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Post-K&C – First Report

InSAR based Ice Velocity and Grounding line Measurements in Antarctica

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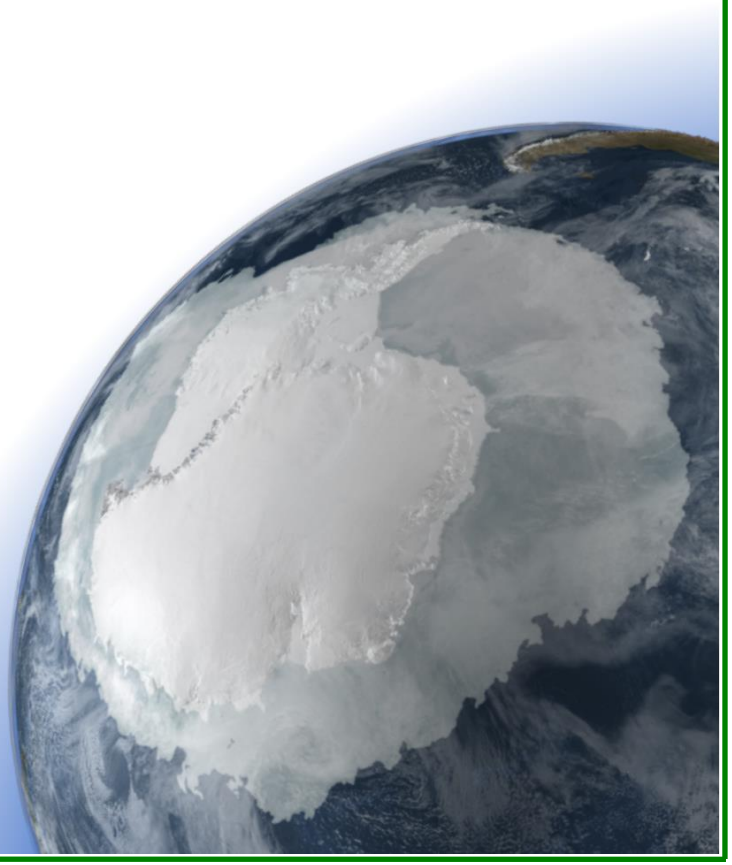
With Funding from NASA MEaSUREs & Cryosphere Science Programs

Post-KC Science Team meeting #1
Tokyo, Japan, January 20-24, 2020



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Climate Change, International Conventions

Motivation for this work

Ice sheets are acknowledged by **WMO** and **UNFCCC** as Essential Climate Variable (ECV) needed to make significant progress in the generation of global climate products and derived information.

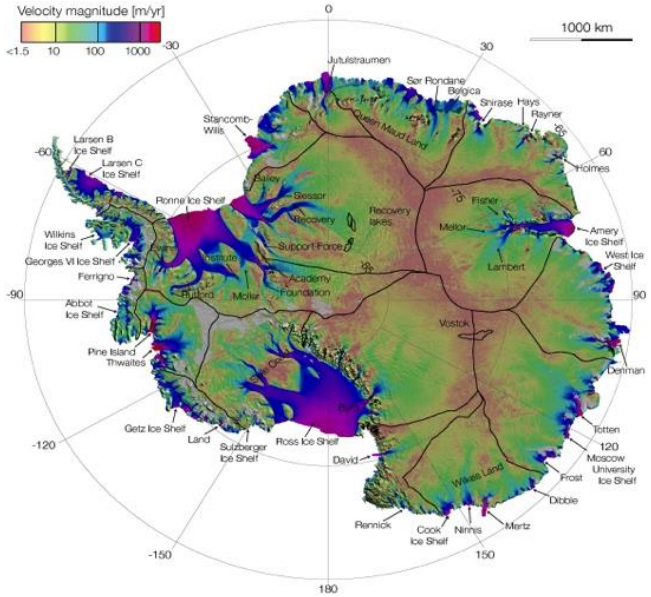
Background

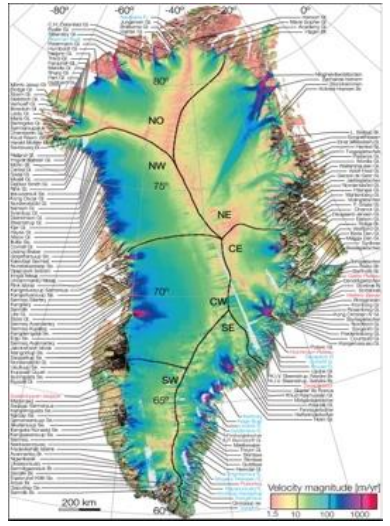
The Polar Space Task Group (**PSTG**) coordinates acquisitions in Polar regions in support of scientific exploitation.

Information Requirements

- Surface Elevation & Elevation Change
- Ice Velocity
- Grounding Line Location
- Calving Front Location
- *Bed Elevation*

→ **Ice Sheet Mass Balance**





CSA ASC Canadian Space Agency / Agence spatiale canadienne
esa
DLR
agenzia spaziale italiana
JAXA Japan Aerospace Exploration Agency
NASA
Norsk Romsenter NORWEGIAN SPACE CENTRE

Key Question: Are the ice sheets in Antarctica and Greenland loosing mass?

Three independent methods are available to measure mass balance:

- Input − Output
- Gravimetry
- Altimetry

Shepherd et al. 2012. Science (47 authors)

A Reconciled Estimate of Ice-Sheet Mass Balance

Andrew Shepherd,[1*] Erik R. Ivins,[2*] Geruo A,[3] Valentina R. Barletta,[4] Mike J. Bentley,[5] Srinivas Bettadpur,[6] Kate H. Briggs,[1] David H. Bromwich,[7] René Forsberg,[4] Natalia Galin,[8] Martin Horwath,[9] Stan Jacobs,[10] Ian Joughin,[11] Matt A. King,[12,27] Jan T. M. Lenaerts,[13] Jilu Li,[14] Stefan R. M. Ligtenberg,[13] Adrian Luckman,[15] Scott B. Luthcke,[16] Malcolm McMillan,[1] Rakia Meister,[8] Glenn Milne,[17] Jeremie Mouginot,[18] Alan Muir,[8] Julien P. Nicolas,[7] John Paden,[14] Antony J. Payne,[19] Hamish Pritchard,[20] Eric Rignot,[18,2] Helmut Rott,[21] Louise Sandberg Sørensen,[4] Ted A. Scambos,[22] Bernd Scheuchl,[18] Ernst J. O. Schrama,[23] Ben Smith,[11] Aud V. Sundal,[1] Jan H. van Angelen,[13] Willem J. van de Berg,[13] Michiel R. van den Broeke,[13] David G. Vaughan,[20] Isabella Velicogna,[18,2] John Wahr,[3] Pippa L. Whitehouse,[5] Duncan J. Wingham,[8] Donghui Yi,[24] Duncan Young,[25] H. Jay Zwally[26]

