K&C Phase 4 – Brief project essentials

Ice Sheet Monitoring using ALOS-2

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Science Team meeting #21 – Phase 4 Kick-off
Kyoto Research Park, Kyoto, Japan, December 5, 2014

Project outline and objectives

The main objective of our project is to generate ice sheet relevant earth system data records (ESDR) based on ALOS-2. The basic observation plan for ALOS-2 includes systematic InSAR data acquisitions over the ice sheets in **Antarctica** and **Greenland**. We propose to utilize a portion of these BOS acquisitions to produce ice velocity and grounding line maps.

A secondary objective of our project is the documentation of the impact of CO2-induced warming on glacier retreat.

The ESDRs produced will contribute to a *reduction of uncertainties related to the climate system*. They will also be useful in developing strategies to prepare for the *adverse impacts of climate change*.

Project outline and objectives

We are interested in continental scale coverage. Appreciating the program data quotas, we focus on selected regions. Within the BOS glacier movement regions covered we have prioritized regions as follows:

- Amundsen Sea Embayment (ASE) West Antarctica
- Antarctic Peninsula
- Totten Glacier – East Antarctica
- Ross and Ronne Ice Shelves (left looking regions)
- Western Greenland
- Other areas in coastal Antarctica

Access to BOS data for all regions may not be possible. Working with JAXA, we will develop an order plan to maximize the impact of the available data.

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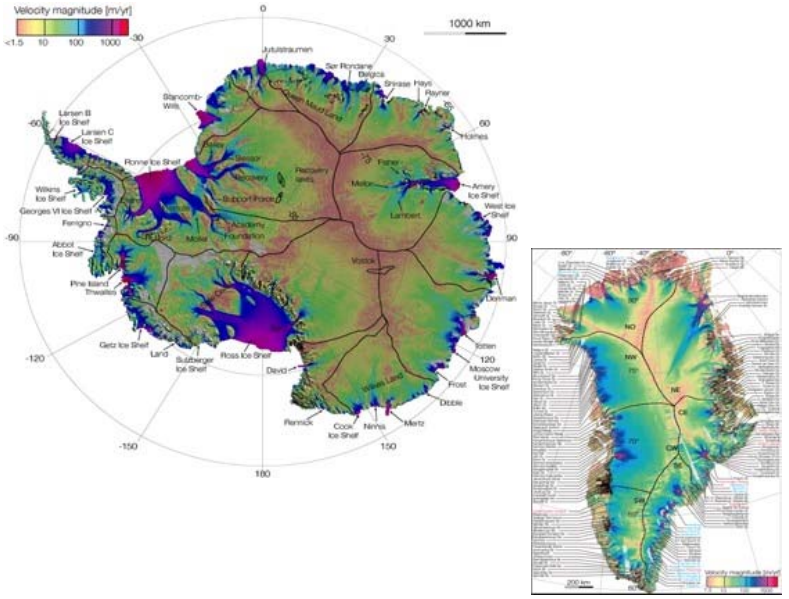
Climate Change, International Conventions

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. The 2011 update for the GCOS Systematic observation requirements for satellite- based data products for climate specifically mentions the need to monitor the great ice sheets.



Background

As contribution to the International Polar Year (IPY, 2007-2009) the Space Task Group coordinated large scale SAR data acquisitions in Antarctica and Greenland. The campaign was a spectacular success and the science community responded by producing continent wide ice velocity maps and related products.

Current situation

Post IPY: 4 missions went offline in relatively short order – resulting in a data gap.
PSTG was established to succeed STG and build on the IPY success.

CSA ASC Canadian Space Agency / Agence spatiale canadienne · esa · DLR · agenzia spaziale italiana · JAXA Japan Aerospace Exploration Agency · NASA · Norsk Romsenter Norwegian Space Centre

Project milestones &

Data sharing

For each year we envision the production of the aforementioned ESDRs roughly 3 months following data delivery.

After year 3, we will also assemble time series products that will be published once the final year (year 4) data can be integrated.

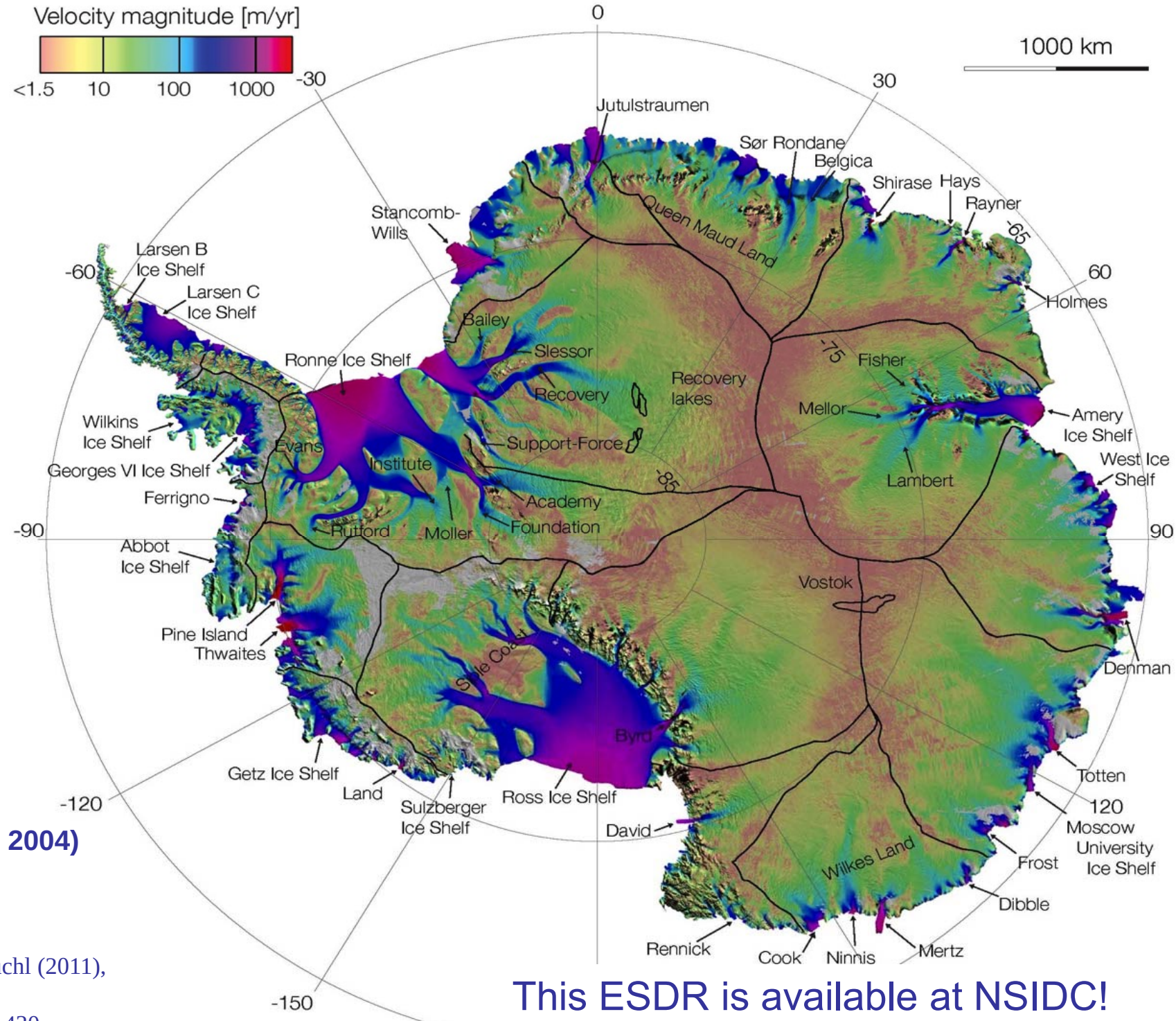
Finally, we plan to integrate the ALOS based ESDRs with ESDRs from other spaceborne SAR data to achieve an ice sheet wide, post IPY reference map.

We will publish our findings in the scientific literature.

