613	• Perdlerfiup Sermis Glacier • Silardleq

Sub-Region Name • **Latitude, Longitude (lower left corner)**	**Geographical Features in Grid**
W71.25N • 71.1917, -51.5587	• Kangerdluarssup
W71.65N • 71.3100, -51.8327	• Kangerluarsuk Glacier • Rink Glacier
W72.00N • 71.6540, -52.8014	• Inngia Fjord • Umiammakku Glacier
W72.90N • 72.5829, -54.8293	• Alangorssup Sermia Glacier • Upernavik Isstorm Glacier
W73.45N • 73.1520, -55.6912	• Kakivfait Sermiat Glacier • Giesecke Glacier • Nutarmiut Glacier • Tuvssaq (populated area)
W73.75N • 73.1520, -55.6912	• Cornell Glacier • Sugarloaf Bugt (sound) • Ussing Glacier
W74.50N • 74.1506, -56.4843	• Cornel Glacier • Alison Bugy (bay) • Illulik (populated area)
W74.95N • 74.5750, -57.6463	• Hays Glacier • Kjer Glacier • Jensen Glacier
W75.50N • 75.1264, -58.5281	• Dietrichson Glacier • Steenstrup Glacier • Sverdrup Glacier
W75.85N • 75.4736, -59.2722	• Nansen Glacier • Nordenskiold Glacier
W76.10N • 75.7205, -60.0987	• Kong Oscar Glacier • Nordenskiold Glacier • Nutarmiut
W76.25N • 75.9067, -61.2365	• Balgoni • Docker Smith Glacier • Fisher • Igssuarssuit Sermia Glacier • Leven
W76.30N • 76.1846, -68.8535	• Pituffik
W76.33N • 76.1538, -64.2165	• Yngvar Nielsen Glacier • Mohn Glacier

Sub-Region Name • **Latitude, Longitude (lower left corner)**	**Geographical Features in Grid**
W76.35N • 75.7416, -63.3988	• Mohn Glacier • Gade Glacier • Meteor Bay • Yngvar Nielson Glacier
W76.40N • 76.0579, -65.9643	• Savigssuaq Helland • Sidebriks
W76.45N • 76.1084, -67.6907	• Dedodes • Harald Moltke
W77.55N • 77.0728, -66.2296	• Leidy • Mane • Heilprin • Mellville • Tracy
W77.80N • 77.2407, -70.5337	• Qaqortaq • Boudoin
W79.75N • 79.3702, -65.1597	• Humboldt
W80.75N • 81.1505, -46.6109	• Chow
S44.15W • 60.5845, -44.5380	• unnamed glacier
S44.84W • 61.0923, -45.3465	• Kiattuut Sermiat Glacier • Qooroq Fjord
S45.43W • 61.2196, -45.8994	• Equlorutsit Kangigdlit • Sermia
S46.31W • 60.9223, -46.7905	• Eqalorutsit Kangigdlit • Sermia West
S46.91W • 60.8876, -47.3303	• Qaleragdlit • Naujat • Sermilik

1.3.4 Coverage Map

The spatial coverage map below shows the locations of all grids on a map of Greenland. A high resolution image of the map can be downloaded as a Portable Network Graphics (.png) file.
A shapefile of the spatial coverage image is also available.