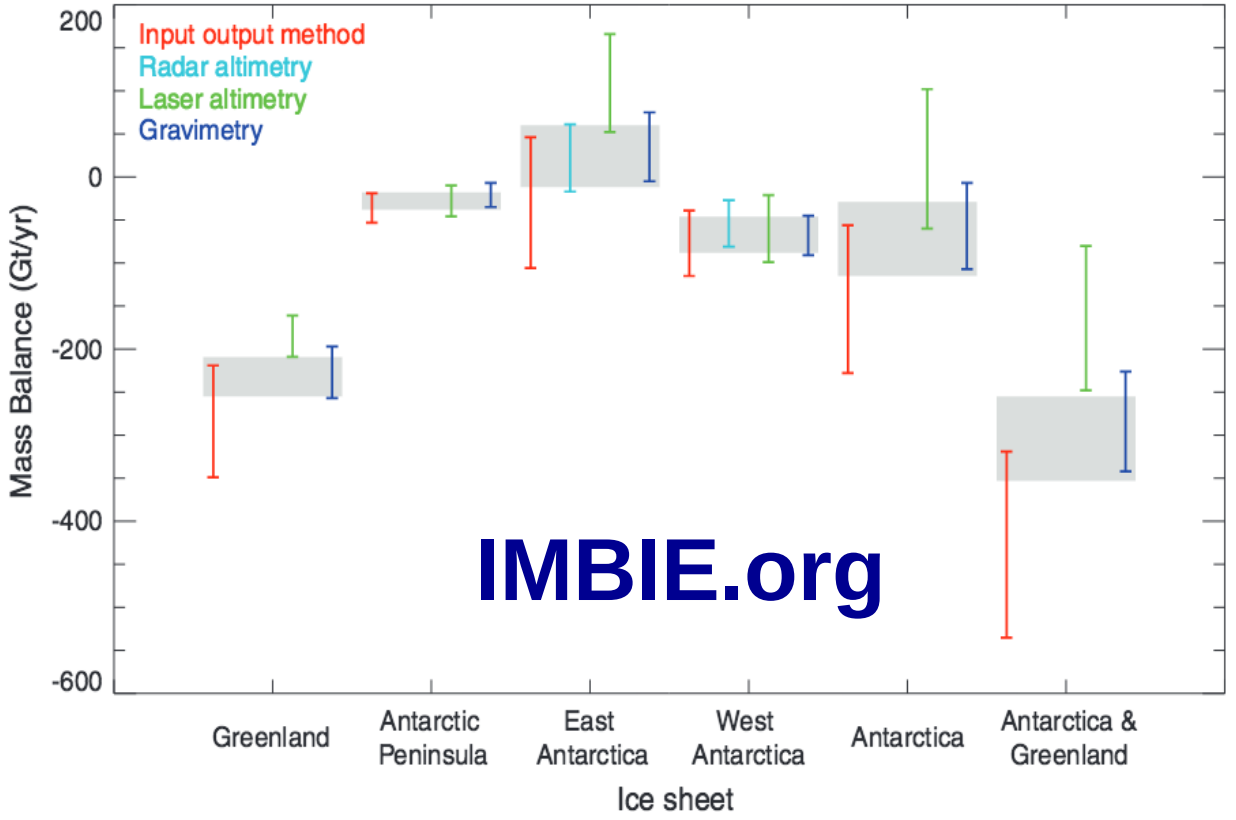
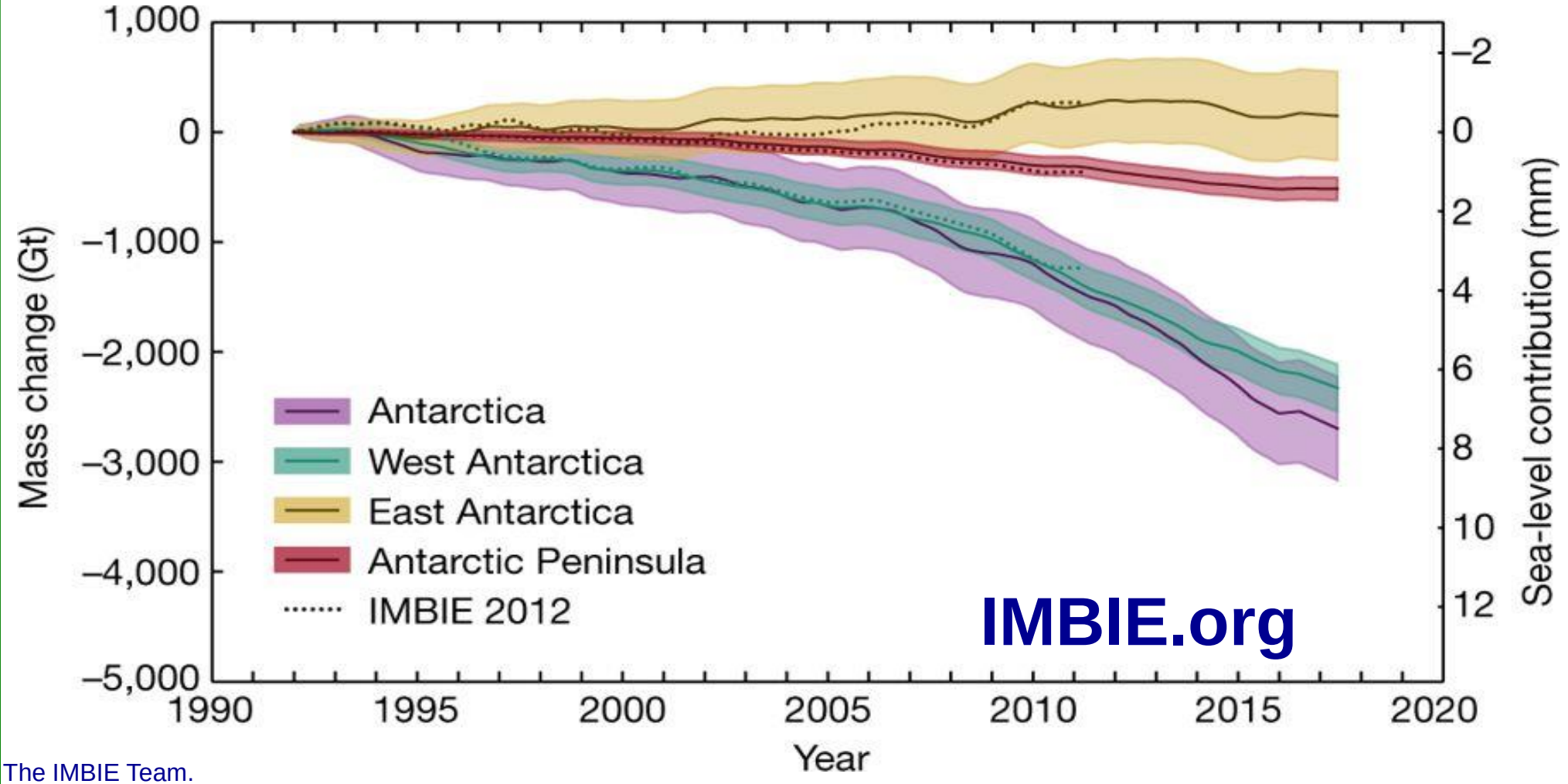


Fig. 3. Intercomparison of mass balance estimates of the GrIS, APIS, EAIS, WAIS, AIS, and the AIS plus GrIS, derived from the four independent geodetic techniques of RA (cyan), IOM (red), LA (green), and gravimetry (blue) over the period 2003 to 2008. Also shown is the reconciled result (gray).

Mass Balance of the Antarctic Ice Sheet



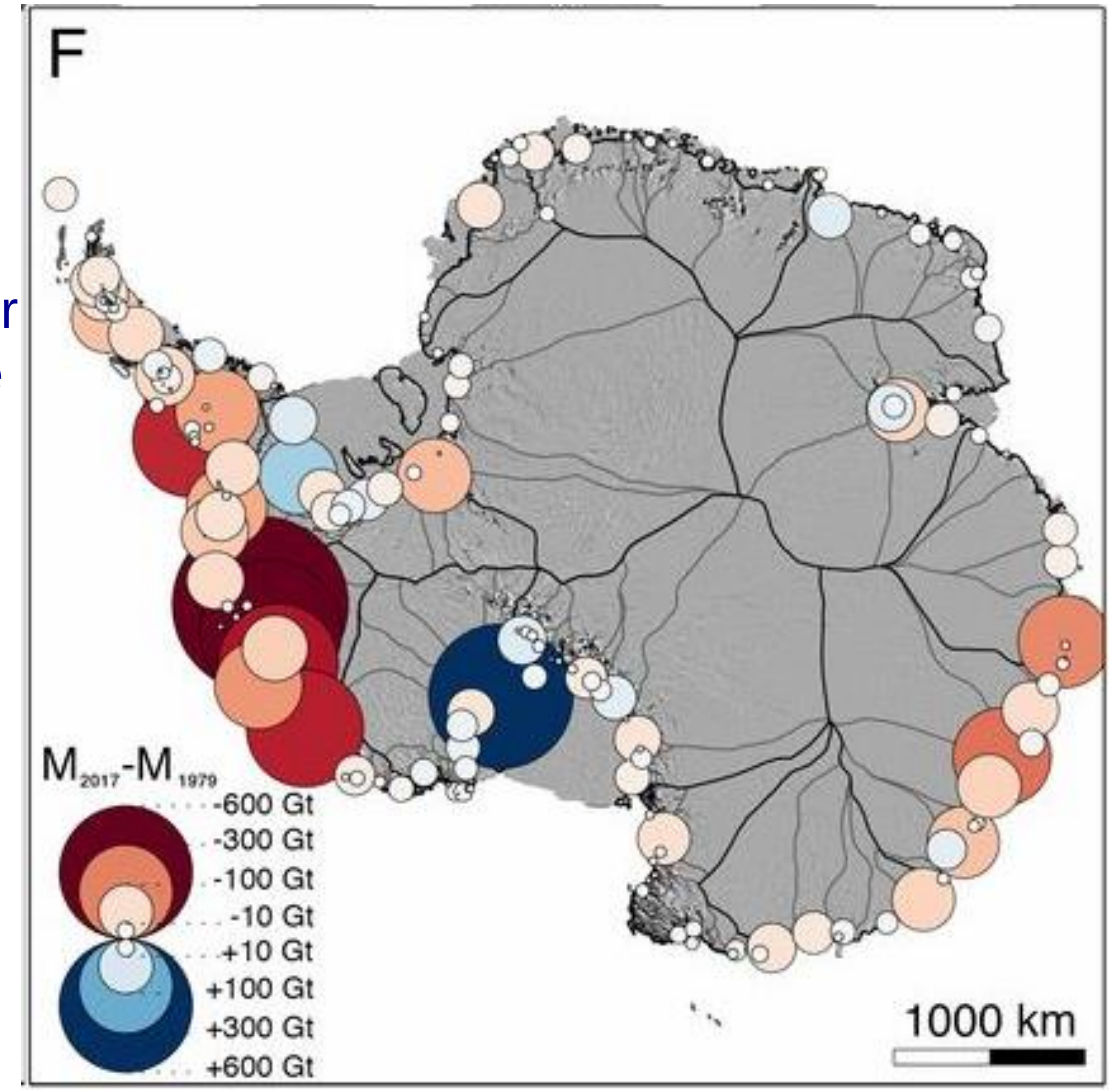
The IMBIE Team.
Mass balance of the Antarctic Ice Sheet from 1992 to 2017. *Nature* 556 (2018)

Mass Balance of the Antarctic Ice Sheet

Using the Input/Output method to analyze data acquired over four decades.

