MEaSUREs Phase-Based Antarctica Ice Velocity Map, Version 1

USER GUIDE

How to Cite These Data

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

Mouginot, J., E. Rignot, and B. Scheuchl. 2019. *MEaSUREs Phase-Based Antarctica Ice Velocity Map, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/PZ3NJ5RXRH10. [Date Accessed].

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FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/nsidc-0754

National Snow and Ice Data Center

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NOTE: This map was generated using InSAR phase analysis, which requires SAR data acquired in different directions to be available. The reason for this is that the interferometric phase is only sensitive to motion in look direction; thus, to resolve a 2D flow, the second direction is required. The map was ultimately mixed with a feature and speckle tracking-based map, specifically to cover coastal areas for which the phase technique does not work. The primary motivation of this map was to get a reference (or measurement) for every point of the Antarctic ice sheet; therefore, all available data sets were used over the period described in the documentation. The map is therefore associated with an acquisition period spanning several years, and not with a specific date. Another product which narrows the acquisition date, such as *MEaSUREs Annual Antarctic Ice Velocity Maps 2005-2017*, is more suitable for such a need. These maps also show the limitation of data availability for the region in question.

1 DATA DESCRIPTION

1.1 Parameters

The main parameter in this data set is ice velocity, with associated errors and standard deviations (in m/yr). The variables included in the data file are described in Table 1. All variables are on a two-dimensional grid of 12445 by 12445 cells, except for x and y, which are unidimensional with 12445 cells each.

Table 1. Parameter Information

Parameter	**Description**	**Units**
CNT	Scene count, used to estimate the values for each pixel	Count
coord_system	Coordinate system	-
ERRX	Ice velocity error in x-direction	m/yr
ERRY	Ice velocity error in y-direction	m/yr
lat	Latitude	° N
lon	Longitude	° E
SOURCE	Data source (0 = no data; 1 = tracking-based; 2 = phase-based; 3 = interpolation-tracking phase)	-
STDX	Standard deviation of ice velocity in x-direction	m/yr
STDY	Standard deviation of ice velocity in y-direction	m/yr
VX	Ice velocity in x-direction	m/yr
VY	Ice velocity in y-direction	m/yr
x	Cartesian x-coordinate	m
y	Cartesian y-coordinate	m

Note: To convert the VX and VY ice velocity components into magnitude (speed) and direction (angle), as well as their relative errors, use the following equations (Mouginot et al., 2012):

1. speed = sqrt ($VX^2 + VY^2$)
2. angle = arctan (VY / VX)
3. error = sqrt ($ERRX^2 + ERRY^2$)
4. error of flow direction = error / (2*speed)

When computing the inverse tangent, users should take note of the function's inherent ambiguities. While the standard arctan function typically does not account for angles that differ by 180°, most modern computer languages and math software packages include the function ATAN2, which uses the signs of both vector components to place the angle in the proper quadrant.

1.2 File Information

1.2.1 Format

This data set includes one data file, `antarctic_ice_vel_phase_map_v01.nc`. The data file is provided in netCDF-4 (`.nc`) format, following version 1.6 of the Climate and Forecast (CF) metadata conventions.

1.2.2 File Contents

The velocity components for the x- and y-direction, as defined by the polar stereographic grid, are stored in the netCDF variables `VX` and `VY` and are recorded in m/yr. Error estimates for the velocity components are provided as variables `ERRX` and `ERRY`; however, these values should be used more as an indication of relative quality rather than absolute error. More information about the error estimates is provided in the Quality, Errors, and Limitations section as well as in Mouginot et al. (2019). The data also include the standard deviations for the velocity estimates (`STDX`, `STDY`), a count of scenes (`CNT`) used to estimate the values for each pixel, and an index denoting the `SOURCE` of the data, i.e., whether the velocity was estimated via tracking-based method, phase-based method, an interpolation of the two, or is missing altogether.

1.3 Spatial Information

1.3.1 Coverage

Spatial coverage includes the continent of Antarctica, namely the entire polar region southwards of 60° S.