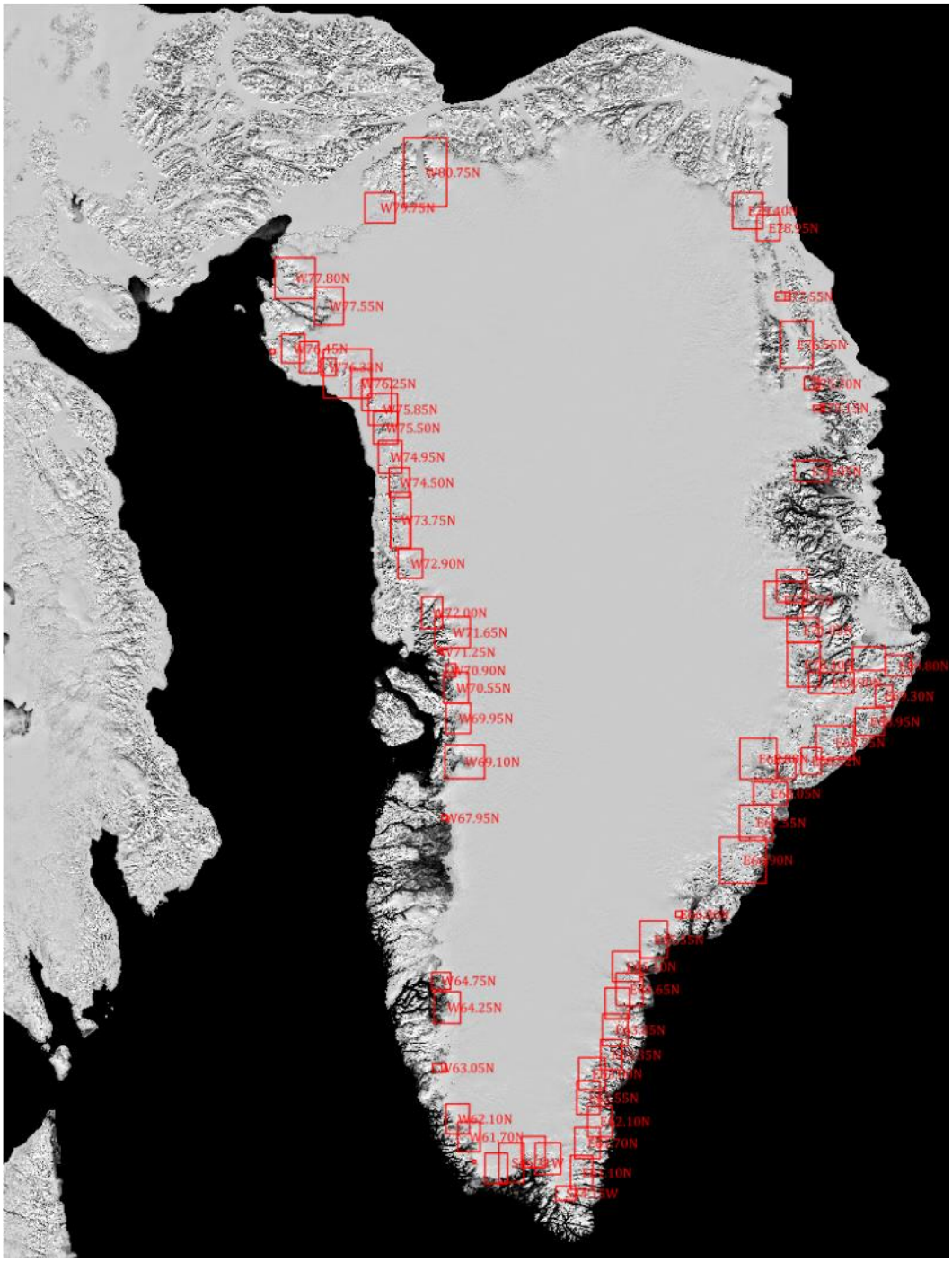

Figure 1. Gridded Spatial Coverage Map

1.4 Temporal Information

1.4.1 Coverage

01 March 1985 to 31 December 2018

1.4.2 Resolution

Monthly

2 DATA ACQUISITION AND PROCESSING

2.1 Acquisition

All Level-1 Landsat imagery was obtained from the U. S. Geological Survey (USGS | Landsat Level 1 Standard Data Products). ASTER (AST14DMO) imagery was obtained from the NASA Land Processes Distributed Active Archive Center (LP DAAC).

2.2 Derivation Techniques and Algorithms

2.2.1 Processing Steps

These data were created using orthorectified Landsat Level L1T or L1G and ASTER (AST14DMO) imagery. Orthorectified images were received in UTM projection and converted to Polar Stereographic using Geographic Data Abstraction Library (GDAL) software. ASTER visible bands 1-3 were reduced to a single grayscale principle component image. The panchromatic band was used for Landsat 7 and 8. For Landsat 4 and 5 TM images, bands 2, 3, and 4 were reduced to a single grayscale principle component image. Velocity fields were constructed using images from the same sensor or combinations of Landsat 4, Landsat 5, Landsat 7, Landsat 8, and ASTER images. In most cases, only Landsat images from the same path/row were correlated to reduce the impact of terrain-dependent errors. To fill in temporal gaps in the 2016 coverage, cross path/row Landsat images were used. To this end, the MEaSUREs Greenland Ice Mapping Project (GIMP) Digital Elevation Model from GeoEye and WorldView Imagery data set and the orthorectifcation algorithm of Rosenau et al. (2012) were used.

Velocity fields were produced by an automated cross-correlation of sequential images using the Multi-Image Multi-Chip (MIMC) algorithm described in Ahn and Howat (2011) and updated in Jeong et al. (2017). The MIMC utilizes a range of image filters and search window sizes as well as both backward and forward matching to generate 64 matches per sample. Neighborhood statistics and an a priori velocity field, consisting of radar-derived velocities closest in time to the image dates from the MEaSUREs Greenland Ice Sheet Velocity Map from InSAR Data data set, were used to select the highest confidence solution and its uncertainty.

This velocity field was then corrected for image re-registration errors by subtracting the average displacement over bedrock or very slow moving ice (< 10 m/year), which is located using the a priori velocity field. The residual deviation of velocities over bedrock then provides the registration

error (see the Error Sources section). Individual velocity image pairs within each region were sampled to the same grid and stacked into monthly medians at each grid point, providing a monthly sampling. The median error was also obtained.