Total **mass change** of major basins for 1979–2017 (blue:gain, red:loss); circle proportional to the absolute mass balance

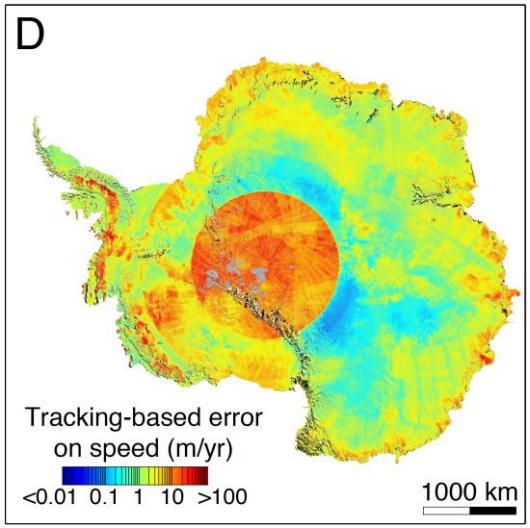
Takeaway message:
Mass loss is dominated by enhanced glacier flow in areas closest to warm, salty, subsurface circumpolar deep water, including East Antarctica.

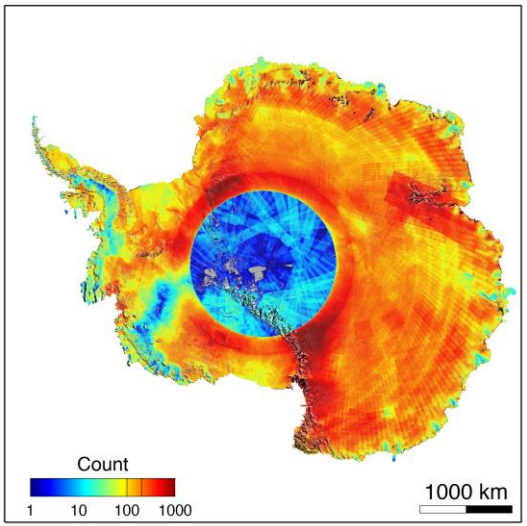


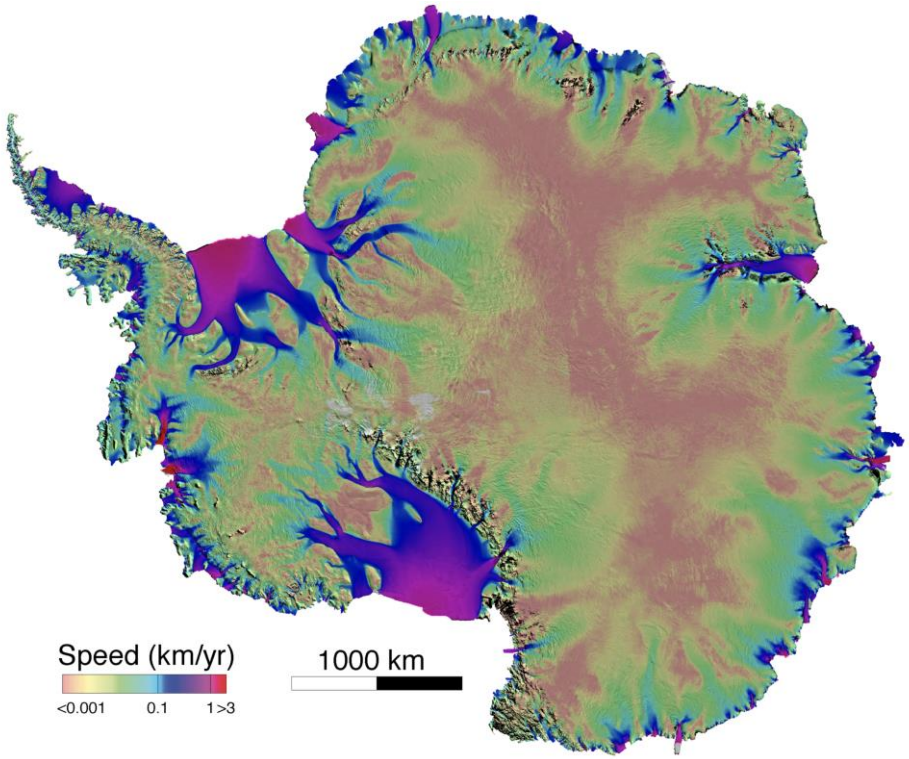
Rignot et al. PNAS 2019;116:4:1095-1103

Mapping ice motion from image cross-correlation

- Correlation of small image chips between 2 consecutive images.
- Ice velocity mapping precision around tens of meter per year
- Composite maps can reach 2-5 m/yr precision

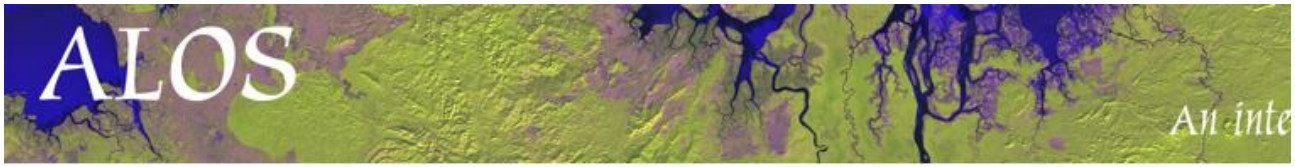






Mouginot et al. 2017
Rignot et al. 2011
https://nsidc.org/data/NSIDC-0484/versions/2

Error on the average speed Number of stacked measurements



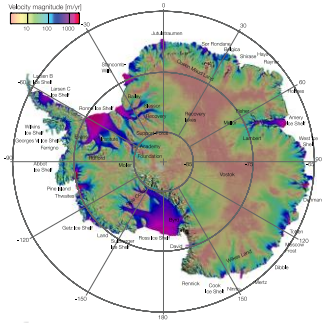
Earth Science Data Records

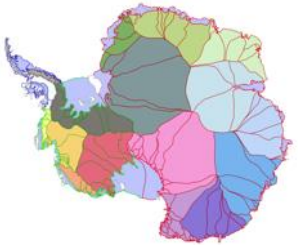
Products:
http://nsidc.org/data/measures/data_summaries

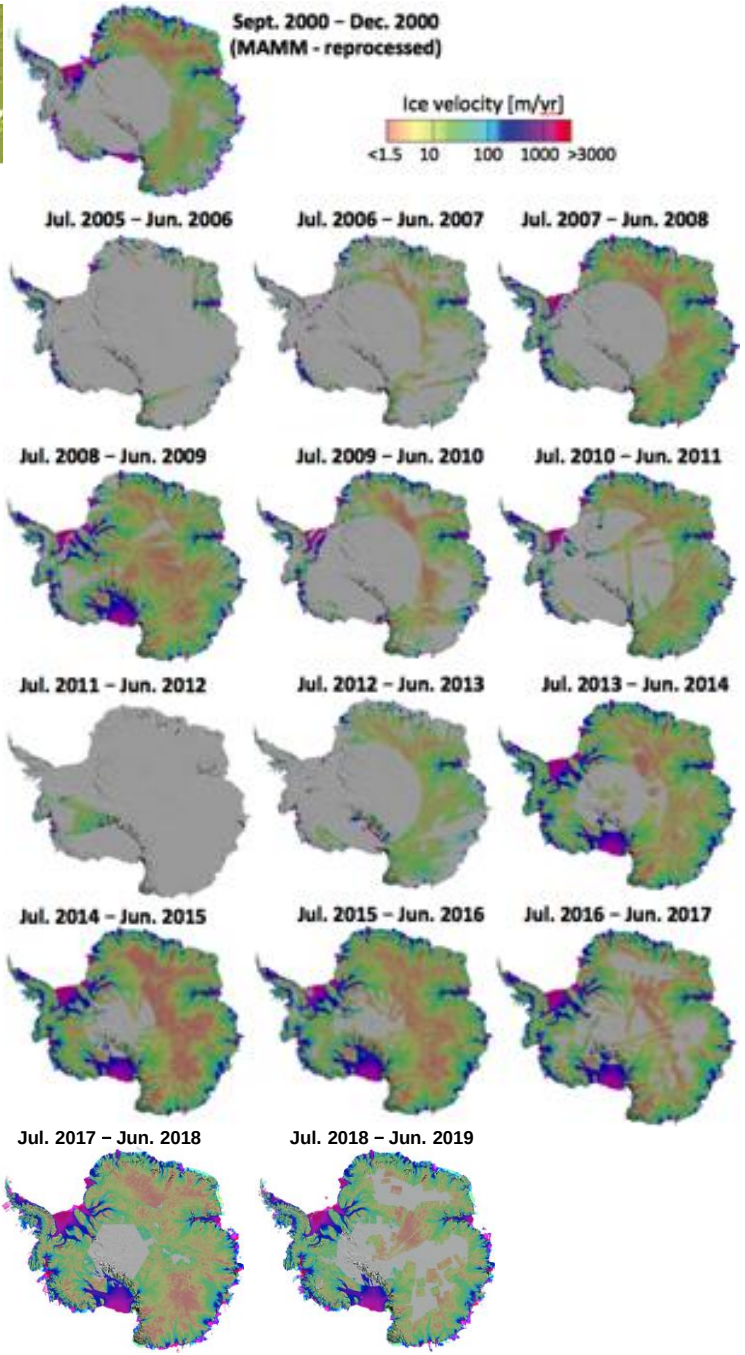
Ice Velocity Maps:
https://nsidc.org/data/NSIDC-0754
https://nsidc.org/data/NSIDC-0484
https://nsidc.org/data/NSIDC-0720
https://nsidc.org/data/NSIDC-0545
https://nsidc.org/data/NSIDC-0525