We do not collect ground truth data for this project but we will share with JAXA all ice sheet ESDRs that were generated using data from multiple SAR satellites

Deliverables

- Annual ice velocity maps over selected regions in Antarctica and Greenland
- Grounding line maps for selected regions in Antarctica where data proves suitable to generate this information (delivery at project end)
- Ice front maps for selected ice shelves and glaciers in Antarctica and Greenland
- Publications



Ice Velocity Map

ALOS PALSAR (2006-2008)
ENVISAT ASAR (2007-2009)
RADARSAT-2 (2009)
RADARSAT-1 (1999, 2000, 2004)
ERS-1, ERS-2 (1992,1996)

Rignot, E., J. Mouginot, and B. Scheuchl (2011),
Ice Flow of the Antarctic Ice Sheet.
Science Vol. 333 no. 6048 pp. 1427-1430
DOI: 10.1126/science.1208336

This ESDR is available at NSIDC!
http://nsidc.org/data/nsidc-0484.html

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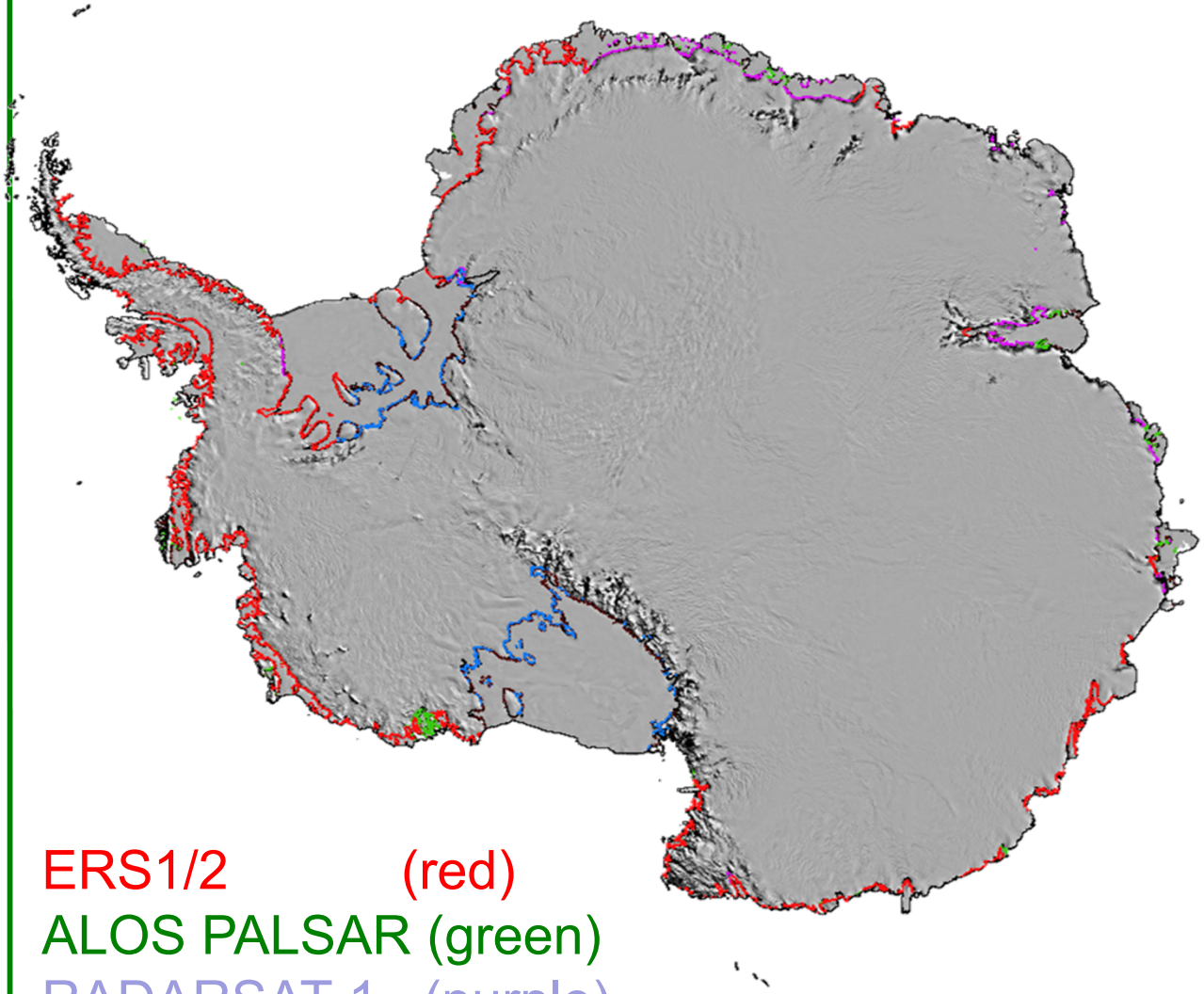
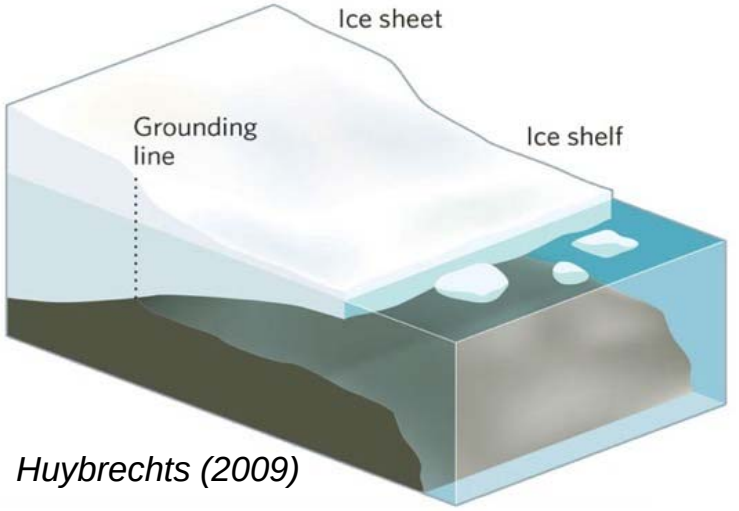
The Antarctic Grounding Line



ERS1/2 (red)
ALOS PALSAR (green)
RADARSAT-1 (purple)
RADARSAT-2 (blue)



Huybrechts (2009)

The Grounding line is the boundary between grounded and floating ice.

We mapped 1.4 million grounding line points experiencing tidal flexure based on double difference interferograms.

This ESDR is available at NSIDC!
http://nsidc.org/data/nsidc-0498.html

Rignot, E., J. Mouginot, and B. Scheuchl (2011), Antarctic grounding line mapping from differential satellite radar interferometry, Geophys. Res. Lett., 38, L10504,doi:10.1029/2011GL047109.

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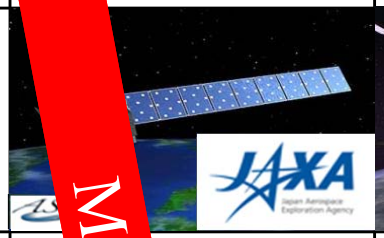
The IPY map data sources and the post IPY data situation

	OS PALSAR	SAT ASAR	RADARSAT-2	RSAT-1	RS-1/2
Sensor / Agency					
Band	L		C		
Repeat	46 ys	35 d	24 days	24 day	1day ays
Coverage	200 2010	2007 009	2009, (2011)	1997,200 04	1992, 6
Look direction	righ	right	left, (right)	right, (le	right
Mosaic				Historic (pre IPY campaign	Historic ta (pre IPY campaic

Mission ended 2011

Mission ended 2012

Mission ended 2013

Mission ended 2011

High Resolution X-band sensors (DLR, ASI)

- Less spatial coverage
- Targeted monitoring of selected sites
- Enable higher temporal resolution