1.3.2 Resolution

The spatial resolution of the grid is 450 m by 450 m.

1.3.3 Geolocation

The following table provides information for geolocating this data set.

Table 2. Geolocation Details

Geographic coordinate system	WGS 84
Projected coordinate system	Antarctic Polar Stereographic
Longitude of true origin	0°
Latitude of true origin	71° S
Scale factor at longitude of true origin	1
Datum	WGS 84
Ellipsoid/spheroid	WGS 84
Units	meters
False easting	0°
False northing	0°
EPSG code	3031
PROJ4 string	+proj=stere +lat_0=-90 +lat_ts=-71 +lon_0=0 +k=1 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs
Reference	https://epsg.io/3031

1.4 Temporal Information

1.4.1 Coverage

The data were collected between 1996 and 2018. Detailed information is provided in the Data Acquisition and Processing section.

1.4.2 Resolution

Not applicable. The maps are an averaged representation of the period in which data were collected.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

This data set provides a new map of Antarctic ice velocity that is ten times more precise than prior maps and reveals ice motion at a high precision over 80% of the continent versus 20% in the past. The ice motion vector map provides novel constraints on interior ice motion and its connection with the glaciers and ice streams that control the stability and mass balance of the Antarctic Ice Sheet.

2.2 Acquisition and Processing

Several analysis techniques using SAR data were used to generate the velocity maps:

1. Combination of interferometric phases of two independent tracks to retrieve the surface flow vector (Mouginot et al., 2019), applied to a vast region of Antarctica
2. Speckle tracking in both along-track (azimuth) and across-track (range) directions, used to augment the phase map in coastal areas (Rignot et al., 2011; Mouginot et al., 2012; Mouginot et al., 2017)
3. Calculation of two-dimensional offsets in amplitude imagery (Mouginot et al., 2012)
4. Combinations of (range) interferometric phases along two independent tracks (Mouginot et al., 2012)

In all cases, surface parallel flow is assumed, a conventional approach for ice sheets. The Landsat-8 data are processed using repeat image feature tracking (see Mouginot et al., 2017).

Phase-derived velocities were mostly acquired between 2007 and 2018, while regions covered by tracking-derived velocity (along the coasts) are mostly representative of the years 2013–2017. Additional data acquired between 1996 and 2018 were used as needed to maximize coverage. SAR acquisitions between 2006 and 2018 were coordinated by the International Polar Year (IPY) Space Task Group and its successor, the Polar Space Task Group (PSTG). Figure 1 shows the distribution of data tracks from different data sources, as well as a complete map of ice motion in Antarctica.