Grounding Line:
https://nsidc.org/data/NSIDC-0498

Boundaries
https://nsidc.org/data/NSIDC-0709



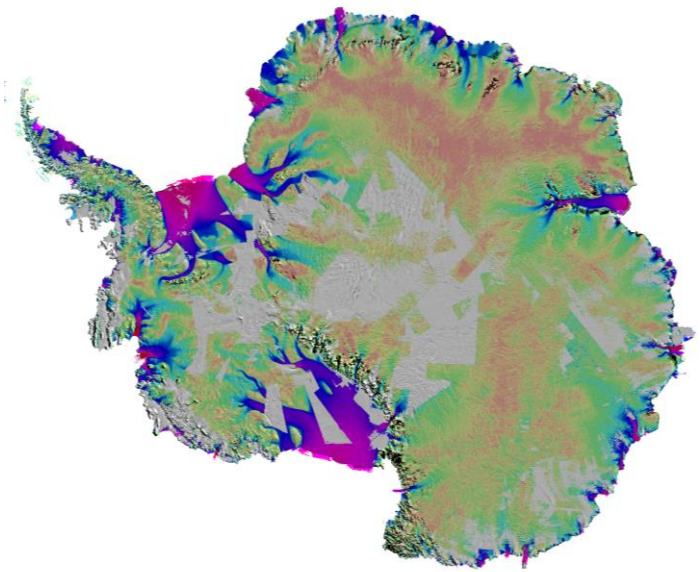




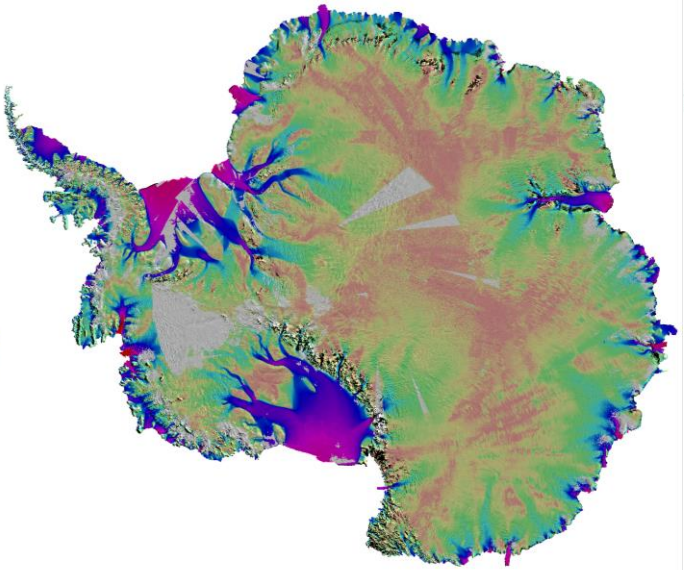
Reference Period Ice Velocity Maps

Objective: Maximize coverage while limiting the observation period.

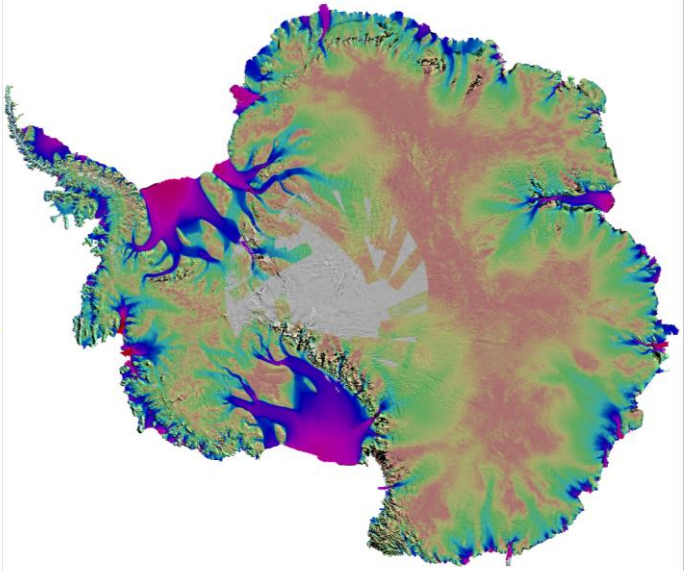
1995 -2000



2007-2009



2014-2016

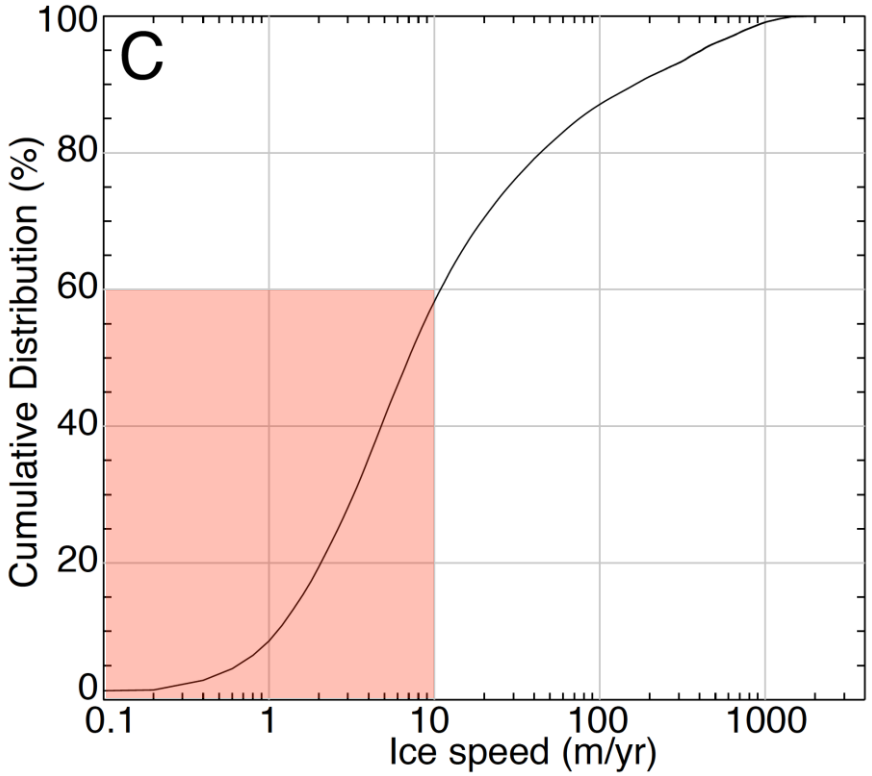


Mapping ice motion from image cross-correlation

About 60% of the Antarctic ice sheet is flowing slower than 10 m/yr.

- Tracking-based ice velocity maps based on tracking are not precise enough to properly describe the ice flow

- Precision is suitable for calculating ice volume fluxes along the periphery, where ice speed ranges from 400 to 4,000 m/yr (Rignot et al., 2019).