TerraSAR-X, TanDEM-X

Cosmo Skymed

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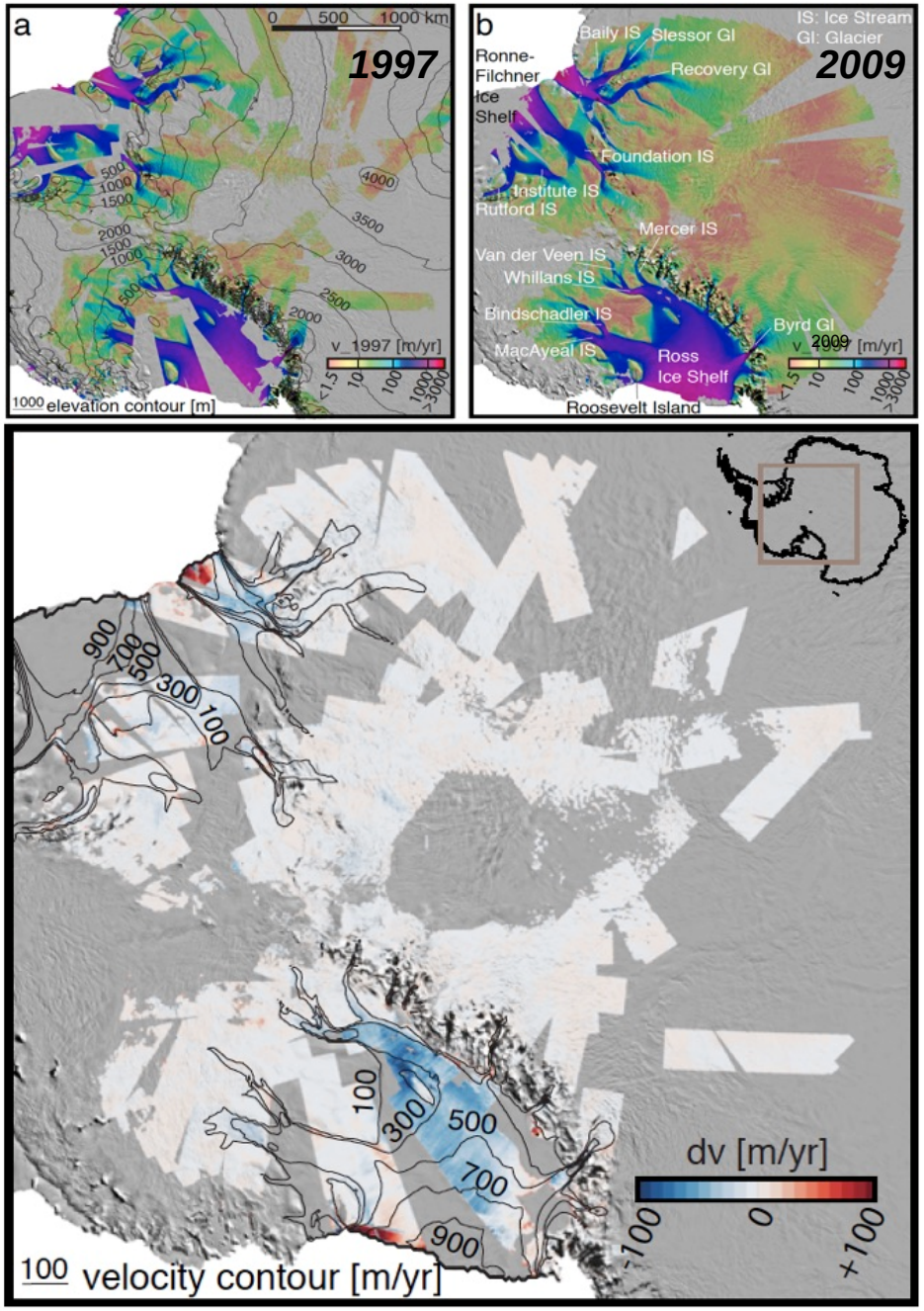
Central Antarctica 1997 and 2009

- We are now looking at large area time series in selected regions
- Refined velocity calibration with the difference map as quality criterion
- Implemented tide correction
- Here we were able to map the spatial extent of the slowdown of an ice stream in central Antarctica for the first time (shown on blue)

This ESDR is available at NSIDC!
http://nsidc.org/data/nsidc-0525.html



Scheuchl, B., Mouginot, J., and Rignot, E., 2012, Ice velocity changes in the Ross and Ronne sectors observed using satellite radar data from 1997 and 2009, The Cryosphere, 6, 1019-1030, doi:10.5194/tc-6-1019-2012

Thomas, R., B. Scheuchl, E. Frederick, R. Harpold, C. Martin, E. Rignot, B. Scheuchl, Continued slowing of the Ross Ice Shelf and thickening of West Antarctic Ice streams, J. Glaciol., Journal of Glaciology, Vol. 59, No. 217, 2013 doi: 10.3189/2013JoG12J122

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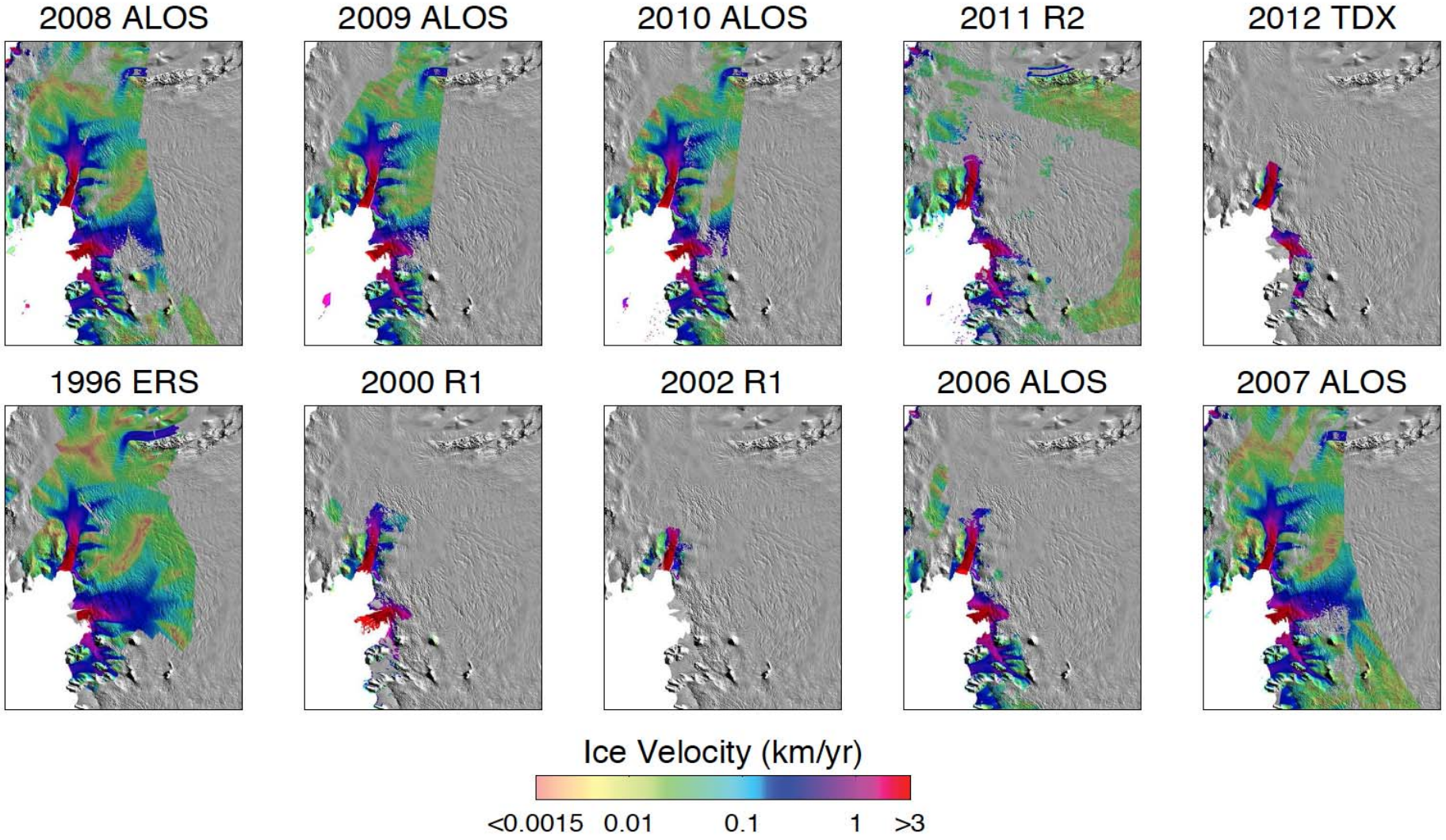
Amundsen Sea Embayment



41 year satellite data record (including Landsat). The SAR record goes back to 1992.