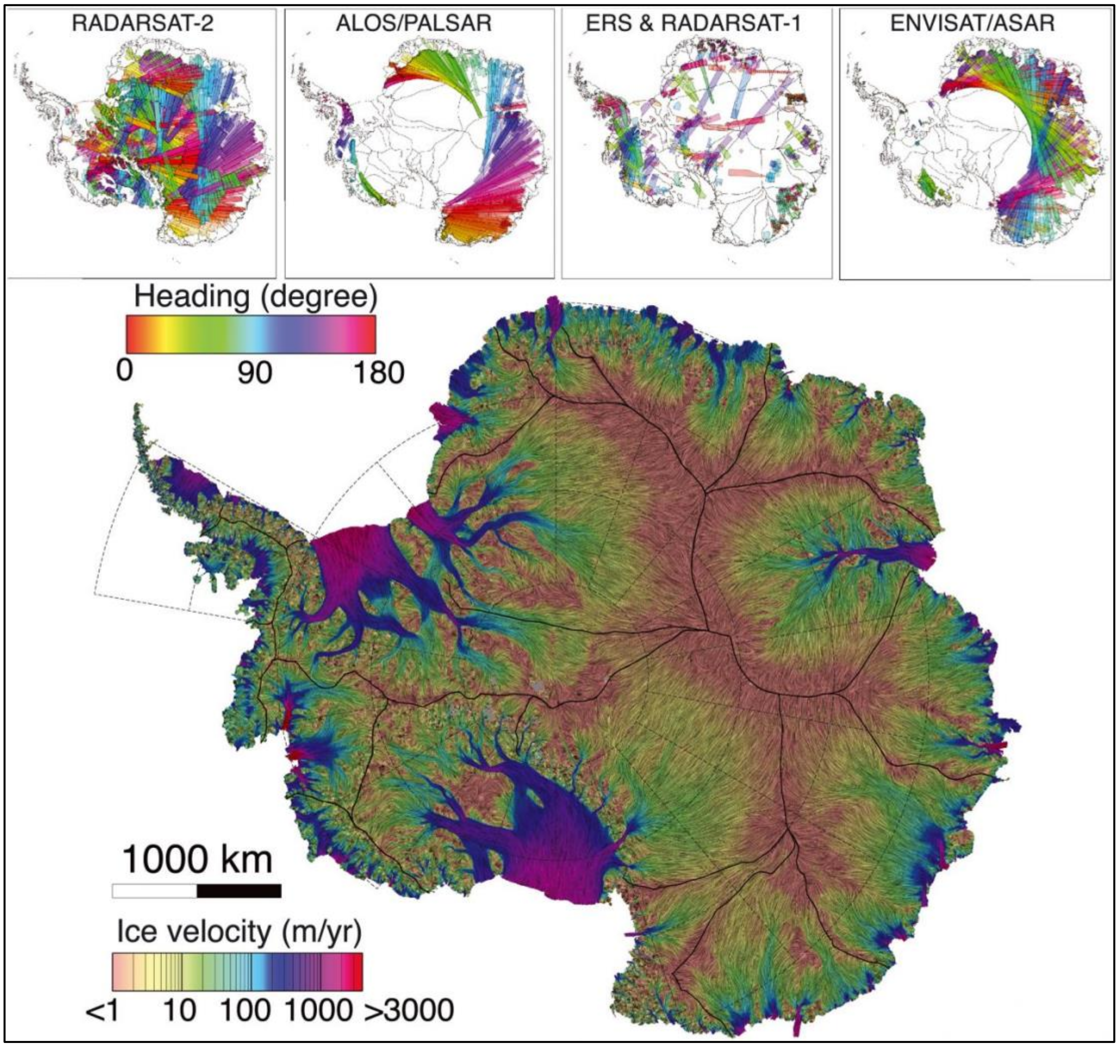

Figure 1. Mapping of ice motion in Antarctica using synthetic-aperture radar interferometric phase data. Upper panels show the distribution of data tracks used from the Canadian RADARSAT-2, Japanese ALOS/PALSAR, European ERS and Canadian RADARSAT-1, and European ENVISAT/ASAR. Lower main panel shows a complete map of ice motion in Antarctica combining phase data in the interior and speckle-tracking in the fast-moving sectors, with speed colored on a logarithmic scale from brown (less than 1 m/yr) to red (more than 3 km/yr) and flow direction indicated by colored lines and showing the flow pattern of ice across the continent (from Mouginot et al., 2019).

The unwrapped phase uses C-Band sensors (~5.5 cm) with 1461 tracks from RADARSAT-1 and RADARSAT-2, 76 tracks from ERS-1 and ERS-2, 319 tracks from ENVISAT/ASAR; and L-Band sensors (~23.6 cm) with 556 tracks from ALOS/PALSAR and 3 tracks from ALOS2/PALSAR2 (Figure 1, top row). The combination of phase and tracking mosaics covers 99.8% of Antarctica (Figure 1, main map), with a significantly improved description of ice flow from the ice divides in the deep interior to the periphery. Figure 2 shows the ice velocity mosaics obtained from each method alone.