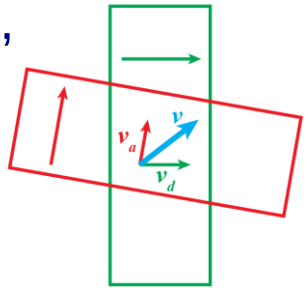


Using the InSAR Phase

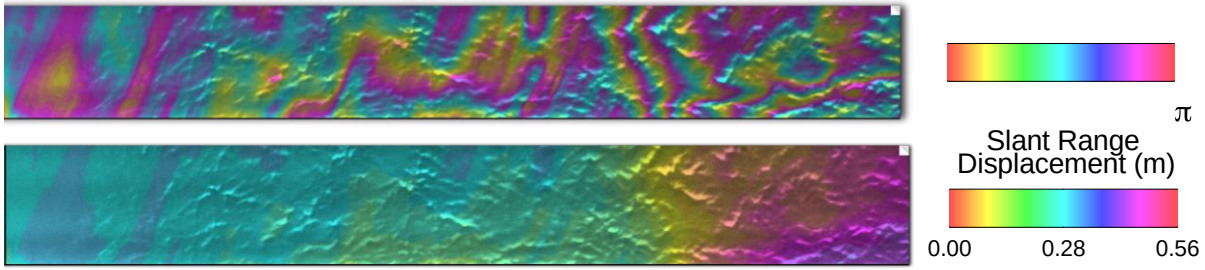
Theoretical precision of ice motion mapping from a single combination of ascending and descending phases is typically 0.15-1.79 m/yr

Difficult in fast flow = aliasing (two many fringes)

Need observations with different geometry, typically asc/des



	Wavelength (cm)	Period (data processed)	Nominal Repeat Cycle (day)	Mapping precision (m/yr)
ALOS/PALSAR	23.6	2006-2010	46	0.47
ALOS2/PALSAR2	23.6	2015	12	1.79
RADARSAT-1	5.5	1997-2001	24	0.21
RADARSAT-2	5.5	2009-2018	24	0.21
ENVISAT/ASAR	5.6	2006-2010	35	0.15
ERS	5.6	1992-1996	1 (3)	5.11 (1.70)

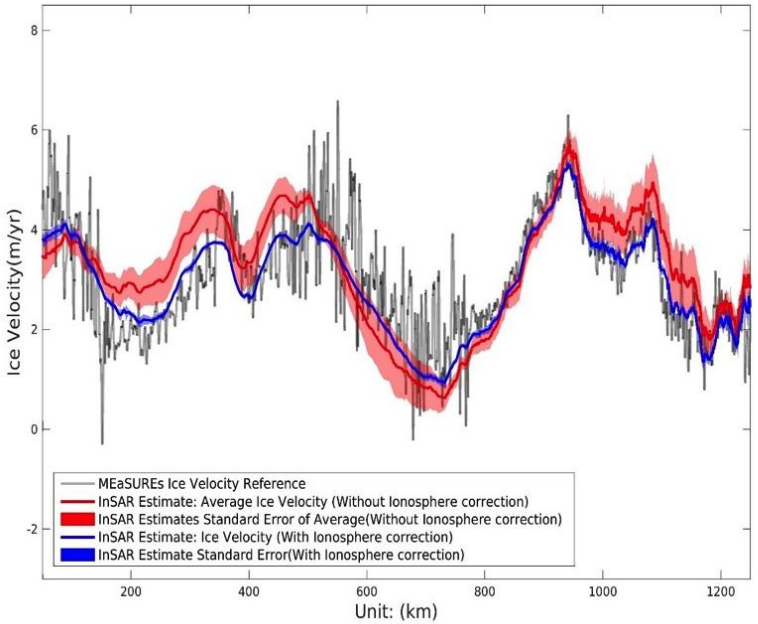


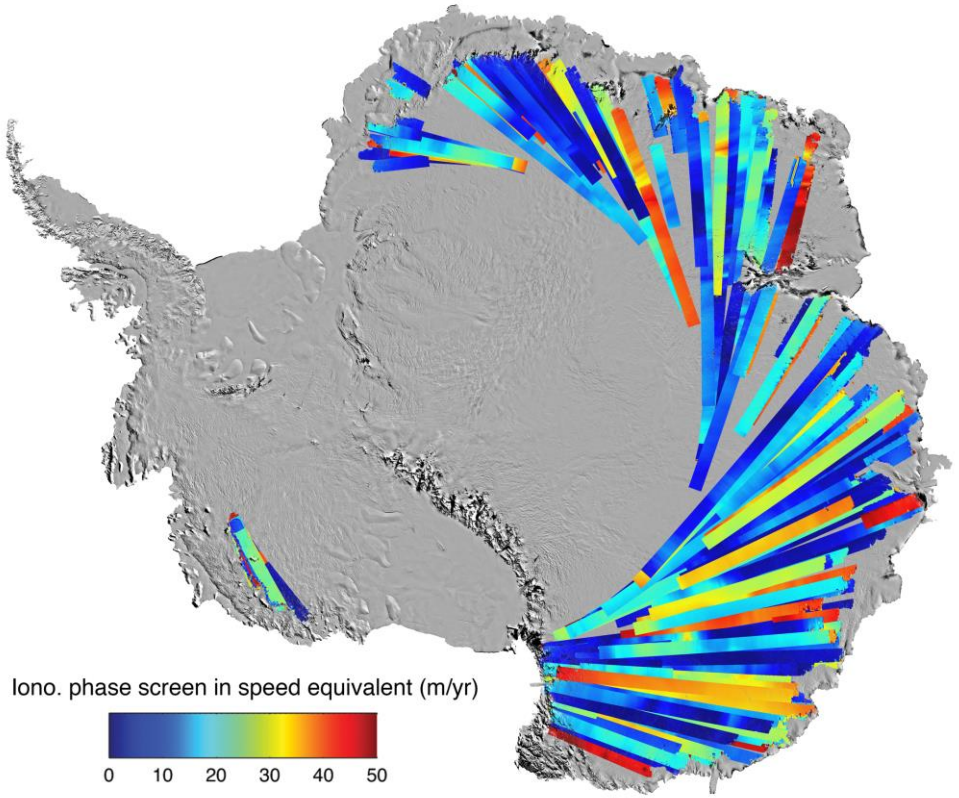
Ionosphere correction for L-band

Used a split spectrum based correction (Liao et al. 2018)

Applied the method on 546 ALOS/PALSAR tracks

Phase noise is reduced by 90%, dropping from 1 m/yr to 10 cm/yr





Average ice velocity and its standard error:

Red line and shading: non-ionosphere-corrected

Blue line and shading: ionosphere-corrected

Gray: tracking-based reference ice velocity

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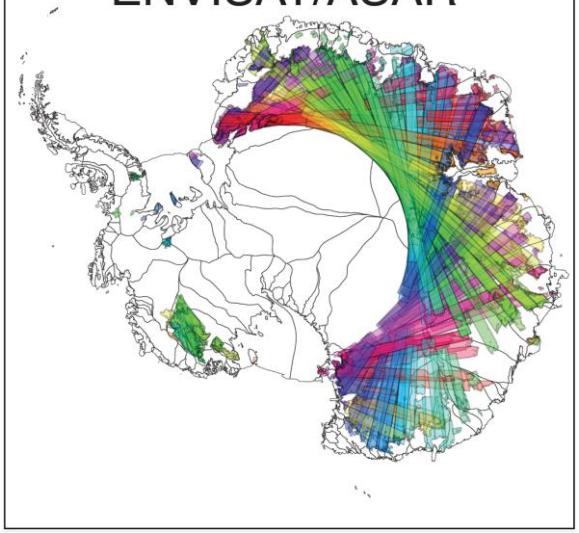
ENVISAT/ASAR

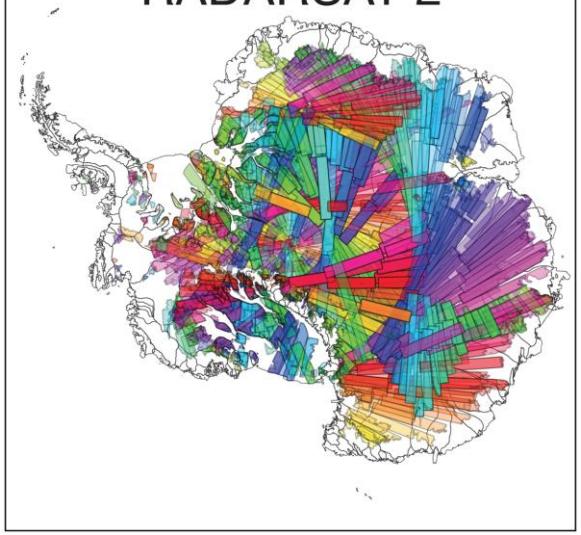


319 unwrapped tracks

ESA

CSA, MDA

RADARSAT-2

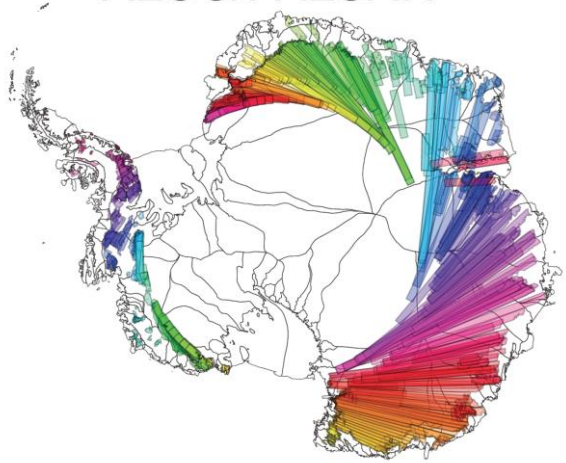


1196 unwrapped tracks

Unwrapped phases for more than 2400 tracks

Stripmap mode data used only

ALOS/PALSAR



559 unwrapped tracks

JAXA

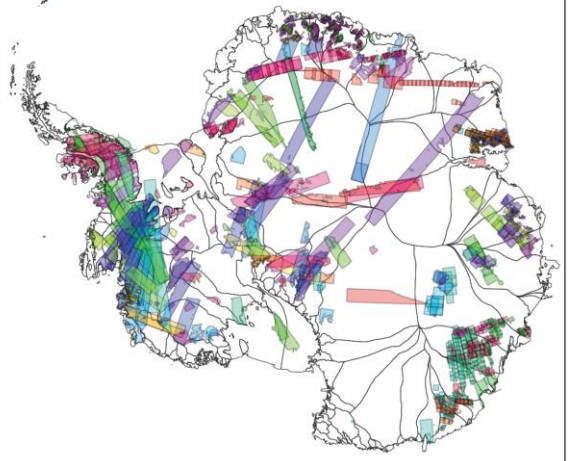
Heading (degree)