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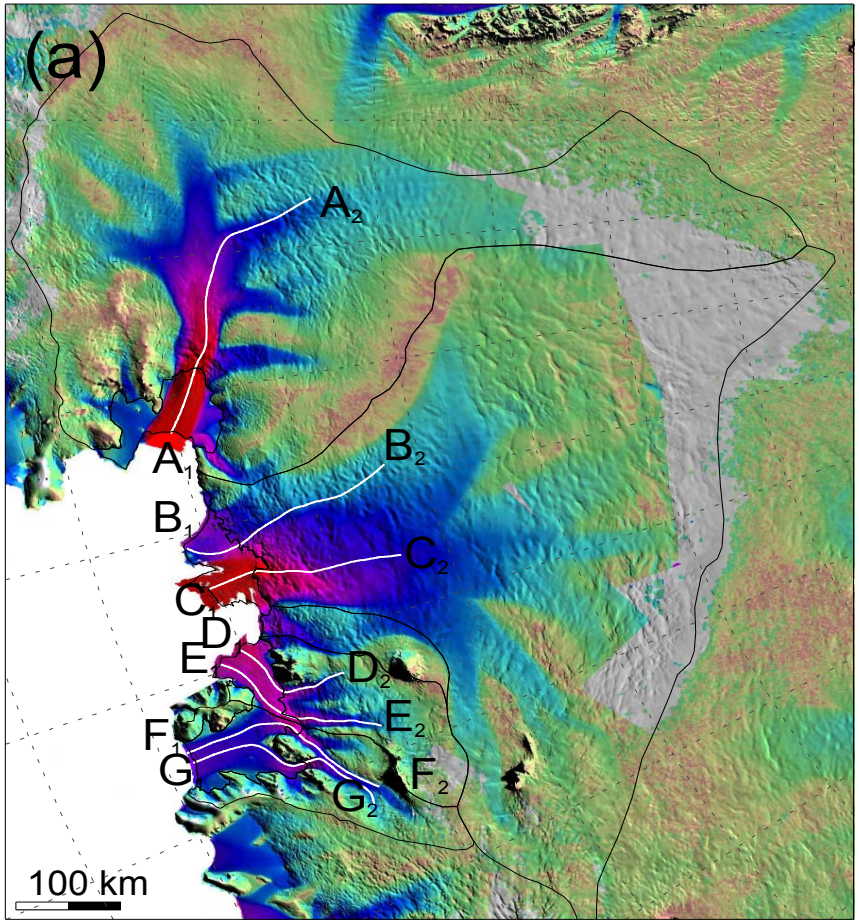
Amundsen Sea Embayment

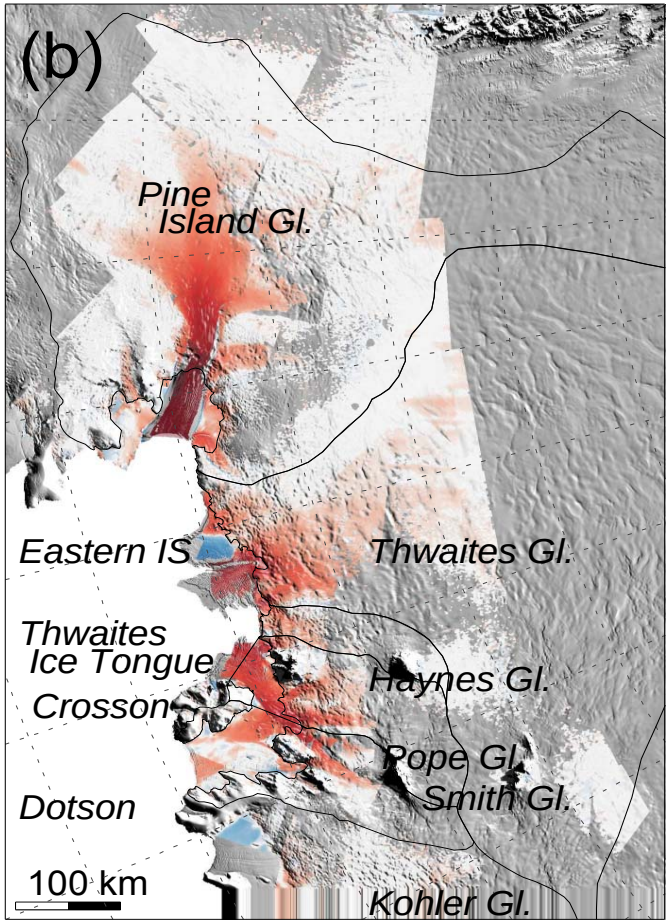
1996



Ice Velocity (km/yr)

<0.0015 0.01 0.1 1 >3

2008 - 1996



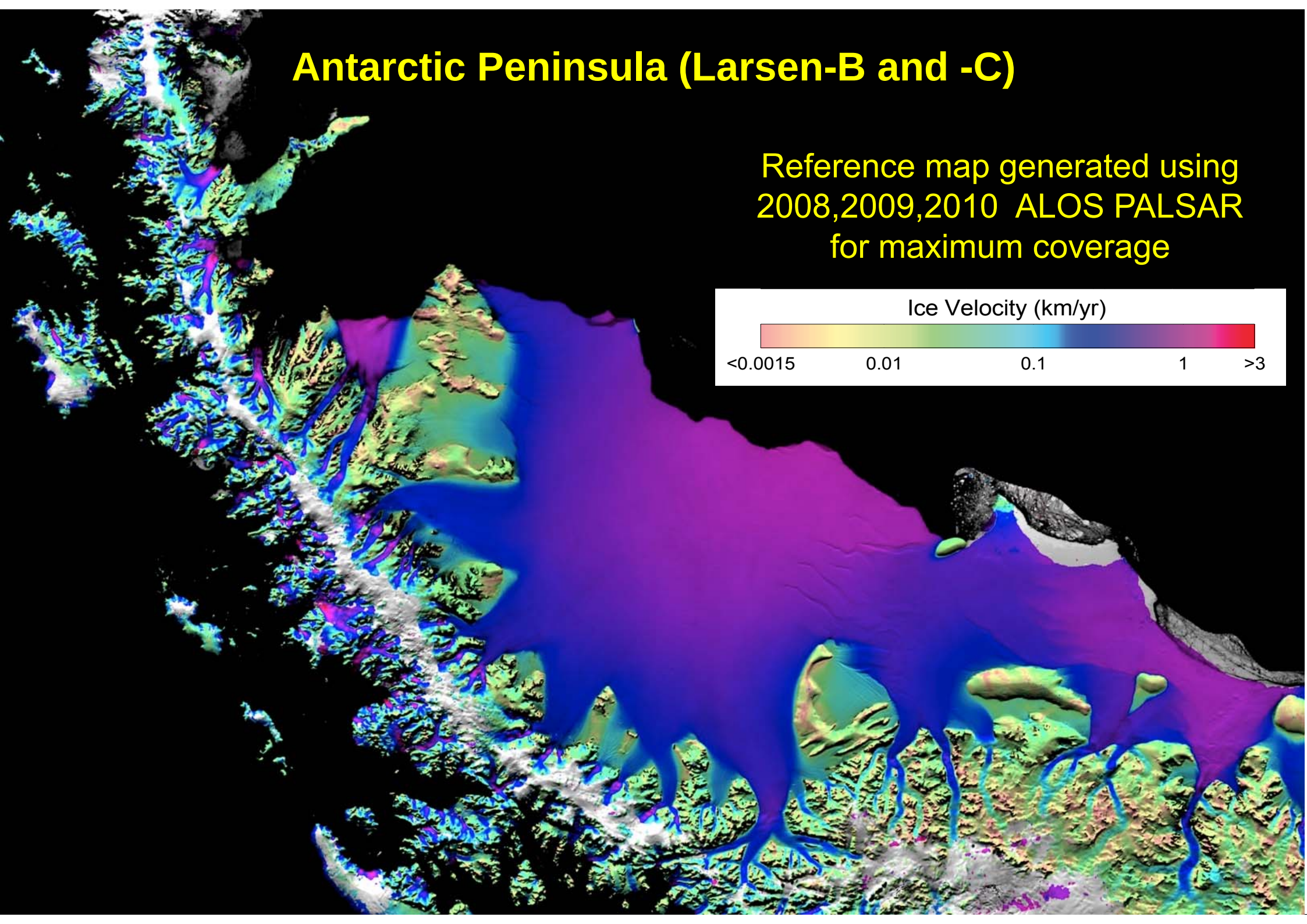
Vel. difference (km/yr)