Note: Monthly means are calculated from images, which may have acquisition dates from the preceding or succeeding month. For the naming convention, the month is determined from where the midpoint Julian dates fall. For example, September monthly means may have been generated from images that were acquired in August or in October but the midpoint Julian date between the images falls within September. The exact dates used are included in the meta file.

2.3 Quality, Errors, and Limitations

2.3.1 Error Sources

Uncertainty in the velocity solution results from uncertainty in the match solution and uncertainty in image co-registration. Match solution uncertainty is estimated at each grid point from the sample of individual velocity solutions that results from the MIMC procedure. This error is typically on the order of one-third of a pixel. Co-registration error, the dominant source of uncertainty, is estimated from the residual velocities obtained over bedrock and very slow ice after the mean is removed. These errors vary considerably, but are typically on the order of 100 m/year.

2.4 Instrumentation

2.4.1 Description

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) obtains high-resolution (15 to 90 square meters per pixel) images of the Earth in 14 different wavelengths of the electromagnetic spectrum, ranging from visible to thermal infrared light. ASTER was launched in December 1999 onboard Terra, the flagship satellite of NASA's Earth Observing System (EOS). For more information, see NASA's Terra | ASTER web page.

The Enhanced Thematic Mapper Plus (ETM+) instrument on board Landsat 7 is a fixed “whisk-broom,” eight-band, multispectral scanning radiometer capable of providing high-resolution imaging information of the Earth’s surface. Orbiting at an altitude of 705 km, the instrument detects spectrally-filtered radiation in visible near-infrared, short-wave near-infrared, long-wave near-infrared, and panchromatic bands from the sun-lit Earth in a 183 km wide swath. Onboard Landsat 4 and Landsat 5, the Thematic Mapper (TM) image data files consist of seven spectral bands. The resolution is 30 m for bands 1 to 7. Thermal infrared band 6 was collected at 120 m, but was resampled to 30 m. The approximate scene size is 170 km north-south by 183 km east-west (106

mi by 114 mi). For more information, visit NASA's Landsat Science | The Enhanced Thematic Mapper Plus web page.

The Operational Land Imager (OLI) on Landsat 8 is an enhanced version of Landsat 7's ETM+ that adds two new spectral bands: a deep blue visible channel (Band 1), specifically designed for water resources and coastal zone investigation; and a new infrared channel (Band 9) to detect cirrus clouds. For more information, visit the USGS Landsat 8 web page.

3 SOFTWARE AND TOOLS

GeoTIFF files can be viewed with a variety of Geographical Information System (GIS) software packages including:

Blue Marble Geographics Global Mapper
QGIS
GDAL
Esri ArcGIS

4 VERSION HISTORY

Table 4. Version History

Version	Description	Effective Date
V2.1	This minor version provides all available data from 1985 through 2018 for all regions. Additionally, the sensor name abbreviations in the `.meta` files have changed. The new abbreviations are listed in Table 3.	July 2019

V2 (Update)	• Temporal coverage expanded to 1985-2016 using data from Landsat 4 and 5
	• A more aggressive filtering method was applied to remove the following small, isolated clusters of data:
	  ○ Ecoast-62.10N: OPT_E62.10N_2003-09, OPT_E62.10N_2003-10, OPT_E62.10N_2004-09, OPT_E62.10N_2004-10
	  ○ Ecoast-64.65N: OPT_E64.65N_2011-09, OPT_E64.65N_2011-10
	• Spatial coverage was increased by 24 new grids
		October 2017

Version	Description	Effective Date
V2	Changes for Version 2 include: • A correction was applied in the processing, which caused error values to appear as NaNs in some of the data • A more aggressive filtering method was applied to remove small, isolated clusters of data • Cross-path Landsat pairs were used to fill in temporal gaps in the 2016 data, using the *MEaSUREs Greenland Ice Mapping Project (GIMP) Digital Elevation Model from GeoEye and WorldView Imagery* data set and the orthorectifcation algorithm of Rosenau 2012 • Spatial coverage was expanded to include include the Wcoast 80.75N grid • Temporal coverage was expanded from September 2015 to September 2016 • To reduce overall size of the data set, GeoTIFFs are produced using Lempel–Ziv–Welch LZW lossless compression	May 2017
V1	Initial Release	March 2016

5 RELATED DATA SETS

Greenland Ice Sheet Mapping Project (GIMP)

6 RELATED WEBSITES

MEaSUREs at NSIDC | Overview

7 CONTACTS AND ACKNOWLEDGMENTS

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9 DOCUMENT INFORMATION

9.1 Publication Date

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9.2 Date Last Updated

August 2019