0 90 180

ESA

CSA

ERS & RADARSAT-1



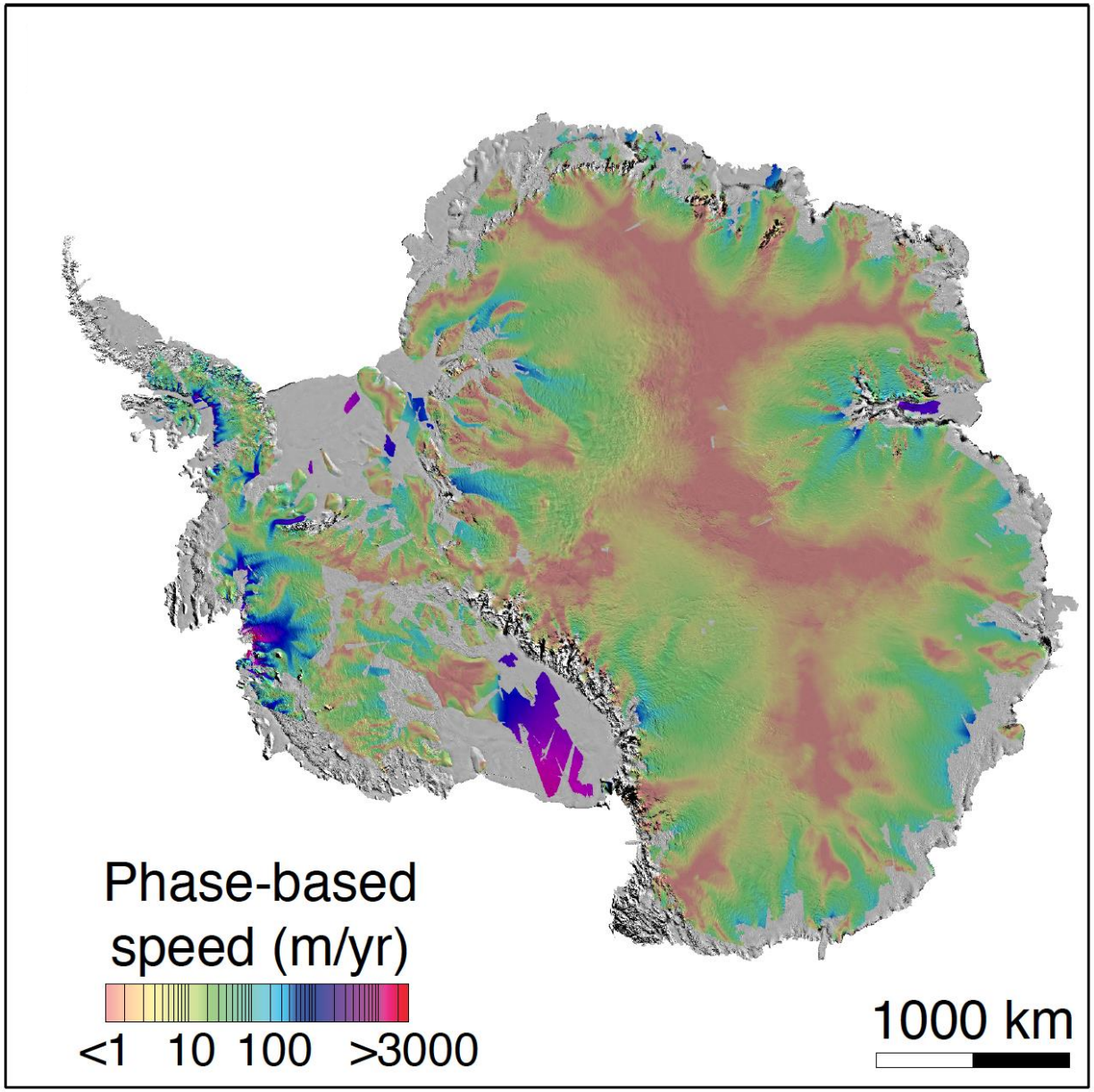
341 unwrapped tracks

InSAR Phase-based Ice Velocity

Phase-based map covers 71% of Antarctica

Limitation :

the interferometric phase is aliased in areas of fast flow



Mouginot et al. 2019

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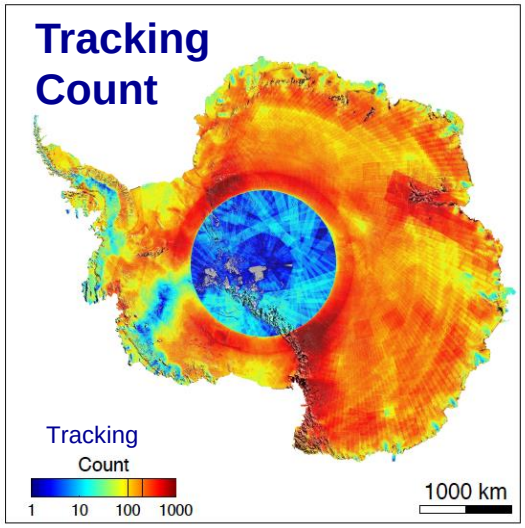
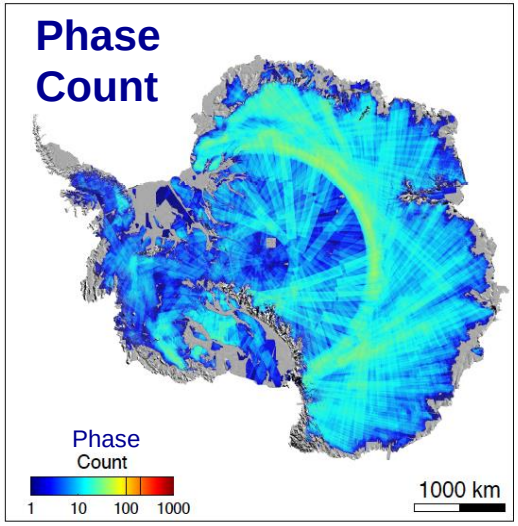
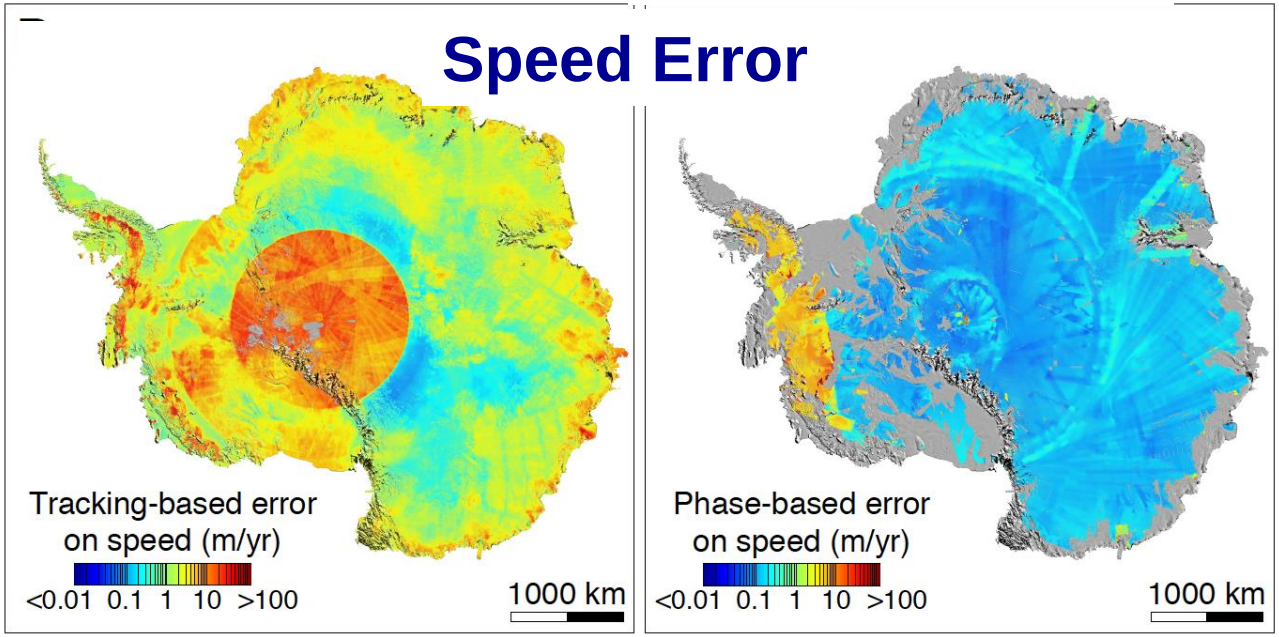
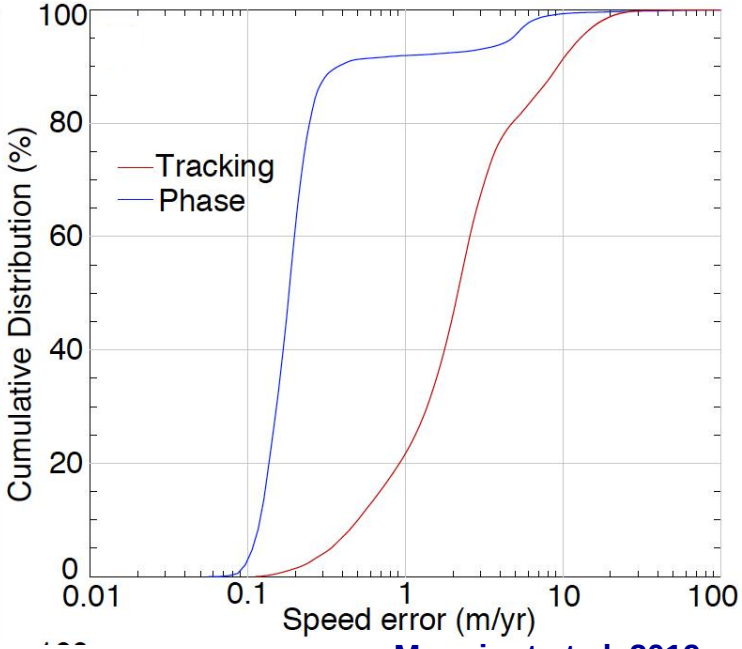