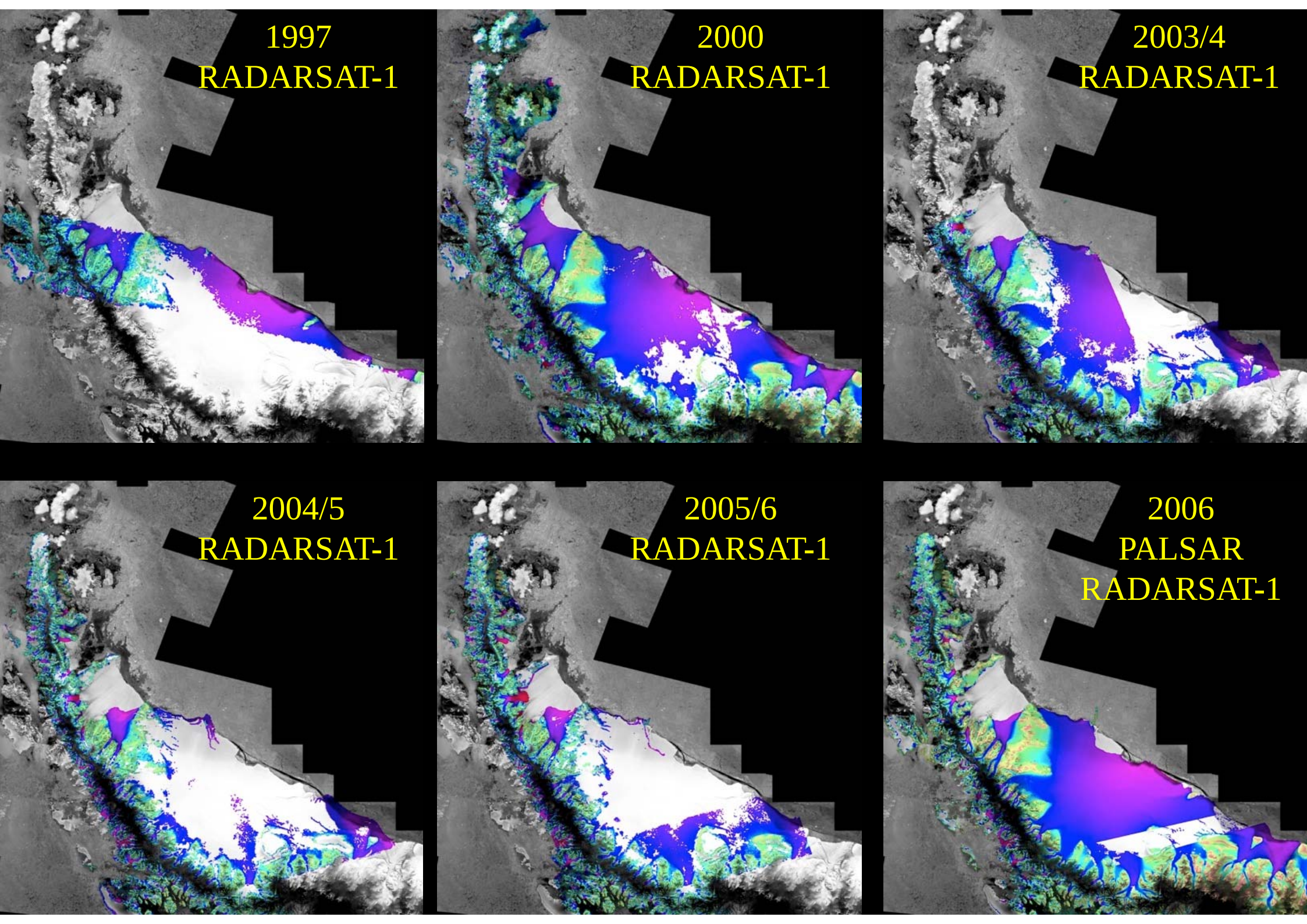
<-1.5 -0.1 -0.01 0.01 0.1 >1.5

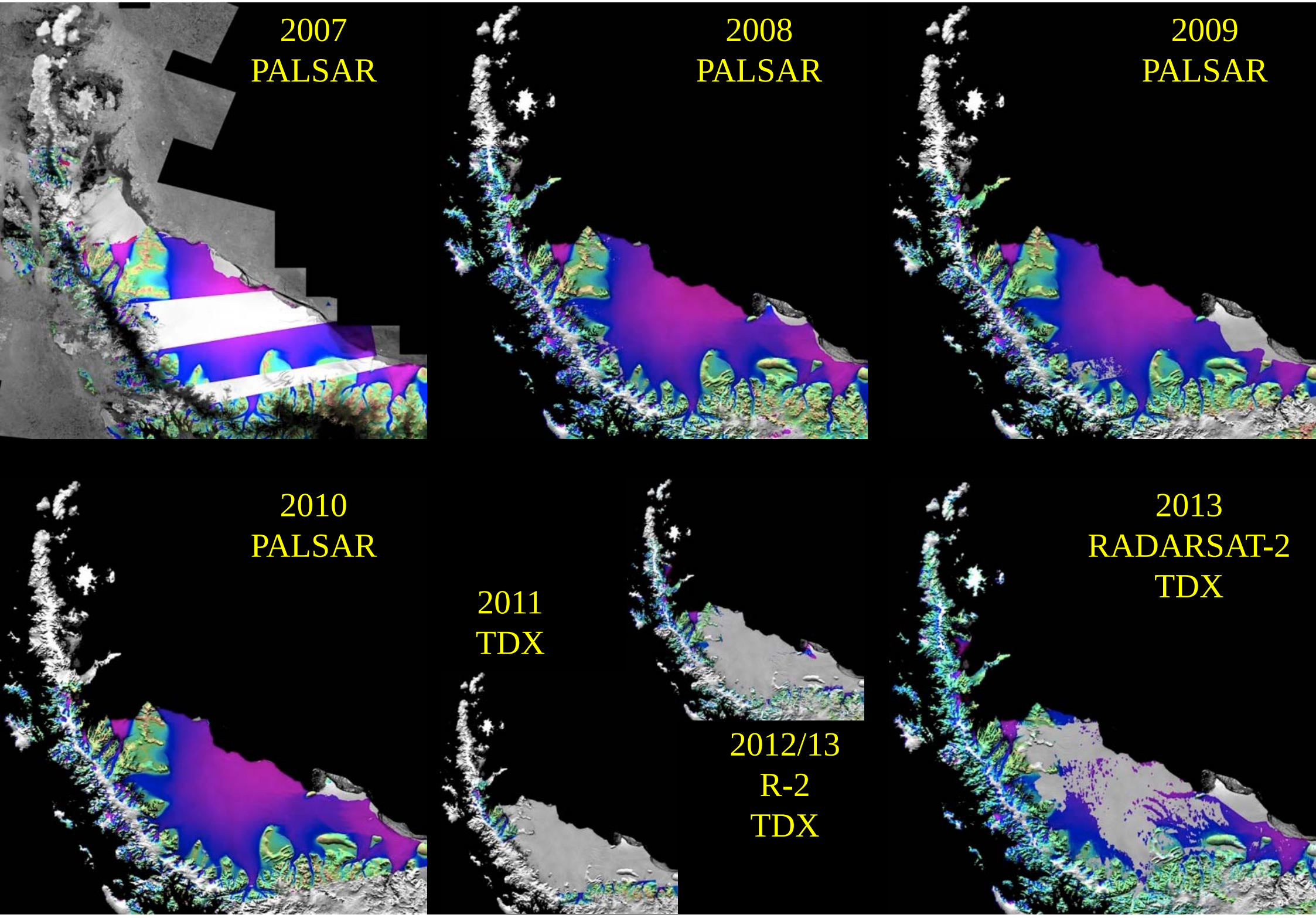
Mouginot, J., E. Rignot, B. Scheuchl, Sustained increase in ice discharge from the Amundsen Sea Embayment, West Antarctica, Geophys. Res. Lett., 41/5, doi: 10.1002/2013GL059069

Antarctic Peninsula (Larsen-B and -C)