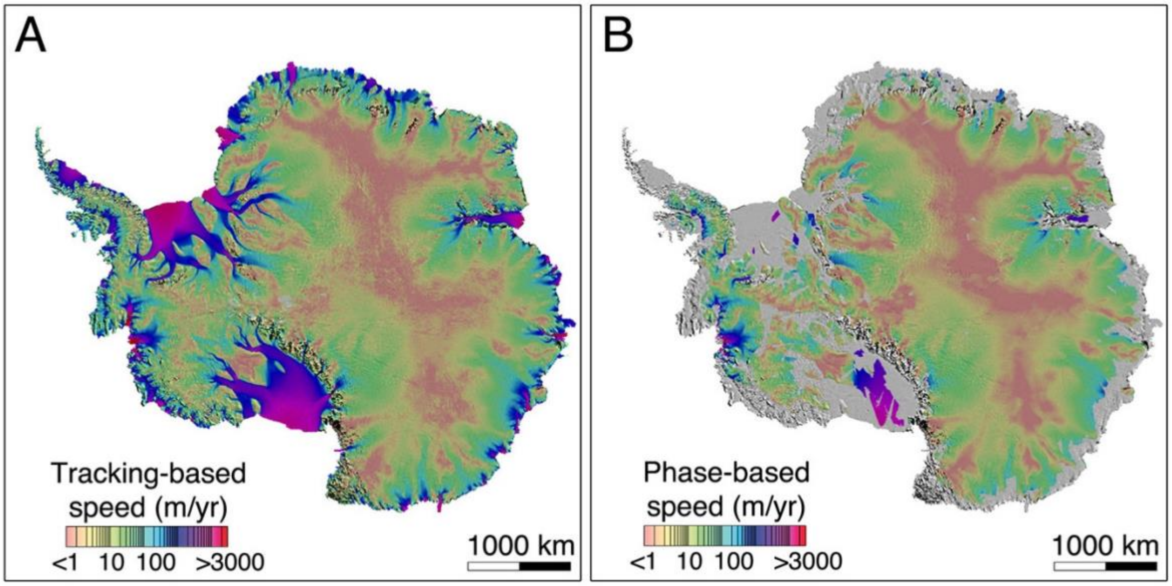

Figure 2. Ice flow in Antarctica from synthetic-aperture radar interferometry using (a) speckle tracking only and (b) interferometric phase only (from Mouginot et al., 2019).

The phase mosaic (Figure 2B) itself does not cover all of Antarctica for two reasons: firstly, the interferometric phase is aliased in areas of fast flow due to the long temporal baseline of the data; and secondly, some sectors do not have sufficient multi-track coverage to provide reliable estimates of the vector ice motion. Overall, the phase-based map covers 71% of Antarctica, or 9.9 million square km, while the tracking-based map (Figure 2A) covers 99.6%, or 13.8 million square km (Mouginot et al., 2017). Figure 3 illustrates how the two mosaics are merged.