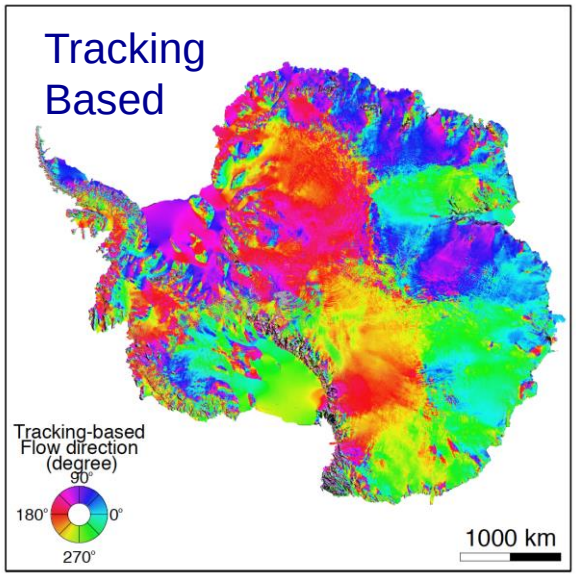
Speed Error

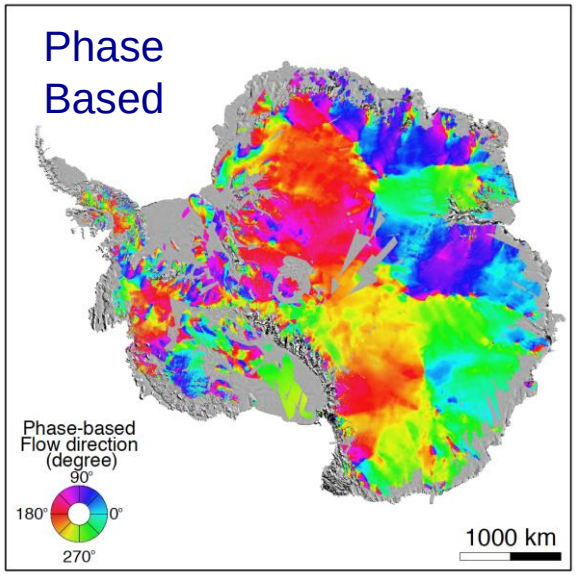
Error of composite map is on average about 2-5 m/yr from the tracking map versus 15-20 cm/yr with the phase data, or about 10x more precise





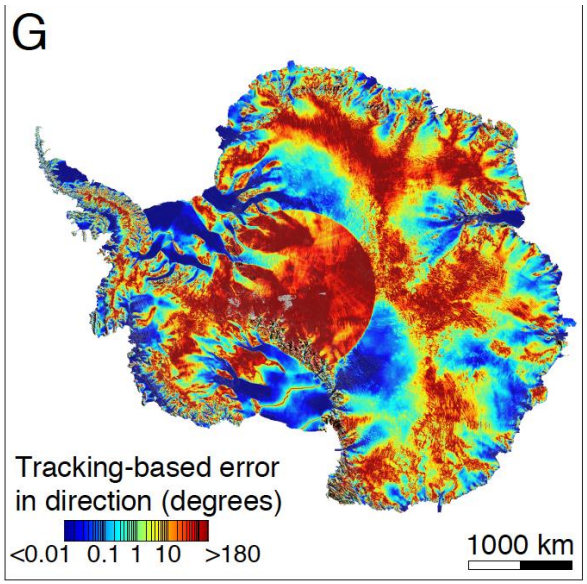
Mouginot et al. 2019

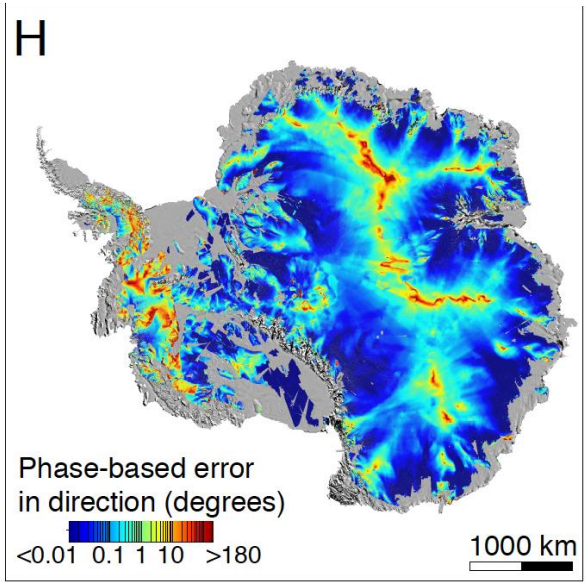


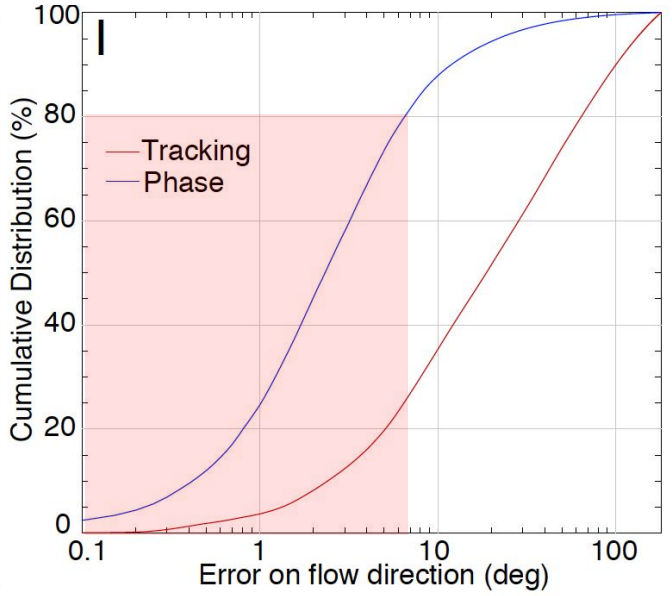


Flow direction

Error in flow direction with phase data is less than 1 degree over 25% of Antarctica and less than 7 degrees over 80% vs. less than 25% from tracking data.