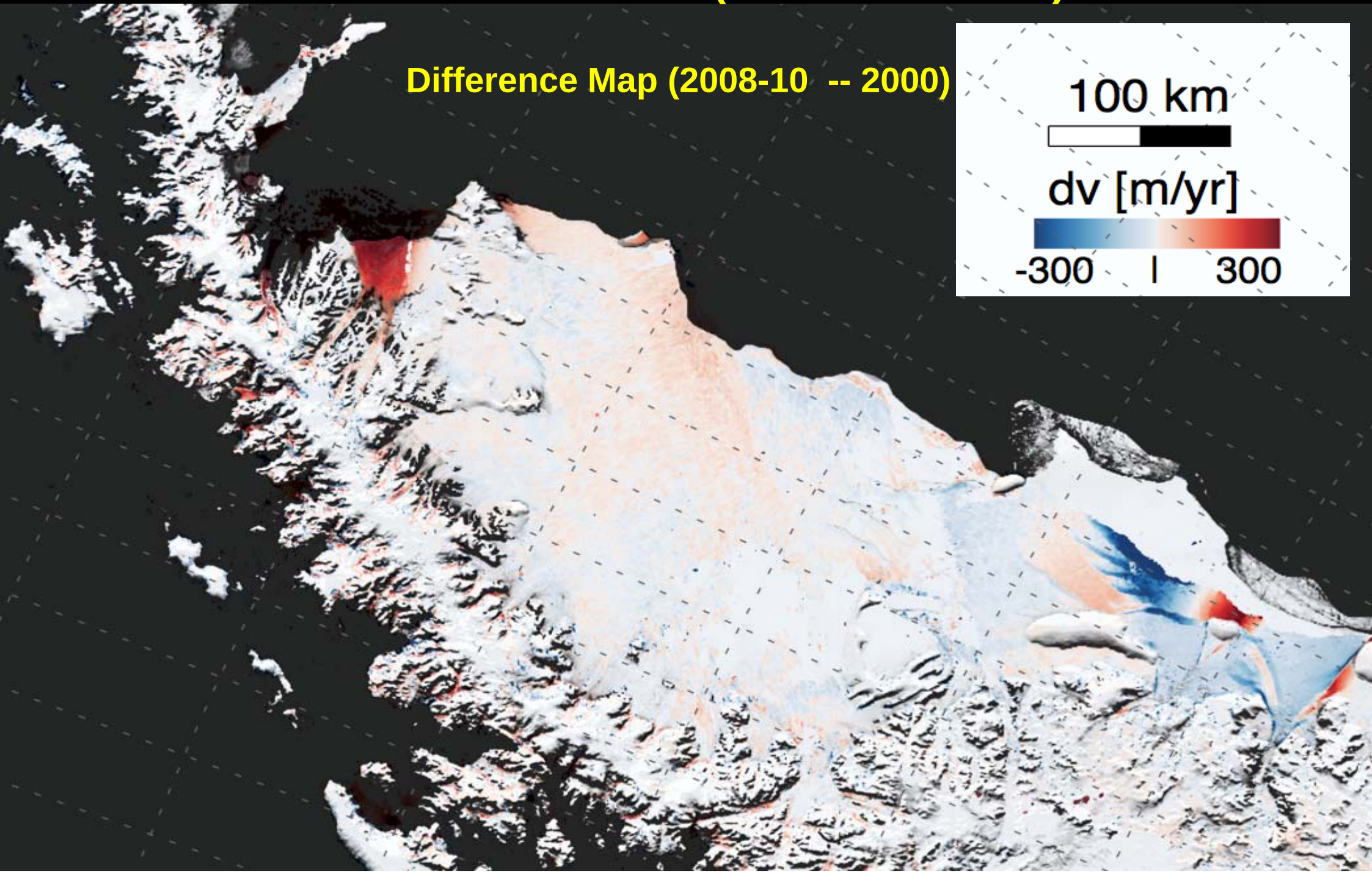
Reference map generated using
2008,2009,2010 ALOS PALSAR
for maximum coverage




1997
RADARSAT-1
2000
RADARSAT-1
2003/4
RADARSAT-1
2004/5
RADARSAT-1
2005/6
RADARSAT-1
2006
PALSAR
RADARSAT-1


2007
PALSAR
2008
PALSAR
2009
PALSAR
2010
PALSAR
2011
TDX
2012/13
R-2
TDX
2013
RADARSAT-2
TDX

Antarctic Peninsula (Larsen-B and -C)

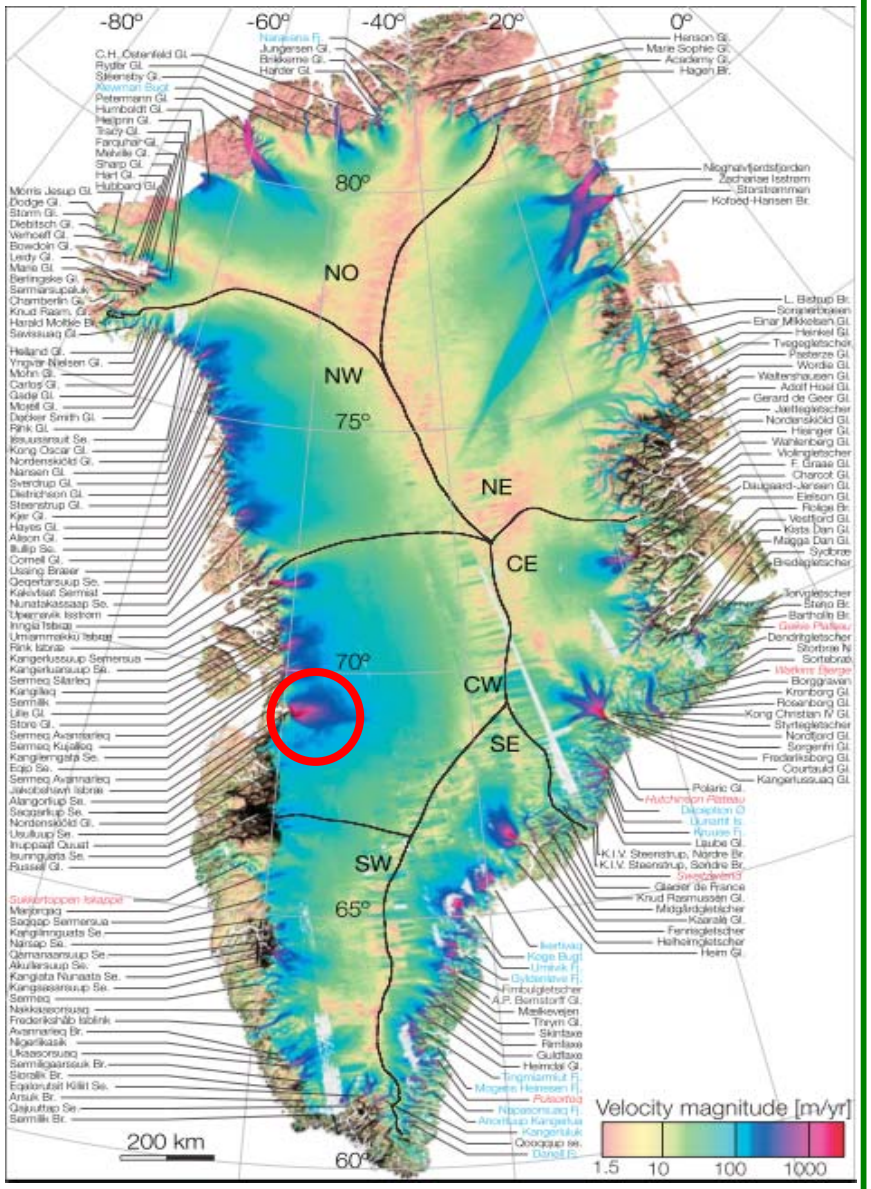


IPY Velocity Map Greenland

Shown on the right is a continent-wide ice sheet map that used data acquired in 2008 and 2009

The Greenland ice sheet is undergoing significant change. One extreme example is Jakobshavn Isbrae (red circle):

- Increase in speed (from 4km/yr in 1992 to 18km/yr in 2014)
- Ice front retreat (about 56 km in 150 years)
- Elevation loss (ice volume loss)



Rignot, E. and J. Mouginot (2012), Ice flow in Greenland for the International Polar Year 2008–2009, Geophys. Res. Lett., 39, L11501, doi:10.1029/2012GL051634.