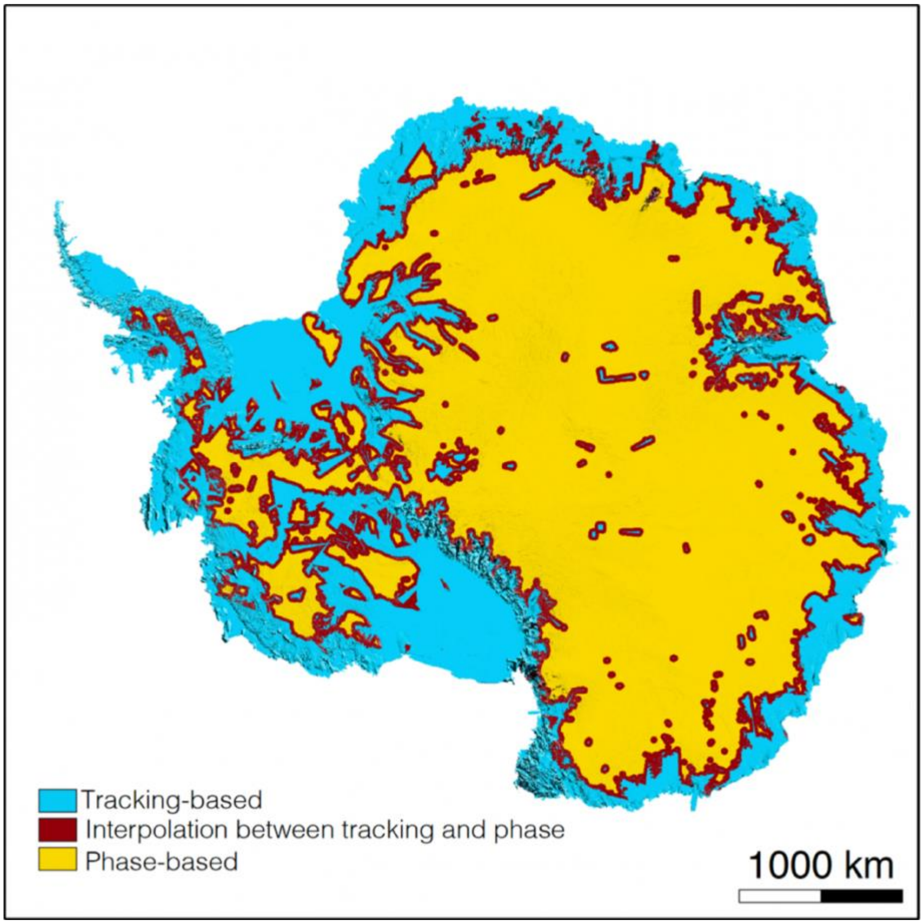

Figure 3. Mask showing where phase data (yellow) and speckle tracking data (blue) are applied, with an area of interpolation in between (from Mouginot et al., 2019, Supporting Information).

2.3 Quality, Errors, and Limitations

A detailed description of the data and their quality is provided in Mouginot et al. (2019). The precision of ice flow mapping varies with the sensor, the geographic location, the technique of interferometric analysis, the time period of analysis, the repeat cycle, and the amount of data stacking. Overall, there is notable improvement in precision from phase-based mapping relative to tracking-based mapping, which is especially significant along ice divides when examining the error in the flow direction. Figure 4 compares errors estimates for the two methods, for both speed and direction.