Flow direction (top) and Error (bottom)

Mouginot et al. 2019

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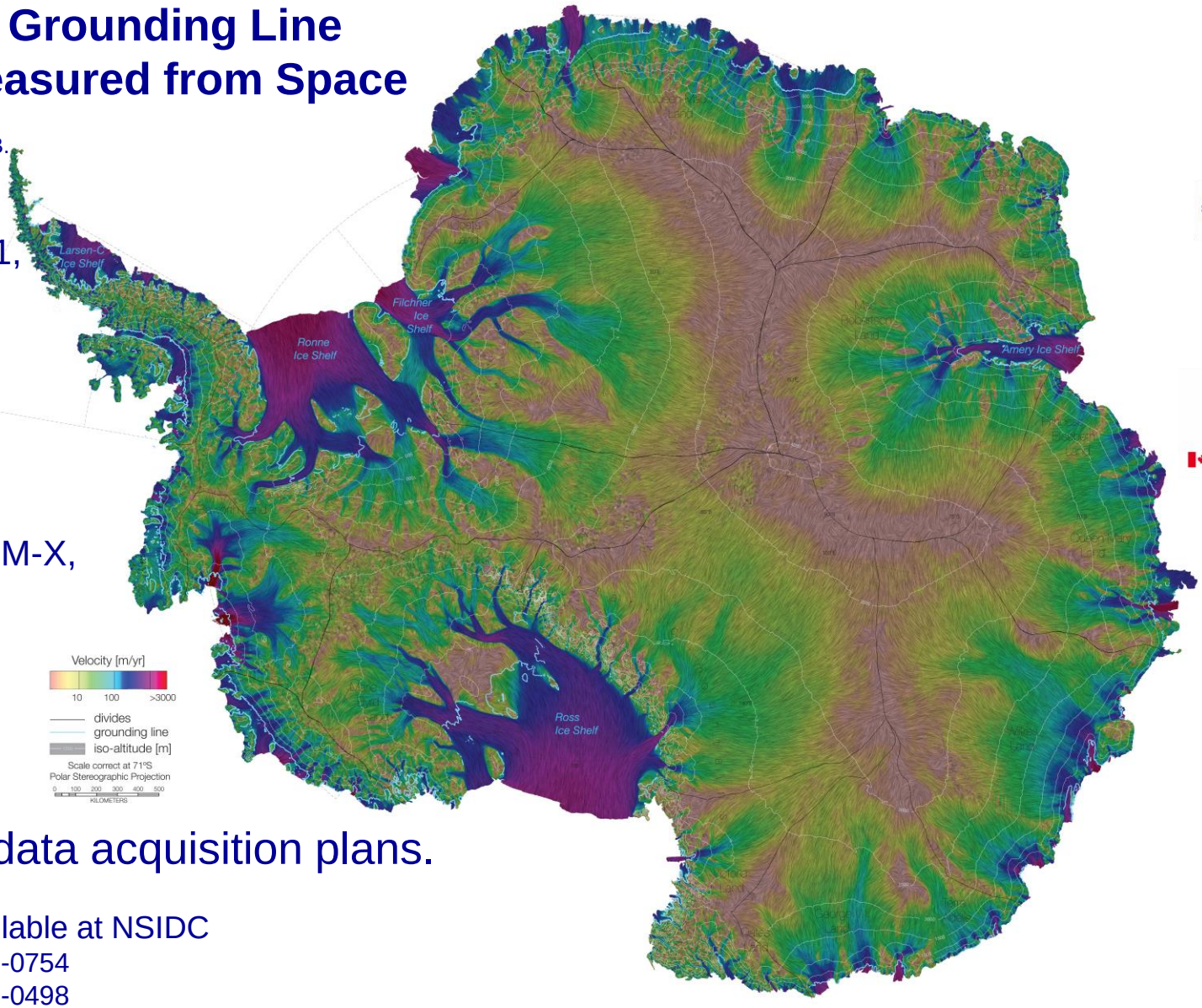
Ice Velocity and Grounding Line in Antarctica Measured from Space

Rignot E., Mouginot J., Scheuchl B.

Data Sources:

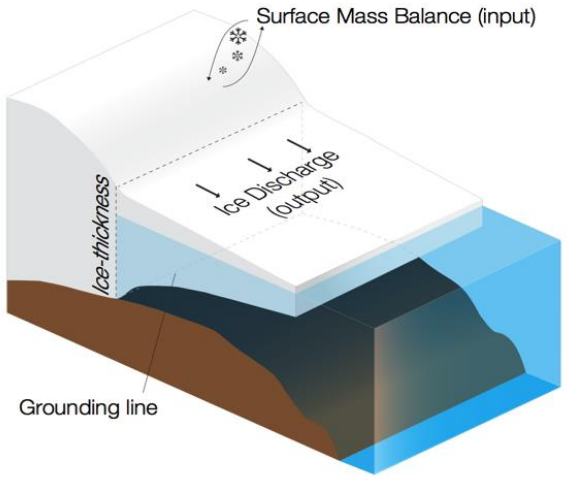
Copernicus Sentinel-1,
ERS-1 & ERS-2,
ENVISAT-ASAR,
RADARSAT-1 & -2,
COSMO SkyMED,
ALOS PALSAR
ALOS-2 PALSAR-2,
TerraSAR-X & TanDEM-X,
Landsat-8



PSTG is acknowledged for its role in coordinating the data acquisition plans.

These data sets are available at NSIDC
https://nsidc.org/data/NSIDC-0754
https://nsidc.org/data/NSIDC-0498

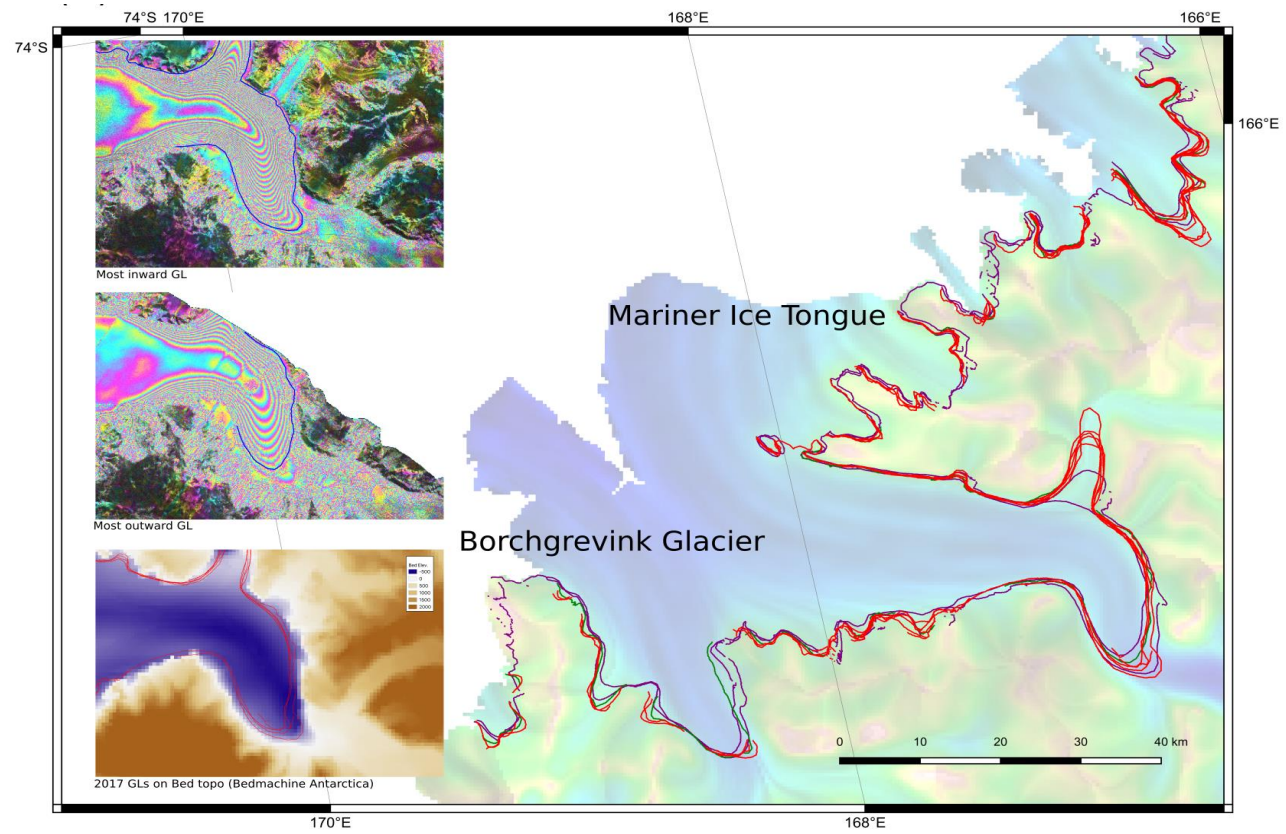
Grounding Line



Require 2 interferograms for a single measurement.

Now looking at multiple grounding line measurements per year − ongoing acquisitions

Tidal influence observed for some glaciers → define a grounding zone



Comments to JAXA

- We use all data available to us and generate a series of *composite multi-sensor* geophysical products for Antarctica.
- JAXA L-band data are a valuable resource for ice sheet mapping in Antarctica (and Greenland).
- Interferometric data is required for ice velocity (speckle tracking & InSAR phase), multiple interferograms are required for grounding line measurements.
- The ALOS-2 quota restriction reduces the impact of ALOS-2 for continent-wide product generation.
- Data suitable for ice sheet monitoring should still be collected – in case future wide releases become an option.