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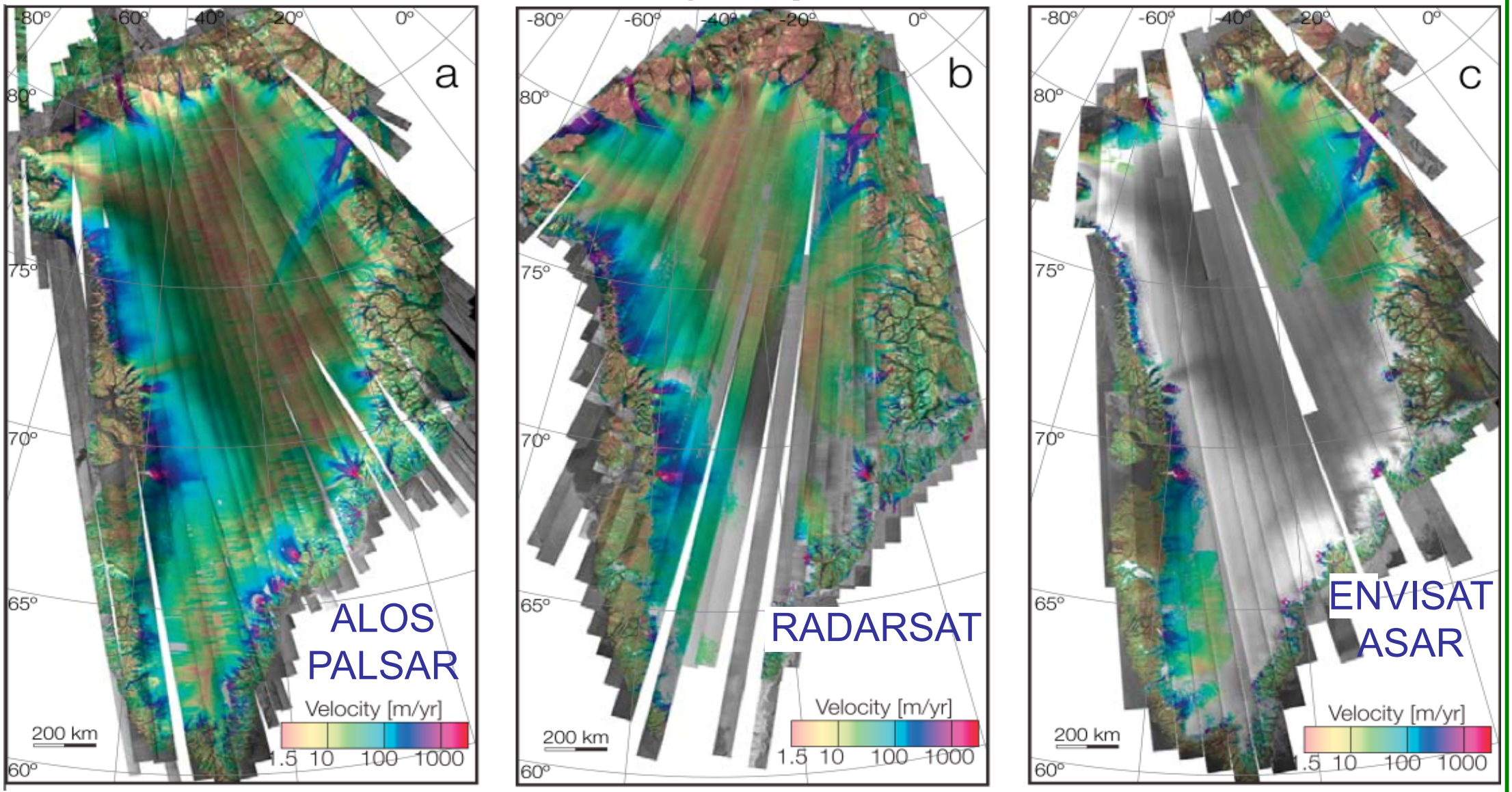
IPY Velocity Map Greenland



Rignot, E. and J. Mouginot (2012), Ice flow in Greenland for the International Polar Year 2008–2009, Geophys. Res. Lett., 39, L11501, doi:10.1029/2012GL051634.

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Thank You

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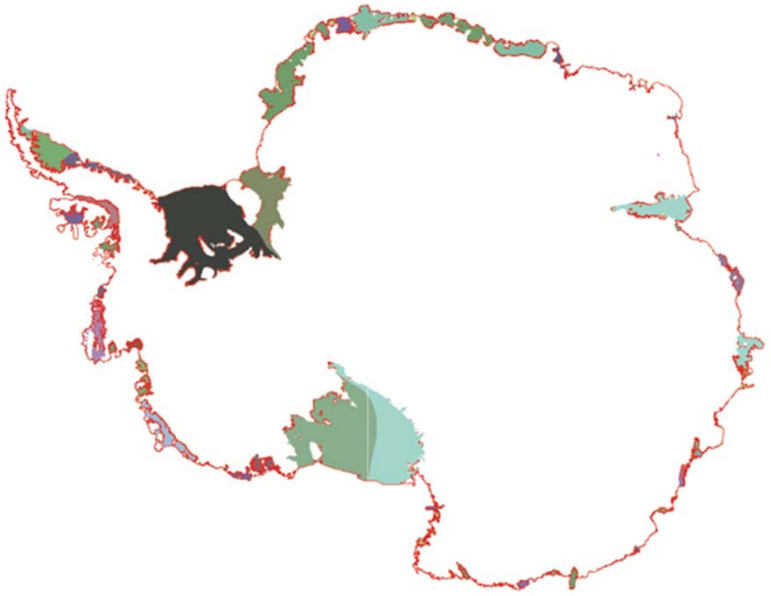
NASA/Goddard Space Flight Center Scientific Visualization Studio

Ice Shelf Melting around Antarctica

Input used:

- Grounding Line (Rignot et al. 2011a)
- Ice front (used here from SAR)
- Ice Velocity (Rignot et al. 2011b)
- BEDMAP-2 ice thickness (Fretwell et al. 2013)
- Thickness change rate (expanded from Pritchard et al. 2012)
- SMB (RACMO-2, Lenaerts et al. 2012)



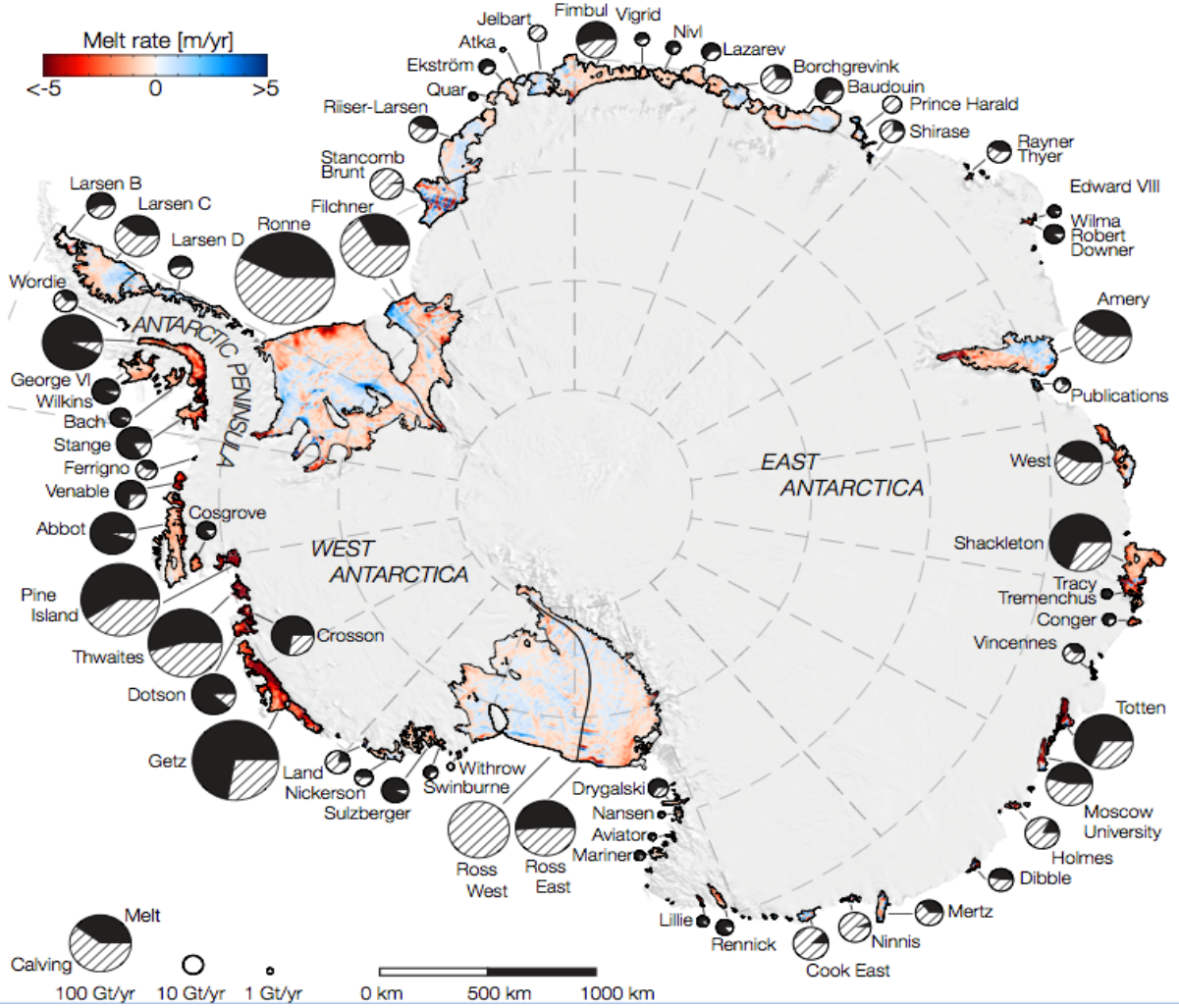
100 ice shelves mapped (99% of total ice shelf area)