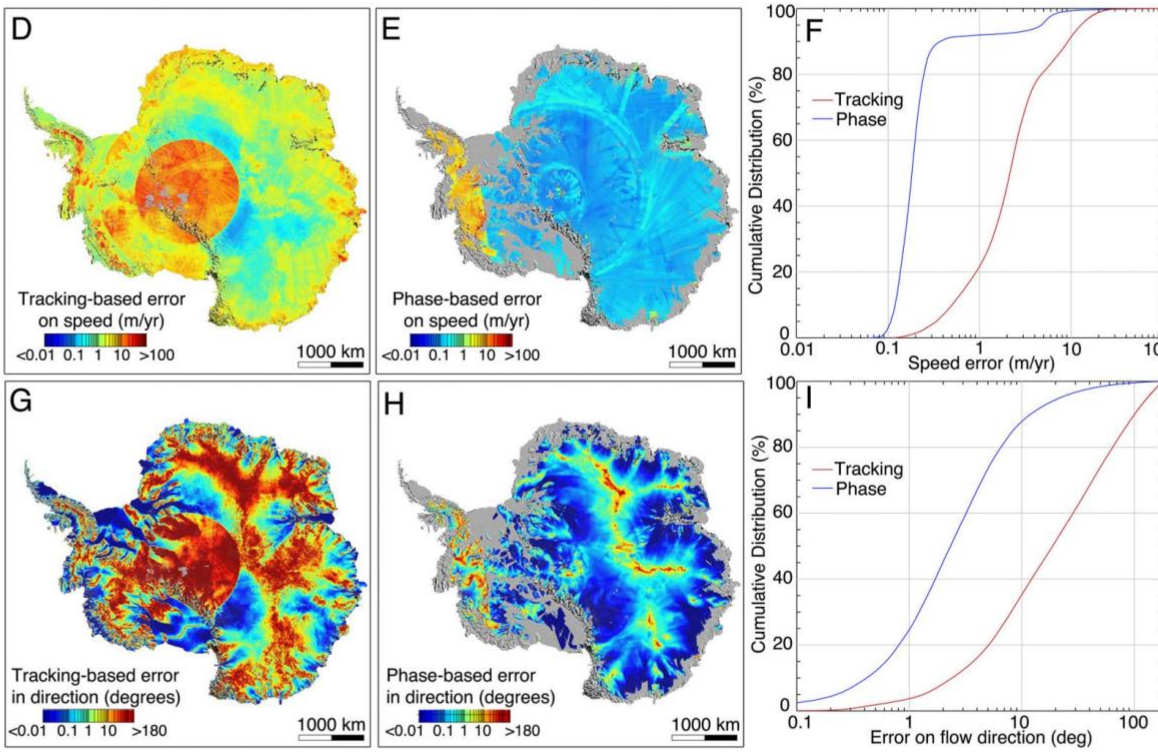

Figure 4. Errors in ice flow speed (top row) and direction (bottom row), as quantified via tracking-based (left column) and phase-based (center column) analyses. Graphics in the right column compare the cumulative distribution of errors in speed (top) and direction (bottom) from both methods (from Mouginot et al., 2019).

Finally, Table 3 provides a phase error for each of the sensors utilized in the phase-based velocity mapping. Note that phase error is determined for a single unwrapped phase using the nominal repeat cycle and assuming a conservative error of π radians (½ cycle) (Mouginot et al., 2019).

Table 3. Phase Error by Source Sensor

Platform/Sensor	**Number of Unwrapped Phases**	**Phase Error (m/yr)**
ERS-1/ERS-2/SAR	76	5.11 or 1.70
RADARSAT-1/SAR	265	0.21
RADARSAT-2/SAR	1196	0.21
ENVISAT/ASAR	319	0.15
ALOS/PALSAR	556	0.47
ALOS2/PALSAR2	3	1.79
Composite Phase / Speckle Tracking Map	N/A	0.15-0.2

2.4 Instrumentation

2.4.1 Description

The ice velocity map was derived from a variety of satellite radar interferometry data from the sensors listed in Table 3.

3 SOFTWARE AND TOOLS

Unidata at the University Corporation for Atmospheric Research maintains an extensive list of freely available Software for Manipulating or Displaying NetCDF Data.

4 RELATED DATA SETS

MEaSUREs InSAR-based Antarctica Ice Velocity Map
MEaSUREs Antarctic Grounding Line from Differential Satellite Radar Interferometry
MEaSUREs InSAR-Based Ice Velocity Maps of Central Antarctica: 1997 and 2009
MeaSUREs InSAR-Based Ice Velocity of the Amundsen Sea Embayment, Antarctica
MEaSUREs Antarctic Boundaries for IPY 2007-2009 from Satellite Radar
MEaSUREs Annual Antarctic Ice Velocity Maps 2005-2017

5 RELATED WEBSITES

NASA MEaSUREs Data at NSIDC
Antarctic Ice Sheet Velocity (AIV) and Mapping Data at NSIDC
NASA MEaSUREs

6 CONTACTS AND ACKNOWLEDGMENTS

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- ALOS PALSAR, ALOS-2/PALSAR-2: Japan Aerospace Exploration Agency (JAXA)
- ENVISAT ASAR, ERS-1, ERS-2: European Space Agency (ESA)
- Sentinel-1: Copernicus/ESA
- RADARSAT-1, RADARSAT-2: Canadian Space Agency (CSA), MDA
- TerraSAR-X, TanDEM-X as well as the TanDEM-X DEM of Antarctica: German Space Agency (DLR)
- Landsat-8 (optical): made available by the United States Geological Survey (USGS).

Data acquisitions made between 2006 and 2018 are courtesy of the International Polar Year (IPY) Space Task Group and its successor, the Polar Space Task Group (PSTG). This data set contains modified Copernicus Sentinel data (2014–2017), acquired by the European Space Agency, distributed through the Alaska Satellite Facility, and processed by E. Rignot, J. Mouginot, and B. Scheuchl.

7 REFERENCES

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8 DOCUMENT INFORMATION

8.1 Publication Date

15 August 2019

8.2 Date Last Updated

16 October 2019