Total IS area: 75% of Antarctica's coastline and accounts for 83% of total ice discharge

Rignot, E., S. Jacobs, J. Mouginot, and B. Scheuchl, 2013, Ice Shelf Melting Around Antarctica
Science, Vol. 341 no. 6143 pp. 266-270, doi :10.1126/science.1235798

Ice Shelf Melting around Antarctica

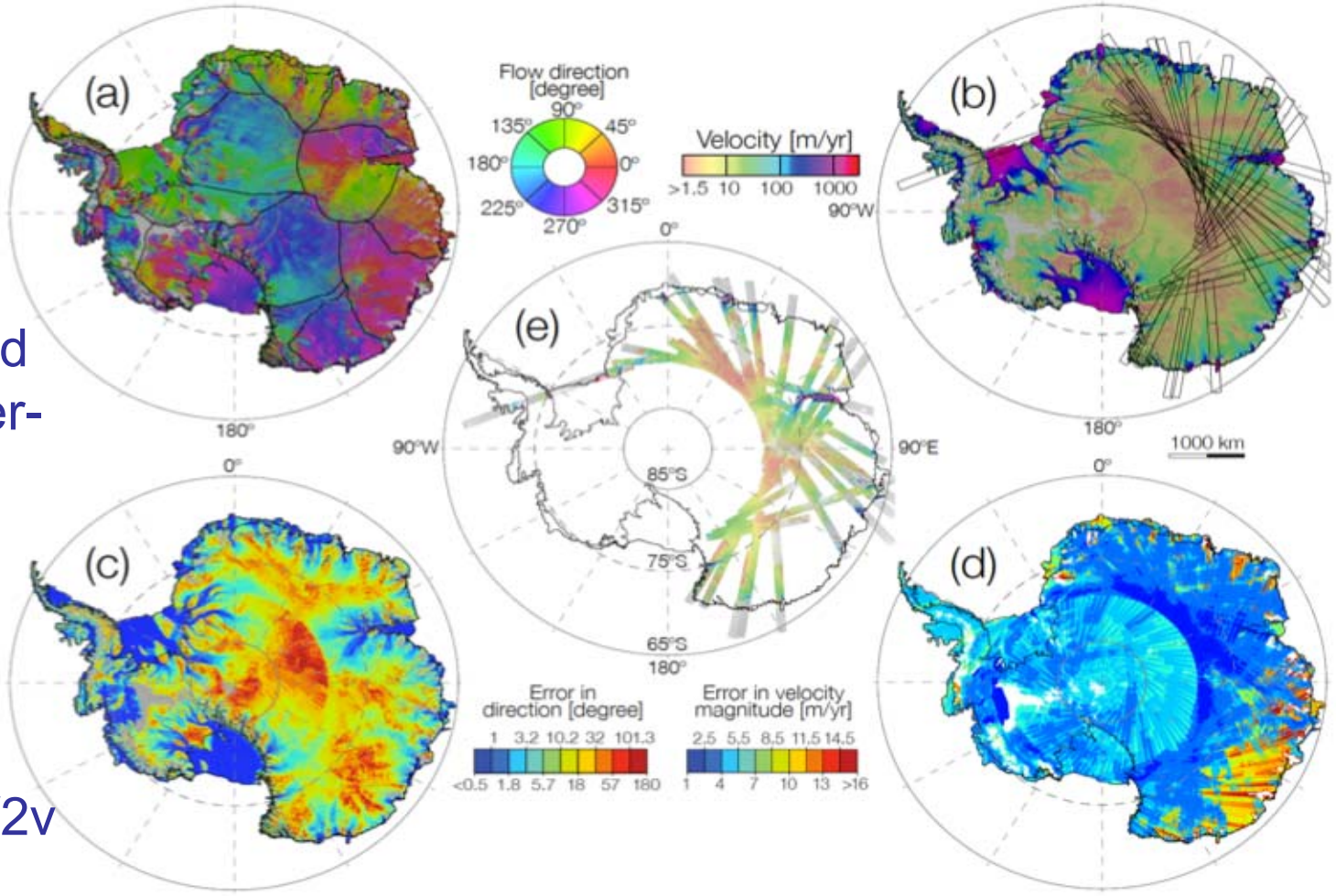
- Basal melt is comparable to - if not larger than - iceberg calving
- Ross, Filchner and Ronne ice shelves cover 2/3 of the total ice shelf area, but produce only 15% of the meltwater.
- 50% of the water production comes from 10 small, warm-cavity southeast Pacific ice shelves occupying 8% of the area (Pine Island, Thwaites, Getz ...)
- 6 East Antarctic ice shelves with 3% of the area contribute to 15% of the meltwater



Rignot, E., S. Jacobs, J. Mouginot, and B. Scheuchl, 2013, Ice Shelf Melting Around Antarctica
Science, Vol. 341 no. 6143 pp. 266-270, doi :10.1126/science.1235798

Velocity Calibration and Error

- Our calibration strategy relies on network of long tracks (b), (e).
- The error in velocity magnitude, σ_v, ((d), part of the ESDR) is estimated on a per track basis. Over-lapping tracks reduce σ_v.
- The velocity data allow the estimation of flow direction (a)
- The error in direction (c) can be derived as $\sigma_\theta = \sigma_v / 2v$

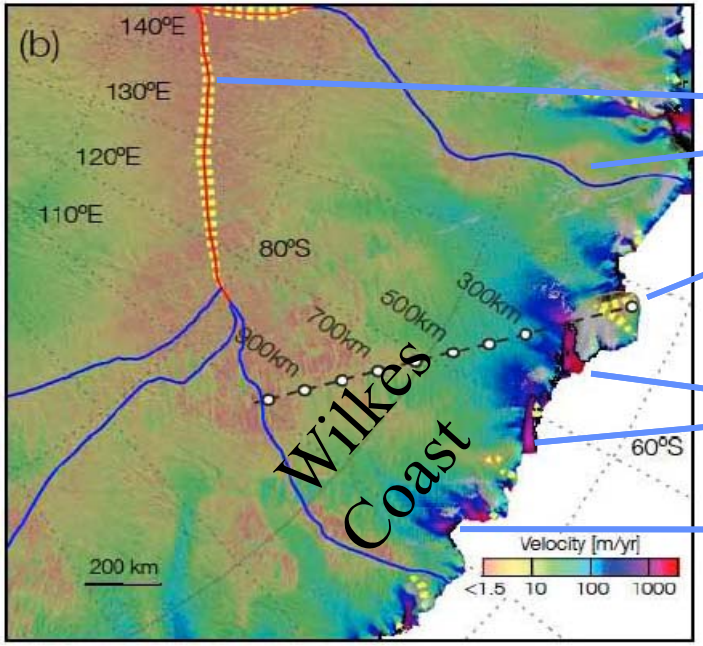


Mouginot, J., B. Scheuchl, E. Rignot, 2012. Mapping of Ice Motion in Antarctica Using Synthetic-Aperture Radar Data. *Remote Sensing* 4 (9), pp. 2753-2767

Velocity Calibration and Track Length

Long Tracks (coast-to-coast, or rock-to-rock) are essential for velocity calibration. Zero slope topographic divides can also be utilized as reference points.

The example shows the impact of track length on the grounding line velocity for Wilkes Coast (Note: no a priori information available).



Topographic divides
- Red: slope <0.1deg
- Blue: otherwise

Reference point

Totten Gl.

Moscow University IS

Frost Gl.

From: Mouginot et al. 2012

Track length [km]	Velocity [m/yr]	Speed error at the GL [%]	Flux error [Gt/yr]
1000	1.8	>0.1	>0.1
900	6.4	0.3	0.2
800	4.3	0.2	0.2
700	4.3	0.3	0.2
600	7.1	0.5	0.4
500	22.4	1.8	1.4
400	43.9	4.5	3.3
300	65.8	9.0	6.7